



Chapter 12

Surface water quality

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Chapter 12 Surface water quality

The Secretary's environmental assessment requirements for the Narrabri Gas Project include a requirement to assess potential impacts on surface water quality. Detailed assessments were undertaken in response to this requirement and are provided as Appendices F, G1, G2, G3 and G4. This chapter draws on the detailed assessments and provides an overall assessment of the potential impacts of the project on surface water quality. It should be read in conjunction with Chapter 11 – Groundwater and geology, Chapter 13 – Hydrology and geomorphology, Chapter 14 in part – Soils and land contamination and Chapter 16 – Aquatic ecology where other potential impacts to water are assessed. The treated water management options assessed in this chapter with respect to potential impact to surface water quality are shown in Figure 12-1.

The key findings of the impact assessment in relation to surface water quality were:

- Bohena Creek and its main tributaries are considered to be highly ephemeral and only flow during periods of heavy rain
- the irrigation scheme was found to be of low impact to surface water quality. Water quality proposed for beneficial reuse in irrigation has total dissolved solids concentrations broadly consistent with irrigation water used regionally and in other parts of NSW
- the potential impacts on surface water systems, including springs within the vicinity of the project area, as a result of depressurisation from water extraction during the operational stage of the project are expected to be minor or negligible
- there were low residual risks on surface water quality from potential construction, operation and decommissioning impacts once design and operation level management and mitigation controls were put in place
- the risks assessed and reported in this chapter was undertaken iteratively using scientific water chemistry studies including a mixing zone assessment reported as Appendix E to Appendix G1 and an irrigation study reported as Appendix G2.

An assessment was undertaken for potential impacts on surface water quality during construction of the project. The assessments assume that dust suppression and construction include the use of treated and amended water for in rehabilitation activities. The assessment found that there would be a low risk of impact on surface water quality from spills assuming that standard procedures were used; including the risk of spills during drilling activities. (Potential impacts to groundwater from drilling activities is reported in Chapter 11 – Groundwater and geology). There was a low risk of turbidity impacts to surface water due to sedimentation from the construction phase of linear infrastructure across watercourses, assuming erosion and sediment control plans are used. Dust suppression impacts would also be low given that treated and amended water qualities that would be used for dust suppression would be relatively consistent with baseline water quality of the receiving catchments.

An assessment was undertaken for potential impacts on surface water quality during the operational phase, including the use of treated and / or amended water for irrigation, stock watering, dust suppression, and managed release of treated water to Bohena Creek under prescribed flow conditions. The assessments assume that dust suppression includes the use of treated and amended water for in rehabilitation activities. The irrigation design process indicated that, consistent with typical irrigated lands, some water may run off irrigated paddocks. Runoff would most likely be driven by rainfall and would carry small amounts of sediment and nutrients. Loss of sediment and nutrients from irrigated project areas would be monitored and managed as part of an irrigation management plan consistent with typical irrigation practices, with irrigation schedules being altered accordingly.

Irrigation scenarios were reported in the *Irrigation General Concept Design Report* (refer to Appendix G2 and Chapter 7). They indicate that at both peak and predicted average long-term operating scenarios for

produced (and therefore treated and amended) water production rates; the rate of salt application to irrigated land would be consistent with regional irrigation water quality.

As a point of comparison, waters used across NSW for agricultural irrigation typically have similar salinities to that of the amended water proposed for irrigation within the project area—being a target value of 368 milligrams per litre. For example, water drawn from the Calivil Formation in the Lower Murrumbidgee Water Sharing Plan has a median total dissolved solids concentration of around 400 milligrams per litre (Parsons Brinckerhoff 2011). Median irrigation water quality from the Gunnedah Formation within the Upper Namoi Alluvium Zone 3 Water Sharing Plan adjacent to the project area has been reported at 680 milligrams per litre total dissolved solids (Parsons Brinckerhoff 2011). Both are comparable to the project’s target amended water quality. The planned irrigation regime and schedule will be managed appropriate to the crop, soil type and meteorological conditions. As such, the risk of impacts on surface water quality is low.

Similarly, impacts on stock from stock watering were considered to be low given that the treated water quality parameters were below ANZECC/ARMCANZ (2000) stock watering criteria.

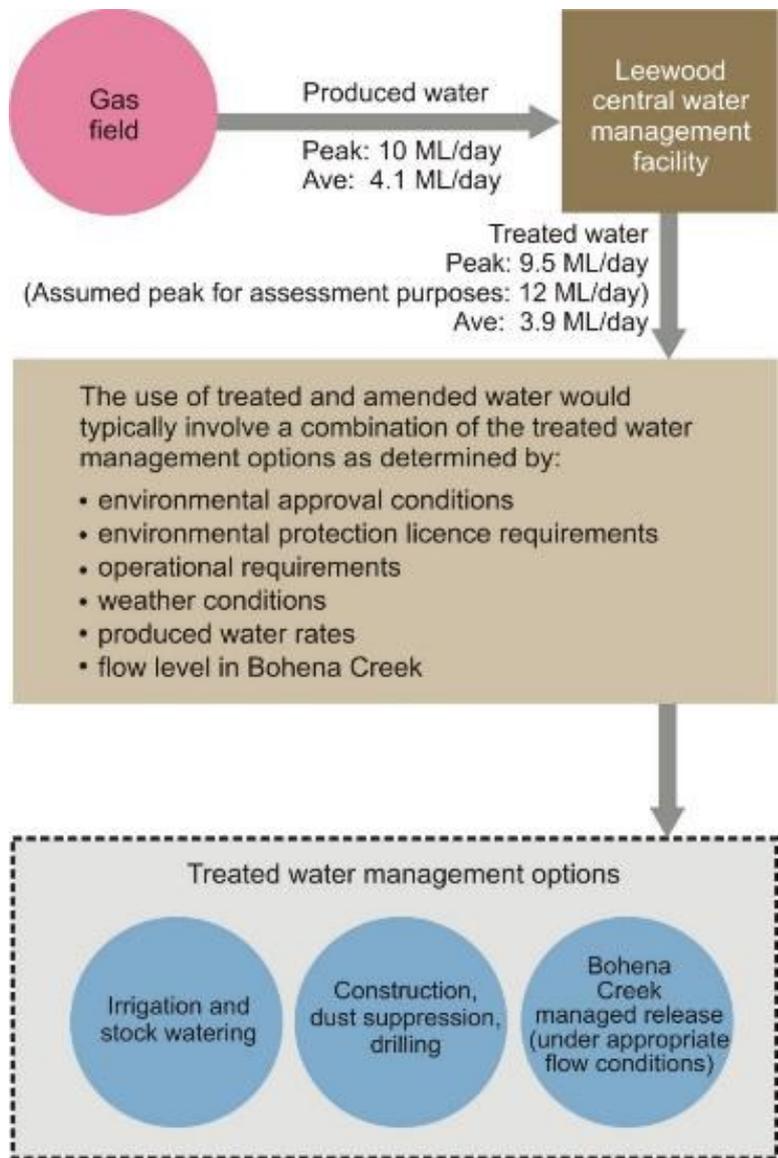


Figure 12-1 Treated water management options

Groundwater modelling predicts no drawdown greater than 0.5 metres in the Pilliga Sandstone, and even smaller drawdown at the water table within alluvial groundwater sources (refer to Chapter 11). On this basis, the potential impacts on surface water systems, including springs within the vicinity of the project area, are expected to be low or negligible (Refer to Chapter 11 – Groundwater and geology for an assessment on groundwater dependant ecosystems). Monitoring in accordance with the project Water Monitoring Plan would be undertaken to ensure a low ongoing risk was realised and appropriate mitigation measures would be implemented as required (refer to Appendix G3).

The managed release of treated water to Bohena Creek is proposed only under flow conditions of equal to, or greater than, 100 megalitres per day at the Newell Highway gauging station. Managed release would be undertaken in accordance with a Produced Water Management Plan. Modelling shows that at 100 megalitres per day flow in Bohena Creek, and with a suitable instream diffuser, a dilution of around one part treated water to 10 parts creek flow could be achieved. The modelling also shows that there would not be an ionic imbalance or impacts from sodium adsorption ratios, or ecological risks from the physicochemical and chemical stressors and potential toxicants would be low when compared to baseline water quality values under guidelines in the *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (ANZECC/ARMCANZ 2000).

Impact assessment has shown that, provided all construction and operational mitigation measures discussed in this chapter (and expanded upon in Chapter 30) were undertaken, there would be low residual risk to surface water quality.

12.1 Methodology

The methodology described below was employed to establish baseline, or pre-project, water quality parameters, in addition to generating an understanding of existing environmental values in Bohena Creek and the Namoi; that is, in the receiving environment. It is these environmental values, including existing water quality, against which impact assessment is undertaken.

12.1.1 ANZECC/ARMCANZ (2000) water quality guidelines

Potential impacts of the project on surface water quality were assessed in accordance with methodology from the ANZECC/ARMCANZ (2000) water quality guidelines. This is the accepted standard under which to manage environmental water quality in Australia. The ANZECC/ARMCANZ (2000) guidelines provide a risk-based framework under which water quality data may be statistically interrogated, trends analysed, and site-specific trigger values may be derived.

A ‘trigger value’, which is generally derived for key potential contaminants of concern, is a quantitative response level for a specific water chemistry ‘analyte’ whereby its exceedance as detected in monitoring data over time may ‘trigger’ a management response for investigative and corrective action. Water chemistry ‘trigger values’ are based on receptor health thresholds as understood by the extensive global literature on aquatic ecotoxicology. An ‘analyte’ in this instance relates to an individual chemical substance in the water that is being analysed by the laboratory.

The ANZECC/ARMCANZ (2000) framework supports water quality across many end uses. For example, when considering the treated water beneficial reuse options proposed under the project’s Produced Water Management Plan, the following ANZECC/ARMCANZ (2000) guidance would be used:

- managed release to Bohena Creek would use the aquatic ecosystem guidelines to ensure environmental values within Bohena Creek are maintained
- water quality under the irrigation scheme (and dust suppression) would be managed under the short term (up to around 20 years) irrigation water quality framework
- stock watering would be managed according to the stock watering guidelines.

The ANZECC/ARMCANZ (2000) guidelines also provide guidance on water quality with respect to recreational water bodies, while drinking water is generally assessed under the *Australian Drinking Water Guidelines* (NHMRC 2011).

Methodology from ANZECC/ARMCANZ (2000) was used for the project to generate water quality baseline statistics for the purposes of impact assessment. The regional baseline water quality data that have been collected over several years for the project provide an understanding of water quality within the Namoi River and Bohena Creek (refer to Appendix G4). These data would be used as comparative during ongoing water quality monitoring throughout all project phases using trend analysis over time so that identified significant variance from the norm can be investigated.

The method above was then interpreted for the purposes of impact assessment using a significance assessment as described in Chapter 10. This method considers the sensitivity of the receiving environment (Bohena Creek for example) and, when multiplied by a magnitude rating, determines likely impact significance.

Baseline water quality data are presented in the existing environment section of this chapter (Section 12.2), guideline values for the purposes of impact assessment are presented in Chapter 7, and monitoring is discussed in the mitigation and management section (Section 12.5), and in Chapter 30 – Environmental Management and Monitoring. The Water Monitoring Plan for the project is included as Appendix G3.

12.1.2 Water quality objectives

There is an established water quality strategy framework in place over the project area that includes Commonwealth and State level policies and action plans. The Produced Water Management Plan for the project would consider and work within this framework, which is summarised below.

Murray-Darling Basin salinity management strategy

The *Basin Salinity Management Strategy 2030* for the Murray-Darling (Murray-Darling Basin Ministerial Council 2015) sets out how Murray-Darling Basin communities and governments would work together to control salinity and protect important environmental values and assets. It provides a framework under Schedule B of the Murray-Darling Basin Agreement (which in turn is Schedule 1 of the Commonwealth *Water Act 2007*) to assist Commonwealth and State Governments, and communities, control salinity levels across the Murray-Darling Basin. A key focus of the *Basin Salinity Management Strategy* is to ensure key Government and community stakeholders have the ability to monitor and manage salt loads in all tributary rivers of the Murray–Darling Basin.

It contains accountability arrangements that are the 'first of a kind' for salinity strategies in Australia. The strategy specifies river salinity targets to be met in the year 2015. In terms of measurable salinity levels, the strategy aims to ensure that the electrical conductivity of water at Morgan in South Australia should be less than 800 microsiemens per centimetre, for 95 per cent of the time. For the Namoi Catchment, the median salinity target as measured by the electrical conductivity of water at Goangra is 475 microsiemens per centimetre (with a peak of 715 microsiemens per centimetre).

At the NSW policy level, for the Namoi Catchment, a median salinity target of 550 microsiemens per centimetre at Goangra has been adopted (DLWC 2000).

Average target salinity as measured by electrical conductivity for treated water quality that would undergo managed released to Bohena Creek has been estimated to be around 357 microsiemens per centimetre. Assuming a normal statistical distribution of the data, the median value may be assumed to approximate the average—a value below the target median salinity values of 800 microsiemens per centimetre at Morgan and 550 (State target) and 475 (Commonwealth target) microsiemens per centimetre at Goangra

respectively. As the project is located in NSW, the proponent would work to ensure all controls or limits associated with the management of salinity levels are adhered to help meet Commonwealth and State river salinity targets.

Salt balances for the short-term daily produced water peak of around 10 megalitres per day, and longer-term average rate over the 25-year project assessment period of 4.1 megalitres per day, are provided in Figure 12-2 and Figure 12-3 respectively. Figure 12-2 and Figure 12-3 complement the salt management detail provided in Chapter 7. Stock watering is excluded from Figure 12-2 and Figure 12-3 as the salt quantities were deemed relatively insignificant in the salt balance for their stated purpose.

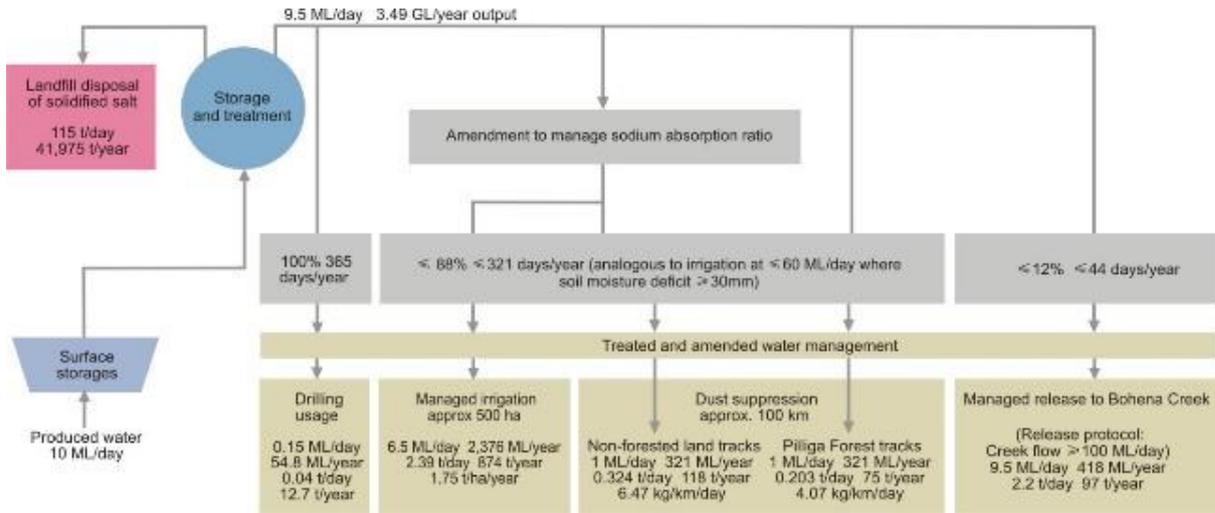


Figure 12-2 Estimated salt balance during the produced water peak in years two to four

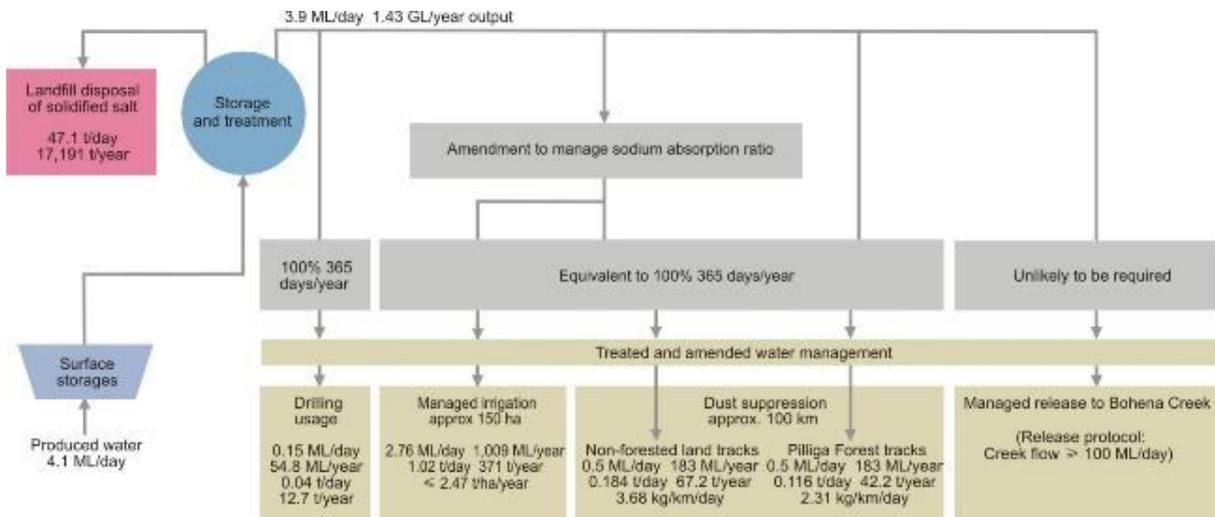


Figure 12-3 Estimated salt balance during the produced water longer-term average

Namoi River Water Quality and River Flow Objectives

In 2006, the NSW Government released the *Namoi River Water Quality and River Flow Objectives* (NSW Government 2006) to guide plans and actions that aim to ensure the long-term health of the Namoi Catchment, which includes Bohena Creek. The objectives also satisfy the NSW Government requirement to meet its inter-governmental obligations to improve river health, such as in the Murray-Darling Basin within which the project is situated.

The water quality objectives are divided into categories depending on the type of stream. The Namoi River downstream of Keepit Dam is classed as a 'major controlled river', while the watercourses within the project area are classified as 'uncontrolled streams'. The exceptions to this are Bohena and Baradine creeks where headwaters are located within 'mainly forested areas'.

The water quality objectives established for Bohena Creek are:

- aquatic ecosystems
- visual amenity
- primary and secondary contact recreation
- drinking water at point of supply – groundwater, clarification and disinfection
- aquatic foods (cooked).

The objectives state as supporting information that 'some of the State forests and other reserves marked on the map contain streams that start in largely cleared land, such as along parts of Baradine and Bohena creeks. The water quality and flow patterns through these vegetated areas generally reflect upstream effects. The public accessibility of these areas, particularly for recreation, leads to a high public expectation for good water quality'.

Namoi Catchment Action Plan

The *Namoi Catchment Action Plan 2010–2020* (Namoi Catchment Management Authority 2010) contains specific thresholds and targets to meet the overall goal for the catchment of 'vibrant communities and landscape for the future'. It establishes a series of targets related to biodiversity, land, water and people that would be considered within the development of a managed release protocol to Bohena Creek.

12.1.3 Establishing a surface water quality baseline

Overview

The potential for surface water quality impacts resulting from the project are assessed in a number of studies appended to this EIS as noted above (primarily in Appendices G1 and G2). In order to establish representative water quality values against which potential impacts on surface water quality from the managed release scheme may be assessed, it is first necessary to establish baseline (or pre-project) water quality parameters for watercourses that may be potentially impacted. In this regard, the Water Baseline Report (refer to Appendix G4) presents baseline conditions for both the regional (Namoi River) and local (Bohena Creek) surface water environments.

The Water Baseline Report (refer to Appendix G4) was prepared to:

- provide a description of the existing, or baseline, surface (and ground) water quality
- inform the project's Water Monitoring Plan (refer to Appendix G3) by establishing the baseline conditions against which implementation of the Produced Water Management Plan for the project may be monitored for operation efficacy. Note that it would not be for compliance purposes—outcomes based ecotoxicological values would be sought under an Environment Protection Licence in that regard.

As new surface water quality data are collected, these will continue to be added to the dataset, which undergoes statistical analysis to ensure it is spatially and temporally representative such that it provides confidence when assessing trends in water quality analytes. This is important so that outlying data points or spikes can be identified during operational water quality monitoring that may flag potential issues.

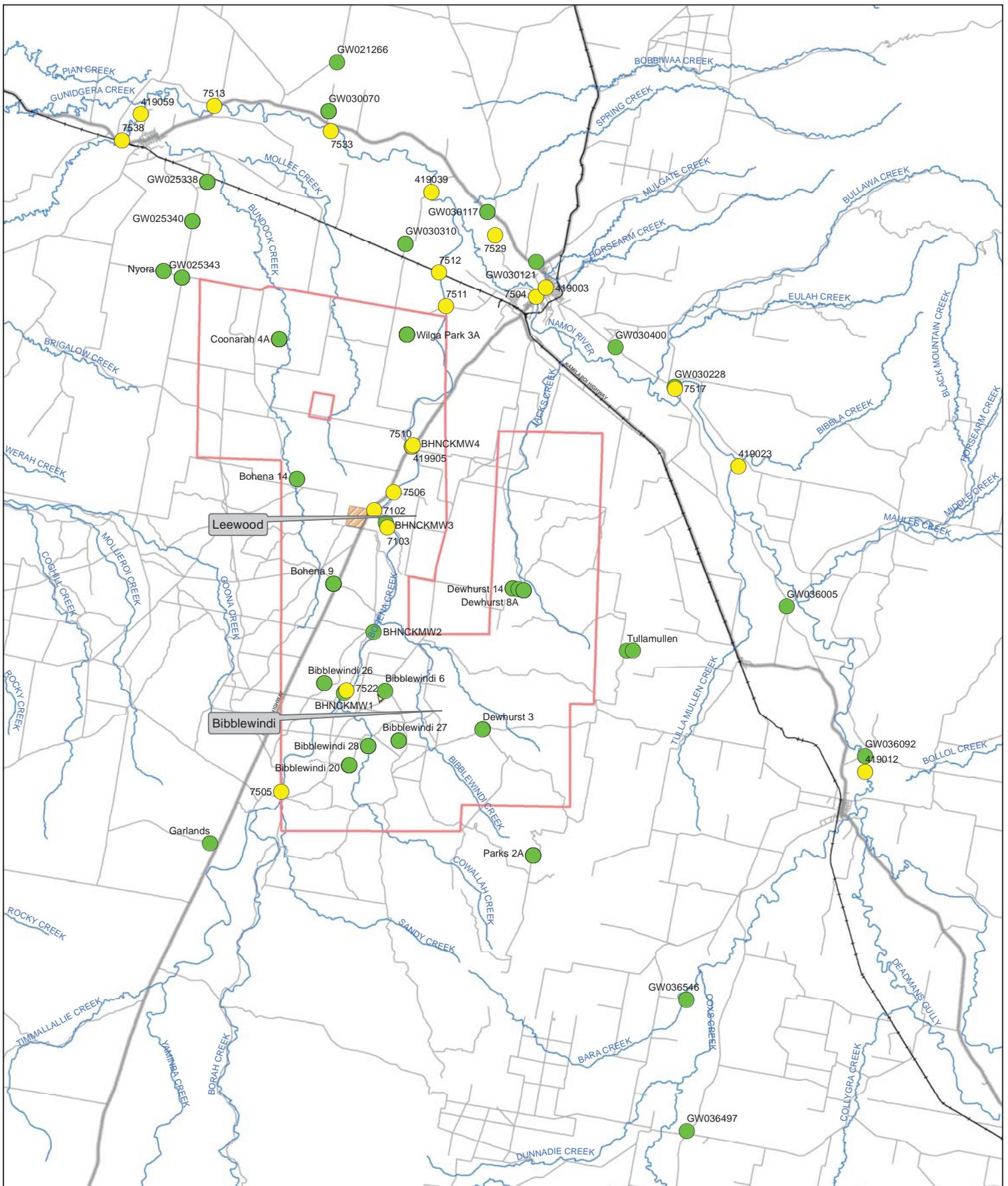
All field-based surface water monitoring data and laboratory results are captured in a centralised database. This methodology allows for automated trend analysis and comparison of data against baseline information and threshold values.

Accordingly, the following sources of data were used to establish baseline surface water quality values for the watercourses potentially impacted by the project:

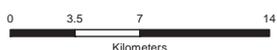
- NSW Department of Primary Industries – Water (DPI Water) surface water monitoring stations (flow gauging). These stations are located on the Namoi River and its tributaries.
- Project sampling locations (water quality). Baseline water quality data has been collected in the study area since 2010. Data collection locations include Bohena Creek and the Namoi River.

The analytes and their concentrations used to establish water quality baseline for Bohena Creek and the Namoi River are presented in Section 12.3.

Refer to Figure 12-4 for the sampling locations used to generate the baseline surface water quality data used in this impact assessment.



- LEGEND**
- Project area
 - Watercourses
 - Baseline surface water monitoring locations
 - Leewood
 - Roads
 - Baseline ground water monitoring locations
 - Bibblewindi
 - Train line



Narrabri Gas Project
Environmental Impact Statement

Job Number | 21-22463
Revision | A
Date | 08 Dec 2016

Baseline surface and groundwater monitoring locations

Figure 12-4

12.1.4 Irrigation

Amended water would be beneficially re-used for crop irrigation in accordance with site assessments consistent with the *Environmental Guidelines: Use of Effluent by Irrigation* (DEC 2004) (refer to Chapter 7). The surface water quality impact assessment for the proposed beneficial reuse of treated water for irrigation is reported in Appendix G2. The assessment identifies that up to around 9,000 hectares of suitable irrigation land may be located within a 20 kilometre radius of Leewood.

The assessment of potential impacts from the proposed beneficial reuse for irrigation (*Irrigation General Concept Report*, BeneTerra 2015 – Appendix G2) used the following methodology:

- a review of available literature, maps and geographical information to identify cropping history and soil boundaries within the study area
- a site visit and discussion with local agronomists, agri-businesses and farmers to investigate crop suitability for the study area
- modelling to assess land area requirements for various crop types and to estimate water storage requirements
- a review of amended water quantity and quality characteristics
- salt balance and assessment of potential soil limitations in accordance with the *Environmental Guidelines: Use of Effluent by Irrigation* (DEC 2004)
- identification of cropping options based on the soil assessment
- development of conceptual layout and design of irrigation infrastructure
- detailed modelling to assess crop water consumption and water storage requirements
- development of an operation, management and monitoring plan.

The water quality used in the irrigation modelling is provided in Table 7-2 in Chapter 7, and represents produced water that has undergone reverse osmosis treatment and amendment with calcium sulfate (gypsum) to decrease, and therefore improve, the sodium adsorption ratio. The addition of calcium and sulfate salts to irrigation water is a relatively common practice, and is undertaken to ensure the water quality is suitable for the receiving environment. The addition of calcium and sulfate salts raises the concentration of total dissolved solids in amended water proposed for beneficial reuse in irrigation from approximately 231 to around 368 milligrams per litre. This salinity is consistent with, or better than, bore water quality used in regional irrigation (Parsons Brinckerhoff 2011).

Computer modelling within the *Irrigation General Concept Design* (Appendix G2) evaluated crop water demands, predicted the storage capacity requirements, and assessed surplus water volumes at the peak estimated (assessed) treated water production rate of around 12 megalitres per day. This approach of assessing nominally higher than the 10 megalitre per day peak treated water production rate provides options for operational flexibility throughout the project.

The irrigation modelling used the short-term (assessed) treated water peak of 12 megalitres per day, estimated to occur in around years two to four of the project. The average treated water volume over the 25-year assessment period for the project would be around 3.9 megalitres per day available for beneficial reuse. Therefore, it becomes apparent that the irrigation infrastructure, including storages, has been designed to a capacity that exceeds its requirements for the majority of the project's 25-year assessment period—that is, all time following the initial two to four-year water peak. The storage capacity over the remaining project life is also more than adequate, with appropriate freeboard in storage ponds build into standard operating procedures.

12.1.5 Dust suppression, construction and drilling

Two water types would generally be used for dust suppression on roads and construction areas—treated water in the forested areas and treated then amended water in the non-forested areas. The treated then amended water would be used in non-forested areas to maintain the permeability and structural longevity of the soil by encouraging aggregate stability of soil particles through reduction of the sodium adsorption ratio of the amended water. As described in Chapter 7, the water amendment balances sodium levels through addition of calcium and sulfate salts such as gypsum.

The potential impacts on surface water quality as a result of beneficially re-using treated, and treated then amended water, for dust suppression and construction (which is also defined in this EIS as drilling activities), were assessed in a semi-quantitative manner using guidance from the ANZECC/ARMCANZ (2000) irrigation guidelines. These guidelines were used as this water reuse option would have largely the same potential environmental impact issues as those assessed for irrigation of treated then amended water to agricultural land. (However, the total quantity of water and frequency of application would be substantially less for dust suppression, drilling and rehabilitation activities than for irrigation).

It is likely that treated water would have an average concentration of total dissolved solids of approximately 200 to 250 milligrams per litre, while treated then amended water would have average concentrations of total dissolved solids of approximately 350 to 400 milligrams per litre (refer to Table 7-2). The difference in total dissolved solids between treated and amended water is due to the addition of gypsum. As noted above, gypsum is typically added to irrigation water to raise the concentration of calcium and improve water quality for the soil. As discussed in Chapter 7, the concentrations of dissolved solids in the treated and amended water are consistent with bore water qualities used regionally for similar activities.

The potential soil impacts from the beneficial reuse of amended water for dust suppression, construction and / or drilling activities are addressed in Chapter 14 of this EIS.

12.1.6 Managed release

Comparative water quality

The potential impacts on surface water quality from managed release of treated water to Bohena Creek were assessed under conditions where a flow rate of 100 megalitres per day, as measured at the Newell Highway gauging station, is met (refer to Appendix G1).

In March 2013, site-specific water quality monitoring was undertaken upstream and downstream of a reach of Bohena Creek proposed for the managed release point. The sample locations for the managed release were a subset of the baseline water quality data collected for the project. Sample results were broadly consistent with historic results, ensuring that the dataset was fit for purpose and representative.

Although Bohena Creek is relatively undisturbed, particularly in the area immediately downstream of the Pilliga State Forest, it also receives runoff from land disturbed to varying degrees by grazing or pastoralism, with exotic species being common (refer to Appendix G1). Under these circumstances and in accordance with ANZECC/ARMCANZ (2000), the default level of protection for 'slightly to moderately disturbed systems' is considered appropriate to meet the management goal of maintenance or improvement of ecological conditions, with the exception of bioaccumulative chemicals such as selenium and mercury. For selenium and mercury, 99 per cent level of protection guideline values for surface water were used as a more conservative and protective approach, as recommended in ANZECC/ARMCANZ (2000). For arsenic and chromium, the guideline values for arsenic V and chromium VI, which are the more toxic forms, were used for evaluating the total concentrations, as a conservative assumption.

A direct toxicity assessment was undertaken to establish site-specific values for boron and fluoride. The assessment was undertaken as boron concentrations in the treated water are expected to exceed the ANZECC/ARMCANZ (2000) default value of 0.37 milligrams per litre. Fluoride on the other hand has no ANZECC/ARMCANZ (2000) value; however, concentrations are expected to exceed the Canadian guideline of 0.12 milligrams per litre (CCME 2009), so a more appropriate site-specific value was derived in accordance with ANZECC/ARMCANZ (2000). In accordance with ANZECC/ARMCANZ (2000), the resulting in-stream guideline values for boron and fluoride were subsequently established at 1.8 and 0.46 milligrams per litre, respectively, against which treated and amended water qualities were compared. Refer to Appendix B of Appendix G1 for detail on the derivation of boron and fluoride in-stream guidelines.

Once guideline values were established, a 'decision tree' framework similar to that presented in ANZECC/ARMCANZ (2000) was used to assess the risk of water quality impacts from the managed release scheme. The following scenarios were undertaken:

- Comparison of treated water concentrations to Bohena Creek guideline values established as described above. As noted above, for boron and fluoride, the in stream, site-specific guideline values determined from a toxicological study as described above were used in place of ANZECC/ARMCANZ (2000) guideline values.
- Comparison of proposed treated water concentrations to baseline concentrations in Bohena Creek.
- Comparison of the baseline concentration of a chemical to its guideline value (when available) to ascertain whether the creek may already be experiencing physicochemical or toxic stresses irrespective of the treated water release.
- Comparison of diluted mixed water (treated water mixed with Bohena Creek water) to parameters that exceed guideline values to ascertain remaining risks following dilution (refer to the discussion below on the model used to undertake the mixing zone analysis).

Mixing zone model

To establish an appropriate dilution ratio for managed release, a mixing zone model was used. The impact assessment used a modelling package recognised by the ANZECC/ARMCANZ (2000) guidelines, as a peer-reviewed model for mixing zone analysis (refer to Appendix E of Appendix G1). The model is an empirical model, based on experimentally derived curve-fit equations that predict the dilution ratio of water quality parameters that verify the accuracy of theoretical models.

The model's major emphasis is on the prediction of dilution characteristics of the initial mixing zone so that compliance with regulatory requirements may be evaluated; or in this instance, impact assessment that would later be compliance monitored against regulatory requirements under an Environment Protection Licence. The system can also predict the behaviour of the discharge plume at larger distances.

In general, the model is suitable for calculating mixing and dilution for a number of different discharge conditions, such as open channel discharges, single pipe discharges, and multiple discharges to rivers, lakes and estuarine systems. The mixing zone modelling considered the conceptual diffuser design as described in Chapter 6, and calculated a blending / dilution ratio to apply to mixing zone calculations such that water quality targets are met.

Supporting documentation

Supporting documentation to assess the potential impacts on surface water quality in Bohena Creek included a *Toxicity Assessment of River Water with the Addition of Boron and Fluoride* (refer to Appendix B of Appendix G1). In addition, the Managed Release Study (Bohena Creek) report (refer to Appendix G1) complements the Water Baseline Report (refer to Appendix G4) by reporting water quality data for the potential release location on Bohena Creek using methodology outlined in ANZECC/ARMCANZ (2000).

12.1.7 Impacts from water extraction

Surface water quality impacts from depressurisation resulting from produced water extraction were assessed in the groundwater impact assessment (refer to Appendix F). A hydrogeological conceptual model was developed to consolidate the current understanding of the groundwater systems of study area broader than the project area (refer Appendix F). The conceptual model is a simplified representation of key features of the groundwater systems, and was based on the interpretation of available data and information.

The conceptual model forms the basis for establishing the environmental values of groundwater and provides the framework for assessing and managing potential groundwater related impacts due to the project, and potentially, subsequent surface water impacts resulting from groundwater impacts identified.

A regional-scale numerical groundwater flow model of the Gunnedah Basin was developed based on the hydrogeological conceptual model referred to above. The groundwater model was used to predict the potential impacts on groundwater sources within the region due to water extraction from the coal seams that would be targeted for gas production.

Simulations of water extraction from the coal seams provide regional-scale predictions of depressurisation and drawdown of hydraulic head within the Gunnedah Basin. They also predict associated induced flows between groundwater sources in successive or neighbouring hydrostratigraphic units, thereby providing a platform for a qualitative approach to assessing potential impacts to surface water quality.

12.2 Existing environment

12.2.1 The Namoi River and tributaries

The Namoi is a major perennial river within the Murray-Darling Basin. It rises on the western slopes of the Moonbi Range and Great Dividing Range, near Niangala, at the convergence of the Macdonald River and Boundary Creek, and flows generally west, joined by 27 tributaries, including the Peel, Manilla and Mooki rivers, before reaching its confluence with the Barwon River, near Walgett. Figure 12-5 shows that the project area lies predominately within the Lower Namoi sub-catchment, with the majority of the project area draining towards the north via two ephemeral creeks, Bohena Creek (running south-east to north) and Jacks Creek, which drain the north-eastern part of the project area.

The Lower Namoi sub-catchment starts at Narrabri and is regulated by two major weirs downstream of Narrabri: Mollee Weir and Gunidgera Weir. Pian Creek is the largest tributary of the Namoi River in the Lower Namoi sub-catchment and is regulated to supply irrigation water to properties along its length. Water generally enters Pian Creek only when the Namoi River is in flood. Water is now diverted into the system from the Namoi River via Gunidgera Weir into Gunidgera Creek, and then into Pian Creek.

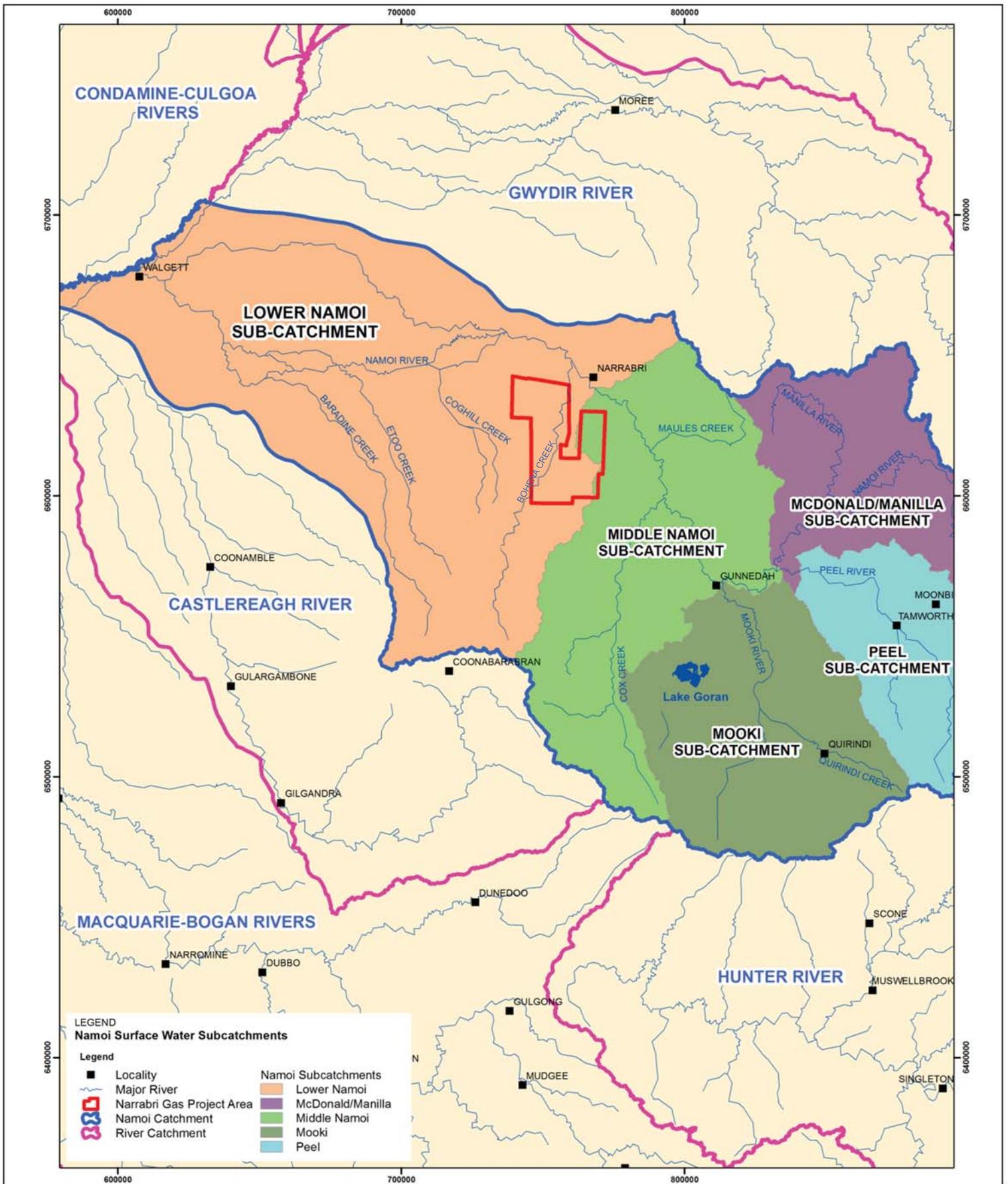
In the northern (primarily flat) areas of the sub-catchment, large areas are used for irrigated cropping including cotton, dryland agriculture and grazing. To the south-west of Narrabri, where the project area is located, is a large low area of land that includes Bohena, Coghill, Etoo and Baradine creeks and many other minor watercourses.

The headwaters of the tributaries are generally in forested conservation areas (Pilliga Forest). The unforested areas of the sub-catchments are used predominately for sheep and cattle grazing and dryland cropping.

The middle Namoi sub-catchment consists of several major tributaries including Bullawa Creek and Maules Creek in the north-east and Cox's Creek in the south. The Cox's Creek Catchment covers around nine per cent of the Namoi catchment area, while Maules Creek Catchment represents around one per cent (NSW Office of Water 2011). The upper reaches of the Bullawa and Maules Creek catchment are in Mt Kaputar National Park and are characterised by steep slopes. The mid slope areas of the sub-catchments are used for grazing while the lower slopes are used for dryland and irrigated cropping.

Cox's Creek rises at the western end of the Liverpool Ranges and flows north towards the Namoi River. Both dryland and irrigated cropping are prominent on the more fertile plains of the sub-catchment. Bohena Creek drains the western, south-western and south-eastern project area, while Jack's Creek drains the north-eastern project area.

The water quality of the Namoi River is generally fresh to slightly brackish. The pH values range from slightly acidic to marginally alkaline. A variety of chemical constituents are recognised as a product of the river's overall catchment, with a primary source of total dissolved solids into the Namoi being agricultural and residential runoff. Those sites that reflect a relatively high concentration of total dissolved solids are located within, or close to, Narrabri township or irrigated areas. Major ions include sodium, chloride, calcium and magnesium, which reflect the dominant water type of the Namoi River. Threshold values derived from the regional water quality baseline data established for the project are shown in Table 12-1.



Kilometres
 0 12.5 25 50

DISCLAIMER
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 Data source: Rivers and Catchments by Geoscience Australia; other data from Santos.



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 Environmental Impact Statement

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Namoi surface water
 subcatchments

Figure 12-5

Table 12-1 Baseline water quality data for the Namoi River

Parameter	Units	No. of samples	Min	Max	Ave	Median	16 th percentile	84 th percentile
Barium	mg/L	93	0.001	0.058	0.030	0.028	0.0207	0.0413
Boron	mg/L	93	0.05	0.44	0.056	0.05	0.05	0.05
Calcium	mg/L	93	3	54	28.66	27	20	40
Chloride	mg/L	93	6	86	31.96	29	12	51
Electrical Conductivity - Field	µS/cm	100	128.1	921	396.7	372.0	271.0	544.6
Fluoride	mg/L	92	0.1	0.5	0.19	0.2	0.1	0.2
Lithium	mg/L	93	0.001	0.004	0.001	0.001	0.001	0.001
Manganese	mg/L	93	0.001	0.68	0.040	0.003	0.001	0.053
pH - Field	pH units	100	5.7	9.3	7.8	8	7.1	8.4
Potassium	mg/L	93	2	11	4.6	4	3	6
Sodium	mg/L	93	7	120	32.9	32	21	46
Sodium Adsorption Ratio	number	93	0.6	3.77	1.18	1.16	0.89	1.42
Strontium	mg/L	93	0.001	0.573	0.310	0.3	0.206	0.45
Total Dissolved Solids - Field	mg/L	93	81	486	247.5	248	165.7	328

The water quality data of the Namoi, including data shown in Table 12-1 suggests that:

- the water quality of the Namoi River ranges from fresh to very slightly brackish, with average electrical conductivity concentrations around 400 microsiemens per centimetre, and average total dissolved solids concentrations of around 250 milligrams per litre
- the water has an average pH value of 7.8
- a variety of chemical constituents are recognised as a product of activities within the greater Namoi Catchment, with the main source of total dissolved solids being agriculture and residential runoff
- major ions include sodium, chloride, and calcium, which reflect the dominant water type of the Namoi River
- electrical conductivity normally exceeds the ANZECC/ARMCANZ (2000) guideline for 95 per cent protection of aquatic species, being 30 to 350 microsiemens per centimetre (upland rivers); though is within the range of 125 to 2,200 for lowland rivers. The background electrical conductivity values may be attributed to agricultural and dryland cropping activities in which accumulated salts can be mobilised and discharged into surface water during rainfall events
- elevated electrical conductivity values are generally observed during periods of low flow with some indications of peaks following small rainfall events.

The interaction between regional surface water and groundwater including regional recharge zones is discussed in Appendix F, including how the groundwater supports groundwater dependant ecosystems (refer to Appendix B of Appendix F).

12.2.2 Bohena Creek

Overview

Bohena Creek is predominantly an ephemeral watercourse that flows in a generally northerly direction through the project area and eastern Pilliga Forest to its confluence with the Namoi River approximately 12 kilometres downstream of the Narrabri township. Being ephemeral, Bohena Creek flows mainly during and after heavy rainfall events and can remain dry for extended periods between rainfall events—sometimes for more than 12 months (refer to Figure 12-6). It is understood that Bohena Creek contributes little inflow to the Namoi River under normal conditions. However, during protracted wet conditions, significant flood inflows to the Namoi River can be generated. Bohena Creek is shown in Figure 12-7, along with the other main watercourses within the project area.

Bohena Creek is classified as a lowland chain of symmetrical, discontinuous ponds separated by poorly defined channel depressions, swampy fills and / or sand deposits (Lampert and Short 2004). Bohena Creek has a naturally low nutrient status due to a sand-dominated substrate lacking in organic matter and perennial flow.

The largest tributaries that drain into Bohena Creek are:

- Spring Creek, which is an undisturbed watercourse that joins Bibblewindi Creek
- Yellow Spring Creek, which runs south-east to north-west to join Bibblewindi Creek
- Bibblewindi Creek, which runs north westwards to Bohena Creek
- Mt Pleasant Creek, which runs north west to Cowallah Creek
- Cowallah Creek, which runs northwards to join Bohena Creek.

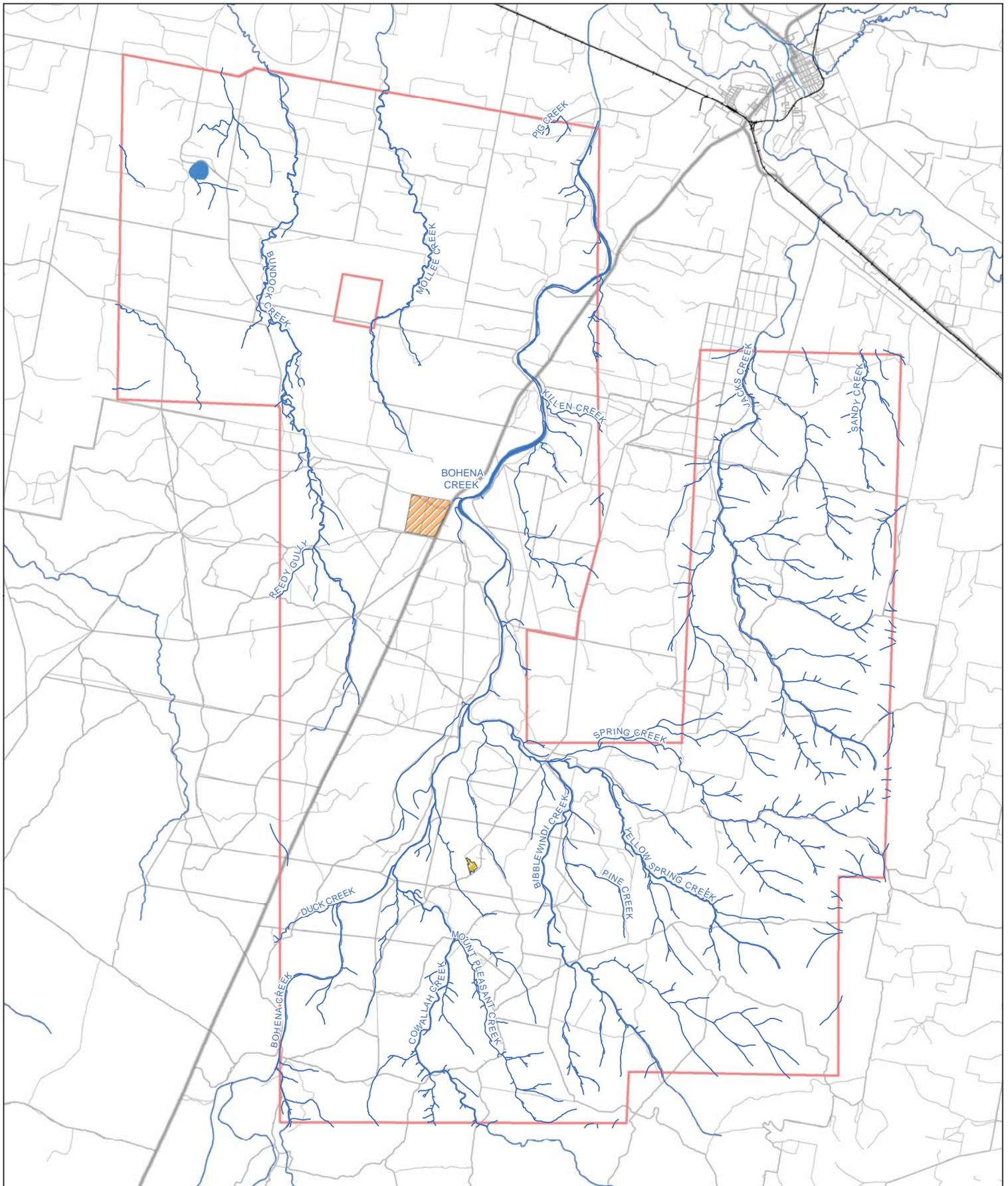
All tributaries draining to Bohena Creek are considered to be highly ephemeral and only flow during periods of heavy rain. The shallow regolith / soil gives high runoff rates and highly variable, peaky discharges (Lampert and Short 2004). As noted above, all creeks ultimately drain to the Namoi River, whose catchment forms part of the Murray-Darling Basin.

As a result of the highly ephemeral nature of the Bohena Creek tributaries, no representative baseline water quality data exists for Spring, Yellow Spring, Bibblewindi, Mt Pleasant or Cowallah Creeks. Note that project water management activities do not directly include these creeks.

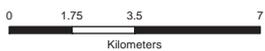
Treated water managed release is limited to Bohena Creek; therefore, baseline monitoring has focused on Bohena Creek and the Namoi River. To compensate for the lack of water chemistry data for the major Bohena Creek tributaries, Bohena Creek surface water monitoring locations (refer to Chapter 30) have been strategically located up and down catchment of the proposed managed release point adjacent to Leewood to detect influences introduced by the proposed project activities.



Figure 12-6 A dry reach of the ephemeral Bohena Creek



- LEGEND**
- Project area
 - Watercourses
 - Leewood
 - Roads
 - Bibblewindi
 - Train line
 - Lakes and dams



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Existing watercourses
in the study area

Figure 12-7

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

Baseline

Due to the regular lack of flow in Bohena Creek, water samples collected during flow events and samples collected from pools within the creek were combined to establish baseline values. The baseline water quality data for Bohena Creek for the period February 2012 to October 2015 for key analytes is shown in Table 12-2.

Table 12-2 Baseline water quality data for Bohena Creek

Parameter	Units	No. of samples	Min	Max	Ave	Median	16 th percentile	84 th percentile
pH - Lab	pH units	40	5.6	8.1	7.1	7.2	6.5	7.6
Barium	mg/L	39	0.023	0.182	0.049	0.041	0.025	0.065
Boron	mg/L	39	0.05	0.05	0.05	0.05	0.05	0.05
Calcium	mg/L	39	2	21	7.4	7	4	10
Chloride	mg/L	39	16	102	37.5	34	24.1	54.8
Electrical Conductivity - Field	µS/cm	39	102.9	447.4	216.0	211.5	128.1	293.5
Fluoride	mg/L	39	0.1	0.1	0.1	0.1	0.1	0.1
Lithium	mg/L	39	0.001	0.001	0.001	0.001	0.001	0.001
Manganese	mg/L	39	0.004	2.63	0.34	0.08	0.01	0.75
Potassium	mg/L	39	2	9	3.46	3	2	4.92
Sodium	mg/L	39	9	47	26.64	25	16	39.76
Sodium Adsorption Ratio	number	39	0.71	3	1.63	1.53	1.07	2.23
Strontium	mg/L	39	0.034	0.295	0.111	0.102	0.060	0.153
Total Dissolved Solids - Field	mg/L	40	86	586	191.5	178.0	127.4	236.1

The baseline water quality data for Bohena Creek can be summarised as follows:

- the water quality of Bohena Creek is generally fresh, with average electrical conductivity concentrations of 216 microsiemens per centimetre, and concentrations of total dissolved solids averaging around 200 milligrams per litre
- the water is generally neutral with an average pH value of 7.1
- major ions include sodium, and chloride, which reflect the dominant water type
- the lower electrical conductivity values measured in Bohena Creek relative to the Namoi River are likely to be indicative of freshwater recharge, consistent with electrical conductivity values in the Bohena Creek alluvium.

12.3 Potential impacts – construction

12.3.1 Erosion and sedimentation

Construction of the project would involve disturbance of the ground surface, most notably at Leewood and Bibblewindi, and along the two infrastructure corridors; particularly at creek crossings. The Bibblewindi to Leewood infrastructure corridor crosses Bohena Creek and an unnamed tributary. Bohena Creek is identified as being at moderate risk of disturbance at the crossing point, while the unnamed tributary is identified as being at high risk (refer to Chapter 13).

Potential impacts associated with watercourse crossings include destabilisation of watercourses due to direct disturbance resulting in localised erosion and off-site sediment mobilisation and transport, potentially leading to turbidity and sedimentation of watercourses.

However, construction during no-flow conditions, and implementation of the erosion and sediment control plan would minimise potential impacts to Bohena Creek and the unnamed tributary.

The Leewood to Wilga Park infrastructure corridor does not pass through creeks, and therefore, water quality impacts are not expected.

12.3.2 Spills

Accidental spills of fuel, drilling additives (although mostly biodegradable), produced water, chemicals and / or cement could impact water quality. If inadequately controlled, changes to water quality could impact on the aquatic ecology of watercourses (refer to Chapter 16 – Aquatic ecology) and / or downstream water users. Refer also to Chapters 14 (Soils and land contamination) and 25 (Hazard and risk) for the assessment of produced water leaks and spills, and pond failure respectively.

The risks of these potential construction impacts would be managed in a comprehensive and routine manner using an environmental management strategy that incorporates materials handling and refuelling protocols, and staff inductions, amongst other initiatives. Construction activities at Bibblewindi and Westport are relatively remote from watercourses, thereby lowering the risk of spills impacting surface water quality, with Bibblewindi being approximately two kilometres from the closest watercourse within the project area.

The risk of impacts would also be managed by handling and storing chemicals in accordance with relevant Australian Standards, including AS 1940-2004 *The storage and handling of flammable and combustible liquids*. Refuelling would occur in areas of suitable containment when volumes greater than 50 litres are involved and not within 40 metres of a waterway.

12.3.3 Dust suppression, construction and drilling

The over-application of treated and / or amended water for dust suppression, construction activities and / or drilling could potentially cause water quality impacts by adding salt, notwithstanding the low salinity of the treated water that would be used. This impact would be managed through routine procedures that would be integrated into the environmental management strategy for the project to ensure that the risk of over-application or use is minimised.

The risk was assessed by comparing the water qualities of the three water types that would be used for dust suppression, construction and / or drilling being bore water, treated water in the forested areas and amended water in the agricultural areas, against baseline values for Bohena Creek (refer to Table 12-3).

It is important to note that no produced water would be used in dust suppression activities. Average bore, treated and amended water chemistry data are presented against a range of key Bohena Creek baseline parameters in Table 12-3.

Table 12-3 Comparison of dust suppression, construction and drilling water with Bohena Creek baseline water quality

Parameter	Treated water ^a	Amended water ^b	Leewood bore water	Baseline ^c 16 %	Baseline ^c 84 %
	Target (mg/L)	Target (mg/L)	Ave (mg/L)	mg/L	mg/L
Electrical conductivity ($\mu\text{S}/\text{cm}$)	357	566	237	128.1	293.5
Total dissolved solids (TDS)	232	368	145	127.4	236.1
Sodium	77	77	19	16	39.76
Potassium	0.8	0.8	20	2	4.92
Calcium	0.01	40.01	3.3	4	10
Manganese	<0.001	<0.001	0.29	0.01	0.75
Boron	0.12	0.12	<0.05	0.05	0.05
Barium	<0.001	<0.001	0.33	0.025	0.065
Chloride	15	15	36.5	24.1	54.8
Fluoride	0.08	0.08	<0.1	0.1	0.1

^a For managed release into Bohena Creek, and beneficial reuse in certain dust suppression scenarios, drilling and construction. Post Stage 5 of treatment as shown in Chapter 7.

^b For beneficial reuse in irrigation, and certain dust suppression scenarios. Post Stage 6 of treatment as shown in Chapter 7.

^c Regional baseline values for Bohena Creek from Appendix G4.

The data in Table 12-3 indicate that for the treated water that would typically be used for dust suppression activities in the forested areas, the electrical conductivity, sodium and boron concentration are likely to exceed the 84th percentile of the Bohena Creek baseline water quality.

The data in Table 12-3 indicate that for the amended water that would be used for dust suppression activities in the agricultural areas, electrical conductivity, total dissolved solids, boron, sodium, calcium and the sodium adsorption ratio would exceed the 84th percentile of the Bohena Creek baseline water quality.

The data in Table 12-3 indicate that for the bore water that would be used for dust suppression activities, electrical conductivity, potassium and barium would exceed the 84th percentile of the Bohena Creek baseline water quality.

Analytes that exceed the 84th percentile baseline provide an indicator of risk should large quantities, spills or over application of dust suppression, construction and / or drilling water find its way into Bohena Creek, by compromising water quality by increasing concentrations of those respective analytes. To mitigate the risk of compromising Bohena Creek water quality, management measures would be implemented whereby the treated and amended water would be used in a manner that prevents and / or minimises runoff and avoids impacts on sensitive environments.

Note also that the comparison above is indicative only and assumes that treated and / or amended water is directly introduced into Bohena Creek by comparing against baseline water quality. It does not consider environmental factors such as dilution effects from rainfall events and / or catchment runoff for example. It

is therefore a conservative assessment. The mixing zone model compares treated water quality against derived and ANZECC/ARMCANZ (2000) guideline values (refer to Appendix E of Appendix G1).

Mitigation measures are provided in Section 12.5 that include:

- managing spraying to avoid ponding and runoff of water
- avoiding spraying during significant rainfall events
- adjusting application rates based on surface conditions and frequency of application
- routine visual inspections to check for ponding or runoff.

The application of these management and mitigation measures reduces the dust suppression, construction activities and / or drilling risk from medium to low as shown in Section 12.6.

12.4 Potential impacts – operation

Key potential surface water quality impacts associated with the operation of the project may include:

- ongoing surface water quality impacts through depressurisation
- accidental spills and / or leaks of produced water
- accidental spills and / or leaks of hydrocarbons and other fluids during routine maintenance activities
- inappropriate stormwater management impacting watercourses
- impacts realised from inappropriate implementation of the Produced Water Management Plan, potentially including:
 - excess water runoff from dust suppression activities
 - excess water runoff from irrigation activities
 - stock watering
 - changes to the water quality of Bohena Creek as a result of the managed release scheme
- erosion and sedimentation.

The potential significance of these impacts is considered below.

12.4.1 Erosion and sedimentation

Potential impacts to water quality from the operation of well pads, linear infrastructure and linear infrastructure at creek crossings may also be realised. Routine maintenance activities, if not adequately managed, could result in an increase in sediment loads entering local watercourses, increasing turbidity and suspended particulate levels.

These potential operational impacts would be comprehensively and routinely managed using an environmental management strategy that incorporates an Erosion and Sediment Control Plan, and staff inductions.

The Erosion and Sediment Control Plan would be prepared and implemented in accordance with the requirements outlined in *Managing Urban Stormwater: Soils and Construction Vol 1'* (Landcom 2004).

The Erosion and Sediment Control Plan would also refer to relevant Volume 2 guidance including:

- *Managing Urban Stormwater: Soils and Construction Vol 2A Installation of Services* (DECC 2008)

- *Managing Urban Stormwater: Soils and Construction Vol 2C Unsealed Roads* (DECC 2008a).

A Soil Management Plan would also be developed for implementation under the project's environmental management strategy (refer to Chapter 30 – Environmental management and monitoring).

Further discussion on erosion and sediment control is provided in Chapter 14.

12.4.2 Water extraction

The potential impacts on surface water systems, including springs within the vicinity of the project area, as a result of depressurisation during the operational stage of the project are expected to be minor or negligible. Potential impacts from depressurisation may include increased concentrations of some chemical constituents as a result of reduced baseflow in watercourses. For significant impacts on aquatic and terrestrial ecosystems to occur, inter-formational flows induced by coal seam depressurisation must first propagate through thick stratigraphic sequences above the target coal seams. Much of the stratigraphy overlying the coal seams has very low permeability (refer to Appendix F), and is likely to significantly impede the rate of inter-formation flows.

Groundwater modelling results from simulated water production curves predict no drawdown greater than 0.5 metres in the Pilliga Sandstone within the project area, and even smaller drawdown at the water table within alluvial groundwater sources within the project area.

The potential impacts on the surface water network and the shallow aquifer systems in the project area are predicted to be negligible.

12.4.3 Spills and leaks

Accidental spills of fuel, produced water and / or chemicals could impact surface water quality. If inadequately controlled, changes to surface water quality could impact on the aquatic ecology of watercourses (refer to Chapter 16 – Aquatic ecology) and / or downstream water users. This risk would be managed by the implementation of standard operating procedures, protocols and inductions. This would include the installation of bunding at hydrocarbon and chemical storage facilities to Australian Standards to contain potential chemical spills or leaks. The risk is further reduced by the relative location of Bibblewindi (approximately two kilometres) to watercourses within the project area. Therefore, and considering the low initial risk of a spill occurring, it is unlikely that if a spill was to occur, that it would find its way into a major surface water body prior to being ameliorated under the Trigger Action and Response Plan and Pollution Incident Response Management Plan.

In addition, spills and / or leaks may come from produced water gathering lines, pipelines and / or produced water or brine ponds at Leewood and Bibblewindi, potentially mobilising naturally occurring radionuclides in the soil. Leaks and / or spills are considered unlikely given design and operational level engineering controls and monitoring, in accordance with relevant guidelines and standards, that would form part of the project.

This risk would be addressed by designing and managing the produced water and brine ponds at the Leewood and Bibblewindi facilities in accordance with relevant standards. They would incorporate a number of design and operational features to ensure that their integrity is maintained, and to avoid the potential for accidental spills and leaks; including:

- the location of the water treatment plant being at Leewood rather than in State forest
- the fact that the water treatment plant is bunded
- Leewood and Bibblewindi produced water and brine pond design meeting or exceeding the requirements in the *Exploration Code of Practice: Produced Water Management, Storage and*

Transfer (NSW Department of Industry, Skills and Regional Development 2015c) with produced water / brine ponds being double-lined with seepage collection pumps installed between the liners and also beneath the secondary liner

- produced water pipelines being monitored for pressure drops that would indicate a leak
- regular equipment inspections
- an equipment maintenance plan would be developed such that water transfer and storage infrastructure is proactively maintained
- the option of well shut in should an incident occur, thereby eliminating the produced water source
- a Produced Water Management Plan would be developed and approved by the NSW Government
- development of a Trigger Action and Response Plan and Pollution Incident Response Management Plan.

The mitigation and risk profile of produced water and / or brine spills acknowledges the historic incidents on site (refer to Chapter 14); however, initiatives and upgrades have and are being made to legacy infrastructure that did not meet Government standards to significantly reduce the likelihood of further incidents.

Impacts would also be managed by handling and storing chemicals in accordance with relevant Australian Standards, including AS 1940-2004 *The storage and handling of flammable and combustible liquids*. Refuelling would occur in areas of suitable containment when volumes greater than 50 litres are involved and not within 40 metres of a waterway.

Refer to Chapter 14 (Soils and land contamination) for additional assessment on the risk of produced water spills, and Chapter 25 (Hazard and risk) for an assessment of the risk of a major incident from produced water and brine ponds.

12.4.4 Stormwater management

A number of relatively impervious areas would be introduced into the project area, particularly at Leewood, Bibblewindi and Westport. If inadequately controlled, runoff from these surfaces could increase potential pollution loads in stormwater, such as hydrocarbons, oils, sediments and dust.

As mitigation, the proposed facilities would have appropriate stormwater design to ensure minimal potential for uncontrolled or untreated runoff into the environment.

12.4.5 Dust suppression

The potential environmental impacts of dust suppression water are discussed in Section 12.3.3. Potential impacts would be applicable throughout routine operations. Around two megalitres per day of treated and amended water at peak produced water generation would be beneficially re-used in years two to four in dust suppression activities, and around one megalitre per day on average thereafter.

Relative water qualities are discussed in Section 12.3.3. In summary, the quality of treated and amended water used for dust suppression is relatively consistent with the baseline water quality of the receiving catchments, with minor exceptions. The comparison is indicative only and assumes that treated and / or amended water is directly introduced into Bohena Creek by comparing against baseline water quality. It does not consider environmental factors such as infiltration, and dilution effects from rainfall events and / or catchment runoff for example. It is therefore a conservative assessment.

Potential impacts resulting from dust suppression would be managed through routine procedures that would be integrated into the environmental management strategy for the project (refer to Chapter 30 – Environmental management and monitoring).

12.4.6 Irrigation and stock watering

The application of amended water for irrigation by a third party has the potential to result in the following water quality impacts:

- excess runoff could disturb the ground surface mobilising sediments and contaminants into receiving waters
- the potential for change in the quality of water leaving irrigation areas as a result of the quality of the irrigation water—either via surface runoff or in deep drainage plumes carrying dissolved solutes or pollutants. The deep drainage impact is discussed in Chapter 11 – Groundwater and geology.

Based on the expected chemistry of the amended water, irrigation water would be classified as 'low to medium strength effluent' in accordance with *Environmental Guidelines: Use of Effluent by Irrigation* (DEC 2004). However, if managed correctly through the use of an Irrigation Management Plan, there is a low risk of irrigation water causing impact to surface water quality through runoff.

Potential impacts on surface water quality from the managed irrigation scheme are addressed in the *Irrigation General Concept Design* (refer to Appendix G2, which involved assessing the viability of using treated water for irrigation in the study area, and the potential for environmental impacts).

As described in the *Irrigation General Concept Design*, the proposed irrigation areas would be selected because of their suitability for operation as part of the water management system. The process of selecting and assessing the suitability of the sites is described in the report.

The assessment determined that there is an excess of suitable land available that could be used for irrigation—approximately 9,000 hectares within a 20 kilometre radius of Leewood. However, as the final site selection would be subject to a commercial arrangement with the landholder, a hypothetical site with applicable soil types, geomorphology and drainage was used in the concept design report.

The operational and management concept for irrigation was developed as an outcome of the assessment, to ensure negligible impacts on soils and water quality. Potential impacts on soils from the irrigation scheme are discussed in Chapter 14 (Soils and land contamination). The concept for irrigation was developed to achieve the performance objectives of *Environmental Guidelines: Use of Effluent by Irrigation* (DEC 2004), in addition to comparison against baseline surface water quality data.

The quality of amended water proposed for use in irrigation is shown in Table 7-2 and Table 12-4. Data indicates that at both peak (assessed at around 12 megalitres per day) and longer-term average (around 4 megalitres per day) treated water production rates, salt application rates to irrigation land would be consistent with, or better than, bore water chemistry used regionally for irrigation (Parsons Brinckerhoff 2011).

The irrigation model was run using the peak (assessed) daily treated water production rate of around 12 megalitres per day on irrigated lucerne to assess the potential impacts from irrigation. The assessment indicated that runoff would most likely be driven by rainfall events and small amounts of sediment and nutrients would be carried. Losses of sediment and nutrients from irrigated project areas would be monitored under an Irrigation Management Plan.

Therefore, if managed correctly through the use of an Irrigation Management Plan, there is a low risk of irrigation water causing impact to surface water quality through runoff.

Table 7-2 also compared the quality of treated water proposed for use in stock watering activities against ANZECC/ARMCANZ (2000) stock watering guidelines for beef cattle, sheep, pigs and horses. The comparison indicates that the treated water is suitable for the proposed activity of stock watering.

12.4.7 Managed release

The proposed managed release of treated water to Bohena Creek would occur only when flow equals, or exceeds, 100 megalitres per day at the Newell Highway gauging station. Modelling undertaken in the Bohena Creek managed release study (refer to Appendix G1) estimates that only a small proportion of treated water may require managed release, primarily during the relatively short duration of expected treated water peak volumes in around years two to four of the project.

The project would seek to operate under a toxicity based Environment Protection Licence issued by the Environmental Protection Authority. The licencing approach is consistent with the Environment Protection Authority Licensing Fact Sheet: *Using Environment Protection Licensing to Control Water Pollution* (NSW EPA 2013).

The treated water quality data and managed release assessment guideline values used for the toxicity assessment (refer to Appendix G1) are presented in Table 12-4.

Table 12-4 Treated water quality data against assessment guideline values

Constituent	Basis of assessment values				
	Units	Target treated water quality ^a	80 th percentile baseline – Bohena Creek ^e	ANZECC/ARMCANZ (2000) guideline value ^b	Basis ^c
Electrical conductivity (lab)	µS/cm	357	197	30 – 350 (upland rivers) 125 – 2,200 (lowland rivers)	ANZECC/ARMCANZ (2000)
pH (Field)	pH Units	7.1	7.4 (lab)	6.5 – 7.5	ANZECC/ARMCANZ (2000)
Total dissolved solids (TDS - calculated)	mg/L	232	115	-	[see note b]
Turbidity	NTU	<0.5	59.2	2.0 - 25.0	ANZECC/ARMCANZ (2000)
Alkalinity (carbonate as CaCO ₃)	mg/L	139	52	-	[see note b]
Calcium (filtered)	mg/L	0.01	6.8	-	[see note b]
Fluoride	mg/L	0.08	<0.1	0.46	Direct toxicity assessment
Nitrogen (total)	mg/L	0.005	0.8	250	80 th percentile background levels
Phosphorus	µg/L	<0.01	0.094	20	80 th percentile background levels

Constituent	Basis of assessment values				
	Units	Target treated water quality ^a	80 th percentile baseline – Bohena Creek ^e	ANZECC/ARMCANZ (2000) guideline value ^b	Basis ^c
Silica	µg/L	23	16,220	-	80 th percentile background levels
Sodium (filtered)	mg/L	77	18	-	[see note b]
Sulphate	mg/L	0.003	<1.0	-	[see note b]
Aluminium	mg/L	<0.001	1.95	0.055	80 th percentile background levels
Arsenic	mg/L	<0.001	<0.002	0.013	ANZECC/ARMCANZ (2000)
Barium	mg/L	<0.001	0.055	-	80 th percentile background levels
Boron	mg/L	0.12	<0.05	1.8	Direct toxicity assessment
Cadmium ^d	mg/L	<0.001	<0.0003	0.0002	ANZECC/ARMCANZ (2000)
Chromium (VI)	mg/L	<0.001	0.004	0.001	ANZECC/ARMCANZ (2000)
Cobalt	mg/L	<0.001	0.004	-	80 th percentile background levels
Copper	mg/L	<0.001	0.001	0.0014	ANZECC/ARMCANZ (2000)
Iron	mg/L	<0.001	7.742	-	80 th percentile background levels
Lead	mg/L	<0.001	<0.005	0.0034	ANZECC/ARMCANZ (2000)
Magnesium (filtered)	mg/L	0.01	7.0	-	[see note b]
Manganese	mg/L	<0.001	0.248	1.9	ANZECC/ARMCANZ (2000)
Mercury	mg/L	0.0000067	<0.0001	0.0006	ANZECC/ARMCANZ (2000)
Nickel	mg/L	<0.001	0.006	0.011	ANZECC/ARMCANZ (2000)
Selenium (total)	mg/L	<0.001	<0.01	0.011	ANZECC/ARMCANZ (2000)
Zinc	mg/L	<0.001	0.003	0.008	ANZECC/ARMCANZ (2000)

a For managed release into Bohena Creek, and beneficial reuse in certain dust suppression scenarios, drilling and construction. Post Stage 5 of treatment described in Chapter 7.

b Triggers are not provided for TDS, alkalinity, calcium, sodium, sulphate and magnesium. ANZECC / ARMCANZ (2000) values provided for south-east Australia freshwater upland rivers at the 95 per cent level of protection (per cent of species. Both upland (30-350 microSiemens per centimetre and lowland 125-2,200 microSiemens per centimetre) are presented for electrical conductivity.

c Proposed managed release limits represent the higher of either the trigger value or the 80th percentile background concentration.

d Note that trigger values are below the analysed laboratory limit of detection, in which case, a value of 50 per cent of the limit of detection has been used for data assessment purposes to be conservative.

e From Table 5-1 of Appendix A to Appendix G1 of this EIS

Where directly comparable, the treated water data do not exceed Bohena Creek trigger values with the exception of 7 microSiemens per centimetre electrical conductivity for the upland river criteria; the target treated water quality is within the lowland criteria (Table 12-4). To support the assessment, a mixing zone assessment was undertaken (refer to Attachment E of Appendix G1) for boron, filtered sodium, copper, arsenic, cadmium, mercury, alkalinity, ammonia as nitrogen, total nitrogen, chloride, fluoride and filtered magnesium. The results showed that none of these analytes exceeded the assessment guideline values.

Baseline water quality was compared to ANZECC/ARMCANZ (2000) default trigger values (when available to ascertain whether Bohena Creek may already be experiencing chemical stress irrespective of the proposed treated water release (refer to Table 5-1 in Appendix G1). A comparison of background concentrations to trigger values suggest that Bohena Creek may already be under stress from increased levels of total nitrogen, phosphorus, aluminium, and chromium from sources unrelated to the project.

On the basis of analysis to date, ecological risks from the physicochemical and chemical stressors and toxicants that may be present in treated water for release are considered low or manageable. In particular, comprehensive numerical mixing zone analysis indicates that rapid mixing can be achieved and effective dilution would eliminate possible toxicity risks in flowing conditions (that is, flow equal to, or greater than, 100 megalitres per day).

It remains important to consider that the guideline values for Bohena Creek were derived for the purposes of impact assessment only. The project would seek to operate under a toxicity based Environment Protection Licence issued by the Environmental Protection Authority for operational compliance.

12.5 Mitigation and management

12.5.1 Erosion and sedimentation

During construction, operation and decommissioning, potential impacts of sedimentation would be managed using an Erosion and Sediment Control Plan, and staff inductions. This mitigation and management tool would be most prevalent when constructing (and maintaining) linear infrastructure positioned across ephemeral watercourses. The Erosion and Sediment Control Plan would include:

- allocation of general site practices and responsibilities
- material management practices
- surface water and erosion control practices
- monitoring practices
- rehabilitation plans.

Site rehabilitation would be undertaken on disturbed areas to minimise the risk of runoff and erosion. Refer to Appendix W for the decommissioning report and Appendix V for the rehabilitation strategy. The Erosion and Sediment Control Plan would be prepared in accordance with the following guidelines:

- *Managing Urban Stormwater: Soils and Construction Vol 1'* (Landcom 2004)
- *Managing Urban Stormwater: Soils and Construction Vol 2A Installation of Services* (DECC 2008)
- *Managing Urban Stormwater: Soils and Construction Vol 2C Unsealed Roads* (DECC 2008a).

A Soil Management Plan would also be developed for implementation under the project's environmental management strategy (refer to Chapter 30 – Environmental management and monitoring).

12.5.2 Spills and leaks

The risk of impacts from produced water, chemical and hydrocarbon spills would be mitigated through both design and operational level mitigation methods. Potential construction, operational and decommissioning impacts would be comprehensively and routinely managed using an environmental management strategy that incorporates materials handling and refuelling protocols, and staff inductions. Further, bunding would be incorporated at hydrocarbon and chemical storage facilities to Australian Standards to contain potential chemical spills or leaks.

An infrastructure monitoring program would be implemented across produced water and brine storage facilities as well as gathering and transfer infrastructure. Storage ponds would be subject to the surveillance requirements for 'prescribed dams' under the *NSW Dams Safety Act 1978*, which include inspection and reporting of the condition of the ponds including embankment slopes, crest and spillway, presence of erosion, vegetation, seepage and monitoring instrumentation.

In relation to the operation of the produced water storage facilities, in the event that an elevated water level, in excess of a pre-defined trigger level (such as the maximum operating level), is recorded, operators would respond in accordance with responses set out in the Trigger Action and Response Plan.

A Trigger Action and Response Plan sets out the actions to be undertaken in response to situations outside of normal operating conditions. The objective of the Trigger Action and Response Plan is to minimise and manage risks to human safety, the environment, property and operations. It would also include directions on internal and external reporting and notification procedures in accordance with legislative requirements. Actions that would be considered if the maximum operating level were exceeded include 'shutting in' wells to cease the production of produced water, reducing the water levels through transferring water to other produced water storages, and removing water for treatment and disposal at an appropriately licensed facility.

A summary of design and operational features to ensure that the integrity of produced water and brine treatment, transport and storage infrastructure is maintained, and to avoid the potential for accidental spills and leaks impacting surface water quality include:

- locating the water treatment plant at Leewood rather than in the State forest
- bunding around the water treatment plant to Australian Standards
- the distance of the water treatment plant from fifth or sixth order watercourses being some 400 metres from Leewood
- the distance of Bibblewindi ponds from fifth or sixth order watercourses being around two kilometres
- Leewood and Bibblewindi produced water and brine pond design meeting or exceeding the requirements in the *Exploration Code of Practice: Produced Water Management, Storage and Transfer* (NSW Department of Industry, Skills and Regional Development 2015c) with produced water / brine ponds being double-lined with seepage collection pumps installed between the liners and also beneath the secondary liner
- monitoring produced water pipelines for pressure drops that would indicate a leak
- regular equipment inspections
- an Equipment Maintenance Plan would be developed such that water transfer and storage infrastructure is proactively maintained
- the option of well shut in should an incident occur, thereby eliminating the produced water source

- a Produced Water Management Plan would be developed and approved by the NSW Government
- development of a Trigger Action and Response Plan and Pollution Incident Response Management Plan.

In accordance with the requirements of the *NSW Dams Safety Act 1978*, a Dam Safety Emergency Plan would be provided to the NSW Dam Safety Committee for new ponds constructed as part of the project. The Plan would provide emergency response procedures for managing ponds in the event of an imminent or actual uncontrolled release from the ponds.

12.5.3 Water extraction

The potential impacts on the surface water network and the shallow aquifer systems in the project area, which are used for accessing surface water and groundwater for stock, domestic and agricultural purposes, are predicted to be negligible as a result of target coal seam depressurisation.

Nevertheless, monitoring would enable confirmation and validation that no change is occurring. Should the monitoring indicate a trend towards a potential impact, this early identification would allow for appropriately scaled management actions to avoid the impacts and 'make good' on potential adverse impacts.

Refer to Appendix G3 – Water Monitoring Plan, for further detail.

12.5.4 Stormwater management

The proposed facilities would incorporate appropriate stormwater design to ensure minimal potential for uncontrolled or untreated runoff into the environment.

The Water Monitoring Plan would also ensure that appropriate assessment criteria were incorporated to identify inappropriate stormwater management practices.

12.5.5 Dust suppression, construction and drilling

Standard operational procedures for dust suppression, construction and drilling (including treated water use in rehabilitation) would be integrated into the environmental management strategy for the project. Dust suppression management would also be incorporated into an Air Quality Management Plan, which would be a sub-plan to the Environmental Management Strategy. Specific mitigation strategies would be integrated into these plans and procedures to ensure that best practices for dust management and dust suppression were implemented.

The project would ensure that only treated, amended or bore water would be used for dust suppression, and rehabilitation activities—no produced water would be used for dust suppression and rehabilitation. The mitigation methods would include a requirement that relatively small quantities of treated and amended water would be sprayed, and only on an 'as needed' basis, to minimise the risk of ponding and runoff. The risk of surface runoff would also be reduced by minimising dust suppression adjacent to watercourses.

Dust suppression and rehabilitation activities will take into consideration:

- managing spraying to avoid ponding and runoff of water
- avoiding spraying during significant rainfall events
- adjusting application rates based on surface conditions and frequency of application

- routine visual inspections to check for ponding or runoff.

12.5.6 Irrigation

The irrigation of amended water would be undertaken in accordance with an Irrigation Management Plan, which would seek to ensure:

- the structure, stability and productive capacity of the soils are maintained
- erosion is minimised
- there are effective surface water and stormwater runoff controls.

Irrigation would also include a program of regular monitoring, with the irrigation schedule being adjusted as needed to address trends identified through the monitoring system.

Runoff generated from irrigation activities on site would be managed through measures typical of irrigation schemes elsewhere. The project would utilise the broader surface water monitoring network to monitor for impacts from irrigation activities.

Loss of sediment and nutrients from the irrigated area would be monitored by utilising stormwater sampling devices up-catchment of the project area, in addition to down-catchment, where runoff from the irrigated areas is likely to flow. This would allow for comparison of the quality of water entering the property to water sampled at the downslope boundaries.

In addition to monitoring the effects on the environment, monitoring the performance of the irrigation system would be undertaken to ensure that the system performs effectively, and to achieve the uniform distribution of treated irrigation water with minimal downtime. This aspect of monitoring would ensure that maintenance is carried out in a timely manner and that maintenance requirements are not extreme.

12.5.7 Managed release

Management and mitigation measures that would be undertaken by the project to ensure the managed release scheme operates with minimal impact include standard design initiatives in the water treatment plant as described in the water management section of the project description (Chapter 7 – Produced water management).

The project would seek to operate under a toxicity based Environment Protection Licence issued by the Environmental Protection Authority.

Given the ephemeral nature of Bohena Creek, monitoring would be specific to periods of discharge, rainfall events and other pre-defined sampling events. Analysis would be specific to the volume and quality of the water discharged and the water quality objectives of the receiving environment. Refer to Chapter 30 – Environmental management and monitoring, and Appendix G3 for further detail.

A Trigger Action and Response Plan and Pollution Incident Response Management Plan would be developed for the Bohena Creek managed release scheme should monitoring identify issues. The process is shown in Figure 12-8.

Table 12-5 provides a summary of the general mitigation measures that would help to manage potential impacts on surface water quality.

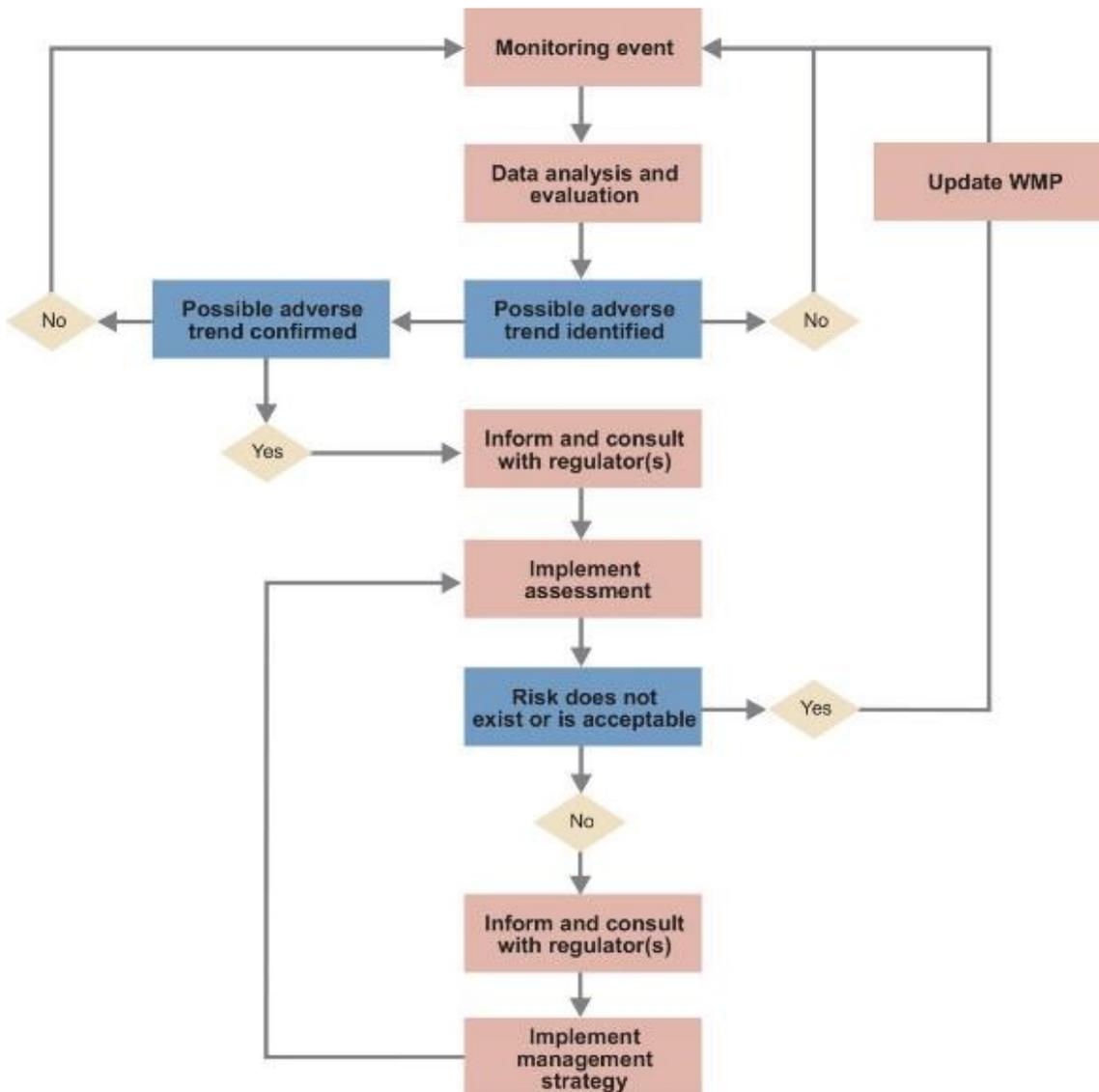


Figure 12-8 Bohena Creek monitoring and response measures

12.6 Significance assessment

As discussed in Section 12.1, impacts were assessed using the significance assessment methodology (also refer to Chapter 10). Table 12-5 summarises the assessment undertaken for the potential impacts of the project on the environmental values detailed in Section 12.2. For each identified potential impact the significance assessment considered:

- the pre-mitigated significance of the potential impact
- the mitigation measures that would be used to manage the potential impact. These measures would reduce the magnitude of the potential impacts
- the residual significance of the potential impact after implementation of the mitigation measure(s). The residual significance takes into account the potential for impact that remains after mitigation measures are applied.

Table 12-5 Environmental significance assessment

Potential impacts		Phase	Pre-mitigated significance			Mitigation	Residual significance		
			Sensitivity	Magnitude	Significance		Sensitivity	Magnitude	Significance
Target coal seam depressurisation	Reduced base flow to rivers and creeks impacting surface water quality	Operation	Moderate	Low	Low	The Water Monitoring Plan (Appendix G3) will be implemented Implementation of 'make good' protocols in accordance with the NSW <i>Aquifer Interference Policy</i>	Moderate	Low	Low
Direct water quality impacts	Surface water quality impacts due to spills or leaks	Construction	Moderate	Moderate	Moderate	Dangerous goods will be stored and transported in accordance with the <i>Australian Dangerous Goods Code</i> . Chemicals will be stored and handled in accordance with relevant Australian Standards, including AS 1940-2004 <i>The storage and handling of flammable and combustible liquids</i> . Refuelling will occur with suitable containment when volumes greater than 50 litres are involved and not within 40 metres of a watercourse.	Moderate	Low	Low
		Operation		Low	Low			Low	Low
		Decommissioning		Low	Low			Low	Low
	Impacts on Bohena Creek water quality due to the managed release	Operation	Moderate	Moderate	Moderate	Treated water will be released to Bohena Creek at the managed release point only during periods when the flow in Bohena Creek is equal to, or greater than, 100 ML/day as measured at the Newell Highway gauging station. The Water Monitoring Plan (Appendix G3) will be implemented.	Moderate	Low	Low

Potential impacts		Phase	Pre-mitigated significance			Mitigation	Residual significance		
			Sensitivity	Magnitude	Significance		Sensitivity	Magnitude	Significance
Surface water quality impacts due to use of treated and amended water for dust suppression, drilling, construction, stock watering and / or irrigation	Construction	Moderate	Moderate	Moderate	Irrigation of treated water will be undertaken in accordance with an irrigation framework, included under the Produced Water Management Plan. Only treated, amended or bore water will be used for dust suppression and rehabilitation. The Water Monitoring Plan (Appendix G3) will be implemented.	Moderate	Low	Low	
	Operation		Low	Low		Low	Low		
	Decommissioning		Low	Low		Low	Low		
Turbidity impacts	Construction	Moderate	Moderate	Moderate	Erosion and sediment control measures will be implemented during construction of watercourse crossings. Construction of watercourse crossings would occur during periods of no flow in the watercourse. Vehicular crossing will be designed and constructed to include appropriate stabilisation. Selection of watercourse crossing points will, where practical: <ul style="list-style-type: none"> • use existing vehicular crossings • be located on straight sections of channel • maximise avoidance of steep, unstable banks, permanent pools and waterholes. 	Moderate	Low	Low	
	Operation		Low	Low		Low	Low		
	Decommissioning		Low	Low		Low	Low		

12.7 Monitoring

The project's Water Monitoring Plan (WMP) is contained in Appendix G3. This section provides a summary of the key monitoring commitments from the WMP that are relevant to surface water. Surface water monitoring in the WMP has been designed 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.

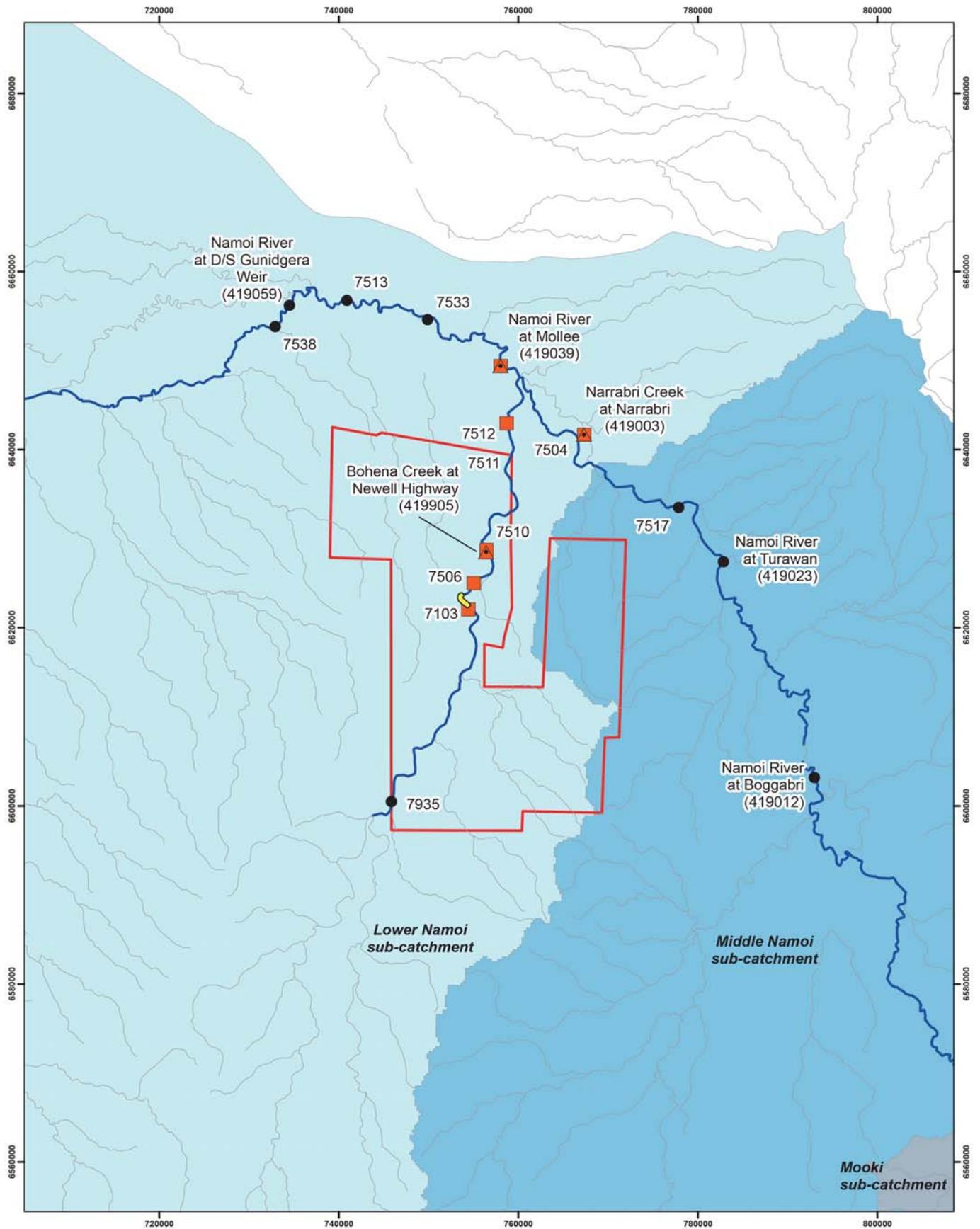
The surface water monitoring locations and their monitoring purpose (flow or water quality) are shown in Figure 12-9.

The regional surface water monitoring program would incorporate a number of the NSW DPI – Water stream flow gauging stations; two stations are located on the Namoi River and one is located on Bohena Creek. The program would also incorporate six water quality monitoring sites maintained by NSW DPI – Water; four of which are located on Bohena Creek and two on the Namoi River.

The rationale used to select the surface water monitoring location included:

- Flow gauging:
 - One station on Bohena Creek to measure flows downstream of the proposed location for managed release.
 - Two stations on the Namoi River, immediately upstream and downstream of the confluence with Bohena Creek to assess for 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 for potential changes in water quality immediately downstream of the proposed managed release, prior to the mixing of Bohena Creek water with Namoi River water (one of these stations is located with the flow gauging station on Bohena Creek).
 - Two stations on the 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.

Surface water monitoring activities including data analysis and evaluation would occur in accordance with appropriate sampling procedures and protocols. Annual reporting of monitoring activities will be undertaken including an evaluation of data and review of any observed changes. Refer to Appendix G3 for further information on the proposed surface water monitoring activities for the project.



Narrabri Gas Project Water Monitoring Plan

Surface Water Monitoring Locations

Legend

▲	NGP Flow	—	Surface Water Course
■	NGP Quality	—	Bohena Creek and Namoi River
●	Other flow and quality locations	■	Potential treated water release
•	DPI operated/maintained	□	Narrabri Gas Project (NGP) Area

Purpose, Priority

▲ NGP Flow
 ■ NGP Quality
 ● Other flow and quality locations
 • DPI operated/maintained

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 Data source:
 Job: SOW130015.01
 Date: 17/10/2016

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Narrabri Gas Project
 Environmental Impact Statement

Job Number | 21-22463
 Revision | 0
 Date | January 2017

Surface water monitoring locations Figure 12-9

12.8 Conclusion

The impact assessment has found that provided the project undertakes all construction and operational mitigation measures outlined in this chapter and Chapter 30 – Environmental management and monitoring, and Chapter 31 - Commitments, then the project would have a low residual impact significance to surface waters (refer Table 12-6). The mitigation and management measures presented in this chapter have been developed iteratively based on impact assessment studies and data collection undertaken for this EIS as reported in Appendices F, G1, G2, G3 and G4.

The residual significance for potential impacts as shown in Table 12-6 assumes that the Produced Water Management Plan is effectively implemented.

Table 12-6 Surface water significance of residual impacts

Potential impacts		Residual significance		
		Construction	Operation	Decommissioning
Target coal seam depressurisation	Reduced base flow to rivers and creeks impacting surface water quality	NA	Low	NA
Direct water quality impacts	Surface water quality impacts due to spills or leaks	Low	Low	Low
	Impacts on Bohena Creek water quality due to the managed release	NA	Low	NA
	Surface water quality impacts due to use of treated and amended water for dust suppression, irrigation, construction, rehabilitation, drilling and stock watering	Low	Low	Low
Turbidity impacts	Increased sedimentation of watercourses at linear infrastructure crossings	Low	Low	Low

NA: Not considered to be a risk at this stage of the project

