Land resources 9

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9 Land resources

9.1 Introduction

This section describes the land resources of the GFD Project area and surrounds. It includes the GFD Project area's geology, soils, topography, as well as existing land contamination and the GFD Project's estimated gas resources and reserves. The potential impacts that may arise from the GFD Project on land resources are assessed, mitigation measures identified, and a framework for further assessment and management outlined. Full details of the land resources assessment are provided in Appendix K: Land resources.

This section has been prepared in accordance with relevant parts of section 4.2 of the *Terms of reference for an environmental impact statement* issued March 2013. The index to locate where each ToR requirement is met within this EIS is included in Appendix B: Terms of reference cross-reference.

9.2 Geology, topography and soils

The primary coal seams in the GFD Project area are the Jurassic age Walloon Coal Measures (Surat Basin) and the late Permian Bandanna Formation (Bowen Basin); these will be targeted by the GFD Project to extract coal seam gas and are the focus of this assessment.

The topography of the GFD Project area includes areas that are characterised by low-relief undulating low hills that dominate in the east. Mesas feature at the border of the GFD Project tenure in the east, north and south-west. Alluvial plains are present across the GFD Project area with the most extensive associated with major watercourses and their tributaries, such as the Dawson River in the northeast, Comet River in the northwest to west, and Balonne River in the southwest.

Soils in the GFD Project area include uniform coarse textured (sandy) soils, uniform and gradational medium-textured (loamy) soils (in particular uniform loams), gravelly loams, red and yellow earths and lateritic red earths. A number of soils that are considered to be 'problem' soils because they are either highly susceptible to erosion, have high salinity or are highly reactive, occur throughout the GFD Project area.

Reflective of the GFD Project area's agricultural history, good quality agricultural land (GQAL) and Strategic Cropping Areas (SCA) occur in parts of the GFD Project area.

9.2.1 Regulatory context

This EIS has been prepared in accordance with the State and Commonwealth regulatory context described within Appendix C: Regulatory framework. The legislation, policies and guidelines that apply to the geology, topography and soils and the potential impacts of the GFD Project are outlined in Table 9-1.

Table 9-1 Regulatory context of the GFD Project – geology, topography and soils

Legislation, policy or guideline	Relevance to the GFD Project
Petroleum and Gas (Production and Safety) Act 2004 (Qld) (P&G Act) The P&G Act regulates petroleum activities with the aim of developing a safe, efficient and viable petroleum and fuel gas industry in Queensland. Petroleum tenure is granted under the Act.	Hydraulic fracturing and depressurisation, can potentially alter the physical characteristics of the coal resources. These indirect impacts are considered in this EIS to ensure compliance with the Act's requirements.

Legislation, policy or guideline	Relevance to the GFD Project
Minerals Resources Act 1989 (Qld) The Mineral Resources Act seeks to facilitate the prospecting, exploration and mining of minerals within Queensland. Central to its purpose is conducting activities in an environmentally responsible manner and with minimal land use conflicts.	GFD Project tenure covers areas subject to mining authorities granted under the Mineral Resources Act. Where such tenements overlap with tenures issued under the P&G Act resolution of issues such as potential for resource sterilisation is required. Agreements need to be negotiated between the overlapping tenure holders to enable developments to proceed.
Environmental Protection Act 1994 (Qld) (EP Act) The EP Act is the principal legislation for the protection and management of environmental values within Queensland. The Act aims to protect the natural environment and associated ecological systems and processes, while allowing for sustainable development.	The EP Act introduces the principal of general environmental duty or duty not to carry out an activity that causes, or is likely to cause, environmental harm unless reasonable and practical measures are taken to prevent or minimise the harm. Santos GLNG has developed numerous management plans which outline commitments to manage land resources associated with the GFD Project in accordance with this Act.
Regional Planning Interests Act 2014 (Qld) (RPI Act) The RPI Act integrates the repealed *Strategic Cropping Land Act 2011* (Qld) policy framework for 'on-tenure' resource activities. The RPI Act protects and manages Queensland's best cropping land from competing land uses, such as agriculture, mining and urban development. The Act uses trigger maps to identify areas of potential strategic cropping land.	SCA within the GFD Project area has been identified and described in this EIS. Santos GLNG will comply with the requirements of the Act in undertaking GFD Project activities.
State Planning Policy (SPP) The single SPP introduced in December 2013 defines Queensland Government policies about matters of State interest in land use planning and development.	The State's interest in planning for agriculture includes: • Considering the strategic economic significance of important agricultural areas by promoting and optimising agricultural development opportunities and enabling increased agricultural production in these areas • Protecting agricultural land classification Class A and Class B land for sustainable agricultural uses • Facilitating growth in agricultural production and a strong agriculture industry. Good quality agricultural land (including Class A and Class B land) within the GFD Project area has been identified and assessed in this EIS.
Darling Downs Regional Plan and *Central Queensland Regional Plan* (DSDIP, 2013) These plans identify the State's interests in land use planning for the Darling Downs and Central Queensland regions. The plans allow for continuing economic development while protecting highly productive agricultural land through the establishment of Priority Agricultural Land Use (PALU) and Priority Agricultural Areas (PAAs) and the future of towns, which are classified as Priority Living Areas (PLAs).	The GFD Project area is located within parts of both the Central Queensland and Darling Downs regional planning areas.
Technical Guidelines for the Environmental Management of Exploration and Mining in Queensland (Department of Minerals and Energy, 1995) The land suitability assessment techniques within this set of guidelines were originally created to assess the impact of mining projects, but are now commonly used to assess the impact of other resource and infrastructure projects.	Land suitability assessment techniques establish the baseline for assessing pre-project and post-project land suitability, including those relating to sampling and data requirements. The assessment techniques include standard assessment criteria in relation to cattle grazing and dryland cropping.

This EIS seeks to obtain primary approvals for the project including the Queensland Government Coordinator-Generals Report and Commonwealth Government *Environment Protection and Biodiversity Conservation Act 1999* (Cth) approval.

Application for or amendments to existing environmental authorities will occur subsequent to this EIS process. Other subsequent approvals required after the EIS process has been completed, corresponding triggers and legislative frameworks applicable to the GFD Project are identified in Section 2: Project approvals.

Approval of this EIS will trigger a number of subsequent approvals required for the GFD Project to proceed. Approvals will be required on tenure and off-tenure. Section 2: Project approvals summarises the key approvals necessary for the planning, construction, operations and decommissioning of the GFD Project. The triggers for each approval, the relevant administering authority and application details are provided. Consultation on the subsequent approvals will be ongoing with the administering authorities.

9.2.2 Assessment methodology

This assessment describes the geology, topography and soils values within the GFD Project area and assesses the GFD Project's potential impacts on these values. Impacts were assessed using the significance assessment methodology, which considers the sensitivity of the underlying environment and the magnitude of a potential impact to assess its level of significance. This methodology is used when it is known that some impact will occur and the significance of that impact is determined by considering its magnitude and the sensitivity to change of the environmental value that will be affected. A summary of the impact assessment is shown in section 9.2.7.

The full description of the significance methodology is described in section 5.6.3 of Section 5: Assessment framework and in Appendix K: Land resources. A summary of the impact assessment is provided in section 9.2.7.

9.2.3 Environmental values – geology

The key geological values with the potential to be impacted by the GFD Project include the physical attributes of the regional and local geological structure underlying the GFD Project area.

9.2.3.1 Regional geology

The GFD Project area is located within the geological Bowen and Surat basins, which are south-dipping basins formed through the inflow and deposition of sediment in a depression within the earth's crust, between the Permian (259 to 251 million years ago (ma)) to Cretaceous (141 ma to 65 ma) periods. These basins have structurally separate sedimentary depositional centres, but are stratigraphically and hydraulically connected (Habermehl, 2002). Most of the basins' sedimentary units dip at shallow angles (generally less than 10 degrees) to the southwest.

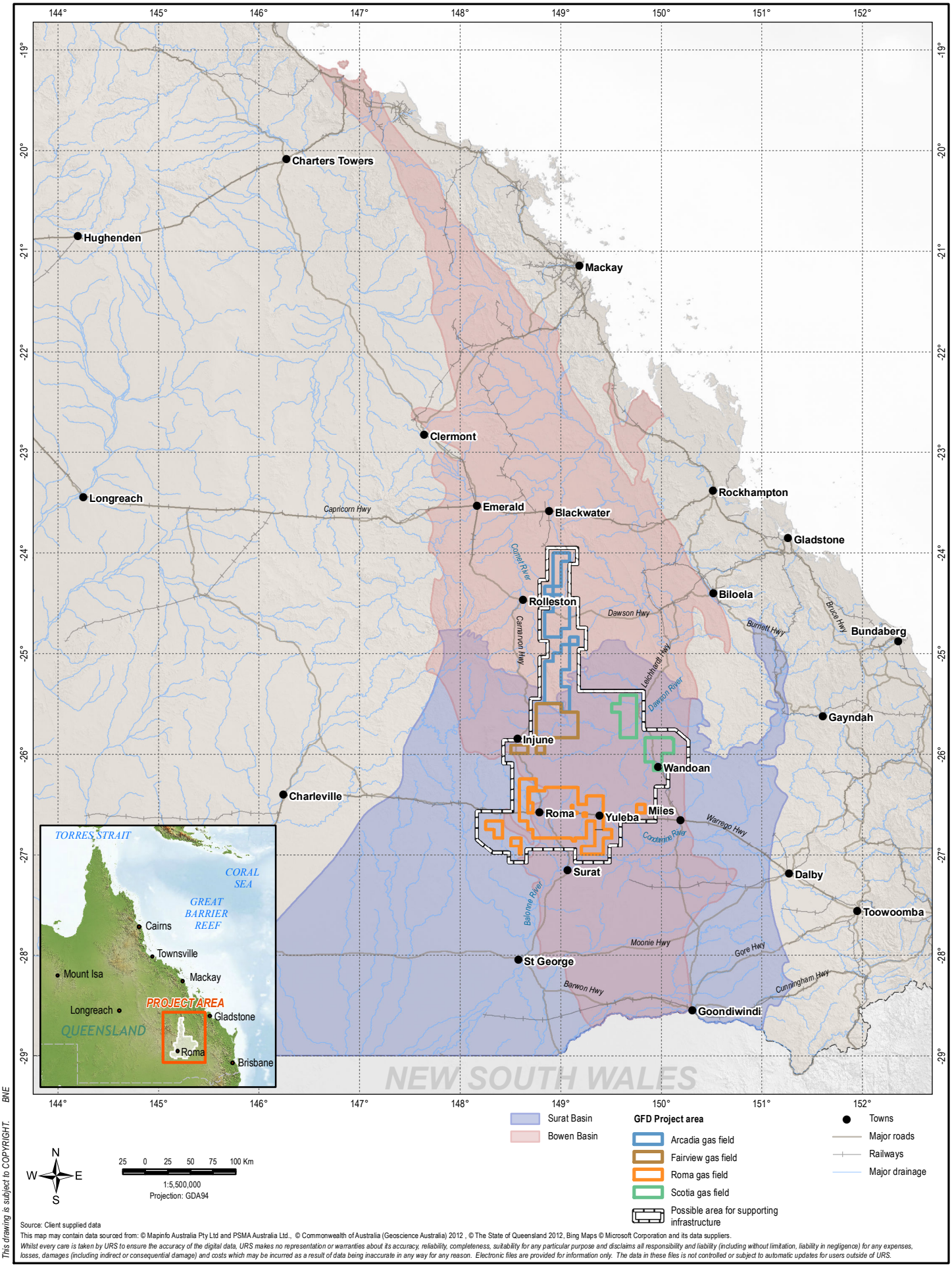
The Early Permian to Mid-Triassic Bowen Basin geological units occur in the northern half of the GFD Project area, to about 100 km north of Taroom and about 50 km northeast of Injune. South of this area, sedimentary rocks of the Early Jurassic to Early Cretaceous Surat Basin sequence overlie the older Bowen Basin units.

The geological setting of the GFD Project area is described in Table 9-2 and shown in Figure 9-1.

Note. The use of a zig-zag line in Table 9-2 is the geological symbol for unconformity, which refers to a gap in the geological record. This is typical for stratigraphy tables.

Table 9-2 Geological stratigraphy

Period	Basin	Group	Formation	Description
Quaternary			Alluvium / colluvium	Clay, silt, sand and gravel deposits; includes areas of colluvium and residual soils.
Tertiary			Main Range Volcanics	Alkali-olivine basalt, minor tuff, sandstone, mudstone.
			Sediments	Undifferentiated poorly consolidated sedimentary rocks; sub-liable to quartzose sandstone, siltstone, mudstone, minor conglomerate, coal, and limestone.
Cretaceous	Surat	Rolling Downs	Wallumbilla Formation – Coreena Member	Glauconitic siltstone, mudstone, very fine-grained sandstone, shelly fossils.
			Wallumbilla Formation – Doncaster Member	Mudstone, siltstone, minor quartz sandstone in part glauconitic, silty limestone, gypsum.
		Blythesdale	Bungil Formation	Glauconitic, labile to quartzose, siltstone, mudstone.
			Mooga Sandstone	Sandstone, siltstone, mudstone.
Jurassic			Orallo Formation	Sandstone, siltstone, mudstone, conglomerate, coal.
			Gubberamunda Sandstone	Sandstone, minor conglomerate, siltstone.
		Injune Creek	Westbourne Formation	Fluvial-lacustrine sediments; fine-grained sandstone interbedded with siltstone, claystone, minor coal.
			Springbok Sandstone	Clayey lithic sublabile to very lithic sandstone; calcareous in part; interbedded with carbonaceous mudstone and siltstone.
			Birkhead Formation/Walloon Coal Measures	Carbonaceous siltstone and mudstone, minor labile sandstone, coal. The Walloon Coal Measures transgressively grade into the siltstone and sandstone units of the Birkhead Formation.
			Eurombah Formation	Shale, siltstone, sandstone.
		Bundamba	Hutton Sandstone	Sublabile to quartzose sandstone, siltstone, mudstone, minor conglomerate and coal.
			Evergreen Formation	Labile and sublabile, sandstone, carbonaceous mudstone, siltstone and minor coal; local oolitic ironstone.
			Precipice Sandstone	Thick-bedded, cross-bedded, pebbly quartzose sandstone; minor lithic sublabile sandstone, siltstone, mudstone.
Triassic	Bowen	Mimosa	Moolayember Formation	Micaceous lithic sandstone, micaceous siltstone.
			Clematis Sandstone	Quartz rich sandstone, conglomerate, siltstone, mudstone.
			Rewan Formation	Lithic sandstone, green to reddish brown mudstone, minor volcanilithic pebble conglomerate.
Permian		Blackwater	Bandanna Formation	Sandstone, siltstone, shale, mudstone, coal, tuff, conglomerate.
			Black Alley Shale	Shale, siltstone, tuff bentonite, labile sandstone.
		Back Creek	Peawaddy Formation	Carbonaceous mudstone and siltstone, lithic sublabile sandstone, coquinitic siltstone.
			Catherine Sandstone	Quartzose to sublabile sandstone, siltstone, mudstone.
			Ingelara Formation	Conglomeratic sandy siltstone, mudstone, sandstone.
			Freitag Formation	Sublabile sandstone, pebbly sandstone, siltstone, mudstone.
			Aldebaran Sandstone	Quartzose to lithic sandstone, siltstone, carbonaceous shale and minor coal.
			Cattle Creek	Quartzose to sublabile sandstone and mudstone and coal.



Source: Client supplied data

BNE

Santos GLNG Project

GFD PROJECT EIS

REGIONAL GEOLOGICAL BASINS

URS

LAND RESOURCES

Figure: 9-1

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Bowen Basin

The Bowen Basin began as an extensive north-south trending back-arc basin developed on the landward (west) side of a continental arc associated with continent-ocean plate convergence. Following the incursion of the sea over the arc, deltaic facies developed, with the subsequent accumulation of extensive coal deposits. Compressive deformation during the Late Permian period resulted in the deposition of volcanolithic sediments. Subsequent infilling of the sea by prograding deltas translated into the formation of wetlands and associated fluvial systems. Compressive tectonics in the Middle to Late Triassic periods (251 ma to 141 ma), terminated sediment accumulation and caused uplifting of the entire area.

Surat Basin

The Surat Basin sequence formed during a widespread subsidence phase subsequent to an extensive period of uplift and erosion during the Middle to Late Triassic periods (251 ma to 141 ma) (Schlumberger, 2010). Sedimentation started in the Triassic and ceased in the Middle Cretaceous period (141 ma to 65 ma).

The geologic succession consists of braided stream deposits, followed by meandering stream and paludal coal-bearing sediments in the Jurassic age, shifting to coastal plain and shallow marine sediment accumulation as a result of the increase in sea level deposits in the Cretaceous period. Thick, semi-impervious units separate the complex multilayered system of aquifers. The lower part of each cycle is therefore predominantly sandstone with mostly siltstone, mudstone and coal in the upper parts.

Target coal seams

The primary coal seams of interest to the GFD Project area are located within Jurassic-age Walloon Coal Measures (Surat Basin) and the late Permian Bandanna Formation (Bowen Basin). A discussion of GFD Project target resource is provided in section 9.3: Resources and reserves.

9.2.3.2 Local geology

Simplified geological cross-sections, identifying the main geological units, are presented in Table 9-2.

Surficial geology

Most of the surface geology is dominated by geological units belonging to the two basins, with the addition of Tertiary (65 ma to 2.6 ma) and Quaternary (2.5 ma to 0 ma) age volcanic and sedimentary rocks, as well as unconsolidated sediments. The surface and near surface layers can be deeply weathered and laterised. The surficial geology also includes silicified profiles, which comprise erosion-resistant surficial silcrete.

Sedimentary deposition in the Tertiary consisted mostly of quartzose sandstone and conglomerate in small and isolated basins. Poorly consolidated siliciclastic sediments occur in the northern-most portion of the GFD Project area, as well as in an almost east-west belt along the Condamine-Balonne River system, south of the Warrego Highway. The second group of Tertiary rocks in the GFD Project area comprise alkali basaltic to trachytic intrusive and extrusive rocks. The basalts and trachytes, in the form of small plugs and flows, generally form topographic highs and plateaux within the western parts of Arcadia gas field and outside of the GFD Project tenure near Roma.

Quaternary alluvium and soil occur in the lower-lying areas throughout the GFD Project region. The area covered by these sediments generally forms elongated belts along existing streams and very gently sloping alluvial plains or slightly elevated terraces. The alluvium sourced from Permian age sedimentary rocks, Mesozoic (252 ma to 66 ma) age fine grained rocks and Tertiary age volcanics, is generally dispersive high shrink-swell clay dominated. Alluvium sourced from sandstone dominated Mesozoic age rocks and silicified or laterised Tertiary age sedimentary rocks generally comprises sand or clayey sand.

Structural geology

Near the northern margin of the Surat Basin, the main geological units do not indicate deformation or complex faulted geology. Faulting and folding, recognised in the older subsurface strata, is either absent or attenuated in the outcropping Jurassic-Cretaceous sediments. Some features are visible in the outcrop including the Alicker and Eurombah Anticlines, the Hutton-Wallumbilla Fault and a number of west-northwest trending faults.

The northwest trending Hutton-Wallumbilla Fault is located west of Roma and is downthrown to the west with a displacement of ~450 m in the basement, but just 30 m in the overlying sediments. Small northwest trending faults elsewhere in the GFD Project area are likely related to the movements that formed the Hutton-Wallumbilla Fault (URS, 2009).

West-northwest trending faults also occur in the Roma area. These faults are likely a result of gradual uplift or subsidence related to the Surat Basin through the Tertiary period (URS, 2009). These faults have limited or no vertical displacement.

The central part of the GFD Project area near Injune is situated between two large reverse fault systems that are oriented approximately north-south. Immediately to the east of Injune is an anticline, which plunges to the south-southeast and corresponds to a southerly extension of the Comet Ridge in the geological basement.

The major structural feature in the north of the GFD Project area is the Comet Ridge, which comprises mainly Devonian (410 ma to 354 ma) age rocks, and is covered by a relatively thin sequence of Permian and Triassic rocks. The Permian and Triassic sequence of sediments was folded during the late Triassic Period. Resultant folds are generally parallel trending northwest to the Comet Ridge axis. The Permian-Triassic folds are truncated by the erosional unconformity surface on which the Precipice Sandstone was deposited. The overlying Jurassic and Cainozoic (65.5 ma to the present) rocks are not folded (Golder, 2009).

Seismic activity

According to Geoscience Australia (2012), the highest seismicity hazard region in Queensland is along the eastern coast and near offshore regions, and along the Queensland/New South Wales border. The largest earthquakes recorded in Queensland occurred offshore of Gladstone in 1918 (Richter Magnitude 6.3) and near Gayndah in 1935 (Richter Magnitude 6.1).

The GFD Project area is a considerable distance from the seismically-active areas of Queensland, (Gladstone is some 500 km from the GFD Project area) and no earthquakes greater than Richter Magnitude 3 have occurred in the region in the last 50 years.

Fossils

No known sites of paleontological significance or geomorphological significance occur in the GFD Project area. However, Rhoetosaurus dinosaur remains were recovered in the Middle Jurassic sandstone near Roma, indicating the potential for dinosaur remains to be located in the Surat Basin sediments. Fossil tree ferns have also been recovered from the Roma area. Although fossil finds are sparse in the Surat Basin, those identified comprise a diverse collection reflective of the depositional environment. There is the potential for further fossil finds within the shallow geology outcrops of suitable age and type.

It is not expected that significant fossil specimens (such as dinosaur tracks) will be encountered during construction or operational activities on the GFD Project area. However if there is a significant find the Queensland Museum will be notified.

9.2.4 Environmental values – topography and soils

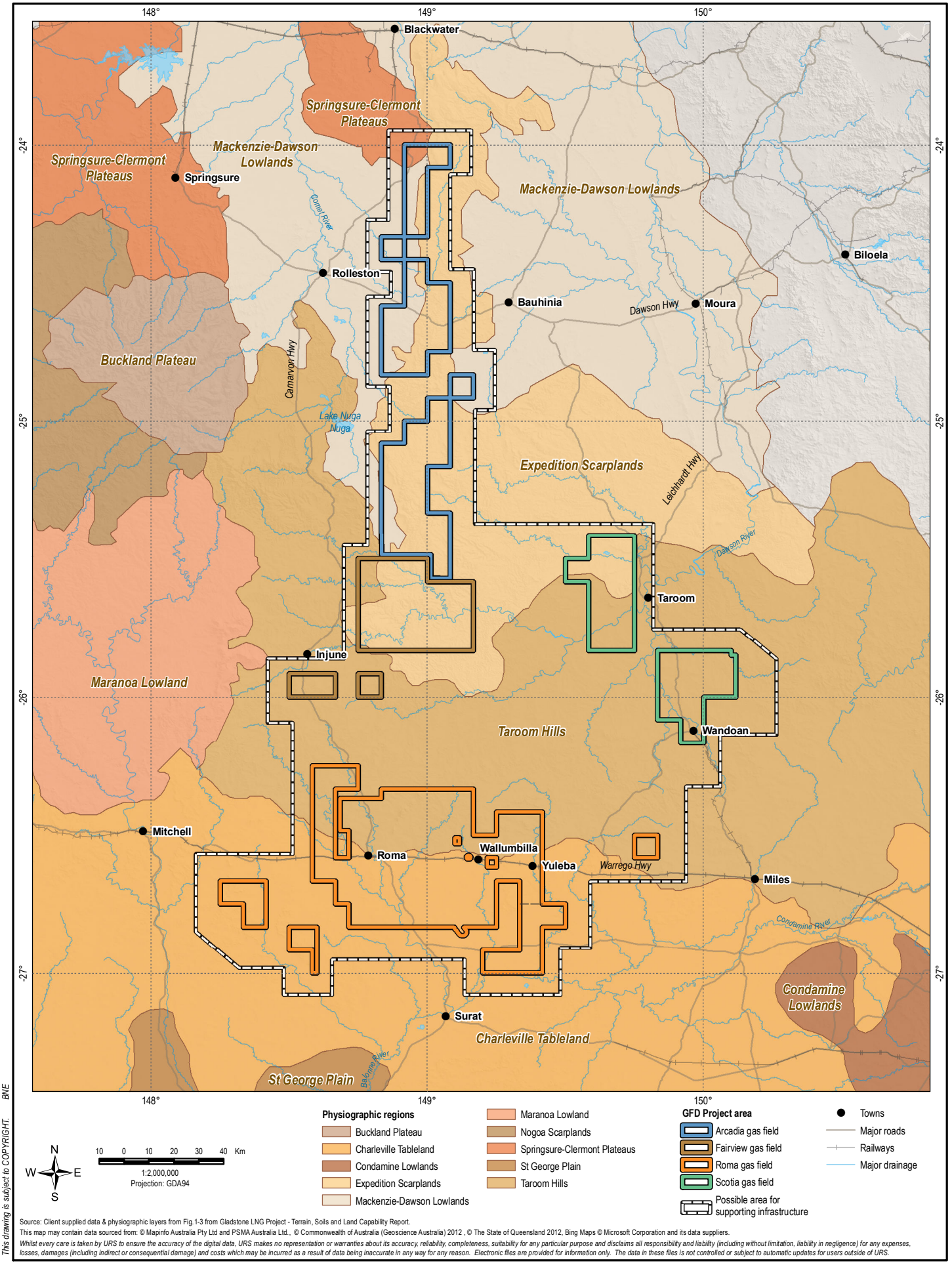
The topography and soils values in the GFD Project area relate to the intrinsic value of soils, which includes topsoil resources, agricultural productivity of soils, and the presence of SCA and/or GQAL.

9.2.4.1 Regional physiography

The GFD Project area is located predominantly within the following physiographic regions from north to south, as shown on Figure 9-2:

- **Mackenzie–Dawson Lowlands.** Consist predominantly of alluvial valleys and lowland plains, interrupted occasionally by residual rises and low hills. The Lowlands drain towards the north by the Brown and Comet rivers and their associated tributaries.
- **Taroom Hills.** Consist of gently sloping to strongly undulating dissected broad upland plateau remnants, predominantly on sandstone, with steep ravines and sandstone escarpments. Some areas consist of broad low interfluves similar to those occurring within the Charleville Tablelands. The region is generally elevated and includes the Carnarvon Range which in turn forms part of the Great Dividing Range watershed.
- **Expedition Scarplands.** This region is similar to the Taroom Hills physiographic region described above, except the Scarplands' remnant plateau areas are smaller in extent, resulting in a greater proportion of the region having very steep escarpments and ravines.
- **Charleville Tablelands.** Consist of elevated, gently sloping to gently undulating terrain, with broad low interfluves formed predominantly on mudrock (siltstone, claystone and mudstone). Lines of low sandstone hills occur sporadically across the gentle terrain. The upper reaches of the Balonne River and its tributaries form narrow to fairly broad alluvial plains within the tablelands.
- **Springsure – Clermont Plateaus.** Consist of a complex array of topographic features, including a large number of flat topped and rounded hills, with steep to moderately sloping sides, piedmont slopes and fans, colluvial slopes and alluvial plains.

Descriptions of the physiographic regions occurring adjacent to the units described above are detailed in Appendix K: Land resources.



Source: Client supplied data & physiographic layers from Fig 1-3 from Gladstone LNG Project - Terrain, Soils and Land Capability Report.

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GFD PROJECT EIS

PHYSIOGRAPHIC REGIONS

URS

LAND RESOURCES

Figure: **9-2**

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9.2.4.2 Topography

The GFD Project area has a north-south trending topographical high of the Expedition and Shotover Ranges and an east-west trending topographical high of the Great Dividing Range. Three major river systems are separated by these topographical highs; the Comet River in the north draining to the northwest, the Dawson River in the east draining to the northeast, and the south-draining Balonne River in the south. The surface elevations within the GFD Project area vary between approximately 164 m to 770 m Australian Height Datum (AHD), as shown in Figure 9-3.

The GFD Project area can be broadly divided into the following terrain units:

- **Undulating.** Comprising broad areas of low-relief, gently undulating low hills with broad ridges and wide, flat bottomed valleys, with occasional isolated low hills and narrow alluvial plains of tributary creeks. Long slopes with less than 5% gradient are typical. While this terrain unit occurs throughout the GFD Project area, it dominates the eastern and southern areas.
- **Mesa.** Comprising flat to undulating plateau surface remnants with very steep slopes and escarpments. This landscape occurs around the edges of the GFD Project tenure in the eastern, northern and southwestern extent of the GFD Project area.
- **Alluvial plains.** Comprises flat and near flat plains along valleys and other subdued topographic areas. Alluvial plains occur along the three main rivers (Balonne, Comet and Dawson) draining the GFD Project area and some of the tributary streams, such as Juandah Creek.

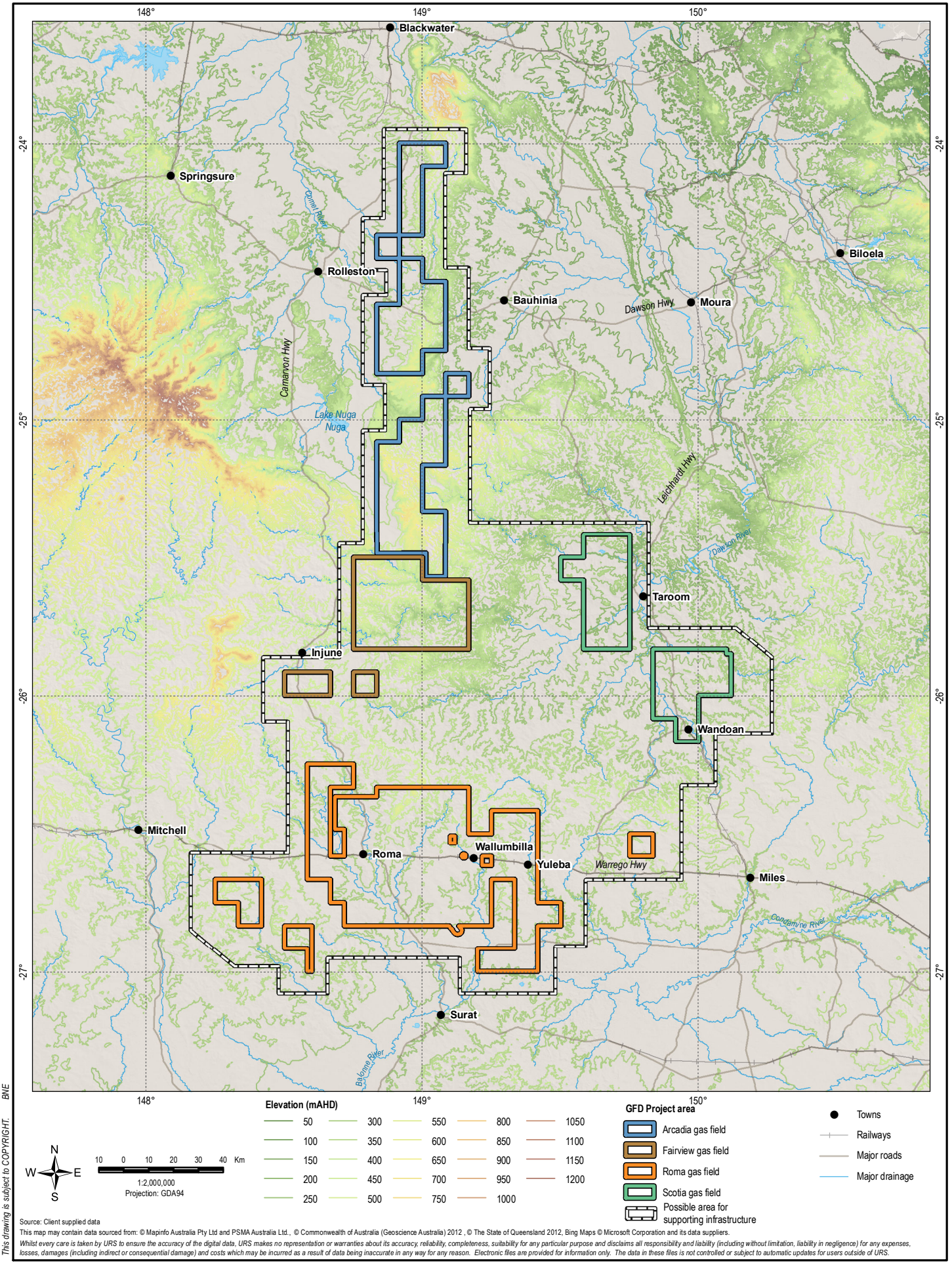
Notable topographic features within the GFD Project area include:

- Broad areas of low undulating terrain and alluvial plains, interrupted by occasional low hills across the southern part of the GFD Project area.
- Near-level to strongly undulating plateau surface remnants cut by very steep-sided ravines and terminating in precipitous sandstone escarpments occurring in the central part of the GFD Project area.
- The board alluvial plains and foot slopes of the Arcadia-Comet valley extending northward from the northern margin of the Fairview gas field to the northern limit of the GFD Project area.

Across all four gas fields, the slopes range from near level (<1%) to near vertical (>50%). The elevation ranges for the four gas fields are presented in Table 9-3.

Table 9-3 GFD Project elevation ranges

Gas field	Elevation range (~m AHD)
Arcadia	190 to 770
Fairview	245 to 633
Scotia	186 to 375
Roma	241 to 635



Source: Client supplied data

Santos GLNG Project

GFD PROJECT EIS

TOPOGRAPHIC OVERVIEW

URS

LAND RESOURCES

Figure: **9-3**

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9.2.4.3 Soils

Eight major soil groups (Stace et al, 1968) were identified within the GFD Project area. The major soil groups cover a wide range of soil types and include uniform coarse textured (sandy) soils, uniform and gradational medium-textured (loamy) soils (in particular uniform loams), gravelly loams, red and yellow earths, and lateritic red earths. Also included are sandy and loamy surface texture contrast (duplex) soils, uniform or gradational fine textured grey and brown non-cracking clays, and black, dark grey and brown cracking clay soils. The soil groups are characterised by increasingly finer texture and higher plasticity in the subsoil layers with increasing soil group number.

Typical soil profile characteristics of the major soil groups have been mapped as 13 soil mapping units (SMUs), which have been determined from various sources including:

- The regional land system and soil mapping conducted by CSIRO (1967, 1968 and 1974)
- The Australian Soil Resource Information System (Department of Agriculture, Fisheries and Forestry, 2012)
- The *Digital Atlas of Australian Soils* (Digital Atlas, Bureau of Rural Science, 1991)
- The Santos GLNG Project EIS (2009 EIS) (URS, 2009).

Each SMU consists of more than one of the soil types and provides an indication of which soil types are likely to occur. Understanding the likely composition of a SMU guides appropriate soil management practices. A description of the SMUs is presented in Figure 9-4, with the distribution of SMUs within the GFD Project area shown in Figure 9-5.

Problem soils

Consistent with the GLNG Project EIS (URS, 2009), this assessment identified four types of 'problem soils' as outlined within Table 9-4.

Table 9-4 Problem soils within the GFD Project area

Problem soil classes	Description
Sodic/dispersive soils	These soils have an exchangeable sodium percentage (ESP) greater than six percent. Sodic cracking and non-cracking clays, together with the majority of the duplex soils within the GFD Project area are dispersive and highly susceptible to degradation if disturbed and managed incorrectly. They are susceptible to rill, gully or tunnel erosion if exposed and left unprotected from rainfall impact or excessive water infiltration.
Sandy Duplex soils	Soils with light textured surface soils, together with sandy duplex soils occurring within the GFD Project area have surface textures (excess of fine sand and silt compared to clay) that have the potential to be hard-setting. When disturbed, these soils are prone to slaking when wet and when allowed to dry out, set hard and become massive, as a result handling properties, infiltration and the establishment of vegetation become difficult.
Reactive soils	Reactive soils (high shrink – swell capacity) are the cracking clay soils (vertosols), with a moderate to high cation exchange capacity, which become compacted if trafficked when wet. These soils may cause damage to infrastructure, foundations and buried services such as pipelines due to differential ground movement.
Saline soils	Soils with saline subsoils (often sodic) occur throughout the GFD Project area. Saline soils can impact plant growth and have the potential to corrode buried steel or concrete infrastructure.

Skeletal and shallow rocky soils (rudosols)

1 Shallow to very shallow (mostly <0.3 m) rocky, stony or gravelly soils (>60% coarse fragments) with a sandy, loamy or clayey soil matrix; as mapped includes Soil Types 1-2.1, 1-4.1, 1-7.1 and some occurrences of shallow to medium deep (<0.6 m) stony or gravelly sand, sandy loam and loamy soils (Types 2.1, 3.1 & 4.1).

Uniform coarse-textured sandy soils (rudosols)

2 Mostly medium to deep (0.6->1.0 m), some shallow yellow, brown and red sandy soils (Type 2.2 and 2.3), some shallow sands (Type 2.1) and medium to deep thick sandy duplex soils (Type 5.2 & 6.3) occur locally.

Sandy red and yellow earths & red and yellow massive earths (tenosols & kandosols)

3 Shallow to medium deep (<0.6 m) sandy red-yellow earths-earthy sand soils (Type 3.1), shallow gravelly loam soils and gravelly loamy red-yellow earth soils (Type 4.1); rock outcrop, broken rock and boulders may occur in parts.

4 Medium to deep (0.6->1.0 m) loamy red-yellow earths and lateritic red-yellow earth soils (Type 4.2); some occurrences of shallow gravelly red earth soils (Type 4.1); minor occurrences of sandy to loamy surface duplex soils (Type 5.2, 5.3 & 6.2), minor deep red sandy soils (Type 2.2).

Texture contrast (duplex) soils (chromosols, kurosols & sodosols)

- Duplex soils with neutral to moderately acidic, locally strongly acidic subsoils

5 Shallow to medium deep (<0.6 m) sandy to loamy surface red, red-brown, brown or dark grey-brown acidic duplex soils (Type 5.1); in parts similar but slightly acidic to alkaline duplex soils (Type 6.1) may also occur; minor deeper duplex soils (Type 5.3 & 6.2) may also occur locally.

6 Medium to deep (0.6->1.0 m) thick sandy surface duplex soils (Type 5.2) with grey-brown, yellow-brown or red-brown coarsely mottled subsoils; similar but thinner sandy to loamy surface duplex soils (Type 5.3) also occur; some uniform sandy soils (Type 2.1, 2.3) and massive red-yellow earth soils (Type 4.1, 4.2) in parts.

- Duplex soils with neutral to moderately alkaline, locally strongly alkaline subsoils

7 Shallow to medium deep (<0.6 m) sandy to loamy surface red, red-brown, brown or dark grey-brown alkaline duplex soils (Type 6.1); in parts, similar neutral to slightly acidic duplex soils (Type 5.1) may also occur together with some deeper duplex soils (Type 6.2); some cracking clay soils (Type 8.2) in lower-lying parts

8 Medium to deep (0.6->1.0 m) fine sandy to silt and clay loamy surface duplex soils (Type 6.2) with dark brown, brown, yellow-brown or red-brown alkaline clay subsoils; may include some occurrences of red and yellow earth soils (4.1 & 4.2) on rises and dark brown and grey-brown soils (Type 7.3) and cracking clay soils (Type 8.2) in lower-lying parts.

Dark brown & grey-brown soils (dermosols)

9 Shallow to medium deep (<0.6 m) mainly uniform fine-textured gravelly clay soils (Type 7.1) often in association with shallow cracking clay soils (Type 8.1); some deeper uniform clays or gradational clay loam over clay soils (Type 7.3) and cracking clay soils (Type 8.2) on mid to lower slopes.

10 Medium to deep (0.6->1.0 m) mainly uniform clays or gradational clay loam over clay soils (Type 7.2 & 7.3); some shallow gravelly uniform or gradational clay soils (Type 7.1) and shallow cracking clays soils (Type 8.1) on upper slopes and rises; some deeper dark grey-brown cracking clay soils (Type 8.2) in lower-lying parts.

Cracking clay soils (vertosols)

11 Shallow to medium deep (<0.6 m) cracking clay soils (Type 8.1) occurring mainly on crests and upper slopes and underlain by basalt and argillaceous sedimentary rock types, in places with shallow gravelly loams and clay loam soils (Type 4.1) and uniform gravelly clay soils (Type 7.1); some medium to deep cracking clay soils (Type 8.2) may occur on mid to lower slopes.

12 Medium to deep (0.6->1.0 m) dark grey-brown, brown or black cracking soils (Type 8.2), locally in association with uniform (non-cracking) clay soils (Type 7.3) and some shallow gravelly uniform clay soils (Type 7.1) on rises; minor shallow to medium deep loamy surface duplex soils (Type 5.1, 5.3 & 6.2) may occur locally.

13 Medium to deep or very deep (0.6->1.5 m) dark grey-brown or black cracking clay soils (Type 8.3) with intensive gilgai micro-relief, often in association with silt to clay loamy surface duplex soils (Type 6.2) on the gilgai mounds; areas of uniform (non-cracking) clay soils (Type 7.3) are also associated; some loamy red earth soils (Type 4.2) may occur locally on low rises.

Santos GLNG Project

GFD PROJECT EIS

SOILS MAPPING UNITS

URS

LAND RESOURCES

Figure: **9-4**

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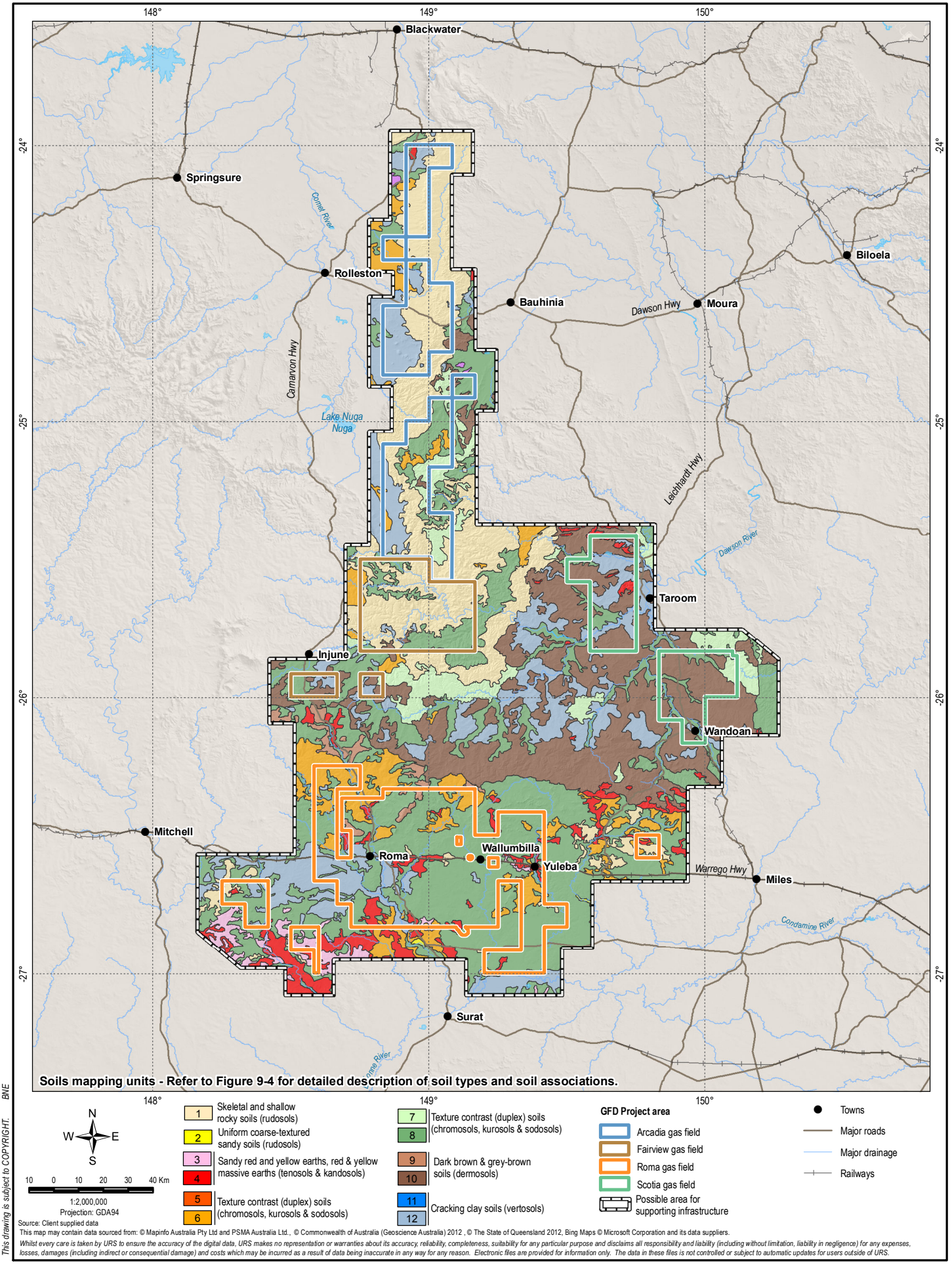

Santos GLNG Project

GFD PROJECT EIS

SOIL MAPPING UNITS IN THE GFD PROJECT AREA

URS

LAND RESOURCES

Figure: 9-5

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Topsoil resources

Suitable soils available for successful plant growth are usually confined to the surficial topsoil (A) horizon and in some situations the upper portion of the subsoil (B21) horizon, as these upper horizons generally contain seed reserves, micro-organisms, organic matter and necessary nutrients. These parameters generally decrease with profile depth, while soil properties affecting soil handling and plant growth, for example soil sodicity, salinity and excessive structure, increase with depth.

The suitability of soils for rehabilitation activities has been assessed from soil characterisation, indicative testing and analytical data from the GLNG Project EIS (2009). Additional soil data were obtained from the land systems and soils mapping by the CSIRO (1967, 1968 and 1974). Indicative stripping depths of suitable soils have been determined for the SMUs and soil types identified (Appendix K: Land resources).

Soil structure, soil depth, texture and soil chemistry (salinity, ESP and pH) are the major factors limiting the suitability of some soils for rehabilitation activities within the GFD Project area.

Existing and potential soil erosion

The GLNG Project EIS (URS, 2009) reported that substantial areas of land are subject to accelerated soil erosion, in particular areas of extensive surface sheet and rill erosion. Areas of gully erosion exist mainly on the approaches or adjacent to the major stream lines. The areas most affected include the Jurassic and Triassic sandstones, the Silurian volcanics and Permian sedimentary and intrusive rock types, and the Tertiary sediments.

All landforms tend to have sand or sandy medium-textured surface soils which in parts have been subjected to extensive grazing and grazing related activities such as the clearing of woody vegetation, which increases the risk of erosion. This is exacerbated by agricultural practices including prolonged dry periods that lead to defoliation/denudation of land through heavy grazing and heavy summer rainfalls.

Details of the erosion potential and estimated erosion rates for each SMU are given in Appendix K: Land resources.

9.2.4.4 Good quality agricultural land

GQAL is land that is capable of supporting sustained levels of agricultural production with reasonable amounts of inputs and without causing degradation. The Agricultural Land Class (ALC) is described using a four-class soil classification system:

- Class A - Arable land (Cropping land):
  - Land that is suitable for current and potential crops, with limitations to production which range from none to moderate levels.
- Class B - Limited arable land (Limited cropping land):
  - Land that is marginally suitable for current and potential crops due to severe limitations; however, it is suitable for pastures. Engineering and/or agronomic improvements may be required before the land is considered suitable for cropping.

- Class C – Pastoral land (Grazing land):
  - Land that is suitable only for improved (Class C1) or native pastures (Class C2) due to limitations which preclude continuous cultivation for crop production; but some areas may tolerate a short period of ground disturbance for pasture establishment. This also includes land suitable for light grazing of native pastures in inaccessible areas (Class C3). In predominantly grazing dominated areas, Class C1 land is also considered as GQAL.
- Class D - Non-agricultural land:
  - Land not suitable for agricultural uses due to extreme limitations. This may be undisturbed land with significant habitat, conservation and/or catchment values or land that may be unsuitable because of very steep slopes, shallow soils, rock outcrop or poor drainage (DPI, 1993).

For the purpose of this assessment land classes A, B and C1 are considered to be GQAL, with the remaining ALCs, C2, C3 and D considered to be non-GQAL. Protection is provided to Class A and Class B land in the SPP by:

- Avoiding fragmentation of Class A or Class B land into lot sizes inconsistent with the current or potential use of the land for agriculture
- Avoiding locating non-agricultural development on or adjacent to Class A or Class B land
- Maintaining or enhancing land condition and the biophysical resources underpinning Class A or Class B land.

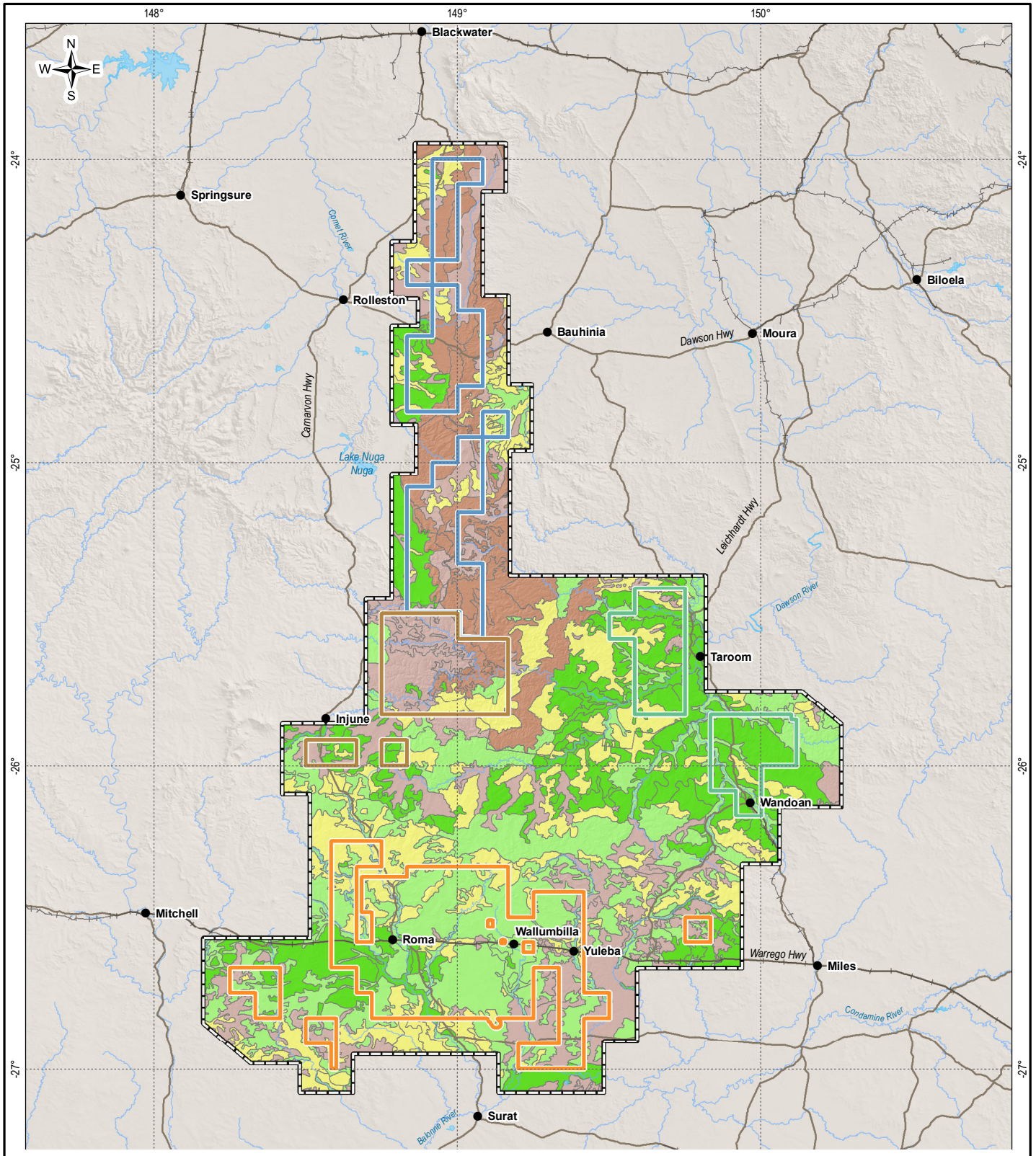
Table 9-5 details the extent of ALCs within the four gas fields and across the remainder of the GFD Project area. The distribution of ALCs across the GFD Project area is presented in Figure 9-6.

Table 9-5 Extent of agricultural land classes (ha)

Gas field	GQAL - Class A (cropping)	GQAL - Class B (arable, grazing)	GQAL - Class C1 (grazing)	Class C2 (grazing)	Class C3 (grazing)
Arcadia	41,795	2,751	38,145	60,704	128,723
Fairview	13,096	9,445	23,278	86,699	29,627
Roma	53,817	277,028	82,486	58,101	0
Scotia	104,906	24,724	24,886	5,865	0
Remainder*	459,688	524,794	465,251	432,830	226,465
Totals	673,302	838,742	634,046	644,199	384,815

*Additional land area within the possible area for supporting infrastructure outside of the gas fields

As discussed in section 9.2.1, the Central Queensland and Darling Downs regional plans seek to resolve competing State interests relating to land use by the agricultural and resource sectors. The plans aim to protect priority agricultural land uses (PALU) while supporting co-existence opportunities for the resources sector. Priority agricultural areas (PAAs) are also identified in these plans and comprise the region's strategic areas containing highly productive agricultural land uses. In these areas, PALUs are the land use priority. The implications of this for the GFD Project are discussed in section 8.4.5.2 of Section 8: Land use and tenure.



Reference - agricultural land classes

A	Crop land - suitable for rainfed cropping or existing irrigation lands, with limitations ranging from nil to moderate for a range of crop production.
B	Limited crop land - marginal lands for crops due to severe limitations for crop production; engineering and/or agronomic improvement may be required to be suitable for cropping.
C1	Pasture land - suitable for sown pastures where ground disturbance is possible for pasture establishment; or, suitable for native pastures on higher fertility soils.
C2	Pasture land - suitable for native pastures with or without the addition of improved pasture species introduced without ground disturbance.
C3	Pasture land - suitable for light grazing of native pastures in accessible areas; otherwise, very steep land more suited for forestry, conservation or catchment protection.

GFD Project area

- Arcadia gas field
- Fairview gas field
- Roma gas field
- Scotia gas field
- Possible area for supporting infrastructure

- Towns
- Railways
- Major roads
- Major drainage

10 0 10 20 30 40 Km

1:2,000,000

Projection: GDA94

Source: Client supplied data

Santos GLNG Project

GFD PROJECT EIS

AGRICULTURAL LAND CLASSES IN THE GFD PROJECT AREA

URS

LAND RESOURCES

Figure: 9-6

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9.2.4.5 Strategic cropping areas

The RPI Act seeks to ensure the productive capacity of land considered highly suitable for cropping is protected from the impacts of development and where impacts are unavoidable, those impacts are managed. The RPI Act integrates the repealed *Strategic Cropping Land Act 2011* (Qld) policy framework for 'on-tenure' resource activities.

The RPI Act carries forward Strategic Cropping Land policies through:

- Declaring the SCA as an area of regional interest
- Applying the *SCA Assessment Criteria* to activities within the SCA that are not also located on a PALU within a PAA
- Providing for the chief executive to condition SCL mitigation as part of a regional interest's development approval issued for an activity in the SCA.

The RPI Act protects land that is highly suited to cropping from development that could lead to its permanent alienation or diminished productivity. The RPI Act has various implications for resource projects depending on the status of tenure and environmental approvals at various prescribed dates as well as the location and the type of development proposed. Trigger maps, which are based on soil, climate and land information, were prepared by the Queensland Government to indicate areas where potential Strategic Cropping Land is likely to exist. The RPI Act will use these existing maps. While the trigger maps are a broadscale indicator of likely SCA, it is on-ground assessment against defined SCA criteria that determines the extent of SCA at a property level.

Under the SCL policy, five SCL zones have been established based on differences in regional climate, landforms and cropping systems within the eastern part of the state. The majority of triggered potential SCA within the GFD Project area is located within the management area of the Western Cropping Zone (Figure 9-7).

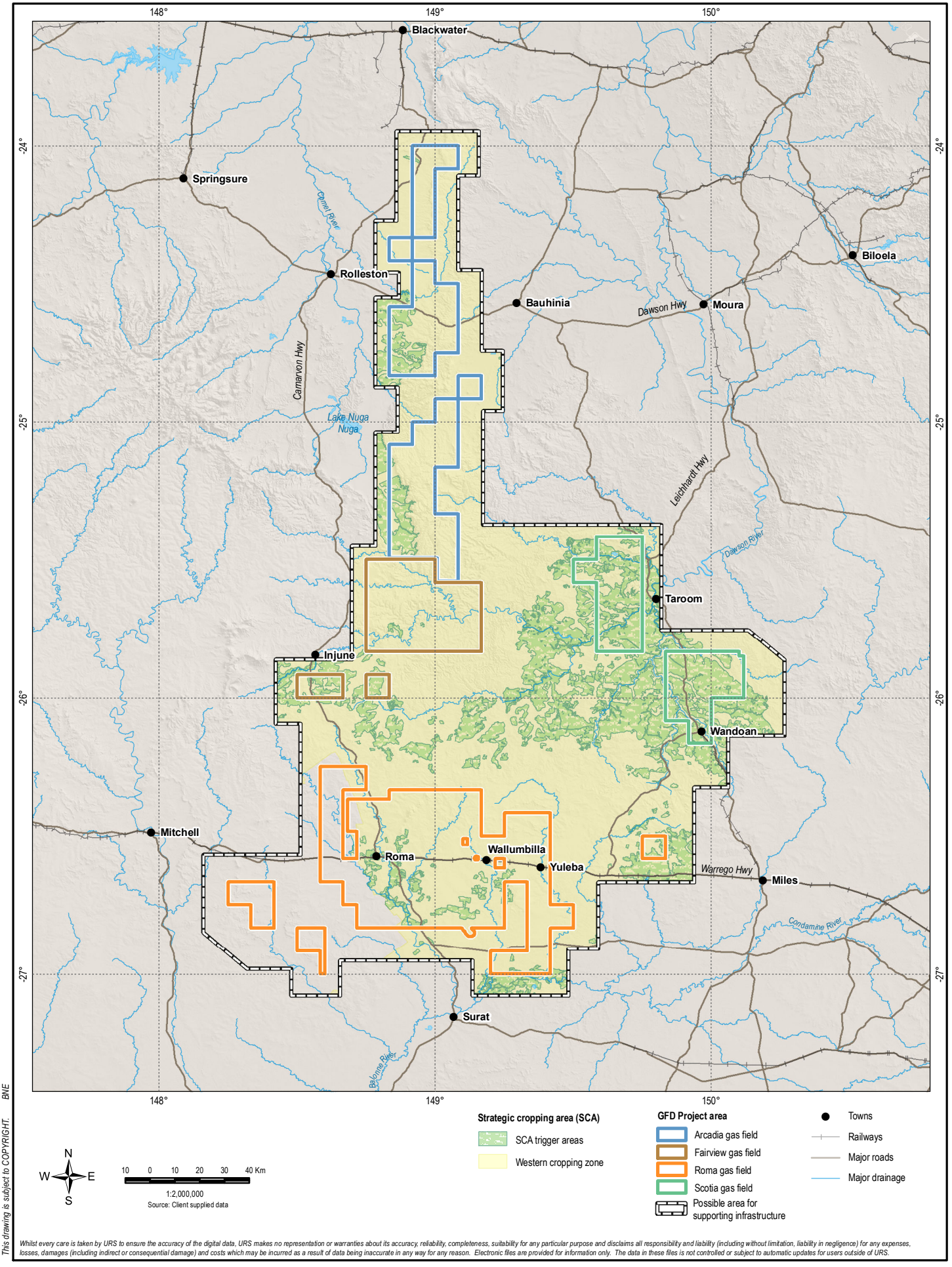
Table 9-6 details the extent of potential SCL within the GFD Project area. These areas are shown on Figure 9-7.

The extent of PAAs within the GFD Project area is identified within section 8.4.5.2 of Section 8: Land use and tenure.

Table 9-6 Distribution of strategic cropping land in the GFD Project area

Gas field	Total SCL trigger area (ha)
Arcadia	36,244
Fairview	12,576
Roma	34,451
Scotia	101,304
Remainder*	411,225
Total	595,799

*Additional land area within the possible area for supporting infrastructure boundary outside of the gas fields



Santos GLNG Project

GFD PROJECT EIS

STRATEGIC CROPPING AREA IN THE GFD PROJECT AREA

URS

LAND RESOURCES

Figure: 9-7

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9.2.4.6 Acid sulfate soils

The SPP sets out the State's interests concerning development involving acid sulfate soils which can occur in low-lying coastal areas. The SPP lists local authorities that may be acid sulfate soils-affected. The GFD Project area is not in a low lying coastal area and is outside of the local authority areas listed in the SPP. Hence, acid sulfate soils are not expected to occur.

9.2.5 Potential impacts

Potential impacts to geology, soils and topography values that may occur as a result of the GFD Project include:

- Altered geological setting
- Change to landform
- Loss of soil resources
- Degradation of soil resources
- Restricted access to productive (agricultural or forestry) land
- Authorised release to soil
- Uncontrolled release to soil
- Damage to fossils.

9.2.6 Mitigation measures

9.2.6.1 Management strategies

Santos GLNG is committed to implementing the mitigation measures in Table 9-7 to manage potential impacts to geology, soils and topography. These measures are components of the Santos GLNG management framework for the GFD Project, as described in Appendix Y: Draft environmental management plan. The application of the management framework is described in Section 6: Management framework.

Table 9-7 Overview of relevant management plans and mitigation measures – geology, soils and topography

Management plan	Commitment
GFD Project environmental protocol for constraints planning and field development (the Constraints protocol)	The Constraints protocol applies to all gas field related activities. The scope of the Constraints protocol is to: • Enable Santos GLNG to comply with all relevant State and Federal statutory approvals and legislation • Support Santos GLNG's environmental policies and the General Environmental Duty (GED) as outlined in the EP Act • Promote the avoidance, minimisation, mitigation and management of direct and indirect adverse environmental impacts associated with land disturbances • Minimise cumulative impacts on environmental values. The Constraints protocol provides a framework to guide placement of infrastructure and adopts the following management principles: • Avoidance — avoiding direct and indirect impacts • Minimisation — minimise potential impacts • Mitigation — implement mitigation and management measures • Remediation and rehabilitation — actively remediate and rehabilitate impacted areas • Offset — offset residual adverse impacts in accordance with regulatory requirements. The Constraints protocol enables the systematic identification and assessment of environmental values and the application of development constraints to effectively avoid and/or manage environmental impacts. Santos GLNG will implement the Constraints protocol to high value soil resources where practical or obtain necessary approvals prior to works commencing in areas such as those identified as SCA.
Chemical and fuel management plan (CFMP)	The CFMP details the appropriate storage and handling practices of chemicals and fuels. The objectives of the plan are to: • Facilitate compliance with relevant legislation, regulations and approvals • Provide a framework for Santos GLNG to store and handle bulk chemicals and fuels in a way that minimises risk to the environment and human health • Assess the potential risk of a chemical or fuel prior to its use • Identify and implement appropriate mitigation measures.
Contingency plan for emergency environmental incidents	The Contingency plan details the management practices in place within Santos GLNG to minimise environmental harm during an emergency environmental incident. The plan identifies potential incidents, and provides response actions, including escalation, communication, reporting and monitoring.
Draft environmental management plan (Draft EM Plan)	The Draft EM Plan identifies the environmental values potentially affected by the GFD Project and proposes measures to manage the risk of potential adverse impact to these environmental values. The Draft EM Plan comprises: • Environmental values potentially affected by the GFD Project • Environmental management objectives and associated management measures • Environmental monitoring and reporting • Coal seam water management • Proposed conditions. The Draft EM Plan contains measures relating specifically to land resources, such as: • The management of coal seam water including releases to soil • Management response to the identification of fossils.

Management plan	Commitment
Erosion and sediment control management plan (ESCMP)	The ESCMP identifies erosion and sedimentation risk and provides an erosion and sediment control strategy that incorporates understanding of the risk inherent to local land resource characteristics. The ESCMP is supported by the Erosion and Sediment Control Manual, which provides erosion, sediment and drainage controls in line with best practice guidelines. Soil loss via erosion from exposed surfaces will be mitigated through implementation of the ESCMP, which will include mitigation measures such as: • Application of the erosion risk assessment process for well pads, bores, camps, pipelines and power lines to identify appropriate level of erosion, sediment and drainage control. • Development of site specific erosion and sediment control plans for all other petroleum activities. • During construction: — Soil testing to identify problem soils and amelioration if required — Stripping and stockpiling of topsoil for reuse for later rehabilitation — Stockpiling and mulching (where available) cleared vegetation for spreading over disturbed areas — Minimising the period that soil is left exposed to erosion through progressive ground cover revegetation — Installation and maintenance of drainage, erosion and sediment control devices appropriate to the erosion and sediment risk of the activity. • During operation: — Spreading of stockpiled topsoil across disturbed areas — Progressive revegetation — Stabilisation of batters — Establishment of permanent drainage. The ESCMP has been developed in accordance with the *Guideline: EPA Best Practice Urban Stormwater Management-Erosion and Sediment Control* (Environmental Protection Agency, 2008)
Decommissioning and abandonment management plan (DAMP)	The DAMP describes the management framework in place for when petroleum activities cease. The objectives of the plan are to: • Undertake decommissioning and rehabilitation of assets in a manner that complies with regulatory requirements and minimises the risk of environmental harm • Undertake decommissioning and rehabilitation activities in a manner that meets stakeholder expectations • Leave a landform that is stable and compatible with intended post-closure land use • Provide for the beneficial reuse of Santos GLNG infrastructure constructed to third parties (e.g. landholders or local authorities) where an appropriate agreement has been signed by both parties and regulatory authorities are satisfied.
Hydraulic fracturing risk assessment: compendium of assessed fluid systems (Hydraulic fracturing risk assessment)	The Hydraulic fracturing risk assessment report synthesises the hydraulic fracturing risk assessments completed on various hydraulic fracturing fluids and provides a framework for including new fluid systems within the risk assessment document. The body of the report provides generalised information, including the geology and hydrogeology of the area, risk assessment methodologies (qualitative and quantitative) and a high level understanding of current results. The appendices include risk assessments of individual hydraulic fracturing fluid systems.
Land release management plan (LRMP)	The LRMP addresses the management of releases of water to land in Santos GLNG's gas fields, including: • Coal seam water use for irrigation, construction and operations purposes • Treated sewage effluent releases to land • Use of treated sewage effluent for construction and operational purposes • Low point drain water releases to land • Hydrostatic test water releases to land. The document includes the principles, methods and controls to effectively manage and minimise the risk environmental harm being caused by release of water to land.

Management plan	Commitment
Pest and weed management plan (PWMP)	The management of pest and weed species will be undertaken in accordance with the PWMP. The plan includes measures such as: • Identification of pest and weed species and areas of infestation • Avoidance of traversing and placing infrastructure in areas of known infestation • Prevention of the spread of pest and weed species by implementing appropriate work practices and promotion of risk awareness • Control of identified pest and weeds through containment, reduction or eradication as required by legislation. Santos GLNG will review local government's pest and weed management plans and apply measures from these to the PWMP where it is appropriate.
Rehabilitation management plan	The Rehabilitation management plan outlines the rehabilitation objectives for Project-related disturbances within the GFD Project area. This includes the phasing of rehabilitation to first achieve stabilisation and subsequently final rehabilitation for disturbances to land (i.e. ground surface). The Rehabilitation management plan: • Describes Santos GLNG's approach to rehabilitation • Identifies key rehabilitation objectives and criteria to deem rehabilitation success • Outlines general rehabilitation actions to be undertaken by Santos GLNG when rehabilitation a disturbance • Provides an overview of monitoring and maintenance actions to be conducted on rehabilitated areas.
Water resource management plan (WRMP)	The WRMP has been developed to proactively detail how Santos GLNG manages and monitors potential adverse impacts to water resources, recently defined as a matter of national environmental significance. The WRMP will be implemented to monitor impacts on geology and associated land and water resources.

9.2.7 Significance assessment

As discussed in section 9.2.2, impacts were assessed using the significance assessment methodology. As the GFD Project area covers a large geographical area over thousands of individual land parcels the general nature of impacts associated with GFD Project activities are identified and assessed within this section.

Table 9-8 summarises the assessment undertaken for the potential impacts of the GFD Project on geology, soil and topography values. For each identified potential impact, the assessment considered:

- The potential pre-mitigated significance, assumes only the application of the Constraints protocol and represents potential impacts at their greatest
- The mitigation measures that will be used to manage the potential impacts on geology, topography and soils values. These measures will reduce the magnitude of the potential impacts
- The residual significance of the potential impact after the implementation of mitigation measures. The residual significance takes into account the potential for impact that remains after the mitigation measures are applied.

Table 9-8 Land resources impact assessment

Potential impact	Phase	Pre-mitigated significance			Mitigation and management measures	Residual significance	
		Sensitivity	Magnitude	Significance		Magnitude	Significance
Altered geological setting	Construction	Moderate	Moderate	Moderate	In addition to the Constraints protocol the following plans will be implemented: • Hydraulic fracturing risk assessment • WRMP.	Low	Low
	Operations		Moderate	Moderate		Low	Low
	Decommissioning		Low	Low		Low	Low
Change to landform	Construction	Moderate	Moderate	Moderate	In addition to the Constraints protocol the following plans will be implemented: • DAMP • Rehabilitation management plan.	Low	Low
	Operations		Low	Low		Low	Low
	Decommissioning		Low	Low		Low	Low
Aquifer depressurisation resulting in subsidence	Construction	Moderate	Low	Low	• Joint Industry Plan • WRMP • Ground deformation monitoring and management plan.	Low	Low
	Operations		Low	Low		Low	Low
	Decommissioning		Low	Low		Low	Low
Loss of soil resources	Construction	Moderate	Moderate	Moderate	In addition to the Constraints protocol the following plans will be implemented: • ESCMP • PWMP.	Low	Low
	Operations		Low	Low		Low	Low
	Decommissioning		Low	Low		Low	Low
Degradation of soil resources	Construction	Moderate	Low	Low	In addition to the Constraints protocol the following plans will be implemented: • Rehabilitation management plan • DAMP • ESCMP.	Low	Low
	Operations		Low	Low		Low	Low
	Decommissioning		Low	Low		Low	Low
Restricted access to productive (agricultural or forestry) land	Construction	Moderate	Moderate	Moderate	In addition to the Constraints protocol the Rehabilitation management plan will be implemented:	Low	Low
	Operations		Low	Low		Low	Low
	Decommissioning		Low	Low		Low	Low

Potential impact	Phase	Pre-mitigated significance			Mitigation and management measures	Residual significance	
		Sensitivity	Magnitude	Significance		Magnitude	Significance
Authorised release to soil	Construction	Moderate	Moderate	Moderate	• Draft EM plan • LRMP.	Low	Low
	Operations		Low	Low		Low	Low
	Decommissioning		Low	Low		Low	Low
Uncontrolled release to soil	Construction	Moderate	Moderate	Moderate	• CFMP • Contingency plan for environmental incidents.	Low	Low
	Operations		Low	Low		Low	Low
	Decommissioning		Low	Low		Low	Low
Sterilisation of coal reserves	Construction	Moderate	Moderate	Moderate	• DAMP.	Low	Low
	Operations		Moderate	Moderate		Low	Low
	Decommissioning		Low	Low		Low	Low
Damage to fossils	Construction	Low	High	Moderate	In addition to the Constraints protocol the Draft EM plan will be implemented.	Low	Negligible
	Operations		Low	Low		Low	Negligible
	Decommissioning		Low	Low		Low	Negligible

9.2.7.1 Monitoring and review

Strategies for implementing monitoring throughout the duration of the GFD Project have been identified. Monitoring programs have been integrated into the management plans and provide a basis to measure the effectiveness of management strategies and enable review and update of processes. These programs will be updated if required to align with GFD Project activities following field development planning. All monitoring will be carried out at a frequency to demonstrate and ensure compliance with regulatory approvals.

9.2.8 Conclusions

The geology, topography and soils impacts that remain after the application of mitigation and management measures are detailed in Table 9-9. The significance assessment found that the residual significance of impacts associated with the GFD Project are expected to be low or negligible.

Table 9-9 Residual impacts – geology, soils and topography

Potential impact	Residual significance		
	Construction	Operations	Decommissioning
Altered geological setting	Low	Low	Low
Change to landform	Low	Low	Low
Aquifer depressurisation resulting in subsidence	Low	Low	Low
Loss of soil resources	Low	Low	Low
Degradation of soil resources	Low	Low	Low
Restricted access to productive (agricultural or forestry) land	Low	Low	Low
Authorised release to soil	Low	Low	Low
Uncontrolled release to soil	Low	Low	Low
Sterilisation of coal reserves	Low	Low	Low
Damage to fossils	Negligible	Negligible	Negligible

9.3 Resources and reserves

This section describes the gas resources and reserves that are to be developed as part of the GFD Project. It has been prepared in accordance with section 4.2.2 of the ToR issued March 2013. The index to locate where each ToR requirement is met within this EIS is included in Appendix B: Terms of reference cross-reference.

9.3.1 Regulatory context

This EIS has been prepared in accordance with the State and Commonwealth regulatory context described within Appendix C: Regulatory framework. The legislation, policies and guidelines that apply to the resources and reserves and the potential impacts of the GFD Project are outlined in Table 9-10.

Table 9-10 Regulatory context of the GFD Project – resources and reserves

Legislation, policy or guideline	Relevance to the GFD Project
Petroleum and Gas (Production and Safety) Act 2004 (Qld) (P&G Act) The P&G Act regulates petroleum activities with the aim of developing a safe, efficient and viable petroleum and fuel gas industry in Queensland. Petroleum tenure is granted under the Act.	The P & G Act is relevant to the GFD Project tenure issued from 2004 onwards. Amongst others, one main purpose of the P & G Act is to manage the State's petroleum resources in a way that has regard to the need for ecologically sustainable development.
The Petroleum Act 1923 (Qld) *The Petroleum Act 1923* regulates the mining for petroleum and natural gas in the State and the conveying of petroleum and natural gas, wherever recovered.	1923 is relevant to the GFD Project for any existing tenure issued prior to 2004. This tenure then fall under the 1923 Act.
Minerals Resources Act 1989 (Qld) The Mineral Resources Act seeks to facilitate the prospecting, exploration and mining of minerals within Queensland. Central to its purpose is conducting activities in an environmentally responsible manner and with minimal land use conflicts.	GFD Project tenure cover areas subject to mining authorities granted under the Mineral Resources Act. As such, Santos GLNG must consider the potential for resource sterilisation and seek agreement between overlapping tenement holders to enable development to proceed.

9.3.2 Gas resource

Santos GLNG petroleum tenure that makes up the Arcadia, Fairview, Roma and Scotia gas fields of the GFD Project area cover 10,676 km^2 of the Surat and Bowen basins in southern central Queensland.

The GFD Project area includes 35 petroleum tenements consisting of 11 authorities to prospect (ATPs) and 24 petroleum leases (PLs). Details of these tenements are given in Table 4–3 of Section 4: Project description.

The primary coal seams of interest to the GFD Project include the Jurassic-age Walloon Coal Measures (Surat Basin) and the late Permian Bandanna Formation (Bowen Basin).

9.3.3 Estimated reserves

9.3.3.1 Reporting method for reserves

Santos Limited prepares its reserves and contingent resources estimates in accordance with the definitions and guidelines in the international standard *2007 Petroleum Resources Management System* (PRMS), approved by the Society of Petroleum Engineers (SPE), World Petroleum Council (WPC), American Association of Petroleum Geologists (AAPG) and the Society of Petroleum Evaluation Engineers (SPEE). In November 2011, the SPE published updated guidance for the estimation of reserves and resources. Santos Limited has applied the new SPE PRMS guidance when preparing their 2012 and 2013 reserves and resources estimation.

9.3.3.2 Gas resources identification summary

Exploration and appraisal activities are currently underway across the GFD Project's petroleum tenure to improve understanding of the available gas resources. These activities have already been approved. As the understanding of gas reserves improves, decisions will be made about the scale, location and timing of the next stages of field development.

Santos GLNG is continuing to undertake basin-wide modelling to estimate the quantity of gas available across the GFD Project's gas fields.

Santos GLNG's knowledge of the GFD Project's gas reserves is based on the exploration and appraisal activities that have been carried out to date. Ongoing exploration across the GFD Project area will continue to build Santos GLNG's confidence of total reserves.

9.3.3.3 Santos GLNG estimates

The estimate of Santos GLNG's reserves and contingent resources (excluding Santos Limited's portfolio and third party gas) on 31 December 2013 for the GLNG Project is given in Table 9-10. Santos GLNG reports the status of its proved plus probable reserves semi-annually to the Queensland Government.

Table 9-10 Santos GLNG share of gas from coal seam reserves and resources

Gas reserves and resources	Santos GLNG share (PJ)					
	2008	2009	2010	2011	2012	2013
1P (Proven)	1,167	1,232	1,432	1,789	1,797	1,844
2P (Probable)	3,246	4,003	5,009	5,268	5,376	5,406
2C (Contingent resources, best estimate)	2,647	2,769	3,732	3,277	1,638	1,374

Source: Santos Limited, 2014

9.3.4 Gas quality

The typical composition of the gas to be extracted by the GFD Project is presented in Table 9-11. The gas quality presented here has been characterised based on the composition of gas from coal seams extracted during the Santos GLNG and Santos Limited exploration and production in and around the GFD Project area.

Table 9-11 Typical gas composition in the GFD Project area

Gas component	Typical composition (mol %)
Methane	97.5
Carbon dioxide	0.1
Nitrogen	2.4
Ethane	<0.1
Propane	<0.01
Butane	<0.01
Pentane	<0.01

9.3.5 Resource development

As stated in section 9.3.3.2, decisions will be made about the scale, location and timing of gas field development as understanding of gas reserves improves.

Current understanding of the gas resource indicates that production from the wells and upgrade of the gas compression facilities in the Scotia gas field will commence in 2016. Production from the Roma, Arcadia and Fairview gas fields will commence in mid-2019. The proposed GFD Project schedule and expected life of each gas field is shown in Figure 4–6 of Section 4: Project description.

9.3.6 Potential impacts

Potential impacts to resources and reserves within the GFD Project area include resource sterilisation and the underdevelopment of resources.

9.3.6.1 Resource sterilisation

Where GFD Project infrastructure is located in areas of overlapping tenure, such as coal mining projects, there is potential GFD Project infrastructure to impact on the future extraction of the resource in the overlapped tenure.

9.3.6.2 Undeveloped resources

The GFD Project uses a constraint field planning and development process known as the Constraints protocol. The Constraints protocol details the process that Santos GLNG will use to identify, assess and manage potential impacts to the environment during field planning and development. This process has been successfully used for the approved GLNG Project, which increases the certainty of GFD Project environmental outcomes.

Constraint classifications have been established according to the potential for the proposed activities to cause adverse impacts on the identified environmental values. Areas where GFD Project activities could cause unacceptable impact to environmental values or where regulations restrict development activities are classified as no-go areas. There will be no petroleum activities permitted in no-go areas and therefore gas resources within these areas will remain undeveloped.

9.3.7 Mitigation measures

Extraction of gas does not preclude the subsequent extraction of the coal. In fact, gas extraction is often required prior to coal extraction (particularly for underground mining) to reduce potential dangerous incidental mine gas concentrations to levels acceptable for mining. It is also of significant benefit for open cut mining as it reduces fugitive emission of methane. Coordinated coal and gas extraction can be mutually beneficial and commercially feasible.

Where GFD Project infrastructure is located in areas of overlapping tenure with coal mining projects, the design and location of project infrastructure, as well as the timing and rate of production, may require consideration of future coal mining operations. In such a case, Santos GLNG will manage and minimise the risk of resource sterilisation by entering into an agreement with the mining lease holder regarding the sequence of resource extraction. Alternatively, the Queensland Government has legislation in place to manage overlapping tenure.

9.3.8 Conclusions

With implementation of the mitigation and management measures outlined in section 9.3.7, the residual impact on resource sterilisation is low.

9.4 Contaminated land

This section addresses the potential for land contamination within the GFD Project area from activities undertaken by both Santos GLNG and third parties. It is based on a review of existing and past land uses and activities as well as current GLNG Project activities and their potential to result in land contamination. The likelihood that GFD Project activities will potentially cause contamination or disturb existing contaminated areas has also been assessed.

This section has been prepared in accordance with section 4.2.4 of the ToR issued March 2013. The index to locate where each ToR requirement is met within this EIS is included in Appendix B: Terms of reference cross-reference.

9.4.1 Regulatory context

This EIS has been prepared in accordance with the State and Commonwealth regulatory context described within Appendix C: Regulatory framework. The legislation, policies and guidelines that apply to the contaminated land and the potential impacts of the GFD Project are outlined in Table 9-11.

Table 9-11 Regulatory context of the GFD Project – contaminated land

Policy, guideline or legislation	Relevance to the GFD Project
National Environment Protection (Assessment of Site Contamination) Measure 1999 (April 2013), (ASC NEPM) The ASC NEPM seeks to protect human health and the environment where contamination has occurred. This is achieved through establishing a nationally consistent approach to the assessment of contamination and ensuring sound environmental management practices by all stakeholders.	Santos GLNG will refer to this guideline in assessing pre-existing land contamination should it be identified during project activities or should a GFD Project activity cause potential contamination.
Environmental Protection Act 1994 (Qld) (EP Act) The EP Act is the principal legislation for the protection and management of environmental values within Queensland. The Act aims to protect the natural environment and associated ecological systems and processes, while allowing for sustainable development.	Provision is made within the EP Act for the management of land that is or may be contaminated. Schedule 3 of the EP Act identifies activities that are likely to cause land contamination as 'notifiable activities'. Land parcels which may be contaminated or where notifiable activities have been undertaken may be listed on the Environmental Management Register (EMR). Where land parcels that are proven to be contaminated and may cause serious environmental harm are listed on the Contaminated Land Register (CLR). Both registers are managed by EHP. Targeted EMR/CLR searches will be conducted as required as the GFD Project's development plans are finalised and where relevant land parcels are identified.
Guideline for Contaminated Land Professionals (Department of Environment and Heritage Protection (EHP), 2012) The guideline establishes best practice for managing contaminated land through the planning and development control process. This guideline outlines minimum assessment requirements and reporting requirements for contaminated land investigations. This guideline supersedes the *Draft Guidelines for the Assessment and Management of Contaminated Land in Queensland* (Department of Environment, 1998).	Santos GLNG will follow the requirements of the guideline in assessing and reporting contaminated land.

This EIS seeks to obtain primary approvals for the project including the Queensland Government Coordinator-Generals Report and Commonwealth Government *Environment Protection and Biodiversity Conservation Act 1999* (Cth) approval.

Application for or amendments to existing environmental authorities will occur subsequent to this EIS process. Other subsequent approvals required after the EIS process has been completed, corresponding triggers and legislative frameworks applicable to the GFD Project are identified in Section 2: Project approvals.

Approval of this EIS will trigger a number of subsequent approvals required for the GFD Project to proceed. Approvals will be required on tenure and off-tenure. Section 2: Project approvals summarises the key approvals necessary for the planning, construction, operations and decommissioning of the GFD Project. The triggers for each approval, the relevant administering authority and application details are provided. Consultation on the subsequent approvals will be ongoing with the administering authorities.

9.4.2 Assessment methodology

An assessment was conducted to identify the potential for existing third party contaminated land in the GFD Project area, contamination that may be a result of current Santos GLNG activities, and the potential for land contamination associated with the construction, operations, decommissioning and rehabilitation phases of the GFD Project.

Impacts were assessed using the risk assessment methodology, which considers the likelihood and consequence of a potential impact to assess its level of risk.

The full description of the risk methodology is described in section 5.6.3 of Section 5: Assessment framework. A summary of the impact assessment is provided in section 9.4.7.

9.4.3 Environmental values

For the purposes of describing environmental values, data were sourced from a range of primary and secondary sources, including complementary technical studies prepared as part of the 2009 EIS, other Santos GLNG documentation relating to contaminated land management, as well as legislation, planning policies and guidelines.

9.4.3.1 Notifiable activities

Land can be contaminated by a range of land uses and activities. Existing contamination with the GFD Project area could have resulted from previous activities associated with urban, industrial and agricultural land uses such as homestead complexes, stockyard complexes, agricultural infrastructure, commercial and industrial areas, equipment laydown areas, landfills, mining and tailings activities and urban development.

Table 9-12 identifies notifiable activities that have the potential to occur within the GFD Project area as well as the potential likelihood of their occurring. Should there be an occurrence of a notifiable activity, its spatial extent is expected to be limited.

Table 9-12 Potential likelihood of notifiable activities pre-existing within the GFD Project area

Notifiable activity with potential to occur	Notifiable activity with potential to occur less frequently	Notifiable activity with potential to occur in developed areas/towns/existing facilities
• Abrasive blasting • Aerial spraying • Asbestos disposal • Battery recycling • Chemical Storage • Landfill • Livestock dip or spray race operations • Petroleum product or oil storage • Railway yards • Scrap yards • Waste storage, treatment or disposal.	• Defence establishments or training areas • Drum reconditioning or recycling • Electrical transformers • Fertiliser manufacture • Gun, pistol or rifle range • Herbicide or pesticide manufacture • Lime burner • Metal treatment or coating • Paint manufacture or formulation • Petroleum or petrochemical industries • Smelting or refining • Tannery, fellmongery or hide curing • Wood treatment and preservation.	• Asphalt or bitumen manufacture • Chemical manufacture/formulation • Coal fired power station • Coal gas works • Dry cleaning • Engine reconditioning works • Explosives production or storage • Foundry operations • Mine wastes • Mineral processing • Pest control • Pharmaceutical manufacture • Printing • Service stations.

As discussed in Table 9-11, land parcels where notifiable activities have been undertaken may be listed on the EMR or CLR. These registers can only be searched by individual lot and plan. Given the large number of land parcels on the GFD Project area (7,817), it is not practical to search the EMR/CLR until the land parcels proposed to be developed are identified by the ongoing field development planning process and the associated risk of contamination being present is assessed.

9.4.3.2 Uncontrolled and unidentified activities

There is the possibility that unidentified or unrecorded notifiable activities or other activities with the potential to cause contamination may have occurred within the GFD Project area. There is a requirement that:

> If the owner or occupier of land becomes aware a notifiable activity is being carried out on the land, or if the land has been, or is being contaminated…the owner or occupier must notify the administering authority (EHP, 2012).

Existing or previous activities likely to have occurred within the GFD Project area that may result in land contamination include:

- Domestic landfills/waste areas/animal disposal areas/burn pits
- Spillage/storage of chemicals/fuels/lubricants
- Agricultural use of pesticides/chemicals (e.g. livestock dips).

9.4.4 Environmental values with potential to be impacted by land contamination

The main land uses in the GFD Project area are rural and agricultural. Key environmental values with the potential to be impacted by land contamination within the GFD Project are listed below:

- Health and safety, being the life, health and wellbeing of people including the GFD Project workforce
- The natural environment, including soils and land, terrestrial ecology, water resources and aquatic ecology
- The productive capability of land, being its potential for use for agricultural, forestry or other uses for economic gain
- Sustainable use of natural resources.

9.4.5 Potential impacts

Potential land contamination impacts within the GFD Project may include impacts resulting from the disturbance of existing contaminated land or contamination caused by GFD Project activities. Without adequate controls, these activities have the potential to contribute to human health risks, or surface water/soil/groundwater contamination, leading to degradation of the natural environment, and a reduction in the productive capability of the land and the sustainable use of natural resources.

Some existing Santos GLNG and proposed GFD Project activities have the potential to result in land contamination. Chemicals and wastes used or generated by the GFD Project with the potential to cause contamination include diesel and other fuels, cleaning and processing chemicals, water extracted from coal seams or concentrated waste from water treatment, chemicals used in water management processes, drilling fluids, hydraulic fracturing chemicals and sewage effluent. These chemicals and wastes will generally be stored or used at the well lease during well drilling and completion and at water management facilities, gas compression facilities, accommodation camps and storage/laydown areas, which are generally located within operational areas.

Some GFD Project activities will be notifiable activities and the land parcels on which they occur are required to be listed on the EMR. Such activities may include:

- Petroleum product or oil storage – Storing petroleum products or oil
  a. In underground tanks with more than 200 litres (L) capacity; or
  b. In above ground tanks with
  - For petroleum products or oil in class 3 in packaging groups 1 and 2 of the dangerous good code more than 2,500 L capacity; or
  - For petroleum products or oil in class 3 in packaging groups 3 of the dangerous goods code more than 3,000L capacity; or
  - For petroleum products that are combustible liquids in class C1 or C2 in Australian Standard AS 1940 – more than 25,000 L capacity.
- Chemical storage – (other than petroleum products or oil) – storing more than 10 tons of chemicals (other than compressed or liquefied gases) that are dangerous goods under the dangerous goods code
- Regulated waste storage and/or treatment
- Abrasive blasting (during pipeline construction).

9.4.5.1 Disturbance of existing contaminated land

The GFD Project has the potential to disturb existing contaminated soil or groundwater during its construction, operations, decommissioning and rehabilitation phases. The disturbance of contaminated soil or groundwater has the potential to contaminate previously unaffected soil or groundwater and affect human health through ingestion/dermal contact with contaminants.

As discussed in Table 9-11, land parcels where notifiable activities have been undertaken may be listed on the EMR or CLR. These registers can only be searched by individual lot and plan. Given the large number of land parcels on the GFD Project area (7,817), it is not practical to search the EMR/CLR until the land parcels proposed to be developed are identified by the ongoing field development planning process and the associated risk of contamination being present is assessed.

Should contaminated land be discovered on Santos GLNG tenure, the process outlined in Figure 9-8 will be followed.

9.4.5.2 Land contamination caused by GFD Project activities

The following GFD Project activities have the potential to cause land contamination:

- Leaks or spills leading to migration of contaminants through surface water/soil/groundwater or exposure to human health risks through ingestion/dermal contact to contaminants from:
  - Permanent/mobile fuel/chemical storage
  - Waste storage areas/facilities (including storage tanks, dams, ponds, sewerage, drilling mud ponds, wash out fluids in flare pits)
  - GFD Project infrastructure (e.g. pipelines, water management facility, fluid (brine) storage, etc.).
- Transport or movement of existing contaminated soil/groundwater leading to migration of contaminants to previously uncontaminated soil/groundwater and affecting human health through contact with contaminants.

Impacts from the potential release of low quality coal seam water from wells, dams and pipelines or the release of fluids (brine) from water treatment facilities, water storage and disposal facilities and any potential for soil, surface water or groundwater impacts is addressed in Section 13: Surface water and Section 14: Groundwater.

For the potential impacts (identified above) to present a risk there must be the following components:

- Source of contamination
- An exposure pathway and
- Environmental values (receptor) that may be affected by this exposure.

Should one or more of these above components be unavailable, then the risk of exposure to an environmental value is likely to be either minimal or non-existent.

9.4.6 Mitigation measures

Santos GLNG has a corporate Environmental Health and Safety Management System that provides a structured framework for effective environmental, health and safety practices across the life of the GFD Project. The Environment, Health and Safety Management System framework consists of multiple layers, a key components being the management standards listed in Table 9-13.

Table 9-13 Existing Santos GLNG management standards

Reference	Summary
EHS01 Biodiversity and and disturbance	EHS01 details the Santos GLNG requirements for planning and conducting operations in a way that avoids or minimises disturbance to land and allows affected areas to be rehabilitated within reasonable timeframes. EHS01 requires land disturbance to be carried out in a manner that minimises environmental impact and in accordance with relevant environmental procedures. The standard aims to minimise disturbance to land and avoid impacts to soil, and minimise disturbance to drainage patterns and avoid impact of surface waters and shallow groundwater resources.
EHS02 Underground storage tanks and bunds	EHS02 details Santos GLNG requirements for managing underground storage tanks and secondary containment bunds in order to minimise potential for spills or leaks of environmentally hazardous substances. This standard was developed in accordance with *Australian Standard AS1940:2004 The storage and handling of flammable and combustible liquids.* This standard outlines inspection, testing and maintenance requirements of underground storage tanks, bunds and associated infrastructure.
EHS04 Waste management	EHS04 specifies minimum acceptable performance standards for waste management processes and procedures for Santos GLNG operations and activities around Australia, including waste generation, transportation, receiving, storage and/or disposal.
EHSMS06 Environmental impact assessment and approvals	EHSMS06 outlines requirements to ensure processes are established and maintained to systematically identify, assess and manage potential environmental impacts associated with development activities, new disturbances and emissions. It outlines internal environmental assessments (including scouting, constraints mapping and risk assessments) to be carried out prior to commencement of activities including new land disturbances which may encounter potentially contaminated land or with the potential to cause contaminated land.

Reference	Summary
EHS08 Contaminated sites	EHS08 defines the requirements for the protection of health and the environment, where contamination has or may have occurred. Outlines a contaminated site management process for identifying, documenting and managing a contaminated site. These include: • Notify incident occurrence as required • Undertake impacted site review • Report contamination to authorities as required • Record contamination on Santos GLNG's Contaminated Site Register • Develop action plan (e.g. contaminated site assessment, risk assessment, contaminated site management plan) • Implement action plan.
EHSMS09 Managing environmental health and safety risks	EHSMS09 details the framework and processes necessary to systematically identify hazards, assess their risk and adopt control strategies to reduce risk to as low as reasonably practicable. This may involve risk assessments to assess appropriate mitigation measures to minimise human health exposure to potentially impacted land or waters.
EHS10 Water resources	EHS10 nominates requirements for sustainable use and protection from degradation of watercourses, lakes, springs, overland flows, groundwater aquifers and other natural ecosystems associated with these water resources. In particular, guidance is given regarding management options to manage water from waste/oil/chemical storage and processing plant.
EHSMS11 Operations integrity	Process safety management deals with the prevention of major hazards or catastrophic events that could lead to fatalities, serious injury, significant property damage or significant environmental harm. Systems and tools are required to manage process safety risks, as a subset of environment, health and safety management. The emphasis is on maintaining effective lines of defence to prevent the occurrence of and mitigate the consequences of major unwanted events. Process safety is addressed across the full lifecycle of assets, from development to operational integrity through to rehabilitation.
EHSMS11.1 Design basis – facility and equipment	A detailed description of the facility operating basis, the fluids and chemicals processed within the facility, and the design basis and operating limits of the equipment involved, along with processes to support consistent operation within design limits is required to provide a basis for personnel associated with the operation, maintenance or design of a facility to identify, understand and manage environment, health and safety risks. These supporting processes include alarm management, operating envelopes and control systems.
EHSMS11.2 Facilities design and construction	Facilities need to be designed and constructed (for new and modified facilities) so that they can be commissioned, started up and operated in compliance with applicable legislation and with as low as reasonably practicable risk of safety, health or environmental incidents.
EHSMS11.3 Pre-startup environment, health and safety review	Prior to the startup of new facilities, modified facilities or facilities that have undergone intrusive maintenance, a pre-startup environment, health and safety review is conducted to ensure that the facility can be started up and operated safely and without environmental harm.
EHSMS11.4 Structural integrity	Management processes are required for developing, implementing and maintaining the structural integrity of structures and equipment to ensure that they are structurally safe and meet relevant regulatory requirements.
EHSMS11.5 Mechanical integrity	Management processes are required for developing, implementing and maintaining the mechanical integrity of assets so that the risk of failure is as low as reasonably practicable.
EHSMS11.6 Ignition control	Ignition sources are a hazard at locations where explosive atmospheres may occur so processes are required to identify and eliminate or otherwise control such sources in order to reduce the risk of a fire and/or an explosion to as low as reasonably practicable.

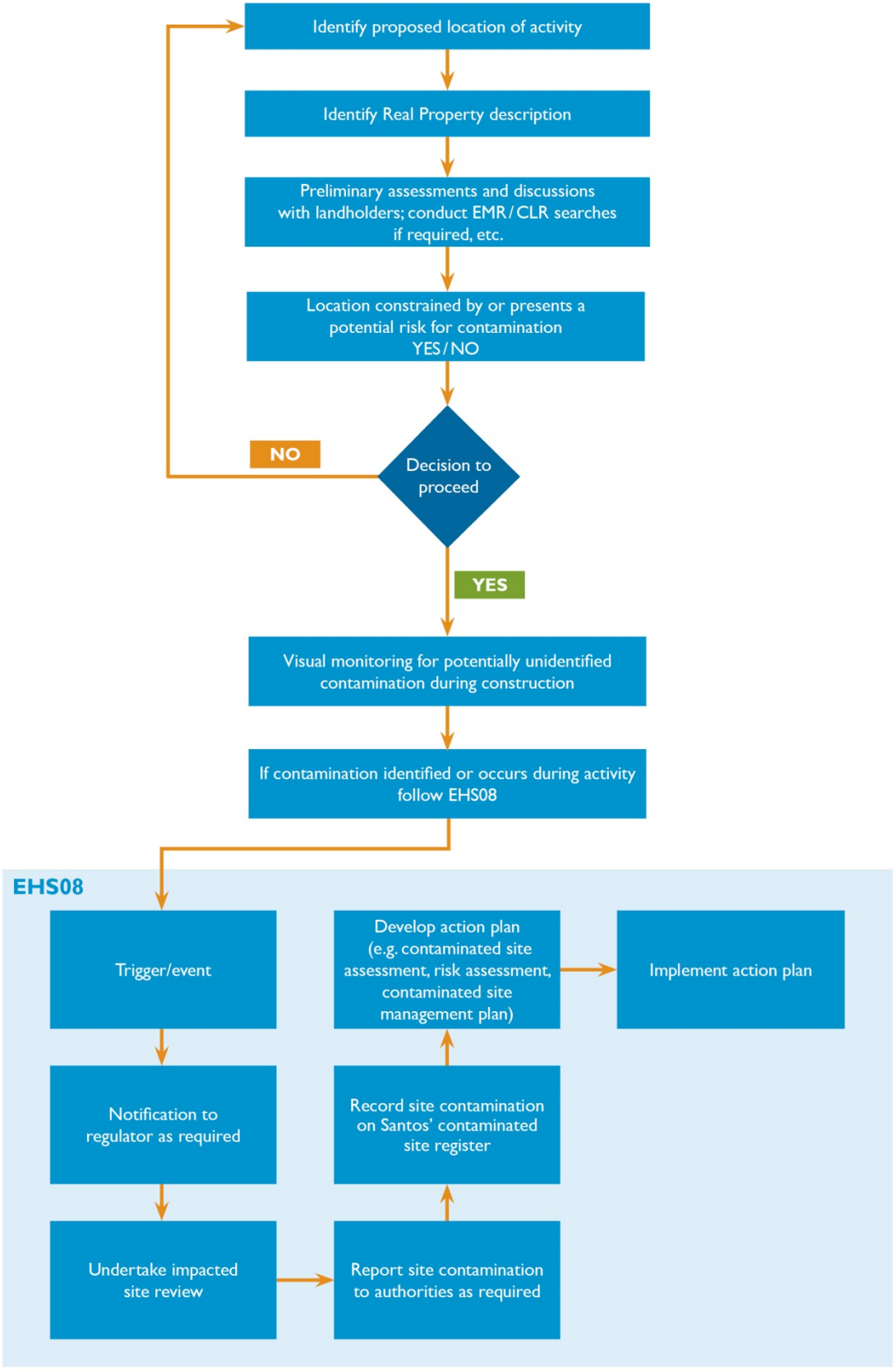
Reference	Summary
EHSMS11.7 Critical protection systems	Critical protection systems are a line of defence to prevent mechanical or electrical integrity being compromised or environment, health and safety incidents escalating so processes are required for the design, assessment, construction, operation, testing, reliability and maintenance of critical protection systems in new and existing facilities.
EHSMS11.8 Operating procedures and safe practices	A controlled system of procedures and safe work practices is required to be developed and maintained to ensure the safety of personnel during operational and maintenance activities, to protect the environment and the safe operation of plant and equipment.
EHSMS11.9 Maintenance	Maintenance specific systems and procedures are required to manage environment, health and safety risks encountered in maintenance operational activities.
EHSMS11.10 Fire risk management	Processes need to be developed and maintained to ensure that fire and fire-related risks in facilities and buildings are managed.
EHSMS11.11 Decommissioning and abandonment	Ensures that environment, health and safety risks associated with the decommissioning and abandonment of plant, equipment and facilities are effectively managed.
EHSMS11.12 Operated by others	Details the Santos requirements for stewarding the environment, health and safety performance of joint venture activities operated by others.
HSHS08 Chemical management	HSHS08 provides guidance to manage the risks associated with the handling, use and storage of chemicals including: asbestos, synthetic material fibres, benzene, mercury, vanadium, nitrogen and hydrogen sulphide, to limit adverse impacts. This provides guidance on PPE to be used through analysis of the safety data sheets for each chemical.
HSH17 Personal protective equipment	HSH17 provides guidance for the selection of personal protective equipment to mitigate risks associated with tasks carried out whilst working for Santos GLNG.

EHS: Environmental hazard standard. HSHS: Health and safety hazard standards.
EHSMS: Environment, health and safety management standards

Santos GLNG will apply its corporate environment, health and safety management system to the GFD Project. Application of the management standards listed in Table 9-13 will be an integral part of the strategies used to reduce the risk of contaminated land impacts.

In addition, a contaminated land process incorporating the requirements of EHS08 as illustrated in Figure 9-8 will be followed. This process will assist with the identification of the nature and risk associated with potential contamination.

Figure 9-8 Contaminated land strategy incorporating EHS08



Santos GLNG is committed to implementing the mitigation measures in Table 9-14 to manage potential contaminated land impacts. These measures will be incorporated into Santos GLNG's management framework, as described in Appendix Y: Draft environmental management plan.

Table 9-14 Existing Santos GLNG management plans relating to land contamination

Management plan	Description
Chemical and fuel management plan (CFMP)	The CFMP details the appropriate storage and handling practices of chemicals and fuels. The objectives of the plan are to: • Facilitate compliance with relevant legislation, regulations and approvals • Provide a framework for Santos GLNG to store and handle bulk chemicals and fuels in a way that minimises risk to the environment and human health • Assess the potential risk of a chemical or fuel prior to its use • Identify and implement appropriate mitigation measures. These measures will be used to manage the risk of uncontrolled release and subsequent potential contamination of groundwater and soil associated with the chemicals and fuels to be used as part of the GFD Project.
Contaminated site management plan	This plan provides direction for Santos GLNG to appropriately manage location specific risks associated with contamination should it be identified during GFD Project activities. The objective of the plan is to document: • Extent and nature of contaminants • Objectives to be achieved and maintained under the plan to manage risk • State what measures to be implemented and maintained to achieve the objectives • Document provisions for monitoring performance. A Contaminated site management plan would only be developed should contamination and associated risks be identified during GFD Project activities.
Contingency plan for emergency environmental incidents	The Contingency plan details the management practices in place within Santos GLNG to minimise environmental harm during an emergency environmental incident. The plan identifies potential incidents, and provides response actions, including escalation, communication, reporting and monitoring.
Decommissioning and abandonment management plan (DAMP)	The DAMP describes the management framework in place for when petroleum activities cease. The objectives of the plan are to: • Undertake decommissioning of assets in a manner that complies with regulatory requirements and minimises the risk of environmental harm • Undertake decommissioning activities in a manner that meets stakeholder expectations • Leave a landform that is stable and compatible with intended post-closure land use • Provide for the beneficial reuse of Santos GLNG infrastructure constructed to third parties (e.g. landholders or local authorities) where an appropriate agreement has been signed by both parties and regulatory authorities are satisfied. The management of contaminated land during the decommissioning of infrastructure will be undertaken in accordance with the DAMP. This includes: • Assessment of potentially contaminated land at areas where notifiable activities have occurred. • Demolition procedures to minimise the potential for contamination, including removal of chemicals and fuels prior to demolition activities, flushing of lines and tanks prior to demolition, and establishment of appropriate handling, transportation and disposal facilities for chemicals and hazardous wastes, including staff training.

Management plan	Description
Land release management plan (LRMP)	The LRMP addresses the management of releases of water to land in Santos GLNG's gas fields, including: • Coal seam water use for irrigation, construction and operations purposes • Treated sewage effluent releases to land • Use of treated sewage effluent for construction and operations purposes • Low point drain water releases to land • Hydrostatic test water releases to land. The plan includes the principles, methods and controls to effectively manage and minimise the risk of environmental harm being caused by release of water to land.
Waste management plan (WMP)	The WMP details the strategy, methods and controls for managing waste generated by Santos GLNG activities. The plan identifies the types of wastes generated by Santos GLNG activities, and describes the waste management framework and how the waste management hierarchy is applied to generated waste. The WMP aims to minimise waste volumes and the risk of potential soil/groundwater contamination through improving operational efficiency and environmental performance. The WMP details: • Legislation, policies and regulations applicable to waste management, transport and disposal • Classification of generated wastes to determine applicable management measures • Management measures for onsite storage, transport and disposal of wastes. Monitoring and reporting of waste generation, transport and disposal will be undertaken in accordance with the WMP.

9.4.7 Risk assessment

As discussed in section 9.4.2, impacts were assessed using the risk assessment methodology. As the GFD Project area covers a large geographical area, the general nature of potential impacts to environmental values associated with GFD Project activities are identified and assessed within this section. Table 9-15 summarises the assessment undertaken for the potential impacts of the GFD Project on environmental values. For each identified potential impact, the assessment considered:

- The potential pre-mitigated risk, where only the Constraints protocol has been applied and the potential impacts are uncontrolled
- The mitigation measures that will be used to manage the potential impacts due to land contamination. These measures will reduce the likelihood of the potential impacts
- The residual risk of the potential impact after the implementation of mitigation measures. The residual risk takes into account the potential for impact that remains after the mitigation measures are applied.

Table 9-15 Impacts and mitigation – contaminated land

Potential impact	Phase	Pre-mitigated risk			Mitigation and management measures	Residual risk		
		Likelihood	Consequence	Risk		Likelihood	Consequence	Risk
Disturbance of existing contaminated soil or groundwater leading to migration of contaminants through soil/groundwater or increased human health risks through ingestion/dermal contact to contaminants.	Construction	Possible	Minor	Low	Implement the following: • Contaminated land strategy, which includes mitigation measures such as: — Identification of contaminated land, allowing avoidance or management of such contamination where practicable — Historical assessments of potential for contaminated land — Implement the contaminated land assessment detailed in EHS08 • EHS01, which includes mitigation measures to minimise disturbance to land and avoid contamination to soil • EHS06, which includes a procedural framework to minimise the likelihood of disturbing pre-existing contaminated land through scouting, constraints mapping and risks assessments • EHSMS09, which includes the framework and processes necessary to systematically identify hazards, assess their risk and adopt control strategies to reduce risk to as low as reasonably practicable • EHSMS11, which ensure consideration of environmental issues in design including, but not limited to secondary containment, HAZOP, HAZAN. • HSH17, which includes identification of appropriate personal protective equipment to minimise human health exposure through inhalation and dermal contact. • DAMP during decommissioning which includes : — Assessment of potentially contaminated land at areas where regulated activities have occurred.	Unlikely	Minor	Low
	Operations	Remote	Minor	Very low		Remote	Minor	Very low
	Decommissioning	Possible	Minor	Low		Unlikely	Minor	Low

Potential impact	Phase	Pre-mitigated risk			Mitigation and management measures	Residual risk		
		Likelihood	Consequence	Risk		Likelihood	Consequence	Risk
					— Demolition procedures to minimise the potential for contamination, including removal of all chemicals and fuels prior to demolition activities, flushing of lines and tanks prior to demolition, and establishment of appropriate handling, transportation and disposal of chemicals and hazardous wastes, including staff training. • WMP and EHS04, which aims to minimise waste volumes and risk of potential soil/groundwater contamination through improving operational efficiency and therefore environmental performance. The WMP details: — Applicable legislation, policies and regulations to waste management, transport and disposal — Classification of generated wastes to determine applicable management measures — Management measures for onsite storage, transport and disposal of wastes.			
Leaks or spills leading to migration of contaminants through surface water/soil/groundwater or increased human health risk through ingestion/dermal contact to contaminants from: • permanent/mobile fuel/chemical storage • waste storage areas/facilities (including storage tanks, dams,	Construction	Possible	Minor	Low	Implement the following: • EHS02, which includes — Measures to minimise potential for spills or leaks of environmentally hazardous substances in accordance with AS1940:2004 — Requirements to develop procedures for inspection, testing and maintenance of underground storage tanks, bunds and associated infrastructure • EHS04 and WMP to minimise risk of potential soil/groundwater contamination through improving waste management efficiency and adhering to relevant guidelines, codes and standards including regular testing and monitoring • EHS08, which includes measures to develop and implement action plan (e.g. contaminated site assessment, risk assessment, contaminated site	Unlikely	Minor	Low
	Operations	Possible	Minor	Low		Unlikely	Minor	Low
	Decommissioning	Possible	Minor	Low		Unlikely	Minor	Low

Potential impact	Phase	Pre-mitigated risk			Mitigation and management measures	Residual risk		
		Likelihood	Consequence	Risk		Likelihood	Consequence	Risk
ponds, sewerage, drilling mud ponds, wash out fluids in flare pits) • GFD Project infrastructure (e.g. pipelines, water management facility, fluid/ brine storage, etc.).					management plan) • EHSMS09, which includes the framework and processes necessary to systematically identify hazards, assess their risk and adopt control strategies to reduce risk to as low as reasonably practicable • EHSMS13, which includes measures to minimise adverse impacts on the safety or health of people or the environment by ensuring that relevant equipment and resources are available to effectively respond to foreseeable emergencies • EHSMS15, which outlines the required incident reporting, investigation and management of corrective actions, to identify underlying system failures and implement appropriate corrective actions to prevent a recurrence. • HSHS08, which includes measures to manage risks associated with handling, use and storage of chemicals • HSH17, which includes identification of appropriate personal protective equipment to minimise human health exposure through inhalation and dermal contact of contaminants. • Contingency Plan for Emergency Environmental Incidents, which includes measures to contain, isolate and cleanup following an incident to minimise further contamination • LRMP, which provides strategies to minimise degradation of soil quality, runoff, subterranean flows of contaminants to waters, surface ponding and spray drift • CFMP, which provides strategies to: — Ensure chemicals and fuels are stored appropriately (i.e. containment system impervious to materials stored within; stored and handled in			

Potential impact	Phase	Pre-mitigated risk			Mitigation and management measures	Residual risk		
		Likelihood	Consequence	Risk		Likelihood	Consequence	Risk
					accordance to relevant Australian Standards when available; managed to minimise risk or release of substance to waters or land); — Identifying and implementing appropriate risk and/or impact mitigation measures. • DAMP, during decommissioning which includes: — Assessment of potentially contaminated land at areas where regulated activities have occurred. — Demolition procedures to minimise the potential for contamination, including removal of all chemicals and fuels prior to demolition activities, flushing of lines and tanks prior to demolition, and establishment of appropriate handling, transportation and disposal of chemicals and hazardous wastes, including staff training.			
Transport or movement of existing contaminated soil/groundwater leading to migration of contaminants to previously uncontaminated soil/groundwater or increased human health risks through ingestion/dermal contact to contaminants.	Construction	Possible	Minor	Low	Implement the following: • WMP and EHS04, which aims to minimise waste volumes and risk of potential soil/groundwater contamination through improving operational efficiency and therefore environmental performance. The WMP details: — Applicable legislation, policies and regulations to waste management, transport and disposal — Classification of generated wastes to determine applicable management measures — Management measures for onsite storage, transport and disposal of wastes. • EHS08, which includes measures to develop and implement action plan (e.g. contaminated site assessment, risk assessment, contaminated site management plan) • EHSMS09, which includes the framework and processes necessary to systematically identify hazards, assess their risk and adopt control strategies to reduce risk to as low as reasonably	Unlikely	Minor	Low
	Operations	Unlikely	Minor	Low		Remote	Minor	Very low
	Decommissioning	Possible	Minor	Low		Unlikely	Minor	Low

Potential impact	Phase	Pre-mitigated risk			Mitigation and management measures	Residual risk		
		Likelihood	Consequence	Risk		Likelihood	Consequence	Risk
					practicable • HSHS08, which includes measures to manage risks associated with handling, use and storage of chemicals • HSH17, which includes identification of appropriate personal protective equipment to minimise human health exposure through inhalation and dermal contact of contaminants. • DAMP during decommissioning, which includes: — Assessment of potentially contaminated land at areas where regulated activities have occurred. — Demolition procedures to minimise the potential for contamination, including removal of all chemicals and fuels prior to demolition activities, flushing of lines and tanks prior to demolition, and establishment of appropriate handling, transportation and disposal of chemicals and hazardous wastes, including staff training.			

9.4.7.1 Monitoring and review

Monitoring will be conducted at storage facilities as required to meet Australian Standards, and as detailed within the CFMP. In addition, monitoring for land contamination would occur on an asset by asset basis and following a contamination event. Monitoring will form part of the contaminated site management plan, as detailed in EHS08 and in accordance with EHSMS14 Monitoring, measurement and review.

9.4.8 Conclusions

The GFD Project has the potential to encounter pre-existing contaminated land. However, due to the largely agricultural nature of the GFD Project area, such areas are likely to be limited in frequency and extent. In addition, GFD Project activities without adequate controls have the potential to impact land and water resources, and pose a risk to human health. Implementing the contaminated land management framework will ensure that residual risks will be low as shown in Table 9-16.

Table 9-16 Residual impacts – contaminated land

Potential impact	Residual risk		
	Construction	Operations	Decommissioning
Disturbance of existing contaminated soil or groundwater during construction, operational or decommissioning activities leading to migration of contaminants through soil/groundwater or increased human health risks through ingestion/dermal contact to contaminants.	Low	Very low	Low
Leaks or spills leading to migration of contaminants through surface water/soil/groundwater or increased human health risks through ingestion/dermal contact to contaminants from: • Permanent/mobile fuel/chemical storage • Waste storage areas/facilities (including storage tanks, dams, ponds, sewerage, drilling mud ponds, wash out fluids in flare pits) • GFD Project infrastructure (e.g. pipelines, water management facility, fluid/ brine storage, etc.).	Low	Low	Low
Transport or movement of existing contaminated soil/groundwater leading to migration of contaminants to previously un-impacted soil/groundwater or increased human health risks through ingestion/dermal contact to contaminants.	Low	Very low	Low