12. GEOLOGY, LANDFORM AND SOILS

This chapter provides a summary of the geology, landform and soils values within the project development area and an assessment of the potential for these values to be affected by direct and indirect impacts associated with the construction, operations and decommissioning phases of the project. For the detailed findings of the project's geology, landform and soils impacts, refer to Appendix E, the Geology, Landform and Soils Impact Assessment. Environmental protection objectives have been developed and the avoidance, mitigation and management measures to achieve these objectives identified. The residual impact assessment assumes that the proposed avoidance, mitigation and management measures have been applied.

This chapter also provides a description of Arrow's approach to contaminated land within the project development area. The issues associated with the project for this aspect generally relate to the historical, current and future use of hazardous materials in the environment, and any resultant contamination of land or groundwater.

12.1 Legislative Context

The following legislation, policy and guidelines are relevant to identifying values, mitigating and managing impacts on geology, landform and soils, and to management of potential impacts associated with land contamination during construction, operations and decommissioning of the project.

***Nature Conservation Act 1992* (Qld).** This act relates to the conservation of nature (including ecosystems and their constituent parts), and all physical and natural resources. This act is relevant to the project in the event that there are impacts on the geology, landform and soils within protected areas (listed under s. 14) that contribute to the biological diversity and integrity, or intrinsic or scientific value of that particular place. For example, Lake Broadwater Conservation Park is a listed protected area within the project development area and is considered to have landforms and soil types of conservation significance.

***Environmental Protection Act 1994* (Qld).** The objective of this act is to protect Queensland's environment while allowing for development that improves total quality of life, both now and in the future. It also includes provisions for the management of land that is contaminated, or that has supported land uses that may have resulted in land contamination, or that supports activities that could result in land contamination. Generally, activities that could result in land contamination are notifiable. Land parcels where notifiable activities have been, or are conducted are listed on the Environmental Management Register (EMR). Land parcels that are proven to be significantly contaminated are listed on the Contaminated Land Register (CLR). The Queensland Department of Environment and Resource Management (DERM) administers both registers.

***Vegetation Management Act 1999* (Qld).** This act aims to ensure that vegetation clearance does not lead to land degradation, and to manage the environmental effects resulting from clearance.

***Sustainable Planning Act 2009* (Qld).** This act seeks to achieve ecological sustainability through managing development processes and associated environmental effects, and to streamline the coordination of planning and local, regional and state planning instruments.

Environmental Offsets Policy 2008 (Qld). This policy guides the appropriate use of environmental offsets in terrestrial and aquatic ecosystems. The policy is of relevance to this project as it applies to all developments assessed under the Environment Protection Act.

State planning policies and their associated guidelines include:

- **State Planning Policy: Mitigating the Adverse Impacts of Flood, Bushfire and Landslide 1/03 (Qld).** Under the Integrated Planning Act 1997, this policy and guideline relates to minimising potential adverse impacts of flood, bushfire and landslide on people, property, economic activity and the environment. For this project, landslide or flood risk may be increased as a result of direct or indirect landscape modifications.
- **State Planning Policy: Protection of Extractive Resources 2/07 (Qld).** Under the Integrated Planning Act, this policy and its associated guideline aim to identify areas of extractive resources of state or regional significance and protect them (via the delineation of key resource areas and associated transport routes). No key resource areas have been identified within the project development area.
- **State Planning Policy: Development and the Conservation of Agricultural Land 1/92 (Qld).** The aims of this policy, prepared under the Sustainable Planning Act, are to protect good-quality agricultural land (GQAL) from competing land uses, and maintain the productivity of agricultural land uses into the future. The following principles directly relate to this project: 1) GQAL should not be built on unless there is an overriding need for the development and no alternatives exist, and 2) the alienation of some productive agricultural land will result from development. However, the government will not support such alienation when equally viable alternatives exist. Two guidelines are associated with State Planning Policy 1/92: 1) The Identification of Good Quality Agricultural Land; and 2) Separating Agricultural and Residential Land Uses.
- **State Planning Policy: Strategic Cropping Land (Draft) (Qld).** Currently in draft form, this policy operates under the Sustainable Planning Act with DERM as the administering agency. It aims to manage and protect strategic cropping land and ensure relevant developments, planning schemes and regional plans appropriately consider strategic cropping land. While the laws have not yet been enacted, the principles are to be taken into account. It will operate in tandem with State Planning Policy 1/92.

Relevant industry guidelines and codes of practice include:

- **Best Practice Erosion and Sediment Control Manual** (IECA, 2008). This manual outlines how to manage erosion and sedimentation through the planning and construction stages of development.
- **Code of Environmental Practice for Onshore Pipelines** (APIA, 2009). This code provides information on methods and techniques to manage environmental impacts associated with construction of onshore pipelines.
- **Healthy HeadWaters Coal Seam Gas Water Feasibility Study: Assessment of the Salinity Impacts of Coal Seam Gas Water on Landscapes and Surface Streams** (DERM, 2010d). This document relates to when and where coal seam gas water can be used for irrigation.
- **Draft Guidelines for the Assessment and Management of Contaminated Land 1998 (Qld)** (DE, 1998). These guidelines establish the processes for all aspects of the assessment and management of contaminated land and serve to facilitate compliance with the Environmental Protection Act. Although the guidelines remain in draft form, they set an industry-accepted standard for works on contaminated lands.

12.2 Assessment Methods

12.2.1 Geology, Landform and Soils

The geology, landform and soils assessment comprised a desktop study and a field survey to describe and gain an understanding of the existing environment. This study method is summarised below.

Desktop Study

The desktop study of geology, landform and soils included a review of relevant legislation, previous studies, databases and mapping. A GIS database was constructed to enable preliminary mapping of environmental constraints and sensitivities.

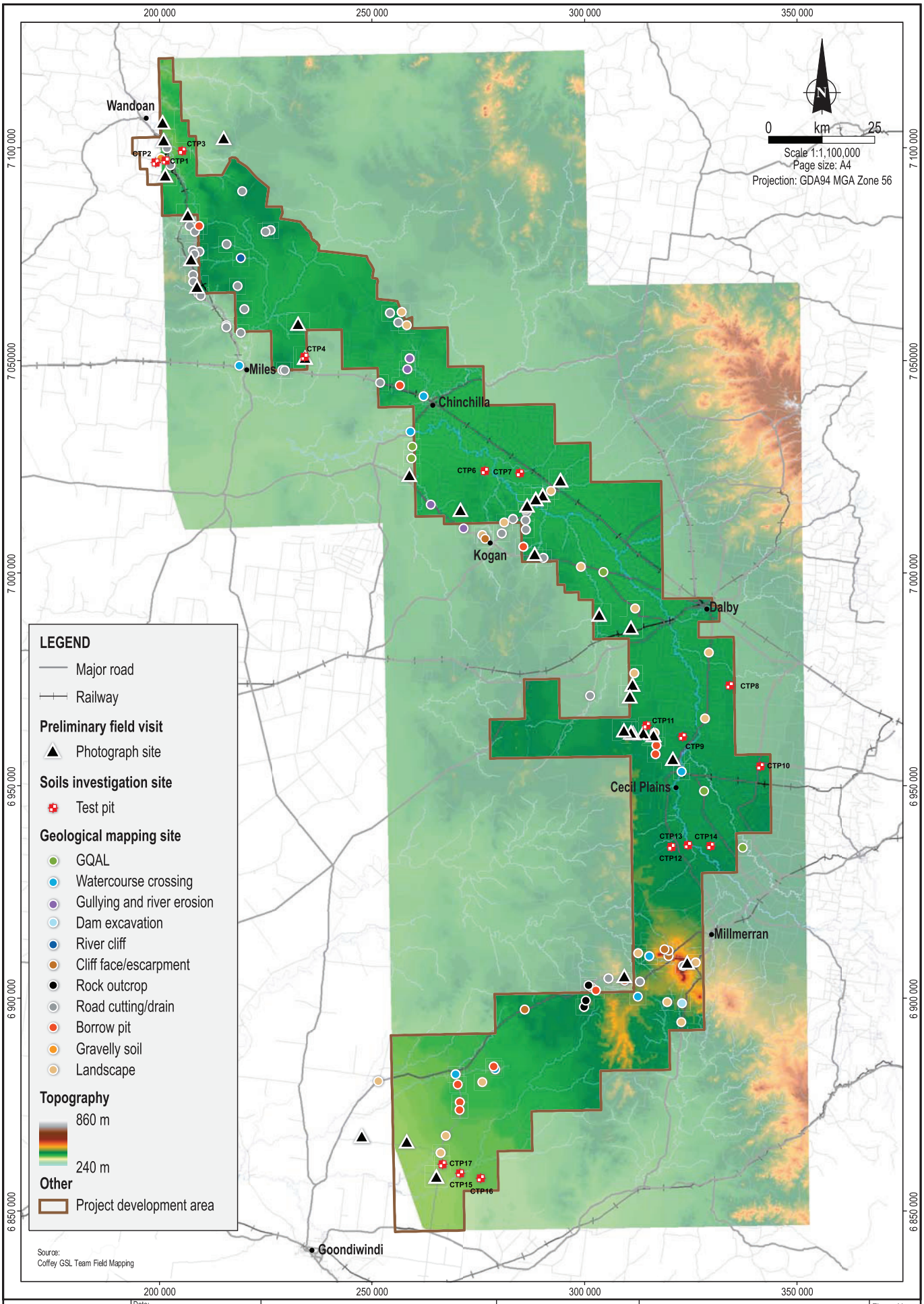
Field Survey

A preliminary field reconnaissance was conducted for the purpose of high-level groundtruthing of the desktop study findings and to identify areas for further investigation. A subsequent field survey was conducted to assess geology and soils using geological mapping of rock exposures and test pits (Figure 12.1). Physical and chemical properties of rock and soil samples were tested.

Assessment of the geology, landform and soils of the project development area was based on land resource areas mapped by the Queensland Government. Identification of these land resource areas was based on a combination of geology, landform, soil and vegetation types. The study reviewed the land resource area mapping within the context of the project.

The study included:

- **Geological Assessment.** The aim was to assess near-surface rock conditions and supplement the information provided in previous geological investigations. Rock exposures were observed at 109 locations throughout the project development area, including road cuttings, natural cliffs, river banks and existing borrow pits, providing an overview of the typical near-surface rock profile. Thirty-seven rock samples were collected and laboratory strength-tested.
- **Landform Assessment.** The terrain of the project development area was assessed using a combination of site observations, aerial imagery and information obtained from previous investigations. Existing 20-m-interval contours were used to create a digital elevation model of the project development area. The digital elevation model was then used to create slope steepness and topographic maps, which further aided in landform assessment and identification.
- **Soils Assessment.** Land resource area mapping was used to assess soil types across the project development area, with each land resource area potentially containing several soil types. Groundtruthing was conducted to clarify the findings of the desktop study and to collect samples for testing of physical, chemical and engineering properties. Sixteen test pits were excavated, targeting commonly occurring soil types across the project development area. Soils were described and classified using texture grade and key features such as colour and grain size.



coffey environments	Date: 28.10.2011 MXD: ENAUBRIS07040AC_9097_F3.4_GLS File Name: 7040_04_F12.01_GIS_GL	Arrow Energy Surat Gas Project	arrow energy go further	Ground investigation locations	Figure No: 12.1

- **Terrain Mapping and Environmental Values Assessment.** The landscape units within each land resource area were reviewed to identify environmental values that could affect landscape response to project activities. A consistent classification system for the project development area was developed by combining and simplifying the various land resource area classifications. Subsequently, the project development area was divided into 'terrain units', which represent areas of the landscape that have broadly similar 'environmental values' (i.e., characteristics, properties and behaviours). The terrain units were verified both in the field and by using historic and current aerial photographs. As part of the project development area was not covered by the available land resource area mapping, fieldwork observations and aerial photography were used to extend the terrain units to the limit of the project development area.
- **Landscape Sensitivity and Constraints Assessments.** The sensitivity of the terrain units (i.e., the environmental values of the landscape) was assessed to provide an indication of the susceptibility of the landscape to change following disturbance. In this context, sensitivity relates to the intrinsic properties of the landscape and the geomorphic processes acting upon the landscape (i.e., resistance to erosion, vegetation cover, slope steepness, and soil texture, profile and chemistry). Possible landscape constraints on the project were also assessed.

12.2.2 Contaminated Land

The assumptions and method relating to the contaminated land assessment are described below.

Desktop Study

A desktop review was conducted to identify the potential nature and frequency of contaminated sites within the project development area. The desktop review established that a number of key constraints influence the amount of certainty that may be obtained about contaminated land in the project development area. Given these constraints, a strategy has been developed to inform the assessment and management of contaminated land as the project progresses, which is presented in Section 12.6, Avoidance, Mitigation and Management Measures. The risks of disturbing or causing contaminated land were assessed with consideration of the constraints and inherent uncertainty. The key assumptions and the constraints are outlined as follows:

- As the project development area covers approximately 8,600 km^2, there will be large tracts of land that are not listed on the EMR or CLR that are free of any known contamination and/or have had no known exposure to historic or current notifiable activities.
- All land upon which Arrow may conduct project activities could have been used previously for notifiable activities or potentially contaminating activities.
- All notifiable and potentially contaminating activities as defined in the EP Act may have been conducted within the project development area.
- All land upon which Arrow may conduct project activities could be listed on either the EMR or the CLR.
- The listing of a parcel of land on the EMR or CLR does not indicate that the entire land parcel is contaminated. This is particularly the case for large rural properties.
- It is not possible to search the EMR or CLR on a spatial basis. The EMR and CLR are searched on a land-parcel-specific basis (based on provision of specific real property descriptions for the land in question). It is, accordingly, not reasonable, practicable or useful to proactively conduct a search of the EMR and CLR for every land parcel within the approximately 8,600-km^2 project development area. Accordingly, no searches of the EMR and

CLR were conducted as part of the desktop review and searches of the EMR and CLR will be conducted in accordance with the strategy outlined below and following initial site selection for project facilities and infrastructure.

- The potential exists for land that has been historically contaminated, but is otherwise unknown or unrecorded on either the EMR of CLR, to be encountered during project activities.
- Contaminants of potential concern could be encountered during development and it will be Arrow's responsibility to have appropriate management plans established in anticipation of such an event. The contaminants that could be encountered may be harmful to project workers, the public, wildlife, stock, native and cultivated vegetation, surface waterways, aquifers and groundwater users. 'Harmful' indicates that they may have acute toxic, carcinogenic, mutagenic or other chronic effects.
- A number of Arrow project activities will be notifiable in their own right and land parcels upon which Arrow conducts project activities may accordingly be required to be listed on the EMR.

Given the above key assumptions and in the absence of detailed information on the actual extent of contaminated land, the precautionary principle is applied, whereby the overarching assumption that land (including soil and/or groundwater) on which Arrow may propose to conduct development activities could potentially be contaminated.

Field Survey

Field environmental assessments form one component of the contaminated land strategy presented in this chapter. Given the assumptions presented above no specific sites were considered relevant or representative of the sites that Arrow may propose to develop. Accordingly, the physical environmental site assessments for the presence of contaminants has been delayed until facility and infrastructure locations are identified through Arrow's site selection process.

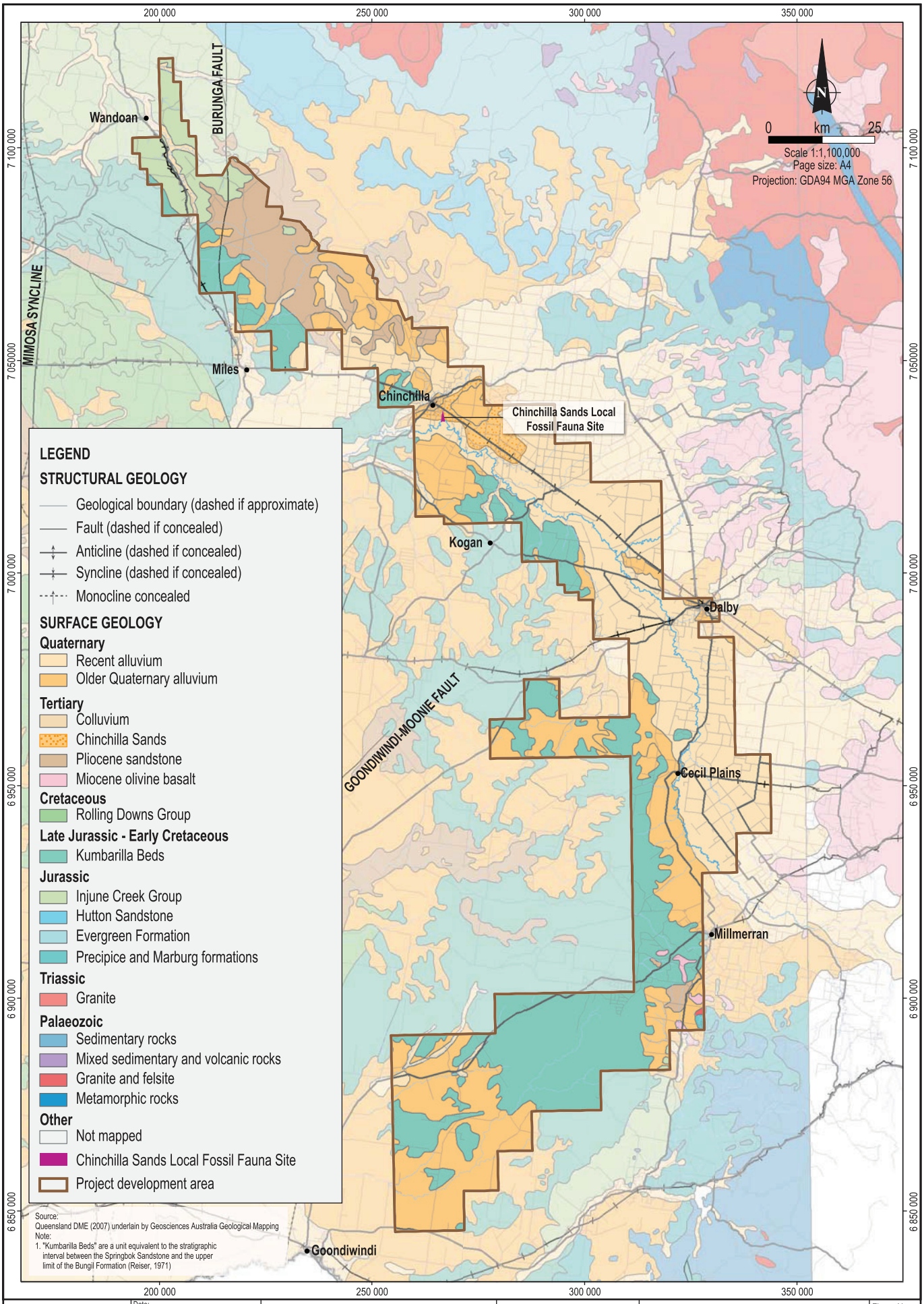
12.3 Existing Environment and Environmental Values

The existing environment of the project development area has a landscape that is strongly related to surface geology, relief, topography, rainfall, soils, land use and erosion. As such, this chapter presents information on geology, landform, soils, GQAL and strategic cropping land, specific sites of geoheritage environmental significance, terrain unit mapping and the environmental values.

12.3.1 Geology

The geology of the project development area is relatively simple, with basement rocks overlain by deep sediments with volcanic intrusions. Figure 12.2 shows the surface geology of the project development area. Further information on subsurface geological formations and groundwater extraction activities is found in Chapter 14, Groundwater.

During the Jurassic period, several thick, fining-upwards sequences were deposited. Fast-flowing creeks deposited coarse quartzose sandstones, grading to finer, more unstable, easily decomposed sediments that were deposited when the gradient decreased. These finer sediments included the Walloon Coal Measures, which are the main source of the coal seam gas that is to be extracted. Figure 5.3 shows the project development area stratigraphic profile.



coffey environments	Date: 28.10.2011 MXD: ENAUBRIS07040AC_9097_F3.3_GLS File Name: 7040_04_F12.02_GIS_GL	Arrow Energy Surat Gas Project	arrow energy go further	Surface geology of the project development area and environs	Figure No: 12.2

The project development area straddles the common boundary of the Surat and Clarence-Moreton basins, as shown on Figure 5.2. The geological formations of these basins are relatively continuous at their adjoining margins; however, given that the majority of Arrow's tenements and project development area are located within the Surat Basin, the project is referred to as the 'Surat Gas Project'. For simplicity, geological descriptions in this section apply to both basins but are only referred to as the Surat Basin. The Surat Basin is separated from the Clarence-Moreton Basin, which lies to the east, by the Kumbarilla Ridge anticline.

On a regional scale, there is continuous basin subsidence and uplift associated with Tertiary volcanic activity in the east causing the Jurassic and Cretaceous sediments to dip gently to the southwest, with a slope of 5° to 10°.

Within the Surat Basin, major faulting is usually an expression of boundary faulting of the underlying Bowen Basin. Relatively young Cainozoic faulting (65 million years old and younger) has not been recorded. However, older minor Mesozoic faults (250 to 65 million years old) are found to the west of the project development area. Compared to the rest of Australia, the area has a moderate level of earthquake activity; however, it is considered that faults within the project development area have a very low risk of reactivation during earthquake activity and, as such, fault movement is considered a low risk.

A deep blanket of clay-rich colluvium and alluvium covers a large portion of the project development area. Therefore, much of the stratigraphic sequence does not outcrop. However, some outcropping rock of the older sequences of the Kumbarilla Beds, comprising variably textured sedimentary formations, occurs along the Kumbarilla Ridge in the western and southwestern portions of the project development area.

Tertiary sandstone outcrops are located in the north of the project development area. The Chinchilla Sands (see Figure 12.2) (late Tertiary (Pliocene) fossil beds) outcrop near Chinchilla. There are also minor outcrops of igneous rock; a small Triassic granite dome is located in the south of the project development area (south of Millmerran) and Tertiary basalt caps the mesas near Guluguba (in the north) and Captains Mountain (in the south).

The brigalow clay sheet covers the major river valley floors. Other fine-grained deposits are associated with erosion of sandstones, siltstones, mudstones and shales. Sandy alluvial material is located along the watercourses and sandy colluvium is found on the fringes of the Kumbarilla Ridge.

Most of the outcropping sedimentary rocks were found to be moderately to extremely weathered medium- to coarse-grained sandstones, with some siltstone and conglomerate. Sedimentary breccia was found at one location. Rock strength was found to vary with the degree of weathering. Characteristic features of outcropping sandstones include distinct layers of very low soil strength, bleached, extremely weathered material, interbedded with medium- to high-strength, moderately weathered, rust-coloured material. Red or rust-coloured material generally indicates higher rock strength due to the presence of ferric oxide. Siltstones recorded high strengths and conglomerates recorded very high strengths.

A number of borrow pits (see Figure 12.1), were found along the Kumbarilla Ridge, indicating that the rock has been used for construction in the past. Crushed sandstone is used for road sub-base throughout the project development area.

12.3.2 Landform

The landscape of the project development area is strongly linked to the underlying geology and geomorphological evolution of the area and is characterised by three physiographic regions: the Great Dividing Range highlands, the Kumbarilla Ridge uplands and four drainage basins, Condamine-Culgoa, Fitzroy, Border Rivers and Moonie.

The following landforms and geomorphological processes were identified within the project development area and contribute to the general features of the landscape.

- **Upland Features.** Remnant basalt outcrops form prominent mesas. Cuestas, formed by gently dipping sedimentary rocks, are present in the north and have a plateau-like appearance.
- **Steep Slopes.** Cuesta escarpments, and plateau and mesa cliff lines, along which rock falls or landslides have the potential to occur, exist in the project development area. However, landslides are considered unlikely due to the limited extent of steep slopes and the material properties of the rock and soil.
- **Gilgai.** Gilgais are irregular mounds and depressions found on the extensive clay plains. On steeper slopes, gilgais are generally elongated, and on flatter ground, roughly circular. Large gilgais (locally known as 'melonholes') can be up to 50 m wide and 2 m in depth. Within the project development area, gilgais are located on Class A GQAL and have commonly been levelled for farming purposes. Topsoil tends to be deeper beneath mounds and shallower under the depressions.
- **Gully Erosion.** Between the mid-1800s and the mid-1900s, vegetation clearing and intensive agriculture led to widespread gullying and soils loss. Overgrazing and pasture burning contributed to this process. Severe erosion resulted from infrastructure, such as tracks, which concentrated flow of water runoff.

  The two mechanisms for gully formation within the project development area are:

  – Rills and gullies formed in heavily disturbed or cultivated clay soils.

  – Erosion of sodic texture contrast soil, which are naturally dispersive and highly erodible, making them susceptible to subsurface piping and tunnelling, and surface rill and gully erosion.

  Soils are generally sodic within the project development area, and are therefore prone to erosion from disturbance. Sodic clay soils can have highly dispersive subsoils (Plate 12.1). However, as these soils tend to occur on low-relief plains, erosion is usually limited to where flows are concentrated (i.e., along fence lines, access tracks or compacted areas). Texture contrast soils that have sodic, dispersive subsoils are commonly found along the fringes of Kumbarilla Ridge. Due to the higher relief there, gullying is more common.
- **Watercourses.** Most of the watercourses in the project development area are incised (Plate 12.2), showing signs of historic and contemporary back erosion and bed scour. As a result, many of the watercourses that once frequently inundated their floodplains now do so only during high-magnitude floods when floodwaters are able to overtop their banks.

Source: Coffey Geotechnics Pty Ltd.

Plate 12.1
Gullying exposing dispersive Vertosol profiles

Source: Coffey Geotechnics Pty Ltd.

Plate 12.2
Incised Condamine River with sandy alluvium base

Source: Coffey Geotechnics Pty Ltd.

Plate 12.3
CTP1 test pit excavation exposing brown Dermosol soil profile

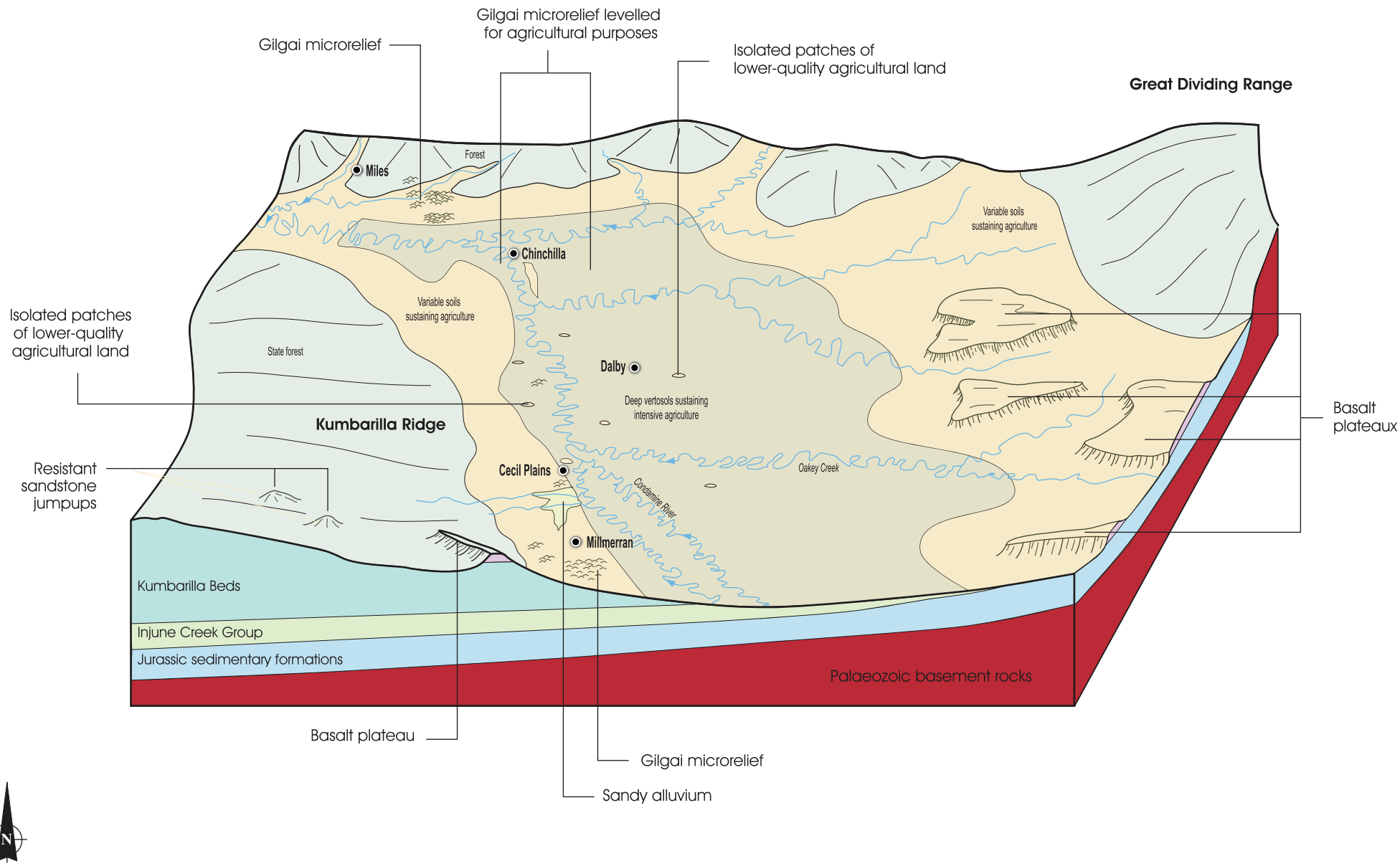
The drainage basins within the project development area are described below. The Moonie River covers less than 1% of the project development area and overall is not a dominating feature controlling landform (and hence is included with the description of the Border Rivers drainage basin).

- **Condamine-Culgoa Drainage Basin.** This drainage basin ranges from 5 km to 50 km in width, lying to the west of the Great Dividing Range and east of the Kumbarilla Ridge (Figure 12.3). The Condamine River is the largest watercourse in the region and lies within this drainage basin. Topography adjacent to the Condamine River is flat to gently undulating and contains densely farmed alluvial and brigalow plains (which are pockmarked with gilgais in the clay soils of the north and south). The erosion-susceptible soils tend to have gully networks. However, the uplands comprise more resistant bedrock. Small, steep, rounded hills (termed 'jumpups') rise about 50 m above the slopes of the Kumbarilla Ridge. Other uplands include Tertiary sandstone cuestas, which rise to approximately 380 m AHD in the north, the Kumbarilla Ridge rising to about 420 m AHD in the west, basalt mesas, which rise to about 620 m AHD near Captains Mountain, and the Great Dividing Range, which rises to over 800 m AHD to the east of the project development area.
- **Fitzroy Drainage Basin.** The Dawson River is part of the Fitzroy drainage basin. Juandah Creek is a major watercourse and tributary of the Dawson River, and flows through Guluguba and Wandoan. The area surrounding Juandah Creek contains mesas (usually capped by basalt) and cuestas (capped by gently dipping laterised sandstone). Sandy alluvium has been deposited next to the creek. Land within the drainage basin is used for grazing.
- **Border Rivers Drainage Basin.** There are two broad terrain types for this drainage basin within the project development area: uplands associated with the sandstone Kumbarilla Ridge falling to the second terrain type, brigalow clay and sandy alluvial plains. Class A GQAL is widespread but grazing is more predominant than cropping due to the lower rainfall, sandy soils and presence of gilgais. There are distinct ridges and swarms of jumpups along the western side of the Kumbarilla Ridge, rising about 40 m to 100 m above the surrounding slopes.

12.3.3 Soils

Soil characteristics are strongly linked to formation process, relief and parent material. Seven broad soil types were identified in the project development area and are characterised below (listed in the order of most to least clay content). They have been classified under the Australian Soil Classification System (Isbell, 2002).

- **Gilgai Clays.** Gilgai clays occur on flat to gently undulating ground, usually on older alluvial sediments subject to seasonal flooding. Gilgai clays were observed north of Warra and Chinchilla, and occur within pockets throughout the project development area, especially around Kupunn and in the Goondiwindi Shire further to the south. Large areas of gilgai have been levelled for agricultural purposes. These soils are characterised by a deep profile, which can be greater than 1.5 m thick. Gilgai clays are poorly drained and often water is retained within the gilgai depression. They are classified as Vertosols.



Not to Scale	coffey environments	Job No: 7040	Arrow Energy	arrow energy go further	Soils and landform characteristics along the Condamine River within the project development area	Figure No: 12.3
		File Name: 7040_04_F12.03_GL	Surat Gas Project			

- **Cracking Clays.** These clays are widespread throughout the project development area, with two types identified:
  - Black cracking clays, which are of high value for agricultural production, are the dominant soil type along the Condamine River valley within the vicinity of Dalby, and to the south and east of Cecil Plains. They are generally well structured and have a deep to very deep profile. The shrink/swell properties of the clay minerals cause them to swell when wet and produce cracks greater than 5 mm wide, which can be observed when dry. They are classified as Vertosols.
  - Uniform cracking clays, which occur in areas around Miles, Chinchilla, Kogan and Brigalow on gentle slopes on a range of materials derived from alluvium, basalt and deeply weathered materials. These clays have poor internal drainage with variably deep profiles and are classified as Vertosols.
- **Uniform Non-cracking Clays.** These clays occur on gently undulating plains and rises, and upper slopes of hills. They are present mainly in the north of the project development area, within the Dawson River catchment (which is within the Fitzroy drainage basin). Although these soils are agriculturally highly productive, they can require erosion control measures. They usually have deep uniform or gradational profiles. These clays are classified as Dermosols.
- **Texture Contrast Soils.** These soils are characterised by an abrupt textural contrast between the surface and subsoil horizons. In general, these soils have little agricultural value but are used for low-density grazing in some areas. Two types of texture contrast soils were identified in the project development area:
  - Dispersive texture contrast soils, which are widespread throughout the project development area on plains, rises and undulating hills. They are typically deep, prone to erosion and can be hardsetting. The subsoils are usually sodic and may be acidic. These soils are classified as Sodosols and Kurosols.
  - Non-dispersive texture contrast soils, which are common throughout the project development area, particularly along undulating to moderately sloping land on the edges of the Kumbarilla Ridge. The profile is typically moderately deep to deep. They can be poorly drained, with a hardsetting surface. They are classified as Chromosols and Kurosols.
- **Uniform Loams and Clays.** Two types were identified within the project development area:
  - Loams and clay loams found along the upper slopes and crests of the Kumbarilla Ridge and other uplands, and also along alluvial drainage channels. These soils can be bleached or gravelly, with acidic subsoils above a transitional zone into weathered rock. They are classified as Tenosols and Kandosols.
  - Clays loams and clays that occur on the lower slopes and edges of sandstone uplands, in depressions and along drainage channels. They are classified as Rudosols, Tenosols and Kandosols.
- **Sands and Sandy Loams.** These soils have a uniform or weakly gradational sandy texture. Two types were identified within the project development area:
  - Alluvial sands, comprising alluvial and colluvial deposits, are found along sandy alluvial plains. They are typically loose-grained sandy soils with a moderately deep profile. These soils are classified as Rudosols and Tenosols.

  - Residual sands and sandy loams that are formed from quartzose sandstone and found on eroded plateau margins, uplands and sometimes on lower slopes. They are variable in depth and underlain by weathered rock. Subsoils are often acidic. These soils are classified as Rudosols, Tenosols and Kandosols.

- **Skeletal, Rocky or Gravelly Soils.** These soils generally occur adjacent to rock outcrops in upland areas. They are typically shallow, with over 60% coarse fragments. They are classified as Rudosols and Tenosols.

Soils that are sodic contain enough sodium to affect the structural stability of the soil. When the soils become wet, the clay particles lose their bond and disperse. Therefore, sodic soils are frequently dispersive. Erosion of dispersive soils tends to occur along existing cracks within the soil mass, with material carried by flowing water. Sodic soils are prone to sheetwash, rilling and gully erosion, particularly during the intense rainfall events that are characteristic of the project development area. Most of the soils in the project development area have sodic subsoils. The exceptions to this are soils associated with basalt or granite outcrops.

Saline soils are those that contain soluble salts in the soil water. The main salt involved in salinity is sodium chloride (often associated with sodic soils), but sulfate, carbonate and magnesium salts may also contribute. Within the project development area, salinity is associated with sodicity and is, therefore, widespread. Saline soils can result from events such as weathering of natural rocks containing high sodium levels, groundwater seepage through naturally saline rocks, and irrigation using poor quality groundwater that has a high salt content.

Acid sulfate soils usually occur below 10 m AHD, and are associated with anoxic, highly organic environments close to saline water. Although these conditions do not exist within the project development area, acid sulfate soils can also occur at higher elevations inland in river and lake beds, irrigation channels, and in saline seepage areas where there are organically rich deposits. Some regional mapping presented in the National Acid Sulphate Soils Atlas (GA, 2011), shows areas of potential acid sulfate soils within the project development area. However, these areas are of limited extent and are considered to represent locations associated with wetlands and watercourses where conditions may be suitable for the formation of acid sulfate soils, rather than groundtruthed and proven instances of acid sulfate soils within the project development area.

The combination of saline groundwater tables rising and salt becoming mobilised via surface water flows, can lead to the salinisation of inland aquatic ecosystems. In these instances, where there are high levels of salt in the landscape, high concentrations of sulfate, and therefore acid sulfate soils, can occur. Acid sulfate soils have been found in the uppermost reaches of the Condamine River catchment (located to the southeast of the project development area), in effluent ponds and some north-draining streams and wetlands (EPHC & NRMMC, 2011), however it is reasonable for the project to progress on the assumption that acid sulfate soils will not be encountered during project activities. Should geotechnical investigations and testing during the course of the development encounter potential acid sulfate soils, site-specific control measures will be adapted accordingly.

Field investigations confirmed that the soil types found were broadly consistent with those expected from the land resource area and desktop assessment. Test pit locations are shown in Figure 12.1, and an example of a brown Dermosol soil profile from one of the test pits included as Plate 12.3.

Laboratory testing showed that the soils of the project development area generally comprise soft, low-plasticity clay with poor bearing capacities. They are likely to provide a poor subgrade for

road pavements. They are also highly dispersive, erodible materials, with high linear shrinkage values, indicating they are prone to cracking. The soils are moderately to highly reactive to moisture, and significant ground movements in response to wetting and drying are likely.

12.3.4 Good-quality Agricultural Land and Strategic Cropping Land

There are four classes of agricultural land defined in Queensland, as outlined in Table 12.1.

Table 12.1 Agricultural land descriptions

Class	Description
A	**Cropland**. Land suitable for current and potential crops. None to moderate limitation levels to production. Considered GQAL in all areas.
B	**Limited cropland**. Land marginal for current and potential crops due to severe limitations. Engineering and/or agronomic improvements may be required before the land is considered suitable for cropping. Suitable for pastures. Considered GQAL in most areas.
C	**Pasture land**. Land suitable only for improved or native pastures due to limitations that preclude continuous cultivation for crop production. Some areas may tolerate a short period of ground disturbance for pasture establishment. Not considered GQAL.
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 due to very steep slopes, shallow soils, rock outcrop or poor drainage. Not considered GQAL.

The project development area lies within the Darling Downs, an area of national agricultural importance (traditionally grain and cotton production). Clay soils, which have higher water-holding capacity and fertility, are considered to have a higher cropping potential than sands or shallow soils. The spatial distribution of GQAL within the project development area is shown in Figure 4.10, and summarised in Table 12.2. DERM's draft strategic cropping land mapping is shown in Figure 4.11.

Table 12.2 Spatial extent and percentage of GQAL within the project development area

GQAL Class	Area (ha)	% of Project Development Area	Agricultural Classification
A	438,000	52	GQAL
B	63,000	7	
C	347,000	41	Pasture land
D	400	Negligible	Non-agricultural land

Most of the GQAL is located along the three major river valley floors, especially the Condamine River valley as it has deep, cracking clays. GQAL is also present between Guluguba and Wandoan in the far north of the project development area, southwest of Captains Mountain and towards Goondiwindi in the south. Although it is prone to erosion, most of the GQAL is being used intensively within the project development area.

Class C land occurs along the sandstone uplands of the Kumbarilla Ridge to the west of the project development area and in the north on plateau areas. It is extensively used for cattle grazing.

As shown on Figures 4.10 and 4.11, the areas of potential strategic cropping land are similar in extent to GQAL, covering 49% of the project development area.

12.3.5 Specific Sites of Geoheritage Environmental Significance

There are several geological, landform or soils features that have been registered on the Australian Register of the National Estate (although this has since been superseded by the EPBC Act), or are indicative sites, which are (or were) being assessed for inclusion on the Register of the National Estate. Within the project development area, the following features are considered to be of national environmental significance:

- **Lake Broadwater Conservation Park.** Located along the eastern flanks of the Kumbarilla Ridge approximately 20 km southwest of Dalby (see Figure 4.1), Lake Broadwater is one of the few inland wetlands in southern Queensland. The heavy clay soils surrounding the lake support vegetation communities typical of the Brigalow Belt South Bioregion. The Lake Broadwater Conservation Park covers 1,200 ha, and the lake itself is approximately 350 ha in size and 4 m deep when full. The park has been protected under the Nature Conservation Act since 1994.
- **Chinchilla Sands Local Fossil Fauna Site.** This site is the last remaining example of undisturbed Chinchilla Sands with an intact profile. It is located approximately 3 km southeast of Chinchilla and is over 120 ha in size. It has been listed on the Register of the National Estate since 2002 and is considered one of the most important Pliocene fossil sites in Australia (see Figure 12.2).
- **Barakula State Forest Area and Scientific Areas.** The Barakula State Forest Area is located approximately 30 km northeast of Miles and represents a largely intact example of brigalow communities existing as part of a larger forest complex. The conservation value of the area is attributed to the unique pattern of soils. It is 31,000 ha in size and is registered as an indicative place on the Register of the National Estate. The Barakula scientific areas represent specific examples of brigalow/belah/softwood communities associated with deep gilgaied clay soils. These areas are located 75 km north-northeast of Chinchilla, within a large forest block of the Barakula State Forest Area, and are approximately 300 ha in size. The areas are registered as indicative places on the Register of the National Estate.

12.3.6 Terrain Unit Mapping

The geology, landform and soils characteristics of each terrain unit represent the landscape environmental values and their sensitivity (i.e., how the landscape responds to disturbance). The project development area was divided into six broad terrain units, which were subdivided on the basis of geology, landform, soils, properties and processes, aspects of which are summarised in Table 12.3 and shown in Figure 12.4. The environmental values of the terrain units have been used to assess the likely response of the landscape to development of the project.

Table 12.3 Terrain unit characteristics, properties and processes

Terrain Unit	Geology	Landform	Soils	GQAL	Intrinsic Landscape Properties	Geomorphological Processes
I – Clay Alluvial Plains						
Ia Ia (f)	Quaternary alluvium	Contemporary floodplain. Area within 10-year flood zone.	Deep cracking clays with texture-contrast soils within unfarmed elevated pockets.	A	• Soft soils. • Prone to waterlogging. • Dispersive, sodic subsoils. • Agricultural land use.	• Gullying and flooding with contemporary flood plain.
Ib		Broad level plains of basaltic alluvium.	Black self-mulching deep cracking clays with texture-contrast soils within unfarmed elevated pockets.		• Intensive agricultural land use.	• Occasional erosive flooding.
Ic		Broad level plains of mixed basaltic/sandstone alluvium.	Grey deep cracking clays.		• Prone to waterlogging. • Soft soils. • Surface crusting. • Strongly sodic and alkaline subsoils.	• Occasional erosive flooding. • Wind/water erosion.
Id		Broad level plains of mixed basaltic/sandstone alluvium.	Texture-contrast soils with pockets of deep cracking clays.		• Can be boggy at boundary of soil types. • Surface crusting. • Subsoils strongly sodic, occasionally saline, strongly alkaline.	• Wind/water erosion.
II – Sandy Alluvial Plains						
IIa	Quaternary alluvium	Alluvial plains and stream terraces of mixed basaltic/sandstone alluvium.	Bleached clay loams/sandy clay loams over dark clays.	B	• Hard-to-penetrate surface, especially after rain. • Strongly sodic.	• Wind/water erosion.

Table 12.3 Terrain unit characteristics, properties and processes (cont'd)

Terrain Unit	Geology	Landform	Soils	GQAL	Intrinsic Landscape Properties	Geomorphological Processes
II – Sandy Alluvial Plains (cont'd)						
IIb	Sandy alluvium/colluvium	Flat/gently undulating sandy alluvial plains.	Deep massive sands over mottled yellow/grey clays. Combination of texture-contrast soils and deep sands.	C	• Loose surface. • Sodic relatively impermeable subsoil with high bulk density. • Highly erodible subsoil. • Prone to waterlogging. • Contains the Chinchilla Sands Local Fossil Fauna Site.	• Wind erosion when cultivated (root structure removed).
IIc		Elevated sand ridges within Border Rivers valley.	Deep aeolian sands.	–	• Loose soils.	• Water erosion. • High/extreme wind erosion risk.
III – Brigalow Plains and Uplands						
IIIa	Underlain by sandstone	Flat to gently undulating clay plains with gilgai.	Very deep grey self-mulching cracking clays.	A	• Shallow gilgai. • Sodic and saline at depth. • Intense agricultural land use. • Fewer constraints than terrain unit IIIb.	• Occasional erosive flooding.
IIIb		Flat to gently undulating clay plains with gilgai.	Very deep grey self-mulching cracking clays.	B	• Deep melonhole gilgai. • Hard-setting surface crust. • Highly sodic and saline at depth.	• Water ponds within gilgai and gilgai remnants after levelling.

Table 12.3 Terrain unit characteristics, properties and processes (cont'd)

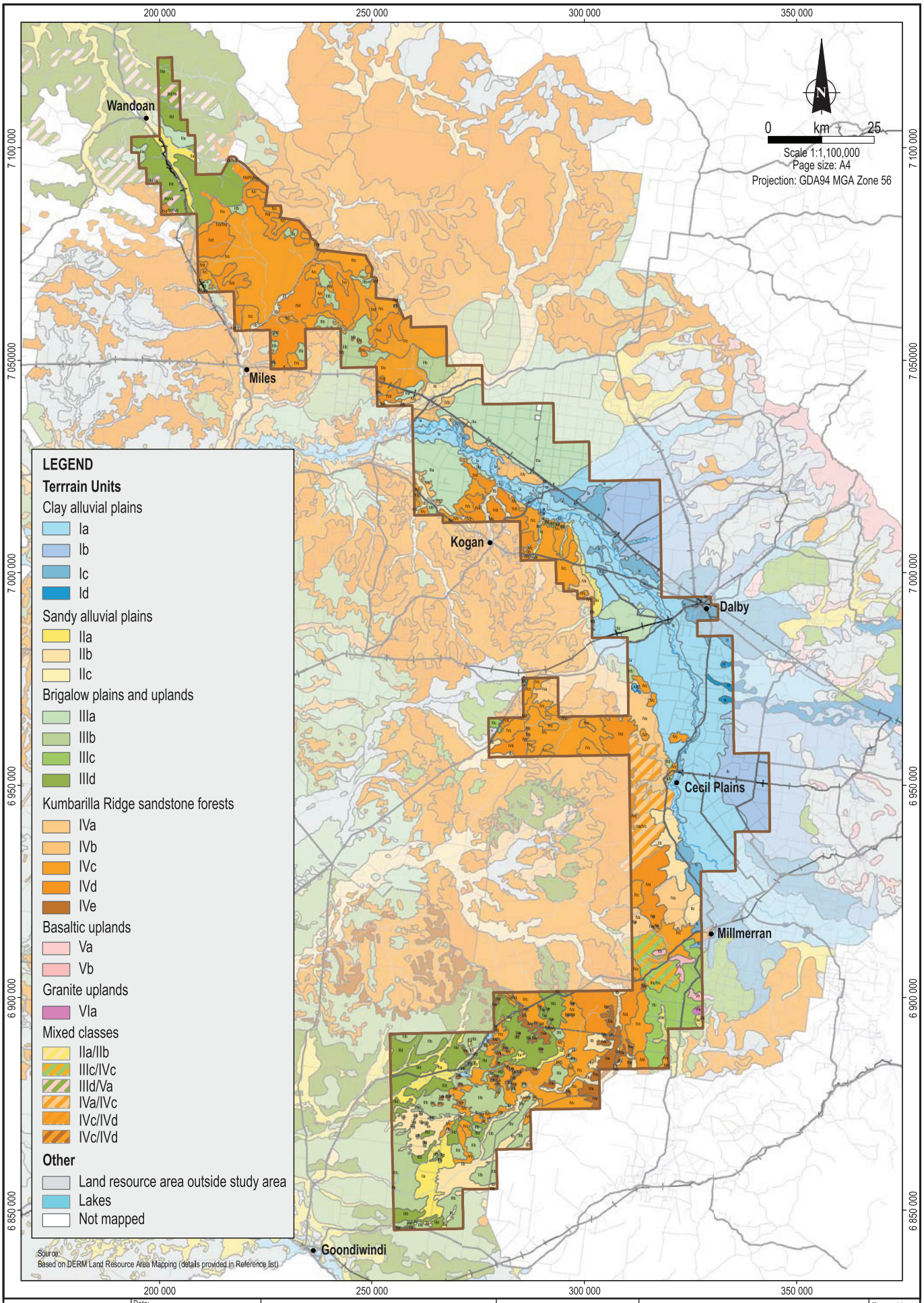
Terrain Unit	Geology	Landform	Soils	GQAL	Intrinsic Landscape Properties	Geomorphological Processes
III – Brigalow Plains and Uplands (cont'd)						
IIIc		Gently undulating rises and plains on sandstone units within the Walloon Coal Measures.	Grey deep cracking clays.	A/B	• Shallow/moderate gilgai. • Sandstone cobbles/boulders. • Strongly sodic and saline subsoils.	• Severe water erosion.
IIId		Undulating plains and rises.	Grey/brown deep cracking clays and texture-contrast soils. Variable soil types.	A/B	• Shallow gilgai. • Strongly saline and sodic at depth. • Can have hard-setting surface.	• Gully erosion.
IV – Sandstone Ridge						
IVa	Sandstone	Gently undulating plains on sandstone along the fringes of the Kumbarilla Ridge.	Bleached sands/loams over brown/grey clays.	C/D	• Prone to waterlogging. • Hard surface layer. • Dense subsoils. • Contains the Lake Broadwater Conservation Park.	• Highly erodible (surface/subsurface).
IVb		Edge of brigalow plains or dissected laterised sandstone remnants.	Texture-contrast soils.	C	• Prone to waterlogging due to impermeable subsoils and sandy surface soils. • Dense subsoils.	• Erosion.

Table 12.3 Terrain unit characteristics, properties and processes (cont'd)

Terrain Unit	Geology	Landform	Soils	GQAL	Intrinsic Landscape Properties	Geomorphological Processes
IV – Sandstone Ridge (cont'd)						
IVc		Undulating plains and rises on sandstone.	Texture-contrast, bleached sands/loams over brown/grey clays.	C/D	• Sodic, saline, dispersive subsoils. • Prone to waterlogging due to impermeable subsoils and sandy surface soils. • Dense subsoils. • Hard-setting surface in places. • Occasional rock outcrops.	• Piping, gullying and surface/subsurface erosion.
IVd		Plateaux and low sandstone hills to undulating plains – lateritic scarps are common.	Texture-contrast soils with areas of shallow gravelly soils.	C/D	• Highly sodic/saline. • Waterlogging. • Dense subsoils. • Rock outcrops.	• Gully/tunnel erosion. • Wind erosion.
IVe		Dissected uplands and scarps – jumpups.	Shallow gravelly soils.	D	• Shallow, gravelly soils. • Slightly acidic. • Steep slopes.	• Water erosion.
V – Basaltic Uplands						
Va	Basalt overlying sandstone	Level to gently undulating plains.	Variable reddish brown to brown clays and loams.	B/D	• Shallow soils. • High gravel content. • Aquifer recharge zone (potential for contamination). • Steep slopes. • Lower slopes can be suitable location for building.	• Some sheet/rill and gully erosion. • Wind erosion possible.

Table 12.3 Terrain unit characteristics, properties and processes (cont'd)

Terrain Unit	Geology	Landform	Soils	GQAL	Intrinsic Landscape Properties	Geomorphological Processes
V – Basaltic Uplands (cont'd)						
Vb		Steep hills and mountains.	Shallow gravelly clays.	D	• Shallow soils. • High gravel content. • Aquifer recharge zone (potential for contamination). • Steep slopes. • High-strength rock.	• Sheet/rill erosion.
VI – Granite Uplands						
VIa	Granite	Steep granite hills with rock outcrops.	Sands over hard pan.	D	• Shallow soils with hardpan. • Rock outcrops. • High quartz-gravel/rock content. • Steep slopes. • Prone to waterlogging.	• Rill and gully erosion.



coffey environments	Date: 28.10.2011 MXD: ENAUBRIS07040AC_9097_F4.1_GLS File Name: 7040_04_F12.04_GIS_GL	Arrow Energy Surat Gas Project	arrow energy go further	Terrain units of the project development area and environs	Figure No: 12.4

12.3.7 Contaminated Land

Land can become contaminated through a range of activities and land uses, many of which continue today. The Queensland Government defines such activities as notifiable activities under the EP Act. Although many of the listed notifiable activities are 'industrial' in nature, a significant number may be reasonably expected in an environment where agricultural activities predominate (e.g., notifiable activities 2, 7, 16, 19, 22, 27, 29, and 36 all have direct links to or service agricultural activity). Accordingly, many notifiable activities will have been carried out somewhere within the 8,600 km^2 project development area. Some affected land parcels may be listed on the EMR and CLR administered by DERM, but others will not have been identified or reported. The EP Act schedule of notifiable activities is presented in Box 12.1.

Box 12.1 Notifiable activities

1. Abrasive blasting	14. Engine reconditioning works	27. Pest control
2. Aerial spraying	15. Explosives production or storage	28. Petroleum or petrochemical industries
3. Asbestos manufacture or disposal	16. Fertiliser manufacture	29. Petroleum product or oil storage
4. Asphalt or bitumen manufacture	17. Foundry operations	30. Pharmaceutical manufacture
5. Battery manufacture or recycling	18. Gun, pistol or rifle range	31. Printing
6. Chemical manufacture or formulation	19. Herbicide or pesticide manufacture	32. Railway yards
7. Chemical storage	20. Landfill	33. Scrap yards
8. Coal fired power station	21. Lime burner	34. Service stations
9. Coal gas works	22. Livestock dip or spray race operations	35. Smelting or refining
10. Defence establishments	23. Metal treatment or coating	36. Tannery, fellmongery or hide curing
11. Drum reconditioning or recycling	24. Mine wastes	37. Waste storage, treatment or disposal
12. Dry cleaning	25. Mineral processing	38. Wood treatment and preservation
13. Electrical transformers	26. Paint manufacture or formulation	

Uncontrolled and Otherwise Unidentified Activities

It is possible that sites where notifiable activities have occurred may not have been reported and/or are not included in the applicable registers. In addition to the specified notifiable activities, uncontrolled and otherwise unidentified activities may also have contributed to contamination of land within the project development area. Such uncontrolled activities may include but are not necessarily limited to:

- Dumping of waste materials in rural areas.
- Unreported spillage of agricultural chemicals, fuels or lubricants.
- Broad acre application of persistent organic chemicals.
- Bulk disposal of stock carcasses after disease, flood or drought.

As Arrow develops land for wells, gathering infrastructure, production facilities and dams, areas of contamination caused by uncontrolled activities may potentially be encountered.

12.3.8 Environmental Values

Geology, Landform and Soils

As indicated by the summary in Table 12.3, each geological, landform and soils terrain unit identified within the project development area has unique characteristics. These characteristics dictate the environmental values of different areas of the landscape, forming the basis of an assessment from which the sensitivity of the value was determined. Table 12.4 summarises the sensitivity of the geological, landform and soils values relating to each existing terrain unit. In some instances, some areas of a terrain unit may have a different sensitivity to other areas based on the variability of environmental values. Examples of this variability can be attributed to the following:

- Conservation status and geoheritage assets.
- GQAL and strategic cropping land.
- Landscape sensitivity to erosion (erodibilty) and erosion hazard (i.e., susceptibility to water erosion and water erosion processes, and soil sensitivity to wind erosion).
- Landscape sensitivity from salinity.
- Landscape sensitivity from soft soils and waterlogging.
- Rehabilitation-potential sensitivity.
- Effect of slope steepness on landscape susceptibility.

Table 12.4 Sensitivity of the value of the existing environment

Existing Environment	Characteristics Contributing to the Value	Sensitivity of the Value
Terrain Unit I – Clay Alluvial Plains	• No geoheritage features. • GQAL and strategic cropping land. • Sodic, saline subsoils susceptible to water erosion. • Soft soils prone to waterlogging, susceptible to flooding near the Condamine River and its tributaries. • Soils generally high in fertility, well-structured, deep cracking clays, with areas of texture contrast soils. • Will be difficult to rehabilitate to predisturbance condition. Particular areas will be more challenging due to lower fertility and distinct soil profiles.	Moderate
Terrain Unit II – Sandy Alluvial Plains	• GQAL and strategic cropping land close to rivers and creeks. • Sodic, saline subsoils susceptible to water erosion, except along some watercourses. Sandy soils susceptible to wind erosion. • Loose sandy soils or soft clays prone to waterlogging. • Low-fertility sandy soils with poor rehabilitation potential, or high-fertility, well-structured soils difficult to rehabilitate.	Moderate
	• Contains the Chinchilla Sands Local Fossil Fauna Site (subunit IIb).	High

Table 12.4 Sensitivity of the value of the existing environment (cont'd)

Existing Environment	Characteristics Contributing to the Value	Sensitivity of the Value
Terrain Unit III – Brigalow Plains and Uplands	• Contains the Barakula State Forest Area and Scientific Areas. • GQAL and strategic cropping land. • Sodic, saline subsoils susceptible to water erosion. Texture contrast soils moderately susceptible to wind erosion. • Soft soils prone to waterlogging. • Well-structured clay soils and gilgai deep cracking clays will be difficult to rehabilitate. Areas of lower fertility with distinct soil profiles will be difficult to rehabilitate.	Moderate
Terrain Unit IV – Sandstone Ridge	• Contains Lake Broadwater and the Barakula State Forest. • Low-relief areas classified as Class C (pasture land). All other areas classified as Class D (non-agricultural land). • Sodic, saline soils susceptible or highly susceptible to water erosion, moderately susceptible to wind erosion and prone to waterlogging. • Steep slopes associated with jumpups, plateaux or mesa edges, and cuesta escarpments locally increase sensitivity. • Soil profile and moderate to low fertility reduces rehabilitation potential.	Moderate
Terrain Unit V – Basaltic Uplands	• Aquifer recharge zone (potential for contamination). • Steep slopes. • Lower slopes can be suitable for building and can be classified as GQAL and strategic cropping land. • Shallow, gravelly, erodible soils with rocky outcrops. Some deeper soils on lower slopes that are susceptible to water and wind erosion. • Steep slopes associated with mesa edges. • Poor rehabilitation potential due to shallow, low-fertility soils. Some areas are fertile, with well-structured soils, which will be difficult to rehabilitate to predisturbance condition.	Moderate
Terrain Unit VI – Granite Uplands	• Shallow soils with a high quartz-gravel or quartz-rock content and hardpan. • Rock outcrops. • Steep slopes associated with isolated steep hills. • Prone to waterlogging. • Poor rehabilitation potential due to shallow, low-fertility soils.	Moderate

Contaminated Land

The existing environment and values relating to contaminated land are summarised below in Table 12.5. These identified values comprise aspects of the existing environment that should be protected and will accordingly inform infrastructure and equipment-siting decisions (on a micro scale) and the appropriate application of mitigations and management controls.

Table 12.5 Existing environmental values relating to contaminated land

Existing Environment (Areas Likely to be Associated with Value)	Values	Sensitivity
National parks, conservation areas, etc.	Greenfield areas where there is a statutory limitation to development	High
Areas with no or low levels of modification	Land that is free from notifiable activities, uncontrolled activities or other contaminating land practices (i.e., greenfield sites)	Moderate
Existing slightly to moderately modified areas	Developed land that has potentially supported notifiable activities	Moderate
Existing highly modified or industrial areas	Sites already recorded on the CLR or the EMR or where known notifiable activities have occurred	Low

The environmental value of the project development area is that large tracts of land will not have been subject to notifiable activities, uncontrolled activities or other contaminating land practices and are accordingly 'greenfield' sites. Greenfield sites have very high environmental value (as they are most likely to be free from contamination) that should be protected from:

- Contamination caused by the disturbance of contaminated land that already exists and is encountered during works.
- Contamination caused by notifiable activities such as those associated with coal seam gas development (particularly chemical storage and petroleum product or oil storage).

Sites that already have existing contamination or a higher risk of contamination due to historical or current activities have lower environmental value.

Given the nature of contaminated land in rural areas, it is reasonable to expect that sites listed on the CLR and or the EMR will be encountered during the course of project construction activities. This land may include any of the notifiable activities but is most likely to include those directly associated with or directly servicing agricultural activity. It is also reasonable to expect that land that has been subject to uncontrolled activities and/or unreported activities will be encountered. It is, however, quite likely that, while a particular lot may be listed on a register, the actual construction or development area may not be contaminated. The frequency with which contaminated land may be encountered cannot be determined without dedicated searches of the EMR and CLR and, even after those searches are conducted, the frequency at which otherwise unidentified contaminated sites may be encountered cannot be estimated. Searches will be conducted in accordance with the contaminated land management strategy as project development progresses. The strategy presented in this document applies the precautionary principle with the knowledge of this uncertainty.

As a predominantly industrial activity, the development of coal seam gas infrastructure may proceed on land that has existing or potential contamination (i.e., land of low and medium environmental value). Some activities associated with coal seam gas development are notifiable activities in their own right (e.g., petroleum product storage and chemical storage). Given the typically large size of rural land parcels, it is common for a land parcel that has supported a notifiable activity, such as a sheep or cattle dip, to be listed on the EMR but only a small portion of the land parcel to be physically or potentially affected by contaminants. Some land parcels are sufficiently large as to contain land representing multiple categories of environmental value from high-value 'greenfield' land to low-value contaminated land. It is expected that all categories of

environmental value are represented across the project development area but existing recording practices do not allow contaminated land environmental values to be mapped to provide a proactive tool for site selection.

Site selection for project facilities and infrastructure will be influenced by the current status of land in terms of contamination. Developing on sites that are contaminated or have a high risk of contamination is not better for the environment, as this could potentially increase the risk of mobilising contamination that may impact on the surrounding environment. This is discussed further in the following sections.

To avoid environmental impacts through the disturbance of contaminated land and to minimise health and safety risks to workers, Arrow will generally avoid development in areas of known existing soil and/or groundwater contamination.

12.4 Issues and Potential Impacts

The significance of potential impacts on the geology, landform and soils values have been assessed by combining the sensitivity of the value and the magnitude of the potential impact (as described in Chapter 7, Impact Assessment Method). Potential impacts on geology, landform and soils values from project activities include:

- Land degradation – erosion and associated sedimentation, dust generation and reduction in soil quality.
- Land contamination:
  - Disturbance of existing contaminated land.
  - Potential to cause land contamination through project activities.
- Disturbance or accidental damage of recognised fossil sites.

Activities with the potential to cause these adverse impacts on geological, landform and soils values during the construction, operations and decommissioning phases of the project are described below in Sections 12.4.1, Construction, 12.4.2, Operations, and 12.4.3, Decommissioning.

Issues relating to contaminated land and project activities may involve the exposure of project workers to contaminated land and/or the disturbance of contaminated land as infrastructure is constructed and installed. During the life of the project, there is also the potential for Arrow activities to result in the contamination of land while conducting a notifiable activity or through the generation of various waste streams.

In these scenarios, potential impacts relate to the exposure to, and disturbance or release of, contaminants of concern into the receiving environment, specifically into high- or very-high-value greenfield areas. Contamination may also involve the introduction of different contaminants (i.e., those that would otherwise not be present) into lower-value areas. This is further discussed in Section 12.4.4, Issues Specifically Associated with Contaminated Land.

12.4.1 Construction

During construction, the following impacts on the geological, landform and soils values from the various project activities could occur:

- Increased erosion resulting from ground disturbance, vegetation clearance, alteration of natural drainage and flow concentration due to construction activities (i.e., excavation,

trenching, drilling, earthmoving) during any activity that disturbs the ground (e.g., the construction of production wells, gathering lines, production facilities and associated infrastructure).

- Deposition downslope or downstream of eroded sediment as flow velocities decrease as an indirect result of project activities that cause erosion (e.g., construction of production wells, gathering lines, production facilities and associated infrastructure).
- Soil compaction potentially affecting long-term crop productivity from spoil placement or vehicular trafficking of access tracks and laydown areas.
- Topographic alteration from the construction of borrow pits for the use of rock in construction activities.
- Leaks or spills from fuel storage and handling leading to soil contamination.
- Outside the registered Chinchilla Sands Local Fossil Fauna Site, fossils being uncovered during site clearance activities or pipeline trenching in excavations that intersect the Chinchilla Sands formation (i.e., within terrain subunits Ia, Ic, IIIa and IVb).

12.4.2 Operations

During operations, the following impacts on the geological, landform and soils values from the various project activities could occur:

- Increased surface or subsurface erosion and waterlogging resulting from flow concentration due to differential settlement of pipeline backfill and padding.
- Leaks or spills from fuel storage and handling or overflow from brine dams leading to soil contamination.

12.4.3 Decommissioning

During decommissioning, the following impacts on the geological, landform and soils values from the various project activities could occur:

- Reprofiling of microrelief leading to patchy exposure of sodic and saline subsoils from inversion of the soil profile during backfill of materials during rehabilitation.
- Importing materials for rehabilitation purposes, particularly in areas of GQAL, affecting agriculture production.

12.4.4 Issues Specifically Associated with Contaminated Land

Disturbance of Existing Contaminated Land

The following mechanisms may contribute to the realisation of impacts associated with contaminated land:

- The siting of project infrastructure over contaminated land.
- Disturbance of contaminated soil and/or groundwater during the drilling of coal seam gas wells.
- Disturbance of contaminated soil and/or groundwater during excavation of trenches for the installation of gathering infrastructure, gas pipelines and other utilities associated with the development.

- Disturbance of contaminated soil and/or groundwater during civil works associated with the construction of production facilities and dams.
- Uncontrolled movement of contaminated soil and/or groundwater after disturbance by project activities.
- Transport to the surface of groundwater that has become contaminated through notifiable or uncontrolled activities (creating an exposure pathway that would otherwise not exist).

Impacts that may be realised through the above mechanisms include:

- Exposure of the public, wildlife, stock or native or cultivated vegetation to contaminants.
- Exposure of project workers to contaminants.
- Contamination of land and water resources (including surface water and groundwater) that are otherwise unaffected by contamination and accordingly have high environmental value.

The level of potential impact will vary depending on the activities being undertaken and extent of land disturbance. For example, drilling a well will only disturb soil within the small footprint of the well pad and will generate relatively small volumes of potentially contaminated soil that will remain controlled within the vicinity of the well, whereas civil works associated with construction of a production facility could expose large volumes of contaminated soil due to the relatively large area of surface disturbance and surface penetration. The risks of groundwater contamination associated with drilling activities and well operations, including aquifer cross-contamination, are discussed separately in Chapter 14, Groundwater.

Prior to implementing mitigation measures, it is possible that project activities involving the disturbance of existing contaminated land could adversely impact the receiving environment. The magnitude of this to environmental values will be high and the significance prior to mitigation is high. It is unlikely that project activities would disturb contaminated land in very high-value areas and, although the magnitude would be higher, the overall significance remains at a high level.

Potential to Cause Land Contamination through Project Activities

Various aspects of the proposed project activities have the potential to result in land contamination and there is currently no notifiable activity addressing coal seam gas development generally. The core activities of coal seam gas extraction and coal seam gas water collection and treatment, although considered environmentally relevant activities under the EP Act, are not necessarily notifiable activities in their own right. Regardless of this formality, the level of potential impact varies according to the type of activity proposed (exploration, field development, construction of roads or infrastructure and operational activities). Although the level of impact will vary depending on the activity, the potential for project activities to result in the contamination of land from notifiable activities includes, but may not be limited to:

- Leaks and spills from onsite fuel storage tanks.
- Leaks and spills from onsite chemical storage facilities.

Fuels, such as diesel, will generally be stored at drilling and construction sites but may also be stored on operational sites as a primary or alternative fuel supply for generators. Chemicals used in the treatment of coal seam gas water and chemicals used for the dehydration of gas (e.g., tri-ethylene glycol) will be stored and used on operational facility sites.

The potential for project activities to result in the contamination of land from non-notifiable activities includes, but may not be limited to, leaks and spills of:

- Fuels and lubricants from the operation of earthmoving, drilling, and associated equipment.
- Lubricants and chemicals from the operation of gas compression and associated equipment.
- Chemicals from the operation of coal seam gas water treatment facilities.
- Waste generated through the drilling of coal seam gas wells (e.g., waste drilling muds).
- Brine generated as a by-product of the treatment of coal seam gas water.

The potential release of untreated coal seam gas water from wells, gathering systems or dams, and the release of brine from treatment facilities and dams, while environmentally relevant and an activity that will be controlled through environmental authorities for petroleum activities, is currently not addressed under contaminated land management guidance.

Prior to implementing mitigation measures, it is possible that project activities could result in land contamination. The magnitude of this to the environmental values will be high and the significance prior to mitigation is high.

Summary of Potential Impacts Prior to Mitigation

There is potential that land upon which Arrow may conduct project activities is contaminated by some historic or current notifiable or uncontrolled activity. In the event that project activities disturb soil or groundwater that has become contaminated as a result of those activities, the potential impact will be exposure of project workers, the public, wildlife, stock, native and cultivated vegetation, and areas of higher environmental value to contaminants that may have acute toxic, carcinogenic, mutagenic or other chronic effects. Similar impacts could occur as a result of Arrow's project activities as they will include notifiable activities. Mitigation of the potential impacts can be achieved through the application of measures that are outlined further in Section 12.6, Avoidance, Mitigation and Management Measures.

12.5 Environmental Protection Objectives

The environmental protection objectives for geology, landform and soils are to:

- Maintain or restore soils and stabilise landforms to support the intended land use.
- Minimise alteration of drainage systems (natural and man-made).
- Protect the Chinchilla Sands Local Fossil Fauna Site.
- Implement erosion and sediment control techniques to minimise project impacts.
- Protect the Barakula State Forest Area and Scientific Areas and the Lake Broadwater Conservation Park.

Environmental protection objectives with respect to land contamination are to:

- Avoid or minimise the disturbance of contaminated land.
- Avoid the contamination of land (including soil and groundwater) or watercourses as a result of project activities (from exploration to decommissioning).

12.6 Avoidance, Mitigation and Management Measures

Avoidance, mitigation and management measures have been proposed to achieve the identified environmental protection objectives.

The primary means by which avoidance is achieved for potential geological-, landform- and soil-related impacts is through design and site selection. Arrow's framework approach focuses on

early identification of sensitive locations that should be avoided by project activities, as described in Chapter 8, Environmental Framework.

Arrow's level of control or influence over the management of contamination will depend on the tenure of the land on which they are conducting project activities. Where Arrow is the landowner, Arrow will have full responsibility for and control of management of any contamination that is disturbed or caused. Otherwise, Arrow will have to consider the requirements of the landowner, while fulfilling its own obligations under the EP Act.

Unless otherwise indicated, the measures detailed in Sections 12.6.1, General Measures, 12.6.2, Land Degradation, 12.6.3, Land Contamination, and 12.6.4, Disturbance or Accidental Damage of Fossils, relate to geology, landform and soils.

12.6.1 General Measures

The following general avoidance, mitigation and management measures will be implemented for all activities:

- Minimise the disturbance footprint and vegetation clearing. [C020]
- Clear areas progressively and implement rehabilitation as soon as practicable following construction and decommissioning activities. [C015]
- Design infrastructure located in cracking clays to withstand the differential shrink-swell ground movement. [C042]
- Develop an erosion and sediment control plan and install and maintain appropriate site-specific controls. [C034]
- Maintain the integrity of private roads and tracks and minimise dust generation, where appropriate, in consultation with relevant landowners and council. [C031]
- Use existing roads and tracks, where practicable. [C032]
- Confine project traffic to designated roads and access tracks, where practicable. [C033]
- Time construction works and access to sites to avoid wetter periods, where practicable. [C045]
- Design and plan the project to avoid steep slopes and areas dissected by gully networks, where practicable. Where these are unavoidable, ensure the required infrastructure (e.g., roads) is appropriately designed for erosion control purposes. [C046]

12.6.2 Land Degradation

The following avoidance, mitigation and management measures will be implemented for all activities that have the potential to cause land degradation:

- Reduce flow concentration and gully creation by minimising disruption to natural overland flow paths through the re-establishment of natural surface drainage lines. [C052]
- Avoid disrupting overland natural flow paths and, where avoidance is not practicable, maintain connectivity of flow in watercourses. [C053]
- Do not disturb or remove flood banks and artificial levees except in consultation with parties benefitting from the structures and the relevant authorities. [C054]
- Avoid disturbance of contour banks and irrigation bays. [C055]

- Locate pipelines to avoid or minimise impact on irrigation flow or current farming practices. If the ROW must cross actively farmed arable land, ensure soil cover above the pipeline is deep enough to allow normal cultivation practices to resume. [C047]
- Avoid mounding of soil along pipelines in irrigated paddocks, to the greatest extent practicable, allowing for settlement of backfill. [C056]
- Conduct pipeline construction to minimise the duration of exposure of soils. [C057]
- Stockpile cleared or mulched vegetation along the inside edge of the work sites (separate from soil stockpiles), to aid the control of runoff and ensure stockpiled vegetation does not pose a bushfire hazard. [C106]
- Prevent subsurface water flows and erosion along the backfilled trench by appropriate means, such as trench blocks and compaction of backfilled soils. [C503]
- Develop rehabilitation plans based on environmental sensitivities that address ground preparation requirements, natural and constructed drainage patterns, soil erodibility, contamination, slope steepness and length, rainfall frequency and intensity, potential flow magnitudes, vegetation cover, land use and landowner requirements. [C070]
- Avoid excessive watering of saline soils to reduce leaching of salts and rising groundwater. [C059]
- Avoid excessive watering of surface-crusting soils to reduce crust formation. [C060]
- Discharge water from project activities at a rate and location that will not result in erosion. Install additional erosion protection measures, including energy dissipation structures, at discharge outlets. [C066]
- Provide regular access points to pipeline construction ROWs to limit rutting and compaction of soils from vehicles travelling along the ROW. [C061]
- Strip, salvage and stockpile topsoil near the work site separately to subsoils (in consultation with landowners). Ensure topsoil stockpiles have a maximum height of 2 m, where the future use is intended for rehabilitation, and are protected from erosion. [C062]
- Backfill and rehabilitate excavations, particularly pipeline trenches and drilling sumps. Conduct backfilling in a manner that will promote successful rehabilitation, including capping of exposed subsoil with topsoil and replacement of the land surface to preconstruction levels to reduce trench subsidence and concentration of flow. Mounding of soils to allow for settling may be required in some areas. However, in laser-levelled paddocks, this may not be practicable, and backfilling should be carried out in consultation with the landowner. [C071]
- Remedy areas of differential settlement associated with buried infrastructure that interrupt the pre-existing surface water flow within intensively cultivated areas. [C072]
- Carry out ground investigations in soils prone to salinity prior to major earthworks to establish the depth at which saline conditions occur. [C063]
- Excavate any saline material during rehabilitation of coal seam water dams or brine dams and select an appropriate option for management for the material (e.g., treat for reuse, or dispose of in a registered landfill). [C073]
- Ensure coal seam gas water used on highly productive soils is of comparable water quality to that used for irrigation in the specific area. [C067]

- Ensure the use of coal seam gas water meets beneficial-use licence conditions where it is to be used on GQAL or strategic cropping land or within heritage-listed or indicative sites. [C068]

12.6.3 Land Contamination

This section relates to geology, landform and soils, and contaminated land.

The avoidance, mitigation and management measures below will be implemented for all activities that have the potential to cause land contamination.

Existing Contaminated Land

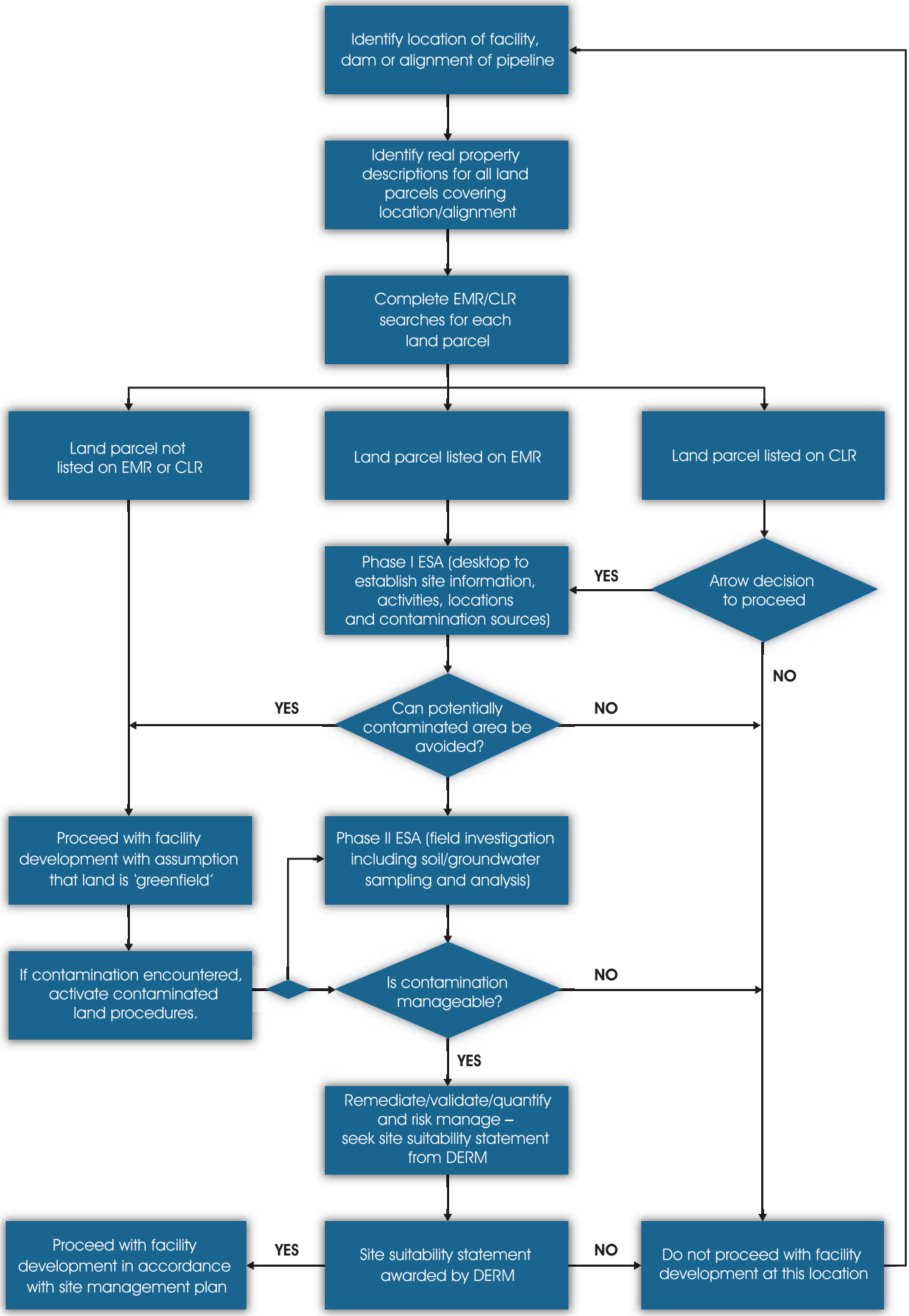
The development of project activities may occur on land that is potentially contaminated. Due to the potential impacts associated with the disturbance of existing contaminated soil or groundwater outlined in Section 12.4.4, Issues Specifically Associated with Contaminated Land, Arrow will seek to minimise impacts through application of the following general hierarchy:

- Avoid development on contaminated land through the completion of appropriate register searches and desktop investigations (i.e., avoid land or the contaminated portion of a parcel of land that is listed on the Contaminated Land Register or the Environmental Management Register, where practicable). [C049]
- Conduct physical investigations on selected parcels of land to influence facility siting decisions on a localised scale (i.e., target the portion of land that is not contaminated by understanding the extent of contamination). [C050]
- Inspect and observe site locations for the presence of contamination prior to commencement of intrusive activities. [C019]
- Avoid disturbance of contaminated soil and groundwater when it is identified or observed during intrusive works. [C064]
- Manage contaminated soil or groundwater that cannot be avoided through physical investigation; manage quantification of the type, severity and extent of contamination; and remediate or manage in accordance with the Queensland Government's Draft Guidelines for the Assessment and Management of Contaminated Land (DE, 1998). [C065]

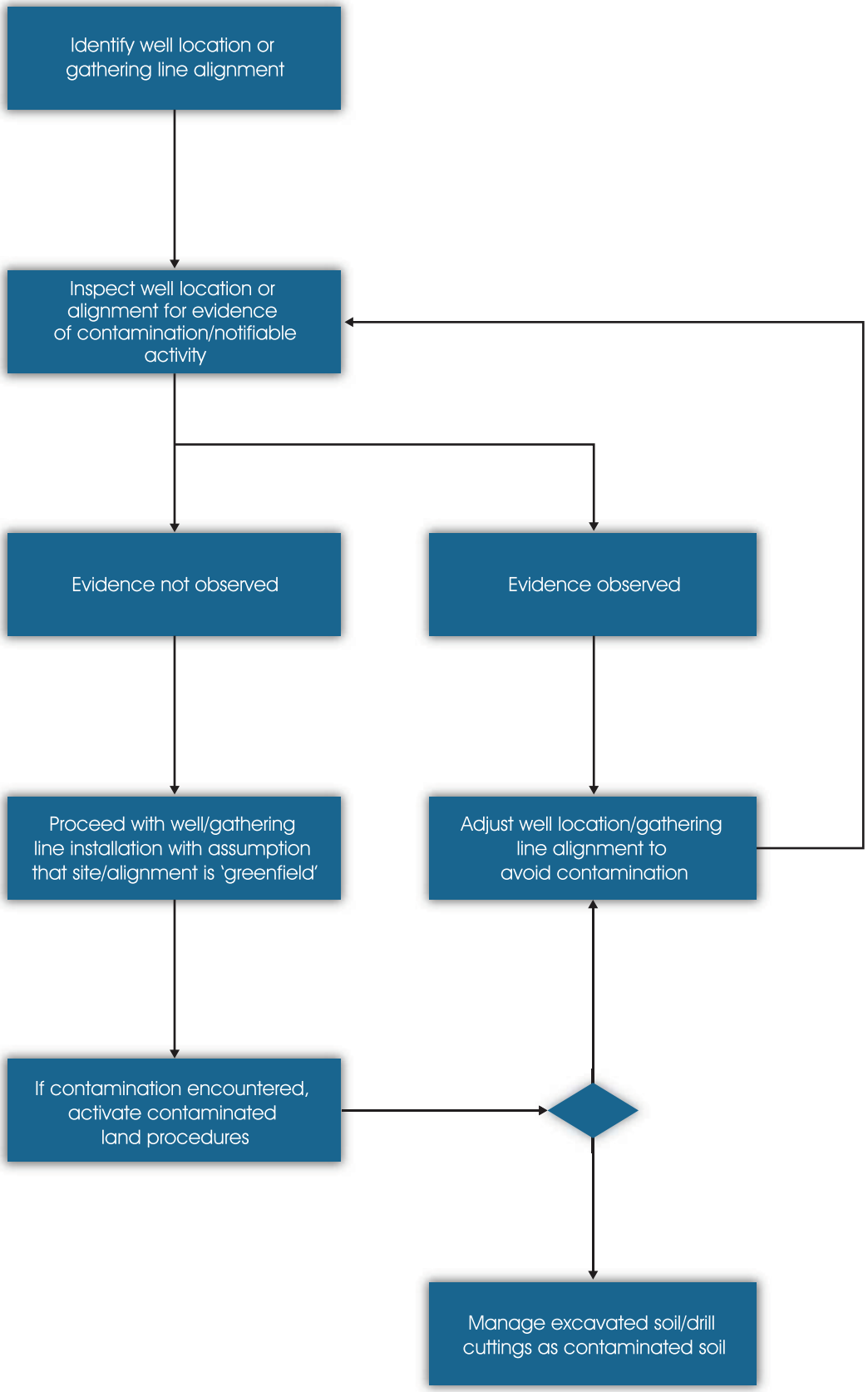
The scale of potential disturbance of contaminated soil or groundwater will differ between project activities and the application of the above hierarchy will be applied depending on the project activity. The application of proactive and reactive avoidance, mitigation and management actions for specified project development activities is presented in Figures 12.5 and 12.6. Note there is a difference between the process indicated for facilities and pipelines, and wells and gathering lines. The predominant difference is in the responsibility that Arrow will hold for the land on which the infrastructure is located.

These figures indicate the contaminated land procedures to be applied should soil or groundwater, which has been contaminated through historical or current notifiable activities, be encountered during project activities. Contaminated land procedures will be included in Arrow's standard operating procedures and will include directions, triggers and decision support materials that address the following:

- Act immediately upon the identification of contaminated soil or groundwater (including actions to protect the health and safety of the project workforce and the public).
- Cease intrusive works involving the disturbance of contaminated soil or groundwater.



coffey environments	Job No: 7040	Arrow Energy	arrow energy go further	Contaminated land strategy: production facilities, dams and pipelines	Figure No: 12.5
	File Name: 7040_04_F12.05_GL	Surat Gas Project			



coffey environments	Job No: 7040	Arrow Energy	arrow energy go further	Contaminated land strategy: wells, gathering infrastructure and utilities	Figure No: 12.6
	File Name: 7040_04_F12.06_GL	Surat Gas Project			

- Quarantine areas containing contaminated soil or groundwater.
- Appoint one or more suitably qualified and experienced contaminated land specialists to assess the contaminated land.
- Conduct a Phase II Environmental Site Assessment should contaminated soil or groundwater be identified.
- Undertake necessary excavation, remediation, characterisation and/or validation activities in response to the identification of contaminated soil or groundwater.
- Review assessment, remediation and validation works by a third-party reviewer, where necessary.

Further detail on the content and application of Arrow's standard operating procedures is presented in the environmental management plan (Attachment 5).

Project Activities

Measures for the avoidance, mitigation and management of the potential contamination of soil and groundwater as a direct result of project activities should include, but are not necessarily limited to:

- Incorporate construction methods and treatments to deal with reactive gilgai and cracking clays in infrastructure design. [C044]
- Incorporate into an emergency response plan or water management plan procedures for the controlled discharge of coal seam gas water under emergency conditions. Procedures will include water balance modelling, weather monitoring and forecasting, stream flow data, notification and reporting. [C069]
- Apply appropriate international, Australian and industry standards and codes of practice for the design and installation of infrastructure associated with the storage of hazardous materials (such as chemicals, fuels and lubricants). [C048]
- Apply appropriate international, Australian and industry standards and codes of practice for the handling of hazardous materials (such as chemicals, fuels and lubricants). [C035]
- Develop and implement emergency response and spill response procedures to minimise any impacts that could occur as a result of releases of hazardous materials or any loss of containment of storage equipment. [C036]
- Ensure appropriate spill response equipment, including containment and recovery equipment, is available on site. [C037]
- Carry out corrective actions immediately upon the identification of any contamination of soil or groundwater that has occurred as a result of project activities. [C038]
- Assess contamination that may have occurred as a result of project activities in accordance with documented operating procedures. Appoint one or more suitably qualified and experienced contaminated land specialists. [C039]
- Undertake an environmental site assessment in response to the identification of contamination that may have occurred as a result of project activities. [C040]
- Complete excavation, remediation, characterisation and validation activities in response to the identification of contamination that may have occurred as a result of project activities. [C043]

Further detail on the content and application of Arrow's standard operating procedures is presented in the environmental management plan (Attachment 5).

12.6.4 Disturbance or Accidental Damage of Fossils

Avoid the Chinchilla Sands Local Fossil Fauna Site and educate project personnel on the importance of the site. [C041]

12.7 Residual Impacts

The avoidance, mitigation and management measures outlined above will enable avoidance of adverse impacts on geological, landform and soils values, or reduce the severity of potential impacts. Similarly, they will reduce the severity of impacts related to contaminated land, either in existence prior to project activities or generated as a result of project activities.

While the sensitivity of the environmental values in the project development area remains constant (at moderate) pre- and post-implementation of the avoidance, mitigation and management measures, the magnitude reduces from high to low in all instances. Similarly an assessment of the significance of impacts shows a reduction from high (for premitigated impacts) to **low** (for residual impacts).

The only exception to this relates to terrain subunit IIb, which contains the Chinchilla Sands Local Fossil Fauna Site. For this subunit, the sensitivity remains high throughout. However, the magnitude and significance, initially high and major respectively, are no longer applicable as the Chinchilla Local Fossil Fauna Site will be avoided.

Table 12.6 summarises the potential impacts prior to mitigation, along with proposed avoidance, mitigation and management measures and the subsequent residual impacts, assuming successful implementation of proposed avoidance, mitigation and management measures.

More specifically relating to the contamination of soil and/or groundwater as a result of project activities, Arrow will avoid project activities within national parks and conservation areas, thereby avoiding impacts on highly sensitive values.

After implementing avoidance, mitigation and management measures, it is unlikely that project activities will disturb existing contaminated land or result in the contamination of land to the extent that could adversely impact the receiving environment. The magnitude of either to the environmental values will be low and the significance after mitigation is **low**.

Table 12.6 Summary of geology, landform and soils impact assessment

Cause of Potential Impacts	Existing Environment	Values Sensitivity	Premitigated Impact		Summary of Avoidance, Mitigation and Management Measures	Residual Impact	
			Magnitude	Significance		Magnitude	Significance
Land Degradation – Erosion and Associated Sedimentation, Dust Generation and Reduction in Soil Quality (Physical and Chemical)							
Construction • Increased erosion resulting from ground disturbance, vegetation clearance, alteration of natural drainage and flow concentration due to construction activities. • Deposition downslope or downstream of eroded sediment as flow velocities decrease as an indirect result of project activities that cause erosion. • Soil compaction potentially affecting long-term crop productivity from spoil placement or vehicular trafficking of access tracks and laydown areas. • Topographic alteration from the construction of borrow pits for the use of rock in construction activities. **Operations** • Increased surface or subsurface erosion and waterlogging resulting from flow concentration due to differential settlement of pipeline backfill and padding. **Decommissioning** • Reprofiling of microrelief leading to patchy exposure of sodic and saline subsoils from inversion of the soil profile during backfill of materials during rehabilitation.	Terrain Unit I	Moderate	High	High	**General Measures** • Minimise the disturbance footprint and vegetation clearing. • Clear areas progressively and implement rehabilitation as soon as practicable. • Design infrastructure located in cracking clays to withstand the differential shrink-swell ground movement. • Develop an erosion and sediment control plan and install and maintian appropriate site-specific controls. • Maintain integrity of private roads and tracks and minimise dust generation. • Use existing roads and tracks. • Confine project traffic to designated roads and access tracks. • Time construction works and access to sites to avoid wetter periods. • Design and plan the project to avoid steep slopes and areas dissected by gully networks, where practicable.	Low	Low
	Terrain Subunits IIa and IIc	Moderate	High	High		Low	Low

Table 12.6 Summary of geology, landform and soils impact assessment (cont'd)

Cause of Potential Impacts	Existing Environment	Values Sensitivity	Premitigated Impact		Summary of Avoidance, Mitigation and Management Measures	Residual Impact	
			Magnitude	Significance		Magnitude	Significance
Land Degradation – Erosion and Associated Sedimentation, Dust Generation and Reduction in Soil Quality (Physical and Chemical) (cont'd)							
Decommissioning (cont'd) • Importing materials for rehabilitation purposes, particularly in areas of GQAL, affecting agriculture production.	Terrain Subunit IIb	High	High	Major	**Specific Measures** • Reduce flow concentration and gully creation by minimising disruption to natural overland flow paths. • Avoid disrupting overland natural flow paths and maintain connectivity of flow in watercourses. • Do not disturb or remove flood banks and artificial levees without prior consultation. • Avoid disturbance of contour banks and irrigation bays. • Locate pipelines to avoid or minimise impact on irrigation flow or current farming practices. Ensure soil cover above the pipeline is deep enough to allow normal cultivation practices to resume. • Avoid mounding of soil along pipelines in irrigated paddocks, allowing for settlement of backfill. • Conduct pipeline construction to minimise duration of exposure of soils. • Stockpile cleared or mulched vegetation along the inside edge of work sites and ensure stockpiled vegetation does not pose a bushfire hazard.	Not applicable. Chinchilla Sands Local Fossil Fauna Site will be avoided.	
	Terrain Unit III	Moderate	High	High		Low	Low

Table 12.6 Summary of geology, landform and soils impact assessment (cont'd)

Cause of Potential Impacts	Existing Environment	Values Sensitivity	Premitigated Impact		Summary of Avoidance, Mitigation and Management Measures	Residual Impact	
			Magnitude	Significance		Magnitude	Significance
Land Degradation – Erosion and Associated Sedimentation, Dust Generation and Reduction in Soil Quality (Physical and Chemical) (cont'd)							
Decommissioning (cont'd) • Importing materials for rehabilitation purposes, particularly in areas of GQAL, affecting agriculture production.	Terrain Unit IV	Moderate	High	High	• Prevent subsurface water flows and erosion along the backfilled trench by appropriate means. • Develop rehabilitation plans based on environmental sensitivities. • Avoid excessive watering of saline soils. • Avoid excessive watering of surface-crusting soils. • Discharge water from project activities at a rate and location that will not result in erosion. Install additional erosion protection measures at discharge outlets. • Provide regular access points to pipeline construction ROWs. • Strip, salvage and stockpile topsoil near the work site separately to subsoils. Ensure topsoil stockpiles have a maximum height of 2 m. • Backfill and rehabilitate excavations, particularly pipeline trenches and drilling sumps. • Remedy areas of differential settlement associated with buried infrastructure. • Carry out ground investigations in soils prone to salinity prior to major earthworks.	Low	Low
	Terrain Unit V	Moderate	High	High		Low	Low

Table 12.6 Summary of geology, landform and soils impact assessment (cont'd)

Cause of Potential Impacts	Existing Environment	Values Sensitivity	Premitigated Impact		Summary of Avoidance, Mitigation and Management Measures	Residual Impact	
			Magnitude	Significance		Magnitude	Significance
Land Degradation – Erosion and Associated Sedimentation, Dust Generation and Reduction in Soil Quality (Physical and Chemical) (cont'd)							
	Terrain Unit VI	Moderate	High	High	• Excavate any saline material during rehabilitation of coal seam water dams or brine dams and select an appropriate option for management for the material. • Ensure coal seam gas water used on highly productive soils is of comparable water quality to that used for irrigation in the specific area. • Ensure the use of coal seam gas water meets beneficial-use licence conditions where to be used on GQAL or strategic cropping land or within heritage-listed or indicative sites. • Implement a decommissioning and rehabilitation plan in accordance with the dam design plan.	Low	Low
Land Contamination							
Construction • Disturbance of existing contaminated land. • Potential to cause land contamination through project activities. • Leaks or spills from fuel storage and handling leading to soil contamination. **Operations** • Potential to cause land contamination through project activities.	Terrain Unit I	Moderate	High	High	**General Measures** The same as for Land Degradation. **Specific Measures** • Avoid development on contaminated land through the completion of appropriate register searches and desktop investigations. • Conduct physical investigations to influence facility siting decisions on a localised scale.	Low	Low

Table 12.6 Summary of geology, landform and soils impact assessment (cont'd)

Cause of Potential Impacts	Existing Environment	Values Sensitivity	Premitigated Impact		Summary of Avoidance, Mitigation and Management Measures	Residual Impact	
			Magnitude	Significance		Magnitude	Significance
Land Contamination (cont'd)							
Operations (cont'd) • Leaks or spills from fuel storage and handling, or overflow from brine dams leading to soil contamination.	Terrain Subunits IIa and IIc	Moderate	High	High	• Inspect and observe site locations for the presence of contamination prior to commencement of intrusive activities. • Avoid disturbance of contaminated soil and groundwater when identified or observed. • Manage contaminated soil or groundwater that cannot be avoided. • Incorporate construction methods and treatments to deal with reactive gilgai and cracking clays in infrastructure design. • Incorporate into an emergency response plan or water management plan procedures for the controlled discharge of coal seam gas water under emergency conditions. • Apply appropriate standards and codes of practice for the design and installation of infrastructure associated with the storage of hazardous materials. • Apply appropriate standards and codes of practice for the handling of hazardous materials.	Low	Low
	Terrain Subunit IIb	High	High	Major		Not applicable. Chinchilla Sands Local Fossil Fauna Site will be avoided.	
	Terrain Unit III	Moderate	High	High		Low	Low
	Terrain Unit IV	Moderate	High	High		Low	Low

Table 12.6 Summary of geology, landform and soils impact assessment (cont'd)

Cause of Potential Impacts	Existing Environment	Values Sensitivity	Premitigated Impact		Summary of Avoidance, Mitigation and Management Measures	Residual Impact	
			Magnitude	Significance		Magnitude	Significance
Land Contamination (cont'd)							
	Terrain Unit V	Moderate	High	High	• Develop and implement emergency response and spill response procedures. • Ensure appropriate spill response equipment is available on site. • Carry out corrective actions immediately upon the identification of any contamination of soil or groundwater. • Assess contamination that may have occurred as a result of project activities. • Undertake an environmental site assessment in response to the identification of contamination. • Complete excavation, remediation, characterisation and validation activities in response to contamination.	Low	Low
	Terrain Unit VI	Moderate	High	High		Low	Low
Disturbance or Accidental Damage of Recognised Fossil Sites							
Construction • Outside the registered Chinchilla Sands Local Fossil Fauna Site, fossils being uncovered during site clearance activities or pipeline trenching in excavations that intersect the Chinchilla Sands formation.	Chinchilla Sands formation (i.e., within terrain subunits Ia, Ic, IIIa and IVb).	Moderate	High	High	**General Measures** The same as for Land Degradation. **Specific Measures** • Avoid the Chinchilla Sands Local Fossil Fauna Site and educate project personnel on the importance of the site.	Low	Low

12.8 Inspection and Monitoring

The objective of the monitoring and inspection program is to ensure a safe, non-polluting landform with self-sustaining soil fertility. Therefore, disturbed and rehabilitated areas will be monitored regularly (including after prolonged rainfall or intense storms), for short- and long-term adverse impacts on landforms, especially in areas sensitive to erosion or in intensive agricultural areas. More specifically, monitoring will include:

- Inspect pipeline ROWs routinely until ground stabilisation and natural revegetation or pasture grasses or crops are established. [C506]
- Monitor soil salinity in salinity prone areas prior to major earthworks. [C514]
- Provide chemical monitoring of contaminated soils and groundwater in relevant monitoring bores. [C515]
- Routinely monitor buffer zones and project footprint using satellite imagery. [C509]
- Inspect erosion and sediment control measures following significant rainfall events to ensure effectiveness of measures is maintained. [C505]
- Routinely inspect spill containment controls and spill response kits. [C516]
- Visually inspect physical form downstream of watercourse discharge locations. [C517]

Implementation of the above strategy, inclusive of avoidance, mitigation and management measures, will be controlled procedurally. Inspection and monitoring will be conducted in accordance with environmental authority conditions and regulatory requirements. [C518]