PROJECT

ARROW ENERGY
SURAT GAS PROJECT
AGRICULTURAL REPORT
SURAT BASIN, QUEENSLAND

PREPARED FOR

COFFEY ENVIRONMENTS PTY LTD

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SYNOPSIS This agricultural report identifies the potential impacts of construction, operation and maintenance, and decommissioning activities of Arrow Energy's proposed coal seam gas development in the Surat Basin, Queensland on agricultural enterprises, particularly Good Quality Agricultural Land and strategic cropping land within the project development area.

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SUMMARY

Coffey Environments Australia Pty Ltd (Coffey Environments) commissioned Gilbert & Sutherland Pty Ltd to prepare an agricultural report to address the requirements of the Final Terms of Reference for the Surat Gas Project Environmental Impact Statement prepared and issued by the Department of Environment and Resource Management (DERM) in September 2010.

Objectives for the study were:

- Identify, describe and map the agricultural enterprises/activities carried out in the study area.
- Identify and describe particular or specific aspects of the agricultural activities that underpin their success and/or viability.
- Identify and describe the key impacts of the investigation, construction and operation of coal seam gas developments on the agricultural activities noting any specific issues pertinent to the activities.
- Propose management measures that address the potential impacts, focussing on the particular or specific aspects, of each potentially affected enterprise.
- Describe how the proposed management measures address Arrow Energy Pty Ltd's (Arrow's) commitments.

The potential impact on land from the drilling, construction, operation, maintenance, and decommissioning of production wells for the Surat Gas Project, comprising alienation, reduced productivity or degradation, has been estimated by Arrow to be between 2 and 3% [1] of a typical 160 acre [2] production spacing.[3] This figure represents an estimate which will reduce if distribution efficiencies are achieved and the typical production unit can be increased. For example, if the gas field development results in a 320 acre[4] spacing, the proportionate land requirement may reduce.

1 Pers. com., G. Coggan (Arrow Energy), 20 July 2011.
2 160 acres approximates 65 hectares.
3 The estimated area is based on a 900m rectangular spacing for a single well head
4 320 acres approximates 130 hectares.

There may also be additional reductions in this area once the extent of rehabilitation is included but this is site specific and variable.

In essence it is important to acknowledge that both SCL and GQAL will be affected, and potentially alienated or degraded, and the current estimates of disturbance range between 2 and 3% of the affected properties, based on the typical production spacing.

Objectives to guide site and route selection, the primary mitigation for potential impacts to agricultural enterprises and farming practices have been proposed. It is recommended they, along with proposed mitigation and environmental management measures, are incorporated in environmental management procedures forming part of Arrow’s Environmental Management System.

This study has identified;

- Agricultural enterprises of the region;
- Gross value of production; and
- Farming practices carried out across a range of enterprises, Particular practices and the issues that contribute to reduced yields (leading to potentially increased capital and operating costs).

This study has described the soil properties that underpin the classification of a large part of the project development area as GQAL and strategic cropping land.

Potential impacts of coal seam gas construction, operation and maintenance, and decommissioning activities on farming operations have been identified and described. These potential impacts are associated with four key issues – disruption to farming infrastructure and practices, disruption to cropping or breeding cycles, disturbance of the soil profile and potential changes to overland flow.

The extent and severity of these impacts on an individual farm were found to be dependent on the size of the production unit and the extent and location of the coal seam gas infrastructure established on the property. In general, larger farms will not be as affected as smaller ones but the overall impact will be determined by the ability of the agricultural enterprise to absorb the impacts of lost productive land, reduced or lost productivity, and changed practices resulting in increased capital and operating costs.

Mitigation and management measures to be incorporated in Arrow's EMS (as part of environmental management procedures or as a specific agricultural management plans) have been proposed. The environmental controls adopt the following hierarchy:

- avoidance;
- minimisation;
- mitigation;
- rehabilitation; and
- inspection and monitoring.

Avoidance and minimisation were identified as the most effective mitigation measures with site and route selection nominated the primary mitigation. Twelve objectives to guide site and route selection are proposed.

The residual effects of coal seam gas development on agricultural enterprises may not be known for some time due to the recovery times for soil function including accumulation of organic matter mass, reestablishment of soil continuity structures (micro and macro pores) and desired surface levels. The latter relates to the extent of settlement of reinstated or reshaped soils and its affect on drainage patterns, water delivery structures and flood flows. The success of rehabilitation will determine the degree and extent to which the disturbed land will achieve pre-disturbance productivity.

Arrow has made public commitments to landholders and other stakeholders in the project. This report notes that the legal obligations on Arrow and its own commitments will provide a framework within which impacts will be identified, addressed and compensated for under relevant statutes.

CONTENTS

GLOSSARY

animal enclosure *n*. an enclosed or partly enclosed industrial-sized shed and/or an enclosure including holding pens, yards and cages for keeping cattle, sheep, pigs, poultry or birds as a commercial farming business.

catchment *n.* the area above a given point which contributes to the run-off.

clay *n.* very fine-grained sediment or soil (often defined as having a particle size less than 0.002 mm, or 2 microns, in diameter).

denitrification *n.* occurs when oxygen levels are depleted and nitrate becomes the primary oxygen source for microorganisms in the soil. The process occurs under anaerobic or anoxic conditions.

DERM *abbr.* Queensland Department of Environment and Resource Management.

erosion *n.* the process by which material such as rock or soil is worn away or removed by wind or water.

GQAL *abbr.* Good Quality Agricultural Land as defined in State Planning Policy 1/92.

groundwater *n.* water contained in interconnected pores located below the watertable in confined or unconfined aquifers.

head ditch *n.* water delivery structure, typically an open channel, located at the upslope end of a field. Water is typically conveyed to the irrigated runs or bays by poly-pipe syphons.

ha *abbr.* hectare.

IFL *abbr.* Intensively Farmed Land is a term developed by Arrow to reflect agricultural areas on sensitive soils (i.e. Black soils, and similar high value soils) that are currently intensively farmed (i.e. Irrigated, cropped or other intensive agricultural enterprise), where relatively minor changes to the landform can have a disproportionate impact on the productivity of the land. This term is primarily used by Arrow in its consultation and liaison processes.

kg *abbr.* kilogram.

loam *n.* medium-textured soil composed of approximately 10% to 25% clay, 25% to 50% silt and less than 50% sand.

NSL *abbr.* natural surface level.

pH *abbr.* the degree of acidity or alkalinity measured on a scale of 0 to 14 with 7 as neutral. From 0 to 7 is acidic; from 7 to 14 is alkaline.

project development area *n.* the approximately 8,600 km^2 area extending from the township of Wandoan in the north towards Goondiwindi in the south, in an arc through Dalby.

QDPI *abbr.* Queensland Department of Primary industries.

sand *n.* sediment with particles of between 63 microns and 2mm.

SCL *abbr*. Strategic Cropping Land as defined by DERM. *Note: The definition of SCL at the time of preparing this report was subject to draft criteria published on 14 April 2011 by DERM to inform the development of draft Strategic Cropping Land legislation.*

sediment *n.* unconsolidated, fine-grained material (typically derived from the weathering of rocks) that is transported by water and settling on the floor of seas, rivers, streams and other bodies of water.

silt *n.* sediment with particles finer than sand and coarser than clay (of between 2 and 63 microns).

study area *n.* the extent of the geographical area required to appropriately assess impacts to environmental values.

sub-catchment *n.* a smaller area within a catchment drained by one or more tributaries of the main water body.

t *abbr.* tonne.

tailwater *n.* water runoff from an irrigated field that is typically collected in drains at the down slope end of the field.

USCS *abbr.* Unified Soil Classification System.

1 Introduction

Arrow Energy Pty Ltd ('Arrow') is seeking to expand its operations in Queensland's Surat Basin with a major coal seam gas exploration, development and production proposal.

The Surat Gas Project is designed to meet the growing demand for gas supply into the future, including domestic and potential export markets.

Construction, operation and maintenance activities associated with the development of the coal seam gas fields will impact on existing land uses including agriculture.

Arrow is preparing a voluntary Environmental Impact Statement (EIS) to address potential impacts of the proposed development. The Queensland Department of Environment and Resource Management (DERM) has issued a Terms of Reference for the Surat Gas Project EIS.

Coffey Environments Australia Pty Ltd (Coffey Environments) engaged Gilbert & Sutherland Pty Ltd to prepare an agriculture report to address the relevant requirements of the Terms of Reference for the Arrow Energy Surat Gas Project EIS (DERM, September 2010).

This report describes the agricultural activities in the project development area, practices specific to those agricultural enterprises, constraints imposed by those practices on development activities, and strategies, measures and options for avoiding and/or mitigating impacts on agricultural industries, where possible. Particular attention is paid to potential impacts on good quality agricultural land and strategic cropping land, as defined in relevant planning policies.

1.1 Objectives

The Terms of Reference for the Arrow Energy Surat Gas Project EIS (DERM, September 2010) stipulate the following requirements for the assessment of potential impacts on agriculture.

> *The potential environmental harm caused by the project on areas currently used for agriculture, urban development, recreation, tourism, other business and the implications of the project for future developments in the project area including constraints on surrounding land uses should be described. Mitigation measures should be proposed for any potentially adverse impacts on stock route operations during the construction and operational phases of the development. If the development adjoins or potentially impacts on good quality agricultural land, then an assessment of the potential for land use conflict is required. Investigations should follow the procedures set out in the planning guideline, The Identification of Good Quality Agricultural Land, which supports State Planning Policy 1/92.*

In addition, following concerns raised during community consultation, Arrow made a number of commitments relating to the relationship between the Arrow's proposed developments and agriculture in the Surat Basin. The commitments made by Arrow include:

- *No development on intensely farmed land until stakeholder concerns are properly addressed.*
- *No construction of dams for coal seam water or brine on intensively farmed land.*
- *Use of surface tanks, not pits, when drilling production wells on black soil.*

The Terms of Reference requirements and Arrow's commitments were translated into objectives for this study, which are:

- *Identify, describe and present on a map the agricultural enterprises/activities carried out in the study area.*
- *Identify and describe particular or specific aspects of the agricultural activities that underpin their success and/or viability.*
- *Identify and describe the key impacts of the investigation, construction and operation of coal seam gas developments on the agricultural activities noting any specific issues pertinent to the activities.*

- *Propose management measures that address the potential impacts, focussing on the particular or specific aspects, of each potentially affected enterprise.*
- *Describe how the proposed management measures address Arrow's commitments.*

1.2 Relevant information

The scope of works undertaken to achieve the objectives of this report included a review of materials as sourced from the public domain and Coffey Environments reports, as well as specific project details supplied by Arrow. Materials include:

- Terms of Reference for the Arrow Energy Surat Gas Project Environmental Impact Statement (DERM, September 2010).
- Geology, Soils and Landform study (Coffey Environments, 2011).
- Surface Water Assessment Part A: Fluvial Geomorphology and Hydrology (Alluvium, 2011).
- Groundwater Assessment report (Coffey Environments, 2011).
- Economic Impact Assessment (AEC Group, 2011).
- Social Impact Assessment (URS, 2011).

2 Project description

A general description of the project including information about Arrow and its activities, as well as key infrastructure and activities proposed as part of the Surat Gas Project, was provided by Coffey Environments.

2.1 Project proponent

Arrow Energy Pty Ltd (Arrow) is an integrated energy company with interests in coal seam gas field developments, pipeline infrastructure, electricity generation and a proposed liquefied natural gas (LNG) project.

Arrow has interests in more than 65,000 km^2 of petroleum tenures, mostly within Queensland's Surat and Bowen basins. Elsewhere in Queensland, the company has interests in the Clarence-Moreton, Coastal Tertiary, Ipswich, Styx and Nagoorin Graben basins.

Arrow's petroleum tenures are located close to Queensland's three key energy markets; Townsville, Gladstone and Brisbane. The Moranbah Gas Project in the Bowen Basin and the Tipton West, Daandine, Kogan North and Stratheden projects in the Surat Basin near Dalby comprise Arrow's existing coal seam gas production operations. These existing operations currently account for approximately 20% of Queensland's overall domestic gas production.

Arrow supplies gas to the Daandine, Braemar 1 and 2, Townsville and Swanbank E power stations which participate in the National Electricity Market. With Arrow's ownership of Braemar 2, and the commercial arrangements in place for Daandine and Townsville power stations Arrow has access to up to 600 MW of power generation capacity.

Arrow and its equity partner AGL Energy have access rights to the North Queensland Pipeline which supplies gas to Townsville from the Moranbah Gas Project. They also hold the pipeline licence for the proposed Central Queensland Gas Pipeline between Moranbah and Gladstone.

Arrow is currently proposing to develop the Arrow LNG Project, which is made up of the following aspects:

- Arrow LNG Plant – The proposed development of an LNG Plant on Curtis Island near Gladstone, and associated infrastructure, including the gas pipeline crossing of Port Curtis.
- Surat Gas Project – The upstream gas field development in the Surat Basin, subject of this assessment.
- Arrow Surat Pipeline Project – (Formerly the Surat Gladstone Pipeline), the 450 km transmission pipeline connects Arrow's Surat Basin coal seam gas developments to Gladstone.
- Bowen Gas Project – The upstream gas field development in the Bowen Basin.
- Arrow Bowen Pipeline – The transmission pipeline which connects Arrow's Bowen Basin coal seam gas developments to Gladstone.

2.2 Project overview

Arrow proposes expansion of its coal seam gas operations in the Surat Basin through the Surat Gas Project. The need for the project arises from the growing demand for gas in the domestic market and global demand and the associated expansion of LNG export markets.

The project development area covers approximately 8,600 km^2 and is located approximately 160 km west of Brisbane in Queensland's Surat Basin. The project development area extends from the township of Wandoan in the north towards Goondiwindi in the south, in an arc adjacent to Dalby. Townships within or in close proximity to the project development area include (but are not limited to) Wandoan, Chinchilla, Kogan, Dalby, Cecil Plains, Millmerran, Miles and Goondiwindi. Project infrastructure including coal seam gas production wells and production facilities (including both water treatment and power generation facilities where applicable) will be located throughout the project development area but not in towns. Facilities supporting the petroleum development activities such as depots, stores and offices may be located in or adjacent to towns.

The conceptual Surat Gas Project design presented in the environmental impact statement (EIS) is premised upon peak gas production from Arrow's Surat Basin gas fields of approximately 1,050 TJ/d. The peak gas production comprises 970 TJ/d for LNG production (including a 10% fuel gas requirement for facility operation) and a further 80 TJ/d for supply to the domestic gas market.

A project life of 35 years has been adopted for EIS purposes. Ramp-up to peak production is estimated to take between 4 and 5 years, and is planned to commence in 2014. Following ramp-up, gas production will be sustained at approximately 1,050 TJ/d for at least 20 years, after which production is expected to decline.

Infrastructure for the project is expected to comprise:

- Approximately 7,500 production wells drilled over the life of the project at a rate of approximately 400 wells drilled per year.
- Low pressure gas gathering lines to transport gas from the production wells to production facilities.
- Medium pressure gas pipelines to transport gas between field compression facilities and central gas processing and integrated processing facilities.
- High pressure gas pipelines to transport gas from central gas processing and integrated processing facilities to the sales gas pipeline.
- Water gathering lines (located in a common trench with the gas gathering lines) to transport coal seam water from production wells to transfer, treatment and storage facilities.
- Approximately 18 production facilities across the project development area expected to comprise of 6 of each of the following:
  - Field compression facilities.
  - Central gas processing facilities.
  - Integrated processing facilities.
- A combination of gas powered electricity generation equipment that will be co-located with production facilities and/or electricity transmission infrastructure that may draw electricity from the grid (via third party substations).

Further detail regarding the function of each type of production facility is detailed below.

Field compression facilities will receive gas from production wells and are expected to provide 30 to 60 TJ/d of first stage gas compression. Compressed gas will be transported from field compression facilities in medium pressure gas pipelines to multi-stage compressors at central gas processing facilities and integrated processing facilities where the gas will be further compressed to transmission gas pipeline operating pressure and dehydrated to transmission gas pipeline quality. Coal seam water will bypass field compression facilities.

Central gas processing facilities will receive gas both directly from production wells and field compression facilities. Central gas processing facilities are expected to provide between 30 and 150 TJ/d of gas compression and dehydration. Coal seam water will bypass central gas processing facilities and be pumped to an integrated processing facility for treatment.

Integrated processing facilities will receive gas from production wells and field compression facilities. Integrated processing facilities are expected to provide between 30 and 150 TJ/d of gas compression and dehydration. Coal seam water received at integrated processing facilities is expected to be predominantly treated using reverse osmosis and then balanced to ensure that it is suitable for the intended beneficial use. Coal seam water received from the field, treated water and brine will be stored in dams adjacent to integrated processing facilities.

It is envisaged that development of the Surat Gas Project will occur in five development regions: Wandoan, Chinchilla, Dalby, Kogan/Millmerran and Goondiwindi. Development of these regions will be staged to optimise production over the life of the project.

Arrow has established a framework to guide the selection of sites for production wells and production facilities and routes for gathering lines and pipelines. The framework will also be used to select sites for associated infrastructure such as access tracks and construction camps.

Environmental and social constraints to development that have been identified through the EIS process coupled with the application of appropriate environmental management controls will ensure that protection of environmental values (resources) is considered in project planning. This approach will maximise the opportunity to select appropriate site locations that minimise potential environmental and social impacts.

Arrow has identified 18 areas that are nominated for potential facility development to facilitate environmental impact assessment (and modelling). These are based on circles of approximately 12 km radius that signify areas where development of production facilities could potentially occur.

Arrow intends to pursue opportunities in the selection of equipment (including reserve osmosis units, gas powered engines, electrical generators and compressors) and the design of facilities that facilitates the cost effective and efficient scaling of facilities to meet field conditions. This flexibility will enable Arrow to better match infrastructure to coal seam gas production. It will also enable Arrow to investigate the merits of using similarly configured layouts and principles for facility development, which may in turn generate further efficiencies as the gas reserves are better understood, design is finalised, or as field development progresses.

3 Relevant guidelines and policies

The following policies and guidelines are applicable to agricultural aspects of the Surat Gas Project:

- *Department of Housing, Local Government and Planning (1992) State Planning Policy 1/92 – Development and Conservation of Agricultural Land, Gazetted 18th December, 1992 ('the GQAL policy').*
- *Department of Primary Industries and Department of Housing Local Government and Planning (1993), Planning Guidelines - The Identification of Good Quality Agricultural Land, January 1993 ('the GQAL guideline').*
- *The proposed draft policy on strategic cropping lands and its associated act and implementation arrangements identified under the Sustainable Planning Act 2009 ('the Strategic Cropping policy').*

Attachment 2 of the GQAL policy identifies the relevant soils and land resource assessments that define GQAL, as shown in Table 1 (end of this section). More recent soils and land resource reports are available for the project development area, as outlined below:

- *Harris, P.S., Biggs, A.J.W., Stone, B.J., Crane, L.N. and Douglas, N.J. (eds.), (1999). Resource Information Book, in Central Darling Downs Land Management Manual. Department of Natural Resources, Queensland. DNRQ990102.*
- *Maher, J.M (ed.) 1996, Understanding and Managing Soils in the Murilla, Tara and Chinchilla Shires, Department of Primary Industries Training Series QE96001, Brisbane.*
- *Thwaites, R.N. and Macnish, S.E. (eds) (1991), Land management manual Waggamba Shire, Queensland Department of Primary Industries and Waggamba Conservation Committee, Parts A to C, Queensland Department of Primary Industries Training Series QE90014.*

These more recent reports have no significant inconsistencies with the previous reports specified in Attachment 2 of the GQAL guideline. GQAL is identified by the agricultural land classes of A and B and are outlined below.

> *Class A - Crop land: Land that is suitable for current and potential crops with limitations to production which range from none to moderate levels.*
>
> *Class B - Limited crop land: Land that is marginal for current and potential crops due to severe limitations; and suitable for pastures. Engineering and/or agronomic improvements may be required before the land is considered suitable for cropping.* [5]

The Strategic Cropping Policy is in draft form (as at April 2011). The 'Draft Trigger Maps' that identify strategic cropping land have been published in the public domain. Consequently, consideration must be given to the impact that the proposed Strategic Cropping Policy and the foreshadowed legislation to support that policy might have on the Surat Gas Project. The aims of the draft policy include:

> *The best cropping land, defined as strategic cropping land, is a finite resource that must be conserved and managed for the longer term. As a general aim, planning and approval powers should be used to protect such land from those developments that lead to its permanent alienation or diminished productivity.* [6]

The policy and the associated legislation will operate in addition to, and in parallel with, the GQAL policy. For the purposes of the Surat Gas Project, the GQAL land and the strategic cropping land are closely aligned as mapped by DERM in the 'Draft Trigger Maps' for the area (labelled as

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[5] Extracted from Table 1 Agricultural land classes Department of Primary Industries and Department of Housing Local Government and Planning (1993), *Planning Guidelines - The Identification of Good Quality Agricultural Land,* January 1993 page 1.

[6] DERM 2010 Protecting Queensland's strategic cropping land: A policy Framework. State of Queensland (DERM) August 2010 page 7.

S1 and S2, copies of which are provided in Attachment 2).

3.1 SCL policy context

Trigger maps are based on current soil, land and climate information and provide a landscape-scale indication of the expected location of strategic cropping land. These trigger maps were prepared using Class A Agricultural Land and Versatile Cropping Land data and 1999 Queensland Land Use Mapping Program (QLUMP) data identified as production from agriculture or plantations.

The trigger maps note;

> *Land is excluded from the trigger map where it is remnant vegetation, or is in a National Park, State Forest, Timber Reserve or Forest Reserve. Land is excluded from the trigger map where it is within the urban footprints for Far North Queensland or South East Queensland, or is in a collection of small cadastral parcels. The trigger map extent is limited to those areas within the five SCL Zones. On-ground assessment against the SCL criteria will be required to identify the best cropping land (strategic cropping land).*

On-ground assessment defines the area of strategic cropping land at a property level. The eight criteria for identifying strategic cropping land are listed below:

1. *Slope*
2. *Rockiness*
3. *Gilgai microrelief*
4. *Soil depth*
5. *Soil wetness*
6. *Soil pH*
7. *Salinity*
8. *Soil water storage*

The Australian Society of Soil Science Incorporated's (ASSI) submission on '*Protecting Queensland's strategic cropping land proposed criteria for identifying strategic cropping land* publication' identified critical errors in Table 3 (Soil texture look-up table) on water holding capacity.

The Surat Gas Project is at present, under the draft policy, not defined as development for which the Minister may declare it to be 'Excepted development'. 'Excepted development' designation applies if there is no alternative site and there is a significant community benefit.

We note that there is considerable debate currently about aspects of the SCL criteria which may or may not be refined further. With respect to the criteria cited above it is the soil water storage criterion that would present the most significant rehabilitation challenge, in our view, given the known importance of plant available water capacity in any of the impacted soils. Each of the other criteria is less complex in terms of measurement and rehabilitation.

The proposal may be considered 'Relevant development' as defined below:

> *Development that will temporarily diminish productivity of strategic cropping land or will permanently alienate the land. This includes urbanisation and mining, but excludes some agriculture and State infrastructure. There are two key types of relevant development:*
>
> 1. *Development that causes temporary diminished productivity—where development that impacts upon the soil resource and/or prevents cropping activity, but where the land can be fully restored following cessation of the use.*
> 2. *Development that will permanently alienate strategic cropping land including where:*
>   a. *a development will endure for 50 years or more, and prevents cropping during that time or in the future (e.g. urban development); or*
>   b. *a land use where a legal impediment prevents the land from being used for cropping for 50 years or more (e.g. permanent forest plantations with a covenant securing carbon rights); or*
>   c. *a development that causes long-lasting impacts that prevents or reduces cropping capability such as subsidence, changes to the soil structure or contamination (e.g. minerals extraction); or*

d. *a development likely to cause a land-use conflict or where reconfiguration of lots result in fragmentation and small lot sizes that would impact on the productivity of strategic cropping land. An example of development likely to cause conflict is high density urban development.* [7]

It is likely the Surat Gas Project would trigger key development type 1 and it has the potential to trigger type 2 (c) of the definition of 'Relevant development', as:

- *the proposed development will cause temporary, and in some instances long-term, disruption to agricultural activities.*
- *the effectiveness of mitigation and*
- *reinstatement measures will determine the nature and extent of any long-lasting effects of coal seam gas development on strategic cropping land.*

This assessment is based on the expected 20 to 30 year life of a production well following which the land will be rehabilitated and the former land use reinstated. Productions facilities are expected to be in place longer, as they service several well fields over a large geographic area. Consequently, reinstatement of former land uses at these production facilities would not occur until production from all the fields ceases.

Whilst consideration of significant community benefit is required under the draft policy, this issue is beyond the scope of this assessment. This report notes that Arrow is subject to specific obligations, including provisions for compensation, under the Petroleum and Gas (Production and Safety) Act 2004.

[7] DERM 2010 *Protecting Queensland's strategic cropping land: A policy Framework.* State of Queensland (DERM) August 2010, Glossary p 16.

Table 1 Old Shire Boundaries within the project development area and the Agricultural classes identified as GQAL

Local Authority	Author and title	Map Units of GQAL	Classes considered GQAL		
			A	B	C
Murrilla	Land Inventory and Technical Guide Miles Area, Queensland (Dawson, N.M., 1972)	A: 1, 3, 4, 5, 6, 7, 8, 9, 10 B: 2, 11, 13, 14, 26, 27, 28	X	X	
Chinchilla (E)	Land Inventory and Technical Guide Jandowae Area (Dawson, N.M., 1972)	A: 2, 3, 4, 5, 6, 7, 9 B: 1	X	X	
Chinchilla (S)	Land Inventory and Technical Guide Miles Area (Dawson, N.M., 1972)	A: 1, 3, 4, 5, 6, 7, 8, 9, 10 B: 2, 11, 13, 14, 26, 27, 28	X	X	
Clifton	Land Inventory and Technical Guide Eastern Downs Area Queensland (Vandersee, B.E., 1975)	A: 2, 3, 4, 5, 6, 7, 8, 9, 10, 14, 15, 16, 17 B: 1, 11, 12, 13	X	X	
Dalby	Land Inventory and Technical Guide Eastern Downs Area Queensland (Vandersee, B.E., 1975)	A: 2, 3, 4, 5, 6, 7, 8, 9, 10, 14, 15, 16, 17 B: 1, 11, 12, 13	X	X	
Wambo (W)	Land Inventory and Technical Guide Miles Area (Dawson, N.M., 1972)	A: 1, 3, 4, 5, 6, 7, 8, 9, 10 B: 2, 11, 13, 14, 26, 27, 28	X	X	
Wambo (N)	Land Inventory and Technical Guide Jandowae Area (Dawson, N.M., 1972)	A: 2, 3, 4, 5, 6, 7, 9 B: 1	X	X	
Tara (N)	Land Inventory and Technical Guide Miles Area Queensland (Dawson, N.M., 1978)	A: 1, 3, 4, 5, 6, 7, 8, 9, 10 B: 2, 11, 13, 14, 26, 27, 28	X	X	
Tara (E)	Land Use Study for the Millmerran-Moonie-Tara Area (Mullins, J.A., 1980)	A: 1, 2, 3, 4, 5	X		
Waggamba	Land Management Manual: Waggamba Shire Part A (Thwaites, R. N. et. al., 1991)	A: 2, 3, 8, 9, 10, 11 B: 4, 12 C: 1	X	X	
Millmerran (E)	Land Inventory and Technical Guide Eastern Downs Area Queensland (Vandersee, B.E., 1975)	A: 2, 3, 4, 5, 6, 7, 8, 9, 10, 14, 15, 16, 17 B: 1, 11, 12, 13	X	X	
Millmerran (W)	Land Use Study for the Millmerran-Moonie-Tara Area (Mullins, J.A., 1980)	A: 1, 2, 3, 4, 5	X		
Pittsworth	Land Inventory and Technical Guide Eastern Downs Area Queensland (Vandersee, B.E., 1975)	A: 2, 3, 4, 5, 6, 7, 8, 9, 10, 14, 15, 16, 17 B: 1, 11, 12, 13	X	X	
Rosalie (W)	Land Inventory and Technical Guide Eastern Downs Area Queensland (Vandersee, B.E., 1975)	A: 2, 3, 4, 5, 6, 7, 8, 9, 10, 14, 15, 16, 17 B: 1, 11, 12, 13	X	X	
Jondaryn	Land Inventory and Technical Guide Eastern Downs Area Queensland (Vandersee, B.E., 1975)	A: 2, 3, 4, 5, 6, 7, 8, 9, 10, 14, 15, 16, 17 B: 1, 11, 12, 13	X	X	

4 Existing environment

The project development area for the Surat Gas Project covers approximately 8,600 km^2 and is located in central-southern Queensland. This agriculture report considers the entire project development area with adjoining agricultural areas included where relevant to the assessment.

The following sections provide background on climate, soils, the development of agriculture in the region, agricultural production for the region, constraints on agriculture development and a definition of intensively farmed agricultural areas.

4.1 Climate

The project development area is characterised as temperate with a warm to hot summer. Table 2 presents the mean monthly rainfall and potential evaporation data for Dalby.[8] The mean annual rainfall is 612.5 mm.

Table 2 Rainfall and evaporation for the project development area [8]

	J	F	M	A	M	J	J	A	S	O	N	D	Annual
Mean Precipitation (mm)	74	89	37	21	39	35	24	20	30	61	83	99	612
Mean Evaporation (mm)	285	220	226	177	115	90	93	130	177	229	243	282	2267

The distribution of rain is summer-dominant with soil moisture stored from the summer rain to establish winter cropping in the region. Annual evaporation is approximately 2267 mm. Monthly mean evaporation shows a significant water deficit when compared with the rainfall data.

The mean monthly temperature ranges from a minimum of 4 degrees Celsius (^{o}C) in winter to a maximum of 34.1 ^{o}C in summer. The main temperature limitation for the area is the incidence of frosts. There may be as many as 20-30 frosts over the late autumn, winter and early spring. Conversely, during summer, high temperatures >40 ^{o}C are common leading to periods of heat stress for crops and animals. An overview of the average temperatures at the peak summer month of January and winter month of July is shown in Table 3.[8]

Table 3. Climatic data for the project development area [8]

Centre	January mean max. (°C)	July mean min. (°C)
Dalby	32.5	4
Goondiwindi	34.1	4.5
Miles	33.5	3.6
Pittsworth	29.9	5
Taroom	33.7	5.1

4.2 Soils

The soils of the study area have been described in detail in Coffey Environments' report '*Geology, Soils and Landform Study - Arrow Energy Surat Gas Project, Surat Basin, Queensland'* (Coffey Environments, 2011).

In summary, the soils used for agricultural purposes are dominated by the Vertosol soil type. The properties of Vertosols of the region are:

- light to heavy clays;
- high plant available moisture holding capacity (up to 200 mm per m soil depth);
- self-mulching surface;

[8] PAEHolmes (August, 2011) *Surat Gas Project Impact Assessment Report – Air Quality.*

- topsoils either neutral to slightly acid (pH 6.5-7.5);
- subsoils that are alkaline in nature (pH>7.5);
- highly reactive shrink – swell soils;
- brown grey or black in colour;
- fertile in virgin state with significant reserves in nutrient labile pool;
- normally base saturated with a high cation exchange capacity (>20cmol$^+$).

Other GQAL significant soils are the Dermosols. These are non-cracking clays with similar characteristics as the Vertosols. Generally these soils have the following properties:

- high clay soils varying from loamy clays to medium to heavy clays;
- medium to heavy clay subsoil;
- high plant available moisture holding capacity;
- fertile;
- prone to soil erosion by virtue of their location on the slopes within the landscape.

The sandy alluvial plains with deeper sandy Rudosols, Tensols and Kandosols are included in the GQAL soils. These soils are sands, sandy loams, loams and clay loams.

Notwithstanding the properties and productivity of these soils, fertiliser is regularly applied to sustain and enhance crop yield. Fertiliser and soil conditioner application rates for the Darling Downs for 2000 to 2001 are provided in Table 4 (following pages).

4.3 Agricultural development

In the mid 1800s, vast pastoral estates dominated agriculture on the Darling Downs. A railway built down the range from Toowoomba to Ipswich during 1865 to 66 allowed produce to be transported to the markets in Brisbane. By 1871, a network of railways extended through the Upper Condamine River system, joining Warwick to Toowoomba.

Mixed farming consisted of various cereal crops including maize and arrowroot, often combined with livestock production such as dairying, calves and pigs.

Further extensions to the railway from 1907 to 1914 saw the end of many of the large pastoral estates. Soldier-settlement schemes and improved dryland farming techniques encouraged the growth of cereal cropping.

By 1912, land cleared by the sawmilling industry made way for butter and cheese making. The dairying industry peaked in the late 1930s at 6,500 farms and more than 200,000 milking cows.

In recent years, interest in high value crops (e.g. cotton and grain legumes) has increased cropping diversity in the Darling Downs. Broadacre farms in the region are mostly family-owned, however a substantial number of properties are owned by both publicly listed and privately owned companies. A very small number are foreign owned. A typical farm size for the region is approximately 500 ha.

Both summer and winter crops are grown. Summer crops are preferred as the project development area experiences higher summer rainfall and economic returns from these crops are generally higher. Winter crops rely on seasonal summer rainfall stored within the predominantly clay-based Vertosols and Dermosols. Lower evaporation rates during winter allow more efficient water use by crops. Both irrigated and dryland cropping systems exist, with some farms exhibiting a mixture of both. Strip cropping and stubble retention are practiced in areas subject to flooding.

Cotton is grown and ginned within the district and transported raw to Brisbane for export. Grain crops are grown to meet human consumption and feedlot demands. A proposed ethanol plant at Dalby is likely to use locally produced grain creating additional markets for grain crops.

The region also produces some specialty grains (e.g. Adzuki beans) to service high value niche export markets. Seed crops (cotton, wheat, etc.) are also grown across the Darling Downs region, both to meet industrial needs and to develop seed stocks for new varieties. There are also a number of certified organic farms operating in the Darling Downs region which will be, as operations, sensitive to any contamination or perception of contamination.

4.4 Agricultural production

Agricultural production in the Darling Downs statistical local areas, as detailed in the 2006 Census, is shown in Table 5 (following pages). Livestock (cattle, sheep and pigs), cereal crops and non-cereal broadacre crops were the predominant agricultural enterprises of the region with a reported gross value of agricultural production of approximately $1.7 billion annually.

4.5 Existing constraints to agricultural development

In general, both Class A and Class B agricultural land has the potential to be used for high value agricultural pursuits, such as irrigated cropping in the project development area. A significant limitation to the agricultural development of this land is the availability of water. Much of this land has historically not been developed for irrigation due to limited availability of water supplies. However, all mapped GQAL, has the potential to be developed for irrigation with high production potential if water supplies are available.

Major soil and landscape limitations on development of GQAL for agriculture include:

- significant gilgai;
- dissected landscapes;
- shallow groundwater < 2.0 m below NSL;
- soil salinity;
- soil sodicity;
- impermeable subsoils;
- erosive flooding;
- slope.

Key features/properties of these limitations are described below.

Gilgai

Significant gilgai is present within the project development area. Gilgai is surface micro-relief associated with soils containing shrink-swell clays, most commonly Vertosols. The gilgai produce localised areas of waterlogging that decreases crop yield. The deformation of the soil surface makes it difficult to use for surface irrigation even when the land is levelled for irrigation purposes. The filled gilgai merely re-appear within a short time and the water distribution efficiency of the irrigation scheme is significantly diminished.

Dissected landscape

The dissected landscape is characterised by frequent gullies, rills and watercourses. This dissected nature limits the size of paddocks and therefore efficiency of farming operations.

Shallow groundwater

Shallow groundwater (<2 m below NSL) increases the risk of salinity problems. Salinity problems arise when the groundwater rises to the surface of the soil and is evaporated resulting in an accumulation of salt at the surface and consequential degradation of the plant production potential of the land. Irrigation and/or land clearing may exacerbate this issue.

Salinity

Salinity may be induced by the use of poor quality irrigation water or may be a product of secondary salinisation from a rising watertable. Saline soils are not suitable for irrigation.

Sodic soils

Sodic soils exhibit impeded subsurface drainage and result in perched watertables and tunnel erosion in sloping sites. These soils are unsuitable for intensive agricultural development.

Impermeable subsoils

Impermeable subsoils have the same limitations as sodic soils, with the impeded drainage resulting in a perched watertable and short-term anaerobic conditions. This affects plant growth and such soils are not suitable for intensive agricultural development such as irrigation.

Erosive flooding

Erosive flooding leads to selective removal of the topsoil from the cultivated soils. The unconsolidated tilled layer (approximately 100 mm thick) is removed during flood events and the plant productive capacity of the remaining soil is significantly diminished. These sites are best left for grazing and act as part of the co-ordinated drainage of a flood plain.

Table 4 Fertiliser and soil conditioner application rates (tonnes) for the Darling Downs and whole of Queensland for 2000-01 (ABS 2008)[9]

Commodity	Darling Downs	Queensland
Nitrogen	103,342	552,126
Nitrogen (Urea)	57,893	196,543
Phosphate (Single, double and triple superphosphate)	3,742	18,781
Potassium (Muriate of potash, potassium sulfate and potassium nitrate)	2,022	32,052
TOTAL FERTILISER	**166,999**	**799,502**
Lime (to correct or stabilise soil acidity)	7,671	72,271
Gypsum (to correct physical soil properties)	24,868	69,375
TOTAL SOIL CONDITIONER	**32,539**	**141,646**

Table 5 Agricultural production for Darling Downs Statistical Local Areas, National Regional Profile for 2006, (ABS 2010)[10]

	Area of holding	Cereals for grain	Vegetables for human consumption	Orchard trees (including nuts)	All fruit (excluding grapes)	Non-cereal broadacre crops	Sheep and lambs	Milk cattle (excluding house cows)	Meat cattle	Pigs	Gross value of crops	Gross value of livestock slaughtering	Gross value of livestock products	Total gross value of agricultural production
	ha	ha	ha	ha	ha	ha	no.	no.	no.	no.	$m	$m	$m	$m
Dalby (R) - Chinchilla	761,817	36,246	630	5	5	5,155	16,163	956	108,082	63,961	30.6	99.0	1.5	131.1
Dalby (R) - Dalby	1,076	182	0	0	0	0	0	0	142	0	0.3	0.0	0.0	0.4
Dalby (R) - Murilla-Wandoan	na	na	na	na	na	na	na	na	na	na	na	na	na	na
Dalby (R) - Tara	998,888	114,161	0	0	0	3,068	111,647	0	166,784	6,968	36.7	98.3	2.5	137.6
Dalby (R) - Wambo	488,639	131,287	52	4	12	24,970	11,768	2,509	89,205	62,671	106.4	102.5	2.9	211.8
Goondiwindi (R) - Goondiwindi	51	0	0	0	0	0	0	0	43	0	0.0	0.0	0.0	0.0

[9] Source - Australian Bureau of Statistics 2000-01, 7125.0 - Agricultural Commodities: Small Area Data, Australia, 'Table 3 Queensland – State And Sd – All Commodities, use of fertilisers and soil conditioners', data cube: Excel spreadsheet, cat. no. 7125.02000-01 < www.abs.gov.au/AUSSTATS/abs@.nsf/ DetailsPage/7125.02000-01?OpenDocument > accessed 22 June 2011.
[10] Source Australian Bureau of Statistics 2006 – National Regional Profile < www.ausstats.abs.gov.au/ausstats/nrpmaps.nsf/NEW+GmapPages/national+regional+profile > accessed July 2011

	Area of holding	Cereals for grain	Vegetables for human consumption	Orchard trees (including nuts)	All fruit (excluding grapes)	Non-cereal broadacre crops	Sheep and lambs	Milk cattle (excluding house cows)	Meat cattle	Pigs	Gross value of crops	Gross value of livestock slaughtering	Gross value of livestock products	Total gross value of agricultural production
Goondiwindi (R) - Inglewood	421,493	4,763	79	356	373	724	197,825	0	93,945	69	7.8	83.7	5.2	96.7
Goondiwindi (R) - Waggamba	1,265,827	242,855	7	2	2	45,564	215,855	0	149,566	36,074	182.7	84.4	4.4	271.5
Southern Downs (R) - Allora	54,596	6,564	353	10	10	618	854	2,891	15,437	20,439	12.0	22.5	2.5	37.0
Southern Downs (R) - Killarney	133,177	10,566	228	10	10	1,330	8,821	8,558	37,992	10,125	11.8	22.8	12.1	46.8
Southern Downs (R) - Stanthorpe	168,876	0	1,772	3,087	3,114	7	135,340	7	16,351	3,905	110.0	5.9	3.6	119.5
Southern Downs (R) - Warwick	2,038	598	61	4	4	98	43	186	534	1	1.8	0.9	0.2	2.9
Southern Downs (R) - West	153,255	895	1	27	27	43	50,182	1,013	24,762	4,505	1.4	10.2	2.3	14.0
Clifton	78,061	24,693	601	3	3	3,111	8,783	3,886	21,383	49,851	25.2	25.9	4.3	55.4
Crow's Nest	105,112	574	12	764	776	38	1,246	5,145	36,060	964	23.3	14.6	6.1	44.0
Greenmount	49,923	7,550	82	31	31	363	679	2,599	13,820	4,047	4.6	10.7	5.0	20.3
Jondaryan	170,142	47,052	17	8	9	13,069	1,087	3,777	56,373	11,485	48.5	106.1	4.4	159.1
Millmerran	356,492	48,337	10	1,510	1,510	12,401	23,775	3	56,978	44,096	52.8	81.0	37.6	171.4
Pittsworth	99,063	37,210	289	0	0	12,526	2,205	3,056	14,573	25,780	45.7	25.2	28.6	99.5
Rosalie	183,755	20,064	93	48	48	1,568	7,268	11,821	56,052	31,304	15.0	53.1	15.4	83.5
TOTAL	**5,492,278**	**733,595**	**4,286**	**5,868**	**5,932**	**124,653**	**793,541**	**46,407**	**958,082**	**376,245**	**716.6**	**846.8**	**138.6**	**1,702.5**

Slope

The slope of the land limits the type of irrigation that can be used. Typical limitations imposed by slope that guide the type of irrigation are listed in Table 6.

Table 6 Slopes influencing type of irrigation

Slope	Type of Irrigation
<2%	Surface or flood irrigation[11]
<15%	Spray irrigation[12],[13]
<25%	Localised; crop dependent[14]

Drawings 10185.1.1 and 10185.1.2 show the extent of GQAL and Strategic Cropping Land in the project development area.

[11] Reid, R.L., 1990, '*The Manual of Australian Agriculture*' (5th Edn.), Butterworths, Brisbane, p 747.

[12] Queensland Department of Natural Resources and Mines, June 2002, 'Land and Water Management Plans – Reference Manual', Section D, Table 2: Slope considerations, pD3.

[13] AS/NZS 1547. 2000. AS/NZS 1547:2000 Onsite domestic-wastewater management, Standards Australia/New Zealand, Strathfield.

[14] Capelin M.A., 1987, *'Horticulture Land Suitability Study, Sunshine Coast, South-East Queensland - QV87001'*, Queensland Department of Environment and Resource Management, Brisbane.

5 Agricultural activities

This section describes the agricultural activities currently undertaken in the project development area including discussion of the extent, productivity, farming practices and key management practices.

5.1 Dryland broadacre farming

Dryland broadacre farming activities encompass cereal, pulse and cotton crops.

5.1.1 Cereal crops - Extent, productivity and practices

During summer, grain sorghum and sunflower are grown over a diverse range of soils throughout the project development area. Maize requires better soil types and is usually grown by specialist growers. Sorghum returns are lower than most other crops, for instance sunflowers, however sorghum stubble may provide valuable grazing following harvest or in the event of crop failure and provides protection against soil erosion.

To exemplify the returns for farmers, QDPI estimated the gross margins in 2008/2009 for sorghum and sunflowers were $126/ha and $947/ha respectively. Irrigated sorghum and sunflowers were estimated as $512/ha and $1217/ha respectively.[16]

The relative gross margins have changed slightly with most up-to-date information for summer 2011-2012 gross margins for sorghum and sunflower available from the NSW Dept. of Primary Industries for northern NSW. The gross margins for dryland north-east no-till sorghum and sunflowers were $294/ha and $424/ha respectively. The gross margins for irrigated northern sorghum and sunflowers were $511/ha and $827/ha. The gross margins for dryland north-west no-till sorghum and sunflowers were $127/ha and $259/ha.[17]

Low stubble levels after harvest can result in severe soil erosion problems. Highest costs are

Table 7 Overview of average yields[15] (tonnes per hectare) for selected winter cereal crops grown in the Darling Downs region from 1989 to 1996.

Geographical area	Wheat	Barley	Canary	Grain oats
Northern Downs* Chinchilla, Wambo	1.93	1.73	0.64	0.72
North East Downs – Cambooya, Crows Nest, Jondaryan, Rosalie	1.84	1.78	0.57	0.98
Central Downs – Millmerran, Pittsworth	2.20	1.94	0.84	1.29
Southern Downs – Clifton, Warwick (includes Allora, Glengallan, Rosenthal), Stanthorpe	2.07	1.61	0.68	1.11
Upper range farm yields (tonnes per hectare) for selected winter cereal crops grown in the Darling Downs region from 1989 to 1996				
Soil group	**Wheat**	**Barley**	**Canary**	**Grain oats**
Box and Brigalow soils	2.5	3.0	1.5	1.4
Open Plain - Waco soils (Wambo, Jondaryan)	3.5	3.5	1.8	1.6
Eastern Upland soils	2.5	2.5	1.2	1.1

15 Source - The State of Queensland (Department of Employment, Economic Development and Innovation) 1995-2010, 'Selecting a winter crop - Darling Downs', Table titled 'Yield in tonnes per hectare of the main winter crops on the Darling Downs' (electronically published at www2.dpi.qld.gov.au/fieldcrops/9512.html) accessed 14 April 2011.

16 http://www.dpi.qld.gov.au/26_11979.htm

17 NSW Department of Primary Industries 'Farm Enterprise Budget Series – North-East, Northern and North-West NSW, Summer 2011-2012' (electronically published at http://www.dpi.nsw.gov.au/agriculture/farm-business/budgets/) accessed 22 November 2011.

Table 8 Production volume (tonnes) of pulse crops grown in the Darling Downs and whole of Queensland for 2006-07[19] (ABS 2008)[20]

Commodity	Darling Downs	Queensland
Chickpea	26,492*	60,595*
Faba Bean	2,251	2,405
Safflower	0	97***
Sunflower	1,203**	2,709*
Soybean	250***	5,377*
TOTALS	30,196***	2,405***

Note: * 10 – 25% relative standard error
** 25 – 50% relative standard error
*** >50% relative standard error

typically associated with seed, insect control and harvesting.

An overview of yields for selected winter cereal crops grown in the Darling Downs region is provided in Table 7. This is the most current data available in this format. The production volume of wheat, barley and grain oats grown in the Darling Downs for 2006-07[18] (ABS 2008) was 0.88, 1.03 and 0.11 tonnes/ha respectively.

An overview of agronomic methods for summer and winter cereal crops grown in the Darling Downs region is provided in Attachment 1 (tables A and B).

5.1.2 Pulse crops - Extent, productivity and practices

A variety of pulse crops are grown throughout the Darling Downs region including chickpea, faba bean, linseed and safflower in winter and sunflower, navy bean and soybean in summer. Production statistics for pulse crops in the Darling Downs region are included in Table 8.

An overview of agronomic methods for summer and winter pulse crops grown in the Darling Downs region is provided in Attachment 1 (tables C and D).

5.1.3 Cotton - Extent, productivity and practices

Major costs for cotton growing include fertiliser, insecticide, irrigation and picking however, returns are high. The production cycle for cotton is provided in Attachment 1 (Table E) whilst an overview of agronomic methods for cotton grown in the Darling Downs region is provided in (Table F).

5.1.4 Key management practices

Cotton and grain crops require pesticide application (either by air or ground-based application methods) throughout the growing cycle. Whilst ground application has become the preferred method in recent years, due to the lower risk of spray drift, heavy clay soils in some parts of the region (particularly on the Condamine floodplain) become inaccessible to ground machinery following rainfall thus requiring aerial spraying for timely application.

At pesticide application times, people cannot be present in the localised area of application. Farming, coal seam gas and other business and recreational activities need to be coordinated with aerial spraying operations to ensure workers and community members are not exposed directly to spray or to spray drift.

Advances in integrated pest management practices mean that spraying of all fields within an enterprise is now rarely done in one event. This means aircraft or ground rigs could be operating on one farm several times a week as fields are treated individually in response to the level of insect or pest threat.

Typically a sorghum crop on the Darling Downs would be sprayed 2 to 4 times and a cotton crop 4

[18] These years were relatively low rainfall years which is reflected in the total production.

[19] These years were relatively low rainfall years which is reflected in the total production.

[20] Source - Australian Bureau of Statistics 2006-07, 7125.0 - Agricultural Commodities: Small Area Data, Australia, 'Table 2 Queensland – State And Sd – All Commodities, pastures and broadacre crops', data cube: Excel spreadsheet, cat. no. 7125.02006-07 < www.abs.gov.au/AUSSTATS/abs@.nsf/ DetailsPage/7125.02006-07?OpenDocument > accessed 22 July 2011.

to 6 times for various pests, depending on the insect pressure experienced that year.

Dryland system productivity is closely linked with the ability to retain soil moisture. Dryland farmers aim to slow runoff (rainfall, overland flow) to maximise infiltration. Laser levelling is often used to establish slopes that optimise infiltration or to remediate flow paths and drainage on low-lying areas.

Dryland cropping will typically occur on permanent beds, where tillage is minimised to help reduce compaction. Soil compaction not only impacts on root penetration for crop growth, but also reduces infiltration.

Stubble retention is practiced across both the cotton and grain industries to encourage moisture retention and to provide cover to minimise erosion (wind and water). Best practice in recent years has made use of satellite technology (GPS systems) to direct the movement of machinery down the same furrows pass after pass, thereby reducing the area exposed to compaction.

Key management practices for specific crops are described below.

Cereals

The fallow period for winter crops is November to May. The fallow period for sorghum, a summer crop is from June to August while millet is double cropped. Winter crops are planted from late April to July and summer crops from late August through to February.

Fertilising requirement may include nitrogen, phosphate and/or zinc. Winter crops are harvested from October to November.

Sorghum is harvested from December to February and maize 4.5 to 6 months following planting. Millet for grazing is harvested at 30 to 80 cm and for grain, just prior to seed head emergence.

Pulse crops

Fallow period ranges from November to June for the majority of winter pulse crops. Major fertiliser requirements include nitrogen and phosphate.

Winter crops are planted from April through to June and harvested from October through to January. Summer crops are planted from mid-November to February. Harvest is dependent on soil moisture content.

Cotton

Where winter crops are to be grown, ground preparation takes place during March and April. Rain fed cotton is planted from late September to Mid-January. Generally no fertilising is required in rain grown cotton. Cotton is harvested from April to June when greater than 80% of the boils open.

5.2 Irrigated broadacre farming

5.2.1 Extent, productivity and practices

Irrigated land requires extensive investment in water storage and delivery infrastructure. Irrigated properties feature dams and a network of water delivery and return channels. The following sections describe the types of irrigation, water supply requirements and key management practices including equipment, scheduling and environmental controls.

Surface irrigation

Surface irrigation usually employs a drainage ditch to convey water to the upslope edge of a field. Siphon tubes (e.g. poly pipe) are then inserted into the head ditch and used to siphon water from the ditch to furrows between planted rows. Furrow irrigation requires a sloping field, normally laser levelled to the appropriate grade. The four main types of surface irrigation are:

1. Border-check is used for close-growing crops and pastures e.g. cereal crops. Low earth banks are constructed across the slope.
2. Furrow irrigation is commonly used on crops such as maize, grain sorghum, cotton, linseed and some vegetables. Furrows are run between individual rows, perpendicular to the slope.
3. Contour bay systems are a cheap method of surface irrigation used on smooth ground of low grade. Bay flow is parallel to the contour.

4. Contour channel systems use closely spaced channels constructed perpendicular to the slope to control overland flow on relatively steep slopes (up to 15%). These systems are used for pastures and permanent cover crops.

Furrow irrigation is the most commonly used surface irrigation method within the study area.

Spray irrigation

Spray irrigation is most commonly employed in broadacre cropping practices and includes sprinkler, centre pivot, lateral move low-pressure boom and high-pressure 'big gun' irrigation systems. The three main types of spray irrigation are:

1. Portable systems that are generally used on several irrigation areas and consist of portable spraylines, mainlines and pumping equipment.
2. Semi-permanent systems use pumping equipment that may be used at several irrigation areas or shifted above flood lines. Mainlines are fixed in position however, spraylines are portable.
3. Permanent systems cover the entire irrigation area with all equipment fixed in position.

Localised irrigation

Localised irrigation refers to low-pressure drip or spray irrigation directly at the plant base or within the root zone. This includes trickle/drip systems, microspray and mini-sprinklers. These systems are employed on perennial crops as installation is labour intensive and removal of plants often results in the destruction of the irrigation lines.

The benefit of localised irrigation is that it allows normal farming practices, such as spraying, pruning and harvesting, to be maintained.[21]

Water supply

Water availability is a key limiting factor for agricultural production on the Darling Downs.

Table 9 Irrigated area (ha) - Darling Downs and all Queensland for 2000-01 (ABS 2008)[23]

Commodity	Darling Downs	Queensland
Total irrigated area	105,683	550,453
Cereal	17,859	37,723
Cotton	61,859	138,720
Vegetables (for human consumption)	4,466	32,027
Fruit (including nuts)	4,406	32,665
Grapevines	750	2,029

Crop selection is generally governed by the growers' assessment of return based on the limited amount of water available.

Mapped watercourses that traverse the area are an important irrigation resource. Additionally, groundwater extraction is integral to irrigation operations in the study area, particularly in recent years when reliability of surface water has been low due to drought conditions.

The Darling Downs region constitutes almost 20% of irrigated land in Queensland.[22] The bulk of this irrigation is for cotton crops (see Table 9).

5.2.2 Key management practices

Field slopes are designed and engineered to facilitate irrigation and drainage and generally a laser-levelling program is prepared for each enterprise to address problems (e.g. low spots, ponding) as they occur in specific fields over time.

Head ditches are graded and engineered to specific heights to deliver water in the required volumes and at higher efficiency rates. Most farms also have water storages to collect overland flow and store allocations (surface or groundwater) in accordance with licences.

[21] Horton, A.J. & Jobling, G.A. (1992) *Farm water supplies design manual*, Volume 2, Rural Advisory Services, Dept. of Primary Industries.

[22] ABS 2000-01, 7125.0 - Agricultural Commodities: Small Area Data, Australia, 'Table 4 Qld – State And Sd – All Commodities, crops and pastures irrigated and tools used for irrigation decision making', data cube: Excel spreadsheet, cat. no. 7125.02000-01 < www.abs.gov.au/AUSSTATS/abs@.nsf/DetailsPage/7125.02000-01?OpenDocument > accessed 22 July 2011

Irrigation equipment

Irrigation equipment is specific to the type of irrigation employed. It may include pipelines, mains, head ditches and supply ditches.

Centre pivot irrigation systems require high volume pumps and use a boom and truss design that rotates around a central point. Spray heads are hung from the booms and the unit is rotated electrically, electro-hydraulically or by water pressure.

Lateral move irrigation systems employ a boom and truss system similar to the centre pivot design, however are not fixed. They move along the length of a paddock powered by the same methods, and are often guided by GPS. High volume irrigation pumps are required.

Localised irrigation systems normally employ low pumping pressures and demand a relatively low supply volume due to their efficiency.

Scheduling

The irrigation requirement for a crop is the water that must be supplied via the irrigation system to ensure the crop receives its full water requirement. Instruments such as tensiometers and neutron probe moisture meters are used to measure soil moisture content. Irrigation scheduling may be calculated using the Penman-Monteith equation to estimate potential evapotranspiration on agricultural lands. Soil moisture deficit may be assessed with MEDLI (a daily time-step hydrological simulation model) or an equivalent.

Environmental controls

Increased percolation may result in raised water tables, water logging and salinisation. However, a sustainable system can be achieved with correct irrigation scheduling, efficient irrigation application and appropriately managed runoff and drainage.[24]

[23] ABS 2000-01, 7125.0 - Agricultural Commodities: Small Area Data, Australia, 'Table 4 Qld – State And Sd – All Commodities, crops and pastures irrigated and tools used for irrigation decision making', data cube: Excel spreadsheet, cat. no. 7125.02000-01 < www.abs.gov.au/AUSSTATS /abs@.nsf/DetailsPage/7125.02000-01?OpenDocument > accessed 22 July 2011.

[24] Clarke, A.L. & Wylie, P.B. (1997) *Sustainable crop production in the sub-tropics*, Dept. of Primary Industries, Qld.

Environmental contamination from fertiliser and pesticide use can be minimised with the reduction and appropriate treatment of tailwater.

5.2.3 Cotton - Extent, productivity and practices

During summer, cotton is one of the major irrigated crops in the Darling Downs area with an estimated 265,700 t of seed cotton (219,607 t irrigated) and 95,988 t of cotton lint (77,881 t irrigated) produced in 2000-2001 (ABS, 2008).

Irrigated cotton is planted in October and may require nitrogen, phosphate, potassium, zinc and sulphur fertilisers.

Cotton is harvested from April to June when greater than 80% of the boils open.

5.3 Horticulture

5.3.1 Extent, productivity and practices

Melons (watermelon, rockmelon, honeydew) are grown in the area surrounding Chinchilla. Approximately 12 growers located in the Charleys Creek sub-catchment have approximately 600 ha under cultivation for melon crops annually. Broccoli, onions and green beans are grown in the Norwin/Brookstead regions and between Cecil Plains and Millmerran on black, self-mulching clays with good soil moisture reserves.

An overview of yields for key vegetables grown in the Darling Downs region is provided in Table 10 (following page). An overview of agronomic methods for horticulture crops of the Darling Downs and surrounds are shown in Attachment 1 (Table G).

5.3.2 Key management practices

The fallow (bed forming) period for crops such as beetroot, Chinese cabbage, carrots and celery is from May to August with planting from July to April. For crops including sweet corn, pumpkins, marrow and cucumber, the fallow period is from March to September, with planting from August through January. Onions however, have a fallow period of November through March and are planted from August to March.

Table 10 Production levels (tonnes) of key vegetables grown in the Lockyer and Fassifern valleys, Stanthorpe, Darling Downs and whole of Queensland for 2005-06 (ABS 2006)[25]

Commodity	Lockyer	Fassifern	Stanthorpe	Darling Downs	Queensland
Asian vegetables	1509	124	636	54	4154
Beetroot	27,634	2465	0	1108	31,475
Broccoli	6762	372	712	2298	10,218
Cabbage	12,691	79	2784	4214	20,373
Capsicum	163	0	7397	0	52,352
Carrot	7400	13,358	1	939	22,148
Cauliflower	8332	33	4956	1153	15072
Celery	2313	0	1407	1494	5458
Green beans	2708	300	313	985	19712
Lettuce	37,058	173	5187	8037	53,152
Melon	4633	161	0	9	105,820
Mushroom	36	3199	1059	0	7193
Onion	14,084	4433	0	7260	27,410
Potato	21,436	744	0	5092	93,589
Pumpkin	9620	2116	65	982	47,161
Spring onion	2388	19	5	81	2897
Sweet corn	8546	495	0	1729	28,014
Tomato	5073	58	3456	0	108,672
Zucchini	156	8	2232	0	16,827
TOTALS	172,542	28,136	30,211	35,434	671,698

The major limitations to the development of a horticultural industry in the Darling Downs are water availability for irrigation and frosts during the winter months. Some areas of the Eastern Downs may experience 20-30 frosts in a year compared with 1-3 frosts in the Lockyer Valley.

5.4 Fruit

5.4.1 Extent, productivity and practices

A variety of fruit crops are grown successfully in the Darling downs region including stone fruit, apples, berries, citrus and pears. In the Millmerran region, approximately six olive growers produce olives on combined holdings of approximately 3,000 ha. An olive processing plant has been established. An overview of yields for key fruit crops grown in the Darling Downs region is provided in Table 11.

An overview of agronomic methods for fruit crops of the Darling Downs and surrounds are shown in Attachment 1 (Table H).

5.4.2 Key management practices

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[25] The State of Queensland (Dept. of Employment, Economic Development and Innovation) 1995-2011, '*Vegetable production in the Lockyer and Fassifern Valleys, Eastern Darling Downs and Stanthorpe regions*' Table 1: Production (tonnes) levels of key vegetables grown in the Lockyer and Fassifern Valleys, Stanthorpe, Darling Downs and whole of Queensland for 2005-06 (ABS 2006), (electronically published at www.dpi.qld.gov.au/26_15332.htm) accessed 14 April 2011.

Apples and pears are picked in February and March. Stone fruit are picked from September to late October. Blueberries are picked from December to May and strawberries from November through January.

Fruit crops generally require nitrogen, phosphate and potassium fertilisers at critical times throughout the year.

The production cycle is critical (spraying, harvesting, processing) and leaves little or no option for incursion. Non-entry periods of up to three days apply within a defined perimeter from the orchard following the application of certain sprays.

Orchards have specific designs and layouts to maximise production space and feature fragile infrastructure (including netting, sprinkler systems and trellises) and there is no tolerance in the agricultural system to any disruption. Orchards are relatively permanent structures. Stone fruit take five years to reach full production.

Table 11 Production volume (kg) of various fruit crops grown in the Darling Downs and all of Queensland for 2006-07[26] (ABS 2008)[27]

Commodity	Darling Downs	Queensland
Apricots	393,027**	393,027**
Cherries	6,608***	6,608***
Nectarines	2,275,271*	3,342,014*
Peaches	2,309,639**	3,080,724**
Plums	925,781**	955,536**
Apples	33,318,515	33,318,515
Strawberries	454,578	17,362,537
Avocado	2,052,200**	33,596,388*
Olives	252,793	351,182*
Orange	911,766***	7,183,469*
Lemon and Lime	672,243***	20,730,773**
Mandarin	6.481,838***	68,873,272*
Pears (excluding Nashi)	538,983	538,983
TOTALS	44,111,404	189,733,028

Note: * 10 – 25% relative standard error
** 25 – 50% relative standard error
*** >50% relative standard error

5.5 Vineyards

5.5.1 Extent, productivity and practices

There are approximately 721 ha of vineyards in the Darling Downs region. Large wine grape producers operate out of Jimbour and Maclagan. Small-scale table grape producers also operate out of the Chinchilla district.

ABS data for 2006-2007[28] indicated that 1,860 kg of grapes was produced in the Darling Downs region while 16,795 kg of grapes was produced in Queensland.

5.5.2 Key management practices

Vineyards are designed to optimise vine performance, maximise bearing potential, minimise soil erosion and facilitate equipment operation. A rectangular layout is favoured over a square pattern as longer rows reduce the number of turns the tractor operator must make.

Drip irrigation is often favoured over sprinkler irrigation to reduce diseases resulting from foliage wetting.

5.6 Animal industries

5.6.1 Extent, productivity and practices

Intensive livestock industries that may be located within the study area include: piggeries, poultry, beef feedlots and horse agistment and breeding.

The Darling Downs contains many pork production units with the pork industry body estimating between 300 and 500 in the region. This is due to the region's grain producing capacity. While the number of piggeries in the region is substantial, 30% of these are responsible for between 70% and 80% of total production. Piggeries are dependent on a reliable water supply, with the quantity and quality of water supplies being important considerations for development.

Egg (rather than meat chicken) production is the predominant poultry activity in this region. Industry groups advise that egg production is dominated

[26] These years were relatively low rainfall years which is reflected in the total production.
[27] Australian Bureau of Statistics 2006-07, 7125.0 - Agricultural Commodities: Small Area Data, Australia, 'Table 5 Queensland – State And Sd – All Commodities, Horticulture – Fruit and Nuts', data cube: Excel spreadsheet, cat. no. 7125.02006-07 < www.abs.gov.au/AUSSTATS/abs@.nsf/ DetailsPage/7125.02006-07?OpenDocument > Accessed 22 July 2011.
[28] These years were relatively low rainfall years which is reflected in the total production.

by family owned operations and that it is likely that there are more free-range egg operations within the study area than laying sheds.

Feedlots were first established in the area in the early 1960s. The Darling Downs is now the most intensively developed feedlot region in Australia. Feedlots vary from stand-alone operations to those attached to grain production enterprises. The year round operation has created stability in the beef industry.

They are an important local grain market in the region. A report produced for the Meat Research Corporation (MRC, 1994) indicates that a 25,000 head feedlot contributes $8.2 million to the regional economy.[29]

Dairy operations on the Darling Downs are extensive, with many located in the Oakey area. Feed systems vary greatly, from total mixed rations to pastures and combinations in between. Most dairies are family owned operations and will have a pasture production component to the enterprise. An overview of the number of animals kept in the Darling Downs region is provided in Table 12.

Table 12 Number of animals kept in the Darling Downs and whole of Queensland for 2006-07[30] (ABS 2008)[31]

Commodity	Darling Downs	Queensland
Sheep (sheep and lambs)	866,595**	4,378,429
Cattle - milk	37,247*	188,743
Cattle - meat	1,310,310*	11,494,873
Cattle - disposal	1,294,997	5,033,698
Pigs	410,769*	695,045
Chickens - laying	3,183,518	4,199,798
Chickens – meat	267,816**	11,018,197
TOTALS	7,371,252	37,008,783

Note: * 10 – 25% relative standard error
** 25 – 50% relative standard error,
*** >50% relative standard error

5.6.2 Key management practices

Pigs

Breeding is an ongoing activity to ensure year-round production. The layout of the piggery, ancillary infrastructure including grain storage, manure/effluent ponds and disposal areas, and operation of the piggery are designed to minimise disturbance of the pigs, which are sensitive to disruption.

Eggs

Disturbance and disease are key management issues for egg production. Chickens are sensitive to noise and vibration. While low-level background noise is generally tolerated, loud sharp noises can disrupt laying and startle egg and meat production chickens. Maintaining shed hygiene through cleaning to remove faeces, shed feathers and other litter is the primary means of controlling disease.

Feedlot

Feedlots comprise several pens, feeding stations, water supplies, as well as supporting infrastructure including feed mills, manure stockpiles/effluent ponds and silage pits. Some of the feedlots will have associated grain operations that may or may not be irrigated.

A reliable water supply is a primary requirement for feedlots, as well as adequate space for effluent storage, treatment and disposal.

Pen size and layout relative to the supporting infrastructure is important to ensure the efficient operation of the feedlot.

Dairy

Dairy farmers identify an 'effective dairy area' within their enterprise which includes the dairy infrastructure (sheds, effluent areas/ponds, feed pads, silage pits, manure pits, etc.) and any pastures or close crops where milk producing

[29] Clarke, M.B. and Sparke, G.J. (1994) *Regional impact of feedlot investment*, Meat Research Corporation, Sydney.
[30] These years were relatively low rainfall years which is reflected in the total production.
[31] Australian Bureau of Statistics 2006-07, 7125.0 - Agricultural Commodities: Small Area Data, Australia, 'Table 6 Queensland – State And Sd – All Commodities, Livestock – Sheep', 'Table 7 Queensland – State And Sd – All Commodities, Livestock – Cattle', 'Table 8 Queensland – State And Sd – All Commodities, Livestock – Pigs, Poultry and other livestock n.e.c', data cube: Excel spreadsheet, cat. no. 7125.02006-07 < www.abs.gov.au/AUSSTATS/abs@.nsf/ DetailsPage/7125.02006-07?OpenDocument > accessed 22 July 2011.

Table 13 Typical beef cattle grazing practice calendar (Darling Downs)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Joining												
Calving												
Marking												
Sowing winter crop pastures												
Sowing summer crop pastures												

Cattle will be mustered and vaccinated/drenched, brought in for sale, etc. at other times of the year. The timing of these activities will vary depending on management and season.

cows are grazed (pastures or a feed source) between milking.

The effective dairy area incorporates the necessary dairy infrastructure and the prime farming land for the operation.

The layout of paddocks in relation to the dairy sheds and feeding stations affects the efficiency of this activity, particularly the distance (and hence time) cows have to walk to be milked.

5.7 Rangeland grazing

5.7.1 Extent, productivity and practices

Extensive livestock enterprises located on the Darling Downs include beef cattle (grazing) and sheep. Extensive beef and sheep activities are typically located on the alluvial Sodosols, Brigalow Plains, Steep Basalt Hills, Poplar Box Sodosols and the Sandstone Forests west of the Condamine River.[32]

Typical herd size is 300 to 400 animals, farmed in conjunction with grain growing. Cattle sales are held at Dalby, Millmerran, Oakey and Toowoomba. Local meatworks are found at Oakey and Toowoomba. Typical operations include yards, loading facilities, shearing shed infrastructure and watering and feed points.

The production cycle for beef cattle in the Darling Downs region is provided in Table 13. The production cycle for sheep in the Darling Downs region is provided in Table 14. Shearing for wool production may occur throughout the year but the main period is from late winter to early spring.

In establishing its operations, Arrow will need to be aware of and accommodate the grazing animal production cycles.

5.7.2 Key management practices

The layout of infrastructure is a key determinant in the efficiency of these operations, particularly the relationship of feeding and watering infrastructure to the pens, sheds or paddocks.

Extensive ancillary infrastructure is often required to support these operations, particularly feed storage and production, and effluent, manure and litter disposal.

Maintenance of fences and gates to ensure the integrity of holding pens and paddocks is a key management activity, as is the integrity of watering systems comprising bores, holding tanks, supply pipes and troughs.

[32] Department of Natural Resources Queensland (1999) Central Darling Downs Land management Manual Resource Information Book.

Table 14 Typical sheep practice calendar (Darling Downs)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Joining												
Fat lambs												
Wool production												

5.8 Timber production

5.8.1 Extent, productivity and practices

A significant amount of timber (cypress pine, spotted gum and ironbark) is harvested from forests on freehold and leasehold land, as well as Crown land (State Forests) in the Surat Gas Project development area. The harvested timber is used for fencing, landscaping, firewood etc.

Demand for specialty craftwood timbers including brigalow (*Acacia harpophylla*), budgeroo (*Lysicarpus angustifolius*), hairy oak (*Allocasuarina inophloia*), and red ash (*Alphitonia excelsa*) is increasing as a boutique timber industry. It is estimated that there is 120,000 ha of privately owned forests in the Darling Downs region (Harrison et al. 2009 p14 [33]).

As at 2001, 65,146 trees were planted in the Darling Downs region for the purpose of timber and wood pulp, while 494,539 trees were planted in Queensland for this purpose (ABS 2001).[34]

Farm forestry industry is at the initial stages of development. Plantations in the Darling Downs region are typically small at less than 10 ha (*Hebron et al.* 2009, p. 530) with most of these plantations on parcels of land with areas less than 100 ha.

5.8.2 Key management practices

Silviculture research concerning the major plantation hardwood species (*Eucalyptus grandis* and hybrids, *Eucalyptus dunnii*) suggests maximum stocking rates of between 625 to 1250 trees per hectare on low and highly productive sites respectively. Trees should be planted on high mounds to ensure good growth, and deep ripping is unnecessary except on compacted clay soil sites.

Good forestry practice includes thinning non-target species and target species that exhibit sub-standard growth, small stature, poor health, mistletoe infestation or an excessive number of dead branches or epicormic (vertical) growth. This ensures only optimal trees remain and improves the health and value of the forest.

Thinning operations in dry forests aim to leave trees standing an average of 7 m apart and no more than 200 trees/ha. Thinning can be conducted using mechanised methods in areas classified as 'non remnant vegetation', however only non-mechanised methods are permitted in areas classified as 'remnant vegetation' under the Code Applying to a Native Forest Practice on Freehold Land (NRW, 2007).

[33] Harrison S and Herbohn J 2009 *Agroforestry and Farm Forestry – Support systems to assess the viability of whole-farm and regional agroforestry enterprises* Publication No. 08/097 Project No. QDN-4A © 2008 Rural Industries Research and Development Corporation.

[34] Australian Bureau of Statistics 2000-01, 7125.0 - Agricultural Commodities: Small Area Data, Australia, 'Table 2 Queensland – State And Sd – All Commodities,Tree and shrub seed sown and seedlings planted', data cube: Excel spreadsheet, cat. no. 7125.02000-01 < www.abs.gov.au/ AUSSTATS/abs@.nsf/ DetailsPage/7125.02000-01?OpenDocument > accessed 22 July 2011.

6 Proposed development infrastructure and activities

This section is derived from information supplied by Arrow and its representatives.

6.1 Pilot wells

Pilot wells comprise five wells drilled in a diamond-shaped arrangement with each well about 200 m apart and a single well located in the centre. Where required to confirm coal seam gas yields, additional pilot wells may need to be drilled at approximately 10 to 20 km intervals in priority exploration areas.

6.2 Production wells

Approximately 7,500 production wells and associated gas and water gathering infrastructure will be installed over the life of the Project. Wells will be drilled at a rate of approximately 400 wells per year. Gas field design will seek to arrange approximately 10 wells around common infrastructure including access tracks and gathering systems thereby reducing the extent of affected land.

Typically, wells will be between 700 m and 1,500 m apart. This flexibility in their placement, including a minimum 200 m from any sensitive receptor, allows yields to be optimised and land use activities to be taken into consideration in siting the wells.

Site preparation may require earthmoving equipment such as graders, excavators and bulldozers, depending on the nature of the site. Production well drilling will require a 50 t truck-mounted drilling rig or hybrid (coil) rig, casing trucks, mud tanks, huts and water trucks. The drilling lease for a standard rig is 70 m by 70 m. The drilling lease for a hybrid rig will be 85 m by 85 m. Additional track works may be required where a hybrid rig is used.

Surface tank collection of drilling mud will be adopted on black soils in accordance with Arrow's commitments. In other areas, pits may be constructed for water and drilling mud.

Gas-engine generators (ranging from 3 to 8 L capacity) will be used to supply power to production wells for dewatering pumps and ancillary equipment until the gas free-flows (up to 6 months). Mufflers will be installed to reduce noise. Additional options are also being considered to power the well head dewatering pumps and ancillary equipment, such as electrical connections (Refer Section 6.6 Electricity Transmission Lines).

On completion of drilling, the well site will be partially rehabilitated to a nominal 10 m by 10 m area that will be fenced to exclude stock and unauthorised access.

Well production life is estimated to be 15 to 20 years. Upon decommissioning, wells will be capped, plugged and abandoned in accordance with all applicable state and federal legislative requirements.

6.3 Low pressure pipelines

A mix of 100 mm to 630 mm high-density polyethylene (HDPE) pipe and associated infrastructure (low point drains and high point vents) will be installed to a minimum depth below surface of 750 mm to top of pipe. Agreement will be made with the landowner on the final depth of burial to minimise risk of damage to infrastructure and disruption to other land uses.

An average of 1,100 m of HDPE pipe for gas and 1,100 m of HDPE pipe for water gathering lines is assumed per production well, generally located in the same trench until reaching the compression or water treatment facility site boundary.

A typical 15 m right of way is required for gathering line installation, although this may range up to 25 m in practice. For areas of environmental sensitivity, the right of way can be narrowed (through the area of sensitivity), however where multiple larger 400 mm to 630 mm HDPE pipelines are installed in parallel this will require a 20 m right of way.

6.4 Medium pressure pipelines

Medium pressure gas pipelines will be constructed of a lightweight, strong, plastic composite, glass (reinforced epoxy) or lined steel pipe and have a minimum depth of burial to top of pipe of 750 mm. Agreement will be made with the landowner on the final depth of burial to minimise risk of damage to infrastructure and disruption to other land uses.

Gas from field compression facilities is saturated with water. This water often collects in low points along the pipelines. This pooling of water requires the pipelines to be drained and pigged (cleaned) on a regular basis to ensure unrestricted gas flow.

Approximately 15 to 25 km of medium pressure gas pipelines will be required to link field compression facilities to the inlet of central gas processing or integrated processing facilities. It is likely that coal seam water gathering lines will be located in the same easement as the medium pressure gas pipelines.

A right of way of between 20 m and 30 m is likely to be required for medium pressure gas pipeline installation. For areas of environmental sensitivity, the right of way can be narrowed for short distances.

6.5 Access tracks

The extent of likely disturbance due to the construction of access tracks can be readily estimated. Where possible, Arrow proposes to use or upgrade existing access tracks in consultation with the landholder to minimise the need to construct additional access tracks.

Arrow is proposing to construct permanent all weather access tracks only to significant facilities, such as integrated processing facilities and compressor stations. The disturbance would be related to the initial forming of the track, laying of track surface material, installation of drainage works and the conduct of run-on and runoff water in and around the tracks.

6.6 Electricity transmission lines

The base case being considered in the EIS is local generation of the electricity to power project requirements at both the well head, and facilities. One of the options being considered during the design process is importing power from the Queensland electricity grid, which would require Arrow major facilities (IPFs, CGPFs and FCFs) to be to be connected to the network service provider substation by a 132 kV double-circuit overhead line with composite insulators and an optical fibre ground wire (earth wire).

A typical configuration would have a single double-circuit pole, vertical conductor configuration with line post insulation and an optical fibre ground wire.

The proposed route, including the location and spacing of poles would be optimised during detailed design. The typical easement width required for overhead lines will be 45 to 60 m and the number of suspension poles versus strain poles will depend on the line route.

Vegetation on the easement will be cleared in accordance with the applicable electricity line safety clearance requirements. Where possible, it is proposed to use existing formed tracks to access powerlines (e.g. to service well heads) to minimise environmental disturbance.

6.7 Facilities

6.7.1 Field compression facilities

Field compression facilities will receive gas from production wells and are expected to provide 30 to 60 TJ/d of first stage gas compression. Compressed gas will be transported from field compression facilities in medium pressure gas pipelines to multi-stage compressors at central gas processing facilities and integrated processing facilities where the gas will be further compressed to transmission gas pipeline operating pressure and dehydrated to transmission gas pipeline quality. Coal seam water will bypass field compression facilities.

6.7.2 Central gas processing facilities

Central gas processing facilities will receive gas both directly from production wells and field compression facilities. Central gas processing facilities are expected to provide between 30 and

150 TJ/d of gas compression and dehydration. Coal seam water will bypass central gas processing facilities and be pumped to an integrated processing facility for treatment.

6.7.3 Integrated processing facilities

Integrated processing facilities will receive gas from production wells and field compression facilities. Integrated processing facilities are expected to provide between 30 and 150 TJ/d of gas compression and dehydration. Coal seam water received at integrated processing facilities is expected to be predominantly treated using reverse osmosis and then balanced to ensure that it is suitable for the intended beneficial use. Coal seam water received from the field, treated water and brine concentrate will be stored in dams adjacent to integrated processing facilities.

6.7.4 Gas flare stacks

Gas Flare Stacks will be located at these facilities and be included within the footprint identified for these facilities. A sterile zone (a potentially hazardous zone where uncontrolled entry is prohibited and that must be maintained free of combustible material) is required around the base of the flare stacks. The radius of the sterile zone may range from 50 to 80 m.

6.7.5 Construction camps

Construction camps will be built at integrated processing facilities in each region and will accommodate between 200 and 350 personnel. The construction camp will be incorporated with facility and hence contained within the area of disturbance required for the facility.

7 Potential impacts to agricultural enterprises

Potential impacts of the proposed development common to all elements of the proposed activities are:

- soil profile function;
- machinery operations;
- specialist operations;
- irrigation;
- crop losses;
- changes to overland flow patterns; and
- associated aggregate impacts.[35]

These potential impacts are discussed separately in the following sections.

7.1 Soil profile

The impact of the development on the soil environment has been identified and characterised by the Coffey Environments report titled 'Geology, Soils and Landform study –Draft' (Coffey Environments, March 2010). In summary these impacts are:

- Compaction associated with the traffic within site works areas and access.
- Soil inversion as a result of excavations and other preparatory works.
- Soil organic matter reduction due to the disturbance.
- Soil structure disruption due to the change in soil constituents (organic matter) and plastic deformation of the soil.
- Crust formation.
- Biological degradation (stockpiling) of the soil reducing soil borne organism vigour and macrophyte seed stores.
- Impeded infiltration and drainage of the soil profile.
- Increase soil run-off during rain events.
- Reduction in plant available water.
- Reduced soil air that may induce anaerobic soil conditions.
- Reduced fallow efficiency of the soil profile.
- Reduced soil fertility due to lowered organic matter, soil water and denitrification in localised parts of the soil profile.

The soils most prone to these degrading impacts are the high clay cracking Vertosols that are associated with the good quality agricultural lands within the proposed development area. The land units subject to these impacts are shown in Table 15 (next page).

The location of the land units containing vertosols is shown in Drawing No. 10185.1.3.

The Vertosol soils are normally classified using the Unified Soil Classification System (USCS) as CH or CL soils. These soils have plastic fines that dominate the soil that have either a high liquid limit (CH) or a low liquid limit (CL). In addition, these soils are highly plastic and, at moisture contents at the lower end of the plant available range, will still be subject to plastic deformation if any load is applied to them. Consequently these soils are the most prone to compaction and soil structure degradation under high traffic conditions.

The management and rehabilitation of these soils is characterised by a lack of scientific literature on the subject. However, on the basis of anecdotal evidence and Arrow's own experience, potentially successful management options may be available. These management options include (but are not limited to):

- Separation of topsoil and the underlying profile horizons as stockpiles to be reinstated after construction or decommissioning;
- Deep ripping to break up compacted layers;
- Incorporation of organic matter to aid nutrient and structure establishment;
- Ley (grass/legume) pastures for micro-structure and overall nutrient improvement.

The maintenance of the topsoil in the uppermost layer of the soil profile does aid the establishment of vegetative cover in the first instance by providing a suitable medium for pant growth.

[35] Aggregate impacts here would include, for example, a reduction in soil water availability as a result of the operation leading to an increased drainage requirement.

Table 15 Land resource areas[36] (original source report land units in ()'s) and soils within proposed development area most sensitive to disturbance and residual impacts and their relationship to GQAL

Land resource area	Soils characteristics	Remnant vegetation	Soil type	Agricultural land class
		Central petroleum tenements		
Recent alluvial plains				
1a (1a[37])	Black and grey cracking clays	Poplar box or Queensland blue gum open woodland, or grassland	Vertosol	GQAL(A)
1b (1b)	Black and grey cracking clays	Queensland blue gum, river red gum and Moreton Bay ash woodland	Vertosol	GQAL(A)
Older alluvial plains				
1b (2a)	Black self mulching cracking clays	Open grassland	Vertosol	GQAL(A)
1c (2b)	Grey cracking clays	Poplar box open woodland	Vertosol	GQAL(A)
1d (2c)	Red or brown loams over red or brown clays with black, self-mulching cracking clays	Poplar box open woodland or grassland	Vertosol	GQAL(A)
1d (2d)	Grey cracking clays	Poplar box and Queensland blue gum woodland with belah and wilga	Vertosol	GQAL(A)
Brigalow plains				
3a (5a)	Grey, self-mulching cracking clays	Brigalow, belah forest with wilga	Vertosol	GQAL(A)
3b (5b)	Grey, cracking clays	Brigalow, belah forest with wilga and some black tea tree	Vertosol	GQAL(B)
Brigalow uplands				
3c (6c)	Grey-brown cracking clays	Brigalow, belah, wilga forest with black tea tree.	Vertosol	GQAL(B)
3d (6d)	Grey and brown cracking clays with brown loams over brown clays	Brigalow, belah, open forest with box or poplar box open woodland	Vertosol	GQAL(A)
		Central western petroleum tenements		

[36] Geology, Soils and Landform Study Arrow Energy Surat Gas Project, Surat Basin, Queensland. Figure 4.9

[37] Harris, P.S., Biggs, A.J.W., Stone, B.J., Crane, L.N. and Douglas, N.J. (eds). (1999). *Resource Information Book, in Central Darling Downs Land Management Manual*. Department of Natural Resources, Queensland.

Land resource area	Soils characteristics	Remnant vegetation	Soil type	Agricultural land class
Clay alluvial plains				
1a (1a[38])	Black and grey cracking clays and bleached sands over brown or black clay	Open grassy woodland of polar box	Vertosol	GQAL(A)
1b (1b)	Black and grey cracking clays and bleached sands over brown or black clay	Coolibah, river red gum open forest and woodland fringe the drainage lines, with poplar box grassy woodland on flat plains	Vertosol	GQAL(A)
1c (1c)	Grey cracking clays	Poplar box grassy woodland	Vertosol	GQAL(A)
Brigalow plains				
3a (4a)	Grey or black cracking clays	Brigalow belah, wilga forest	Vertosol	GQAL(A)
3b (4b)	Grey cracking clays	Belah forest	Vertosol	GQAL(B)
North western petroleum tenements				
3d (8)	Black earths, grey clays brown clays	Brigalow Belah, bauhinia forest, softwood scrub and grassland	Vertosol	GQAL(A)
3d (8)	Black earths, grey clays brown clays	Brigalow Belah, bauhinia forest, softwood scrub and grassland	Vertosol	GQAL(A)
South western				
3b (8[39])	Grey cracking clay	Brigalow-belah	Vertosol	GQAL(A)
3d (9)	Subsoils are uniform non-cracking clays (some Gilgai evident)	Belah	Mixed sodosols, vertosols and dermosols	

[38] Maher, J.M (ed) 1996, *Understanding and Managing Soils in the Murilla, Tara and Chinchilla Shires*, Department of Primary Industries Training Series QE96001, Brisbane

[39] Thwaites, R.N. and Macnish, S.E. (eds) (1991), *Land management manual Waggamba Shire*, Queensland Department of Primary Industries and Waggamba Conservation Committee, Parts A to C, Queensland Department of Primary Industries Training Series QE90014.

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However, the rehabilitation of the disturbed or degraded soil profile needs to re-establish the micro and macro-pore connections between the layers. These connections maintain the flow of water through the soil profile either forming the basis for the water to be retained within the profile or transmission to deeper layers for storage or further and deeper percolation as part of the local groundwater system.

The physical placement of the soil layers as part of the profile results in a residual physical interface (a smear zone or aggregate size sorted zone) that separates the layers (Figures 1 and 2).

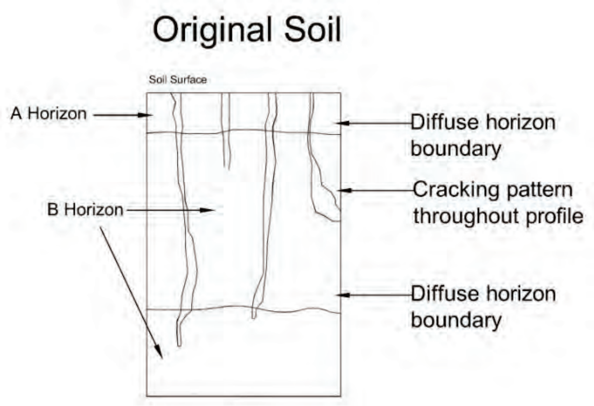

Figure 1 Typical in-situ soil profile showing structural continuities (vertical section).

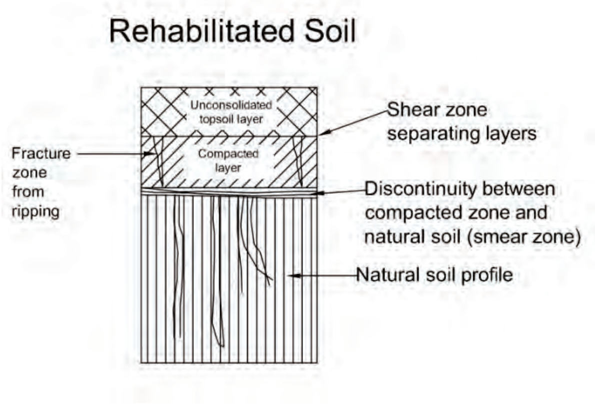

Figure 2 Typical rehabilitated soil profile showing structural discontinuities (vertical section)

The effect of the interface is to impose a discontinuity in the macro-structure such as large drainage pores or the drying cracks that are common in Vertosols.

There may be short-term ponding at the interface, as water infiltrates and percolates down the surface soil layer that will induce short term waterlogged conditions within the surface layer. Once the layer is saturated there is a risk that there will be increased run-off with consequent erosion potential as well as reduced fallow efficiency in agricultural terms.

The structural discontinuity of the layering also predisposes the surface layer to erosion due to the lack of a structural connection between the layers.

Deep ripping breaks up the large blocks of compacted soil and immediately establishes large fractures and cracks for water penetration. This may ameliorate an impediment to deep percolation, but this amelioration is localised to the rip or fracture zone itself and only to the depth of the ripper. Between the rip zones the soil is still compacted. This compacted zone will significantly restrict root extension of crops.

Continued ripping of the soil will not result in further breakdown of the compacted blocks as:

- Subsequent ripping will merely shift the original blocks of compacted soil as they disengage from the underlying layers.

- The machinery used to rip the soil will itself cause further compaction of the ripped layer.
- The ripping traffic will result in an additional compacted layer that would be located at the depth equivalent to the depth of the ripping (physical compaction as well as smearing).

A theoretical pattern of ripping and its impact are shown in Figure 3. A mitigating factor may be the cracking nature of the clays in the Vertosols. The cracking is in response to changes in moisture content. However, the compaction restricts the ingress and egress of water as well as root growth within the compacted layer. In the absence of wetting and drying, the cracking event cannot occur and the benefits of these natural characteristics of this soil will be lost.

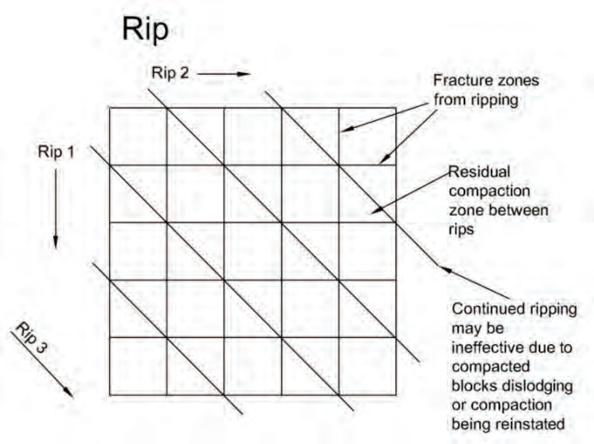

Figure 3 Plan view of soil site showing theoretical pattern of ripping and its impact

Deep cultivation and ripping prior to topsoiling may have similar outcomes and also transfer the compaction zone to the deepest extent of the cultivation or ripping.

The incorporation of organic matter will improve the structure and nutrient status of the surface topsoil layer. The topsoil is the most active biological zone of the soil profile and the organics would be a source for this activity. The organic fraction may have restricted action at depth due to a lack of mixing, poor water transmission in the lower layers and inhibited biological activity caused by the restrictions in soil water and air.

The use of ley pastures as a method to aid rehabilitation introduces organic matter and actively extracts soil water to enhance cracking. The main location of the pasture impact will be in the surface layer of topsoil. Pasture plants still have the residual problem of the compacted layer at depth. In addition, the time required to observe any impact of the pasture on the soil profile productivity may be considerable.

Potential long-term impacts resulting in reduced productivity may arise from disturbance, compaction, continued use and rehabilitation that don't reinstate the soil profile and its function. The degree of reduced productivity will be dependent on the following:

- The care and management of soil horizons during initial site preparation, during construction and in rehabilitation.
- The type, extent and duration of traffic and disturbance.
- The soil properties at each site which although categorised will be unique to that location.
- The requirements of specific crops which may have different responses to the soil conditions e.g. sunflowers (tap root system) will react differently to wheat (fibrous root system) due to the root system differences.

7.2 Machinery operations and farm workability

Mechanised agriculture is sensitive to changes in paddock configuration that alter the pattern of tillage, planting and harvesting. The sensitivity of mechanised farming is related to:

- Compaction of soils especially at headlands that are subject to traffic with consequent yield losses;
- Irregular shapes and the need for double passes of machinery with the consequent increased compaction (yield losses) and economic costs of machine use;
- Uneven planting rates (planter issues);
- Tillage gaps and unplanted areas causing a loss of yield per hectare (planter issues);

- Tillage gaps and weed banks that cause increased cost of weed control.

The definition of workability in this sense relates to the management of machinery operations within a cultivation paddock of a farm. The workability of any cultivation is dependent on:

- Machine management issues such as tillage and planter widths, tractor selection, state of machine repair, traverse speeds and the like;
- Operator skill in using the tractor/implement combination;
- Operating patterns such as turning methods e.g. is the tool disengaged from the ground or not and;
- Field conditions such as paddock size and shape, soil type, moisture content, obstructions (posts, trees, fences, tracks, wells etc), and paddock relief (i.e. humps, hollows and soil conservation banks) that cause turning and implement depth management problems.

7.2.1 Compaction and yields

Headlands are formed at the end of each tillage or planter run adjacent to the edge of the farming area (paddock). The headlands are where the machine turns to start the next run down the paddock. The soil engaging implement is normally lifted and the headland area traversed to the next tillage run.

This area is subject to significant compaction by virtue of the repeated traffic of the turns. The headland area is then tilled as the last operation but still subject to the final compaction run of that operation.

A hypothetical tillage operation on a square paddock is shown in Figure 4 with potential impacts of development activities and possible management responses shown in figures 5 to 8. Figure 4 shows a typical layout of operations in an unobstructed paddock.

The headlands are located at the ends. The impact on tillage of the placement of a well and track within the paddock is shown in Figure 5.

The well and track form an obstruction to the normal operation creating an additional headland adjacent to the track and the well, reducing the productive area of the paddock. This causes additional compaction, as well as additional cost and the inconvenience of additional turns and headlands.

The operator may take the option of lifting the tool bar of the implement and crossing the track but there will still be a requirement for an additional run adjacent to each side of the track to complete the tillage operation. This has the effect of producing another headland in the operation.

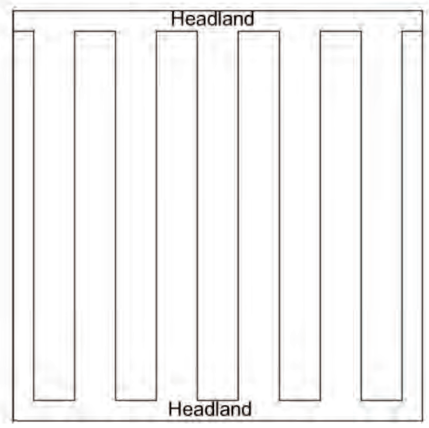

Figure 4 Typical unobstructed pattern of machinery movement

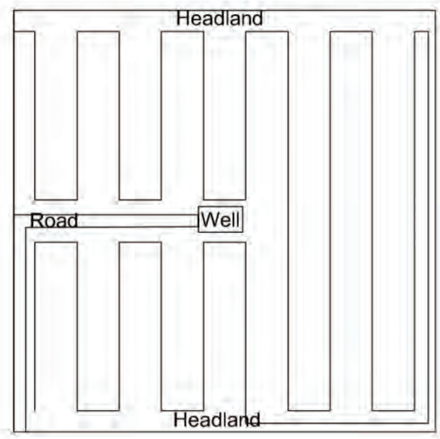

Figure 5 Example pattern of machinery movement to avoid wells and access tracks installed in paddock

Figure 6 shows the effect of placing the well and track at the edge of the cultivation (paddock). In this location the impact is substantially reduced but there still will be a small headland associated with the well pad, as well as the loss of agricultural land associated with the well and track.

Changing the orientation of the tillage runs will further minimise the impact, but it is normal practice to alternate the machinery runs in low slope land in an attempt to further minimise the in-field compaction caused by tillage.

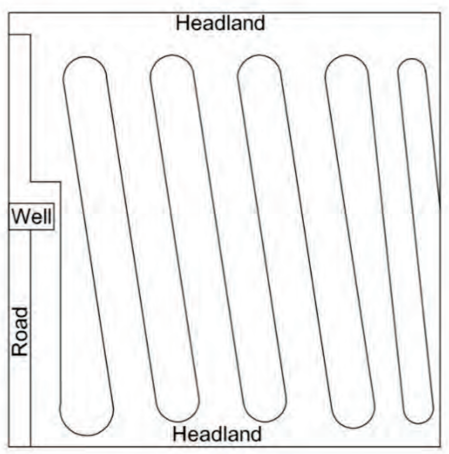

Figure 6 Example pattern for machinery movement resulting from relocation of well to edge of paddock with track adjacent to paddock boundary

Multiple wells significantly increase the impact on the operation of cultivation as shown in Figure 7. The additional headlands are evident and irrespective of the orientation of the tillage runs the increase in headland development is significant.

Headlands can be reduced (Figure 8) by placing the infrastructure (wells and tracks) adjacent to the edges of paddocks as shown in Figure 6 above, or by aligning the infrastructure with the direction of tillage.

The orientation of the tillage may alter from year to year on low sloping land and hence aligning the infrastructure with the direction of tillage may have limited benefit in reducing impacts.

On slopes greater than 0.5% the orientation of the cultivation will be determined by the direction of the slope. In these instances it would be normal practice to adopt contour cultivation and planting to minimise the erosion potential of the tillage operations.

Aligning infrastructure with the direction of tillage would reduce the number of additional headlands and hence loss of productive land.

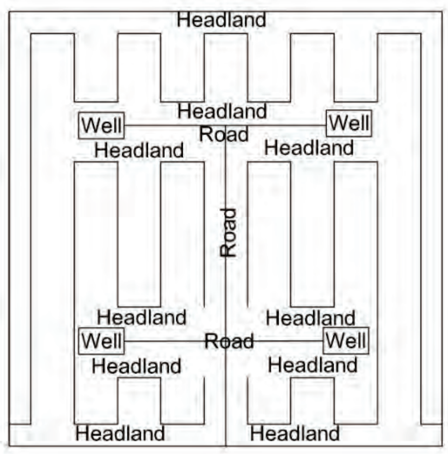

Figure 7 Example pattern of machinery movement resulting from multiple wells with track network

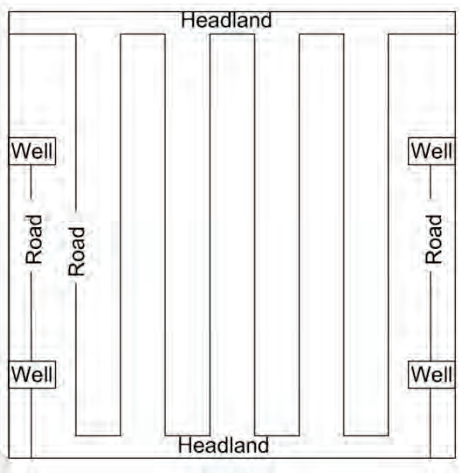

Figure 8 Example pattern for machinery movement resulting from relocation of wells and tracks to edges of paddock or in line with direction of tillage

7.2.2 Planter and cultivation issues

Table 16 Seeding variability in terms of the middle run plus or minus a percentage of the middle run in relation to machine width and radius of curvature of the turn.

Machine width (m)	Inside curve 5 m	Inside curve 10 m	Inside curve 15 m	Inside curve 20 m
20	67%	50%	405	33%
15	60%	43%	33%	27%
10	50%	33%	25%	20%
5	33%	20%	14%	11%

The key issue is the management of the planting operation to accommodate:

- differentials in plant populations across the planter (especially for summer crops such as sunflowers); and
- unplanted islands between adjacent runs which require special operational procedures.

This planting management may be difficult where the bends within the cultivation are too acute.

Plant populations

The impact of the planter turn on plant population is determined by the physical nature of the planting machine (while the planter is engaged with the ground). Planters fixed on a parallelogram mounting have very limited turning ability. The lateral forces during turning put undue strain on the connections to the tool bar of the machine.

Tight turns in this situation are achieved by lifting the planter out of the ground before executing the turn. Once this is done, the turn may be executed within one length of the tractor. This means an additional run which must be taken to cover the resultant gap.

There will be some overlapping of the runs which will alter the plant population for an exceedingly small area of land. This achieves full coverage of the paddock. The issue is an increase in the cost and time of planting.

For continuous ground engaging machines, a curve in the planting run occurs. For example, air-seeders and combines may virtually turn within their own length. The corners of paddocks give a good example of this ability.

As these types of planters traverse a curve the seeding rates vary between the inside and outside part of the curve. This is due to a constant seed delivery rate and differential distance of travel. For example, a 20 m wide machine travelling through a 90^{o} bend with the inside of the machine scribing a 5 m radius arc, the seeding rate will approximately be the middle run planting rate ± 67% at the inner and outer edges of the planter. The planting rate is the ratio of the difference between the circumference of a circle of 5 m radius and one at 25 m radius.

As the machine becomes narrower (using the above scenario) the variability becomes less and similarly as the inside radius becomes larger the variability becomes less (see Table 16).

The impact of this seeding variability is dependent upon season and crop type. Seasonal variations are somewhat unpredictable, and hence the extent to which the effects of seeding variability on yield would be exacerbated. Different crops respond differently to seeding variability and this can affect crop yields. For example, winter cereals such as wheat are very insensitive to plant populations or density in terms of possible yield.

Low plant population crops require significant tillering to maintain yields. Conversely, high plant population crops require lower tillering to maintain yields. Crops that are yield-sensitive, in terms of plant population, will be more affected by seeding variability e.g. sunflowers.

For unit planters that are individually driven, this variability in plant population does not occur to the same extent. Each planter unit has its own drive and the seed delivery rate is maintained as it passes over ground.

Cultivation islands

Table 17 Uncultivated crescent areas (m^2) between adjacent machine runs associated with turns with changing machine width, radius and turn angle (follows principles form Hunt, 1975[40]).

Machine width (m)	Radius of inside of machine (m)	Angle (degrees)	Unplanted area per curve(m^2)
Change width of machine with constant radius of turn and total angle			
10	20	30	3.02
12	20	30	3.77
14	20	30	4.57
16	20	30	5.42
Change radius of turn with constant machine width and total angle			
10	20	30	3.02
10	25	30	3.63
10	30	30	4.23
10	35	30	4.84
Change of total angle with constant machine width and radius			
10	20	30	3.02
10	20	40	7.38
10	20	50	14.90
10	20	60	26.77

Unplanted islands in a cultivated paddock are not desirable as they harbour weeds and may represent a physical loss in production. Tight turns create unplanted islands between the adjacent runs. This is due to the small radius of curvature of the inside of the machine which is now adjacent to the outside of curvature for the adjacent runoff of the machine (see Figure 9).

In the simplest theoretical terms the machine scribes a simple circle. The area (see Table 17) of the unplanted island (or crescent) is dependent on:

- the width of the machine (wide machines increase the size of the island);
- the included angle of the required turn (big angle big area); and
- the radius of curvature scribed by the machine.

The impact of these factors is exemplified in Table 17. The interpretation of turning radius in the table is not as simple as the numbers suggest. The implication from the analysis suggests that a small radius has a small area and is possibly good. However, tight turns are not appropriate as they:

- stress the machine;
- cause significant seeding variations; and
- cause crescents which are short in length but very wide.

Table 17 indicates that in physical terms the actual land lost is quite small. The major determinant of the area left unplanted is the included angle of the circular path of the machine. The normal practice to cope with these curves and unplanted islands is to make a run with the planter straight down the apex of the curves.

This practice is exemplified by examining the planting patterns of the corners of any paddock

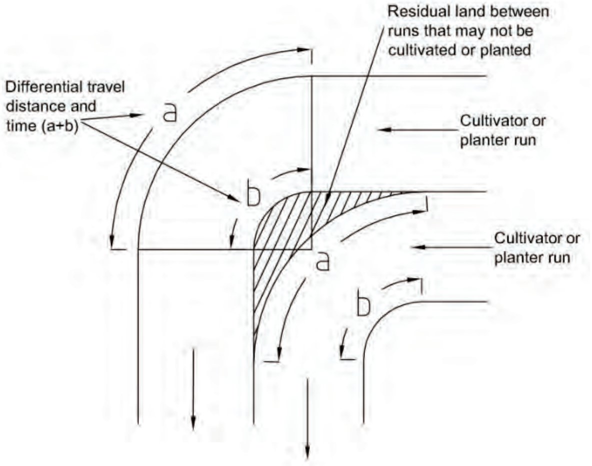

Figure 9 Impact of corners or turns on machinery runs in a cultivation paddock that will need additional machine movements to accommodate.

[40] Hunt, D. (1983) *Farm Power and Machinery Management.* Iowa State University Press, Ames Iowa.

where this may be observed. This additional run causes further compaction associated with the tractor pass and alters the planting density. Both outcomes may lower crop yields in corner areas.

Large or wide curvatures (radii) create long and thin islands which may be accommodated by a slight overlap along the edges of each curve in adjacent runs. Similarly, small included angles may be handled by a simple overlap. The impact of this practice is of no issue in crops that are reasonably yield insensitive to plant density (e.g. wheat). However, in crops that are yield sensitive to planting density (e.g. sunflowers) it is an issue. Current practice is to leave the islands or to do a final run down the apex of the curve, but this increases plant populations. This in turn has an adverse impact on crops such as sunflowers.

The machinery groups that are most susceptible to these workability issues are those that have a rigid tool bar or limited pivot planes. Therefore, the arrangement of wells, gathering lines and access tracks in cultivation paddocks will determine the number of additional turns or planter runs required to ensure effective coverage and the extent to which under or over seeding will affect plant populations and crop yields. These impacts will lead, in varying degrees, to:

- probable depressed yields in crops sensitive to plant populations;
- increased compaction within the paddock with consequent yield suppression;
- additional costs in terms of machinery use; and
- time imposts on the actual management of the paddock.

7.2.3 Specific farming operations

Specific farming operations carried out in the region have the potential to be affected by the proposed development activities. These operations and potential impacts of construction, and operation and maintenance activities on those practices are discussed in the following sections. The specific farming practices vulnerable to disturbance and disruption are:

- controlled traffic;
- soil conservation structures;
- strip cropping;
- overland flow control; and
- irrigation.

Controlled traffic

Controlled traffic sites have a system of permanent wheel track locations within the paddock. This localises the compaction associated with tillage, planting, spraying and harvesting to small specific locations within the paddock. The management objective of this approach is to maintain the soil structure throughout the remainder of the paddock to maximise water penetration (fallow efficiency and infiltration during the crop growth cycle).

Obstructions to or severance of the controlled traffic lanes and associated cultivation runs will affect the efficiency of the operation and possibly lead to the loss of part or a whole cultivation run. Figure 10 shows a typical controlled traffic arrangement in a cultivation paddock.

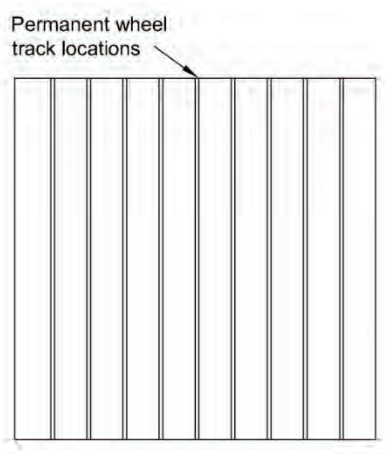

Figure 10 Typical controlled traffic arrangement in a cultivation paddock

Figure 11 shows the impost of a well and track within that traffic system with the consequent potential losses in cropping area. The extent of severance or disruption would determine whether part or the whole of a run was lost to production.

A further impact is the need to cultivate the runs adjacent to the gathering lines or access track with a different machine adding time and cost to the operation. This might be impractical and uneconomic and ultimately result in those runs being taken out of production.

Uncultivated land within the paddock increases weed control costs, further adding to the cost of production.

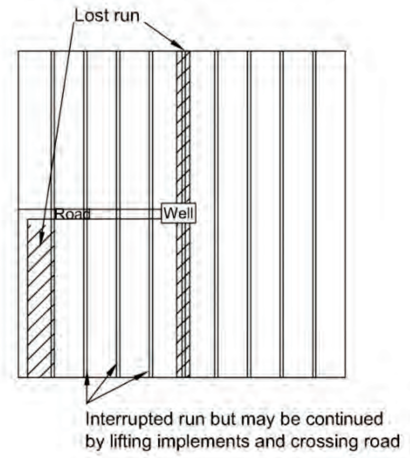

Figure 11 Potential impact of well and track placement on controlled traffic system

Figure 12 shows that placement of the well, gathering lines and access track at the edge of the paddock or parallel to the controlled traffic lanes would reduce the impact on this farming operation. Locating the access track in the turning lane (head and/or bottom of paddock) of the controlled traffic system is another means of reducing impacts on this type of operation. The use of equipment and machinery that is able to utilise permanent wheel track locations to access and transport materials to the well site may also reduce impacts on controlled traffic sites.

Soil conservation

Soil conservation measures are designed to maximise infiltration and limit soil loss. Conservation measures used in the region include:

- orientation of the cultivation;
- graded banks;
- waterways; and
- spillways and chutes.

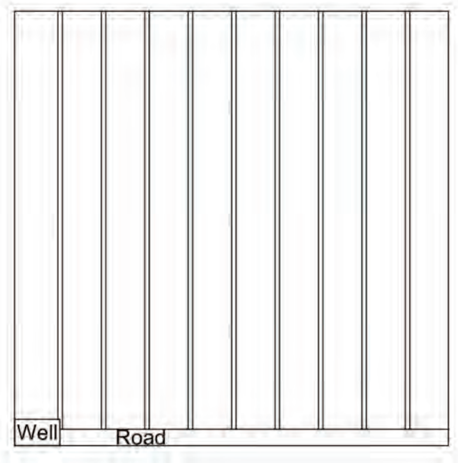

Figure 12 Example arrangement of wells and tracks that reduces impacts on controlled traffic systems

Contour cultivation is a soil erosion control measure that has some flexibility in the orientation and direction of the tillage operations. Up and down slope cultivation is not adopted by the agricultural sector and hence placement of wells and tracks in line with the direction of cultivation will reduce impacts but not completely overcome headland effects at well pads.

The soil conservation works associated with graded banks and the placement of waterways are designed structures that are permanent features of the farming operation. Figure 13 (following page) shows a typical cultivation paddock using graded banks and waterways.

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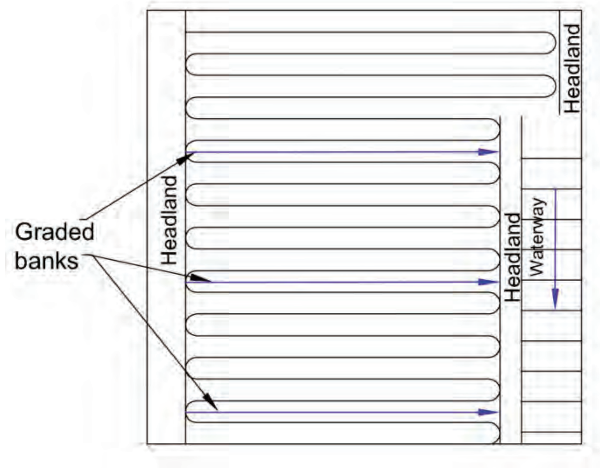


Figure 13 Typical arrangements of graded banks and waterways

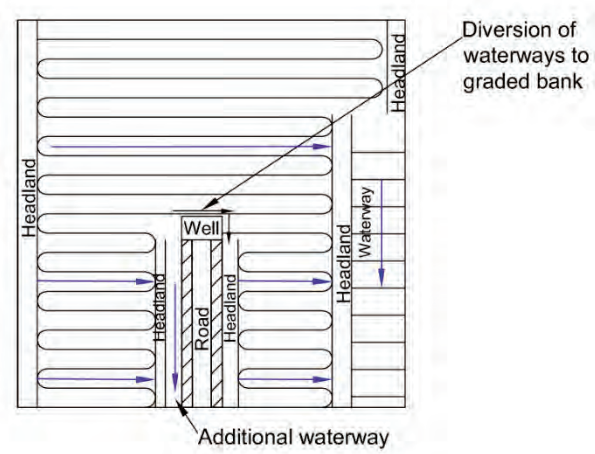


Figure 14 Additional soil conservation works required for centrally placed well and access track

Figure 14 shows the effect of placing a well in a central location and the shortest track route to service that well. The disruption is significant with the imposition of additional headlands required by the contour cultivation.

The well requires additional soil conservation diversion works with waterways to the existing graded bank and there would be a need for table drain waterways and associated soil conservation works to minimise the impact of the track on the adjacent cultivated land.

Figure 15 shows alternative arrangements with the well and track being placed at the edge of the cultivated paddock (Location A) or in line with the direction of cultivation (Location B). If the well is placed at Location B, it should be positioned below the graded bank and the track aligned parallel with the graded banks and along the headland to reduce impacts on cultivation.

Key aims of soil conservation are to preserve the soil profile to protect the soil horizons from exposure which can lead to erosion and degradation of soil organic matter. Structures built to assist soil conservation are typically sloping landforms designed to minimise disturbance and exposure of the soil horizons.

Earthworks to establish a drill pad have the potential to expose the B horizon in undulating

Table 18 Estimate of maximum cut required for the development of the level platform for the drilling of wells as either a cut platform only or as a cut and fill balance.

	Maximum depth of cut (m)			
	75mX75m platform		85mX85m platform	
Slope %	Cut platform only	Cut and fill balance	Cut platform only	Cut and fill balance
0.5	0.38	0.19	0.43	0.21
1	0.75	0.38	0.85	0.43
1.5	1.13	0.56	1.28	0.64
2	1.50	0.75	1.70	0.85
2.5	1.88	0.94	2.13	1.06
3	2.25	1.13	2.55	1.28

terrain. Table 18 provides an estimate of the maximum cut (for a range of slope gradients) needed to make a level platform for the drilling of wells as either a cut platform only or as a cut and fill balance.

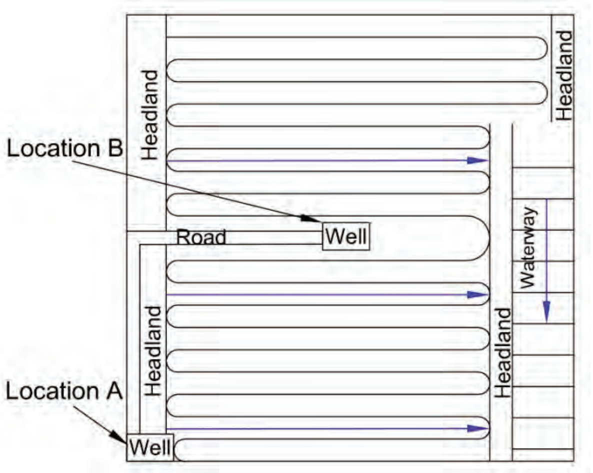


Figure 15 Alternative arrangements of wells and tracks to reduce impacts on graded banks and waterways

A depth of cut greater than 0.4 m would expose the B horizon and lead to disruption of the soil profile. This will exacerbate the existing soil rehabilitation difficulties already described previously. Arrow advises that only the area occupied by the drill rig and drill rod/casing handling area (approximately 10 m by 20 m) needs to be level which would reduce the potential for the B horizon to be exposed.

An additional impact will be the change in the soil hydraulic properties and the impact this will have on the hydrology of the affected sites. These impacts may include:

- increased erosion potential;
- increased run –off;
- impeded drainage due to disruption of the macro-pores with the soil profile;
- residual compaction at greater depths that will be more difficult to remediate (if at all).

Waterways are more intolerant to disturbance as gradient, and channel structure and stability are important in avoiding scouring, piping erosion and channel diversion.

Strip cropping

Strip cropping involves laying out strips (cultivation runs) normal to the expected flow direction of run-off on the floodplain. Strip cropping is normally found only on low slope floodplain areas where overland flows will have a low velocity and not lead to erosion of the tilled land.

The orientation and location of the strips are fixed and any disruption to the controlled flow pattern of flood flows through the strips will lead to scouring and the formation of rills with subsequent soil loss.

Barriers created by the establishment of well drill pads or access track formations, and channels created by wheel ruts from heavy traffic concentrate water leading to higher velocity flows that can result in erosion if appropriate control structures are not constructed and maintained.

As with the other specialised agricultural systems, well and track placement at the edges of paddocks or in line with the strips will reduce disruption to machinery operations. Regardless of the location of coal seam gas infrastructure, erosion control measures will need to be implemented and properly maintained to ensure flood flows are not channelled leading to erosion and soil degradation.

Overland flow control

Agricultural enterprises rely on surface flows to varying degrees, dependant on the nature and configuration of the land use. Those enterprises more reliant on surface flows (often located on flood plains) may invest heavily to maximise their return on the use of this resource. Such investments typically include laser levelling, dams and captures, intricate drainage configurations (flow controls and routing), terracing and complex erosion and sediment management measures.

The proposed development has the potential to interfere with overland flows, primarily through the construction of tracks and drill pads, but also through machinery impacts (compaction), drainage realignment and other direct or indirect alterations to surface and subsurface features.

Development that interferes with overland flows requires additional, specialist assessment to identify and quantify the hydrological and hydraulic impacts. Such assessments need to consider the land unit in its landform context, i.e. on a local, catchment and regional basis. Typically, these assessments consider the impacts on the site as well as on upstream and downstream locations.

Irrigation

Irrigation poses a constraint on the location and operation of coal seam gas infrastructure. The constraints are:

- soil conditions; and
- irrigation infrastructure.

Irrigation increases the soil moisture content of the soil profile and increases its susceptibility to soil compaction. The general considerations in previous sections relating to compaction issues are magnified for irrigation enterprises.

Irrigation is a significant infrastructure investment in the operation of a farm. The location and operation of the infrastructure is fixed in the landscape. Modification of infrastructure (e.g. shortening centre-pivot booms) or operations (e.g. shortening spray gun travel or coverage arcs) reduces the effectiveness of the irrigation leading to increased costs of production and reduced yields if coverage is affected.

The irrigation methods used in the region are:

- Spray irrigation technologies such as centre pivot, lateral boom, low pressure booms and to some extend large traveller irrigators;
- Surface irrigation mainly furrow irrigation; and
- Localised irrigation such as trickle (sprays and drippers) and T-tape types mainly in the horticultural industries.

Spray irrigation

The large spray technologies relying on centre pivot lateral boom and low-pressure boom have fixed locations and operations due to the location of supply mains and the physical size and orientation of the equipment.

The centre pivot is a large boom (in some instances hundreds of metres long) with a centrally located main water supply. The boom moves around the central supply as a circle of irrigated land.

The boom has large wheel assemblies that support the structure that move in a fixed pattern through the landscape. The emitters or sprays used by the boom are normally positioned close to the soil surface to minimise water losses during irrigation.

Lateral irrigators are similar to the centre pivot except that they are a self propelled boom (maybe hundreds of metres long) that moves across the landscape to form an irrigated rectangle.

The low-pressure booms are self-propelled booms but are significantly smaller in width (between 50 and 90 m wide) and are low to the soils surface to minimise water losses during irrigation.

The placement of wells, gathering lines, pipelines and access tracks should take into consideration the arrangement of irrigation infrastructure and seek to avoid locations that obstruct or limit operation of the equipment and its effective coverage of the irrigated paddock.

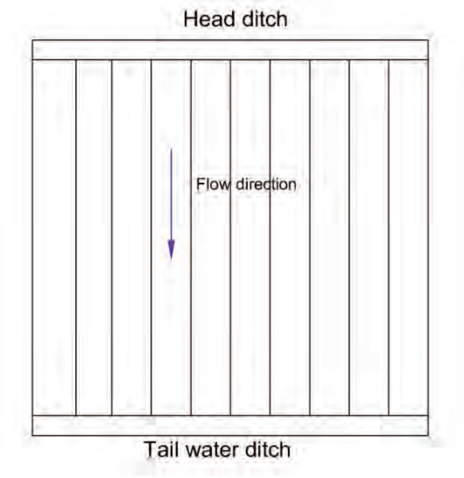
The high-pressure travelling irrigators (guns) have more flexibility than the other methods as the irrigators have the capacity to throw water over the top of any obstructions.

Surface irrigation

Surface irrigation such as furrow irrigation relies on the soil surface to transfer water down a slope to all parts of the paddock. This method is sensitive to any alterations to the soil surface conditions as a result of either the soil structure or the grade (slope) of the furrows.

he supply infrastructure is normally in the form of head ditch, graded pipe or flexible fluming (Figure 16).

Figure 16 Typical arrangement of furrow irrigation system



Soil surface, furrows and head ditches typically have very low grades to overcome erosion and to ensure adequate soaking of the soil and plant root system.

Laser grading is often used to establish the appropriate grades usually in the form of bays between berms or border checks.

Interruption or obstruction of the head ditch and bay/furrow grades would affect delivery rates of the supply ditches, advance rate of the water, tail-water collection and reuse, and distribution and infiltration efficiency of the system.

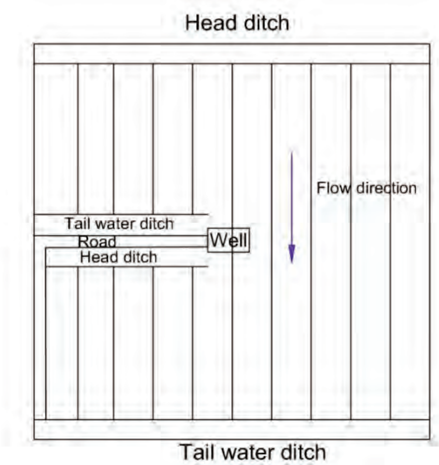


Figure 17 Typical arrangement of furrow irrigation system showing effects of placing well and road at a central location

Figure 17 shows the effect of placing a well and its associated access track (and gathering lines) in the centre of the paddock with the consequent disruption of the flow pattern, need for additional irrigation infrastructure and loss of productive land.

As with cultivation, placing wells and tracks at the edges of paddocks or in line with the direction of flow (Figure 18), reduces the loss of productive land and impacts on the irrigation infrastructure and operation.

To minimise direct impacts on irrigated land, non-irrigated land (e.g. access lanes, headlands) should be used for coal seam gas infrastructure, where possible.

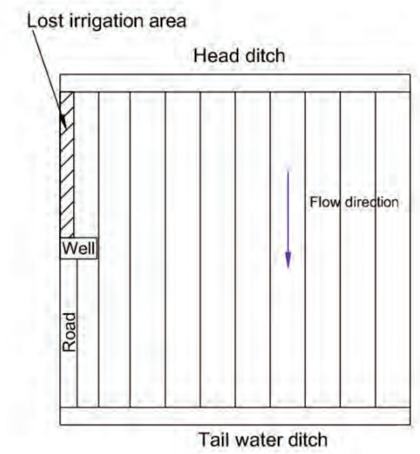


Figure 18 Typical alternative arrangement of furrow irrigation that reduces impact of coal seam gas infrastructure of farming operation.

Localised irrigation

Localised irrigation involving trickle (sprays and drippers) and T-tapes is mainly used in the horticultural industries including in orchards and vineyards. It is installed on an annual basis from main supply lines, and water storage and pumping systems. It is used less frequently for vegetable crops which typically use surface (furrow) or spray irrigation depending on the crop.

Horticultural enterprises are relatively small compared to broadacre farming operations, and hence the infrastructure is not readily relocated or modified. Disturbance to or interruption of these holdings results not only in the loss of productive land but also affects the efficiency of the operation leading to higher capital and operating costs including establishment, maintenance, management and harvesting.

8 Potential impacts of development activities

The potential impacts of proposed development activities on agricultural enterprises have been described in Section 7. This section describes the particular impacts of drilling, construction, operation and decommissioning, as well as providing an assessment of the GQAL potentially affected by these activities.

8.1 Drilling activities

For the purposes of this report, all drilling activities have been accounted for together, whether for exploration or production.

Drilling activities have the potential to impact agricultural activities and production through:

- soil compaction;
- soil erosion;
- altered surface and subsurface drainage;
- disruption to farming operations;
- crop losses;
- weeds; and
- site contamination from hydrocarbon spills (oils and lubricants) and waste materials.

Additional disturbance will be related to the access tracks and vehicular damage to the land surrounding the drilling well pad and laydown areas. It is expected, that these impacts would be greater at pilot well sites due to the number and close proximity of the wells (five or six wells arranged in a diamond pattern).

8.2 Construction activities

Construction activities have the potential to significantly impact individual farms and farming operations if not properly planned and managed. Regardless, impacts will occur and result in reduced productivity and increased capital and operating costs. The impacts most likely to affect agricultural enterprises during the construction phase are:

- Temporary loss of productive land associated with the footprint of the construction areas associated with wells, tracks, pipelines and production facilities;
- Loss of or reduced crop productivity during construction;
- Soil degradation resulting from disturbance of the soil structure with consequential impacts on fertility and biologic function, and crop productivity;
- Disruption to paddock operations such as tillage, planting, irrigation, weed control and harvesting;
- Changes to drainage, erosion control and sediment management;
- Diversion of flows and changes to the hydrology of the landscape;
- Farm hygiene issues relating to weeds and disease management; and
- Site contamination from hydrocarbon spills (oils and lubricants) and waste materials.

8.3 Operation and maintenance activities

The impacts of operation and maintenance activities while generally less than those of construction activities result in residual impacts with potential long-term effects on farm operation and productivity. Impacts of the operation and maintenance phase include:

- Temporary loss[41] of land associated with the residual footprint of the infrastructure such as wells, tracks and production facilities;
- Temporary loss of productive land associated with the footprint of the construction area required for well workovers;
- Residual impacts of the construction phase on the soil structure and crop productivity;
- Residual impacts on the paddock workability such as tillage, planting, weed control and harvesting;

[41] Temporary loss corresponding to the full time of operations plus rehabilitation after decommissioning

- Diversion of flows and changes to the hydrology of the landscape;
- Changes to drainage, erosion control and sediment management;
- Farm hygiene issues relating to weeds and disease management; and
- Site contamination from hydrocarbon spills (oils and lubricants) and waste materials.

8.4 Decommissioning activities

Decommissioning of the project involves activities that are essentially similar to the construction phase. Additional land will typically be required to decommission facilities involving soil and site disturbance beyond the well pad and to a lesser extent outside the access tracks and production facilities. Impacts of decommissioning activities are likely to include:

- Temporary loss of productive land associated with the footprint of the decommissioning work areas including well sites, tracks, pipelines and production facilities;
- Loss of crop productivity of the directly affected land during decommissioning;
- Soil degradation associated with soil structure, fertility and biologic function and crop productivity;
- Disruption to paddock operations such as tillage, planting, irrigation, weed control and harvesting;
- Changes to drainage, erosion control and sediment management;
- Farm hygiene issues relating to weeds and disease management; and
- Site contamination from hydrocarbon spills (oils and lubricants) and waste materials.

8.5 Estimate of affected GQAL and strategic cropping land

The location of proposed infrastructure (wells, low pressure gathering lines, medium pressure pipelines and production facilities) is not known at this stage. Consequently, the direct impacts of the proposed development on GQAL (types A and B), strategic cropping land and particular agricultural enterprises, cannot be assessed. However, it is important to understand the area of land that may be disturbed or alienated from agricultural production and this is dealt with below.

The Soils, Landform and Geology study undertaken as part of the Surat Gas Project EIS (Coffey Environments, 2011) indicates that GQAL covers approximately 59% of the project development area, with the balance comprising other agricultural land, Crown Land, State Forest and industrial areas. Potential strategic cropping land comprises approximately 49% of the project development area, based on Queensland Government mapping (Attachment 2) and is mostly consistent with GQAL.

Information about the typical land requirements for the proposed coal seam gas infrastructure is provided in the following sections, and where relevant, an indication of the potential for production facilities and pipelines to be located in GQAL and/or SCL.

8.5.1 Pilot wells

Pilot wells comprise five wells drilled in a diamond-shaped arrangement, with each well about 200 m apart and a single well located in the centre. The proximity of the pilot well to existing access tracks will influence the ultimate land requirement, which could be up to 4.08 ha. The extent of GQAL affected by pilot well development will be heavily influenced by the specific location of drilling priority areas and the drilling technique used. At the time of preparing this report, these factors were not known.

8.5.2 Production wells

The land required for each production well is dependent on a number of factors. Site-specific features such as slope, drainage, landform and infrastructure design may increase the extent of the estimated footprint. Conversely, opportunities to reduce the required area exist where there are existing access tracks, and where the access track can be combined with the gathering lines right of way. Furthermore, where the gathering lines are separate to the access track, the right of way will be rehabilitated to the former land use thus reducing the overall area of affected land.

Arrow, based on operational experience, advises that development of a typical production well and associated gas and water gathering infrastructure results in the disturbance of 2-3% of the land associated with a typical production spacing [42] of 160 acres.[43] This advice provides a probable potential overall impact on agricultural land from development of coal seam gas wells and associated infrastructure.

We understand Arrow has committed to planning and designing development on agricultural land in a manner to minimise:

- the alienation of land;
- disruption to farming activities; and
- impacts on farm productivity.

It may well be that larger farming units offer further opportunities to reduce the proportion of affected land by virtue of the increased size of the farm.

The efficacy of rehabilitation methods will also determine the extent of agricultural land affected by the proposed development. Rehabilitation of Vertosol soil is a key issue, in particular rehabilitation to pre-disturbance soil water conditions.

Practices arising from the proposed rehabilitation trials[44] may provide effective methods that will reduce the residual impact as well as overall impact of the proposed development. Consequently, the estimated 2-3% land disturbance may result in an area of residual impact less than the expected disturbance. That being the case, 3% would most likely be the upper limit of disturbance that would reduce with successful rehabilitation and the implementation of the recommendations of this report.

[42] The estimated area is based on a 900m rectangular spacing for a single well head

[43] 160 acres is approximately 65 ha and is based on a notional well spacing of 1200m

[44] Pers. com., G. Coggan (Arrow Energy), 20 July 2011.

8.5.3 Medium pressure pipelines

The project description indicates medium pressure pipelines between 15 and 25 km long will be required to connect field compression facilities to either central gas processing facilities or integrated processing facilities. While the exact length of pipelines is not known, an understanding of possible impacts can be deduced using the upper value for pipeline length i.e. 25 km, and a typical 20-m-wide right of way.

Five of the six possible field compression facilities may be developed in or adjacent to GQAL resulting in connections from those facilities to adjacent central gas or integrated processing facilities potentially located in intensively farmed land. Arrow has advised that it would seek to avoid GQAL in selecting sites for production facilities, and that it would seek to reduce impacts on GQAL by designing pipeline routes to avoid intensively farmed areas. Rehabilitation of the pipeline right of way to former land use would substantially reduce the overall impact of medium pressure pipelines on intensively farmed land, subject to productivity of the disturbed land being reinstated. Loss of productivity would be addressed through compensation.

8.5.4 Production facilities

Eighteen production facilities (including six field compression facilities, six central gas processing facilities and six integrated processing facilities) are required for the proposed development with the facilities located to optimise coal seam gas recovery.

Electricity zone substations will be established adjacent to central gas and integrated processing facilities. It has been assumed the zone substations will adjoin these facilities adding to the area requirements at those sites. Coal seam water ponds will be installed at each integrated processing facility adding to the area required for those facilities.

A field compression facility typically requires 0.50 ha, a central gas processing facility 18 ha and an integrated processing facility up to 223 ha.

The areas in which the facilities might be developed have been nominated by Arrow. Analysis of the conceptual field development information provided by Arrow indicates that nine of the eighteen production facilities could be located in areas mapped as GQAL. Arrow has stated its intention to, where possible, avoid locating production facilities in areas that would disrupt existing intensive agricultural land uses.

When coal seam gas extraction ceases, production facilities will be decommissioned. Any contamination will be remediated and brine will be removed and processed offsite into salt products, or disposed to an approved landfill. The sites will be rehabilitated to enable agricultural production, with grazing being the minimum standard.

8.6 Summary of potential impacts

Impacts to agricultural enterprises result from three key issues – disruption to farming infrastructure and practices, disruption to cropping or breeding cycles and disturbance of the soil profile.

The extent and severity of these impacts on an individual farm are dependent on the size of the production unit and the extent and location of the coal seam gas infrastructure established on the property. In general, larger farms will not be as affected as smaller ones but the overall impact will be determined by the ability of the agricultural enterprise to absorb the impacts of lost productive land, reduced or lost productivity, and changed practices resulting in increased capital and operating costs.

8.6.1 Disruption to farming infrastructure and practices

All farming operations rely on infrastructure to support the activities carried out on the property. The configuration of the farm (e.g. layout of paddocks and irrigation infrastructure) is important to the productivity of the enterprise.

Drilling, construction, operation and maintenance activities that adversely alter the configuration of a farm will result in reduced efficiency of operation, and reduced productivity or increased costs to maintain productivity.

Farming practices (e.g. planting regimes) are designed to maximise yields and reduce costs. Development activities that adversely disrupt the practices will result in increased costs and potentially reduced yields or productivity where the disruption goes beyond that normally encountered in such farming operations (e.g. over sowing to eliminate unplanted crescent or corner islands in cultivation paddocks).

Unless landholders are consulted regarding future farming plans and practices, there is the potential for CSG activities to disrupt future farming infrastructure and activities in the same way as discussed above.

The extent and severity of these impacts on an individual farm will be dependent on the extent and location of the coal seam gas infrastructure established on the property.

The potential for the landholder to adopt new farming practices or crops may be restricted where CSG infrastructure has been planned around existing practices and farm layout.

8.6.2 Disruption to cropping or breeding cycles

Drilling and construction at inopportune times can disrupt cropping and to a lesser extent breeding. The latter is dependent on the proximity of the development activities to the breeding animals and the nature and intensity of any noise or vibration.

The diversity of crops grown in the project development area makes timing of drilling and construction activities to avoid cropping cycles (cultivation, planting and harvesting) difficult. However, disruption can be reduced by avoiding cultivation or periods of high traffic movements (e.g. harvesting). Disruption to cultivation patterns, once established, can result in greater crop losses than if the disturbance occurred in the fallow period allowing the property owner to adjust the pattern to account for the obstacle.

Piggeries, poultry farms and feed lots comprise extensive infrastructure and work spaces (pens, sheds, feeding stations and yards) that are not amenable to reconfiguration. Although developed on relatively small acreages, vineyards comprise fixed infrastructure including vine trellises, watering systems and grape crushing and storage facilities. This intensive farming activity is not readily amenable to reconfiguration.

8.6.3 Disturbance of soil profile

Soil and water are the most important assets of agricultural enterprises. They determine the types of crops that can be grown and the productivity of those crops. The soil structure is a key factor in the productivity of the land. It determines soil water retention, resistance to erosion and efficiency of biological and chemical processes.

Soil compaction, and mixing and inversion of soil horizons are the most significant impacts, as they directly affect the intrinsic properties of the soil. Reduced productivity is the primary impact of soil compaction, as water penetration and soil aerobic processes are directly affected. Poorly managed, soil compaction can lead to soil loss through erosion caused by accelerated overland flows and channelling of flows.

As described in Section 7.1, compaction, mixing and inversion of soil horizons breaks down the internal structures of the soils resulting initially, in reduced productivity and ultimately in potential long-term degradation. Vertosols and Dermosols are the soils most susceptible to disturbance and least able to be reinstated and rehabilitated to pre-disturbance function and productivity.

As has been described, the fertility of soils is dependent on their capacity to absorb and retain water. Rainfall, overland flood flows and irrigation are the key sources of soil water in the region. Two key impacts to water supplies and delivery are interruption or diversion of overland flood flows and disruption to irrigation infrastructure including apparatus and structures.

Section 7.2 has described how the impacts to irrigation infrastructure can reduce the extent of land that can be irrigated (e.g. shortening of centre-pivot irrigator or traveller irrigator) or the efficiency with which water can be delivered to the paddocks (e.g. head ditches, tailwater drains) or the effectiveness of the infiltration (e.g. integrity of contour banks, flood flow gradients).

In-situ infrastructure is less amenable to disturbance and reconfiguration because it has been designed to address the site-specific constraints (opportunities) of the property. The extent to which changes to irrigation infrastructure and soil conservation structures will reduce productivity, potentially contribute to soil degradation by erosion and increase capital and operating costs is dependent upon the placement of wells and gathering lines, the design of access tracks, construction methods and rehabilitation of disturbed structure.

9 Proposed mitigation and management measures

Mitigation and management of the potential impacts to agricultural enterprises and activities by coal seam gas exploration, construction, and operation and maintenance activities adopts the following hierarchy:

- avoidance;
- minimisation;
- mitigation;
- rehabilitation;
- inspection and monitoring.

Avoidance is implemented by either not undertaking a development activity at a site, or timing the activity to avoid interaction with the agricultural activity. For instance, it may be appropriate to exclude all development infrastructure and activities from high intensity agricultural activities such as vineyards, particularly the vine trellises. An example of a time separation may be works within a cotton irrigation site will only be permitted during the fallow period between crop cycles.

Minimisation may be achieved by changing the construction, operation and maintenance methods to minimise the area of impact or the actual procedure. For instance;

- stockpiling topsoil separately for reuse in rehabilitation of the work site
- investigating alternative drilling, construction and/or operational methodologies that could reduce the footprint on agricultural enterprises.

Mitigation may be undertaken by adopting procedures that stop or reduce the severity of an impact such as erosion and sedimentation on adjacent land not used for the proposed works, or stockpiling of topsoil for reuse in rehabilitation of the work site.

Rehabilitation will consist of procedures that will be performed either during the development process (placement and separation of stockpiles) or immediately afterwards (deep ripping and remediation of compacted temporary access ways) to repair any impacts on the agricultural system.

Inspection and auditing of development activities to ensure correct implementation of standard operating (environmental management) procedures and monitoring of rehabilitation to ensure the management objectives have been met and the outcomes achieved. Where rehabilitation has not met the desired outcomes, remedial measures shall be implemented to address the identified issue and ensure desired outcomes are achieved.

Avoidance and minimisation are most effectively achieved through design and project planning, as the location of coal seam gas infrastructure has been shown to directly affect capital and operating costs, and the long-term productivity of the agricultural enterprise, as a consequence of land lost to production or reduced yields. Consultation with landholders early during the design and project planning processes for specific enterprises will be essential to avoiding and minimising potential impacts on those enterprises.

Mitigation measures implemented through Arrow's Environmental Management System (EMS) should identify the environmental management objectives, outcomes, procedures and performance indicators to be assessed through inspection and monitoring.

Section 9.1 describes the objectives that should be incorporated in the design and planning phase of the project and are applicable to all agricultural enterprises. Best practice environmental management measures, generic to all farming operations, are detailed in Section 9.2.

9.1 Design and planning objectives

Site and route selection is the primary mitigation for avoiding and minimising impacts to agricultural enterprises and farming operations. The design and planning objectives are focused on the areas of agricultural land that represent the greatest constraints to the placement of the project infrastructure.

Highly constrained agricultural areas are strategic cropping land containing vertosol soils. Moderately constrained lands are the residual strategic cropping land and GQAL that are not associated with vertosol soils. Low constraint areas are agricultural land class C and D or pastoral lands. The distribution of the three levels of agricultural constraints is shown in Drawing No. 10185.1.4.

The following objectives should be included in the site and route selection procedures developed as part of Arrow's EMS.

Objective 1 Integrate development activities
To integrate development activities (and infrastructure) with farming operations recognising and understanding the particular farming practices and property specific development plans. Consult landowners on the location of infrastructure and construction methods to reduce overall impacts to the farming operation including capital and operating costs, and productivity.

Note: This could include groups of landholders where activities undertaken in one location may have the potential to impact other enterprises in the area, i.e. floodplain areas.

Objective 2 Intensive farming operations
Avoid infrastructure and associated farm management areas of intensive farming operations including piggeries, feed lots, vineyards, orchards, horticultural enterprises, poultry farms and small lot plantations.

Maintain a minimum separation (nominally 200 m) between animal enclosures and production wells and production facilities, to ensure biosecurity and/or animal health, as agreed with landholders.

Objective 3 Production facility site selection
Site production facilities, electricity substations and associated access tracks to avoid or reduce loss of cultivation areas and irrigation infrastructure.

Objective 4 Medium pressure pipelines
Route medium pressure pipelines along boundary fences or parallel to the direction of cultivation or parallel to soil conservation structures or in the lowest quality soils to reduce impacts on cultivation and irrigation systems.

Objective 5 Cultivation paddocks
Minimise the introduction of additional headlands in cultivation paddocks, by (in order of preference):

- Locating infrastructure outside cultivation areas;
- Locating infrastructure in headland areas or at the corners of cultivated areas;
- Utilising existing access tracks, or permanent controlled traffic access, to provide construction and operational access;
- Locating access tracks in headland areas or adjacent to boundary fences;
- Aligning access tracks and gathering lines parallel to the direction of cultivation and avoiding perpendicular or lateral connections;
- Locating infrastructure in areas identified as the lowest quality soil in the paddock.

Objective 6 Controlled traffic operations
Minimise the loss of productive land in controlled traffic paddocks, by (in order of preference):

- Locating infrastructure adjacent to boundary fences;
- Utilising existing access tracks and trafficked areas.
- Utilise controlled traffic runs for construction and operational access, if possible
- Aligning access tracks and gathering lines parallel to the controlled traffic runs and avoiding perpendicular or lateral connections;

Objective 7 Soil conservation structures
Maintain the operation and effectiveness of soil conservation structures, by (in order of preference):

- Where possible, avoid breaching, diversion or disturbance of contour banks, waterways and dams;
- Where possible, avoid earthworks that affect waterway function including slope and orientation;

- Locating wells, access tracks and gathering lines immediately downhill and parallel to soil conservation structures and avoiding perpendicular or lateral connections;
- Utilising existing access tracks and trafficked areas.

Objective 8 Spray irrigation
Locate wells, gathering lines and associated access tracks outside swept paths (effective coverage) of centre-pivot, and lateral and low pressure boom irrigators.

Objective 9 Surface irrigation
Maintain the integrity and efficiency of surface irrigation systems, by (in order of preference):

- Locating production wells and gathering systems at or adjacent to the end of head ditches or tailwater drains to avoid severance or fragmentation of those water delivery systems;
- Locating wells, gathering lines and access tracks adjacent to boundary fences;
- Aligning gathering lines and access tracks perpendicular to the direction of head ditches and tailwater drains i.e. parallel to the direction of surface flows and cultivation.

Objective 10 Cropping cycles
Maximise the opportunity to schedule development and routine maintenance activities, particularly drilling and construction (production well establishment), with the cropping cycle i.e. with fallow periods.

Objective 11 Access track design
Develop construction methods and design access tracks in cultivation paddocks to maintain the existing hydrologic and hydraulic regime of the site. It is important that the material used for construction of access tracks be evaluated for potential impacts to the farming operations (e.g. gravel above a certain size can cause damage to farm machinery).

Objective 12 Well pad design
To minimise disturbance and temporary loss of productive land associated with drilling wells by agreeing the layout of the drill pad and associated work areas with the landowner subject to any safety requirements.

9.2 Standard mitigation and management measures

Environmental management procedures developed as part of Arrow's EMS should include the following requirements, as specific management plans for agricultural land and/or as part of relevant plans e.g. erosion and sediment control. The environmental controls should be incorporated in standard operating procedures or work plans for construction, and operation and maintenance activities to ensure that the management measures are integrated with the work procedures promoting a consistent approach to work on agricultural land.

The following mitigation and management measures that address key issues raised in the above impact assessment should be incorporated in environmental management procedures comprising the Arrow EMS.

9.2.1 Site access

Access to private land must be undertaken in accordance with the provision within the Petroleum and Gas (Production and Safety) Act 2004:[45]

> ***555 Compliance with land access code***
>
> *A petroleum authority holder must—*
>
> *(a) comply with the mandatory provisions of the land access code to the extent it applies to the holder; and*
>
> *(b) ensure any other person carrying out an authorised activity for the petroleum authority complies with the mandatory provisions of the land access code.*

The location of infrastructure to be established on the property will be clearly identified on scaled

[45] *Petroleum and Gas (Production and Safety) Act 2004* Chapter 5 Common petroleum authority provisions Part 8 General provisions for conditions and authorised activities.

plans and be in accordance with the outcome of discussions and agreement reached with the landowner.

Access routes to well sites, to and along gathering lines and medium pressure gas pipelines shall be agreed with the landowner in advance of access being required.

Agreed access routes shall be clearly documented and marked out on the property including agreed points of ingress and egress. Where necessary, gates or grids of an acceptable standard will be installed in fences to restrict access to authorised personnel, vehicles, plant and equipment.

Notifications to landholders should be in accordance with land access agreements and the Queensland Government's Land Access Code, and shall be provided to the landowner to enable stock to be moved and access routes to be cleared of machinery and/or materials e.g. irrigation lines. The notice of entry will include a scaled map of the location and type of infrastructure to be developed on the property.

An Arrow representative shall be in attendance at the time of first entry to ensure the contractors have the appropriate environmental management procedures and any property specific information including agreed access routes.

A complaints management procedure shall be developed to ensure the timely and effective resolution of complaints regarding access or the activities being undertaken or the conduct of contractors on a property.

Works should be suspended when rainfall or storm events produce on-site conditions that if trafficked or worked would comprise the effectiveness of erosion and sediment control structures, lead to rutting and compaction of soils, and mixing or inversion of soil horizons.

The work site and associated access routes shall be inspected for notifiable weeds and pest plants and animals prior to access being obtained. If identified, weeds shall be managed in accordance with ‘Petroleum Industry - Minimising Pest Spread Advisory Guidelines, Queensland Department of Primary Industries and Fisheries, June 2008’.

All vehicles, plant and equipment shall be washed down and certified clean pursuant to the above guidelines and in accordance with the land access agreement which incorporates the results of a risk assessment of notifiable weeds and pest plants.

9.2.2 Site establishment

The work site shall be clearly delineated, using means and methods appropriate to the nature of the works (e.g. temporary fencing, barricade tape, traffic control measures). The selection and implementation of site establishment measures must ensure construction activities do not extend beyond the agreed extents of the work site, and people, stock and wildlife are excluded from the work site.

Vegetation shall be cleared from the site and stockpiled within the work site and soil conservation works, separately from soil stockpiles. Where appropriate, vegetation shall be mulched and reused in site rehabilitation, unless environmental obligations dictate otherwise.

Construction site erosion and sediment control structures shall be established prior to ground disturbance and be consistent with best practice erosion and sediment control and Technical Guidelines for Environmental Management of Exploration and Mining in Queensland - erosion control. Implementation of these requirements shall ensure:

- Clean water diversion (graded bank discharges and spillways) designed by a competent soil conservationist is installed up-gradient of the proposed cleared pad and water collected and disposed in a manner that does not cause erosion of the site or adjacent land;
- Interception drains and temporary sediment storages designed by competent soil conservationist are constructed down gradient of the proposed site pad to collect run-off events to at least Q-3-month discharge.

Topsoil is to be assessed and managed as per Technical Guidelines for Environmental Management of Exploration and Mining in Queensland Part D - Growth Media Management.

Topsoil shall be stripped and stockpiled separately to subsoils. Where necessary, stockpiles will be separately established for each soil horizon. Topsoil stockpiles shall be:

- A maximum height of 2 m;
- Protected from erosion by implementation of appropriate erosion and sediment control structures;
- Used within 12 months of stripping or protected and sown (and periodically resown) with sterile pasture grasses or legumes to maintain organic matter and biological function.

Batters and embankments of drill pads and production facility benches shall be constructed at appropriate slopes and protected using soil stabilisation methods and treatments to minimise erosion.

9.2.3 Construction and operation

When operating on black soils (Vertosols or Dermosols), drilling fluids and wastewater to be collected and stored on-site in sealed storage tanks until recycled or treated (if necessary) and disposed.

Collected wastewater to be taken off site and disposed of in an appropriate manner unless otherwise agreed with the landowner.

Cuttings are to be stockpiled adjacent to the well or in containers and disposed of in accordance with the environmental authority conditions and landowner requirements.

At the conclusion of drilling the well is to be appropriately completed (capped or fitted with well head equipment) to ensure there are no uncontrolled releases of gas or water.

All waste (solid and liquid) is to be managed in accordance with a waste management plan (prepared as part of the Arrow EMS) that includes procedures for the collection, containment, treatment (if necessary) and disposal of waste.

All chemicals, oils, fuels and greases are to be stored in appropriate containers and, if necessary, in appropriately constructed bunds in accordance with a hydrocarbon or chemical management plan prepared as part of the Arrow EMS.

Soils contaminated by oil, fuel and grease spills shall be managed in accordance with a hydrocarbon management plan (prepared as part of the Arrow EMS) that includes procedures for excavation and removal to a licensed landfill or remediation at site.

Where contamination has occurred, the site shall be investigated and remediated in accordance with the *Draft Guidelines for the Assessment and Management of Contaminated Land in Queensland*, Qld Dept. of Environment[46], 1998 (80pp).

Stockpiles of imported fill for bedding of pipes are to be placed adjacent to trench separately from vegetation, topsoil and subsoil stockpiles.

The root systems of shelter belt and shade trees to be retained will be protected by reference to the definition of the tree protection zone in AS 4970 2009: Protection of trees on development sites.

9.2.4 Rehabilitation

Rehabilitation of disturbed areas is to be progressive and immediately following the completion of construction. Rehabilitation should be completed in accordance with a procedure, developed with consideration of relevant guidelines. All excess imported fill and residual subsoil shall be removed from work site and reused or disposed by agreement and in accordance with the landowner's requirements.

Deep ripping and cross ripping of all construction areas and temporary access tracks prior to topsoiling should be to a depth of at least 0.3 m.[47]

Backfilling of soils shall be in the reverse order of removal: imported fill or padding material (pipelines only), subsoil and finally topsoil. Backfilling shall be progressive and undertaken regularly during pipeline construction.

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[46] Now the Department of Environment and resource Management

[47] The purpose of the deep ripping is to establish a disturbance zone that after top soiling approximates the expected root zone of crops and pastures.

Padding material and subsoils used to backfill pipeline trenches shall be compacted to reduce slumping. Compaction shall not extend beyond 0.5 m below NSL.

Topsoil shall be replaced to the depth of the original soil profile.

Topsoil backfilling shall be continued to 0.1 m above NSL over the pipeline trench to account for slumping and settlement of reinstated land.

Residual topsoil shall be salvaged and stockpiled near the work site, out of farm operations areas at landholder's direction.

Once reinstated the topsoiled area shall be again ripped to a depth of 0.3 m below NSL to promote infiltration and assist the reestablishment of micro and macro-pore connections between the soil horizons.[48]

Following reinstatement, the work site shall be regraded to original surface contours except for any pipeline trench crown left to account for settlement. Regrading of trench area shall be integrated with farm crop preparation.

Erosion and sediment control structures shall be retained until reinstated soils have been stabilised including by the sowing of sterile pasture grasses or legumes or crops.

Clean water diversions, down gradient soil erosion control works and temporary sediment dams shall be rehabilitated to pre-construction site levels and the site ripped prior to sowing with crops.

Sediment fencing shall be removed prior to cultivation and disposed in accordance with landowner requirements, or in accordance with the waste management plan of the Arrow EMS.

All disturbed infrastructure shall be replaced or rehabilitated to pre-disturbance function.

[48] The combined ripping pre and post top soiling should establish a disturbance zone for root extension up to 0.5m deep

Production well sites shall be fenced to exclude stock and restrict unauthorised access as per standard operating procedures.

9.2.5 Inspection and monitoring

Erosion and sediment control structures should be inspected regularly to ensure their effectiveness.

Prior to and following storm events and periodically during long periods of rain, erosion and sediment control structures should be cleaned and, if necessary, reinstated to ensure their effectiveness.

Rehabilitated work sites shall be visually inspected for flow diversions and evidence of erosion associated with trench slumping or incomplete reinstatement of surface contours.

Rehabilitation shall be monitored on an ongoing basis, in accordance with a rehabilitation monitoring procedure that defines objectives of the rehabilitation to reach a stable landform, based on existing land use, and includes landholder requirements. Monitoring will assess its success, and identify and implement any remedial works required to rectify observed deficiencies. The success of rehabilitation will be determined by performance measures agreed with the landowner that reflect the soil properties and productivity of agricultural activities carried out on the property.

A method for assessing impacts to productivity (crop yields) shall be developed and should incorporate an appropriate number of control and sampling sites in the adjacent and rehabilitated areas. A typical assessment method involves the sampling and analysis of the rehabilitated and adjacent undisturbed land using ten 1 m^2 quadrats in each area to assess crop yield or pasture health.

9.3 Residual impacts

Without mitigation, CSG development has the potential to have residual impacts on agricultural enterprises. The effects may not be known for some time due to the recovery times for soil function including accumulation of organic matter mass, reestablishment of soil continuity structures (micro and macro pores) and desired surface levels. The latter relates to the extent of settlement of reinstated or reshaped soils and its affect on drainage patterns, water delivery structures and flood flows.

To manage these potential impacts a series of objectives and mitigation measures have been identified in Section 9 of this report, which are focused on addressing the issues identified in Section 8.

The success of rehabilitation will determine the degree and extent to which the disturbed land will achieve pre-disturbance productivity. It may take some time before the degree of success, or otherwise, of the mitigation measures can be assessed. A detailed monitoring program is required to ensure the success of the mitigation measures is monitored and additional actions taken as required.

10 Conclusions

The project development area of the Surat Gas Project covers some 8,600 km^2 of which 59% is classified as GQAL and 49% as potential strategic cropping land. The majority of strategic cropping land is encompassed by GQAL.

Arrow proposes to develop the extensive coal seam gas reserves through the development of wells, gathering lines, medium pressure pipelines and production facilities (field compression facilities, central gas processing facilities and integrated processing facilities).

Concerns about the impact of development activities on GQAL, strategic cropping land and other agricultural land has prompted Arrow to commit to understanding agricultural enterprises and farming practices in the region and to develop appropriate measures to avoid, minimise or manage the impacts of its activities on farm productivity, particularly enterprises based on black soils.

This study has identified the agricultural enterprises of the region and the gross value of production. It has described the farming practices carried out across a range of enterprises, particular practices and the issues that contribute to reduced yields leading to potentially increased capital and operating costs. Importantly, this study has described the soil properties that underpin the classification of a large part of the project development area as GQAL and strategic cropping land.

Potential impacts of drilling, construction, operation and maintenance, and decommissioning activities on farming operations have been identified and described.

Using project description information provided by Coffey Environments and an estimate of the disturbance and alienation impacts from Arrow, the upper extent of land disturbance associated with production well development has been estimated to be 3%, based on Arrow's current operational experience.

The actual extent of the impact on GQAL, potential SCL, grazing and other land, will be quantifiable once the location and layout of the well fields, pipelines, tracks, electricity transmission lines, zone substations and production facilities has been designed.

The efficacy of rehabilitation methods will also determine the extent of agricultural land affected by the proposed development. The rehabilitation of Vertosol soils has been noted as a key issue, in particular, the rehabilitation to original soil water conditions.

Practices developed during rehabilitation trials may provide additional methods that will reduce the residual impact as well as overall impact of the proposed development.

Consequently, the estimated 2-3% land disturbance from production wells and gathering systems may result in an area of residual impact less than expected disturbance. The 3% may be an expected upper limit of disturbance that would reduce with successful rehabilitation and the implementation of the recommendations of this report.

This study has found that the potential impacts are associated with four key issues – disruption to farming infrastructure and practices, disruption to cropping or breeding cycles, disturbance of the soil profile and potential changes to overland flow.

The extent and severity of these impacts on an individual farm were found to be dependent on the extent and location of the coal seam gas infrastructure established on the property.

Compensation will address issues such as the ability of the agricultural enterprise to absorb the impacts of lost productive land, reduced or lost productivity, and changed practices resulting in increased capital and operating costs.

In our view, Arrow will need to work closely with landholders during the planning and design process, to ensure that the potential impacts on individual agricultural enterprises are fully considered during this process. Mitigation and management measures to be incorporated in Arrow's EMS as part of environmental management procedures or as a specific agricultural management plans have been proposed. The environmental controls adopt the following hierarchy:

- avoidance;
- minimisation;
- mitigation;
- rehabilitation; and
- inspection and monitoring.

Avoidance and minimisation were identified as the most effective mitigation measures with site and route selection nominated the primary mitigation. Twelve objectives to guide site and route selection are proposed.

The residual effects of coal seam gas development on agricultural enterprises may not be known for some time due to the recovery times for soil function including accumulation of organic matter mass, reestablishment of soil continuity structures (micro and macro pores) and desired surface levels. The latter relates to the extent of settlement of reinstated or reshaped soils and its affect on drainage patterns, water delivery structures and flood flows. The success of rehabilitation will determine the degree and extent to which the disturbed land will achieve pre-disturbance productivity.

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12 Attachment 1 – Agronomic methods

Table A Overview of agronomic methods for summer cereal crops grown in the Darling Downs region

Summer							
Crop	Uses	Environment required	Major inputs	Planting	Growth season	Harvest	Fallow
Sorghum	Stockfeed	Deep, fertile, clay loams. With adequate rainfall and irrigation, may yield 11T ha-1.	Nitrogen (0-30 kg ha^{-1} dryland; 120-150 kg ha^{-1} irrigated) Phosphate (0-10 kg ha^{-1} dryland; 10-20 kg ha^{-1} irrigated) Total water requirements (500-600mm)	Early-mid Sep	Sept-Jan	Dec-Feb	June-Aug
Maize	Stockfeed, industrial starch, confectionary	Soils with good moisture holding capacity; pH 5.6 – 7.5. With adequate rainfall and irrigation, may yield 12T ha-1.	Nitrogen (0-40 kg ha^{-1} dryland; 80-200 kg ha^{-1} irrigated) Phosphate (0-5 kg ha^{-1} dryland; 0-20 kg ha^{-1} irrigated) Total water requirements (500-600mm) Zinc (1-1.5 kg ha^{-1} w/ equal parts urea)	Dryland & irrigated: Jan-Feb. Irrigated or good rain grown conditions: Late Aug-early Sep	Mid Sept to Feb	4.5-6 months following planting	-
Millet	Grain, grazing	Light textured, neutral to slightly acidic soil. For grazing 0.4-0.6ha Millet required per head; 2-3 grazings.	Nitrogen (25-30 kg ha^{-1}) Phosphate (5-10 kg ha^{-1})	Mid Sep-Feb	5-7wks for grazing. 80-100 days for grain.	Grazing: at 30-80cm height. Grain: at boot stage just prior to seed head emergence.	Double - cropped

Table B Overview of agronomic methods for winter cereal crops grown in the Darling Downs region

Winter							
Crop	Uses	Environment required	Major inputs	Planting	Growth season	Harvest	Fallow
Barley	Human consumption, stockfeed	Deep, fertile, friable, clay soils	Nitrogen	Late Apr-mid Jul	Apr- Nov	Oct-Nov	Nov-Apr
Oats	Human consumption, stockfeed (race-horses)	Deep, fertile, friable, clay soils	Nitrogen (13-26 kg ha^{-1}) Phosphate (16-32 kg ha^{-1}) Dependent upon row spacing	Early-mid May	May-Nov	Oct-Nov	Nov-May
Triticale	Human consumption, stockfeed	Deep, fertile, friable, neutral to acid clay soils	Nitrogen Water	Jun-Jul	June-Nov	Oct-Nov	Nov-Jun
Wheat	Human consumption, stockfeed	Deep, fertile, friable, clay soils	Phosphate (6-10 kg ha^{-1}) Zinc	May-Jul	May-Nov	Oct-Nov	Nov-May
Canary	Birdseed	>60cm of wet soil	Water	May-Jun	May-Nov	Oct-Nov	Nov-May
Rye	Human consumption	Most soil types	-	May-Jun	May-Nov	Oct-Nov	Nov-May

Table C Overview of agronomic methods for summer pulse crops grown in the Darling Downs region

Summer							
Crop	Uses	Environment required	Major inputs	Planting	Growth season	Harvest	Fallow
Sunflower	Oilseed, bird seed and confectionary	Deep soils w/ good subsoil moisture; well drained. Plantings at 25-50,000 plants/Ha for dryland and 60,000 plants/Ha for irrigation.	Dependent upon row spacing; Nitrogen (5-10 kg ha^{-1}) Phosphate (10-25 kg ha^{-1}); applied pre planting	Mid-Aug if full profile of stored water; late plant Jan-Feb	Approx 70-85 days to seed maturity.	Harvest maturity approx 130 days. Moisture <10%	Leave little stubble cover for fallow.
Mungbean	Export for 'bean sprouts'	Avoid heavy, poorly drained soil or light, sandy soil	Nitrogen – not necessary Phosphate (0-10 kg ha^{-1}) Zinc (20-30 kg ha^{-1}) where deficiencies occur	Jan-mid Feb	Indeterminate flowering habit	Moisture at 12-14%, when >90% pods physiologically mature	Not greater than 12 months to avoid long fallow disorder.
Navy bean	Culinary use	Well-drained sandy loam or light clay loam. Dryland average yield 0.75t/ha; irrigated average yield 1.8t/ha.	Nitrogen (100-200 kg ha^{-1}) Phosphate (0-10 kg ha^{-1}) Sulfur (100-150 kg ha^{-1}) where deficiencies occur Zinc (20-30 kg ha^{-1}) where deficiencies occur	Later season varieties late Dec - late Jan; quicker varieties early Jan - mid Feb.	12-17wks.	Generally 14-16 wks	-
Soybean	Human consumption, stockfeed	Friable non-crusting soils. Common yield 1-2t/ha dryland; 2-4t/ha irrigated; up to 50% higher in favourable conditions.	Nitrogen – not recommended Phosphate (0-25 kg ha^{-1}) Potassium (40 kg ha^{-1}) where deficiencies occur Zinc (30 kg ha^{-1} on clay soils; 15-20 kg ha^{-1} on sandier soils)	Dec; may extend from mid-Nov to mid-Jan under favourable conditions	115-150 days.	Apr-May; moisture >16%	-

Table D Overview of agronomic methods for winter pulse crops grown in the Darling Downs region

Crop	Uses	Environment required	Winter Major inputs	Planting	Growth season	Harvest	Fallow
Chickpea	Human consumption	Well-drained, neutral to slightly alkaline, friable loams and clays	Nitrogen inoculated Phosphate (6-10 kg ha^{-1}) Zinc	Late-mid Jun	Jun-Nov	Oct-Nov	Nov-Jun
Faba bean	Human consumption, stockfeed	Well-drained, good depth, neutral to alkaline (grey/black), friable, clay soil	Nitrogen inoculated Phosphate (6-10 kg kg ha^{-1})	May	May-Nov	Oct-Nov	Nov-May
Fenugreek	Fodder, spice crop	Well-drained, deep soils	Nitrogen inoculated	Late Apr-June	-	- n/a	-
Field pea	Human consumption, stockfeed.	Acid sands to heavy, friable, alkaline clays	Nitrogen inoculated	May-Jun	-	- n/a	-
Lentil	Human consumption	Light, well-drained, friable soils	Nitrogen inoculated	Late Apr-Jun	Apr-Nov	Oct-Nov	Nov-Apr
Lupin	Human consumption Stockfeed	Well-drained, light textured, acid to neutral soil	Nitrogen inoculated	April-Jun	-	- n/a	-
Linseed	Oilseed	Light to medium textured clays and loams	Nitrogen (up to 30 kg ha^{-1} dryland; up to 50 kg ha^{-1} irrigated) Phosphate according to soil test Alkaline clay soils may require Zinc fertiliser	May-mid Jun	May-Jan	Nov-Jan	Jan-May
Rapeseed	Oilseed	Friable clays and clay loams	Nitrogen (up to 40 kg ha^{-1} dryland; 100 kg ha^{-1} irrigated) Superphosphate (7.5 -12.5 kg P ha^{-1})	Mid Apr-mid Jun	Apr-Dec	Oct-Dec	Dec-Apr
Safflower	Oilseed	Warm dry environment Deep (>1m), fertile, neutral to alkaline clay soil	Nitrogen (30 kg ha^{-1}) Phosphate according to soil test Demanding of water	Mid Jun	Jun-Jan	Nov-Jan	Jan-Jun

Table E Cotton practice calendar

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec

Soil preparation												
Planting												
Irrigation activities												
Chemical application window												
Picking												
Ground prep for winter crops where grown												

Table F Overview of agronomic methods for cotton grown in the Darling Downs region

Crop	Uses	Environment required	Major inputs	Planting	Growth season	Harvest	Fallow
Cotton	Fibre	With adequate rainfall and irrigation may, yield 12 bails ha-1. Yields decrease with later plantings. Irrigation requirement 4-5ML/ha.	Irrigated: Nitrogen (0-180 kg ha-1) Phosphate (0-25 kg ha-1) Potassium (60-125 kg ha-1 Muriate of Potash) Zinc (20 kg ha-1) Sulphur where deficiencies occur Raingrown: Generally no fertiliser required	Irrigated: Mid-end Oct Raingrown: Late Sep-mid Jan. Soil temp >17DegC for 3 consecutive days.	>200 days for average season day degrees 2190. Peak flowering usually late Jan-Feb	Apr-Jun. >80% bolls open.	Long fallow 18 months no rotational crops. Short fallow 6 months legume rotational crops after above average autumn/ winter rain.

Table G Overview of agronomic methods for horticulture crops grown in the Darling Downs region

Crop	Environment required	Major inputs	Planting	Growth season	Harvest	Fallow
Beetroot	Wide range of soils from sands to clay loams, to clays -will grow well in alkaline soils	Fertiliser as per soil tests Irrigation Pesticides	July-March	July-May	September-May	May-July
Broccoli	Wide range of soils from sands to clay loams, optimum pH slightly acidic, however will grow well in alkaline soils	Fertiliser as per soil tests Irrigation Pesticides	December-May	December-August	March-August	August-December
Brussel Sprouts	Wide range of soils from sands to clay loams, optimum pH slightly acidic, however will grow well in alkaline soils	Fertiliser as per soil tests Irrigation Pesticides	December-March	December-mid June	Late march-mid June	Mid June-December
Cabbage	Wide range of soils from sands to clay loams, optimum pH slightly acidic, however will grow well in alkaline soils	Phosphate (60-80kg kg ha^{-1}) Nitrogen (60-85kg ha^{-1}) Potash (60-180kg ha^{-1})	June-April	All year	August-June	-
Chinese Cabbage	Wide range of soils from sands to clay loams, however will grow well in clay alkaline soils	Fertiliser as per soil tests Irrigation Pesticides	July-April	July-June	September-June	June-July
Carrots	Slightly acidic, deep, well drained, friable soils	Fertiliser as per soil tests Irrigation Pesticides	July-March	July-June	October-June	June-July
Cauliflower	Wide range of soils from sands to clay loams, optimum pH slightly acidic, however will grow well in alkaline soils	Fertiliser as per soil tests Irrigation Pesticides	December-March	December-June	Mid March-June	June-December
Celery	Grows in variety if soils from sands to clays, requires reasonable drainage	Fertiliser as per soil tests Irrigation Pesticides	August-February	August-Mid June	December-Mid June	Mid June-August
Cucumber	Deep, friable, slightly alkaline, well-drained soils	Fertiliser as per soil tests Irrigation Pesticides	September-January	September-March	November-March	March-September
Lettuce	Well drained slightly alkaline soils	Nitrogen (up to 200 kg ha^{-1}) Phosphate according to soil test (up to 100 kg ha^{-1}) Potassium (up to 150 kg ha^{-1})	Year round	Year round	Year round	-
Marrow	Deep, friable, slightly alkaline, well-	Fertiliser as per soil tests	September-	September-	November-	March-

Crop	Environment required	Major inputs	Planting	Growth season	Harvest	Fallow
Squash and Zucchini	drained soils	Irrigation Pesticides	January	March	March	September
Melons	Deep, friable, slightly alkaline, well-drained soils	Fertiliser as per soil tests Irrigation Pesticides	September-December	September-March	December-March	March-December
Spring onion	Deep, well drained, slightly alkaline, medium to heavy friable clay loams	Fertiliser as per soil tests Irrigation Pesticides	August-May	August-July	October-July	July-August
White and brown onion	Deep, well drained, slightly alkaline, medium to heavy friable clay loams	Nitrogen (100-150 kg ha^{-1}) Phosphate (0-70 kg ha^{-1})	March-July	March-early November	August- early November	Early November-March
Pumpkins, triambles, trombones etc.	Deep, friable, slightly alkaline, well-drained soils	Fertiliser as per soil tests Irrigation Pesticides	September-December	September-March	December-March	March-September
Sweet corn	Sandy loam to clay loam over a wide pH range, with the optimum neutral to slightly alkaline	Fertiliser as per soil tests Irrigation Pesticides	August-January	August-late March	Mid October-late March	Late March-August

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Table H Overview of agronomic methods for fruit crops grown in the Darling Downs region

Crop	Uses	Environment required	Major inputs	Planting	Growth season	Harvest	Fallow
Stone fruit	Human consumption	Sandy loams or well-drained soils, pH 5.5 – 6.5; no heavy clay or rock within 1m of surface, elevated well-aired position. Yields >20T ha^{-1}; tree life 8-12yrs.	13:6:12 N:P:K fertiliser; 95kg ha^{-1} during bud movement; 40 kg ha^{-1} during Sept; 80 kg ha^{-1} during Dec; 55 kg ha^{-1} during March. Not required in winter dormancy phase. Requires regular spray program.	Maturity 18 mnths – 2 years. Full bearing stage 4 yrs.		Sept-late Oct	Winter dormancy.
Apples	Human consumption	Granite belt, well-drained loam soil, pH 6.0-6.5.	High density: Non-bearing 200-250g per year of tree age of an N:P:K 15:4:11, half in Aug, half in Nov. Bearing 800-1000g per year of tree age of an N:P:K 12:5:14, half in Aug, half in Nov.	Winter. Maturity at 4 yrs.		Feb-Mar	Winter dormancy.
Berries	Human consumption.	Fertile, friable soils, light sandy soils or heavy clays not suitable. Strawberries pH 6.5 – 7.0; raspberries pH 5.5-6.5; blueberries pH 4.5-5.5. Yield for raspberries 2-3kg/plant at 4 years; blueberries 4-7kg/plant; 500-750g/plant.	Well-composted animal manure at 8 –10 t/ha several weeks before sowing a green manure crop. Subject to leaf tissue analysis results, generally after 2nd year 60-100kg ha^{-1} N, 40-60 kg ha^{-1} P, 80-100 kg ha^{-1} K. When mature, 80-140kg ha^{-1} N, 60-80 kg ha^{-1} P, 100-140 kg ha^{-1} K	After frosts, blueberries may fruit after 15 mnths.	Flowering spring, summer and autumn.	Blueberries – early summer to autumn. Strawberries Nov-Jan.	May become dormant if night temps <5DegC.
Citrus Trees; orange, lime, lemon, mandarin	Human consumption	Deep, well-drained loam to sandy loam; pH 6.0-6.5. Normal density planting yield approx 9 kg/tree in the third year, high density planting 18kg/tree to the sixth year; 150-180 kg/tree mature tree in tenth year.	No pre-plant fertiliser. Rates determined from leaf-soil analysis. Per year of tree: 100 g N: 10 g P: 50 g of K/tree; equivalent to 400 g of N:P:K mixed fertiliser 13:2:13, plus 100 g urea applied June-July.	Autumn-late winter	Main leaf flush and flowering in spring, fruit development Nov-Dec.	March-Jul with picking occurring Jan-Oct.	Root/ shoot growth slowed in winter
Pears	Human consumption	Deep, well-drained clay loam to sandy loams. pH 6.0-6.5. Low humidity, 500-1500 hrs chilling.	High density bearing: 40g N/tree/year for each year of tree age	Winter		Feb-Mar, subject to flesh firmness and TSS results	Winter dormancy

13 Attachment 2 – SCL trigger maps

metres

SCALE
1 : 1 000 000

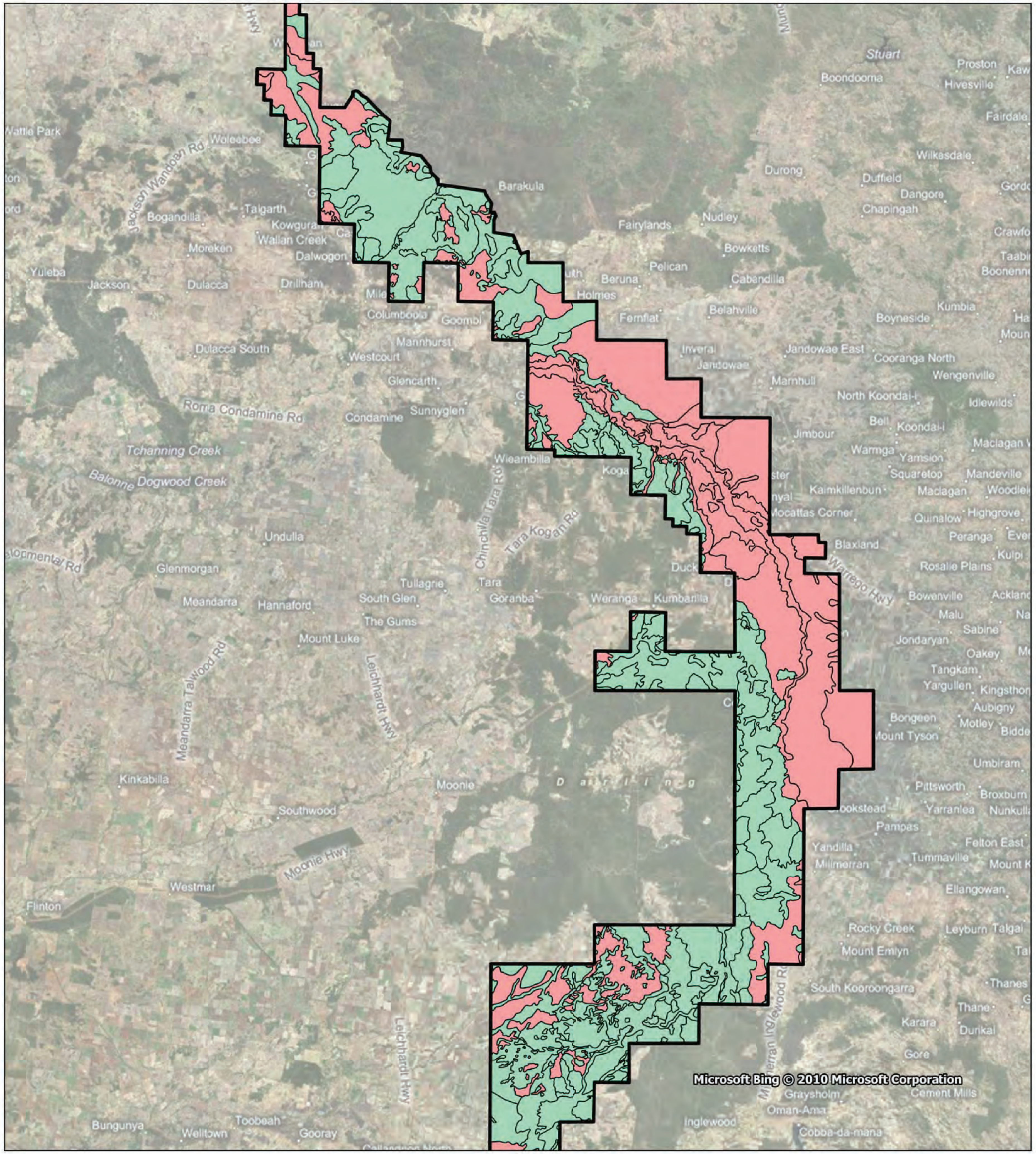
ORIENTATION
NORTH

SOURCES

LEGEND

Vertosols

Non-Vertosols



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AGRICULTURE WATER ENVIRONMENT

PROJECT
SURAT GAS PROJECT

CLIENT
ARROW ENERGY

DRAWING
DISTRIBUTION OF
VERTOSOLS
IN PROJECT AREA

DATE	DRAWN
MAY 2011	BWS
SCALE	CHECKED
1:1 000 000	PLM

PROJECT NO	DRAWING NO	REVISION
10185	1.1	A

metres

SCALE
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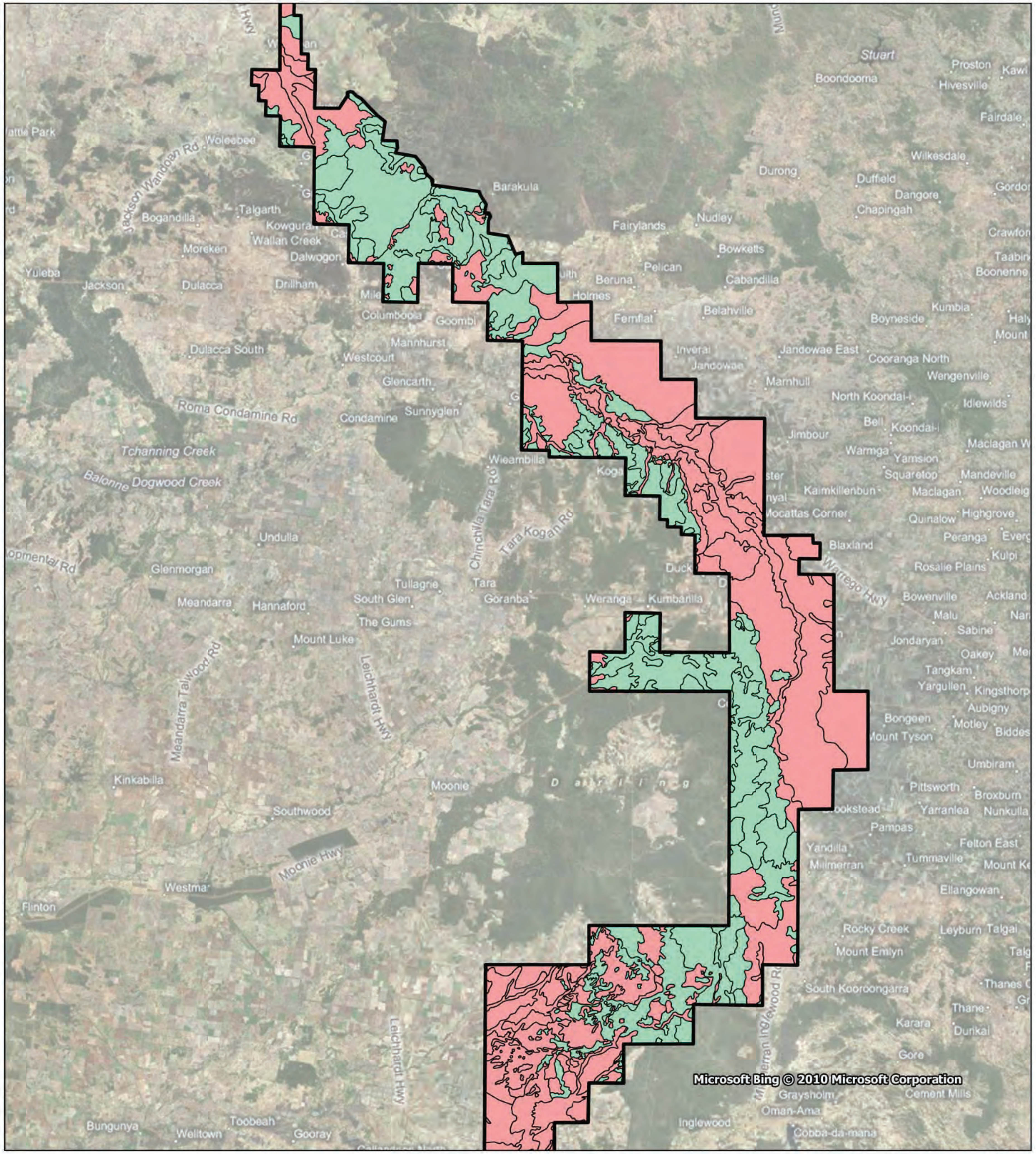
ORIENTATION
NORTH

SOURCES

LEGEND

Good Quality Agricultural Land

Not Good Quality Agricultural Land



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AGRICULTURE WATER ENVIRONMENT

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PROJECT
SURAT GAS PROJECT

CLIENT
ARROW ENERGY

DRAWING
DISTRIBUTION OF
GOOD QUALITY AGRICULTURAL LAND
IN PROJECT AREA

DATE		DRAWN
MAY 2011		BWS
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PROJECT NO	DRAWING NO	REVISION
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metres

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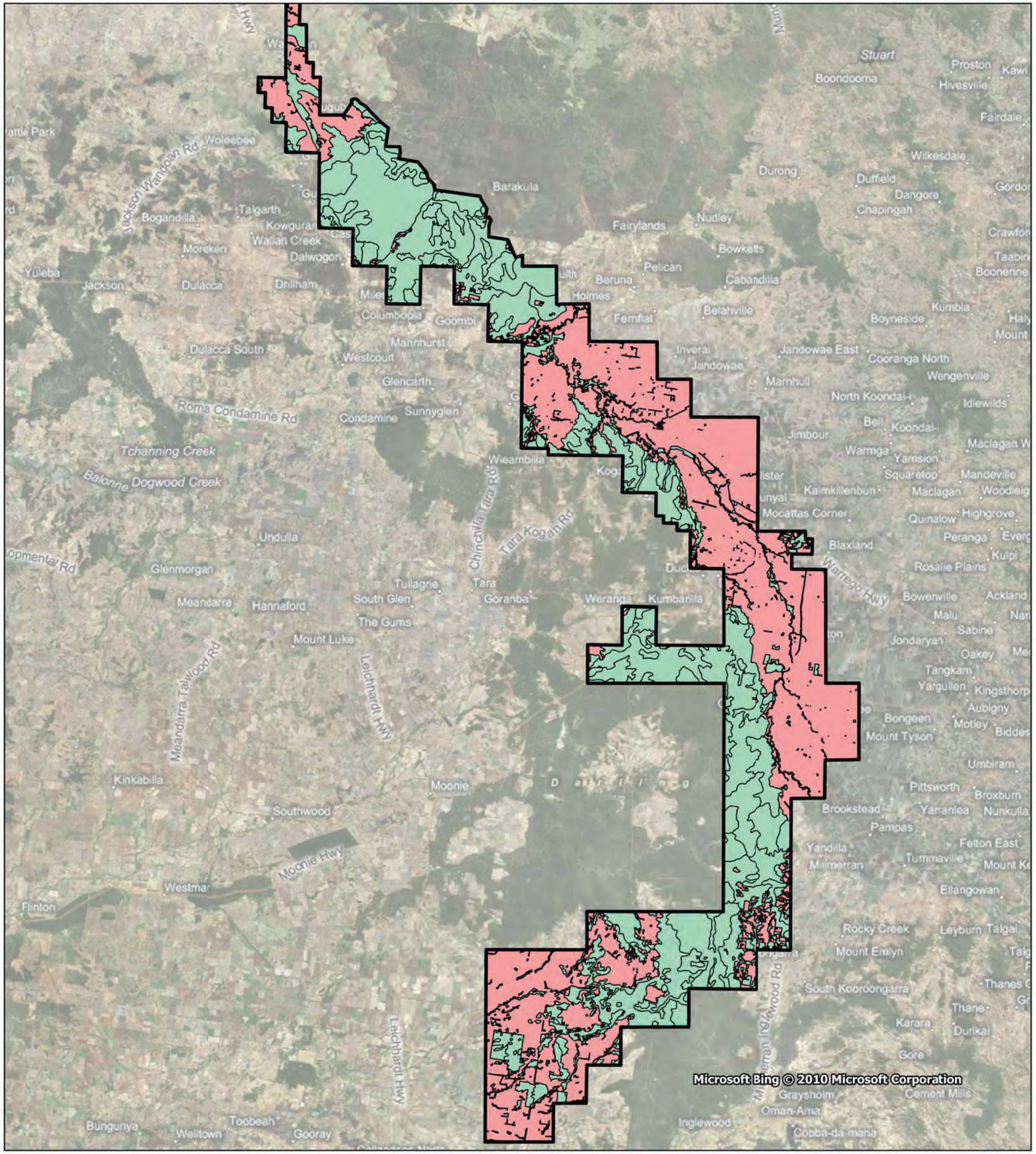
ORIENTATION
NORTH

SOURCES

LEGEND

Strategic Cropping

Non-Strategic Cropping



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PROJECT
SURAT GAS PROJECT

CLIENT
ARROW ENERGY

DRAWING
DISTRIBUTION OF STRATEGIC CROPPING IN PROJECT AREA

DATE	DRAWN
MAY 2011	BWS
SCALE	CHECKED
1:1 000 000	PLM

PROJECT NO	DRAWING NO	REVISION
10185	1.3	A

metres

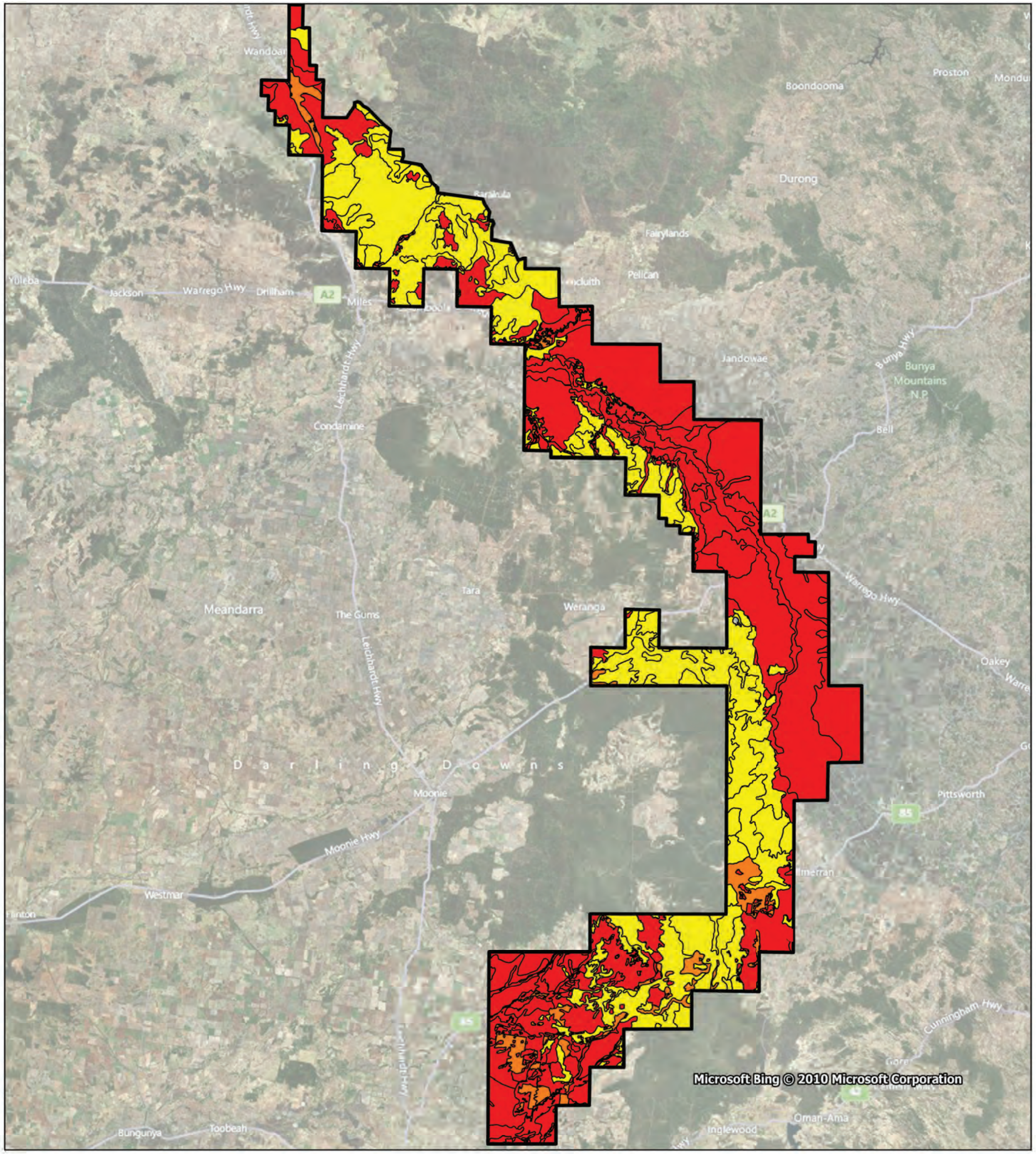
SCALE
1 : 1 000 000

ORIENTATION
NORTH

SOURCES

LEGEND

- High Constraints
- Moderate Constraints
- Low Constraints



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PROJECT
SURAT GAS PROJECT

CLIENT
ARROW ENERGY

DRAWING
AGRICUTURAL CONSTRAINTS IN PROJECT AREA

DATE		DRAWN
MAY 2011		BWS
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1:1 000 000		PLM
PROJECT NO	DRAWING NO	REVISION
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