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South Galilee Coal Project
Soil quality and land suitability assessment

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Purpose of this report

This report describes the work undertaken during a soil quality and land suitability assessment as part of the environmental impact statement for the South Galilee Coal Project (SGCP). The SGCP is a proposal to develop and operate a thermal coal mine near Alpha in the Galilee Basin of central Queensland.

The SGCP is located within Mining Lease Application area (MLA) 70453 which is between 7 and 31 km west of Alpha. An infrastructure corridor is proposed to connect the SGCP to the common user rail line proposed by other proponents to link the Galilee Basin to the Abbot Point Coal Terminal. The infrastructure corridor commences in the north eastern corner of MLA 70453 and extends approximately 35 km northwards.

The study aimed to assess the environmental issues and impacts associated with development of MLA 70453 and the infrastructure corridor in relation to soils. Many soil features are closely related to topographic position in the landscape and thus assessment of topography is an integral part of soil assessment.

A soil survey was undertaken with sufficient data collection to generate 1:100,000 mapping for areas not expected to be impacted or expected to be subject to indirect disturbance. More intensive investigation at a mapping scale of 1:50,000 was undertaken for those areas with expected direct disturbance.

The soils identified during the soil survey formed the basis for soil quality and land suitability assessment in this study.

Environmental values of the area

Topography

The existing landscape is dominated by very gently sloping plains and rises of low relief. The plains and rises generally decline from more elevated low hills along the western boundary of the study area towards the north-east and east.

Very gentle slopes of up to 3% on plains, drainage depressions and gently undulating rises account for just over 56% of the SGCP study area. Gently undulating to undulating rises with steeper slopes of up to 10% occupy almost 37% of the area.

Scarps with outcrops of deeply weathered bedrock are scattered in narrow strips throughout the gently undulating rises, occupying less than 1% of study area. Slopes on the scarps are commonly steep but can vary from 3 to 60%.

Steep to rolling low hills in the west occupy just over 6% of the SGCP study area. The hill slopes are commonly more than 30% though some crests may be as low as 3%.

Soils

Soils associated with these landform components include uniform sands and sandy loams, dispersive texture contrast soils and a non-dispersive texture contrast soil but more than 75% of the area is covered by gradational red and yellow earths.

Individual soils were identified to span the range of soil features observed and recorded at field sites located throughout the SGCP study area and from samples submitted for laboratory analysis.

Eleven soils have been identified within the SGCP study area and are described in detail in the report. Only nine could be mapped separately as the dominant soil in any particular area. The eleven soils are:

- *Rocky sands and sandy loams* on little weathered rock;
- *Ironstone sands and sandy loams* on strongly weathered rock;
- *Shallow red-yellow earths* on strongly weathered rock;
- *Deep red-yellow earths* on strongly weathered rock;
- *Shallow red-grey TC soils* on strongly weathered rock;
- *Deep red-grey TC soils* on strongly weathered rock;
- *Deep yellow-grey TC soils* on strongly weathered rock;
- *Alluvial red TC soils* on unconsolidated sediments of alluvial plains;
- *Alluvial yellow-grey TC soils* on unconsolidated sediments of alluvial plains and drainage depressions;
- *Alluvial sands and sandy loams* on alluvial plains and drainage depressions; and
- *Alluvial loams and earths* on alluvial plains.

The last two soils could not be mapped separately but occur as minor soils associated with other alluvial soils.

Names for the soils have been chosen to portray their distinguishing characteristics. An equivalent taxonomic description from the Australian Soil Classification (Isbell 2002) is also provided for each soil in the report.

<u>Acid sulfate soils</u>
Conditions for development of acid sulfate soils are only met inland where there are organically enriched deposits at the edges of saline lakes and waterways.

Environmental conditions suitable for the development of acid sulfate soils were not observed within the study area and it is extremely unlikely that acid sulfate soils are present.

<u>Land contamination</u>
No potential land contamination issues were identified during the field investigation but inspection was precluded in some areas due to the absence of access tracks and wet conditions.

Extensive cattle grazing has been the industry historically undertaken across the SGCP study area. Given the extensive nature of this grazing, it is highly unlikely that any contamination issues exist, other than cattle dips. No cattle dips were observed during the field investigation.

<u>Good Quality Agricultural Land</u>
According to the Queensland Department of Environment and Resource Management, none of the SGCP study area has cropping potential but 2.5% represents high quality pasture land and belongs in Agricultural Land Class C1.

This land contains *Deep yellow-grey TC soils* that either wholly or partly supported brigalow forests. It has reasonable water storage capacity combined with a raised level of soil fertility, resulting in better quality pastures.

Land with any cropping potential (Agricultural Land Class A and B) is generally designated as Good Quality Agricultural Land (GQAL) for the purpose of protecting agricultural productivity under State Planning Policy 1/92. However in local authorities where the pastoral industry is the dominant form of land use and income generation, Class C1 is often designated as GQAL.

Thus for the SGCP study area, the high quality pasture land represents GQAL. This land is located mainly in the west and south of MLA 70453, although there is also one small area within the infrastructure corridor, approximately 14 km north of MLA 70453.

All other land supports only lower quality pastures and was assigned Agricultural Land Class C2, which is not GQAL.

Strategic Cropping Land

The Queensland Government released a policy framework in August 2010 for protecting Queensland‟s strategic cropping land (SCL). Under the Government‟s SCL framework, five cropping zones are nominated in which the Policy will apply.

The SGCP study area is outside all five zones, being located inland of the Western Cropping Zone and does not need to be assessed under this policy.

Existing erosion

The land use practises within the SGCP study area have been, and still are, related to grazing beef cattle on native and improved pastures.

Whilst many of the soils are highly erodible, the grazing practices and mainly gentle slopes have restricted erosion to relatively few areas.

Minor to severe sheet erosion is widespread across the *Ironstone sands and sandy loams*. Where these soils occur on scarps, rill and gully erosion is also occurring on the footslopes below the scarps.

Minor to severe rill and gully erosion is evident in several drainage depressions containing *Alluvial yellow-grey TC soils.*

Minor gully erosion was also observed in southern areas of the *Shallow red-yellow earths*.

Potential constraints and impacts

A number of constraints to construction and production activities associated with the proposal and potential impacts of these activities on the soils have been identified, including:

- depth to bedrock;
- stoniness and presence of rock outcrop;
- soil erodibility;
- soil fertility;
- saline subsoil;
- potential to generate dust;
- suitability for topsoil stripping and use in rehabilitation;
- potential to generate acid; and
- potential loss of GQAL.

The severity of each constraint or impact has been assessed using information obtained from the desktop analysis, field investigation and laboratory analyses of selected soil samples. A 5-category rating system has been used for the assessment:

Nil	No constraint or impact due to the feature.
Minor	A slight constraint or impact that is readily overcome or controlled with standard management practices and mitigation measures.
Moderate	A substantial constraint or impact but is overcome or controlled with a combination of standard and special practices and mitigation measures.
Severe	A substantial constraint or impact that may be overcome or controlled only with special practices and mitigation measures.
Extreme	A constraint or impact that cannot usually be overcome or controlled even with special practices and mitigation measures.

Constraints and impacts that are rated as moderate or worse are considered to be significant as specialised mitigation or control measures are required.

Severity of each constraint or impact

Approximately 7% of the SGCP study area consists of steep to rolling low hills or scarps and has a severe to extreme topography constraint. Topography is considered to be a moderate constraint for a further 20 ha of land with undulating rises located in the south-west of the study area.

The same land with a severe to extreme topography constraint also has bedrock outcropping or at very shallow depth. The dominant soils are *Rocky sands and sandy loams* and *Ironstone sands and sandy loams* and they have been assigned an extreme depth to bedrock constraint. In addition, 40 ha of *Shallow red-grey TC soils* at the northern end of the infrastructure corridor overlie bedrock usually between 0.4 and 0.75 m depth. This area has been assigned a moderate to severe constraint.

Abundant gravel and outcropping bedrock also give the *Rocky sands and sandy loams* an extreme stoniness and rock outcrop constraint. The *Ironstone sands and sandy loams* have a moderate rating but cover <1% of the SGCP study area.

Almost 46% of the SGCP study area has a moderate erosion hazard rating of which 38% is due to the presence of weakly coherent *Shallow red-yellow earths* and *Deep red-yellow earths* on undulating plains and rises. The remaining 8% of the area with a moderate rating consists of dispersive texture contrast soils on gently undulating to undulating rises and on gently sloping drainage depressions. Approximately 2.5% of the SGCP study area represents dispersive texture contrast soils on steeper undulating rises, resulting in a severe hazard rating. Those areas with a moderate to extreme topography constraint also have an extreme erosion hazard.

All soils have a low to very low level of at least one major nutrient and thus have a soil fertility constraint of some degree. The constraint is moderate on almost 96% of the SGCP study area mainly due to a combination of low to very low organic matter and predominantly low to very low available phosphorus. However, a combination of extremely acid pH and low exchangeable potassium also creates a moderate constraint on the *Rocky sand and sandy loams*. A severe soil fertility constraint applies to <1% of the SGCP study area, on land dominated by *Ironstone sands and sandy loams*.

Stripping too much "topsoil" may not only include unsuitable subsoil in the planting media but also leave highly erodible subsoil exposed within the stripped areas. However, the presence of thin, suitable "topsoil" only creates a moderate constraint on the *Rocky sands and sandy loams* and *Ironstone sands and sandy loams*, covering 7% of the SGCP study area.

Salinity at or near the surface is not a significant constraint within the SGCP study area. However, subsoil salinity reaches high to extreme levels in the *Deep red-grey TC soils* and smaller areas of *Shallow red-grey TC soils*, creating a moderate to severe constraint over 2.5% of the SGCP study area.

All land has at least a partial moderate dust constraint. The *Alluvial yellow-grey TC soils*, representing approximately 6% of the SGCP study area, have a minor to moderate capacity to generate dust. The remaining 94% of the SGCP study area has a moderate capacity to generate dust due to the presence of either loamy sand, sandy loam, sandy clay loam or clay loam, sandy at the surface.

The *Rocky sands and sandy loams* have an extremely acid pH but the minimal clay content means this soil has a limited capacity to generate acid. In fact, soil data indicate there is no potential within the top 1.8 m of all soil profiles for acid generation by disturbance of potentially acid forming materials during earthworks and construction.

Instability due to soil wetness is a minor constraint on almost 72% of the SGCP study area and a moderate constraint on a further 7%.

Approximately 780 ha within the SGCP study area are designated by the Queensland Government as being either wholly or partly GQAL. However, just over 5 ha of this GQAL pasture land are expected to be directly disturbed and loss of this land constitutes a minor impact. The remaining areas of GQAL pasture land are not expected to be disturbed or are expected to have indirect disturbance only and mining activities are therefore likely to create minimal, if any, loss.

Thus, loss of GQAL under this proposal represents a minor impact. As described above, the SGCP is outside the SCL zones so there will be no effect on SCL.

<u>Cumulative effects for individual soils</u>
Cumulative constraints and impacts for each individual soil are summarised in the report.

The *Rocky sands and sandy loams* and *Ironstone sands and sandy loams* have the largest number of severe or extreme issues. *Shallow red-yellow earths* and *Deep red-yellow earths* each have one moderate constraint and one moderate hazard as well as at least one minor to moderate issue. The *Alluvial yellow-grey TC soils* are similar with one moderate constraint and one moderate hazard and two minor to moderate constraints and hazards.

The other dispersive texture contrast soils have at least one severe to extreme issue as well as several moderate issues. In contrast, the *Alluvial red TC soils* have only one minor constraint and one moderate hazard.

Apart from the *Alluvial red TC soils*, all soils have a partly moderate or worse erosion hazard and at least moderate soil fertility constraint. If the erosion hazard is not appropriately managed, resultant erosion and sedimentation can have a pronounced impact on the environment and the soil fertility constraint associated with these soils means that the appropriate management procedures must involve correct appropriate revegetation measures.

Mitigation measures
A range of mitigation measures are available for the constraints and impacts identified during this study.

<u>Timing of major disturbance</u>
A moderate to extreme erosion hazard has been identified as affecting more than 55% of the study area and the four-month, December to March, period produces 67% of the average total erosive potential of rainfall for an entire 12 months.

Thus, avoiding major earth works programmes between December and March would substantially reduce the risk of erosion. However, if earthworks must be undertaken during this period, it is essential that all standard erosion control measures be adopted and special measures be implemented on sloping areas with dispersive texture contrast soils.

Adopting erosion control measures
Erosion control measures should be implemented for all works that disturb the land surface where slopes exceed 1%. Where this land contains dispersive texture contrast soils (*Shallow red-grey TC soils*, *Deep red-grey TC soils*, *Deep yellow-grey TC soils* and *Alluvial yellow-grey TC soils*), special precautions will be required in addition to the standard measures.

Eleven standard measures and eight special measures are recommended and described in the report.

Stripping and re-using topsoil
"Topsoil" refers to any natural soil (and artificial planting) material that is suitable for use as planting media. "Topsoil" is usually stripped from the ground surface before construction of buildings, roads and hardstand areas. Wherever soil is to be excavated, the "topsoil" should be stripped first. The stripped material should be stockpiled for reuse during revegetation and rehabilitation of these areas.

Recommended stripping depths are provided in the report, based on thickness of the soil surface and subsurface layers. There is considerable variation in recommended stripping depth for some mapping units and detailed field checking should be undertaken before areas are stripped to determine the appropriate depth.

Material that is suitable for stripping and stockpiling has low to very low fertility and all stockpiled material should be ameliorated with NPK fertilisers and would benefit from incorporation of composted organics.

Measures need to be taken to ensure dispersive clay subsoil is not stripped and mixed with suitable "topsoil" and stockpiles should be constructed on the contour, protected from run-on water with diversion banks or similar devices upslope, and formed with run-off control devices immediately down slope.

The duration of stockpiling should be minimised to reduce nutrient rundown and colonisation by weeds. Stockpiling should not commence until immediately before bulk earthworks start and rehabilitation of disturbed areas should proceed as soon as works are completed.

However, stockpiles that are to be kept until reuse during decommissioning should be sown with an appropriate plant mix and managed to ensure adequate ground cover is maintained. This will minimise erosion and leaching of nutrients from the soil material and will provide a seed source when the material is eventually used. Such stockpiles should be landscaped into low mounds to reduce potential for anaerobic conditions to develop at the bottom, to reduce dust, noise and wind and to improve visual amenity.

Where there is insufficient material for stripping on-site, suitable "topsoil" may need to be imported, where practicable.

Dissected terrain
There is an extreme topography constraint on almost 7% of the SGCP study area, comprising mainly steep to rolling low hills with *Rocky sands and sandy loams* in the west but with smaller, scattered areas of scarps containing *Ironstone sands and sandy loams*.

This land also has very shallow depth to bedrock and excavation may require specialist equipment but it is largely outside areas with expected direct disturbance.

There are also 20 ha of *Deep yellow-grey TC soils* with dispersive subsoil on steep slopes that create a severe erosion hazard.

The dissected topography and moderate to severe fertility constraint of these soils (and severe erosion hazard in the dispersive *Deep yellow-grey TC soils*) will make it extremely difficult to control erosion during construction and to revegetate and rehabilitate any disturbed areas.

Although it would be preferable to exclude this land from development, appropriate mitigation measures are recommended in the report in the event that it is disturbed.

<u>Areas with severe subsoil salinity</u>
The *Deep red-grey TC soils* have high to extreme salinity below 1 m depth and it is likely that subsoil salt levels will also be high in the *Shallow red-grey TC soils*. More intensive salinity sampling is recommended wherever major earthworks involving concrete and steel are to be located on these soils. The sampling should be aimed at clarifying the depth at which salt levels reach problematic levels.

Medium salt levels can retard plant growth and care should also be exercised when excavating or otherwise affecting subsoil from the *Deep yellow-grey TC soils* and *Alluvial yellow-grey TC soils*.

Excavated subsoil should be buried deep or capped with at least 300 mm of suitable "topsoil" following construction activities. This will allow plants that are being established to achieve a reasonable root layer before encountering the saline material.

If saline subsoil is to be stockpiled for a short period, the stockpile should be surrounded with a berm to prevent water running onto the pile from further upslope and to detain run-off water within the stockpiled area.

<u>Waste rock emplacements</u>
The potential erosion of waste rock emplacements is primarily determined by slope grade on the upper surface and on the side batters of these artificial landforms and by the chemical and physical features of the spoil material.

To minimise this impact, several measures are identified in the report to be implemented, including appropriate design of the final surface topography for controlled run-off, capping the emplacements with suitable topsoil or with rock mulch on the batter slopes and revegetating with appropriate plant species.

<u>Areas of subsidence</u>
The major environmental impact of subsidence is on overland flow and stream flow conditions and these issues are considered separately as part of the EIS. However soil infiltration, internal drainage and erosion may be affected by subsidence following longwall mining if cracks develop due to tension around the zones where surface buckling occurs.

As part of the rehabilitation process, areas with surface cracks should be rehabilitated through ploughing to a minimum 300 mm depth and regrading and then reseeded with an appropriate plant species.

<u>Use of treated water for construction activities</u>
Only water that complies with quality standards set by the Environmental Authority should be applied to soils as dust suppression during construction activities.

Borrow pits

Borrow pits may impact on the environment, both during and after their active use, through accelerated soil erosion, leaching of soluble salts and loss of productive rural land. Environmental impact at and from borrow pits can be controlled using the control measures outlined in the report.

Apart from careful site selection, implementation of run-off control devices is essential to prevent water running over the cut faces from further upslope and to detain run-off water within the disturbed area.

The final cut faces should be left as close to vertical as possible to minimise erosion due to raindrop splash.

Minimising impact at minor stream crossings

Crossings for access tracks and pipelines on minor streams require special attention because many of the streams will have dispersive texture contrast soils. Any cutting or incision into these soils could create severe erosion.

Tracks should only cross streams at points where:

- the turbulence of stream flow is least;
- there is no active undercutting of either bank; and
- there is no dumping of sediments within the stream bed.

Crossing at bends in streams or close to where two streams meet should be avoided. Such areas often represent sections of active, unstable stream flow with a potential high risk of stream bank erosion if disturbed.

Environmental impact can be controlled with a series of control measures outlined in the report. Apart from careful site selection, implementation of run-off control devices is essential to prevent water running over the cut faces from further upslope and to detain run-off water within the disturbed area.

Erosion monitoring plan

Given that erosion and sedimentation can have a pronounced impact on the environment, an erosion monitoring program has been developed based on the erosion hazard across the SGCP study area and appropriate mitigation strategies have been identified and described.

The erosion monitoring program is indicative only and will need to be reviewed and updated following detailed engineering design.

1. Introduction

1.1 Background

The South Galilee Coal Project (SGCP), a joint venture between AMCI (Alpha) Pty Ltd and Alpha Coal Pty Ltd (the proponent), is a proposal to develop and operate a 17 million tonne per annum (Mtpa) coal mine in the Galilee Basin in central Queensland. The mine will service export markets for thermal coal.

The SGCP is located south-west of the township of Alpha, which is approximately 170 kilometres (km) west of Emerald and 450 km west of Rockhampton.

The key components of the SGCP would include the following:

- coal mining operations, including:
    - open cut and underground mining within Mining Lease Application area (MLA) 70453, producing up to 17 Mtpa of product coal for the export market;
    - placement of waste rock and rejects in out-of-pit waste rock emplacements;
    - progressive backfilling of the open pits with waste rock and rejects as mining develops;
- development of a mine water management system including clean water diversions, mine affected runoff collection, sediment dams, pit water management process and on-site water reuse procedures and a permanent diversion of Sapling Creek;
- underground services area;
- Mine Industrial Area (containing administration, bath house, storage, vehicle parking, workshops, washdown, refuelling, controls and communication infrastructure);
- Coal Handling and Preparation Plant;
- coal handling infrastructure (including conveyor systems, raw coal and product coal stockpiles);
- development of a Mine Access Road and on-site haul roads and light vehicle roads;
- construction of an on-site rail component (including loading loop, breakdown and fuel sidings);
- construction of a SGCP rail spur component to connect to the common user rail component;
- on-site accommodation village;
- fuel, oil and explosives storage facilities;
- soil stockpiles, laydown areas and a gravel borrow pit;
- raw water supply infrastructure (e.g. pipeline, groundwater bores and Raw Water Dam);
- sewage and waste water treatment infrastructure;
- on-site landfill facility;
- electrical and telecommunications infrastructure;
- ongoing monitoring and rehabilitation;
- ongoing exploration activities within existing exploration tenements; and
- other associated minor infrastructure, plant, equipment and activities.

Development of the SGCP will involve a staged ramp-up to the maximum production level of 17 Mtpa.

The Coordinator-General has declared the project to be a „significant project" requiring an environmental impact statement (EIS) under section 26(1) (a) of the *State Development and Public Works Organisation Act 1971*.

The joint venture proponents have commissioned Land Resource Assessment and Management Pty Ltd (LRAM) to conduct a soil quality and land suitability assessment as part of the EIS for the SGCP.

This technical report describes the work undertaken during that study and presents the study results. The intention is to include the report as a supporting document for the EIS.

1.2 Study objectives

The study is to assess the environmental issues and impacts associated with development of the project in relation to soils.

Specific objectives of the study were to:

- describe and map the topography within the project study area;
- identify and describe the soils and map their distribution within the study area;
- assess the soil quality with regards to the Strategic Planning Policy 1/92 for protecting Good Quality Agricultural Land and with regards to the Draft Strategic Cropping Land Policy, released in August 2011;
- identify topography and soil related constraints to development;
- assess topography and soil related impacts that the development may have on the environment;
- recommend appropriate mitigation measures to minimise any significant potential impacts; and
- provide an outline of an erosion monitoring program.

Many soil features are closely related to topographic position in the landscape and thus assessment of topography is an integral part of soil assessment.

1.3 Study area

The SGCP is located west of Alpha within the Barcaldine Regional Council Local Government Area in central west Queensland (Figure 1).

The area proposed to be mined is located within the northern part of MLA 70453. The MLA lies between 7 and 31 km west of Alpha. Its northern boundary is 1 to 2.5 km south of the Capricorn Highway and the area extends up to 19 km further south.

An infrastructure corridor is proposed to connect the SGCP to the common user rail line proposed by other proponents to link the Galilee Basin to the Abbot Point Coal Terminal. The infrastructure corridor commences in the north eastern corner of MLA 70453 and extends approximately 35 km northwards. At the commencement of this study the corridor was 500 m wide along most of the route expanding to a width of 2 km wide near the proposed mining area. However, after field inspection was completed, the proposed corridor was revised to a uniform width of 100 m with minor realignment at the northern and southern ends.

The SGCP study area for soil quality and land suitability assessment comprises MLA 70453 and the revised infrastructure corridor (Figure 2).

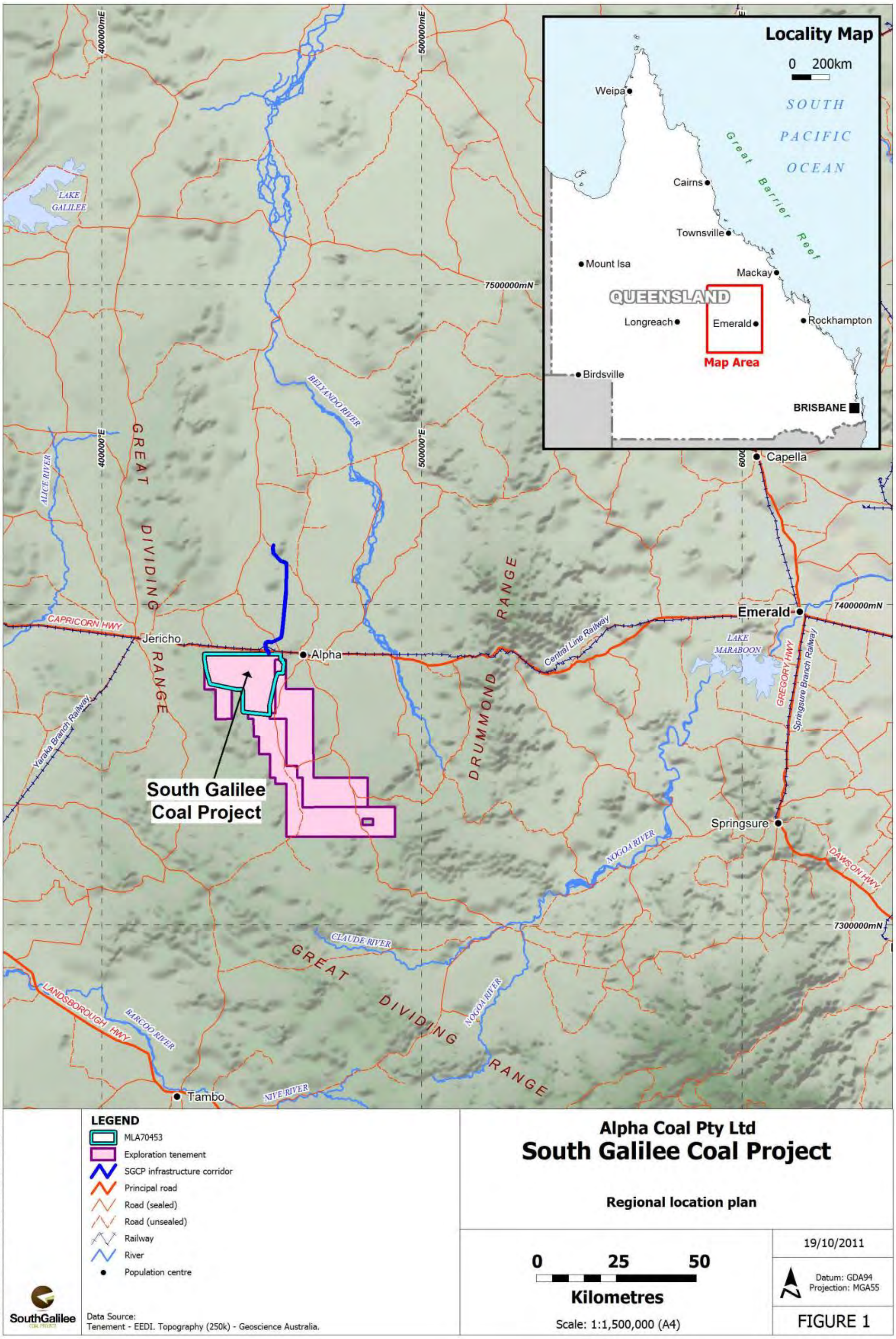

Figure 1. SGCP locality map

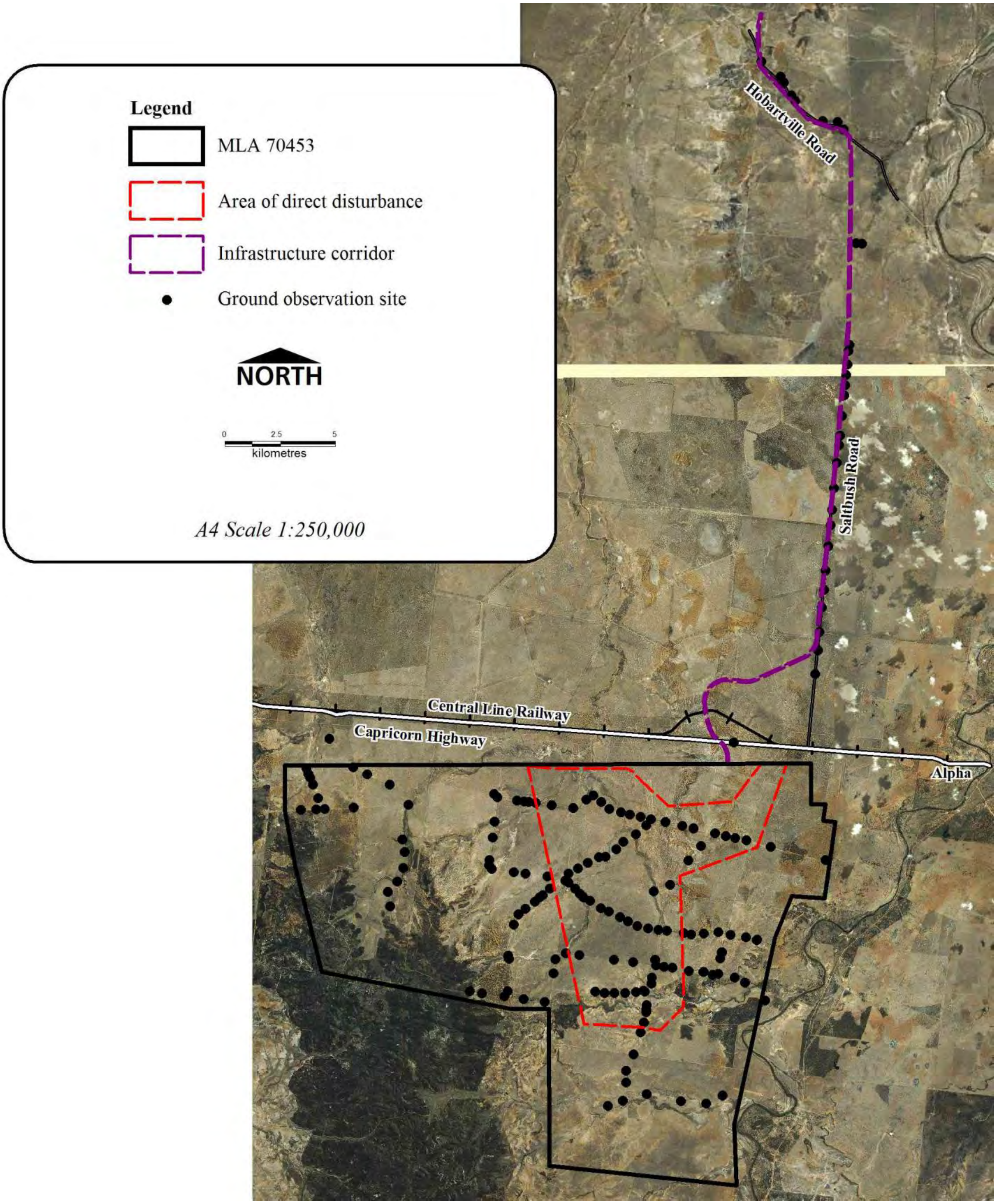

Figure 2. Location of SGCP study area

2. Study methodology

The study was undertaken in five stages as outlined below.

2.1 Desktop analysis of existing information

2.1.1 Collation of available land resource data

Land systems have been mapped and described across the SGCP study area by CSIRO (Gunn et al. 1967) and later by the Queensland Environmental Protection Agency (Lorimer 2005). A land system represents a unique landscape pattern that contains a distinctive combination of geology, landform, soil and vegetation features. This pattern is usually repeated across the landscape but may occur in only one location. As land systems are based on distinctive soil patterns, they can be used to develop a separate map of soil distribution.

Geological information in the associated land system reports also contains descriptions of the geological weathering that has occurred to create the existing landscape. This information can be used to attain an overview of the weathering history and resultant layer of unconsolidated materials above the bedrock (regolith). The distinctive landform components of each land system are also described in the reports. As soil features are related to geological parent material, weathering history and topographic position in the landscape, the geological and landform information in the land systems report provides a basis for identifying different soils.

Though geology and landform are fairly uniform for each land system, soils can vary substantially within the defined pattern. However, the accompanying reports separate each land system into individual land units with much less soil variation occurring within a unit than in a land system. Individual land units described by CSIRO (Gunn et al. 1967) are not mapped but the soil content and relative proportion of each unit is described in the report. The later report (Lorimer 2005) describes and maps individual land units.

Land system mapping by CSIRO and the later land unit mapping by the Queensland Environmental Protection Agency (Lorimer 2005) were extracted as separate layers within MapInfo GIS to provide an overview of the anticipated land resources within the SGCP study area.

Detailed contour data produced at 0.5 m intervals using an optical remote sensing technology (LiDAR) were provided by the Proponent. Contour information with 1 m intervals was used to refine the landform descriptions and to determine the grade of slope.

2.1.2 Review of collated data

The preliminary mapping based on land systems and land units, associated data and reports were then reviewed to:

- determine the accuracy and reliability of the two information sets and thus plan the amount of new information that would need to be acquired;
- identify the range of soils expected to be present; and
- delineate specific locations for field investigation to ensure the soil variation would be covered during the study.

2.2 Selection of an appropriate mapping scale

The Final Terms of Reference for the EIS require a soil survey to be conducted at a uniform mapping scale of 1:100,000.

However, the proposed degree of disturbance varies considerably during both the development phase and on-going operations.

Areas with expected direct disturbance include the following:

- open cut coal mining operations, including -
    - placement of waste rock and rejects in out-of-pit waste rock emplacements;
    - progressive backfilling of the open pits with waste rock and rejects as mining develops;
- development of a mine water management system including clean water diversions, mine affected runoff collection, sediment dams, pit water management process and on-site water reuse procedures and a permanent diversion of Sapling Creek;
- underground services area;
- Mine Industrial Area (containing administration, bath house, storage, vehicle parking, workshops, washdown, refuelling, controls and communication infrastructure);
- Coal Handling and Preparation Plant;
- coal handling infrastructure (including conveyor systems, raw coal and product coal stockpiles);
- development of a Mine Access Road and on-site haul roads and light vehicle roads;
- construction of an on-site rail component (including loading loop, breakdown and fuel sidings);
- construction of a SGCP rail spur component to connect to the common user rail component;
- on-site accommodation village;
- fuel, oil and explosives storage facilities;
- soil stockpiles, laydown areas and a gravel borrow pit;
- raw water supply infrastructure (including pipeline, groundwater bores and raw water dam);
- sewage and waste water treatment infrastructure;
- on-site landfill facility;
- electrical and telecommunications infrastructure; and
- other associated minor infrastructure, plant, equipment and activities.

(The final location of the raw water supply infrastructure was not known at the time of planning field work and could not be considered when identifying the expected areas of direct disturbance.)

A much lower degree of predominantly indirect disturbance is expected within the remaining parts of the MLA.

A 1:100,000 mapping scale was considered appropriate for areas not expected to be disturbed or expected to be subject to indirect disturbance only. This is also the recommended scale for this type of development in the technical guidelines for environmental management of mining in Queensland (DME 1995).

However, more intense investigation was considered necessary for those areas expected to be subject to direct disturbance. For these areas, a mapping scale of 1:50,000 has been used. This scale is within the range recommended for strategic planning of intensive land use development in the Australian soil survey guidelines (Schoknecht et al 2008).

The relative size of these areas is shown in Table 1.

Table 1. Size of the SGCP study area

Component	Area (ha)
Areas with expected direct disturbance - within MLA 70453 - within infrastructure corridor	 7,585 400
Areas with no disturbance or only indirect disturbance expected	23,235
Entire SGCP study area	**31,220**

2.3 Field investigation

Field investigation was undertaken during July 2011 and was designed to:

- view as many land system-land unit combinations as possible;
- record specific soil-landform information for all combinations;
- determine the actual soil variation; and
- check location of geographic boundaries between the different soil types being identified.

2.3.1 Ground observations

The density of ground observations was varied according to the mapping scale.

Soil profile and landscape features were recorded at 102 sites within those areas with expected direct disturbance and at 87 sites within the remaining areas expected to experience no or indirect disturbance. This represents:

- 1 ground observation every 78 ha for the 1:50,000 scale mapping; and
- 1 ground observation every 267 ha for the 1:100,000 scale mapping.

Detailed profile descriptions were recorded at 15% of sites within the areas of direct disturbance and at 18% of sites within areas planned for no or indirect disturbance. Both overall density and proportion of detailed profile descriptions are well within the minimum acceptable figures cited in Australian soil survey guidelines (Schoknecht et al 2008) for both mapping scales.

The location of all ground observation sites is shown in Figure 2.

Actual ground observation sites were chosen using a free survey technique so that the most appropriate location for a particular site was chosen whilst in the field on the basis of local landscape features.

Field inspection was precluded in some areas due to the absence of access tracks and wet conditions.

Soil profiles were mainly exposed with a vehicle mounted sampling tool which extracted a 38 mm intact soil core and with a hand held auger drilling a 75 mm diameter hole. However, pits and cuttings were used at 17 sites.

Detailed soil profile descriptions were collected to a maximum depth of 1.8 m at a total 32 sites. The remaining ground observations represent check sites where only sufficient information was collected to reliably determine soil type and its constraints.

Landscape position, vegetation, ground surface features and substrate material (where evident) were also recorded at each site to assist in soil classification and mapping.

All site descriptions used standard terminology of the Australian Soil and Land Survey Field Handbook (The NCST 2009). Site location was recorded with a hand-held GPS receiver which has an accuracy of ± 5-10 m. The location of all ground observation sites is provided in Attachment A.

2.3.2 Soil sampling for laboratory analysis

In total, 58 soil samples from 13 profiles representing the main soils within the SGCP study area were submitted for laboratory analysis. A further four surface samples were collected for testing general fertility and one subsoil sample was taken for testing soil erodibility.

Samples collected at each site were taken from the surface layer or from each distinct layer below to a maximum depth of 1.8 m.

Samples collected from the surface layer were analysed using the following tests:

- soil pH;
- electrical conductivity (EC), as a measure of salinity;
- chloride (Cl), as an alternative measurement of salinity;
- exchangeable cations (Calcium, Magnesium, Sodium, Potassium and Aluminium);
- cation exchange capacity (CEC);
- total nitrogen (Total N);
- organic matter (OM) content (derived from Organic carbon);
- available phosphorus (Olsen P);
- moisture content when air dry and at -15 bar pressure; and
- clouding and slaking as a measure of dispersion.

The moisture content, clouding and slaking tests were not performed on the four additional samples collected to enhance assessment of general fertility.

Subsoil samples were analysed using:

- soil pH;
- EC, as a measure of salinity;
- Cl, as an alternative measurement of salinity;
- exchangeable cations (Calcium, Magnesium, Sodium, Potassium and Aluminium);
- CEC;
- moisture content when air dry and at -15 bar pressure; and
- clouding and slaking as a measure of dispersion.

Texture was recorded for each sample during site inspection.

Analytical methods for all tests were performed according to the relevant Australian laboratory handbook (Rayment and Lyons 2011). Full results are presented in Attachment B.

2.4 Data analysis

2.4.1 Soil classification and mapping

Soil profile descriptions and analytical data were used to confirm and refine the preliminary soil mapping legend created during field investigation.

Each soil was correlated with an equivalent taxonomic unit in the revised edition of the Australian soil classification (Isbell 2002).

General notes collected during field investigation were used to adjust boundaries to the soil mapping units, where necessary. A series of maps was then produced to portray landform and soil distribution.

The reliability with which a soil map can accurately reflect the soil at any one point on the ground is largely dependent upon the scale used for compilation with 1:50,000 mapping being more reliable than 1:100,000 mapping.

Mapping scale also affects the positional accuracy of boundaries between mapping units. At 1: 50,000 scale, the accuracy of mapping unit boundaries is a minimum ± 100-150 m; at 1:100,000 scale the accuracy is a minimum ± 200-300 m.

2.4.2 Constraint and impact analysis

Landform descriptions and modal slope ranges were derived for each mapping unit using 1 m contour intervals and used to assess a topographic constraint on infrastructure development.

Each soil mapping unit was assessed for the following constraints and environmental impacts:

- depth to bedrock;
- stoniness and presence of rock outcrop;
- soil erodibility;
- soil fertility;
- saline subsoil;
- potential to generate dust;
- suitability for topsoil stripping and use in rehabilitation;
- potential to generate acid; and
- potential loss of GQAL and SCL.

Several data sources were used together to make these assessments, including:

- landform descriptions from the land system reports and 1 m contour information supplied by the proponent;
- descriptions of soil features from the land system reports;
- field observations during this study; and
- soil analytical data from sampling undertaken during this study.

A Queensland Department of Environment and Resource Management (DERM) assessment of GQAL is provided in the Jericho Shire Planning Scheme (Campbell Higginson Town Planning Pty Ltd 2006) for the former shire. This information was used to locate GQAL within the SGCP study area.

2.5 Reporting

Reporting was aimed at clearly identifying the:

- environmental values of the area;
- potential impacts of the proposal on those values; and
- recommended management measures to minimise adverse impacts.

A series of thematic maps displaying the distribution of various land resources, their constraints to infrastructure and the likely environmental impact following development were included as figures in the report.

For convenience, report figures were produced at a scale of 1:100,000 but they are based on GIS data layers which are appropriate to use at a scale of 1:50,000 within the areas of expected direct disturbance.

3. Environmental values of the area

3.1 Topography

Topography is a major determinant of soil features and their distribution and thus affects soil related constraints and impacts.

The existing topography within the SGCP study area is summarised in Table 2 using standard terminology of the Australian Soil and Land Survey Field Handbook (The NCST 2009).

The topographic analysis and description is based on 1 m contours which were created using LiDAR remote sensing technology.

Figure 3 displays the distribution of various landform components with a 10 m contour overlay. The figure shows that the existing landscape is dominated by very gently sloping plains and rises of low relief. The plains and rises slope from the north-east and east towards elevated hilly terrain along the western boundary.

Very gentle slopes of up to 3% account for just over 56% of the SGCP study area. Level to gently undulating plains, level alluvial plains and gently sloping drainage depressions with a relative relief of less than 9 m comprise approximately 17% whilst the remainder consists of gently undulating rises where the relief is up to 30 m.

Gently undulating to undulating rises, also with a relief of up to 30 m but with steeper slopes of up to 10%, occupy almost 37% of the SGCP study area, mainly in the centre and south.

Scarps with outcrops of deeply weathered bedrock are scattered throughout the gently undulating rises in narrow strips, especially bordering the alluvial plains and drainage depressions. In total the scarps occupy less than 1% of study area. Slopes on the scarps are commonly steep but can vary from 3 to 60%. Relief can vary from 10 to more than 30 m.

Steep low hills and one very small area of rolling low hills occur in the west where they occupy just over 6% of the SGCP study area. Relief on the low hills is up to 90 m and the hill slopes are commonly more than 30% though some crests may be as low as 3%.

Table 2. Landform components

Landform component	Modal slopes (%)	Area	
		(ha)	(%)
Steep low hills	3-60%	1,950	6.2
Rolling low hills	10-40%	10	<0.1
Undulating rises	0.5-10%	4,970	15.9
Scarps	3-60%	245	0.8
Gently undulating rises			
	0.5-3%	12,220	39.1
	0.5-6%	6,440	20.6
Level to gently undulating plains	0-3%	2,240	7.2
Level alluvial plains	0-1%	1,375	4.4
Drainage depressions	0-2%	1,770	5.7
Total		**31,220**	**100.0**

3.2 Soils

3.2.1 Review of available mapping

The most detailed soil information available for the SGCP study area is available as part of land system mapping (Gunn et al. 1967, Lorimer 2005).

The earlier CSIRO mapping (Gunn et al. 1967) was published at a scale of 1:500,000 and covered the entire SGCP study area with only six land systems. The later mapping by Queensland Environmental Protection Agency delineated 13 land systems at a scale of 1:100,000 (Lorimer 2005).

Soils can vary substantially within a land system; individual land units identified within each land system contain much less soil variation. The individual land units described by CSIRO (Gunn et al. 1967) are not mapped but the soil content and relative proportion of each unit is described in the report. Individual land units are both mapped and described in the later study (Lorimer 2005) but the soil descriptions for each land unit are not as detailed as would be expected from a soil survey. Moreover, though field inspection for the land unit mapping was appropriate for 1:100,000 mapping soil information was not collected at every site.

Thus, the available land system and land unit information (Gunn et al 1967, Lorimer 2005) provided a basis for producing a tentative working soil map but were not adequate for compiling a reliable soil map at either 1:100,000 or 1:50,000 mapping scale. A comprehensive soil survey was therefore required to confirm the range and distribution of soils within the SGCP study area.

3.2.2 Field investigation

Field investigation has confirmed that the available land system and land unit mapping requires substantial refinement for the assessment purposes of this study and new soil mapping has been created, based on more intensive field investigation and more detailed description and analysis of soil features.

Field work during this study was undertaken at an intensity that is appropriate for producing soil mapping at 1:100,000 scale for areas expected to experience no or indirect disturbance and at 1:50,000 for those areas with expected direct disturbance.

3.2.3 Framework for soil identification

The range of soils within the SGCP study area has been identified from the soil features described during field investigation.

As soil features are related to geological parent material, weathering history and topographic position in the landscape, geological and landform features have been used as a framework for identifying different soils. An outline of the geological and landform framework is provided below.

The steep and rolling low hills are on sedimentary rocks (sandstone, mudstone, siltstone and shale) that were formed largely during the Triassic Period, approximately 250 to 200 million years ago.

However, the majority of soils overlie sedimentary rocks and unconsolidated sediments that were formed more recently during the Tertiary Period, approximately 65 to 2 million years ago. During this period, much of the older landscape was subjected to strong weathering and erosion and parts were buried during re-deposition of the eroded material. The result was formation of a gently undulating Tertiary landscape of plains and rises overlying ferricrete, also referred to as laterite. Much of this Tertiary landscape remains within the SGCP study area but very small areas of older Permian sedimentary rocks outcrop in the north east. The Permian rocks are mainly sandstone with minor siltstone and coal and were formed approximately 300 to 250 million years ago. These rocks would have been covered by the Tertiary landscape but have been re-exposed by subsequent erosion. Erosion has also created scarps along the edges of the Tertiary landscape with ferricrete outcrop evident along many of these scarps.

In comparison, the Triassic sedimentary rocks and re-exposed Permian rocks have undergone much less weathering.

The alluvial plains and drainage depressions are formed on unconsolidated sediments that were only recently eroded and deposited (during the Quaternary period, i.e. last 2 million years) from the Tertiary landscape and older sedimentary rocks.

Within this framework, each identified soil has a limited range of attributes (profile features and chemical and physical properties) that is different from other soils within the area. The soil attributes require similar management inputs to ensure sustainable use and to minimise environmental impact.

3.2.4 Standard terminology

All descriptions of soils in this report use standard terminology of the Australian Soil and Land Survey Field Handbook (The NCST 2009). Descriptions of field pH measurements (such as medium acid) are from a handbook for interpreting laboratory analyses of Queensland soils (Baker and Eldershaw 1993).

The report describes the numerous soil layers that may occur through a soil profile as being either:

- surface layers which extend down from the ground surface and are generally darkened (compared to any underlying layers) due to the accumulation of organic matter;
- subsurface layers which occur below, and are very similar to, the surface layer in texture and structure but are usually paler in colour (due to much less organic matter); or
- subsoil, which refers to any layer below the subsurface layer (or below the surface layer if there is no subsurface layer) which has much higher clay content, brighter colours or markedly different structure.

The term "topsoil" is generally avoided in soil survey reports because its common usage covers a wide range of soil material that may be sourced from any part of the soil profile, though usually not clay. The term has also been applied to any natural soil (and artificial planting) material that is used for topdressing.

3.2.5 Description of the soils

Table 3 summarises the soils identified within the study area. Their distribution is shown in Figure 4.

Table 3 also provides a correlation of each soil with the equivalent taxonomic unit from the Australian Soil Classification (Isbell 2002) to facilitate comparison with other soil reports.

Soil chemical and physical properties ascertained from laboratory analysis are provided in Attachment B and discussed in Section 4 with respect to their effect on potential constraints and impacts.

The soils have been given descriptive names that reflect their key soil profile features. The descriptive names are based on the following system:

- Soils referred to as sands and sandy loams have uniform texture consisting of sand, loamy sand or sandy loam throughout their profile.
- Similarly, loams have uniform texture consisting of loam or sandy clay loam throughout their profile.
- Texture contrast (TC) soils have profiles with either sandy or loamy textured surface and subsurface layers that rapidly change (over ≤50 mm) into much heavier textured (usually clay) subsoil.
- Earths are gradational soils that have a sandy textured surface layer and clay content gradually increasing with depth to a heavier texture deep in the subsoil.
- In texture contrast and gradational soils, the colour description refers to the dominant colour of the subsoil.

In Figure 4, the dominant soil is shown for each mapping unit. For many units the dominant soil is estimated to cover at least 70% of the mapping unit. However in some mapping units, no one soil accounts for 70% of the area and the soil shown is simply the most widespread within that unit.

Rocky sands and sandy loams

Rocky sands and sandy loams are the dominant soil on steep to rolling low hills along the western border and cover almost 6.5% of the SGCP study area.

The *Rocky sands and sandy loams* have a thin (100-150 mm), grey surface layer of loamy sand or sandy loam that either directly overlies weathered rock or grades into a paler subsurface layer of similar texture which then overlies rock.

The ground surface is hard setting when dry and both the surface layer and subsurface layer (if present) have massive structure[1].

Field pH varies from slightly acid to medium acid through the profile.

Many coarse fragments varying in size from large pebbles to stones are present on the ground surface and through the soil profile. Up to 10% of the ground surface may also contain outcrops of bedrock.

Total soil profile depth varies from less than 150 mm up to 300 mm.

Ironstone sands and sandy loams

Ironstone sands and sandy loams are the dominant soil on small, isolated areas within the gently undulating plains and rises and on top of scarps flanking these plains and rises. The underlying bedrock, ferricrete, is close to the surface and outcrops are often present on the scarp face. Less than 1% of the SGCP study area has been mapped with *Ironstone sands and sandy loams* as the dominant soil but many smaller areas that could not be delineated at the scale of mapping are also present.

The *Ironstone sands and loams* have a red surface layer of sandy loamy texture and variable thickness (80-250 mm) that either directly overlies weathered rock or grades into a similarly coloured subsurface layer of loamy sand which then overlies rock.

[1] Strong structure refers to soil material consisting of >⅔ natural soil aggregates (peds).
Moderate structure refers to soil material consisting of ⅓ to ⅔ peds.
Weak structure refers to soil material with <⅓ peds.
Massive structure refers to coherent soil material with no peds.
Single grain structure refers to a loose, incoherent mass with no peds.

The ground surface is hard setting when dry and both the surface layer and subsurface layer (if present) have massive structure.

Field pH varies from slightly acid to medium acid through the profile.

Iron-stained coarse fragments varying in size from medium-sized pebbles to stones may be common on the ground surface and through the soil profile.

Total soil profile depth varies from less than 100 mm up to 400 mm.

Shallow red-yellow earths

Shallow red-yellow earths are the dominant soil on almost 66% of the SGCP study area, occupying level plains to undulating rises that have developed on strongly weathered sedimentary rocks.

The *Shallow red-yellow earths* have a (120-200 mm) thick, grey or brown surface layer of sandy loam that merges into red or yellow subsoil. Texture in the subsoil gradually increases with depth from sandy loam to sandy clay loam and occasionally to sandy light clay.

At relatively shallow depth (between 400 mm and 1 m) the subsoil has a clear boundary change into another layer that is mottled yellow and grey (with some red) and generally gravelly. Texture of this mottled, gravelly layer varies from clay loam, sandy to sandy medium clay. The subsoil immediately above this deeper layer may be similarly mottled.

The ground surface is hard setting when dry and structure is massive throughout the profile.

There are no coarse fragments on the ground surface or through the upper part of the profile but the mottled, gravelly layer below contains a few to common, iron stained pebbles of medium size.

Field pH may vary from medium acid to neutral in all layers.

Coarse iron-manganese nodules are also occasionally present in the mottled, gravelly layer. The mottling and presence of iron-manganese nodules indicate a perched watertable may regularly develop within this layer. In fact during field investigation, the mottled, gravelly layer was much wetter than the profile above and contained a perched watertable below the level plains that cover the southern half of the infrastructure corridor.

Deep red-yellow earths

Deep red-yellow earths are closely associated with the *Shallow red-yellow earths* and are the dominant soil on almost 11% of the SGCP study area. The *Deep red-yellow earths* occupy the same landforms as their shallower counterparts.

The *Deep red-yellow earths* have similar profile features to the *Shallow red-yellow earths* apart from having a:

- clear to gradual boundary from the subsoil into the mottled, gravelly layer below 1,000 mm depth; and
- slightly thicker (150 to 250 mm) surface layer.

Shallow red-grey TC soils

Shallow red-grey TC soils occur on strongly weathered sedimentary rocks where the underlying bedrock is close to the ground surface. They are mapped as the dominant soil only at the northern end of the infrastructure corridor where they occur on gently undulating plains and undulating rises, occupying 0.1% of the SGCP study area.

The *Shallow red-grey TC soils* have a red, surface layer of sandy loam texture and variable thickness (100-250 mm) that overlies a conspicuously bleached (white or almost white), subsurface layer of sandy loam to sandy clay loam. Between 250 and 400 mm depth the subsurface layer rapidly changes into a mottled, red and grey subsoil of sandy light clay to sandy medium clay.

The ground surface is hard setting when dry and structure in the surface and subsurface layers is massive. The clay subsoil may also have massive structure in its upper part but is moderately to strongly structured below with coarse ped size (≥ 20 mm diameter).

A few small to medium-sized pebbles of quartz and ironstone may be present on the ground surface and through the surface and subsurface layers. Similar sized pebbles of sedimentary rock and ironstone are present in the clay subsoil, increasing with depth to be common above the underlying bedrock.

Field pH is neutral in the surface and subsurface layers but can vary from medium acid to mildly alkaline in the clay subsoil. A few, small nodules of iron may be present in the subsurface layer and clay subsoil.

The clay subsoil becomes slippery and difficult to wet evenly for texture determination, indicating the soil material is probably sodic and therefore dispersive (see also section 4.6.1).

Strongly weathered sedimentary rock is usually encountered between 400 and 750 mm depth but may be as deep as 1 m.

Deep red-grey TC soils

The *Deep red-grey TC soils* also occur on strongly weathered sedimentary rocks but are mapped as the dominant soil in only one large location which represents just over 2% of the SGCP study area. However, *Deep red-grey TC soils* are closely associated elsewhere as a minor soil with the *Deep yellow-grey TC soils*.

Deep red-grey TC soils have a thin (100-150 mm), brown or dark grey, surface layer varying in texture from sandy loam to clay loam, sandy. A thick (250-300 mm) subsurface layer of similar texture but paler in colour is occasionally found below the surface layer. Between 100 and 450 mm depth, the surface layer (or subsurface layer, if present) rapidly changes into mottled, red to brown and grey subsoil of sandy light clay to medium heavy clay. There is no evidence of a bleach within both the surface and subsurface layers.

The ground surface is hard setting when dry and the surface layer and subsurface layer (when present) are either massive or weakly structured with a few peds of fine size (≤ 10 mm diameter). The clay subsoil is weakly to moderately structured but peds are of coarser size.

Where this soil supports brigalow vegetation in the western part of the SGCP study area, small to large pebbles may be common on the ground surface and through the profile. Elsewhere, very few (if any) coarse fragments are on the ground surface or through the profile.

Field pH varies from medium acid to slightly acid in the surface and subsurface layers, and then either remains the same through the clay subsoil or increases with depth to become moderately alkaline to strongly alkaline in the lower part. A few, medium-sized to coarse, iron nodules may be present in the clay subsoil and soft segregations of calcium carbonate may be common where pH is strongly alkaline.

The behaviour of soil material during field texturing indicates the clay subsoil is probably sodic and therefore dispersive (see also section 4.6.1).

Strongly weathered sedimentary rock is not encountered before 1 m depth and is usually below 1.5 m.

Deep yellow-grey TC soils

Deep yellow-grey TC soils occupy a range of landform components, from level plains to undulating rises, which overlie strongly weathered sedimentary rocks. They are mapped as the dominant soil in the south and west, covering 4.5% of the SGCP study area.

The *Deep yellow-grey TC soils* have a grey surface layer of variable texture (sandy loam to clay loam, fine sandy) and thickness (100-450 mm). A subsurface layer of similar texture and thickness but with a conspicuous or sporadic (blotches of white or almost white) bleach is usually found below the surface layer. There is a rapid change into mottled yellow, grey and red subsoil of sandy light medium clay to heavy clay between 100 and 1,100 mm depth.

Occasionally, the upper part of the subsoil will contain a transitional layer of yellow coloured clay loam, sandy to sandy light clay texture.

The ground surface is hard setting when dry and the surface and subsurface layers are either massive or weakly structured with a few peds of fine size (≤ 10 mm diameter). The clay subsoil is moderately to strongly structured but ped size is coarse (≥ 50 mm diameter) and often columnar. Where present, the transitional layer in the upper part of the subsoil is massive.

The ground surface and most of the profile have no coarse fragments though a few, fine-sized quartz pebbles may be present deep in the subsoil.

Field pH varies from medium acid to neutral in the surface and subsurface layers and from neutral to moderately alkaline in the clay subsoil which may have small iron-manganese nodules present in varying amounts.

The behaviour of soil material during field texturing indicates the clay subsoil is probably sodic and therefore dispersive (see also section 4.6.1).

Strongly weathered sedimentary rock is not encountered before 1 m depth and is usually below 1.5 m.

Alluvial red TC soils

Alluvial red TC soils are mapped as the dominant soil on alluvial plains flanking the main drainage lines flowing into Alpha Creek in the southern part of the SGCP study area. As mapped, this soil covers approximately 3.5% of the SGCP study area.

The *Alluvial red TC soils* have a thick (300-400 mm), dark surface layer of sandy loam that overlies a paler, red subsurface layer of similar texture. Between 500 and 600 mm depth, the subsurface layer rapidly changes into red subsoil of sandy light clay in which grey, medium-sized mottles may be common. The clay subsoil often overlies a buried layer of mottled red, yellow and grey sandy clay loam.

The ground surface is soft to firm when dry and the surface and subsurface layers are massive. The clay subsoil is weakly to moderately structured and the buried layer varies from massive to weak structure.

There are no coarse fragments on the ground surface or through the surface layer, subsurface layer and subsoil but a few, small, quartz pebbles may occur in the buried layer below.

Field pH is mildly acid in the surface layer, neutral through the subsurface layer and subsoil, and then becomes mildly alkaline in the buried layer.

The behaviour of soil material during field texturing indicates the clay subsoil is not sodic and therefore not dispersive (see also section 4.6.1).

Total soil profile depth, including any buried layers is more than 1.5 m.

Alluvial yellow-grey TC soils

Alluvial yellow-grey TC soils are the dominant soil on most alluvial plains and drainage depressions inside the SGCP study area and occupy 6% of the SGCP study area.

The *Alluvial yellow-grey TC soils* have a grey to dark surface layer of variable texture (sandy loam, sandy clay loam or clay loam) and thickness (100-400 mm). The surface layer is often underlain by a thick (150-400 mm) paler subsurface layer of similar variable texture and is either sporadically or conspicuously bleached. If the subsurface layer is not present, the bottom of the surface layer is sporadically bleached. There is a rapid change into mottled grey, yellow and red subsoil of sandy light clay to sandy medium heavy clay between 180 mm and 650 mm depth.

The ground surface is hard setting when dry and structure of the sandier surface and subsurface layers is massive but where texture is clay loam these layers are weakly structured with a few peds of fine size (≤ 10 mm diameter). The clay subsoil is moderately structured with coarser ped size though it may become massive at depth.

The ground surface, surface layer and subsurface layer have no coarse fragments though very few, fine-sized quartz pebbles may be present through the subsoil.

Field pH varies from medium acid to neutral in the surface and subsurface layers and from slightly acid to mildly alkaline in the clay subsoil which may have small iron and manganese nodules present in varying amounts.

The behaviour of soil material during field texturing indicates the clay subsoil is probably sodic and therefore dispersive (see also section 4.6.1).

Total soil profile depth, including any buried layers that may be present, is more than 1.5 m.

Alluvial sands and sandy loams

Small, isolated areas of *Alluvial sands and sandy loams* occur on the alluvial plains and in drainage depressions. This soil occurs on lower-lying terraces alongside major streams and on sand splays of minor drainage lines where the flooding has overtopped the low stream banks and spread deposition over the adjacent landscape. At the scale of mapping used for this study, the *Alluvial sands and sandy loams* could not be mapped separately but represent minor soils closely associated with *Alluvial red TC soils* in the south and with *Alluvial yellow-grey TC soils* in the west.

The *Alluvial sands and sandy loams* have a thin (100-150 mm), grey or brown, surface layer of loamy coarse sand to sandy loam texture that grades into a slightly browner or redder subsurface layer. Between 350 and 70 mm depth, the subsurface layer grades into brighter coloured, red or brown subsoil. Texture of the subsurface layer and subsoil is similar to the surface layer. Buried layers of coarse sand, representing earlier deposition events, may occur below 1.5 m depth.

The ground surface is loose to soft when dry and structure varies from single grain to massive throughout the profile.

Field pH may vary from medium acid to neutral in the surface layer but is generally neutral to moderately alkaline below.

A few small pebbles may occur below 1 m depth.

Total soil profile depth, including any buried layers, is more than 1.5 m.

Alluvial loams and earths

The *Alluvial loams and earths* also represent minor soils on lower-lying terraces of the alluvial plains that could not be mapped separately. They are closely associated with *Alluvial yellow-grey TC soils* in the south and west.

The *Alluvial loams and earths* include two distinct profiles:

- stratified loams with a moderately thick (300-600 mm), dark sandy clay loam surface layer that overlies buried layers of varied texture, colour and thickness; and
- loamy gradational soils similar to the *Deep red-yellow earths* but overlying buried layers of varied texture, colour and thickness rather than a mottled, gravelly layer.

The buried layers may vary in texture from loamy sand to sandy light clay, from dark grey to yellow or red in colour and from massive to moderate structure.

The ground surface is firm to hard setting when dry and structure is massive above the buried layers.

Field pH may vary from medium acid to neutral throughout all layers.

Very few, if any pebbles are present on the surface and through the profile.

Total soil profile depth, including any buried layers, is more than 1.5 m.

3.3 Acid sulfate soils

Acid sulfate soils (ASS) refer to soil profiles, soil layers and sediments that contain iron sulfides, the most common of these being pyrite. When disturbed, ASS can have highly negative effects on the immediate and surrounding environment.

ASS characteristically occur in estuaries, tidal mangroves, wetlands, floodplains, lakes and other areas at elevations less than 5 metres above sea level. ASS can also be found at higher elevations and further inland, where pyrite forming conditions are present. Pyrite can form where there is an abundance of iron in the sediment, organic matter, saline water and anaerobic conditions.

These conditions are only met inland where there are organically enriched deposits at the edges of saline lakes and waterways.

Field investigation found that conditions suitable for the development of acid sulfate soils were not present within the study area and it is extremely unlikely that ASS are present.

3.4 Land contamination

No potential land contamination issues were identified during the field investigation although inspection was precluded in some areas due to the absence of access tracks and wet conditions.

Cattle grazing has been the only industry historically undertaken across the SGCP study area. Given the extensive nature of this grazing, it is highly unlikely that any contamination issues exist other than at cattle dips. No cattle dips were observed during the field investigation.

Table 3. Soils within the SGCP study area

Soil	Terrain unit [1]	Brief description	ASC Suborder [2]	Area	
				(ha)	(%)
Rocky sands and sandy loams	Steep to rolling low hills on little weathered sedimentary rocks	Shallow soil with many large pebbles to stones and frequent rock outcrop and thin, grey, loamy sand or sandy loam that either directly overlies weathered rock or grades into a paler subsurface layer of similar texture which then overlies rock; weathered rock at <150 to 300 mm depth	Clastic Rudosols and Leptic Tenosols	1,960	6.3
Ironstone sands and sandy loams	Scarps on strongly weathered sedimentary rocks	Shallow soil with iron-stained medium pebbles to stones common and red sandy loam of variable thickness that either directly overlies weathered rock or grades into a similarly coloured subsurface layer of loamy sand which then overlies ferricrete; weathered rock at <100 to 400 mm depth	Clastic Rudosols and Leptic Tenosols	245	0.8
Shallow red-yellow earths	Level plains to undulating rises on strongly weathered sedimentary rocks	Gradational soil with thick, grey or brown sandy loam merging into red or yellow subsoil increasing in texture with depth from sandy loam to sandy clay loam and occasionally to sandy light clay; clear change into gravelly, mottled (yellow-grey and some red) clay loam, sandy to sandy medium clay between 400 and 1 m depth	Red and Yellow Kandosols	20,535	65.8
Deep red-yellow earths	Level plains to undulating rises on strongly weathered sedimentary rocks	Gradational soil with thick, grey or brown sandy loam merging into red or yellow subsoil increasing in texture with depth from sandy loam to sandy clay loam and occasionally to sandy light clay; clear to gradual change into mottled (yellow-grey and some red), gravelly clay loam, sandy to sandy medium clay below 1 m depth	Red and Yellow Kandosols	3,370	10.8
Shallow red-grey TC soils	Gently undulating plains and rises on strongly weathered sedimentary rocks	Red sandy loam of variable thickness over conspicuously bleached sandy loam to sandy clay loam that rapidly changes into mottled, red and grey sandy light clay to sandy medium clay; strongly weathered rock usually at 400 to 750 mm depth	Red and Grey Sodosols	40	0.1
Deep red-grey TC soils	Gently undulating rises on strongly weathered sedimentary rocks	Thin, brown or dark grey, sandy loam to clay loam, sandy over occasionally thick subsurface layer of similar texture but paler colour with rapid change into mottled (red to brown and grey) sandy light clay to medium heavy clay; strongly weathered rock below 1 m and usually below 1.5 m depth	Red, Brown and Grey Sodosols	660	2.1
Deep yellow-grey TC soils	Level plains to undulating rises on strongly weathered sedimentary rocks	Grey sandy loam to clay loam, fine sandy of variable thickness usually over conspicuously bleached subsurface layer of similar texture and thickness that rapidly changes into mottled (yellow, grey and red) sandy light medium clay to heavy clay between 100 mm and 1.1 m depth; strongly weathered rock below 1 m and usually below 1.5 m depth	Yellow and Grey Sodosols	1,415	4.5

Soil	Terrain unit [1]	Brief description	ASC Suborder [2]	Area (ha)	Area (%)
Alluvial red TC soils	Alluvial plains on recent alluvium	Thick, dark sandy loam over paler, red subsurface layer of similar texture that rapidly changes into red sandy light clay which may contain grey mottles often overlying a buried layer of mottled (red, yellow and grey) sandy clay loam often; total profile depth including buried layer at least 1.5 m	Red Chromosols	1,120	3.6
Alluvial yellow-grey TC soils	Alluvial plains and drainage depressions on recent alluvium	Grey to dark surface layer of sandy loam, sandy clay loam or clay loam and variable thickness often over a thick, sporadically or conspicuously bleached paler subsurface layer of similar variable texture with a rapid change into mottled (grey, yellow and red) sandy light clay to sandy medium heavy clay; total profile depth including buried layer at least 1.5 m	Yellow and Grey Sodosols	1,875	6.0
Alluvial sands and sandy loams [3]	Alluvial plains and drainage depressions on recent alluvium	Thin, grey or brown, loamy coarse sand to sandy loam grading into a slightly browner or redder subsurface layer then into brighter coloured, red or brown subsoil of similar texture; soil profile depth at least 1.5 m but buried layers of coarse sand may occur below this depth	Stratic Rudosols and Leptic Tenosols	nd [3]	nd [3]
Alluvial loams and earths [3]	Alluvial plains and drainage depressions on recent alluvium	Either • stratified loams with a moderately thick, dark sandy clay loam over buried layers of varied texture, colour and thickness; or • loamy gradational soils similar to the *Deep red-yellow earths* but overlying buried layers of varied texture, colour and thickness rather than a mottled, gravelly layer	Stratic Rudosols, Grey Dermosols and Red and Yellow Kandosols	nd [3]	nd [3]
			Total	**31,220**	**100.0**

Notes:

1. A terrain unit is based on weathering history of the underlying rocks and resultant regolith cover.
2. ASC Suborder represents the soil taxonomic classification (to its second or suborder level) using the Australian Soil Classification (Isbell 2002).
3. The *Alluvial sands and sandy loams* and *Alluvial loams and earths* only occur as minor soils associated with other dominant soils and therefore their area could not be determined (nd).

3.5 Good Quality Agricultural Land

Grazing cattle for beef production is the only land use within the SGCP study area, apart from the Capricorn Highway and Rockhampton-Longreach Railway crossing the revised rail corridor.

The differing soil profile features, chemical properties and physical properties between soils results in a varying capacity to support pasture production within this area.

The Queensland Government introduced a State Planning Policy in 1992 (SPP 1/92) to protect GQAL. In support of this policy, four classes of agricultural land were defined for Queensland:

- Class A Crop land;
- Class B Limited crop land;
- Class C Pasture land; and
- Class D Non-agricultural land.

For the Jericho Shire 2006 Planning Scheme (Campbell Higginson Town Planning Pty Ltd 2006), DERM used information provided with the CSIRO land system survey (Gunn et al. 1967) to assign Agricultural Land Classes to rural land within the shire. As part of the allocation process, DERM also divided Pasture land into two subclasses:

- Class C1 – higher productivity pasture land based on high quality native pastures or on pastures that can be readily improved; and
- Class C2 – lower productivity pasture land based on low quality native pastures on which pasture improvement is not economically viable.

DERM classified all soils within the SGCP study area as being Pasture land. Land with texture contrast soils that originally supported brigalow forests was allocated to Class C1. These soils are considered to have reasonable water storage capacity and a raised level of soil fertility resulting in better quality pastures. All other land was assigned to Class C2.

Generally, crop land (both Class A and Class B) is designated as GQAL for the purpose of protecting agricultural productivity under State Planning Policy 1/92. However in local authorities where the pastoral industry is the dominant form of land use and income generation, Class C1 is often designated as GQAL as well.

Table 4 presents the results of applying the DERM classification to the soil mapping units identified during this study for land within the SGCP study area. The DERM classification separates Class C1 and C2 land on the basis of original vegetation. Remnant vegetation mapping and original vegetation descriptions in the available land system mapping (Gunn et al. 1967, Lorimer 2005) have been used to identify all soil mapping units which originally supported brigalow forests. These soil mapping units have been allocated to Class C1 whereas all other units have been designated Class C2. Table 5 provides the relative area of GQAL and other Agricultural Land Classes.

The vast majority (97.5%) of the study area is considered to be Class C2 pasture land which is not GQAL. Only 2.5% of the SGCP study area contains texture contrast soils that either wholly or partly supported brigalow forests. This Class C1 land represents GQAL.

The distribution of these land classes is shown in Figure 5.

The GQAL pasture land is located on areas of *Deep yellow-grey TC soils* located mainly in the west and south of the SGCP study area but with one small area approximately 14 km along the infrastructure corridor. These are the only areas where brigalow forests appear to be the original natural vegetation.

Table 4. Agricultural land classes

Soil	Natural vegetation	Agricultural Land Class [1]
Rocky sands and sandy loams	Eucalypt woodlands	Class C2
Ironstone sands and sandy loams	Eucalypt woodlands	Class C2
Shallow red-yellow earths	Eucalypt woodlands	Class C2
Deep red-yellow earths	Eucalypt woodlands	Class C2
Shallow red-grey TC soils	Eucalypt woodlands	Class C2
Deep red-grey TC soils	Eucalypt woodlands	Class C2
Deep yellow-grey TC soils	Brigalow closed forests	Class C1
	Brigalow closed forests/Eucalypt woodlands	Class C1/C2
	Eucalypt woodlands	Class C2
Alluvial red TC soils	Eucalypt woodlands	Class C2
Alluvial yellow-grey TC soils	Eucalypt woodlands	Class C2

Notes:

1. Using the DERM criterion, Class C1 has been applied to soils that originally supported brigalow closed forests; Class C2 has been applied to all other soil mapping units.

Table 5. Area of GQAL and other land

Agricultural Land Class	Status	Area (ha)	(%)
Class C1	Pasture land - GQAL	620	2.0
Class C1/C2	Pasture land –part GQAL	160	0.5
Class C2	Pasture land - other	30,440	97.5
	Total	**31,220**	**100.0**

3.6 Strategic Cropping Land

The Queensland Government released a policy framework in August 2010 for protecting Queensland‟s strategic cropping land (SCL). The Queensland Government approach to protection involves developing and implementing legislative and planning tools, including a specific Act of Parliament for SCL resources and a new State Planning Policy under the Sustainable Planning Act 2009 (DERM 2011a).

The SCL policy framework highlighted that on-ground assessment against a defined set of criteria would be necessary to identify SCL, and the criteria would be released as the SCL framework was further developed and implemented.

Trigger maps showing where SCL is expected to exist were released in early 2011 and draft criteria and thresholds for five nominated cropping zones were released in April (DERM 2011a). Guidelines for applying the criteria and thresholds were released in September 2011 (DERM 2011b).

Trigger maps provide the starting point for determining whether an area is SCL by identifying areas where SCL may exist. The maps show land within the five zones where SCL is expected to exist based on the best soil, land and climate information currently held by the Queensland Government (DERM 2011b).

The five zones accommodate regional differences in climate, landform and cropping systems but only apply to the key cropping landscapes of Queensland.

The SCL framework does not apply outside these zones. As the SGCP study area is inland of the Western Cropping Zone and thus outside all five zones it does not need to be assessed under this policy.

3.7 Existing erosion

Soil erosion is governed by the inherent erodibility of the soil profile, the topography of the site, volume and intensity of the incident rainfall and the land use practices which determine the amount of vegetative cover and condition of the ground surface.

Approximately 56% of the SGCP study area consists of plains, rises and drainage depressions with very gentle slopes of up to 3%.

Undulating rises with slopes of up to 10%, occupy almost 37% of the SGCP study area.

Steep to rolling low hills with slopes commonly more than 30%, though some crests may be as low as 3%, occupy just over 6% of the SGCP study area whilst scarps on ferricrete are commonly steep but can vary from 3 to 60%. The scarps occupy less than 1% of study area.

The land use practises within the SGCP study area have been, and still are, predominantly related to grazing beef cattle on native and improved pastures.

Whilst many of the soils are highly erodible (see section 4.6), the grazing practices and mainly gentle slopes have restricted erosion to relatively few areas.

Figure 6 shows those areas in which some erosion was observed during field investigation.

Minor to severe sheet erosion is widespread across the *Ironstone sands and sandy loams*. Where these soils occur on scarps, rill and gully erosion is also occurring on the footslopes below the scarps.

Minor to severe rill and gully erosion is evident in several drainage depressions containing *Alluvial yellow-grey TC soils.*

Minor gully erosion was also observed in southern areas of the *Shallow red-yellow earths*.

4. Potential constraints and impacts

This section describes the constraints for constructing infrastructure associated with the proposal and also assesses the potential impacts of the proposed activities on the geology, topography and soils.

4.1 Relevant activities

The SGCP involves the following key elements that may be affected by, or impact upon, the soil resource:

- coal mining operations, including:
  - open cut and underground mining within MLA 70453, producing up to 17 Mtpa of product coal for the export market;
  - placement of waste rock and rejects in out-of-pit waste rock emplacements;
  - progressive backfilling of the open pits with waste rock and rejects as mining develops;
- development of a mine water management system including clean water diversions, mine affected runoff collection, sediment dams, pit water management process and on-site water reuse procedures and a permanent diversion of Sapling Creek;
- underground services area;
- Mine Industrial Area (containing administration, bath house, storage, vehicle parking, workshops, washdown, refuelling, controls and communication infrastructure);
- Coal Handling and Preparation Plant;
- coal handling infrastructure (including conveyor systems, raw coal and product coal stockpiles);
- development of a Mine Access Road and on-site haul roads and light vehicle roads;
- construction of an on-site rail component (including loading loop, breakdown and fuel sidings);
- construction of a SGCP rail spur component to connect to the common user rail component;
- on-site accommodation village;
- fuel, oil and explosives storage facilities;
- soil stockpiles, laydown areas and a gravel borrow pit;
- raw water supply infrastructure (e.g. pipeline, groundwater bores and Raw Water Dam);
- sewage and waste water treatment infrastructure;
- on-site landfill facility;
- electrical and telecommunications infrastructure;
- ongoing monitoring and rehabilitation;
- ongoing exploration activities within existing exploration tenements; and
- other associated minor infrastructure, plant, equipment and activities.

Ongoing exploration and maintenance activities may also be constrained by, or have an impact on soils.

All relevant construction and operational activities have been considered when assessing each prospective constraint and potential impact.

4.2 Data and rating system used

Information used to assess the constraints and impacts has been obtained from available soil information reviewed during the desktop analysis and from data collected during field investigation. This has been supported by laboratory analyses of selected soil samples collected during field investigation and from published data when assessing erosion, soil fertility and salinity.

The assessment involves rating the severity of each constraint or impact into one of five categories:

Nil	No constraint or impact due to the feature.
Minor	A slight constraint or impact that is readily overcome or controlled with standard management practices and mitigation measures.
Moderate	A substantial constraint or impact but is overcome or controlled with a combination of standard and special practices and mitigation measures.
Severe	A substantial constraint or impact that may be overcome or controlled only with special practices and mitigation measures.
Extreme	A constraint or impact that cannot usually be overcome or controlled even with special practices and mitigation measures.

Constraints and impacts that are rated as moderate or worse are described as being "significant" throughout this report, as specialised mitigation or control will be required.

4.3 Topography

Steep slopes and deeply dissected terrain can:

- limit access of specialist heavy machinery;
- impede excavation; and
- require special measures to build access tracks with an appropriate grade.

Grade of slope and slope length also have a strong influence on potential erosion but this aspect of topography is considered under the issue of erosion hazard (see section 4.6).

Landform descriptions developed during this study have been used to develop a decision matrix, shown in Table 6, which rates the severity of topography as a constraint to access, building tracks and excavation.

Figure 7 shows where the topography is a constraint within the SGCP study area.

Approximately 59% of the SGCP study area has no topography constraint and an additional 34% has only a minor constraint to any development activities.

The remaining 7% represents predominantly steep low hills, rolling low hills and scarps with a severe to extreme constraint though 20 ha of undulating rises in the south-west have also been allocated a moderate constraint.

Table 6. Decision matrix for rating topography

Landform component	Relief [1] and modal slopes [2]	Constraint rating
Rolling to precipitous mountains Steep to precipitous low hills and hills	Relief >300+ m; slopes >10% Relief 30-300 m; slopes >30%	Extreme
Undulating to rolling hills Rolling low hills	Relief 90-300 m; slopes 3-30% Relief 30-90 m; slopes 10-30%	Severe
Undulating low hills Rolling to steep rises	Relief 30-90 m; slopes 3-10% Relief 9-30 m; slopes 3-30%	Moderate
Undulating rises Rolling plains	Relief 9-30 m; slopes 3-10% Relief <9 m; slopes 10-30%	Minor
Gently undulating rises	Relief 9-30 m; slopes 1-3%	Nil
Level to gently undulating plains	Relief <9 m; slopes 1-3%	Nil

Notes:

1. Relief refers to the difference in elevation between the highest and lowest levels of the landform component.
2. Modal slopes are the most common slopes within the landform component.

4.4 Depth to bedrock

Depth to bedrock will mainly affect the ability to:

- lay underground pipelines;
- construct roads and rail of appropriate grade; and
- excavate trenches for building foundations and associated services.

The constraint has been assessed by considering soil depth. Soil depth is usually reported as depth to weathered rock which can be either soft or hard. However, for the purpose of this study all weathered rock is assumed to be hard.

Table 7 presents the decision matrix used to rate the severity of depth to bedrock for infrastructure development that involves excavation.

Table 7. Decision matrix for rating depth to bedrock constraint

Depth to rock		Constraint rating
(m)	Category	
< 0.3	Very shallow	Extreme
0.3-0.6	Shallow	Severe
0.6-0.9	Moderately deep	Moderate
0.9-1.2	Deep	Minor
>1.2	Very deep	Nil

Depth to hard rock across the study area and its related constraint to excavation activities are shown in Figure 8.

Almost 93% of the SGCP study area has no constraint caused by shallow bedrock.

Bedrock can occur at very shallow depth wherever the *Rocky sands and sandy loams* and *Ironstone sands and sandy loams* occur. These are the dominant soils across almost all of the remaining area (7%) and create an extreme constraint. Any excavation for trenches or foundations below 100 mm depth on these soils will require using heavy duty equipment that can cut through hard rock.

At the northern end of the infrastructure corridor is 40 ha of *Shallow red-grey TC soils* which overlie bedrock usually between 0.4 and 0.75 m depth. This area has been assigned a moderate to severe constraint.

4.5 Stoniness and rock outcrop

Presence of cobbles, stones or boulders (with >60 mm diameter) and outcropping bedrock can:

- limit the suitability of an area for locating hardstand areas;
- lower the efficiency of excavation; and
- reduce the working life of excavation equipment.

Table 8 presents the decision matrix used to rate the severity of stoniness and rock outcrop to constraining the creation of hardstand areas and to excavation.

Table 8. Decision matrix for rating stoniness and rock outcrop

Stoniness [1] or rock outcrop [2] (%)	Constraint rating
>50	Extreme
25-50	Severe
10-25	Moderate
2-10	Minor
<2	Nil

Notes:

1. Stoniness refers to the presence of cobbles (60-200 mm diameter), stones (200-600 mm diameter) and boulders (>600 mm diameter).
2. Rock outcrop refers to the presence of bedrock outcropping at the surface.

The stoniness and rock outcrop constraint across the entire study area is shown in Figure 9.

Almost 93% of the SGCP study area has no constraint caused by stoniness and rock outcrop.

The remaining area consists of *Rocky sands and sandy loams* and *Ironstone sands and sandy loams*. Stones may be abundant throughout the soil profile of the *Rocky sands and sandy loams* and bedrock also outcrops at the surface. This soil has been assigned an extreme rating, covering almost 6.5% of the SGCP study area. Stones are also common on the surface of the *Ironstone sands and sandy loams* and this soil has a moderate rating but covers <1% of the SGCP study area.

4.6 Erosion hazard

Environmental impact due to soil erosion can result from activities associated with the SGCP that will disturb the ground surface and ground cover, including:

- clearing vegetation;
- construction of the mine access road, heavy vehicle and light vehicle roads, on-site rail component and the rail line inside the infrastructure corridor;
- topsoil stripping;
- excavation for all infrastructure listed in section 4.1; and
- concentrating run-off water flow from disturbed areas.

4.6.1 Wind erosion

Wind erosion can be a substantial issue with soils containing incoherent soil material at the ground surface where sparse vegetation cover does not adequately protect it from the influence of strong winds. The largest areas affected by wind erosion in Australia are inland dryland farming areas where the soils are predominantly sandy and average annual rainfall is below 375 mm (Charman and Murphy 1991).

Wind erosion is usually negligible in semi-arid and wetter agricultural areas where there is sufficient rainfall to maintain adequate ground cover but can be significant on coastal sands where there is very little vegetation cover.

Though sandy soils occur within the SGCP study area, the average annual rainfall is 559 mm (Source: Bureau of Meteorology) and there is no cultivation leaving large areas of bare ground.

The overall wind erosion hazard is nil throughout the SGCP study area.

Small areas of bare land may be created on the sandy soils during the SGCP and the dust hazard generated as a result of these activities is assessed in section 4.10.

4.6.2 Water erosion

Water erosion is governed by the inherent erodibility of the soil profile, topography, volume and intensity of the incident rainfall and land use practices which determine the amount of vegetative cover and condition of the ground surface.

Though the rainfall regime for the study area is characterised by low average rainfall (compared with the coast), intensity can be very high due to occurrence of summer storms that move through the district with weather fronts and to the occasional incidence of low pressure systems which are remnants of tropical cyclones.

The water erosion hazard associated with the proposal has been determined within the existing rainfall regime. Two factors have been primarily used to determine erosion hazard – soil erodibility and slope grade. Though slope length, land use practices and vegetation cover also have an influence, these factors can be manipulated by management decisions and can thus be changed to reduce and manage the overall risk.

4.6.3 Soil erodibility indicators

The erodibility of soil is determined by the rate of infiltration at its surface, permeability of the soil profile and coherence of the soil particles. Coherence and permeability are related to structure, texture and chemical properties such as organic matter content. These properties often vary between the surface layer and subsoil. Thus, the overall potential of a soil profile to erode is a combination of the inherent erodibility for its surface layer (often referred to as topsoil erodibility) and the erodibility of any underlying subsoil.

Even coherent and structured soils can be highly erodible due to clay dispersion. Dispersion of clay particles can damage soil structure by destroying large, flocculated aggregates and filling the voids between these aggregates with much smaller dispersed material. The porosity and permeability of the soil declines and the erodibility increases as the small dispersed particles are easily moved in water that ponds and then seeps along the top of the dispersed material.

A direct measure of soil erodibility is very difficult to obtain and this attribute is usually estimated through identification of key soil features such as texture, surface condition, consistence, colour and structure. Laboratory analyses are also used to determine surrogate chemical and physical properties for dispersion.

The erodibility of soils within the SGCP study area has been assessed using key soil features supported by sampling of the main soils to confirm their tendency to disperse.

Soil samples from thirteen profiles and four extra surface layer samples plus one additional subsoil sample were submitted for laboratory analysis. Full results are presented in Attachment B and relevant analytical results for soil erodibility are summarised in Table 9.

The Exchangeable Sodium Percentage (ESP) and Exchangeable Calcium : Exchangeable Magnesium (Ca:Mg) ratio are two chemical properties used as independent estimates of dispersion. They are determined from analysis of the relative proportion of exchangeable calcium, magnesium, sodium, potassium and aluminium.

ESP and Ca:Mg ratio are derived from chemical analyses and must be interpreted with care. When the actual exchangeable cation levels are very low, any small change in one value can cause a disproportionate change in the percentage or ratio calculation and thus significantly alter the dispersion rating.

Sodic soil (ESP 6-14) is usually considered as being dispersive and strongly sodic (ESP ≥ 15) soil is nearly always dispersive. Ca:Mg ratios of 0.5 or less have been reported to be associated with dispersion in Australian soils and ratios of less than 0.1 are considered significant and used to differentiate magnesic subsoil in the Australian Soil Classification (Isbell 2002).

Soil dispersion can also be estimated by testing aggregate stability after a small piece of soil is placed in distilled or deionised water. Several aggregate stability tests have been developed and the test used for this study involves recording and rating the clouding and slaking behaviour of the soil over time (Hughes and Evans 1999). Clouding and slaking have been tested for all SGCP soil samples with soil behaviour being rated from 0 to 4. Structural instability increases as the ratings increase from 0 and Ratings 3 and 4 are considered to indicate substantial capacity for dispersion.

Table 9 shows that all samples from the surface and subsurface layers are non sodic (ESP <6) except for one subsurface sample from the *Alluvial yellow-grey TC soils* which has an ESP of 6. All Ca:Mg ratios are ≥0.9.

ESP and Ca:Mg ratios in the surface and subsurface layers have been calculated from low levels of exchangeable cations and may not necessarily be reliable indicators of dispersion. However, the Clouding and Slaking ratings vary from 0 to 2 except for one subsurface sample from the *Deep red-grey TC soils* which has a Clouding rating of 2 and a Slaking rating of 3. There is little likelihood of dispersion occurring in any of these layers.

Data in Table 9 also show that subsoil in the *Shallow red-yellow earths*, *Deep red-yellow earths*, *Alluvial red TC soils* and *Alluvial sands and sandy loams* are non-sodic and have Ca:Mg ratios >1 as well as Clouding and Slaking ratings of 0 to 2.

The mottled, gravelly layer beneath subsoil of the *Shallow red-yellow earths* and *Deep red-yellow earths* displays similar properties. However, one of the four samples is strongly sodic with a low Ca:Mg ratio and has a Clouding rating of 3 (though the Slaking rating is only 2). This layer is generally non dispersive but there may be areas where it displays some capacity for dispersion

Table 9 also shows that subsoil of the *Deep red-grey TC soils* and *Alluvial yellow-grey TC soils* is dispersive, confirming field observations that the soil material appeared sodic during texturing. The upper part of the clay subsoil in the *Deep yellow-grey TC soils* is non sodic and has Ca:Mg ratios of >1 with Clouding and Slaking ratings of <2. However, the lower subsoil is sodic and has a Clouding rating of 3.

Table 9. Analytical results for soil erodibility

Soil [1]	Soil layer	pH	EC [2] (dS/m)	CEC [3] (meq%)	ESP [4] (%)	Ca:Mg [5]	Clouding rating [6]	Slaking rating [6]
Rocky sands and sandy loams	Surface layer	4.3	0.04	2	3	1.9	1	0
Ironstone sands and sandy loams	Surface layer	5.9	0.02	3	2	2.4	0	1
Shallow red-yellow earths	Surface layer	6.5-8.3	0.03-0.11	4-32	<1-2	2.3-10.7	0-1	0-1
	Upper subsoil	6.6-6.7	0.02-0.03	3-5	1-2	1.8-2.9	0-1	0-1
	Lower subsoil	6.8-6.9	0.03	3-6	1-5	0.5-2.3	0-1	0-2
	Mottled, gravelly layer	7.2-8.2	0.04-0.08	7-12	5-21	0.2-1.7	0-3	1-2
Deep red-yellow earths	Surface layer	5.7-7.2	0.03-0.04	3-6	<1-5	1.4-4.2	0	1-2
	Upper subsoil	6.8-7.3	0.03	4-5	1-2	2.2-4.8	0	1-2
	Lower subsoil	6.5	0.02	4-5	1	1.2-2.3	1	2
	Mottled, gravelly layer	7.1	0.03	5	1	0.7	1	1
Deep red-grey TC soils	Surface layer	6.4-6.5	0.05-0.07	4-15	1-2	1.4-3.0	1	0-1
	Subsurface layer	5.9	0.04	3	2	2.0	2	3
	Upper subsoil	8.0-9.0	0.22-0.92	11-28	9-20	0.3-0.7	2-4	1-4
	Lower subsoil	8.5-8.8	0.66-2.12	14-29	19-30	<0.1-0.3	3-4	3-4
Deep yellow-grey TC soils	Surface layer	5.5-6.0	0.06-0.10	4	1-2	2.2-4.8	0	1
	Upper subsoil	6.9-7.1	0.07-0.32	13	3-5	1.2-1.4	1-2	2
	Lower subsoil	7.1	0.04	14	11	1.0	3	2
Alluvial red TC soils	Surface layer	6.1	0.02	5	<1	4.2	0	1
	Upper subsoil	6.5	0.02	4	1	2.4	0	2
	Lower subsoil	7.1-7.4	0.02	5-6	1	2.6-2.8	0	2
	Buried layer	7.4	0.05	4	1	2.3	0	2
Alluvial yellow-grey TC soils	Surface layer	5.0-6.0	0.02-0.28	2-5	2-5	0.9-2.4	0-1	1-2
	Subsurface layer	5.8-6.4	0.02-0.07	2	3-6	0.9-1.3	1	1-2
	Upper subsoil	6.6-8.0	0.11-0.37	7-10	12-39	0.1-0.6	3-4	2-4
	Lower subsoil	6.5-7.4	0.04-0.45	8-10	20-44	<0.1-0.6	3-4	3-4
Alluvial sands and sandy loams [7]	Surface layer	6.9	0.03	4	1	6.1	0	1
	Upper subsoil	7.3-7.5	0.03	3	1	8.1-8.8	0	2
	Lower subsoil	7.8-7.9	0.03-0.04	3	1	7.8	0	2

Notes:

1. *Shallow red-grey TC soils* were not sampled for laboratory analysis as they cover only 40 ha and should have the same chemical and physical properties as the *Deep red-grey TC soils*. *Alluvial loams and earths* were not sampled as they represent only a very minor soil on the alluvial plains and drainage depressions.
2. EC represents Electrical Conductivity which is a measure of soil salinity.
3. CEC represents Cation Exchange Capacity and is a measure of the soil ability to retain positively charged nutrients (such as calcium, magnesium, potassium, ammonium) for use by plant roots, as well as sodium and aluminium; CEC is measured in milliequivalents per 100 g soil (meq %). For soil samples with acid to neutral pH, CEC is measured with an extractant at pH 7 and is referred to as Effective CEC (ECEC); for alkaline soils an extractant at pH 8.5 is used.
4. ESP represents Exchangeable Sodium Percentage and is the percentage of CEC that is due to exchangeable sodium.
5. Ca:Mg is the ratio of exchangeable calcium to exchangeable magnesium.
6. Clouding and Slaking are rated from 0 to 4 with tendency for structural instability increasing from nil for Rating 0 to complete at Rating 4.
7. Though not mapped as a dominant soil, the *Alluvial sands and sandy loams* were sampled, as they are an important minor soil on the alluvial plains and drainage depressions.

Overall, the data indicates that the *Deep red-grey TC soils*, *Deep yellow-grey TC soils* and *Alluvial yellow-grey TC soils* represent dispersive texture contrast soils. The *Shallow red-grey TC soils* were not sampled for laboratory analysis as they cover only 40 ha but should have the same chemical and physical properties as the *Deep red-grey TC soils*. In contrast, the *Alluvial red TC soils* represent a non-dispersive texture contrast soil.

4.6.4 Overall soil erodibility

Table 10 gives the inherent soil profile erodibility of the soils based on all available evidence.

Soils with either incoherent to weakly coherent surface layers or with lower permeability and with a substantial tendency to disperse in the subsoil have a higher erodibility rating than others.

Table 10. Inherent erodibility of the soils

Soil	Erodibility rating	Factors
Rocky sands and sandy loams	Moderate	Incoherent to weakly coherent sandy material which is quite permeable but can be easily detached by flowing water
Ironstone sands and sandy loams	Moderate	Incoherent to weakly coherent sandy material which is quite permeable but can be easily detached by flowing water
Shallow red-yellow earths	Moderate	Sandy profiles with incoherent to weakly coherent surface layer and quite permeable profile though the mottled, gravelly layer below the subsoil may be partly dispersive
Deep red-yellow earths	Moderate	Sandy profile with incoherent to weakly coherent surface layers and quite permeable profile though the mottled, gravelly layer below the subsoil may be partly dispersive
Shallow red-grey TC soils	Very high	Coherent, permeable surface layer overlying very slowly permeable subsoil causing water to pond then seep along the top of the very dispersive subsoil
Deep red-grey TC soils	Very high	Coherent, permeable surface layer overlying very slowly permeable subsoil causing water to pond then seep along the top of the very dispersive subsoil
Deep yellow-grey TC soils	High	Coherent, permeable surface layer overlying very slowly permeable subsoil causing water to pond then seep along the top of dispersive subsoil
Alluvial red TC soils	Low	Weakly coherent surface layer and quite permeable profile
Alluvial yellow-grey TC soils	Very high	Coherent, permeable surface layer overlying very slowly permeable subsoil causing water to pond then seep along the top of the very dispersive subsoil
Alluvial sands and sandy loams	Moderate	Incoherent to weakly coherent sandy material which is quite permeable but can be easily detached by flowing water

4.6.5 Grade of slope

Generally, water erosion of soil is minimal on slopes of less than 1% unless dispersive soil material is exposed to running water. Tunnel and gully erosion can develop on exposed dispersive soil material, even on land with minimal slope. With increasing slope, the capacity for run-off increases and thus the potential for dislodging and moving soil particles also rises.

Contours of 1 m interval have been used to determine the modal slope range for each soil mapping unit. Modal slopes are reported in Table 2 and are:

- 3% or less over 56% the SGCP study area;
- up to 10% on another 37% of the area; and
- much steeper (up to 60%) occurring on the remaining 7% of the SGCP study area.

4.6.6 Water erosion hazard rating

An erosion hazard rating has been determined to account for the high level of disturbance associated with most construction and operational activities proposed for the SGCP study area. Table 11 summarises the decision matrix developed to assign an erosion hazard rating to individual soils. Figure 10 shows the water erosion hazard rating for the study area.

Table 11. Decision matrix for rating water erosion hazard

Soil erodibility	Landform-slope categories [1]	Constraint rating
Very low to low Moderate High to very high	Steep to precipitous mountains, hills, dissected plateaus and plateau scarps Rolling hills and low hills Undulating low hills and rises	Extreme
Very low to low Moderate High to very high	Rolling mountains, hills and low hills Undulating low hills and rises Undulating rises and plains	Severe
Very low to low Moderate High to very high	Undulating low hills and rises Undulating rises and plains Gently undulating rises Level to gently undulating plains	Moderate
Very low to low Moderate High to very high	Undulating rises and plains Gently undulating rises Gently undulating rises Level to gently undulating plains and plateau surfaces Level plains	Minor
Very low to low Moderate	Level to gently undulating plains and plateau surfaces Level plains	Nil

Notes:

1. Slope categories are from the third edition of the Australian soil and land survey field handbook (The NCST 2009):

Steep to precipitous	≥ 32%
Rolling	10-32%
Undulating	3-10%
Gently undulating	1-3%
Level	<1%

Less than 4% of the SGCP study area has no erosion hazard and represents the *Alluvial red TC soils* on level alluvial plains.

Another 41% has been assigned a minor erosion hazard. *Shallow red-yellow earths* and *Deep red-yellow earths* on levels plains to gently undulating rises account for most of this rating but 6% of the area represents *Alluvial yellow-grey TC soils* on alluvial plains and drainage depressions with slopes ≤2%. Also included are 20 ha of *Deep yellow-grey TC soils* on level plains.

Almost 46% of the SGCP study area has a moderate hazard rating of which 38% is due to the presence of *Shallow red-yellow earths* and *Deep red-yellow earths* on undulating plains and rises. The remaining 8% of the area with a moderate rating consists of *Shallow red-grey TC soils*, *Deep red-grey TC soils* and *Deep yellow-grey TC soils* on gently undulating to undulating rises and *Alluvial yellow-grey TC soils* on drainage depressions with slopes of 2 to 3%.

Approximately 2.5% of the SGCP study area represents *Deep yellow-grey TC soils* on undulating rises, resulting in a severe hazard rating.

Just over 7% has an extreme erosion hazard. This land consists of *Rocky sands and sandy loams* on steep to rolling low hills and *Ironstone sands and sandy loams* on scarps. Also included are 20 ha of *Deep yellow-grey TC soils* on steeper sloping undulating rises.

4.7 Soil fertility

Soil fertility is a prime determinant of the ability to successfully revegetate disturbed areas. Low soil fertility can result in:

- inadequate establishment of plant species used for revegetation;
- on-going exposure of bare land in poorly rehabilitated areas;
- increased soil erosion due to greater exposure of bare land; and
- damage to infrastructure through soil erosion.

Soil fertility is usually determined using laboratory analyses of the surface layer as plant roots for most species are concentrated in the top one to two hundred millimetres of soil.

Table 12 summarises the analytical results for 17 surface layer samples collected from 13 profiles and from four additional surface samples as part of this study. Full results are presented in Attachment B.

Table 12 shows that exchangeable calcium levels vary considerably but available phosphorus and exchangeable potassium levels are less variable. Levels of these latter two nutrients have been shown to be closely related to source geology and history of weathering throughout Queensland, though land use history still has some effect. Organic matter content is strongly influenced by vegetation cover and land use history.

The *Rocky sands and sandy loams* and *Ironstone sands and sandy loams* have lower calcium and potassium levels than the other soils.

The *Rocky sands and sandy loams* still support a low closed forest of lancewood (*Acacia shirleyi*) whereas all other sample sites were collected from cleared pastures. This difference is reflected in the much higher organic matter content, which is probably the cause for the elevated level of available phosphorus.

However, the surface pH is extremely acid in the *Rocky sands and sandy loams* whereas the other soils have a predominantly medium acid to moderately alkaline pH in the surface layer.

One of two samples from the *Deep yellow-grey TC soils* and one of four samples from the *Deep red-yellow earths* have elevated levels of available phosphorus. All other surface samples from soils overlying strongly weathered sedimentary rocks have much lower phosphorus levels (<10 mg/kg). The *Alluvial red TC soils* and *Alluvial sands and sandy loams* also have elevated phosphorus levels, probably due to more frequent enrichment by flood deposition.

The *Shallow red-grey TC soils* were not sampled for laboratory analysis as they cover only 40 ha but should have the same chemical and physical properties as the *Deep red-grey TC soils*.

Table 12. Soil fertility analytical results

Soil [1]	pH	EC [2] (dS/m)	CEC [3] (meq%)	Exch Ca [4] (meq%)	Exch K [4] (meq%)	OM [5] (%)	Olsen P [6] (mg/kg)
Rocky sands and sandy loams	4.3	0.04	2	0.5	0.29	4.5	17
Ironstone sands and sandy loams	5.9	0.02	3	1.7	0.17	1.0	8
Shallow red-yellow earths	6.5-8.3	0.03-0.11	4-32	2.7-27.9	0.31-1.08	1.0-1.3	4-8
Deep red-yellow earths	5.7-7.2	0.03-0.04	3-6	1.2-4.1	0.32-1.81	1.0-1.7	3-20
Deep red-grey TC soils	6.4-6.5	0.05-0.07	4-15	2.2-7.9	0.63-0.74	1.2-3.2	6-9
Deep yellow-grey TC soils	5.5-6.0	0.06-0.10	4	2.5-2.7	0.33-0.39	0.6-1.8	6-29
Alluvial red TC soils	6.1	0.02	5	2.8	0.41	1.1	16
Alluvial yellow-grey TC soils	5.0-6.0	0.02-0.08	2-5	2.5-3.2	0.31-0.35	1.4-2.3	5-9
Alluvial sands and sandy loams [7]	6.9	0.03	4	2.8	0.41	1.1	16

Notes:

1. *Shallow red-grey TC soils* were not sampled for laboratory analysis as they cover only 40 ha and should have the same chemical and physical properties as the *Deep red-grey TC soils*. *Alluvial loams and earths* were not sampled as they represent only a very minor soil on the alluvial plains and drainage depressions.
2. EC represents Electrical Conductivity which is a measure of soil salinity.
3. CEC represents Cation Exchange Capacity and is a measure of the soil ability to retain positively charged nutrients (such as calcium, magnesium, potassium, ammonium) for use by plant roots, as well as sodium and aluminium; CEC is measured in milliequivalents per 100 g soil (meq %).
4. Exch Ca and Exch K represent exchangeable calcium and exchangeable potassium respectively, and are measured in meq %.
5. OM represents organic matter which is calculated by multiplying Organic carbon by 2.2.
6. Olsen P represents available phosphorus and is a measure of the amount of phosphorus, expressed in milligrams per kilogram of soil (mg/kg), which is readily available for plant use.
7. Though not mapped as a dominant soil, the *Alluvial sands and sandy loams* were sampled, as they are an important minor soil on the alluvial plains and drainage depressions.

Levels for phosphorus, potassium and organic matter content (which provides an indication of nutrient reserves surface layer) are summarised for each soil in Table 13.

The individual nutrient ratings used in Table 13 are based on:

- the typical range for organic matter in Australian soils (Baker and Eldershaw 1993);
- existing ratings for available phosphorus in grazing lands of central and north-east Queensland grazing lands (Ahern et al. 1994); and
- a literature review of potassium adequacy for grazing lands in central and north-east Queensland grazing lands (Ahern et al. 1994).

A soil fertility constraint rating that reflects the likelihood of having plant deficiencies in any of the major nutrients has been determined for each soil and is also given in Table 13. Organic matter content, phosphorus and potassium levels and pH have been considered during this process. The fertility constraint across the entire study area is shown in Figure 11.

Table 13. Soil fertility levels and constraint rating

Soil	OM [1]	Avail P [2]	Exch K [3]	Constraint rating
Rocky sands and sandy loams	Very high	High	Low	Moderate
Ironstone sands and sandy loams	Low	Low	Very low	Severe
Shallow red-yellow earths	Low	Very low-low	Medium-very high	Moderate
Deep red-yellow earths	Low	Very low-high	Medium-very high	Moderate
Shallow red-grey TC soils [4]	Low-high	Very low-low	High	Moderate
Deep red-grey TC soils	Low-high	Very low-low	High	Moderate
Deep yellow-grey TC soils	Very low-low	Very low-very high	Medium	Moderate
Alluvial red TC soils	Low	High	Medium	Minor
Alluvial yellow-grey TC soils	Low	Very low-low	Medium	Moderate
Alluvial sands and sandy loams [5]	Low	High	Medium	Minor

Notes:

1. OM represents organic matter and is an indication of the nutrient reserves in the surface layer.
2. Avail P represents available phosphorus and is a measure of the amount of phosphorus that is readily available for plant use.
3. Exch K represents exchangeable potassium and is a measure of the amount of potassium that is readily available for plant use.
4. Though not sampled for laboratory analysis, the *Shallow red-grey TC soils* should have the same chemical and physical properties as the *Deep red-grey TC soils*.
5. The *Alluvial sands and sandy loams* are not mapped as a dominant soil but represent an important minor soil on the alluvial plains and drainage depressions.

All soils have a low to very low level of at least one of the major nutrients and so all have been given a soil fertility constraint of some degree.

Approximately 3.5% of the SGCP study area has a minor soil fertility constraint and represents alluvial plains dominated by *Alluvial red TC soils*. Low organic matter is the only significant constraint on this soil.

Almost 96% of the SGCP study area has a moderate constraint. For approximately 90% of the area, this constraint is due to a combination of low to very low organic matter and predominantly low to very low available phosphorus. However, a combination of extremely acid pH and low exchangeable potassium also create a moderate constraint on the *Rocky sand and sandy loams*, which represent just over 6% of the area.

A severe soil fertility constraint applies to <1% of the SGCP study area and is land dominated by *Ironstone sands and sandy loams*. This soil has low to very low levels of organic matter, available phosphorus and exchangeable potassium.

4.8 Topsoil depth

This refers to the depth of soil material within a landscape that is suitable for use as "topsoil" during rehabilitation, especially revegetation, activities. Use of unsuitable material as "topsoil" during rehabilitation can decrease establishment and growth of ground cover and thus increase the erosion hazard through the presence of:

- coarse peds and clods that can‟t be worked to produce an adequate seedbed;
- highly erodible material; or
- material that is too saline for plant growth.

The Queensland Main Roads Department has issued specifications for identifying and classifying "topsoil" material that is suitable for use as planting media (DTMR 2009).

These specifications have been adopted for rating “topsoil” depth as a constraint within the SGCP study area. According to the specifications, any soil material from sand to light clay in texture is suitable for use as planting media, though amelioration may be required. Amelioration is undertaken to raise plant nutrients to adequate levels and to reduce acidity or any tendency to disperse.

Soils of medium to heavy clay texture are usually not used for revegetation as they are:

- too coarsely structured to maintain sufficient contact of moist soil with small seeds;
- only slowly permeable and can quickly saturate; and
- very hard when dry, thus restricting plant establishment.

However, medium to heavy clays that self-mulch upon drying to form a loose layer of fine soil aggregates may be suitable for use if no other material is available.

Both surface and subsurface layers may be used as “topsoil” but fertility usually declines below the surface layer and amelioration is usually required for subsurface layers to ensure successful revegetation.

Table 14 presents the decision matrix used to determine the severity of “topsoil” depth as a constraint to stripping for later use as planting media.

Table 14. Decision matrix for rating “topsoil” depth

“Topsoil” depth [1] (%)	Description	Constraint rating
Nil [2]	Not usable [3]	Extreme
≤100	Very thin	Severe
<100-300	Thin	Moderate
100-300	Thick	Minor
≥300	Very thick	Nil

Notes:

1. “Topsoil” consists of any surface layer and subsurface layer with a texture of sand to light clay or with strongly, self-mulching medium to heavy clay where soil aggregates are less than 5 mm diameter.
2. Nil refers to clay soils with a texture in the surface layer that is predominantly heavier than light clay and do not self-mulch to form loose soil aggregates less than 5 mm in diameter.
3. Not useable refers to soil material that should not be used as “topsoil” unless ameliorated beforehand.

Figure 12 shows “topsoil” depth across the entire study area.

Approximately 80% of the SGCP study area has very thick layer(s) suitable for use as “topsoil” and thus has no “topsoil” depth constraint. This land consists of *Shallow red-yellow earths*, *Deep red-yellow earths* and *Alluvial red TC soils*.

Another 13% has thick to very thick layer(s) suitable for “topsoil” with a nil to minor depth constraint. Included in this land are the *Shallow red-grey TC soils*, *Deep red-grey TC soils*, *Deep yellow-grey TC soils* and *Alluvial yellow-grey TC soils*.

The remaining 7% of the SGCP study area represents *Rocky sands and sandy loams* and *Ironstone sands and sandy loams* with only a thin cover of soil material that is suitable for “topsoil” and a resultant moderate “topsoil” depth constraint.

4.9 Salinity

Salinity refers to the concentration of soluble salts in the soil water. Soil sodicity refers to the relative abundance of sodium retained on clay surfaces where it can exchange with other ions in the soil water. High levels of soil sodicity primarily affect dispersion of clay particles, thus increasing soil erodibility and decreasing permeability. Therefore, the effects of soil sodicity are discussed section 4.6.

Elevated soil salinity within the root zone can retard plant growth. Very high to extreme levels of salt can also corrode concrete and steel foundations and steel pipe. With regard to the proposed development, soil salinity can:

- reduce revegetation efforts on disturbed areas;
- affect plant growth surrounding disturbed areas if saline water is released from excavations and thus increase erosion hazard; and
- corrode inappropriately designed foundations for infrastructure.

Available soil information and supporting data in Table 9 indicate that some soils have elevated levels of soluble salts in their profiles.

Salinity is very low to low in all surface and subsurface layers except for the *Alluvial yellow-grey TC soils* in which salinity of the surface layer varies from very low to medium.

Salinity remains very low through the soil profile of the *Rocky sands and sandy loams*, *Ironstone sands and sandy loams*, *Shallow red-yellow earths*, *Alluvial red TC soils* and *Alluvial sands and sandy loams*. Salinity varies from very low to low in the mottled, gravelly layer below the *Deep red-yellow earths* but is very low through the profile above.

In the other soils, salinity increases with depth through the subsoil to:

- remain at high to extreme levels below 1 m depth in the *Deep red-grey TC soils*;
- reach medium levels in the *Deep yellow-grey TC soils* before declining to very low at around 1 m depth; and
- reach medium levels in the upper subsoil of the *Alluvial yellow-grey TC soils* before declining to become very low to low at around 1.5 m depth.

Salinity at or near the surface is not a significant constraint within the SGCP study area. However, any activity that disturbs saline subsoil and brings it to the surface or just below can impact upon rehabilitation and revegetation and result in soluble salts being leached from the soil material and moved down slope and into local waterways.

Subsoil salinity categories and their corresponding hazard rating for construction activities within the study area are presented in Table 15.

Table 15. Decision matrix for rating subsoil salinity

Subsoil salinity [1]	Hazard rating
Very high to extreme	Severe
Medium to high	Moderate
Low to medium	Minor
Low to very low	Nil

Notes:

1. Subsoil salinity categories are from the Queensland salinity management handbook (DNR 1997).

Figure 13 shows where subsoil salinity is a hazard across the SGCP study area.

The vast majority of the SGCP study area (87%) has no subsoil salinity hazard.

Another 10.5% of the SGCP study area has only a minor hazard and consists of land with *Deep yellow-grey TC soils* on level plains to undulating rises and *Alluvial yellow-grey TC soils* on alluvial plains and in drainage depressions.

The remaining 2.5% of the SGCP study area consists of *Deep red-grey TC soils* and smaller areas of *Shallow red-grey TC soils* which have a moderate to severe constraint.

4.10 Dust generation

All soils have a capacity to create dust when the vegetative cover is removed and when they are subjected to vehicular traffic or disturbance by machinery. Dust can impact upon:

- occupational health and safety of workers;
- health and working conditions and amenity within the surrounding areas;
- efficiency and working life of nearby machinery; and
- pasture production where dust conditions are extreme.

Sands and soils with a clayey texture in the surface layer create the least dust whereas surface layers dominated by fine sand and silt can generate overwhelming clouds of "bulldust". Bulldust is often associated with vehicular traffic using roads and tracks where the road base contains a high proportion of fine sand and silt.

All soils within the SGCP study area have been rated according to their capacity to generate dust.

The rating system has been based solely on texture of the surface layer and, in particular, the presence of fine sand or silt. Though actual particle size of the sand, silt and clay fractions was not determined on any samples collected during this study, the presence of fine sand and silt can be detected during field texturing.

Field textures were used to rate dust generation as a hazard as shown in Table 16. The capacity to generate dust across the study area is shown in Figure 14.

Table 16. Decision matrix for rating dust generation

Surface layer texture	Hazard rating
Loamy fine sand; Fine sandy loam; Loam; Silty loam; Fine sandy clay loam; Silty clay loam	Severe
Sand; Clayey sand; Loamy sand; Loamy coarse sand; Sandy loam; Coarse sandy loam; Sandy clay loam; Coarse sandy clay loam; Clay loam, fine sandy; Clay loam, sandy	Moderate
Clay loam, Clay	Minor

Fine sand and silt were not detected in large quantities at any inspection sites during the field investigation and there are no soils within the SGCP study area assigned a severe dust hazard.

On the other hand, all soils do have at least a partial moderate dust constraint.

Approximately 6% of the SGCP study area has a minor to moderate capacity to generate dust. This land contains the *Alluvial yellow-grey TC soils* which have a surface layer varying in texture from sandy loam to clay loam.

The remaining 94% of the SGCP study area has a moderate capacity to generate dust due to the presence of either loamy sand, sandy loam, sandy clay loam or clay loam, sandy at the surface.

4.11 Acid generation

Environmental conditions for development of acid sulfate soils were not observed within the study area and it is extremely unlikely that acid sulfate soils are present (see section 3.3).

Apart from the *Rocky sands and sandy loams* and *Ironstone sands and sandy loams*, all soils within the SGCP study area have only slightly acid to strongly alkaline pH at depth in the subsoil.

The very shallow *Rocky sands and sandy loams* have an extremely acid pH. The minimal clay content in this soil means it has a limited capacity to generate acid. Moreover, it is located outside the areas expected to be directly disturbed by mining activities.

Soil features of the *Ironstone sands and sandy loams* are similar to the *Rocky sands and sandy loams* except soil pH is only medium acid.

The data indicate there is no potential within the top 1.8 m of all soil profiles for acid generation by disturbance of potentially acid forming materials during earthworks and construction.

4.12 Instability due to soil wetness

All soils lose some degree of stability as they become wet but the loss of stability varies with the level of soil wetness. Soil wetness is governed by incident rainfall, soil texture and structure and position in the landscape.

Soil wetness is worst in intermittent swamps and lakes that can be inundated for up to several months but is also pronounced where permeable (usually sandy or loamy) surface and subsurface layers overlie soil layers of much lower permeability (usually clay). The surface and subsurface layers saturate with relatively low rainfall amounts and the water cannot readily drain into and through the much less permeable layers below. These soils tend to develop intermittent and perched watertables either on top of or within the heavier soil layers. Lateral seepage of the watertables is very slow where the land has very low slopes. Sandy and loamy, surface and subsurface layers have little soil strength when saturated, resulting in very low load bearing capacity. Vehicles and machinery often sink to the top of the heavier textured layers below, thus the common term of “spewy” for these soils.

Shrink-swell clays (also referred to as active clays, reactive clays, expansive clays and cracking clays) expand in volume with increasing moisture content and shrink as they dry and also create an unstable medium for machinery operations and building foundations.

Soil instability due to wetness can affect:

- use by vehicular traffic;
- heavy machinery operations; and
- capacity of the soil to support buildings.

There are no shrink-well clays within the SGCP study area but the *Shallow red-yellow earths*, *Deep red-yellow earths* and various dispersive TC soils have sandy or loamy, surface and subsurface layers that overlie heavier textured layers of much lower permeability.

Soil profile features and landscape position are used to rate the constraint of instability due to soil wetness, as shown in Table 17.

Figure 15 shows the extent of the instability constraint due to soil wetness.

There is a minor constraint on almost 72% of the SGCP study area. This land consists of *Shallow red-yellow earths* and *Shallow red-grey TC soils*, *Deep red-grey TC soils* and *Deep yellow-grey TC soils* on gentle slopes of more than 1%. Though intermittent, perched watertables develop close to the surface in these soils, there is sufficient sideslope to enhance lateral seepage and the soils do not generally remain saturated for prolonged periods.

A further 7% of the study area consists of *Alluvial yellow-grey TC soils* and *Deep yellow-grey TC soils* in drainage depressions and on level plains and alluvial plains as well as *Shallow red-yellow earths* on level plains. The intermittent, perched watertables that form close to the surface in these soils cannot readily drain downwards or sideways and these soils have a moderate constraint due to soil wetness. In fact during field investigation, a perched watertable was observed below the level plains with *Shallow red-yellow earths* along the southern half of the infrastructure corridor.

The remaining land (almost 22% of the study area) consists of either well-drained soils or *Deep red-yellow earths* that have an intermittent, perched watertable but at more than 1 m below the soil surface. These soils have no soil wetness constraint.

Table 17. Decision matrix for rating instability due to soil wetness

Soil	Landscape position	Hazard rating
Shallow red-yellow earths all dispersive TC soils	drainage depressions alluvial plains level plains	Moderate
Shallow red-yellow earths all dispersive TC soils	sloping land (>1%)	Minor
Rocky sands and sandy loams *Ironstone sands and sandy loams* *Deep red-yellow earths* *Alluvial sands and sandy loams* [1]	any	Nil

Notes:

1. The *Alluvial sands and sandy loams* are not mapped as a dominant soil but represent an important minor soil on the alluvial plains and drainage depressions.

4.13 Loss of GQAL and SCL

Approximately 780 ha within the SGCP study area are designated by the Queensland Government as GQAL or partly GQAL. This GQAL pasture land consists of *Deep yellow-grey TC soils* that once supported various forms of brigalow forests.

Activities associated with the construction and operation of the SGCP have the capacity to impact on GQAL pasture land by:

- reducing the productive area;
- impeding optimal paddock layout and stock management practices for efficient production;
- modifying overland flow patterns, especially around access tracks, thereby increasing erosion and sedimentation of the nearby waterways; and
- introducing weed species into the pastures or increasing the distribution of weed species.

However, just over 5 ha of the GQAL pasture land are likely to be directly disturbed and loss of this land will be a minor impact. The remaining GQAL pasture land is not expected to be disturbed or is likely to be indirectly impacted resulting in negligible, if any, impact on GQAL.

As described in section 3.6, SCL status is not pertinent to the SGCP.

4.14 Cumulative effects for each soil

The range of constraint and hazard issues identified for each soil is summarised in Table 18.

The table shows that issues not only differ between soils but can also vary within a particular soil. Variation within a particular soil can be due to three reasons. Firstly, some soil features such as profile depth can vary sufficiently within one soil to affect the severity of a particular issue. Secondly, an issue may be primarily determined by a landscape feature other than soil type, such as topography, and the soil occupies differing landscape components. Thirdly, an issue may be a combination of soil and landscape features, such as erosion hazard and soil fertility, and the soil spans several combinations.

Table 18 also shows that the cumulative effect of issues is greater in some soils than with others. The *Rocky sands and sandy loams* and *Ironstone sands and sandy loams* have the largest number of severe or extreme issues. In contrast, the *Alluvial red TC soils* have only one minor constraint and one moderate hazard.

The *Shallow red-yellow earths* have one moderate constraint and one moderate hazard and two minor to moderate constraints or hazards. *Deep red-yellow earths* have the same moderate constraints and hazards but only additional one minor to moderate hazard. The *Alluvial yellow-grey TC soils* have one moderate constraint and one moderate hazard as well as two minor to moderate issues.

The other dispersive texture contrast soils have at least one severe to extreme constraint or hazard as well as several moderate issues.

Apart from the *Alluvial red TC soils*, all soils have a partly moderate or worse erosion hazard and at least moderate soil fertility constraint. If the erosion hazard is not appropriately managed, resultant erosion and sedimentation can have a pronounced impact on the environment and the soil fertility constraint associated with these soils means that the appropriate management procedures must involve correct revegetation measures.

Table 18. Cumulative development issues for each soil

Soil	Topography [1]	Depth to bedrock	Stoniness and rock outcrop	Erosion hazard [2]	Soil fertility	"Topsoil" depth	Salinity	Dust generation	Instability due to soil wetness	Loss of GQAL
Rocky sands and sandy loams	Extreme	Extreme	Severe	Extreme	Moderate	Moderate	Nil	Moderate	Nil	Nil
Ironstone sands and sandy loams	Minor-extreme	Extreme	Moderate	Moderate-extreme	Severe	Moderate	Nil	Moderate	Nil	Nil
Shallow red-yellow earths [5]	Nil-minor	Nil	Nil	Minor-moderate	Moderate	Nil	Nil	Moderate	Minor-moderate	Nil
Deep red-yellow earths	Nil-minor	Nil	Nil	Minor-moderate	Moderate	Nil	Nil	Moderate	Nil	Nil
Shallow red-grey TC soils	Nil	Moderate-severe	Nil	Moderate	Moderate	Nil-minor	Moderate-severe	Moderate	Minor	Nil
Deep red-grey TC soils	Nil	Nil	Nil	Moderate	Moderate	Nil-minor	Moderate-severe	Moderate	Minor	Nil
Deep yellow-grey TC soils	Nil-moderate	Nil	Nil	Minor-extreme	Moderate	Nil-minor	Minor	Moderate	Minor-moderate	Nil-minor
Alluvial red TC soils	Nil	Nil	Nil	Nil	Minor	Nil	Nil	Moderate	Nil	Nil
Alluvial yellow-grey TC soils	Nil	Nil	Nil	Minor-moderate	Moderate	Nil-minor	Minor	Minor-moderate	Moderate	Nil

Notes:

1. The topography constraint is based on landform and slope categories and will vary for individual soils that occur across a range of landforms.
2. Erosion hazard rating is a product of soil erodibility and topography factors and thus can vary within a soil according to landform characteristics.

5. Mitigation measures

A range of mitigation measures are available for the constraints and impacts identified in section 4. Most of the measures recommended for the SGCP study area are already used for mitigation in similar activities. However, some have been adapted from existing industry-acceptable inputs to address the specific constraints and impacts associated with the SGCP.

5.1 Universal measures for the entire study area

Several measures can be applied universally throughout the SGCP study area to ensure environmental impacts are minimised.

5.1.1 Timing of major disturbance

An erosion hazard of at least moderate rating has been identified across more than 55% of the study area (see section 4.6) and as rainfall is highly seasonal in central inland Queensland, careful timing of major earth works can be significant in reducing actual erosion.

The Queensland Department of Transport and Main Roads has analysed long-term rainfall records to determine the monthly and annual erosive potential (termed erosivity) throughout the State (DTMR 2010). Rainfall erosivity at Emerald between the four-month, December to March, period represents almost 67% of the average total erosivity for an entire 12 months.

Thus, scheduling major earth works programmes to avoid the December to March period can substantially reduce the risk of erosion.

However, if earthworks must be undertaken during this period, it is essential that all standard control measures (section 5.1.2) be adopted and special measures be implemented on sloping areas with dispersive texture contrast soils (section 5.2.1).

5.1.2 Standard erosion control measures

Because of the widespread erosion hazard, standard erosion control measures should be implemented for all works that disturb the land surface where slopes exceed 1%.

The measures outlined in this section have been determined with regard to the principles outlined in:

- *Best Practice Erosion & Sediment Control*, published by the International Erosion Control Association (IECA) Australasia Chapter in 2008 and which replaces the Soil Erosion and Sediment Control – Engineering Guidelines for Queensland Construction Sites (Institute of Engineers Australia 1996); and
- *EPA Best Practice Urban Stormwater Management - Erosion and Sediment Control* published by the Queensland Environmental Protection Agency (undated).

The standard erosion control measures include:

- minimising access and disturbance to only essential areas;
- surrounding all bare earth areas with a berm to divert upslope stormwater run-off from around the site;
- incorporating run-off control devices to reduce slope length on access tracks and on other disturbed areas of bare ground (Such devices include permanent “whoa boys” and berms and temporary sediment fences, straw bale banks or geotextile socks of at least 300 mm diameter filled with coarse filter media);
- undertaking stripping and stockpiling of “topsoil” immediately before starting bulk earthworks;
- ensuring topsoil and subsoil stockpiles are constructed on the contour, protected from run-on water with diversion banks or similar device upslope, and formed with run-off control devices immediately down slope;

- revegetating or rehabilitating disturbed areas as soon as works are completed;
- designing channels/drains and inlet and outlet works to convey water at least up to the design peak flow;
- incorporating rock filter dams, sediment traps and/or sediment basins into storm water run-off control for all major disturbance areas to slow peak discharge and avoid sediment laden water entering the local waterways;
- installing energy dissipaters at drainage outlets to local watercourses; and
- placing all water quality and quantity control structures above the riparian zone.

5.1.3 Stripping and re-using topsoil

"Topsoil" is usually stripped before construction of buildings, roads and hardstand areas. Wherever soil is to be excavated, the "topsoil" should be stripped first and stockpiled for reuse during revegetation and rehabilitation.

As described in section 4.8, not all surface layers within the study area are suitable for reuse as "topsoil". Surface layers with medium clay texture or heavier can be unsuitable for reuse and any dispersive soil material is also unsuitable.

Table 19 lists recommended stripping depths for disturbance areas. Stripping these areas may provide insufficient "topsoil" material for later use, requiring additional areas outside the earth works footprint to be stripped. Less material should be stripped from these additional areas so that a minimum 100 mm of suitable "topsoil" material is left on-site to encourage revegetation and to minimise erosion.

The variation in recommended stripping depth in some soils means that detailed field checking should be undertaken before areas are stripped to determine the appropriate depth.

Where there is insufficient material for stripping on-site, suitable "topsoil" may need to be imported from elsewhere.

Table 19. Recommended stripping depths

Soil	Stripping depth [1] (mm)
Rocky sands and sandy loams	100
Ironstone sands and sandy loams	50-100
Shallow red-yellow earths	300
Deep red-yellow earths	300
Shallow red-grey TC soils	250-400
Deep red-grey TC soils	100-350
Deep yellow-grey TC soils	100-300
Alluvial red TC soils	300
Alluvial yellow-grey TC soils	150-300

Notes:

1. The recommended stripping depth includes suitable soil material from the surface layer and from the underlying subsurface layer (if present) or subsoil.

Material that is suitable for stripping and stockpiling has low to very low fertility (see section 4.7) and will require soil ameliorants to ensure successful growth of plants. The minimum requirement would be amelioration with an NPK fertiliser but using a product that also contains calcium would be preferable. Organic matter is low to very low in all soils except the *Rocky sands and sandy loams* (see Table 12). Regardless of initial content, organic matter can be reduced during stockpiling.

All stockpiled material would benefit from incorporation of composted organics with a nitrogen drawdown index (NDI) > 0.5. Use of this organic amendment will increase soil water holding, soil drainage (leaching) and nutrient retention and help stabilise the topsoil to resist erosion and promote healthy plant growth. If controlled or slow release fertilisers are applied, the composted organics will ensure nutrients are not leached from the root zone. A suggested rate of incorporation is 30% by volume of compost.

Measures need to be taken to ensure dispersive clay subsoil is not stripped and mixed with the "topsoil". Inclusion of this material can result in a hard setting, or crusting planting media that impedes seed germination, restricts water entry and enhances erosion of the revegetated area.

As mentioned previously, topsoil stockpiles should be constructed on the contour, protected from run-on water with diversion banks or similar device upslope, and formed with run-off control devices immediately down slope.

The duration of stockpiling should be minimised to reduce nutrient rundown and colonisation by weeds. Stockpiling should not be commenced until immediately before bulk earthworks start and revegetation or rehabilitation of disturbed areas should proceed as soon as works are completed.

However, stockpiles that are to remain throughout the production period for use during decommissioning should be sown with an appropriate plant mix and managed to ensure adequate ground cover is maintained. This will minimise erosion and leaching of nutrients from the soil material and will provide a seed source when the material is eventually used. Such stockpiles should be landscaped into low mounds to reduce anaerobic conditions developing at the bottom, to reduce dust, noise and wind and to improve visual amenity.

5.2 Special measures

In addition to measures described in section 5.1, which should be applied universally across the SGCP study area, a number of special measures are recommended for specific areas.

5.2.1 Dissected terrain

There is an extreme topography constraint on approximately 2,145 ha (almost 7% of the SGCP study area). This land comprises mainly steep to rolling low hills with *Rocky sands and sandy loams* in the west with smaller areas of scarps containing *Ironstone sands and sandy loams*.

This constrained land is largely outside areas with expected direct disturbance. Should construction be required in these areas, it will probably involve extensive cut and fill operations.

This land also has very shallow depth to bedrock and excavation may require specialist equipment.

There are also 20 ha of *Deep yellow-grey TC soils* with dispersive subsoil on steep slopes creating a severe erosion hazard.

The *Rocky sands and sandy loams* and *Deep yellow-grey TC soils* have a moderate soil fertility constraint and the *Ironstone sands and sandy loams* have a severe constraint. Any disturbed areas in these soils will not revegetate readily without boosting the soil fertility.

It will be extremely difficult to control erosion during construction and to revegetate and rehabilitate any disturbed areas.

It would be preferable to exclude this land from development but if it must be included, appropriate mitigation measures should include:

- avoiding location of ancillary facilities within the area (though none are planned at present);
- keeping access tracks to a minimum;
- locating any essential tracks on gentle grades diagonally across the slope rather than perpendicular to it;
- minimising drainage line crossings or, where necessary, locating entry and access points at an angle to the drainage line and leaving sufficient capacity for uninterrupted stream flow;
- incorporating all special erosion control measures described in section 5.2.2; and
- incorporating general all-purpose fertilisers into local "topsoil" material used as planting media during revegetation or importing special planting media.

5.2.2 Sloping areas with dispersive texture contrast soils

Any land with slopes of 1% or more and containing dispersive texture contrast soils (*Shallow red-grey TC soils*, *Deep red-grey TC soils*, *Deep yellow-grey TC soils* and *Alluvial yellow-grey TC soils*) has a moderate to severe soil erosion hazard. Special precautions in addition to the standard measures described in section 5.1 need to be adopted on this land. As for the standard measures in section 5.1, the special precautions have been identified with regard to published best management practices for erosion and sediment control. Special precautions that need to be adopted are:

- Clearing and grubbing operations should avoid inverting the soil, thereby leaving clay subsoil on top.
- Any clay subsoil that is exposed on cut batters or areas of hard fill should be treated as soon as possible through amelioration, capping (with planting media or impermeable material) or both.
- Grubbing operations outside any earth works footprint should leave at least 100 mm of undisturbed soil material (surface and/or subsurface layers) on top of the clay subsoil.
- The land surface outside an earth works footprint should be levelled immediately after any clearing and grubbing operations are finished. The levelling should create a slight convex shape that spreads run-off water away from the disturbed area rather than allowing it to concentrate.
- In particular, any holes should be filled with soil material from the surface and/or subsurface layers. If necessary, suitable "topsoil" should be brought in from elsewhere to ensure no clay subsoil remains exposed. The levelled surface should be lightly compacted to ensure it is not easily moved by raindrop splash and running water.
- The land surface on top of laid pipelines and adjacent service tracks should be left in a slight convex shape that spreads run-off water away from the pipeline or track rather than allowing it to concentrate.
- The pipeline mound should have a cap of at least 100 mm of suitable, ameliorated "topsoil" and this planting media should be seeded with appropriate plant species.
- If a pipeline or access track is not mounded, slope length along the disturbed area should be reduced by placing run-off control devices (such as "whoa boys", sediment fences, straw bale banks or geotextile socks) at regular intervals to intercept and slowly spread water off the area; such devices should be used even on very gentle slopes of 1-2%.

5.2.3 Areas with severe subsoil salinity

Salinity at or near the surface is not a significant constraint within the study area. However, subsoil salinity can:

- reduce revegetation efforts on disturbed areas;
- affect plant growth surrounding disturbed areas if saline water is released from excavations and thus increase erosion hazard; and
- corrode inappropriately designed foundations for infrastructure.

The *Deep red-grey TC soils* have high to extreme salinity below 1 m depth and it is likely that subsoil salt levels will also be high in the *Shallow red-grey TC soils*. More intensive salinity sampling is recommended wherever major earthworks involving concrete and steel are to be located on these soils. The sampling should be aimed at clarifying the depth at which salt levels reach problematic levels.

Medium salt levels can retard plant growth and care should also be exercised when excavating or dealing with subsoil from the *Deep yellow-grey TC soils* and *Alluvial yellow-grey TC soils*.

Excavated subsoil should be buried deep or capped with at least 300 mm of suitable "topsoil" following construction activities. This will allow plants that are being established to achieve a reasonable root layer before encountering the saline material.

If saline subsoil is to be stockpiled for a short period, the stockpile should be surrounded with a berm to prevent water running onto the pile from further upslope and to detain run-off water within the stockpiled area.

5.2.4 Waste rock emplacements

Waste rock emplacements are created at the end of mining from spoil that has been used to fill the void. Slope grade on the upper surface and on side batters of these artificial landforms and the chemical and physical features of the spoil material are the major determinants of their potential erosion impact.

To minimise this impact, the following measures should be implemented:

- appropriate design of the final surface topography to ensure surface water run-off is adequately controlled;
- maximum slope of the external batters should be 33% (1V:3H);
- capping emplacement with a minimum 100 mm of suitable topsoil as specified in section 5.1.3;
- if there is insufficient suitable topsoil material, mulch with rock fragments of at 60 mm diameter on batter slopes;
- revegetate with appropriate plant species.

5.2.5 Areas of subsidence

Subsidence is created by underground longwall mining as the completed mined areas collapse. The major environmental impact of subsidence is on overland flow and stream flow conditions and these issues are considered separately as part of the EIS. However soil infiltration, internal drainage and erosion may also be affected if cracks develop due to tension around the zones where surface buckling occurs.

As part of the rehabilitation process, areas with surface cracks should be rehabilitated through ploughing to a minimum 300 mm depth and regrading and then reseeded with an appropriate plant species.

5.2.6 Use of treated water for construction activities

Poor quality water applied to soils during construction activities such as dust suppression can cause soil salinisation and dispersion as well as affect worker health. Only water that complies with quality standards set by the Environmental Authority should be used for these activities.

5.2.4 Borrow pits

Borrow pits are used to provide local sources of crushed aggregate, gravel, sand and soil during construction and may be used during the operational phase for on-going maintenance. Unlike most other excavations, borrow pits are not fully rehabilitated when they are no longer required.

Borrow pits may impact on the environment both during and after their active use through:

- accelerated soil erosion on disturbed cut faces and in the floor of the pit; and
- leaching of soluble salts from exposed soil material onto surrounding land and into local waterways; and
- loss of productive rural land and interruptions to its efficient use.

Environmental impact can be controlled by:

- adopting relevant standard erosion control measures (section 5.1.2);
- implementing relevant special measures on sloping areas with dispersive texture contrast soils (section 5.2.2);
- careful location of pits in dissected terrain (section 5.2.1); and
- surrounding any pits that expose saline subsoil with a berm.

Apart from careful site selection, implementation of run-off control devices is essential to prevent water running over the cut faces from further upslope and to detain run-off water within the disturbed area.

The final cut faces should be left as close to vertical as possible to minimise erosion due to raindrop splash.

5.2.5 Minimising impact at minor stream crossings

Minor streams in the area generally have *Alluvial yellow-grey TC soils* as the dominant soil with minor areas of *Alluvial sands and sandy loams* and *Alluvial loams and earths*. Crossings for access tracks and pipelines on minor streams require special attention because the main soil being traversed will be a dispersive texture contrast soil and any cutting or incision could create severe erosion.

Tracks should only cross streams at points where:

- the turbulence of stream flow is least;
- there is no active undercutting of either bank; and
- there is no dumping of sediments within the stream bed.

Crossing at bends in stream or close to where two streams meet should be avoided. Such areas often represent sections of active, unstable stream flow with a potential high risk of stream bank erosion if disturbed.

At stream crossing points, there should be as little disturbance to the stream bank as possible. Unless absolutely necessary, vegetation on the stream bank should not be disturbed and any cleared vegetation should not be placed in the stream. Following disturbance, these crossing points should be restabilised as soon as possible by refilling and slightly compacting, capping with at least 100 mm of suitable "topsoil" and revegetating the site.

5.3 Erosion monitoring

Erosion and sedimentation can have a pronounced impact on the environment and the soil fertility constraint associated with all soils means that the appropriate management procedures must involve correct revegetation measures.

An Erosion and Sediment Control Plan (ESCP) should be developed prior to the commencement of construction activities. The ESCP should consider the erosion hazard across the SGCP study area, provide mitigation strategies to address erosion and provide an erosion monitoring program. The ESCP should be developed following detailed engineering design. An indicative erosion monitoring program is provided in Attachment C.

6. Conclusions

Eleven soils have been identified within the SGCP study area but only nine could be mapped separately as the dominant soil in any particular area. The soils include uniform sands and sandy loams, dispersive texture contrast soils and one non dispersive texture contrast soil but more than 75% of the area is covered by gradational red and yellow earths.

Conditions required to form acid sulfate soils were not observed within the SGCP study area and it is extremely unlikely that acid sulfate soils are present. No land contamination was observed during field investigation and the grazing land use suggests that contamination issues will only occur at cattle dips. No cattle dips were observed during the field investigation.

Only 780 ha of texture contrast soils that once supported brigalow forests are designated as high quality pasture land and therefore GQAL for the purpose of protecting agricultural productivity under State Planning Policy 1/92. SCL status is not pertinent as the SGCP study area is outside the nominated SCL cropping zones.

Whilst many of the soils are highly erodible, the grazing practices and mainly gentle slopes have resulted in erosion being restricted to relatively few areas. Minor to severe sheet erosion is widespread across the *Ironstone sands and sandy loams*. Where these soils occur on scarps, rill and gully erosion is also occurring on the footslopes below the scarps. Minor to severe rill and gully erosion is also evident in several drainage depressions containing *Alluvial yellow-grey TC soils.* Minor gully erosion was also observed in southern areas of the *Shallow red-yellow earths*.

Identified constraints to SGCP activities and potential impacts on the soils are:

- topography;
- depth to bedrock;
- stoniness and rock outcrop;
- erosion hazard;
- soil fertility;
- "topsoil" depth;
- salinity;
- dust generation; and
- instability due to soil wetness.

The *Rocky sands and sandy loams* and *Ironstone sands and sandy loams* are rated as having the largest number of severe or extreme issues. The *Shallow red-yellow earths* and *Deep red-yellow earths* each have one moderate constraint and one moderate hazard as well as at least one minor to moderate issue. The *Alluvial yellow-grey TC soils* have one moderate constraint and one moderate hazard as well as two minor to moderate issues. The other dispersive texture contrast soils have at least one severe to extreme issue as well as several moderate issues. In contrast, the *Alluvial red TC soils* have only one minor constraint and one moderate hazard.

The potential loss of GQAL is minimal as just over 5 ha are predicted to be subject to direct disturbance and mining activities are likely to create minimal, if any, loss of GQAL outside these areas.

Apart from the *Alluvial red TC soils*, all soils have a partly moderate or worse erosion hazard and at least moderate soil fertility constraint. If the erosion hazard is not appropriately managed, resultant erosion and sedimentation can have a pronounced impact on the environment and the soil fertility constraint associated with these soils means that the appropriate management procedures must involve correct revegetation measures.

A range of mitigation measures are available for addressing the constraints and impacts and for ensuring that the SGCP proposal does not adversely affect the environment. Mitigation measures that can be applied universally to the entire study area are:

- timing all major disturbance to avoid the December to March period;
- adopting a range of standard erosion control measures on all sloping land; and
- only stripping "topsoil" to recommended depths and ameliorating stockpiled "topsoil" before using as planting media.

In addition, a number of special measures are recommended for specific areas and issues. These include:

- avoiding major disturbance within the Rocky sands and sandy loams and Ironstone sands and sandy loams;
- implementing additional measures and management practices on all sloping land with dispersive texture contrast soils;
- taking precautions to adequately deal with subsoil that may have significant subsoil salinity;
- designing and implementing appropriate run-off control measures on waste rock emplacements and capping with suitable topsoil and revegetating with appropriate plant species;
- ploughing to a minimum 300 mm depth and regrading subsidence areas with surface cracks and then reseeded with an appropriate plant species;
- implementing appropriate run-off control measures at borrow pits; and
- minimising impact at stream crossings on minor streams.

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8. Glossary

Alluvial plain A level landform with extremely low relief formed by the accumulation of alluvium from overbank stream flow over a considerable period of time; this accumulation may still be occurring (flood plain) or may have ceased (terrace)

Alluvium Deposits of gravel, sand, silt, clay or other debris, moved by streams from higher to lower ground

Clays Soils with a uniform clay texture throughout the soil profile

.... cracking Clay soils that develop vertical cracks when dry
.... non-cracking Clay soils that do not develop vertical cracks when dry

Dispersive Soil material that readily disperses in water (see soil dispersion); also referred to as **dispersible**

Earths Soils with a sandy to loamy (including clay loam) surface soil gradually increasing to a loamy to light clay subsoil

.... massive Earths in which the subsoil is not arranged into natural soil aggregates and appears as a coherent, or solid mass

.... structured Earths in which the subsoil is arranged into natural soil aggregates which can be clearly seen

Ferricrete A layer formed from the weathering of rocks in humid tropical conditions and consisting mostly or iron and aluminium oxides; a complete laterite exposure will display a strong, hardened reddish surface horizon (which can contain 90-100% iron) breaking up with depth into a mottled (red, yellow, grey) horizon, which in turn passes down to a (white) pallid zone and finally reaching bedrock

Flocculated Soil material in which the individual particles have come together to form small aggregates

Floodplain An alluvial plain characterized by frequently active erosion and aggradation by channelled or overbank stream flow

Gradational soils Soils in which the texture gradually increases with depth below the surface; there are no rapid texture changes between the sandy loam to clay loam surface layers and the sandy clay loam to clay subsoils

Gravel A mixture of coarse mineral particles larger than 2 mm diameter; the individual particles may be either separate from each other (unconsolidated) or bonded together (cemented) by chemical agents

Horizon A layer of soil, roughly parallel to the land surface, with morphological properties different from layers below and/or above it.

Jump-up A narrow ridge bounded by moderately inclined side slopes or steeper scarps and with a level to gently inclined ridge crest

Laterite	see **Ferricrete**
Lateritised rocks	Rocks which have been partially or completely weathered to laterite
Levee	A very long, low, narrow, nearly level, sinuous ridge immediately adjacent to a stream channel that is built up by overbank flooding
Loams	Soils with a uniform loamy texture throughout the soil profile
Massive earths	see **Earths .... massive**
Massive structure	see **Soil Structure .... massive**
Mulch	Vegetation that has been shredded and applied either as a blanket cover on top of the soil surface or incorporated into the topsoil
Nodules	Discrete segregations that have accumulated in the soil because of the concentration of some constituent, usually by chemical or biological action
Non-cracking clays	see **Clays .... non-cracking**
Non-sodic	Soil material that has an ESP of less than 6
Ped	A natural soil aggregate that consists of a cluster of primary particles clearly separated from adjoining aggregates
Run-on	Water that accumulates at a site (compared with runoff water that exits a site)
Sands	Soils with a uniform sandy (including sandy loam) texture throughout the soil profile
Sedimentary rocks	Rocks formed from the accumulation of material which has been weathered and eroded from pre-existing rocks, then transported and deposited as sediment by wind, water or ice; the sediments can be compacted and cemented together to form sedimentary rocks such as sandstone, or precipitated from material dissolved in water to form sedimentary rocks such as limestone
Slaking	The natural collapse of a soil aggregate in water due to its low mechanical strength being insufficient to withstand the force of air being compressed within the aggregate
Sodicity	A measure of the Exchangeable Sodium Percentage (ESP) of soil material Soil material with an ESP of <6 is referred to as non sodic Soil material with an ESP of 6-15 is referred to as sodic Soil material with an ESP >15 is referred to as strongly sodic
Soil dispersion	The process by which soil aggregates disperse into individual particles (clay, silt and sand) in water
Soil structure	Soil structure refers to the arrangement (distinctness, size and shape) of natural soil aggregates

.... single grain	Loose incoherent mass of individual particles with no observable natural soil aggregates; when displaced, soil separates into ultimate particles
.... massive	Coherent mass with no observable natural soil aggregates; when displaced, soil separates into fragments which maybe crushed to ultimate particles
.... weak	Natural soil aggregates are indistinct and barely observable in undisplaced soil; when displaced, up to one-third of the soil material consists of aggregates
.... moderate	Natural soil aggregates are well formed and evident but not distinct in undisplaced soil; when displaced, more than one-third of the soil material consists of aggregates
.... strong	Natural soil aggregates are quite distinct in undisplaced soil when displaced, more than two-thirds of the soil material consists of aggregates
.... coarse	Natural soil aggregates are relatively large with an average size (across the least dimension) of more than 50 mm
.... medium	The average size of the natural soil aggregates is between fine and medium
.... fine	Natural soil aggregates are relatively small with an average size (across the least dimension) of 20 mm or less
Field texture	Soil texture is determined by the size distribution of mineral particles finer than 2 mm and is an estimate of the percentage clay, silt and sand; it is estimated in the field by measuring the behaviour of a small handful of soil when moistened and kneaded into a ball and then pressed out between thumb and forefinger
Subsoil	Soil layers below the surface with one of the following attributes: • a larger content of clay, iron, aluminium, organic material (or several of these) than the surface and subsurface soil; • stronger colours than those of the surface and subsurface soil above or the substrate material below
Subsurface layer	Soil layer(s) immediately below the surface layer which usually have less organic matter, paler colours and may have less clay than the surface layer
.... bleached	Subsurface soil that is white, near white or much paler than adjacent soil layers
Surface condition	Surface condition refers to the characteristic appearance of the surface soil when dry
.... cracking	Cracks at least 5 mm wide extends upwards towards the surface
.... crust	A distinct layer, often laminated, ranging from a few millimetres to a few tens of millimetres, which is hard and brittle when dry and cannot be readily separated from the underlying soil material
.... firm	Coherent mass of individual particles or aggregates; surface is disturbed or indented by moderate pressure of the forefinger

.... flake	A thin, massive surface layer (usually less than 10 mm thick) which, on drying, separates from and can be readily lifted off the soil below
.... hard setting	A compact, hard surface forms on drying but softens on wetting; when dry, the material is hard below any surface crust or flake that may occur, and is not disturbed or indented by pressure of forefinger
.... loose	An incoherent mass of individual particles or aggregates; surface easily disturbed by pressure of forefinger
.... self-mulching	A strongly structured loose surface mulch in which the aggregates fall apart naturally as the soil dries; a **fine** self-mulching surface has natural aggregates that are commonly less than 5 mm in dimension; a **coarse** self-mulching surface has natural aggregates that are commonly greater than 5 mm in dimension
.... soft	A coherent mass of individual particles or aggregates. Surface easily disturbed by pressure of forefinger
Surface layer	The soil layer extending from the soil surface down, which has some organic matter accumulation and is usually darker in colour than the underlying soil layers
Terrace	A flat aggraded or eroded by stream flooding that is standing above a scarp; now defined as land that represents as land that represents a former flood plain on which alluvial deposition and erosion are barely active or inactive
.... high	A term frequently used in Queensland to describe a terrace that is a former flood plain on which alluvial deposition and erosion are barely active or inactive
.... low	A term frequently used in Queensland to describe a flat that continues to be subject to flooding; see **Channel bench**
Texture	see **Field texture**
Texture contrast soils	Soils with a sandy to loamy surface material (including clay loam) rapid changing into a clay subsoil
.... colour	The colour of a texture contrast soil refers to the colour of the clay subsoil
.... depth	The depth of a texture contrast soil refers to the total depth of surface soil and clay subsoil
Topsoil	Any natural soil or artificial planting material that is suitable for use as planting media
Tunnel erosion	The removal of subsoil by water while the surface remains relatively intact; also referred to as piping
Uniform clays	see **Clays**
Uniform loams	see **Loams**
Uniform sands to	see **Sands**

sandy loams

Uniform soils	Soils in which texture differences between the surface soils and subsoils are minimal; uniform soils may be uniform clays, uniform loams or uniform sands to sandy loams

Based on the Australian soil and land survey field handbook (The NCST 2009).

Attachment A
Ground observation sites recorded during field investigation

Site	Soil type	Easting	Northing
1	Shallow red-yellow earths	433,098	7,384,407
2	Alluvial yellow-grey TC soils	433,192	7,384,164
3	Alluvial yellow-grey TC soils	433,267	7,383,990
4	Shallow red-yellow earths	433,386	7,383,679
5	Shallow red-yellow earths	433,629	7,383,060
6	Deep red-yellow earths	432,841	7,382,529
7	Ironstone sands and sandy loams	433,921	7,382,580
8	Deep red-yellow earths	435,238	7,382,644
9	Deep yellow-grey TC soils	435,207	7,384,461
10	Deep yellow-grey TC soils	435,861	7,384,147
11	Deep red-grey TC soils	436,890	7,378,168
12	Shallow red-grey TC soils	436,790	7,378,816
13	Alluvial loams and earths	437,716	7,382,765
14	Shallow red-yellow earths	436,876	7,383,671
15	Shallow red-yellow earths	434,140	7,385,746
16	Shallow red-yellow earths	453,486	7,376,657
17	Shallow red-yellow earths	452,975	7,376,767
18	Shallow red-yellow earths	452,287	7,376,876
19	Shallow red-yellow earths	451,825	7,375,806
20	Ironstone sands and sandy loams	452,476	7,374,956
21	Deep red-yellow earths	451,740	7,377,002
22	Ironstone sands and sandy loams	451,073	7,376,943
23	Shallow red-yellow earths	450,509	7,376,903
24	Deep yellow-grey TC soils	450,173	7,376,950
25	Alluvial yellow-grey TC soils	449,397	7,377,060
26	Alluvial yellow-grey TC soils	449,024	7,377,114
27	Shallow red-yellow earths	448,549	7,377,179
28	Shallow red-yellow earths	448,076	7,377,277
29	Shallow red-yellow earths	447,637	7,377,484
30	Shallow red-yellow earths	447,284	7,377,674
31	Shallow red-yellow earths	446,772	7,377,933
32	Shallow red-yellow earths	446,429	7,378,091
33	Deep yellow-grey TC soils	445,929	7,378,425
34	Shallow red-yellow earths	445,643	7,378,568
35	Shallow red-yellow earths	445,463	7,378,747
36	Alluvial yellow-grey TC soils	445,259	7,378,977
37	Alluvial yellow-grey TC soils	444,959	7,379,240
38	Deep red-yellow earths	444,800	7,379,324
39	Shallow red-yellow earths	444,117	7,378,962
40	Shallow red-yellow earths	443,793	7,378,686
41	Shallow red-yellow earths	443,425	7,378,372
42	Shallow red-yellow earths	443,015	7,378,059
43	Deep red-yellow earths	442,195	7,374,340
44	Rocky sands and sandy loams	440,494	7,374,340
45	Deep red-yellow earths	441,038	7,374,237
46	Shallow red-yellow earths	442,477	7,377,345
47	Shallow red-yellow earths	444,951	7,379,653
48	Shallow red-yellow earths	445,392	7,379,893
49	Shallow red-yellow earths	445,830	7,380,135
50	Shallow red-yellow earths	446,328	7,380,396
51	Alluvial yellow-grey TC soils	446,628	7,380,416
52	Alluvial yellow-grey TC soils	447,114	7,380,753

Site	Soil type	Easting	Northing
53	Alluvial yellow-grey TC soils /Shallow red-yellow earths	447,444	7,381,081
54	Shallow red-yellow earths	448,014	7,381,431
55	Shallow red-yellow earths	448,464	7,381,831
56	Deep red-grey TC soils	448,687	7,382,098
57	Shallow red-yellow earths	448,219	7,382,216
58	Shallow red-yellow earths	447,737	7,382,328
59	Alluvial yellow-grey TC soils	447,322	7,382,426
60	Shallow red-yellow earths	446,791	7,382,582
61	Shallow red-yellow earths	446,451	7,382,895
62	Deep red-yellow earths	446,091	7,383,186
63	Deep red-yellow earths/Shallow red-yellow earths	445,761	7,382,987
64	Deep red-grey TC soils	445,174	7,382,612
65	Shallow red-yellow earths	447,553	7,370,735
66	Shallow red-yellow earths	447,573	7,370,201
67	Alluvial sands and sandy loams	447,422	7,369,370
68	Alluvial red TC soils	448,494	7,369,671
69	Alluvial red TC soils	450,050	7,369,365
70	Deep red-yellow earths	451,919	7,369,605
71	Shallow red-yellow earths	447,911	7,371,485
72	Shallow red-yellow earths	448,219	7,372,479
73	Shallow red-yellow earths	448,359	7,372,912
74	Ironstone sands and sandy loams	448,471	7,373,390
75	Alluvial loams and earths	448,481	7,373,513
76	Alluvial sands and sandy loams	448,406	7,374,309
77	Shallow red-yellow earths	448,009	7,374,289
78	Shallow red-yellow earths	447,529	7,374,242
79	Shallow red-yellow earths	447,034	7,374,244
80	Shallow red-yellow earths	446,590	7,374,255
81	Ironstone sands and sandy loams	446,172	7,374,314
82	Shallow red-yellow earths	448,347	7,374,363
83	Deep yellow-grey TC soils	448,717	7,374,946
84	Deep yellow-grey TC soils	449,667	7,375,388
85	Shallow red-yellow earths	450,410	7,375,246
86	Deep yellow-grey TC soils	451,736	7,375,110
87	Shallow red-yellow earths	453,008	7,381,149
88	Deep red-yellow earths	452,498	7,381,255
89	Deep red-yellow earths	451,576	7,381,470
90	Ironstone sands and sandy loams	452,078	7,381,353
91	Alluvial yellow-grey TC soils	454,115	7,380,867
92	Deep red-yellow earths	456,578	7,380,257
93	Deep yellow-grey TC soils	457,656	7,403,550
94	Deep red-yellow earths	457,633	7,403,290
95	Deep yellow-grey TC soils	457,571	7,402,675
96	Deep red-yellow earths	457,517	7,402,207
97	Deep red-yellow earths	457,480	7,401,745
98	Deep red-yellow earths/Shallow red-yellow earths	457,427	7,401,282
99	Deep red-yellow earths/Shallow red-yellow earths	457,330	7,400,332
100	Deep red-yellow earths	457,238	7,399,446
101	Shallow red-yellow earths (wet)	457,193	7,399,027
102	Deep red-yellow earths	457,089	7,398,221
103	Shallow red-yellow earths (wet)	456,976	7,397,069
104	Shallow red-yellow earths (wet)	456,882	7,396,102

Site	Soil type	Easting	Northing
105	Deep yellow-grey TC soils	456,812	7,395,403
106	Shallow red-yellow earths	456,705	7,394,452
107	Shallow red-yellow earths	456,512	7,392,483
108	Shallow red-yellow earths	456,408	7,391,675
109	Shallow red-yellow earths	456,311	7,390,580
110	Shallow red-yellow earths	456,118	7,388,667
111	Deep red-yellow earths	455,797	7,385,359
112	Shallow red-grey TC soils	453,689	7,416,376
113	Deep red-yellow earths	454,549	7,415,687
114	Shallow red-grey TC soils	454,706	7,415,426
115	Shallow red-grey TC soils	455,036	7,414,859
116	Deep red-yellow earths	457,415	7,413,303
117	Shallow red-yellow earths/Alluvial yellow-grey TC soils	457,126	7,413,646
118	Shallow red-yellow earths	456,449	7,413,682
119	Ironstone sands and sandy loams	455,206	7,414,603
201	Shallow red-yellow earths	433,538	7,382,559
202	Alluvial sands and sandy loams	437,209	7,379,283
203	Shallow red-yellow earths	437,482	7,379,913
204	Deep yellow-grey TC soils	437,547	7,380,623
206	Shallow red-yellow earths	437,431	7,381,198
207	Shallow red-yellow earths	453,478	7,376,651
208	Shallow red-yellow earths	451,877	7,376,093
209	Shallow red-yellow earths	451,903	7,376,098
210	Shallow red-yellow earths	448,874	7,375,746
211	Shallow red-yellow earths	447,878	7,375,644
212	Deep red-grey TC soils	447,022	7,375,763
213	Shallow red-yellow earths	445,449	7,375,967
214	Alluvial yellow-grey TC soils	444,828	7,376,049
215	Deep red-grey TC soils	444,366	7,375,765
216	Deep red-yellow earths	444,279	7,375,135
217	Deep red-yellow earths	443,880	7,373,844
218	Shallow red-yellow earths	442,929	7,373,979
219	Shallow red-yellow earths	442,063	7,374,095
220	Ironstone sands and sandy loams	442,263	7,375,796
221	Alluvial yellow-grey TC soils	442,234	7,375,938
222	Alluvial yellow-grey TC soils	442,694	7,377,810
223	Shallow red-yellow earths	443,648	7,378,563
224	Shallow red-yellow earths	443,997	7,379,517
225	Shallow red-yellow earths	443,017	7,379,649
226	Shallow red-yellow earths	442,481	7,379,718
227	Alluvial yellow-grey TC soils - gullied	441,477	7,379,863
228	Shallow red-yellow earths	441,359	7,380,024
229	Deep red-yellow earths/Shallow red-yellow earths	441,389	7,380,269
230	Shallow red-yellow earths	441,519	7,381,285
231	Alluvial yellow-grey TC soils	441,605	7,382,001
232	Shallow red-yellow earths	441,733	7,383,094
234	Shallow red-yellow earths	441,598	7,383,242
235	Deep red-yellow earths	442,627	7,382,963
236	Alluvial yellow-grey TC soils	442,937	7,382,919
237	Alluvial yellow-grey TC soils	443,156	7,382,894
238	Alluvial yellow-grey TC soils	443,475	7,382,856
239	Shallow red-yellow earths	444,205	7,382,742

Site	Soil type	Easting	Northing
240	Alluvial red TC soils	446,734	7,369,139
241	Shallow red-yellow earths	451,176	7,369,242
243	Alluvial red TC soils	448,498	7,373,692
244	Deep red-grey TC soils	448,708	7,374,682
245	Deep red-grey TC soils	448,910	7,375,489
246	Deep red-grey TC soils	449,282	7,375,432
247	Deep red-grey TC soils	451,083	7,375,194
248	Deep red-grey TC soils	451,065	7,375,199
249	Ironstone sands and sandy loams - gullied	451,476	7,375,084
250	Alluvial red TC soils	452,949	7,374,718
251	Alluvial red TC soils	453,862	7,373,913
252	Shallow red-yellow earths	450,616	7,381,690
253	Shallow red-yellow earths	450,100	7,381,807
254	Deep yellow-grey TC soils	449,348	7,381,970
255	Shallow red-yellow earths	450,609	7,381,698
256	Shallow red-yellow earths (wet)	456,592	7,393,352
257	Shallow red-yellow earths (wet)	456,236	7,389,755
258	Shallow red-yellow earths	458,236	7,408,127
259	Shallow red-yellow earths	457,953	7,408,155
260	Deep red-yellow earths	450,955	7,380,903
261	Deep red-yellow earths	450,374	7,380,249
262	Shallow red-yellow earths	449,556	7,379,147
263	Alluvial yellow-grey TC soils	448,804	7,378,842

Notes:

1. The Easting and Northing location reference is based on the Map Grid of Australia, Zone 55 using GDA 94.

Attachment B
Soil analytical results

Agricultural Chemistry Pty Ltd

For Info Refer ESSA PO Box 442
Sunnybank Qld 4109

Phone: 0403245560

email: e.s.s.a@bigpond.net.au

Reference: **11/43/51926** Sheet: 1 of 5

Date Received: 27/7/2011
Date Completed: 11/9/2011

FINAL REPORT

Project:

South Galilee Coal Project

All results in this report relate only to the items tested. Results are expressed on an "as received basis".

Client Name: LRAM

Contact: Mr P Shields

Sample Type: Soil

Number of samples: 47

Agricultural Chemistry Pty Ltd

Soil Analysis Report

Reference: 11/43/51926

Date Received: 25/7/2011

Date Completed: 11/9/2011

Client: LRAM Sth Galilee

Lab No	Profile	Depth	pH	EC	Cl	NO3-N	P(Bic)	Ca	Mg	K	Na	ECEC	ESP_	Ca/Mg	15Bar	ADMC
		mm		mS/cm	mg/kg	mg/kg	mg/kg	meq/100g	meq/100g	meq/100g	meq/100g	meq/100g	Na/CEC%	Ratio	Moist %	%
SAH1511	Site 44	0-100	4.3	0.04	18	1	17	0.5	0.3	0.29	<0.1	2	3	1.9	8	1.1
SAH1512	Site 11	0-100	6.4	0.07	30	1.2	9	7.9	5.7	0.74	0.3	15	2	1.4	12	2.3
SAH1513	Site 11	150-250	8	0.39	205			16.0	13.9	0.64	3	33	8	1.2	19	3.5
SAH1514	Site 11	300-400	9	0.92	856			26.2	19.0	0.7	5.5	51	11	1.4	24	4.5
SAH1515	Site 11	800-900	8.5	2.12	2951			16.0	23.5	0.9	6.3	47	13	0.7	25	4.9
SAH1516	Site 11	1100-1200	8.6	1.97	2727			12.8	23.2	0.93	6.3	43	14	0.6	24	4.9
SAH1517	Site 20	0-180	5.9	0.02	20	<1	8	1.7	0.7	0.17	<0.1	3	2	2.4	3	0.6
SAH1518	Site 16	0-150	6.5	0.03	13	1.8	6	2.7	1.2	0.31	<0.1	4	1	2.3	5	0.7
SAH1519	Site 16	200-500	6.7	0.03	16			1.8	1.0	0.23	<0.1	3	2	1.8	5	0.8
SAH1520	Site 16	500-700	6.8	0.03	17			0.9	1.9	0.23	0.2	3	5	0.5	8	1.2
SAH1521	Site 16	1200-1500	7.7	0.08	151			0.8	5.0	0.18	1.6	8	21	0.2	14	1.9
SAH1522	Site 64	0-100	6.7	0.05	24	1.3	8	2.8	1.0	0.74	<0.1	5	2	2.9	6	0.9
SAH1523	Site 64	200-300	6.6	0.03	23			2.6	0.9	0.59	<0.1	4	1	2.9	6	1.0
SAH1524	Site 64	500-600	6.7	0.02	16			3.1	1.2	0.48	<0.1	5	1	2.6	8	1.3
SAH1525	Site 64	800-900	6.9	0.03	16			3.8	1.6	0.39	<0.1	6	1	2.3	11	1.6
SAH1526	Site 64	1100-1200	7.2	0.04	21			3.8	2.2	0.35	0.3	7	5	1.7	14	1.7
SAH1527	Site 64	1400-1500	8.2	0.06	45			6.1	4.1	0.52	0.7	12	6	1.5	16	2.5
SAH1528	Site 89	0-100	6.7	0.04	21	1.1	6	4.1	1.0	0.32	<0.1	6	0	4.2	5	0.7
SAH1529	Site 89	400-600	6.8	0.03	17			2.0	0.9	0.31	<0.1	4	2	2.2	5	0.7
SAH1530	Site 89	800-1000	6.9	0.02	12			2.4	1.0	0.34	<0.1	4	1	2.3	7	0.9
SAH1531	Site 89	1300-1500	6.5	0.02	13			2.5	1.3	0.35	<0.1	5	1	1.9	11	1.5
SAH1532	Site 98	0-100	6.2	0.03	13	1.2	3	2.4	0.9	0.32	<0.1	4	1	2.7	5	0.7
SAH1533	Site 98	200-300	7	0.03	9			3.0	0.6	0.33	<0.1	5	1	4.8	7	1.0
SAH1534	Site 98	500-600	7.3	0.03	9			2.5	0.8	0.27	<0.1	4	1	3.0	8	1.1
SAH1535	Site 98	800-900	7.4	0.03	15			2.1	1.1	0.28	<0.1	5	3	1.9	9	1.1
SAH1536	Site 98	1100-1200	7.4	0.02	27			1.7	1.4	0.38	<0.1	4	1	1.2	9	1.2
SAH1537	Site 98	1400-1500	7.1	0.03	19			1.3	1.9	0.36	<0.1	5	1	0.7	10	1.2
SAH1538	Site 245	0-100	6.5	0.05	20	3.6	6	2.2	0.7	0.63	<0.1	4	1	3.0	4	0.7
SAH1539	Site 245	200-400	5.9	0.04	18			1.8	0.9	0.3	<0.1	3	2	2.0	4	0.8
SAH1540	Site 245	600-800	8	0.22	177			1.7	7.2	0.24	2.4	12	20	0.2	12	1.9
SAH1541	Site 245	1100-1200	8.8	0.66	509			1.2	9.9	0.27	4.5	16	28	0.1	13	2.4
SAH1542	Site 245	1400-1500	8.6	0.92	749			0.7	10.0	0.26	5.2	16	32	0.1	14	2.3
SAH1543	Site 245	1700-1800	8.6	0.92	0.3			0.74	10.5	0.29	5.5	17	32	0.1	12	2.5

Agricultural Chemistry Pty Ltd

Soil Analysis Report

Batch Number: 11/43

Date Received: 25/7/2011

Date Completed: 11/9/2011

Client: LRAM Sth Galilee

Lab No	Profile	Depth	pH	EC	Cl	NO3-N	P(Bic)	Ca	Mg	K	Na	ECEC	ESP_	Ca/Mg	15Bar	ADMC
		mm		mS/cm	mg/kg	mg/kg	mg/kg	meq/100g	meq/100g	meq/100g	meq/100g	meq/100g	Na/CEC%	Ratio	Moist %	%
SAH1544	Site 105	0-100	5.5	0.06	27	1.2	6	2.5	1.1	0.39	<0.1	4	1	2.2	6	1.2
SAH1545	Site 105	200-300	6.9	0.07	44			6.3	4.7	0.94	0.4	13	3	1.4	16	2.8
SAH1546	Site 105	500-600	7.1	0.32	253			6.0	5.2	0.69	0.7	13	5	1.2	16	3.0
SAH1547	Site 105	900-1000	7.1	0.04	11			5.8	6.0	0.64	1.6	14	11	1.0	16	2.8
SAH1548	Site 67	200-300	6.9	0.03	11	2.3	13	3.0	0.5	0.15	<0.1	4	1	6.1	1	0.2
SAH1549	Site 67	500-600	7.5	0.03	13			2.6	0.3	0.11	<0.1	3	1	8.8	1	0.2
SAH1550	Site 67	800-900	7.3	0.03	16			2.4	0.3	0.12	<0.1	3	1	8.1	1	0.3
SAH1551	Site 67	1100-1200	7.8	0.03	16			2.0	0.3	0.09	<0.1	3	1	7.8	1	0.3
SAH1552	Site 67	1400-1500	7.9	0.04	16			2.1	0.3	0.1	<0.1	3	1	7.8	1	0.2
SAH1553	Site 240	0-100	6.1	0.02	21	<1	16	2.8	0.7	0.41	<0.1	5	<1	4.2	4	0.8
SAH1554	Site 240	400-600	6.5	0.02	33			1.8	0.8	0.18	<0.1	4	1	2.4	4	0.7
SAH1555	Site 240	800-900	7.1	0.02	28			3.1	1.1	0.31	<0.1	6	1	2.8	7	1.2
SAH1556	Site 240	1100-1200	7.4	0.02	49			2.2	0.8	0.25	<0.1	5	1	2.6	6	0.9
SAH1557	Site 240	1500-1650	7.4	0.05	19			1.9	0.8	0.23	<0.1	4	1	2.3	5	0.7
SAH1558	Site 25	0-100	5.1	0.04	17	1	9	2.5	1.1	0.35	0.1	5	3	2.4	8	1.6
SAH1559	Site 25	200-450	5	0.28	315			0.8	0.9	0.2	0.1	2	5	0.9	3	0.7
SAH1560	Site 25	600-900	7.5	0.37	369			0.4	4.5	0.18	3.1	8	37	0.1	11	1.7
SAH1561	Site 25	900-1200	8	0.36	366			0.4	5.5	0.21	4.1	10	39	0.1	11	1.7
SAH1562	Site 25	1200-1500	7.4	0.45	451			0.1	4.7	0.14	3.9	9	43	<0.1	10	1.5
SAH1563	Site 25	1500-1800	6.5	0.04	23			<0.1	5.0	0.14	4.3	10	44	<0.1	11	1.8
SAH1564	Site 238	0-100	6	0.02	19	1.2	5	3.2	1.4	0.31	0.1	5	2	2.3	5	1.1
SAH1565	Site 238	250-450	5.8	0.02	18			1.0	0.8	0.19	<0.1	2	3	1.3	3	0.6
SAH1566	Site 238	450-650	6.4	0.07	57			0.7	0.8	0.14	0.1	2	6	0.9	2	0.4
SAH1567	Site 238	800-900	6.6	0.11	112			2.2	3.5	0.27	0.9	8	12	0.6	10	1.7
SAH1568	Site 238	1000-1200	6.8	0.24	260			1.8	2.9	0.23	1.1	7	16	0.6	7	1.1
SAH1569	Site 238	1300-1500	6.7	0.12	42			2.4	3.7	0.28	1.7	8	20	0.6	9	1.4
SAH1570	Site 9	0-100	7.2	0.03	19	2.9	20	2.5	1.6	1.81	0.3	6	5	1.6	NR	0.8
SAH1571	Site 21	0-100	5.7	0.04	21	<1	7	1.2	0.9	0.33	<0.1	3	1	1.4	NR	0.5
SAH1572	Site 33	0-100	6	0.1	17	<1	29	2.7	0.6	0.33	<0.1	4	2	4.8	NR	0.6
SAH1573	Site 65	0-100	8.3	0.11	22	<1	4	27.9	2.6	1.08	0.1	32	<1	10.7	NR	1.0
SAH1574	Site 116	600-900	8.1	0.11	0.29			10.9	3.9	0.72	0.2	16	1	2.8	13	2.6

Agricultural Chemistry Pty Ltd

Soil Analysis Report

Batch Number: 11/43

Date Received: 25/7/2011

Date Completed: 11/9/2011

Client: LRAM Sth Galilee

Lab No	Profile	Depth	Soil S	Soil Mn	Soil B	Soil Cu	Soil Fe	Soil Zn	OM	Ca alch	Mg alch	K alch	Na alch	Clouding	Slaking
		mm	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	%	meq/100g	meq/100g	meq/100g	meq/100g	Rating	Rating
SAH1511	Site 44	0-100	6	<0.2	0.1	-0.1	70	<0.1	4.5					1	0
SAH1512	Site 11	0-100	5	20.9	0.4	0.7	33	0.7	3.2					1	0
SAH1513	Site 11	150-250								7.8	11.4	0.46	1.89	2	1
SAH1514	Site 11	300-400								7.8	15.2	0.45	4.54	3	3
SAH1515	Site 11	800-900								5.1	17.7	0.57	5.61	3	3
SAH1516	Site 11	1100-1200								4.6	16.8	0.62	5.80	4	3
SAH1517	Site 20	0-180	2	17.8	0.4	0.2	22	<0.1	1					0	1
SAH1518	Site 16	0-150	2	20.9	0.4	0.3	19	<0.1	1					1	0
SAH1519	Site 16	200-500												0	1
SAH1520	Site 16	500-700												1	2
SAH1521	Site 16	1200-1500												3	2
SAH1522	Site 64	0-100	3	19.7	0.4	0.4	23	<0.1	1.1					0	1
SAH1523	Site 64	200-300												1	0
SAH1524	Site 64	500-600												0	1
SAH1525	Site 64	800-900												0	0
SAH1526	Site 64	1100-1200												0	1
SAH1527	Site 64	1400-1500								6.6	4.0	0.47	0.64	0	1
SAH1528	Site 89	0-100	2	20.5	0.4	0.4	10	<0.1	1.5					0	2
SAH1529	Site 89	400-600												0	2
SAH1530	Site 89	800-1000												1	2
SAH1531	Site 89	1300-1500												1	2
SAH1532	Site 98	0-100	3	25.4	0.2	0.3	11	0.2	1.3					0	1
SAH1533	Site 98	200-300												0	1
SAH1534	Site 98	500-600												0	2
SAH1535	Site 98	800-900												1	2
SAH1536	Site 98	1100-1200												1	2
SAH1537	Site 98	1400-1500												1	1
SAH1538	Site 245	0-100	2	19.8	0.2	0.4	50	<0.1	1.2					1	1
SAH1539	Site 245	200-400												2	3
SAH1540	Site 245	600-800								1.87	7.0	0.16	2.21	4	4
SAH1541	Site 245	1100-1200								1.39	8.8	0.18	3.88	4	4
SAH1542	Site 245	1400-1500								0.95	9.2	0.17	4.49	4	4
SAH1543	Site 245	1700-1800								0.86	9.8	0.18	4.63	4	4

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Soil Analysis Report

Batch Number: 11/43 **Date Received: 25/7/2011**

Date Completed: 11/9/2011

Client: LRAM Sth Galilee

Lab No	Profile	Depth	Soil S	Soil Mn	Soil B	Soil Cu	Soil Fe	Soil Zn	OM	Ca alch	Mg alch	K alch	Na alch	Clouding	Slaking
		mm	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	%	meq/100g	meq/100g	meq/100g	meq/100g	Rating	Rating
SAH1544	Site 105	0-100	3	7.3	0.4	0.5	90	0.1	1.8					0	1
SAH1545	Site 105	200-300												1	2
SAH1546	Site 105	500-600												2	2
SAH1547	Site 105	900-1000												3	2
SAH1548	Site 67	200-300	2	44.3	0.3	0.4	18	0.9	0.6					0	1
SAH1549	Site 67	500-600												0	2
SAH1550	Site 67	800-900												0	2
SAH1551	Site 67	1100-1200								1.47	0.09	0.08	0.02	0	2
SAH1552	Site 67	1400-1500								1.26	0.15	0.07	0.01	0	2
SAH1553	Site 240	0-100	3	28.3	0.2	0.4	23	2.6	1.1					0	1
SAH1554	Site 240	400-600												0	2
SAH1555	Site 240	800-900												0	2
SAH1556	Site 240	1100-1200												0	2
SAH1557	Site 240	1500-1650												0	2
SAH1558	Site 25	0-100	5	20.6	0.3	0.7	125	0.2	2.3					0	1
SAH1559	Site 25	200-450												1	2
SAH1560	Site 25	600-900								0.59	4.8	0.11	3.16	3	4
SAH1561	Site 25	900-1200								0.54	5.9	0.13	4.35	4	4
SAH1562	Site 25	1200-1500												4	4
SAH1563	Site 25	1500-1800												4	4
SAH1564	Site 238	0-100	3	27	0.3	0.4	49	0.3	1.4					0	1
SAH1565	Site 238	250-450												1	2
SAH1566	Site 238	450-650												1	1
SAH1567	Site 238	800-900												3	2
SAH1568	Site 238	1000-1200												3	3
SAH1569	Site 238	1300-1500												3	3
SAH1570	Site 9	0-100	4	6	0.5	0.3	80	1.5	1.7					NR	NR
SAH1571	Site 21	0-100	2	5.7	0.3	0.3	15	<0.1	1					NR	NR
SAH1572	Site 33	0-100	3	22.1	0.3	0.4	28	<0.1	0.6					NR	NR
SAH1573	Site 65	0-100	8	18.9	1.4	0.5	44	0.5	1.3	6.0	1.28	0.81	0.03	NR	NR
SAH1574	Site 116	600-900	3	38	2.5	0.5	19		0.7	10.5	3.66	0.75	0.1	1	2

NR=Not Reqd

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METHOD DESCRIPTIONS

Soil

Reference: **11/43/51926**
Sheet 4 of 5

Methods used for Sample Analysis

Analyte	ALHS*	Uncertainty %	LOQ	Unit	Name	Method Description
pH	4A1	1.1	0.1	pH	pH	1:5 water extr, pH meter
EC	3A1	5.4	0.01	dS/m	Electrical conductivity	1:5 water extr, EC meter
Cl	5A2	10.0	10.0	mg/kg	Chloride	1:5 water extr, (AA) colorimetric
NO3-N	7C2	6.7	1.0	mg/kg	Nitrate-nitrogen	1:5 water extr, (AA) colorimetric
NH4-N	7C2	7.8	0.6	mg/kg	Ammonium-nitrogen	1M KCl extr, (AA) colorimetric
Bicarb.P	9C2	16.8	1.0	mg/kg	Olsen.ext.phosphorus	0.5M NaHCO3 @ pH 8.5, (AA) colorimetric
Tot P	ALS				Total P	Sulphuric acid digest
TN	7A2	12.9	0.01	%	Total Kjeldahl Nitrogen	Sulphuric acid digest, (AA) colorimetric
OC	8B1	9.7	0.02	%	Organic Carbon	Leco
Ca (Neut)	15A1	10.3	0.10	meq/100g	Exchangeable calcium	1M NH4Cl @ pH 7.0 shake, AAS
Mg (Neut)	15A1	6.6	0.10	meq/100g	Exchangeable magnesium	1M NH4Cl @ pH 7.0 shake, AAS
Na (Neut)	15A1	7.3	0.03	meq/100g	Exchangeable sodium	1M NH4Cl @ pH 7.0 shake, AAS
K (Neut)	15A1	3.9	0.02	meq/100g	Exchangeable potassium	1M NH4Cl @ pH 7.0 shake, AAS
ECEC	15J1	5.0	1	meq/100g	Effective cation ex.capacity	Sum of exchangeable cations
ESP	15N1	5.0	3	%	Exchangeable Na%	(Exchangeable Na/sum of exch.cations)%
Moisture	2A1				Moisture @ 103deg C	Oven Dry Moisture (Oven)
Ca (Alcoholic)	15C1	10.3	0.10	meq/100g	Exchangeable calcium	1M NH4Cl @ prewash, pH 8.5 leach, AAS
Mg (Alcoholic)	15C1	6.6	0.10	meq/100g	Exchangeable magnesium	1M NH4Cl @ prewash, pH 8.5 leach, AAS
Na (Alcoholic)	15C1	7.3	0.03	meq/100g	Exchangeable sodium	1M NH4Cl @ prewash, pH 8.5 leach, AAS
K (Alcoholic)	15C1	3.9	0.02	meq/100g	Exchangeable potassium	1M NH4Cl @ prewash, pH 8.5 leach, AAS
DTPA Trace Elements	12A1			mg/kg	Copper,Zinc, Iron,Manganese	DTPA extract
Boron	12C2			Boron	CaCl2 Extract	ICP
ADMC	2A1	11.9	0.4	%	Air Dried Moisture Content	Gravimetric oven dry @ 105C
R1	NA	20.2	NA		Dispersion Ratio	Ratio [Aqueous dispersible (Silt + Clay):Total (Silt + Clay)]
ESP	15N1	5.0	3	%	Exchangeable Na%	(Exchangeable Na/sum of exch.cations)%
Sand	no ref	22.1	1.0	%	Particle size, sand	Hydrometer, gravimetric
Silt	no ref	16.6	1.0	%	Particle size, silt	Hydrometer, gravimetric
Clay	no ref	12.7	1.0	%	Particle size, clay	Hydrometer, gravimetric
Organic Matter	no ref					OM = Organic Matter for Organic C =Org Mat/2.2
Clouding	no ref					Scale 0-4 Nil to Soil Fully Dispersed
Slaking (Dispersion)	no ref					Scale 0-4 Nil to Soil Fully Collapsed

For Manager
Analytical Services:

*** Australian Laboratory Handbook of Soil and Water Chemical Methods (1992)**

Agricultural Chemistry Pty Ltd

QUALITY CONTROL DATA

Reference: **11/43/51926**

Soil **Sheet: 5 of 5**

*** Australian Laboratory Handbook of Soil and Water Chemical Methods (1992)**

Test Method	Units		Actual Value	Acceptance Criteria [Range]
pH	pH	rv	7.63, 7.64	7.4 - 7.8
EC	dS/m	rv	.079, .079	.070 - .115
Cl	mg/kg	rv	10, 10	8 - 12
NO3-N	mg/kg	rv	5, 5	3 - 8
NH4-N	mg/kg	B	86, 85	76-90
Olsen P	mg/kg	rv	18, 17	15 - 20
Total Kjeldahl N	%	aspac 34	.100, .100	
Total P	%	aspac 34	.019, .019	
Organic Carbon	%	rv		1.82 - 2.3
Ca (Exch. cations)pH7	meq/100g	rv	15.6, 15.1	14.8 - 18.5
Mg (Exch. cations)pH7	meq/100g	rv	8.1, 7.68	7.0 - 8.8
Na (Exch. cations)pH7	meq/100g	rv	.05, .04	.02 - .18
K (Exch. cations)pH7	meq/100g	rv	.57, .60	.50 - .68
Exch. Acidity	meq/100g			NA
ECEC	meq/100g	A		NA
CEC	meq/100g	S12		58 - 73
ESP	%	A		NA
Coarse sand	%	rv		1.4 - 2.8
Fine Sand	%	rv		13.1 - 19.1
Silt	%	rv		20.2 - 26.1
Clay	%	rv		55.4 - 60.2
R1		rv		0.18 - 0.29

Attachment C
Indicative erosion monitoring program

Environmental Protection Objectives

The objectives of this program are:

(1) To minimise soil erosion due to rainfall and surface run-off caused by construction, operation and decommissioning activities associated with the SGCP

(2) To match appropriate mitigation practices to the erosion hazard

(3) To minimise the need for appropriate remediation strategies should unacceptable erosion inadvertently occur

(4) To select appropriate rehabilitation strategies during decommissioning

Performance Indicators

The performance indicators are developed to ensure erosion or sedimentation does not occur above rates already occurring on undisturbed areas with the same erosion hazard:

(1) No sheet, rill or gully erosion observed during regular monitoring events

(2) No sheet, rill or gully erosion observed during event-based monitoring above rates already occurring on undisturbed areas with the same erosion hazard

(3) No deposition of sediment onto infrastructure or off-site

(4) Any unacceptable erosion or sedimentation to be remediated to its original condition

Procedure for selecting appropriate mitigation practices

The following practices are to be adopted prior to any disturbance being commenced:

(1) Soil type (as per section 3 and Table 3) and landform-slope category (as per section 4.6 and Table 11) are to be identified

(2) Erosion hazard rating (nil, minor, moderate, severe, extreme) is to be determined from soil type and landform-slope category (as per section 4.6 and Table 11)

(3) For soils with a minor erosion hazard appropriate mitigation procedures listed in Table A are to be adopted

(4) For soils with moderate or severe erosion hazard appropriate mitigation procedures listed in Table B are to be adopted

(5) For soils with an extreme erosion hazard, an alternative site should be sought; if an alternative site is not available, mitigation procedures listed in Table B are to be adopted and specialist advice is to be sought from a land management expert prior to any disturbance

Procedure for selecting appropriate rehabilitation practices

The following practices are to be adopted for revegetation and rehabilitation:

(1) Determine suitable stripping depth for topsoil prior to commencing disturbance (as per section 5.1.3 and Table 19)

(2) Stockpile topsoil and unsuitable soil separately

(3) Topsoil stockpiles are to be no higher than 2 m

(4) Stockpiles are to be constructed on the contour, protected from run-on water with diversion banks or similar device upslope, and formed with run-off control devices immediately down slope

(5) Stockpiling should not be commenced until immediately before bulk earthworks start

(6) The duration of stockpiling should be minimised to reduce nutrient rundown and colonisation by weeds

(7) Revegetation or rehabilitation of disturbed areas should proceed as soon as works are completed

(8) Stockpiles that are to remain throughout the production period for use during decommissioning should be sown with an appropriate plant mix and managed to ensure adequate ground cover is maintained

(9) The nutrient status of long-term topsoil stockpiles should be tested prior to re-spreading to determine whether fertilisers are required to ensure seedling establishment

(10) When being reinstated, unsuitable soil should be capped with suitable topsoil

Monitoring frequency

Monitoring is to be undertaken as follows:

(1) All temporary structures designed to control erosion and sedimentation during construction should be monitored weekly as well as after every 1:10 storm event, until construction ceases and the disturbed area is revegetated and stabilised

(2) All other temporary structures designed to control erosion and sedimentation during revegetation and rehabilitation should be monitored weekly as well as after every 1:10 storm event, until the disturbed area is revegetated and stabilised

(3) All permanent sediment and erosion control structures should be monitored monthly as well as after every 1:10 storm event until the disturbed are is decommissioned

(4) Any remediation practises that need to be undertaken should be monitored weekly until it is rehabilitated and stabilised

Responsibility and Reporting

The responsibility for monitoring and reporting is as follows:

(1) The Proponent should conduct erosion monitoring and report monitoring results to the appropriate Queensland Government authority on an annual basis

(2) The Proponent should report any incident that requires remediation within a week of its occurrence

(3) The proponent should record any remediation progress on a weekly basis

(4) It is the responsibility of the appropriate Queensland Government authority to provide timely, written direction to the mining entity in response to any soil erosion issue if the direction is not specified as part of the Environmental Authority

Table A. Standard mitigation practices

Practice	Description
A1	Avoid major earth works programmes between December and March
A2	Minimise access and disturbance to only essential areas
A3	Surround all bare earth and hardstand areas with a berm to divert upslope stormwater run-off from around the site
A4	Incorporate run-off control devices to reduce slope length on access tracks and on other disturbed areas of bare ground - Permanent devices such as "whoa boys" and berms to be installed at areas where vegetation cover will not re-establish within 12 months - Temporary devices such as sediment fences, straw bale banks or geotextile socks (of at least 300 mm diameter filled with coarse filter media) can be used at areas where cover will re-establish within 12 months.
A5	Only undertake stripping and stockpiling of "topsoil" immediately before starting bulk earthworks
A6	Ensure stockpiles are constructed on the contour, protected from run-on water with diversion banks or similar device upslope, and formed with run-off control devices immediately down slope
A7	Topsoil stockpiles to be a maximum 2 m high
A8	Revegetate or rehabilitate disturbed areas as soon as works are completed
A9	Design channels/drains and inlet and outlet works to convey water at least up to the design peak flow
A10	Incorporate check dams and/or sediment retention basins into storm water run-off control for all major infrastructure to slow peak discharge and reduce sediment load in water entering the local streams
A11	Place all water quality and quantity control structures above the riparian zone
A12	Design sediment retention basins to adequately handle dispersive soil material in the dispersive texture contrast soils and to handle clayey subsoil material in all other areas except where the three "sand and sandy loam" soils occur
A13	Install energy dissipaters at drainage outlets to local streams

Table B. Special mitigation practices

Practice	Description
B1	Avoid disturbing areas with an extreme topography constraint; if an alternative site is not available seek specialist advice from a land management expert prior to any disturbance
B2	Avoid inverting the soil during clearing and grubbing operations
B3	Treat any clay subsoil that is exposed on cut batters or areas of hard fill as soon as possible through amelioration, capping (with planting media or impermeable material) or both.
B4	Leave at least 100 mm of undisturbed soil material (surface and/or subsurface layers) on top of dispersive clay subsoil during grubbing operations outside any earth works footprint
B5	Level the land surface outside an earth works footprint immediately after any clearing and grubbing operations are finished; the levelling should create a slight convex shape that spreads run-off water away from the disturbed area rather than allowing it to concentrate
B6	Ensure any holes in a surface to be levelled are filled with soil material from the surface and/or subsurface layers
B7	Lightly compact the levelled surface to ensure it is not easily moved by raindrop splash and running water
B8	Leave the land surface on top of laid pipelines and adjacent service tracks in a slight

Practice	Description
	convex shape that spreads run-off water away from the pipeline or track rather than allowing it to concentrate
B8	Cap a pipeline mound with at least 100 mm of suitable, ameliorated "topsoil" and this planting media should be seeded with appropriate plant species
B9	Leave final cut faces on borrow pits as close to vertical as possible to minimise erosion due to raindrop splash
B10	Locate stream crossing points to avoid - sections of high turbulence - active undercutting of either bank - sections where sediments are dumped within the stream bed

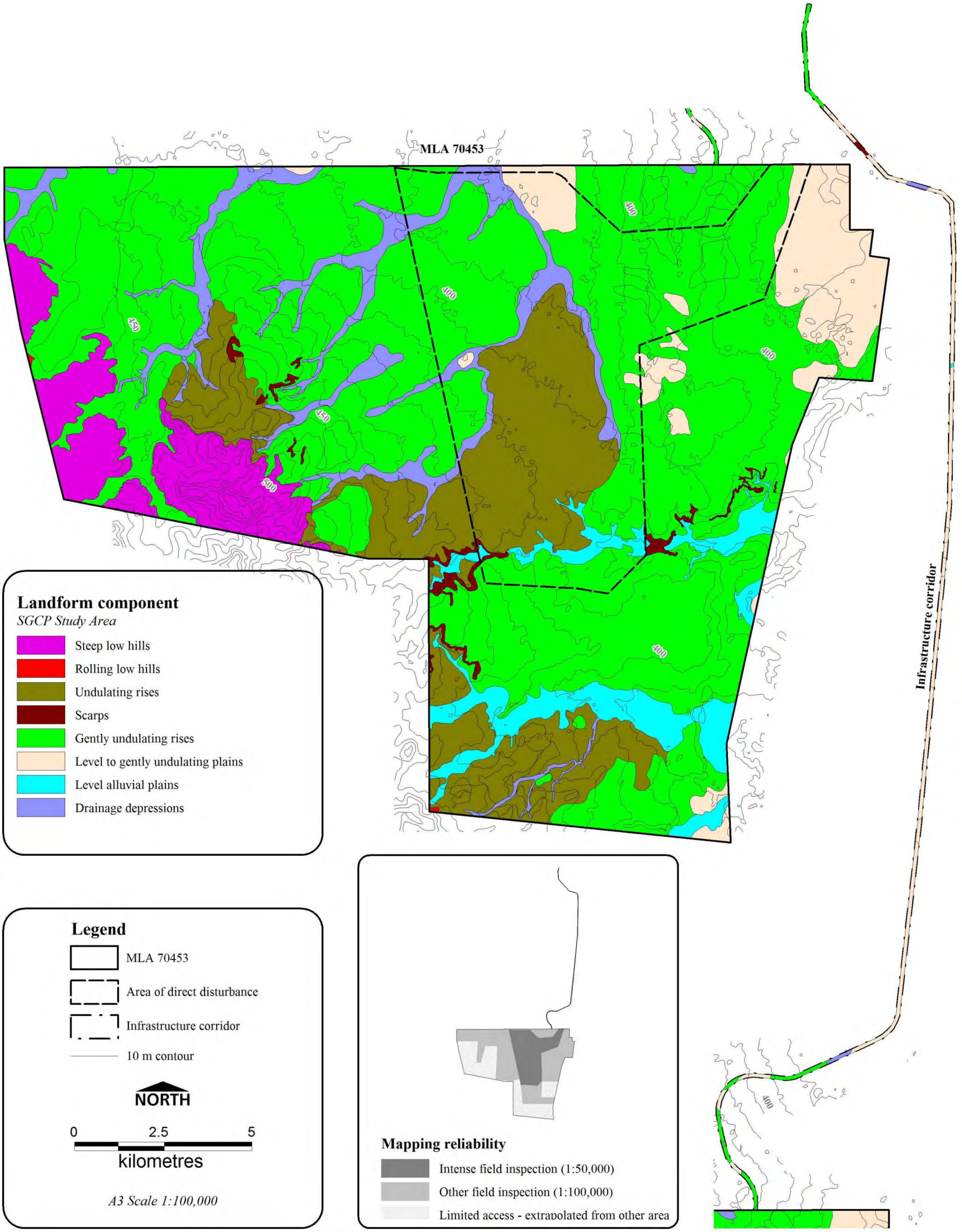

Figure 3. Landform

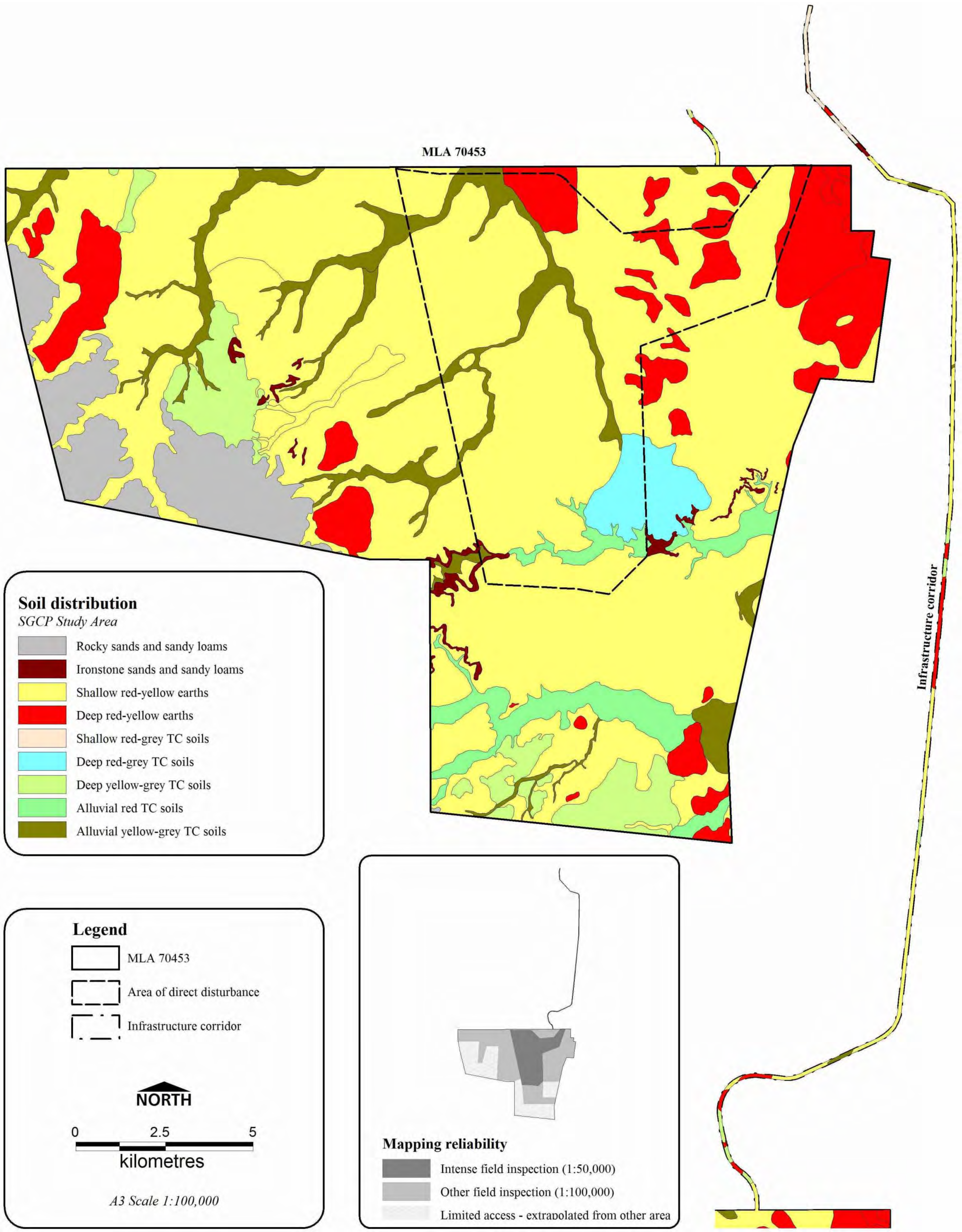

Figure 4. Soil distribution

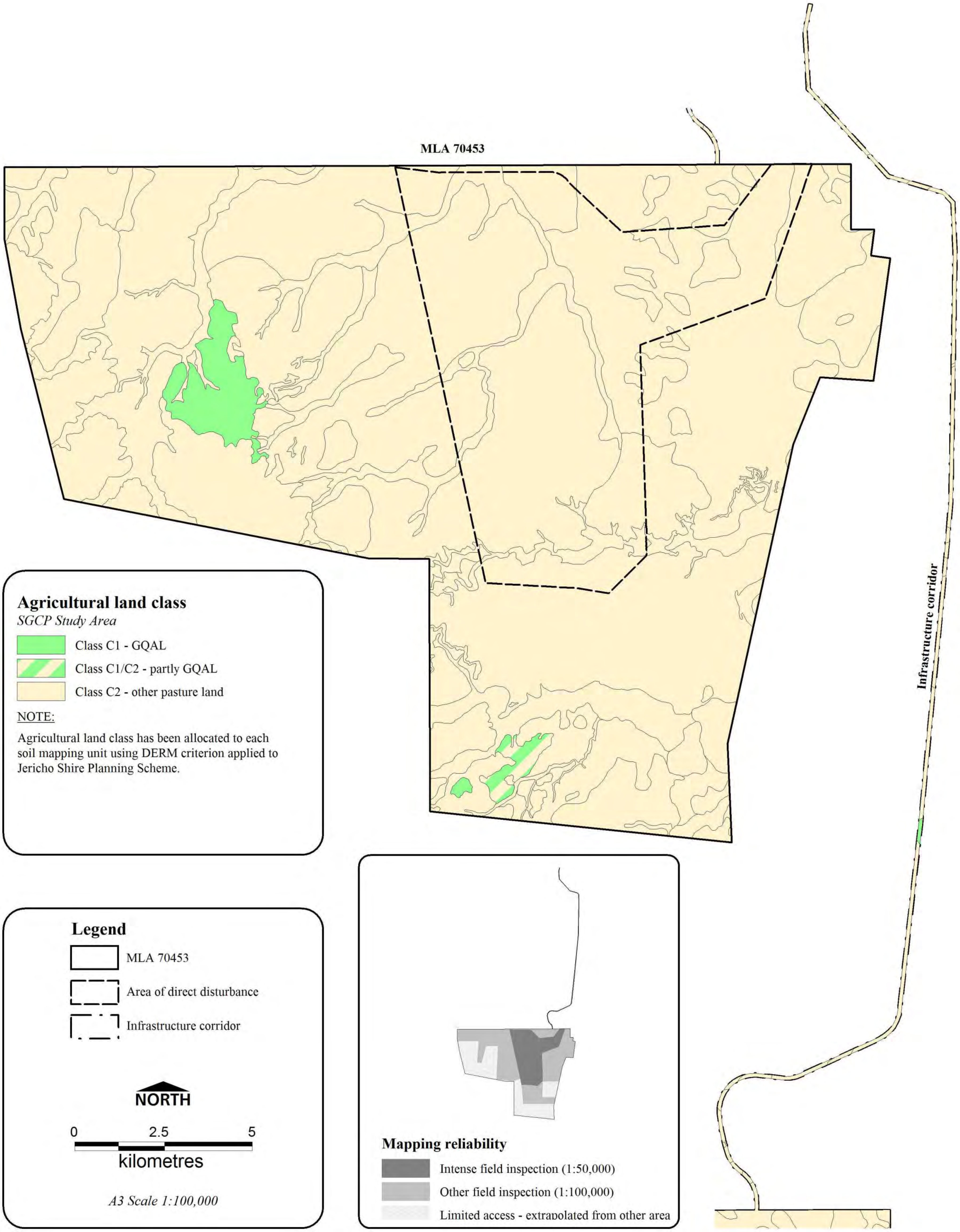

Figure 5. GQAL within the SGCP study area

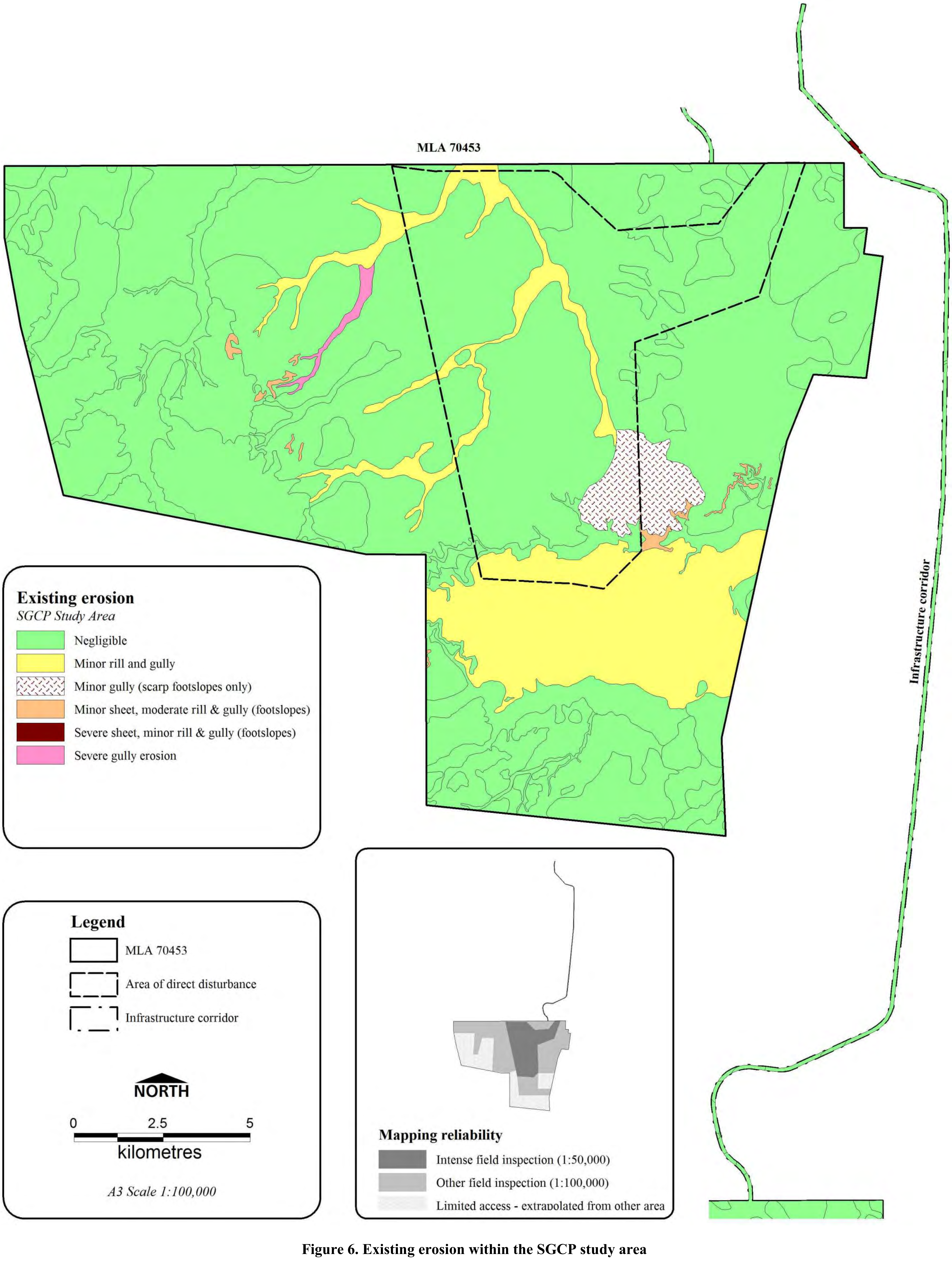

Figure 6. Existing erosion within the SGCP study area

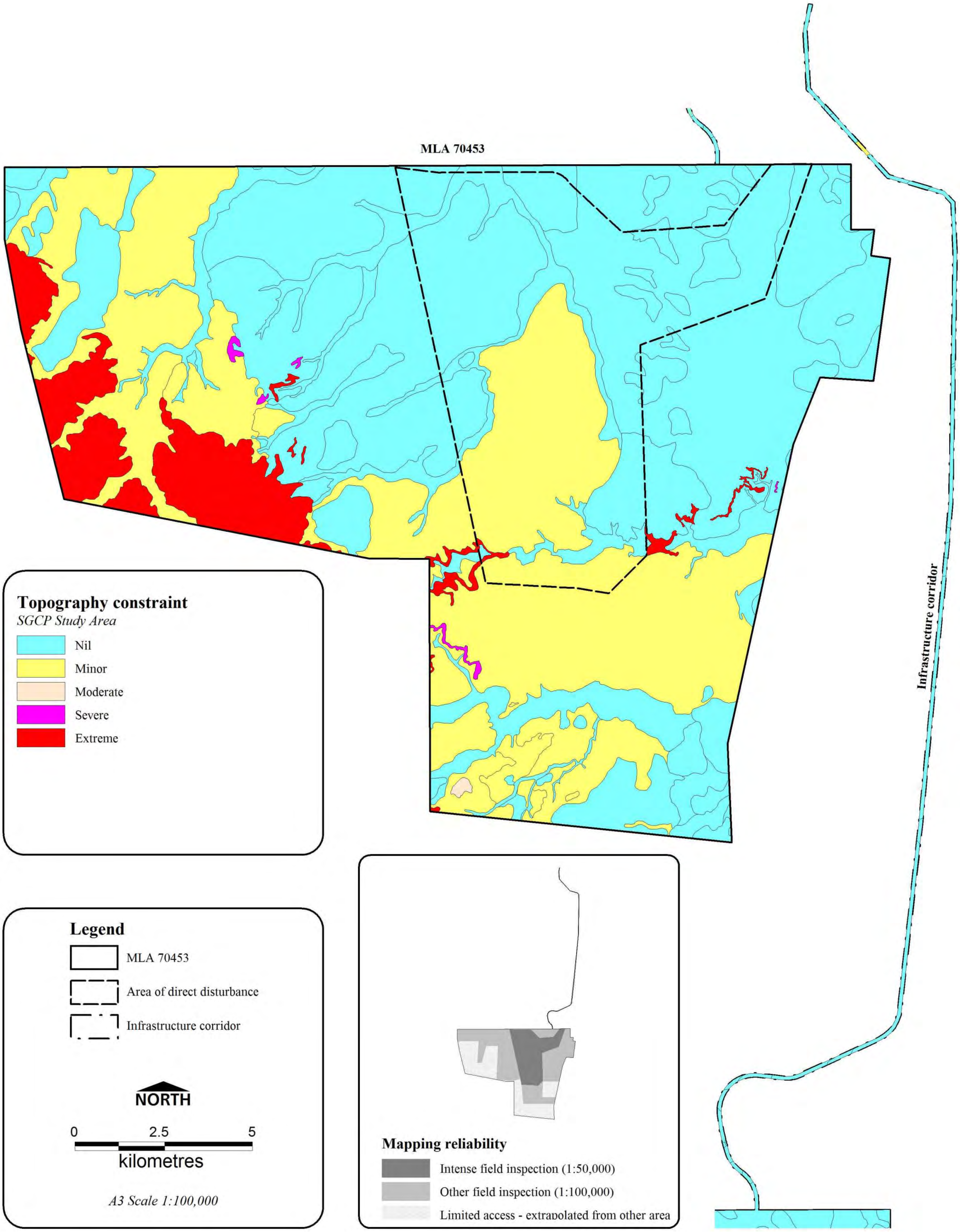

Figure 7. Topography constraint across the SGCP study area

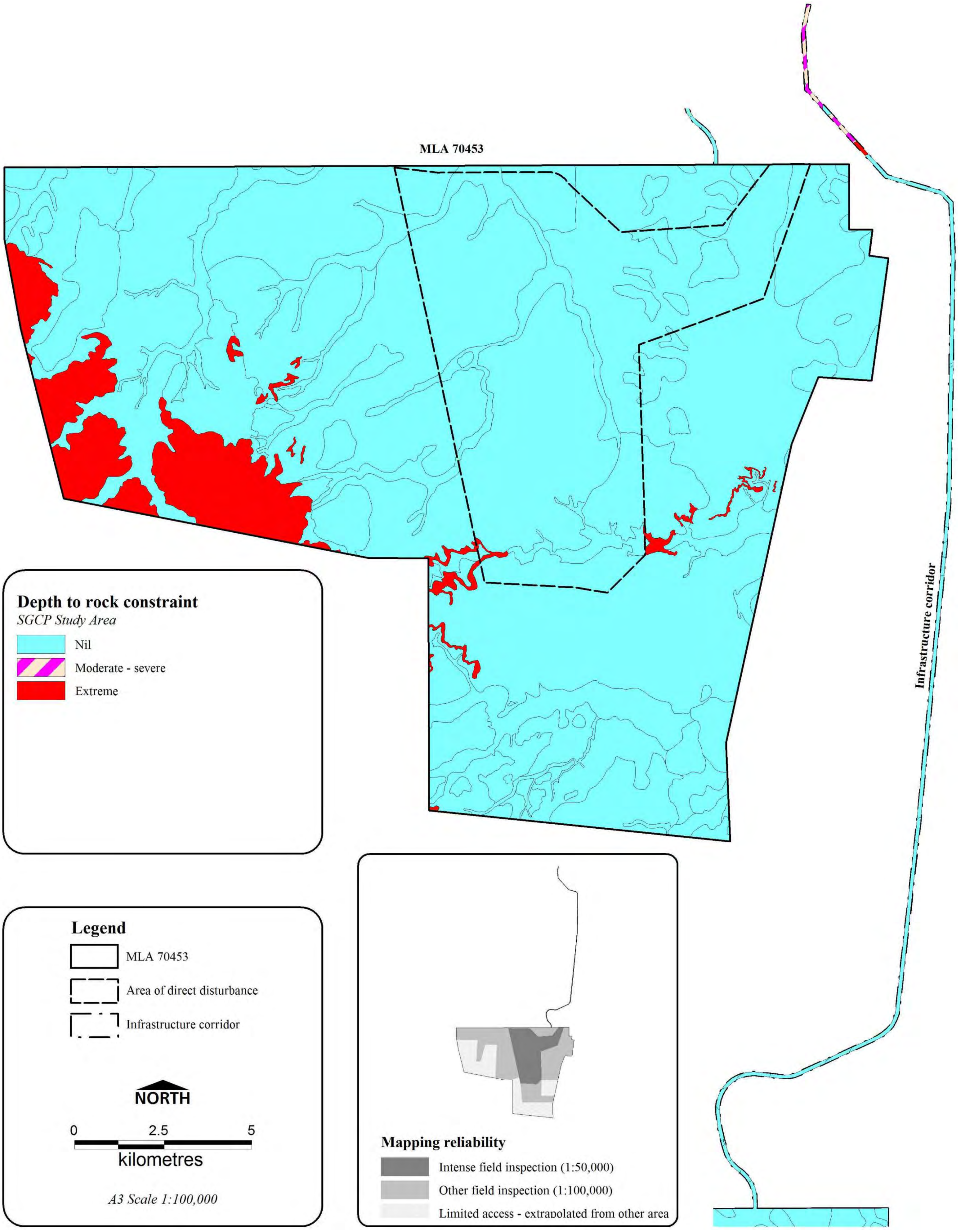

Figure 8. Depth to rock as a constraint

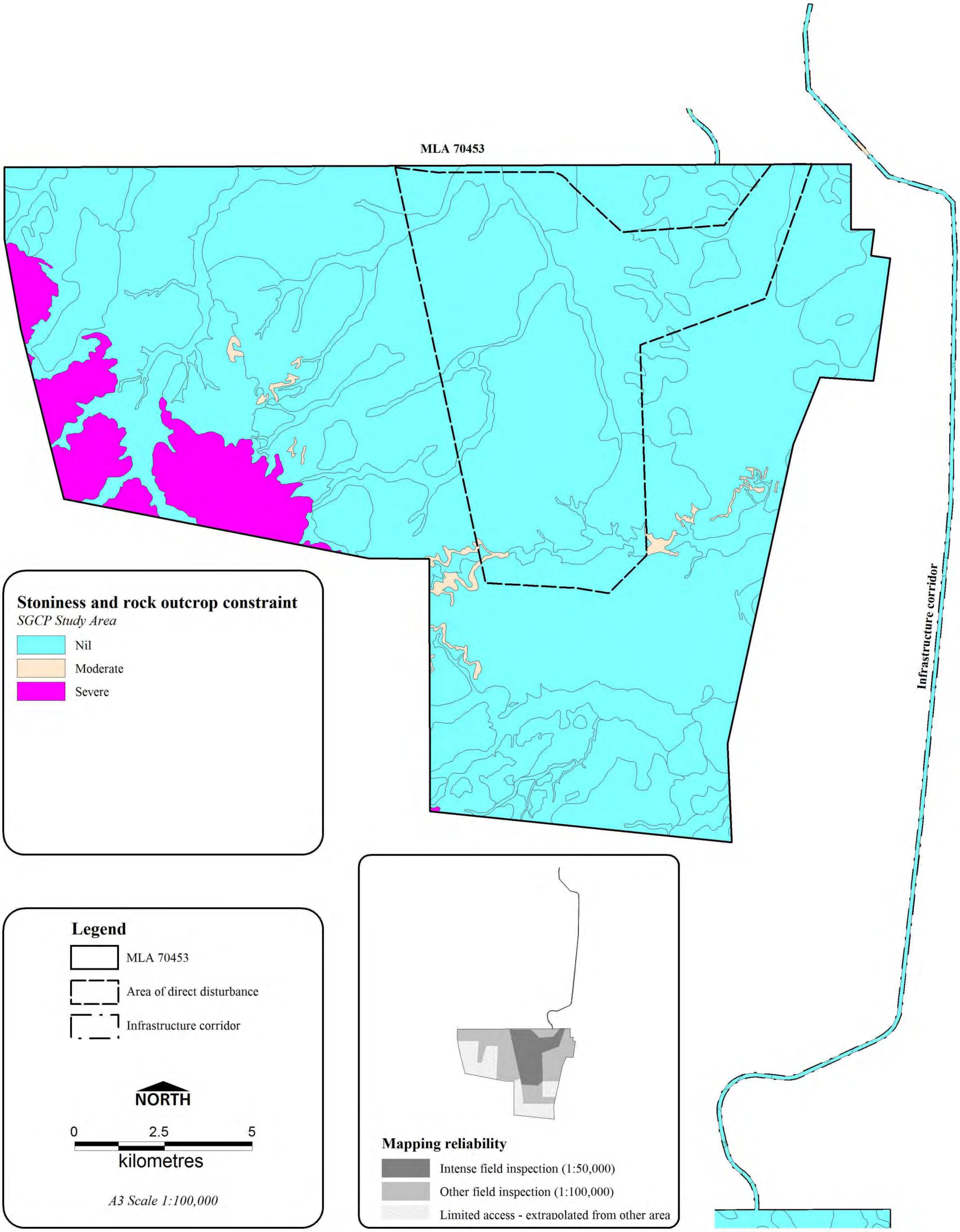

Figure 9. Stoniness and rock outcrop across the SGCP study area

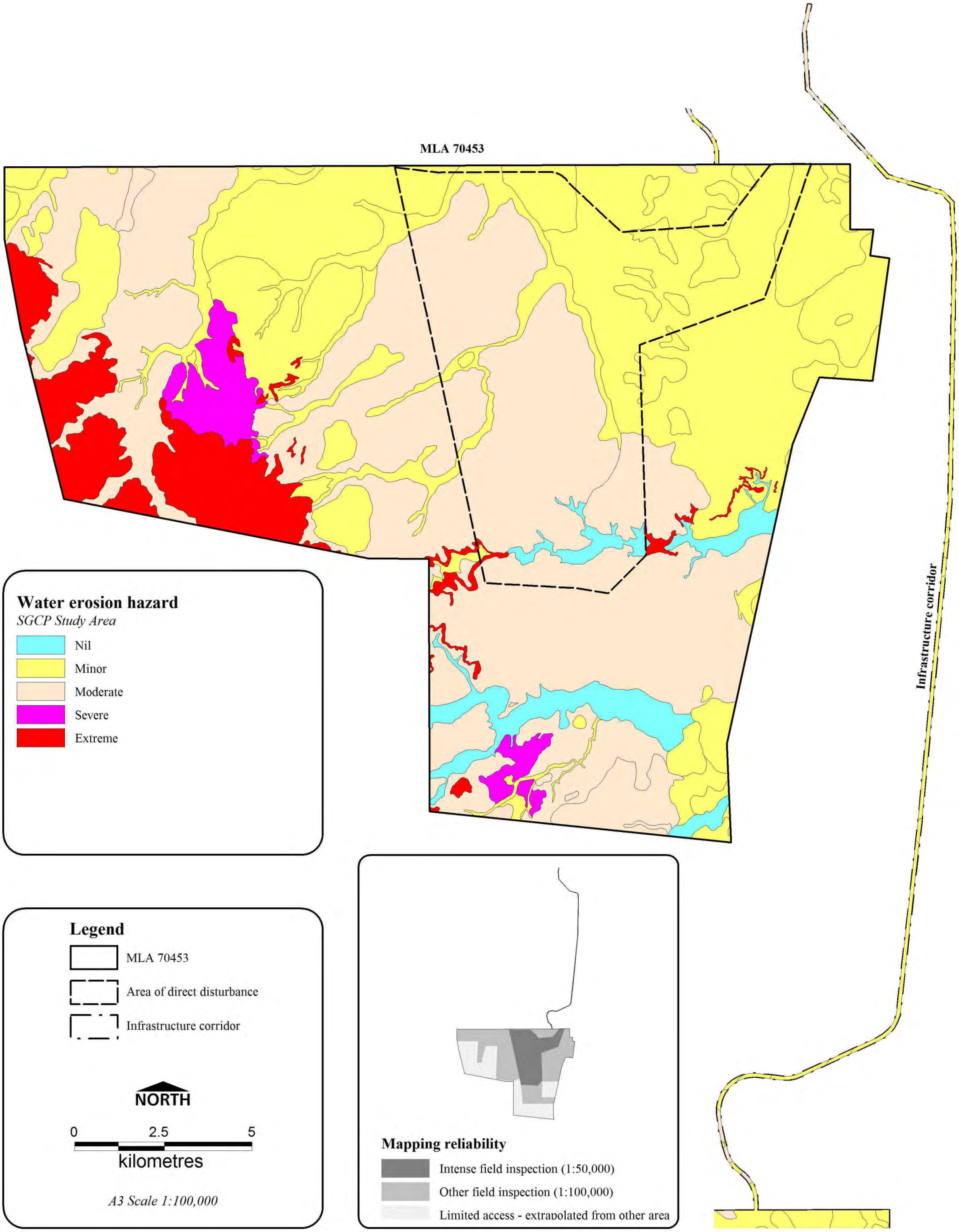

Figure 10. Water erosion hazard across the SGCP study area

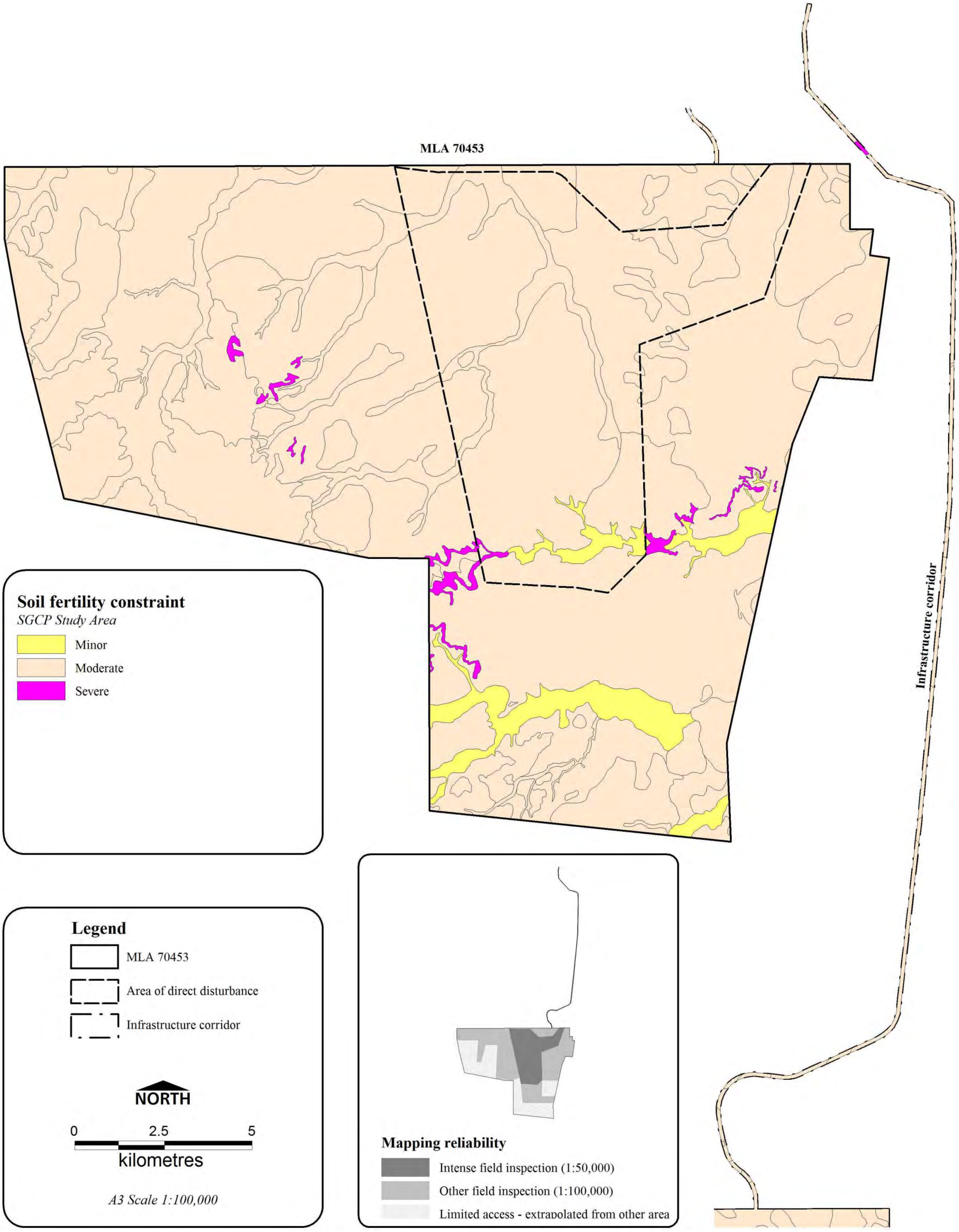

Figure 11. Soil fertility as a constraint

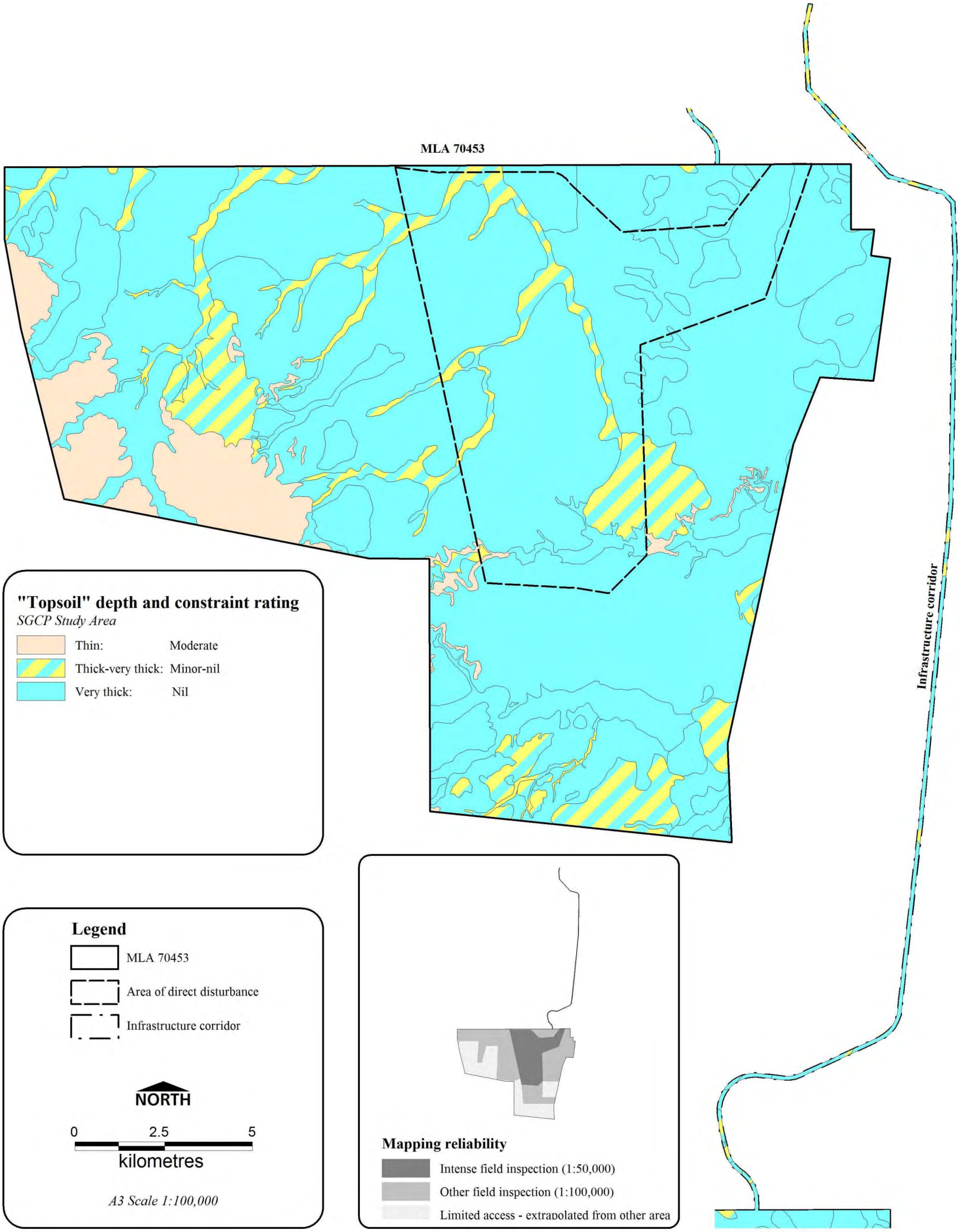

Figure 12. "Topsoil" depth as a constraint

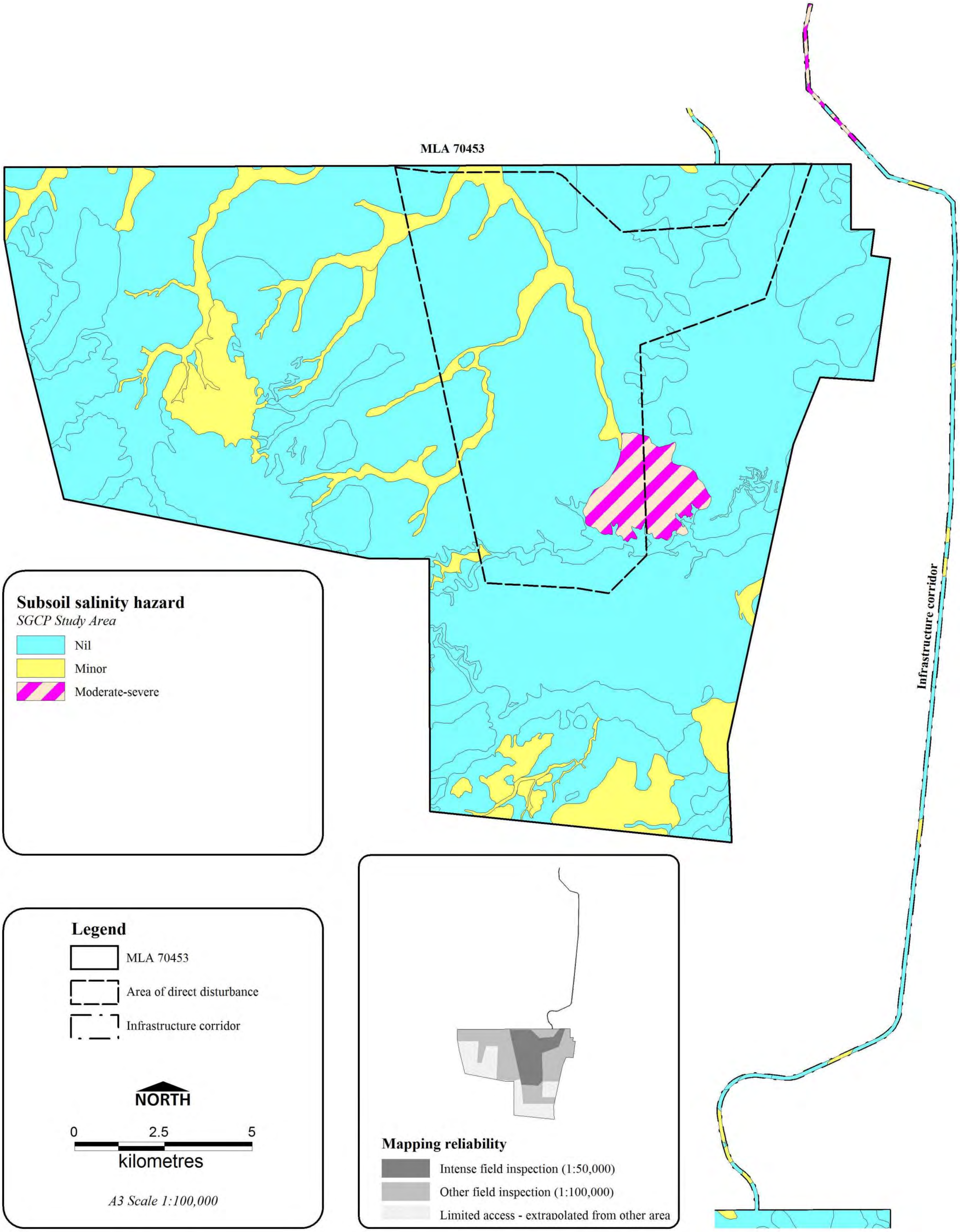

Figure 13. Subsoil salinity hazard across the SGCP study area

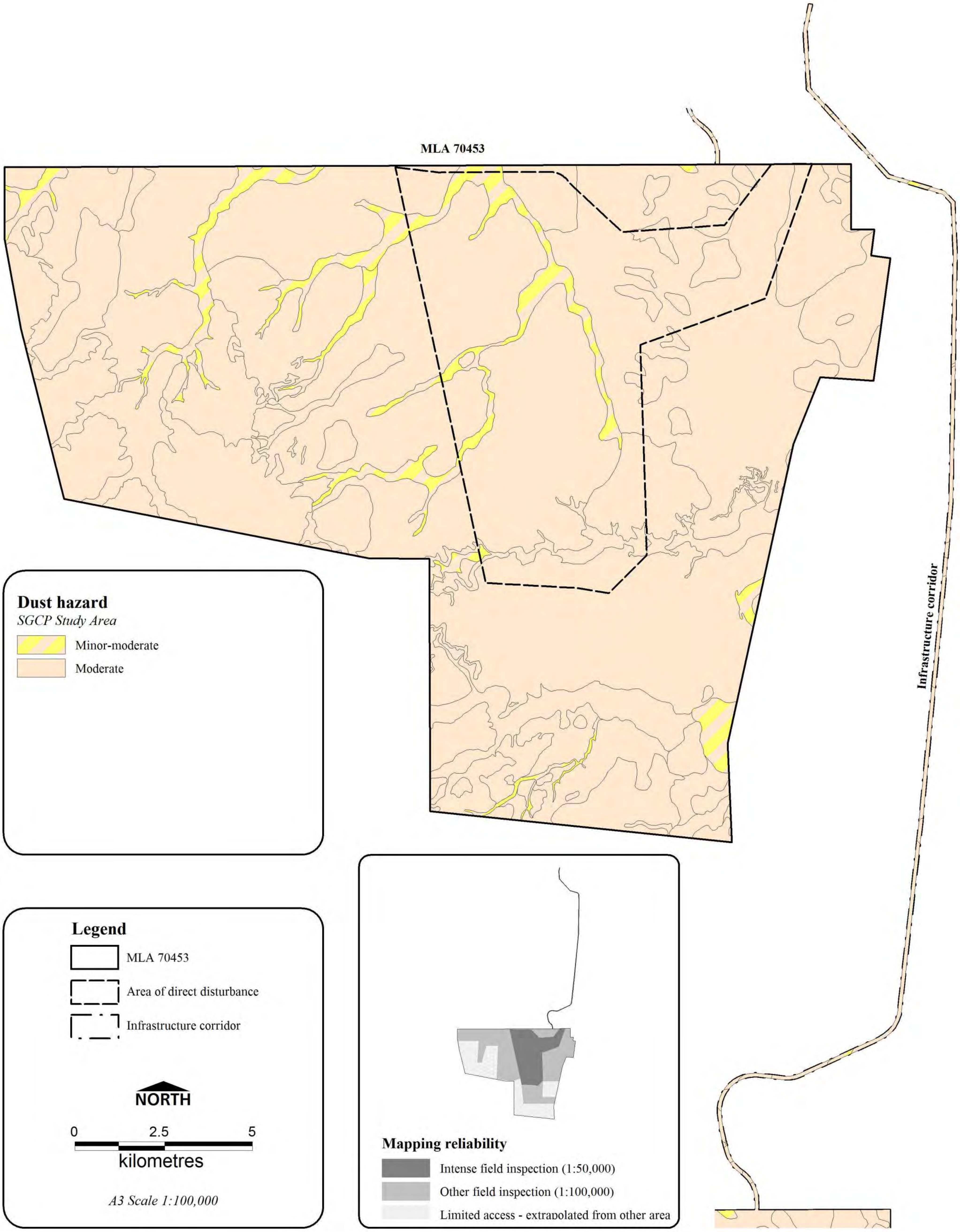

Figure 14. Dust hazard across the SGCP study area

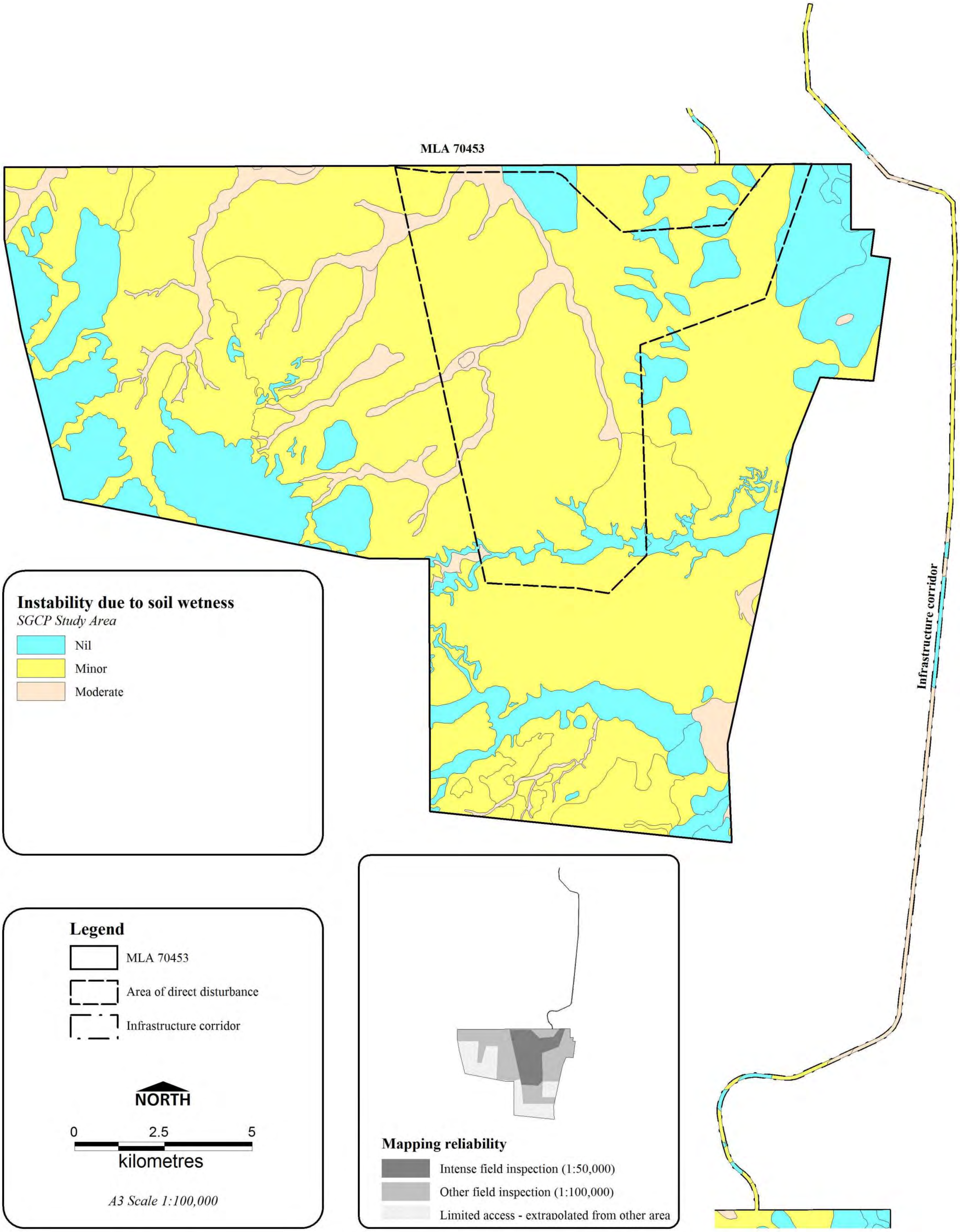

Figure 15. Instability due to soil wetness as a constraint