CHAPTER 10 – GEOLOGY, TOPOGRAPHY AND SOILS

GULF ALUMINA LTD – SKARDON RIVER BAUXITE PROJECT
# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>10.1</td>
<td>Overview</td>
<td>10-1</td>
</tr>
<tr>
<td>10.2</td>
<td>Environmental Objectives and Performance Outcomes</td>
<td>10-1</td>
</tr>
<tr>
<td>10.2.1</td>
<td>Environmental Objectives</td>
<td>10-1</td>
</tr>
<tr>
<td>10.2.2</td>
<td>Performance Outcomes</td>
<td>10-1</td>
</tr>
<tr>
<td>10.3</td>
<td>Legislative and Policy Context</td>
<td>10-2</td>
</tr>
<tr>
<td>10.3.1</td>
<td>Soil Conservation Act 1986</td>
<td>10-2</td>
</tr>
<tr>
<td>10.4</td>
<td>Environmental Values</td>
<td>10-2</td>
</tr>
<tr>
<td>10.4.1</td>
<td>Topography and Terrain</td>
<td>10-2</td>
</tr>
<tr>
<td>10.4.2</td>
<td>Geology</td>
<td>10-5</td>
</tr>
<tr>
<td>10.4.2.1</td>
<td>Overview</td>
<td>10-5</td>
</tr>
<tr>
<td>10.4.2.2</td>
<td>Geological Sequence</td>
<td>10-6</td>
</tr>
<tr>
<td>10.4.2.3</td>
<td>Hydrogeology</td>
<td>10-6</td>
</tr>
<tr>
<td>10.4.3</td>
<td>Geochemistry and Acid Mine Drainage</td>
<td>10-8</td>
</tr>
<tr>
<td>10.4.4</td>
<td>Mineral Resources and Quarry Material</td>
<td>10-9</td>
</tr>
<tr>
<td>10.4.5</td>
<td>Soils</td>
<td>10-9</td>
</tr>
<tr>
<td>10.4.6</td>
<td>Acid Sulphate Soils</td>
<td>10-12</td>
</tr>
<tr>
<td>10.4.6.1</td>
<td>ASS Investigation - 2004</td>
<td>10-12</td>
</tr>
<tr>
<td>10.4.6.2</td>
<td>Geological Investigations - 1994</td>
<td>10-13</td>
</tr>
<tr>
<td>10.4.6.3</td>
<td>ASS Investigations – Skardon River 2015</td>
<td>10-13</td>
</tr>
<tr>
<td>10.5</td>
<td>Potential Impacts</td>
<td>10-15</td>
</tr>
<tr>
<td>10.5.1</td>
<td>Impacts to Topography</td>
<td>10-15</td>
</tr>
<tr>
<td>10.5.2</td>
<td>Impacts to Soil Quality</td>
<td>10-15</td>
</tr>
<tr>
<td>10.5.3</td>
<td>Acid Sulphate Soils</td>
<td>10-19</td>
</tr>
<tr>
<td>10.5.4</td>
<td>Acid Mine Drainage</td>
<td>10-19</td>
</tr>
<tr>
<td>10.5.5</td>
<td>Erosion and Sediment Transport</td>
<td>10-19</td>
</tr>
<tr>
<td>10.6</td>
<td>Management Measures</td>
<td>10-19</td>
</tr>
<tr>
<td>10.6.1</td>
<td>Final Landform Design</td>
<td>10-19</td>
</tr>
<tr>
<td>10.6.2</td>
<td>Soil Management</td>
<td>10-20</td>
</tr>
<tr>
<td>10.6.2.1</td>
<td>Timing</td>
<td>10-20</td>
</tr>
<tr>
<td>10.6.2.2</td>
<td>Soil Stockpiles</td>
<td>10-20</td>
</tr>
<tr>
<td>10.6.2.3</td>
<td>Soil Handling</td>
<td>10-20</td>
</tr>
<tr>
<td>10.6.2.4</td>
<td>Soils Testing</td>
<td>10-21</td>
</tr>
<tr>
<td>10.6.3</td>
<td>Acid Sulphate Soils</td>
<td>10-22</td>
</tr>
<tr>
<td>10.6.3.1</td>
<td>Procedure for Early Detection and Treatment of Acid Sulphate Soil</td>
<td>10-22</td>
</tr>
<tr>
<td>10.6.3.2</td>
<td>Treatment of Excavated ASS</td>
<td>10-22</td>
</tr>
<tr>
<td>10.6.3.3</td>
<td>ASS Treatment Pad</td>
<td>10-23</td>
</tr>
<tr>
<td>10.6.3.4</td>
<td>Namaleta Creek Crossing</td>
<td>10-23</td>
</tr>
<tr>
<td>10.6.4</td>
<td>Acid Mine Drainage</td>
<td>10-23</td>
</tr>
<tr>
<td>10.7</td>
<td>Risk Assessment</td>
<td>10-23</td>
</tr>
<tr>
<td>10.8</td>
<td>Conclusion</td>
<td>10-24</td>
</tr>
</tbody>
</table>

## Tables

<table>
<thead>
<tr>
<th>Table</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Table 10-1</td>
<td>Summary Geochemistry Data</td>
<td>10-8</td>
</tr>
<tr>
<td>Table 10-2</td>
<td>Land Units on Laterite/Bauxite Plateau and Slopes and Low Lying Clay Soil Areas</td>
<td>10-17</td>
</tr>
</tbody>
</table>
Table 10-3  Risk Assessment and Management Measures for Impacts to Topography and Soils ......................................................................................................................... 10-24

**Figures**

| Figure 10-1 | Regional Topography and Drainage .......................................................... 10-3 |
| Figure 10-2 | Local Topography and Bauxite Resource Areas ........................................... 10-4 |
| Figure 10-3 | Regional Geology .......................................................................................... 10-7 |
| Figure 10-4 | Cape York Peninsula Soils ............................................................................ 10-11 |
| Figure 10-5 | Potential Acid Sulphate Soil Risk Areas ...................................................... 10-14 |
| Figure 10-6 | Schematic Representation of Pre Bauxite Mining Land Unit ...................... 10-16 |
| Figure 10-7 | Twin Powered Scrapers Connected in Push and Pull Mode ......................... 10-21 |
10. GEOLOGY, TOPOGRAPHY AND SOILS

10.1 Overview
This chapter describes the existing environmental values of the geology, topography and soils that may be affected by the construction and operation of the Project, the impacts and associated risks to those environmental values and the strategies to mitigate the risks to environmental values.

Topics addressed in this chapter include topography and geology of the region, and subsoil and topsoil characteristics and classifications. Information in this chapter is based on data collected by the proponent.

10.2 Environmental Objectives and Performance Outcomes

The environmental objectives and performance outcomes below are based on Schedule 5, Table 2 of the Environmental Protection Regulations 2008 (EP Regulation). The mitigation and management measures presented in this chapter are designed to achieve these environmental objectives and performance outcomes. The environmental management plan (EM Plan) presented in Appendix 13 provides a consolidated description of these mitigation and management measures.

10.2.1 Environmental Objectives

- The activity is operated in a way that protects the environmental values of land including soils, subsoils, landforms and associated flora and fauna.
- The activity will be operated in a way that protects environmental values of waters.
- Salvage soils resources for use in progressive rehabilitation.
- Minimise impacts to the quality of soils, including soils to be used in rehabilitation.
- Minimise soil stockpiling duration and volume.

10.2.2 Performance Outcomes

- Activities that disturb land, soils, subsoils and landforms will be managed in a way that prevents or minimises adverse effects on the environmental values of land.
- Conserve carbon content at pre-mining level, or replenish through vegetation regeneration process post mining.
- Conserve mineral content at pre mining level, or replenish during vegetation regeneration process.
- Soil stockpiling is preferentially undertaken during a single dry season.
- The disturbance of any acid sulphate soil, or potential acid sulphate soil, will be managed to prevent or minimise adverse effects on environmental values.
- Acid producing rock, if any, will be managed to ensure that production and release of acidic waste is prevented or minimised, including impacts during operation and after the environmental authority has been surrendered.
10.3 Legislative and Policy Context

10.3.1 Soil Conservation Act 1986

The Soil Conservation Act 1986 (SC Act) regulates the conservation of soil resources and facilitates the implementation of soil conservation measures by landholders for the mitigation of soil erosion. On Project areas subject to an approved project plan, persons can be required to undertake, construct and maintain soil conservation measures.

10.4 Environmental Values

This section describes the environmental values as they relate to geology, topography and soils of the Project study area.

10.4.1 Topography and Terrain

The area surrounding the Project mining leases is close to the coast, generally low lying and flat with topography rising towards a ridge where bauxite deposits are located. The Project mining leases are at around 5 – 20 mAHD elevation where bauxite deposits occur, 3 - 8 mAHD at the Port infrastructure area and lower in creek and wetland areas.

The Project area is at the southern end of the Mapoon Plain which is typified by swamp country defined by two sets of beach reaches. The area between the ridges is intertidal with salty mud flats, mangroves, and vegetated swales. Surface geology consists of sands, silty sands and clays of the Pleistocene and Quaternary.

To the north of the Project is the Skardon River which divides into three principal tributaries to the east which are populated by mangroves.

Namaleta Creek drains an east-west orientated swamp which lies at the southern end of the Project area. The creek flows west and then at the Mapoon Plain, changes direction sharply to flow to the south through mangroves, to discharge into Port Musgrave to the north of Mapoon. Port Musgrave estuary also receives water from Dulhunty, Ducie and the Wenlock Rivers.

The Skardon River flows all year while the Namaleta Creek and the Ducie River are ephemeral. Catchments and watercourses are further described in Chapter 12.

Figure 10-1 shows the regional topography and drainage features across the Project area. Figure 10-2 shows the local topography and bauxite resource areas, demonstrating that bauxite deposits are located at the higher elevations. Figure 10-2 also shows that the Port infrastructure area is located on land that is greater than 4 mAHD. AHD for the Skardon River estuary has been established at approximately 1.6 m below highest astronomical tide (HAT). Bathymetrical information is provided in Chapter 17.
Figure 10-2

Local Topography and Bauxite Resource Areas

Legend
- Mining Lease Boundaries
- Project Footprint
- Port of Skardon River
- Watercourses

Gulf Alumina Limited

Date: 14/03/2016

Revision: 17


We hereby give no warranty in relation to the data (including accuracy, reliability, completeness or suitability) and accept no liability (including without limitation, liability in negligence) for any loss, damage or costs (including consequential damages) arising from or in connection with the use of the data. Use of the data is subject to the conditions of use and the data must not be used for direct marketing or be used in breach of privacy laws. Tenures © Geos Mining (2015).
10.4.2 Geology

10.4.2.1 Overview

The Project area is located within the Carpentaria Basin, which is a Jurassic to Cretaceous age (200 to 66 million years before present (b.p.)) basin which covers the majority of the Western Cape York Peninsula (Jell, P.A., 2013). In detail, the geology that sub-crops across the majority of the Project area is the Tertiary age (66 to 2 million years b.p.) Bulimba Formation (SRK, 2014).

Figure 10-3 illustrates the surface geology of the Project area, together with the zones of Holocene muds / estuarine deposits within the mining leases.

The Bulimba Formation is of fluviatile origin (that is, formed by deposits from rivers and streams), dominated by sands and clayey sands. This formation is deeply weathered (lateritic and ferruginous) and hosts the bauxite resource. The Bulimba Formation extends to a depth of around 17 m below surface, near the Skardon River Landing. Beneath the Bulimba Formation is the Cretaceous age (145 to 66 million years b.p.) Rolling Downs Group. The Rolling Downs Group in the Project area is dominated by mudstone / clays of marine origin. The Rolling Downs Group is at least 500 m thick in the Project vicinity (SRK 2014). The Bulimba Formation was formed by the erosion of the Rolling Downs Group, to the east of the Project area.

The formation of the bauxite deposits is by a weathering process called lateritisisation. This process generally takes place in areas of high rainfall (preferably seasonal), good drainage and generally flat topography (Taylor and Eggleton, 2008). These climatic conditions lead to the oxidation and dissolution of reactive components of the rock matrix, leaving behind the immobile elements as a relic soil. The lateritisisation process leads to the oxidation of any mineral sulphides that may have been present in the parent rock material. In the right conditions, the relic soil left behind can reach thicknesses in excess of 10 m. The laterisitation process leads to the formation of relic soils rich in aluminium hydroxides, iron oxides, clays (kaolinite) and immobile elements, such as titanium and zircon (Taylor and Eggleton, 2008). It is the high proportion of aluminium hydroxides that make this material sought after as a raw material for aluminium production.

This process has taken place since the upper Cretaceous (approximately 100 million years b.p.) when the hot, wet climate resulted in extensive weathering of the Rolling Downs Group, forming deep lateritic profiles with gibbsite nodules and pisoliths in a kaolinitic matrix in the upper weathering horizon, and oxyhydroxides and kaolinitic peds in the lower mottled zone. Uplift and erosion of the Rolling Downs Group, resulted in the deposition of the Bulimba Formation, which continued to develop a new lateritic profile in-situ.

More recent geological processes has resulted in the erosion of the Bulimba Formation by riverine systems (Skardon River and Namaleta Creek), with associated Quaternary age (2.5 million year b.p.) alluvium deposits (sands, silty sands and clays).

West of the Project area, coastal processes have deposited Quaternary age dune sands, overlying the Bulimba Formation and Quaternary alluvium.

During the Holocene age period (11,700 years b.p.) sea level rise resulted in the deposition of estuarine sediments within coastal areas, particularly areas which had been eroded in the Quaternary age period. Within the Project area, Holocene age sediments have been identified within and directly adjacent the current path of Namaleta Creek (Smith CD and Hall IR, 2004). These sediments are described as soft sulphidic estuarine muds and sands. There will be no Project activities, other than the crossing of Namaleta Creek, within the Holocene age sediments.
10.4.2.2 Geological Sequence

The bauxite deposit is located on part of the Weipa plateau and is partly dissected by drainage channels and consists of deeply weathered profile of bauxite, ferricrete and clay capping the Bulimba Formation (Douglas and Partners, 1995). Exploration drilling near Skardon River landing has indicated that the Bulimba formation extends about 17 m depth and below this are shales and mudstones of the Rolling Downs formation.

Nearby bores drilled intersecting the Mesozoic Sandstones are Comalco’s oil and gas test wells, “Pennefather Bore” and “Rum Bottle Bore” were drilled in 1991 and area located south of Mapoon near Wenlock River. A review of seismic data and bore logs indicates that the Rolling Downs Group extends to 530-600 m depth and is underlain by about 100 m Mesozoic sandstone (Douglas and Partners, 1995)

The underlying sedimentary sequence listed from oldest to youngest is:

- Rolling Downs Group, comprising mainly of clays of marine origin (Mesozoic)
- Bulimba Formation, comprising sands and clayey sands (Tertiary)
- Valley Fill Deposits, comprising sands, silty sands and clays (Pleistocene and Quaternary).

The geological sequence as relevant to the hydrogeology of the Project area is described in Chapter 13.

10.4.2.3 Hydrogeology

The hydrogeology of the Project area is described in Chapter 13.
Regional Geology

Figure 10-3

Gulf Alumina Limited

Date: 14/03/2016

Legend
- Mining Lease Boundaries
- Port of Skardon River
- Watercourses
- 10m Elevation Contours

Geology Rock Unit - Surface

HOLOCENE
- Qhm - Beach Sand
- Holocene Estuarine Deposits

QUATERNARY
- Qpm - Sand Ridges

PLEISTOCENE
- TQd`a - Aluminous laterite, including bauxite
- Ti - Bulimba Formation

TERTIARY
- Qac - Aluvium

A no warranty is given in relation to the data (including accuracy, reliability, completeness or suitability) and accept no liability (including without limitation, liability in negligence) for any loss, damage or costs (including consequential losses or costs) arising out of or in connection with the use of the data. Data must not be used for direct marketing or be used in breach of privacy laws. Tenures © Geos Mining (2015). State Boundaries and Towns © Geoscience Australia (2006). Geology data © DEEDI (2011).
10.4.3 Geochemistry and Acid Mine Drainage

The ore materials are high in aluminium, iron and silica oxide. Geochemical analysis of the excavated materials is summarised in Table 10-1 below.

Table 10-1 Summary Geochemistry Data

<table>
<thead>
<tr>
<th></th>
<th>Al₂O₃</th>
<th>Fe₂O₃</th>
<th>SiO₂</th>
<th>TiO₂</th>
<th>LOI</th>
<th>CaO</th>
<th>Cr₂O₃</th>
<th>K₂O</th>
<th>MgO</th>
<th>P₂O₅</th>
<th>V₂O₅</th>
<th>ZrO₂</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>43.71</td>
<td>12.8</td>
<td>22.69</td>
<td>2.36</td>
<td>17.69</td>
<td>0.07</td>
<td>0.03</td>
<td>0.07</td>
<td>0.06</td>
<td>0.04</td>
<td>0.05</td>
<td>0.18</td>
</tr>
<tr>
<td>Max</td>
<td>54.2</td>
<td>44.6</td>
<td>65.6</td>
<td>3.62</td>
<td>42.81</td>
<td>0.4</td>
<td>0.1</td>
<td>0.4</td>
<td>0.31</td>
<td>0.14</td>
<td>0.23</td>
<td>0.29</td>
</tr>
<tr>
<td>Min</td>
<td>0</td>
<td>2.69</td>
<td>7.48</td>
<td>0</td>
<td>0</td>
<td>0.01</td>
<td>0.01</td>
<td>0.01</td>
<td>0</td>
<td>0.01</td>
<td>0.01</td>
<td>0.04</td>
</tr>
<tr>
<td>SD</td>
<td>6.72</td>
<td>4.92</td>
<td>8.21</td>
<td>0.42</td>
<td>3.22</td>
<td>0.06</td>
<td>0.01</td>
<td>0.05</td>
<td>0.03</td>
<td>0.02</td>
<td>0.02</td>
<td>0.03</td>
</tr>
<tr>
<td>Count</td>
<td>480</td>
<td>478</td>
<td>478</td>
<td>480</td>
<td>471</td>
<td>425</td>
<td>413</td>
<td>422</td>
<td>431</td>
<td>425</td>
<td>413</td>
<td>413</td>
</tr>
</tbody>
</table>

LOI = loss on ignition (essentially moisture %)

Source – Gulf Alumina 2015

Above the ore, the subsoil is in the order of 40 - 50 cm. The soil properties are discussed in Section 10.4.5 below.

The results from elemental analysis of shallow ore samples indicate that the maximum sulphur content of the materials is 0.03% S (Gulf Alumina, 2015).

Analysis of the metals content of the shallow samples (Gulf Alumina, 2015) indicates low values of the elements of interest as follows:

- Arsenic, maximum 15.5 mg/kg
- Cadmium, maximum 0.01 mg/kg
- Chromium, maximum 184 mg/kg
- Cobalt, maximum 16.25 mg/kg
- Copper, maximum 11.4 mg/kg
- Lead, maximum 16.55 mg/kg
- Manganese, maximum 1055 mg/kg
- Mercury, maximum 0.07 mg/kg
- Nickel, maximum 20.1 mg/kg, and
- Zinc, maximum 2.5 mg/kg.

The unique nature of bauxite deposits is that they are essentially a result of a deep weathering and oxidation process of the outcropping geology. As described in Section 10.4.2 the lateritisation process would have resulted in the oxidation of any sulphide minerals (if there were any present) in both the subsoil and laterite. The maximum total sulphur content of the samples tested was 0.03% S, which is expected to present a very low risk of acid mine drainage resulting from the excavation of the bauxite at the Project site.

The concentration of heavy metals in the ore samples were all low. For any ore that was stockpiled at surface for any extended period, it would not be expected that drainage from these stockpile would contain concentrations of metals that present a risk to the environment.
10.4.4 Mineral Resources and Quarry Material

Initial drilling in December 2007 was followed by a further drilling campaign in June 2008 and October 2009 enabling a JORC complaint resource estimated in excess of 50 million tonnes to be issued in February 2010.

The resource has been identified with in situ grades high enough in alumina and low enough in silica to form a direct shipping ore (DSO) and, as a result, beneficiation of the ore is not required.

Resource drilling and assaying of raw bauxite grades was conducted through 2014 to confirm the DSO resource.

The Project is unlikely to lead to the sterilisation of other mineral resources, as mining occurs to depths of approximately 5m below the surface. Typically kaolin is found in low lying areas not associated with bauxite mining, however some kaolinite materials may be removed during bauxite mining. Exploration tenures in the vicinity of the Project area are for bauxite or mineral sands. Exploration tenements associated with mineral sands are located to the west and north of the Project’s mining leases along the coastal margins. Mineral sands typically occur along the coastal margin where concentration of the heavy minerals through coastal processes (including dune formation) can lead to economic deposits being formed. Although mineral sands may be present in the soils above the bauxite resources, these are unlikely to be economic as they are not likely to have undergone sufficient concentration via coastal processes.

There are no coal or petroleum tenures in the vicinity of the Project area, reflecting that these resources are not present in the Project area.

Notwithstanding the above, following mining, rehabilitation of the land will take place, and any subsequent exploration or mining for resources of other minerals (that may or may not occur at depth below the bauxitic horizon) will not be impeded.

Project mining activities will not impact any extractive or quarry resources at strategic locations. Quarry materials required for the Project (e.g. road base and laydown pads), will be obtained from former kaolin mine stockpiles or from existing borrow pits within the mining leases, typically located in areas proposed for bauxite mining. If required, materials not available on-site (e.g. sand and aggregate for cement making) will be brought in by ship.

10.4.5 Soils

Mining will be conducted on two basic land types:

- bauxite plateau with bauxite and lateritic subsoil; and
- low lying seasonally flooded clay soil areas.

The soil of the bauxite plateau is Red Kandosol soil type. This soil corresponds to the Weipa Soil type mapped in Figure 10-4 (Biggs and Philips, 1995, sourced from Soils of the Cape York Peninsula - State of Queensland (Department of Science, Information Technology and Innovation) 2015). Red Kandosols have a topsoil depth of 10 - 20 cm. Subsoil (40 - 50 cm) of soil covers 1-6 m of pisolitic bauxite, which is underlain by ironstone. The loamy topsoil is blackened by organic content (carbon), while the subsoil is red with a gravelly structure increasing with bauxite pisolites at depth.

The soils are well drained and leached, therefore having low moisture holding capacity, low organic content and mineral deficiencies. The soils are neutral to moderately acidic (pH 5-7). This soil dominates the Project area, and correlates with Weipa soil type described by Biggs and Philips (1995).
There are smaller areas of Yellow Kandosols and Yellow Kandosol acid soils in areas of lesser drainage and on lower slopes fringing drainage lines. This soil corresponds to the Andoon Soil type (Biggs and Philips, 1995), and occurs on the margins of the Weipa Soil type. This soil type is not distinctly mapped on Figure 10-4. The Kandosol soils, being weathered and of low fertility, support vegetation adapted to such conditions. Carbon, nitrogenous and mineral nutrients are concentrated in the thin topsoil layer. This layer also contains seed and vegetative propagules.

The Kandosol soil types have low potential to develop accelerated erosion when cleared of vegetation for mining or infrastructure development. The predominantly sandy surface soils, together with the low slopes on the bauxite plateau, facilitate infiltration and reduce the rate of runoff. Drop-off-slope areas, particularly near drainage lines have a higher erosion potential and will be avoided in mining.

The other soil type in the Project area is a redoxic hydrosol (deep duplex or gradational soil over mottled grey clay) associated with swampy areas. This soil corresponds to the Mapoon Soil type (Biggs and Philips, 1995) mapped in Figure 10-4.

Soil testing has been conducted on and adjacent to areas proposed for bauxite mining at Skardon River, with the purpose of informing the rehabilitation plan. The results are presented in Chapter 7.
Figure 10-4

Legend
- Mining Lease Boundaries
- Port of Skardon River
- Watercourses
- 10m Elevation Contours

Soils of the Cape York Peninsula
- Mapoon
- Marina
- Bertie
- Caravan
- Skardon
- Somerset
- Grevil

Cape York Peninsula Soils

Date: 14/03/2016

Gulf Alumina Limited

No warranty is given in relation to the data (including accuracy, reliability, completeness or suitability) and except no liability (including without limitation liability in negligence) for any loss, damage or costs (including consequential damages) arising from or in connection with the use of or reliance on the data. Data must not be used for direct marketing or be used in breach of privacy laws. Tenures © Geos Mining (2015). State Boundaries and Towns © Geoscience Australia (2006). Soils of the Cape York Peninsula © Queensland Government (2015). Education 10m contours © State of Queensland - Department of Natural Resources and Mines (2015).
10.4.6 Acid Sulphate Soils

Potential acid sulphate soils (PASS) (i.e. soils that contain iron sulphides or sulphidic material which have not been exposed to air or oxidised), present a potential environmental risk when disturbed, as they will become very acidic when exposed to air and oxidised.

Acid sulfate soils (ASS) are commonly found less than 5 m above sea level, particularly in low-lying coastal areas. Such areas include mangroves, salt marshes, floodplains, swamps, estuaries and brackish or tidal lakes. When exposed to atmospheric oxygen through disturbance such by excavation, sulphides in these soils are oxidised to sulphuric acid and metal oxides, mainly iron (red colour), as well as mobilisation of heavy metals and toxic aluminium. This can cause vegetative die-back, fish kills and algal blooms. There are two classes of acid sulphate soils:

- potential acid sulphate soils (PASS):
- actual acid sulphate soils (AASS)

PASS are soils or sediments containing iron sulfides or sulfidic material which have not been exposed to air and oxidized. The field pH of these soils or sediments in their undisturbed state is usually >4, and can be neutral or slightly alkaline. These soils or sediments are saturated with water and anaerobic in their natural state.

AASS are soils or sediments containing highly acidic soil horizons or layers as a result of oxidation of soil materials that are rich in iron sulfides such as pyrite (FeS$_2$). This oxidation produces acid in excess of the soil’s capacity to neutralise the acidity, resulting in a pH of 4 or less. The presence of pale yellow acidic mottles and coatings of jarosite or related products confirms an AASS, but jarosite need not be present. Soils or sediments with pH 4.1-5.5 may also contain acid or remnants of iron and aluminium ions from previous oxidation and hence require treatment.

Regional Australian Atlas of Acid Sulphate Soils$^1$ mapping (published by Australian Soil Resource Information System (ASRIS) indicates areas of PASS risk adjacent to Skardon River. This information has been used to illustrate Project ASS risk areas (Figure 10-5). The mapping indicated areas of ‘high’ PASS risk (predicted with a ‘fair’ degree of confidence), generally located adjacent to Skardon River or close to Namaleta Creek.

10.4.6.1 ASS Investigation - 2004

During the kaolin mine operations, the only kaolin excavation that encountered acid sulphate soil was in the fluvial pit in 2004, in one of several mining campaigns. PASS was not encountered in the claystone pits in any of the kaolin mining campaigns.

An acid sulphate soil investigation was undertaken in the vicinity of Namaleta Creek in 2004 by the Department of Natural Resources and Mine’s Queensland Acid Sulphate Soils Investigation Team (Smith and Hall, 2004). The purpose of the investigation was to identify if the sediments associated with the Bulimba Formation and Rolling Downs Group were PASS.

The investigation identified that Holocene age sediments associated with the Namaleta Creek channel were PASS. These sediments were described as soft sulphidic estuarine muds and sands. Net acidity for these estuarine muds varied from 0.87% S to 6.12% S.

---

The investigation further established that these Holocene sediments were host to vegetation dominated by *Melaleuca quinquenervia* (broad-leaved paperbark). The report noted that “A sharp boundary occurs between the sulfidic estuarine sediments (SES) and the next observed surficial, slightly more elevated sedimentary entity. This boundary is readily indicated by a change (from *Melaleuca quinquenervia*) to a *Melaleuca viridiflora* community, where dense, heavy, non-sulfidic mottled clays with ferruginous segregations were found.”

The report concluded that “The site investigation carried out at Skardon River Kaolin has confirmed that the sulfidic estuarine sediments (i.e. acid sulfate soils) are laterally restricted to the present and former *Melaleuca quinquenervia* communities, being confined and underlain by the Pliocene laterite of the Weipa plateau and/or the fluvial kaolin of the Bulimba Formation. Within this area, the highest natural ground elevation where acid sulfate soils were found was 2.306 m ADH. Adopting a conservative approach, it seems reasonable to assume that acid sulfate soils are highly likely to be present in areas associated with present and former *M. quinquenervia* communities where the natural ground elevation is less than 2.5 AHD.”

Therefore outside of areas of *M. quinquenervia*, and above 2.5 m Australian Height Datum there is insignificant risk of disturbance of acid sulphate soils (ASS) in and around Namaleta Creek.

### 10.4.6.2 Geological Investigations - 1994

Geological investigations in 1994 (Golder 1994) comprised six over water bores on the bank and in the channel of the Skardon River and six land based boreholes in the Port Infrastructure area.

The land based investigations confirmed that the Port infrastructure area was underlain by dense clayey silty gravels, hard gravelly sandy clay over hard silty clay. While limited acid sulphate soil testwork was undertaken, these lithologies correlate with the Bulimba and Rolling Downs Formation which are not considered to be acid sulphate soil risk material. The maximum depth investigated was 15.4m.

Investigations over water at the Port infrastructure area (Golder 1994) indicated subsurface conditions consisted of thin loose gravel, overlying very stiff gravelly sandy clay, overlying hard silty clay, overlying siltstone. While these materials were not investigated for acid sulphate soil potential, they do not appear lithologically similar to the Holocene age estuarine deposits described near Namaleta Creek. The maximum depth investigated was 19.5m.

### 10.4.6.3 ASS Investigations – Skardon River 2015

The potential for acid sulphate soils in the estuarine environment of the Skardon River was analysed through sediment samples, as described in Chapter 17.

Gulf Alumina has developed a procedure for early detection and treatment of acid sulphate soil (see Section 10.6).
Legend

Atlas of Australian Acid Sulfate Soils (CSIRO Lands and Water 2014)

Probability of Occurrence / Confidence

- High Probability (>70% chance) / No necessary analytical data are available but confidence is fair, based on a knowledge of similar soils in similar environments
- High Probability (>70%) / No necessary analytical data are available and classifier has little knowledge or experience with ASS, hence classification is provisional
- Low Probability (6 - 70%) / No necessary analytical data are available and classifier has little knowledge or experience with ASS, hence classification is provisional
- Extremely Low Probability (1 - 5%) (with occurrences in small localised areas) / No necessary analytical data are available and classifier has little knowledge or experience with ASS, hence classification is provisional

Potential Acid Sulfate Soil Risk Areas

Figure 10-5

Gulf Alumina Limited

Date: 14/03/2016

We warranty is given in relation to the data (including accuracy, reliability, completeness or availability) and accept no liability for its use or omission. Liability in replacement for any loss, damage or costs (including consequential damages) arising in any use of the reference data. Data must not be used for direct marketing or be used in breach of privacy laws. Tenures © Geos Mining (2015). State Boundaries and Towns © Geoscience Australia (2006). Atlas of Australia Acid Sulfate Soils © CSIRO Lands and Water (2014). Imagery Sources: Esri, HERE, DeLorme, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster ... Japan, METI, Esri China (Hong Kong), swisstopo, MapmyIndia, © OpenStreetMap contributors, and the GIS User Community.
10.5 Potential Impacts

10.5.1 Impacts to Topography

Pits areas will be backfilled with overlying subsoils and topsoils and rehabilitated. However these areas will form shallow depressions in the landscape, with the potential to alter runoff and groundwater recharge behaviour. This is described below and further assessed in Chapter 13.

10.5.2 Impacts to Soil Quality

Topsoil and subsoil will be stripped in advance of mining will be placed immediately on areas to be rehabilitated.

When the 50 – 60 cm topsoil and subsoil layer is stripped off during mining and placed immediately on open mine floor for rehabilitation, there is expected to be a loss in soil quality. Field studies in Weipa, noted a 45% reduction in surface-soil carbon (C) and nitrogen (N) in the first year after mining. The reported microbial biomass C declined by 19% in topsoil, 34% in mixed soil and 61% in exposed subsoil, while organic C declined by 26% in topsoil, 18% in mixed soil and 12% in subsoil. Phosphorus (P) declined with organic content while S has been found to be unaffected, probably due to its natural presence in the subsoil (Schwenke 1992).

Bauxite mining will lower the ground level and removal of bauxite from the profile places subsoil on ironstone, creating a profile similar to that found on ironstone ridges. Figure 10-6 provides a schematic representation of pre and post bauxite mining land units (same land units defined by Gunness et al. 1987) in relation to depth to ‘wet season’ water table.

The upper diagram represents pre-mining land units, while the lower presents hypothesized land units anticipated post mining by Reddell and Hopkins (1994).

Reddell and Hopkins (1994) suggest that changes in the depth of the soil profile and hydrology will have the effect of creating a new vegetative land unit. Referring to Figure 10-6 in conjunction with Table 10-2, the diagrams show the effect of mining on the soil profile, i.e. reduction of depth of B horizon and water table from surface, while the table indicates changes in dominant plant species.

Reddell and Hopkins (1994) predict that plant species predominating in the land unit 5k, describing vegetation on laterite slopes with ironstone outcrops, are more likely to succeed than species found on the pre-mining bauxitic red earths (land unit 2b). Further, the post-mining areas that lie below the wet season water table are likely to support plant species found in land units 7b and 3b. It is stressed that the information in Figure 10-6 and Table 10-2 is a conceptual model of post mining landform and vegetation types originally published by Reddell and Hopkins in 1994. Actual vegetation proposed for rehabilitation id described in Chapter 7.

The bauxite profile at Skardon is thinner (averaging one meter) than that generally found at Weipa, so where only bauxite is extracted, the final rehabilitated land surface will be closer to the original surface in elevation. The removal of the bauxite layer is expected to result in wet season inundation of some mine areas. In Weipa it has been found easier to re-vegetate such areas than the higher ground, Melaleuca and other flood tolerant trees being easier to grow.
Upper diagram before mining, lower diagram with hypothesized land units anticipated post mining, both in relation to depth to 'wet season' water table (Redell & Hopkins, 1994).

Land Units:

Figure 10-6 Schematic Representation of Pre Bauxite Mining Land Unit
<table>
<thead>
<tr>
<th>Land Units:</th>
<th>2b</th>
<th>5k</th>
<th>2c</th>
<th>7b</th>
<th>3b</th>
</tr>
</thead>
<tbody>
<tr>
<td>RE Type &amp; VMA Status</td>
<td>RE 3.5.2 : Not of concern</td>
<td>RE 3.7.3 : Not of concern</td>
<td>RE 3.5.7 &amp; 3.5.10 : Not of concern</td>
<td>RE 3.3.9 &amp; 3.3.50 : Not of concern</td>
<td>RE 3.3.14 : Not of concern</td>
</tr>
<tr>
<td>Soil Structure/Topography</td>
<td>laterite/bauxite plateau</td>
<td>eroding gentle laterite slopes with ironstone outcrops</td>
<td>bauxite plateau</td>
<td>alluvium/colluvium deposits podzolics/clays</td>
<td>alluvium/colluvium deposits podzolics/clays</td>
</tr>
<tr>
<td>Soil Profile</td>
<td>&gt;1.5m</td>
<td>shallow</td>
<td></td>
<td>mottled below 0.5m</td>
<td></td>
</tr>
<tr>
<td>Hydrology</td>
<td>excessive internal drainage no surface run-off</td>
<td>excessive surface run-off</td>
<td></td>
<td>water-logged for long periods</td>
<td>swamp - below wet season watertable</td>
</tr>
<tr>
<td>pH</td>
<td>slight-strong acidity</td>
<td></td>
<td></td>
<td>strongly acid</td>
<td></td>
</tr>
<tr>
<td>Vegetation Structure</td>
<td>Grassy tall layered woodland</td>
<td>Open scrubby woodland</td>
<td>Grassy tall woodland</td>
<td>Tall shrubland/low woodland</td>
<td>Closed/open forest</td>
</tr>
<tr>
<td>Foliage protective cover</td>
<td>15%</td>
<td>25%</td>
<td>25%</td>
<td>30%</td>
<td>54%</td>
</tr>
<tr>
<td>Framework/Canopy</td>
<td>Eucalyptus tetrodonta (d)</td>
<td>Eucalyptus nesophila</td>
<td>Eucalyptus tetradonta</td>
<td>Melaleuca viridiflora</td>
<td>Melaleuca viridiflora</td>
</tr>
<tr>
<td>Species</td>
<td>Ery. Chlorostachys; Eucalyptus nesophila</td>
<td>Eucalyptus tetradonta; Eucalyptus dicromophloia</td>
<td>Eucalyptus nesophila; Ery. Chlorostachys (uc)</td>
<td>Lophostemon suaveolens; Calycopeplus casuarinoides; Melaleuca stenostachya</td>
<td>Melaleuca cajuputi &amp; leucadendra; Lophostemon suaveolens; Calycopeplus casuarinoides</td>
</tr>
<tr>
<td>Understorey Species</td>
<td>Ery. Chlorostachys; Parinari nonda; Planchonia careya; Grevillia paralela &amp; glauco; Coelospermum reticulatum; Acacia</td>
<td>Acacia rothii; Xylomelum scottianum; Planchonia careya; Parinari nonda; Ery. Chlorostachys</td>
<td>Acacia rothii; Grevillia paralela &amp; glauco; Planchonia careya; Parinari nonda; Lophostemon suaveolens; Livistona muelleri</td>
<td></td>
<td>Melaleuca symphyocarpa may form sub-canopy or understorey, if present</td>
</tr>
<tr>
<td>Land Units:</td>
<td>2b</td>
<td>5k</td>
<td>2c</td>
<td>7b</td>
<td>3b</td>
</tr>
<tr>
<td>----------------</td>
<td>--------------------</td>
<td>------------------------------</td>
<td>------------------------------</td>
<td>------------------------------</td>
<td>------------------------------</td>
</tr>
<tr>
<td></td>
<td>rothii; Livistona muelleri</td>
<td>Grevillia parallela &amp; glauco; Lophostemon suaveolens</td>
<td>Heteropogon triticeus; Sorghum plumosum; Coelorachis rottboelliioides; Eriachne sp.; Pandanus sp.; Spermacoce sp.; annual herbs</td>
<td>Philydrum lanuginosum; Eragrostis interrupta; Ectrosia leporina</td>
<td>Philydrum lanuginosum; Sporobolus virginicus; Eleocharis dulcis</td>
</tr>
<tr>
<td>Ground Cover</td>
<td>Heteropogon triticeus; Sorghum plumosum; Schizachyrium sp; Thaumastochloa sp; Alloteropsis semialata; annual herbs and legumes</td>
<td>Heteropogon triticeus; Sorghum plumosum; Coelorachis rottboelliioides; Eriachne sp.; Pandanus sp.; Spermacoce sp.; annual herbs</td>
<td>Heteropogon triticeus; Alloteropsis semialata; annual herbs and legumes</td>
<td>Philydrum lanuginosum; Eragrostis interrupta; Ectrosia leporina</td>
<td>Philydrum lanuginosum; Sporobolus virginicus; Eleocharis dulcis</td>
</tr>
</tbody>
</table>

Source: Gunness et al. (1987)
10.5.3 Acid Sulphate Soils

Based on previous geological and geotechnical studies (discussed in Section 10.4 above), together with the information from the Atlas of Australian Acid Sulphate Soils (ASRIS) a map has been developed to illustrate the areas of acid sulphate soil risk on site (Figure 10-5). When the proposed mining and Port infrastructure area are overlain on this figure, it can be observed that mining activities and most infrastructure activities will avoid areas of PASS risk.

Mining will not occur in ASS risk areas associated with tidal zones, as these areas do not typically contain economic bauxite.

At the Skardon River infrastructure area, some construction activities over water (for example, pile driving) may occur in areas of PASS. However, during these activities, PASS will remain below water level and therefore not oxidise and generate acid. Further information on the ASS risk in the estuarine environment of the Skardon River is provided in Chapter 17 – Coastal Processes.

The presence Melaleuca quinquenervia along Namaleta Creek indicates a natural presence of PASS. The only encounter with these soils in the Project will be in construction of the Namaleta Creek haul road crossing. At the Namaleta Creek crossing construction may result in small volumes of acid sulphate soil being exposed. These volumes will be very limited and can be managed using the Queensland Acid Sulphate Soil Technical Manual Soil Management Guidelines (Dear et al 2002) (refer to Section 10.6) and the prescribed mitigation outlined in Section 10.6.3. In addition, disturbance has already occurred in this area from the construction of the existing crossing.

Based on the geological data and site investigations, there is a very low risk of disturbing ASS in the proposed bauxite mining operation. None of the areas planned for bauxite mining are in acid sulphate soil zones and bauxite mining is unlikely to go below 5 m AHD anywhere. In low lying areas bauxite is either absent or becomes too thin to be economic. Bauxite ore deposits in low areas are less than a meter thick, while in plateau areas there can be up to 3 meters.

10.5.4 Acid Mine Drainage

The risk of acid mine drainage impacts from the excavation of subsoil or bauxite ore is negligible, based on the geology, weathering process and chemistry described in Section 10.4.3 above.

10.5.5 Erosion and Sediment Transport

An Erosion and Sediment Control Plan (ESCP) for the management of runoff from disturbed areas is described in Chapter 12 – it will be developed and implemented prior to commencement of mining activities and will manage erosion and stability issues and impacts to waterways. This will be complemented by water management measures described in the water management plan (refer Chapter 6) to limit the release of sediment affected water from active mining areas to the receiving environment.

10.6 Management Measures

10.6.1 Final Landform Design

Final landform design is described in Chapter 7. Landform will be similar to pre-mining conditions as pits will be backfilled with subsoil and topsoil.
10.6.2 Soil Management

Methods used for stripping topsoil and subsoil as bauxite overburden, as well as placement on the mine floor affect preservation of soil quality/health (nutrients and soil organisms). Stripping-to-floor and maintaining the topsoil-subsoil-profile, minimizes the loss of soil quality. Compaction resulting from handling of moist soil and stockpiling topsoil for extended periods, especially over a wet season, greatly reduces soil quality. This Project will adopt the following soil handling processes:

- All soil handling operations will be conducted on dry soil during the dry season to avoid soil compaction.
- Minimize or avoid stockpiling through the mine planning process.
- Topsoil and subsoil will be separated in stockpiling.
- Storage in stockpiles beyond the following wet season will be avoided as far as possible.
- Scrapers will be used for stripping and placement of topsoil and subsoil.
- Topsoil from subsoil will be separated in mine stripping, unless the thickness of the two combined is less than 30 cm.

As far as practicable, topsoil and subsoil will be placed on the mine-floor in the same thickness as stripped, parallel to mine floor and in the correct soil profile sequence. Where the combined thickness of topsoil and subsoil is less than 30 cm, the soil will be stripped and placed (or stockpiled) as mixed substrate.

A Soils Management Plan, based on the information provided in this section, will be developed prior to Project operations and will cover all aspects of the stripping, handling, transfer and placement of soils.

10.6.2.1 Timing

Mining activities not occur during the wet season – approximately 3 months from January to March. To minimise impact of mining on soil quality and maximise vegetation regeneration success, clearing, stripping, mining, soil placement and revegetation will be conducted as far as practicable on each mining area within one dry season. Mined areas will be prepared and sown with native vegetation seed in October and November of each year of operation. Avoidance of compacting moist soil is a priority, thus soil will be worked in the late dry season before December, when storms can set in. Soil health will be considered at all stages – also realising the greenhouse value of preserving or increasing soil carbon.

10.6.2.2 Soil Stockpiles

When stockpiling of soil is necessary, such as at the commencement of operations in a new area (pit), stockpiles will be created in non-inundated areas of the pit. The height of the stockpile will be limited to 4 m. If the stockpile is to remain beyond one dry season, it will be sown with native grass and legumes to maintain soil health, prevent erosion and prevent weed infestation. Inventories will be kept for long-term stockpiles. Stockpiles will be located within mining areas, where any sediment will be contained, and constructed with a shallow gradient to prevent erosion. Therefore, any stockpiles that remain during the wet season will not pose a risk of releasing sediment to undisturbed areas.

10.6.2.3 Soil Handling

Bauxite mining areas are prepared for re-vegetation in the mining process of strip-to-floor and deep ripping. On opening a new mining area topsoil and subsoil is stripped from the first few hectares by scrapers and placed in separate holding stockpiles. Subsequently either of the following strip-to-floor processes will be used, though the first method is preferred.

1. Twin powered scrapers work in pairs, connected together by a bail arm on the front as well as push pad on the front (Figure 10-7). The rear scraper is loaded first, stripping topsoil with the
help of the front scraper pulling. As the stripping progresses down the pit they leave a tail of sub-soil. Then on a second run, the front scraper picks up the long tail of sub-soil with the rear scraper pushing. The pair then dump their loads on mined floor, the front scraper dumping sub-soil first and the back scraper dumping its load immediately of top-soil on top, i.e. in the same profile sequence as the natural soil.

2. Operating individually, one or more scrapers strip topsoil and place on a temporary stockpile. Either scrapers or loaders and trucks strip the subsoil and immediately place on open mine floor. Scrapers then take the topsoil from the holding pile and place over the subsoil.

The ironstone floor is deep ripped through the placed soil. Deep ripping cannot be conducted prior to soil placement due to it creating too rough a surface for earth moving machinery to operate. Where both topsoil and subsoil have been stockpiled, due to non-availability of open mine floor at time of stripping, the soil is placed on the mine floor by scrapers in the correct sequence.

![Twin Powered Scrapers Connected in Push and Pull Mode](image)

**Figure 10-7** Twin Powered Scrapers Connected in Push and Pull Mode

### 10.6.2.4 Soils Testing

Analysis of post mining soils in Weipa, along with fertilizer response trials, indicated deficiencies in nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), sulphur (S), copper (Cu), zinc (Zn) and molybdenum (Mo), with P identified as the most limiting to plant growth (Lawrie 1985, Schwenke 1992 and Mulligan 1996).

On the proposed mining areas, operational soil testing will be conducted prior to vegetation clearing and post revegetation in each area of bauxite mining. The preferred method is Albrecht and total nutrient methods for analysis. This testing includes assessment of levels of major nutrient elements; calcium to magnesium ratio (Ca:Mg); cation exchange capacity; organic matter (OM) and carbon to nitrogen ratio (C:N). Environmental Analysis Laboratory (EAL) at Southern Cross University is currently the closest reliable provider of this service.

As an example of this soil testing, Chapter 7 provides results of samples taken on three sites at Skardon River, each having different soil texture and colour. Each sample was collected by using a handheld stainless steel 100 mm core drill to randomly collect 25-30 samples within a radius of 40 m of a GPS
point, mixing in a clean bucket and taking one sample for analysis. Soil testing, post mining and revegetation, will reveal changes in carbon and nutrient levels from pre-mining.

Should post-mining soil tests indicate decline in levels of key macro and trace minerals found in pre-mining soil tests, minerals may be applied. It is expected with strip-to-floor mining that soil carbon levels will not drop significantly and will recover with revegetation.

10.6.3 Acid Sulphate Soils

There are anticipated to be only limited volumes of PASS disturbed in the vicinity of the Namaleta Creek crossing and the wharf construction at the Port of Skardon River. Detection and management of PASS at the Port are is described in Chapter 17, but follows the measures described below.

The area and volume of ASS that may be disturbed by the Namaleta Creek crossing will only be known once the final details regarding the crossing design, construction methodology are decided. Any ASS will be managed (test and treat the soils) in accordance with the detailed methods outlined in the Queensland Acid Sulphate Soil Technical Manual (Dear et al 2002).

Gulf Alumina has a procedure for early detection and treatment of acid sulphate soil, developed as a consequence of ASS investigations for the kaolin mine.

Any ASS investigations will be undertaken in accordance with the Guidelines for Sampling and Analysis of Lowland Acid Sulfate Soils (ASS) in Queensland (QASSIT Guidelines) (QASSIT, 1998).

10.6.3.1 Procedure for Early Detection and Treatment of Acid Sulphate Soil

Construction excavation below 5 meters AHD can be at risk of disturbing acid sulphate soil. A risk assessment will be conducted on the likelihood of encountering any PASS or ASS for any activities within 5 m AHD. If a risk of PASS is suspected, a survey of the area to be excavated will be conducted, including vegetation and soils analysis and testing drill samples (in accordance QASSIT Guidelines). Drill samples for the area will be analysed and field sampling undertaken to map PASS using either a mobile auger rig or hand auger. Adjacent surface and groundwater will be assessed to gain an understanding of the environmental values to be protected. A result indicating PASS or ASS from testing and analysis requires:

- mapping the area of PASS or ASS identified by drill sampling
- redesign of excavation works to avoid disturbing the suspect material
- additional testing and specialist advice from a soil/environmental scientist or equivalent with experience in the management of ASS
- earthworks will not commence until best practice management strategies have been determined.

The only place ASS has previously identified on the Project area associated with kaolin mine activities near Namaleta Creek, as explained above. The following treatment procedure was developed from this experience, and would be implemented during the Project should ASS be encountered.

10.6.3.2 Treatment of Excavated ASS

To prevent continuing exposure to oxidation and acidification of ASS layers they will be treated and covered according to QASSIT recommendations and similar to successful remediation conducted during the 2004 kaolin mining campaign.

- Exposed ASS layers will be covered with a layer of kaolin clay excavated from the existing tailings dam, kaolin from the adjacent product pile, or fluvial clay overburden providing an impermeable clay cover. Lime will be applied during the spreading of the clay material to raise pH.
Further treatment with lime can be conducted if necessary over a few days, or at least until a permanent cover is placed.

- The treated ASS will be covered with at least 0.5 m of inert waste or clay and battered to a stable slope of no more than 45 degrees.
- The fill will be covered with an impermeable clay layer (claystone overburden), which will extend over the entire area.

10.6.3.3 ASS Treatment Pad

An ASS treatment pad is not expected to be required for the Project activities within and near Namaleta Creek. If required, excavated ASS can be placed on a bunded pad, constructed in the decommissioned wet plant tailings dam area and treated as follows:

1. The treatment pad will be created with a layer of kaolin clay excavated from the existing tailings dam, kaolin from the adjacent product pile, or fluvial clay overburden.
2. The ASS will be spread on the pad around 30 cm thick.
3. Lime will be spread over the surface (using a fertiliser spreader) at a rate estimated from the sampling and analysis in accordance with QASSIT Guidelines.
4. Steps 2 and 3 will be repeated until all the acid sulphate soil that needs to be treated is placed on the treatment pad.
5. After a few days, the soil will be tested to find it neutralisation has been achieved, if not, the soil will be reworked with further applications of lime.
6. After neutralisation, the soil can be removed for deep backfill in mine pits or soil in rehabilitation areas, subject to approval by QASSIT.

10.6.3.4 Namaleta Creek Crossing

Given the presence of Melaleuca quinquenervia along Namaleta Creek and indications of ASS affected water in dry season pig wallows, precautions will be taken to prevent exposure of ASS in construction of the haul road crossing. The following steps will be conducted in construction of the Namaleta Creek haulroad crossing:

- Construction will be in the late dry season when Namaleta Creek is dry and groundwater level at its lowest.
- Exposed ASS layers will be covered with a layer of kaolin clay excavated from the existing tailings dam, kaolin from the adjacent product pile, or fluvial clay overburden providing an impermeable clay cover. Lime will be applied during the spreading of the clay material to raise pH.
- The core of the crossing will be constructed with claystone overburden, providing a very thick impermeable clay cover.

10.6.4 Acid Mine Drainage

There will be no material on site that has the potential for acid mine drainage, therefore a specific management plan for this aspect is not required.

10.7 Risk Assessment

A risk assessment assessing the likelihood and significance of impacts to topography and soils from the Project is provided in Table 10-3. The risk assessment considers mitigated risk; that is, the impact from the Project with the implementation of management measures. The risks to topography and soils are low to medium.
Table 10-3  Risk Assessment and Management Measures for Impacts to Topography and Soils

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Topography</td>
<td>Refer Section 10.5.1</td>
<td>Refer Section 10.6.1</td>
<td>Likely</td>
<td>Minor</td>
<td>Medium</td>
</tr>
<tr>
<td>Other mineral resources and quarry material</td>
<td>Refer Section 10.4.4</td>
<td>None proposed</td>
<td>Rare</td>
<td>Minor</td>
<td>Low</td>
</tr>
<tr>
<td>Soil suitability for use in rehabilitation</td>
<td>Refer Section 10.5.2</td>
<td>Refer Section 10.6.2</td>
<td>Unlikely</td>
<td>Minor</td>
<td>Low</td>
</tr>
<tr>
<td>Water and land potentially affected by ASS</td>
<td>ASS exposed and not managed. Refer Section 10.5.3</td>
<td>Refer Section 10.6.3</td>
<td>Unlikely</td>
<td>Minor</td>
<td>Low</td>
</tr>
<tr>
<td>Water and land potentially affected by AMD</td>
<td>Refer Section 10.5.4</td>
<td>Refer Section 10.6.4</td>
<td>Rare</td>
<td>Minor</td>
<td>Low</td>
</tr>
</tbody>
</table>

10.8 Conclusion

Existing geological, soils and landform data for the Project was derived from publically available data, historical reporting and field investigations. The Project area is close to the coast, generally low lying and flat with bauxite deposits located at the higher elevations of local catchments.

The geology of the Project area comprises the Rolling Downs Group, (Mesozoic clays of marine origin) below the Bulimba Formation, (Tertiary sands and clayey sands), below the surface lying Valley Fill Deposits, (Pleistocene and Quaternary sands, silty sands and clays). The geology that sub-crops across the Project area is generally the Tertiary age Bulimba Formation which is formed by deposits from rivers and streams. The sands and clayey sands of the Bulimba Formation are deeply weathered and host the bauxite resource. Formation of the bauxite deposits is a result of the weathering process known as lateritisation that leads to the oxidation and dissolution of reactive components of the rock matrix and the oxidation of any mineral sulphides.

The Project is unlikely to lead to the sterilisation of other mineral resources and quarry resources.

Holocene age sediments have also been identified within and directly adjacent to Namaleta Creek. These sediments contain soft sulphidic estuarine muds and sands. There will be no Project activities, other than the crossing of Namaleta Creek, within the Holocene age sediments.

The soil of the bauxite plateau is predominantly Red Kandosol soil type which is underlain by ironstone. These soils are well drained and leached, having low moisture holding capacity, low organic content and mineral deficiencies. They are of neutral to moderate acidity (pH 5-7). The Kandosol soil types have low potential to develop accelerated erosion when cleared of vegetation, the predominantly sandy surface
soils, together with the low slopes on the bauxite plateau, facilitate infiltration and reduce the rate of runoff. Drop-off-slope areas, particularly near drainage lines have a higher erosion potential and will be avoided in mining.

An ESCP for the management of runoff from disturbed areas will be developed and implemented prior to commencement of mining activities. This will be complemented by water management measures to limit the release of sediment affected water from active mining areas.

Topsoil and subsoil will generally be stripped in advance of mining and will be placed immediately on other mining areas to be rehabilitated. Mined areas, once backfilled, will form shallow depressions in the landscape. Soil handling and management measures are proposed to maintain soil quality for rehabilitation. The removal of the bauxite layer is expected to result in wet season inundation of some mine areas, thereby altering the suite of native vegetation within rehabilitated areas compared to pre-disturbance conditions.

The deep weathering and oxidation (as part of lateritisation) process has resulted in the oxidation of any sulphide minerals associated with the bauxite deposits and is therefore expected to present a very low risk of acid mine drainage resulting from the excavation of the bauxite. There will be no material on site that has the potential for acid mine drainage.

Regional Australian Atlas of Acid Sulphate Soils mapping indicated areas of ‘high’ PASS risk, generally located adjacent to Skardon River or close to Namaleta Creek. An acid sulphate soil investigation was undertaken in the vicinity of Namaleta Creek in 2004 to identify whether sediments were PASS. The investigation identified that Holocene age sediments associated with the Namaleta Creek channel were PASS. Geological investigations in the Port infrastructure area in 1994 identified that the geological formations are not considered to be acid sulphate soil risk material. ASS investigations were also undertaken for sediments within the Skardon River.

None of the areas planned for bauxite mining are in acid sulphate soil zones and bauxite mining is unlikely to go below 5 m AHD. In low lying areas bauxite is either absent or becomes too thin to be economic. At the Skardon River infrastructure area, some construction activities over water (i.e. pile driving) may occur in areas of PASS. However, during these activities, PASS will remain below water level and therefore not oxidise and generate acid. At the Namaleta Creek crossing construction may result in small volumes of acid sulphate soil being exposed.

Where there is a risk of PASS or ASS, investigations will be undertaken and any identified ASS managed in accordance with the Queensland Acid Sulphate Soil Technical Manual Soil Management Guidelines. Gulf Alumina developed a procedure for early detection and treatment of ASS and an ASS Management Plan will be prepared if required.

With the implementation of proposed mitigation measures, the risk of impacts to topography is medium, the risk of impacts to soil suitability is low, and the risk of impacts from exposure of ASS or from AMD is low.