9 Ground conditions

9.1 Introduction

The Cairns area has a fascinating earth history with landforming processes that span 300 million years and several ice ages. Early events are responsible for the basic geology, but geomorphological processes as recent as the last 4,000 years have shaped the land as it is currently known. In particular, sea levels were some 1,000mm higher than at present as recently as 5,500 years ago (Nott 2002), inundating much of the area between The Esplanade and the foothills at Manunda. This has left a legacy in terms of landform and soils.

9.2 Methodology

This chapter is based on a desktop analysis of available information. An overview only is provided, with material of a general nature being selected in order to provide an appreciation of the landforms that are currently experienced.

9.3 Analysis

9.3.1 Topography

Topography in the study area is generally flat and low-lying. The Cairns Transit Network corridor alignment is generally around 10m in elevation north of the city centre and 20m to the south. Exceptions are:

- the climb from Freshwater Creek through Whites Gap, Kanimbla, where the existing Cairns Western Arterial Road (CWAR) rises to approximately 50m above sea level (Section W2)
- from Whites Gap east along Reservoir Road (land falls from 50m to 10m over this length (also Section W2).

Topography can be expected to pose little constraint on grades for the Cairns Transit Network.

Red Hill (Section S3) is a local topographic constraint and restricts the land available for the transport corridor. Planning associated with the Cairns Bruce Highway Upgrade is examining this area.

Section W1 (Lake Street to Reservoir Road) traverses a low lying area in the vicinity of the Cairns Central Swamp. This is a small remnant of what was once an extensive wetland that ran south to Trinity Inlet and north and east through what is now Centenary Lakes to Cairns Bay via Saltwater Creek. The southern part of Cairns Central Swamp (towards Mulgrave Road from the Cairns Transit Network alignment) is very low and it floods significant areas of adjacent lands during some high tide events.

9.3.2 Geomorphology

The principal landforms of the study area are the:
• rim of forested mountains that dominate the Cairns area and give it much of its character
• lower slopes of the old mountain ranges which have largely been historically developed first for agriculture and more recently for housing
• narrow coastal plain east of the Captain Cook Highway to the north of the Barron river comprising Cairns’ northern beaches
• alluvial plains of the Barron river delta including the northern beaches of Cairns, the Freshwater Valley, and east of the Bruce Highway in the Cairns/Gordonvale corridor
• old sand ridges and intervening swales that characterise the city centre and Portsmith areas
• low-lying land in the Manunda area that was once an extensive wetland and is now largely in-filled, with the exception of the remnant Cairns Central Swamp
• mangrove fringe bordering Trinity Inlet in the south and the network of small coastal streams that separate the various townships of the northern beaches (Marlin Coast).

The main features of this landscape are expanded upon below:

• The heavily forested Macalister Range and its companion ranges the Whitfield Range and Islay Hills that run largely south to north and frame the western part of the study area. Principal peaks are (north to south) Saddle Mountain, Mount Whitfield, Mooroobool Peak, White Rock Peak/Mount Sheridan and Mount Peter. The Kuranda Range Road section of the Kennedy Highway runs to the west from Smithfield, traversing the eastern escarpment before reaching the elevated Atherton Tablelands.

• The narrow coastal plain east of the Captain Cook Highway to the north of the Barron River comprising Cairns’ northern beaches. These beaches are characterised by a series of small coastal streams that have served to isolate each of the beach settlements from one another. This landform has significantly influenced early settlement patterns and continues to do so.

• The Barron River delta consisting of the Barron River itself and its major distributary, Thomatis Creek. The delta is regularly flooded, particularly when large amounts of rain fall in its extensive inland catchment. The Captain Cook Highway traverses the floodplain and is often inundated. Flooding constraints have so far limited residential development in the delta and sugar cane largely prevails.

• The Freshwater Valley that flows into the Barron upstream of the Cairns Western Arterial Road. Lake Morris/Copperlode Dam is located at the headwaters of Freshwater Creek and supplies much of the water for Cairns city. The dam also regulates floods to some extent. The land is slightly higher along Cairns Western Arterial Road than the Captain Cook Highway, affording a higher immunity to flooding.

• The Cairns plain south of the Barron River is a low-lying alluvial plain of late Holocene age, characterised by roughly parallel systems of dunes and swales. Much of this underlying formation has been altered by urbanisation but some remnants remain in the
form of the Cairns Central Swamp and the dunes that underlie the Esplanade and the streets parallel to it.

- City centre and Manunda. The 1,000mm sea level drop that occurred early in the Holocene (approximately 5,500 years ago) left a network of sand ridges (cheniers) and intervening depressions (swales) on the exposed beach edge. These sand ridges now support the north-south parallel road network of the city centre and lie under much of the Portsmith area. Further west, the low-lying areas of Manunda and Manoora were once part of an extensive wetland that connected south to Trinity Inlet via the Fearnley Street drain and north and east through Centenary Lakes and to Cairns Bay at the airport via Saltwater Creek. The high point in this system is where Anderson Street now lies. Drainage modifications and in particular the installation of tide gates initially favoured the formation of freshwater communities in the southern part of the Cairns Central Swamp but over the past 30 years the removal of the gates has led to the death of the melaleuca forest and its replacement with mangroves.

- Trinity Inlet. South-east of the city lies Trinity Inlet which is the old mouth of the Mulgrave River, abandoned when differential sedimentation associated with the falling sea level of the last ice age diverted the river to its current mouth at Russell Heads. Trinity Inlet is fringed by largely intact heritage listed wetlands and is characterised by the large Admiralty Island that splits the Inlet into two streams. Trinity Inlet has been a traditional barrier to road transport and urban settlement and the lands to the east (the foothills and slopes of the Murray Prior and Malbon Thompson Range and the Yarrabah peninsular) are effectively cut off from the city.

- Southern corridor. South of the city, the study area follows the narrow coastal plain, with the Bruce Highway lying roughly at the base of the foothills. Most of the urban development is to the west on the colluvial slopes while land to the east is comprised of largely undeveloped alluvial soils with some remnant vegetation.

- Walsh’s Pyramid and Green Hill. These two remnants of past volcanism dominate the landscape and provide visual interest.

### 9.3.3 Geology

The geology of the study area can be simplified into three main units (Bureau of Mineral Resources, Geology and Geophysics 1964):

- the coastal plain, city and southern corridor west to the foothills and including Trinity Inlet consist of Quaternary alluvium with mainly recent beach sands (Qa) interspersed in places with old beach sands (Qr)

- the mountains of the Atherton Tablelands to the west and Murray Prior Range to the east consist of old (lower Permian) Mareeba granites (Pgm)

- lying between these two formations are the eroded hills consisting of the Barron River metamorphics of the middle Palaeozoic (Pzb).

More detailed descriptions can be based on maps produced in CairnsPlan (Cairns Regional Council 2003) and the 1:100,000 geological series (Willmott et al 1985).
9.3.4 Soils

9.3.4.1 Overview

Soils mapping at a scale of 1:50,000 has been produced by the Department of Primary Industries (Murtha et al 1996). This mapping shows that the study area traverses predominantly alluvial soils in the Barron River Delta and Freshwater Creek corridor; alluvial soils formed on beach ridges and poorly drained alluviums in the area north of the Barron River through to Earlville; and predominantly colluvial soils of metamorphic origin elsewhere. Further details are provided in Table 9.1 below:

Table 9.1: Major soils associations

<table>
<thead>
<tr>
<th>Section</th>
<th>General location</th>
<th>Details</th>
<th>Planning issues</th>
</tr>
</thead>
<tbody>
<tr>
<td>N4 and, N3</td>
<td>Palm Cove to Smithfield</td>
<td>Typically sandy colluvial soils of metamorphic origin, with the main association being the <em>Clifton</em> series. Other minor associations include more clayey deposits (<em>Buchan</em>) and some beach ridges</td>
<td>No major issues</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Small areas of swampy ground lie east of the Captain Cook Highway and these could present some foundation problems and possibly acid sulphate soils in more low-lying sections</td>
</tr>
<tr>
<td>Part of N2 and</td>
<td>Smithfield to the Barron River via the Captain Cook Highway and CWAR</td>
<td>Well drained alluvial soils of the Barron River delta, principally of the Liverpool series. Mangrove soils exist at creek and river crossings</td>
<td>Soils are flood-prone and are likely to have low subgrade strengths in places. Possibly acid sulphate soil issues in more low-lying sections</td>
</tr>
<tr>
<td>part of, W2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Part of N2, N1 and</td>
<td>Barron River to McCoome Street via the Captain Cook Highway and Bruce Highway</td>
<td>Alluvial soils formed on beach ridges (<em>Hull</em>) and poorly drained alluviums (<em>Holloways</em>)</td>
<td>No major issues</td>
</tr>
<tr>
<td>part of S1</td>
<td></td>
<td></td>
<td>Some settlement problems can be expected at the eastern extent of the study area towards Trinity Inlet</td>
</tr>
<tr>
<td>Part of S1, S2 and</td>
<td>McCoome Street to Woree via the Bruce Highway</td>
<td>Typically clayey soils of metamorphic origin (<em>Buchan</em>) Red Hill marks the eastern extent of the metamorphic Mission and Mountainous associations</td>
<td>No major issues</td>
</tr>
<tr>
<td>S3</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
## 9.3.4.2 Acid sulphate soils

According to CairnsPlan (Cairns Regional Council 2008), soils in a band approximately 6km from the coast can be regarded as having acid sulphate soil potential, especially in low-lying areas (i.e., below 2m Australian Height Datum (AHD)). Particular soil associations with recognised acid sulphate soil potential (see Murtha 1996) are organic soils that have formed in the lower parts of the area and include Mangrove, Nind, Needep, Bulguru and Hewitt. However, all soils of Holocene age can experience acid sulphate conditions and it is prudent to undertake specific investigations as part of impact assessment/design investigations.

Acid sulphate soils are not generally considered a major constraint to route selection although their presence does complicate the management of excavations and the design of concrete and steel structures in low areas. A management approach during construction is usually sufficient to avoid any significant environmental issue.

The following map (Figure 9.1) extracted from CairnsPlan shows the main areas of potential acid sulphate soil.
9.3.5 Geotechnical conditions

9.3.5.1 Hazards - Earthquakes

A strategic assessment of earthquake risk was undertaken by the Australian Government Survey Office (AGSO) (Granger et al 1999). This confirmed that whilst the earthquake hazard in Cairns is moderate by global standards, it is not negligible. Over the past 100 years there have been at least 11 significant earthquakes reported within 200 km of Cairns, the most damaging being the Richter magnitude 4.3 event of 1896. In many places of...
Australia, moderate to strong earthquakes of Richter magnitudes 5 to 6 make up about 90% of the total contribution to the overall earthquake hazard. The occurrence of such an earthquake close to Cairns would be a rare event. However, its impact could be great.

The report includes earthquake hazard zonation maps and notes that any earthquake of a magnitude likely to cause damage in Cairns will have an effect across all suburbs. The amount of damage, and consequently risk, will increase with the intensity of the event. The report also concludes that whilst all suburbs have some degree of exposure, structural damage is likely to be greater on the soft sediments of the coastal plains and riverine deltas, or the sands, silts and clays of the lower foot slopes. These sediments amplify earthquake shaking.

Mapping included in the report shows the distribution of suburbs according to their overall contribution to community vulnerability for earthquakes. Vulnerability is a combination of risk and consequence, and the distribution strongly reflects the development history of the city, with the areas of greatest significance being the original city area (Cairns Transit Network sections N1 and city centre), the original villages of Edmonton and Gordonvale to the south (S3 and S4) and the Yarrabah Aboriginal Community to the east.

### 9.3.5.2 Hazards - Landslides

The AGSO (Granger et al 1999) also assessed landslide risk. This reveals that for Cairns, landslide has been, and remains, a significant risk, as evidenced by events such as the massive Ellis Beach debris flows that buried 10 km of the Captain Cook Highway in 1951, and the frequent impact on road and rail links to Kuranda and elsewhere. Local DTMR experience shows that the Kuranda Range Road (DMR 2003) and Captain Cook Highway (Environment North 2007) are prone to landslides, with both roads (especially the Kuranda Range Road) being regularly closed during the wet season due to landslides (DMR 2003).

According to the AGSO, most landslides recorded in the Cairns area appear to be associated with disturbances of the natural surface by activities such as the construction of roads and the excavation of building sites. As development extends increasingly onto the hill slopes in areas such as the Freshwater valley, the risk of landslide impact will increase unless appropriate mitigation strategies and engineering design standards are applied. Experience over at least 70 years has demonstrated that flash flooding and/or debris flows in the Freshwater valley have the potential to severely dislocate the Cairns water supply.

Mapping included in the AGSO report shows the distribution of suburbs according to their overall contribution to community vulnerability for landslides. This mapping shows that for the Cairns Transit Network the highest risk areas are on the foothills of the Captain Cook Highway (N4) and along the Cairns Western Arterial Road (W2).

Local knowledge within the former Department of Main Roads (DMR 2003) reveals that the Kuranda Range Road and Captain Cook Highway regularly experience slips. These are as a result of:

- slumping or rotational failure in soil type material (this type of failure may generate a debris flow if the slope is long enough)
• rock falls (wedge, planar and toppling failures) caused by the unfavourable orientation of rock defects and the broken nature of the rock.

Almost all failures have a common trigger of either an intense rainfall event or an episode which causes saturation of the material in the slope.

9.3.5.3 General geotechnical conditions

It is beyond the scope of this report to describe geotechnical conditions in any detail. Much material is available from the many geotechnical investigations undertaken throughout the study area as part of studies for specific projects and developments. An appreciation of the likely conditions to be encountered can be obtained from the previous discussions on topography, landform, geology and soils.

The key geotechnical issues affecting the Cairns Transit Network route are likely to be:

• subgrade conditions – these can be expected to vary from soft unconsolidated marine sediments in the creek systems of the northern beaches and southern corridor to firm rock in the upper sections of the Cairns Western Arterial Road. It is likely that any new work in the Barron delta will encounter soft subgrades over more than just localised areas and may require special treatments such as lime stabilisation. Structures will most likely require pile foundations at all creek crossings
• acid sulphate soils can be expected to occur for excavations that disturb strata below about 2m AHD or perhaps higher
• any major excavations at Red Hill will need to be supported by slope stability assessments.

9.4 Opportunities and constraints

9.4.1 Opportunities

Route opportunities from a landform perspective (ie areas where there is a low probability of encountering topographic or ground constraints) include:

• flat and gently sloping land that dominates the study area and poses little constraint on grades
• existing roads, cuttings and embankments (providing that these are shown to be stable)
• land above about 5m AHD where flooding is not an issue and soft soils with potential acid sulphate properties are unlikely to occur
• land distant from steep slopes where slope stability could be an issue.

9.4.2 Constraints

Route constraints from a landform perspective (ie areas where there is a high probability of encountering topographic or ground constraints) include:

• new riparian areas of the Barron River, Freshwater Creek, Saltwater Creek (especially Airport Avenue) and Chinaman Creek where soft soils could be encountered (these pose foundation challenges)
• land below about 5m AHD where flooding may be an issue and soft soils with potential acid sulphate properties are likely to occur (in particular in the vicinity of Cairns Central Swamp (Section W1))

• land adjacent to steep slopes with impeded drainage and where slope stability could be an issue (in particular Red Hill, (S3) and the foothills of the Captain Cook Highway such as Aeroglen to Stratford (S2) and James Cook University to Reed Road (S3))

• Red Hill (Section S3) itself is a local topographic constraint and restricts the land available for the transport corridor

• areas with high vulnerability to earthquakes (ie the original city area (Cairns Transit Network Sections N1 and Cairns City) and the original villages of Edmonton and Gordonvale to the south (Sections S3 and S4)).

9.5 **Recommendations for further investigations**

Future detailed design and impact management of the Cairns Transit Network will require detailed geotechnical investigations. This will be associated with the design of pavements and structures (bridges and stations) and the identification of any special constraints, in particular acid sulphate soils and soft foundations.
9.6 References


Cairns Regional Council, 2008. CairnsPlan: Potential or Actual Acid Sulfate Soil Material (PASS or ASS). Figure Acid_Sulphate.WOR


Nott, J.F, 2002. The Urban Geology of Cairns, Queensland. Australia School of Tropical Environment Studies and Geography, Faculty of Science and Engineering, James Cook University