Northern Link

TECHNICAL REPORT NO. 2

GEOLOGY AND SOILS

- May 2008

Contents

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1. Topography, Geology & Soils

1.1 Description of Existing Environment

1.1.1 Topography

Elevations within the study corridor are up to 70m above the Australian Height Datum (AHD) on Musgrave Road and 50m on other ridge lines such as the Frederick Street – Birdwood Terrace intersection. In general the topography is undulating with several steep ridges radiating from Mt Coot-tha. The proposed portal areas are at elevations of approximately 20m for the Toowong portal and approximately 25m for the Kelvin Grove portal on the Inner City Bypass (ICB) (**Figures 1 and 2**).

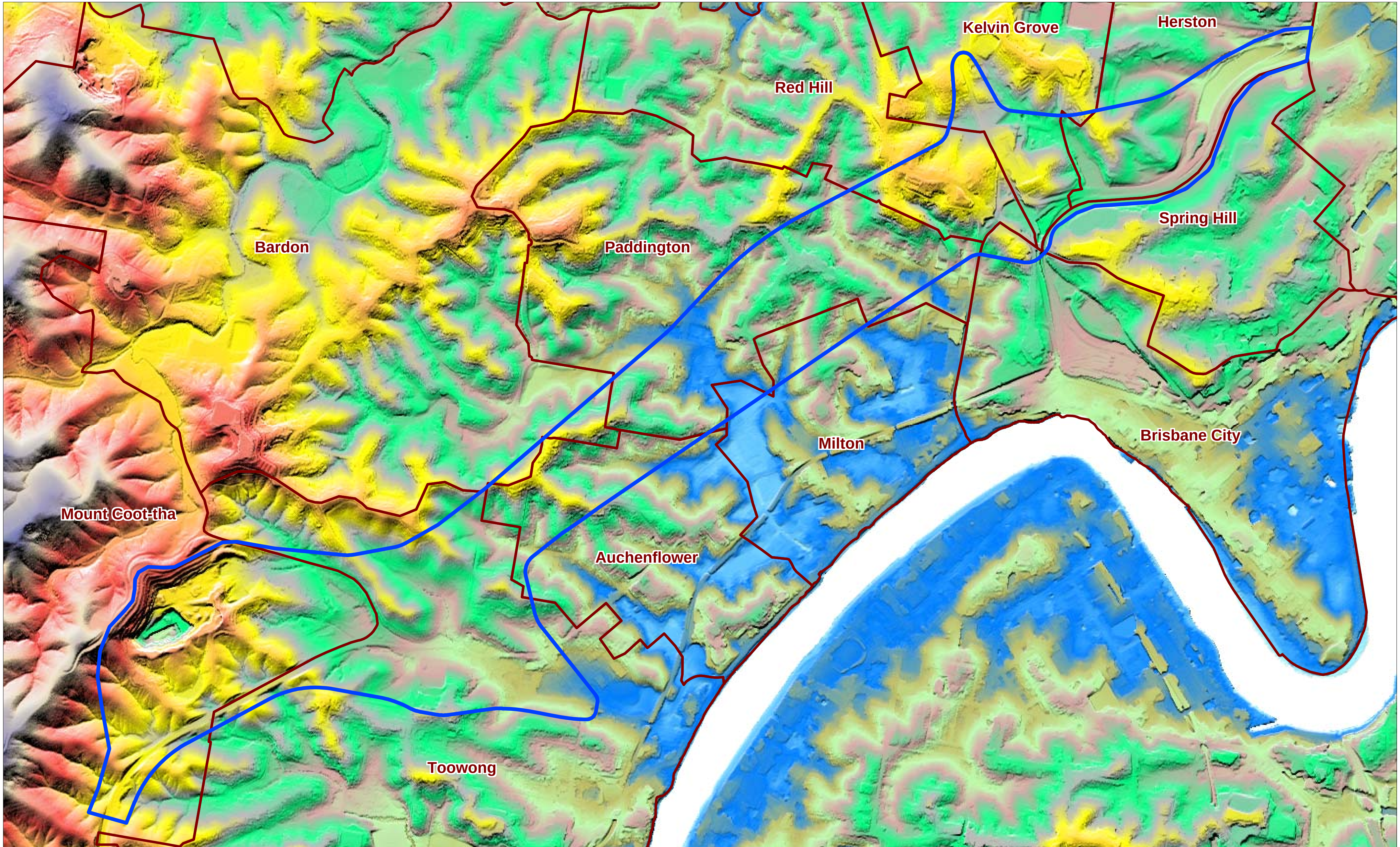
1.1.2 Geomorphology

Between Toowong and the Kelvin Grove – Herston area, the inner western suburbs of Brisbane, including the study corridor, are situated on undulating ground dissected by three relatively short drainage systems emptying into the Milton Reach of the Brisbane River along its left bank. Between the drainages are several steep ridge crests, most of which are now capped by suburban roads. The geomorphology of the area is dominated by the Mt Coot-tha massif in the west. Mt Coot-tha owes its elevation to the intrusion of the Enoggera Granite during the late Triassic. This intrusion has been uncovered by erosion at the northern end of Mt Coot-tha where the granite has been quarried at The Gap and Keperra. Although granite is not evident at the surface in the southern part of Mt Coot-tha it is very close to the surface as evidenced by the hornfels of the Mt Coot-tha Quarry which formed as a thermally metamorphosed aureole when the country rock was heated up and welded by the great heat of the molten granite cauldron before it cooled and crystallised. This application of excessive heat causing hardening of the rock above the granite intrusion made the Mt Coot-tha massif more resistant to weathering and thus it has retained its elevation. Over eons of weathering Mt Coot-tha has become the centre of a generally radial drainage system as the less resistant rocks further from the granite intrusion weathered more readily and their detritus was transported down streams and the river to the ocean.

The ridges of the inner western suburbs are the watersheds between the streams draining off the eastern side of Mt Coot-tha. These ridges may be traced by the roads on their crestlines which are from west to east:

- Swann Road, Stanley Terrace;
- Kensington Terrace, Sherwood Road, Dean Street and Elizabeth Street;
- Birdwood Terrace; and
- Given Terrace, Latrobe Terrace.

The underlying Bunya Phyllite generally forms poor soils and in many places road cuttings or other exposed excavations show the very thin soil cover characteristic of the study corridor. This generally thin soil cover accentuates the steepness of the relatively low ridges between drainages as significant rain events over geological time have removed much of the soil from the higher ground.



LEGEND

Study Area Corridor

Suburbs Boundary

00 20 30 50 75 100 150 200

Meters

0 500 1000

metres

Scale 1: 25,000 (A4)

N

NORTHERN LINK
ENVIRONMENTAL IMPACT STATEMENT

Figure 1

Topography

Northern Link

SKM Connell Wagner
JOINT VENTURE

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LEGEND

- Study Area Corridor
- Suburbs Boundary
- 10m Contours

0 500 1000
metres

Scale 1: 25,000 (A4)

N

NORTHERN LINK
ENVIRONMENTAL IMPACT STATEMENT

Figure 2

Contours (10m)

Northern Link

SKM Connell Wagner
JOINT VENTURE

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Sediment has accumulated along the lower sections of the drainage lines with most of the significant deposits of alluvium close to the Brisbane River. In the study corridor the only appreciable accumulation of alluvium is in the vicinity of the Mt Coot-tha Botanic Gardens near the Toowong portal. This is likely to be less than 10m deep.

Lowered sea levels during the Pleistocene ice ages rejuvenated erosional down-cutting by the Brisbane River and its tributaries. With subsequent rising sea levels, these channels were inundated to deposit the alluvium now filling the bottoms of drainages. The history of the Brisbane River is likely to have begun long before the Quarternary with indications the drainage pattern incised into the upper erosion surface during the Tertiary (about 20 million years ago) and with the pattern of drainage being defined to some extent by block faulting tectonic events that took place in the Permian and/or Triassic. From extensive geomorphological research along the southeastern Queensland coastline, Cranfield et al (1976) considered the present sealevel to be within 3m of the highest known sealevel of the area. The sediments filling the tributary drainages of the Brisbane area are not so well known that their mode of deposition can be clearly defined. Marine sediments are known in the Bulimba area whereas extensive areas of sediments in the valley of Moggill Creek in Brookfield or in the valley of Cedar Creek at Ferny Grove and Upper Kedron are certainly deposited well above any marine influence as braided stream deposits in nonmarine conditions. Just how far the marine influence extended to deposit sediments in the tributary drainages of the Brisbane River is not certain. Indeed maps of the city show virtually all alluvial deposits as undifferentiated gravel, sand, silt, mud and clay without indicating whether they are laid down under marine or freshwater conditions. Moreover, the marine influence has extended up the river very dramatically since the arrival of European settlement in the 1800s. We know from the diaries of Tom Petrie that mangroves (good indicators of marine conditions) did not extend upstream of Breakfast Creek in 1859.Dredging of the river mouth for the shipping channel and later construction of Somerset Dam allowed far greater penetration of saltwater. There is no known evidence of marine influence (such as subfossil shells) in the Quarternary Alluvium along the small tributaries of the Brisbane River that drain the study corridor. The topography of the study corridor taken with the assertion that the present sea level is within 3 metres of its highest Cainozoic level suggests that none of the alluvium in the study corridor (especially in the vicinity of the portals) is likely to have been deposited under marine conditions. Indeed the Brisbane 1:100,000 Geological Sheet (1st ed.) 1986 shows the area of Quarternary Alluvium from the Brisbane River near Cribb Street north through Castlemaine Street and Suncorp Stadium across Given Terrace as land fill by man.

1.1.3 Geology

Surface geological mapping of the study corridor (**Figure 3**) has traditionally shown it to encompass two low grade metamorphic rock units, namely the Bunya Phyllite and the Neranleigh-Fernvale Beds. The Bunya Phyllite occupies the area from the western end of the study corridor as far east as approximately Musgrave Road at the Normanby Fiveways. Further east the study corridor has been mapped as including the Neranleigh-Fernvale Beds. Traditional mapping (Bryan & Jones (1954) invoked a major thrust, the Normanby Fault, along the line of separation of these two units and a succession of other thrust faults, further to the east to and beyond Hamilton, to account for the recurrence of the Bunya Phyllite within the area mapped as Neranleigh-Fernvale Beds. Holcombe (1978) accepted a line of lithological distinction in the vicinity of the so-called Normanby Fault but could not substantiate a tectonic fault zone. He inferred that the Bunya Phyllite and Neranleigh-Fernvale Beds comprised a single continuous succession of terrigenous rocks with the repetition of the Bunya Phyllite through the Neranleigh-Fernvale Beds due to facies differences and not due to structural dislocation. Holcombe (1978) identified the steepening of the S1 foliation and S2 structure in the area of the so-called Normanby Fault and provided possible structural cross sections that would explain such variation in attitude in a structural sense without necessarily invoking a major fault zone. Nevertheless two different lithological units can be recognised in the study corridor as follows.

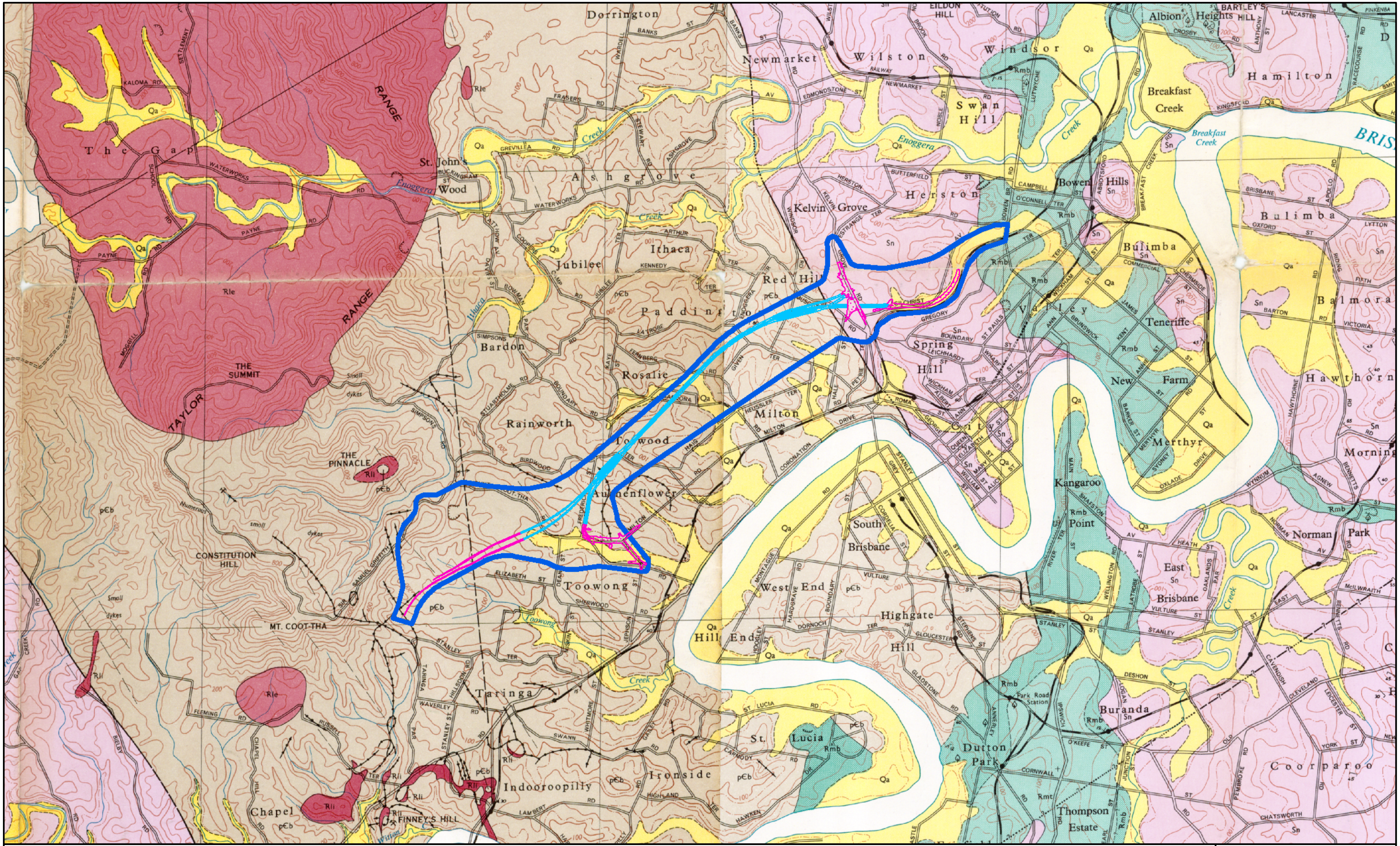
Bunya Phyllite

The formation consists of phyllite, minor arenites and basic volcanics regionally metamorphosed to greenschist grade. The rocks were originally probably marine mudstones and siltstones deposited during the Carboniferous or older Palaeozoic on the outer continental shelf, slope or abyssal sea floor. The phyllites are dark blue to black when fresh and consist principally of quartz, albite, muscovite and chlorite. Alternating micaceous and quartzose layers are present as are pervasive quartz veins. Layers of fine-grained basic metavolcanic and what may be altered dolerite sills are present, particularly in the north-east. These consist of generally strongly foliated actinolite schist with albite, actinolite and epidote and minor chlorite, sphene and stilpnomelane.

Mobilisation of silica is widespread throughout the unit. The phyllite is transacted by quartz veins which were subsequently contorted. The phyllite may be unveined but differentially altered to a fine-grained grey-black quartzite. Silicification is commonly associated with the basic intercalation in that adjacent phyllite is replaced by quartz.

Neranleigh-Fernvale Beds

This unit includes shale, chert, jasper, feldspathic and lithic arenite, conglomerate and basic volcanics. Typical arenites consist of sericite, chlorite, quartz and epidote with accessory zircon. Fine-grained, thinly bedded, grey shale and siltstone that occur throughout are commonly sheared and phyllitic. Commonly interbedded with shale and arenite is reddish chert but this may also be white, grey, black or green though only grey or white in highly recrystallised zones. The unit may be up to 7000m thick and overlies the Bunya Phyllite probably in a conformable relationship though this is not clearly seen anywhere. The much quoted thrust fault concealment of this boundary is discussed below.



LEGEND

- Study Area Corridor

Proposed Alignment

- Surface Work
- Tunnel Underground

Geological Seetings

- Alluvium
- Brisbane Tuff
- Enoggera Granite
- Neranleigh Fernvale
- Bunya phyllite

0 1,000 2,000
metres

Scale 1:50,000 (A4)

N

NORTHERN LINK
ENVIRONMENTAL IMPACT STATEMENT

Figure 3

Geology

Northern Link

SKM Connell Wagner JOINT VENTURE

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1.1.4 Faults and folds

The Normanby Fault was described by Bryan & Jones (1954) as "The most conspicuous and probably the most important of the other normal faults is the Normanby Fault which approximately follows the regional north-westerly strike for at least 12 miles from a point in Bracken Street Moorooka, where it is strongly developed and where an arresting fault breccia may be seen, to the city boundary near Bunyaville." A second normal fault, to the west, the Kenmore Fault, was also introduced by Bryan & Jones (1954) to separate Bunya Phyllites from the Neranleigh-Fernvale Beds on the western side of the Indooroopilly Antiform. Cranfield et al. (1976) quoted fieldwork in the D'Aguilar Range and extensive drilling by the Department of Main Roads in 1971 as being unable to produce evidence for the existence of either of these faults. However, they showed on their figures (Cranfield et al., 1976, plates 4 and 5), shear zones or thrust faults, respectively, along the boundaries between the Bunya Phyllite and Neranleigh-Fernvale Beds in much the same position as the normal faults introduced by Bryan & Jones (1954). Cranfield et al. (1976) considered the north-east to south-west cross-sectional structure through central Brisbane to have resulted from a single nappe structure overthrust from the north-east with subsequent erosion producing the present surface distribution of rock units.

Holcombe's (1978) detailed structural analysis of the Bunya Phyllite, across the same cross-section investigated by Bryan & Jones (1954), lead him to conclude that the structural and lithological boundaries between the Bunya Phyllite and Neranleigh-Fernvale Beds only coincided in one area studied, Red Hill. He found no evidence for the thrust faults postulated by Bryan & Jones (1954) and illustrated by Cranfield et al. (1976, pl. 5). He went on to consider the stratigraphic relationship of the Bunya Phyllite to be equivocal. It may underlie the Neranleigh-Fernvale sequence as generally accepted but there is a strong possibility that it is merely one thin unit within the general Neranleigh-Fernvale sequence. A large part of the outcrop area is on the sub-horizontal limb of a fold thus grossly exaggerating its outcrop width. That the Bunya Phyllite is an integral part of the Neranleigh-Fernvale sequence is strongly supported by a comparison of the phyllites from boreholes in that unit (eg: NL-2, NL-4, NL-5 and NL-6) with phyllites logged in several boreholes for the Airport Link project along Lutwyche Road (eg: APL1, APL13, APL15 and APL16). These phyllites, mapped as belonging to different lithological units and ascribed different grades of metamorphic deformation, are difficult to distinguish in the cores and even the degree of contortion of the thin quartz beds is often comparable. Cranfield et al. (1976) acknowledged that fine grained argillaceous shale and siltstone are widespread throughout the Neranleigh-Fernvale sequence and are commonly sheared to be phyllitic in places.

Thus although a surface lineament is discernable along the lithologically defined boundary between Bunya Phyllite and Neranleigh-Fernvale sequences in the vicinity of the line previously mapped as the Normanby Fault there is growing evidence to refute the contention that a major fault zone exists.

1.1.5 Rock Defects

A pervasive foliation is present throughout the Bunya Phyllite and the Neranleigh-Fernvale Beds and occurs to a lesser extent in the hornfels formed from the thermal metamorphism of the Bunya Phyllite. Foliation partings occur throughout these rocks and become more widely spaced with depth. Within the Neranleigh-Fernvale Beds, the foliation is fairly planar and generally dips at low to moderate angles in a mostly north-east direction. The Bunya Phyllite appears to have been subjected to more than one phase of deformation and consequently the foliation is wavy to contorted and varies frequently in dip and dip direction.

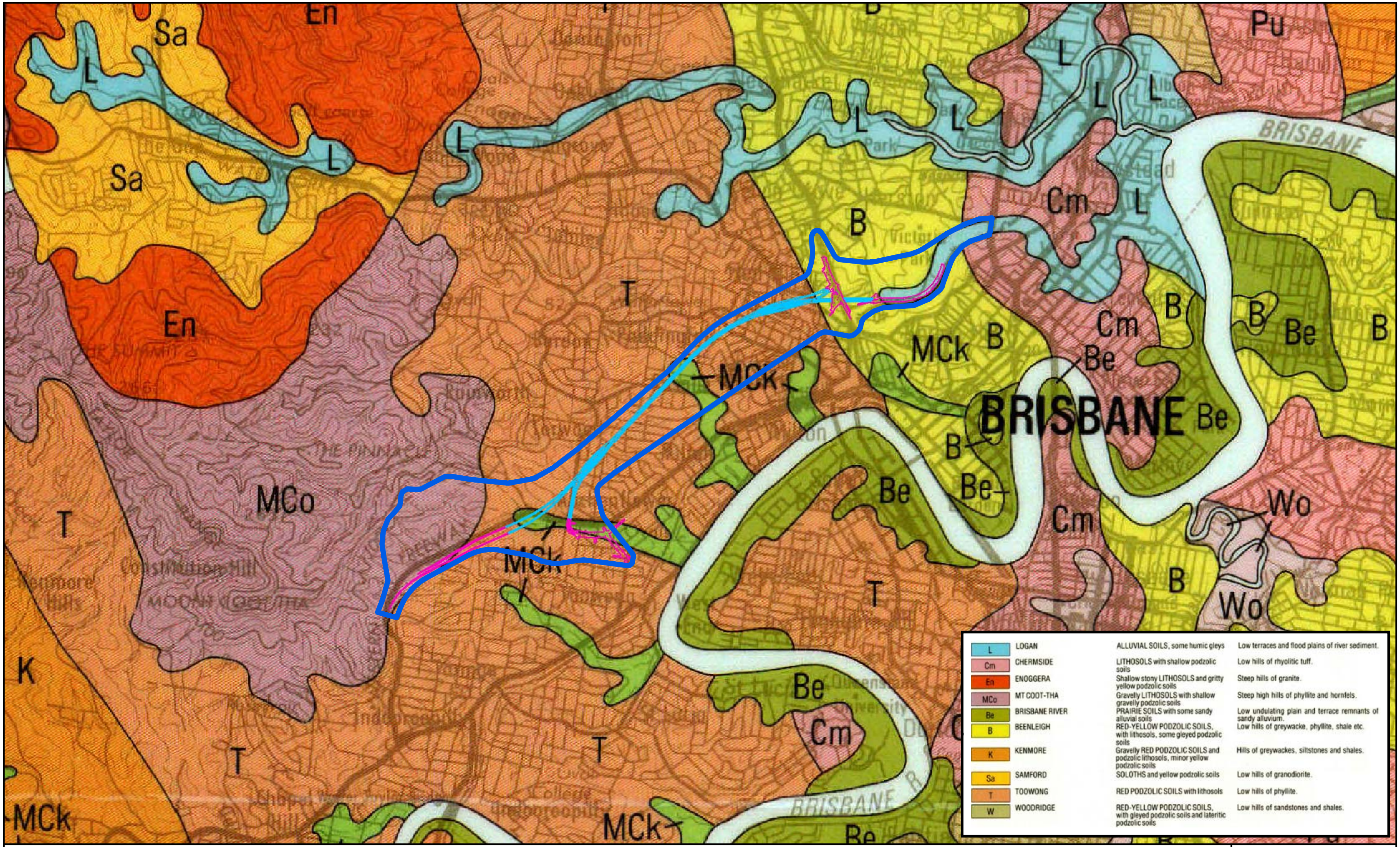
Joints within all of the rocks appear to belong mostly to two major moderate to high angle sets striking north-west to south-east and north-north-east to south-south west. Minor sets of indeterminate orientation are also present. As with the foliation partings, the spacing of the joints increases with depth. Specific details of the orientation and spacing of the rock defects would be available at the completion of the detailed geotechnical investigations.

1.1.6 Economic Minerals

An assessment of the potential for economically significant mineral, energy or extractive resources within the study corridor, based on review of the City of Brisbane Economic Geology Map, Sheet 3 and Sheet 4 (Department of Mines 1965) indicates no significant mineral, energy or extractive resources and no economically significant minerals have been noted in the core logs, recorded during the geotechnical investigations at the time of preparing this document. The Mount Coot-tha Quarry is an important extractive resource. Some 410,000 tonnes are removed from the quarry each year, principally to supply aggregate for asphalt and for concrete.

1.1.7 Soil types

The Soil Landscapes of Brisbane and South-eastern Environs 1:100,000 Map (Beckmann et al. 1987) illustrates the soil landscapes and dominant soil groups within the study corridor (**Figure 4**). Extending from Mt Coot-tha in the west to Herston in the east, the soil landscape and dominant soil groups are described in **Table 1** below.



LEGEND

Study Area Corridor

Proposed Alignment

Surface Work

Tunnel Underground

0 1,000 2,000

metres

Scale 1:50,000 (A4)

N

NORTHERN LINK
ENVIRONMENTAL IMPACT STATEMENT

Figure 4

Soil Types

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Table 1 Soils

Soil Landscape[1]	Dominant Soil Groups[1]	Landscape and Parent Rock[1]	Location within the Project Area
Mt Coot-tha (MCo)	Gravelly lithosols with shallow gravelly podzolic soils	Steep high hills of phyllite and hornfels	The western extent of the project area at the connection with the Western Freeway alignment and adjacent to the lower southern and south-eastern slopes of Mt Coot-tha
Toowong (T)	Red podzolic soils with lithosols	Low hills of phyllite	Extending east from the lower south-eastern slopes of Mt Coot-tha to immediately west of Kelvin Grove Road.
Beenleigh (B)	Red-yellow podzolic soils, with lithosols, some gleyed podzolic soils	Low hills of greywacke, phyllite, shale, etc.	Extending east from the vicinity of the Musgrave Road – Hale Street overpass to the south-eastern side of Victoria Park.
Moggill Creek (MCk)	Gleyed podzolic soils with minor prairie and alluvial soils	Creek flats of sandy and clayey alluvium	Narrow deposits of Moggill Creek soils occur in the study corridor (within the Toowong and Beenleigh soils) between Mt Coot-tha Road and Croydon Street, beneath Baroona Road and at the south-east end of Given Terrace. They are associated with topographical depressions, which act as surface drainage lines. Narrow deposits of these soils are also located immediately south of the project area in the vicinity of Moggill Road Miskin Street and Broseley Road in the west and Roma Street Parklands in the east.
Logan (L)	Alluvial soils, some humic gleys	Low terraces and flood plains of river sediment	A narrow deposit of Logan soil occurs in the vicinity of Victoria Park and the ICB alignment.

Table Note: 1 - Beckmann et al. (1987)

Within the Mt Coot-tha landscape, lithosols 20-40cm thick are dominant and occupy the crests and upper slopes, while gravelly red podzolic soils occur on the mid to lower slopes and are generally less than 50cm thick. Thicker bodies of parent material including accumulated colluvial material of deeper red and yellow podzolic soils dominate the lowerslopes (Beckmann et al. 1987).

Soils of the Toowong soil landscape are dominated by red podzolic soils with fine angular quartz and phyllite gravel in the A horizon and structured or moderately dense red heavy clay B horizons. Higher parts of the landscape tend to thin gravelly lithosols with a pale pinkish subsurface horizon mingled with shallow red podzolic soils. Moister lower slopes within this soil landscape tend to indicate deep, mottled red-yellow podzolic soils with a coarsely mottled yellow-brown and light grey stiff plastic to friable clay horizon in the deep subsoil. Where alluvial material has accumulated on the drainage floors, minor areas of gleyed podzolic soils and humic gleys are recorded (Beckmann et al. 1987).

Within the Beenleigh soil landscape red-yellow podzolic soils are dominant, with red profiles more common on hill crests and on some upper slopes and the mottled or yellow profiles on lower slopes. Lithosols with loam textures are common on many hill crests and on some of the steeper slopes. Most of these soils are hard setting at the surface (Beckmann et al. 1987).

Soils of the Moggill Creek soil landscape have a tendency to be poorly drained and are dominated by gleyed podzolic soils with sandy to loamy surface horizons and mottled grey and yellow-brown sandy clay or heavier subsoils (Beckmann et al. 1987).

Within the Logan soil landscape alluvial and prairie soils tend to occupy stream banks. With gleyed clays and humic clays on lower parts of plains. Gleyed clays tend to be more common on flood plains high upstream (Beckmann et al. 1987).

1.1.8 Acid Sulfate Soils

Acid Sulfate Soils (ASS) are a characteristic feature of lowland coastal environments in Queensland, particularly where landform elevations are below 5m AHD. ASS contain iron sulfides generally in the form of pyritic material that is a product of the natural interaction between iron-rich organic matter and sulfate-rich seawater present in anaerobic low energy estuarine environments. Undisturbed, these soils are generally present in an anaerobic state within the subsurface profile (below the water table) of Holocene marine muds and sands in the form of Potential Acid Sulfate Soils (PASS). Actual Acid Sulfate Soils (AASS) are the oxidised (disturbed) form, which may occur as a result of natural or anthropogenic disturbance from changes in groundwater levels and/or exposure to oxygen (Powell & Ahern, 1999).

A review of the Acid Sulfate Soils Tweed Heads to Redcliffe Map 1 (NRW 2002) illustrated that the project area has been mapped as *NA – Land not assessed for ASS*. Mapping of potential for ASS occurrence as compiled by the Brisbane City Council is presented in **Figure 5.**

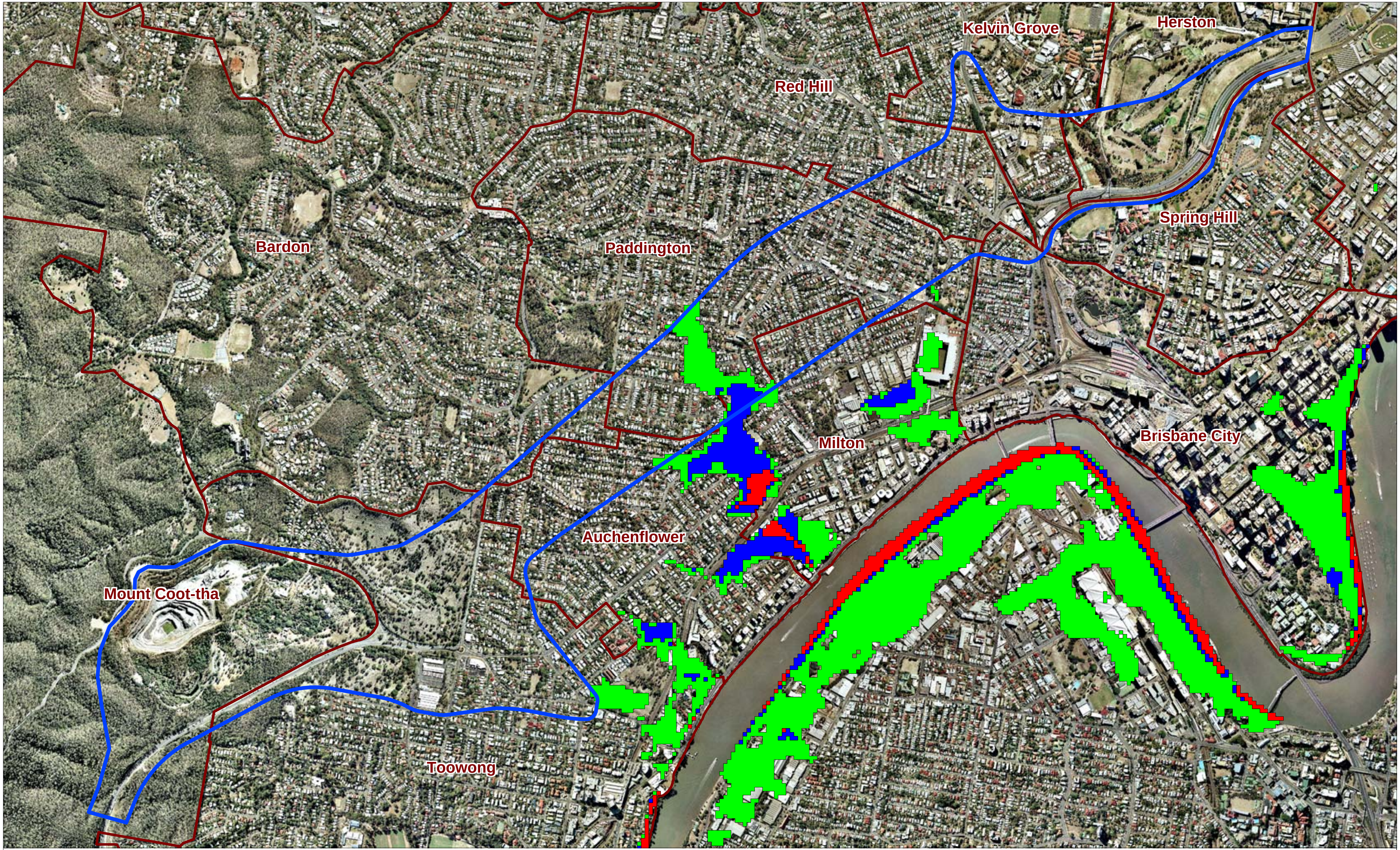
Digital Elevation Model (Figure 1) and Acid Sulfate Soils mapping (Figure 5) have been reviewed in conjunction with topographical and geological mapping information and small areas with a low risk of ASS have been identified within or closely adjacent to the study corridor:

- In the vicinity of Toowong Memorial Park on Sylvan Road
- The eastern end of Baroona Road
- The south-east end of Given Terrace in Neal Macrossan Park.

However, none of these areas is likely to be excavated or otherwise disturbed for Project construction.

ASS in an undisturbed condition may have a pH of neutral or slightly alkaline value and no visual appearances indicating its acidic potential. However, when exposed to air whether by direct excavation or indirectly through changes to the surrounding water table, pyritic material inherent in the soil matrix is oxidised by sulfur-oxidising bacteria leading to the formation of sulfuric acid. Following rainfall, sulfuric acid associated with soil oxidation can then be released into surface runoff and receiving waters and mobilised in groundwater, resulting in mortality of aquatic flora and fauna and the deterioration of ecosystem health as well as impacts to structures and existing infrastructure.

There is also the potential for the acidic environment created within the soil and associated receiving waters (surface and groundwater) to mobilise metal contaminants (especially aluminium and iron) if present. These metals become soluble under acidic conditions and are readily leached from the soil profile by surface runoff and groundwater flows. Therefore, runoff or drainage water from uncontrolled or inadequately managed disturbed ASS has the potential to significantly impact flora, fauna and ecosystem health.



LEGEND

Study Area Corridor

Suburbs Boundary

Hazard Rate of Acid Sulphate Soil

Low

Medium

High

0 500 1000

metres

Scale 1: 25,000 (A4)

N

NORTHERN LINK
ENVIRONMENTAL IMPACT STATEMENT

Figure 5

Acid Sulphate Soil

Northern Link

SKM Connell Wagner JOINT VENTURE

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1.2 Potential Impacts and Mitigation Measures

1.2.1 Effects on Economic Minerals

The *City of Brisbane Economic Geology Map* (Sheet 3 and 4) show no significant mineral, energy or extractive resources and no economically significant materials have been noted in the core logs. Proximity of the Mt Coot-tha quarry and quality of the tunnel spoil are significant factors in the proposal to transport spoil on conveyor directly from the tunnel exit to the quarry where it would be handled in the same way and for the similar purposes as quarried materials. This proposal would not affect the ability of the quarry to maintain its supply to industry. The project would have no other impact upon existing economic mineral deposits.

1.2.2 Soil Erosion

1.2.2.1 Potential Impacts from Soil Erosion

Potential erosion impacts have been considered for worksites, tunnel portals, areas associated with cut and cover tunnel works and the spoil disposal sites, and impacts are possible during construction works, vehicle access and spoil removal activities.

The Western Connection worksite is likely to intercept the Mt Coot-tha Soil type, Frederick Street worksite is likely to intercept the Toowong Soil type, and the Lower Clifton Terrace worksite is likely to intercept the Beenleigh Soil type. These soils are considered to be moderately dispersive and there is the potential for erosion impacts to occur if appropriate erosion and sediment control measures are not implemented and maintained during site works. The nature of the proposed works at each of the sites during construction are likely to include (but not be limited to) the following activities.

- Vegetation clearing and site preparation at each site
- Construction of laydown, material storage, handling, preparation and spoil stockpile/treatment areas
- Construction of embankments for the elevated road alignment
- Construction of new bridges and overpasses including placement of abutments,, piers and footings
- Modification of existing road infrastructure
- Installation/construction of stormwater/drainage control and sediment control measures
- Construction of haul routes and vehicular access tracks
- Construction sites.

The potential impact resulting from soil erosion to the surrounding environment within these worksites, portal areas and spoil disposal sites for construction and access purposes includes:

- potential surface water quality impacts from sediment and contaminants entrained in surface runoff resulting from construction related activities such as exposed soils, spoil stockpiles and material storage;
- loss of valuable topsoil material during site preparation and from stripping and stockpiling for extended periods;

- erosion due to vegetation clearing and soil disturbance to create space for the stockpiling of material, laydown activities and to establish access routes;
- erosion of exposed vulnerable soils by wind or water action; and
- embankments constructed over weak alluvium may undergo settlement.

1.2.2.2 Soil Erosion Mitigation Measures

Mitigation measures would be implemented throughout various stages of the project to control and reduce the risk of erosion due to construction and operation activities. These would be developed during the design phase of the project and incorporated into the EMPs prepared for the construction and operation of the project, and their requirements are outlined in detail in Chapter 19, Environmental Management Plan.

Specific erosion and sediment control plans would be prepared and adopted for all areas of surface disturbance to ensure that erosion and sediment control measures are implemented and adequate to the nature and scale of disturbance and would include site reinstatement measures once works are complete.

1.2.3 Settlement

1.2.3.1 Potential Impacts from Settlement

Settlement resulting from tunnel excavation/construction activities may arise due to the following effects.

- Elastic ground settlements caused by the excavation of the tunnel.
- Consolidation settlements caused by groundwater drawdown into the tunnel.

Potential settlement effects have been assessed based on the design and geotechnical information in the reference design. The results of this assessment are illustrated in Sketches EIS-SC-01 to EIS-SC-07 in Volume 2 of the EIS. These findings would inform the detailed design of the Project and further modelling of potential settlement impacts would be undertaken during the detailed design phase when the final project design is determined. From this detailed modelling the contractor would identify individual properties that may be potentially impacted and initiate consultation with those property owners and tenants with a view to undertaking pre-construction condition reports of the individual properties including improvements. Such reports would be the starting point for any subsequent claims of damage due to settlement.

Given the anticipated high strength rock conditions for the majority of the tunnel, the areas which may have some impacts on the surrounding infrastructure are low cover and/or poorer quality rock and are as follows:

- Areas in the vicinity of the tunnel portals.
- Kelvin Grove Road Y Junctions.

Tunnels of all types can cause drawdown of the water table, with subsequent consolidation settlements of susceptible soils. As noted in *Technical Report No. 4 - Groundwater in Volume 3* of the EIS settlement from drawdown of the watertable is likely to be negligible. The areas where consolidation settlements might be expected are:

- the cut and cover tunnels at the Western Freeway connection;
- the low point in the vicinity of Baroona Road and Fernberg Road; and
- possibly some of the cut and cover tunnels at the ICB connection

Critical utilities and sensitive buildings along the proposed route of the tunnel would be identified during the reference design phase, and an assessment of these impacts from the tunnel induced settlements would be undertaken. The initial assessment is the impacts are likely to occur in some of the locations identified above.

1.2.3.2 Settlement Mitigation Measures

Where elastic ground settlements and consolidation settlements combine, some areas of damage are predicted if no mitigation measures are implemented. To minimise the risk associated with settlement, it is important to adhere to suitable engineering design in the detailed design phase and ensure that effective management and monitoring approaches are implemented and reviewed from the onset of construction.

Appropriate mitigation measures would be implemented during the detailed design process. Issues which would require careful consideration at that stage are tunnel face loss, design of tunnel support and liners, stability assessment of portals, as well as the driven tunnel and groundwater modelling of any impact by the tunnel. Comprehensive geotechnical investigations are required to fully define the subsurface profile and materials along the alignment. These measures would ensure that predicted settlements are such that predicted damage is negligible, slight or very slight (and hence easily repairable).

All buildings and structures within the areas where surface settlements and possible damage are predicted would have a building condition survey completed. Surveys and other displacement monitoring would be used to monitor the effects of settlement, if any, from tunnelling. The actual settlements would be compared to predicted settlements and further mitigating measures taken where adverse departures from predictions are noted.

1.2.4 Acid Sulfate Soils

1.2.4.1 Potential Impacts from Acid Sulfate Soils

The nearest sites with any possibility of encountering ASS are in Toowong Memorial Park on Sylvan Road, the eastern end of Baroona Road and the south-eastern end of Given Terrace in Neal Macrossan Park. However, it is not expected that any of these areas would be disturbed during project construction.

The potential environmental impacts associated with ASS include:

- changes to water chemistry of receiving water bodies and groundwater resources;
- sedimentation and erosion (due to loss of aquatic vegetation);
- impacts to the aquatic ecosystem within the receiving water bodies;
- fill material creating downward loading pressure on unconsolidated sediments resulting in surface heaving, subsurface extrusion or displacement of ASS material above the groundwater table resulting in oxidation of ASS sediments;
- temporary exposure of ASS material within the area of influence of groundwater dewatering activities and subsequent inundation during post construction recharge of the water table resulting in potential mobilisation of acid leachate in groundwater;
- changes to water flows resulting from the advent of structures may restrict flows and alter flow pathways, particularly flood flows that can deliver significant volumes of surface water to receiving environments, which if impacted by the uncontrolled release of acid leachate would result in fauna and flora mortality and fundamental changes in the ecosystem characteristics downstream of the project corridor;
- increased risk of soil degradation, erosion and instability due to deterioration of the structure of vulnerable soils; and
- increased risk of damage to infrastructure and reduced life expectancy of concrete and steel structures due to attack from acidified runoff/leachate and/or direct contact with ASS material.

The severity of these environmental impacts would be determined by a number of factors, including:

- the nature of the soil (eg: soils have varying acid generating potential subject to their texture characteristics, pyritic concentration and natural buffering/neutralising capacity);
- the period and frequency of ASS exposure/disturbance;
- the buffering capacity of receiving water bodies; and
- the adoption of ASS management measures specifically developed to minimise the potential impacts of ASS disturbance.

1.2.4.2 Acid Sulfate Soils Mitigation Measures

Mitigation measures would implement best management and monitoring practices (eg: commencing from the reference design phase and extending through to the pre-construction and construction phases) to ensure potential environmental impacts associated with ASS are minimised and controlled. Site specific ASS mitigation measures would be developed in consultation with the Department of Natural Resources and Water, and would incorporate the hierarchy of ASS management principles in line with the *Queensland Acid Sulfate Soil Technical Manual Soil Management Guidelines (version 3.8)* (2002), which include:

- avoidance;

- minimisation of disturbance;
- neutralisation;
- hydraulic separation; and
- strategic re-burial (least preferred management measure).

If necessary, the State Planning Policy 2/02- Planning and Managing Development involving Acid Sulfate Soils and the EPA's 2001 Instructions for the Treatment and Management of Acid Sulfate Soils would be referenced. In particular, the ASS mitigation measures would specifically ensure:

- minimisation of any changes in natural groundwater levels;
- the acid generating potential of material to be excavated is adequately treated and managed throughout the construction phase;
- where ASS may be disturbed, soil treatment with fine agricultural lime or other project approved neutralising agents would be used on site to prevent the downstream or offsite impacts from acid leachate drainage;
- the ASS material treatment pads and stockpiling areas (if required) would be constructed, bunded and prepared prior to commencement of construction and located in areas where overland flow can be adequately controlled and diverted; and
- all fill to be used on-site would be certified as ASS free or first evaluated for the presence of ASS and if found, would be treated with fine agricultural lime or other project approved neutralising agents.

Water management is one of the key elements for the management and mitigation of potential impacts resulting from the disturbance of ASS material. Therefore, it is essential to identify runoff and drainage control points within and exiting the construction site and design suitable control measures and structures to be installed during construction that would divert or contain runoff from ASS areas. Design considerations would incorporate the following as a minimum.

- Diversion and runoff control measures are to be implemented, with respect to the protection of nearby waterways and containment of runoff from disturbed areas and stockpile/treatment areas.
- Minimisation of disturbance of the natural surface and subsurface drainage regimes, such as retaining/maintaining existing flow pathways and directions for both surface water and groundwater resources and minimising changes to water table levels and tidal influences.
- Design of embankments and other construction activities should incorporate measures to minimise/prevent subsidence, uncontrolled settlement of unconsolidated alluvial material, settlement creep, surface or subsurface heaving or deformation.
- Avoidance of disturbance/construction activities in areas rated as having moderate to extreme risk for ASS to ensure that disturbance is minimised and rehabilitation/reinstatement is progressive and timely.

1.3 Conclusions

1.3.1 Economic Minerals

Given that no economic minerals are identified within in the project area, no impacts or mitigation measures would be implemented.

1.3.2 Erosion and Sediment Control

Sediment and erosion control measures would be implemented throughout the construction stages of the project to mitigate potential impacts and reduce the risks associated with wind and water erosion during construction and operation. Particular attention shall be paid to the construction sites to ensure that rehabilitation of the sites is completed as soon as practicable after construction is completed. Specific erosion and sediment control plans would be developed during reference the design phase and incorporated into the construction and operational EMPs.

1.3.3 Settlement

To minimise the risk associated with settlement, it is important to adhere to suitable engineering practices and ensure that effective management and monitoring approaches are implemented and reviewed from the onset of construction. Appropriate mitigation measures applied in the detailed design phase would include design of tunnel support and liners, stability assessment of portals and driven tunnel and groundwater modelling of impacts resulting from construction of the tunnel. Comprehensive geotechnical investigations would fully define the subsurface profile and materials along the alignment. All buildings and structures within the areas where surface settlements and possible damage are predicted would have a building condition survey completed. Surveys and other displacement monitoring would be used to monitor the effects of settlement (if any) from tunnelling.

1.3.4 Acid Sulfate Soils

In the unlikely event of intercepting ASS mitigation measures for managing acid sulfate soils would involve implementing best management and monitoring practices. The ASS mitigation measures would be developed in consultation with the Department of Natural Resources and Water, and would incorporate the hierarchy of ASS management principles in line with the *Queensland Acid Sulfate Soil Technical Manual Soil Management Guidelines (version 3.8)* (2002).

1.4 References

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