Table of Contents

Figures

Tables

4. Topography, Geomorphology, Geology and Soils

4.1 Topography Existing Environment

The Hinze Dam is located downstream of the confluence of the Nerang River and Little Nerang Creek. The height of the dam from toe to crest is approximately 63.5m. The existing dam crest level is at 93.5m AHD and the current full supply level of the dam is 82.2m AHD (refer to **Figure 4-1**).

The immediate sub-catchment surrounding the current dam impoundment area is covered with native vegetation. The topography is generally highly dissected with very steep slopes throughout the Project site. Spot heights for a number of the hills in the immediate area are in the order of 250m to 350m AHD. The location of areas with slopes exceeding 30 degrees is shown in **Figure 4-2**. These slopes have been derived from 1 m contour data that was used to produce a digital elevation model. The more gently sloping areas are found above and below the dam in the valleys. There are also some gentle slopes on the lower hillslopes above the impoundment and in some of the valleys.

▪ **Figure 4-1 View Across the Dam Wall to the Existing Quarry**

The most dominant topographical feature within the vicinity of the dam and impoundment area is Pages Pinnacle, which is located near the southern boundary of Lot 4 SP 164198. Pages Pinnacle is an exposed igneous rock, with an elevation of 398m AHD and dominates the landscape in this area (**Figure 4-4**). The Tallai Range to the east of the lake drains to Little Nerang Creek via typically short steep gullies. Spot heights for the top of the peaks in the Tallai Range vary between 108m and 369.5m AHD.

A quarry is located immediately west of the existing dam wall. The current void is located above the current full supply line and is approximately 300m in length and 70m in height above the current FSL. Photographs of the quarry are shown in **Figure 4-1** and **Figure 4-3** . The quarry will be the source of approximately 2.1million m^3 rock for the construction of the dam. The extraction of this volume of rock will result in the final landform at the quarry site being significantly different to the existing situation.

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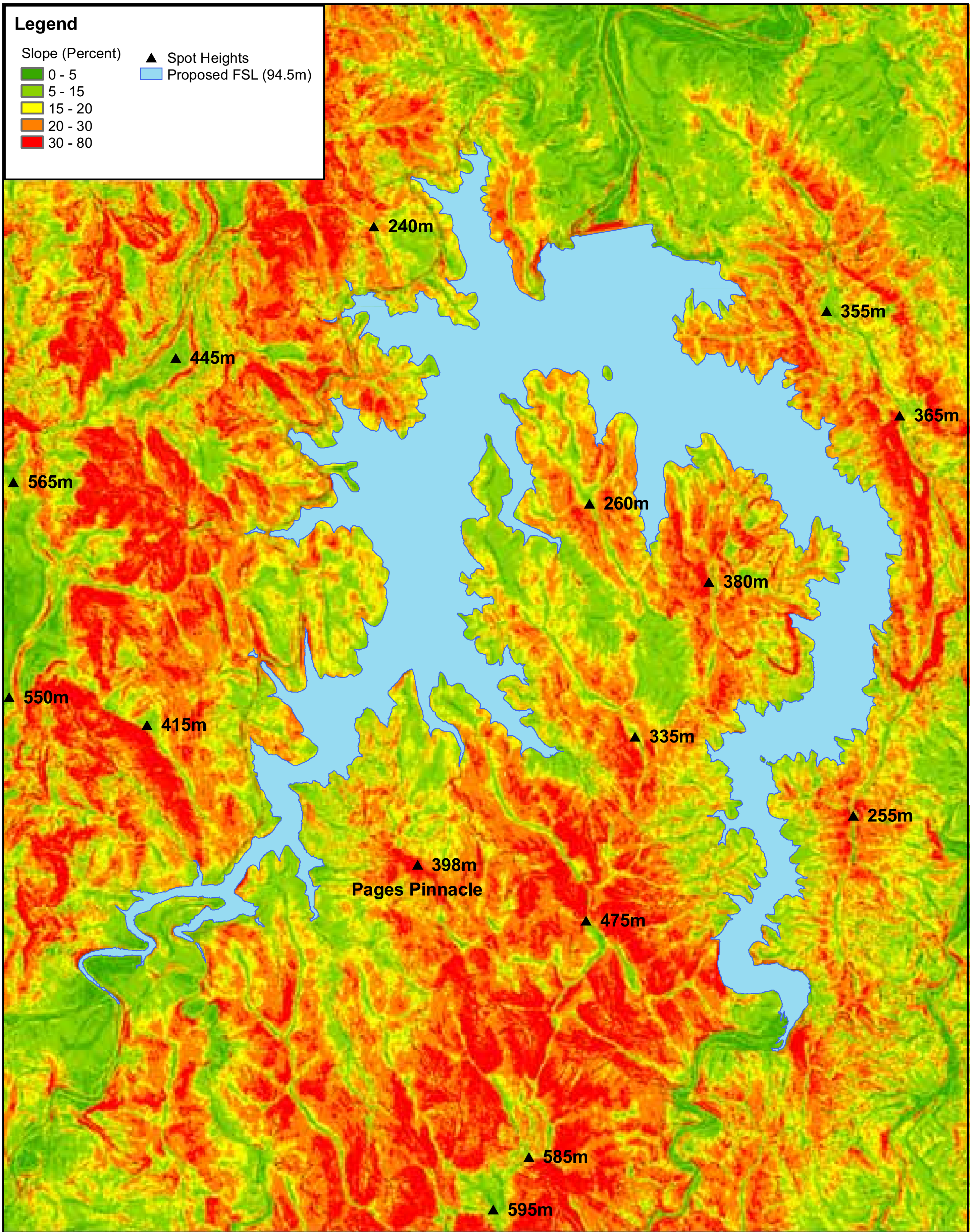

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Kilometres

Scale - 1:50,000

Projection: MGA Zone 56

Figure 4-2

Location of areas where the slope exceeds 30 degrees

Hinze Dam Stage 3 EIS

- **Figure 4-3 View from the Lake of the Existing Quarry**

- **Figure 4-4 View Looking up the Two River Valleys to Pages Pinnacle**

A small island (known as Ian's Island) in the Nerang River arm of the lake will be inundated under full supply conditions. Further upstream, the impoundment consists of two arms extending along the steep, narrow valleys of the Nerang River and Little Nerang Creek. These valleys continue southwards from the dam, increasing in elevation towards the Springbrook area. The Nerang River flows north from the mountain range on the Queensland – New South Wales border through the Numinbah Valley. The topography in this area continues to be steep and deeply bisected with valleys and gullies.

4.2 Geomorphology Existing Environment

4.2.1 General Site Description

The Nerang River represents a northern drainage of the ancient Tweed Volcano (Wilmott 1992, 2004). It rises on the Springbrook Plateau and flows across lavas of the Focal Peak and Tweed Volcanics and the Chillingham Volcanics in a northerly direction, before shifting to a north-east direction generally at the Beechmont area. At this point, the river traverses the Neranleigh-Fernvale Beds the remainder of its course. Downstream of Advancetown Lake, the river flows in a predominantly easterly direction into the Coral Sea.

Upstream of the Advancetown Lake, the river has a steep gradient and is characterised by 'flashy' hydrology (rapid hydrograph rises and falls in response to storm activity). The transport of sediment along this section of the river would therefore be periodic and dependant on weather conditions. Broad scale geological mapping in this reach indicated that relatively, there is little valley alluvium present within the river corridor. However mobile bars of alluvium (mostly gravels and cobbles) can be frequently observed within and immediately adjacent to the river, and cobble and boulder size material situated within these extensive alluvial bars would be visibly mobile at higher flows. Terraces can also be seen along this reach, and would likely be caused by cut-and-fill activity (short term erosion and deposition cycles), as the river periodically cuts down through alluvial and colluvial deposits that would be deposited in the valley during larger floods or mass movements of the banks or lower valley walls.

Between Advancetown Lake and Nerang the form of the river changes dramatically and is characterised by large meanders. Evidence of former (abandoned) channel paths can be seen here, which indicates that the processes of river migration and meander cut-offs have occurred in the past. The river flows through a wider alluvial corridor, and geological mapping indicates a more extensive alluvial pocket in the vicinity of Nerang. In addition to alluvial terraces, frequent bed and bank rock outcropping can also be observed adjacent to the River in this reach. Most of these alluvial terraces are relic features, likely formed when the sea level was higher than at present. Although the Neranleigh-Fernvale beds generate sand from weathering processes, overall there is relatively little surficial sand in the river corridor both upstream and downstream of Advancetown Lake.

Below Nerang, the floodplain has been extensively developed and is characterised by a number of residential canal estates. The tidal limit of the Nerang River is located upstream of the Weedon's Crossing Bridge.

The Nerang River estuary is approximately 21km long and comprises an area of approximately four square kilometres. It consists of a single entry to the sea that is about 150m wide. It is a river-dominated estuary (sub-class wave-dominated delta) (Geoscience Australia 2005), highly modified and has poor geomorphic value. A substantial area of intertidal land has been reclaimed, and excavation of navigation channels and canals has occurred. Regular dredging of these channels has also led to very little geomorphic variability within the estuarine reaches. Further, the construction of bridges, culverts, weirs, locks and floodgates have all altered localised hydraulics and regional hydrodynamics.

The single connection to the ocean is a man-made seaway. Due to the enlargement of the estuary through the construction of the canal system, the effectiveness of tidal flushing has been greatly reduced. Existing water resource development upstream has also reduced freshwater inflows by 70% from pre-development condition, further impacting on estuarine flushing and sediment deposition and reworking (Brizga 2006).

A fixed sand bypass system, which was constructed to maintain a navigable channel and to minimise accumulation of sediments, is located on the southern rock groin of the mouth of the Nerang River. This has effectively stabilised and maintained the river mouth.

4.2.2 Method

An assessment of current geomorphic processes, features and values of the Nerang River was undertaken using a rapid-appraisal geomorphic field assessment at a number of sites that were considered, collectively, to be representative of the range of geomorphic features, processes and values in the study area. The location of these sites is shown in **Figure 4-5** .

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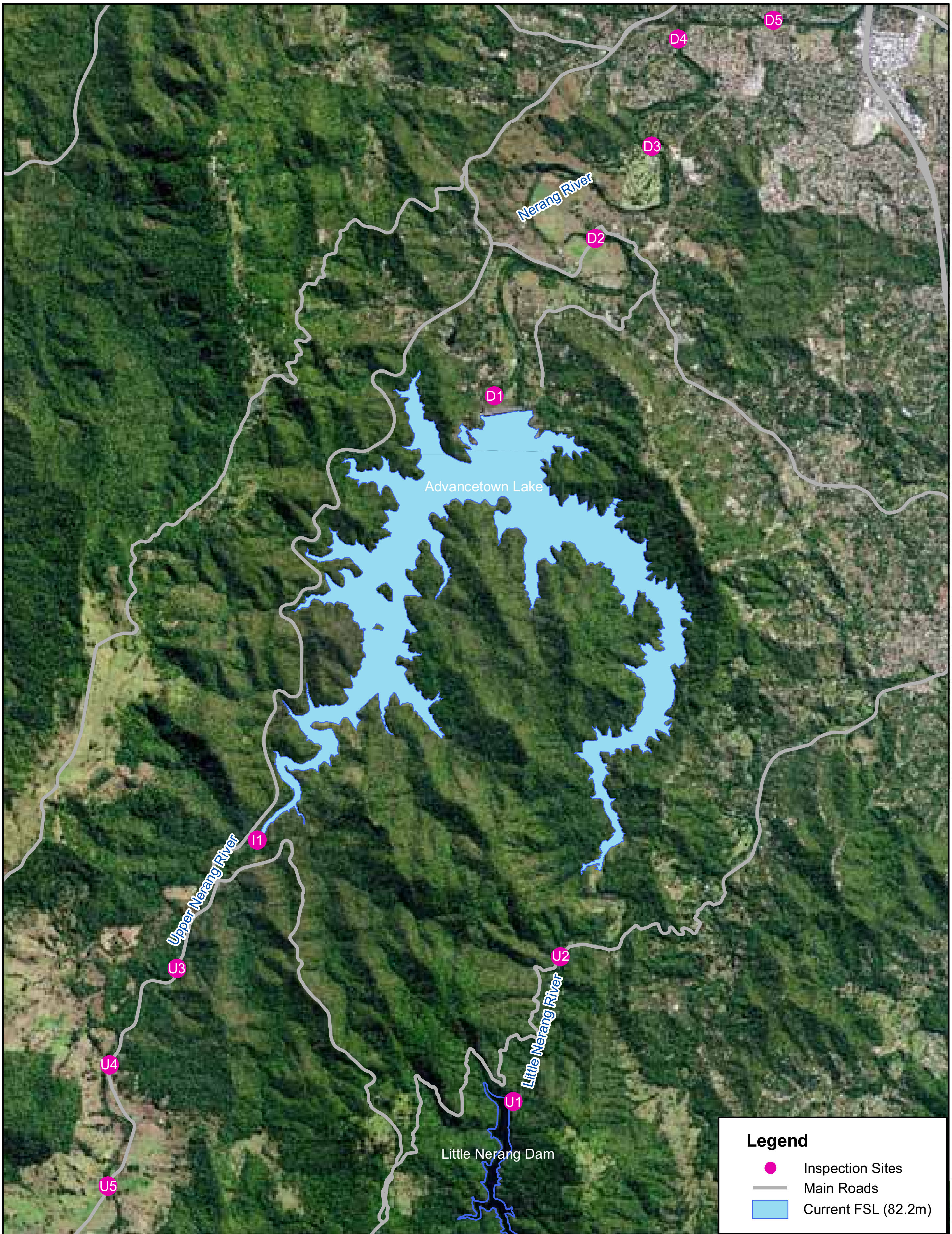

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Kilometres

Scale - 1:75,000

Projection: MGA Zone 56

Figure 4-5

Locations of Inspection Sites

Hinze Dam Stage 3 EIS

This figure must be read in conjunction with the data disclosure in Appendix H of this document

For the purposes of this report, geomorphic "condition" was assessed by considering the form of the low flow channel and flood channel, the processes within those zones (mainly flow driven erosion and sediment deposition, but also considering other non-flow related impacts), and comparing those attributes between reaches downstream from the Hinze Dam, and those upstream of the Advancetown Lake. The condition that might naturally be expected to occur in streams of these types, was also considered. This assessment was done largely using professional judgement from field observations, and supporting data. For the purpose of this EIS, particular attention was paid to any values that may potentially, be impacted by Stage 3, and whether these values were represented elsewhere on the river system. It was noted that reaches downstream of Hinze Dam were already significantly affected by the existing dam, and coastal development.

The key elements of this appraisal included descriptions of:

- habitat features;
- bed and bank stability;
- channel pattern; and
- geomorphic processes.

4.2.3 Description of Geomorphic Values

The rapid appraisal method was undertaken at three reaches:

- upstream of the proposed Stage 3 inundation zone;
- upstream limits of proposed Stage 3 inundation zone; and
- downstream of exisiting Hinze Dam wall.

Upstream of the Proposed Stage 3 Inundation Zone

Sites inspected included:

- Little Nerang Creek below spillway (U1);
- Little Nerang Creek at Springbrook Road Crossing (U2);
- unnamed tributary at Pocket Road (U3);
- Nerang River at Numinbah Valley Picnic Park (U4); and
- Nerang River at Priems Crossing (U5).

Upstream sites on the Nerang River mostly rated highly in terms of their geomorphic attributes, although some impacts were noted. The sites were generally incised, with occasional bed and bank outcrops providing control on vertical and lateral movement and promoting habitat value through processes of scour, deposition and pool formation. Large woody debris was also observed within the channel. Gravel and cobble bars generally had a cover of vegetation, however this vegetation cover was lees dense than that observed at sites downstream of the Hinze Dam. Active processes of bedrock weathering and delivery of sand to the Nerang River channel were observed at tributary site U3 although, generally, little active erosion was evident on well-vegetated slopes. At the upper end of the existing inundation zone, a transition zone exists between the ponded water and the unaffected upstream reach. Here, there was progressive inundation of habitat features such as pools and riffles.

Impacted sites were also noted (e.g. near Priems Crossing) where cattle access and water extraction methods had affected bank stability and low flow conveyance (refer **Figure 4-6**).

Two sites were inspected between Little Nerang Dam and Advancetown Lake. These sites showed a range of values and were generally rated as good, despite changes to flow patterns from Little Nerang Dam. This was attributed largely to extensive bedrock control and a coarse substrate that maintained a range of hydraulic habitats despite the altered flow regime.

▪ Figure 4-6 'Good' and 'Poor' Sites on Nerang River Upstream of Advancetown Lake


Overall, geomorphic condition was rated as 'good' for representative sites immediately upstream from Advancetown Lake. This rating was in accordance with the findings of Brizga (2006), which rated the deviation from reference condition for a range of environmental values as 'minor' to 'moderate'.

A summary of the condition and values assessments is presented in **Table 4-1**. A full description of the condition attributes are contained in **Appendix F.4.3**.

▪ Table 4-1 Summary of Upstream Condition Assessment

Attribute	U1	U2	U3	U4	U5
Flow	Low	Low	None	Low	Low
Channel Pattern	Meandering	Sinuous	Straight	Sinuous	Sinuous
Habitat Features*	C/G/P	Ri/G/P	W/C/Ra/P	G/P	G/P (weir)
Bed Material^	Bo/Be	Bo	S/Be	G	G/Bo
Bed Stability#	Stable	Stable	MD	Stable	MD
Bed Control	None	Outcrop/Crossing	Outcrops	Bo	Rock weir
Bank Stability	Excellent	Excellent	Good	Good	Moderate
Bank Works	None	None	None	Trees	Rock
Conveyance	Excellent	Good	Excellent	Moderate	Good
Channel Alteration	Good	Good	Excellent	Good	Moderate
In Stream Habitat	Excellent	Moderate	Excellent	Good	Moderate
Geomorphic Value	Good	Good	Good	Good	Poor

*W=Waterfall, C=Cascade, Ra=Rapid, Ri=Riffle, G=Glide, P=Pool, D=Dry Rocky Channel.
^ M=Mud, G=Gravel & Cobbles, Bo=Boulders, Be=Bedrock.
# MD=Minor Degradation.

4.2.4 Proposed Stage 3 Inundation Zone

One site was inspected with this located at Nerang Murwillumbuh Road Crossing (adjacent Numinbah Environmental Education Centre) (I1).

This site exhibited a variety of habitat types including cascades, riffles, glides and pools **(Figure 4-7).** The channel was incised to bedrock and, therefore, stable, and set between vegetated benches of predominantly bedrock and coarse alluvial material. The bank stability was rated as good. Both channel alternation, in-stream habitat and conveyance were all rated as excellent, while flow and sediment transport processes appeared near-natural. Overall geomorphic values were rated as good.

A summary of the condition and values assessments is presented in **Table 4-2**. A full description of the condition attributes are contained in **Appendix F.4.3**.

Table 4-2 Summary of Condition in the Proposed Stage 3 Inundation Area

Attribute	I1
Flow	Low
Channel Pattern	Sinuous
Habitat Features*	C/Ri/G/P
Bed Material^	G/Bo/Be
Bed Stability#	Stable
Bed Control	Outcrops
Bank Stability	Good
Bank Works	None
Conveyance	Excellent
Channel Alteration	Excellent
In Stream Habitat	Excellent
Geomorphic Value	Good

*W=Waterfall, C=Cascade, Ra=Rapid, Ri=Riffle, G=Glide, P=Pool, D=Dry Rocky Channel.
^ M=Mud, G=Gravel & Cobbles, Bo=Boulders, Be=Bedrock.
# MD=Minor Degradation.

Figure 4-7 Upstream and Downstream Views at Stage 3 Inundation Area

4.2.5 Hinze Dam to Nerang

The sites inspected included:

- Nerang River at Advancetown Road Bridge (downstream from existing wall) (D1);
- Nerang River at Latimer's Crossing Road (D2);
- Nerang River at Grand Golf Club (D3);
- Nerang River at R. A. Stevens Bridge (McLaren Road) (D4); and
- Nerang River at Weedon's Crossing (Birribi Road Bridge) (D5).

The reach immediately downstream from the dam wall is heavily modified with poor geomorphic value. Prolonged low flows has caused extensive growth of understorey and grasses in the valley floor and bars and sediment deposits have stabilised. There are swampy areas adjacent to the low flow channel due to extended pools creating areas of standing water within the grasses. Further down stream(to approximately Fyfes Road), the river assumes a meandering form and aerial photographs show evidence of former channel paths and meander cut-off channels as previously described. These are also evident on the south bank upstream of Weedon's Crossing Bridge. These floodplain features indicate the presence of more extensive floodplain alluvium and less frequent bed and/or bank rock control. At Latimer's Road Crossing (**Figure 4-8**), extensive gravel/cobble bars have been vegetated indicating a reduced frequency of mobilisation. A lack of silt and sand bed material suggested armouring have occurred (preferential removal of finer sediment fractions from the bed leaving a resistant pavement) and the channel appeared incised to a minor degree. In addition to flow regime change, cattle access and other land use impacts (e.g. the golf course, power boats, urbanisation and canal development) are also impacting geomorphic integrity in the reach as a whole.

Higher geomorphic values are largely restricted to the low flow channel with a range of habitat features present including pools, riffles and glides. Extensive bars, including floodrunners, were observed along the reach (e.g. upstream from R. A Stevens Bridge). Elevated debris marks indicated that higher flows still occurr through this reach and these would be important for pool scouring, mobilisation of bar material and transport of large woody debris. However, the extent of vegetation across the bars suggest that these higher "resetting" flows capable of reworking the outer bars and transporting organic matter is much less frequent compared as a result of the existing dam, as would be expected. Although a range of geomorphic values are present, the overall geomorphic condition is rated as 'moderate" to 'poor' and largely modified. Brizga (2006) rated the deviation from reference condition for a range of environmental values as 'minor' to 'moderate' in the reach downstream from the dam.

A summary of the condition and values assessments is presented in **Table 4-3**. A full description of the condition attributes are contained in **Appendix F.4.3**.

Table 4-3 Summary of Downstream Condition Assessment

Attribute	D1	D2	D3	D4	D5
Flow	Low	Low	Low	Low	Low
Channel Pattern	Straight	Sinuous	Sinuous	Sinuous	Meandering
Habitat Features*	P	R/P	C/Ri/G/P	P	Ri/P
Bed Material^	?	G	G	M/G	G/M?
Bed Stability#	Stable	MD	Stable	MA	Stable
Bed Control	Crossing, Rock	Bars	Placed rock	Bridge works	None
Bank Stability	Excellent	Good	Moderate	Good	Excellent
Bank Works	Riprap	None	Intermittent	None	None
Conveyance	Good	Good	Poor	Moderate	Good
Channel Alteration	Poor	Good	Moderate	Moderate	Moderate
In Stream Habitat	Poor	Moderate	Poor	Poor	Moderate
Geomorphic Value	Poor	Poor/Mod	Poor	Poor	Moderate

*W=Waterfall, C=Cascade, Ra=Rapid, Ri=Riffle, G=Glide, P=Pool, D=Dry Rocky Channel.
^ M=Mud, G=Gravel & Cobbles, Bo=Boulders, Be=Bedrock.
# MD=Minor Degradation.

Figure 4-8 Stable Alluvial Bars and Bank Outcropping

4.2.6 Summary of Processes and Values

The geomorphic processes and values are summarised in **Table 4-4.**

Table 4-4 Summary of Geomorphic Processes and Values

Reach	Values
Downstream from existing Hinze Dam.	A range of low flow habitat values maintained by prolonged low flows including riffles, glides and pools. Occasional higher flows promoting scouring and mobilisation of flood channel sediments.
Upstream from Stage 2 Inundation Area.	Near-natural flow and sediment transport processes. A range of low flow habitat values maintained by low flows including cascades, riffles, glides and pools. A range of flood channel habitats on bars, benches and terraces and maintained by inundation and sediment transport processes for higher flows.

4.2.7 Summary of Existing Impacts on Geomorphological Values

The existing impacts on the geomorphological values of the study area are detailed in **Table 4-5**.

Table 4-5 Summary of Existing Impacts on Geomorphological Values

Reach	Values
Downstream from existing Hinze Dam.	Reduced frequency of flushing flows capable of remobilising and resetting outer channel bars and benches, and promoting growth of instream grasses and flood channel understorey. Reduced frequency of transport of large woody debris and organic matter across bars and flood channel benches. Armouring of bed substrate due to interruption of sediment supply. Reduced frequency of sediment delivery to the estuary. Reduced frequency of flushing flows capable of scouring deeper pools. Land use impacts causing direct impacts to the flood channel (e.g. bank protection, recreational use, urban and infrastructure development) and obstructions in the low flow channel (e.g. creation of artificial waterfalls for recreation purposes).
Pondage area	Inundation of existing channel. Transition zone at upper end of pond with periodic submergence of fluvial features due to pond backwater.
Upstream from Stage 2 Inundation Area.	Land use impacts (largely agricultural and recreational).

4.3 Geology Existing Environment

A comprehensive description of the rocks and geological history of the Gold Coast and hinterland areas can be found in Willmott (1992). The geology of the Hinze Dam and Advancetown Lake have been described in a number of previous reports prepared by Damcorp for Stage 1 and Stage 2 of the Dam Project. The geological formations of the Project area are shown in **Figure 4-9**.

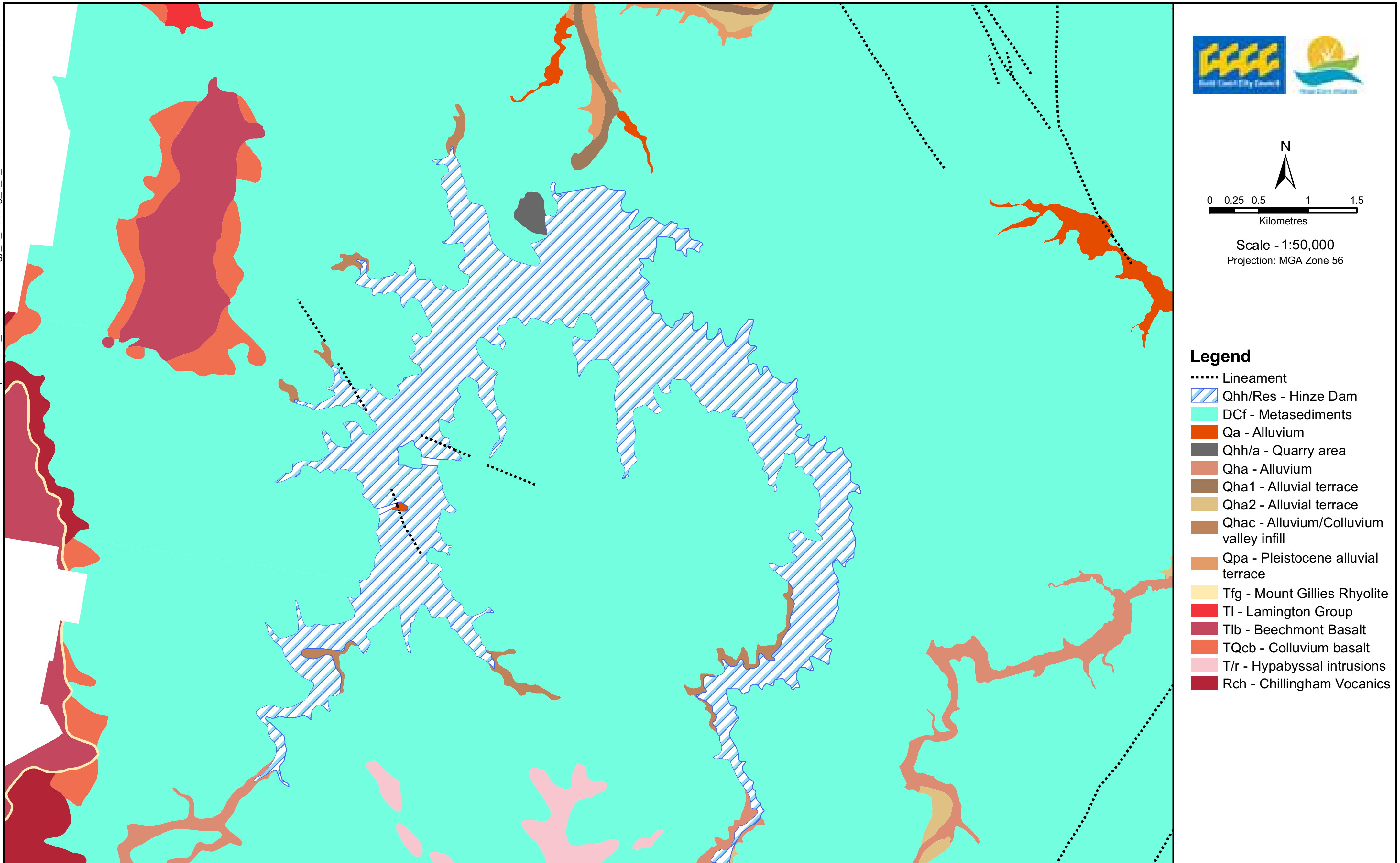


Figure 4-9

Geological Map

Hinze Dam Stage 3 EIS

4.3.1 Geological History

A brief geological history of the area is described below to assist in understanding the structure and composition of the geology in the Hinze Dam Catchment; sourced primarily from Willmott (1992).

The Neranleigh-Fernvale beds are a range of metamorphosed sedimentary rocks, which are the oldest rocks within the catchment, originating as sediments deposited on the continental shelf and deep sea basins. About 300 million years ago, towards the end of the Carboniferous period, these deep sea sediments underwent large scale compression, folding and eventual uplift to form mountainous terrain. Where these rocks are exposed they reveal steeply dipping beds with compression resulting in recrystallisation of rock minerals, forming very resistant rocks such as greywacke. Volcanic lava flows occurred at this time; hence pillow lavas form part of these 'meta-sedimentary rocks'. About 225 million years ago, in the Triassic period, violent volcanic eruptions took place along the continental margins. The Chillingham Volcanics are the rhyolitic lavas and rock fragments from these eruptions that covered parts of the Neranleigh-Fernvale Beds. Following this volcanic phase, a more stable geological period ensued during which sediments were deposited in inland basins. These include the Woogaroo Subgroup rocks which developed from braided river deposits infilling alluvial plains and outcrop locally today within the upper Nerang River valley.

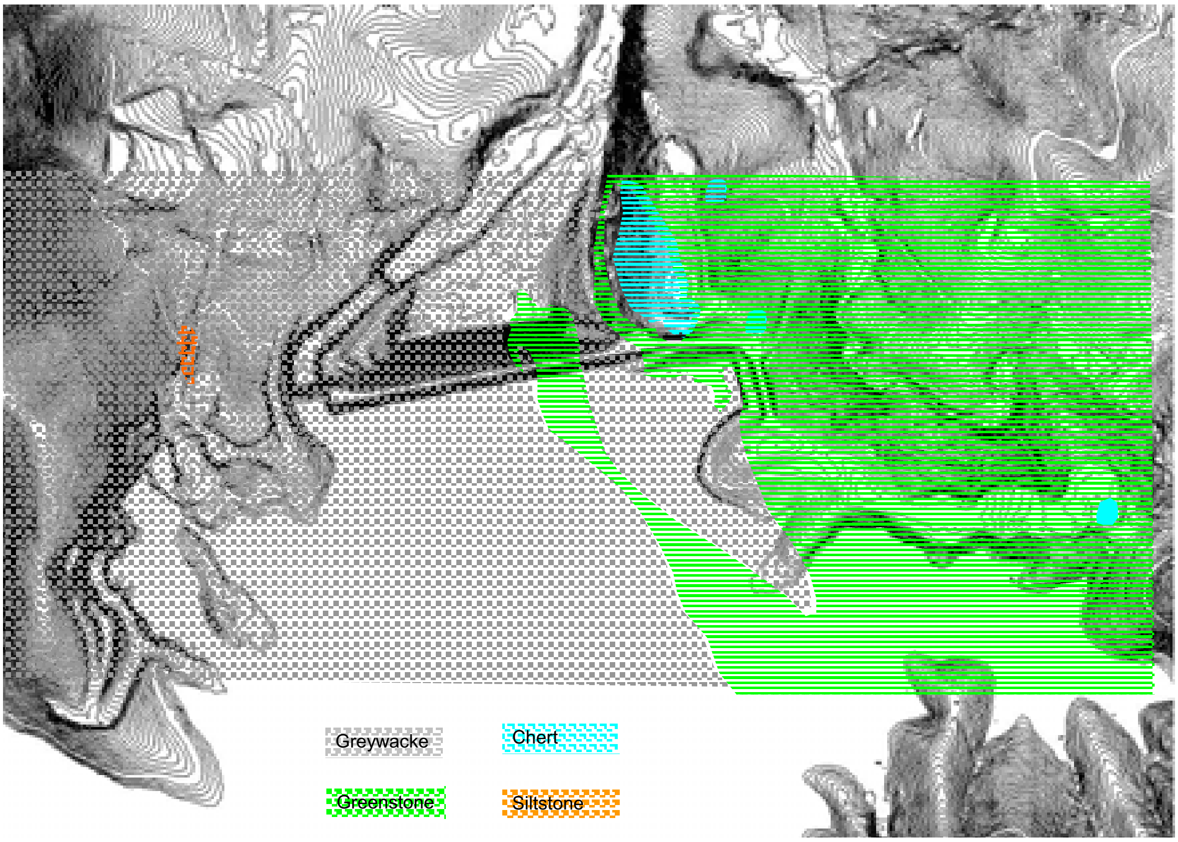
Beginning some 23 million years ago (during the late Tertiary), there was renewed volcanic activity with extrusion of basaltic lavas from vents of a volcano thought to be located west of Mount Barney. These lavas formed the Albert Basalt. Continued volcanic eruptions were associated with a massive 2000m high shield volcano, the Tweed Volcano, centred over Mount Warning in New South Wales. These resulted in the formation of thick sequence of interbedded olivine-rich basaltic and rhyolitic rocks, including the Beechmont Basalt, Binaburra Rhyolite, Springbrook Rhyolite, Hobwee Basalt and the Lamington Group basalts which form the major plateaux and ranges which make up the southern and elevated parts of the Hinze Catchment.

Following the extinction of the Tweed Volcano, the continental landmass was stable once again. The mountainous terrain was subjected to weathering and erosion processes, with formation of the major river valleys and coastal plains of today. Topographic inversion has occurred since the Tweed Volcano lava flows filled the 'landscape lows' at the time of the lava extrusion events. These lava flows occur in the contemporary landscape as basalt and rhyolite capping on plateaux and ridges at Springbrook and Beechmont. Fluctuation in sea levels in recent geological times (the last 2 million years), has resulted in several phases of infilling and entrenchment of major valley sediments. The alluvial infills and river terraces within the lower reaches of the Numinbah Valley and the Little Nerang Creek valley are associated with these phases of sea level fluctuation, especially within the last few thousand years. The most recent (Holocene) unconsolidated deposits comprise mass movement materials on steep slopes. Some of the main landslip zones in the valley have been depicted as 'colluvium basalt : soil, clay, cobbles, boulders', but most slopes underlain by basalts have an uneven veneer of unconsolidated weathered material and boulders.

4.3.2 Geology at Hinze Dam

The dominant geological formation of the area, as shown in **Figure 4-9**, is the Neranleigh Fernvale Beds belonging to the Beenleigh Block. Neranleigh Fernvale Beds are typically comprised of Greywacke (arenite), shale, siltstone, Chert, jasper and basic metavolcanics. **Figure 4-10** provides an overview of the geology within the Project site. As part of the geotechnical investigations for the feasibility and engineering design of the dam wall, additional geological descriptions are available around the dam wall. A description of the rocks found in these areas is described below.

Figure 4-10 Geology within the Major Construction Area



Greywacke is present over the majority of the dam foundation, the left abutment and generally fresh rock in the spillway and rock quarry. There is a 'weathered rind', approximately 5m thick, in the upper rock face and left abutment. There is a minor occurrence of shale / siltstone on the left abutment and entering the rock quarry. Fresh Greywacke is hard, suitable for the rock shell of the dam. The permeability increases with the degree of weathering and Greywacke contains distinct jointing that will also contribute to permeability. Weathered Greywacke is suitable for general fill but not for clay core.

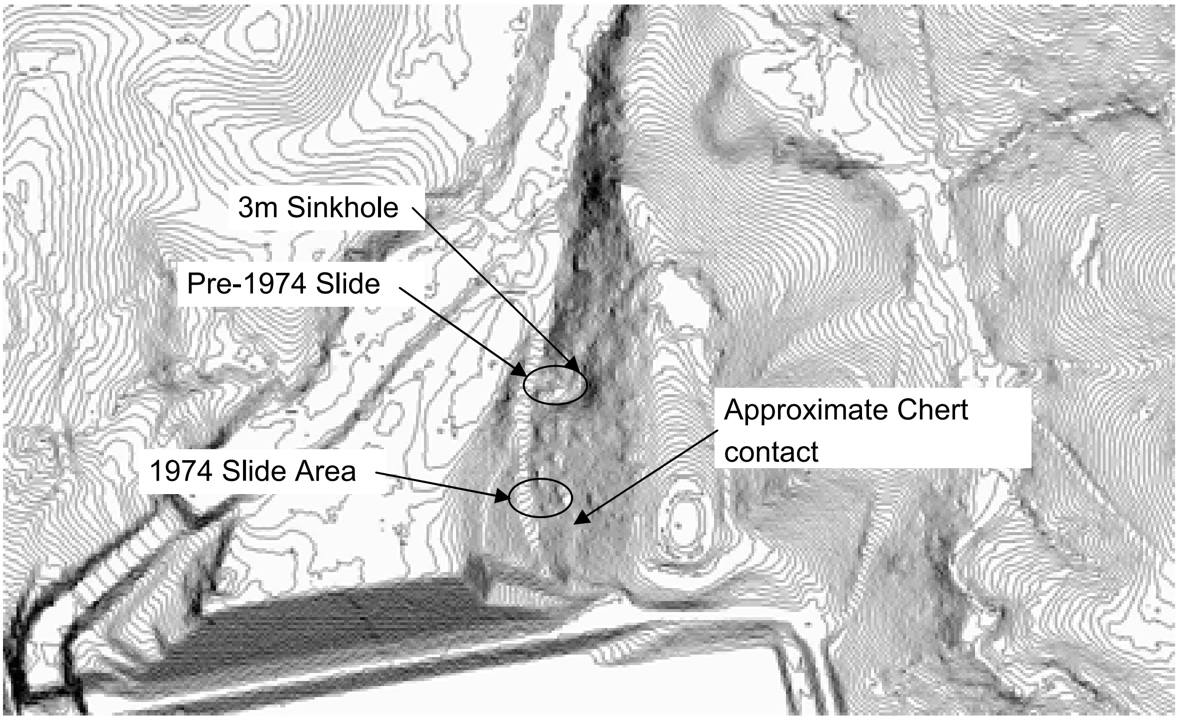
Greenstone / Greenschist (interbedded with Greywacke and Chert) occur on the right abutment and along the footprint of the proposed saddle dam. Greenstone is foliated at the contact zones with other rocks and these areas will have moderate permeability where they occur near the surface. Otherwise the permeability of Greenstone will be relatively low. Areas of weathered Greenstone are considered a good source of clay for the dam core and the proposed borrow area is shown in **Figure 4-10**.

Chert occurs as inclusions or beds in Greywacke and Greenstone. There is a Chert bed on Kiosk Ridge (right abutment of the dam) and inclusions which have not been fully defined, are located along the saddle dam footprint. The permeability of near surface Chert will vary from moderate to high.

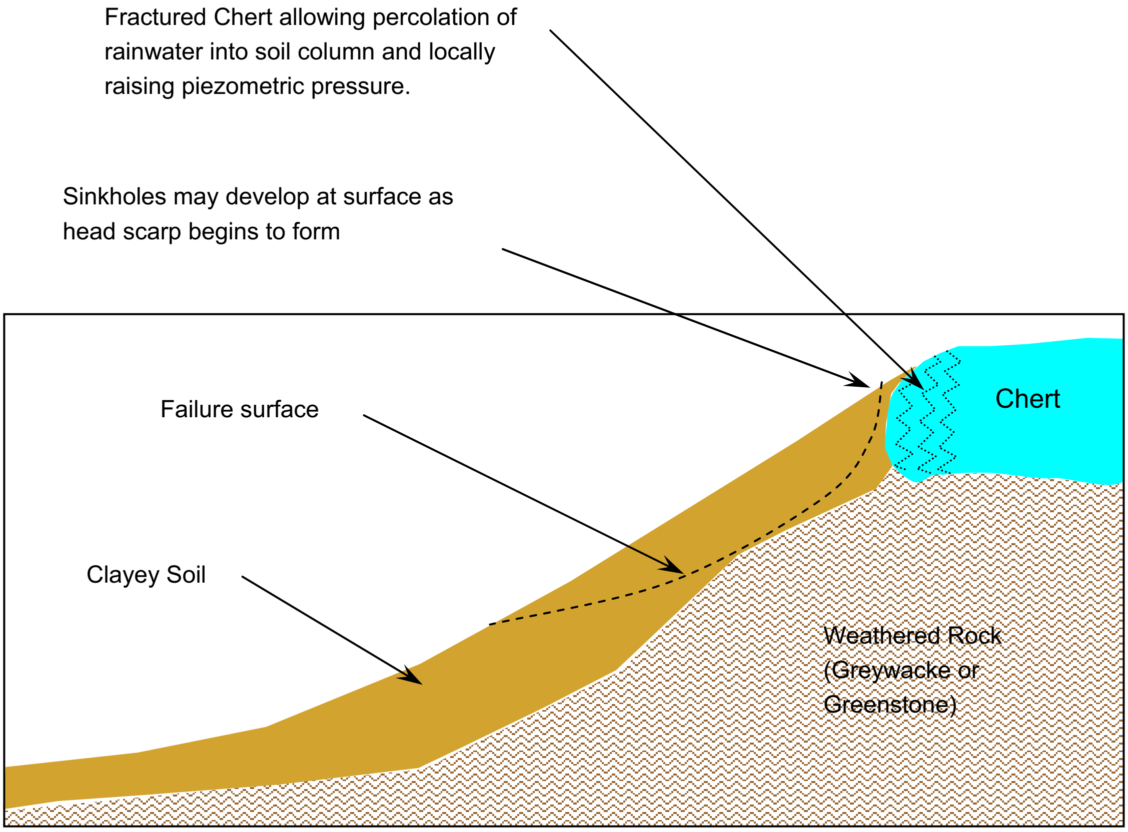
There are sinkholes and areas of mass movement on the right abutment where highly fractured Chert allows infiltration of water that causes failure of the weathered soil on the adjacent slopes. The locations of existing areas of mass movement are shown in **Figure 4-11** and the process for their formation is shown in

Figure 4-12**.** There are no other areas that have been identified within the Project area where this arrangement of materials occurs.

■ **Figure 4-11 Location of Areas of Existing Mass Movement**



■ **Figure 4-12 Process of Mass Movement**



There are no geological limitations which cannot be overcome for the raising of the dam wall. No geological faults have been identified that will impact on the dam wall, however there are Greenstone foliation areas associated with contact zones with other rock types. As described earlier these zones have a moderate permeability where they appear near the surface and these considerations have been used in the design of the dam wall. All quarry and borrow material will be sourced from on-site locations.

4.4 Soils Existing Environment

The provisional soil associations units for the Gold Coast and hinterland have been mapped at a scale of 1:100 000 (Whitlow 2000b). The soil map has been produced from linework that was derived from a variety of sources. For the Project area the 1:100 000 geology mapping was re-interpreted to map the distribution of soils. The soil associations at the Project site are shown in **Figure 4-13** and have been described using the Australian Soil Classification System (ASC) (Isbell 1996). A brief description of the ASC Soil Orders is presented in **Table 4-6**. The soils within the Neranleigh Fernvale beds are mapped as Kurosols, Ferrosols and Tenosols. These soils would be associated with particular rock types within this unit and can therefore be further delineated in the areas of major disturbance around the dam wall where the rock types have been identified as part of the geotechnical investigations (**Figure 4-11**). A brief description of which soils form on the different rock units has been included below.

Greenstone is a basic metavolcanic that will weather to form clay soils and these would be the Red Ferrosols. Such soils are associated commonly with basic or ultrabasic (sometimes termed *mafic*) igneous rocks such as basalts which are dominated by ferro-magnesian mineral groups. These minerals weather to produce the clay-rich soils which are high in iron content, hence soils are often deep red colours although ferrosols may also be brown, yellow, grey or black. Ferrosols lack strong texture contrasts between the A and B horizons and are characterised by B2 horizons that are high in free iron oxide. The Red Ferrosols are generally well drained with stable well structured surfaces and polyhedral structured subsoil.

The rhyolitic formations and the more resistant quartzitic rocks within the Neranleigh-Fernvale beds (ie Greywacke and Chert) would form Kurosols and possibly Sodosols in the highly weathered areas tending towards low flat areas. In general, where these rocks occur in steeper and more elevated areas Tenosols are found. However, Tenosols may occur at any position from ridges to footslopes subject to the nature of the bedrock. Given the steeply dipping strata within some of the Neranleigh-Fernvale beds, soil depths can vary quite markedly over short distances as evident in road cuttings. Tenosols are poorly developed soils that are often shallow and rocky directly overlying hard unweathered rock or decomposed rock (formerly termed lithosols).

Kurosols are characteristic of the hard rock areas notably on the Neranleigh-Fernvale beds, with red, grey yellow, brown and brown kurosols, some mottled and some bleached, found on this rock formation. These are defined as soils with strong texture contrasts between the A and strongly acid B horizons. The red and yellow podzolic soils of the Great Soil Groups classification of Stace *et al* (1968) fall within the Kurosol order.

The soil types of the alluvium along the major creeks will depend on the source of the deposited sediment. The soil types range from Rudosols, Dermosols, Sodosols and Kandosols. Below the dam wall is predominately fill material that has not been characterised. These are defined as soils that have negligible pedological organisation generally because soil forming processes have not operated for very long; that is, they are 'young soils'. Rudosols in the Project area are found on very recent alluvial deposits, with the river terraces generally Dermosols. Dermosols are characterised by an absence of clear or abrupt textural B horizons but the subsoils (B2 horizons) have structured soil materials.

Along the lower western banks of Little Nerang Creek alluvial deposits are also present. In the uppermost reaches of the Little Nerang Creek terraces of Rudosols and Dermosols are present, along with active channel alluvium also including cobbles at lower elevations. In the middle reach of Little Nerang Creek, alluvium and colluvium formed by valley infill is also present, which again comprises mainly Rudosols and Dermosols with gravel and cobbles.

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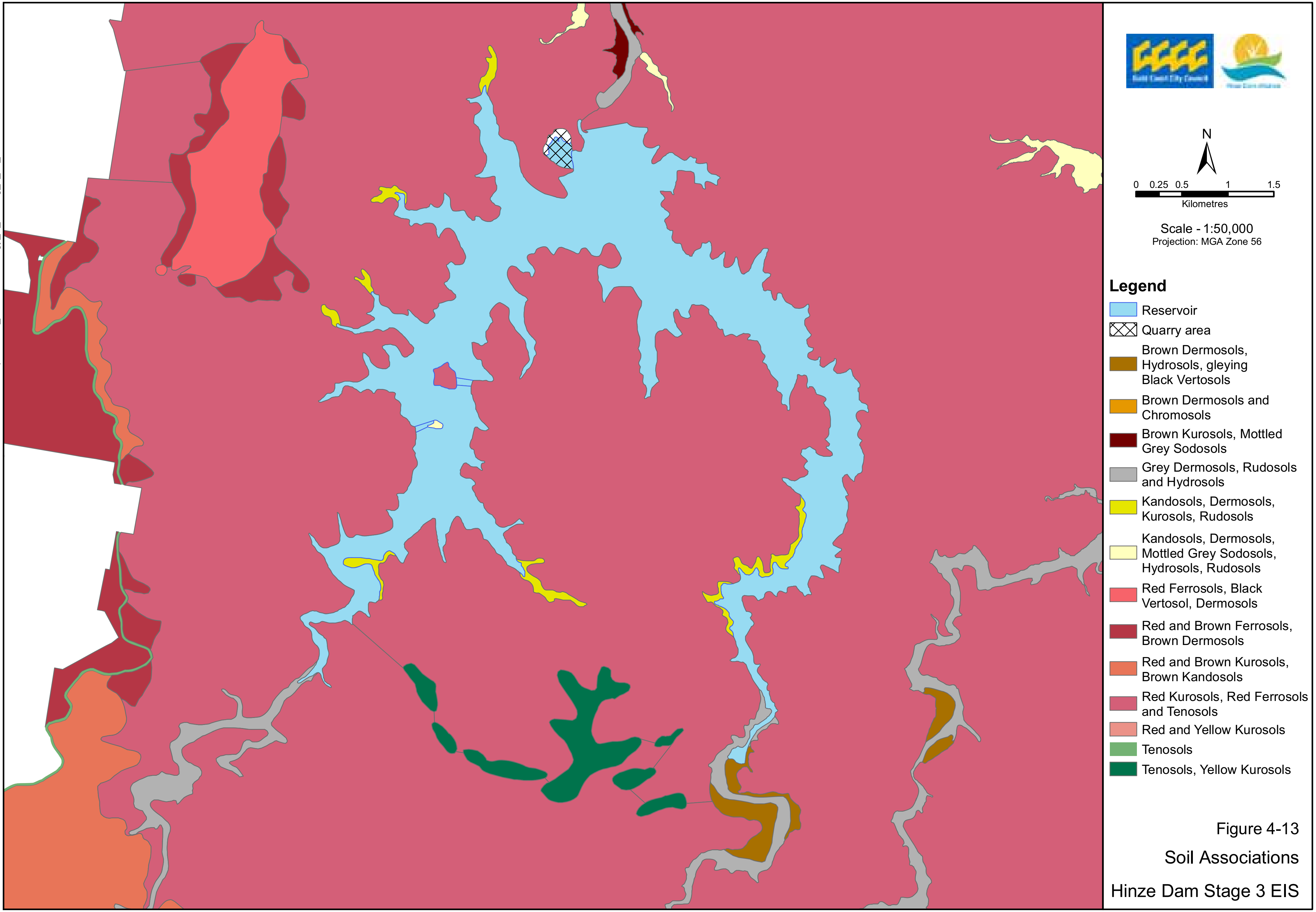

Figure 4-13

Soil Associations

Hinze Dam Stage 3 EIS

This figure must be read in conjunction with the data disclosure in Appendix H of this document

The Nerang River arm also includes areas of valley infill alluvium and colluvium in lower lying areas. In the upper most reaches of the proposed full supply line area of Nerang River upper level terrace alluvial deposits are also present.

- **Table 4-6 Soil Orders Found in the Project Area**

Soil Order	Description
Rudosols	Soils with negligible pedological organisation
Tenosols	Soils with weak pedological organisation
Vertosols	Soils with high clay content (>35%), cracks & slickensides
Kurosols	Soils with strong texture contrast and having pH <5.5 in B horizon
Ferrosols	Soils lacking strong texture contrast and having high free iron in B horizon
Dermosols	Soils lacking strong texture contrast and having a structured B horizon
Kandosols	Soils lacking strong texture contrast and having a massive B horizon

4.4.1 Soils Field Work

The purpose of the field work was to confirm the broadscale mapping and to examine the distribution of soils within mapping units, with a particular focus on the characterisation of soil erodibility. The recognisance survey concentrated on sampling the soils of major geologies / rock types particularly in areas that would potentially be impacted by the proposed raising of the dam wall. There were significant access limitations around some parts of the dam which restricted observations.

All sites were described using the standards in the *Australian soil and land survey field handbook* (McDonald et al. 1998). All sites were recorded with a hand-held GPS receiver with an accuracy of approximately ±5 m. Descriptions of the detailed soil sites have been included in **Appendix F.4.1** and the locations of the detailed sites undertaken as part of this study are shown on **Figure 4-5** .

The field sites generally confirmed the relationship between rock type and the soils formed. Soil depths and soils types can vary quite markedly over short distances, in some areas, as evident in road cuttings (as shown in Error! Reference source not found. where variable depth of weathering, nature of materials and soils found within a couple of hundred meters) due to the steeply dipping strata within some of the Neranleigh-Fernvale beds.

Erosion due to wavelet action was not found to be worse in any particular area of the impoundment. No areas of mass movement have been identified on the surrounding slopes due to water level changes and this is not expected to be an issue with the higher FSL.

4.4.2 Analytical Results of Sampled Soils

Samples were taken from the detailed soil sites for laboratory analysis to characterise the soil types and assist in determining their fertility and erodibility. The results are presented in **Table 4-7**, **Table 4-8** and **Table 4-9**. All soils were found to be strongly acid to very strongly acid with pH values usually below 5.5.

The salinity levels in all soils were found to be very low. The phosphorous levels were very low to low for all sites. These low pHs were associated with high exchangeable Aluminium which will be limiting plant growth due to the elevated levels in some subsoils, with the Aluminium saturation up to 40 % at site five. Subsoils exposed during construction activities, such as around the borrow pit or haul road embankments, will benefit from liming to assist with the establishment of vegetation as part of stabilisation or rehabilitation.

■ **Figure 4-14 Examples of the Dominant Soil Types in Road Side Cuttings**

Table 4-7 Soil Laboratory Results

		SITE 1		SITE 2		SITE 3		SITE 4	SITE 5	
		0-10 cm	20-30 cm	0-10 cm	50-60 cm	0-5 cm	20-30 cm	0-10 cm	0-10 cm	20-30 cm
pH Value	pH Unit	5.2	5.4	5.5	5.1	5.4	5.5	5.8	5.3	5.5
Electrical Conductivity @ 25°C	µS/cm	27	17	45	27	78	21	33	13	25
Exchangeable Calcium	meq/100g	3.1	1.9	2.5	0.2	2.1	<0.1	2.8	0.5	<0.1
Exchangeable Magnesium	meq/100g	3.9	4.7	2.4	1.3	2.1	4.0	3.0	1.0	2.5
Exchangeable Potassium	meq/100g	0.6	0.5	0.6	0.4	0.9	0.5	0.4	0.2	0.1
Exchangeable Sodium	meq/100g	0.3	0.4	0.3	0.2	0.3	0.3	0.2	0.2	0.5
Exchangeable Al	meq/100g	<0.1	3	<0.1	<0.1	<0.1	2.1	<0.1	<0.1	2.3
Effective Cation Exchange Capacity	meq/100g	7.9	10.5	5.8	2.2	5.4	7	6.4	1.9	5.5
Aluminium Saturation	%	-	29	-	-	6	30	-	-	41
Exchangeable Sodium Percentage (ESP)	%	4	4	5	9[#]	5	4	3	10[#]	9
Copper	mg/kg	<1.00		<1.00		<1.00		<1.00	<1.00	
Iron	mg/kg	53.1		72.3		44.4		26.6	103	
Manganese	mg/kg	5.21		3.57		98.5		16.8	1.52	
Zinc	mg/kg	<1.00		<1.00		<1.00		<1.00	<1.00	
Total Kjeldahl Nitrogen as N	mg/kg	1150		1890		3280		2650	1270	
Total Phosphorus as P	mg/kg	114		256		195		722	122	
Bicarbonate Ext. P (Colwell)	mg/kg	2		<2		3		15	22	
Total Organic Carbon	%	1.84		3.45		3.96		4.75	3.67	

[#]These values are considered un-reliable due to the very low ECEC

Table 4-8 Particle Size Distribution of the Sampled Soils

Sample	Gravel (%)	Sand (%)	Silt (%)	Clay (%)
Site 1 (0-10 cm)	1	48	34	17
Site 1 (20-30 cm)	0	32	34	34
Site 2 (0-10 cm)	0	44	27	29
Site 2 (50-60 cm)	2	25	21	52
Site 3 (0-5 cm)	3	15	52	30
Site 3 (20-30 cm)	0	6	44	50
Site 4 (0-10 cm)	15	21	44	20
Site 5 (0-10 cm)	8	52	22	18
Site 5 (20-30 cm)	3	29	19	49

The high proportion of silt and sand in the surface of some of the soils indicates the potential for soils to set hard especially when devoid of surface cover.

Table 4-9 Test Results for a Number of Subsoil Samples

Site Number	Depth (cm)	Field texture	Emerson Class Number#
1	30	Light medium clay	8
2	60	Medium clay	8
3	30	Light medium clay	5
4	30	Light clay	6
5	35	Light medium clay	2 (slight)

- The Emerson Class Number (ECN) rate how dispersible soils are. ECNs of 5 and higher are rated as non dispersive.

The subsoil at site five was found to be sodic (ESP of 9 %) and disperse slightly in the Emerson test. All other subsoils were not sodic and did not disperse. The high Aluminium saturation generally would tend to limit dispersion in these subsoils and therefore represent a high erosion risk instead of very high erosion risk. Dispersible soils were found to occur on the broad ridge below the dam wall (at site five), where one of the site offices is proposed to be located.

4.4.3 Acid Sulfate Soils

The Project site is well above 5m AHD and Acid Sulfate Soils (ASS) will not be encountered in these geomorphological environments (ie they are not conducive to their formation or retention), as part of the proposed construction works.

4.4.4 Erosion Hazard Assessment

Given the steep slopes around the impoundment there is a high potential for soil erosion, however there was minor erosion observed around the current impoundment area or within gullies draining into the dam, as these slopes are currently heavily vegetated. Minor erosion has been caused by wavelets around the impoundment and an example of this is shown in **Figure 4-15**.

The soils of the catchment above Hinze Dam appear to be well stabilised with siltation in the dam reported to be minor (SKM, 2005). This is probably attributable to the high proportion of forest cover in the catchment above Hinze Dam.

The erosion hazard of the soils are presented in **Table 4-10** and are based on the results of physical and chemical testing of soils found in the Project area as well as the general characteristics of these soil types.

- **Figure 4-15 Evidence of Erosion in the Recreation Area**

- **Table 4-10 Erosion Hazard of the Soil Types in the Project Area**

Soil types	General occurrence and erosion hazard	Wind erosion	Water erosion
Red Ferrosols	Formed on Greenstone, known occurrences include the right abutment and eastern side of the impoundment. These soils are relatively stable, but sheet and rill erosion will occur in disturbed areas.	Low	Moderate risk of sheet and rill erosion
Tenosols	Common over the Project area, on hill summits and steep slopes. Will form preferentially on hard rocks (ie sequence is generally Greywacke, Chert, Rhyolite, Siltstone, and then Greenstone). These soils are highly erodible due to where they are located in elevated steeply sloping areas.	Moderate - high	High risk of erosion
Kurosols	Common over the Project area where slopes are not as steep and deeper weathering has occurred. These soils are moderately to highly erodible. The sandy loam surface is highly erodible if disturbed.	Moderate – high	Highly risk of sheet and rill erosion
Sodosols	Alluvium of mixed sources, often upper terraces. These soils are very highly erodible. Care should be taken not to expose the highly erodible subsoil. Small areas may also exist in the Neranleigh-Leigh Fernvale Beds.	Moderate – high	Very high risk of erosion including gullying
Rudosols	Young soils adjacent to active stream channels. These soils are generally sandy and moderately erodible.	Moderate – high	Moderate erosion risk
Dermosols	Well structured uniform or gradation soils formed on basalt and some alluvium.	Moderate - high	Moderately to highly erodible

Significant erosion can be prevented by using basic erosion and sediment control techniques such as:

- rapidly revegetating areas;
- minimising the time areas are left exposed;
- diverting run-on from the site;
- controlling run-off though drains and disposing to stable drainage lines;
- bunding stockpiled material;
- confining traffic to defined roads;

- compacting high traffic areas; and
- any excavations should be backfilled and covered with topsoil.

Access for heavy vehicles such as trucks and excavators to the site will require construction of access roads which need to be suitably scour protected and drained. Wherever practicable, the order of construction of surface protection works including grassing will shall be such that they provide erosion and sediment control to the parts of the works that they are designed to protect as those parts of the works are constructed.

Before commencing earthworks on any part of the Project, sufficient materials to protect against erosion will be available on Site. Work will be scheduled to ensure that temporary erosion control works are in place by the end of work each day, especially before weekends, if rain is imminent or when permanent erosion control works are not in place. Construction activity will be schedule so that work in sensitive areas can be completed and rehabilitated as quickly as feasible. The use of good practice for erosion and sediment control measures include (but not limited to) minimum disturbance of existing ground cover and vegetation, stockpiling and replacing topsoil, cut-off drains around stockpiles and borrow areas, hydroseeding and hydromulching, geofabric, restoration of surface conditions, sediment traps / basins and mesh fences.

Sedimentation traps and detention basins will be designed for a 24 hour storm event of a return period of 10 years and cleaned out regularly and managed to ensure the required retention capacity is maintained.

If detention basins are incapable of removing suspended matter effectively and standards for suspended solids contents are being exceeded in the river, environmentally benign chemicals will be added to aid settling subject to approval from the Environmental Protection Agency (EPA). Exposed areas shall be protected as soon as possible after finishing by hydroseeding or other appropriate processes to provide a protective cover.

The Erosion and Sediment control plan prepared for the Project is contained in **Appendix F.4.2**. This plan has been based on the on Erosion and Sediment Control: Engineering Guidelines for Queensland Construction Sites (Institute of Engineers Australia 1996).

4.5 Potential Impacts

The construction and operation of the Project will involve the clearing of vegetation, changes to the current flow regime, disturbance of soils and the movement of spoil and other materials across the site. The activities that may have potential impacts with regard to the terrain, soils, geology or geomorphology include:

- quarrying;
- development of borrow areas;
- raising of the main dam embankment;
- construction of the saddle dam;
- construction of the fishway;
- construction and operation of access / haul roads;
- establishment of site offices and worksites;
- clearing of trees for the new inundation level;
- raising existing road heights;
- construction of boat ramps; and
- construction of other recreation facilities.

The location of the major construction activities is shown in **Figure 4-16** .

Figure 4-16

Location of major Construction Activity

Hinze Dam Stage 3 EIS

4.5.1 Construction Related Impacts - Terrain

Raising the Hinze Dam wall will permanently change the topography in the vicinity of the wall, adding about 13 metres to the wall height at the dam wall and saddle dams. These walls will also become wider.

Quarrying activities will permanently remove rock from hillsides on Pelican Point and back towards the dam wall. A total of 2.1M m^3 of 'fresh' rock will be removed as well as approximately 780 000m^3 of overburden material which will be used as general fill, predominately for the new recreation area. The final cut will extend back from Pelican Point, west of the ridge, to be level with the dam wall. The base of the quarry site will be excavated to 85m AHD which will be below the final full supply line of 94.5m AHD. This will result in benching of slopes and exposed rock faces to a maximum height of approximately 90m AHD. Part of the quarry site will be rehabilitated and landscaped for the construction of the new recreation area and facilities. The concept plan for this area is shown in **Figure 4-16** .

The water level in the impoundment will increase by about 10m in height. The steepness of the Nerang and Little Nerang valleys means that this does not equate to a significant expansion in the surface area of the dam, however the raising will result in an additional 533ha of land potentially being inundated. Some additional land areas will also be more likely to flood. The NerangMurwillumbah Road and the western end of the Gold Coast Springbrook Road will require treatment of the road embankments to maintain slope stability and block water from infiltrating where embankments are partially inundated. Approximately 370m of the Gold Coast-Springbrook Road east of Little Nerang Creek (bridge) will be inundated by the 1 in 50 year ARI flood levels of the dam. This section of road will be raised with surface works a total of approximately 700 m required to tie into the existing road surface levels.

There will be no significant changes to topographical features downstream of the dam wall. The topography of the Nerang River and Little Nerang Creek valleys upstream of the new impoundment area are also not expected to change as a result of the Project.

4.5.2 Potential Impacts Geomorphology

As flow is an important independent control on channel geomorphology (primarily because flow controls erosion and deposition), flow modelling was used to assess the impact of the proposed Stage 3 scenario on the geomorphology of the Nerang River downstream from Hinze Dam.

Impacts

Changes to flow regime were modelled using the IQQM (Integrated Quantity and Quality Model). This model is a daily water balance model that is able to simulate catchment runoff, the passage of streamflows along watercourses, storage (dam) behaviour, and abstraction of flows from streams or storages for consumptive use, losses due to evaporation and seepage, and other processes such as releases from storages. The model is used to simulate the above processes over a long historical period (typically 100 years), to include sufficient wet and dry periods to be representative of the long-term climate (DNRW 20067b).

The model was run for three scenarios, pre-development, Stage 2 and Stage 3. For each scenario, flow statistics relating to flood frequency, daily flow exceedence, zero flows and low flows were determined for three sites, Hinze Dam Outflow, Glenhurst Gauging Station and Nerang.

Flood Frequency (Average Recurrence Intervals)

The moderate to large floods with return periods typically between two and five years are generally referred to as "channel forming flows". This is because, in the long term, they transport most sediment due to their magnitude and frequency of occurrence. These flows are well above the sediment transport threshold, and are capable of flushing pools, and mobilising alluvial bars. Channel forming flows are the most important part of the flow spectrum for maintaining geomorphological form and process.

IQQM results predicted that there would be negligible change for the 1.5 and 2 year ARI events. The magnitudes of 5, 10, 20 and 50 year ARI floods are predicted to be between 40% and 50% of the Stage 2 values for the freshwater reaches. For the 100 year ARI flood, this value is predicted to be between 50% and 60%.

The geomorphic impacts of these changes were expected to be as follows:

- reduced frequency of bar flushing causing further encroachment of vegetation into the channel, increased growth of vegetation on bars, increased roughness and potential increased localised deposition of sediment. The risk of impact is considered to be minor due to the low frequency of occurrence of these larger floods;
- reduced pool flushing. The risk of impact is considered to be minor as pool flushing would still occur at lower flood levels and the rate of accumulation of sediment in the pools is still much less compared to natural due to the reduced supply of sediment from upstream;
- changes to bank wetting resulting in potential drying, cracking and failure of channel banks. The risk of impact is considered to be negligible due to the low frequency of occurrence of floods and the nature of the existing banks;
- increased frequency of estuarine tidal penetration and tidal influence. The risk of impact is considered to be negligible due to the low frequency of occurrence of floods and the observed level of impact; and
- increased residence times of sediment within the estuary resulting from reduced freshwater flushing, potentially leading to an increase in sediment accumulation. The risk of impact is considered to be minor.

A summary of IQQM model results for flood frequency is presented in **Table 4-11**.

Table 4-11 Summary of IQQM Model Results for Flood Frequency

Location	Hinze Dam Stage 2	Hinze Dam Stage 3	
	Flow (ML / day)	Flow (ML / day)	% of Stage 2 Flow
1.5 Year ARI			
Hinze Dam Outflow	9	9	100
Glenhurst GS	762	655	86
Nerang EOS	8342	8342	100
2 Year ARI			
Hinze Dam Outflow	9	9	100
Glenhurst GS	1194	959	80
Nerang EOS	15111	14476	96
5 Year ARI			
Hinze Dam Outflow	9112	3605	40
Glenhurst GS	10 071	4289	43
Nerang EOS	30 959	30 458	98
10 Year ARI			
Hinze Dam Outflow	14 825	6181	42
Glenhurst GS	17 116	7320	43
Nerang EOS	42 384	40 496	96
20 Year ARI			
Hinze Dam Outflow	21 862	9725	44
Glenhurst GS	23 469	10 804	46
Nerang EOS	53 352	51 525	97

Location	Hinze Dam Stage 2	Hinze Dam Stage 3	
	Flow (ML / day)	Flow (ML / day)	% of Stage 2 Flow
50 Year ARI			
Hinze Dam Outflow	27 441	13 151	48
Glenhurst GS	31 743	15 633	49
Nerang EOS	72 821	71 701	98
100 Year ARI			
Hinze Dam Outflow	34 217	18 362	54
Glenhurst GS	38 510	21 741	56
Nerang EOS	92 518	86 423	93

Low Flow Statistics

Changes to low flows, particularly those below the threshold of sediment transport, are generally less important for maintaining geomorphic form and process. IQQM modelling predicted:

- negligible difference between the Stage 2 and Stage 3 flows for the 50% and 90% daily flow exceedences (low to median daily flows). Therefore no geomorphic impacts are predicted;
- no change to the percentage of time that flows of less than 1 ML.d-1 are equalled or exceeded. Therefore no geomorphic impacts were predicted; and
- negligible difference between the Stage 2 and Stage 3 flows with respect to the number of zero flow spells for a range of zero flow durations. Therefore no geomorphic impacts are predicted.

Impacts on increased pondage area

The geomorphic impacts of these changes are expected as follows:

- reduction in geomorphic variability (more deep 'pool' habitat, no riffles / runs) in upstream reaches. The risk of geomorphic impact is expected to be minor because these features are found in upstream reaches; and
- bank pore-water pressure may change due to altered frequencies of inundation and drawdown leading to bank weakening. The risk of geomorphic impact is predicted to be minor to moderate. Although steep slopes and gullies surrounded the impoundment, these are generally well-vegetated and the existing (Stage 2) rate of siltation in the dam is reported to be minor (GHD 2006). However, short-term increases in sediment inputs may be expected as new areas become inundated.

4.5.3 Construction Related Impacts – Soils and Geology

During construction, vegetation will be cleared and soils exposed in quarry areas, for access roads and haul roads and for road upgrades.

The borrow area, as shown on **Figure 4-16** , will have approximately 250 000m^3 of material removed for the construction of the dam clay core. Following construction the borrow area will be re-profiled and rehabilitated so the site is safe and stable.

The Project will require approximately 318ha of remnant vegetation to be cleared and/or flooded below the proposed FSL, to enable permanent inundation for the water storage. Wherever soils are exposed, the potential for erosion to occur is exacerbated. This is particularly the case on steep slopes in high rainfall areas. Rainfall at Hinze Dam is high, and intense daily rainfall events in excess of 500mm have been recorded at Mt Tambourine.

Erosion risk during construction of the Hinze Dam raising is therefore considered high, and steps will be taken to control erosion in all areas of construction activity. A detailed erosion and sediment control plan will be included in the Construction Environmental Management Plan and will be implemented.

The main consequences of erosion are loss of topsoil/subsoil and degraded water quality. Loss of topsoil and subsoil will reduce the ability to reinstate disturbed areas following completion of construction, thus exacerbating erosion impacts in the longer term. Water quality issues are discussed further in **Section 7**.

Erosion also causes visual impacts, particularly where revegetation cannot be achieved because of loss of topsoil. Severe erosion may also destabilise structures such as roads, saddle dams and the dam wall.

Within the dam localised water quality issues may arise in areas where soils are disturbed and erosion occurs, washing soils into the water body. This would result in:

- increased suspended solids and increased turbidity in the water body;
- increased sedimentation of the dam which may have implications for the volume of the storage if sedimentation levels are high; and
- transport of nutrients into the dam. This may then create conditions suitable for algal blooms.

Sediment released into the impoundment is unlikely to travel downstream of the dam wall as it would tend to be deposited out of the water column before the water spills over the existing spillway. Sediment released into the Nerang River and Little Nerang Creek upstream of the impoundment may wash into the upper reaches of the impoundment. It may also be deposited in the stream beds, resulting in changes to the stream's hydrological profile and damage to aquatic ecosystems, particularly streambed flora and fauna. Ecological effects would probably be short lived, however hydrological impacts could result in exacerbation of localised flooding in rain events.

The generation of dust during construction will be controlled using dust suppression methods (eg water trucks) for all construction sites and access / haul roads. Dust will be a paticular issue in winter months with stronger winds from the south-west, which corresponds to drier seasonal conditions as discussed further in **Section 11**.

The Recreation Master Plan identifies new multi-purpose recreation trails to be developed. These are likely to be constructed in the same areas as they are currently and will traverse the rehabilitated clay borrow area. The rehabilitation plan for this area will consider the potential end users.

4.5.4 Operation Related Impacts – Soils and Geology

Ongoing impacts to soils and geology once construction is complete are likely to be minimal provided that topsoil loss during construction is controlled and areas of exposed soil are reinstated with vegetation or other protective surface cover following construction.

Waves may cause minor erosion around the banks of the impoundment, especially when the water level is below the full supply level line, and banks are exposed.

Rainfall can cause erosion in catchments and streams due to runoff and concentration of water flows. The cover provided by natural vegetation, over most of the local sub-catchments, reduced the erosivity of rainfall by minimising rainfall impact, reducing runoff and increasing the stability of soil. Where the proposed works clear vegetation and/or disturb the soil there is increased potential for erosion and an ESCP should be developed and implemented. The proposed raising of Hinze Dam will not change the hydrology in the catchment; however a variety of other recreation activities and site access may increase the potential for soil erosion and sedimentation. Major flood events may be reduced in the Nerang River downstream of Hinze Dam due to the flood storage capacity to be provided in the raised dam and flood related erosion may therefore be slightly diminished.

4.6 Mitigation Measures

4.6.1 Topography

There will be significant modification to the topographical features around quarry and the dam wall including abutments where saddle dams are to be constructed. A full description of recommended potential mitigation measures with respect to visual amenity are presented in **Section 18**. No mitigation measures are proposed for the increased height and mass of the dam wall. A rehabilitation plan an Recreation Master Plan has been developed to minimise potential impacts from the proposed saddle dam. Mitigation for the increased area of inundation is only possible through managing visual impact and relocating infrastructure likely to be affected. The visual impact will be managed through the clearing of vegetation up to the full supply line in highly visible and accessible areas. The Nerang Murwillumbah Road is likely to be affected, however the affected section of the road will be raised in consultation with the Department of Main Roads.

4.6.2 Geomorphology

As previously identified, increases in vegetation density may occur on bars within the flood channel due to the predicted reduced frequency of scouring flows. Vegetation encroachment towards the low flow channel may also occur. This may, eventually, change the roughness and flow conveyance properties of the channel, and further stabilise bars that would otherwise be periodically mobile. Vegetation management and opportunities for habitat enhancement exist along the flood channel corridor.

4.6.3 Soils and Geology

The current geotechnical information indicates that the geological foundations beneath the wall are generally suitable for the proposed raising. The geotechnical surveys have identified the detailed geology and geological properties (i.e. areas of foliation or faulting) in the dam wall surrounds and any weaknesses / zones of higher permeability in the material have been accommodated in the design and construction of the walls.

The quarry operations will require development approval for the operation of a number of Environmentally Relevant Activities (ERAs) from the EPA. The approval of this activity will require a quarry plan and environmental management plan, which have been prepared and are presented in **Section 19**. No re-profiling or landscaping is proposed for the quarry site, apart from where the new recreation facilities will be constructed.

The construction of the saddle dam on the eastern side of the main dam wall will involve excavation of fill and weathered rock to a depth of approximately three metres to allow a solid foundation. Spoil from this activity is likely to be placed in drainage lines, in close proximity to the site, below the final full supply level. Spoil to be placed in this manner will be compacted to reduce potential erosion.

The borrow area will extract some 250 000 m^3 of clay. Following construction, the borrow area will be re-profiled and rehabilitated in accordance with a rehabilitation plan specifically developed for the site. A topsoil management plan will be developed for the site to allow the 300mm of topsoil to be stripped and used in the rehabilitation of the site. The rehabilitation plan should consider the proposed use of mountain biking, as outlined in the Recreation Master Plan, in the rehabilitation design.

The new recreation facilities will be constructed on the quarry site which will be rehabilitated with general fill and landscaped. A rehabilitation and landscaping plan will be developed for the site to accommodate the proposed recreation activities. As part of this plan toilet facilities should be located outside the dam surface water catchment if possible and consideration should be given to the use of native vegetation from the surrounding area where ever possible.

Erosion control will need to be incorporated into the construction Environmental Management Plan for any site where vegetation clearing and/or soil disturbance is to occur. All disturbed areas should be reinstated at the completion of construction with either vegetative cover or other protective surfacing. The design and implementation of the erosion and sediment control plan will be in accordance with the Institute of Engineers Erosion and Sediment Control Guidelines (1996).

Vegetation that will be inundated due to the new full supply level will be cleared in highly visible locations, where accessible. This work is described in **Sections 3, 7 and 18**. To minimise erosion, it is recommended that soil disturbance is minimised and clearing methods of blading and grubbing are not recommended. Staging of the works will reduce the impact on water quality at any one time. Activities should also be scheduled to avoid the summer months where high intensity storms are more prevalent.

Soils with dispersible subsoil (Sodosols) have been identified below the dam wall where some of the site offices will be located. Particular attention to soil erosion control measures is required in these soils. No other Sodosols were identified in the Project area and if they do occur, they are only in limited areas, which is consistent with the geology of the area.

Proponent Commitments

- spoil excavated from the saddle dam (to be replaced with more suitable foundations) will be placed and compacted in a manner to reduce potential erosion, in drainage lines below the new FSL. Scour protection and other erosion control measures will be used where appropriate;
- a rehabilitation plan for the clay borrow will be developed with this considering recreation as the end use;
- a topsoil management plan will be developed for the clay borrow area to assist with rehabilitation of the area;
- a quarry rehabilitation plan will be developed that reduces the impacts identified in the visual amenity section and facilitates use consistent with the Recreation Master Plan;
- site specific erosion and sediment control plans will be developed and implemented as part of construction EMPs for any vegetation clearing and/or soil disturbance as part of the construction activities; and
- clearing of vegetation to the new FSL will minimise impact on the dam water quality though, avoiding the use of blading and grubbing clearing methods, staging of works to reduce the impact on water quality at any one time and the scheduling of clearing outside summer months when high intensity storms are more prevalent.