9.2 Geology

9.2.1 General description

The underlying physical geological foundation of the area gives rise to specific landscape features. It also controls the occurrence, distribution and type of water resources in the area, including the groundwater. The geology of the broader area can be divided into two broad types that are generally separated by the N2 road (**Figure 8**)[1]. The description of the geological sequence in this map[2] is currently under review by the SACS Cenozoic Task Group[3].

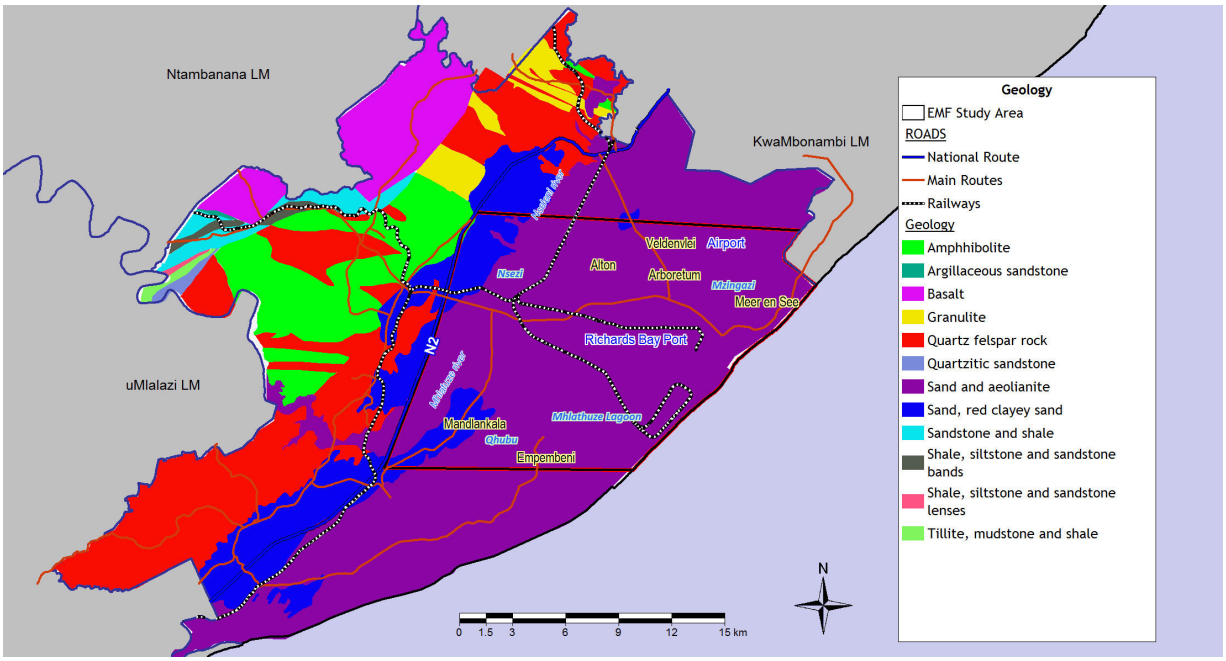

Figure 1: Geology of the Study Area

Empangeni lies on the older hard rock formations of the **pre-Cenozoic Era**[4] in the west while Richards Bay (including most of the study area) lies atop the unconsolidated **Cenozoic Era** sediments of the Maputaland Lithological Group that stretch along the Maputaland coastal plain and into Mozambique (**Figure 9B**). The distinction between the two geological groups is fundamental in understanding the

[1] Golder (2004) *Strategic Level Assessment of Geohydrological Conditions in the uMhlathuze Municipal Area*. Report No: 6223/6568/1/G, 3 November 2004.
[2] Botha G A (1997) *The Maputaland Group: A Provisional Lithostratigraphy for Coastal KwaZulu-Natal*. In Maputaland - Focus on the Quaternary Evolution of the South-East African Coastal Plain. Edited by GA Botha. Council for GeoScience, Silverton, South Africa.
[3] Miller W R (2001) *The bathymetry, sedimentology and seismic stratigraphy of Lake Sibaya – Northern KwaZulu-Natal*. Bulletin 131, Council for GeoScience, Pretoria.
[4] Cenozoic is the geologic era that is associated with the time that continents moved into their current positions. It is also known as the "age of mammals". It is divided into geologic periods and again in the following geologic time divisions (epochs) based on specific physical and chemical characteristics in rock layers.

difference in the groundwater regimes of the two areas and their ecological importance. The deeper groundwater in the hard rock fracture zones has little direct influence on the surface ecological features. In contrast the shallow groundwater in the Maputaland Group primary aquifer is strongly linked to various ecological functions[5].

Between the two broad geological units lie the unconsolidated **Cretaceous[6]** age sediments of the Zululand Group (St Lucia Formation) that forms a distinct hydrogeological unit (**Figure 9A**)[7]. The St Lucia Formation underlies much the same area as the Cenozoic sediments but these sediments generally have such low permeabilities and poor water quality that they are considered a separate hydrogeological unit.

One of the principle purposes for describing the geology is the water bearing properties of the different hydrogeological units. Consequently, this report describes the collective features of the three main hydrogeological units formed by (1) the Maputaland Group, (2) the St Lucia Formation and (3) the hard fractured rocks of the pre-Cretaceous Period. It suffice to say that the groundwater is contained within the voids formed between the soil particles in the unconsolidated layers of the Maputaland Group while the water is mainly associated with the faults and fractures in the consolidated (hard rock) formation. The unconsolidated sediments of the St Lucia Formation are separated from the Maputaland Group because they have very low void spaces due to the fine nature of the clay and silt particles that make up a large proportion of these sediments. This inhibits the storage and movement of water to create an aquitard/aquiclude between the other two hydrogeological units.

9.2.2 Hard Rock Geology of the Empangeni Region

The basement of the greater area consists predominantly of volcanic successions extruded during the break-up of Gondwana[8]. These basement rocks[9] crop out to the west of the study and form the main geological succession in the Empangeni region. Of the granitic-gneiss form, these hard fractured rocks covered by a thin mantle of weathered soil occupy the western region of the study area. They form a sound geotechnical basement for construction while the fractures and faults form the main groundwater bearing features. These fractured rocks forming the Natal Monocline slope toward the sea beneath the study area at an angle of about 5o as shown in **Figure 9A.** However, most of the study area lies to the east of these geological outcrops.

[5] Taylor R, B. Kelbe, S. Haldorsen, G. Botha, B. Wejden, L. Vaeret and M. Simonsen, (2006), Groundwater-dependent ecology of the shoreline of the subtropical Lake St Lucia estuary. *Environmental Geology* 49; 586-600.R
[6] Cretaceous refers to a geologic time period and system that was characterized by mass extinction.
[7] Adapted from Worthington 1978
[8] Miller W.R. 2001. The bathymetry, sedimentology and seismic stratigraphy of Lake Sibaya – Northern Kwazulu-Natal. Bulletin 131, Council for Geoscience, Pretoria.
[9] Dingle R V, Siesser W. G. and Newton A. R. 1983. Mesozoic and Tertiary geology of southern Africa. A. A. Balkema. Rotterdam. 375 pp

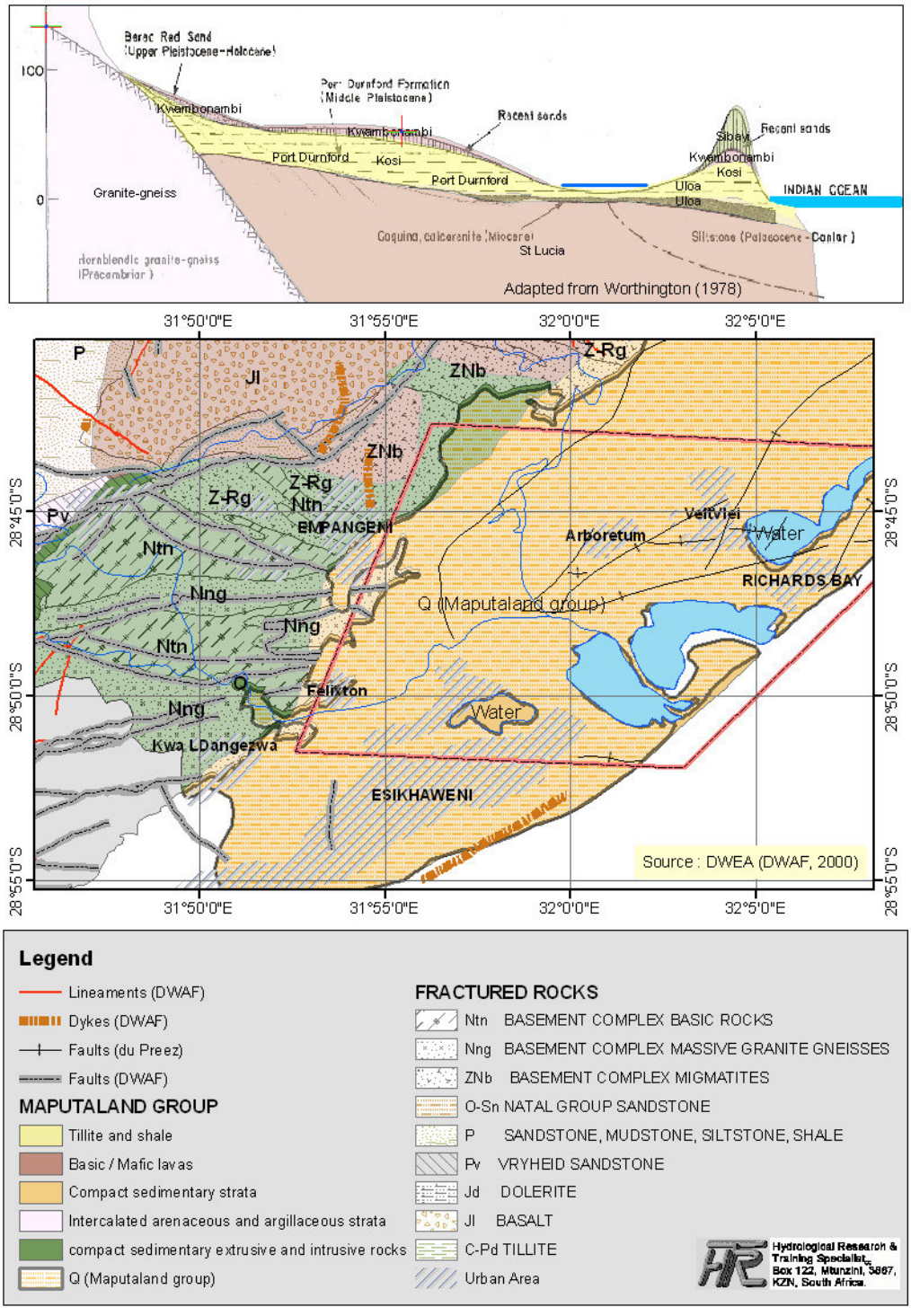

Figure 2: (A) A generalised vertical cross-section from West to East through the study area. Adapted from Worthington, 1978. (B) A map of the main geological features (from DWAF, 2005). Superimposed on the map are the geological fault lines and the shaded areas of urban settlements.

9.2.3 Basement Rocks Underlying the Maputaland Group

Overlying the basement rocks to the east of the N2 are the Cretaceous-age sediments of the St Lucia Formation. These sediments form an effective basement that seals the groundwater in the main sedimentary layers forming the Maputaland Coastal Plain and is an important feature in defining the extensive primary aquifer in the study area The St Lucia Formation is also important for geotechnical reasons and the depth below the surface is a major consideration in future developments[10].

The St Lucia Formation sediments underlie the entire Zululand coastal plain and are several hundreds of metres thick (up to 2500m in Mozambique) all dipping seaward at 1° to 3°[11]. The *lower layers* of the of this formation were formed when the sea level was more than 100m below present and consist of *alluvial*[12] and beach deposits where the main rocks are chalky sandstone, shale and limestone. However, the upper layers consists of deep water marine sediments that have been deposited on a seaward sloping continent during the subsequent Cretaceous period, when the coastal areas of KwaZulu-Natal were beneath the sea, sediments where deposited along the continental shelf to form siltstone and mudstone marine strata. Following coastal upliftment and declining sea level, these marine strata were elevated and eroded so that they are now exposed along the banks of the principal rivers in Zululand (Umfolozi, Hluhluwe, Umzinene and Mkuze) and around sections of the coastal lakes in the north leaving an abundance of fossils where they are exposed.

The erosion of the St Lucia Formation left a deep paleochannel that runs through the harbour and estuary which was formed during the ice age regression and was infilled by subsequent alluvial deposits when the sea level rose again above the present levels. The erosion also created paleochannels through Lake Mzingazi and Lake Nsezi. Little data is available to define the morphology below Lake Cubhu but it is assumed that it lay within the broader Mhlathuze paleochannel. Subsequent deposition and infilling of these paleochannels with alluvial sediments is described in the next section along with the Maputaland Group of sedimentary deposits forming the coastal plain.

9.2.4 Maputaland Group

The sedimentary sequence of the Maputaland Group overlying the Cretaceous mudstone forms the main stratigraphic features of the primary coastal aquifer. The stratigraphic sequence of the Maputaland Group covering the coastal plain is illustrated in the schematic composite section in **Figure 10**.

[10] Transnet-Richards Bay CT and MPT Expansion Feasibility Study Report – Volume 2: Port Terminals. Annexure 14:Geotechnical Investigation.
[11] Dingle R.V. , Siesser W. G. and Newton A. R. 1983. Mesozoic and Tertiary geology of southern Africa. A. A. Balkema. Rotterdam. 375 pp
[12] Alluvial relates to water - soil or sediments deposited by water.

Overlying the Cretaceous are the Miocene sediments of the Uloa and Umkwelane Formations. An estimate of their spatial extent in the study area is shown in **Figure 10.** These formations are discontinuous and appear to be isolated remnants following erosion during the last Glacial Maximum when sea levels dropped more than 100m below the present sea level about 10,000 years ago although there have been suggestion that they may represent paleoreefs. These formations have been described as the main aquifers in the region[13].

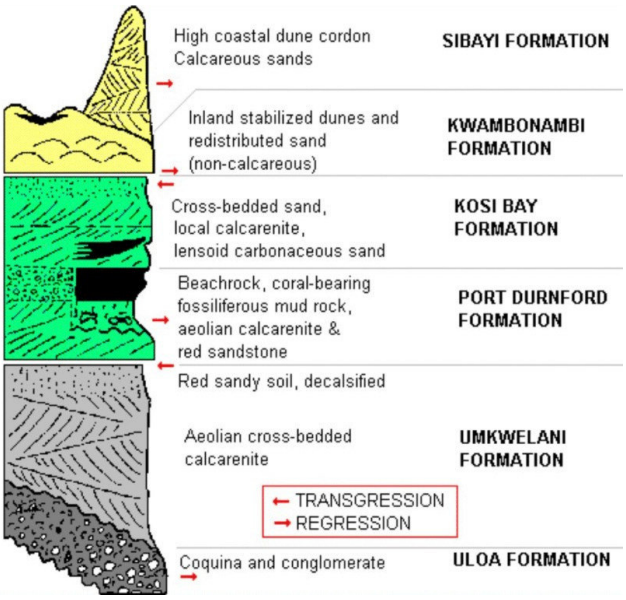

Figure 3: Schematic composite section through the proposed Maputaland Group as proposed by Dr G.A.Botha. The subdivision has been proposed by the SACS Cenozoic Task Group but has not yet been formally recognized by SACS (Miller, 2001)

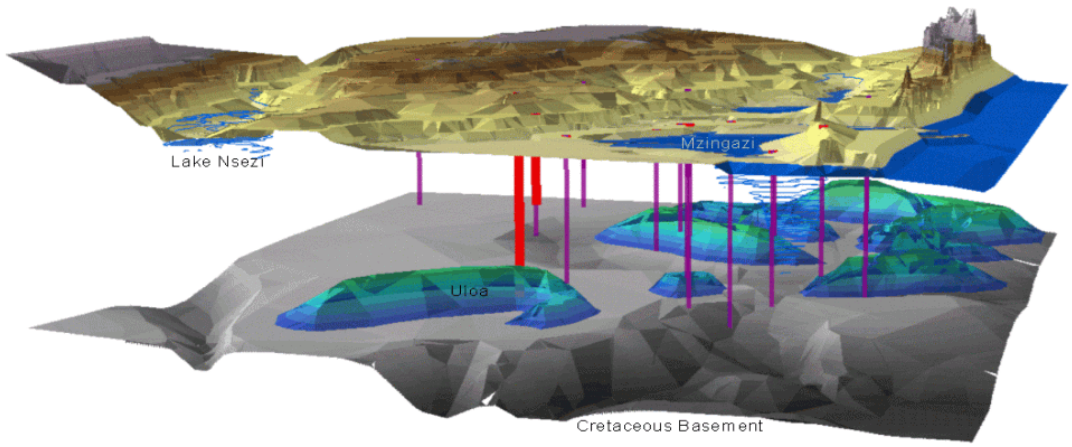

Figure 4: Three dimensional representation of the top and base of the primary aquifer. The vertical lines represent boreholes. The green-blue contour area represents the Uloa Formation lying between the incised paleochannels in the Cretaceous bedrock.

[13] Worthington P. F. (1978) Groundwater conditions in the Zululand Coastal Plain around Richards Bay. An integrated case history of detailed hydrogeological evaluation. Report RFIS 182, CSIR, Pretoria.

Miocene Formation

The Miocene deposits are discontinuous strata comprising a lower coquina (Uloa Formation) and an upper calcarenite (Umkwelane Formation)[14] that have recently been given their separate formation status[15]. While these deposits are discontinuous and confined by the overlying and less permeable clayey sand deposits of the Port Durnford Formation, there are indications that they may be in hydraulic contact with major drainage boundaries such as coastal lakes[16], harbour and the Ocean. The linkage with the drainage patterns of Lake Mzingazi would enhance the groundwater "flow through" nature of these lakes which could have important consequences for the potential yield of these water resources.

These deposits have been described as the main aquifer in the study area. There are significant differences in the pressure head and water quality trends between the Miocene deposits and the overlying strata in the Alton and Meerensee area that indicate a lack of hydraulic connectivity between these sediments.

Port Durnford Formation

Overlying the Miocene deposits is an extensive layer of varying sedimentary types comprising clayey sands, sandy clays to lignite bands that form the Port Durnford Formation deposited during regressions and transgressions in the late **Pliocene**[17] to Early Pleistocene Eras. The Port Durnford is exposed along many sections of the coast line in the study area. Near eSikhawini, these beachrocks cause the local water table to be raised above sea level and may be responsible for much of the dune erosion. These deposits have varying hydraulic properties but are generally much lower than the Miocene. Their lower hydraulic properties provide a confining layer overlying the Miocene.

Kosi Formation

The red sandy soils; local calcarenites and lensoid carbonaceous sand[18] of the recently classified Kosi Formation of Mid to late Pleistocene age generally overly the Port Durnford across the study area. It is difficult to separate these from the other geological formations in borehole logs because of their classification.

Kwambonambi Formation

Much of the coastal plain in the interior of the study area is covered by ancient stabilised dunes and reworked sand that are very permeable. In areas with very shallow water table there are

[14] Maud R R and W N Orr (1975) Aspect of post Karroo geology in the Richards Bay area. Trans. Geol. Soc. S. Afr. 78, 101-109

[15] Botha G A (1997) The Maputaland Group: A provisional lithostratigraphy for coastal KwaZulu_Natal.

[16] Kelbe, B. E., and T. Germishuyse. 2000. The Interaction between Coastal Lakes and the surrounding Aquifer. International Association of Hydrogeologists. XXX Congress 2000, Cape Town. 26 Nov - 1 Dec 2000.

[17] Pleistocene is a geologic period that is associated with the time that humans evolved and spread throughout the world; it ended approximately 10 000 years ago.

[18] Calcareous sands are associated with marine deposits.

accumulations of peat. Where the peat has been disturbed and becomes undercut, severe erosion can occur, as happened on the stream between Hillside and the harbour.

Sibayi Formation

The high frontal dunes, formed by recent (Holocene Era) aeolian processes comprise the Sibayi Formation that overly the Kosi or Kwambonambi Formations. These deposits are comprised of fine to medium sands that highly erodible and permeable. In St Lucia, the water table can be as much as 80-90m below the top of these dunes because they are so permeable. These dunes are rich in heavy minerals and are being mined to the north and south of the study area.

Alluvium

These sediments overlying the coastal plain have been eroded with the transgressions and regression of the sea where there are major drainage channels. These eroded channels have been infilled with alluvium and covered by recent aeolian sands[19]. The quaternary-aged alluvial (estuarine and lagoonal) deposits have completely filled the deep burried paleochannels in the Mhlathuze Floodplain that were incised into the bedrock during the last Weischelian regression when the sea level was more than 100m below the present sea level (Transnet, 2007). These eroded channels were filled during the Flandrian transgression when the sea level rose in stages to its present position. Where the rate of rise in the sea level was greater than the sedimentary deposition by the Mhlathuze River, a lagoon (partly closed estuarine) environment would develop with relatively quiet water conditions that were conducive for the deposition of fine material (clays) that created the Harbour Beds. The Harbour Beds typically consist of unconsolidated and interstratified sediments that range in particle size from sand through clay. These soils are of a lagoonal or estuarine origin. The sand layers are fine through to coarse grained, often silty, lensoids in form and vary from very loose through to very dense in consistency. The interqlayered silty clay/clayey silt generally occurs as a dark grey, very soft deposit (known as Hippo Mud), in places thicker than 20m, and a deeper brownish grey, soft through very stiff, silty clay. Gravel and boulders of various origins, size and shape are sometimes found at or near the bottom of the Harbour Beds.

The youngest naturally occurring soils in the Port are the recent littoral deposits of beach and dune sands that extend to depths generally not much deeper than 5 m below the natural surface. A description of the geological and geotechnical developments during the harbour developments has been described in Transnet (2007).

[19] Aeolian relates to the wind – carried, deposited or eroded by the wind.

9.2.5 The Occurrence of Mineral Resources

The coastal dunes of the area are of aeolian origin and comprise calcareous sandstones and unconsolidated sand overlying boulders and pebble deposits. These sands contain exploitable heavy minerals that were deposited by the ocean in the form of titanium oxide bearing sands (ilmenite, rutile, leucoxene) and zircon sands. The mining of these minerals in the broader area are meeting 100% of South Africa's demand for titanium oxide and pig iron. A survey of mineral commodities in KwaZulu-Natal highlights the importance of these minerals for the provincial economy[20].

The area is also rich in building sand and clay deposits. The Quaternary sands of the Maputo-Beira Formation is reportedly a good source of silica (the highest potential source area for silica in KwaZulu-Natal is located approximately 18km northwest of Richards Bay). An area of particularly high potential for the mining of aggregate for building material has also been identified about 15km west of Richards Bay[21].

[20] MINTEK (2007) *A survey of precious metals, base metals, nuclear sector minerals, ferrous minerals and selected industrial minerals in KwaZulu-Natal*. Report produced for Trade & Investment KwaZulu-Natal, May 2007.

[21] MINTEK (2007) *A scan of building sector materials and related products in KwaZulu-Natal*. Report produced for Trade & Investment KwaZulu-Natal and dated May 2007.