6. GEOLOGICAL ASSESSMENT

The evolution of the landscape in the Eastern Cape can be traced from the Late Proterozoic to the present (Toerien and Hill, 1989). This section provides a brief overview of the bedrock geology and the historical development of the various landforms, and outlines the geo-hazards prevalent in the study area, identifying areas potentially susceptible to slope failure and high erosion risk. Slope gradients used within this study were calculated using a Digital Terrain Model (DTM), and would require verification in the field prior to construction activities proceeding.

6.1. Geomorphology of the Landscape

6.1.1. Topography

From the planation surface below Zuurkop (1 017 m), which overlooks the Poseidon Substation, the topography descends into the Fish River Valley. The Zuurberg mountains rise gradually above this valley (> 900 m) before descending steeply onto the coastal plain. The topography within the study area is deeply dissected in the Zuurberg mountains, but becomes subdued in the south near the Coega River Mouth and along the lower reaches of the Sundays River. Planation surfaces are evident on the interfluves and along the tops of the ridges. Much of the area between the Zuurberg mountains and the coast at Grassridge lies between 150 m and 250 m above mean sea level.

6.1.2. Soils

The soils within the study area are typical of those from dry arid areas, and appear to be closely associated with both the underlying geology and topography. From the Poseidon Substation to the foot of the Zuurberg mountains, the soils are rich in carbonates, often cutanic and have an over-riding clastic texture. Exceptions occur on the steep slopes below the Poseidon Plateau, where the soils are rocky and variable in character, and the area below the substation itself, which have a cutanic horizon; in the immediate vicinity of Eureka, west of Kommadagga, where the soils are red, well-drained, deeper than 300 mm and have a high base status; and on the floodplains of the Little and Great Fish Rivers is underlain by undifferentiated soils within fluvial sediments (De Corte *et al.*, 1987).

The lower slopes of the Zuurberg are covered by soils with a cutanic character and Red B horizon, while the upper north-facing slopes are covered in rocky soils of variable character.

For a short distance on entering the mountain-land, the study area crosses red eutrophic soils in the upper catchment of the Krom River. As the topography of the Zuurberg reduces in height towards the south, there is a concomitant increase in the lime content of the soils. On the southern footslopes of the Zuurberg mountains, the Red Apedal B horizon persists, and the soils take on a cutanic character, which is not present at higher elevations (De Corte *et al.*, 1987).

At Wolwekop, the study area descends into a tributary valley of the Sundays River for a short distance, with undifferentiated soils similar to those associated with its main channel at Addo, before traversing well-drained soils with Red Apedal B horizons. These soils are more than 300 mm deep, but still have a high base status (De Corte *et al.*, 1987). From Wolwekop to the railway station at Lendlovu, the study area crosses calcic soils similar in structure to those between Grassridge and Koega Kamma (De Corte *et al.*, 1987). From the edge of the Sundays River floodplain at Addo to Koega Kamma, the study area traverses well-drained sandy soils with a Red Apedal B horizon. These soils have a high base status and are less than 300 mm deep. The Sundays River floodplain is underlain by undifferentiated soils within fluvial sediments, similar to those found in the same environment in the Little and Great Fish Rivers floodplains. The southern section of the study area between Koega Kamma and Grassridge traverses a coastal plain rich in fossil marine deposits. This calcareous material has contributed to the widespread occurrence of carbonates within the soil profiles of the area (De Corte *et al.*, 1987).

6.2. Geology

6.2.1. Stratigraphy

The oldest sequence of rocks in the area belongs to the Palaeozoic Cape Supergroup, which in turn can be divided into the Table Mountain, Bokkeveld and Witteberg Groups of decreasing age. These sediments are overlain by the Karoo Sequence, which is comprised of the Ecca and Beaufort Groups. The Dwyka Formation separates the Cape Supergroup and the Karoo Sequence. These sediments underlie the Uitenhage Group and Tertiary to Recent deposits associated with pedogenic and marine processes. Pelitic rocks with subordinate sandstones and quartzites of the Cape Supergroup, within an eroded anticline, form the resistant spine of the Zuurberg Range. These sediments are separated from the more recent Jurassic and Cretaceous sediments of the Uitenhage Group by the Jurassic basalts, tuffs and breccias of the Zuurberg Group. The sediments of the Uitenhage Group decrease in age towards the coast from the conglomeritic Enon Formation to the fine grained muds and subordinate sandstones of the Kirkwood and Sundays River Formations.

The study area north of the Fish River is underlain by mudstones and sandstones of the lower Beaufort Group. In the far north of the study area, a limited number of dolerite dykes are evident. Between the Fish River Valley and the northern flank of the Zuurberg, the study area crosses a syncline dominated by the sandstones of the Ecca Group and an anticline dominated by the shales of the upper Witteberg Group.

In the southern portion of the study area, a small section of the highly fossiliferous limestones and conglomerates of the Tertiary Alexandria Formation is traversed west of Olifantskop. The lower Sundays River has cut into these sediments and has laid down extensive deposits of river gravels on the southern bank, the remnants of which now form low level fluvial terraces (e.g. Soetgenoeg).

6.2.2. Seismicity

The area in which the study area falls is dominated by the topographic expression of the Cape Fold Belt (CFB), a Permian to Triassic orogenic event (Toerien and Hill, 1989). Axial planes dip towards the south-west, with the intensity of the folding decreasing northwards. Thrusts are present in places and show displacement of up to 4,5 km on the Baviaanskloof Thrust (Toerien and Hill, 1989). Normal faults subsequently developed south of the CFB due to tensional stresses which accompanied the break-up of Gondwana. These faults now form the boundary along which the half-graben Algoa Basin developed, becoming filled with sediments of the terrestrial and marine Late Mesozoic Uitenhage Group (Toerien and Hill, 1989). Evidence of epeirogenic tectonic activity during the Cenozoic, and the Quaternary has recently been found, although of much less magnitude than that described above (Partridge and Maud, 1987; De Klerk and Read, 1988; Hill, 1988; Toerien and Hill, 1989; Andreoli *et al.*, 1996). Fernandez and Guzman (1979a) have suggested that Modified Mercalli Scale Intensities (MMI) are unlikely to exceed VI every 100 years or VII every 500 years in the study area. Table 6.1 lists the historical record of earthquakes in the study area.

Table 6.1: Historical Record of Seismic Activity in the immediate vicinity of the study area and the co-ordinates of the epicentres where known

Date	Time (Sast)	Latitude (Degrees)	Longitude (Degrees)	Richter Magnitude	Modified Mercalli Intensity	Region
1850/05/25	-	-	-	-	-	Port Elizabeth
1883/09/30	22:00:00 GMT	33,9 S	25,7 E	-	III	Port Elizabeth
1910/10/21	20:40:00 SAST	-	-	-	-	Port Elizabeth
1912/02/20	15:00:00 SAST	-	-	-	-	Port Elizabeth & Somerset East
1920/12/04	08:00:00 SAST	-	-	-	-	Port Elizabeth
1932/08/09	14:55:00 SAST	-	-	-	-	Port Elizabeth
1968/01/12	01:00:08 GMT	33,7 S	25,2 E	5.5	VI	Uitenhage
1969/09/29	22:07:00 SAST	-	-	-	-	Port Elizabeth
1977/11/05	-	-	-	-	-	Port Elizabeth
1986/10/06	-	-	-	-	-	Eastern Cape

After Fernandez and Guzman (1979b); De Klerk and Read (1988); Smith (*pers. comm.*, 2000)

6.2.3. Mineral Deposits

Very few metalliferous deposits are known from the region, none of them of economic importance (Toerien and Hill, 1989). Building and road materials are quarried at a number of locations. However, none of these are located within the immediate vicinity of the alternative corridor alignments. The only site of note is of historical interest, namely a borehole sunk near Addo (by SOEKOR) which had an uneconomic oil showing.

6.3. Slope Stability

6.3.1. Rainfall

Slope failure could be triggered by rainfall or seismic activity within the study area, the former being the most likely. Caine (1980) developed empirical formulae to describe the relationship between rainfall events and shallow landslides, such as those present in the Zuurberg range. These equations were used to estimate the risk of slope failure within the study area.

Equation 1:

$$I = 14.82D^{-0.39}$$

Where: I = Rainfall Intensity (mm/hr)

D = Duration of rainfall (hr)

No debris flow activity occurs when $I < 14.82D^{-0.39}$ (Innes, 1983).

Similarly slope failure can be described by the threshold:

<u>Equation 2:</u>

$$d = 14.82D^{0.61}$$

Where: d = rainfall (mm)

Using equation 1, at least one rainfall event has exceeded the threshold. This occurred on 1 September 1968 in Port Elizabeth, when 429 mm fell in 24 hours. If equation 2 is adopted, the threshold for slope failure has been exceeded at least 10 times. These events are listed in Table 6.2 below.

Table 6.2: Extreme rainfall events which have exceeded the threshold for slope failure at sites within the study area

Location	Date	Rainfall (24 hr)
Somerset East (Hospital)	21 August 1971	116 mm
Cookhouse (SAR)	11 February 1975	118,2 mm
Cookhouse (SAR)	27 May 1944	118,4 mm
Cookhouse (SAR)	30 October 1941	131,6 mm
Addo	26 May 1957	117 mm
Addo	21 July 1970	132 mm
Port Elizabeth	11 February 1961	121 mm
Port Elizabeth	25 March 1981	224 mm
Port Elizabeth	26 April 1962	105 mm
Port Elizabeth	1 September 1968	429 mm

Shallow landslides are present on some of the steeper slopes within the Zuurberg area. Some of these have been attributed to heavy rains in 1995 (Mrs Adendorf, *pers. comm*, 2000), which are not reflected in the rainfall record above. The greatest risk to landslides is within the Zuurberg range but are unlikely to pose a major threat to a Transmission line if those slopes with a gradient greater than 20^{o} are avoided. The impact is of low significance if this guideline is adopted.

6.3.2. Seismicity

Slope failure can be triggered by seismic activity on both steep and flat slopes. Keefer (1984) found that "the predominant minimum intensity for disrupted slides and falls was MMI (Modified Mercalli Intensity) VI, and the lowest reported in any earthquake was MMI IV. The predominant minimum intensity for coherent slides, lateral spreads, and flows is

MMI VII, and the lowest intensity reported was MMI V." The study area falls within an area Fernandez and Guzman (1979) suggested would not experience an earthquake greater than V-VI in the next 100 years or VI-VII in the next 500 years. Therefore, the chances of slope failure are negligible, if any. The minimum slope angles on which the various types of slope failure can be expected to occur at MMI greater than VII are, however, listed in Table 6.3. These minimum slope angles susceptible to failure can be used to assess the potential stability of tower sites selected for a new Transmission line in the unlikely event of seismic activities occurring.

Table 6.3: Slopes susceptible to slope failure at Modified Mercalli Intensities greater than VII (After Keefer, 1984)

Slope Failure Type	Minimum Slope for Failure
Soil Falls	63^o
Rock Falls	40^o
Rock Slides	35^o
Rock Avalanches	25^o
Soil Avalanches	25^o
Rock Slumps	15^o
Rock Block Slides	15^o
Disrupted Soil Slides	15^o
Slow Earth Flows	10^o
Soil Slumps	7^o
Soil Block Slides	5^o
Rapid Soil Flows	2.3^o
Subaqueous Landslides	0.5^o
Soil Lateral Spreads	0.3^o

Although a risk does exist, it is highly improbable that seismic activity will cause slope failure within the study area. The impact is of low significance.

6.4. Erosion Risk

The erosion risk within the study area is largely limited to slopes greater than 20°, although accelerated erosion may occur on any un-vegetated slopes. Morgan (1986) regards any slope greater than 20° as a "*...high to very high erosion hazard*". Few towers tend to be located on slopes greater than 20° due to the associated construction, stabilisation and re-enforcement difficulties, as well as the risk of erosion. The existing Poseidon-Grassridge 400 kV and 220 kV Transmission lines only have one and two towers respectively which are constructed on slopes of such a steep nature, despite their routes crossing the rugged Zuurberg mountains.

Construction is to be avoided on the sites with slopes greater than 20°. If no other sites are available, great care should be taken that the construction site is not left denuded of vegetation for any length of time. Immediately after erection of the towers, disturbed areas should be re-vegetated with appropriate species as soon as possible. In addition, sufficient supports and re-enforcement must be introduced to the site for stability. Great care should also be exercised in the construction and maintenance of the access/service road to these sites, as it is likely to pose a very high erosion risk in the future. Ideally, the steep sections of any service/access road should be paved to mitigate against the erosion hazard.

Those towers located on floodplains would be at risk from flood waters which would scour away sediment from around the base of the towers. However, this is unlikely to pose any real threat to the overall stability of the Transmission line. The effects of the flood waters will be of low intensity and significance, unless a tower is located close to an active channel where a real risk that the tower could be undercut and collapse exists. This can easily be avoided by ensuring that towers are erected well away from river banks.

6.5. Conclusions

The study area covers a wide range of land types exposed to a wide variety of geomorphic processes, the most significant of which are the risk of slope failure and erosion. Both of these pose little threat to a Transmission line in the long- or short-term, with the exception of those towers erected on slopes greater than 20°. These are anticipated to pose a high erosion risk and special care should be taken in their final placement and construction.