Geomorphic Considerations in the deterioration of Rural Roads: The Case of Inkandla, Indwedwe and Ga-Modjadji

Nkhensani Khandlhela

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UNDERTAKING

The research reported herein was undertaken in the Discipline of Geography, School of Applied Environmental Sciences, University of Natal, Pietermaritzburg, and in the Inkandla and Indwedwe areas, KwaZulu Natal Province, and the Ga - Modjadji area in the Northern Province, under the supervision of Prof H.R. Beckedahl.

The work represents an original undertaking by the author. Where use has been made of the work of others it has been duly acknowledged in the text. This dissertation has not been submitted in any form for a degree to any other university.

Nkhensani Khandlhela
University of Natal, Pietermaritzburg
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ABSTRACT

The condition of the rural road network in South Africa is in a severe state of deterioration and remains a matter of concern for inhabitants of rural areas. Apart from heavy use, the main problem is that road development is often neglected and the main focus is placed on the geomorphic environment. The objective of this study is to identify the nature of the geomorphic constraints of vehicular access on unarmoured roads in the rural areas of KwaZulu Natal and the Limpopo Province of South Africa, and to gain a better understanding of how these function. It is hoped that some of the insights gained can then be used to inform policy decisions regarding the location and design of rural roads in the future.

In this study, a number of unarmoured roads were studied in detail to identify the possible environmental constraints on vehicular access. A number of soil physical and chemical properties were used to examine the state of road degradation. These properties included particle size analysis, soil strength, Cation Exchangeable Capacity and Exchangeable Sodium Percentage. The results of the investigation of soil properties have shown that they play a significant role in road degradation. The major geomorphic factors involved in road deterioration include soil type, soil erosion and precipitation characteristics, mass movements, slope conditions and human activity.

The physical characteristics, especially the soil and slope conditions, make the access roads in all study areas susceptible to soil loss. Factors such as geology, drainage and friable soils vulnerable to mass movements have been identified as seriously constraining vehicular access. Soil erosion problems in the study area are largely the result of physical and chemical properties of soils combined with steep gradients and have been identified as the primary cause of road degradation. It was further found that the socio-economic conditions, together with the anthropogenic influences such as the construction of rural access roads on vulnerable slopes, population density and the removal of vegetation cover in all the study areas have significantly enhanced road deterioration.

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CHAPTER 1

Rural Access Roads in Context

1.1 Introduction

Reliable access from villages to markets, larger centres and social services is an essential component of the quality of life of rural populations (Schelling and Liu, 2000). The provision of basic "all-weather" road access serves as a valuable instrument for rural poverty alleviation (Jacoby, 1998). Roads facilitate transportation between producers and markets, improve access to health facilities, cultural, educational and domestic services, and provide local residents with employment options (Creighteney, 1993; Heggie and Vieckers, 1998; KwaZulu Natal Department of Transport (KZNDOT), 1999). Unfortunately, poorly maintained roads have resulted in high transport costs and deficient transport services throughout many areas in Africa and other developing regions.

Many villages in developing countries do not have "all- weather" road access and are often cut off for long periods during the wet season, when access roads become impassable. In sub-Saharan Africa, for example, people travel along rural roads and seasonal tracks that are poorly maintained, and walk long distances on treacherous paths and footbridges to transport crops and obtain water and firewood. As a consequence, the social and the economic development of these rural regions is greatly impeded.

In South Africa, the condition of the rural road network has long been recognized as a major impediment to the economic development in the more remote rural areas and has remained a major problem (Howe and Richards,1984; Riverson and Carapetis, 1991; Carns Consultant Group, 1997; Heggie and Vieckers, 1998). A large proportion of the inhabitants of rural South Africa lives in remote areas without adequate access to social, technical and economic facilities. Such conditions ensure that visits to clinics, schools and markets are infrequent because of the prolonged and exhausting journeys rural people must undertake.

Most community access roads in the rural areas of South Africa have been neglected and have deteriorated to such an extent that many are no longer usable. The crisis regarding the state of South Africa's roads, particularly for the poorest of the poor in the rural areas of the former homelands, has drawn media attention. This is illustrated by many newspapers articles, for example the *Daily Dispatch* of the Eastern Cape Province reports that several roads in the Haga-Haga and Kei mountain areas have deteriorated to such an extent that transport operators have declared the roads no-go areas as a direct consequence of the damage to vehicles and the slow progress vehicles make along these routes (*Daily Dispatch* Reporter, 1999). The same newspaper has reported that Winterstrand residents have repeatedly repaired damage to roads in their area by their own manual labour after applications to the Amatola District Council failed (Naki, 1999).

The province of KwaZulu Natal, together with the Eastern Cape and the Northern Provinces, host the majority of South Africa's poor, with many people living in the rural areas having inadequate road access (Ndebele, 2000). In most instances, poor accessibility and mobility in rural areas has been interpreted as the result of the natural environment and has the effect of limiting the social and the economic growth of the region.

It is generally accepted by politicians that the provision of a road infrastructure should be considered as a basic essential economic and social infrastructural service which supports not only economic growth and development, but also social development. President Kennedy once said: *"It is not wealth that creates roads, but roads that create wealth",* (Carns Consultant Group,1997, p 1.1),a view supported by Omar (1997) in his capacity as Minister of Transport, and reiterated by former President Mandela in 1998, at the opening of the Noluntu project in the Eastern Cape. It has been reiterated by President Mbeki in his inaugural speech in 1999 in the context of the importance of accessibility to essential services such as clinics. The views cited above serve to highlight the need and urgency for rural road network development in South Africa and further display the importance of an adequate infrastructure in the context of poverty alleviation and rural development.

The deterioration of roads and the absence of adequate rural road networks can be attributed to a number of environmental factors interacting with the geomorphic environment. These factors include topography, climate, geology, soils, poor drainage and other related processes.

Limited literature exists on the geomorphic constraints affecting vehicular access to rural areas. The measurement and documentation of soil loss and the effect of vehicles have been done at a number of scales. Wilshire (1978) noted how motorcycles in California (USA) have resulted in conspicuous modification of soil and vegetation. Wheel traffic studies by Voorhees *et al.*(1978) have revealed a greater degree of soil compaction in Minnesota resulting from the passage of heavy machinery but did not investigate the primary cause. Ohu *et al.*(1993) in their investigation of vehicular traffic on the physical properties of sandy loam soil profiles in a semi-arid region of Nigeria, concluded that the results of loading on the soil showed that dry bulk density and penetration resistance increased with the number of tractor passes.

Very little work has been done in South Africa on investigating how the natural geomorphic environment (i.e the physical landscape incorporating the ruggedness morphology and assemblage of processes which affect the landscape) impacts on rural road access. Beckedahl *et al.*(2001)have shown how effective vehicular access can enhance infrastructural development in the rural areas of South Africa. Moodley (1997) has shown that off-road vehicles (ORV) have impacted negatively on the geomorphic environment by altering the basic properties of the soil surface, such that accelerated erosion is favoured. While these studies emphasized the effect of vehicles in causing soil erosion, they did not consider the environmental constraints on rural road access in relation to unarmoured roads. It is therefore important to undertake studies that will explore the nature and causality of geomorphic constraints surrounding rural access roads. Such quantitative studies will serve as evidence to support rural development projects aimed at upgrading of the rural road network in South Africa.

The deterioration of South African rural roads due to the natural environment remains a matter of concern, especially in the former homelands. Commonly, rural road networks in developing countries consist mainly of earth and gravel roads and tracks and are characteristically in a poor condition. Generally, a track can be explained as the simplest road. Tracks are passable by vehicles during long dry seasons and cannot be used in rainy seasons. By definition, an earth road is made by merely scraping away the surface vegetation and they are thus rarely passable in bad weather. Beckedahl *et al.*(2001), define tracks as *informal roads*. These roads, at most, carry an average of a few dozen vehicles a day. By contrast, a gravel road is made of a layer of gravel on top of an earth formation which will, according to Beckedahl *et al.*(2001), be classified under *formal low cost roads*. These roads carry more traffic than village roads or tracks. If properly maintained, gravel roads or formal low cost and earth roads can be all-weather passable.

The nexus between rural access roads and development has been extensively researched by development economists and politicians (Derman and Maasdorp, 1981; Ahmed and Mahabub,1990; Creighteney,1993). Researchers agree that the construction of roads to provide access to rural communities will create opportunities for economic growth and development. Commonly mentioned are the opportunities for agriculture and other economic activities, better access to schools, health and other community services, installation of electricity and telephones and an enhancement of the social order which forms the fabric of modern society. According to Williams (1988), an inadequate road infrastructure reduces the quality of living, as access to employment opportunities and services are limited.

In a study conducted in Jamaica, improvement of roads has resulted in or been associated with, rural electrification, water supply and new housing schemes(Howe and Richards, 1984). Time saving benefits linked to productivity are also raised by Derman and Maasdorp (1981) as a factor related to the development and improvement of road networks in Swaziland. In Columbia, the improvement of rural roads in areas previously inaccessible by vehicles resulted in travel times falling to a fifth or sixth, with transport costs following a similar pattern (Bryceson and Howe, 1993). The diagram below sets out the results of Osborne (1998) case study conducted in Malawi. Figure 1.1 shows the cause and effects of poorly maintained roads in Dzedza District Malawi. Following this figure, it is apparent that inadequate access as a result of poor access roads leads to a multitude of problems in many developing countries.

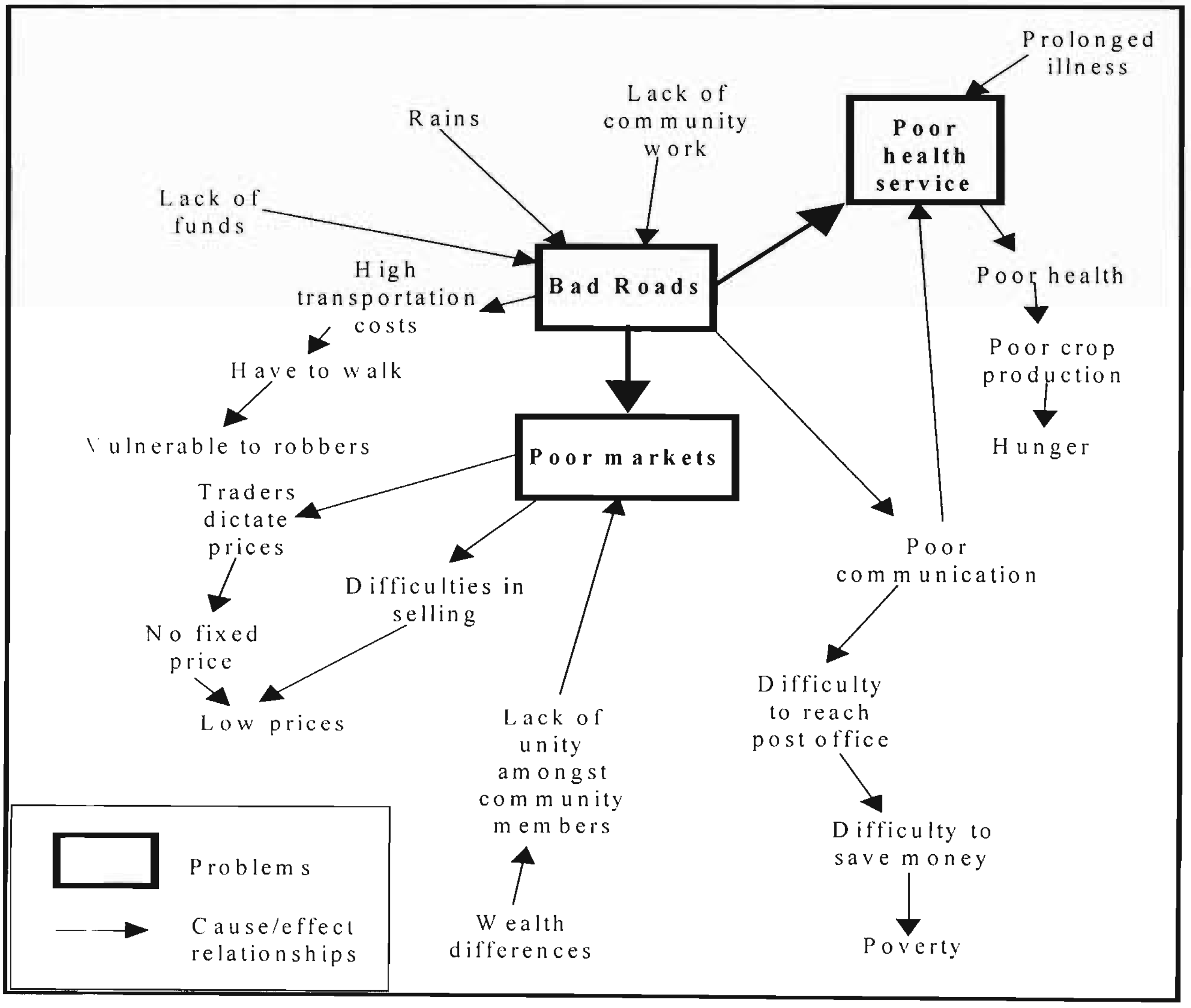


Figure 1.1. The effect of poorly maintained roads: community perspective, Kasumba Village (Malawi). Source: Malawi Participatory Livelihood Assessment exercise (Synthesis Report, Care International: Osborne, 1998).

1.2 Rationale for the study

Basic road accessibility from villages to markets is vital for the socio-economic development of rural areas. The provision of services such as health, water and education in most rural areas is hindered by the fact that some areas are inaccessible by road thus, for example, emergency vehicles are often unable to reach rural homes and businesses because of the bad state of roads in the rural areas. The primary concern is that road development is strongly dominated by the physical environment. This includes environmental factors such as topography, climate, soil and geology, which potentially cause serious limitations to the development of transport infrastructure in the rural areas of South Africa.

In the light of the aforegoing discussion, it is hypothesized that the upgrading and construction of rural roads should be based on an understanding of the environment and especially of the local geomorphology. In order to test this hypothesis, the present study intends to examine geomorphic constraints affecting vehicular access and to assess the difficulties experienced by the rural dwellers in the KwaZulu Natal and Northern Provinces of South Africa resulting from the poor conditions of the existing rural road network.

1.3 Aim and Objectives

The aim of this research is to explore the constraints of the natural geomorphic environment on rural road access and the consequent effect on the social and economic status of rural communities. This will be achieved by addressing the following specific objectives:

- To identify and explain the nature and causality of environmental constraints affecting vehicular access in the study areas.
- To identify the primary factors which affect poor road maintenance;
- To understand how these constraints affect the socio-economic life of villagers, including people's perceptions and attitudes about their local environment; and
- To advise land managers and local development workers on possible action which is in concert with the prevailing environmental processes operating

A number of degraded roads were studied in detail to identify the possible geomorphic constraints on vehicular access in three rural areas: Inkandla and Indwedwe in the province of KwaZulu Natal and Ga-Modjadji area in the Northern Province. For the purpose of this study, *geomorphic constraints* may be regarded as any circumstance in the biophysical environment which impacts upon vehicular access to a given area. It includes determinants such as topography, slope instability (rockfall and rockslides), surficial slips, bad drainage and floods disasters resulting in bridge or road collapse, overland flow and soil erosion processes.

Vehicular traffic includes all vehicles irrespective of whether they are animal drawn or self-propelled, although emphasis will be on motorised forms of transport. Access roads in the study can be defined as those roads that improve mobility between settlements and provide access from the main feeder road to public infrastructures such as schools, clinics and community facilities, or provide access to a market.

In order to meet the stated objectives, it is necessary first to review the relevant literature, thereby contextualising the study within a broader geomorphological debate. Geomorphic processes and variables that are integral to the study of the rural road access include climate, soil erosion, mass movement, terrain and drainage. These are discussed and examined in Chapter 2. Chapter 3 will present a detail environmental context of the three regions. In Chapter 4, the methodological framework and the relevant study methods are discussed. Chapter 5 describes and briefly explains the physical geomorphic findings of the rural roads studied, based on the quantitative data obtained. The findings pertaining to the human dimension are discussed in Chapter 6. Chapter 7 reviews the importance of the findings presented, and conclusions that were drawn about the geomorphological aspects of rural road access are presented in Chapter 8.

CHAPTER 2
Literature Review

2.1 Environmental Factors on Rural Roads Access

On the basis of the information presented in the previous chapter, it is necessary to review the environmental factors which are related to rural access roads. The construction and the maintenance of unarmoured roads can be better understood by comprehending geomorphic processes and variables associated with access roads. Roads are inherently dependent upon their local natural environment, both during their construction and afterwards. If this is not anticipated at the planning stage, both the road and the surrounding environment are likely to become degraded overtime. The durability of the road will be reduced and the local environment damaged. In brief, a road changes the natural equilibrium. The task of the planner is to ensure the integrity of both the road and the environment are preserved as closely as possible. Environmental factors such as slope instability problems, climate, rockfalls and landslides, drainage and soils can often inhibit vehicular access in any area. Investigating the link of these factors to rural road degradation is an essential measure towards developing sustainable remedial techniques and much needed approaches to road access options. In order to develop or upgrade rural roads, it will be important to evaluate the environmental influences on both road construction and maintenance.

2.1.1 Climatic Control on Rural Road Access

The significance of climate on road development cannot be underestimated. The need for a road also depends on the climate. This includes variables such as rainfall, temperature, wind, humidity and fog. Most African roads have dirt surfaces of varied quality and they often become impassable during wet weather. Some roads are only usable on a seasonal basis, for heavy rain can quickly damage surfaces and erode or compromise the foundations.

According to the report Technical Recommendations for Highway TRH 17 (1988), climate is the most important single influence on weathering and the durability of natural road building materials. Precipitation and evaporation for example, many rocks especially of the crystalline type, may decompose in high precipitation or may readily disintegrate. Decomposition and disintegration are principal forms of weathering and decomposition and are more detrimental to the quality and durability of natural road building materials (TRH 17, 1988).

Extreme rainfall also plays a major role in making the roads impassable. In tropical grasslands, for example, tracks are passable by vehicles during long dry seasons, but they cannot be used in rainy seasons (White and Senior,1983). Heavy rainfall can cause serious difficulties due to micro pore water pressure and decreased internal shear strength. Poorly constructed roads in tropical areas are regularly breached by washouts in each rainy season. White and Senior (1983) illustrate the potential role by citing the case of the road between Kano and Guru, Nigeria, which had to be abandoned. These problems do not only exist in Africa, however. Heavy rainfall during summer caused flooding in South Eastern Scotland, washing away bridges, culverts and embankments and again restricting access (Barwell *et al.*1988).

In high rainfall areas such as the West African coastline and high relief areas such as the mountainous areas of Rwanda and Malawi, downpours make it difficult to maintain good roads (Hoyle, 1988). It is further evident from the same study that mass movements involving land slipping or major slumps occur along the roads after periods of heavy rainfall. The frequent recurrence of such weather phenomena reduces the value of roads. They also affect vehicular access to the local communities.

In southern Africa, the effects of floods were extensive in the early months of the year 2000 in Mozambique, Zimbabwe and the Northern Province of South Africa. The floods seriously affected the road network. In many parts of the Northern Province, heavy abnormal rainfall of approximately 1160 mm experienced during February 2000 resulted in roads, bridges and other infrastructure being washed away. Floods that occurred in Mozambique during February / March 2000 disrupted all connecting roads and bridges in the Gaza province and turned tarred roads into dirt tracks, while bridges were washed away, leaving vast areas inaccessible (Dateline ACT, 2000).

Damage to roads caused by flooding are outlined in the KwaZulu Natal Department of Transport (2000) report. The damage which South African rural roads commonly face as a result of floods include:

- Link roads are washed away;
- Road verges are washed away or undermined;
- Bridge walls are damaged;
- Extensive potholes and sink holes develop;
- Low level crossings are washed away;
- Approaches to bridges are washed away.

Dry weather deterioration is also mentioned by Dierke (1992) as one of the most important condition for road deterioration. He summarizes the deterioration mechanisms under dry weather circumstances as follows:

- Wear and abrasion of the road surface which generates loose material and develops ruts
- Loss of fines of the surfacing by traffic and wind.
- The movement of loose material into corrugations under traffic action.
- Ravelling of the road surface caused by insufficient binding power of the material to keep an intact wearing course. This results in the forming of depressions with results in decreasing riding qualities.

Since climate may also influence the equilibrium moisture content, the designer of roads should always consider the climatic conditions and avoid using excessively water susceptible or temperature sensitive materials (TRH 4, 1985).

2.1.2 Roads and Mass Movement

Slope movements can be caused by human activity, or be entirely a natural phenomenon. The stability of both rock and soil slopes is an important factor and influences the pattern of land use. Many mass movements can interrupt or impede transportation and communications and eliminate some options for future land use. Mass movement, according to Howard and Remson (1978), involves falling, sliding, flowing and subsidence and their expressions include falls, avalanches, landslides, flows, creeping soils and collapsing or settling ground.

Factors which influence slope stability are cited by Mathewson (1981) as those which:

- Decrease resistance, for example increased pore water pressure and decrease of shear strength;
- Decrease shear stress, for example removal of support, increased loading and transitory earth stress.

Slope movements are generally caused by a decrease in shear resistance of soil or rock materials due to the presence of water and / or an increase in the disturbing force. Increased disturbing forces leading to slope failure may be caused by the removal of base support of a slope, for example by river erosion or man-made excavations, by increasing the load on a fill, from earthquakes or volcanic activity, by removal of lateral pressure caused, for example, by pore water in joints, soil voids and swelling of clay minerals (Varnes, 1978).

Mass movements present serious challenges for road development in hilly terrain. Mass movements such as flows, slides and falls can lead to the frequent need for road re-construction and can pose a considerable safety risk for road users. When constructing access roads, areas prone to mass movement must be identified and should be avoided, where possible.

Hillslope instability has a significant implication for both rural land use and accessibility (Kakembo, 2000). Failures in rock slopes are controlled by structure and discontinuities of the mass (Goudie, 1992). It is important to assess the stability of a rock slope along a road side, as failures cost time and money to repair, besides being life-threatening. To determine the stability of a rock slope, the most important factors are the structure and geometry of the rock mass, which may be obtained by the collection of geological data, for example mapping, core logging and use of exploration adits and to measure the shear strength of material to determine potential for movement (Thomas, 1991).

A common cause of slope instability on rural roads is pore water pressure, but the role of human activity cannot be ignored when explaining slope instability. This situation is frequently exacerbated by activities such as bad drainage or clearing of protective vegetation that normally resist shallow slope failure. Such activities have the potential to affect road access development in rural areas. In many cases, road development in hilly areas is directly or indirectly responsible for the occurrence of mass movements. Through excavations at the base of the slope, humans not only create steep slopes, but they also remove some of the basal support at the foot of the slope, diverting too much water onto the slope.

Slope instability problems are common along roads due to alterations in slope and drainage characteristics and play a role in restricting access (Parizek, 1971). Slope stability can be further upset by the creation of road cuts or embankments. Excessive steepness of cut slopes, a deficiency of drainage, modification of water flows and excessive slope loading are emphasized by Tsunokawa and Hoban (1997) as potential causes of landslides. This lends credibility to the argument that the changes resulting from road building increase the potential for erosion and mass movement. Hence, road-building to increase accessibility in the Alps in Europe is seen as one reason for the increased occurrence of landslides, as slopes are destabilized by undercutting and consequently lead to degradation (White and Senior, 1983). The building of roadways at the top of slopes can result in excessive slope loading, causing failure downslope of the road, particularly where road runoff is not carefully managed.

The steeper the slope, the more likely it is to be unstable. Steep slopes predominate in areas of deep valleys, as do bedrock cliffs, which are potential rockfall sites. Such phenomena make the area unsuitable for road building. The steep slope characteristics of cut and fill along ravines and deep dongas also increases the probability of erosional processes, such as mass movement, and this can result in poorly constructed roads failing (Skempton and Hutchison,1969; Young,1972).

According to Gerrard (1981) rockfalls are small landslides where individual blocks or a series of blocks become detached from the cliff face. Common causes of rockfalls include high rainfall, freeze-thaw and desiccation weathering. The significance of rockfalls as constraints to effective vehicular access are demonstrated by Bushing *et al.* (1987), in his study on conservation road maintenance reports in Santa Calina Island (California). He observes that heavy rains and wind may combine to loosen soils and rocks from slopes adjacent to roadbeds, causing land or rockslides to fall on the road's surface. Such occurrences pose a safety hazard as they narrow the passable road surface.

Cuts into slopes can intercept groundwater and slopes can become prone to landslides as a result of weakening of overlying strata. Where cuts are located below the water table, the probability of rockfalls and landslides increases. Ground water pressures such as pore water pressures in joints are critical in many slope instability problems. According to Cooke and Doornkamp (1990), rockfalls occur where a steeply sloping rockface consists of well-jointed rocks, a situation outlined in the work of Selby (1993). It is the lack of support from the base of the rocks that leads to such falls. This also occurs when the slope material is no longer able to resist the force of gravity.

Slope stability can be improved by quite a number of methods, which will be discussed in greater detail in Chapter 6. They essentially focus on removing unstable or potentially unstable material, and by flattening the slope gradient or removing weight from the upper slope. Finally, by cutting benches into the slope and by excavating to reduce the driving forces acting upon the slope, as suggested by Thomas (1991). Use of vegetation for erosion control and slope stabilization has been emphasized by a number of researchers. Lewis and Johnson

(1995) suggest a plantation of *Kudzu* as one method of minimizing slope instability along roads to provide a dense ground-cover along road slopes.

Vetiver grass (*Vetiveria zizanioides*) is receiving increasing international attention for its special properties in stabilizing slopes and resisting soil erosion. Hengchaovanich (1996) stressed the successful use of vetiver grass as a means of erosion control and slope stabilisation. According to Erskine (1992), vetiver grass has the prospect of being an economic and efficient means of protecting land against erosion in rural areas. It is a fast grower, a soil binder (Karar *et al.*, 1997) and it is also appropriate for gully stabilisation as its fibrous roots go as deep as 3 metres. It is unpalatable to livestock and can withstand temperatures as low as -9 ^{0}C (Kakembo, 2000). Its unique characteristics and properties are recommended by Hengchaovanich (1996), who further emphasizes the use of fast growing trees such as *Acacia* species for stabilising slopes which show shallow mass movements. Other conservation methods on slopes include replanting of herbaceous plants and ligneous or woody plants.

2.1. 3 Terrain Conditions Related to Road Access Development

In many developing nations, the problems of topography, especially mountains, presents important challenges to the construction and maintenance of reliable transportation networks. White and Senior (1983) caution that the whole question of a relationship between terrain and transport is not a simple one and must be approached with caution. Terrain conditions encompass variables such as slope declivity, slope direction, elevation and relief.

The role which terrain plays in restricting accessibility has been reviewed by a number of authors. Carns Consultant Group (1997) states that terrain combination of topography and geology, steep sloping ground with boulders and a rocky outcrop provides the worst conditions for infrastructural development. Conversely, flat rolling terrain with firm soils provides the best conditions. TRH 4 (1985) indicates that variations of topography are variations of slopes, and since such variations have an effect on runoff, they also influence the mode, the intensity and the depth of weathering. Terrain conditions can adversely impact on the establishment cost of basic infrastructures such as health and education facilities, roads and water supply. Bryceson and Howe (1993) cite case studies of firewood and water collection, which emphasize the importance of the physical terrain. They consider the number of hours on average a household will spend traveling to meet subsistence or basic needs. To choose an easier route might mean a lower cost of construction per kilometre, but would entail a longer distance and therefore a higher total cost (White and Senior, 1983).

Ardington (1984) stresses that steep hills have serious implications and also pose limitations on the extent of a potential infrastructure in terms of costs and accessibility. The rugged terrain has serious implications for the development of a road infrastructure. In hilly areas it is too costly to provide villages at higher elevations with all-weather roads. This raises serious problems of access.

2.1. 4 Soil Erosion and Road Construction

Erosion of soil by water has been regarded as one of the major problems causing considerable damage to roads (Parizek, 1971; Carrara and Carroll, 1979; Hindson, 1983; and Walter *et al.*, 1983). The main cause of erosion is intense rain. It is responsible for the widespread damage which so often occurs on earth roads (Hindson, 1983). The most immediate and the obvious effect of any road development project on soil is the elimination of the productive capacity of the soil covered by roads and the secondary effects of soil erosion.

The association between roads and soil erosion has not been extensively dealt with in the literature and much attention to soil erosion studies in South Africa is being given to its causes, its significant contribution to land degradation and its effects on the socio-economic conditions of people (Dardis *et al.*, 1988; Cooper, 1991; Garland *et al.*, 1994; Beckedahl, 1998 and Watson, 2000). More research and understanding of the subject of soil erosion in relation to roads is needed.

Water runoff has become the major culprit for erosion on rural access roads in the former homelands of South Africa . Dominant erosional forms in rural roads include sheetwash, rilling and gullying as depicted in Figure 1.1. Often, when runoff from poorly designed road drainage is channeled through culverts, gully erosion occurs. Kenya is often mentioned as one example where runoff has caused intense erosion on roads (Parizek, 1971). Factors favouring the erosion potential in roads include rainfall erosivity, soil characteristics, vegetation cover, slope effect and human impact (Morgan, 1979; Bridges, 1982; Stocking, 1988; Marker, 1988; Moodley, 1997).

According to Hindson (1983), erosion on roads and roadsides or road verges also results from too much water being allowed to accumulate. Most roads have a slight gradient, and if large volumes of water collect on them it will begin to flow. As the volume of water increases so does its speed, causing the likelihood of erosion to increase. Such processes are often responsible for extensive road degradation in rural areas.

Hindson (1983) has attempted to categorise erosion on earth roads as avoidable and unavoidable erosion. He defines avoidable erosion as road failures occurring when water flow on roads is allowed to continue unabated. In each season, under this category, the level of the road sinks a little due to the removal of soil. The more the road sinks, the more difficult it will be to drain the water off the road. This suggests that erosion damage, although imperceptible at first, is liable to increase rapidly in later years.

In addition, roads are subject to unavoidable erosion. Hindson (1983) defines unavoidable erosion as the loss of soil from the road surface, either in the form of dust that has been pulverized by the passing traffic or as mud which is splashed out of tracks by passing vehicles during heavy rains. In the USA for example, Carrara and Carroll (1979) and Walter *et al.*(1983) found that exposed tree roots were the major cause of accelerated erosion on road cuts which is also unavoidable erosion. Erosion and landslide failure became widespread through root-derived cohesion on New Zealand North Island (Preston and Crozzier, 1999). Such losses are difficult to prevent but are nearly always insignificant compared with the loss by avoidable erosion. Simple maintenance procedures to combat or reduce unavoidable erosion on roads include widening of side drains and filling of potholes before and after rains. Common erosion processes that affect most rural roads in South Africa are gullying, rilling and sheet erosion (see Figure 2.1).

Figure 2.1. An example of commonly occurring erosion forms on rural roads, photograph taken after a severe downpour

On-site damage to the roads is defined by Beckedahl *et al.* (2001) as the degradation of the road and off-site refers to soil instability arising as a consequence of road construction. Erosion in the carriageway or in the side drain of the road can also result from too much water being allowed to accumulate. On roads which have a slight gradient, water collecting on them will result in surface flow and as the volume of water increases so does the speed, causing the potential for erosion to increase to a much greater extent. Obviously, such roads will have only a short life-span if nothing is done to divert the flow of water. In due course, they will not be worth repairing and new ones will have to be constructed.

In order to quantify the surface flow of water and erosion on roads, Manning's equation may be used (Selby, 1993,p 183). The equation provides a basis for estimating the velocity of surface flow in relation to channel form characteristics: $V = 1/n\ R^{2/3}\ S^{1/2}$

where V is the average velocity of flow (m /s)

R is the hydraulic radius (m)

S is the average gradient of the channel (m / m)

n is known as Manning 's roughness coefficient

In terms of this equation, hydraulic radius is approximately equal to flow depth, so reducing the concentration of flow by reducing the contributing area for runoff, or increasing water losses by infiltration, or uptake by plants, could reduce flow depths (White *et al.*,1984, Selby, 1993).

Recent studies have challenged the equation regarding the hydraulics and erosion of surface water flows. Nearing *et al.* (1998) argue that the equation has a limited value in eroding rills because of the insensitivity of velocity to slope. Such conclusions are related to the fact that rill roughness tends to be greater at steeper slopes because of the greater erosion induced roughness for the steeper conditions.

Roads are therefore potentially susceptible to hydraulic erosion processes and may contribute substantially to stream sedimentation even during low magnitude rainfall events (Ziegler and Sutherland, 2000). Road-induced erosion in some cases results in cumulative impacts far beyond the road itself, affecting slopes, streams, rivers and dams at some distance from the initial impact (MacDonald *et al.*, 1997; Tsunokawa and Hoban; 1997, Russow and Garland, 2000) and inevitably results in some degree of soil erosion and environmental damage. It is therefore important that any road drainage standards be assessed and planned to effectively reduce road erosion.

An appropriate technique for reducing the amount of water on the road is to reduce the amount of storm-water reaching the road from the surrounding area. Much of the water arrives down footpaths, cattle and cart tracks, coming from the land above the road. If small diversion banks are made along these tracks, the water is diverted into the surrounding bush vegetation and less water will reach the road. In addition, surface retention is increased, increasing the lag time of the storm hydrograph. Erosion on roads can also be prevented by diverting all the water into the surrounding bush vegetation at frequent intervals, so that no excessive build-up of water is allowed on the road surface (Hindson, 1983).
Besides the long-term environmental problems caused by erosion, there are many other problems that create hardship for road users in the study area. Ruts, bumps and potholes can destroy a car's suspension, mud or washouts can make a road difficult or impossible to drive. It then becomes very important to understand each of these problems because it is impossible to discuss erosion control problems without reference to them.

2.1. 5 Problems of Drainage

According to the Technical Recommendations for Highways 4 (TRH 4, 1985), inadequate drainage is responsible for more pavement distress in Southern Africa than Inadequate structural or material design. A proper road drainage is a vital design factor influencing the service life of the road. Drainage design is discussed in detail in the TRH 15 (1984). Drainage associated with any road can be divided into three broad categories: the drainage of the catchment area transversed by the road and the drainage of the road reserve and the drainage of the road surface itself. It is the duty of the geometric designer to ensure that construction materials, particularly in the design layers will not loose their bearing capacity by becoming saturated and they must ensure that the road surface can drain quickly to reduce the possibility that vehicles will hydroplane or skid out of control (TRH. 17, 1988). There is thus a dual potential for conflict here between the engineering and geomorphic criteria affecting roads. The faster the water drains from the road surface, the less the risk for hydroplaning but the greater the erosive power of the surface flow, hence the more likely the degradation of unarmoured roads and the faster the water is carried away from the roadbed, the less likely the bearing capacity of the material is to deteriorate, but the greater will be the erosive power of the water in the road drain for reasons similar to those outlined in section 2.1.4. In extreme cases the road drain will incise (see Figure 2.1) thereby compromising the safety and integrity of the entire road.

Rivers, whether incised or not, provide obstacles, and the larger the river, the fewer the crossing points (White and Senior, 1983). When planning rural roads, major rivers and streams should be avoided as far as possible. Rivers and streams with bridges, or poorly constructed bridges, add to the difficulty of access, particularly after stream flooding.

Culverts, rivers and streams can have tremendous impact on inhibiting vehicular access. Many of the roads are often subject to extreme erosion due to the undercutting of roadbeds, bridges and culverts by adjacent streams (Bushing *et al.*,1987). Culverts beneath roads are used to direct runoff under the roadbed instead of below it, which helps prevent erosional cutting. Culverts can increase the erosion in natural landscapes below the roads, focusing water down streams and creating gullies in slopes below the roads. Based on Manning's equation, such changes in diffuse surface flow intercepted by the road to concentrated flow along road verges and culverts will cause a decrease in resistance to flow and therefore an increased velocity, with possible development of channel-scouring.

The effects of railway culverts in promoting erosion are emphasized by Kakembo (2000), in his study of artificial drainage induced erosion in Alice in the Eastern Cape Province. He claims that the impermeability of roads concentrates 90- 95% of runoff usually in culverts to discharge considerable volumes over short periods. As a result, outlets from concrete channels and culverts are sites of potential erosion problems, since, at these locations, concentrated flow is released and deep gullies can form as a result.

The size and the type of bridges are also discussed by Nir (1983) as a problem limiting effective vehicular access. He argues that when a bridged stream is not only too narrow to carry all of the volume of a flood, but its flanks near the bridge are also unprotected by an erosion-resistant construction, heavy erosion of the banks might occur. Thus culverts of insufficient capacity to carry flood water may have dangerous consequences, with erosion destroying highways where culverts have been over-topped.

Finally, alteration of the drainage regime of slopes brought about by road-building can induce instability through erosion or increased pore pressure. Tsunokawa and Hoban (1997) caution that when roads are built care should be taken not to undercut or overload steep slopes and particular attention should be paid to implementation of drainage measures, taking into account the impelling and resisting forces operating in surface flow dynamics.

The role played by climate, various erosional processes, terrain conditions, drainage conditions and soil characteristics have been alluded to as central when examining road access problems. The review of literature indicates that very little has been written in South Africa on the influence of geomorphic environment on road access, especially in rural areas. Given the main concern of this study, i.e. how the geomorphic environment impact on rural access roads, it is notable that while there is consensus that access roads in rural areas are constantly deteriorating and generally inadequate, not enough attention has been given to this matter. The environmental context of the three regions will be discussed prior to reporting on the context of the research, which is detailed in the next chapter.

CHAPTER 3

Study Area

In attempting to gain insight into the nature and the extent of the geomorphic constraints on road access, three study sites were selected for detailed investigation. The location of study sites is shown in Figure 3.1. The research concentrated on two provinces within South Africa, namely, KwaZulu Natal with particular attention to the Inkandla and Indwedwe areas, and the Northern Province,focusing on the Ga-Modjadji Area.

Reasons for choosing the specific study areas include: the deterioration in the state of access roads area due to the natural environment, the study areas being located in remote rural areas of varying bioclimatic zones and of different geological substrate. A further constraint was the ease of access from the University in Pietermaritzburg (Inkandla and Indwedwe) and the fact that the researcher 's home is in Giyani (Ga-Modjadji). Also of importance was the availability of community support for the research in terms of provision of local perspective and accommodation. Similar characteristics of the landscapes in all the three study areas are the rugged, hilly terrain and numerous incised valleys. Before discussing the locality of each study site in detail, a brief overview of the physiographic setting of South Africa is necessary in order to give a broader environmental setting.

3.1. Physiographic setting of KwaZulu Natal and Northern Provinces of South Africa

3.1.1 Topography

South Africa occupies the whole of the southern extremity of the African continent, bounded by Namibia in the west. KwaZulu Natal region is dominantly occupied by Zulu-speaking people and has a surface area of 96 967 km^2. It covers 7.6 % of the national territory of South Africa (Schulze, 1982) and is adjacent to the Free State province. The KwaZulu-Natal Drakensberg is physiographically part of the main escarpment and has been described as the most prominent physiographic feature of eastern South Africa. The Northern Province covers an area of approximately 123 910 km^2.

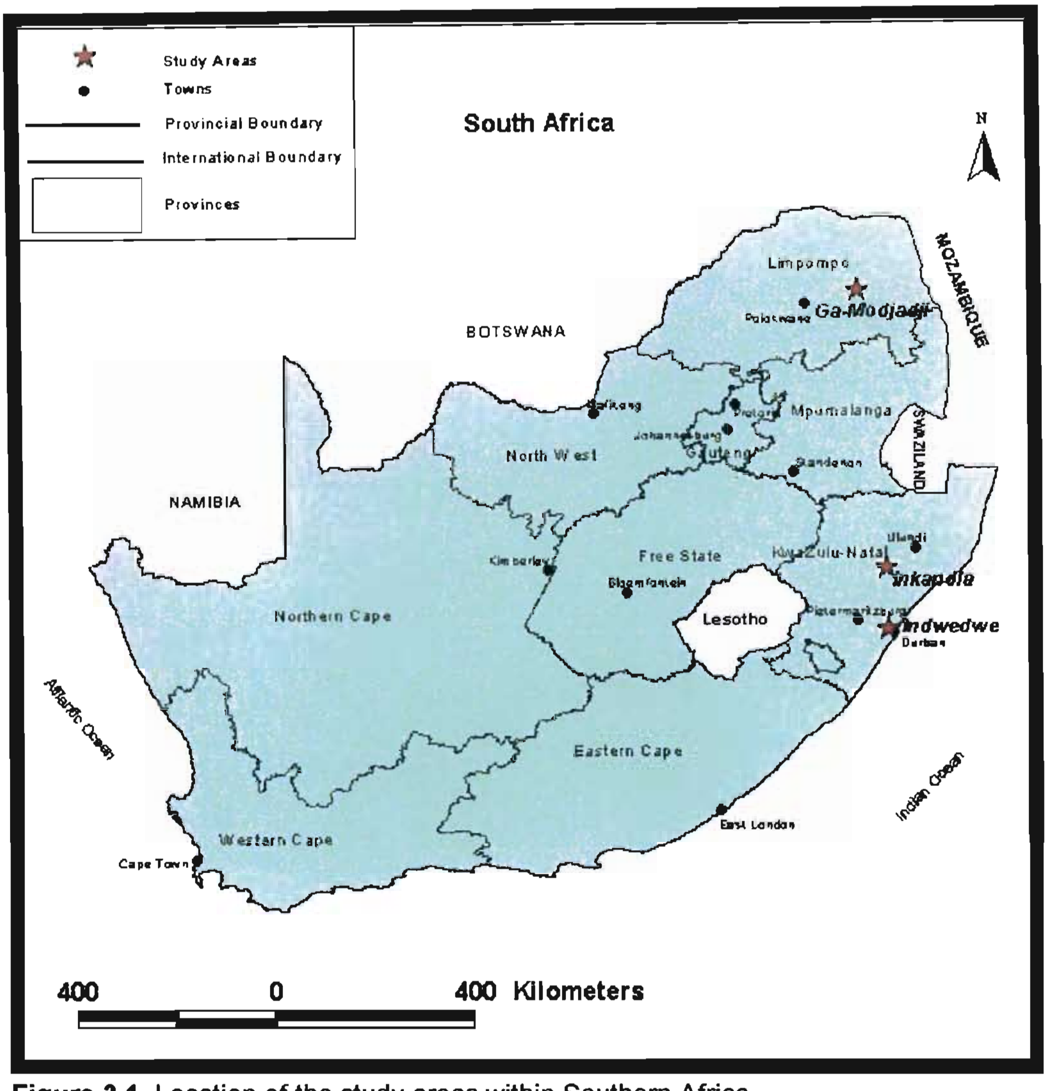


Figure 3.1. Location of the study areas within Southern Africa

South Africa consists essentially of an elevated interior with raised margins. Physiographically, the Republic of South Africa is dominated by a plateau running south to north. It is a high-lying country and the greater part of its land area has an elevation of over 1350 m. South African topography is generally rugged, due to deep incision by rivers following extensive Tertiary uplift and the subsequent recession of the Great Escarpment. The Great Escarpment is the major topographic feature in Southern Africa and is thought to have formed during the continental break-up of Gondwana (Fox and Rowntree, 2000). The Escarpment separates the interior Highveld region from the surrounding middleveld and coastal lowveld regions.

The wide latitudinal extent of South Africa and the great variation in altitude and mountain barriers are important topographical factors of significance in determining accessible areas for road network development.

3.1. 2. Climate

It is generally accepted that climate is a major influencing element, not only in soil and vegetation development, but also in the utilisation of the land. This, in turn, implies that people need to be able to access these lands, the constraints of which have been briefly highlighted in Chapter 1 and which are the focus of this research. The weather and climate of South Africa are strongly influenced by the position of the country relative to the major global circulations (both maritime and atmospheric)and have a major impact on its landscape and people. Southern Africa is predominantly a dry region, with highly erratic rainfall, both in time and space. Such variability in rainfall has important consequences in terms of both antecedent moisture and of extreme events such as floods, which have severe impacts on roads.

From the perspective of road access development in South Africa, rainfall appears to be the most significant variable of all the climatic factors. The annual rainfall over the greater part of the country is extremely variable in quantity, intensity, seasonality and its spatial and temporal distribution. Over much of the country, high intensity precipitation, such as torrential downpours associated with thunderstorm activity, often do a great deal of harm to rural roads, which are most commonly unarmoured. The work of various authors such as Wischmeier and Smith (1958), Hudson (1965;1981) and (Morgan, 1986) indicates that erosivity is entirely a property of the rainfall and is usually dictated by climatic regimes. This view, in the context of the present research, implies that areas with high rainfall intensities could possibly be more susceptible to road erosion and degradation than would areas with low rainfall intensities.

The effect of rainfall intensity is illustrated in Figure 3.2, which shows the isoerodent map of EI_{30} for Southern Africa. The EI_{30} parameter on the map is defined as the product of the kinetic energy of the storm and the greatest average intensity experienced in any 30 minute period, obtained from the storm trace of an autographic rain gauge (Hudson,1981). Estimates of the probable erosivity condition for areas where there are no long-term autographic rainfall records can be obtained through interpolation between isoerodent values.

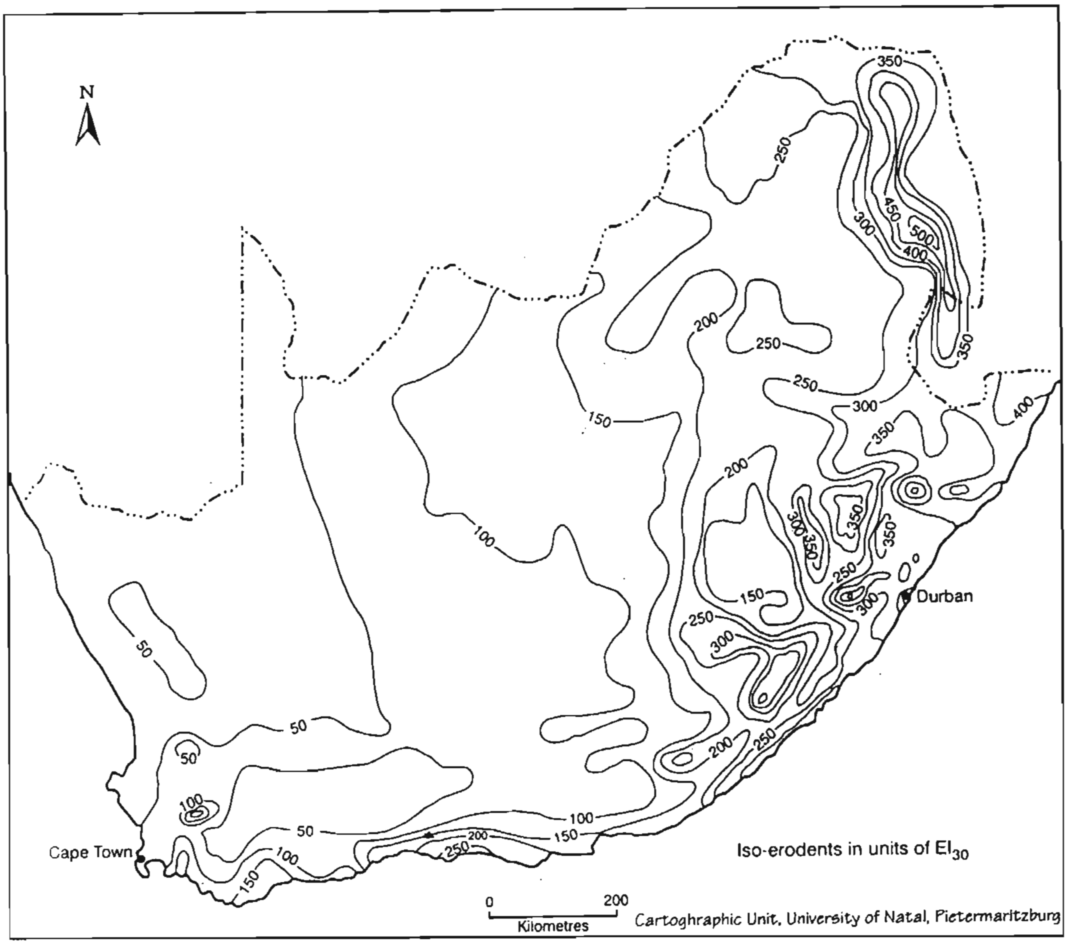


Figure 3.2 Isoerodent map of Southern Africa showing a progressive increase in rainfall erosivity eastwards (Beckedahl, 1996, after Smithen, 1981).

Temperature over the interior of South Africa is linked to the high-pressure field over the region (Fox and Rowntree, 2000). The combined influence of the warm Mozambique current, the presence of the Escarpment and subsequent orographic lifting of moisture laden air, as well as its location with regard to latitude, give the region a climate with relatively high rainfall in the summer months, with the maximum mean monthly temperature rainfall being received in December (Figure 3. 2),slight temperature variations and a long growing season. Winter weather in the interior of South Africa is normally sunny and cloudless and the warm summer months in KwaZulu Natal and the

Northern Province are marked by intense thunderstorms which, when accompanied by hail, can cause extensive damage to roads.

Four climatological regions are found in the Northern Province, ranging from humid latitudinal though followed by an arid to semi-arid region in the north, and finally the sub-humid region (Development Bank South Africa (Northern Province),1998). These regions have been demarcated according to the annual rainfall and average annual statistics for day and night temperatures. The arid region has an average rainfall of 300-360 mm north of the Soutpansberg. The arid to semi-arid region in the Limpopo and Olifants river valleys receives an annual rainfall (mainly as thunderstorms) between 360-600 mm in the lowveld, to 360-540 mm north of the Soutpansberg, and 700 mm of rain is received in some parts of the Waterberg area. The semi-arid region which is east of the Drakensberg Escarpment receives an average rainfall that varies from 600 -700 mm, whereas the sub-humid region has an average rainfall of 850 mm -900 mm. Northern Province is a summer rainfall zone and receives 90% of its total annual rainfall during the period October to March. The average annual evaporation is well in excess of the annual rainfall, which affects surface runoff from rainfall significantly and causes high evaporation in dams (Department of Water Affairs Forestry,1998).

KwaZulu Natal climatological regions are classified into three rainfall areas, of approximately 1400 -2000 mm per annum, 1000 -1200 mm per annum and 700 -750 mm per annum. The highest mean annual precipitation values (MAPs) are recorded in the high Drakensberg range and the Little Berg (1200 -2000 mm per annum). Areas of high rainfall (1000-1200 mm per annum) includes the foothills of the Drakensberg, Richards Bay and the coastal strip south of Durban. The lowest rainfall is recorded in the north-east, on both sides of the Lebombo mountains, part of the basin plainlands of northern KwaZulu Natal and parts of the incised river valleys. KwaZulu Natal is the province with the highest rainfall in South Africa between September and March (Development Bank South Africa KZN, 1998). Most of the coastal regions have a subtropical climate, but the rapid increase in altitude results in a transformation into a more moderate summer rainfall, with regular snowfalls in the upland regions along the Drakensberg in winter. Summer thunderstorms provide the major source (50%) of the total rainfall (Tyson, 1986).

Rainfall is generally in excess of evaporation which, however, does become more significant during winter (when rainfall is low), contributing to the water deficit of the region in winter. According the TRH 4 (1985), Southern Africa can be divided into three climatic regions that is, a large dry region, a moderate region and a small wet region. It is therefore up to the road designer to identify problems that may be caused by the different climates.

KwaZulu Natal and the Northern Province experience a relatively wide variation in temperatures. Temperature not only influences evaporation, but the alternate heating and cooling will also enhance the weathering processes, both mechanical and chemical. Temperatures in the Northern Province vary between 15 ^{0} C and 38 ^{0} C, with an average evaporation of 1750-2500 mm per annum. As the climate varies from warm to very hot, with high humidity, summer days are extremely hot.

In the KwaZulu Natal region, temperatures range from moderately hot summers and moderate winters along the coast to moderately hot summers to cool moderate winters in the interior. The highlands of KwaZulu Natal experience regular snowfalls in the winter, as does the entire province, with the exception of the coastal strip. In KwaZulu Natal, latitude and distance from the coast appear to exert little influence. Altitude is thus a dominant factor (Development Bank of South Africa (KZN), 1998). Throughout the year, there is never a difference of more than 12 ^{0} C between the mean daily temperature at the northern and southern limits of the region at sea level, but an altitude of 1800 m, over a distance of 150 km, makes a difference of 9 ^{0} C in January alone.

3.1.3 Soils

No comprehensive detailed account of South African soil has been compiled. The last generalised soil map of South Africa was published by de Villiers (1962). In discussing the classification of soil of Southern Africa, de Villiers (1962) stated that geology of South

Africa is varied and in many instances the various rocks differ considerably in chemical composition. The soil types of South Africa differ in their physical makeup from gravelly coarse sands to heavy clay with 60 -70% clay.

Erskine (1992) observed that shallow soils such as Mispah and Glenrosa forms are dominant in the lowveld of Mpumalanga and Northern Province and are associated with relatively low, ineffective rainfall. While a few small-scale soil surveys of the KwaZulu Natal area have been undertaken (Granger, 1976, de Villiers, 1962), a comprehensive soil survey for the KwaZulu Natal Drakensberg has not yet been undertaken (Sumner, 1995). Van der Merwe (1962) maintains that the combined effects of high summer rainfall and low dry-season temperatures and the long exposure to weathering are instrumental in the genesis of the general acidic, highly leached, highly weathered and less structured characteristics of the Little "Berg" soils.

3.1.4 Geology

Geology can be an important factor in controlling road degradation. South African geology can be understood in the context of plate tectonics and mantle plumes. An outline of the main geological events which have brought about the present day landscape of South Africa is detailed in Fox and Rowntree (2000). The geological history of South Africa forms part of the broader global processes which formed the earth and its continents and oceans, between 5 and 2,5 billion years ago. The country is part of one of the world 's oldest continents and consists of the world 's oldest rocks. According to Hawkins and Associates (1980) and McKenzie (1984), major geological formations in Southern Africa indicate that there are five major identifiable geological eras. These include the Archean, Pre-Cambrian, Palaeozoic Pre-Karoo, Karoo and Post- Karoo. Each of these eras were separated by igneous, erosion and earth movement activities.

According to Brink (1981), the Karoo Supergroup dominates the geological map of South Africa, covering a large portion of the country. This Supergroup consists of four main divisions, which include the Dwyka Group, the Ecca Group, the Beaufort Group and the

Stormberg Group, indicated in order of age. The Dwyka Group is the oldest (approximately 300 million years) and consists mainly of tillite. The Ecca Group consists of soft dark blue shales, with grits, sandstones, coals and black shales. Ecca rocks are rich in plant fossils, particularly *Glossopteris* and *Gangamopteris* leaves which closely resemble the leaves of modern-day proteas. The Beaufort Group (approximately 250 million years) is exposed over the whole of the Great Karoo and consists of massive buff or yellow weathering sandstones alternating with bright red, blue, green and purple shales and mudstone. Finally, there is the Stormberg Group, which forms the basement rock underlying the Kalahari sands and also covers the whole of Lesotho and the eastern Free State (Fuggle and Rabie, 1992).

The geology of KwaZulu Natal consists predominantly of lithologies belonging to this Karoo supergroup, with moderate exposures of the Natal group sandstone and basement granites and gneisses of the Namaqua Natal Mobile Belt. Structures preserved in these sandstones indicate that the sediments were transported and deposited by rivers that drained highlands to the north east (King and Maud, 1964). The geology of KwaZulu Natal is dominated by the Natal Monocline which is thought to have resulted from the Mesoizic breakup of the Gondwanaland (South African Committee of Stratigraphy (SACS), 1980; King, 1982; Tankard *et al.*,1982). The geological stratigraphy relevant to the KwaZulu Natal region and Northern Province is shown on Table 3.1.

The geology of the Northern Province is referred to by Wellington (1955) as being formed entirely of the pre-Karoo rocks consisting mainly of old granite and the primitive Swazian Erathem, formerly known as the Primitive Swaziland System. Du Toit (1954) states that the granite and the various types of gneisses built the northern parts and the eastern parts of the Northern Province.

Table 3.1 Stratigraphy of KwaZulu Natal and Northern Province (after Tickell, 1974; Truswell, 1977; Kent, 1980, Brandl, 1987, Beckedahl, 1996).

Supergroup	Group	Lithology	age
Quaternary sediments	Berea	Red sand, subordinate white, yellow brown sand, basal conglomerate	11ka
Karoo	Ecca	Medium to coarse-grained sandstones with thin grit beds	280 ka
		dark grey shale, siltstone	280 ka
	Dwyka	Diamictite, varved shale and boulder shale	350 ka
		coarse- grained conglomerate and sandstone	
		blackish greyish mudstone	
	Natal	Red brown coarse, subarkosic sandstone, small pebbles conglomerate, subordinate siltstone and mud stone	500 ka
Namaqua Natal Mobile belt		Biotite.subordinate pelitic schist and gneiss	1500 ka
Waterberg	Soutpansberg	feldspar, quartz	3000 Ma
Transvaal	Wolkberg	shale, greyish white quartzites	
	Rooiberg	gabbroic rocks, feldspar	
		albite, quatrz	2900 Ma
Murchison	Gravellote	ultramafic schists,	2600 Ma
		actinolite, tremolite,	
		chloritic schists, quartzitic schists, conglomerates, mataquartzites	
		quartz, mica and schists,	2961 Ma
	Giyani	ultra mafic schists and amphibolite	2600 Ma
	Pietersburg	ultramafic schists, amphibolite	3000 Ma
		amphibolite, magnetie quartzites	<3000 Ma
Protozoic	Goudplaats gneiss	medium- grained quartz, biotite, muscovite	3500 Ma

The oldest lithostratigraphic unit inTable 3.1 is the Goudplaats Gneiss, which is mainly tonalitic with a small portion having a granodioritic composition. The Murchison sequence comprises the Giyani, Gravelotte and Pietersburg Groups, which occur as elongated to irregularly shaped belts. The various lithologies of the Group show typical characteristics of Archean greenstone belts and are thought to have developed either in a rifting environment or in back-arc backspin. The Soutpansberg Group occurs along the northern edge of Northern Province, where it forms mountainous terrain rising to approximately 800 mm above the undulating country to the south. This group comprises a volcanic-sedimentary assemblage thought to have been deposited in a fault-bounded graben structure (Tickell, 1974).

3.2. Socio-Economic Conditions

South Africa's economy is supported principally by manufacturing, mining, electricity, tourism, agriculture and forestry. The gross geographic product (GGP) was approximately 0.5 % in 1998 with inflation of 6% (Department of Environmental Affairs and Tourism,2000). Following the depressed economic conditions of the late 1980's and the early 1990' s, South Africa has experienced positive economic growth rates of between 2.5 % and 3% over the three-year period 1994 to 1996. This was followed by a downward trend in the business cycle, resulting in growth rates of lower than 2% during 1997 to 1999. It is expected that the new growth cycle will commence during the first few years of the new millennium (Central Statistics,1996).

Over 40 million people live in South Africa and the population is growing. According to the Central Statistics Services (1996,1999), KwaZulu Natal has the highest estimated percentage of people (42 %) with 13% percent of the total population estimated to be living in the Northern Province. The proportion of the population living in non-urban areas is considerably greater than those living in urban areas. In KwaZulu Natal, approximately 62% live in rural areas, with only about one-tenth of the population in the Northern Province living in urban areas. Such estimations make the region the least urbanised and living conditions lower.

Unemployment is one of the major crises facing the country, with 17% in the whole of South Africa and higher in rural areas than urban areas, with 20 % of the national population earning less than R500 per month. Access to education, clean water, electricity, proper sanitation and housing is not equally available to all thepeople of South Africa and varies from urban to non-urban areas. Although much health care in public institutions is provided free of charge, clinics often do not have sufficient resources. For example, there is one clinic for every 22 000 people in South Africa (Central Statistics Services, 1999).

It is clear from the brief outline above that the socio-economic needs of the population (particularly in rural areas) and the imbalances in the distribution of income, employment and wealth have to be urgently redressed in the majority of the rural areas of South Africa. Due to the differences in location and physical setup of the sites, each study site will be described separately in the remaining section of the chapter.

3.3 Inkandla

3.3.1 Location

The geographical focus of the present study is the Chube area at Inkandla in KwaZulu Natal, under the authority of Inkosi Shezi, within the Inkandla Magisterial District. Inkandla is located in KwaZulu Natal Province and located at 28'00 S latitude and 31^0 07' E longitude. It is 60 km from Eshowe, with an altitude ranging from 803-1370 metres. It is part of the coastal hinterland of KwaZulu Natal, inland of the coastal zone (Ardington, 1988).

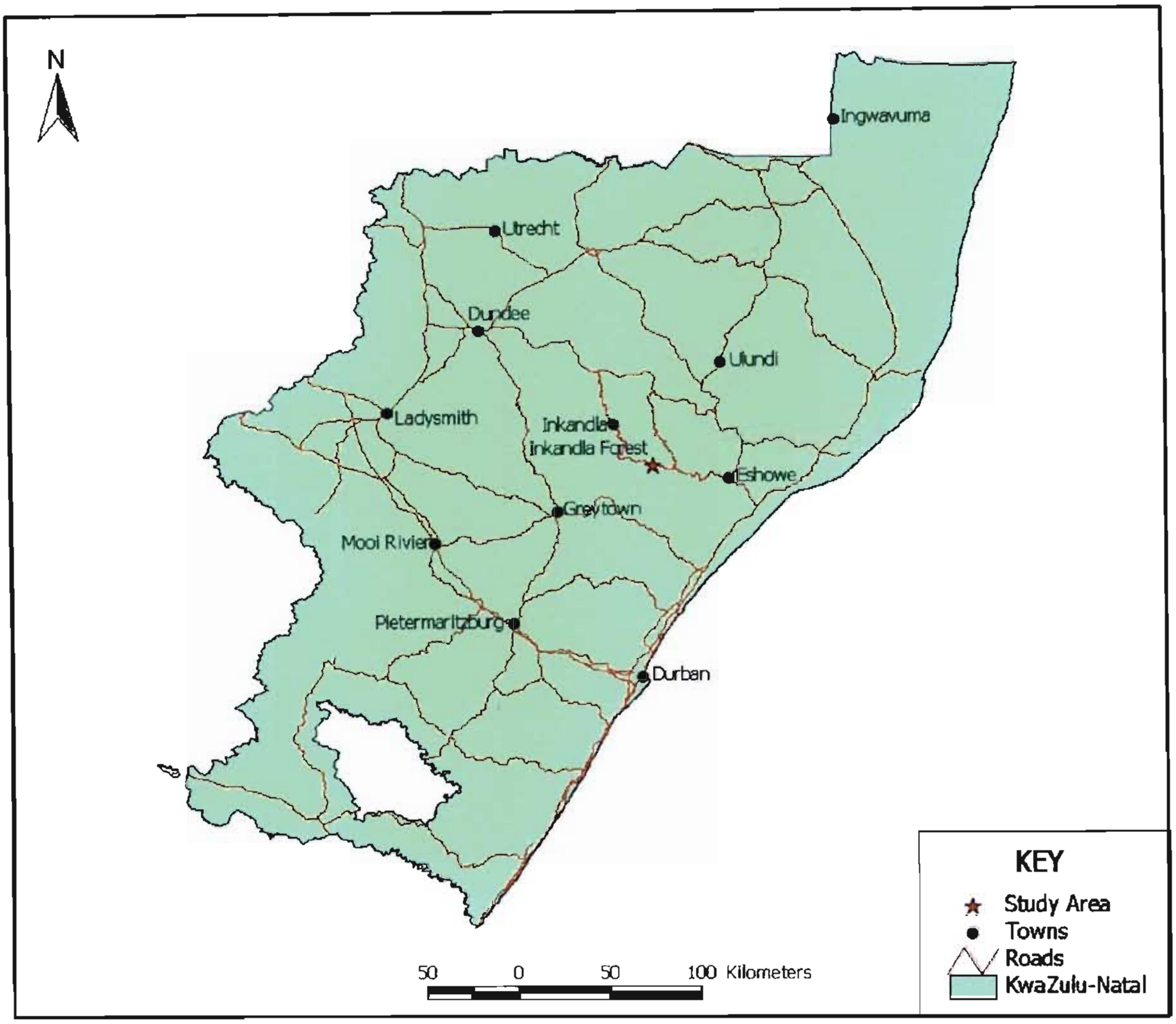


Figure 3.3 The Inkandla area in KwaZulu Natal

The study area is covered, to a substantial degree, by forest, including the 2217 hectare Inkandla forest reserve, which is rated as the second largest mistbelt *Podocarpus* forest in South Africa and is known to be the representative of this biome (Anon, 2000). The study area includes the section of the Provincial road passing through the Inkandla forest reserve and the district road (D166) that lead to the Chube communities. The P100 road connects Inkandla town with Eshowe and the D166 connects the Cube village to the provincial road. The road is networked with an insufficient number of poorly constructed community access roads, which themselves do not adequately service the majority of local homesteads.

3.3.2 Topography of the Inkandla area

In general, the topography of the study area is extremely rugged in the south, but moderates north of the Tugela valley. Inkandla is fragmented by numerous incised valleys and lies along the Natal monocline and has a very rugged topography (von Brunn, pers.comm,2000).

The chief characteristic of the landscape is its rugged hilly terrain and numerous incised valleys, as shown in Figure 3.4. These topographic characteristics, steep slopes and incised valleys restrict the provision of basic infrastructure. The topography of the area causes itself to the difficulties in accessibility and high costs in providing and maintaining roads in the area.

The case of rural road access difficulties, as a result of terrain, is stressed by Groenewald (1984). He maintains that communication between different parts of the Inkandla region is not easy, due to lack of proper infrastructure and terrain. It is on the basis of such terrain conditions that the present government finds it very difficult to provide adequate roads and to develop a basic infrastructure in the area.

It has been observed that the streams rising in the forest have cut deep gorges leading into the Nsuze river, which runs along the base of the ridge. It has a broken terrain and very steep slopes which further limit the construction of roads.

Figure 3. 4 The ruggedness of Inkandla terrain impedes the construction of roads in the area

The topography is characterized by deep valleys with steep slopes. Due to its steep topography the area becomes vulnerable to degrading processes such as soil erosion and slope instability.The most physical feature is immense erosion on many slopes. Therefore, the Water Research Commission designates the Inkandla area as one of the most highly susceptible areas to erosion in the country (van de Riet *et al.*, *1997*).

3. 3. 3 Climate of the Inkandla area

The climate of Inkandla is generally warm and humid with a seasonal rainfall. The area has 1023 mm of rain during spring and summer and114 mm during winter. The highest rainfall occurs between November and January months. The rains often occur in the form of torrential downpours, which contribute to higher runoff and erosion. With such a heavy and intensive rainfall pattern and soils which are sandy loam in texture, erosion and slope instability problems are acute and chronic. The high rainfall in the area can thus be expected to have an effect on the state of the roads.

The largest part of the coastal regions has a subtropical climate, but the rapid increase in elevation results in a transformation into a more moderate summer rainfall climate, with regular snowfalls in the most elevated areas in winter. The rainfall of the area, which varies between 600 mm and 1300 mm per annum, is more reliable than in most of the other regions of the RSA. Periodic times of exceptionally high rainfall, usually associated with the presence of tropical cyclones in the Mozambique channel, result in floods which reach disaster proportions and destroy roads and bridges, mainly in rural areas.

The steep topography of the Inkandla study area results in the drainage of cold air on calm nights into the Tugela river valley below the region. The climate is generally warm and humid, with temperature ranging from 5^0 C to 33^0 C. Cold temperatures during the winter season have an average of 12^0 C, while warm temperatures are experienced during most of the year with an average of 23 ^{0} C.

Mist is common in the Inkandla forest reserve and is the primary form of precipitation in terms of occurrence, though in quantity. Heavy mists, rather than the condition of the roads, are likely to be a constraint to vehicular access in between the forest road and Eshowe. The area does not experience severe frosts, as the cold air is able to drain away into the valleys at night. Occasional to frequent light frosts occur on the flat and in the valleys of the grassland areas on approximately 9 days in the winter months.

The prevailing winds in summer, from December to February, are the north east and south west winds. The frequency of the winds decreases from March to May. June and July are generally the calmest months of the year due to the increase in westerly winds over the interior. Windy weather occurs from August to November (gale force winds may occur frequently during spring and can blow for several days).The hot, dry berg wind occurs during August to September, toward the end of the dry season and coincides with the times of fire hazards in the dry grasslands.

3.3.4 Soils of Inkandla

In general, the topography of this area is that of broken terrain with steep slopes. As mentioned earlier, the soils of the study area are often shallow and usually have well-weathered underlying parent material due to high rainfall in the area (Anon: 2000).

According to Guy (1977), the upper grassland slopes have soils with high humic topsoils mainly of the Nomanci form, other shallow soils occurring in the area are classified in the Glenrosa and Mispah forms. Lithosolic phases are present, as well as outcropping rock (granite) in many places. The upper grassland slopes of the area have soils which are acidic and leached, derived from Insuzi, Inkandla and Archean granite geological formation (Guy, 1977). In the less steep midslope positions, soils are predominantly deep and are of the Hutton formation derived from megacrystic and gneissic granodioritics and quartzites (Cairns, 1990).

Fairly deep soils occur at the bottom of some of the minor valleys. Soils in the study area are fertile and this is evidenced by numerous vegetable gardens. Geologists claim that soil is abundant and much of the ground is under the forest (Brink, 1988;Groenewald,1984;Johnson,1976). In less steep midslope, shallow to moderating deep soils have formed. The soil is badly eroded and large dongas are common in the study area and van de Riet *et al.* (1997) marks Inkandla as one of the most highly susceptible areas to erosion in the country. Measures against increased soil erosion resulting from poor drainage of existing roads are one example of inadequate or poor infrastructural development.

3.3.5 Detailed Geology of the Inkandla area

The geology of KwaZulu Natal consists predominantly of lithologies belonging to the Karoo Supergroup, with moderate exposures of the Natal Group sandstone. The geology of the study area is very complex (von Brunn, pers comm 2000). The difficulty of the description, interpretation and use of the updated lithostratigraphic nomenclature has resulted from revised concepts introduced by years of research, first geologically mapped in remarkable detail by Du Toit (1936).

The area is underlain by ancient rock formations, most of which have been deformed and altered by the effects of pressure and temperature predating the Karoo Supergroup. This has led to a very complex geology, consisting primarily of metamorphosed igneous rocks, in the study area. The most common rock groups include quartzites, quartz schists, mica schists and granite.

The area surveyed by the present researcher lies at the approximate boundary between the ancient granitoid greenstone Kaapvaal Craton "basement" and the relatively younger Natal metamorphic belt to the south. This basement complex comprises the oldest craton rocks of the Inkandla forest region and is represented by the metamorphosed "greenstone" rocks of the Nondweni Group and the associated granitoids, comprising several types of granite and granite gneiss.

North and west of the Inkandla Forest reserve, sedimentary rocks of the Natal Group are represented by flat-lying undeformed beds of quartzitic sandstone, while the sedimentary deposits of the Dwyka Group form the basal unit of the Karoo Supergroup in the region(Loxton, Hunting and Associates,1985), overlain by the Ecca shales. The lithologies are dissected by dolerite dykes. Overall, the geology generally give rise to a dissected topography free of ledges.

3.3.6 Vegetation of the Inkandla area

Knowledge of vegetation and its dynamics is a prerequisite to the production of a sound development plan of any area. The study area falls into bioclimatic region 2a humid to sub humid coastal hinterland (Phillips,1969), or Nongoni veld with its natural vegetation, described by Acocks (1988) as sour grasslands. Most of the study area is covered by grasslands which are influenced by the underlying geology.

The Inkandla forest reserve is described as semi-coast forest and is known to be the best representative of this type (Anon, 2000). The total area of the forest extending beyond the Inkandla forest boundaries is 829 hectares, of which 550 hectares is part of the *mome* forest. The total forest area beyond the boundaries, formed by a number of other proclaimed areas, expressed as a percentage of the total forested area, which is 31%. Approximately 15% of the forest reserve is covered by grasslands (Khanyile, pers.comm,2000). Within the Inkandla reserve boundaries, approximately 1770 hectares (85%) are covered with semi coast forest and the remaining 310 hectares (about 15%) is covered by a number of *Themeda triandra* and secondary *Aristida junciformis* grassland patches, varying in size from approximately a quarter of a hectare to several hectares in extent.

Acocks (1975) maintains that this thornveld is generally very open, except at the edges of the bush-filled valleys. In the study area the grasslands are of particular importance to the local people as grazing lands for their livestock. Ardington (1988) and Acocks (1988) claim that this natural pasture has deteriorated to become Nongoni veld, which is known to be unpalatable to grazing animals.

Although most burning takes place during winter and early spring, fire is mentioned as the most commonly occurring phenomenon on the grasslands. The effect of fire has led to changes in species composition and a decrease in basal cover in most of the areas in the study area. In affected areas within and around the forest, the forest has been replaced by scrub and grass leading to an expansion of grasslands areas. The decrease in vegetation cover is also associated with animal trampling and overgrazing and contributes to erosion in most parts of the grasslands.

The altitude of the forest reserve varies from 1100 to 1300 metres above mean sea level (Anon, 2000).The Inkandla forest and surrounding forest represent a rare relict type of high wet rain forest, of which very few examples survive. There is a number of pockets of indigenous forest remaining in the valleys and throughout the study area.

The tallest trees in the semi-coast forest, emergent from the continuous an upper canopy, are generally 16 -22 metres high, which provides a dense canopy that keeps the road moist for a long time and will make the road slippery and affect accessibility to the area. On deep soils and in kloofs, the trees may be more than 30 metres high, whereas on rocky ridges, common in the Inkandla forest, the tallest may average only 13 to 17 metres. The average diameter at breast height is from 40-90 cm.

According to Anon(2000) frequent and abundant species include *Olea capensis. Macrocoarpa, Holmalium dentatum, Combretum kransii, Cryptocarya latifolia, Vepris undulata, Rapanea melanophophloeos, Branchylaena transvaalensis, Nuxia floribunda and Syzyguim gerrardii.* At Inkandla, *Olea capensis* is distributed throughout the forest. *Holmalium dentatum* is locally dominant. The low relative abundance *of Podocarpus latifolias* and *Ptaeroxylon obliguum* is probably due to past utilization. Along stream banks dominant emergents are *Ficus capensis* and *liex mites.* The wattle trees are also common and appear on the banks of most streams and rivers. This is used by the communities for fuel wood but it is known to be accelerating the drying of streams and rivers because of the type of root systems (DWAF, 1998). Similar to Acocks 's clasiification, Low and Rebelo (1996) also describe the vegetation in this area as Ngongoni veld with *Arstida junciformis* almost entirely dominant.

3. 4. Indwedwe

3.4.1 Location

Indwedwe district is formerly a tribal area previously designated as part of the KwaZulu homeland by the then Nationalist Government. Indwedwe is connected by road with Verulam, Inanda, Noodsberg and Tafamasi. Indwedwe is located, 30 kilometres from

Durban, west of Tongaat and Verulam and north of Pinetown. It is situated between latitudes 29 ^{0} 15' S and 29^0 45' S and longitudes 30 ^{0} 47' and 31^0 00 E.

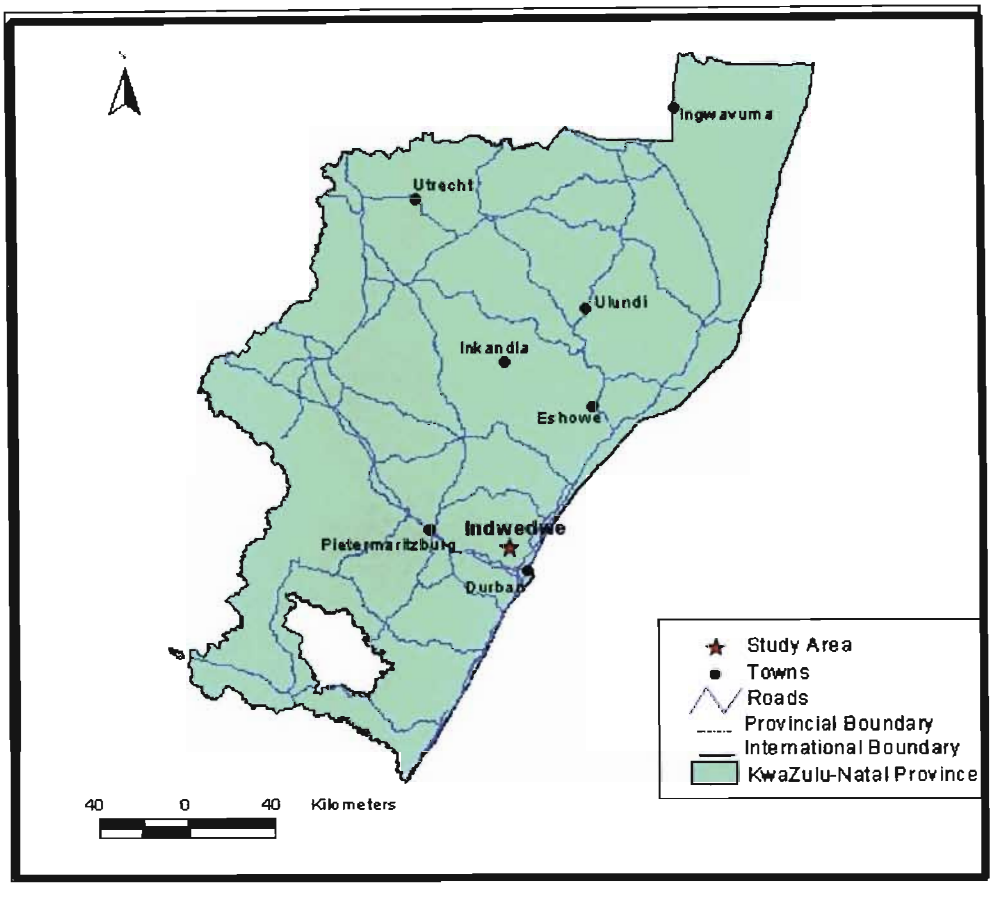


Figure 3.6 Location map of Indwedwe in KwaZulu Natal.

The district of Indwedwe was considered an ideal setting for the purpose of the present study and was identified as one of the most marginalised and one of the economically poorest district in KwaZulu Natal. Although Indwedwe is approximately 30 kilometres from Durban, it remains one of South Africa's underdeveloped tribal areas (Moller,1997, p21). Indwedwe is traversed by several gravel and dirt roads which, according to Russow and Garland (2000), are responsible for causing erosion in the area. The KwaZulu Natal provincial road that connects Indwedwe with Verulam was chosen for the purpose of this study because it is the major road that connects Indwedwe with Verulam and is deteriorating with time.

3. 4. 2 Topography of the Indwedwe area

Despite considerable differences in elevation, the character and distribution of topographic features show little variation. The topography of the study area is characterised by gently undulating hills in the lower reaches of the Mdloti catchment, varying in altitude from 100 - 450m above mean sea level. The topography becomes steeper and more rugged with distance inland (Currie, 1997). Topography being the major limiting factor in the study area, it is observed that the area may not be capable of being used for access road development because of the broken nature.

A large numbers of streams and rivers transverse the region, the most important of which is the Mdloti river. Drainage from the area is by tributaries of the Mdloti river, which flows in a southward direction, before veering eastwards toward the Indian ocean. Minor tributary streamlets exist; they seem to be narrow and have irregular valleys. These tributaries include the Mdlotshaan, Kwamwema, Mwangala, Kwazini and Msunduzi (DWAF, 1994). Common features of these tributaries are the steep rise in the beds from the past of which is explained by the geological movements which have occurred over the ages.

3.4.3 Climate of the Indwedwe area

Climatic data for the study area was obtained from the Indwedwe Weather Station, with no recent rainfall statistics available. Rainfall data for the years 1920 to 1994 was available from the CCWR. There are no rainfall statistics on the floods that occurred in 1999. Indwedwe is situated in the Subtropical Climate Zone of Southern Africa (Schulze, 1965). The climate is warm, temperate rainy, a type of the humid mesothermal climate. Using the Koppen symbols it would be classified as Cfwa.

Rainfall is well-distributed in the summer months and the winters are dry. Occasional heavy rainfall events transpire in short periods of time due to convective storms. Instability showers and cut-off lows bring floods and cause extensive damage to the road infrastructure, as will be shown later. The month of maximum rainfall in the study area is generally December and much of the rainfall occurs in thunderstorms which are often accompanied by hail. This hail might cause considerable damage to the road network. Rainfall is fairly reliable and droughts occur about once in seven years (Currie, 1997).

Approximately 90% of the annual rainfall occurs as heavy downpours during the period October to March. The fact that most of the rainfall is intense is of importance to vehicular access in wet seasons.

3.4.4 Soils of the Indwedwe area

Soils in the study area tend to be sandy, low in fertility and erodible. Rocks of the Natal group dominate the geomorphology, particularly in coastal KwaZulu Natal and the immediate hinterland. Resistant quartzites of the Mkunya Sandstone Formation, which outcrop as near vertical cliffs of the extensive plateaux and mesas are commonly found (Brink, 1981). The climatic, soil and topographical conditions of the study area are highly suited for intensive farming east of the study area, which has predominantly taken place in the form of sugar cane growing, making this the most productive area in the region.

3.4.5 Geology of the Indwedwe area

The stratigraphy of the Indwedwe area consists of Dywka Formation, dolerite, Namaqua Natal Belt, Natal Group, Pietermaritzburg Formation, Vryheid Formation and the Berea Formation (Currie, 1997).The Namaqua Natal Mobile Belt of Indwedwe is characterised by crystalline granite, gneiss and schists formed from pre-existing crustal rocks at depth (King and Maud,1964; and King, 1982) and are developed throughout much of the coastal KwaZulu Natal Monocline Axis (Truswell, 1977).

The Natal Group sandstone constitutes a large portion of the geology at Indwedwe (Currie, 1997) and is composed entirely of sandstone, with subordinate quartzites bands, some pebbles beds and lenses of shales or mudstone, irregularly distributed within the sequence

(King and Maud, 1964). The Natal Group lies unconformably on the Archean granite-gneiss of the Namaqua Natal Mobile Belt.

The Karoo Supergroup in KwaZulu Natal is evident through a succession of interbedded shales, varvites and diamictites, although very little is seen as an outcrop in KwaZulu Natal (Johnson, 1976). The Dwyka Formation and the Ecca Group are the only evident litholigies in the Indwedwe area.

The Dwyka formation of the Natal Group lies above rocks of the Natal Group and is characterised by the presence of clastic rocks containing rudaceous material of diamictite, varved shale and mudstone, with dispersed stones and conglomerate (SACS, 1980). Outcrops of the Dwyka formation are restricted to a narrow band that tends northwest to south west in the vicinity of the Hazelmere dam and is controlled by the presence of numerous faults which are visible in the area (Currie, 1997).The Ecca Group is divided into various formations, which are the Pietermaritzburg, Vryheid and Volkrust formations. The Pietermaritzburg formation consists predominantly of shale and the Vryheid formation consists of sandstone, shale and subordinate bed of coal and the soft blue shales of the Volkrust formation. According to Currie (1997), the Pietermaritzburg formation is situated downstream of the Hazelmere dam in a northwest to south east trend and truncated out to the south of the Mdloti River by a fault that trends almost east-west. Outcrops of the Vryheid formation are limited to the area between Canelands, near the town of Verulam.

3. 4. 6 Vegetation of the Indwedwe area

The natural vegetation of the Indwedwe area, which falls under the Mdloti River Catchment has a high biodiversity (Acocks,1988;Low and Rebelo,1996). Acocks (1988) classification includes vegetation of the coastal forest and thornveld in the lower reaches of the catchment and ' Ngongoni veld and Natal mist belt Ngongoni veld in the interior areas and upper reaches of the catchment. According to the classification of South African vegetation by Low and Rebelo (1996), the Indwedwe area consists of Coastal Forest, valley thicket, Coastal Bushveld-Grassland and Coastal-Hinterland Bushveld. Common species in this vegetation type include Coast Red Milkwood *Mimusops caffra*, Natal Guarrir *Euclea natalensis*, Cape Plane *Ochna arborea*, *Apodytes dimidiata*, *Cassine aethiopica*, *Sideroxylon inerme*, *Combretum kraussi, Tricalysia lanceolat.*

3.5. Ga- Modjadji

3. 5.1 Location

The study area is located in the north eastern part of the Limpopo Province. Until 1994 it was a part of the former Lebowa homeland. The study area Ga-Modjadji is a rural area in the Northern Province and is sometimes referred to as the Bolobedu. Ga-Modjadji is located at latitude 30 ^{0} 28' 35"S and longitude 23 ^{0} 30' 51"E. It is north east of Tzaneen (main trading centre), east of Duiwelskloof and south east of Limpopo (the capital of the Northern Province). It is located between two ranges of the Bolobedu mountains and closer to the holy rain forest (Modjadji nature reserve), 35 kilometres from Duiwelskloof.

The Modjadji region is well known for its old nature reserve which has the greatest concentration of indigenous cycad species in the world. The tallest cycad reaches 13 metres in height (Orfer, 1999; Sunday Times, 1999). Of special importance is the fact that the nature reserve attracts tourists from various parts of the country. However, the area is semi-arid and rocky, with numerous dongas that make road accessibility difficult. Electricity, schools and health care are provided, but water supply, roads and sanitation remain a problem.

Rocky outcrops on road surfaces, rockfalls, gullied drainage along the roads, rills on road surfaces, potholes, deteriorating bridges, heavy dust, impassable roads during rainy seasons and time spent driving on these roads become serious constraints to local motorists and tourists visiting the area. If the deteriorating mud and gravel roads are not repaired soon, it willresult in far-reaching long term damage to the local economy and the general economy of the country and will impact on the quality of life of the residents.

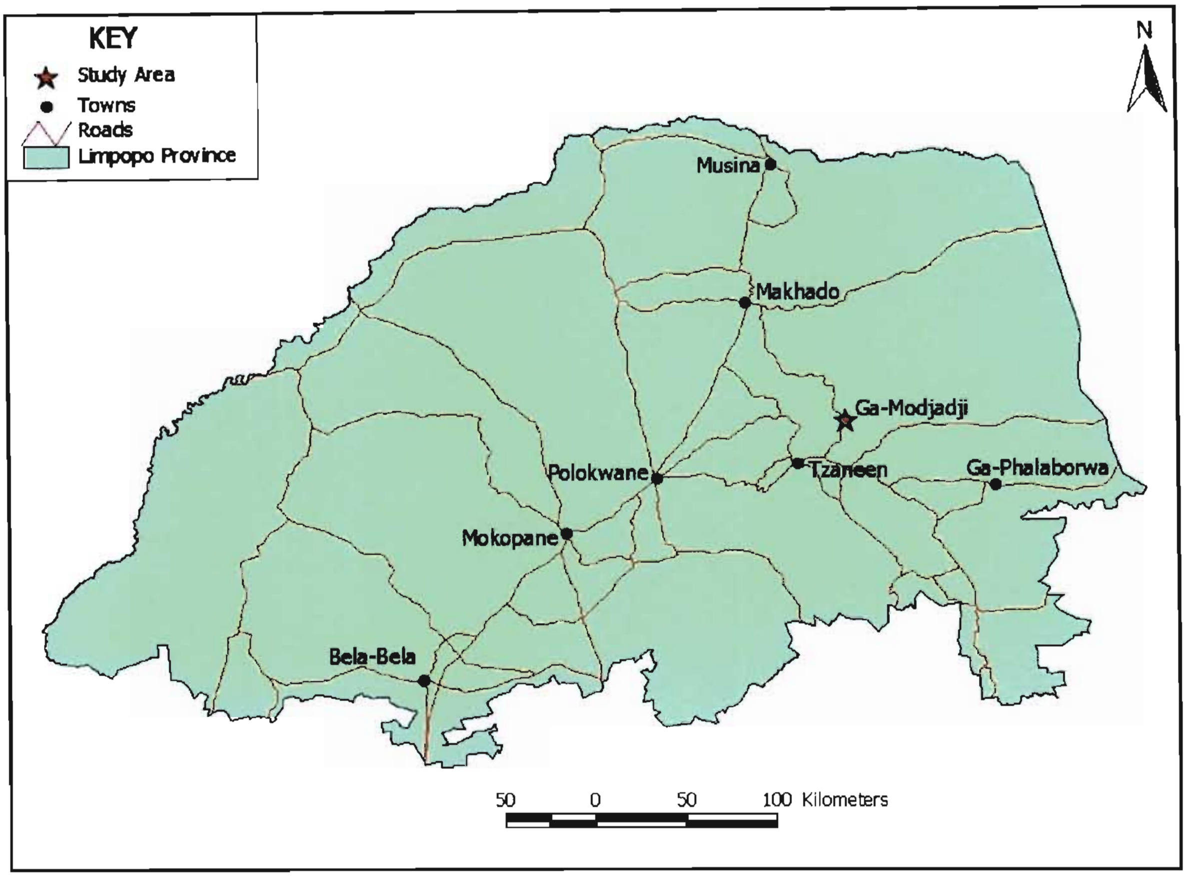


Figure 3 .7 Location map of the Ga-Modjadji area in the Northern Province

The selection of the study area is based on the fact that most roads in the area have been reduced to gullies and also on the general familiarity which the researcher with the area.

3.5.2 Topography of the Ga-Modjadji area

The Northern Province falls into what is known as the Limpopo-Olifants river system, which can be divided into Drainage Regions. These are Limpopo, Olifants and a small section of the Komati System. The study area is part of the Olifants Drainage Region, which drains the Province to the east of the Escarpment and includes flowing tributaries such as Shingwidzi, Groot Letaba and Klein Letaba rivers (DWAF, 1998).

The study area (1179km^2), is located between two ranges of the Bolobedu mountains, where the Molototsi riveris one of the three main tributaries of the Groot Letaba river is fed by streams from the bush-covered slopes. The are several streams that flow from west to east to join the Molototsi river, which flows on to join the perennial Great Letaba river. The rivers and streams only carry water during rainy seasons and during flash floods after heavy rains.

Generally, most of the Northern Province is low-lying, but it has a few steep slopes which restrict the construction of roads in the area. The Modjadji area is dominated by the Drakensberg, forming the western watershed, with a maximum elevation of 2126 meters above mean sea level (amsl). This mountainous feature has a major influence on the construction of access roads. Rocky hillsides also characterize most parts of the study area.

The Ga-Modjadji area falls within a physiographic region below the Great Escarpment and has been structurally and geomorphologically divided into three units, that is the Eastern Plateau slopes, the Southern Marginal belt and the Western Plateau slopes. The study area forms part of the Eastern Plateau slopes, which have been fashioned by the headward erosion of the rivers draining to the Indian ocean (Cole, 1961).

The relief of the study area is mountainous and hilly, with deeply dissected steep-sided valleys. The land rises abruptly from an altitude of 650 m above mean sea level at the foot of the mountains to over 1000 m or more at the summit of the mountains in the northwestern part of the study area. The average slope map of the Ga-Modjadji area gives certain clues with regard to the formation of the land. The land has generally steep slopes of 80^0 to more than 100^0 while the dominant eastern part slopes are much steeper. The relief of the land has much significance in the construction of access roads.

3.5.3 Climate of the Ga-Modjadji area

The study area Ga-Modjadji falls within the subhumid areas of the lowveld. This region has the coolest climate of all regions, with the lowest minimum temperatures being recorded here. Generally, light winds prevail except during thunderstorms, although infrequent tornadoes may occur.

Climatic data were provided by the CCWR for Modjadji nature reserve and by the Department of Water Affairs and Forestry (DWAF) for Modjadji dam. Rainfall data from CCWR was for the years 1986 -1995 (Modjadji nature reserve) and for Modjadji dam rainfall statistics were for the years 1998 -1999. Both sets of climatic data were incomplete with some years having only four months recorded and data for some months missing. Detailed information on the 2000 floods was unfortunately not available in either of weather stations.

The climate of Ga-Modjadji area is characterised by long, hot summers in the lowveld, with the mean annual rainfall (85% during the summer months) increasing gradually towards the west, with approximately 700 mm occurring in the foothills near Tzaneen. Rainfall increases rapidly with elevation in the mountainous zone to approximately 1800 mm per annum in some surrounding areas. The Modjadji area enjoys a subtropical climate, with summer rainfall of approximately 1500 mm. The averages maximum temperature for December/January (mid-summer) is approximately 29°C and average minimum temperature for June/ July (mid winter) is approximately 7°C. Most of the rain during the rainy seasons occurs in heavy downpours and is of importance to soil erosion and road access in the area. The unusual floods that have occurred in the year 2000 have had serious effects on the access roads in the area. The wettest year recorded in the study area occurred in 2000, when the area received more than1100 mm of rain. About 90% of this rain fell in only 3 days (DWAF, pers. comm.). Evening temperatures cool to approximately 10°C. There are occasional afternoon thunderstorms. Winters are mild with temperatures reaching 20° C and dry with cold nights, of not less than 10°C.

The construction and maintenance of the roads in the area are seriously hampered by these climatic conditions. Rainfall conditions characterised by heavy downpours and floods, have serious effects on the roads. Road-conditions and they will deteriorate further in the future.

3.5.4 Soils of the Ga-Modjadji area

Knowledge of the soils is of fundamental importance in an accessibility study, because soils are extremely important in road construction. Cole (1961) draws attention to the fact that soils of the Northern Province lowveld are of the Subtropical Brown Forest types. These soils "owe the characteristic features to soil forming processes governed by the prevailing climatic conditions-notably the high temperatures throughout the year and the erratic incidence of rainfall, which comes in torrential downpours in summer, separated by long dry periods" Cole (1961:88).

High temperatures and rainfall bring about the decomposition of mineral constituents but the dry periods are unfavourable for their removal soil minerals. As a result, soils are not leached of their bases. The predominant soil forms present according to MacVicar (1977), are Hutton and Shortlands. Hutton soils have an orthic A horizon overlying a red apedal B and include the series Farningham, Balmoral, Msinga and Doveton. Duplex and paraduplex soils are found in the study area. These are soils that differ distinctly from subsoils with regard to texture, structure and consistency. These soils are not generally utilised as arable soils because of their erodibility.

3.5.5 Geology of the Ga-Modjadji area

The geology of the Ga-Modjadji area is that of the Northern Province lowveld because the study area falls within the Northern Province lowveld region. According to the Geological Map of Southern Africa compiled by Houghton (1968), the Ga-Modjadji area is underlain by granite gneisses and diabase dykes, parallel to Tzaneen Lineament. According to DWAF (1998), the granite Gneiss surrounds various formations of the Pietersburg group. The most widespread rock type is a leucocratic biotite gneiss, probably tonalitic in composition, which shows clear intrusive relationships. Du Toit (1954) stated that the granite and the various types of gneisses build the northern parts and the eastern parts of the Transvaal. The same region is referred to by Wellington (1955) as formed entirely of the pre-Karoo rocks, consisting mainly of old granite and the primitive Swazian Erathem, formerly known as the Primitive Swaziland System.

However, the Geological Map of the Republic of South Africa by Vissers (1984) indicates that the Modjadji area is underlain by migmatite, gneiss and ultrametamorphic rocks (Vissers, 1984). Volcanic rocks are found along the eastern part of the study area and sedimentary rocks of the Karoo sequence are limited to north-south bands along the eastern border of the study area. The Ga-Modjadji area consists mostly of rocks of the Rooiwater Complex, with Novengilla site consisting of gabbroic rocks and the upper Beesplaas Suite, mostly of dioritic rocks (DWAF,1998).

3.5.6 Vegetation of the Ga-Modjadji area

According to Acocks (1975), the vegetation of the study area falls within the Lowveld Sour Bushveld type. This vegetation is transitional between the Lowveld and the North eastern Mountain Sourveld and occurs on the lower eastern slopes and foothills of the Drakensberg. The climax is tropical forest, the rainfall ranging from 500 mm per annum at the lower margin where it merges into the lowveld, to more than 1000 mm at its upper margins, where it merges into the North eastern Mountain Sourveld, its limits being somewhat indefinable (Acocks, 1975).Low and Rebelo (1996) indicates that the grass layer is poorly to moderately developed and grasses such as Tassel Three -awn *Aristida congesta,* Guinea Grass *Panicum maximum,* Common Fingergrass *Digitaria eriantha, Setaria lindenbergiana, Loudetia simplex, Heteropogon contortus* are the conspicous species.

The Northern Province lies in the Savannah Biome, which is an area of mixed grassland and trees known as the Bushveld. The vegetation in the study area is mostly subtropical. A high rainfall and the warmth of the lowveld ensure that everything grows here in abundance: nuts, avocados and other vegetables, fruits (especially citrus mangoes, bananas and lichees), coffee, tea and cotton.

The environmental setting of the study area has been dealt with extensively in this chapter. Sampling methodology and laboratory procedures used in the research are outlined in the next chapter,prior to detailing the findings of the research in Chapter 5.

CHAPTER 4

Methodology

As stated in Chapter 1, the primary objective of the present research is to explore the geomorphic constraints affecting access to rural areas, principally those factors pertaining to unarmoured roads. In order to meet this objective, both qualitative and quantitative methods need to be used to gather data to quantify the environmental conditions and to record the perceptions and experiences of the affected communities. Due to the complex nature of this research, techniques were categorized into human and physical approaches, aimed at integrating the physical geomorphic environment and the socio-economic context of the research. This chapter outlines the methods adopted in the research.

4.1 Environmental field data

The purpose of the fieldwork is to identify environmental constraints related to access roads. In order to gain insight into the role and significance of the geomorphic environment in relation to road access in relation to road access, different field sites were chosen. The specific sites within each of the locations were selected in such a way that data from the locations should be comparable, particularly regarding factors such as gradient and intensity of use. In order to gain an understanding on the possible environmental constraints on roads, soil physical characteristics, topographic properties, vegetation conditions, micro climate and geology were recorded for each site within the respective localities mentioned. Variations of topography, climatic conditions and underlying geology, road conditions, socio economic conditions, proximity to an urban area influenced the selection of the study area. Since selection of individual sites was based on the above characteristics, no fixed standards were set for the specific distance between sites during the field survey, hence three sites were chosen at Inkandla, five sites at Indwedwe and four sites at Ga-Modjadji.

Due to the complex nature of the problem of road degradation, several methods were employed. These are discussed below.

4.1.1. Site description and Mapping

The erosion survey undertaken for this research consisted of mapping the rills, gullies in the area. The severity of erosion was rated using the Southern African Regional Commission for the Conservation and Utilisation of the Soil (SARCCUS), 1981 criteria. This criterion classifies the principal forms of soil erosion, indicating the degree of severity on the basis of soil surface morphology (Beckedahl, 1988). SARCCUS system from 1981 is a fairly detailed system (Haag and Haagland, 1998), dealing with erosion caused by both water and wind and dividing the severity of each type of erosion mainly into five classes. The erosion is subdivided into erosion causal process of water and wind being one of this.

The SARCCUS (1981) method involves the delimitation and classification of erosional land units on a large scale (e.g. 1:30 000) aerial photographs. The soil erosion classification system identifies the degree and intensity of erosion within a given area of land or agro-ecological unit. For the purposes of this study, three field map sketches for each study area were provided to illustrate the geomorphic characteristics of each site as will be seen later. The field map sketches provide site specific erosion forms and other possible constraints noted in the field.

The system for classification of soil erosion, developed by SARCCUS during a number of years and presented in 1981, serves to meet the demand for a classification that could work as tool for planners, serve for educational purposes and to be an aid in identifying research needs. SARCCUS also draws the attention to the fact that the conservation effort should emphasize prevention rather than cures, and states that the classification system intends to "facilitate the identification of problem areas" (SARCCUS, 1981). It was for the above-mentioned reasons that the system was used here to investigate the effect of different erosion forms on rural roads. In the study, sheet, gully, landslide erosion were studied, as these were the only types of erosion apparent in the area (see Table 4.1).

Table 4.1. Summary of the types and classes of soil erosion (after SARRCUS, 1981)

Type of erosion	Class of erosion	Symbol	Description and remarks
1. Erosion caused by water			
Sheet (surface) Uniform removal of surface soil	None apparent	S1	No visible signs of erosion on air photo. Level of management appears to be high.
	Slight	S2	Areas of light –tone observed on air photos. Erosion deduced from poor cover, sediment deposits and plant pedestals.
	Moderate	S3	Eroded areas obvious on air photos. Plant cover very poor and sediment deposits extensive. Associated with small rills
	Severe	S4	Sheet erosion of such severity always associated with rills and gullies
	V. severe	S5	Much or all of the A-Horizon has been removed.
Rill Removal of soil in small channels or rivulets, mainly on arable land	None apparent	R1	As for sheet erosion
	Slight	R2	Small, shallow (mainly <0.1 m) rills present but not readily observed on air photos
	Moderate	R3	Rills of considerable depth (mainly 0.1 to 0.3m) and intensity usually observed on air photos
	Severe	R4	An abundance of deep rills (less than 0.5 m) easily observed on air photos. Subsoil may be exposed
	V. severe	R5	Large well defined rills but may be crossed by farm machinery. Associated with gully erosion
Gully (donga) Removal of soil in large channels or gullies by concentrated runoff from large catchment areas	None apparent	G1	As for sheet erosion
	Slight	G2	Clearly observed on air photos and usually up to 1m deep. Cannot be crossed by farm machinery.
	Moderate	G3	Intricate pattern of deep gullies (mainly 1-3 m) exposing entire profile in places.
	Severe	G4	Landscape dissected and truncated by large (3-5m) gullies. 25% -50% of area unproductive
	V. severe	G5	Large and deep (often >5m) gullies have totally denuded over 50% of the area
Landslide Soil mass slumps downwards, leaving vertical scarp	Five class ratings also apply to these types of erosion but are seldom used	L	Usually visible in air photos. Over saturation causes soil mass to slide downslope leaving a vertical scarp at top
Terracete Step like formation on steep slopes		T	Easily observed on air photos. Usually associated with steep slopes (over 15%) in high rainfall areas. Aggravated by trampling
Creep Gradual viscous movement of the soil mass down slope		C	A natural phenomenon, which may be observed in mountainous areas. Recognition aided by observation of other features. Not readily observed on air photos
Streambank Undercutting and slumping in stream and river banks		B	Occurs on outer curves of streams and rivers where fast flowing water undercuts the banks, may or may not bee seen on air photos
2. Erosion caused by wind			
Wind Sandy materials (> 85% sand) removed by suspension, saltation and creep during strong winds	None apparent	W1	Seldom observed in well vegetated and humid areas where clayey soils predominate.
	Slight	W2	Not readily observed on air photos. Field checks show evidence of removal and deposition and loamy soils (15-35 % clay and 65-85% sand) may predominate.
	Moderate	W3	Easily observed on air photos. Sand deposited against obstructions and small dunes are formed. Soils are mostly sandy (<15% clay and > 85% sand).
	Severe	W4	Large parallel sand dunes observed on air photos. Vegetation is sparse and soils very sandy (<10% clay)
	V. severe	W5	Over 50% of the area rendered unproductive by so called " blow outs" and deposition of sand

4.1.2. Soil sampling strategy

A soil analysis was carried out as part of the study in an effort to examine the extent to which soil loss relates to road degradation and to determine different aspects of erosion between the study sites in the three regions. A total of 42 soil samples were collected from horizons exposed in soil profiles, on the road embankments, on road surfaces, and in areas adjacent to the study sites where road degradation was observed to be severe, based on SARCCUS (1981).

In order to understand the nature of the degradation observed at Inkandla, a total of 23 samples were collected for analysis in the laboratory. The samples were collected from the first study site within the Inkandla area to represent the different forms of erosion on the abandoned road and to contrast these soil conditions with those found on the new road, which is still in use.

In the second site at Inkandla, soil samples were collected in two locations, from horizons down the vertical profile (A, B, and C). The overall depth of the soil profiles reached a maximum of 50cm. Because of the extent of slumping processes that were observed on the roadside walls, a further set of soil samples were collected from slump material that was observed. Within the Inkandla forest road section, which represents the third Inkandla site, five sites were identified and soil samples were taken on road surfaces to represent differing types of road degradation by vehicle traction.

The nature of the observed constraints and the factors already outlined (such as dominant sidewall processes, gradient, geology and soil properties, and drainage and road infrastructural problems) were found to be more complex than at Inkandla, hence five sites were required to represent geomorphic constraints. A total of 19 soil samples were collected from this area. At study sites where soil was well developed (Lower Mzinyathi), soil samples were collected from each horizon for laboratory investigation. Where road embankments were longer than 35m, (Ekukhanyeni and Egonweni), soil samples were taken along the slope transects (crest and footslope), representing the different types of erosion.

No soil sampling was conducted at Ga-Modjadji because of the technical problems related to accessing the field sites with equipment, given the large distances that needed to be covered on foot. This area was therefore used as a control to verify observations and to further validate the results of the survey. The study was based on the description of surface characteristics.

4.1.3. Soil shear strength

One of the physical characteristics that have been considered important in this study is the shear strength of the soil, which is also an indicator of soil erodibility (Stocking, 1996). Soil shear strength is defined by Smith (1980) as the maximum resistance of the soil to shearing stress under any given condition and indicates the cohesiveness and the resistance to shearing forces exerted by external forces (Morgan, 1986). These forces include factors such as the raindrop impact and trampling due to animals. An increase in moisture content of the soil decreases its shear strength. In the present study, a Farnell-type hand shear vane was used to determine the shear strength. The use of the Farnell type instrument requires that five readings be taken for each measurement with the lowest and the highest being discarded. The mean *in situ* shear strength is then obtained from the remaining three values. This method was successfully used by Moodley (1997) and Sinclair (1998) to determine shear strength in order to infer erodibility.

4.1.4 Slope gradients

Slope profile measurements were determined using an Abney level, a tape measure and a ranging rod, described by Young (1972), Gardiner and Dackombe (1983) and King (1985). A tape measure was used to determine the width of the roadway at each site within a given area.

4.2 Laboratory analysis and procedures

Properties of soil have been used by many authors as indicators for assessing the state of soil degradation (Lal, 1996; Valentin, 1985; Hartemink, 1998). Soil characteristics were determined in order to decide on soil suitability for the construction and location of access roads. Laboratory procedures listed below were designed to investigate how particle size, cation exchange capacity and exchangeable sodium percentage impact on the erodibility of soils in the study area. The laboratory procedures were performed in the Soil Science laboratories of the University of Natal.

The following laboratory procedures were followed to determine the erodibillity of the soil samples collected:

- Particle size distribution of the soil;
- Cation exchange capacity;
- Exchangeable sodium percentage.

4.2.1 Particle size distribution

An important soil property with regard to erodibility is the particle size distribution or texture (Morgan, 1995; Courtney and Trudgill, 1981). Particle size is a commonly used measure of the physical character of sediments and soils (McTainsh *et al.*, 1997). It also provides an indication of the distribution of the relative amount of sand silt, and clay within a sample (Hazelton and Murphy, 1992) and allows for the classification of the soil.

Soil texture influences erodibility by affecting both detachment and transport processes (Lal, 1988). Larger particles are resistant to transport as a result of the greater force needed to entrain them, whilst finer particles are resistant to detachment because of their cohesiveness. This means that the least resistant particles are silt and fine sands. Soils with high silt content are more vulnerable to erosion than those with coarser particles (Morgan, 1986). Textural analysis in this research was undertaken using the technique outlined by Fitzpatrick (1986) in order to establish sensitivity of the soil and infer erosional processes occurring on the roads. The relative percentage of sand, silt and clay was determined using dry sieving and the hydrometer method discussed in many introductory soils analysis texts (Briggs, 1977; Whalley, 1981; Gee and Bauder, 1986, Goudie, 1992). Each soil sample was spread on a tray dried in an oven at 105^0 C for 24 hours. The texture of the dried soil was analysed by means of a vibrating sieve stack (Briggs, 1977).

In this method, a measured amount of soil is suspended in water and the suspension density is determined with a specialized hydrometer. As soil particles settle, the suspension density decreases. Because larger particles settle faster, the particle size and summation percent remaining for that size can be calculated for each measurement time using the observed hydrometer level, and these results are graphed. From the relationship on the graph, the percent of a particular particle size class can be estimated (Day, 1965). The accuracy of the size class distribution estimate depends on a constant temperature, careful particle dispersal, and proper timing of the density observations. Chemical dispersal in this procedure is accomplished by adding 5% Calgon. Sieves were arranged according to the Wentworth Scale (Briggs, 1977 and King, 1985). This was the scale that matched the sieve tests available and the results were plotted onto a texture diagram.

4.2.2 Chemical Analysis

The Indwedwe soils show high magnitude of soil dispersion than the Inkandla soils, hence chemical analysis was performed. An understanding of the chemistry of soils is central to the understanding of the erodibility of soil. The potassium (K), calcium (Ca), magnesium (Mg) and sodium (Na) contents of the collected samples were measured by atomic absorption spectrophotometry, carried out at the University of Natal, Pietermaritzburg. The atomic absorption spectrophometer is an instrument capable of providing radiant energy of variable wavelength. The extent to which the intensity of beams of radiation are decreased upon passing through the aliquot from the soil sample is related to the absorbing substance in the solution and thus to the concentration of the respective soil cations (Na, Mg, Ca and K). Exchangeable cations were extracted with 1M-ammonium acetate (1:50 soil extractant ratio for two hours) and the filtered extract was analysed for K, Ca, Mg and Na by atomic absorption by the spectrophotometer.

The CEC is calculated as the sum of the exchangeable cations a soil can absorb (Shainberg *et al.*, 1980). CEC gives an indication of the level of exchangeable cations such as Ca, Mg, Na, and K. Lack of these cations makes the soil less fertile and therefore unable to sustain plant growth. This results in inadequate protection of the soil by plants against erosion. In leached soils, the sodium content is almost zero, but may be up to 50% of the CEC in sodic soils, whilst K may be up to 5% of CEC (Rowell, 1994). The cation exchange capacity (CEC) and the exchangeable sodium percentage were calculated from the results obtained by the above-mentioned method. CEC can be referred to as the measure of a soil's ability to retain and supply plant nutrients (NSW Agriculture and Fisheries, 1989).

Exchangeable sodium is the percentage of exchangeable sodium ions compared to cation exchange capacity (Northcote and Skene, 1972).Stocking (1976) and Beckedahl (1998), stress that the higher the values of Exchangeable Sodium Potential (ESP) and Sodium Absorption Ratio (SAR), the greater the availability of sodium to cause dispersion and hence the more susceptible the soil is to erosion. The values of SAR and ESP are used as the index of sodicity. Many researchers for example Stocking (1976), Selby (1993) and Beckedahl (1998) have shown that sodium exerts a negative influence on aggregate stability by its effect on the clay dispersion process. Dispersion is a process which separates clay particles by breaking the bonds between them (Selby, 1993).

$$SAR = \frac{[Na^{+}]}{\sqrt{\frac{1}{2}([Ca^{2+}]+[Mg^{2+}])}}$$

Equation 4.1

$$ESP = (Na+/CEC) \times 100$$

Equation 4.2

According to Jones (1981) soil is usually classified as dispersive when the ESP is greater than 15% of the total exchange capacity. Heede (1971), Donaldson (1975) and Stocking (1976) stress that soil chemistry is the major factor in soil pipe formation. It is generally agreed that the dispersion of soil is likely to occur when the ESP is greater than six (Ritchie, 1963 in Beckedahl, 1998).

Table 4.2 gives a comprehensive summary of the various sampling strategies and laboratory procedures used to collect data. These soil samples were then subjected to analysis in the laboratory. There are field techniques for the determination of soil texture but laboratory techniques can determine accurately the particle size distribution of the soil (Smith and Atkinson, 1975).

Table 4.2.Summary of various sampling strategies and laboratory methods used to gather data

Study area	Variable	Technique used at each site within a given area	Location	No of samples per site
Inkandla	Particle size	Sieving and hydrometer	Road surface	3
			Embankments (side walls)	3
			Individual soil horizons (A, B, C)	3
			Road verges	3
	Surface strength/ soil strength	Farnell type hand shear vane	*In situ soil*	5 complete determinations
	Slope gradients	Abney level, ranging rod and tape measure	Top to bottom of slope	n/a
Indwedwe	Soil chemistry	Cation exchange capacity	Road surface	3
			Embankments (side walls)	3
		Exchangeable sodium percentage	Individual soil horizons	3
			Road verges	3
	Particle size	Sieving and Hydrometer	Crest and footslope (soil	6
			Soil horizons (A, B, C)	3
			Embankments (side walls)	3
	Surface strength	Farnell Type hand shear vane	*In situ soil*	5 complete determinations
	Slope gradients	Abney level, ranging rod	Top to bottom of slope	n/a

4.3 The Human Dimension

It is vital to have knowledge of the socio-economic status of the area together with the local perceptions and attitudes for which environmental problems are being studied. In order to achieve these, a cross-sectional qualitative survey (Branch *et al.,* 1984) was conducted with a view to understand people's perceptions and attitudes towards rural road access associated with geomorphic constraints. A study based upon a qualitative process of inquiry has the goal of understanding a social or human problem from multiple perspectives and is conducted in a natural setting and involves a process of building a complex and holistic picture of the phenomenon of interest (Creswell, 1994). A thorough understanding of the dynamics of a society will enhance the understanding of the reasons behind the changes in the environment that is taking place and will also help to predict future changes (Hall and Conning, 1992).

In depth interviews and discussions with key members of the communities such as the headmen, local business owners, school principals, taxi owners, officials from the Department of Transport, other important key informants in the area and service providers were conducted. Discussions with the above mentioned stakeholders within the communities in the area helped in assessing the extent in which the states of rural roads directly affect them. Other respondents in the study area included people who were located in closer proximity to the main access road where study sites are positioned.

The attitude of the above-mentioned key persons (rural stake-holders) is important in understanding the extent of accessibility problems and can help researchers and planners in policy formulation pertaining to transport planning. It is through the gathering of such data that opportunities for agriculture and other economic activities, better access to schools, health and other community services, installation of electricity and telephones and supply of drinking water can be created (Howe and Richards, 1984; Heggie and Vieckers, 1998).

Wiesberg *et al.* (1996), in Naude (1999), state that surveys are used to determine classes, or groupings according to certain criteria:

1) Attitudes, beliefs and behavior
2) changes in these over time
3) differences between groups of people with respect to their attitudes, beliefs, behavior and causes resulting in these attitudes, beliefs and behavior
4) causes resulting in these attitudes, beliefs and behavior.

As a general principle, Peil *et al.* (1982) state that having as large a sample as possible is best. In this study, due to time constraints and problems of access to the study area, the use of a smaller sample was necessary.

A total of 150 structured questionnaires were distributed, of which 90 responses were obtained, which consisted of 30 respondents for each study area. The study sample consisted of respondents who were located closer to the study sites and areas of notable road degradation. The questionnaire (Appendix 1) consisted of socio-economic and demographic aspects and attitudes and perceptions of local communities to accessibility in the area.

The study sample consisted of respondents from different sexual backgrounds in the community. Each interview represents a different household. Considerations of sex, age and occupation were taken into account. The interviews were semi- structured and open ended in order to give respondents room to elaborate upon certain issues pertaining to access they considered as being of importance. Their own perceptions on various issues were brought forward, including information that may not have been revealed if predetermined questionnaires had been used. Most of the respondents spoke freely and many were glad to discuss issues that were of central importance in their daily lives.

4.3 Methods of data analysis

To aid the interpretation of quantitative data obtained from the study area, SPSS (Statistical Package for Social Sciences) was used to determine the correlation analysis and analysis of variance (ANOVA) was used in order to determine the validity of the Null Hypothesis formulated for various parameters, as described by Lindeman *et al.* (1980). Students T-tests were used to compare results obtained. A correlation analysis was undertaken to find out if soil particle size distribution and soil shear strength were related.

Chapter 4 has outlined the laboratory and field techniques used to obtain the results presented in the next chapter. It is now possible to investigate the geomorphic context of the three areas outlined, to analyse the data obtained. This information is presented in the next chapter, whereas Chapter 6 considers the social context of the communities living within the three areas and their perceptions concerning the problems of access.

CHAPTER 5

Analysis of the Geomorphic Controls Affecting Access Roads

In attempting to understand the geomorphic constraints affecting rural road access, a number of degraded roads were examined, the location of which was discussed at the end of Chapter 3. Data presented in this chapter are the results obtained from the fieldwork techniques and laboratory procedures outlined in the previous chapter. The geomorphic results obtained from each study area are separated into three broad categories, namely, site description and the physical and chemical properties. The physical properties of soils include texture and shear strength, while the soil chemistry focuses mainly on the Cation Exchange Capacity (CEC) and the Exchangeable Sodium Percentage (ESP). The geomorphic context and implication of these parameters are considered for each location, prior to analysing the social context of the three field sites in Chapter 6.

5.1 Inkandla

5.1.1 Site Description

Numerous sites portraying different geomorphic constraints on rural road access were identified in the Inkandla area. Of these, three representative sites were selected to examine the nature and causes of such geomorphic constraints. The location of the specific study sites within the Inkandla area is shown in Figure 5.1. The study sites are positioned on the community access road (D166) to the Chube community and the Inkandla forest road (P100) that connects Inkandla with Eshowe. These will be reviewed briefly, prior to discussing the geomorphic characteristics within the context of soil erosion for the Inkandla area as a whole.

Upper Kwa-Dlabe

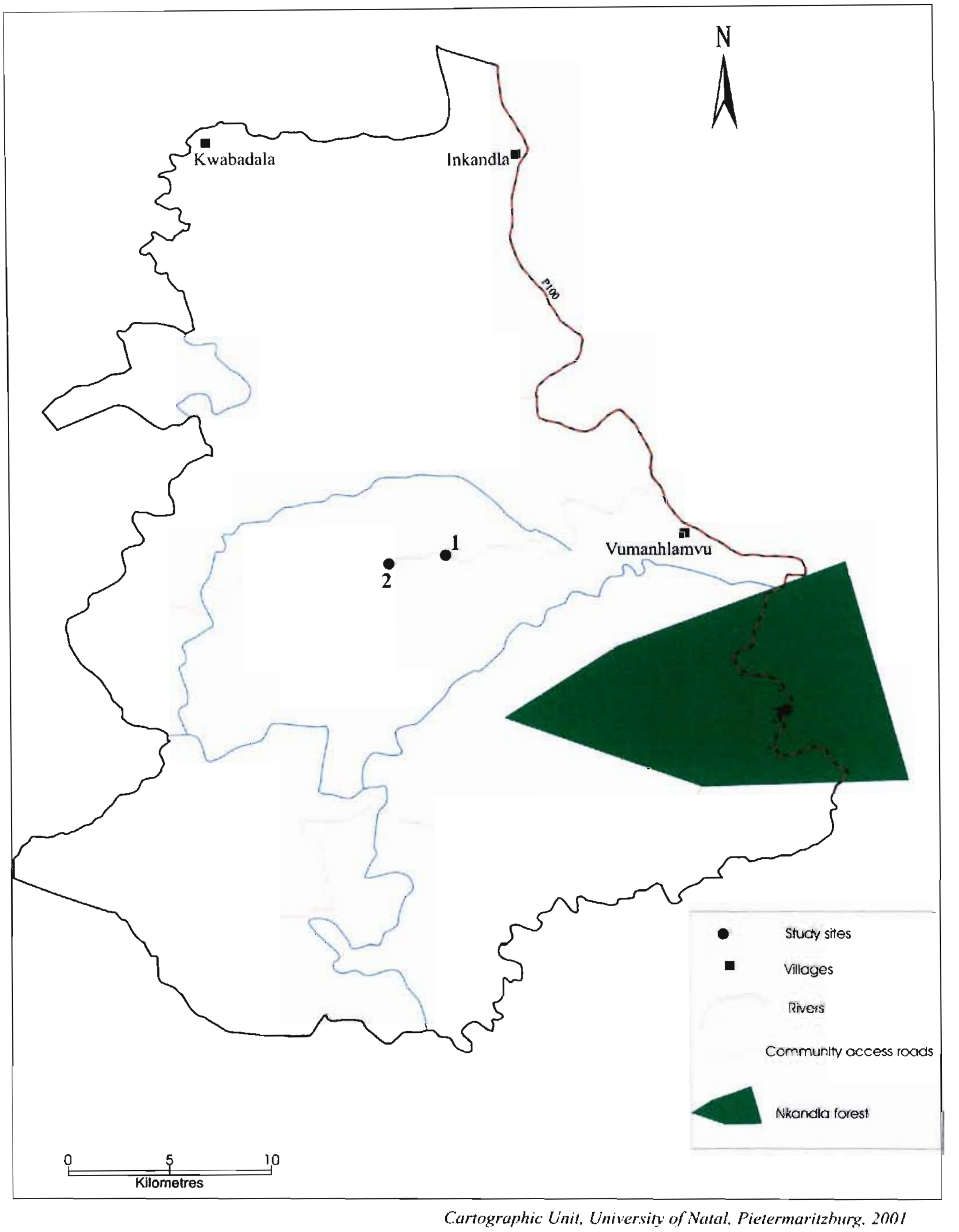
This is located on the District road D166 leading to the home of the Amachube's chief, Inkosi Shezi, as shown in Figure 5.1(site 1). It is situated seven kilometres away from the junction with the main road (P100) to Inkandla. From the researcher's and the local people 's observation, this has been noted as a site which raises serious vehicular access problems, especially during the rainy season. It was thus chosen on the basis of its geomorphic characteristics as being representative of possible geomorphic constraints limiting vehicular access. Gullies and rills have occurred over much of the road surface. There are two deteriorating roads which were selected for the study. Figure 5.1.

The Main Kwa-Dlabe study site

This is the last section of the D166 road (site 2, Fig 5.1), located nine kilometres away from the main road that leads to Inkandla. It is important to note that this road leaves hundreds of households within the Inkandla area stranded due to its poor quality. It is an unarmoured road of inconsistent width, varying from 5,5 m to 8 m. Several constraints and erosional processes occur on the road surface.

Inkandla Forest Reserve

The P100 road from Eshowe to Inkandla goes through the indigenous Inkandla forest reserve (see site 3, Figure 5.1). The particular section of the road used as the third representative site is approximately 12 km in length. Most sections of the Inkandla forest road are covered by forest canopy, which implies that the surface is not subjected to the direct impact of raindrops, but rather to throughfall from the canopy, which in turn prevents the road from rapid drying by providing shade.



Cartographic Unit, University of Natal, Pietermaritzburg, 2001

Figure 5.1. Location of specific study sites within the Inkandla area

5.1.2 Field observation and geomorphic characteristics

In the Inkandla area, gullies and rills have occurred over much of the road surface. According to the SARCCUS (1981) classification, this erosion type is moderate to severe (class 3 and 4). Road A (Figure 5.2) is an abandoned community access road that has severely deteriorated due to erosional processes that have acted on it over the past six years. Road B (Figure 5.2) is a road that is still in regular use by the community. It is an alternative route which the community claims to have constructed in 1996 to improve road access.

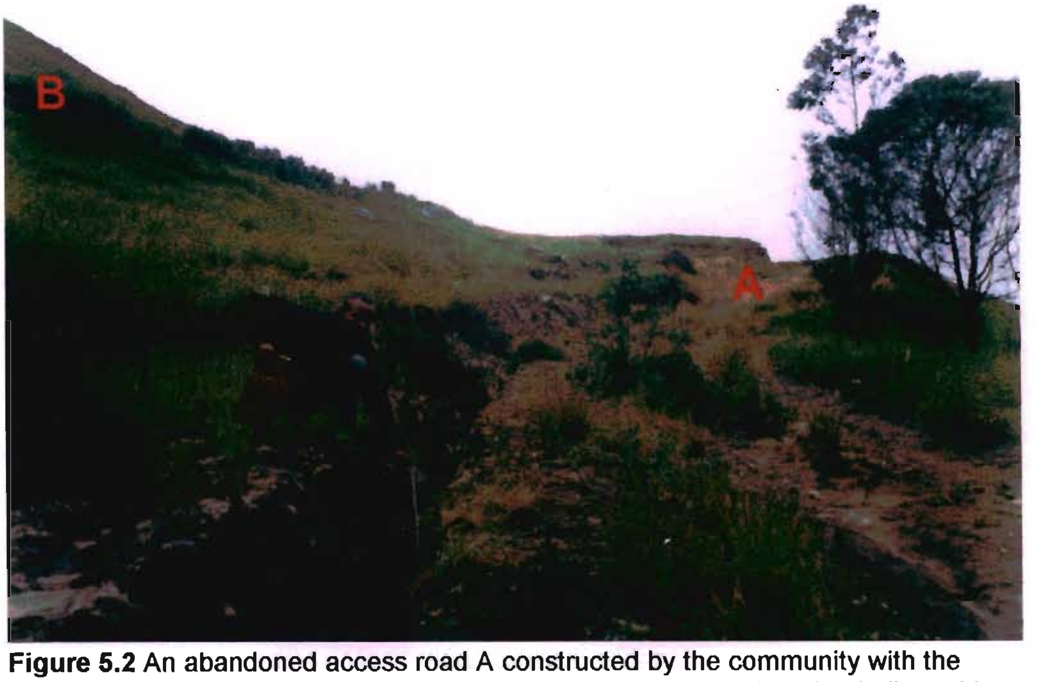


Figure 5.2 An abandoned access road A constructed by the community with the newly constructed road marked B. Note the 1.8 metre deep gully being indicated by the field assistant

Soil erosion on both roads is severe, especially on the abandoned road (A). Rill erosion on Road B is observed to be the dominant process acting on this section of the road and has played a significant role in the deterioration of the road. Rills have developed into gullies extending 300 m in length and are up to 1.8 m in depth (see Figure 5.2 and Figure 5.3). The influence of slope angle on soil entrainment by sheetwash and rill erosion triggered by the lack of protective cover, have also had an effect on this road. Slope angles perpendicular to the road section were found to be in the range of 17^0-22^0, which is steep for road construction.

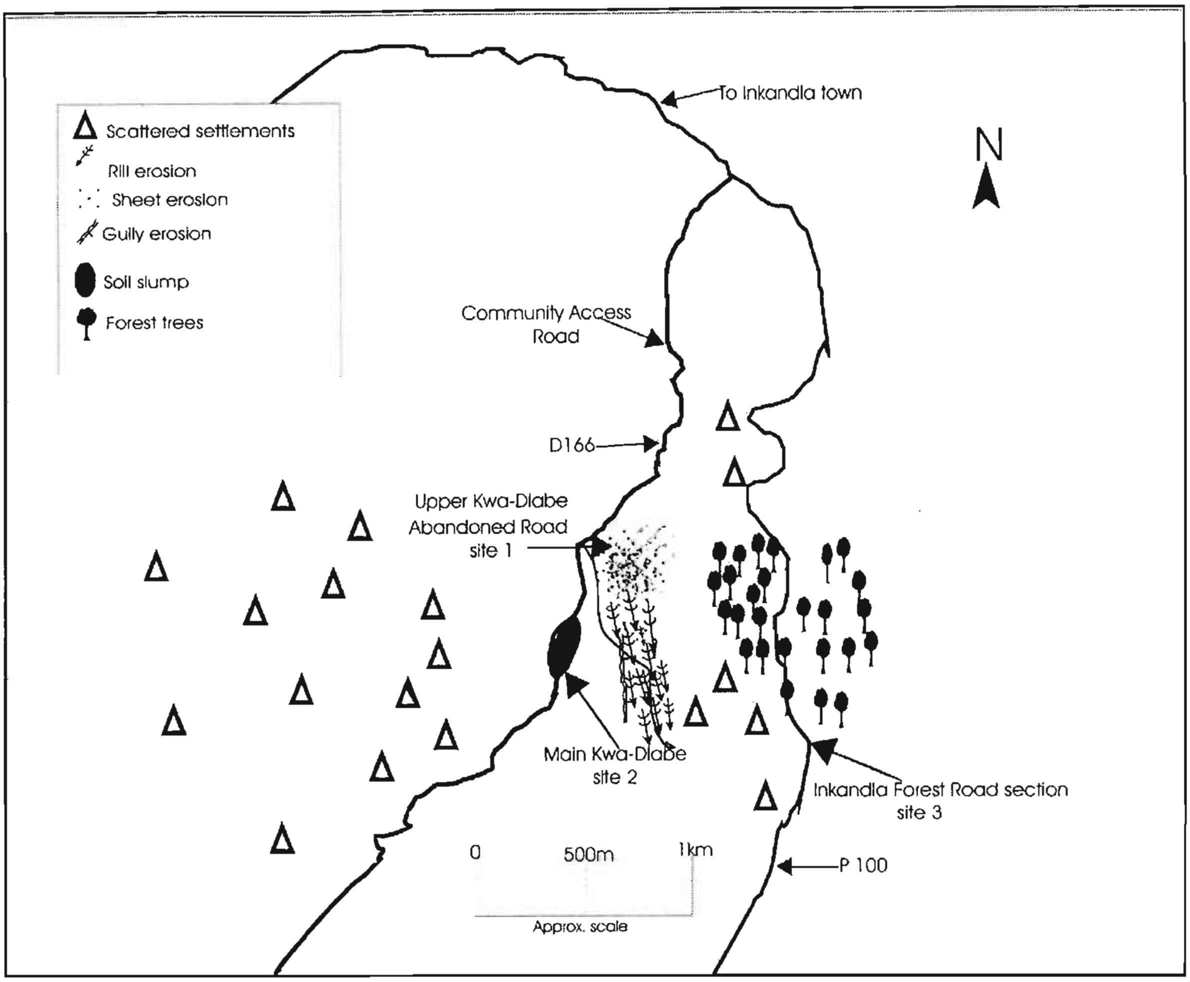


Figure 5.3 Field map illustrating the geomorphic characteristics of the representative sites in the Inkandla area

The direct effect of the kinetic energy of precipitation on the upper Kwa Dlabe road section is also seen to have played a role in soil loss. This again emphasizes the importance of vegetation as a protective cover for the soil against the action of raindrops and in increasing the infiltration capacity of soil, as reflected in the literature (see for example Kirkby (1979), Cooke and Doornkamp (1990), Selby (1993),Morgan (1995) and Stocking (1996). The road embankment in the Upper Kwa Dlabe site is largely bare of vegetation, although reestablishment of vegetation was noticeable on some parts of the abandoned road. Raindrop erosion is recognised by Selby (1993) as being responsible for disaggregation of soil and the splashing of soil particles into the air exists, both on the abandoned causeway and on the cut embankments. Although it was not possible to quantify the effect of raindrops and their torrential effect, the effect of erosion at the Upper Kwa Dlabe site is mostly observed where little or no grass cover exists both on the abandoned causeway and on the cut embankments (Figure 5.4).

The formation of rills in the Inkandla area can generally be attributed to an increase in hydraulic gradient as a result of slope gradient. Theoretically, erosion is expected to increase with an increase in slope steepness and length, both as a result of the increase of velocity and of volume of surface runoff (Hudson,1981; Morgan,1986). Morgan (1995) attests that rills are initiated at a critical distance downslope where overland flow becomes channeled and breaks into rills, as is the case at Inkandla. Figure 5.4 is an example of the extent to which such soil erosion can destroy a road to such a degree that it becomes unusable.

Figure 5.4 An access road constructed by the community on a steep slope and later abandoned because of severe erosion (Upper Kwa-Dlabe, site 1, Fig 5.3).

There is no doubt that human activity has contributed to road degradation in the Inkandla area. Local residents dig soil and white lime for construction of huts and for the beautification of their homesteads from the eroded area adjacent to the road. Such activities accelerate soil erosion induced by the position of the road. This, in turn degrades the road and further increases problems of access along the road. The construction of a road by local residents on steep gradients has further contributed to the deterioration of the Upper Kwa-Dlabe site, as shown in Figure 5.4.

Extensive slumping was observed as an additional factor in road degradation. An embankment of 1.14 m exists on the main Kwa-Dlabe road section (see site 2, Fig 5.3), with slumping being the major erosional process degrading the embankment (Figure 5.5). Representative soil samples were collected from the different soil horizons of the embankment itself and from the slumped material, for laboratory analysis. Although the texture will be discussed in greater detail later, the material collected from the slump material in this study site shows high sand values with a low clay fraction and thereby confirms the susceptible nature of the soil from this location. In terms of the recommendation by the TRH 4 (1985), a proper balance of stones, sand and fines must be maintained when constructing roads, in order to attain proper and long term stability. When any of these is missing or present in wrong proportions, stability problems will occur.

Figure 5.5 Road degradation as a result of soil slumping at the main Kwa-Dlabe site, Inkandla

A different form of soil loss in the Inkandla area was observed on the forest road section (see site 3,Figure 5.3). The problem is largely attributable to the nature of the forest canopy, which covers most sections of this road. The interception of rainfall by the vegetation canopy affects soil erosion by reducing rainsplash, as illustrated in Selby (1993). The height of the canopy is critical however, as leaf interception may coalesce the raindrops, thus exacerbating the problem.

Previous findings show that if the vegetal ground cover is destroyed by grazing animals, the energy of falling drops may actually be greater under the forest than in the open (Selby, 1993). Selby (1993) found that in some tropical forests, where soil is left bare or where leaf litter is rapidly decomposed, low intensity rainfall may collect on the leaves of the canopy and drip from the leaves in large drops. These drops will reach their terminal velocity if the canopy is 10m or more above the ground and they may have considerable splash effects upon the soil. This consideration is particularly important within the Inkandla forest, given the high incidence of mist discussed in Chapter 3.

A further contributing factor is presented by stemflow from trees coalescing on the forest soil surface, leading to sheet and rill erosion. This latter condition is important at Inkandla, given the high average precipitation by summer thunderstorms. The canopy further slows down evaporative drying, ensuring that the road has a high antecendent moisture content throughout the wet summer months. Soil erosion problems on the forest road, most frequently in the form of ruts and slippages, are observed after heavy rains. These features are attributes of vehicular degradation, which Moodley (1997) found have a detrimental impact on the geomorphic environment under grassland conditions and could imply the same conditions in forest environment. Heavy rains increase the soil moisture, resulting in deep mud and a lack of traction for vehicles, rendering the road impassable, thus restricting or negating access completely.

5.1.3 Particle Size Analysis for the Inkandla area

The textural analysis of soil samples collected in the Inkandla area from different road sections have revealed a high percentage of sand, followed by silt and lastly clay (Fig 5.6). The mean percentage of sample sizes is shown in Table 5.1. A total of 24 soil samples were collected at Inkandla, In study site 1 (Upper Kwa-Dlabe), a total of 9 soil samples were collected, six from the abandoned road and three from the new road. At the Main Kwa-Dlabe site, 10 soil samples were collected in two locations, from three soil horizons of a vertical profile and the other set was collected directly on a slump material observed on the road embankments. In the Inkandla forest road, 5 soil samples were collected. The soils are thus highly susceptible to wash processes, but are stable with aggregation. An analysis of texture for all three locations shows each to have a characteristically mean high phi value, with the coarsest particles being found within Inkandla forest.

Table 5.1 Mean particle size distribution of representative samples collected at Inkandla

Nkandla site as in Fig. 5.8	Mean sample no.	%sand	%silt	%clay
Upper Kwa Dlabe	1	66	28	6
	2	36	55	8
	3	88	10	2
New Road	4	50	28	22
Slump (Main Kwa-Dlabe	5	62	34	4
Main Kwa-Dalbe (soil horizons)	6	68	22	10
	7	58	26	16
	8	70	28	2
Inkandla Forest Road	9	80	14	6
	10	72	26	2
	11	76	22	2
	12	88	8	4

All soils collected at Inkandla show a high percentage of coarse materials (in this case, weathering of the underlying bedrock is likely to have controlled the soil texture and resulted in the erodible material). These results are in agreement with other studies (see Zachar, 1982; Morgan,1986), which have shown that the low clay content makes the soil susceptible to erosion, mainly by water, and explains the degradation of the road surface by rilling.

At Inkandla, soil samples reveal textures of sand, loamy sand, sandy loam, loam and silt loam. The majority of soil samples are sandy loam as evident from Figure 5.7. Although TRH 14 (1985) suggest a sand equivalent of no less than 30% on gravel roads, this guideline has not been followed on the Inkandla road at site 2. Clay proportions in all samples collected are much lower than those of silt and clay, fractions which are highly significant as binding agents. The low clay content while in overall accord with TRH 14 (1985) also has implications for soil strength, since cohesion in soils is influenced in part by the abundance of clay particles. In this context it is interesting to note that the new section of the road has an even higher percentage of sand than the old (abandoned road) as in Figure 5.6. It is therefore more likely to be stable, but to compact to a further degree forming ruts which are likely to act as incipient rills.

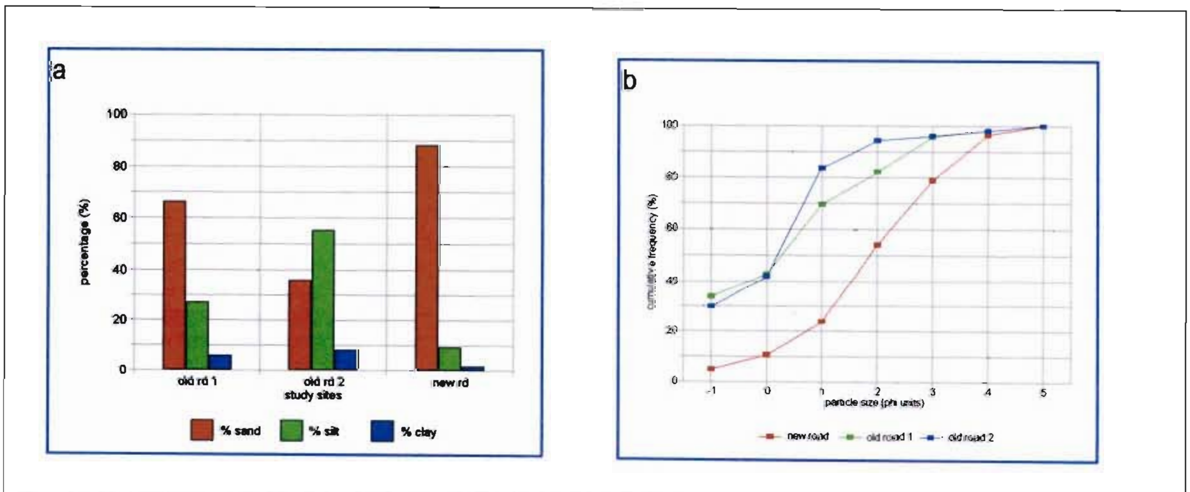


Figure 5.6 Mean textural fractions(a) and cumulative frequency plots (b) of representative samples collected at Upper Kwa-Dlabe (site 1, Fig 5.3)rd on graph=road

Texture analysis for the new road shows a phi mean value (1.93) with a slight increase in finer particles as compared to the samples collected in the abandoned road. The old road 1 has shown a coarsening texture (phi mean=2.90) with a more finer material observed in old road 2 (phi mean=3.00).

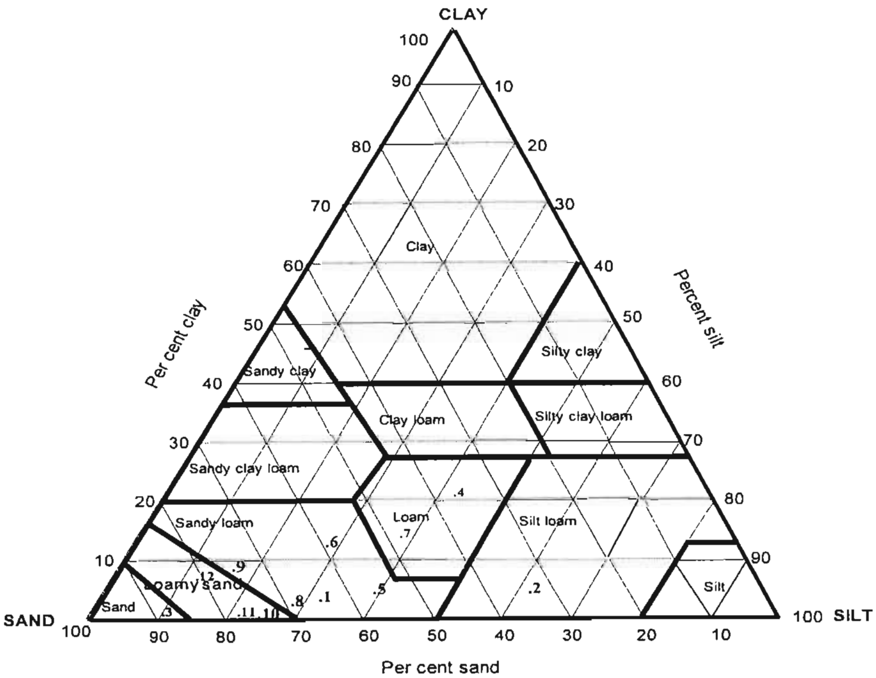


Figure 5.7 Texture plots of representative samples collected from the Inkandla area, numbers represent sample numbers.

Soil collected in differing horizons as outlined in Chapter 4, reflect a slight change in particle size distribution within soil horizons. Their mean phi values (A horizon= 0.4, B horizon=1.16 and C horizon=1.36), suggest a fining of material down the profile, probably due to the elluviation of clays. As has been mentioned before, the texture of the soil collected here was compared with that of the slumped material as shown in Figure 5.8. The slump material approximates (phi value= 1.3) the texture of the undisturbed C horizon (see Figure 5.8). The B-horizon in the Main Kwa-Dlabe area has shown a greater percentage of coarse material compared to the C-horizon. The clay fraction increases with depth. The disturbed sample(i.e .slump) also, displays a finer texture than the samples collected from the soil horizons

The texture of the A and B horizons are not greatly different (A horizon=0.4 and B horizon=1.16), whereas the C-horizon is significantly finer with a mean phi value of 1.36.

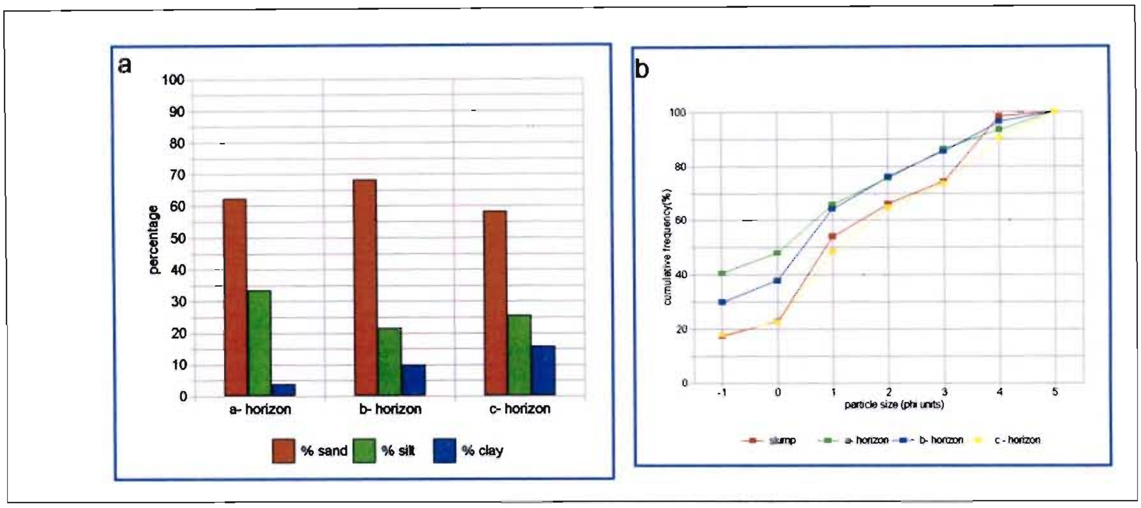


Figure 5.8 Mean textural fractions (a)and cumulative frequency(b) of representative samples collected at the Main Kwa Dlabe site

The susceptibility of the forest road to splash erosion as previously outlined is evident from Figure 5.9 The sand fraction (which is poorly aggregated) is again dominant and the material will thus be easily mobilised by the impact of water drops from the forest canopy.

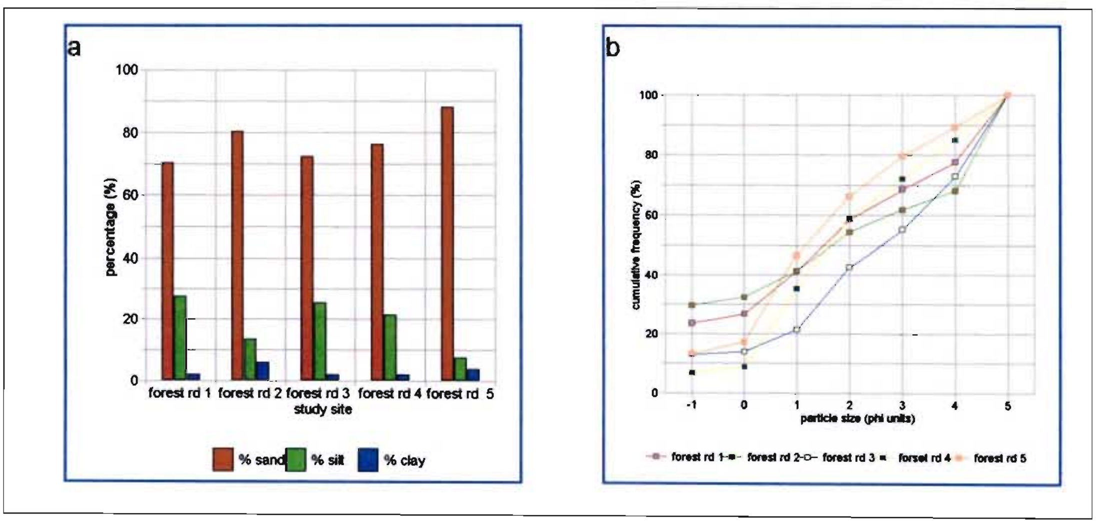


Figure 5.9 Mean textural fractions (a)and cumulative frequency plots (b) of representative samples collected from the Inkandla Forest road (site 3, Fig 5.3),frst rd on graph=forest road.

Texture analysis of soil samples obtained from the forest road show a fining of material for all samples (forest road 1=1.26, forest road 2=1.33, forest road 3=2.63,forest road 4=1.73 and forest road 5=1.73) relative to the texture of the other Inkandla soils.

5.1.4 Mean Soil Shear Strength Analysis for the Inkandla area

One of the physical characteristics that has been considered important in this study is the shear strength of the soil, which is an indicator of soil erodibility. Soil shear strength indicates the cohesiveness and the resistance to shearing forces exerted by external forces (Morgan,1986). These forces include factors such as raindrop impact, trampling animals and gravitational slumping. In this study, a Farnell-type hand shear vane was used to determine the resistance of soil to shear stress.

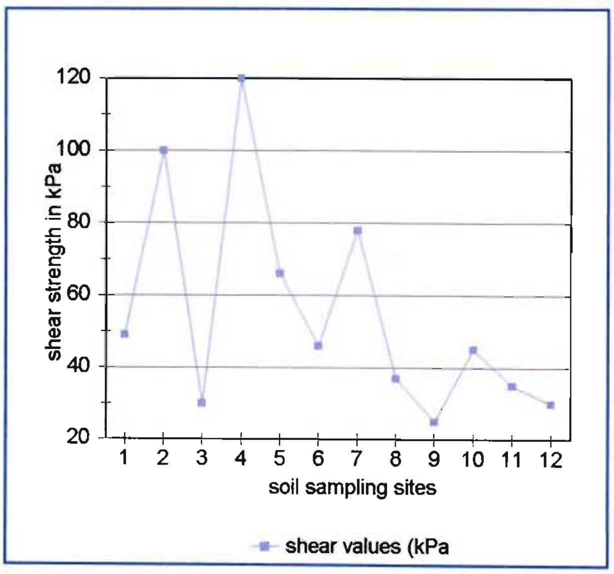


Figure 5.10 Mean Soil Strength for Soils collected at different sites (Inkandla)

Soils collected in the Inkandla forest road have displayed higher shear resistance (shear strength values varying from 25.0 to 37.0 kPa) despite their sandy loam and loamy sand texture (see sampling site no 8 to 10). In the Main Kwa-Dlabe site,(slump) displays the highest shear value (120 kPa) with the other samples collected in the slumping embankment displaying low shear strength (shear values ranging from 46.0-78.0 kPa).

In the Upper Kwa-Dlabe very low shear shear resistance (shear value 100 kPa) was observed on the abandoned road probably due to weak compaction as illustrated in TRH 4 (1985). A lower shear resistance displayed by most soils collected at Inkandla can be attributed to the sandy nature of the soil. For instance, on the sandy loam soil type (sample sites 1, 5,6,8 and 9) the graphs show a lower shear strength values as compared to the high shear values observed in soils displaying a different texture. An decrease in shear resistance (80-120 kPa) of soil in sample sites 2,4, and 7 to a lesser extent can be attributed to the increased clay content within that soil. This is in accordance with Lal (1990) observation that shear strength is also influenced by soil texture, a point substantiated by the Pearson correlation results presented later in the chapter.

Hand shear vane values at the Main Kwa-Dlabe site show a decrease in shear resistance down the soil profile with an increasing clay content. Soils collected in the Inkandla area have shown a lower shear resistance relative to the Indwedwe soils as will be seen later. Such a decrease can be ascribed to the high percentage of sand displayed in the majority of the soil samples. This suggests that soil in the Inkandla area may be less compacted and thus porous, resulting in increasing pore water pressure after rainfall events. This is important as the increased pore water pressure can increase erosion by lowering the inter-particulate cohesion.

From the shear strength results (Figure 5.10), it is clear that the soil types found at Inkandla are very erodible because of their generally low shear strength which in turn can explain the observed extent of soil erosion in the area.

Particle size distribution of soil samples and soil strength results were subjected to a correlation test in order to determine the relationship between particle size and soil strength at the Inkandla sites. Correlation of shear strength and sand content for the upper Kwa-Dlabe has revealed a very strong negative relationship (r^2=-0.97) implying a marked relationship between soil shear strength and sand content, as sand content decreases, strength will increase. A similar negative relationship between shear strength and sand content was found by Preston and Crossier (1999) and Phillip (2000). In their studies they concluded that lack of cohesion can be attributed to the sandy texture of the soil. This argument is further supported by the observation of a very strong positive relationship between soil strength and clay (r^2=0.81)and silt percentage (r^2=0.98) for the region.

An analysis of variance for soil strength and particle size for the Inkandla textural data (null hypothesis= there is no significant difference between shear strength and texture) revealed no significant relationship at the 95% confidence limit for sand and soil strength, silt and soil strength and clay and soil strength ($p<0.005$). This may be attributed to the relatively small population used, rather than interrelationship. The correlation data suggest that reductions in clay content in turn are likely to decrease the soil resistance to erosion processes.

A negative relationship exists between particle size and soil strength in soil samples collected at the main Kwa-Dlabe study site. Sand content and soil strength are negatively correlated (r^2= -0.99), in this case, again implying that as sand content increases, shear strength decreases. It is important to note however, that such a near perfect relationship could be due to the constraints of the limited sample size imposed in this project by practical considerations and would therefore require further research verification. Beside the negative relationship between sand and strength, a slight positive correlation exists between soil strength and silt, and strength and clay (r^2=0.13 and r^2= 0.21) suggesting that the controls on soil strength in non-sandy soils are more complex than merely texture dependent.

The particle size distribution of the soil samples collected from the Inkandla Forest Road section at Inkandla were again correlated with soil shear strength results. Again, a negative relationship exists between soil strength and sand content (r^2=-0.47). The notably lower r^2 value for these sandy soils may be explained by the increased moisture content. Whereas the previous sandy soils had a soil moisture of <10%, it has already been stated that the forest soils are kept moist by the canopy cover (moisture values averaged some 12-15% by weight).

The moisture is likely to be responsible for an increase in cohesion of the particles. Silt content and soil strength have a positive relationship (r^2=0.58).Although differences exist between sand and soil strength between sites the overall relationship is strongly negative (r^2=-0.802) and is significant at the 95% confidence level. Silt and clay content and soil strength are well correlated and positive but not significant.

5. 2 Indwedwe

5.2.1 Field observations, sample detail and geomorphic characteristics

At this location, five representative sites were selected for thorough investigation as they depict the constraints along the road from Inanda to Verulam (Figure 5.11). The geomorphology of each site is discussed briefly in the next section and the field characteristics are shown in Figure 5.12. More site specific information is contained in the next section, which deals specifically with the sampling and geomorphic observations carried out on each site.

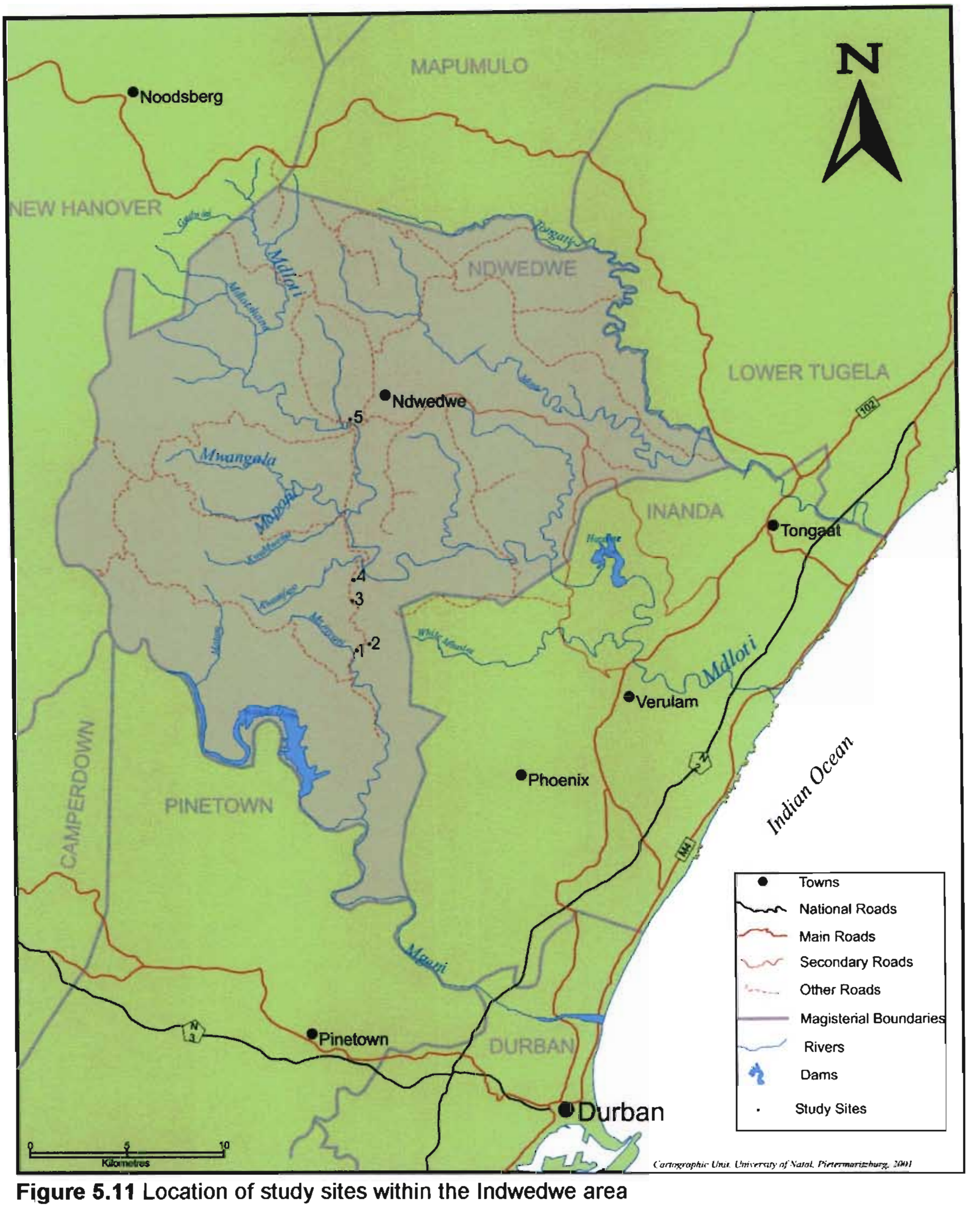


Figure 5.11 Location of study sites within the Indwedwe area

At Indwedwe, many footpaths and dust tracks are visible leading to the various homesteads. These visible tracks have been hand dug by the communities in an attempt to improve vehicular access to their homesteads (see Figure 5.13). In most cases where hand digging is practiced, there are indications that new gullies might develop and these will lead to further deterioration.

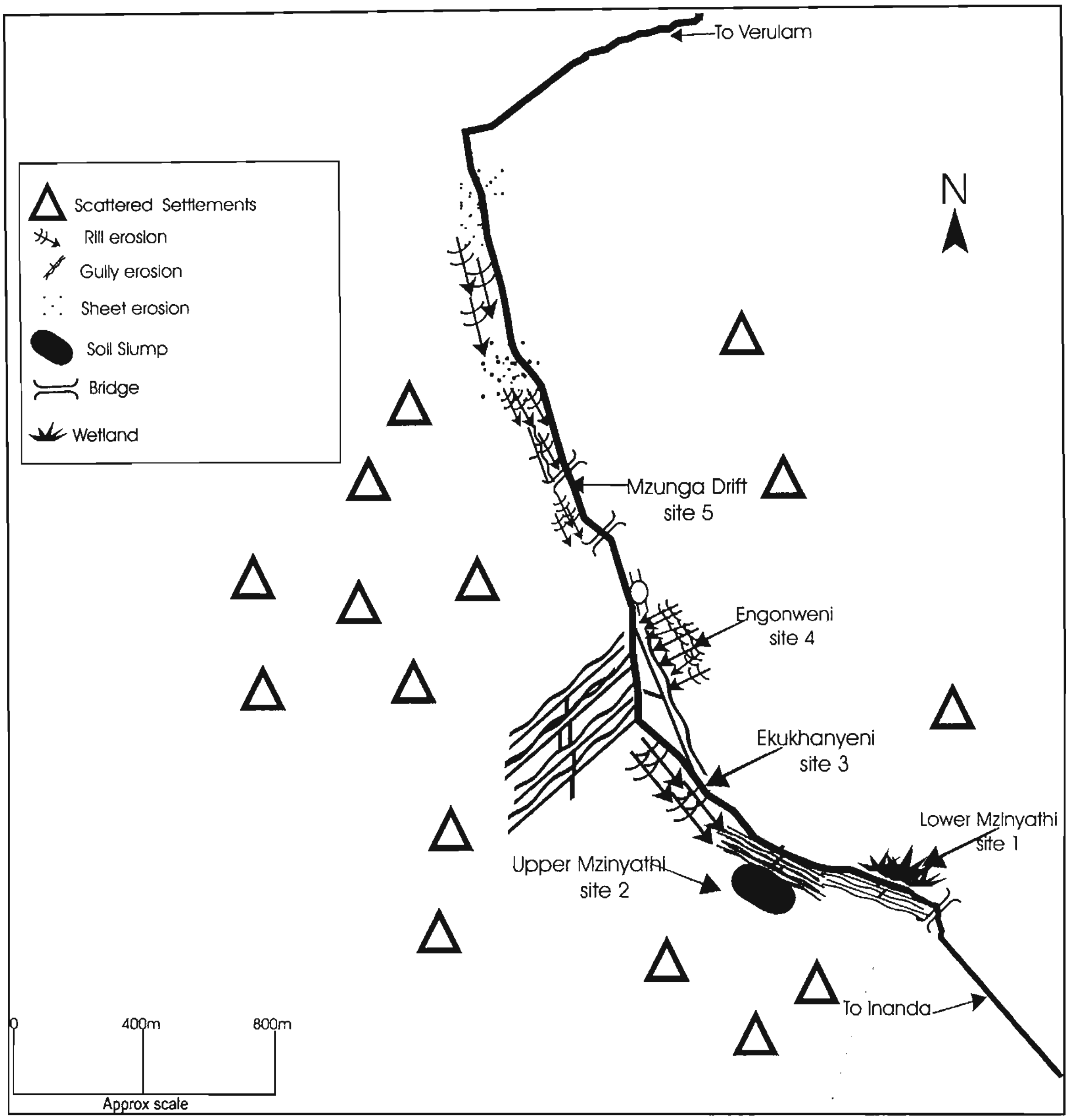


Figure 5.12 Field map illustrating the geomorphic characteristics of the five representative sites in the Indwedwe area

Lower Mzinyathi

The site is situated at the bridge across the Mzinyathi river (site 1, Figure 5.11 and Fig 5.12). This river channel is observed to be a meandering channel of approximately 2.5 metres width, with an ephemeral flow. The channel is eroding sideways, mainly towards the road and will, in due course, reduce the passage of cars and make the road impassable. The road beyond this point is impassable in wet weather and this site represents the point where local transport operators then offload passengers.

Figure 5.13 A villager hand digging a household access road at Lower Mzinyathi

Tracks and paths are responsible for much of the pronounced erosion on roads. The reason is that the tracks serve as waterways during heavy downpours directing runoff to the main roads. This means that the contribution of these access roads in accelerating soil erosion is significant. It was also observed from the study that such hand-constructed community access roads can be primary sources of sediment production within a watershed, as previously observed by Duck (1995), Megahen and Ketcheson (1996), MacDonald *et al.* (1997) and Russow and Garland (2000).

As is the case in the majority of villages in KwaZulu Natal, most residents in the Indwedwe area are linked to the main road by trails or poorly maintained tracks, resulting in erosion (see Figure 5.13). The Mzinyathi river, which is located a few metres away from the main road, poses serious problems of access to people staying across this river, particularly during the wet season. Figure 5.18 shows a poorly constructed low-level bridge at Mzunga Drift that was constructed by the community with the help of the local government and was washed away. This has seriously hindered vehicular access to the area. The collapsing and washing away of the bridge has resulted in local businesses suffering because they were cut off from the main road. During the study, residents staying across the river were observed carrying food items and other goods, head loading back to their homesteads.

In general, soil physical and chemical characteristics have had a major influence in the degradation of the road in the area. At lower Mzinyathi, six representative samples were collected from two vertical profiles (A, B, and C) of a slumping embankment for physical (particle size distribution) and chemical analysis (ESP and CEC) as previously outlined (Chapter 4). The results of the laboratory analysis are explained in detail in section 5.2.2.

Upper Mzinyathi

This site is situated a few metres from the second bridge, some distance away from the Lower Mzinyathi study site, on the road to Indwedwe Mission(site 2, Figure 5.11 and Fig 5.12). A major constraint to effective vehicular access here is the location of a wetland adjacent to the roadside, as in Figure 5.14. The wetland has formed adjacent to the road and has resulted in pooling of water on the causeway due to poor drainage. It is this wetland that makes vehicular access in this section of the road a problem, especially after heavy rains, when the wetland experiences heavy flooding, partially submerging the road surface due the high water table effects.

Figure 5.14 A wetland on the roadside(upper Mzinyathi) makes vehicular access difficult in periods of prolonged rains.

In a manner similar to that described for the Inkandla area, major slumping was observed mainly onto the roadside, as shown in the Figure 5.15 (site 2, Fig 5.12).

Figure 5.15 Soil slumping at upper Mzinyathi commonly occurs on road cut slopes.

At the Upper Mzinyathi area, three soil samples were collected. One representative sample was collected from the slump itself (Figure 5.15) observed on the road and the other set was collected from the undisturbed crest and base of the road unit respectively.

Ekukhanyeni

The third site is a degraded road embankment of approximately 600 m in length and up to 8m in height (site 3, Figure 5.11 and Fig 5.12). Erosional features include large severely eroded gullies, several metres deep. *This study site is a steep eroded embankment along the provincial road.* Particle size analyses were obtained from samples taken along the slope transects (crest, midslope and footslope). Two samples were collected from each slope transect to represent different erosion types.

Erosion along the Ekukhanyeni embankment can be described as severe to very severe (class 4 and 5 of the SARCCUS (1981),classification). According to Brinkcate and Hanvey (1996),this classification is characterized by large areas of land totally denuded by sheet erosion, as in a large road embankment with widespread dissection by rills and gullies. Wemple (1998) has shown that road cuts have the potential to intercept groundwater and thus increase the amount of surface runoff, thereby causing road degradation and destabilizing slope. Although no direct evidence supporting Wemple 's (1988) work was observed in the field, it is likely that a similar situation would arise due to perched watertables during the wet summer months. This would explain the mass movements in the form of soil slumps that were observed to be accumulating at the base of the slope and appear to be the most dominant process responsible for the movement of unconsolidated material in the embankment. They could however also be triggered by the high rainfall in the area.

Rilling occurred mostly in places where culverts were incorrectly placed on the side of the road. Mean rill width varied between 5 and 90 cm, with the depth varying between 2 and 40 cm. These rills have been created by the high quantity of surface water. Slope angle, which is a cardinal determinant of the runoff velocity (Kakembo, 2000) is a critical variable. In the Indwedwe area, mean slope angles vary between 12^0 and14^0.

Egonweni

This is a severely eroded road cut located at the village of Engonweni (site 4, Figure 5.11 and 5.12). This study site consists of an embankment approximately 500 m long, with heights ranging from 9 m to13 m. Gullies on the roadside are approximately 400 m long, with a depth of to two and half metres. The first part of the slope cut is sparsely vegetated, with large erosion scars which appear to have occurred through gully and pipe erosion, where vegetation is bare, as shown in Figure 5.16. The width of the road in this section has decreased from 7,5m to 4,5 m because of the erosion occurring on the side of the road.

Figure 5.16 Extensive erosion of an embankment in a road cutting at Engonweni, Indwedwe. Note the sparse vegetation cover.

Theoretically erosion increases with an increase in the length of slope. Young (1972) and Selby (1993) have shown that the erosive effect of runoff is higher where there is a reduction in slope gradients largely due to increased turbulence generated by the hydraulic jump. This is the case at the present site.

Rilling on the road embankment is obvious and ultimately results in the development of gullies both on the embankment and on the roadside. This is most evident on the roadside where channeling is linked to the formation of extensive gullying on the road (see Figure 5.17). These erosional processes are seen to have played a role in the reduction of the width of the usable roadway at Egonweni.

Gullies are' relentless destroyers of roads', particularly earth roads (Hindson, 1983). At the Engonweni site (see Fig 5.17, site 4), a deep extensive, active gully exists below the road cutting. The gully seems to have developed through slumping and acts as a means of transporting water from the road surface downslope. Water erosion thus plays a dominant role in this instance. Gully head retreat is actively occurring, contributing to the general increase of the gully and affecting the width of the carriageway.

Figure 5.17 Gully erosion below a road cutting at Egonweni in the Indwedwe area. Note the depth of the gully . The soil surface is approximately 2m above the irrigation pipe, which is 3m long.

According to Oostwoud and Bryan (2001), processes related to gully head retreat and expansion include the hydraulic shear by overland flow on the rim and on the vertical walls, splash impact from a plunge pool at the foot of a headcut and the vortex erosion in the pool, mass wasting of the walls due to the development of tension and dessication cracks, seepage erosion and tunneling. The gully at this site is retreating backwards and eating back into the road by means of slumping triggered by the action of water. This problem is considered in greater detail later in Chapter 7.

Overland flow occurring on the surface of this road section caused ponding (causing the road to become impassable in rainy weather) and the flow entering the gully is responsible for the retreat of the gully head and severe slumping. A relatively inexpensive way of preventing further development of the head cut is the use of gabions to protect the head cut and the use of suitable channels to divert water into the stream.The embankments on the roadside are completely unvegetated (see Fig 5.16), with gullies approximately three metres deep, four metres wide and 14 metres in length. Soil erosion at these sites can be attributed to a number of factors, viz. slope length, slope angle, soil type and human factors. At this location, four soil samples were collected to determine the particle size distribution and the chemical properties as described in Chapter 4 and the results are fully discussed in section 5.2.2.

Mzunga drift

Study site 5 (Figure 5.11 and 5.12) is located in Mzunga village, next to a poorly constructed bridge with streams crossing to join the Mdloti river. However, with increased flow of the river during the December 1999 and January 2001 floods, the bridge was partially damaged by erosion, as is shown in Figure 5.18.

Figure 5.18 **A culvert that was destroyed by heavy rains at Mzunga Drift, Indwedwe**

At the time the field investigation was being conducted at Mzunga Drift it was observed that the road was impassable, resulting in the road being closed. Damage to this bridge was permanent, with major structures lost, and consequently the stream changed its course. In this case the condition that has exacerbated bridge deterioration was the intense scouring due to inadequate protection work. The use of insufficient and poor-quality materials in the construction of the bridge exposed the bridge to further damage.

Pronounced rock outcrops with sharp edges are observed on most sections of the road surface and are dangerous to road users due to the risk of tyre blow-outs associated with impact fractures of the tyre casings. They can also shorten the life-span of vehicles by loosening the chassis.

5.2.3 Particle Size Analysis for the Indwedwe area

The results of mean particle size analysis for soil samples taken at Indwedwe are presented in Figure 5.19 a-b and Table 5.2. Soil samples collected at Indwedwe have a sand loam texture, with 10% clay, 8% silt and 34% sand fractions (see Figure 5.20).

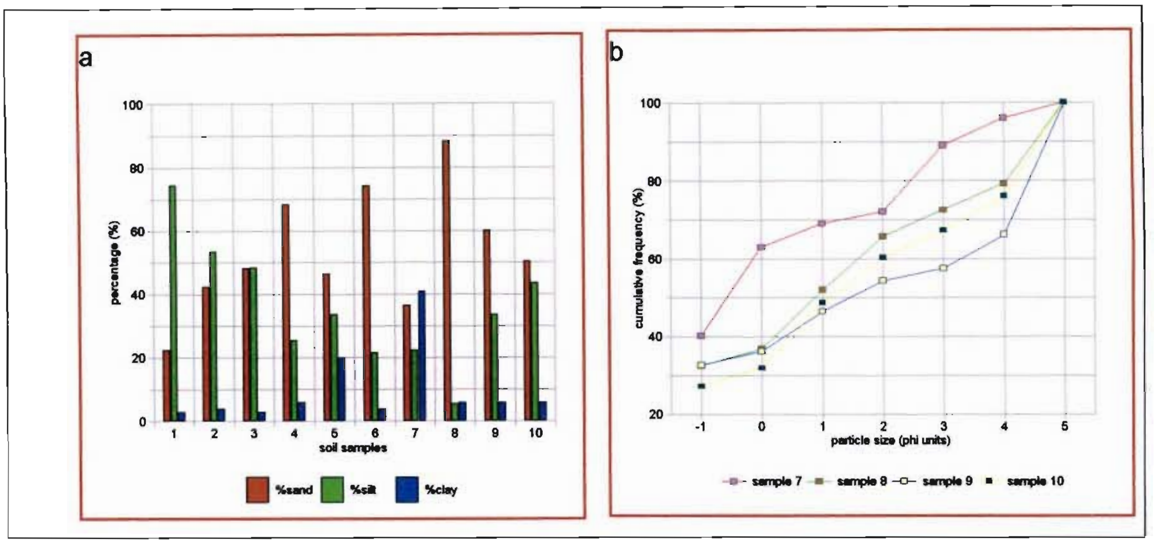


Figure 5.19 Mean textural fractions for representative samples (a) and particle size phi units(b) from severely eroded road embankments in the Indwedwe region.

For Indwedwe, the major mechanism responsible for the high percentage of sand can be ascribed to the weathering of the parent rock in the area. Slope angle is also responsible for much erosion in the area and has the greatest impact in facilitating road degradation.

Table 5.2 Mean particle size distributions of representative samples collected at Indwedwe

Indwedwe sites as in Fig. 5.12	study site	% sand	% silt	% clay
Lower Mzinyathi	1	22	74	4
	2	42	53	5
	3	48	48	4
Upper Mzinyathi	4	68	25	7
	5	46	34	20
	6	74	22	4
Ekukhanyeni	7	36	23	41
	8	88	6	6
Egonweni	9	60	34	6
	10	50	44	6

As shown in Figure 5.20, Indwedwe soil samples range from silt to silt loam and sandy loam, with only a few samples showing a silty clay texture. Soil samples number 1, 2 and 3 were collected from exposed soil profiles in horizon A -B. As shown in Figure 5.19, sand increases down the profile, with high silt content. Though the silt content is the highest, the sand content is fairly high and the clay content is the lowest (Fig 5.20).

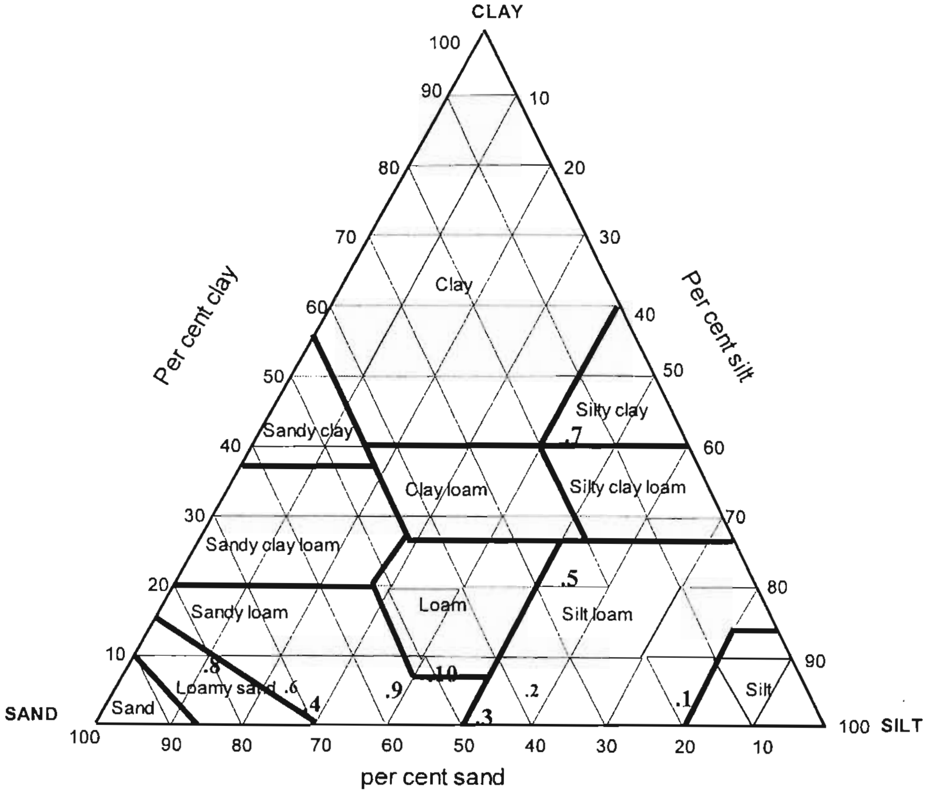


Figure 5.20 Texture plots of representative soil samples collected in the Indwedwe area

Particularly remarkable from this study area is the mean particle size distribution taken from the upslope, midslope and footslope of the road cut embankments, as shown in Figure 5.19. It is evident from Figure 5.19 (sample no 8,9 and 10) that sand content decreases downslope whereas the initial expectation would be that it would be removed by erosion upslope and deposited at the footslope. The mean phi values (0.83 (upperslope), 1.06(midslope),and 1.33

(upperslope),1.06(midslope),and 1.33 for the (footslope)) imply a fining of material. Another reason for such a decrease in sand content downslope could be the slope angle and length. Morgan (1995) indicates that erosion frequently increases with an increase in slope length and steepness. According to Granger (1984), there is roughly two-thirds of the total area of Transkei in which slope length conditions are conducive to pronounced soil erosion. However, on clay soils, soil erosion does variably increase with the length of a slope.

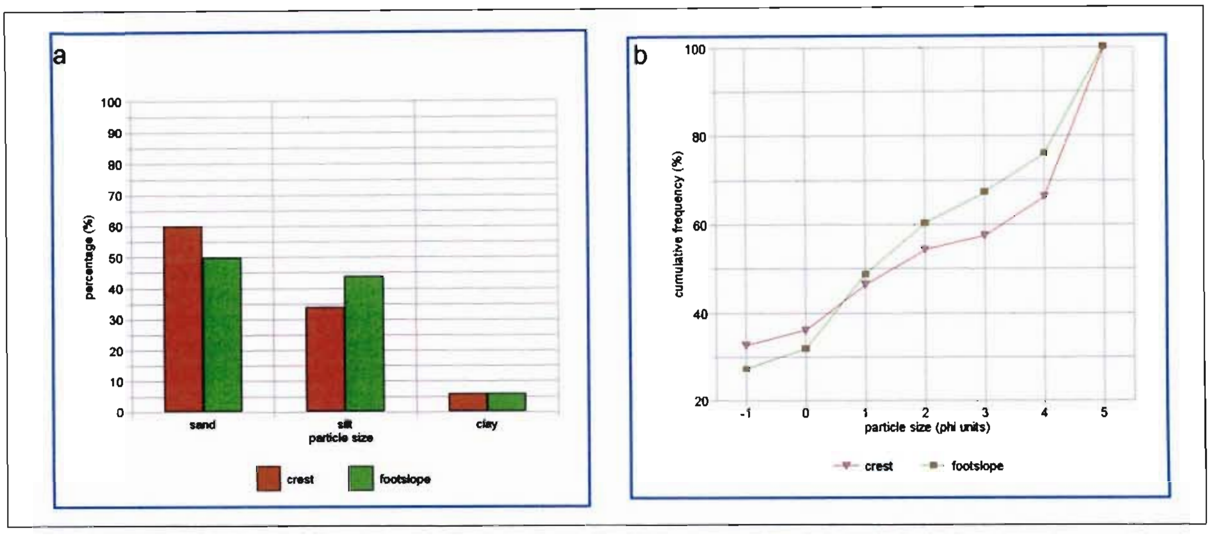


Figure 5.21 Mean textural fractions (a) and cumulative frequency(b) of representative samples collected at Egonweni in the Indwedwe area

The result of particle size distribution of soil samples collected at the Engonweni site has shown that soils contain a high percentage of sand, with clay the least dominant, which again is in broad agreement with the principles of the TRH 14 (1985). Particle size analysis between the crest (phi mean value=1.6)and the footslope (phi mean value=1.36)shows similarities in sediment distribution characteristics and also confirms the presence of coarser material (Figure 5.21). Based on this observation of the characteristic of soils from this study site, the presence of a coarse fraction in this sample could be occurring as a result of finer particles removed by wash processes from upslope to downslope, through alluviation, or it could be related to local variations in the weathering products of the bedrock, as the base of the embankment is in the C and R horizon.

Analysis of Variance with a null hypothesis stating that there is no significant difference between particle size and soil strength in most samples revealed no significant difference between sand, silt and strength at the 95% confidence interval. Soil strength and sand determined from soil samples collected in the Egonweni area have shown a very strong negative correlation whereas a strong positive correlation was observed between silt and soil strength. This suggests that the sandy soils(coarse textured) investigated were more susceptible to erosional processes than silt soils and the effects of mass movements proccess were more severe on the sandy soils.

The extent of the erosion is further illustrated by the fact that culverts are exposed through surface wash processes and overland flow. It is thus of utmost importance for scientists, engineers and planners to have the necessary construction skills and knowledge before building a road, especially as such projects have serious cost implications.

The role played by human activity at the Egonweni study site was further manifested by the activities taking place on the upperslope section. For example, the construction of houses and access roads on vulnerable steep slopes has exacerbated the problem. Where vegetation cover has been destroyed along the road section, the soils are susceptible to extreme erosion which, in turn, will cause an increase in road degradation.

5 2.4 Mean Soil Shear Strength

Soil shear strength results are similar to those found at Inkandla. Differences were, however evident between sites. Samples number 5 and number 7 have shown high soil shear strength, shear values higher than those of other soil samples. This can be attributed to the clay percentage and may suggests that soil shear strength is a function of field moisture content. The high sand content increases pore water pressure and thus reduces the shear strength of the soil. Soils collected at Indwedwe have shown a low shearing resistance and such a decrease can be ascribed to the sandy loam nature of the soil.

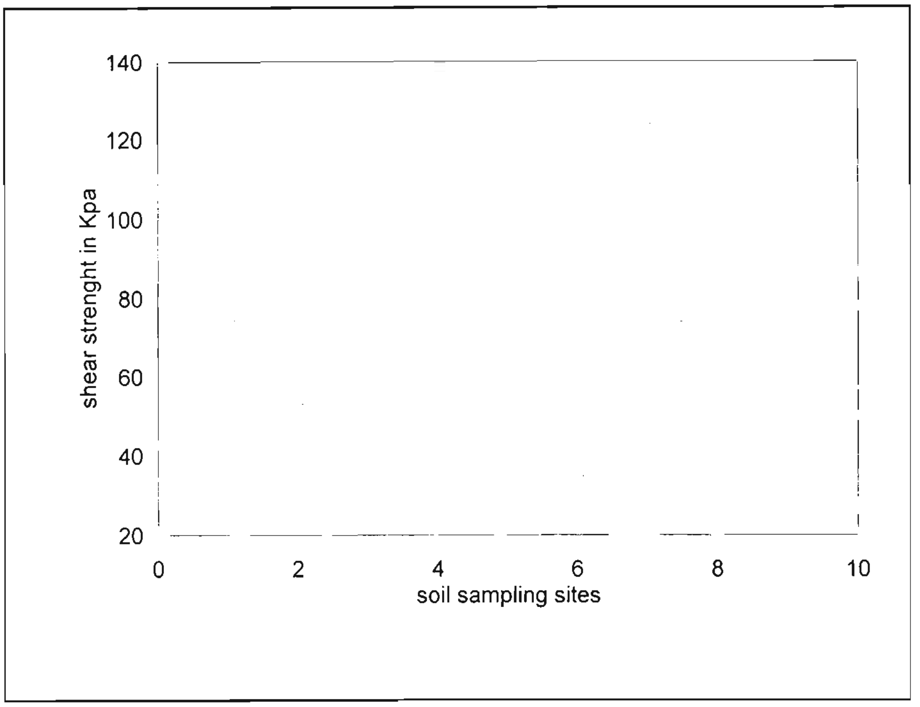


Figure 5. 22 Mean soil shear strength values for soils collected at Indwedwe

High shear values were observed in soil samples 1, 5, 7 and 10. All other soil samples have had high soil shear resistance and a high sand percentage. Such observations can be related to the extent of the erosional processes in the area.

Analysis of variance was used to determine the validity of the null hypothesis formulated, that there is no significant difference between particle size distribution and soil strength. The anticipated trend therefore is that soil strength is dependent on the sand, silt and clay percentage. Sand content has shown to be the most significant variable that determines the shear resistance of soil.

The results of correlation analysis at the Lower Mzinyathi indicate that texture and strength are strongly related, with a significant difference between sand and soil strength $p=0.001$). Of all the samples tested, few samples were not significant at the 0.05 level. Such findings suggest the existence of a relationship between particle size and strength. The findings further support those of visual observation, that is the use of scatter grams to identify relationships between particle size and soil strength. Consequently, the correlation revealed a fairly strong relationship between particle size and strength.

A very strong positive correlation exists between clay and soil shear strength(r^2=0.96). A very strong negative relationship exists between sand and strength(r^2=-0.98). A weaker positive correlation (r^2=0.42) exists between soil strength and silt. Analysis of variance for the three textures indicates no significant difference between sand and strength, (p=0.083) and silt and strength (p = 0.549), with a closer relationship existing between clay and strength (p = 0.115)which is however still not significant at the 95% confidence interval.

From soil samples collected at the Upper Mzinyathi site, a very strong positive correlation exists between soil strength and silt, (r^2=0.92) and a very strong negative relationship exists between sand and soil strength(r^2=-0.94). No correlation exists between clay and soil strength (r^2= 0.04). The sandy loam nature, which increases the pore water pressure of the soil, accounts for such relationships, as documented in soil analysis texts. ANOVA between sand, silt and soil strength between the five representative sites revealed no significant difference at the 95% confidence level($p<0.05$). The variance between clay and soil strength as determined by ANOVA was also not significant (p=0.007) despite being closely linked, as shown by the correlation analysis.

5.2.5 Soil chemistry

According to Jones (1981), soil is usually classified as dispersive when the ESP is greater than 15% of the total exchange capacity. Heede (1971), Donaldson (1975) and Stocking (1976) stress that soil chemistry is the major factor in pipe formation. In the present study, soil chemistry analysis was only performed from soil samples collected at Indwedwe, considering the extent and the nature of soil piping observed. The CEC of samples collected from the Indwedwe study area CEC is the measure of soil capacity to retain and release elements such as K, Ca, NA,. Soils with high clay or organic content tend to have a high CEC. Soil CEC is relatively constant overtime. CEC were determined by ammonium acetate extraction as outlined in Chapter 4.

An examination of soil chemistry (see Table 5.1 and Figure 5. 23 a-b) has revealed that some soils are likely to be dispersive and that ESP values decrease down the profile. The acceptable base saturation limit for sodium is 15%. This is also called the Exchangeable Sodium Percent or ESP. Sodium levels higher than 15% on the exchange site could result in soil dispersion, poor water infiltration, and possible sodium toxicity to plants. Brink (1981) showed that soils are dispersive when the ESP is greater than 5% and between 5-15%, but combined with CEC greater than 15 cmol/kg.

In this research, the total amount of cations is low in most samples as shown in the table below. It is only in sample 8 where Total Exchangeable Bases (TEB, sum Na+,K+,Mg+ and Ca+) exceed 4%. These soils can be regarded as sodic and therefore as structureless and easily erodible (see Bertman and Bronman, 1999). Soils that contain very low to moderate amounts of exchangeable sodium (i.e., exchangeable sodium is <0.7 me/100 g) and have sufficiently low cation exchange capacities to qualify as being sodic or strongly sodic often do not display dispersive soil properties in the field. High percentages of exchangeable magnesium are thought to contribute to sodic soil symptoms as well (Tucker, 1983). CEC is only higher in sample 8 , with the rest of the samples showing low values, the low CEC values in most samples can be explained by the lower Ca+ content. Soils with a high CEC provide good fertility, but if the base saturation is low, most of the CEC is occupied by H+ ions and such soils are regarded as only potentially fertile.

Table 5. 1 The results of soil chemistry analysis for the Indwedwe area(significant ESP and CEC values are highlighted

Sample number	Ca meq/ l	Mg meq/ l	Na meq/l	K meq / l	ESP %	CEC cmol/ kg	TEB
1	0.8	0.69	0.28	0.02	**15.9**	1.81	1.79
2	0.79	0.44	0.1	0.01	7.47	1.33	1.34
3	0.23	0.95	0.09	0.01	7.71	1.29	1.28
4	1.25	1.06	0.12	0.01	4.94	2.43	2.44
5	1.24	1.04	0.13	0.01	5.69	2.43	2.42
6	2.27	1.79	0.19	0.04	4.5	4.25	4.29
7	2.5	2.13	0.76	0.01	**14.16**	5.4	5.4
8	4.81	8.13	4.56	0.01	**26.05**	**17.5**	17.5
9	1.63	1.67	0.12	0	3.52	3.43	3.42
10	0.42	0.98	0.09	0.01	6.08	1.49	1.5

It appears from the results in Figure 5.23 a - b that soils collected in the Indwedwe area are vulnerable to dispersion. A low salt content in the soil water increases the potential for cation exchange and hence the susceptibility of the soil to dispersion (Sherard and Dekker.,1977 in Beckedahl, 1996). The K values of all soils at Indwedwe are relatively low (0,01-0,02) and therefore render the soil susceptible to wash processes and to surface erosion, noting that the vegetation cover was damaged in areas where sub surface erosion was observed. The ESP of soil samples collected at Indwedwe are high. Jones (1981)observes that dispersivity can result when the combination of exchangeable sodium plus magnesium percentage exceeds 15% of the total ESP.

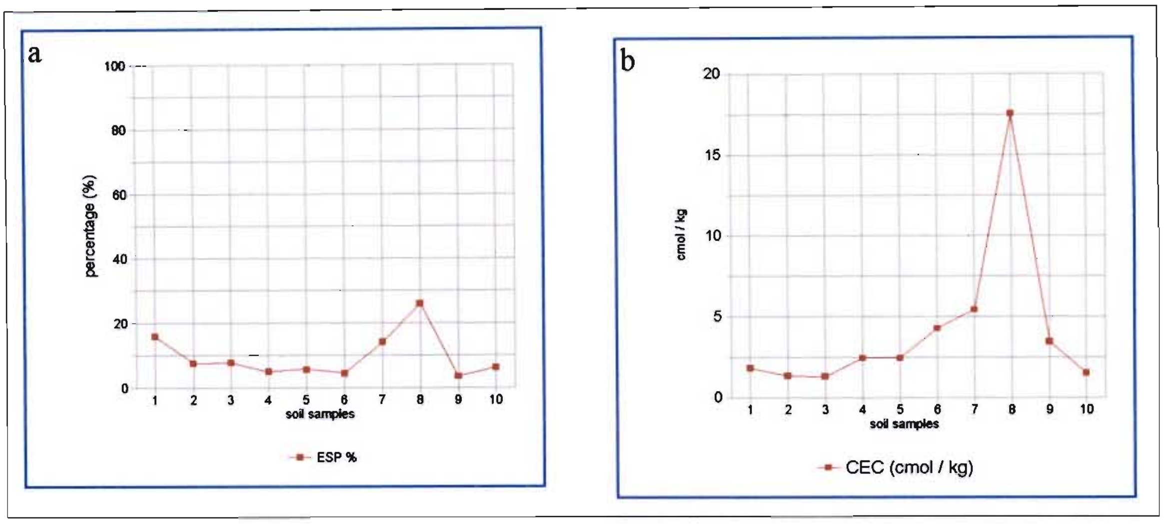


Figure 5.23 ESP (a)and CEC (b) of representative samples collected in the Indwedwe area

It can therefore be concluded that the field soils represented by sample 8 (and to a lesser extent by 7)both collected on the segment of the prevailing slope are susceptible to pipe development. The results of the dispersion tests related to soil chemical analysis showed a high tendency of the soil to disperse. This is suggested by the high ESP values between 15.9% and 26.05%,and the high cation ion exchange capacity values of 17.51 cmol/kg observed in sample 8. Such results support the hypothesis that dispersivity of soils contributes to the road degradation observed at Indwedwe, but that texture and strength (as at Inkandla) also plays a major role.

5.3.Ga-Modjadji

Several sites depicting environmental constraints on vehicular access were observed but, for practical purposes, four representative sites were selected to examine the nature and causality of such constraints. As mentioned earlier, no extensive quantitative measurements were undertaken to evaluate and assess the nature of geomorphic constraints in the area due to technical problems related to accessing field sites with equipment, and taking meaningful samples back to the laboratory for analysis. It was observed in all road sections of the study area that the community access roads are deeply rilled and gullied.

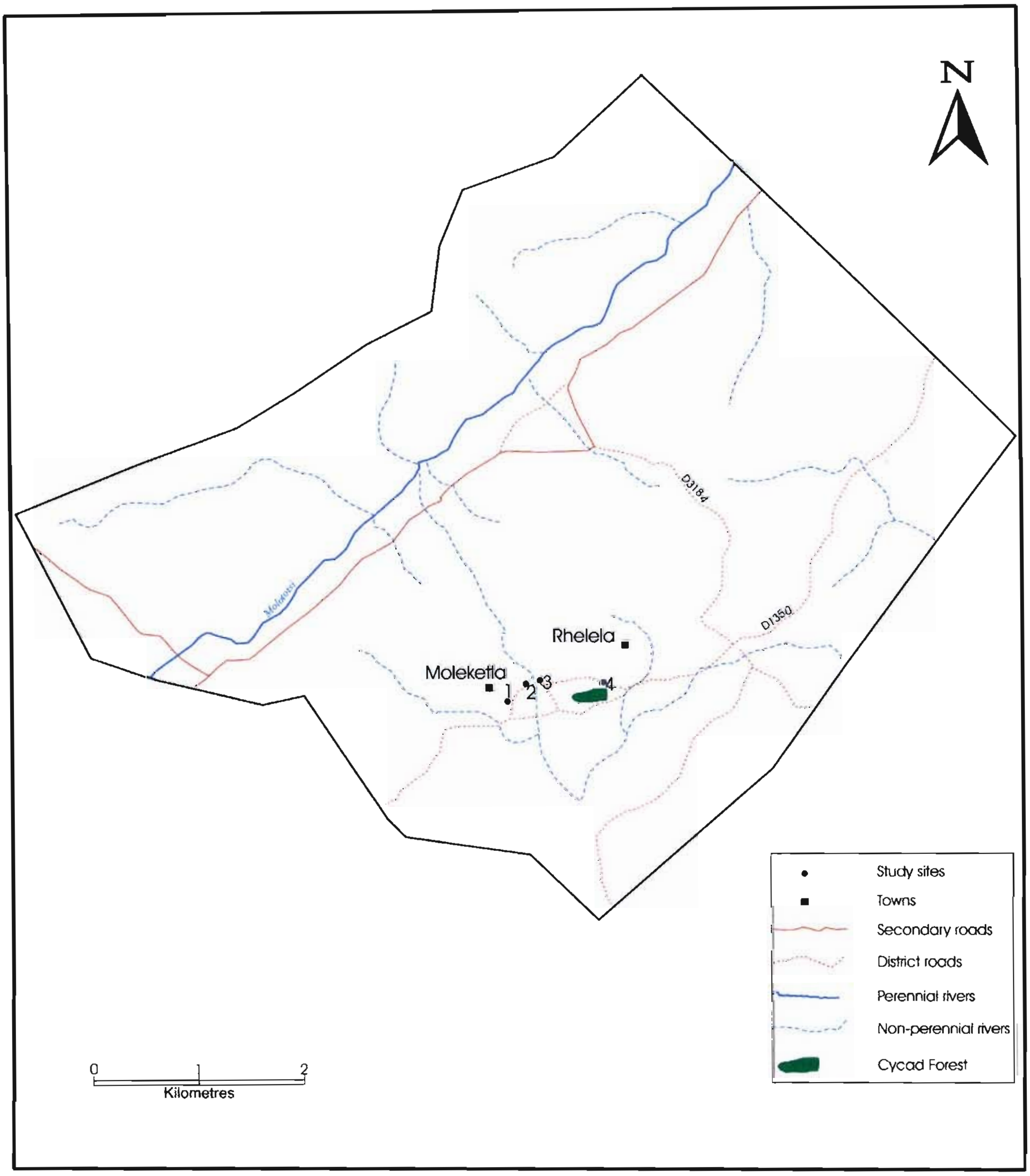


Figure 5.24 Location map of study sites within the Ga-Modjadji area

Ga-Modupa

The site is located in the Modupa area. Land use in this area includes subsistence farming. Gullies along the road observed at this study site vary from 5 to 150 metres long and have severely affected the width of the carriageway, which is approximately 2 m wide. Figure 5.27 shows a downpour that has caused gully erosion.

Upper Moleketla

This is a road section that becomes impassable in rainy weather and was severely damaged as a result of the February 2000 floods. Road-users often experience difficulties when driving through this section. At this section, sheet and rill erosion, seem to have predominantly played a role in the degradation of this road section and evidence of soil compaction was also noted.

Lower Moleketla

This was the most interesting road section to study. Various erosional processes are responsible for the destruction of road access. Mass movements, gully erosion, rill erosion surface sealing and compaction were the most evident processes occurring on this road section. The study site is approximately 500m long, with the road width varying from approximately 6 m and with the road cut height varying from 5m to 8 m.

Ga-Modjadji Cycad Reserve

This is the part of the road which is approximately 100 metres away from the Modjadji cycad nature reserve entrance. Common geomorphic constraints on this road section include rock falls, huge rock outcrops on the road surface, rill and gully erosion. Erosion occurs primarily as a result of slope angle or steepness.

5.3.1 Field Observation and Characteristics

The Ga- Modjadji results are based on observations and inferences of geomorphic processes in the field. The field characteristics are shown in Figure 5.25. Erosional processes, including mass movement exacerbated by the February 2000 floods, were evident on almost all road embankments. The Upper and Lower Ga- Moleketla sites need special mention, in terms of the scale of erosional processes observed to be occurring mainly in the form of rills and gullies which spread by headward erosion and have severely degraded roads in the area. Other sites that were studied in the Ga-Modjadji area included the Ga-Modupa and the Ga- Modjadji cycad reserve access road.

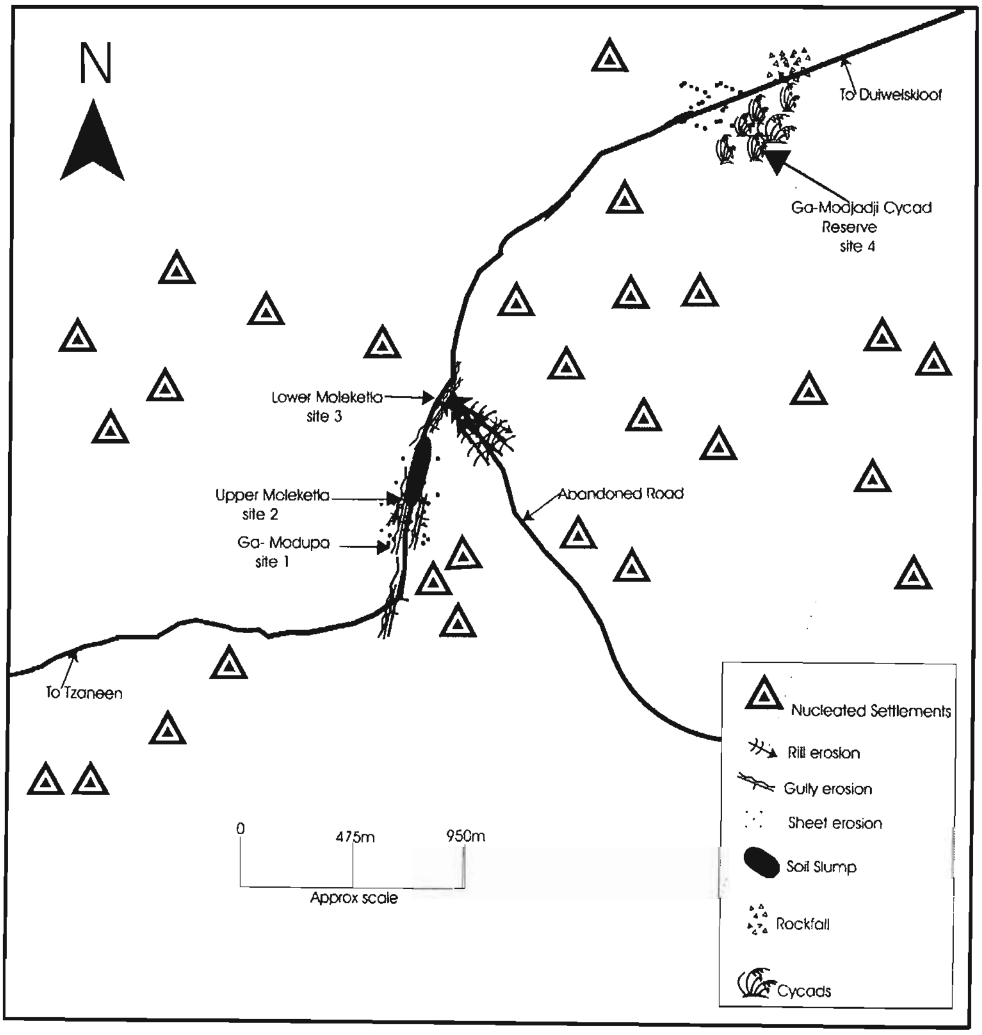


Figure 5.25 Field map illustrating the characteristics of the four representative sites in the Ga-modjadji area

Figure 5.26 Undercutting of the embankment at Lower-Moleketla by an incipient gully before the floods. Figure 5.27was taken at the same location after further severe rainfall in February 2000.

Figure 5.27 Slumping of an undercut embankment (A) at Lower-Moleketla after the February 2000 rains, at the same location as Figure 5.26.

The occurrence of such processes has significantly reduced the size of the causeway and has made driving and access on this road difficult. Soil slumping on the embankment is the most dominant process and is currently reducing the angle of the cut embankment and making it more unstable and unable to support the growth of vegetation, as is shown in Figure 5.26 and Figure 5.27.

Photographs taken in the area in July 1999 show lesser soil slumping than the ones taken in February 2000 after the flood, as in Figures 5.26 and 5.27. This can be ascribed to an increase in moisture content of the soil. The higher the moisture content of the soil the more liable or vulnerable the soil is to slumping.

In Figure 5.27, the embankment is observed to have experienced an increase in size within a seven-month period. Topographic properties and soil type are responsible for the recession of the embankment or this slope failure. It is important to mention that no soil samples were collected at the study site Ga-Modjadji. The reason for this is the long distance between this study site and the researcher's place of study. Cracks on the slope have been noted as factors responsible for the slope failure. Water infiltrating from the soil surface into the cracks increases pore water pressure acting on the failure surface. Brady (1993), thus initiating slumping. Other processes occurring on the road surfaces include surface runoff and gully and rill erosion.

Gully erosion has again played a role in promoting the slumping of the gully wall. It is the most evident erosional process taking place on the road side and severely affecting the carriage way. Figures 5.26 and 5.27 show the extent of gully erosion on the Lower Ga-Moleketla before and after the floods. At this study site, two types of gullies have been distinguished and the distinction stems from their mode of formation. Most of the gullies have eventually developed through soil collapses and headward erosion.

The gradient of the road is steep, ranging from 9^0 to 14^0. The erosive force is greatest at the base of the slope and it is for such reasons that gullies are initiated (Kirkby, 1979). Headward erosion at this study site is responsible for the growth and expansion of the deepest and widest gully. The gully in question is approximately 200 m long and approximately two to three metres deep. Exposed boulders and rocky outcrops have been noted inside gullies with weathered bedrock materials. Erosion from water is mainly responsible for exposing such features. No evidence of stabilisation was observed within the gully system.

Figure 5.28 shows the effects of gully erosion in degrading rural road access. The gully in this road section has extended mainly through the soil slumping process and the effect of flood rains in February 2000. The retreat of the gully toward the carriage way takes place largely through the effect of slumping of vegetated blocks, accelerated by the flood waters.

Figure 5.28 A road section damaged by the February 2000 rains at study site one (Ga-Modupa) in the Ga-Modjadji area (Fig 5.25, site 1).

Pipe erosion seems to have played a significant role in the sideward and headward extension of the gully side of the road and eventually soil collapse. These pipes appear to be enhanced by the occurrence of periodic high intensity rainfall as mentioned earlier in Chapter 2. According to Beckedahl and de Villiers (2000), the potential for soil pipes to develop as a form of accelerated erosion has serious economic and environmental implications with respect to road construction. This is the case in the present study. In the Ga-Modjadji area, the extent of erosion at this site is further indicated by the undercutting taking place at the bottom of the gully, thereby promoting slumping.

The gully shown in Figure 5.28 is approximately 3,5 metres wide and typically bare of vegetation. The width of the road where this gully is located increases, with rill erosion predominant on the road edges. Surface materials include bed rock outcrops exposed by erosion and some part of the road surface severely compacted. Such compaction was observed to have occurred as a result of vehicular traction.

Rill erosion was observed to have significantly accelerated road degradation at the Lower Moleketla site. Rill erosion was not as dominant and widespread as gully erosion. It occurs slightly on the road surface and is widespread on the feeder road. Beckedahl *et al.* (2001) state that the existence of rills represents a more drastic erosive mechanism of sediment removal than sheetwash and therefore a higher rate of road surface degradation. Rill erosion is, however, predominant on the feeder road that adjoins the main road which is now no longer usable. Figures 5.29 and 5.30 show an abandoned road built on impermeable material derived from younger sediments which are susceptible to rill erosion.

Rill erosion has prevailed and has affected the whole road surface, which means that as precipitation water reaches the soil, it flows away through the dense network of rills virtually cutting the slope. Flowing water has a tendency to collect in channels or gullies and will continue to degrade the road. This is more evident on the roadside, where channeling is linked to the formation of extensive gullying, as in the Indwedwe area. Beckedahl *et al.* (2001) further point out that rill development on low-cost formal road systems are precursors to the formation of gullies. Not only is rill erosion in this area a result of the flow of water or precipitation processes, runoff and climate consequences, but the physical properties of soil are visually observed to have played a role.

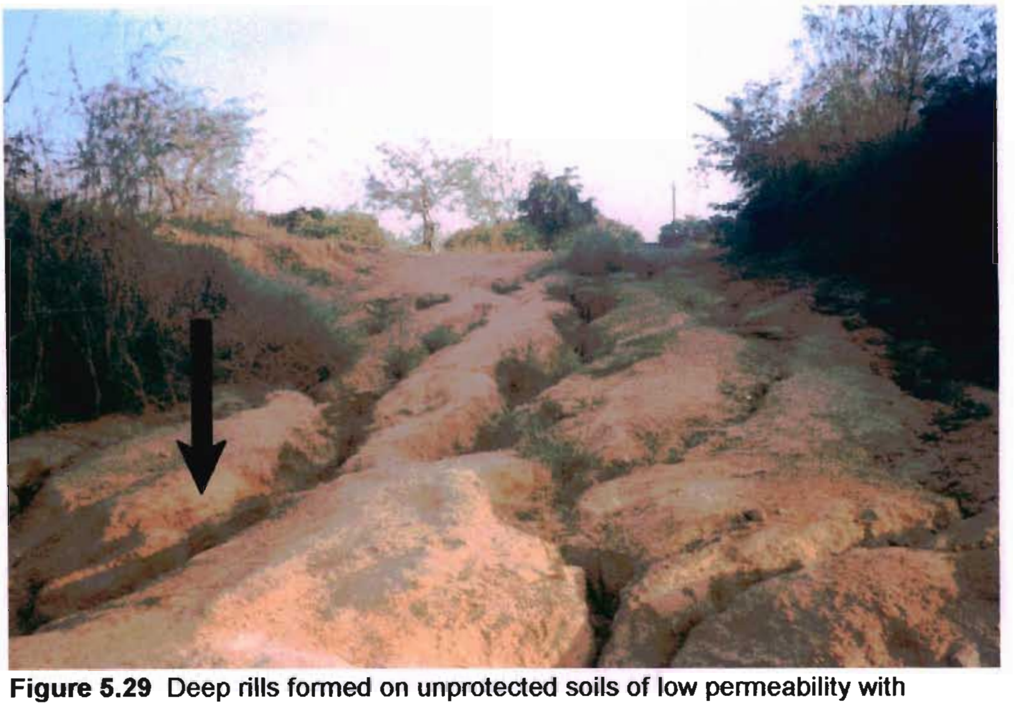


Figure 5.29 Deep rills formed on unprotected soils of low permeability with moderate gradient at Ga-Modjadji before the heavy rainfalls of 2000.

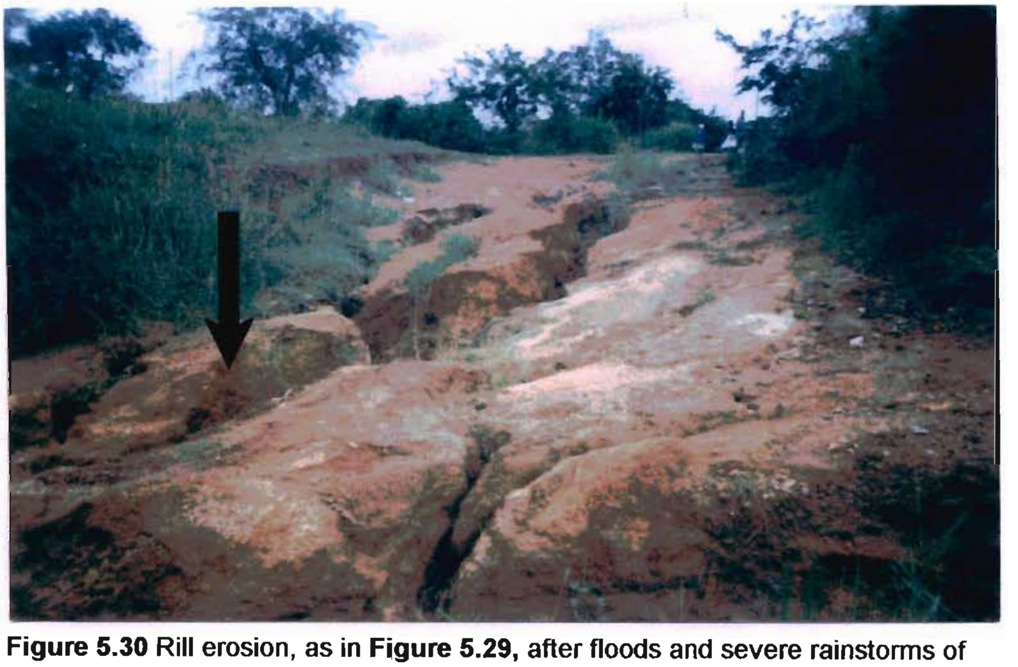


Figure 5.30 Rill erosion, as in **Figure 5.29,** after floods and severe rainstorms of 2000 at Ga- Modjadji. Note the difference in rill width and depth after the runoff (designated by the arrows above).

The literature shows that rill erosion usually begins to appear in the lower parts of a slope (Zachar,1982). At this study site, the difference can be pronounced in terms of rill dimensions before and after the floods. The floods have caused excessive rill erosion at the study sites. An increase in rill depth and width and vertical erosion can be seen in photographs.

Surface wash erosion is observed to be the dominant process on the road surface, giving way to rill formation and gullying on the side of road. The efficiency of surface wash erosion on road surfaces is enhanced by the mechanical dislodgement of soil particles by vehicle wheels and can be recognised by the coarser-sized sediments on the road surface, with tailings of fine materials deposited on the downslope Beckedahl *et al.,* (2001) noted that compaction by wheels reduces the infiltration and increases runoff, which was also observed at this study site. Figure 5.31 shows the early stages of erosion in degrading the road surface.

Figure 5.31 Ga-Modjadji villagers employ low cost conservation techniques (the use of sand bags) in controlling road erosion in the Upper Maleketla. Note how sheetwash and low grade rilling have degraded the road.

Local communities at the Upper Maleketla study site have made efforts to save the only access road to their area by trying to stop erosion, as shown in Figure 5.31. The use of this conservation method has not been effective in controlling road erosion and has in fact turned out to be detrimental and thereby enhancing sheet erosion. Sandbags (sacks filled with sand) have been used to protect the entrances to their homes. Note the extent of sheet erosion in Figure 5.31.

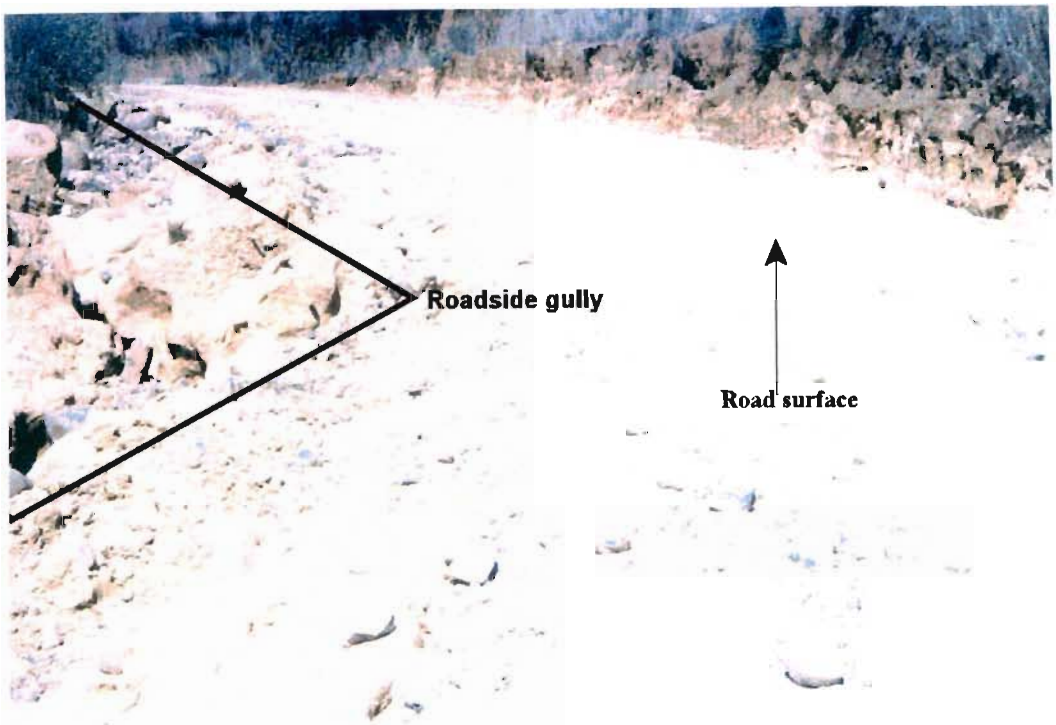


Figure 5.32 Road gullies worsened by a weathered bed rock on the road surface, constrain access near the Ga-Modjadji cycad and nature reserve.

The available evidence gathered at all study sites indicates that both the physical and the chemical properties of soil play a significant role in road deterioration. The results of the soil chemistry (ESP and CEC) reveal that the soil collected at Indwedwe displays dispersive soil properties and is easily eroded. The physical properties indicate that soil consisted mainly of sands with very low clay content and it is thus susceptible to erosion. Significant differences were observed between particle sizes and soil shear strength in all sites, particularly at Inkandla and Indwedwe. It is also apparent that soil erosion processes particularly at Inkandla and Indwedwe. It is also apparent that soil erosion processes have triggered the deterioration of roads in all study sites. The factors influencing the nature and speed of road erosion observed in the study were mainly climate, vegetation, topography, and the nature of the soil itself but perhaps the most important one, the one that is accelerating the problem, are the influence from human activity. In order to fulfill one of the objectives of the study, the next chapter will focus on linking human activities, perceptions and attitudes towards rural road access with the environmental factors already discussed. The significance and the implication of the results are then explored in Chapter 7.

CHAPTER 6

Social Survey Data

6.1 Perceptions and Attitudes of People affected by Rural Road Access

The attitudes and perceptions of the local people in the areas served by three rural access roads were studied. Data were collected using informal interviews in the form of questionnaires applied in the present work with a view to understand how poor access affect the socio economic life of the local people as outlined in Chapter 4. (Appendix 1).Interviews were open-ended, in order to give respondents the opportunity to elaborate upon issues which they consider important, pertaining to road access to rural areas. Most of the respondents in the study area were people who were located near the main feeder roads where the previously discussed study sites are located. The responses were analysed using qualitative methods and are discussed in detail in the following sections.

6.1.1The respondents

This section is concerned mainly with a description of the demographic factors and the occupation of the respondents so as to understand their respective contexts. At total of ninety people were chosen (30 in each study site) to form the sample population for each of the three areas previously discussed. One of the most striking features of the demographics of the study areas was the male representation. As may be seen from Tables 6.1, 6.2 and 6.3, Inkandla had the highest representation of males (70%) with Indwedwe having 58% of males and the Ga- Modjadji showing 60% male members. It is important to note that the gender disparity stems from the manner in which people were chosen to be part of the sample surveyed, rather than the gender distribution of the communities studied. It is likely that the discrepancy stems from the fact that most of the active mobile people are men living at home due to retrenchment from mines or the closing of other industries in Durban, Richards Bay or Gauteng.

Unemployment is prominent with few of the respondents being permanently employed. Of the 90 people interviewed, only 18 respondents were permanently employed (20%) which is very low. Of those who were employed, the only profession represented was teaching remainder were either self employed, unskilled or the semi skilled labourers. Many of the respondents (72%), mentioned the difficulties involved in traveling in order to find employment. According to them, this was attributable to poor road access.Commuting or sometimes walking between the villages and the nearby towns would impose great physical or financial hardship on the community.

Table 6.1 Interviewed persons at Inkandla with reference to gender, age and occupation

Gender	%	n	Age category	%	n	Occupation	%	n
Male	70%	21	Below 25 years	10%	3	Employed	10%	3
Female	30%	9	26 -50 years	60%	18	Unemployed	50%	15
			51 ->60 years	30%	9	Students	10%	3
						Pensioners	30%	9
Total	**100**	**30**		**100**	**30**		**100**	**30**

Table 6.2 Interviewed persons at Indwedwe with reference to gender, age and occupation

Gender	%	n	Age category	%	n	Occupation	%	n
Male	58%	17	Below 25 years	33%	10	Unemployed	33%	10
Female	42%	12	26-50 years	51%	16	Employed	18%	5
			51- > 60 years	16%	4	Students	33%	10
						Pensioners	16%	5
Total	**100**	**30**		**100**	**30**		**100**	**30**

Table 6.3 Interviewed persons at ga-Modjadji with reference to gender, age and occupation

Gender	%	n	Age category	%	n	Occupation	%	n
Males	60%	18	Below 25 years	20%	6	Employed	35%	10
						Unemployed	15%	5
Females	40%	12	25-50 years	30%	9	Self-employed	20%	6
			51-> 60 years	50%	15	Students	10%	3
						Pensioners	20%	6
Total	**100**	**30**		**100**	**30**		**100**	**30**

Respondents from Ga -Modjadji were less likely to view unemployment as a problem since there are a number of surrounding farms in Tzaneen and Duiwelskoof which can absorb many of the unskilled labourers. At Inkandla and Indwedwe, however, employment opportunities are scarce. It can thus be concluded that problems of poverty associated with unemployment will continue into the future.

6.1.2 Communities' s perceptions and attitudes to road access

All the interviewed villagers claimed that accessibility to their settlement was a "problem" This view reflects a convincing response, in that 60% of the respondents interviewed were located closer to the main access road and still regard road access as a problem. It then becomes obvious that people who live a distance away from the main road would have regarded inaccessibility as more "problematic" than those living near to the main road. They also claimed that the standard of road maintenance is poor and that many roads have deteriorated so much that routine maintenance by the Department of Transport offers no solution (pers.comm). The view is supported by the fact that Department of Transport is unable to perform periodic, let alone, routine maintenance on roads in response to wash-aways, especially on the Inkandla forest road. These communities feel that surfacing of rural roads with low-cost materials could be more cost-efficient than regravelling which is the current method of rural road maintenance.

It was apparent from the study that walking was the main mode of travel to access services. Out of the 90 people interviewed , seventy eight people (86%) were reliant on walking as the primary mode of travel. In the Inkandla area, people who are staying across the Nsuze river raised long walking distances as a problem. At Inkandla and Indwedwe, most of the school-children have to walk for long distances because there is no link road between the village and the school, people still reliant on footpaths. The use of non-motorised means of transport such as bicycles and animal carts in the study area are unpopular and this brings up the problem of mobility and access for the comparatively poor Inkandla and Indwedwe villagers. This conforms with the observation by Starkey, *et al.*, (2002) who found that in areas of low transport availability, poor people's inability to easily access their daily needs (resources, services, markets and job opportunities) constrains their efforts to develop sustainable livelihoods.

In addition to mobility problems, adverse topographical and terrain conditions render large segments of the rural road network impassable or very costly to users. This impedes development and contributes further to the isolation of poor rural communities, particularly to Inkandla and Indwedwe, the area with the highest prevalence of extreme poverty (Ardington, 1988) Terrain has been raised by many school-going children(25%) as a factor in lengthening the distance between schools and their homes. This problem is more acute when combined with poor surface conditions during rainy seasons .Local residents have blamed topography for not using bicycles, because they claim it is very difficult to ride a bicycle on such steep and rugged terrain. All area studied have a broken topography that is fragmented by a number of streams and rivers that make the land very steep. This makes it very difficult for villagers to walk from their homes to school and back and could be with time lead to serious degradation problems. At Inkandla, the average distance which a schoolchild staying across the Nsuze river travels varies between 5 and 20 kilometres a day.

Vehicle ownership is low, particularly at Inkandla and Indwedwe. The majority of the respondents (80%) did not have vehicles and were pedestrians. This suggests that the majority of the respondents relied on public transport for traveling. In general, walking is the main mode of transport to and from different destinations. At Indwedwe, villagers rely on one local taxi to travel from the village to the nearby town of Verulam and their main trading centre

Durban. Respondents at all study sites have expressed concern regarding the fact that local kombis and buses drop passengers on the main road, often far from their homesteads because of non existent access roads. They walk long distances from the drop off points, headloading the items bought in town.There were particular community concerns about the affordability of public transport. "As long as transport costs 'consume' large proportions of the household income, people are going to opt for the cheapest mode of travel." (Rama, 1999). It was further observed from this research that most of the respondents are unemployed and low- income earners and will obviously opt for the cheapest mode of travel which is walking. The bad condition of roads and the low percentage of vehicle ownership somewhat has a bearing on frequency with which respondents visit their nearest town, for example, at Ga-Modjadji, 10% of the respondents, most of whom were teachers visit town once a month.

Respondents between the ages of 10-25 years raised problems of poor school attendance during the rainy season. This poor attendance, in turn, affects the level of performance at schools in the area during wet weather, because slippery roads and swelling rivers after heavy downpours hinder access (see Figure 6.1). Heavy rainfall has also been viewed by most respondents (88%) from all study sites as a significant factor affecting road deterioration. Generally, rainfall was seen as a great cause of stress to all roads studied. At Inkandla, the continual deterioration of the Inkandla forest was attributed to the rainfall factor.It is quite common for the Inkandla forest road to be impassable during most parts of the year during heavy rainfall. After heavy rains the road becomes impassable for three to four weeks and the bus driver has complained of the uneven road surface on this road even during dry weather. Notwithstanding the significant contribution that the local bus services contribute to rural life, there is a cost associated with their operation in wet weather.Whereas at Ga -Modjadji the effects of heavy rainfall were felt during the February 2001 floods when local access roads were totally inaccessible.

The Inkandla forest road section featured strongly as most "problematic" and as the main hindrance to the community 's local development. A strong need for the upgrading of the road was raised and reinforces the view that this road needs some special attention, a point that ties with the earlier discussion of the environmental data discussed in Chapter 5.The bus driver also commented on the danger of driving along the forest road because of its winding nature and the narrowness of the road, due to the effects of erosion. Use of such narrow roads by heavy vehicles can lead to serious road accidents with the associated danger to life. Such problems affect the profit margins of the bus company. Twisting roads are regarded by Hindson (1983) not only as a nuisance, but more expensive to maintain and may be even dangerous. For example, high grass and tree growth on sharp corners decrease the visibility and it is then necessary to cut down trees inside road curves for safety reasons.

Figure 6.1 Slippery roads after heavy rains were identified by respondents from Inkandla as one of the road access problems

Most respondents (94%) from the local communities recognised the lack of access to facilities, such as basic health, water and education as a result of poor road infrastructures as an issue. Although the provision of such facilities is hindered by the nature of the landscape, local people believe that the construction and upgrading of roads in the area will facilitate the provision of such basic services. Accessing resources, seeking or generating employment, attending school, hospitals or clinic depends on the mode of travel available, the proximity of the facilities and the ease at which these can be reached (Rama, 1999).The International Fund for Agricultural Development report IFAD (2001) acknowledges that rural road maintenance is a problem everywhere in the world and frequently undermines the benefits of rural road improvements.

As mentioned earlier, the present study indicates that half the total number of respondents in the area are unemployed. It is interesting to note that local people are aware that it is the natural landscape that denies them access to employment opportunities and basic services. When asked if they intend migrating to other areas for a better life, 80% of the interviewed sample claimed that they liked living in their community because they were born and married there and did not express a wish to migrate to other areas for a better life. Despite the lack of industrial development for employment opportunities and better life, the inhabitants of Inkandla area had no problems in remaining in the area. Although expressing the desire for better life, most communities were observed to be vehement about leaving the area.

Local business owners have raised concerns about the effects the bad condition of roads has on their vehicles. They are worried about the high cost of car repairs caused by the poorly maintained roads. At Inkandla, a similar response was obtained from a local transport owner who transports villagers from the village to the nearby town. Unlike at Inkandla (where respondents did not have any intentions to migrate), at Indwedwe, respondents who have stayed in the area (50%) have shown intention of migrating to other areas in search of a better life. This can be linked to the fact that Indwedwe is just 20 kilometres away from a metropolitan area Durban and this might have been influential to the local people in terms of searching for better opportunities. The majority of people who expressed this view were students and young people.

Development to the people in the communities studied means infrastructural development. Their perceptions of development are clearly presented in Figure 6.3. Ninety four percent (94%) of the respondents have raised poor quality of life as a problem resulting from poor road access. It is clear from the study that the lack of roads is regarded as highly detrimental to development by virtually all respondents (94%). To the question concerning the view of development in the area, all the respondents interviewed answered that development is very poor in the area. This proves that the Inkandla community is aware of the development backlog as the following statement illustrates:

" *We will never develop here, the government is only selective and choosy to areas they want to develop. For example, all the villages under Nkosi Biyela are well developed. They have good roads, electricity, water, clinics and schools. We just put hopes on you that now that you know our problem, you will do something about it."* (Mkhize, pers. comm, 2000). From the statement it appears that development to them is infrastructural development. Their view on development tallies with the definitions or the understanding by President Mbeki. He states " *for the provision of a physical infrastructure (housing, water, power supply) to become a reality in rural areas, there should be a serviceable road network "* (Mbeki, 1999). The importance of an infrastructure to the rural development issue is that it serves as an indicator of the general development and as a mechanism of studying the mobility of people in the area (Haag and Haagland, 1998). The community is aware that the area cannot develop in the absence of road networks and have prioritized improvement of local roads as they believe this would allow access to other infrastructure outside the community.

The extent of the access problem raised is further emphasized by the fact that half the total number of respondents (50%) have dug roads by hand in trying to improve access to their households, with many of the respondents still relying on footpaths to get to their homesteads. This was mainly observed to be occurring at Indwedwe. Respondents who still use footpaths as the only access to their homesteads claim that for them to improve access to their homes is difficult since it demands hard labour and proper implements, following the complexity of the topography. At Indwedwe where access roads have been constructed by household members, considerable erosion has begun to take place. Part of the reasons is that the community does not have the necessary expertise and skills to deal with such erosion problems. This could be an opportunity for local government to be proactive in finding solutions for road funding and involving local communities in taking a lead in improving access in their own communities.

On the question concerning whom should be responsible for improving access roads, different views were expressed. The majority of the respondents (60%) from all study sites (with Ga- Modjadji showing the highest percentage (70%)) believed that it is the government 's responsibility to upgrade and build roads. Reasons provided were that local people do not have proper equipment and resources at hand to work on roads; others claimed that they have no knowledge or skills. Some respondents see upgrading of roads as the responsibility of the local government (40%). They raise questions of lack of commitment by local government to the improvement of the quality of life in the area. This was also expressed by the Inkandla respondents. A similar response was found by Pile (1996) in a study of the Cornfields community in KwaZulu Natal and Madikizela (2000) in a study of soil erosion in Mt. Ayliff and Mt. Frere.

Respondents were asked about general problems they were facing in their villages which could be related to poor access. Most people (94%) raised poor quality of life as a problem which is an indication of service delivery problems. As mentioned earlier, these support the observation that all communities studied is poor and lacking many basic needs.

6.1.3 Community perceptions and way forward

In the previous section it was shown that local people are aware of the problems associated with access roads and because of poverty and lack of resources have little alternative to the improvement of road access.Discussion of the attitudes and people 's perceptions have highlighted issues, which also has been posed as present problems. It should be noted that some of the issues posed are not new, in fact they occur in most of the South African rural areas where access roads are non existent or poorly maintained. A significant number of road access problems raised by the three communities is attributed, to a larger extent, to natural geomorphic environment and to a lesser extent to socio-economic conditions.

The communities are aware that the area cannot develop with the absence of road networks and has its attention focused on the improvement of access roads. The lack of standard roads was mentioned as an important area of concern by virtually all members of the three communities studied. When asked what beneficial impacts are expected from the improvement of roads, most households in villages, both those who have an access road nearby and those who were unconnected with all-weather access roads, responded with predictions of more seasonal work taken outside the villages to maintain and upgrade the roads. The survey results provide strong empirical evidence to support the social and economic justifications for the provision of basic all-weather access to the villages in question. A common characteristic is that all respondents have expressed a dire need for roads in the area Inkandla and Indwedwe.

Although people's perceptions and attitudes on road access in the study areas have shown that the natural geomorphic environment accelerates the degradation of access roads, it is evident that the socio-economic setting of communities and inadequate government support also play a contributory role. It appears from the data presented in this chapter that the problems pertaining to the access roads need to be fully addressed and that the views of the affected communities should be taken into account and be resolved as soon as possible as envisaged under the National Environmental Management Act NEMA (1998). From the conducted interviews, it is evident that the opinion of people staying in the three communities investigated calls for upgrading of the access roads in the areas.

CHAPTER 7

Implications of Rural Road Access

The results presented thus far have shown that the physical and the chemical properties of soil and the geomorphic processes operating in each road section contribute significantly to the degradation of rural roads. The natural geomorphic environment has a profound effect on rural road access for the communities in the study areas. It has also been shown that the people's perception about their environment is strongly influenced by the prevailing environmental conditions. An important point to note from the previous chapter is that most respondents are aware that road access is a problem and something needs to be done to solve the problem. It has been shown that the poor condition and the inadequate rural network is a major constraint to rural development in the study areas. Hence, numerous issues associated with rural road development were identified.

The government is committed to provide road access to all villages but it is constrained due to the shortage of funds. Funding shortages have led to road neglect in the form of poor road conditions and maintenance resulting in overall low quality of life in the study areas. Given the fact that the study areas in question have no all - weather road access, it therefore becomes a priority for the government to provide all weather standard roads. This can however only be achieved by ongoing and adequate maintenance of the rural road networks.

When constructing roads, conventional engineering practice requires the use of design standards. It was seen from this study that communities are willing to take a lead in facilitating their own access by constructing their household access road as in the case of the Kwa Dlabe community. These roads have however shown some decline overtime because numerous environmental parameters were not taken into account. There is a need to develop and promote cost effective construction of rural roads, bridges and other drainage structures which will take into account geomorphic constraints. Part of the reason is that the current available guidelines on rural roads are principally developed for urban roads and they aim at different environmental conditions and hence different standards than those required for rural roads. As a result, the rural roads in the study areas might have been designed according to the urban standards and are not well suited for rural conditions. It is therefore the task of the administrators in charge of the rural roads to review the existing design standards of rural roads and identify and also develop optimal design standards using least cost approaches.

It appears from the research that people of the three areas studied recognize the many opportunities upgrading the quality of roads can bring, particularly in terms of greater access to services. It is of the utmost importance that officers from the Department of Transport be made aware of the issues of concern to the communities relating to expectations of road construction and upgrading. If these issues are not dealt with carefully by the authorities, it is possible that service delivery could face severe problems in future, particularly since the people are already of the perception that upgrading of roads will trigger major service delivery in the area.

7.1 Terrain, Physiography and Landscape

The common characteristic of the landscape in the three chosen areas is the rugged terrain. The rugged nature of the terrain, with its steep hills and high intensity seasonal downpours during the summer months favours soil erosion, mostly in the form of rapid movements such as landslides and slumping along steep uncovered slopes, or by wash processes.

Terrain imposes serious limitations in terms of infrastructural development, accessibility and economic costs. The research has shown that the location of basic services and physical characteristics of an area impact on the number of hours an average rural household spends on travelling to meet their basic needs. The main concern here is that lack of adequate access roads due to the complex physical terrain increases the travel time and the expenses of travel for the rural poor. This, it is argued, leads to the isolation of the rural poor from the wider society and from participation in economic and social activities (Carns Consultant Group, 1997; KwaZulu Natal Department of Transport, 1999). This again emphasizes the necessity for the provision and upgrading of rural access roads to improve the people's access to basic services.

In all areas considered, large gullies are prevalent where roads are badly eroded, thus making travel hazardous. In order to avoid excessive gully erosion, the road surface should be given a slight outwards slope to disperse water. The most common sustainable local technologies that can be employed to control gully erosion in the study areas could include techniques such as the construction of dry stone walls, without cement in order to safeguard the roadbed. In the study, numerous perennial rivers also raise the problems of access during flood or high flow conditions. This will be discussed further in the Section 7.4 dealing with drainage.

7.2 Soil Characteristics and Soil loss

As previously mentioned, Fuggle and Rabie (1992) view soil erosion as potentially being South Africa's greatest environmental problem and it has serious implications for sustainable agriculture and economic development . Soil erosion however also poses a serious threat to the country's road infrastructure.

A detailed survey of soil characteristics was carried out at Inkandla and Indwedwe, while specific soil characteristics at Ga-Modjadji were considered. All the soil samples collected are sandy and can thus be considered to be almost cohesionless. It is, however, evident that significant differences exist between particle size distributions for each of the three respective areas, a fact supported by the difference in the shear strength of each area. The TRH 4 (1985) guidelines requires that there be a proper balance of gravel sand, silt and clay when constructing roads to avoid instability problems. Is it of importance for the administrators in charge to contract competitive road contractors to ensure sustainable rural accessibility. Where communities choose to take the initiative to construct roads themselves, adequate support services need to be in place to advise them with respect to materials and methods to facilitate an acceptable end product.

It has been shown that soil shear strength for Inkandla and Indwedwe decreases with an increase in sand percentage. This emphasizes the notion previously established in the literature that shear strength is influenced by the particle size distribution of a soil. Further, it was shown in Chapter 2 that shear strength is a function of moisture, that is, shear values decrease with an increase in moisture content. An increase in shear resistance was observed only in soils with higher clay content in the dry state. Soils at Indwedwe, in particular, are extremely sandy rendering them weak under dry conditions and prone to wash away during heavy rain. Clay soils, by contrast will be resistant when dry, but have a low shear resistance when wet, rendering them potentially impassable.

Literature has shown that building of roadways produce subsidence in the underlying materials and this is in most instances followed by structural damage (Coates, 1981) often manifest as slumping as is the case at Indwedwe.

Soils which are derived from the Natal Group sandstones are generally shallow and characteristically young and unstable and are, as a result, vulnerable to erosion (Du Toit, 1936; Brink, 1981; Currie, 1997). Soil samples that were randomly collected have revealed the highest percentage of sand with least clay percentage and have significantly contributed to the instability of road cuts. Because sand is loosely consolidated, change in the shape of road embankments occurs rapidly. Freely moving sand below surface areas will create difficulty and therefore expensive conditions for constructing foundations for roads.Exposed soils with little vegetation, high runoff velocities and volumes, sandy or silty soil types, and poor compaction increase the potential for erosion.Erosion by the concentrated flow of surface water has been observed to play a considerable role in the deterioration of roads.

In the study, rill erosion was the more widespread on the road surface itself than gully and sheet erosion in the study area. It however has frequently led to the development of gullies at the road verge and sides leading away from the road.

The potential for rill development has also been noted in many sections of the road through excessive longitudinal soil compaction and rut development which is then utilised by runoff. This was observed to be occurring in areas where surface runoff is channelled either by coarser-sized sediment and early rut development below the centre-line of the wheels, as observed elsewhere by Beckedahl *et al.* (2001).With constant movement of vehicular traffic within the inter-rut area, especially after rains, ruts will begin to deepen and consequently form rills that significantly reduce road quality as was seen in the present study. This finding emphasizes the need for adequate compaction of road materials during the construction phase, thus reducing the likelihood of rut information.

The Guideline for Maintenance and Service of Unpaved roads Manual Practice (2000) and the TRH 17 (1988) suggest that problems such as rutting can be corrected by adding suitable material, grading, crowning, and rolling the road surface. Filling ruts with stone can lead to new ruts being generated beside the original ones and thus would be an expensive and temporary "fix"which can also interfere with grading. The surface must be re-mixed and properly bladed or graded in more severe cases. Areas of sustained and repeated rutting may require more severe measures. An elaborate drain system and/or geotextile fabric foundation with a crushed stone road fill may be used to correct severe rutting problems.Although the recommended techniques require a huge amount of capital outlay, preventative measures in these rural areas are more cost efficient than curative ones. Proper road surface maintenance in some road sections will in the long run get rid of ruts as well as bumps and potholes and it is important that adequate feed - back structures between communities and road authorities be put in place to facilitate early warning of deteriorating conditions.

Soil chemistry was determined only in samples collected at Indwedwe, as this was the study site where severe soil piping was observed on road cuts. Pipe formation appears to be enhanced by the occurrence of periodic high-intensity rainfall. The results of soil chemical analysis carried out showed a tendency for the soil to be dispersive. The CEC values were low, with relatively high exchangeable sodium values which has resulted in inadequate protection of road embankments by vegetation. Maintaining the vegetation cover reduces soil erosion while bio- engineering and the growth of grass, shrubs and trees along the edges of the road helps to stabilise earthen banks.

7.3 Slope Failure

Slope failure has played a significant role in road deterioration in the study areas. Many of the cut road embankments could make those sections prone to erosion as the slopes have been oversteepened and are made of materials that erode easily. It should be noted when constructing roads that these slopes should not be so steep that it becomes difficult to establish vegetation or hold stone on them. Numerous slope failures occurred in the three study areas. Intense failures as a result of undercutting by the floodwaters occurred mainly in the Ga-Modjadji area. The causes were undercutting by high roadside discharge, lack of cohesion due to high pore water precipitation and low cohesion due to absence of retaining structures or roots to increase internal friction.

Soil slumps in all the study areas were observed to be occurring as a result of surface materials that had not yet reached stable angles of repose in relation to the geological structure or where oversteepening had occurred as a consequence of undercutting by the roadway. Erosion and mass movements in the form of soil slumping have impacted greatly on road degradation, thus areas noted to have such erosional processes should not be considered for road construction. To minimise these problems, it is important to always keep cut and fill slopes as flat as possible and well covered with vegetation in order to minimise surface erosion. The use of mixture of good ground cover plus deep rooted vegetation (For example, *vetiver grass, cactus* and *alder*) minimize mass instability as well as offering surface erosion control protection.

7.4 Drainage

Problems of drainage were seen to fall into two categories: that is:

1) Topographic, where stream bank flooding and overtopping impacts on roads and

2) Poor drainage of the road surface and roadbed through ditches and culverts.

Many of the roads in the rural areas KwaZulu Natal and Northern Province were originally formal low-cost roads and, because of this, their location and drainage control is usually not effective and they are vulnerable to damage in periods of bad weather. In this research, numerous landscapes are dissected by a number of perennial rivers, which also raise serious problems of access during rainy weather and have implications to bridge and road construction. Also bridges built over streams where water erosion is very active were observed to have washed away. Where cheap and low-grade materials were used to construct small bridges, the latter were noticed to be wearing down. In the study area some of the bridges (particularly at Indwedwe), require replacement, however and there is a lack of finance to realistically address the problem. Some bridges in the are a road safety hazard, others are unfit for the vehicles wanting to use them, and many have both problems.

It has been found from the study that lack of drainage facilities, surface runoff and lack of proper geometric standards are the main reasons for road failure. Foundation failure and the scouring effect of the low-level bridges at Indwedwe were responsible for the destruction of bridges. Schaffner (1992) suggests that retaining and foundation structures should be placed on bedrocks or firm and should not be placed on shallow colluvial soils or on loose fill material.

7.5 The Importance of Road Access for Inkandla, Indwedwe and Ga-Modjadji

Human activity has been identified and stressed by most researchers as prominent factors in environmental deterioration. In all study areas, excavation works to construct roads and the steepening of the slopes for road-building has weakened the geological support structures. Such activities, exacerbated by poorly designed drainage measures, trigger road erosion.

Most of the slopes in the respective study sites are bare, without significant woody vegetation, due to human activities such as clearing trees for firewood, excavation for building sites and quarrying. All of this contributes to slope erosion and road deterioration. Since run-off rapidly increases on land devoid of vegetation (Cooke and Doornkamp, 1990; Kinlund,1996), little water infiltrates into soils, thereby exposing the soil to the erosional powers of rainfall. The same view was emphasized by Russow and Garland (2000) during their study of the siltation of Hazelmere Dam in KwaZulu Natal.

It was the general opinion of the surveyed residents of the study areas that the construction of more roads and the upgrading of existing roads were more urgent than the provision of other basic services. They all identified improvement and construction of community access roads as a development priority. This shows that communities are aware of the development backlog. The respondents believed that the construction and upgrading of access roads was fundamental for any development to take place in the area. Due to the dire need for roads, it was seen that the communities constructed their own roads and took a lead in maintaining roads, using their little knowledge and without proper implements and facilities. The community generally views the development and management of the road network as the role of Government. Government has a clear role in planning and regulation for the benefit of the community as a whole.

As suggested earlier in this chapter, road infrastructure is crucial to the survival of the people and to the potential for sustainable development within the area. In order to establish a sound tourism industry within the Inkandla Forest Reserve and the Ga-Modjadji Cycad Reserve (significantly both in a cultural and conservation sense), it is essential that the existing roads be maintained. The improvement of the road (P100) in the Inkandla study area is part of the Department of Transport's upgrade plan, but because of financial constraints the road has not yet been surfaced or repaired.

The KwaZulu Natal Department of Transport has shown its commitment to achieve a more balanced road network throughout KwaZulu-Natal and, at the same time, to create new jobs and business opportunities for disadvantaged communities (Ndebele ,2001). The KwaZulu-Natal Department of Transport recognises the point that the construction of roads leads to the creation of markets for other goods and services and that other projects of an infrastructural nature such as schools, clinics, government depots, agricultural research stations, are likely to have a similar effect. Amongst the KwaZulu Natal Department of Transport rural road strategy are those that will benefit the majority of the poor.

The Department has recently introduced the Zibambele Road Maintenance Contract System which is a poverty alleviation programme initiated by the KwaZulu-Natal Department of Transport. This innovative programme which was adapted from the Kenyan Lengthman model, contracts a household rather than an individual to maintain a length of road. Zibambele contracts stabilize destitute families to break their poverty cycle. The Zulu name given to the "Lengthman" Contract System is Zibambele, which means "doing it for ourselves'. The name, Zibambele, captures its unique adaptation to meet the social condition prevailing in rural KwaZulu -Natal. However, their implementation is problematic mainly due to lack of adequate assets and resources, and skills. These are challenges which urgently require attention..

In many countries, the costs of local access roads are shared between governments and benefiting local communities, Kumar *et al.*, (2000). In China, for example, government provides material, equipment, and technical assistance, and local communities provide voluntary labour for construction. In Lesotho, government provides limited financial assistance and training and labour based work methods to villagers who wish to construct rural roads and paths on voluntary basis, Kumar *et al.*, (2000).

In this study, there was not much active participation of communities in road development, not withstanding the work of the Kwa Dlabe community. It is thus imperative for Departments of Transport to increase local community participation in rural roads through the provision of incentives. While government and contractors may contribute in terms planning, designing, financing and management of rural roads, the local people at large can contribute through sharing of indigenous knowledge in terms of the local environment as well as by participation in the actual construction and maintenance activities. Approaches to encourage local community participation in rural roads could include village meetings especially during the planning stage to ensure that road plans are properly and timely taken into direct participation of local stakeholders in the funding allocation.

Rural people require access to roads of an adequate standard (in terms of reliability and safety), for buses and minibuses to operate effectively and at an affordable cost. There is very little public transport in all the study areas and that which exists is very expensive due to the costs of maintenance of vehicles on such bad roads. In the Ga-Modjadji area, the majority of vehicles that are used as public transport are vans that are not road-worthy as shown in Figure 7.1. Vehicles are poorly maintained due to poverty, ignorance (overloading) and other factors which warrant investigation. All these factors are controllable by government policies. Governments in these study areas owe their inhabitants the duty to keep roads safe and ensure that only road-worthy vehicles ply the roads. There are many safety, environmental concerns attached to these used vehicles. The road worthiness of public transport is a primary concern because of the many accidents that have claimed the lives of the poor people working in farms. With it comes the safety of driver and passenger as well as of other road users.

Figure 7.1 Poorly maintained access roads at Ga-Modjadji reduces the lifespan of vehicles. These *bakkies* are used to transport local people to the nearby towns and villages.

Further backlogs in road maintenance and upgrading are caused by the fact that there is no clear policy frameworks showing how local government and the Department of Transport should be involved in the prioritising of upgrading and maintaining the roads. There are tensions between the two levels of local government, and who should carry out which roles. For example, local governments are often reluctant to implement road plans because they feel that provincial governments do not include them in the planning process. It is of utmost importance that both governments ensure that policies are openly agreed upon, and clear delegation of responsibilities and fair allocation of resources towards the construction and maintenance of rural roads. Officials in both governments (local and provincial)claimed to be taking a lead in improving the road network in the study areas in the KwaZulu Natal.

The construction and the maintenance of community roads are a local government responsibility. However, local governments in the study area have no resources and proper equipment to keep the roads in good repair. Most local governments in South Africa, particularly those in rural areas, do not have the resources to engage in infrastructural development. The responsibility therefore lies in the hands of the national Department of Transport.

The final chapter draws on the observations, results and recommendations in the a foregoing discussion to draw conclusions concerning the geomorphological aspects of rural road access.

CHAPTER 8

Conclusion: Geomorphology and Rural Accessibility

8.1. The Value of Geomorphology to the Planning of Rural Roads

There is no doubt that the natural geomorphic environment has a considerable effect on rural access roads. From the results of the present study, it is clear that adequate road access in rural areas demands urgent attention. The poor condition of rural roads has much to do with the natural environment and, to a certain extent, with institutional weakness. The often rugged topography, combined with numerous streams and complex geological conditions, make the construction, upgrading and maintenance of road networks in rural areas is extremely difficult and costly as illustrated by the case studies of Inkandla, Indwedwe and Ga-Modjadji. The study has highlighted that no one factor can be singled out as being solely responsible for road deterioration, but different factors are interrelated and significantly affect rural road access.

The physical characteristics, especially soil and slope conditions, aggravated by climatic conditions, make the access roads in all the study areas susceptible to soil erosion. Geology, soil erosion, streams and rivers and friable soils which are vulnerable to mass movement are the main factors identified as seriously constraining vehicular access. Socio-economic conditions together with anthropogenic influences such as construction of rural access roads on vulnerable slopes farming practices on steep slopes, removal of vegetation cover cannot be ignored when evaluating road accessibility in the areas.

In KwaZulu Natal in particular, it is unclear whether local government or central government should take responsibility for rural road maintenance programmes. Without a clear policy as to who owns and is responsible for the maintenance of rural roads, well-intended efforts aimed at improving rural access will be short-lived. The management of the road is the responsibility of the central Department of Transport. As in many parts of the world, rural road maintenance and funding has long been inadequate, resulting in a backlog of periodic maintenance. For example, from the present study all the rural access roads investigated were observed to be deteriorating. They were generally built and/ or maintained with limited funds (see Appendix 2). As seen in Chapter 5, some roads in the study areas are falling into disrepair, others have been abandoned, while still others are not maintained properly due to insufficient funds. Road development and maintenance require a huge amount of investment. Given the fact that government funds are limited, only limited road networks can be covered in rural areas. May be increasing budgets could help in diminishing the backlog, the more funds that are provided, the sooner the backlog will disappear and road upgrading and construction will be expedited.

In some cases, the road builder often lacked specialist technology and skills. In the study areas, most households who had no access road were hand-digging access roads, without any consideration for the local geomorphic or environmental factors. The local governments have a responsibility to ensure that functional design standards are adopted in order to achieve sound management of rural access roads. Local government must also ensure that there is sufficient maintenance and constant monitoring of the existing rural access roads to avoid complete deterioration of roads.

The study has shown that the majority of the rural roads are in poor condition and are vulnerable to heavy rains, frequently becoming impassable as a result of these. The lack of a road infrastructure has resulted in many adverse social consequences. The absence of well-constructed and well-maintained roads have hindered accessibility to schools, clinics and places of employment, since transport to these facilities is costly due to the high cost of maintaining the vehicles providing the transport.

Rural households undertake most of their transport activities away from roads by walking on tracks and paths. Transport by walking is inefficient and slow and thus restricts rural income and social development. Given the low density and scattered distribution of the homesteads at Inkandla and Indwedwe, it is far too costly to provide roads and other amenities for each homestead. However, appropriate and cost-effective technologies can be provided which, when properly managed, can meet the needs of the communities concerned. This can be effectively executed by well-managed committees formed at community level which can then be targeted for resource allocation and skills training.

8.2 Recommendations

It has been established in the present research that the continual deterioration of rural roads is the result of a number of factors interacting. This factors include the use of poor geomorphic materials, excessive gradient and poor drainage. Poor maintenance due to lack of funds and local resources such as skills and finances are also constraints. It is the responsibility of the Department of Transport to adopt a sound and inexpensive engineering technique that must be used to ensure that the roads meet specifications for their intended use and that maintenance requirements are in line with operating budgets.

Future planning must take into consideration low-cost but durable structures, as recommended by Ware (1988). Drift structures and low-level, wash-over type structures on intermediate roads are examples of these methods and structures. In the study area, slope failure (such as slumping of embankments rather than landsliding) was identified to be the major constraint to rural road access. Barnes *et al.*(1988) have made certain recommendations to minimize the potential hazards from slope failure:

- identify problem areas;
- divide problem areas into zones, so that developers can make adequate plans and local authorities can control development of these areas;
- provide guidelines for development in these problem areas.

Local technologies and materials are used, except for the wire to construct gabion boxes. The most common local technology is the construction of dry stone walls, without cement, to fill the roadbed. These walls are built by local labourers who are skilled at trimming and fitting the rocks. Using local construction materials makes roads more economical and sustainable. The Department of Transport needs to look at the cheapest way to stabilise road embankments. The use of *vetiver* grass, for example, is cheap and effective and should be investigated further

The soils, slopes and climatic conditions of all the study areas were shown to be unfavourable for the construction of roads. Sliding road banks and eroded areas must be vegetated. Maintaining the vegetation cover reduces soil erosion and bio-engineering, the planting of shrubs and trees along the edges of the road, helps to stabilise the earthen banks. If the use of vegetation is not possible, protection against erosion is needed. In many cases, the use of vegetation alone may not be enough to prevent erosive damage and various engineering measures can be used to complement vegetation cover.

Other geomorphological measures for slope protection include:

- the laying down of guidelines, for example, similar to those reflected in *Landschaftgestaltung;* (1983) issued by the German Board of Road engineers;
- the possibility of capacity building within the community to oversee sections/zones and do minor maintenance but to report on problems as they develop prior to becoming too large;
- tiered embankments to reduce heights and so minimise slumping;
- interception ditches at the top and bottom of slopes;
- terraced or stepped slopes to reduce steepness;
- retaining structures such as gabions;
- shotcreting and geotextiles.

Drainage mitigation measures include:

- cutoff drains to catch water before it reaches critical areas and diverging drains which avoid concentrations of flow;
- concrete dissipation structures to impede fast-running water in drains, and hence reduce its downstream erosive potential;
- natural materials for energy dissipation in drains, including various combinations of sticks, hay bales, rocks and planted vegetation.

Non-vegetative materials such as gravel or concrete or mulches can be used. Erosion from cut banks and side slopes must be minimised by vegetation strategies. To avoid excessive gully erosion, the road surface is given a slight outwards slope to disperse rainwater. On steep slopes the material excavated for new roads should be end-hauled and stabilised. However, this does not suggest that cheap alternatives should be used for rural roads, but rather a cost effective and a long-term rural road network planning structure should be investigated as an option.

8.3 The Need for Further Research and Directions for the Future

The study has brought to light several other issues that need to be examined in Inkandla, Indwedwe and Ga-Modjadji. While no general theory on geomorphological considerations of rural access roads can be drawn from this study, it is evident from the discussion that, the geomorphic environment is of paramount importance when examining rural access roads. Because road degradation in the form of soil erosion is endemic and acute, persisting, the following research topics are presented for consideration:

- Rural life is very closely integrated with the biophysical aspects of the environment and issues such as deteriorating water quality as a consequence of sedimentation and siltation of rivers caused by road degradation deserve special attention.

- The effect of siltation on reservoirs and impoundments.
- The effect of poor accessibility and quality of life of the rural poor.
- Research work on effective methods of protecting unarmoured roads against water erosion needs attention.
- The problems of accessibility and mobility and how they contribute to the poverty and isolation of the rural poor in South Africa, need further research.

The primary aim of the present research was to explore the geomorphic constraints associated with access roads in rural areas and the consequent effects on the socio-economic status of the rural people involved. The study has highlighted several geomorphic factors that need to be considered when planning rural access roads in the future.

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APPENDIX 1

QUESTIONNAIRES ON RURAL ROAD ACCESS

LOCAL COMMUNITY

Name of the village...

1. Sex

   [1] Male   [2] Female

2. In which age group do you belong?

   [1] Below 25 yrs

   [2] 25- 50 yrs

   [3]> 60 yrs

3. What is the level of education reached?

   [1] Primary

   [2] High school

   [3] Tertiary

   [4] Never went to school

   [5] Others (Specify)----------------------------

4. Occupation

   [1] Self employed

   [2] Unemployed

   [3] Student

   [4] Pensioner

   [5] Others--

5. How long have you been staying hear?

   [1] More than 40 yrs [2] 30 yrs [3] 20 yrs [4] 10 yrs [5] Less than 1yrs

   [6] Others (specify)--

6. Do you intend migrating to some other places in the future?

   [1] Yes   [2] No

7. What interests you about this area?

8.Is there a vehicle in your household?

[1] Yes [2] No

9. What kind of vehicle do you own?

[1] Self propelled

[0] Animal drawn

10. Are there any environmental problems related to vehicular access you have experienced in this area.

[1] Yes [2] No

11. If yes, which are those environmental constraints?

1.---
2.---
3.---
4.---
5.---

12. What are your views on the state of roads in the area?

[1] Excellent [2] Good [3] Fair [4] Poor [5] Bad [6] Very bad

13. What are your views on the absence of community access roads?

---

14. What problems do you encounter as a result of absence of access roads and poor conditions of roads?

1.---
2.---
3--
4--
5--
6--

15. What problems related to vehicular access do you experience as a result of bad roads?
1---
2.---
3. ---
4.--

16. To what extent does soil erosion affect vehicular access in the area?

----

17. What do you think are the causes of such erosion problems?
[1] Natural
[2] Physical build of the area
[3] Climatic conditions
[4]
[5]
[6]Others---

18. What techniques have you employed in improving access to your household?

----

19. Are the techniques sufficient in reducing the problem?
[1] Yes [2] No

20. If yes how and if no why?

----

21. How often do you visit the nearest town?
[1] More than 5 times a week
[2] 3-5 times a week
[3] once or twice a week
[4] once a month
[5] Every second month
[6] Others--

22. What mode of travel do you use to access basic facilities such school, work, health, etc?

[1] Bus
[2] Car
[3] Foot
[4] Bicycle
[5] Animals
[6] Others (Specify)--

23. Do you find the mode of travel effective?

[1] Yes [2] No

24. If yes why, and if no why?

____
____
____
____
____
----

25. How long does it take you to reach the main road?

[1] Half an Hour
[2] 1 Hour
[3] 1 Hour an Half
[4] 2 Hours
[5] More than two hours
[6] Others (specify)---------------------------------------

26. What is your view about the development in the area?

[1] Poor [2] Very poor [3] Fair [4] Good [5] Very good [6] Excellent

27. What would you like to see happening in the improvement of access in the area?

____
____
____
____
----

28. Who do you think is responsible for improving and construction of access roads?

[1] The local community

[2] The government

[3] Non governmental organizations (ngo's)

[4] Community based organizations (cbo 's)

[5] Others (specify)--

29. Why do you think so?

----

30. Has there been any intervention from the above chosen with regard to improving of the bad state of roads in the area?

[1] Yes [No]

31. If yes, when was the intervention?

[1] 20 yrs back [2]15 yrs ago [3] 10 yrs ago [4] 5 yrs ago [5] I don't remember

---

----

32. How effective was the intervention?

APPENDIX 2

Estimated Costs of roads

Given the budgetary constraints facing the national department of transport, provision of tarred roads in most rural areas has become a problem because of high cost implications. Commonly found access roads in most rural areas of South Africa are gravel (Type 7A) (KZN DOT, 1999) which have proved to be cost effective when compared with the cost of constructing a tarred road. A cost estimate for a typical gravel road project of 5km, in which 5 labour teams and 6 auxiliary teams are working, including tools and equipment, contingencies, contract supervision and bank charges for the KZNDOT are given below, excluding bank charges and cost control.

Estimated costs of a 5km road in 1999:

Construction costs	
Subgrade Teams	R28 750, 00
Transverse drains	R29 250, 00
Rock collection	R16 500, 00
Mitre drains	R33 750, 00
Water haul	R12 000, 00
Water haul	R28 000, 00
SUB TOTAL	R348 250, 00
Tools and Equipment	
Estimated from previous projects	R10 000, 00
SUB TOTAL	R10 000, 00
Extra costs	
Loader to stockpile gravel	R20 000, 00
Construction of accesses and bolsters	R25 000, 00
SUB TOTAL	R45 000, 00
Contract supervision	
Professional fee (13% const. Cost)	R45 275, 00
Supervision (R8 000,00)	R51 200, 00
SUBTOTAL	R96 475, 00
TOTAL COST	**R499725,00**

Source: KwaZulu Natal Department of Transport: 1999

Working on an average rate of inflation of 10% per annum, the current cost estimate would be approximately R549697.50 in 2000, R604667.50 in 2001, R665133.98 in 2002.