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# **SPECIFICATIONS FOR THE CONSTRUCTION OF ROADS IN THE KNP AND CONCESSION AREAS**

## **1. PREFACE**

South African National Parks has embarked on a commercialisation programme to increase funds for SANP's core function, nature conservation. The principle is to have private operators build and operate tourism facilities within the national parks, under stringent and monitored conditions.

SANP's programme is called "Commercialisation as a Conservation Strategy", the essence of which is to re-focus on SANP's core business: conservation of protected areas. Under this strategy, SANP will concentrate its operational resources on its core areas of concern, whilst simultaneously monitoring the provision of facilities and services in the Parks by private sector operators who are capable of performing these functions efficiently and effectively.

SANP's strategy is intended to generate additional revenues in order that SANP can ensure a higher level of conservation within South Africa's national parks. The strategy allows private enterprise to operate within national parks without alienating any of its assets. This approach should increase the value of assets which are under the control of SANP's.

Private operators will be granted rights in terms of a concession contract in which the concession area, the concession period and the concession fees are clearly defined. As a counterpart to the rights of occupation and commercial use, there are obligations on the part of the concessionaire – regarding financial terms, environmental management, social objectives, empowerment and other factors. Failure to meet the specified obligations by the concessionaire will incur penalties and could end in the termination of the contract, with the assets reverting to SANP.

## **BACKGROUND**

### **2.1 Need to compile this road manual**

The need for a set of uniform norms applicable to the Kruger National Park emerged from the SANP's concern that a new network of roads will have to be constructed for each concession area which will negatively impact on the ecosystems and the environment in general.

The production of a road manual has entailed the services of a consultant to compile a set of uniform and functional guidelines for the construction of new roads and the upgrading and maintenance of existing roads within the boundaries of the Kruger National Park.

These guidelines are intended to be applicable to all the concession areas and the remainder of the Kruger National Park and in broad terms cover the following aspects for each of the main civil engineering services:

- Design criteria
- Road construction materials
- The construction of various categories of roads
- The maintenance of various categories of roads
- The monitoring of roads and storm water systems

All the materials and methods of construction not specifically listed in these guidelines shall be in accordance with the relevant Standard Road Specifications which form part of this manual.

These guidelines are applicable for new and existing roads and the design criteria, materials and methods of construction shall be subject to review and updating from time to time.

## **2.2 Concession areas in the KNP**

Six areas were identified and allocated to private concession holders and a brief description of these areas is given in the following paragraphs. Maps, indicating the extent of each concession area and its position within the boundaries of the KNP can be found in **Annexure A**.

### **2.2.1 Lwakahle Concession Area**

This area is located to the north-east of Malelane Gate. The Biyamiti River forms the northern boundary. The existing tourism road network along the Crocodile River and the eastern road from Malelane to Skukuza form the southern, eastern and western boundaries. Part of the concession includes the Biyamiti camp. Although some of the traversing area along the river will be shared with the Biyamiti camp, the camp is not expected to otherwise impact the concession.

The total area available for exclusive traversing is approximately 15 000 ha and much of the concession is located in the Sabie/Crocodile River thorn thickets, with portions of mixed bush willow woodlands and thornveld situated on gabbro. The natural ground in this area consists out of sand, clay and heavy dark clay associated with the gabbro formation. Tracks on these soils can be impassable during periods of high rainfall. The area is also interspersed with patches of duplex soils and the construction of roads on these problem soils should be avoided where possible. There are, however, several areas with granitic and doleritic intrusions, which are better suited to vehicle traffic.

The topography of the area is general undulating with no high mountains or koppies. The KNP will retain responsibility for maintaining the existing road that runs along the Biyamiti River and is accessible to users of the Biyamiti bush camp. There are a limited number of management tracks within the area, however, these are not passable during certain periods of the year and are usually closed during the normal rainy season. SANP will allow the concession holder to develop another 75km length of roads and tracks within the concession area.

### 2.2.2 Jock of the Bushveld Concession Area

Jock of the Bushveld is located halfway between Malelane and Skukuza on the main tarred road. It is situated on the Biyamiti River in what is described as mixed bush willow woodland on granite or gneiss.

The total area available for exclusive traversing is approximately 6 000 ha. This area lies primarily to the west, north and south of the existing Jock of the Bushveld camp.

Jock of the Bushveld is located in a good game-viewing area of the KNP, especially for the "Big 5" and is ideal leopard habitat. Buffalo and elephant occur along the drainage lines. It is mostly undulating countryside with rocky koppies punctuating the landscape.

There are a limited number of roads and tracks in the concession area, including an access road to the camp, as well as several management tracks.

There is little water in the area, except for that from natural rainfall. There are no dams or any other permanent water facilities. The camp itself is supplied by two boreholes.

### 2.2.3 Mluwati concession area

The Mluwati concession is adjacent to the Manyeleti Reserve, which forms the western boundary of both KNP and the concession area. The concession lies to the south of the Talamati entrance road and is bounded by the Muzandenzi-Nhlangeni road to the east and the Nwaswitsonto River to the south.

The total area available initially for exclusive traversing is approximately 10 000 ha.

Mixed bush willow woodland (on granite or gneiss) dominates the area on gently undulating topography. Shallow granitic soils occur on the crests of the ridges, with sandy, leached soils on the seeps and heavier, clayey, and deeper soils at the base. Sodic patches are scattered throughout the area and **no developments will be permitted on these soils**. A number of streams and small tributaries run through the concession, and are a feature of the landscape. None of the streams are perennial. The area offers a very good wildlife product : the "Big 5" are seen regularly, especially leopard and lion. Cheetah also occur and wild dogs are numerous in the area.

There are currently no buildings or other infrastructure within this concession area.

There are a limited number of management tracks in the area. These are not considered to be adequate in quantity or quality for the concession, and are only passable to 4X4 vehicles. The concessionaire will therefore need to develop additional roads and tracks for game viewing

purposes, as well as for access to the camp. SANP will allow an additional 80km of roads and tracks in the concession area. In addition, the concessionaire may use the public road and track network, under the same general rules and conditions that apply to the general public. Driving the dry sandy riverbeds will be permitted, but entry and exit points must be predetermined in conjunction with KNP staff, and properly designed and constructed. **No other entry or access to the riverbed will be permitted.**

There is no perennial surface water within the concession area, although dams exist in both the south-western and south-eastern corners. These dams are not considered to be perennial. Boreholes are present in the area. These have been reliable in the past but will need to be tested before undertaking any development. If these are not adequate, new boreholes are likely to be the best option.

A water hole for game viewing at the camp may be permitted, depending on the location of the camp and availability of water. KNP management may close any water hole at any time as necessary for Park management purposes.

#### **2.2.4 N'wanetsi concession area**

The N'wanetsi Concession of about 15 000 ha lies in the eastern south-central part of KNP. It is bordered in the north-west by the Mbatsane firebreak, by Mozambique in the east, the N'wanetsi and Sweni Rivers in the south, and the S41 tourist road in the west.

The climate is semi-arid sub-tropical with average annual rainfall about 400 mm. The main rivers, the N'wanetsi and the Sweni, arise wholly within KNP. They flow east and join near the present N'wanetsi tourist camp where they incise the Lebombo Mountains.

The Mountain Bushveld on the stony Lebombo rhyolite is a succulent-deciduous savanna with bushwillow, euphorbia, white seringa, round-leafed teak and mixed to sweet grass. To the west are basalt plains with stunted knobthorn and sweet grass, dissected by shallow drainage lines with fever tree, jackalberry, leadwood and sycamore fig. The Big-5 and other game are present.

The N'wanetsi and Sweni Rivers are ephemeral and cease flowing most dry seasons. Dumbana is a natural pool on the N'wanetsi and is reputed to be the most permanent of surface water in the Concession. Small pools in the Lebombo can also hold water long into the dry season most years. Artificial water features are the Gudzani Dam off the S41 tourist road, a Department of Water Affairs (DWAF) gauging weir (called the Wenela Dam) on the N'wanetsi River and another weir (called the N'wanetsi dam) below the confluence of the N'wanetsi and Sweni Rivers. These impoundments hold water year-long except under extreme drought.

The only developments within the concession are the section ranger's outpost, a 16-bed tourist camp and management tracks. The N'wanetsi Concession is part of the 10% of Kruger Park that is classified for limited motorized recreation. In addition to the tourist-camp, there is a weekly 4x4 trail run by SANP that traverses the concession along the so-called sisal road that runs about one km west of the Mozambique border.

### **2.2.5 Mpanamana Concession Area**

This is a “green field” concession area and is located in the south-eastern corner of the Kruger National Park. The Crocodile River forms the southern boundary, with the northern boundary about 12 km north of the river. The concession area is bounded in the east by the Mozambique international border and Lebombo Mountains, while the western boundary runs parallel to this line about 10 km to the west.

The total concession area available for exclusive traversing is about 15 000 hectares (ha).

The concession area includes the scenically attractive and diverse Lebombo Mountains, while the eastern plains are flat knob thorn/marula savannah. This is an excellent game viewing region, including common sightings of the “Big 5”, with perennial water in the Crocodile river (and frequently in the Mpanamana dam as well). The soils in the flat, low-lying areas are clay, which are prone to water-logging during wet periods. Those in the Lebombo Mountains offer slightly better drainage, but the often-rugged nature of the terrain will make road and track construction and maintenance more difficult and expensive.

There is a South African National Defence Force (SANDF) military camp, as well as a ranger outpost, located on the Crocodile River south of the proposed concession area. These developments are not expected to affect tourism development opportunities within the concession area.

Although there are a number of existing management tracks in the area, these are not likely to be sufficient for the type of tourist venture appropriate to the site. SANP will allow an additional 75km of tracks to be developed, subject to SANP approval as to alignment and construction methods and to the findings of the EIA. The concessionaire will be expected to make any and all new tracks accessible to SANP for Park management purposes.

There is one dam in the area used for game. It is essentially perennial, although it may dry up during periods of extreme low rainfall. Water for the development will be either from the Crocodile River or boreholes, however the quantity and quality of underground water is not known. A permit will be required from the Department of Water Affairs and Forestry (DWAF) to extract water either from the Crocodile River or from boreholes.

### **2.2.6 Jakkalsbessie concession area**

Jakkalsbessie was an operational camp before the flooding that occurred in early 2000. It is situated approximately 5 km upstream from the current Skukuza rest camp, just slightly west of the Skukuza airport. The exclusive concession area for this facility includes a strip of land immediately west of the camp, approximately 2 000 ha in size, which follows the Sabie River. The Sabie forms the northern boundary of the concession and the Paul Kruger Gate – Skukuza Road forms the southern boundary. A second exclusive traversing area available to this concession is a strip of land between the Sabie and Sand Rivers, to the east of the concession, of approximately 1 500 ha.

The total area available for exclusive traversing is approximately 3 500 ha. As noted, this is not contiguous. The eastern block is separated from the camp by the Skukuza – Airport road and the Skukuza – Tshokwane Road.

The vegetation in the area is described as the Sabie/Crocodile thorn thicket (on granite/gneiss). This occurs in an area that is relatively flat, although it is slightly undulating with some small streams running through it and draining into the Sabie river. The Sabie and Sand Rivers are significant features with abundant riparian vegetation. Soils in the area are generally shallow, although there are some alluvial soils adjacent to the river and some sodic patches scattered throughout the concession. The area has a good game-viewing product. Some parts of the concession are particularly good for black rhino, and the rest of the “Big 5” are visible throughout the area.

This area of the Park is heavily developed, with the Skukuza rest camp, Park headquarters and the Skukuza airstrip all located nearby. As a result, the area is well supplied with roads, electricity, telecommunications and water.

There are a number of existing management tracks in the concession area. These are likely to be sufficient for game viewing purposes, although they may need to be upgraded. An additional 40km of tracks will be permitted in the area, subject to an EIA. **No tracks will be permitted on sodic patches.** The maintenance of all tracks currently in the concession area, as well as any new tracks that the concessionaire develops, will be the responsibility of the concessionaire.

This area is well supplied with water, but water conservation practices must be adhered to. The Sabie River is a perennial river and purified water is currently available on site which it is supplied from Skukuza.

### 3. DEFINITIONS AND TERMS

Unless inconsistent with the context, in these guidelines, the following terms, words or expressions shall have the meanings hereby assigned to them. In order to facilitate and simplify the reference thereof, most of the relevant terms and definitions used in this document are taken from the Standard Specifications.

(a) **Asphalt**

A mixture to predetermined proportions of aggregate, filler and bituminous binder material prepared off the road and usually placed by means of a paving machine.

(b) **Asphalt surfacing**

The layer or layers of asphalt constructed on top of the base, and, in some cases, the shoulders.

(c) **Base**

A layer of material constructed on top of the subbase, or in the absence thereof, the selected layer. A base may extend to outside the travelled way.

(d) **Borrow area**

An area with designated boundaries, approved for the purpose of obtaining borrow material. A borrow pit is the excavated pit in a borrow area.

(e) **Borrow material**

Any gravel, sand, soil, rock or ash obtained from borrow areas, dumps or sources other than cut within the road prism and which is used in the construction of the works. It shall not include crushed stone or sand obtained from commercial sources.

(f) **Bridge**

A structure erected over a depression, river, watercourse, railway line, road or other obstacle for carrying motor, railway, pedestrian or other traffic or services and having a length of 6m or more, measured between the abutment faces along the centre line of the road at girder-bed level, except that road-over-rail or rail-over-road structures are always classed as bridges.

(g) **Carriageway**

The surface normally traversed by vehicles and which consists of one or a number of contiguous traffic lanes, including auxiliary lanes and shoulders.

(h) **Catchwater drain or bank**

A longitudinal drain or bank outside the road prism for diverting water that would otherwise flow into the road prism.

(i) **California bearing ratio**

The California Bearing Ratio (CBR) of an untreated soil or gravel as determined by means of Method A8 of TMH1 is the load in Newtons, expressed as a percentage of California standard values, required to allow a circular piston of 1 935mm<sup>2</sup> to penetrate the surface of a compacted material at a rate of 1.27mm per minute to depths of 2.54, 5.08 and 7.62mm. The California standard values for these depths are 13.344kN, 20.016kN and 25.354kN respectively.

(j) **Cemented material**

Material in an existing pavement which cannot be broken up with the tines of a type 140G caterpillar or similar road grader.

Cemented crushed stone is cemented material constructed with crushed stone.

An existing stabilised pavement layer will not necessarily be classified as cemented material.

(k) **Culvert**

A structure other than a bridge, which provides an opening under the carriageway or median for drainage or other purposes.

(l) **Cut**

Cut shall mean all excavations from the road prism including side drains, excavations for cross-roads, interchange, and, where classified as cut, excavations for open drains.

(m) **Excess overburden**

Overburden within a borrow area which is not required or is unsuitable for use in construction.

(n) **Fill**

That portion of the road prism consisting of approved imported material which lies above the roadbed and is bounded by the side slopes, shown on the typical cross-sections on the drawings running downwards and outwards from the outer shoulder breakpoint and on which the selected layer, subbase, base, shoulder and, in the case of dual carriageways, the median, are to be constructed. Material imported to replace unsuitable material in the roadbed shall also be classified as fill.

(o) **General conditions of contract**

The appropriate edition of the General Conditions of Contract for National and Provincial Road and Bridge Works, together with the special conditions of contract forming part of the contract.

(p) **Grade line**

The grade line is a reference line in the drawings of the longitudinal sections of the road indicating at regular intervals the elevations according to which the road is to be constructed. The grade line may refer to the level of the completed road, base or any other layer and may indicate the elevations either along the carriageway centre line or along any designated positions on the road cross-section.

(q) **Grading modulus (GM)**

The cumulative percentages by mass of material in a representative sample of aggregate, gravel or soil retained on the 2.00mm, 0.425mm and 0.075mm sieves, divided by 100.

(r) **Inlet and outlet drains**

Channels leading into or discharging from culverts, stormwater conduits and minor bridges.

(s) **Lane**

Part of a travelled way intended for a single stream of traffic in one direction, which has normally been demarcated as such by road markings.

(t) **Levelling course**

One or more layers of asphalt of varying thicknesses, but with a specified minimum total thickness, which are applied to improve the riding quality of a road so that it will meet specified standards or so that constructing the final surfacing or resurfacing layer in accordance with the required standards for levels, thickness and surface grading will be possible. A levelling course is a type of overlay.

(u) **Lot**

A sizable portion of work or quantity of material which is assessed as a unit for the purpose of quality control and selected to represent material or work produced by essentially the same process and materials.

(v) **Median**

The area between the two travelled ways of a dual carriageway, excluding the inner shoulders.

(w) **Median drain**

A longitudinal drain situated between the inner shoulders of a dual carriageway.

(x) **Mitre drain and bank**

A drain constructed at an angle to the centre line of the road to divert water from a side drain. Mitre drains include mitre banks placed across the side drains.

(y) **Overlay**

An additional pavement layer applied on top of an existing road for strengthening the pavement and/or for improving the riding quality.

(z) **Pavement layers**

The upper layers of the road comprising the selected layers, subbase, base or gravel wearing course, and the shoulder layers.

(aa) **Pavement planning**

Planning of an existing road surface by the removal of a layer of material by means of a milling machine or other equipment.

(bb) **Pioneer layer**

An initial layer constructed over a weak roadbed where selected material is used to provide a stable platform for the construction of subsequent layers.

(cc) **Project Specifications**

The specifications relating to a specific project, which form part of the contract documents for such project, and which contain supplementary and/or amending specifications to the standard specifications.

(dd) **Rehabilitation**

Measures aimed at maintaining or improving the condition and/or riding comfort of an existing road.

(ee) **Roadbed**

The natural in situ material on which the fill, or in the absence of fill, any pavement layers, are to be constructed.

(ff) **Road prism**

That portion of the road construction included between the original ground level and the outer boundaries of the slopes of cuttings, fills and side drains. It shall not include the selected layer, subbase, base, surfacing, shoulder or roadbed.

(gg) **Road reserve**

The entire area included by the boundaries of a road as proclaimed.

(hh) **Roller passes**

Unless otherwise specified in the specifications or the project specifications, an area will be taken to have received one roller pass when a roller has passed over such area once. Additional passes made only as a result of nominal overlapping so as to ensure full coverage shall not be taken into account.

(ii) **Screed**

A layer of fine-graded asphalt or slurry placed to fill in slacks in existing seals and to improve the riding quality of the road.

(jj) **Seal**

The application of one or more layers of bituminous binder with or without layers of crushed stone, sand or slurry in successive layers on the carriageway, shoulders or on any other compacted layer on which movement of traffic takes place.

(kk) **Selected layer**

The lower layer or layers of the pavement which is constructed direct onto the fill, or in some cases the roadbed. It may include roadbed material compacted in situ.

(ll) **Services**

Cables, pipes or other structures to provide, inter alia, conduits for electricity, telephone and telegraph connections, water, sewage, etc.

(mm) **Shoulder**

(a) When referring to this as a surface : The area between the outside edge of the travelled way and the shoulder breakpoint.

(b) When referring to this as a pavement layer : The upper pavement layer lying between the outside edge of the base and the shoulder breakpoint.

(nn) **Shoulder breakpoint**

The line along which the extended flat planes of the surface of the shoulder and the outside slope of the fill and pavement intersect. This edge is normally rounded to a predetermined radius.

(oo) **Stabilisation**

The treatment of the materials used in the construction of the roadbed, fill or pavement layers by the addition of a cementitious binder such as lime or Portland cement or the mechanical modification of the material through the addition of a soil binder or a bituminous binder. Asphalt and concrete shall not be considered as materials that have been stabilised.

(pp) **Slope**

Unless otherwise stated, slope is given in terms of the ratio of the vertical difference in elevation between any two points and the horizontal distance between them. This ratio may also be expressed as a percentage.

(qq) **Spoil (material)**

Material originating from construction operations and which is not utilised for construction purposes.

(rr) **Subbase**

The layer of material on top of the selected layers or fill and below the base and shoulders.

(ss) **Subsoil drainage system**

A system of subsoil drainage pipes (including any permeable material) constructed to intercept and remove subsoil water.

(tt) **Travelled way**

That portion of the carriageway which includes the various traffic lanes and auxiliary lanes but excludes the shoulders.

(uu) **Verge**

The area between the outer edge of the road prism and the boundary of the road reserve.

(vv) **Wheel track**

The path followed by the wheels of a vehicle during normal riding movements. The wheel tracks cover approximately the outer metre width on both sides of a traffic lane.

## **Abbreviations**

For the purpose of this manual the abbreviations listed below shall apply and shall have the meanings as given. Abbreviations of units of measurement shall be the standard abbreviations as set out in the SI system. Where necessary, further abbreviations and their meanings will be shown on the typical drawings given elsewhere in this document.

AASHTO	:	American Association of State Highway and Transportation Officials
ASTM	:	American Society for Testing and Materials
BS	:	British Standards Institution
CBR	:	California Bearing Ration
CP	:	British Standard Code of Practice
DEAT	:	The national Department of Environmental Affairs and Tourism
EIA	:	Environmental Impact Assessment
EMP	:	Environmental Management Plan

CSIR	:	Council for Scientific and Industrial Research
CKS	:	SABS Co-ordinating Specification
OMC	:	Optimum Moisture Content
PI	:	Plasticity Index
SABS	:	South African Bureau of Standards
TMH	:	Technical Methods for Highways of the National Institute for Transport and Road Research
KNP		Kruger National Park
SANP		South African National Parks

#### **4. DOCUMENTS WHICH FORM PART OF THIS DOCUMENT**

This manual is based on the following Standard Specifications:

- The General Conditions of Contract for Road and Bridge Works for State Road Authorities (1998 Edition)
- The standard Specifications for Road and Bridge Works 1998 for State Road Authorities.

Both the above-mentioned documents are prepared and drafted by COLTO (Committee of Land Transport Officials) Department of Transport and all future tender documents should be based on these specifications.

### **GENERAL DESIGN PRINCIPLES AND PROCESSES**

#### **5.1 Scope**

The procedure for the structural design of road pavements in this manual are applicable to gravel and dirt roads in the concession areas of the Kruger National Park. The procedures are based on a combination of existing methods, experience obtained in the KNP and fundamental theory on the behaviour of structures and materials in the various parts of the Park. However, it must be kept in mind that the procedures proposed in this document do not necessarily exclude other design methods.

It is important to attend to layout planning and drainage design before the structural design of a road is addressed. The structural design of a pavement is aimed at the protection of the subgrade through the provision of pavement layers or gravel wearing courses.

#### **5.2 Needs Analysis**

In the concession areas the type and quality of the tourism product to be offered to potential visitors will necessitate a certain network of road and two way tracks. The road network should be sufficient to accommodate guests and supplies to and from the game lodge within the concession area and for game viewing for guests.

The concessionaire may utilise existing roads and tracks in it's concession area but will be responsible for maintaining the infrastructure as specified in this document, the relevant Standard Specifications and to the satisfaction of the SANP. Detail of the roads, such as locality, length, category, anticipated utilisation, etc. should be finalised in writing before being taken over by the concessionaire.

### **5.3 Creation of Road Networks**

All existing roads in a concession area should be taken over by the concessionaire on a "voetstoots" basis and the concessionaire will be responsible for the maintenance of these roads throughout the concession period. These roads do not form part of the length of road allocated to each concessionaire.

The following approximate, additional lengths of road were allocated by SANP to be developed by the concessionaire within his area:

- **Lwakahle:** 75,0km
- **Jock of the Bushveld:** There is an access road to the camping site and several management tracks can also be utilised in this area. The length of additional road allocated to this concessionaire is unknown.
- **Mluwati:** 80km
- **Mpanamana:** 75km
- **Jakkalsbessie:** 40km
- **N'wanetsi:** Additional length of roads allocated unknown.

The position of any road, irrespective of category, should be well planned and the de-commissioning of any road soon after it has been created should be avoided at all cost, because any road, once created, can never be rehabilitated one hundred percent successfully.

If the concessionaire decides not to utilise any road for whatever reason this road should be de-commissioned and rehabilitated as described in chapter 15 of this document.

## 5.4 Design Process

A very simple diagram of the design process discussed in this document is shown in Table 5.1. The diagram has seven sections. Each section should be treated separately, but all sections represent the basic inputs to pavement design, namely road category, design strategy, design traffic, materials available and the environment. With these as inputs the designer will use the proposed pavement types in Section 9 to obtain possible pavement structures. This will also assist in future maintenance measures and some construction considerations.

The proposed designs in Section 9 is based on experience of pavement construction and pavement behaviour in the Kruger National Park. These designs should be adequate to provide the basic design required. However, different and special conditions may require other methods of design. The four typical road categories mentioned in table 5.1 are defined in Section 7 (table 7.1).

**Tabel 5.1**

	<b>SELECT ROAD CATEGORY</b>		<b>STRUCTURAL DESIGN</b>
<b>Section 1</b>	A, B, C or D	<b>Section 5</b>	<ul style="list-style-type: none"> <li>• Pavement behaviour</li> <li>• Pavement type selection</li> </ul>
<b>Section 2</b>	Estimate design traffic	<b>Section 6</b>	Include practical considerations
	<ul style="list-style-type: none"> <li>• Consider construction traffic</li> </ul>		<ul style="list-style-type: none"> <li>• Drainage</li> <li>• Compaction</li> <li>• Problem subgrades</li> <li>• Cross-section</li> </ul>
<b>Section 3</b>	Consider materials	<b>Section 7</b>	Do cost analysis
	<ul style="list-style-type: none"> <li>• Availability of materials</li> <li>• Unit costs</li> <li>• Past experience</li> </ul>		<ul style="list-style-type: none"> <li>• Present worth of construction costs</li> </ul>
<b>Section 4</b>	Define environment		
	<ul style="list-style-type: none"> <li>• Topography</li> <li>• Climatic region</li> <li>• Delineate subgrade areas</li> <li>• Design CBR</li> </ul>		

## **6. ENVIRONMENTAL FACTORS AFFECTING ROAD LAYOUT**

### **6.1 General**

The environment in which a road is built has a greater influence on its life and performance than is generally realised. This environment has to be accepted as it is and the design and method of construction must be suitably adapted. The environment of a road is the sum of all those external conditions, inorganic as well as organic, to which a road is exposed and the more the road is in harmony with this environment, the better its performance will be.

The environment is characterised by topography, the climatic conditions (moisture and temperature) under which the road will function, and the underlying sub grade conditions. Environmental factors must be taken into account in the design of pavement structures.

## 6.2 Topography

The importance of the influence of the topography on the structural design and functional use of roads is clearly reflected in the drainage and maintenance requirements of roads in general. Macro drainage is relevant to this discussion. In rolling or mountainous landscapes there may be steep gradients which result in the erosion of gravel roads and in particular erosion of their drainage facilities, with direct implications for their safety and functional use. Roads that cross contours at an angle, or even perpendicularly, pose the most drainage problems. In such cases functional rather than structural requirements may require that a road be paved or provided with erosion protection.

## 6.3 Climate

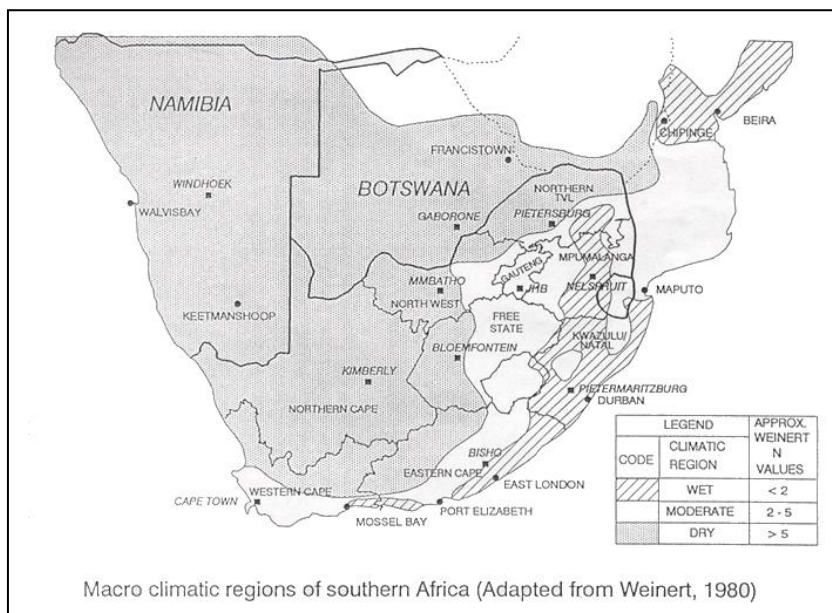
The climate will largely determine the weathering of natural rocks, the durability of weathered, natural road building materials and also, depending on drainage conditions, the stability of untreated materials in the pavement. The climate may also influence the equilibrium moisture content. The designer should always consider climatic conditions and avoid using materials that are excessively water-susceptible or temperature-sensitive in adverse conditions. It is also possible to accommodate climatic conditions by either adjusting CBR values or by weighting the equivalent traffic (not both).

Southern Africa can be divided into three climatic regions:

- a large dry region
- a moderate region and
- a small wet region

Figure 6.1 shows a map of Southern Africa which indicates the different climatic regions. The KNP is situated in the *moderate* region and it should be noted that this is a macro climate region and that different micro climates could occur within this region. The designer should, therefore, identify problems that may be cause by local micro climates.

FIGURE 6.1



## 6.4 Landscapes in which the Concession Areas are situated

### 6.4.1 General

According to **Koedoe 26:9-21 (1983)** a landscape is defined as an area with a specific geomorphology, climate, soil and vegetation pattern together with the associated fauna. On this basis 35 landscapes in the KNP were identified and described in terms of the components mentioned in the definition. The objective of classification is that future management should be based on these landscapes. Relevant management considerations may change, but the landscape as a basic functional unit should not be negotiable. A map of the KNP which indicates the various landscapes can be found in **Annexure B** of this document

For the purpose of this document the landscapes in which the six concession areas are situated are briefly described in order to provide the designer with some information and background regarding the general geomorphology, climate, and soil pattern he can expect in a specific concession area. Any information needed about the vegetation and fauna in the concession areas can be obtained from the publication: **Koedoe 26:9-21 (1983)**.

#### 6.4.2 Landscape 4: Thickets of the Sabie and Crocodile Rivers

Concession areas situated within this landscape:

- Jakkalsbessie
- Lwakahle

#### Location and Geomorphology

***As the name indicates this landscape consists of the low lying areas along the two rivers and is underlain by archian granite and gneiss intersected by dolerite intrusions. The landscape is horseshoe-shaped, starting at the Sabie River with the Mtshawuspruit as the western boundary, along the Sabie eastwards to Lubyelubye, then southwards across the watershed to the Crocodile River and then westwards following the river banks to the vicinity of the Malelane restcamp. The topography is concave to relatively flat but is intersected by numerous spruits that flow into the two rivers. Spruits worth mentioning are the Nwaswitshaka, Nwatimwambo, Nwatimhiri and Lubyelubye that flow into the Sabie River and the lower Mbyamide, Bume and Mlambane that flow into the Crocodile River. A few granite koppies occur in the landscape of which Shirimanthanga, Renoster Koppies, Thekwane, Mlaleneni, Siyalo and Sihehleni are the most important.***

The altitude varies between 200 and 350 metres and the landscape occupies 1 242km<sup>2</sup> or 6.2 percent of the KNP, which makes it one of the largest landscapes in the southern district.

#### Climate

The climate of this low-lying landscape shows greater extremes than the adjacent landscapes. As far as temperature is concerned a great variation between day and night-time temperatures is experienced. The average daily maximum temperature is above 31°C for the months of November to March (Table 2) while sporadic frost occurs in the winter in the bottomlands. The rainfall varies between 500 and 550mm per year with an annual average of 546mm for Skukuza (Gertenbach 1980).

**Table 2**

Temperature data for Skukuza

(Data collected since 1965)

Temperature °C

<b>Month</b>	<b>Average daily maximum</b>	<b>Absolute maximum</b>	<b>Average daily minimum</b>	<b>Absolute minimum</b>
January	32.3	42.3	19.6	7.2
February	32.2	40.3	19.4	7.2
March	31.2	40.3	17.9	8.3
April	29.8	38.3	14.8	3.3
May	27.4	37.0	10.2	2.2
June	25.6	35.3	6.1	-2.2
July	25.4	36.1	5.6	-2.5
August	27.2	37.9	7.6	-0.1
September	29.4	40.6	11.6	1.1
October	30.8	41.7	15.1	6.6
November	31.8	44.5	17.5	6.7
December	32.3	44.4	19.2	8.3

#### Soil pattern

*The soils in this landscape are normally shallow and where it is deeper it is usually saturated with sodium. It developed mainly as a result of the accumulation of clay and mineral elements in the low lying areas. Harmse & Van Wyk (1972) identified two groups of soils in this landscape, namely Mispah and Glenrosa soils on the uplands and Sterkspruit, Estcourt and Valsrivier soils in the bottomlands. Dundee, Oakleaf and Inhoek Forms of soil are usually found on the banks of spruits and rivers. The soils present in the vicinity of dolerite intrusions are usually darker in colour and forms that can be expected are Mayo, Milkwood and Swartland. As a rule it can be said that the soils of this landscape are usually shallow and show no signs of a recurrent pattern.*

#### 6.4.3 Landscape 5: Mixed Combretum spp. / Terminalia sericea Woodland

Concession areas situated within this landscape:

- Mluwati
- Jock of the Bushveld

## Location and Geomorphology

This landscape is discontinuous due to the fact that it consists of two areas which are separated by Landscape 4 *viz.* the thickets of the Sabie and Crocodile Rivers. One portion of this landscape occurs in the southern district and the remainder forms the south western part of the Central District as far north as the Orpen/Timbavati area. The geological substrata are granite and gneiss with numerous dolerite intrusions which never exceed 10 metres in breadth (Schutte 1974). This landscape occurs mainly on or close to the watersheds and therefore includes only the upper courses of most spruits *viz.* the Mbyamite, Mlambane, Nwatimhiri and Nwatimwambu in the southern sub-region and the Nwatindlopfu, Nwaswitsontso, Sweni and Nwanedzi in the northern sub-region. The landscape is undulating with distinct uplands, ecotones and bottomlands. The altitude varies between 350 and 500m and the landscape occupies 1 578km<sup>2</sup> of 8.1 percent of the KNP.

<b>Table 3</b>				
Temperature data for Satara				
<b>(Data collected September 1981)</b>				
<b>Temperature °C</b>				
<b>Month</b>	<b>Average daily maximum</b>	<b>Absolute maximum</b>	<b>Average daily minimum</b>	<b>Absolute minimum</b>
January	33.0	41.6	21.0	17.5
February	33.6	39.0	20.8	16.0
March	33.3	38.0	19.8	14.5
April	29.6	34.0	17.4	12.0
May	28.0	31.4	13.0	8.3
June	25.8	28.0	8.9	8.0
July	26.8	32.6	10.7	7.4
August	27.6	36.0	11.9	9.9
September	28.1	35.0	14.3	11.0
October	26.3	37.5	13.7	12.0
November	31.4	40.0	18.7	13.5
December	30.7	40.5	19.0	13.0

## Climate

The landscape has a temperate climate with the occurrence of sporadic frost confined strictly to the bottomlands. The phenomenon of temperature inversions (Oosting 1956) is very distinct in this undulating landscape. During daytime higher temperatures are experienced in the bottomlands than on the uplands, but at night it becomes colder in the bottomlands. Table 3 gives the temperature data for Satara which is also applicable to this landscape. Rainfall

varies between 550 and 600mm per year with the average annual rainfall for Skukuza, Tshokwane and Kingfisherspruit 546.3, 561.3 and 582.3mm respectively.

## Soil pattern

This landscape has an interesting and most unique centenary sequence of soils that correspond strongly with position in the topography. The upland soils are sandy with between 6 and 15 percent clay and the dominant soil Forms are Hutton and Clovelly with Portsmouth/Swartfontein and Denhere/Makuya respectively as the dominant Series. Where the slopes become steeper Glenrosa soils can be expected. Venter (1981) shows a diagrammatic representation of a catena on granite which explains the situation in this landscape (fig 7). Where the convex topography changes into a concave topography conditions of temporary water saturation prevail and gleyed sandy soils are present (Cartref and Fernwood). Over a period of time and accumulation of clay has taken place in the bottomlands and therefore the soil in the bottomlands has become clayey, often sodium saturated with a massive prismatic structure in the underground horizons. Dominant soil forms are Estcourt, Sterkspruit, Swartland and Valsrivier.

The banks of the spruits are formed by recent alluvial soils of which Oakleaf, Dundee and Inhoek are the most important forms.

The frequent occurrence of dolerite intrusions in the granite of this landscape sometimes has the potential to obscure the catenary sequence, as described above. The soil on the dolerite intrusions is darker in colour (Mayo, Milkwood, Bonheim) and usually much more clayey (15 to 35 percent for the A-horizons). In the vicinity of a dolerite intrusion the weathered material from the dolerite and granite blends and it sometimes happens that the A-horizon originates from dolerite but the B-horizon from granite. These soils accommodate a heterogeneous vegetation that does not always fit in with the recurrent pattern (Mayo, Glenrosa).

### 6.4.4 Landscape 17: *Sclerocarya caffra* / *Acacia nigrescens* Savanna

**Concession areas situated within this landscape:**

- **Mpanamana**
- **N'wanetsi**

## Location and Geomorphology

This landscape extends from the Crocodile River in the south to just north of Satara with the Lebombo Mountains as the eastern and the Karoo sediments as the western boundary. It is one of the largest landscapes and occupies 1 411km<sup>2</sup> or 7.2 percent of the KNP. A characteristic of this landscape is that it consists of reasonably flat plains with individual well defined drainage channels. All the larger rivers such as the Crocodile, Sabie, Nwaswitsonto, Nwanedzi and Sweni cut through the landscape while smaller spruits such as the Nhlowa,

Mlondozi, Guweni, Mrunzuluku, Gudzane, and Mtomene drain this area. According to Bristow (1980) the underlying parent material of this landscape is Sabi River Basalts with a possibility of dolerite intrusions in the basalt.

The altitude varies from 170 metres in the vicinity of Crocodile Bridge to as much as 250 metres above sea level, just north of Satara.

## Climate

Gertenbach (1980) states that the rainfall of this landscape diminishes from south to north. The long-term average annual rainfall at Crocodile Bridge is 599.6mm while the average for Satara is 548.2mm. The temperature experienced in this landscape probably varies as well, but Table 3 gives the temperature for Satara which is probably applicable to this landscape as a whole. Frost is limited to the bottomlands along the rivers and even then on an irregular basis.

## Soil pattern

The Sabi River Basalts weather to form a black, brown or red clayey soil. The soil depth does not normally exceed one metre and the dominant forms are Bonheim, Shortlands, Swartland, Milkwood, Mayo, Glenrosa and Valsrivier. In the low lying areas vertisols of the Arcadia and Rensburg Forms can also be expected. The soil pattern is relatively homogeneous and no great changes in soil types occur over short distances. The clay contents in the soil varies between 25 and 50 percent and it is rich in plant nutrients. Table 8 indicates the quantity of exchangeable plant nutrients of a typical soil sample.

### 6.4.5 Landscape 18: Dwarf *Acacia nigrescens* Savanna

**Concession areas situated within this landscape:**

- **N'wanetsi**

## Location and Geomorphology

The basalts in the vicinity of the watershed between the Olifants and Nwanedzi Rivers north of Satara contain a lot of amygdales and olivine and decompose to form dark coloured soils. The area is reasonably flat to concave, high lying plains and is drained by the Mtomeni, Mapetane and Gudzane spruits. Shitsalaleni is a well known pan in this area. The altitude varies between 250 and 300 metres and the landscape is relatively small (356km<sup>2</sup> or 1.8 percent of the KNP).

## Climate

According to Gertenbach (1980) this area receives between 500 and 550mm of rain annually and the temperature is comparable to that of Satara which is given in Table 3.

## Soil pattern

The catenary sequence of soils in this landscape include the occurrence of darkly coloured clayey soils on the uplands with dominant forms Swartland, Bonheim, Milkwood and Mayo. The percentage of clay in the A-horizons, which originate from rhyolite, varies between 15 and 35 percent and the pH between 5.6 and 6.8 (Coetzee). The B-horizons, which originate from dolerite, contain between 35 and 55 percent clay and the pH varies between 6.1 and 7.7. In situations where there is a concave topography clayey soil of the Arcadia Form can be expected. These are soils with dark coloured vertic characteristics that sometimes granulate spontaneously on the surface.

### 6.4.6 Landscape 19: Thornveld on Gabbro

#### Concession areas situated within this landscape:

- **Mluwati**

## Location and Geomorphology

The park's "Gabbro intrusion" (Brandt 1948; Gertenbach 1978; Schutte 1982) extends from Malelane in the south of the KNP to Phondaheuwels west of Shingwedzi. The southernmost section of this intrusion in the vicinity of Orpen, is characterised by a thorn savanna with a dense grass cover. This landscape is a series of islands of gabbro origin, sometimes linked by narrow dykes. It extends from Malelane including koppies such as Ship Mountain and Sithlave, extending beyond the borders of the KNP at Mkhuhlu Station. A number of sub-units of this landscape occur between the Sabie and Nwawitsontso rivers and at Orpen it forms extensive outcrops. Coetzee (1983) describes the geology of this landscape as dolerite, but evidence indicates that it is gabbro (Brandt 1948; Schutte 1974; Gertenbach 1978).

The landscape generally has a higher altitude than the surrounding granite (between 550 and 600 metres a.s.l.) and it is flat to slightly undulating with prominent koppies such as Ship Mountain and Sithlave. North of Orpen the thornveld on the gabbro is replaced by a shrub *Colophospermum mopane* community (Landscape 24). This landscape covers 685km<sup>2</sup> or 3.5 percent of the KNP.

## Climate

The rainfall of this landscape varies considerably from south to north. At Malelane in the south an average rainfall of 620mm prevails while that of Kingfisherspruit is 582mm. Temperature

data from Pretoriuskop (Table 1), Skukuza (Table 2) and Satara (Table 3) are applicable of this landscape.

## Soil pattern

The soils that develop from gabbro are usually dark in colour and clayey. Where the terrain is flat to slightly concave, the soil becomes deeper and the following soil forms can be expected : Bonheim, Mayo, Milkwood, Glenrosa and even Hutton soil forms can be expected. In the southern parts of this landscape the soils are darker in colour and the grass cover more dense. Loose rock is often present on the surface and there is little soil development on the koppies and it can be classified as lithosols.

Where the gabbro and surrounding granite are in contact a mixed soil sometimes develops. It frequently happens that the A-horizon originates from gabbro that has spilled over the B-horizon (which originated from granite).

#### **6.4.7 Landscape 29: Lebombo South**

**Concession areas situated within this landscape:**

- **Mpanamana**
- **N'wanetsi**

#### **Location and Geomorphology**

The Lebombo Mountains on the eastern side of the KNP form a physiographical unit of its own. Because of climatological reasons this range of mountains is divided into two landscapes. The area between the Crocodile River and Pumbe pan will be dealt with in this landscape. It is an undulating terrain with north/south running ridges and bottomlands. The geological formation is rhyolite and granophyre of the Lebombo Group, Sequence Karoo (Schutte 1982). The altitude varies between 360 metres in the south to 300 metres in the northern areas. The Lebombo Mountains are situated almost 100 metres higher than the adjacent basalt plains and sometimes form a low escarpment on the western slopes. All the large rivers and spruits that either flow through, or originate in the KNP, break through the Lebombo Mountains at some stage to form deep incisions or gorges. Of these Crocodile, Sabie, Nwaswitsontso and Nwanedzi River gorges are certainly the best known. This landscape covers 765km<sup>2</sup> or 4.8 percent of the area of the KNP.

#### **Climate**

The rainfall on the Lebombo Mountain diminishes from south to north. In the vicinity of the Crocodile River the average annual rainfall is probably close to 700mm and it drops to 500mm in the vicinity of Pumbe. According to Gertenbach (1980) the isohyets turn northwards on the Lebombo Mountains which implies that the area is wetter than the adjacent basalt plains. The temperature on the western mountain side becomes extremely high in summer with no possibility of frost in winter.

#### **Soil pattern**

The soils in the Lebombo Mountains can best be described as lithosols. Occasionally shallow soils from the Mispah and Glenrosa forms can be expected, but this is the exception. The terrain is less undulating to the east of Muntche and deeper soils of the Swartland and Glenrosa forms are present.

### **6.5 Research Monitoring Sites**

There are approximately 1000 research monitoring sites in the KNP and the following requirements should be adhered to:

- All research monitoring sites should be identified and carefully mapped with the aid of the game ranger responsible for that area.

- No road, track, borrow pit or development of whatever nature shall be created in or nearby these areas.
- Nature conservation officials should be consulted when planning the layout of roads in the vicinity of research sites.

## **6.6 Areas of Red Data Book Species**

The exact number and locations of areas of Red Data Book Species in the KNP are unknown, but for the purpose of this document the following requirements should be strictly adhered to:

- All sites should be identified and carefully mapped with the aid of the game ranger responsible for that area.
- No road, track, borrow pit or development of whatever nature shall be created in or nearby these areas.
- Nature conservation officials should be consulted when planning the layout of roads in the vicinity of these sites.

## **6.7 Problem soils**

### **6.7.1 General**

The in situ material on which a road is normally constructed is in fact the natural ground consisting out of rock and soil. In the civil engineering field, terms such as *subgrade*, *formation* and *road bed* are normally used to describe the natural ground on which a road is to be constructed. This material is never imported and it is sometimes necessary to improve the quality thereof by stabilisation, or other pre-treatment measures, such as moistening and compaction, or it may be partly removed and replaced by better quality road building material. During the construction of category C and D roads it is important to minimise the construction costs by making use of the in situ material as far as possible. There are two types of natural ground, with almost opposite properties, which can be treated as problem soils in general, viz. expansive soils and collapsing soils.

### **6.7.2 Expansive soils**

#### **(a) General**

Expansive soils (also called active soils) are always highly plastic with Plasticity Indexes between 20 and 60 and when wet their bearing capacity is very low. They are therefore unsuitable as foundation soils and their removal and replacement with some more stable material would be the best way to cope with them. In the KNP these soils are predominantly montmorillonitic clayey soils and are usually overlaying basic crystalline rocks. In certain areas or on slopes with a gradient of more than about 5 degrees kaolinite may predominate in the very top layer of residual soil but with montmorillonite lower down.

#### **(b) Road construction on expansive soils**

No two-track road (Category C and D) shall be constructed on expansive clays without a cover layer of at least 200mm gravel as explained below or without the in situ material being stabilised with a suitable stabilising agent. Most of the soils classified as expansive clays will lose their stability during rainy periods or as a result of wetting and vehicular movement of whatever nature on these clays and will cause severe damage to the track and its immediate environment.

The removal of the clay and replacement with suitable material is uneconomical when the construction of category C and D roads is envisaged. There are several ways in handling with expansive clays when constructing roads, but most of these methods are normally very expensive and also need sophisticated equipment and highly skilled personnel to implement. The most appropriate way to address the problem of construction category C and D roads in the concession areas must be used and the following two views should be considered as a guideline:

- The first method would be to cover the clay with a layer of approximately 200mm thick G6 or better quality gravel. This layer will reduce the effect of expansion of montmorillonitic or otherwise expansive natural ground to a certain extent because of the increased load of the overburden and the porosity and compressibility of such a layer. This method has major disadvantages in terms of the negative impact on the environment, cost of exploring borrow materials, transporting of gravel and the high costs involved in the rehabilitation of areas damaged as a result of these activities.
- The second method would be to stabilise the top 200mm of the in situ material with a suitable stabilising agent. However, all expansive soils are unsuited for construction purposes and most of them cannot be stabilised with conventional agents, such as lime, slagment, PBFC, etc. Cement is the only stabilising agent that has an enviable track record of success. However, it also cannot be used on its own in the stabilisation of expansive clays because the major shortcomings of cement are:
  - Shrinkage
  - Lack of tensile strength
  - Water permeability

Details of the different types of stabilising agents suitable for in situ stabilisation can be found in Section 12.10 of this document.

### **6.7.3 Collapsing soils**

#### **(a) General**

These soils are single-sized and very loose, but normally contain a limited quantity of a natural binder. The internal structure of these soils gives them a fairly high bearing capacity as long as their moisture content does not increase. With an increase of moisture and when under load, however, these materials change immediately and spontaneously to a condition which is in equilibrium with the load, for example, a building or road and the new moisture content

**(Jennings and Knight 1975).** Such sudden settlement which may lead to severe damage to structures occurs in soils which are known to possess a collapsible grain structure.

Collapse as a result of wetting may occur in all loose materials, including fills and embankments, very dry clays and also highly decomposed basic crystalline rocks (**Barden et al, 1973**). Most recorded cases of collapse with damaging consequences, however, have occurred in certain types of sandy soil, such as, collapsing sand, collapsing residual granite and collapsing arkose.

### **(b) Collapsing sand**

Collapsing sand has been studied in detail by **Knight – 1958, 1959**. This sand which **Knight** considers to be of eolian origin and to have consisted originally of quartz and other mineral grains, is characterized by the presence of two principal grain sizes, a larger sandy and a smaller more clayey one, while sizes in between are poorly represented. The grading curve of these materials normally have a characteristic S-shape. The sand grains are held together by bridges of iron hydroxide and clay. The clay is kaolinite in most cases derived from the decomposition of the originally admixed mineral grains. These sands possess an open structure, the void ratio is high, and there is very little interlock between the sand grains, because the structure is held together by the clay and iron hydroxide bridges.

As long as such sand is not disturbed and is kept dry, these bridges provide considerable bearing strength and their hold on the sand grains is such that the sand will form vertical faces in excavations several meters deep.

If the sand is wetted, however, the bonding bridges between the grains soften and, under pressure above a certain limit, the bridges break and collapse occurs. When this happens, these sands can spontaneously lose up to 20% of their original volume.

### **(c) Collapsing residual granite**

Structurally, collapsing residual granite or rather acid crystalline rocks are very similar to collapsing sand. Again they possess an open, poorly graded structure, high void ratio and bridges, in this case consisting mostly of kaolinite, which keep the quartz and unweathered feldspar grains together. Again, as long as the material is dry, the bearing capacity is high and the soil will form vertical faces in excavations. If the soil is wetted and the load on it exceeds a certain minimum, it will collapse.

This soil structure is mostly confined to residual acid crystalline rocks whose minerals react differently during decomposition. The most common of such rocks is granite although it is not the only one.

### **(d) Collapsing arkose**

Arkose, a member of the group of arenaceous rocks, is a sandstone which contains 25% and more feldspar, mostly orthoclase. If such a rock weathers the orthoclase changes into kaolinite clay. Under favourable environmental conditions, for example, when the topography and the

climate provide for the removal of part of the clay in the weathered rock, collapsible soil structures develop which are similar to those from acid crystalline rocks.

### **(e) The recognition of collapsing soils**

Several methods of identification are available and they have been described by ***Knight (1958)*** and ***Dehlen (1963)*** and ***Jennings and Knight (1975)***. In accordance of ***Jennings and Knight (1975)*** there are a few criteria which can be used easily during field inspections or centre line surveys and which may serve as guides for the recognition of a potentially collapsing soil. The most important prerequisite is probably the partial desiccation of the soil because collapse can only occur in a soil under load when the moisture content of this soil increases. Soils below the water table do not collapse. Definite identification of a collapsible soil is, however, best done by laboratory tests and it has been suggested that every soil whose dry density is less than 1600kg/m<sup>3</sup> must be suspected of being collapsible.

Collapsible properties are particularly likely to be found in materials or soils such as:

- Loose fills
- Windblown sands or hillwash of loose consistency
- Highly decomposed acid crystalline rocks and occasionally even highly decomposed basic crystalline rocks
- Certain weathered sedimentary rocks, such as, arkose but also greywacke.

Most collapsing sand in the KNP possesses a dark reddish colour which is caused by the high amount of iron hydroxide normally present in the soil. This need not, however, always be the case and the colour may be dirty whitish when the iron is absent as is often the case with collapsing granite or arkose. All shades between dark reddish and dirty whitish are actually possible. Therefore not every red sand is a collapsing sand and the whitish colour of a sand or soil does not exclude the possibility of collapsible properties.

### **(f) Road construction on collapsing soils**

Many areas in the KNP are underlain by materials with a collapsible grain structure and particularly collapsible sand but is suitable for road construction. Since the property of potential collapse is a consequence of the undisturbed structure of these soils, this property is lost entirely once the soil has been disturbed or wetted and compacted as part of a road pavement.

In the preparation of collapsing soils for road construction the following suggestions can be used as guidelines:

### **(g) Category A and B roads**

The material should be pre-wet and compacted with a heavy vibration roller or with a heavy pneumatic roller with low tyre pressure. It is important to destroy the collapsible grain structure of the soil to the depth of about one metre, which is possible by using the correct equipment and rolling technique. The achievement of such deep compaction of the soil may pose problems and such compaction is best done during the rainy season. Impact rolling is another suitable method for the deep compaction of such soils

and compaction of down to a depth of one metre can be obtained on dry collapsible soils. Once settlement or collapse has occurred the surface of the road should be levelled and lightly compacted, where after the importation of the pavement layer can proceed.

### **(h) Category C and D roads**

These roads will be mainly two-track roads and it will not always be possible to avoid all areas containing collapsible and/or dispersive soils. The most cost effective and sufficient way to solve the problem of collapsible soils is a three pass-roller compaction effort with a heavy vibrating roller after pre-wetting the soil. The material will settle when subjected to this kind of compaction and backfill should be done by using material from gravel imported from the nearest borrow pit. No side drains or mitre drains should be constructed in soils with a collapsible grain structure. In these areas all roads should be built up at least 200mm above natural ground level and the sides of cuts and fills should be protected with rock or stone pitching.

#### **6.7.4 Drainage channels/access/egress, etc.**

The construction of any category road in a natural drainage channel should be avoided at all cost. It will , however, be impossible to avoid crossing a channel under certain circumstances and normal construction procedures should take place in such events. The banks and floor of the channel should be treated with great care and should be protected with rock and concrete grouted stone pitching. Similar measures should be taken to prevent erosion at the access and egress of the channel. A spruit of whatever size will be treated as a drainage channel.

**Riverbeds and banks:** Driving in riverbeds is a highly sensitive aspect which is of great concern to most of the nature conservation officials of the KNP. The following guidelines should be followed closely when driving in a riverbed:

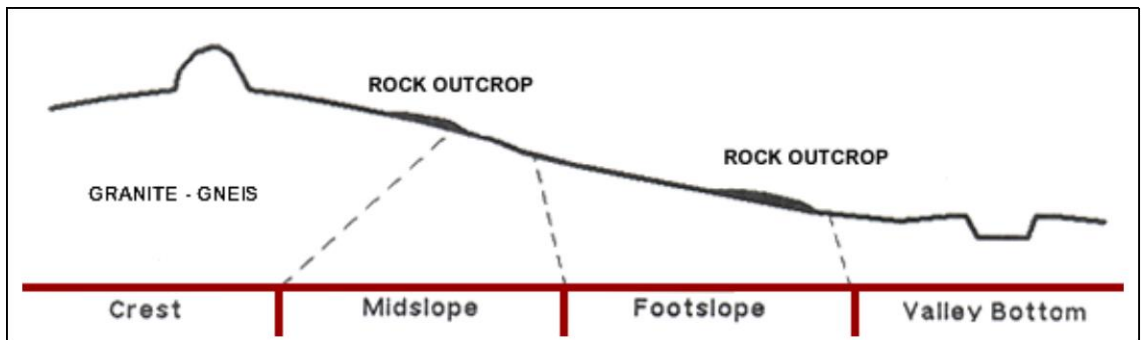
- (a) Permission should be obtained from the KNP before any access or egress to a riverbed will be constructed.
- (b) If a situation prevails where driving on a riverbed is possible, only one access and one egress shall be allowed for every one kilometre continuous length of passable riverbed. At any section of passable riverbed shorter than one kilometre only one entrance shall be allowed which should be used for access and egress simultaneously.
- (c) All accesses and egresses at rivers should be constructed and protected by using suitable and innovative measures as explained elsewhere in this manual.
- (d) Certain bird species and crocodiles utilise river banks and riverbeds for nesting and breeding. When entering any riverbed for the first time the vehicle should be accompanied by a nature conservation official to assist with the layout of the tracks in the riverbed.
- (e) The same set of tracks shall be used when driving in the riverbed and any deviation from these tracks will be treated as a serious matter.

- (f) If the tracks are removed or covered up during the flooding of the river, the same procedure as explained in paragraphs (b) and (d) shall be followed to create new tracks.
- (g) No vegetation of whatever nature shall be disturbed during the layout of tracks in a riverbed and whilst driving in a riverbed.

**6.7.5 Description of different soil types/conditions**

In this section and Table 6.1 the general soil types identified in the different concession areas are briefly described. In Section 6.7 typical problem soils expected in the KNP are described. The problem soils mentioned in Table 6.1 are also classified (highlighted) below the description according to the criteria described in Section 6.7.

The following diagram indicates a typical land type found in all the concession areas which can be related to the soil descriptions in Table 6.1.



**Table 6.1 General description of the dominant soils identified in the different concession areas. The problem soils labeled in bold mean that they are likely to be found in the specific landscapes.**

<i>Name</i>	<b>Crest</b>	<b>Midslope</b>	<b>Footslope</b>	<b>Valley bottom</b>
<b>Jock of the Bushveld</b>	Moderately deep to deep eutrophic red and yellow apedal coarse sand and occasionally loamy sand	Shallow to moderately deep eutrophic grey coarse sand occasionally overlying plinthic subsoil horizons <b>Collapsing sand</b>	Duplex soils with shallow grey and brown sand to loam abruptly overlying prismatic or gleycutanic clay. Calcareous in low lying areas. <b>Expansive clay</b> <b>Dispersive soils</b>	Complex association of deep brown sand to clay, (calcareous along large drainage lines) and shallow to deep brown sand to clay with rock outcrops (small drainage lines) <b>Expansive clay</b>
	Shallow and stony brownish coarse sand and loam. Rock outcrops frequently occur	Shallow grey eutrophic coarse sand over weathered rock or greyish-brown clay <b>Expansive clay</b>	Shallow to moderately deep eutrophic grey coarse sand occasionally overlying plinthic subsoil horizons. Shallow and stony brown coarse loam and rock outcrops also frequently occur. <b>Collapsing sand</b>	Complex association of deep brown sand to clay, ( frequently calcareous along large drainage lines) and shallow to deep brown sand to clay with rock outcrops (small drainage lines) <b>Expansive clay</b>
<b>Lwakahle</b>	Shallow and stony brownish and reddish medium and coarse sand and loam	Shallow grey or brown eutrophic medium to coarse sand to loam over either weathered rock or greyish-brown clay <b>Expansive clay</b>	Shallow melanic or orthic clay over weathered rock or pedocutanic calcarious clay <b>Expansive clay</b>	Complex association of deep brown sand to clay, ( frequently calcareous along large drainage lines) and shallow to deep brown sand to clay with rock outcrops (small drainage lines) <b>Expansive clay</b>

<i>Name</i>	<b>Crest</b>	<b>Midslope</b>	<b>Footslope</b>	<b>Valley bottom</b>
<b>Jakkalsbessie</b>	Shallow and stony brownish and reddish medium and coarse sand and loam	Shallow grey eutrophic coarse sand over weathered rock or greyish-brown clay <b>Expansive clay</b>	Duplex soils with shallow (10 - 20 cm ) brown and grey loam abruptly overlying prismatic clay which is frequently calcareous. Shallow to moderately deep red and brown eutrophic loam and pedocutanic clay also occur frequently <b>Expansive clay</b> <b>Dispersive soils</b>	Complex association of deep brown sand to clay, ( frequently calcareous along large drainage lines) and shallow to deep brown sand to clay with rock outcrops (small drainage lines) <b>Expansive clay</b>
<b>Mluwati</b>	Deep to moderately deep eutrophic red and yellow apedal coarse sand and loamy sand	Shallow to moderately deep eutrophic grey coarse sand occasionally overlying plinthic subsoil horizons	Duplex soils with shallow (20-40 cm ) brown and grey loam abruptly overlying prismatic clay which is frequently calcareous. <b>Expansive clay</b> <b>Dispersive soils</b>	Complex association of deep brown sand to clay, ( frequently calcareous along large drainage lines) and shallow to deep brown sand to clay with rock outcrops (small drainage lines) <b>Expansive clay</b>
	Shallow to moderately deep eutrophic red and yellow coarse sand and loamy sand	Shallow grey eutrophic coarse sand over weathered rock or greyish-brown clay <b>Expansive clay</b>	Duplex soils with shallow (10 - 20 cm ) brown and grey loam abruptly overlying prismatic clay which is frequently calcareous. Shallow to moderately deep red and brown eutrophic loam and pedocutanic clay also occur frequently <b>Expansive clay</b> <b>Dispersive soils</b>	Complex association of deep brown sand to clay, ( frequently calcareous along large drainage lines) and shallow to deep brown sand to clay with rock outcrops (small drainage lines) <b>Expansive clay</b>
<b>Mpanamana</b>	Lithosols and rock outcrops in association with very shallow greyish brown eutrophic apedal laom	Mainly rock outcrops and lithosols	Lithosols (mainly talus) and rock outcrops in association with very shallow to moderately deep brown eutrophic apedal loam and clay	Mainly rock outcrops and lithosols. Shallow to moderately deep brown structured clay occur occasionally <b>Expansive clay</b>

	Moderately deep to shallow red and brown structured and paraduplex clay <b>Expansive clay</b>	Shallow red and brown orthic and melanic loam and clay <b>Expansive clay</b>	Deep to moderately deep black and brown vertic and pedocutanic frequently calcareous clay <b>Expansive clay</b>	A complex association of black and brown calcareous alluvial clay and loam in various stages of profile development <b>Expansive clay</b>
<b>N'wanetsi</b>	Moderately deep to shallow black vertic and pedocutanic clay <b>Expansive clay</b>	Shallow black melanic clay <b>Expansive clay</b>	Deep to moderately deep black vertic frequently calcareous clay <b>Expansive clay</b>	A complex association of black and brown calcareous alluvial clay and loam in various stages <b>Expansive clay</b>
	Moderately deep to shallow red and brown structured and paraduplex clay <b>Expansive clay</b>	Shallow red and brown orthic and melanic loam and clay <b>Expansive clay</b>	Deep to moderately deep black and brown vertic and pedocutanic frequently calcareous clay <b>Expansive clay</b>	A complex association of black and brown calcareous alluvial clay and loam in various stages of profile development <b>Expansive clay</b>
	Lithosols and rock outcrops in association with very shallow greyish brown eutrophic apedal loam	Mainly rock outcrops and lithosols	Lithosols (mainly talus) and rock outcrops in association with very shallow to moderately deep brown eutrophic apedal loam and clay <b>Expansive clay</b>	Mainly rock outcrops and lithosols. Shallow to moderately deep brown structured clay occur occasionally <b>Expansive clay</b>

## 7. ROAD CATEGORY

### 7.1 Definition of road categories

Generally, the Kruger National Park may have a number of road categories to suit the different levels of service the system has to deliver based on the associated service objectives. Each of these road categories will necessitate certain geometrical and structural standards to ensure that the service objective(s) of the road can be met and maintained throughout its analysis period. The more important a road, the higher its level of service and thus its physical properties and standards, hence these roads have reduced risk of failure (ie higher design reliability) over the structural period. In this document four typical road categories, are considered, as defined in Table 7.1.

**Table 7.1**  
**Definition of the road categories in the KNP and Concession areas**

<b><i>ROAD CATEGORY</i></b>					
	<b>A</b>	<b>B</b>	<b>C</b>	<b>D</b>	<b>E</b>
Description	Surfaced link road between other areas in the Park or the access road to the game lodge	All weather gravel roads, access road to game lodge	Lightly trafficked all weather two track roads, ring roads	Lightly trafficked two track roads, link roads	Occasional trafficked way towards a specific spot or area
Importance	Very Important	Important	Less important	Less important	No importance
Service level	High level of service	High level of service	Moderate level of service	Moderate to low level of service	No level of service
<b><i>TYPICAL PAVEMENT CHARACTERISTICS</i></b>					
	<b><i>RISK</i></b>				
	<b><i>Very low</i></b>	<b>Low</b>	<b>Medium</b>	<b>High</b>	<b>N/A</b>
Approximate Design Reliability (%)	95	90	70	50	10

Total Equivalent Traffic Loading (E80/lane)	0,3-1,0 x 10 <sup>6</sup> over 20 years	0.1-0,3 x 10 <sup>6</sup> over 20 years	0,3-1,0 x 10 <sup>4</sup> Depending on design strategy	0,3-1,0 x 10 <sup>4</sup> Depending on design strategy	Not Applicable
Typical Pavement Class	ES1 – ES6	ES1 – ES5	ES1 – ES2	ES1 – ES2	ES1
Daily Traffic (vehicles/day/lane)	200 - 400	<200	< 50	< 20	<10

## 7.2 Characteristics of roads in the hierarchy

- **Off-road driving (Category E)** will take place on no constructed road or two-way track of whatever nature, with the only purpose to get a closer and better view of a game catch or to look for the presence of game in densely vegetated areas. Off-road driving could originate from any category A, B, C or D road and full details of every occurrence should be recorded in a suitable log book.
- **Earth two-tracks (Category D)** are the simplest “low volume roads” and generally consist of parallel ruts separated by vegetation, delineating (for example) an access route to a water hole or a link between a two-track ring road. These tracks are not engineered and are often impassable during or after wet weather conditions. In most cases they will carry less than about twenty vehicles per day.
- **Earth two-track roads (Category C)** are classified as those roads on which very little imported gravel is used, but the in situ material is cleared of vegetation and lightly compacted by low mass compaction equipment. Gravel should be applied at problem areas, such as muddy or sandy sections. Alternatively, a suitable stabilising agent can be applied to the in-situ material to enhance the bearing capacity thereof.

The roads should be shaped to some extent to prevent the accumulation of storm water by using material from both sides of the road. This is used to form a small embankment and raise the road slightly. These roads should be conventionally constructed by the Concessionaire and will be important ring roads covering the concession area and leading to the game lodge. Unlike the category D earth tracks, periodic maintenance should be applied to these roads.

- **Gravel roads (Category B)** have a designed layer of imported material which is typically constructed to a specified standard and width and provides an all-weather surface. The vertical and horizontal alignment is generally upgraded to appropriate standards. Maintenance of gravel roads is carried out on a more regular and systematic basis and a higher level of service is obtained, although the roughness varies considerably with time and depends significantly on the maintenance activity. These roads will act as access roads to a game lodge, with a fixed alignment and a possibility to be surfaced in future.
- **Surfaced roads (Category A)** will normally be the heaviest trafficked road in a concession area and the road alignment will normally be fixed with a high certainty of not changing. The probability exist that roads in this category were previously utilised as category B roads which needed to be upgraded.

This manual is primarily intended for use with gravel roads but many of the guidelines and recommendations are equally applicable to earth and earth track roads. Some roads may in fact be a combination of earth and gravel (category C roads), where gravel is only imported for certain sections, for which the in situ material is unsuitable.

### 7.3 Importance, service level, traffic and road standards

The designer should ascertain whether the traffic volume and other factors comply with those furnished in Table 1 and whether they are acceptable to the KNP under specific circumstances.

The level of service that a user (visitors to the KNP) expects from a road is related to the function of the road, to the general standard of the facility and partly to the volume of traffic carried. For example, visitors to a concession area and any other part of the park will expect a better riding quality on a access road than on a two-track dirt road. The design traffic is expressed in terms of the total number of equivalent standard axles (E80s) over the structural design period.

## 8. LAYOUT, PLANNING AND GEOMETRIC DESIGN

## 8.1 Layout design principles

The geometric design is not considered in any detail in this manual. Guidelines on geometric standards for unpaved roads (specifically in developing areas) are discussed in various documents. The road alignment should, however, be adapted to the prevailing conditions. A different philosophy should be applied to roads opening up areas (ring roads) and those which are likely to be forerunners of paved roads (gravel access roads). It is not usually economically feasible to construct deep cuts, high fills or large radius horizontal curves in mountainous areas in order to accommodate the recommended geometric standards. Economic constraints usually dictate that the geometric standards have to be compromised (with speed restrictions or warning signs where necessary). Where possible, construction along watersheds is recommended.

## 8.2 Roadway widths

A significant problem in Southern Africa is the occasional construction of unnecessarily wide unpaved roads (roads with travelled ways of up to 10m and up to 14m between shoulder breakpoints have been recorded). This results in unnecessarily excessive surfacing gravel and grader maintenance being required and a rapid loss of shape of the road. On the other hand, excessively narrow roads result in deep rutting, poor safety standards and high gravel losses. In the Kruger National Park the same phenomenon occurs in certain areas and the total gravelled widths of the various categories of roads envisaged to be constructed in the concession areas are as follows:

- Access roads (category B) to game lodges carrying more than 50 vehicles per day, 6m gravelled width but the width can be reduced for roads carrying less than 50 vehicles per day. However, in mountainous terrain and roads carrying large vehicles such as fuel and heavy delivery trucks the gravelled width should not be less than 6m.
- All weathered 2-track roads (Category C) should be constructed to a width of 3m.
- 2-track roads (Category D) should be constructed to a width of 2m.

The width and alignment of Category A and B roads should generally be appropriate to the prevailing traffic, climate, topography and the geometric standards for unpaved roads should be flexible enough to provide for this. Care should, however, be taken on category B roads to create a speed environment with matching geometry to eliminate the element of surprise and avoid unsafe conditions to which driver awareness is not sensitive.

### 8.3 Road gradients

- **Category A and B roads**

Design speed:	40km/h
Gradient:	5% maximum
Cross fall:	4%

- **Category C , D and E roads**

Design speed:	Not relevant
Gradient:	12% maximum, or as approved by a responsible KNP official on site.
Cross fall:	Should follow the existing land pattern

## 9. STRUCTURAL DESIGN

### 9.1 Category A and B roads

### 9.1.1 Design Philosophy

The structural design of paved roads has, in the last two or three decades developed into a highly sophisticated branch of engineering. The design of unpaved roads, on the other hand, has received minimal attention. In the KNP Category B unpaved roads may form an initial stage towards paved (Category A ) roads and designs should take this into consideration.

No scientific structural design procedure for unpaved roads is presently used regularly in Southern Africa. The Maintenance and Design System (MDS) (Visser, 1981) incorporates work carried out at the Waterways Experiment Station (Barber et al, 1978) where models to predict the rut depth from material properties, traffic and surfacing thickness were developed. Unfortunately no design thickness models were included, but the Visser (1981) transposed model produced a more realistic cover thickness than the models developed earlier, indicating that for subgrade CBR values greater than 5 (at Proctor compaction) with 150mm of surfacing material (Proctor CBR greater than 30) some 10 000 truck repetitions would be required to produce a rut of 75mm.

### 9.1.2 Pavement design

The failure criteria of 75mm deep ruts is considered excessive for typical rural roads in Southern Africa, especially in the wetter eastern areas where the ruts may trap water for lengthy periods. This increased rut depth is a short-coming affecting the applicability of most overseas work to local conditions. Although the rut would normally be removed by routine grader maintenance, a significant proportion of it would be in the form of subgrade deformation resulting in a loss of wearing course material. The actual gravel loss which occurs with time and under traffic results in a dynamic situation and the optimum wearing course thickness is, therefore, effectively valid for only a short period of time. Based on this consideration and extensive observations and measurements carried out locally, a structural design procedure for use under Southern African conditions has been developed. The design thickness (T in mm) recommended for imported gravel wearing courses is therefore :

$$T = t + (1 + C_i/100) \times (GL_p \times L_d) \quad (\text{Model 1})$$

Where  $t$  = minimum thickness required for subgrade protection (mm)  
 $C_t$  = traffic induced compaction (%)  
 $GL_p$  = predicted annual gravel loss (mm)  
 $L_d$  = design life of road or regravelling frequency (years)

The minimum thickness required for subgrade protection can generally be excluded from Model 1, certainly for subgrade materials with a field CBR in excess of 5%. The value of the in situ CBR can be easily determined using the Dynamic Cone Penetrometer (DCP) (Kleyn, 1984). A DCP penetration of more than about 32mm per blow indicates that the CBR is 5 per cent or less for most subgrade soils. Kruger National Park subgrades typically consist of sandy materials, unaffected by moisture because of the deep water tables. These sands, although relatively strong in themselves, require confinement to mobilise their strength and are thus not suitable for wearing courses. It has been observed that under these typical KNP material and environmental conditions and applied loads, no minimum thickness is required for subgrade protection, ie the subgrade is unlikely to be over stressed.

Recent developments in the field of geotextiles and Geogrids has led to their successful use in reinforcing unpaved roads over very weak subgrades (Giroud and Noiray, 1981; Giiroud et al, 1984; Hausmann, 1987). These are not discussed further in this document, but can be considered for the rare occurrence of very weak subgrades in special cases (CBR always less than about 3%). If they are used, the wearing course should not be allowed to become less than 100mm thick in order to provide some protection from wheel contact, grader maintenance, exposure to the atmosphere and ultra-violet light.

### 9.1.3 Design Traffic

Wearing courses which have been compacted with a nominal number of passes of a grid-roller can lose up to 30 percent of the constructed thickness within a short period due to traffic compaction (Paige-Green, 1989). It is, therefore, important to ensure adequate compaction or allow for the loss in pavement thickness caused by traffic compaction in the thickness design. This is especially relevant when the materials are relatively dry of optimum moisture content during grid-rolling, as the air voids are high and traffic compaction will occur rapidly.

If a density equivalent to that at about 95% Mod AASHTO effort is achieved, the air voids are about 5 per cent, but at a compaction moisture content 25 per cent dry of optimum (ie about 75 per cent of optimum moisture content), the density is reduced by about 10 per cent and the

air voids may be up to 20 per cent. This air void percentage will decrease rapidly under traffic and an estimate of this compaction needs to be obtained.

The following can be used as approximate estimates of the potential traffic compaction :

Compaction during construction	Moisture content during construction	Potential loss of gravel thickness
3 passes of a grid roller	5%	10%
3 passes of a grid roller	>5%	20%
3 passes of a pneumatic tyred roller	5%	5%

Local experience and field trials may be necessary to quantify these estimates more accurately.

The compaction which occurs during normal construction should not be neglected and up to about 30 per cent more bulk material is required to allow for this and still produce the required thickness.

The annual gravel loss (AGL expressed in mm) can be predicted with a high degree of confidence to within 11mm per year (Paige-Green, 1989a) by the following :

$$\text{AGL} = 3.65 [\text{ADT} (0.059 + 0.0027n - 0.0006 P26) - 0.367N -$$

$$0.0014 PF + 0.0474 P26]$$

where ADT = average daily traffic

N = Weinert N-value

P26 = Percentage passing the 26.5mm sieve\*

PF = product of plastic limit and percent passing 0.075mm sieve\*

\* grading analysis carried out according to the TMH 1

The product of the annual gravel loss and the design period will indicate the material which will be lost by erosion and traffic whip-off over the design life of the road.

It is important to regravell the road before the subgrade is exposed in order to avoid unnecessary maintenance problems. Potholes form rapidly if the subgrade is exposed.

#### **9.1.4 Practical considerations**

Numerous specifications are currently available for the selection of materials for unpaved road wearing courses in Southern Africa (Netterberg et al, 1988). These have been compared with the properties of a number of in-service roads in Southern Africa and found to be generally lacking in their ability to predict the performance of roads (Paige-Green, 1989b). Many satisfactory materials are rejected while many materials which perform poorly are deemed acceptable.

Performance-related specifications have been developed for Southern African conditions (Paige-Green, 1989a). These are based on the sampling, testing and monitoring of the performance of 110 sections of unpaved road in Southern Africa over a period of more than three years (Paige-Green, 1989a) as well as previous research on this topic. The importance of material durability in unpaved roads was found not to be important during the experiment. However, mudrocks in certain areas may be subject to rapid disintegration and should be investigated

by the 5-cycle wet-dry test (Venter, 1989). Other tests such as the Los Angeles Abrasion may be useful as indicators of excessively soft or hard material which may break down under traffic or will not break down under a grid-roller, respectively.

The following specifications for materials for unpaved roads in the KNP are recommended (table 9.1) :

**Table 9.1 : Recommended material specifications for unpaved roads**

Maximum size	37.5mm
Oversize index ( $I_o$ ) <sup>a</sup>	$\leq 5$ per cent
Shrinkage product ( $S_p$ ) <sup>b</sup>	100 – 365 (max of 240 preferable)
Grading coefficient ( $G_c$ ) <sup>c</sup>	16 – 34
CBR $\geq 15$ at $\geq 95$ per cent Mod AASHO compaction and OMCd	

- a  $I_o$  = Oversize index (per cent retained on 37.5mm sieve)
- b  $S_p$  = Linear shrinkage x per cent passing 0.425mm sieve)
- c  $G_c$  = Per cent passing 26.5mm – per cent passing 2.0mm) x per cent passing 4.75mm/100
- d = tested immediately after compaction

## 9.2 Category C and D roads

No scientific structural design procedure for category C and D roads is prescribed for the KNP and the concession areas.

***It is, however, recommended that an engineering geological map for each concession area should be compiled. These maps should contain data and information such as soil types, areas of problem soils (active clays, collapsing sand and dispersive soils), stability problems, availability of existing and potential construction material sources, etc.***

The layout of all category C and D roads should then take place within the framework of the relevant soil maps and the environmental factors as dealt with in chapter 6.

### **9.3 Category E roads (Off-road viewing)**

No structural design procedure for category E roads is prescribed. Refer to Section 12.9 for more detail about the off-road viewing concept. Off-road viewing should also take place within the framework of the relevant soil maps and the environmental factors as dealt with in chapter 6.

## **10. BORROW MATERIALS**

### **10.1 General**

This section covers the procedures stipulated in the EIA and EMP to be adhered to in obtaining borrow material for the construction and/or maintenance of any of the different categories of roads in the Kruger National Park. No new borrow pit will be allowed within or outside any concession area without the existing or redundant gravel pits being investigated as a first step.

All the relevant clauses stipulated in the Standard Specifications should be followed closely unless otherwise specified in the project specifications of the particular project.

### **10.2 Existing borrow pits within and outside the concession area**

The existence of a borrow pit in an area, whether it is situated within a concession area or not, does not necessarily imply that material from the pit is available and can be used for road building purposes. Borrow materials for the construction or maintenance of paved and gravel roads coming from existing sources shall closely follow the requirements as stipulated in the EMP and shall only be obtained with the written approval by a responsible KNP official.

### **10.3 Opening and working of borrow pits and haul roads**

#### **(a) Introduction**

A borrow pit and haul road which is in use is normally very unsightly especially when it is situated nearby a game lodge, camping site or game viewing road. It is furthermore annoying and can even cause dangerous situations for animals, if for instance not properly finished off. It is therefore important that every borrow pit commissioned for use, shall be properly planned, developed and eventually rehabilitated. This aspect is a pre-requisite in accordance of section 9 of the Mineral Law of 1992.

#### **(b) Planning**

The overburden removed from all the borrow areas should be reserved for the later rehabilitation of the borrow area. It is assumed that the materials underlying the overburden will be suitable for the construction of pavement layers, such as gravel sub bases and gravel wearing courses. Before exploitation of a borrow area takes place, it should be decided in advance which type of material is to be removed and for what purpose. It very often happens that material of subbase quality is used for the construction of fills with the result that material only suitable for fills has then to be modified at high cost to be used in the construction of, for instance, sub base or wearing course layers. Without the thorough, advance planning of a borrow area it can be that a potentially good source of material could change into a useless mix-up.

#### **(c) Development**

It is important that the development of all the borrow areas should take place according to a fixed pattern and that the removal of material will take place from one side of the borrow pit. By following this method of work, the rehabilitation of the borrow area can take place almost simultaneously which could generate high cost savings in the long term.

## **10.4 Finishing-off borrow areas and haul roads**

### **(a) Borrow areas**

On completion of his operations in a borrow area, the concession holder/contractor shall reinstate the entire area so as to blend it with the surrounding area and to permit the re-establishment of vegetation. For this purpose the borrow pit shall be shaped to even contours without any slopes being steeper than 1 in 3, except where the engineer so permits in specified cases. All material in and around the borrow area, whether spoil from road-building operations, excess stockpiled material, oversize material left in the borrow pit, material resulting from clearing and grubbing operations or excess overburden, shall be used or disposed of as directed by the engineer. Material incapable of supporting vegetation shall be buried and used for shaping the borrow area and shall subsequently be covered with soft material. All available soft material shall be spread evenly to the prescribed thickness, and where sufficient material is not available for so covering the entire area, the remaining portions shall be scarified along the contours so as to avoid undue erosion.

The shaping and finishing-off of the borrow pit shall be done in such a manner that the borrow pit will be properly drained wherever practicable, and, where required, the contractor shall place earth banks to divert surface water from the borrow area.

The finishing-off of any borrow pit shall be to the entire satisfaction of the engineer, and the concession holder/contractor shall furnish the engineer with a signed certificate from the Parks Authority stating that they are fully satisfied with the finishing-off of any borrow area. The contractor's attention is also drawn to the provisions of clause 1214 of the Standard Specifications in this respect.

### **(b) Haul roads**

All haul roads shall be obliterated and their surfaces scarified. Earth banks shall be constructed to prevent erosion.

Where materials from a borrow pit are hauled on existing paved or gravelled roads, such roads shall be restored to their original condition to the satisfaction of the engineer and the Parks Authority when borrow operations at the borrow pit are completed, unless otherwise specified.

## 10.5 Rehabilitation of borrow areas and haul roads

### 10.5.1 Introduction

***Concessionaires are responsible for the rehabilitation of all newly developed borrow pits and of existing borrow pits, should these be used.***

For the purpose of this manual, rehabilitation is defined as all those activities which could be used to improve a disturbed, degraded or neglected area. Rehabilitation is therefore not applicable to the establishment of a suitable ground cover only, but it is a much wider conception which is aimed to create a functional, self-supporting ecosystem. Rehabilitation includes, above all, soil preservation, the stockpiling and utilization of topsoil, the establishment of a suitable ground cover and a comprehensive maintenance programme.

Rehabilitation is divided into several phases and in order to implement it successfully the following aspects should at least be kept in mind:

- The aim of rehabilitation
- Site evaluation and preparation
- The selection of suitable plant species
- Maintenance and monitoring
- Detail of rehabilitation

If any of the above-mentioned aspects are done in a slipshod manner, there is a great possibility that the rehabilitation process could fail.

### **10.5.2 The purpose of rehabilitation**

The most important consideration during the compilation of a proposed rehabilitation programme is the re-use of the site or area in which the borrow pit is situated. In the Kruger National Park for example, after rehabilitation the area can be used as a water hole, developing of a camping site or as a normal grazing area. All the different ways of re-using the borrow areas will undoubtedly lead to different actions and intensities in the rehabilitation process. Will the Park Authority decide to create ecosystems around the borrow areas? Will the re-use be to create proposed sites for rest camp development or sites for viewing purposes, or will the aim only be to establish a suitable ground cover (for instance, to prevent erosion)? All these aims implicate different types of site preparation, the choice of plant species and other vegetation, etc. The final goal of rehabilitation will therefore have a influence on the planning, different steps and the execution of the process. It should, however, be clear that for example, different actions will be followed to cover the area with grass only, than to rehabilitate the area for developing a game lodge or rest camp.

It is seldom that the necessary attention is paid to the economic implications of rehabilitation. The rehabilitation of areas is normally neglected at the conclusion of a project, because at that stage the funds are also normally exhausted. During the initial planning for the development of a borrow area sufficient funds should be made available for the proper rehabilitation of the area after the removal of all suitable material. If this does not take place, it can result in the failure of the rehabilitation activity.

### **10.5.3 Evaluation and preparation of the site**

In order to rehabilitate any site in the best possible way, it is of great importance to ascertain the condition of the area. In the case of all future proposed borrow areas investigated, the environmental conditions will be known. For the purpose of this manual, it is expected that that all the borrow areas will be provided with a suitable grass cover with the aim to reinstate the areas into grazing areas for animals. However, the initial planning of the areas will determine the utilisation thereof.

The topsoil and other material unsuitable for construction purposes, should be stockpiled in all cases. Special attention and consideration should be paid to the positions of these stockpiles. The correct positions of all stockpiles adjacent to the excavations will decrease the costs necessary to backfill the excavations. It is senseless, for example, to stockpile topsoil at such a position so that trucks have to cart the material back.

As far as possible, topsoil should be placed in stockpiles well away from stockpiles of gravel and other material suitable for construction. This will prevent the contamination of the fertile topsoil by the relatively infertile subsoil. Topsoil should be placed in stockpiles not higher than 2,0m. If these stockpiles are built too high or too big, the possibility exist that, because of the natural processes of combustion, the status of the nutritious matter in the topsoil can be negatively influenced. In order to prevent the loss of valuable nutrients, the stockpiles should be flattened on top, which will also eliminate the accumulation of water. Before any topsoil is put back in the excavations it should be analysed to determine and supplement any shortage of nutrients if necessary.

Further aspects which should also be investigated are the climate (also micro climate), the patterns of plant successions in the vicinity, a survey of the vegetation growth and the topography of the area. The various types of vegetation occurring in the area will give an indication of the types of plants that can be established successfully. All these factors will provide an indication of the potential of the site regarding the suitable re-use and rehabilitation thereof.

The preparation for the rehabilitation of the areas can proceed after a complete evaluation of each site. It is important during this phase of the rehabilitation process to implement measures regarding the control of surface and seepage water.

All proposed borrow areas should already be prepared for rehabilitation throughout the development phases of the borrow pits. This will ensure that the entire rehabilitation process can take place at a relatively low cost.

#### **10.5.4 Suitable types of plants**

A variety of factors should be considered when selecting suitable plants for the rehabilitation process and only species which need low maintenance should receive preference. An ecological approach should be taken towards the establishment of plants with obvious preference to indigenous plants. Indigenous species should establish more easily and will need lesser maintenance because they have already adapted to the local conditions.

The growing pattern should also be born in mind and choices should be made between different types of ground covers, shrubs and trees. The size, shape and growing potential of the plant specie should also be taken into account, especially options between evergreen and deciduous plants.

Serious consideration should be given to the utilisation of legume plants. Legume plants have the ability to store nitrogen and to make it available for the use of other plant species. Nitrogen is the most important nutrient necessary for the normal growth of plants. The supplying of sufficient quantities of nitrogen during the rehabilitation period is normally problematic, and the effective utilisation of legume plants can eliminate this problem to a certain extent.

Problems are normally experienced in establishing legume plants with success, because they do not react positively towards nitrogen which is present in normal commercial fertiliser. It is therefore essential to establish legume plants separately from other plants in order to avoid the unnecessary competition between the various plant species. Legume plants are normally established about three weeks in advance of other plant species to give them some advantage in obtaining much needed nitrogen. It is still desirable to include legume plants with seed mixtures despite all the problems mentioned.

Several methods can be followed to successfully establish a proper vegetation cover but the normal conventional agricultural methods are still proving to be effective. Recently sowed areas should be covered with a suitable cover. A more favourable micro climate is created by the application of a cover layer which will enhance the germination and growing potential of the seedlings.

#### **10.5.5 Maintenance and monitoring**

The need for and the importance of a sufficient maintenance and monitoring programme cannot be over emphasised.

A self-supporting ecosystem cannot be created during one phase only and this process can take a couple of years. To avoid the deterioration and even the decay of the plants during this process it is essential to implement a maintenance and monitoring programme.

A suitable maintenance programme should contain at least the following aspects:

- The application of fertiliser as and when required.
- Irrigation, especially after the establishment of the vegetation cover and during droughts. The feasibility of this aspect will not be possible throughout the KNP.

- Pest and disease control, to prevent the plants being exposed to unnecessary stress which will be detrimental to their growth.
- The re-application of topsoil.
- Re-sowing, when bare areas are discovered or when plants are dying.
- Maintenance of the irrigation system where feasible.
- Monitoring.

The monitoring of the rehabilitation areas need not be time consuming or cumbersome. Periodic inspections of the areas will determine if any remedial actions are necessary.

Maintenance should proceed for at least three growing seasons. The ignoring of this important aspect could lead to the failing of the rehabilitation process.

#### **10.5.6 Rehabilitation detail**

With regards to the rehabilitation of all new and existing borrow areas the following is recommended:

##### **(a) Site preparation**

The preparation of the various rehabilitation sites should already commence at the beginning of the exploitation phases of the borrow pits. All excavations created during the exploitation process should be back-filled with spoil material from roads constructed, soil or any other suitable rock-bound material. It is however important that the importation of any type of filling material should be properly controlled. This is to ensure that the areas will not be subjected to any form of contamination or unsuitable ground conditions.

The back filling of all borrow pits should take place in a layer thickness of not more than 1,0m, after which each layer should be levelled properly and compacted by means of a heavy vibratory or impact roller. Each layer should be subjected to at least three roller passes or until the layer appears to be stable. The back filling of the borrow pit should proceed by using this method until the required level of back filling has been reached. Provision should however be made for the importation of approximately 300mm of topsoil if the area is not be developed into a game lodge or rest camp in the near future.

(b) **The handling of topsoil**

The topsoil to be used on the site should be analysed well in advance to determine the nutrient value of the material. The analyses will reveal certain shortcomings which should be replenished before the establishment of vegetation can take place. This activity will ensure the successful establishment of plant species.

(c) **Water control**

The control of all surface water should be done in such a way that the following important measures will be applied:

### **Erosion measures**

The finishing of the borrow areas should be done in such a way that no steep slopes are created. If this is not feasible, the borrow pit should be finished off in a terrace pattern and be covered with suitable vegetation.

### **Drainage**

The proper drainage of the borrow pit, including the flow of water over the entire area is important. The accumulation of water on the surface should be prevented at all costs. The drainage of the surface of the borrow area should be done in such a way that storm water will be lead away fast and efficiently without any erosion taking place.

### **The irrigation of cultivations**

In the Kruger National Park the installation of permanent or even temporary irrigation systems in borrow areas will not be feasible in practice and will also depend on the future use of the land. Whatever the case might be, any injudicious manner of irrigation should be prevented, as this will expedite the erosion process.

(d) **The choice of suitable plant species**

Before final decisions about the choice of plant species are taken the Integrated Environmental Management Department should be approached first for their advice. The following characteristics should, however, be borne in mind before making any final choices:

- Growing pattern (ground covers, grass, shrubs or trees).
- Irrigation and water system (If rest camp development is envisaged)
- Hardiness
- Germinative power of the seeds.
- Deciduous versus evergreen.
- Low maintenance costs.
- Suitability regarding erosion control.

The use of intruders or plants with an intruding potential should be prevented at all cost during the rehabilitation process.

There are various methods to re-establish plants and the Integrated Environmental Management Department should be approached for advice about this aspect.

(e) **Maintenance**

The maintenance of a borrow area on a regular basis is very important. This will prevent the deterioration and possible dying of plants. Basically a maintenance program should entail the following:

- Fertilisation.
- Irrigation.
- Weed control.
- The re-application of topsoil.
- The re-sowing of grass seed.

(f) **Monitoring**

The monitoring of the areas needed not to be a time consuming or a cumbersome process and visual inspections at regular periods will indicate if any affirmative actions will be necessary.

10.6 Procedure for obtaining approval to utilise existing borrow pits and to establish new borrow pits

Regarding the use of existing borrow pits or the establishment of new borrow pits whether in or outside the concession area, the following procedures should be strictly adhered to:

- An EIA should be undertaken for all new borrow areas and all existing borrow areas should adhere to the EMP for that area.
- The concessionaire shall put in writing his needs in respect of borrow material with accompanying drawings, maps or sketches and the following matters should be clearly addressed:
  - The location of the proposed or existing borrow pit.
  - The extent and anticipated use, with estimated material quantities of the borrow pit.
  - The location and extent of haul roads.
  - Compensation, if applicable for land or existing material or stockpiles taken.
  - The entire proposed area needed for a borrow area shall be surveyed.
  - Measures taken to protect borrow pits against the ingress of surface water and any threat caused to game.
  - The proposed procedure for the reinstatement or rehabilitation of the borrow area.

- On completion of his operations in an area, the concessionaire shall obtain from the KNP authorities a written statement to the effect:
  - that the concessionaire has fulfilled his obligations under any written agreement, or in the absence of a written agreement,
  - that the KNP authority is satisfied that all borrow areas, haul roads, temporary construction sites and construction roads, have been properly restored and are in a satisfactory condition.

## **11. STORMWATER MANAGEMENT**

### **11.1 Objective principles**

The main objectives of storm water management can be stated as follows:

- To provide guidelines for the safe drainage of stormwater within the Kruger National Park without disturbing the natural conditions, to assist the designer regarding the policies and standards of stormwater drainage structure implementation.

### **11.2 Discharge of stormwater**

The control of discharge should take place in as natural form as possible without disturbing the adjacent environment and without any negative effects thereon. The concentration of stormwater should be avoided as far as possible except in cases where the natural topography so necessitates. In such cases proper provision should be made for effective protection of the waterway and the waterway embankments.

### **11.3 Runoff on roads**

The presence of runoff on road surfaces constitutes the most common dangerous road surface conditions. In the design of roads, the depth of surface water flow will not be a design variable, because normal design standards ensure that this depth remains within acceptable levels. Depending

on the type of road and traffic volume factors furnished in Table 1 the designer should ascertain whether the measures taken to control surface water on roads are acceptable to the Kruger National Park.

#### **11.4 Geotechnical aspects of drainage areas**

The Geotechnical aspects of soils should be investigated prior to the commencement of the designs phase to ensure that the soils in which stormwater systems are to be constructed adhere to the proper requirements to avoid problems that may arise due to the nature of the soils. Competent and experienced engineers familiar in this field should perform this investigation. Table 11.1 and 11.2 list the different classes of soils and include brief notes on engineering problems associated with these soils.

**TABLE 11.1 : RESIDUAL SOILS AND POSSIBLE ENGINEERING PROBLEMS**

<b>Residual soil category</b>	<b>Common example</b>	<b>Soil texture</b>	<b>Problems to anticipate</b>
Residual acidic crystalline rock	Residual granite	Clayey sand	Collapsible grain structure: high erodibility
Residual basic igneous rock	Residual diabase	Clay	Heave; compressibility
Residual calcareous rock	Residual dolomite	Chert rubble	Sinkhole development; doline development
Residual argillaceous rock	Residual mudrock	Silt or silty clay	Heave; slope instability
Residual arenaceous rock	Residual sandstone	Sand	Problems not common but collapsible grain structure may develop from highly felspathic sandstone

**TABLE 11.2: TRANSPORTED SOILS AND POSSIBLE ENGINEERING PROBLEMS**

<b>Origin of transported soil</b>	<b>Agency of transportation</b>	<b>Source</b>	<b>Soil type</b>	<b>Problems to anticipate</b>
Talus (coarse colluvium)	Gravity	Any rock out-cropping directly above talus deposit	Unsorted angular gravel and boulders	Slope instability
Hillwash (fine colluvium)	Sheetwash	Acid crystalline rock	Clayey sand	Collapsible grain structure
		Basic crystalline Arenaceous	Clay Sand	Heave Collapsible grain

		sedimentary Argillaceous sedi- mentary	Clay or silt	structure Heave or high compressibility; dispersive soils
Gulleywash	Gulleywash	Local catchment	Gravels, sand, silts or clays	All possible problems
Lacustrine deposit	Stream depositing in pan, lake or subterranean pool in cavernous rock	Usually mixed source	Sand (Silt Clay)	Compressibility Heave or high compressibility
Estuarine deposit	Rivers and tides	Mixed	Sand (Silt Clay)	Quicksand High sensitivity; compressibility
Aeolian deposit	Wind	Usually mixed source	Sand	Collapsible grain structure; compressibility
Littoral deposit	Waves	Mixed	Beach sand	Collapsible rain structure

Origin of transported soil	Agency of transportation	Source	Soil type	Problems to anticipate
Biotic soils	Termites	The underlying soil	Often a clayey or silty sand	Collapsible grain structure
Alluvium	Streams	All materials within the catchment	Gravel, sand, silts or clays	Clays commonly heaving
Slide debris	Mass wasting	Upslope rock and soil	Mixture of poorly sorted debris	Slope instability; high permeability

## 11.5 Active soils

Active soils are those soils that undergo change in their volume with changes in their moisture content. These soils typically swell when wet and shrink when drying. Changes in the moisture content of these soils can be brought about by changes in the level of the underground water table as well as abrupt changes in climatic conditions.

Stormwater systems constructed in active soils should be designed to alter the local moisture regime nominally. Structures like canals should have flexible watertight joints at appropriate intervals to accommodate movement due to these active soils. When installing pipe systems care should be taken in the selection of appropriate bedding material to alleviate pipe movement as far as possible. They should also be fitted with flexible watertight joints.

## 11.6 Potentially unstable slopes

In some areas sloping terrain can become potentially unstable should the water regime in the soil be altered. This may be ascribed to the underlying geological formations, the configuration of faults, bedding planes or joints. Under natural conditions these slopes may exhibit few problems, but a small alteration to the water regime could precipitate a landslide.

In the design and construction of stormwater systems in sloping terrain, care should be taken not to excessively soften the material causing pore water pressure to build up in the lower slopes which will result in slope failure.

## **11.7 Dispersive soils**

With dispersive soils are meant soils that can be classified by their physio – chemical properties of allowing water to permeate through them causing extensive erosion and leading to the formation of flow routes or ‘pipes’. The end result is the ultimate failure of the embankments.

No positive field test exists for their identification resulting in these soils not being readily recognised.

When constructing embankments in such materials, specialist in the field of Geotechnical engineering should be consulted on the suitability and treatment of dispersive soils. In some cases adequate compaction and lime stabilisation may be required to treat the soils.

## **11.8 STORMWATER MATERIALS AND CONSTRUCTION DETAILS**

Stormwater materials and construction details should be selected from:

SABS 1200LE stormwater

SABS 1200DB pipe trenches and

Other manuals pertaining to the installation of prefabricated products.

The capacities and dimensions of drainage structures must be calculated from an approved method commonly used.

### **11.8.1 Drains**

Drains refer to excavated channels or natural gullies, which are protected against scour by either concrete linings or stone pitching. These structures should be flat in profile and preferably as natural as possible. Refer to figure 11 at the end of this chapter.

### 11.8.1.1 Permissible slopes

The permissible slopes of such drains may not be less than 0.5% and those that are concrete lined not less than 0.25% (1) unless regular sedimentation occurs.

Acceptable maximum side slopes for drains are as follows:

<b><i>SOIL TYPE</i></b>	<b>SLOPE (1 vert : x hor)</b>
Rock	Almost vertical
Stiff clay, soil with concrete lining	1:1 to 1:2
Soil with stone pitching	1:1
Firm clay	1:1.5
Loose sandy soil	1:2.5
Sandy clay, porous clay	1:3
*Grassed channels	1:3-4

11.8.1.2 For maintenance purposes the channels should not be steeper than 1:3.

11.8.1.3 Flow velocities

**At low velocities sediment may deposit and at high velocities erosion may occur. This may have severe effects in areas especially where dispersive soils are present.**

High velocities should be avoided as far as possible even in lined channels because at high velocities pulsating pressure changes occur that may cause pieces of the drain to break away especially at weak joints.

Using protective stone layers is an economical procedure to prevent erosion through the process of decreasing the velocity. A great advantage of stone layers is their ability to deform and still remain effective.

### **11.8.1.3 Linings**

A drain may be directly or indirectly protected against erosion. With directly protected channels, the bottom and sides of the channel are lined with a material less erodible than the natural material. In the case of indirectly protected channels the channel is protected by introducing larger isolated obstructions in order to decrease the flow velocity and decrease erosion. Other types of linings include:

- i) concrete
- ii) stone pitching
- iii) gabions
- iv) hyson cells

Various design manuals exist for the construction and design of stone lined, stone pitched and rip-rap channels and should be referred to for more information.

### **11.8.2 Speed humps**

Speed humps should be placed in such a way and location not to interfere with the natural flow of water. In situations of road fills care should be taken as to the direction of water flow being from upstream to downstream to prevent the damming of water on the upstream side.

### **11.8.3 Culverts**

The term culvert denotes a relatively short structure constructed for the purpose of conveying water underneath a road or embankment. Culverts should be placed at the lowest location in a road crossing. Wide, flat culvert profiles are recommended for use but other design criteria should still be the primary deciding factors. The inlets and outlets to the culverts should be protected to prevent erosion, scouring and collapses. In areas where piping in soils occur, all culvert joints should be watertight. The possibility of soil mechanical failure must be taken into account, especially in the case of non-cohesive materials.

Numerous design manuals exist for the design and construction of culverts and should be referred to for more information.

The basic elements considered shall distinguish clearly between the different category of roads.

The basic need to calculate run-off for each category of road in relation with recurrence interval must be performed by the engineer to determine optimum economic stormwater handling.

The selection of recurrence interval for the different category of roads shall be done with management. Roads shall be prioritised in terms of elements such as :

- Geotechnical characteristics of the soil (avoiding problems occurring from the nature of the soil).
- Minimisation of risks to human life in flood area (upstream side).
- Increase rate of water level and possible period of warning.
- Road under consideration :
  - Category (Category A – recurrence interval for culverts 1:20).
  - Is this the only access road to a certain area?
  - Is there other escape routes?

- Time span (period) of inaccessibility.
- Topography of flood zone or stream (influences velocity and flow depth).
- Cost benefit relationship (relation between cost of flood damage and repair work).

Each road should be treated individually for each category with the above factors taken into account. The table below provides guidance of recurrence interval from which a first estimate can be selected :

<b><i>Table : Design flood frequencies</i></b>	
Major bridges	50 – 100 years
Large culverts (in major storms) > 6m in length	50 years
Roads Category A	15 years
Roads Category B	5 – 20 years *
Roads Category C	2 – 5 years *
Roads Category D	0 – 2 years *

\* Refer to section 11.8.4 of this report regarding low level crossings.

Where steep gradients occur the flow speed must be determined for the recurrence interval for the specific culvert size and the flow velocity should be less than 3.5m/s. Velocity in excess of 3.5m/s indicate the need of erosion control on the outlet and down stream side to prevent loss of topsoil and erosion.

In the case of flat (shallow) gradients the minimum desirable slope in the culvert should not be less than 0.5% to ensure that maintenance and silting-up within the system can be kept to a minimum.

Each culvert should be treated individually and factors regarding slope of immediate adjacent areas and / or streams also play part in the deciding factor.

In the event of damage on existing structures problem solving should be done based on engineering principles. All information regarding natural elements must be considered, eg :

- Rainfall (determination of run-off and flood recurrence)
- Slopes
- Soil characteristics

Determine optimum solutions from the above based on the cost-benefit relationship between the cost of flood damage (inaccessibility, distresses, etc) versus cost and time of repair work.

#### **11.8.4 Low water structures**

In cases of category B, C and possible D type roads, low water structures can be constructed at crossings with a natural waterway. Wide, flat culvert systems or pipe culverts normally not bigger than 600 mm Ø may be installed to convey the water. Erosion protection measures must be introduced at both the inlets and outlet sides of such structures and especially to the embankments. These structures can be overtopped in certain conditions and should be designed to withstand minor to mild floodings. In waterways with occasional flow conditions, wide concrete lined or stone pitched channels can be used as a low water crossing. These channels should be able to withstand the loads of occasional traffic and not break away under such loads.

Once again the selection of specific remedies or low level river/stream crossings must be determined in conjunction with management and taking certain factors as stipulated in section 11.8.3 in this report into account.

Design flood frequencies given in the table in section 11.8.3 are regarded as guidelines. Prioritisation should take place individually for each crossing with the factors as discussed.

Design decision should be base on simple principles, such as :

- Permanent flow of water (perennial)
- Flow after each and every rainstorm
- Flow – rare / occasional within rain season

Low level structures / crossing in the simplest case can consist of rocks which are hand packed and well placed within the crossing where flow is very rare and where there is not nominal flow of water. This measurement can be seen as remedial action in erosion prevention at these specific areas where vehicle movement occurs.

In the event where there is at least nominal flow the principal of constructing more permanent crossings shall be investigated, once again the feasibility of such a more permanent structure versus the cost-beneficiary aspect should be taken into account.

Culverts must be utilise to accommodate at least the nominal flow, up to a certain run-off for a specific recurrence interval.

Flood lines and levels must be determine for increased run-off due to recurrence intervals greater than the interval used in the determination of nominal flow. The flood plain must then be protected against erosion in the even of over-topping (hand packed rocks / concrete drifts). Furthermore the design must take into account for greater recurrence intervals allowing for natural ways of protecting embankments, approaches and even accommodating over-topping by means of other spill-ways on approaches.

The table below provides guidance of recurrence interval from which a first estimate can be selected :

**Table : Guidance for low level crossings and protection**

<i>Road category</i>	Recurrence intervals	Culvert design (nominal flow)	Erosion (see note 1) protection (permanent/semi)
B	5-10/15 years	5 years	At least 10 years

C	2-5/10 years	2 years	At least 5 years
C (see note 2)	2-5 years	-	At least 2 years

**Note :**

1. In case of over-topping flood plain erosion protection must be done (permanent/semi).
2. For a road Category C where nominal flow occurs rarely / occasionally.

Erosion protection can be done in the provision of permanent or semi-permanent means of protection, depending on the road category and other factors as inaccessibility.

The packing and placing of rocks without grout is typical “semi-permanent” measures of erosion protection, but by the addition of cement grouting or concrete slab placing this can be seen as “permanent” erosion protection.

**11.8.5 Protection against erosion**

Various protective measures exist for the protection of stormwater infrastructure.

The primary objective of erosion protection is to release water into the natural channel at velocities no greater than the original velocity and in the same direction.

For energy dissipation and erosion protection at the inlets and outlets of drains, culverts and mitre drains the following protective measures could be considered:

- i) grass cover
- ii) different levels of stone pitching
- iii) a stilling basin with baffles (in the case of culverts)
- iv) concrete

- v) gabions
- vi) rip-rap

Where grass covers are used the outlet should be above ground level, to prevent deposits of sediment from blocking the outlets.

For the protection of slopes and embankments the methods and materials used should comply with those used in the TRH9 manual.

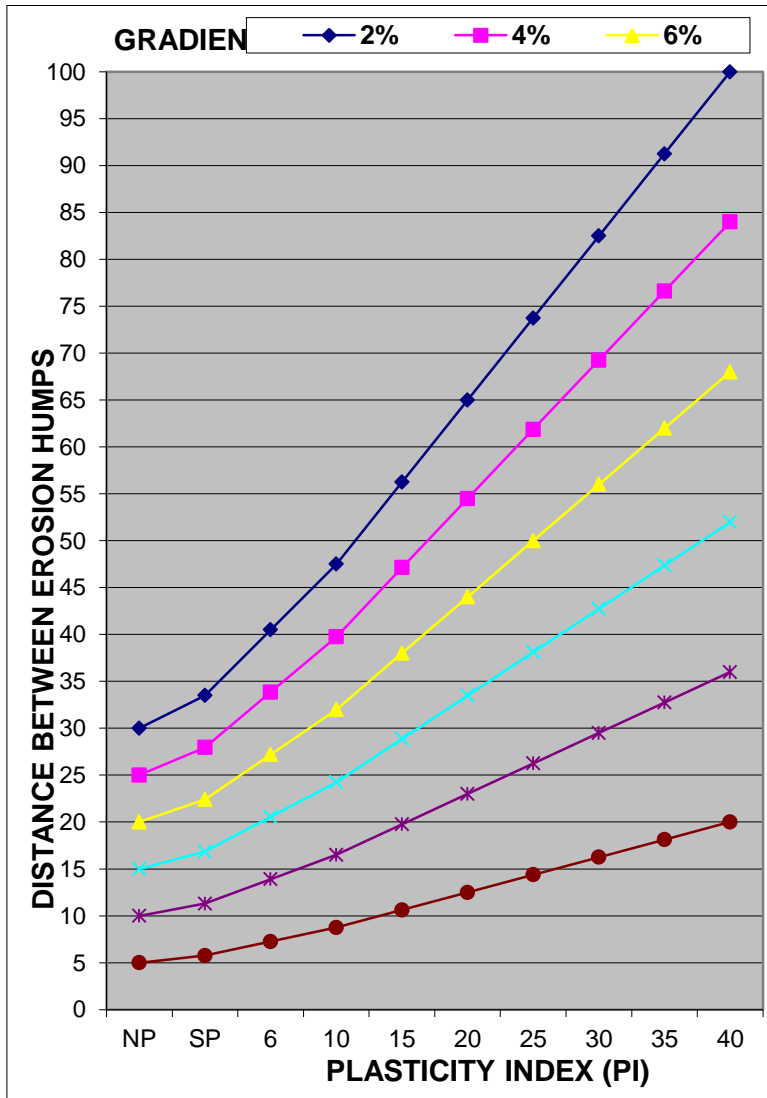
If another type of protection is preferred, it must be checked to see whether it may be used under the prevailing conditions.

#### **11.8.6 Erosion humps**

When constructing category C and D roads, mitre drains and V-shaped side drains should not be used to accommodate storm water. Erosion humps should be placed at regular intervals and appropriate locations on these roads. These structures should follow the same profile as a speed hump, but for the only purpose to prevent erosion and to slow down the flow of storm water.

The hump should be constructed to a height of approximately 300mm by using in situ material, stabilised with cement and compacted to approximately 95% of the MOD AASHTO density of the material. The distance between the erosion humps varies for different types of material and the gradient of the road. The intervals for constructing humps in clayey areas will be larger than in areas overlain with collapsible sand. A guideline at which intervals these humps should be constructed can be found in Figure 11.

**FIGURE 11 : Intervals of erosion humps**



## **12. ROAD CONSTRUCTION**

### **CATEGORY A (PAVED) AND B (UNPAVED) ROADS**

#### **12.1 General aspects**

In the Kruger National Park and proposed concession areas, category B roads, however lightly trafficked at the time of construction, will with the passage of time capture more traffic and increase in use (and importance) as the influx of tourists increases. They may eventually be upgraded to higher standard unpaved roads or even relatively lightly trafficked surfaced (category A) roads.

This manual is based on the fact that in situ material should be utilised where possible without the execution of unnecessary mass earthworks or the construction of high fills and deep cuttings. Good preparation of the subgrade for a new unpaved road is, therefore, extremely important as this will often be the subgrade for a large part of the future improved road (access roads to game lodges, etc.).

#### **12.2 Clearing and grubbing and construction of formation**

Initially the roadbed should be cleared of bush and trees over the full width. Adequate roadbed compaction reduces the possibility of subgrade deformation and reduces the permeability and strengthens the subgrade. The subgrade should then be formed, smoothed and shaped with a suitable crossfall about 2 per cent).

Material of at least subgrade quality ( $\text{CBR} \geq 3\%$ ) should be used to build up the formation to a height of not less than 300mm above the natural ground level in flat terrain. This material can usually be obtained during the construction of side drains parallel and on each side of the road and mitre drains to remove water from the side drains. However, if the material emanating from the side and mitre drains appears to be unsuitable or insufficient in quantity, material should be imported from the nearest approved borrow pit.

The drains should be deep and wide enough to remove all the expected surface water during wet periods from the road and its adjacent areas without ponding or excessive erosion. In flat areas, the formation should be high enough to allow the placement of drainage structures (usually pipes or flat box culverts) at adequate depths beneath the wearing course. It is important that the construction of the formation does not interfere with the

natural drainage of the surrounding area and cause ponding. The material used for the formation should be slightly plastic with a plasticity index of about 4 in order to provide a stable platform for construction of the wearing course.

Other material from a borrow pit may be required to build up the formation. Once adequate material has been dumped on the subgrade, the formation should be compacted at about OMC to a density of 90% Mod AASHO and smoothed and shaped as for the subgrade. It is important that the formation level is smooth and has an adequate crossfall to ensure that any water that soaks through the wearing course does not pond at formation level, should a permeability differential exist.

The wearing course is placed directly on the formation in most unpaved roads, although “subbases” may be used if the subgrade is poor or large numbers of heavy vehicles are likely to use the road.

### **12.3 Gravel operations**

The location, winning and transportation of wearing course gravels is one of the most expensive operations associated with the development of unpaved roads. It is, therefore, important that the optimum material be located nearby and used to maximum advantage.

It is important to demarcate the extent of the suitable materials in the borrow pit clearly and ensure that material is only obtained from this area. Similarly, the depth of excavation should be carefully controlled so as not to excavate into less weathered or different material (often with significantly different properties) at greater depths.

Stockpiles should be kept as low as possible to reduce segregation of the material (Ferry, 1986). The gravel operations should be carried out in a manner which ensures a consistent gravel of the required quality.

Optimally, the material should be processed to remove or reduce oversize in the borrow pit as far as possible. One such device for doing this is a “Grizzly”. This is a cheap, portable method of sieving out oversize material using a slow down material production in the borrow pit, it is capable of a high production rate (Ferry, 1986) and should be used wherever possible. The material should be excavated and processed in the borrow pit before removal of the gravel to the construction site commences.

The use of a grid roller to break down oversize material on the road is not always successful. Adequate supervision and the correct use of the roller is essential for satisfactory results. Certain materials such as decomposed dolerite and andesite may disintegrate adequately, but often corestones of hard unweathered material and pedocrete boulders survive the grid rolling and result in excessive roughness of the completed road.

If a significant portion of the material is oversize, a portable crusher should be used to reduce this to the maximum size specified. It may be economic in some cases to windrow the oversize materials in or next to the borrow pit, and reduce them with a mobile hammer-mill (eg rockbuster). Although mobile hammermills can be used on the material dumped on the road, it is recommended that they be used at the borrow pit in order to reduce the transportation of oversize material, which is not broken down by the hammermill. For roads carrying over 50 vehicles per day it is cost-effective (in terms of the vehicle operating and maintenance costs) to crush oversize material to pass a 37.5mm sieve. The most economic means of removing oversize in a borrow pit with only a limited quantity of large stones is manually, by hand picking.

If blending is necessary to achieve the required shrinkage product or alter the particle-size distribution of the gravel, this can be done in the borrow pit if the sources of gravel are in close proximity, but is usually most effective on the road. Careful supervision of the dumping and mixing of the materials is necessary to ensure that the correct proportions are combined and mixing is complete.

Where possible the material should be moistened in the borrow pit before being hauled to the road. This reduces segregation during hauling and assists with the compaction of the material. Construction in the wet season permits the use of rainfall to provide this moisture.

Some materials such as mudrocks and highly weathered basic igneous rocks which slake on exposure to the atmosphere often require stockpiling for a period varying from a few days to a few weeks to achieve the required breakdown. These should be allowed to break down in the borrow pit and must not be left on the side of the road being regravelled while they disintegrate (for obvious safety reasons). Materials which slake to a fine powdery material are undesirable for wearing courses and should be avoided.

The direction of transportation of the gravel should be such that the newly constructed road is not trafficked by the construction traffic. If the road is compacted as previously recommended, trafficking by construction vehicles results in more damage to the road (ravelling and potholing) than the benefits gained from further compaction. If the compaction is minimal (not recommended) the passage of the construction traffic may be beneficial.

One of the main problems with the construction of unpaved roads is the lack of supervision. Greatly improved unpaved roads would result from close supervision by experienced personnel during the borrow-pit working and actual construction.

The techniques described in this section apply equally to the regravelling operation.

## **12.4 Wearing course construction**

Good construction practices for wearing courses will :

- Provide the correct thickness of material.
- Provide adequate compaction.
- Provide a smooth finish with a good cross-sectional shape.
- Provide a subbase for future upgrading to surfaced road standard.

### **12.4.1 Thickness**

It is important that the material be dumped on the road at the correct spacing to provide for the expected thickness of gravel after spreading and compaction. If the constructed thickness is incorrect, the management of the maintenance of the road network will be disrupted as premature regravelling may be necessary or the road may need a thinner layer of gravel when being regravelled. Both of these variations affect the budgeting requirements. The thickness must be as consistent as possible over the length of the link to avoid total loss of gravel over portions of the link only.

### **12.4.2 Compaction**

Good compaction produces a tightly bound gravel with optimum particle interlock, minimum permeability and porosity and significantly increased strength.

The importance of adequate moist compaction has been clearly shown by Poolman (1988) who found that a high degree of moist compaction resulted in a road with a lower roughness than similar materials which were poorly compacted in a dry condition. The roughness deterioration was much slower and gravel loss and dust emission were significantly reduced.

A poor degree of compaction results in a low density, permeable material which ravels easily and is highly moisture sensitive. Deep rutting, compaction under traffic, potholing, corrugations and passability problems under soaked conditions are common problems with poorly compacted material. The initial traffic-induced compaction and increased gravel loss again interfere with the maintenance management strategy for the road.

In order to take advantage of the moisture added to the material before hauling, the material should be dumped, spread and compacted before a significant quantity of the water has evaporated. This requires careful project planning and management. Construction during the wet season results in additional moisture being available (from rain) and often lower evaporation.

Numerous commercial proprietary compaction aids are available in Southern Africa. Many of these are suitable only for certain material types, while others have little benefit or are not cost-effective. Potential use of these should be preceded by laboratory investigations concerning their suitability or trial sections where possible.

### **12.4.3 Finish and shape**

The roughness of a road is one of the most important factors influencing vehicle operating cost, affecting every contributor except depreciation (Harral et al, 1975). It is important, therefore, to make use of competent grader operators who can provide a smooth, well-finished riding surface. A good surface after construction can be maintained to a much better standard than a poorly finished surface.

The cross-section and shape of the road should ensure a definite crown with a cross-fall of about 4 per cent (not more than 5 per cent). Large stones (greater than 50 or 75mm), which have found their way into the gravel, should be removed (manually if necessary) and discarded at a distance from the road into a stockpile to ensure that they are not bladed onto the road during routine blading or drain clearing. These small stockpiles of oversized material should be removed to the borrow pit on a frequent basis.

### **12.4.4 Stabilisers to reduce gravel lost**

Gravel wearing courses of Category B roads should be treated to either improve its properties, to reduce dust pollution, to reduce maintenance activities and to reduce gravel lost because of frequent blading. Environmental considerations, such as dust near game lodges or sensitive vegetation necessitate special treatment. Ionic soil stabilisers, calcium chloride stabilisers or bitumen emulsion treatment alternatives must be considered. Refer to section **12.10** for more information about soil stabilisers.

A common problem is the use of oversize material which is repeatedly rolled (usually with a grid roller) until it is embedded well into the layer and often, even the subgrade. In a short time these stones and boulders protrude from the surface, causing a rapid deterioration in the roughness and significant maintenance problems. Construction crews should, where possible, be trained to refrain from this practice.

## 12.5 Drainage

Category B, C and D roads are totally exposed to the elements and rainfall can result in significant maintenance problems. The importance of well planned drainage cannot be over-emphasised.

The water in all the various categories of roads can only come from two sources :

- Surface water from precipitation (including flooding);
- Subsurface water from high water tables, seepage, springs and capillary suction.

### 12.5.1 Surface water

Surface water is predominantly in the form of rain (not necessarily in the specific area in the case of flooding) but may arise from snow and hail to a lesser extent. Infiltration of this water into the wearing courses can be limited by ensuring a compact, tightly-bound wearing course with an adequate cross-fall which removes the water rapidly from the road surface into the side drains without causing scouring. Side drains should only be used where natural dispersion of surface water is disrupted, as concentration of water is the root cause of erosion.

The side drains should run parallel to the road, collecting the surface water from the pavement and shoulders and removing it through mitre drains (or turnouts) as far from the road as practically possible, where it can soak into the ground or flow into a natural drainage course without influencing the road structure. The distance between mitre drains (which need not necessarily always be associated with side drains) depends on their grade with greater spacing on flat grades and smaller spacing between them on steeper grades. The principle is to place the mitre drains at intervals which avoid ponding adjacent to the road but not far apart enough to allow the build-up of high concentrations and flow velocities which lead to scouring. Flow velocities can also be decreased by using mitre drains constructed with a grader. The width of mitre banks should generally be 1 to 1.5 metres.

The importance of the road surface being raised above the surrounding area is obvious. When the surrounding area is higher than the road surface, the road becomes the drain during periods of heavy rainfall and rapidly becomes deformed or even impassable if the water soaks in.

The drains should be deep and wide enough to contain the expected water volumes and avoid flooding of the carriageway. Their dimensions should be such that the velocity of flow is not excessive (which results in scouring and erosion) and the intended maintenance is practical (ie wide enough for graders if grader clearing is anticipated). Flat-bottomed drains are less susceptible to erosion than V-shaped ones and where graders are to be used for maintenance it should be ensured that they are wide enough to accommodate the graders. On steeper grades some form of erosion protection of the drains is usually necessary.

If the natural topography is such that water will disperse by itself and drains can be avoided, significant cost-savings can be effected and potential problems avoided. It is important that the road structures do not interfere with the cross drainage of the area. Adequate means of cross drainage such as culverts are necessary with careful attention being paid to their size and inlet and outlet control.

### **12.5.2 Subsurface water**

Subsurface water is derived mainly from high ground-water levels (temporary or permanent) and seepage, but occasionally springs beneath the road may be encountered, especially in cuttings. Capillary rise of water from relatively high ground-water levels may occur in clayey soils. Subsurface drainage problems are usually manifested as damp areas on the road surface which eventually results in potholes. The remedial actions may require subsurface drains if the water is due to high water tables or capillary suction, or cut-off side drains when the water seeps from areas adjacent to the road. These are, however, not recommended as they are expensive and often require careful maintenance. The use of rock-fill embankments is a possible alternative, but Geotechnical assistance should be obtained to identify the source of the water and propose remedial measures in these cases.

## **CONSTRUCTION OF CATEGORY C AND CATEGORY D TWO-TRACK ROADS**

### **12.6 General**

The majority of roads to be constructed in the concession areas will be two-track roads (category C and D roads) and the general layout of these roads should closely follow the following guidelines:

- All the areas in a concession area where problem soils prevail should be carefully mapped and avoided, where possible during the layout of two-track roads especially category D roads.
- No tree of a trunk diameter exceeding 200mm should be removed without the written permission of the KNP and densely wooded areas should be avoided where possible.
- The construction of these roads in river beds or watercourses is permitted, provided that access through rivers, water course banks or drainage channels of whatever nature shall be done according to the requirements stipulated in **section 6.7**.
- The construction of two-track roads will mainly take place on in situ material that should be chemically or mechanically modified, if necessary, in order to adhere to the prevailing circumstances and soil conditions.
- The philosophy behind the creation of two-track roads should be to allow vegetation to re-establish on the road soon after construction has been completed, which will prevent erosion and reduce the cost of maintenance in the long term. The application of stabilising agents or gravel to improve the nature of the in situ material can be done with success, but is normally an expensive exercise, with the disadvantage that vegetation may not established itself successfully on stabilised and gravelled roads.

## 12.7 Category C two-track roads

The construction of two separate all weather tracks cannot be done cost effectively and it is suggested that conventional construction methods be implemented to create these 3m wide roads. The ideal situation would be not to construct two-track roads on any problem soil such as duplex and other soils with dispersive characteristics. However, this would not always be possible and different soil and material types need different construction methods. The following methods described should be followed as a guideline :

- The route should be cleared by blading of all grass and vegetation.

- The exposed roadbed should be ripped with a motor grader to a depth of 150mm. (CAT 140G or equivalent)
- The subgrade should then be formed, smoothed and shaped with a suitable crossfall (about 3 per cent).
- Additional material can be obtained by importing material from the nearest borrow pit.

***At this stage the quality of the in situ material should be confirmed. If the material encountered is a G6 quality or better construction method A should be followed and if the quality of the material is G7 - G10 method B should be followed. An explanation of these materials is given in Table 12.1***

#### **Method A**

- The material should be moistened to the OMC of the material and compacted to at least 95% MOD AASHTO density.
- Vegetation should be allowed to establish on the route.
- Any depressions caused in the tracks in the long term, especially at bends or junctions, should be levelled by means of suitable gravel or coarse sand. The material should have a PI of approximately 14 and compaction should take place to at least 95% MOD AASHTO density of the material. Alternatively these areas should be stabilised with a suitable stabilising agent.

#### **Method B**

- The material should be stabilised with any suitable stabilising agent and compacted to at least 95% MOD AASHTO density.

***If any problem spoils are encountered (expansive clays, collapsing sands) the procedure to deal with these soils as described in chapter 6 should be followed closely.***

## **12.8 Category D two-track roads**

In the creation of these roads no conventional construction equipment should be used and all areas where problem soils exist should be avoided. The following method could be implemented as a guideline:

- No clearing and grubbing of grass and other vegetation should be done on the route. The grass and vegetation should preferably be cut by hand or else with a heavy duty slasher drawn by a suitable tractor.
- Any depressions, soft or loose patches discovered during the clearing and grubbing operation should be levelled by adding gravel or coarse sand with a PI of approximately 14. These areas should then be compacted by hand tampers or a small hand operated drum type vibratory roller.
- Further compaction of the route should take place by game viewing vehicles and vegetation should be allowed to cover the route to prevent erosion.
- Any loose sections created in the long term, especially at bends or junctions, should be levelled by means of a tyre or under carriage blade.

#### 12.9 Category E roads (off-road viewing)

The concept of off-road viewing in the KNP is new and of great concern to certain nature conservationists. However, if properly controlled and managed this concept can play an important role as a major tourist attraction in a concession area.

The following guidelines should be followed closely in order to allow off-road game viewing:

- No off-road driving on any area where problem soils (as defined in this document) exist shall be permitted. In order to ensure that this requirement is followed strictly the compilation of a soil map as mentioned elsewhere in this document is of great importance. All game viewing vehicle operators should be able to identify the three basic types of problem soils described in this document and they should, furthermore, be made familiar with the areas these soils can be expected in.
- No large trees or sensitive vegetation shall be damaged or disturbed.

- In a situation where any animal larger than an Impala has been caught in an area underlain by problem soils, the carcass should be dragged to the nearest Category A, B, C or D road. A suitable way as to cause the less disturbance or damage to vegetation should be utilised to drag or remove the carcass. This could be done by using a four wheeled drive tractor or it can be dragged with a cable and winch, especially in open areas.
- No off-road driving shall take place during rain spells. Off-road driving in areas covered with clay or clayey material will only be allowed after a period of five (5) days has elapsed since the last rain spell. In well drained environments, such as areas covered with sandy material, the vehicle operator should use his own discretion as to how long after a rain spell an off-road activity can resume.
- If off-road driving is necessary, for example, to get a better view of some lion lying behind a densely vegetated area, vehicles should not follow each other in the same tracks. The same should take place when returning to the nearest approved track or road.
- Any areas damaged because of turning actions, resuming of off-road viewing too soon after a rain spell, etc. shall be rehabilitated, at the latest the following day. This should be done by lightly scarifying the surface by hand to a depth of approximately 50mm. Alternatively this can be done with a rotavator or any other suitable tool or equipment. Grass seed as described in Section 15.3.4 must be spread by hand over the entire scarified area.
- No off-road viewing will be allowed into riverbeds or natural drainage channels, except where allowed as explained in Section 6.7.4.
- Each game viewing vehicle operator should have a suitable logbook in which every off-road viewing activity should be recorded. The log should contain details, such as date, time, GPS reading of the position clearly indicated on a map or sketch, reason for off-road driving, any rehabilitation actions taken, etc. These logs should be kept on file and summarised in a report which should be submitted on a monthly basis to the KNP game ranger and the independent monitoring ecologist responsible for that area.

## **12.10 The use of alternative stabilising agents in road construction**

### **1. General**

The dwindling supplies of natural sources of road building material in the KNP are being further curtailed by the high cost of exploitation and rehabilitation of borrow pits and under the present circumstances several environmental considerations. This fact gives greater emphasis to the need for improving the utilisation of marginal, sub marginal and problem in situ materials through stabilisation techniques. Some of the most important advantages of stabilisation are:

- The strength of the material is increased;
- Durability and resistance to the effects of water are improved;
- Wet soils can be dried out; and
- The workability of clayey materials can be improved.

Although soil is an abundant natural resource, many types cannot be used for construction purposes due to the lack of a suitable and affordable stabilisation technology. There are many stabilisers that are marketed as a replacement for the conventional stabilising agents, such as cement, lime, etc. From a risk management point of view, there is reluctance by engineers to employ these so-called replacement stabilisers. The marketing of these products is done conventionally by product representatives who may lack objectivity. The role of an independent materials engineer to act as an "honest broker" is often missed.

2. Although these products compete in the same market, several product types are mainly used in South Africa, ie.

- Ionic soil stabilisers (ISS) (**Paige Green, 1996**)
- Calcium chloride treatment (CCS) (**Jones, 1994**)
- Bitumen or tar emulsion treatment (**Sabita Manual 11**)
- Modified waxes (**Jones, 1998**)
- Lignosilphonates (**Jones, 1998**)
- Cement additives

**2.1 Ionic soil stabilisers** are mainly related to their ability to influence the properties and moisture susceptibility of clayey materials. They are therefore used as a "compaction aid" to improve the gravel properties (by stabilisation) and to reduce dust (dust palliative). Products in this category are, inter alia, Conaid, ISS 2500 and Roadamine.

**Approximate cost of application:** Between R8.00 and R20.00/m<sup>2</sup>.

**2.2 Calcium chloride treatments** have the ability to absorb water equivalent to between 5-10 times its own mass when the humidity is high enough and to retain one to two thirds of it through the heat of the day. It is therefore very efficient as a dust palliative. Improved strength properties have also been tested on materials treated with calcium chlorides. Roadtreat falls within this category.

**Approximate cost of application:** Between R6.00 and R12.00/m<sup>2</sup>.

**2.3 Bitumen treatment.** The use of bitumen emulsion in the base layers of surfaced roads is well documented. However, the treatment of gravel haul roads with bitumen emulsions is extensively used in the mining industry and is reported to be very sufficient. Dustaside is a patented product in this range.

The foamed bitumen technique produces gravel with properties equivalent to hot mix asphaltic material. It can be stockpiled for a period of three months and can be easily transported, placed and compacted unheated (cold). Foamed bitumen is made by injecting a small amount of water into hot bitumen. Foam gravel is an excellent wearing course for low volume roads.

**Approximate cost of application:** Between R6.00 and R25.00/m<sup>2</sup>.

**2.4 Modified waxes** are manufactured as part of the oil from coal process and exhibits soil binding properties. The potential for use as a dust palliative seems positive (Jones, 1998).

**Approximate cost of application:** Between R8.00 and R12.00/m<sup>2</sup>.

**2.5 Cement additives** are mainly used to improve the strength and reduce the water permeability of concrete products. Because of high costs very few of these additives have been used in road stabilisation successfully.

The only product that has been used with success in and outside Southern Africa is a non-toxic liquid concrete additive for use in building and road construction by the name of Renolith. It allows concrete to be made without coarse aggregate, instead is using soil as the filler. Renolith and Portland Cement together bind and waterproof the soil particles to form a stable and durable polymer with improved compressive load bearing and flexibility. Renolith may be applied by using in situ material, such as sand, clay, any clay/sand/silt mix, sea sand etc.

**Approximate cost of application:** R17.00/m<sup>2</sup> plus the cost of cement added.

## 2.6 Product types.

The chemical and physical mechanisms of patented types must be understood to obtain optimal performance. The conditions influencing treatment type selection include :

- Material type (clay, sand or gravel)
- Material properties (PI, grading, etc)
- Traffic (not relevant for category C and D roads).
- Alignment
- Rainfall
- Purpose of application (environmental friendly, safety or health reasons, cost criteria)

The existing market provides a great variety of products that can be used to stabilise in situ material in the KNP, without using any borrow materials. There is, however, no "one solution" for the treatment of low volume roads and no supplier can claim that his product is the ultimate.

A brief discussion on some products is used to illustrate applications where a better rate of success can be expected :

- Ionic stabilisers will only be efficient if applied to clayey materials.

- Calcium chloride treatments will retain moisture on the road surface which will be efficient in dry periods but may be slippery in wet periods.
- Treatment of material with calcium chloride stabilisers will not negatively influence the future chemical stabilisation of the material in an upgraded pavement design.
- The application of a tar-prime can hinder the soil-lime or soil cement reaction (**Netterberg, 1994**).
- Prime coats will have a limited life span and the costs of the layers to be protected and the elected prime or surface type must be in balance.
- Lignosulphonates are susceptible to leaching by water which means that application must be frequently repeated during wet periods.
- Cement additives are normally successful under most circumstances, but very expensive. Renolith has been applied successfully in areas, where construction material was not available, by the utilisation of the in situ material. In several cases pure sand and even clayey material were used to construct base courses successfully. Although the initial cost of the product seems to be high, savings of almost 40% on the construction of pavement layers were generated, because no construction material of whatever nature was imported. The cement content can vary between 2% and 8% per m<sup>2</sup>.

*Table 12.1 : Specifications of construction material*

Code	Material	Abbreviated specifications
G1	Graded crushed stone	Dense – graded unweathered crushed stone; Maximum size 37.5mm; 86-88% apparent relative density; Soil fines PI>4
G2	Graded crushed stone	Dense – graded crushed stone; Maximum size 37.5mm; 100-102% Mod AASHTO or 85% bulk relative density; Soil fines PI<6

<b>Code</b>	<b>Material</b>	<b>Abbreviated specifications</b>
<b>G3</b>	<b>Graded crushed stone</b>	Dense – graded stone and soil binder; Maximum size 37.5mm; 98-100% Mod AASHTO; Soil fines PI<6
<b>G4</b>	<b>Crushed or natural gravel</b>	Minimum CBR = 80% @ 98% Mod AASHTO; Maximum size 37.5mm; 98-100% Mod. AASHTO; PI<6; Maximum swell 0.2% @ 100% Mod AASHTO. For calcrete PI <sub>≤</sub> 8
<b>G5</b>	<b>Natural gravel</b>	Minimum CBR = 45% @ 95% Mod AASHTO; Maximum size 63mm or 2/3 of layer thickness; Density as per prescribed layer usage; PI<10; Maximum swell 0.5% @ 100% Mod AASHTO
<b>G6</b>	<b>Natural gravel</b>	Minimum CBR = 25% @ 95% Mod AASHTO; Maximum size 63mm or 2/3 layer thickness; Density as per prescribed layer usage; PI<12; Maximum swell 1.0% @ 100% Mod AASHTO
<b>G7</b>	<b>Gravel / Soil</b>	Minimum CBR = 15% @ 93% Mod AASHTO; Maximum size 2/3 of layer thickness; Density as per prescribed layer usage; PI<12 or 3GM + 10; Maximum swell 1.5% @ 100% Mod AASHTO
<b>G8</b>	<b>Gravel / Soil</b>	Minimum CBR = 10% @ 93% Mod AASHTO; Maximum size 2/3 of layer thickness; Density as per prescribed layer usage; PI<12 or 3GM + 10; Maximum swell 1.5% @ 100% Mod AASHTO

Code	Material	Abbreviated specifications
<b>G9</b>	<b>Gravel / Soil</b>	Minimum CBR = 7% @ 93% Mod AASHTO; Maximum size 2/3 of layer thickness; Density as per prescribed layer usage; PI<12 or 3GM + 10; Maximum swell 1.5% @ 100% Mod AASHTO
<b>G10</b>	<b>Gravel / Soil</b>	Minimum CBR = 3% @ 93% Mod AASHTO; Maximum size 2/3 of layer thickness; Density as per prescribed layer usage.

### 13. MAINTENANCE OF ROADS AND STORM WATER SYSTEMS

#### 13.1 General

The annual expenditure on maintenance of unpaved roads in the KNP could easily be of the same order as that of paved roads. The management of maintenance is, therefore, necessary to maximise the benefits from the available finance. Maintenance management systems should provide answers to questions such as the following :

- What budget is required?
- How many graders and staff are required?
- How often should each road be bladed?
- What is the resultant level of serviceability?
- What volume of gravel needs to be replaced annually?
- Which roads should be upgraded to bituminous standard?

The frequency of grader maintenance tends to be based primarily on the number of graders available with a systematic type of programme being followed to utilise each grader to maximum advantage.

The importance of the maintenance management of unpaved road networks has been recognised by the KNP and they are presently developing maintenance management systems for unpaved roads to suit their specific needs.

Maintenance requirements and costs are based almost entirely on the required level of serviceability which should be appropriate to the traffic. A level of serviceability acceptable for a remote, rural unpaved road with low traffic would generally be unacceptable for an unpaved feeder road to a densely populated developing area. No guidelines for levels of serviceability for unpaved roads in the KNP exist at present but the following based on performance criteria could be taken as a basis :

- The maximum roughness is generally used to determine the grader blading frequency in maintenance management systems and can be programmed into the maintenance management system.
- The level of serviceability should be adapted to the primary use of the road. Important tourist routes, such as access roads to game lodges may be maintained at a level of service higher than that which the traffic dictates, for obvious reasons.

## **13.2 Routine maintenance activities**

Despite all the programming and time spent on maintenance it is not worth doing if it is not done cost-effectively. The importance of sufficient maintenance carried out by experienced and conscientious machine operators and back-up staff cannot be overemphasised. Once the condition of a road deteriorates beyond a certain point, restoration of the road to an acceptable condition can seldom be achieved with routine maintenance and requires a considerable mechanical and labour input.

The major categories of maintenance covered in the document are :

Roadside maintenance;  
Drainage maintenance;  
Surface maintenance.

### **13.2.1 Roadside maintenance**

In the KNP the roadside could be defined as the first 20m adjacent to the edge of the shoulder or pavement.

The main maintenance activity affecting the roadside is the thinning out of shrubs and small trees. The first three metres adjacent to the edge of the shoulder or pavement should be cleared of long grass and shrubs. This procedure is carried out mainly for better game viewing but also to avoid damage to vehicles from vegetation overhanging the pavement edge and to reduce the fire hazard in some areas. The frequency of this maintenance depends on the relevant level of serviceability and should be adapted for the district under consideration. Areas with a high rainfall and short-radius horizontal and vertical curves (ie short sight distances) will require considerably more vegetation control than long straight roads in arid areas.

Vegetation control on unpaved road reserves is best carried out manually although mechanised control may be cost-effective in some areas.

Another roadside maintenance activity which should not be neglected is the repair and prevention of erosion affecting cut and fill slopes and ditches. The most cost-effective way of preventing this erosion is the establishment of vegetation. Cuts and fills should be constructed at suitable batters to allow the establishment of vegetation (preferably less than 1 vertical : 2 horizontal) with a cut-off drain or catchwater bank just behind the crest of the cut or fill. Should erosion occur, the erosion channels should be back-filled with rocks and grouted if possible. The erosion of drains could also be prevented by a rock lining and some form of obstacle (eg rock dams, vegetation) to retard the speed of water flow. Care should be taken with vegetation as the siltation often results in vigorous growth and eventual filling of the drain.

Erosion of culvert inlets and outlets is a common problem and control structures, eg rock rip-rap or concrete wing-walls may be considered at problem sites. With time the erosion protection measures themselves may require significant maintenance.

Most of the roadside maintenance is labour intensive and great scope exists for the contracting of this type of work to local residents in the areas surrounding the KNP.

### 13.2.2 Drainage maintenance

In both the wetter areas of the KNP, where prolonged periods of rain occur, and in the more arid areas where high intensity thunder-storms of short duration are common, drainage problems affecting unpaved roads are significant. Many of these can be overcome by improved drainage maintenance. Although the overall drainage systems are usually adequate, with time the drains often become eroded and/or silted up and free drainage of water from the road is impeded.

The first significant problem is to remove the bulk of the rainwater from the road surface without causing erosion of the gravel wearing course. For this to occur effectively the surface of the road should be well maintained with a good shape (definite crown), no potholes, deep corrugations or ruts and an adequate cross-fall. Local experience shows that a cross-fall of about 4 or 5 per cent is the optimum which allows adequate run-off without erosion. Longitudinal slopes and cross-falls steeper than about 5 per cent are prone to erosion. On the steep slopes commonly encountered in the eastern areas of the KNP, erosion is a significant problem and no cost-effective way of avoiding this has been developed as yet.

The important drains which require maintenance are the side drains and mitre drains. These should be designed with widths and side-slopes (1:2 or 1:3) which permit ready access of a motorised grader so that maintenance can be carried out during the routine pavement surface maintenance. Graders are, however, adaptable implements and the extension and angles of their blades can be adjusted for most purposes. The grader operators should ensure that all drains have an adequate fall with no low spots where water may accumulate. It is important to ensure that routine grader blading does not leave windrows blocking the entrance to mitre drains.

Deep V-shaped side drains are difficult to maintain (even manually), not always effective and are often unsafe, even for lightly trafficked roads. The construction of this type of drain should be avoided where possible.

In many cases it is cost-effective to clean drains of their silt and excessive vegetation manually. Drain maintenance should endeavour to retain the grass cover which reduces the erosion potential. This is especially necessary during manual clearing around culverts and drains. It is important that silt excavated from drains should be removed as far as possible from the drains (disposed into the nearest borrow pit) and should under no circumstances be used to patch or repair the road surface. The reason for this is that the material is usually uniformly graded (ie single-sized particles) generally non-plastic.

Excessive silting of drains is indicative of inadequate water flow velocities while erosion is indicative of excessive velocities. An ideal drain should be graded to provide the optimum velocity with no siltation or erosion.

The maintenance of culverts is a necessarily labour intensive operation and should be carried out regularly to avoid damage to the culvert and surroundings, should they become blocked and flooding occur. It is important once again that the material removed from the culverts is not used to maintain the road and is disposed of in the nearest borrow area. Cleaning of the outlet of culverts to ensure free-flow conditions on the downstream side should not be neglected.

### 13.2.3 Surface maintenance

The maintenance of the surface of unpaved roads is the major cost factor in the maintenance programme. Grader blading may be carried out at anything from a one week to six-monthly interval depending on the climate, traffic and required level of serviceability while regravelling is necessary at intervals of between five and ten years depending on the traffic.

The standard procedure for surface maintenance is grader blading. A grader is run across the surface of the road with the blade set to smooth and shape the surface. After grading, no potholes, corrugations, excessive loose material, large boulders, ruts or erosion channels should be present and straight portions of the road should have a definite crown and cross-fall while curves should have an adequate super-elevation for safety. Experience has, however, shown that cross-falls and super-elevations greater than about 5 per cent result in excessive erosion. A balance is required for the super-elevation not to result but to be adequately safe.

Blading should be carried out during periods of average moisture when the material is most easily cut, moved and compacted. In fact, practice has shown that during the dry season the hard upper crust or “blad” should not be cut. Blading can be classified as either light or heavy.

**Light blading** consists of a light trimming of the road surface on a routine basis. During the dry season, the surface loose material should be moved towards the side of the road, while during the wet season the loose material should be graded towards the centre of the road. It must be remembered, however, that the fine materials are slowly lost from the road surface in the form of dust and the repeated return of the loose surface material which is deficient in fines may lead to the formation of corrugations. “Sand blankets” are usually placed during light grading.

**Heavy blading** should be carried out when inspection reports indicate excessive defects. The road surface is scarified and cut to the bottom of the deformations and reshaped. This should only be done when the material is moist and more than 75mm of surfacing aggregate remains. Heavy grading is often necessary when “fixed corrugation” has formed. These corrugations may need initial lining or deeper cutting to break them up before being graded and recompact.

### 13.3 Special maintenance activities

Grading alone can make some roads rougher, especially those which are slightly “self-cementing” and form a crust or “blad”, or those with large stones as they often tend to be torn under the grader. Spot-regravelling is usually required to patch these. Excessive large stones cause problems with grader blading, as the stones are plucked out and dragged along the road causing long, deep gouges. They also cause excessive wear to the grader blades.

Loose material is a significant problem on unpaved roads. Many single vehicle accidents on unpaved roads are caused by windrows (“sandwallejtjies”) of loose material on the roads. These windrows interfere with the directional stability of the vehicles which may eventually overturn; the higher the vehicle speed, the greater the interference. It is important that these windrows not be permitted to become higher than 50mm. In addition to the vehicle handling aspect, high windrows often conceal large stones which can cause extensive damage to the tyres and underparts of vehicles (especially modern compact cars with ground clearances of less than 150mm). A common problem caused by poor grading practices is damming of water on the roads by windrows left at the edge of the road. Often the material deposited at the end of the grader blade during the last run forms a bank which retains water. This should not be permitted and should either be removed by the grader, or manually after grading.

Some grader operators leave a windrow like this at the edge of the prism and blade it onto the road when it is damp and will bind with the existing surface ie not create a loose layer. Periodic openings should be constructed in these windrows to allow the escape of surface water. Excessive grader maintenance with the production of banks often results in the level of the road being below the adjacent shoulders. Heavy grading and reshaping should be carried out in this case to avoid canalisation of the water along the road surface.

It is a common practice to spread a thin layer of fine sandy material (“sand blanket”) over the road, ostensibly to protect the surface. A thin “blanket” over a well-developed “blad” is certainly beneficial, though it often causes dust and may cause slipperiness for certain materials when dry. However,

many grader operators place a thick layer of mixed material (sand, gravel and boulders) over the entire road. This results in damage to vehicles (windscreens in particular), decreased safety, increased rolling resistance of the vehicles (and hence fuel consumption), the quicker development of corrugations (as the fine material has usually been removed). The rapid development of windrows of loose material (affecting lateral drainage) and an overall poorer riding quality and safety. The use of these thick “sand blankets” or “sand duvets” should be avoided. If “sand blankets” are used, the maintenance gang should ensure that no stones larger than 25mm are incorporated in the “sand blanket” or obscured by it. If such stones are obscured by the “sand blanket” it is too thick.

The development of ruts should be controlled during grader maintenance. Grading should occur before ruts have become deeper than about 25mm, with the ruts being filled with loose material. Prolonged rut development results in channelling of run-off and subsequent erosion and loss of shape of the road. On excessively wide roads (more than 8m) the vehicles tend to hollow out the centre of the road and the crown is totally destroyed. Particular care should be taken to restore and maintain this crown during grader blading.

The use of selective maintenance of certain links or even sections of a link is often appropriate and economically justifiable.

Instances have been observed where permanent corrugation with a 2.5 to 3m wave-length occur in the road. These have been caused by bouncing of the grader during blading and once formed cannot be removed by the same grader without lining as their wave-length is the same as the distance between the front wheels of the grader and the blade. A grader with a different wheel-blade length can be used to cut them.

A less expensive method of blading is to use underbody blades mounted beneath trucks or towed graders but these do not give as good a finish as a grader.

The lowest class of surface maintenance is dragging. Other than the “sand-track grader” of Namibia, drags have not been used to any significant extent in Southern Africa but are recommended in developing areas for sandy roads carrying less than about 50 vehicles per day. Many different types of drag are available, ranging from steel bars, branches or small trees, tyre drags, or custom made drags presently being developed at the Division for Roads and Transport Technology of the CSIR.

Proper training of grader operators is the basis of good grader maintenance practice. Although experience is extremely important, it is recommended that all grader operators be given high quality training in the theoretical and practical aspects of unpaved road maintenance and regular refresher courses. Bad maintenance habits (eg “sand duvets”, windrows along the edge of the road, etc) should be explicitly addressed.

For labour intensive maintenance and in developing areas, use of simple devices such as “camber boards” should be encouraged to raise the overall standard of the maintenance.

## **13.4 Regravelling**

### **13.4.1 Full regravelling**

Regravelling is the most expensive single maintenance procedure for unpaved roads. It is carried out when the important gravel on the road has been almost totally lost through erosion by rain and wind or abrasion by traffic, or when inappropriate material exists in the road. Regravelling should take place before the subgrade is exposed in order to avoid :

- (a) deformation which will necessitate reconstruction; and
- (b) loss of strength has been built up in the subgrade by traffic moulding over time.

Improvements to any drainage deficiencies should be made prior to regravelling. The quality of the new gravel should comply with the required specifications.

The regravelling process should follow the same procedure as the construction process with respect to the winning, hauling, spreading and compaction of the material.

### **13.4.2 Spot regravelling**

Spot regravelling is carried out to replace the gravel over areas where it has become excessively thin or worn through, and for filling potholes, ruts, erosion channels and even corrugation.

Spot regravelling is predominantly a manual operation and restricted to potholes and subgrade failures. It should make use of the same material as the wearing course gravel. Potholes should be cleaned out, the loose material removed from the sides, moistened with water, and then back-filled with moist gravel in 50 to 100mm layers. Each layer should be compacted (a hand rammer is adequate) until the hole is filled to about one centimetre above the surrounding road.

It is useful during the regravelling process to stockpile small supplies of wearing course aggregate in the borrow pit, at the maintenance camp or along the road at strategic places for maintenance purposes.

### **13.4.3 Reworking and compaction**

It is sometimes necessary to rework the existing gravel, breaking down or removing oversize material, perhaps blending in some fines, adding moisture and re-compacting. This is especially necessary when an adequate thickness of gravel exists on a road but the roughness becomes excessive under increased traffic or for a different traffic mix.

### **13.4.4 Safety aspects**

It is not the intention of this document to provide guidance on all aspects of maintenance but brief mention must be made of safety. Poor safety conditions are likely to occur in the Kruger National Park on unpaved roads during maintenance operations. The roads are dusty, a windrow exists along the road, labourers are on and off the road, the grader moves at a low speed, potholes often occur and boulders may lie on the road during the operation.

It is thus important that the section being maintained is fully signposted with the correct warning signs, irrespective of the fact that the maximum speed allowable on unpaved roads is 40 km/hour. Many of the signs used are often in a poor condition, as they are used under fairly severe conditions of dust, exposure to the elements and sometimes animals. The quality and condition of the signs should, therefore, be closely controlled and the signs timeously repaired where possible or replaced. The grader should be clearly visible over adequate distances.

Windrows left temporarily on the road should not be allowed to become too high (greater than 100mm) and should be left for as short a time as possible. Under no circumstances should a road be left partly graded over weekends or public holidays. An effective way of improving safety with respect to the presence of windrows is for the graders to work in tandem or even "tridem" (three in line). Caution must be exercised to ensure that the crown is retained.

Labourers should be supplied with high visibility safety clothing which should be kept in an acceptable state of cleanliness. Wearing of these during maintenance should be made compulsory.

## **14. MONITORING OF ROADS AND STORMWATER SYSTEMS**

### **14.1 Introduction / policy**

The use of Pavement Management Systems is becoming generally accepted as essential for determining the maintenance needs of pavements in a network of roads. Most of the road authorities started off by implementing a Pavement Management System (PMS) on paved roads, but realised with time that a Road Management System (RMS) is the ultimate goal. The RMS will then consist of different sub-systems that will include the PMS, the Gravel Road Management System (GRMS), materials, road furniture, transport and all other relevant information that is necessary to manage the total road network. KNP implemented a GRMS during 1994 and has updated the system on a regular basis.

The system provides management with information on the following:

- How often should every link be bladed to ensure optimal economic allocation of the maintenance funds?
- How many motor graders are required to perform the maintenance and what routine blading budget is required?
- What volume of material will be required annually for regravelling and how much should be budgeted for?
- What are the consequences if the required funds cannot be provided?
- Which roads are economically justified to be upgraded to bituminous standard and what funds are required for this?

These answers are relevant to Category A, B & C roads but in the case of category D roads the most important criteria is probably protecting the environment and/or to ensure that potential problems are identified at an early stage and rectified.

It must be emphasized that the GRMS is essentially a network level tool. Visual monitoring forms the basis of evaluating the condition of the road and the need for specific actions. The network is monitored to determine the global deterioration over time as well as to identify and prioritise maintenance

actions. The network evaluation is then used as a strategic input for the detailed project level investigations where the actual design is carried out with the aid of further refined investigations and tests. As the focus is at the network level, care must be taken to collect only that information which is relevant and required at the network level. The collected information is then processed to provide the output for management for strategic and budgeting purposes as well as for maintenance engineers for tactical planning and execution purposes.

## 14.2 DATA COLLECTION

Considerable data is involved in network assessment. This data is essentially of three types:

- network definition
- network characterisation
- pavement condition.

Descriptions of each are given below:

### 14.2.1 Network definition

Because each item of information is coupled to a specific portion of road, it is important to define a suitable permanent reference system for the network as a first step. This is usually achieved by dividing the network into sections (or links) with a maximum length of 500m, by the systematic allocation of nodes. Such nodes must be fixed points and are usually assigned to:

- (i) road intersections, i.e. where roads cross or join,
- (ii) intersections of roads with any other boundaries,
- (iii) a change from a gravel to a surfaced road.

Sections are identified by the name of the road concerned and the names of the intersecting roads or other features used as nodes or kilometre distances.

### 14.2.2 Network characterisation

A number of semi-permanent characteristics of the road are used in the analysis and should therefore be determined for each section. These characteristics are described by the following:

(a) **Geometry**

The length and width of each section are necessary to determine the size of maintenance projects.

(b) **Functional class and traffic**

The route functional classification (primary, secondary, main tertiary and tertiary or A, B, C, D) and the volume and type of traffic (light, medium and heavy) each has an important role in determining maintenance needs and priorities.

(c) **Climate**

Temperature and rainfall can have an influence on the materials in a road and therefore have an influence on maintenance needs and priorities. The climatic impact is determined from the Weinert n-value of the area.

### 14.2.3 Pavement condition (Visual assessment)

The visual assessment is carried out by means of the evaluation form below. Four different data sets of the road section are considered. These are:

- \* Fixed information;
- \* Structural assessment;
- \* Gravel properties;
- \* Functional assessment

These data sets and assessment will be discussed in the appropriate annexure.



## V&V CONSULTING ENGINEERS PAVEMENT ASSESSMENT (UNPAVED)

CLIENT : \_\_\_\_\_  
 AREA : \_\_\_\_\_  
 ROAD NAME : \_\_\_\_\_  
 FROM : \_\_\_\_\_  
 TO : \_\_\_\_\_  
 LINK/S : LENGTH \_\_\_\_\_ m  
 : WIDTH \_\_\_\_\_ m

DATE : \_\_\_\_\_  
 ROUTE : \_\_\_\_\_  
 TRAFFIC : \_\_\_\_\_  
 TERRAIN : \_\_\_\_\_  
 MOISTURE : \_\_\_\_\_  
 ROAD TYPE : \_\_\_\_\_

A	B	C	D	
VL	L	M	H	VH
F	R	M		
Wet		Moist		Dry
Gravel		Dirt		0

### STRUCTURAL ASSESSMENT

STRUCTURAL	DEGREE					EXTENT				
	SLIGHT		SEVERE			ISOLATED		EXTENSIVE		
	1	2	3	4	5	1	2	3	4	5
POTHoles	0									
CORRUGATIONS	0									
RUTTING	0									
LOOSE MATERIAL	0									
STONINESS : FIXED	0									
: LOOSE	0									
EROSION : LONGITUDINAL	0									
: TRANSVERSE	0									
GENERAL CONDITION	Very Good		Good		Fair		Poor		Very Poor	

GRAVEL PROPERTIES					
TYPE	FERRICRETE	CALCRETE	QUARTZITE	CHERT	DOLOMITE
	SANDSTONE	GRANITE	SHALE	DOLORITE	SAND
MAXIMUM SIZE	> 50 mm		25 - 50 mm	13 - 25 mm	< 13 mm
CLASSIFICATION	COARSE		MEDIUM	FINE	
APPROXIMATE 'PI'	< 6		6 - 15	> 15	
GRAVEL THICKNESS (mm)					

### FUNCTIONAL ASSESSMENT

RIDING QUALITY	Very Good	Good	Fair	Poor	Very Poor
SKID RESISTANCE		Good	Fair	Poor	
DRAINAGE : ON THE ROAD		> 4%	0 - 4%	< 0%	
: SIDE OF THE ROAD		Good	Fair	Poor	
DUST		None	Minor	1, 10+	Severe



### **14.3 AUDIT INTERVALS**

Assessment of the condition of unpaved roads differ significantly from that of paved roads: unpaved roads are highly dynamic systems with the appearance and condition varying almost from day to day. Although paved roads are also dynamic systems, the rate of change of typical performance characteristics is much slower and annual observation is generally sufficient to identify changes and provide timeous inputs for maintenance intervention activities. This is considerably more difficult for unpaved roads, and it is thus recommended that these roads are assessed bi-annually.

## **15. DE-COMMISSIONING OF ROADS**

### **INTRODUCTION**

In this document it is assumed that once a road has been identified for de-commissioning it will never be needed again in future for whatever purpose. The latter could include such subsequent use as for inspection, ecosystem monitoring, law enforcement, research, etc tied to the general management of the park.

### **15.1 GENERAL**

Roads which have become unnecessary for commercial use in the KNP, could not just be closed and left unattended over a long time for “nature to take over”. Gravel roads in particular, if not maintained properly, could fall into disrepair and form large erosion gullies during successive heavy rainstorms. This will not be acceptable from a conservation perspective and the barren scars left by erosion will also affect the aesthetics of the tourist’s experience.

Even if unnecessary roads are closed for tourist traffic and no concerted effort is made to rehabilitate the road area, animals might use the route as a convenient thoroughfare to move from one area to another thereby continually disturbing any natural re-vegetation that might occur. Again the threat of erosion becomes very real over time.

A de-commissioning strategy for superfluous roads will depend largely on the following parameters:

- The surface of the road
- The width of the road
- The gradient of the road
- The original purpose of the road, for example temporary or permanent.
- The time allowed for rehabilitation
- The costs involved in different methodologies for de-commissioning.

All of these factors have to be considered in an integrated plan for decommissioning, before a final decision can be taken.

## 15.2 DE-COMMISSIONING POLICY

It goes without saying that the de-commissioning policy of the KNP should be formulated to harmonise with the organisation's strategic conservation policy. The basis for the latter policy can be found in Section 4 of the National Parks Act, No 57 of 1976. This Section reads as follows:

*“The object of the constitution of a park is the establishment, preservation and study therein of wild animal, marine and plant life and objects of geological, archaeological, historical, ethnological, oceanographic, educational and other scientific interest and objects relating to the said life of the first-mentioned objects or to events in or the history of the park, in such a manner that the area which constitutes the park shall, as far as may be and for the benefit and enjoyment of visitors, be retained in its natural state.”*

In view of the above statement a de-commissioning policy for excess roads should read as follows:

KNP management will ensure that the activities related to and the results of the de-commissioning of excess or superfluous roads in the park will not thwart or detract from the conservation objectives contained in Section 4 of the National Parks Act, No 57 of 1976.

*The strategy to achieve the policy objectives will become clear from the methods recommended for de-commissioning below.*

## 15.3 Rehabilitation methods

The methods below are aimed primarily at avoiding unnecessary costs and to ensure a reasonable level of re-vegetation after a period of about 5 years.

### 15.3.1 Activity 1

The entrances to the road, of whatever category, to be de-commissioned must be effectively blocked and clearly sign-posted to prevent any inadvertent access by tourists or park staff.

### 15.3.2 Activity 2

This activity will only be necessary for surfaced roads, which are to be de-commissioned. It will involve the following:

- The road surface is ripped to break up the seal.
- The surfacing layer is then collected and stored in dumps of a convenient size for removal.
- The collected surface waste is transported to the original or nearest borrow area and should be covered with 150mm thick top soil.

Obviously the above activity is not applicable to category B, C and D roads.

### 15.3.3 Activity 3

The next step is to rip the compacted base material of the road surface right down to the original subsoil to allow for water to penetrate. (Also applicable to Category C and D roads).

To prevent any erosion of the ripped and denuded road surface the now loosened material should be used to construct transverse berms at suitable intervals to inhibit the surface flow of water, especially on roads with a significant gradient, where erosion poses a real threat.

#### **15.3.4 Activity 4**

This activity is concerned with the selection and sowing of seed of a robust pioneer grass species. The grass species to be used, should be selected locally by the ecological staff of the KNP. The grass seeds must be spread by hand over the entire ripped surface of the road, including the berms.

#### **15.3.5 Activity 5**

In order to minimise the risk of grass seeds being blown or washed away, the sowing process should be followed immediately by scarifying the road surface to ensure the maximum retention of the seed material.

The next step would be to cover the entire road surface with 50 mm layer of topsoil mixed with the residues of vegetation. Although this process is generally accepted practise for the rehabilitation of denuded land areas, this method is not recommended, because

- The topsoil will have to be obtained from other areas, which will cause larger areas to be exposed to denudation and possible erosion
- Topsoil on top of the ripped road surface will erode more easily than the uneven road surface itself.
- The spreading of topsoil without additional retention procedures, will not necessarily enhance the growth potential of the introduced grass seeds.
- The costs of collecting, transporting and spreading of topsoil will be prohibitive.

### 15.3.6 Activity 6

The presence of organic material will enhance the in situ retention of moisture and the subsequent growth potential of the grass seeds as well as preventing the erosion of berms. Therefore, the desired action would be to collect and spread enough cut grass or other vegetation (or a mulch produced from such vegetation) over the road surface to provide for composting material. Also, if enough thorn trees are available to allow for thinning, the branches could be cut and spread over the surfaces, especially the berms to inhibit erosion. However, any of these methods should only be used if the process is approved by the KNP staff and if sufficient plant material is available in the immediate vicinity of the road.

In the case of temporary construction or borrow pit access roads the topsoil mixed with the original plant material pushed to the road sides during construction, if available, could be re-spread over the disused road surface to provide a better seedbed.

## 15.4 Monitoring

The rehabilitated road surfaces should be monitored for at least five years assuming that rainfall during that period will be normal for the KNP. The purpose of monitoring will be to:

- Ascertain whether the rehabilitation methods are successful or not
- Combat any erosion which might occur during heavy rainstorms
- Prevent the subsequent use of the rehabilitated road corridor
- Study the plant succession on the road surface and any impacts from animal movements or veld fires.
- Progressively learn from the rehabilitation experience and to review and adapt methods for future use should it be necessary.

If a prolonged drought is experienced during the five years of monitoring, the surveillance exercise will have to be extended.

For ease of reference the following tables refer to the relevant sections in the manual where detail about the four main activities regarding the construction of roads on the different soil types can be found.

SOIL TYPE	CONSTRUCTION OF THE FOLLOWING ROAD TYPES				
	Category A	Category B	Category C	Category D	Category E
Expansive soils (Heaving clays)	Section 6.7.2	Section 6.7.2	Section 6.7.2	Section 6.7.2	Section 12.9
Collapsing sand	Section 6.7.3 (f & g)	Section 6.7.3 (f & g)	Section 6.7.3 (f & h)	Section 6.7.3 (f & h)	Section 12.9
Collapsing residual granite	Section 6.7.3 (f & g)	Section 6.7.3 (f & g)	Section 6.7.3 (f & h)	Section 6.7.3 (f & h)	Section 12.9
Dispersive soils (Duplex soils)	Section 6.7.3 (f & g)	Section 6.7.3 (f & g)	Section 6.7.3 (f & h)	Section 6.7.3 (f & h)	Section 12.9
Suitable material	Section 12.1 - 12.4	Section 12.1 - 12.4	Section 12.6 - 12.8	Section 12.6 - 12.8	Section 12.9

SOIL TYPE	MAINTENANCE OF THE FOLLOWING ROAD TYPES				
	Category A	Category B	Category C	Category D	Category E
Expansive soils (Heaving clays)	Section 13	Section 13	Section 12.7	Section 12.8	Section 12.9

Collapsing sand	Section 13	Section 13	Section 12.7	Section 12.8	Section 12.9
Collapsing residual granite	Section 13	Section 13	Section 12.7	Section 12.8	Section 12.9
Dispersive soils (Duplex soils)	Section 13	Section 13	Section 12.7	Section 12.8	Section 12.9
Suitable material	Section 13	Section 13	Section 12.7	Section 12.8	Section 12.9

SOIL TYPE	DRAINAGE OF THE FOLLOWING ROAD TYPES				
	Category A	Category B	Category C	Category D	Category E
Expansive soils (Heaving clays)	Section 6.7.3 Section 11	Section 6.7.3 Section 11	Section 6.7.3 Section 11	Section 6.7.3 Section 11	Not applicable
Collapsing sand	Section 6.7.3 Section 11	Section 6.7.3 Section 11	Section 6.7.3 Section 11	Section 6.7.3 Section 11	Not applicable
Collapsing residual granite	Section 6.7.3 Section 11	Section 6.7.3 Section 11	Section 6.7.3 Section 11	Section 6.7.3 Section 11	Not applicable
Dispersive soils (Duplex soils)	Section 6.7.3 Section 11	Section 6.7.3 Section 11	Section 6.7.3 Section 11	Section 6.7.3 Section 11	Not applicable
Suitable material	Section 6.7.3 Section 11 Section 12.5	Section 6.7.3 Section 11 Section 12.5	Section 6.7.3 Section 11 Section 12.5	Section 6.7.3 Section 11 Section 12.5	Not applicable

SOIL TYPE	DECOMMISSIONING/REHABILITATION OF THE FOLLOWING ROAD TYPES				
	Category A	Category B	Category C	Category D	Category E

Expansive soils (Heaving clays)	Section 15.3	Section 15.3	Section 15.3	Section 15.3	Section 12.9
Collapsing sand	Section 15.3	Section 15.3	Section 15.3	Section 15.3	Section 12.9
Collapsing residual granite	Section 15.3	Section 15.3	Section 15.3	Section 15.3	Section 12.9
Dispersive soils (Duplex soils)	Section 15.3	Section 15.3	Section 15.3	Section 15.3	Section 12.9
Suitable material	Section 15.3	Section 15.3	Section 15.3	Section 15.3	Section 12.9

## REFERENCES

The following documents were extensively consulted and used in the compilation of this manual:

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