

AN INVESTIGATION OF THE ENVIRONMENTAL  
IMPACT OF SURFACE DIAMOND MINING  
ALONG THE ARID WEST COAST OF SOUTH AFRICA

by

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A thesis submitted in partial fulfilment  
of a Master of Science degree in the  
School of Environmental Studies,  
University of Cape Town

September 1982

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## ABSTRACT

An outline of the main features of the West Coast environment establishes that it has potential value for recreation, tourism and nature conservation, in addition to that of diamond mining, and that it is sensitive to disturbance. The diamond mining process is analysed and mining actions that cause environmental impact are identified. A matrix approach is employed to relate particular mining actions to specific environmental elements. It is found that there is major impact on scenic and vegetation elements and that primary impact is magnified significantly through the process of wind erosion. It is argued that much environmental impact can be prevented if the objective of environmental protection was incorporated into the management of mine sites and that unavoidable impact can be mitigated by rehabilitation, which is a reasonable requirement.

*That land yields a cultural harvest is  
a fact long known, but latterly often  
forgotten*

- Aldo Leopold

## TABLE OF CONTENTS

	Page
LIST OF TABLES AND FIGURES AND MAP	vii
ACKNOWLEDGEMENTS	ix
PREFACE	x
CHAPTER 1 INTRODUCTION	
Introduction to the Topic	1
Scope and Terms of the Investigation	3
Objectives of this Investigation	5
Approach to the Investigation	6
CHAPTER 2 THE WEST COAST ENVIRONMENT	
Introduction	9
The Physical and Biological Environment	10
Topography	10
Geomorphology and Geology	12
Vulnerability of the Coastal Foreland	13
Soils	15
Climate	17
General	17
Radiation	18
Temperature	19
Precipitation	20
Winds	21
Vegetation	29
Fauna	33
Rivers and Estuaries	34
Ground Water	35
Marine Environment	36

	Page
The Socio-economic Environment	37
Archaeological and Historic Sites	37
Present Population	38
Infrastructure	39
Resource Use	40
Marine Resources	40
Agriculture	42
Recreation, Tourism and Nature Conservation	43
Mining	49
Summary	52
Sensitivity of the West Coast Environment	52
Value of the West Coast Environment	55
 CHAPTER 3 THE MINING ACTIONS	
Background Information	57
Introduction	57
Geology of the Diamond Deposits	58
General	58
Coastal Terrestrial Deposits	59
River Deposits	63
Marine Deposits	64
History of Exploitation for Diamonds along the West Coast	65
Past Exploitation on Land	65
Past Marine Exploitation	67
Present Exploitation	68
The Mining Actions	74
Introduction	74
Mining Actions by the Large Enterprises	75
Prospecting	75
The Mining Operation	81
Treatment of Diamondiferous Gravels	86
Induced Actions	90

	Page
Developed Infrastructure	92
Future Mining Actions	94
Mining Actions of Selected Smaller Enterprises	95
DBCM Inland Operation	95
Small Companies near Olifants River	96
Marine Mining Operations	98
Summary	100
CHAPTER 4 ENVIRONMENTAL IMPACT	
Introduction	104
Environmental Impact of Large Enterprises	105
The Matrix Approach	105
Discussion of Impacts	109
Wind Erosion	128
Natural Revegetation	133
Environmental Impact of Smaller Enterprises	141
DBCM Inland Operation	141
Smaller Companies near Olifants River	142
Marine Mining	144
Summary	145
CHAPTER 5 REHABILITATION	
Introduction	148
Reasons for Rehabilitation	150
Magnification of Impacts	150
Future Land Use	151
Ethics, Public Opinion and Economics	152
Present Situation	155
Present Rehabilitation Measures	155
Natural Rehabilitation	156
Benefits of Rehabilitation for Mining Enterprises	157
Public Image	157
Inhouse Benefits	159

	Page
Practical Aspects of Rehabilitation	159
Feasibility of Revegetation	159
Suggested Rehabilitation Actions	163
Financial Feasibility	169
Summary	173
 CHAPTER 6 CONCLUSION	 176
 REFERENCES	 178
 APPENDIX A Definitions of Elements of Impact Matrix	 189
 APPENDIX B Data Source for Determining Total Area of Mining-disturbed Land	 190
 APPENDIX C Investigation of Sand Plume Spread	 191
 APPENDIX D Analysis of Soil Samples	 192

## LIST OF FIGURES, TABLES AND MAP

		Page
Fig. 2.1	Vulnerability of the coastal foreland.	14
Fig. 2.2	Wind roses.	23
Fig. 2.3	Diurnal variation of speed and direction of wind resultants at Alexander Bay.	24
Table 2.4	Annual wind parameters along the West Coast of southern Africa.	25
Fig. 2.5	Annual sand roses, Cape Town to Walvis Bay.	26
Fig. 2.6	Latitudinal variation in annual resultant drift potential, Cape Town to Walvis Bay.	27
Fig. 2.7	Vegetation zones on the West Coast.	30
Table 2.8	GGP according to economic sector of Namaqualand.	49
Table 2.9	Diamond sales West Coast, 1975-1980.	50
Fig. 2.10	West Coast diamond production compared to South Africa and world for 1980.	51
Fig. 2.11	Diamond sales of West Coast and South Africa in 1979.	51
Fig. 3.1	Typical stratigraphy of sediments along West Coast.	61
Fig. 3.2	Diamond mining zones.	69
MAP 1	Land allocated to diamond prospecting and mining.	70
Table 3.3	Total diamond production from the West Coast	72
Fig. 3.4	Diamond production share of mining enterprises.	73
Fig. 3.5	Diamond production share of land and sea concessions.	73
Fig. 3.6	Prospecting trench system.	79
Fig. 3.7	Auger drilling grid.	79
Table 3.8	Overburden stripped by SAD and DBCM.	82
Table 3.9	Area disturbed by mining through primary actions.	85

		Page
Fig. 3.10	Diamond mine treatment process	88
Table 3.11	Treatment plants in use and abandoned by SAD and DBCM.	89
Table 3.12	List of mining actions.	102
Table 4.1	Impact matrix.	108
Fig. 4.2	Action-effect network.	129
Table 4.3	Land area disturbed by mining.	131
Table 4.4	Expansion of sand plume areas on SAD land.	132
Table 4.5	Natural revegetation at SAD.	136
Table 4.6	Natural revegetation at Annex Kleinzee (DBCM).	139
Fig. 5.1	Possible control of wind erosion.	166
Fig. 5.2	The use of perimeter tipping to reduce visual intrusion.	166
Table 5.3	Estimated mine revenue per hectare.	171
Fig. 5.4	Increase of West Coast diamonds in rand value per carat.	172

## ACKNOWLEDGEMENTS

I acknowledge with thanks the assistance of the following:

Professor Richard Fuggle for supervising this thesis;

Professor John Grindley, Roy Stauth, Jonathon Shopley and Susan Lane for information, advice and encouragement;

Janet Harding for assisting with editing;

Leonora Fox for typing the manuscript;

Annelise le Roux for identifying curious plant specimens;

the Branch of Environmental Conservation, Department of Environment Affairs for supporting this study during my employment with them;

the South African Breweries for a post-graduate bursary for two years;

the University of Cape Town for awarding the Siri Johnson and Twamley post-graduate bursaries for one year ; and

the General Managers of the State Alluvial Diggings and De Beers Consolidated Mines Limited, Namaqualand Division, for hospitality and assistance during my stay at Alexander Bay and Kleinzee.

## PREFACE

A number of conservation bodies have stated their concern about the effects of diamond mining on the environment of the west coast of South Africa. Their reports prompted a visit to the area by an inter-departmental group of officials from central and provincial government in February 1981. This group reported that mining activity appeared to dominate the use of resources along the West Coast. It was felt that there was a need to review the situation - not to retard the mining industry - to ensure the future availability of other resources.

Subsequently the author was employed by the Branch of Environmental Conservation of the then Government Department of Water Affairs, Forestry and Environmental Conservation (now the Department of Environment Affairs) to investigate the environmental impact of such diamond mining activity. In the course of this investigation the author undertook one month of fieldwork in the Alexander Bay, Kleinsee and Koingnaas mining area. He also paid a visit to the mining operations near the Olifants River mouth.

Mining was not a completely new field to him. He is a qualified electrical engineer with three years experience in the South African gold mining industry.

# CHAPTER 1

## INTRODUCTION

### 1.1 INTRODUCTION TO THE TOPIC

It has been generally accepted that mining activity has impacts on the environment. The very nature of mining, and of surface mining in particular, requires disturbing the land surface (Doyle, 1976).

"Surface mining necessitates alienation and radical disturbance of land" (Chamber of Mines of South Africa, 1981). There has also been an increasing awareness of the need to preserve or rehabilitate the environment. For some years, therefore, mining companies, legislators and others have moved to increase their knowledge of mining's environmental effect (Down & Stocks, 1977).

The concept of the rehabilitation of mining-disturbed land as an integral part of the mining process also seems to have become widely acknowledged. In the Federal Republic of Germany, for example, a land restoration programme was planned, from the outset, for the large-scale surface mining of brown coal, this in the 1950s. This restoration programme has been so successful that strip-mining is no longer a controversial public issue in Germany (Doyle, 1976). In the

United States of America legislation for the rehabilitation of mining-disturbed land has been standardised only recently with the Surface Mining Control and Reclamation Act of 1977. In South Africa such legislation has been introduced even more recently with the amendment of the regulations (regulations 5.11 to 5.14) of the Mines and Works Act (Act 27 of 1956) in March 1980 and which state, "Rehabilitation of the surface of any opencast mine shall form an integral part of the mining operations". It is noteworthy, however, that coal-mining companies in South Africa acknowledged the need for surface reclamation in the planning of their opencast operations as early as 1973 (Roper, 1977), and thus showed a willingness to self-regulate their activities well in advance of specific statutory regulations.

On the West Coast of South Africa a great deal of surface mining activity is taking place for the exploitation of diamond resources. There it is generally held that mining activities cause little impact or that impact is not important on the environment because of its arid nature. Consequently it is believed that rehabilitation or control of mining impacts is unnecessary. This thesis investigates this aspect in some detail.

Along the West Coast a resource of great economic value is being exploited. To some this justifies the activity irrespective of cost. Opposed to this view is the notion that future land use must not be compromised. Thus Venn *et al.* (1980) state, "... as important and as it may economically be in the short term, mining is an

ephemeral industry of finite life span...". By contrast a sustainable resource use, such as agriculture or tourism can endure indefinitely and could therefore be more important in the long term. This does not necessarily make it irrational to undertake some form of mineral exploitation at the expense of some other resource, such as soil. Such a trade-off must be weighed in terms of the potential benefits that can be gained from future use of the land.

## 1.2 SCOPE AND TERMS OF THE INVESTIGATION

Environmental impact has been broadly defined by Munn (1975) as "the change (good or bad) in man's health and well-being (including the well-being of the ecosystems on which man's survival depends) that results from an environmental effect and is related to the difference between the quality of the environment as it would exist 'with' and 'without' the same action". The same author has defined environmental impact assessment as an activity designed to identify and predict the impact on man's health and well-being, of legislative proposals, policies, programmes, projects and operational procedures, and to interpret and communicate information about the impacts.

This investigation of environmental impact of mining activity is not a comprehensive environmental impact assessment. Such a study should be undertaken by a multi-disciplinary team co-ordinated by a team leader (Fuggle, 1979), particularly to obviate bias in subjective assessments, such as impacts on aesthetics or scenery. This

one-man investigation is therefore limited in scope. It is also not intended to provide a detailed quantification of the environmental effects of mining. Instead the emphasis in this investigation has been on the identification and understanding of the mining activities and their impacts; some quantitative assessments have been attempted.

Others terms used in the context of this thesis are defined as follows:

**WEST COAST:** The coastline along the west coast of South Africa from the mouth of the Orange River at latitude  $28^{\circ}40'S$  and longitude  $16^{\circ}27'E$  to Donkins Bay just south of the Olifants River at latitude  $31^{\circ}56'S$  and longitude  $18^{\circ}17'E$ . This represents some 400 km of coastline.

**SURFACE DIAMOND MINING:** The diamond mining activity on land along the immediate coastline, i.e. generally not more than 3 km from the sea. The emphasis of this investigation has been on this activity, as it constitutes the major part of diamond exploitation on the West Coast.

**INLAND DIAMOND MINING:** The diamond mining activity further inland, upstream of the Orange and Buffels Rivers. This exploitation for diamonds is on a small scale relative to that on land along the coast and was investigated only briefly.

**MARINE DIAMOND MINING:** The diamond mining activity taking place in

the sea along the West Coast. This activity is mainly concentrated in the surf zone, i.e. the zone extending some 30 m out to sea from low-water mark. This activity, although still on a relatively small scale, appears to be growing rapidly; it also has been investigated only briefly.

**LARGE MINING ENTERPRISES:** The two largest mining enterprises in terms of diamond production are firstly, the De Beers Consolidated Mines Ltd, Namaqualand Division (DBCM) and secondly, the only State-owned mining enterprise in South Africa: the State Alluvial Diggings (SAD).

**SMALLER MINING ENTERPRISES:** A number of smaller private mining enterprises operate mainly on land concessions to the north and south of the Olifants River and on sea concessions along the West Coast. Some of these operations were briefly investigated. In this thesis this aspect is dealt with together with the Inland Mining and Marine Mining enterprises.

### 1.3 OBJECTIVES OF THIS INVESTIGATION

This study attempts to achieve three things. First, it attempts to outline the main features of the West Coast environment in which diamond mining is occurring. Second, it analyses the particular features of the diamond mining operations so as to allow identification of particular aspects of mining operations that cause environmental impacts. A matrix approach will be employed to relate particular

mining actions to the specific environmental elements which they affect. Third, the potential for rehabilitation of mined areas will be briefly examined.

Although this holistic study is too wide-ranging to lend itself to a strict scientific methodology of hypothesis, test and conclusion, the investigation has been structured around the following three-part hypothesis:

- a) that the West Coast, because of its arid nature, has no value other than its mineral resources and that it is insensitive to human disturbance;
- b) that mining activity therefore has little impact, and that such impact is of negligible consequence;
- c) that rehabilitation of mining-disturbed land is consequently both unnecessary and impracticable.

This hypothesis forms the framework for the study though no attempt is made to provide quantitative experimental data to test the hypothesis. Rather, objective qualitative perspectives are used in an attempt to provide evidence which will enable the hypothesis to be evaluated.

#### 1.4 APPROACH TO THE INVESTIGATION

Chapter 2 gives a description of the West Coast. A literature review

covers the physical and biological characteristics of this environment. A presentation of the socio-economic situation is intended to show the present land use pattern and the potential of the resources of the West Coast.

Chapter 3 renders a detailed account of the mining actions. Initially a brief examination of the geology of the diamond deposits helps to explain the nature of the mining process, and a literature review of the history of diamond mining exploitation reveals the scale of past exploitation. The present nature of exploitation is also depicted. From field work the phases of mining are analysed through the identification of individual mining actions and this facilitates the investigation of environmental impacts in Chapter 4.

Chapter 4 presents the juxtaposition of the mining activity and the environment. From field observations the environmental impacts identified by the author are listed. Although he does not attempt to quantify the mining impacts in detail, an indication of the extent of these impacts is given. The development of sand plumes arising from mining disturbances and the natural re-establishment of vegetation cover on overburden dumps is examined more closely. (Since these environmental impacts appeared particularly significant to the author, additional field data were collected on them.)

Chapter 5 discusses rehabilitation in mitigation of the environmental impacts of mining. Reasons why such efforts may be necessary on the

West Coast are discussed. This chapter also looks at possible means of rehabilitation and includes a cost analysis of such efforts.

Finally, conclusions are drawn in Chapter 6.



Photo 2A Nimbus satellite image of 9 May 1979, showing airborne silt in the vicinity of the Orange River mouth being blown out to sea by a northeast Berg wind. (Shannon & Anderson, in press).

Wind erosion is a major hazard on the West Coast; this is described in chapter 2 of this study (northern and southern limits of the study area are indicated by arrows).

## CHAPTER 2

### THE WEST COAST ENVIRONMENT

#### 2.1 INTRODUCTION

A description of the environment affected by the mining actions is required to enable one to understand the effects of these actions. Such a description must highlight the most critical components of that environment. Impacts on these critical components of the environment will be of particular interest. Often components of the environment are affected only indirectly by an action of man and therefore may be overlooked. This danger can be reduced by investigating any potential impact on those components of the environment which have been identified as critical.

Another factor that inhibits awareness of environmental impact is ignorance of valuable or sensitive features of the environment. This lack of knowledge appears to apply particularly in the case of arid areas, perhaps because less is known about them than about other ecosystems, and because, until recently, the desert biome was regarded as "dangerous, unwanted wasteland" (Sutton, 1981). The West Coast seems to be no exception. Very few studies have been conducted on the

fauna, flora or ecology of this area and the author has met the view that the West Coast is "just a monotonous wasteland".

This chapter will thus attempt to sketch the most important features of the West Coast to provide the background for the description of the mining actions and impacts described in subsequent chapters.

## 2.2 THE PHYSICAL AND BIOLOGICAL ENVIRONMENT

### 2.2.1 TOPOGRAPHY

The coastline runs fairly linearly with few bays and indentations. Wave-formed rock platforms at various levels, from the infratidal to the splash zone, occur along almost the entire coast (Heydorn & Tinley, 1980). This rocky shore is the substrate for a rich marine life. Discontinuous high cliffs bound the coast at places, such as between Port Nolloth and Alexander Bay, and north and south of the Olifants River, rendering some spectacular scenery. The undulating coastal plain is covered with fixed and active sand dunes, aligned more or less parallel to the prevailing wind direction, i.e. north - south. This coastal plain ascends gradually and merges with a deeply dissected planation surface at about the 150 m contour (Heydorn & Tinley, 1980). The width of the coastal land below 150 m varies from 50 km to 80 km, except for the Orange River and Olifants River basins which extend further into the interior. Few hills occur in this coastal tract of low relief. Of note are the Boegoe twins: two inselbergs south of Alexander Bay.

The fact that the coastline trends NNW is significant. This orientation exposes the coastal land to strong prevailing southerly winds during summer and this has consequences for unconsolidated land surfaces. Several of the intermittent rivers in Namaqualand show dune plumes to the north of their mouths. The Swartlintjies and Bitter Rivers have the most distinctive plume fields (Serial Photographs, Trig. Survey, Job 763 No's 7375 and 7386 to 7390). Rogers (1977) suggests that such plumes have formed with strong unidirectional southerly winds initially blowing sand off exposed beaches at the mouth of the rivers.

Salt pans are another feature of the coastal plain. Hallam (1959) puts forward the theory that these are due to bays having been closed by deposition of sediments transported by longshore movement along the coast. Another theory is that pans are formed by wind action (King, 1951): it is held that in the past water collected in some slight depression and evaporated in the dry season. Wind carried away disintegrated products on the floor, thereby deepening the depression. With repetition of the process pans become deeper and greater in size. This explanation seems plausible for the West Coast with its strong southerly winds. Also, the elongated shapes of the pans are well aligned with the direction of the prevailing winds rather than with the coastline, e.g. Dreyers Pan.

Sand plumes are also evident north of nearly all diamond prospecting trenches along the coast. They are very conspicuous on aerial photographs. This phenomenon is dealt with in Chapter 4.

### 2.2.2 GEOMORPHOLOGY AND GEOLOGY

The Namaqualand west coast with the Olifants River at its southern boundary has been included in a geomorphological subdivision of the Namib Desert by some authors, and is referred to as the Namaqualand Sandy Namib (Rogers, 1977). Thick sediments of Tertiary to Recent origin overlie older basement rocks (Heydorn & Tinley, 1980). At the bottom of the sedimentary sequence are marine sands. Above these, and comprising the bulk of the overburden, is a wedge of mixed terrigenous sands with gravels and inconsistent calcrete cappings. Aeolean sands form the top surface (De Beers, 1979).

Underlying these sediments is bedrock, predominantly of the Namaqualand-Natal granite gneiss series. The Namaqualand or West Coast monocline has tilted the bedrock seaward (Heydorn & Tinley, 1980), and there is evidence of coastal warping (Tankard, 1976; De Beers, 1979). This has a bearing on the occurrence of diamonds.

Usually diamonds on the West Coast occur in a series of raised beach deposits, which correspond to former static sea levels (De Beers, 1979). These levels now appear in considerably different elevations. Thus diamond deposits on the farm Kareedoornvlei are found at higher elevations and are further away from the coastline than on the farm Annex Kleinzee (De Beers, 1979). Typically, however, the geology of the diamond deposits is such that diamonds are mined in a narrow belt along the coastline. This belt stretches over a width of from 100 m behind the beach to 3 km from the coastline.

Exceptions to this general rule are diamond deposits further inland, which are associated with river systems. There the main deposits, which are also actively mined, occur along the Orange River and the Buffels River beds.

Another general feature of the geology of the diamond deposits is that they are covered by thick sediments. This dictates the nature of the mining operations.

The geology of the diamond deposits is described further in Chapter 3.

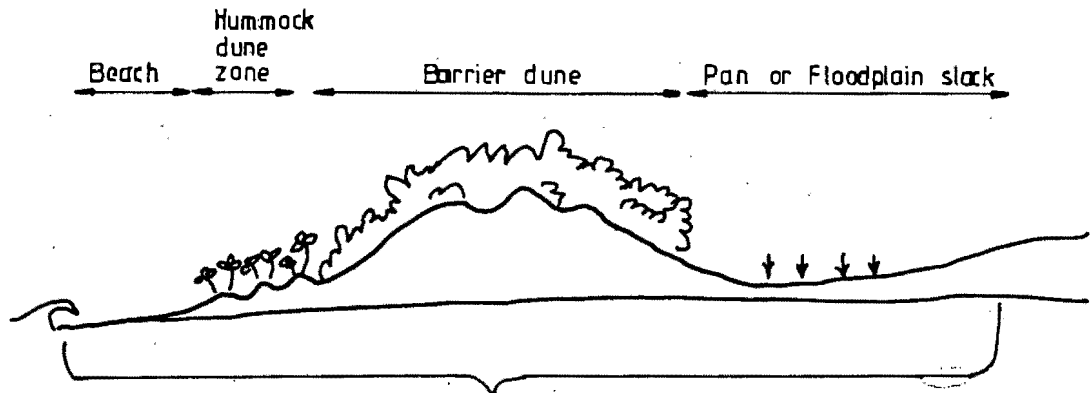
### 2.2.3 VULNERABILITY OF THE COASTAL FORELAND

Heydorn and Tinley (1980), in an investigation of the dynamic processes of shoreline development show the West Coast to be predominantly subject to erosion. A summary of their account follows:

The greater part of the West Coast foreland consists of plant-covered dunes, which are constantly eroded by undercutting of wave action and blowouts by wind. This foreland is therefore highly vulnerable to any factor which disturbs the vegetation cover. Clearings made for buildings or road construction, or even footpaths can cause blowouts or initiate dune slumping by opening fresh surfaces for wind erosion.

Despite their vulnerability to disturbance, sand coasts have a high durability afforded by their malleability, i.e. their ability to

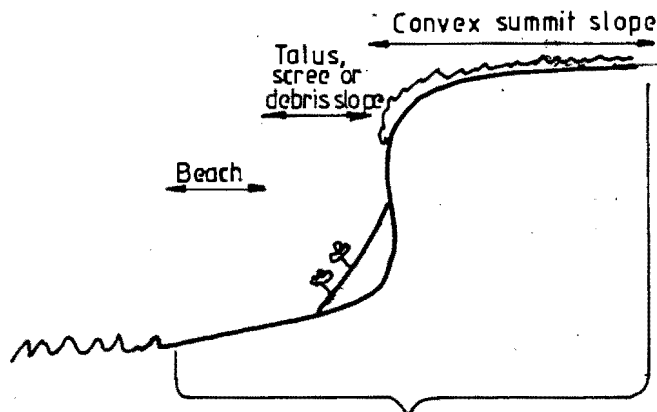
## BARRIER DUNE WITH SLACK :



### Intrinsically unstable area :

Highly vulnerable to damage by human activities. Under natural conditions fixing plant cover grows & retreats in face of cut & fill processes by wind & water.

## CLIFFED COAST WITH BEACH :



### Intrinsically unstable area :

Highly vulnerable to the elements and to damage by human activities, which either accelerate the natural erosional processes or initiate new ones.

Source : Adapted from Heydorn & Tinley (1980)

FIG. 2.1 : Vulnerability of the coastal foreland.

advance or retreat with changes in intensity of the element. Beside natural vegetation the sandy coastline is maintained by beaches, which buffer the land against wave action. In turn, beaches depend on sources of sand to maintain their profile of equilibrium and cutting off of sediment sources can result in erosion of the shoreline.

Any human interference to unconsolidated sediments stabilized by plants, be this on dunes or in estuaries, must take care not to destroy the stability which is imparted by the malleability of their response to erosive forces. Heydorn and Tinley therefore recommend to avoid a number of land uses in the intrinsically unstable area of the foreland (Fig. 2.1). For instance, permanent structures and main roads should be built above this zone and access to beaches should be at the most stable or sheltered sites. Yet, mining actions, such as prospecting trenches and roads often extend into this zone.

Steep foreland coasts and estuaries also have intrinsically unstable zones. A dune-type foreland generally found on the West Coast and steep foreland coast-type with cliffs, which is found north of the Olifants River is shown in Fig. 2.1.

#### 2.2.4 SOILS

Von Harmse (1978) broadly classified soils along a coastal tract from the Orange River to well south of the Olifants River, as sandy soils (aeranosols) and loose littoral sands. Soils further away from the

coast were classified as weakly developed soils of arid regions and lithosols: Calcareous sands and loams mainly overlying calcrete, with sandy and clayey sediments. Soils often contain free lime and gypsum in areas where rainfall is less than 300 mm. Van der Merwe (1962) also mentions saline and alkaline soils in this region. These sandy soils are of various colours which relate to their origin and subsequent environmental history (Heydorn & Tinley, 1980). In general, dunes along the West Coast are light coloured, white to grey but become progressively redder away from the coast (Hallam, 1964).

All arid soils of the world are subject to active processes of salt accumulation (Kovda *et al.*, 1979). Soil samples taken by the author along the West Coast between Kleinsee and Alexander Bay revealed high alkaline and saline soil characteristics (Appendix D). Although indigenous vegetation appears to have adapted to these alkaline and saline soil characteristics, these conditions impose an additional stress on plants besides the arid climatic stresses.

The existence of definite soil horizons does not seem to be generally appreciated. Studies of soils in arid lands elsewhere have shown clear profile structures with important biochemical activity in shallow surface layers. In the top 5 - 10 cm micro-organisms play a large part in the cycling of organic matter and nitrogen (Evenari, 1979). In the United States investigations have shown a sharp difference between the biochemical activity in the surface soil horizon and in the rest of the arid soil mass (Kovda, 1979).

Further, it is not often realized that desert soil profiles, although shallow, are very fragile and take many years to form. In a study of the recovery of soils and vegetation in the Mojave desert, U.S.A., Webb and Wilshire (1980) report recovery times for soil of the order of a century.

## 2.2.5 CLIMATE

### 2.2.5.1 General

Climatically the West Coast south of the Orange River and north of the Olifants River has been classified as a southern subregion of the Namib Desert, transitional to the temperate Mediterranean region of the southwest coast (Wellington, 1955). It is a Mediterranean desert, receiving rain in winter and frequent fog throughout the year (Schulze, 1965, 1978).

The subtropical belt of high pressure cells exerts a dominant influence on the climate: the stable south Atlantic anticyclone lies close to the West Coast, generally centered over latitude 30°S. It shifts equatorward in winter and poleward in summer. It causes persistent subsidence, divergent windflow and consequent aridity (Van Zinderen Bakker, 1976). In summer a subsidiary anticyclone frequently lies south of Cape Agulhas (35°S) causing the sequence of southerly winds, upwelling, fog and aridity along the west coast. The presence of a low pressure cell travelling south over the West Coast during summer

increases the pressure gradient at the coast and powerful winds result. (Van Zinderen Bakker in Rogers, 1977, p.59). Coastal lows are an important feature of the Cape Coast, appearing five to six times a month. They are shallow, weak circulation patterns but show sharp changes in wind direction, temperature and relative humidity, and bring light intermittent rains (Tyson, in Heydorn & Tinley, 1980). In winter the anticyclonic cells shift northward and the southwestern and southern coasts are brought under the influence of successions of east-moving cyclones. This cyclonic winter rain is precipitated orographically on the Western Cape mountains and on the Great Escarpment as far north as the Orange River, where it falls as a gentle drizzle (De Villiers & Söhnge, in Rogers, 1977).

#### 2.2.5.2 Radiation

In summer the Namaqualand coast experiences high radiation values with Alexander Bay recording one of the highest values for a coastal region in the world (Drummond & Vowinkel, in Heydorn & Tinley, 1980). Here maximum radiation densities of  $290 \times 10^5 \text{ J. m}^{-2} \text{ day}^{-1}$  occur. The high radiation values are due to general clear skies caused by the extremely dry subsiding air of the anticyclone over the South Atlantic Ocean (Schulze, 1978). In winter radiation flux densities increase to  $140 \times 10^5 \text{ J. m}^{-2} \text{ day}^{-1}$  along the West Coast. Sea fogs are responsible for radiation density isolines being curved parallel to the Namib Coast from near Port Nolloth (Heydorn & Tinley, 1980).

### 2.2.5.3 Temperature

The Namaqualand Coast is the coolest section of South African shores. The relatively cool conditions along the coast throughout the year are in marked contrast to the very hot and dry inland region. Port Nolloth shows the lowest mean annual temperature of 14,1°C at the land-sea junction (Heydorn & Tinley, 1980). Schulze (1978) shows a mean annual temperature range of 8 - 10°C for most of the West Coast. Port Nolloth exhibits the third highest annual temperature range for the South African coast. Heydorn and Tinley (1980) ascribe this to frequent Berg winds, bringing hot and dry conditions to the coast. Berg winds are extremely hot and dry winds which have their origin in subsiding air masses blowing seaward from the interior. They can bring an increase in temperature of over 10°C day or night followed by a drop in temperature of more than 15°C with the arrival of a cold front. In South Africa Berg winds occur most frequently on the West Coast, about 50 times per year (Tyson, in Heydorn & Tinley, 1980). An unusual incident of a gale-force Berg wind was recorded on a Meteosat satellite photo on 13 June 1979, showing dust carried over 500 km seawards in the vicinity of Orange River mouth (Heydorn & Tinley, 1980).

Frosts occur rarely on the coastal belt. At Port Nolloth an absolute minimum of -0,6°C has been recorded (Weather Bureau, in Heydorn & Tinley, 1980).

#### 2.2.5.4 Precipitation

Rainfall along the coastal belt is low. Schulze (1965) gives a mean annual rainfall of 53 mm for Alexander Bay and 59 mm for Port Nolloth. Rainfall recordings by DBCM show an annual average of 72 mm for Kleinsee from 1970 to 1980. Rainfall tends to increase towards the south. No reliable rainfall figures were obtainable for the coastal belt south of Kleinsee up to Verlorenvlei (32°S). At Verlorenvlei the average rainfall is 275 mm (Lane, 1980).

Besides being low, the rainfall is highly erratic. Leistner (1979) says that the variability of rainfall on the West Coast attains a maximum of 80% and that single showers can account for as much as the normal annual rainfall.

In a 64 year period of observation Port Nolloth received an annual minimum of 12,7 mm and an annual maximum of 158,5 mm (Weather Bureau, 1950).

Yet despite low rainfall the West Coast belt experiences significant amounts of fog. Heydorn & Tinley (1980) give the following account: Fog develops when the South Atlantic anticyclone off the coast advects warm moist oceanic air across the cold Benguela Current. This results in the cooling of air and resultant condensation of moisture in the form of low stratus fog or drizzle. Fog is also usually associated with the longshore movement of coastal lows after cold water upwelling has occurred. Again warm moist air entrained by the

lows is cooled and condensed when flowing across cold inshore waters. The West Coast has the highest frequency of fog in South Africa. Port Nolloth experiences a long-term mean of 146 days of fog per annum.

Fog is a significant source of moisture for the coastal vegetation. Wellington (1955), Schulze (1965) and Leistner (1979) say that coastal vegetation thrives largely due to condensation from low cloud and fog. Schulze (1978) reviews the importance of fog in South Africa as an ecological agent. He points out that considerable amounts of moisture due to fog are not recorded by conventional rainfall gauges despite being intercepted and utilised by vegetation cover. Systematic fog precipitation measurements undertaken by Nagel (1962) at Swakopmund give an indication of the severe miscalculations that could result if conventionally recorded rainfall figures are taken as total precipitation values. Nagel cites 121 fog days per annum with the amount intercepted in 1958 equivalent to 130 mm of rainfall. This is almost seven times the recorded annual rainfall. This illustrates that there is more moisture available to plants than is apparent from rainfall figures. Nagel estimates fog precipitation between the sea and longitude 20°E, at latitude 32°S, to be 300 mm per annum.

#### 2.2.5.5 Winds

Figure 2.2 shows that in summer the West Coast is dominated by strong southerly surface winds. In winter, winds are less strong and Alexander Bay experiences a sea breeze - land breeze pattern with prevailing winds blowing at right angles to the coast (Heydorn & Tinley,

1980). Summer winds along the coast are unimodal. Figure 2.3 shows this, particularly for Alexander Bay. Also apparent is the diurnal increase in wind strength in the afternoon.

Parts of the west coast of southern Africa are possibly the windiest in the world. Rogers (1977) closely examined the wind regime in the coastal region 25°S to 30°S. It is worthwhile to pay particular attention to his data and results, because it is important to realize (a) that the winds are exceptionally strong, and (b) that the strong winds have serious consequences for land disturbed by mining. Large tracts of vegetated land are subjected to sandblasting from destabilized land surfaces, and in turn become destabilized themselves. This impact is discussed in more detail in Chapter 4.

Rogers constructed wind roses for seven coastal and near-coastal localities (Fig. 2.2). He then analysed his wind data following a procedure developed by the U.S. Geological Survey. By this procedure it is possible to calculate the potential for wind to transport sand. Thus the amount of sand drift is obtained by calculating the drift potential for each wind direction. By resolving the drift potential (DP) into x- and y-components, the resultant drift potential (RDP) and resultant drift direction (RDD) are calculated and the ratio RDP/RDD is a measure of the constancy of wind direction. Results of this analysis are shown in Table 2.4.

From annual drift potentials for each direction and the annual resultant drift potential Rogers constructed annual sand roses (Fig. 2.5).

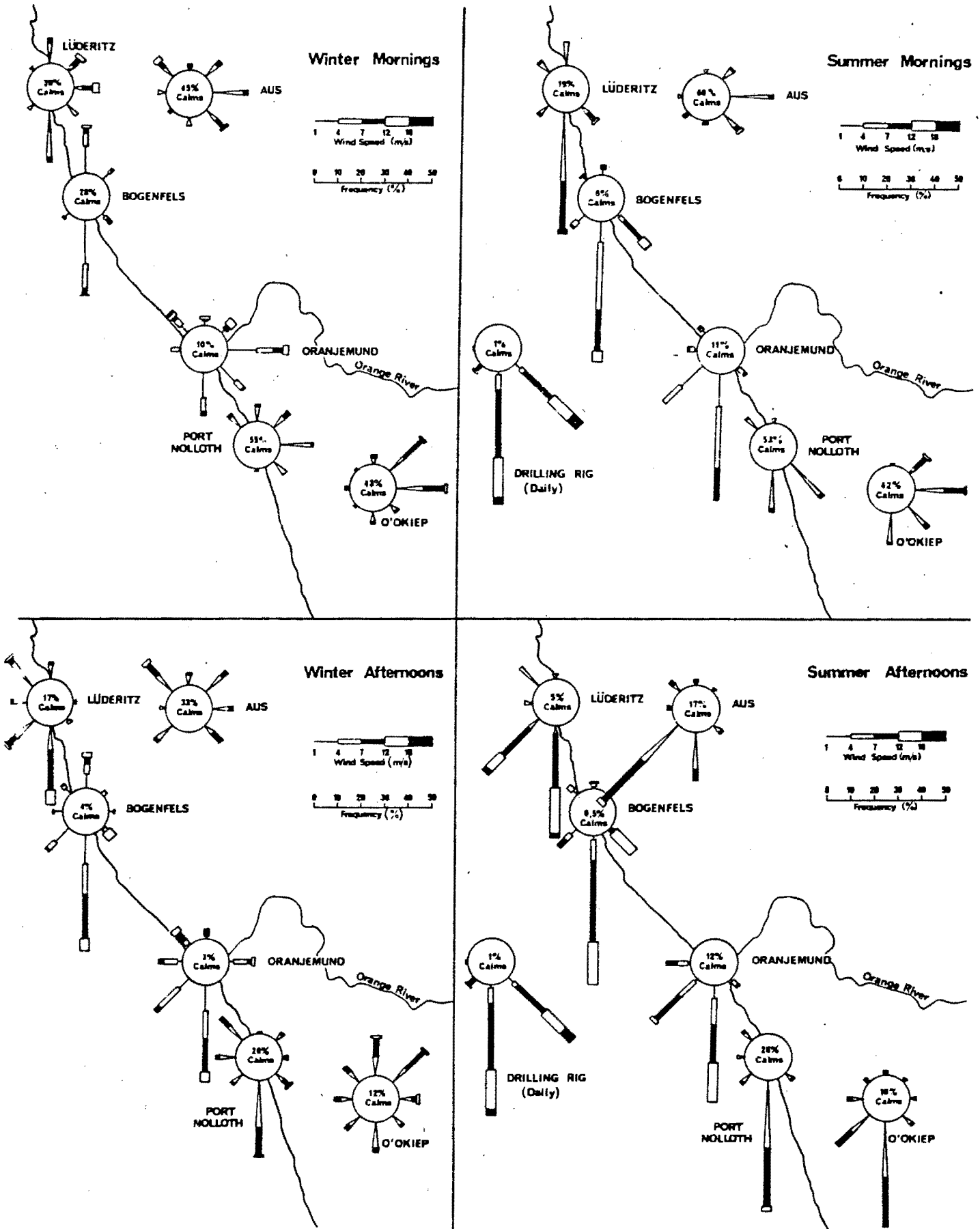


Fig. 2.2 Wind roses.  
Source: Rogers (1977)

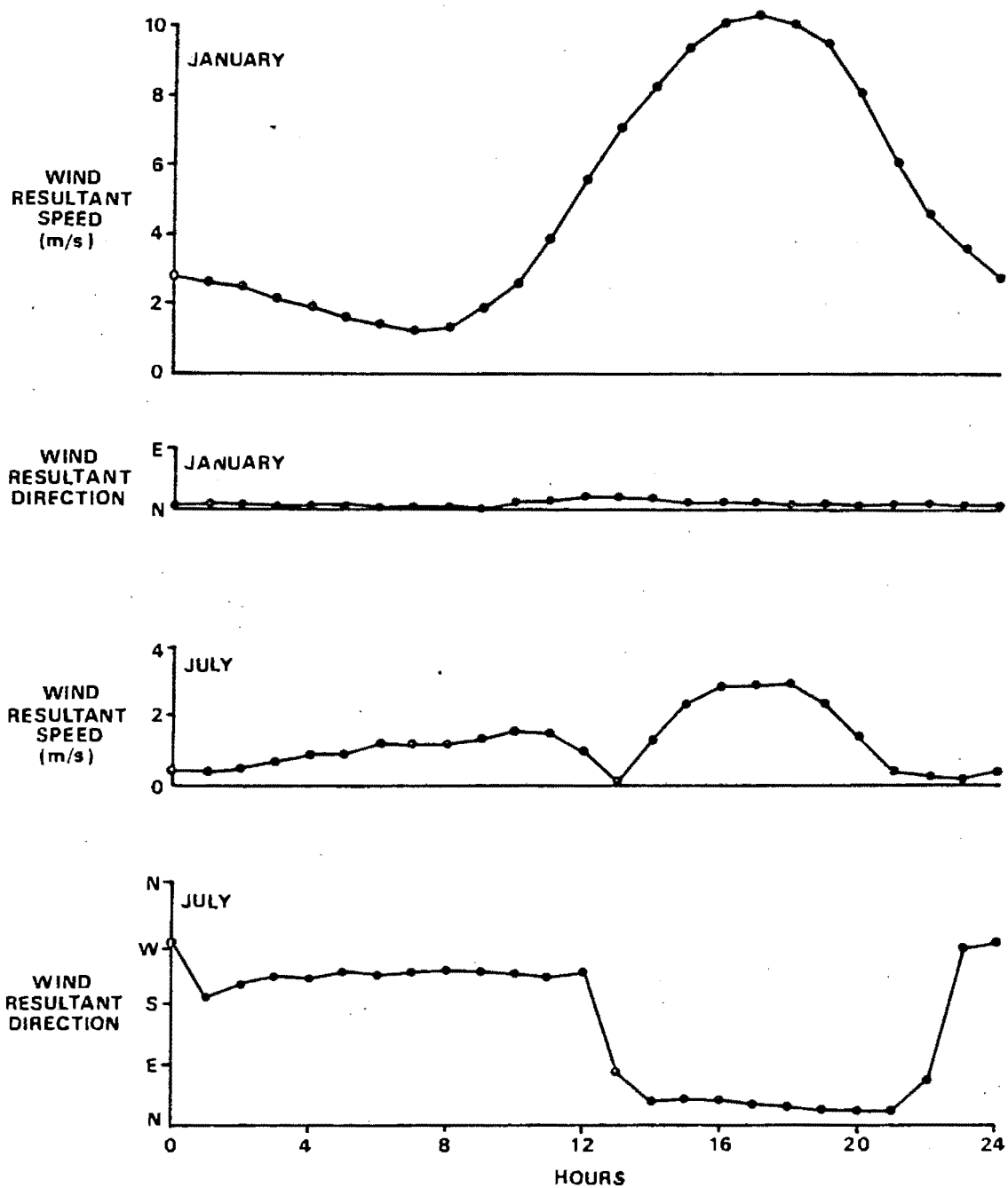


Fig. 2.3 Diurnal variation of speed and direction of wind resultants at Alexander Bay.

Source: Schulze in Rogers (1977).

TABLE 2.4 Annual wind parameters along the west coast of southern Africa

	Drift Potential (DP) vector for units	Resultant Drift Potential (RDP) vector units	RDP/DP	Resultant Drift Direction (RDD)	Sand-rose Classification
Walvis Bay (Pelican Point)	492 (high energy)	456	0,93 (Constant)	30,8°	Narrow unimodal
Pomona	2823 (high energy)	2731	0,97 (Constant)	347,7°	Narrow unimodal
Bogenfels	2252 (high energy)	2065	0,92 (Constant)	342,3°	Narrow unimodal
Alexander Bay	2346 (high energy)	1990	0,85 (Constant)	355,2°	Wide unimodal
Cape Town (Wingfield)	653 (high energy)	618	0,95 (Constant)	1,1°	Narrow unimodal
Rain-bearing winds excluded					

Source: Rogers (1977)

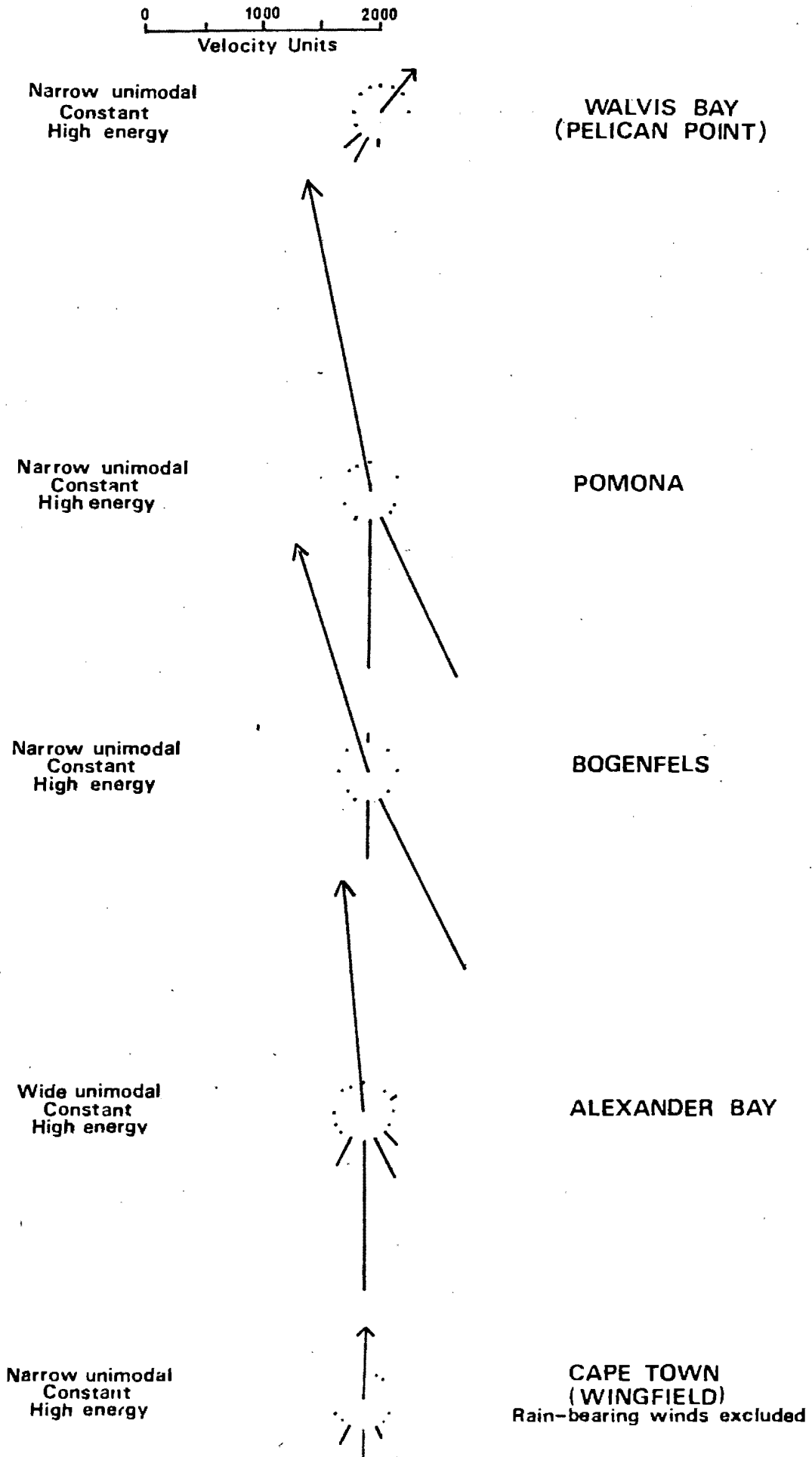


Fig. 2.5 Annual sand roses Cape Town to Walvis Bay.

Source: Rogers (1977)

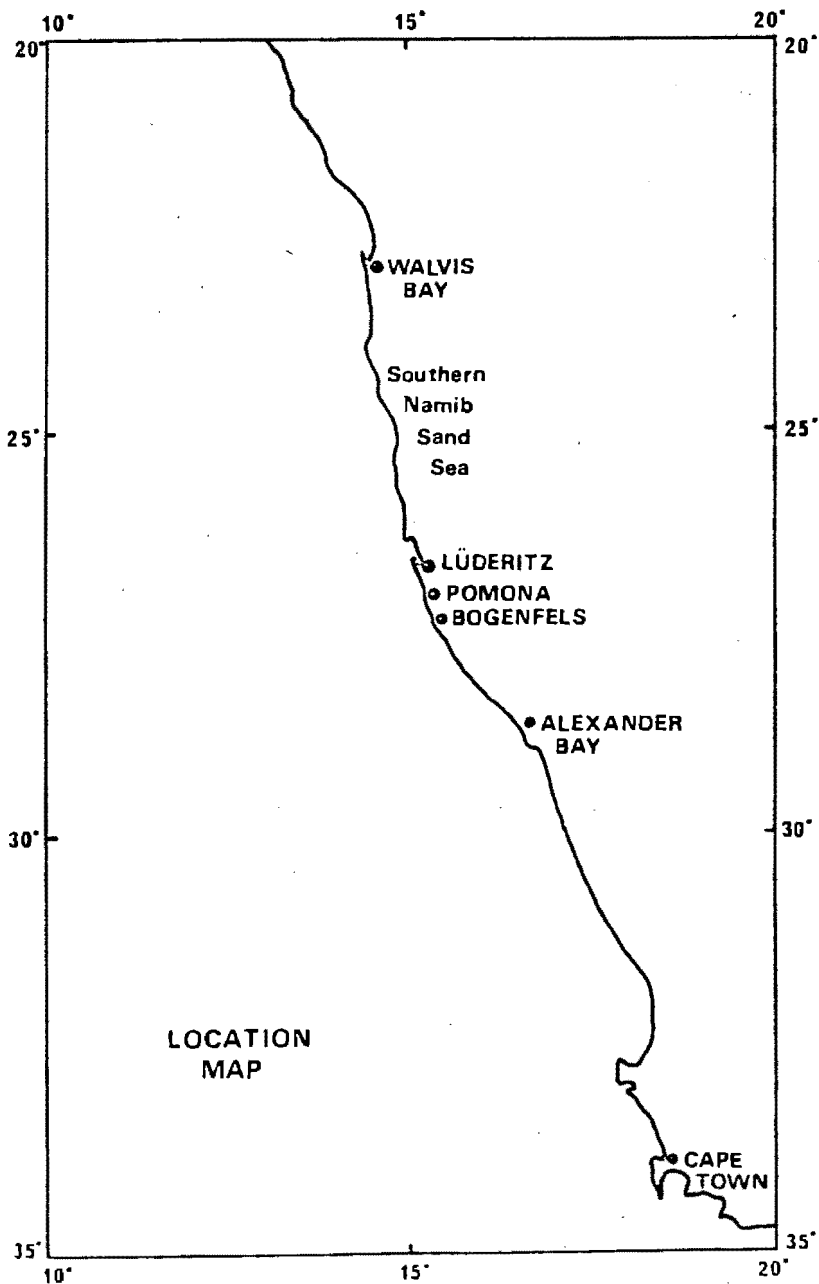
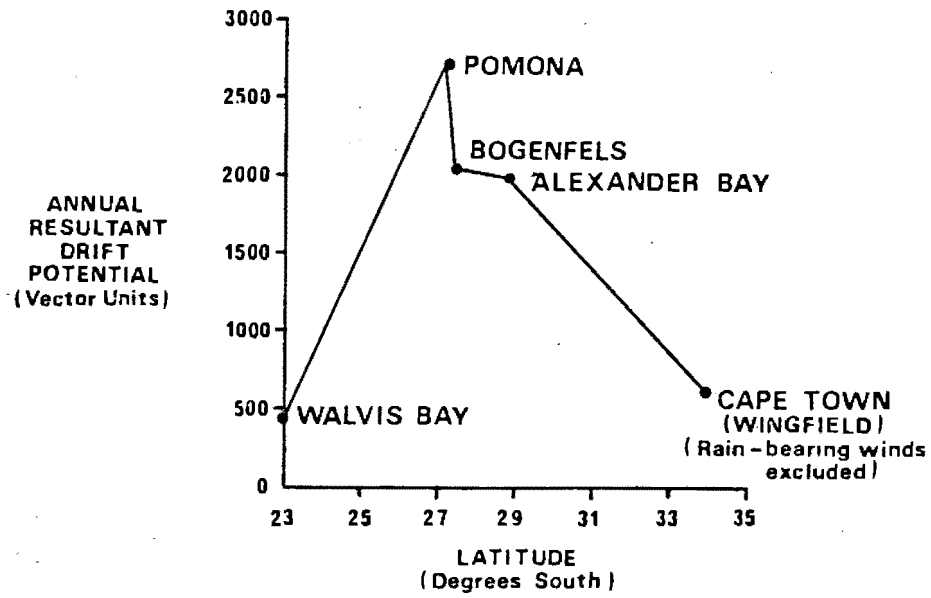


Fig. 2.6 Latitudinal variation in annual resultant drift potential Cape Town to Walvis Bay.

Source: Rogers (1977)

The wind regime along the West Coast is of high energy and constant direction. Rogers states that Pomona seems to have the highest recorded RDP of any coast in the world. Here the calculated RDP reaches a maximum of 2731 vector units. The resultant drift potential decreases northwards and southwards from Pomona (Fig. 2.6). Alexander Bay has a calculated RDP of 2065 vector units (vu). This is more than three times the value for Cape Town with 618 vu, though for the latter rainbearing cyclonic winds were excluded. It is thus apparent that the coast south of Alexander Bay is subjected to exceptionally strong (unidirectional) winds (in summer), highly capable of transporting sand.

Rogers' calculations appear to be well borne out in practice:

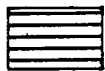
- a) The dune plumes to the north of many Namaqualand rivers (described in section 2.2.1) have dunes of barchanoid form typical of unidirectional winds. It also appears that the dune plumes derive their sand sources from exposed beach areas at and north of the river mouths.
- b) Prospecting trenches and other land disturbances by diamond mining activity show distinctive sand plumes to the north of the actual excavation and related overburden dumps. This evidence is particularly clear on aerial photographs of prospecting trenches to the north of Port Nolloth (Aerial Photographs, Trig. Survey, Job 763, No's 7408-7412 & Job 812 No's 5257-5265) (Also see photos 4D, 4E).

## 2.2.6 VEGETATION

According to Werger's (1978a) phytogeographical subdivision of southern Africa, the West Coast vegetation belt falls wholly into the Western Cape Domain except for a short 30 km stretch of coastline south of Alexander Bay, which represents an intrusion of the Namib Domain. Both domains are part of the Karoo-Namib Region. Acocks (1975) further distinguishes a number of veld types within this region, of which the Strandveld and Succulent Karoo are of interest here (Fig. 2.7). The Strandveld stretches as a narrow corridor along the west coast from the Orange River to south of the Olifants River. The Succulent Karoo forms a long belt between the Strandveld of the coast and the mountains of the escarpment in Namaqualand. The narrow Hummock Dune Zone (Fig. 2.1) is recognized as a further, although discontinuous, biome along the coastline (Heydorn & Tinley, 1980). Boucher and Le Roux (1981) recognize three distinct Strand vegetation communities in this zone (Fig. 2.7). Locally the approximately 30 km wide coastal belt from the Orange River to the Olifants River is known as the Sandveld.

Acocks (1975) describes the vegetation of the West Coast as "open, semi-succulent scrub of Fynbos form and intermediate between the Coastal Fynbos and the Succulent Karoo". Werger (1978b) says that succulent dwarf scrub formations are characteristic of the Western Cape Domain and that grasses are rare there. He also asserts that the Strandveld has strong affinities with fynbos communities particularly at its southern boundary where rainfall is 250 mm or

LEGEND :



ACOCKS VELDTYPE NO. 34 :  
STRANDVELD PROPER



ACOCKS VELDTYPE NO. 31 :  
SUCCULENT KAROO



STRAND VEGETATION  
ALONG THE SHORELINE  
ACCORDING TO BOUCHER  
& LE ROUX (1981)

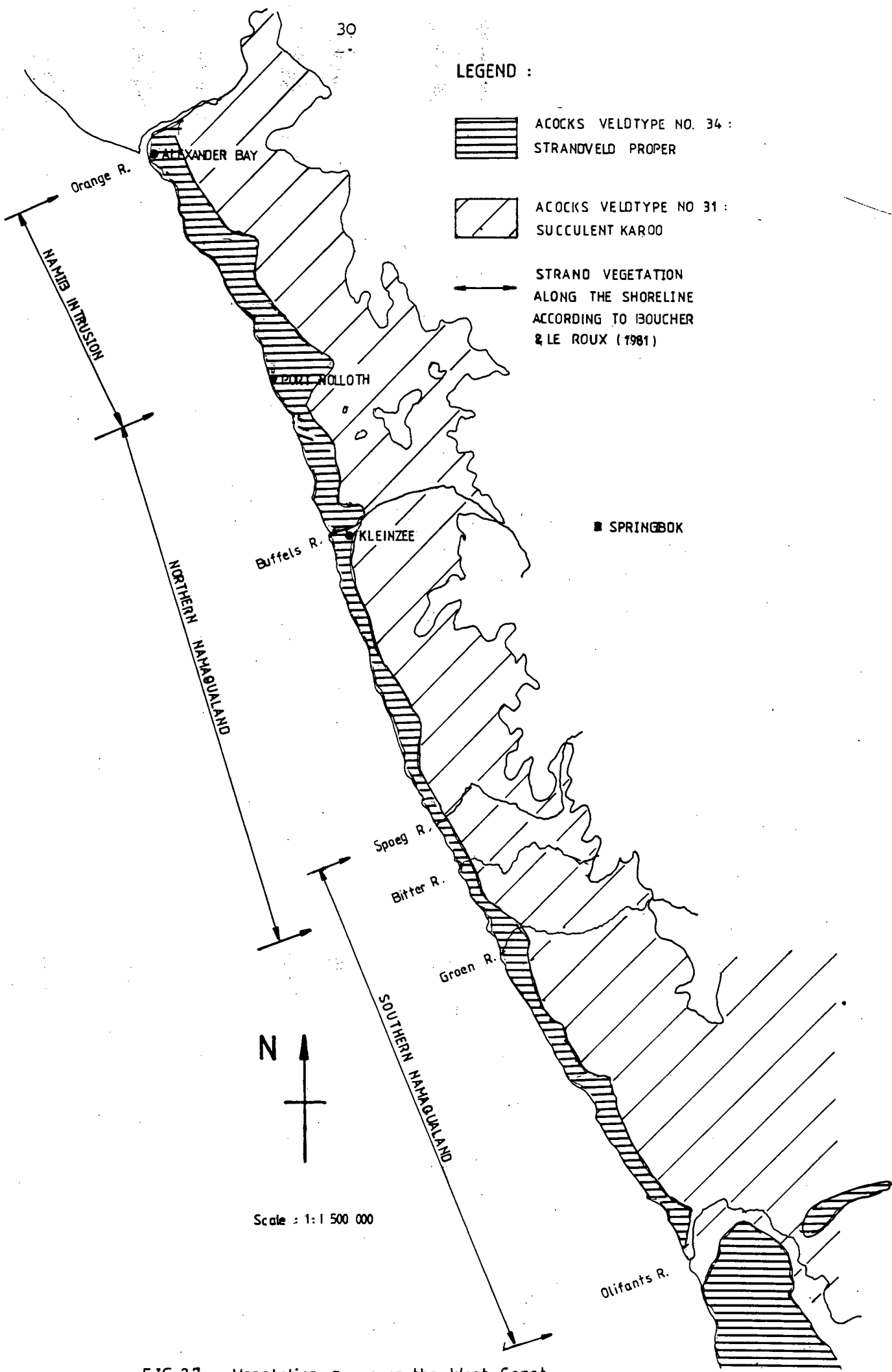


FIG. 2.7 : Vegetation zones on the West Coast

more. Further north the succulent element increases and there is a gradual transition into the Succulent Karoo to the east.

The low and erratic rainfall of this region has been discussed in section 2.2.5.4. The climate has led to adaptations of the plants for survival during moist winters and dry, hot summers. Werger (1978b) states that the variability of the rainfall is as important to plant life as the amount of precipitation. Plants are adapted to unreliable water conditions by having complex mechanisms of germination, seed longevity and diversification. Adaptation to the dry climate is also expressed in various forms of succulence as well as other forms of xerophytism such as narrow or dissected leaves, sclerophylly and leaflessness for prolonged periods of the year. Ephemerality is another adaptation. Annuals evade the dry summer period by quickly germinating, growing, flowering and setting seed during the moist winter and spring. They then die off and survive the dry period in the form of seed (Le Roux & Schelpe, 1981). These annuals give rise to the popular spectacle of the "Namaqua Daisies". Namaqualand wild flowers are, however, not as prolific on the coast as in the interior.

Plants are also adapted to wind-blown and shifting sands, e.g. "The cushion form of dwarf shrubs, a cespitose shrubby form in grasses, and the development of a life form, transitional between hemipterophytes and geophytes, which either possess underground storage organs or a marked ability to form suckers" (Werger, 1978b).

In the Littoral Dune Zone the strand plants have to contend with salt

spray, strong onshore winds and drift sand. This narrow zone is thus a naturally fragile ecosystem and therefore easily disturbed and destroyed (Taylor, 1978). Heydorn and Tinley (1980) state that the strand plants fluctuate with phases of accretion (dune building) followed by wave erosion during onshore gales, storm surges or equinoctial tides.

The importance of fog in supplementing moisture from rainfall has been pointed out in sections 2.2.5.4 and most authors recognize its influence on vegetation along the West Coast (Wellington, 1955; Schulze, 1965; Schulze & McGee, 1978; Leistner, 1979).

Soil substrate obviously plays a significant role in plant growth. Unfortunately no detailed study of vegetation or soil has yet been undertaken along the West Coast. Adaptations and the degree of tolerance of vegetation of the Strandveld or Succulent Karoo to alkaline and saline soil conditions are thus largely unknown. Such conditions are, however, known to be characteristic of desert and semi-desert environments (Kovda *et al.*, 1979).

Boucher and Jarman (1972) in their study of vegetation of the Langebaan area, which is broadly classified by Acocks as West Coast Strandveld, though it receives more than 250 mm of rain per annum, encountered alkaline soil conditions with pH's approaching 7,30. Selective soil samples taken by the author from the Kleinzee and Alexander Bay areas showed highly alkaline characteristics with pH's exceeding 8 and approaching 9 (Appendix D). Coastal vegetation of

the West Coast thus appears to be adapted to alkaline soil conditions.

#### 2.2.7 FAUNA

Information on terrestrial fauna of the West Coast environment is very scant. Hardly any research or studies have been conducted.

The Estuarine Coastal Research Unit (ECRU) has undertaken brief surveys of the West Coast estuaries. Assuming that most bird and mammalian life along the West Coast would concentrate at open estuarine and riverine water bodies, information from the ECRU reports should give a fair reflection of fauna that can be found on the West Coast.

Heydorn and Grindley (1981) report 53 bird species sighted at the Buffels River, 36 at the Spoeg River, 52 at the Groen River and 13 at the Swartlintjies River. There are at least seven local races of terrestrial birds found only on the West Coast.

Counts of migratory water birds in 1980 indicate that the Groen is an important resting or feeding ground. It is likely that many individual birds survive migration because of the Groen; it is situated midway between major bird areas on the West Coast and is the only permanent water body on this stretch of coast (J. Cooper, in Stauth, 1982).

Heydorn and Grindley report sightings of 16 different mammal species

on the West Coast. One species of mammal is endemic to the West Coast.

Seven species or subspecies of lizards are probably coastal endemics and one species of frog is a coastal endemic (J. Greig, in Heydorn & Grindley, 1981).

#### 2.2.8 RIVERS AND ESTUARIES

The Orange and the Olifants are the only perennially flowing rivers in this study area. The other rivers have episodic flow. The following, in order from north to south, reach the coast: Holgat, Kamma, Buffels, Swartlintjies, Spoeg, Bitter, Groen, Brak and Sout Rivers.

The Buffels River has a large subterranean aquifer at its mouth which is used to supply fresh water to the Kleinzee township. The Spoeg River is believed to have an underground aquifer as well (Heydorn & Grindley, 1981). The Kamma River is thought to have been dry for a considerable period of time. Boreholes sunk in the valley have, however, struck water of fair quality (Keyser, 1972). The Brak and Spoeg Rivers, as their names suggest, are rivers of the brak water type, i.e. calcareous or saline alkaline waters with a pH 7,5 (Heydorn & Tinley, 1980). The Buffels, Spoeg, Bitter and Groen Rivers had surface water pools or lagoons at their mouths, according to an ECRU survey, in 1980.

Estuaries are unique environments in that water and sediments of terrestrial and marine origin mix at the land-sea junction to create conditions which are entirely different to those on land or in the sea. The biological response to this situation is in the form of an exceptional diversity of habitats, animals and plants. Moreover, most estuaries are also of great aesthetic value. Although the West Coast estuaries, with the exception of the Orange and the Olifants, have closed river mouths and have relatively small surface water areas, they are of great ecological importance as wetland habitats in an otherwise arid environment. Besides the Orange and the Olifants, the Buffels, Groen and Spoeg are the most important estuaries along the West Coast as they always contain some water and therefore support an abundance of diverse birds and mammals (2.2.6). The Holgat, Swartlintjies and Bitter Rivers are not true estuaries but, when they do contain water, are important short-term habitats for water birds (Heydorn & Grindley, 1981).

#### 2.2.9 GROUND WATER

As mentioned in section 2.2.8, subterranean aquifers are associated with the Buffels River and possibly the Spoeg River, but subterranean water also occurs all along the coast. Keyser (1972) reports that on the State Alluvial Diggings water was struck in most boreholes reaching the floors of large subsurface depressions. These boreholes were drilled at regular intervals all along the coast up to 3 km inland (see Chapter 3). In the West Coast environment with deep

surface sands it is likely that water collects underground in lenses above bedrock depressions. The township Koingnaas obtains fresh water from such an underground water body. Most pans have a water-table very close to the surface, but such water is of poor quality (Keyser, 1972).

#### 2.2.10 MARINE ENVIRONMENT

The following brief account of the marine environment of the West Coast is summarised from Brown and Jarman (1978).

The marine environment of the coast between the Orange and the Olifants Rivers falls into the marine province of southern Africa called the cold-temperate west coast. A characteristic feature of this environment is the remarkable degree of upwelling caused by the movement of water bodies in the Benguela Current system and by off-shore winds. In this process surface water from the coast is replaced by cold, nutrient-rich central Atlantic water. This water supplies the nutrients for rich phytoplankton communities which provide the primary production level of a trophic structure, which is exploited by a major fishing industry.

The intertidal and shallow water fauna of the West Coast relative to other marine provinces shows little diversity, but a great abundance of a few species. Thus the black mussel *Choromytilus meridionalis* is prolific on rocks in sandy areas, while *Aulacomya ater* is abundant

in less sandy conditions. These two species of mussel form the staple diet of the lobster *Jasus lalandii*, which is of great commercial importance. *Jasus* does not occur in deeper water as here the substratum frequently consists of anoxic barren mud, believed to result from the death of extensive plankton blooms.

The intertidal zone is subject to battering by particularly powerful waves causing stress to benthic organisms and plants. The water movement may, however, play an important part in the functioning of the plants, and plants and animals may have adapted to the wave action. Thus sandy beaches show a great number of mobile forms capable of living under the stress of extreme wave action and unstable beach conditions. The harshness of the intertidal zone is also alleviated by frequent fog throughout the year.

Another feature of the West Coast are the abundant kelp beds consisting mainly of *Laminaria*.

## 2.3 THE SOCIO-ECONOMIC ENVIRONMENT

### 2.3.1 ARCHAEOLOGICAL AND HISTORIC SITES

There are strandloper middens in the dune plume north of the Groen River and there are probably further deposits in other parts of the region. Archaeological sites between Eland's Bay and the Orange

River have not yet been investigated, but have significant potential for extending knowledge as prehistoric peoples who inhabited this part of the coast lived differently to other peoples farther south (Stauth, 1982).

Near the Spoeg River there are the remnants of the first police station in Namaqualand (Dept of Water Affairs, Forestry & Environmental Conservation, 1981). The author also found signs of early diamond diggings on the farm Oubeep north of Kleinzee and near the Boegoeberg south of Alexander Bay.

### 2.3.2 PRESENT POPULATION

The West Coast and its inland region is sparsely populated with a density of less than 4 per km<sup>2</sup> (Zietsman & Van der Merwe, 1981). There is no rural population on the coastal belt as practically that entire region has been leased for diamond mining and prospecting and, as such, is controlled as a security area which is not open to the public. The towns Alexander Bay, Kleinzee and Koingnaas are exclusively diamond mining towns, inhabited almost entirely by mine employees and their families. Port Nolloth, Hondeklip Bay and Doring Bay are mainly fishing centres. Employees of the smaller diamond mining companies centred at the Olifants River mostly live in Doring Bay and Lutzville but only make up a small fraction of the population of these towns. The 1980 official population census figures give a population total of 63 323 for the district of Namaqualand. The region thus has a

sparse population clustered in small towns associated with mining activity.

### 2.3.3 INFRASTRUCTURE

In a socio-economic investigation of Namaqualand the Prime Minister's Planning Office (1980) found the established infrastructure for the region to be 'fairly adequate'. Further needs were considered to lie in the construction of more and better roads and particularly in the provision of fresh water supplies. The secondary roads link Port Nolloth, Kleinsee and Hondeklip Bay on the coast to the arterial national road in the interior. Besides security restrictions, access to other parts of the coast is made difficult by the lack of proper roads. An exception is the road to the Groen River mouth, a popular camping ground. No rail network feeds the region. The only rail head is at Bitterfontein, far south in the region. Transport of goods is thus mainly by motor trucks. Port Nolloth, with a turnover load of 6400 tons per month, is the smallest commercial harbour in South Africa. It is interesting to note that although the harbour is owned by South African Railways and Harbours, it has been leased for 20 years to Consolidated Diamond Mines, a company mining diamonds in Namibia just north of the Orange River (Office of the Prime Minister, Physical Planning Branch, 1980).

It is striking that the two largest diamond mining enterprises on the West Coast, De Beers Consolidated Mines (DBCM) and the State Alluvial

Diggings (SAD) have developed and are maintaining almost all the infrastructure necessary for their operations. This includes the complete townships of Alexander Bay, Kleinzee and Koingnaas with all ancillary services. Further, SAD maintains the provincial road from Port Nolloth to Alexander Bay and the airport at Alexander Bay, while DBCM has built its own tar road from Kleinzee to Koingnaas as well as the airport outside Kleinzee.

The Electricity Supply Commission (ESCOM) has linked these towns and Port Nolloth to the national power grid, but Hondeklip Bay generates its own electricity.

The supply of water is a shortcoming of the region. Alexander Bay has a plentiful source from the Orange River. Kleinzee, although drawing water from the local Buffels River mouth aquifer has to augment this source with a water pipeline from the Orange River Henkries scheme. Koingnaas obtains water from an underground aquifer, while Hondeklip Bay has to maintain water storage tanks and import water by trucks. Coastal settlements further south around the Olifants River obtain water from that river.

#### 2.3.4 RESOURCE USE

##### 2.3.4.1 Marine Resources

The Benguela system provides a rich fishing ground. Pelagic fishing

takes place off the entire West Coast but the bulk of the catch is brought home from regions south of Lambert's Bay, which is also the only landing point for pelagic fish on the West Coast. Rock lobster is of considerable commercial value. Landing points and processing factories are at Port Nolloth, Hondeklip Bay, Doring Bay and Lambert's Bay. Although rock lobster occurs in shallow water all along the West Coast, half of the total production is processed at Elands Bay. The coast from around Hondeklip Bay to the Orange River is less rich in rock lobster resources than the coast further south. The reason for this is thought to lie in the poor recruitment of juveniles inshore along the Hondeklip Bay coast. The total rock lobster catch of the coast from the Orange River to Elands Bay amounted to about 900 tons, representing an export value of R4,5 million in 1980. (D. Pollack, Dept of Sea Fisheries, pers. comm.).

Seals, guano and kelp are exploited on a minor scale. Colonies of Cape Fur Seals occur in localised colonies along the coast, such as at the Boegoe inselbergs, south of Alexander Bay, and at Seal Island, north of the Olifants River, but only the large colony at Kleinzee is harvested. Returns from skins of baby seals is estimated to have been around R20 000 in 1980 (P. Best, pers. comm.). Guano is obtained from breeding colonies of ganets, cormorants and pelicans. There are three colonies of cormorants at Port Nolloth. Kelp is collected from the beach. In 1980 this amounted to 10 922 wet tons for the entire west coast of South Africa and had a wholesale value of R148 100.

#### 2.3.4.2 Agriculture

Agricultural use of the coastal belt lies chiefly in the grazing of small-stock but the economic yield is low. The present stocking rate is 5 ha per small-stock unit which gives a yield of about R6 per ha p.a. according to Mr Brand, extension officer for the Department of Agriculture and Fisheries in Springbok. On the other hand there is a view by some Namaqualanders that the coastal belt, known locally as the Sandveld, offers better farming conditions than inland regions (Stauth, 1982).

Economic viability of farming is further hindered by the small size of the farms. This has been brought about by the successive subdivision of land when farms were handed down from father to sons over the generations. Mr Brand does not consider the present average size of individually owned farms, which is 3200 ha, to be economically viable. The farms owned by the De Beers mining company are larger, averaging 8000 - 9000 ha. De Beers bought up most of their Namaqualand farms in the 1930s and 1940s (Kotze, 1943). Since then these farms have not been subdivided. Where there is no mining activity, De Beers have leased their land to tenant farmers.

The State Alluvial Diggings run a farming enterprise along the banks of the Orange River, which makes them self-sufficient in fruit, vegetables, dairy products and almost in meat, but their agricultural produce is not exported.

Although agriculture does not appear to be a lucrative resource, it provides employment for a significant section of the Namaqualand population, 18,1% of Whites and 21,0% of Coloureds (Office of the Prime Minister, Physical Planning Branch, 1980).

#### 2.3.4.3. Recreation, Tourism and Nature Conservation

There has been very little development of the West Coast for the purposes of recreation and tourism. Likewise there has been little provision for nature conservation in that area.

Along the entire coastline from Donkins Bay to the Orange River, some 400 km, there are only two small established villages that are functioning as holiday resorts: Strandfontein and McDougall's Bay. At the Groen River and Brak River mouths there are designated camping sites without any facilities. Gert du Toit se Baai, a few kilometres north of the Olifants River, has traditionally been used by the nearby population as a recreation resort. This has, however, brought about conflict with the mining company holding the diamond mining rights for that area.

Apart from these resorts and camping sites the public has practically no access to the coastline. The regions in which mining and prospecting are actively taking place are enclosed by a security fence. Movement of people into and out of these areas is stringently controlled by the mining enterprises, not so much to prevent theft of diamonds by visitors, but to prevent smuggling of diamonds from mine

workings by mine employees. The general public is strictly excluded from these security areas. Regions that are subject to this rigorous control include the stretch of coast from Alexander Bay to Port Nolloth (concession of State Alluvial Diggings) and from McDougall's Bay to south of Kleinsee (mostly concessions of De Beers Consolidated Mines Ltd).

Other areas along the West Coast are not enclosed by security fences but access to the coast for the general public is still virtually impossible. Roads are often rough sandy tracks that are blocked by farm gates. Moreover, legal provisions for the regulation and control of prospecting and mining for precious stones (Act 73 of 1964) empowers the holder of a mining lease to keep out the general public even from areas where no active prospecting or mining is taking place. Mining representatives refer to Section 30 of the Act in this connection. This section stipulates the restrictions as to who may work or reside on an alluvial digging or claim.

Section 123 of the same Act gives the holder of the mining or prospecting lease the further right to search any person and his vehicle on any land for which surface rights are held. Such a search can include the dismantling of the person's vehicle. Naturally such a prospect is prohibitive to any casual visitor or pleasure seeker.

In a 1980 socio-economic investigation of Namaqualand, the Prime Minister's Planning Office indicates that these restrictions prohibit further development of recreation in the region.

Yet although few provisions have been made to allow for recreational activities along the West Coast, the area appears to have remarkable potential for providing such outlets. The most outstanding features of the West Coast are:

(i) The cold but nutrient-rich sea water which supports many sought-after marine organisms including rock lobsters and angling fishes.

(ii) The lagoon and estuarine waters of the coast which support a great deal of fauna, particularly aquatic bird life. Here the Orange, Spoeg, Groen and Olifants rivers are the most important areas and represent viable individual ecosystems. Other smaller areas are the Buffels, Brak and Sout rivers.

(iii) In addition to estuaries there are ecologically important areas where rare plants and animals occur along the coast (Heydorn & Tinley, 1981). For instance, the Boegoeberg is a rich habitat for succulents, the coastal tract between the Spoeg and the Groen carries a variety of vegetation veld types which have remained largely unspoilt and Humewood Bay harbours a small seal colony.

(iv) There are scenic areas too. Much of the coastline shows vivid rock formations which are particularly spectacular at places such as Humewood, Boegoeberg and the Cliffs. The popular seasonal Namaqualand flowers also appear on the coast although not to the same extent as in inland regions.

(v) The West Coast has a wilderness aspect. This characteristic is becoming an increasing attraction for pleasure seekers, and

tourists wishing to find a diversion from congested city life.

Amateur botanists, ornithologists and other nature lovers seek out such areas (Sutton, 1981).

(vi) A coastal setting generally holds an attraction for tourists. Thus Stauth (1982) lists a January 1980 report by Market and Opinion Surveys (Pty) Ltd, called "Final Report on a Tourism Survey for the Department of Tourism", in which a sample of 2200 White households were asked to list their main considerations for choosing a particular holiday area. The most frequently mentioned attraction was "seaside and beaches" (35,2%), followed by "peaceful relaxation" (32,5%), and "natural scenery" (16,4%).

(vii) There are some places of historic interest. Strandloper midden deposits have been found near the Groen River and near the Spoeg River there are the ruins of the first police station post in Namaqualand. The author also found traces of early diamond diggings on the farm Oubeep north of Kleinzee. There is no doubt that the present diamond mine workings would be a great attraction to visitors to the region. Besides interest in the mining process, there are ancillary features worthy of attention. Thus, for instance, the formation of a former coastline with wave-cut cliffs has been uncovered in mining operations south of Alexander Bay. In a 1979 conservation study of the coastal town Lüderitz, which is situated north of the Oranjemund mining operations in Namibia, the School of Architecture of the University of Natal proposed a tourist route from Port Nolloth to Lüderitz. The report concedes that there are problematical aspects of security. If these could be solved the

route would offer "some of the most exciting coastal scenery in the whole of southern Africa". Similar spectacular scenery is to be found between Port Nolloth and Alexander Bay and such a route would provide a stimulating insight into early and present diamond workings.

The Department of Environment Affairs and the National Parks Board have recognized the West Coast as a valuable nature and recreation area and recommended that the section between the Groen and the Spoeg Rivers be proclaimed a national park and marine reserve. This area was considered representative of West Coast ecosystems and is relatively undisturbed. It is also thought to have significant conservation value because veld types found here are not adequately conserved elsewhere, migratory water birds use the Groenrivier lagoon as a resting place, several of Namaqualand's endemic species could be afforded a measure of protection with the proclamation of a park, and there are potentially valuable archaeological sites in the area (Stauth, 1982). The proposed national park, however, has not materialised because of opposition by the mining parties who wish to maintain their options on mining the area in question, although no such plans are envisaged at the moment.

It appears that a demand for recreational outlets on the West Coast already exists. The small Groen River mouth camping site receives about 300 visitors every year, mainly from the local area (Stauth, 1982). McDougall Bay is visited by holiday makers from Namaqualand, southern Namibia, Upington and even from as far afield as the Transvaal and Natal (Office of the Prime Minister, Physical Planning

Branch, 1980). At Gert du Toit se Baai a conflict has developed between holiday makers and a diamond mining company. The mining company intends to mine a stretch of beach, which has traditionally been used by the local community for weekend outings. Holiday makers are strongly opposed to the mining plan.

A wilderness and arid area, such as the West Coast, holds attractions for many people as experience elsewhere has shown. For example, deserts have become so popular in the United States that the number of parks in desert areas in that country far exceeds that in other geographic regions (Sutton, 1981). Sutton states that the intended functions of such reserves included: (a) preservation of unique segments of the national heritage; (b) protection of flora and fauna; (c) provision of opportunities for outdoor recreation, scientific research and public education; and (d) economic benefits, including tourism.

With the current growth rate in population, leisure time, and disposable income, one also might expect a growing demand for a park on the West Coast which will have the attraction of being situated at the coast as well as in a desert environment. Also, as the managing director of Springbok Atlas Safaris has pointed out, the burgeoning "Coloured" population in the Western Cape is becoming more affluent and will be seeking holiday sites (Stauth, 1982).

2.3.4.4 Mining

The 1980 report of the Planning Region of Namaqualand by the Physical Planning Branch of the Office of the Prime Minister, "Streek 1, in sosio-ekonomiese ondersoek", shows that mining constitutes a substantial part of the Gross Geographic Product (GGP) of the region.

TABLE 2.8 GGP according to economic sector, 1955-1972 (Planning region 1 of S.A. - Namaqualand). Source: Office of the Prime Minister, Physical Planning Branch, 1980 - adapted from Table 30.

ECONOMIC SECTOR	R MILLION				
	1955	1960	1968	1970	1972
PRIMARY: Agriculture	2,2	2,9	2,2	3,3	4,4
Mining	17,0	17,1	50,5	52,2	56,2
SECONDARY: (Industry, Electricity, Construction)	1,0	1,0	2,1	1,9	1,8
TERTIARY: (Commerce, Trans- port and other services)	3,9	6,0	4,9	4,7	8,1
TOTAL	24	27	60	62	71

(The figure for "mining" in Table 2.8 comprises mainly copper and diamond mining, which both contributed equal proportions to the GGP in 1970, but by 1976 diamond mines produced R74 million compared to R45 million produced by the copper mines. Table 2.8 reflects the bulk of West Coast diamond production but contributions from smaller mining operations near the Olifants River and marine operations are not included.)

From Table 2.8 it can also be seen that the GGP of Namaqualand increased

in absolute terms in the period 1960 to 1968 largely due to the expansion of mining. This dominance of mining in the economy is continuing at present.

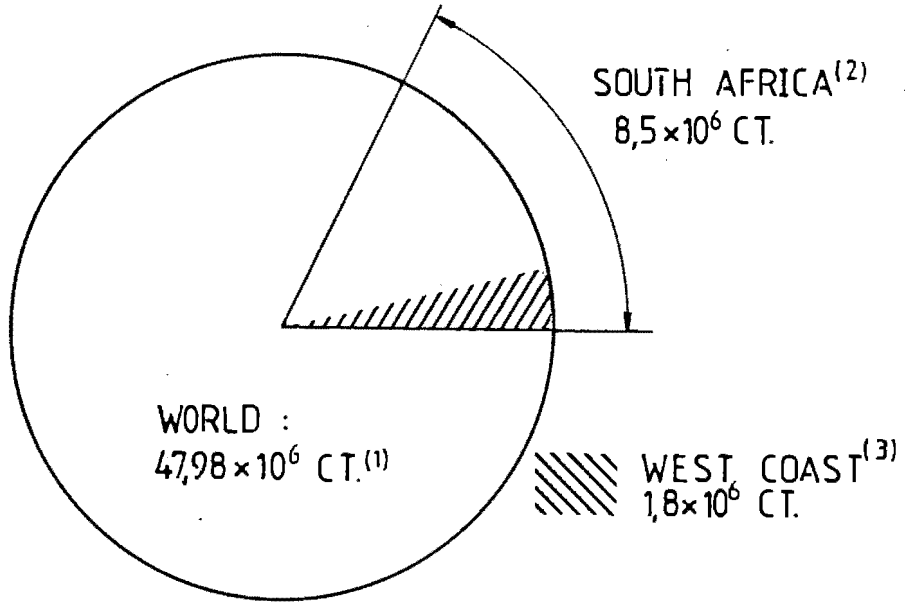
Total diamond production from the West Coast, including all marine, inland and coastal mining, yields substantial sales. Table 2.9 shows that diamond sales amounted to R229 million for the region in 1980.

TABLE 2.9 Diamond sales West Coast, 1975-1980.

YEAR	S A L E S		
	Carats	Rand-Value	Rand/Carat
1975	1 338 573	70 770 657	52,87
1976	1 400 134	94 732 377	67,66
1977	1 363 006	144 108 581	105,73
1978	1 431 814	180 750 806	126,24
1979	1 932 313	265 280 083	137,29
1980	1 638 607	229 622 712	140,13

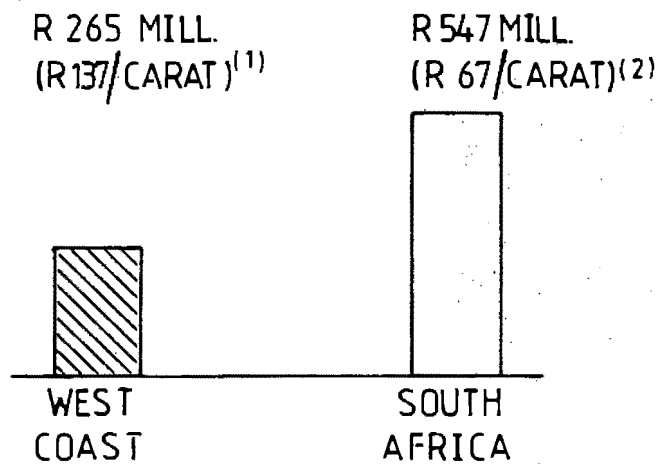
Source of data: Minerals Bureau, Department of Mineral and Energy Affairs, 1981, pers. comm.

Diamond production from the West Coast makes a considerable contribution to the total diamond production of South Africa and the world (Fig. 2.10).



Source of data: (1) *Mining Annual Review*, 1980.  
 (2) Dept of Mineral & Energy Affairs, Annual Report 1980.  
 (3) Minerals Bureau, Dept of Mineral & Energy Affairs, 1981, pers. comm.

Fig. 2.10 West Coast diamond production compared to South Africa and world in 1980.



Source of data: (1) Minerals Bureau, Dept of Mineral & Energy Affairs, 1981, pers. comm.  
 (2) Dept of Mines, Mining Statistics 1979.

Fig. 2.11 Diamond sales of West Coast and South Africa in 1979.

Whereas diamond production from the West Coast amounted to just more than one-fifth of the diamond production of South Africa in 1979, their sales constituted nearly half the income obtained for diamonds in South Africa as a whole. The reason for this lies in the fact that West Coast diamonds are mostly of gem quality, some 98%, and fetch more than twice the average price per carat (Fig. 2.11).

Diamond mining concessions have been granted on land and in the sea along almost the entire coastline of the West Coast. A further detailed description of this diamond mining activity is presented in Chapter 3.

## 2.4 SUMMARY

### 2.4.1 SENSITIVITY OF THE WEST COAST ENVIRONMENT

Cooper and Zedler (1980) determine the sensitivity of an ecosystem according to three factors: (a) significance of the ecosystem, regionally and globally; (b) rarity or abundance; (c) ecosystem resilience.

In this regard the following can be said about the West Coast:

- a. The environment is of regional and global scientific interest in that it boasts three distinct strand vegetation communities and a

coastal vegetation veld type, and a number of species of fauna are only found on the West Coast. Further, the marine environment has been classified as a separate marine province of southern Africa. Also of scientific interest are potential archaeological sites of prehistoric dwellings along the coast.

The marine environment is also of regional commercial significance sustaining mainly a rock lobster and to some extent a pelagic fishing industry. Due to dwindling resources this significance has declined in recent years.

b. Vegetation communities are regionally abundant but are not represented elsewhere. Some terrestrial faunal species and estuarine organisms are regionally rare. Marine organisms are regionally abundant but are globally rare.

c. Resilience or stability has been described by Orian (1975) in a number of terms, three of which are: (i) "Inertia - the ability of a system to resist external perturbations"; (ii) "Elasticity - the speed with which the system returns to its former state following a perturbation"; and (iii) "Amplitude - a system has a high amplitude if it can be considerably displaced from its previous state and still return to it."

Arid land ecosystems have low stability to any external disturbances. Vegetation and soils take a long time to re-establish themselves to their former state, if at all. Thus Sutton (1981) says: "The

fragility of desert ecosystems and their slow recovery from damage renders them especially vulnerable to heavy use". In a study of the recovery rates of soils and vegetation in the Mojave desert, Webb and Wilshire (1980) conclude: "The long recovery times of disturbed soils and vegetation are important factors which must be taken into consideration in land-use planning". And Cloudsley-Thompson (1977) comments: "The natural vegetation of arid regions is of vital importance, because desert conditions swiftly follow if it is destroyed". Thus, in terms of Orian's definitions, arid environments appear to have low elasticity, low inertia and low amplitude.

It is also known that flora and fauna in arid environments have developed special adaptations in order to cope with prevailing harsh climatic conditions but adaptation implies a lowered ability to handle other states or tasks (Orian, 1975). This means that vegetation in arid zones is in a naturally stressed state and vulnerable to additional man-imposed stresses.

As the West Coast is an arid environment these general conclusions of the fragility of such environments also apply here. It has been shown that rainfall in the region is low and erratic, that soils are alkaline and saline, i.e. that the West Coast has the general attributes of arid environments and that consequently vegetation and animals have had to adapt to these natural stresses. Moreover, it has been shown that the West Coast environment imposes additional stresses not normally encountered in deserts. There are exceptionally strong winds in the region which greatly contribute towards the

dangers of erosion. The NNW trend of the coastline exposes the West Coast to these prevailing unimodal southerly winds in summer. The foreland is particularly susceptible to this erosive force.

On the other hand the West Coast has mitigating features, such as a generally cool and temperate climate and significantly frequent fogs. Unconsolidated sediments are stabilized by a plant cover which has allowed limited grazing of small-stock.

It can be concluded that the West Coast environment is sensitive. It satisfies conditions (a), (b) and to some extent (c) of Cooper and Zedler's definition of sensitivity.

✓ The contention of point (a) of the hypothesis that the West Coast is not sensitive to human disturbance is therefore rejected. The aridity of the West Coast does not permit negligence of environmental consequences from human disturbances. In fact, the environmental characteristics of the West Coast are such that any development must be conducted carefully. Particular attention must be paid to any action that disturbs the vegetation cover in view of the vulnerability of the West Coast to wind erosion. ~

#### 2.4.2 VALUE OF THE WEST COAST ENVIRONMENT

Diamond mining is highly profitable and constitutes the major part of the GGP of the region. By contrast the fishing and agricultural

industry appear less lucrative. Nevertheless these industries are significant. They provide employment for more than 20% of the Namaqualand population and present sustainable resource uses.

Besides mineral resources, the West Coast also has major value for recreation, tourist and scientific interests (2.3.4.3). Scenic landscapes, aesthetic and wilderness qualities, a coastal setting and vegetation communities that are only represented on the West Coast are particularly attractive to these interests. These qualities are so highly valued that a large national park has been proposed for the West Coast by Government authorities.

The contention of part (a) of the hypothesis, that the West Coast has no value besides its mineral resources, is rejected. The West Coast has significant value for the agricultural and fishing industries and has particular great value for recreation, tourism and nature conservation, which can be of great importance in the future.



Photo 3A Mining operations have become large-scale earth-moving operations: overburden stripping at Cape Voltas, south of Alexander Bay.

## CHAPTER 3

### THE MINING ACTIONS

#### 3.1 BACKGROUND INFORMATION

##### 3.1.1 INTRODUCTION

The occurrence of diamonds and the coastal geology are discussed briefly to help explain the nature and extent of the mining operations subsequently described. Similarly, the scale and extent of the mining operations are put into perspective with a brief account of past and present exploitation for diamonds.

It will be shown that due to the nature of the diamond deposits, mining operations are both widespread and intensive, affecting particularly the sensitive coastal zone. It will be pointed out that mining operations have expanded greatly since the late 1950s and early 1960s and that more recently, since 1978, further substantial growth is apparent both in terrestrial and marine mining.

### 3.1.2 GEOLOGY OF THE DIAMOND DEPOSITS

#### 3.1.2.1 General

The diamond deposits along the South African West Coast have been described by Hallam (1959), Keyser (1972) and the Geology Department De Beers Consolidated Mines (1976, 1979). Geological information has largely been extracted from these sources.

Diamonds occur along the West Coast of southern Africa from Doring Bay in the south to Angola in the north. The diamondiferous deposits are gravel deposits near the present day surface and are spread thinly on the basement rock over a large area. They are covered mostly by aeolian sands and mining requires extensive stripping of this overburden. The R.S.A. Official Yearbook 1980/81 states the following about the origin of the diamond deposits.

"It is considered probable that the Orange River and former rivers that have followed similar courses over millions of years carried diamonds downstream to the Atlantic Ocean and that these diamonds after distribution along the coast by ocean currents formed the great alluvial diamond fields of Namaqualand and on the sea-bed off-shore."

This theory explains the occurrence of diamonds along a narrow coastal belt on land and in the adjoining sea as well as inland along rivers such as the Orange and the Buffels.

Diamonds are rare in the gravels and many tons of ore have to be mined to obtain them.

### 3.1.2.2 Coastal Terrestrial Deposits

Generally the diamondiferous deposits of the Namaqualand coastline extend to the 100 m contour above mean sea level. This coastal zone is at its narrowest at the Buffels River mouth where it is less than 2 km wide, but it progressively broadens to the north and south reaching a maximum width of about 7 km at the Groen- and Brak River region. Diamondiferous gravels are found in a series of raised beaches or marine terraces, each terrace corresponding to former static sea levels during the Quaternary and Late Tertiary period.

At the State Alluvial Diggings four such terraces are recognized and mined: Lower Terrace, just above present beach elevation and Middle-, Upper- and Grobler Terraces, the last of which is found at an elevation of about 84 m above sea level 7,5 km from the sea. On the farm Annex Kleinzee only two terraces are mined, the Lower-Middle and Middle Terrace, 42 m to 52 m above sea level. At Koingnaas the typical raised beach sequence is not found. On the coastal farms north and south of the Olifants River, where the beach is rocky and steep, there are marine gravels on top of the sea cliffs, but only the lower terrace deposits lying between the foot of the cliff and low water mark are mined. On the farms Klipvley Karookop and Geelwal Karoo, however, diamonds were initially obtained from gravels.

at the 23 m elevation.

Diamonds are found mostly at the bottom of gravel deposits and are concentrated in potholes and gullies cut into the bedrock by the sea. The bedrock is therefore literally swept clean during mining operations to ensure that no diamonds are left behind. The uncovered basement rock consists generally of either gneisses, schists or quartzites and presents no currently useful resource.

Overlying these gravel deposits is a layer of overburden, consisting mostly of sand of varying thickness. Initially mining was undertaken where this layer was only a few centimetres to a few metres deep, e.g. Alexander Bay. At many present operations the overburden reaches much greater depths, e.g. Cape Voltas - 35 m, Annex Kleinzee - 20 m, Dreyers Pan - 15 m and Koingnaas - 25 m. Present mining activities have therefore developed into earth-moving operations. In 1980 DBCM stripped 56 million tons of overburden and treated 7,8 million tons of gravel. On average DBCM had to remove 45 tons of sand and gravel to obtain one carat of diamonds (DBCM Annual Report, 1980).


At the smaller operations north and south of the Olifants River the diamondiferous gravels are covered by a shallower layer of sand 0,5 m to 2 m in depth.


The typical stratigraphy of the sediments overlying the basement rock is shown for the State Alluvial Diggings in Fig. 3.1. De Beers (1979) give a more detailed description of the geological column of


GEOLOGICAL SECTION AT CAPE VOLTAS

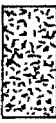
SOURCE : Adapted from Keyser (1972).

LEGEND

 Aeolian Coastal Dune Sand. (Mostly sub-angular medium-grained light-coloured unconsolidated quartzose sand with vein-quartz and schist float, gypsaceous nodules and land snail shells.)

 Calcrete and Calcareous Sand. (Calcrete carries sand grains, vein quartz and schist fragments, land snail shells and forms the hard upper layer. Downwards it gradually grades into a calcareous sand.)

 Terrestrial Sand Deposits. (Mostly sub-angular fine to coarse-grained yellowish and reddish sand with irregular lenses of rock waste containing land snail shells. Probably represent aeolian shore dunes of pre-calcrete age.)

 Littoral Deposits. (Marine sand and sandstone, sea shells, breccias, conglomerate and shingle.)

 Crystalline Schists. (Archeozoics into which marine terraces have been wave-cut.)

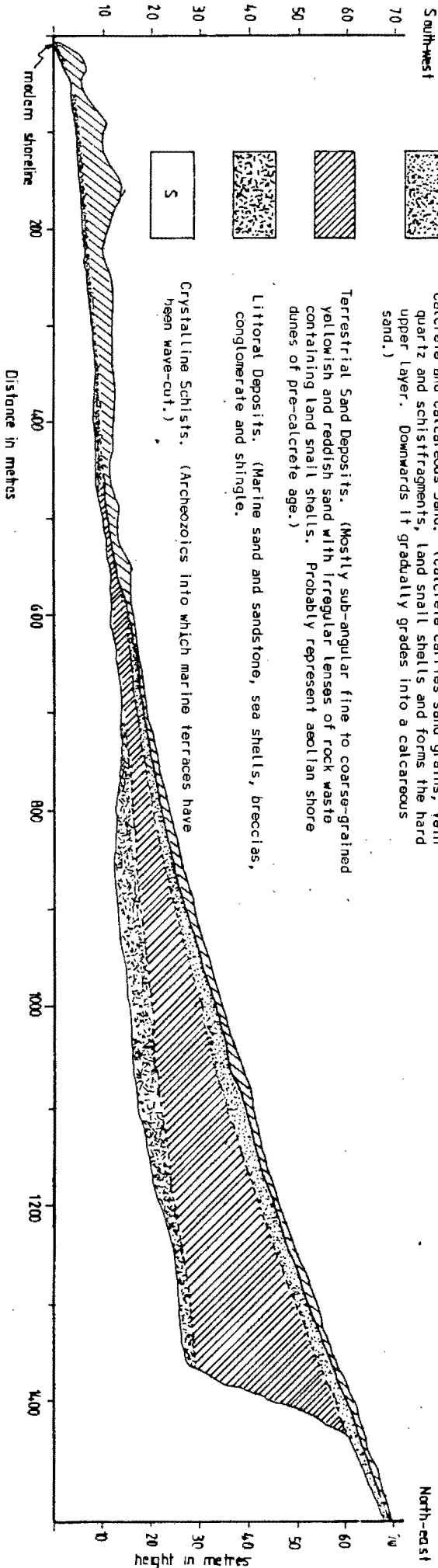


Fig. 3.1 Typical stratigraphy of sediments along West Coast.

the farm north of the Buffels River, as well as for the area around the Koingnaas operations. For this treatise it is of particular interest to note that:

1. There is a ubiquitous band of calcareous sand which is cemented in places to form calcrete, beneath a cover of aeolean sand (Fig. 3.1). This layer is highly variable in composition and thickness, varying from rich calcareous sands to almost pure lime up to 1 m in thickness. Calcareous sands are also found in deeper layers.
2. Clay is associated with some sediments such as the fine green sands overlying marine gravels. This clayey sediment seems to be most abundant at Koingnaas. Terrigenous sands are also laden with clay and silt, particularly in areas at Annex Kleinzee.
3. Significant salt concentrations, particularly sodium, are also present in the sediments.

When this overburden layer is stripped in the mining process it is deposited in great heaps elsewhere. The top layer of such an overburden dump can be of material derived from anywhere in the sedimentary sequence. No attempt is made to preserve the top layer of soil. The effect of this practice will be described in Chapter 4.

In order to delineate ore bodies accurately, prospecting has to be done in a closely spaced pattern. This pattern is necessary for two reasons: 1. Terraces have been eroded erratically so that at one place a considerable width of a particular terrace may be preserved, whereas not far away the whole of the terrace may have been eroded. 2. Diamonds occur sporadically in the gravels so that it

does not pay to mine some zones, while others are lucrative to mine.

The uneven grade of the diamondiferous ore bodies has led to the mining of many zones or blocks simultaneously, rather than systematically mining an ore body from one end to the other, as is done in open cast coal mining. This enables ore grades to be mixed to obtain a more even average grade which is important for the ore treatment process, as well as for achieving planned revenue from the whole mine.

#### 3.1.2.3 River Deposits

Along the Orange River known diamondiferous gravels occur at Sendelingsdrif, between Bloeddrif and Koeskop and near Witvoorkop (Map 1). Here the terrace deposits appear 20 m, 30 m and 45 m above river elevation and vary in thickness from less than 1 m to greater than 15 m.

Along the Buffels, Spoeg, Horees, Groen and Swartdorings River systems known diamondiferous gravels are restricted to the lower regions of the drainage systems. Because of the patchy arrangement of the sediments, the sporadic distribution of diamonds within these gravels and the small average diamond size, profitable mining of these deposits has been confined to the Buffels River. But even there the Langhoogte mine was closed in 1971 due to a drop in market demand for small stones, the mine was subsequently recommissioned in 1978.

A further complicating factor at Langhoogte is a layer of tough calcareous sandstone which renders mining more difficult than in other areas. Overburden thickness at Langhoogte reaches 10 m. On the farm Nuttabooi, where De Beers plan to mine in the near future, the sedimentary sequence is 20 m thick.

#### 3.1.2.4 Marine Deposits

Because diamonds occur widely along the West Coast of the Republic there has been reason to look for diamonds in the sea. Submarine sediments off the Namaqualand coast have been investigated under a marine geoscience programme and an outline on submarine sedimentation in this area has been given by O'Shea (1971) and Rogers (1977). Prospecting for diamonds in the deep sea has been without success; only 13 carats have been recovered by one company (Commission of Inquiry into the Diamond Industry, 1973).

Present marine mining activity is conducted in shallow water, centred in the surf zone. Present methods (see section 3.2) limit mining operations to a depth of 20 m of water. Mining takes place on a relatively soft sand or gravel seabed. Yields vary vastly, often gravel is barren, but one "lucky strike" produced about 750 carat in 2 m<sup>3</sup> of gravel (Gurney, pers. comm.).

Diamonds have been found in sediments in sea concession areas 2, 5, 6, 7, 8, 9, 10, 11, 12 (Map 1) with sea concession areas 1, 3 and 4

not yet allocated. Payable diamond concentrations ( 5 to 6 carats /m<sup>3</sup>) have been found in all zones except 8, 9, 10, where diamondiferous gravels are overlaid by a thick layer of sand, and economic deposits have not yet been proven (D. Pollock, pers. comm.).

### 3.1.3 HISTORY OF EXPLOITATION FOR DIAMONDS ALONG THE WEST COAST

#### 3.1.3.1 Past Exploitation on Land

As far back as 1863 a Hottentot Chief was granted a concession for the prospecting of diamonds along the coast between Lüderitz and the Orange River, but the first diamonds were found in 1908 near Lüderitz. The German South West African diamond fields were subsequently opened up to Elizabeth Bay and Pomona about 200 km north of the Orange River (Jessup, 1979). This encouraged the search for diamonds elsewhere along the coast and in August 1925, Jack Carstens discovered diamonds while prospecting on the farm Oubeep, 10 km south of Port Nolloth. Further discoveries followed at the Cliffs, Boegoeberg and Alexander Bay, where in 1926 the geologist, Dr H. Merensky, made spectacular finds. The new discoveries attracted a large number of fortune hunters and diggers, many of them from the alluvial diamond fields at Lichtenburg discovered shortly beforehand in 1926. Anxious to control the situation and avoid another tumultuous diamond rush as occurred at Lichtenburg, the South African Government froze all prospecting activity on State land in Namaqualand by proclamation in February 1927. The Precious Stones Act of 1927

was promulgated and in April 1928 a 2500 ha area around Alexander Bay was declared a State Alluvial Diggings. In 1931 this area was enlarged to about 60 000 ha, extending to Port Nolloth (Alluviale Staatsdelwery Alexanderbaai, 1978).

The new diamond control bill effectively halted other prospecting and mining activity along the coast, except on the farm Kleinzee.

Carstens had moved there in 1926 after his initial discovery and made further good finds. The Cape Coast Exploration Co. obtained mining rights there in 1928. In 1942 the company fell under the control of De Beers who by then had bought a large number of coastal farms. By 1957 Kleinzee farm was mined out and the government granted mining rights in respect of Annex Kleinzee. As part of the lease consideration the State received a share of the profits over and above taxation of the company's profit (Carstens, 1962). This provision was introduced under the Precious Stones Act of 1927 and applied to all subsequent diamond mining leases elsewhere on the West Coast; it is still in force today.

In 1960 mining rights were granted to small companies on the farms Klipvley Karoo, Graauw Duinen, Geelwal Karoo and De Punt just north of the Olifants River and on the farm Wolfberg on the Buffels River (Dept of Mines, Annual Report, 1960). In 1961 Proclamation 75 of 1929, which had prohibited prospecting for precious stones on all land in Namaqualand, was repealed. There had been a small number of exemptions from this proclamation prior to this date, but in 1963, 93 prospecting permits were issued (Dept. of Mines, Annual Reports 1961, 1963).

The State Alluvial Diggings had embarked on a systematic prospecting programme in 1950 (Keyser, 1972), while De Beers started extensive prospecting of their coastal farms in 1958 (Dept of Mines, Annual Report 1958). In 1964 the Diamond Development Advisory Committee was set up to consider 151 applications for prospecting leases in respect of unalienated State land in the Namaqualand and Van Rhynsdorp districts. The Committee recommended that smaller concerns be given the opportunity to gain admission to the industry and that preference be given to applications from local Coloured enterprises in the Coloured Reserves.

In 1971 there was a setback in diamond mining with a bad market for small stones, and De Beers operations at Koingnaas and Langhoogte were stopped (De Beers, 1971). By 1978 diamond market conditions had improved markedly when the general price of rough gem stones increased by 30%. Production at the two mines recommenced with Koingnaas boosting annual West Coast diamond production by 643 000 carats (Table 3.3). De Beers further expanded with mining operations at Tweepad, Mitchell's Bay and Sandkop in 1980. In 1981, however, due to depressed market conditions, Tweepad plant was again shut down (De Beers, 1979, 1980, 1981).

### 3.1.3.2 Past Marine Exploitation

Prospecting and mining of diamonds in the sea started off the South West African/Namibian coast in 1957 and became possible in the Republic when the Precious Stones Amendment Act (Act 12 of 1960) came

into operation. These early operations were conducted in deep water and up to 1972 only poor results had been obtained (Commission of Inquiry into the Diamond Industry, 1973).

Mining in shallow water was sparked off in 1975 with the development of a pump to suck gravels from the sea (Dept of Mines, Annual Report 1975). Since 1978 a number of smaller companies, notably Dawn Diamonds, have been operating successfully in the shallow water zone (Fig. 3.2), though with a relatively small production of diamonds (Fig. 3.5). Despite operations still being on a small scale there has been a remarkable increase in off-shore mining activity over the last three years. Some companies have enlarged their fleets from one to twenty boats over this period (D. Pollock, pers. comm.).

### 3.1.3.3 Present Exploitation

Map 1 shows the area for which prospecting and mining rights have been granted. These concessions extend over the following regions:

- a. The entire coastal stretch from the Orange River to Doring Bay, with two further concessions near Donkins Bay.
- b. A number of inland farms situated predominantly along the Buffels River.
- c. The Richtersveld, areas along and south of the Orange River.
- d. Sea areas stretching along the coastline from the Orange River to Donkins Bay. Further concessions have been declared

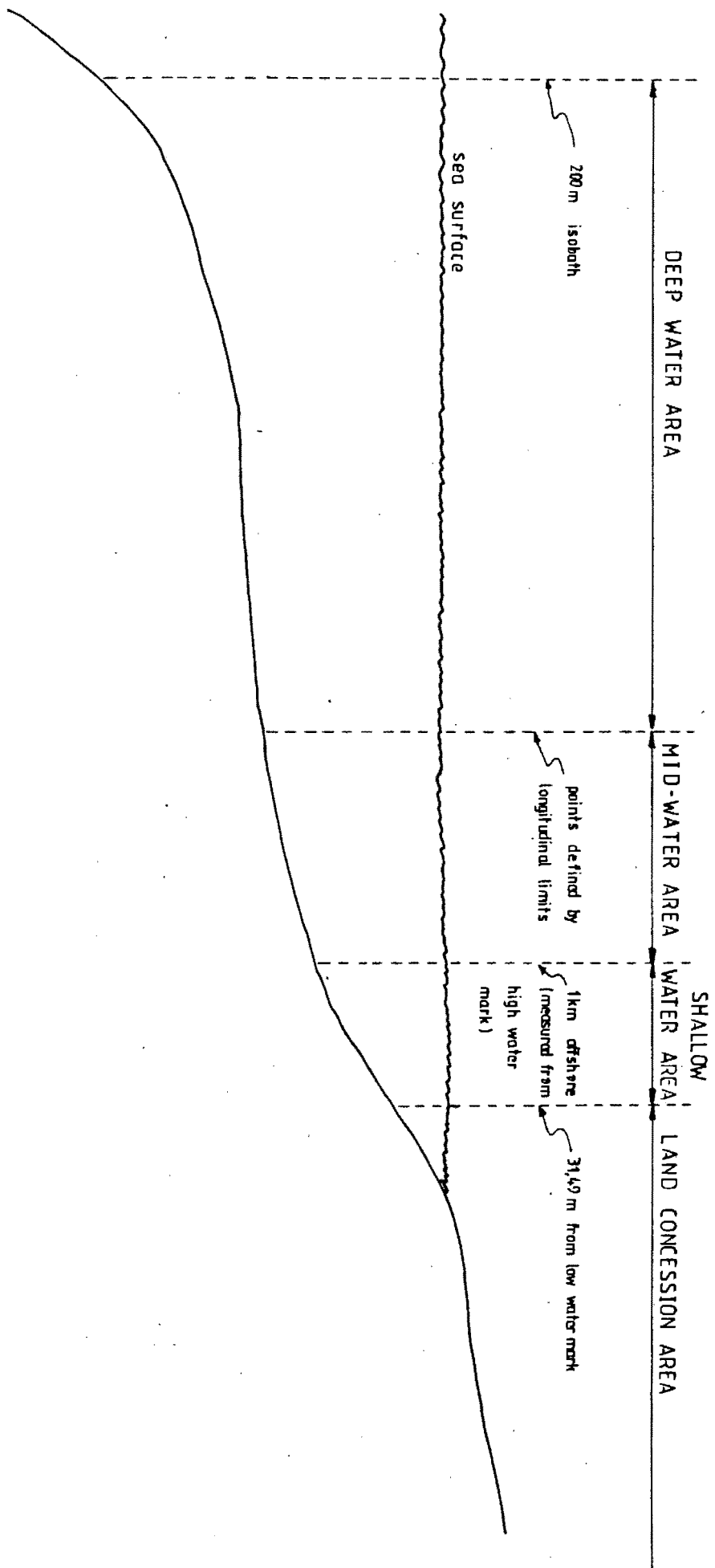
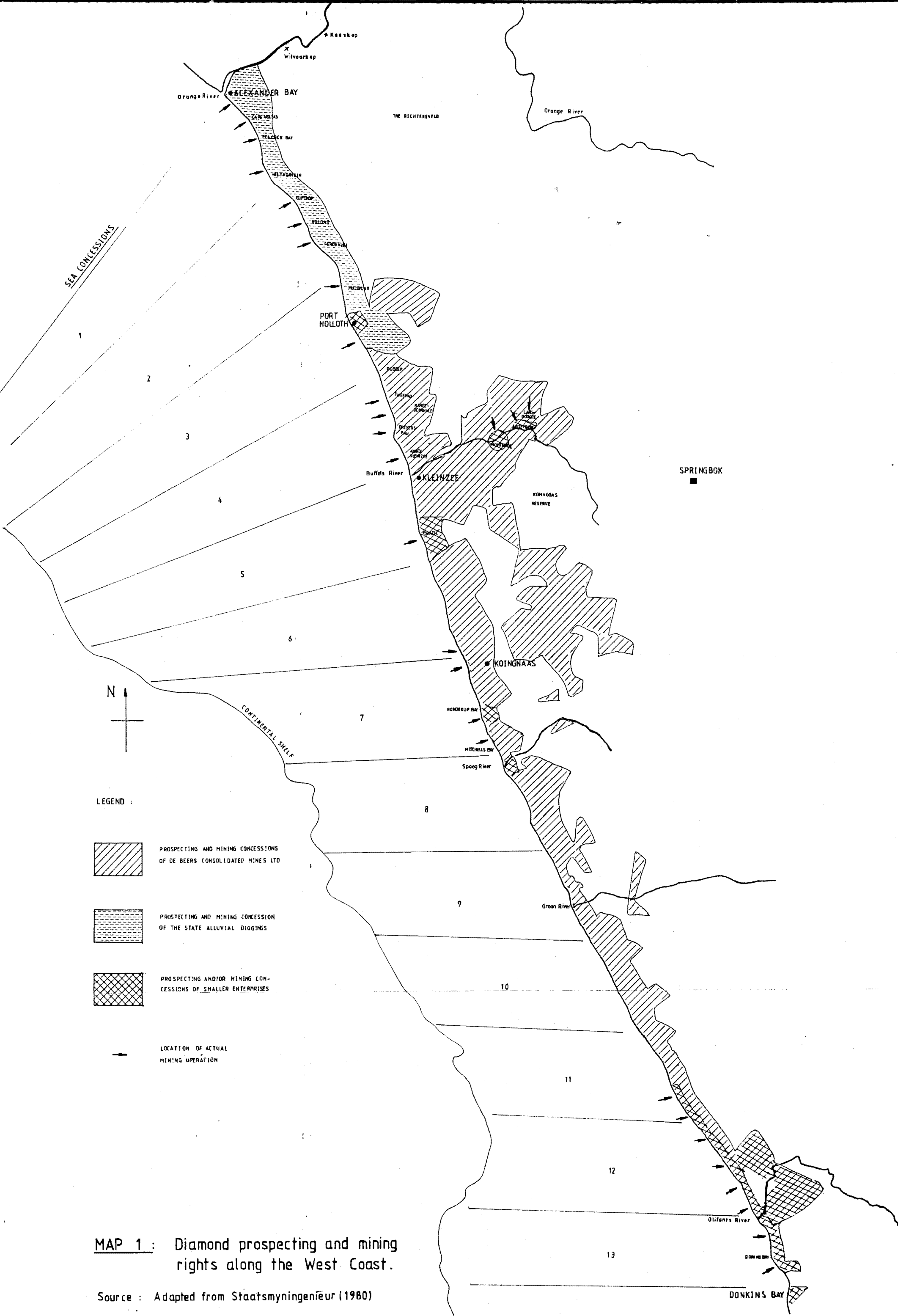


Fig. 3.2 Diamond mining zones.



**MAP 1 :** Diamond prospecting and mining rights along the West Coast.

Source : Adapted from Staatsmyningenieur (1980)

southward to Cape Columbine since 24 July 1981 (Dept. of Mineral & Energy Affairs, 1981).

Mining rights have been granted for sub-marine and terrestrial deposits covering the entire area stretching from the outer edge of the continental shelf (200 m isobath) to the inland boundary of coastal land concessions. This area has been divided into two mining zones, the land concessions and the sea concessions. Since 24 July 1981, the latter has been sub-divided into three further zones as shown in Fig. 3.2.

The enterprises that are engaged in the exploitation of the diamonds are the State and 12 private companies, of which De Beers Consolidated Mines (DBCM) is by far the largest, measured both in diamond production figures (Fig. 3.4) and the extent of land owned and/or held under diamond mining rights.

Map 1 shows the places where active mining for diamonds took place in 1981. The largest mining operations are those of DBCM north of Kleinsee, at Koingnaas and Mitchell's Bay and those of SAD at a number of places between Alexander Bay and Port Nolloth. The smaller companies mostly have mining concessions north and south of Olifants River. Trans-Hex Investments, third largest company after DBCM and SAD, is mining on the coastal farms Brazil and Hondeklip Bay as well as inland in the Komaggas Reserve (along the Buffels River) and in the Richtersveld (along the Orange River).

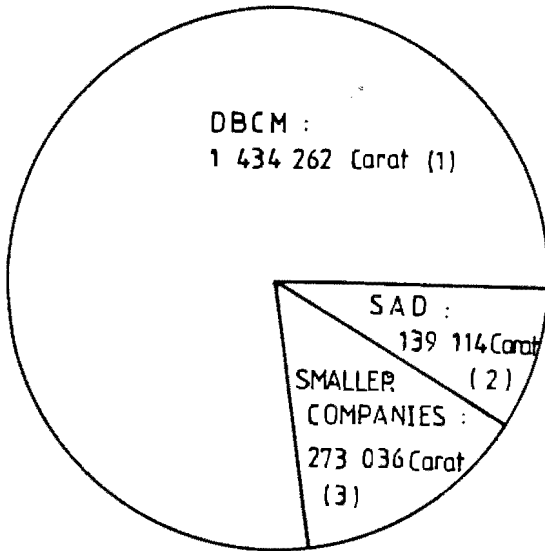
TABLE 3.3 Total diamond production from the West Coast

<u>Date</u>	<u>Production in Carats</u>
1967	405 776
1968	615 503
1969	820 056
1970	989 537
1971	826 288
1972	848 759
1973	922 806
1974	1 150 728
1975	1 332 197
1976	1 335 638
1977	1 497 912
1978	1 557 978
1979	1 937 852
1980	1 846 412

Source: 1) De Beers Consolidated Mines Ltd, 1976.  
 2) Minerals Bureau, Department of Mineral and Energy Affairs, pers. comm., 1981.

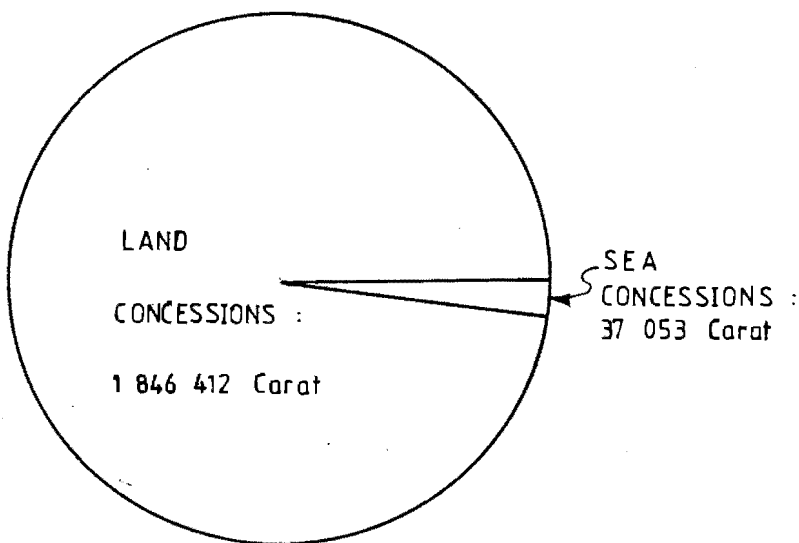
The biggest marine operator is Dawn Diamonds, producing nearly half the diamonds from marine concessions in 1980.

Table 3.3 shows that there has been a substantial increase in diamond production from 1967 to 1980 with a more than fourfold increase in the number of carats produced over this period. DBCM, the largest operator, produces about ten times more than SAD (Fig. 3.4), who in turn produces nearly as much as all the remaining diamond mining enterprises put together. It is also apparent that marine exploitation



Source: (1) De Beers C.M. Ltd, Annual Report 1980.  
 (2) Dept of Mineral & Energy Affairs, Annual Report 1980.  
 (3) Minerals Bureau, Dept of Mineral & Energy Affairs,  
 pers. comm., 1981.

Fig. 3.4 Diamond production share of mining enterprises.



Source: Minerals Bureau, Dept of Mineral & Energy Affairs, 1981,  
 pers. comm.

Fig. 3.5 Diamond production share from land and sea concessions.

of diamonds is still on a small scale with 37 053 carats, 2,7% of total West Coast production in 1980 (Fig. 3.5).

## 3.2 THE MINING ACTIONS

### 3.2.1 INTRODUCTION

This outline of the mining process and its ancillary activities is described for the purpose of identifying the individual mining actions that cause significant environmental impact.

The coastal mining operations of the State Alluvial Diggings and those of De Beers Consolidated Mines Ltd, on land, are similar and are dealt with together. The emphasis on these operations is because they are the largest in scale and produce by far the greatest number of diamonds on the West Coast. Other mining operations further inland, in the sea, and those undertaken along the coast by the smaller companies were not investigated in as much detail. Nevertheless they are briefly outlined to put the diamond mining activity along the West Coast into perspective. Also, these operations are significant in terms of environmental impact, despite their comparatively low production of diamonds.

Finally all identified mining actions are listed in the form of a checklist in Table 3.12 to present an overview of mining actions and to facilitate the investigation of environmental impact.



Photo 3B

Remains of early (1940s) small-scale diamond diggings at Oubeep.

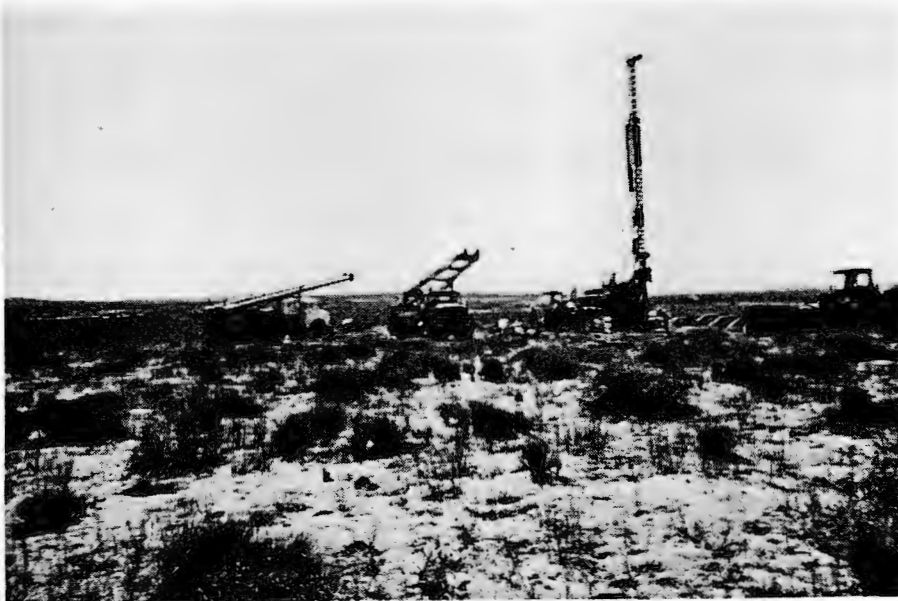


Photo 3C

Heavy machinery in use for auger-drilling prospecting operation at Elandsvlei.



Photo 3D

Prospecting trench operation south of Alexander Bay.

### 3.2.3 MINING ACTIONS BY THE LARGE ENTERPRISES

#### 3.2.2.1 Prospecting

Three prospecting methods are used, small diameter percussion drilling, trenching and large diameter auger drilling.

##### a. Small diameter percussion drilling

Information on this method was obtained from a report by Keyser (1972) and through verbal communication with the mining engineer at the State Alluvial Diggings. No personal observation of this prospecting activity was made by the author as no drilling rigs were operating at the time of his field work.

Small diameter percussion drilling is used by the State Alluvial Diggings prior to prospecting by trenching. It serves to determine the distribution and general features of the diamondiferous gravel deposits.

The machine used for drilling is a conventional percussion rig similar to those used in boring for water. The rig drills a 150 mm borehole to bedrock depth at regular 91 m intervals along boring lines. These boring lines are aligned at right angles to the coast line. Primary boring lines are spaced 914 m (3000 ft) and 305 m (1000 ft) respectively. The first borehole on a boring line was placed 91 m inland from the high-water mark. Subsequent boreholes were drilled at 91 m intervals along the boring line until bedrock

elevation reached 90 m above sea level. This is usually 3 to 4 km from the sea. Where terrace gravel deposits are encountered, boreholes are drilled in intermediate positions again at 91 m intervals.

To map a gravel deposit more accurately secondary boring lines are run at 100 m intervals. Boreholes are drilled at 30 m intervals along these lines.

The State Alluvial Diggings embarked on their drilling programme in April 1950 and completed primary boring lines in June 1961, operating with four drilling rigs by 1958. Secondary line boring will be continued where prospects for diamondiferous gravel deposits are good.

Small diameter drilling does not give information on diamond concentration in the gravel deposits. It is therefore not a complete prospecting operation on its own. Two methods that enable assaying of diamonds are trenching and large diameter auger drilling.

#### b. Trenching

Prospecting by trenching is undertaken in a regular pattern to systematically search a large area for diamond deposits. Primary trenches are excavated at fairly regular distances to give a general indication of diamond content in diamondiferous gravels.

Secondary trenches delineate payable zones where a promising deposit is encountered.

Trenches are aligned at right angles to the coast and can range from a few hundred metres up to about three kilometres in length.

Primary trenches are set out at 500 m intervals, and secondary trenches every 100 m or less (Fig. 3.6).

In each trench the overburden is removed down to the gravel bed.

The trench is about 11 m wide on the surface of the gravel. Overburden is removed by giant rubber tyred scraper units which are pushed by bulldozers, as occurs in mining operations (see Photo 3D).

The volume of overburden that has to be moved depends on the required length of the trench, the depth of overburden and the nature of the overburden material. With loose sand, having an angle of repose of  $33^\circ$ , a much wider surface width results than where trench walls are near-vertical as in clay and calcrete overburden (see Photo 4B). All overburden is removed in one continuous operation before gravel beds are sampled. Overburden material is deposited as overburden dumps on the surface next to the trench.

For economic reasons these dumps are built up as near as possible to the source trench (to save transport costs), but away from any underlying diamondiferous gravel deposits. This is to obviate having to move the overburden dump again at a later stage should mining be undertaken. Usually two overburden dumps result from an excavated prospecting trench, one on either side. The size of the overburden dump is directly related to the quantity of overburden material removed.

Table 3.9 shows the extent of developed prospecting trenches. SAD generated a total of 127 km of trenches, removing 19 683 000 m<sup>3</sup> of overburden in the period 1958 to 1970. DBCM had no data available for trenching carried out by them, but their operations probably equal those of SAD.

Once diamondiferous gravels have been exposed, two sampling procedures are used. At SAD the gravel bed is sampled by cutting a narrow 1 m trench to bedrock either manually or more usually by excavator (Photo 3D). The gravels are then put through a small-scale treatment plant, which recovers diamonds on site. There are 6 to 8 prospecting teams at SAD. Each team is equipped with 6 trommel sieves, 6 heavy media separation jigs and 1 crusher. Tailings from the treatment process consist of rock pebbles the total volume of which is insignificant when compared to the volume of overburden dumps.

At DBCM the gravel beds are excavated to bedrock over the complete trench width of 11 m. Gravel ore is taken by haulage trucks to a central bulk sampling plant, which is similar in size and mode of operation to a normal treatment plant.

Today, prospecting by trenching is undertaken by DBCM only where the overburden is shallow (less than 10 m). Where overburden reaches greater depths, the company resorts to large diameter auger drilling.

#### c. Large diameter auger drilling

Where overburden depth is large prospecting by trenching becomes an

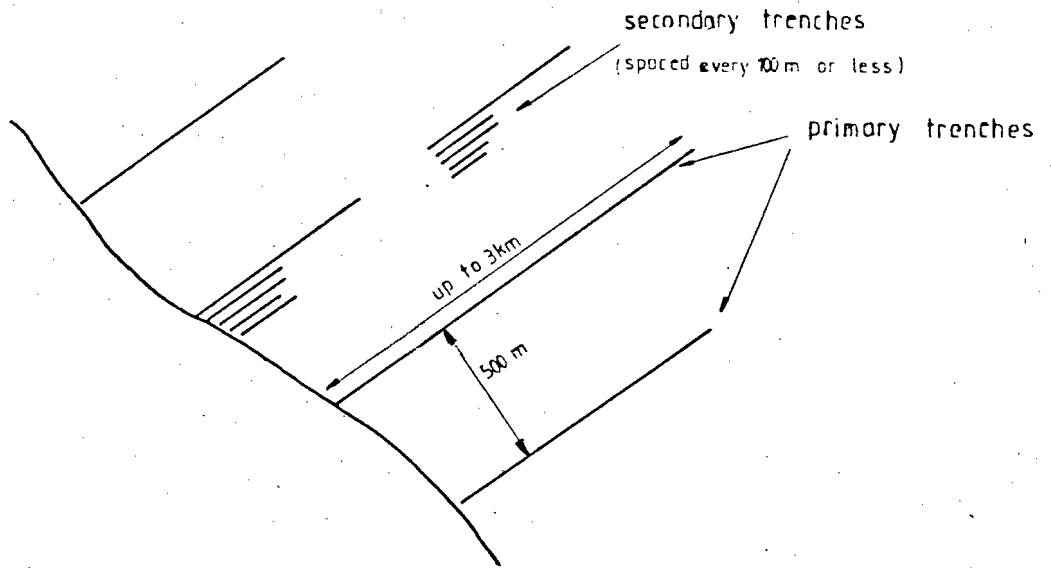


Fig. 3.6 Prospecting trench system.

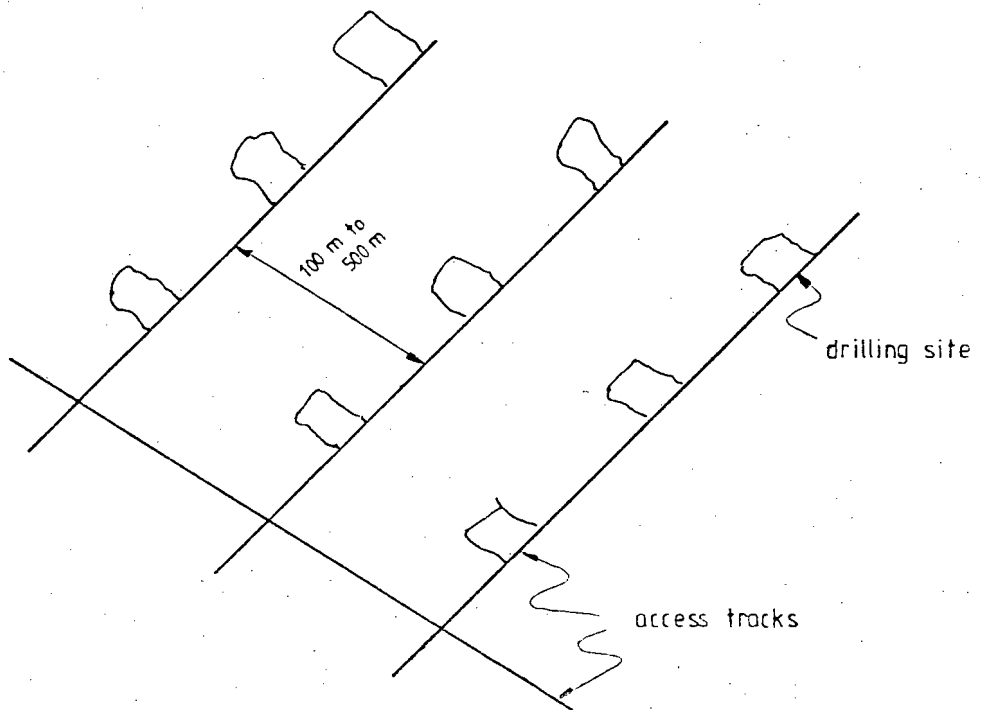


Fig. 3.7 Auger drilling grid.

immense and time-consuming task. Large diameter auger drilling is therefore used as a quicker method, allowing not only examination of the sedimentary stratigraphy, but also assay of diamondiferous gravels.

In this operation 1 m holes are drilled in a grid pattern over a selected area. The spacing of the grid lines varies from about 500 m to 100 m. The strategy of large diameter auger drilling is similar to other prospecting methods: Primary auger drilling takes place on a widely-spaced grid to establish the potential occurrence of diamonds. Secondary auger drilling is planned on a closely-spaced grid to delineate the payable ore body (Fig. 3.7).

The auger drilling rig is capable of boring to a depth of 43 m. Excavated material is laid out in two or three rows of heaps with a sequence corresponding to the stratigraphy. If diamondiferous gravels are encountered they are sent by truck to the central bulk sampling plant. After inspection by a geologist the remaining excavated sediments are used to refill the borehole at a later stage. Due to the increased volume of the loosened material three or four overburden heaps usually remain on the surface. Drilling of the borehole itself is usually completed within one day.

The machinery used is: a large drilling rig; two 20-ton trucks for transporting ancillary equipment including the 1 m steel pipes which temporarily line (to prevent collapse) the side walls of the borehole; one front loader, a portable camp structure, housing the drilling team.

On the inland farms where auger drilling is practised on a widely-spaced grid, DBCM has the policy of aligning the drilling grid as far as possible with existing farm roads and fences so as to lessen the disturbance to the natural vegetation through the movement of the drilling vehicles.

### 3.2.2.2 The Mining Operation

After prospecting has been completed, the payable ore body intended for mining is blocked out on a plan. Several such blocks are mined simultaneously, exploiting both high and low grade ore. This enables the mine to maintain an even grade of diamond concentration in the ore put through the treatment plants. An even grade of diamond ore is important for the treatment process, but is particularly so for the financial planning of the mine by allowing a projected fixed revenue return thereby increasing the life of the mine. This practice leads to workings at a mine face being closed down and restarted again at a later stage. This can also occur due to a change in demand for diamonds. The average size of diamonds is thus as important as the overall yield of diamonds from an ore body. For example, operations at Tweepad were closed down in 1981 due to a drop in demand for small stones on the diamond market.

Diamond mining along the coast should thus be termed surface area mining rather than strip mining. The latter term is usually used for the surface mining of coal where exploitation proceeds in a



Photo 3E

Scraper machines at Annex Kleinzee travelling in round-fashion, stripping overburden on right and building up dump on left of photo.

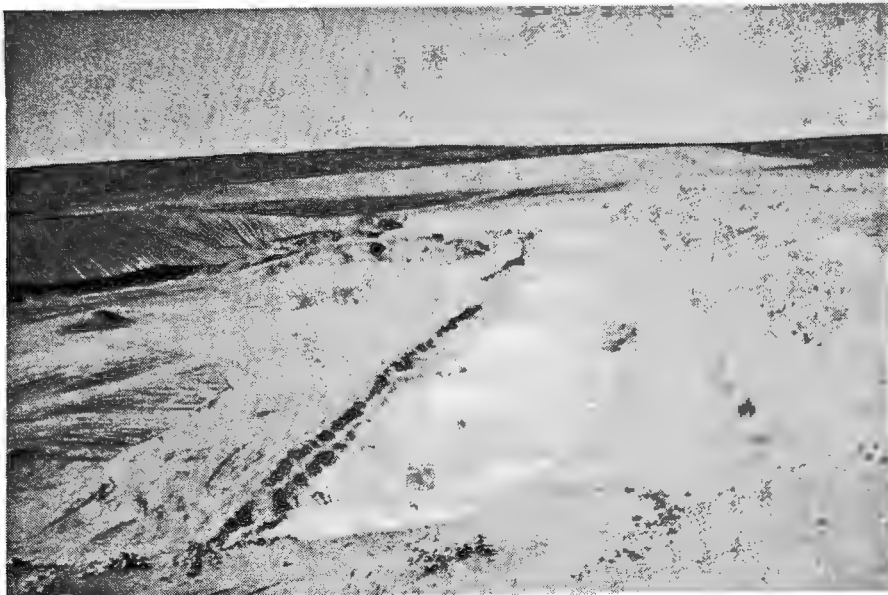


Photo 3F

Mining block north of Kleinzee: mined-out site with exposed bed-rock (middle), site with overburden stripped, but with diamondiferous gravel bed still in place (left) and site where overburden will be stripped next (right).



Photo 3G

Three mining actions south of Alexander Bay: rock tailings dump (background), haulage road (foreground) and quarry used for road material (middle).

linear fashion from one end of the ore body to the other. This is important: in strip mining backfilling of overburden in mined-out strips is part of the mining technique and rehabilitation can directly follow mining. In the surface mining for diamonds, however, backfilling is not an integral part of the mining process, and as exploitation is not final there is no incentive for immediate rehabilitation of the area.

The mining process itself is simple in concept. Overburden is removed to expose the thin layer of diamondiferous gravels which are then loaded and hauled to a treatment plant where diamonds are recovered. In execution the task is not that easy. The immense volume of overburden that has to be moved transforms the process into a giant earth-moving operation. The magnitude and recent increase of the present operations of SAD and DBCM can be gleaned from Table 3.8.

TABLE 3.8 Overburden stripped by SAD and DBCM

Mine	Overburden stripped (metric ton)		
	1978	1979	1980
SAD 1)	1 507 668	2 681 065	4 853 268
DBCM 2)	34 616 000	35 522 500	56 713 400

Source: 1) Dept of Mineral and Energy Affairs, Annual Report, 1980

2) De Beers C.M. Ltd, Annual Reports, 1980, 1979.

Overburden is removed with large diesel-driven scrapers fitted with giant rubber tyres (see Photo 3A). These machines are push-loaded by track-type bulldozers, scooping up about 12 m<sup>3</sup> of ground in one load. The scraper then travels to and dumps its overburden load at a site, which for economic and practical reasons is as near as possible to the excavation area but not over an unexploited ore body.

Several scrapers, travelling in round-trip fashion, strip overburden in a designated area and build up an overburden dump (Photos 3E, 3F). Overburden is mostly loose sand, but where hard calcrete layers are encountered these are ripped by a bulldozer with a rip-arm appendage. Overburden stripping is complete once diamondiferous gravels are exposed.

The diamondiferous gravels are loaded by mechanical shovels onto 12 - 15 m<sup>3</sup> capacity loading trucks which haul the ore to the screening plants. Where the gravel layer is thin (about 1 m), it is pushed into heaps by bulldozers and is then loaded with front-end loaders onto the haulage trucks. Finally the bedrock is cleared of all remaining sand and gravel by labourers. This bedrock cleaning is done meticulously, the bedrock surface even being hand-swept with brushes. All sand and gravel is removed from crevices, gullies and potholes, leaving an absolutely bare bedrock surface (Photo 4D).

At SAD the removal of overburden was, until recently, planned separately from the mining of the gravel beds. Scrapers stripped all overburden from a large ore zone, which would be mined weeks or months

later. Obviously no backfilling of overburden occurred, as it would be uneconomical to recall the overburden stripping fleet to move overburden back to the mined-out site. This technique has now been changed because it was found that windblown sand soon covered the gravel bed necessitating further stripping. Now, as in operations by DBCM north of Kleinzee, stripping of overburden and mining of gravels are undertaken together.

On the farms north of Kleinzee, the ore body seems to have a less patchy distribution pattern than those on SAD land. The ore body delineated by DBCM has an oblong shape, stretching over several kilometres. The mining technique here resembles that of strip mining. A first cut is developed, usually 200 m long and 100 m wide. Overburden is removed from this block and dumped on adjoining natural surface terrain. Once this strip has been mined the mining advances over another strip 200 m x 100 m (roughly). Overburden is now dumped on to the bare bedrock of the previously mined strip. Gravel is hauled away, exposing bedrock which becomes the next site for overburden. The mining face advances in this manner until an entire block of the ore body zone has been exploited. The last strip of the block is left with bare bedrock. Theoretically, this is the only site not to be backfilled. In practice, however, several patches of bare bedrock remain in an exploited block. The reason for this is that mining policy is such that overburden is dumped in the most economical way. The mining strategy does not set out deliberately to cover the exposed bedrock surfaces. It is thus incidental that backfilling is undertaken. Backfilling is not

DBCM undertakes backfilling over most of its mined-out sites. SAD is planning to undertake backfilling at all future exploitation sites.

No other rehabilitation efforts such as revegetation or landscaping are undertaken.

### 3.2.2.3 Treatment of Diamondiferous Gravels

The treatment of diamondiferous gravels can be conveniently described under three sections: ground preparation, gravity concentration and final recovery (Fig. 3.10).

#### Ground Preparation:

Haulage trucks tip mined gravel through coarse screens, which screen off oversize material ( $\pm 25$  mm). This oversize material is disposed of in the mine, usually being dumped in small heaps at mined-out sites. At the Annex Kleinzee plant all oversize material is crushed and fed into the process flow. All sand and fines ( $< 2$  mm), which can comprise up to 80% of mine ground, is eliminated in a washing and screening process. Sea water is used to scrub fines off the gravels and the resultant slime is either pumped into prepared settling dams or into inland depressions (e.g. Dreyers Pan) or into the sea (at Annex Kleinzee and Alexander Bay). In one case, at Muisvlak SAD, slime was discharged onto the natural terrain, but this has been stopped.

The volume discharge of slime from the washing and screening process is quite high. The DBCM's plant at Annex Kleinzee puts out about 7000 tons of sand per day.

#### Gravity Concentration:

Concentration of diamonds in the screened gravel is achieved by a heavy medium separation process which exploits the high specific gravity of diamonds. Ferrosilicone powder is mixed with water to produce a suspension with a specific gravity of 2,70 or greater. This suspension is added to the diamondiferous gravels. All quartz, limestone and other light material with a specific gravity less than 2,70 is separated from diamonds and heavier material in a hydro-cyclone. The light material is discarded onto a tailings dump which is essentially a dump of rock pebbles of the size fraction, >2 mm to <10 mm. The diamonds together with the heavy concentrate are collected and sent to the Recovery Plant. Both the light and heavy separated material is washed with sea water to recover the ferrosilicone powder, which is recycled.

#### Final Recovery:

At this stage of the treatment process the volume of ore has diminished considerably, the quantity of tailings is thus very much less than from the previous gravity concentration stage.

In the Final Recovery stage the diamond rich concentrate is dried and further concentrated by passing through either X-ray sorting or

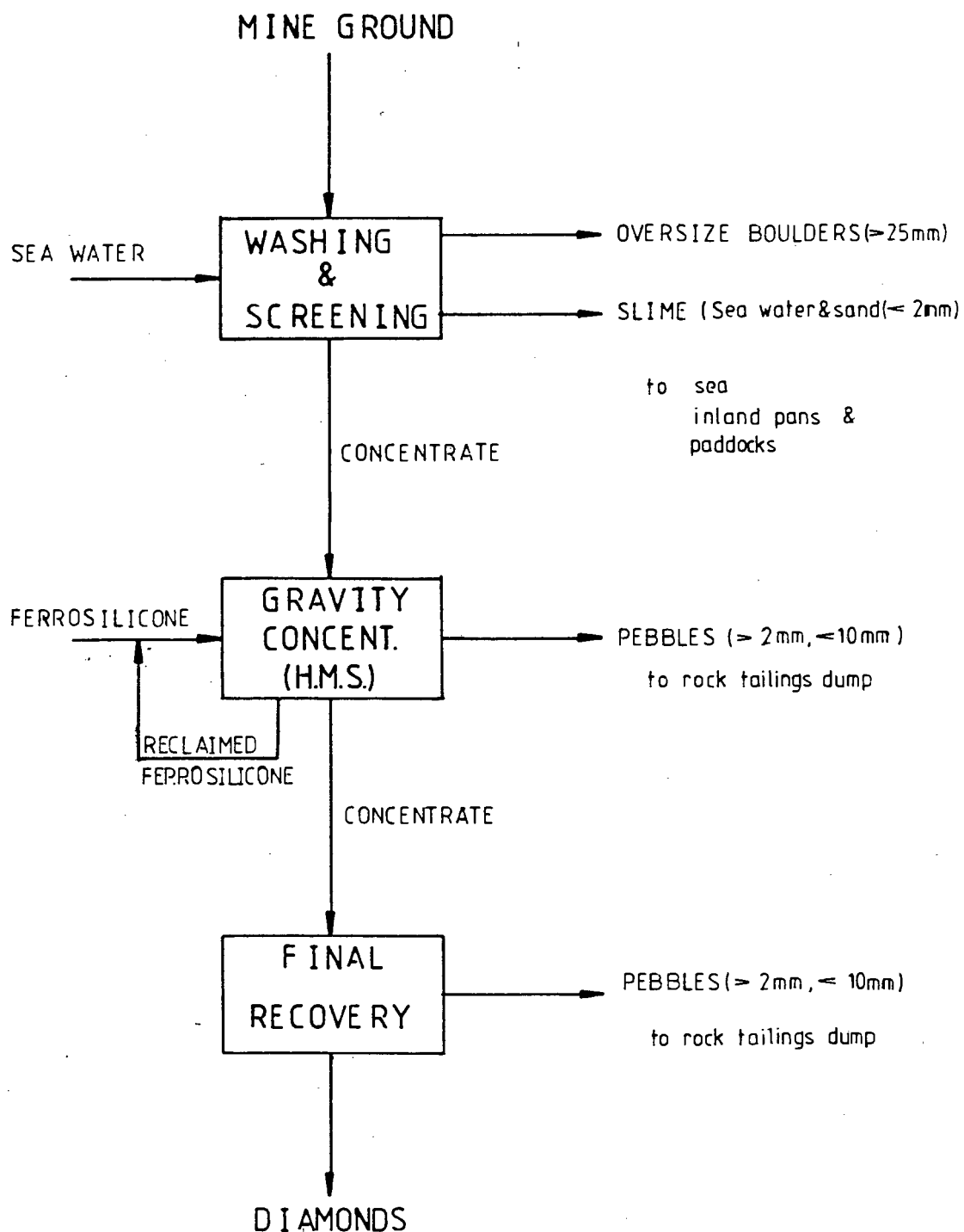


Fig. 3.10 Diamond mine treatment process.

electrostatic separation machines. Diamonds are finally recovered by hand sorting of the concentrate.

In 1980 the annual production of diamonds was 139 114 CT for SAD and 1 434 262 CT for DBCM, corresponding to about 28 kg and 287 kg respectively. The final product from the mines is dispatched by aeroplane to Kimberley. The waste outputs from the treatment process are summarized in Fig. 3.10. There are no other discharges, effluents or gases. The only chemical employed in the treatment process is ferrosilicone, which is recycled. There are some losses of this material, which together with very small amounts of flocculant chemicals, make up a trace constituent of the rock tailings and the discharged slime. The ferrosilicone and flocculent trace quantities have no apparent environmental consequence.

To conclude this review Table 3.11 summarizes the number of active and abandoned plants of various types within the study area.

TABLE 3.11 Treatment plants in use and abandoned by SAD and DBCM

Type of Treatment Plant	IN USE		ABANDONED	
	SAD	DBCM	SAD	DBCM
Ground preparation and gravity concentration plants	5	4	4	2
Ground preparation plant only		1		
Final recovery plants	1	1		
Small prospecting plants			2	

#### 3.2.2.4 Induced Actions

The mining operations give rise to a number of activities additional to the obvious mining actions. These are termed *induced actions* and can have environmental impacts as important as those of the mining activities themselves, sometimes even more. These actions and the effect they have on the environment are often overlooked or not anticipated. The following induced actions were noted from SAD and DBCM operations along the coast:

Roads: Due to the wide distribution of the diamondiferous gravels a proper road network is laid down by the mine, providing transport routes between the mine township, mining plants and the mining faces. Haulage roads carry heavy (20 ton) trucks from the mine face to the treatment plants and are therefore wide, well constructed roads. Haulage roads are rerouted with changes in mine face locations. (The aim of the mining concern being to provide the shortest possible route for hauling ore from the mining site to the treatment plant, for obvious economic reasons.) These roads are constructed with clayey or limey sand that occurs widely in the area. This material is mostly obtained from quarries which are dug next to the road. Sometimes clayey material is taken from an overburden dump, but the objective of the mine is to obtain suitable road material from the closest and cheapest source. These road quarries can be large. One quarry on SAD territory was estimated to cover an area of approximately 4 ha.

Although most quarries are no deeper than 2 metres, their impact on

the environment is similar to a mining site: surface layers and vegetation are bulldozed into heaps on the sides of the quarry site.

During prospecting no wide roads are necessary, but numerous small roads and tracks are generated. This is because the area assigned for prospecting is systematically covered by a prospecting team. Where this prospecting operation is conducted in a closely-spaced pattern, the landscape is totally criss-crossed by tracks, e.g. the auger-drilled area on Dreyers Pan (see Photo 4J).

Discarded material: At many places there is evidence of mining equipment and material that has been discarded in the veld. This ranges from barbed wire rolls (SAD security fence) to heavy earth-moving machinery (at Spoeg River). It is particularly on the mining concessions of smaller companies that such littering is encountered. The larger mining concerns have adopted a well-applied housekeeping policy to which great importance is ascribed by the mine management. The policy is aimed at increasing safety standards and reducing material wastage, and consequently mining sites and plants are kept in a tidy condition. Unfortunately, once mining activity has ceased at a site, the housekeeping policy no longer seems to apply and mine equipment is frequently abandoned.

Fences: For security reasons the mining areas are enclosed by a high barbed-wire fence. At SAD a continuous fence runs from Port Nolloth to Alexander Bay. DBCM has fenced their coastal operations from the farm Oubeep to the Kleinzee township as well as the farms of their

Koingnaas and Mitchells Bay operations (Map 1). Other coastal farms of DBCM are enclosed by farm fences and gates.

Human influence: The presence or movement of people, for instance at camp sites during prospecting operations, has influence on the environment. Habitat of birds and mammals can be disturbed and hunting of game can take place. However, these actions are limited on SAD and DBCM land as shooting of wildlife is prohibited and mine security restrictions do not allow uncontrolled movement of people in the actual mining area. Domestic animals from the mine townships are known to have strayed into the wild, where they can disturb fauna, for instance, nesting of birds. On DBCM farms over 300 stray cats have been shot in the past (A. van Wyk, Security Officer, DBCM, pers. comm.).

#### 3.2.2.5 Developed Infrastructure

Both mining enterprises, SAD and DBCM, have built up almost entirely on their own the infrastructure necessary for pursuing their mining activity. The towns Alexander Bay, Kleinsee and Koingnaas were established by the mining industry, and except for institutions such as the police, the post office and banks, all structures and facilities are owned by the mine which also provides all services.

Thus SAD has established the following major infrastructure:

- i) The town Alexander Bay, catering for 1816 employees in 1981.  
The town includes 360 houses for Whites, 5 Hostels for single

accommodation for Coloureds and Blacks, 1 General Dealer, Sports and Recreation facilities, 1 Primary School, a well-equipped hospital with a complement of four doctors (only one doctor in 1981) serving the whole Richtersveld area.

- ii) The gravel road from Port Nolloth to Alexander Bay is maintained by the mine on behalf of the Provincial Council which, however, reimburses costs.
- iii) The airport at Alexander Bay is maintained by the mine.
- iv) 350 ha of farmland, making Alexander Bay self-sufficient in pork, poultry, fruit, vegetables and dairy products. Beef and mutton are supplied from elsewhere.

DBCM has established the following major infrastructure:

- i) The towns Kleinsee and Koingnaas, catering for 3229 employees in 1981. The towns include 342 family houses at Kleinsee, 108 family houses at Koingnaas, Sport and Recreation facilities, 2 Primary Schools, a Sewerage Plant, a well-equipped hospital with a staff of two doctors.
- ii) A 70 km tarred road linking the town Koingnaas with Kleinsee.
- iii) The airport at Kleinsee.
- iv) Stock farming on land where mining does not take place (120 000 ha).

Water and power consumption: All mining plants along the coast use sea water for the treatment of mine ore. Domestic fresh water is obtained for Alexander Bay from the Orange River. Kleinzee utilizes underground water from the Buffels River, though this source has been supplemented with a water supply pipe-line from the Orange River Henkries scheme via Nababeep since 1980, as the Buffels River supply has been dwindling. Koingnaas is supplied with fresh water from an artesian borehole.

The Electricity Supply Commission (ESCOM) provides electric power to the townships and to all treatment plant operations.

Sewage treatment plants have been installed to treat the effluent from Kleinzee and Koingnaas.

#### 3.2.2.6 Future Mining Actions

Prospecting activity has not been completed in the declared prospecting and mining areas. SAD is planning to continue with prospecting trenches in its area. DBCM will continue prospecting with auger drilling on their inland farms. On the coastal farm Oubeep prospecting is to be carried out by trenching.

DBCM will soon be mining an ore body on the farm Nuttabooi, an inland farm near their present Langhoogte mine. The ore body on this farm is characterised by a deep (40 m) layer of overburden. Consequently

mining this ore body will require large earth-moving operations.

With increasing amounts of overburden having to be moved in the future, electrically-powered earth-moving machinery is being considered to replace diesel-driven scrapers (De Beers Annual Report, 1979). DBCM is already assembling a dragline on the farm Dreyers Pan for removing overburden in that area. This machine has a 46 m<sup>3</sup> bucket with an annual stripping capacity of 16 million tons (De Beers Annual Report, 1980). Mining operations will be conducted very similarly to the dragline stripping operations at open-cast coal mines.

### 3.2.3 MINING ACTIONS OF SELECTED SMALLER ENTERPRISES

#### 3.2.3.1 DBCM Inland Operation

DBCM's inland operation at Langhoogte differs from its coastal land operation in surface mining technique and in the treatment of diamond-iferous gravels. It is particularly noteworthy, that at this operation backfilling and landscaping of mined-out sites is practised.

At Langhoogte the mining is more localised than at the coast and is conducted on a smaller scale. The ore body is mostly overlain by a thick layer of tough calcareous sandstone. This layer has to be blasted in two stages. Resultant large sandstone boulders are loaded by front-end loader onto trucks and are taken to one large overburden dump. Alternatively, the overburden is used directly in the

backfilling of a mined-out site. It is interesting that in this case backfilling is enforced because of space problems. Within the narrow boundaries of the farm there is not room for dumping waste except in the already mined-out sites. Backfilled overburden is covered and levelled with a layer of overburden sand to enable movement of mine vehicles on this surface.

At Langhoogte diamondiferous gravels are treated and concentrated on site. As there is no readily available water dry screening and crushing is used. Concentration of diamondiferous gravels is achieved initially in rotary washing pans where ore is mixed with puddle, a suspension of fines in water. Material for fines is obtained from the overburden sand. Further concentration of the diamond-bearing ore follows and the process is like that employed in the treatment plants on the coast.

One large rock tailings dump is generated by the Langhoogte treatment process but only a small slimes dam is created as the output of slime is small. Revegetation is not attempted on mined-out sites.

#### 3.2.3.2 Smaller Companies Near Olifants River

A number of smaller diamond mining companies are established to the north and to the south of the Olifants River. Ten individual concerns hold mining rights declared over a narrow coastal zone, extending mostly from the upper boundary of the admiralty zone to 31,49 m

below low water mark. On average a 200 m wide beach zone is exploited (De Beers, 1976). Where the coastline is rocky, mining of the beach zone is restricted by the foot of the cliff on the landward side.

The mining operations for this stretch of coastline are all very similar and basically of two kinds, a land and a marine operation.

Land operation: The beach zone above low water mark is worked with excavators, bulldozers and manual labour. Only small-scale machinery is employed. Practically the entire length of coastline is worked from Brand-se-Baai to Doringbaai, some 64 km. A special technique that has been developed is the construction of "wave breakers" which lead to an accumulation of sediment; this raises the beach elevation and pushes out the low water mark, thereby enabling the exploitation of a wider beach zone (De Beers, 1976).

Sea operations: As in marine exploitation, 100 mm to 150 mm Ø suction hoses are handled by divers. These suck gravels from the sea bed directly onto trucks for transport to the treatment plant.

Treatment of gravel: The diamondiferous gravels are treated in relatively small plants. The treatment process is similar to that employed by DBCM at Langhoogte, puddle is mixed with the diamondiferous gravels and fed into rotary washing pans. The use of puddle has important environmental consequences. To obtain the necessary fine material, quarries are dug in clayey sand, usually just above the beach zone. Thus the zone subject to mining activity is much

wider than just the beach region.

Induced Actions: Numerous tracks run parallel to the coastline, and contribute further to the impact of mining activity on the coastal zone. These tracks make up a corridor over 100 m wide in places (see Photo 40).

Discarded mine equipment was found all along the coastline north of the Olifants River. At Brand-se-Baai an entire treatment plant was left abandoned in 1981 by an operator who had gone bankrupt.

Mining activities by these smaller concerns do not appear to have given rise to the development of any significant infrastructure.

### 3.3.3.3 Marine Mining Operations

The whole length of the coastline from Donkins Bay to the Orange River has been divided into concession areas. Further concession areas have been added from Donkins Bay to Cape Columbine for which tenders were invited on 24 July 1981. On that date the Department of Mineral and Energy Affairs declared its intention (in the Government Gazette) of rezoning sea concessions. Exploitation of the sea will now take place in four zones: a land zone, a shallow-water zone, a mid-water zone, and a deep-water zone (Fig. 3.2).

This new allocation of sea concessions is to stimulate mining of the

sea in deeper areas. At present marine operations take place to depths of 20 m only.

#### Mining Technique:

Land concessions: Divers take suction hoses from the land into the sea and pump gravel ashore. 100 mm Ø and 150 mm Ø hoses are used. By July 1981 at least 26 divers were engaged in this operation in concession areas 9 and 10 and at Alexander Bay. Operations are hampered by stormy seas and during periods of bad visibility. It is likely that this kind of operation will expand rapidly in the future as can be deduced from the 1981 report of SAD:

"In spite of this (the stormy sea), however, it (the work in the breaker zone) is a highly profitable undertaking, which will be tackled on a larger scale at such time as more qualified divers become available."

Sea concessions: Mining is centred mainly in the breaker zone. Divers have confined their operations to depths of about 20 m. Operations are conducted from 16 m boats, some of which are hired from the rock lobster fishing industry. In total about 70 boats and 250 divers are engaged in this mining activity. Divers use 100 m and 150 mm Ø suction hoses to pump gravel on board the boat where fine sand is sifted out in a revolving drum. The concentrated gravel is collected in plastic bags and brought ashore for further treatment. In 1980 Dawn Diamonds, the largest operator, removed 5000 tons of gravel working an average of six-and-a-half days per

month. Landing facilities for the mining boats are at Port Nolloth, Hondeklip Bay and Doring Bay.

Total marine exploitation along the West Coast in the calendar year 1980 resulted in the pumping of 4678 m<sup>3</sup> of gravel, producing 42 321 carats.

Marine mining for diamonds has expanded rapidly since 1978. Certain companies have increased their number of boats from 1 to 20 since then. Further increase is likely: SAD reported in their 1981 annual report that marine mining in the breaker zone is highly profitable. According to the Department of Mineral and Energy Affairs mining in the surf zone has been proved to be economically viable in all allocated sea concession areas except numbers 8, 9 and 10. In the latter cases thick layers of sand have hampered operations.

### 3.3 SUMMARY

Diamonds on land occur sporadically and, on average, in low concentration in gravel deposits below a layer of overburden mainly in a narrow zone along the coastline. This distribution dictates the nature of the mining operations, which are conducted over a wide area and have become large earth-moving operations. At any one time there are many working faces which can be closed and reopened to facilitate blending of diamond ore.

Diamonds in the sea are at present mined only in the narrow surf zone. Operations are conducted at low intensity practically all along the coast, both from the sea and from land.

The scale of mining has increased substantially in the past and still appears to be on the increase. The largest mining enterprise, De Beers Consolidated Mines Limited, for example, increased its production of diamonds from 636 871 carats in 1970 to 1 434 262 carats in 1980 (a two-fold increase in diamond production). In the same period the earth-moving operations themselves have been scaled up due to the mining of deeper-lying diamond deposits. Thus the amount of overburden stripped by De Beers Consolidated Mines Ltd increased from 8 669 900 tons in 1970 to 56 713 400 tons in 1980 (a six-fold increase in overburden stripping).

In the sea, mining in the surf zone began with the development of a new mining technique in 1975. It appears that marine operations are on the brink of further expansion.

In this chapter the individual actions of the various mining operations have been examined in an effort to identify the causes of environmental impact. These actions are summarized in Table 3.12.

TABLE 3.12 Mining actions

Action Group	Specific Action
LARGE DIAMETER AUGER DRILLING	a) development of road and tracks
	b) clearance/damage of vegetation at drilling site
	c) drilling excavation
	d) establishment of camp site
TRENCHING	a) removal of vegetation
	b) Stripping of overburden
	c) creation of overburden dumps
	d) creation of primary trench excavations
	e) creation of secondary trench excava- tions
	f) generation of road tracks
	g) establishment of camp sites
SURFACE MINING OPERATION	a) removal of vegetation
	b) stripping of overburden
	c) creation of overburden dumps
	d) creation of bedrock sites
	e) extraction of diamondiferous gravels
	f) backfilling of mined-out sites
TREATMENT	a) disposal of oversize boulders
	b) discharge of slime into the sea, into settling dams, into inland pans
	c) creation of rock tailing dumps
	d) establishment of mining plant buildings

- continued

Action Group	Specific Action
INDUCED/ANCILLARY ACTIVITY	<ul style="list-style-type: none"> <li>a) construction of haulage roads</li> <li>b) quarrying for road material</li> <li>c) generation of roads and tracks</li> <li>d) random discarding of material</li> <li>e) abandonment of mining plants</li> <li>f) orderly discarding of material, equipment</li> <li>g) security fencing</li> <li>h) general presence of people</li> </ul>
M I N I N G ASSOCIATED MINING INFRASTRUCTURE	establishment and maintenance of: <ul style="list-style-type: none"> <li>a) townships</li> <li>b) major access roads</li> <li>c) airports</li> <li>d) power lines, water supply pipe-lines</li> <li>e) crop farming and stock farming</li> <li>f) discharge of sewage</li> <li>g) consumption of water, electricity, diesel, material resources</li> </ul>
SOCIAL/ECONOMIC ACTIONS	<ul style="list-style-type: none"> <li>a) export and sale of rough diamonds</li> <li>b) provision of employment, training, housing, education facilities, health services, recreation facilities</li> </ul>



Photo 4A Aerial photograph of sand plume development north of prospecting trench (north of Port Nolloth) shows that primary impact from mining is significantly magnified by wind erosion.

## CHAPTER 4

### ENVIRONMENTAL IMPACT

#### 4.1 INTRODUCTION

This chapter examines the impact of the mining actions on the West Coast environment identified in the previous chapter. Again the emphasis of the investigation has been on the large enterprises, SAD and DBCM, but the smaller operations are also dealt with briefly.

Environmental impact studies are best undertaken by a small interdisciplinary team of persons as this enables knowledge from a wide field to be pooled (Fuggle, 1979). This results in a better appreciation of the intricacies of the environment and largely reduces bias. This one-man investigation therefore has its limitations: Certain impacts may have been overlooked and bias may have been introduced in those evaluations which are of a subjective nature, e.g. assessing the impact on scenic views. Nevertheless, environmental impact was investigated in a methodic manner using the matrix approach: The impact of each mining action on the elements of the environment was assessed by means of field observations, collection of data and re-

viewing of the literature. In areas where insufficient knowledge was at hand, where the author did not feel competent to make an assessment, or where bias may have been introduced, this is clearly indicated.

A distinction is made in the literature between *primary impacts* and *secondary impacts*. These are defined by Shopley (1981) as follows: *Primary impact* is any effect in the bio-physical and socio-economic environments that arises from a cause directly related to the project. *Secondary impacts* are those effects on the bio-physical and socio-economic environments which arise from an action, but which are not initiated directly by that action. Thus the loss of vegetation is a direct or *primary impact* of the excavation of a prospecting trench. Wind that then blows sand out of the trench causes a *secondary impact* by smothering and sandblasting vegetation outside the trench.

Some authors use the term *secondary impact* for impacts resulting from induced action, e.g. the quarrying for road material for the construction of haulage roads is an induced action of the mining activity. These impacts are referred to as *impacts from induced actions* in this thesis.

## 4.2 ENVIRONMENTAL IMPACT OF LARGE ENTERPRISES

### 4.2.1 THE MATRIX APPROACH

The matrix method is a frequently used tool for environmental analysis.

The matrix consists of two lists, one lists environmental characteristics and the other, human actions. These are aligned at right angles to one another and along the edges of a grid forming the matrix cells. In its application in this thesis the mining actions (identified in Chapter 3) are listed along a horizontal axis and elements of the West Coast environment (selected from on-site observations by the author and the description in Chapter 2) are listed along a vertical axis (Table 4.1). The impact of each action on each element of the environment is assessed and recorded in the corresponding matrix cell.

This method was chosen as it is simple to use and provides a convenient way of relating project actions to environmental elements. Its strength lies in that it enables one to readily identify impacts and it leads one to think about the possible consequences of each specific action on the environment. It is also effective as a communication device as it displays all impacts in one table.

The method, however, has several weaknesses (Munn, 1975; Fuggle, 1979). It does not show how an impact score was derived. This is explained in an accompanying text (4.2.2). The matrix also does not reveal explicitly interactions between cause and effect and links between environmental elements. Thus it was decided to explain secondary impacts due to wind erosion more fully by using a flow chart in section 4.2.3.

The original matrix method was the Leopold Matrix, which has been adapted by Fuggle (1979). This author has developed his own adaptation,

which is basically a simplification of the above two approaches: For each matrix cell, present observed impact was assessed in terms of importance and benefit. In addition, where no present impact had yet been observed, the potential for future impact was assessed. Using appropriate symbols this information was entered in each cell (key in Table 4.1). Major detrimental impact was shaded to indicate the main issues or significant detrimental impacts.

Definitions of terms of assessment:











*Importance* is defined by Fuggle (1979) as the subjective judgment as to the significance that a particular action on a specific environmental characteristic has for the environment as a whole. It combines the terms used in the Leopold Matrix of magnitude (the extent or scale of an impact submitted on the basis of facts) and the importance of an impact (subjective judgment of its significance). An impact is judged as being of high importance (H) or of low importance (L). A finer degree of classification, it was felt by this author, would be difficult to substantiate for a subjective judgment by a single investigator. Where there is inadequate information on which to form a judgment a "?" is used.

*Benefit:* An assessment of whether the impact will be beneficial (+), detrimental (-) or indeterminable (?).

*Potential Impact (P):* An assessment of whether a particular action could potentially cause an impact on a specific environmental

WEST COAST SURFACE DIAMOND MINING OF LARGE ENTERPRISES : IMPACT MATRIX			PRO							
			AUGER DRONOMIC							
			ROAD TRACKS	CLEARING OF DRILLING SITE	PROVISION OF EMPLOYMENT	PROVISION OF WELFARE SERVICES	SECURITY RESTRICTIONS	STOCK & CROP FARMING		
BIOLOGICAL & PHYSICAL ENVIRONMENT	AESTHETIC	SCENIC VIEWS 1)	/	/	.	.	.	+L		
		WILDERNESS QUALITY	/	/	.	.	.	+H -L		
	ECOLOGICAL	AIR QUALITY	.	.	.	.	.	.	.	
		SURFACE WATER	.	.	.	.	.	.	.	
		GROUND WATER	.	.	.	.	.	.	.	
		SOIL	/	/	.	.	.	.	+L ??	
		VEGETATION	/	/	.	.	.	.	+L -L	
		TERRESTIAL FAUNA	-?	-?	.	.	.	.	+H ??	
		ESTUARIES	-P	-P	.	.	.	.	+H	
		MARINE FAUNA&FLORA	.	.	.	.	.	.	+L	
		SCENICAL	UNIQUE ECOSYSTEMS	-?	-?	.	.	.	.	+L -L
			RARE/ENDANGERED SPECIES	??	??	.	.	.	.	+H ??
	PROCESSES	WIND EROSION	/	/	.	.	.	.	+L ??	
		COASTAL EROSION	-?	-?	.	.	.	.	+L ??	
		COASTAL DEPOSITION	.	.	.	.	.	.	.	
	SOCIO-ECONOMIC ENVIRONMENT	CULTURAL	HISTORIC SITES	-P	-P	.	.	.	.	+H
			ARCHAEOLOGICAL SITES	-P	-P	.	.	.	.	+H
		SOCIAL	COMMUNITY WELFARE	.	.	.	.	.	.	+H +H / +L
HEALTH & SAFETY			.	.	.	.	.	.	-L +H +H -? +?	
ECONOMIC		REGIONAL INFRASTRUCT.	.	.	.	.	.	.	.	+L
		REGIONAL INDUSTRY	.	.	.	.	.	.	.	-L
RESOURCE USE		MARINE FISHING	.	.	.	.	.	.	.	.
		AGRICULTURE	-L	-L	.	.	.	.	.	-L +?
		TOURISM	/	/	.	.	.	.	.	.
		RECREATION	/	/	.	.	.	.	.	.
	NATIONAL RE SOURCES	.	.	.	.	.	.	.	.	

KEY TO ENTRY  
IN MATRIX CELLS :

-  LOW NEGATIVE IMPACT
-  HIGH NEGATIVE IMPACT
-  LOW POSITIVE IMPACT
-  HIGH POSITIVE IMPACT
-  POTENTIAL NEGATIVE IMPACT IN FUTURE
-  POTENTIAL POSITIVE IMPACT IN FUTURE
-  NEGATIVE IMPACT OF UNCERTAIN/UNKNOWN IMPORTANCE
-  POSITIVE IMPACT OF UNCERTAIN/UNKNOWN IMPORTANCE
-  UNKNOWN /UNCERTAIN IMPACT
-  NO INTERACTION

1) Where terms are not considered self-explanatory, or are not described in text, they are defined in appendix A.

TABLE 4.1 IMPACT MATRIX

characteristic in the future, although such an impact may not yet have occurred.

#### 4.2.2 DISCUSSION OF IMPACTS

The assessed impact as shown in Table 4.1 is further explained by discussing each environmental element individually and indicating the extent to which the initial hypothesis is supported or rejected (emphasis is placed on major negative impacts):

##### Scenic Views and Wilderness Quality

Aesthetic impacts are difficult to discuss because of their subjective nature. However, a few criteria apply: Visual intrusions relate to the degree of visibility and nature of the local landscape (Down & Stocks, 1977). The West Coast landscape is flat, thus protruding objects become conspicuous and are visible over a long distance. Colour contrasts, such as light dumps against a darker background, are also prominent.

Any action that leaves a permanent mark on the landscape has impact on the pristine or wilderness quality of the environment. Even a well-constructed tar road, that may be visually pleasing in another environment, gives a negative impression in a wilderness area, such as the West Coast, because it interferes with the aesthetic and spiritual perception of "being alone with nature". However, there



Photo 4B

High vertical wall left from mining operation at Annex Kleinzee



Photo 4C

Mined-out site at Annex Kleinzee backfilled, but still appears unsightly, because there are no landscaping efforts. Surface crust prevents natural revegetation.



Photo 4D

Mined-out site near Alexander Bay with overburden dumps in background and exposed bedrock in foreground.

are degrees of intrusions on the wilderness quality, similarly to degrees of visual intrusions on scenic views. But impact on the wilderness aspect is more severe, because a pristine environment can hardly be restored. "Wilderness is a resource which can shrink but not grow" (Leopold, 1966).

Scenic and wilderness aspects on the West Coast are spoilt markedly by overburden dumps. Dumps are either sparsely or completely unvegetated and, therefore lighter coloured than surrounding landscape; they are conspicuous. Some overburden dumps are very large (e.g. overburden dump just south of Koingnaas). Others have developed a hard crust (e.g. at Koingnaas and Annex Kleinzee) which has prevented all plant growth and has led to erosion gullies (Photo 4L). Some sites resemble a moon landscape (Photos 4C, 4D). If, during stripping operations, smaller dumps were built up their tops would be rounded off naturally by the scraper machines and leave less steep slopes (Photo 5B). This would make dumps more visually appealing and improve the possibility of their revegetation.

Trenches create prominent, abrupt breaks in the landscape, often with high vertical walls, particularly where ground is clayey (Photo 4B) or calcareous. Where ground is sandy, trench walls are inclined, some natural revegetation occurs and impact is less drastic. Stripping operations could possibly be planned such that overburden is dumped into prospecting trenches located nearby a working mine block.

The extraction of gravels exposes bedrock surfaces which can be

relatively even (Photo 4D), but mostly appear as rough terrain with deep gullies. Covering of these exposed bedrock areas in backfilling operations potentially could have a positive effect, but no land-scaping occurs and the impact is thus similar to that from overburden dumps.

Discharge of rock tailings creates dumps that protrude against the landscape background because of their great size (Photo 3G). Fifteen rock dumps occur on SAD and DBCM concessions (Table 3.11). Rock dumps dwarf buildings and structures of treatment plants and screen their visual impact. Slime is discharged into natural depressions and pans and is not visually obtrusive, although such slimes dam surfaces are unvegetated.

Haulage roads on the whole do not cause major visual impact. However, since DBCM's new haulage road network has been laid out, the old abandoned routes now scar the landscape. Numerous quarries appear as even greater scars. They are used for road material and the light coloured lime or gypsum ground contrasts with the surroundings. Top burden is bulldozed in messy heaps at the sides of the quarries (Photo 3G). The mine road from Kleinzee to Koingnaas is tarred and neatly laid out. The access road from Port Nolloth to Alexander Bay, however, has wide messy road boundaries, and a number of quarries have been dug to provide road material for its maintenance.

Road tracks generated during auger drilling have a major visual impact where they have been laid down in a regular, closely-spaced pattern.

This subsequently causes damage to surrounding vegetation leaving a barren landscape (Photos 4H, 4I) (see Wind Erosion).

Discarded mining equipment (e.g. barbed wire rolls, old conveyor belts) and abandoned buildings and structures of treatment plants mar the landscape. Powerlines and high security fences stand out obtrusively.

The above seems to indicate that one of the impacts of the mining activity is to cause conspicuous visual effects over considerable distances. The entire mood and character of the desert environment is changed by the presence of large buildings and dumps. Such impact is not conducive to the desert environment being utilized in the future for recreational pursuits based on the area's wilderness quality and atmosphere. This contributes to the rejection of point (b) of the initial hypothesis.

#### Air Quality

There are no gas or particulate emissions from the mining actions. Stripping and excavating machinery release diesel exhaust fumes and stir up dust, but this seems to have minor impact compared to the natural dust that can be stirred up in windy conditions. The more serious effect of dust production is that it can smother vegetation downwind of mining operations.

### Surface Water

Slime is discharged into natural pans, e.g. Dreyers Pan. It is unknown to the author how much plant and animal life is supported by these pans. They are possibly important short-term habitats for birds when they have collected water after rain. The fine mud material from discharged slime would probably smother small plant and animal organisms, but the extent of such impact is unknown to the author.

### Ground Water

Drilling, trenching, stripping and excavation operations could interfere with ground water bodies which would occur in lenses in bedrock depressions (2.2.9). Extent of such impact is unfortunately unknown. The township Kleinzee draws water from the Buffels River mouth aquifer. As this aquifer also supports riverine plant communities, which in turn provide habitat for numerous forms of fauna (Heydorn & Grindley, 1981), depletion of the aquifer has a major impact. Furthermore, aquifer systems that have subsided because of overdraft will never again be able to hold as much water as they did before overdraft began (Holzer in Sheridan, 1981). This would represent a lost resource which could be used if small farms or tourist towns were established.

### Soil and Vegetation

Soil and vegetation is destroyed permanently in overburden stripping

operations. No stockpiling of topsoil occurs. An area of 1400 ha + 800 ha has been affected directly so far since the beginning of operations. Stripping operations, however, have increased in scale: In 1980, 50 ha and 200 ha were mined by SAD and DBCM respectively (Table 3.9). Further areas are destroyed directly by numerous small road tracks near actual mining sites, rock tailings dumps, built-up slimes dams, haulage roads and associated quarries. A closely-spaced grid of roads generated during auger drilling has damaged vegetation over a significant area (Photos 4H, 4I, 4J). Further vegetation is damaged and soil is lost through secondary impact by wind erosion (see Wind Erosion).

Where bedrock has been exposed, sites carry no significant growth. Rock surfaces would take a long time to weather (of the order of centuries). At places some growth does occur where nooks and crevices have collected windblown material but vegetation cover is insignificant. Rock tailing dumps support no vegetation. Surface compactness of abandoned haulage roads (at Annex Kleinzee and Dreyers Pan) prevents plant growth. Overburden dumps at places show reasonable vegetation growth that has re-established naturally. Others do not show any growth at all. Natural revegetation therefore, is examined more closely in 4.2.4.

Destruction of vegetation means a loss of part of the vegetation communities. This may not be so important for the Strandveld which is widely represented along the West Coast, but appears important for the Strand vegetation communities which are represented only in the

narrow primary dune zone along the coast (2.2.6). Loss of vegetation cover also means a loss of habitat for fauna and a decrease in the grazing potential of the land for small-stock. Vegetation is of major importance in stabilizing the land surface consisting mainly of unconsolidated sands. Because of the strong winds on the West Coast, topsoil and lower surface layers are blown away and destroy further vegetation by sandblasting. Therefore, every mining action that exposes unvegetated sand surfaces destabilizes such areas and in fact leads to destabilize further areas (see Wind Erosion). This erosive effect is a particular hazard on immediate coastal foreland (2.2.3). Prospecting trenches and roads developed within this vulnerable zone have a major negative impact on the stability of this region. This contributes to the rejection of point (b) of the hypothesis.

### Terrestrial Fauna

Little is known about the terrestrial fauna of the West Coast. Thus impact from specific mining actions is largely unknown. Generally, mining operations would destroy small fauna and permanently alter their habitat in the actual mining area. Lack of vegetation or a reduced vegetation cover would leave a major detrimental effect on the mining-disturbed site, but the importance of such impact for the whole region is unknown. Some endemic species of lizards and amphibians could be affected. Game and birds would possibly not be seriously affected because of their mobility and the availability of habitat elsewhere. An exception to this may be, where mining operations disturb important localised nesting and breeding sites, for instance

of the Damara tern which nests on dune slacks on the coast. Potential future damage to water bodies, such as estuaries, by mining actions would have a major negative effect on birds and game. A declared mine policy of prohibiting the shooting of game, and security restrictions that limit the movement of people is of major benefit for terrestrial fauna. At present mining may therefore not be of major detriment to terrestrial fauna but may be so in future, if important habitats (e.g. estuaries) are disturbed. This shows that where mining policy is sensitive to environmental elements, mining operations can greatly limit their impact and that the mining operations as such do not necessarily cause environmental problems, but it is the manner of their execution that is important. Impact on terrestrial fauna therefore does not contribute to point (b) of the hypothesis, but lends strength to the rejection of point (c) of the hypothesis, that control of impact is possible.

### Estuaries

Prospecting trenches and a road have resulted in minor impact on the Swartlintjies estuary, but a rock tailings dump, roads and a golf course for the Kleinzee township have major impact on the Buffels estuary. The Groen, the Spoeg and the Bitter have not been affected by mining operations so far. Potentially, however, mining operations could be conducted in or near estuaries in the future. The consequent impact would be major. Estuaries are important ecological habitats for the region (2.2.7; 2.2.8) and they have major value in contributing to the scenic and aesthetic appeal of the coast. Estuaries

therefore, are of major importance to potential future recreational and tourist use of the region. As there is no consideration in the planning of mining operations for limiting or even withholding actions on such important and sensitive areas, there is no guarantee that estuaries would not be subject to major impact in the future. An extended vision of 'housekeeping' by the mining enterprises would provide such a safeguard. Control of impact, therefore, could be possible and this contributes to point (c) of the hypothesis.

#### Marine Fauna and Flora

Treatment plants at Annex Kleinzee and Alexander Bay discharge slime directly into the sea. The plant at Annex Kleinzee releases about 7000 tons of sand per day (2,1 million tons per year). The plant was erected in 1969 and is planned to operate until 1988. A great amount of sediment is therefore discharged into the sea. A memorandum of the Department of Sea Fisheries states that marine fauna and particularly flora is affected for about 2 km of coastline. However, no quantitative study was done. Marine organisms are smothered by the sediment outfall and it was noted that the beach had extended seaward by about 300 m at the point of outfall. The length of coastline that is affected can be deduced from the length of beach (2,5 km) blackened by the concentration of the heavy mineral ilmenite. (This mineral is present in mined ground and is therefore discharged with the slime output. Wave action on this shore gradually washes out the fines but leaves behind heavier material such as ilmenite.)

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#### Marine Fauna and Flora

REPEAT

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It is likely that rock lobster is seriously disturbed for this length of coastline and this has a negative impact on the fishing industry. The coastline north of Hondeklip Bay is not a major rock lobster fishing ground (2.3.4.1), so the slime outfall into the sea at Klein-zee may not be of major significance to the West Coast fishing industry. The local effect of this impact is the reduced value of 2,5 km of this coast for beach-combing in the future, as intertidal zone organisms appear to have been destroyed. As the extent of this detrimental impact is unknown to the author this impact is not taken to contribute towards the evaluation of point (b) of the initial hypothesis.

#### Unique Ecosystems

Three distinct littoral dune vegetation communities and the Strandveld are vegetation types unique to the West Coast (2.2.5). Source of impact on these zones is similar to that on soil and vegetation. It is uncertain whether the ecosystem represented by the Strandveld is seriously affected as a whole. However, much larger areas than those disturbed by *primary* mining action are affected (4.2.3). With the increase of the area disturbed by mining through *secondary impact* due to wind erosion (4.2.3), the Strandveld ecosystem may be seriously degraded (it is described later (4.2.4) that vegetation cover on sites disturbed by wind erosion is less than one-third that of pristine sites). If wind erosion was controlled, this would prevent major damage to the Strandveld.

Impact on the littoral dune vegetation communities may be particularly

major as they occur only in a narrow zone, along a shorter length of coastline than the Strandveld, and are particularly sensitive. Prospecting trenches and coastal roads represent the major hazard to this zone. Impact could be limited if roads were located further inland away from this fragile zone. This therefore contributes to the rejection of point (c) of the hypothesis, impact can be controlled and also contributes to the rejection of point (b) of the hypothesis, impact on the vegetation communities may be significant.

#### Rare and Endangered Species

Rare and endangered species of mammals, reptiles, amphibians and birds as classified by the S.A. National Scientific Programmes Report Nos. 7, 8 and 23, are not known to occur along the West Coast. There are, however, a number of endemic species: 7 spp. terrestrial birds, 7 spp. lizards, 1 sp. of frog and 1 sp. (possibly 4) of mammal. Impact of mining operations on these species is unknown. The S.A. National Scientific Programmes Report No. 45 on threatened plants lists a number of taxa for the region that includes the coast. It is also unknown if mining operations have had impact on these species.

If mining enterprises employed the services of a botanist or zoologist, areas particularly important for conservation could be identified. Mining operations in these areas could then be conducted with greater care or prevented altogether. For instance, roads and quarries could be located elsewhere. Significant impact would thus be prevented and this contributes to the rejection of point (c) of the hypothesis.

### Wind Erosion

The process of wind erosion is promoted wherever vegetation cover is disturbed or removed, and wherever areas are left with bare and unstabilized ground surfaces. The source of impact is similar to that on soil and vegetation. Auger drilling road tracks and drilling sites, prospecting trenches, overburden dumps and haulage roads with associated quarries, cause major impact (Photos 4A, 4F to 4J).

Sandplumes north of many mining-disturbed sites, particularly prospecting trenches and overburden dumps, are evidence of wind erosion taking place through *secondary impact*. This impact is of major significance and as chapter 2 indicated that the West Coast was vulnerable to wind erosion (due to strong winds and a shallow layer of topsoil), this phenomenon was investigated in more detail and is discussed in 4.2.3.

Wind erosion causes serious impact because the vegetation cover on the affected sites is significantly reduced to less than one-third of its original pristine state and its composition of plant species is significantly altered. The diversity of plant species is reduced and a number of plant species are eliminated and make way for dune type vegetation, for instance *Eragrostis cyperoides* (4.2.4). Wind erosion therefore has significant impact on the grazing potential of the region and it seriously degrades the Strandveld ecosystem, i.e. it affects pastoral and nature conservation interests. Moreover, the areas subjected to wind erosion greatly lose their aesthetic and visual appeal (Photos 4H, 4I), thereby affecting the future potential

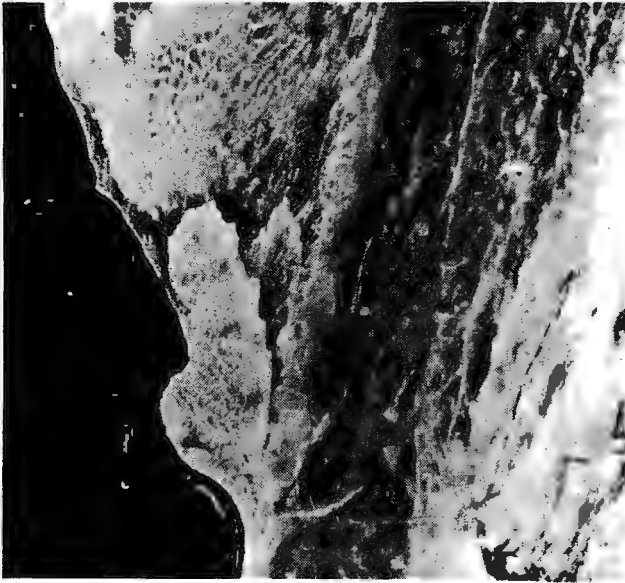


Photo 4E

Natural sandplume development north of exposed beach placer north of Kleinzee (DBCM aerial photograph, 1975, 1:20 000).



Photo 4F

Aerial photograph of sandplume development due to wind erosion north of prospecting trench located north of Port Nolloth.



Photo 4G

Significantly reduced vegetation cover in sandplume north of prospecting trench at Holgat North (plot A14, Table 4.5).

Photos 4H & 4I

Wind erosion impact from auger drilling operation at Annex Kleinzee: vegetation is sandblasted from destabilized surface of tracks (right) and actual auger drilling site (left middle of Photo 4H).

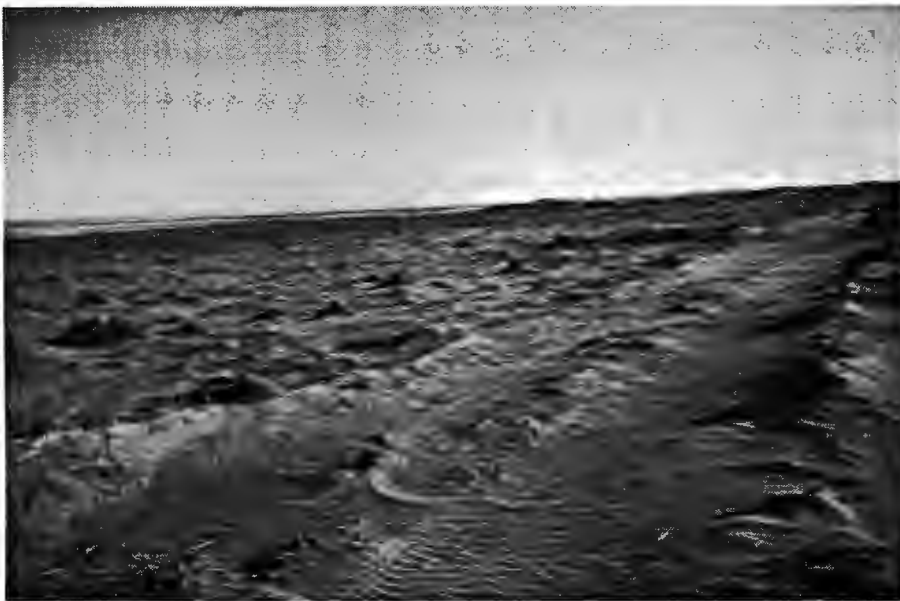
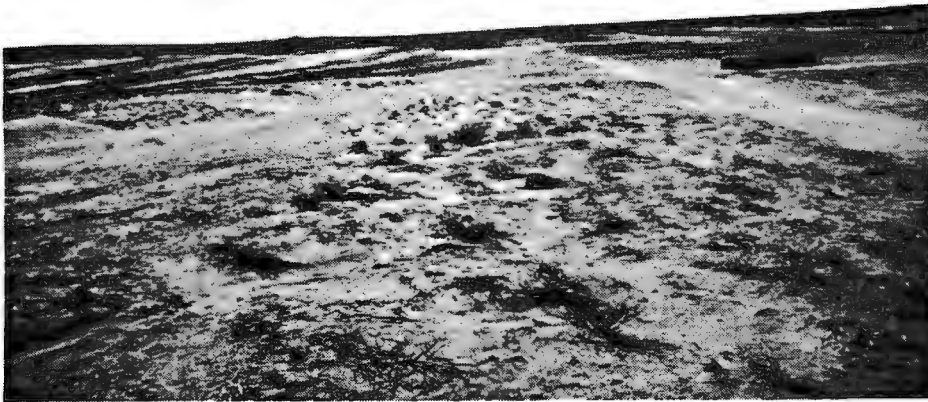


Photo 4J

Aerial photograph (1:20.000), taken for DBCM in 1975, clearly showing wind erosion impact on vegetation between grid of parallel tracks generated during auger drilling.

for recreation and tourism in the region. This contributes to the rejection of point (b) of the hypothesis.

### Coastal Erosion

The vulnerability of the coastal foreland to erosion has been indicated (2.2.3). Mining disturbances such as road tracks, prospecting trenches and overburden stripping would initiate coastal erosion processes. Such actions occur at Koingnaas (DBCM) and on SAD land, where mining operations stretch into the primary dune zone. It has been indicated (Fig. 2.1) that such coastal erosion can be prevented by locating roads further inland, away from the particularly fragile zone. This contributes to the rejection of point (b) and point (c) of the hypothesis.

### Coastal Deposition

As has been mentioned previously, the Annex Kleinzee treatment plant discharges 2,1 million tons of sand (about  $3/4$  million  $m^3$ ) per year. This could have an impact on longshore sediment transport, which is of the order of half to 2 million  $m^3$  for South African coasts (H. Swart in Heydorn & Tinley, 1980). As effect and extent of such impact is unknown to the author this is not evaluated in terms of the hypothesis.

### Historic and Archaeological Sites

It is unknown whether mining actions have caused impact on archaeolo-

gical sites as their location is largely unknown. Historic sites, such as the first Namaqualand police station near the Spoeg River, and some early diamond digging sites on the farm Oubeep and near the Boegoeberg, have not yet been affected by mining operations, but this may occur in the future (DBCM is planning extensive prospecting operations at Oubeep). Sites of past human features are of significant scientific interest, and together with historic sites, such as early diamond diggings, could provide important tourist attractions for the area. Possible mining impact in the future would therefore be of major significance and contributes to the rejection of point (b) of the hypothesis. If mining policy considered such impacts, these sites (which are small in area and may therefore not significantly interfere with mining operations, if left alone) could be identified and saved from destruction, i.e. this also contributes to the rejection of point (c) of the hypothesis.

### Community Welfare

SAD and DBCM have a major beneficial impact on the regional community with the provision of opportunities for employment. Also, SAD provides medical services for the inland Richtersveld region and DBCM has supported regional community centres with financial grants (DBCM Annual Report 1979). Security restrictions have a negative but also a positive impact. They restrict the community's access to the major part of the regional coast (2.3.4.3, 3.2.2.4) but also prevent the uncontrolled movement of people (for instance indiscriminate use of off-road vehicles) which prevents possible disturbance of the desert

environment. This therefore contributes both to an acceptance and to the rejection of point (b) of the hypothesis.

### Health and Safety

Mine employees enjoy associated social and medical benefits with employment, including provision of housing, diverse recreational facilities and job training opportunities.

Employees also expose themselves to the risk of accidents during the mining process, which is reduced by a declared mine safety policy. SAD had four fatal accidents from 1970 to 1980, which appears relatively low.

Turnover of labour figures appear low (in the order of 10 - 15%) except for Coloureds at SAD (about 90% p.a.), which is very high (Personnel Dept's, SAD & DBCM, pers. comm.).

On the whole this contributes to an acceptance of point (b) of the hypothesis.

### Regional Infrastructure

The regional infrastructure has benefited from the mining activities particularly through the establishment and maintenance of three townships, including two airports and two major access roads. This infrastructure can be of benefit to any future use of the area. Here the

mining actions have had positive impact and this contributes to the acceptance of point (b) of the hypothesis.

### Regional Industry

The mining activities have had little impetus for the regional industry, since mines import their requirements mostly from outside the region or supply their own needs. There is basically no development of any secondary industry. This is indicated in a hierarchy ranking of towns in the Namaqualand region according to their number of available services by the Office of the Prime Minister, Physical Planning Branch (1980), which has assigned a low status to the mining towns Alexander Bay and Kleinsee. Mine settlements in other arid regions also have not developed local secondary industry spin-offs (Barnard, 1974). Mining representatives on the West Coast do not wish to make projections of the remaining life-span of their enterprises, but diamond exploitation must eventually come to an end. An interesting question is what will become of the mine townships then? There are no plans for such an eventuality. If other resource uses, such as tourism and recreation, were allowed at the same time as mining, this may lead to a smoother transition to the future use of the land once mining has ceased. Mining townships would probably be of benefit to tourism in the future. Although mining does not have a negative impact on the regional industry, which contributes to an acceptance of point (b) of the hypothesis, mine townships could make a positive contribution to the development of the region, if this is allowed for in future mine planning.

### Marine Fishing

Discharge of slime into the sea (see impact on marine fauna and flora) probably affects the rock lobster population, but this detrimental impact may not be of major significance as rock lobster catches for that part of the coast are low (2.3.4.1). However, the extent of this impact is largely unknown and therefore this impact is not evaluated against point (b) of the hypothesis.

### Agriculture

Mining actions that destroy vegetation or result in reduced vegetation cover have a negative impact on the grazing potential of the land. Because of *secondary impacts* through wind erosion (4.2.3), vegetation cover is reduced by two-thirds and drops in species diversity (4.2.4). Such a vegetation cover will probably not allow any grazing of small-stock. About 7000 ha of land has been disturbed to this extent (Table 4.3). This impact is spreading with time (Table 4.4), therefore the impact is judged to be significant and to contribute to the rejection of point (b) of the hypothesis.

### Recreation and Tourism

As mining operations have a major impact on scenic views and on the wilderness quality of the West Coast and potential impact on historic and archaeological sites and unique vegetation communities of the region, these actions also have a secondary impact on the recreation

and tourism potential of the land. It has been outlined (2.3.4.3) that the West Coast has much scope for such resource use, particularly as a wilderness coastline, an asset which is rapidly increasing in scarcity. "One of the fastest-shrinking categories of wilderness is coastlines" (Leopold, 1966). Demand for such a resource use is likely to increase in the future. At present security restrictions have a major direct impact by preventing public access to a major part of the coastline (2.3.4.3). This contributes to the rejection of point (b) of the hypothesis.

Impact on the potential recreation and tourist use of the West Coast in the future could be mitigated by rehabilitating mining-disturbed land and by protecting areas of particularly great aesthetic value. Diamond mining and future utilization of the land for recreation and tourism need not necessarily be mutually exclusive resource uses if rehabilitation is part of the mining process: "...if proper land rehabilitation follows in the wake of mining, then the alienation of land need be no more than temporary..." (Chamber of Mines of S.A., 1981). This is investigated further in chapter 5.

Present conflict between diamond mining and recreation and tourism could perhaps be resolved. The security aspect appears to be the major hurdle if the two land use options are to run concurrently. The question is if this obstacle is really impossible to overcome. The proposed national park for the coast between the Spoeg and the Groen Rivers did not materialize, because the mining enterprises did not want to give up their options of possibly mining that region.

Such a right could be ceded to the mining enterprises, but until actual mining is to take place, is there really a problem with allowing tourist and recreational use of the area? Diamonds occur beneath a deep overburden pile and on average very rarely in the gravel beds. It therefore seems unlikely that diamonds will be picked up by the casual visitor. Conversely, the lure that diamonds may be found in the area would act as an added tourist attraction to the region. Prospecting operations such as auger drilling could even be conducted while the area is open to visitors. With this prospecting method (a prospecting hole can be drilled and filled up immediately afterwards) security would still not pose a problem. Once the mining enterprise decides to mine on the basis of the prospecting results, the particular area can be zoned off for exploitation. This illustrates that mining impacts can be mitigated if mine policy adopted environmental considerations. This contributes to the rejection of point (c) of the hypothesis.

### National Resources

Diamond mining has a negative impact by consuming national electricity and diesel fuel resources (3.2.2.5). DBCM has a maximum electricity demand of 14MVA, and DBCM and SAD together used about 2,1 million litres of diesel fuel per month in 1980.

On the other hand, diamond mining has a major positive impact on national resources by returning a large amount of revenue to the State. The State obtains 100% of profits from SAD and participates

in about 63% of profits from DBCM. Diamond sales figures appear in Table 2.9. On the whole this contributes to an acceptance of point (b) of the hypothesis.

#### 4.2.3 WIND EROSION

From the previous overview of the environmental impacts of diamond mining by SAD and DBCM it is apparent that wind erosion is one of the major impacts induced by mining. This impact was examined in some detail, including a quantitative investigation. An account of this investigation follows:

Mention has been made of the exceptionally strong, unimodal, southerly winds blowing at the West Coast in summer. These winds cause disturbance to vegetation to be far more widespread than simply the disturbance due to *primary impact*, i.e. direct damage from trench excavations, road tracks etc. From field observations it was evident that north of every mining-disturbed site (i.e. on the leeward side) sand plumes stretched out, and vegetation cover was significantly less than in pristine areas. This phenomenon is particularly noticeable on aerial photographs of the region (e.g. Job No. 763, photo nos. 7410 to 7412 and Job No. 812, photo nos. 5259 to 5261 as well as in aerial photographs taken by the author). Photos 4A and 4F show sand plumes extending north of prospecting trenches. Photo 4G shows reduced vegetation cover in a sand plume.

King (1951) describes wind erosion as follows: "Sand impelled by

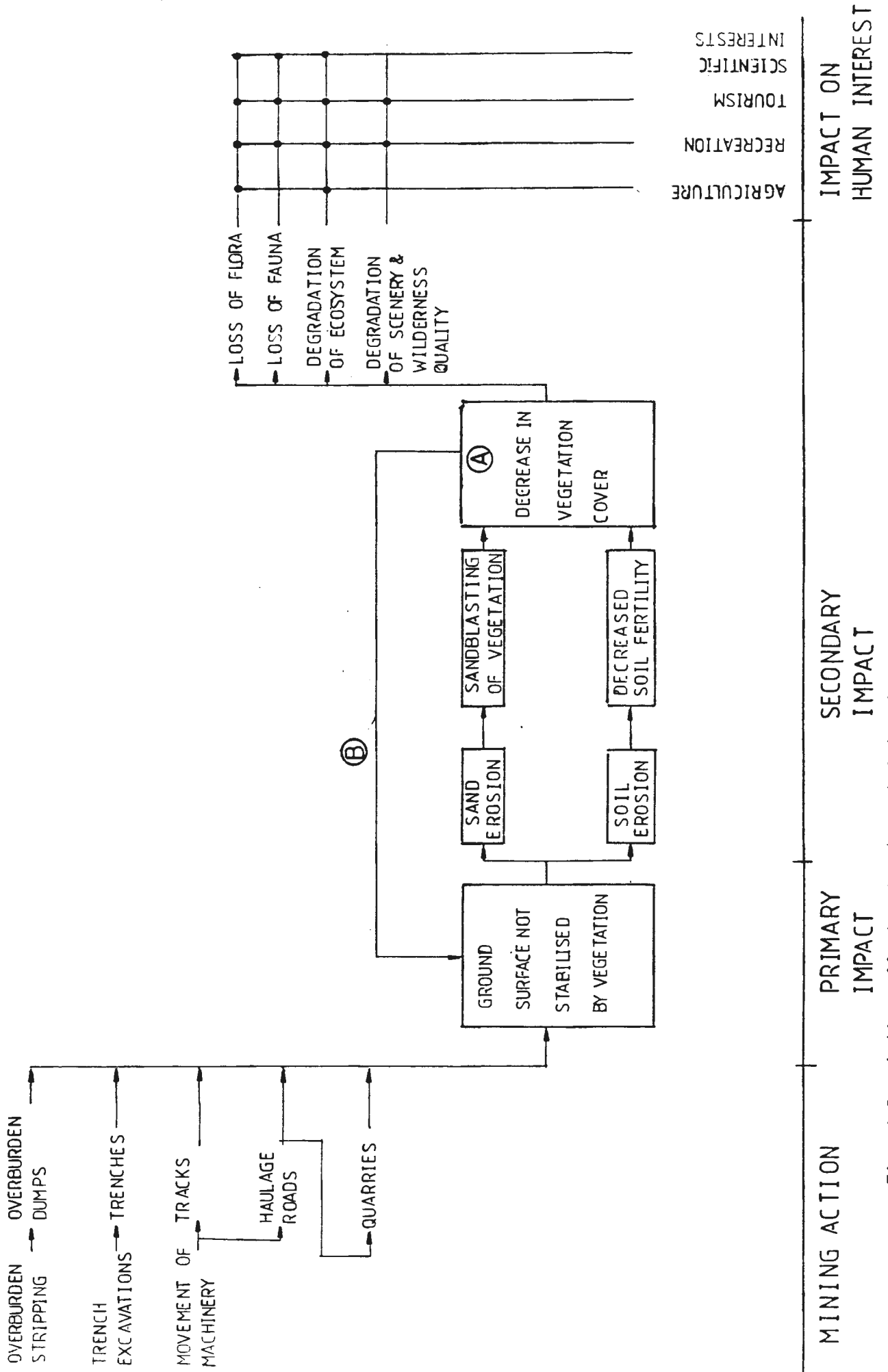


Fig. 4.2 Action-effect network explaining impact of wind erosion.

wind, driving over the surrounding country, and coming to rest for longer or shorter periods in small patches, destroys the vegetation which it covers during its stillstand. When the sand moves on, the soil on which the vegetation previously grew is dispersed by the wind, and formerly grassed and fertile country is ruined even though the sand has not remained in one place for more than a short period. The margins of deserts and coasts, where considerable quantities of sand are available for drift, are thus often rendered barren, though the general climatic conditions are suitable for the establishment of pastures".

This description explains the observed wind erosion at the West Coast very well. Sources of plentiful sand are made available with every disturbance of vegetation cover by mining actions. Winds have also been shown to have a high drift potential (2.2.5.5).

The wind erosion process and its impact on the West Coast is further explained in Fig. 4.2, which portrays the action-effect-impact relationship in a flow diagram similar to the method used by Sorensen (1971).

The extent of impact "A", decrease in vegetation cover (Fig. 4.2), was investigated by examining aerial photographs of SAD and DBCM mining operations. With the aid of a planimeter the total area of mining-disturbed ground was measured, i.e. including all distinguishable sand plumes. (Disturbance from road tracks and haulage roads was not measured as this proved to be difficult).

TABLE 4.3 Land area disturbed by mining

Mine	Approximate Total Area of Land disturbed by Mining (1)	Area of Land mined (1980) (2)
DBCM	3000 ha (1976)	1410 ha
SAD	4000 ha (1976-78)	800 ha

Source of data: (1) Appendix B  
(2) Table 3.6

Table 4.3 shows that the actual area disturbed by mining is considerably larger than appears from direct mining figures (Total wind area disturbed by DBCM is proportionally smaller than for SAD, as with the former, operations are more area-intense. This means that secondary impact is often covered by subsequent primary impact.)

The question arose as to whether sandplume areas are continuing to expand. Also, does a decrease in vegetation cover in turn destabilize further areas which would continue the chain reaction? (This is represented by feedback loop "B" in Fig. 4.2). The question was investigated by measuring the sand plume areas of trenches that appeared in aerial photographs of 1976 or 1978, as well as on 1964 aerial photographs where plume areas had not been disturbed by subsequent mining actions in this period. Results are shown in Table 4.4

TABLE 4.4 Expansion of sand plume areas on SAD land

Source of sand plumes	Sand Plume Area			Increase in area	
	1964	1976	1978		
6 selected trenches	72 ha	94 ha		22 ha	31%
5 selected trenches	82 ha		108 ha	26 ha	32%

Source of data: Appendix C

Table 4.4 indicates that sand plume areas continue to expand. The rate of expansion, however, appears to slow down. The rate of excavation of the selected trenches is unknown, but Keyser (1972) states that the prospecting programme at SAD was only instigated in 1950. If this date is taken as the start of sand plume development, although the actual date was probably later, then Table 4.4 shows that in the initial 14 year period (1950-1964) five selected trenches developed 82 ha of sand dune area. In the subsequent 14 year period (1964-1978) the same trenches developed only a further 26 ha of sand plume area.

These figures prove beyond doubt that the mining operations are affecting much larger areas than is realized. This is because many areas disturbed by *primary impact* are destabilized: These sites become sand-blowing sources which lead to the sand-blasting and destruction of further vegetation. Due to this wind erosion the total area disturbed by mining on SAD land is five times the area affected by

direct mining and prospecting. At DBCM the magnification of impact is two-fold. (Operations are more intense, therefore secondary impact is often covered by subsequent primary impact. Also, some areas on DBCM have clayey overburden material which is less susceptible to wind erosion because of the formation of surface crusts.) This *secondary impact*, due to the force of wind erosion, is a major contribution to the rejection of point (b) of the hypothesis.

The extent of mining impact would be much smaller if active steps were taken to prevent the blowing of sand from mining-disturbed sites. A possible method is revegetation. The success of natural revegetation is investigated in the following section, while the feasibility of revegetation efforts is discussed in chapter 5.

#### 4.2.4 NATURAL REVEGETATION

In field observations it was noted that some overburden dumps had revegetated naturally to a certain degree, while others had not done so at all, or only very sparsely. Recovery trends were therefore investigated.

At SAD, records of the dates of prospecting trench excavations were available. The present shape of overburden dumps was also compared with aerial photographs from Trig. Surveys of 1964 (Job No. 525) and 1978 (Job No. 812) to check whether there had been subsequent disturbance to dumps since these dates. Where the age of overburden

dumps could be precisely determined a basic vegetation survey was undertaken. Similarly, the size of overburden dumps could be determined from colour aerial photographs of scales 1:12 000 and 1:20 000, which were taken for DBCM on 3.9.1975.

The vegetation analysis was done using 10 m x 10 m quadrats. Percentage cover was noted and plant species were collected and identified later by Miss A. le Roux, botanist with the Cape Provincial Department of Nature and Environmental Conservation. Aspect, slope, dominant vegetation species and nature of substrate of the plot site were also noted. For comparison a vegetation analysis was done in a control plot in a representative pristine area near each overburden dump or trench. Results are shown for the SAD area in Table 4.5 and for the DBCM area in Table 4.6.

The following conclusions may be drawn from Table 4.5, SAD area:

- i) No overburden site or trench site was revegetated to its former pristine state.
- ii) Recovery trends of vegetation (% cover) do not appear to be uniform. For instance, the overburden dump of trench E, Holgat North area (plot A13) has acquired a vegetation cover of only 4 - 6% after 25 years. Overburden dumps of trench F, Cape Voltas area, have reached a similar vegetation cover after 11 years (Plot A5).
- iii) The nature of the substrate appears to be a decisive factor in

revegetation success. Calcareous ground seems to hamper growth, while wind accumulated sand supports a greater amount of growth, although mainly *Eragrostis cyperoides*.

- iv) Slope also appears to be an important factor. Thus trench F, Cape Voltas area, supports a higher growth on top of the dump than on its side (cf plot A4 with A5). However, most dumps show little growth on the major part of the top surfaces, due to compaction by scraper units. In pristine areas, sites with a high slope also support less growth than flat areas (cf. C4A, C2A with C3A, C5A). Also, trenches generally show better recovery than overburden dumps. Here substrate and wind shelter could play a roll.
- v) It would appear that relatively successful naturally revegetated sites will resemble dune-type environments as portrayed by plots C2A and C4A. These have significantly lower vegetation covers than pristine flat-lying areas, i.e. a permanent change in the nature of the vegetation cover must be expected after mining operations.
- v) Some overburden dump sites have not recovered significantly even after 18, 25 or even 35 years (Plots A9, A14, A1).
- vi) Plot A14 shows that areas of sand plume have a markedly reduced vegetation cover, one-third that of a corresponding pristine area (C6A).

TABLE 4.5 Natural revegetation at SAD

PLOT	SITE TYPE	AGE	% COVER	DOMINANT SPECIES	Spp.	SLOPE & ASPECT	SUBSTRATE
BAY	A1	35*	4-6	<i>Salsola, Zygophyllum</i>	9	Flat	Calcareous
	A2	16*	4-6	<i>Salsola, Didelta carnosia</i>	7	35°W	Calcareous
	A3	45*	8-10	<i>Asteraceae, Ruschia</i>	12	Flat	Yellow sand
	C1A	-	12-15	<i>Asteraceae, Salsola</i>	13	Flat	Yellow sand
ALEX.	A4	11	6-8	<i>Eragrostis cyp., Ruschia</i> <sup>u</sup>	4	Flat	Yellow sand
	A5	11	4-6	<i>Eragrostis cyp., Ruschia</i>	5	30°W	Yellow sand
	A6	22	12-15	<i>Asteraceae, Salsola</i>	8	Flat	Yellow sand
	C2A	-	23-25	<i>Asteraceae, Salsola</i>	8	Flat	Yellow sand
	C3A	-	12-15	<i>Ruschia, Eragrostis cyp.</i>	8	20°W	Dune slope
	CAPE	A7	21	8-10	<i>Eragrostis cyp., Salsola</i>	13	Flat
A8		7	2-4	<i>Psilocaulon</i>	2	20°N	Compacted
C4A		-	12-15	<i>Salsola, Asteraceae</i>	13	30°W	Hill slope
A9		18	406	<i>Psilocaulon</i> <sup>u</sup>	5	20°W	Calcareous
PEACOCK	A10	18	2-4	<i>Salsola</i>	4	Flat	Calcareous
	A11	18	2-4	<i>Eragrostis cyperoides</i>	2	30°W	Calcareous
	A12	18	10-12	<i>Eragrostis cyperoides</i>	7	Flat	White sand
	C5A	-	30-35	<i>Salsola, Ruschia</i>	13	Flat	Brown sand

- continued

\* Age ± 2 years (otherwise ± 1 year)

O/B - overburden dump, T - trench, P - pristine SP - sand plume

Table 4.5 (continued)

PLOT	SITE TYPE	AGE	% COVER	DOMINANT SPECIES	Spp.	SLOPE & ASPECT	SUBSTRATE
A13	O/B	25	4-6	<i>Salsola</i>	3	20°W	Calcareous
A14	SP	25	10-12	<i>Salsola, Ruschia</i>	3	Flat	Yellow sand
C6A	P	-	35-40	<i>Ruschia, Othonna</i>	12	Flat	Brown sand

Conclusions which may be drawn from studies of DBCM sites, Table 4.6, are:

- i) No overburden site has recovered to its former pristine state.
  - ii) Recovery trends of vegetation do not appear to be uniform. (For instance, plot K7 showed higher growth after 5 years than plot K2 after 21 years ).
  - iii) The nature of the substrate appears to be a decisive factor in revegetation success. Some overburden dump surfaces show a hard crust which does not allow any growth at all, e.g. plots K9, K10. Kovda *et al.* (1979) propose the following explanation for this crust formation: Rapid precipitation of calcium carbonate occurs with liberation of carbon dioxide in highly calcareous soil when, after moistening, it is quickly heated and dried. Numerous pores are formed, carbonates cement the soil mass and give rigidity. The authors also state that such crust formation is particularly characteristic of arid soils in temperate climates, which is the case at Kleinzee.
- Sites with accumulated wind-blown sand support mostly *Eragrostis cyperoides*. It is interesting that revegetation often occurs in the tracks left by scraper machines, probably because more moisture collects in these troughs (Photo 4K).
- iv) Some sites showed reasonable recovery, e.g. plots K1 and K6, but this vegetation composition resembles that of a dune environment. Their vegetation cover and species diversity is



Photo 4K Plant growth (mostly *Eragrostis cyperoides*) that has established mostly in tracks left by scraper machines (Plot K7, Table 4.6).



Photo 4L Surface crust has prevented only revegetation of this six-year-old overburden dump at Annex Kleinzee. (Plot K10, Table 4.6).

TABLE 4.6 Natural revegetation at Annex Kleinzee (DBCM)

PLOT	AGE	% COVER	DOMINANT SPECIES	Spp.	ASPECT /SLOPE	SUBSTRATE
K1	21*	15-18	<i>Ruschia, Salsola</i>	7	30°W	Yellow sand
K2	21*	4-6	<i>Ruschia</i>	3	30°W	Calcareous & crust
K3	19*	8-10	<i>Salsola, Ruschia</i>	4	25°W	White sand
K4	6	4-6	<i>Eragrostis cyperoides</i>	1	20°S	White, beach sand
K5	6	4-6	<i>Eragrostis cyp., Ruschia</i>	7	25°S	Calcareous sand
K6	13*	10-12	<i>Eragrostis cyp., Ruschia</i>	4	25°S	Yellow sand
K7	5	8-10	<i>Eragrostis cyperoides</i>	4	25°S	White sand
K8	6	4-6	<i>Eragrostis cyperoides</i>	3	30°E	Calcareous sand
K9	6	0-1	-	1	30°W	Hard crust
K10	6	0	-	0	30°S	Hard crust
K11	5	2-4	<i>Eragrostis cyperoides</i>	4	25°S	White sand
K12	4	4-6	<i>Eragrostis cyperoides</i>	2	30°N	White beach sand
K13	10*	8-10	<i>Eragrostis cyperoides</i>	4	30°N	White sand
K14	18*	4-6	<i>Eragrostis cyperoides</i>	4	25°E	Slight crust
K15	?	4-6	<i>Eragrostis cyperoides</i>	1	Flat	Yellow sand
K16	6	4-6	<i>Eragrostis cyperoides</i>	3	Flat	Brown sand
CK1	-	23-25	<i>Ruschia, Othonna, Atriplex</i>	7	Flat	Brown sand
CK2	-	25-30	<i>Ruschia, Othonna, Atriplex</i>	10	Flat	Brown sand

1. Ages are accurate to within one year, unless marked \*, then accurate within two years.

2. Survey plots were not widely separated, therefore only two control plots were selected at 2 km (CK1) and 4 km (CK2) from the sea.

lower than their former pristine state as indicated by CK1 and CK2.

- v) Sites subjected to sandblasting leeward from a mining site (plot K15) and a former auger drilling site (plot K16) show significantly lower vegetation cover.

Lack of nutrients in the surface layers may be a major problem for plant growth at mining-disturbed sites of both SAD and DBCM. Organic litter, a source for such nutrients, was evident on pristine sites, but absent on mining-disturbed sites, probably due to a higher exposure of these sites to wind.

From this investigation it appears that natural revegetation of mining-disturbed sites has not been successful and that there are no uniform recovery trends. There is evidence that some sites have hardly revegetated even after twenty years. Factors such as calcareous surface ground and formation of surface crusts hamper plant growth. At some sites, where natural revegetation has been relatively successful, the vegetation is degraded in percentage cover and species diversity. Areas of sand plume (i.e. subjected to wind erosion) have lost more than two-thirds of their vegetation cover and are dominated by one plant species, *Eragrostis cyperoides*. This investigation, therefore, contributes to the rejection of point (b) of the hypothesis. However, it also appears that with some assistance, for instance wind screens, breaking up of surface crusts and burying of highly calcareous ground, revegetation could be successful. This is discussed further in chapter 5.



Photo 4M Mining operations north of Olifants River. Note that coastal erosion is mainly due to impact from mining-induced actions (roads and quarries) and not from direct mining impact, i.e. impact is unnecessary. (Source: Estuarine Coastal Research Unit, 1979.)

### 4.3 ENVIRONMENTAL IMPACT OF SMALLER ENTERPRISES

#### 4.3.1 DBCM INLAND OPERATION

The DBCM mining operation at Langhoogte is small in scale (in 1980, 329 000 tons of ore was treated, compared with DBCM total of 7,8 million tons for the whole West Coast) and confined to a very localised ore body. Consequently the environmental impacts are also very localised.

The operations are conducted on a hill slope and therefore the one large rock tailings dump and one temporary overburden dump are not that visually obtrusive from a distance. Mined-out sites do not contribute to the visual impact as backfilling and levelling is practised. (This is in marked contrast to the neighbouring Wolfberg mining operation, where numerous overburden heaps scar the landscape and which have a greater visual impact than the two large DBCM dumps.) Wind erosion does not appear to be a problem as most of the overburden material is calcareous sandstone, which does not present a hazard of blowing sand.

Wilderness and scenic value of the Langhoogte area is not as great as that of the coastal region and as backfilling and levelling actions significantly mitigate visual impact of the mining site, impact on potential recreation and tourism interests is moderate. Vegetation is destroyed, but not over a large area and may have a chance of re-establishing itself due to surface levelling operations. Impact on

the grazing potential of the region is therefore moderate. The vegetation veld type affected by the operation is the succulent Karoo (Acocks, 1975) which is widely represented elsewhere and so impact on nature conservation is also considered moderate.

Backfilling and levelling practices at Langhoogte show that rehabilitation efforts are feasible and minimize environmental effects. With additional revegetation efforts, negative environmental impacts would be minor. This contributes to the rejection of point (c) of the hypothesis.

#### 4.3.2 SMALL COMPANIES NEAR OLIFANTS RIVER

Mining actions along the coast near the Olifants River mouth have a major negative environmental impact which is quite out of proportion with the mining operations on land and in the sea, which are both small in scale.

Visual and aesthetic impact: The overburden heaps left from beach mining and particularly the numerous parallel tracks running along the coastline (Photo 40) as well as quarries, which are excavated for puddle material needed in the treatment process, significantly mar the scenic and aesthetic appearance of the coastal landscape. Further impact is caused by derelict mine equipment and abandoned mine plants (e.g. treatment plant at Brand-se-Baai).



Photo 4N Pristine coastline south of the Olifants River. Strand vegetation in sensitive primary dune zone is distinctly visible.

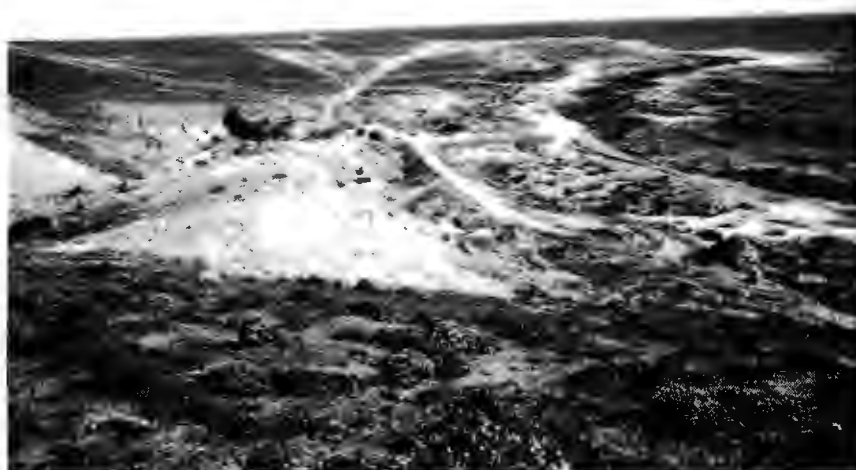


Photo 40 Unnecessary impact from mining induced actions south of the Olifants River. Tracks can be confined to a single road, which together with quarries (left middle of photo) can be sited further inland.

Impact on vegetation: Mining actions take place in a zone which is highly sensitive to disturbance (2.2.3, 2.2.6). The vegetated primary dunes stabilize the sand between the inland Strandveld and the beach; this zone is distinctly shown on photo 4N. Overburden heaps and, in particular, road tracks and quarries destroy a major part of the vegetation (Photos 4M, 4O).

Impact on coastal erosion: Quarries and road tracks destroy the stabilizing plant cover, and sand is subject to strong wind erosion (2.2.3). Parts of the coastline are steep and deep erosion gullies develop from surface water run-off where stabilizing vegetation has been disturbed (Photo 4M).

Impact on marine fauna and flora: South of Brand-se-Baai the rocky shore was found to be barren of fauna and flora in the intertidal zone. This site had been mined fifteen to twenty years previously (A.G. Visser, Asst. Director, Dept of Environment Affairs, pers. comm.), but had not recovered since. The reason for this denudation is unclear, but it may have been brought about by an increased sediment load in the sea resulting from the beach mining operations. Impact from mining operations below the low-water mark on marine fauna and flora in the subtidal zone are unknown but are probably insignificant at present (4.3.3).

These mining operations, although conducted only in a narrow zone along the coast, can be seen to have had major environmental impact: Firstly, it is precisely this zone which is the most sensitive part of the coast

from an aesthetic and an ecological point of view. Secondly, mining operations are conducted with complete disregard for any environmental impact on land. The DBCM inland operation has shown that it is not the operation as such which has maximum effect, but the degree to which the operations are controlled so as to minimize environmental effects. There is much scope for reducing environmental impact of the Olifants River mining operations, simply by implementing some control. The indiscriminate layout of tracks and quarries is unnecessary. Instead of numerous tracks there could be a single coastal road which, as well as the quarries, can be sited further inland (as is recommended by Heydorn & Tinley (2.3.3)). This would remove the major cause of environmental impact at negligible extra cost to the mine.

Such control is necessary to maintain ecological stability of the coast and to ensure that the potential for future recreational and tourist use is not seriously degraded.

Evidence of these operations, therefore, contributes to the rejection of points (b) and (c) of the hypothesis.

#### 4.3.3 MARINE MINING

Dr Pollack, Senior Research Officer with the Sea Fisheries Institute, has commented that ecological impacts by mining operations are probably insignificant, at this stage, when compared to natural

disturbances (storm events). Mining operations appear to be confined to gravel areas and do not seriously disturb kelp beds. However, there is concern about potential impacts of future developments. More efficient pumps and machines are likely to be employed. Their use will put heavy loads of sediment into suspension with possible adverse ecological consequences. Thus, if mussel beds are smothered by sediment, rock lobster feeding ground will be reduced and the mining industry will be directly affecting another economic resource of the region.

The mining authorities maintain that there is control of environmental impact from marine mining, because there are legal provisions, which state that the holder of a mining lease may not cause any disturbance to marine life, particularly not to rock lobster feeding ground. The enforcement of this regulation is unfortunately not easy. However, the point that seems to be overlooked is, that where marine mining is conducted from land, impact can result from induced mining actions (e.g. roads and quarries) as discussed in the previous section. Marine mining can therefore have significant negative impact and this contributes to the rejection of point (b) of the hypothesis.

#### 4.4 SUMMARY

The mining actions have far greater impact that is superficially obvious. Primary impact from overburden stripping and prospecting trench

excavations alone covers an area of about 2200 ha (on SAD land, and DBCM land north of Kleinzee), but this impact is magnified through wind erosion and has increased the area disturbed by mining to more than 7000 ha. Sites subjected to this secondary impact lose two-thirds of their vegetation cover and are degraded in plant composition. Consequently the grazing potential is reduced, the Strandveld ecosystem is degraded and aesthetic appeal of the affected area is diminished. This multiplier effect is unnecessary and the extent of mining impact can be significantly reduced, if mining-disturbed areas are stabilized. This could be achieved with revegetation.

Natural revegetation, unfortunately, shows no uniform recovery trends. Plant growth is hampered by factors such as calcareous surface ground, formation of surface crusts, possible lack of plant nutrients and exposure to strong winds. There is evidence that some sites have not recovered adequately even after twenty to thirty years.

Revegetation would also mitigate impact on the scenic and aesthetic quality of the landscape. This impact, in turn, affects the potential for recreation and tourist use of the land which is largely dependent on the aesthetic and wilderness character of the coast. Nature conservation interests are further affected by the degradation of the vegetation communities that are only represented on the West Coast. Beside mining, the greatest resource value of the region lies with recreation, tourism and nature conservation. If not mitigated, the mining impacts therefore, significantly reduce the future land use potential of the West Coast.

Mitigation of impacts through the control of mining actions has proved possible at the DBCM inland operation at Langhoogte, where backfilling and surface levelling practices have greatly reduced mining impact. Control of mining actions would also remove the major source of impact from mining actions by small companies operating near the Olifants River. Here operations are conducted with no regard ~~of to~~ the vulnerability of the coastal foreland. Tracks and quarries are unnecessarily located in the most sensitive zone, both from an aesthetic and ecological point of view. Simply by siting these actions further inland, at negligible cost to the mining enterprises, environmental impact could be substantially reduced. It is overlooked that the same cause of impact applies for marine mining operations that are conducted from land.

The evidence of significant negative impact from mining actions leads to the rejection of point (b) of the hypothesis. There is also evidence that mining impact can be substantially reduced if mining actions were controlled to minimise environmental effects, and this contributes to the rejection of point (c) of the hypothesis. This point is examined further in chapter 5.

## CHAPTER 5

### REHABILITATION

#### 5.1 INTRODUCTION

This chapter examines the possibility of rehabilitation of mined areas for combatting the detrimental environmental impact due to mining. Rehabilitation goals may differ. Harthill and McKell (1979) state that a United States National Academy of Science Study Committee has put forward three different philosophies and adopted the following terminology:

*Restoration* is the replication of site conditions prior to disturbance. *Reclamation* renders a site habitable to indigenous pre-mining condition organisms - ~~or organisms nearly so.~~ *Rehabilitation* implies that disturbed land will be returned to a form and productivity in conformity with a prior land use plan including a stable ecological state that does not contribute substantially to environmental deterioration and is consistent with surrounding aesthetic values.

*Restoration* aims to reshape the topography to its former state and return all plants removed. This may be the ideal of the preservation-

ist but its purpose is unclear. With the definition of *rehabilitation* motives are more apparent. The concept visualizes a stable ecological state. The United States Surface Mining Control and Reclamation Act of 1977, Section 406, for instance, begins "In order to provide for the control and prevention of erosion and sediment damages... and to promote the conservation and development of soil and water resources..."

Harthill and McKell (1979) comment that the above definition of reclamation suggests that "reclamation regulations" actually ought to be "rehabilitation regulations" with emphasis on providing post-mining conditions conducive to the evolution of a stable ecological state. It also envisages a future land use. Disturbed land is not merely something to be screened from view, but rather a resource that has potential value (Ripley *et al.*, 1978). Finally, it envisages a plan for rehabilitation drawn up before mining commences and in accordance with envisaged future land use. The regulations of the South African Mines and Works Act (Act 27 of 1956), amended in March 1980, have adopted this concept: "Rehabilitation... shall form an integral part of the mining operations... in accordance with a programme..."

The investigation of mining impacts on the West Coast will thus be examined in the light of principles of rehabilitation rather than those of restoring the original environment. It will be argued that point (c) of the hypothesis is invalid: Rehabilitation of mining-disturbed land on the West Coast is necessary first, to prevent the magnification of impacts through wind erosion (i.e. to promote

ecological stability) and second, to allow for the constructive future use of the land which lies mainly with scientific interests and potential recreation and tourism. Finally it will be suggested that rehabilitation is also practicable. There is much scope in improving land management on the mines that can be implemented at comparatively little cost and which would not threaten the economic viability of the diamond mining process.

## 5.2 REASONS FOR REHABILITATION

### 5.2.1 MAGNIFICATION OF IMPACTS

It has been shown in 4.2.3 that mining impacts magnify over time because of the process of wind erosion. It has further been shown that this magnification of impacts is significant, having led to a more than three-fold increase in the land area disturbed by the large mining enterprises (Table 3.6). Thus if immediate rehabilitation of mining disturbed sites succeeded in stabilizing the environmental conditions, this would substantially reduce the extent of the impact of mining.

The Chamber of Mines of South Africa (1981) has recognized the hazard of mining disturbances spreading with time: "It is accepted by the industry... that timely action is required to minimize the undesirable effects of disturbance and return the land to a stable and useful condition".

### 5.2.2 FUTURE LAND USE

Although the date is unknown, it must be recognized that surface mining along the West Coast will eventually come to an end. Mining is an ephemeral industry of finite life-span (Venn *et al.*, 1980). Therefore land that has been allocated to mining temporarily as a primary use should eventually be put to other productive uses. Barnard (1974) in an investigation of mining in the arid regions of South Africa and Australia points out that a basic characteristic of mine settlements in such regions has been their temporary nature, because such mining does not develop local secondary industry spin-offs. The latter has been shown to also apply at Kleinsee and Alexander Bay (4.2.2).

Because of its temporary nature it appears wise that mining shall be conducted in such a fashion that it does not prevent future land use. It has been shown that the West Coast has significant potential for recreation and tourism (2.3.4.3) and to a limited extent for grazing of small-stock (2.3.4.2). Although, in comparison with diamond mining, these uses yield low returns in the short term, they can be sustained indefinitely and are therefore important in the long term.

It has also been shown that the major negative impacts of diamond mining along the West Coast affect its grazing potential, but more particularly its potential for recreation and tourism (4.2.2). Mining without rehabilitation thus interferes significantly with the potential future use of the West Coast.

### 5.2.3 ETHICS, PUBLIC OPINION AND ECONOMICS

The question arises, what has prompted rehabilitation measures of mining-disturbed sites to be launched elsewhere in South Africa and the world?

One view holds that the motive for rehabilitation has been a realization that such undertakings can be translated into profit which is possible on land with high agricultural value. This does not appear to be valid in South Africa. In 1977 South African opencast coal mines spent up to R6000 per ha, rehabilitating land with an agricultural value of less than R600 per ha (Van Wyk, 1979). Since then rehabilitation costs have risen to R18 199 per ha (Engelbrecht, 1981). (These cost figures can be questioned, see 5.3.3 ). Thus, economic returns in the short term are unlikely. Even in Germany, with high land values, an economic break-even point has been reached only in recent times as rehabilitation costs have decreased, due to more efficient methods, and land prices have risen. Nevertheless, land rehabilitation was required in Germany long before it became marginally profitable (Doyle, 1976). Economic considerations do not thus appear to be a primary motive for rehabilitating mined land in South Africa.

The real push for rehabilitation appears to have originated from public opinion. Although this is not clearly stated in the literature on surface mining and rehabilitation, this seems to be implied with references such as: "Given that there is a growing sense of concern...

surface coal mining has the potential to become a sensitive environmental issue..." (Chamber of Mines of S.A., 1981); "...Strip mining is no longer a controversial public issue in Germany " (Doyle, 1976); "...Most significant mining proposals are greeted with strenuous opposition from some section of the community" (Down & Stocks, 1977).

Such public opinion may be based on ethical considerations. A land ethic that "land is to be loved and respected... implies respect for fellow members and also respect for the community as such" (Leopold, 1966). An ethic of "leaving land as found" implies *restoration* of land (5.1). Also acceptable would be exploiting and leaving land at no "cost" to others, which denotes *rehabilitation*.

This standard has been translated into economic terms and called "internalizing external costs". On the West Coast diamond mines are only concerned with their private working costs and the benefits which will flow to them as a result of mining. The social costs of losing the aesthetic, wilderness and ecological quality of the West Coast environment are "external costs", because they are foregone opportunities, which are external to the mining decision-making process. Since private profit and loss calculations are misleading, the environmental economist evaluates resource usage in terms of the costs and benefits to society over long-time horizons. There are three criteria for evaluating the contribution resource usage makes towards the goal of maximizing social well-being; The efficiency criterion, the equity criterion and the sustainability criterion. A resource use is efficient if benefits exceed costs, i.e. if gainers could compensate

losers and still be better off. A resource use is equitable if costs and benefits are distributed fairly over the population. If net benefits can be generated indefinitely, then the resource use is sustainable (Stauth, 1982b).

Diamond mining on the West Coast may be efficient as the large revenue produced by mining could possibly more than compensate the losers. However, the losers (conservationists, holiday-makers and tourists) are not compensated, and the benefits are not distributed fairly over the population and mining is therefore not equitable (Although the general public derives some benefit from mining through taxes paid by the miners to the State, this may not be sufficient compensation ). Mining is also not sustainable, it has a finite life-span, and costs remain after benefits are exhausted. These costs would prevent future users from taking advantage of the nonexhausting resources such as the aesthetic and wilderness qualities of the West Coast and this must be taken into account. Say Herfindahl and Kneese (1980): "Our actions should not be such as to foreclose the attainment of a position, with respect to nonexhausting resources by future populations, that is attainable by us".

The diamond mines could meet the equity and sustainability criteria by rehabilitating mining-disturbed land, and thereby reducing costs (preventing losses) to the other potential users of the land. An interesting question is, who should pay for rehabilitation costs? If the price of West Coast diamonds increases, because rehabilitation measures are implemented, then the end user pays. If diamond mines

absorb the rehabilitation costs (which is possible - 5.5.3) then, because mining company profits are taxed, the public would pay nearly two-thirds and the shareholders of the company could pay about one-third of the rehabilitation costs (5.5.3). The important point is that rehabilitation is necessary to compensate those who would bear costs as a result of the mining process. This makes the mining process more equitable. Point (c) of the hypothesis that rehabilitation is unnecessary is therefore rejected.

The principle that rehabilitation costs must be considered as part of the overall mining process appears to have been accepted generally by the mining fraternity: "Mining as an extractive process alone is outdated" (Doyle 1976), "...the responsibility for carrying out rehabilitation rests with the industry..." (Chamber of Mines of S.A., 1981); "Rehabilitation of the surface at any opencast mine shall form an integral part of the mining operations..." (Dept of Mineral and Energy Affairs, 1980).

### 5.3 PRESENT SITUATION

#### 5.3.1 PRESENT REHABILITATION MEASURES

Few measures are being undertaken to rehabilitate land disturbed by mining on the West Coast. Backfilling of mined-out sites does take place, but only where this is expedient for the mining process

(see 3.2.2.6). There are no landscaping or revegetation efforts, no landscape architects or horticulturalists are employed and there appears to be little concern for the scarring of the landscape. However, some rehabilitation measures can be noted: DBCM has a policy of aligning the road grid generated during auger drilling operations as far as possible with existing farm roads and fences (3.2.2.1). This is only practicable where the drilling grid is widely-spaced. Both SAD and DBCM have prohibited shooting of game on their land. The township Kleinzee has an installed sewage treatment plant which conserves fresh water resources. The smaller mining companies near the Olifants River do not appear to have implemented any rehabilitation measures.

Present rehabilitation efforts on diamond mines are inadequate. Further, much more effective rehabilitation measures must be implemented and therefore point (c) of the hypothesis is rejected.

### 5.3.2 NATURAL REHABILITATION

It has been shown that natural revegetation of overburden dumps occurs to some extent. Where it has re-established, vegetation is degraded in percentage cover and species composition (see 4.2.4). At many places, however, vegetation growth is severely hampered by the formation of surface crusts, calcareous ground, steep slopes and the probable lack of a fertile, nitrogen-rich layer of topsoil. It is possible that top soil can reform, i.e. that the former equilibrium

of soil nutrients can be restored, but "if nature is left alone to reach such an equilibrium, too much time may elapse and destructive forces, like soil erosion on steep slopes, may constantly counteract the establishment of the original plant cover" (Hagin, 1982). It has been pointed out that on the West Coast wind erosion is a particularly destructive force which not only counteracts natural revegetation but also leads to the disturbance of further vegetated land (see 4.2.3).

Moreover, it will take a long time (more than a century) before surfaces of bedrock sites will have weathered sufficiently for soil to form. Similarly, vertical high walls and deep trench excavations in clayey ground or calcrete will remain visually obtrusive if not attended to.

It can thus be concluded that mining-disturbed land, if left to nature, will not only rehabilitate inadequately, but will increase further in area due to the destructive force of wind erosion. Rehabilitation measures must therefore be implemented and point (c) of the hypothesis is rejected.

#### 5.4 BENEFITS OF REHABILITATION FOR MINING ENTERPRISES

##### 5.4.1 PUBLIC IMAGE

It appears that rehabilitation measures generally have been undertaken

because the public has urged that they be implemented. Stated in economic terms, this means that public opinion placed a sufficiently high value on benefits that would be derived from rehabilitated land to justify the costs of such rehabilitation. In South Africa mining companies have responded to this pressure (e.g. opencast coal mines of South Africa) before rehabilitation was legally required, presumably to enhance their public image. Public image has perhaps not been a high priority for diamond mines on the West Coast, because they are located in a remote part of the country. Furthermore, security restrictions have kept the public from this region. The public, therefore has not been widely aware of the mining impacts. The situation is likely to change with an increasing spread of population and an increasing scarcity of pristine and wilderness areas and a corresponding increase in awareness of such natural areas. There is also a change in the value people attach to them. Also, "many people attach great value to the knowledge that wildlife and natural ecosystems still exist, even though they may never have the opportunity to see or otherwise utilise these resources, and they also value the prospect of leaving these things intact to their descendents" (Stauth, 1982).

As has been indicated (5.2.3), rehabilitation of disturbed land would not only show respect for the land itself, but also respect for the human community. Thus the large mining enterprises of the West Coast, which are accountable to many people (i.e. shareholders of DBCM, citizens of the State in the case of SAD) stand to gain from implementing rehabilitation programmes in terms of their public

image and corporate responsibility to society.

#### 5.4.2 INHOUSE BENEFITS

Besides reducing visual impact to visitors, rehabilitation would provide the local communities, which comprise mostly mine employees on the West Coast, with a more pleasing environment. It would also show that the company involved is concerned with neighbourhood welfare. These benefits are perhaps as important as the more obvious protection of human health and safety (Ripley *et al.*, 1978).

### 5.5 PRACTICAL ASPECTS OF REHABILITATION

It has been shown in Chapter 4 that the most important negative impacts from mining are visual impacts and damage to vegetation, particularly by wind erosion. The possibility of mitigating these impacts is now discussed.

#### 5.5.1 FEASIBILITY OF REVEGETATION

Revegetation would best alleviate visual impact and would also provide the most economical method of controlling erosion of mining-disturbed sites on the West Coast. This has been found to be the case on

copper mine waste slopes in the arid region of U.S.A. (Day & Ludeke 1980). But, is revegetation at all feasible on the arid West Coast?

Revegetation of mining-disturbed land has proved possible in the arid regions of the U.S.A., where rehabilitation is obligatory. Although coal mines in the U.S. West are not located in truly arid zones they have encountered difficulties comparable to the West Coast. Problems of sand-blasting have been overcome by restricting revegetation activities to periods of low wind intensity, retaining some type of surface cover during windy months and creating wind screens where necessary. Salinity has been countered by burying saline spoils in the overburden pile, avoiding the use of saline topsoil and selecting plant species resistant to salinity (C.M. McKell, Inst. of Land Rehab., Utah State Univ., 1981, pers. comm.). However, rehabilitation has also proved successful in truly arid regions of the U.S.A. (less than 10 inches of precipitation). Day and Ludeke (1980) conducted rehabilitation experiments on copper mining wastes in Arizona, which had, amongst other characteristics, high salinity and low levels of nitrate nitrogen. Although the removal, separation and respreading of topsoil is not practised, rehabilitation proved successful with the aid of supplemental elemental nitrogen and water. In areas of low precipitation direct seedings of shrubs have generally failed but transplanting of bare-root stock or container-grown stock has been successful (Van Epps & McKell, 1978; Doyle, 1976).

Evidence of relatively successful natural re-establishment of vegetation at some overburden dumps and prospecting trenches indicates

that revegetation efforts, are also possible on the West Coast. The difficulties experienced with such efforts and some suggestions as to how they may be overcome are as follows:

Aridity: The West Coast may seem exceptionally arid from rainfall figures. However, total precipitation is significantly supplemented by means of fog (2.2.5.4). Harthill & McKell (1979) and Doyle (1976) recommend the use of water harvesting traps by surface shaping to form small depressions, pits, gouges or dozer bazins to provide run-off to seedlings. On the West Coast it has been noted that vegetation established most successfully in track depressions left by scraper machines (Photo 4K).

pH and salinity: Overburden material has high salinity and pH. However, these conditions seem to prevail in natural layers of topsoil as well. Thus indigenous vegetation appears to have adapted to such conditions. Where levels are excessive, saline layers must be buried in the overburden pile.

Wind: Revegetation activities may be restricted to periods of low wind intensity. Wind screens can be erected. One and a half metre high nylon mesh fences have been used in the rehabilitation of dune mining near Richards Bay to resist strong coastal winds (Camp, 1979). Some form of screening from sand movement should be possible at economic levels.

Crusts: These are found in clayey soils. They must be broken by

ploughing. If the top layer is mixed with sand, this will prevent formation of crusts and improve the water regime (Kovda *et al.*, 1971).

Plant nutrients: Lack of organic matter and low levels of nitrate nitrogen could be one of the major problems. Fertilizing will probably be required.

Topsoil separation: It is unclear whether this is necessary or even useful. Although the shallow top layer has definite characteristics beneficial to plant growth and is different to lower layers in the overburden pile (see 2.2.4), "The sowing and spreading of topsoil can do more harm than good, for instance, where the calcium carbonate layer underlying much arid land soil is mixed with the nitrogen-rich organic layer and the biologic carbon-nitrogen balance destroyed" (Doyle, 1976).

Source of seedlings: The Institute of Land Rehabilitation (1979) suggests that "seedlings in wildland plant populations can often be found under the canopy of parent shrubs following a year of adequate moisture. Normally few of these survive because of intense competition from other plants. Therefore, a high percentage of these may be collected and transplanted with little disturbance to the habitat". Sowards and Le Roy Belzer (1979) advocate harvesting of cuttings from mature stands for transplants. A detailed revegetation technique that will be successful on the West Coast will no doubt have to be determined by deliberation and experimentation conducted by trained experts. Revegetation successes elsewhere in South Africa, for

instance at gold slime dams which are highly hostile to plant growth, indicate that such expertise is available.

Revegetation therefore appears feasible on the West Coast and point (c) of the hypothesis is rejected again.

#### 5.5.2 SUGGESTED REHABILITATION ACTIONS

It is suggested that there is much scope for improved land management practices on the West Coast diamond mines. Many impacts result, because no attention is given to potential environmental consequences of mining actions in the first place. It is probable that the mining enterprises are largely unaware of the impacts caused by wind erosion, because their concern has only been with the actual mining operation. If environmental considerations were incorporated in the overall mining process, impacts could be obviated. For instance, if ground material for the construction of roads were taken from overburden dumps, road quarries would often not be necessary. Rehabilitation measures could also be implemented at a lower cost if rehabilitation was conducted in conjunction with, rather than after, mining. Much environmental impact could therefore be mitigated if mining enterprises adopted a rehabilitation programme. Some features of such a rehabilitation programme are now suggested:

In line with its definition (5.1), a rehabilitation programme must be based on a plan which takes cognisance of environmental characteristics

and potential use of the land. The Chamber of Mines of South Africa (1981) has set out guidelines for the rehabilitation of land disturbed by surface coal mining in South Africa. A rehabilitation plan on the West Coast could follow these basic management principles: planning, budgeting, monitoring and recording.

Rehabilitation plans should incorporate the following considerations:

#### Evaluation of the Environment before Mining:

- a) Evaluation of sensitive physical and biological resources, where disturbance by mining must be minimised. For instance, the primary dune zone along the coast (2.2.3). Here mining must be conducted with great caution.
- b) Evaluation of important sensitive physical and biological resources, which must be preserved. For instance, estuarine ecosystems would be destroyed if directly mined. Also places of spectacular beauty, such as the Cliffs, would be difficult to restore if access roads were blasted into them, as has been proposed. Here no mining must be tolerated.

#### Planning Impact of Mining Actions

The location of roads, quarries, rocktailing dumps must be planned. For instance, if smaller enterprises operating near the Olifants River sited their roads and quarries further inland (say half to 1 km), they would not be located in or disturb the most sensitive

ecological and scenic part of the coastal zone (4.3.1). Also material for road construction could be obtained from existing overburden dumps instead of excavating quarries along the haulage road itself.

Wind erosion could be limited by working a mine block (3.2.2.2) upwind and not downwind. If the first cut was made downwind and the resultant overburden dump located on the downwind side of the mine block was immediately stabilized and provided with a wind screen, the dump could block all sand that would normally sandblast undisturbed vegetation downwind of the block (Fig. 5.1).

#### Setting Standards for Rehabilitation

The standard of rehabilitation required would vary for different mining-disturbed sites. Sensitive zones must be stabilized quickly. For instance, if auger drilling sites and service roads were stabilized immediately after completion of operations, this would prevent erosion of a large surface area, with minimal effort. Conversely, rock-tailings dumps do not cause secondary impact. No sand blows off them and there are not a great number of them. In this case revegetation may prove too costly for the benefits that would be derived and it may be best only to locate them at sites where they would be least visually obtrusive.

Prospecting trenches could be rehabilitated adequately by battering vertical walls or pushing in overburden sand to provide sloping sides that can be revegetated. At places this has happened naturally (Photo 5A). Overburden dumps should not be built up too high and be

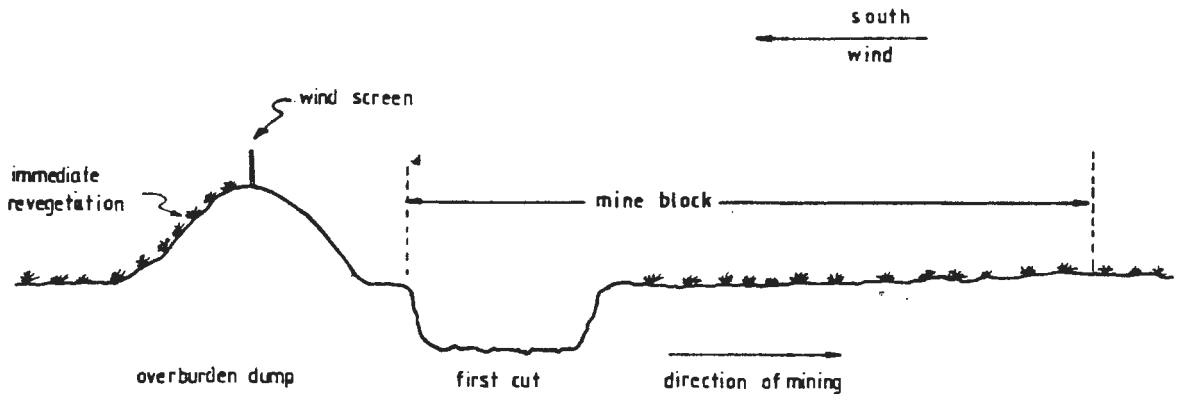
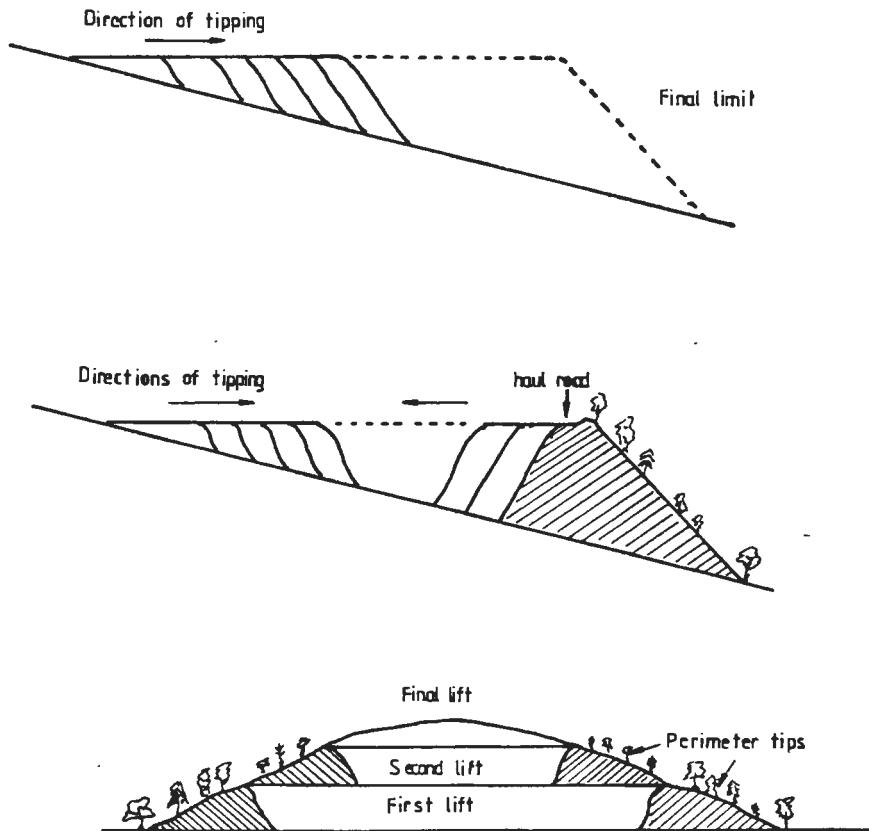


Fig. 5.1 Possible control of wind erosion.



Source: Doyle (1976)

Fig. 5.2 The use of perimeter tipping to reduce visual impact.

left with gentler slopes which are visually more pleasing (see Photo 5B).

Mining sites abandoned in previous years will have to be attended to. In this case the most critical requirement is to provide ecological stability, i.e. control of wind erosion.

#### Planning Specific Rehabilitation Techniques

A technique which has considerable visual benefits and which could reduce total revegetation requirements, is perimeter tipping (Fig. 5.2). It has been used to screen a tipping area by the construction of an amenity bank around its perimeter. The outer face of the bank is rapidly revegetated while tipping can proceed within the screen thus formed (Down & Stocks, 1977). This technique could be applied on the West Coast to provide a visual screen and control wind erosion around a mine block, slimes dam and possibly even screen rocktailings dumps.

#### Planning Revegetation Technique

Soil will need to be evaluated and optimum planting times established. Some techniques in overcoming characteristic West Coast difficulties have been mentioned (5.5.1).

#### Implementation of Rehabilitation

Rehabilitation efforts should run concurrently with mining operations. Doyle (1976) reports that rehabilitation costs of abandoned mine land in the U.S. could probably have been reduced by at least one half if

rehabilitation had been conducted along with mining. Further advantages would be derived from the immediate stabilization of bare ground, which is important.

Large mining enterprises have adopted effective housekeeping policies to control human safety and material wastage. Such policies could be extended to incorporate "Environmental housekeeping".

A "rehabilitation team" could be set up and provided with an annual budget until rehabilitation costs can be calculated accurately.

#### Rehabilitation Control

Smaller companies can often not be relied upon to complete satisfactory rehabilitation work as they are liable to bankruptcy. A safeguard against this may be a rehabilitation fund to which companies would be required to make an initial deposit and subsequent contributions with ongoing mining operations.

A time limit could be placed on prospecting and mining operations in particular areas. This would make land available for alternative uses. Potential conflict could thus be resolved in areas which are in particularly high demand for recreational activities, e.g. certain bays and estuaries along the coast.

From an operational point of view rehabilitation measures are practicable and point (c) of the hypothesis is therefore not valid.

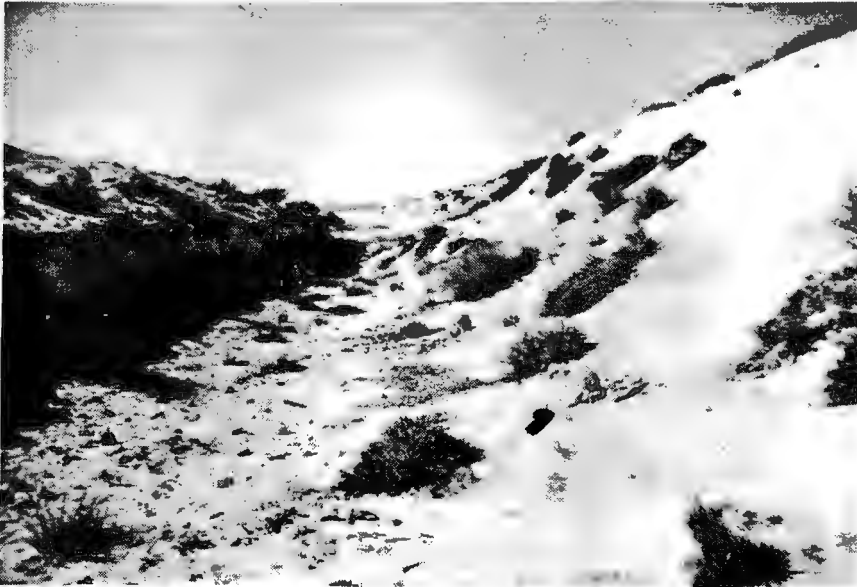


Photo 5A

Old prospecting trench partially filled-in on the right by wind-blown sand. This has less visual impact than the abrupt vertical line of northern wall of trench.



Photo 5B

Smaller overburden dump with gradual slope at Annex Kleinzee shows that dumps can be left with acceptable visual impact.



Photo 5C

Overburden dumps of Annex Kleinzee, where some natural revegetation has occurred. With some surface landscaping and assistance to revegetation, this scenery may become visually pleasing.

### 5.5.3 FINANCIAL FEASIBILITY

Rehabilitation costs elsewhere:

Rehabilitation costs of mining-disturbed land elsewhere in South Africa and the U.S.A. are as follows:

- a) Opencast coal mining, Eastern Transvaal, 1977  
(Annual Report 1977, Dept. of Mines) R6000/ha
- b) Opencast coal mining, Optimum Collieries, 1981  
(Engelbrecht, 1981) R18 000/ha  
(Cost is constituted by ground levelling - R8600,  
topsoil covering - R7300, vegetating - R2100)
- c) Dune mining, Richards Bay, 1981 (Camp, Tisand  
(Pty) Ltd, 1981, pers. comm.). R2500/ha
- d) Surface coal mining, U.S.A. West, 1981  
(C. McKell, Institute for Land Rehabilitation,  
Utah State Univ., 1981, pers. comm.). \$2000-\$15 000

The above costs can be questioned as to their accounting procedure: Are these costs additional to the alternative disposal of overburden and mine waste, or are they total costs? Also, rehabilitation costs of South African opencast coal mines in 1981 (b) appear high when compared with rehabilitation costs in 1977 (a).

Anticipated rehabilitation costs for the West Coast:

Rehabilitation costs for the West Coast are purely speculative. Nevertheless, it can be said that costs for the rehabilitation of West Coast mining sites will be nearer to the cost for Richards Bay, which also has a sandy coastal environment, than the cost for coal mines of the Eastern Transvaal. In coal mining the bulk of the rehabilitation costs lie in the earth-moving operations (5.5.3.1). In loose, sandy overburden material as on the West Coast, earth-moving is easily achieved. Also, only grading and reshaping of overburden dumps will be required, not complete retransfers of overburden dumps. Costs on the West Coast would therefore be much reduced as shown by costs for dune mining at Richards Bay. Ten thousand rands per hectare would be a reasonable "guesstimate" for the rehabilitation of West Coast mining sites.

Estimated Rehabilitation Costs compared with Estimated Mine Revenue:

From published mine production figures multiplied by the average price fetched per carat from total West Coast sales as supplied by the Minerals Bureau of the Department of Mineral and Energy Affairs an estimate of mine revenue was derived. From survey statistics obtained directly from the respective mine, a figure of revenue per hectare was calculated (Table 5.3).

Thus, at R10 000/ha rehabilitation costs would constitute 1% of DBCM revenue and 2,5% of SAD revenue.

TABLE 5.3 Estimated mine revenue per hectare

Mining Enterprise	1980 Production (carats)	1980 Avg. price Per carat from tot. West Coast sales	Estimated Revenue (R)	Area Mined (ha)	Revenue per ha (R)
SAD	139 114 <sup>1)</sup>	R140,13 <sup>3)</sup>	19 499 045	50 <sup>4)</sup>	389 881
DBCM	1 439 262		200 983 134	200 <sup>4)</sup>	1004 916

Source of Data: 1) Annual Report 1980, Dept of Mineral & Energy Affairs  
 2) Annual Report 1980, DBCM  
 3) Minerals Bureau, Dept of Mineral & Energy Affairs, pers. comm.  
 4) Survey Depts, SAD & DBCM, pers. comm.

It would also appear that the large diamond mines operate at a high profit margin. It was calculated that in 1977 DBCM revenue was about R123 million and working costs R17 million (Data from DBCM Annual Report 1977 and Table 2.9).

#### Effect of Rehabilitation Costs:

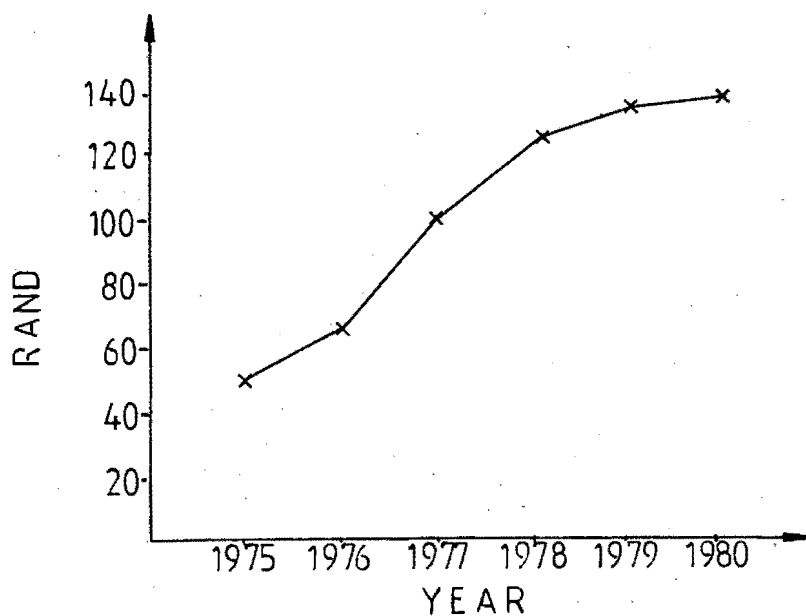
Adding rehabilitation costs to the working costs of the diamond can manifest itself in two ways:

a) the price of diamonds can increase:

As the market for gem diamonds is controlled by the Central Selling

Organization (CSO), a marginal rise in the price of diamonds will have little effect on the sale of diamonds. The sharp rise in the sale price of West Coast diamonds can be gleaned from Fig. 5.4.

Thus for instance in 1977, a surcharge of 40% was introduced in the basic selling prices simply because there was a high level of speculation in the market (H. Oppenheimer, DBCM Ltd, Annual Report 1978). A price rise of 1% or 2,5% due to rehabilitation costs is likely to have negligible effect on the market.



Source: See Table 2.9

Fig. 5.4 Increase of West Coast diamonds in rand value per carat.

a) Mining enterprises absorb rehabilitation costs:

As mining enterprises appear to operate with a high profit margin, they could afford a loss of revenue without cutting back on operations.

However, the loss of revenue they would suffer would not equal total rehabilitation costs, but in fact only about one-third of these costs. This is because the State participates in diamond mine profits to the order of 63% through taxes. Thus the State would in fact subsidize rehabilitation costs by 63%!

Rehabilitation therefore appears financially feasible and point (c) of the hypothesis is invalid.

#### 5.6 SUMMARY

Rehabilitation does not mean restoring the former environment but should provide a stable ecological state of the land and safeguard it for planned, future usage. For this to be achieved rehabilitation must be planned.

No major rehabilitation efforts take place on the West Coast. No rehabilitation programme has been implemented, no landscape architects or horticulturists are employed on the mines and there appears to be little concern for the scarring of the landscape. Although there is evidence of some natural revegetation occurring, this is not adequate to provide ecological stability of the land or to allow a constructive future land use.

On the West Coast rehabilitation measures are necessary to prevent

diamond mining impacts magnifying over time through the destructive force of wind erosion. Further, primary impacts of mining degrade the potential for the future use of the land which lies mainly with recreation, tourism and nature conservation interests. This must be taken into account as mining has a finite life span. Rehabilitation would also make the diamond mining process more equitable and sustainable by preventing losses to the present and future users of the land. Initial rehabilitation efforts elsewhere appear to have been spurred on by public opinion, which, intuitively perhaps, placed a value on the benefits of rehabilitation for the community, which is high enough to outweigh its costs. On the West Coast there has not yet been widespread public demand for the rehabilitation of mining sites, probably because of their remote location. Mines, however, would derive benefit from launching rehabilitation efforts by enhancing their public image in the long term.

The hypothesis that rehabilitation on the West Coast is unnecessary (point (c)) is therefore rejected.

Rehabilitation measures can be put into practice on the West Coast: Revegetation will have to overcome some difficulties, but this has proved feasible elsewhere, and by evidence of local, although limited, natural revegetation. Many impacts result, because environmental considerations play no part in the mine-planning process. There appears to be much scope on the diamond mines for adopting better land management practices. If rehabilitation efforts were conducted concurrently with mining, impacts could be reduced and rehabilitation

could be implemented at a lower cost. Such rehabilitation costs are roughly estimated to be of the order of R10 000 per ha which would constitute 1 to 2,5% of mine revenue. This would have little effect on the economic viability of the mines.

The hypothesis that rehabilitation of mining-disturbed land on the West Coast is impracticable (point (c)) is also rejected.

## CHAPTER 6

### CONCLUSION

This study has first outlined the main features of the West Coast environment. It has then analysed the mining process and has identified the mining actions that cause environmental impact. Environmental impact was examined by relating particular mining actions to specific environmental elements using a matrix approach. Impact on wind erosion and the advance of natural revegetation was examined quantitatively. Finally, the potential for rehabilitation of mined areas was discussed.

The major findings of this investigation are as follows:

Aridity, and particularly, the hazard of wind erosion, make the West Coast an environment that is sensitive to disturbance. Beside rich diamond resources the West Coast also has aesthetic and biotic qualities that have prompted government authorities to propose a national park between the Spoeg and Groen Rivers to provide for recreation, tourist and nature conservation interests. Mining actions have impact on these potential interests by degrading the scenic and wilderness quality of the landscape. Mining actions have far greater

impact than is realised. Primary impact from overburden stripping operations alone cover an area of about 2200 ha along the coast between Kleinzee and Alexander Bay, but this impact is magnified through wind erosion and has increased the area disturbed by mining to more than 7000 ha. Sites subjected to this secondary impact lose two-thirds of their vegetation cover and in turn become sources of blowing sand which destabilises further areas. Mining impact, therefore, can be substantially reduced, if initially disturbed sites are stabilised by revegetation. Natural revegetation, unfortunately, has not been successful on the whole; it appears to be hampered by calcareous ground, exposure to wind, surface crusts and possibly by lack of nutrients. Generally, mining impacts could be reduced significantly by making environmental protection a part of mine 'housekeeping', and planning mining activities to minimize environmental effects. For example, simply siting necessary roads and quarries inland away from the vulnerable coastal foreland would do much to minimize environmental impact from mining operations near the Olifants River.

Mining impacts that are unavoidable can be mitigated by subsequent rehabilitation. This is a reasonable requirement, as it can be implemented at relatively little cost and would allow a constructive use of the land in the future.

The hypothesis that formed the basis of this investigation is therefore rejected.

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STATE ALLUVIAL DIGGINGS. Mine layout map showing prospecting trench development. 1:40 000.

## APPENDIX A : DEFINITIONS OF ELEMENTS OF IMPACT MATRIX

Terms used in the impact matrix that are not considered self-explanatory or are not described in the text are defined as follows:

**WILDERNESS QUALITY:** An area has a wilderness quality if it is virtually unmodified by man and its natural ecological processes are unimpaired.

**UNIQUE ECOSYSTEMS:** Terrestrial ecosystems based on vegetation types that are only represented on the West Coast.

**COASTAL DEPOSITION:** The process of shoreline growth due to the deposition of longshore sediments.

**COMMUNITY WELFARE:** The social well-being of the rural and urban population nearby the diamond mining area.

**HEALTH AND SAFETY:** The physical and social well-being of diamond mine employees.

**NATIONAL RESOURCES:** Monetary, material and energy resources of South Africa.

## APPENDIX B : AREA OF MINING-DISTURBED LAND

SAD LAND

Area measurements were taken with a planimeter from the following aerial photographs of Trig. Survey:

Job No. 763 Photo Nos. 7408, 7410, 7412

Job No. 812 Photo Nos. 5259 to 5266.

DBCM LAND NORTH OF KLEINZEE

Area measurements were taken with a planimeter from the following aerial photographs of Trig. Survey: /

Job No. 763 Photo Nos. 7398, 7400, 7402, 7404.

Dates and scale of aerial photographs:

Job No. 763 : 21.8.1976, 1:50 000

Job No. 812 : 23.6.1978, 1:50 000

Estimated error of measurements:

Instrument measuring error ( $< 1\%$ ) and photographic distortion error ( $< 1\%$ ) is negligible compared to "interpretation error", i.e. error in identifying exact boundaries of mining-disturbed land.

Estimated worst error is 20%, therefore, estimated standard error is

$$\frac{2}{3} \times 20\% = 13,3\%.$$

## APPENDIX C : SPREAD OF SANDPLUME AREAS

Eleven prospecting trenches were selected that showed sand plume development on aerial photographs of 1964 and showed no subsequent disturbance from mining actions on aerial photographs of 1976 and 1978. Prospecting trench names were identified from SAD mine layout maps.

Results of planimeter area measurements are as follows:

Prospecting Trench	Aerial Photo No.	Area in ha.	Aerial Photo No.	Area in ha.
Langpan E	525/1199	10,3	763/7410	11,6
Cliffs O	1199	9,0	7412	15,4
Cliffs M	1201	5,1	7412	7,7
Cliffs K	1201	18,0	7412	24,4
Cliffs I	1201	6,4	7412	9,0
Cliffs H	1201	23,1	7412	25,7
TOTAL AREA		71,9		93,8
Perdevlei F	1206	14,1	812/5259	23,1
Perdevlei D	1208	12,9	5259	18,0
Holgat N. A	1223	10,3	5261	15,4
Holgat N. E	1223	21,9	5261	25,7
Holgat N. T	1223	23,1	5261	25,7
TOTAL AREA		82,3		107,9

Error in measurement:

1 Planimeter unit (pu) = 10,3 mm<sup>2</sup> = 25,8 x 10<sup>-2</sup> ha

Standard error in individual measurement (with two observations) :

0,7 pu = 0,18 ha.

## APPENDIX D : ANALYSIS OF SOIL SAMPLES

Selected soil samples from the author's vegetation survey plots (Tables 4.6 and 4.5) were analysed by the Elsenburg College of Agriculture of the Department of Agriculture and Fisheries at Stellenbosch. Results are as follows:

Mine Area	Plot	pH (KCl)	Resistance (ohms)	Saturated Extract (ppm)			
				Na	Ca	Mg	K
DBCM - KLEINZEE	K1	8,3	210	497	50	22	22
	K2	8,5	136	322	14	4	18
	K9	8,1	54	2226	212	132	32
	K10	8,2	34	2871	306	155	82
	K14	8,8	530	200	6	3	24
	CK2	8,4	95	1132	149	56	100
STATE ALLUV. DIGG.	A2	8,4	330	301	932	16	22
	A4	8,5	1630	62	20	6	11
	A8	8,1	1690	54	532	20	18
	A10	8,7	520	51	86	15	16
	C1A	8,5	94	112	34	9	16
	C3A	9,1	610	156	46	19	27
	C5A	8,7	620	89	33	9	33