QUARRY REHABILITATION :
THE NEED TO ADOPT A PRE-PLANNING APPROACH TOWARDS REHABILITATION

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ABSTRACT

Quarry operations are only a temporary use of the land, while the environmental impacts associated with them are more long term. For this reason, it is unacceptable to merely abandon a quarry once operations have ceased.

This study considers the role of rehabilitation in providing solutions for the disturbances caused by quarrying. The value of adopting a pre-planning approach towards rehabilitation is considered, and the components of a rehabilitation programme are identified. Using this information a rehabilitation checklist is drawn up. A survey of thirty rehabilitation reports, submitted to the Cape Town regional offices of the Department of Mineral and Energy Affairs, was undertaken using the checklist.

Results of this survey indicate that rehabilitation reports are submitted merely to meet the minimum legal requirements contained in the Minerals Act of 1991 (Act No 50 of 1991). This study recommends that successful rehabilitation will only be achieved when rehabilitation reports function as effective working documents.

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CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

" Mining and quarrying are essential activities if we are to have the raw materials for our present-day civilisation. As a result, disturbances must occur, but what should now be clear to people, both inside and outside the industry, is that this disturbance need not lead to degradation of our landscape, but to its enhancement." (Bradshaw, 1984, p46)

Quarries are open cast excavations from which fairly massive and deep deposits of hard or soft rock are extracted, usually for the production of aggregates (Coppin and Bradshaw, 1982). Since the demand for these aggregates is created by society, quarries are an indispensable part of life. Every community is, or has been, serviced by at least one operating quarry or gravel pit during its history. After agriculture, mining is therefore, one of the worlds oldest and most important industries (Down and Stocks, 1977).

The aggregates produced by quarrying are generally characterised by a high volume to low cost ratio. In order to accommodate these low values and avoid prohibitive transportation costs, the source of supply must be located as close to the market as possible. Since urban centres account for the greatest demand, quarries have traditionally been located near towns and cities. The majority of these quarries were originally located on the outskirts, beyond the built up urban environment. Rapid urbanisation, accompanied by urban sprawl has however, resulted in a growing number of these quarries becoming incorporated into the urban environment (Carter, 1989). This has placed increasing pressure on scarce land resources. The competition on land for living space, recreation, industry and agriculture is becoming more intense. Quarrying, unfortunately conflicts with all of these uses (Ramani and Grim, 1978).

Furthermore, the encroachment of urban areas has made a growing number of people aware of the environmental damage caused by quarrying. This is not a recent development, the damage caused by mining was described in 1556 by Georgius Agricola in **De Re Metallica**, the worlds first mining textbook. The scale of the disturbances have however, increased dramatically as technological advances have enabled lower grade deposits to be exploited on a larger scale. Unfortunately this has often been at the expense of greater environmental damage (Down and Stocks, 1977).

While the nature of quarrying makes it impossible to avoid disturbances, it is, nonetheless, only a temporary use of the land. Land is a valuable and productive natural resource, and unless measures are taken to address the damage caused by quarrying, future land use options are severely reduced (Randall, Johnson and Pagoulatos, 1978). It is therefore, unacceptable to abandon quarries once the operations have ceased (Ramani and Grim, 1978). Once operations have ceased quarries do not have to become unusable pieces of land. If this is allowed to happen it is because sound rehabilitation thinking has not been applied to addressing the issues (Blauch, 1978).

Rehabilitation should, therefore, be seen as an essential component of the quarrying operation. Unless there is a clear commitment to rehabilitation once the operations have ceased, permission to develop a quarry should be denied. The growing awareness of environmental issues, accompanied by tighter legislation has made more and more quarry owners aware of the economic advantages of looking beyond the returns from immediate production, to the benefits that can be gained from rehabilitation and developing alternative uses for quarry sites once the reserves have been exhausted (Carter, 1989). A sound rehabilitation programme is beneficial to both the operator and the public: the operator can ensure long term operation of the quarry and economic returns from the future use of the site, while the public gain from the assurance that the impacts will be addressed and the disturbed area will be put to some productive future use once operations have ceased.

While rehabilitation inevitably increases the costs of production, these costs represent social costs, which until fairly recently have been largely ignored by quarry operators. The long term costs associated with rehabilitation can, however, be reduced by careful planning (Haan and Walmsley, 1985). The pre-planning approach probably offers the most cost-effective approach for dealing with the problems that are likely to be encountered during rehabilitation (Riddle and Saperstein, 1978). This approach recognises the need to incorporate rehabilitation goals into the development of the mining operations form the outset. This enables rehabilitation to form an integral part of the decision process regarding the development of the mining operations (Jeffrey, Maybury and Levinge, 1975; Haan and Walmsley, 1985), and demonstrates a clear commitment to rehabilitation once operations have ceased.

The success of the pre-planning approach depends on the ability of the initial site survey to collect baseline data and provide a detailed inventory of the environmental factors likely to inhibit the implementation of the rehabilitation programme (Bradshaw and Chadwick, 1980; Haan and Walmsley, 1985). In the past the initial site survey was traditionally confined to evaluating the economic viability of the deposit. However, it has now become widely accepted that rehabilitation should be preceded by a detailed site investigation. Ideally this should be carried out before quarrying starts (Bradshaw and Chadwick, 1980). Once the baseline data from the initial site survey has been collected and analysed, realistic long term rehabilitation goals can be established. This approach enables the rehabilitation programme to identify the constraints facing the implementation of the programme during the early planning stages.

Due to the longevity of most quarry operations the rehabilitation programme should be reviewed on a regular basis and, where necessary, updated to ensure that the proposed after use is still compatible with future land uses in the area (Blauch, 1978). The rehabilitation programme should also be sufficiently flexible to enable it to accommodate changes in the actual mining operations.

1.2 RATIONALE

This study looks at rehabilitation procedures and assesses the content and adequacy of rehabilitation reports submitted in terms of Section 39 of the Minerals Act (No. 50 of 1991). Rehabilitation of areas disturbed by quarrying is dealt with in Chapter Six, Rehabilitation of Surface, of the Act and Chapter Five of the Regulations. Legislation pertaining to rehabilitation is administered by the Department of Mineral and Energy Affairs.

Section 38 of the Minerals Act requires that rehabilitation of the surface shall:

(a) be carried out in accordance with an approved rehabilitation programme;
(b) form an integral part of the mining operations;
(c) unless exempted by the Regional Director be conducted simultaneously with such operations; and,
(d) be to the satisfaction of the Regional Director.

In terms of Section 39, a layout plan of the operations and a rehabilitation programme must be submitted to the Department of Mineral and Energy Affairs before the commencement of operations.

The first regulations pertaining to rehabilitation were incorporated into the Mines and Works Act of 1956, in 1980 (Government Notice R. 537 of 21 March 1980) following recommendations made by the Advisory Committee an Open Cast Mining (Hoogervorst, 1985). This was later amended by the Minerals Act, No. 50 of 1991. The new regulations, covered in sections 5.11 to 5.14.3, introduced an environmental dimension to work of the Government Mining Engineer. Whereas in the past the Government Mining Engineer had been concerned solely with matters relating directly to the operation of mines and safety, and health and welfare of workers and the public, with the new regulations a number of specialised fields such as, environmental impact assessments, revegetation procedures, soil analysis, aesthetics and visual impact analysis were introduced (Hoogervorst, 1985).

Hoogervorst (1985) noted at the time of writing his thesis, **An Environmental Evaluation System in the Planning Process of Quarries in South Africa**, that the regulations had not been in operation long enough to assess their effectiveness. Hoogervorst (1985) also noted that it was too early to evaluate the extent to which the new regulations were being used by the Government Mining Engineer to assess rehabilitation reports. Since the introduction of the regulations the profile of the environment has increased dramatically. With the growing awareness of environmental issues, both the public and the mining industry are beginning to recognise the importance of successful rehabilitation. The role of rehabilitation has been brought to the attention of the public by the controversy surrounding the proposals to mine heavy mineral sands at St Lucia, Natal north coast, and kaolin in the Noordhoek Valley, Cape Peninsula. Within the mining industry, the growing concern for environmental issues has been reflected in the literature. Five out of the nine papers presented at the 1990 Annual General Meeting, Symposium and

Exhibition of the Institute of Quarrying of South Africa, dealt with the environment and rehabilitation.

1.3 OBJECTIVES OF THE STUDY

The National Academy of Sciences (NAS, 1974) defines rehabilitation as the return of a disturbed site to a form and level of productivity that conforms to a prior land use plan. This definition implies that alternative land uses have been examined along with evaluating the potential for achieving each alterative. To consider rehabilitation and its role, the objectives of this study are:

(1) To outline the procedures for drawing up a rehabilitation programme and the value of adopting a pre-planning approach. Successful rehabilitation requires careful planning and a clear understanding of the factors that are likely to inhibit the implementation of the programme. The pre-planning approach satisfies both of these requirements.

(2) To draw up a comprehensive rehabilitation checklist based on the pre-planning approach. The checklist emphasises the importance of collecting baseline data during the initial site survey and the need to link this data to the development of the rehabilitation programme.

(3) To use the rehabilitation checklist to assess the content of rehabilitation reports, their ability to function as effective working documents and the extent to which the pre-planning approach has been adopted.

1.4 OUTLINE OF THE REPORT

This study involved a literature survey which collected data on rehabilitation and identified the components of a rehabilitation programme. The pre-planning approach (Riddle and Saperstein, 1975) offers the best approach for achieving successful rehabilitation. Chapter 2 outlines the pre-planning approach and lists the four major components of a rehabilitation programme, namely, the initial site survey, landscaping, revegetation and monitoring and after-care. In Chapters 3, 4, 5 and 6 these components are detailed separately. Chapter 7 introduces the rehabilitation checklist, developed as part of this study. The format of the checklist is based on the pre-planning approach and also reflects the need for rehabilitation reports to function as effective working documents. The checklist was used to assess thirty rehabilitation reports submitted to the Cape Town regional office of the Department of Mineral and Energy Affairs. The findings of this study are discussed in Chapter 8 and the conclusions of and recommendations to the study are given in Chapter 9.

CHAPTER 2

A PRE-PLANNING APPROACH TO REHABILITATION

2.1 INTRODUCTION

The impacts associated with quarrying are linked to sudden, and often major disturbances to habitats, the topography and aesthetic qualities of the landscape. Although the area may, in some cases, recover naturally, this usually takes a number of years. Procedures, therefore, need to be implemented to ensure that these disturbances are treated as temporary in nature, and addressed within an acceptable period of time.

2.2 DEFINITIONS

A number of terms are used to describe the procedures carried out to address the disturbances caused by quarrying. The definitions listed below are those adopted by the National Academy of Sciences (1974). Each definition is evaluated in terms of its applicability to quarries and quarrying.

2.2.1 Restoration

Restoration implies a replication of the conditions that existed prior to the disturbance of the site. Due to the nature of quarrying and the complex inter-relationships that exist within ecosystems, complete restoration of a natural environment disturbed by quarrying is rarely, if ever, possible. Restoration is, therefore, not regarded as a suitable procedure for dealing with the disturbances caused by quarrying.

2.2.2 Reclamation

Reclamation implies that the organisms originally present on the undisturbed site will be able to inhabit the 'new' site. Due to the longevity of most quarries, the original land uses are, however, seldom compatible with the future land uses. The failure of reclamation to address the issue of changing land uses over time limits its applicability to quarries and quarrying.

2.2.3 Rehabilitation

Rehabilitation implies that the disturbed area is returned to a use that conforms with a future land use plan for the site. This involves assessing a number of alternative land uses for the site.

The final choice is based on the chances of achieving the proposed land use and its compatibility with future land uses in the area (Box, 1978). The use of a future land use plan emphasizes the need to establishing rehabilitation goals before quarrying starts. This makes rehabilitation, as a procedure, well suited to the pre-planning approach.

2.3 PRE-PLANNING APPROACH TO REHABILITATION

"In all industries, but particularly mining, planning is recognised as the key to success." (Riddle and Saperstein, 1978, p. 223)

The importance of this statement applies not only to mining, but equally so to rehabilitation. Most experts agree that a sure way to incur high rehabilitation cost, is to initiate mining operations without considering an ultimate end use for the site (Carter, 1989).

The selection of an acceptable and suitable end use for a site requires careful planning. Riddle and Saperstein's, (1978), Pre-planning Approach for Maximising Effective Land Use, provides a useful approach for addressing rehabilitation problems. This approach involves identifying the problems and the measures to effectively deal with them, during the early planning stages. Unfortunately this approach has not been widely used in the past and rehabilitation has, in many cases, simply been carried out as an after thought (Box, 1978). However, due to mounting public pressure, comprehensive rehabilitation programmes are becoming an accepted condition for ongoing operations and a prerequisite for future projects (Carter, 1989).

The collection of accurate baseline data is the key to adopting a successful pre-planning approach. Once the baseline data has been collected and assessed, the problems facing the rehabilitation programme can be identified. Since the majority of rehabilitation programmes are site specific, the baseline data should enable planners to gain a clear understanding of the factors that are likely to inhibit the implementation of the rehabilitation programme (Down and Stocks, 1977; Bradshaw and Chadwick, 1980; Coppin and Bradshaw, 1982). Once these factors have been identified a set of realistic long term rehabilitation goals can be drawn up.

This approach enables the rehabilitation goals to be incorporated into the development of the mining operations so enabling rehabilitation to become an integral part of the planning and management decisions relating to the mining operations (Haan and Walmsley, 1985). The rehabilitation programme should, therefore, be drawn up in consultation with the mining engineer and become part of the overall mine plan. By incorporating rehabilitation goals into the development of the mining operations, rehabilitation and mining, two activities frequently regarded as mutually exclusive, are combined and co-ordinated to achieve the dual goals of production and rehabilitation. This reduces the impacts caused by mining and provides a final land use for the site once operations have ceased (Riddle and Saperstein, 1978). By linking the two and recognising that rehabilitation is an integral part of the mining operations, the programme is also in a position to utilise the labour and equipment already on site.

A failure to co-ordinate rehabilitation and mining activities towards specific post mine land use objectives frequently results in the creation of undesirable and unsuitable land forms (Blauch, 1978). These unplanned or "fix-up" rehabilitation programmes generally tend to be more costly and less effective, and seldom result in the best possible future land use for the site (Blauch, 1978). Effective and economical rehabilitation programmes, therefore require careful planning from the outset (Coppin and Bradshaw, 1982).

Haan and Walmsley, (1985), list six points which outline the pre-planning approach:

(1) The rehabilitation programme must be conceived and developed from the initial site investigations into the feasibility of the mining operation.

(2) The initial site survey must provide a complete inventory of the environmental factors of the site.

(3) The rehabilitation programme must be recognised as an integral part of planning other mining activities.

(4) The rehabilitation programme must identify the final land use objectives for the site. Mining and rehabilitation must then be planned to work towards achieving the final land use.

(5) The rehabilitation programme should be sufficiently flexible in order to accommodate any changes in the mining operations brought about by changing economics, technological or social conditions.

(6) The rehabilitation programme must attempt to minimise the delay between mining and rehabilitation. Rehabilitation and mining should, wherever feasible, be planned to enable concurrent rehabilitation of the site.

When the pre-planning approach is adopted, care must be taken to avoid too much detailed planning during the early planning stages. Changing economic conditions, social attitudes and mining techniques can render even the best planned rehabilitation programmes obsolete (Blauch, 1978). It is also highly unlikely that a rehabilitation programme can be produced in which every detail and procedure functions according to the design forecast. In the light of this, the dual principles of flexibility and adaptability, rather than finality and rigidity, should be adopted in order to achieve the objectives (Downing and Hackett, 1975). Rehabilitation programmes should, therefore, be reviewed on a regular basis and updated to ensure that the approaches to, and objectives of rehabilitation are appropriate.

2.4 DEVELOPING A REHABILITATION PROGRAMME

The scale of environmental damage caused by quarrying is likely to vary depending on the scale of operations, the methods of extraction, the volume of overburden, the properties of the overburden and the local environmental conditions (Randall, Johnson and Pagoulatos, 1978). In order to take into account the environmental factors that are likely to inhibit successful rehabilitation, rehabilitation programmes need to be site specific. This, as has been shown, can be achieved by adopting the pre-planning approach. This, however, is only an approach towards drawing up a rehabilitation programme, the components that make up the programme are equally important.

The majority of rehabilitation programmes consist of two major components: engineering and biological (Coppin and Bradshaw, 1982). The engineering component involves the creation of a landform that is compatible with the surrounding landscape, and satisfies the drainage and stability requirements of the new landform. The biological component involves the establishment and maintenance of a stable and self sustaining plant community on the disturbed site. The terms landscaping and revegetation have also been used to describe the engineering and biological components (Down and Stocks, 1977; Verma and Thames, 1978). These terms are used in this study.

Coppin and Bradshaw, (1982), in their authoritative work, **Quarry Reclamation**, identify four components of a rehabilitation programme. These include:

(1) Initial Site Survey
(2) Landscaping
(3) Revegetation
(4) Monitoring and After-care

The components are ordered in the sequence in which they should be implemented. The development of a rehabilitation programme should therefore, start with the initial site survey and end with monitoring and after-care. The components of a rehabilitation programme are illustrated in Figure 2.1. The role of each component is outlined below and discussed in greater detail in Chapters 3, 4, 5 and 6.

It is necessary to note that the function of the landscaping component in this study differs from Coppin and Bradshaw's, (1982), engineering (landscaping) component. In this study the landscaping component includes the amendments carried out to the overburden to provide a suitable medium for plant growth. In the case of Coppin and Bradshaw, (1982), this function is performed by the biological (revegetation) component.

INITIAL SITE SURVEY
(Provide baseline data on the local site conditions)

- location
- land uses
- infrastructure
- mining operations
- topography and visual aspects
- vegetation
- natural soils
- geology
- surface hydrology
- sub-surface hydrology
- climate
- overburden properties
- financial aspects
- alternative after uses

↓

INTERPRET BASELINE DATA

↓

IDENTIFY FACTORS LIKELY TO INHIBIT REHABILITATION

↓

ESTABLISH REHABILITATION GOALS

↓

LANDSCAPING PROGRAMME
(Provide a stable land form that is suitable for plant growth and compatible with future land uses)

Based on :

- topography and visual aspects
- mining operations
- volume of overburden
- overburden properties
  - physical
  - chemical
  - biological
- drainage requirements
- climate
- amendments to the overburden
- timing of operations
- preparation of the seed bed

↓

REVEGETATION PROGRAMME
(Provide a stable, maintenance free plant community)

Based on :

- climate
  - rainfall
  - temperature
  - wind
- selection of suitable species
- collection of seeds and plants
- properties of the overburden
  - physical
  - chemical
  - biological
- timing of operations
- mining operations

↓

MONITORING AND AFTER-CARE PROGRAMME
(Ensure success of the rehabilitation programme)

↓

SUCCESSFUL LONG TERM REHABILITATION

Figure 2.1 : Components of a rehabilitation programme.

2.4.1 Initial Site Survey

The objective of the initial site survey is to collect baseline data on the environmental factors likely to inhibit the implementation of a successful rehabilitation programme. To achieve this the initial site survey should provide data on a number of factors including; the mining operations, volume of overburden, equipment being used, properties of the overburden, climate, geology, soils, topography, vegetation, surface hydrology, sub-surface hydrology and land uses in the area (Down and Stocks, 1977; Bradshaw and Chadwick, 1980; Chamber of Mines of South Africa, 1981; Coppin and Bradshaw, 1982). Realistic long term rehabilitation goals can only be established once this data has been collected, analysed and interpreted. The success of the remaining three components of the rehabilitation programme, therefore, depends on the quality of the data obtained from the initial site survey.

2.4.2 Landscaping

The objective of the landscaping programme is to provide a stable landform that is suitable for plant growth and compatible with future land uses for the site (Glover, Augustine and Clar, 1978; Coppin and Bradshaw, 1982). To achieve this the landscaping programme must take into account; the scheduling of operations, volume of overburden, properties of the overburden, mining methods and equipment available, drainage requirements and future land uses for the site (Down and Stocks, 1977; Coppin and Bradshaw, 1982). This is only possible once the initial site survey has been carried out.

Since landscaping involves amendments to the overburden, the properties of the overburden are of particular importance. These properties vary from site to site and within the quarry itself. These properties must therefore, be accurately assessed during the initial site survey (Ramani and Grim, 1978; Coppin and Bradshaw, 1982). This enables suitable and unsuitable material to be identified before the landscaping programme is implemented. Unsuitable material can then be either buried or treated accordingly. Suitable material, on the other hand, should be stockpiled and used on the surface to provide a suitable medium for plant growth (Glover, Augustine and Clar, 1978; Gee, Bauer and Decker, 1978; Coppin and Bradshaw, 1982). Where amendments to the overburden are required to improve its suitability as a medium for plant growth, these can only be carried out once the nutrient deficiencies have been determined.

2.4.3 Revegetation

The objective of the revegetation programme is to establish a stable and maintenance free plant community on the new landform (Jeffrey, Maybury and Levinge, 1975; Coppin and Bradshaw, 1982). In so doing the revegetation programme can fulfil a number of important functions including; improving soil conditions, slope stabilisation, erosion control and screening (Coppin and Bradshaw, 1982). The success of the programme depends largely upon the ability of the landscaping programme to provide a suitable medium for plant growth and the use of the relevant baseline data to develop the programme. The baseline data should be used to identify the start of the growing season, suitable plant species and appropriate planting techniques (Box, 1978; Bradshaw and Chadwick, 1980; Coppin and Bradshaw, 1982). The data should also be used to identify dry periods and the need for additional irrigation.

2.4.4 Monitoring and After-Care

The objective of the monitoring and after-care programme is to ensure successful rehabilitation. While no less important than the other components, monitoring and after-care is frequently neglected (Bradshaw and Chadwick, 1980). The failure to appreciate its importance is one of the most common causes of poor rehabilitation (Coppin and Bradshaw, 1982).

The monitoring aspect of the programme involves regular and systematic checks to assess the progress of the landscaping and revegetation programmes. The development of negative off site effects, such as ground water contamination, should also be monitored (Chamber of Mines of South Africa, 1981).

After-care provides the remedial response to the problems detected by the monitoring programme. These vary from slope stabilisation measures and repairs to the drainage system, to removing and replacing failed seeds and plants and additional fertiliser applications to the overburden to overcome nutrient deficiencies (Coppin and Bradshaw, 1982). Ultimately, the success of the after-care programme depends on the quality of the information gained from the monitoring programme, and the timing of the responses.

On one hand a well developed monitoring and after-care programme should both identify problems before they get out of hand, and enable the appropriate responses to be implemented. A haphazard programme, on the other hand, may lead to serious problems developing unnoticed. This may threaten the success of the entire rehabilitation programme. While careful planning of the early components of the rehabilitation programme can make monitoring and after-care more straight forward, it does not obviate the need for it completely (Foister, 1977).

2.5 SUMMARY

The chances of implementing a successful rehabilitation programme can be significantly improved by adopting a pre-planning approach. This approach is illustrated in Figure 2.1. The basic requirements of this approach involve:

(1) A thorough knowledge of the local site conditions (initial site survey);
(2) The establishment of realistic rehabilitation goals;
(3) Planned and proper placement of the overburden (landscaping);

(4) Appropriate amendments to the overburden (landscaping);

(5) Selection of suitable plant species and planting techniques (revegetation);

(6) Correct timing and application of the procedures (landscaping, revegetation, monitoring and after care); and

(7) Adequate monitoring and after care (monitoring and after care).

The success of the pre-planning approach depends on the quality of the baseline data from the initial site survey, and the manner in which the data is interpreted and used to develop the remaining three components of the rehabilitation programme. Without this data there is no measure of the pre-mining conditions against which the success of the programme can be assessed, and no prior indication of the factors that are likely to inhibit the implementation of the rehabilitation programme. The individual components are discussed in more detail in the following four chapters.

CHAPTER 3

THE INITIAL SITE SURVEY

3.1 INTRODUCTION

Successful rehabilitation depends largely upon the ability of the rehabilitation programme to overcome the environmental factors that are likely to inhibit it's implementation (Bradshaw, Dancer, Handley and Sheldon, 1975; Bradshaw and Chadwick, 1980). The first step involved in drawing up a rehabilitation programme should, therefore, be a detailed and systematic site survey of the local conditions. This provides planners with baseline data on the local conditions, so enabling them to identify the factors likely to inhibit or enhance the implementation of a successful rehabilitation programme.

Bradshaw and Chadwick, (1980), note that the need for detailed site investigations to precede full scale rehabilitation has become widely accepted, and that ideally, they should be carried out before quarrying starts. This pre-planning approach not only improves the chances of implementing a successful rehabilitation programme, but also reduces the costs associated with rectifying the disturbances caused by quarrying (Smith and Sobek, 1978). The value of the initial site survey to the rehabilitation programme is illustrated in Figure 3.1. The advantages gained from this approach however, depend upon the quality of the data, and the manner in which it is interpreted and linked to decisions regarding the design and implementation of the remaining three components of the rehabilitation programme. Without an adequate understanding of the factors likely to affect the implementation of the landscaping, revegetation, and monitoring and after-care components, the rehabilitation programme is unlikely to be successful.

The baseline data required from the initial site survey depends upon the local site conditions and the final objectives of the rehabilitation programme (Coppin and Bradshaw, 1982). Where rehabilitation involves the implementation of full scale landscaping and revegetation programmes the survey should provide baseline data on the following:

(1) The mining activities
(2) Topography and visual aspects
(3) Climate
(4) Properties of the Overburden (Physical, Chemical and Biological)
(5) Surface and Sub-surface hydrology
(Down and Stocks, 1977; Coppin and Bradshaw, 1982)

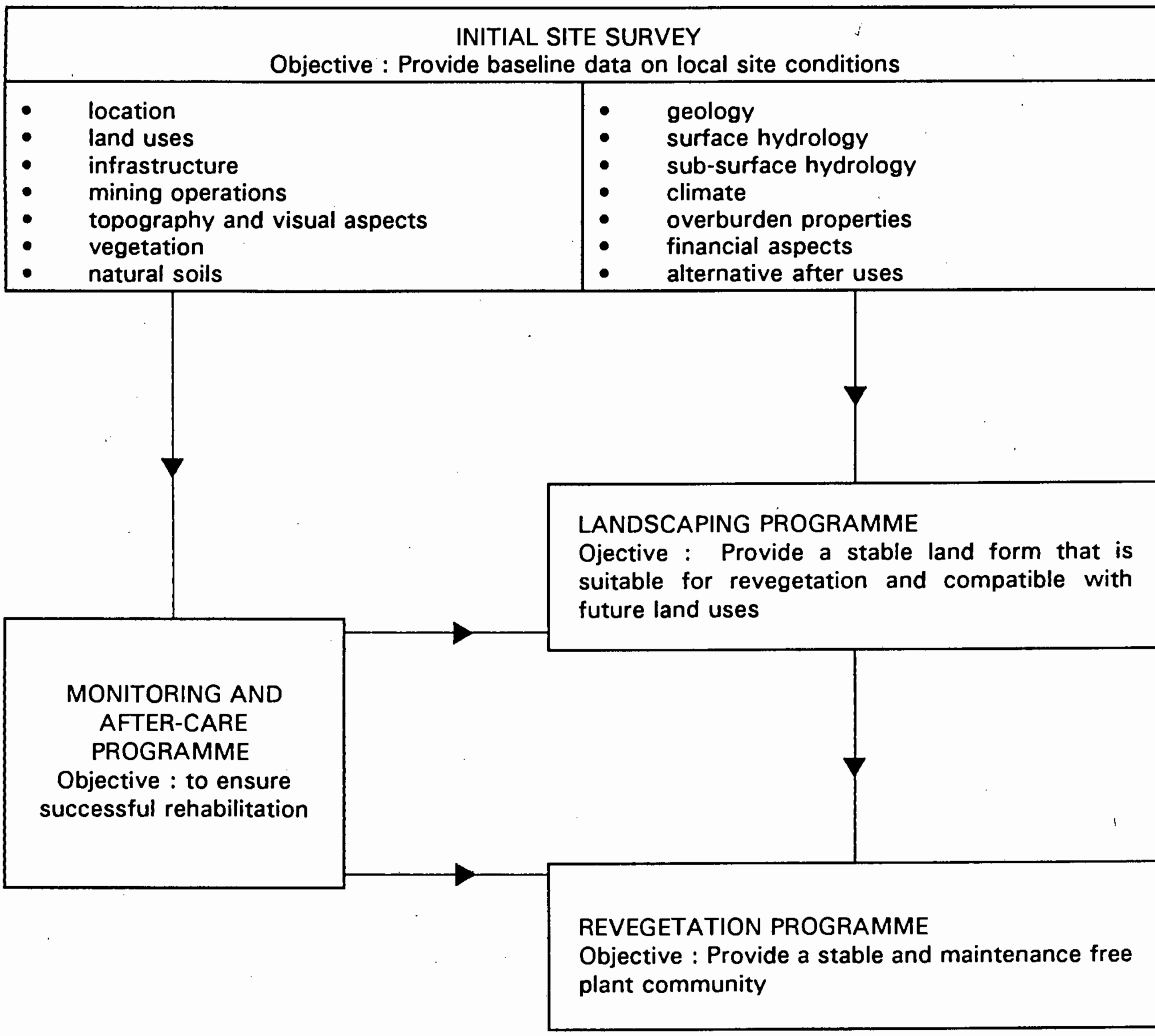

Figure 3.1 : **The importance of the initial site survey to the rehabilitation programme.**

3.2 DESCRIPTION OF THE MINING ACTIVITIES

A basic knowledge of the mining procedures involved is crucial to the design of a successful rehabilitation programme (Law, 1984). Mining procedures tend to vary and are often complicated, depending on the material being mined, the local conditions and the equipment available. Before the rehabilitation programme can be co-ordinated with the mining operations, data on the scale of operations, rate of production, life span of the quarry, methods of extraction, volume of overburden and the final dimensions of the quarry, should be collected (Law, 1984). The incorporation of this data into the design of the rehabilitation programme improves the chances of long term success.

3.3 TOPOGRAPHY AND VISUAL ASPECTS

The visual impacts commonly associated with quarrying are linked to the quarry itself and the overburden generated during the operations. The severity of these impacts depends largely upon the scale of the operation, the visibility of the quarry and the general topography of the area (Downing, 1971). To enable the landscaping programme to effectively address the visual aspects, the initial site survey should include a topographic survey. The survey should extend beyond the boundaries of the site to assess the general topography of the area (Downing, 1977b). The survey should also identify sightlines and view points from where the quarry is likely to be visible. This data should be used to establish the need to construct berms for screening purposes. Where berms are necessary, care must be taken with their design to ensure that they themselves do not become visually intrusive (Downing, 1977a).

In order to effectively minimise the visual impacts, the new landform should attempt to blend into the natural surroundings. At the same time the design must contend with the topographic limitations imposed upon it by the volume of overburden produced and the proposed future land uses for the site (Hackett, 1971). During the early stages of rehabilitation, before the implementation of the revegetation programme, the visual aspects of the landform are aesthetically important (Hackett, 1971). During these early stages the ability of the landscaping programme to reduce the visual impacts will depend on the ability of the design to recognise the capacity of the landscape to absorb the visual intrusions caused by both the quarry and the new landform. This capacity is largely dependant upon the dominant landforms of the area and the surrounding topography (Downing, 1977a). Unless the future land uses for the site requires the creation of a new landform, designs that mimic the natural topography of the area have, on the whole, achieved the best aesthetic and functional results (Downing, 1977a).

Besides the influence of topography on the visual aspects of the rehabilitation programme, topography also plays an important role in the design of a stable landform. The design of a stable landform and an efficient drainage system requires close attention to be paid to the topographical features of the site and those of the surrounding watershed area (Downing, 1977a).

3.4 CLIMATE

Since climate has an important bearing on the timing and success of both the landscaping and vegetation components of rehabilitation, and to a lesser extent monitoring and after-care, data on the local climatic conditions is an essential requirement for all rehabilitation programmes (Power, 1978). The three most important climatic parameters that need to be assessed during the initial site survey are rainfall, temperature and wind. In some cases it may also be necessary to assess the microclimatic modifications caused by variations in slope, aspect, elevation and the colour of the overburden (Coppin and Bradshaw, 1982).

The climatic data required for the rehabilitation programme is usually available from the local or regional meteorological station. This source provides a valuable historical record that can be used to identify seasonal changes in weather patterns. These changes can have an important bearing on the timing of operations. Where possible, information should also be obtained from the local inhabitants. These people are often in a position to provide meaningful and useful information on the local weather patterns. In some cases it may also be necessary to take measurements on the site.

3.4.1 Rainfall

The baseline data from the initial site survey should provide data on:

* mean annual rainfall
* monthly rainfall

Data on the rainfall patterns can have an important bearing on the implementation of the landscaping and revegetation programmes.

Seasonal variations in rainfall patterns play an important role in scheduling the contouring and grading operations undertaken during the landscaping programme. These operations should be scheduled to coincide with periods of low precipitation to avoid any unnecessary damage to the wet soils caused by compaction (Coppin and Bradshaw, 1982). Run-off and erosion during periods of high precipitation also tends to be higher. Earthmoving operations during these periods are likely to exacerbate the problem and should, therefore, be avoided (Glover, Augustine and Clar, 1978).

Rainfall data is also crucial to the design of an effective drainage system. To meet the sites drainage requirements the design must take into account seasonal variations in run-off values for the area. Seasonal changes in the moisture content of the overburden may also affect the overall stability of the landform.

For the revegetation programme, rainfall provides the primary source of water for seed germination and plant growth. In arid and semi-arid regions water overshadows all the other factors regulating plant growth and is the key to a successful revegetation programme (Down and Stocks, 1977; Power, 1978; Verma and Thames, 1978). The timing of the revegetation programme is crucial to its success. Revegetation, therefore, should be timed to coincide with the start of the growing season and the most favourable moisture conditions (Coppin and Bradshaw, 1982). The selection of suitable plant species is also largely dependant on the rainfall for the area.

3.4.2 Wind

The baseline data from the initial site survey should provide data on:

* Mean monthly wind speeds
* Prevailing monthly wind directions

Strong winds during the early stages of rehabilitation can threaten the success of the programme by causing mechanical damage to young plants and shrubs, and removing valuable topsoil and seeds (Bradshaw and Chadwick, 1980; Coppin and Bradshaw, 1982). Before any effective protective measures, such as wind breaks, can be erected, baseline data on wind speeds and prevailing wind directions must be collected. Wind also increases the rate of evapotranspiration which in turn reduces the moisture content of the overburden, making revegetation more problematic.

The timing of certain earthmoving and seeding operations may also be affected by seasonal variations in wind speeds and direction.

3.4.3 Temperature

The baseline data from the initial site survey should provide data on:

* Mean annual temperatures
* Mean monthly minimum and maximum temperatures

Different plant species function more effectively under different temperature ranges. Temperature therefore, plays an important role in the selection of suitable plant species for the revegetation programme (Bradshaw and Chadwick, 1980). Temperature also influences germination, the length of the growing season, evapotranspiration rates and the frequency of frost events occurring (Gardner and Woolhiser, 1978). Temperature, therefore, strongly influences both the timing of the revegetation programme and the selection of suitable plant species.

3.5 OVERBURDEN PROPERTIES

The success of the rehabilitation programme will, to a large extent, depend on the ability of the landscaping programme to provide a landform that is stable and suitable for plant growth (Glover, Augustine and Clar, 1978; Bradshaw and Chadwick,1980). To achieve this, the landscaping programme must take into account the physical, chemical and biological properties of the overburden, and the effects they are likely to have on fertility and stability.

Since the properties of the overburden vary from site to site and within the quarry itself, they need to be analysed before an effective rehabilitation programme can be drawn up (Bradshaw and Chadwick, 1980; Coppin and Bradshaw,1982). Once this has been done, re-working the overburden can be co-ordinated with the mining activities. This enables suitable material to be identified and separated from unsuitable material. Suitable material can then be placed on the surface to provide a medium for the revegetation programme, and unsuitable material can be either buried or treated (Gee, Bauer and Decker, 1978; Smith and Sobek, 1978; Coppin and Bradshaw, 1982).

While the physical, chemical and biological properties of the overburden are usually analysed separately, they are closely linked. It is important to bear this in mind when the landscaping programme is being drawn up.

3.5.1 Physical Properties

The physical properties of the overburden can affect both the stability of the landform and its ability to act as a suitable medium for plant growth. To appreciate the influence of the physical properties on the rehabilitation programme the initial site survey should provide information on:

* Texture
* Structure
* Engineering properties

(A) Texture

As a physical property, texture is relatively stable and has a strong influence on the capacity of the overburden to retain water and nutrients (Down and Stocks, 1977). This makes texture an extremely useful indicator of the ability of the overburden to act as a suitable medium for plant growth. Unfortunately the overburden seldom exhibits the texture of a well developed soil that is both stable and suitable for revegetation. These deficiencies can, however, be addressed once they have been identified during the initial site survey.

Texture also influences the engineering properties of the overburden and is, therefore, an important criteria for stability.

(B) Structure

During the implementation of the landscaping programme, compaction is likely to cause varying degrees of damage to the structure of the overburden (Lyle, 1987). Compaction reduces infiltration and the capacity of the overburden to store water, which in turn makes revegetation more difficult. The damage caused to the structure by compaction can ,however, be addressed by ripping, scarifying and the addition of organic matter (Lyle,1987).

Improving structure improves aeration, infiltration and drainage, and increases the capacity of the overburden to store water (Russell, 1973). This in turn improves the ability of the overburden to act as a suitable medium for plant growth and increases the chances of implementing a successful revegetation programme.

(C) Engineering Properties

To provide a stable landform, the landscaping programme has to take into account the engineering properties of the overburden. These properties are closely linked to the textural properties of the overburden and give an indication of its mechanical strength (Capper and Cassie, 1976). Stability problems that are linked to the engineering properties can, in some cases, be addressed by manipulating the physical properties. To do this successfully, however, requires a prior knowledge and understanding of both sets of properties.

3.5.2 Chemical Properties

The chemical properties of the overburden strongly influence the ability of the material to act as a suitable medium for plant growth. To enable the landscaping programme to provide a landform that is suitable for revegetation the initial site survey should provide information on:

* Nutrient levels
* pH
* Cation exchange capacity (CEC)
* Toxicity levels
* Soluble salts

(A) Nutrient Levels

Plants require at least twenty different nutrients to grow and develop, of these, the six macro-nutrients (nitrogen, potassium, phosphorus, calcium, magnesium and sodium) are essential (Bradshaw and Chadwick, 1980). The failure of the overburden to provide a suitable medium for plant growth is commonly linked to a shortage of these macro-nutrients. They can, however, be readily added to the overburden by using organic and inorganic fertilizers (Coppin and Bradshaw, 1982). However, before any meaningful steps can be taken to address the deficiencies, the current nutrient status of the overburden must be accurately assessed.

(B) pH

As a chemical property pH plays a very important role in controlling the availability of nutrients to plants (Russell, 1973). Most nutrients tend to be more soluble under slightly acidic conditions, and in this state they also become more available for use by the plants (Courtney and Trudgill, 1984). Excess acidity can, however, cause serious problems for plant growth. These problems are linked to a reduction in the availability of nutrients, rising toxicity and adverse affects on the activities of the soil organisms (Lyle, 1987).

(C) Cation Exchange Capacity (CEC)

A measure of the CEC reflects the ability of the clay minerals and the organic matter in the material to yield nutrients for plant growth (Russell, 1973). This makes it a useful indicator of the ability of the material to act as a suitable medium for plant growth.

The presence of organic matter commonly accounts for at least fifty percent of the materials CEC (Brady, 1974). However, overburden seldom contains organic matter. The CEC exchange capacity is therefore, usually low, making it a poor medium for plant growth (May, 1975). This situation can however, be amended by adding organic matter, such as sewage sludge, to the overburden (Halderson and Zenz, 1978) or finer, clay rich material.

(D) Toxicity

While nutrients are essential for plant growth, when they occur in large or toxic concentrations they can have a negative effect. Contamination from heavy metals such as lead, copper and zinc can also affect plant growth when they occur in toxic quantities (Coppin and Bradshaw, 1982).

To enable toxic material to be identified before the landscaping programme, the initial site survey should assess the toxicity levels of the overburden (Gee, Bauer and Decker, 1978; Glover, Augustine and Clar, 1978; Coppin and Bradshaw, 1982). Overburden that is found to be toxic can then be either buried or treated.

(E) Soluble Salts

In arid and semi-arid areas there is often insufficient precipitation to leach out the salts produced during the natural weathering processes. These salts tend to accumulate near the surface where they come into contact with the roots of plants (Bradshaw and Chadwick, 1980). This can cause problems for plant growth during the revegetation programme, leading to the development of dwarf or stunted plants. This situation becomes more noticeable with an increase in salt content (Russell, 1973).

3.5.3 Biological Properties

The biological component of the soil is made up of plants and organisms that are both living and dead. The decomposition of the organic matter, which is carried out by the soil organisms, releases nutrients which in turn become available to the plants to support growth (Daubenmire, 1959). This process is essential for the development of the nutrient cycle. Without a nutrient cycle, long term rehabilitation cannot be achieved (Jeffrey, Maybury and Levinge, 1975). For a nutrient cycle to develop, the overburden must contain organic matter and a population of soil fauna and flora (Down and Stocks, 1977). In the majority of cases however, the overburden is devoid of organic matter and soil organisms (May, 1975).

To achieve successful long term rehabilitation the biological deficiencies of the overburden have to be addressed. One of the best ways of doing this is to improve the organic matter content of the overburden (Lyle, 1984). Once this has been done, natural colonisation by the soil fauna and flora will lead to decomposition of the organic matter and the release of nutrients (Brady, 1974). The establishment and maintenance of the biological properties of the overburden is therefore an essential part of the rehabilitation programme (Briggs, 1977). To achieve this requires a knowledge and understanding of the biological properties of the overburden and the ways in which they can be addressed. The initial site survey should, therefore, provide information on:

* The organic matter content of the overburden
* Soil fauna
* Soil flora

3.6 SURFACE AND SUB-SURFACE HYDROLOGY

An understanding of the effects of water moving over the surface and through the overburden, is essential for the development of a landform that is both stable and suitable for revegetation (Gardner and Woolhiser, 1978). To achieve this understanding the initial site survey should provide baseline data on:

* Depth of the water table
* Ground water characteristics
* Run-off values for the catchment area and the site
* Natural drainage patterns on the site and the surrounding area
* Storm water disposal
* Potential for polluting the natural water courses in the area
* Movement of ground water through the overburden

Erosion caused by the movement of water over and through the overburden can threaten the stability of the landform and the overall success of the rehabilitation programme. The development of an effective drainage system to control surface run-off and reduce erosion will depend on a detailed knowledge of the site's hydrological conditions (Downing, 1977c). The layout and the siting of the outlets will depend to a large extent on the topography and the natural drainage patterns. The incorporation of the natural drainage pattern into the final design can greatly reduce the costs of construction (Hackett, 1977a). The capacity of the system should be based on the run-off values for the catchment area.

The initial site survey should also assess the ability of the natural water courses in the area to cope with increased run-off from the site, and the potential threat of pollution. Run-off from overburden tips can contain significant amounts of suspended solids and leached chemicals which may threaten the local riverine ecosystems (Down and Stocks, 1977).

The movement of water through the overburden often poses a far more serious threat to the stability of the landform and the success of the rehabilitation programme than run-off flowing over the surface of the landform. Due to the difficulties that are associated with monitoring and controlling this movement, slope failure and slumping can occur without prior warning. To avoid, this the properties of the overburden and the affects of water movement on the engineering principles of the design, should be addressed during the initial site survey (Capper and Cassie, 1976).

3.7 SUMMARY

By providing the necessary baseline data the initial site survey enables planners to adopt a pre-planning approach towards rehabilitation. Without this data the factors that are likely to inhibit the implementation of the rehabilitation programme cannot be identified and addressed. Collecting detailed and accurate data on the local conditions is, therefore, a vital component of the rehabilitation programme. Equally important, however, is the way in which this data is then interpreted and applied to developing the remaining three components of the rehabilitation programme. Chapter 4 describes the landscaping component of the rehabilitation programme.

CHAPTER 4

LANDSCAPING

4.1 INTRODUCTION

The objectives of the landscaping programme are:

(1) Provide a stable landform
(2) Provide a medium that is suitable for plant growth
(3) Ensure that the final landform is compatible with future land uses (Glover, Augustine and Clar, 1978)

Because landscaping usually involves major earthmoving operations it is often the most expensive component of the rehabilitation programme (Down and Stocks, 1977). The costs however, are usually justified. Experience has shown that successful long term rehabilitation is unlikely without the implementation of a well planned landscaping programme (Coppin and Bradshaw, 1982). The pre-planning approach (Riddle and Saperstein, 1978), offers the best approach for implementing a well planned landscaping programme. This approach is illustrated in Figure 4.1.

To enable a successful pre-planning approach to be implemented the initial site survey should provide accurate baseline data on a number of factors. These include: rates of production, mining methods, equipment available for reworking and contouring, volume of overburden, area available for stockpiling and spreading, climatic conditions, properties of the overburden, drainage requirements, available topsoil and the future land uses for the site (Glover, Augustine and Clar, 1978; Verma and Thames, 1978; Coppin and Bradshaw, 1982). Without this data the landscaping programme is unlikely to achieve it's objectives.

The advantages of adopting a pre-planning approach are twofold. Firstly, the factors that are likely to inhibit the success of the programme can be identified during the early planning stages of the programme, and secondly, the appropriate remedial measures can be taken to address the problems. (Gee, Bauer and Decker, 1978; Coppin and Bradshaw, 1982).

While the design and development of a successful landscaping programme obviously depends as a number of factors, the physical, chemical and biological properties of the overburden play a major role (Coppin and Bradshaw, 1982). The lateral and vertical variations that often occur within quarries make a detailed site analysis of these properties important (Grube, et al, in Down and Stocks, 1977). These properties should, ideally be assessed before quarrying starts. This can be achieved without incurring additional drilling and sampling costs by analysing the samples taken during the initial exploration programme (Power, 1978; Smith and Sobek, 1978).

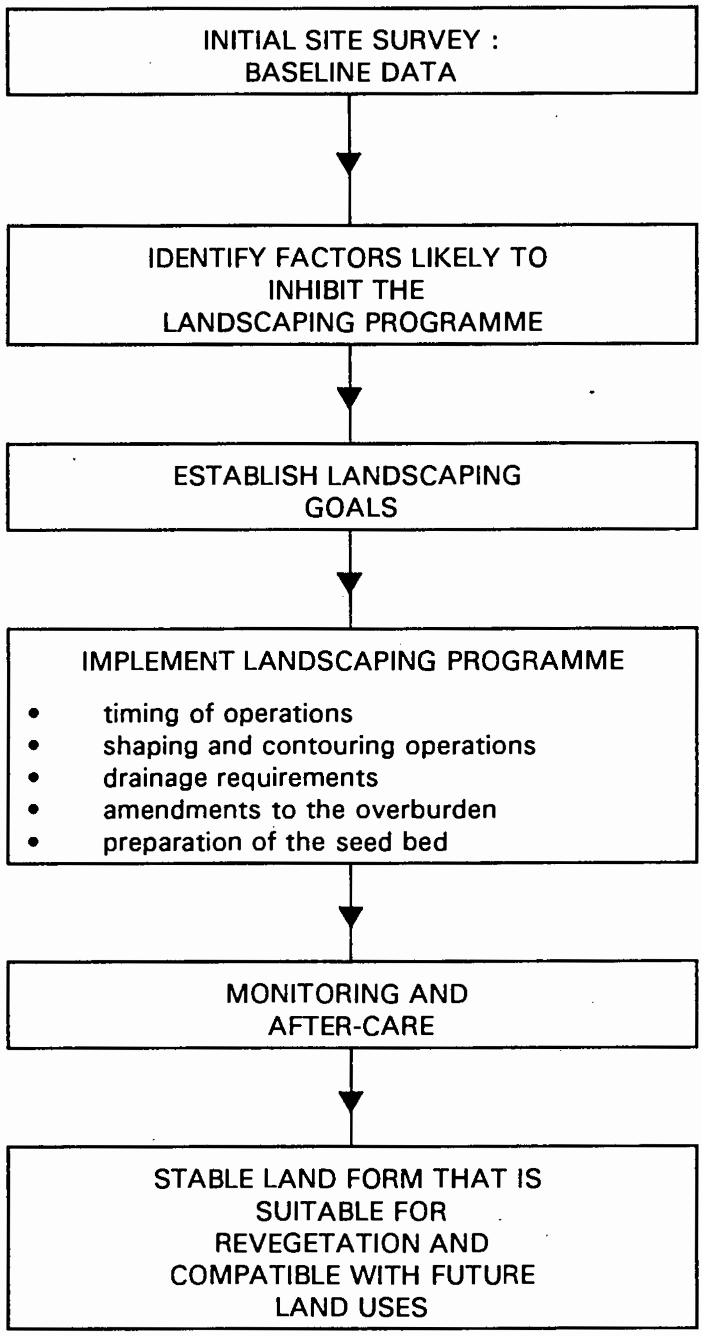

Figure 4.1 : **Steps involved in a landscaping programme. (After: Jeffrey, Maybury and Levinge, 1975, p 383).**

Once this information has been collected and used to assess the stability of the overburden and it's suitability as a medium for plant growth, the landscaping programme can be planned to ensure that suitable material is separated from the unsuitable material. Unsuitable material can then be either treated or buried. Suitable material should be stockpiled on the surface and used as a medium for plant growth (Gee, Bauer and Decker, 1978; Smith and Sobek, 1978; Coppin and Bradshaw, 1982).

Any topsoil on the site, even small quantities, should be treated as a valuable asset to the landscaping programme (Coppin and Bradshaw, 1982). The presence of nutrients, microbial populations and organic matter usually makes even poor quality topsoil, a better medium for plant growth than overburden (Power, Sandoval and Ries, 1979). Where topsoil does occur, the quality and the quantity of topsoil available should be established during the initial site survey. Care should then be taken to ensure that it is removed and stockpiled separately to prevent it from being destroyed by mixing with the overburden (Coppin and Bradshaw, 1982). Down and Stocks (1977) note however, that topsoil usually undergoes a marked deterioration when it is stockpiled for periods of longer than six months. The best way to reduce the damage caused by stockpiling is to transfer the topsoil directly from its native site to the newly constructed landforms (Schuman and Power, 1981). This form of on-going rehabilitation is both economically and biologically sound, since the double handling involved in stockpiling increases both the costs involved and the chances of damaging the properties of the topsoil (Coppin and Bradshaw, 1982).

4.2 PROPERTIES OF THE OVERBURDEN

4.2.1 Physical Properties

The importance of the physical properties of the overburden to the success of the landscaping programme is linked to their influence on the stability of the landform and its suitability as a medium for plant growth. To appreciate the important role played by the physical properties of the overburden it is useful to distinguish between the factors that affect plant growth directly, and those that have an indirect affect (Letey, 1985).

Four factors, water, oxygen, temperature and the mechanical strength of the parent material, have a direct affect on plant growth (Russell, 1973). The physical properties of the overburden, in turn, have an indirect affect on plant growth through their influence on water, aeration, temperature and the mechanical strength of the parent material (Letey, 1985). Amendments to the physical properties of the overburden that influence the factors that directly affect plant growth can, therefore, improve the ability of the overburden to act as a suitable medium for plant growth.

Soil fertility is, therefore, not solely dependant on the chemical properties that affect the availability and supply of nutrients. In many cases it is the physical properties of the overburden, those which are responsible for regulating the supply of water and air to the plant roots and soil organisms, that are more important for producing a fertile medium (Richardson, 1977). Of the physical properties that need to be considered the two most important are:

* Texture
* Structure

(A) Texture

Soils are composed of particles that vary in size and shape. A textural classification system based on the particle size distribution within the soil is used to describe the textural make up of soils. Examples of the composition of the textural classes is illustrated in Figure 4.2. This the commonly recognised textural classification system and is used by the American and British Soil Surveys and in South Africa.

Texture influences drainage, the water-holding capacity of the material and the ability to store and supply nutrients (Law, 1984). This makes texture an extremely useful indicator of the overburdens ability to act as a suitable medium for plant growth (Courtney and Trudgill, 1984). Unfortunately the overburden produced by quarrying seldom exhibits the textures of a well developed soil that is both stable and suitable for revegetation (May, 1975). These deficiencies can, however, be addressed once the initial site survey has established the properties and the problems associated with them.

Overburden with a coarse sandy texture will enable water to infiltrate easily, but also allows water to pass through without retaining many of the nutrients for plant use. The ability to retain water is crucial to the success of the revegetation programme. Not only does it affect the water available to the roots, but it also influences the factors that directly affecting plant growth, namely, temperature, mechanical strength and the aeration status of the soil surrounding the root (Letey, 1985).

The inability of overburden with a high sand content to retain water and nutrients generally makes the implementation of a revegetation programme more difficult (Lyle, 1987). The water and nutrient holding capacity of coarse textured sandy and rocky overburden can, however, be improved by adding mulch and/or finer clays and silts (Coppin and Bradshaw, 1982). The clays and silts added to the overburden absorb water and act as a major store for plant nutrients (Russell, 1973). Down and Stocks (1977) point out that even the presence of as little as twenty percent of fine material can have a marked effect on the success of revegetation programmes. However, in the absence of organic matter and well developed structures the water holding capacity of even fine clay materials is still impaired (Brady, 1974).

While clay rich overburden is, on the whole, more likely to provide a suitable medium for plant growth than overburden with a sandy coarse texture, clay rich overburden is prone to water logging and instability due to the tendency of the clay minerals to expand and contract when they are subjected to wetting and drying (Fitzpatrick, 1986). Overburden with a high clay content also tends to be more susceptible to damage caused by compaction, which can in turn complicate the implementation of the revegetation programme. This situation can, however, be amended by the addition of coarse sandy material to the overburden (Coppin and Bradshaw, 1982; Lyle, 1987).

Overburden with intermediate textures, such as silt loams, sandy loams and sandy clay loams (see Figure 4.2), are ideally suited for landscaping. These textures allow water to enter the soil easily and retain the available water and nutrients in the root zone for plant use (Lyle,1987). The ability to retain both water and nutrients for plant growth while at the same time providing structural stability and relatively free drainage makes them ideal mediums for the implementation of a successful revegetation programme.

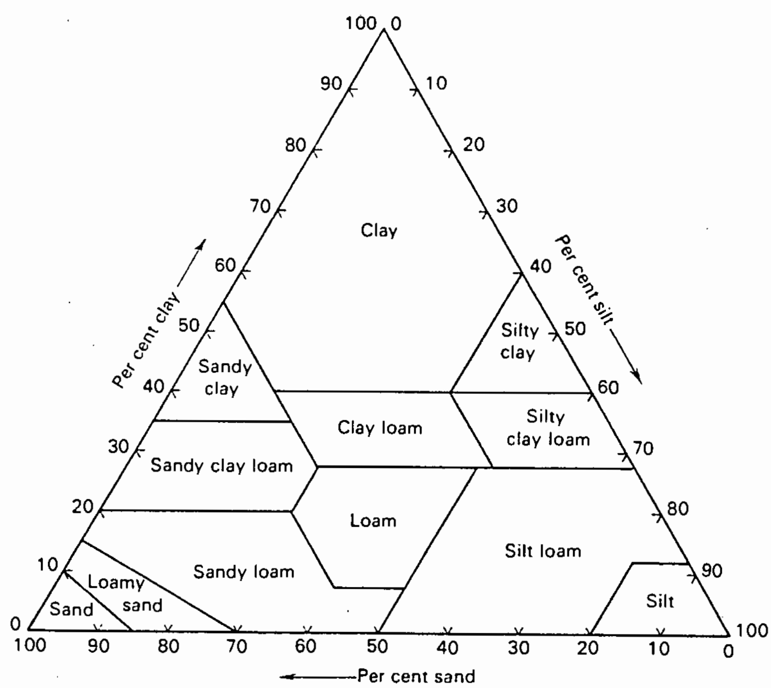

Figure 4.2 : The composition of textural classes of soils used by the United States Soil Survey. (Sand 2-0,05 mm; silt, 0,05-0,002 mm; clay, below 0,002 mm) (From Russell, 1973).

(B) Structure

Structure, as a physical property, is produced by the aggregation of coarse and finer mineral particles together with the organic matter in the soil. This produces loose friable clusters that frequently display distinctive shapes and sizes (Russell, 1973). A network of small and large pores develops between these clusters which improves the aeration, water holding capacity and the drainage of the material (Russell, 1973). These pore spaces encourage the development of the root system, and provide habitats for the soil fauna and flora (Richardson, 1977). Overburden with a well developed structure is, therefore, usually a suitable medium for plant growth.

As a property, however, structure is relatively unstable and can be altered during quarrying and landscaping operations (Lyle, 1987). Compaction, caused by the large earthmoving equipment used to move, re-work and contour the overburden during the landscaping programme, is a common problem. Compaction destroys the pore spaces between the soil particles. This in turn reduces infiltration rates and the capacity of the material to store water (Down and Stocks, 1977). The damage caused by compaction can severely hamper the revegetation programme, but is usually an unavoidable cost associated with the provision of a stable landform (Goodman, 1974). The initial scale of damage can, however, be reduced by careful planning of the landscaping programme and the implementation of ameliorative measures. This can be achieved by confining vehicle movement over the final surface to clearly defined haulage roads and minimising the handling of the overburden (Coppin and Bradshaw, 1982). The final levelling and preparation of the surface should also be carried out using vehicles that are specifically designed to reduce the damage caused by compaction. Landscaping should also be timed to avoid wet periods of the year when the likelihood of compaction occurring is greater, especially in cases where the clay content of the overburden is high (Coppin and Bradshaw, 1982).

Once the surface has become compacted a number of ameliorative measures can be implemented to reduce the damage and enhance the chances of implementing a successful revegetation programme. These usually involve ripping and scarifying the surface layer to improve the final seed bed, using equipment that is designed to shatter, cut, loosen and mix the material. The coarse, friable surfaces produced by ripping and scarifying encourages root growth, improves infiltration and reduces run-off, making revegetation easier (Coppin and Bradshaw, 1982; Larson, Swan and Schaffer, 1983). The benefits that are gained from ripping and scarifying do, however, depend on the timing, depth and frequency of the operations (Hillel and Rawith, 1972). Timing in particular can be very important. Under dry conditions ripping and scarifying can damage the structure and cause the surface layer to dry out, while under wet conditions it can produce dense clods and cause additional compaction (Lyle, 1987).

Improvements to the structure can also be achieved by increasing the organic matter content of the overburden. Organic matter provides the basis for the development of the structure. The addition of organic matter increases the capacity of coarse textured, sandy overburdens to hold water and nutrients and improves aeration and drainage in fine textured overburdens (Coppin and Bradshaw, 1982). The addition of organic matter also reduces bulk density. Bulk density is a measure of the ratio of soil mass to volume, and it provides a useful index of structure (Brady, 1974). Low bulk density values are generally an indication of well structured soils with abundant pore spaces while high values are associated with compacted soils with structural damage (Lyle, 1987).

4.2.2 Engineering Properties

To develop a stable landform, the landscaping programme must take into account the engineering properties of the overburden. This is a specialised field, and a full and in depth discussion of the engineering properties is beyond the scope of this study. The need to assess the engineering properties of the overburden is, however, an important element of the landscaping programme and requires input from a geotechnical engineer or an engineering geologist.

The engineering properties, which are closely linked to the physical properties of the overburden, give an indication of the load bearing capacity of the overburden which in turn gives an indication of its mechanical strength (Marshall and Holmes, 1988). Mechanical strength is controlled by the cohesive forces that exist between the mineral particles and the frictional resistance that develops when they are forced to slide over one another (Marshall and Holmes, 1988). To avoid slope failure and slumping jeopardising the stability of the landform, the behaviour of the overburden under different load bearing conditions should be assessed before the landscaping programme is implemented (Capper and Cassie, 1976).

Texture has an important bearing on the load bearing capacity of the overburden. In coarse grained, sandy materials, strength is controlled by the friction between the individual grains, while in finer grained clay rich materials, cohesion and water content play a more important controlling role (Courtney and Trudgill, 1984). The load bearing capacity of materials also varies considerably with water content. Clay rich materials, therefore, tend to be more prone to slumping during wet periods, due to the ability of the clay minerals to retain water (Coppin and Bradshaw, 1982).

Some of the problems that are linked to the engineering properties of the overburden can be addressed by manipulating the physical properties. Compaction and stabilisation are two techniques commonly used to improve the load bearing capacity of materials (Capper and Cassie, 1976). However, while compaction can improve the stability of the final landform it also reduces infiltration and the ability of the overburden to retain water. Care, therefore, should to be taken to weigh up the benefits derived from increasing the stability of the landform against the costs of impairing the revegetation programme.

The second technique, stabilisation, involves any process that is aimed at improving or maintaining the natural load bearing capacity of the overburden. This can be achieved in two ways (Capper and Cassie, 1976). The first involves the addition of aggregates or a binder to the overburden. An example of this would be the addition of sand or gravel to a clay rich overburden. Stabilisation involves improving the stability of the overburden by improving the drainage. A well developed drainage system can improve the stability of the landform by controlling the water content of the material. Once again, care has to be taken to ensure that the benefits of securing a stable landform do not outweigh the costs of making revegetation more difficult.

4.2.3 Chemical Properties

A number of the problems encountered during rehabilitation are related to meeting the nutrient demands of the vegetation. If the nutrients required are not available in adequate quantities plant growth is restricted (Bradshaw, 1983). The ability of the overburden to meet the nutrient demands of plants and act as a suitable medium for plant growth is strongly influenced by the chemical properties of the overburden (Coppin and Bradshaw, 1982).

For the development and growth of healthy plants a balance has to be established between at least twenty different nutrients. Of these, six (nitrogen, potassium, phosphorus, calcium, sulphur and magnesium) are essential. They are referred to as the macro-nutrients. The remaining nutrients, referred to as the micro-nutrients, are required only in trace amounts (Bradshaw and Chadwick, 1980). The pool of nutrients in the soil available to plants is made up of ions in the soil solution and exchangeable ions held by clay minerals and the organic matter (Fitzpatrick,1986). Fertile soils act as a store for these nutrients, releasing them slowly into the soil solution from where they can then be taken up for use by plants (Fitzpatrick, 1986).

While the concentration of the macro-nutrients required for satisfactory growth is extremely low and differs from species to species, there has to be a constant supply to meet the continual demands made by the plants (Russell, 1973). The ability of the overburden to provide a constant supply of these nutrients will determine its ability to act as a suitable medium for plant growth. In the majority of cases the overburden produced during quarrying provides a poor medium for plant growth (Hargis and Redente, 1984). The failure of the overburden to provide a suitable medium for plant growth is commonly linked to its inability to provide an adequate and constant supply of macro-nutrients (Bradshaw and Chadwick, 1980).

Although all six macro-nutrients are required for healthy plant growth only three (nitrogen, potassium and phosphorus) are usually lacking in the overburden to the extent that corrective action is required (Down and Stocks, 1977). These three macro-nutrients can, however, be readily added in the required amounts in the form of organic and inorganic fertilisers.

Various compound fertilisers, that provide combinations of nitrogen, potassium and phosphorus, are readily available. The use of these fertilisers is the cheapest and most widely used method of applying plant nutrients and if used correctly can be very effective (Coppin and Bradshaw, 1982). They provide nutrients for the soil organisms as well as the plants, and thereby also increase the biological activity of the soil (Szegi, Ohah, Fekete, Halasz, Varallyay and Bartha, 1988). The short term success achieved with fertilisers can, however, often conceal longer term problems, and a well developed monitoring and after-care programme is essential to ensure that the initial inputs do, in the long term lead to the development of a stable and maintenance free plant community (Bradshaw, 1983).

Of all the macro-nutrients required for plant growth, nitrogen is essential. The nitrogen that occurs in the soil is held by organic matter. Since overburden seldom contains significant amounts of organic matter it is more often than not characterised by a nitrogen deficiency (Lyle, 1987). The inability of the overburden to retain nitrogen, due to the lack of organic matter, also makes the use of nitrogen bearing fertilisers problematic. In addition to this, inorganic nitrogen fertilisers are soluble in water and care has to be taken to avoid losses caused by leaching when they are applied (Lyle, 1987). The most effective way of applying nitrogen fertilisers is to spread them on the surface in small amounts on a regular basis and allow rainfall or water from an irrigation system to transport them into the overburden (Cooke, 1975). A more economical alternative is to follow natural processes and use nitrogen fixing plants such as legumes (Bradshaw,1984). This approach is discussed further in Chapter 5.

Potassium and phosphorus fertilisers combine with the soil and are less mobile. For effective results, these fertilisers should always be placed below the surface, where they can be reached by the roots of plants (Cooke, 1985). It must be stressed though, that before any meaningful steps can be taken to address the nutrient deficiencies of the overburden, the current nutrient status must be evaluated (Bradshaw, 1984). This requires soil tests to be carried out as part of the initial site survey. Ideally soil samples should be taken before quarrying starts. This can be achieved by analysing the samples taken during the exploration programme (Power, 1978). To provide the rehabilitation programme with meaningful results, the tests should distinguish between the total quantity of nutrients in the overburden and the amount actually available for use by the plants (Richardson, 1977). The results can then be used to make recommendations about the type and quantities of fertilisers required to make up the nutrient deficiencies. The recommendations should also take into account the method of application, plant species selected for revegetation, planting techniques and the final land uses for the site (Coppin and Bradshaw, 1982).

Soil fertility is also influenced by a number of other chemical properties. These interact with the physical and biological properties of the overburden to produce conditions that may or may not be favourable for plant growth (Russell, 1973). Of these the pH and the cation exchange capacity (CEC) are among the more important properties affecting fertility (Russell, 1973).

pH plays an important role in affecting the availability of nutrients. Most nutrients tend to be more soluble under slightly acidic conditions and in this state also become more available for use by the plants (Courtney and Trudgill, 1984). While the optimal pH for plant growth generally appears to be slightly acidic, excess acidity can also lead to serious problems for plant growth. These unfavourable conditions are caused by a reduction in the availability of nutrients, rising toxicity levels and the adverse affects this has on the activities of the soil organisms (Lyle, 1987). Most plants also exhibit fairly narrow pH ranges within which they can grow. These ranges vary from species to species, but for the majority of cases the pH range for natural soils can be taken to be between six and eight (Fitzpatrick, 1986). Overburden that is highly acidic and unsuitable for plant growth can be treated by adding finely ground lime to neutralise the acidity (Brady, 1974; Lyle, 1987).

The cation exchange capacity (CEC) of the overburden reflects the ability of the clay minerals and the organic matter present to yield nutrients for use by the plants (Russell, 1973). Next to photosynthesis, the release of nutrients through this ability to exchange cations is one of the most important processes in nature, since it is the primary mechanism for plant nutrition (Courtney and Trudgill, 1984). The rate of release varies with the type of clay minerals present, the organic matter content and the total content of cations (Cope and Evans, 1985). Overburdens with a high clay content generally have a higher (CEC) and are usually more suitable for plant growth. However, due to an almost total lack of organic matter the exchange capacity of most overburdens is low (Lyle, 1987).

The lack of organic matter content can, however, be addressed by adding organic matter, in the form of farm manure and sewage sludge, to the overburden (Halderson and Zenz, 1978; Coppin and Bradshaw, 1982). The addition of organic matter can significantly improve the chances of implementing a successful rehabilitation programme. This is because organic matter accounts for at least fifty percent of the (CEC) of a soil and is also responsible, perhaps more than any other single factor, for improving structural stability (Brady, 1974). Overburden that lacks both structure and organic matter will always have little or no ability to retain and supply nutrients, and until they are either added or develop, regular additions of fertilisers will continue to be necessary for plant growth to develop (Down and Stocks, 1977).

4.2.4 Biological Properties

The biological component of a fertile soil is extremely varied, and is made up of plants and animals that are both living and dead. The plants and organisms that die accumulate in the soil and are broken down to form organic matter. The organic matter is, in turn, colonised by a wide variety of soil organisms that are grouped according to size into the macrofauna, microfauna and micro-organisms (Richards, 1974).

The importance of soil organisms in creating favourable conditions for plant growth is widely recognised. This aspect, however, is seldom addressed during rehabilitation (Goodman, 1974). Soil organisms, in particular the micro-organisms, play a crucial role in breaking down and dispersing organic matter within the soil. This complex and important process leads to the release of nutrients. These nutrients become part of the organic store, from where they are available to the plants to sustain growth (Richards, 1974). The supply of nutrients from the organic matter to the plants is not a one way flow. As the plants and organisms die they accumulate in the soil, adding to the organic matter content and providing a new source of nutrients for the next generation of plants (Richards, 1974). This release, accumulation and transfer of nutrients forms the basis of the nutrient cycle. Without it, the soil would be unable to sustain plant growth.

A medium that is suitable for plant growth is, therefore, one that is rich in both organic matter and soil organisms (Richardson, 1977). Overburden, however, is usually completely devoid of organic matter and soil organisms (May, 1975). In the absence of organic matter and a population of soil organism the nutrient cycle cannot be established, and without a nutrient cycle a stable, maintenance free plant community cannot developed (Cundell, 1977; Down and Stocks, 1977). The establishment and maintenance of the biological properties of the overburden is, therefore, an essential part of the landscaping programme (Briggs, 1977).

One of the first steps towards achieving this is to improve the organic matter content of the overburden. While the addition of fertilisers can help to speed up the early establishment of the nutrient cycle it can never fully replace the role played by the organic matter and the soil organism (Coppin and Bradshaw, 1982).

The benefits to the landscaping programme of improving the organic matter content of the overburden should not be underestimated. The addition of organic matter to both sandy soils and heavy clays not only increases their ability to retain and supply nutrients, but also improves their structure, aeration and ability to retain water (Richardson, 1977). Materials that are rich in organic matter also tend to be structurally more stable. The presence of the organic matter and the activities of the soil organisms produces organic compounds that bind the particles into stable aggregates and clusters that improve stability, aeration and drainage (Briggs, 1977).

4.3 DRAINAGE

The design of a new landform should take the drainage requirements into account at all times (Downing, 1977c; Verma and Thames, 1978). Without addressing drainage the landscaping programme is unlikely to provide a landform that is stable and suitable for revegetation (Gardner and Woolhiser, 1978).

The function of the drainage system is twofold. Firstly, to reduce erosion by controlling surface run-off and secondly, to conserve on site moisture (Verma and Thames, 1978). To effectively control run-off and conserve on site moisture the design has to take into account a number of factors. These include: natural drainage patterns, hydrological conditions, areas of standing water, properties of the overburden, topography, long term rehabilitation goals and the future land uses of the site (Verma and Thames, 1978). Observations of the hydrological conditions should also include an estimate of the additional watershed area beyond the site itself (Downing, 1977c).

In arid and semi-arid regions the design should also take into account the need to conserve on site moisture and the efficient use of water (Verma and Thames, 1978). In these environments water is the single most important factor affecting the success of rehabilitation programmes involving revegetation (Down and Stocks, 1977). Contouring and shaping to produce gentle slopes can conserve on site moisture by reducing run-off and increasing infiltration rates (Platt, 1975; Glover, Augustine and Clar, 1978). Surface treatments that enhance water accumulation, infiltration, moisture retention and detention, or reduce moisture losses improve the chances of providing a medium that is suitable for plant growth (May, M., 1975)

During the early stages of the landscaping programme high run-off and erosion rates, due to the poorly developed surface cover, can jeopardise the success of the rehabilitation programme by threatening the stability of the landform and removing valuable topsoil, seeds and plants (Downing and Hackett, 1975). This can also pose problems for the design of the drainage system. A more complex system is usually required for higher run-off rates. However, since high capacity drainage systems are often only required during the early stages the design should try to meet the short term requirements without incurring excessive costs (Downing, 1977c). This usually means that the design will incorporate both temporary and permanent measures to meet the drainage requirements.

The temporary measures should be simple, effective, inexpensive and easy to remove when and if it becomes necessary to do so (Downing, 1977c). The design should also take into account that high erosion and siltation rates during the early stages are likely to increase the chances of the system becoming overloaded (Downing, 1977c). A number of measures aimed specifically at controlling high run-off velocities during the early stages have been developed. These include contour terracing, contour furrowing, contour trenching and scarifying (Verma and Thames, 1978).

Contour terracing, furrowing and trenching all perform the dual function of reducing run-off velocities, by manipulating slope lengths, and acting as silt traps. This traps valuable topsoil that is often lost during run-off. These structures can also be designed to retain and carry excess run-off from the site to planned outlets or storage areas (Verma and Thames, 1978). In arid and semi-arid areas this run-off, if collected, can provide a valuable source of water for the revegetation programme.

Scarifying reduces run-off velocities by increasing the roughness of the surface. In doing so it also increases infiltration and reduces evaporation. This in turn improves the moisture content of the overburden and the conditions for implementing a revegetation programme. Scarifying can also be used to address the problems caused by wind erosion. Wind speeds can be effectively reduced by the rough, cloddy surfaces produced and by aligning the furrows and ridges at ninety degrees to the prevailing wind directions (Larson, Swan and Schaffer, 1983).

The implementation of a permanent drainage system usually involves the provision of a functional pattern of french drains (Downing, 1977c). The costs associated with establishing a permanent system are usually higher, however, savings can be achieved by incorporating the natural drainage patterns on the site into the final design (Hackett, 1977a). The layout and design of a permanent system is largely dependent upon the future land uses for the site, hydrological conditions, topography and the natural drainage pattern. To avoid any damage to the system caused by subsidence, the design should also take into account the engineering properties of the overburden and the overall stability of the landform (Glover, Augustine and Clar, 1978). Care should also be taken to ensure that, once rehabilitation has been completed, the system is compatible with and can be incorporated into the future land uses for the site. To achieve this the design must be sufficiently flexible to allow for changes in the final land use before rehabilitation is completed (Downing, 1977c).

Both permanent and temporary drainage systems need to be monitored and maintained until the area has been stabilised by a successful revegetation programme (Verma and Thames, 1978). This involves regular checks and repairs to ensure that the system is functioning effectively, a function that should be fulfilled by the monitoring and after-care component of the rehabilitation programme. This aspect is, however, commonly neglected, and as such can threaten the success of the entire rehabilitation programme (Verma and Thames, 1978).

4.4 SUMMARY

Successful rehabilitation depends largely upon the ability of the landscaping programme to provide a landform that is stable and suitable for revegetation. However, a successful landscaping programme cannot be implemented without an adequate understanding of the factors that are likely to affect stability and fertility.

The physical, chemical and biological properties of the overburden influence both stability and fertility and, therefore, the success of the landscaping programme. Unless these properties are assessed and taken into account, landscaping is unlikely to provide a landform that is stable and suitable for the implementation of a successful revegetation programme.

CHAPTER 5

REVEGETATION

5.1 INTRODUCTION

The objective of the revegetation programme is to establish a stable and maintenance free plant community on the disturbed site (Jeffrey, Maybury and Levinge, 1975). The success of the programme depends, to a large degree, on the success of the landscaping programme.

Due to the ability of plants to stabilize the surface, to achieve rapid aesthetic improvements and provide a wide range of future land use options, revegetation has proved to be one of the most successful approaches for achieving long term rehabilitation (Jeffrey, Maybury and Levinge, 1975). Because revegetation has the ability to provide long term solutions to the problems associated with disturbances, it is also cheaper than most other forms of soil stabilisation (Lyle, 1987).

Down and Stocks (1977) identify two approaches for revegetating disturbed sites. The first approach accepts the poor conditions of the overburden as they exist. Revegetation is then carried out using plant species that are adapted to the poor conditions. This approach relies on the natural process of ecological succession. This involves introducing pioneer species, followed by secondary species and finally the climax communities (Coppin and Bradshaw, 1982). However, the properties of the overburden often precludes the growth of many common species (Bradshaw, 1984). As a result, this approach seldom provides the rapid cover often required from a revegetation programme.

The second approach involves improving the conditions of the overburden, to provide a medium that is suitable for plant growth. While the bulk of these amendments are carried out during the landscaping programme they should also be seen as a necessary and on-going component of the revegetation programme. The costs associated with this approach added to the monitoring and after-care requirements, usually ensures that the second approach is the more costly of the two. It does, however, have the advantage of being able to provide rapid results using a wider range of species (Down and Stocks, 1977). In practice, however, most revegetation programmes employ a combination of the two approaches (Coppin and Bradshaw, 1982). This combined approach is referred to by Jeffrey, Maybury and Levinge (1975) as the, "ecological ameliorative approach".

The degree to which the two are combined depends largely upon the local conditions and the long term goals of the rehabilitation programme. Ultimately, however, the success of the programme depends on a clear knowledge and understanding of the factors affecting plant growth on the site. The pre-planning approach, which utilises the baseline data from the initial site survey, enables planners to identify the physical, chemical and biological constraints likely to affect the implementation of the revegetation programme. This approach is illustrated in Figure 5.1, and is very much in keeping with Jeffrey, Maybury and Levinge's (1975) "ecological approach" to revegetation, which recognises that the success of a revegetation programme entails not only the establishment of suitable plant species but also a broader recognition of the importance of the biological processes that influence plant growth.

5.2 FACTORS AFFECTING PLANT GROWTH

Of all the factors that commonly affect plant growth during the implementation of the revegetation programme, climate and the properties of the overburden are the two most important (Jeffrey, Maybury and Levinge, 1975; May, 1975; Coppin and Bradshaw, 1982).

5.2.1 Climate

The most important climatic variables affecting the success of the revegetation programme are, rainfall, temperature and wind.

(A) Rainfall

Without an adequate and regular supply of water plants cannot be successfully established. In many areas rainfall provides the only input of water for the revegetation programme. The implementation of a revegetation programme is, therefore, strongly influenced by the macro-climatic conditions of the area and to a lesser extent the degree to which the micro-climatic conditions have been modified by the landscaping programme (Coppin and Bradshaw, 1982).

In arid and semi-arid environments, where water shortages are likely to occur, a clear understanding of the rainfall patterns is crucial to the implementation of a successful revegetation programme. In these environments water shortages are the single most important factor affecting the success of revegetation programmes (Down and Stocks, 1977). Rainfall data from the initial site survey should be used to identify the best time of the year to implement the revegetation programme, and in the selection of suitable plant species.

The timing of the planting operations is crucial to the success of the revegetation programme. The introduction of plants should coincide with favourable climatic conditions and the start of the growing season. In arid and semi-arid environments, which are characteristic of large parts of Southern Africa, the growing season is effectively linked to the rainy season when there is sufficient water around to enable plants to germinate and establish themselves. The climatic data should also be used to identify times of the year when water shortages are likely to develop. Young plants and seedlings are sensitive to water shortages (Coppin and Bradshaw, 1982).

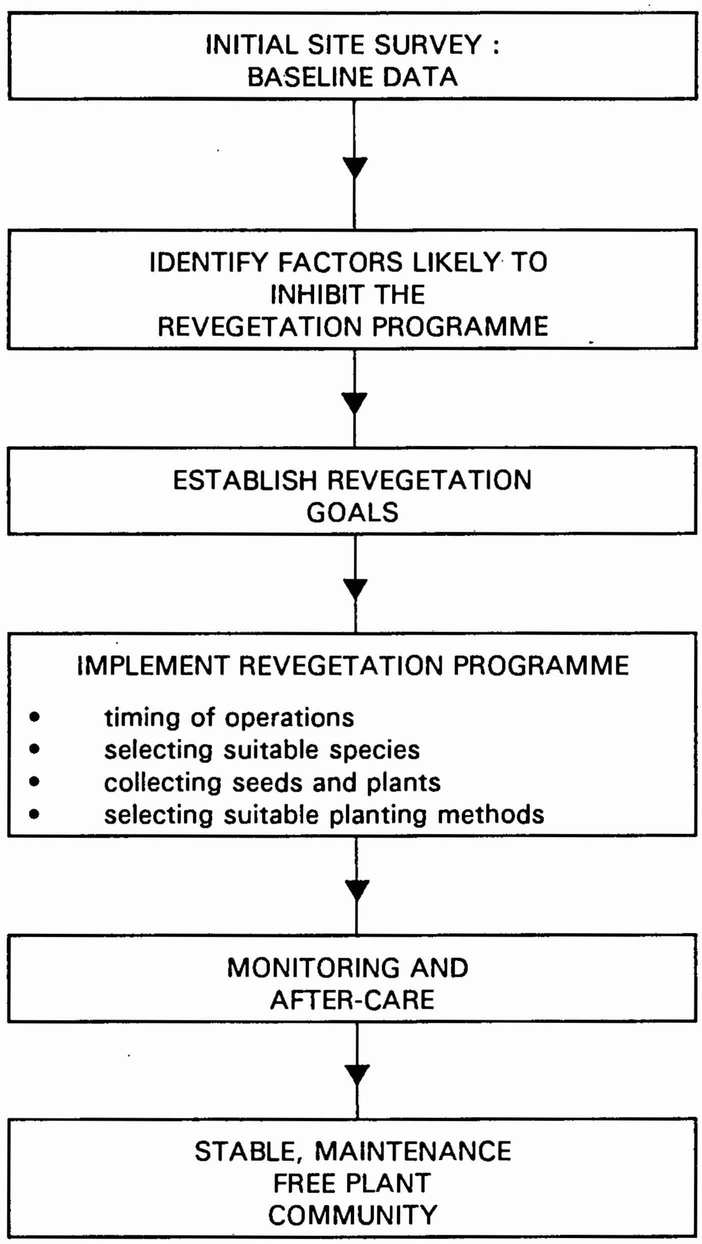

Figure 5.1 : **Steps involved in a revegetation programme (After: Jeffrey, Maybury and Levinge, 1975, p 383).**

Where rainfall is low and erratic it can be supplemented with limited amounts of water. In some areas additional water applications may be necessary for the implementation of a successful revegetation programme. The aim of the irrigation programme should be to supply enough water, in addition to the natural precipitation to ensure that the initial establishment of the vegetation is successful, and enable the development of a stable, maintenance free plant community (Ries and Day, 1978). Where irrigation is being considered the properties of the overburden which could reduce infiltration, permeability and the storage of water, should be considered along with application rates, timing, water quality and the costs involved, before the irrigation programme is implemented (Ries and Day, 1978).

(B) Temperature

The start and duration of the growing season is also influenced by seasonal changes in temperature. These changes should be considered, together with the rainfall figures to select suitable plant species and identify the best time of the year to plant. Some plants, and in particular germinating seedlings, are more vulnerable to extreme temperature fluctuations (Lyle, 1987). Also, there is very little biological activity in plants when temperatures drop below zero or rise above fifty degrees centigrade (Daubenmire, 1959).

Apart from the changes brought about by the macro-climatic conditions, temperatures can also be influenced by slope angles, slope aspect, the moisture content and colour of the overburden (Daubenmire, 1959; Down and Stocks, 1977). The effects of dark coloured overburden on solar energy absorbtion and re-emission can produce temperature extremes that inhibit germination and plant growth (Goodman, 1974). In some cases it may be necessary to take these factors into account.

(C) Wind

Wind action during the early stages of the revegetation programme can remove seeds, valuable topsoil and damage newly germinated seedlings (Coppin and Bradshaw, 1982). Wind turbulence tends to be exacerbated by the rough broken terrain produced by overburden tips and excavations (Goodman,1974). The damage caused by wind turbulence can be reduced by developing smoother landforms. Effective protective structures can also be established if the baseline data is used to identify prevailing wind directions, wind velocities and seasonal changes.

Baseline data should also be used to identify the occurrence and frequency of dry, windy periods. When these occur evapotranspiration rates are likely to increase, which in turn reduces the moisture content of the overburden, creating unfavourable conditions for plant growth. During such periods it may become necessary to supplement the water supply by irrigating.

5.2.2 Overburden Properties

The importance of overburden properties to the rehabilitation programme have already been discussed in Chapter Four. Before a successful revegetation programme can be implemented, the landscaping programme has to provide a landform that is stable and suitable for plant growth. On the whole, the physical, chemical and biological properties of overburden do not provide an environment that is ideally suited to plant growth.

The ability of the overburden to retain water and nutrients is usually low, due to the absence of organic matter and poorly developed soil structures. The essential macro-nutrients, nitrogen, potassium and phosphorous are usually in short supply, to the extent that corrective action is required, and biologically, the overburden is usually devoid of soil fauna and flora essential for recycling nutrients.

The measures that are taken to improve the overburden and prepare a suitable seed bed are directly linked to the success of the revegetation programme that follows. This link illustrates the importance of collecting detailed baseline data during the initial site survey. This data enables the planners to make informed decisions about the factors likely to affect the implementation of the revegetation programme, and the manner in which the landscaping and revegetation programmes can be integrated to achieve successful long term rehabilitation.

5.3 SPECIES SELECTION

The selection of suitable plant species plays an important role in the implementation of a successful revegetation programme. In selecting suitable species for revegetation, the proposed after uses for the site, the role of the species selected, the climatic conditions and the properties of the overburden, should all be carefully considered (May, 1975; Copping and Bradshaw, 1982). Bearing these factors in mind, the selection should attempt to provide a balanced and ecologically sound mixture of species that are adapted to the local conditions, and are capable of developing into a stable and maintenance free plant community (May, 1975; Coppin and Bradshaw, 1982).

Species that are specifically adapted to the local conditions should be used wherever possible. Results have shown that no amount of maintenance and after-care will enable unsuitable species to survive in a hostile environment (Down and Stocks, 1977). When species are being considered for the revegetation programme one of the most important basic principles, and one that is often overlooked, is simple observation (Down and Stocks, 1977). Observations of the natural vegetation that has become established on and around previously disturbed areas and spoil heaps can provide valuable information on the species best adapted to the local site conditions.

It is also important to consider the roles that different species can play in terms of achieving successful revegetation (Coppin and Bradshaw,1982). Primary colonisers and pioneer species can be used to control erosion and stabilise the overburden during the early stages of the programme. Secondary stage species have the ability to help build and develop the soil structure and improve the fertility of the overburden, while climax species are often used to provide the final, maintenance free plant community (Coppin and Bradshaw, 1982).

Primary colonisers and pioneer species chosen for revegetation programmes are usually represented by quick growing grasses. These fulfil the role of providing rapid cover under nutrient poor overburden conditions (Coppin and Bradshaw,1982). Quick growing grasses can achieve rapid visual results, reduce erosion rates, stabilise the overburden and initiate soil forming processes (Richardson, 1975). In this role grasses provide the widest range of species for achieving rapid ground cover, making them one of the most common components of revegetation programmes (Bradshaw and Chadwick, 1980).

The secondary stage species, selected due to their ability to build and establish soil structure and improve fertility, are often used in combination with primary colonisers. The use of species mixtures improves the chances of producing a stable and maintenance free plant community that can cope with diverse overburden and climatic conditions (Lyle, 1987). Results have also shown that revegetation programmes benefit from species mixtures that contain at least one legume species (Bradshaw and Chadwick, 1980).

The use of legume species provides an effective and natural way of addressing the nitrogen deficiencies commonly found in disturbed materials. It also goes a long way to improving the chances of achieving successful long term rehabilitation (Richardson, 1975; Downs and Stocks, 1978). Not only do legumes themselves grow well, but as soon as the accumulated nitrogen is released into the soil, the surrounding vegetation also benefits (Palaniappan, Marrs and Bradshaw, 1979). The ability to fix atmospheric nitrogen is carried out by bacteria of the genus Rhizobium that occur in nodules found on the roots of legumes (Lyle, 1987). Since different legume species rely on different species of bacteria to enable them to fix atmospheric nitrogen the choice of the legume species will depend on local conditions (Bradshaw and Chadwick, 1980). If the required Rhizobium strain is absent from the overburden the legume will be unable to fix atmospheric nitrogen. When this occurs the legume has to be inoculated with the correct Rhizobium culture before it can benefit the revegetation programme (Bradshaw and Chadwick, 1980).

The climax stage represents the final desired plant community chosen for the site, in some cases this can be achieved without having to establish the earlier stages (Coppin and Bradshaw, 1982). The final choice of species for the climax stage will depend on the local conditions and the final land use chosen for the site. In most cases, however, the most suitable species are usually those that are also natural pioneers (Bradshaw and Chadwick, 1980).

Where trees and shrubs are introduced as part of the revegetation programme, sturdy transplants with well developed root systems are usually more successful (Richardson, 1975). The most successful trees for revegetation are those with extensive fibrous root systems (Down and Stocks, 1977). There are also a number of leguminous tree species that have the ability to fix atmospheric nitrogen, making them well suited for revegetation programmes.

The implementation of a successful revegetation programme also depends on a reliable supply of seeds and plants. Nurseries established on site offer one of the best solutions to this problem. Not only does this option ensure a regular supply of seeds and plants, it reduces the chances of damaging the plants during transporting, and provides a supply that is adapted to local climatic conditions. On site nurseries can also be used in combination with field trials to identify species suited to the local conditions and capable of meeting the long term goals of the revegetation programme. To be effective the nurseries should be established well before the revegetation programme is implemented. This will ensure that plants are available when the revegetation programme is implemented.

5.4 METHODS OF REVEGETATION

Once the plant species for the revegetation programme have been selected, ways of establishing them have to be considered. Broadly speaking there are two ways of introducing plant species, namely, seeding and planting (Bradshaw and Chadwick, 1980; Coppin and Bradshaw, 1982). The choice of method depends largely upon the terrain and the type of vegetation being introduced, but in both cases timing is important.

In order to enable the seeds and plants introduced to germinate and establish themselves before the advent of unfavourable weather conditions or plant dormancy, both seeding and planting should coincide with the start of the growing season. Climatic data from the initial site survey and the results from field trials should be used to establish the start of the growing season (Coppin and Bradshaw, 1982). Field trials can provide valuable information on the start and the length of the growing season, which in some cases may vary between different species.

5.4.1 Seeding

Traditional agricultural seeding techniques are well developed making it the cheapest, quickest and most flexible method of revegetation (Coppin and Bradshaw, 1982). The seeds can either be broadcast on to the surface or placed within the overburden. The latter approach provides greater protection for the seeds from heat and drought and generally improves the chances of achieving successful germination (Coppin and Bradshaw, 1982). However, seeds that are planted too deeply may also have problems germinating due to oxygen shortages, or may be unable to break through the soil and reach the surface once they have germinated (Lyle, 1987).

Broadcasting onto the surface can be carried out by hand or by machine. Mechanical broadcasting is, on the whole, quicker and more economical than the manual approach but it can be limited by the terrain and accessibility (Down and Stocks, 1977). To improve the chances of successful germination, the seeds broadcast onto the surface should be incorporated into the surface layer by lightly scarifying the surface. Seeds that are left on the surface are exposed to environmental stresses, and except where the moisture conditions are perfect successful germination tends to be patchy (Coppin and Bradshaw, 1982). Texture can also influence the chances of successful germination. Coarse textured materials with cracks and crevices provides favourable micro-environments for the seeds to germinate, and are better suited to surface broadcasting. The landscaping programme therefore, plays an important role in the success of the revegetation programme by preparing a surface that is suitable for seeding.

Mulches, made up of straw, wood shavings, cut branches and municipal compost can also be used to good effect to protect seeds broadcast onto the surface (Coppin and Bradshaw, 1982). The application of mulches can be combined with the seeding operations by hydro-seeding. Hydro-seeding is a specialised form of broadcasting that involves spraying an aqueous mixture of seeds and high bulk particulate matter, mulch, onto the disturbed surface. Developed in the United States of America, hydro-seeding is now widely used to revegetate disturbed areas. Hydro-seeding has the advantage of being able to reach areas that are unaccessible to most other conventional mechanical seeding methods. It is, however, usually more expensive than the conventional seeding methods.

When planning the seeding operation, the seed source is important. Where commercial seed species are being used a reliable supplier of good quality seed should be identified well before the programme is implemented. For indigenous seeds, a seed collection programme, timed to coincide with the time of the year when the plants are in seed, should be carried out well in advance. Topsoil on and around the site may also provide a good source of indigenous seeds (Wathern and Gilbert, 1978). While all the plant species may not be represented in the seed bank, the local topsoil has the advantage of providing a seed source that is adapted to local conditions. Most of the seeds are usually found in the top two centimetres of the topsoil (Gillham and Putwain, 1977; Tracey, 1979) and can be collected by mechanically stripping the surface layer or by vacuuming the surface. This should be done well in advance of the start of quarrying operations. Once the seeds have been collected they should be cleaned, dried and stored in dry, well aerated conditions. Stored in this way they can remain viable for a number of years (Coppin and Bradshaw, 1982). Indigenous seeds should also be used to establish nursery stocks of plant species that are adapted to local conditions. These stocks can in turn be used as an additional seed source.

5.4.2 Planting

When used during revegetation, trees and shrubs are usually introduced as partly grown plants and are seldom if ever established from seeds. This can achieve quick visual results and also enables the initial germination and early growth stages to take place under favourable nursery conditions (Coppin and

Bradshaw, 1982). On the whole younger trees have been found to transplant more easily and successfully than mature trees. The best age for transplanting is when trees are between two and three years old (Down and Stocks, 1978).

Transplanting operations are usually carried out by hand, and care has to be taken to ensure that the roots are not damaged during the process. More transplant failures are attributed to the damage caused to the roots during transplanting than the harshness of the local conditions encountered after planting (Richardson, 1977). The success of the transplanting programme also depends upon the speed at which it can be achieved. The longer the plants spend out of the soil the greater the chances are of damaging the roots. During this time the roots are extremely vulnerable to damage caused by drying out (Richardson, 1977). To obtain the best results therefore, trees should be transplanted quickly and in large numbers.

Transplanting is also an expensive operation, and requires careful planning to ensure that unnecessary costs are avoided. Trees and shrubs are particularly sensitive to different conditions on planting. The chances of success can however, be improved by using imported topsoil to fill the holes into which trees are being transplanted (Bradshaw, 1983). The size and depth of the holes required depends on the species and the extent of the root system. As a general rule though, the tree should be planted to the depth of its root collar, and the roots should be spread outwards and downwards before being firmed in (Richardson, 1977). The spacing between trees also varies depending on the species chosen, the growth rates, and the final land use planned for the site.
Densities for transplanted trees tend however, to be low, which means that large areas of the site often require additional ground cover. To avoid competition for available water and nutrients between the grasses and the young transplants, the selection of grass species to provide this protective cover has to be undertaken with care (Bradshaw and Chadwick, 1980).

The establishment of an on site nursery before the revegetation programme is implemented can improve the success rates of a transplanting programme. The proximity of the nursery to the site reduces the time that the plants have to spend out of the soil and the damage caused during transportation. The nursery also provides a reliable supply of trees and shrubs that are adapted to the local conditions.

5.5 SUMMARY

The success of the revegetation programme depends on the ability to overcome the factors that are likely to inhibit plant growth. Of these, the two most important are the properties of the overburden and climate. The properties of the overburden can be amended to improve the conditions for plant growth. Climate, however, cannot be altered and the revegetation programme must therefore, take into account the limitations imposed upon it by the climatic conditions.

These limitations affect the timing of the operation, the selection of suitable species and planting techniques. However, a stable, maintenance free plant community is unlikely to develop unless the revegetation programme is backed up by an effective monitoring and after-care programme.

CHAPTER 6

MONITORING AND AFTER-CARE

6.1 INTRODUCTION

The objective of the monitoring and after-care programme is to ensure the success of the rehabilitation programme. While extensive research has been devoted to landscaping and revegetation, very little attention has been paid to the subsequent needs once these programmes have been implemented (Bloomfield, Handley and Bradshaw, 1982). This aspect of rehabilitation has frequently been regarded as unimportant and has been ignored. The failure to implement a monitoring and after-care programme is however, one of the most common causes for poor rehabilitation (Bradshaw and Chadwick, 1980; Coppin and Bradshaw, 1982). The time, money and effort spent on the initial site survey, landscaping and revegetation is often wasted by failing to recognise that monitoring and after-care is a fundamental component of the rehabilitation programme (Goodman, 1974).

The function of an effective monitoring and after-care programme is to check for problems, establish their causes, and implement the appropriate remedial measures. The approach adopted to achieve this depends upon the local site conditions and the final land use objectives (Coppin and Bradshaw, 1982). Like the earlier components of the rehabilitation programme, the problems faced by the monitoring and after-care programme can be overcome by adequate and timely planning.

By analysing the baseline data from the initial site survey, the level of monitoring and after-care required can be estimated at a relatively early stage of the planning process (Coppin and Bradshaw,1982). This gives planners an idea of the time and costs involved and enables them to budget accordingly. The failure of rehabilitation programmes to implement a monitoring and after-care programme is frequently linked to poor budgeting and the subsequent shortage of funds (Goodman,1974). This in turn can threaten the success of the entire rehabilitation programme.

6.2 MONITORING

Monitoring involves regular and systematic checks to ensure the on-going success of the rehabilitation programme. Where rehabilitation involves revegetation the role of the monitoring programme includes assessing the nutrient status of the overburden and the condition of the vegetation (Coppin and Bradshaw, 1982). This must be done on a regular basis to ensure that the success of the revegetation programme is not jeopardised by the development of nutrient deficiencies.

Once the initial hurdle of establishment has been safely negotiated, monitoring and after-care is required to ensure the establishment of a stable, maintenance free plant community (Goodman, 1974). To provide the monitoring programme with a measure for assessing changes in the nutrient status of the overburden, the baseline data from the initial site survey should be combined with the data, regarding the amendments to the overburden, from the landscaping programme. This should enable planners to monitor changes more accurately.

In setting up a monitoring programme, care must be taken to ensure that the soil samples taken are representative of the overall properties of the overburden and reflect the prevailing nutrient conditions. Based on these results, recommendations can then be made and implemented as part of the after care-programme. Nutrient deficiencies in the overburden can also be linked to the condition of the vegetation. Plants often exhibit characteristic deficiency symptoms for different nutrients. The first symptom is usually a lack of growth. This however, is often difficult to pick up and would not be as obvious as a change in leaf colour (Lyle, 1987). Because these symptoms are often linked to a combination of deficiencies, the monitoring programme may need to combine visual checks with plant tissue and soil analyses to ensure that the appropriate after-care measures are implemented (Lyle, 1987).

Where on-going rehabilitation is being practised, a well planned and carefully implemented monitoring programme can function as an important feedback mechanism for the landscaping and revegetation programmes. Inappropriate soil amendments, poor planting and seeding techniques and unsuitable plant species can all be identified by careful monitoring. This information can then be used to modify and improve the programme, thereby increasing the chances of implementing a successful rehabilitation programme.

In addition to the nutrient status of the overburden, and the condition of the vegetation, monitoring should cover the drainage system, negative off-site effects and the long term stability of the landform. For drainage, the monitoring programme should check for damage caused by erosion and blockages and ensure that the drainage requirements are being met (Downing, 1977c). This can be extended to assess the off-site effects of run-off from the site. Suspended solids and chemicals leached from the newly exposed overburden can pose potentially serious pollution threats to down stream water consumers, riverine ecosystems and the ground water supply in the area. An effective monitoring programme can ensure that the potential impacts caused by these negative off-site effects are minimised.

With regard to the stability of the landform, the monitoring programme should ensure that the movement of water through the overburden, subsidence, slope failure and mass movements do not occur on a scale that could threaten the success of the landscaping programme. Any potential problems picked up by the monitoring programme can then be addressed by the after-care programme.
While this "fix it approach" may be adequate for minor problems, more serious problems may require major changes to the way in which the overburden is re-worked during the landscaping programme. This demonstrates the value of the feedback mechanism provided by the monitoring and after-care programme.

6.3 AFTER-CARE

The after-care programme provides the remedial responses to the problems detected by the monitoring programme. To function effectively, the correct measures must be implemented before the problems become unmanageable. Timing and the appropriateness of the response are, therefore, crucial to the success of the after-care programme.

Where rehabilitation involves the implementation of a revegetation programme, the primary function of the after-care programme is to ensure that the overburden can support a stable, maintenance free plant community. This involves amendments to the overburden to improve the nutrient status. The nutrient cycle usually takes time to develop and requires inputs of nutrients on a regular basis (Coppin and Bradshaw, 1982).

The success of the after-care programme depends on the quality of the data from the monitoring programme. To enable the programme to effectively address the problems that develop, the monitoring programme must provide data that is accurate and appropriate. This can then be combined with the data from the initial site survey and used to effectively address any nutrient deficiencies that may develop. In most cases, this involves additional fertiliser amendments. However, to be effective they must be nutrient specific (Coppin and Bradshaw, 1982). The accuracy of the monitoring programme is, therefore, crucial to the success of the after-care programme. Fertiliser amendments to the overburden are not the only after-care measures that can be taken to improve the condition and development of a healthy plant community. Controlled grazing, cropping and mowing can benefit all grass types by encouraging the development of denser swards of vegetation (Down and Stocks, 1977). After-care of this nature also involves removing dead or dying trees and ensuring that they are timeously replaced.

After-care involving the stability of the landform and drainage system usually involves undertaking some form of physical repair. In the case of stability, addressing problems such as slope failure or slumping may require additional grading and contouring to reduce slope angles, or the construction of retaining walls. Where spring lines, caused by ground water moving through the overburden threaten the stability of the landform, the after-care programme may require the entire landform to be re-worked in order to address the problem.

For drainage systems, the level of after-care required is closely linked to the original design and the construction of the system. Well designed and uncomplicated systems tend to, on the whole, require less after-care (Downing, 1977c). The level of after-care required can vary from the having to re-construct the entire system to simply removing blockages caused by silt and other debris (Downing, 1977c). Most of the design and field layout defects that do develop usually appear after the first rainfall event, and these need to be addressed immediately. Failure to do so often results in higher costs being incurred at a later date (Verma and Thames, 1978). While early after-care costs associated with maintaining a drainage system are usually high, due to the damage caused by greater run-off during this period, they tend to drop once a stable, maintenance free plant community becomes established.

6.4 SUMMARY

The implementation of the monitoring and after-care programme is the final step involved in rehabilitation and also the most commonly neglected. Most quarry operators fail to appreciate the long term nature of successful rehabilitation programmes. This, coupled with poor budgeting and a lack of commitment to rehabilitation, has resulted in monitoring and after-care programmes seldom being implemented. The failure to implement a monitoring and after-care programme is however, one of the most common causes of poor rehabilitation (Bradshaw and Chadwick, 1980).

CHAPTER 7

A CHECKLIST FOR REHABILITATION

7.1 INTRODUCTION

Successful rehabilitation depends upon the ability of the rehabilitation programme to overcome the environmental conditions that are likely to inhibit implementation (Bradshaw, Dancer, Handley and Sheldon, 1975; Bradshaw and Chadwick, 1980). Since these conditions vary from site to site, each rehabilitation programme should carry out a systematic and detailed site investigation, before any rehabilitation measures are implemented. The value of these investigations preceding full scale rehabilitation, has become widely accepted (Bradshaw and Chadwick, 1980; Coppin and Bradshaw, 1982). This also provides the foundation for adopting a pre-planning approach to rehabilitation. While the scope and the detail of the initial site survey will vary, depending on the local conditions and the final land use objectives, there are a number of common factors that need to be addressed by most rehabilitation programmes.

Addressing these factors can be aided by the use of a checklist. A checklist provides a comprehensive list of structured questions or points. This assists the collection of baseline data, helps to order thinking and alerts planners against the omission of important data (Fuggle, in Fuggle and Rabie, 1983). The use of checklists to aid the data collection process for rehabilitation purposes has been widely used in a number of fields, including rehabilitation (Downing, 1977b). A checklist is used by the Department of Mineral and Energy Affairs to list the minimum requirements for rehabilitation reports submitted in terms of the Minerals Act of 1991 (Annexure 1). On the important role that checklists can perform in rehabilitation, Downing notes:

> "It is with this information that stages of programme acquisition, design and execution of a reclamation project can be appropriately organised within a critical path analysis or similar programme arrangement" (Downing, 1977b, pp 32, 35).

The use of checklists has been criticised in some circles for the set manner in which they lead investigators through the analysis process. This, it is argued, can limit one's perceptions of the problems and restrict the approach adopted (Fuggle, in Fuggle and Rabie, 1983). Despite this however, checklists do provide a valuable summary of expert knowledge in an accessible and easily understandable format. This enables checklists to play an important educating role. The educational value of checklists is supported by the Assistant Government Mining Engineer of the Cape Province, Mr Mulke. Commenting on the checklist drawn up by the Department of Mineral and Energy Affairs, for the minimum requirements for rehabilitation reports, Mulke notes:

"Many would agree that small mine managers would throw it (the guidelines) in the waste paper basket, pretending not to understand the questions put forward. The view held by this office is that even if the recipient answers thirty percent of the questions, it is that much time that will be saved by the inspector when he visits the mine on a rehabilitation visit and has to get all the answers. Moreover the mere fact of sending the official document and its contents brings to the attention of all managers the necessity of doing some form of rehabilitation" (Mulke, 1984, p1).

Checklists, therefore, not only provide the reader with a summary of valuable information they can also serve as an important educating tool. Having said this, however, the author felt that the checklists that had been looked at could be improved. While the majority of the checklists provided a comprehensive list of the baseline data required from the initial site survey, they failed to highlight the need to interpret the information and link it to the development of the remaining three components of the rehabilitation programme. As a result, the majority of rehabilitation reports looked at provided no details on how rehabilitation would actually be achieved. They merely described the local conditions without attempting to indicate how they would influence the implementation of the rehabilitation programme.

To overcome this problem a more detailed checklist was developed as part of this study (Annexure 2). The objectives of the checklist are:

(1) To assist the collection of baseline data during the initial site survey.

(2) To help organise the data gathered.

(3) To illustrate the importance of interpreting the baseline data from the initial site, and linking it to the development and implementation of the remaining three components of the rehabilitation programme.

To achieve these objectives the checklist is divided into two sections. Section 1 deals with the collection of baseline data during the initial site survey. Section 2 addresses the question of interpreting and linking this data to the remaining three components of the rehabilitation programme, namely, landscaping, revegetation and monitoring and after-care.

7.2 SECTION 1 : BASELINE DATA

Based on the literature survey, a comprehensive checklist of the baseline data required from the initial site survey was drawn up (Annexure 2). While the list is comprehensive, it is not necessarily exhaustive. Additional baseline data may need to be collected, depending on the local conditions and the final land use objectives. It is important to bear this in mind when checklists are being used. Items that do not occur on the list are often overlooked (Fuggle, in Fuggle and Rabie, 1983). At the same time, given the local conditions and final land use objectives, it may not be necessary to address all the factors listed in the checklist during the initial site survey. Likewise, the level of detail required is also likely to vary from site to site. The checklist does, however, provide a comprehensive list of the baseline data required from the initial site survey.

The list of baseline data required from the initial site survey is shown in Table 7.1. A complete breakdown of the questions asked under each of the headings is contained in the full rehabilitation checklist presented in Annexure 2. The majority of these factors need to be addressed during the initial site survey to enable the rehabilitation report to serve as an effective working document.

Table 7.1 Section 1 : Baseline Data

REHABILITATION CHECKLIST SECTION 1 : BASELINE DATA			
(1)	Location and Setting		
(2)	Current land uses		
(3)	Infrastructure and servitudes		
(4)	Development of the mining operations		
(5)	Topography and visual aspects		
(6)	Vegetation		
(7)	Natural Soils		
(8)	Geology		
(9)	Surface and Sub-Surface Hydrology		
(10)	Climate	-	macro
		-	micro
(11)	Properties of the Overburden		
		-	Physical
		-	Chemical
		-	Biological
(12)	Financial Planning		
(13)	Alternative after uses		

7.3 SECTION 2 : LANDSCAPING, REVEGETATION, MONITORING AND AFTER-CARE

Based on the literature survey, the important elements of the three remaining components of the rehabilitation programme were identified. Each component is dealt with separately, and the elements are presented in the format of a checklist. To emphasise the need for the rehabilitation report to function as an effective working document, and the importance of linking the baseline data from the initial site survey to the development of the rehabilitation programme, the format of the checklist reflects the chronological order in which each component should be developed. To illustrate this point the entire checklist, for each component is listed in Table 7.2.

Table 7.2 Section 2 : Landscaping, Revegetation, Monitoring and After-Care

REHABILITATION CHECKLIST
SECTION TWO : LANDSCAPING, REVEGETATION, MONITORING AND AFTER-CARE

LANDSCAPING

(1) Does the rehabilitation report cover the implementation of a landscaping programme.
Does this section take into account;
(2) The topography, visual aspects and dominant landforms
(3) The shape and dimensions of the final landform
(4) The total volume of overburden involved
(5) The area available for dumping overburden
(6) The engineering properties (stability) of the overburden and material being used during the landscaping programme
(7) Slope angles, lengths and contour intervals
(8) The best time of the year to carry out landscaping and contouring, in order to minimise the damage caused by compaction and erosion
(9) The volume of overburden suitable for use as a medium for plant growth
(10) The volume of overburden unsuitable for use as a medium for plant growth
(11) Amendments to the physical, chemical and biological properties of the overburden
(12) Nutrient deficiencies of the overburden
(13) Fertiliser amendments to the overburden
(14) Topsoil stockpiling / topsoil requirements
(15) Drainage requirements for the site
(16) Seed bed preparation (scarifying, ploughing, mulching etc)
(17) Infrastructure that needs to be removed to facilitate the programme
(18) Duration of the landscaping programme
(19) Monitoring and after-care
(20) Does this section incorporate the baseline data from the initial site survey (topography, visual aspects, climate, properties of the overburden, etc) into the design of the landscaping programme.

REVEGETATION

(1) Does the report cover the implementation of a revegetation programme
Does this section take into account;
(2) The selection of suitable plant species
(3) The supply of seeds and plants
(4) The establishment of nurseries at an early stage
(5) The selection of appropriate planting and seeding methods
(6) The best time of the year to establish plants (climatic)
(7) The development of a nutrient cycle
(8) Irrigation requirements
(9) Monitoring and after-care
(10) How long it will take before the system becomes self sustaining
(11) Does this section incorporate the information collected during the initial site survey (climate, properties of the overburden, hydrology, etc) into the design of the revegetation programme.

MONITORING AND AFTER-CARE

(1) Does the report cover the implementation of a monitoring and after-care programme.
Does this section take into account;
(2) **Monitoring**
- Nutrient status of the overburden
- Condition of the vegetation
- Development of a nutrient cycle
- Stability of the landform
- Functioning of the drainage system
- Movement of surface and sub-surface water
- Pollution of the ground water supply
- Visual impacts
- Water stress

(3) **After Care**
- Additional fertilizer amendments
- Additional topsoil
- Additional planting
- Additional irrigation
- Repairs to the drainage system
- Additional landscaping

7.4 ROLE OF THE CHECKLIST

The format of the checklist enables it to perform two different functions. Firstly, it can be used to draw up rehabilitation reports and secondly, it can be used to evaluate the content of rehabilitation reports.

In its first role, by providing a comprehensive summary of information, the checklist serves as a useful aid to those involved in drawing up rehabilitation reports. Section one of the checklist assists the process of data collection during the initial site survey. Section two stresses the need to link this data to the development and implementation to the remaining three components of the rehabilitation programme. By linking the baseline data from the initial site survey to the remaining three components, the checklist highlights the value of adopting a pre-planning approach to rehabilitation, and the need for rehabilitation reports to function as effective working documents.

In its second role the checklist can be used by clients and the authorities to evaluate rehabilitation reports drawn up in terms of the Minerals Acts of 1991 (No. 50 of 1991). To test this, the checklist was used to evaluate thirty randomly selected rehabilitation reports submitted to the Cape Town office of the Department of Mineral and Energy Affairs. The results of this evaluation are presented in Chapter 8.

CHAPTER 8

RESULTS OF CHECKLIST SURVEY

8.1 INTRODUCTION

The checklist outlined in Chapter 7 was used to assess thirty rehabilitation reports submitted to the Department of Mineral and Energy Affairs in terms of Section 39 of the Minerals Act of 1991. The aim of the exercise is not to criticise individual reports, but rather to assess the overall standard of rehabilitation reports submitted in terms of the Minerals Act of 1991. The objectives of the study were to:

(1) Evaluate the scope of the initial site survey and the quality of the baseline data.

(2) Establish to what extent the baseline data had been used to draw up the rehabilitation reports.

(3) Establish if the rehabilitation reports served as effective working documents.

8.2 APPROACH TO THE SURVEY

A pilot study, using five randomly selected rehabilitation reports, was undertaken to test the checklist and the feasibility of the approach. As a result of the pilot study the format of Section 1 of the checklist, Baseline Data was altered to conform with the Guidelines for Rehabilitation of Land Disturbed by Surface Mining and Minimum Requirements for Rehabilitation Programmes (Annexure 2)(Department of Mineral and Energy Affairs, 1984) The content of the checklist, however, remained relatively unchanged. The pilot study was followed by a survey of thirty randomly selected rehabilitation reports.

The only criterion used to select the reports was the date of submission. Reports that had been submitted before 1985 were not considered. The reason for this being that legislation requiring quarry operators to submit rehabilitation plans was only enacted in 1980. Hoogervorst (1985) in his thesis, **An Environmental Evaluation System in the Planning Process of Quarries in South Africa**, noted that at the time of writing, the legislation had not been in operation long enough to assess how effective the new regulations were, and to what extent the Government Mining Engineers had been able to incorporate them into their working structures. It was felt that a period of five years should be allowed, during which time the Department of Mining and Mineral Affairs would have had the opportunity to establish the criteria for evaluating acceptable rehabilitation reports. Of the thirty reports selected, ten were submitted in 1985, four in 1986, seven in 1987, two in 1988 and the remaining seven in 1989. All of the reports were for quarries located in the Cape Province, South Africa. The majority (twenty) were located in the Western Cape.

Each rehabilitation report was assessed in terms of the rehabilitation checklist developed for this study (See Annexure 2). This involved rating each section of the rehabilitation report on a rating scale. A five point rating scale was used:

1: Very Poor
2: Poor
3: Adequate
4: Good
5: Very Good

While an objective evaluation of the content and standard of the rehabilitation reports was not possible using this approach, it did nonetheless provided useful and meaningful results. The rating results from the survey are contained in Table 8.1.

A mean and modal analysis of the ratings was carried out. The mean, calculated for each report, gave an indication of the overall standard of the individual reports. Some sections of the checklist are more relevant to the implementation of a successful rehabilitation programme than others. The properties of the overburden, for example, are more important to rehabilitation than location and setting. The mean value did not highlight these differences and, therefore, did not provide useful information about the overall standard of the rehabilitation reports. Due to this, the results from the mean analysis are not discussed further.

A modal value, for thirty reports, was calculated for each section covered by the checklist. Because a modal rating was calculated for each section, an indication of how well each section had been dealt with was given. This provided an overall indication of how well different sections had been dealt with by the thirty rehabilitation reports looked at. The majority of reports, for example, dealt with climate more effectively than the properties of the overburden.

8.3 DISCUSSION OF THE RESULTS

8.3.1 Section 1: Baseline data

Section 1 of the checklist was used to assess the baseline data collected during the initial site survey. Although the initial site survey should provide baseline data on a wide range of factors the most important of these were identified in Chapter 3 as:

(1) Description of the mining activities
(2) Topography and visual aspects
(3) Surface and sub-surface hydrology
(4) Climate
(5) Properties of the overburden

Table No 8.1 : Results from the survey of 30 rehabilitation reports using the rehabilitation checklist

QUESTION NUMBER	REHABILITATION REPORTS : 1 TO 30																														MODE
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	
SEC 1																															
Q 1	4	4	3	2	4	3	4	3	3	2	3	4	4	3	3	2	4	2	4	1	3	3	2	3	4	3	3	3	2	3	3
Q 2	3	3	3	3	3	3	3	3	2	2	3	3	3	3	2	3	3	2	3	1	3	2	2	1	3	2	2	2	2	3	3
Q 3	1	1	1	1	1	1	1	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Q 4	3	3	3	2	3	3	3	3	2	2	3	3	3	2	2	3	3	2	5	2	3	2	3	3	4	4	2	3	2	3	3
Q 5	3	4	4	1	4	1	3	1	3	2	3	4	4	1	2	3	3	1	3	1	3	3	1	3	4	4	3	2	4	3	3
Q 6	3	3	3	3	4	3	2	3	2	3	2	2	3	3	2	3	4	4	2	3	3	2	3	3	2	3	2	2	2	3	3
Q 7	1	3	2	1	3	1	2	3	2	2	2	4	3	2	2	3	5	4	2	4	2	3	2	2	1	1	3	2	2	2	2
Q 8	4	4	4	4	4	2	3	3	3	2	3	4	4	2	3	1	3	4	1	4	3	4	4	3	5	3	3	2	3	3	3
Q 9	3	2	4	2	4	2	2	2	2	3	2	3	2	1	2	3	2	2	3	2	2	2	4	2	3	2	2	1	2	2	2
Q 10	3	4	4	4	3	4	4	2	4	4	4	1	4	4	3	3	4	1	4	3	4	4	3	4	3	4	4	1	3	3	4
Q 11.1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2	1	1	1	1	1	1	1	1	1	1	1	1	1
Q 11.2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	3	1	2	1	1	1	1	1	1	1	1	1	1	1
Q 11.3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Q 12	3	1	2	2	1	2	1	2	1	2	1	1	1	1	2	2	1	3	1	4	2	1	1	1	1	1	1	1	1	1	1
Q 13	3	2	3	2	3	3	3	3	2	3	3	3	1	1	1	4	4	4	4	2	2	2	2	3	3	3	2	2	2	2	3
SEC 2																															
Q 1	2	1	2	1	2	2	2	2	2	2	2	3	2	2	1	3	3	3	2	2	2	1	2	2	2	2	1	1	1	1	2
Q 2	2	2	2	1	2	2	2	2	2	2	2	3	2	2	1	3	2	4	1	3	2	1	3	2	2	2	2	1	1	2	2
Q 3	2	2	1	1	3	2	2	2	1	1	1	2	1	1	1	2	3	2	1	1	1	1	1	1	2	1	1	1	1	1	1
MEAN	2.4	2.3	2.4	1.8	2.6	2.1	2.2	2.2	1.9	2.0	2.1	2.4	2.3	1.8	1.7	2.3	2.7	2.5	2.2	2.1	2.2	1.9	2.1	2.1	2.4	2.2	1.9	1.6	1.8	2.0	

QUESTION DETAILS

Section 1

Q1. Location and setting.
Q2. Current land uses.
Q3. Infrastructure and utilities.
Q4. Development of the mining operations.
Q5. Topography and visual aspects.
Q6. Vegetation.
Q7. Natural soils.
Q8. Geology.
Q9. Surface and sub-surface hydrology.
Q10. Climate - macro and micro.
Q11.1 Overburden - physical properties.
Q11.2 Overburden - chemical properties.
Q11.3 Overburden - biological properties.
Q12. Financial planning.
Q13. Alternative after-uses.

Section 2

Q1. Landscaping.
Q2. Revegetation.
Q3. Monitoring and after-care.

RATING

1 : Very poor.
2 : Poor.
3 : Adequate.
4 : Good.
5 : Very good.

Financial planning was added to the list. The failure to budget for future rehabilitation costs appears to be one of the major stumbling blocks facing the implementation of a successful rehabilitation programme.

These six factors are covered in section 1 of the checklist by questions 4, 5, 9, 10, 11 and 12 respectively. Each is considered separately below.

(A) Description of the Mining Activities

The modal analysis of question 4 gave a value of three. Sixty seven percent of the reports achieved a rating of 3 or more. Seventeen reports were adequate (rating of 3), two were good (rating of 4) and one was very good (rating of 5). The remaining ten reports were all poor (rating of 2)(See Figure 8.1). Twenty reports contained plans or diagrams to illustrate their descriptions. These reports were generally found to be more informative than the reports that relied on a description in the text alone. **These results indicate that the majority of rehabilitation reports looked at did provide sufficient baseline data on the mining activities.**

Only eight of the thirty reports, however, gave an estimate of the volume of overburden that was likely to be produced. Without an estimate of the volume it would be difficult, if not impossible, to assess the scale of the landscaping programme, and the shape and the dimensions of the final landform.

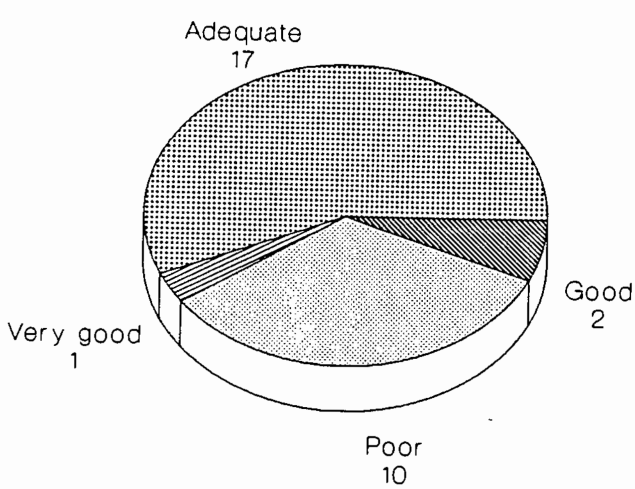

Figure 8.1 : Results of modal analysis: Mining activities

(B) Topography and Visual Aspects

The modal analysis of question 5 gave a value of three. Sixty seven percent of the reports achieved a rating of three or more. Twelve reports were adequate (rating of 3) and eight reports were good (rating of 4). Of the remaining ten reports, three were poor (rating of 2) and seven were very poor (rating of 1) (See Figure 8.2). **These results indicate that the majority of rehabilitation reports looked at did provide sufficient baseline data on the topography and visual aspects of the site.**

Only six reports contained a contour map of the area. An accurate contour map of the site and its surroundings should be a basic requirement for all rehabilitation reports. A contour map provides the reader with a clear indication of the sites topography and visual aspects. It can also be used as a base map to illustrate the location, current land uses, infrastructure and utilities, the mining operations, vegetation, the occurrence of natural soils, surface geology and the surface hydrology.

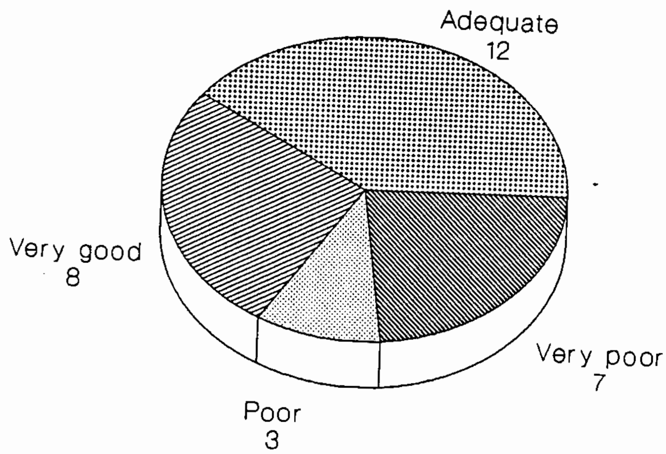

Figure 8.2 : Results of modal analysis: Topography and visual aspects

(C) Surface and Sub-Surface Hydrology

The modal analysis of question 9 gave a value of two. Seventy percent of the reports achieved a rating of two or less. Nineteen reports were poor (rating of 2) and two were very poor (rating of 1). Of the remaining nine reports, six were adequate (rating of 3) and three were good (rating of 4)(See Figure 8.3). **These results indicate that the majority of rehabilitation reports looked at did not provide sufficient baseline data on the surface and sub-surface hydrology.**

For surface hydrology, only three reports used a contour map to illustrate the natural drainage patterns, and only one report gave a run-off value for the site. The drainage requirements are an integral component of the landscaping programme. Without baseline data on the natural drainage patterns and run-off values, an effective drainage system cannot be designed.

For sub-surface hydrology, only nine reports indicated the depth of the water table and only eight considered the movement of ground water. Quarrying and rehabilitation can have an impact on the ground water in the area and this may affect the implementation of the landscaping programme. Without baseline data on the ground water in the area, these effects cannot be accurately assessed.

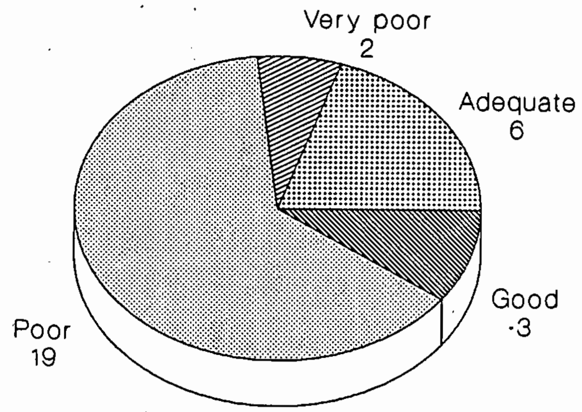

Figure 8.3 : Results of modal analysis: Surface and sub-surface hydrology

(D) Climate

The modal analysis of question 10 gave a value of four. Eighty seven percent of the reports achieved a rating of three or more. Seventeen reports were good (rating of 4) and nine reports were adequate (rating of 3). Of the remaining four reports, one was poor (rating of 2) and three were very poor (rating of 1)(See Figure 8.4). **These results indicate that the majority of rehabilitation reports looked at did provide sufficient baseline data on the climatic conditions.**

Ninety three percent of the reports provided rainfall data, eighty seven percent provided temperature data and eighty percent presented wind data.

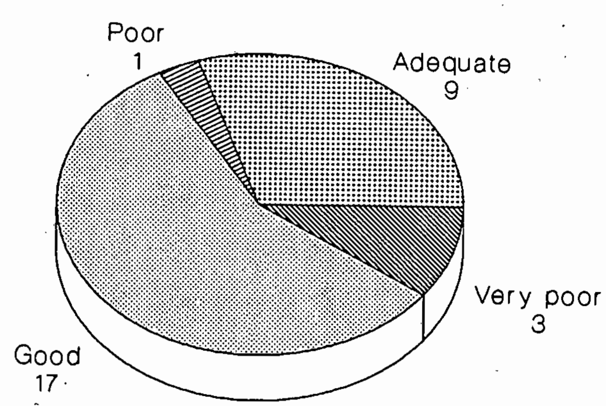

Figure 8.4 : Results of modal analysis: Climate

(E) Properties of the Overburden

Question 11 is divided into three sections: 11.1 addresses the physical properties, 11.2 the chemical properties and 11.3 the biological properties. The modal analysis of each question gave a value of one.

For question 11.1 (physical properties), twenty nine reports were very poor (rating of 1) and one report was poor (rating of 2) (See Figure 8.5). None of the reports considered any of the following physical properties, structure, water retention and storage capacity, bulk density or infiltration rates. Only one report mentioned texture and one other report considered both the engineering properties and the erosion potential. **The majority of rehabilitation reports looked at, neglected to provide sufficient, if any, data on the physical properties of the overburden.**

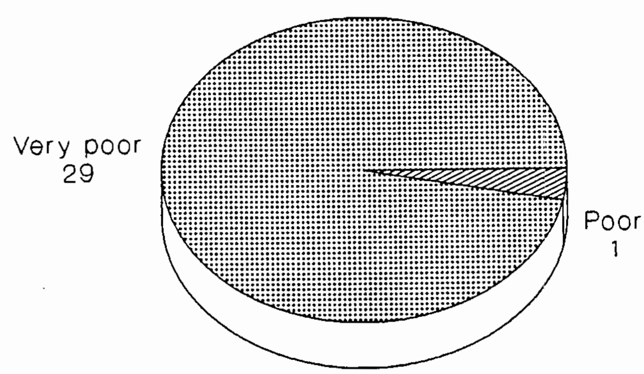

Figure 8.5 : Results of modal analysis: Overburden properties - physical

For question 11.2 (chemical properties), twenty eight reports were very poor (rating of 1), one report was poor (rating of 2) and one was adequate (rating of 3)(See Figure 8.6). None of the reports considered cation exchange capacity, soluble salts or potential toxicity. Four reports provided pH data, two considered the nutrient status of the overburden, and one gave electrical conductivity values. **The majority of rehabilitation reports looked at, neglected to provide sufficient, if any, data on the chemical properties of the overburden.**

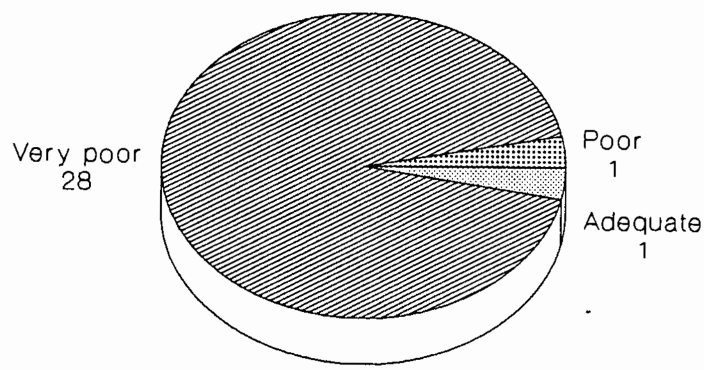

Figure 8.6 : Results of modal analysis: Overburden properties - chemical

For question 11.3 (biological properties), all of the reports were very poor (rating of 1)(See Figure 8.7). None of the reports provided any data on the organic matter content of the overburden, the soil fauna or flora. **None of the rehabilitation reports looked at provided any data on the biological properties of the overburden.**

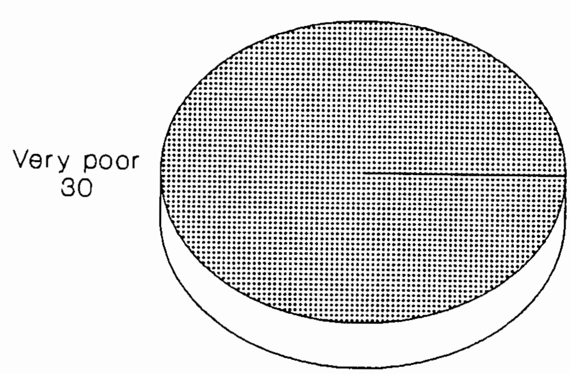

Figure 8.7 : Results of modal analysis: Overburden properties - biological

These results indicate that the majority of rehabilitation reports looked at did not provide sufficient baseline data on the properties of the overburden.

(F) Financial Planning

The modal analysis of question 12 gave a value of 1. Ninety percent of the reports achieved a rating of two or less. Nineteen reports were very poor (rating of 1), eight reports were poor (rating of 2), two reports were adequate (rating of 3) and one report was good (rating of 4)(See Figure 8.8). **These results indicate that the majority of rehabilitation reports looked at did not provide sufficient baseline data on the financial planning aspects of the rehabilitation programme.**

Nineteen reports gave no indication of the costs involved. Nine reports provided an estimate which was merely given as a cost per unit ton of production. Only one report provided a breakdown of the cost associated with each stage rehabilitation. None of the reports, however, provided any specific proposals for financing the rehabilitation programme or committed themselves to setting up a rehabilitation fund that would be used at a later date.

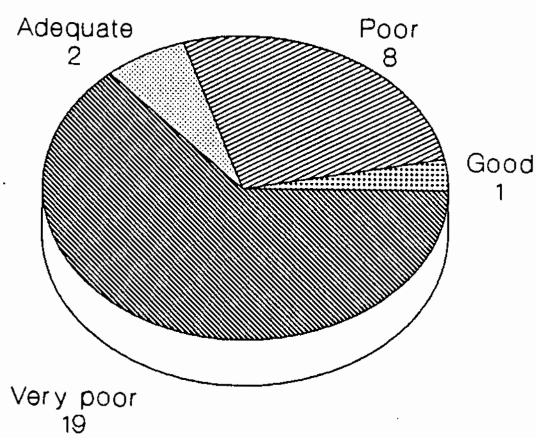

Figure 8.8 : Results of modal analysis: Financial planning

8.3.2 Section 2: Landscaping, Revegetation, Monitoring and After-care.

Section two of the checklist outlines the remaining three components of the rehabilitation programme, and the baseline data required for the implementation of each component. The objective of this section was to establish the extent to which the baseline data from the initial site survey had been linked to the development of the remaining three components of the rehabilitation programme. This provides an indication of the rehabilitation reports' ability to function as an effective working document.

(A) Landscaping

The modal analysis of question 1 gave a value of two. Eighty seven percent of the reports had a rating of two or less. Eighteen reports were poor (rating of 2) and eight were very poor (rating of 1). The remaining four reports were adequate (rating of 3)(See Figure 8.9).

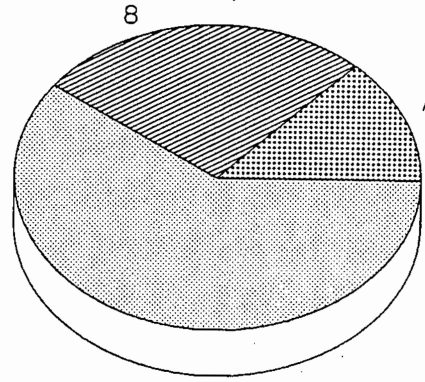

Figure 8.9 : Results of modal analysis: Landscaping

Although twenty six out of the thirty rehabilitation reports (87%) specifically indicated that landscaping was a component of the rehabilitation programme, there was very little evidence to suggest that the baseline data from the initial site survey had been used to draw up the landscaping programmes.

* Fourteen reports indicated what the shape of the final landform would look like after rehabilitation;
* Eight reports gave an indication of the total volume of overburden involved in the landscaping programme;
* Eight reports indicated what fertilizer amendments to the overburden where required;
* Eight reports considered the drainage requirements for the site;
* Three reports identified the nutrient deficiencies of the overburden;
* Two reports took cognizance of the engineering properties of the overburden;
* None of the reports indicated what time of the year would be the most favourable for carrying out the landscaping operations.

These results indicate that the majority of rehabilitation reports looked at, did not effectively link the baseline data from the initial site survey to the development of the landscaping programme. As far as landscaping is concerned, the majority of rehabilitation reports did not function as effective working documents.

(B) Revegetation

The modal analysis of question 2 gave a value of two. Eighty three percent of the reports achieved a rating of two or less. Nineteen reports were poor (rating of 2) and six reports were very poor (rating of 1). Of the remaining five reports four were adequate (rating of 3) and one was good (rating of 4)(See Figure 8.10).

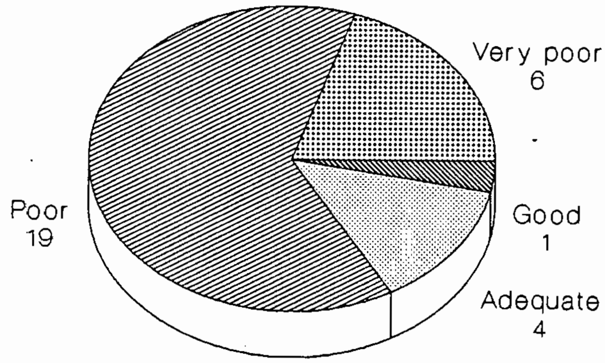

Figure 8.10 : Results of modal analysis: Revegetation

Although twenty seven out of the thirty rehabilitation reports (90%) specifically indicated that revegetation was a component of the rehabilitation programme there was very little evidence to suggest that the baseline data from the initial site survey had been used to draw up the revegetation programme.

* Sixteen reports considered the selection of suitable plant species;
* Eleven reports identified the appropriate planting and seeding techniques;
* Five reports addressed the supply of seeds and plants;
* Three reports identified the best time of the year to establish plants;
* Three repórts gave an estimate of how long it would take before the system became self-sustaining;
* One report discussed the need for additional irrigation requirements.

These results indicate that the majority of rehabilitation reports looked at, did not effectively link the baseline data from the initial site survey to the development of the revegetation programme. As far as revegetation is concerned, the majority of rehabilitation reports did not function as effective working documents.

(C) Monitoring and After-care

The modal analysis for question 3 gave a value of one. Ninety three percent of the reports achieved a rating of two or less. Nineteen reports were very poor (rating of 2), and nine reports were poor (rating of 1). The remaining two reports were adequate (rating of 3)(See Figure 8.11).

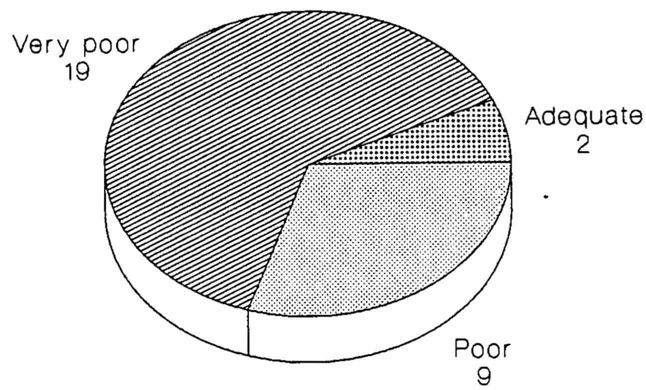

Figure 8.11 : Results of modal analysis: Monitoring and after-care

Only two out of the thirty rehabilitation reports (7%) elaborated on the need to implement a monitoring and after-care programme. The majority of rehabilitation reports looked at, failed to recognize the importance of the monitoring and after-care to the overall success of the rehabilitation programme.

8.4 SUMMARY

The majority of the rehabilitation reports looked at provided sufficient baseline data on the mining activities, topography and visual aspects and climate. The majority, however, failed to provide sufficient baseline data on the surface and sub-surface hydrology, properties of the overburden and the financial planning aspects of rehabilitation. The almost total lack of baseline data on the properties of the overburden was a major weakness in all the reports.

The reasons for this are probably linked to the ease and the costs associated with collecting this data. Baseline data on the mining activities, topography and visual aspects and climate is readily available from the mining plans, topographical maps, orthophotos, aerial photographs and meteorological offices. Most of this data can be collected from a desk top study, and is unlikely to require any detailed site analyses. The costs are, therefore, unlikely to be high. The baseline data on the surface and sub-surface hydrology and properties of the overburden is usually not readily available. The collection of this data usually requires site visits and testing. The process is, therefore, likely to be more expensive and time consuming. The lack of data on the financial aspects of rehabilitation reflects the lack of commitment to rehabilitation. This is borne out by the inability of the majority of rehabilitation reports to function as effective working documents.

With regard to Section 2 of the checklist, the majority of rehabilitation reports looked at failed to link the baseline data from the initial site survey to the development of the landscaping and revegetation components of the rehabilitation programme. As far as monitoring and after-care was concerned, only two reports elaborated on the need to implement a monitoring and after-care programme. Bradshaw and Chadwick (1980) point out, that the failure to implement a monitoring and after-care programme is one of the most common causes for poor rehabilitation. This would also appear to be the case for the thirty rehabilitation reports looked at in this study. It also reflects a basic lack of commitment to rehabilitation.

The majority of rehabilitation reports looked at, therefore, failed to function as effective working documents. The majority merely complied with the minimum requirements set out in the guidelines issued by the Department of Mineral and Energy Affairs (1984). The guidelines, in their current format, enable rehabilitation reports to list baseline data without indicating how rehabilitation is to be achieved. This provides a site description, but does not address the question of rehabilitation.

CHAPTER 9

CONCLUSIONS AND RECOMMENDATIONS

9.1 CONCLUSIONS

While quarrying is recognised as an essential component of modern society, it can result in large scale disturbances. Quarrying is only a temporary use of the land. Therefore, it is unacceptable to merely abandon a quarry once the operations have ceased. By implementing a rehabilitation programme, steps can be taken to ensure that disturbances caused are only temporary in nature. This study looks at rehabilitation and the need to adopt a pre-planning approach.

The objectives of the study were to:

(1) To outline the components of a rehabilitation programme and the value of adopting a pre-planning approach.

(2) To draw up a comprehensive rehabilitation checklist based on the pre-planning approach.

(3) To use the rehabilitation checklist to assess the content of rehabilitation reports submitted to Department of Mineral and Energy Affairs in terms of Section 39 of the Minerals Act, 1991, and their ability to function as effective working documents.

9.1.1 Components of a Rehabilitation Programme

Successful rehabilitation depends on the ability to identify and overcome the factors that are likely to inhibit the implementation of the rehabilitation programme (Bradshaw and Chadwick, 1980). Riddle and Saperstein's (1978) pre-planning approach offers the best approach for achieving this. Pre-planning is based on collecting baseline data on the local conditions before quarrying starts. The advantages of implementing a detailed investigation before quarrying starts are widely acknowledged (Chadwick and Bradshaw, 1980). The factors that are likely to inhibit the implementation of the rehabilitation programme can be identified during the early planning stages. This enables realistic long term rehabilitation goals to be drawn up. These goals can be incorporated into planning the mining operations.

The initial site survey is essential to the pre-planning approach. This is the first of four components, making up a rehabilitation programme. The remaining three, in the order in which they are implemented, are, landscaping, revegetation, and monitoring and after-care.

The initial site survey provides the baseline data that enables the rehabilitation programme to identify the factors that are likely to inhibit successful implementation. Once the baseline data has been collected, it must be interpreted and linked to the development of the remaining three components. This step, interpreting the baseline data and linking it to the development of the remaining components, is the crucial difference between a rehabilitation report that functions as an effective working document and one that merely provides a site description. Once this has been done, the remaining three components of the rehabilitation programme can be implemented.

While each component of the rehabilitation programme has separate objectives, these objectives cannot be achieved in isolation. The objective of the landscaping programme is to provide a stable landform that is suitable for revegetation and compatible with future land uses in the area. In doing so landscaping usually involves major earthworks and requires amendments to the overburden to improve its suitability as a medium for plant growth. The ability of the revegetation programme to provide a stable and maintenance free plant community, therefore, depends to a large extent on the success of the landscaping programme. The long term stability of the landform, however, depends on the ability of the revegetation programme to provide a protective vegetation cover that is stable and maintenance free. The success of both the landscaping and the revegetation programmes, in turn, depends on the ability of the monitoring and after-care programme to detect and rectify problems that develop. Unless landscaping and revegetation are followed up by a comprehensive monitoring and after-care programme the time and money spent on implementing them is often wasted. Unfortunately this aspect of rehabilitation is frequently the most neglected and is one of the most common causes for poor rehabilitation.
Each component is essential to the overall success of the rehabilitation programme. The initial site survey however, is the key component of the pre-planning approach. Without baseline data there is no way in which the factors likely to inhibit the implementation of the remaining three components of the rehabilitation programme can be identified. Futhermore, it provides a measure of the pre-mining conditions, against which the success of the programme can be assessed.

9.1.2 Rehabilitation Checklist

In terms of Section 39 of the Minerals Act, 1991, a rehabilitation report must be submitted to the Department of Mineral and Energy Affairs before the commencement of operations. To assist quarry owners the Department has drawn up a checklist of minimum requirements that rehabilitation reports must meet (Annexure 1). The checklist provides a reasonably comprehensive list of the baseline data required from the initial site survey. The checklist however, does not illustrate the importance of interpreting the baseline data and linking it to the development of the remaining three components of the rehabilitation programme. As a result the majority of the rehabilitation reports considered merely listed the baseline data required, without indicating how this would affect the implementation of the rehabilitation programme.

To overcome this problem a more comprehensive rehabilitation checklist was developed as part of this study (Annexure 2). The checklist is broken into two sections. Section 1 lists the baseline data required from the initial site survey, while Section 2 indicates how this data should be linked to the development of the remaining three components of the rehabilitation programme.

The broad baseline data categories in Section 1 of the checklist are similar to those of the Department of Mineral and Energy Affairs, but are dealt with in greater detail. Futhermore, two important additions are made to the checklist. The first is, Properties of the Overburden, question 11. Since the majority of rehabilitation programmes involve some form of revegetation, it is essential to determine the ability of the disturbed material to act as a suitable medium for plant growth. There is no reference to the properties of the overburden in the Mineral and Energy Affairs checklist. The second is, Financial Planning, question 12. If rehabilitation is to form an integral part of the mining operations (Section 38 (c), Minerals Act, 1991), a breakdown of costs is required. The Mineral and Energy Affairs checklist lists capital expenditure, purchase of mineral rights, plant and machinery, buildings and the establishment of infrastructure, but there is no reference to rehabilitation costs. To become an integral part of the mining operations the cost of rehabilitation must be included in the overall production cost equation.

Section 2 of the checklist is divided into three sub-sections, landscaping, revegetation, and monitoring and after-care. The objective of Section 2 is to illustrate how the baseline data from Section 1 should be used to develop the remaining three components of the rehabilitation programme. Each sub-section has been structured to reflect the chronological order in which each component should be developed and the relevant baseline data required. Section 2 of the checklist illustrates the link between the baseline data and the development of the rehabilitation programme. This enables the rehabilitation report to become an effective working document.

9.1.3 Assessment of Rehabilitation Reports

The checklist was used to asses thirty rehabilitation reports submitted to the Cape Town regional offices of the Department of Mineral and Energy Affairs. Each rehabilitation report was assessed in terms of the checklist developed as part of the study. This involved rating sections of the report using a five point rating system. A mean and modal analysis of the ratings was carried out. The mean was calculated for each report. This value, however, did not reflect how well individual sections had been dealt with and did not provide any meaningful results. A modal value was calculated for each section. This provided an indication of how different sections had been dealt with by the thirty rehabilitation reports considered. This approach was used for both Section 1 and Section 2.

In terms of Section 1, the study found that the majority of the rehabilitation reports provided sufficient baseline data on, the mining activities, topography and visual aspects, and climate. The majority of the reports, however, failed to provide sufficient baseline data on, surface and sub-surface hydrology, properties of the overburden and the financial planning aspects of rehabilitation. The major weakness of all the reports was the total lack of sufficient baseline data on the properties of the overburden. The reasons for this are probably linked to the ability and cost associated with collecting this data.

Baseline data on the sections that were adequately dealt with is readily available from plans, topographical maps, aerial photographs and the regional meteorological office. Most of this data can be collected as part of a desk top study. Baseline data on surface and sub-surface hydrology and the properties of the overburden is not as readily available. The collection of this data usually requires site visits and testing. The process is likely to be more costly and time consuming. In addition, the minimum requirements published by the Department of Mineral and Energy Affairs do not list the properties of the overburden. It is, however, difficult to understand how successful long term rehabilitation can be achieved without assessing the ability of the overburden to support a plant community. The lack of data on the financial aspects of rehabilitation reflects a lack of commitment to rehabilitation and suggests that rehabilitation reports are seen merely as a legal requirement.

As far as Section 2 of the checklist was concerned, the majority of the rehabilitation reports that were considered, failed to link the baseline data from the initial site survey to the implementation of the landscaping and revegetation programmes. Monitoring and after-care was discussed in only two of the thirty reports considered. Most of the rehabilitation reports therefore, failed to function as effective working documents. The majority of reports merely complied with the minimum requirements set out in the guidelines issued by the Department of Mineral and Energy Affairs (Annexure 1). This enabled the reports to describe the site conditions without indicating of how they would affect the implementation of a successful rehabilitation programme, or for that matter, how the rehabilitation programme was going to be implemented. It would appear therefore, that the majority of rehabilitation reports are seen as a legal requirement and are not drawn up to provide long term solutions to the disturbances caused by quarrying.

9.2 RECOMMENDATIONS

Meeting the minimum legal requirements does not ensure successful rehabilitation. Unless the rehabilitation report functions as an effective working document the commitment to rehabilitation is doubtful. In this respect the consultants involved in drawing up rehabilitation reports have an important role to play. The rehabilitation report should function as an effective working document that enables the quarry operator to implement the programme without having to rely on additional input from the consultants. To do this the rehabilitation report must provide more than just a site description. The report should identify the factors that are likely to inhibit successful rehabilitation and indicate how they can be overcome. The details regarding the implementation of each component of the rehabilitation programme should be clearly outlined in the report. The individual components of a rehabilitation programme are discussed below.

Initial site survey:

The initial site survey is essential to the pre-planning approach. The objective of this component is to provide baseline data on the local conditions. To serve a useful purpose, however, this data must be used to identify the factors that are likely to inhibit the implementation of the rehabilitation programme. Baseline data, therefore, has to be analysed and interpreted and not merely listed.

Landscaping:

The objective of the landscaping programme is to provide a stable landform that is suitable for revegetation and compatible with future land uses for the area. To achieve this objective the rehabilitation report must identify the factors that are likely to inhibit the implementation of the landscaping programme, and how they can be overcome. Since the overburden is usually not a suitable medium for plant growth the report should identify what the problems are and how they can be addressed. In this regard the report should indicate what amendments are required (fertiliser, mulch, organic matter), the quantities required and when and how they should be applied. The report should also identify the drainage requirements, and the best time of the year to carry out the contouring operations.

Revegetation:

The objective of the revegetation programme is to establish a stable and maintenance free plant community on the disturbed area. To do this the rehabilitation report must identify the factors that are likely to inhibit the implementation of the revegetation programme, and how they can be overcome. The report should identify, the best time of the year to implement the programme, suitable species, planting techniques, reliable supplies of seeds and plants and the quantities of seeds and plants required.

Monitoring and After-care:

The objective of the monitoring and after-care programme is to ensure that the implementation of the landscaping and revegetation programmes is successful. The rehabilitation report should outline the requirements of a comprehensive monitoring and after-care programme. This would involve a system of regular checks on the nutrient status of the overburden, the condition of the vegetation, the stability of the landform and the state of the drainage system. Provision must also be made to ensure that adequate steps can be taken to rectify the problems once they have been identified.

ANNEXURE ONE

DEPARTMENT OF MINERAL AND ENERGY AFFAIRS : MINIMUM REQUIREMENTS FOR REHABILITATION PROGRAMS (1984)

ANNEXURE ONE

MINIMUM REQUIREMENTS FOR REHABILITATION PROGRAMS (1984)

(A) Name of the mine.

(B) Locality.

Mention:

(a) Distance from nearest town

(b) Roads in vicinity (Freeways, main national, secondary etc.).

(c) Zoning of adjacent land:

(i) Agricultural farmland.

(ii) Township development.

(iii) Educational use (schools).

(iv) Recreational facilities.

(v) Other: Specify.

(C) Climatic conditions:

The following minimum information is required:

(a) rainfall normals (mean monthly and annual)

(b) maximum rainfall intensities.

(c) temperature normals (mean monthly, maximum and minimum).

(d) frost incidence.

(e) hail incidence.

(f) evaporation (mean monthly).

(g) wind speed and direction.

(D) Topography:

(a) Surface configuration and pre-mining landform of the entire property.

(b) Visibility of mining activities and associated structures.

(E) Pre-mining land use and soil capability.

(F) Natural vegetation:

Dominant or otherwise significant plant species to be listed - not in botanical terms. (Detailed botanical survey only required in ecologically sensitive areas where plants may need to be protected).

(G) Geology and Stratigraphic Column:

Submit only sufficient information to identify geological formation as well as a concise picture of the stratigraphic column down to and including the stratum immediately underlying the deepest depth to be mined to.

(H) Hydrology:

(a) Depth of watertable.
(b) Surface contours and run-off
(c) Storm water disposal.
(d) Ground water seepage (Estimated quantity and disposal).
(e) Natural water courses.
(f) Eventual drainage pattern of mined out area.

(I) Product to be mined.

(J) Extent of lease area and estimated reserves.

(K) Production rate : Present and future as well as expected life.

(L) Capital Expenditure: e.g.
Purchase of mineral rights.
Plant and machinery.
Buildings.
Establishment of infrastructure

(M) (a) Estimated net profit per unit of production excluding rehabilitation costs.
(b) Estimated rehabilitation cost per unit of production.

(N) Proposed method of working:

(a) Visual impact screening.
(b) Ecological impact and rehabilitation.
(c) Stacking of overburden and topsoil.
(d) Slimes disposal.
(e) Placing of plant and structures.
(f) Mining method.

(O) Rehabilitation procedures:

(a) Dominant vegetation.
(b) Method of seeding or planting.
(c) Slopes and landscaping.
(d) Method of topsoiling.
(e) Irrigation.

(P) Plan: First year to 5 year plan, 5 - 10 year plan, etc.

ANNEXURE TWO

REHABILITATION CHECKLIST

REHABILITATION CHECKLIST

SECTION 1

BASELINE DATA

		YES	NO	N/A	DES	DIA
1.	**LOCATION AND SETTING**					
1.1	Does the report contain a locality map of the area.					
	Does the report contain information on :					
1.2	The important cultural features of the area. (Towns, Roads, Railway lines)					
1.3	The magisterial boundaries.					
1.4	Local Authorities in the area.					
1.5	The affected farms and properties.					
1.6	The total area of the site.					
2.	**CURRENT LAND USES**					
	Does the report contain information on :					
2.1	Current land uses on the site and adjacent properties.					
2.2	The existing zoning of the area.					
2.3	Current land values.					
2.4	Archaeological, historical and cultural land uses.					
2.5	Overlapping land uses.					
3.	**INFRASTRUCTURE AND UTILITIES**					
	Does the report contain information on :					
3.1	Buildings and roads on the site.					
3.2	Power lines, cables, pipelines and stormwater drains on the site.					
3.3	Public servitudes across the site.					
4.	**DEVELOPMENT OF THE MINING OPERATIONS**					
	Does the report contain information on :					
4.1	A plan of the mining operations.					
4.2	Phases of development.					
4.3	The final quarry dimensions (area, depth and shape).					
4.4	The estimated reserves.					
4.5	The rates of production.					

<u>CHECKLIST RESULTS</u> : YES = Yes NO = No N/A = Not Applicable DES = Descriptive DIA = Diagrammatic

		YES	NO	N/A	DES	DIA
4.6	The life span of the quarry.					
4.7	The expected volumes of material to be removed :					
	- Product					
	- Overburden					
4.8	Methods of extraction.					

5. TOPOGRAPHY AND VISUAL ASPECTS

Does the report contain information on :

		YES	NO	N/A	DES	DIA
5.1	The dominant landforms in the area.					
5.2	The visibility of the operation, taking into account sight lines and view points.					

6. VEGETATION

Does the report contain information on :

		YES	NO	N/A	DES	DIA
6.1	The natural veld types of the area.					
6.2	The occurrence and distribution of dominant species on the site.					
6.3	The occurrence of rare and endangered species.					
6.4	The extent of alien vegetation on the site.					
6.5	Species growing naturally on abandoned old workings on the site.					

7. NATURAL SOILS

Does the report contain information on :

		YES	NO	N/A	DES	DIA
7.1	Depth of the soil profile.					
7.2	Description and/or classification of the soils.					
7.3	The occurrence and extent of natural soils occurring on the site.					
7.4	The volume of suitable topsoil available for rehabilitation.					
7.5	The agricultural potential of the soils on the site.					

8. GEOLOGY

Does the report contain information on :

		YES	NO	N/A	DES	DIA
8.1	The underlying geology and stratigraphy of the area.					

<u>CHECKLIST RESULTS</u> : YES = Yes NO = No N/A = Not Applicable DES = Descriptive DIA = Diagrammatic

		YES	NO	N/A	DES	DIA
9.	SURFACE AND SUBSURFACE HYDROLOGY					
	Does the report contain information on :					
9.1	The natural surface drainage patterns on the site and in the surrounding area.					
9.2	The runoff values for the site's catchment area.					
9.3	The depth of the water table on the site.					
9.4	The movement of groundwater in the area.					
9.5	The pollution potential to surface water and groundwater in the area.					
9.6	The effects of quarrying and rehabilitation on the water table in the area.					
9.6	Stormwater disposal from the site.					
10.	CLIMATE - MACRO AND MICRO					
	Does the report contain information on :					
	MACRO CLIMATIC DATA					
10.1	Rainfall data					
	- annual rainfall figures.					
	- monthly rainfall figures.					
	- average number of rainy days per month.					
	- maximum rainfall figures for 60 minute and 24 hour periods.					
10.2	Temperature data					
	- mean annual temperature.					
	- mean monthly maximum and minimum temperatures.					
10.3	Wind data					
	- wind speed records.					
	- monthly prevailing wind directions.					
10.4	Evaporation data					
	- mean monthly evaporation.					
10.5	Relative Humidity data					
	- mean monthly relative humidity.					
10.6	Frost incidence.					

CHECKLIST RESULTS : YES = Yes NO = No N/A = Not Applicable DES = Descriptive DIA = Diagrammatic

		YES	NO	N/A	DES	DIA
10.7	Hail incidence.					
	MICRO CLIMATIC DATA					
10.8	Aspect.					
10.9	Slope.					
11.	**PROPERTIES OF THE OVERBURDEN**					
	Does the report contain information on :					
11.1	Physical properties					
	- texture.					
	- structure.					
	- infiltration rates.					
	- water retention and storage capacity.					
	- bulk density.					
	- engineering properties.					
	- erosion potential.					
11.2	Chemical properties					
	- pH.					
	- cation exchange capacity.					
	- soluble salts.					
	- nutrient status.					
	- electrical conductivity.					
	- potential toxicity.					
11.3	Biological properties					
	- organic matter content.					
	- soil fauna.					
	- soil flora.					
12.	**FINANCIAL PLANNING**					
	Does the report contain information on :					
12.1	The total expected cost of rehabilitation.					
12.2	A breakdown of the costs associated with the various phases of rehabilitation.					
12.3	Specific proposals for financing rehabilitation.					

<u>CHECKLIST RESULTS</u> : YES = Yes NO = No N/A = Not Applicable DES = Descriptive DIA = Diagrammatic

	YES	NO	N/A	DES	DIA
13. ALTERNATIVE AFTER-USES					
Does the report contain information on :					
13.1 Alternative after-uses for the quarry.					
13.2 Alternative after-uses for the overburden.					
13.3 The structure plans and guide plans drawn up for the area.					

<u>CHECKLIST RESULTS</u> : YES = Yes NO = No N/A = Not Applicable DES = Descriptive DIA = Diagrammatic

REHABILITATION CHECKLIST

SECTION 2

LANDSCAPING, REVEGETATION MONITORING AND AFTER CARE

		YES	NO	N/A	DES	DIA
1.	**LANDSCAPING**					
1.1	Does the report cover the implementation of a landscaping programme.					
	Does this section take into account :					
1.2	The topography, visual aspects and dominant landforms of the area.					
1.3	The shape and dimensions of the final landform.					
1.4	The total volume of overburden involved in the landscaping programme.					
1.5	The area available for dumping of the overburden material.					
1.6	The engineering properties of the overburden and the material to be used during the landscaping programme.					
1.7	The slope angles, slope lengths and contour intervals of the final landform.					
1.8	The best time of the year to carry out landscaping operations in order to minimise the damage caused by compaction and erosion.					
1.9	The volume of overburden suitable for use as a medium for plant growth.					
1.10	The volume of overburden unsuitable for use as a medium for plant growth.					
1.11	The amendments to the physical, chemical and biological properties of the overburden that need to be carried out.					
1.12	The nutrient deficiencies of the overburden.					
1.13	The fertilizer amendments to the overburden.					
1.14	The topsoil requirements and measures for stockpiling topsoil.					
1.15	The drainage requirements for the site.					
1.16	The final seedbed preparation. (tillage, ploughing, mulching etc.)					
1.17	The infrastructure on the site that needs to be removed before the landscaping programme can be implemented.					
1.18	An estimate of the duration of the landscaping programme.					
1.19	The monitoring and after-care requirements.					

<u>CHECKLIST RESULTS</u> : YES = Yes NO = No N/A = Not Applicable DES = Descriptive DIA = Diagrammatic

		YES	NO	N/A	DES	DIA
1.20	Does this section indicate that the relevant baseline date from section 1 has been used to draw up and develop the landscaping programme.					

2. REVEGETATION

		YES	NO	N/A	DES	DIA
2.1	Does the report cover the implementation of a revegetation programme.					
	Does this section take into account :					
2.2	The selection of suitable plant species.					
2.3	The supply of seeds and plants.					
2.4	The establishment of nurseries at an early stage.					
2.5	The selection of appropriate seeding and planting methods.					
2.6	The best time of the year to establish plants.					
2.7	The development and maintenance of a nutrient cycle.					
2.8	The irrigation requirements.					
2.9	The monitoring and after-care requirements.					
2.10	How long it will take before the system becomes self-sustaining.					
2.11	Does this section indicate that the relevant baseline date from section 1 has been used to draw up and develop the revegetation programme.					

3. MONITORING AND AFTER-CARE

		YES	NO	N/A	DES	DIA
3.1	Does the report cover the implementation of a monitoring and after-care programme.					
	Does this section take into account :					
3.2	Monitoring					
	- the nutrient status of the overburden.					
	- the condition of the vegetation.					
	- the development of a nutrient cycle.					
	- the stability of the landform.					
	- the functioning of the drainage system.					
	- the movement of surface and sub-surface water.					
	- the pollution of the groundwater supply.					
	- the pollution of natural water courses.					
	- the moisture content of the overburden.					

<u>CHECKLIST RESULTS</u> : YES = Yes NO = No N/A = Not Applicable DES = Descriptive DIA = Diagrammatic

	YES	NO	N/A	DES	DIA
3.3 After-care					
- additional fertilizer requirements.					
- additional topsoil requirements.					
- the removal of dead plants and plant replacement procedures.					
- additional irrigation requirements.					
- repairs to the drainage system.					
- additional landscaping requirements.					

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