CLOSURE OF THE UMLAZI LANDFILL: MEETING STATUTORY REQUIREMENTS FOR ENGINEERING AND PLANT COVER

BY

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ABSTRACT

This study investigated the establishment of vegetation cover planted in plug and seedling form in the closure phases of the Umlazi Landfill. It also investigated the various facets of the closure process of the Umlazi Landfill and the effect these have on the establishment and choice of vegetative cover, and the grass technology used to make the establishment of vegetation a success. The setting up of trials and the gathering of basic data were undertaken to assess the alternative vegetation options available to researchers. The cover provided by the grasses was assessed in the investigation.

The capping of landfill sites is a relatively new approach and it is soon to become a mandatory requirement by the Department of Water Affairs and Forestry (*Minimum Requirements for Waste Disposal) (*DWAF, 1998). This systematic investigation used in the closure of the Umlazi Landfill, will provide a model for the capping of landfills in South Africa.

Seeing that this was the first hazardous (H:h) landfill site in the country to be closed according to the Minimum Requirements for Waste Disposal (DWAF, 1998), every attempt was made to ensure that all aspects in the closure of the site met with the Minimum Requirements. The Minimum Requirements document mentions only briefly that the landfill must be vegetated with some grass type. Prior to 1994, capped landfill sites were usually planted with traditional grass seed mixes and these were not widely successful, as seen on many older landfills that have been partially or completely capped, and where vegetation cover is sparse.

There is much literature in the developed countries on the closure of landfills (e.g., Erickson, 2006), but little literature is available about this specific area of landfill management technology in South Africa, apart from Mannie (2002).

During the site inspections in June 2001 and February 2002, it was noted that many species of alien plants had established themselves in the poor soil conditions. This

made it even more important to find indigenous vegetation to vigorously establish itself that would prevent the establishment of alien invaders.

Samples of grass species established on some part of the site were also taken for identification. The dominant grass was identified as *Cynodon dactylon*. In view of establishing a balanced vegetative cover on top of the Umlazi Landfill, *Acacia karoo* trees (in seedling form) were also planted. Three bunch grass species, *Melinis nerviglumis*, *Melinis minutiflora* and *Hyparrhenia hirta*, were tested to see if thatching grass could be grown on the site to generate a cash crop for local residents of Umlazi township. Preparation and planting of the capped areas took place in the latter part of 2003 and were completed in early 2004. Measurements and field data were recorded and statistically analysed.

The trials revealed three key findings:
Firstly, both creeping grasses studied, namely *Cynodon dactylon* var. "Sea Green" and *Panicum natalense* var. "Natal Buffalo Grass" grew well on the site. Initially *P. natalense* grew faster but after a month, *C. dactylon* overtook it. At the end of the trial (six months, *P. natalense* provided a higher level of soil cover. However, *C. dactylon* grew more consistently over this period. Hence both species provided good growth and cover on this site.

Secondly the three bunch grasses, *Melinis nerviglumis, Melinis minutiflora* and *Hyparrhenia hirta*, all grew well and had similar survival rates. Hence the potential for growing these grasses as a cash crop has potential.

Thirdly, all the *Acacia karoo* trees survived, i.e., they achieved 100% survival. The average height increase and stem width was similar in all trials and growth was consistent over the six month growing period. Hence the tree species would be a good choice for planting on landfills in its ecologically suitable zones.

It is therefore feasible to envisage the planting of a mixture of grasses under the cover of *A. karoo* trees, to provide a balanced mixture of indigenous grasses to cover a freshly capped landfill. Such a system should provide for stable growth of vegetation for many years.

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INTRODUCTION

The capping and closure of landfills in South Africa is a relatively new requirement for landfill managers and the scientific community (DWAF, 2002). Increased pressure from various environmental groups to sustain a healthier environment has necessitated the move to find solutions and formulate policies to cap closed landfills appropriately. Previously, landfills were grassed using a standard ‘highway mix’ of grass seeds (DWAF, 1998). However, because inadequate quantities of topsoil were placed over the waste body, and in the absence of capping, vegetation rarely grew well. The vegetation usually died as a result of gas emissions in areas typically showing bare ground and with a strong gas smell. In the absence of vegetation, erosion occurs on slopes in varying levels.

Since the implementation of the *Minimum Requirements for Waste Disposal by Landfill* in 1994 (DWAF, 1994), increased attention has been given to the operational and technical issues surrounding landfills throughout the country. Specific technical attention to the closure and capping of landfill sites has been gathering momentum because of a requirement to ensure that landfill sites ‘fit’ into the existing landscape. Meeting the requirement demands an integrated approach that encompasses initial design, planning to meet closure requirements and post-closure use.

This study was initiated to investigate aspects of closure and post-closure on a low hazard (H:h) landfill site. This process closely approximates the second ‘problem - solving phase’ outlined by Chadwick and Goodman (1975). These authors distinguished between two different phases involved in the ‘Ecology of Degraded Land’:

(A) “The initial problem-posing phase” – the simplest phase, which uses qualitative data; and

(B) “The second problem solving phase” – the more difficult phase, which demands solutions based on relevant quantitative data.

Chadwick and Goodman (1975) were of the opinion that failure to achieve the transition from the first to the second phase affects the future quality of the environment.

The aim of the grass and tree trials was to plant creeping grasses (*Cynodon dactylon* and *Panicum natalense*), bunching grasses **(***Melinis nerviglumis*, *Melinis minutiflora* and *Hyparrhenia hirta*), and the dominant tree of the region (*Acacia karoo*) over a six-month period, the specific objectives being:

a) To measure the growth of the *C. dactylon* and *P. natalense* grasses on the surface of the landfill, and to quantify the percentage final soil cover that they provided;

b) To measure the levels of survival and biomass generation by *M. nerviglumis, M. minutiflora* and *H. hirta*;

c) To plant *Acacia karoo* trees, and to measure their survival, height and stem diameter.

The overall goal was to see which indigenous grasses could provide good soil cover and biomass, and whether an Acacia/grass savannah could be established on the capped landfill. It was also designed to improve on the traditional method of vegetating landfills and to provide a framework of information that could be used in the closure of other landfill sites.

The landfill site investigated in this study was the Umlazi Low Hazard Landfill (H:h) in Durban, which was capped in 2003 according to *The Minimum Requirements for Waste Disposal by Landfill* (DWAF, 1998). The capped area was grassed by a contractor over a six-month period, during which time the grass, *Cynodon dactylon* var. “Sea Green” fully established itself. Grass trials and tree trials were also done on the eastern side of the site to assess growth and survival rates of alternative grass types, and growth and survival rates of a single species tree. The grass trials and tree trials were monitored over a six-month period, the specific objectives being:

a) To collect and collate the relevant legislation, re: capping of a landfill.

b) To document the engineering aspects of capping a landfill.

c) To study the grassing of the landfill.

The long-term goal of all landfill closure programmes involving the rehabilitation of landfills, particularly of hazardous sites, is the establishment of a sustainable plant community. This incorporates the provision of an adequate protective vegetative cover that ensures ‘soil’ stability. The specific objectives outlined for this study was to determine whether this could be achieved in the rehabilitation of the Umlazi landfill. However, the project was too short in duration to determine whether the landfill was stabilized in the long term.

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CHAPTER 1. LANDFILLS AND THE LAW

In South Africa, there are several different classes of landfills. Each landfill class accepts different waste streams. These waste streams, in turn, present different pollution problems. A landfill can only operate for a limited period, which is prescribed in the licensing permit. A closure permit is issued after the landfill has been filled to capacity. It often becomes necessary to undertake establishment of vegetative cover over exposed areas. Ideally vegetation will tolerate the gases emitted from the waste body (typically dominated by CO_2 and CH_4), will ensure long-term stability of the capping layers, and will limit erosion. The design of the cover must protect the people living around the landfill from exposure to deposited waste and the by-products of decomposition such as methane and noxious odours.

Landfills are meant to be located in geologically suitable areas. However these areas have varying climatic conditions, which require different types of vegetative cover to be planted. The chosen landfill vegetation type is expected to grow, survive and protect the soil capping in its particular region.

1.1 Definition of a landfill

A most comprehensive definition of “landfill”, is that of DEFRA (2000):

a) “tipping above or underground;

b) “land treatment of waste;

c) “surface impoundment of waste by placing liquid or sludge into pits, ponds or lagoons;

d) “specifically engineered landfill by placing waste into lined and discreet cells which are capped and isolated from one another.”

Senior (2005) defined a landfill as, “a designated area to receive solid waste such as municipal solid waste, construction debris and sludge from sewage treatment and other processes”.

The Environmental Health Centre (EHC, 2005) defined a landfill as, "a method for final disposal of solid waste on land. The refuse is spread and compacted and a cover of soil is applied so that effects on the environment (including public health and safety) are minimised. An industrial landfill disposes of non-hazardous industrial waste. A municipal landfill disposes of domestic waste including garbage, paper plastics and dry waste".

Waste Management - Landfills and the Law

1.1.1 *Legal operational profile*

Three legal requirements are applicable with regard to the identification of a site suitable for a landfill. These are:

a) A permit in terms of Section 20 (I) of the Environment Conservation Act 1989 (Act 73 of 1989) (DEAT, 1989);

b) Land use rezoning; and

c) An environmental impact assessment (EIA) in terms of the Environmental Conservation Act (1989) (DEAT, 1989) and its Regulations, and the National Environment Conservation Act (No. 107 of 1998) (DEAT, 1998a).

The following other legislation, codes and policies apply to the operation of a landfill:

a) The Constitution of the Republic of South Africa, (Act 108 of 1996) (DOH, 1996);

b) The Environment Conservation Act (No. 73 of 1989) (DEAT, 1989);

c) The National Environmental Management Act (No. 107 of 1998) (DEAT, 1998b);

d) The Health Act (No. 63 of 1977) (DOH, 1977);

e) The Natal Prevention of Environmental Pollution Ordinance (No. 21 of 1981) (DAEA, 1981);

f) The Local Government: Municipal Systems Act (No. 32 of 2000) (DOLG, 2000);

g) The National Water Act (No. 36 of 1998) (DWAF, 1998d);

h) Local by-laws;

i) Other policy documents.

1.1.2 *The Constitution of the Republic of South Africa*

The Constitution (Act 108 of 1996) (DOH, 1996) is relevant to waste management in two ways. Firstly, the Bill of Rights (Chapter 2 of the Constitution) contains a number of rights, including environmental rights. Secondly, it provides the legal basis for allocating powers to different spheres of government (Schedules 4 and 5) and is thus relevant to the institutional regulation of pollution and waste management.

The most pertinent fundamental right in the context of pollution and waste is the environmental right (S 24), which provides that:

"Everyone has a right
to an environment that is not harmful to their health or well-being; and
to have the environment protected, for the benefit of present and future generations
through reasonable legislative and other measures that
prevent pollution and ecological degradation;
promote conservation;
secure ecologically sustainable development and the use of natural resources while promoting justifiable economic and social development".

Section 24A places a duty on all citizens not to cause a situation in which the environment is detrimental to health or well-being, and also to prevent others from creating such an environment.

1.1.3 *Environment Conservation Act*

The Environment Conservation Act (No. 73 of 1989) (DEAT, 1989) refers to littering and waste disposal.

1.1.3.1 Littering

Firstly, the Environment Conservation Act (DEAT, 1989) contains a prohibition of littering and provides that "No person shall discard, dump or leave any litter on any land or water surface, street, road or site in or on any place to which the public has access, except in a container or at a place which has been specially indicated, provided or set apart for such purpose" [S 19(1)].

It also places responsibility and obligation on every person and the relevant authorities to ensure that provisions are made for the proper discarding of litter (S 24).

Section 19A further provides that "every person or authority in control of or responsible for the maintenance of any place to which the public has access, shall within a reasonable time after any litter has been discarded, dumped or left behind at such a place (with the inclusion of any pavement adjacent to, or land situated between, such a place and a street, road or site used by public to get access to such a place) remove such litter or cause it to be removed".

Section 24A allows for the making of regulations by the competent authority with regard to the control of the dumping of litter mentioned in Section 19 (1). In response to this provision, local municipalities have passed by-laws on litter.

1.1.3.2 Waste

Section 20 (1) of the Environment Conservation Act (1989) (DEAT, 1989) prohibits anyone from establishing, providing, and operating any disposal site without a permit issued by the Minister of Water Affairs and Forestry. It also gives the Minister the exclusive powers to:

a) issue a permit subject to conditions;

b) alter or cancel the permit;

c) refuse to issue the permit S20(1)a–c).

In order to facilitate the enforcement of the landfill permit system as provided for in Section 20 (1), the Department of Water Affairs and Forestry (DWAF) produced three documents on waste management in 1994 (*Minimum Requirements for Monitoring at Waste Management Facilities*; *Minimum Requirements for Waste Disposal by Landfill*; and *Minimum Requirements for Handling, Classification and Disposal of Hazardous Waste*) (DWAF 1994a; 1994b; 1994c). Second, revised editions were issued in 1998 (DWAF 1998a; 1998b; 1998c). This series established a reference framework of standards for waste management in South Africa.

1.1.4 *National Environmental Management Act*

Of fundamental importance are the environmental management principles that form the cornerstone of this Act (No. 107 of 1998) (DEAT, 1998). These include three pollution- and waste-related principles, namely the precautionary principle; the polluter "pays" principle, and the preventative principle (Glazewski, 2000).

The Act provides that sustainable development requires the consideration of all relevant factors including:

"(a) (ii) that pollution and degradation of the environment are avoided or where they cannot be altogether avoided, are minimised and remedied...

(iv) that waste is avoided... minimised and reused or recycled where possible and otherwise disposed of in a responsible manner...

(vii) that a risk averse and cautious approach is applied... and

(viii) that negative impacts on the environment and on people's environmental rights be anticipated and prevented, and where they cannot be altogether prevented, are minimised and remedied...

(p) The cost of remedying pollution, environmental degradation and consequent adverse health effects and of preventing, controlling or minimising further pollution, environmental damage or adverse health effects must be paid for by those responsible for harming the environment." [Section 2(4)(a)(ii), (iv), (vii), (viii) and (p)].

Section 28 provides for the care and remediation of environmental damage. It provides that, “every person who causes, has caused or may cause significant pollution or degradation of the environment must take reasonable measures to prevent such pollution or degradation from occurring, continuing or recurring...to minimise and rectify such pollution or degradation of the environment”.

This includes an owner of land or premises, a person in control of land or premises or a person who has the right to use the land or premises [S 28(1); S 28(2)].

All of the above provisions apply directly to waste and litter. However few or no prosecutions have been reported on their applications. This could be because people perhaps do not see litter as creating a serious threat to their lives and their environment in the same way as hazardous waste does. But if one considers the impact of illegal dumping, mainly by constructors, industries and factories, on our landscapes, and the cost incurred by our local municipalities in clean up campaigns, then strict application of these provisions is warranted.

1.1.5 *Health Act*

This Act (No. 63 of 1977) (DOH, 1977) has provisions that relate directly to waste, and others that relate to nuisance, of which solid waste is part thereof. The Act defines “nuisance” as including “any ash heap or dung heap so foul or in such a state or so situated or constructed as to be offensive or to be injurious or dangerous to health and any accumulation of refuse, offal, manure or other matter that is offensive or injurious of dangerous to health” [S 1(a)-(i)]. Other relevant provisions of the Act are in respect of the duties and powers of local authorities and a number of areas in terms of which the Minister is given the power to make regulations.

The Act provides that:

"Every local authority shall take all lawful, necessary and reasonably practicable measures:

(a) to maintain its district at all times in a hygienic and clean condition;

(b) to prevent the occurrence within its district of -

(i) any nuisance;

(ii) any unhygienic condition;

(iii) any offensive condition or

(iv) any other condition, which will or could be harmful or dangerous to the health of any person within its district or the district of any other local authority" [S 20(1)].

1.1.6 *KwaZulu-Natal Prevention of Environmental Pollution Ordinance*

The objective of this Natal Ordinance (No. 21 of 1981) (DAEA, 1981) is to provide for the prevention of pollution of the environment; for the prevention of littering on land, whether public or private; and, on private land, such littering as is visible or detectable from a public road or place; to provide for the appointment of officers to enforce this legislation; and to provide for other matters incidental thereto. The Ordinance provides that:

"No person shall in any manner whatsoever and whether wilfully or negligently perform any act of littering or pollution on, in or into any land whether public or private or the sea or inland waters unless such act is authorised by law or unavoidable" [S 2(1)(a)-(f)].

Any person contravening the above provisions shall be guilty of an offence [S 2(2)] and liable to a fine not exceeding R1 000 or imprisonment for a period not exceeding twelve months (S 6).

1.1.7 *Local Government: Municipal Systems Act*

Chapter 5 of this Act (No. 32 of 2000) (DOLG, 2000) is about integrated development planning (IDP). It compels all municipalities to undertake developmentally oriented planning. The IDP must be a strategic plan to give direction to all development. It identifies development priorities and supports optimal allocation of resources. More importantly, it forms the basis for Municipal, Provincial and National project budgeting.

The Act requires municipalities to adopt the IDP after municipal election and review it annually (S 24). Section 35 states that an IDP adopted by the Council is the principal strategic planning instrument, which guides and informs all planning and development. The prioritisation process is critical to the IDP process.

1.1.8 *National Water Act*

Part 4 of Chapter 3 of this Act (No. 36 of 1998) (DWAF, 1998d) deals with pollution prevention and, in particular, the situation where pollution of a water resource occurs or might occur as a result of activities on land. The Act puts responsibility on the person who owns, controls, occupies or otherwise uses the land to take measures to prevent pollution [S 19(1) (a)-(b)].

If the person responsible fails to comply with this provision, the still-to-be-established Catchment Management Agency may remedy the situation and such costs be recovered from such a person [S 19(4)].

1.1.9 *Local By-Laws*

As stated in Section 3.1 under the Constitution (Act 108 of 1996) (DOH, 1996)), refuse removal, refuse dumps and solid waste disposal fall under Schedule 5B and are a function of local government competence. Municipalities regulate their waste management by means of by-laws.

1.1.10 *Other Policy documents*

1.1.10.1 National Waste Management Strategy

The *National Waste Management Strategy* (DEAT, 1999) presented the government's strategy for integrated waste management in South Africa. The strategy presented a long-term plan (up to the year 2010) for addressing key issues, needs and problems experienced with waste management in South Africa. It gave effect to the Bill of Rights and further translated into action the government's policy on waste, as set out in the *White Paper on Integrated Pollution and Waste Management for South Africa* (Government Gazette, Vol. 417, No. 20978, 17 March 2000) (DEAT, 2000a). The objective of this white paper was to move away from fragmented and uncoordinated waste management to integrated waste management. Such a holistic and integrated approach covered the prevention, generation, collection, treatment and disposal of waste.

The *National Waste Management Strategy* (DEAT, 1999) aimed to reduce both the generation and the environmental impact of waste. It presented a plan for ensuring that socio-economic development of South Africa, the health of its people and the quality of its environmental resources should no longer be adversely affected by uncontrolled and uncoordinated waste management. It established a waste management system that concentrated on avoiding, preventing and minimising waste and made provision for waste management services for all by extending an acceptable standard of waste collection, transportation, treatment and disposal services to all communities. The key elements of the strategy included:

a) Integrated waste management planning;

b) Waste information systems;

c) Waste collection and transportation;

d) Waste minimisation and recycling;

e) Waste treatment and disposal; and

f) Capacity building, education, awareness and communication.

This was a first generation strategy that initiated action by both government and civil society and which should culminate in the implementation of an integrated waste management system for South Africa. Critical factors affecting the successful implementation of the strategy will be securing the necessary financial and human resources, practical realities, changing needs, new priorities and receiving the commitment, support and input of all stakeholders. Government accepted that this strategy would have to be reviewed periodically, for example, every five years.

1.1.10.2 White Paper on Environmental Management Policy for South Africa

The *White Paper on Environmental Management Policy for South Africa* (DEAT, 2000b) was an overarching framework policy, governed by the democratic values and principles enshrined in the Constitution. Through this policy, the government undertook to give effect to the many rights of the Constitution that relate to the environment. Furthermore, it defined sustainable development as a combination of social, economic and environmental factors. The white paper accepted sustainable development as the appropriate approach to resource management and utilisation, thus entrenching environmental sustainability in policy and practice.

The white paper set a number of objectives for integrated pollution and waste management. Some of these objectives were:

“(p) to prevent, reduce and manage pollution of any part of the environment, due to human activity, and in particular from radioactive, toxic and hazardous substances;

“(q) to set targets to minimize the amount of waste and pollution that is generated at source…;

“(r) to promote a hierarchy of waste management practices, namely, reduction of waste at source, reuse, recycling and safe disposal.”

The vision of this policy was one of a society in harmony with its environment. It sought to unite the people of South Africa in working towards a society where all people have sufficient food, clean air and water, decent homes and green spaces in their neighbourhoods, enabling them to live in spiritual, cultural and physical harmony with their natural surroundings.

1.1.10.3 Agenda 21, an Agenda for Sustainable Development Into the 21st Century

Agenda 21, created in 1992, was an action plan and blueprint for sustainable development adopted by more than 178 governments at the United Nations Conference on Environment and Development (UNCED, 1992) in Rio de Janeiro in 1992. As one of the global partners, South Africa committed itself to a national programme for sustainable development by the year 2002. Agenda 21 integrated environmental concerns and social and economic development in the decision-making process.

Agenda 21 set out programme areas and objectives for environmentally sound management of solid wastes and sewage related issues. These broad objectives were: minimising waste, maximising environmentally sound waste reuse and recycling, promoting environmentally sound waste disposal and treatment, and extending waste service coverage.

1.1.10.4 KwaZulu-Natal Draft Policy on Waste Management

The *KwaZulu-Natal Draft Policy on Waste Management* (DAEA, 2002) was drawn up by virtue of the assignment of substantial portions of Section 24 of the *Environment Conservation Act of 1989* to Provinces (DEAT, 1989a) and provided for a province to make regulations with respect to waste management. The *National Environmental Management Act of 1989*, Section 11 (DEAT, 1989b), also required scheduled organs of state, and every province, to prepare Environmental Management Plans, of which a Waste Management Plan was an integral part.

Therefore, the KwaZulu-Natal government engaged in a consultative process, in conjunction with the national integrated pollution and waste management process, to develop a waste management policy.

The purpose of the draft policy was to inform the public what the provincial government's objectives were and how it intended to achieve its objectives, and to inform government agencies, in the provincial sphere, what their objectives should be and what they must do to achieve those objectives. The policy started by defining the key concepts of waste management, the scope and purpose of the policy and the consultative process.

It then stated that the vision of the provincial government in terms of waste management, and covered issues such as the principles governing waste management, strategic goals and objectives, issues around governance, institutional framework, regulatory mechanisms and time frames.

1.2 Landfills in South Africa

In South Africa dry waste (both domestic and industrial), waste sludge, liquids, toxic waste and other waste streams are disposed of in low-hazard (H:h) landfill site. By legislation, the different types of waste are disposed of into different classes of landfill. A low-hazard (H:h) landfill will accept waste of Hazard Ratings 3 and 4, whereas a high-hazard (H:H) landfill accepts waste with Hazard Ratings 1, 2, 3 and 4. The hazard rating is determined by the toxicity of the waste before disposal, and a hazard rating 1 denotes extreme risk, 2 denotes high risk, 3 denotes moderate risk and 4 denotes low risk (DWAF, 1998c).

Landfill sites, commonly called simply 'landfills' by those who work with them, differ from one another in terms of size, type and the threat they posed to the environment. Landfills are normally located on the outskirts of suburban areas and relatively accessible, to reduce transport costs.

1.2.1 *The environment and the environmental impact assessment*

The environmental impact of a landfill is a strongly contested and debatable subject because numerous social and environmental subject need to be addressed in the planning process, in daily operations, the landfill site closure and in post-closure care of the landfill. Siting of a landfill is a lengthy process, involving in-depth research into numerous alternative sites, and justification for the chosen site (DWAF, 1998a). Consultation with various stakeholders and communities forms an integral part of the process. Only after due consideration and approval by the relevant authority can the process move forward. It is important to have economic, environmental and public acceptance, as well as acceptance by the affected parties.

1.2.2 *Construction and siting of landfills*

Landfill sites are generally constructed in valleys or by the excavation of flat ground to form a deep basin and then that basin or valley is filled with waste (DWAF, 1994). The excavated area is lined with clay and/or a plastic liner to prevent any contamination of the ground, ground water and the surrounding environment. The layout of the landfill must be planned to take into account its end use. The closed landfill must be capped to contain the waste body and all odours. The drainage system must be designed to capture run-off liquid and leachate. The capping layer, which is vegetated, acts as a barrier so that noxious odours are contained within the waste body and the liner ensures that leachate is not released into the environment. High levels of methane and carbon dioxide gases can be emitted and the release of hydrogen sulphide would be unpleasant if the landfill is not capped (DWAF, 1998a).

1.2.3 *Problems caused by landfills*

Landfills can cause different kinds of environmental pollution, i.e.; to air, water, and soil.

1.2.3.1 Air pollution

Air pollution can be caused by movement of dust, windblown waste, loose cover material, and gases from the landfill site into the surrounding neighbourhood (DWAF, 1998a). High winds and a lack of suitable cover, or uncapped portions of the landfill, aggravate the emission of dust, methane and carbon dioxide gases. The height of the landfill may favour wind scatter of loose waste and gas emissions into surrounding homes and neighbourhoods. Dust emissions from site operations as well as from the disposal of dusty or odourous waste streams, increase the problems for employees and communities. Hazardous substances such as asbestos contain a large number of dust particles which easily become air borne, thus increasing the risk they pose and as such all operations must be carried out in conformity with the Occupational Health and Safety Act (DOH, 1994), and DWAF requirements (DWAF, 1998c).

1.2.3.2 Water source contamination

The contamination of streams, rivers and the water table may be associated with landfills. It allows rainfall to percolate into the landfill and enhance the volume of leachate and leachate streams which could pose a degree of threat and risk to aquatic life, plant and animal communities and local inhabitants in close proximity to the landfill. This is dependent on the nature of the pollution. Leachates contain specific elements, such as sulphides, sulphur, cyanide and heavy metals that could contaminate water, and as such, they must be contained to restrict environmental contamination. Regular monitoring of boreholes should be used to identify and track contamination levels in the ground water. Surface water monitoring points form part of the inspection and sampling protocol required in landfill permits. Integrity monitoring of pumps, tanks and pipelines to avoid spillages and leaks must be done regularly (DWAF, 1998d).

1.2.3.3 Soil contamination

The seepage of contaminated water or leachate generated in a landfill (unlined or lined), which filters into the surface or groundwater and into wells or streams can pose a health and environmental risk. Soil sampling, analysis, monitoring of ground and regular inspections of the lining of the landfill have to be done to track pollution levels in terms of the permit as described and required in the *Minimum Requirements for Disposal by Landfill* (DWAF, 1998a).

1.3 Minimum requirements for waste disposal by landfill

The *Minimum Requirements* are the basis for the research undertaken in this thesis. The overall objective was to document and research the practical implementation of the

Minimum Requirements as applied to the capping and closure of a landfill. This applied to the engineering and vegetation requirements of the *Minimum Requirements*.

In 1994, the Department of Water Affairs and Forestry (DWAF, 1994a;1998a) teamed up with representatives from various organizations in the landfill industry to provide a set of standards for all role players in the waste industry. The aim was to:

a) improve the standard of waste disposal in South Africa;

b) provide guidelines for environmentally acceptable waste disposal;

c) provide a framework of minimum waste disposal standards within which to work and upon which to build.

These standards are referred to as the *Minimum Requirements for Waste Disposal by Landfill* (DWAF,1994a; 1998a).

The Minimum Requirements are based on the integrated environmental management (IEM) approach, which promotes the pro-active control of pollution and integrates other environmental aspects.

The *Minimum Requirements for Waste Disposal by Landfill* (DWAF,1994a; 1998a) provided clear guidelines for the design and construction of the various classes of landfill and for the condition in which the landfill must be left at closure and part closure.

The factors that influence design and operation, are:

a) on-site leachate and odour management;

b) length and angle of slopes;

c) erosion control; and

d) capping material and vegetation selection.

Additional technical recommendations and capping requirements included in the *Minimum Requirements for Waste Disposal by Landfill* (DWAF,1994a; 1998a) include:

a) The properties of the soil from which a slope is to be constructed should be tested for its shear strength;

b) Terraces or intermediate berms should be constructed on long slopes to prevent erosion and should have drains to collect storm water; and

c) The cover should be stabilized with a suitable vegetation type to prevent erosion.

d) The capping should isolate the waste from long term effects of wind and water erosion.

e) It should limit and control the quantities of precipitation that enters the waste body. It should also allow water to leave the landfill by evapo-transpiration and vent landfill gas in a safe manner.

f) The capping layers for a hazardous site are the waste body, drainage layer, geo textile layer, compacted clay layer and a layer of top soil.

1.4 Earliest attempts to re-vegetate landfills

Graber (1999) noted that the first ordinance for waste management was enacted in 1795, in Georgetown, Virginia in the United States. The ordinance prohibited the extended storage of refuse on private property or the dumping of it on a public thoroughfare. In the 1970s, the general public in the United States attained an awareness of the environment and sought a harmonious result for closed landfills, visually and ecologically. As a result, revegetation and rehabilitation have become part of technology involved in the closure of landfills. This has led to the investigation of alternative grasses and other vegetation types for closed landfills. The appropriate post-closure use of landfill sites is an issue that is also now being addressed in the permits of newly constructed landfills and landfills destined for closure.

The legislated capping and closure of landfills is relatively new to the South African waste sector and is largely promoted by the contemporary focus on more environmentally friendly methods of waste disposal and dispensation. In other parts of the world, the same management requirements has occurred as more ordinances and laws are enacted by authorities to ensure safe landfill environments.

In South Africa, no regulations on revegetation methods have yet been prescribed for landfills sites. Only in 1994 was the first set of *Minimum Requirements for Waste Disposal by Landfill* (DWAF, 1994a) put out by Government as a guideline. However, neither this document nor its predecessor makes any mention of specific criteria for vegetation for landfills.

The norm until now has been to use a ‘Highway Mix’ of grass seeds (Mannie, 2002), a mixture of grass species widely used to grass the banks next to highways. The mix comprises mixed grass seed, mainly of indigenous grass types, and is used for vegetating open spaces and disturbed soil. The layer above the waste is a compacted clay layer followed by a top soil layer. The level of establishment of grass cover has been poor because of:

a) Poor quality parent seed

b) Low tolerance levels by the chosen grass species to the landfill environment

c) A lack of continued horticultural maintenance at the landfill

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CHAPTER 2. DESCRIPTION OF THE UMLAZI LANDFILL, DURBAN

2.1 History

The Umlazi IV H:h Landfill site is situated on Lot 1435 in the suburb of Umlazi, Durban, KwaZulu-Natal and is shown in Figure 1.1 and Figure 1.3. The site was opened to urban solid waste in 1987 and ceased operations in February 1997.

Shortly before closure, a new lined cell was created in the northern area of the landfill site in accordance with the DWAF (1998a) *Minimum Requirements for the Handling, Classification and Disposal of Hazardous Waste.* This cell, commonly known as the ‘northern cell’, was filled with inert waste types, namely bark, ash and paper pulp.

In August in 1999, a meeting was held between representatives from the Department of Water Affairs and Forestry (DWAF) and Enviroserv to discuss the final rehabilitation and closure of the site. At the meeting, it was agreed that a final closure report and rehabilitation plan would be submitted within three months.

In accordance with Section 20 of the *Environmental Conservation Act*, No 73 of 1989, and the *Minimum Requirements for Waste Disposal by Landfill* (DWAF,1998b), the site was to be closed as a low hazardous (H:h) landfill since uncertainties exist regarding the nature of some the waste disposed of at the site.

Further to the final closure reports and remediation plans being submitted to the DWAF, investigations were made and research was conducted to assess the landfill site condition and issues that might arise after closure.

The landfill site was closed in three phases: The first phase entailed improving the collection and management of storm water and leachate on the site in order to prepare it for capping. The second phase of closure aimed at capping the domed section of the landfill site and monitoring the performance of the installed leachate seepage collectors.

The final phase of closure aimed at capping the remaining portions of the site, namely the northern section and western section, finalising the waste water drainage from the northern cell, and finalising the clean water drainage from the remainder of the site.

2.2 Geography

The 16,2 hectare area of the landfill site concerned lies in a gully incising a moderately steep hillside slope that terminates in the Sipingo River to the south, Figure 1.2. The northern side of the site is formed by the hill crest and gully head, while the eastern and western boundaries are flanked by a cemetery and the residential township of Umlazi respectively, Figure 1.3. The Isipingo Secondary School is located some 300 metres southeast of the landfill site. The incised valley to the south is densely vegetated.

Figure 1.1 Map of the Umlazi Landfill Site (Shamrock, 2002a)

Figure 1.2 Contour map of the Umlazi Landfill (Shamrock, 2002a)

Figure 1.3. Vertical view of the Umlazi Landfill (Ethekwini Municipality, 2004)

2.2.1 *Geology*

The regional geology of the area was described in detail by King and Maud (1964). The general stratigraphic column representative of the larger area around the disposal site is shown in Table 1 and those geological formations that occur beneath and in the immediate vicinity of the disposal site are marked with an asterisk in the table. The general geology is displayed on the geological map **(**Fig.1.4).

Table 1 General stratigraphic column representative of the larger area around the Umlazi disposal site

<table>
<tr><th colspan="4">GEOLOGICAL SUCCESSION</th></tr>
<tr><th>LITHOLOGY</th><th>FORMATION</th><th>GROUP/SUB-GROUP</th><th>SEQUENCE</th></tr>
<tr><td>Alluvium and beach sand</td><td></td><td></td><td></td></tr>
<tr><td>Red sand; subordinate white, yellow, brown and purple sand; basal conglomerate</td><td>Berea Red Sand *</td><td rowspan="3"></td><td rowspan="3">Quarternary</td></tr>
<tr><td>Calcarenite; highly calcareous sandstone; conglomerate in places</td><td rowspan="2">Bluff</td></tr>
<tr><td>Dolerite</td></tr>
<tr><td>Dark-grey shale, silstone, subordinate mudstone</td><td>Pietermaritzburg *</td><td>Ecca</td><td rowspan="2"></td></tr>
<tr><td>Diamictite, subordinate carved shale and boulder shale</td><td>Dwyka *</td><td></td></tr>
<tr><td>Red-brown coarse grained arkosic sandstone and micaceous sandstone</td><td></td><td>Natal Group Sandstone (NGS)*</td><td>Cape Supergroup</td></tr>
<tr><td colspan="4">* Outcrops on or in close proximity to the site investigated.</td></tr>
</table>

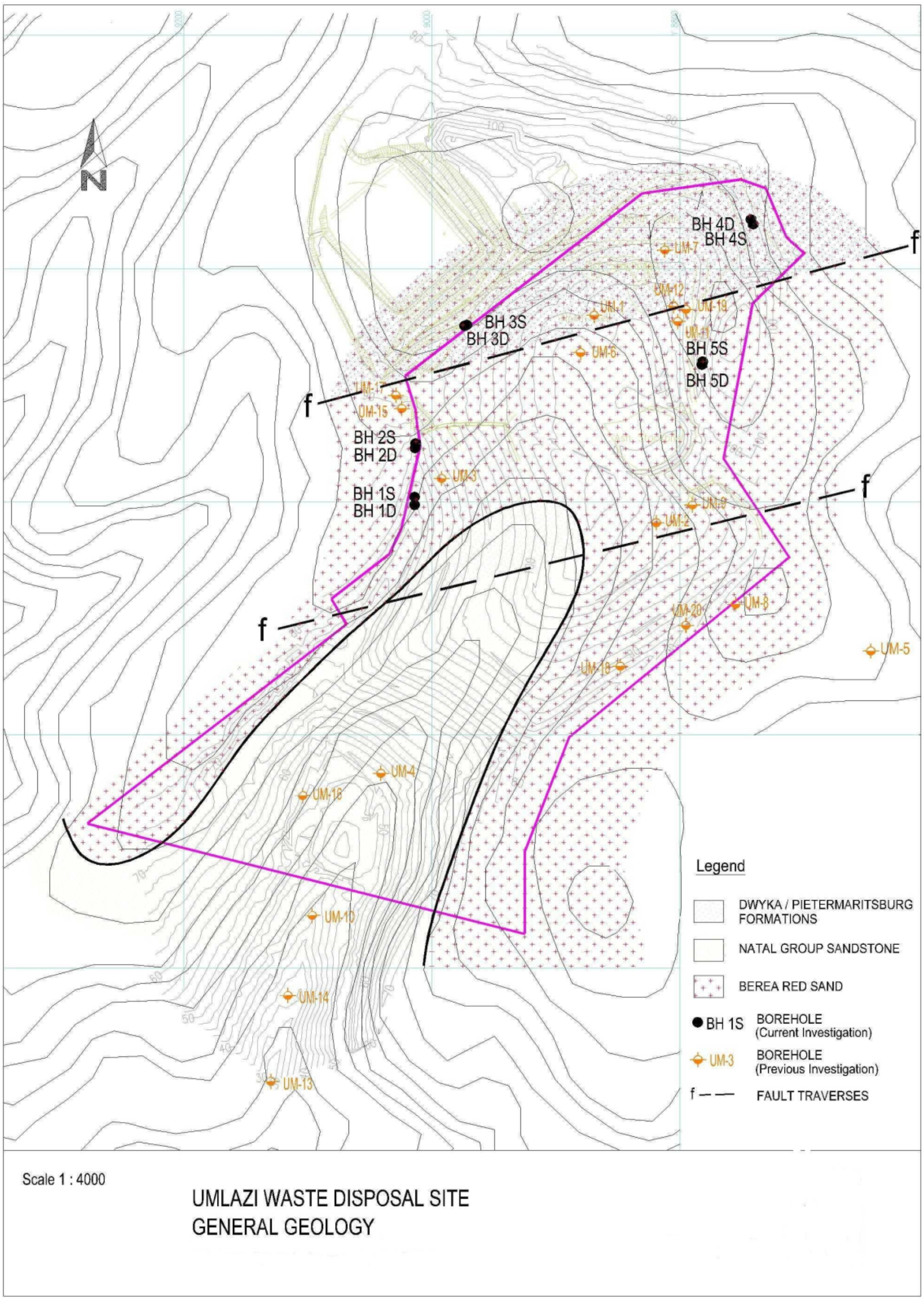

Figure 1.4. Regional Geology of the Umlazi Landfill (Shamrock, 2002b)

The bedrock formations underlying the area comprise continental, glacial, marine and deltaic sedimentary rock of the Cape Supergroup and the Karoo Sequence, into which dolerites intrude. The bedrock formations are unconformably overlain by Upper Cretaceous age siltstones of marine origin in the St Lucia Formation, but these only occur below sea level in the greater Durban area. Deposited on the siltstones and directly on the older bedrock formations are Quaternary sediments of aeolian, alluvial and estuarine origin. These are in the Berea Red Sands and the Bluff formation. The Bluff formation is almost entirely restricted to the coast and immediate environs. The Berea formation or 'Berea Red Sand'; as it is locally known, is the *in-situ* weathered product of the Bluff formation and blankets large portions of the higher-lying area (Maud, 1989). Maud (1989) states further at the base of the Berea Red Sand, a boulder bed is often developed. Alluvial and estuarine sediments underlie the partially infilled estuaries and lower courses of rivers cutting across the area. In the flood plain of the Isipingo River to the south of the site, and in the lower lying parts of some valleys formed by the tributaries of the Isipingo, recent sandy alluvium is found. These deposits are generally only very thin (Maud, 1989).

2.2.2 *Borrow pit*

The site of the existing borrow pit lies to the north of the landfill and covers a rectangular area approximately 150 × 200 m in plan. To the northeast is an open area with two derelict buildings and the remnants of an old road. To the north and west are small cultivated lands.

A substantial amount of soil material has already been removed from the borrow pit for daily cover and the depth of the borrow pit varies from about 2.0 m along the northeast boundary to about 0.5 m at the southeast corner.

The soil material in the borrow pit contains a maximum of 38% clay (King and Maud 1964) as shown in Figure 1.5.

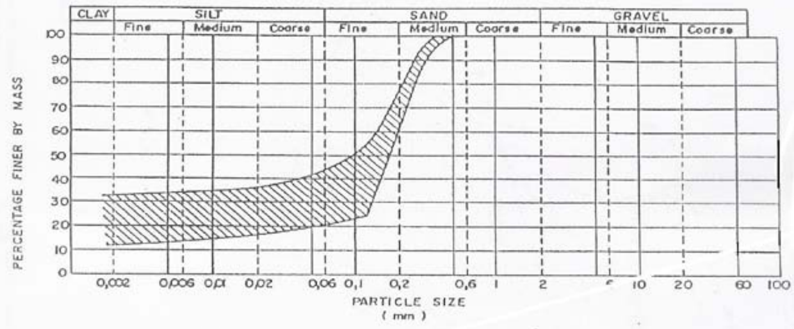

Figure 1.5. Grading envelope of "Berea Red" sand (Shamrock, 2002a)

2.3 Status of the site as of March 2002

After the site inspection in June 2001, a further and final site inspection was held at the beginning of March 2002 to finalise the assessment of the site before capping could take place on the entire southern portion of the site.

Mannie (2002) noted that the following factors limited plant and grass growth and prevented the natural establishment of vegetation on the Umlazi landfill site in the areas of the previous capping:

g) The pH (3,0-5,5) of the soil;

h) The fineness of the topsoil, which is subjected to continuous wind movement;

i) Compaction of the topsoil (25mm-50mm) and the underlying layers;

j) The absence of plant nutrients and organic material (Fig 1.29 and Fig 1.30) in the topsoil in some parts of the capping;

k) Angle of slope: The maximum angle for the successful establishment of vegetation is 34° and some areas steeper in angle had not achieved 100% cover by vegetation;

l) Methane gas is trapped in the waste body, unable to escape controllably into the atmosphere, thus harming the vegetation resulting in die back in pockets all over the capped areas.

It was noted that, throughout the site, various species of alien invaders were present, as well as species of indigenous grasses in limited numbers, and some kikuyu grass. No extensive survey of the area was undertaken because all parts of the site were to be capped and re-vegetated. No systematic grassing had taken place on the site previously. Only a thin cover of soil, approximately 100 mm thick was placed over the waste in most of the southern, west and east sides of the landfill. Although the site had bands of alien vegetation Figure 1.6, there were also large exposed areas and areas where the capping had eroded, Figure 1.7, forming gullies of variable depth. These gullies had exposed the geofabric and stone of the underlying seepage collectors in some places (these seepage collectors had been constructed in Phase I in 1999). Leachate was flowing in the gullies and running over the remaining capped areas (Figure 1.8), causing more damage.

In the areas where the leachate flowed, the vegetation died back (Figure 1.9). The topsoil also eroded creating a gully from the top to the bottom of the site, filling up in the silt trap on the southern side of the landfill.

Strong gas emissions were also noted throughout the site, especially where vegetation was lacking.

Figure 1.6 South side of landfill: methane eroded areas and lack of vegetation probably due to gas emissions

Figure 1.7 Eroded slopes with geofabric exposed, estimated at 25% of the south cell

Figure 1.8 Formation of gullies and flow of leachate, affecting an estimated 25% of the south cell

Figure 1.9 Excessive Erosion on previously capped area, affecting an estimated 40% of the south cell

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CHAPTER 3. ENGINEERING

The Umlazi Landfill (H:h) was decommissioned in 1997 after an inspection by the Minister of the Department of Water Affairs and Forestry due to non –compliance by the operator. The Durban City Council was then mandated to close the site and rehabilitate it to the standards stipulated in the *Minimum Requirements for Landfill Closure (*DWAF, 1988). Consulting engineers were then contracted to evaluate the process required for site closure but no manual or literature available.

The objectives of Chapter 3 was to document the engineering process and modify to meet the Minimum Requirements for capping, closure and for future referencing for other landfills. This is not an experimental chapter but a historic document, recording engineering decisions and processes.

The engineers report (Shamrock, 2002a) made recommendations on the following closure processes:

a) Application for closure permit;

b) The current status of the site;

c) The geology and hydrological aspects of the site;

d) Current and future gas management on the site;

e) The leachate management problem on the site;

f) The exposure of waste on the southern part of the site;

g) The erosion on the southern side and seepage of leachate on the side slopes;

h) The lack of capping or insufficient capping on the landfill;

i) The lack of a storm water management plan for the site and proposals on how to manage this in future;

j) The capping of the north cell;

k) The proposed capping detail for the landfill;

l) The linking of the north cell and old cell;

m) The clay type.

Closure design

The closure and rehabilitation design (Closure Report, Shamrock, 2002b) for the site was set out in terms of the following:

a) Ground water management;

b) Surface water management;

c) Leachate management;

d) Air quality management;

e) Aesthetic considerations;

f) Stability considerations.

Each of the above aspects was investigated and designs were formulated according to the following considerations:

a) Current status;

b) Closure objectives;

c) Proposed actions;

d) Proposed monitoring protocol.

The client and the consultant proposed a phased approach over three years to achieve the closure and rehabilitation of the site, and this was accepted by the authorities and the community. The main reasons for adopting a phased approach was to allow for the time required to fill the northern section of the site so as to allow free drainage. The time was also required for the practical requirements of constructing clay capping layers in a high rainfall area, and for the installation and assessment of leachate seepage collectors before capping layers were installed over them.

3.1 Closure Phase 1

Phase 1(Closure Report, Shamrock, 2002a) of the closure and rehabilitation plan involved improving the collection and management of storm water and leachate on the site in order to prepare it for capping. Leachate seepage collector, (Figure 1.10) were installed on all the areas on the side slopes that showed signs of leachate emerging from the surface (at the weakest point). These collectors consisted of a 150mm-thick collection blanket of stone, (Figure 1.10), capped off with 2 x 200mm layers of compacted low-permeability clay soil cover and a geotextile separation layer, which forces the seepage flow to remain in the stones.

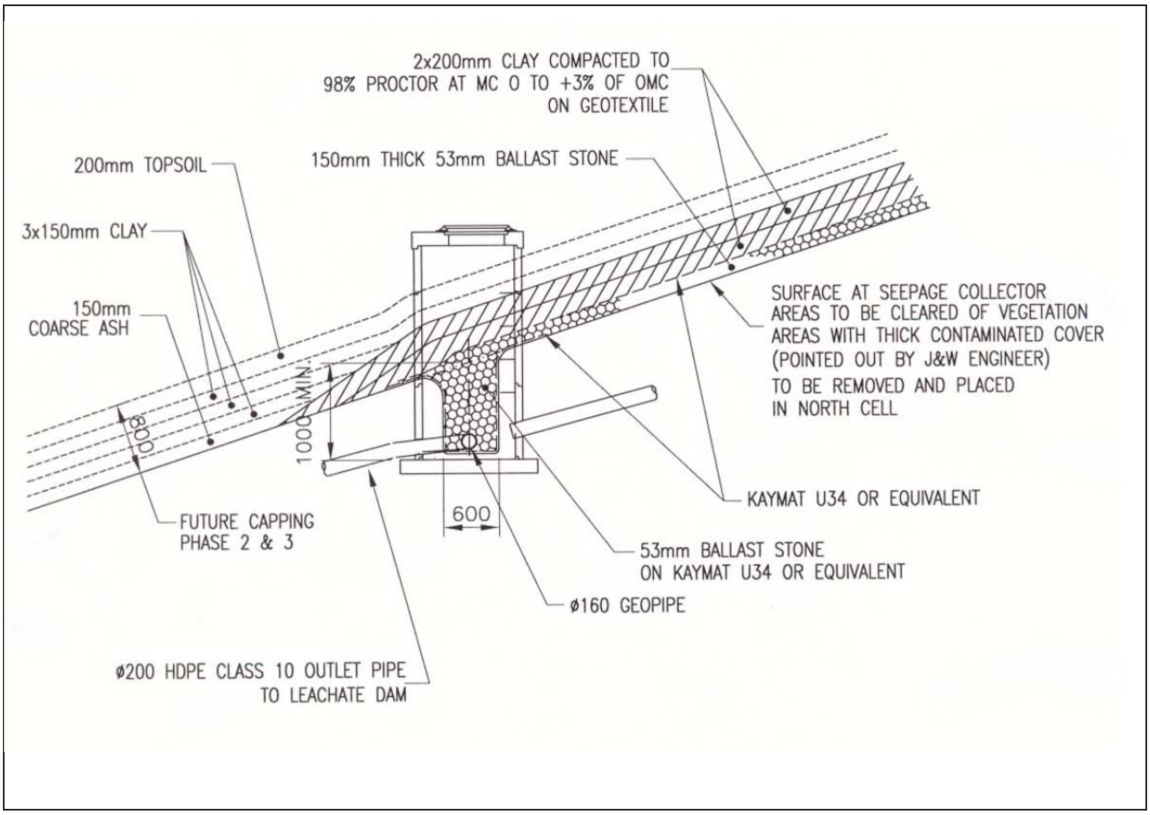

Figure 1.10 Detail of leachate seepage collector (Shamrock, 2002a)

The intercepted seepage then drains into perforated collection pipes in seepage collector trenches filled with stone, which in turn drain to outlet pipes that discharge into the leachate storage dam. The reason for installing leachate seepage collectors before the final capping was to prevent the capping being contaminated by seepage from underneath it, thus resulting in contaminated runoff, vegetation die-back and erosion of the capping layers once again.

Deeper, 1,8m leachate toe drains filled with large stones to delay biological clogging, and with a flexible membrane liner on the downstream side, replaced the existing leachate toe drains (Figure 1.11). The drains were also tied into a seepage collector blanket covering the toe of the landfill. The seepage collector was covered with a 600mm layer of compacted low-permeability soil. A separate collection trench for contaminated storm water was installed to channel runoff into the silt trap and storage dam for leachate/contaminated storm water. The collection trench was erosion-protected by installing grouted stone pitching, and was sized to take a 1 in 100 year's occurrence storm.

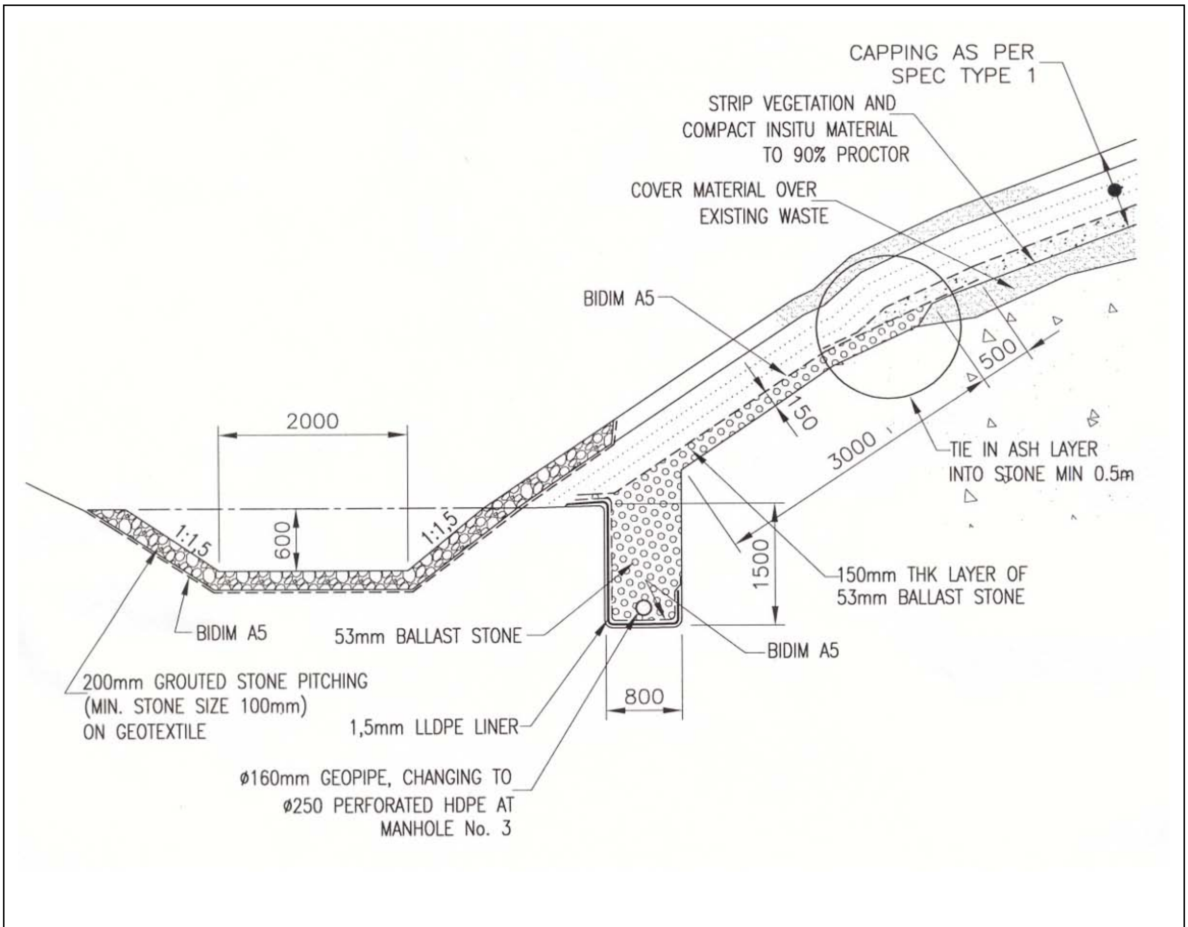

Figure 1.1Detail of toe drain and storm water canal (Shamrock, 2002b)

This system prevents the leachate drains from being clogged by silt from surface runoff. The runoff was discharged into the contaminated storm water system until the capping was completed and the runoff could be considered clean.

The final step of Phase 1 of the closure was the investigation and repair of the silt trap and the storage dam for leachate/contaminated storm water.

3.2 Closure Phase 2

The second phase (Closure Report, Shamrock, 2002b) of the closure and rehabilitation process aimed at capping off the domed top section and southern area of the site, whilst monitoring the performance of the installed leachate seepage collectors. The final capping layers were installed in areas where no seepage had occurred, as per the 2nd Edition of the *Minimum Requirements* (DWAF, 1998a).

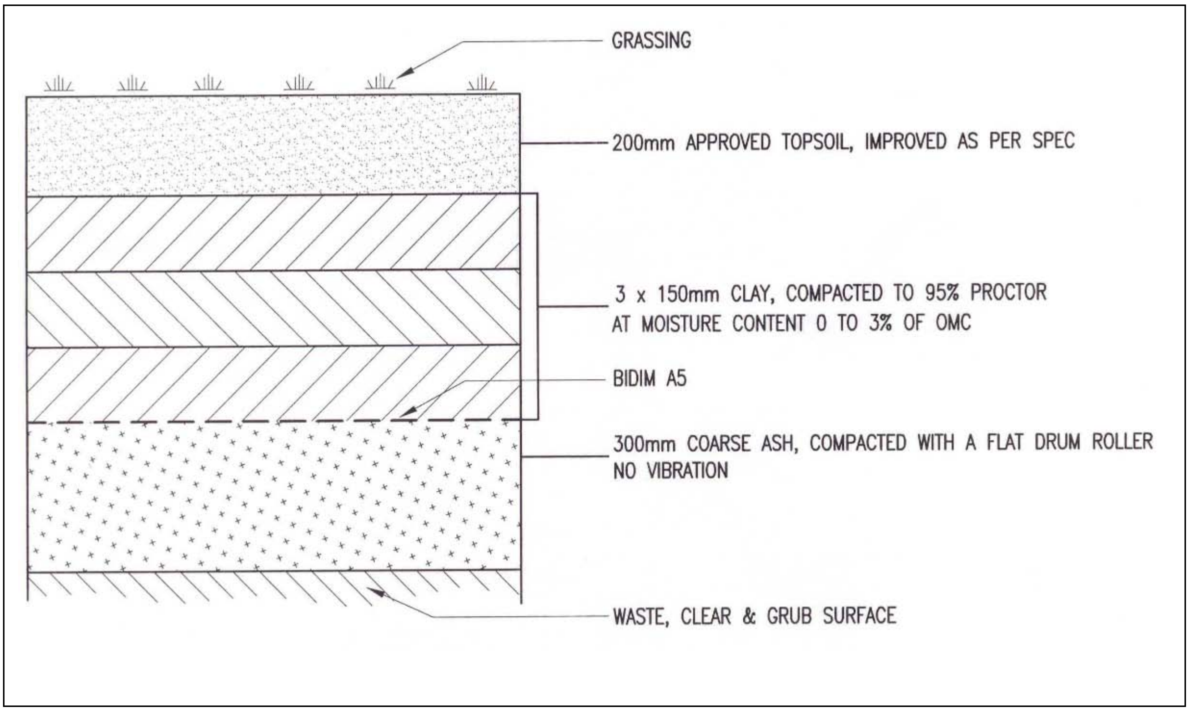

Figure 1.12 Detail of landfill capping layers (Shamrock, 2002b)

The capping was done by first clearing the existing vegetation and compacting the *in-situ* intermediate cover. The compacted cover was then covered by a 300 mm layer of coarse ash with the dual purpose of draining gas and collecting condensate/leachate seepage. The ash layer was tied into the leachate toe drains so that any seepage from the waste body or gas condensate would be directed into the toe drains and hence into the leachate drainage system. The ash layer was overlain by a geotextile separation layer. This was followed by 3 x 150 mm layers of compacted low permeability soil (Figure 1.12).

These in turn were covered by 200 mm of suitable topsoil, which was then vegetated (Figure 1.11). Areas where seepage collectors had been installed in Phase 1 were covered with an additional 150 mm of compacted low-permeability soil and a 200 mm layer of suitable topsoil and vegetation.

Clean storm water coming off the capped areas was intercepted by means of clean storm water berm drains at 10 m vertical intervals along the slope. The berm drains in turn drain into the new clean storm water runoff canal by means of storm water down chutes. The down chutes were erosion protected by means of gabion boxes and Reno mattresses. The new clean storm water runoff canals bypassed the contaminated storm water dam, thus decreasing the amount of contaminated water pumped into the sewer. The berm drains prevent the runoff from gaining energy and eroding the slopes by collecting the water and directing it into erosion protected canals and down chutes (Figure 1.13).

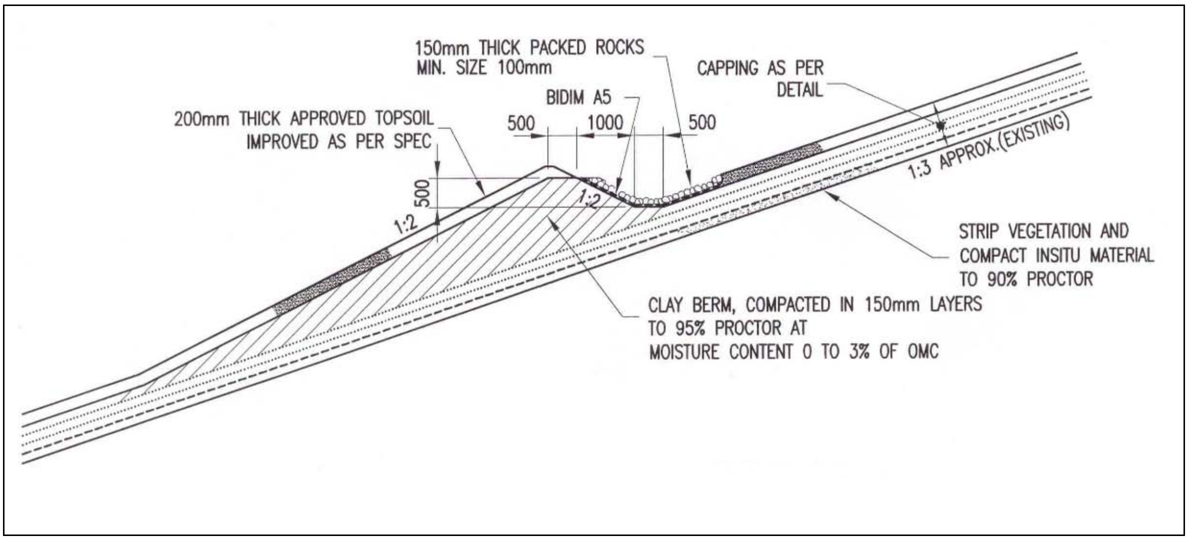

Figure 1.13 Detail of storm water berm drain (Shamrock, 2002b)

The final aspect of installing the capping layers was to address landfill gas (LFG) build-up and venting. As the site had been closed for a number of years before the capping was installed, it was felt that it was not necessary to install an active gas control system. The gas collection layer was therefore linked into a large gas-venting trench with perforated pipes at the crest of the site. The gas-venting trench in turn discharged into the atmosphere by means of Whirlybird vents through an activated carbon gas filter.

This passive system (Figure 1.14) was monitored as part of the new monitoring programme for the site (Sanner, 2003). If the discharge levels of LFG did not subsequently improve, then active measures would be investigated, using the existing wells.

3.3 Closure Phase 3

The third phase (Closure Report, Shamrock, 2002b) of the closure and rehabilitation was aimed at being completed in early 2004 and aimed at capping off the remaining portion of the northern cell (which at that stage was at final landform), as well as finalising the clean storm water drainage from that area. The final landform for the north cell was profiled to ensure adequate drainage of the cell and that it blended in with the surrounding landscape. The proposed landform included a runoff canal at the toe of the fill, with a relatively flat slope that directs runoff from the north-eastern side of the site to the north-western side, tying in with the new clean storm water runoff canal. The domed landform allows for increased runoff and therefore less infiltration under the cover, as well as providing a sufficiently sloped surface, so that when settlement occurs, there is no ponding of water. The runoff trench was erosion protected. Once the entire site was capped, all the runoff could be considered clean and was therefore directed to bypass the leachate/contaminated storm water dam via the new clean storm water canal.

A passive gas extraction system was constructed on the plateau of the site to extract gas and control the build up of gas over the capped site. Figure 1.14 details the design and extraction process of the passive venting system. Due to non-uniform settling of the topsoil, cracks in the clay layer may be routes for the methane gas to escape. The gas may also be trapped in the topsoil layer and the increase in gas concentrations may be the reason for vegetation die-back or stunted growth. As shown in Figure 1.6, there were brown and bald patches in the areas where gas concentrations and leakages were a problem. The Whirlybird functions by means of wind and the activated carbon filters (pellet form) where changed once the carbon had changed to a sand form upon six weekly inspections.

The post-Phase 3 closure involved the monitoring and maintenance of the capping system:

a) The monitoring of ground water to indicate whether the capping system and toe drains were sufficient to stop further pollution of the ground water in the vicinity of the site. If contamination trends continued to deteriorate then the need for ground water cut-off trenches would be investigated.

b) The monitoring of the gas levels around the site would indicate whether the passive gas venting installed was sufficient. If levels did not improve then the need for active-degassing measures will be investigated.

c) The planting and maintenance of a vegetated screen around the site and a dense vegetative cover over the capping was vital for the success of the capping.

d) All of the newly installed drainage measures would also need maintenance for continued performance.

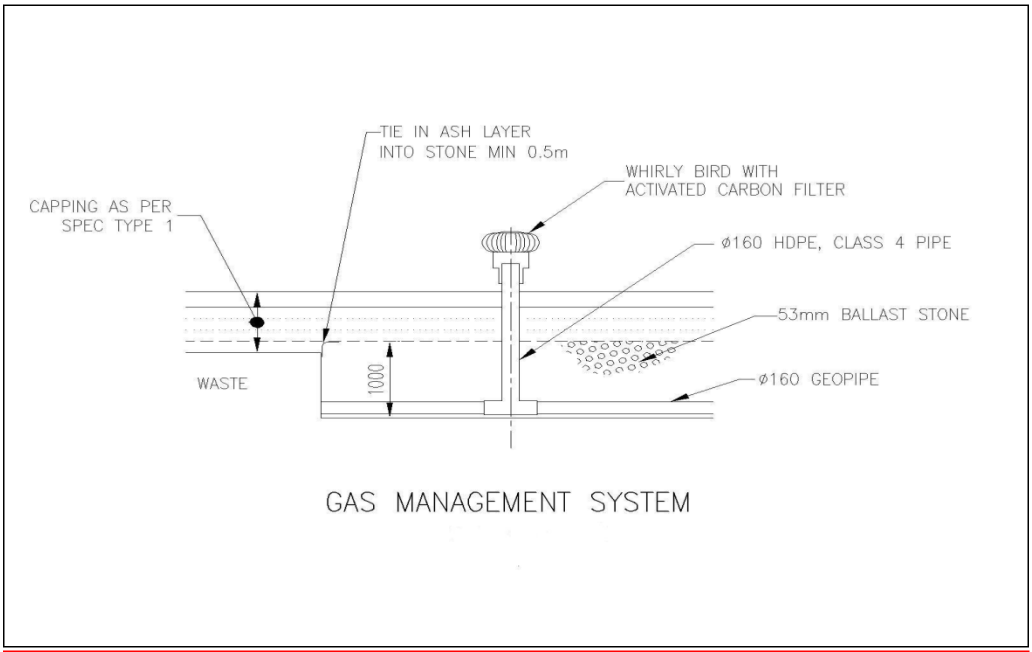

Figure 1.14 The passive methane venting system (Shamrock, 2002b**)**

3.4 References

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CHAPTER 4. RESEARCH INTO THE VEGETATING OF A LANDFILL AT CLOSURE

In the *Minimum Requirements* (DWAF, 1998), DWAF requires that vegetation be planted after capping. In order to meet these requirements, research was undertaken to identify grass and tree species that would grow best on the landfill to provide long term cover.

4.1 Specific Objectives of Chapter

The aim of the grass and tree trials was to plant *Melinis nerviglumis* and *Melinis minutiflora***,** bunching grasses, and *Hyparrhenia hirta***,** the common thatching grass, and *Cynodon. dactylon* and *Panicum natalense*, creeping grasses and *Acacia karoo* over a six-month period, the specific objectives being:

a) To measure the survival rate and biomass of *M. nerviglumis, M. minutiflora* and *H. hirta*;

b) To measure the area of spread of the *C. dactylon* and *P. natalense* grass types in the grass trials;

c) To plant *Acacia karoo* trees, and to measure their height and stem diameter;

The larger goal was to see which indigenous grasses provided the best cover and biomass, and whether an Acacia/grass savannah could be established on the capped landfill.

4.2 Literature Review and Background

4.2.1. Cynodon dactylon (Bermuda grass) (creeping grass)

4.2.1.1 General characteristics

Van Oudtshoorn (1999) described Bermuda grass, *Cynodon dactylon*, as an indigenous, perennial, mat-forming, warm season grass (Figure 1.18). It is both rhizomatous and stoloniferous (Gibbs Russell *et al.*, 1991). Erect or ascending culms grow 0.1-0.4 metres tall. The panicle has 2-7 digitate branches. Rhizomes are hard, scaly, and 0.01-3.3 mm in diameter. Stolons are flattened and several millimetres long, rooting at nodes. Root hairs contribute 64 – 95% of the total root length (Gibbs Russell *et al.*, 1991). Although the *Cynodon* grass species reproduces by seeds, it spreads most rapidly by stolons and rhizomes (Figure 1.19).

Gibbs Russell *et al.* (1991) mentioned that although adaptable to most soil types, *C. dactylon* grass grows best on fertile, sandy to silty soils or alluvium. It occurs in regions that receive more than 410 mm of rainfall a year and, in areas with less rainfall, it requires a surface source of water or irrigation. *C. dactylon* grass is generally tolerant of low soil pH and high salt concentrations.

Figure 1.18. ***Cynodon dactylon*** **at an early stages of a grass mat development**

Figure 1.19 ***Cynodon dactylon*** **plugs being planted and subsequently spreading on a landfill slope**

4.2.2 *Cynodon dactylon var. 'Sea Green'*

4.2.2.1 General characteristics

This *Cynodon dactylon* cultivar is a medium coarse-leafed grass with a dark green colour (Figure 1.20).

Kruger (2002) noted that it was chosen for its suitability for use in warm areas, on rugby or soccer sports fields and on golf fairways. The grass grows tall but will withstand mowing to 50 mm without stress. Its major advantage was on the landfill that it could be used as a summer cover and stabiliser. Furthermore the grass has the ability to cover extremely quickly, with a rapid rate of re-growth after being dug out.

Cynodon dactylon 'Sea Green' grows extremely well in quality soils with adequate fertilizer, water and favourable temperatures but has also proven to withstand high levels of salinity and poorly structured soils. Initially this grass cultivar was chosen as a vegetative cover for the Umlazi Landfill site because of its ability to handle those conditions.

The grass is relatively disease resistant , even when grown under poor conditions (Kruger 2002).

Figure 1.20 *Cynodon dactylon* var. 'Sea Green"

4.2.3 *Panicum natalense (Natal buffalo grass)(creeping grass)*

4.2.3.1 General characteristics

Panicum natalense is a short, rhizomatous and tufted perennial that grows 500–800 mm tall. The leaf blades are rolled, blue-green in colour, 500 mm long, and up to 3.5 mm wide. The leaves are mainly basal and the plants have a knotty base. The culms are seldom erect, usually slanted. The leaf sheath is round and relatively thin. The inflorescence is an open panicle with green spikelets. Spikelets are 1.7–2.2 mm long and rounded in outline (Van Oudtshoorn, 1999).

This is an unpalatable grass with hard, rolled leaves so it is utilised as a fodder crop early in the season after a fire when the leaves are still soft. The dense tufts are important in protecting the soil in mountain grassland from erosion. It grows best in well drained and gravely soils (Figure 1.21).

Figure 1.21 ***Panicum natalense***

4.2.4 *Melinis nerviglumis (Bunching grass)*

4.2.4.1 General characteristics

This perennial grass species grows in tufts of rolled, blue-green leaves that reach about 250 mm in length (Figure 1.22). The flowers appear mostly in summer (September to April) and fade from purple through rose pink to white as they mature (Gibbs Russell *et al.*, 1990; King and Oudolf, 1998; Van Oudtshoorn, 1999).

It grows in undisturbed veld in stony soil, usually on slopes (Van Oudtshoorn, 1999).

Figure 1.22 *Melinis nerviglumis*

4.2.5 *Melinis minutiflora (bunching grass)*

4.2.5.1 General characteristics

This is a perennial grass, its culms are usually decumbent, viscid-glandular throughout, rooting at lower nodes up to 1.8 m long (Figure 2.25). Leaves are 50–175 mm long, 4–13 mm broad, minutely to densely hairy, the hairs viscous with a characteristic somewhat sweet odour (Duke, 1983).

This grass usually occurs on rocky ground, sometimes forming pure stands. It grows in both moist and dry areas (Holm *et al*., 1979).

Figure 1.23 ***Melinis minutiflora***

4.2.6 *Hyparrhenia hirta (bunching grass)*

4.2.6.1 General characteristics

This grass is characterized by its tall appearance, normally over a metre (Fig. 1.24), which appears forming carpets, since it has underground rhizomes (Herbario Virtual, 2003). Jacobs and McClay (2006) described the leaves “with sheath usually glabrous;

ligule 2–3 mm long; blade 2–3 mm wide, glaucous, glabrous or with a few scattered hairs". "The spikes are long, brown or yellow and are found in pairs and are quite hairy and the spikelets have whitish hairs" (Sharp, 2002). "It is drought resistant and can become old and hard after a fire" (Victor *et al.,* 2005). This grass occurs in dry, hot places, often on slopes, paths and roadsides (Herbario Virtual, 2003).

Figure 1.24 *Hyparrhenia hirta* trial

4.2.7 *Acacia karoo*

4.2.7.1 General Characteristics

Venter and Venter (1996) describes *Acacia karoo* as "an evergreen tree, with elongated thorns, deep yellow flowers and round inflorescences grouped towards the tips of branches (Fig. 1.25), adapted to various soil and climate conditions". *Acacia karoo* has "a rounded crown, branching fairly low down on the trunk. It is variable in shape and size, reaching a maximum of about 12m where there is good water" (Palmer and Pitman, 1972). The leaves are finely textured and dark green. The flowers appear in early summer in a mass of yellow pompoms (Pooley, 1993). It is found in a variety of habitats from low lying areas to highveld, although not usually found in mist belt and montane areas (Barnes *et al*., 1996).

Figure 1.25 *Acacia karoo* tree trial

4.1.8 Plug Technology

Containerized trays were invented and developed by George Todd in 1968 in the United States (McDonald and Kwong, 2005). The aim was to improve on production volumes, quality of seedlings and space availability in nurseries. The Speedling containerized system (supplied by Starke Ayres Seeds (Pty) Ltd) was introduced to the South African agricultural industry and there was a rapid shift from direct seeding and bare root transplanting to planting crops using plugs grown in seedling trays.

In South Africa, the technology has been used for the last twenty-five years. Originally, the emphasis was on producing ornamentals and bedding plants but, more recently, there has been a shift to producing grass in seedling trays too. This has been offered as an alternative to retail nurseries, especially for the home gardener.

However there are only a few production nurseries in South Africa produce grass plugs in this form because it is a specialized operation. The trays are manufactured from plastic or polystyrene, cells or cavities 50 millimetres deep (Speedling Inc. 2004). “Speedling” trays are sold with variable plug sizes in the trays containing 72, 98, 128 or 200 cells (Figure 1.26). Prior to use, the trays are usually dipped in a solution of 12% copper carbonate in PVA paint, which helps to stop root penetration into the polystyrene and helps with disease control (Barnett *et al.*, 1974).

The reasons for using seedling trays instead of the more usual direct seeding or bare root transplanting methods are as follows (Thomas, 2002):

a) The transplants develop a secondary root system, resulting in greater survival in the field, especially under adverse conditions;

b) They make handling easier in the field than other methods;

c) There is better plant survival with this method; and

There is less use of pesticides on the field with this method.

Figure 1.26 Seedling tray types: Top- 128 cavity; middle – 72 cavity and bottom – 50 cavity

4.1.9 Super Absorbent

A super absorbent, Supersorb, was used during the planting of the grass plugs and the grass trials at the Umlazi Landfill (Figure 1.27) because of the lack of a continuous water supply on site and the poor soil in which the grass plugs were planted. When the super absorbent is mixed with water, it forms a gel, which holds the soil together and prevents water loss from around the root plug due to evaporation or percolation. This gives the grass plug greater resistance to drought, and improves plant survival. Rainfall occurs mainly in the summer and the prevailing wind conditions are almost parallel to the coastline. The mean climatic statistics for the Umlazi Landfill were described by Meyer (1995) and are shown in Table 2. The monthly rainfall and evaporation from the period of 1956 to 1995 is shown in Table 2.

The super absorbent also contains fertiliser, which is supplied to the root zone where it is needed. The N.P.K. fertiliser contained in the super absorbent is at a ratio of 3.1.5(10). The super absorbent was applied at a rate of 5 g per plant hole.

Figure 1.27 Application of Supersorb to plant holes prior to planting

Table 2 Climate Statistics of the Umlazi Landfill Environs

CLIMATE STATISTICS

	Durban Airport	Umlaas Waterworks
Mean Annual Precipitation (MAP)	994 mm	900 mm
Maximum precipitation in 24 hrs	163 mm (13/12/1963)	
Highest Monthly Precipitation	402 mm (September 1987)	601 mm (September 1987)
Mean daily maximum air Temperature	23,9ºC	
Mean daily minimum air Temperature	9,1ºC	
Mean annual evaporation from soil surface (Durban Airport) *	1431 mm	

(Meyer, 1995)

4.1.2.1 Grass Options

The grass species were chosen on the basis of:

a. *Cynodon dactylon* species were found on the site at the time of the site inspection. The grassing contractor advised further the specific use of *Cynodon dactylon* var. “Sea Green” because it has the ability to cover quickly and develop within poorly structured soils (Kruger, 2002)

b. Kruger (2002) further advised the use of the bunching and thatching grasses because it has the ability to grow in dry areas and the thatching grass could be off economic benefit.

4.1.2.2 Tree Options

Acacia karoo trees were chosen because they existed in the surrounding environment where it seemed they grew well. By growing them as seedlings in the landfill cover, the researcher wanted to observe their growth rates.

4.3 Introduction

The study aimed to quantitatively assess the long-term effectiveness of establishing vegetation on landfill sites as shown in Figure 1.28. It was also designed to improve on the traditional method of vegetating landfills and to provide basic quantitative data that could be used in the planning of closure of other landfill sites.

Figure 1.28 Aerial photograph: Umlazi Landfill January 2004

4.4 Material and Methods

Upon completion of the final capping layer and placement of the topsoil layer, the grassing contractor prepared the surface area on the landfill site.

Samples of the soil that we were to plant in were submitted to the Cedara Soil Laboratory for analysis. Recommendations for fertilization were provided based on the samples submitted for analysis as shown in Figure 1.29 and Figure 1.30. The specific fertilizer types were broadcast by the grassing contractor over the area to be planted.

The marking of quadrants for easy relocation is an important consideration in any study but is of particular importance where valuable information is acquired by re-assessing the same quadrants at a later time.

Wooden pegs were considered as permanent markers, with dimensions of $35mm^2$ and between 1.2 and 1.5 m long, hammered into the ground until 1 metre of the peg remains above the ground. However, they did not prove viable as the pegs were constantly vandalised and stolen. Granger (2002) suggested the use of transponder balls, which contain a magnetic marker that can be detected by means of a metal detector. These balls were successfully used instead of wooden pegs. They were placed in holes at the corners of each block and buried.

Three trials with three replications each were undertaken namely;

Trial 1. Creeping grasses

Trial 2. Bunching grasses

Trial 3. Trees

Grass plugs of grasses (*C. dactylon, M. nerviglumis* and *M. minutiflora* and *H. hirta),* purchased from Super Lawn (Pty), Ltd, were planted by the grassing contractor in a complete randomised block. A portable aluminium frame that enclosed one square metre was used to sample the grass. The number of grass plugs was recorded for each species occurring in the quadrant.

In the grass trial, the aluminium frame was randomly placed six times within each quadrant, with one hundred recordings being noted for grass cover as a percentage at each placement. These readings were recorded weekly until 100% cover had been achieved in the entire trial. The survival rate of each grass type was recorded monthly. After a 10-month recording period of grass plug survival, the grasses were cut and weighed for their biomass respectively. The above ground biomass was measured of each grass type.

The trees, all potted seedlings of *Acacia karoo*, were planted in a block (5m × 6m), with each tree equal distances apart, from centre to centre, with three replications. One recording of tree height, stem diameter and survival rate was done monthly for each block over ten months. The height of the tree was measured with a 1.2m ruler and the stem diameter was measured with a calliper. The grass growth rate was analysed statistically. Data was subjected to analysis of variance (ANOVA) using Analyse-it 2007 Statistical Analysis Software to determine any difference between grass type means and the regression curves.

Your sample ID	Lab num	Sample density g/mL	P mg/L	K mg/L	Ca mg/l	Mg mg/L	Exch. Acidity $cmol_c/L$	Total cations $cmol_c/L$	Acid sat. %	pH (KCl)	Zn mg/L	Mn mg/L	NIRS organic carbon %	NIRS clay %	Cu mg/L
UM 203	F16555	1.31	9	167	383	188	0.11	4.00	3	4.41	4.4	13	<0.5	35	1.7
UM 103	F16556	1.28	4	130	364	153	0.25	3.66	7	4.22	2.1	61	<0.5	46	1.3

Figure 1.29 Soil analysis results

		NITROGEN		PHOSPHORUS			POTASSIUM			LIME				ZINC
Sample ID	Lab num	Yield target t/ha	Required kg N/ha	Sample soil test mg/L	Target soil test mg/L	Req. P kg/ha	Sample soil test mg/L	Target soil test mg/L	Req. K kg/ha	Sample acid sat. %	PAS %	Req. lime t/ha	Lime type	Zinc fert reqd
UM 203	F16555	6.0	110	9	13	20	167	100	0	3	40	.0		No
		10.0	230	9	17	35	167	120	0	3	40	.0		No
		14.0	350	9	20	45	167	140	0	3	40	.0		No
UM 103	F16556	6.0	110	4	13	40	130	100	0	7	40	.0		No
		10.0	230	4	16	50	130	120	0	7	40	.0		No
		14.0	350	4	19	50	130	140	25	7	40	.0		No

Figure 1.30 Soil analysis recommendations

In Fig. 1.30, it can be seen that phosphorous levels was very low and was required in both samples of soil. The nitrogen quantities also needed to be increased to achieve the yield target in both soil samples. The soils did not require potassium or lime.

4.5 Results

Table 3. Creeping Grass Performance

Grass	Final % cover	Mean AUGC over 6 months
C. dactylon	75.61	2328.29
P. natalense	99.88	2046.28
F test	0.391935327	
P - value	0.772223	
Means difference%	10.25	

In Table 3, it can be seen that *P. natalense* has a higher final % cover as compared to *C. dactylon*. The Mean AUGC of *P. natalense* is less than *C. dactylon*. The F test is not significant.

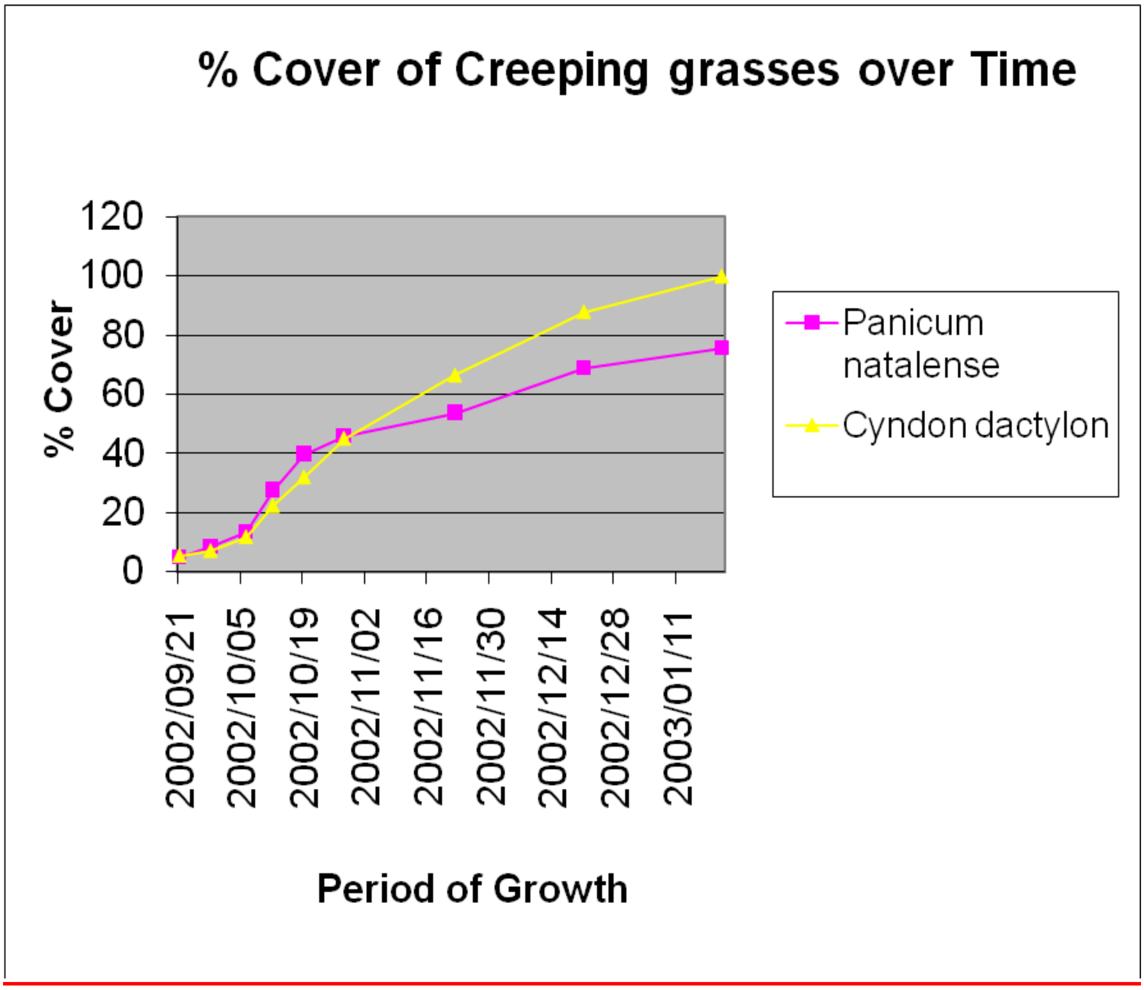


Figure. 1.31 **Creeping grass growth over time**

In Fig. 1.31, it can be observed that *P. natalense* is overtaken by *C. dactylon* after the beginning of November. *P. natalense* did not achieve 100% cover in the trial period as compared to *C. dactylon*.

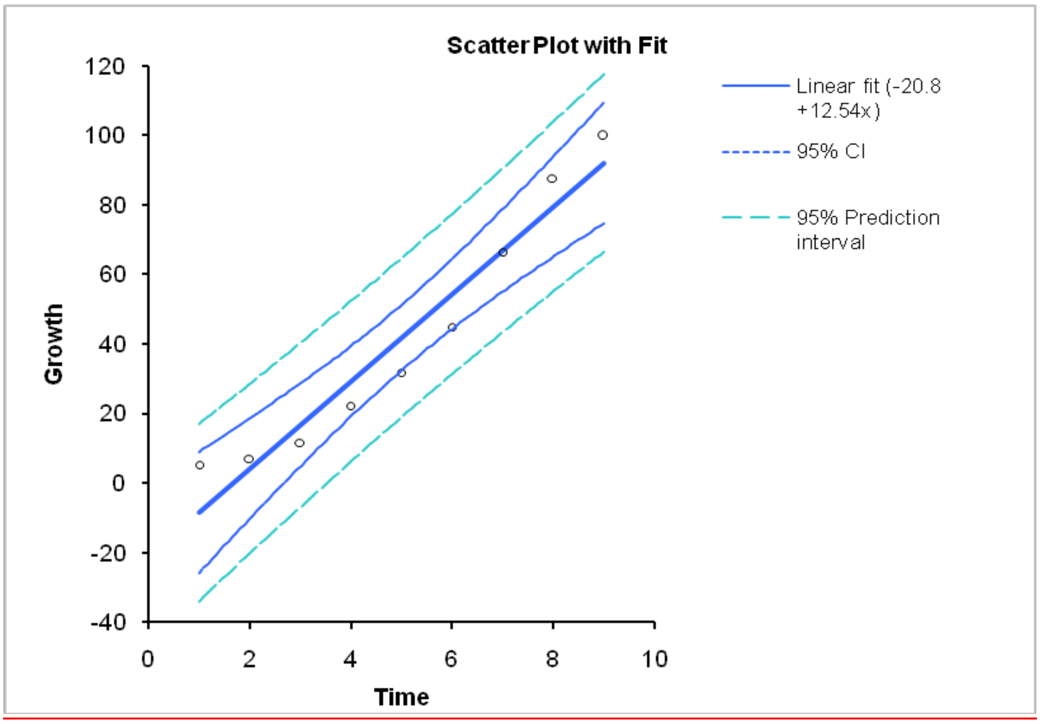


Figure. 1.32 Cynodon dactylon regression curve

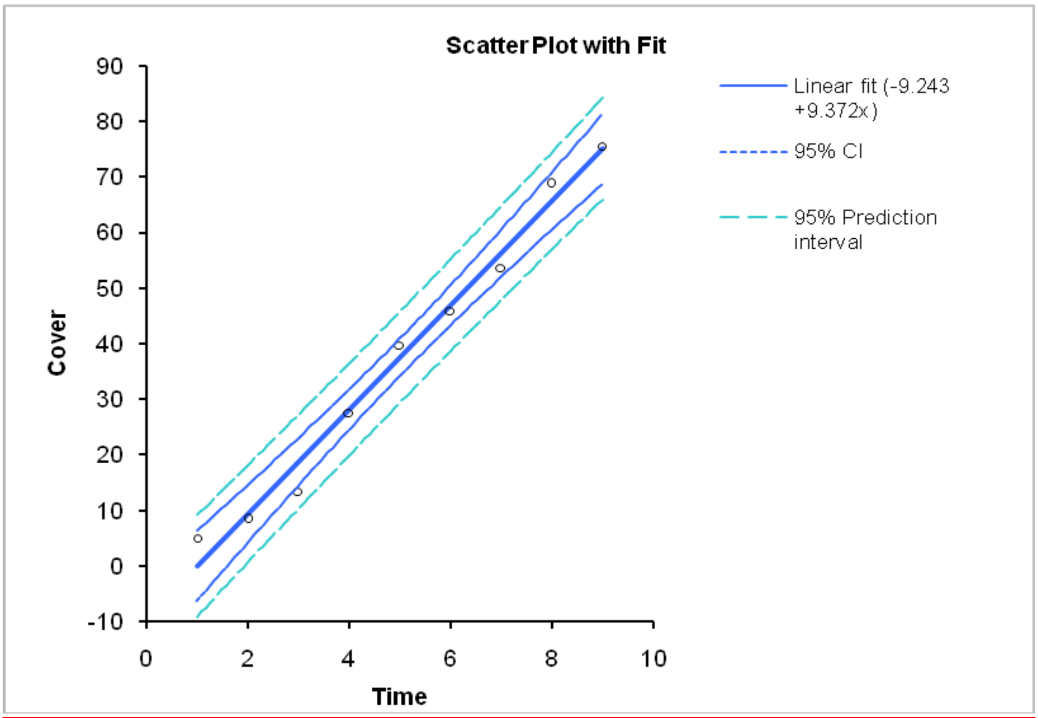


Figure. 1.33 Panicum natalense regression curve

Table 4 Bunching Grass Performance

Grass	Mean Dry Weight (g)	Mean Difference	Survival Rate %
M. nerviglumis	5.36	17.38	95.91
M. minutiflora	22.74		96.24
H. hirta	9.56g	13.18	93.84
F test	0.001824		
P-value	0.000533		

In Table 4, it is seen that *M. minutiflora* has the greatest Mean dry weight and Survival rate %. *M. nerviglumis* had the lowest Mean dry weight while *H. hirta* had the lowest survival rate.

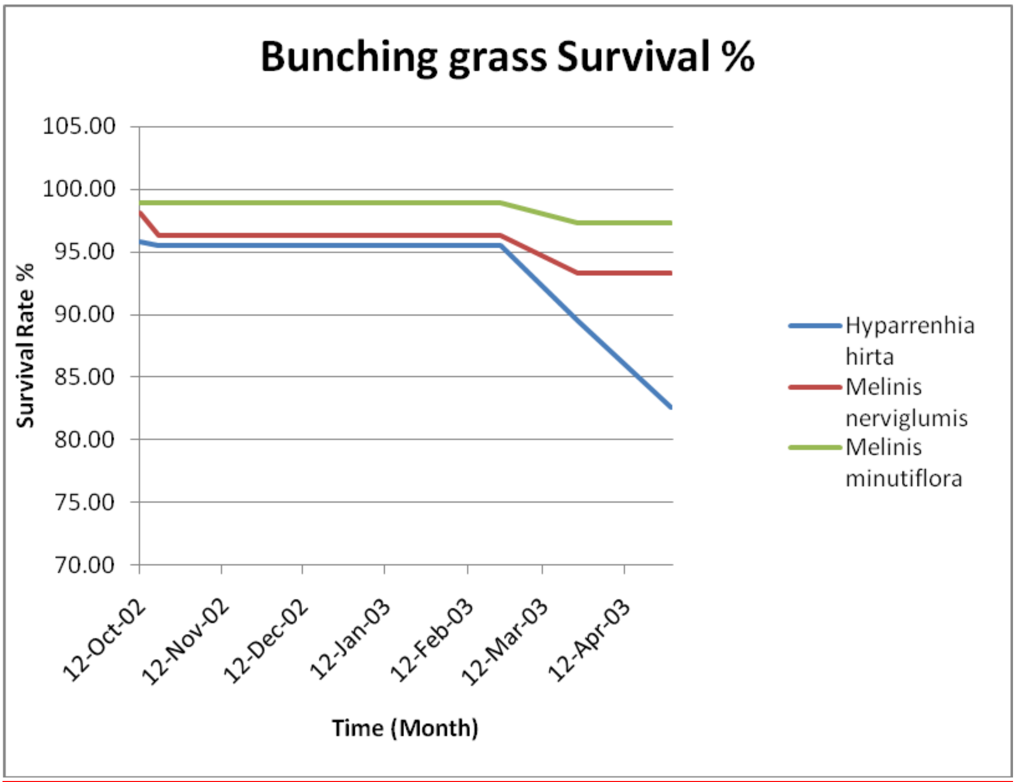


Figure 1.34 Bunching grass survival %

In Fig. 1.34, it can be seen that *M. minutiflora* maintained its survival rate consistently as compared to *H. hirta* and *M. nerviglumis*.

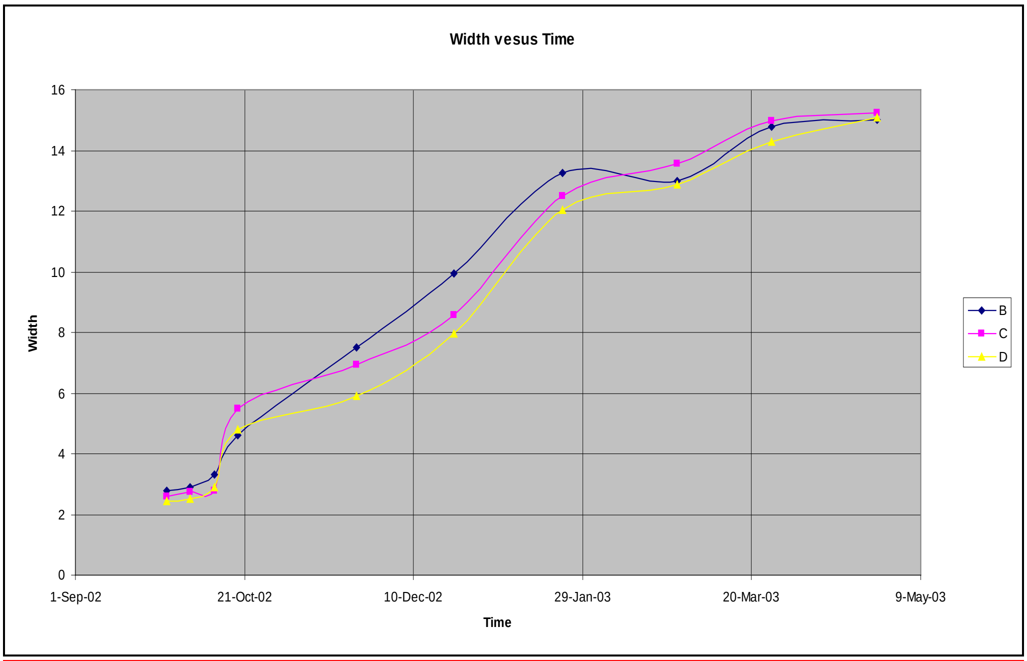
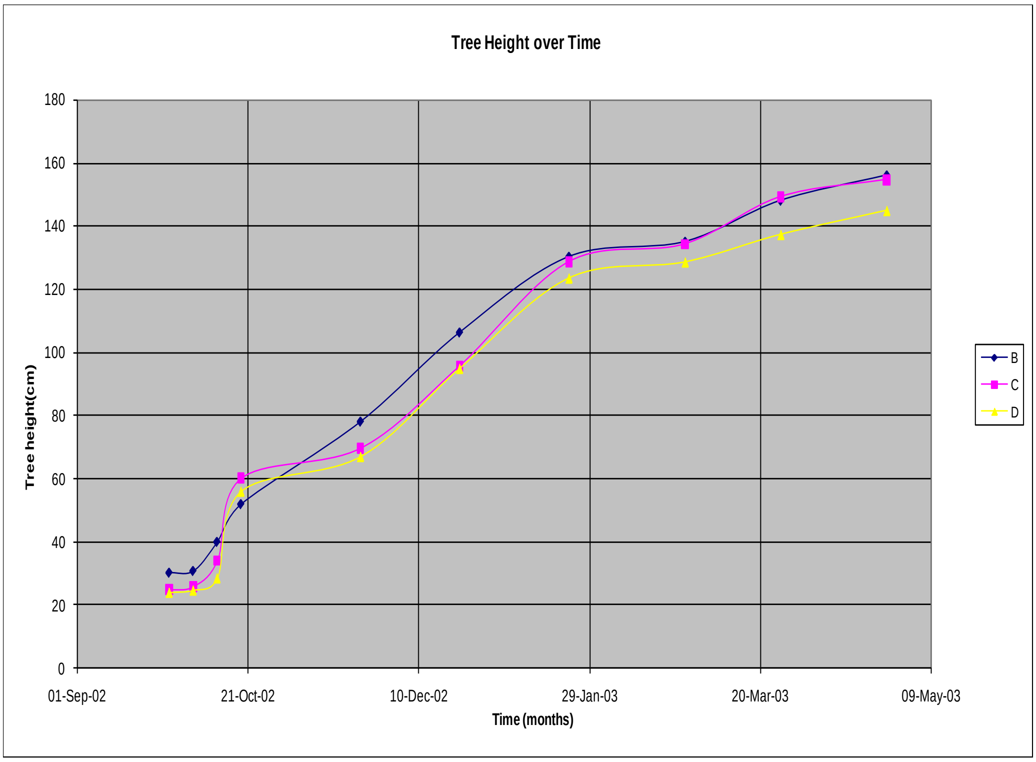


Figure 1.35 Tree diameter over time



In this observational trial, the results of the three blocks were very similar for both stem diameter and tree height (Figures 1.35 and 1.36).

Figure 1.36 Tree height over time

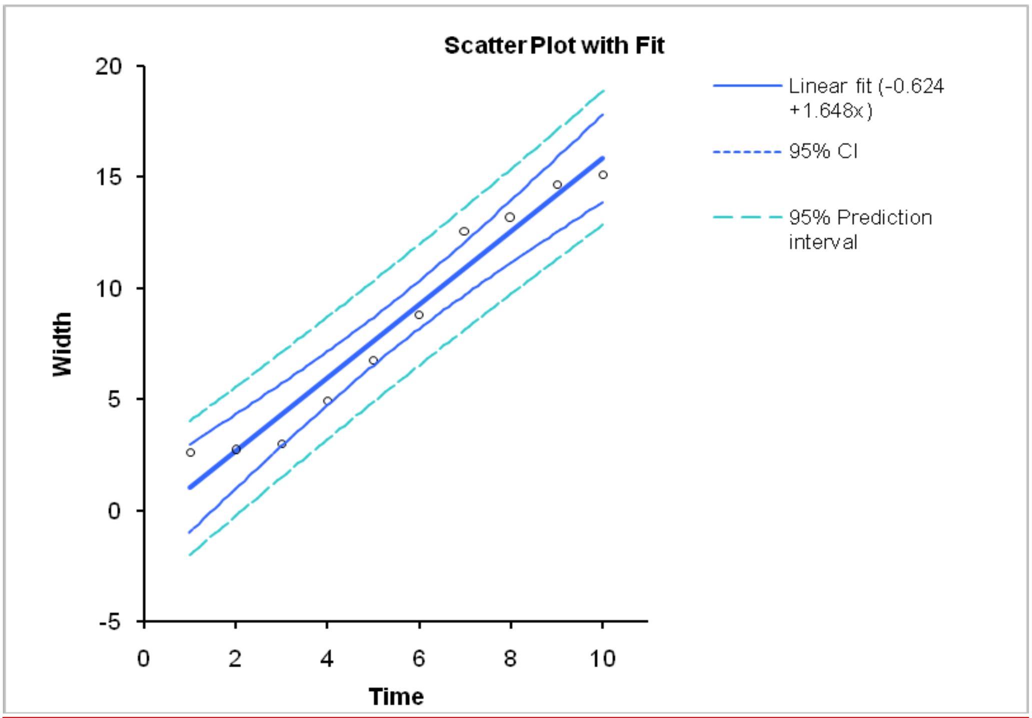


Figure 1.37 Regression curve of tree width

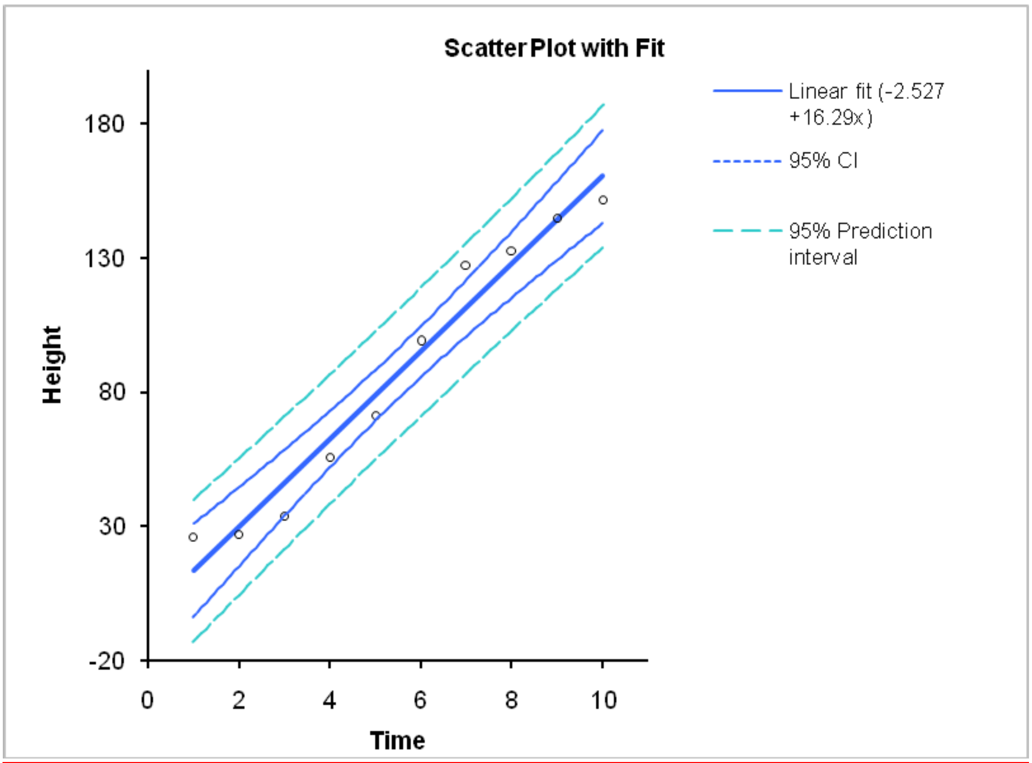


Figure 1.38 **Regression curve of tree height**

1. The results of the regression curve for stem width indicate a close fit (Figure 1.37) and for tree height also indicates a close fit (Figure 1.38). The R^2 value for stem diameter was .95 and tree height was .97.

2. The survival and growth of the trees indicate that it can been grown on a landfill environment

4.5 Discussion

In Trial 1(creeping grasses):

1. The above results indicate that *Cynodon dactylon* has a quicker rate of spread.

In Trial 2 (bunching grasses):

1. The harvesting of *Melinis minutiflora* could contribute economically for thatch production in the long term.

In Trial 3 (trees):

1. The successful cover of the grass and growth of the trees indicates that an eco system can be developed on a landfill and be integrated into the surrounding environments.

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CHAPTER 5. OVERVIEW

In order to ensure that aspects such as leachate seepage, storm water run off and erosion are controlled, it is important that ongoing site assessments are carried out in ensuring that good quality topsoil with good soil properties and structure is available to ensure continued growth of the vegetation. Infiltration of rain into the topsoil should be minimal once the grass has established. Neglecting to establish a correct vegetative cover over the capping could cause the capping to be destroyed, resulting in costs being incurred to rectify the ineffective vegetative cover. The pH, soil structure, water supply, moisture of the soil and nutrient availability associated with soil, establishment and survival of vegetation must be remedied upon appearance of a noticeable problem.

The success in the establishment of all five grasses in the grass trials with regard to survival rate, growth rate and rate of spread, indicated that the grasses used in the trials, and the plug technology used to plant the grass was effective on this site. This approach can be used to plant a mixture of grasses on the capped portion of the landfill to "green" a landfill. . The integrated approach to the closure requirements for the Umlazi Landfill was developed to achieve maximum grass cover on the capped areas and create an aesthetic acceptable site (Figure 2.37). The success in containing erosion on the slopes, gas emissions, "bald" patches and sparse vegetation as previously highlighted has been eliminated by a self –perpetuating grass species. The specific choice of these indigenous grass types in the graph trials and on the large scale planting and the tree trial clearly demonstrate that they are tolerant and suitable for other landfill sites of a similar nature and the Acacia-grass savannah could be established on the landfill.

The process of a multi – disciplinary approach to the Closure of the Umlazi Landfill was a successful achievement. The integration of the different disciplines, namely, Engineering, Botany, Grassland Science, Plant Pathology and Hydrology made the closure process less difficult to manage and implement.

The novel features of the process included:

a) The Engineering design was based on DWAF's Minimum Requirements Document (DWAF, 1998);

b) The construction of erosion protection berms on the long slopes prevented rainfall run-off from building up to levels that would cause serious surface erosion;

c) The construction of leachate seepage collectors around the southern side of the landfill managed landfill leachate effectively;

d) The directing of leachate back into the waste body and its containment was effective;

e) The establishment of a Passive Gas Management System at the top of the site vented gas from the landfill;

f) The five species of grass grew well despite a poorly structured soil type being used for the topsoil;

g) The two creeping and three bunching grasses were assessed for use on the landfill;

h) The grass plugs were successfully established despite the harsh conditions of the landfill, with all grasses establishing at greater than 90% survival levels;

i) The use of a soil moisture retainer in the planting phase may have improved survival of grass plugs;

Problems identified include the following: -

a) The emergence of landfill gas occurred on parts of the site, which resulted in the absence of grass in those patches.

b) The formation of soil clods inhibited root penetration of the grass, which resulted in stunted growth.

The Berea Red soil type used as the topsoil on top of the capping clay was extremely difficult to work in, as it is very sticky, thus making planting difficult, especially during periods of rainfall.

Future research should focus on long term sustainability of specific grass types in specific regions. The establishing of grass that would add economic benefit should be researched further.

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