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Disposal of Contaminated Construction and Demolition Debris and Hazardous Waste in Clayey Soil

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ABSTRACT

This project examines the design of a landfill on clayey soil for storing construction and demolition debris (C & D) and hazardous waste. The best practices in reducing C & D waste is to opt for recycling or reusing these solid waste products. However, in many cases these solid wastes can be contaminated by some chemical elements harmful to the human health and environment. This is also applicable for the case of hazardous wastes as they cannot be recycled. Thus, ground disposal using landfills is imperative in this case and could be one of the best solutions. This kind of disposal (i.e. using landfill) indicates how important the humans can improve the environmental quality of any region by disposing the waste in a safely and correct way. This project includes a geotechnical and geo-environmental design of a landfill for the disposal of contaminated waste in clayey soil. The site of the project will be located in the southern region of the Kingdom of Saudi Arabia.

The main objective of this project is to carry out a geotechnical and geo-environmental design of a landfill destined for the disposal of contaminated construction and demolition debris, and hazardous waste. The stratigraphy of the site of the project is composed mainly of clayey soil where the landfill will be founded.

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CHAPTER 1: INTRODUCTION

1.1 General

Integrated waste management is a way of tackling wastes through merging different policies of waste management and waste reduction. Waste reduction methods like composting and recycling are also part of integrated waste management systems implementing an integrated system of waste management is quite a complex process. To ensure a correct implementation of the system a comprehensive plan consisting of three priorities is required. The Three Priorities are:

a) Source Reduction, also known as waste prevention, aims at reducing unnecessary waste generation. Source reduction strategies may include a variety of approaches,
b) Recycling and Composting, Recycling is a process that involves collecting, reprocessing and recovering. While, Composting is the conversion of materials that are rich in nutrients to soil additives,
c) Disposal, in particular through the use of landfills and combustion, are the activities undertaken to manage waste materials that are cannot be prevented or recycled.

Construction and demolition debris (C& D) is generated when new structures are built and when existing structures are renovated or demolished. In other words, C & D waste consist of materials that are derived from activities such as; construction, demolition, development of structures, buildings, roads, bridges, surface cleaning, sewer systems and remnants of materials such as glass, slabs wood, and Asphalt. These materials are estimated to account for about 50% of the disposed waste stream.

Hazardous waste is defined as anything which, because of its quantity, concentration, or physical, chemical, or infectious characteristics may cause, or significantly contribute to, an increase in mortality; or cause an increase in serious irreversible, or incapacitating reversible, illness; or pose a substantial present or potential hazard to human health and the environment when improperly treated, stored, transported, or disposed of. Primary characteristics: ignitability, corrosively, reactivity and toxicity.

The best practice in reducing C & D waste is to opt for recycling or reusing these solid waste products. However, solid wastes can be contaminated by some chemical elements harmful to human health and environment. Moreover, hazardous waste is waste that poses substantial or potential threats to public health or the environment. Primary characteristics: ignitability, corrosively, reactivity and toxicity. In practice, ground disposal of such materials is imperative and could be one of the best solutions.

1.2 Project Objectives

The main objective of this project is to carry out a geotechnical and geo-environmental design of a landfill destined for the disposal of contaminated construction and demolition debris, and hazardous waste. The stratigraphy of the site of the project is composed mainly of clayey soil where the landfill will be founded. The design steps include the following:

1) Analyzing the different components of the site of the project.
2) Determining the maximum height of the landfill by verifying the following two principles: :
    a) Bearing capacity of the soil foundation, and
    b) Settlement of the landfill on the clayey soil.
3) Assessment of the slope stability of the excavated area which will accommodate the landfill.
4) Determining the minimum depth of the clay strata which should be adopted, during the ground excavation, to prevent the swelling of the clay layer caused by the hydrostatic water pressure.
5) Determining the rate of percolation of contaminated liquids contaminant through the ground layer located beneath the designed landfill.
6) Designing a permanent drainage system beneath the base of the landfill to prevent the raise of groundwater table.
7) Proposing and analyzing the different landfill accessories that are required for the disposal of hazardous waste such as drainage System, flexible membrane liners, multiple cover layers of different types, etc.)

1.3 Scope of the report

The present report is composed of five chapters. A detailed description of the project and a historical background is presented in chapter 2. The soil report is introduced in chapter 3 including site and laboratory investigations, and soil profile. Following that, the design of the landfill is given in chapters 4. The report is achieved by some specific and general conclusions.

CHAPTER 2: Literature Review

2.1. Introduction

Saudi Arabia annual total wastes coming from hazardous materials, demolition matter and construction site products are a primary source of wastes to the environment account for the only small amount of wastes. The nature of this material makes it tough to be recovered or even be recycled. For a waste form road demolition, it could be reused in another construction site, its other application is that it may be used as a backfill material in the rehabilitation of mining site. This kind of implementation is usually set aside for stuff in the excavation. The primary condition before such use of waste management is ensuring the necessity of environmental inertness to material and treatment. Recovering and recycling of building particular construction and demolition waste take in splitting elements from one another during construction, demolition and processing each material by its specific characteristics and possible uses. The Saudi Arabia Statistical data on the composition of the extensive material in C&D waste not very detailed. Some studies carried out on different experimental sites served as a source of relevant examples.

2.2 Construction waste and demolition

Construction wastes are usually non-hazardous (but in many cases hazardous) materials derived from activities such as; construction, demolition, development of structures, buildings, roads, bridges, surface cleaning, sewer systems and remnants of materials such as glass, slabs wood, and Asphalt. In recent years, the population and construction have increased drastically within the kingdom. This has resulted in millions of construction and demolition waste being generated, and it is steadily increasing, according to the information from SEPCO Environment and needs to be managed. The materials, which can reused to send to landfills.

This waste will differ from one construction site to next. Nevertheless, the merits in reducing recycling remain constant, and this is where the reuse of construction and demolition waste is among the main components of a viable development. When handling building and demolition of waste, the first measure to be considered is the reduction and the nature of the landfill. Here we seek to make a combined system to manage waste from construction and demolition.

The kingdom through companies like SEPCO Environment ensures that regulations and instructions are followed in the management of hazardous materials and are now designing rehabilitation of sites that have been contaminated. This waste material is numerous in regions within the urban centers in the Kingdom. A clayey soil consists of at list one sheet of soil that is cohesive and has been compacted to attain low permeability. The clayey soil in waste management landfill is used to provide a barrier between the material to be disposed of, and the hydrogeological environment through controlling seepage coming from a facility then offer support to the overlying facility components.

Construction on the clayey soil is done on a native soil, which has appreciated the level of particles that are clay-sized. When the clay is insufficient in the ground, it could be mixed with materials like bentonite to achieve the required texture. It can be superimposed by a single or many flexible membrane liners with latches collection system that will limit steady seepage state from the facility (Figure 2.1).

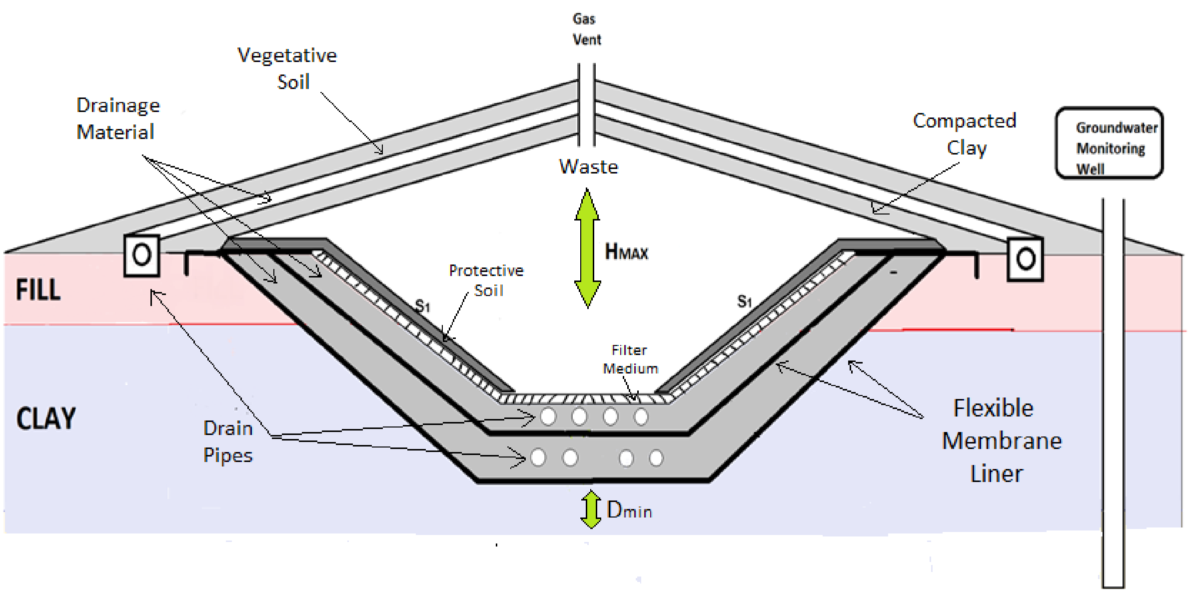


Figure 2.1. Cross section of an idealized clay liner system

A compacted clayey soil has a low hydraulic conductivity .the design in facilities for waste management is such that it allows the delay of leachate release for a longer period. Furthermore, to have enough structural stability for own stability and any other facility component that will lie above it. The application of clayey soil is not only limited to management of waste facilities; it can be used for the storage of water and construction of conveyance.

Information about the performance of clay soil ability in reducing seepage coming from the waste facility is very limited although it is used widely. Performace determination has been primarily based on outcomes from laboratory tastes on the permeability of compacted soils. Test from the laboratory have provided a substantial amount of data shows hydraulic conductivity attained with several soil structures, its method of compaction and how different types of soil materials can associate with permittivity change.

2.3 Hazardous Waste matter

The hazardous waste matter is any waste material that is viewed as toxic, reactive chemically, flammable or destructive. Chemically reactive waste is usually unstable and would react when exposed to another substance or on their own, Hazardous waste which is chemically reactive will blow up or produce dangerous fumes if they react with other compounds. A flammable easily catches fire, and a corrosive material will cause corrosion to other materials. Most hazardous waste comes from industries more so the petroleum and other chemical manufacturing sector. Common types of hazardous waste materials from industries include cleaning solutions; oil refinery waste water. Since hazardous was will cause enamors danger to the environment. Their disposal needs to be different from the nonhazardous wastes

Being that hazardous waste can be harmful in a variety of ways, it needs to be disposed of differently than non-hazardous waste. There are three chef methods for disposing of hazardous waste. First, you can put the substance in a sanitary landfill. Here the waste is buried underneath the ground or in big piles this method can also be used for the disposal of non-hazardous materials. Landfills for waste that are hazardous are build using a thicker, waterproof liners with a heavy-duty removal system for materials that are leaching. The there construction site is away from aquifers to minimize water contamination risks. Liquid Hazardous waste is usually put in ground impoundments; this is shallow holes on the ground that are lined with waterproof materials. After dumping the liquid wasted in the impoundment, it left to vaporize. Once evaporation has taken place, the remaining solid hazardous waste residue at the bottom of the impoundment is removed and taken to a landfill.

The last method is by deep-well injection; liquid waste substance is drained into a well created with a porous rock under the water table. Although waste disposal using the method is meant to last for long, occasionally the wells will leak or get damaged then waste pollutes the supply of water.

2.3.1 Types of Hazardous Waste

Although there are many types of hazardous was they can be classified into two categories, dioxins, and PCBs. The types of hazardous toxic chemicals Formed during the process of combustion is called Doxies. The can also be formed naturally by fires or volcanoes, but the largest emitter of dioxins are industries that produce herbicides. Doxines are Ejected into the atmosphere and are absorbed into the fat tissue of both human and animals and can lead to cancer

PCBs means ‘polychlorinated biphenyl’ it is another form hazardous waste substantial that has led to a massive amount of destruction. They are organic chemical manufactured by men used in several manufacturing industries then ejected into the surroundings. PCBs ejection was banned in 1979, but they disintegrate slowly and hence be found today, commonly in electrical appliances and insulation materials.

2.4 Integrated Waste Management

Dealing with waste materials has been a complicated issue for many years quite a percentage apply to waste management to manage the waste products. Waste management is the process in which the created waste material is collected and deposited in a manner so that the can reduce environmental degradation .waste management canals lead to the reduction of produced waste products in general and making use of the product wastes

The strategies to employ in waste management varies depending on the person applying it nowadays there is a better way of tackling wastes that combine bring the two opposing strategies together. The type of system is referred to as integrated waste management; it merges different policies for management of wastes and reduction of waste. Waste reduction methods like composting and recycling are also part of integrated waste management systems.

2.4.1 Priorities of Integrated Waste Management

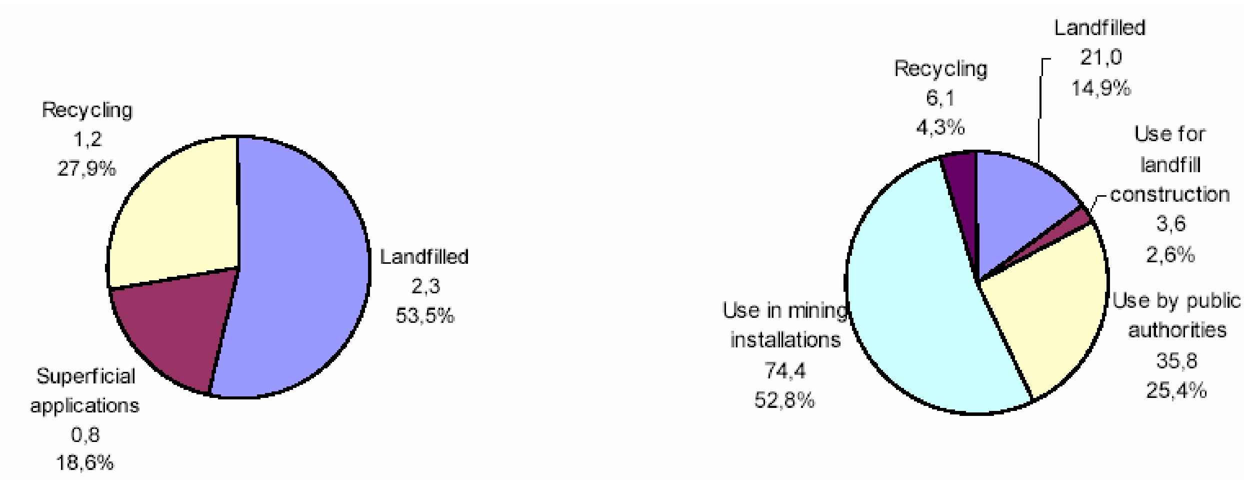
Implementing an integrated system of waste management is quite a complex process. You nee a comprehensive plan to make, its implementation include three priorities

First, involves the primary avoidance of materials that are toxic. This is done by enforcing the strict measures to industries requiring them to reduce the waste material that they release to the environment. It is achieved by encouraging industries to manufacture goods that last longer and lessen the number of materials that they use for parking. Recycling of the parking material invited to refuse disposal.The main target for this priority is large industries that have the ability to produce many wastes.

The main target for the second priority is small enterprises and single persons. Its primary focus is on prevention of secondary wastes and pollution. The major input in this is education. People have educated the importance of recycling and reuse of goods. The third priority focuses mainly on management of waste. Including waste treatment to decrease toxicity, waste incinerating and releasing smaller amounts of waste into the atmosphere for dispersal. Some analysis of the priorities it can be established that for waste management to carry on as efficiently as possible, the priorities need to be clearly followed, however, even if priorities are designed scientifically several countries including Saudi Arabia, still tend to concentrate more on waste management

2.4.2. Emission of waste material in the main cities in Saudi Arabia

A study in the emission of waste material in the main cities in Saudi Arabia revealed the following Figures (Figures 2.2):



Figures 2.2. Beackdown waste materials distribution (extracted from; landfill site design. published by the environmental protection agency)

In this study, concrete, blocks, and rubble coming from one or more materials are among the standard stuff. The different measuring techniques are because of the mixed materials, samples and regional differences in construction methods but highlight the requirement for standard classification of materials to avoid confusion among actors in the C&D waste recycling industry.

Kingdom of Saudi Arabia has adopted a similar European waste classification mechanism into law and categorizes every type and ranges of C&D wastes as shown below:

Table 2.1. Regulated Waste Listing (extracted from; Environmental management of landfill facilities, municipal solid waste and commercial and industrial general waste (January 2007))

Regulated Waste Listing			
Arsenic 5.0	1,4-Dichlorobenzene 7.5	Lead 5.0	Silver 5.0
Barium 100.0	1,2-Dichloroethane 0.5	Lindane 0.4	Tetrachloroethylene 0.7
Benzene 0.5	1,1-Dichloroethylene 0.7	Mercury 0.2	Toxaphene 0.5
Cadmium 1.0	2,4-Dinitrotoluene 0.131	Methoxychlor 10.0	Trichloroethylene 0.5
Carbon Tetrachloride 0.5	Endrin 0.02	Methyl ethyl ketone 200.0	2,4,5-Trichlorophenol 400.0
Chlordane 0.03	Heptachlor (and its epoxide) 0.0081	Nitrobenzene 2.0	2,4,6-Trichlorophenol 2.0
Chlorobenzene 100.0	Hexachlorobenzene 0.131	Pentachlorophenol 100.0	2,4,5-TP (Silvex) 1.0
Chloroform 6.0	Hexachlorobutadiene 0.5	Pyridine 5.0	Vinyl Chlor

The recycling procedure applied in this material are economical and straightforward. Recyclers mainly use wood for energy generation. Recovered concrete is limited in its reusability. So as to be employed in any other application materials must first conform These will give recyclers and other major contractor's vibrant suggestions about what will and that will not be done with any explicit material, likewise facilitating simple approximation of a C&D waste cost. A detailed understanding of waste material properties is very crucial to thorough recycling. The following Factsheets describe the unique contexts and properties of each the significant material in the waste stream, as well as the post-recycling, uses, both real and potential.

Chapter 3: Soil Report

3.1. Introduction

This chapter is concerned by the description of the site and laboratory investigations, soil report and ground profile of the site project. The information obtained in these investigations is used to design the landfill and the abutment foundation of the landfill for both variants (i.e. C & D waste and hazardous waste) in the clayey ground.

3.2. Nature and description of soils

The soil stratigraphy at the location of the two performed boreholes is composed of a granular to coherent fill horizon resting directly on the natural ground followed by the bedrock intercepted in the two boreholes. The stratigraphy of the natural ground is composed of a thick cohesive soil horizon composed manily by silty clay and a till consisting of silt and sand layers with some gravel up to the bedrock intercepted at depths 11.79 m and 12.66 m in boreholes BH-01 and BH-02, respectively (Table 3.1 and Figure 3.1)

Table 3.1: Stratigraphy of the ground in the two boreholes (SM group)

Boreholes	Eleven. (M)	Fill (M)	Silt Sand (M)	Till (M)	Rock (M)
BH-01	16.23	0 to 1.32 (16,23 to 14,91)	1.32-8.24 (14.91 to 7.99)	8.24 to 11.79 (7.99 to 4.44)	> 11.79 (> 4.44)
BH-02	16.53	0 to 2.59 (16,53 to 13,94)	2.59-9.46 (13.94 to 7.07)	9.46-12.66 (7.07-3.87)	> 12.66 (> 3.87)

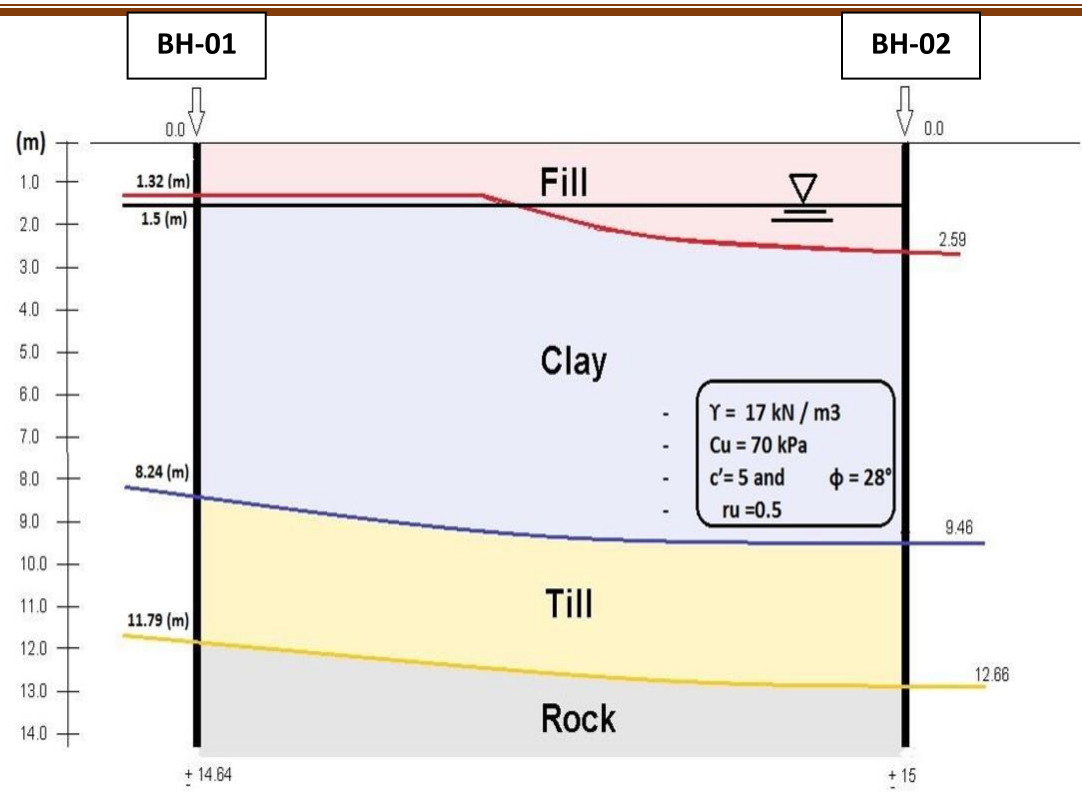


Figure 3.1: Stratigraphy of the site project (SM group)

3.2.1 Fill

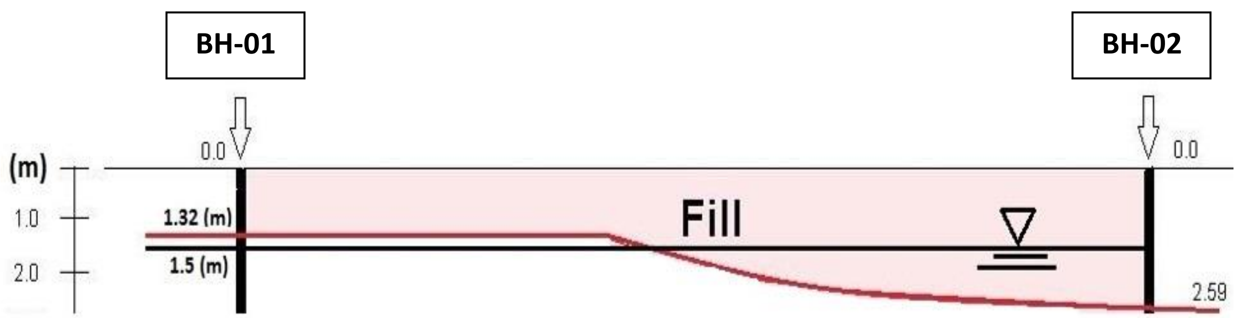


Figure 3.2: Fill Layer (SM group)

At the surface of the two boreholes, a fill from varying in composition from sand with little gravel and traces of silt to silt with little sand and trace of clay, or silt clay with traces of wood was crossed before reaching the natural soil. The backfill is generally of medium thickness at drilling BH-01, between 0 and 1.32 m. While at drilling BH-02, its depth is greater than 2.59 m.

The fill consists of sand, gravel, and silts in varying proportions and contains plant roots and wood debris. One Particle size analysis was performed on fill samples taken from drilling BH-02 between depths 0.61 m and 1.22 m. The tests results were summarized in the following Table 3.2. The results indicate that the particle size composition of the fill materials in the level of BH-02 drilling can be classified as sand with traces of silt. The sand proportion is about 93.3%, while; the proportion of silt is in the order of 6.7%. This information suggests that the backfill in the area of BH-02 is rather permeable. At the BH-01 borehole, the fill consists of two horizons: a layer of clayey silt with little sand followed by a layer of sand with trace silt.

The values of index *N* recorded in the backfill layer vary from 0 to 69. However, if the small values of index *N* measured in the fill in contact with the natural ground in the two boreholes are discarded, the compactness of the fill may be described as compact to dense. The result of the tests of the water contents carried out on samples taken at different depths in the fill are also summarized in Table 3.2.

Table 3.2: Summary of particle size distribution analysis and measurements of moisture content of the fill (SM Group)

Boreholes/ Samples	**Depth (m)**	**W (%)**	**Gravel (%)**	**Sand (%)**	**Silt (%)**	**Description**
BH-01; SS-02	0.61-1.22	43.57				
BH-02; SS-02	0.61 to 1.22		-	93.3	6.70	Sand with traces of salt
BH-01; SS-03	1.22 to 1.83	22.50				

3.2.2 Silty clay

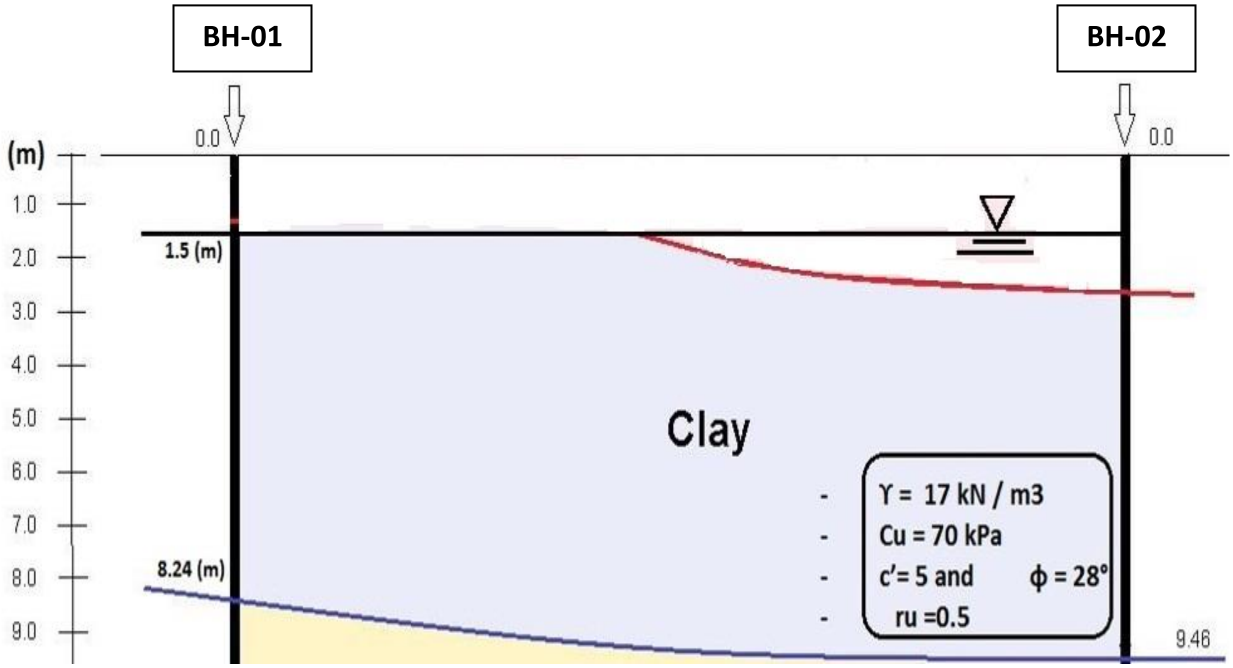


Figure 3.3: Clay Layer (SM group)

Beneath the fill layer in both boreholes, a layer of silty clay is intercepted. For simplicity, this deposit is noted in this report as a deposit of silty clay. This deposit is located between 1.32 to 8.24 m depth in the BH-01 drilling and between 2.59 to 9.46 m in the BH-02.

Two-particle size distribution analyses were carried out on samples taken from these layers indicate that the layer of silty clay is composed of 0.20 to 0.37% sand, 33.13 to 40.95% silt and of 58.85 to 66.5% of clay (Table 3.3).

Table 3.3. Summary of particle size distribution analysis (SM Group)

Boreholes / Sample	Depth (m)	Sand (%)	Silt (%)	Clay (%)	Description
BH-01; SS-08	4.88 to 5.49	0.4	33.1	66.5	Silt sand
BH-02; SS-10	6.10-6.71	0.2	40.9	58.8	Clay and silt

The results of the consistency limit tests and the water content measurements carried out on samples taken at different depths in this layer are summarized in Table 3.4.

Table 3.4: Summary of the water Content measurements and consistency limits (SM group)

Boreholes/ Samples	Depth (m)	W (%)	Liquidity limit (%)	Plasticity limit (%)	Plasticity index (%)	Liquidity index (%)	Classification unified (USCS)
BH-01/ SS-04	1.83 to 2.52	66.61	69.1	26.8	42.3	0.94	CH
BH-01/ SS-12	7.32-7.93	51.5	35.0	23.6	11.4	2.45	CL2
BH-02/ SS-11	6.71-7.32	57.8	43.0	23.6	19.5	1.76	CL2

The results of the consistency limit tests show that silty clay deposit is classified as CL2 or CH clay according to the Unified classification, with a liquidity limit of between 35.0 and 69.1%, a limit of plasticity between 23.6 and 26.8% and a plasticity index of between 11.4 and 42.3%. It is noted that the natural water contents of the silty clay are systematically close to and even above its limit of liquidity, which is indicative the silty clay is sensitive.

Seismometer tests were carried out in this clay deposit in both boreholes BH-01 and BH-02. The results obtained show a shear strength (C_u) varying between 58.94 and 87.83 kPa with an average of about 73.9 kPa. Based on the measured values of $C_{u,}$ the silty clay sand can be classified as a stiff layer.

The shear strength of the clay was also measured in the laboratory using a Swedish cone. The measured intact and reconstituted resistance values of samples taken from borehole BH-01 (between depths 1.83 m and 2.52 m) are 156.8 kPa and 2.93 kPa, indicating a high sensitivity of the clay of the order of 53.52 (greater than 40).

One Odometer consolidation test was performed on samples of this clayey soil taken from borehole BH-01 between depths 2.30 and 2.40 m. The results are presented in Table 3.5. Overall, the pre-solidification pressures of the clay samples tested are 310 kPa for CH silty clay between depths 2.30 and 2.40 m.

Thus, assuming that the groundwater level is 1.32 m deep at the right of the two boreholes, the over the consolidation of the clay would then be 310 kPa depending on the samples tested. These values, therefore, indicate that the silty clay layer is over-consolidated, with a degrees of over consolidation (OCR) of 9.68. Under an overload of about 102 kPa, the coefficient C_v is in the range of 1.3×10^{-3} m^2/s (4.1 m^2/year).

Table 3.5: Odometer test result (SM Group)

Sample	Depth (m)	W (%)	σ'_p (kPa)	σ'_{V0} (kPa)	Cr	Cc	e0	$\sigma'_p - \sigma'_{V0}$ (kPa)
BH-01 ; TS-04	2.30-2.40	66.14	310	32	0.0702	6.467	1.822	278

3.2.3 Till

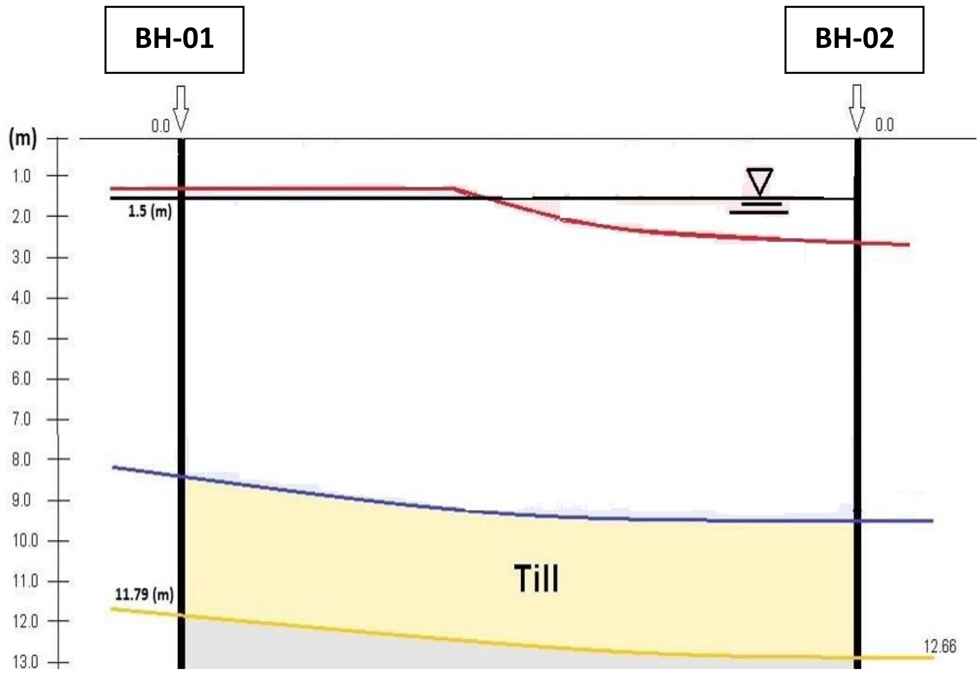


Figure 3.4: Till Layer (SM group)

Beneath the layer of silty clay in both boreholes, a deposit of silt and sand with little gravel is encountered having 3.20 to 3.35 m thick. One particle size analysis were carried out on samples taken from the till deposit. The tests results are summarized in Table 3.6.

The results indicate that the particle size composition of the deposits is composed of silt and sand with some gravel. The gravel proportions is situated between 11.64 and 12.31%, the sand proportions is between 37.98 and 43.5%, while the sediment fractions varied between 44.19 and 44.19%. The values of index *N* recorded in the layer vary from 7 to 15, which makes it possible to qualify the compactness of the deposit from loose to average.

Table 3.6 - Summary of Till Particle Size Analyzes (SM Group)

Boreholes / Sample	Depth (m)	W (%)	Gravel (%)	Sand (%)	Silt (%)	Description
BH-01; SS-15	9.15 to 9.76	19.47	-	-	-	-
BH-02; SS-16	10.68 to 11.29	-	11.64	37.98	50.38	Silt and sand with little gravel
BH-01; SS-16	10.68 to 11.29	11.11	-	-	-	-
BH-01; SS-17	12.20 to 12.33	-	12.31	43.5	44.19	Silt and sand with little gravel

The results of tests of the water contents carried out on samples taken at different depths in this layer are also summarized in Table 3.5 above. The natural water contents of the deposit range from 11.11% to 19.47%.

3.2.4 Rock

Under the till layer, the rock bedrock was drilled in boreholes BH-01 and BH-02. The latter is described as a dark gray shale, in which thin sandstone and siltstone are observed. The rock lies approximately at depths 12.2 m to 12.56 m. Fractures and joints, with angles either oblique or vertical were observed in all collected samples.

The quality of the rock base obtained from the RQD (Rock Quality Designation) index indicates that rock quality varies from weak to medium. The percentage of recovery achieved during drilling also reflects the variable quality of the bedrock, since it ranges from 75% and 97%. In general, rock is much fractured and of poor surface quality, while its quality increases more in depth.

3.3 Hydraulic conductivity of clay

The coefficient of hydraulic conductivity of the clay deposit is undoubtedly the most important parameter for the design of the landfill.

Thus, the coefficient of hydraulic conductivity of clay deposit in place was determined using the following methods:

A. By comparing the particle size disctributions.

B. Laboratory testing on samples of clay.

A Triaxial cell permeability test was performed on samples of clay collected from the two boreholes. The test was conducted on the SS-04 clay sample taken between the depths 1.83 m and 2.52 m in borehole BH-01. At this level, the SS-04 clay sample was classified as a CH-type clay, and hydraulic conductivity of clay test indicates a hydraulic conductivity of k of about 1.9 x 10^{-7} cm/s, which is less than the requirements of section 20 of the REIMER.

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CHAPTER 4: Landfill Design

4.1 Introduction

An engineered hazardous waste landfill facility is the final resting place for hazardous waste. It should be designed to prevent or control any effects of the waste on groundwater, surface water and air. An engineered hazardous waste landfill facility design includes a combination of natural protection and engineered systems that work together to contain or control the waste (CCME, 2006). A careful design must be implemented to the level of what the legislation states be build based on the required lifetime on which the design will be operational.

Several principals are considered in developing a landfill for hazardous wastes. Mainly there are two broad categories that must be factored into account when considering the design. These are; Firstly, The engineered components should be used in combination with natural protection to contain or control the escape of contaminants for the contaminating lifespan of all wastes.. Secondly the facility should be designed to not degrade the quality of groundwater or surface water such that they fail to meet a reasonable use for the water resource. A design which fully eliminates waste percolation is ideal, but several functions of this kind of concepts must be deliberated. Most hazardous waste landfill sites are designed using this approach.

Since the construction and demolition debris considered in this project, contains hazardous materials, this project will demonstrate a single landfill designed to be applicable for the disposal of the two types of waste: hazardous and C & D waste.

4.2 Landfill Design

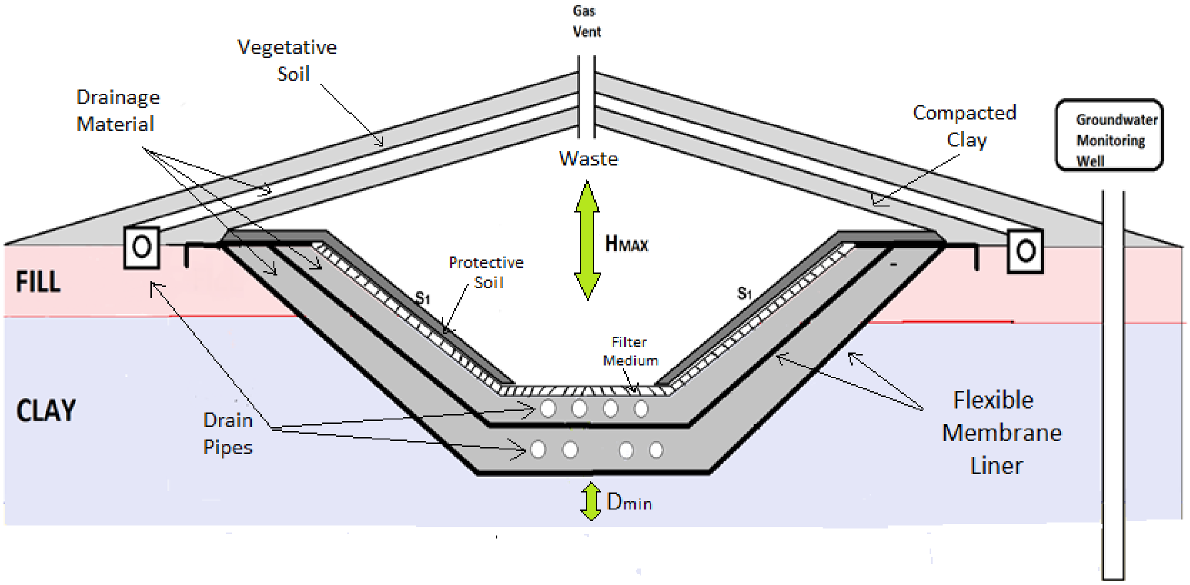

Figure 4.1: Configuration of the landfill

Figure 4.1 clearly demonstrates the configuration of a well-designed engineered hazardous waste landfill that has the ability to serve as long as the contaminating lifespan of all the waste that are considered for this landfill. Accomplishing this task requires numerous measures that needs to be taken.

These measures are divided into two main parts which are: Firstly, the landfill's ability to withhold the heavy materials that are disposed in the weak clay layer. Secondly, the landfill should be designed in a manner that does not degrade the quality of groundwater or surface water or severly affect the envirnomental quality of the surronding area.

Each part is divided into sub-parts that will explained individually as this chapter moves onn beginning with the parameters which needed to be calculated in order to satisfy the requirement of the first part.

4.2.1 Net Bearing capacity

Bearing capacity q_u is used to refer to the capacity in which the soil can carry a load. Ground will continue to support a given load until it attains a certain level, this point is called the ultimate bearing capacity, this is the minimum amount of gross pressure that will result in shear failure of the soil supporting the structure just immediately below the foundation.

The net ultimate bearing capacity (q_{un}) is defined as the ultimate bearing capacity less the stress caused by the ground surcharge up to the foundation level. Therefore:

$$q_{net(u)} = q_u - \gamma D_f$$

where, D_f is the depth of the footing,

The ultimate bearing capacity of a foundation can be determined by the Meyerhof equation:

$$q_u = c\, N_c\, F_{cs}\, F_{cd}\, F_{ci} + q\, N_q\, F_{qs}\, F_{qd}\, F_{qi} + \frac{1}{2}\, \gamma\, B\, N_\gamma\, F_{\gamma s}\, F_{\gamma d}\, F_{\gamma i}$$

From the soil report it has been established that the clay has these following characteristics: C_u = 70 kPa, φ = 0 and γ = 18 kN/m^3 ,

$$q_{all} = \frac{q_u}{FS}$$

The factor of safety in general can be taken FS = 3 and after applying the factor of safety on the bearing capacity, The net allowable bearing capacity was found to be 180 KPa.

Careful planning should be done in the design of the landfill so that the total pressure that will be exacted by the landfill contents should not exceed this net allowable bearing capacity.

Since the foundation of the landfill goes deeper into the water level especially during the rainy season this can affect the bearing capacity since it reduces with increase in saturation, the excellent drainage facilities should also be put into consideration to avoid the underlying clay soil from being saturated. The impervious base further prevents the saturation of the clay soil.

4.2.2 The Minimum Depth Beneath the Excavated Area to Prevent Swelling of the Clay Layer

The clay water content and swelling ability relationship are very nonlinear. Usually, for dry clay, its ability to swell will decreases speedily with an increase in the content of water. In addition, With an increase in the content of water the water station rate decreases and finally leading to disappearing of the swelling ability at the point where the clay is also fully saturated.

The clay initial moisture content determines its swelling ability, in the final moisture content it is usually assumed to be already saturated hence less heavy.wet clays have a lower ability to swell as compared to dry clay liner.this is why in places that have a higher water table swelling risks are less. Clay liner on top of the ground water table is almost saturated because of the capillary action whereas clay liner below the ground water table is submerged already.

The compressional force that is applied from the external source of unsaturated samples of clay will result to decrease in the sample volume. There is a relationship among the swelling pressure, the content of water, clay particles and activity of clay. It is a very complicated relationship to be derived mathematically, hence, numerous types of research approximate this relation from the experimental results applying different methods such as multivariable regression and much more.

The minimum depth to prevent swelling is the depth that corresponds to the ground water level. If the depth is deeper into the ground water level, it will result in more water infiltrating the clay liner while upwards results to less water. This is found from the experimental procedures that will calculate the vertical and the horizontal strains that the landfill will exert on the clay liner in the foundation.

Four meters is the optimum depth of the clay layer beneath the base of the landfill in which the effect of pressure will also be optimum.

4.2.3 Settlement of the clay

The landfill will have to undergo settlement due to the pressure exerted on the base by the overlaying material. Settlement of clay liner is usually deferential and can be characterized by the distortion ∆S. This is caused by the stress exerted vertically on the landfill by the heavy disposed materials. One of the project's main objectives was to determine if it is feasible to construct a landfill on a clayey soil that has the capability of withstanding heavy C&D wastes. Meaning that finding and verifying the settlement is a major problem that needs expert analysis and mathematical equations that have been used in practice before to find this crucial parameter.

A detailed study was conducted to determine which formula this project is going to use. The study included: Statistically analyzing the different results obtained from different formulas, focusing on the formulas that gave results similar to other formulas, looking up which formulas are used the most in practice and taking into account the supervisor's judgment, it was concluded that the formula issued by Braja M. Das was the one that will be used in this project. The formula is:

$$\Delta S = \frac{C_c}{1 + e_o} \log \left(\frac{P_2}{P_1} \right) H$$

***C_r* = Recompression index**
***P_1* and *P_2* are applied pressure on a given point before and after the application of the foundations (*$P_2 = P_1 + \Delta P$*)**
e_o = Void ratio

(Das, 1999)

The settlement is a result of the clay layer consolidation. However, there are two other factors that are capable of affecting the settlement of the clay layer, which are; the final cover and the vertical depth of a landfill. These two factors are among the most important considerations in the landfill design.

4.2.4 The Slope Stability of The Landfill

Taking into account numerous researches about the slope stability of projects similar in shape to this project, it has been established that the maximum slope for the design of any foundation is 4H:1V, this is considered a moderate slope. Setting up a linear structure with this angle of the slope will offer steadiness that has a minimum safety factor of about 1.5.

Regarding the method used to verify this number, an analysis was conducted using the GEO-Studio software which has the option of verifying slope stability using the GEO-Slope feature.

Four different situations were analyzed using the Geo-Slope, which are :

- 3H : 1V (without earthquake)
- 3H : 1V (with earthquake)
- 4H : 1V (without earthquake)
- 4H : 1V (without earthquake)

Each situation was analyzed separately as demonstrated in the figures below, with a table of results being presented after the analytical figure of all the situations.

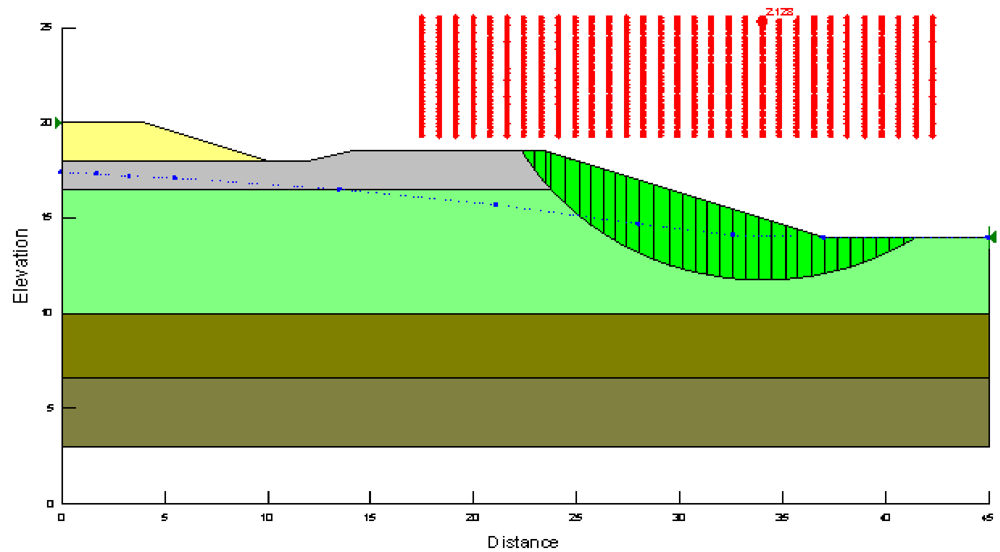

Figure 4.2: Slope Stabillity Calculation 3H : 1V (without earthquake)

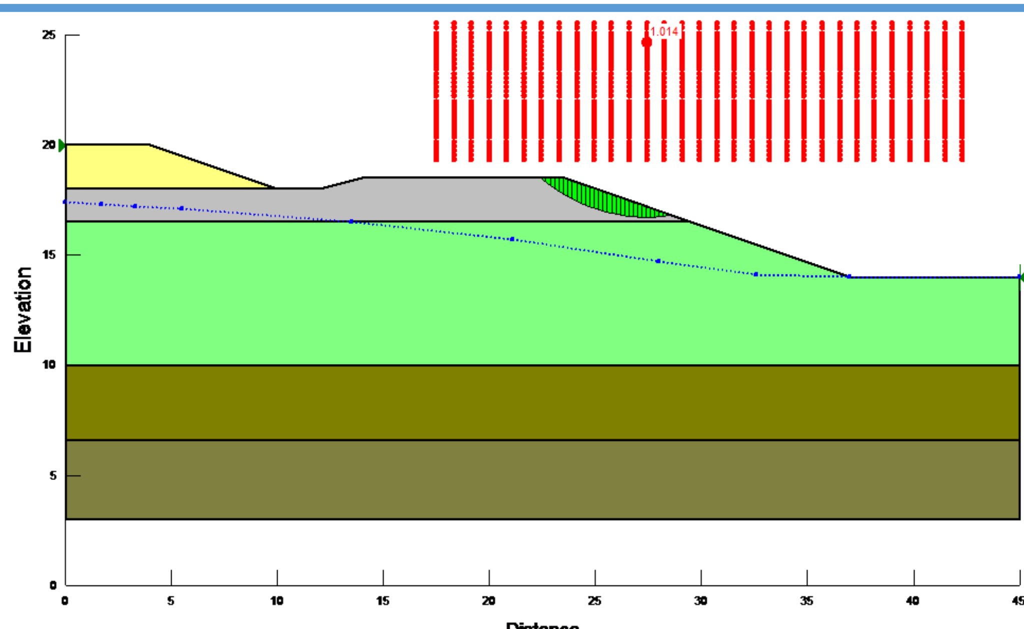

Figure 4.3: Slope Stabillity Calculation 3H : 1V (with earthquake)

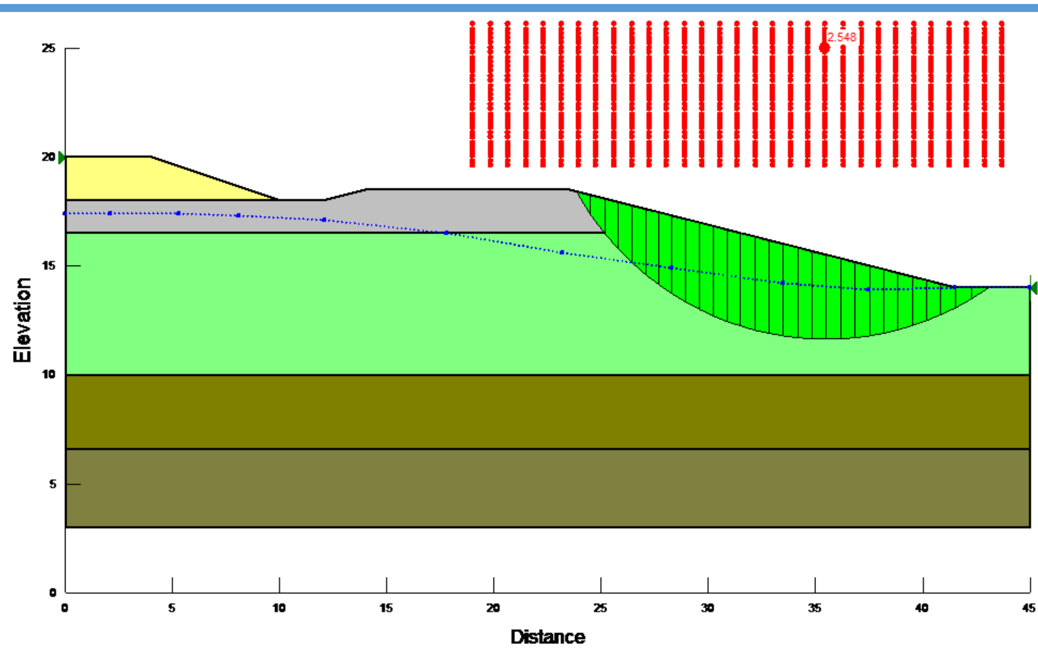

Figure 4.4: Slope Stabillity Calculation 4H : 1V (without earthquake)

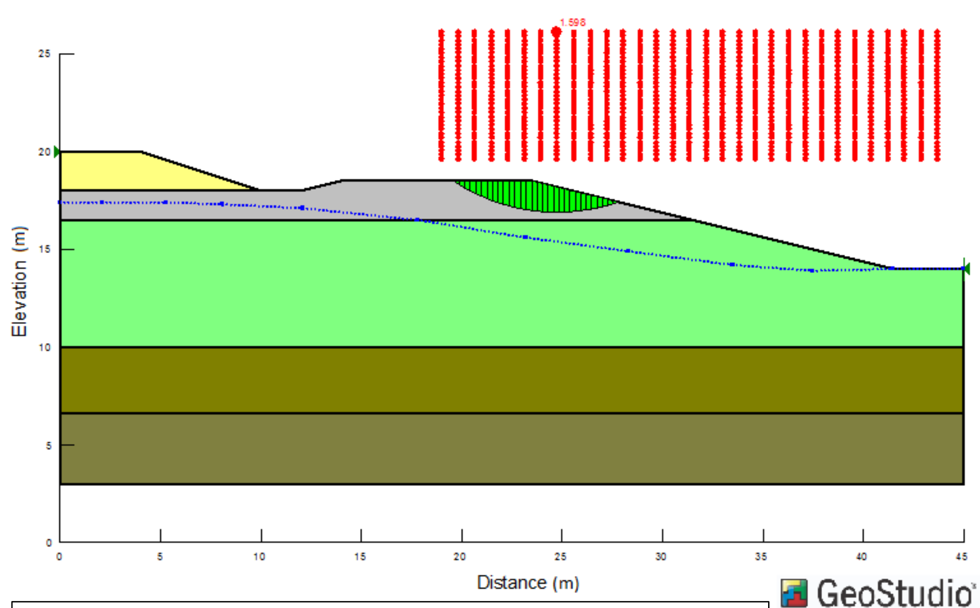

Figure 4.5: Slope Stabillity Calculation 4H : 1V (with earthquake)

Table 4.1. Slope Stability Result.

Slope Dimension	Slope Stability	
	With Earthquake (FS > 1.1)	Without Earthquake (FS > 1.3)
3H : 1V	1.014	2.128
4H : 1V	1.598	2.548

While analyzing the results of the slope dimension: 3H:1V, It is shown in the table above that this slope dimension doesn't meet the allowable factor of safety for stability with earthquake. This is considered a steep slope, for this case other variables are taken into considerations. The stabilizing material should be added to make it stronger and be able to resist erosion. For this case, the laying of the granules will be more focused on thickness to prevent erosion and it also results in more maintenance procedures and it will be difficult to lay the materials at the bottom of the landfill foundation.

For these reasons, the landfill design should be limited to a slope steepness of 4H:1V. There are other benefits that come with the construction on a slope that has ≤ 4H:1V: this includes

1. Natural appearance.
2. Reduced prospect for erosion-related destruction on the foundation.
3. Less maintenance is required for the cover materials.
4. Easier laying of the liner materials and any other layers forming part of liner system.
5. Preparation of subgrade and compaction is made easier.

4.2.5 Drainage system

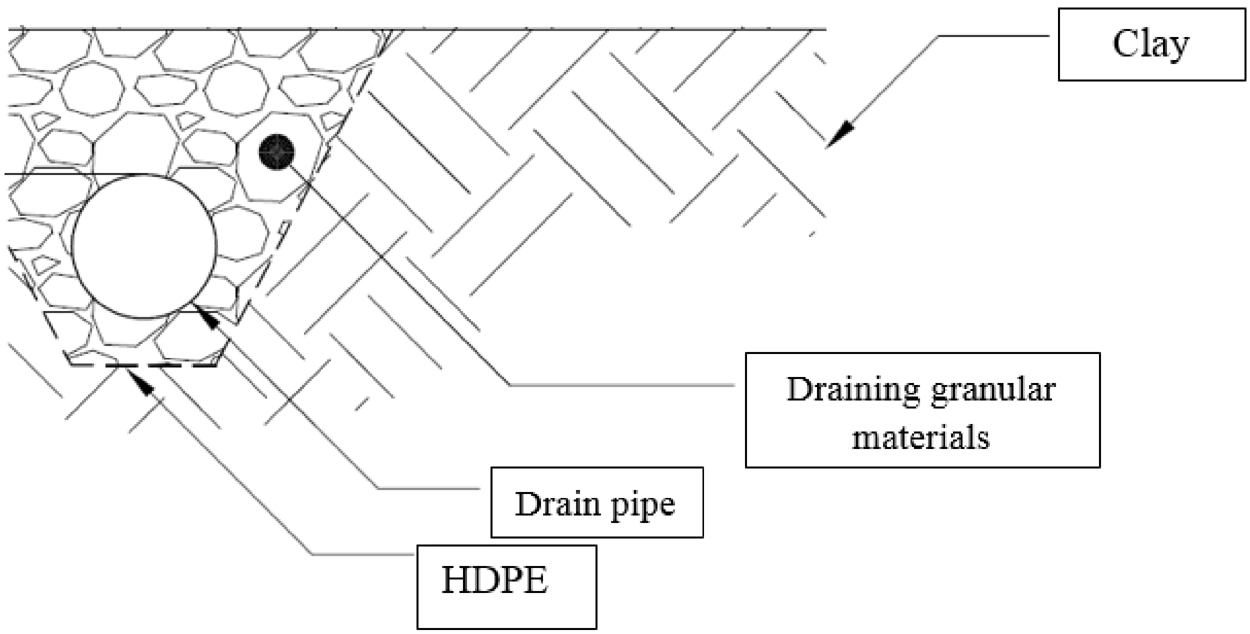

Figure 4.6: Draining System

It was found that the groundwater level is located at a depth of about 1.5 m. Therefore, since the depth of the landfill is below the depth of 1.5 m, it is recommended to provide a permanent long-term drainage system at the perimeter of the sides and below the base of the landfill. Generally, permanent drainage is proposed as a required means or as a preventive means. In this study, and given that the groundwater level is at about 1.5 m, required drainage is suggested, and is summarized as follows:

1. It is recommended that the peripheral sides and base of the landfill be waterproofed by means of a suitable coating or membrane and that a collection / pumping system of the infiltration water should be installed.
2. Directly under the base of the landfill, place a granular cushion, at least 300 mm thick, of granular materials meeting the particle size requirements of a 0-20 mm crushed stone compacted at least 95 % Of the maximum dry bulk density of the material, as determined in the modified Proctor test. This stone must be free of pyritic materials susceptible to swelling by Culpability.
3. To ensure the segregation of granular materials and that of the embankment, the use of a geotextile is desirable.
4. Provide a perimeter drainage system consisting essentially of 100 mm diameter drain pipes. The drain pipes must be installed around the structure of the projected landfill. They must be wrapped by a layer of crushed stone and coated with filtering membranes.

5. Installation of a sump at the corner located in the direction of percolation of the groundwater (the collection corner of the waters of the peripheral drains). The sump includes a sump pump and a drain hose. The sump collects water from the drains around the periphery of the base and sides (peripheral drainage). The drying pump is activated automatically when the water in the sump reaches a certain threshold (a certain level). It should be pumped to the surface and drain on the ground. Alternatively, water can also be pushed out to the municipal sewer.
6. In the case of drainage of the sump in the municipal sewer, an anti-return valve must be provide. It is a device was prevents sewage from an overloaded main sewer branch under the base of the landfill. The flap closes automatically when the sewage is discharge. A suitably installed valve must be located so that the discharge is blocked and that it does not find an outlet elsewhere in the base. It must be accessible at all times.

4.2.5.1 Pumps and Sumps

Pumps result in a more rapid discharge of water out of the landfill. Sump pump capacity is also a major factor to consider when designing a sump. If a small capacity pump is installed, then the ability of the sump will have to be more to compensate the pump size. It is important for the sump to be capable of packing the anticipated capacity of leachate, which is projected to move in the sump between every pumping cycle. These Sump pump frequencies may be automatically set by presetting sequence periods of the pumps. Otherwise, if rates of flow are random, pumps may be put to turn on when the leachate reaches a programmed level automatically. Further features to reflect when designing a leachate sump are the maintenance of sump and pump breakdown. Leachate is characteristically drained by a group of pipes that channel towards the sump by gravity. After it is gathered in the sump, the last phase is pumping it out into a truck for elimination offsite, or into a storage tank or treatment facility. An automatic pump that pumps away the infiltrate water from the landfill will allow the landfill to be dry at all time and reduce the cost of maintaining the landfill.

4.2.5.2 Pump Size

The volume of water which is expected in the sump determines its area and pump sizes, also the pump capacity and the least drawdown of the pump. The sump should be sufficient to stock the maximum quantity of water anticipated between every pump sequence, plus an extra amount equal to the capacity of the least drawdown of the pump. When establishing the sump size, the landfill operators must take consider the area for conducting examinations and maintenance. Larger sump in places with high perspiration will allow the landfill to drain away the water as fast as possible hence resulting to a dry landfill. This in turn will reduce the contamination of the ground water.

4.2.6 Anti-Overflow Systems

High precipitation leads the drainage system to overflow. This will result in the movement of the contaminated water in a backward direction. This is hazardous since it may contaminate the ground water. This is avoided by installing the following:

4.2.6.1 Non-Return Valves

Non-return valves are used with the drainage piping system to prevent the prospects of the draining water from moving in an opposite direction. The valve may be placed in horizontal or vertical positions, the valves result in the water moving in only one direction under gravity. This reduces the costs of maintaining the landfill. Moreover, the landfill will be dry at all times.

4.2.7 Liner system

Liners in Landfill are intended to form a barrier in the middle of the waste, especially hazardous waste and the surrounding environment, therefore draining the leachate towards collection than to treatment areas. In addition to preventing the leachate from seeping into the groundwater, the liners serve another purpose, which is to prevent landfill gas from migrating out of the landfill below grade there are three arrangements of liners, which are:

- Single liner.
- Double liner.
- Composite liner.

Liner Collection is founded on the compatibility of chemical, characteristics of stress-strain, permeability, and survivability. Single liner one-liners mainly consisting of clay liner, geosynthetic clay liner, and geomembrane. The Single liners can be used in landfills that contain debris from construction and demolition. Clay liner availability is easy and is robust. Manufactured geomembranes are made from polymers like as Thermoplastics. Crystalline thermoplastics, thermoplastic elastomers. However, Due to the hazardous waste that will be disposed of in the landfill, It has been decided that double liners made from the material: High Density Polyethylene (HDPE), are the best choice for installment. The liners will be installed in the following manner as the figure shows:

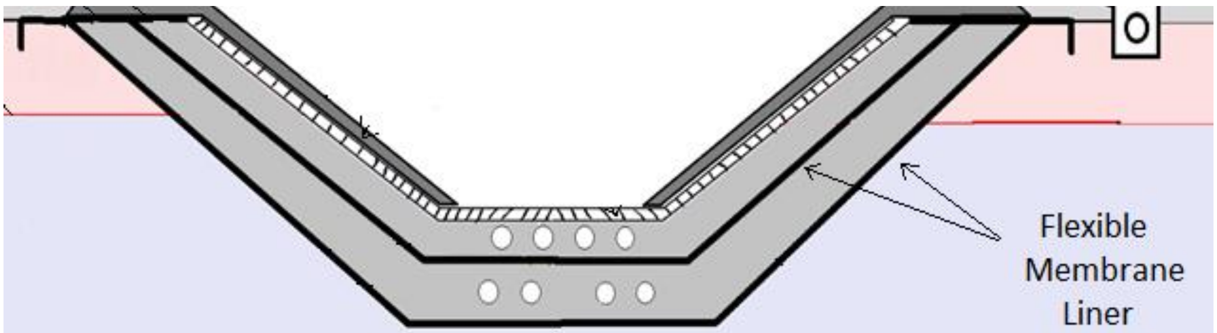

Figure 4.7. Flexible Membrane Liner

Equipment 4.1

4.2.8 Gas monitring system:

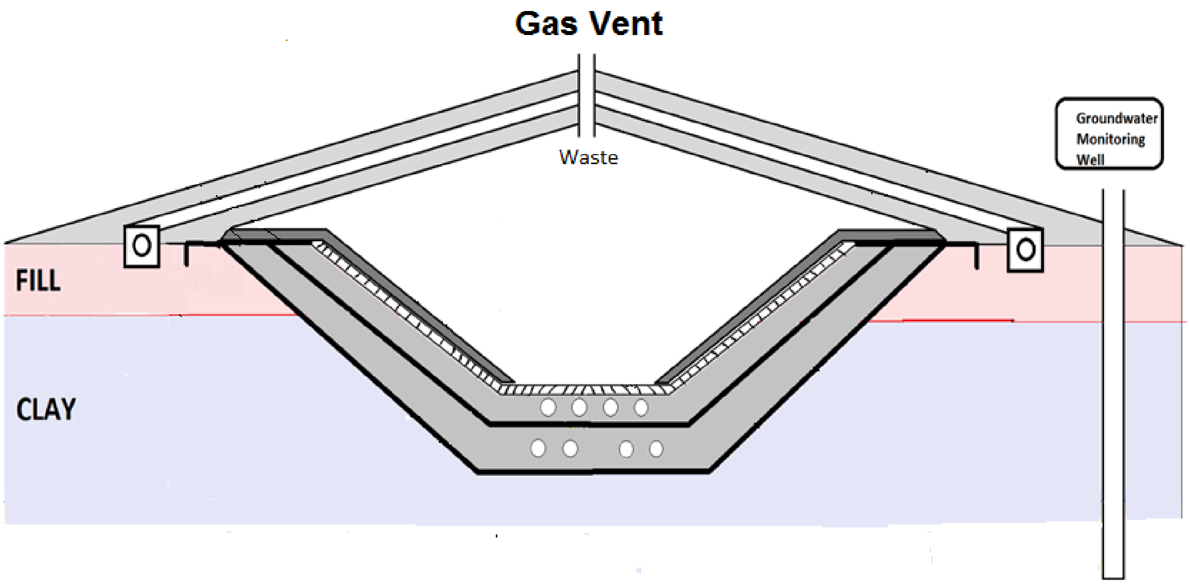

Figure 4.8. Gas monitring system

4.2.8.1 General overview of the gas monitoring system

Landfill gas is generated by the decomposition of organic materials in waste deposited at the landfill. Typically, the gas is a mixture of methane (up to 65% by volume) and carbon dioxide (up to 35% by volume). It also contains many minor constituents at low concentrations (typically less than 1% volume contains 120-150 trace constituents).

The rate of gas generation at a landfill site varies throughout the life of a landfill and is dependent on several factors such as waste types, depths, moisture content, degree of compaction, landfill pH, temperature and the length of time since the waste was deposited.

1- <u>The Landfill Directive requires the following:</u>

a) That appropriate measures are taken in order to control the accumulation and migration of landfill gas.

b) That landfill gas should be collected from all landfills receiving biodegradable waste and the landfill gas should be treated and used. If the gas collected cannot be used to produce energy, then it should be flared.

c) That the collection, treatment and use of landfill gas should be carried on in a manner which minimizes damage to or deterioration of the environment and risk to human health.

2- <u>The Landfill gas poses various risks including:</u>

a) Flammability and explosion risks.

b) Asphyxiation risks.

c) Potential health impacts due to many minor constituents present at low concentrations.

d) Odor impacts from trace constituents, e.g. hydrogen sulphide and mercaptans.

e) Environmental impacts due to global warming potential of methane and carbon dioxide.

f) Vegetation dieback.

g) It is important therefore that landfill gas is properly monitored and controlled.

3- <u>The reasons for monitoring landfill gas may be summarized as follows:</u>

a) To ensure the facility is compliant with its waste license.

b) To ensure the facility is not causing environmental pollution.

c) To ensure the facility is not posing a risk to human health.

d) To compare actual site behavior with expected/modelled behavior.

e) To assess the effectiveness of any gas control measures installed at the site.

f) To establish a reliable database of information for the landfill throughout its life.

4.2.8.2 Landfill Gas Safety

The flammability, toxicity and asphyxiate characteristics of landfill gas requires personnel involved in the monitoring, operation, construction or any other aspect of a gas management system to be adequately trained. A safe system of work with rehearsed emergency procedures should be developed and undertaken before any monitoring of landfill gas is carried out.

Stringent safety measures should be incorporated into equipment for landfill gas monitoring and all electrical equipment should comply with appropriate relevant standards.

4.2.8.3 Landfill Gas Within and Outside the Waste Body

Monitoring should take place both within the waste to identify both the quantity and quality of gas generated and outside of the waste to assess whether gas is escaping in an uncontrolled manner. The methane content of landfill gas is flammable, forming potentially explosive mixtures in certain conditions, resulting in concern about its uncontrolled migration and release.

Landfill gas can move in any direction within the waste body and may migrate from a site. The potential for gas migration will depend on the gas quality and volume, the site engineering works, geological characteristics of the surrounding strata and on man-made pathways such as sewers, drains, mine shafts or service ducts.

The monitoring programme should commence prior to waste disposal and should continue until the biodegradation process has ceased. It is important in the case of new sites to get naturally occurring background levels of methane and carbon dioxide, which may vary depending on local geology. These levels should be established prior to the commencement of landfilling at the site.

4.2.8.4 Monitoring Locations

1- Within the waste body:

The Landfill Directive requires that gas monitoring be representative for each section of the landfill. It is recommended that the locations for gas monitoring within the waste body should be at a density of at least one monitoring point per cell in lined landfills and one monitoring point per hectare of filled area in unlined landfills.

Monitoring wells constructed within the waste body are for monitoring landfill gas concentrations and fluxes within the waste. These wells should be independent of the gas collection and extraction system and used as dedicated monitoring points for ascertaining the state of degradation within the waste body and how it responds to environmental conditions.

The monitoring of collection wells and associated manifolds is undertaken to determine the effectiveness of the gas extraction and collection system and to facilitate the balancing of the extraction and collection system. Collection well monitoring is necessary for the efficient management of an extraction system.

2- Outside the waste body:

The monitoring of boreholes outside the waste body is essential to detect any gas migrating from the waste body and to demonstrate the efficient management of gas within the site. Boreholes for monitoring gas outside the waste body may be located both on-site and off-site.

The spacing and location of gas monitoring points outside the deposited wastes should be determined on a site-specific basis. A detailed exposure and risk assessment should be undertaken with potential pathways and receptors identified. Some factors, which need to be taken into account when selecting monitoring locations, include:

a) Quality and volume of gas being generated.
b) Geology of the site.
c) Type of waste.

d) Containment measures adopted, e.g. landfill lining or capping.
e) Proximity of buildings and developments to the site.
f) Permeability of the waste.

The spacing of the monitoring locations is unlikely to be uniform around the site. It is probable that more monitoring points would be needed near building developments, where there are changes in the site geology and where there is no containment.

It is recommended that monitoring boreholes are located a minimum of 20m from the waste body and should be installed at least to the depth of the maximum depth of waste within the waste body. Where appropriate, groundwater-monitoring boreholes may also be used for gas monitoring. Landfill gas monitoring should also be undertaken in any buildings on the site. For some sites, this may take the form of a permanent monitoring system.

4.2.8.5 Pressure monitoring

Atmospheric pressure should be measured regularly in order to aid understanding of gas pressure readings within the waste body. Rapid drops in atmospheric pressure can cause the pressure of landfill gas to rise significantly above that of ambient atmospheric pressure, resulting in possible migration. The monitoring of pressures within the waste body may give an indication of the likelihood of gas migration occurring.

Inversely, a sudden rise in atmospheric pressure after a prolonged low-pressure period can lead to an artificial depression of the monitored methane concentration. At some landfills very frequent recordings of barometric pressure trends may be necessary so that fluctuating methane concentrations can be related to barometric pressure conditions.

4.2.8.5 Monitoring Frequency and Parameters for Analysis

The frequency of monitoring required is site specific and should be established from the results of the investigations. The frequency will depend on a number of factors, such as:

a) The age of the site.
b) The type and mix of waste.
c) The possible hazard or nuisance from gas escaping from the site.
d) The results of previous monitoring.
e) The control measures that have been installed.
f) The development surrounding the site.
g) The geology of the site and its environs.

1- Monitoring should be increased when:
  a) increases in gas quantity or changes in gas quality are observed during monitoring
  b) control systems are altered by landfill operations
  c) capping of part, or all, of the site takes place
  d) pumping of leachate ceases or leachate levels rise within the wastes
  e) buildings or services are constructed within 250 m of the boundary of the waste.

2- Monitoring should continue until either:
  a) The maximum concentration of methane from the landfill remains less than 1% by volume (20% LEL) and the concentration of carbon dioxide from the landfill remains less than 1.5% by volume measured at all monitoring points within the wastes over a 24 month period taken on at least four separate occasions, including two occasions when atmospheric pressure was falling and was below 1,000 mb
  b) An examination of the waste using an appropriate sampling method provides a 95% level of confidence that the biodegradation process has ceased.

4.2.8.7 Trigger Levels

Unless otherwise determined from baseline monitoring results, the trigger levels for emissions of methane and carbon dioxide in boreholes outside the waste body are shown in Table 4.2. These trigger levels for landfill gas emissions also apply to measurements in any service duct or manhole on, at or immediately adjacent to the landfill.

Table 4.2: Landfill gas trigger levels for boreholes outside of the waste body (EPA).

Parameter	Trigger concentration
Methane	Greater than or equal to 1% v/v or
Carbon dioxide	Greater than or equal to 1.5% v/v

If either of these trigger levels are attained within buildings then the affected areas should be evacuated and the emergency services notified. Monitoring should be undertaken to identify the point of gas ingress and control measures should be implemented to prevent further ingress. Methane has explosive and flammability risks and carbon dioxide is an asphyxiate.

4.2.8.8 Monitoring Surface Emission

The surface methane emissions of landfill gas from a site cap and from other parts of a landfill should also be monitored from time to time. This gives a measure of the methane escaping to atmosphere and checks the integrity of the gas management system and the capping system.

A walkover survey may be undertaken using a portable flame ionization detector (FID) held as close to the surface of the landfill as possible. More detailed measurements of changes in methane concentrations above a specific small area of the landfill surface may be undertaken using a flux box. These flux boxes are most suitable for use on completed areas of a landfill site. They will produce high flux measurements if used on waste that is not capped or covered by an intermediate layer of soil or other inert material.

It has been established that on a capped landfill with active landfill gas abstraction that a limit value of 1 x 10-3 mg/m2 /s of methane surface emissions or better can be achieved (Environment Agency, 2002a). Monitoring of other surface emissions such as hydrogen sulphide or non-methane volatile organic compounds (NMVOCs) should also be undertaken if required.

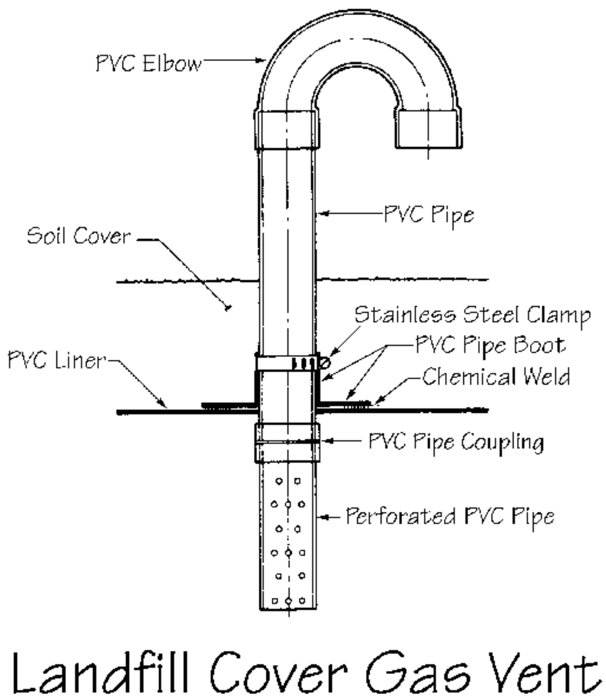

Figure 4.9: (web site 'geo memberen.com')

4.2.9 Groundwater Monitoring System

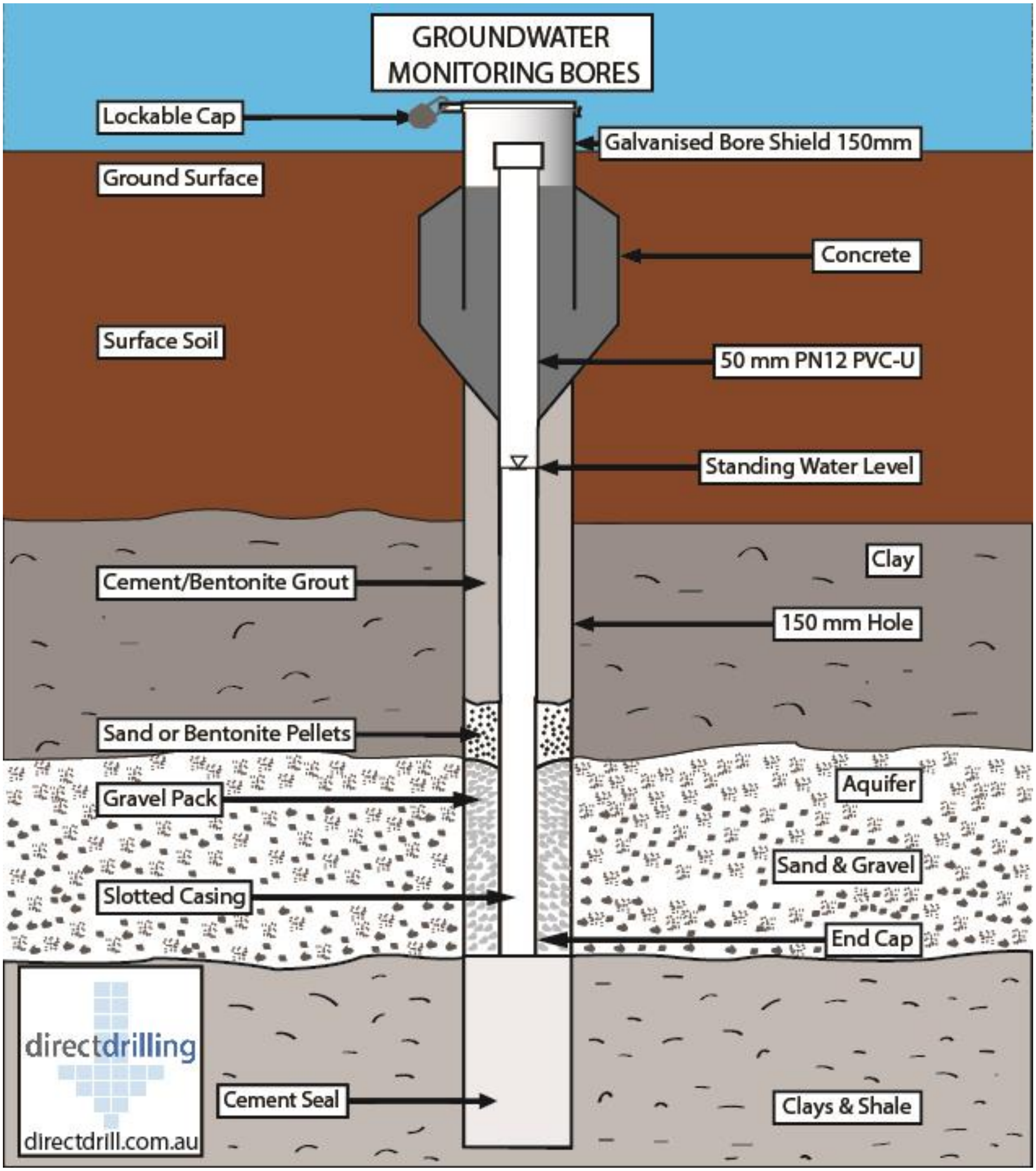

Figure 4.10: Ground Monitring Bores

4.2.9.1 Introduction

Groundwater is that part of the subsurface water, which is in the saturated zone. The saturated zone is the subsurface zone in which all interstices are filled with water. The top of the saturated zone is called the water table and can be identified by measuring the water level in a borehole, which extends into the saturated zone. Groundwater is a major natural resource of both ecological and economic value and its protection is of prime importance.

The fundamental objectives of a groundwater monitoring programme at a landfill are to assess groundwater quality and quantity and to determine the effectiveness of the environmental control systems in order to ensure the continued integrity of the groundwater quality and quantity. These objectives are achieved through the collection and analysis of representative groundwater samples.

The efficiency of a monitoring program is dependent on a thorough understanding of the hydrogeological conditions of the site, coupled with the appropriate location and construction of monitoring boreholes.

4.2.9.2 Monitoring Locations

Monitoring boreholes should be installed at appropriate locations and depths to:

- Provide samples representative of the quality of groundwater up gradient of the site.
- Provide samples representative of the quality of groundwater down gradient of the site.
- Permit an accurate water level or pressure (piezometric) level of groundwater to be measured and recorded to an elevation expressed as meters above ordnance datum.
- Provide data to show the direction of groundwater flow (minimum of three monitoring boreholes necessary).

For groundwater monitoring at a landfill, the Landfill Directive specifies a minimum of one up gradient and two down gradient boreholes (APPENDIX A Table A.4.2).

In reality, a number of site-specific factors will determine the actual number and locations of the boreholes required. Such factors may include:

- The area of the landfill.
- Heterogeneity of the aquifer(s).
- Permeability of the aquifer(s).
- Groundwater abstraction.
- Groundwater flow velocities.
- Anticipated composition of leachate (based on expected wastes types).
- Baseline water quality.
- Proximity of potential external influences such as contaminated lands.
- Proposed containment system.
- License requirements.
- Ease of access to the borehole by sampling personnel.
- Safety issues.

The location for groundwater boreholes should be based on the information derived from the site investigation. Monitoring locations may include:

- Existing groundwater discharges and abstractions, e.g. springs, water supply boreholes or wells.
- Existing monitoring points, e.g. those installed for other monitoring purposes by adjacent landowners or for site investigations
- Construction of new boreholes. This allows the monitoring points to be located and designed specifically to meet monitoring objectives.

Existing structures should only be used if they are capable of fulfilling the monitoring objectives of the site. Borehole logs and design details are essential to evaluate the usefulness of existing monitoring points. This is because boreholes could be screened at different intervals or screened into a different aquifer to the one that is required to be monitored. The use of trial pits is generally not acceptable for groundwater monitoring. The groundwater-monitoring programme at a landfill site should contain the following information:

- Number and location of boreholes – the precise location of the boreholes should be recorded on the logs using a grid reference and marked on a drawing or a map.
- Depth of boreholes.
- Screen area/level.
- Pump tests, yield information etc.
- Information on soils.
- Borehole construction material.
- Nested borehole configurations.
- Direction of groundwater flow.
- Groundwater recharge and discharge areas.
- Groundwater abstraction points near the landfill.

4.2.9.3 Design and Construction of Boreholes

Detailed construction drawings or borehole logs for each monitoring point should be produced. When constructing new boreholes, the method of drilling, lining materials, screen design and sealing method should all be given careful consideration to ensure the monitoring objectives are met. Following installation, each monitoring borehole should be cleaned out and developed to remove silt and other fine materials from the lining, gravel pack and surrounding strata.

Further information on the construction of new boreholes is available from the Geological Survey of Ireland (GSI). Details of all borehole logs including precise location should be submitted to the GSI to contribute to the knowledge pool of the national groundwater database.

In order to facilitate groundwater sampling and protect boreholes the following is recommended:

- Each borehole should have standpipes that are approximately half a meter above the ground, cased in metal, set in concrete, and surrounded by protective poles. These measures will help to avoid accidental burial of boreholes during landslides and also protect against accidental damage from plant and machinery.

- The borehole should be capped to avoid damage or blockage to the tubing and the casing should be padlocked so that there is no access to the borehole other than by authorized personnel.
- The borehole should be at least 50mm in diameter so that a representative sample can be obtained. However, boreholes with diameters wider than 50mm can be very time-consuming to purge and thus can reduce the number of samples that can be taken in a day.
- The borehole should have a marker detailing the location name and type of sample and this should be visible from a distance. It is useful if all groundwater monitoring points are coded a particular color. Most groundwater monitoring boreholes will require periodic maintenance. Any boreholes that become damaged should be repaired or replaced as soon as possible. Boreholes and wells that are no longer required need to be made safe, structurally stable, backfilled or sealed (e.g. with bentonite) to prevent groundwater pollution and flow of water between aquifer units and to prevent confusion with active monitoring points.

4.2.9.4 Trigger Levels

The Landfill Directive states that significant adverse environmental effects should be considered to have occurred in the case of groundwater when an analysis of a groundwater sample shows a significant change in water quality. A trigger level must be determined taking account of the specific hydrogeological formations and groundwater quality in the location of the landfill and must be laid down in the waste license where possible. To determine trigger levels, a review of the baseline monitoring results should be undertaken including a statistical summary of all data on certain specific indicators. Trigger levels should be evaluated by control charts with established control rules and levels for each down gradient well.

When setting trigger levels it is important to consider the following:

- The substances for which the trigger levels should be set – this may depend on the type of waste which will be accepted in the landfill and the subsequent type of leachate which will be formed.
- The levels at which they should be set – typical groundwater quality in the area needs to be assessed.
- The monitoring locations for which they should be set - the specific hydrogeological formations in the location of the landfill should be identified and trigger levels should be set for each of the down gradient monitoring points that are included in the overall groundwater-monitoring program.

The Landfill Directive recommends setting trigger levels for certain parameters such as pH, TOC, phenols, heavy metals and fluoride. For a typical non-hazardous landfill accepting biodegradable wastes, trigger levels should be set for substances such as ammonia, TOC and chloride as a minimum. Other appropriate substances for determining trigger levels for non-hazardous landfills may include some volatile/semi-volatile organic compounds. Further guidance on setting environmental quality objectives and standards for groundwater may be found in the Agency's Interim Report 'Towards Setting Guideline Values for the Protection of Groundwater in Ireland' (2003a).

An assessment monitoring programme should be implemented after the detection of a release of a contaminant to the groundwater or on attaining a trigger level. When a trigger level is reached, verification is necessary by repeating the sampling. If repeat sampling shows that the trigger level has been breached then a contingency plan including possible remedial actions must be prepared and implemented. The assessment programme may require an increase in monitoring frequencies, installation of extra monitoring boreholes and/or additional analyses of the contaminant transport patterns.

A number of computer based contaminant transport models are available. These require data regarding the location and concentration of contaminant sources, the distribution of effective porosity, fluid density variations and natural concentrations of solutes distributed through the groundwater regime. Contaminant transport may be estimated by using the model to compute the direction and rate of fluid movement. Contaminant loading on the groundwater system may then be estimated from solute-transport equations and flow model predictions.

Following the completion of the assessment-monitoring programme, the appropriate corrective measures should be implemented to reduce the impact of releases on the environment and to minimize further contaminant releases from the landfill.

4.2.10 Leachate

4.2.10.1 Introduction

Leachate may be defined as any liquid percolating through the deposited waste and emitted from or contained within a landfill. This leachate picks up suspended and soluble materials that originate from or are products of the degradation of the waste. If this leachate is allowed to migrate from the site, it may pose a severe threat to the surrounding environment and in particular to the groundwater and surface water regimes.

Effective environmental protection requires an understanding of the composition and volumes of leachate being generated and the implementation of control measures. The composition of leachate within a landfill is unique, as the characteristics of the leachate will vary depending on the wastes deposited. The main factors that influence the generation of leachate include:

- Meteorological conditions at the site.
- Waste composition.
- Waste density.
- Waste age.
- Depth of landfill.
- Moisture content.
- Rate of water movement.
- Lining system (if any).

The purposes of a leachate-monitoring programme are:

- To confirm that the leachate management systems are operating as designed.
- To provide information on the progress of decomposition of the waste.
- To provide information for the potential revision of groundwater and surface water monitoring parameters.

4.2.10.2 Monitoring Locations

The Landfill Directive requires that sampling and measurement of leachate (both volume and composition) must be performed separately at each point at which leachate is discharged from the site. Each cell in a landfill should be treated as a separate unit for determining the number and location of leachate monitoring points.

Table A.4.3 in Appendix A typical leachate monitoring requirements for a non-hazardous landfill. The precise location of these monitoring points will be decided on a site specific basis, but they should be located taking into account the likely flow-paths of the leachate within the cell, so as to provide samples representative of the leachate composition.

On-site processes such as leachate treatment plants or other leachate management schemes should also be monitored, e.g. treated leachate discharged from a site and leachate storage lagoons

4.2.10.3 Monitoring Frequency and Parameters for Analysis

The frequency of leachate monitoring at a landfill site will be site specific and governed by the waste license. It should be reviewed on a regular basis to reflect changes in:

- Quantity and types of waste deposited.
- Operational practice.
- Size of operational cell.
- The effectiveness of the leachate drainage and collection system.

The Landfill Directive specifies minimum monitoring frequencies for leachate volume and composition during the operational and aftercare phases of a landfill. Monitoring of leachate levels within the waste body is important to ensure that the leachate head is successfully controlled. The volume of leachate discharged or transported from a landfill should be recorded on an ongoing basis.

Table A.4.2 in Appendix A lists the parameters to be analyzed for characterization. Tables B.4.4 and B.4.5 in Appendix B outline guideline minimum reporting values for these parameters. The composition of leachate is variable and depends on a number of factors including:

- Age of the landfill.
- Composition of the waste.
- The rate of decomposition within the landfill.
- The amount of rainwater infiltration.
- Temperature.

Therefore, the parameters to be analyzed should reflect these influences and should provide for the anticipated characteristics of the leachate.

4.2.10.4 Toxicity Testing

Occasionally toxicity limits may be set in a waste license or toxicity testing of a substance may be required, e.g. if treated leachate is discharged to surface water. These toxicity limits are equivalent to emission limit values for chemical and physical parameters. The tests are not intended to replace assessments of the biological impacts of discharges in the natural environment. Test species may range from bacteria and algae through to invertebrates and fish. The use of systems based on luminescence measurement is useful for assessment of toxicity patterns (ISO, 1998).

When setting an emission toxicity limit, it is important to consider the effluent mixing conditions within the receiving water body or otherwise toxicity limits may not give adequate protection to aquatic life downstream. Information is therefore needed on the receiving waters (e.g. the minimum flow of a river) and the number of dilutions of the discharge available. Further information on Aquatic Toxicity Testing is available in the Agency's Wastewater Treatment Manual 'Characterisation of Industrial Wastewaters' (1998a).

4.2.11 Final Cover System:

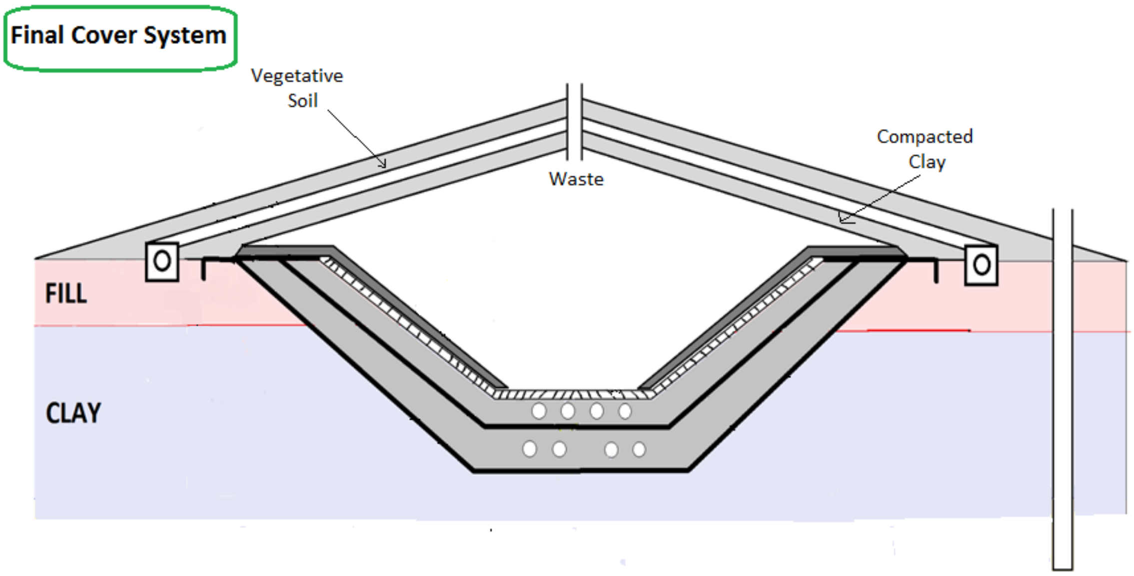

Figure 4.11. Final Cover System

4.2.11.1 Overview of the final cover system

It is necessary that the landfill operators install an engineered cover to the landfill the moment the landfill cell has touched its ultimate capacity.

An engineered cover (also known as the "final cover") for an engineered hazardous waste landfill facility is designed to control, minimize or eliminate (as necessary to protect the environment and human health) the escape of any material from the facility to the ground, to surface waters or to the atmosphere.

Unless determined not to be hazardous, these releases should be managed as a hazardous waste and may include landfilled waste, leachate, vapors/gases, contaminated runoff or decomposition products (CCME, 2006).

The proposed configuration of this engineered cover includes three layers each one containing different types of materials to serve multiple purposes.

The thickness (SCRT, 2003) of the three layers and the materials that each layer is composed of:

1st layer: Low Permeability Layer (Compacted Clay) at least 60 cm thick.

2nd layer: Protective Layer (Compacted Crush Stones) at least 30 cm thick.

3rd layer: Vegetative soil (Fill) typically 60 cm thick.

Each layer serves different purposes resulting in a minor system that serve these multiple purposes, The overall purpose of this system is to accomplish the following tasks:

- To minimize leachate production by shedding precipitation rather than allowing it to percolate through waste.
- To prevent leachate pop-outs.
- To provide a barrier (due to the protective layer) between the waste and receptors.
- To prevent uncontrolled emission of landfill gas into atmosphere through top of landfill.
- To provide a durable, low maintenance surface.

The barrier layer of the cover system should be joined securely to the landfill liner system at the perimeter of the landfill cells. The cover system should be thick enough that the damage from freeze/thaw cycles is minimized.

Over the time frame of between 5 and 20 years, the clay layer cover has to be substituted and superimposed for the purpose of further decreaseing the quantity of liquid penetrating down the waste.

4.2.12 Measuring and recordkeeping

The amount of the incoming wastes from construction, demolition, and hazardous materials will represent the main information of the landfill to the operators, for instance, determining the allowable area of the landfill for disposal. Measuring and recordkeeping of the incoming wastes is necessary to ensure that the waste do not exceed the planned height. Failing to do so will lead to dire consequences that is caused by the settlement of the clay layer.

4.2.12.1 Quantities of Generated Waste and Landfilled

The amount of incoming waste material could be worked using weighbridge facility or by just counting the number of trucks carrying wastes going in to the landfill then approximating their waste weight. If the same waste trucks were used for transportation, taking the burden of a few number of waste will be very efficient and lead to the saving of time. Data on the mass of the waste in the landfill could also be significant for monetary accounting .for example if one landfill serves several areas, the costs of landfill have to be divided following the amount of waste material (C&D) that is delivered from each site in different areas.

CHAPTER 5: CONCLUSION

5.1 Introduction

As the reduction of waste and the administration of waste continue to be more complex, the best course of action involves communication with the industrial sector and joining forces for the purpose of reducing the disposal of wastes to the environment especially the demolition and construction material wastes and the hazardous materials. Due to the extensive nature of the environment, achieving the goal of positively dealing with the environment, there is need to join forces with both the local authority and the government.

It will involve several activities including implementing a modern integrated waste management system that safely and efficiently deals with the waste that cannot be neither prevented or recycled. This is important since Saudi Araba has had a rapid growth in the construction industry. This has led to an increase in the construction sites that will result in the production of construction and demolition waste. Then there is other waste that is created due to the increased population caused by influx of people from different places coming from around the world.

5.2 General Conclusion

Landfills form one of a major part of an integrated management system for wastes.If properly designed and managed in the context of available infrastructure and resources, landfills will provide the simple and safe way of disposing of wastes.. If not probably designed especially in the disposal of hazardous waste, landfill like any other designed system may fail, and this leads to dire consequences to the environment. However, landfills, can not be treated as the sole means of dealing with waste in the region.

An integrated system could prioritize its management of waste according to the chemical content or types of waste and landfill. All the procedures of the integrated method can enhance the landfill operations and allow for more landfill lifetime.

It is necessary to perform In-situ monitoring so as to understand more about the process of waste degradation, which characteristically takes place for many years. In these design, proper engineering procedures were followed to ensure that the landfill does not only serve its purpose but also serve as long as the contaminating lifespan of all the wastes disposed of in this landfill.

APPENDIX A

Appendix A: Project Management

A.1 Project Plan

No.	Task	February		March				April				May	
		W3	W4	W 1	W 2	W 3	W 4	W 1	W 2	W 3	W 4	W1	W2
1	Literature Review												
2	Data Collection												
3	Design Calculation												
4	Modelling and verification												
5	Final Report												

A.2 Contribution of Team Members

The work has been evenly divided among the team members. Each team participated in writing the report and planning the project. Munther is interested in the Literary Review. Mohamed Ali is interested in the design and drawing of the Landfill. Abdul-Ella and Abdulrahman were interested in collecting information on all parts of the Landfill. All members of the team have contributed to solving mathematical problems and also to consulting in the face of any problem.

- Munther: did the literary review, collecting data, write the report (25%)
- Abdulellah: Report writing, collect data, organizing meeting (25%)
- Mohammed: drawing, collecting data, meeting, writing report (25%)
- Abdulrahman: Collecting data, meeting (25%)

A.3 Project Execution Monitoring:

List various activities:

Meeting:

- The meeting with Dr. Taher was at the beginning of the semester to re-explain some of the articles that relate to the project. The meetings were weekly with Dr. Taher to see the progress of the team.
- Meeting with Dr. Omar to clarify some issues regarding the Hazardous West.

Team meeting:

The Team is daily meeting because the schedule is made the same for them in order to stay together and work properly.

A.3 Challenges and Decision Making

- The availability of the data was challenging to find, and still not the required one, So the team collected similar data from outside.
- Reaching to people, required from the team a lot of effort and time, to find the responsible people.
- Organizing the work between the team was challenging, where each member lives in a different city.

APPENDIX B

Appendix B: Project Analysis

In this section, you will analyze your project in terms of the following:

B.1 Life-long Learning

During the research period, some experiences, information, skills and software have been utilized, studied and improved. They include the following:

- Geo-slop
- Teamwork and communication skills
- Presentation and advertisement skills
- Meeting new people with great Real-Life experience
- Time management skill and its importance

The main source of information was Dr. Taher Ayadat, who provided the research for books and information. The Secondary source of information is Google and Google Scholar, where previous researches have been available.

B.2 Impact of Engineering Solutions

This research help us to protect the environment for comminute especially when collecting data that people Contribute to conservation the environment. So, should be first use the other solution for waste such as recycling and reuse.

B.3 Contemporary Issues Addressed

Some waste information and data is difficult to find and often confidential which was not included in the research. Some of these data are important to consider especially hazardous waste. This may introduce new opportunities, which was unfortunately not used for this research.

APPENDIX C

TABLE A.4.1 MINIMUM BASELINE MONITORING REQUIREMENTS FOR A NON- HAZARDOUS LANDFILL (EPA).

Monitoring Medium	**Parameters**	**Monitoring Points**	**Frequency of Monitoring**
Surface water	Flow/level and composition. See Table A.4.2 for further details.	At least two monitoring points in each watercourse – one upstream and one downstream of the proposed landfill.	Quarterly intervals over a one year period (pre-operational).
	Biological assessment.	At least two monitoring points in the main watercourse adjacent to the landfill – one upstream and one downstream of the proposed landfill.	At least once between June & September.
	Sediment assessment.	Site specific.	Site specific.
Groundwater	Level and composition. See Table A.4.2 for further details.	Minimum of three boreholes, one upgradient and two downgradient of the proposed landfill.	Quarterly intervals over a one year period (pre-operational).
Landfill Gas	Gas composition (methane, carbon dioxide, oxygen).	Three perimeter boreholes.	Two readings over a year prior to waste deposition to establish background gas concentrations.
Meteorological Data	See Table C.6.	Historical data from nearby meteorological station.	Sufficient data required to be able to predict leachate generation and to undertake air dispersion modelling of e.g. odour or emissions from flare/utilisation plant.
Other Aspects	Noise, dust, PM_{10} and odours.	Sensitive receptors. Potential sources. Perimeter locations.	Site specific.
	Topography, ecology, archaeology.	Assessment of facility and surrounding locality needed.	Site specific.

TABLE A.4.2: PARAMETERS FOR MONITORING OF GROUNDWATER, SURFACE WATER & LEACHATE (EPA)

	Surface Water	**Groundwater**	**Leachate**
Monitoring Parameter [1]	**Baseline (pre-operational)**	**Baseline** [2] **(pre-operational)**	**Characterisation (when site is operational)**
Fluid Level	•	•	•
Flow rate [3]	•		
Temperature	•	•	•
Dissolved oxygen	•		
pH	•	•	•
Electrical conductivity [4]	•	•	•
Total suspended solids	•		
Total dissolved solids		•	
Ammonia (as N)	•	•	•
Total oxidised nitrogen (as N)	•	•	•
Total organic carbon		•	
Biochemical oxygen demand	•		•
Chemical oxygen demand	•		•
Metals [5]	•	•	•
Total alkalinity (as $CaCO_3$)	•	•	
Sulphate	•	•	•
Chloride	•	•	•
Molybdate Reactive Phosphorus [6]	•	•	•
Cyanide (Total)	•	•	•
Fluoride	•	•	•
Trace organic substances [7]	•	•	•
Faecal & Total Coliforms [8]		•	
Biological assessment [9]	•		

TABLE A.4.3 TYPICAL LEACHATE MONITORING REQUIREMENTS FOR A NON-HAZARDOUS LANDFILL (EPA).

Parameter	**Monitoring Points**	**Monitoring Frequency (operational and aftercare)**
Leachate levels	• For lined landfills, at the leachate collection point and at two other points per cell. • For unlined landfills, three points per five hectares of filled area. • Leachate lagoon.	As required by waste licence.
Leachate composition See Table A.4.2 for details.	• Sampling point representative of the landfill body. • Leachate lagoon. • Treated leachate before discharge.	As required by waste licence.
Leachate discharge volume	• Treated leachate discharge point.	As required by waste licence.

Table B.4.4 Guideline Minimum Reporting Values (EPA)

Determinand [1]	Units	Recommended Analytical method	MRV 'clean'	MRV 'dirty'
Temperature [2]	°C	Thermometry	± 1	± 1
pH [2]	pH units	Electrometry	± 0.2	± 0.2
Electrical conductivity [3]	µS/cm	Electrometry	10	50
Dissolved oxygen [2]	mg/l	Electrometry	± 0.1	± 5
Dissolved oxygen [2]	% saturation	Electrometry	± 1	± 5
Total suspended solids	mg/l	Gravimetry	5	10
Total dissolved solids	mg/l	Gravimetry	10	20
Ammonia (as N)	mg/l	Ion selective electrode/Colorimetry	0.05	1
Total oxidised nitrogen (as N) [4]	mg/l	Colorimetry/Ion chromatography/Ion selective electrode	1	1
Total organic carbon [5]	mg/l	TOC Analyser	2	10
Biochemical oxygen demand [6]	mg/l	Electrometry or Titrimetry	2	10
Chemical oxygen demand	mg/l	Digestion/Colorimetry	10	20
Calcium [7]	mg/l	Atomic spectroscopy/Ion chromatography	1	10
Magnesium [7]	mg/l	Atomic spectroscopy/Ion chromatography	1	10
Sodium [7]	mg/l	Atomic spectroscopy/Ion chromatography	1	10
Potassium [7]	mg/l	Atomic spectroscopy/Ion chromatography	1	10
Iron [7]	mg/l	Atomic spectroscopy/Colorimetry	0.05	0.2
Manganese [7]	mg/l	Atomic spectroscopy/Colorimetry	0.02	0.05
Cadmium [7]	mg/l	Atomic spectroscopy/Colorimetry	0.0005	0.005
Chromium (Total) [7]	mg/l	Atomic spectroscopy/Colorimetry	0.005	0.05
Copper [7]	mg/l	Atomic spectroscopy/Colorimetry	0.005	0.05
Lead [7]	mg/l	Atomic spectroscopy/Colorimetry	0.005	0.05
Nickel [7]	mg/l	Atomic spectroscopy/Colorimetry	0.005	0.05
Zinc [7]	mg/l	Atomic spectroscopy/Colorimetry	0.008	0.1
Arsenic [7]	mg/l	Atomic spectroscopy	0.005	0.05
Boron [7]	mg/l	Atomic spectroscopy/Colorimetry	0.2	2
Mercury [7]	mg/l	Atomic spectroscopy	0.0001	0.001
Cyanide (Total)	mg/l	Colorimetry/Ion chromatography/Ion selective electrode after distillation	0.01	0.05
Total alkalinity (as CaCO3)	mg/l	Potentiometric or Acidimetric titration	5	50
Sulphate	mg/l	Ion chromatography/Turbidimetry	20	50
Chloride	mg/l	Colorimetry/Ion chromatography/Ion selective electrode	2	25
Fluoride	mg/l	Ion chromatography/Ion selective electrode	0.1	1
Phosphorus [8]	mg/l	Atomic spectroscopy/Colorimetry	0.02	0.2
Trace organic substances	µg/l	See Table D.2	-	-
Dissolved methane	µg/l	Sensor/GCMS/GCFID	5	5
Total & Faecal coliforms [9]	No./100ml	Membrane filtration, MPN or Colilert™, dilution as required	<1	10

TABLE B.4.5 RECOMMENDED CORE DETERMINANDS FOR TRACE ORGANICS ANALYSIS & GUIDELINE MRVS (EPA)

Determinand [1] (include representative compounds from the following groups)	**MRV 'clean'** **μg/l**	**MRV 'dirty'** **μg/l**
VOCs		
e.g. trichloroethylene, tetrachloroethylene, 1,2-dichloroethane, 1,2-dichlorobenzene, toluene, xylenes, hexachlorobutadiene, trichlorobenzene, dichloromethane, chlorobenzene, benzene.	1.0 [2, 3]	1.0 [2]
SEMI-VOCs		
Organochlorine pesticides e.g. aldrin, γ-HCH (Lindane), dieldrin, endosulfan, trifluralin, hexachlorobenzene.	0.1 [2, 3]	1.0 [2]
Triazine herbicides e.g. atrazine, simazine.	0.1 [2, 3]	1.0 [2]
Organophosphorus pesticides e.g. dichlorvos.	0.1 [2, 3]	1.0 [2]
Herbicides e.g. dichlorprop, mecoprop, bromoxynil.	0.1 [2, 3]	1.0 [2]
Phenols e.g. 2-chlorophenol, pentachlorophenol, 2,4,6-trichlorophenol.	0.1 [2, 3]	1.0 [2]
Organotin compounds e.g. tributyltin	Note 4.	Note 4.
Polycyclic Aromatic Hydrocarbons (PAHs) e.g. benzo(a)pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene, benzo(g,h,i)perylene, indeno(1,2,3-cd)pyrene, napthalene .	0.1 [2, 3]	1.0 [2]

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