REHABILITATION OF SG KEMBONG OPEN DUMPSITE USING GEOGRAPHIC INFORMATION SYSTEM: A CASE STUDY

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ABSTRACT

Municipal solid waste disposal site has always posed serious environmental issues since its construction until the post closure stage. Generation of landfill gas and leachate towards the surroundings has caused various environmental and health hazards. To prevent the situation from deteriorating, landfill rehabilitation of any unsanitary disposal sites is momentous.

In accordance to the Tenth Malaysia Plan (2011-2015), the government will close and rehabilitate the existing 158 unsanitary landfills by 2015 to ensure that solid waste management is well-managed in a sustainable manner. Sungai Kembong Open Dumpsite (SKOD) has been identified as one of the unsanitary landfill under the the Kajang municipality in Selangor, Malaysia. It has been urged to close down due to its leakage of leachate into the water body which has polluted the water treatment plant in Semenyih that supplies the water to millions of residents. Therefore, SKOD was chosen as a study area for the rehabilitation and safe closure process based on the guidelines published by the Ministry of Housing and Local Government of Malaysia.

Given the increasing concern about the environmental and health hazard posed by the open dumpsite, it is vital to rehabilitate the closed SKOD in a systematic and technically-sound way. This research study was carried out to rehabilitate the closed SKOD describing the conditions and evaluations on the environmental aspects including groundwater quality, surface water quality, ambient air quality, landfill gas and leachate characteristic. From the monitoring process, of particular concern was the high concentration of coliform found in all groundwater samples ranging from 100 to 16000 CFU/100mL. Groundwater quality at NW3 was among the most polluted points. Besides, the surface water quality at the downstream of Sungai Beranang has deteriorated due to the activities carried out at SKOD. The methane gas produced was considered high when the volume of methane gas recorded was 53.4%.

Inevitable, there is ample discussion on technical management on upgrading an open dumpsite, but either little or no focus on how this management can be gathered and integrated for easier access. This is because data related to the waste disposal sites are generally lacking in Malaysia. Thus, this research study was carried out by using the Geographic Information System (GIS) which can store and integrate data in facilitating the process of rehabilitation in SKOD.

For the rehabilitation of SKOD, relevant data such as geological, groundwater quality, water quality, leachate characteristic, landfill gas and waste composition were gathered and assessed. The collected data was input in a GIS-based inventory. The proposed database can accommodate new information on the landfill by updating the qualities of groundwater, surface water and air. Besides, the database introduced can also accommodate all the data in a comparable manner which can help the stakeholders in making new policy and decision to improve the rehabilitation of SKOD.

The outcome of this research would definitely facilitate all the stakeholders and practitioners involving in solid waste management. It can be served as a case study to help in setting up a database in planning and management which is one of the technical capability developments proposed in the National Strategic Plan for Solid Waste Management in Malaysia.

ABSTRAK

Tapak pelupusan sisa pepejal perbandaran selalunya menimbulkan isu yang serius terhadap alam sekitar sejak bermulanya peringkat pembinaan sehingga peringkat penutupan. Gas dan air resapan yang terhasil dari tapak pelupusan telah mengakibatkan pelbagai masalah terhadap alam sekitar dan kesihatan. Untuk mengelakkan keadaan bertambah teruk, adalah sangat penting untuk memulihkan tapak pelupusan sampah.

Menurut Rancangan Malaysia Kesepuluh (2011-2015), pihak kerajaan akan melancarkan penutupan dan pemulihan bagi 158 tapak pelupusan menjelang tahun 2015. Ini adalah untuk memastikan pengurusan sisa pepejal diuruskan dengan cara yang baik dan mampan. Tapak pelupusan sampah Sungai Kembong atau nama inggerisnya Sungai Kembong Open Dumpsite (SKOD) adalah di bawah pengurusan Majlis Perbandaran Kajang di Selangor, Malaysia. SKOD harus ditutup dengan segera disebabkan oleh pengaliran air resapan dari tapak perlupusan tersebut telah mencemarkan aliran air sungai yang berdekatan. Kejadian ini telah mengakibatkan pencemaran kepada loji rawatan air Semenyih yang membekalkan air kepada berjuta-juta penduduk di sekitarnya. Oleh yang demikian, SKOD telah dipilih sebagai tapak kajian untuk proses pemulihan dan penutupan yang selamat berdasarkan garis panduan daripada Kementerian Perumahan dan Kerajaan Tempatan (KPKT) Malaysia.

Memandangkan kesedaran terhadap isu alam sekitar dan kesihatan yang semakin meningkat, penutupan dan pemulihan SKOD dengan cara yang sistematik dan mampan adalah sangat penting. Kajian ini telah dijalankan untuk memulihkan SKOD melalui kaedah penilaian aspek-aspek alam sekitar termasuk kualiti air bawah tanah, kualiti air sungai, kualiti udara, gas dan air resapan yang dihasilkan dari SKOD. Hasil daripada

kajian telah menunjukkan kepekatan koliform yang tinggi (100 – 16000 CFU/100mL) yang terdapat dalam semua sampel air bawah tanah adalah amat membimbangkan. Didapati sampel kualiti air bawah tanah di NW3 adalah paling tercemar. Keadaan bertambah teruk apabila kualiti air sungai di hilir Sungai Beranang telah merosot disebabkan oleh aktiviti-aktiviti yang dijalankan di SKOD. Gas metana yang dilepaskan juga adalah tinggi, iaitu 53.4%.

Seperti yang sedia maklum, terdapat banyak perbincangan mengenai pemuliharaan tapak pelupusan dari segi teknikal, akan tetapi tiada penekanan diberi terhadap pengurusan data mengenai pemuliharaannya. Hal ini adalah kerana kekurangan data berkaitan dengan tapak pelupusan sampah di Malaysia. Oleh itu, kajian ini telah mengaplikasikan penggunaan Sistem Informasi Geografi (SIG) bagi tujuan penyimpanan dan penyepadukan data untuk memudahkan proses pemulihan SKOD.

Pelbagai data diperlukan bagi proses pemulihan SKOD. Antara data yang diperlukan adalah seperti data geologi, data kualiti air tanah, data kualiti air sungai, air resapan, gas bahan buangan dan komposisi sisa. Data yang dikumpulkan akan dimasukkan ke dalam satu inventori berasaskan SIG. Pangkalan data yang dihasilkan boleh menampung maklumat baru seperti kualiti air tanah, air sungai dan udara dengan mengemaskinikan data yang di simpan dalam SIG. Di samping itu, pangkalan data yang diperkenalkan juga dapat menampung semua data dalam format yang sama bagi membantu pihak-pihak yang berkenaan dalam membuat keputusan dan panduan baru untuk meningkatkan proses pemulihan SKOD.

Hasil daripada kajian ini akan memudahkan semua pihak yang terlibat dalam pengurusan sisa pepejal. Hasil kajian ini juga boleh dijadikan sebagai satu kajian kes dalam menubuhkan pangkalan data dalam perancangan dan pengurusan yang mana ini merupakan salah satu perkembangan keupayaan teknikal yang telah dicadangkan dalam Pelan Strategik Kebangsaan untuk pengurusan sisa pepejal di Malaysia.

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LIST OF ABBREVIATIONS AND NOTATIONS

APHA	American Public Health Association
BOD	Biochemical Oxygen Demand
CH_4	Methane
CLEAR	Contaminated Land Environment Remediation Sdn Bhd
CFU	Colony Forming Unit
CO_2	Carbon dioxide
COD	Chemical Oxygen Demand
DO	Dissolved Oxygen
DOE	Department of Environment
DSS	Decision Support System
EPA	Environmental Protection Agency
EQA	Environmental Quality Act
GDP	Gross Domestic Product
Gg	Gigagram
GIS	Geographic Information System
GPRS	General Packet Radio System
GPS	Global Positioning System
INWQS	Interim National Water Quality Standards
JICA	Malaysia and the Japan International Cooperation Agency
JUPEM	Jabatan Ukur dan Pemetaan Malaysia
LCS	Leachate Collection System
LFG	Landfill Gas
LOADSS	Lake Okeechobee Agricultural Decision Support System
MAAQS	Malaysian Air Quality Guidelines
MHLG	Ministry of Housing and Local Government
MPKj	Majlis Perbandaran Kajang

MSW	Municipal Solid Waste
NH_3N	Ammoniacal Nitrogen
NSP	National Strategic Plan
NSWMD	National Solid Waste Management Department
PI	Plastic Index
RDF	Refused Derived Fuel
RESB	Recycle Energy Sdn. Bhd.
RFID	Radio Frequency Identification
RM	Ringgit Malaysia
RSO	Rectified Skew Orthomorphic
SBR	Sequential Batch Reactors
SG	Sungai
SKOD	Sungai Kembong Open Dumpsite
SPT	Standard Penetration Test
SS	Suspended Solids
TDS	Total Dissolved Solid
TNB	Tenaga Nasional Berhad
USD	United State Dollar
WEAP	Water Evaluation and Planning
WHB	Worldwide Holdings Berhad
WQI	Water Quality Index
WtE	Waste to Energy
˚	degree
‘	minute
“	second
˚C	degree Celsius
µg	microgram
%	percent

h	hour
km	kilometer
L	litre
m	meter
mg	milligram
mm	millimeter
ppm	parts per million

CHAPTER 1

INTRODUCTION

1.1 Background

Open dumping is always considered as one of the best option in managing solid waste since it is the most economical and promising option despite its production of landfill gases and leachate (Khan & Narulkar, 2010). It is particularly popular in the context of the poor and developing countries. In Malaysia, open dumping is a common disposal method for municipal and non-scheduled waste. However, due to the unprofessional management of solid waste at landfill site, there are always issues or problems such that the number of landfill is increasing and most of the landfills are reaching the maximum capacity. 80% of the existing landfill will face closure by 2005 either because they have been filled up to the brim or they do not comply with the requirement.

Under the Tenth Malaysia Plan (2011-2015), the government has planned to upgrade, rehabilitate or close the existing 114 unsanitary landfills, or more commonly known as open dumpsites. The government has apparently known the adverse consequences that might happen in the future if there are no actions taken now. Currently, over 40% of disposal sites are operating as open dumpsite in remote areas with no proper treatment and collection. In Selangor, the situation becomes worse when 70% of the landfills in Selangor are situated near rivers and water catchment areas. For example, the Sungai Sedu landfill in Kuala Langat is near to Sungai Sedu, the Ampar Tenang landfill in Sepang is close to Sungai Labu, the Sungai Besar landfill in Sabak Bernam is close to

Sungai Panching Bedena and the closed Kundang dump in Selayang was close to Sungai Kundang.

There are 290 landfills throughout Malaysia as in 2009 as listed in Table 1.1. The current number of landfills that is not in operation is 114 while the number of landfills in operation is 176. Only 8 out of 176 landfills are classified as sanitary landfills, featuring anti-pollution measures (NSWMD, 2009).

Table1.1: List of landfills in Malaysia

	Operating	End of Life	Sanitary
Johor	13	21	2
Kedah	10	5	-
Kelantan	13	4	-
Melaka	2	5	-
Negeri Sembilan	8	10	-
Pahang	19	13	-
Perak	20	9	-
Perlis	1	1	-
Pulau Pinang	1	2	-
Sabah	21	1	-
Sarawak	51	12	3
Selangor	6	12	3
Terengganu	9	12	-
WP Kuala Lumpur	1	7	-
WP Labuan	1	-	-
Total	**176**	**114**	**8**

Source: National Solid Waste Management Department (2009)

1.2 Problem Statement

Improved environmental quality, environmental management and environmental conservation are prerequisites for Malaysia to achieve Vision 2020 to become one of the developed nations. Hence, an effective solid waste management is a critical component to be accomplished. One of the aims formulated by National Solid Waste Management Department (NSWMD) is to establish a solid waste management system which is holistic, integrated, cost effective, sustainable and acceptable to the community that emphasizes the conservation of the environment, selection of affordable technology and ensuring public health. With the rapid industrialization and urbanization coupled with the economic growth, many dumpsites in Malaysia have achieved their lifespan and have been closed. One of the efforts NSWMD has made is to close and rehabilitate the unsanitary landfill. 16 critical landfills have been identified and urged to close down in a safe, sanitary and environmentally-friendly manner (The Star, 2007).

The National Strategic Plan (NSP) for Solid Waste Management (SWM) was formulated and adopted by the NSWMD. It serves as a guide for SWM policies and measures up to year 2020. By 2020, Malaysia should have closed all the dumpsites. One of the targets established is to close the dumpsites following the improvement plans as stated in Table 1.2. The efficiency of its implementation would be reviewed periodically during the planning period.

Table1.2: Targets by NSP

Level of Service	Present	2003-2009	2010-2014	2015-2020
Extend Collection Service	75%	80%	85%	90%
Reduction & Recovery	3-4%	10%	15%	17%
Closure of Dumpsites	112 sites	50%	70%	100%
Source Separation (Urban Areas)	None	20%	80%	100%

Source: National Strategic Plan (2005)

In line with the Tenth Malaysia Plan, there is an urgent need to rehabilitate the unsanitary landfill. This is due to the environmental degradation that has happened caused by the landfill operation. Issues related to contamination by leachate, migration of landfill gas and bad odour has been the results of these sanitary landfills. According to Idris et al. (2004), it is most likely that proper waste disposal will be one of the most challenging environmental and health issues in the developing countries of Asia. Many disposal sites remain as open dumps which are poorly managed and normally left unattended by the local authority.

Studies by past researchers have focused a lot on the benefits and general framework on landfill rehabilitation. There is little or no work has been done to explore the best management way to facilitate the rehabilitation process. To add onto the problem, reliable information of solid waste management is scarce and hardly obtained. It has been a complicated process to gather and understand the information regarding the landfill issues which has been widely distributed. Apart from that, the information is usually in different formats which are incomparable. Stakeholders often find difficulties in implementing corrective measures when the monitoring indicated the levels of impacts were not permissible. Therefore, this research study is meant to produce a database by using Geographic Information System (GIS) to assist the landfill rehabilitation management of a closed open dumpsite in Malaysia. Through GIS, it is believed that the inventory system produced can easily facilitate the rehabilitation of open dumpsite through pollutant inventory management.

1.3 Study Area

The study area chosen for this study is Sungai Kembong Open Dumpsite (SKOD) which is located at Lot 2246, Beranang Mukim under the district of Hulu Langat. It is located 5km to the south of Semenyih town. Figure 1.1 has clearly showed the location of SKOD. The site lies between latitudes N02^{o}52’58.46” and N02^{o}53’15.71”, longitudes E101^{o}49’01.33” and E101^{o}49’35.35”. It can be reached by paved road of 15km from University of Kebangsaan. The climate of SKOD is warm and humid with average high and average low temperatures of 31.9°C and 23.2°C, respectively. The average rainfall received in a month is 20.02mm.

The SKOD occupies 84 acres of land. It is adjacent to Sungai Beranang which is a tributary of Sungai Semenyih and within the Langat river basin. SKOD is classified as open and unsanitary landfill or known as open dumpsite with no proper solid waste management and leachate treatment system. Under the authority of Kajang Municipal or Majlis Perbandaran Kajang (MPKj), only registered waste collection vehicles namely compactor, roro or open tipper were allowed to enter SKOD.

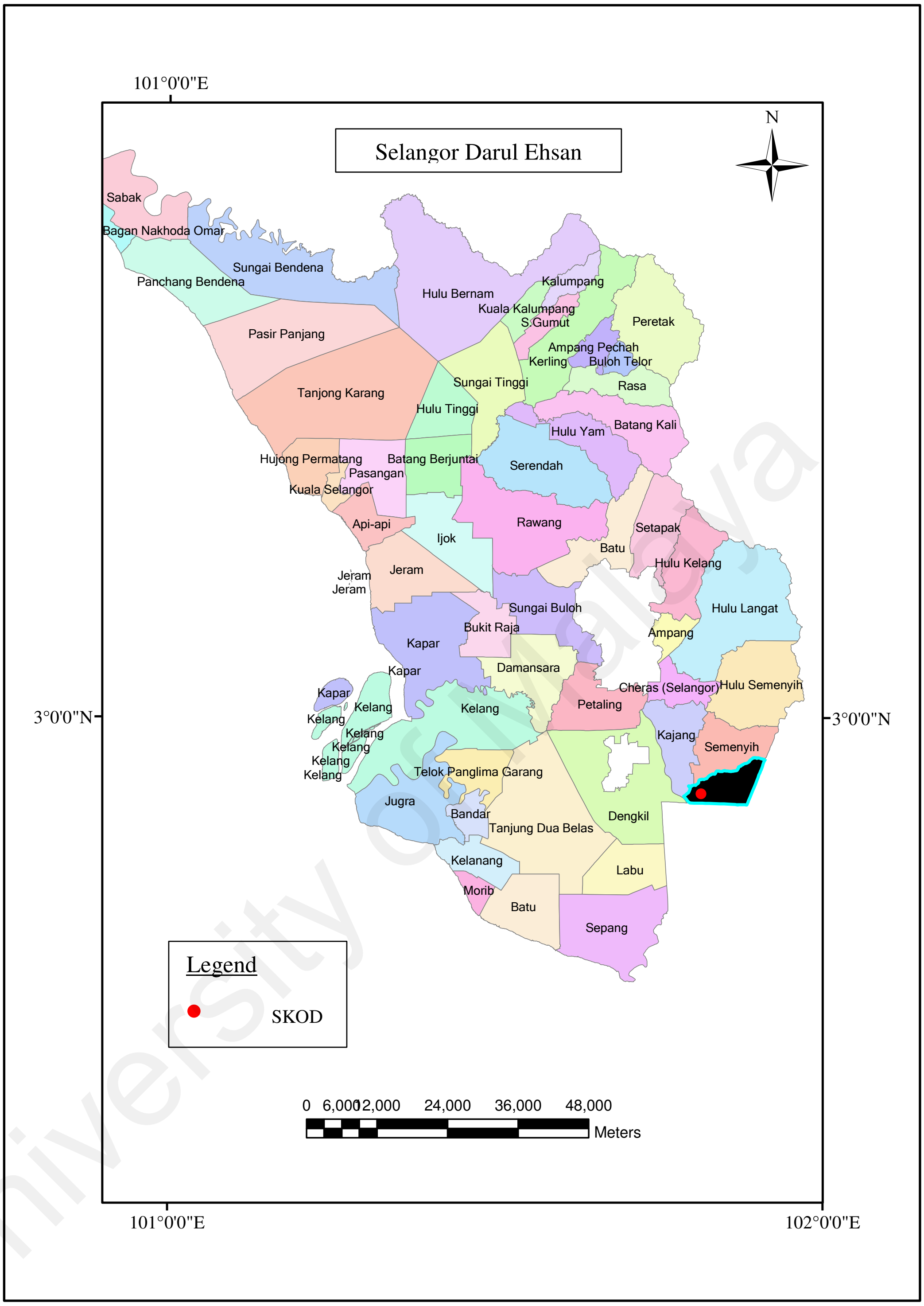

Figure 1.1: Location of SKOD at Mukim Beranang

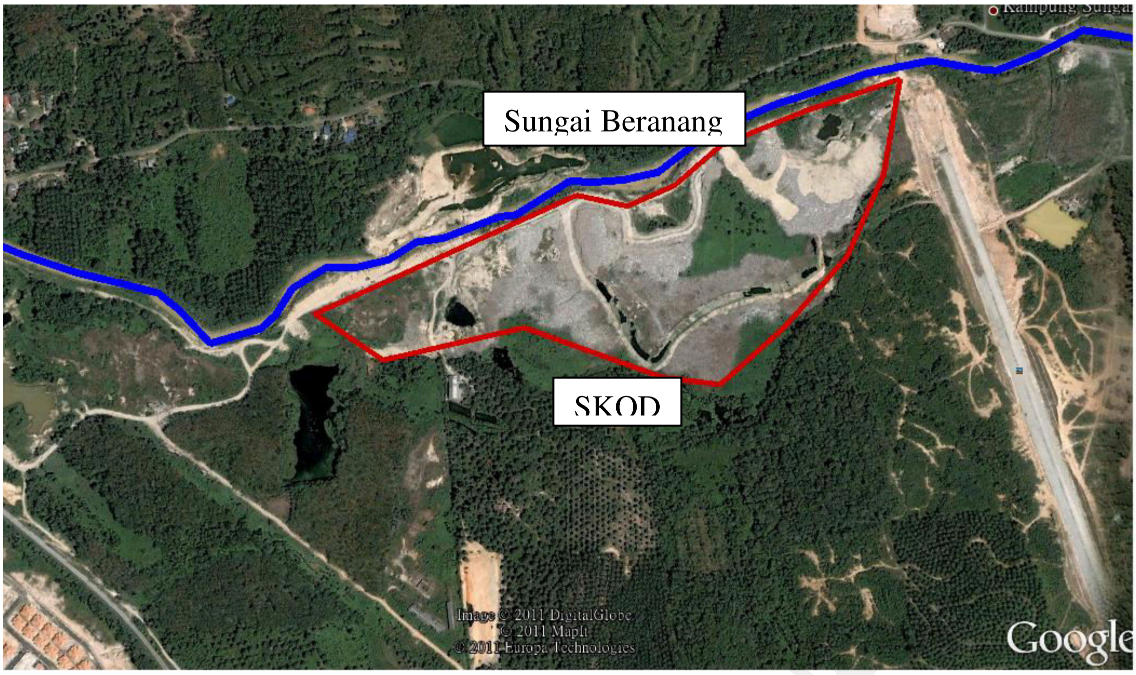

Figure 1.2: Satellite image of SKOD from Google Earth

A satellite image map of the area (Figure 1.2) shows that it is an undulating mountaineer rugged terrain that covered the entire area of SKOD. Most of the area in SKOD has a flat slope gradient of almost 0 degree. The Sungai Beranang river flowing adjacent to the entire SKOD was located less than 1km away. It supplies water to the Semenyih water treatment plant. Before the land is used as an open dumpsite, it was a secondary forest with few water bodies surrounded by oil palm plantation, rubber plantation and residential areas namely Kampung Sungai Kembong Hilir at the west and Kampung Sungai Kembong Hulu at the east.

It has being used for almost 14 years since the year 1996 until August 2010. Prior to closure, SKOD is managed by the Kajang municipal or MPKj. It is used to dispose solid waste from the sub districts of Kajang, Cheras, Semenyih, Beranang, Hulu Langat and Hulu Semenyih except Ampang. The solid waste collected ranges from municipal solid waste (MSW), construction waste, garden waste to bulky waste. There is no official record of the total amount of solid waste collected. However, it is estimated that 600 tons of solid waste was collected every day in the year 2004 based on the secondary data obtained from Worldwide Holdings Berhad (WHB).

1.4 Site History

On 13th January 2004, MPKj had reached a consensus with Recycle Energy Sdn. Bhd. (RESB) to collect the MSW from SKOD to be processed for the production of Refused Derived Fuel (RDF) through its Waste to Energy (WtE) technology. RDF is a type of renewable energy which can be used to generate electricity. MSW consisted of combustible components such as plastics and biodegradable waste were shredded and dehydrated to produce the RDF in the plant located at Taman Industi Megah, Semenyih. The plant had the capacity to produce 8.9 megawatts of electricity hourly from 700 tons of MSW collected each day. 5.5 megawatts were channeled to our national power grid of Tenaga Nasional Berhad (TNB). The remaining 20% of the inert and compostable components were then sent back to the SKOD. It was believed to prolong the lifespan of the landfill by five times through the WtE technology.

According to Lim (2004) in the New Straits Times, the Government has been urged to close down the SKOD located beside Sungai Beranang. It has been identified as one of the sources of pollution for the Semenyih water treatment plant in Dengkil, Selangor. The other two sources were generated from the discharge from the pig farm in Semenyih and the organic fertilizer factory in Sungai Kembong.

SKOD was in operation until April 2006 when the bund surrounding the SKOD was damaged in a storm resulting in leachate run off into Sungai Beranang and Sungai

Kembong. Thus, the water treatment plant of Sungai Semenyih was forced to close down after the detection of high level of ammonia causing a 14h of water supply disruption. About two millions of consumers in Petaling Jaya, Semenyih, Bangi, Hulu Langat, Sepang, Salak Tinggi, Cyberjaya, USJ, KLIA, Kuala Langat and Putrajaya were affected then (The Star, 2006).

Sungai Semenyih is the main watercourse from Semenyih dam that supplies water to millions of residents in Putrajaya and the Hulu Langat, Petaling, Sepang and Kuala Langat districts. As reported by Konsortium ABASS Sdn Bhd who is the management of Sungai Semenyih Water Treatment Plant, SKOD was the main perpetrator that caused the closure of water treatment plant in April 2006 due to the detrimental ammonia pollution. The nine-hour shutdown had affected a million households, shops and factories. The ammonia content was 4.8mg/L which exceeded the recommended safe limit of 1.5 mg/L. After this incident, SKOD was instructed to be closed down by the Ministry of Natural Resources and Environment and the Ministry of Housing and Local Government (MHLG).

However, in December 2009, due to some technical problems encountered, the RDF plant was forced to shut down for few weeks which have caused a disruption in MSW management of MPKj. As there was no any viable option to dispose the scheduled waste, SKOD was re-opened until the RDF plant was fixed. Another technical problem happened again in February 2010, forcing SKOD to be re-opened for waste disposal. SKOD was finally closed on 20th July 2010. After that, Worldwide Holdings Berhad (WHB) was appointed to take charge of the rehabilitation process officially since August 2010. The post closure process is estimated to complete in 5 years.

For a proper and sustainable waste management, the closure of SKOD is important. The execution of safe closure and rehabilitation processes are carried out by the Worldwide Landfill Sdn. Bhd. As SKOD is located near to the water body, it makes the rehabilitation process difficult. Earthwork activities followed by hydro-seeding activities are initiated to cover the SKOD with soil layer. A leachate collection system was proposed to collect and treat the leachate. SKOD is now securely guarded and fenced to prevent any free access to the site. However, there was no liner material in SKOD.

Rehabilitation of landfills in Malaysia is essential and pertinent because most of the landfills are reaching their brim. Improper solid waste management gives rise to a series of other environmental problems. When the capacity is reached, there must be closure and rehabilitation process as required by National Solid Waste Management Department (NSWMD). This process will be discussed in detail in Chapter 2.

1.5 Objectives

The primary objectives of this study are:

- To determine the general conditions, existing conditions and environmental conditions of SKOD.
- To investigate and monitor the river water, ambient air, landfill gas, groundwater and leachate during the rehabilitation of SKOD.
- To formulate a proposed database that facilitates landfill rehabilitation management through pollutant inventory management by using the Geographic Information System (GIS).

1.6 Significance of Study

The main contribution of this research is ultimately to produce a database through environmental management and pollutant inventory management. This database will facilitate in rehabilitating and upgrading the current SKOD into sanitary landfill with proper upgrading facilities such as leachate treatment plant. In this regard, the expected outcomes of this research are:

- An environmental inventory in landfill rehabilitation by generating reports about the source of pollutant.
- An easier access to all the data pertaining to SKOD including detailed information on topography of SKOD and its surrounding.
- Information on groundwater quality and surface water quality status of the nearby river in the proposed area with respect to water parameters.

1.7 Scope of Work

This research study was initiated by the idea of the Tenth Malaysia Plan (2011-2015), where the government was urged to upgrade, rehabilitate or close the existing 114 unsanitary landfills which are normally known as open dumpsites. The importance of dumpsite rehabilitation work was to prevent environmental pollutions and health hazards from the closed SKOD. The research study started with the understanding of landfill safe closure and rehabilitation process based on the "Guideline for Safe Closure and Rehabilitation of Municipal Solid Waste Landfill Sites" published by the Ministry of Housing and Local Government (MHLG) in Malaysia and the Japan International Cooperation Agency (JICA). The guideline was chosen because it was adapted to the regional conditions and organization situation of Malaysia. Literatures from various sources were carefully analyzed focusing on the landfill rehabilitation and the application of GIS.

It was followed by carrying out site investigation, fieldwork and meeting with the person in-charged of SKOD in order to determine the general conditions, existing conditions and environmental conditions of SKOD. However, not all the data were managed to be collected due to the lack of resources and data availability. Several parameters were identified to be monitored throughout the landfill rehabilitation process. After the identification, all the data related to the determined parameters were collected and compared with the permitted requirements in Malaysia.

All the collected data were consolidated and compiled in a spreadsheet in Excel format. The coordinate systems were also standardized and converted to the coordinate system which can be interpreted in ArcGIS. A GIS-based inventory database was then created to facilitate and enhance the landfill safe closure and rehabilitation process.

1.8 Organization of Thesis

This dissertation has been divided into five main chapters. Generally, the first chapter is the introductory of this research study. It presents the research background and the problem statement that reflect the purpose in carrying out this research study. Description of the study area chosen and its site history are presented. The objectives, significant of study, scope of work and organization of dissertation are also included to clearly define the research study.

Chapter 2 comprises the literature reviews by past researchers related to this area. It begins with solid waste management in Malaysia and the overview of waste generation. This chapter includes the study of open dumpsite and its impact towards the environment. Chapter 2 also highlights the importance of landfill rehabilitation and safe closure as well as the application of GIS. Lastly, this chapter proposes the application of GIS in landfill rehabilitation.

Chapter 3 outlines the research methodology adopted in this study. It gives the overview and concept on the research methodology used to carry out the field works and to test all the selected parameters. Besides, the research method applied while using GIS is included too.

Chapter 4 shows all the results and findings collected throughout the rehabilitation process. Evaluation and assessment on the findings are discussed and analyzed. The outputs generated from GIS are used to discuss the importance of incorporating GIS in landfill rehabilitation.

Chapter 5 compiles and concludes the research findings. It also contains the recommendations for future work by presenting some feasible improvements needed to enhance future research.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction of Solid Waste Management

Open dumping is a common method of disposing municipal solid waste in most of the Asian countries including Malaysia. It has being a disposable option for many decades (MacDonald, 1996). Managing MSW in a sustainable manner is a big challenge faced due to the consequent technical difficulties in sitting and establishing a sanitary landfill.

Solid waste management requires a huge amount of expenditure. Report from the World Bank has shown that an estimated 50-70% of the revenues are spent on waste management by the urban authorities in Asia. Neglecting the impact on the environment is said to cost an average 5% of the Gross Domestic Product (GDP). (Thematic Working Group on Solid and Hazardous Waste, 2010)

Rapid industrialization and urbanization coupled with the increase in population have caused dramatic changes in the production of solid waste (Joseph et al., 2003), (Idris et al., 2004) and (Kanchanabhan et al., 2011). It is believed that the amount of waste produced increased with the rapid development, population growth and the income generated. The descriptions towards the amount of solid waste produced are available in reviews from (Manaf et al., 2009).

The official GDP in Malaysia has increased to RM559,554 million in 2011 (Department of Statistics Malaysia, 2011a) with an approximately 5.5% of the real growth rate of GDP achieved in early 2011. In 2011, the population in Malaysia has reached 28.3million (Department of Statistics Malaysia, 2011b) and the income per capita is targeted to increase to RM38,845 (USD12,139) by 2015. These growing of GDP and income per capita will further generate more solid waste resulting in insufficient solid waste facilities to cope with the overwhelming production. This implies the necessity to have a proper managed in solid waste to reduce any adverse impact towards the environment. The various impacts includes air, water and soil pollution (Han et al., 2010).

In order to prevent the situation from becoming worse, the safe closure and rehabilitation of any open dumpsite is momentous. According to Joseph & Nagendran (2007), the rehabilitation process should be conducted in a phased manner from open dump, controlled dump, engineering landfill to sustainable landfill. The phased approach of dumpsite rehabilitation is encouraged in developing countries due to its minimum investment but significant improvement. Therefore, the methodology of managing a post-closure landfill process involves undertaking technical, environmental and economic considerations.

2.2 Solid Waste Management in Malaysia

One of the three major environmental problems identified in Malaysia is the issue of solid waste management. It continues to be a major challenge in urban areas throughout the world particularly in the rapid growing cities and towns of the developing countries (Manaf et al., 2009).

The issues of solid waste management have caught everyone's attention. This can be proven with the promotion of public awareness towards waste reduction and the implementation of all sorts of activities such as recycling and recovery of solid waste program, composting program, waste-to-energy scheme and cleaner production program.

A National Solid Waste Management Department was established under the Ministry of Housing and Local Government in 2007. In September 1995, the federal cabinet has decided to privatize the solid waste management under the responsibilities of the two private sectors. The latest privatized to three concessionaires was done in September 2011 under the Tenth Malaysia Plan (2011-2015), with the 22-year concession agreement under the Solid Waste and Urban Cleansing Management Act 2007 (Act 672). The three concessionaires are Alam Flora Sdn Bhd, Environment Idaman Sdn Bhd, and SWM Environment Sdn Bhd. They are responsible for the solid waste collection and urban cleaning services in three different zones of West Malaysia.

Many recycling activities have been carried out throughout our nation. Malaysian has also gradually participated in the recycling programs which can further reduce in waste production. The recycling rate is targeted to have 22% of the waste recycled by 2020 alongside with the National Recycling Program. Besides that, our Department of National Solid Waste Management has also aggressively come out with new policy and made improvement towards a sustainable solid waste management. However, there is still lack of resources in managing solid waste and public cleansing due to the limitation of knowledge, technical and financial supports.

Developing countries often have to adopt technology from the developed countries due to the insufficient knowledge in landfill management. The transfer of technology has caused several problems in functionality of facilities and operational efficiency. These problems originated from the differences in waste composition and climate factor (Joseph, et al., 2003).

2.3 Overview of Solid Waste Generation

As recorded, over 23,000 tons of waste was produced each day in Malaysia in year 2008. This amount is expected to rise to 30,000 tons by the year 2020. In order to achieve a well-planned and designed MSW management, the estimation of MSW produced is important. (Yu et al., 2010). In Malaysia, approximate 31,000 tons of MSW was produced each day in 2009 (Agamuthu & Al-Abdali, 2009).

About 76% of the waste generated was collected with less than 5% of the waste was recycled. Most of the developing countries have insufficient waste management where the waste generated is not collected regularly as the people has no access to waste collection services. Averagely, 95% of the collected wastes are dumped solely to landfill (Alaribe et al., 2010). The cost for waste management services in 2001 was about RM360 million with RM 70 per ton charges. 85% of the cost was accounted for collection, 16% for disposal and 1% for recycling.

The amount of waste generated continues to increase due to the increasing population and development. In general, the per capita generation rate varied from 0.5 to 1.44kg/person/day depending on the economic status of the particular place. According to Chong et al. (2005), the land requirement for Malaysia to dispose the projected 1,556,279 tons of waste in the year 2020 will be 20 hectares. Recently, rehabilitation of the 16 critical open dumpsites accounts for RM480 million.

Figure 2.1 best illustrates the waste composition in Malaysia in year 2006. The waste collected was mainly organic kitchen waste which contributed up to 46% of the waste composition in Malaysia. It was followed by paper 15%, plastic 14%, metals 4%, glass 3% and other waste like textiles, wood and rubber. (Ministry of Housing and Local Government, 2006).

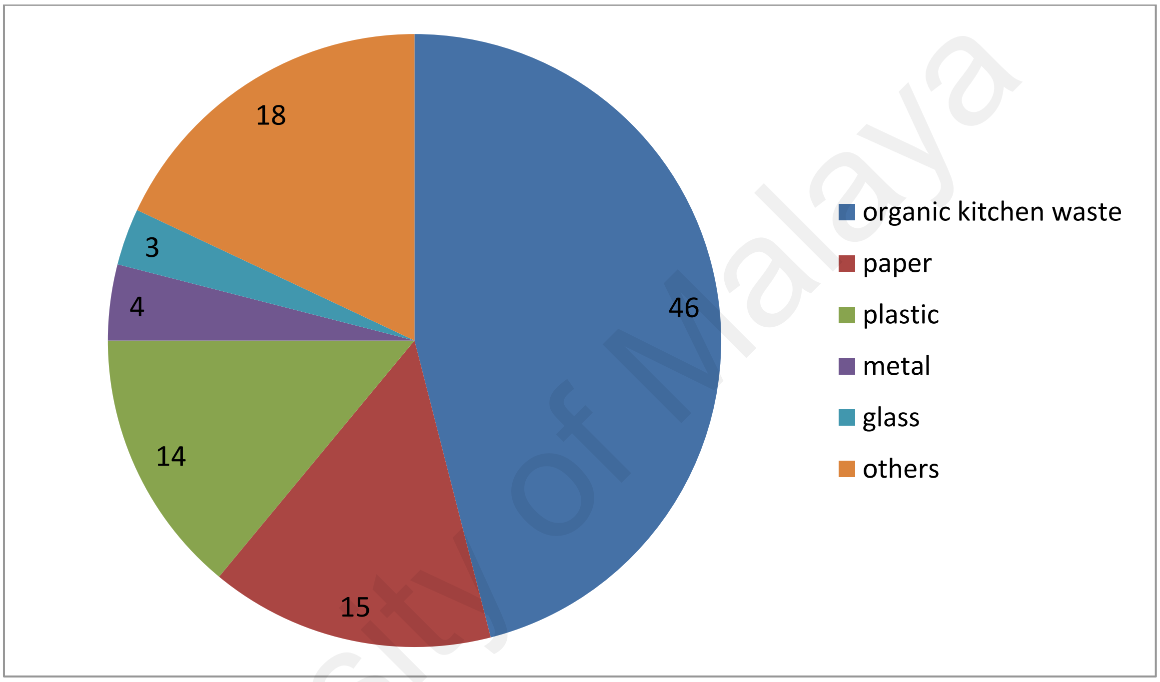

Figure 2.1: Waste composition in Malaysia 2006

2.4 Open Dumpsite

Open dumping is considered to be the earliest and the primary method in solid waste management other than incineration, composting and recycling. It is the common practice in developing countries (Inanc et al., 2004). It remains as the main disposal option because it is economically feasible with RM35/ton as compared to incineration and composting which cost RM500/ton and RM216/ton (Agamuthu & Fauziah, 2005).

Besides, waste is not disposed in a well-managed manner but leading to open burning, scavengers, breeding of disease vectors. In many open dumpsites, scavengers or waste pickers can be easily spotted. They are not only posing safety hazard but also causing serious air pollution by burning the waste in order to collect the valuable items.

Existing open dumpsites are mostly left unattended due to insufficient void space. There is seldom or no liner underlying in an open dumpsite. Hence, it creates groundwater pollution and uncontrollable gas migration. Moreover, unlined landfills will lead to series of problems towards the environment and human health (Singh et al., 2010). The heaps of wastes are left exposed to the surroundings leading to hazardous air and water emissions.

2.4.1 Landfill and Dumpsite Classification

Idris et al. (2004) mentioned that there is no uniform classification system used in Asian countries. Different countries are applying different classification systems. However, in this study, the classification of landfill in Malaysia was referred. Basically, there are five major types of landfill:

- Anaerobic Landfill
- Anaerobic Sanitary Landfill with Daily Cover
- Improved Anaerobic Sanitary Landfill with Buried Leachate Collection Pipes
- Semi-aerobic Landfill with Natural Ventilation and Leachate Collection Facilities
- Aerobic Landfill with Forced Aeration

Table 2.1: Level of improvement of the sanitary landfill system (MHLG)

Level	**Description**
Level 1	Controlled tipping
Level 2	Sanitary landfill with a bund and daily cover soil
Level 3	Sanitary landfill with leachate recirculation system
Level 4	Sanitary landfill with leachate treatment facilities

The table above shows the level of improvement of the sanitary landfill system. The new landfill proposed must achieve Level 3 or Level 4 according to the Ministry of Housing and Local Government (MHLG & JICA, 2004b). Therefore, the SKOD is now in the progress of upgrading to Level 4.

2.4.2 Problem of Landfill

The need to have a sustainable solid waste management has been put into light after the identification of serious environmental hazards originated from the landfill. Most of the studies have addressed the deteriorating in groundwater quality, surface water quality, leachate quality, land value and slope stability as the common issues faced. The following sections will discuss in detail the major issues that must be dealt.

2.4.2.1 Groundwater

Landfill is one of the major pollutant sources towards groundwater. Groundwater surrounding the landfill area are likely to be polluted by the leachate percolation (Mor et al., 2006). The groundwater quality was found to become better with the increase distance and depth of groundwater from the landfill. Groundwater pollution is the most significant landfill hazard since leachate is known as long-lasting emission (Kylefors et al., 2003).

Groundwater may become a feasible source of clean water supply during any dry season (Mohamad Roslan et al., 2007). It is also identified as one the potential water sources by the government.(Ahmad Fariz Mohamed et al., 2009). Therefore, to protect the aquifer from any contamination, the proximity of landfill to a groundwater sources must always adhere to the guideline in sitting a landfill.

2.4.2.2 Surface Water

The surface water will be polluted by the landfill activities in regards of its construction, operational or closure stage. Every stage of landfill activities contributes towards the surface water contamination. The emission of pollutants into surface water is generated particularly from the leachate and sediment erosion. Leakage of leachate into the surface water has resulted in serious water pollution which can pose a health hazard if the water is used for consumption. Landfill must be situated at a fair distance away from biophysical elements such as water, wetlands, critical habitats and wells to reduce the risk of pollution. (Sharifi et al., 2009)

2.4.2.3 Land Value

Studies pertaining to the landfills have shown that landfill at most location has made the surrounding land value to decrease. Most of the people or property owner has less interest on it due to the dust pollution and emission of offensive odour. Existing landfill if not well-managed will always result in the degradation of environmental quality and its aesthetics. In fact, the limited land availability also becoming one of the problems in most of the developing country. Therefore, it is a wise option to rehabilitate the landfill to minimize the wastage of land.

2.4.2.4 Landfill Gas

Generally, landfill gas is produced after the degradation of waste. It consists of methane (CH_4), carbon dioxide (CO_2) and oxygen. Landfill gas in Malaysia comprises 50%-60% of CH_4 and 30%-40% of CO_2 (Abushammala et al., 2011). It is generated from the waste degradation process which relates to the type of waste and landfill technology applied. Landfill gas is highly flammable and explosive when the methane concentration reaches 5% to 15% by volume in the air. Despite the fire hazard, landfill gas like hydrogen sulphide gives offensive odour when it reaches the concentration of 1-2ppm.

Landfill gas especially methane is a source of renewable energy that is economic and environmental friendly (Ilyas Omar & Mncwango, 2005). It can be used to generate electricity depending on the age of landfill, the depth and quantity of waste as well as the water level. The energy value of landfill gas in Malaysia is RM 4million annually (Mekhilef et al., 2011). According to Abushammala, et al. (2011), the CH_4 generated from waste sector in Malaysia will be 1.3Gg in a year. Thus, landfill is one of the major sources for the production of CH_4.

The production of landfill gases such as methane and carbon dioxide are among the main contributions towards the greenhouse effect. About 50-60% of methane gas is produced from the decomposition of municipal solid waste under anaerobic condition. It is followed by 30-40% of carbon dioxide gas (Abushammala et al., 2010).

Emission of landfill gas must be monitored regularly to prevent fire or explosion. Besides that, monitoring also can reduce the damage of landfill gas towards the vegetation as well as the equipment at the landfill.

2.4.2.5 Leachate

The generation of leachate is when the water is percolating through the solid waste. It is clear that leachate can pose potential pollution towards the surface water and groundwater.(Abu-Zeid et al., 2004).

Leachate production will increase quite rapidly after precipitation especially in a relatively warm climate region. In the review of Qdais (2010), unmanaged leachate will pollute the groundwater, surface water, soil leading towards detrimental environmental and public health effect. Besides, leachate normally ended up in water bodies nearby causing high contamination of heavy metals. Thus, the solid waste is needed to be compacted to reduce the filtration rate which will further decrease the generation of leachate. Besides, landfill must be installed with leachate treatment facility to treat the leachate before it is discharged. However, Ilyas Omar & Mncwango (2005) stated that leachate with high salinity is hard to be treated.

The amount and quality of the leachate produced always vary according to the landfill period, amount, method, landfill waste shape and weather condition (Won et al., 2007). Each ton of MSW may generate 150litres of leachate with a total of 3.0million litres estimated everyday according to Agamuthu & Al-Abdali (2009).

2.4.2.6 Slope Stability

The determination of slope stability is important to check its stabilization to avoid any landslide or collapse of the landfill site. Practically, the stability is affected by the waste type, compaction practices, depth of fill, and steepness of side slopes. Slope failure is commonly caused by high moisture conditions in the waste mass. (Ayalon et al., 2006). The gradient of the slope should be less than 1:2 to prevent soil erosions or any spillage (MHLG & JICA, 2004a). Artificial barrier like storage bank or retaining wall is built if the filled waste is found to be unstable.

2.4.3 Introduction of Landfill Safe Closure and Rehabilitation

Landfill is a semi natural terrestrial ecosystem reconstructed on lands which is used to collect waste. It is a temporary land use before its rehabilitation and transformation process into a new site. Researchers have found the necessity to rehabilitate the landfill. Landfill rehabilitation is deemed an approach used to expand MSW landfill capacity and to extend the lifespan. Recovering of the recyclables and reusable materials can be done at the same time during the rehabilitation process. Moreover, high cost of acquiring additional land for waste disposal site can be avoided (Manaf, et al., 2009). In Malaysia, the cost of rehabilitating one hectare of land is approximated to be RM50,000 per year. In order to upgrade the prevailing open dumpsite, the technology and financial aspects have to be taken into serious consideration particularly in developing countries.

The execution of safe closure and rehabilitation activity are required when the capacity of a landfill site is exhausted. The process includes sealing the site, collection of the landfill gas and leachate, and its continued operation as a closed landfill, including monitoring stability and continuous collection of leachate and biogas.

Misgav et al. (2001) concluded the four main problems in the reclaimed landfill site as differential subsidence, water percolation, slope instability and the presence of gas in soil. After the rehabilitation and safe closure process, a period of 30 years after closure is needed in order for the landfills to reach its stability. A set of procedure to select a suitable open space for a closed landfill site is introduced. This procedure comprised the planning suitability criteria and physical compatibility criteria.

Chu (2008) stated that the closed landfill can be converted into a habitat for wildlife conservation after the gradual and orderly process of change in ecosystems brought about by the progressive replacement of one community by another after its closure with the planting of selected early successional species. A proper management of the closed landfill is essential to achieve this development.

Constructed wetlands method is widely used in landfill rehabilitation in Slovenia. It is considered to be a viable and sustainable option due to its closed loop technology that can help to reduce the problem of water contamination and long term environmental impact (Bulc et al., 2004).

In UK, landfill prevails the municipal waste industry with majority of the active landfill sites will be infilled and returned to agricultural or recreational use within the next 15 years.(Read et al., 1997)

2.4.3.1 Examples of Rehabilitated Landfills

There are many successful examples on the landfill sites that have been rehabilitated into a public area throughout the world. Landfill constructed in Milan, Munich and Cario were transformed into a green lung and park. Tunisian has also done research on the rehabilitation of the Henchir El Yahoudia landfill in order to convert the landfill into a green space (ZaÏri et al., 2004).

2.4.3.2 Landfill Safe Closure and Rehabilitation Process

Every landfill must go through the stage of landfill safe closure and the rehabilitation stage. In this research study of SKOD, the guideline for safe closure and rehabilitation of MSW landfill sites published by MHLG in 2004 was referred. The guideline was chosen because it was formulated based on all the criteria, conditions, standards and aspects pertaining to solid waste management in Malaysia. According to the guideline, the safe closure and rehabilitation processes include compaction of waste, surface water collection system, isolating the waste, leachate collection system and final cover system.

Landfill safe closure is an ultimate step to protect public health and the environment and to prevent environmental pollution and risks from the closed landfill sites as well as from the uncontrolled development of closed landfill sites (MHLG & JICA, 2004a). The process of landfill safe closure is shown in Figure 2.2.

There are three landfill closure stages:

- Physical closure of landfill sites.
- Post closure management of landfill sites.
- Post closure land use of closed landfill sites.

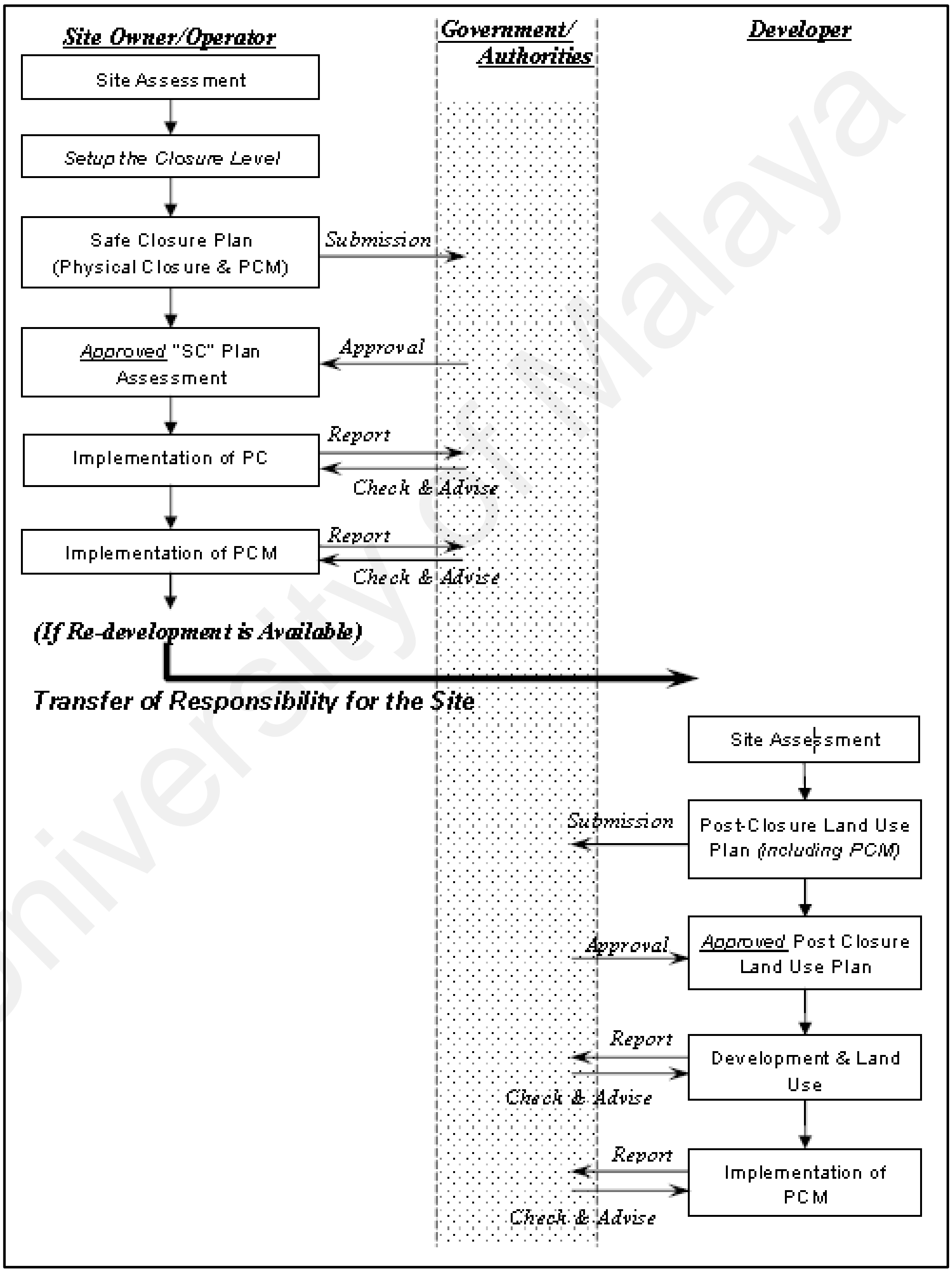

Figure 2.2: Landfill safe closure and rehabilitation process

In brief, the steps taken for landfill rehabilitation are:

Step 1: Documentation of the actual situation of the selected site

Step 2: Planning and management of monitoring and rehabilitation works

Step 3: Carrying out of the rehabilitation works

Basically a minimum period of 10 years is needed for the landfill to stabilize in order to minimize the effects of land subsidence and landfill gas generation. Any post-closure land use plan can be considered after this period. Surface layer of the closed landfill exceeded 5 years may be considered with limitation on people accessing the site.

Based on the MHLG & JICA (2004a), there are four closure levels. The table below shows the different measures and facilities required for different closure level.

Table 2.2: Closure levels and required measures

Measures	**Safe Closure Level**			
	C1	**C2**	**C3**	**C4**
Final cover soil	++	+++	+++	+++
Storm-water drainage	+	++	+++	+++
Safely closure	+	++	+++	+++
Gas vent		++	+++	+++
Leachate		+	+++	+++
Groundwater			+++	+++
Early stabilization		+	+++	+++
Post closure measures		+	+++	+++
Monitoring	+	++	+++	+++
Landfill system			Semi-aerobic System	

Notes: +: minimum equipped/operated, ++: fair, +++: fully equipped/operated

Source: MHLG (2004a)

2.4.3.3 Types of Data Required

To start an efficient rehabilitation or closure of a dumpsite, it is most important to collect and evaluate all available information about the site. There are several data required in safe closure of a landfill site which includes:

- Surrounding Environment
  - Topography
  - Geology
- Nuisance Condition
  - Odour
  - Vector
  - Land Subsidence
  - Leachate discharge
  - Landfill gas
  - Slope collapse
- Facility Condition
  - Top cover
  - Surface drainage on the top cover
  - Cut-off drainage around the site
  - Gas ventilation pipes
  - Leachate collection pipes
  - Leachate treatment facilities

2.4.3.4 Monitoring Parameter

The important parameters to be monitored during landfill stabilization are the leachate, landfill gas and subsidence rate as stated in (MHLG & JICA, 2004a). The frequency to carry out the monitoring program as stated in Table 2.3 has been identified by the MHLG in Malaysia.

Table 2.3: List of monitoring parameter and its proposed frequency

Monitoring Parameters	**Proposed Frequency by MHLG**
Site Investigation	Once (before monitoring)
Groundwater	Once a year
Surface Water	Once a year
Leachate	Quarterly
Landfill Gas	Half Yearly

2.5 Geographic Information System

Geographic Information System (GIS) is a field that arises instantly and integrates into everyday life. It provides tools that are able to convert topological data and information in a standardized format. Other than solving the widest range spatially related problems, GIS can perform simulation and modeling to assist in social, economic, politic and environmental applications.

GIS is a generic term expressing the use of computer to integrate, store and edit geographical data. All the data stored in GIS environment can be easily retrieved updated, analyzed and displayed (Hu & Zhou, 2008).

GIS is associated with art, science, engineering and technology to create and depict the Earth's surface in digital format. Rapid development in computer technology has always contributed to rapid advance in GIS. There has been significant interest in developing GIS-based multi-criteria decision analysis in many different filed of studies including ecological sciences, urban-regional planning, waste management, hydrology and water resource, agriculture, forestry, natural hazards, recreation, tourism, housing or real estate, geological sciences, manufacturing and cartography (Malczewski et al., 2003)

2.5.1 GIS in Environmental Planning and Management

Various managements of solid waste are relied on sophisticated spatial analysis facilitated by the development of GIS. The applications of GIS technology have been utilized to resolve numerous environmental planning and design. There are many examples of the GIS application in solid waste management (Ghose et al., 2006)

(Kanchanabhan, et al., 2011), (Amin Sharee et al., 2010). The researches have used GIS in the study of the optimal routing for transportation and collection of solid waste.

An integrated technology between radio frequency identification (RFID), global positioning system (GPS), general packet radio system (GPRS), and geographic information system GIS) with a camera was used in the solid waste bin monitoring system (Arebey et al., 2010). Another study presented by Arribas et al. (2010) designed an economical urban solid waste collection system applying tools of GIS and mathematical modeling. Landfill sitting process has also employed GIS application in selecting the best landfill location (Sharifi, et al., 2009).

Besides, study on geo-environmental of urban land use planning in Lanzhou City, China also used GIS in this contest (Dai et al., 2001). Application of GIS is been widely used in groundwater studies. Nas & Berktay (2010) have studied the groundwater quality applying GIS and geostatistics techniques in Konya City of Turkey.

Integration of multi geo-referenced spatial data can be done within GIS database which is used as an inventory in many research fields. There were several research studies that developed the air emission inventory by using GIS in order to analyze the spatial distribution of air pollutants (Gumrukcuoglu, 2011),(Elbir et al., 2010)

GIS has been incorporated in many decision making process particularly in the environmental planning. Take for example, the development of LOADSS (Lake Okeechobee Agricultural Decision Support System) which used the GIS environment to help in solving problems created by phosphorus runoff into Lake Okeechobee (Negahban et al., 1995). In this respect, Assaf & Saadeh (2008) have incorporated the

GIS into the Water Evaluation and Planning (WEAP) model in order to develop a decision support system that can help the policy makers to come out with a comprehensive water quality management in the Upper Litani Basin through assessments.

GIS is also applied in the Decision Support System (DSS) of an integrated solid waste management (MacDonald, 1994). DSS has been developed to opt for the best waste management program by providing analytical tools for developing and evaluating the magnitudes of resources needs and potential environmental impacts.

The results of all the research are interactive and computerized tool which allow the stakeholders to consider more options more thoroughly, thus enabling them to improve upon, or at least understand the status quo.

2.5.2 Application of GIS in Malaysia

Although GIS has been widely applied in other countries, studies using GIS are relatively limited in Malaysia. The application of GIS is considered to be in a preliminary stage as most of the researches related to GIS are restricted to certain areas of study. Only a few district councils and municipalities invested in GIS due to the little knowledge in GIS (Yaakup et al., 2003).

In Malaysia, there have been studies carried out that incorporated GIS. Al Fugura et al. (2011) have used GIS to enhance the flood mitigation management where different flooding scenarios were displayed in a 3D hydrological GIS modeling. A flood susceptible mapping in the Kelantan River Basin was also developed in a GIS environment (Pradhan & Youssef, 2011)

There were also landslide evaluation applying GIS conducted in part of Klang Valley areas (Sezer et al., 2011) and Selangor area which can delineate landslide susceptibility map (Pradhan, 2011). Besides, GIS is being deployed in field like health care to predict the risk of Dengue Fever (DF) and Dengue Hemorrhagic Fever (DHF) (Shafie, 2011). It is also incorporated in renewable energy field (Chiew et al., 2011) to come out a comprehensive analysis of alternative systems in optimizing the energy production.

2.5.3 Introduction of GIS in Landfill Rehabilitation Management

Surging demand for conservation of the environment and public health is tremendous to which closed dumpsite must be well rehabilitated. Rehabilitation and safe closure of landfill are required to minimize the negative impacts posed towards human health and the environment. It is also to avoid any tragedy that might happen like in Payatas dumpsite in Manila and Leuwigajah dumpsite near Bandung where 330 people and 147 people were killed respectively due to landfill collapse (Agamuthu, 2006).

In general, only few countries have comprehensive data on waste generation, waste composition and waste management. Due to the lack of data available, the stakeholders often faced difficulties in making a good decision. Information concerning solid waste management was either incomplete or not available.

In Malaysia, it has being a complicated and difficult process to gather and understand most of the information regarding landfill issues because the information is widely distributed. There are very limited and unreliable information available for the stakeholders in finding ways out to improve the situation or to propose a new policy. Not to say that, the information required is presented in different formats which is impossible for the stakeholder to compare. Thus, decision maker is unable to identify all the available and necessary information during the decision making process (Sharifi, et al., 2009).

For the case of landfill rehabilitation management, it has to integrate diverse environmental, social, political and economic aspects. In order to integrate such a significant amount of inputs like spatial data, regulations, correlation between attributes, GIS must be incorporated.

GIS will be used to map, query and analyze all the collected data in this study which will benefit the stakeholders greatly. Application of GIS in environmental planning can reduce the time and cost as it can perform synergistic process regardless the large amount of information. It standardizes data, elaborates digital maps on the decision making basis. All the inputs stored in GIS can provide inventory for long-term monitoring process (Sumathi et al., 2008).

Lack of appropriate management of municipal solid waste collection and landfilling system of Sg Kembong have led to a waste of energy, increasing environmental pollution, and increasing costs. Thus in this research study, GIS is used in the rehabilitation process of SKOD by facilitating the evaluation process on the effects of environmental and geological aspects.

CHAPTER 3

RESEARCH METHODOLOGY

3.1 Introduction

Among the main objectives of this research study was to produce a GIS-based inventory system to facilitate the current landfill rehabilitation process implemented in SKOD. The landfill rehabilitation process was designed on the basis of geology and environmental aspects according to the guidelines published by MHLG. Thus, the integrated of landfill rehabilitation process into GIS database development shall comprise the following information and features:

a) Integration of raster database in terms of remote sensing application (e,g., satellite images and photos).

b) Data including detailed characteristic of solid waste (the type of solid waste) collected in SKOD and surrounding land use.

c) The geological condition of SKOD.

d) The surface water quality of Sungai Beranang.

e) The groundwater and ambient air qualities within the vicinity of SKOD.

f) The landfill gas emission and leachate characteristic.

Several fieldworks such as groundwater, surface water and landfill gas sampling were carried out. All the results were transferred to GIS environment to come out with an inventory system of SKOD rehabilitation. The inventory system of the SKOD can be assessed easily by the stakeholders to find out the situation of SKOD particularly the contaminants detected within the landfill.

3.2 Study Approach

The scope of landfill rehabilitation work using GIS was divided into three major steps namely (1) data collection, (2) data processing and (3) data analyzing. The basic framework is clearly illustrated in figure 3.1. This framework was followed throughout the study.

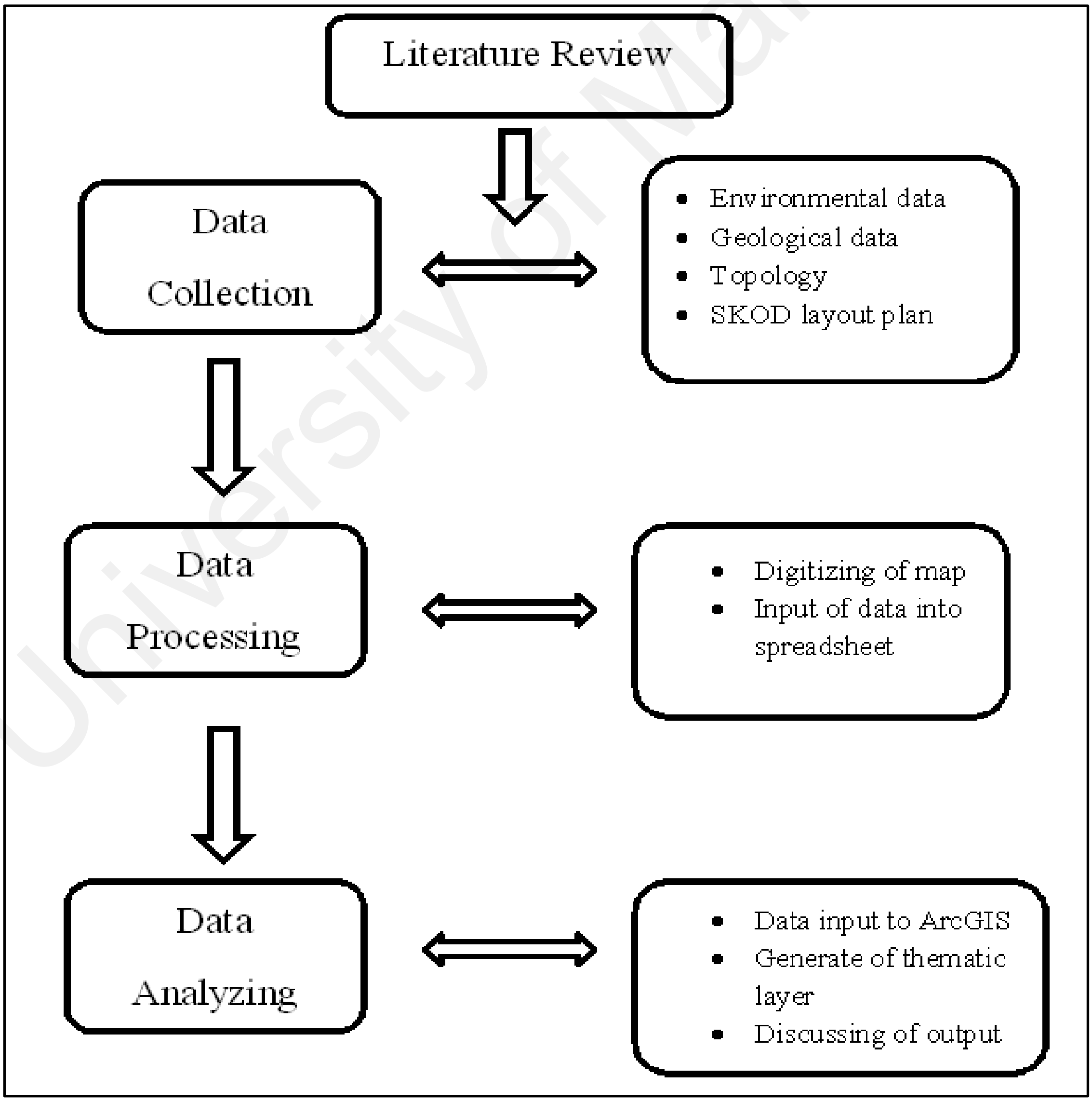

Figure 3.1: Basic framework adopted in this research study

3.3 Data Collection

It was necessary to account for all types of data in order to input into the GIS-based inventory. The data collected were both primary and secondary data. The primary data collection was done through the field work executed in SKOD. Meanwhile, secondary data collection was carried out through several meeting with the engineers and contractors in-charged of SKOD. There are different consultancies and companies participated in the SKOD activities since its commencement. As mentioned in chapter one, RESB which is the brainchild of Core Competency Sdn Bhd, has involved in the rehabilitation of SKOD until August 2010 before Worldwide Holdings Berhad (WHB) took over the rehabilitation process. Therefore, data was collected from the two companies throughout this research study

The data acquired from RESB was the waste composition of SKOD in year 2009. Meanwhile, data such as layout plan, ambient air, leachate quality and water quality were collected from WHB.

The missing data was then identified. A number of field survey and field works were carried out to procure the missing information of SKOD such as the groundwater quality, surface water quality, landfill gas and leachate characteristic.

Another essential requirement in data collection stage was the acquiring of related data in the form of maps, diagram and aerial photographs. The spatial data was mainly acquired through Jabatan Ukur dan Pemetaan Malaysia (JUPEM).

3.3.1 Site Investigation

The site investigation was carried out in April 2010 to determine the existing conditions of the site to evaluate the proper measures for safe closure. Several factors like the surrounding environment, nuisance condition, geology study, structures and facilities in SKOD, type and shape of filled waste, total amount of disposed waste, degradation of the filled waste, surrounding environment and surrounding land use were examined.

3.3.2 Construction of Boreholes

In order to investigate the geological conditions and to examine the depth and quality of groundwater of SKOD, five deep boreholes to the average depth of 28.1m through boring method were conducted. Another two points were drilled by Hand Auger method to the depth less than 6m. The locations of the boreholes' points as shown in Figure 3.2 were decided so that the direction of groundwater flow can be determined. The nature of the underlying strata found in SKOD can be presented based on the results obtained.

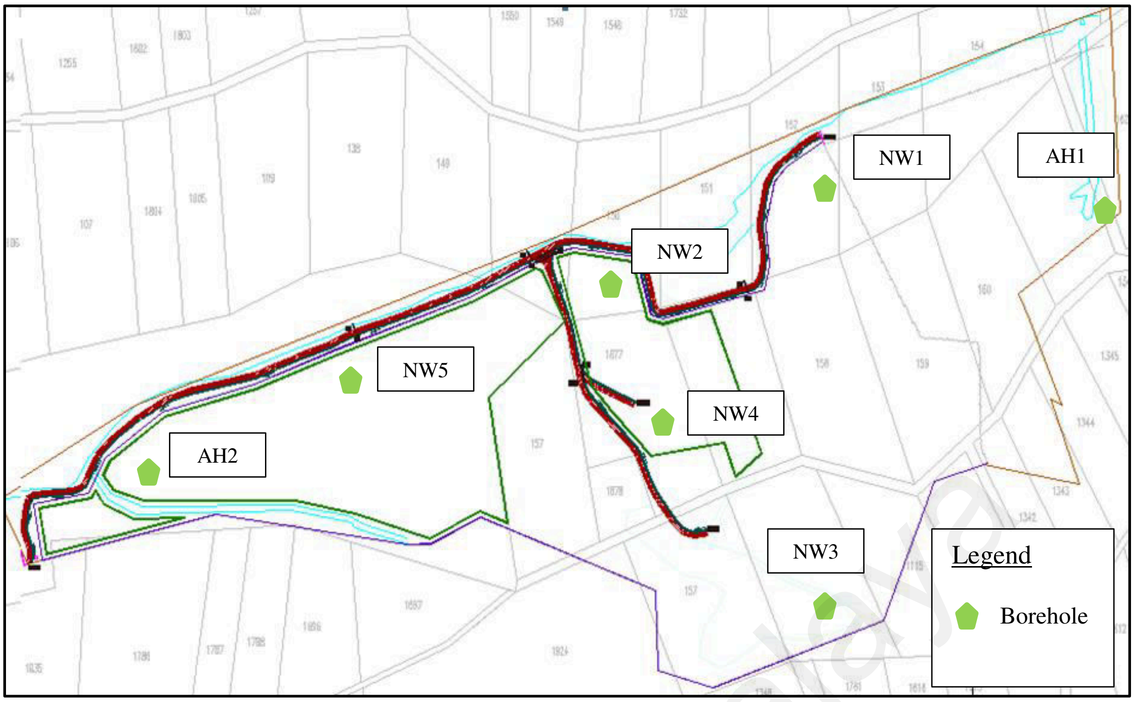

Figure 3.2: Location of the borehole points within SKOD

Five boreholes namely NW1, NW2, NW3, NW4 and NW5 were constructed using the multi-speed rotary boring machine. AH1 and AH2 represented the holes drilled by hand auger method. The soil drilling works were done in accordance to the BS 5930, BS 1377 and JKR Standard, Specification for soil drilling works.

The rotary wash boring must with adequate capacity and accessories to perform the drilling works. The extent of site investigation mainly depends on the character and variability of the subsoil and ground water, salinity and the amount of existing information available.

Boring was terminated after 100m depth or at the depth when impermeable layer was encountered at fourth aquifer layer. It also can be terminated if rock was encountered. The water level in each borehole was recorded while drilling was in progress and after the completion of the boreholes.

Standard Penetration Test (SPT) was carried out at 1.5 m interval in both cohesive and non-cohesive soils. A split spoon sampler of 50mm O.D. was driven into the soil by a 63.5kg weight operated automatically. The weight was dropped from a height of 750mm at a sufficient number of times to secure the 450mm sampler penetration or a maximum of 50 blows. The number of blows for the beginning 150mm was recorded for reference and the following 300mm penetration was recorded as the N-value. Each sample obtained from the sampler in the field was examined and classified. Representative portions of each sample were sealed in polythene bags and labeled according to the sample numbers and depths taken. The bags were then sent to the laboratory for testing.

The laboratory tests were executed according to the procedures that complied with BS 1377 for all typical disturbed samples at various distinct strata. The soil classification tests were as follow:

- Natural moisture content
- Atterberg limits
- Particle size distribution for coarse grained soil
- Particle size distribution for fine grained soil

3.3.3 Construction of Groundwater Monitoring Wells

The boreholes namely NW1, NW2, NW3, NW4 and NW5 were used as groundwater monitoring wells by installing a vertical pipe, screen, grout and filter pack. Monitoring wells were also sealed with the locking covers to prevent any leakage to the well from the surroundings. The groundwater monitoring well and its specification are best illustrated in Figure 3.3 and Figure 3.4 respectively.

Figure 3.3: Constructed groundwater monitoring well

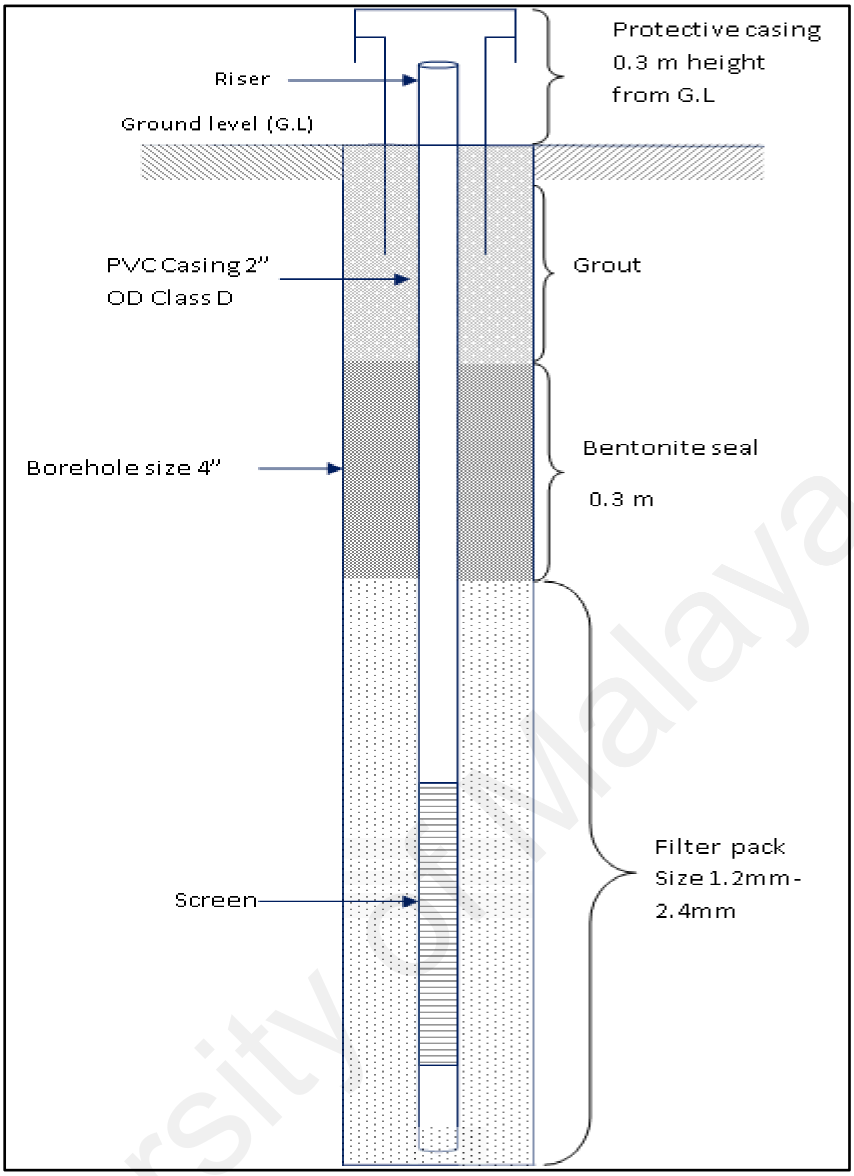

Figure 3.4: Groundwater monitoring well specification

3.3.4 Sampling Procedure

Due to the lack of data, several samples on groundwater, surface water and leachate were collected. The section below will further discuss the standard procedure of sampling that has been applied throughout the sampling process. The standard procedures included positioning, sample delivery and laboratory analysis.

3.3.4.1 Location Positioning

To identify the sampling location, the positioning and recording of actual hand-coring coordinates was conducted using a handheld Global Positioning System (GPS).

3.3.4.2 Sample Delivery

Individual sample bottles were covered properly to prevent leakage. Samples were stored in a cooler box which got sufficient ice. This is to ensure that the temperature of the samples was kept at 4°C until they were delivered to the laboratory. The cooler box was clearly labeled with sufficient information to enable easy identification.

3.3.4.3 Laboratory Analysis

The analysis was carried by an accredited laboratory. Additionally, it was tested based on recognized standard methods such as American Public Health Association (APHA). The test methods to be adopted for the analysis of the various parameters were outlined in Table 3.1.

Table 3.1: Analysis methods for proposed parameters

Parameter	**Method**
Mercury as Hg	A PHA 3112 B, 2005
Cadmium as Cd	APHA 3120 B, 2005
Total Chromium as Cr	APHA 3120 B, 2005
Arsenic as As^{2+}	APHA 3114 C, 2005
Lead as Pb^{2+}	APHA 3120 B, 1995
Copper as Cu^{2+}	APHA 3120 B, 2005
Manganese as Mn^{2+}	APHA 3120 B, 2005
Zinc as Zn^{2+}	APHA 3120 B, 2005
Iron as Fe^{2+}	APHA 3120 B, 2005
Phenol	APHA 5530 B&D, 2005
Chloride as Cl^-	APHA 4500-Cl- B, 2005
Sulfate as SO_4^{2-}	APHA 4500-SO4-B,2005
Total Coliform	APHA 9222 B, 2005
Nitrate as NO_3^-	APHA 4500-NO3
Hardness as $CaCO_3$	APHA 2340 B, 2005
Selenium as Se^{2-} In-house method (ESL/L/W-03)	based on PE B3505:Se, 1994
Total Dissolved Solids	APHA 2540 C, 2005
Biochemical Oxygen Demand @ 5days at 20 °C	APHA 5210 B, 1995 & APHA 4500-O G, 1995
Chemical Oxygen Demand	APHA 5220 B, 1995
Total Suspended Solids	APHA 2540 D, 2005
Chromium Hexavalent as Cr^{6+}	APHA 3500 Cr-B, 2005
Chromium Trivalent as Cr^{3+}	IH : APHA 3120 B, 2005 & APHA 3500-Cr B, 2005: By Calculation (ESL/L/W-01)
Cyanide as CN	APHA 4500-CN C & F, 1995
Nickel as Ni^{2+}	APHA 3120 B, 2005
Tin as Sn^{4+}	In House Method based on : APHA 3120 B, 2005 (ESL/L/W-08)
Boron as B^{3+}	APHA 4500-B C, 2005
Free Chlorine as Cl_2	APHA 4500-Cl B, 2005
Sulphide as S^{2-}	APHA 4500-S2 F, 2005
Chloride as Cl^-	ASTM D 512, 1981
Total Coliform	APHA 9222 B, 2005
Nitrate as NO_3^-	APHA 4500-NO3- B, 2005
Hardness as $CaCO_3$	APHA 2340 B, 2005
Selenium as Se^{2-}	APHA 3120 B, 2005
Oil & grease	APHA 5520 B, 1995

3.3.4.4 Groundwater Sampling

Samples collected were analyzed for physiochemical properties in March 2011. Five samples of groundwater were collected at NW1, NW2, NW3, NW4 and AH5. The locations of the five sampling points were illustrated in Figure 3.2. Prior to groundwater sampling, all instruments were calibrated appropriately according to the calibration standards.

The five water samplings were collected using the sampling bailer. The water level was first measured and then purged at least three times of the volume by using the foot valve attached to a bailer. The purging of groundwater was done to allow fresh formation water to move upward into the well to further displace the standing water. This was to make sure that the groundwater samples collected were at least 95% of the water originated from the aquifer formation. The groundwater sample collection was carried out as soon as the well has been recovered to a level sufficient for sampling. The samples collected directly from the bailer were used to fill up completely into the labeled sample bottles. They were then preserved and sent back to the laboratory for analysis.

The results were than compared with the National Guidelines for Raw Drinking Water Quality from the Ministry of Health (Revised in December 2000) as shown in Table 3.2 to determine its quality.

Table 3.2: National Guidelines for Raw Drinking Water Quality (Revised in December 2000)

Parameter	Symbol	Benchmark
Sulphate	SO_4^{2-}	250 mg/L
Hardness	$CaCO_3$	500 mg/L
Nitrate	NO_3^-	10 mg/L
Coliform	-	Must not be detected in any 100 ml sample
Manganese	Mn^{2+}	0.1 mg/L
Chromium	Cr	0.05 mg/L
Zinc	Zn^{2+}	3 mg/L
Arsenic	As^{2+}	0.01 mg/L
Selenium	Se^{2-}	0.01 mg/L
Chloride	Cl^-	250 mg/L
Phenolics	-	0.002 mg/L
TDS	-	1000 mg/L
Iron	Fe^{2+}	0.3 mg/L
Copper	Cu^{2+}	1.0 mg/L
Lead	Pb^{2+}	0.01 mg/L
Cadmium	Cd	0.003 mg/L
Mercury	Hg	0.001 mg/L

Source: Ministry of Health, Malaysia (2006)

3.3.4.5 Surface Water Sampling

The surface water quality was conducted at the upstream downstream of Sg. Beranang which was located next to the SKOD as shown in Figure 3.5. The sampling of Sg. Beranang was aimed to provide a description of the present river water quality and sources of pollution so that a relationship between the pollution sources and the receiving water bodies can be established. The current status of river water quality will be further discussed in the next chapter.

Surface water samples were collected by using grab sampling technique. The methodology applied for collecting and preservation of surface water samples will be in accordance to the procedures specified in ASTM D 5358, 1993.

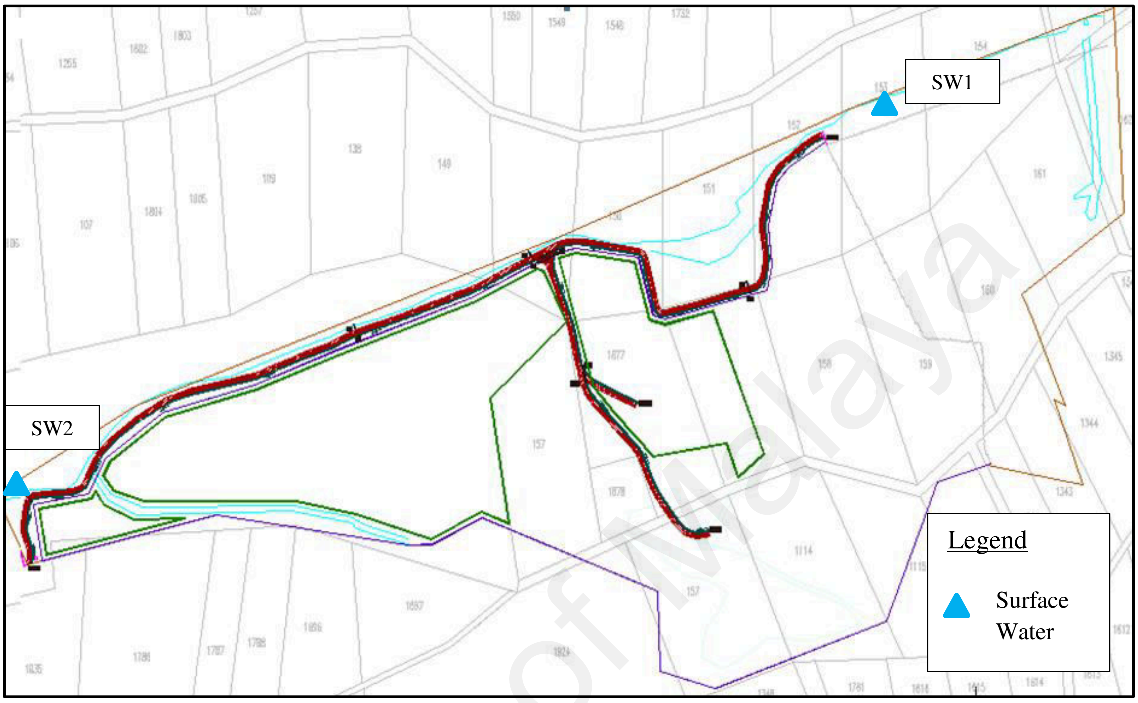

Figure 3.5: Sampling points of surface water

The water quality data was classified based on two classifications according to DOE, Malaysia. The river water quality statuses were classed in clean, slightly polluted or polluted category according to the Water Quality Index (WQI). The second classification was to categorize the river into Class I, II, III, IV or V based on the Interim National Water Quality Standards for Malaysia (INWQS).

Water Quality Index (WQI) was evaluated based on 6 main parameters:

- Biochemical Oxygen Demand (BOD)
- Chemical Oxygen Demand (COD)
- Ammoniacal Nitrogen (NH_3N)

- pH
- Dissolved Oxygen (DO)
- Suspended Solids (SS)

WQI expresses the river water quality by considering selected physical, chemical and biological parameters. It ranges from 0 to 100 where the higher index indicates good river water quality. It can be classified into five classes based on the degree of pollution as shown below:

WQI ≥ 92.7	-	Class I (Clean)
WQI ≥ 76.5	-	Class II
WQI ≥ 51.9	-	Class III (Slightly Polluted)
WQI ≥ 31.0	-	Class IV
WQI < 31.0	-	Class V (Polluted)

3.3.4.6 Leachate Sampling

The leachate samples were collected before and after the rehabilitation process started. The first sample was collected in December 2010 which was considered as the baseline study. The rest of the samples were collected after the leachate collection system (LCS) was built. The LCS consists of three pumping chambers (W-PC1, W-PC2 and W-PC3) and three leachate treatment ponds (WS-SBR.1, WS-SBR.2 and W-EQ). The leachate samples were collected at locations as shown in Figure 3.6 and Figure 3.7 by using grab sampling technique.

The characteristic of the leachate samplings were then compared with the Malaysia Environmental Quality Regulations 2009.

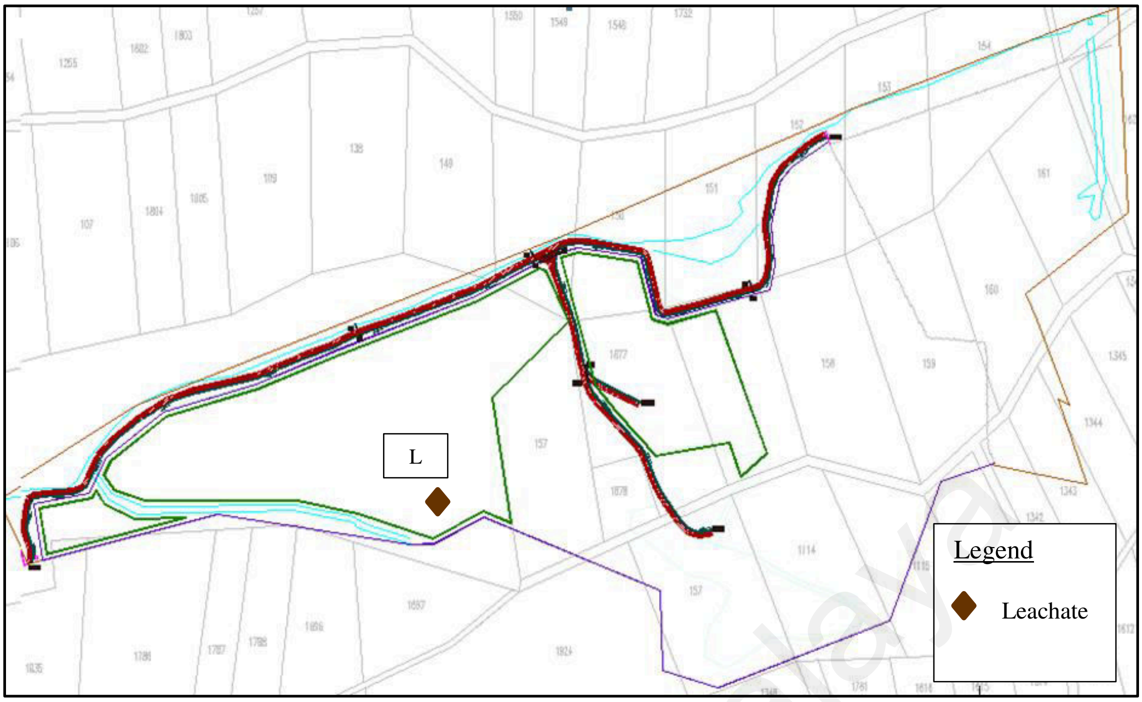

Figure 3.6: Location of first leachate sample

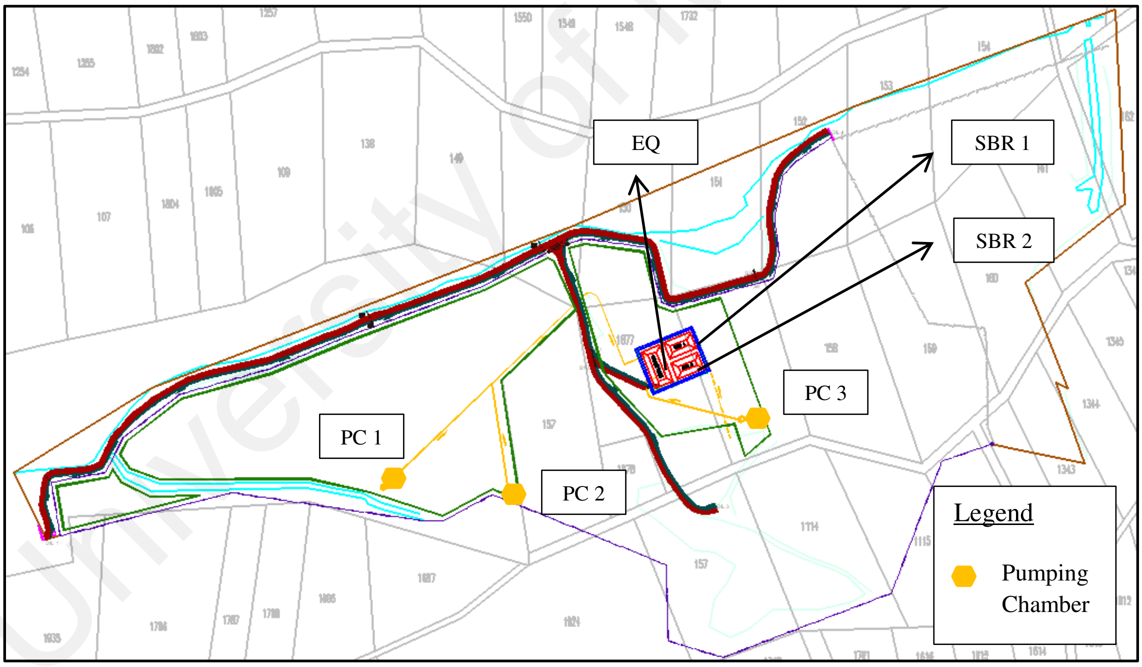

Figure 3.7: Location of pumping chambers, SBR supernatant lagoons and equalization pond

3.3.4.7 Waste Composition

The waste composition data was collected from the RESB. It was then computed into a pie chart to clearly present its composition. The waste composition was said to be best represented the economic status or the economic situation and the life style of the particular community (Bandara et al., 2007). It was also a good practice to keep track of the waste composition and waste generation data. The data was important for the formulation of the collection strategy and policy.

3.3.4.8 Landfill Gas Sampling

Landfill gas (LFG) samples were collected twice in May and November 2011 as shown in Figure 3.8. The LFG samplings were carried out half yearly based on the monitoring frequency fixed by Ministry of Housing and Local Government. The parameters and the testing methodology are presented in Table 3.3.

Table 3.3: Summary of landfill gas analysis method

Parameter	**Method**
Hydrogen Sulfide	Probe
Carbon Dioxide	Portable analyzer
Carbon Monoxide	Portable analyzer
Oxygen	Portable analyzer
Methane	ASTM D2820

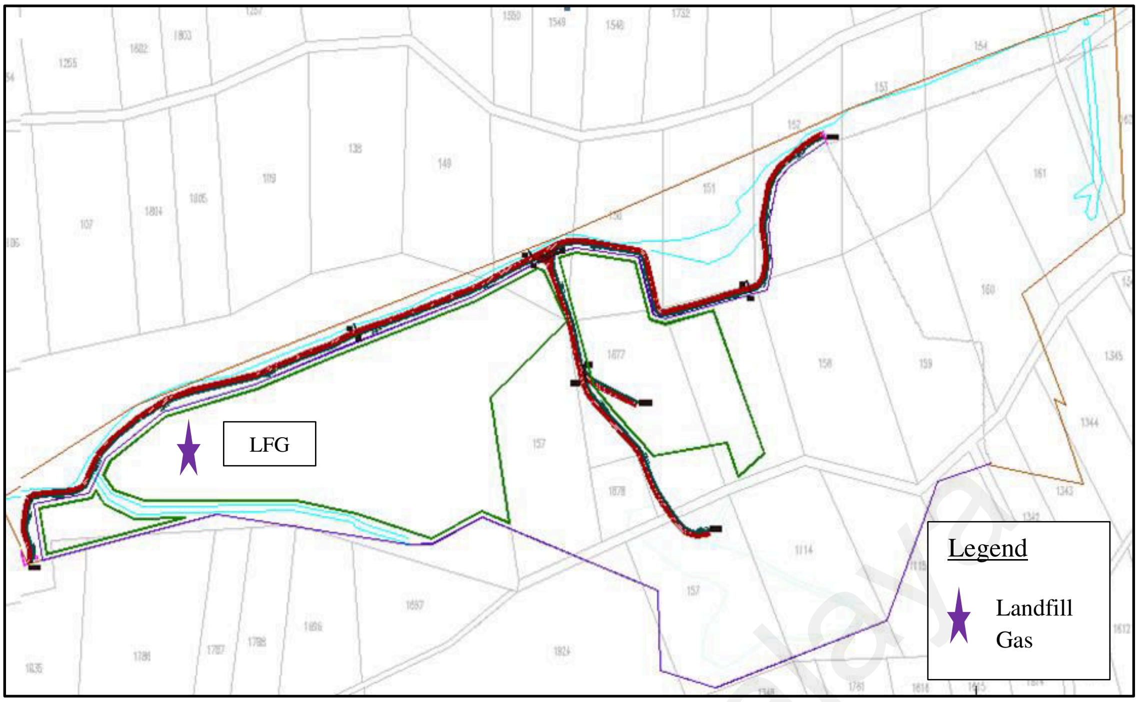

Figure 3.8: Landfill gas sampling point

3.3.4.9 Ambient Air Sampling

The ambient air quality data was gathered from WHB. It was conducted at an open space within the SKOD area as shown in Figure 3.9. The ambient air quality must be in accordance with the Malaysian Recommended Air Quality Guidelines. The parameters tested were total suspended particulate, carbon dioxide, carbon monoxide, methane and hydrogen sulfide. Table 3.4 shows the summary of ambient air quality analysis method.

Table 3.4: Summary of ambient air quality analysis method

Parameter	**Method**
Particulate Matter 10µm	ASTM D 4096, 1993
Hydrogen Sulfide	APHA 812, 1992
Carbon Dioxide	Portable analyzer
Carbon Monoxide	APHA 126
Methane	ASTM D2820

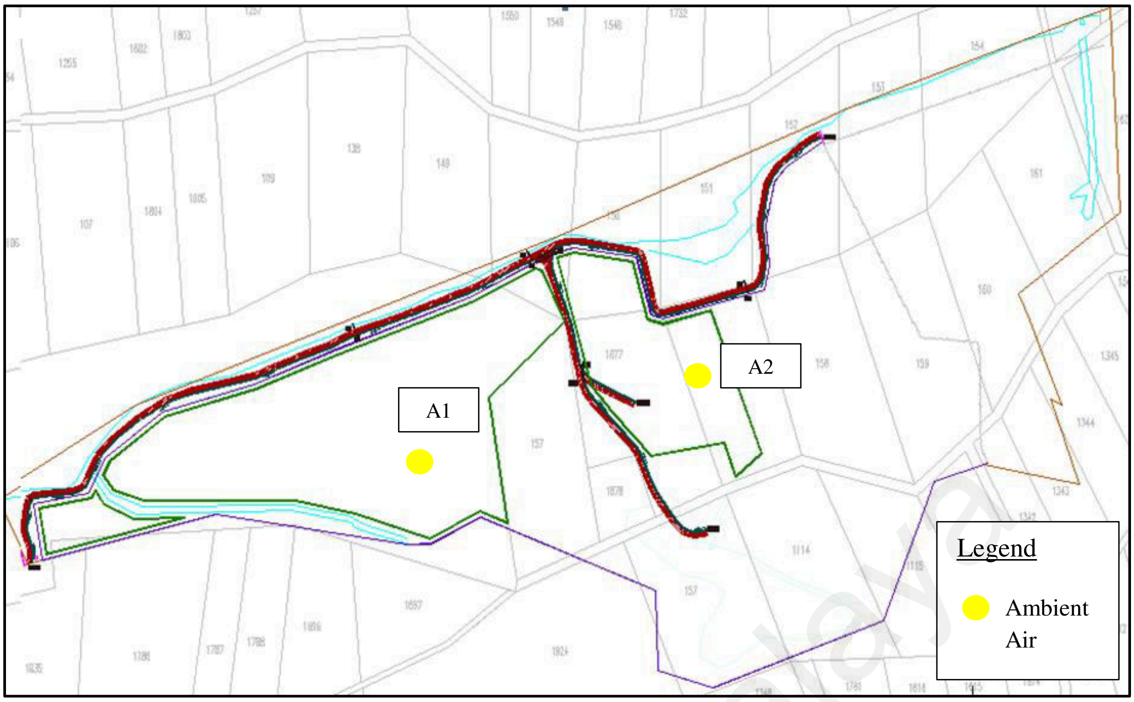

Figure 3.9: Ambient air quality sampling point

3.4 Data Processing

During the stage of data processing, a GIS software package of ArcGIS 9.3 was used to map, query and analyze all the data obtained. The collected data was computed into spreadsheet using Microsoft Office Excel.

3.4.1 Conversion of Coordinate Systems

The data collected was in different formats, scales and of different coordinate systems. They were almost inapplicable for direct implementation in this study. All the data was of little value until it was processed. Therefore, the data must be converted into appropriate data inputs of a standard coordinate system. These data inputs included satellites images, existing digitized data, topography map, results from fieldwork and reports. Each data input described each attributes in point or polygon features stored in vector or raster format.

There was always a need to perform the conversion of coordinate systems of all the collected data. It was executed to achieve a standardization of the referenced coordinate system used in GIS. Most of the data collected from the government agencies have been projected with Rectified Skew Orthomorphic (RSO) Malaya in Meters (Kertau_RSO_Malaya_Meters). The false easting position was 804671m.

In this study, GCS_Kertau was set as the referenced coordinate system. The coordinate system used D_Kertau as its datum. Therefore, all the Geo-referenced dataset was converted to GCS_Kertau.

The coordinates of all the sampling points and site coordinates were recorded directly from the handheld GPS. The coordinate readings were in the degrees/minutes/second format. However, ArcGIS software can only interpret and display x,y points coordinates written in decimal degrees format. Thus, all the coordinates must be converted to decimal degrees format before they were tabulated in ArcGIS. The conversion was executed by using a simple conversion formula as follow:

Decimal Degrees = Degrees + ((Minutes/60) + (Seconds/3600))

3.4.2 Data Conversion (*.xls) to Geo-Database

All the datasets were compiled using Microsoft Office Excel in (*.xls) format. For this case study, only tabular data under this format would be extracted in ArcGIS for conversion to (*.shp) layers and (*.mxd) project format.

The data was first stored in Excel workbook comprised of different spreadsheets. ArcGIS can open and read the spreadsheet directly. It was added into ArcMap through the Add Data icon. Any worksheets can be browsed through the dialog box and then accessed in ArcMap. Each spreadsheet would appear as a separate table in ArcMap.

Once the spreadsheet was added in ArcMap, it can be interpreted and exported as a thematic layer of (*.shp) format. Any records can be edited in ArcMap in (*.shp) format. However, data in (.xls) format would not be able to edit or export.

3.4.3 Data Consolidation

At the present study, various attribute data and spatial data were involved in the computational process. All the spatial data obtained was clustered into GIS layer containing metadata and object features code of geographic description. Each GIS layer contains a group of single-type components, such as digitized river, road and lot. Most of the data were presented as polylines except some in polygons. The spatial data included:

- River water map
- Road map
- Lot map
- Town map

These attributes were clustered into geology, hydrology and environmental criteria of different layers. The layers that have been described in GIS-based environment in respect to the rehabilitation of SKOD were as follow:

- Layer of groundwater quality
- Layer of landfill gas emission
- Layer of surface water quality
- Layer of ambient air quality
- Layer of geology
- Layer of leachate characteristic

All the layers were digitized and stored in GIS environment. Hyperlink tool on the toolbar of ArcMap granted the possible access to any photos or pictures related to the SKOD. Thus, when click on a point with the hyperlink tool, a photo showing the location point would be launched.

3.5 Data Analysis

After the processing of data, each thematic layer was generated. An auxiliary set of satellite images and aerial photos obtained from Google Earth was used for assistance and geometric corrections, geo-referencing and re-scaling process. The composite and extensive map would comprise the following features and information of SKOD:

- Information on land use, topography and nearest town
- Data including detailed information ambient air quality and LFG
- Pollution source spatial database and pollutant inventory mapping

- Information of existing groundwater and surface water quality status with respect to different parameters like BOD, COD and TSS
- Information on leachate characteristic.

The geospatial database used the overlay method to generate the final map showing the background information of the locality map, the location of sampling points and sampling sites' information.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Background

This chapter described all the primary and secondary results obtained. The results were gathered from the field works executed in SKOD and the data collected from various authorities. The information was then collated in order to determine whether the monitored parameters have met the permitted requirements. The most important part of this chapter would be the outcome generated by the GIS.

4.2 Site Investigation

Following the first SKOD site visit in early 2010, it was observed that the segregation of rubbish was still in the process. It was done by Contaminated Land Environment Remediation Sdn Bhd (CLEAR) to separate plastic component through the milling process. The recovered plastic components were sent to a cement manufacturing plant to be used as fuel. A material recovery facility was found in the middle of the SKOD (Figure 4.1). The facility was dismantled and relocated after the safe closure work started in August 2010.

The west part of SKOD was piled up with heaps of waste without any proper final cover. The solid waste dumped was left exposed and only some parts of the waste were covered with big sheet of plastic bag to reduce the rain water to percolate through it. Nevertheless, it was observed that there was still flowing of leachate towards the Sungai Beranang. Bad odour was emitted everywhere within the SKOD. There was also a number of scavengers spotted, hunting for the valuable materials in SKOD. Generally, the SKOD was not well managed and maintained in a suitable manner. The figures below illustrate the condition of SKOD during the first site visit.

Figure 4.1: Material recovery facility owned by CLEAR

Figure 4.2: Leachate was found flowing within SKOD

Figure 4.3: Uncovered solid waste

Figure 4.4: Garbage piled up in SKOD

4.3 Site Topography and Geology

The accurate description of sub-surface conditions was critical to understand the localized transport mechanisms that may affect the migration of any contaminants detected in SKOD. Hence, the geology condition must be studied in the safe closure of SKOD. The table below showed results from the geological study.

Table 4.1: Summary of sub-surface condition of the borehole

Bore Hole	Depth (m)	Soil Description	No. of Blow/300mm
NW 1	0.00 – 1.50	Dark Brown, grey, clayey SILT	–
	1.50 – 3.00	Loose, rubbish	4
	3.00 – 4.50	Loose, rubbish	8
	4.50 – 6.00	Medium dense, rubbish	11
	6.00 – 7.50	Very loose to loose, rubbish	7
	7.50 – 9.00	Loose to medium dense, rubbish	10
	9.00 – 10.50	Medium dense, rubbish	12
	10.50 – 12.00	Hard, light grey, clayey SILT of high plasticity with some fine to coarse sand and traces of gravels	46
	12.00 – 13.50	Hard, light grey, clayey SILT with gravels	>50
	13.50 – 15.00	Hard, yellowish grey, clayey SILT of intermediate plasticity with some fine to coarse sand and gravels	>50
	15.00 – 16.83	Hard, yellowish grey, clayey SILT with gravels	>50
	16.83 – 18.00	Very dense, brownish yellow, silty fine to coarse SAND with traces of clay and some gravels	>50
	18.00 – 19.50	Very dense, grey, silty fine to coarse SAND	>50
	19.50 – 21.00	Very dense, grey to dark grey, silty SAND	>50

	21.00 – 22.50	Very dense, grey to dark grey, silty fine to coarse SAND with little clay and some gravels	>50
	22.50 – 25.50	End of bore hole	
NW 2	0.00 – 1.50	Dark brown, grey, clayey SILT	–
	1.50 – 3.00	Very loose, rubbish	3
	3.00 – 4.50	Very loose to loose, rubbish	4
	4.50 – 6.00	Very loose to loose, rubbish	4
	6.00 – 7.50	Very loose to loose, rubbish	4
	7.50 – 9.00	Very loose to loose, rubbish	5
	9.00 – 10.50	Very loose to loose, rubbish	6
	10.50 – 12.00	Medium dense, rubbish	11
	12.00 – 13.50	Medium dense, rubbish	13
	13.50 – 15.00	Dense, brown, silty fine to coarse SAND with little clay and some gravels	49
	15.00 – 16.83	Hard, dark grey, silty CLAY of low plasticity with some fine to coarse sand and gravels.	>50
	16.83 – 18.00	Very dense, dark brown, clayey SAND	>50
	18.00 – 19.50	Very dense, grey, dark grey, clayey fine to coarse SAND with traces of silt and some gravels	>50
	19.50 – 21.00	Very dense, grey, dark grey, clayey fine to coarse SAND with traces of silt and some gravels	>50
	21.00 – 22.95	Very dense, dark grey, clayey fine to coarse SAND with little silt and much gravels	>50
	22.95 – 25.50	End of bore hole	
NW 3	0.00 – 1.50	Dark brown, grey, clayey SILT	–
	1.50 – 3.00	Loose, rubbish	6
	3.00 – 4.50	Loose, rubbish	7
	4.50 – 6.00	Medium dense, brownish grey, silty fine to coarse SAND with little clay and rubbish	13
	6.00 – 7.95	Very loose to loose, rubbish	4

	7.95 – 9.45	Very loose to loose, rubbish	5
	9.45 – 10.50	Very loose to loose, rubbish	7
	10.50 – 12.00	Very loose to loose, greyish brown, silty fine to coarse SAND with traces of clay and gravel	4
	12.00 – 13.50	Medium stiff, grey, silty CLAY of intermediate plasticity with much fine to coarse sand and very little gravels	5
	13.50 – 21.00	Very dense, grey, clayey fine to coarse SAND with little silt and some gravels	>50
	21.00 – 24.50	Very dense, grey, clayey fine to coarse SAND with little silt and much gravels	>50
	24.50 – 30.00	No recovery	
		End of bore hole	
NW 4	0.00 – 1.50	Dark brown, grey, clayey SILT	–
	1.50 – 3.00	Loose, dark grey, clayey fine to coarse SAND with little silt and some gravels	5
	3.00 – 4.50	Loose, grey, silty SAND	6
	4.50 – 6.00	Loose, grey, silty SAND	9
	6.00 – 7.50	Medium stiff, dark grey, clayey SILT of intermediate plasticity with much fine to coarse sand and very little gravels	5
	7.50 – 9.00	Loose, brown, silty SAND	7
	9.00 – 10.50	Medium dense, brown, clayey fine to coarse SAND with little silt and much gravels.	14
	10.50 – 12.00	Very dense, dark grey, gravelly SAND	>50
	12.00 – 13.50	No recovery	>50
	13.50 – 15.00	Hard, dark grey, fine to coarse sandy CLAY with little silt and some gravels	>50
	15.00 – 19.73	Hard, dark grey, fine to coarse sandy CLAY with some gravels	>50

		End of bore hole	
NW 5	0.00 – 1.50	Dark Brown, grey, clayey SILT	–
	1.50 – 3.00	Soft to medium stiff, grey, silty CLAY of intermediate plasticity with some fine to coarse sand and very little gravels	4
	3.00 – 10.50	No recovery	4 – 6
	10.50 – 12.00	Hard, dark grey, silty CLAY of low plasticity with some fine to coarse sand and traces of gravels	>50
	12.00 – 13.50	Very dense, dark grey silty SAND	>50
	13.50 – 15.00	Very dense, dark grey, clayey fine to coarse SAND with traces of silt and some gravels	>50
	15.00 – 16.83	Very dense, dark grey, silty SAND	>50
	16.83 – 19.50	Very dense, dark grey, clayey fine to coarse SAND with little silt and some gravels	>50
	19.50 – 19.64	Dense, dark grey, silty CLAY of intermediate plasticity with some fine to coarse sand and gravels	>50
	19.64 – 30.00	End of bore hole	

The N-value was the number of blow counts in a Standard Penetration Test (SPT) test for penetration of 300mm. The higher the N-value, the harder the soil behaved. N-value less than 10 showed that it was loose or soft soil. The N-values ranged 10-50 indicated that the ground was fairly easy to be excavated. When the N-value exceeded 50, the ground may be hard to excavate. Easier illustrations of the sub-surface conditions are shown in Figure 4.5 until Figure 4.9.

Figure 4.5: Sub-surface condition at NW1 at different depths in meter

Figure 4.6: Sub-surface condition at NW2 at different depths in meter

Figure 4.7: Sub-surface condition at NW3 at different depths in meter

Figure 4.8: Sub-surface condition at NW4 at different depths in meter

Figure 4.9: Sub-surface condition at NW5 at different depths in meter

Generally, the top soil was formed mainly by clayey silt up to 1.5m depth. Rubbish was found immediately after the top soil until 10.5m depth for NW1 and NW3 (Figure 4.5 and Figure 4.7). The rubbish strata found in NW2 was formed up to 13.5m depth (Figure 4.6). There were no rubbish layer in NW4 and NW5 (Figure 4.8 and Figure 4.9). This was because the location of NW4 was near to the access road in SKOD while NW5 was at the far end west side of the border. Therefore, the sub-surface profiles of these two boreholes were slightly different from the rest.

The sub-surface profile encountered in the NW1, NW2 and NW3 (Figure 4.5, Figure 4.6 and Figure 4.7) boreholes were quite similar. Their borings results showed a lithological sequence formed after the rubbish layer was mainly clayey silt to coarse sand at the end of the borehole.

The water level encountered in the borings NW1 until NW5 were at the depths 5.1m, 8.09m, 1.18m, 3.2m and 5.3m to the groundwater respectively. On the other hand, the water levels measured in the auger holes AH1 and AH2 were 0.54m and 1.88m. The flow direction was mainly towards the north-west direction of SKOD where the Sungai Beranang situated. Like surface water, groundwater tends to move downward in whichever the direction the water table slopes. However, the groundwater flow rate was always slower than that of surface water.

During the construction of boreholes, selective soil samples were collected for laboratory tests. The collected soil samples were tested for moisture content, Atterberg limits and particle size distribution. The results of the soil tests are summarized in Table 4.2.

Table 4.2: Summary of soil test

Borehole	Depth (m)	Moisture Content (%)	Atterberg Limits			Particle Size Distribution			
			LL	PL	PI	Gravel	Sand	Silt	Clay
			%	%	%	%	%	%	%
NW1	10.50 – 10.95	24	46	29	17	19	27	46	8
	13.50 – 13.95	13	35	33	2	21	20	49	10
	16.50 – 16.95	6	35	27	8	40	36	13	11
	21.00 – 21.45	11	31	24	7	34	48	11	7
NW2	13.50 – 13.95	12		N.P		24	24	24	24
	15.00 – 15.45	8	30	30	30	31	31	31	31
	18.00 – 18.45	10	33	33	33	29	29	29	29
	21.00 – 21.14	6	31	31	31	41	41	41	41
NW3	4.50 – 4.95	12		N.P		33	62	3	2
	10.50 – 10.95	28	35	24	11	11	58	18	13
	12.00 – 12.45	25	40	21	19	1	52	23	24
	15.00 – 15.22	9	35	22	13	35	47	8	10
	21.00 – 21.14	9	33	22	11	40	44	7	9
NW4	10.50 – 10.95	15		N.P		26	64	5	5
	6.00 – 6.45	26	34.00	24	10	1	76	13	10

	9.00 – 9.45	81				55	37	5	3
	13.50 – 13.84	7	32.00	22	10	28	51	10	11
	19.50 – 19.73	6	32.00	21	11	51	35	6	8
NW5	1.50 – 1.95	47	48	21	27	2	32	24	42
	10.50 – 10.85	8	30	20	10	14	51	17	18
	13.50 – 13.77	9	36	22	14	25	45	14	16
	16.50 – 16.71	9	35	22	13	28	46	10	16
	19.50 – 19.64	10	35	23	12	29	36	17	18

The average moisture content of each borehole soil samples were 13.5%, 9%, 16.6%, 27% and 16.6%. Atterberg limit is a common measure of the nature of a fine-grained soil. The soil samples had the plastic index (PI) ranged within 8.5 and 31.33. The average PI value of 21.2 indicated that the soil was high in plasticity and tended to be clay. Generally, the recommended soil types for dumping site were silt and clay. Their characteristics made them suitable to be used as lined materials and acted as a natural barrier to infiltration of leachate to groundwater. Even though clay and silt were suitable liners, consideration towards the groundwater quality and gas migration must be well taken care (Inanc et al., 2004).

4.4 Groundwater Quality

There was groundwater quality monitoring program initiated by Department of Environment (DOE) since 1997 as stated in Malaysia Environmental Quality Report 2010. In this report, all the parameters tested were compared in accordance with groundwater quality standard in Malaysia which is the same as the National Guidelines for Raw Drinking Water Quality (Revised December 2000) as prescribed by Ministry of Health. The standard was used to compare the groundwater quality of the site to assess the suitability. Groundwater quality was important to be assessed since it might be a potential source of clean water supply during the dry seasons in Malaysia (Mohamad Roslan et al., 2007). Table 4.3 shows the groundwater quality of SKOD.

Table 4.3: Groundwater quality of SKOD

Parameter	Symbol	Unit	Benchmark	NW 1	NW 2	NW 3	NW 5	AH 1
Mercury	Hg	mg/L	0.001 mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Cadmium	Cd	mg/L	0.003 mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Chromium	Cr	mg/L	0.05 mg/L	<0.001	0.001	0.001	<0.001	<0.001
Arsenic	As^{2+}	mg/L	0.01 mg/L	<0.005	<0.005	<0.005	<0.005	<0.005
Lead	Pb^{2+}	mg/L	0.01 mg/L	0.002	<0.001	0.012	<0.001	0.003
Copper	Cu^{2+}	mg/L	1.0 mg/L	<0.001	0.001	0.001	<0.001	0.0001
Manganese	Mn^{2+}	mg/L	0.1 mg/L	0.085	0.001	0.128	<0.001	<0.001
Zinc	Zn^{2+}	mg/L	3 mg/L	0.005	<0.001	0.015	<0.001	0.001
Iron	Fe^{2+}	mg/L	0.3 mg/L	0.250	0.004	1.200	0.001	0.171
Phenolics	-	mg/L	0.002 mg/L	<0.1	<0.1	<0.1	<0.1	<0.1
Chloride	Cl^{-}	mg/L	250 mg/L	4.5	23.2	23.2	23.8	1658
Sulphate	SO_4^{2-}	mg/L	250 mg/L	<1	4	7	24.0	83
Coliform	-	CFU/100mL	Must not be detected in any 100 mL sample	200	600	100	400	16000
Nitrate	NO_3	mg/L	10 mg/L	5.7	95.5	107.7	2.9	40.0
Hardness	$CaCO_3$	mg/L	500 mg/L	94.0	245.7	106.9	79.1	414.0
Selenium	Se^{2-}	mg/L	0.01 mg/L	<0.001	<0.001	<0.001	<0.001	1.18
TDS	-	mg/L	1000 mg/L	168	192	548	372	11366

Results from the groundwater study revealed that some of the groundwater quality parameters determined have exceeded the standards for raw drinking water. The groundwater samples were poor in quality in terms of coliform, nitrate, chloride, total dissolved solids, iron, lead, manganese, and selenium recorded. This was not surprise because 60% of the wells in Malaysia have the iron value exceeded the limit (Department of Environment Malaysia, 2006). This may be due to the dissolution of ferrous boreholes.

The groundwater study indicated that the quality of groundwater in SKOD was considered to be poor in bacteriological analysis aspects. This was because there were high contain of coliform detected ranging from 100 CFU/100mL to 16000 CFU/100mL at all the sampling points. All the groundwater samples exceeded the limit of the benchmark of coliform where there should not have any count of coliform in 100mL of sample. The results indicated the presence of coliform bacterial pollution and the possibility of pathogenic microorganisms that would cause severe groundwater pollution. It might be resulted from the faeces or animal droppings originated from the cows that were grazing at the grassland nearby the SKOD. There was also research study that has identified the agricultural activities as one of the major pollution sources to groundwater in the Langat Basin. The leading agricultural activity was oil palm plantation and followed by rubber plantation (Mohamed et a1., 2009). The groundwater containing coliform should not be used as drinking water as it may lead to water-borne diseases like cholera and diarrhea.

Besides, the nitrate content also exceeded the standard with the values varied from 2.9mg/L to 107.7mg/L with NW2, NW3 and AH1 recorded more than 40mg/L. The level of nitrate should not exceed 10mg/L. Infants below six months may suffer from shortness of breath and blue baby syndrome by drinking the water containing nitrate in excess (EPA, 2011). The possible sources of nitrate in SKOD may originate from the surrounding agricultural activity that uses the fertilizers or even the disposed nappies within the dumpsite. A nitrate content of more than 100mg/L as detected in NW3 will cause the water to taste bitter and may cause physiological problem.

Among the heavy metal parameters examined, the concentration of iron, lead and manganese have exceeded the permissible level was found at NW3 sampling point. The concentration of heavy metals must be monitored carefully as they were not biodegradable. Heavy metals can also accumulate in living tissue and cause serious diseases. Heavy metals were toxic if present higher than minimum requirement particularly lead which is associated with brain damage, behavioral disorders and even death (Mayo Clinic Staff, 2011).

The concentration of chloride recorded in AH1 was 1658mg/L which has far exceeded the limit of 250mg/L. The total dissolved solid (TDS) and selenium level were also far above the allowable limit with the readings of 11366mg/L and 1.18 mg/L respectively. One of the possible reasons was likely due to the mixing of rainwater with some stagnant leachate that drained from the site which percolated into the groundwater.

From the results obtained, the most possible hazards was dominated by the high nitrate, TDS, iron and coliform contain. The more vulnerable groundwater will be within the NW3. Due to the natural attenuation and different attenuation rate, the travel distance of the pollutant will vary (Rao & Shantaram, 2003). Thus, the concentration of every parameter tested decreased towards the north-west direction with increase distance from the sampling points.

The groundwater quality has been affected by the percolation of leachate. Of particular concern was the contamination found in NW3. Leachate has posed a threat towards the groundwater quality particularly at NW3 since the concentration of lead, manganese, iron, coliform and nitrate have exceeded the limit.

4.5 Surface Water Quality

A water quality monitoring program was initiated by DOE in 2008 throughout the whole Malaysia. According to the report from DOE in 2008, the Sungai Beranang located adjacent to SKOD fell into Class II or with the WQI of 84 (Figure 4.10). Thus, all the result obtained for surface water quality will be compared with the Class II standard as shown in Table 4.4.

STATE	CODE WQR	RIVER BASIN	NO. OF STATIONS	OVERALL WQI	RIVER	NO. OF STATIONS	WQI	RIVER STATUS	CLASS
SELANGOR/ WPKL		KLANG			BATU	3	72	SP	III
					BUNOS	1	55	P	III
					DAMANSARA	3	64	SP	III
					GOMBAK	3	82	C	II
					JINJANG	2	52	P	III
					KERAYONG	2	51	P	IV
					KEROH	2	51	P	IV
					KLANG	10	63	SP	III
					KUYOH	1	64	SP	III
					PENCHALA	1	46	P	IV
					SEMELAH	1	83	C	II
SELANGOR	19	LANGAT	28	75 (79)	ANAK CHUAU	1	78	SP	II
					BALAK	1	61	SP	III
					BATANG BENAR	2	66	SP	III
					BATANG LABU	2	78	SP	II
					BATANG NILAI	2	54	P	III
					BERANANG	1	84	C	II
					BUAN	1	77	SP	II
					CHUAU	2	89	C	II

Figure 4.10: Water quality status of slightly polluted river basins in Malaysia, 2008

Table 4.4: Sg. Beranang surface water quality at the upstream point (SW1) and downstream point (SW2)

Parameters	Unit	SW1	SW2	Class II
Biochemical Oxygen Demand @5days at 20°C	mg/L	6	4	3
Chemical Oxygen Demand	mg/L	25	22	25
Total Suspended Solids	mg/L	220	345	50
Mercury as Hg	mg/L	<0.001	<0.001	0.001
Cadmium as Cd	mg/L	<0.005	<0.005	0.01
Chromium Hexavalent as Cr^{6+}	mg/L	<0.01	<0.01	NA
Chromium Trivalent as Cr^{3+}	mg/L	0.01	0.01	NA
Arsenic as As^{2+}	mg/L	<0.005	<0.005	0.05
Cyanide as CN	mg/L	<0.02	<0.02	0.02
Lead as Pb^{2+}	mg/L	0.04	0.06	0.05
Copper as Cu^{2+}	mg/L	0.008	0.013	0.02
Manganese as Mn^{2+}	mg/L	0.082	0.156	0.1
Nickel as Ni^{2+}	mg/L	0.005	0.005	0.05
Tin as Sn^{4+}	mg/L	<0.004	<0.004	NA
Zinc as Zn^{2+}	mg/L	0.038	0.058	5
Boron as B^{3+}	mg/L	0.6	0.6	1
Iron as Fe	mg/L	5.72	6.71	1
Phenol	mg/L	<0.001	<0.001	10 µg/mL
Free Chlorine as Cl_2	mg/L	<0.01	<0.01	NA
Sulphide as S^{2-}	mg/L	<0.05	<0.05	NA
Oil & Grease	-	<1	<1	NA

The results showed that most of the samples had values within the class II standard of Interim National Water Quality Standards (INWQS). However, the BOD_5, TSS and iron values were considerably high and exceeded the limit for both SW1 and SW2.

The BOD_5 concentration for SW1 and SW2 were 6mg/L and 4mg/L respectively which exceeded the permissible level of 3mg/L. The relative higher BOD level as compared to the standard would accelerate the bacterial growth and further depleted the oxygen level in the river which was needed by the aquatic living organisms.

The concentration of TSS at SW2 was 345mg/L which was very much higher than SW1. This has proven that the landfill activities have made the river water more turbid. The suspended solids can prevent the light penetration and further influence the aquatic life. This is because the light is required in the growth of algal which is one of the food sources for the aquatic life.

Iron was one of the metals that presented in high concentration of 5.72mg/L and 6.71mg/L at SW1 and SW2. There was also elevated concentration of TSS, lead, copper, manganese, zinc and iron found when the water flowed towards the downstream.

The water quality indexes (WQI) calculated at SW1 and SW2 were 63 respectively. The WQI has shown that the river water quality has become poorer. The river status at Sungai Beranang has fallen to class III from class II which has become slightly polluted.

4.6 Leachate Characteristic

Environmental Quality Act (EQA) 1974 is a legislation used to abate, control and prevent pollution and at the same time enhance the environment in Malaysia. There are 38 sets of regulations and orders that have been introduced and enforced. In order to control the discharge of leachate into the water body nearby, the Environmental Quality (Control of Pollution from Solid Waste Transfer Station and Landfill) Regulations 2009 was applied as a standard to compare the results obtained. The comparison of the leachate quality and the environment quality standard is clearly shown in Table 4.5.

Table 4.5: Leachate quality and the environmental quality standard

Parameter	**Unit**	**Results**	**Standard**
Temperature	°C	25.2	40
pH	-	7.7	6.0-9.0
Biochemical Oxygen Demand @5days at 20°C	mg/L	100	20
Chemical Oxygen Demand	mg/L	387	400
Total Suspended Solids	mg/L	556	50
Mercury as Hg	mg/L	<0.001	0.005
Cadmium as Cd	mg/L	<0.005	0.01
Chromium Hexavalent as Cr^{6+}	mg/L	<0.01	0.05
Chromium Trivalent as Cr^{3+}	mg/L	0.01	0.2
Arsenic as As^{2+}	mg/L	<0.005	0.05
Cyanide as CN	mg/L	<0.02	0.05
Lead as Pb^{2+}	mg/L	0.02	0.1
Copper as Cu^{2+}	mg/L	0.023	0.2
Manganese as Mn^{2+}	mg/L	0.167	0.2
Nickel as Ni^{2+}	mg/L	0.015	0.2
Tin as Sn^{4+}	mg/L	<0.01	0.2
Zinc as Zn^{2+}	mg/L	0.069	2
Boron as B^{3+}	mg/L	0.258	1
Iron as Fe	mg/L	12.5	5
Silver as Ag	mg/L	<0.005	0.1
Selenium as Se	mg/L	<0.01	0.02
Barium as Ba^{2+}	mg/L	0.06	1
Fluoride as F^{-}	mg/L	1.4	2
Phenol	mg/L	0.014	0.001
Sulfide as S^{2-}	mg/L	8.87	0.5
Oil and Grease	mg/L	2	5
Ammoniacal Nitrogen as N	mg/L	220	5
Color	ADMI	245	100
Formaldehyde	mg/L	<0.5	1

Based on the baseline results obtained for the leachate quality dated on 14th December 2010, there were few parameters that exceeded the limit. They were BOD_5, TSS, iron, phenol, sulfide, ammoniacal nitrogen and colour with the results stated as 100mg/L, 556mg/L, 12.5mg/L, 0.014mg/L, 8.87mg/L and 220 mg/L respectively.

In SKOD, the ammoniacal nitrogen value has far exceeded the limit of 5mg/L. Ammoniacal nitrogen was formed due to the biological degradation of amino acids and other nitrogenous organic matter. The concentration of ammoniacal nitrogen may be used to estimate the remaining potential and the aftercare period of a landfill (Jaffar et al., 2009). BOD_5 were detected five times higher than the permissible level of 20mg/L. As mentioned earlier on, high BOD level can accelerate the bacterial growth and further deplete the oxygen level in the river which was needed by the aquatic living organisms.

The leachate contained high concentration of color 245 ADMI and TSS 556mg/L. The TSS was high in the leachate due to the presence of organic and inorganic solid (Agamuthu & Al-Abdali, 2009) It also contained high heavy metal of iron of 12.5 mg/L. Iron can accumulate in any biological tissues leading to serious disease. It must be monitored carefully because iron was not biodegradable.

During the process of rehabilitation, a leachate collection system within the SKOD was installed. A gravity flow collection system was found towards the three pumping chambers. The pumping chambers were used to pump the leachate to the leachate treatment ponds where gravity flow was not possible. From the pumping chamber, the leachate was forced to flow towards the leachate treatment plant located above ground level. The three leachate treatment ponds were Kolam SBR1 (SBR 1), Kolam SBR2 (SBR 2) and equalization pond (EQ).

The leachate was directed towards SBR1 and subsequently to SBR2 for treatment utilizing the Sequential Batch Reactors (SBR) process. The leachate was aerated and the sediment was allowed to settle in the same tank. The treated leachate will be transferred to equalization pond (EQ) before it was discharged into the nearby water body.

Continuous monitoring of leachate was executed at the three pumping chambers, two SBR supernatant lagoons and the equalization pond. The collected leachate samples were analyzed for parameters nammely temperature, pH, BOD_5, COD, TSS and ammoniacal nitrogen respectively. These selected parameters were monitored closely as they have exceeded the allowable concentration during the baseline study. Table 4.6, Table 4.7 and Table 4.8 show the monitoring results of the leachate characteristic

Table 4.6: Monitoring results of leachate at PC1, PC2 and PC3

Parameter	Unit	14 September 2011			30 September 2011			13 October 2011			Standard
		PC 1	PC 2	PC 3	PC 1	PC 2	PC 3	PC 1	PC 2	PC 3	
Temperature	°C	25.1	25.2	25.3	25	25.1	25.2	25.4	25.9	26	40
pH	-	7.3	7.7	7.5	7.5	7.7	7.2	7.1	7.7	7.1	6-9
Biochemical Oxygen Demand @5days at 20°C	mg/L	17	92	28	3	33	14	7	52	20	20
Chemical Oxygen Demand	mg/L	115	1142	207	168	1107	130	116	901	317	400
Total Suspended Solids	mg/L	20	36	6	11	24	14	6	54	115	50
Ammoniacal Nitrogen as N	mg/L	46.3	733	331	226	632	92	85	777	415	5

Table 4.7: Monitoring results of leachate at SBR1 and SBR2

Parameter	Unit	14 September 2011		30 September 2011		13 October 2011	Standard
		SBR 1	SBR 2	SBR 1	SBR 2	SBR 1	
Temperature	°C	25.2	25.1	25.1	25.0	25.1	40
pH	-	10.0	9.5	9.7	9.9	9.8	6-9
Biochemical Oxygen Demand @5days at 20°C	mg/L	16	14	18	10	10	20
Chemical Oxygen Demand	mg/L	120	102	160	98	133	400
Total Suspended Solids	mg/L	66	24	75	30	73	50
Ammoniacal Nitrogen as N	mg/L	1.4	0.6	2.5	1.6	0.5	5.0

Table 4.8: Monitoring results of leachate at equalization pond (EQ)

Parameter	Unit	14 September 2011	30 September 2011	13 October 2011	Standard
Temperature	°C	25.2	25.1	25.1	40
pH	-	10.1	9.2	9.0	6-9
Biochemical Oxygen Demand @5days at 20°C	mg/L	15	8	6	20
Chemical Oxygen Demand	mg/L	103	99	90	400
Total Suspended Solids	mg/L	44	36	35	50
Ammoniacal Nitrogen as N	mg/L	0.9	3.7	3.1	5.0

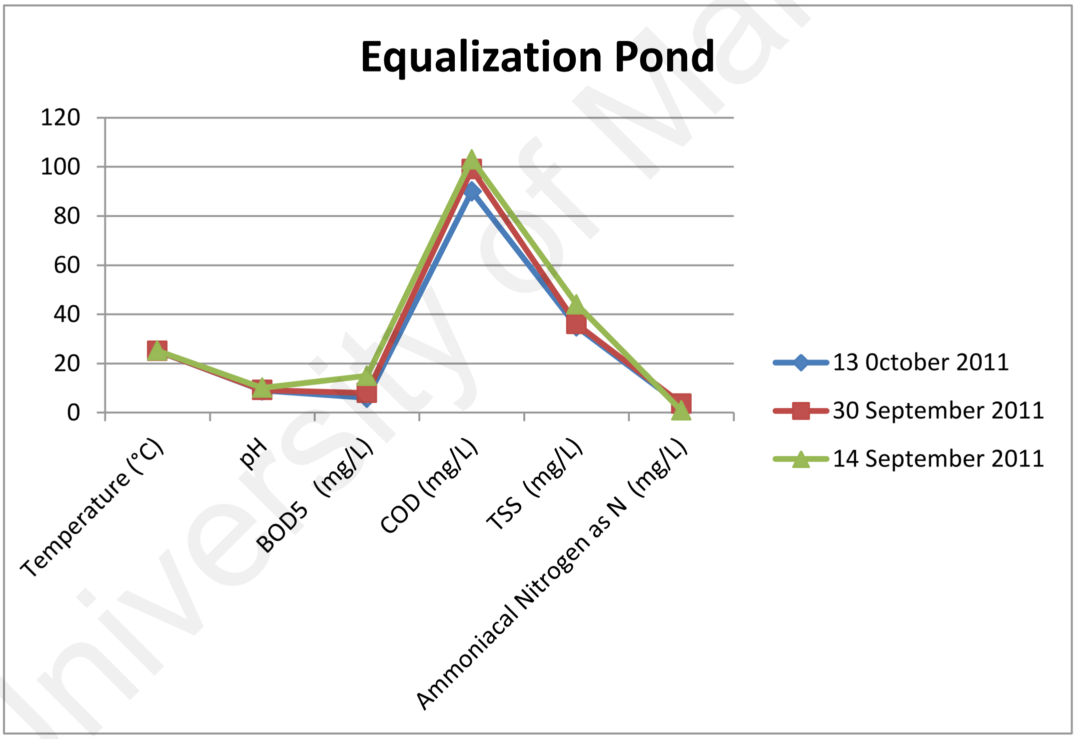

Figure 4.11: Monitoring results of leachate at equalization pond

Based on the monitoring results conducted in September and October 2011 (Figure 4.11), it was observed that there was stabilization of the leachate found. The treatment of leachate was efficient. There were trends of decreasing in every selected parameter which were best illustrated by the line graph at the equalization pond. Most of the parameters have fallen back within the standard limit set in the EQA. Thus, in December 2011, the management of SKOD has decided to transform the equalization pond into a normal algae pond in order to reduce the cost of the treatment facility.

4.7 Composition of Solid Waste

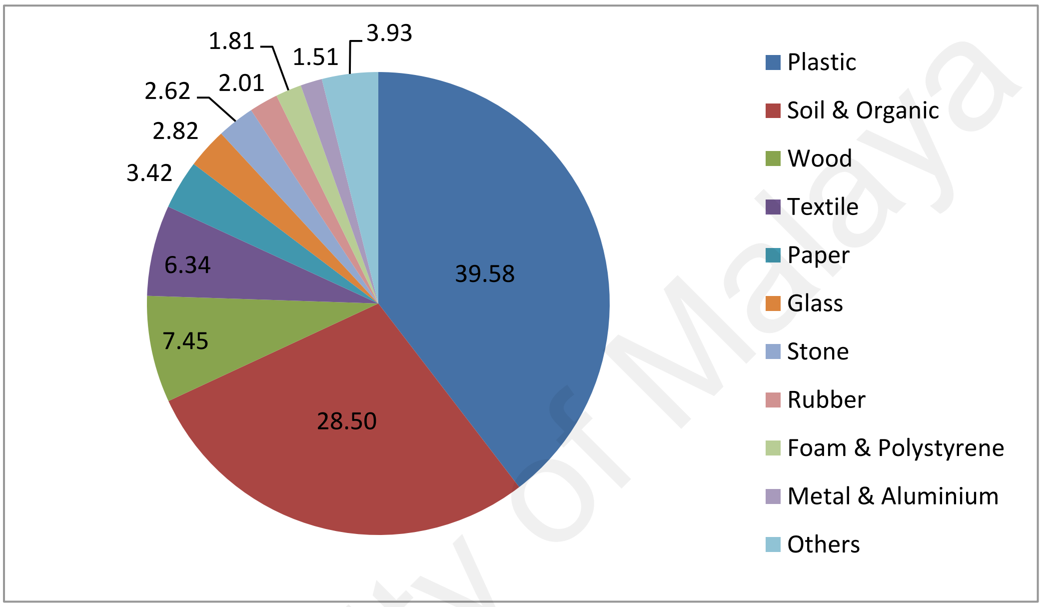

Figure 4.12: Waste composition in SKOD

Figure 4.12 shows the waste composition in SKOD. A total of 979 kg waste was sampled in October and November 2009 by RESB. It was cleared that the waste composition reported to be nearly 40% plastic, 28.5% soil and organic, 7.45% wood and 6.34% textile. The waste collected in SKOD had higher composition of plastic instead of food waste if compared to the overall solid waste composition in Malaysia published by the NSWMD. The big amount of plastics collected has contributed towards the production of RDF.

4.8 Landfill Gas

Table 4.9: Landfill gas composition

Parameter	Unit	16 May 2011	23 November 2011
Oxygen as O_2	% v/v	8.4	5.2
Hydrogen Sulfide as H_2S	$\mu g/m^3$	<20	<20
Carbon Monoxide as CO	ppm	5.7	2
Methane as CH_4	% v/v	53.4	53.4
Carbon Dioxide as CO_2	% v/v	8.4	11.8

Table 4.9 shows the landfill gas composition at SKOD. The two main compositions of landfill gas are methane and carbon dioxide. The concentration of methane gas should be less than 500ppm or less than 5% to 15% in the air to prevent the fire hazards (Fauziah et al., 2004). From the result obtained, the volume of the methane gas recorded was 53.4%. Due to the high emission of methane gas in SKOD, a flaring system has been installed to destroy the harmful methane gas without producing any useful energy. The production of carbon dioxide was recorded as 8.4% averagely.

4.9 Ambient Air Quality

Table 4.10: Ambient air quality within SKOD

Parameter	**Unit**	**A1**	**A2**	**Malaysian Recommended Air Quality Guidelines**
Particulate Matter 10µm and below (PM10)	µg/m^3	18	24	150 µg/m^3 (24 hours averaging time)
Carbon Dioxide as CO_2	µg/m^3	550	548	-
Carbon Monoxide as CO	ppm v/v	0.4	0.43	9 ppm (8 hours averaging time)
Methane as CH_4	ppm v/v	<1	<1	-
Hydrogen Sulfide as H_2S	µg/m^3	<10		5 ppm v/v

From the result obtained, the SKOD has relatively pristine air quality as shown in Table 4.10. The results of all the air parameters were within the Malaysian Air Quality Guidelines (MAAQS). The likely sources of air contamination was the dust or particulate emitted from the earthwork during the rehabilitation process.

4.10 GIS

The application of GIS in this study is to accomplish the objective in developing a database which would integrate all the available information and data collected in assisting the landfill rehabilitation process. As mentioned by Inanc et al., (2004), significant effort was required to gather most of the information regarding landfill. Most of the reports published were in different formats causing the stakeholders to have difficulties in making comparison. The proposed database could be used by the stakeholders during the process of decision making by assembling and centralizing all the required data. The database consisted of the existing quality of all monitored parameters and their relevant national requirements. The system has the capability to generate maps depicting the site topography and geology, groundwater, surface water, landfill gas, ambient air and leachate characteristic.

The fundamental aspect of landfill rehabilitation was to review and assess landfill activities coupled with the pollutant impacts of all types. The database produced would facilitate landfill rehabilitation through pollutant inventory management, monitoring and documenting the adverse impact on the surroundings water bodies and air quality. It would further facilitate an evaluation of pollution sources by generating reports and managing inventory data. All the data obtained was compared with the national environmental requirements and standards.

There were six main GIS layers of SKOD that contained the geology, groundwater, surface water, leachate characteristic, landfill gas and ambient air data. The sections below would show all the output interfaces generated from ArcGIS.

4.10.1 Geology Layer

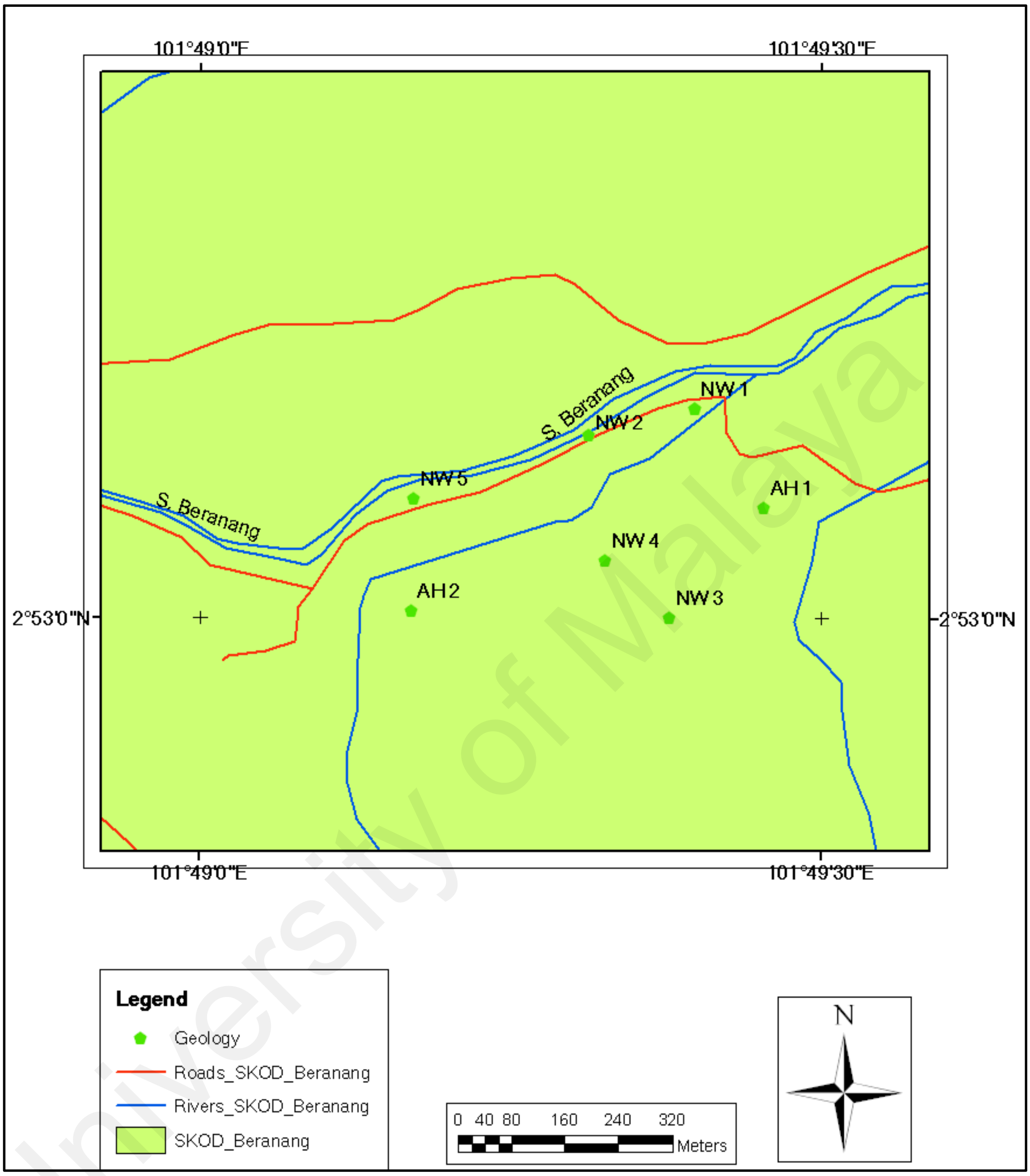

Figure 4.13: Borehole map

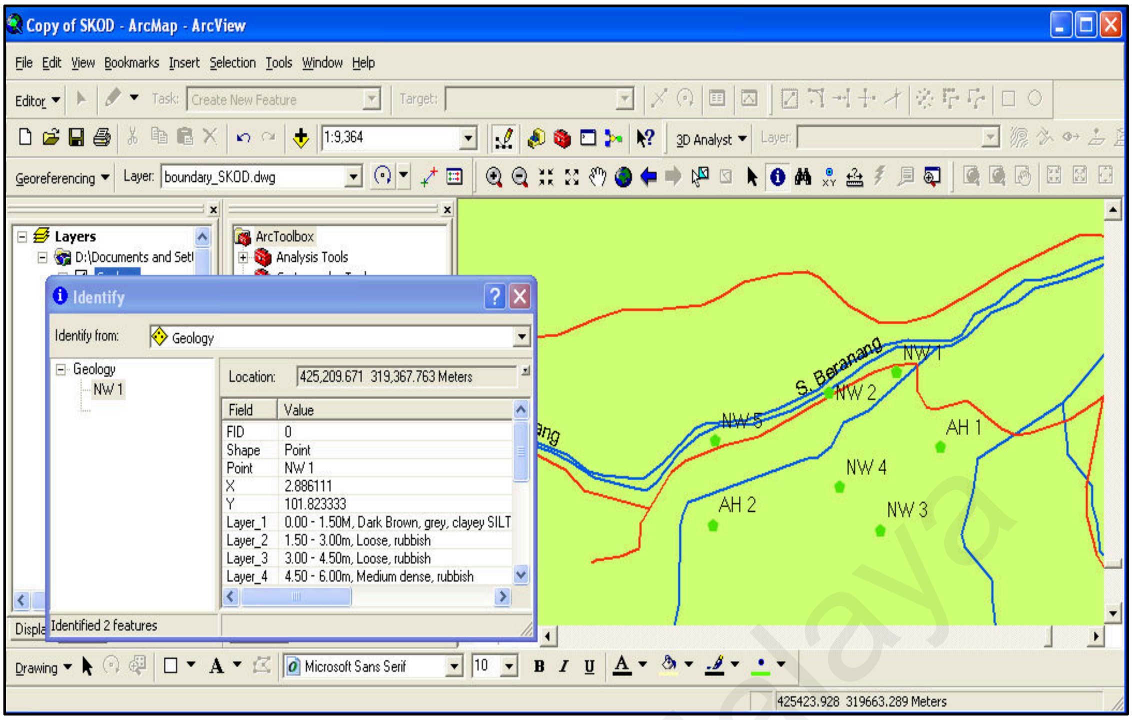

Figure 4.14: Output interface in ArcGIS showing geology thematic layer

4.10.2 Groundwater Layer

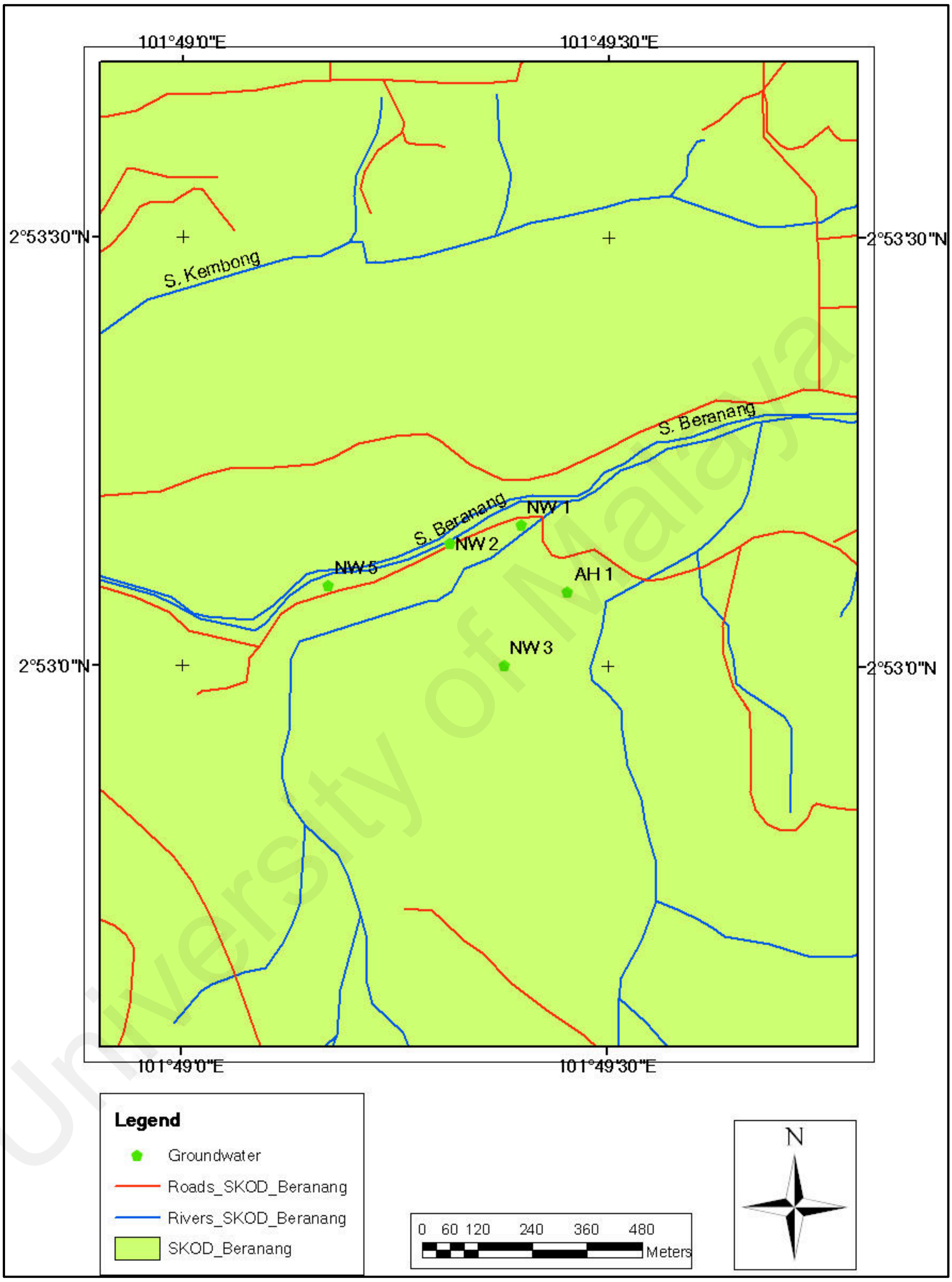

Figure 4.15: Groundwater sampling points map

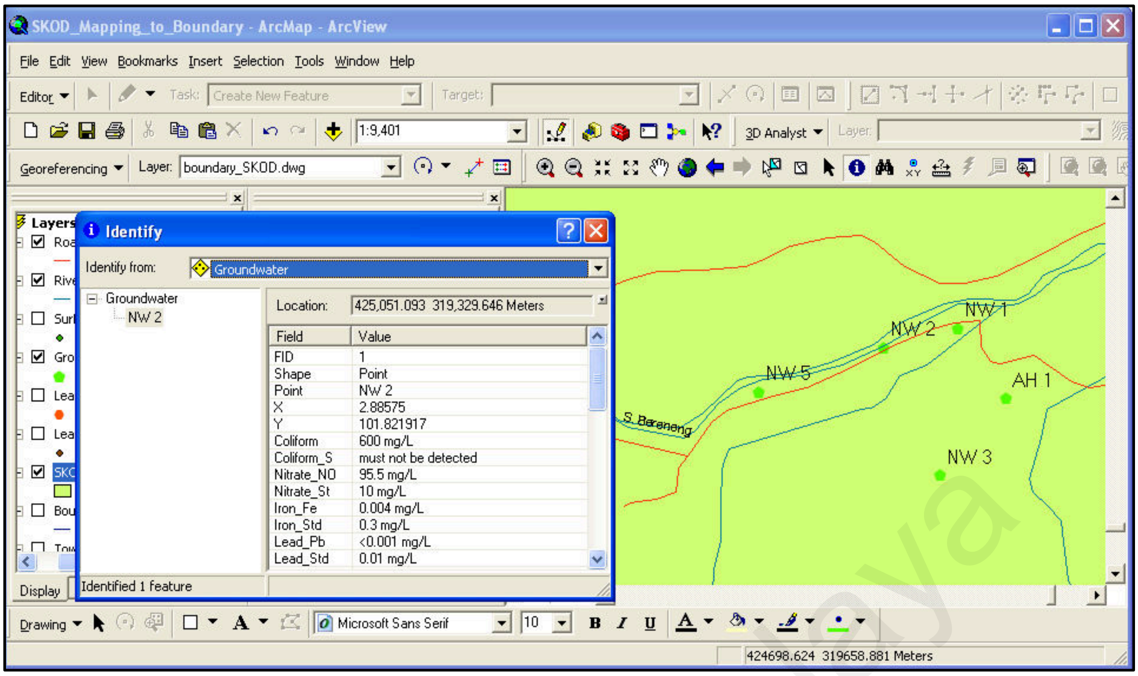

Figure 4.16: Output interface in ArcGIS showing groundwater thematic layer

4.10.3 Surface Water Layer

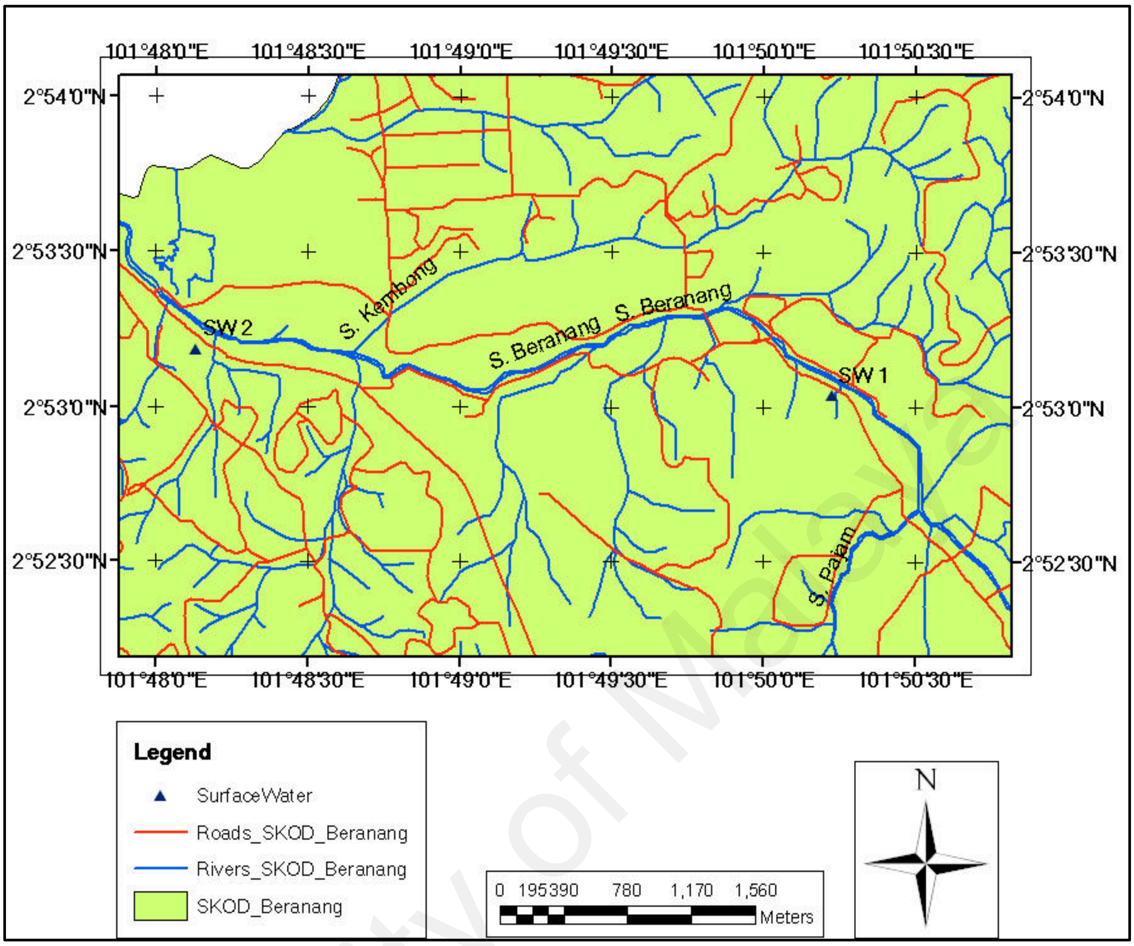

Figure 4.17: Surface water sampling points map

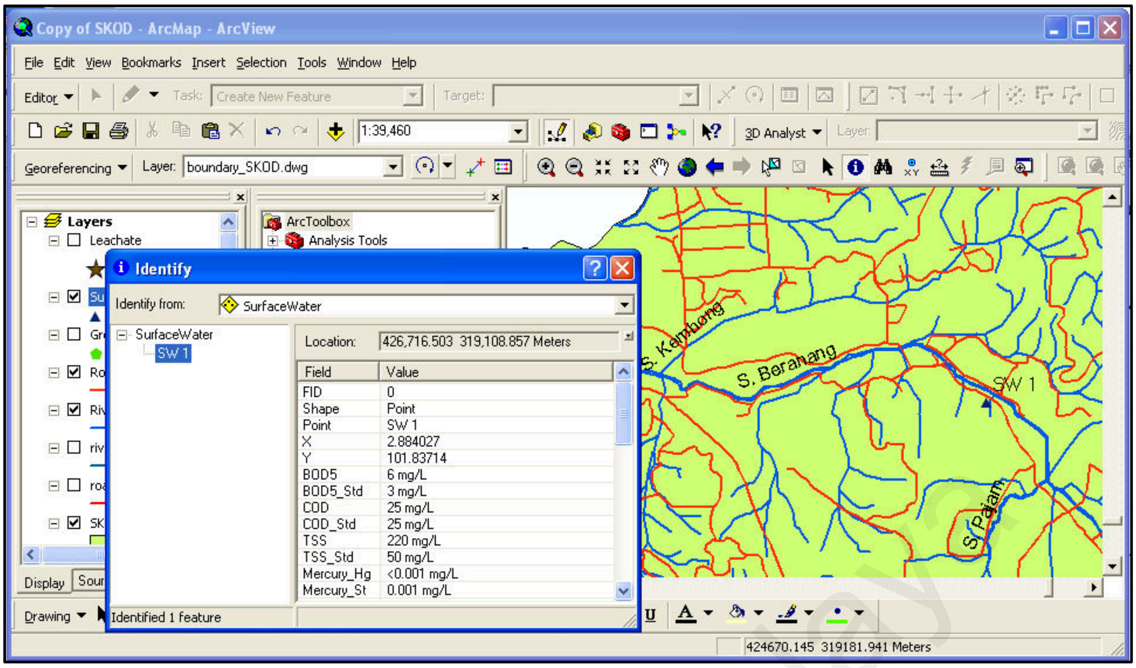

Figure 4.18: Output interface in ArcGIS showing surface water thematic layer

4.10.4 Leachate Layer

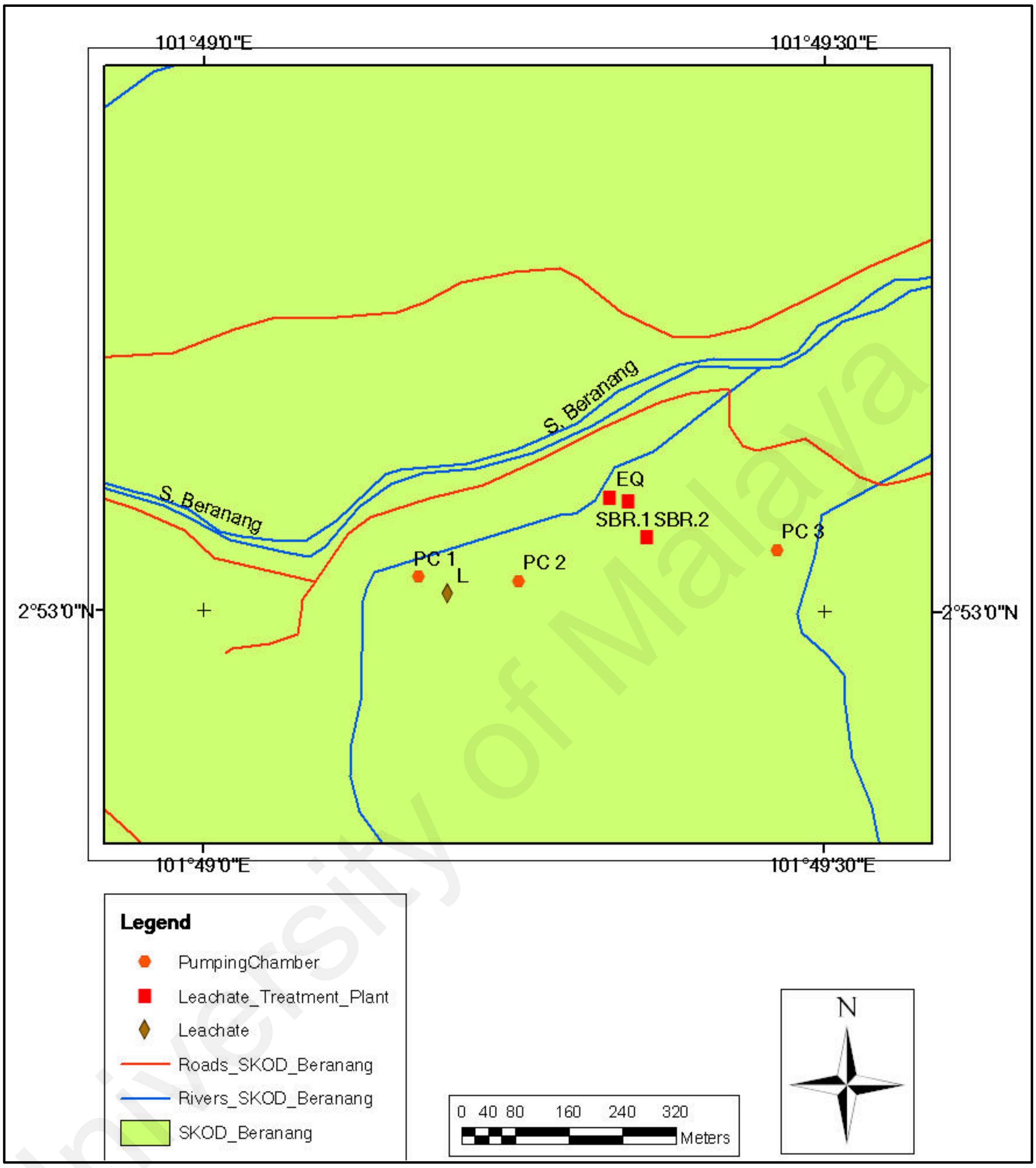

Figure 4.19: Leachate sampling points map

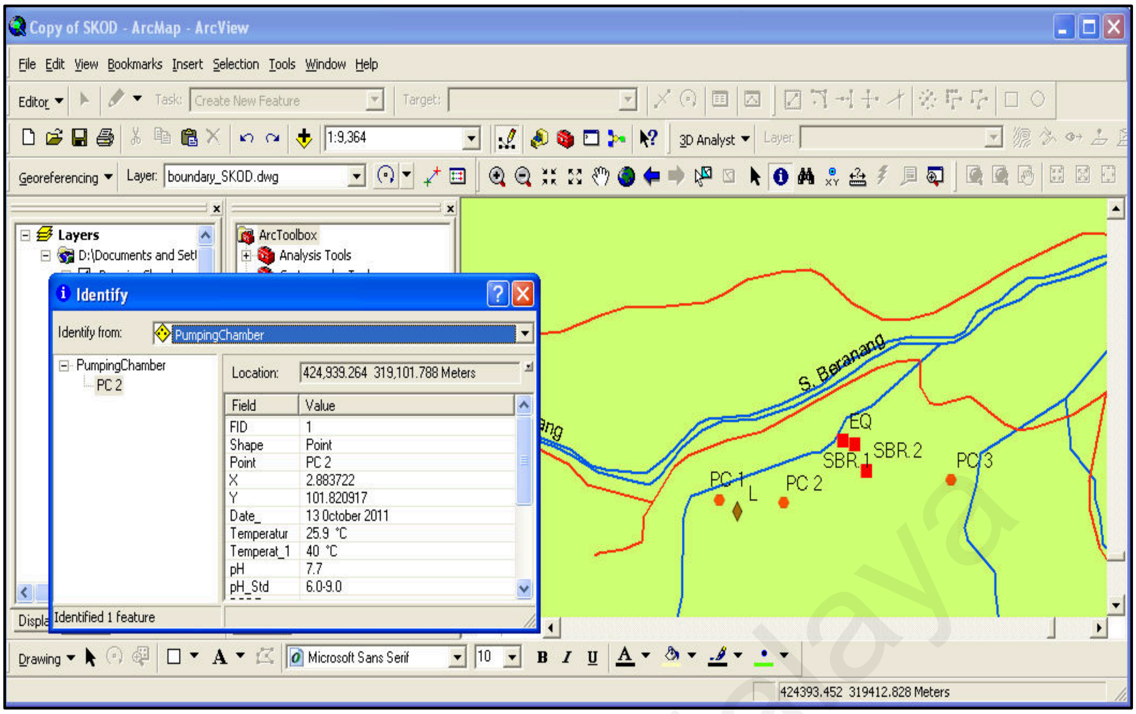

Figure 4.20: Output interface in ArcGIS showing leachate thematic layer

4.10.5 Landfill Gas Layer

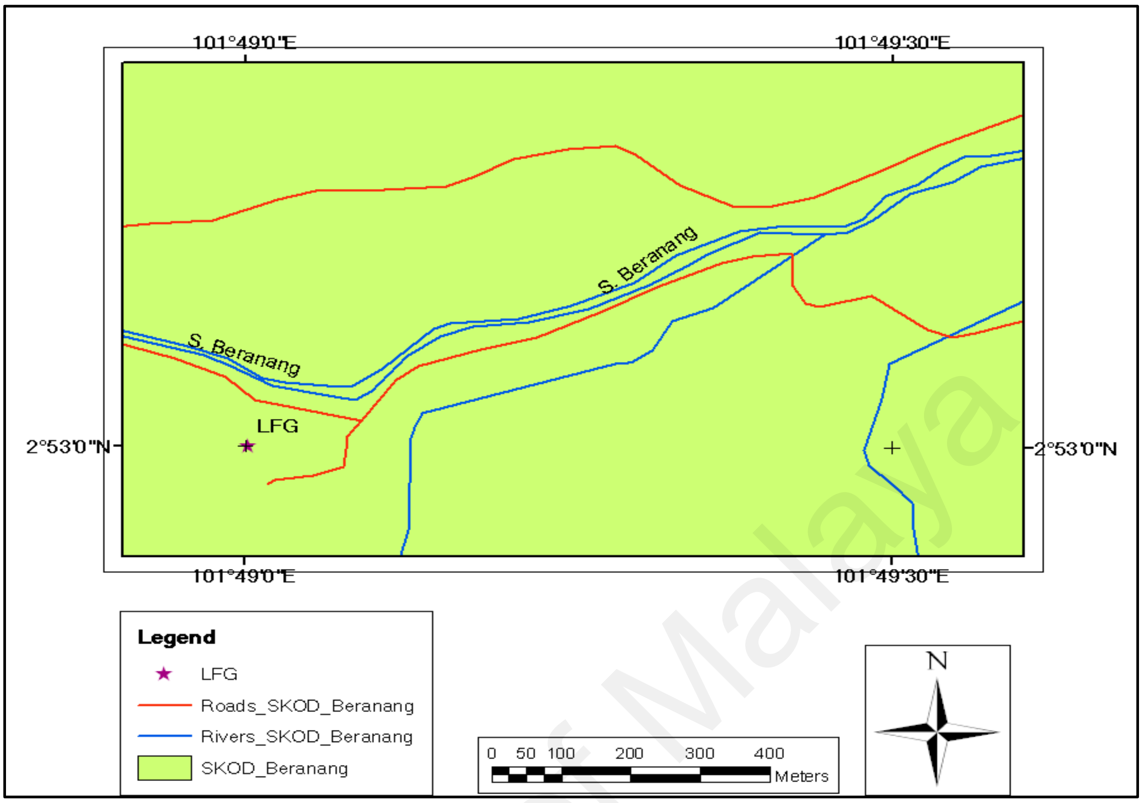

Figure 4.21: Landfill gas sampling point map

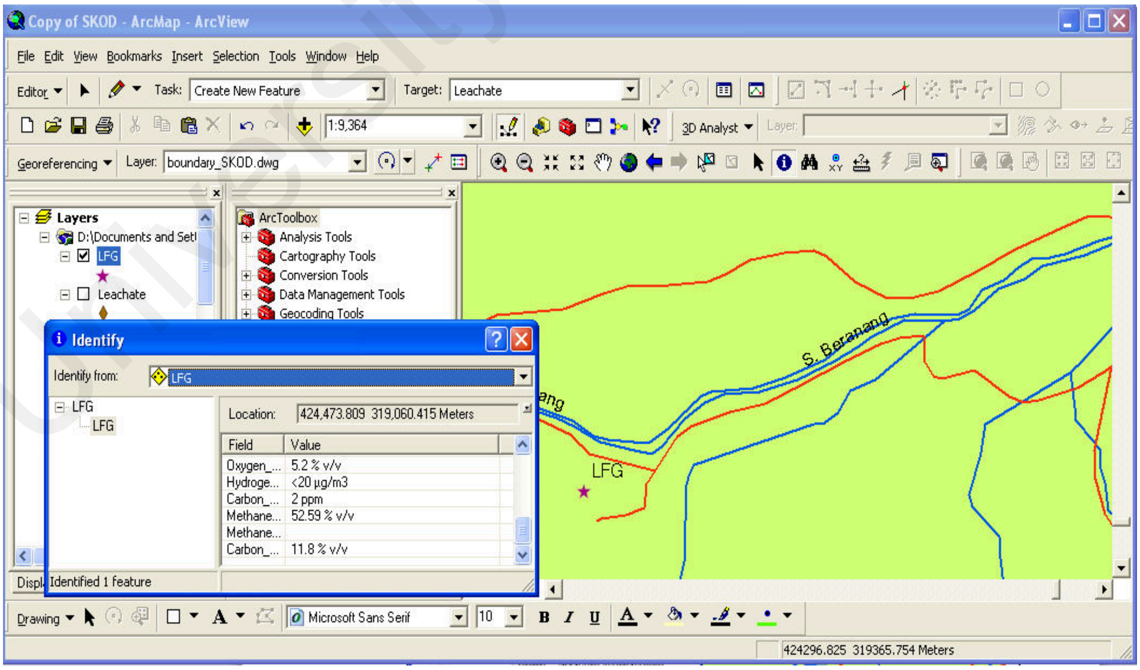

Figure 4.22: Output interface in ArcGIS showing landfill gas thematic layer

4.10.6 Ambient Air Layer

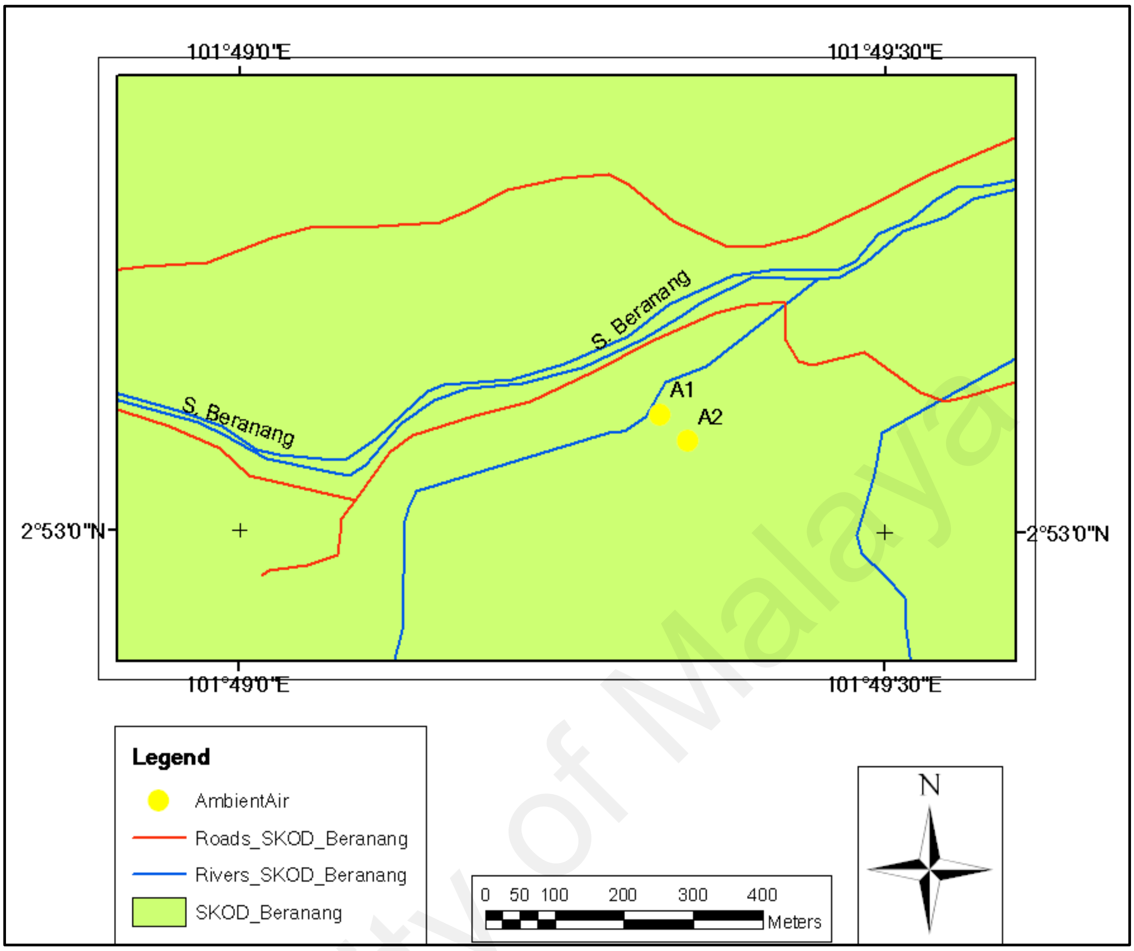

Figure 4.23: Ambient air sampling point map

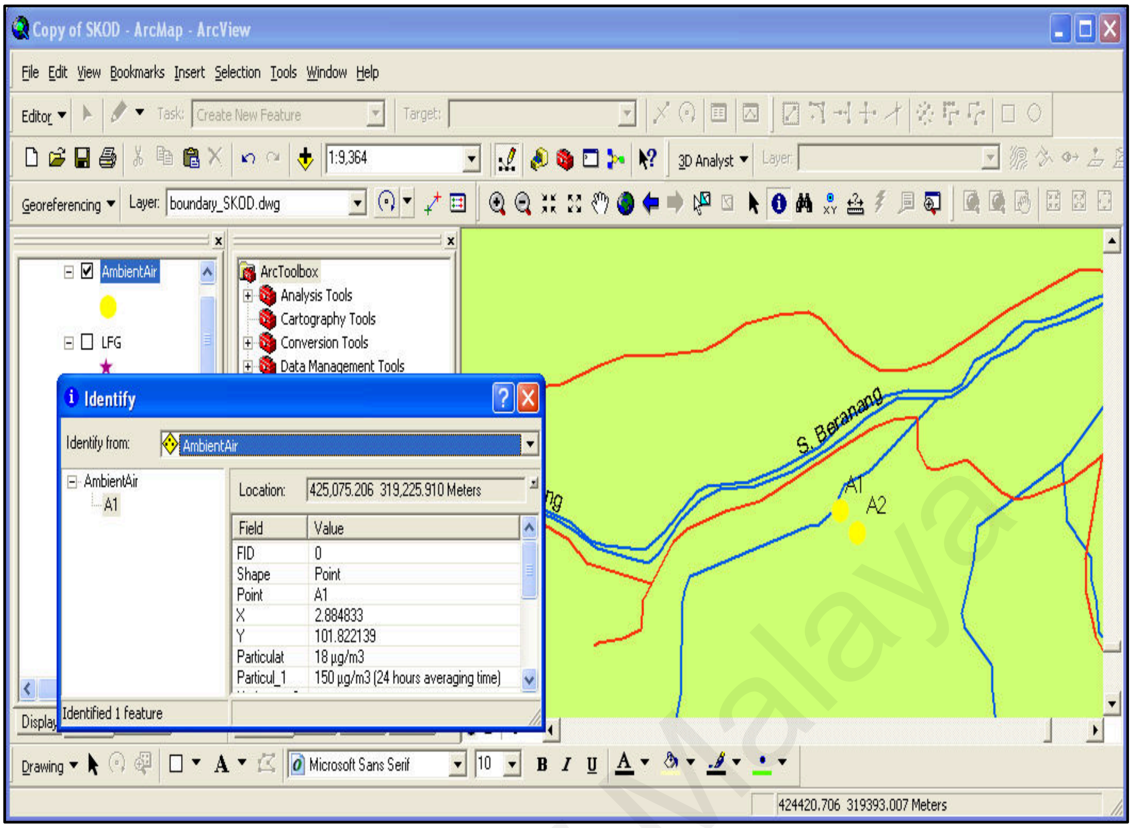

Figure 4.24: Output interface in ArcGIS showing ambient air thematic layer

4.10.7 Discussion of GIS's Output

The application GIS in SKOD rehabilitation has helped extensively in the collection and management of the data and further depict the data in spatially manner. The interface shown in Figure 4.16, for example, was part of the output showing the groundwater data stored through pollution inventory management in ArcGIS. The GIS-based database established can display the on-site attribute data and other spatial information.

The attribute table showed the exact location of the groundwater sampling points as well as the qualities of every selected parameter. The existing concentration of each parameter was compared with the national environmental standards set in Malaysia.

This was done to check its compliance and again emphasized the need of close monitoring of any contaminants found in SKOD. Based on the information stored in ArcGIS, an environmental quality management and monitoring plan for SKOD can be proposed by taking the relevant past studies into the consideration to determine the accuracy and sufficiency of the monitoring data.

One of the common problems faced in solid waste management was the lack of data to be gathered and analyzed. Normally the monitoring data was scattered and not in a comparable format (Sharifi, et al., 2009). Through the GIS-based database, the stakeholder can easily access the necessary and updated data and make decision in accordance to the national policy and regulations.

GIS is a useful tool for predicting any environmental and health hazards that might be posed in SKOD and its surroundings. Hence, stakeholders can formulate and come out with an effective mitigation measures and sound action plan by accessing the comprehensive database stored in ArcGIS. The developed database enabled the stakeholders to continue update and edit the data stored meeting the needs for future planning. It has enhanced the process of evaluation and assessment of the potential environmental and health hazards.

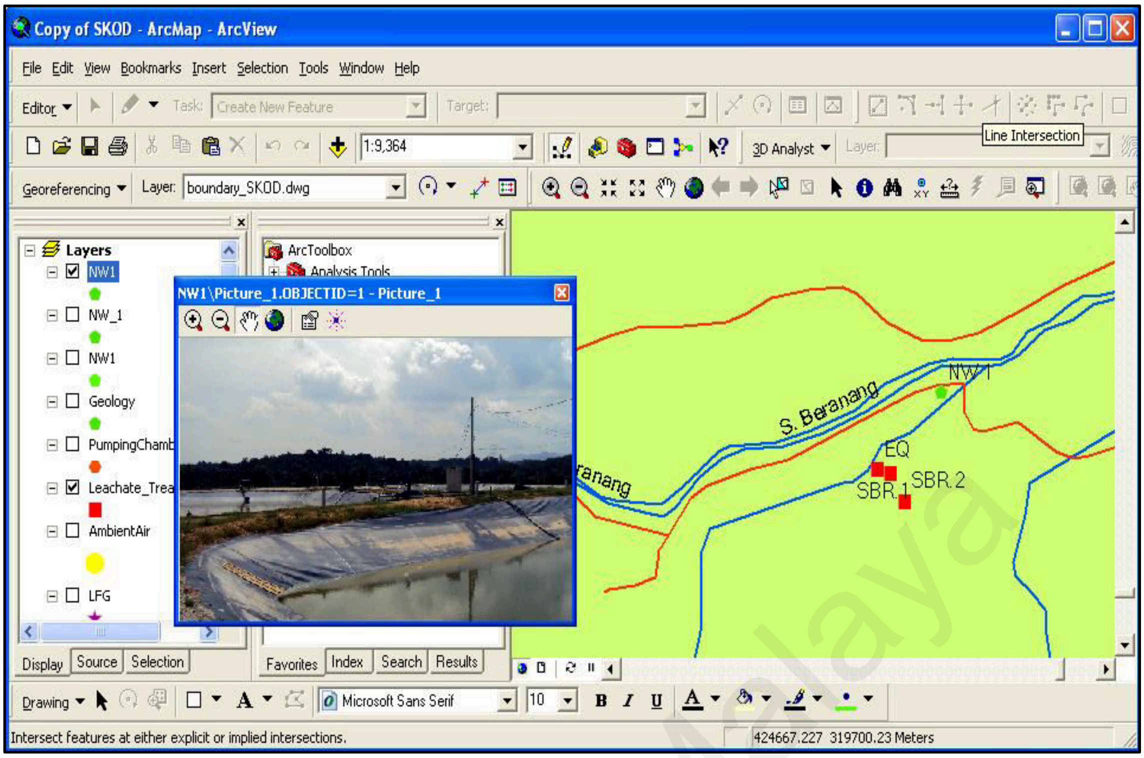

Figure 4.25: Output interface in ArcGIS showing raster image of leachate treatment pond

Moreover, the hyperlink tool on the toolbar of ArcMap can clearly present and depict any pictures showing the condition and situation of SKOD. Figure 4.25 represented one of the output interfaces which showed the picture of an existing leachate treatment pond located in SKOD. Reasonably, stakeholders needed reliable and clearly illustrated data to make their decisions. This can further reduce the time and cost for them to propose a new policy and to find the solutions to improve any environmental pollutions detected.

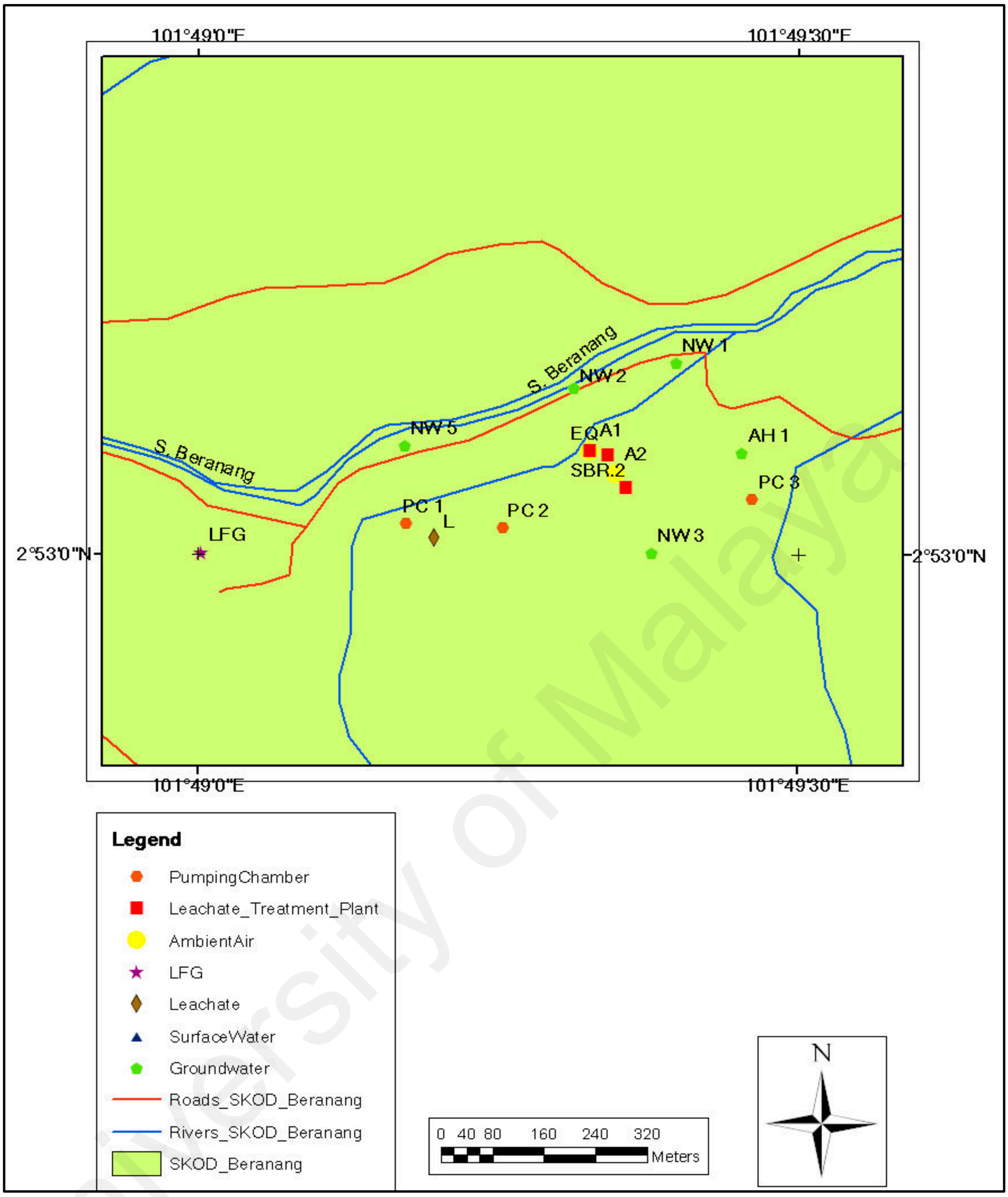

Figure 4.26: Output interface in ArcGIS showing the combination of all thematic layers

A comprehensive map was produced by turning on all the thematic layers together (Figure 4.26). The locations of all the sampling points and leachate treatment pond were easily identified. The database created was to aid in the rehabilitation of SKOD particularly during the monitoring period which would take up a minimum of 10 years for the landfill to stabilize (MHLG & JICA, 2004). The future monitoring data obtained can then be stored in this GIS-based database in order to generate a complete and comprehensive dataset. Future conditions of SKOD can be predicted based on the current and historical data kept.

Overall, GIS was a good tool for environmental planning. In the context of decision making basis, GIS can be used to integrate such a significant amount of inputs required for a good planning. It was also obvious that GIS was a potential tool to aid in landfill rehabilitation by providing all the available and necessary information and at the same time effectively convey the complex information into graphical presentations.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

Eventually all the open dumpsites will reach their capacity to additional waste leading to the need for the safe closure and rehabilitation process. Rehabilitation process of any open dumpsites is necessary to be implemented at the end of their lifespan. It is particularly important to prevent any environmental pollutions and health hazards. Besides, rehabilitation process will help to erase the often held impression that the existing open dumpsites were always left unattended. Open dumpsite is a temporary land use which can then be transformed into a beneficial site fulfilling the aspects of social, economic and environmental. Therefore the rehabilitation process must be executed in a proper and sustainable manner in such a way to ensure the conservation of the environment and public health. This must be done in accordance with our national solid waste management policy.

For the case of SKOD rehabilitation, the open dumpsite has been upgraded based on the guidelines published by the Ministry of Housing and Local Government. It has been changed completely from a disgusting and unattended open dumpsite into a guarded, proper-managed and aesthetically accepted controlled dumpsite. Proper treatment facilities and gas venting system have been installed at SKOD in achieving environmental improvement. No stench was noticed in SKOD and vegetation has been found growing over the land. A period of monitoring time is still required to make sure the landfill stability is reached. Continuous monitoring of SKOD must be done at least

10 years since its closure in July 2010 as recommended by the Ministry of Housing and Local Government (MHLG).

This research study outlined a series of landfill rehabilitation activities that support the achievement of the study objectives mentioned. It was aimed to evaluate and assess the conditions of SKOD and its monitoring process during the rehabilitation. The landfill rehabilitation of SKOD discussed the method to identify, quantify and classify all physically measurable and recordable pollution source that was detected in SKOD. Besides, this study also contained the sustainable planning and management in landfill rehabilitation that complied with the regulation and standards applied in Malaysia. The information on SKOD condition was particularly important in the process of upgrading SKOD to a controlled landfill. It was to ensure that the impacts identified after the operation of SKOD were effectively mitigated. Of particular concern was the high concentration of coliform found in the groundwater ranging from 100 to 16000 CFU/100mL. The presence of coliform in groundwater was a warning sign that action must be taken. In addition, the methane gas produced at SKOD which was recorded at 53.4% has far exceeded the recommended safety level. The quality of Sungai Beranang has also deteriorated when the WQI has fallen from 84 to 63. Mitigation measures must be implemented to prevent the river water from becoming unreliable sources of water supply. This again emphasized the needs of closed monitoring of the SKOD.

Inevitable, data monitoring and management were particularly important throughout the landfill rehabilitation process. It required an integrated system approach to be established in an effective manner. Thus, a feasible study of an integrated investigation of rehabilitating an open dumpsite using GIS was presented in this study. The GIS database through pollutant inventory management was produced. All the data and information stored in GIS maps would then be accessed directly and quickly by the stakeholders involved. This would definitely expedite the rehabilitation process. Without such database, decision makers will have a high percentage and probability in making bad decisions. Besides, the monitoring processes and updating of data can be executed in lesser time and easiest way. GIS-aided SKOD rehabilitation was an integrated approach that would help the stakeholders in an effective manner in terms of cost and time. Undeniable, GIS would definitely become one of the potential tools in facilitating the landfill rehabilitation management. In conclusion, the development of rehabilitation assessment using GIS for SKOD can serve as a case study for future rehabilitation process that would be carried out by the government to achieve the targets of National Strategic Plan for Solid Waste Management in Malaysia.

5.2 Recommendations

5.2.1 Recommendations for Future Research Work

The rehabilitation of SKOD was carried out based on the guidelines of MHLG that emphasized on the environmental aspects. Although the rehabilitation process of SKOD was aimed to minimize the pollution effect towards the surrounding environment, there are always other technical or financial considerations to be taken into account. These considerations include the technology or knowledge of rehabilitation and the cost associated with the operation of rehabilitation. Landfill rehabilitation of SKOD focusing on the environmental aspects without detailed hydrogeological and slope stability analyses are of limited relevance. Also, health impact assessment coupled with social impact assessment, should be become integral parts right from the beginning of landfill rehabilitation. It would be further enhanced by taking into the interests of the public, government, NGOs, private sectors, researchers and the relevant parties.

Besides, the establishment of a standard procedure in collecting, storing and integrating the data is another crucial step to assure the reliability of the information. Basically, there is no consensus on the use of common geospatial dataset across the various agencies and department in Malaysia. This is due to the fact that the dataset is managed and maintained by different organizations with different policies for different applications. Thus, it has been a great challenge to come out with a standard and localized framework such as the spatial data infrastructure in managing the dataset which would be compatible in terms of data accuracy. It can also prevent the redundancies of effort in collecting, processing and producing of datasets by having the standard framework.

The outcomes generated from the GIS should be made accessible and available by everyone in order to ensure that there is seamless data integration. The system can be improved by receiving all the feedback and comments from the stakeholders including the public. Undeniable, public participation at the right stage of decision making process may increase the chances of success of the landfill site after use and the positive response of the public to its rehabilitation process.

5.2.2 Recommendations for Promotion of GIS Application in Landfill Rehabilitation and Environmental Management

There are also several recommendations to achieve an optimal contribution of GIS in landfill rehabilitation and safe closure. Firstly, expanding the awareness of GIS value and its usefulness is the primary step in order to promote its application among the stakeholders. Gaining a greater understanding towards GIS technology would help in developing GIS at different levels of solid waste management.

In addition, the application of GIS in this research could be applied to a broader context. GIS can be used to examine the suitability of the land uses such as golf courses and park on a rehabilitated landfill. In addition, the GIS outcomes generated from this research study can be further investigated on the environmental risk assessment. This could be done by sorting out an appropriate scoring or weighting system. In future research work, potential attributes or features found in the landfill can be evaluated in terms of its feasibility and cost effectiveness by developing and implementing algorithms. It would be much better if the establishment of the algorithms can account in a precise policy with an updated data available.

In terms of future application, the outcome generated from the GIS is important for rational planning of future disposal facilities. Based on the outcomes, policy makers could assess the effectiveness of the existing management in landfill rehabilitation and foresee the potency of using GIS to offer a systematic approach that integrates many aspects particularly the environmental planning of landfill rehabilitation for the benefit of the community.

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