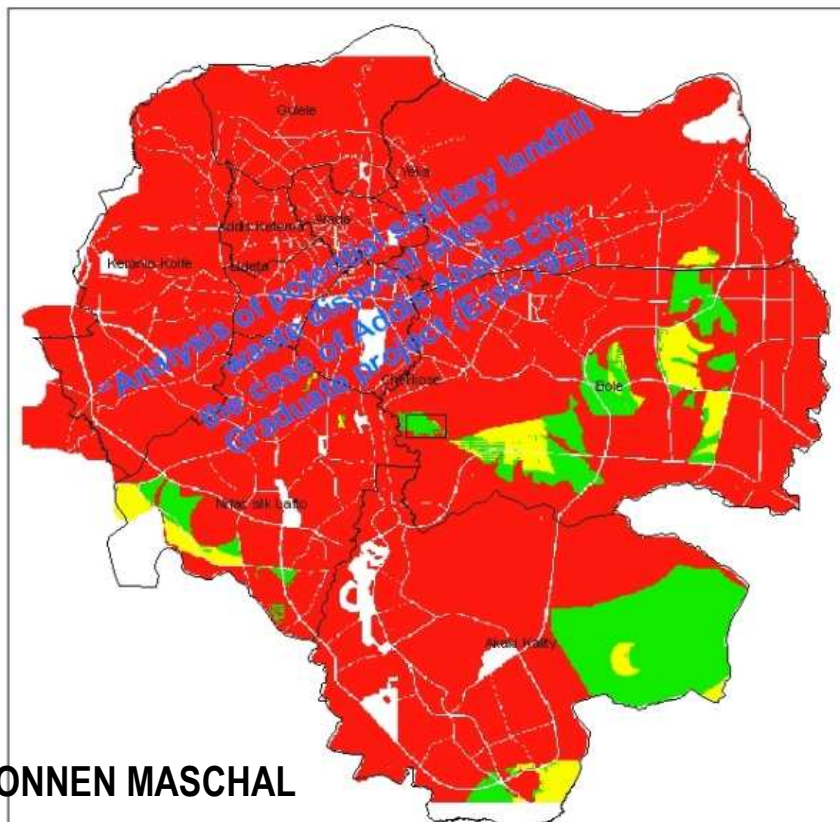


Addis Ababa  
University  
(Since 1950)



**ADDIS ABABA UNIVERSITY**  
**SCHOOL OF GRADUATE STUDIES**  
**EARTH SCIENCES PROGRAMME**

“Analysis of potential sanitary landfill waste disposal sites”; the case of Addis Ababa city



**BY: MEKONNEN MASCHAL**

**A Graduate project submitted to Addis Ababa University**

**School of graduate studies**

**In partial fulfillments of the requirements for the degree of Master of Science in**

**Earth science/urban geology**

**June, 2009**

**“Analysis of potential sanitary landfill  
waste disposal sites”, the case of Addis Ababa city.”**

**GRADUATE PROJECT (Ersc.792)**

**Submitted to: Department of Earth sciences  
Graduate programs**

**Advisor: Mohammed umer (PHD)**

**Submitted by: Mekonnen Maschal**

*June 2009,  
Addis Ababa / Ethiopia*

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## **Abstract**

Urban population growth together with the development of new industries and commercial centres generate huge amount of solid waste daily. Like in many developing world cities a rapid population growth and high rural-urban migration poses many environmental challenges for the Addis Ababa city. One of these is dry waste management and disposal system. Inadequate dry waste management has resulted in the accumulation of solid waste on open lands, in rivers, in drains and in the living area of many people, causing a nuisance and foul-smelling pools, environmental pollution through leaches from piles (water and soil pollution) and burning of waste (air pollution), clogging of drains, and the possible spread of diseases. This situation is believed to result in poor environmental conditions and an ever-present risk of epidemics, which in turn present a formidable threat to health and productivity.

The present method of disposal is crude open dumping; hauling the wastes by truck, spreading and leveling by bulldozer and compacting by compactor bulldozer at the only one dumpsite 'koshe'. The dumpsite is getting full; it is partly surrounded by residents and institutions and has no gas control. The gas generated from landfill causes spontaneous fire and air pollution. It contributes enormous amount of methane (green house gas) to the atmosphere. The site has low area capacity (25 ha), poor protection of ground water and surface water pollution. Now, for the time being, the environmental impact of this disposal sites on human beings, soil, air and water quality makes this issue a subject of many researchers in addressing the safe way disposal system. Proper disposal site selection of the waste is a challenging issue that must be addressed adequately. Land filling is one of the common methods used for waste disposal. GIS (Geospatial Information System) is a computerized tool for solving environmental problems. It can then be used to optimize the selection process of landfill site. Through various functionalities, GIS is able to provide a better understanding of the effects of the sites on the environment.

The objectives of this project are to identify and evaluate the major earth related factors on landfill site selection, and to describe the methods for proper landfill location estimation. As a case study to the whole part of Addis Ababa city has been selected to evaluate the candidate locations. The data used included geologic condition (hydraulic conductivity), soil type distribution, underground water (depth), surface hydrology (rivers), topographic maps and geomorphology (slope), land use property and distance from the main road. The data are combined together using DRASTIC procedure on a commercial GIS software package to locate and visualize the selected site. The paper elaborates all the

methodologies used, and the scientifically evaluated results. Finally, this project paper produced a more recommended suitable landfill sites map for Addis Ababa city. Also the project paper forwarded a scientifically analyzed recommendation for a previously proposed landfill and existing open dump site in the city

## **1. Introduction**

### **1.1 Back ground to the problem**

Urbanization introduces society to a new, modern way of life, an improved level of awareness, new skills, a learning process, and so on. However, when the rate of urbanization gets out of control by increasing population due to both natural growth and rural urban migration, it poses a big challenge to manage a large amount of solid waste generated from an aggregated human settlement. The problem is more acute in developing countries where the pace of urbanization with rate of population growth is faster.

Municipal solid waste management (MSWM) is the generation, separation, collection, transfer, transportation and disposal of waste in a way that takes in to account public health, economics, conservation, aesthetics, and the environment, and is responsive to public demands (WWF, 2005). According to the World Bank, overall goal of solid waste management should be to collect, treat and dispose solid wastes generated by all population groups in an environmentally and socially satisfactory manner. Solid waste management is in crisis in many of the worlds largest urban areas as population attracted to cities continues to grow and this has lead to an ever increasing quantity of domestic waste while space for disposal decreases (World Bank, 1999). In Ethiopia, alike other developing countries, the increase of solid waste generation is resulted from rapid urbanization and population booming. According to Dawit and Alebel (2003), the amount of solid waste in Addis Ababa and other fast growing areas in the country has been increasing over time, largely attributed to rapid population growth rate.

Addis Ababa which is the capital city of Ethiopia, diplomatic capital for Africa (OAU, ECA), regional head quarters like UNDP, UNICEF, UNHCR, FAO, ILF, ICO, and ITU has a rapid population growth rate of 3.8% resulting in a rise of approximately 5% of urban waste generation per year (Addis Ababa City Administration, 1998). The same authors indicated that from the total solid waste released by the population in the city, about 50-60% was collected and the rest was unattended. Recently the municipality has increased its coverage to about 85% (AACG-SPBA-2005). In spite of the relative improvement in waste collection by employing more efficient means as planned by the city, volume of actual uncollected waste will continue to increase in proportion to the population. Inadequate municipal and industrial dry waste collection, disposal mechanisms and disposal sites creates a range of environmental problems in Addis Ababa. The entire urban space confirms that

managing solid waste is a matter of great concern. The rivers are widely used as disposal sites. As simple observation around rivers bank indicates, large percentage of the uncontrolled waste goes to the rivers. While walking in the city from any corner all public spaces like roadsides and open spaces attest eye-catching piles of garbage, flying 'festal' (which is increasingly used for packaging), rubbish, construction demolitions and moved-earth from new construction sites littering the urban space indefinitely. Obnoxious odors emanating from decomposing solid wastes are sickening all citizens. Although the hygiene and environmental sanitation regulation issued by the Addis Ababa city administration (Pro.No.1,1994) prohibits people from disposing waste along roads, avenues, rivers, ponds, and other sites, the regulation is continuously violated by the people due to lack of alternative means for disposal.

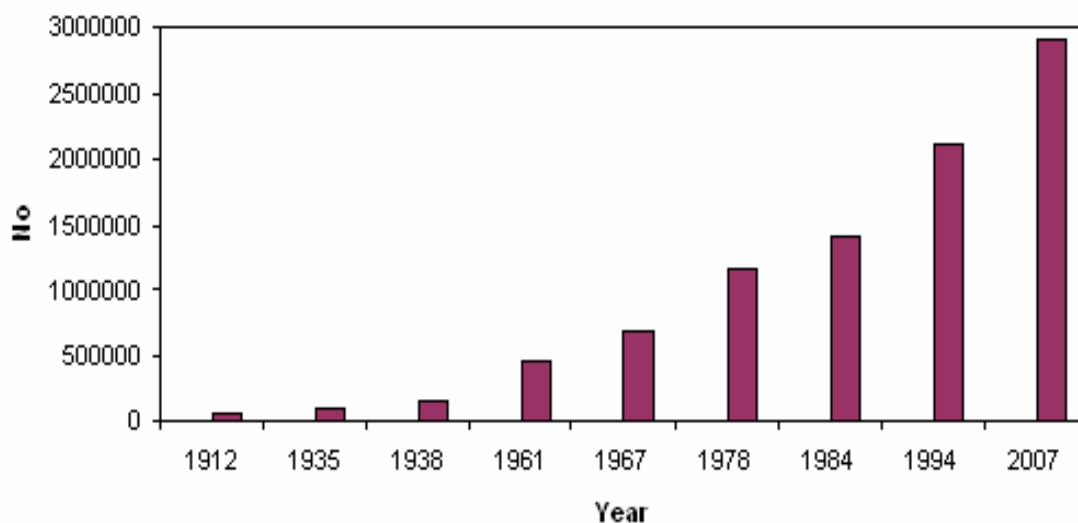
This creates a poor environmental quality city that can deprive citizens of a good quality of life as it affects their health and consequently, adversely affect productivity and economic development (Geenhuizen and Van Nijkamp, 1995). Various concepts have been developed and recommended to provide the basis for improving the solid waste management in the past for developing countries. Among them, integrated dry waste management (DWM) provides a framework, i.e., decisions of waste handling by taking into account the environmental, economic and social dimensions (R.Gerlagh, et al., 1999). This includes prevention, recycling, energy recovery and sound land filling of solid waste, which has been very successful in various countries. But, open dumps unfortunately still mostly observed in developing countries where the waste is dumped in an uncontrolled manner, can be detrimental to the urban environment. Many governments now acknowledge the dangers to the environment and to public health derived from uncontrolled waste dumping. However, obtaining sites for new landfills is becoming increasingly difficult due to a subject to growing public opposition, unavailability of land, financial problems of the responsible authorities to construct a land fill with enough distance from residents, insufficient guidelines, baseline studies and trained personnel for determining location, design and operation of new landfills, or for upgrading of old dumps.

So, most local governments and urban agencies have, time and again identified waste management as a major problem that has reached proportions requiring drastic measures. They are trying to select a proper management system and to identify secured disposal site that is free from any kinds of environmental impact like water pollution, air pollution, aesthetic, public health and others.

In the present study an attempt has been made to identify potential landfill sites depending upon the integration of voluminous and varied data set pertaining to several earth related factors. This project would aim at demonstrating the utility of earth science in identification and selection of sites for waste disposal in and around Addis Ababa city. It is hoped that this study will have paramount importance in providing relevant information that is basic to design and select appropriate solid waste management system and management site.

## 1.2 Populations and settlement

Addis Ababa had a population of 65,000 in 1912, which grew to 100,000 in 1935. In a little over three years it had increased to 143,000 (Tekeste, 1987). The population of Addis Ababa has grown from 443,728 in 1961 to 683,530 in 1967, 1,167,315 in 1978, 1,423, 111 in 1984 and 2,112,737 in 1994. According to Central Statistic Authority (CSA, 2007), the total projected population of Addis Ababa for July 2007 is to 2.7 million. The growth of the population of Addis Ababa from 1912 to 2007 is shown in figure below.



**Figure-1: Bar graph projection of Addis Ababa city population**

Source: Central statistics agency

Exponential population growth in Addis Ababa

## 1.3 Solid waste management in Addis Ababa city

### 1.3.1 Solid waste generation rate, source and types in Addis Ababa

The daily waste generation is estimated 0.252kg/capita/day. The current daily waste generation of the city is 2,297m<sup>3</sup> or 851 tones with density of waste 333kg/m<sup>3</sup>. Of municipal waste per day, 65 % (1,482m<sup>3</sup>) is collected (Addis Ababa city SBPDA, 2003). The remaining 35 percent of waste is disposed off through informal means, except smaller percentage going to incineration and dumped on open sites, drainage channels, rivers and valleys as well as on the streets. Most of the solid waste (~76%) is generated from the residential/ house hold waste and others 9% from trade institution, 6 % from streets, 5 % from industries, 3 % from hotels and 1% from hospitals. Of the collected wastes 70% by volume , 50% by weight is organic recyclable waste, in general fruit residue /4.2%/ paper /2.5%/ plastic and tire /2.9%/ wood /2.3%/ bone /1.1%/ textile /2.4%/ metals /0.9%/ glass and broken bottles /0.5%/ easily burnable leaves /15%/ stones /2.5%/ and minor things a general /65%/.

Year (EC)	Solid waste generation rate (m <sup>3</sup> )	Disposed solid waste (m <sup>3</sup> )	Solid waste collection coverage (%)
1995	686,678.4	452,192	65.85
1996	651,136	547,327	84.06
1997	763,215	623,624	81.71
1998	772,325	540,266.91	70.00
1999	787,305	615,335.65	78.16
2000	No data found	No data found	No data found

**Table-1; Solid waste collection and disposal coverage in Addis Ababa**

Source: Addis Ababa city sanitation, beautification and parks development agency 2000 E.C. annual final report

### ***1.3.2 History of solid waste management in Addis Ababa***

The increasing problem of urban waste management has its roots in history. According to IDWS (Beyene Geleta), there was no potential threat of waste, when the city was built as an administrative centre in 1880s. Neither the settlement pattern nor the mind set up of residents was in conformity with waste management issues. Haphazard physical development without regard for sanitary and utility facilities characterized the development pattern of the city even up to 1980s. Rural tradition of disposing waste, including human excreta, in the open air ways instantly transferred to the emerging city to perpetuate to these days. Thus the current problems are, at least in part, the cumulative effects of the historical development patterns of the city through the century and the traditions of its people.

The municipal services run a waste collection and disposal service for a long period which was under the responsibility of the Region 14 Health Bureau. Several practices exist that contribute to the management of waste, but none of the mechanisms can alleviate the waste accumulation in the city. Waste collection, either on door-to-door basis or communal collection has been employed as the sole waste management method. The collected waste was usually dumped in the only open landfill site located south west of the city. Other waste disposal methods such as composting of agricultural wastes, incineration and recycling of wastes were not used.

### **1.3.3 Current solid waste disposal system in Addis Ababa**

The present method of disposal is crude open dumping; all the solid waste collected by the municipality is brought to a single open dump landfill at Repi. This is sited 13km south west of the city centre; it has been serving starting 1964 EC. The dump site is getting full; it is partly surrounded by residents and institutions and has no gas control. The gas generated from landfill causes spontaneous fire and air pollution. It contribute enormous amount of methane (green house gas) to the atmosphere. The site has low area capacity (25 ha), it is very poorly equipped, with only two ageing bulldozers and one roller compactor. The road to the site is in a very poor condition and becomes virtually unusable during the heavy rains. Hence there are often days when no waste can be collected from the city. Rapid urbanization around the site and the lack of any segregation and characterization of different types of waste results in over many people, including children, scavenging through the refuse with all the associated health risks.



Rivers as a disposal site in Addis Ababa



Overlook of river water color in Addis Ababa

**Figure-2: overlook pictures of Addis Ababa rivers as disposal sites**

### 1.3.4 Effects and impacts of solid wastes at koshe landfill

#### 1.3.4.1 Public health concerns

The concerns of public health are related primarily to the infestation of areas used for the storage of solid wastes with vermin and insects that often serve as potential reservoirs of disease. The practice of throwing wastes into unpaved streets, road ways and vacant land led to the breeding of rats, with their attendant fleas carrying the germs of disease that result in disease outbreak. The lack of any plan for the management of solid wastes led to the epidemic of various diseases. Throwing of hazardous wastes to the environment can cause direct toxicity to the children and waste scavengers. Even if the city Health Bureau takes a number of precautions before dumping hazardous type of waste at the landfill including using a specific truck for carrying, burying and digging and informing scavengers at Repi to the dangerous nature of the waste, they will never completely prevent scratching the waste through the dumpfill in search of something to eat or sell (Rahel Shiferaw, 1997). Information gained from the informal interview of one stackholder in kolfe keraneo subcity, "Bascilios" junior school students located besides koshe were always in danger of the toxic waste and corrosive industrial chemical disposed in the very near landfill. On the other side the adoption of toxic and trace metals by fruits and vegetables grown at the landfill sites can cause human health indirectly by involving through human diet.



Bascilios Junior school near koshe site      photo: at margin of disposal site in winter season

**Figure – 3: Pictures that show the public concern of Addis Ababa**

### 1.3.4.2 Aesthetic concerns

Aesthetic considerations are related to the production of odors and the unsightly conditions that can develop when adequate attention is not given to the maintenance of sanitary conditions. Most odors can be controlled through the use of containers with tight lids and with the maintenance of a reasonable collection frequency. If odor persists, the container can be sprayed as a temporary expedient. To maintain aesthetic conditions the container should be scrubbed and washed periodically. Even noise pollution and traffic pressurizes the aesthetic of the environment. Koshe open dump fill site as a main residential area (center of the city)



Unsightly condition at koshe



urban smog resulted from koshe landfill

**Figure – 4: picture shows the aesthetic concern for koshe site**

### 1.3.4.3 Environmental impact and Ecological Concerns

(Ecology, ground water, surface water and soil pollution)

The decomposition of waste into constituent chemicals is a common source of local environmental pollution.

**Ecological concern** such as water and air pollutions, also have been attributed to improper management of solid wastes. The contamination of ground water through leaching and surface water through runoff is highly likely, especially during the heavy rainy season in July and August. This leachate from the dump and poorly engineered landfill contaminate surface waters and ground waters that causes deposition of toxic elements such as copper, arsenic, cadmium, zinc and other toxic metals.

The organic waste leachate down from the site deplete the dissolved oxygen in the water body that creates unsuitable ecology for aquatic life.

A major environmental concern also Methane and other gasses released by decomposing garbage as a by-product of the anaerobic respiration of waste by bacteria. Methane concentrations can reach up to 50% of the composition of landfill gas at maximum anaerobic decomposition (Cointreau-Levine, 1996). So, even it can cause fire hazard around the sites if not properly handled. Since the site has no proper methane venting and/or flaring, the gas seeps into porous soil surrounding the waste and eventually migrates into nearby basements and homes, posing an explosion risk. Carbon dioxide is a second predominant gas emitted by landfills; although it is less reactive, it buildup in nearby homes could be a cause of asphyxiation. A second problem with these gasses is their contribution to the so-called greenhouse gasses (GHGs) which are blamed for global warming. Also, special non biodegradable plastics can decrease the soil fertility and affect the circulation of free air in the soil , can affect the urban agriculture around the site.



*urban agriculture on the site*



*Fire inside the koshe open dump landfill*

**Figure-5: picture that shows the ecological concern at koshe site**

**Ground water pollution:** leach ate down from the open dump site affect the physical, chemical and microbiological parameters of the natural ground water around a landfill site. This makes it out of WHO drinking water standard. According to sewit (2006) the quality of ground water with WHO quality standard is presented below.

**Table – 2: Ground water quality at Koshe open dump site**

No.	Parameters	*GW sample (0.85km from koshe)	Mekanissa well (1.80km from koshe)	WHO drinking water standard
1.	Physical parameters			
	Turbidity, NTU	1	less than 1	less than 5
	Color mg pt/l	5	9	less than 15
	Odor	non objectionable	Non objectionable	non-offensivable
	Taste	non objectionable	non objectionable	non-offensivable
	PH	7.01	7.57	6.5-8.5
	TDS mg/l	306	266	1
	Total hardness as CaCO <sub>3</sub> ,mg/l	322	248	500
2.	Chemical parameters			
2.1	Anions in mg/l			
	Chloride as Cl <sup>-</sup>	1.5	9	250
	Chlorine as free	nil	nil	0.5
	Fluoride F	1.04	0.87	1.5
	Nitrate,NO <sub>3</sub>			
	Sulfate ,SO <sub>4</sub> <sup>2-</sup>	186.4	26	400
2.2	Cations (mg/l)			
	Ammonium ion as NH <sub>4</sub> <sup>+</sup>	0.33	nil	2
	Iron total as Fe	0.08	.016	0.3
	Manganese as Mn	nil	nil	0.3
	Copper as Cu	less than 0.0014	nil	1
	Chromium as Cr	less than 0.003	nil	0
	Aluminum as Al	nil	nil	0.2
3	Micro bacterial parameters			
	Total colliform,***mpn/100ml	1,700.0	nil	nil
	E.colli,***MPN/100ml	1,700.0	nil	nil

\*GW sample - ground water sample ,

\*\* NTU- nephelometric turbidity units, \*\*\* MPN-most probable number

(Source: modified from sewit, environmental science unpublished MSc-thesis, AAU-2006)

**Surface water pollution:** leachate down from the open landfill changes the natural physical, chemical and the microbiological composition of rivers present in its downstream. The following table confirms koshe open dump clearly affect the quality of surface water.

Parameters		Upstream river	Down stream				Down stream average (average of 2,3 and 4)
			sample 1	sample 2	sample 3	sample 4	
Physical parameters	PH	7.49	7.79	7.95	8.17	8.03	
	conductivity s-m/cm	1102	3462	1771	3733	2988.67	
	alkalinity as CaCO <sub>3</sub> mg/l	368	750	575	962	763.33	
Chemical parameters	anions (mg/l)						
	chlorides	101	405	174	553	377.33	
	fluorides	0.46	0.49	0.41	0.47	0.47	
	nitrate	4.18	13.2	19.36	30.86	21.14	
	sulfate	53	342	71	82	165	
	cations (mg/l)						
	sodium	60	215	103	281	199.67	
	potassium	50	251	85	388	241	
	calcium	86	185	88	106	126.33	

Source: sewit, AAU unpublished environmental science MSc thesis -2006

**Table-3: Chemical and physical appearance of river water around koshe open dump site**

**Soil pollution:** the solid waste dumped at the site release heavy metals , toxic metals and other trace metals to the soil makes beyond the permissible capacity of the soil. Fruit and vegetable grown at the site can adopt such metals and indirectly accumulated in the human diet. The following table sumerises heavy metals of koshe landfill site soil as compared with the Dutch permissible limits :

Samples	Heavy metals in ppm				
	Co	Ni	Cu	Zn	Pb
Soil 1	60	97	30	109	14
Soil 2	47	91	34	121	19
Soil 3	40	78	35	240	23
Average (koshe soil)	49	88.7	33	156.7	18.7
Controlled sample	36	85	28	89	2
Dutch permissible limit	20	35	36	140	85

Modified from Sewit, AAU-2006

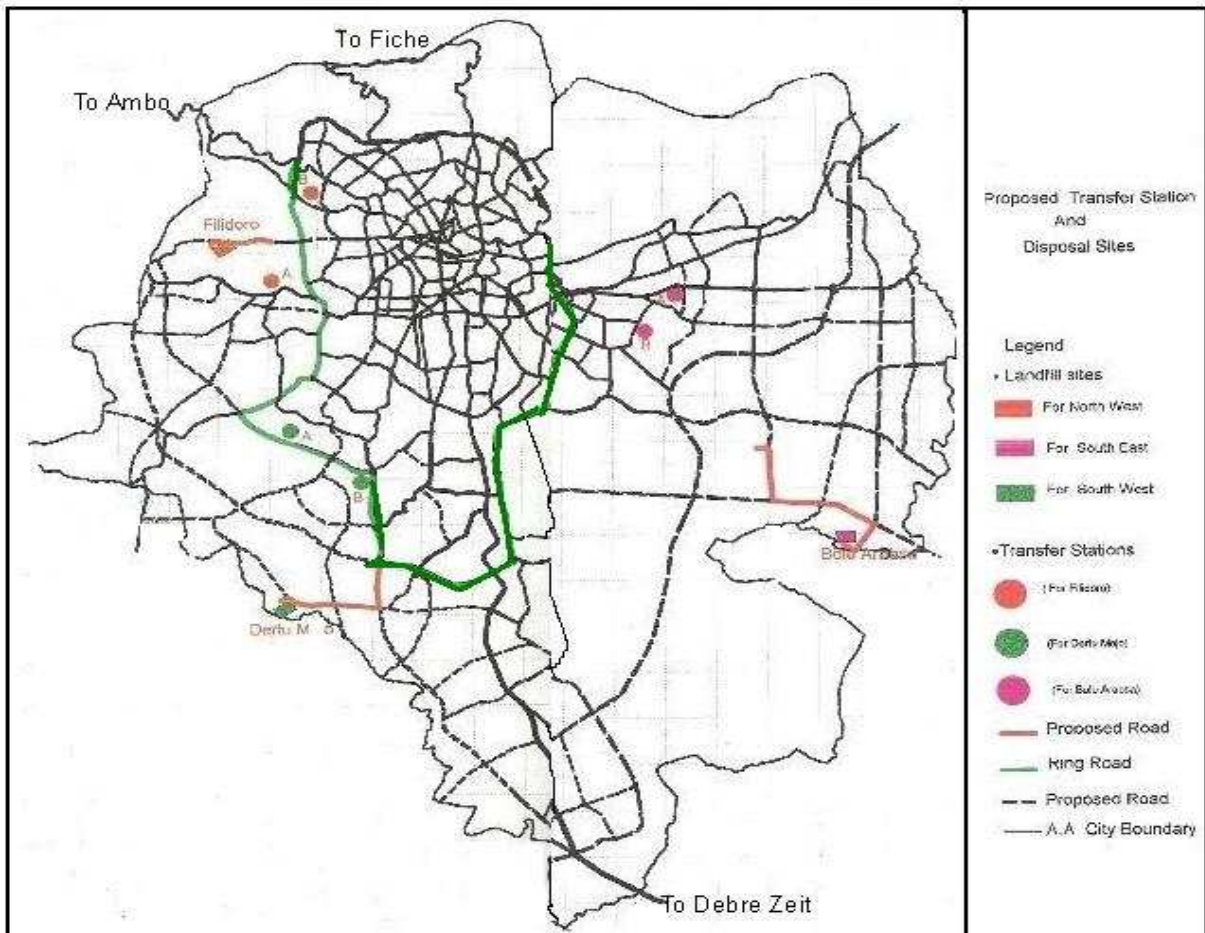
**Table -4: heavy metal concentration at koshe site soil**

### 1.3.5 Programs of landfill disposal site development

Since the present old site in the south west of Addis Ababa koshe (repi) is not enough to accommodate the ever increasing population waste generation and also needs to be rehabilitated, the development of

another site is required. The present situation shows that there are settlements clustered around the site and public health is at risk, on the other hand the newly constructed ring road is too close to it, which makes it nuisance.

The disposal of trash also needs separation to compostable, recyclable, biodegradable, hazardous...etc if it is to be disposed of. Such site used to separate and characterize the waste is called a temporary transfer site, which should be near the landfill site. But, practically no transfer and alternative landfill site is developed in Addis Ababa. So, there is a need to find alternative sanitary landfill site to replace the koshe one. The office for the revision of Addis Ababa master plan (ORAAMP) has made proposal of a few four sites; however scientific evaluation of these sites did not be conducted to serve the purpose.



**Source: Modified from Addis Ababa city master plan prepared by ORAAMP**

**Figure -6: location of proposed landfill sites in Addis Ababa masterplan**

## 1.4 significance of the project study

The management of municipal solid wastes is one of the most important challenges faced by our urban and industrial societies. Due to the inadequacy of controlled waste management strategies and waste disposal sites in Addis Ababa, people are forced to discharge wastes both on open surface and with in water bodies (rivers). Even the officially collected and transferred wastes are disposed off at the uncontrolled open dump koshe site. Uncontrolled (improper) waste disposal activity in the koshe has deteriorated the quality of surface water (streams, rivers, reservoirs) and ground water by changing the chemical, physical and organoleptic properties of water. It changes the composition of unwanted metals in soil. Even it can not meet the minimum criterions set by environmental protection authority which is clear from environmental pollution and other aesthetic impacts. None of the proposed landfill sites in the master plan is coming in to practice. Even they are not scientifically evaluated when they were proposed. There fore the adverse effect of inadequate solid waste service on the productivity and economic development of the city expected to be very significant. So, in order to meet the proper solid waste disposal need of exponentially increasing population, the introduction of new appropriately evaluated alternative disposal sites are required.

## 1.5 Objectives:

Selection of landfill site involves integration of voluminous and varied consideration pertaining to several earth related factors. This project would aim at demonstrating the utility of earth science in identification and selection of sites for waste disposal in and around the city of Addis Ababa.

General objectives:

- ✓ Study the underlying geology, hydrology/hydrogeology, geomorphology and topography, pedology and other relevant related parameters for safe landfill waste disposal site.
- ✓ Identifying and selecting an alternative sanitary landfill waste disposal site.

Specific objectives:

- ✓ To evaluate and analyze the various solid waste treatment mechanisms
- ✓ Set criteria for locating a landfill site
- ✓ To identify and analyze parameters for landfill site selection

- ✓ To recommend the possible designs and alternatives of future landfill site
- ✓ To produce Suitable Landfill Map of Addis Ababa City

## 2. General setting of the project area

### 2.1 Location, Physiography and Drainage of Addis Ababa

The city lies at the center of the country and on the western escarpment of the main Ethiopian rift. It is bounded by 38°43' and 38°50' E longitudes, and 8°56'10'' and 9°05'N latitudes.

The altitude ranges from 2700 meters a.s.l. in the north to 2200 meters a.s.l. in the south. Steep slopes and rugged topography of the Intoto ridge in the north rise to 3000 meters a.s.l. Southwest of Addis Ababa, the plateau also is rugged, but its elevation is slightly lower than northern section.

The drainage in the area shows dendrite pattern. These drainages are denser to the southern part. Big and Little Akaki Rivers, with their different tributaries, drain the city from north to south.

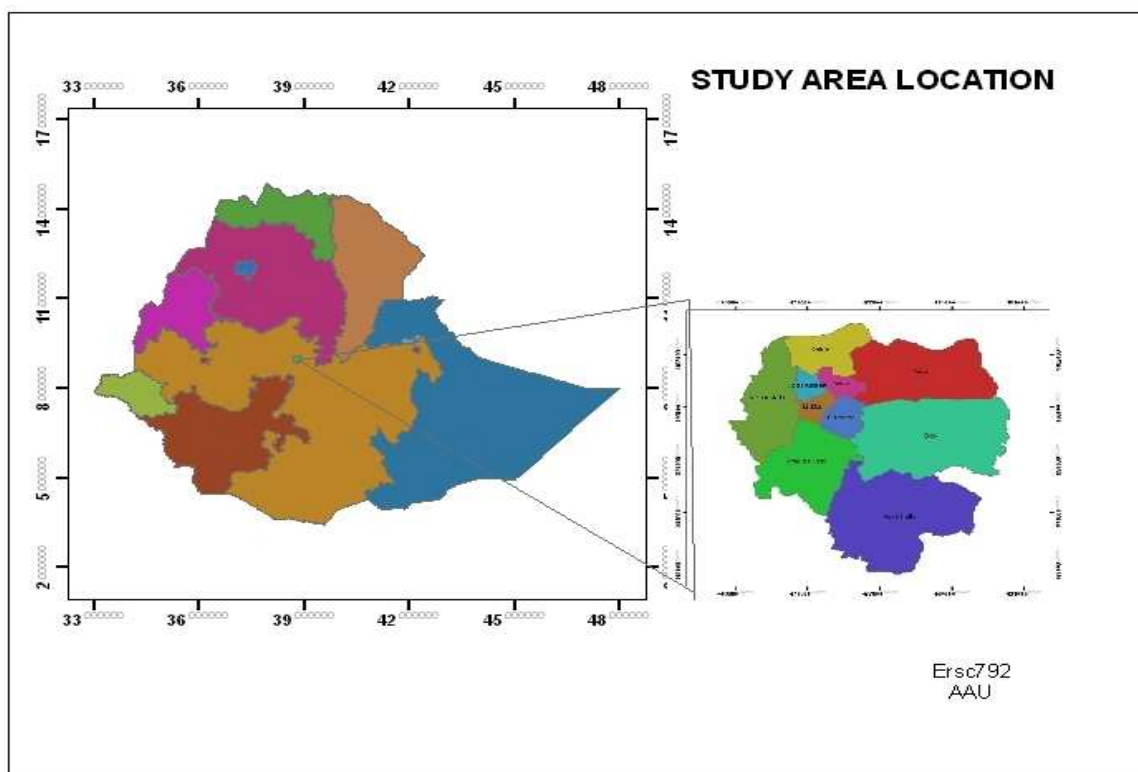


Figure -7: picture of project study area

## **2.2 Geology of Addis Ababa**

### **2.2.1 Geologic distribution**

Many researchers systematically proposed the geology and volcanic stratigraphic sequences of Addis Ababa area. The suggested Miocene-Pleistocene volcanic succession in the Addis Ababa area from bottom to top are: Alaji basalts, Entoto silicics, Addis Ababa basalts, Nazareth group, and Bofa basalts.

#### ***ALAJI BASALTS***

The Alaji group volcanic rocks (Alaji rhyolite and Basalt) in this part of the escarpment were outpoured from the end of Oligocene until middle Miocene (Zanettin et al., 1974). This unit is composed of basalts, which show variation in texture from highly pophyric to aphyric. Within this unit there is an intercalation of gray and glassy welded tuff. The outcrop of Alaji basalt extends from the crest of Entoto (ridge bordering the northern parts of Addis Ababa) towards the north (Haileselassie Girmay and Getaneh Assefa, 1989). This unit is underlain by tuffs and ignimbrites; Mohr (1967) proved that the Entoto trachyte overlies the Alaji basalt.

#### ***ENTOTO SILICICS***

These early Miocene age silicic volcanics could represent localized terminal episodes to massive Oligocene fissure basalt activity in the Addis Ababa region (Morton et.al. 1979). The thickness of the flow become maximum on the top of Entoto ridge and thin both towards the plateau and the plain east of Addis Ababa. According to Zanettin and Justin-Visentin (1974) these lavas make up a thick pile of flows accumulated along east west fissures (east-west fault running from Kassam river to Ambo) and uplifted northwards. The unit is unconformably overlain by Addis Ababa basalt on the foothill of Entoto and underlain by Alaji basalt. The Entoto silicics composed of rhyolite and trachyte with minor amount of welded tuff and obsidian (Haileselassie Girmay and Getaneh Assefa 1989). The rhyolitic lava flows outcrop on the top and the foothills of the Entoto ridge, predominantly in the western side. It also outcrops in the eastern part of the town from the Kokebe Tsebah School to the Benin Embassy. The thickness is quite variable as it frequently forms dome structure. In this rock unit flow banding, folding and jointing are common. The rhyolites are overlain by feldspar porphyritic trachyte and underlain by a sequence of tuffs and ignimbrites. Tuffs and ignimbrites are welded and characterized by columnar jointing.

The rhyolite made up of phenocrysts of plagioclase and altered rebeckite in a groundmass of glass with iron oxide. The trachytic lava flows outcrop on the top of Entoto ridge and its foothills. The thickness varies and reaches the maximum of 30m near by Kotebe covering the rhyolitic lava flows. It shows a quite uniform texture, and is constituted by phenocrysts of oligoclase, sandine and rebeckite within a groundmass of plagioclase, iron oxide and minor quartz and mafic minerals. Two varieties of trachytic lava flows have been identified in the eastern side of the town, near Kotebe: a pale gray and a pink trachyte. The latter one is characterized by veins of hematized opal and by feldspar phenocrysts, which are often completely or partially altered with fine fractures filling of hematite (Varnier et al., 1985).

### ***ADDIS ABEBA BASALT***

In the project area the oldest visible rock post-dating the Entoto silicic is the Addis Ababa basalt. These units, which are mainly present in the central part of the town, are underlain by the Entoto silicics and overlain by Lower welded Tuff of the Nazareth group. The maximum thickness exceeding 130 meters was found at Ketchane stream. It is porphyritic in texture, composed of labradorite, -bytownite, olivine and augite as phenocrysts. The ground mass is made of andesine, labradorite, olivine, magnetite and pyroxene (Haileselassie Girmay and Getaneh Assefa 1989).

Olivine porphyritic basalts outcrop in the central part of the town that includes Mercato, Teklehaymanote and Sidist Kilo. The distribution of plagioclase porphyritic basalt is almost the same as that of the olivine porphyritic basalt, but only little more northwards. It outcrops in an area, which includes Sidist Kilo, General Winget School and French Embassy. The thickness of the former varies from 1m or less in the foothills of Entoto, Lideta Airfield and Filwoha to greater than 130 meters at Ketchane stream (Morton, 1974; Varnier et al., 1985). The Lower Welded Tuff overlies both types of basalt nearby the Building College, the Kolfe Police School, the Kokobe Tseba School and Yeca Mariam Church. On the other hand, only in the gorge of the Ketchane stream the olivine porphyritic basalt is overlain by the plagioclase porphyritic basalt, while elsewhere the relationship between them is very difficult to determine (Varnier et al., 1985).

## ***NAZARET GROUP***

The units identified in this group denoted as Lower Welded Tuff, Aphanitic basalt and Upper Welded Tuff. The group is underlain by Addis Ababa basalt and overlain by Bofa basalts. The rocks outcrop mainly south of Filowha fault and extend towards Nazareth.

### ***Lower Welded Tuff***

This rock outcrops as small discontinuous body in Filwoha, western parts of Addis Ababa and Sululta. It is glassy with abundant fiamme and has columnar joints. Generally it is overlain by the aphanitic basalt and underlain by the olivine and plagioclase prophyritic basalt.

### ***Aphanitic Basalt***

This basalt covers the southern part of the town, especially the areas of Bole International Airport and Lideta Airfield. The rock body shows vertical curved columnar jointing together with sub-horizontal sheet jointing. It consists of: Labradorite, augite, rarely olivine and magnetite. The crystals of plagioclase show marked flow alignments. It is underlain by the plagioclase and olivine porphyritic basalt and overlain by the younger ignimbrite from which it is separated by tuffs and agglomerates.

### ***Upper Welded Tuff***

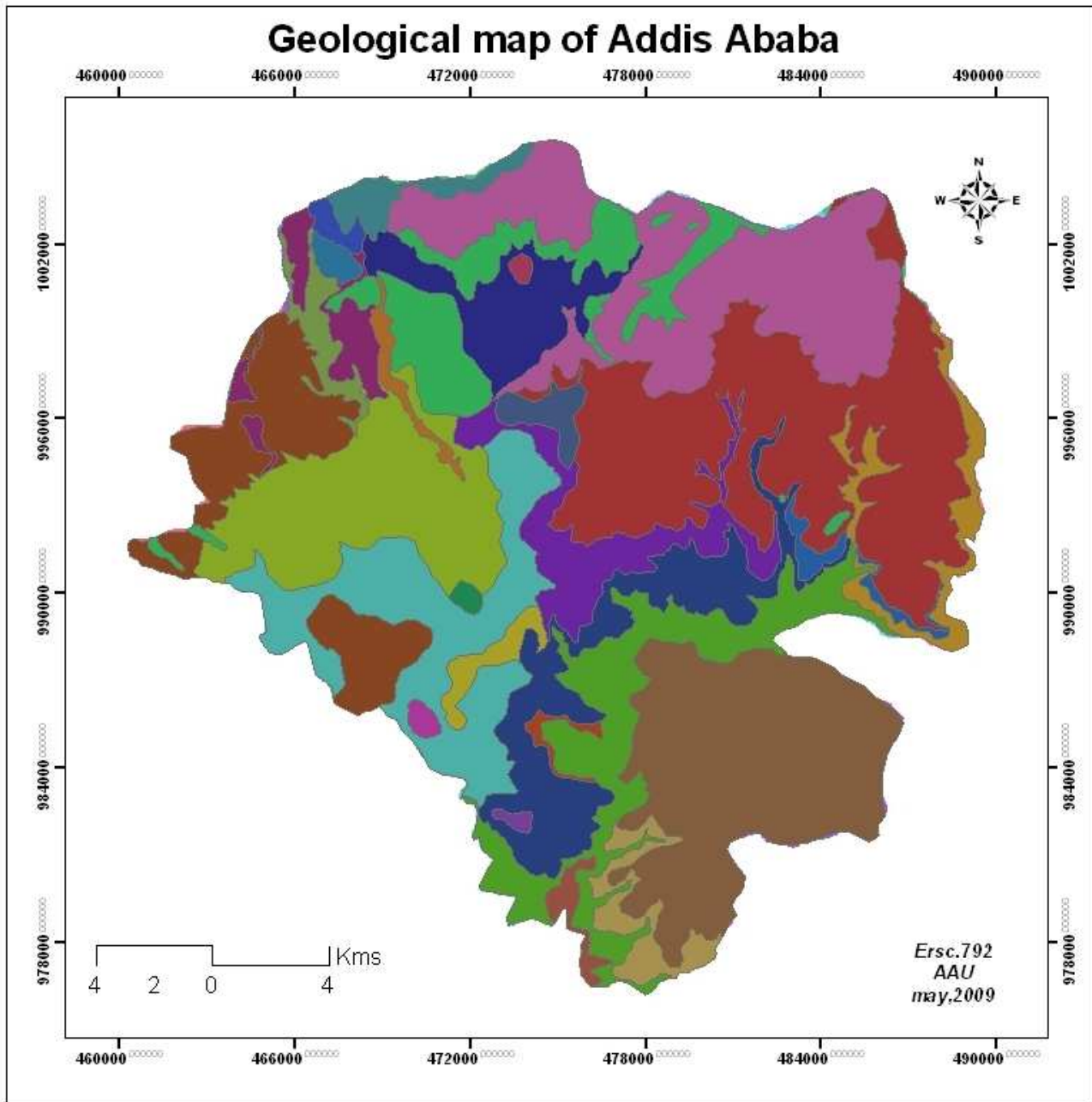
This rock outcrops all over the southern part of the town including Bole, Nefas Silk and Railway station; nevertheless it is also present in the central and northern parts of the town. It is gray colored, vertically and horizontally jointed and composed of sandine, anorthoclase, rebecite, quartz, pumice and unidentified volcanic fragments (Getaneh Assefa et al., 1989). The welded tuff is underlain by aphanitic basalts and overlain by young olivine basalts.

### ***Young Trachyitic Flow***

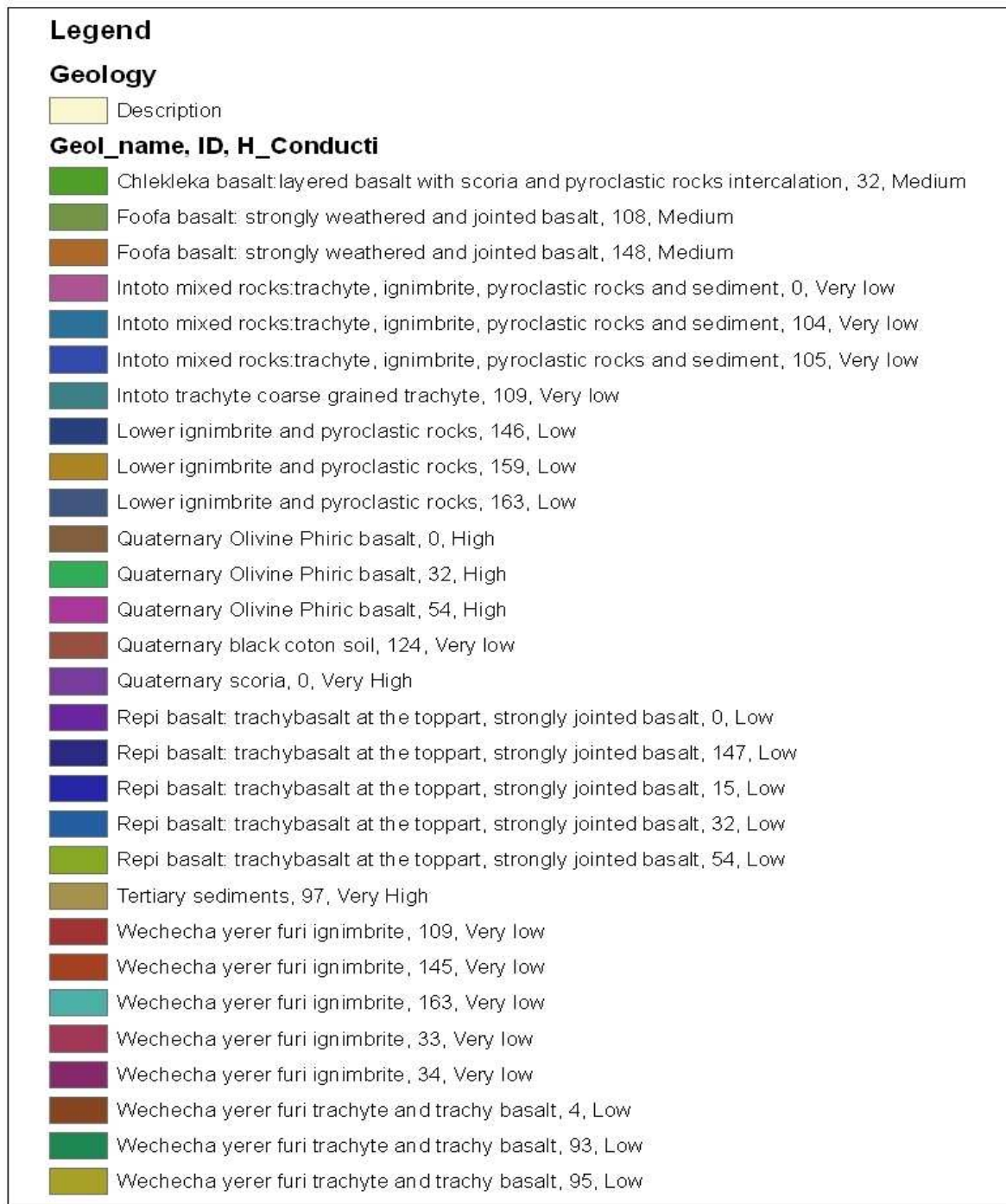
According to Tamiru Alemayehu (2003) predominating in the southwest part of the town, from Dama hotel towards Furi and Repi along the hills and foothills of Hana Mariama and Tulu Iyou. It is porphyritic with phenocrysts of plagioclase (albite-oligoclase) sandine, biotite within a groundmass of microlites of feldspar. Moreover, it is underlain by the tuffs that cover the young ignimbrite and overlaying by alternating flows of plagioclase porphyritic basalt and rhyolite especially in the Repi hill.

***Young Olivine porphyritic basalt***

They outcrop southward from Akaki River where they appear in the form of boulders reaching a thickness of 10 meter. They are restricted and dominant in the southeast part of the city i.e. Debre Zeit Road. They contain phenocrysts of plagioclase, olivine that is partially and completely altered to iddingsite and augite within a ground.



**Figure - 8: Geological map of Addis Ababa city , legend is as shown below**



**Figure-9 description of the geological map of Addis Ababa city**

## 2.2.2 Geological structures

In Addis Ababa the occurrence of faults, joints and other structures within the different volcanic rocks were reported by different authors. Long fault line running east-west via Kassam river, Addis Ababa

cut across the western rift escarpment and uplifted its northern block (Zanettin et al., 1978) at about 8 My ago. This fault marks the upper (outer) boundary of the western Ethiopia Rift margin immediately north of Addis Ababa-Ambo road (Zanettin et al., 1974). The Entoto silicics confined along this fault and form a ridge. This ridge bounded the city in the northern direction. The fault has a down thrown to the south in the Addis Ababa area (Haileselassie Girmay, 1989). An other prominent normal fault in the city is the Filowha Fault. This fault has a trend of NE-SW (Kundo, 1958; Morton, 1974; Haileselassie Girmay, 1989). The fault has a northwest down thrown side according to Morton (1974). However, Haileselassie (1985) found that the fault has down thrown to the south, shallow depth and covered by very thin soil layer (1-4m). Kundo (1958) suggest that the hot springs in Filowha are the indicative of this fault. The Filowha fault, having a trend of N55<sup>o</sup>E (Haileselassie Girmay, 1989) is thought to be a major NE fault that continues up to Debre Berehan (Mohr, 1964). Moreover, Al consult (1996) interpretation map indicates the continuation of the Filowha fault towards the southwest periphery of the city in the same direction. Morton (1974) map shows four other north-east trending faults, which have south-west and north-east down thrown side. The other major structural feature in the study area is joints, which have different spacing, opening and orientation. The dominant preferred orientation of joints occurring in different rock unit is NNE-SSW (Kebede et al., 1990), which is sub parallel with the general trend of rifting. They found joint spacing of 15-200 cm (in most basalt), 5-100 cm (in trachy basalt, trachyte and rhyolite) and 2-100 cm (in ignimbrite) landmass composed of plagioclase magnetite pyroxene and olivine. This basalt is underlain by the tuffs, which cover the welded tuff.

### **2.3 Hydrogeology of Addis Ababa**

The groundwater circulation and the dispersion of pollutants are depending on the hydrogeological characteristics of the material more specifically hydraulic properties such as porosity, permeability, transmissivity etc. The origin, flow and chemical constituent of groundwater is controlled by the type of lithology, distribution, thickness and structure of hydrogeological units through which it moves (UNESCO, 1972). Moreover, the stresses due to tectonism and weathering govern the hydrogeochemical characteristics of earth materials. Therefore, to identify the path way and final destination of pollutants it is necessary to describe the earth materials occurring in the project area with a particular reference to their infiltration capacity. Volcanic rocks mainly basalts, rhyolites, trachytes,

scoria, trachy-basalts, welded and unwelded tuffs are the dominant rock outcrops in the area. These rocks are the major groundwater supply for large parts of Addis Ababa.

#### BASALTIC LAVA FLOWS

The texture of basaltic lava flows in the Addis Ababa area varies from porphyritic (olivine and plagioclase) to aphanitic. Basically, high water storage and transmitting capacity of basaltic lava flows is due to joints caused by cooling, lava tubes, vesicles that are interconnected, tree moulds, fractures caused by buckling of partly congealed lava (lava surface) and voids left between successive flows. Old porphyritic basaltic lava flows dominantly cover the slopes of Entoto, central and western parts of Addis Ababa. Its water circulation and storage capacity is dependent on the degree of weathering and secondary fractures (weathering types). The presence of faults and fractures modify the hydraulic properties of the rock. The young porphyritic basalt that outcrops in the southern parts of Addis Ababa varies from massive to fractured type. It is fresh to slightly weathered. The fractured variety is the most permeable and productive aquifer in Akaki area (Anteneh Girma, 1994). Aphanitic basalts dominantly cover the southern and southwestern parts of Addis Ababa. Outcrop of this rock vary from massive to vesicular type. Vesicles, which are abundant on the aphanitic basalts, are not interconnected and in some cases partially filled by secondary minerals. Thus, vesicles have little or no effect on the overall rock permeability. However, in some localities (e.g. near Bole Air Port) due to weathering fractures and/or tectonic discontinuity, vesicles are interconnected. Consequently, the water transmitting capacity of vesicular basalts increases to some extent. The shape of vesicles varies from circular to cylindrical cavities.

The presence of vertical and horizontal fractures significantly increase the water circulation and storage capacity of massive aphanitic basalts. However, the same rock shows difference in hydraulic property depending upon the fracture spacing, extent and openings. Measurements taken from different places show that there is variation in the spacing of vertical fractures form about 0.3 to 1 meter and horizontal fractures from about 1.5 to 2 meters. Likewise, the aperture in the vertical and horizontal fractures varies from about 10 to 30 mm and 10 to 20 mm respectively. Moreover, there are also inclined fractures that run in different directions and intersect at some point. The other difference in water transmitting capacity is related to the extent to which the aphanitic basalts affected by weathering. The permeability becomes high in area where this basalt is intensively intersected by weathering fractures. In the southwestern Addis Ababa, near ALERT, for example the aphanitic basalt

is highly weathered and affected by horizontal and inclined local weathering fractures. The spacing in the horizontal fractures varies from about 3 to 5 cm and the aperture reached up to about 2 cm. In some localities, the basaltic lava flow is slightly weathered and consequently, possesses low infiltration capacity. Moreover, the degree of weathering, fracturing and morphology of the area plays a great role in controlling the development and thickness of soil horizon above the aphanitic basalts. The physical disintegration and chemical decomposition become more pronounced along the surface of joint sets.

#### **WELDED TUFF**

This rock unit is widely distributed in the northern, central and eastern Addis Ababa. The strongly welded tuff is exposed in the central and western parts of the study area. While, young welded tuff varieties cover extensive area in the central and southern parts of Addis Ababa. According to Davis (1966) welded tuffs have medium to low primary porosity and very low permeability. Thus the water circulation and storage capacity of welded tuff depends on the secondary porosity and permeability developed through fracturing and weathering processes. However, the degree of weathering and fracturing is not uniform throughout the study area on this rock unit. In most places the welded tuffs are fresh to slightly weathered and there is thin soil cover or bare rock exposed. On the other hand, in the flat-laying areas of southern and southeastern parts of Addis Ababa as well as along most river valleys the welded tuff are deeply weathered and covered by soils having different thickness.

The secondary fractures, are mainly the results of weathering and tectonic activity, affected the ignimbrite in different manner. In some localities the welded tuff is massive, slightly weathered and fractures are scarce or absent. Thus, the secondary processes produce only small increases in the overall water circulation and storage capacity of welded tuff. On the contrary, block fractures divided the massive welded tuff into rectangular blocks in large parts of the study area. Mostly these fractures are open to a considerable depth and transmit large amounts of water. On average the spacing and aperture of vertical fractures in ignimbrite varies from about 0.5 to 2 meter and 2 to 4 cm respectively. Likewise, the horizontal fractures vary from about 1 to 4 meters in spacing and 1 to 3 cm in fracture opening. Therefore, in most localities welded tuff developed good secondary permeability largely from open fractures and to some extent from weathering zone. When there is high degree of fracturing and weathering, welded tuffs have the capacity to hold water and become a productive aquifer.

#### **Silicic lava flows and domes**

The rhyolitic and trachytic lava flows are mostly considered as impervious rocks. The water storage and transmitting capacity is thus largely dependent upon secondary porosity and permeability. Rhyolitic lava flows are found dominantly along the slopes and foothills of Entoto ridge. The secondary porosity in rhyolite is due to weathering and associated fractures. In the western parts of Addis Ababa weathering deeply obliterated the rhyolite that occurred in gentle slopes of Entoto. Weathering in this locality produce soils having a thickness of greater than 10 meter.

Moreover, weathering fractures locally increases the porosity of the rhyolitic lava flows. In some localities vertical fractures having about 0.5 to 1 meter spacing and about 10 to 20 mm opening intersect the rocks. Thus, the weathering fractures and weathering zone significantly modify the limited primary porosity and permeability of rhyolitic lava flows. On the other hand, the rhyolitic lava flows outcrop in eastern parts of Entoto ridges is slightly weathered and less fractured. Consequently, there is poor soil development particularly on the slope and top parts of the ridge. Rock fragments are dominantly covering this part. Relatively shallow soil profile constitutes the gentle slope and foothills of the ridge. Therefore, in some place where the rhyolitic lava flows are intensively weathered and highly fractured, infiltrated water through fractures feeds the aquifers that lie on flat-laying areas. In slightly weathered massive part most of the precipitated water is readily lost as runoff. Trachytic lava flows having different ages are found in the study area. Since trachytic rocks vary in age, structure and weathering conditions, their water circulation and storage capacity also vary accordingly. Trachytic domes have steeper slopes, massive and weathered slightly in the outer parts. There is thin or no soil formation. Therefore, the water that precipitated on the trachytic domes of Mt. Wechecha, Mt. Furi and Mt. Yerer are mostly lost as runoff rather than vertical infiltration. The trachytic lava flows cover the foothills and moderately dipping topography of the southern and southwestern parts of Addis Ababa. Due to thick black cotton soil cover outcrops are scarce. It is slightly to moderately weathered and intersected by fractures. The fractures separate the flows into different columns, which may extend to the bottom of the flow. The major vertical fractures on the trachytic lava flow, that outcrop along the road side have spacing of about 0.5 to 1 meter and the opening in this fracture vary from about 2 to 3 cm. Likewise, local vertical fractures that have about 5 to 20 cm fracture spacing and up to 5 mm fracture opening are also observed in the same outcrop.

The occurrence of major tectonic displacement and deep weathering zone in trachytic lava flows strongly changes the hydraulic characteristics of the rock. On the other hand, minor fractures have local permeability effect. However, an intensively weathered and fractured trachytic lava flow under favorable conditions develops not only water transmitting but also water holding properties. The trachy-basalts are the major outcrops in the western parts of Addis Ababa, around Repi and General Wingate School. They are slightly weathered and intersected by fractures. The fractures are dominantly inclined and fracture spacing varies from about 20 to 40 cm. Although the spacing of fractures in trachy-basalts is small compared to other rock type, due to the tight fracture openings the resulting water infiltration capacity is minimum. Due to slight weathering there is thin soil cover on trachy-basalts.

### **INTERGRANULAR POROSITY**

Alluvial sediments are deposited in the southern and southwestern parts of Addis Ababa along the channel and terrace of the major valley. It is a loose material consisting of clay, silt, sand and gravel in different proportions. The thickness of alluvium deposits varies from place to place depending on the topographic variation in the area. As it was confirmed from the lithologic log of boreholes, alluvium deposits occurred interbedded with different lava flows, pyroclastic materials and paleosols at different depths. Borehole drilled in Central Park (adjoining the Bantyketu stream), for example, cut across about 24m thick sand layer before it encountered the underneath materials. Alluvial deposits also occur in flat-laying topography where there are swampy or waterlogged areas. The thickness of alluvium that covers swampy area of Filowha, for example, varies from 2 to 4 meters. The alluvial sediments in Addis Ababa are poorly sorted, highly porous and permeable. Thus under favorable conditions they may store appreciable amount of water and characterized by high water infiltration capacity. Although very localized colluvial deposits having high porosity and permeability occur in the foothills of Intoto ridge, Mt. Wochacha, Mt. Furi, Mt. Yerer and other elevated areas. On the contrary, tuff has low permeability, but the secondary processes specifically weathering increases significantly the water infiltration capacity of tuff. Weathering products of volcanic rocks cover most parts of the study area.

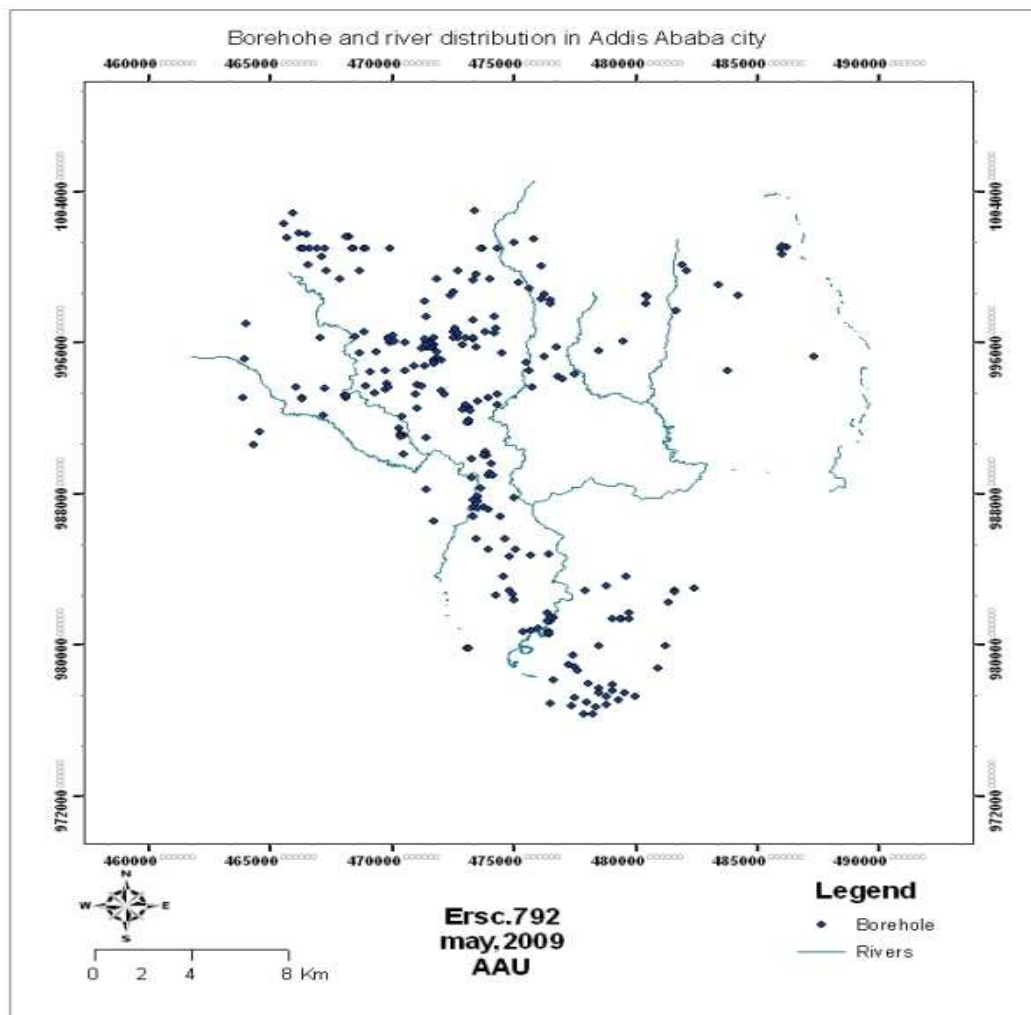
## **2.4 Hydrology of Addis Ababa**

### **2.4.1 Surface water (Streams, *boreholes and Rivers*)**

The total catchment area of the Akaki river basin, includes Addis Ababa, is divided into two sub-catchment areas by approximately north-south running surface water divide. These are the Big Akaki

river (Eastern) sub-catchment and the Little Akaki river (Western) sub catchment. In the project area the stream drains towards the south from the Entoto ridge; southeast direction from Mt. Wechecha and Mt. Furi; and towards southwest direction from Mt. Yerer and other elevated areas of the eastern outskirts of the city. The perennial streams in the city are Little Akaki, Bantiyktu, Kurtume, Kebena, Ginfile, and Big Akaki. Other streams are intermittent in nature.

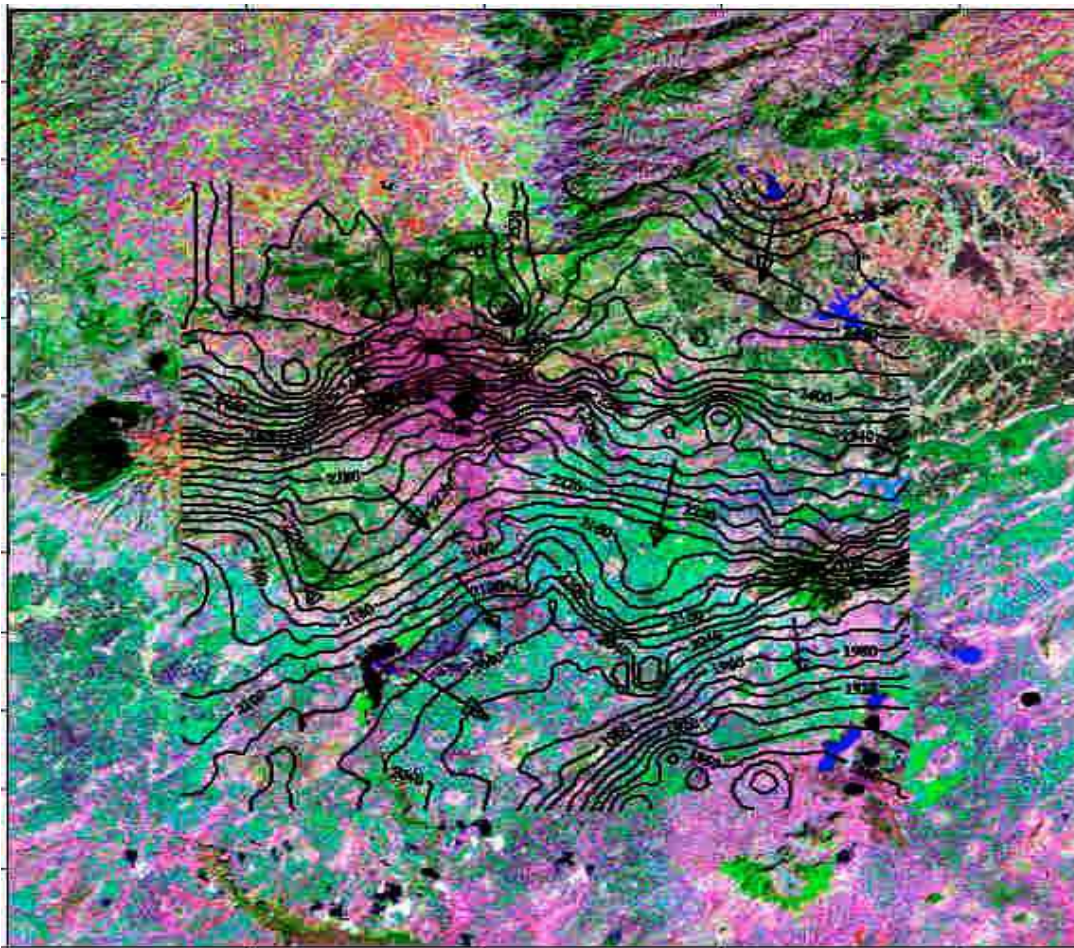
On the top of the mountain streams are dense forming radial drainage pattern, whereas on the slope and most parts of the city core they form dendritic drainage pattern. On the other hand, in the center and southern parts of the city the density of the streams is reduced and the main rivers or big tributaries show a wide meandering type of flow.



**Figure - 10: Hydrology of Addis Ababa city**

## 2.4.2 Groundwater flow direction

The study of groundwater flow direction is essentially in identification of the movement of contaminant, once enter the groundwater from high grounds. The elevation difference of the city together with different hydraulic conductivity values of the aquifer can be used to determine the general groundwater flow direction in the study area. The groundwater movement direction in the figure below is dominated by north-south and east-west flow. The flow lines converge towards the southern parts of Addis Ababa. SEURECA (1990) stated groundwater flow from Southwest to southeast in western parts of the city and from east to west in the eastern parts of the city. In some localities, however, the groundwater flow direction changes, mostly towards the nearby streams.



Groundwater flow pattern indicated by arrows (contour lines are in m. a.s.l).

Source: Tamiru Alemayehu and et al, 2003

**Figure-11: Ground water flow direction in Addis Ababa**

### **2.4.3 Depth of ground water level**

As confirmed by the data interpolated from Addis Ababa boreholes depth, the depth of ground water varies from 0.5 up to 125.925 meters (see fig.16).

## **2.5 Soil type distribution**

The variation in the characteristics of soils makes them different in water infiltration and holding capacity. The porosity and permeability of soil control the vertical as well as horizontal movements of contaminants. The soil development in Addis Ababa area is mostly due to the physical disintegration and chemical decomposition of volcanic rocks. The weathering products are either remain in places and form residual soils or transported and deposited in the areas of Addis Ababa. Meanwhile, the difference observed in the type and development of soils in the city is mostly depends on the topography, parent materials and the degree of weathering. Although there is significant difference in the degree of weathering on the slopes, mostly soils are highly eroded and result in thin soil cover. In the localities where the topography is plain to gentle (central and southern part) of the area is covered by thick soil profile.

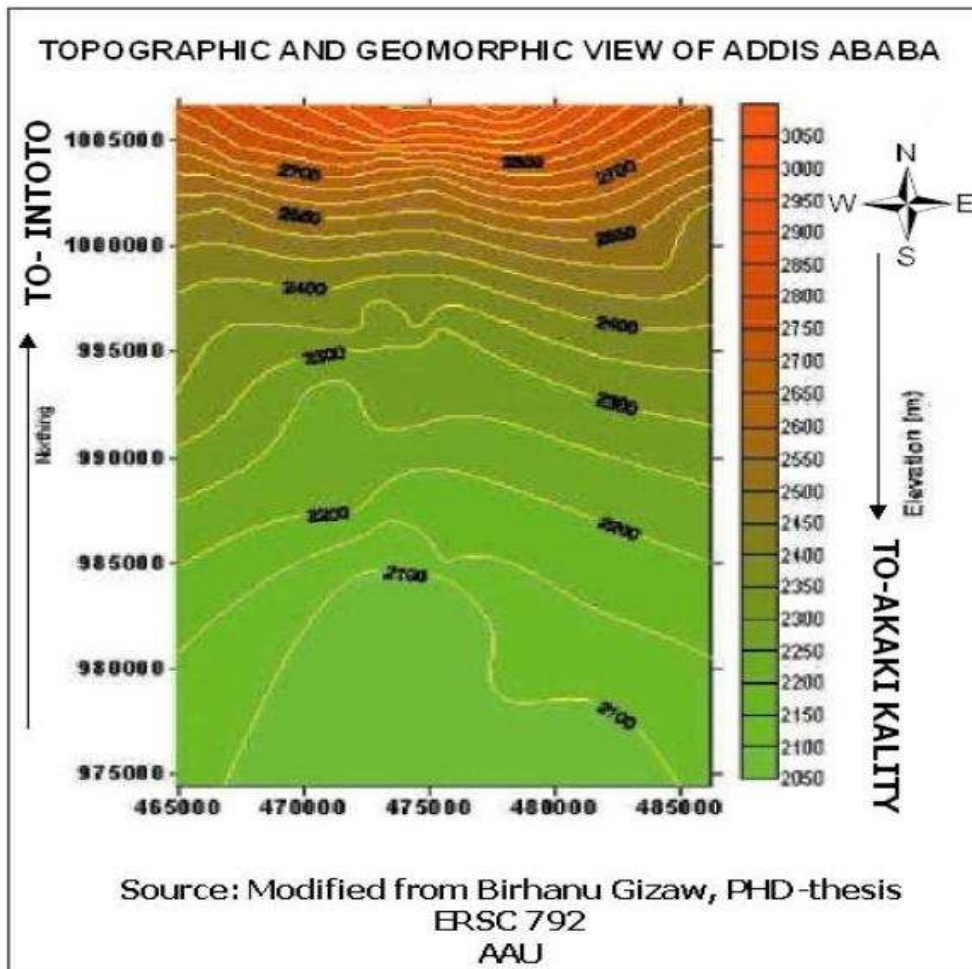
The type of parent material and the length of time to which the parent material is subjected to weathering, control the variation in the thickness of soil. Thus, old basic and acidic rocks that outcrop in the central, western and southwestern parts of Addis Ababa are weathered and form thick soil profile. In places where young basalt and welded tuffs occur, the thickness of the soil cover is reduced. The grain size distribution made by Kebede Tsehayu (1990) showed that the residual soil in central part, Gulele and Kolfe regions have 62 % clay, 33% silt and 5% sand. In some localities reddish brown soil with a thickness of more than 10 meter is commonly seen. Moreover, according to Lulseged Ayalew (1990) studies the residual has a thickness of about 2-6 meters and characterized by very high clay fraction with respect to silt and sand.

The color varies from reddish brown to black depending on the type of parent materials. The detrital materials that are derived from elevated area of Entoto, Wechecha, Furi and Yerer are transported and deposited in the piedmont and along the stream courses of Addis Ababa. It covers most parts of Mekanisa, Ayere Tena, Kaliti, Akaki, Lideta, and Bole. The soil is black in color and the thickness varies from place to place primarily depending on the slope of the area. Samples taken from Mekanisa

are has 76% clay, 22% silt, and 2 % sand. It shows extremely high plasticity and very high degree of swelling (Kebede Tsehayu, 1990). The same work identified 46% silt, 34% clay and 20% sand in alluvial soil collected near Addis Ababa Bole Airport. In areas where there is great contrast in the topography alluvial soils are found. These are loose and incoherent deposits, consisting of fine to coarse grain. The shape of the particles varies from angular to sub-round. Therefore the thickness, permeability, porosity and shrink/swell characteristics of soils are crucial and control largely the infiltration of pollutants into subsurface.

## **2.6 Topography of Addis Ababa**

Addis Ababa is located on the shoulder of the Western Main Ethiopian Rift Escarpment. The morphology is a direct reflection of the different volcanic stratigraphic successions, tectonic activities and the action of erosion between successive lava flows. The city was founded at the southern flank of Intoto ridge (3199m a.s.l.) and expanded in all directions. Other prominent volcanic features surrounding the city are Mt.Wochacha in the west (3385m a.s.l.), Mt. Furi (2839m a.s.l.) in the southwest and Mt. Yerer (3100 a.s.l.) in the southeast. These typical volcanic features are mainly built up of acidic and intermediate lava flows. Thus, they are characterized by rugged landscapes and steeper slopes. The general inclination of the slope becomes lower towards the southern part of the Addis Ababa. The center of the city lies on an undulating topography with some flat land areas. The topography is undulating and form plateau in the northern, western and southwestern parts of the city, while gentle morphology and flat land areas characterize the southern and southeastern parts of the city. Moreover, it is not uncommon to see sharp changes in the inclination of the slope and some flat land areas in different parts of the city. See the following figure.



**Figure -12: Topographic view of Addis Ababa**

## 2.7 Climate and weather condition

Weather is a physical condition of the atmosphere at a specific time and place with regard to wind, temperature, cloud cover, fog, and precipitation. Weather is highly variable and somewhat unpredictable. But it may depend on the physical setup of the environment. But climate is the long term set up of weather of a given environment.

National Atlas of Ethiopia (1981) defined five traditional climatic zones: "Kur" (Alpine), 3000m and above; "Dega" (temperate), 2300m to about 3000m; "Weina Dega" (Sub tropical), 1500 to about 2300m; "Kolla" (Tropical), 800m to about 1500m and "Bereha" (Desert), less than 800m.as shown in

the fig.11 Addis Ababa city relies of different deferent altitude level from the bottom Akaki to the northern part intoto ridge. So it may face different weather type fron one part to anather.

According to the analysis from the scientific report of AAWSA and AAU in 2003 to UNEP/UNESCO/ECA the monthly mean records of rainfall for thirty-five years shows that the mean annual rainfall at Addis Ababa Observatory (at an elevation of 2408m a.s.l.) Bole (at an elevation of 2324m a.s.l.), and Akaki Mission (at an elevation of 2120m a.s.l.) are 1205.19mm, 1091.8mm and 1154.2mm respectively. The higher temperature is present at the southern part which has lowest altitude and nearest to the rift valley area. The lower part of the city is characterized by lower rainfall and higher temperature. Incase it can make the area to higher suitable to landfill disposal site.

### **3. Related literature review**

#### **3.1 waste management strategies**

Municipal Solid Waste Management (MSWM) is the generation, separation, collection, transfer, transportation and disposal of waste in a way that takes into account public health, economics, conservation, aesthetics, and the environment, and is responsive to public demands (WWF, 2005).

Sanitary landfills are disposal sites which are built and operated according to engineering principles in order to minimize pollution of air, water and soil, and other risks to man and animals. C. Zurbrugg, February 2003, USWM-Asia

However, waste disposal in urban areas of developing countries (Africa and Asia) is still largely uncontrolled and large quantities of waste go uncollected. According to IDWS-Addis Ababa (Beyene Geleta, 1999) considerable amount of waste ends up in open dumps or drainage system, threatening both surface water and ground water quality and causing flooding, which provides a breeding ground for diseases - carrying pests.

#### **3.1.1 Waste collection, transport and disposal practices**

.The term collection includes not only the gathering or picking up of solid wastes from the various sources, but also the hauling of these wastes to the location where the contents of the collection vehicles are emptied (Tchobanoglous et al., 1993). Solid waste can be collected from door to door or by using communal containers. Collection in many developing countries is done by using communal

containers in which containers are placed at a place where the residents of the area are required to bring their refuse and dump in. There are three basic types of collection equipments: Human powered, Animal powered, and Engine powered (Hagerty et al., 1977). According to ENDA (1999), municipal waste collection in Addis Ababa is handled in three ways: Door-to-door collection, for households located along accessible streets; block collection, for clients (large hotels, enterprises and institutions) requesting the municipality to provide them with refuse containers (charged service); Container system, which expects residents to carry and dump their waste in 8m<sup>3</sup> refuse containers placed at supposedly accessible sites. In practice, 85% of the waste is collected through the container system in Addis Ababa (ENDA, 1999).

### **Transfer**

A higher solid waste density also has many implications for the 'traditional' methods of collection and disposal; collection containers and transfer trucks which are able to achieve high potentials enough to go with the generated waste.

Many cities employ neighborhood-level collection points, where households are responsible for transport to the transfer point and the municipal or private enterprise transports the waste from there to the ultimate disposal location. Transport also relies on operational vehicles, and frequent breakdowns coupled with parts shortages can immobilize collection vehicles for extended periods of time. UNEP (1996) estimates that in cities in West Africa, up to 70% of collection/transfer vehicles may be out of action at any one time.

In areas where there exist collection services which remove waste from individual households or streets, often have no standardized containers used to store waste prior to pickup. In an examination of current problems in Kenya, Mungai (1998) agreed that the first step in "sanitary and efficient" waste management must be to ensure that all households use some form of corrosion-resistant container with lids in order to facilitate collection.

A major problem is that of development at or on top of landfills; many shantytowns are built from disposed-of waste and in some cases entire neighborhoods are sited on top of existing landfills. To mitigate leachate problems; much more frequent collection is needed in hot, drier areas than would be needed in cooler, humid climates.

### **3.1.2 Waste management, disposal systems and practical limitation.**

According to the World Bank, overall goal of solid waste management should be to collect, treat and dispose of solid wastes generated by all population groups in an environmentally and socially satisfactory manner using the most economical means available.

#### **Integrated approach**

In terms of the Integrated Waste Management approach, progressive authorities are making concerted efforts to reduce the amount of waste that goes to their landfills for final disposal. Notwithstanding this, waste disposal by landfill remains the way in which almost all waste in African and other developing countries is currently disposed. Consequently, landfills and the provision of landfill airspace remain essential elements in most waste management systems and strategies. An integrated approach to waste management will have to take into account community- and regional-specific issues and needs and formulate an integrated and appropriate set of solutions unique to each context (Senkoro 2003, Schübeler 1996, UNEP 1996, de Klundert et al 2001).

As with any issue in developing nations, solutions which work for some countries or areas will be inappropriate for others. Specific environmental conditions will dictate the appropriateness of various technologies, and the level of industrialization and technical knowledge present in various countries and cities will constrain solutions. Studies on MSW issues however repeatedly discuss certain approaches as being at least adaptable to many developing nation scenarios. These approaches emphasize waste reduction (creation of less waste and increased material recovery) and appropriate disposal options as part of an integrated evaluation of needs and conditions.

Many mechanisms have been used over the last few decades to assist in developing more efficient solid waste management programs. These models vary in their intent, assumptions, and solution procedures. So many scholars recommend different waste treatment strategies before they are going to dispose at a landfill site.

#### **Waste reduction**

These goals may be achieved through a variety of measures, including legislative action and the creation of market forces and economic incentives which would drive these reforms forward; applicability of each goal and method would depend on circumstances present in each situation.

It would seem that the easiest and most effective way to reduce the amount of waste to be disposed of would be to simply produce less in the first place. This is a strategy that seems simple in concept

and has shown promise; however the amount of waste produced, even in developed countries, is often a function of culture and affluence. An emphasis on mass production and the development of cheap consumer goods has caused quality and longevity of goods to be sacrificed in the name of lowest market price, causing people to be more likely to simply throw away and replace items instead of repairing or maintaining them. The movement toward a “throw-away” has been mirrored in the developing world, especially in more affluent urban areas. In examinations of refuse generation in the USA, India, and South Africa, Blight and Mbande (1996) found that affluent communities generate 3 to 5 times as much waste as poor communities. This is not surprising since not only do poor communities have less disposable income to spend on anything aside from necessities, they also are much more ingenious in reusing and recycling materials, preventing much of their waste from ever entering the disposal stream. At the national level, there are several methods which can be employed to reduce the production of waste. These include redesign of packaging, encouraging the use of minimal disposable material necessary to achieve the desired level of safety and convenience; increasing consumer awareness of waste reduction issues; and the promotion of producer responsibility for post-consumer wastes (UNEP 1996). This of course has a positive effect on the MSW situation, however it is important to realize that as nations become more industrialized and their per capita income rises; they are likely to generate more waste per person, not less. More importantly, the availability of mass-produced items will reduce markets for used materials and goods, reducing an important incentive. National reduction strategies such as these may not be relevant to the poorest of countries at present, but as these nations develop over time and their per-capita income rises (and the expected increase in post-consumer waste occurs), these measures would have more effect.

### **Recycling**

On the local or regional level, waste reduction can be accomplished through the increased use of source separation and subsequent material recovery and recycling. Separating waste materials at the household level occurs to some extent almost universally, and prevents the most valuable and reusable materials from being discarded. Following in-home retention of valuable material, waste-pickers currently remove most valuable materials either before garbage enters the waste stream or en route, especially in the lower and middle income areas of many municipalities. Even in the more affluent areas of developing cities, often there are found itinerant “buyers” of waste materials such as cardboard and glass. These buyers will help to divert many materials out of the waste stream, and illustrate a key point. If recycling materials is an economically viable undertaking, small enterprises will continue to

spring up whenever there is an opportunity in both developed and developing nations (UNEP 1996). Municipalities embrace by allowing small enterprise to address the problem, valuable funds are saved (the municipality does not have to create a formal recycling program for most materials), jobs are created, and landfill space is saved.

According to SBPDA (2003), the general physical composition of the waste generated from Addis Ababa and disposed on the Koshe open landfill site is 70% organic recyclable and 30 % others. Still, composting has not been overwhelmingly successful and widespread in practice throughout the developing world facilities would be required to return the collected materials to a usable form. For small nations, it may not be economically justifiable to spend the money required to erect plants capable of processing recycled material. Fig.below show the onsite recycle and reuse activity at koshe.

### **Composting**

A somewhat more low-technology approach to waste reduction is composting. The waste of many developing nations would theoretically be ideal for reduction through composting, having a much higher composition of organic material than industrialized countries. In developing countries, the average city's municipal waste stream is over 50% organic material (Hoornweg, et al 1999); studies in Bandung, Indonesia and Colombo, Sri Lanka have found residential waste composed of 78% and 81%

### **Incineration**

Another option for waste reduction and disposal is incineration. Incineration should not be considered a 'disposal' option, since following incineration there is still some quantity of ash to be disposed of (probably in a landfill), as well as the dispersal of some ash and constituent chemicals into the atmosphere. It should instead be considered more in terms of its waste-reduction potential, which can be 80-95% in terms of waste volume (Rand, et al 2000). This appears to be an extremely attractive option, however, with occasional exceptions; incineration is an inappropriate technology for most low-income countries. Above all, the high financial start-up and operational capital required to implement an incineration facility which is a major barrier to successful adoption in developing countries (Rand et al 2000, UNEP 1996).

A large portion of that cost is the environmental hazard mitigation components, including emissions "scrubbers"; use of best available technology in the United States can cost as much as 35%

of the overall project cost (Rand et al 2000). Additionally, specific technical expertise and related general repair and maintenance technology are often absent in developing nation scenarios. High costs and environmental problems have led to incinerators being shut down in many cities, among them Buenos Aires, Mexico City, Sao Paolo and New Delhi (UNEP 1996).The additional level of infrastructure and planning required to implement such a scheme is most likely well beyond the realm of possibility in most developing nations.

## **3.2 Landfills**

The placement of solid waste in landfills is probably the oldest and definitely the most prevalent form of ultimate garbage disposal. It means simply deposition of waste on land whether it be the filling of excavation or creation of landfill above the ground. It may be open, sometimes controlled dumps. But the nature of waste should be characterized before landfill.

### **3.2.1 Classification of landfill**

DWAF (1998) classifies landfills according to the type of waste involve (i.e. based on hazardous nature), the size of waste stream and the potential for significant leachate generation. Accordingly general wastes are dumped in a landfill and hazardous waste is buried in a separate area with in the landfill site covered with appropriate soil materials (national engineer's plc consulting engineers, 1986).

EPA Ethiopia (2002) identifies three types of landfills on the basis of sanitation and quality of management: open dump, controlled dump and sanitary landfill. The main characteristics of open dumps are they are poorly sited, have unknown capacity, no cell planning , no site preparation, no leachate management, have only occasional cover , no waste compaction, no fence, no record keeping and containing waste picking and trading. They can be easily accessed; have extended life time with low initial cost, aerobic decomposition, access to waste pickers for material recovery and source of income. But they cause environmental, ground and surface water contamination; need remediation, has risk of explosion, indiscriminate use and no record of content.

Controlled dumps are sited with respect to hydrogeology, have planed capacity, no cell planning, have drainage on site preparation , partial leachate and gas management, regular cover, compaction in some cases, fence, basic record keeping and uncontrolled waste picking. They have less risk of environmental contamination, permits long term planning, low initial cost, less rainfall runoff,

less risk, extended life time controlled access and use, valuable information material recovery and low risk to waste pickers. The disadvantages are less accessible, environmental contamination, cost, slower decomposition, maintenance and loss of recyclable resources.

For sanitary landfills, the site is selected based on environmental risk assessment, has designed cell development, extensive site preparation, full leachate and gas management, daily final cover, compaction, fence and gate, record waste volume and type etc...and no waste picking. The main advantages are minimized environmental risk, long term planning reduced risk, vector control, and aesthetics, extended life time, secure access, gate record valuable information and eliminate risk to pickers. The disadvantages are access longer sitting process, cost, longer preparation time, slower decomposition, cost of maintenance and equipment, displacement of pickers and loss of recyclable resources. The main features of landfill technology are the prevention of environmental pollution from leachate and recovery of landfill gas. Therefore, to national engineer's plc consulting engineers (1986), a sanitary landfill site a waste disposal facility where waste is deposited in to the ground and covered. Traditionally it is defined as an engineering method of disposing solid waste on land in a manner that protects the environment. This is achieved by spreading the waste in thin layers, compacting it to the smallest practical volume and covering it with soil by the end of each working day.

In an examination of landfills throughout the developing world in 1997-1998, Johannessen (1999) found varying amounts of planning and engineering in MSW dumping; among the various regions visited, African nations (with the exception of South Africa) had the fewest engineered landfills, with most nations practicing open dumping for waste disposal; waste managers in Asian and Latin American nations were more likely to be aware of environmental effects of improper.

If the waste is dumped untreated, it can promote the proliferation of rats, flies, and other vermin, encourage growth of disease-carrying organisms, contaminate surface and underground water, scar the land, and preempt open space. An alternative method of solid waste disposal is the sanitary landfill, first employed in Fresno, Calif., in 1937: waste is spread in thin layers, each tamped compactly and covered by a layer of earth. While more expensive than open dumping, the sanitary landfill eliminates health hazards and permits reclamation of the site for construction, recreation, or other purposes.

'Sanitary' landfills are sites where waste is allowed to decompose into biologically and chemically inert materials in a setting isolated from the environment. Cointreau (1982) outlined four features that must be present in order for a landfill to be considered sanitary:

**I.** Hydro geological isolation through the use of liners to prevent leachate infiltration into the soil and groundwater; collection and treatment infrastructure should be used where leachate is expected to be generated.

**II.** Formal engineering preparations with an examination of geological and hydrological features and related environmental impact analysis, waste tipping plan and final site restoration plan

**III.** Permanent control, with trained and equipped staff to supervise construction and use.

**IV.** Planned waste emplacement and covering, with waste and soil placed in compacted layers as well as daily and final soil cover to reduce water infiltration and reduce odors and pests. Other practical and social considerations must be addressed when planning landfills, especially in the context of developing nations and their problems as outlined above. One of the most important is the siting of landfills in proximity to urban areas. If they are located too far from collection points and transfer stations, waste transport could become prohibitively expensive due to the distance point waste is transported.

### **3.2.2 Landfill site development**

It is obvious that a proper, engineered landfill is more expensive to design, implement and maintain. This is naturally the main constraint in developing countries, and therefore landfill construction is a focus of pre-investigation and development of appropriate sanitary landfill site. These responses outline the likely acceptability of landfills in each groundwater protection zone (as described in *Groundwater Protection Schemes* (DoELG/EPA/GSI, 1999)) and the recommended level of response/restriction, which depends on the groundwater vulnerability, the value of the groundwater and the contaminant loading.

A significant factor in siting all landfills is the protection of groundwater, which is an important resource and source of water supply in developing country, particularly a maximum risk to urban adjacent rural areas. The geology and hydrogeology of any region have a major bearing on: (i) the availability of suitable areas for landfill sites; (ii) the level of natural protection for groundwater from contamination by landfill leachate; and (iii) the design, operation and monitoring of landfills.

Groundwater protection schemes, supported by detailed investigations, provide hydro geological information for landfill site selection. They are used to identify areas where landfills should normally be excluded and areas where they are less likely to pose a risk to groundwater. The groundwater protection responses outlined here require that new landfills should not generally be

developed on regionally important aquifers. Developers of landfills should have regard to both the resource potential and the vulnerability of the underlying and adjacent aquifers. The groundwater protection responses combine both of these factors in a matrix which facilitates rational decisions on the acceptability of a landfill from a hydrogeological point of view. The risk to groundwater from the landfilling of waste is mainly influenced by: the nature of the waste; the leachate composition; the volume of leachate generated; the groundwater vulnerability; the proximity of a groundwater source; the value of the groundwater resource; the landfill design; and the landfill operation and management practices.

The pollution potential can be evaluated by calculating the volume and predicting the composition of leachate that will be generated. The volume of leachate depends principally on the area of the landfill, the meteorological and hydrogeological factors and the effectiveness of the capping. Leachate composition varies due to a number of different factors such as the age and type of waste and operational practices at the site. The conditions within a landfill vary over time from aerobic to anaerobic, thus allowing different chemical reactions to take place. Most landfill leachates have high BOD, COD, ammonia, chloride, sodium, potassium, hardness and boron levels. Ammonia is a contaminant, which may be used as an indicator of contamination, particularly in terms of surface water, as it can be toxic to fish at low concentrations (1 mg/l). Chloride is a mobile constituent, which is often used as an indicator of contamination. The leachate from non-hazardous waste landfills may produce reducing conditions beneath the landfill, allowing the solution of iron and manganese from the underlying deposits. Leachates from landfill sites for non-hazardous waste often contain complex organic compounds, chlorinated hydrocarbons and metals at concentrations which pose a threat to groundwater and surface waters. Solvents and other synthetic organic chemicals are a significant hazard, being of environmental significance at very low concentrations and resistant to degradation. Moreover, they may be transformed in some cases into more hazardous compounds. Landfills have the potential to produce leachate for several hundred years. It is essential that the volume of leachate generated be kept to a minimum. The site selection, design and operation of the landfill should ensure that the risk of groundwater and surface water is minimized and controlled.

### **3.3 Ideal landfill site selecting Criteria**

The principal aims of the overall site selection process from an environmental perspective are to find a landfill site, which will safeguard public health, have minimal impact on the environment, and provide

for a safe disposal of waste. Proper landfill site selection is the fundamental step in sound waste disposal and the protection of the environment, public health and quality of life. The criteria involved in landfill site selection include environmental, economic and sociopolitical criteria, some of which may conflict. This project assesses only the environmental awareness and impact criteria with increasing population while selecting the landfill site.

U.S. Geological Survey (USGS) considers contours, drainage, topography, surficial deposits, geologic formations, bedrock depth and type, and depth to groundwater for further defining the suitability.

### **3.3.1 Hydro geologic parameters**

Hydrogeological investigations should include assessment of the type and distribution of aquifers. The importance of the groundwater distribution, thickness and depth of the aquifers together with the permeability or transmissivity of the aquifers also need consideration. The importance of the groundwater resource should be established including protection zones, beneficial uses and the interaction between groundwater and surface water resources. Data on water levels and water quality should also be collected at this stage.

Special attention should be given to checking for the presence of high permeability zones, high recharge zones, elevation of ground water level, and the nature of the aquifers etc. If such zones are present then the landfill should only be allowed if it can be proven that the risk of leachate movement to these zones is insignificant and that special attention has been given to existing wells down-gradient of the site and to the projected future development of the aquifer.

Groundwater control measures such as cut-off walls or interceptor drains may be necessary to control high water table or the head of leachate may be required to be maintained at a level lower than the water table depending on site conditions.

The site is not generally acceptable, unless it can be shown that: The groundwater in the aquifer is confined; or it is proven that there will not be a significant impact on the groundwater.

#### **➤ Regionally Important Aquifers**

The landfills on or near regionally important aquifers should only be considered: where the hydraulic gradient (relative to the leachate level at the base of the landfill) is upwards for a substantial proportion of each year (confined aquifer situation). Where the proposed landfill is located in the discharge area of an aquifer. In this case surface water may be more at risk. Where a map showing a

regionally important aquifer includes low permeability zones or units which cannot be delineated using existing geological and hydro geological information but which can be found by site investigations.

➤ **Surface water bodies**

Streams, rivers, lakes, estuarine and coastal within the impact zone of a possible landfill site should be considered including any designations. Account should be taken to the ecological rating (Q rating) for rivers and the importance of water bodies in terms of ecological, amenity, fisheries or commercial value.

### **3.3.2 Geologic parameters**

It is essential to have an accurate understanding of the local geological setting of the sites involved in order to evaluate site suitability and the capability to provide protection from contamination. This will include aspects of the topography, details of the structure and characteristics of the solid strata, the composition and distribution of the subsoil including the final cover materials.

➤ **Geological Fault**

In locating areas suitable for landfill, it is difficult to avoid being on, or close to geological ‘faults’. New units and lateral expansions may not be located within 200 feet of faults that have experienced displacement in Holocene time, unless it is demonstrated that a smaller setback distance will be protective of human health and the environment.

Equally the absence of faults should not be taken as an absolute assurance that a site is geologically suitable. Fault zones in permeable rocks (generally regionally important aquifers) are usually more significant than in low permeability rocks (generally poor aquifers). The factors of interest in the solid strata include the type of rock, the state of weathering, the extent and distribution of structural features such as faults, joints and bedding planes, the effects of karstification and the permeability of strata with geological faults. Construction of potentially polluting landfills in direct contact with faults should be avoided in situations where investigations show that the fault zone is excessively permeable. The availability of suitable cover for the duration of the land filling operation is essential. This includes daily cover material and cover for final restoration

➤ **Seismically active and geologically Unstable Areas**

Geologically unstable areas are defined as locations where natural or manmade features pose a substantial risk to the integrity of the landfill structure. Landfills should generally not be sited within

these areas. Typical unstable areas would comprise; areas directly underlain by karstified limestone; areas prone to subsidence caused by previous mining activity; areas underlain by weak or unstable subsoils not capable of remediation; and areas prone to landslip or slope failure.

Seismic Impact Zones New units and lateral expansions may not be located in seismic impact zones unless it is demonstrated that the facility is designed to resist the maximum horizontal acceleration in lithified material for the site. Unstable Areas existing units, new units, and lateral expansions may not be located in unstable areas unless it is demonstrated that engineering measures have been incorporated into the design to ensure that the integrity of the structural components of the unit will not be disrupted.

### **3.3.3 Soil type parameters**

#### **➤ Soil setting of landfill site**

Soil setting gives information on soil profile characteristics; provide useful information about potential sites. The topsoil and subsoil, depending on their type, permeability and thickness, play a critical role in preventing groundwater contamination and mitigating the impact of many potential pollutants. It is important in landfill development for three basic reasons:

- **Cover:** Material used to cover the solid waste daily and when an area of the landfill is completed. The permeability of the final cover will greatly influence the quantity of leachate generated.
- **Migration control:** The material that controls leachate and methane movement away from the landfill. An impermeable formation will retard movement; a permeable soil will provide less protection and may require installing additional controls within the landfill.
- **Support:** The soil below and adjacent to the landfill must be suitable for construction. It must provide a firm foundation for liners, roads and other construction.

Ideally, sites should be located in silt and clay soils that restrict leachate and gas movement. A landfill constructed over a permeable formation such as gravel, sand or fractured bedrock can pose a significant threat to groundwater quality. There is a minimum consistent thickness of 3 meters of low permeability subsoil present; or it is proven that there will not be a significant impact on the groundwater; and unless a geomembrane cover and liner have to be installed.

### **3.3.4 Topographic and geomorphic parameters**

Topographical data are used in the assessment of the likelihood of slope failure, failure over unstable ground and in the interpretation of the topographical expressions of the geology, hydrology and hydrogeology. EPA recommends topography with less than or equal to 10% gradient. A contoured map can be used to identify areas with steep slopes that may complicate construction or access to the site.

The watershed that drains into or across a particular area can be determined from the contours. The watershed area determines the amount of run-off a site will receive from upstream areas. Existing natural depressions may also be identified which offer an advantage for landfill development with respect to visual screening and noise attenuation.

#### **➤ Flood Plains**

Developers of landfills should ensure that the landfill is not located within the 50 year floodplain of rivers. The area is defined as the floodplain covered in water for return periods of less than 1 in 50 years. It reduces the temporary water storage capacity of the floodplain, or result in the washout of solid waste so as to pose a hazard to human health or the environment. The only exception is where the containment levels and access roads are constructed above the anticipated flood levels.

### **3.3.5 Climatic/metrological parameters**

According to to EPA landfill site selecting manuals landfill site should be located a place where higher probability of evaporation takes place. This kind of site is found where there is a metro logically lower rainfall record, higher temperature and drier climate areas. Akaki kality sub city has suitable climatic behavior in Addis Ababa city.

### **3.3.6 Others considerations**

#### **➤ Archaeological Heritage, air port ,**

The Department of the Environment, Heritage & Local Government manages the State's responsibilities for built heritage. In sitting landfills, developers shall, as may be relevant have regard to the recommendations of the International Civil Aviation Authority (ICAO). Whether or not a landfill creates a potential hazard to aircraft depends on the location of the landfill in relation to airport flight paths, the nature of waste deposited, and the types of birds expected in the vicinity.

➤ Proximity to housing

A distance of 250m between housing (and similar sensitive receptors) and a landfill Foot print should be maintained for new ‘green field’ landfills that are handling potentially polluting.

➤ Airport Safety

Existing units, new units, and lateral expansions located within 10,000 feet of any airport runway end used by turbojet aircraft, or within 5,000 feet of any airport runway end used only by piston type aircraft must demonstrate that the facility does not pose a bird hazard to aircraft.

### 3.4 Geotechnical consideration of landfill

To verify that the contemplated landfill development will not adversely affect groundwater, surface water and other environmental resources. So, geotechnical regulations require that a number of aspects be adequately addressed. These include:

- ✚ Depth to groundwater
- ✚ Delineation of regional confined and unconfined aquifers
- ✚ Direction and rate of groundwater flow, including possible spatial and temporal variations
- ✚ Aquifer characteristics including thickness and saturated and as applicable unsaturated) hydraulic conductivity.
- ✚ Regional uses of the groundwater
- ✚ Background groundwater quality.
- ✚ Site aquifer characteristics and soil permeability

Additional geotechnical factors which must also be considered in the formulation of investigation programs include:

- ✚ Presence of near-surface bedrock
- ✚ Interrelated topographic/geotechnical considerations (e.g., substantial cuts or fills)
- ✚ Stability of natural and cut slopes
- ✚ The presence of soft, compressible, collapsible, or otherwise unsuitable foundation soils.
- ✚ Availability of cover materials and uses for any excavated soils.

✚ Remedial and correction measure will be under taken while there is no satisfactory site is available/ or if a problem probably faced. Leachate gas collection system, clay sub base liner system,

soil final cover system , slop stability preparation , buffer systems are a few of the activities under geotechnical consideration.

## 4. Data, materials and methods

### 4.1 Data types, source and collection

In this project, different datasets were collected from different sources. Primary data are collected using personal checklist at the site, observation and interview of the stakeholders. Also, secondary datasets are collected from different sources.

<b>Data set or Layer</b>	<b>Source</b>	<b>Format</b>	<b>Datum</b>	<b>Projection</b>
<b>Geology</b>	<b>Geological survey of Ethiopia</b>	<b>Shape</b>	<b>Adindan</b>	<b>UTM zone 37</b>
<b>Borehole</b>	<b>AG-consult</b>	<b>Shape</b>	<b>Adindan</b>	<b>UTM zone 37</b>
<b>SRTM data</b>	<b>Department of Earth sciences, Addis Ababa university</b>	<b>Shape</b>	<b>WGS 84</b>	<b>UTM zone 37</b>
<b>Land use</b>	<b>Addis Ababa city administration</b>	<b>Shape</b>	<b>Adindan</b>	<b>UTM zone 37</b>
<b>River / stream</b>	<b>AG-consult</b>	<b>Shape</b>	<b>Adindan</b>	<b>UTM zone 37</b>
<b>Soil</b>	<b>Department of Earth sciences, Addis Ababa university</b>	<b>Hard copy</b>	<b>WGS 84</b>	<b>UTM zone 37</b>
<b>Road or infrastructure</b>	<b>AG-consult</b>	<b>Shape</b>	<b>Adindan</b>	<b>UTM zone 37</b>

**Table -5: Sources of secondary Dataset**

## **4.2 Materials used**

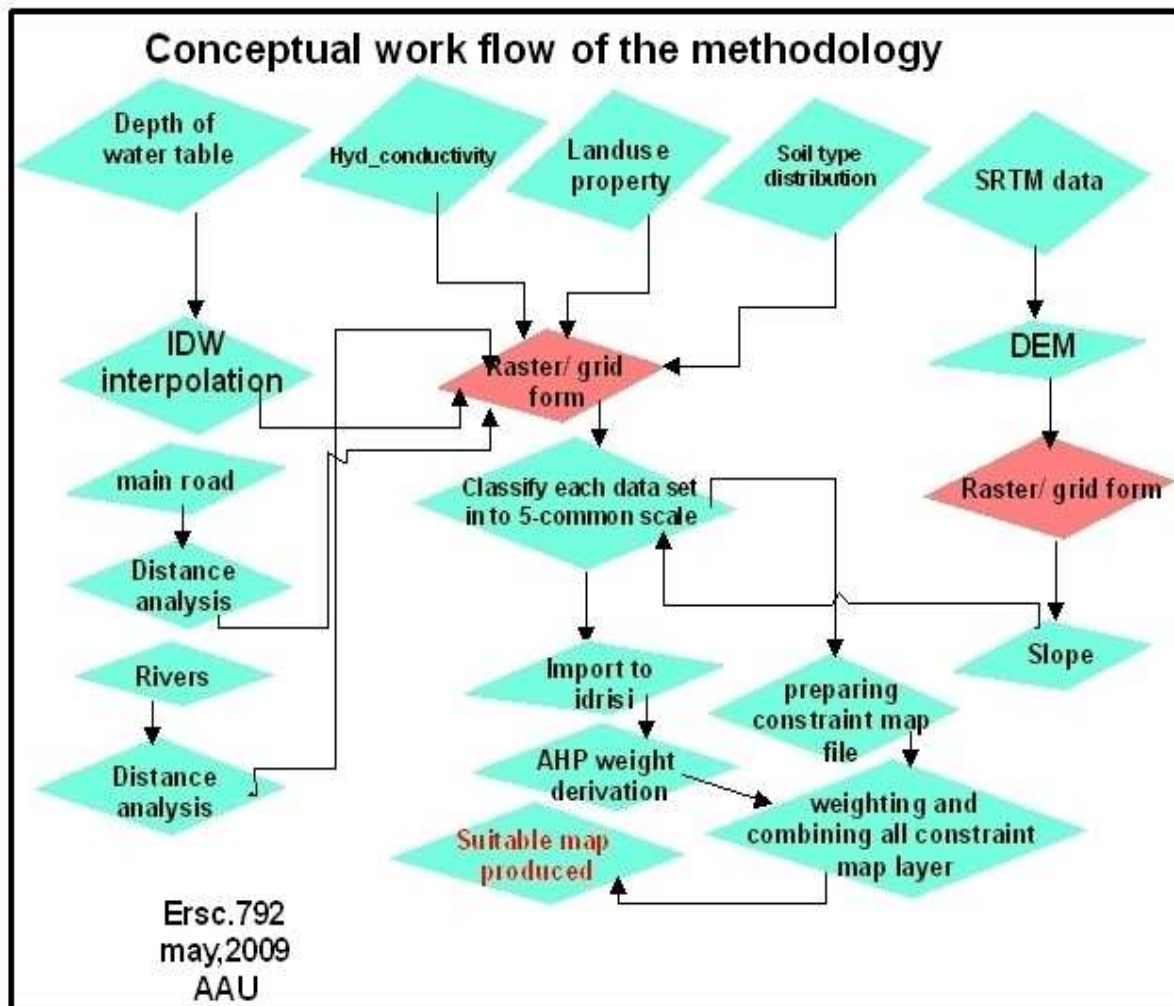
### **➤ GIS-Software**

The software used in the project are ArcGIS 9.2 used for GIS analysis, Mapping and Presentation, MapInfo 8.0 used for digitizing map, IDRISI32 used for Multicriteria Spatial Decision Support Systems and 3DEM used for generating DEM data from SRTM Data to derive slope.

## **4.3 Methodologies**

First the input data (grid and shape files) of the study area were clipped and imported in to the established geodatabase. Soil map of Addis Ababa was digitized using MapInfo and converted into ESRI shape file using Universal Translator and imported to the ArcGIS geodatabase. The Digital Elevation Model (DEM), geology, river, road and borehole datasets of the study area were clipped by the study area boundary. Slope was derived from the DEM using surface analysis.

Next all shape files were converted in to a raster data model (grid files) so as to make it compatible to the suitability model using Boolean Operation techniques. Then, the changed raster files were again reclassified and constraint maps were developed. After this step, a multicriteria evaluation technique was carried out using iddirisi multicriteria Spatial Decision Support tool to overweight each layer in pair wise. Finally, these pair wise overweighed constraint maps joined/overlaid by boollen raster overlay calculator. As an out put graded landfill site map of Addis Ababa city produced. Detail methodology is described below in the conceptual framework model.



**Figure – 13: conceptual work flow of the methodology**

## **5. Data analysis, results and discussion**

### **5.1 Data analysis**

Although there are a number of solid waste disposal site selection criteria worldwide, environmental, social, economical factors as discussed briefly above such as geology (hydraulic conductivity), depth to water table, soil, roads, rivers, slopes and land use were considered for this suitability analysis.

The site selection model involves three steps: preliminary analysis, multi-criteria evaluation, and identification of the most suitable site. The preliminary analysis stage involves creating a study area map to input the rasterized data layers, then creating constraint maps and factor maps from the input datasets.

The second step involves performing a Multicriteria Evaluation (MCE), which is conducted by weighting the factor maps and combining them with the overlaid constraint map. The final step relates to finding the most suitable site using the information in the final MCE map. A number of factors were taken into considerations: depth to water table, proximity to main rivers, land use, slope, geology (hydraulic conductivity), soil properties, and distance from the main road. Since all analyses over layers have to be limited to the extent of the study area, a city boundary map was used to clip the datasets.

### Reclassified map

To find the best location for the landfill site, feature datasets were converted to raster/grid, datasets of distances and slope were derived, each dataset was reclassified to common scale within a range 1 – 5 giving the higher values to high suitable and low values to least suitable attributes using Reclassify options of the spatial analyst. And the criteria for this analysis were identified as high suitable, suitable, and moderately suitable; less suitable and least suitable. The layers generated in this step were used in Boolean and Overlay operations.

#### Layer-1

**Geology** - Earth materials with low hydraulic conductivity, low effective porosity, and high retention or absorption of hazardous solutes are ideal for landfill locations.

**Table -6: Hydraulic conductivity classification of Addis Ababa city geology**

Hydraulic Conductivity	Value	Suitability Rank	Geology
Very High	1	Least suitable	Tertiary sediment
High	2	Less suitable	Quaternary olivine phiric basalt and quaternary scoria
Medium	3	Moderately Suitable	Fofa strongly weathered and jointed basalt, chelekleka layered basalt with scoria and pyroclastic rocks.
Low	4	Suitable	Wechecha yerrer furi trachyte and trachy basalt, repi strongly jointed basalt, lower ignimbrite and pyroclastic rocks
Very Low	5	High suitable	Wechecha yerrer furi ignimbrite, intoto coarse grained trachyte, intoto mixed rocks trachyte, ignimbrite, pyroclastic and sediment

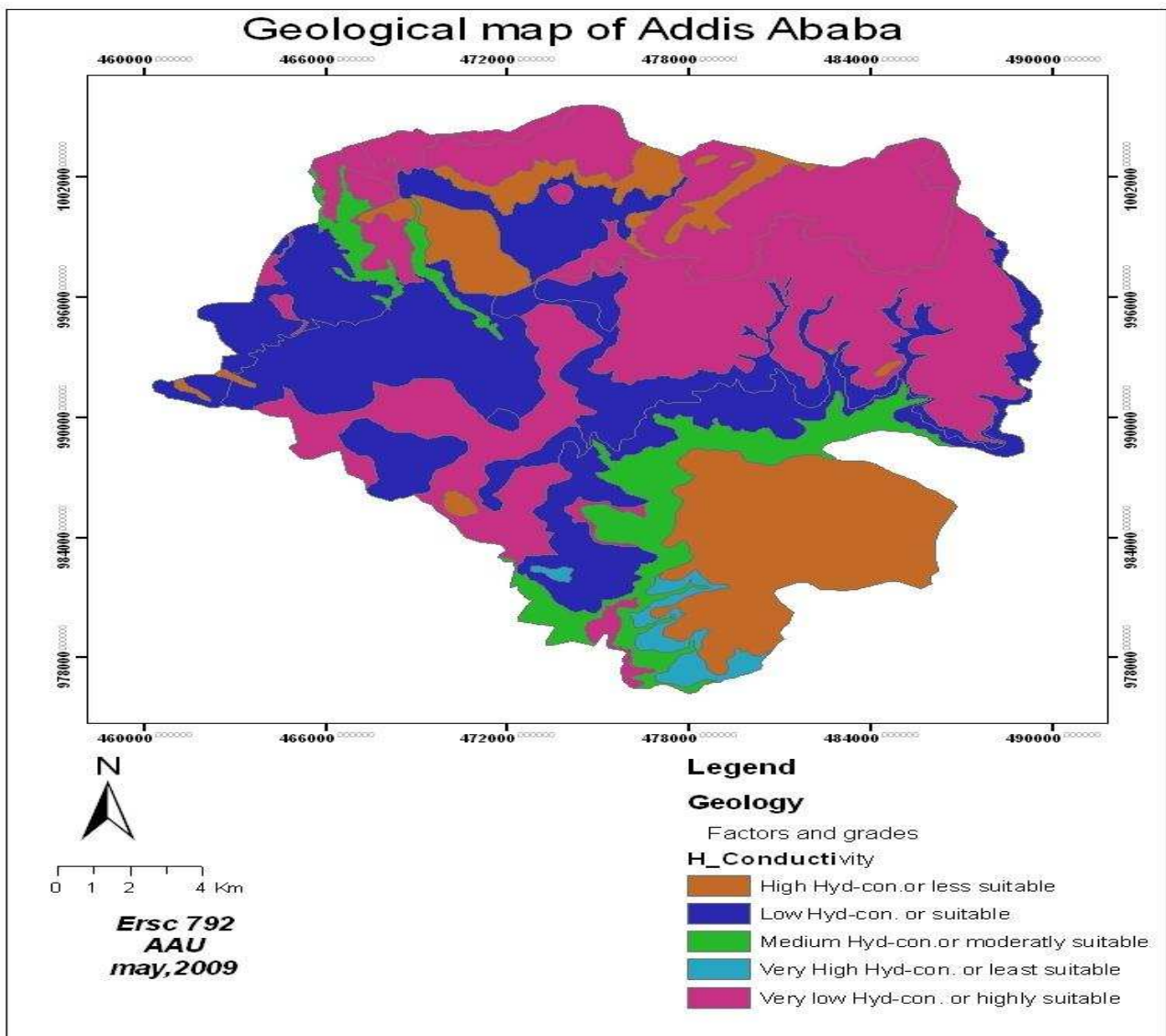


Figure - 14: Reclassified map of Addis Ababa geology

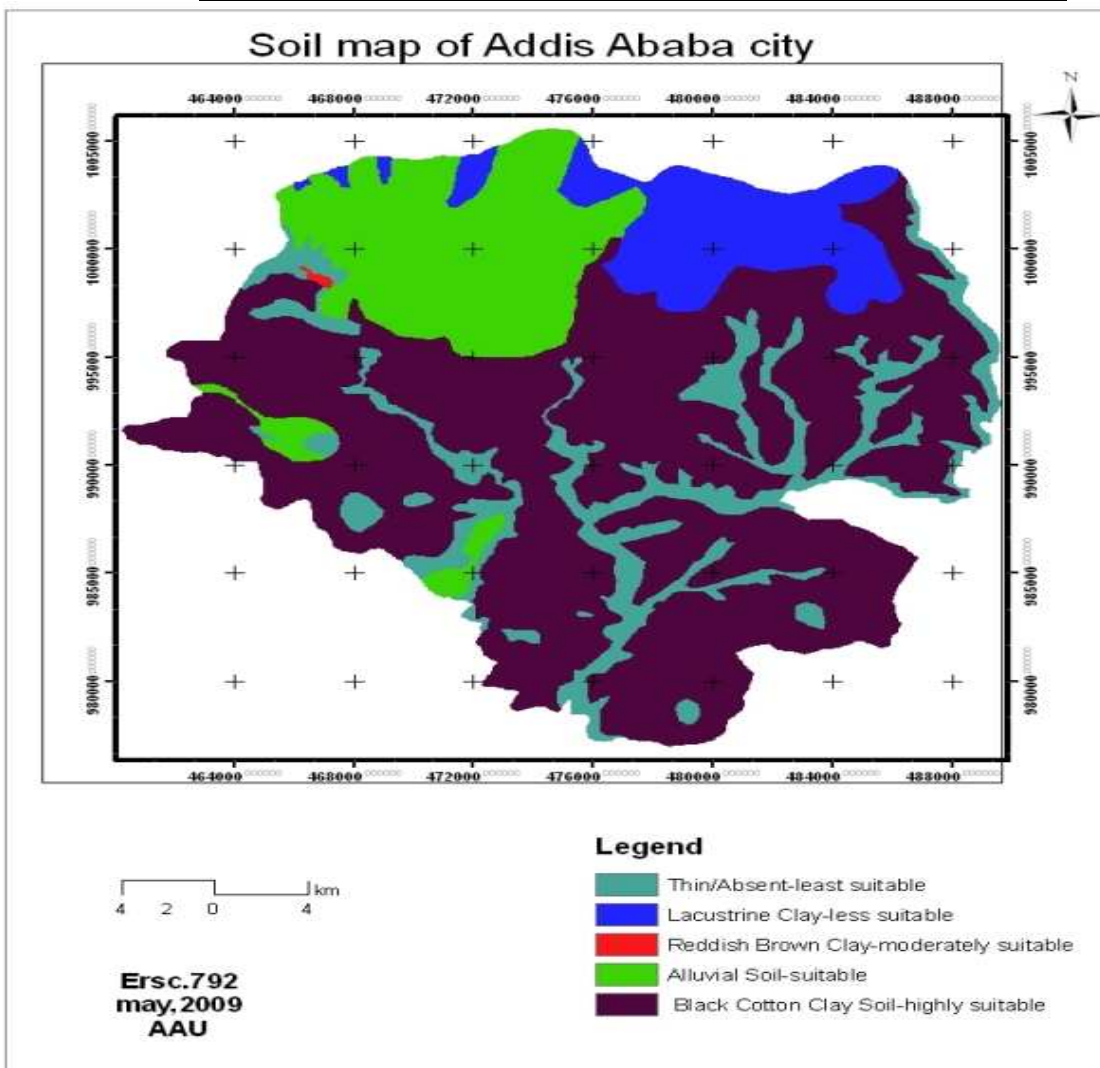
## Layer-2

**Soil** - Permeability and effective porosity are important soil considerations for landfill site selection. The highly permeable and porous quaternary alluvial deposits and thin/none of soil cover sites are discarded as a poorest site. Soils with high silt and clay fractions provide groundwater protection and are an economically cheaper means to construct a landfill line. Few literatures (EPA) recommends a

minimum consistent thickness of 3m impermeable soil cover. In this paper only the type soil distribution is considered for suitability analysis.

**Table -7 soil classification of Addis Ababa city**

Soil	Value	Suitability Rank
Thin/Absent	1	Least suitable
Lacustrine Clay	2	Less suitable
Reddish Brown Clay	3	Moderately Suitable
Alluvial Soil	4	Suitable
Black Cotton Clay Soil	5	High suitable



**Figure – 15: Reclassified map of Addis Ababa soil.**

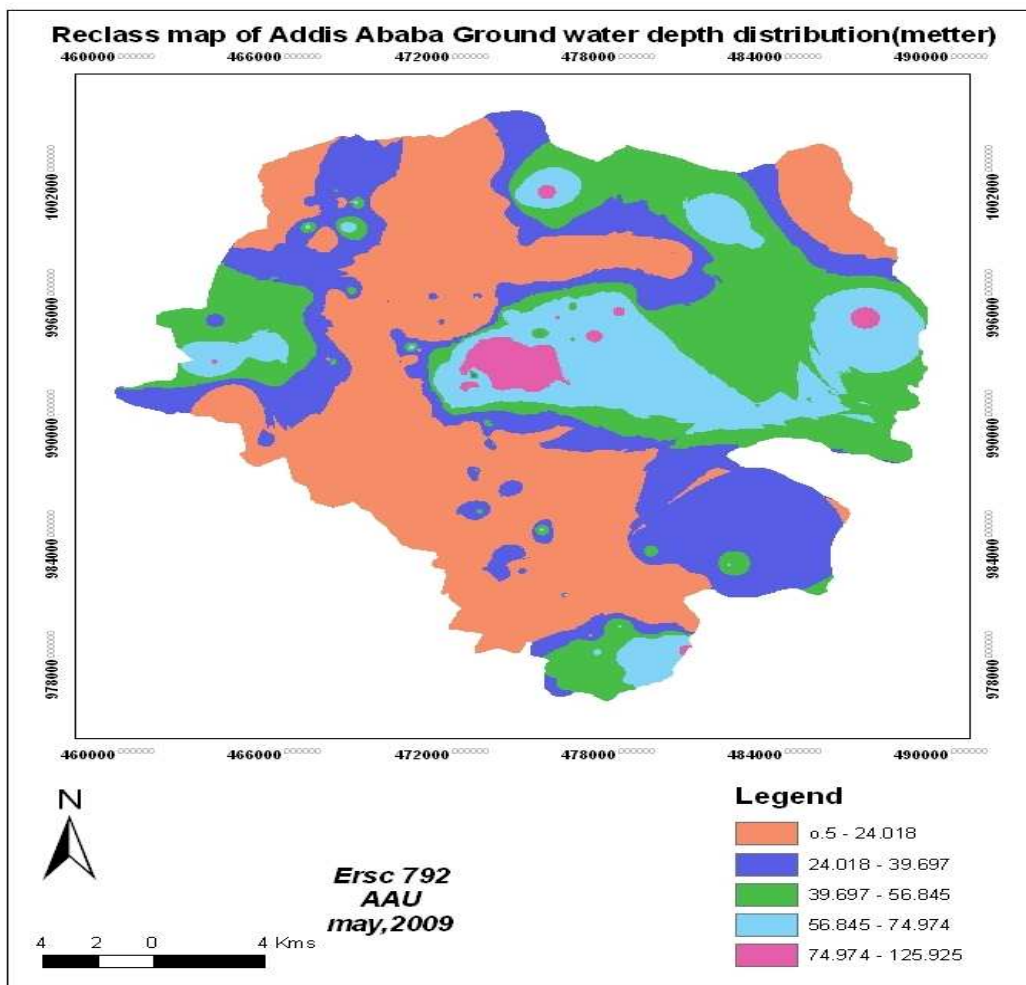
### Layer-3

#### Depth to ground water table –

The closer the water table to the surface the more vulnerable to contamination and unsuitable to landfill. Areas where the ground water depth is less than 80m are discarded so that the ground water is safe from contamination that might occur from leakage of the leachate from landfill.

**Table -8: reclassified ground water depth of Addis Ababa city**

Depth WT (m)	Value	Suitability Rank
0.500 – 24.018	1	Least suitable
24.018 – 39.697	2	Less suitable
39.697 – 56.845	3	Moderately Suitable
56.845 – 74.974	4	Suitable
74.974 – 125.929	5	Highly suitable



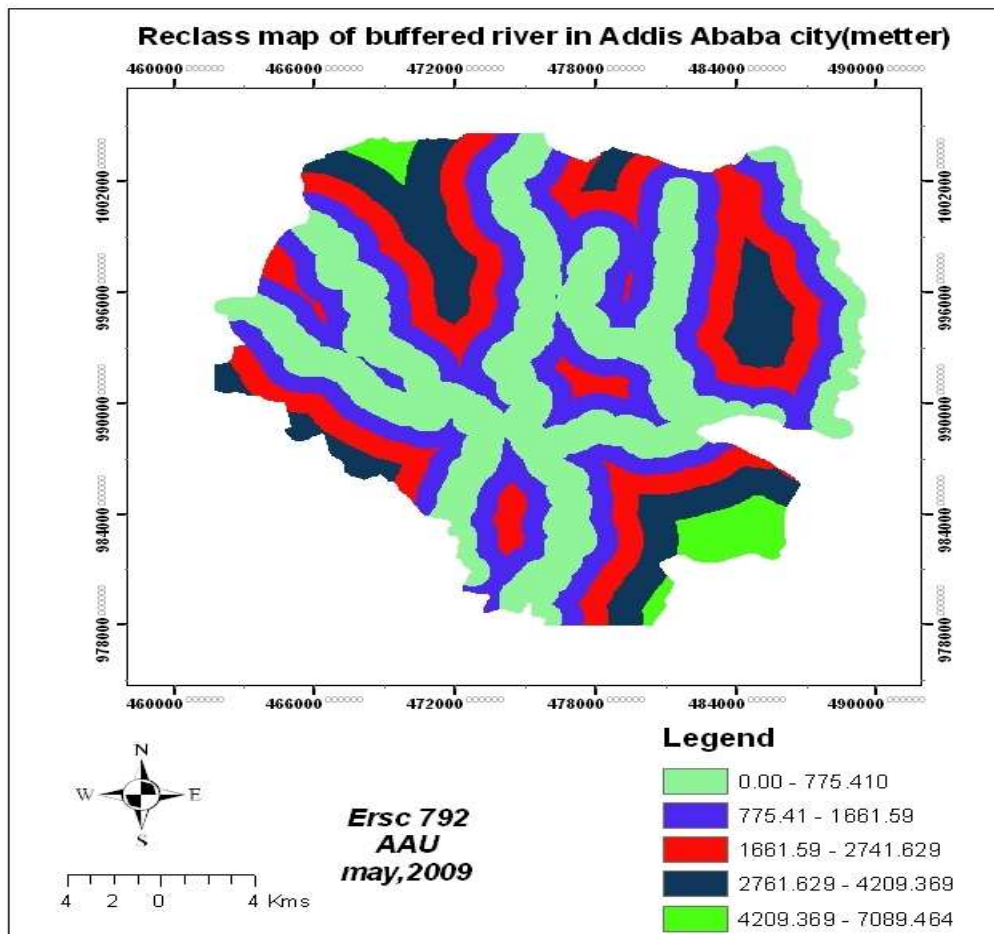
**Figure -16: Reclassified map of ground water depth in Addis Ababa**

### Layer-4

**Proximity to Main Rivers** - Landfill sites should be far away a considerable distance from water sources. A 2 mile buffer of all surface water bodies is constructed from the solid in USA-Georgia, while 1000ft in state of Vermont and 1000m in Canada (MLAP, 1993). 1000m buffer of streams and rivers taken in this paper for Addis Ababa.

**Table -9: Reclassified main river distances for landfill suitability**

Distance from Main River (m)	Value	Suitability Rank
0 – 775.410	1	Least suitable
775.410 – 1661.59	2	Less suitable
1661.593 – 2741.629	3	Moderately Suitable
2741.629 – 4209.369	4	Suitable
4209.369 – 7089.464	5	High suitable



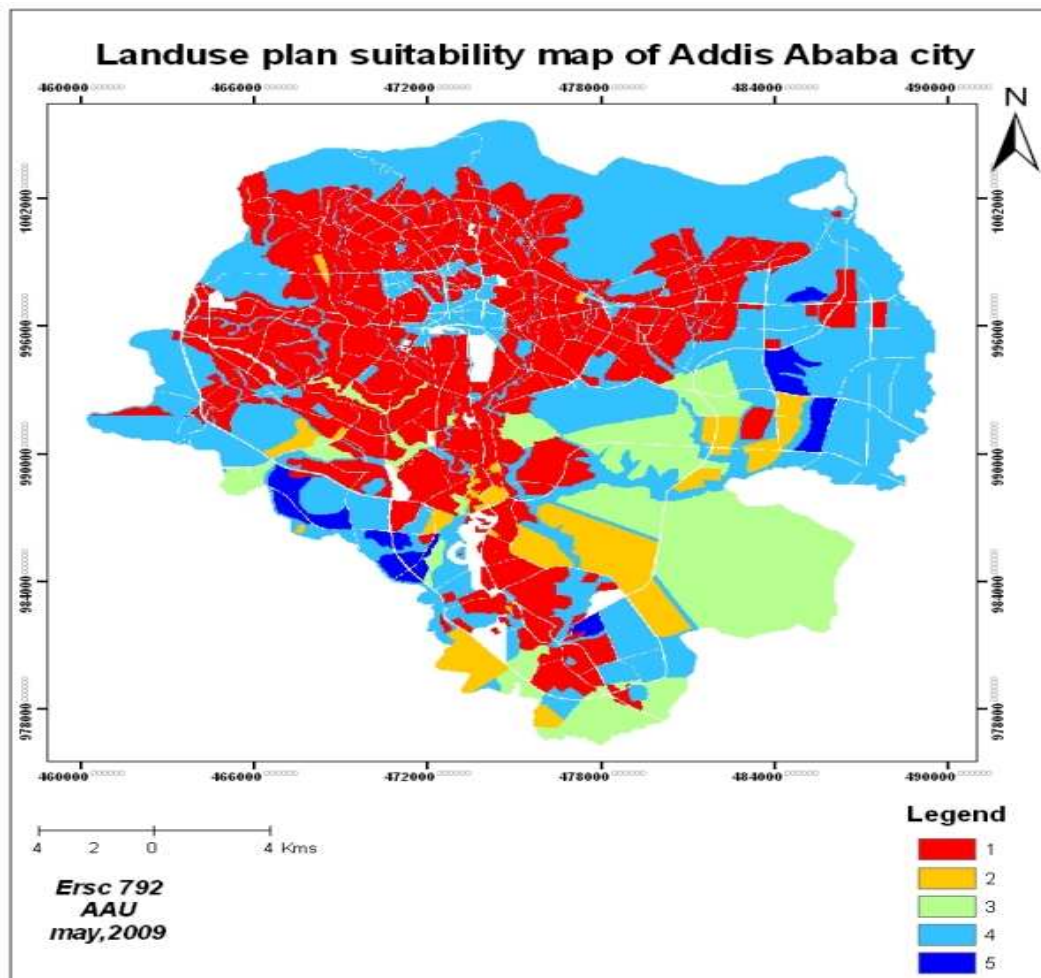
**Figure -17: reclassified map of main river distance for landfill site**

### Layer-5

**Land Use** - Land-use of lowest value in public opinion reduces conflict over higher valued land-uses. Not located in areas of resident, industry, existing and proposed social developments, and agricultural land. These were considered as restriction zones.

**Table-10: land use property classification of Addis Ababa city**

Land use	Value	Suitability Rank
settlement/Industry/social existing/Social Proposal sites	1	Least suitable
Industry Proposal sites	2	Less suitable
Agriculture sites	3	Moderately Suitable
House Expansion sites	4	Suitable
Reserve/ open sites	5	Highly suitable



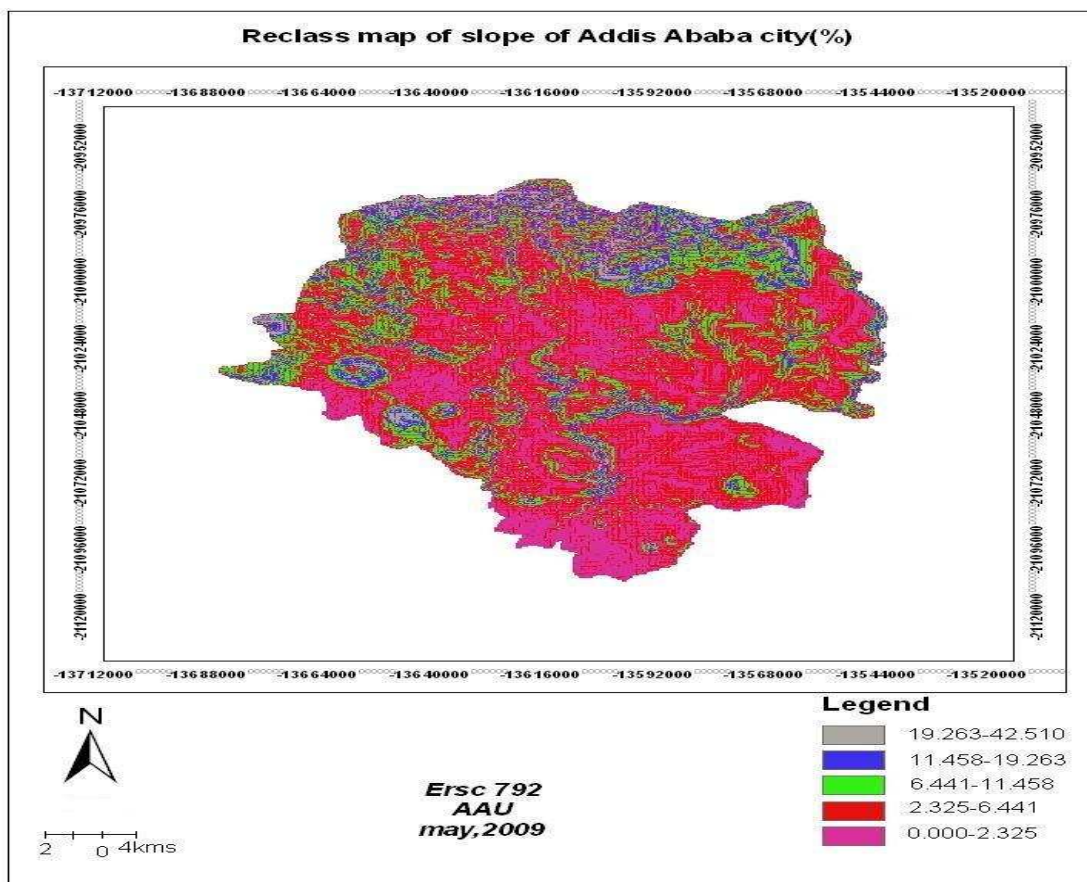
**Figure -18: Reclass map of Addis Ababa land use property for landfill site**

## Layer-6

**Slope** - Higher slopes would increase runoff of pollutants from the landfill, and difficult and costly to construct the landfill. Thus, slope is an important factor when sitting a landfill. A us geological survey use less than 25% slope rating of the landfill site(David R.H,1991). Again EPA Ethiopia (2002) recommends appropriate slop of a terrain less than 3%. But according to EPAA (1998) landfill must not be situated on hilly, areas with ground slopes greater than 10%. So this project discarded sloppy areas greater than 10% for which safe sites selected.

**Table -11: slope classification of Addis Ababa city**

Slope (%)	Value	Suitability Rank
19.263 – 42.510	1	Least suitable
11.458 – 19.263	2	Less Suitable
6.441 – 11.458	3	Moderately Suitable
2.325 – 6.441	4	Suitable
0 – 2.325	5	Highly suitable



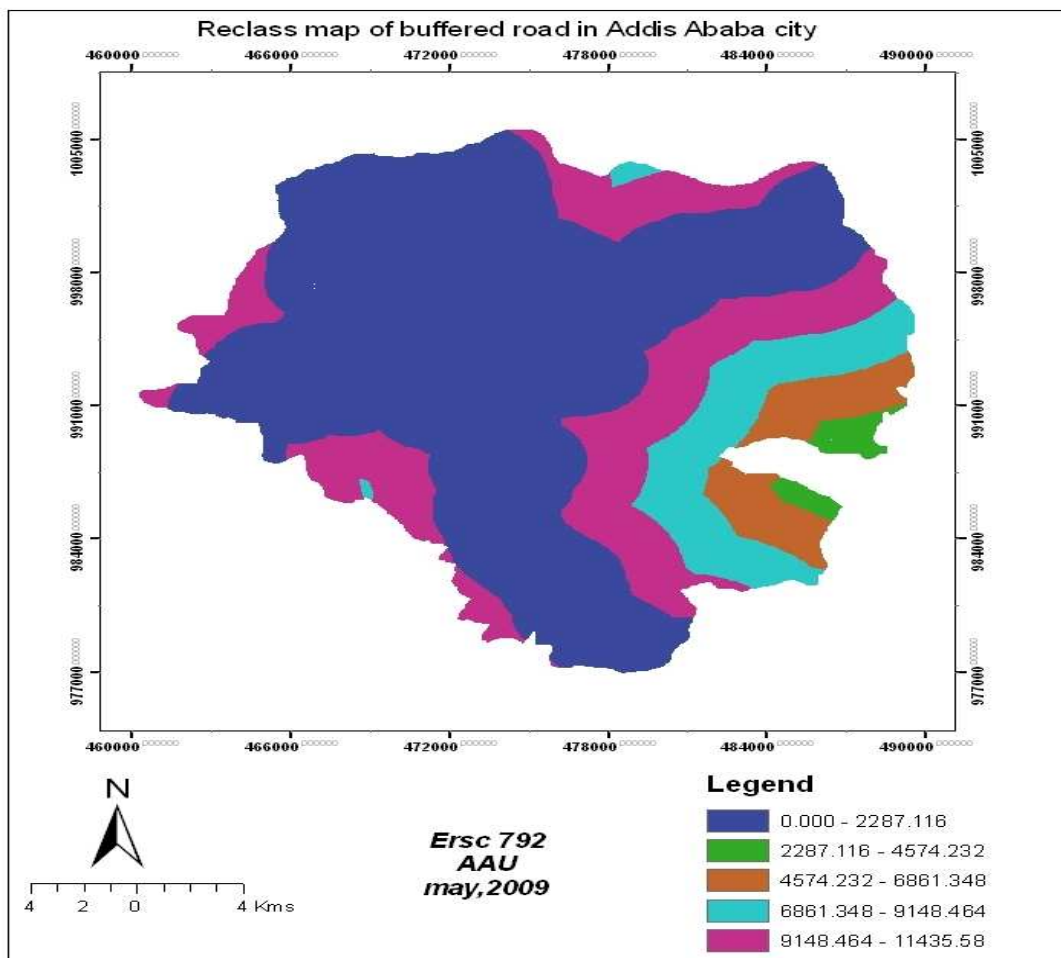
**Figure -19: Reclass map Addis Ababa city slope distribution for landfill site**

## Layer-7

**Distance from the main road** - Economical factors such as dumping site should be at minimum distance from roads so that collection vehicles can travel through the optimum route. From the literature, Malaysia with specific distance 100m from road (Gaim, 1995). A 100m distance buffer is taken for major roads. This is because the site should be out of scenery and at the same time accessible to the main roads.

**Table -12: Distance classification of main roads in Addis Ababa for landfill site.**

Distance from Main Road (m)	Value	Suitability Rank
0 – 2287.116	1	Least suitable
2287.116 – 4574.232	2	High suitable
4574.232 – 6861.348	3	Suitable
6861.348 – 9148.464	4	Moderately Suitable
9148.464 – 11435.580	5	Less Suitable



**Figure -20: Main road distances map of Addis Ababa city for landfill site**

## Constraint Map

Constraint maps are used to distinguish between lands that are suitable for landfill sitting and those lands that are restricted. The constraint maps are produced by merging each individual theme with the study area. This procedure creates a constraint map for each theme or layer containing only three classes represented by 3 for suitable, 2 for less suitable land and 1 for unsuitable.

### Layer 1

Table -13 Constraint hydraulic conductivity values

Hydraulic conductivity	Suitability Rank	Value
Very high and high	unsuitable	1
Medium	Less suitable	2
Very low / low	Suitable	3

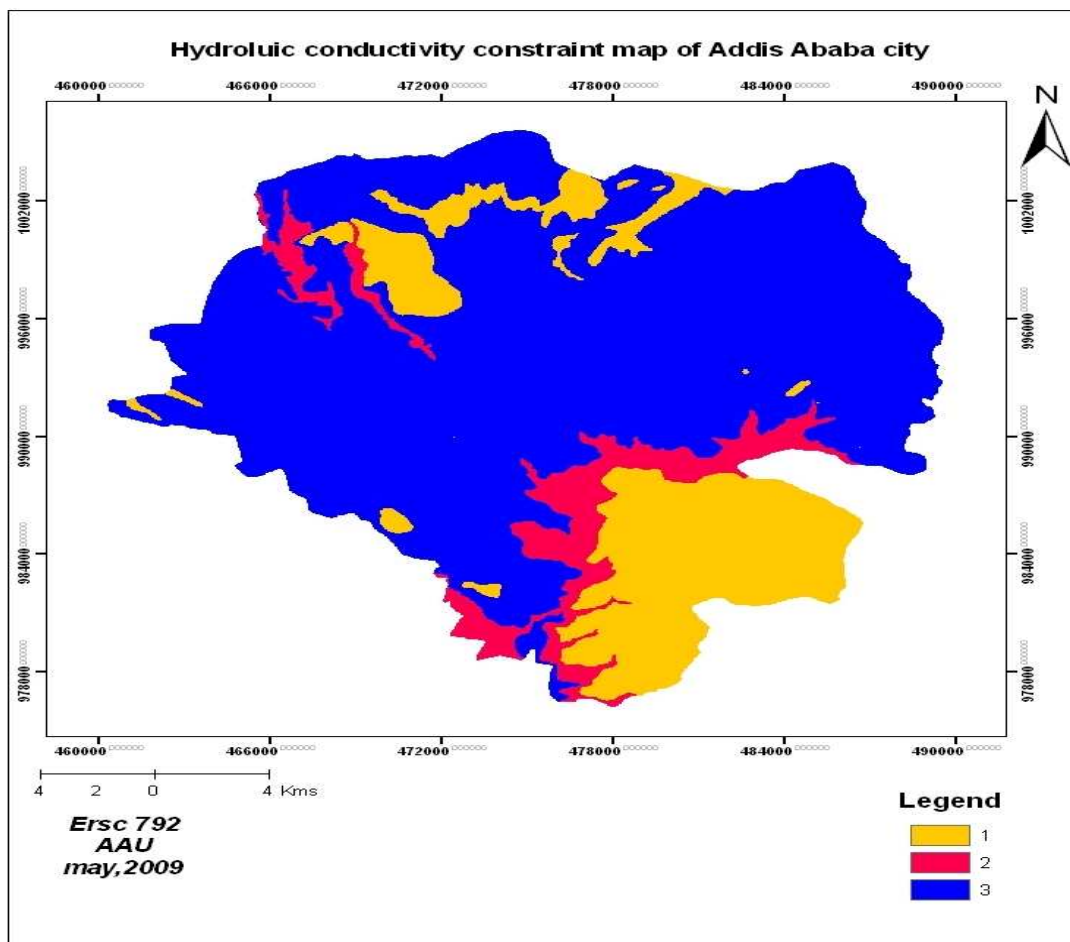
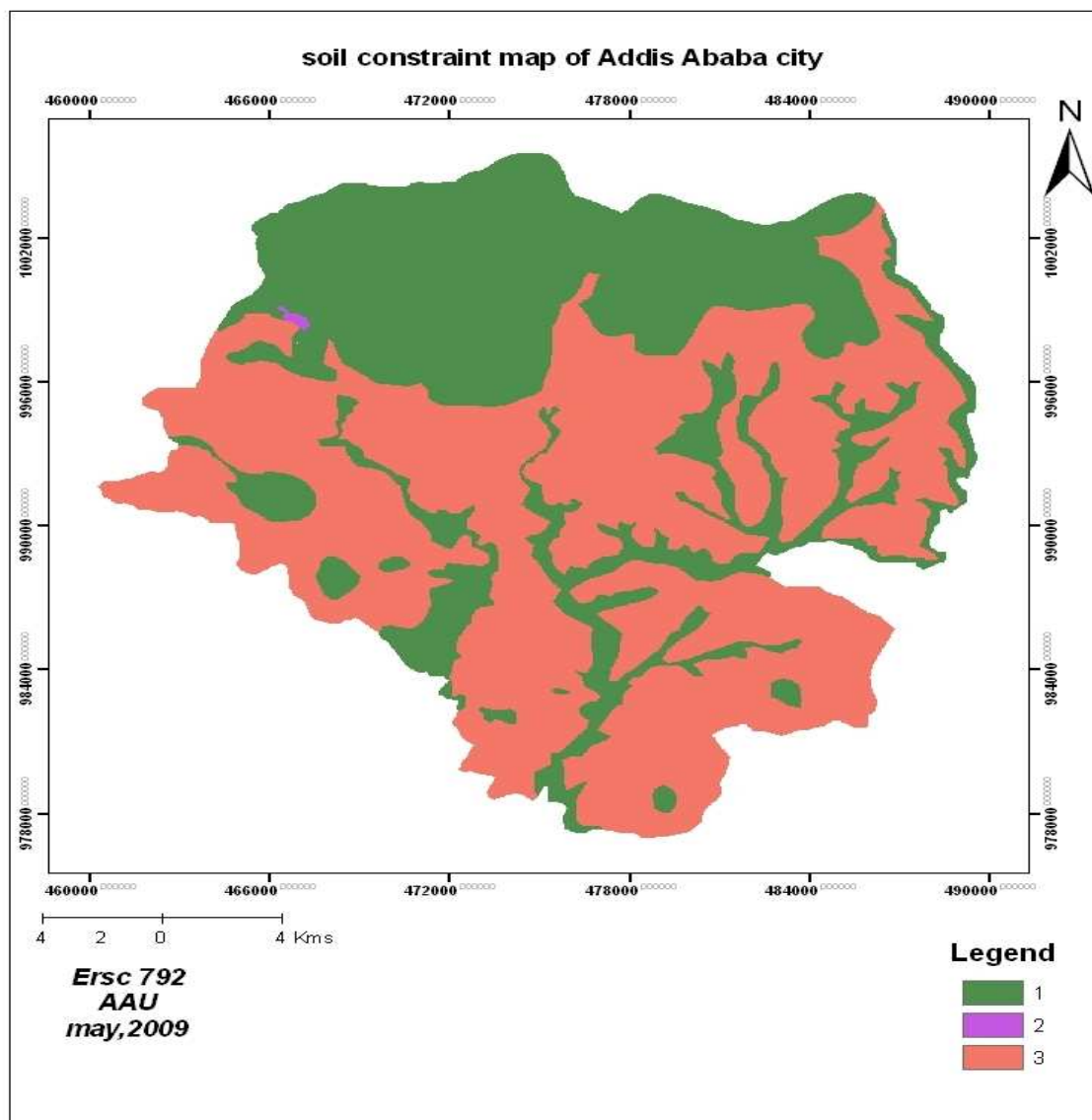


Figure -21: Constraint map of geology

**Layer 2:**

**Table -14: constraint value of soil type**

Soil type	Suitability Rank	Value
Absent/thin, lacustrine clay and alluvial soil	unsuitable	1
Reddish brown clay	Less suitable	2
Black cotton clay	Suitable	3

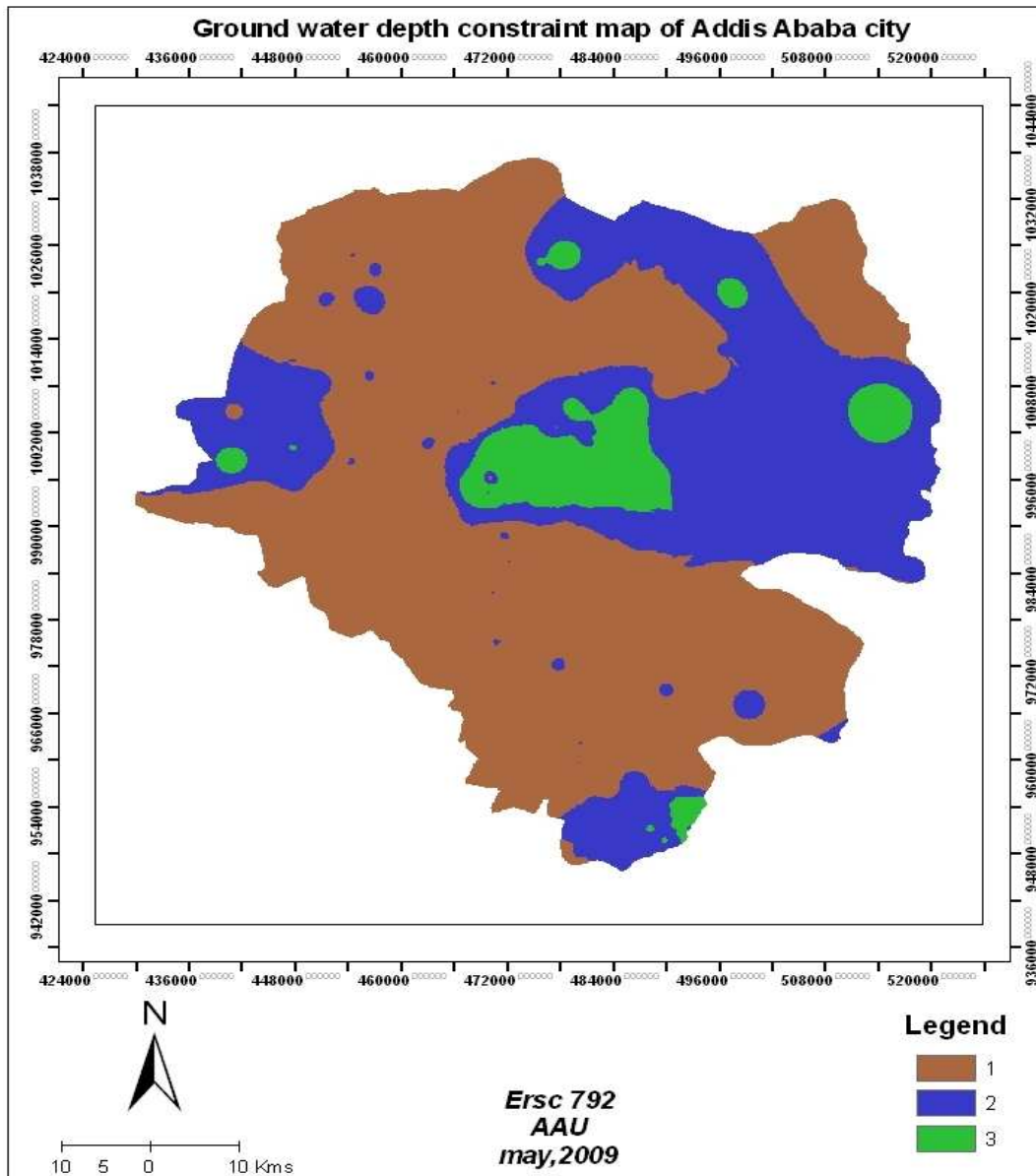


**Figure -22: constraint map of soil for landfill**

**Layer-3**

**Table -15: constraint value of ground water for landfill site**

Ground water depth (m)	Value	Suitability Rank
0.5 – 35.78	1	unsuitable
35.78 – 60.76	2	Less suitable
60.76 – 125.93	3	Suitable

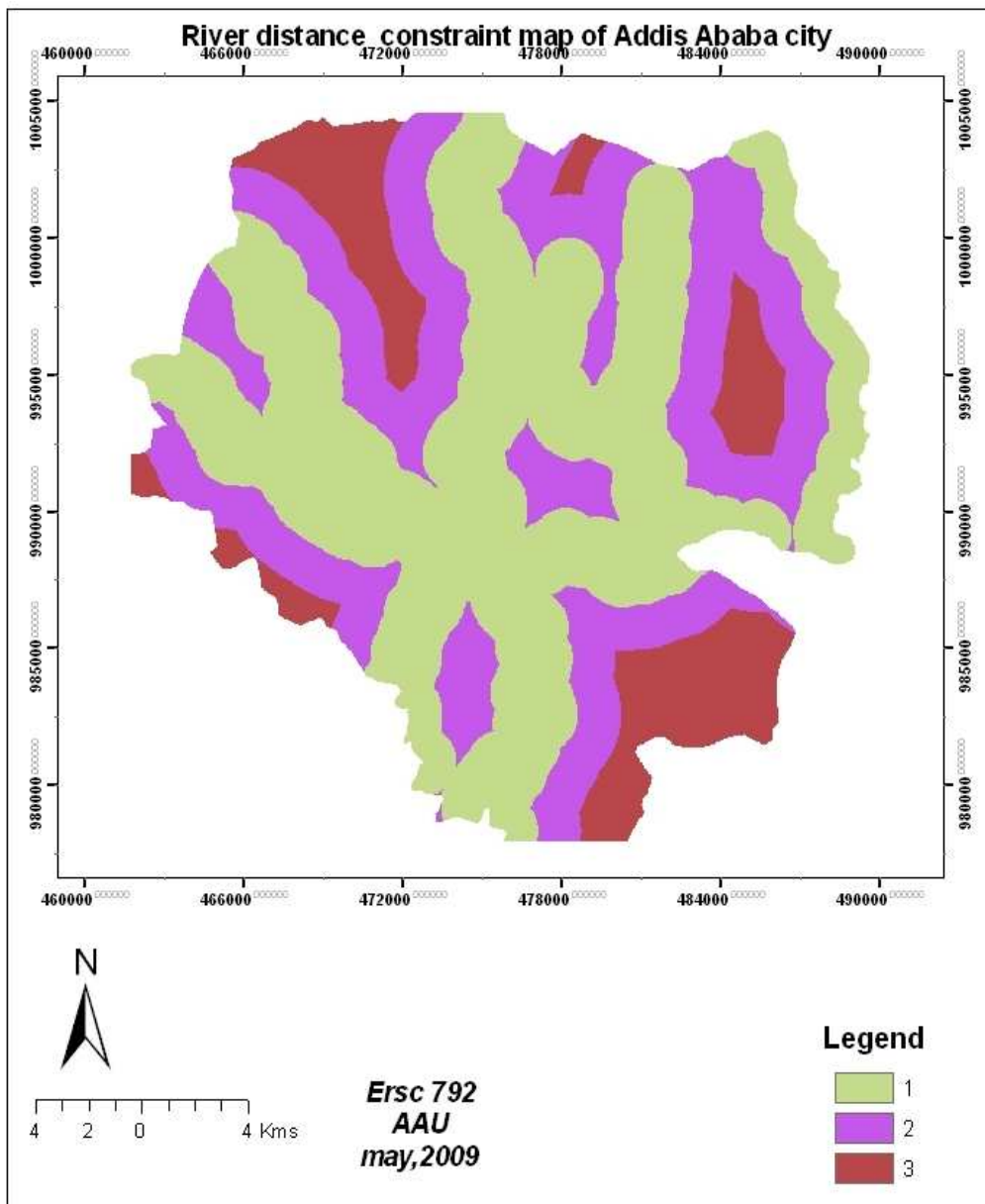


**Figure -23: Constraint map of ground water depth**

**Layer: 4**

**Table – 16: constraint value of the river distance for landfill sites**

Distance from main river (m)	Suitability Rank	Value
0 - 1246.195	unsuitable	1
1246.195 - 2852.401	Less suitable	2
2852.401 - 7089.464	Suitable	3



**Figure -24: constraint map of river distance for landfills  
Layer -5**

Table -17: Constraint value of the land use property for landfills

Landuse property	Suitability Rank	Value
Settlement, social, industry existing and social proposal sites	unsuitable	1
Industry proposal and agriculture sites	Less suitable	2
Reserve/open sites	Suitable	3

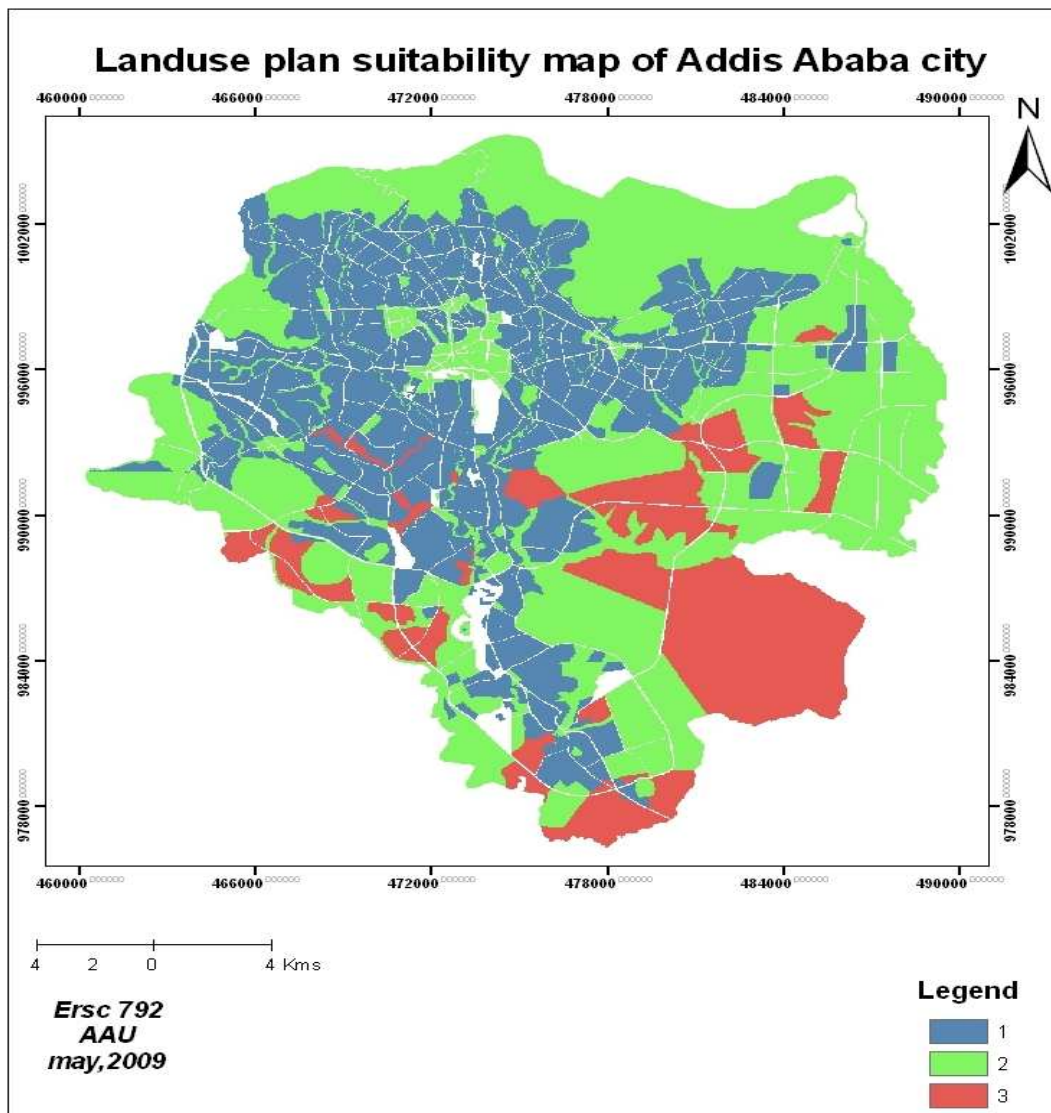
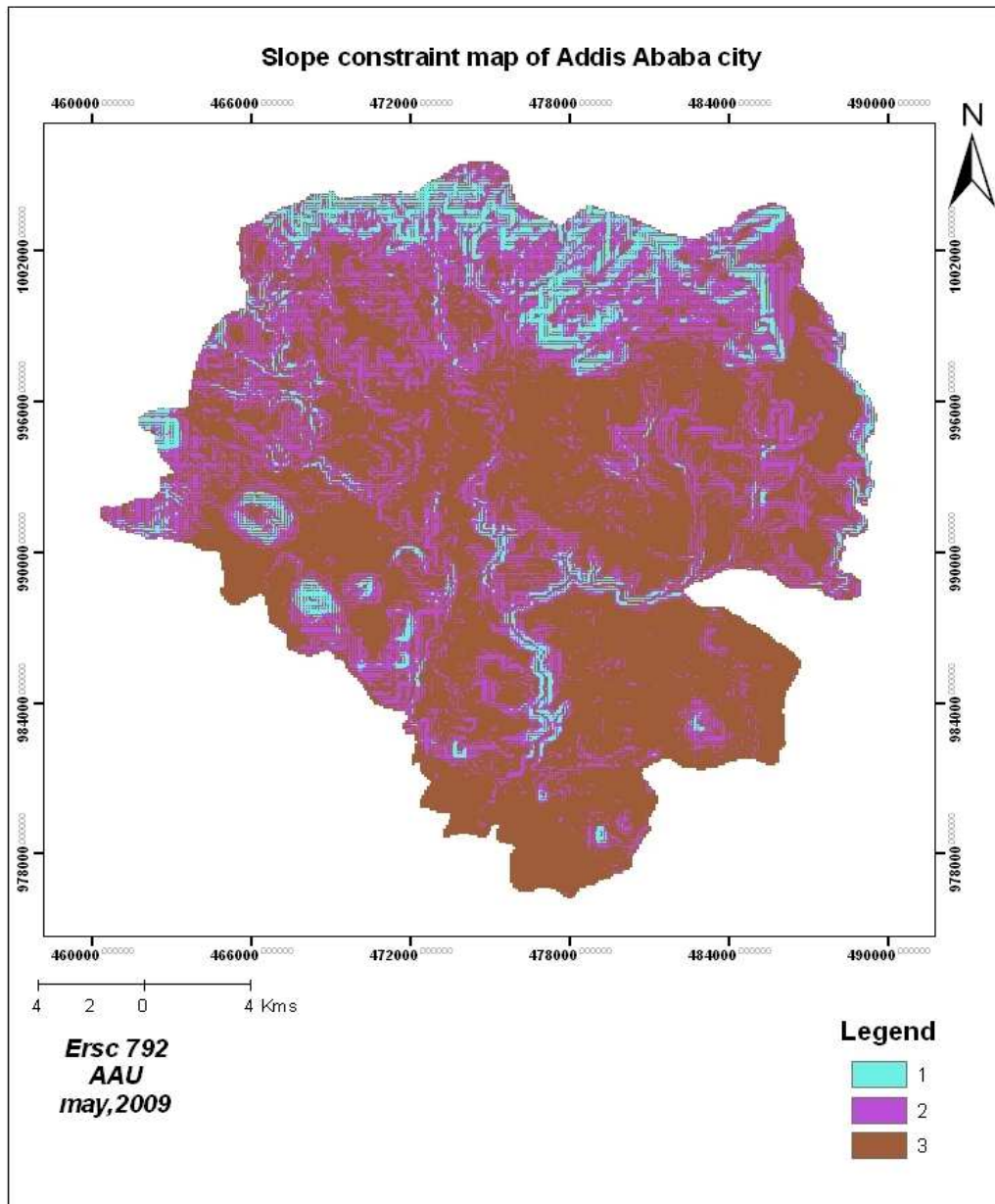


Figure -25: constraint map of the land use property.

Layer -6

**Table -18: Constraint value of slope (%) for landfill site**

Slope in %	Value	Suitability Rank
22.17 – 42.51	1	unsuitable
10.67 – 22.17	2	Less suitable
0 - 10.67	3	Suitable

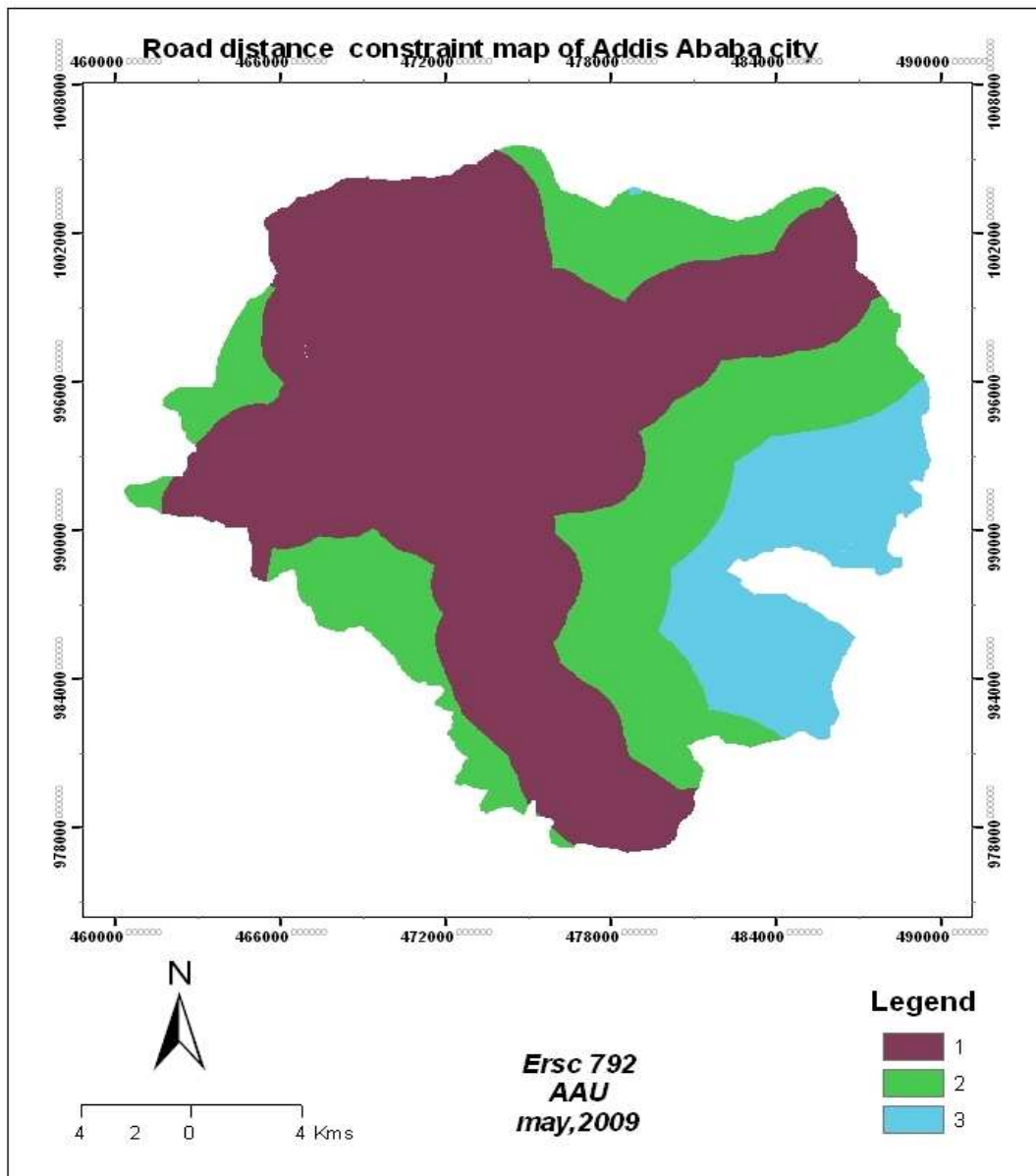


**Figure -26: constraint map of the slope for landfill site.**

**Layer – 7**

**Table -19: constraint value of road distance for landfill site**

Distance from the main road (m)	Value	Suitability Rank
0 – 2010.16	1	unsuitable
2010.16 - 5226.42	2	suitable
5226.42 - 11435.58	3	Suitable



**Figure -27: Constraint map of the road distance for landfill site**

## 5.2 Results

In this project suitability analysis, WEIGHT, IDRISI Decision Support analysis module, was used to develop a set of relative weights for a group of factors in a multi-criteria evaluation. The weight of each factor was developed by providing a series of pairwise comparisons of the relative importance of factors to the suitability of pixels for the activity being evaluated. The weighted coefficients of each layer determined by idrisi sum to 1. The factors and their resulting weights used as input for the MCE module for weighted linear combination. This procedure by which the weights are produced follows the logic developed by T. Saaty under the Analytical Hierarchy Process (AHP). Weight rates are given based on Pairwise Comparison of 9 Point Continuous Scale.

1/9	1/7	1/5	1/3	1	3	5	7	9
Extremely	Very Strongly	Strongly	Moderately	Equally	Moderately	Strongly	Very Strongly	Extremely
<b>Less Important</b>					<b>More Important</b>			

**Table-20: Pair wise Comparison 9 Point Continuous Scale**

	Land use	Depth of ground water	River distance	Geology (hyd-cond.)	Soil type	Slope (%)	Road distance
Land use	1						
Depth of ground water	1/3	1					
River distance	1/3	1	1				
Geology (H-C)	1/5	1/3	1/3	1			
Soil type	1/7	1/5	1/5	1/3	1		
Slope	1/7	1/5	1/5	1/3	1	1	
Road distance	1/9	1/7	1/7	1/5	1/3	1	1

AHP weight derivation

**Table -21: Analytic hierarchical derivation for eigenvector weight**

Using Pair wise Comparison 9 Point Continuous Scale, the eigenvector weights for the seven factors were determined with an acceptable consistency ratio of 0.03

<b>Factors</b>	<b>Eigenvector weights</b>
Land use	0.3985
Depth of ground water	0.1966
River distance	0.1966
Geology (hyd-cond.)	0.0960
Soil type	0.0461
Slope (%)	0.0385
Road distance	0.0276

**Table-22: Eigenvector weights for the seven factors**

Based on the above calculated eigenvector weights of the factors, all the model layer parameters are weighted with their respective percent of influence to the suitability analysis criteria. The final Suitability map is created using an arithmetic overlay of the ArcGIS Map Calculator options of the spatial analyst extension as shown below.

$$0.3985 * [\text{Reclass of land use}] + 0.19666 * [\text{Reclass of depth of gwt .im}] + 0.1966 * [\text{Reclass of river d.im}] + 0.0960 * [\text{Reclass of hyd\_con}] + 0.0461 * [\text{Reclass of soil}] + 0.0385 * [\text{Reclass of slope}] + 0.0276 * [\text{Reclass of dist\_road}]$$

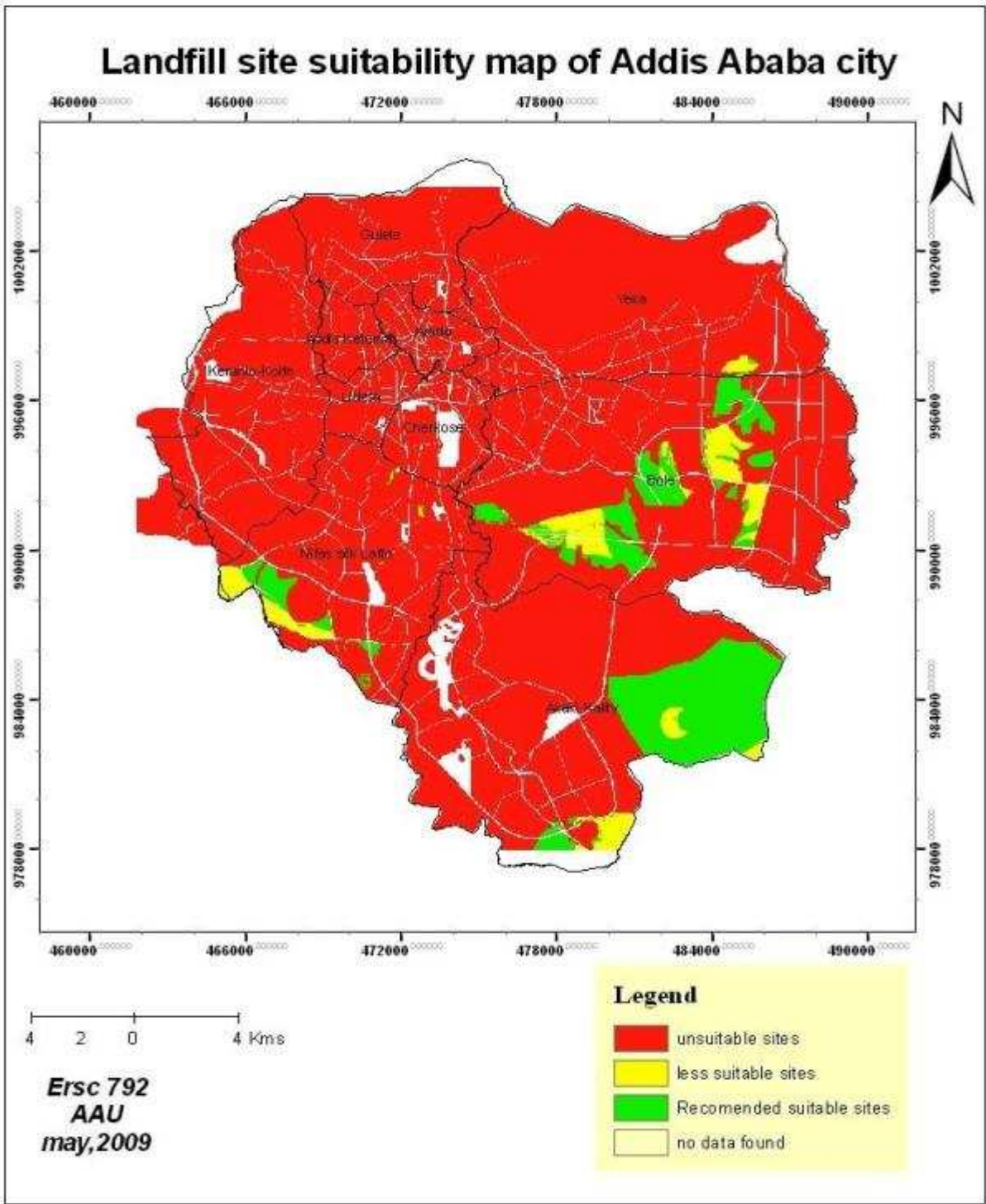
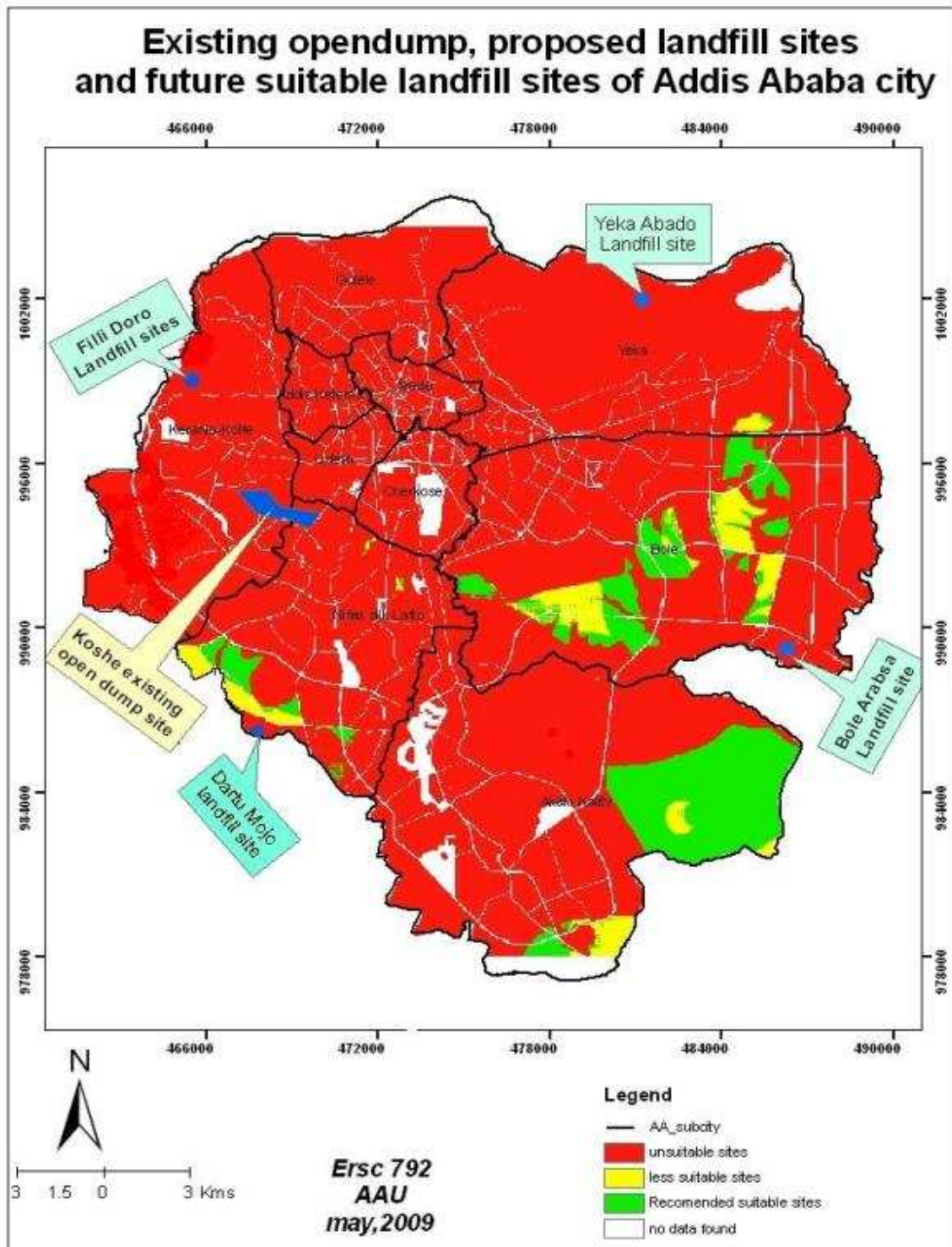


Figure -28: suitable landfill site map of Addis Ababa city

### **5.3 Discussion**

As discussed by different researchers and scholars, also reviewed in this project from the literature survey of different works on Koshe site up to the onsite observation of the open dump environment, Koshe has dropped a black scar on the environment (ground water, surface water, soil fertility by accumulating a high density plastics and non biodegradable litters, toxic metal accumulation in the site soil, air pollution, organic combustible gas accumulation and release to the environment etc...). Even Koshe is located on the centre of aviation zone; it may be a danger, especially for small air crafts since there are scavengers and flying birds across the disposal site. By all means, it couldn't meet the criteria of disposal site. In this project, suitable landfill waste disposal site is selected and a suitable map is produced. The existing dump site and proposed sites were merged on the developed suitable map (see fig.28). Any one can conclude the condition of all proposed sites on the suitable map. None of them could meet the parameters. So, appropriate recommendations are forwarded below.

The higher temperature and lower rainfall zone is the appropriate landfill site as it was discussed earlier. So, the best site investigated below is the green area of the map at the lower part of Addis Ababa city which has lower altitude, high temperature and lower monthly mean rainfall, probably to have high degree of evaporation. The green area in the developed map, at Bole sub-city, inside the aviation zone of Bole international air port is not preferable. Even investigated green areas at Nefas silk lafto sub city is near the aviation zone. So the green areas in both sub cities are avoided from the proposed best sites even if they meet the GIS and AHP analysis criterion. Therefore, the only site that meets all parameters in this paper is south eastern part of Akaki Kality sub city (See the following figures; fig. 29 and fig.30)



**Figure – 29: Existing open dump, proposed landfill and future suitable landfill sites of Addis Ababa**

### Proposed landfill sites and aviation zone map of Addis Ababa City

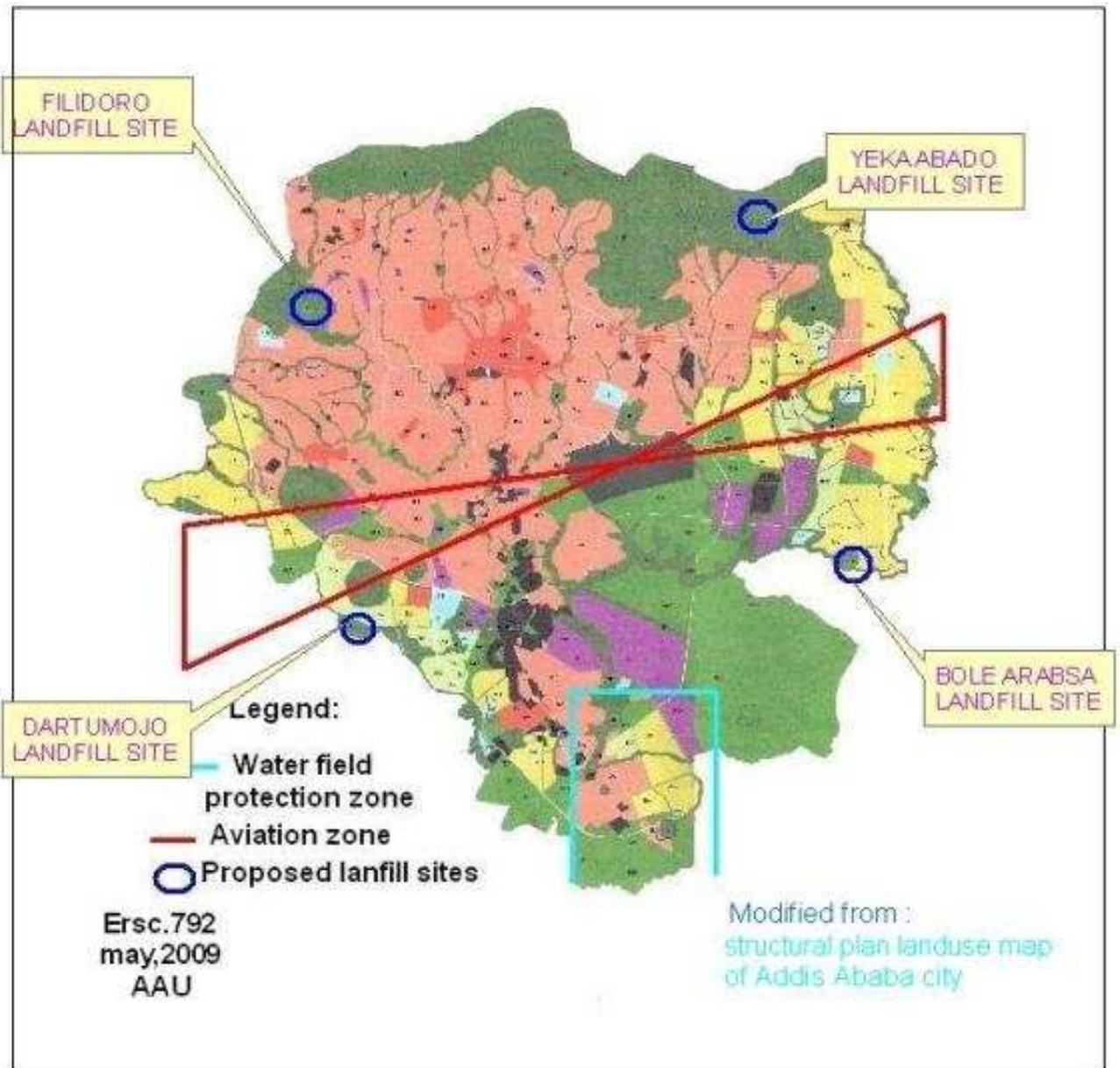


Figure -30: Aviation zone, proposed landfill site, existing open dump site and the restricted akaki well field

## 5.4 Findings

**Table -23: Findings of the project**

Proposed sites	Yeka abado	Filidoro	Dartu Mojo	Bole Arabsa
Aviation zone	Far distance	Far distance	Near distance	Near zone
Slope	Less suitable slope	Moderately suitable	Moderately suitable	Suitable slope
Geology(Hyd-con)	Highly suitable	Medium to low hyd-conductivity (suitable)	Low Hyd-conductivity i.e. suitable	Medium to low hyd-conductivity (suitable)
Soil	Lacustrine clay i.e. less suitable soil	Mixture of reddish brown clay, alluvial soil dominantly black cotton soil to Addis ketema and Lideta sub city side and thin/absent to west border of the landfill , generally suitable soil	Black cotton soil i.e. highly suitable soil type	Few / absent soil cover with black cotton soil to the near north of landfill i.e. unsuitable soil class
Ground water head	39.697-74.974 meters deep i.e. from moderately suitable to suitable	0.50-39.697 meters deep i.e. least suitable sites	0.50-24.018 meters deep ,least suitable class of the depth	39.697-56.845 meters deep i.e. moderately suitable depth of ground water
Recharge zone	Ground water recharge zone even at the recharge area* near distance to river and least suitable	Ground water recharge zone even at the recharge area* recharge area of little Akaki and its tributaries like Jemmo river also the site is located near distance to river i.e. least suitable	Relatively far distance from rivers and recharge areas, covered by forest and reserve/open sites.	Sited on Akaki river, recharge of big Akaki, i.e. unsuitable class recharge zone for landfill
Surface water/river, stream, drinking water supply	Affect Hanku river	Large number of boreholes around the site i.e. affect quality of discharged water	Far from a river and stream	Affect Akaki river
Land use property	Nothing is around the site and covered by forests	The site is covered by forest near social existing like stadium and festival	Reserve / open areas of the city covered by forests i.e. suitable class	Near the mixed development properties of the cities and potential

	Suitable class of i.e. land use property	sites, with mixed development. i.e. unsuitable class of land use property	of land use	mining and quarry sites i.e. less suitable class of the land use property.
Accessibility	Do not be considered!	Do not be considered!	Do not be considered!	Do not be considered!

## 5. Conclusion and Recommendations

In general, previously the rationale for the proposition of disposal sites for the city was based on reducing travel time and without crossing the city. Later on, with the upcoming of new policies, the master plan project office has recognized the need to protect surface water and ground water resources and the wind criteria to position the sites away from development and aviation zones as main criteria. Certain/some of such sites did not match the criteria, especially in the northern part of the city, but they were proposed as they were. It was supposed that every scientific evaluation, review and modification would further be conducted. Therefore, the master plan project office believed that it needs further investigation of the sites. According to the analysis in this project, all the proposed landfill sites including the existing open dump sites cannot match or meet even the minimum scientific criteria as a whole, so this project recommends the following points:

1. Further scientific study should be conducted on the proposed sites.
2. Suitable sites should immediately be selected as permanent transfer sites for the present working koshe open dump site.
3. Another alternative site should be investigated based on scientific criterion that may replace the proposed sites and the existing open dump landfill.
4. Cleaning, plantation of indigenous and legume plants and recreational land use property with appropriate rehabilitation are recommended for koshe open dump as a remedial action.
5. A scientifically evaluated engineering design and modifications should be undertaken as remedial measures for the proposed sites before they extend their service.
6. The city can use the proposed suitable landfill sites either as disposal sites by considering other non-inclusive criteria in this project or as a base line study for suitable landfill site investigations.
7. The recommended best disposal sites of Addis Ababa city are found in the south eastern part of Akaki Kality sub-city distant from restricted Akaki well fields (fig.30 as shown below)



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## Appendix: Checklist questions

*Note: Questionnaire listed below is a main check list questions answered by observation, interview and literature survey of the study area that are used for better understanding the seriousness of the problem .*

### 1. House holds waste management condition check list

#### 1.1 General Cleanliness of the environment (By observation)

Dirty \_\_\_\_\_

Fairly Clean \_\_\_\_\_

Clean \_\_\_\_\_

#### 1.2 Temporary house hold waste handling habits

✓ Do you have temporary storage container for generated refuse at home?

Yes \_\_\_\_\_ No \_\_\_\_\_

✓ Use and throughewn in to the near ditches, drainage cannels etc?

yes \_\_\_\_\_ No \_\_\_\_\_

✓ If others specify \_\_\_\_\_

### 2. Solid Waste Disposal practices

2.1 Do the society reuse household wastes? Yes \_\_\_\_\_ No \_\_\_\_\_

2.1.1 If Yes, Type of reused wastes \_\_\_\_\_

Purpose of Reused wastes \_\_\_\_\_

2.2 Do the society compost wastes? Yes \_\_\_\_\_ No \_\_\_\_\_

2.2.1 If yes, what type of wastes? \_\_\_\_\_

2.3 Is there the incineration of household wastes? Yes \_\_\_\_ No \_\_\_\_\_

2.3.1 If yes what type of wastes? \_\_\_\_\_

2.3.2 Where do they incinerate? Inside the compound \_\_\_\_\_

Outside the compound \_\_\_\_\_

2.4 Do societies use open dump as a disposal method? Yes \_\_\_\_\_ No \_\_\_\_

2.4.1 If yes, where do you dump?

Inside the compound \_\_\_\_\_

Outside the compound \_\_\_\_\_

2.4.2 Why do they prefer the dump? \_\_\_\_\_

2.4.3 How far is the container from societies home?

20-50 meters \_\_\_\_\_

51-100 Meters \_\_\_\_\_

101- 200 Meters \_\_\_\_\_

201-500 Meters \_\_\_\_\_

> 500 meters \_\_\_\_\_

2.4.4 Is there accessible road to the nearest container? yes \_\_\_\_ No \_\_\_\_

2.5 Do society dump solid waste in to the river? Yes \_\_\_\_\_ No \_\_\_\_\_

2.5.1 If yes, why? \_\_\_\_\_

2.5.2 How far clean the drainage channels around the area (by observation)?

2.6 Do you sell wastes? Yes \_\_\_\_\_ No \_\_\_\_\_

2.6.1 For whom do they sell wastes?

-Koraleos \_\_\_\_\_

-Formal recycling centers \_\_\_\_\_

-Others Specify \_\_\_\_\_

2.7 Do most societies have contractual agreement with Micro and small enterprises?

Yes \_\_\_\_\_, No \_\_\_\_\_ ,

2.7.1 If yes, how much do you charged monthly?

2.7.2 If no, who Collect and transport wastes to the containers?

2.8. Is there anybody who monitors that waste is properly collected and transported to the containers? Yes \_\_\_\_ No \_\_\_\_\_

• If yes, who? \_\_\_\_\_

2.9 Is the existing waste management of the municipality satisfactory?

Yes \_\_\_\_\_ No \_\_\_\_\_

If no, what measures do you think should be taken to improve?

2.10 If you have any suggestion about controlling of MSW of Addis Ababa city

## **Annex 2. General waste management monitoring check list**

1. Is there municipality service for managing the MSW? Yes \_\_\_\_ No \_\_\_\_

1.1 If yes, specify the department \_\_\_\_\_

2. How many landfill sites Addis Ababa city have? \_\_\_\_\_

3. How far are/is the landfill site(s) from the sub cities and each kebeles in km? \_\_\_\_\_.

Is the landfill site protected (Fenced etc...)? \_\_\_\_\_

4. Are there street cleaning organizations in the town which are organized by the municipality? Yes

\_\_\_\_\_ No \_\_\_\_\_

5. Are there Micro Enterprises organized in the town for collecting solid waste?

Yes \_\_\_\_\_ No \_\_\_\_\_

If yes, Please list names of MSE and their numbers;

6. How many containers are there in the town? \_\_\_\_\_

7. How is the distribution of the containers in each kebele? \_\_\_\_\_

8. How many waste lifting tracks in the city? \_\_\_\_\_

Are they functioning by now? Yes \_\_\_\_\_ No \_\_\_\_\_

8.1 If No, what means does the municipality use? \_\_\_\_\_

8.2 Are there NGOs or any organization that support the municipality to control or to lift solid waste? \_\_\_\_\_

9. Duration of the tracks emptying the containers

“ Every day \_\_\_\_\_

“ Every other day \_\_\_\_\_

“ Once in 3-5 days \_\_\_\_\_

“ Once per week \_\_\_\_\_ “others \_\_\_\_\_

10. Is there a river crossing the sub city? Yes \_\_\_\_\_ No \_\_\_\_\_

How far is clean the river from dumped waste?

10.1 Is any controlling mechanism that people not to dump in it?

11. Does the municipality practiced to create awareness about SW and its positive and negative consequences to the community? \_\_\_\_\_

12. What actions does the municipality take on individuals who improperly dispose waste? \_\_\_\_\_

13. Do you think existing financial, technical, material and manpower support for the control of MSW of sub city satisfactory? Yes \_\_\_\_\_ No \_\_\_\_\_

14. If no, in your opinion, what must be done to improve solid waste management?

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

Annex-3

**About the existing landfill, proposed landfill and scientific Evaluations**

1. Do Addis Ababa city has a previously scientifically evaluated landfill site?

Yes \_\_\_\_\_ , No \_\_\_\_\_

2. How koshe was selected best as a disposal site in 1964 EC?

3. What are the impacts of Koshe open dump landfill on the environment?

3.1 health effect\_\_\_\_\_

3.2 aesthetic effect \_\_\_\_\_

3.3 environmental pollution\_\_\_\_\_

3.3.1 surface water pollution\_\_\_\_\_

3.3.2 Ground water pollution \_\_\_\_\_

3.3.3 Soil pollution\_\_\_\_\_

3.4 If others\_\_\_\_\_

4. Is there the habit of waste characterization on the site before it is being disposal off? Yes \_\_\_\_\_

No \_\_\_\_\_

4.1 If yes, does the city has a temporary transfer sites? Yes \_\_\_\_ No \_\_\_\_

4.1.1 If yes, how far is from the disposal sites and from the averagely collected sites?

4.1.2 What is the practical input of waste characterization at the transfer sites?

4.2 If No, how and where the collected waste is characterizes?

5. How far koshe site was scientifically evaluated after it was designed as a disposal site?

6. What will be the future land use plan of Koshe open dump site after it will be transferred to new proposed disposal site ? Why?

7. Is there any environmental impact assessment done on koshe open dump site?

Yes \_\_\_\_\_, No \_\_\_\_\_ if yes, how often it was conducted and what remedial measure was under taken? \_\_\_\_\_

8. Is there any proposed land fill sites in the city master plan? Yes \_\_\_\_\_, No \_\_\_\_\_

8.1 If yes, what were the criterions of proposition? Where the sites are proposed?

8.2 If no, what is the city future solid waste management plan? \_\_\_\_\_

9. What will be the primary safety and precautions that were considered in selecting proposed landfill site? Was there a scientific evaluation conducted?

10. When they will come in to practice? How long they will sustain in the future? How is the city plan in using these proposed land fill? Has the city planed to use integrated solid waste management (IWM)

I.e. Reduction, reuse, recycle, disposal by waste characterization and separation? Yes/No

10.1 If yes, is there any proposed temporary waste transfer site along with the new landfill? Yes\_\_\_\_, No\_\_\_\_

10.1.1If yes, what are the criterions?\_\_\_\_\_

10.1.2 If no, how would you characterize and separate wastes? On site

Characterization \_\_\_\_\_ or others\_\_\_\_\_

