A case study for sanitary landfill site selection

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ABSTRACT: The solid waste disposal is becoming a major concern for the local administrations of big cities in Turkey as the solid waste disposal problem grows rapidly along with other environmental problems. The Greater Municipality of Bursa in Turkey, have had an insight for the growing problem of solid waste disposal and therefore appointed Seyaş-Taylor Binnie & Partners J.V. at the pre-feasibility stage and Seyaş-Evans-ERL J.V. at the feasibility stage to select new sanitary landfill site(s), considering various aspects. Zetaş Earth Technology Corp. is involved in site selection study as the geotechnical consultant. The study carried out for the site selection of new sanitary landfills is presented as a case study which represents the first application of the engineering site selection considering appropriate factors. The local geology, hydrogeology and hydrology, access to the site, availability of cover material and environmental aspects are among the governing factors that are considered for the site selection. There existed four alternative sites besides the present dumping location used without any remedial measures located on agricultural land. These four sites are investigated considering their geotechnical and environmental aspects and the other governing factors. As a result, priorities of the alternative sites on comparison basis are developed.

1 INTRODUCTION

Environmental geotechnics is becoming more emphasized in todays world. The development and flourish of geotechnology plays an important role in finding solutions to environmental problems. Together with the inputs of environmental and groundwater engineering, geotechnology is a tool for establishing the solutions to specific problems. In this context, a case study for sanitary landfill site selection is presented with special emphasis on the geotechnical engineering aspects of the problem.

2 HISTORICAL BACKGROUND

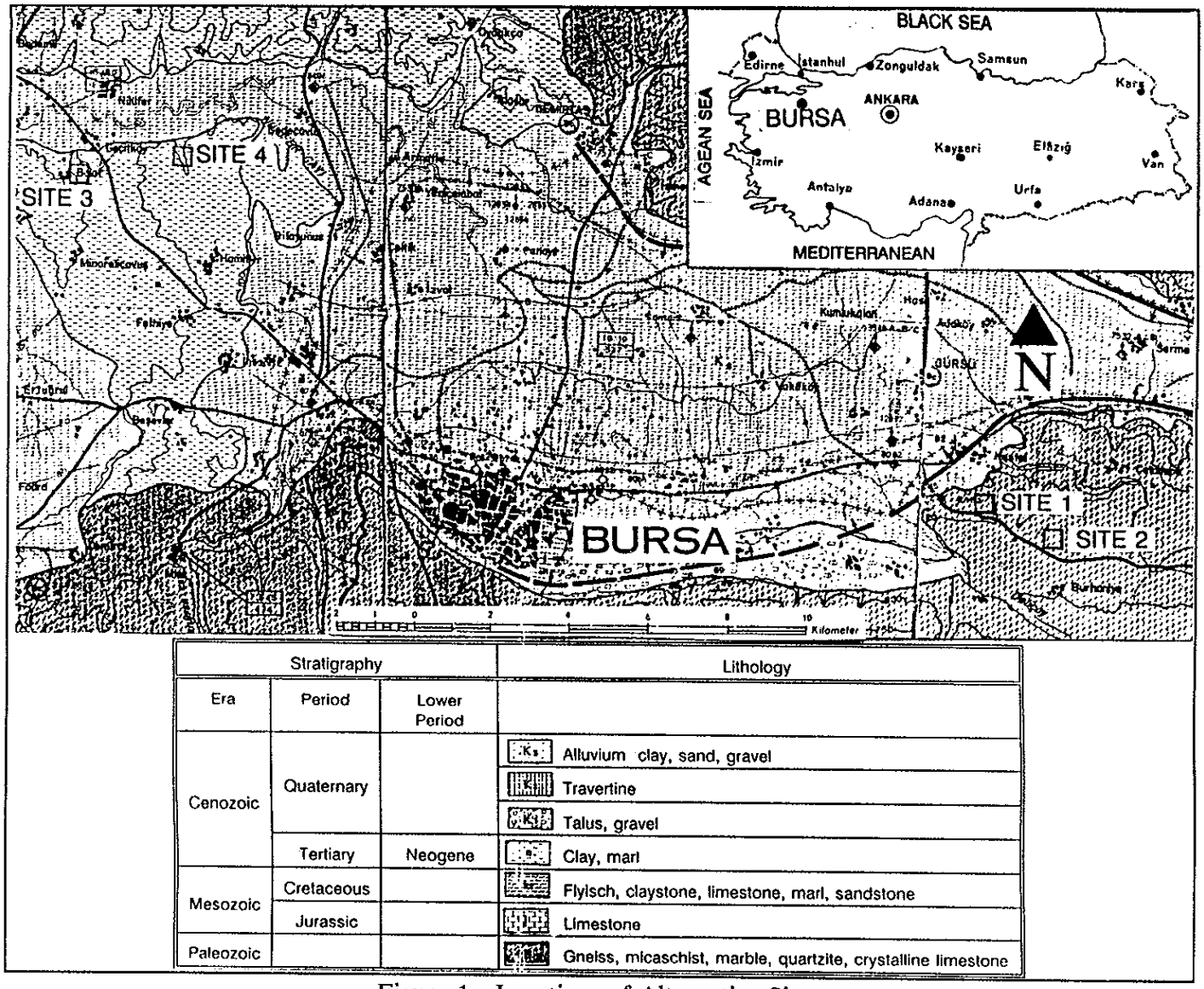
Being closely related to the rapid growth of the population and cities, the solid waste disposal is a problem that is much more pronounced within the last decade in Turkey. The Greater Municipality of Bursa in Turkey have had intuition for the growing problem of solid waste problem and therefore appointed Seyaş-Taylor Binnie & Partners J.V. at the pre-feasibility stage during 1989 and Seyaş-Evans-ERL J.V. at the feasibility stage during 1991 to select new sanitary landfill site(s) within the content of solid waste management project for the city of Bursa, considering various aspects.

Bursa is one of the major big cities in west of Turkey. It is located at the skirts of Mountain Uludağ which is an inactive volcano. The population of the city was reported to be around 700,000 based on the figures of the year 1989, and which is over a million presently. The city has major industries such as automobile and textile together with many sub-branches of other industries. Besides the city has a considerable agricultural and tourism potential because of fertile Bursa plain and the historical, thermal springs and sports attractions.

The existing solid waste disposal facility of the city is located to the north of city within alluvial Bursa plain on agricultural land. The disposal is presently carried out by dumping in an uncontrolled manner forming stock hills of waste on agricultural land. It is obvious that the contamination, nuisance and odor created from the existing site has adverse effects on the environment. Therefore, the importance of a properly established and operated sanitary landfill site is much more pronounced. A two step approach is performed for the site selection. The pre-feasibility study concentrated on the general advantages and disadvantages of the potential sites with emphasis on environment, geology and hydrogeology. The feasibility study, as a second step, consisted of evaluation of potential sites based on operational criteria together with further evaluations on the geotechnical and environmental aspects.

3 ALTERNATIVE SITES

There existed four alternative sites during the pre-feasibility study cited by the Greater Municipality of Bursa for the development and evaluation of sanitary



Stratigraphy			Lithology
Era	Period	Lower Period	
Cenozoic	Quaternary		Alluvium clay, sand, gravel
			Travertine
			Talus, gravel
	Tertiary	Neogene	Clay, marl
Mesozoic	Cretaceous		Flysch, claystone, limestone, marl, sandstone
	Jurassic		Limestone
Paleozoic			Gneiss, micaschist, marble, quartzite, crystalline limestone

Figure 1 - Locations of Alternative Sites

landfill besides the existing site. The two of these sites are located to the west and the others to the east of city. These sites are listed in Table 1. The locations of alternative sites are given in Figure 1.

Table 1

Site no	Name/general location	Distance from city center
1	Cement factory Limestone quarry/ east	13 km
2	Cement factory Clay pit/east	14 km
3	Balat/west of Mudanya road, industrial area	10 km
4	Hamitler valley/ west of city, east of Mudanya road	12 km

4 CRITERIA FOR SITE SELECTION

The criteria for sanitary landfill site selection could be evaluated separately for each site. Among the alternative sites cited by the Municipality a selective evaluation is carried out in order to concentrate on the feasible alternatives. The relevant criteria for site selection given by ASCE could be listed as:

1. protection of health and safety,
2. prevention of pollution and environmental damage,
3. economics of operation,
4. public and political acceptability.

To satisfy the above four main categories of site selection criteria

. geomorphology,
. geology,
. hydrogeology,
. surface and groundwater hydrology,
. access to site,
. evaluation of lining and remedial measures,
. availability of cover material,
. environmental aspects,
. land ownership,

for each site should be assessed. For this purpose,

geological and hydrogeological investigations for each site is conducted during the pre-feasibility stage. In addition, further detailed subsoil investigations for the potential sites are conducted and the subsoil conditions are determined by means of borings. The subsoil hydraulic conductivities for the sites are determined by means of in-place permeability tests. The features of each site are described briefly.

4.1 *Site 1 - Cement factory limestone quarry*

This site is located by the cement works to the east of the city at the skirts of mountain Uludağ. It is the limestone quarry of the cement factory and is still under use. A highly metamorphosed, extensively jointed and fractured limestone was observed on the excavation faces of the quarry. The limestone formation could be classified as hard rock and was observed that it requires blasting for excavation.

High surface runoff is expected at the site due to steep slopes behind the site. The lowest elevation of the site is at north from where the surface runoff is expected to discharge to lower elevations and ultimately to the alluvial Bursa plain. Although no seepage faces are observed on the faces of the quarry a relatively high permeability of the limestone formation is expected due to the extensively weathered nature of the formation. Groundwater travels through these fissures and at this part of the region is suspected to recharge the aquifer within the Bursa plain. Under these circumstances, it is foreseen that the site would require synthetic lining against leachate due to the steep excavation faces of the quarry.

The access to site is via approximately 500 m of dirt road through cement factory after primary state highway. The highway up to the cement factory is sufficiently wide enough to allow passing of two lorries at the same time. The site has an estimated capacity around 10,000,000 m^3. There seems to be a limited material for the cover material in the vicinity of the site. No residential properties are present near to the site. However, cement factory is in the close vicinity. The site is the property of cement factory.

4.2 *Site 2 - Cement factory clay pit*

This site is located close to the cement works to the east of the city at the skirts of mountain Uludağ. It is the abandoned clay quarry of the cement factory and was used previously. A reddish brown clay was observed at the bottom of the pit. However, the massive limestone outcrops are observed around the boundaries of the site.

High surface runoff is expected at the site due to the wide catchment basin. Water in the form of pools within the site is observed. Besides a small creek exists crossing the site along south-west north-east direction diagonally. A large perennial stream runs approximately 500 m north of the site. The small creek ultimately discharges to the stream at the north-east of the site.

The capacity of site is estimated approximately 2,000,000 m^3. The access to the site is via state highway which is sufficiently wide to allow two trucks to pass with ease. The material at the site seemed appropriate for lining and cover material, however, some cover material might be imported. This borrow pit is not close to any buildings. The nearest building is the cement factory which is a few kilometers away. The site is the property of the cement factory.

4.3 *Site 3 - Balat site*

This site is located to the west of city near the industrial area. There exists urban development around the site. The dominant formations encountered at the site is neogene aged clayey formations. The topography of the site is gently undulating. There is access to site, however, the roads passing through industrial and/or urban areas. In addition, the site topography seemed not suitable for landfill operation. The site was observed to have poor drainage pattern due to soft topography. The proximity to industrial/urban areas was considered as an other disadvantage. The land is owned by the Municipality.

4.3 *Site 4 - Hamitler valley*

This is wide valley to the north-west of city at the east of Mudanya highway. The site is composed of a main valley and four side valleys in a gently rolling area. The area is a low quality agricultural land. There are not any urban development in the close vicinity of the site. The Hamitler village is the closest residential area which is about two kilometers away. There exists a small stream at the bottom of the valley. The underlying geology comprised neogene aged deposits, characterized by clays with local sand and gravel lenses, on the hills and slopes, with quaternary alluvial sediments along the valley bottom, but of limited extent. These deposits are comprised of clayey subsoil with occasional sands and gravel.

Groundwater was only encountered within the quaternary deposits, although sandy lenses within the neogene deposits have given rise to small springs on the slopes. The estimated total capacity of the site is around 17,000,000 m^3. However, it is also possible to landfill the side valleys within the main valley in a consecutive order for operational ease. The access to site exists through the Hamitler village, however, a short access road could be reconstructed form the highway to Mudanya by-passing the village. The in-situ subsoil seemed appropriate for lining and cover material, which might require some in-place compacting for the case of lining. The drainage pattern of the valley is through the stream present at the bottom of valley.

5 EVALUATION OF THE ALTERNATIVES

Based on the above criteria and features of the alternative sites, a preliminary evaluation of the four sites are carried out and the alternative sites are reduced to two for further detailed investigations and evaluations at the feasibility stage.

The four sites are investigated considering their geotechnical and environmental aspects and other governing factors. The evaluation of the alternative sites, based on the geotechnical and environmental criteria revealed that the priorities could be established for the alternatives.

Site 3 has the least advantage for sanitary landfill operations considering its proximity to industrial/ urban areas. Environmental factors such as odor, noise, aesthetics, air pollution, and dust would hinder public acceptance for the site. Besides, the gently undulating topography of Site 3 is considered not suitable for sanitary landfill. The leachate control and lining requirements for Site 3 would be similar to Site 4 due to the similar formations present at both sites. Access to site is another negative factor, since the traffic that would be induced on the existing roads passing through the industrial and/or urban areas would create congestion and nuisance. Therefore, Site 3 is ignored for further investigations after the pre-feasibility study, considering the disapproval introduced by the selection criteria.

Site 1 although being a potential landfill site has the disadvantage of being presently utilized by the cement factory. This would bring operational constraints. An other disadvantage that could be mentioned is the higher costs associated with the leachate control. Since the site is located within fractured and fissured limestone formation lining would be necessary for leachate control. Due to the steep excavation faces of the quarry, application of synthetic lining has difficulties, whereas, application of clay lining seems not possible. Site 1 is also ignored for the above reasons for further evaluations after the pre-feasibility stage.

Concentration given mainly on Site 2 and Site 4, during the feasibility stage and a preliminary subsoil investigation program is conducted. Both sites are considered as potential sites during the feasibility stage.

The results of the subsoil investigations served for a comparative evaluation between the two sites. Measured in-situ permeabilities of the subsoil for Site 4 were generally between 10^{-8} to 10^{-10} m/sec, although in particular places were slightly higher, around 10^{-6} m/sec. On the other hand, measured permeabilities in Site 2 were in the order of 10^{-3} to 10^{-5} m/sec after a limited thickness of low permeability clay.

Doubts arising from the increased permeabilities within Site 2 made this site less attractive due to the susceptibility of the continuity of clay layer observed on the surface of the clay pit. The trial pits excavated within Site 2 revealed that the top clay layer is limited in thickness and there exists fractured limestone formation underneath. This indicated that a further detailed study is to be conducted for Site 2 in order to determine the extent of lining requirements. On the other hand, non-uniformity of the subsoil at Site 4 indicated the necessity of a further detailed study of this site for lining requirements, as well. The clayey subsoil within Site 4 is variable, but much of it may meet the Turkish Ministry of the Environment's permeability standard of 10^{-7} m/sec for at least 10.0 m. The Site 2 appears less suitable for landfilling than anticipated in this context. Furthermore, during the course of study, it has been indicated by the administration of water and wastewater for Bursa that the underlying aquifer near Site 2 has been designated for possible use in the forthcoming future.

The size and content of the drainage precautions of the two sites is an other means of comparison. Although both sites contain a small stream, the catchment basin for Site 2 appears to be somewhat larger than that of Site 4. Therefore, a diversion channel is to be constructed for surface waters ahead of the Site 2. The diversion ditches for surface waters for Site 4, on the other hand, would have limited extent and easy to construct, when compared with Site 2. However, the stream within the valley in Site 4 could not be diverted and possibly a re-alignment of the stream would be necessary in the form of an open channel.

Among the site selection criteria land ownership should also be quoted for the factors affecting the site selection. In view of the above criteria Site 2 was less attractive being a property of the cement factory.

6 SITE SELECTION

The existing landfill (dump) site has only 150,000 m^3 capacity remaining which is estimated to last for about a six months period. Besides, a political commitment has been given to the early closure, so an immediate priority appeared to establish a new well engineered landfill site as quickly as possible. The evaluations on site selection for both short-term and long-term has to be carried out. Especially, in the long-term a further evaluation of both sites would be beneficial including the environmental impact assessment.

In the short-term, the site selection study concluded that one of the side valleys within Site 4 appears to be suitable as a containment site with an engineered natural clay liner. Therefore, a conceptual design for the site is carried out. The short-term capacity of the side valley within Site 4 is estimated to be about 1,000,000 m^3 which would last for approximately for 4 years based on the estimated solid waste amounts. In the long-term, the estimated total capacity of Site 4 would be about 17,000,000 m^3, which would last for probably more than 30 years. Based on the conceptual design for the Site 4, short-term capital development costs are summarized in Table 2, for reference purposes.

7 CONCLUSIONS

The evaluation of criteria for sanitary landfill site selection for the four alternative sites indicated that the alternative sites could be reduced to two. Considering the factors of leachate control, gas migration, odor, noise, aesthetics, air pollution, dust and burrowing animals both Site 2 and Site 4 had similar advantages being away enough from the residential areas.

Table 2 - Capital Development Costs for Site 4

Description	Quantity	Cost
Access road from public highway to site entrance	3.5 km	$2,450,000
Access road from site entrance to landfill area	0.2 km	$ 60,000
Office	1 no.	$ 20,000
Weighbridge	1 no.	$ 10,000
Vehicle/equipment maintenance	1 no.	$ 75,000
Site excavation and land clearing	40,000 m^2	$ 80,000
Base preparation	N/A	$ 100,000
Surface water controls	2 km	$ 30,000
Fencing	2 km	$ 60,000
Leachate collection and treatment	N/A	$ 100,000
Mobile plant	Total	$ 900,000
TOTAL		$3,885,000

However, it could be concluded that in the long-term the both sites had the potential for landfilling provided that the highest possible standards of landfilling is achieved, with the correct infrastructure and operational methods.

The operational concepts and solid waste management studies are outside the scope of this paper, and therefore, not mentioned. The site selection criteria and evaluations briefly presented. As a result, evaluations of the alternative sites on comparison basis are developed.

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