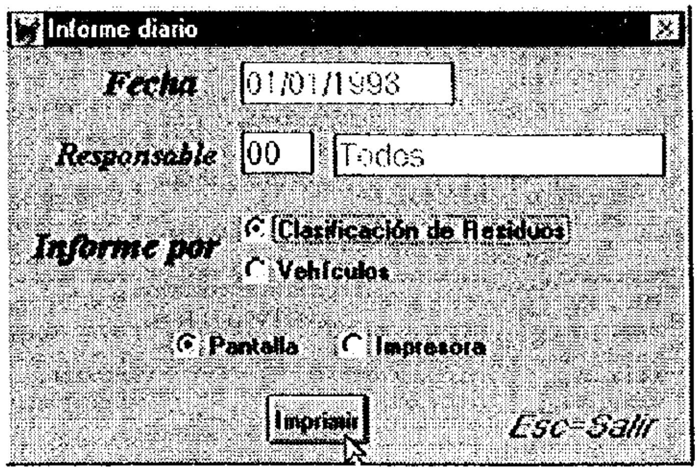
E. *Informes*

1. Registros diarios

a) Diarios

Para obtener informe de los registros diarios de los vehículos que ingresan al sitio de disposición final , dentro del menú **Informes**, seleccione la opción **Diarios** y le aparecerá la siguiente pantalla.

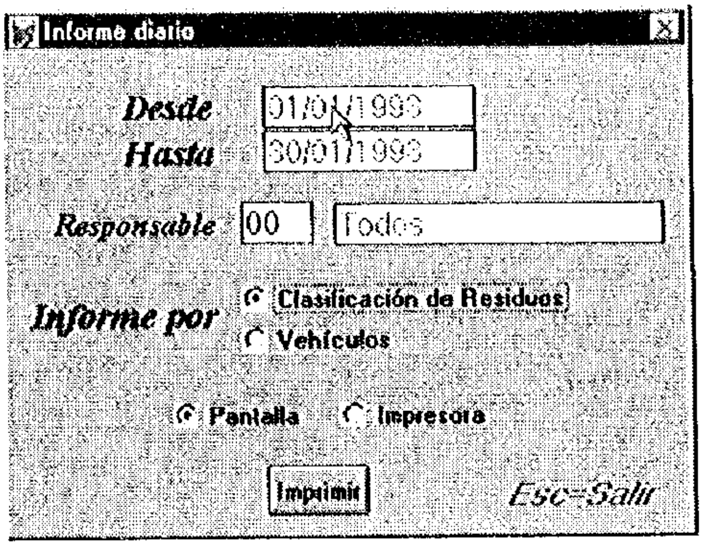


1. Ingrese la fecha del informe
2. Ingrese el código de responsable, si desea el informe de un solo responsable o "00" para incluir todos los responsables. Si no se acuerda del código del responsable presione µ para buscar.
3. Elija el tipo de informe.
4. Elija el dispositivo de salida, si desea imprimir en la impresora, prepare primeramente la impresora y luego elija el botón imprimir y presione p.

> ∀*Nota:* En esta opción solo se pueden obtener informe de un solo día.

b) Fechas

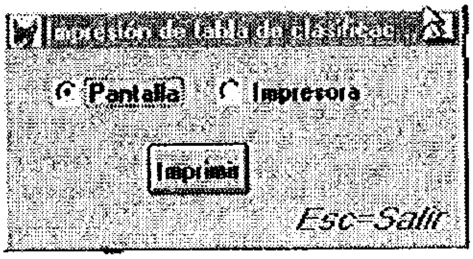
Para obtener informe de los registros diarios de varios días, dentro del menú **Informes**, seleccione la opción **Fechas** y le aparecerá la siguiente pantalla.



1. Ingrese la fecha inicial.
2. Ingrese la fecha final.
3. Ingrese el código de responsable, si desea el informe de un solo responsable o "00" para incluir todos los responsables. Si no se acuerda del código del responsable presione μ para buscar.
4. Elija el tipo de informe.
5. Elija el dispositivo de salida, si desea imprimir en la impresora, prepare primeramente la impresora y luego elija el botón imprimir y presione p.

2. *Vehículos*

Para obtener informe de todos los vehículos registrados, dentro del menú **Informes**, seleccione la opción **Vehículos** y le aparecerá la siguiente pantalla.



Elija el dispositivo de salida, si desea imprimir en la impresora, prepare primeramente la impresora y luego elija el botón imprimir y presione p.

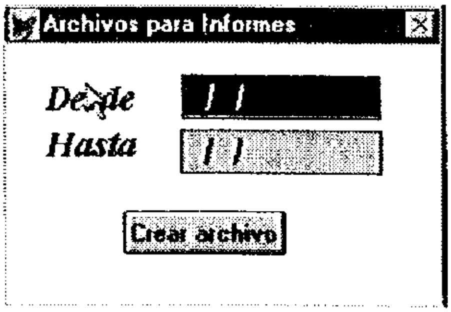
F. Archivos

1. Registros

Esta opción del sistema le permite transportar la base datos de los registros diarios a un formato de archivo de Microsoft Excel. El archivo creado, se puede abrir con la planilla electrónica y es posible la manipulación de los datos, y crear informes acorde a sus necesidades cotidianas.

a) Crear archivos de los registros diarios

Dentro del menú **Archivos**, seleccione la opción **Registros** y le aparecerá la siguiente pantalla.



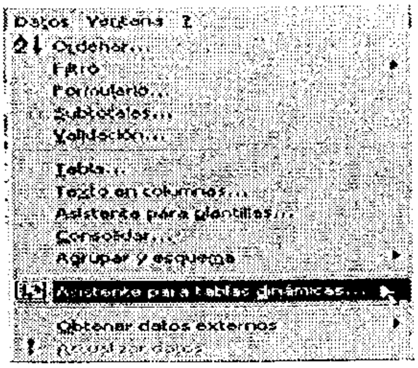
1. Ingrese la fecha inicial.
2. Ingrese la fecha final.
3. Seleccione el botón **Crear archivo** y presione p
4. Se creará un archivo con formato de Excel en el siguiente directorio: C:\SYS\AMDC\FILE\datos.xls

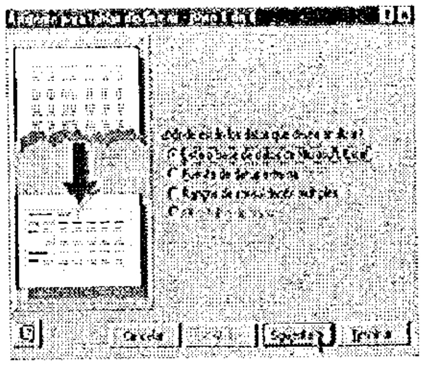
A continuación se le ilustrará unos ejemplos de Microsoft Excel.

- Primeramente abra el archivo datos.xls

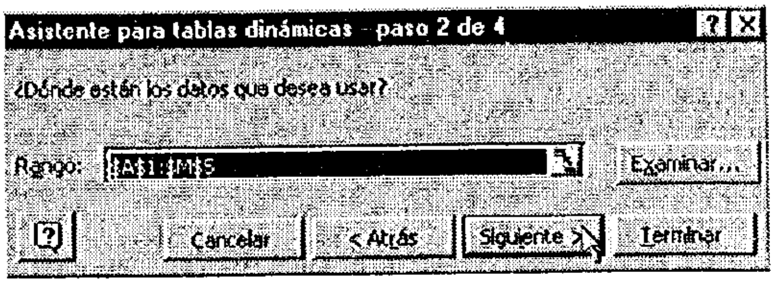
	A	B	C	D	E	F	G	H
1	unidad	rd_cod	marca	tipo	residuo	clasif	zona	resp
2	01	3	Nissan	Fiat volqueta (8m3)	Residuos	Hoteles y Restaurantes	R01	AMDC
3	01	1	Nissan	Fiat volqueta (8m3)	Residuos	Barrido de calles	R01	AMDC
4	03	2	Fiat	Fiat volqueta (8m3)	Residuos	Contaminantes	R01	AMDC
5	01	4	Nissan	Fiat volqueta (8m3)	Residuos	Barrido de calles	R01	Empresas Privadas
6								

- Elija el asistente de tabla dinámica, en el siguiente menú

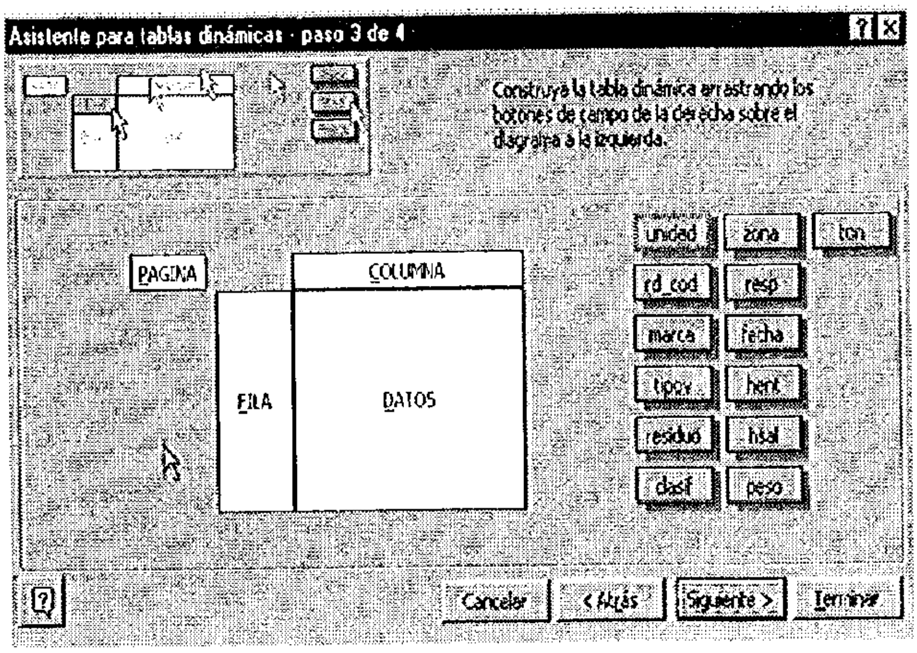




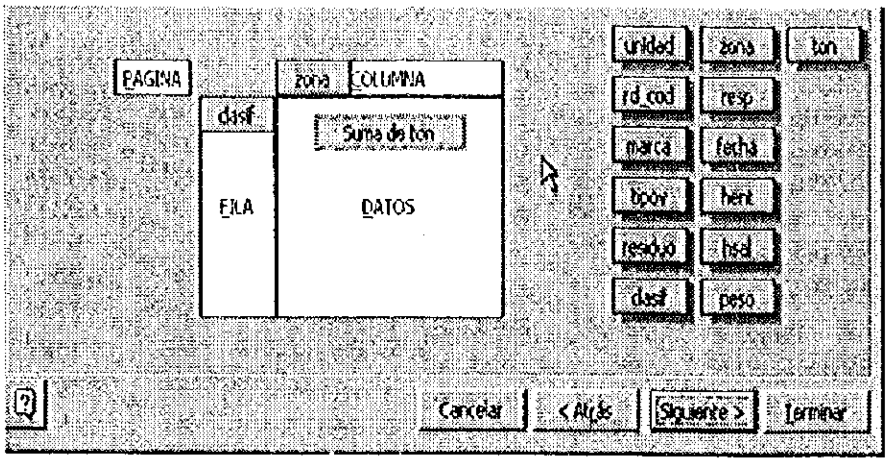
- Siga los pasos siguientes



- Dentro de la siguiente pantalla elija los datos que desea incluir en el informe



- Por ejemplo si se elige por fila la clasificación y por columna la zona y como datos la suma de toneladas



- Se obtiene el siguiente informe, para más detalle véase en los manuales de usuarios de Microsoft Excel o en el Help de dicha aplicación.

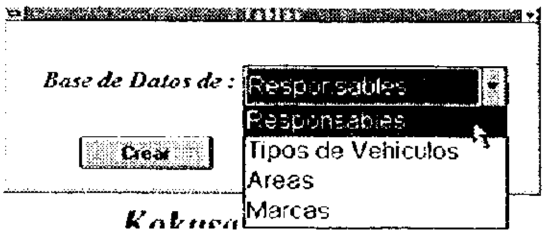
	A	B	C	D
1	Suma de ton	zona		
2	clasif	R01	Total general	
3	Barrido de calles	7.44	7.44	
4	Contaminantes		2.9	
5	Hoteles y Restaurantes	2.9	2.9	
6	Total general	13.24	13.24	
7				
8				

2. *Tablas*

Esta opción del sistema le permite transportar la base datos de las tablas utilizadas por el sistema a un formato de archivo de Microsoft Excel. El archivo creado, se puede abrir con la planilla electrónica y es posible la manipulación de los datos, y crear informes acorde a sus necesidades cotidianas.

a) Crear archivos de las tablas

Dentro del menú **Archivos**, seleccione la opción **Tablas** y le aparecerá la siguiente pantalla.



Elija la tabla deseada y seleccione el botón Crear y presione p

III. Bases de datos del Sistema

A. *Registro diario de los vehículos*

Nombre	REGDIA.DBF		
Detalle	Registro de todos los vehículos que ingresan		
	Campos		
Nomnre	***Tipo***	***Ext.***	***Descripción***
RD_COD	Numeric	7	Código
RD_UNIDAD	Character	7	Unida
RD_TIPO	Character	1	Código de tipo de residuo
RD_CODCLA	Character	4	Código de clasificación
RD_CODZONA	Character	3	Código de zona
RD_CODRESP	Character	2	Código de responsable
RD_FECHA	Date	8	Fecha de registro
RD_HSENT	Character	5	Hora de entrada
RD_HSSAL	Character	5	Hora de salida
RD_PESO	Numeric	5	Peso real si es que se pesa
RD_TON	Numeric	4,2	Peso estimado según el estudio

B. *Vehiculos*

Nombre	VEHICULO.DBF		
Detalle	Registro de todos los vehículos		
	Campos		
Nomnre	***Tipo***	***Ext.***	***Descripción***
V_UNIDAD	Character	7	Código de la unidad
V_PLACA	Character	7	Nro. De placa
V_MARCA	Character	2	Código de marca
V_MODELO	Character	15	
V_TIPO	Character	2	Código de tipo de vehículo
V_AÑO	Numeric	4	
V_PROP	Character	2	Código de responsable
V_PESO	Numeric	2	Peso tara

C. *Marca*

Nombre	MARCADBF		
Detalle	Registro de todos las marcas de vehículos		
	Campos		
Nomnre	***Tipo***	***Ext.***	***Descripción***
M_COD	Character	2	Código
M_DETALLE	Character	15	Detalle de la marca

D. *Tipo de Vehículos*

Nombre	TIPOV.DBF		
Detalle	Registro de todos los tipos de vehículos		
	Campos		
Nomnre	***Tipo***	***Ext.***	***Descripción***
TV_COD	Character	2	Código
TV_DETALLE	Character	25	Detalle
TV_PESO	Character	4,2	Peso promedio según estudio

E. *Responsables*

Nombre	PROPIETA.DBF		
Detalle	Registro de todos los responsables		
	Campos		
Nomnre	*Tipo*	*Ext.*	*Descripción*
PR_COD	Character	2	Código
PR_DETALLE	Character	25	Detalle

F. *Zona de Recolección*

Nombre	ZONA.DBF		
Detalle	Registro de todas las zonas de recolección		
	Campos		
Nomnre	*Tipo*	*Ext.*	*Descripción*
ZO_COD	Character	3	Código
ZO_DETALLE	Character	20	Detalle
ZO_UNIDAD	Character	7	Unidad de recolección
ZO_RESP	Character	2	Código de responsable

G. *Residuo*

Nombre	RESIDUO.DBF		
Detalle	Registro de todos tipos de residuo		
	Campos		
Nomnre	*Tipo*	*Ext.*	*Descripción*
RE_COD	Character	4	Código
RE_DETALLE	Character	25	Detalle

H. *Categoría de Residuo*

Nombre	CATEG.DBF		
Detalle	Registro de todas las categorías de residuo		
	Campos		
Nomnre	*Tipo*	*Ext.*	*Descripción*
CA_COD	Character	2	Código
CA_DETALLE	Character	20	Detalle

I. *Area*

Nombre	AREA.DBF		
Detalle	Registro de todas las áreas de la ciudad		
	Campos		
Nomnre	*Tipo*	*Ext.*	*Descripción*
AR_COD	Character	1	Código
AR_DETALLE	Character	10	Detalle

J. *Nivel de vida*

Nombre	NIVEL.DBF		
Detalle	Registro de todos los niveles de vida		
Campos			
Nomnre	*Tipo*	*Ext.*	*Descripción*
NI_COD	Character	1	Código
NI_DETALLE	Character	10	Detalle

IV. Recomendaciones Generales

- Como el sistema es implementado por primera vez en la AMDC, de aquí en adelante se tendrán que ir ajustándose a las exigencias diarias. Pero manejar una base de dato de las generaciones de los residuos es fundamental para la planificación futura de manejo de residuos sólidos.
- En la actualidad no se cuenta con una báscula y en estas condiciones es muy difícil obtener datos certeros de la generación. Tiene que ser una prioridad del departamento adquirir una báscula para ir obteniendo datos mas fiables.
- Se tendrán que ir ajustando las rutas de recolección, haciendo los estudios de tiempo y movimiento.

14.6 Evaluation on the Proposed System in the Master Plan by Pilot Projects

a. Campaign for Raising Awareness on Solid Waste Issues

a) The execution of the campaign project and the presentation of educational panels and films opened the eyes of the people to the environmental problems that currently prevail. The majority of community leaders and residents participated and cooperated fully during the campaign project.

b) The experiment made the people realize how dirty their towns are and how important appropriate solid waste disposal is. The continuation of the sanitary education programs will further motivate the people to continually keep their towns clean and beautiful.

c) Many people understand that the conduct of the campaign and sanitary education programs would significantly contribute to solving current environmental and health problems, as these programs are instrumental to the proper conduct of waste collection and disposal services. This is why the residents were considerably grateful for the conduct of the pilot projects.

d) The method of community education on solid waste used for the experiment was found to be very effective in San Martin, Ayestas and Tres de Mayo. Aside from slight modifications in accordance with town/city characteristics, the method is considered applicable to many areas and other cities in Honduras as well.

b. Experiment on the Implementation of the Best Collection System for Marginal Areas

a) The residents basically understood the container collection system, thanks mainly to the instructions given in the workshops. Due to time restrictions, however, it was impossible to confirm whether the residents kept the areas surrounding the containers clean. Nonetheless, there was no waste discharge in illegal dumpsites (A1 & A2) after the cleansing activities.

b) The campaign project, clean-up operations, and the collection experiment, carried out in the pilot project areas, helped to promote SWM improvement in other neighboring *colonias*, such as Zapote Norte west of Tres de Mayo, that requested the AMDC to provide equipment and a container for cleansing activities. The clean-up operation of Zapote Norte which took place on August 8, was carried out by the initiative of the residents, with the AMDC providing the cleansing equipment and the container.

c) Although there was a time constraint, it was possible to confirm, through the evaluation of the proposed objectives, that the experimental collection system were successful. The results were promising as residents in beneficiary areas were highly cooperative. Further, public motivation in the project areas spread to other neighboring *colonias*, that undertook their own clean-up operations with the help of the AMDC. The residents efforts are highly commedable and are seen as an invaluable achievement of this experiment.

c. Experiment on the Improvement of Existing Final Disposal

a) Implementation of the on-the-job training of AMDC staff and the installation of essential sanitary landfill facilities were very successful. AMDC's engineer quickly grasped all of the concepts that were explained to him, and attained the respect of fellow landfill staff and scavengers. His ability to manage, however, is greatly hindered by poor facilities.

b) Equipment operators are skilled and after only a few days of instruction and trials, sanitary landfilling methods were being carried out smoothly and in a professional manner.

c) The installation of basic facilities was done without problems and all were operating as planned at the end of the pilot project stage.

d) Scavengers cooperated and understood that the changes being made were also in their interests.

e) Even though every one was made clearly aware of the importance of sanitary landfilling methods and understood how to implement them. Once the experiment was over and the study team left, sanitary landfilling immediately ceased and the landfill staff reverted back to the previous landfilling methods. Because of institutional problems the AMDC administration is not supplying a sufficient amount of fuel for the bulldozers to continue applying the methods learnt.

f) Scavenging activities are again not being controlled. Frequent change is discouraging and confusing to them. Because constant supervision and assistance is necessary for the scavengers to gain confidence in the newly introduced methods.

g) Even though the condition of the disposal site markedly improved through the implementation of this experiment, sustained improvement is vital. And sustained improvement can only occur with institutional reform thus ensuring the provision of spare parts and fuel, the coordinating the use of landfill equipment, support for the proper management of the site and scavengers, and planning of future disposal activities.

d. Improvement of the Managerial Capability of the Cleansing Section

a) The SWM program for computer proved that the present record keeping system is unreliable because considerable data were found to be inconsistent. It can conclude that the improvement of basic information should go together with the improvement of management system.

b) Some of AMDC staff have realized the importance of monitoring the performance with the data.

Chapter 15

Preliminary Design for the Improvement and Overall Development of the Existing Disposal Site

15 Preliminary Design for Improvements and Overall Development of Existing Disposal Site

15.1 Introduction

During the first study phase a workshop was held to gain an understanding of the problems associated with current landfilling practice and to reach consensus on what needs to be done to counter these problems. Section 3.10 of the Master Plan describes the events of the workshop and how that with the participation of concerned stakeholders the "core problem" was identified as being **landfill site operations are inadequate**. Subsequently it was agreed upon that the central objective of an improvement plan should be the **improvement of landfill site operations**. This section continues on from this point by expanding on the objective and then formulating a plan for the improvement and overall development of the disposal site.

The central objective is expanded to include a *target group*, or expected beneficiaries. The target group is added in order to ascertain what improvements are required and to monitor these improvements. People living and working in the vicinity of the landfill and passing motorists using the Olancho Road (a busy road leading to the Department of Olancho) are the most affected by inadequate landfill operations and were chosen as the target group.

Therefore the overall development objective becomes to "Improve Existing Disposal Site Operations to Significantly Lessen the Impact on Locals and Passersby". To reach this objective various activities are necessary and these are described in detail in section 15.4.

Policies for the Improvement and Overall Development of the Disposal Site

An assessment of existing conditions in Honduras showed that there are various important factors that limit improvements. Taking into account these factors (i.e., lack of financial resources, low level of technical and managerial capabilities, etc) policies for the improvements plan and overall development of the disposal site are formulated.

- All improvements included in this plan propose applying suitable technologies, i.e., low cost technologies, facilities that can be constructed given the level of construction technology in Honduras, and can be operated and maintained by training available staff.
- The improvement plan proposes to continue using the existing landfill as preliminary studies have shown the existing site to have potentially several more years of use, and because new sites are traditionally difficult to develop due to environmental concerns of nearby residents.
- A safe and sanitary final disposal site. A major step towards achieving this is the proposed implementation of the cell method of landfilling. Waste is compacted in layers and covered daily, thickness no more than 3 meters, with a thin layer of cover soil to significantly reduce odor, windblown waste, water and gas intrusion, landfill fires, and the breeding of disease carrying vectors.

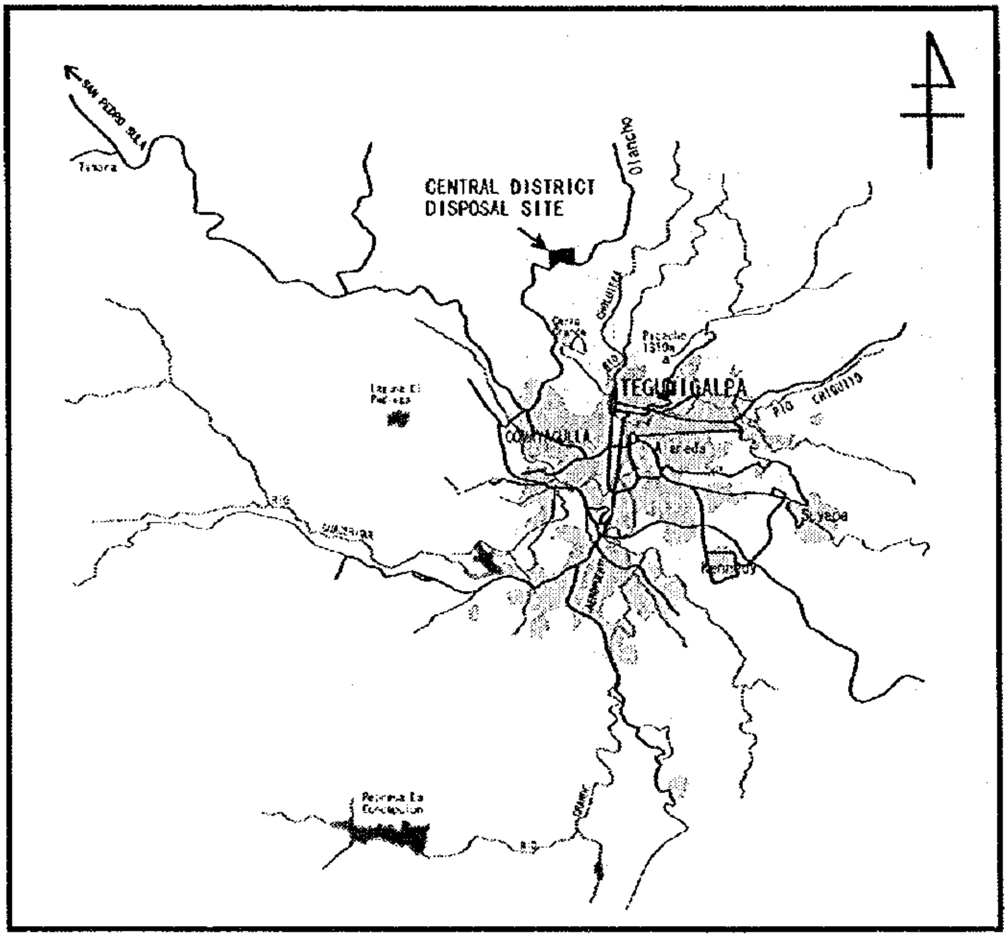
Further, leachate recycling is achieved by spraying collected leachate over the covered waste. Gas vents are installed at regular intervals to release gases generated by the anaerobic decomposition of organic waste.

- No plan for the installation of landfill gas energy recovery systems is proposed. Priority has been placed on getting the existing disposal site operating in an efficient and sanitary manner. Once this has been achieved a pilot project involving the processing of landfill gas could be undertaken.
- Supervision and monitoring of the site is maintained on a regular basis, during operation and after the site has reached capacity and has been closed, to ensure minimal impacts on the surroundings.
- Scavengers will be organized and controlled so that they do not disrupt the operation of the site. While landfilling activities take precedence over the activities of scavengers, scavengers are included in future development plans because they provide a valuable resource recovery system.

15.2 Location of the Central District Disposal Site

The Central District Disposal Site is located north of the Central District urban area at KM 6.5 on the Olancho Road in the Tusterique – Guanabano district (Figure 15-1:).

Figure 15-1: Location of Central District Disposal Site



15.3 Conditions of the Preliminary Improvement Plan

15.3.1 Site and Surroundings

The site is elevated between 1070 and 1150m above sea level and occupies 31.7 hectares of the valleys that form the Los Limones and Los Jutes creeks. Originally waste was disposed of solely in the Los Limones valley and was not visible from the Olancho Road, however, after 20 years of landfilling the waste hill has increased in size and is now partly within the water catchment of the Los Jutes Creek and is now clearly visible from Olancho Road and surrounding areas.

a. Surrounding the Site

Bounding the northern edge of the site, and running parallel to the Los Limones, is a high-voltage electricity trunk line. Beyond this and as far as the eye can see is sparsely populated undulating terrain, with patches of natural forest and small farms. Despite the severe pollution of the Los Limones and the effects of landfill fires, the forested areas bordering the northern edge of the disposal site are rich in native wildlife. Most of the farmland is either left idle or farmers are running some cattle or cultivating crops such as beans, corn, and bananas.

In the opposite direction lies another prominent feature, the Olancho Road, which bounds the site to the south. Along the Olancho Road, in the vicinity of the disposal site, exist several factories, storage depots, warehouses, gas stations, small convenience stores, businesses dealing in recovered waste materials, and residential areas. Businesses are mainly centered around the community of Cerro Grande a locality situated about 1.5 km in the Tegucigalpa direction (southwest) from the disposal site's access. The area between Cerro Grande and the disposal site forms a valley through which the Los Jutes Creek flows.

Both the Los Jutes and the Los Limones empty themselves into the Choluteca River, about 2 km to the east of the site.

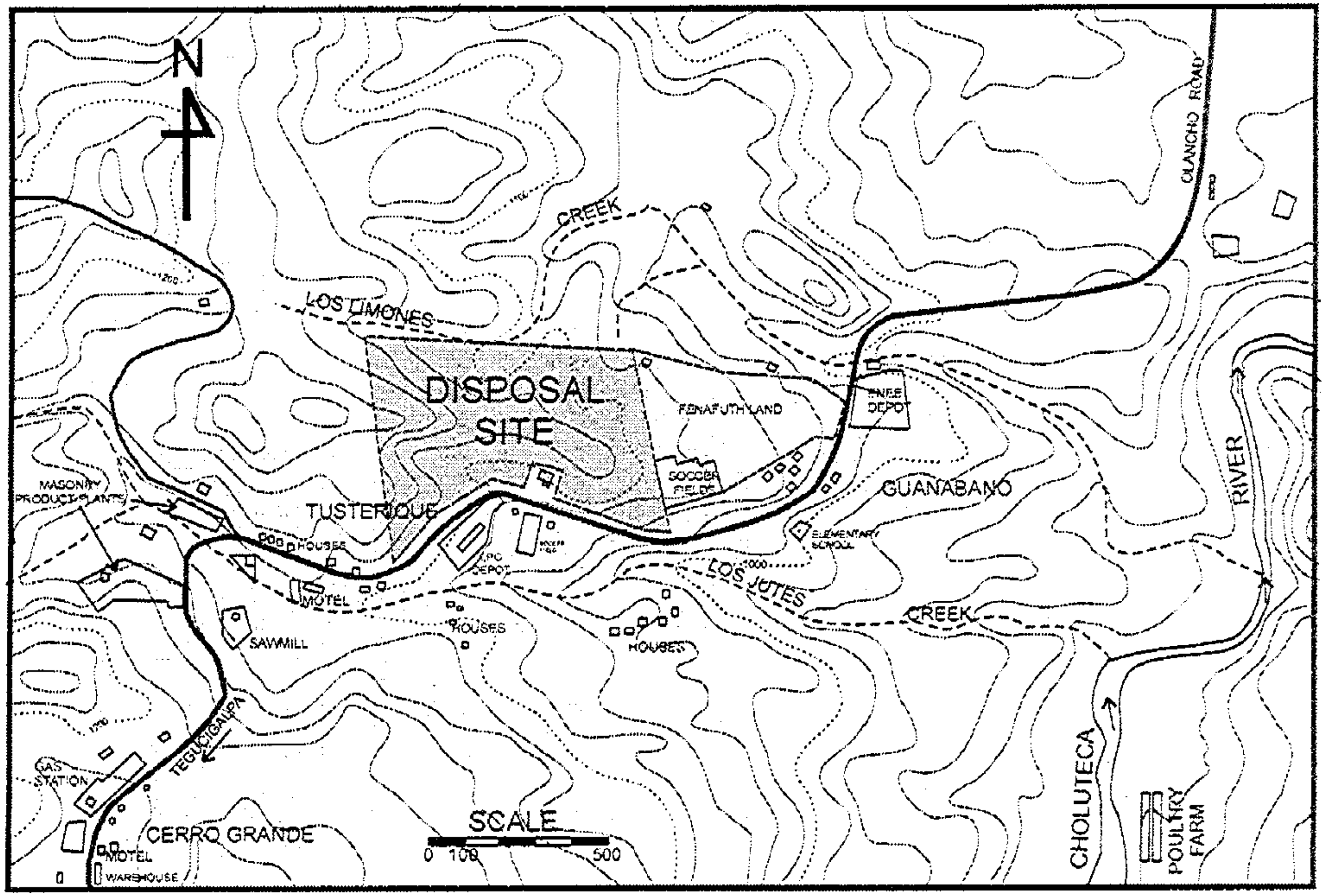
b. General Condition of Site

The disposal site receives, not only municipal solid wastes such as residential, commercial and institutional wastes, and garbage from public areas, but also construction debris, industrial, agricultural, agro-industrial, hospital wastes, among others. The Study Team estimated that in 1998 approximately 123,000 tons of waste will be disposed of at the final disposal site, that is equivalent to 428 tons of wastes are disposed of daily, except on Sundays, at the disposal site.

b.1. Existing Facilities within the Disposal Site

During the first study period in Honduras there was found to be no gate or instruction board at the entrance of the disposal site. The site was also not fenced to prohibit the entry of private individuals including vehicles. Therefore, various waste types are constantly being brought to the site. In addition, anybody, including children, can gain access to the site. The length of the access road from the entrance to the filling area is approximately 500 meters, 300 meters of which slope at approximately 8 % and is unpaved.

Figure 15-2: Map of Disposal Site and Surroundings



The site is equipped with only a small wooden hut, approximately $15m^2$ for the storage of a few tools and stationery owned by the AMDC. Equipment repair is conducted in the open. The site is not provided with a water supply system, water tank, or sewerage. Neither does it have toilets, facilities for personal hygiene or a communication system in case of emergency, should an accident occur. There are no stormwater drains in the site to protect access roads as well as the workers.

b.2. Landfill Operations

Three 215 Hp bulldozers, a wheel loader and three $8m^3$ dump trucks are operated at the site. The bulldozers are used for waste compaction and soil covering: two have blades for spreading waste, while one has a blade for spreading and leveling the cover soil. The wheel loader is used to excavate and load the cover soil, and the dump trucks are used to transport soil from the borrow pit within the site to the filling area. However, due to lack of diesel, at times this equipment are not being used. The bulldozers are only operated for about four to five hours daily, and the excavation and hauling of soil can only be carried out a few days a week.

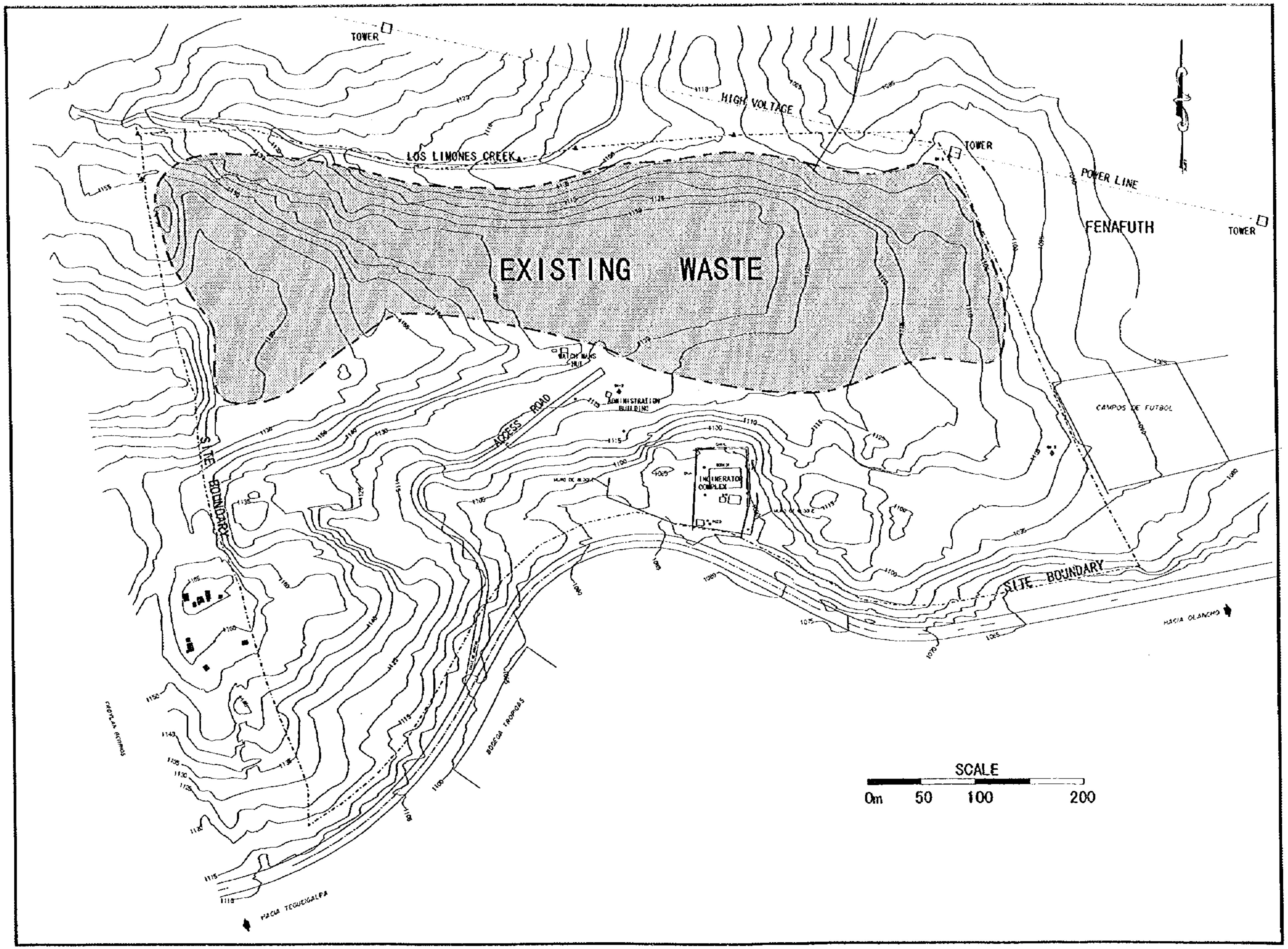
The AMDC employs four heavy equipment operators, three dump truck drivers and seven other staff including supervisors, foremen and workers. In addition, three mechanics commute to the site from the central workshop daily. One of the AMDC staff is in charge of counting the number of incoming vehicles at the site.

The site is not equipped with a bottom liner and leachate collection facilities for the landfill. To control leachate, a thick layer of soil is required. However, a large section of the landfill's embankment adjacent to the Los Limones Creek does not have soil cover, allowing leachate – as observed in several places – to flow freely into the creek.

The landfill site does not house any facilities to collect and control the landfill gas generated through the anaerobic decomposition of organic fractions in the waste. Neither does it have facilities or a plan to implement such facilities to control odor emission, vermin proliferation and the generation of fires inside the landfill. There are also no barriers to prevent the scattering of light waste, such as paper and plastic, and spraying cover soil with water to reduce dust is not carried out.

The landfill method employed is the formation of terraces between a hillside and a small creek. There are three terraces constructed at intervals of approximately 25m and 10m; the smallest is 35m above the level of the highway.

Figure 15-3 : Topographical Plan of Existing Disposal Site



15.3.2 Hydrological Conditions

The study on the hydrological conditions of the area is based on reports from previous investigations, namely the FRISA Engineering SA study, and investigations undertaken by the JICA study team during the first and second study phases.

a. Rainfall and Evaporation Data

Table 15-1: Meteorological Data taken at Toncontin International Airport

Month	Mean Rainfall[1] (mm)	Mean Pan Evaporation[2] (mm)
January	6.6	129
February	3.7	146
March	8.7	162
April	38.9	162
May	149.9	157
June	162.2	140
July	82.0	146
August	94.1	140
September	179.8	115
October	110.4	131
November	33.3	130
December	9.8	135
Totals	879.2	1694

The year is distinctly divided into two seasons: the wet season, from May to October, and the dry season, from November to April.

b. Surface Water Runoff

Lighter rainfall from November to April usually either infiltrates into the ground or evaporates and there is no runoff. Only rainfall from heavy showers, mainly occurring between May and October, make it to the two creeks near the site, the Los Limones to the north and Los Jutes to the south.

Generally flow in the Los Limones is intermittent flowing after heavy rains and as a result of leachate emanating from the landfill. The flow of leachate is constant throughout the wet season, while in the dry season the flow of leachate is reduced to near nothing and downstream reaches are usually dry. Therefore the quality of water is extremely poor, usually being dark brown or black in color.

Los Jutes on the other hand flows throughout the year, has a larger catchment and is spring fed. Runoff from the landfill rarely reaches the Los Jutes and when it does it is heavily diluted with the runoff from other sources.

The Los Jutes weaves through dense natural forest and the water is clear and appears to have no visible pollution problem, however, locals do not drink it and complain

[1] Rainfall data taken at Toncontin airport, 1948 to 1995
[2] Evaporation is estimated from evaporation pan levels taken at Toncontin airport, 1996 and 1997

that the water is difficult to lather. Tests of the water show it to have a pH of around 11.0; this is well above international water quality standards for drinking water and indicates a significant pollution source. About 1 km upstream from the disposal site and very near to the Los Jutes Creek are two plants that manufacture masonry products. It is therefore assumed that the discharge from these two factories is responsible for the high pH.

Both creeks empty into the Choluteca River, which is heavily polluted as a result of untreated influent from industry and households in Tegucigalpa.

c. Hydrogeology

According to the Hydrogeological Map of the Central Zone of Honduras (1995) the landfill site is located in an area of extensive Tertiary volcanics. These reach up to 400 m in thickness and consist of primarily of rhyolithic ignimbrites, interstratified volcanic sediments, reworked pyroclastics, and water deposited tuffs. Average borehole yields are in the order of 0.5 to 4 l/s and groundwater quality is generally high.

Results of the geological survey, undertaken during the second study phase (by GEOCONSULT), correspond with the above description. Core samples from five 10-meter deep test wells indicate that the geology of the site consists predominantly of 3 types of rock: rhyolite, weathered rhyolite, and tuffs.

c.1. Permeability in the area

The disposal site predominantly consists of the weathered rhyolite and volcanic ash. The permeability of the weathered rhyolite is estimated to be in the range 10^{-1} cm/sec to 10^{-3} cm/sec, while for the volcanic ash it is between 10^{-3} cm/sec and 10^{-6} cm/sec. So it is concluded that the natural geology of the disposal site is moderately to highly permeable.

c.2. Groundwater in vicinity of landfill

Though none of GEOCONSULT's test boreholes drilled for the geological survey hit the water table, there are indications that ground water flows near the surface in some places. During the second study period water filtering out of slopes and road cuttings was observed on the downstream side adjacent to the landfill. Further, residents in a nearby community (1 km. downstream from the landfill) have drilled wells and water has been found at shallow depths (between 6 to 8 meters).

Regarding groundwater quality, it is concluded from reports undertaken by SANAA and the Center to Study and Control Pollutants (CESCCO), and from conversations with locals that water from wells on the downstream side of the landfill, (i.e., in the general direction of the Choluteca River) and in the vicinity of the Los Limones Creek, that ground water is heavily contaminated. As there are no other significant pollution sources in the area and because the pollution is consistent with what is expected from leachate contamination it is concluded that the pollution source is the disposal site.

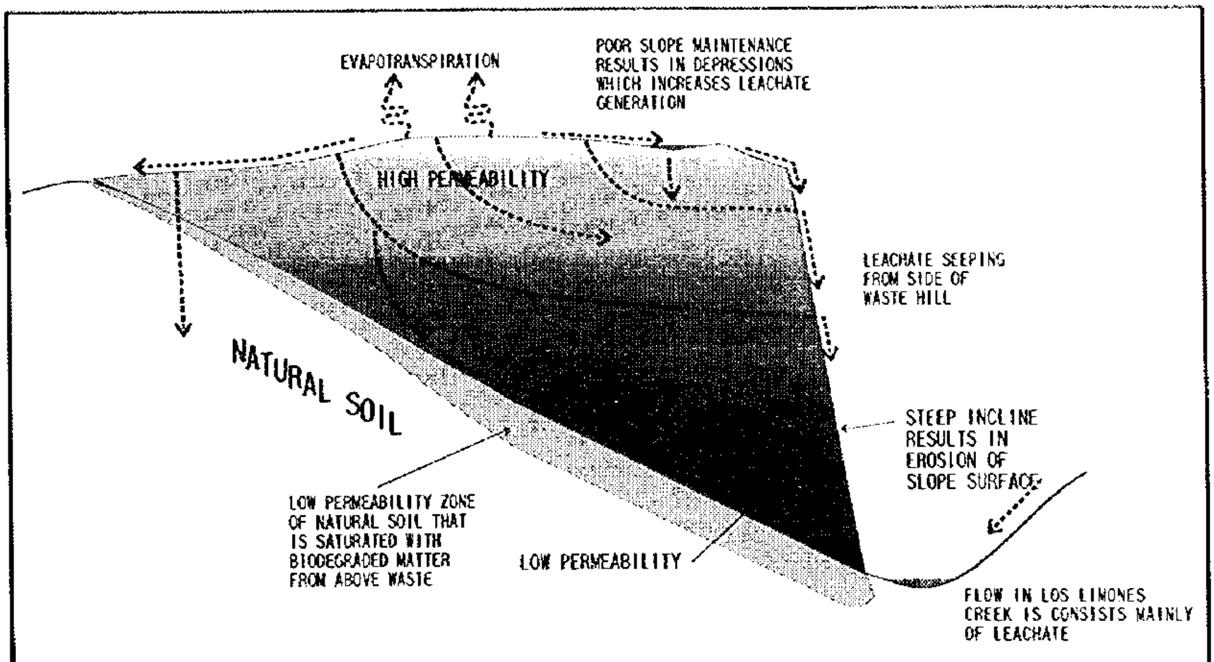
At present water is being pumped from a well to the west (and upstream) of the disposal site for human consumption. During the second study phase local residents were installing a 2" PVC pipe along the Olancho Road to conduct water to households on the downstream side.

c.3. Permeability of Existing Waste Hill

The permeability of the existing waste hill has significant differences to underlying geology so it is assessed separately. The first layers of the landfill were placed in the late 1970s. The natural biodegradation process of the bottom layers is now virtually complete meaning that the waste has broken down in to very smaller particles. With the addition of the over burden pressure from above (the landfill hill is over 30 meters high in places) the material near the bottom of the landfill is fine grained and well compacted. The permeability of the bottom layers is, therefore, assumed to be significantly lower than more recently placed layers above. Moreover the pores of the underlying natural soil are assumed to have been saturated with the small particles resulting from the biodegradation process, thus decreasing the permeability.

Based on the above and because the previous soil covering and compaction of slopes has been poor the flow of leachate through the landfill is reckoned to be as shown in the following figure.

Figure 15-4: Flow through the Existing Landfill



15.3.3 Availability of Cover Material

a. Background

Cover material has the purpose of isolating the deposited solid waste from the surrounding environment, in such a way as to create anaerobic conditions in order to obtain microbiological stability in the shortest period possible; additionally, it is needed to prevent rainwater from infiltrating. Cover material thickness should be at least 15 cm to ensure the conditions previously stated and to prevent fly larvae from migrating to the surface. Final cover should be, at least, 60 cm thick.

Intermediate and final cover effectiveness will be determined by the material characteristics and techniques employed to place it.

The two main characteristics of cover material are permeability and field (water retention) capacity. These two properties determine the infiltration capacity and, consequently, the potential production of leachate from rainfall.

The U.S.C.S (Unified Soil Classification System) classifies soils by particle size and by proportion of sand, silt and clay. In general, a well-graded mix has a lower permeability than soil with uniform sized particles. The permeability of different types of soils can be quantified by the permeability coefficient, K, which is a function of its texture and structure.

A cover material's field capacity describes a soil's capacity to absorb or, at least, hold temporarily water within the cover layer that would otherwise permeate into the landfill.

Taking into account the problems associated with water infiltration at landfill sites and neighboring populations, it is absolutely necessary to control rainfall infiltration and prevent liquids contained inside the landfill from reaching the surface. This can be achieved by using a suitable cover material and placing it correctly.

Cover material to be employed at the cells should be homogeneous; and have a permeability coefficient of no less than 10^{-4} cm/sec. This material should be compacted sufficiently in order to obtain on-site a permeability as close as possible to the optimum value for the material being used. This material should not have bricks, debris, or waste. Nor more than 5% of particles larger than 50mm and none should exceed 4".

Sanitary landfill operation becomes easier if cover material is found in good quantity and quality nearby the disposal site. If material is brought from far away its acquisition becomes expensive resulting in increased operation costs that may cause the continued use of a disposal site to be infeasible.

b. Cover Material available at Tegucigalpa's final disposal

GEOCONSULT's report and soil mechanic tests (including bores and drilling up to 10 meters deep) show that the potential cover material found in the southwestern and southeastern sectors has the following characteristics.

The predominant material is sandy clayey gravel derived from weathered rhyolite and gravely silty sand derived from tuffs (volcanic ash); both materials are available at the borrow sites where they can easily be removed; they are easily distinguished by rhyolite's purplish color and the tuffs' yellowish color.

In general, both predominant materials at the site can be used for cover material; although clayey gravel derived from weathered rhyolite can reach a higher degree of compaction. In addition non weathered rocks of different sizes are found at the disposal. These are the rhyolite and black vitrified lava rocks in color and can not be used due to their hardness.

c. Estimate of Amount of Available Cover Material

Based on the topographical survey made by CINSA and the geological data obtained by GEOCONSULT which is shown in the following table (Table 15-2), calculations were made to obtain an estimate of available cover material.

Table 15-2: GEOCONSULT's Geological Test Results

Boring No.	Max. useful depth (m)	Rock (%)	Weathered Rhyolite or derivative (%)	Tuffs (%)	Total (%)
1	6.00	15	85	0	100
2	Discarded (waste)	-	-	-	-
3	8.00	30	70	0	100
4	10 or more	5	45	50	100
5	10 or more	20	20	60	100

Boring 1 and 2 are located in the southeastern sector, while boring 3, 4, and 5 are located in the southwestern sector nearby the entrance gate.
Calculations show that in the southeastern sector (Area A_2) there is approximately 40,000 m^3 and in the southwestern (Area A_1) sector there is 290,000 m^3 of cover material available. These amounts ensure the development of the sanitary landfill with cover material coming from the existing disposal site until mid 2007 (see Table 15-3).

15.3.4 Space Available for Landfilling and Future Utilization

The total amount of space required for the disposal of waste until the year 2010 was calculated based on waste quantity projections determined in earlier sections and the assumption that the amount of cover soil necessary for sanitary landfilling is approximately 15% of the waste amount. This figure is rather conservative as it allows for the construction of additional works such as earth walls and embankments.

Table 15-3: Calculation of Disposal Site Space Requirements

Year	Waste Received tons/year	Cumulated waste amount tons	Compacted waste (D=0.8) m³	Cumulated Compacted Waste	Cover Soil m³	Cumulated Cover Soil m³	Required Capacity
1998	129,000	129,000	161,250	161,250	24,188	24,188	185,438
1999	131,000	260,000	163,750	325,000	24,563	48,750	373,750
2000	139,000	399,000	173,750	498,750	26,063	74,813	573,563
2001	166,000	565,000	207,500	706,250	31,125	105,938	812,188
2002	177,000	742,000	221,250	927,500	33,188	139,125	1,066,625
2003	189,000	931,000	236,250	1,163,750	35,438	174,563	1,338,313
2004	219,000	1,150,000	273,750	1,437,500	41,063	215,625	1,653,125
2005	235,000	1,385,000	293,750	1,731,250	44,063	259,688	1,990,938
2006	250,000	1,635,000	312,500	2,043,750	46,875	306,563	2,350,313
2007	266,000	1,901,000	332,500	2,376,250	49,875	356,438	2,732,688
2008	303,000	2,204,000	378,750	2,755,000	56,813	413,250	3,168,250
2009	323,000	2,527,000	403,750	3,158,750	60,563	473,813	3,632,563
2010	344,000	2,871,000	430,000	3,588,750	64,500	538,313	4,127,063

a. Available Space

Taking into account the information obtained from a visual inspection of the site, what long time workers conveyed to us, and estimations produced about cover material extracted from two sectors; we can make an approximation about the available space.

'Area A' all those areas where no landfilling has occurred and where cover material is presently being extracted. 'Area B' is all areas where landfilling has been done and landfilling can take place in the future. 'Area C' those areas where landfill has been done and waste can not be placed anymore at the site. And 'Area Z' those areas that can no longer be used for landfilling and will be used as a buffer zone.

We propose landfilling should be done using terraces. The available space is estimated as shown below.

Table 15-4: Landfilling by Area

Area	Period Filled	Area (m^2)	Average landfill height	Available space (m^3)
A_1	2005-6	40,000	20	800,000
A_2	2000	20,000	12	240,000
B_1	2001-4	84,000	12	1,008,000
B_2	1998-1999	27,000	16	432,000
C	-	30,000	no further filling	-
Z	-	116,460	no further filling	-
Totals		317,460	60	2,440,000

Current available space inside the final disposal site is 2,440,000 m^3, which according to Table 15-3 is sufficient until early 2007. This figure also corresponds with the amount of cover material presently available within the site.

It should be pointed out that after all the cover material has been extracted around 40,000 m^3 of boulders remain which have limited use at the landfill. It is recommended that this rock be used for civil works round the Central District.

b. Future Use

It is convenient to continue working in B_2 during 1998 and 1999 by creating a platform. We should take advantage of the proximity of A_2 to extract as much cover material as possible.

Landfilling should begin in Area A_2 from the year 2000; this area is located close to the Olancho Road so it is necessary to install a fixed mesh waste fence along the southern perimeter to prevent waste blowing onto the road. During the filling of this area cover material should be extracted from Area A_1. From 2001 to 2004, the filling of B_1 will be executed, beginning from the western boundary of the site and filling towards the east, continuing all the way until areas A_2 and B_2 along the eastern boundary of the site.

The filling of A_1 will begin around the start of 2005, and continue until the capacity of this section has been reached. Cover soil for Area A_1 will be obtained from the same area so it is important that provision be made in the filling plan for this area for this, i.e., stockpiling soil.

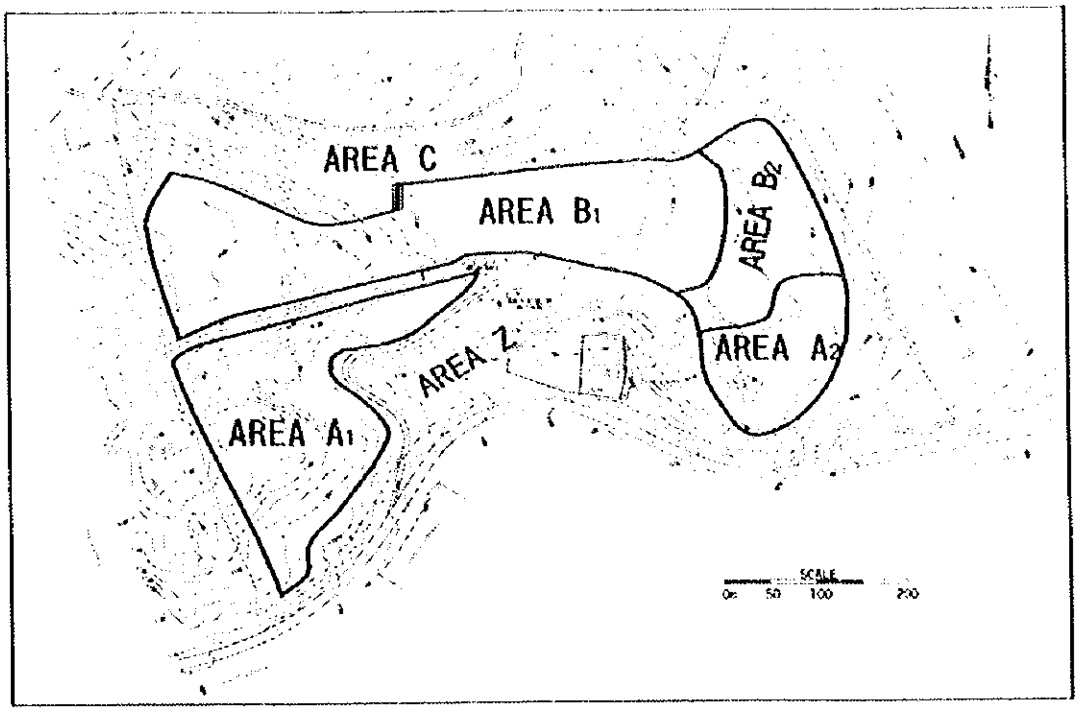


Figure 15-5: Division of Disposal Site

It is possible to use more of Area A_1, i.e., up to the boundary with Olancho Road for landfilling and as a source of cover material. However, due to aesthetic reasons and its proximity to Olancho Road, this is considered unacceptable and it is proposed that this area preserved as a buffer zone.

15.3.5 Waste Composition

The landfill is expected to receive the following types of waste:

- Residential waste (e.g. food waste, paper, plastics, etc.)
- Bulky waste (furniture, refrigerators, etc.)
- Commercial waste (from shops and restaurants)
- Market waste (mainly vegetables and paper)
- Institutional waste
- Garden waste
- Street sweeping waste
- Industrial waste (non hazardous waste)
- Construction and demolition waste.
- Stabilized non-toxic dry sewage sludge

The most common type of waste to be disposed at the new landfill will be waste from residential areas, i.e. waste mainly derived from households and including a substantial portion (60 %) of organic matter.

Until the current problem concerning the incinerator situated adjacent to the disposal site is solved, infectious waste, hypodermic syringes, etc., from hospitals, clinics and dentists should be deposited in a separate section of the landfill.

Disposal of hazardous and chemical wastes (batteries, paint residues, infectious waste from hospitals etc.) should not be allowed on the sanitary landfill. These types of waste must be collected separately and treated chemically or by incineration to neutralize them before being disposed of in the disposal site. Thus, the landfill will not receive the following types of waste.

- Hazardous and toxic waste from industries, commerce, institutions etc.
- Radioactive waste of any type.
- Liquid waste of any type.

15.3.6 Landfill Gas

a. Introduction

Organic solid waste deposited at the sanitary landfill decomposes fundamentally through the process of anaerobic biodegradation. This process includes the methanogenic phase where a combustible gaseous mixture is release as a result of microbial activity. This mixture is volumetrically composed of methane (50 to 65%), carbon dioxide (30 to 45%), in addition to soluble ammonium ions and other gases such as H_2, N_2, and H_2S. The calorific potential of this mixture is around 4,500 $Kcal/m^3$.

Gas produced by sanitary landfill forms an inflammable mixture that can reach concentrations of between 7% and 21% in the air. Therefore, the existing disposal site is planned with landfill gas venting and controlled gas disposal systems with the purpose of preventing fires or explosions at the disposal site or surrounding areas.

b. Landfill gas production at the sanitary landfill site

Through a stoichiometric model and the chemical formula for organic waste, the maximum theoretical production amount of landfill gas produced by waste can be determined.

This theoretical amount represents a maximum value. Domestic solid waste, as it is discharged at the landfill site, produces less than the theoretical amount because the following factors are not considered:

- A large percentage of the waste is water
- Part of the waste is inorganic; and does not generate landfill gas
- Part of the organic content decomposes very slowly
- Some organic waste decomposes aerobically during the initial stage.

It is calculated that maximum landfill gas production (derived from a stoichiometric model) can reach between 800 and 1000 l/kg. If this value is adjusted, taking into account above factors, this figure decreases to between 200 and 300 l/kg.

If we consider just the landfill gas amount that can actually be extracted which will be flared, the figure becomes even smaller due to surface and lateral landfill gas migration. Additionally, the methane concentration must be sufficiently high to burn, further reducing the figure.

Previous experimental results point out that it is possible to obtain between 50 to 80 m^3 of landfill gas per ton of domestic solid waste, as they are discharged in the landfill site over a period of 10 years.

c. Landfill gas production at the AMDC sanitary landfill site

Landfill gas production derived from a ton of waste is not constant in time; the highest amount is registered in the first two years and then decays slowly in the next years.

In order to simplify our calculation and to obtain an approximate landfill gas useful production, we will consider that a ton of waste produces 70 m^3 of landfill gas during a 10 year period at a constant rate of 7 m^3/year; annual waste production will also be considered. As a result, landfill gas production until 2010 will be as shown in the following table.

Table 15-5: Estimation of Annual Landfill Gas Production

Year	Waste Production (tons/year)	Landfill gas Production (m^3/year)	Landfill gas Production (m^3/day)
1999	131,000	917,000	2,512
2000	139,000	1,890,000	5,178
2001	166,000	3,052,000	8,362
2002	177,000	4,291,000	11,756
2003	189,000	5,614,000	15,381
2004	219,000	7,147,000	19,581
2005	236,000	8,799,000	24,107
2006	250,000	10,549,000	28,901
2007	266,000	12,411,000	34,003
2008	303,000	14,532,000	39,814
2009	323,000	15,876,000	43,496
2010	344,000	17,311,000	47,427

Landfill gas generation shown in Table 15-5 does not include landfill gas generated as a result of waste discharged before 1999. Beginning in 2009, the rate in increase in the generation of landfill gas begins to slow as older waste stabilizers. Once the no more waste is being brought into the site the generation of gas begins to steadily decreases until the amount of landfill gas generated is negligible. This is forecast to happen 10 or more years after closure.

15.3.7 Leachate Generation

Liquid that has percolated through solid waste is term leachate. Leachate from landfills usually contains extracted, dissolved, and suspended materials, some of which may be harmful.

The amount of leachate generated was calculated for two different conditions. Firstly, for leachate generated under existing conditions, and secondly for leachate generated once improved landfilling method are being carried out.

a. Leachate generation under existing conditions

Previous landfilling practice has been poor. Because of inadequate covering and compaction, indiscriminant burning, poor surface drainage, and the layered nature of the landfill, each being of unknown age and depth, it is now very difficult to predict the amount of leachate generated or its composition through traditional methods.

Therefore the amount of leachate currently being generated was determined by field observations. It was observed that between December and April rainfall falling onto the landfill either evaporated or infiltrated and is consumed in the biodegradation process, little if any moisture becomes leachate. Approximately 0.1 l/sec percolates from the landfill. Then from May, when the first significant rains occur the moisture content of the waste increases until the soil and waste is saturated, from then on leachate flows out. Because of the large size of the existing waste hill it is expected that the recharging of the landfill will take over a month.

Then from sometime in June leachate begins to flow from the waste. Field observations estimate that between 3 and 5 liters of leachate per second is emanating from the landfill. This flowrate remains consistent until the rainfall decreases in October and the flowrate peters out to near zero in November.

It is assumed that 4 L/sec. of leachate flows from the landfill into the Los Limones Creek between June and November. A further 1 L/sec. is estimated to be infiltrating into the ground below the landfill.

Given that approximately 13 hectares of the site is covered with landfilling it is calculated that on average approximately 500 mm/year (or 55%) of the total rainfall percolates into the waste hill. Taking into account that the landfill has poor surface drainage characteristics and ponding is common, poor cover soil practice, and because waste burning is common (reducing the amount of water consumed during anaerobic degradation) this estimate is reasonable.

b. Leachate Generation from Improved Landfilling Methods

Improved landfilling methods include daily covering of disposed waste with a low permeability layer of soil, improved grading of slopes and installation of catch drains to reduce ponding, and finally the application of an impermeable final cover layer and the growing of grass and trees.

The estimation of the amount of leachate generated for this case was estimated using the water balance calculation ('Top Layer' model) for two the cases (intermediate cover layer and final cover layer).

$$Q_L = P-(R+EVT)+CMD$$

Q_L:	Leachate generation (mm)
P:	Precipitation (mm)
R:	Runoff (mm)
EVT:	Evapotranspiration (mm)
CMD:	Cover material deficit (mm)

Case A: **Intermediate cover layer**

Thickness of intermediate layer :	150 mm
Material:	Sandy clay.
Slope:	2-18%
Surface Runoff (C):	0.2
Field Capacity (FC)[3]:	14%
Permanent Wilt Percent (PWP)[4]:	6%
Moisture Storage Capacity (FC-PWP):	8% or 12 mm
Evapotranspiration as percentage of evaporation:	45%

Determination of the actual evapotranspiration at the disposal site requires knowledge of various data (e.g., rainfall data, temperature, solar radiation, wind speed, etc.), as well as soil and vegetation data. Much of this data is scarce in Honduras so it was estimated based on experience of the study team.

For the intermediate cover case evapotranspiration is estimated to be 45% of the pan evaporation value. This assumes that there is no vegetation growing on the intermediate layer and hence very little transpiration. Field capacity and permanent wilt percent were estimated according to the soil type (sandy loam).

Table 15-6: Intermediate Cover — Water Balance

Month	Mean Precipitation (1944-1995) (mm)	Mean Pan Evaporation (1996, 1997) (mm)	Runoff (mm)	Evapotranspiration	Moisture gain (+) or loss (-)	Cover material deficit	Leachate Generation
January	6.6	129	58.05	1.40	-52.45	-12.00	0.00
February	3.7	146	65.7	0.80	-62.50	-12.00	0.00
March	8.7	162	72.9	1.80	-65.70	-12.00	0.00
April	38.9	162	72.9	7.80	-41.70	-12.00	0.00
May	149.9	157	70.65	30.00	49.35	0.00	49.35
June	162.2	140	63	32.40	66.60	0.00	66.60
July	82.0	146	65.7	16.40	-0.10	-0.10	0.00
August	94.1	140	63	18.80	12.20	0.00	12.20
September	179.8	115	51.75	36.00	92.25	0.00	92.25
October	110.4	131	58.95	22.00	29.05	0.00	29.05
November	33.3	130	58.5	6.60	-32.10	-12.00	0.00
December	9.8	135	60.75	2.00	-52.75	-12.00	0.00
Total							249.45

[3] Tchobanoglous, Teisen, Vigil, *Integrated Solid Waste Management—Engineering Principles and Management Issues*, 1993, p. 456.
[4] Ibid.

Case B: Final cap and Surface egetation

Thickness	600 mm
Material	Sandy clay.
Slope	2-18%
Surface Runoff (C)	0.15
Field Capacity (FC)	14%
Permanent Wilt Percent (PWP)	6%
Moisture Storage Capacity (FC-PWP)	8% or 60 mm
Evapotranspiration as percentage of evaporation	70%

The surface vegetation restricts the surface runoff so the runoff coefficient is estimated to be less than for Case A. Vegetation also increases transpiration and hence increases evapotranspiration, so the potential evapotranspiration is estimated to be 70 % of the pan evaporation value.

Table 15-7: Final Cap and Surface Vegetation — Water Balance

Month	Mean Precipitation (1944-1995) (mm)	Mean Pan Evaporation (1996, 1997) (mm)	Runoff (mm)	Evapotranspiration	Moisture gain (+) or loss (-)	Cover material deficit	Leachate Generation
January	6.6	129	90.3	1.05	-84.35	-60.00	0.00
February	3.7	146	102.2	0.60	-98.80	-60.00	0.00
March	8.7	162	113.4	1.35	-105.75	-60.00	0.00
April	38.9	162	113.4	5.85	-80.25	-60.00	0.00
May	149.9	157	109.9	22.50	17.60	-42.40	0.00
June	162.2	140	98	24.30	39.70	-2.70	37.00
July	82.0	146	102.2	12.30	-32.50	-35.20	0.00
August	94.1	140	98	14.10	-18.10	-53.30	0.00
September	179.8	115	80.5	27.00	72.50	0.00	72.50
October	110.4	131	91.7	16.50	1.80	0.00	1.80
November	33.3	130	91	4.95	-62.95	-60.00	0.00
December	9.8	135	94.5	1.50	-86.00	-60.00	0.00
Total							111.30

Annual leachate generation is approximated at 110 mm/year under final cover layer conditions, 250 mm/year under the intermediate cover conditions, and 500 mm/year under existing conditions. These generation results are then multiplied by corresponding areas in accordance with the filling schedule described in section 15.3.4 as well as the FENAFUTH land that is tentatively proposed as the disposal site between 2006 and 2010 to determine the amount of leachate generated each year.

The waste within Area C has been there for various periods, some dating back to the 1970s therefore the strength of the leachate emanating from this area will be lower than leachate generated from recent disposal. Also the topography of Area C is very steep. Taking both these factors into account it is assumed that leachate emanating from this area will gradually decrease until around 2008 when no leachate will be generated.

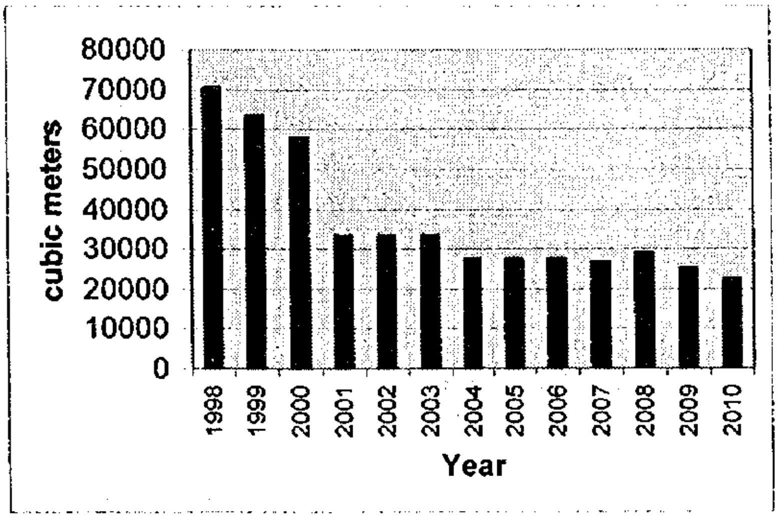
Area D means the FENAFUTH extension. This will be gradually brought in to use from the year 2006. It is tentatively projected that 2 hectares will be opened up each year.

Table 15-8: Leachate Production by Area (m³)

	Area A_1			Area A_2			Area B_1				Area B_2				Area C				Area D			Maximum Leachate (m³)
	I	F		I	F		E	I	F		E	I	F		E	I	F		I	F		
1998	0	0	0	0	0	0	8.4	0	0	42000	2.7	0	0	13500	3	0	0	15000	0	0	0	70500
1999	0	0	0	0	0	0	8.4	0	0	42000	0	2.7	0	6750	3	0	0	15000	0	0	0	63750
2000	0	0	0	2	0	5000	4.2	4.2	0	31500	0	0	2.7	6750	3	0	0	15000	0	0	0	58250
2001	0	0	0	0	2	2200	0	8.4	0	21000	0	0	2.7	2970	0	3	0	7500	0	0	0	33670
2002	0	0	0	0	2	2200	0	8.4	0	21000	0	0	2.7	2970	0	3	0	7500	0	0	0	33670
2003	0	0	0	0	2	2200	0	8.4	0	21000	0	0	2.7	2970	0	3	0	7500	0	0	0	33670
2004	0	0	0	0	2	2200	0	4.2	4.2	15120	0	0	2.7	2970	0	3	0	7500	0	0	0	27790
2005	4	0	10000	0	2	2200	0	0	8.4	9240	0	0	2.7	2970	0	0	3	3300	0	0	0	27710
2006	4	0	10000	0	2	2200	0	0	8.4	9240	0	0	2.7	2970	0	0	3	3300	0	0	0	27110
2007	0	4	4400	0	2	2200	0	0	8.4	9240	0	0	2.7	2970	0	0	3	3300	2	0	5000	29310
2008	0	4	4400	0	2	2200	0	0	8.4	9240	0	0	2.7	2970	0	0	3	3300	2	2	7200	29310
2009	0	4	4400	0	2	2200	0	0	8.4	9240	0	0	2.7	0	0	0	3	0	2	4	9400	25240
2010	0	4	4400	0	2	2200	0	0	8.4	9240	0	0	2.7	0	0	0	3	0	0	6	6600	22440

E: area (ha) under existing conditions, I: area under intermediate conditions, F: area under final conditions

Figure 15-6: Leachate Production from Existing Disposal Site, 1998 to 2010



The annual leachate generation amount is then plotted (Figure 15-6) to show the trend. This chart indicates an immediate reduction in the amount of leachate generated as the new cell method is implemented and surface runoff is improved. The decrease continues until 2001, stabilizing once improved methods are being utilized in all existing and new areas.

Leachate generation will continue beyond 2010. However, over time the strength of the leachate will decrease as the waste in the landfill stabilizes. This has possibly already occurred to a large degree in the lower layers.

c. Leachate Composition

The following table presents the typical compositions of "young" leachate from 2-5 year old landfill sections and "old" leachate from older landfill sections. The compositions are based on experience from Japanese and European sanitary landfills receiving municipal solid waste only, i.e. mainly waste from households.

A substantial variation in the leachate composition is usual from landfill to landfill, depending on the actual type of waste being disposed of. However, it is assumed that the composition of leachate from the Central District landfill will be similar to the compositions presented in Table 15-9.

Table 15-9: Forecast for the Leachate Composition.

Typical leachate composition	'young' leachate	'old' leachate
pH	6-7	7-8
BOD_5 mg/l	15,000	200
COD mg/l	21,000	2,000
NH_4-N mg/l	900	900
TN mg/l	1,000	1,000
TP mg/l	Max. 15	Max. 15
Cl mg/l	2,000	2,000
Na mg/l	1,500	1,500
Ca mg/l	1,200	100
Sulfate, SO^{2-}_4 mg/l	500	20
Sulfide, S mg/l	0	- varies -
Fe mg/l	500	25
Zn mg/l	Max. 10	Max. 0.5
Pb mg/l	Max. 0.5	Max. 0.05
Cr mg/l	Max. 0.5	Max. 0.05
Cd mg/l	Max. 0.1	Max. 0.01

Source: RAMBOLL's (Danish consultants) experience from supervision of many landfills receiving municipal solid waste (i.e. not including cinders/fly ash from waste incineration).

15.3.8 Identification of Problems

As a result of the lack of adequate infrastructure and the poor operation of the site the following environmental problems are occurring. Environmental problems do not just impact the immediate site but surrounding areas as well.

a. Propagation of Parasites and Microorganisms

The Central District's high proportion of organic municipal solid wastes and year round warm weather makes the waste a suitable medium for the rapid proliferation of parasites and microorganisms. The current operation of the landfill leaves waste uncovered over long periods, allowing all types of animals to feed on the waste and scavengers, including children, to have direct contact with the waste. This type of operation converts the disposal site into a fertile breeding ground of parasites and microorganisms.

People and animals become mediums for parasites and microorganisms. Pathogens are transmitted to populated centers or homes, causing some of the serious diseases that prevail in the area.

b. Water Resource Modification

Flat plain areas resulting from landfilling works are not provided with sufficient slope and ponding is common following rains. Ponding is a problem because it results in greater amounts of water infiltrating into the waste and hence generating leachate. Ponding also provides a breeding area for mosquitoes as well as obstructing vehicles.

Catch drains are not constructed so surface flows uncontrolled within the site. Uncontrolled runoff has resulted in leachate contaminated runoff flowing into the Los Jutes Creek. Moreover, steep slopes formed by poor landfilling practice increase erosion of soil.

For the existing disposal site, the amount of leachate produced is difficult to quantify as it either infiltrates the ground or is drained over the hillside and runs toward Los Limones Creek. Several observations made in February confirmed a leachate flow of no more than 0.1 l/sec. However, during the rainy season, leachate production is higher and was observed to be flowing at approximately 4 l/sec.

c. Air Modification

There is no landfill gas removal system or system to flare the gas, the latter resulting in the conversion of methane (CH_4) to CO_2 and H_2O – compounds that cause less harm to the atmosphere. Methane and other landfill gases are flammable and potentially toxic; posing a risk to public health as well as being an occupational hazard for landfill workers and scavengers. Flaring is a recommended means to remove the harmful properties of landfill gas. In the case of the existing disposal site methane production may not be that high, as the aerobic decomposition of other waste constituents due to the daily combustion of organic matter produces no methane.

Uncovered waste, the burning of waste, landfill gas and leachate all contribute to the emission of odor. Odor diffuses and affects nearby areas, including sites along the highway to Olancho, in varying degrees depending on the velocity and direction of the wind.

Dust results from suspended particles generated by the transportation of cover material, vehicular traffic into and within the landfill site, and wind. This problem, however, has the least effect on air conditions and only occasionally affects areas beyond the landfill limits.

Compounding air pollution problems generated from the disposal site is the fact that the prevailing wind direction is from the north[5] meaning the populated areas to the south and southwest are specially impacted by emissions from the disposal site.

[5] Source: Wind data recordings taken at Toncontin International Airport

d. Land and Landscape Deterioration

Previous poor landfilling methods, in particular filling resulting in the steep slopes observed along the northern edge of the existing disposal site cause several problems. Firstly the risk of slope failure is increased, which has occurred in some parts of the landfill and is likely to occur more frequently as the waste hill increases in size. Secondly, it is very difficult to establish a compacted cover layer on steep slopes existing at the landfill as vehicles cannot traverse such steep terrain, and leachate flows freely from the slopes, and fast flowing surface runoff erodes any cover that may develop. Finally, future development of the land is severely restricted, and the steep slopes are a hazard.

Light wastes, e.g. paper and polyethylene shopping bags, that are scattered due to wind also influence soil conditions and adversely affect humans and animals that make use of the surrounding vegetation.

The extraction of soil for use as waste cover material also affects soil characteristics. Hence, it is necessary to take measures that will allow the soil to recover after the landfill is closed.

As a large part of the waste in the disposal site is currently left uncovered or uncompacted over long periods, the wind often scatters it outside the final disposal site boundaries. This destroys the beauty of landscapes inside and outside the final disposal site. Furthermore, this condition complicates the use of soil for landfilling, as frequent soil cleaning prior to use becomes a necessity.

e. Visual Obtrusion

The height of the landfill has increased to the point that it is now clearly visible to from the Olancho Road and nearby areas. This causes two visual problems first, the landfill hill is barren and unattractive. Second, wind-blown waste now has no natural obstacle and freely scatters round areas to the south of the site, i.e., residences and businesses.

Further waste falling off the back of collection vehicles and the reckless activities of dealers of recovered waste materials located along Olancho Road means that the road is heavily littered and is an eyesore to passersby.

f. Road Safety

The exit from the landfill is very dangerous. The Olancho Road near where the disposal site's access road meets is a gentle curving high-speed section of road. This is one of the first sections of roads where vehicles can overtake slower ones as they leave the built-up urban areas of Tegucigalpa. The problem is acerbated by poor visibility caused by a large hill blocking the vision of the drivers.

During the study phases many vehicles were observed overtaking and several times this resulted in near misses between smaller vehicles speeding away from Tegucigalpa and larger collection vehicles exiting the site. Any accident occurring at this point is likely to be catastrophic.

15.4 Preliminary Improvement Plan

The preliminary improvement plan for the existing disposal site has been set out in a logical manner, Figure 15-7outlines the logical links between the activities and the overall development objective.

Figure 15-7: Logical Links

OVERALL DEVELOPMENT OBJECTIVE

Improve the operation of the existing disposal site to significantly lessen the impact of landfill activities on locals and passersby

↑

IMMEDIATE OBJECTIVES

- A Landfill controlled
- B Landfilling methods improved
- C Buffer zone in place
- D Litter reduced along main road leading to landfill
- E Road safety at intersection improved
- F The site is being supervised
- G Surrounding areas are monitored
- H Closure and post-closure plan in place

↑

ACTIVITIES

A. Control of landfill A1 Develop rules and system for scavenging activities A2 Construct fence, gates, & signboards at access points	F. Road safety F1 Widen and mark intersection and erect caution signs
B. Improve landfilling methods B1 Train landfill AMDC staff in "cell" landfilling method B2 Instruct landfill staff on gas venting procedures B3 Instruct landfill staff on leachate control procedures B4 Place permanent and moveable waste fences B5 Placement of final cover layer B6 Construct internal roads B7 Adopt surface drainage plan	G. Administrative Improvements G1 Construct administration office G2 Install security lighting G3 Install water supply and sewage system G4 Pave and improve access road G5 Construct garage G6 Purchase truck scale G7 Maintenance of civil works
C. Buffer zone C1 Plant and maintain trees in areas designated for buffer zones	H. Monitoring H1 Regular monitoring of local water sources H2 Periodic questionnaires given to locals
D. Reduce litter along main road leading to landfill D1 Establish ordinances for businesses along road D2 Organize street sweepers D3 Purchase tarpaulins for dump trucks	I Closure and Post-Closure Plan I1 Establish closure and post-closure plan

In order to achieve the overall development objective in the first box of Figure 15-7 it is first necessary meet the 'immediate' objectives. And in order to achieve the immediate objectives it is necessary to successfully complete the 'activities' described in the lower box.

The smoothness of this process is dependent on external factors that must be overcome in order to implement many activities; most crucial being improvements in the managerial capacity of the Cleansing Section. For example, improved managerial capacity enhances coordination and funding capabilities, allowing timely acquisition and replacement of materials and spare parts, availability of fuel and oil, periodic replacement of major equipment such as bulldozers, and essential staff training (institutional improvements are discussed in detail in Chapter 11).

The improvement plan will be implemented by undertaking the above activities. These are described in the following sections. Many of these activities relate to the improvement of the existing disposal site. The layout plan of the proposed improved disposal site is shown below.

15.4.1 Control of Disposal Site

To undertake proper landfilling procedures it is essential to first gain control of the site, i.e., control of what enters and exits the site and movements within the site. As described above at the present time there is little control of what is being brought into the disposal site and when it is brought in. Moreover, scavengers, children, and animals freely enter the site doing as they please, obstructing vehicles, and spreading waste around the site. Two methods are proposed to control of the landfill site.

Scavenging provides important benefits for the Central District and therefore is proposed to be included in future disposal site development plans. Through the recovery of materials at the landfill site valuable resources are obtained. Correspondingly scavenging provides a livelihood to hundreds of lower class persons and their families who may not be capable of finding alternative sources of income.

a. Construction of fence, gates, and sign board at access point.

Works necessary for the control of the site were implemented during the pilot project stage (see section 8.4). These include the erection of a 2 meter high perimeter fence near the access point, steel gates, sign board (explaining conditions of entry) at the access point to disposal site, and directional signs within the site showing incoming vehicles exactly where waste is being dumped.

In addition to these completed works it is proposed that the perimeter fence be extended to enclose the whole site to ensure control of entry is complete.

b. Development of regulations and system for scavenging

Regulations are developed to limit the impact of scavenging activities on other activities being undertaken at the landfill, as well as for the protection of the scavenger's health and safety.

Figure 15-8 : Layout Plan of Improved Disposal Site