K.5.3 Environmental Impact Assessment of the Final Disposal System

a. Description of the Proposed Project

This section describes the proposed project, the Final Disposal System.

a.1 Background

The project of Final Disposal System is a part of the Master Plan (M/P). The need to ensure capacity for the final disposal of wastes until 2015 was established as one of the targets in the M/P. Current capacity at the landfill has been estimated at 1.8 million cubic meters or equivalent to approximately 3 to 4 years. Thus, the Study conducted preliminary design of a new landfill in the current final disposal site.

a.2 Objectives of the Project

The prime objective of the project is **to establish an appropriate final disposal system** where final disposal capacity by 2015 is ensured and quality of operation meets with norms established in the country. This is one of policies to lead the principal goal of the Master Plan, i.e., to establish a sound Solid Waste Management by 2015 in the Municipality of Panama.

a.3 Justification of the Project

a.3.1 Legal Justification

Law No. 41 dated August 27th, 1999, transfers the administration, operation and exploitation of the services provided by Dirección Metropolitana de Aseo (Metropolitan Cleaning Office, or DIMA) to the municipalities of Panama, San Miguelito and Colón. With the enforcement of this law, the Urban and Domiciliary Cleansing Office (DIMAUD) was created in each of the municipalities of Panama, San Miguelito and Colón.

For purposes of compliance with the law, it is stipulated in the same law that the municipalities mentioned above have powers, responsibilities and functions to direct, plan, research, inspect, operate and exploit urban and household cleansing services. As for the Cerro Patacon Landfill, it is also stipulated that the municipality of Panama has administrative responsibility of the Cerro Patacon Landfill and the Mayor administering a sanitary landfill can subcontract its operation to third parties.

Consequently, the Municipality of Panama has responsibilities to appropriately operate the Cerro Patacon Landfill and to ensure final disposal of waste generated from the municipality. te project aims to realize the both issues.

a.3.2 Social Justification

The need for an appropriate place to dispose of solid wastes is a problem of all cities in the World, especially after a municipality reaches a certain size. As populations in towns and cities become larger, the amount of solid wastes generated increase and impacts caused by disposing of such a large amount of waste become serious. Such serious impacts deteriorate natural environment, living conditions and socio-economic activities.

According to current estimates, the daily amount of solid wastes disposed of at the Cerro Patacon Landfill is around 1,200 tons per day. The project will provide a solution to the need to provide an appropriate facility to dispose of solid wastes until 2015.

a.4 Location and Land Ownership

The 130 ha Cerro Patacon Final Disposal Site is located at the Ancon Corregimiento in Panama District, at approximately 5 km from the Via Ricardo J. Alfaro, within a polygon defined by UTM coordinates N1002030, E657540; N1002000, E657900; N1000000, E656900, y N1000000 E658100. The area is within a land reverted to the Republic of Panama during implementation of the Panama Canal Treaties of 1977, and adjacent to the Las Cruces National Park.

The whole project site belongs to Panama Inter-Oceanic Region Authority (ARI), although the Municipality of Panama has a right to operate final disposal of waste in the Cerro Patacon Final Disposal Site.

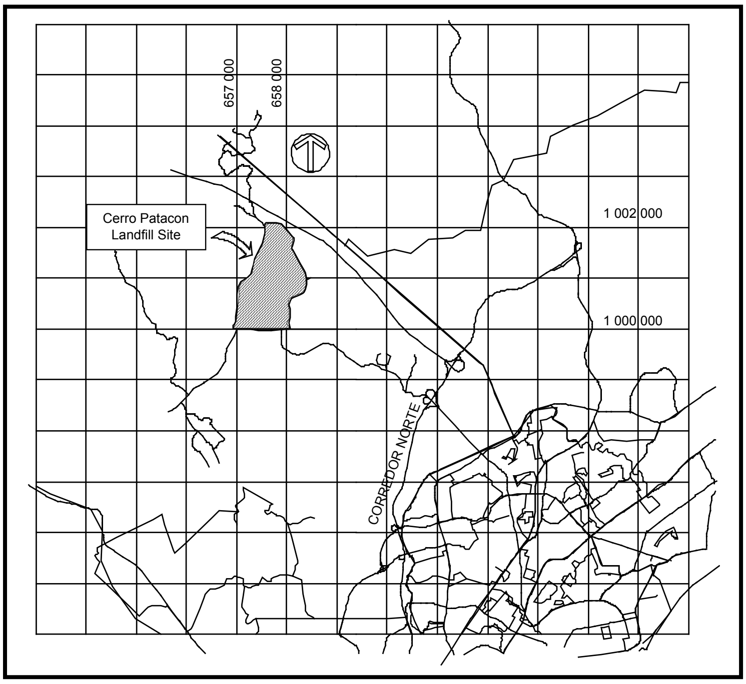


Figure K-40: Location Map of Cerro Patacon Final Disposal Site

a.5 Description of the Work

a.5.1 Project Outline

The new landfill will have capacity of 6.4 million cubic meters. It will be developed in 4 phases. Table K-70 describes the outline of the project.

Table K-70: Outline of the Project of Final Disposal System

Items	Facilities				
	Overall	Phase 1	Phase 2	Phase 3	Phase 4
Construction site	Cerro Patacon Area				
Construction period	-	2005 to early 2006	2007 to early 2008	2009 to early 2010	2011
Operation period	2006 to 2015	early 2006 to early 2008	early 2008 to early 2010	early 2010 to end of 2011	2012 to 2015
Area	Site area :28 ha Filling area : 20.4 ha	6.9 ha	6.5 ha	6.3 ha	20.4 ha
Landfill waste	Municipal waste				
Landfill capacity	6,400,000 m^3	1,300,000m^3	1,200,000m^3	1,100,000m^3	2,800,000m^3
Access	Existing road and internal road Length of internal road : 2,570 m	Length of internal road : 1,300 m	Length of internal road : 800m	Length of internal road : 470m	-
Waste transport control facilities	Gate : 2 (existing), Weighbridge : 2 (existing), Car washing : 1 (existing), Site office :1, Work shop :1				
Leachate management	**Seepage control works**: installation of 1.5 mm HDPE synthetic liner with 10 mm geotextile (under and upper of synthetic liner), installation of soil layer for protection of synthetic liner				
	Collection and treatment system				
	Collection pipe: 6,690m(dia. 200 to 900mm)	2,070 m	2,020m	1,830m	770m
	Treatment system Regulation pond : 24,000 m^3,Treatment capacity : 800 m^3/day (oxidation ditch with chemical sedimentation, sand filtration and activated carbon absorption) Intake water quality : BOD 10,000 mg/l, COD 18,000 mg/l, Org-N 200 mg/l, NH_3-N 200 mg/l, P 30mg/l Treated water quality ; BOD 35 mg/l, COD 100 mg/l, Org-N 10 mg/l, NH_3-N 3 mg/l, P 5mg/l (comply the ANAM discharge limit)				
Landfill gas management	Gas ventilation pipe (PVC 200 mm) : 92 nos.	23 nos.	22 nos.	21 nos.	26 nos.
Rain water management	Trapezoidal lined ditch (wide 800 to 1,700 mm): 2,300 m and daily cover soil	1,190 m	700 m	410 m	-
Landfill operation	Cell method with compaction, daily soil cover thickness15cm, final soil cover thickness 60cm				
Aesthetic design	Daily soil cover				
Closure and post-closure	Final soil cover 60 cm Greening by seeding the final cover with grass				

a.5.2 Project Site

The project site is a part of the existing Cerro Patacon Final Disposal Site where two areas have been developed as landfills, Etapa 1 and Etapa 2. Then, the new landfill is called as Etapa 3. The project site involves a part within the Cerro Patacon Final Disposal Site and an additional about 9 ha that is next to the former part but out of the Cerro Patacon Final Disposal Site.

Currently, soil for covering waste is excavated from a part of the project site. Rest of the site is covered with grass and sparse trees.

There is a small hill at the north and a shallow valley at the south in the project site. Around the project site, there is a hill at the north, the existing landfill (Etapa 1) at the south, a river at the east and other existing landfill (Etapa 2) at the west. Profile of the project site is as follows.

- The maximum height: 106 masl
- The minimum height: 43 masl
- Area: about 28 ha

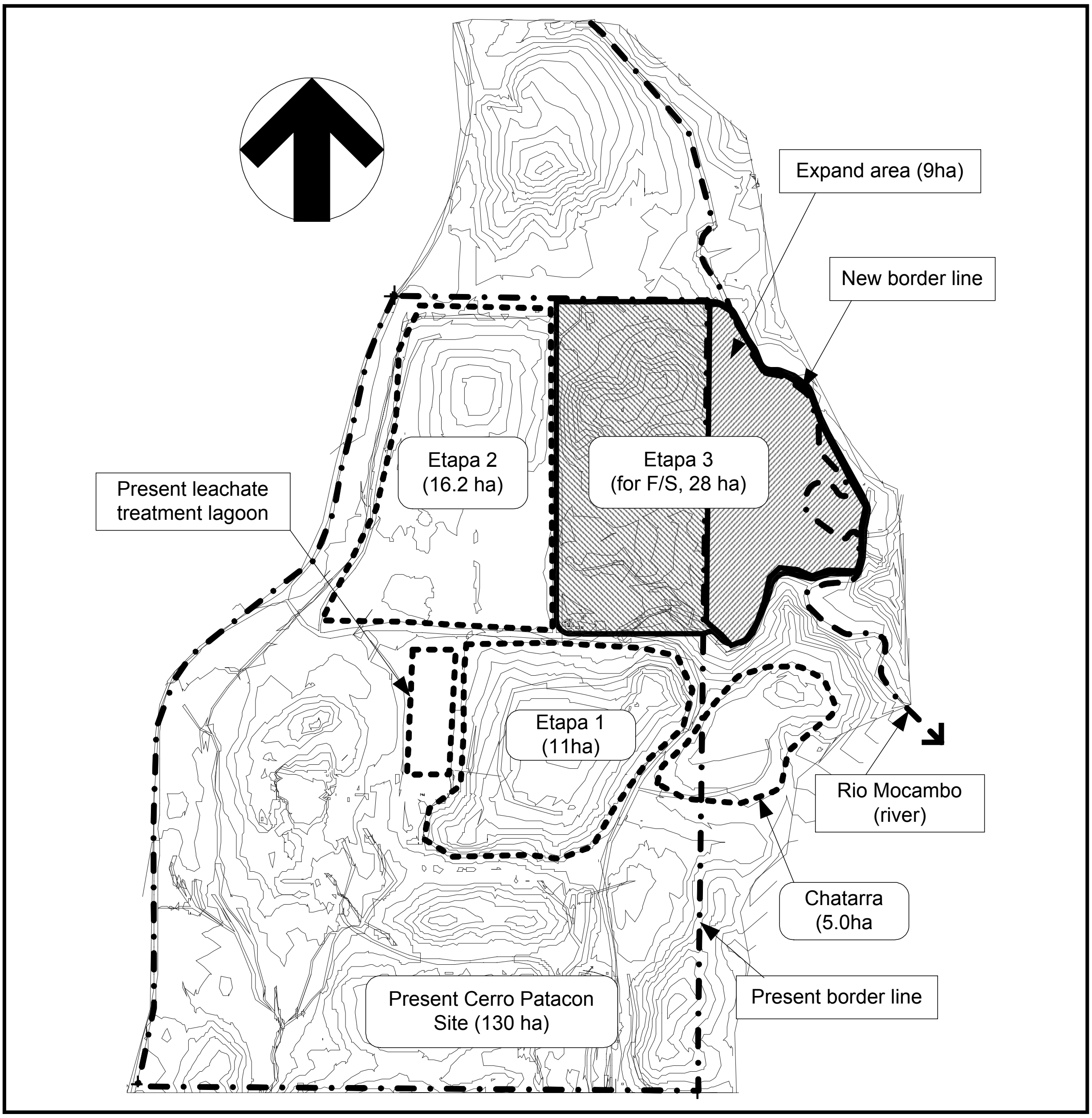


Figure K-41: Project Site

a.5.3 Types of Waste to be disposed of

Wastes to be disposed of in the new landfill are all municipal solid wastes except hazardous waste.

a.5.4 Site Development Plan

Basic Concept

The planed landfill capacity is about 6.4 million m^3. Possible development area is about 26 ha with taking into account 50 m width of a buffer zone along the river. The landfill will have a maintenance road at its periphery. Consequently, an area to be used for a landfill is about 20 ha.

A layout plan and a land reclamation plan are formulated based on the basic concept shown in Table K-71 with taking into account of examples in Japan and safety. Due to the land features of the site, there are some points where 50 m of buffer zone from the river cannot be achieved. In such points, it is aimed at securing 30m at least.

Table K-71: Basic Concept of Site Development Plan

Item	Descriptions
Internal road	width :10.0m
Access road	width : 10.0 m, maximum vertical slope : 8.000%
Access road for leachate treatment facilities	width : 6.0 m, maximum vertical slope : 8.000%
Cut slope grade	1:2
Bank slope grade	1:3
Slope grade in the landfill site	1:2, width of scarcement : 2.0m
Landfill slope grade	1:3, width of scarcement : 2.5m
Elongation from river	norm :50 m, minimum : 30 m

Site Development Plan

The landfill construction is divided in three phases as shown in Figure K-42. Phase 1 is the southern part, Phase 2 is the northwestern part and Phase 3 is the northeastern part. The depth of the landfill is set at 10 m. Waste will be raised up to 80 (meters above sea level) masl at each phase. Then, the three areas will be combined and the height will reach at 110 masl as Phase 4. Capacities of respective those phases are shown Table K-72, which are estimated based on a map of 1 in 2,500.

Table K-72: Prospective Landfill Amount

Phase	Landfill amount (m^3)
Phase 1	1,300,000
Phase 2	1,200,000
Phase 3	1,100,000
Phase 4	2,800,000
Total	6,400,000

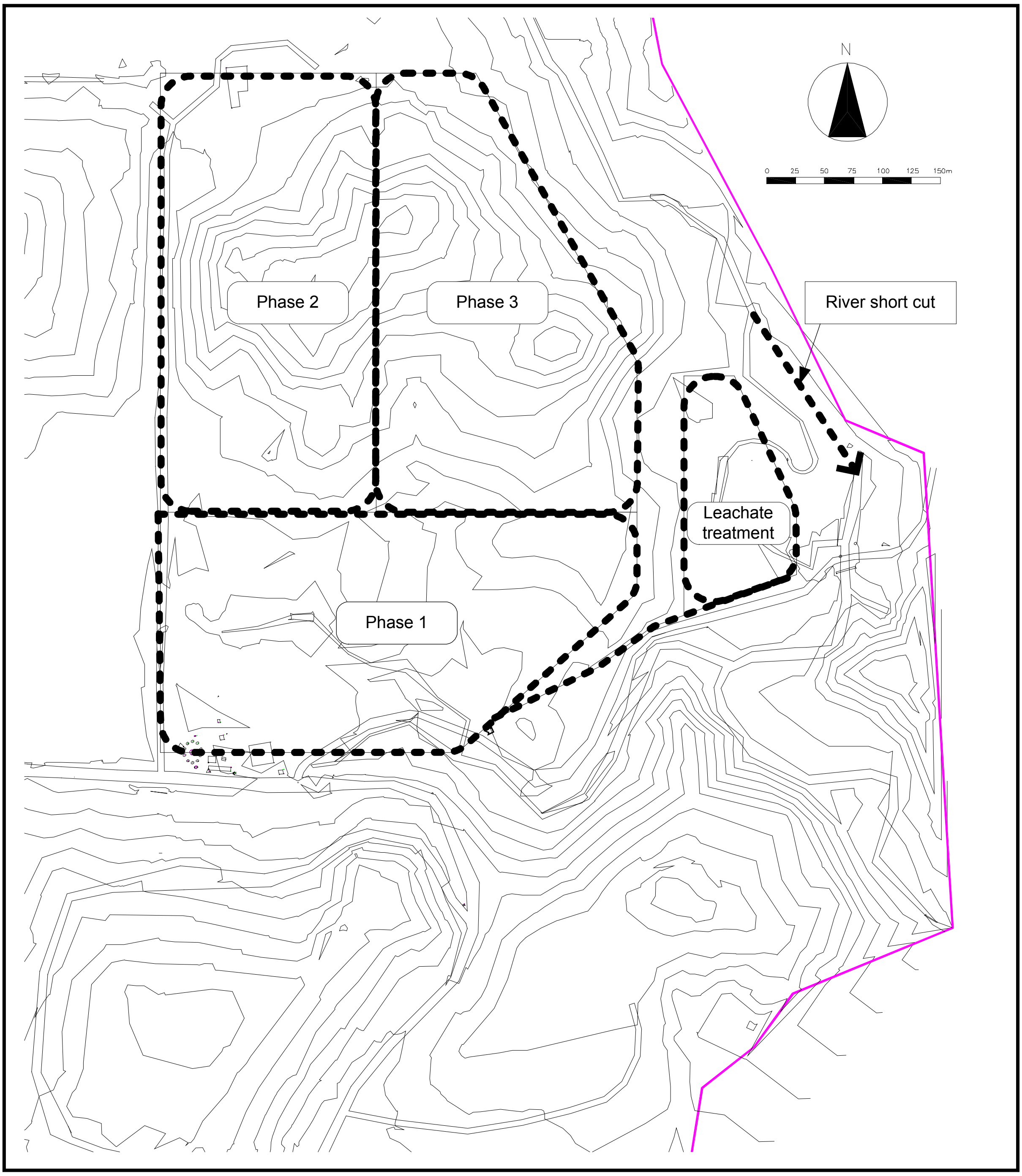


Figure K-42: Site Development Plan

Earth Wok Plan

Table K-73 shows required earthwork. The huge earthwork in Phase 2 and 3 will be unavoidable in order to obtain enough capacity of landfill. If the excess soil will be used for about 1.4 million of cover material, the remains will be about 2.1 million. The northern area next to the project site has capacity to receive 2.2 million of soil (See Figure K-43).

Table K-73: Earth Work Volume

	Cut volume (m^3)	Embankment volume (m^3)	Balance (m^3) (cut – embankment)
Phase 1	406,000	15,000	391,000
Phase 2	1,973,000	4,000	1,969,000
Phase 3	1,192,000	26,000	1,166,000
Phase 4	0	1,000	-1,000
Total	3,571,000	46,000	3,525,000

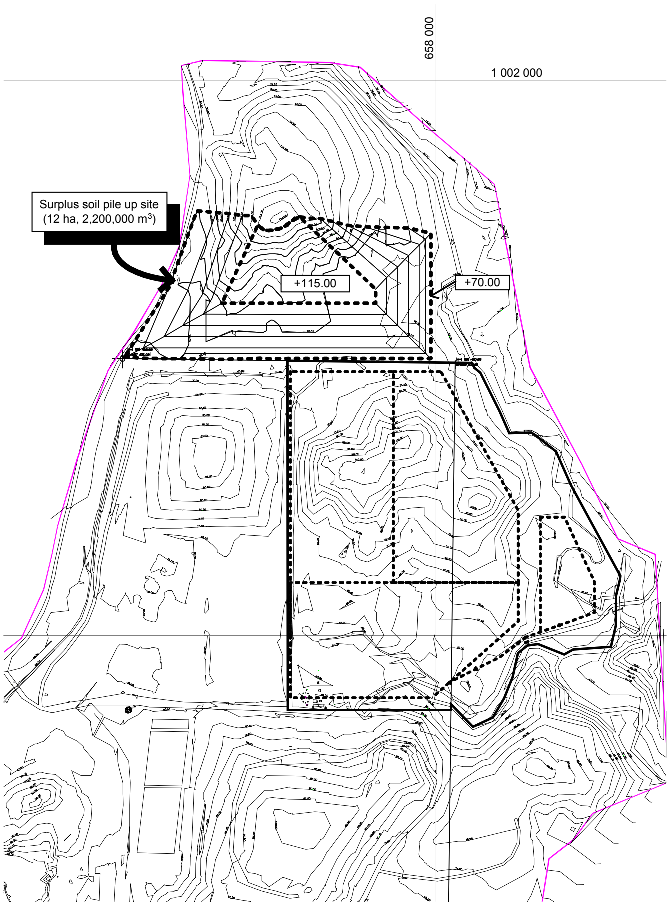


Figure K-43: Surplus Soil Pile Up Site

Table K-74: Total Volume of Surplus Soil Pile Up Site

Level	Area 1(m^2)	Ave. area (m^2)	Height (m)	Volume (m^3)
+70.00	48,500			
		58,300	5	291,500
+75.00	68,100			
		63,900	10	639,000
+85.00	59,700			
		55,150	10	551,500
+95.00	50,600			
		45,350	10	453,500
+105.00	40,100			
		33,800	10	338,000
+115.00	27,500			
Total				2,273,500

Waste Retaining Structure

The waste retaining structure, embankment, serves to contain waste in the landfill and to temporally store unexpected large amount of leachate caused by heavy rain. The construction of embankment will be partially, as the majority of the landfill will be dig up. The height of the embankment is to be 10 m from the bottom of the landfill. The inner slope of the embankment has ascent of 1 to 2 and the outer has 1 to 3 with taking into account stability. The embankment will be made of a good material obtained in the project site.

a.5.5 Groundwater Collection Plan

Present Situation

According to the geological survey, the groundwater level is fairly shallow. It is conjectured that the groundwater would flow from the northwest to the southeast. Rock is found at a shallow level. However, it will not be impermeable layer, as there exists many cracks through which the groundwater can flow.

Set Out of Groundwater Drainage Facility

Drainage facility will be distributed to drain the ground water under the landfill. The drainage facility is to consist of main lines and branch lines. The main lines will be placed at foot of the embankment and at the scarcement. The branch lines will be distributed in 3,000 m^2 (about at an interval of 30 m).

Structure of Groundwater Drainage Facility

Structure of the groundwater drainage facility is shown in Figure K-44. The structure is designed based on case examples in Japan. Perforated polymer pipes are to be surrounded by crushed stones. The main line has a diameter of 300 mm. The branch line is 200 mm, which can avoid to block up with soil.

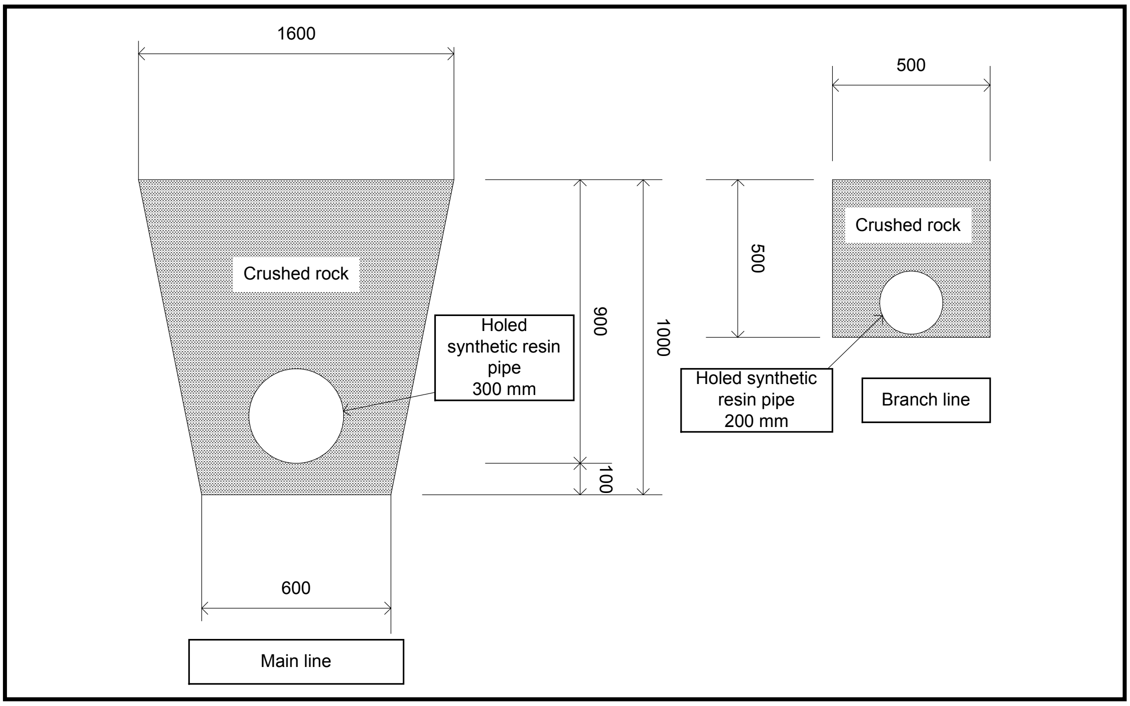


Figure K-44: Cross Section of Ground Water Drainage

a.5.6 Rainwater Drainage Plan

Rainwater Runoff Amount

The rational formula is also applied to obtain design rainwater runoff amount.

$$Q=1/360\times f\times r\times A$$

where ;

Q	:	rainwater runoff amount (m^3/sec)
f	:	runoff rate
r	:	rainfall intensity (mm/hour)
A	:	catchments area (hectare)

Runoff rate

Runoff rate, “f,” is depending on surface conditions of catchment area. Characteristics of the rainwater catchment area are hilly and vegetated. Therefore, 0.6 is applied for “f” according to Table K-75.

Table K-75: Runoff Ratio for Peak Flow

Topographic features	f p
Precipitous terrain	0.75～0.90
Rolling hill and/or forest	0.50～0.75
Agricultural land	0.45～0.60

source: Japan Society of Civil Engineers,1999

Rainfall intensity

The probability precipitation in two years of 65 mm/hr is to be used, which was obtained from Panama Canal Authority.

Catchments area

Catchment area will change according to progress of landfilling, e.g., the area will be the largest at completion of Phase 4. Drainage ditches are designed based on the largest catchment area.

Drainage system

Trapezoid drainage ditch with concrete pavement will be employed. Size of drainage ditches is computed by means of Manning Formula with 20% of depth of freeboard.

a.5.7 Leachate Management Plan

i) Seepage Control Plan

The basic layer at the project site is rock. The rock has many cracks and it is conjectured that the groundwater will flow through the cracks as aforementioned. Even though the rock itself has high impermeability, the layer as a whole should be regarded as permeable. Therefore, seepage control is to be planned in order to avoid contamination of groundwater with leachate.

There are two type of seepage control. One is construction of vertical impervious wall, which can be applied when an impermeable layer exists clearly. The other is surface lining, which covers whole surface of bottom of landfill with impermeable material. According to the geological condition, the surface lining is recommendable.

Synthetic liner is commonly used as impermeable liner. The liner is not thick, then, it could be damaged by improper manner. Major causes that possibly damage the liner are summarized in Table K-76.

Table K-76: Major Causes of Synthetic Liner Damage

Item	Trigger
Ground	salience, round settlement, ground depression, etc.
Ground water	up lifting, etc.
Landfill work	scratching of landfill equipment, etc.
Waste	keen-edged waste, live load of waste
Climate	ultraviolet degradation, thermal stress, stress cracking, etc.
Installation	scratching of construction equipment, joint defects, etc.

Major causes to damage the liner are physical stress from above. In order to avoid that the liner is damaged, the liner is to be protected enough thickness of soil and geotextile. Consequently, a surface lining system presented in Figure K-45 is designed.

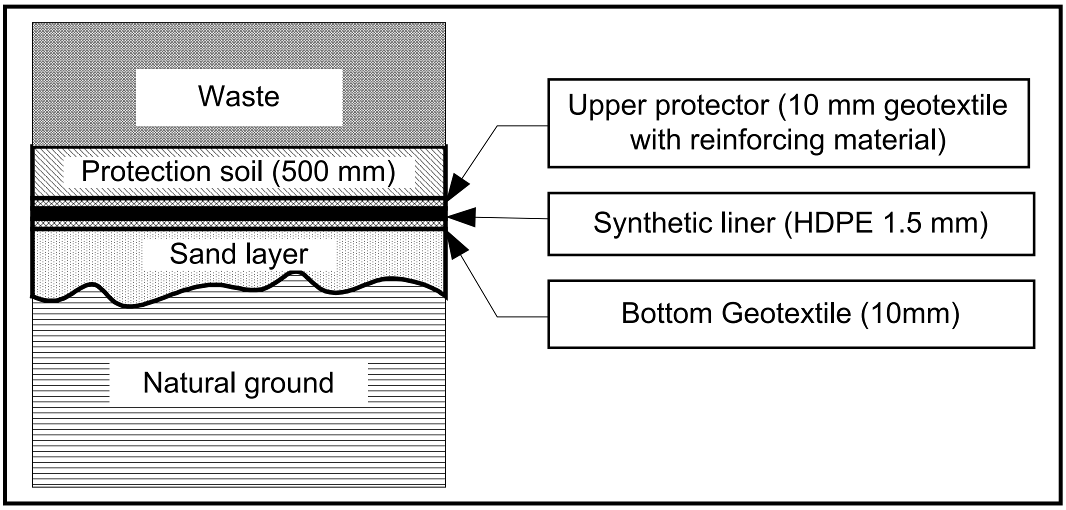


Figure K-45: Seepage Control Lining System

ii) Leachate Collection

Leachate Runoff Amount

Leachate has to be drained immediately so as not to hamper landfill operation. Meanwhile, leachate will not seep from the damaged part of the lining system, if there is no leachate stored in the landfill. Therefore, the leachate collection system should have enough capacity to drain the leachate immediately. Design leachate runoff amount is computed by the rational formula, where the same amount of leachate as rainfall will be drained immediately.

$$Q=1/360\times c\times r\times A$$

where ;

- Q : leachate runoff amount (m^3/sec)
- c : runoff rate
- r : rainfall intensity (mm/hour)
- A : catchments area (hectare)

Runoff rate

Between 0.6 and 0.7 is commonly used as runoff rate, "c." In order to shorten retention time of leachate in the landfill, 0.7 is applied for "c."

Rainfall intensity

The probability precipitation in two years of 65 mm/hr is to be used, which was obtained from Panama Canal Authority.

Catchment area

Landfill areas of respective phases are regarded as catchment areas.

Arrangement of collection pipe

Collection pipes consist of main lines and branch lines. Main lines are to be placed at centers of landfills and branch lines are distributed in every 3,000 m^2 (about an interval of 30 m).

Size of collection pipe

Perforated polymer pipes will be used as collection pipes. Size of pipes is to be decided based on computation by means of Manning Formula. It is assumed that whole cross section area is to be used in the computation.

iii) Leachate Treatment Plant

Leachate treatment facility will be constructed, which has an objective to make effluent comply with the standards set by ANAM, "Normas para Agua Residuales, ANAM/DGNTI-COPANIT 35-2000." Table K-77 outlines the leachate treatment facility.

Table K-77: Summary of Leachate Treatment Facility

Item	Description
Regulation pond	24,0000 m^3
Treatment capacity	800 m^3/day
Treatment method	Oxidation ditch with chemical sedimentation, sand filtration and activated carbon absorption
Oxidation ditch	17,600 m^3 (detention time 22 days)
Sedimentation tank	200 m^3 / 54 m^2 (detention time 6 hour)
Chemical sedimentation tank	200 m^3 / 54 m^2 (detention time 6 hour)
Sand filter	Pressed sand filter (diameter : 3.5 m, nos. : 2)
Activated carbon absorber	Pressed type (diameter : 3.5 m, nos. : 2)

Design Conditions

Design conditions for the leachate treatment facility is set as shown in Table K-78 based on typical leachate quality data and the objective is to comply with the standards for effluents from ANAM.

Table K-78: Design Conditions for Leachate Treatment Facility

	Influent quality (mg/liter)	Effluent quality (mg/liter)
BOD	10,000	35
COD	18,000	100
Organic nitrogen	200	10
Ammonia nitrogen (NH_3-N)	200	3
Total phosphorus	30	5
Nitrate	25	6

Source: Integrated Solid Waste Management, McGraw-Hill

Treatment Process

Oxidation ditch method, which can remove nitrogenous matters and is relatively easy to operate, with physico-chemical treatment to remove phosphorus and heavy metals is applied in this plan. Figure K-46: shows the planed leachate treatment process.

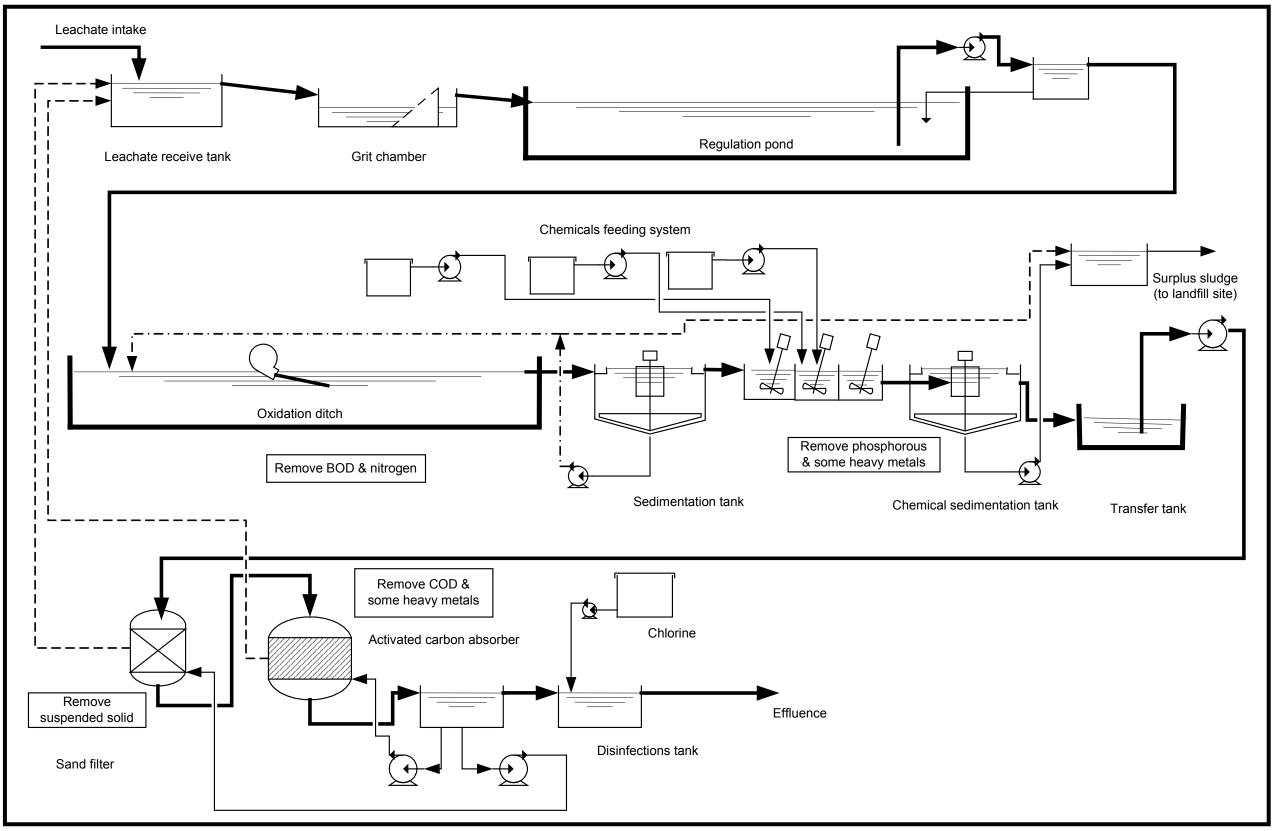


Figure K-46: Leachate Treatment Process Flow Sheet

a.5.8 Landfill Gas Management Plan

The passive control manner is to be employed for the landfill gas management. Uncontrolled dispersion of the gas from the landfill surface will be minimized by installation of gas removal pipes. 92 PVC pipes with diameter of 200 mm will be constructed over the 20.4 ha of filling area.

a.5.9 Landfill Operation Method

Cell method is applied, where waste will be compacted by heavy equipment appropriately and be covered with soil (15cm of thickness) at the end of operation of the day in order to control birds and vectors as well as to avoid wind-blown wastes. Besides, such daily cover is effective to reduce leachate amount generated, as a certain amount of rainfall will run over the soil cover to the outside landfill without infiltrating into waste.

a.5.10 Closure and Post-closure Care

Closure

A final cover structure, which consists of several layers as shown in Figure K-47, will be employed when the operation is completed. Major purposes of the final cover are i) to reduce leachate generation, ii) to avoid uncontrolled landfill gas diffusion, and iii) to improve outward appearance.

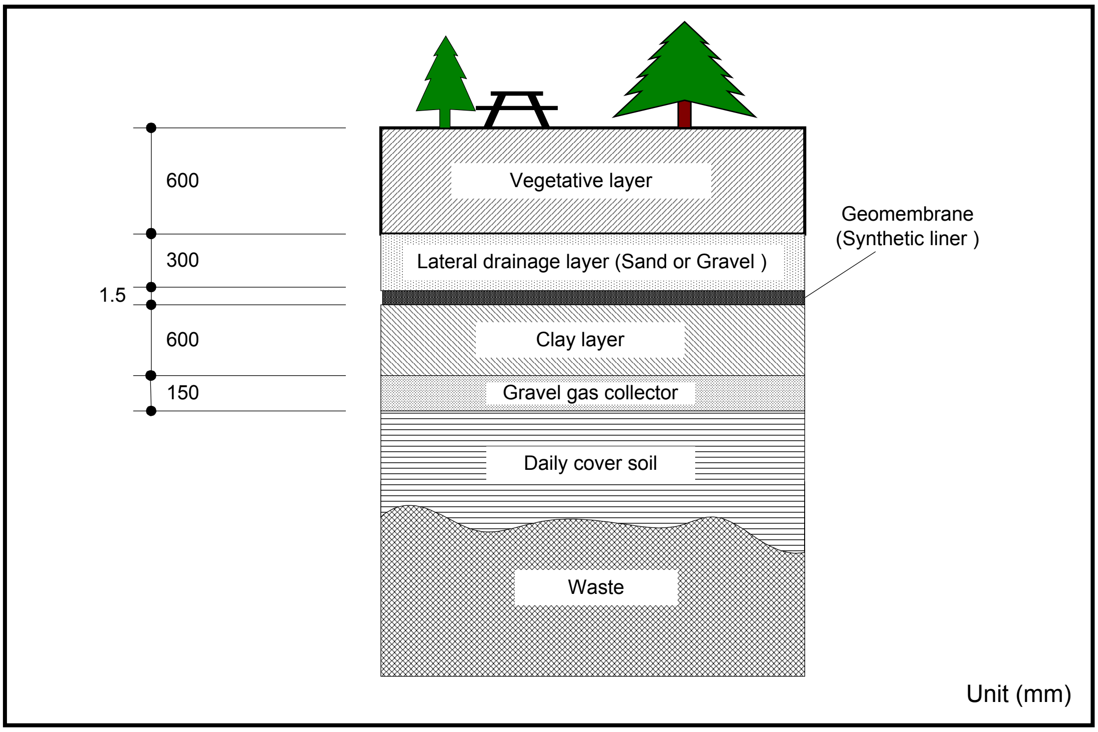


Figure K-47: Proposed Final Cover Structure

Post-closure Utilization Plan

The closed landfill site will be planted with trees to harmonize with the national park and to use a partial area as a park. Greening of the landfill surface is to be effective to encourage evapotranspiration on the surface, and this results in the reduction of leachate generation.

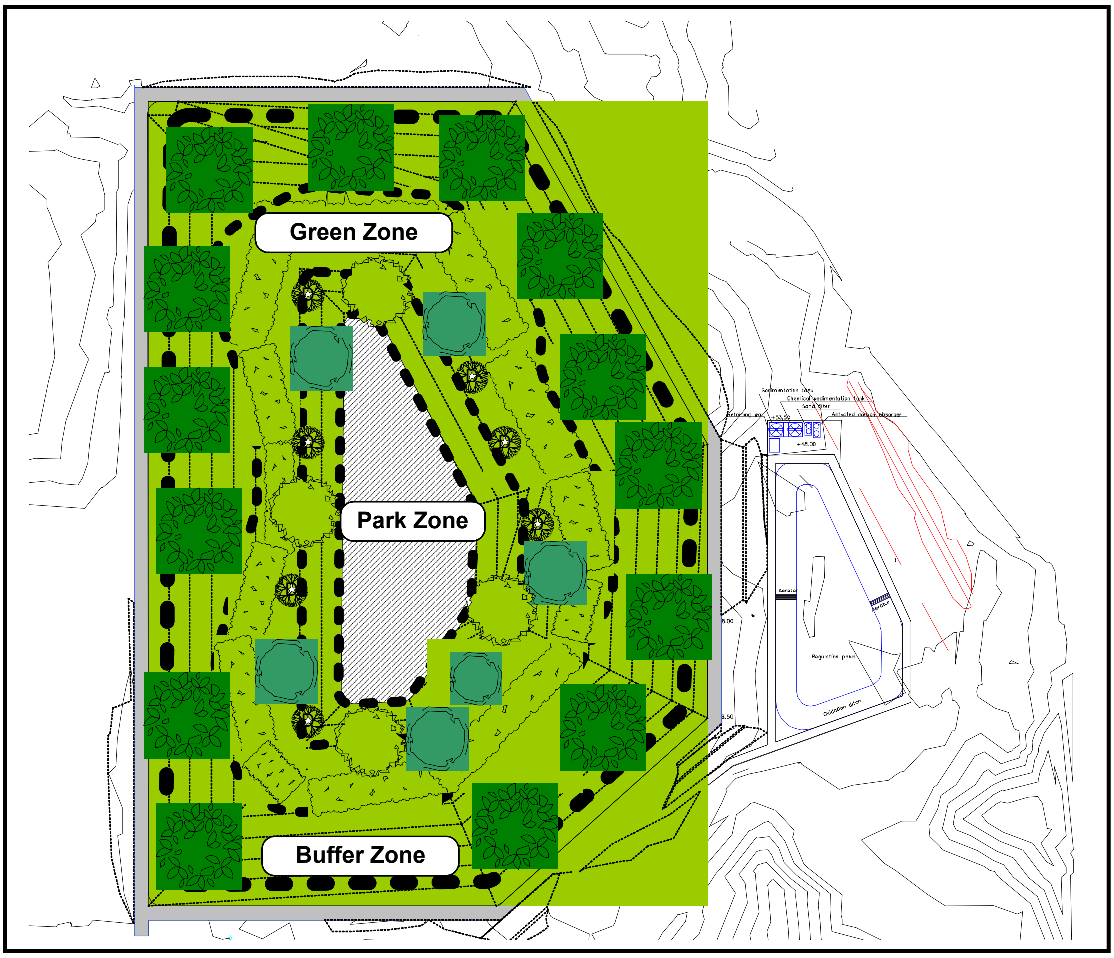


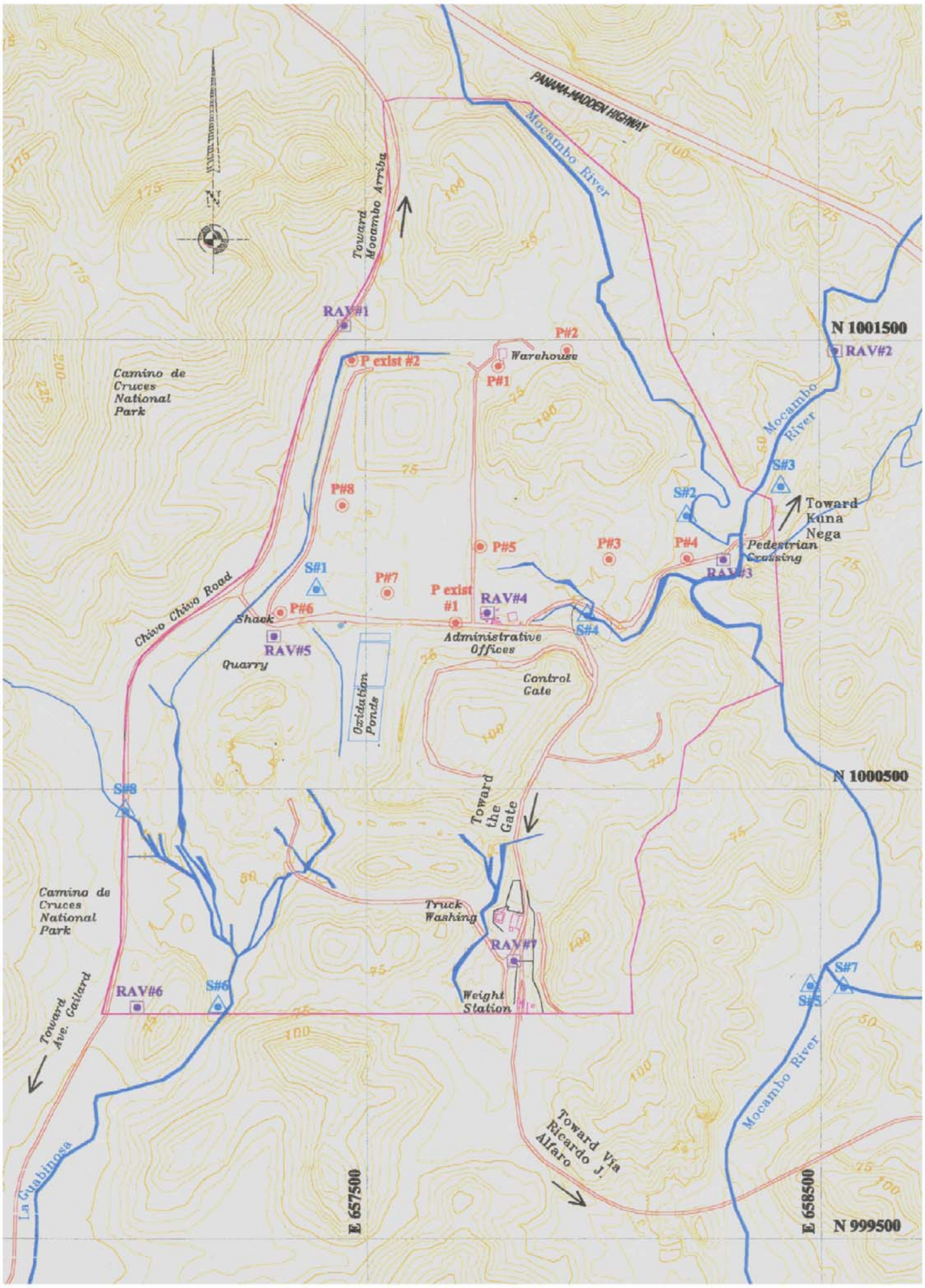
Figure K-48: Utilization Plan of the Closed Landfill

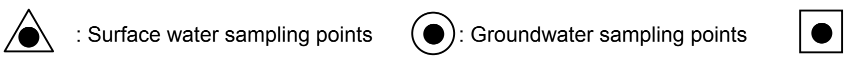
b. Natural and Socio-economic Environment

This section describes the environmental and socio-economic aspects of the project site and its surrounding mainly based on an environmental baseline survey conducted in July to September 2002 by local companies under supervision of the Study Team in the scheme of the Study. Table K-79 outlines the survey.

Table K-79: Items of Environmental Baseline Survey

General information	
Required items	a) Wind direction b) Wind velocity c) Temperature d) Humidity e) Rainfall f) Solar radiation, sunshine hour
Geology	
Boring Survey:	8 boreholes, about 10m respectively, in and around the Cerro Patacon Final Disposal Site. Test and data required are penetration test, loading test, groundwater level, in-situ permeability test, internal soil test (triaxial compression test, consolidation test)
Topsoil investigation:	100 units at about 2 m depth over 100 ha in and around Cerro Patacon Final Disposal Site.
Surface water	
Sampling:	8 samples in and around Cerro Patacon Final Disposal Site
Analysis items:	Flow volume, temperature, pH, electric conductivity, turbidity, color, alkalescency, oil content, number of colon bacillus, BOD5, COD, SS, ammoniac nitrogen, total nitrogen, major ions (Na+, Ca2+, HCO3-, SiO2, Cl-), total phosphorus, heavy metals (cadmium, cyanogen, lead, total chromium, hexavalent chromium, arsenic, total mercury, copper, zinc, iron, manganese), PCB
Groundwater	
Sampling:	10 samples (2 samples from the two monitoring wells and 8 samples from boreholes for geological survey)
Analysis items:	Pumping-up volume, temperature, pH, electric conductivity, turbidity, color, alkalescency, oil content, number of colon bacillus, BOD5, COD, SS, ammoniac nitrogen, total nitrogen, major ions (Na+, Ca2+, HCO3-, SiO2, Cl-), total phosphorus, heavy metals (cadmium, cyanogen, lead, total chromium, hexavalent chromium, arsenic, total mercury, copper, zinc, iron, manganese), PCB
Air pollutants	
Survey site:	7 points in and around Cerro Patacon Final Disposal Site
Analysis items:	sulfur dioxide, nitrogen dioxide, suspended particulate matter, odor
Noise and Vibration	
Survey site:	7 points that are the same as for Air pollutants
Analysis items:	noise and vibration
Fauna and Flora	
Survey site:	about 200 ha of in and around Cerro Patacon Final Disposal Site





: Surface water sampling points　: Groundwater sampling points　: Air, noise and vibration sampling points

Figure K-49: Location Map of Baseline Survey (Surface Water, Groundwater, Air, Noise and Vibration)

b.1 Natural Environment

b.1.1 Meteorology

Precipitation, Temperature and Wind

Climate in the area has been classified as Tropical Savannah type according Koppen, with average annual rainfall of around 2,100 mm and average maximum temperature of 27.5 °C and an average minimum of 25.7°C. Winds in the area tend to be low, with an average high in the month of March of around 8.5 km/hr, primarily from the North and Northeast.

Table K-80: Annual Precipitation (1992-2001)

Unit: (mm)

Year	Balboa FAA Station (A Type Station) Latitude: 08° 58' 08'' N Longitude: 79° 32' 58'' W Height 10 masl	Pedro Miguel Station (PV Type Station) Latitude: 09° 01' 22'' N Longitude: 79° 37' 02'' W Height 30 masl
1992	2,207.26	2,044.70
1993	2,443.48	2,197.10
1994	2,100.58	1,968.50
1995	2,875.28	1,971.04
1996	2,451.10	2,367.28
1997	1,905.00	1,668.76
1998	1,953.26	2,189.48
1999	1,940.56	2,270.76
2000	1,927.86	2,138.68
2001	1,648.02	1,963.42
Average	2,148.84	2,077.97

Source: Panama Canal Authority, Engineering Division (2002).
Note: A Type Station registers rain, temperature, relative humidity, pressure, wind, solar radiation, sun exposure hours
PV Type Station measures precipitation amount

Table K-81: Average Monthly Precipitation (1992-2001)

Unit: mm

Month	Balboa Station FAA			Pedro Miguel Station		
	Average	Maximum	Minimum	Average	Maximum	Minimum
January	55.88	170.18	0.0	40.64	144.78	0.0
February	27.94	99.06	0.0	15.24	81.28	0.0
March	40.64	91.44	0.0	27.94	142.24	0.0
April	66.04	127.00	0.0	78.74	162.56	17.78
May	276.86	487.68	96.52	238.76	381.00	154.94
June	266.70	566.42	137.16	261.62	459.74	121.92
July	218.44	462.28	119.38	228.60	299.72	119.38
August	185.42	299.72	71.12	233.68	342.90	142.24
September	271.78	490.22	142.24	238.76	337.82	149.86
October	289.56	431.80	167.64	304.80	353.06	218.44
November	287.02	411.48	157.48	279.40	355.60	167.64
December	162.56	251.46	10.16	119.38	259.08	5.08

Source: Panama Canal Authority, Engineering Division (2002)

Table K-82: Average Annual Temperature (1992 – 2001)

Unit: °C

Year	Temperature
1992	26.70
1993	27.00
1994	27.00
1995	26.66
1996	26.01
1997	26.88
1998	27.08
1999	26.02
2000	26.10
2001	26.37
Annual Average	26.6

Source: Panama Canal Authority, Engineering Division (2002)

Table K-83: Average Monthly Temperature (1992 – 2001)

Unit: °C

Month	Average	Maximum	Minimum
January	26.55	27.83	25.38
February	27.05	27.94	26.11
March	27.38	28.66	26.50
April	27.66	28.50	27.00
May	27.05	27.94	26.27
June	26.66	27.33	25.88
July	26.61	27.50	25.83
August	26.27	27.33	25.16
September	26.11	27.00	25.33
October	26.11	26.55	25.55
November	25.83	26.33	25.38
December	26.11	27.33	25.00
Average	26.61	27.55	25.78

Source: Panama Canal Authority, Engineering Division (2002)

Table K-84: Average Monthly Direction and Wind Speed at Balboa Station (1992 – 2001)

Month	Speed (Km/h)	Heading	
January	7.40	333.4°	NW
February	8.21	338.6°	NW
March	8.53	341.9°	NW
April	7.56	336.4°	NW
May	6.28	298.7°	NW
June	5.47	293.7°	NW
July	5.95	308.9°	NW
August	5.79	308.8°	NW
September	5.31	263.9°	SW
October	5.47	255.4°	SW
November	5.63	296.0°	NW
December	6.12	325.0°	NW

Source: Panama Canal Authority, Engineering Division (2002)

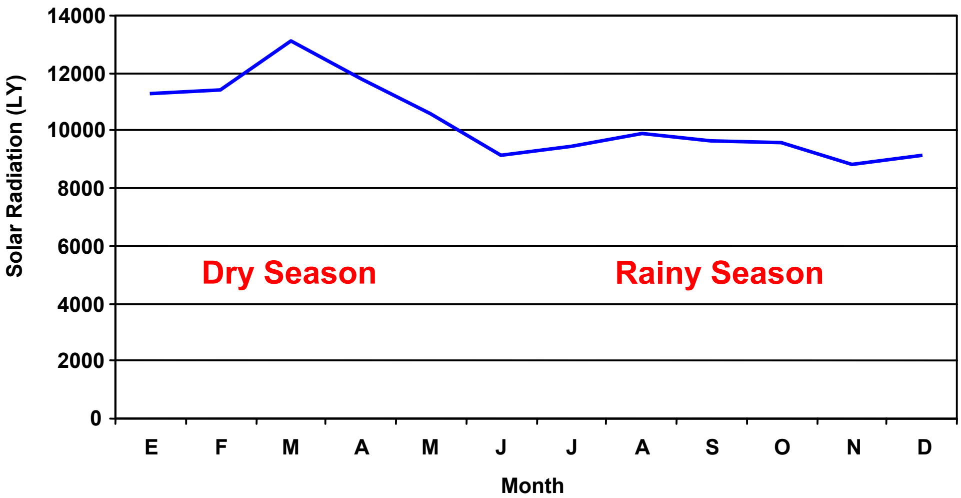
Solar Radiation, Sunshine hours and Humidity

A 10 year data (1992 – 2002) obtained from the Balboa Station FAA has determined that the average annual solar radiation for the study region is 123,914.1 Ly. It is clear that solar radiation during dry season (January, February, March and April) is higher than during rain season (rest of months except the dry season). This tendency is stronger in data of sunshine hours as shown in Figure K-51. Average annual relative humidity is 78.0%. During dry season, average monthly humidity ranges between 67.4% and 73.0%. It increases in rain season between 79.5% and 84.6% as shown in Table K-86.

Table K-85: Average Annual Solar Radiation (1992-2001)

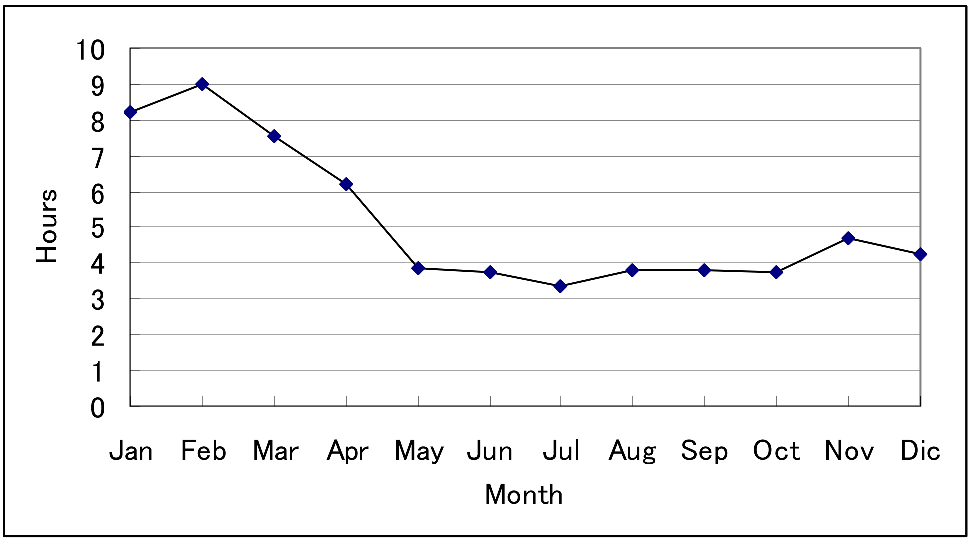
Year	Solar Radiation (Ly)
1992	127,334.3
1993	129,155.2
1994	132,265.8
1995	134,191.1
1996	119,239.8
1997	110,866.5
1998	119,757.7
1999	117,930.3
2000	121,137.4
2001	127,263.2
Annual Average	123,914.1

Source: Panama Canal Authority, Engineering Division (2002)



Source: ACP, Albrook Station

Figure K-50: Average Daily Solar Radiation (1992-2001)



Source: Authority of the Panama Canal, Albrook Station

Figure K-51: Average Daily Sunshine Hours (2000-2001)

Table K-86: Average Monthly and Annual Relative Humidity

Unit: %

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Average
1992	63.9	61.6	61.5	62.1	70.5	74.3	68.8	74.0	74.0	67.9	81.9	76.7	69.8
1993	73.8	64.8	65.9	70.4	76.3	77.7	76.4	75.9	75.9	82.3	81.3	75.7	74.7
1994	68.9	65.0	65.3	66.0	75.6	77.1	75.6	78.4	77.5	77.3	77.0	70.9	72.9
1995	66.4	61.5	64.8	79.0	83.1	81.4	85.1	86.1	84.7	85.4	86.0	83.7	78.9
1996	80.1	75.2	72.8	74.2	83.7	85.3	83.6	84.0	84.9	84.1	83.2	79.9	80.9
1997	75.3	72.3	66.1	69.3	77.3	83.5	82.5	82.7	85.2	85.2	85.4	75.9	78.4
1998	70.5	70.2	64.9	70.9	81.1	84.6	84.3	84.7	82.5	82.8	84.3	84.3	78.8
1999	76.2	70.7	69.9	75.3	82.2	84.2	83.0	84.1	82.5	82.9	83.3	82.7	79.7
2000	73.7	68.8	65.4	69.8	80.4	83.0	81.8	88.8	90.0	90.0	88.9	87.3	80.6
2001	81.3	77.2	77.9	76.8	84.7	87.3	87.8	87.7	89.6	89.7	89.4	89.4	84.9
Average	73.0	68.7	67.4	71.4	79.5	81.8	80.9	82.6	82.7	82.7	84.1	80.6	78.0

b.1.2 Geology

Geological Conditions

Geological condition of the project site consists of silt and/or clay at the upper part and weathered rock at the lower part. Hydraulic conductivity of the upper part is between 10^{-4} and 10^{-6}(cm/sec). In the Study, a geological survey was conducted. Locations of drilling surveys carried out in the geological survey are shown in Figure K-52. Figure K-53, Figure K-54, Figure K-55 and Figure K-56 present cross sections of the geological condition. As the figures show, the base layer of the project site consists of rock. Therefore, it can be judged that the base layer will bear increased stress to be caused by waste disposition.

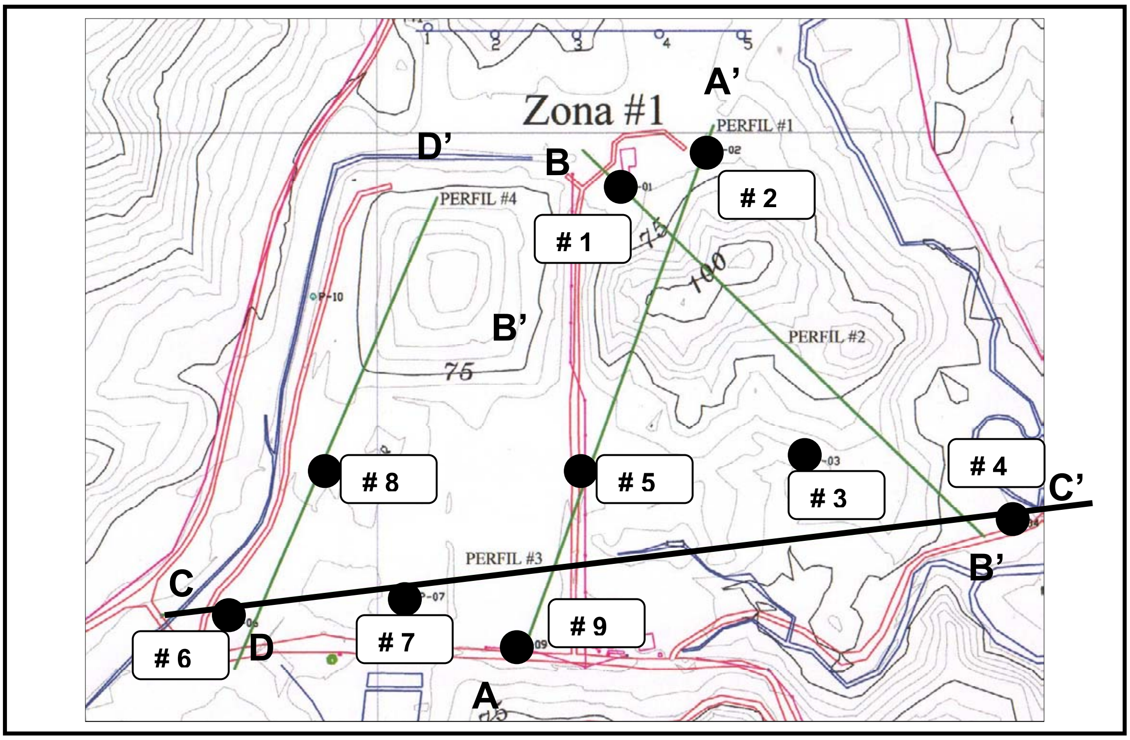


Figure K-52: Location Map of Boring Survey

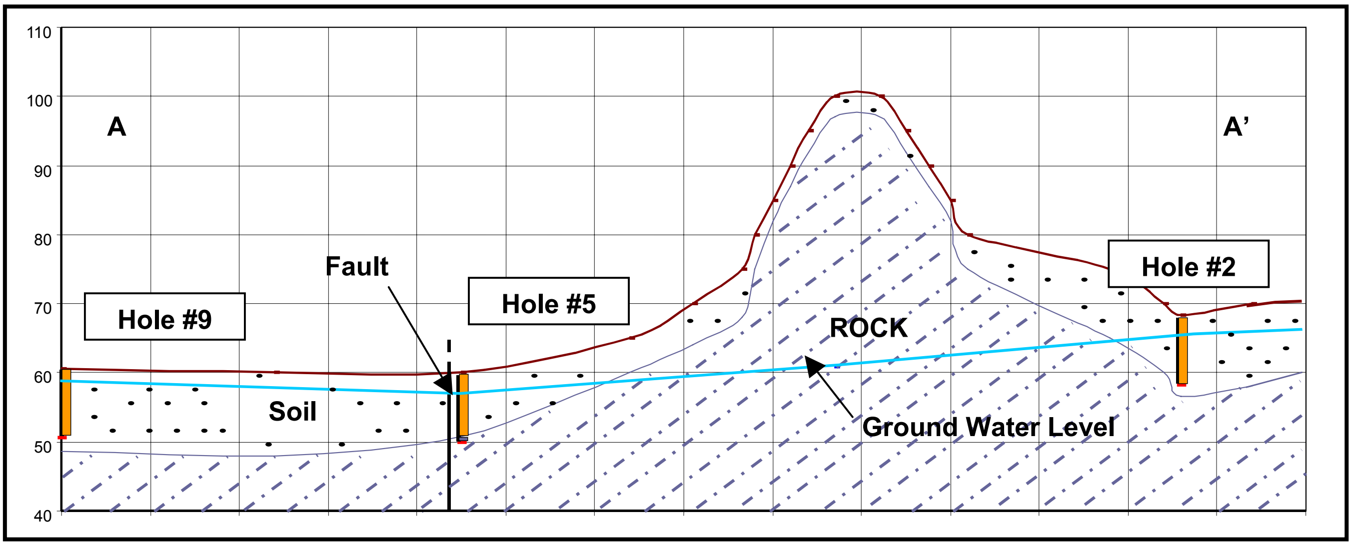


Figure K-53: Section A-A'

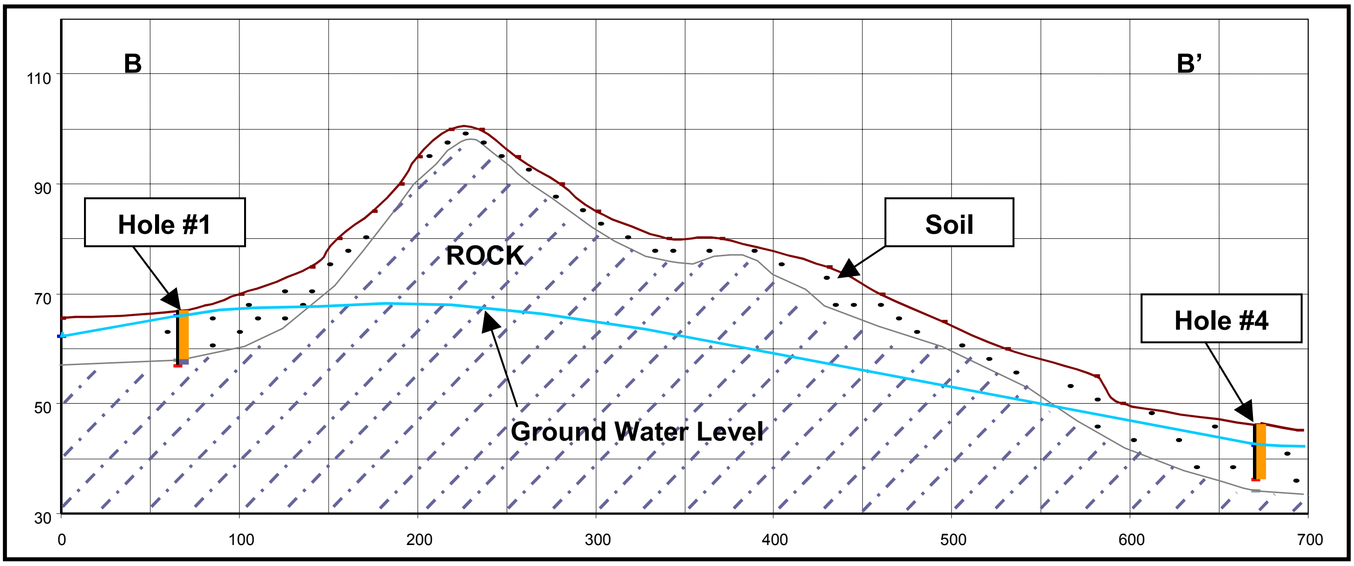


Figure K-54: Section B-B'

Figure K-55: Section C-C'

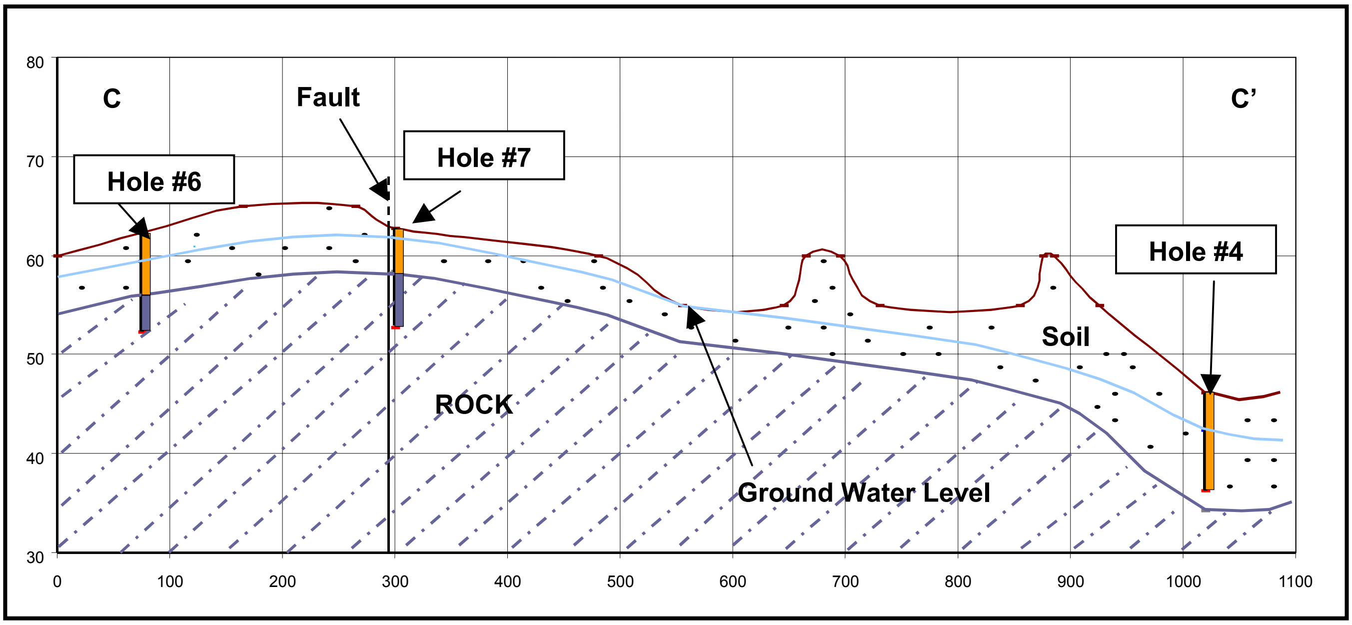
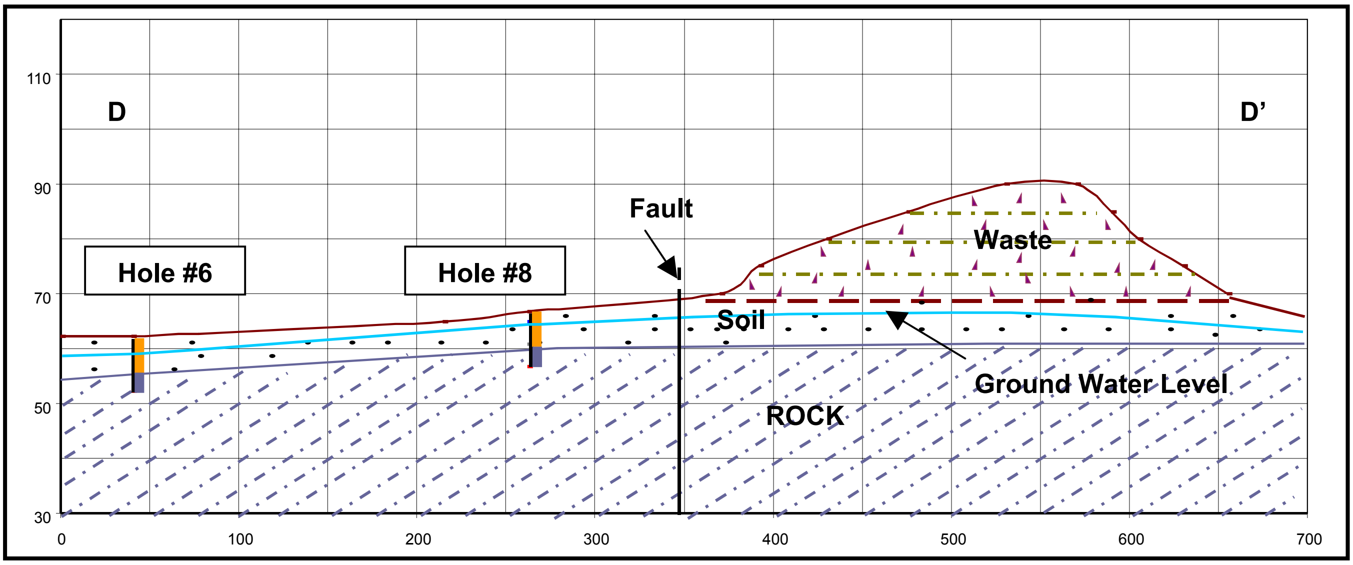


Figure K-56: Section D-D'



Permeability

In situ permeability tests were carried out at the drilling wells. Table K-87 shows results of the test.

Table K-87: Results of Permeability Survey

Number of holes	LOCATION	K (m/s)	K (cm/s)	PERMEABILITY CLASS
P # 1-02	**1001434.42 N, 657796.87 E**	**8.24 E-07**	**8.24 E-05**	Very small
P # 2-02	**1001478.89 N, 657900.95 E**	**5.09 E-07**	**5.09 E-05**	Practically impermeable
P # 3-02	**1000987.18 N, 658073.14 E**	**3.59 E-08**	**3.59 E-06**	
P # 4-02	1001028.35 N, 658260.56 E	1.57 E-07	1.57 E-05	
P # 5-02	**1001090.35 N, 657757.58 E**	**2.14 E-07**	**2.14 E-05**	
P # 6-02	1000909.59 N, 657317.57 E	2.32 E-06	2.32 E-04	Very small
P # 7-02	1000940.26 N, 657542.50 E	6.84 E-08	6.84 E-06	Practically impermeable
P # 8-02	1001097.23 N, 657425.56 E	6.00 E-08	6.00 E-06	

No. 1, 2, 3, and 5 are in the project site. All of them indicate considerably lower permeability, i.e., between 10^{-5} and 10^{-6} cm/sec. The values imply that the site might not need synthetic liner at the bottom of a landfill. However, the base layer consists of the weathered rock and fissure water exists. Therefore, it can be concluded that the bottom of the landfill will require a synthetic liner, although the upper part show the low permeability.

b.1.3 Surface Water

Surface Water Quality

The surface water survey conducted at eight points around the Cerro Patacon Final Disposal Site. The most important water body around the site is the Mocambo (or Cardenas) River, which receives effluents from the landfill and neighboring communities. The water sampling and flow measurements were conducted in July and August 2002.

Table K-88 presents the main results from the laboratory analysis. As the table shows, the results obtained are compared to Florida, U.S. standards for superficial water (recreational use, propagation and maintenance of a balanced fish and wildlife population). This was done since Panama has standards for wastewater, but not for evaluation of natural water body quality.

Many of the parameters exceed the standards used as reference from which it can be inferred that in general terms, the superficial water quality in the area is of low quality. It is evident that the superficial water in the area is impacted by human activity, since it shows considerable concentrations of fecal coliform and biochemical oxygen demand. Besides, the fieldwork showed low dissolved oxygen amounts, typical of contaminated water. This is specially true for sampling point #4, which showed very high BOD, COD, fecal coliform and phosphate levels, among others. During fieldwork it was observed that the water at this point was practically in an anaerobic condition (dissolved oxygen under 1 mg/L) and it had a muddy appearance and an unpleasant smell.

BOD concentrations in the study area varied from < 1 mg/L to 30 mg/L, whereas COD concentrations varied from 1 mg/L to 274.3 mg/L. Fecal coliform levels detected were high, they varied from 800 to 3×10^6 UFC / 100 ml. This indicates that the superficial waters in the study area receive organic matter and human and/or animal wastes.

Regarding heavy metal concentrations detected, some of the comparison criteria were exceeded from which it can be inferred that superficial water in the study area is moderately contaminated with these elements.

In summary, superficial water in the study area possesses a low quality from a bacteriological point of view and of general quality parameters such as turbidity, dissolved oxygen and nutrients. Contamination by human activities is evident, reflected on the levels detected on nutrients (nitrogen, phosphates), heavy metals and bacteriological parameters (BOD, Fecal coliforms, COD). Because of this, in general terms, superficial water in the study area is not adequate for recreation activities, human consumption or the maintenance of a healthy fish and wildlife population.

Table K-88: Results of Surface Water Quality Survey

ANALYSIS	Florida*	SURFACE WATER SAMPLES							
		No. 1	No. 2	No. 3	No. 4	No. 5	No. 6	No. 7	No. 8
1. Acidity (mgCaCO3/L)	---	18.4	4.1	4.1	< 1.0	12.2	12.2	18.4	< 1.0
2. Alkalinity (mgCaCO3/L)	> 20	229.3	105.8	129.4	1070.2	168.6	126.4	131.3	65.7
3. Suspended Solids (mg/L)	----	< 1.0	< 1.0	< 1.0	85	20	< 1.0	8	30
4. Turbidity (NTUFORMAZIN)	5.7	16.8	923	7.6	213	5.5	30.8	5.9	38.7
5. Ammonium Nitrate (mgNH3/L)	<0.02	35.3	0.31	0.1	392	29.6	2.38	0.08	0.08
6. BOD5 (mg O2/L)	a.	3.7	< 1.0	< 1.0	30	15.3	12	1.9	< 1.0
7. COD (mg O2/L)	a.	5	1	2	274.3	15	15	2	1
8. Oils (mg/L)	<5.0	10	5	2	15	< 1.0	15	5	8
10. Total Phosphates (mg P/L)	0.04	0.1	0.09	0.12	0.19	0.08	0.7	0.06	0.08
11. Chlorine (mg /L)	---	137	7	4	370	13	40	2	4
12. Organic Nitrogen (mg /L)	0.7	0.99	1.34	1.07	1.8	1.39	0.89	0.32	1.15
13. Fecal Coliforms (UFC/100ml)	800	1000	3000	2 x106	3x106	5 x104	1000	800	3000
14. Calcium (mg Ca/L)	---	100	17.5	20.5	94.3	25.4	57.3	18.8	9.1
15. Sodium (mg Na/L)	---	28.3	16.8	19	28.9	20.5	30.5	17.6	26
16. PCBs (mg/L)	---	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
17. Silica (mg Si/L)	---	0.07	0.3	0.2	0.08	0.2	0.05	0.4	0.06
18. Copper (mg Cu/L)	<0.012	< 0.05	0.06	<0.05	< 0.05	< 0.05	0.97	< 0.05	0.06
19. Manganese (mg Mn/L)	---	1.5	<0.02	0.09	0.17	0.59	2.9	0.06	0.23
20. Iron (mg Fe/L)	<1.0	2.1	0.05	0.3	2.2	0.35	6.4	0.17	2
21. Zinc (mg Zn/L)	<0.1	< 0.1	0.05	0.05	< 0.1	< 0.05	< 0.05	< 0.05	< 0.1
22. Arsenic (mg As/L)	<0.05	< 0.05	< 0.05	< 0.05	<0.05	< 0.05	< 0.05	< 0.05	< 0.05
23. Lead (mg Pb/ L)	<0.003	< 0.05	< 0.05	< 0.05	<0.05	< 0.05	< 0.05	< 0.05	< 0.05
24. Cadmium (mg Cd/L)	<0.001	< 0.05	< 0.05	< 0.05	<0.05	< 0.05	< 0.05	< 0.05	< 0.05
25. Total Chromium (mg CrT / L)	---	< 0.05	< 0.05	< 0.05	<0.05	< 0.05	< 0.05	< 0.05	< 0.05
26. Chromium (VI) (mg Cr6+ /L)	<0.011	< 0.05	< 0.05	< 0.05	<0.05	< 0.05	< 0.05	< 0.05	< 0.05
27. Bicarbonate (HCO3-/L	---	1.4	1.1	1	< 1.0	2.2	2.2	1.8	< 1.0
28. Cyanide (mg CN/L)	---	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2
29. Mercury (mg Hg)	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02

* Florida, U.S. standards, 62-302.530, for superficial water (recreational use, propagation and maintenance of a balanced fish and wildlife population)

Water Flow

Water flows were measured at the same points as surface water quality survey. The flows registered varied significantly, from small to important water bodies, such as the Mocambo River. The smallest flow registered was 0.018 m^3/min at sampling point No 1, while the largest flow was 14.25 m^3/min, registered at the Mocambo River (point No 5). Table K-89 shows results of the flow measurement.

Table K-89: Surface Water Flow

Sampling Point	Flow (m^3/s)	Flow (m^3/min)
1	0.0003	0.018
2	0.0632	3.792
3	0.1699	10.194
4	0.0197	1.182
5	0.2375	14.250
6	0.1478	8.868
7	0.0254	1.524
8	0.1152	6.912

b.1.4 Groundwater

In order to grasp groundwater conditions in the Cerro Patacon Final Disposal Site, water samples obtained from 10 wells were analyzed at the field and a laboratory of a university (Universidad Tecnologica de Panama). Besides, geological survey estimated the direction of groundwater flow in the site.

Groundwater Flow

According to the drilling survey, it is estimated that the groundwater flows from the northwest to the southeast under the project site. There will be fissure water as the rock has many cracks.

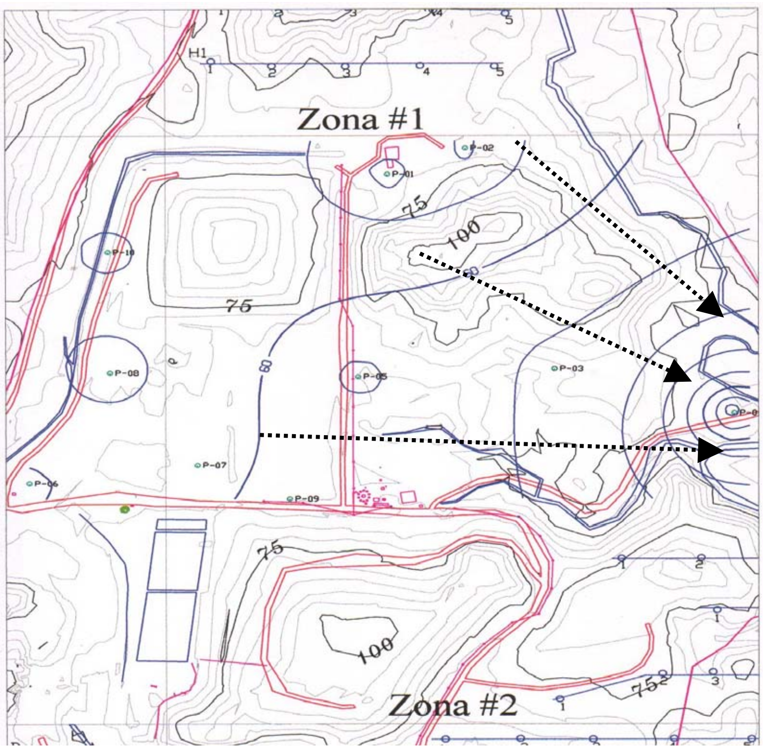


Figure K-57: Direction of Ground Water Flow

Groundwater Quality

Table K-90 presents the main results from the laboratory analysis for groundwater quality compared to superficial water quality in the study area. It can be observed that groundwater has a similar composition to the surface water, with the exception of its bacteriological quality and some general parameters. For example, bacteriological parameters analyzed were detected at lower concentrations in the groundwater BOD (1.2 – 3.8 mg/L), COD (1 – 34.3), and Fecal Coliforms (0 – 8,000 UFC / 100 ml). Nevertheless, the concentration of suspended solids (4 – 8,584 mg/L) and turbidity (0.94 – 3,110 NTU) detected in groundwater are much higher than those detected in surface water. This situation is not common, since typically the suspended solids content is lower in groundwater. This might be caused by disturbed samples. The presence of high concentrations of oils (5 – 259 mg/L), relatively high for groundwater, is also worth mentioning.

Because of the reasons described, it can be concluded that the superficial groundwater in the project area is contaminated mainly by organic material at levels lower than superficial waters and by oils.

Table K-90: Groundwater Quality

Analysis Items	No.1	No. 2	No. 3	No. 4	No. 5	No. 6	No. 7	No. 8	Exist. No. 1	Exist. No. 2
1. Acidity (mgCaCO3/L)	36.7	< 1.0	< 1.0	22.4	< 1.0	< 1.0	18.4	16.3	299.9	49
2. Alkalinity (mgCaCO3/L)	46	188.2	220.5	76	88	98	448.8	229.3	933	503.7
3. Suspended Solids (mg/L)	8584	485	440	3248	2264	885	85	4	84	120
4. Turbidity (NTUFORMAZIN)	229.3	426	361	2690	1995	3110	334	2.74	0.94	191
5. Ammonium Nitrate (mgNH3/L)	0.45	0.09	0.45	3.9	0.52	0.07	0.02	0.16	2.57	0.08
6. BOD5 (mg O2/L)	< 1.0	< 1.0	1	1.6	3.8	2	3.6	< 1.0	2.2	1.2
7. COD (mg O2/L)	4	1	1	2	4	10	5	2	34.3	2
8. Oils (mg/L)	73	9	34	61	76	259	32	7	38	5
10. Total Phosphates (mg P/L)	0.16	0.12	0.3	0.57	0.1	0.3	0.12	0.08	0.05	0.08
11. Chlorine (mg /L)	9	7	2.5	24	35	54.5	36	10.5	614.8	80
12. Organic Nitrogen (mg /L)	0.35	1.8	1.47	0.35	1.42	1.42	1.15	0.46	0.56	1.31
13. Fecal Coliforms (UFC/100ml)	0	20	8000	0	0	0	120	4	0	40
14. Calcium (mg Ca/L)	5	10.9	8.4	18.2	7.1	107.6	18.2	32.3	120	44.9
15. Sodium (mg Na/L)	25	11.9	28.5	21.3	30.2	26.4	21.8	21.3	26	30.5
16. PCBs (mg/L)	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
17. Silica (mg Si/L)	0.14	0.05	0.06	0.1	0.03	0.11	0.1	0.05	0.05	0.07
18. Copper (mg Cu/L)	< 0.05	< 0.05	0.73	< 0.05	<0.05	0.1	< 0.05	0.07	<0.05	< 0.05
19. Manganese (mg Mn/L)	0.02	< 0.02	0.7	<0.02	0.05	4.1	< 0.02	3.2	80	0.6
20. Iron (mg Fe/L)	2.7	1.2	6.5	0.04	0.25	0.9	1.1	1.4	0.2	0.3
21. Zinc (mg Zn/L)	< 0.1	0.48	< 0.05	< 0.05	< 0.05	< 0.1	< 0.05	< 0.1	0.47	< 0.1
22. Arsenic (mg As/L)	<0.05	< 0.05	< 0.05	<0.05	< 0.05	< 0.05	<0.05	< 0.05	< 0.05	< 0.05
23. Lead (mg Pb/ L)	<0.05	< 0.05	< 0.05	<0.05	< 0.05	< 0.05	<0.05	< 0.05	< 0.05	< 0.05
24. Cadmium (mg Cd/L)	<0.05	< 0.05	< 0.05	<0.05	< 0.05	< 0.05	<0.05	< 0.05	< 0.05	< 0.05
25. Total Chromium (mg CrT / L)	<0.05	< 0.05	< 0.05	<0.05	< 0.05	< 0.05	<0.05	< 0.05	< 0.05	< 0.05
26. Chromium (VI) (mg Cr6+ /L)	<0.05	< 0.05	< 0.05	<0.05	< 0.05	< 0.05	<0.05	< 0.05	< 0.05	< 0.05
27. Bicarbonate (HCO3-/L	1.7	< 1.0	< 1.0	2.4	< 1.0	< 1.0	1.4	2	9.9	4
28. Cyanide (mg CN/L)	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2
29. Mercury (mg Hg)	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02

b.1.5 Air Quality

SO_2, NOx and H_2S

Table K-91 shows the results of the measurements performed for SO_2, NOx and H_2S. SO_2 concentrations detected varied between 0.1 ppm and 0.625 ppm and in every case were higher than the 24 hour value recommended by the World Health Organization (WHO), 0.04 ppm. It should be noted that there is also a recommended value for a 10 minute exposure (0.175 ppm). For this case, only three points analyzed would be in compliance with the WHO guidelines. In the case of NOx, all samples analyzed are below WHO guidelines for a 1 hour or 1 year exposure. Even though guidelines for H_2S are not presented, it can be stated that concentrations are low.