A9.3 GEOTECHNICAL INVESTIGATION

INSTITUTO NACIONAL DE RECURSOS HIDRÁULICOS

Investigaciones y Proyectos
HIDRÁULICOS HABANA

RESEARCH DIRECTION

GEOTECHNICAL INVESTIGATION

The Improvement of Sewerage and Drainage System for The Havana Bay in the Republic of Cuba

October 2003

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The Improvement of Sewerage and drainage System
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PART:

GEOTECHNICAL INVESTIGATION

PROVINCE:
Havana City.

P.O. Santander

Made by:
M.Sc. Eddy Hernández
Getechnical specialist.

Santander

Checked by:
Eng. Raúl Santander
Chief of Project.

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Index

Investigaciones y Proyectos
HIDRÁULICOS HABANA

Contract: The Improvement of Sewerage and drainage System for The Havana Bay In the Republic of Cuba.

General location: Southern and western shoreline of the Havana Bay.

(Appendix 1).

Subject: Engineering geological report.

Introduction:

This report includes the results of the investigation requested by the JICA Study Team from Japan. The purpose of this work is to obtain geotechnical data from a series of boreholes drilled in the area in which a wastewater treatment plant and the collector system are planed to be built.
As a conclusion of this report the following aspects should be covered:

- Type, thickness and location in the profile of different layers of soils and rocks at maximum to 20 m in depth.
- Physical and mechanical properties of all different soil and rock types are in the study area.
- Ground water records.

This document is divided in two parts; the first one is called **Factual Report** in which all the results of the work carried out are included and the second one **Interpretative Report** in which the interpretation of the results and the general engineering geological conditions of the study area are included.
For better understanding of the presentation and interpretation of the results, the study area is divided in three sectors which are the followings:

Sector 1: It is located closed to Via Blanca Street and river Luyanó. Here the boreholes 1 and 2 were drilled.

Sector 2: It is located along Fabrica Street, near the SASA office and the railway.

Sector 3: It is located in the Ave del Puerto Street, between streets O´Relly and Obispo.

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I.- Factual Report.

1.1- General description of the study area.

Sector 1.

The area of the borehole 1 is flat and located few meters from a gas station and on one side of Via Blanca Street. It is covered by grass and trees.
The area of the borehole 2 is located behind a warehouse, 30 m approximately from Via Blanca Street. The terrain is flat and has a slightly inclination to the east. It is covered by bushes, grass and vegetables (See appendixes 1, 2 and 3).

Sector 2.

The borehole 4 was made in a place with no vegetation, 2 m from the pavement boundary of Fabrica Street, near the gas station.
The borehole 5 is in front of SASA office in a place with a slightly inclination to the north (See appendixes 1 and 5).

Sector 3.

The borehole 3 is located inside the boundary of a demolished building. The ground level is approximately 1m above the street ground level.

1.2- Description of the carried out works.

A total of 5 boreholes were made with the minimum depth of 8.5 m (borehole 3) and a maximum of 20 m (boreholes 4 and 5). The total amount of boring is 85 m (See appendixes 6 to 10). The boring was carried out using the split tube sampler and a total amount of 31 SPT records was taken. In addition, a rotary boring method was used preferably without water, but in some occasions, depending of the soil type, water was added to assist the borehole advance.
The boring machine used was the Stratadrill 36 (See appendix 12). The location of the boreholes was suggested by the specialist representing the JICA Study Team.
The sample description was made by the geotechnical specialist in charge of the investigation.
The amount of samples taken for the laboratory is the following:
Undisturbed thin walled tube (Shelby) samples----------4
Undisturbed sealed with paraffin samples----------6
Disturbed samples in airtight containers----------8
After boring the ground water level was measured in all boreholes and two hydro geological tests were made in the borehole 2 which consisted on lowering the water

Investigaciones y Proyectos
HIDRÁULICOS HABANA

level in the borehole and then measure the recovery to finally determine the permeability of the soil layers.
The following laboratory tests were carried out:
Water content----------13
Specific gravity----------7
Density----------8
Plasticity limits ----------6
Grain size----------4
Direct undrained shear box tests----------9
Undrained triaxial tests----------6
Consolidation tests----------2 (16 load steps)
The laboratory test results are included in the appendix 11.

II.- Interpretative Report.

2.1. Engineering geological conditions.

2.1.1 ***Sector 1 and 2.***

Soil conditions.

Both sectors are similar. Sector 1 (boreholes 1 and 2) is located near river Luyanó and its mouth in Havana Bay. Sector 2 (boreholes 4 and 5) is located closed to the SASA office and railway in Fabrica Street. It is found in the place that in the past was below the water of Havana Bay. Both sectors are characterized by the presence of fine alluvial, swamp and marine quaternary sediments which consist of highly compressible and low bearing capacity clay.
Overlaying the soft quaternary clay an anthropogenic backfill is located. This backfill is the result of human activity in the city. It is generally very heterogeneous, mainly formed by dumped material from construction and can contain pieces of concrete in different sizes.
Underlying the soft quaternary clay a layer of cretaceous over consolidated sandy clay and claystone are encountered. This layer belongs to Via Blanca geological formation and it is characterized by a low compressibility and high bearing capacity. For more details see appendixes 1 to 10.
The physical, mechanical properties and detailed description of the above mentioned layers or elements for sectors 1 and 2 are exposed below.

Element 1: Heterogeneous, loose to medium dense backfill made of dumped material, fragments of rocks, pieces of concrete, sand and clay of different color, etc. Due to its composition samples to the lab were not taken. It appears in all boreholes. (See appendixes 6 to 10)

Investigaciones y Proyectos
HIDRÁULICOS HABANA

Element 2: Dark grey and greenish grey soft clay occasionally with thin layers of fine sand. It has high plasticity, low dry strength and none dilatancy. It was found in the boreholes 1, 2, 4, and 5 underlying the backfill (See appendixes 6 to 10). It classifies as CH.

The physical and mechanical properties are as follows:

Water content, %----------42.3
Specific gravity ----------2.68
Density, KN/m^3 ----------17.1
Dry density, KN/m^3 ----------12.01
Liquid limit, %----------52
Plastic limit, %----------21
Plasticity index, %----------31
Undrained cohesion, KPa----------20
Friction angle, degrees----------0
Deformation modules (Odometer), KPa
Load interval
0.0-50 KPa----------1700
50-100 KPa----------1800

Element 3: Stiff to very stiff brown and greenish brown clay, sometimes with white spots rich in calcium carbonate. It has high plasticity and dry strength. With the depth, intervals of claystone are found. It classifies as CH.

The physical and mechanical properties are as follows:

Water content, %----------32.7
Specific gravity ----------2.7
Density, KN/m^3 ----------18.3
Dry density, KN/m^3 ----------13.8
Liquid limit, %----------77
Plastic limit, %----------32
Plasticity index, %----------45
Undrained cohesion, KPa----------150
Friction angle, degrees----------0
Deformation modules (Odometer), KPa
Load interval
0.0-100 KPa----------10500
100-200 KPa----------15300
200-400 KPa----------19500

Ground water.

The ground water is partially located inside the backfill, which classifies as permeable with a permeability coefficient kf between 1 and 10 m/day. Based on the hydrogeological

test carried out in the borehole 2 the permeability coefficient kf for the backfill is 2.6 m/day.

There is also ground water in the quaternary soft clay and in the underlying stiff brown clay. They have a low permeability with a measured in the borehole permeability coefficient of 0.01 m/day. The ground water levels are shown in the borehole logs (See appendixes 6 to 10).

2.1.2 *Sector 3*.

Soil conditions.

Regardless the position of the borehole 3 inside the limits of a demolished building, this sector is characterized by the presence of heterogeneous backfill which is originated by the human activity. This backfill is mainly formed by dumped material from construction and can contain pieces of concrete in different sizes.

Underlying the backfill a poor cemented quaternary limestone is found. From geotechnical point of view this is a sandy soil rich in calcium carbonate with gravels.

A detailed description of the above mentioned layers or elements are exposed below

Element 1: Heterogeneous, loose backfill made of dumped material, fragments of rocks, and pieces of concrete of light color. Due to its composition, samples to the lab and SPT record were not taken.

Element 2: Sandy soil rich in calcium carbonate with gravels. The attempt to measure the SPT record failed due to the presence of hard fragments of limestone.

Ground water.

The ground water is partially located inside the backfill and in the underlying sandy soil. Both layers are pervious with an estimated value of the permeability coefficient between 1 and 10 m/day. The level of the ground water is shown in the borehole log (Appendix 8).

2.2. Conclusions and recommendations.

After analyzing all the gathered data we can conclude the following:

1. The presence of the partially saturated backfill with significant thickness in all boreholes and studied sectors is a factor which should be taken in to account when a new construction is planed to be located. Generally a backfill like this has a bearing capacity between 100 and 300 KPa, but its deformation under a certain load can be very significant. This should be considered in the design of any new structure. It is advisable to avoid using it as foundation base. In addition, the backfill can be excavated by hand or using mechanical means.

Investigaciones y Proyectos
HIDRÁULICOS HABANA

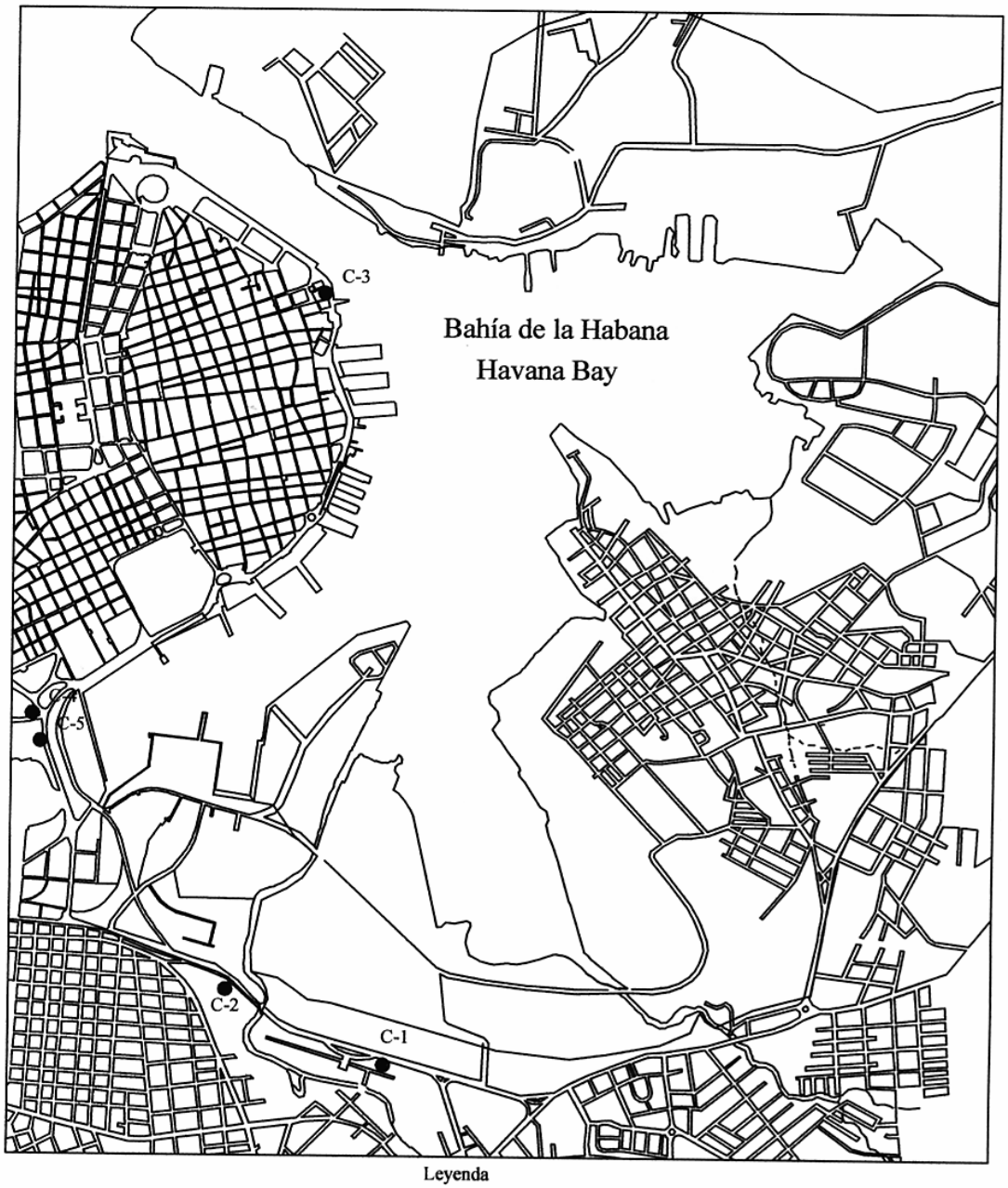
2. The soft quaternary clay found in the sectors 1 and 2 are very compressible and has low bearing capacity of about 30 KPa. That's why it is advisable to avoid using it as foundation base. Besides, serious slope instability problems can be generated in the excavations inside this soil because of its low strength properties.

3. The brown stiff clay found in the sector 1 and 2 is much appropriated for being used as base for any kind of foundation. The only problem in this case is the lying depth, which establishes the condition of using pile foundation which is at the same time is more expensive.

4. The poor cemented limestone or sandy soil with gravel located in the sector 3 has an estimated bearing capacity of 300 KPa. In this case, the presence of ground water in it and its high permeability constitute the main difficulty for making an excavation for foundation. The lowering of water table is practically impossible in this type of soil. Here, the only way to avoid those problems is using pile foundation.

Anexo 1
Appendix 1

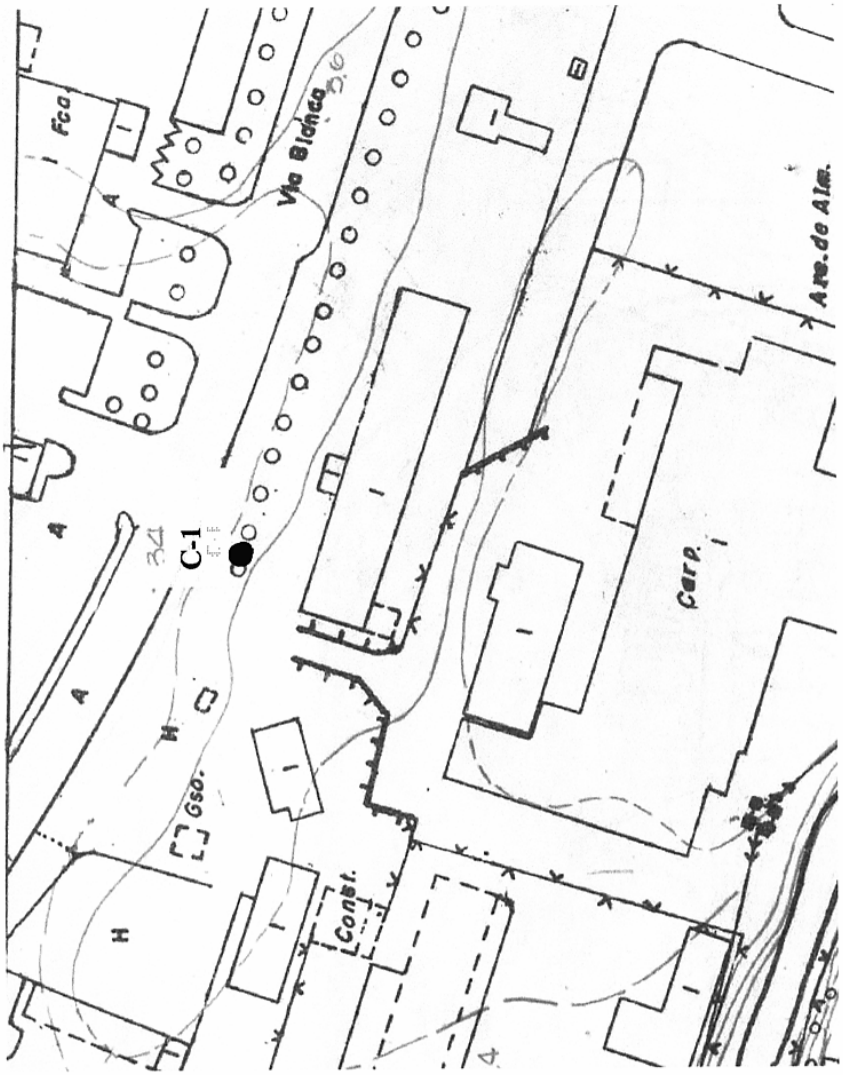
Plano general de ubicación de las calas perforadas.
General Location Map



Leyenda
Legend

C-1 Cala perforada
● Borehole

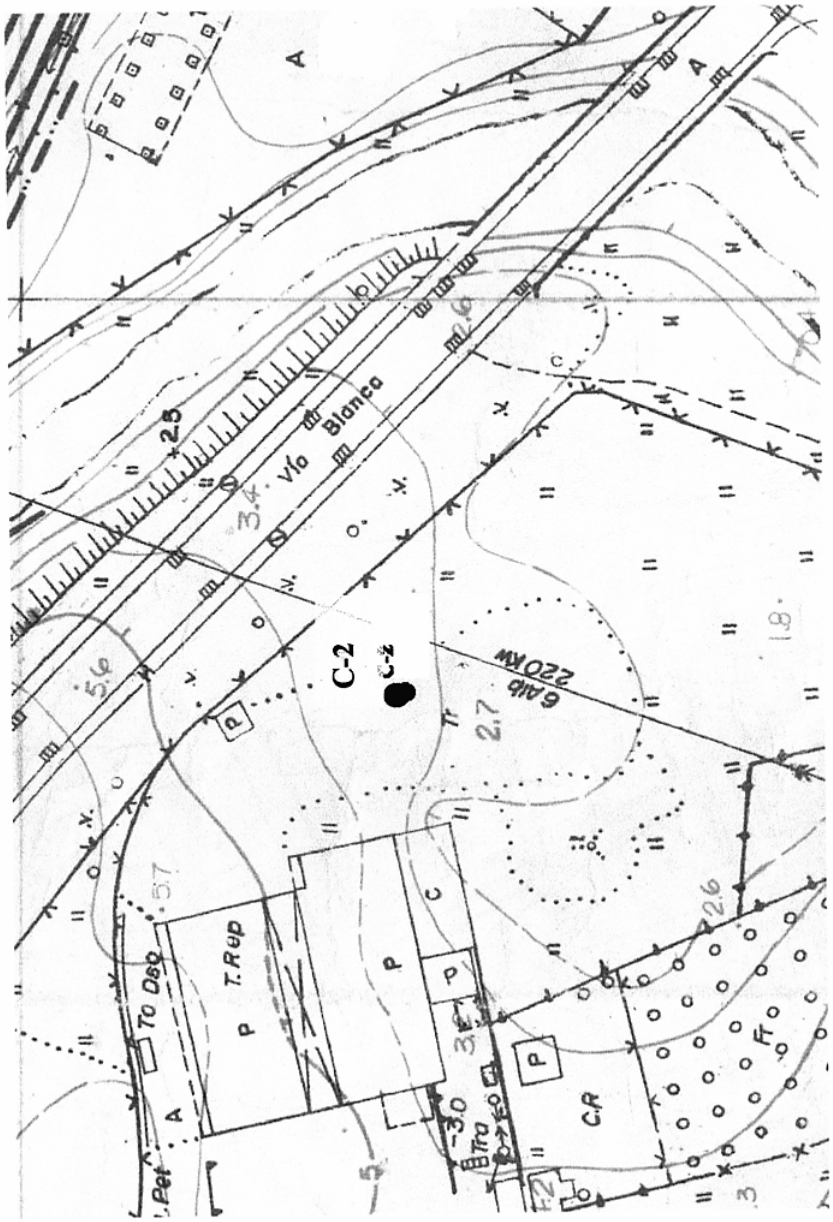
Anexo 2
Appendix 2



Plano de ubicación de la cala 1.
Location map of Borehole 1.

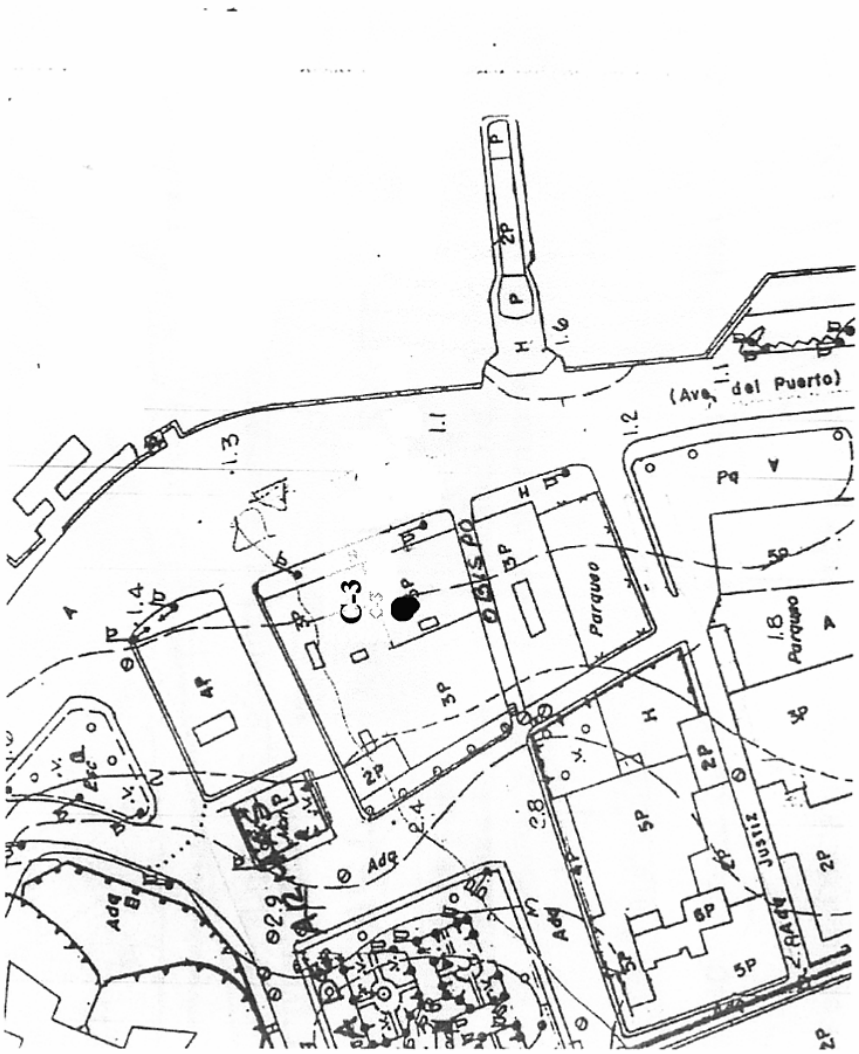
Anexo 3
Appendix 3

Plano de ubicación de la **Cala 2**.
Location map of **Borehole 2**.



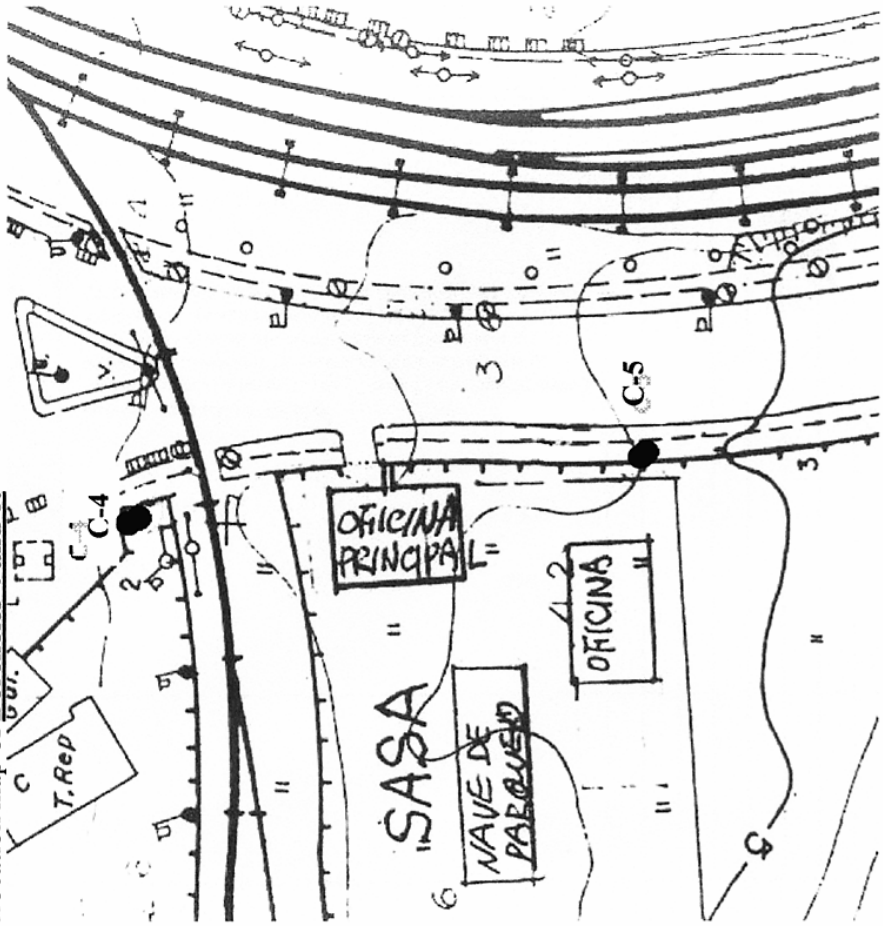
Anexo 4
Appendix 4

Plano de ubicación de la **Cala 3**.
Location map of **Borehole 3**.



Anexo 5
Appendix 5

Plano de ubicación de la **Cala 4 y 5**.
Location map of **Boreholes 4 and 5.**



Anexo 6

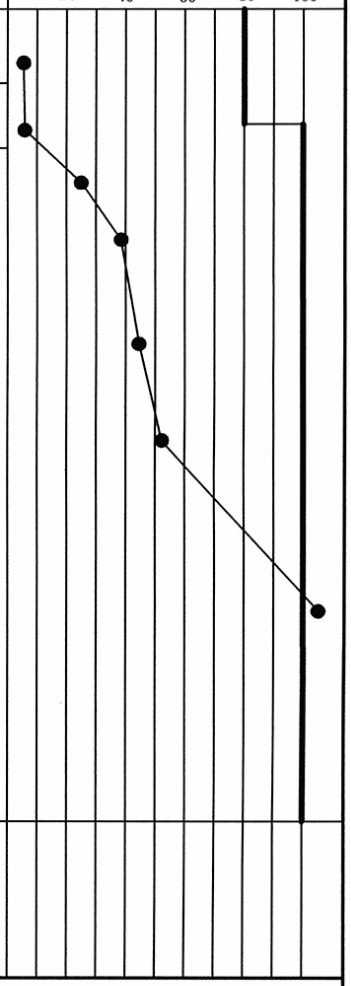
ENIA UIC Habana	COLUMNA LITOLOGICA	CONFECCIONADO	Ing. E.Hernandez
	OBRA: Planta de Tratamiento de Residuales Río Luyanó.	DIBUJADO	Ing. E.Hernandez
	SITUACION: Vía Blanca, en la margen este del Río Luyanó. 15 m de la gasolinera.	REVISADO	Ing. W.Gonzalez
	CALA No: 1 COORDENADAS:	PESO MARTILLO	
	FECHA: 15/9/03 X= 362196 Y= 364808 Z= 2.9 m	ALTURA DE CAIDA	

Cota del N.F.y Estrato. (m)	Escala Vertical	Profundidad del N.F.y Estratos (m)	Intervalo de perforación	Tipo de muestreador.	No. de golpes por 30 cm	Muestras de laboratorio.	Simbología de la Columna	Descripción
				ST				Relleno heterogéneo carbonatado compuesto por fragmentos rocosos, escombros, ladrillos etc. Estado suelto. Los primeros 0.3m son de capa vegetal.
				SS	7			
1.3		1.6		ST				
1.1	2	NF 1.8	4	SH		■		Arcilla de color gris oscuro de consistencia muy blanda, húmeda, de alta plasticidad. La dilatancia nula y la resistencia seca baja.
-0.1		3.0	5	SS	6	▲		
				ST				
	4			SS	25	▲		
			8	ST		■		
			9	SS	38			
	6		10	ST				
			11	SS	44			
	8		12	ST		■		
			13	SS	52	▲		
	10		14	ST				Arcilla carmelita clara con manchas blancas de carbonato de consistencia dura hasta los 6 m de profundidad y mas abajo se torna muy dura. La plastcidad es alta, la resistencia seca es alta. Se observan fisuras manchadas de carmelita rojizo. A partir de los 13 m de profundidad se torna a intervalos una argilita fisurada.
	12		15	SS	>100			
	14		16					
	16		17	ST				
-14.6		17.5						
	18							
	20							

No de golpes / 30 cm ●

R.Q.D. ——

Recuperación de la muestra %

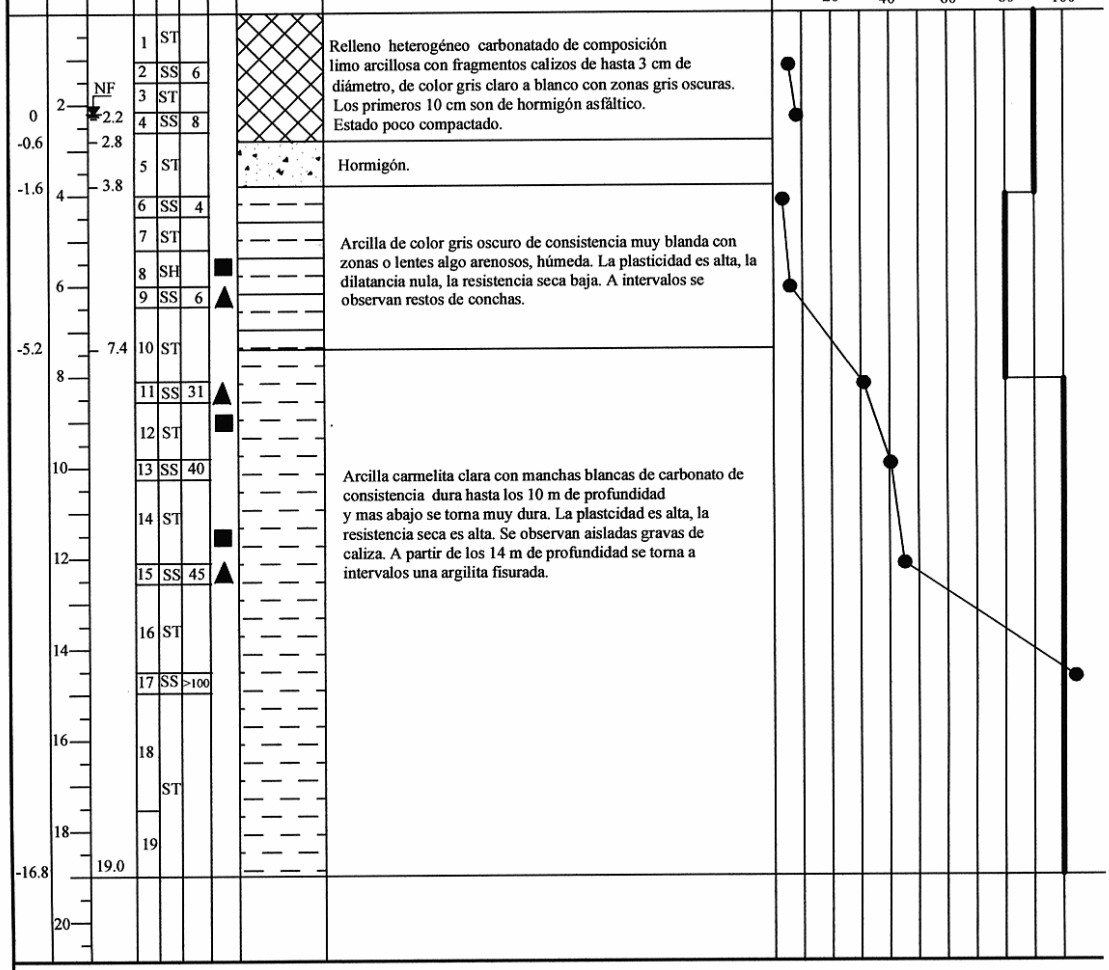


SS. CUCHARA
LP: LIMPIADOR
ST: PORTATESTIGO SIMPLE TUBO
HD. PORTATESTIGO DOBLE TUBO
SH: SHELBY ■ Muestra inalterada.
OS: OSTERBERG ▲ Muestra alterada.

OBSERVACIONES
Los muestreadores simple tubo utilizados fueron de 127 mm y 108 mm de diámetro.

Anexo 7

ENIA UIC Habana	COLUMNA LITOLOGICA	CONFECCIONADO	Ing. E.Hernandez
	OBRA: Planta de Tratamiento de Residuales Río Luyanó.	DIBUJADO	Ing. E.Hernandez
	SITUACION: Vía Blanca, en la margen occidental del Río Luyanó.	REVISADO	Ing. W.Gonzalez
	CALA No: 2 COORDENADAS:	PESO MARTILLO	
	FECHA: 10/9/03 X= 361524 Y= 365105 Z= 2.2	ALTURA DE CAIDA	



SS. CUCHARA
LP: LIMPIADOR
ST: PORTATESTIGO SIMPLE TUBO

HD. PORTATESTIGO DOBLE TUBO
SH: SHELBY ■ Muestra inalterada.
OS: OSTERBERG ▲ Muestra alterada.

OBSERVACIONES
Los muestreadores simple tubo utilizados fueron de 127 mm y 108 mm de diámetro.

Anexo 8

ENIA U/A 2	COLUMNA LITOLOGICA		
	OBRA: Planta de Tratamiento de Residuales Río Luyanó y Martin Perez.	CONFECCIONADO	Ing. E.Hernandez
	SITUACION: Ave.Puerto e/ Obispo y O'Relly, H. Vieja, C.Habana.	DIBUJADO	Ing. E.Hernandez
	CALA No: 3 COORDENADAS:	REVISADO	Ing. W.Gonzalez
	FECHA: 17/9/03 X= 361889 Y= 368372 Z= 2.3	PESO MARTILLO	
		ALTURA DE CAIDA	

No de golpes / 30 cm ●

R.Q.D. ——————

Recuperación de la muestra % (20, 40, 60, 80, 100)

Cota del N.F.y Estrato (m)	Escala Vertical	Profundidad del N.F.y Estratos (m)	Intervalo de perforación	Muestreador	No de golpes /30 cm	Muestras de laboratorio.	Simbología de la Columna	Descripción
			1					Relleno heterogéneo compuesto por fragmentos de roca caliza, ladrillos, arena, arcilla , gravas, restos de metal, de color gris claro,blanco amarillento con zonas carmelitas. Los últimos 10 cm lo constituye una losa de hormigón armado.
0.2	2	NF 2.1	2	ST				
-1.1		3.4	3					Suelo gravo-arenoso carbonatado con abundantes fragmentos de caliza . A intervalos se recuperan testigos de caliza de hasta 6 cm de largo. El color es blanco grisáceo. Litológicamente es una caliza fragmentaria,muy poco cementada.
	4		4	SS	R			
			5	ST				
			7	SS	R			
	6		8	ST				
			9					
-6.2	8	8.5	10					
	10							
	12							
	14							
	16							

SS. CUCHARA
LP: LIMPIADOR
ST: PORTATESTIGO SIMPLE TUBO

HD. PORTATESTIGO DOBLE TUBO
SH: SHELBY
OS: OSTERBERG

OBSERVACIONES

Dos intentos de ensayos SPT, pero en el tercer y ultimo tramo del muestreador se detuvo el avance por la presencia de una zona de más alta resistencia. La perforación se realizó salvo pequeños intervalos a rotación en seco.

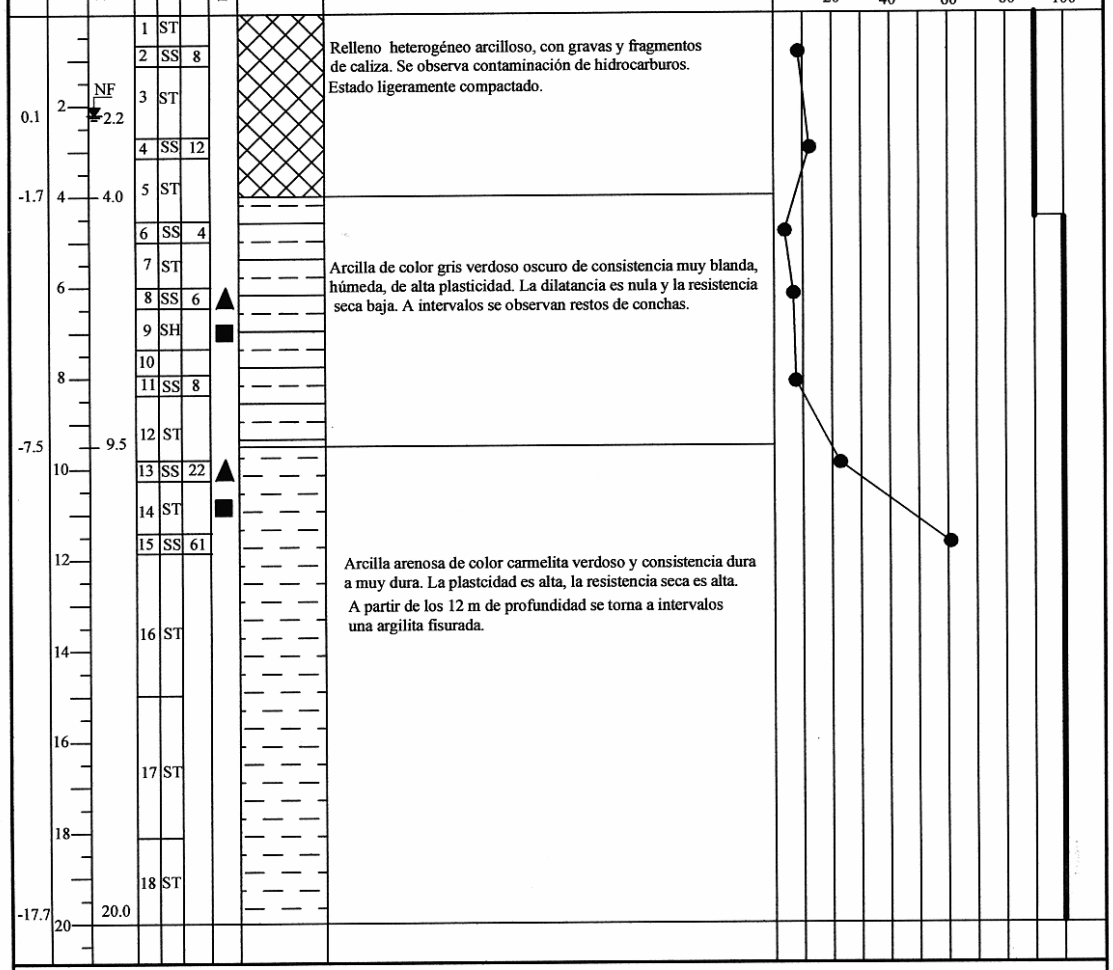
Anexo 9

ENIA UIC Habana	COLUMNA LITOLOGICA	CONFECCIONADO	Ing. E.Hernandez
	OBRA: Planta de Tratamiento de Residuales Río Luyanó y Martín Pérez.	DIBUJADO	Ing. E.Hernandez
	SITUACION: Calle Fábrica y Arroyo, a un costado de la gasolinera.	REVISADO	Ing. W.Gonzalez
	CALA No: 4 COORDENADAS:	PESO MARTILLO	
	FECHA: 19/9/03 X= 360553 Y= 366427 Z= 2.3 m	ALTURA DE CAIDA	

No de golpes / 30 cm ●

R.Q.D. ——

Recuperación de la muestra %



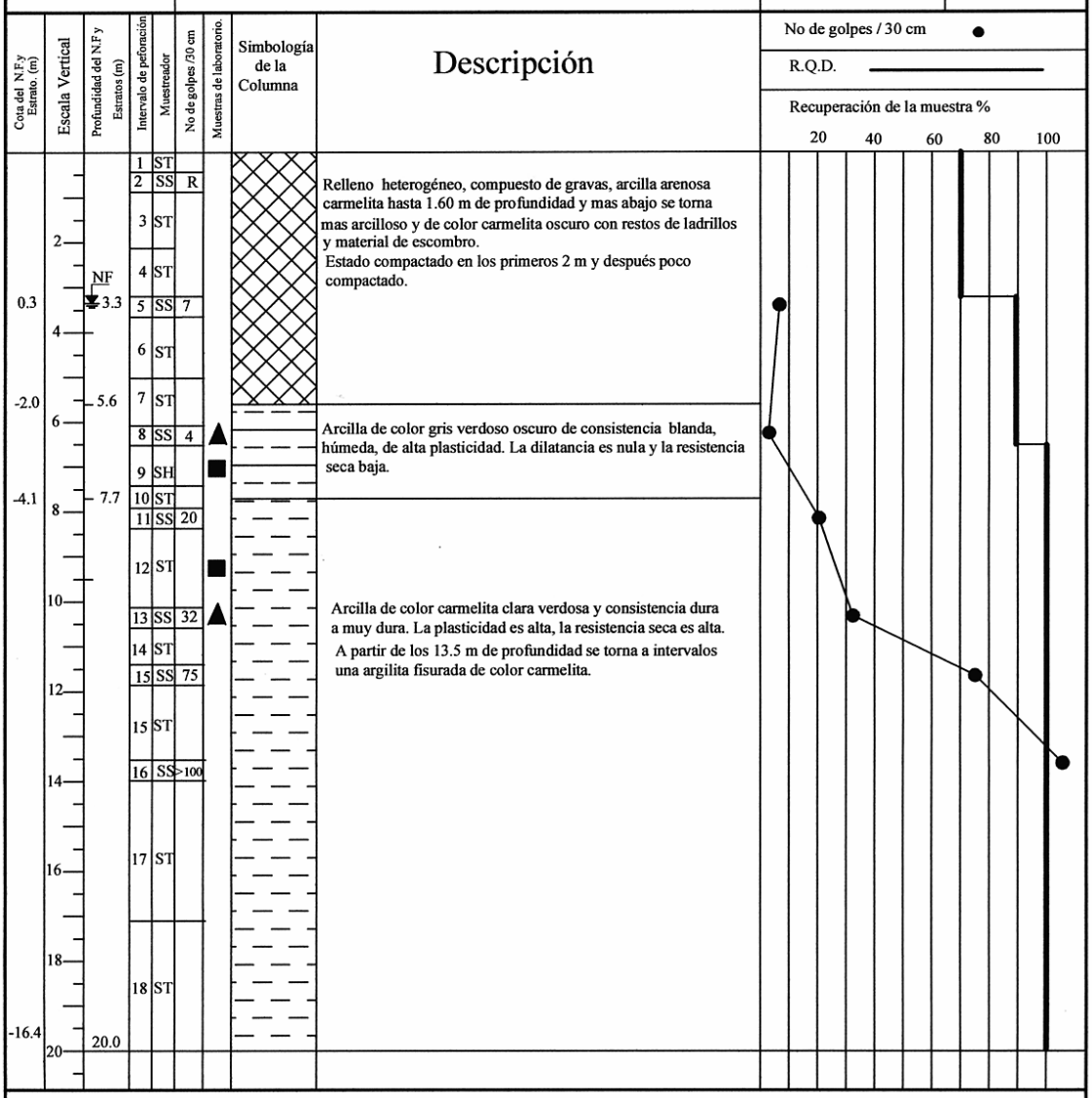
SS. CUCHARA
LP: LIMPIADOR
ST: PORTATESTIGO SIMPLE TUBO

HD. PORTATESTIGO DOBLE TUBO
SH: SHELBY ■ Muestra inalterada.
OS: OSTERBERG ▲ Muestra alterada.

OBSERVACIONES
Los muestreadores simple tubo utilizados fueron de 127 mm y 108 mm de diámetro.

Anexo 10

ENIA UIC Habana	COLUMNA LITOLOGICA	CONFECCIONADO	Ing. E.Hernandez
	OBRA: Planta de Tratamiento de Residuales Río Luyanó y Martín Pérez.	DIBUJADO	Ing. E.Hernandez
	SITUACION: Calle Fábrica, frente a la empresa Sasa.	REVISADO	Ing. W.Gonzalez
	CALA No: 5 COORDENADAS:	PESO MARTILLO	
	FECHA: 22/9/03 X= 360580 Y= 366306 Z= 3.6 m	ALTURA DE CAIDA	



SS. CUCHARA
LP: LIMPIADOR
ST: PORTATESTIGO SIMPLE TUBO

HD. PORTATESTIGO DOBLE TUBO
SH: SHELBY ■ Muestra inalterada.
OS: OSTERBERG ▲ Muestra alterada.

OBSERVACIONES
Los muestreadores simple tubo utilizados fueron de 127 mm y 108 mm de diámetro.
Un intento de ensayo SPT en el relleno tuvo rechazo por un fragmento de caliza.

InvesCons UIC Habana

Tabla Resumen de Ensayos de Suelos
Laboratory Test Results

OBRA: Planta de Trat
SITUACION:Vía Blanc

Cala No. Bore-hole	Muestra Sample No.	Profundidad,m Depth,m Desde	Hasta	Breve descripción Brief description	Gs	Wnat %	γ f kN/m³	Plasticidad Plasticity LL %	LP %	IP %	Granulometría Grain size distribution Gravel Gravas 72,6-4,76(mm)	Arena (%) Sand Gruesa Coarse	Media Medium	Fina Fine	Silt Limo (%) 0,074-0,005(mm)	Clay Arcilla(%) <0,005(mm)
1	SH-1	1.70	2.40	Arcilla gris blanda. Grey soft clay	2.69	42	16.9	50	20	30						
1	P-1	2.40	2.85	Arcilla gris blanda Grey soft clay	2.68	40.6										
1	P-2	3.70	4.15	Arcilla carmelita dura. Brown stiff clay.							0	0	4	6	20	70
1	M-1	4.15	4.40	Arcilla carmelita dura. Brown stiff clay.	2.7	32	18.2									
1	M-2	8.20	8.45	Arcilla carmelita dura. Brown stiff clay.		33.1	18.7	74	30	44						
1	P-3	9.30	9.75	Arcilla carmelita dura. Brown stiff clay.							0	0	3	8	15	74
2	SH-1	5.20	6.00	Arcilla gris blanda. Grey soft clay		45.6	16.8									
2	P-1	6.00	6.45	Arcilla gris blanda Grey soft clay		43.5		54	22	32						
2	P-2	8.15	8.60	Arcilla carmelita dura. Brown stiff clay.				85	35	50	0	0	5	4	19	72
2	M-1	9.00	9.25	Arcilla carmelita dura. Brown stiff clay.	2.71	32.6	18.3	73	34	42	0	0	5	7	17	71
2	M-2	11.20	11.45	Arcilla carmelita dura. Brown stiff clay.		30.2	18.7									
4	P-1	6.00	6.45	Arcilla gris blanda Grey soft clay		39.5										
4	SH-1	6.45	7.25	Arcilla gris blanda. Grey soft clay	2.67											
4	P-2	9.80	10.25	Arcilla carmelita dura. Brown stiff clay.		28.7										
4	M-1	10.60	10.85	Arcilla carmelita dura. Brown stiff clay.	2.71	29.7	18.5									
5	P-1	6.10	6.55	Arcilla gris blanda. Grey soft clay		42.8										
5	SH-1	6.55	7.35	Arcilla gris blanda. Grey soft clay	2.68	39.6	16.9									
5	M-1	9.00	9.25	Arcilla carmelita dura. Brown stiff clay.												
5	P-2	10.20	10.65	Arcilla carmelita dura. Brown stiff clay.				82	36	46						

Gs- Specific gravity, Wnat- Water content, γf- Natural density, γf- Dry density, LL- Liquid limit, PL- Plastic limit, e-Void ratio, S-Saturatión, Def Axial- Axial strain.

amiento de Residuales Río Luyanó y Martín Pérez.
a y Río Luyanó, Elevados del ferrocarril y Ave del Puerto e/ O'Relly y Obispo .

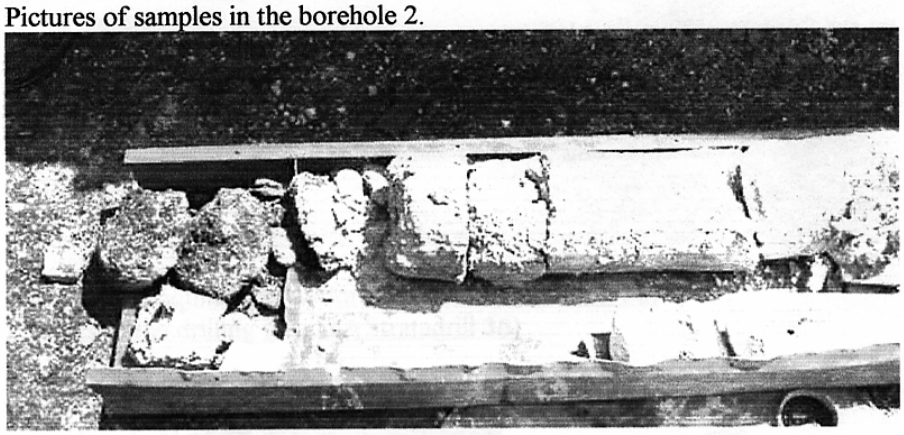
Appendix 11
ANEXO 11

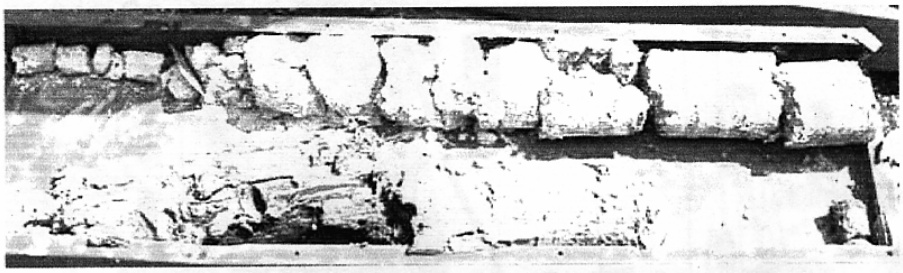
Resultados del Ensayo de Triaxial y Cortante Rápido no drenados. Undrained Triaxial and Shear box test Results											Resultados del Ensayo de Consolidación, Consolidación Test Results										
											Condiciones Naturales Natural conditions					E para Cargas Edometric Modules					
W %	γ f kN/m³	γ d kN/m³	e	S %	σ Kpa	τ Kpa	σ3 KPa	σD KPa	σ1 KPa	Def.Axial %	W %	γ f kN/m³	γ d kN/m³	e	S %	25 Kpa	50 Kpa	100 KPa	200 KPa	400 KPa	800 KPa
43.2	17.3	12.08	1.21	96	50	20															
41.4	16.8	11.88	1.25	90	100	21															
40.7	16.9	12.01	1.23	89	200	23															
33.7	18.4	13.76	0.97	96			100	315.6	415.6	10	35.2	17.85	13.16	1.05	90			10500	15300	19500	26400
32	18.31	13.86	0.85	91			200	319.4	519.7	8											
44.5	16.98	11.89	1.27	94	50	12															
40	17.58	12.33	1.19	91	100	13															
42.5	17.23	12.07	1.2	95	200	15															
33.8	18.2	13.6	0.98	92			200	360.3	660.3	10											
31.4	18.3	13.9	0.94	90			300	330.2	630.2	8											
41.2	17.1	12.11	1.21	91	50	30															
42.3	17.5	12.29	1.17	96	100	31															
44.7	16.8	11.67	1.31	98	200	28															
32.9	18.6	13.9	0.99	93			200	295	495	9											
											43.6	17.32	12.06	1.22	96	2000	2600	4100	4600		
30.5	18.7	14.32	0.89	93			300	272.5	572.5	8											

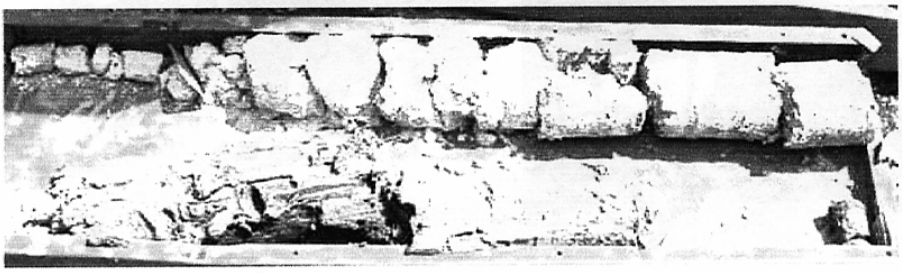
1

Anexo 12
Appendix 12

Fotos del muestreo en la cala 2.
Pictures of samples in the borehole 2.

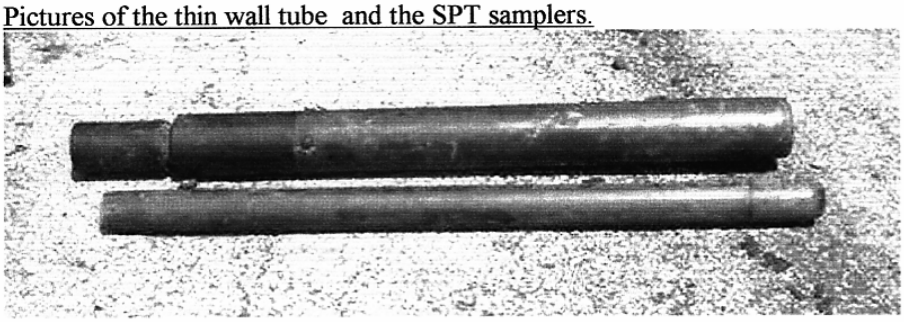






2

Fotos del muestrador de paredes finas y la cuchara o muestrador de tubo dividido.
Pictures of the thin wall tube and the SPT samplers.



Fotos de la máquina perforadora empleada (Stratadrill 36)
Pictures of the drilling machine(Stratadrill 36)