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Division de Proyectos de Capicidad del Canal

THE PANAMA CANAL

ENGINEERING SERVICES

Work Order No. 11
Upper Chagres Water Supply Project

Feasibility Study

Volume 2 APPENDICES A-B

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In association with
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Feasibility Design For
The Upper Chagres Water Supply Project

Volume	Title
1	Main Report
2	**Appendix A – Hydrology, Meteorology and River Hydraulics** **Appendix B – Geology, Geotechnical and Seismological Studies**
3	Appendix C – Operation Simulation Studies Appendix D – Project Facilities Studies Appendix E – Power and Energy Studies Appendix F – Cost Estimates

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FEASIBILITY DESIGN FOR THE UPPER CHAGRES WATER SUPPLY PROJECT

APPENDIX A

HYDROLOGY, METEOROLOGY AND RIVER HYDRAULICS

Prepared by

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EXECUTIVE SUMMARY

Hydrologic analyses were performed for the Upper Río Chagres development to estimate the long-term monthly flow sequence, net reservoir evaporation, construction period floods, spillway design flood and depletion of reservoir storage due to sedimentation.

The long-term monthly flow sequence at the proposed dam site was developed from the streamflow data recorded on the Río Chagres at Chico. The gauging station is maintained and operated by the ACP. The flow data at the station is available from March 1933 to date with the data missing for years 1968 and 1969, and a few additional months. The missing data was filled-in using statistical procedures to complete a data set for the period from January 1933 to December 2000. The data set was checked for consistency and homogeneity and was judged to be reasonable for representation of long-term future conditions. The mean annual flow is about 30.2 m^3/s. Because of very small intervening area between the gauge and dam site, the recorded mean annual flow was considered to represent flow at the damsite.

Lake evaporation data for Madden Lake was obtained from ACP. Annual net reservoir evaporation was about 1,321 mm. This rate was considered applicable for the Upper Río Chagres reservoir.

Construction period floods were estimated on an annual basis using annual maximum instantaneous flood peak data. The Log Pearson Type III (LP III) probability distribution was fitted to the annual peaks. The distribution indicated a reasonable goodness of fit. The estimated 10-, 20-, 25, 50- and 100-year flood peaks were about 1710, 2000, 2110, 2420 and 2740 m^3/s, respectively.

The design flood for the project was adopted to be the probable maximum flood (PMF) and was based on a 24-hour probable maximum precipitation (PMP) of about 657 mm. The time distribution of the PMP was based on depth-duration data of historic storms. The unit hydrograph for the basin was derived using dimensionless unit graph-lag curve method. The resulting PMF had a peak of about 9,940 m^3/s and 3-day volume of about 271 million cubic meters.

ACP is collecting suspended sediment samples on the Río Charges, Río Pequeni and Río Boqueron, all three rivers are draining into Madden Lake. ACP analyzed these data and provided monthly, suspended sediment discharges for the three rivers. ACP also performed reservoir sedimentation survey of Madden Lake. Based on these data, the mean annual sediment inflows were estimated to be about 602,800 metric tons. Analysis for the depletion of the live storage of the reservoir was made using the method of empirical area reduction method developed by the United States Bureau of Reclamation. The analysis indicated that the live storage would be reduced from one to three percent after about 50 to 100 years of operation. Thus, sedimentation effect on the live storage would not be significant.

FEASIBILITY DESIGN FOR THE UPPER CHAGRES WATER SUPPLY PROJECT

APPENDIX A – HYDROLOGY, METEOROLOGY AND RIVER HYDRAULICS

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1 INTRODUCTION

The ACP has determined that currently available water supply is limited and may not be sufficient to meet the future transit demands to lock ships across the Isthmus. New sources of water have been investigated at pre-feasibility and feasibility levels to determine their potential contributions to the existing system in order to provide increased traffic service. As a part of these investigations, a dam is proposed on the Upper Río Chagres to form a reservoir, which will be operated to store water during the periods when the water from the lower basins would be sufficient to meet the demands and release water when needed. A hydropower plant will also be located at the dam site.

1.1 OBJECTIVE AND SCOPE

This Appendix describes the hydrologic analyses performed at a feasibility level for the development on the Upper Río Chagres. The procedures and basic data used in the determination of the following hydrologic parameters are discussed.

- Streamflow Availability
- Reservoir Evaporation
- Construction Period Flood
- Spillway Design Flood
- Reservoir Sedimentation
- Channel Stability Downstream of the Dam

1.2 LOCATION AND ACCESSIBILITY

The Río Chagres contributes to Madden Lake and the basin is located to the northeast of the Lake. The proposed dam on the Río Chagres would be approximately 15 km northeast of Panama City and 500 meters downstream from the confluence of the Río Chico and Río Chagres, at latitude 9^0 16' 00" north and longitude 79^0 30' 25" west. A Location Map is shown on Exhibit 1. The dam would be about 150 meters upstream from the stream gauging station located on the Río Chagres. The drainage area at the gauge is about 414 km^2. Because of a short distance between the dam and the gauge, the drainage area at the dam site was assumed to be same.

2 CLIMATE

2.1 GENERAL

The general climate of Panama is tropical with wet and dry seasons induced by the annual movement of the intertropical convergence zone (ITCZ). During the dry season, generally the months of February, March and April, the ITCZ is located south of Panama near the equator. In March or April, the ITCZ moves northward generally reaching Panama in late May or early June. Its passage results in heavy rainfall over a major portion of Panama. When the ITCZ is well north of Panama, occasionally the strength of the rainy season subsides and the months of July or August or both become a secondary dry season. In late summer or early autumn, the ITCZ starts its southward migration and it passes over Panama in late October or early November. During the months of October through December and occasionally in January, heavy rainfall occurs over Panama. When the ITCZ has moved well south of Panama, the dry season is established again. In general, the wet season is characterized by mild humid winds from a southerly direction while less humid, but somewhat stronger, northerly winds are more typical of the dry season (La Fortuna Project, 1976)

2.2 RAINFALL

A regional isohyetal map, taken from Atlas (1988), is shown on Exhibit 2. There are two recording rainfall stations in the Río Chagres basin for which historic rainfall data are available. The stations are named as Chico and Río Piedras. Daily rainfall data at Chico is available from October 1932 to date with data missing for a few months. At Río Piedras, the data is available from May 1985 to date. Monthly rainfall data at both stations were generated for the period from 1911 to 2000 as part of a study made by Montgomery Watson Harza (MWH) entitled, "Study of Variations and Trends in the Historic Rainfall and Runoff Data in the Gatun Watershed" (MWH, December 2000).

Table 1 shows the monthly rainfall data for Chico. Time series and a mass curve of annual rainfall data are plotted on Exhibits 3 and 4, respectively. The corresponding data and curves for Río Piedras are shown on Table 2 and Exhibits 5 and 6. Mean monthly rainfall for the two stations is shown in the following tabulation:

Month	Rainfall at Chico (mm)	Rainfall at Río Piedras (mm)
January	40	38
February	19	34
March	15	28
April	83	96
May	276	263
June	317	273
July	321	264
August	331	257
September	323	295
October	398	318
November	340	281
December	167	166
Annual	**2,631**	**2,314**

Exhibit 7 shows the location of the two rainfall stations. The names of the stations referenced on Exhibit 7 are given in Table 3. Exhibit 8 shows the mean annual isohyetal pattern over the Río Chagres basin. The map shows that mean annual rainfall is higher in the head reach of the Río Chagres and decreases in the downstream direction. This pattern was developed by ACP based on the rainfall data for the period from 1974 to 1998 (and thus does not necessarily match the regional isohyetal map). ACP has recently installed three more rain gauges in the watershed. These are located at Chamon, Esperanza and Limpio (see Exhibit 7 and Table 3).

Estoque in 1985 (Estoque, et al., 1985) studied the effect of El Niño on the rainfall in Panama. They listed thirteen episodes of El Niño for the period from 1920 to 1983, and compared the annual rainfall during an El Niño with the long-term mean annual rainfall. The results indicated that El Niño produced below normal rainfall in almost all regions of Panama. The average annual rainfall anomaly, based on all El Niño episodes was about 8 percent below normal. In case of the strong El Niño episodes of 1976 and 1982, the corresponding anomalies were about 28 percent and 24 percent below normal, respectively. The driest month of the year 1982 (December) had a rainfall anomaly of about 60 percent below normal. The study also indicated that there was a considerable geographic variation in the rainfall anomalies. In case of the 1976 El Niño, the largest

magnitudes of negative anomalies were located in the southwestern part of Panama, just south of the Central Cordillera on the Pacific side. On the other hand, El Niño had the opposite effect (positive anomalies) in some basins north of the Cordillera in the Atlantic coastal region. The 1997-1998 El Niño episode also resulted in low rainfall in Panama, particularly in Panama Canal Area.

During the MWH study of December 2000, it was determined that, in the Canal Area and neighboring basins, the effect of El Niño has been a slight to significant decrease in rainfall during the episodes. The decrease in annual rainfall recorded at Chico and Río Piedras during the El Niño episodes are shown in Table 4. Generally, the decrease varies from 20-30% at Chico and 30 to as much as 60% at Río Piedras. The percentage decrease was significantly higher on monthly basis.

2.3 TEMPERATURE

Mean monthly temperatures vary within about 2^0 C throughout the year. Mean annual temperature varies from about 26^0 C near the dam to about 24^0 C in the head reach. The lowest temperature is in September-October and highest in March-April at lower altitudes. At higher altitudes, maximum temperature usually occurs in June.

3 TOPOGRAPHY AND DRANAGE

The Río Chagres flows in a general northeast to southwest direction from the Continental Divide. The river rises on the southern slopes of the Divide to about 1,000 meters above mean sea level. The river is relatively steep in the head reach and gradually becomes relatively flat near the dam site. The mean elevation of the basin above the stream gauging station at Chico is about 460 meters (verbal communication with ACP). Topographic maps with contours are not available for much of the basin above the dam site. However, based on a relief map of 1:200,000 scale, prepared by ACP in September 2001, the relief in the basin above the dam site may vary between 100 to 1,000 meters.

The river basin is fan-shaped with a length of about 30 km and maximum width of about 20 km. The Río Piedras is the major left bank tributary, which joins the Río Chagres about 12 km upstream from the dam site. The Río Esperanza and Río Limpio and Río Chico are the right bank tributaries joining the river at about 18 km, 8 km, and 0.5 km above the dam site, respectively. The drainage area at the dam site is assumed to be about 414 km^2, the same as measured at the stream gauging station 500 m downstream.

Surface area and reservoir storage volume were computed from digital topography generated from an aerial survey using IFSAR (Interferometric Synthetic Aperture Radar) and detailed topographic surveys at the site. The area and capacity information are presented in Table 5.

4 STREAMFLOW ANALYSIS

4.1 STREAMFLOW DATA

A stream gauging station was established on the Río Chagres at Chico (drainage area about 414 km^2) in early 1933 by the ACP. A Steven's A-35 water level recorder was installed in a stilling well. It has been replaced with an A-71 recorder. The recorder is connected to a manometer servo that is, in turn, connected to a Vaisala/Handar data logger through a shaft encoder and to a VHF telecommunication system through a Sutron (Novalynx) shaft encoder. The gauge height data are transmitted to a central computer in ACP office in Balboa Heights via the VHF system.

A staff gauge is installed on the steps near the stilling well. Periodic discharge measurements are made from an overhead cableway, located near the well. Suspended sediment samples are taken on the surface of the river from the bank using United States Geological Survey (USGS) D-48 depth integrating sampler.

The stage-discharge relationship (rating curve) is controlled by channel conditions. The riverbed consists of sand, gravel, and cobbles. The bed is not stable during high flows. Periodic discharge measurements are required to update the rating curve. The flow record was judged to be good to fair.

The historic record includes data from March 1933 to December 2000 with data missing for November 1966, and January 1968 to June 1971,

4.2 STREAMFLOW CHARACTERISTICS

Mean annual flow based on the recorded data is about 30.2 m^3/s. The missing monthly flows were filled-in by MWH using statistical procedures (MWH, December 2000). For the filled-in record of 68 years (from 1933 to 2000), the mean annual flow is about 30.2 m^3/s. Table 6 presents the completed monthly flows at Río Chico. The maximum monthly flow of record of about 177.5 m^3/s occurred in November 1935 and the minimum flow of record of about 4.8 m^3/s occurred in March 1995.

The wet period is generally from October through December but quite often, high flows can occur in the month of September and January. The months of low flows are generally from February to April. Floods generally occur during the months of September through January due to general type of storms. The floods due to thunderstorms can occur during any time of the year but mostly in the months of June through August. The highest flood of record (from 1933 to 2000), about 3,810 m^3/s, occurred in 1966.

The flows of the Río Chagres are affected by El Niño. The reduction of the mean annual flows from the long-term mean during the periods of El Niño are shown in Table 4 and generally vary from 20 to 35%.

4.3 STREAMFLOW ANALYSIS

4.3.1 Monthly Streamflow Sequence

Monthly discharges from 1933 to 2000 for the Río Chagres at Chico are given on Table 6. Since the proposed dam would be located about 150 meters upstream from this gauging stations, these flows are considered applicable to the dam site. Exhibits 9 and 10 show the mass curve and the time series of annual flows. These exhibits show that the annual flows are consistent, homogeneous and there is no significant trend in the data. However, there are significant variations in flows from year to year. The minimum annual flow was recorded in 1957. The highest flow occurred in 1996 followed by significantly low flow in 1997.

4.3.2 Flow Duration Curves

Flow duration curves were developed based on monthly flows. This was considered reasonable because of the long record of 68 years for the Río Chagres. Daily flow data was not collected. Exhibit 11 shows the annual flow duration curve. Based on this, minimum monthly flow exceeding 90 and 95 percent of time were about 11.0 and 8.6 m^3/s, respectively. A flow duration curve was also developed for the dry period (February to April) and is shown on Exhibit 12.

4.3.3 Drought-Duration-Frequency Analysis

The method of analyzing drought frequencies and duration is based on the assumption that meteorological conditions recorded in the past would be repeated. In most cases, absence of long records, potential long-term variation in rainfall and runoff, and the topographic changes brought by man, make it rather difficult to make precise forecasts.

For drought analysis, data is selected by one or two methods: for either one, an extreme value is chosen for each time unit, such as the lowest monthly flow in a year or the lowest monthly flows for selected duration in the period of record, regardless of when they occurred. With the latter method, the number of values chosen need not to be equal to the number of years of record.

The first method is not very useful since this deals with a discrete value of flow and reveals nothing about the sequence of low flows. The second method is more useful. In this case, the analysis is made by determining the flows over a given period of consecutive days, months or years. A difficulty encountered in frequency analysis of sequential events is the overlapping of data and repeated appearance of extreme values. Thus, in the analysis of droughts lasting say for 24-months (or two years), certain low flow months might appear twice. The overlapping is eliminated as illustrated by the following example of monthly flows for the Río Chagres.

Monthly flows of the Río Chagres at dam site (Chico gauging station) were arrayed in one column. Running totals of 3-, 6-, 12-, 18-, 24-, 30- and 36-month periods were computed. For the flows in each period, the following procedure, illustrated for the 12-month period, was used.

- Select the lowest 12-month value.
- To avoid overlapping, exclude the 11 totals prior and subsequent to the selected lowest value.
- After excluding the values, select the next lowest value and again exclude the 11 totals prior and subsequent to the selected value.
- Continue until all totals have been used either by selection or exclusion.
- Array the selected values from lowest to highest and assign 1 to the lowest value.

- Compute the return period of the lowest value as "number of years of record plus 1 divided by the order", that is, "(68+1)/1." Thus, the return period for the second lowest value was "69/2 = 34.5."

In the case of the 3-, and 6-month periods, there were more than 68 values or more than the years of record. In these cases only the 68 lowest values were used. Exhibits 13-15 show the frequency curves for 12-, 24, and 36-month periods, respectively.

The 3-, 6-, 12-, 18-, 24-, 30- and 36-month flows and their assigned recurrence intervals furnish estimates of average length of time in years which can be expected to elapse between the beginning of the various events. For example, the third ranking event in the 12-month series has a recurrence interval of 69/3 = 23 years. Thus, it can be said that in any year the probability is 1 in 23 for the start of a 12-month period during which the total flow would be as low as 578 MCM.

5 NET RESERVOIR EVAPORATION

Monthly net reservoir evaporation for a reservoir is generally computed using the following relationship:

$$NRE = A(PE) - (PPT-RO)$$

in which,

NRE = monthly net reservoir evaporation
A = pan coefficient
PE = monthly pan evaporation
PPT = monthly precipitation over the reservoir
RO = runoff presently contributed by the area that will be inundated by the reservoir

ACP has computed the net reservoir evaporation rates for Madden Lake. The monthly lake evaporation data in mm for the period from 1933 to 2000 obtained from ACP is shown in Table 7. As per verbal communication with the Senior Hydrologist of ACP, this data is the net reservoir evaporation. The data was considered applicable to the proposed Chagres reservoir. The total annual net reservoir evaporation is estimated to be 1,321 mm.

6 CONSTRUCTION PERIOD FLOODS

6.1 PREVIOUS REGIONAL FLOOD ANALYSIS

The *Instituto de Recursos Hidraulicos y Electrificacion* (IRHE) performed a regional flood frequency analysis in June 1986 for the river basins west of about 79^0 west longitude in the Republic of Panama. Annual maximum instantaneous peaks for the Río Chagres at Chico were available for 52 years (1933 to 1985) at the time of this study. The station was used in the regional analysis.

The study region was divided into seven zones. For each zone, relationships between drainage areas and mean annual floods, and between ratios of flood peak and mean annual flood were developed. According to these relationships, the Río Chagres was located in Zone 1. The flood peaks corresponding to various return periods listed in this report for the Río Chagres at Chico are given in Table 8. The flood peaks were estimated up to return period of 10,000 years.

6.2 AVAILABLE FLOOD DATA

Analysis of extreme flood events involves the selection of the largest events from a set of flow data. The flood frequency analysis uses the largest recorded floods for each year at a representative stream gaging station. For the present analysis, the annual instantaneous flood peaks for the Río Chagres at Chico were obtained from the ACP. The data are presented in Table 9. The data are available from 1933 to 2000 (68 years). The maximum instantaneous peak of record, which occurred in 1966, is about 3,812 m^3/s. The peak was estimated from high water marks.

6.3 CURRENT ANALYSIS

The Log-Pearson type III (LP III) distribution, recommended by the Hydrology subcommittee, United States Geological Survey (March 1982) was first fitted to the annual peaks. A computer program developed by the United States Army Corps of Engineers, Hydrologic Engineering Center was used. The results are given in Table 8. The frequency curve is shown on Exhibit 16.

The skew coefficient of the flood peaks was zero (log-transferred values). Based on a visual review of Exhibit 16, the LP III distribution shows a reasonable fit to the flood peak data except the highest recorded peak of 1966. The peak is considered approximate because this was estimated from flood marks.

Table 8 shows that the flood peaks based on the regional analysis (IRHE estimates) are higher than those computed using LP III distribution and station data but lower than those with 5 percent upper confidence limit. Because of the length of record of the flood peak data at Chico, the values from regional analysis are not recommended. The use of 1966 flood peak in the analysis, resulted in higher 5 percent upper limit providing larger flood peaks for the selected return periods. Therefore, the use of values with 5 percent upper limit will be overly conservative. It is recommended to use the flood peaks values computed using the LP III distribution.

6.4 FLOOD HYDROGRAPHS

Flood hydrographs for 20-, 25- and 50-year return periods were developed for the Río Chagres at Chico using the following procedure:

- The historic floods (hourly discharge data) at Chico were reviewed and the duration of floods were determined to be about one day.
- The annual maximum one-day flood-volumes was estimated.
- Selected historic flood(s) with peak discharge(s) close to the 20-, 25- and 50-year flood peaks, about 2,000, 2,110 and 2,420 m^3/s, respectively were selected. The flood of December 1985 had a peak of 2,057 m^3/s. This peak was judged to be close enough to the three peaks.
- The December 1985 flood was adjusted to represent flood peaks and volumes equal to the 20- 25- and 50-year floods.

The derived flood hydrographs are shown on Exhibits 17-19.

7 SPILLWAY DESIGN FLOOD

The probable maximum flood (PMF) based on the probable maximum precipitation (PMP) was used as the spillway design flood for the Río Chagres dam. The derivation of the PMF involved the following sub-tasks:

- Estimation of PMP, its duration and time distribution
- Estimation of Retention Losses
- Development of a Unit Hydrograph
- Estimation of Base Flow
- Transformation of PMP to PMF
- Evaluation of PMF

The above sub-tasks are discussed in the subsequent paragraphs.

7.1 PROBABLE MAXIMUM PRECIPITATION (PMP)

7.1.1 Rainfall Regime

In Panama, October and November are the heaviest rainy months. This period of extreme rainfall is associated with the southward traverse of the inter-tropical convergence zone (ITCZ). November dominates the high values on the Atlantic side. Higher values occur in October than in November on the Pacific side because of more frequent southerly winds in October.

Reports on PMP by the United States Weather Bureau (WS, 1965) and National Weather Service (NWS, 1978) discussed the possibility of hurricane in Panama. A necessary condition for hurricane is a coriolis force sufficiently strong to cause the winds to spin around the center of low pressure. On the equator, the coriolis force is zero and still relatively weak within 10^0 of the equator. Therefore, only rarely there are hurricanes within 10^0 of the equator. Thus, hurricanes generally do not occur over Panama. (The exception was Hurricane Martha. The track of this hurricane is discussed in the 1978 report by NWS.) However, the influences of the peripheral circulation, both direct and

indirect, cannot be ruled out. Heavy rainfalls have occurred in southwest Panama because of peripheral circulation.

Both general type and local storms have been recorded in Panama. Local storms are of relatively small aerial extent, covering from about 500 to 1,300 km^2. General storms can cover relatively larger areas. The months of October through December are the season of large-area rainfalls. Of the 22 storms analyzed in the 1965 and 1978 reports, 15 occurred during these months.

During the months of October through December, strong air outflows come from the northern latitudes. This implies northerly winds, at least for some times during major storms which impinge on the mountains, and augment the rainfall through stimulation or triggering of convergence or otherwise giving additional lift to saturated air. Generally, most intense rainfall occurs over the northern slopes of the Continental Divide.

The northerly winds, coming from Atlantic Ocean, pass over Panama and have their first encounter with the coastal hills. These hills trigger convergence and heavy rainfall occurs over the coastal area. The rainfall amount and intensity decrease further inland but are increased near the Continental Divide. This pattern is clear from the regional isohyetal map shown on Exhibit 2. The pattern is controlled by the local topography. A generalized map of the topography in the Canal Area and adjacent basins is shown on Exhibit 20.

7.1.2 Methods for Estimating PMP

Two approaches were used to estimate the PMP for the Upper Chagres Basin:

- Study the storm patterns of major storms listed (up to 1976) in WS 1965 and NWS 1978 reports that occurred over the Canal Area. Also develop storm isohyetal patterns of major storms (since 1976) that occurred over the Río Chagres basin including the Canal Area. Maximize, transpose and locate the most severe storm over the Río Chagres basin to produce critical flood conditions.

- Use the 24-hour, 10-mi^2 PMP developed in the NWS 1978 Report and depth-area-duration curves of WB 1965 Report and estimate basin average PMP.

For the above approaches, a relationship between elevation and mean October – December rainfall, and a mean October-December rainfall map were required to develop the storm isohyetal patterns and to transpose the storms. These maps were developed using the following procedures

7.1.3 Relationship between Elevation and Mean October-December Rainfall

A relationship between elevation and mean October-December rainfall was developed by the NWS and presented in their 1978 Report. The relationship was based on the rainfall for the period 1941-70.

For the present study, the mean October-December rainfall amounts were computed for the period 1966 through 1995 at a number of stations in the Canal Area and adjacent basins. Exhibit 7 shows the locations of the stations as per Table 3. The new data points did not indicate a need for revising the relationship. Therefore, the previous relationship was adopted for this study. The purpose of this relationship was to extrapolate the mean October-December rainfall at higher altitudes (where no rainfall stations exist) for preparing the October-November isohyetal map.

7.1.4 Mean October-December Rainfall Map

The mean October-December rainfall developed by the NWS for their 1978 Report was checked as follows.

The latest 30-year mean October-December rainfall amounts for the period 1966-95 were calculated. The values in the Canal Area confirmed the shape of the isohyets in that area. Therefore, the isohyetal pattern was not changed. The derived map is shown on Exhibit 21.

7.1.5 Major Storms

In the NWS 1978 Report, a detailed discussion is presented for the criteria used for the selection of major storms. These criteria were also used for this study and are discussed below.

The 1978 Report concluded that storm rainfall of the late fall and early winter cold-outbreak would be the prototype to the PMP for the Gatun Lake watershed. Three-day rainfall amounts were added to represent storm period. About 24 three-day storms up to 1976 were reviewed. The storms with more than 150 mm rainfall in a day or 254 mm in three days were considered as the major storms. This resulted in the selection of 10 storms. The selected storms are listed below and their isohyetal patterns are shown on Exhibits 22-31.

November 17-19, 1909
October 22-24, 1923
November 7-9, 1931
November 27-29, 1932
November 5-7, 1939
October 12-14, 1941
December 18-20, 1943
December 12-14, 1944
November 3-5, 1966
April 7-9, 1970

The locations of the storm centers on Exhibits 22-31 were reviewed and compared with the general topography (Exhibit 20). The centers of most of the storms were near Lake Madden. The heavy rainfall was caused due to high altitudes on the east and north of the lake. Some of the storms had their centers near or at elevations varying from 150 to 300 meters near Lake Gatun. Probably, due to no rainfall data in the Upper Chagres basin, the storm isohyets of these storms were not extended to cover the Upper Chagres basin.

The isohyetal patterns of the above storms were carefully reviewed and the storm of October 22-24, 1923 was judged to be the most critical in respect of rainfall amount and aerial extent over the Upper Chagres basin. This storm shows a rainfall of about 26 inches (data were provided in English units and were retained) at the center of the storm located in the Río Chagres basin. This is the highest rainfall of all storms.

For the major storms since 1976, daily rainfall data were obtained for the stations in the Canal Area. The data was reviewed and the following four storms centered over the Canal Area and its vicinity were judged to be critical.

December 4-6, 1985
January 13-15, 1996
November 27-29, 1996
December 30-31, 2000

The rainfall amounts associated with the above storms and recorded at various stations are shown on Exhibits 32-35. The storm of December 30-31, 2000 had heavy rainfall over the Río Chagres basin with the storm center near the Río Piedras station (two-day rainfall about 343 mm). The location of the center was nearly same as that of October 1923 storm.

7.1.6 Duration of PMP

All storm isohyetal maps from the NWS 1978 Report were for three-day rainfall. For the storms since 1976, three-day rainfall amounts were also used. However, the hourly rainfall data available for the stations in the Canal Area and adjacent basins indicated that the actual maximum rainfall duration in the major three-day storms was about 24 hours with some intermittent rainfall extending to 48 hours. For this reason, a duration of 24 hours was considered appropriate for the PMP. All 3-day storms plotted on Exhibits 22-35 were considered to be of 48 hours durations.

7.1.7 PMP Estimate

The isohyetal map of the October 22-24, 1923 storm, the most critical storm for the Río Chagres basin from the NWS 1978 Report) and the storm of December 30-31, 2000, the critical storm since 1976 were compared. For the 1923 storm, the isohyets were extended over the whole basin using the general trend. The basin average 3-day rainfall was about 588 mm (assumed for 48 hours). A review of Exhibit 35 showed that the December 30-31, 2000 storm did not produce as much rainfall over the basin. Therefore, the 1923 storm was selected for further analysis.

As stated by the Weather Bureau (WB, 1965), moisture maximization of the largest storm rainfall in Panama is less meaningful in estimating PMP than in the United States because the variation in precipitation intensity from storm to storm depends mostly on the variation in the mechanism that lifts the moist air in cloud masses and less on the availability of the moisture. However, the Weather Bureau considered storm

maximization in their 1965 study. Therefore, for this study attempt was made to maximize the storm of October 22-24, 1923 in place. Since the storm occurred within the basin and was controlled by the local topography, transposition of storm was not considered justified.

Dew point data during the storm and 12-hour persisting dew point data were not available. Based on MWH's experience in the tropical area, the maximization factor could vary from about 1.2 to 1.5. The storm of 1923 appeared to be quite efficient in respect of moisture contents. Therefore, a factor of 1.2 was adopted. This resulted in a 48-hour PMP of 706 mm. For the 414 km^2 area, the depth-area-duration curves (D-A-D), presented on Exhibit 36 (WB 1965) show that the ratio between 24- and 48-hour rainfall amounts is about 0.79. This resulted in a 24-hour basin average rainfall of about 560 mm.

For the second approach to estimating the PMP, the 24-hour, 10 mi^2 PMP map given in the NWS 1978 Report (Exhibit 37) was used. This map gave a 24-hour 10 mi^2 PMP of about 28.1 inches (about 713 mm) over the Upper Río Chagres basin. To obtain the basin average PMP, the depth-area-duration curves shown on Exhibit 36 were used. For durations of 24 and 48 hours and a drainage area of 414 km^2 (159.8 mi^2) at the dam site, the PMP were about 25.85 and 32.88 inches, respectively, (about 657 and 835 mm). These PMP amounts are greater than 560 and 706 mm obtained by maximization the October 1923 storm. Therefore, a 24-hour basin average PMP of 657 mm was adopted for this study. It may be pointed out that if we use a maximization factor of 1.5, the 24-hour PMP would be about 697 mm. This is not much different from the recommended PMP of 657 mm.

7.1.8 Depth-Duration Curve for the Río Chagres Basin

The depth-duration curve for the Río Chagres basin can be determined in any of the following three ways depending upon the data available.

1. Develop envelope depth-area-duration curves for various durations for major storms in the region of project area, read rainfall amounts for various durations corresponding to the basin area, and draw smooth depth-duration curve.

2. Construct dimensionless rainfall mass curves of point rainfall of major storms in the region and draw near-envelope curve which envelopes the low values in the low end and high values in the high end.

3. Use actual depth-are-duration curves of the actual storm, determine rainfalls for various durations corresponding to the basin size, and develop a depth-duration curve.

Methods 1 and 2 could be used for this study. For method 1, the D-A-D curves are available as shown on Exhibit 36. For the second approach, hourly rainfall data at Chico for the storms of August 18, 1980, October 01, 1986 and December 30-31, 2000, and at Río Piedras for the storm of December 30-31, 2000 were obtained from ACP. These data were plotted as mass curves. The storm rainfall duration was about 24 hours in each case with about 70 percent rainfall occurring in about 3 hours. The rainfall distributions during the months of August and October appeared to be typical for local storm while the December pattern was typical of general storms. The December pattern was considered for further analysis.

Using the December hourly rainfall data, envelope curve was developed. The curve is shown on Exhibit 38. The point data was converted into basin average rainfall using a factor of 0.89 based on the size of the basin. The data was smoothed. The basin average mass curve is also shown on Exhibit 38.

The basin average rainfall amounts for various durations were obtained from D-A-D curves shown on Exhibit 36. This data in plotted on Exhibit 39 with the depth duration curve based on the basin average rainfall. Exhibit 39 shows that the basin average depth duration curve is critical compared to the curve based on the D-A-D data. Therefore, the basin average depth duration was adopted. Table 10 shows one-hour rainfall increments from the basin average mass curve.

7.2 RETENTION LOSSES

In a rainfall-runoff process, two types of retention losses are considered. First is the initial loss to satisfy interception and depression storage and soil moisture deficiency. The second is the uniform loss during the duration of the storm that occurs once the

initial loss has been satisfied. In a single event-oriented rainfall-runoff model, these losses are considered to be lost and do not contribute to the flood.

A preferred method is to estimate these losses through calibration of a hydrologic model like HEC-1 (COE, 1981) using concurrent observed hourly rainfall and flood discharge data. An attempt was made to use this method. Hourly flood stages and rating curve (river stage and discharge relationship) were obtained for six major floods recorded on the Río Chagres at Chico. These floods and HEC-1 model calibration are discussed under sub-section 9.3 entitled "Unit Hydrograph."

The COE (1981) has discussed four methods to consider infiltration losses – initial loss and uniform loss rate, exponential loss rate, United States Soil Conservation Service (SCS) curve number and Holtan loss rate, to compute retention losses. For all methods, the rates should be estimated through calibration of HEC-1 model. For this study, initial loss and uniform loss rate method was used because of its simple concept. The method requires only two parameters that can be derived even if limited rainfall-runoff data are available.

7.2.1 Initial Loss

A review of the daily rainfall data at stations within and in the vicinity of the Río Chagres watershed indicated that during the months of October through December, the rainfall occurs quite frequently. Therefore, during these months when the PMP is most likely to occur, there is a strong likelihood of significant storms prior to the PMP storm. The antecedent rainfall could be substantial. As a result, the initial retention was considered negligible on the assumption that the soil moisture deficiency and other abstractions would be satisfied by an antecedent storm.

7.2.2 Uniform Loss

The uniform loss represents the rate at which the soils in the basin will allow the rainfall to percolate through during the storm period. From the study of soils and geology from the Atlas (1988), and based on the field reconnaissance, the soils in the basin were judged to be predominantly of SCS soil group C. The recommended minimum infiltration rate for this group varies from 0.05 to 0.15 inches (1.3 to 3.8 mm) per hour. A rate of 2.5 mm

(0.10 inches) per hour was used. No infiltration loss was considered from the reservoir area.

7.3 UNIT HYDROGRAPH

Hourly discharge data were obtained for the following six major floods.

- May 1975
- July 1975
- May 1983
- December 1985
- November 1996
- December 2000

The floods of November 1996 and December 2000 had multi-peaks and were not suitable for deriving a unit hydrograph. Hourly rainfall data corresponding to the flood discharges was available for the December 1985 flood only. Thus, only one flood event was available to derive the unit hydrograph and to estimate the uniform infiltration rate through calibration of HEC-1 model. Because of limited rainfall-runoff data, it was decided to use dimensionless unit graph – lag curve method to derive a preliminary unit hydrograph for the Chagres River at Chico and refine this using HEC-1 model and the December 1985 flood with corresponding rainfall.

7.3.1 Dimensionless Unit Graph

In a dimensionless unit graph, the time base is expressed as abscissa (X-axis) in terms of time (T) as percent of the time Tcv, that is, 100T/Tcv, where T is the time of successive ordinates and Tcv represents the lag time of the basin plus half the duration of the rainfall excess (USBR, 1987). The lag time is defined as the time from the center of the rainfall excess to half the volume of the direct runoff. Dimensionless discharge is expressed on the ordinate scale (Y-axis) in terms of "Q * Tcv/Vol," where Q is ordinates of a hydrograph in cubic meters per second (or cubic feet per second) and Vol is direct runoff volume in cubic meters per second-hour (or cubic feet per second-day).

Dimensionless unit graphs were developed from the four historic floods as shown on Exhibit 40. Since the duration of rainfall excess that caused the flood was not available

for each flood, the Tcv was approximated as the time from the rise of the hydrograph to the occurrence of half the volume of direct runoff. An average dimensionless unit graph based on these four graphs is shown on Exhibit 41.

7.3.2 Lag Time

Basin lag time is related to the watershed parameters by the following equation:

$$Lg = C * (L * Lc / (S^{0.5}))^N$$

where

Lg = lag time in hours
C = coefficient
N = exponent
L = length of the longest watercourse from the point of interest (gauge or dam site where a hydrograph is desired) to the boundary of the drainage basin (from Design of Small Dams), km or mi
Lc = length along the longest watercourse from the point of interest to a point opposite the centroid of the drainage basin (from Design of Small Dams), km or mi
S = overall slope of the longest watercourse, m/km or ft/mi

Watershed parameters L, Lc and S could not be determined because complete topographic maps are not available for the Chagres watershed. Therefore, the above relationship could not be used. The only indication of basin lag time could be from the hourly rainfall data at Río Piedras corresponding to the December 1985 flood. This data indicated that the basin lag time could be about 4 to 5 hours. A lag time of 4.5 hours was selected.

7.3.3 Derivation of Unit Hydrograph

Using a lag time of 4.5 hours and the average dimensionless graph, a preliminary one-hour unit hydrograph was developed. HEC-1 model was set up using the preliminary unit hydrograph and assumed uniform loss rate, and the December 1985 hydrograph was simulated and compared with the observed hydrograph. Through successive trials, a reasonable match was obtained. Attachment 1 shows the HEC-1 output (English units). A summary of the comparison is shown below:

COMPARISON OF OBSERVED AND RECONSTITUTED HYDROGRAPHS OF DECEMBER 1985 FLOOD

	Observed	Computed	Difference	Percent
Sum of Flows, cfs-hr	441,129	460,205	19,076	+4.32
Equivalent Depth, inches	4.276	4.461	0.185	+4.33
Mean Flow, cfs	9,003	9,392	389	+4.32
Peak Flow, cfs	72,635	74,479	1,844	+2.54
Time to Peak, hrs	6.0	6.0	0.0	

The above comparison was considered reasonable. The derived unit hydrograph in SI units is shown on Exhibit 42 and the ordinates are given in Table 11. The uniform infiltration rate used in this comparison was 0.05 inches per hour. This was judged to be low. As stated earlier, a rate of 2.5 mm (0.1 inches) per hour was used.

7.3.4 Base Flow

The base flow was estimated from the selected four flood hydrographs. The flow varied from about 30 to 50 m^3/s. A flow of 50 m^3/s was adopted.

7.3.5 Transformation of PMP to PMF

The HEC-1 computer model was used to develop the PMF resulting from the 24-hour PMP. The input to the model included: drainage area, base flow, 24-hour PMP, time distribution of the PMP, retention losses, and unit hydrograph. The resulting PMF peak was about 9,940 m^3/s and a 3-day volume was 271 MCM. Attachment 2 provides the HEC-1 output. The PMF inflow hydrograph is presented on Exhibit 43.

7.4 EVALUATION OF PMF

Generally, a PMF estimate is compared with the historic floods and the 100-year flood at the site. Also based on MWH's experience, the value of coefficient C in the Creager's formula (Creager, 1950), given below, also provides a reasonable comparison between peaks of PMFs in hydrologically similar drainage basins.

$$Q = 1.303 * C * (0.386\ A)^{0.936A\wedge(-0.048)}$$

in which

Q = flood peak, m^3/s

A = drainage area, km^2

The 100-year flood at Chico was estimated to be 2,739 m^3/s (see Table 9). The maximum historic flood at Chico occurred in 1966 and the peak was about 3,812 m^3/s. The flood peaks at the dam site were assumed to be same as that at Chico. The ratios between the PMF peak and these flood peaks are about 3.6 and 2.6, respectively, which are reasonable for the hydrologic conditions in the basin.

The value of Creager's C was about 218. This is somewhat on a high side in the range of the values expected in similar areas. Therefore, the estimated PMF is in the upper range of the expected values. However, it should be realized that the Upper Chagres basin experiences the most intense rainfall of any basin in the Gatun Lake watershed. A high value of "C" should be expected.

A PMF study of La Fortuna Dam was made available by ACP. The dam is located downstream from the confluence of Río Hornitos and Río Chiriqui. The basin upstream from the dam receives intense rainfall similar to that over Upper Chagres basin. The value of "C" was estimated to be 201.

The 6-hour PMP for La Fortuna project was about 450 mm. In the present study, the 6-hour PMP was about 460 mm.

A comparison of unit hydrograph was also made. A unit hydrograph was developed for the Río Chagres at Chico in a study entitled "I.C.P. Memo 55, Design of Drainage Facilities," made in 1948. A copy was provided by ACP. The unit hydrograph peak was about 38.1 m^3/s compare to a peak of 31.7 m^3/s for the present study.

MWH has made a PMF study for the Río Indio basin, located west of Gatun watershed. The PMF peak for the basin was about 4,345 m^3/s giving a value of 99 for the Creager's C. The estimated 100-year flood peak was about 859 m^3/s. This gives a ratio of about 5.0 between the PMF and 100-year flood peaks. For the Upper Chagres, the ratio is about 3.6 as discussed above. A comparison of 24-hour basin average PMP was also

made for the two basins. The PMP amounts were about 555 mm for the Río Indio and 657 mm for the Upper Chagres.

The shape of a basin affects the peak of a unit hydrograph and consequently the peak of the flood. The shape of the Río Indio basin is quite elongated and resulted in a one-hour unit hydrograph peak of about 13 m^3/s. The Upper Chagres is fan-shaped and resulted in a one-hour unit hydrograph peak of 31.7 m^3/s. The drainage areas at the sites are 381.1 and 414 km^2, respectively, not very much different.

Based on the above comparison, the PMF peak for the Upper Chagres project should be higher than that of Río Indio. Therefore, the PMF for the project is judged to be reasonable.

8 RESERVOIR SEDIMENTATION

8.1 DATA SOURCE

The ACP collects suspended sediment samples on the streams entering Lake Madden and Lake Gatun. The sampling locations include:

Stations on Streams Entering Madden Lake
- Río Chagres at Chico
- Río Pequeni at Candelaria
- Río Boqueron at Peluca

Stations on Streams Entering Gatun Lake
- Río Gatun at Ciento
- Río Trinidad at Chorro
- Río Ciri Grande at Los Canones

Monthly suspended sediment transport estimates, developed by the ACP for the above stations, are presented in Table 12. According to the ACP hydrologists:

- Daily sampling is performed during low flows and more frequent samples are taken during a flood event.
- The flows corresponding to the sample dates are either measured or derived from rating curves.
- River stage is recorded at the time of sampling.
- All samples (for low or high flows) are taken near the banks of the rivers using DH-48 sampler.

The ACP conducted a sedimentation survey of Madden Lake in 1983 when the Lake was at an elevation of 235 feet (PCC 1987). Jack R. Tutzauer, ACP revised this report in March 1990 (Tutzauer, March 1990). He estimated the sediment deposited between elevations, 235 feet and 252 feet (normal pool elevation), which was not surveyed in 1983.

Suspended sediment sampling data also were collected by Empresa De Transmision Electrica, S.A., Departmento De Hidrometeorologia, Seccion Hidrologic (ETESA) for the following gaging stations.

Río Coclé del Norte at Canoas
Río Toabre at Batatilla

At Canoas, a total of 46 suspended samples with corresponding discharge measurements were collected from November 1983 to August 1998. The maximum observed concentration was about 33.6 milligram per liter (mg/l) corresponding to a measured flow of about 25.9 m^3/s on September 04, 1991. The maximum measured flow was about 58.5 m^3/s with a corresponding concentration of about 9.7 mg/l on November 16, 1996.

At Batatilla, a total of 56 suspended sediment samples were collected from February 03, 1982 through August 12, 1998. The maximum measured concentration was about 282 mg/l corresponding to a flow of about 73.6 m^3/s. A concentration of 120 mg/l was measured corresponding to the maximum measured flow of about 94.9 m^3/s.

During a field visit, the methods of collection of suspended sediment samples and sample analysis were discussed with ETESA. They reported that the agency is using standard methods of United States Geological Survey (USGS) for the collection and analysis of the samples.

8.1.1 Analysis by ACP

The ACP Report of 1987 indicated a unit yield (included bed load) of about 177.6 cubic feet per acre per year (cuft/ac/yr) from the total drainage area contributing to Lake Madden. Tatzauer (March 1990) added the sediment deposited between elevations 235 to 252 feet and also revised the suspended sediment estimates of the three rivers – Chagres, Pequeni and Boqueron. The revised estimate of the sediment yield at Madden Lake (including bed load) was about 203 cuft/ac/yr or about 1.4 mm/year. For the Río Chagres at Chico, the suspended sediment yield based on the published data was about 0.25 mm/year. This was judged to be low because the suspending sampling was done from the river bank. The revised estimate by Tatzauer could not be obtained.

For three rivers (Gatun, Trinidad and Ciri Grande) entering Lake Gatun, the unit suspended sediment yield varied from about 0.10 to 0.27 mm/year. These values were judged to be too low.

ETESA prepared sediment rating curves for the Río Coclé del Norte and Río Toabre. Best-fit curves were developed using the available data. For the Río Toabre, for all flows greater than 107.2 m^3/s, the suspended sediment concentration was assumed to be the maximum observed concentration. Similarly, for the Río Coclé del Norte, the suspended sediment concentration was assumed to be the observed maximum concentration for all flows greater than 84.7 m^3/s. Mean annual sediment transport rates at the two stream gauging stations could not be obtained from ETESA.

8.1.2 Previous Analysis by MWH

MWH estimated the mean annual suspended sediment discharges for the Río Cocle del Norte (drainage area about 571 km^2) and Río Toabre (drainage area about 786 km^2) as part of the hydrologic investigations for the Río Indio development. The suspended sediment rating curve – flow duration curve method was used for each river. From the field reconnaissance and the experience of the MWH hydrologist, a limiting concentration of about 10,000 mg/l was adopted for both the rivers. The estimated discharges were about 676,330 and 873,800 metric tons per year (mt/yr), respectively. Assuming 15 percent as bed load and a specific weight of about 1.04 mt/m^3 (about 65 pounds per cubic feet, estimated by ACP), the total volumes were about 747,900 and 966,200 m^3/yr, respectively. These are equivalent to about 1.31 and 1.23 mm/yr.

8.1.3 Estimated Sediment Yield

The above analysis indicated that the sediment yield (including bed load) could vary from 1.23 to 1.4 mm/yr from the drainage basins considered in this study. For a conservative estimate of the reservoir sedimentation analysis, a unit yield of 1.4 mm/yr was adopted for the Río Chagres basin. However, it should be realized that this yield is indicative of the current land use in the Río Chagres basin. If deforestation and increased agriculture occur in future, the yield could increase significantly. Therefore, the land use conditions in the basin should be monitored periodically to assess any increase in the sediment yield.

The drainage area at the Río Chagres dam site is about 414 km^2. Using a yield of 1.4 mm/yr, the mean annual total sediment inflow in the reservoir would be about 579,600 m^3/yr. Using the ACP computations for sediment deposition in Madden Lake, the annual yield would be about 602,800 mt/yr in term of weight.

8.1.4 Trap Efficiency

The maximum normal pool elevation for the Río Chagres reservoir is planned to be about 200 or 220 meters. The reservoir volumes at these elevations are about 436 and 748 MCM respectively. Long-term mean annual flow is about 30.2 m^3/s. Thus, the capacity-inflow ratio is about 0.46 or 0.79.

To estimate the trap efficiency of the reservoir, Brune's method (USBR, 1987) was used. From the sediment deposited along the banks of the Río Chagres and the general soils in the watershed, it was judged that the sediment entering the reservoir would be of medium to coarse sizes. Therefore, average of the Brune's curves for medium and coarse sediment sizes was used as the representative trap efficiency. For capacity-inflow ratio of 0.46 and 0.79, the trap efficiencies would be about 97 and 98 percent, respectively. This resulted in mean annual deposits of about 584,700 and 590,700 metric tons, respectively. Since the two rates are nearly same, an annual rate of 590,700 metric tons per year was used.

8.2 ANALYSIS OF STORAGE DEPLETION AND SEDIMENT DEPOSITION

Depletion in the reservoir storage was estimated using the methods developed by the United States Bureau of Reclamation (USBR, 1987). An annual sediment deposit of 590,700 metric tons was used.

The reservoir operation was assumed as type 2 (USBR classification, normally moderate to considerable drawdown). The particle size distribution of the deposit was not available. For the purpose of estimating specific weight of fresh deposit and the weights after a period of reservoir operation, the particle size distribution of the sediment was assumed to be about 10 percent clay, 40 percent silt and 50 percent sand. Using the USBR procedure (USBR, 1987), the specific weight of the fresh deposit was about 80.4 pounds per cubic feet (about1.29 mt/m^3). The average specific weights for 5-, 10-, 25-, 50- and 100-year of operation were about 1.30, 1.30, 1.31, 1.32 and 1.33 mt/m^3,

respectively. Using these values, the volume of deposit at the end of 25, 50, and 100 years of operation is estimated to be 11.2 MM, 22.0 MCM, and 44.5 MCM respectively.

Sediment distribution in the reservoir and the elevation of the deposit at the dam were determined using a computer program obtained from USBR. For sediment distribution and deposition at the dam, the empirical area-reduction method was used.

As per current investigation of the project, the initial maximum and minimum operating reservoir elevations would be 210 and 155 meters, respectively. The invert of the low-level sluice was assumed at about El 90. The incoming sediment will partly deposit in the dead storage (below elevation of 90 meters), partly between elevations 90 to 155 meters and partly in the operating volume (live storage, above elevation of 155 meters). Using these operating limits, the operating volume and the loss in the original volume after a given period of operation is given in Table 13. The table shows that reservoir sedimentation is significant, but will not be a major problem for the project. After 100 years of reservoir operation, the loss in live storage capacity would be about 5 percent. In addition, it is estimated that after 100 years, the sediment will reach to about El 115 at the dam.

9 PROJECT IMPACT ON WATER QUALITY

9.1 IMPACT DURING CONSTRUCTION PERIOD

Sediment production (erosion) will increase due to construction activities such as excavation, construction of dirt roads, construction of temporary buildings for construction staff, etc. The increased erosion, if not properly controlled, will make river water turbid and unsuitable for drinking or other uses.

9.1.1 General Concepts

The erosion process is influenced primarily by climate, topography, soils and vegetative cover. The climatic factors influencing the erosion include the frequency, intensity and duration of rainfall and temperature extremes. These factors will be unchanged due to construction activities. However, the size, shape and slope characteristics of the disturbed area will be changed by construction activities and will influence the erosion. .

Properties determining the erodibility of a soil are texture, structure, organic matter content and permeability. Soils containing high percentages of fine sands and silt are normally the most erodible. The erodibility decreases as the clay and organic matter contents increase. The soil horizon exposed at a particular location during construction will determine the severity of erosion.

A general procedure is to estimate the soil erosion rates using the universal soil loss equation or modified universal soil loss equation. The various factors in the equation include: rainfall intensity, soil-erodibility, length and steepness of slopes, cropping management, and erosion control practice. The equation should be used to estimate potential erosion rates from disturbed lands during construction.

Construction sites or borrow areas will be in their most vulnerable bare conditions for only part of a year, when erosion potential will be high. In the Río Indio basin, the general type storms occur during October through December, but local thunderstorm with intense rainfall could occur any time during the year. However, during the dry months of February through April, the erosion may be minimum.

9.1.2 Mitigation Measures During Construction

A water quality management plan (WQMP) should be prepared by the contractor and submitted for approval. The plan should ensure that unclean water or foreign material would not enter any surface waters or watercourses in the area.

Mitigation measures for erosion and sedimentation will be in full compliance with the local standards and requirements. The contractor should ensure that the bare slopes are exposed for a minimum period and are protected from the erosive forces of wind, rain and runoff as soon as possible. The eroded soil will be captured on-site and not allowed to enter the water bodies. Major land clearing and grading should be scheduled during season of relatively low runoff potential. A combination of both vegetative and structural measures should be employed.

The plan for controlling sediment should apply to all aspects of construction activities including, but not limited to: clearing, operation, all excavation spoil area, drilling and grouting, fills, and roadwork. Sediment control methods such as silt fences, sediment barriers, sediment ponds, ditches, interceptor dikes, perimeter dikes, leaving of buffer zones, graveling after grading, and other such devices or actions will be constructed and maintained, or performed, as necessary to comply with the local requirements.

The contractor should ensure that the following principles guide the construction activities and these principles are integrated with the mitigation measures to prevent off-site sedimentation:

- Fit the Activities to Existing Site Conditions
  Construction activities should follow the existing topography, especially the cutting of borrow areas and road grading should follow the natural contours. Steep slopes, areas subjected to flooding and highly erodible soils should be avoided to the extent feasible.

- Minimize the Extent and Duration of Exposure
  The construction activities should be scheduled such that the exposed areas are stabilized as quickly as possible.

- Protect Disturbed Areas from Runoff
  Measures should be taken to intercept runoff and divert it away from cut-and fill slopes or other disturbed area. The selected measures should be installed before clearing and grading.

- Stabilize Disturbed Areas
  After the land is disturbed, temporary or permanent vegetation, mulches or other protective measures should be implemented as quickly as possible.

- Keep Runoff Velocities Low
  This should be achieved by conveying the storm water runoff away from the steep slopes, preserving natural vegetation where possible and mulching and vegetating exposed areas immediately.

- Retain Sediment On-Site
  Some erosion would occur in spite of well-planned mitigation measures. These sediments should be retained on-site using sediment basins, sediment barriers and related structures. If on-site sedimentation is required, the sediment traps or basins should be constructed prior to land disturbing activities.

- Do Not Encroach Upon Watercourses
  Where feasible, the project related buildings, access roads and borrow areas should not be constructed in flood-prone areas. If unavoidable, temporary bridges and culverts should be employed to permit passage of selected peak discharges.

9.2 POTENTIAL LONG-TERM IMPACT

The project operation may have three longer-term impacts on water quality. First, normal daily fluctuations in the reservoir may cause reservoir bank erosion or landslides. Second, the flow released from the reservoir may cause bank and bed erosion in the reach of the Río Chagres between the dam and Lake Madden, and third, the water released through the low level outlets for in-stream flow requirements may be cooler than normal.

Based on an inspection of the reservoir area, the reservoir rim is not expected to exhibit much erosion except in very limited areas. It is not expected that this local erosion will have any significant impact. The most likely areas will be in the vicinity of the tunnel portal, however, as a part of construction, all disturbed areas will be stabilized and restored to natural conditions as far as feasible.

The stability of the river channel downstream from the dam is addressed in the next section. The low-level outlet and spillway, to the extent possible, will be operated to control the maximum hourly increase or decrease in flow so that it would be comparable with natural conditions. This would check the erosion of river banks and bed.

10 STABILITY OF THE RÍO CHAGRES CHANNEL

The assessment of the Río Chagres channel stability consisted of the estimation of flood conditions without and with the project, a determination of the hydraulic and bed material characteristics of the channel downstream from the dam, and an evaluation of channel stability.

10.1 FLOOD REGIME DOWNSTREAM FROM THE DAM

Pre-project flood conditions are discussed in Section 6. The pre-project flood peaks with return intervals are presented in Table 8.

Flood hydrographs were developed for the 20-, 25-, and 50-year return periods using flood peak, and 1-day flood volumes of the selected return periods. The hydrographs were shaped after the historic flood of December 1985, and adjusted for the flood peak and volumes. The hydrographs for the 2-, 5- and 10-year return periods were shaped after the flood of 20-year return period using ratios of respective peaks. The hydrograph for 100-year return period was developed using the 50-year flood hydrograph and a ratio between the peaks. Ordinates of the seven flood hydrographs are presented in Table 14.

The seven flood hydrographs were routed through Chagres reservoir and the resulting maximum outflow peaks are given in Table 15.

10.2 HYDRAULIC CHARACTERISTICS

The ACP surveyed six cross sections identified by MWH downstream from the proposed dam site. The cross sections were located about 400, 515, 775, 1685, 2320 and 3175 meters downstream from the dam axis.

A review of the cross sections indicated that the river channel widens from upstream to downstream. The river banks have nearly same slopes at all cross sections.

The FEQ computer model was used to determine the hydraulic characteristics of all cross sections. The characteristics included: area, depth, top width and channel mean velocity. Uniform discharge rates ranging from 200 to 3,000 m^3/s were used.

All cross sections were plotted on one sheet. The shapes of the cross sections and the hydraulic characteristics were compared. Cross section No. 4 was judged to represent the hydraulic condition of the 3-km channel reach downstream from the dam. Therefore, this section was used as a representative cross section to investigate the channel stability. The hydraulic characteristics of the cross section are given in Table 16 and the section is shown on Exhibit 44.

10.3 CHARACTERISTICS OF BED MATERIAL

ACP took six bed material samples at the locations of the surveyed cross sections and analyzed the samples for particle size distribution. Exhibit 45 shows the particle size distribution curves and an average, representative curve is shown on Exhibit 46. Based on this curve, the median bed material size is 62 mm (based on USBR method) and the characteristics are summarized below.

Size Designation	Particle Size (mm)
D35	27
D50	46
D65	86
D90	150
Median	62

10.4 RIVER CHANNEL STABILITY

The sediment transport capability of a river depends upon flood flows. A natural flowing river transporting sediment is usually in a state of regime or quasi-equilibrium with no long-term trend toward aggradation or degradation. When a dam is constructed on the river, three potential effects could be experienced – downstream effects due to changed time distribution of flow, reduction in sediment load, and reduced competence to transport sediment. These effects are discussed below.

Downstream effects due to changed time distribution of flow are generally manifested as degradation at the mouths of the tributaries. At the time of flood in the tributary, the water level in the main river could be much lower than that under without/dam conditions. This would cause relatively steep water surface slope at the mouth of the tributary providing the potential for scour at the mouth.

A reduction in the sediment load occurs as the sediment is trapped in a reservoir. The downstream effects are generally degradation of the channel and banks as the sediment-free reservoir releases pick up sediment from the bed. The degradation continues until a stable, gravel-armored bed is formed or until the slope is reduced to a value that prevents further sediment removal from bed. However, if a reservoir is designed to pass sediment through low-level outlets, most of the sediment passes to the downstream channel and there is no degradation downstream. The trap efficiency of this type of reservoir is quite low. For reservoirs with no low-level sediment excluders, the trap efficiency is high. The released water is sediment-free and is capable of picking up bed material.

The reduced transport capability is due to the storage effect of a reservoir, *i.e.,* flood flows are significantly reduced. A river may no longer be able to move the bed loads carried by its tributaries. This could cause extensive aggradation at the mouths of some tributaries. In some cases, the main channel may not show any degradation.

10.4.1 Computation of Degradation Potential

The techniques for computing degradation below a dam vary considerably depending on the size of sediments in the riverbed and banks, the magnitudes of release discharges at the dam, and sophistication desired in the results. Sophisticated mathematical computer models have become available for computing degradation. Such models simulate the behavior of an alluvial channel by combining a steady-state backwater computation for defining channel hydraulics with a sediment transport model. The models need detailed hydraulic properties of the river channel, sediment characteristics of river bed and suspended sediment in the releases, and flow pattern of the releases. These data are not available for the Río Chagres. Therefore, a mathematical computer model was not used.

In Design of Small Dams, the United States Bureau of Reclamation (the Bureau) recommends two approaches, each specific to the type of bed material composing the downstream channel. If the streambed is composed of sufficient quantity of large and

coarse material that cannot be transported by normal river discharges, an armor layer will develop. The smaller particles in the riverbed are picked up and transported further downstream. Large particles that cannot be transported by the flood releases remain on the river bed and gradually form an armor layer that stops further degradation below a dam. The armor layer is formed for a certain magnitude of flood. If this flood release is exceeded, the layer is disturbed and a new layer is formed. If the conditions required to for an armoring are not present, then a second approach can be used. If the stream bed is composed of fine transportable (usually sand and small gravels) material and the depth of this material is greater than expected depth of degradation, stable channel slope (or limiting slope) method is used. The method consists of computing the limiting slope, estimating the volume of expected degradation and then determining a three-slope channel profile that fits these values. Since the Río Chagres has sufficient coarse material, this later approach was not used.

As discussed above, the armor layer method is applicable if there is large or coarse material in the channel bottom that cannot be transported by normal releases and there is enough of this material to develop an armor layer. In the armoring process, transportable material is sorted out, and vertical degradation proceeds at a progressively slower rate until the armor is deep enough to control further degradation. Usually, an armoring layer should be expected below a dam if 10 percent or more of the bed material is larger than the armoring size corresponding to the flow magnitude (the Bureau).

The armoring layer is assumed to form as follows:

$$Y_A = Y - Y_D$$

in which

Y_A = thickness of the armoring layer,
Y = depth from original stream bed to bottom of the armoring layer
Y_D = depth from the original streambed to top of armoring layer (depth of degradation)

By definition

$$Y_A = p * Y$$

where 'p' is decimal percentage of material larger than the armoring size.

By combining the above two relationships, the depth of degradation can be computed as:

$$Y_D = Y_A ((1/p) - 1)$$

As per the Bureau, the thickness of an armoring layer (Y_A) is usually three times the armoring particle diameter or 0.15 meters, whichever is smaller. Therefore, if the armoring size and the percentage of streambed material larger than that size are available, the depth of degradation (Y_D) can be computed.

10.4.2 Required Armor Sizes

The sediment particle sizes required for armoring can be computed by several methods, and each is regarded as a check on the others. Each method indicates a different size and, therefore, experience of the investigator and judgment are required to select the most appropriate size. The basic data required to compute particle size includes:

- Samples of streambed material in the reach selected for degradation to a depth anticipated to the scour zone.
- A discharge rate that will cause degradation equivalent to long-term degradation below a dam, defined as dominant discharge and is equivalent to mean annual flood (approximately a flood of 2-year return period).
- Average hydraulic properties of the channel reach – width, depth, velocity and gradient.

The Bureau has recommended the following methods:

- Meyer-Peter, Muller (Meyer 1948, Sheppard 1960)
- Competent bottom velocity (Mavis 1948)
- Shield diagram (Pemberton and Lara 1982, ASCE 1975)
- Yang incipient motion (Yang 1973)
- Critical tractive force (Bureau 1952)

Meyer-Peter, Muller:

$$D = (S * d) / (K * ((N_s/(D_{90})^{1/6})^{1.5})$$

in which

$K = 0.19$ English units (0.058 SI units)
N_s = Manning's roughness coefficient for streambed
D_{90} = bed material diameter in mm, 90 percent material finer than the diameter
D = armoring size , mm
S = stream gradient, ft/ft or m/m
d = channel depth, ft or m

Competent Bottom Velocity:

$$V_B = 0.7\ V_M$$
$$D = 3.84\ (V_B)^2 \text{ (English units)}$$
$$D = 41.6\ (V_B)^2 \text{ (SI units)}$$

in which

V_M = mean velocity, ft/sec or m/sec
V_B = competent bottom velocity, ft/sec or m/sec
D = armoring size, mm

Shield's Method:

The following method is used for material >1.0 mm and Reynolds's number R* >500

$$Tc / ((Ws - Ww)*D) = 0.06$$

$$\text{or } Tc/0.06 = (Ws-Ww)*D$$

$$\text{or } D = Tc/((0.06\ (Ws-Ww))$$

in which

Tc = Ww * d * S, critical shear stress, lb/ft^2 or gm/m^2
Ws = unit weight (mass) of particle, 165 lb/ft^3 or 2.65 mt/m^3

Ww = unit weight (mass) of water, 62.4 lb/ft^3 or 1.0 mt/m^3
d = depth of water, ft or m
S = stream gradient, ft/ft or m/m
D = armoring size, mm

Yang Incipient Motion

$Vcr / w = 2.05$
$w = 6.01\ D^{1/2}$ (English units)
$w = 3.32\ D^{1/2}$ (SI units)
$D = 0.00659\ (Vcr)^2$ (English units)
$D = 0.0216\ (Vcr)^2$ (SI units)

in which
Vcr = critical average velocity, ft/sec or m/sec
w = terminal fall velocity, ft/sec or m/sec
D = armoring size, mm

Critical Tractive Force:

$t.f. = Ww * d * S$

in which
t.f. = tractive force, lb/ft^2 or gm/m^2
Ww = unit weight (mass) of water, 62.4 lb/ft^3 or 1.0 mt/m^3
d = water depth, ft or m
S = stream gradient, ft/ft or m/m

After computing the tractive force, Figure 4 given by Pemberton and Lara (1984), should be used to find armoring size in mm. Usually the recommended set of "curves for clear water in coarse non-cohesive material" gives the lower size limit of the non-transportable material corresponding to a critical tractive force. Because a number of curves are provided and sufficient field data were not available to select an appropriate curve, this method was not considered.

Four methods (Meyer-Peter, Muller, Competent Bottom Velocity, Shield and Yang Incipient Motion) were applied to compute the armoring size (the particle size that would not be removed or eroded from the bed under given hydraulic conditions). The armoring sizes derived by using the Competent Bottom Velocity and Yang methods were judged to be too large and were not considered representative. The estimated armoring sizes using Meyer-Peter, Muller and Shield methods are given in Table 17 for both the pre- and post-project flooding conditions.

10.4.3 Potential for Degradation and Aggradation

A comparison of pre-project armoring sizes (Table 17) with the median diameter of 62 mm indicates the potential for degradation in the Río Chagres. During a field visit the river bed was smooth and appeared to be armored. Under pre-project conditions, the required armor sizes (average of the sizes computed using Meyer-Peter, Muller and Shield methods) corresponding to the selected flood peaks are greater than the median diameter of the available bed-load material. Therefore, channel degradation is expected during each major flood. However, due to supply of coarse particles, the river channel is in quasi-equilibrium. Degradation-aggradation-armoring process occurs during each major flood.

Under post-project conditions, the required armor size is also larger than the median diameter of the available bed load material for all floods except the 2-year event. Degradation could occur. Estimates of potential degradation were made for flood peaks of the 25-, 50- and 100-year floods. Depths of degradation would vary from slightly less than 0.3 m to slightly more than 0.3 m for the three flood conditions. These rates are for instantaneous peaks and actual degradation could be less. For design of any downstream structure, a degradation of about 0.3 m should be expected during most significant flood events between the dam and the next major downstream tributary, Río Esperanza.

Aggradation would occur at the mouths of the small tributaries downstream from the dam up to Río Esperanza, because the reduced flood peaks will not be able to transport the bed load deposited by the tributaries.

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GLOSSARY

Alluvial Stream: A stream whose channel boundary is composed of appreciable quantities of the sediments transported by the flow, and which generally changes its bed forms as the rate of flow changes.

Basin-Average Rainfall: Rainfall considered uniformly distributed over a basin, derived from point rainfall measured at a number of stations in the basin.

Bed Load: Material moving on or near the stream bed by rolling, sliding, and some times making brief excursion into the flow a few diameters above the bed.

Bed Load Discharge: The quantity of bed load passing a transect in a unit of time.

Bed Material: The sediment mixture of which the bed is composed. In alluvial streams bed material particles are likely to be moved at any moment or during some future flow condition.

Boulders: Particle sizes larger than 256 mm.

cfs: Cubic feet per second.

Clay: Particle sizes of sediment less than 0.004 mm.

Climate: Long-term manifestation of weather.

cms or m^3/s: Cubic meters per second.

Cobbles: Particle sizes between 64 and 256 mm.

Coefficient of Skew: This parameter represents lack of symmetry in a sample. A positive skew indicates more observations of higher magnitudes than the mean of the sample, and a negative skew shows more observations of lower magnitudes than the mean.

Concentration: The ratio of the mass of dry sediment in a water-sediment mixture to the mass of the mixture. This concentration when determined on a mass basis as parts per million (ppm) may be converted to grams per cubic meter (gm/cum) or milligram per liter (mg/l).

Consistency: Also called "stationarity." A time series is consistent (or stationary) if it remains in equilibrium about a constant mean value, that is, the statistical properties

(mean and variance) of the time series do not change with absolute time. The series is divided into sub-sets and mean and standard deviation of each set are determined. If the values of these parameters are same for each sub-set at a selected confidence level, the series is consistent.

Correlation: The degree of association of the variables involved is called correlation and defined by the parameters of correlation, covariance and correlation coefficient.

Correlation Coefficient: Correlation coefficient between two variables X and Y is defined as the ratio between covariance and product of standard deviation of X and Y.

Deposition: The mechanical or chemical processes through which sediments accumulate in a resting place.

Drainage Area: Also called as drainage basin or watershed, is an area at a point of interest from which surface runoff is carried to that point by a single drainage system.

El Niño: El Niño is named after a Peruvian Christmas festival where the warming of the waters off Peru is said to occur near the birthday of "The Boy" (El Niño), or Christ child. Meteorologists thus named the phenomenon as "El Niño Southern Oscillation" or ENSO.

Gauging Station: A particular site on a stream where systematic observations of gauge height and discharge are obtained. The station is equipped with water level sensor (manual or automatic continuous) and facility for discharge measurements.

Homogeneity: If the means and standard deviation of the series do not change along a line, that is, there is no trend in the series, the series is called homogeneous.

Hydrology: Hydrology is the science that treats the waters of the earth, their occurrence, circulation, and distribution, their chemical and physical properties, and their reaction with their environment, including their relation to living things.

Inconsistency: Jumps in a time series make it inconsistent or non-stationary. Jumps are created by sudden changes that are either man-made or they occur by various kind of changes in nature.

Isohyet: A line drawn through geographical points recording equal amounts of rainfall during a given time period or for a particular storm.

Isohyetal Map: A map containing a set of isohyets.

Isthmus: A narrow strip of land, bordered by water on both sides, which connects two large bodies of land.

ITCZ: Intertropical convergence zone (also called equatorial trough) is the zone located in the tropical region where the trade wind trajectories converge from northern and southern hemispheres.

La Niña: The cooling of the eastern Pacific waters, reverse of El Niño, is named as La Niña, "the Girl."

Mass Curve: A curve of cumulative values of rainfall or flow plotted against time.

MCM: Million cubic meters.

Mean: Arithmetic mean of a sample of observations is usually referred to as the mean of the sample. This is equal to sum of the observations divided by the number of observations.

Measured Sediment Discharge: The quantity of sediment passing a stream transect in a unit of time that is computed with information derived from sampling.

Median Diameter: The size of sediment such that one half of the mass of the material is composed of particles larger than the median diameter, and the other half is composed of particles smaller than the median diameter.

Meteorology: The science concerned with the atmosphere and its phenomena, temperature, wind, clouds, precipitation, etc., and their variations.

Particle Size: A linear dimension, usually designated as "diameter," used to characterize the size of a particle. The dimension may be determined by any of several different techniques, including sedimentation, sieving, micrometric measurement, or direct measurement.

Particle Size Distribution: The frequency distribution of the relative amounts of particles in a sample that are within specified size ranges, or a cumulative frequency distribution of the relative amounts of particles coarser or finer than specified sizes. Relative amounts are usually expressed as percentages by mass.

Precipitation: Precipitation is the discharge of water, in liquid or solid state, out of the atmosphere, generally upon a land or water surface. The term is also commonly used to designate the quantity of water that is precipitated. The term precipitation includes rainfall, snow, hail and sleet.

Range: The difference between the largest and the smallest values of a specific data set.

Rainfall: The quantity of water that falls as rain only.

Rain Gauge: Instrument for measuring the depth of water from precipitation (or rainfall) that is assumed to be distributed over a horizontal, impervious surface and not subjected to evaporation.

Recording Rain Gauge: A rain gauge that automatically records the amount of precipitation (or rainfall) collected as a function of time.

Regression: A curve fitted to all mean values of Y (mean or expected value of Y for a given interval of X around Xi) is called regression of Y versus X.

Reservoir: An impounded body of water or controlled lake where water is collected and stored.

Runoff: The portion of precipitation (or rainfall) on the land that ultimately reaches the selected point on a stream.

Sand: Particle sizes between 0.062 to 2.0 mm.

Sediment Discharge: The mass or volume of sediment (usually mass) passing a transect in a unit of time. The term may be qualified as suspended sediment discharge, bed load discharge or total sediment discharge. The term is synonymous to sediment transport.

Sediment Load: A general term that refers to material in suspension and/or in transport. It is not synonymous with discharge or transport.

Sediment Yield: The total sediment outflow from a drainage basin in a specified period of time. It includes bed load as well as suspended load, and usually is expressed in terms of mass, or volume per unit of time.

Sensor: The part of a measuring instrument that responds directly to changes in environment.

Silt: Particle sizes between 0.004 and 0.062 mm.

Standard Deviation: This represents a measure of variability of observations in a sample. The square of standard deviation is called "variance."

Time Series: A time series is a sequence of observations arrayed in order of their occurrence. An observation can be a quantity either observed at discrete times, averaged over a time interval or recorded continuously with time. Hydrologic time series are sequences of daily, monthly or annual rainfall, streamflow, sediment transport, etc.

Trend: Trends are linear or non-linear slow changes in mean, variance, coefficient of variation and serial correlation coefficients of a time series. These render a time serious non-homogeneous.

Variance: It is square of the standard deviation.

Watershed: An area draining to a lake or a specified point on a stream, it lies upstream of the point and is enclosed by a hydrologic surface drainage divide, also called drainage area or drainage basin.

Watershed Divide: A ridge of section of high ground between watersheds, also called drainage divide.

Weather: The state of the atmosphere, mainly with respect to its effects upon life and human activities. As distinguished from climate, weather consists of the short-term (minutes to months) variations of the atmosphere.

TABLES

Table 1

MONTHLY RAINFALL AT CHICO (MM)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1911	22	103	20	22	320	246	98	205	358	571	289	105	2360
1912	23	7	16	80	289	291	221	276	246	385	322	38	2192
1913	53	0	0	55	306	286	141	243	327	236	235	227	2108
1914	34	0	20	67	221	226	117	274	439	397	330	118	2243
1915	11	107	20	240	190	383	599	475	337	504	470	239	3576
1916	2	47	23	208	206	315	422	254	370	611	342	76	2876
1917	0	0	2	5	275	308	581	470	278	351	680	267	3218
1918	89	20	20	179	339	399	387	256	274	245	224	59	2490
1919	94	24	20	243	119	171	323	410	403	396	286	122	2612
1920	49	12	23	104	236	293	419	366	279	488	240	16	2527
1921	17	23	2	113	207	371	481	425	438	627	287	281	3272
1922	136	28	0	38	385	391	167	247	278	338	334	210	2554
1923	39	22	17	22	205	389	363	157	316	656	266	0	2452
1924	18	51	3	98	313	283	612	359	342	271	240	64	2653
1925	52	0	0	28	166	388	354	304	244	495	251	163	2447
1926	0	6	0	30	174	332	317	393	339	441	239	223	2494
1927	48	66	32	109	415	489	787	260	307	318	360	327	3519
1928	51	22	61	40	169	272	447	471	297	521	325	152	2827
1929	4	11	14	6	230	197	259	313	304	521	330	156	2344
1930	0	0	9	144	341	121	333	162	322	287	190	52	1961
1931	73	7	40	47	532	413	199	271	420	341	853	114	3311
1932	84	0	21	154	251	265	221	418	327	513	600	112	2966
1933	27	1	23	7	269	139	305	337	309	264	478	223	2383
1934	24	0	7	49	440	241	293	274	247	390	385	147	2496
1935	54	25	9	23	365	384	560	485	266	302	1082	276	3831
1936	16	4	4	67	419	286	322	300	429	322	262	61	2492
1937	127	9	7	55	180	188	392	318	422	474	424	496	3092
1938	8	22	9	112	617	305	373	593	334	476	312	356	3517
1939	5	0	11	5	149	318	97	260	407	393	567	264	2476
1940	39	30	8	21	139	186	118	290	322	370	364	11	1896
1941	20	100	30	62	268	372	341	324	370	430	368	113	2799
1942	18	6	5	60	310	330	287	323	390	442	310	333	2813
1943	43	31	30	83	305	277	224	263	440	469	257	308	2729
1944	38	5	8	189	291	308	372	408	254	503	190	232	2799
1945	15	5	6	70	230	330	450	553	185	278	362	230	2713
1946	17	7	6	8	368	363	389	222	379	308	314	242	2623
1947	9	19	9	34	191	354	319	335	320	479	435	179	2682
1948	17	5	4	29	176	282	560	149	246	371	347	101	2286
1949	10	6	4	44	295	495	445	306	334	432	367	116	2854
1950	8	23	13	116	421	408	406	425	290	215	443	375	3145
1951	16	140	6	144	376	268	290	360	449	357	280	75	2760
1952	34	8	1	153	305	243	287	261	450	493	257	261	2754
1953	142	9	20	149	409	264	410	236	278	410	381	166	2876
1954	5	17	27	27	500	368	426	312	389	248	342	107	2768
1955	175	7	35	1	140	359	352	576	276	269	425	131	2746
1956	171	26	24	43	333	290	445	250	254	409	424	97	2766
1957	3	10	2	2	102	201	229	178	217	463	364	47	1815
1958	67	9	24	38	348	406	354	269	284	234	282	67	2383

Table 1, cont.

MONTHLY RAINFALL AT CHICO (MM)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1959	8	1	2	11	110	337	132	278	291	294	178	379	2022
1960	107	3	21	66	503	282	389	334	303	602	331	486	3426
1961	9	1	4	98	210	362	258	402	417	335	267	207	2569
1962	13	*0*	*11*	*25*	*357*	*262*	*287*	*407*	*241*	*445*	246	122	2414
1963	89	21	0	182	245	383	401	474	235	219	233	8	2490
1964	0	*0*	*0*	*130*	*183*	*328*	*418*	*300*	*274*	511	323	117	2583
1965	*53*	*16*	*5*	*0*	*226*	*174*	*300*	*250*	*333*	*380*	*486*	*211*	*2435*
1966	*0*	*0*	*22*	152	272	228	442	321	421	516	546	490	3410
1967	16	1	3	166	*256*	*477*	388	294	368	460	369	145	2943
1968	3	26	3	27	246	351	237	380	300	626	291	51	2542
1969	30	0	36	42	170	232	184	512	407	192	317	217	2338
1970	271	30	35	300	430	169	361	432	409	306	309	387	3439
1971	50	7	74	23	307	318	399	429	353	333	307	13	2612
1972	69	15	3	193	213	302	74	152	277	282	251	81	1913
1973	8	5	0	8	269	300	279	340	363	427	475	132	2606
1974	10	229	3	30	122	518	173	262	356	366	244	30	2342
1975	0	3	3	23	259	246	353	307	284	427	333	170	2408
1976	15	5	10	79	272	295	102	345	251	239	224	36	1872
1977	23	3	3	13	267	279	112	363	292	414	226	64	2057
1978	18	5	23	173	269	467	343	373	241	282	284	69	2548
1979	5	3	3	193	152	178	523	371	239	297	272	76	2311
1980	36	36	23	23	226	251	175	396	234	315	366	97	2177
1981	53	10	36	348	269	348	312	389	193	229	241	244	2672
1982	81	0	0	76	234	201	287	157	229	422	127	53	1867
1983	10	0	23	112	157	208	208	246	417	587	495	315	2779
1984	10	5	8	0	320	480	284	554	218	490	320	33	2723
1985	30	10	23	48	173	544	404	254	409	300	185	274	2654
1986	15	3	20	122	140	279	140	193	259	681	262	36	2149
1987	13	15	3	249	417	287	500	381	455	467	351	122	3259
1988	3	25	13	46	343	224	455	478	470	518	361	97	3030
1989	20	53	5	25	160	363	325	386	201	320	358	132	2350
1990	61	5	20	20	211	150	259	411	368	627	351	155	2639
1991	10	10	48	114	320	269	224	257	262	312	264	119	2210
1992	10	5	8	94	419	546	351	401	262	300	150	102	2647
1993	41	3	58	147	272	516	178	165	391	373	168	71	2383
1994	18	5	25	36	262	310	175	244	295	406	295	18	2088
1995	15	0	41	84	305	356	246	424	236	389	302	150	2548
1996	254	28	30	127	302	536	183	340	406	338	386	145	3076
1997	10	8	3	64	135	302	188	119	318	284	376	5	1811
1998	5	3	5	64	414	330	381	287	399	401	391	287	2967
1999	38	71	15	53	361	381	356	307	290	353	442	472	3139
2000	43	3	5	66	226	404	165	460	333	478	157	500	2840
Mean	40	19	15	83	276	317	321	331	323	398	340	167	2631
Max	271	229	74	348	617	546	787	593	470	681	1082	500	3831
Min	0	0	0	0	102	121	74	119	185	192	127	0	1811
Std	51	34	15	73	103	96	134	103	72	114	139	125	433
Skew	2.6	3.8	1.5	1.3	0.7	0.4	0.5	0.3	0.2	0.4	2.5	1.0	0.4
CV	1.3	1.7	1.0	0.9	0.4	0.3	0.4	0.3	0.2	0.3	0.4	0.7	0.2

Note : Estimated rainfall in *italics* values.

MWH / TAMS

Table 2

MONTHLY RAINFALL AT RIO PIEDRAS (MM)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1911	15	104	24	183	276	164	119	131	352	604	235	4	2212
1912	0	11	0	60	190	227	213	136	258	382	326	14	1818
1913	29	25	0	5	361	321	220	281	420	337	266	142	2408
1914	0	0	0	0	135	291	77	317	448	242	275	99	1885
1915	0	133	76	320	135	367	374	300	207	297	373	88	2670
1916	27	60	8	157	189	247	329	221	225	320	255	7	2046
1917	0	0	3	72	224	279	292	299	351	158	378	16	2074
1918	81	37	30	144	456	362	205	88	267	262	155	16	2104
1919	92	37	22	237	133	178	145	254	434	279	209	83	2102
1920	12	0	37	82	222	345	275	189	266	388	256	0	2072
1921	40	67	46	269	234	362	449	459	566	481	235	187	3395
1922	67	41	0	68	306	345	80	197	235	396	252	334	2322
1923	0	25	8	37	100	240	221	169	338	572	251	0	1961
1924	19	45	20	129	274	187	529	334	452	48	167	0	2202
1925	37	0	0	36	196	434	243	244	250	418	195	163	2217
1926	0	45	28	75	169	477	312	280	315	328	282	403	2714
1927	48	109	88	186	280	209	446	111	292	238	308	409	2724
1928	65	6	93	70	232	173	259	284	269	331	313	171	2265
1929	0	36	52	33	238	215	167	290	271	259	240	44	1846
1930	46	22	25	143	329	135	292	107	270	183	135	0	1687
1931	23	10	95	17	376	259	253	197	381	389	601	154	2755
1932	71	0	25	180	279	171	160	373	366	547	423	70	2665
1933	91	23	63	34	345	421	358	193	248	121	393	92	2382
1934	21	0	3	81	383	203	315	166	301	337	244	80	2136
1935	0	80	4	9	354	312	614	375	319	296	719	170	3252
1936	45	0	0	77	346	90	185	204	289	371	214	0	1821
1937	94	0	0	50	225	185	247	127	316	342	325	388	2299
1938	7	29	7	130	665	268	232	531	325	287	213	622	3317
1939	27	0	7	0	101	335	172	268	372	290	392	194	2157
1940	33	5	18	55	126	116	190	196	209	200	211	0	1359
1941	19	119	60	76	249	309	161	139	360	501	257	0	2252
1942	0	0	31	30	316	113	153	262	257	285	101	173	1722
1943	109	49	80	61	345	393	218	270	324	310	196	412	2766
1944	9	11	38	221	181	387	185	475	263	408	213	243	2632
1945	14	0	0	192	330	330	432	411	165	193	312	147	2525
1946	21	4	20	32	290	347	395	150	393	222	185	120	2181
1947	0	25	19	31	34	210	126	227	182	213	232	281	1579
1948	18	0	0	21	187	170	417	224	211	232	291	97	1868
1949	0	0	17	23	171	405	265	273	264	313	336	10	2075
1950	7	11	0	45	243	398	686	313	215	92	253	257	2521
1951	29	116	0	91	281	93	252	340	384	335	225	183	2329
1952	8	0	0	28	236	379	325	323	424	427	253	459	2862
1953	174	16	48	69	421	43	114	139	120	352	323	64	1884
1954	0	74	0	0	336	362	375	258	466	362	392	135	2759
1955	129	18	84	0	88	292	278	353	232	268	467	144	2353
1956	122	122	53	154	446	298	394	280	254	299	310	86	2819
1957	0	23	8	45	217	143	106	79	142	318	168	106	1355
1958	48	23	12	4	199	388	244	281	220	186	281	0	1886

MWH / TAMS

Table 2, cont.

MONTHLY RAINFALL AT RIO PIEDRAS (MM)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1959	*0*	*0*	*0*	*46*	*178*	*325*	*184*	*399*	*366*	*364*	*121*	*196*	*2179*
1960	*78*	*3*	*12*	*136*	*445*	*201*	*433*	*275*	*212*	*225*	*173*	*503*	*2696*
1961	*6*	*0*	*3*	*145*	*264*	*589*	*159*	*232*	*372*	*268*	*169*	*167*	*2374*
1962	*8*	*0*	*0*	*72*	*204*	*133*	*202*	*271*	*284*	*272*	*234*	*268*	*1948*
1963	*38*	*54*	*17*	*291*	*255*	*387*	*341*	*421*	*269*	*164*	*161*	*0*	*2399*
1964	*0*	*13*	*0*	*41*	*80*	*350*	*297*	*261*	*187*	*377*	*462*	*122*	*2190*
1965	*16*	*0*	*13*	*65*	*168*	*131*	*196*	*308*	*340*	*319*	*349*	*149*	*2053*
1966	*50*	*20*	*31*	*236*	*435*	*219*	*288*	*372*	*394*	*420*	*360*	*418*	*3243*
1967	*7*	*36*	*60*	*183*	*226*	*585*	*359*	*240*	*266*	*349*	*353*	*148*	*2810*
1968	*0*	*44*	*48*	*0*	*315*	*181*	*242*	*227*	*155*	*352*	*334*	*120*	*2017*
1969	*39*	*9*	*99*	*155*	*196*	*91*	*235*	*273*	*292*	*173*	*263*	*250*	*2075*
1970	*250*	*96*	*49*	*175*	*352*	*178*	*247*	*349*	*361*	*248*	*238*	*362*	*2905*
1971	*33*	*23*	*64*	*0*	*393*	*331*	*428*	*296*	*353*	*277*	*288*	*28*	*2516*
1972	*102*	*26*	*13*	*167*	*265*	*392*	*101*	*156*	*238*	*399*	*189*	*7*	*2054*
1973	*23*	*9*	*5*	*0*	*178*	*200*	*301*	*182*	*258*	*385*	*407*	*102*	*2048*
1974	*6*	*248*	*42*	*53*	*77*	*194*	*197*	*124*	*349*	*274*	*218*	*126*	*1907*
1975	*0*	*39*	*0*	*18*	*419*	*293*	*327*	*214*	*304*	*651*	*307*	*267*	*2838*
1976	*2*	*0*	*6*	*42*	*112*	*108*	*0*	*162*	*230*	*173*	*112*	*0*	*947*
1977	*49*	*0*	*16*	*15*	*193*	*124*	*152*	*253*	*242*	*311*	*208*	*26*	*1590*
1978	*1*	*28*	*65*	*206*	*477*	*309*	*249*	*241*	*265*	*382*	*303*	*122*	*2647*
1979	*0*	*0*	*0*	*118*	*87*	*123*	*353*	*162*	*151*	*345*	*431*	*388*	*2158*
1980	*86*	*82*	*16*	*29*	*148*	*317*	*221*	*275*	*159*	*191*	*281*	*302*	*2108*
1981	*139*	*18*	*59*	*482*	*256*	*369*	*215*	*273*	*178*	*169*	*198*	*114*	*2468*
1982	*9*	*0*	*0*	*18*	*160*	*262*	*216*	*77*	*265*	*449*	*110*	*0*	*1566*
1983	*9*	*41*	*18*	*167*	*289*	*178*	*110*	*155*	*376*	*436*	*295*	*309*	*2384*
1984	*12*	*68*	*0*	*0*	*15*	*134*	*215*	*350*	*157*	*328*	*246*	*5*	*1528*
1985	*52*	*1*	*72*	*19*	30	168	231	165	320	175	107	284	1624
1986	28	0	41	191	290	234	130	112	284	528	284	74	2195
1987	33	41	13	310	462	201	330	318	340	373	340	99	2860
1988	13	102	23	48	478	404	406	394	406	447	330	109	3160
1989	56	114	30	51	102	185	389	264	206	292	353	193	2235
1990	0	0	0	0	307	69	274	259	371	470	226	236	2212
1991	13	38	81	91	257	216	335	178	353	254	277	28	2121
1992	13	5	10	58	366	345	201	300	234	399	264	109	2304
1993	61	3	147	188	368	577	193	188	399	310	163	74	2670
1994	28	28	41	30	401	251	213	239	165	340	483	66	2286
1995	23	0	8	28	244	470	381	467	244	206	259	168	2497
1996	226	84	74	213	455	290	287	396	251	351	414	297	3338
1997	10	33	10	104	216	231	58	112	264	198	312	28	1577
1998	20	15	33	84	472	145	429	290	394	264	419	335	2901
1999	79	155	48	175	315	650	302	348	371	254	300	716	3713
2000	119	28	33	142	274	455	244	460	452	462	287	719	3675
Mean	38	34	28	96	263	273	264	257	295	318	281	166	2314
Max	250	248	147	482	665	650	686	531	566	651	719	719	3713
Min	0	0	0	0	15	43	0	77	120	48	101	0	947
Std	48	44	31	90	121	126	118	99	87	111	104	161	519
Skew	2.2	2.1	1.3	1.4	0.4	0.6	0.8	0.4	0.3	0.4	1.2	1.4	0.4
CV	1.3	1.3	1.1	0.9	0.5	0.5	0.4	0.4	0.3	0.3	0.4	1.0	0.2

Note : Estimated rainfall in *italics* values.

MWH / TAMS

Table 3

LIST OF RAINFALL AND STREAM GAGING STATIONS
(shown on Exhibit 7)

Rainfall Station

01. San Miguel
02. Escandalosa
03. Río Piedras
04. Candelaria
05. Peluca
06. Chico
07. Salamanca
08. Alhajuela
09. Santa Rosa
10. Balboa Heights
11. FAA
12. Diablo Heights
13. Miraflores
14. Pedro Miguel
15. Hodges Hills
16. Empire
17. Cascadas
18. Gamboa
19. Ciento
20. Agua Clara
21. Barro Colorado
22. Monte Lirio
23. Coco Solo
24. Gatun
25. Limon Bay
26. Gatun West
27. Guacha
28. Cano
29. Raises
30. Humedad
31. Chorro
32. Canones
33. Icacal
34. Miguel de la Borda
35. Boca de Uracillo
36. Santa Ana
37. Chiguiri Arriba
38. Sabanita Verde
39. Coclé del Norte
40. San Lucas
41. Boca de Toabre
42. Coclesito
43. Tambo
44. Toabre
45. Chamon
46. Esperanza
47. Limpio

Stream Gaging Stations

A. Río Trinidad at el Chorro (drainage area 172 km^2)
B. Río Ciri Grande at Los Canones (drainage area 186 km^2)
C. Río Indio at Limon (drainage area 376 km^2)
D. Río Indio at Boca de Uracillo (drainage area 365 km^2)
E. Río Toabre at Batatilla (drainage area 788 km^2)
F. Río Coclé del Norte at El Torno (drainage area 672 km^2)
G. Río Coclé del Norte at Canoas (drainage area 571 km^2)
H. Río Chagres at Chico

Table 4

DEPARTURES OF ANNUAL RAINFALL AND STREAMFLOW FROM LONG-TERM MEAN DURING SELECTED EL NIÑO EPISODES

Chico Rainfall Station

El Niño Episode (year)	Long-Term Annual Rain (mm)	Annual Rainfall (mm)	Percent Departure
1930	2631	1961	-25
1957	2631	1815	-31
1976	2631	1872	-29
1977	2631	2057	-22
1982	2631	1867	-29
1997	2631	1811	-31

Rio Piedras Rainfall Station

El Niño Episode (year)	Long-Term Annual Rain (mm)	Annual Rainfall (mm)	Percent Departure
1930	2314	1687	-27
1957	2314	1355	-41
1976	2314	947	-59
1977	2314	1590	-31
1982	2314	1566	-32
1997	2314	1577	-32

Chico Streamflow Gage

Year of El Niño	Mean Annual Flow (cms)	Annual Recorded Flow (cms)	Percent Departure from the Mean
1957	30.2	18.9	-37
1976	30.2	21.1	-30
1977	30.2	24.0	-21
1982	30.2	25.1	-17
1997	30.2	19.8	-34

Table 5

UPPER CHAGRES RESERVOIR AREA-VOLUME DATA

Elevation (m)	Area (km^2)	Cumulative Volume (MCM)
88	0	0
90	**0.02**	**Negligible**
95	**0.10**	**0.3**
100	0.15	0.9
105	**0.20**	**1.7**
110	0.40	3.6
120	**0.75**	**8.5**
125	1.0	12.0
130	**1.3**	**18.5**
135	**1.7**	**25.8**
140	2.1	36.0
145	**2.7**	**47.4**
150	3.2	61.0
155	**3.8**	**79.0**
160	4.4	100
165	**5.1**	**123**
170	5.7	151
175	**6.4**	**180**
180	7.3	215
185	**8.2**	**253**
190	9.1	296
195	**10.2**	**345**
200	11.4	399
205	**12.6**	**459**
210	13.9	526
215	**15.3**	**598**
220	16.8	680
225	**18.5**	**767**
230	20.2	864
235	**22.1**	**970**
240	24.0	1090
245	**26.1**	**1,210**

Values in **BOLD** indicate measured contour data; all other values interpolated from curve

Table 6

MEAN MONTHLY FLOW, RIO CHAGRES AT CHICO
(cubic meters per second)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1933	**25.5**	**14.9**	11.4	9.0	19.5	21.3	20.4	24.3	30.9	19.1	42.1	67.6	25.5
1934	24.9	11.0	8.2	12.3	31.9	32.8	**32.3**	**35.3**	**34.1**	51.5	62.9	41.8	31.6
1935	39.5	17.7	11.7	8.5	26.8	25.3	64.6	43.4	34.9	30.4	177.5	103.6	48.7
1936	15.9	9.5	7.8	9.4	38.2	24.4	30.5	33.5	40.2	38.8	42.6	24.8	26.3
1937	38.5	20.3	11.2	9.9	20.0	22.1	24.5	28.6	34.1	44.4	54.5	80.3	32.4
1938	20.4	14.5	11.0	26.7	53.6	41.2	37.2	67.8	41.1	41.5	51.0	106.9	42.7
1939	25.8	12.1	9.3	8.9	10.1	19.7	15.0	23.1	23.9	23.4	49.3	41.1	21.8
1940	22.0	16.0	14.2	11.9	15.5	18.2	15.6	26.9	22.4	35.6	31.8	21.4	21.0
1941	15.0	22.1	17.5	11.9	22.2	37.3	28.1	37.5	40.4	75.6	66.9	43.4	34.8
1942	21.2	15.9	15.9	24.8	17.9	29.7	33.1	32.2	39.1	52.2	40.8	34.6	29.8
1943	28.8	20.5	15.8	17.0	33.6	35.4	27.3	31.9	31.6	45.4	41.1	76.6	33.8
1944	26.7	20.2	10.7	17.8	37.7	31.1	42.0	42.9	37.5	56.3	53.5	89.1	38.8
1945	29.4	17.8	11.2	11.4	25.3	28.9	30.7	40.2	36.1	34.8	31.4	65.6	30.2
1946	19.8	14.4	9.8	12.7	24.1	27.7	39.6	42.8	34.9	30.8	25.5	58.7	28.4
1947	19.9	13.6	8.6	9.5	13.9	22.9	32.2	33.7	28.5	32.1	35.6	39.3	24.2
1948	16.6	9.0	6.3	6.1	14.2	23.7	40.0	31.5	26.6	38.9	45.8	29.5	24.0
1949	15.0	9.4	6.9	7.2	23.5	39.1	51.0	48.3	38.3	45.0	61.3	53.5	33.2
1950	20.6	17.1	10.8	20.0	40.4	30.1	53.9	45.8	32.9	26.2	50.8	60.1	34.1
1951	19.7	43.2	23.2	19.4	25.8	30.5	33.2	24.8	28.7	24.8	28.9	28.2	27.5
1952	18.4	12.4	9.0	10.6	24.1	23.8	31.5	38.2	35.0	49.4	31.5	53.2	28.1
1953	41.4	27.0	14.0	12.5	37.6	27.6	32.6	31.4	28.1	33.6	39.6	34.3	30.0
1954	18.3	13.7	12.4	12.8	21.7	34.6	34.7	39.0	38.1	25.0	64.2	63.2	31.5
1955	64.8	18.3	12.7	10.2	15.3	17.5	28.3	48.7	31.4	28.5	77.0	44.0	33.1
1956	62.4	21.7	19.2	19.8	43.4	37.2	63.9	34.1	35.7	44.6	86.3	41.5	42.5
1957	17.5	11.6	8.2	6.9	13.1	12.7	11.9	13.9	18.2	30.6	49.0	33.0	18.9
1958	32.8	14.8	10.7	7.3	17.6	21.2	22.1	25.2	27.0	27.7	33.3	27.2	22.2
1959	12.7	8.6	6.7	9.7	17.9	17.5	16.4	18.4	32.1	33.2	54.9	89.5	26.5
1960	53.9	12.3	8.9	21.4	27.4	29.6	30.8	29.1	30.2	34.3	35.6	94.0	34.0
1961	18.4	10.1	8.2	11.9	18.5	43.1	26.8	33.5	31.5	37.7	45.0	28.4	26.1
1962	17.6	11.2	9.0	9.5	27.6	20.2	33.0	44.1	38.1	36.4	40.6	31.7	26.6
1963	37.8	19.3	12.9	27.3	39.0	41.3	47.7	45.7	49.4	37.7	43.9	25.3	35.6
1964	15.4	12.1	9.9	16.9	26.9	45.5	28.0	26.4	31.7	27.9	39.2	22.2	25.2
1965	18.2	14.1	11.9	10.7	23.7	33.1	23.2	30.7	40.3	50.8	50.1	51.4	29.9
1966	25.9	16.8	12.6	34.7	41.0	32.7	34.0	30.4	38.1	**42.3**	73.0	77.1	38.2
1967	33.9	19.9	13.4	31.2	43.0	49.5	44.8	33.9	35.3	30.5	36.1	37.1	34.1
1968	**13.8**	**13.3**	**6.9**	**7.3**	**14.4**	**15.2**	**24.9**	**35.8**	**39.6**	**31.8**	**34.0**	**17.7**	21.2
1969	**11.9**	**13.8**	**10.7**	**20.4**	**28.1**	**21.1**	**22.7**	**30.6**	**30.7**	**28.9**	**38.7**	**86.7**	28.7
1970	**46.6**	**18.0**	**13.7**	**26.7**	**36.7**	**35.1**	**37.3**	**43.2**	**45.4**	**57.2**	**48.2**	**50.4**	38.2
1971	43.6	**20.4**	**13.6**	**9.1**	**22.0**	**47.8**	46.4	38.7	33.2	31.1	39.3	**21.6**	30.6
1972	57.4	14.6	10.3	25.8	17.6	21.7	14.1	25.3	19.7	31.7	34.0	19.9	24.3
1973	11.9	8.4	5.6	5.1	16.3	28.4	28.3	32.3	28.3	36.1	60.4	46.0	25.6
1974	27.2	13.2	9.7	7.5	13.0	16.8	21.9	31.3	31.3	42.8	39.7	26.7	23.4
1975	12.1	7.5	5.1	**5.2**	**20.3**	28.8	44.8	52.0	34.7	46.6	58.0	58.0	31.1
1976	25.8	14.0	11.2	12.7	19.9	18.5	12.9	15.0	22.3	39.8	42.6	17.9	21.1
1977	15.8	11.0	8.2	8.2	14.7	17.1	22.5	28.8	26.7	56.3	45.2	33.1	24.0
1978	13.8	11.7	8.4	26.6	28.2	39.8	46.7	48.8	32.4	34.6	42.6	23.5	29.8
1979	12.1	8.9	6.9	17.8	17.1	23.7	27.3	36.7	31.7	28.5	42.8	41.1	24.6

Table 6, cont.

MEAN MONTHLY FLOW, RIO CHAGRES AT CHICO

(cubic meters per second)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1980	30.8	18.5	10.1	10.7	22.3	29.3	17.9	21.2	23.5	30.4	43.6	39.6	24.8
1981	17.7	14.4	100.6	46.3	37.2	40.0	38.9	27.9	33.1	40.7	61.6	32.1	40.9
1982	32.1	14.6	9.2	12.3	22.0	19.2	32.7	31.1	29.5	45.9	31.9	20.4	25.1
1983	8.5	6.2	5.4	36.6	22.2	19.6	21.6	27.7	34.3	40.0	76.5	25.6	27.0
1984	25.6	15.5	8.9	6.3	18.7	30.3	39.1	67.8	48.4	55.1	55.8	35.1	33.9
1985	12.9	12.9	9.4	19.5	34.2	26.2	21.2	37.8	30.6	29.8	51.9	17.7	25.3
1986	17.7	11.8	12.1	21.9	49.3	30.6	25.3	22.0	36.6	57.6	64.7	30.2	31.7
1987	12.6	8.2	28.5	55.9	36.0	36.4	44.2	51.5	39.7	60.6	29.8	13.7	34.8
1988	13.7	14.5	9.1	7.0	24.5	22.3	43.8	57.2	40.8	50.8	44.4	32.4	30.0
1989	19.9	12.1	8.6	17.2	31.9	34.4	37.8	32.3	58.5	67.4	36.2	29.7	32.2
1990	29.7	17.6	14.0	22.3	74.5	21.0	19.1	34.1	44.7	57.4	58.6	63.0	38.0
1991	19.6	12.7	15.4	11.8	31.4	21.9	22.8	23.0	33.3	33.4	57.3	33.6	26.4
1992	16.4	10.9	8.8	14.0	46.6	45.2	34.9	49.8	41.1	33.4	48.8	31.1	31.8
1993	25.3	12.2	17.0	26.8	36.3	47.8	36.1	25.8	37.7	58.1	40.7	26.5	32.5
1994	12.9	8.6	7.3	6.4	25.4	36.7	37.9	33.0	34.4	37.0	65.2	30.3	27.9
1995	15.4	8.3	4.8	6.1	19.1	36.4	43.6	41.3	28.7	31.0	38.5	50.0	26.9
1996	73.2	30.5	22.6	19.3	47.5	42.5	45.3	49.9	33.7	42.1	83.2	94.7	48.7
1997	29.0	16.8	9.1	7.8	31.3	26.8	16.2	13.5	18.4	24.6	21.9	21.6	19.8
1998	12.2	8.4	5.0	14.3	39.6	24.0	31.0	33.9	34.2	33.5	38.5	54.8	27.5
1999	30.8	24.0	14.8	17.5	25.7	36.2	45.3	53.8	44.3	40.5	52.1	126.7	42.6
2000	50.9	19.6	11.7	9.0	21.8	41.7	28.2	32.8	40.8	53.9	33.3	84.2	35.7
Mean	25.5	14.9	12.4	15.7	27.6	29.6	32.3	35.3	34.1	39.8	49.3	46.4	30.2
Maximum	73.2	43.2	100.6	55.9	74.5	49.5	64.6	67.8	58.5	75.6	177.5	126.7	48.7
Minimum	8.5	6.2	4.8	5.1	10.1	12.7	11.9	13.5	18.2	19.1	21.9	13.7	18.9
St. Dev	14.0	5.9	11.7	9.8	11.7	9.1	11.5	11.3	7.2	11.6	21.0	25.6	6.5

Table 7

NET RESERVOIR EVAPORATION
(Period 1933 to 2000)

Month	Evaporation (mm)
January	143
February	147
March	168
April	153
May	104
June	81
July	88
August	86
September	82
October	82
November	79
December	108
Annual	**1,321**

Table 8

FLOOD PEAKS FOR SELECTED RETURN PERIODS
RIO CHAGRES AT CHICO
(annual peak series)

Return Period (years)	IRHE Estimate (m^3/s)	LP III Computed [1] (m^3/s)	LP III, 5 % Upper Limit (m^3/s)
2	1,031	957	1,048
5	1,546	1,399	1,569
10	1,882	1,708	1,956
20	2,241	2,002	2,365
25	2,353	2,113	2,487
50	2,689	2,421	2,917
100	3,081	2,739	3,342
200		3,059	3,795
500		3,512	4,446
1,000	4,425		
10,000	5,938		

[1] Recommended values

Table 9

RIO CHAGRES AT CHICO
ANNUAL MAXIMUM INSTANTANEOUS FLOOD PEAKS

Year	Peak (m^3/s)	Year	Peak (m^3/s)	Year	Peak (m^3/s)
1933	793	1956	1,209	1979	640
1934	552	1957	640	1980	535
1935	1,495	1958	473	1981	1,433
1936	1,031	1959	1,872	1982	770
1937	1,541	1960	634	1983	1,453
1938	1,119	1961	1,470	1984	768
1939	617	1962	498	1985	2,059
1940	374	1963	850	1986	1,433
1941	1,736	1964	295	1987	1,323
1942	940	1965	1,153	1988	544
1943	1,116	1966	3,812	1989	1,133
1944	1,342	1967	736	1990	1,079
1945	1,008	1968	728	1991	677
1946	1,371	1969	1,832	1992	779
1947	679	1970	700	1993	946
1948	799	1971	1,212	1994	872
1949	1,246	1972	935	1995	969
1950	1,020	1973	969	1996	1,662
1951	371	1974	527	1997	1,068
1952	1,068	1975	838	1998	1,164
1953	1,314	1976	810	1999	1,357
1954	1,371	1977	722	2000	1,903
1955	935	1978	711		

Table 10

HOURLY PMP INCREMENTS
PERCENT OF 24-HOUR PMP

Hour	Increment (mm)
1	1.5
2	1.6
3	1.6
4	1.6
5	1.8
6	2.0
7	2.5
8	5.0
9	14.0
10	25.0
11	18.0
12	5.0
13	3.0
14	2.0
15	2.0
16	1.6
17	1.6
18	1.6
19	1.5
20	1.4
21	1.4
22	1.4
23	1.4
24	1.4

Table 11

ORDINATES OF THE ONE-HOUR UNIT HYDROGRAPH

Hours	Discharge (m^3/s)
0	0.0
1	3.0
2	11.1
3	31.7
4	25.1
5	13.9
6	8.9
7	6.1
8	4.8
9	3.8
10	3.0
11	2.5
12	2.1
13	1.5
14	1.2
15	0.8
16	0.4
17	0.2
18	0.1
runoff	1.04 mm

Table 12

MONTHLY SUSPENDED SEDIMENT DISCHARGE
(metric tonnes)

RIO CHAGRES AT CHICO DRAINAGE AREA 160 SQ MI (414 SQ KM)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1980													
1981	762	981	368	73,458	16,517	7,687	31,683	44,578	18,956	26,299	27,001	51,198	299,489
1982	677	126	73	226	526	280	8,607	3,724	4,326	9,457	2,207	993	31,221
1983	439	161	101	2,148	34,182	5,040	4,618	10,474	8,859	10,158	12,553	41,637	130,370
1984	271	32	30	42	9,510	11,156	6,866	27,779	8,747	42,323	14,020	2,932	123,708
1985	280	224	239	149	3,832	16,072	4,919	5,636	14,475	6,223	886	47,053	99,987
1986	216	86	1,365	3,068	55,169	3,471	2,759	4,505	11,290	10,918	24,437	1,037	118,319
1987	72	55	49	13,452	60,093	3,160	14,173	16,010	52,045	10,314	65,068	2,286	236,778
1988	48	92	40	27	7,117	1,602	12,057	7,762	3,429	5,427	8,530	1,324	47,454
1989	353	1,847	194	377	3,517	6,146	9,140	2,769	2,854	20,496	9,413	2,894	59,999
1990	550	302	275	1,520	41,260	1,223	1,964	5,541	5,885	12,230	11,296	18,557	100,601
1991	168	155	3,270	1,542	7,168	1,892	2,948	1,885	11,397	4,639	24,619	790	60,474
1992	132	227	82	1,247	5,033	9,745	5,090	16,957	9,539	2,486	14,108	374	65,022
1993	1,388	57	3,067	6,365	6,094	18,594	2,826	1,745	5,600	13,872	1,642	591	61,842
1994	126	155	183	53	4,713	9,303	7,583	3,051	3,100	6,391	16,728	716	52,103
1995	273	12	0	439	24,706	12,492	12,881	7,547	1,994	2,790	7,227	23,238	93,599
1996	13,781	357	1,078	1,210	11,776	3,756	2,371	8,819	3,234	9,252	119,678	23,109	198,423
1997	69	43	2	208	19,841	1,894	762	1,825	1,046	1,394	1,033	768	28,884
1998													
Mean	**1,153**	**289**	**613**	**6,208**	**18,297**	**6,677**	**7,720**	**10,036**	**9,810**	**11,451**	**21,203**	**12,912**	**106,369**

RIO PEQUENI AT CANDELARIA DRAINAGE AREA 52 SQ MI (135 SQ KM)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1980													
1981	1,548	461	512	289,267	40,078	10,710	35,101	12,365	5,818	3,981	3,463	14,661	417,964
1982	377	107	71	119	234	198	733	5,522	4,780	37,676	1,653	343	51,812
1983	146	65	56	10,652	26,589	26,012	7,267	3,874	5,874	11,140	13,975	124,654	230,302
1984	159	144	52	21	930	4,593	3,264	6,249	1,716	2,404	3,562	1,575	24,667
1985	74	16	64	127	3,259	5,046	1,388	294	3,709	2,161	1,581	8,908	26,626
1986	280	59	156	3,558	33,621	6,406	5,652	4,003	10,318	1,111	6,242	250	71,656
1987	49	53	17	4,095	38,666	17,912	5,839	12,933	12,806	6,164	13,175	2,228	113,936
1988	46	118	71	74	2,357	1,758	17,269	9,568	800	7,790	1,828	1,456	43,134
1989	237	1,881	49	25	5,251	5,988	14,774	5,745	2,693	19,416	11,614	8,470	76,142
1990	668	38	103	202	7,188	1,318	1,834	8,067	2,994	7,788	3,397	1,901	35,498
1991	95	38	473	464	6,037	1,331	1,069	3,340	18,429	1,432	17,751	479	50,938
1992	99	31	65	1,894	11,770	1,956	3,067	10,770	3,731	539	6,084	2,196	42,201
1993	824	26	393	10,433	1,768	3,193	1,173	833	3,236	8,436	1,719	5,651	37,684
1994	74	51	77	43	2,386	8,828	1,270	9,706	972	2,510	7,900	186	34,002
1995	448	26	17	838	2,491	1,730	1,835	698	683	1,020	2,421	21,627	33,833
1996	10,534	52	1,325	738	6,652	4,434	1,123	2,816	2,035	1,248	65,551	4,510	101,018
1997	68	417	15	122	5,901	1,754	1,332	4,804	2,177	1,543	440	24	18,597
1998													
Mean	**925**	**211**	**207**	**18,981**	**11,481**	**6,069**	**6,117**	**5,976**	**4,869**	**6,845**	**9,550**	**11,713**	**82,942**

Table 12, cont.

MONTHLY SUSPENDED SEDIMENT DISCHARGE
(metric tonnes)

RIO BOQUERON AT PELUCA DRAINAGE AREA 35 SQ MI (91 SQ KM)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1980													
1981	948	143	722	66,910	15,804	18,587	46,485	9,464	3,422	7,204	51,819	111,843	333,351
1982	1,437	2,018	437	2,954	2,310	3,948	7,082	23,462	8,835	25,567	2,345	552	80,947
1983	192	25	23	5,080	9,711	6,599	13,583	8,298	9,104	11,826	19,483	136,506	220,427
1984	351	61	29	17	1,866	31,857	8,719	11,414	1,696	2,080	9,304	2,909	70,301
1985	28	7	29	26	1,278	7,986	4,279	1,227	3,048	3,104	2,417	5,660	29,087
1986	161	71	32	4,610	8,963	3,793	1,889	1,879	11,684	1,309	5,081	118	39,589
1987	21	79	25	14,670	51,760	5,174	2,523	6,099	8,830	3,611	5,771	831	99,393
1988	45	127	49	41	2,465	742	18,947	8,217	891	8,932	1,598	1,679	43,733
1989	84	453	17	5	6,337	2,430	5,447	4,517	1,090	6,606	4,348	2,741	34,075
1990	99	69	205	171	5,346	892	1,171	5,573	2,067	4,021	2,459	883	22,956
1991	87	15	493	441	8,881	666	606	1,434	13,660	563	14,593	410	41,849
1992	3	3	3	1,463	6,890	1,421	2,049	13,484	2,731	712	5,175	1,715	35,648
1993	547	1	211	7,176	708	3,924	3,295	2,098	3,395	5,144	2,645	3,688	32,831
1994	14	6	45	4	2,514	3,645	1,406	6,267	1,633	599	8,385	825	25,342
1995	1,284	0	0	173	519	3,544	4,103	166	1,255	403	3,653	19,395	34,495
1996	5,324	123	819	1,014	7,599	1,058	1,035	1,764	1,262	1,795	73,898	20,589	116,280
1997	19	365	7	3	5,422	5,024	865	3,168	1,792	1,660	198	2	18,523
1998													
Mean	**626**	**210**	**185**	**6,162**	**8,140**	**5,958**	**7,264**	**6,384**	**4,494**	**5,008**	**12,539**	**18,256**	**75,225**

RIO GATUN AT CIENTO DRAINAGE AREA 45 SQ MI (116.6 SQ KM)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1980													
1981													
1982													
1983													
1984													
1985													
1986													
1987	23	25	13	14,193	2,666	906	1,466	2,251	5,317	24,423	20,392	1,905	73,580
1988	39	20	11	11	604	316	8,358	10,995	6,246	32,806	3,526	2,642	65,573
1989	41	124	15	17	845	430	3,810	1,695	1,206	4,737	17,508	2,224	32,653
1990	67	6	19	6	1,808	309	839	4,049	3,612	6,541	2,638	809	20,704
1991	15	4	15	81	1,866	116	479	554	4,053	2,287	12,454	304	22,226
1992	22	26	13	138	7,458	2,298	743	4,855	3,821	2,281	1,387	1,177	24,218
1993	329	11	80	652	601	1,339	3,624	968	4,091	4,245	4,103	484	20,526
1994	688	0	4	3	188	2,061	1,052	1,040	425	2,270	7,502	68	15,300
1995	344	23	5	21	333	1,783	1,762	2,803	1,007	1,502	6,872	3,863	20,318
1996	7,423	22	43	151	2,377	2,096	1,087	1,697	901	1,296	39,636	4,237	60,966
1997	46	32	6	9	790	874	268	95	1,562	763	2,084	61	6,589
1998													
Mean	**822**	**26**	**20**	**1,389**	**1,776**	**1,139**	**2,135**	**2,818**	**2,931**	**7,559**	**10,737**	**1,616**	**32,968**

Table 12, cont.

MONTHLY SUSPENDED SEDIMENT DISCHARGE
(metric tonnes)

RIO TRINIDAD AT CHORRO DRAINAGE AREA 67 SQ MI (173.5 SQ Km)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1980													
1981													
1982													
1983													
1984													
1985													
1986													
1987	16	25	28	99	696	502	1,085	2,774	4,042	5,328	793	838	16,226
1988	135	6	1	77	2,221	924	1,366	4,756	4,639	2,916	1,707	1,722	20,470
1989	199	37	19	8	968	727	2,053	2,935	3,047	2,529	1,487	3,377	17,387
1990	180	21	5	5	450	1,829	2,492	1,667	9,023	7,462	4,318	896	28,347
1991	32	6	29	6	767	646	197	391	1,386	2,246	1,689	795	8,189
1992	14	5	2	91	501	1,794	352	1,232	3,741	1,343	2,009	462	11,545
1993	41	12	11	184	714	2,243	467	563	3,307	2,163	4,234	941	14,879
1994	3	0	22	10	790	505	226	176	3,110	3,165	1,715	182	9,902
1995	9	1	0	20	1,179	2,345	1,939	3,320	2,832	5,818	2,342	470	20,274
1996	13,475	63	134	13	2,896	5,388	3,352	5,367	4,534	6,586	3,374	1,997	47,178
1997	416	1	0	22	13	389	67	28	285	1,557	840	7	3,625
1998													
Mean	**1,320**	**16**	**23**	**49**	**1,018**	**1,572**	**1,236**	**2,110**	**3,631**	**3,737**	**2,228**	**1,062**	**18,002**

RIO CIRI GRANDE AT LOS CANONES DRAINAGE AREA 72 SQ MI (186.5 SQ KM)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1980													
1981													
1982													
1983													
1984													
1985													
1986													
1987	47	32	12	57	2,812	1,094	1,437	4,412	6,187	8,753	3,255	3,758	31,854
1988	49	22	7	29	728	1,551	1,469	4,645	4,173	5,040	3,939	1,801	23,451
1989	364	87	20	5	1,135	844	2,180	4,607	4,737	9,667	2,846	2,095	28,588
1990	596	12	26	7	1,042	1,062	1,494	1,074	7,588	5,774	2,740	2,929	24,345
1991	109	48	184	31	591	537	158	428	1,836	3,041	1,455	876	9,293
1992	46	13	6	286	1,047	1,267	1,268	4,005	3,686	1,974	2,977	357	16,932
1993	154	46	39	272	485	2,461	467	582	3,883	3,449	8,735	1,634	22,206
1994	15	8	39	33	859	1,348	391	141	1,957	3,960	3,224	224	12,198
1995	27	0	18	163	4,297	3,246	2,299	3,217	3,896	4,584	2,339	1,892	25,980
1996	93,184	150	216	31	3,695	6,064	9,620	14,255	8,190	13,264	7,511	7,214	163,392
1997	27	33	0	44	119	533	253	94	1,165	1,551	2,172	67	6,057
1998													
Mean	**8,602**	**41**	**52**	**87**	**1,528**	**1,819**	**1,912**	**3,405**	**4,300**	**5,551**	**3,745**	**2,077**	**33,118**

Table 13

UPPER CHAGRES RESERVOIR
LOSS IN LIVE STORAGE BETWEEN 180 AND 200 METERS

Period of Operation (years)	Live Storage (MCM)	Loss in Storage (MCM)	Percent Loss
0	450	0	
50	439	11	2.4
100	427	22	4.8

Table 14

ORDINATES OF FLOOD HYDROGRAPHS
RIO CHAGRES AT DAMSITE

2-Year Flood Peak = 957 cms		5-Year Flood Peak = 1399 cms		10-Year Flood Peak = 1708 cms		20-Year Flood Peak = 2002 cms		25-Year Flood Peak = 2113 cms		50 -Year Flood Peak = 2421 cms		100-Year Flood Peak = 2739 cms	
Time (hr)	Discharge (cms)	Time (hr)	Discharge (cms)	Time (hr)	Discharge (cms)	Time (hr)	Discharge (cms)	Time (hr)	Discharge (cms)	Time (hr)	Discharge (cms)	Time (hr)	Discharge (cms)
1	68	1	99	1	121	1	142	1	149	1	171	1	193
2	122	2	178	2	218	2	255	2	269	2	308	2	348
3	338	3	495	3	604	3	708	3	747	3	856	3	968
4	745	4	1089	4	1329	4	1558	4	1644	4	1884	4	2131
5	957	5	1399	5	1708	5	2002	5	2113	5	2421	5	2739
6	880	6	1286	6	1571	6	1841	6	1942	6	2226	6	2518
7	677	7	990	7	1208	7	1416	7	1494	7	1712	7	1937
8	474	8	693	8	845	8	991	8	1046	8	1199	8	1356
9	338	9	495	9	604	9	708	9	747	9	856	9	968
10	271	10	396	10	483	10	566	10	598	10	685	10	775
11	203	11	297	11	363	11	425	11	448	11	514	11	582
12	163	12	238	12	290	12	340	12	359	12	411	12	465
13	149	13	218	13	266	13	312	13	329	13	377	13	427
14	135	14	198	14	241	14	283	14	299	14	342	14	387
15	122	15	178	15	218	15	255	15	269	15	308	15	348
16	110	16	161	16	196	16	230	16	242	16	278	16	315
17	103	17	151	17	184	17	216	17	228	17	262	17	296
18	97	18	142	18	173	18	203	18	214	18	246	18	278
19	91	19	133	19	162	19	190	19	200	19	230	19	260
20	85	20	124	20	151	20	177	20	186	20	214	20	242
21	78	21	114	21	139	21	163	21	172	21	197	21	223
22	72	22	105	22	128	22	150	22	158	22	181	22	205
23	65	23	96	23	117	23	137	23	144	23	165	23	187
24	59	24	86	24	105	24	123	24	130	24	149	24	169
25	53	25	77	25	94	25	110	25	116	25	133	25	150
26	46	26	68	26	83	26	97	26	102	26	117	26	132

Note: the flood hydrographs for various return periods were generated using ratios of peaks.

Table 15

PRE AND POST PROJECT FLOOD PEAKS

Return Period (years)	Pre-Project Flood Peak (m^3/s)	Post Project Flood Peak (m^3/s)
2	957	459
5	1,399	703
10	1,708	924
20	2,002	1,121
25	2,113	1,194
50	2,421	1,397
100	2,739	1,604

Table 16

HYDRAULIC CHARACTERISTICS OF REPRESENTATIVE CROSS SECTION

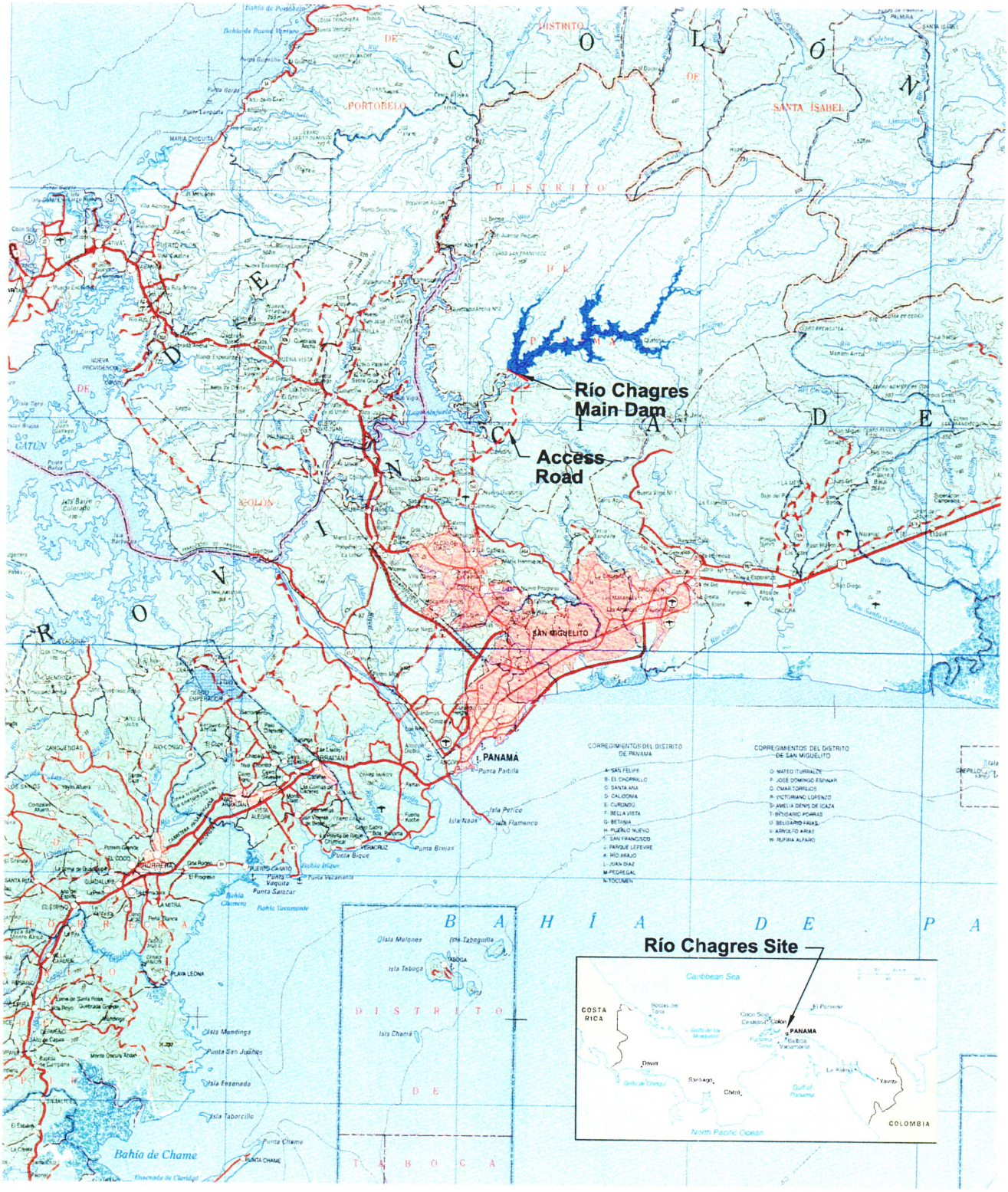
Discharge (cms)	Water Surface Elevation (m)	Top Width (m)	Maximum Depth (m)	Average Depth (m)	Area (sq m)	Mean Velocity (m/s)
200	83.48	42.20	2.78	2.10	88.70	2.25
400	84.56	48.57	3.86	2.83	137.26	2.91
700	85.65	56.89	4.95	3.43	195.15	3.59
950	86.37	59.78	5.67	3.96	236.71	4.01
1400	87.43	63.63	6.73	4.75	302.36	4.63
1700	88.01	64.90	7.31	5.23	339.49	5.01
2000	88.53	66.04	7.83	5.66	373.53	5.35
2115	88.72	66.45	8.02	5.81	385.82	5.48
2420	89.19	67.47	8.49	6.19	417.59	5.80
2740	89.64	68.46	8.94	6.55	448.41	6.11
3000	89.99	69.21	9.29	6.83	472.79	6.35

Table 17

ARMORING SIZES – RIO CHAGRES DOWNSTREAM FROM DAM

	Armoring Size (mm) for Indicated Flood					
Method of Estimation	**2-Yr**	**5-Yr**	**10-Yr**	**25-Yr**	**50-Yr**	**100-Yr**
Pre-Project						
Meyer-Peter, Muller	99	118	130	145	154	163
Shield's	120	144	158	176	188	198
Post-Project						
Meyer-Peter, Muller	50	60	67	75	80	85
Shield's	60	76	84	94	100	105

EXHIBITS



5 0 5 10 15 20 km

GRAPHIC SCALE

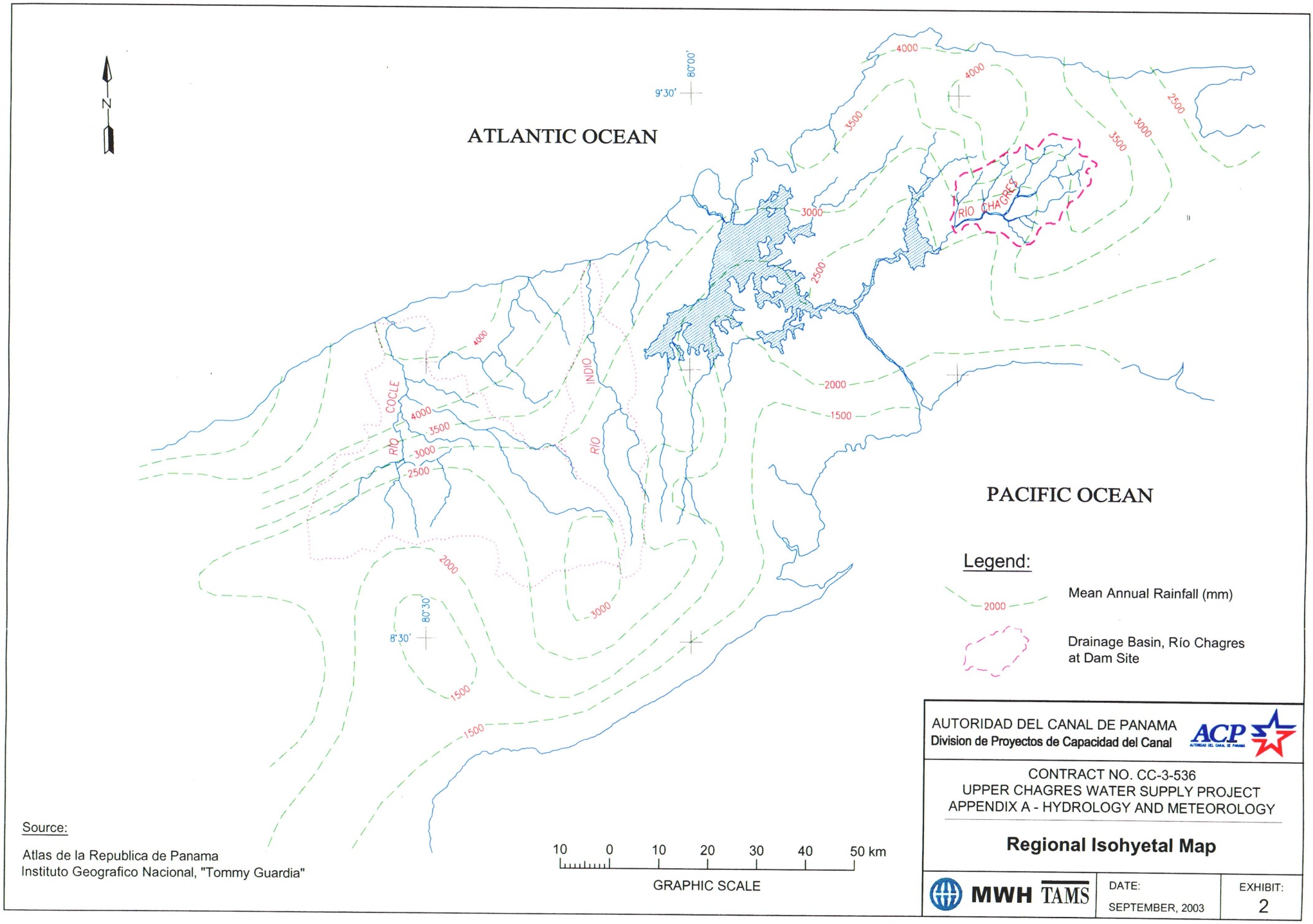
AUTORIDAD DEL CANAL DE PANAMA
Division de Proyectos de Capacidad del Canal

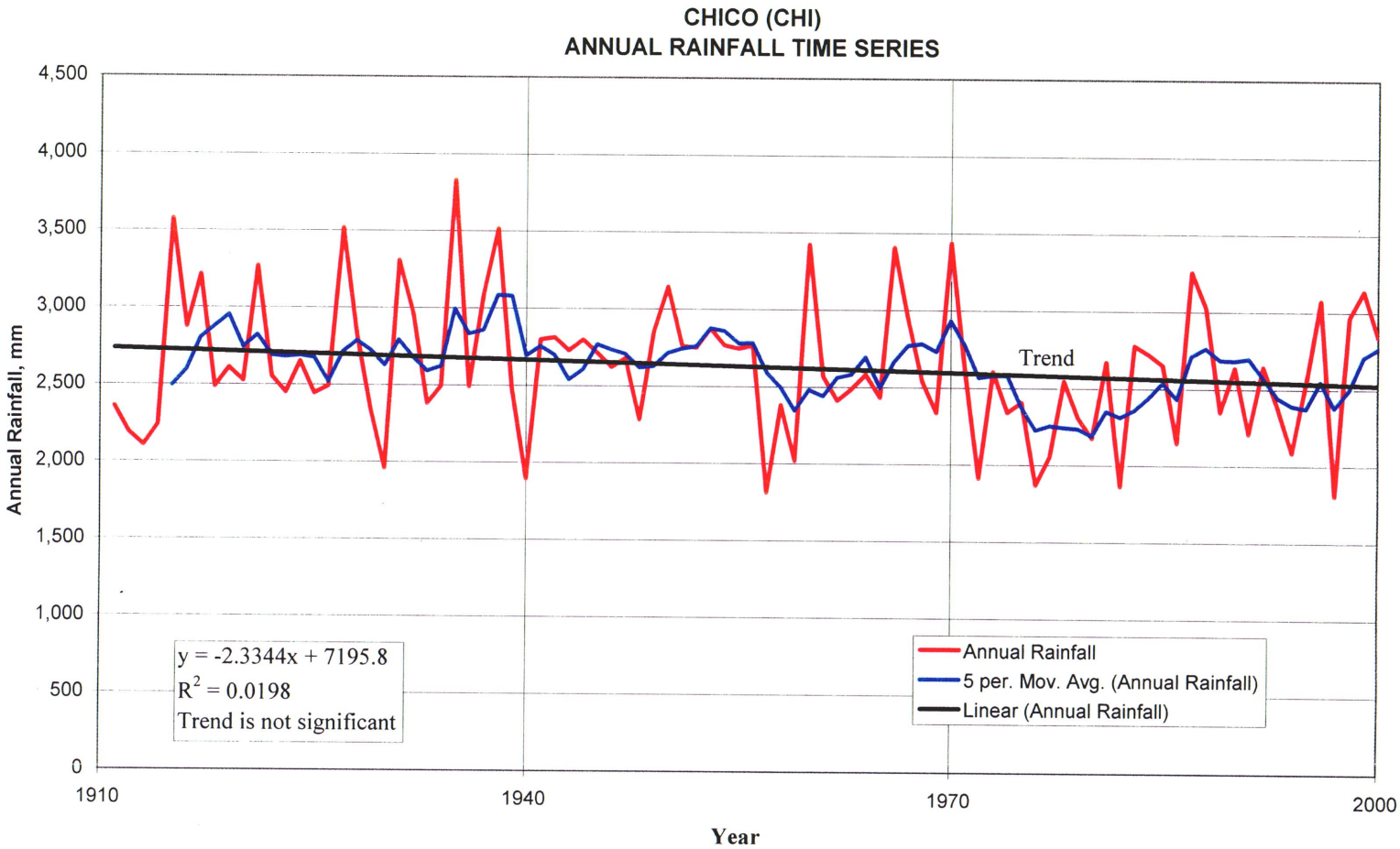
CONTRACT NO. CC-3-536
UPPER CHAGRES WATER SUPPLY PROJECT
APPENDIX A - HYDROLOGY AND METEOROLOGY

Location Map

MWH TAMS

DATE:	EXHIBIT:
SEPTEMBER, 2003	1


N
ATLANTIC OCEAN
PACIFIC OCEAN
9°30'
80°00'
8°30'
80°30'
RÍO CHAGRES
RÍO COCLE
RÍO INDIO
4000
3500
3000
2500
2000
1500
Legend:
Mean Annual Rainfall (mm)
Drainage Basin, Río Chagres at Dam Site
10 0 10 20 30 40 50 km
GRAPHIC SCALE
Source:
Atlas de la Republica de Panama
Instituto Geografico Nacional, "Tommy Guardia"
AUTORIDAD DEL CANAL DE PANAMA
Division de Proyectos de Capacidad del Canal
ACP
CONTRACT NO. CC-3-536
UPPER CHAGRES WATER SUPPLY PROJECT
APPENDIX A - HYDROLOGY AND METEOROLOGY
Regional Isohyetal Map
MWH TAMS
DATE:
SEPTEMBER, 2003
EXHIBIT:
2



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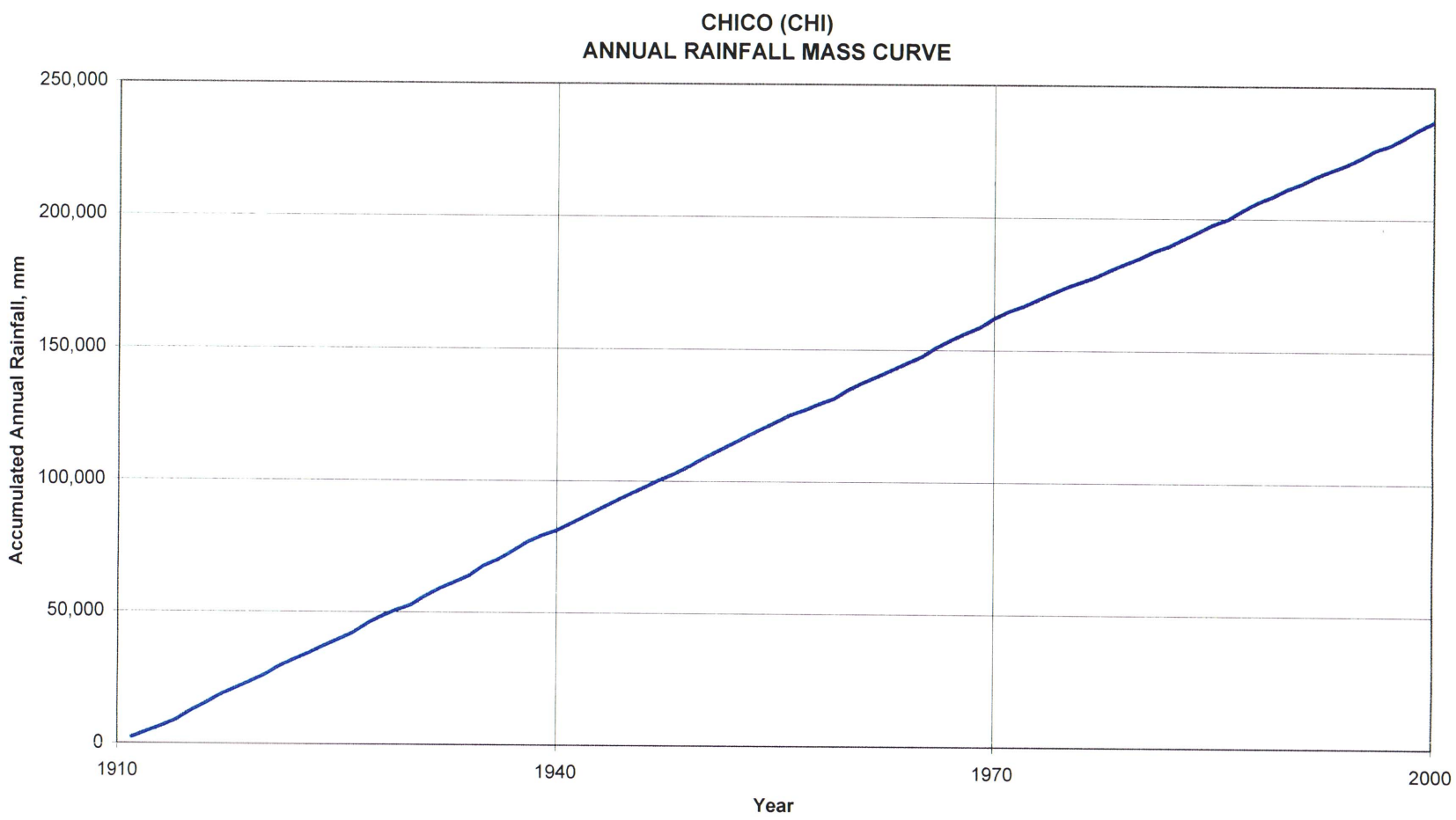
CONTRACT NO. CC-3-536
UPPER CHAGRES WATER SUPPLY PROJECT
APPENDIX A - HYDROLOGY AND METEOROLOGY

Annual Rainfall Time Series
Chico

MWH TAMS

DATE: SEPTEMBER, 2003

EXHIBIT: 3



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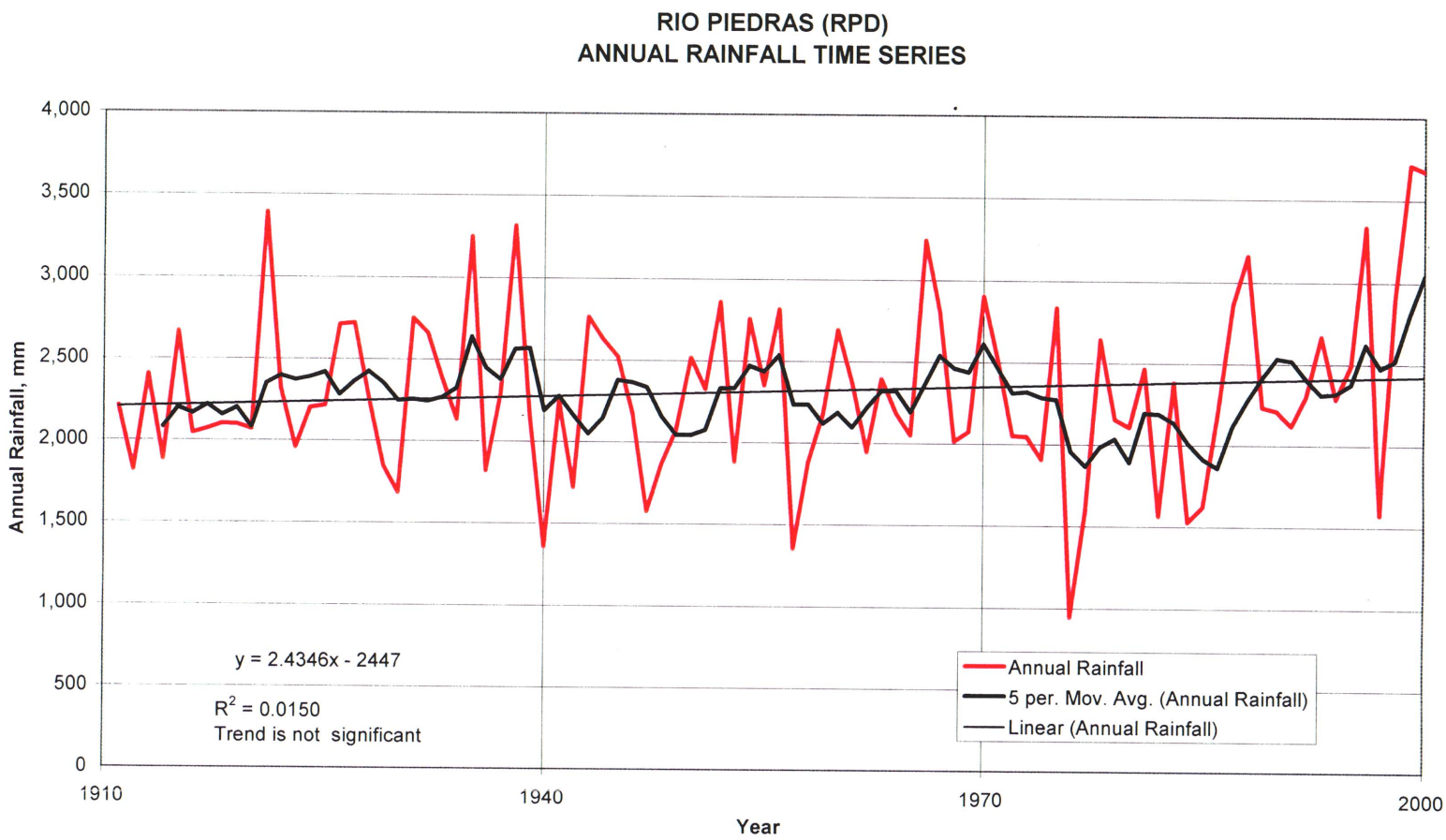
CONTRACT NO. CC-3-536
UPPER CHAGRES WATER SUPPLY PROJECT
APPENDIX A - HYDROLOGY AND METEOROLOGY

Annual Rainfall Mass Curve
Chico

MWH TAMS

DATE: SEPTEMBER, 2003

EXHIBIT: 4



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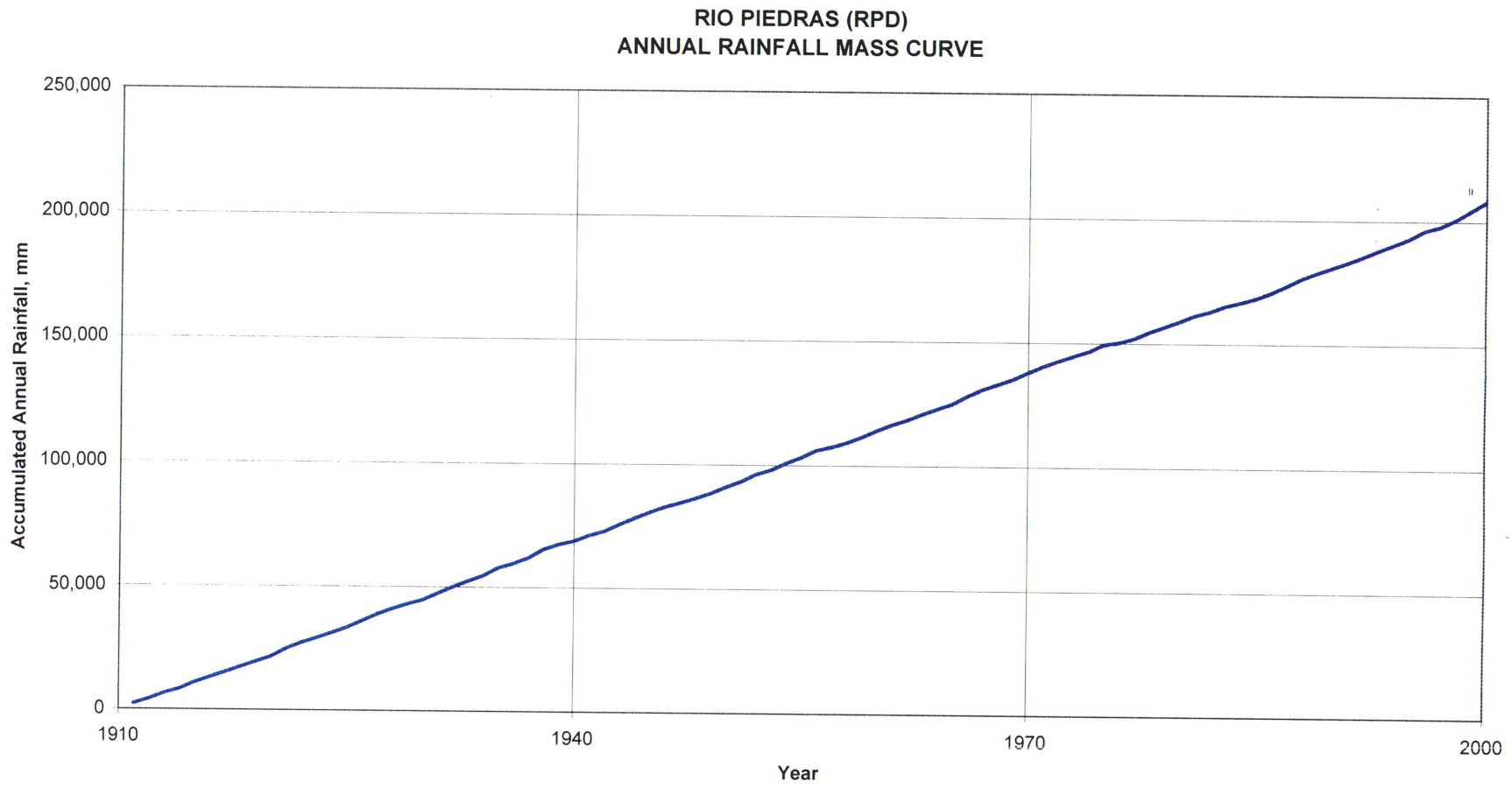
CONTRACT NO. CC-3-536
UPPER CHAGRES WATER SUPPLY PROJECT
APPENDIX A - HYDROLOGY AND METEOROLOGY

Annual Rainfall Time Series
Río Piedras

MWH TAMS

DATE: SEPTEMBER, 2003

EXHIBIT: 5



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Division de Proyectos de Capacidad del Canal

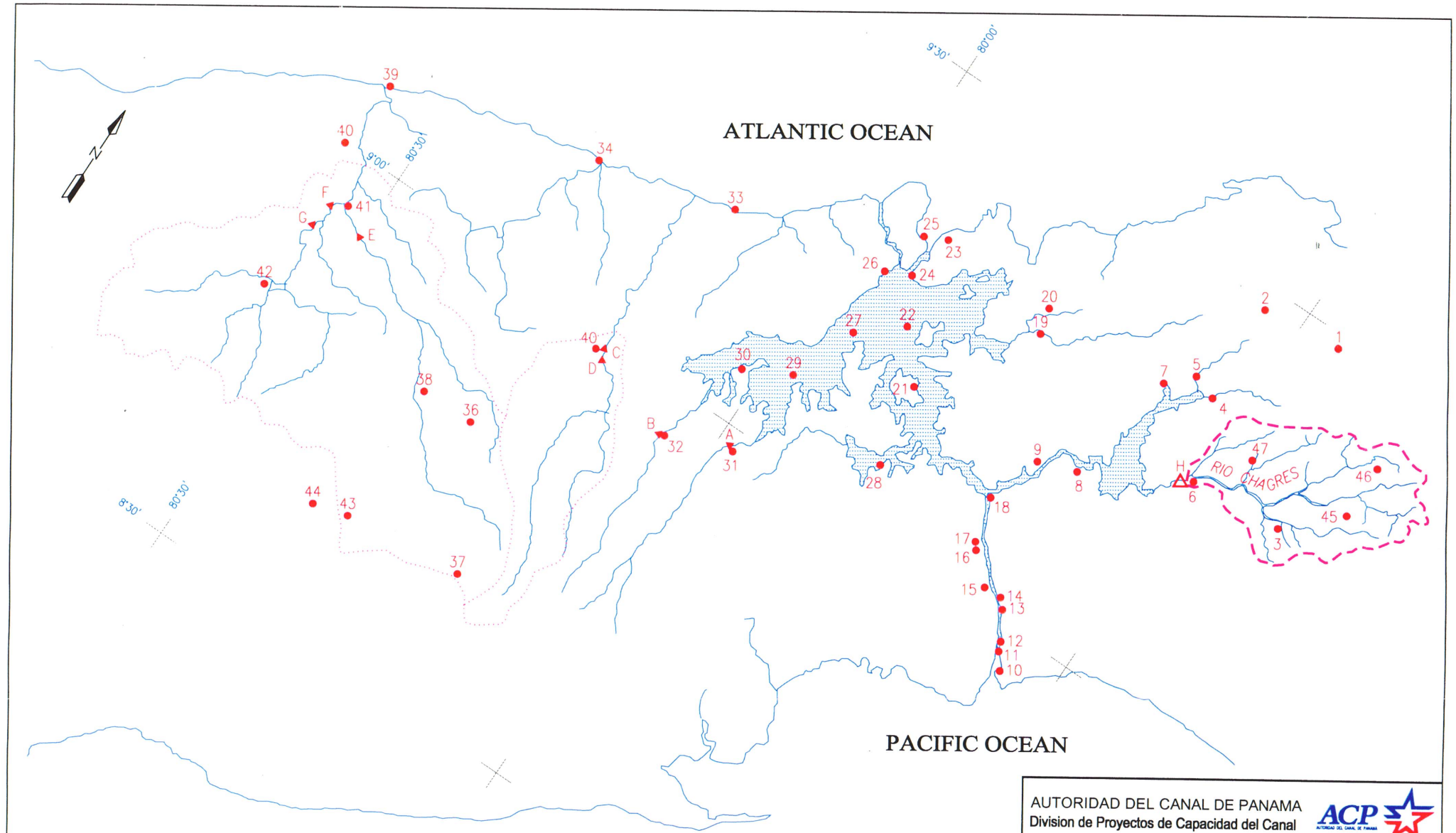
CONTRACT NO. CC-3-536
UPPER CHAGRES WATER SUPPLY PROJECT
APPENDIX A - HYDROLOGY AND METEOROLOGY

Annual Rainfall Mass Curve
Río Piedras

MWH TAMS

DATE: SEPTEMBER, 2003

EXHIBIT: 6



Note:

See Table 3 for Names of Stations

10 0 10 20 30 40 50 km

GRAPHIC SCALE

AUTORIDAD DEL CANAL DE PANAMA
Division de Proyectos de Capacidad del Canal

ACP

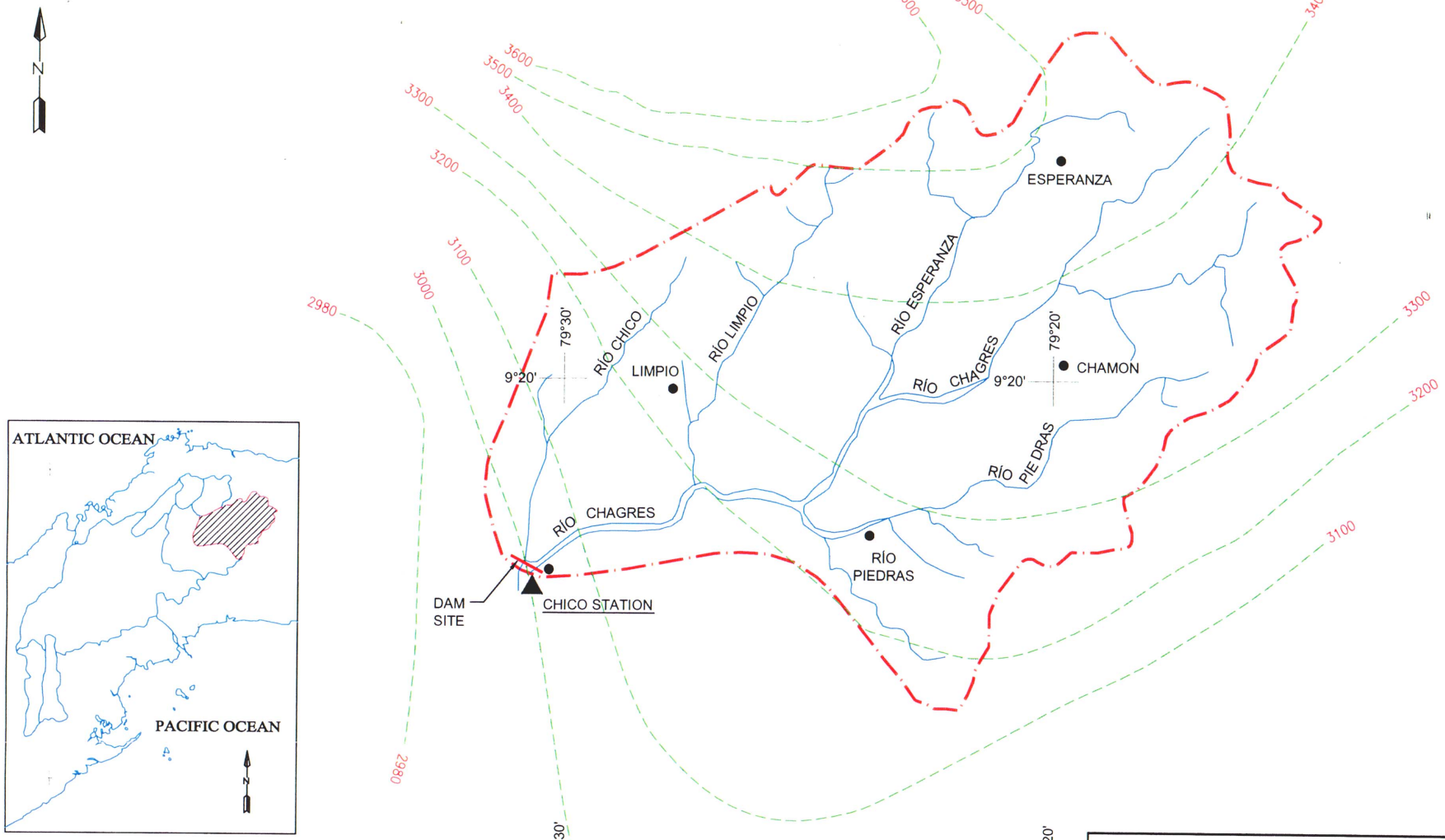
CONTRACT NO. CC-3-536
UPPER CHAGRES WATER SUPPLY PROJECT
APPENDIX A - HYDROLOGY AND METEOROLOGY

Location of Stream Gaging and Rainfall Stations

MWH TAMS

DATE: SEPTEMBER, 2003

EXHIBIT: 7



LEGEND:

- Mean annual rainfall, mm
- ▲ Stream gauging station
- ● Rainfall station

Source: ACP

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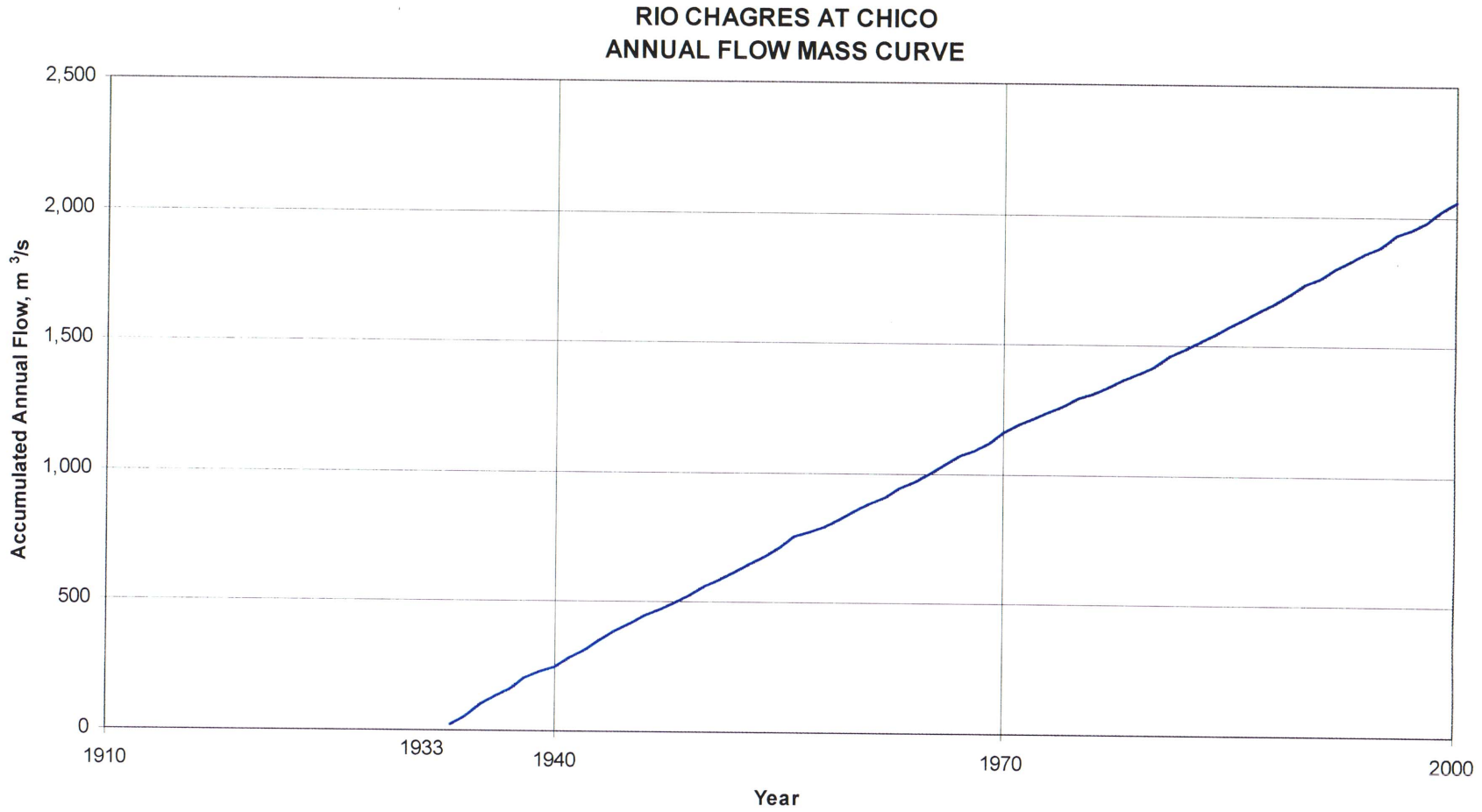
UPPER CHAGRES WATER SUPPLY PROJECT
APPENDIX A - HYDROLOGY AND METEOROLOGY

Annual Rainfall Pattern on Río Chagres Watershed

MWH TAMS

DATE: SEPTEMBER, 2003

EXHIBIT: 8



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Division de Proyectos de Capacidad del Canal

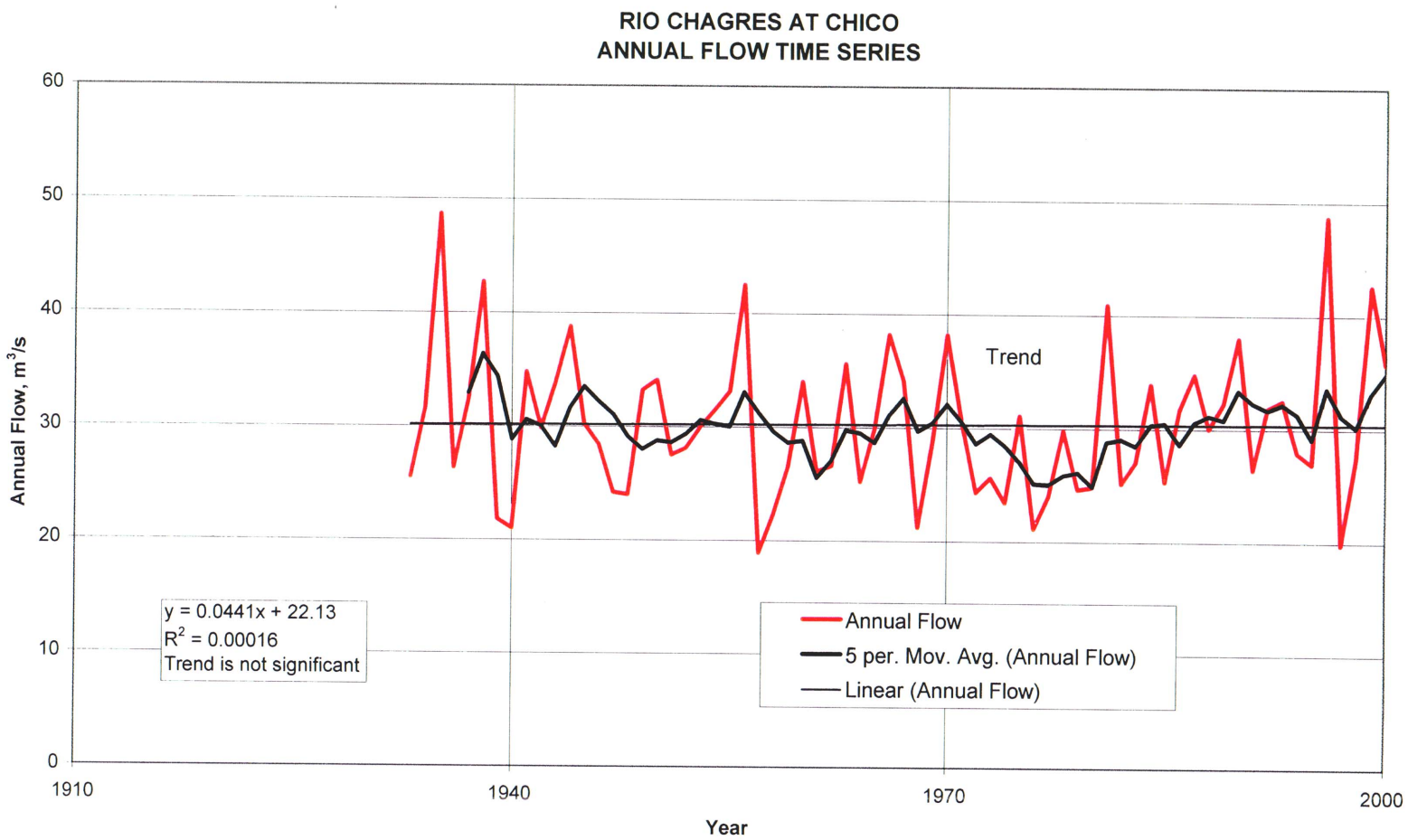
CONTRACT NO. CC-3-536
UPPER CHAGRES WATER SUPPLY PROJECT
APPENDIX A - HYDROLOGY AND METEOROLOGY

Río Chagres at Chico
Annual Flows Mass Curve

MWH TAMS

DATE: SEPTEMBER, 2003

EXHIBIT: 9



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UPPER CHAGRES WATER SUPPLY PROJECT
APPENDIX A - HYDROLOGY AND METEOROLOGY

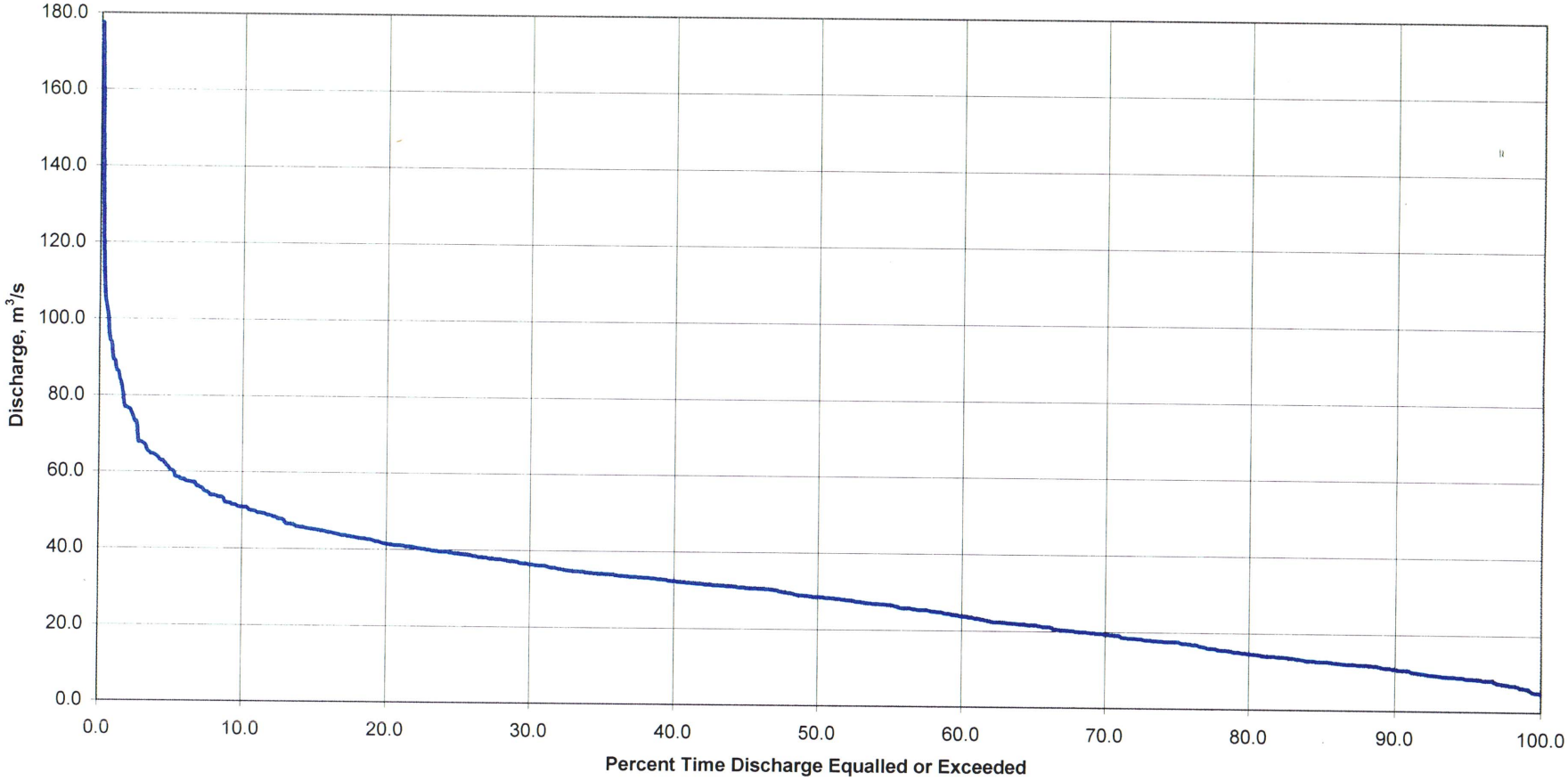
Río Chagres at Chico
Annual Flows Time Series

MWH TAMS

DATE: SEPTEMBER, 2003

EXHIBIT: 10

ANNUAL FLOW DURATION CURVE BASED ON MONTHLY FLOWS - RIO CHAGRES AT CHICO



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Division de Proyectos de Capacidad del Canal

CONTRACT NO. CC-3-536
UPPER CHAGRES WATER SUPPLY PROJECT
APPENDIX A - HYDROLOGY AND METEOROLOGY

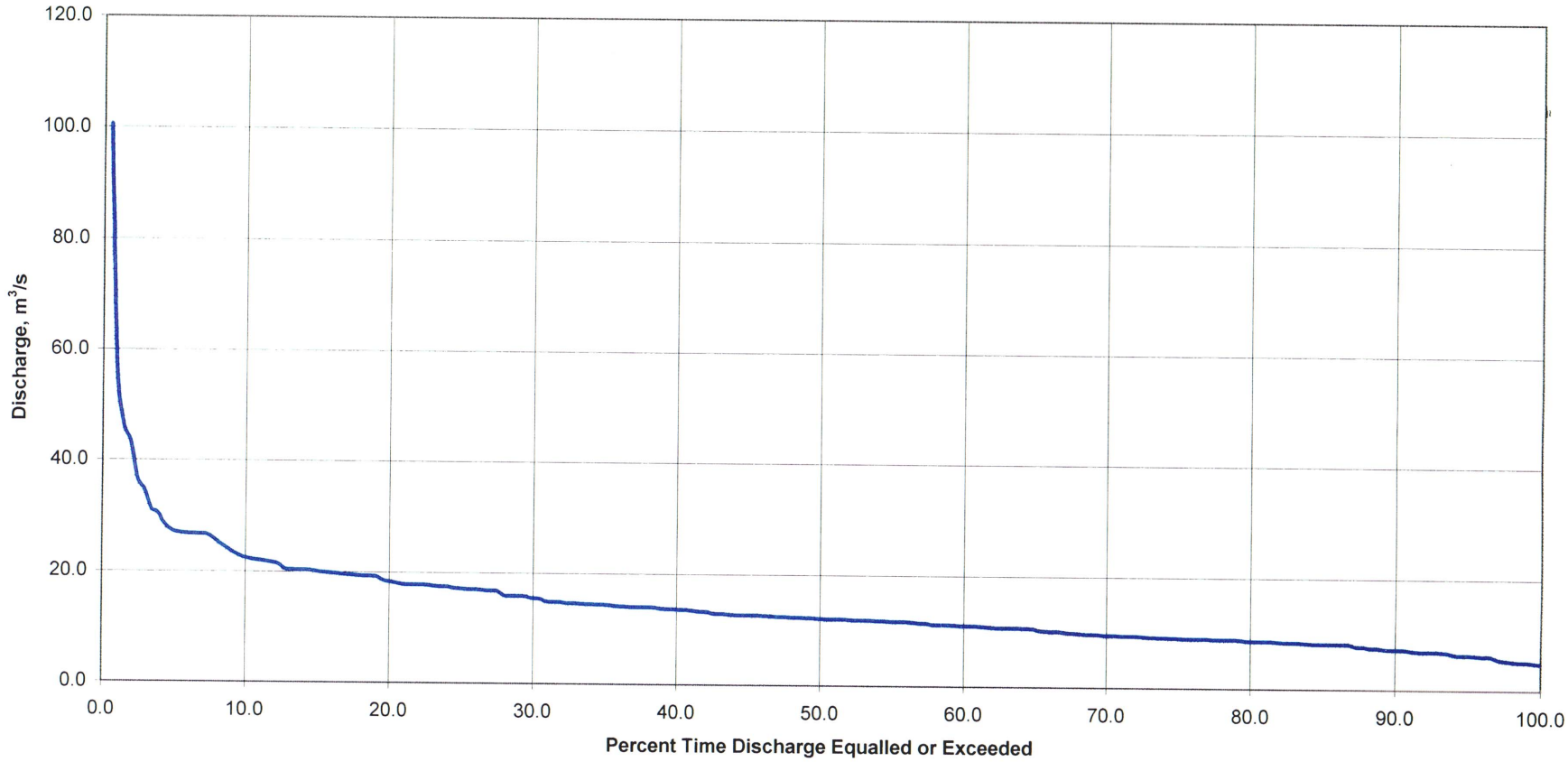
Annual Flow Duration Curve based on Monthly Flows
Río Chagres at Chico (Upper Chagres Damsite)

MWH TAMS

DATE: SEPTEMBER, 2003

EXHIBIT: 11

FLOW DURATION CURVE FOR DRY PERIOD FEBRUARY TO APRIL BASED ON MONTHLY FLOWS - RIO CHAGRES AT CHICO



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Division de Proyectos de Capacidad del Canal

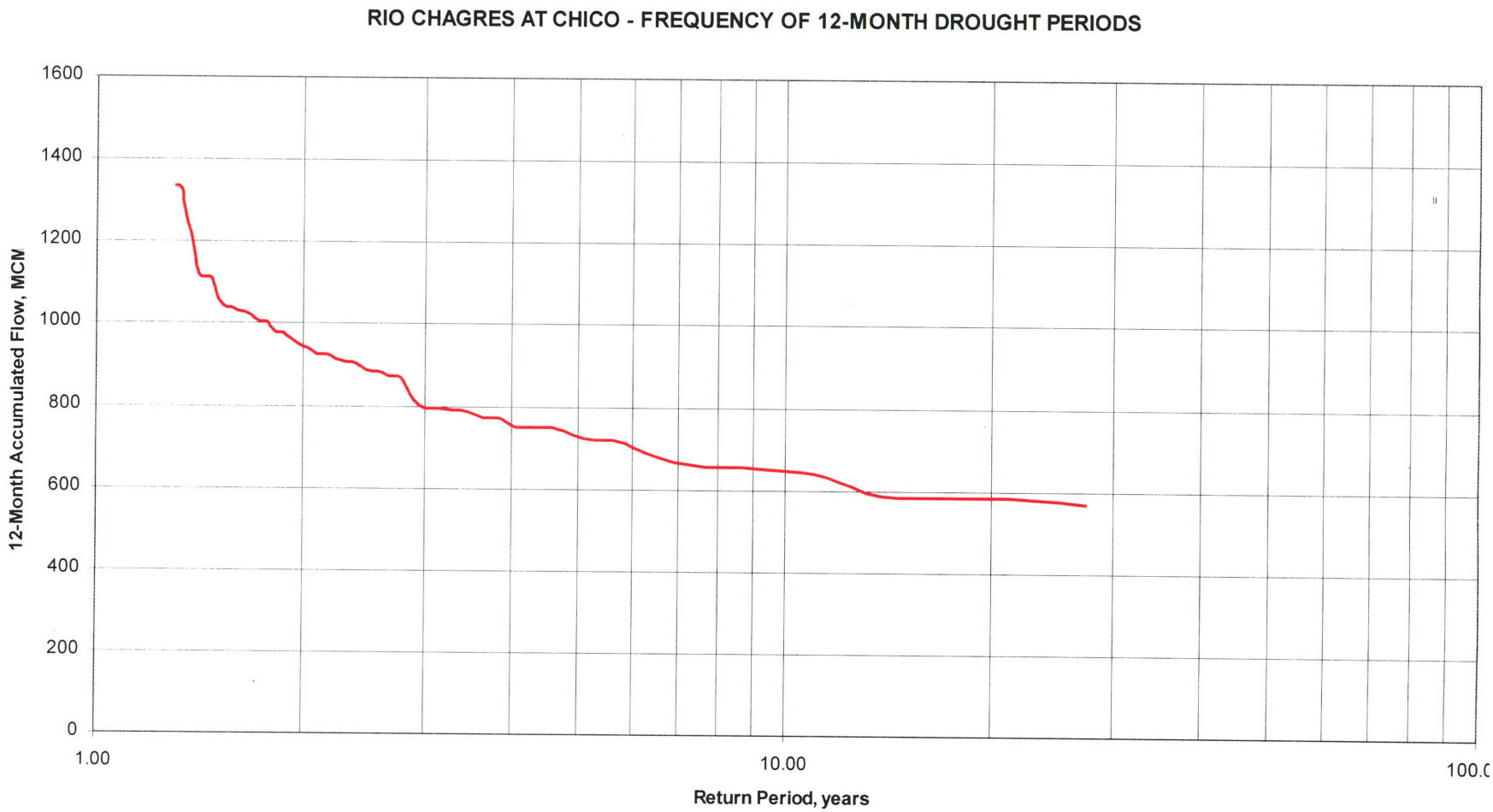
CONTRACT NO. CC-3-536
UPPER CHAGRES WATER SUPPLY PROJECT
APPENDIX A - HYDROLOGY AND METEOROLOGY

Flow Duration Curve for Dry Period, February to April, based on Monthly Flows Río Chagres at Chico

MWH TAMS

DATE: SEPTEMBER, 2003

EXHIBIT: 12



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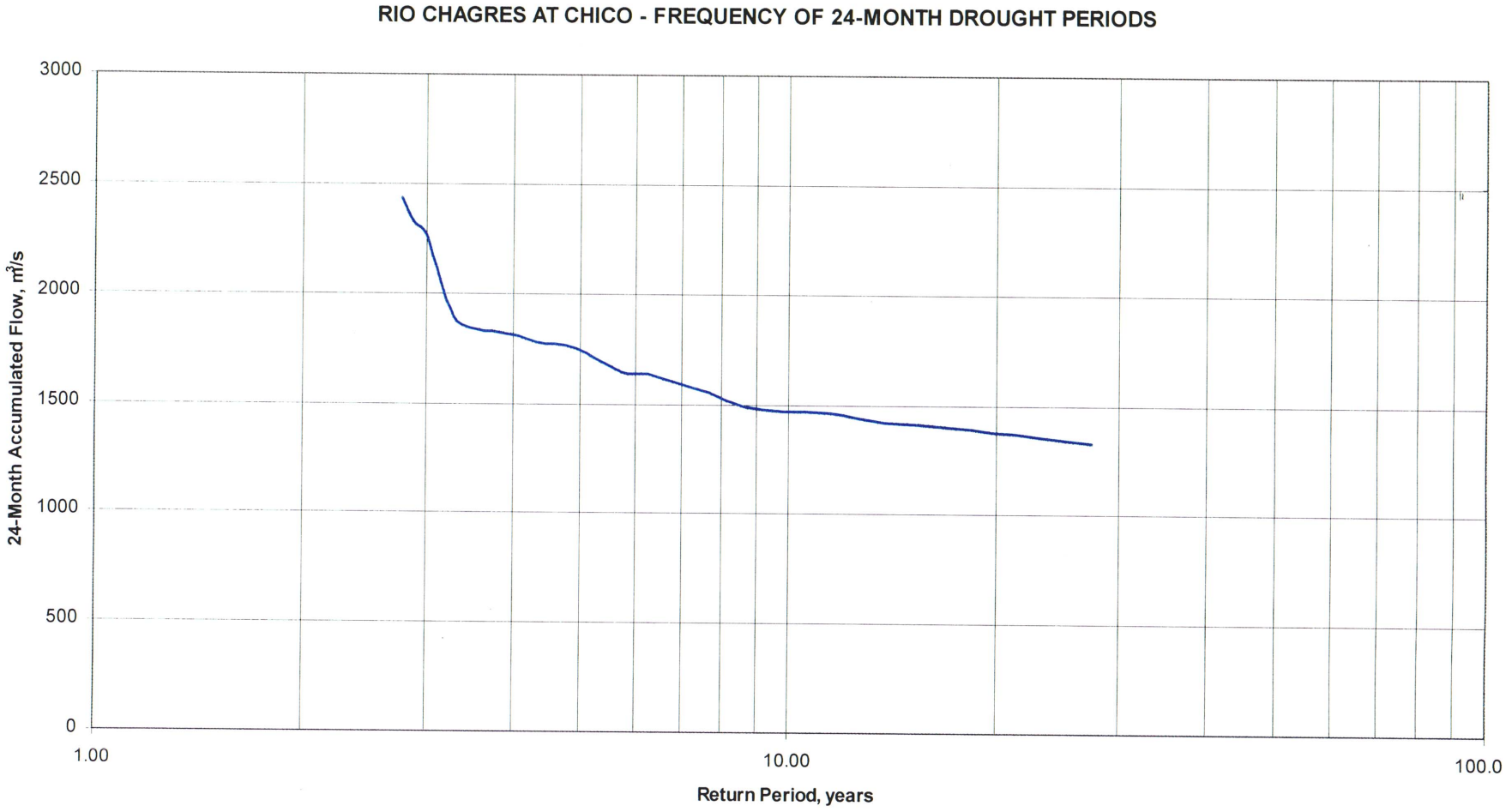
CONTRACT NO. CC-3-536
UPPER CHAGRES WATER SUPPLY PROJECT
APPENDIX A - HYDROLOGY AND METEOROLOGY

Río Chagres at Chico
Frequency of 12-Month Drought Periods

MWH TAMS

DATE: SEPTEMBER, 2003

EXHIBIT: 13



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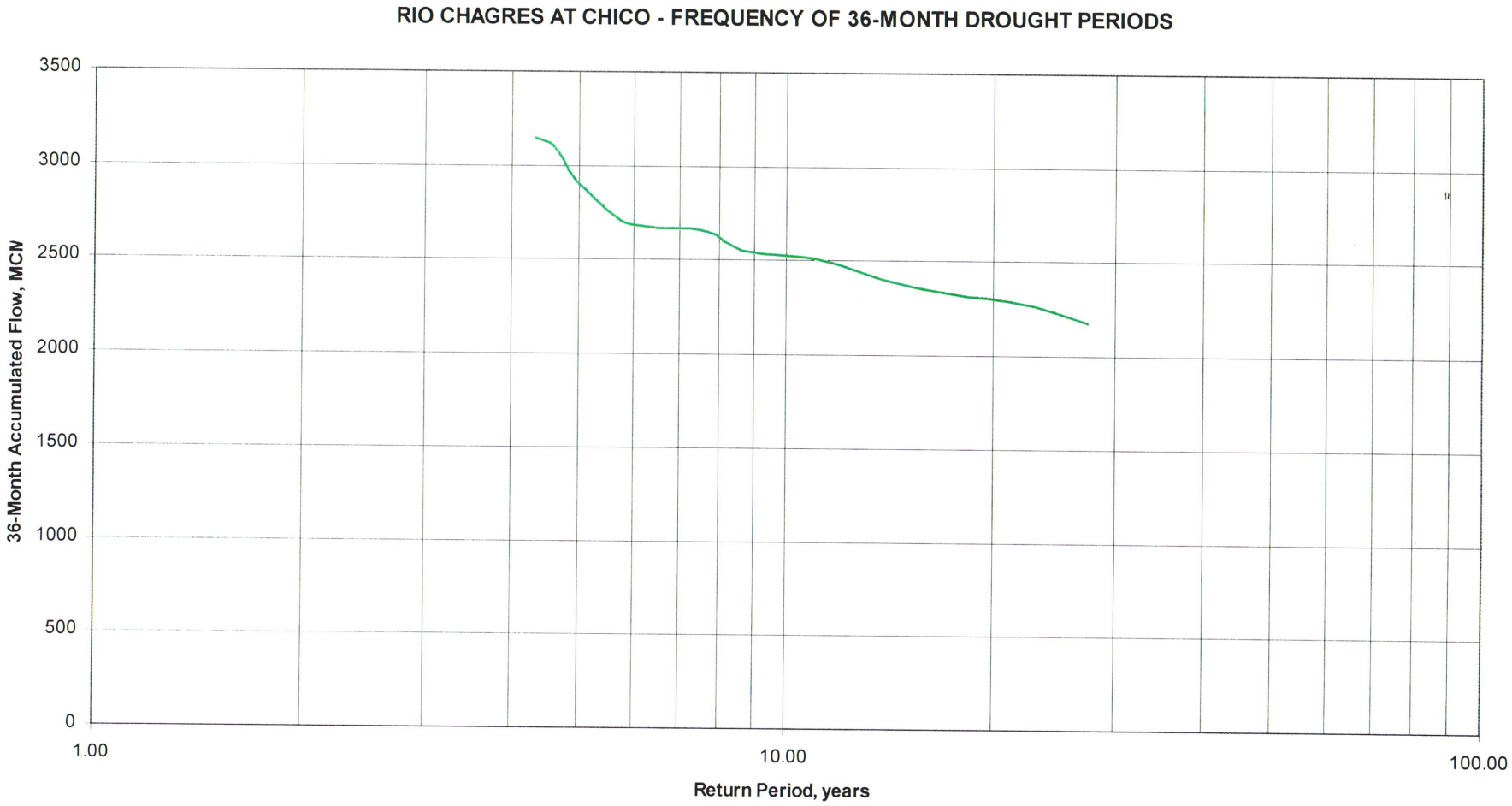
CONTRACT NO. CC-3-536
UPPER CHAGRES WATER SUPPLY PROJECT
APPENDIX A - HYDROLOGY AND METEOROLOGY

Río Chagres at Chico
Frequency of 24-Month Drought Periods

MWH TAMS

DATE: SEPTEMBER, 2003

EXHIBIT: 14



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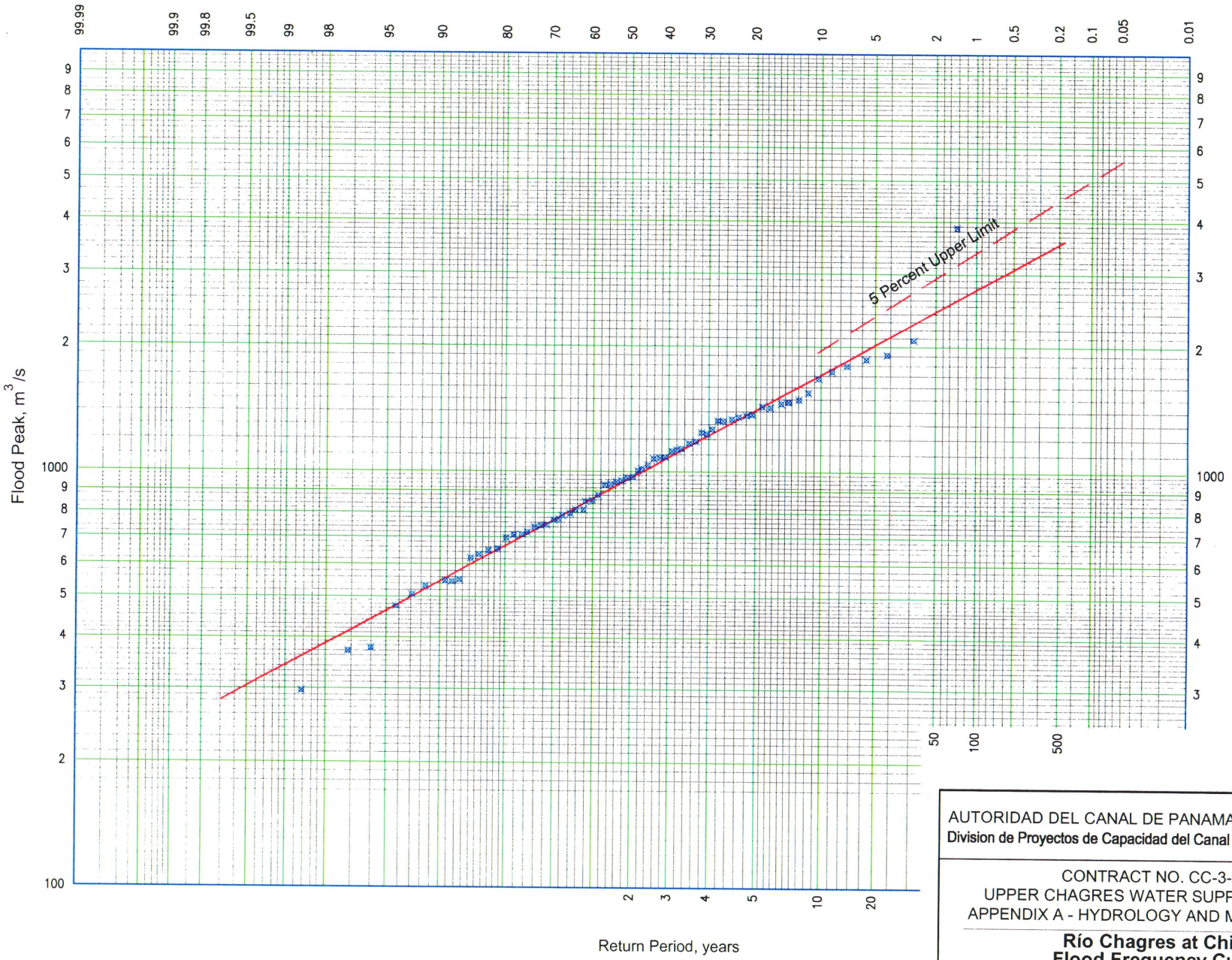
UPPER CHAGRES WATER SUPPLY PROJECT
APPENDIX A - HYDROLOGY AND METEOROLOGY

Río Chagres at Chico
Frequency of 36-Month Drought Periods

MWH TAMS

DATE: SEPTEMBER, 2003

EXHIBIT: 15



Period of record: 1933-2000 (68 years)

AUTORIDAD DEL CANAL DE PANAMA
Division de Proyectos de Capacidad del Canal

CONTRACT NO. CC-3-536
UPPER CHAGRES WATER SUPPLY PROJECT
APPENDIX A - HYDROLOGY AND METEOROLOGY

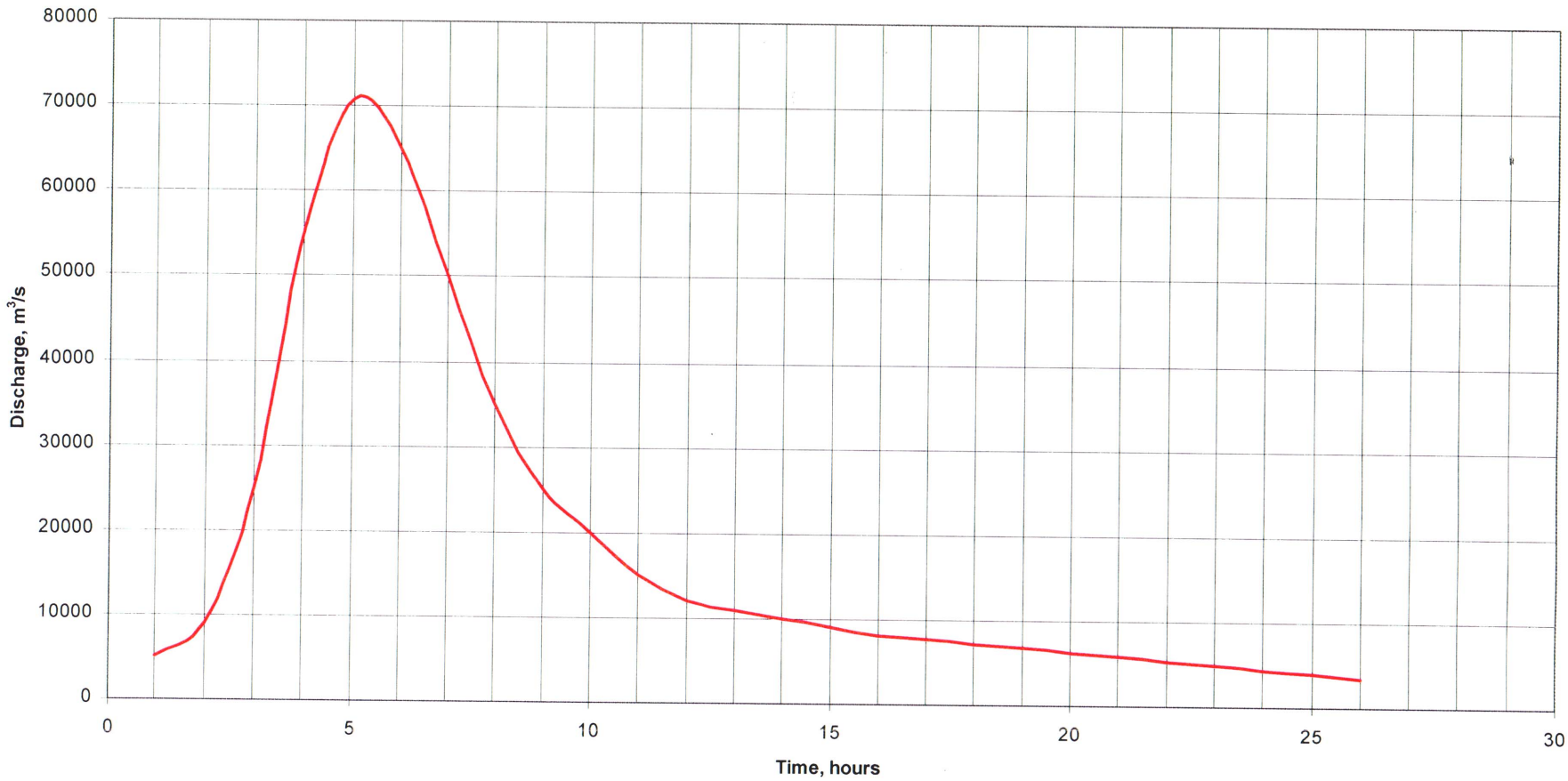
Río Chagres at Chico
Flood Frequency Curve
Log Pearson Type III Distribution

MWH TAMS

DATE: SEPTEMBER, 2003

EXHIBIT: 16

RIO CHAGRES AT CHICO - FLOOD HYDROGRAPH OF 20-YEAR RETURN PERIOD



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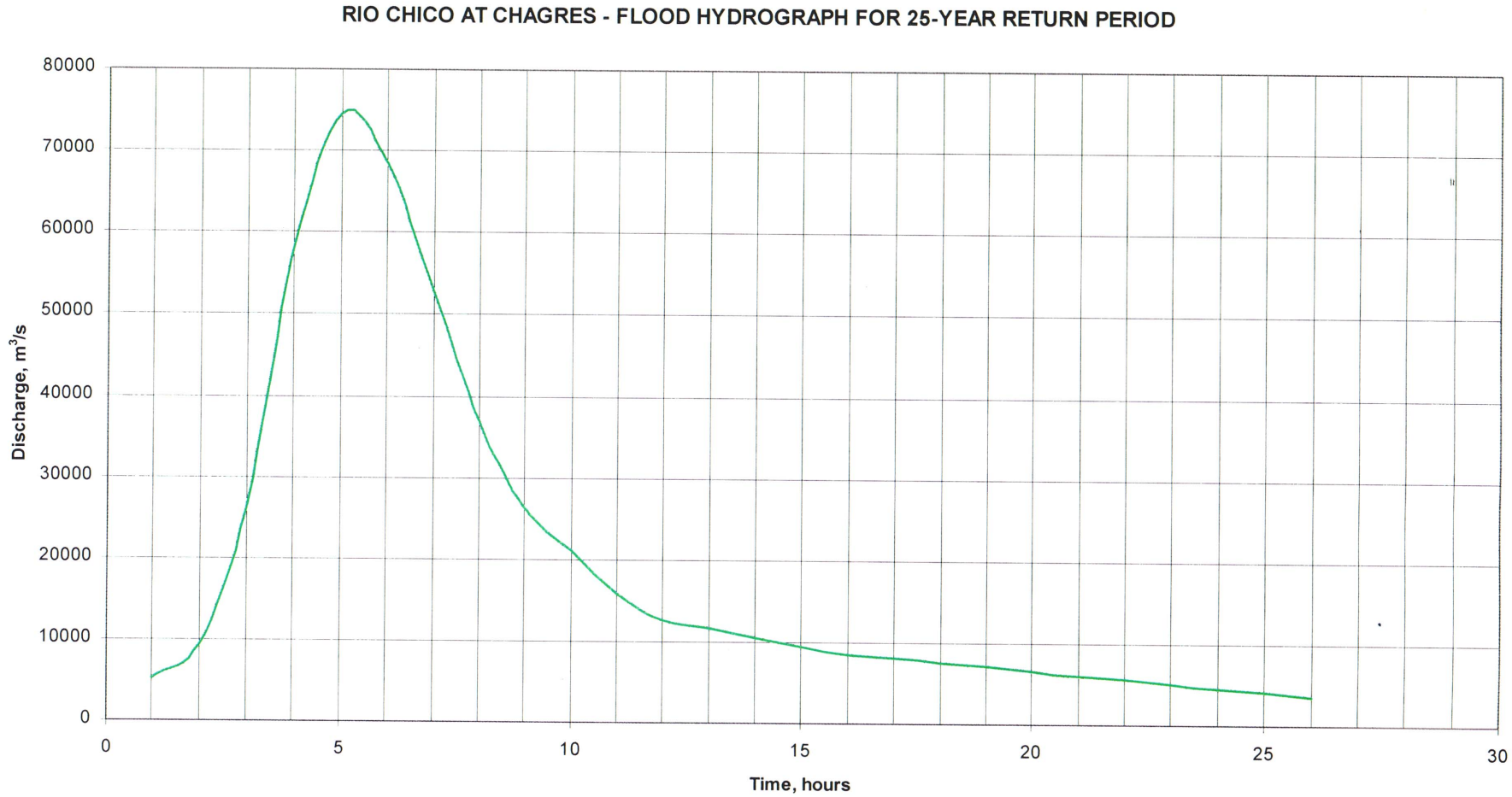
UPPER CHAGRES WATER SUPPLY PROJECT
APPENDIX A - HYDROLOGY AND METEOROLOGY

Río Chagres at Chico
Flood Hydrograph for 20-Year Return Period

MWH TAMS

DATE: SEPTEMBER, 2003

EXHIBIT: 17



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Division de Proyectos de Capacidad del Canal

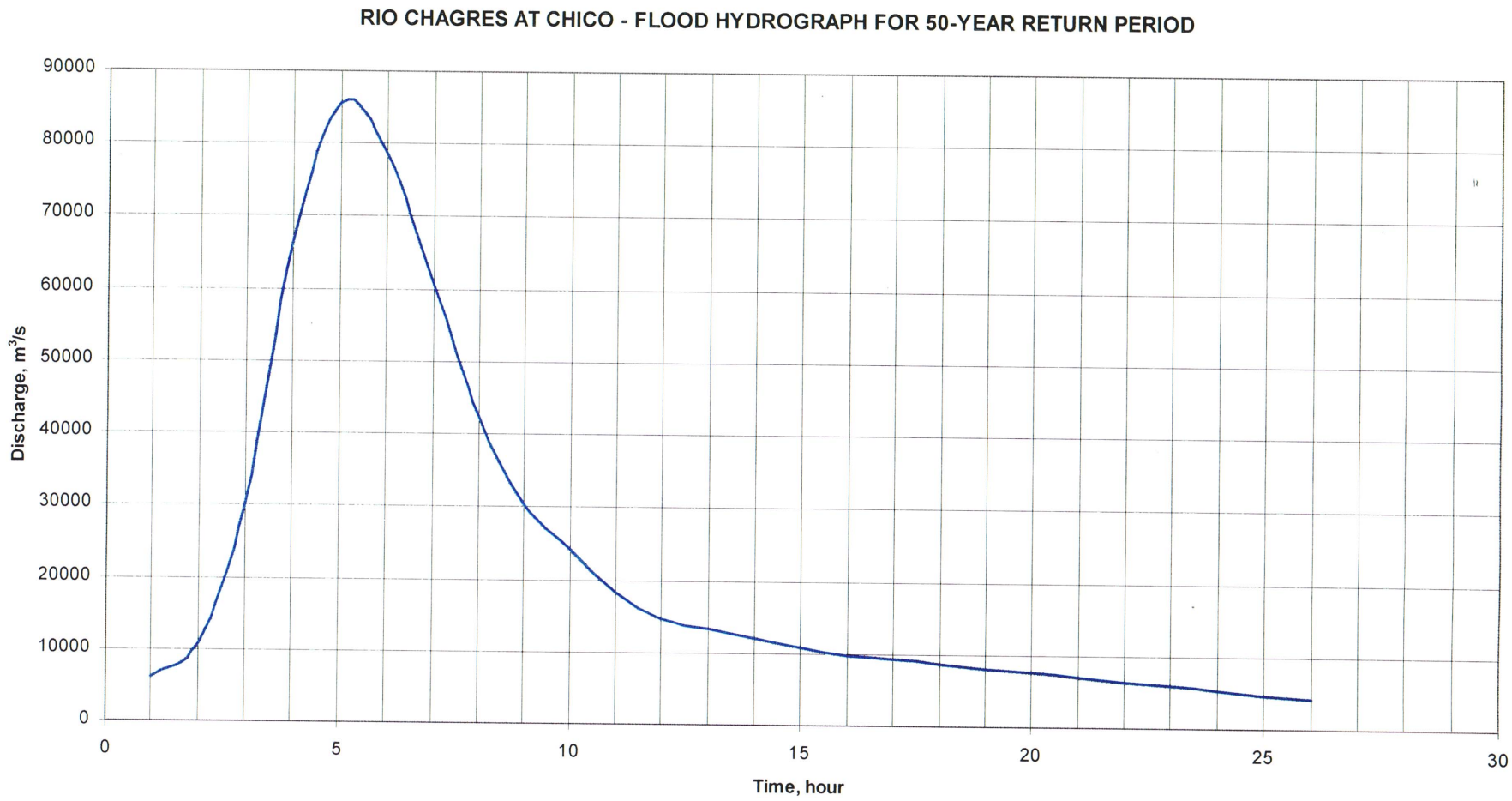
CONTRACT NO. CC-3-536
UPPER CHAGRES WATER SUPPLY PROJECT
APPENDIX A - HYDROLOGY AND METEOROLOGY

Río Chagres at Chico
Flood Hydrograph for 25-Year Return Period

MWH TAMS

DATE: SEPTEMBER, 2003

EXHIBIT: 18



AUTORIDAD DEL CANAL DE PANAMA
Division de Proyectos de Capacidad del Canal

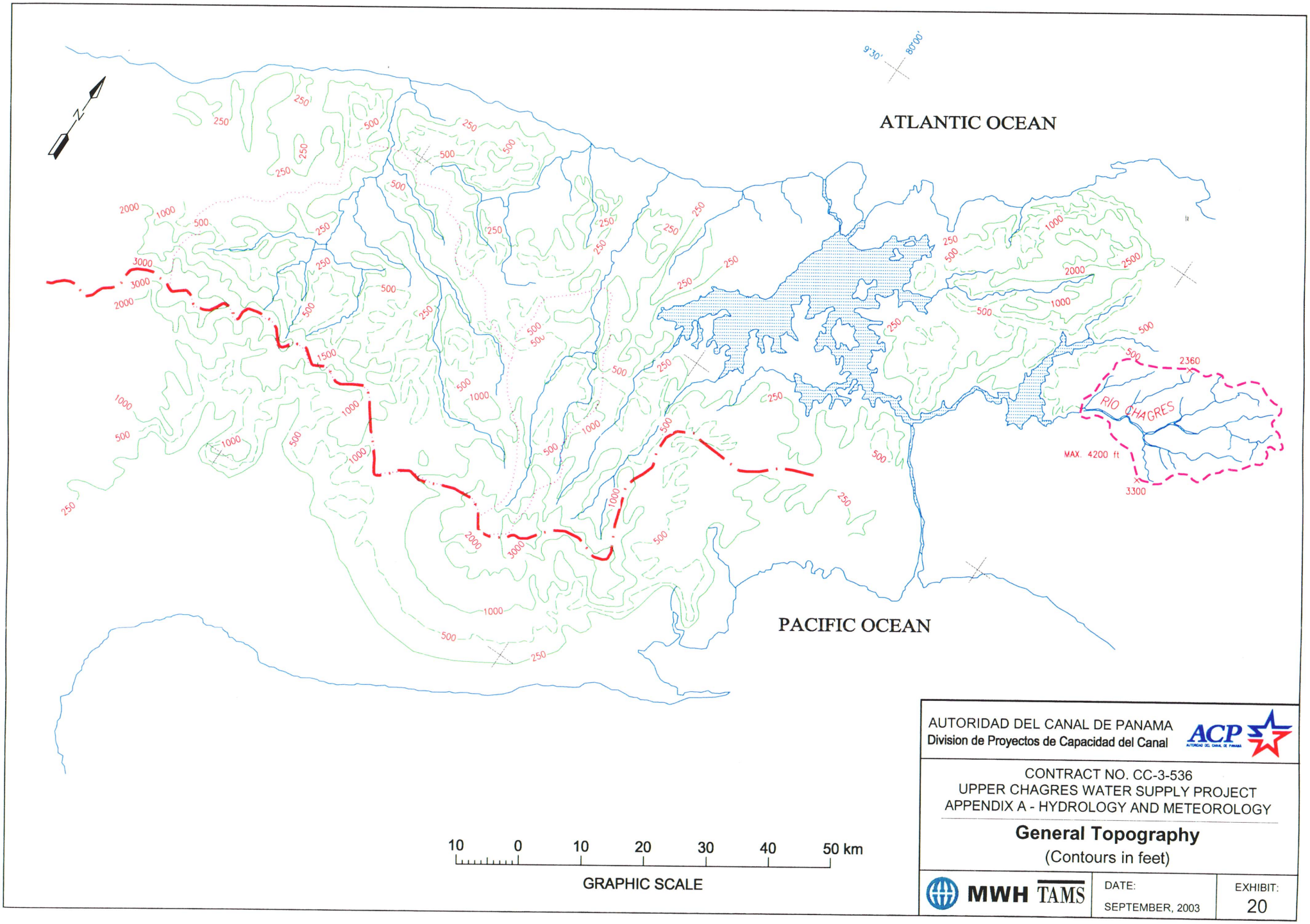
CONTRACT NO. CC-3-536
UPPER CHAGRES WATER SUPPLY PROJECT
APPENDIX A - HYDROLOGY AND METEOROLOGY

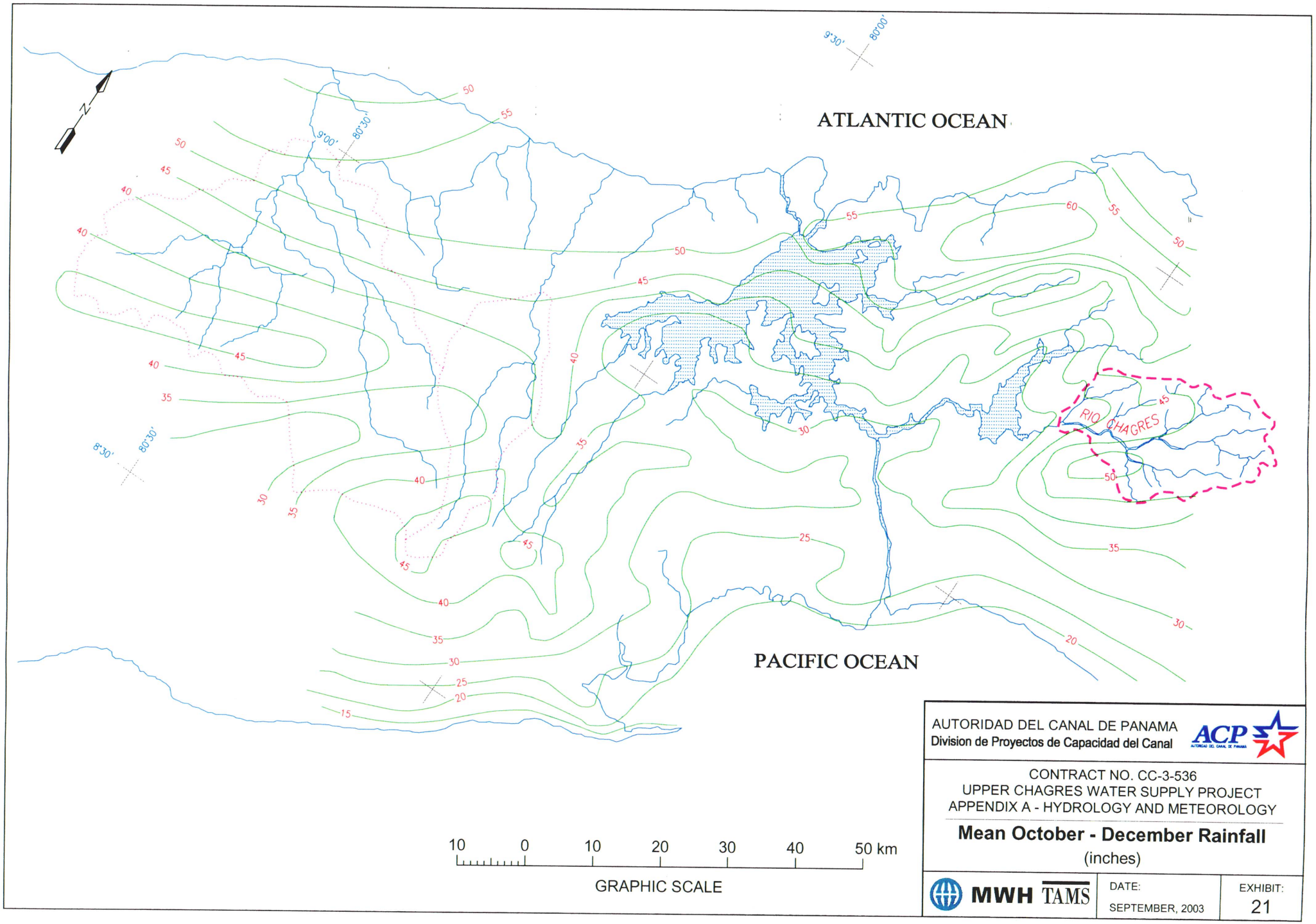
Río Chagres at Chico
Flood Hydrograph for 50-Year Return Period

MWH TAMS

DATE: SEPTEMBER, 2003

EXHIBIT: 19


ATLANTIC OCEAN
PACIFIC OCEAN
RIO CHAGRES
MAX. 4200 ft
2360
3300
9°30'
80°00'
10 0 10 20 30 40 50 km
GRAPHIC SCALE
AUTORIDAD DEL CANAL DE PANAMA
Division de Proyectos de Capacidad del Canal
ACP
CONTRACT NO. CC-3-536
UPPER CHAGRES WATER SUPPLY PROJECT
APPENDIX A - HYDROLOGY AND METEOROLOGY
General Topography
(Contours in feet)
MWH TAMS
DATE:
SEPTEMBER, 2003
EXHIBIT:
20



AUTORIDAD DEL CANAL DE PANAMA
Division de Proyectos de Capacidad del Canal

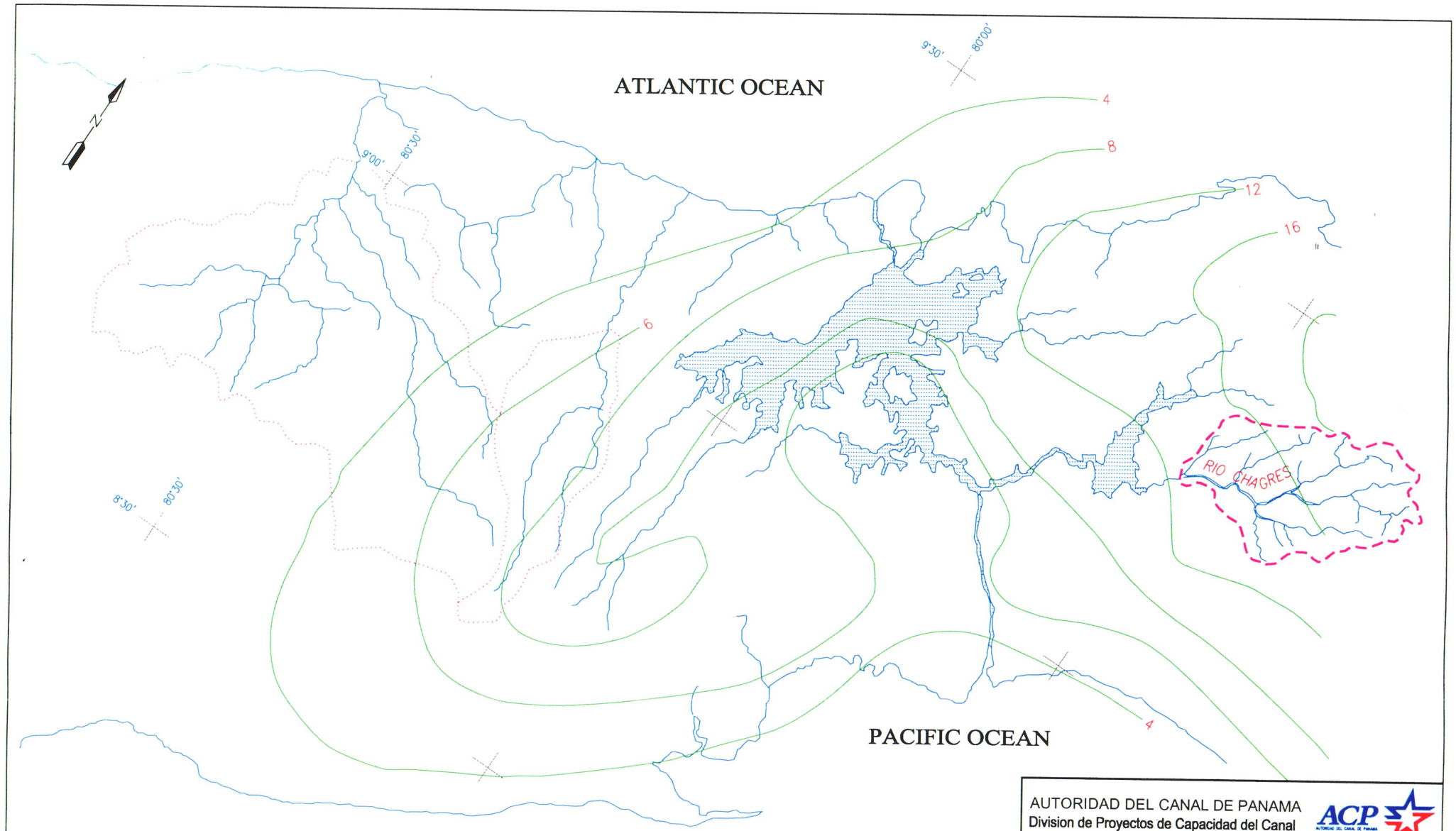
CONTRACT NO. CC-3-536
UPPER CHAGRES WATER SUPPLY PROJECT
APPENDIX A - HYDROLOGY AND METEOROLOGY

Mean October - December Rainfall
(inches)

MWH TAMS

DATE: SEPTEMBER, 2003

EXHIBIT: 21



Source:

US NWS, February 1978 Report

10 0 10 20 30 40 50 km

GRAPHIC SCALE

AUTORIDAD DEL CANAL DE PANAMA
Division de Proyectos de Capacidad del Canal

ACP

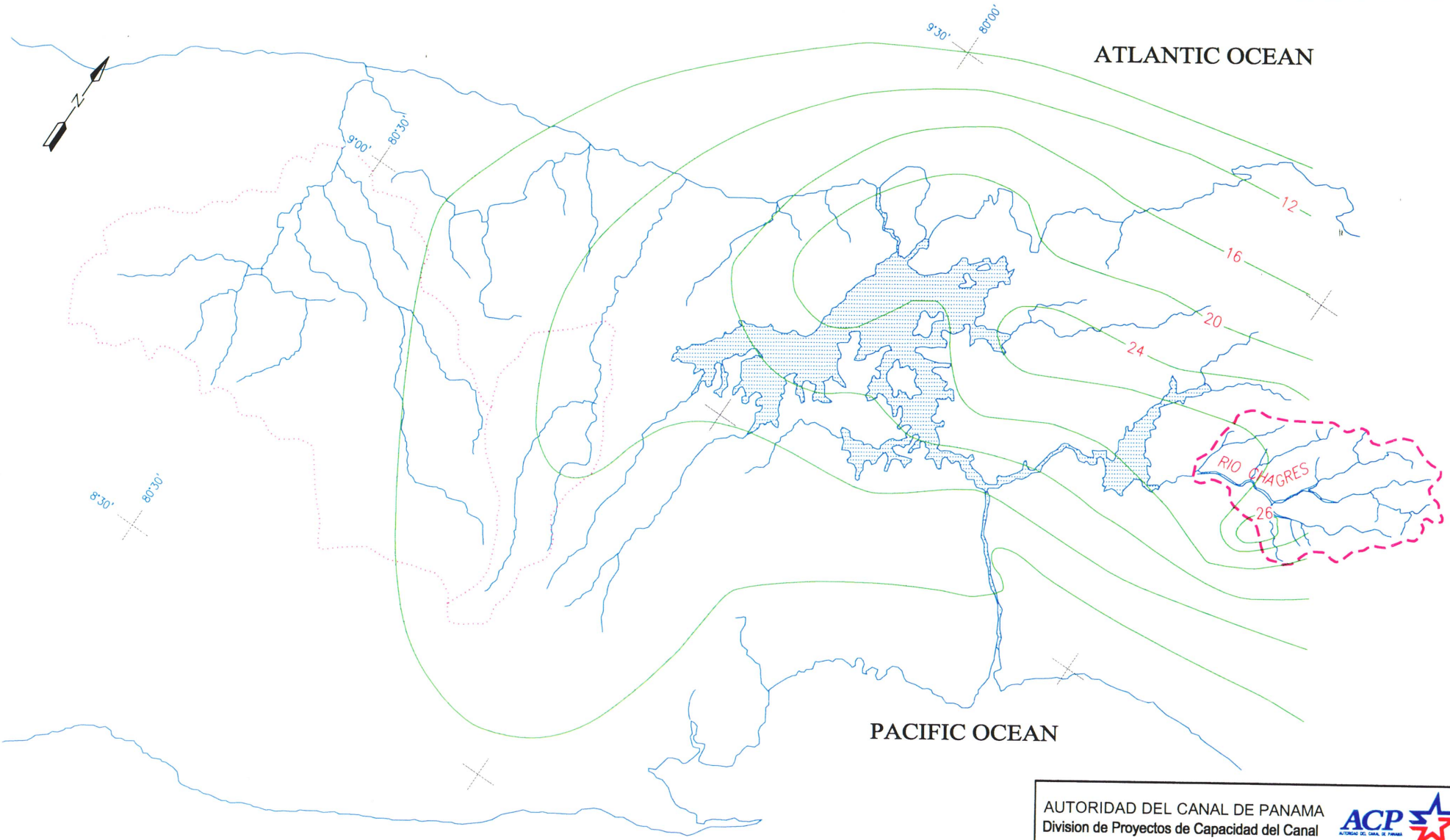
CONTRACT NO. CC-3-536
UPPER CHAGRES WATER SUPPLY PROJECT
APPENDIX A - HYDROLOGY AND METEOROLOGY

Rainfall Depths (inches) during Storm of November 17-19, 1909

MWH TAMS

DATE: SEPTEMBER, 2003

EXHIBIT: 22



Source:

US NWS, February 1978 Report

10 0 10 20 30 40 50 km

GRAPHIC SCALE

AUTORIDAD DEL CANAL DE PANAMA
Division de Proyectos de Capacidad del Canal

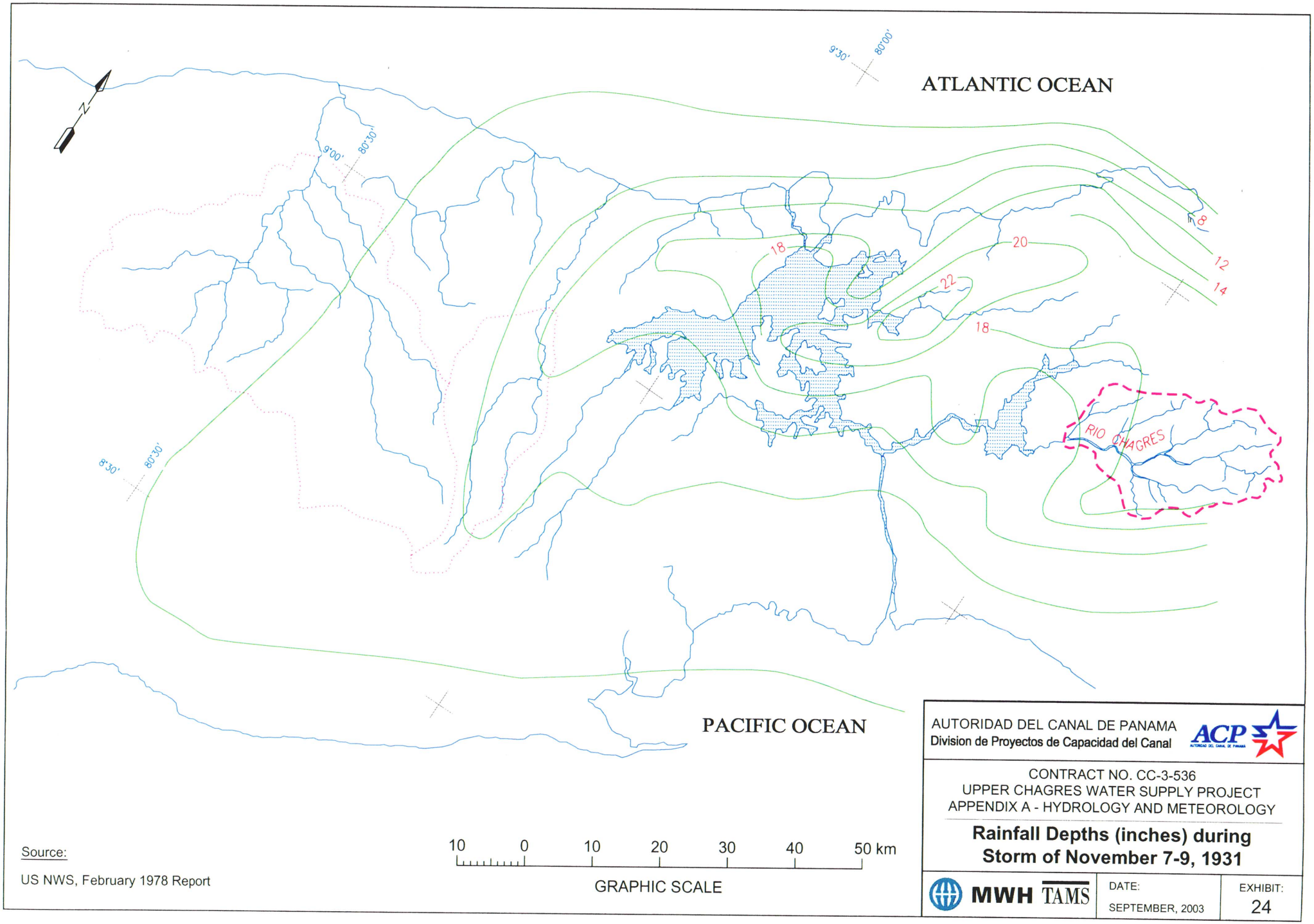
CONTRACT NO. CC-3-536
UPPER CHAGRES WATER SUPPLY PROJECT
APPENDIX A - HYDROLOGY AND METEOROLOGY

Rainfall Depths (inches) during Storm of October 22-24, 1923

MWH TAMS

DATE: SEPTEMBER, 2003

EXHIBIT: 23



Source:

US NWS, February 1978 Report

AUTORIDAD DEL CANAL DE PANAMA
Division de Proyectos de Capacidad del Canal

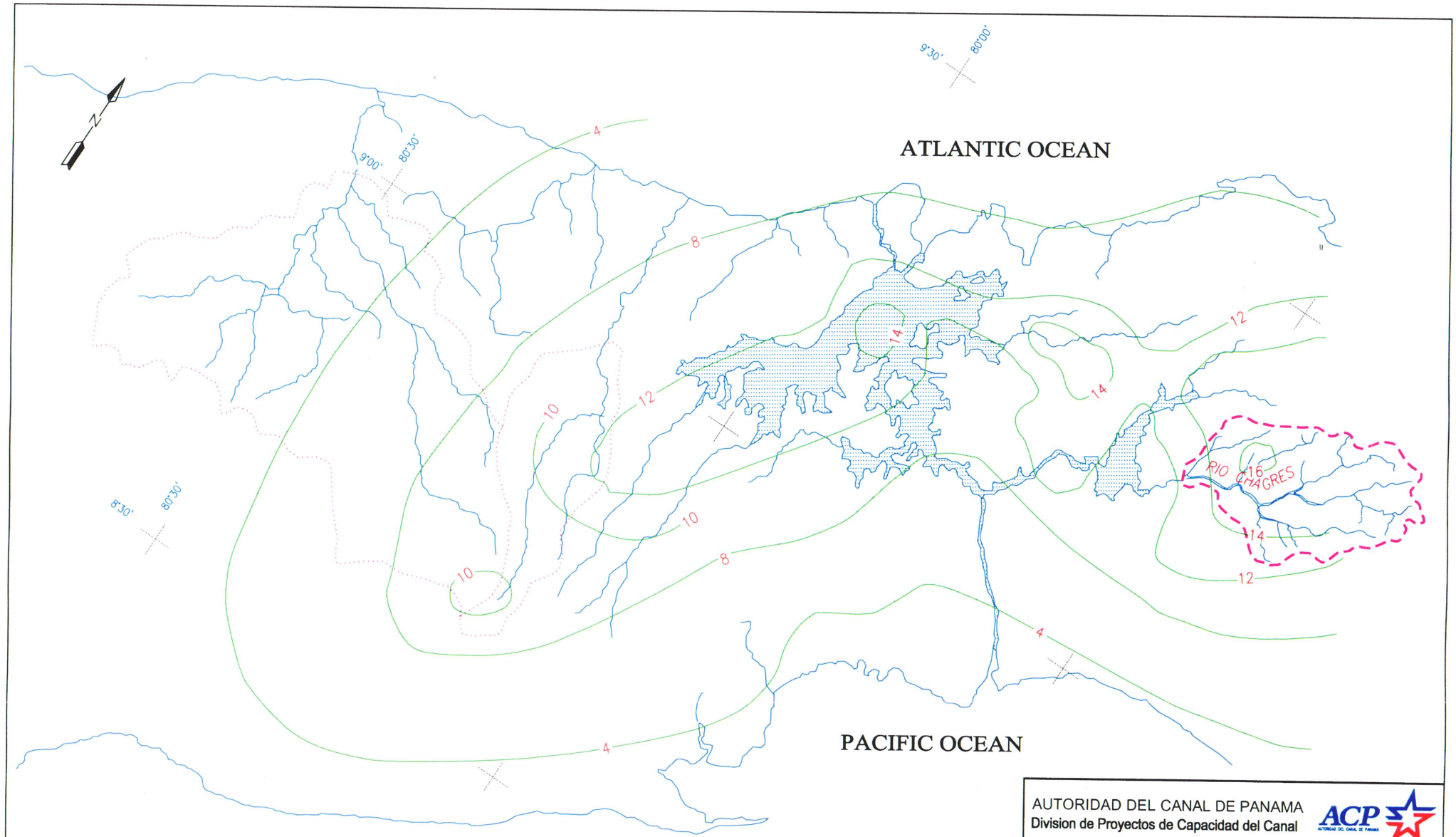
CONTRACT NO. CC-3-536
UPPER CHAGRES WATER SUPPLY PROJECT
APPENDIX A - HYDROLOGY AND METEOROLOGY

Rainfall Depths (inches) during Storm of November 7-9, 1931

MWH TAMS

DATE: SEPTEMBER, 2003

EXHIBIT: 24



Source:

US NWS, February 1978 Report

AUTORIDAD DEL CANAL DE PANAMA
Division de Proyectos de Capacidad del Canal

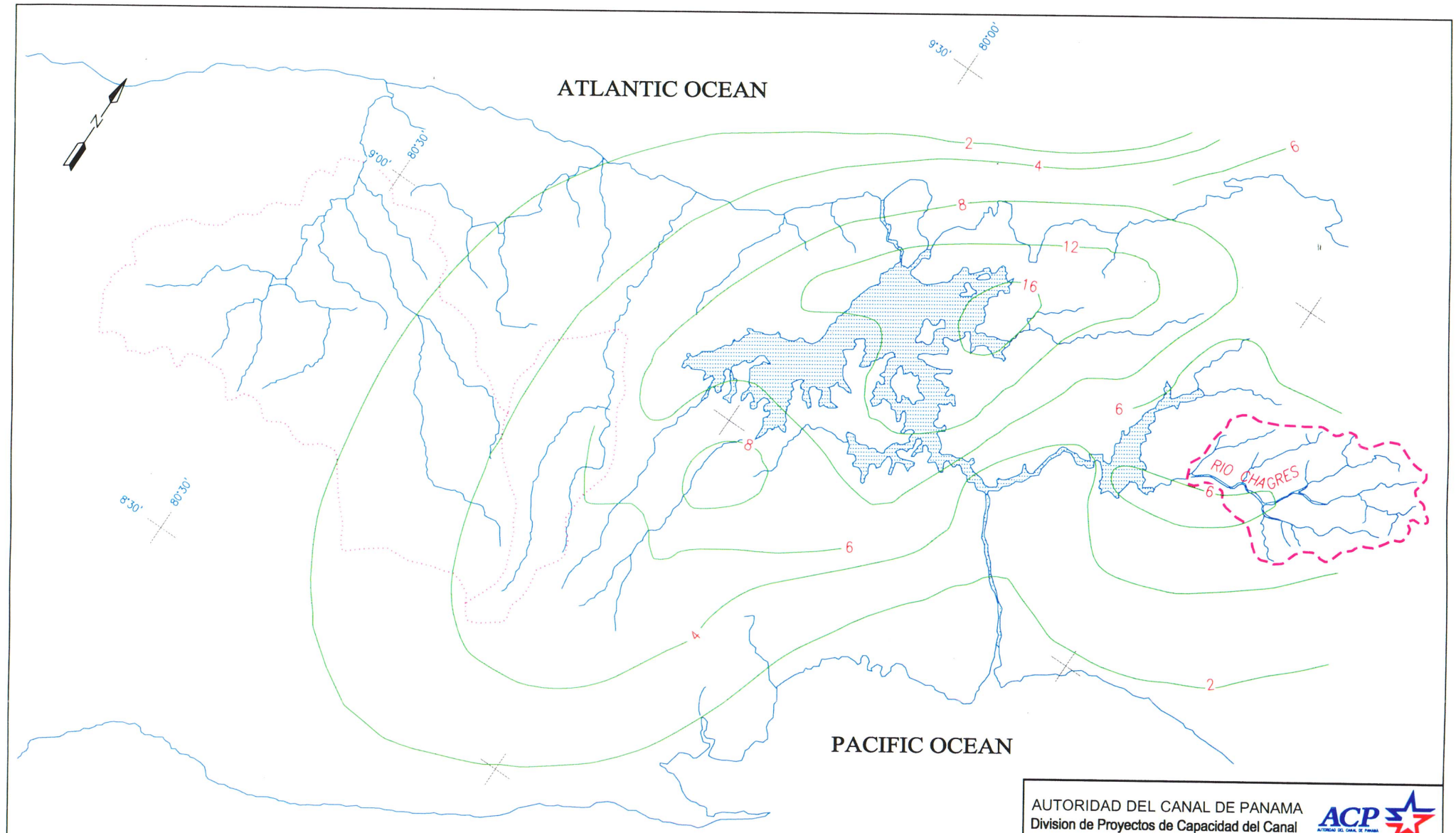
CONTRACT NO. CC-3-536
UPPER CHAGRES WATER SUPPLY PROJECT
APPENDIX A - HYDROLOGY AND METEOROLOGY

Rainfall Depths (inches) during Storm of November 27-29, 1932

MWH TAMS

DATE: SEPTEMBER, 2003

EXHIBIT: 25



Source:

US NWS, February 1978 Report

10 0 10 20 30 40 50 km

GRAPHIC SCALE

AUTORIDAD DEL CANAL DE PANAMA
Division de Proyectos de Capacidad del Canal

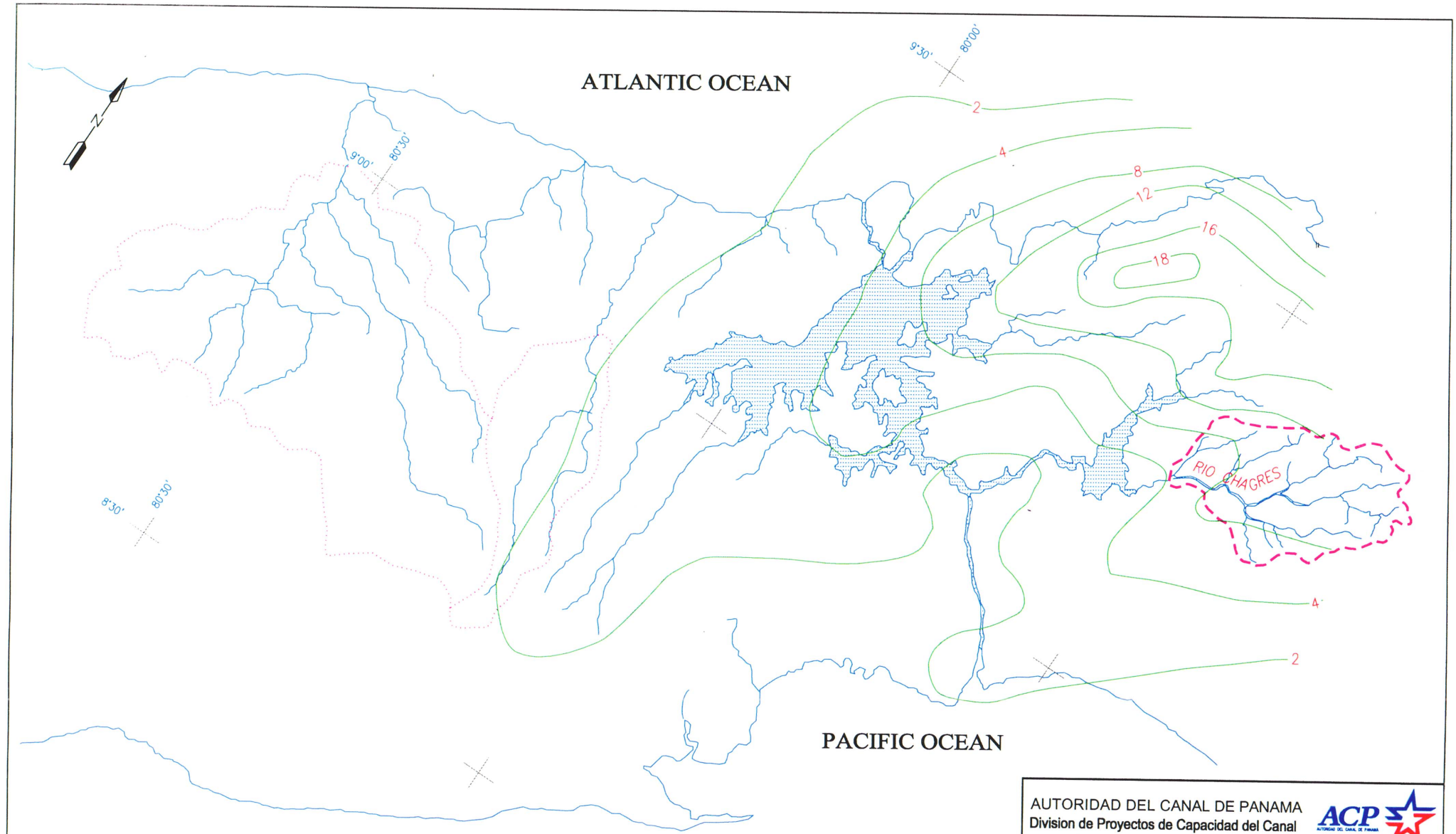
CONTRACT NO. CC-3-536
UPPER CHAGRES WATER SUPPLY PROJECT
APPENDIX A - HYDROLOGY AND METEOROLOGY

Rainfall Depths (inches) during Storm of November 5-7, 1939

MWH TAMS

DATE: SEPTEMBER, 2003

EXHIBIT: 26



Source:

US NWS, February 1978 Report

10 0 10 20 30 40 50 km

GRAPHIC SCALE

AUTORIDAD DEL CANAL DE PANAMA
Division de Proyectos de Capacidad del Canal

ACP

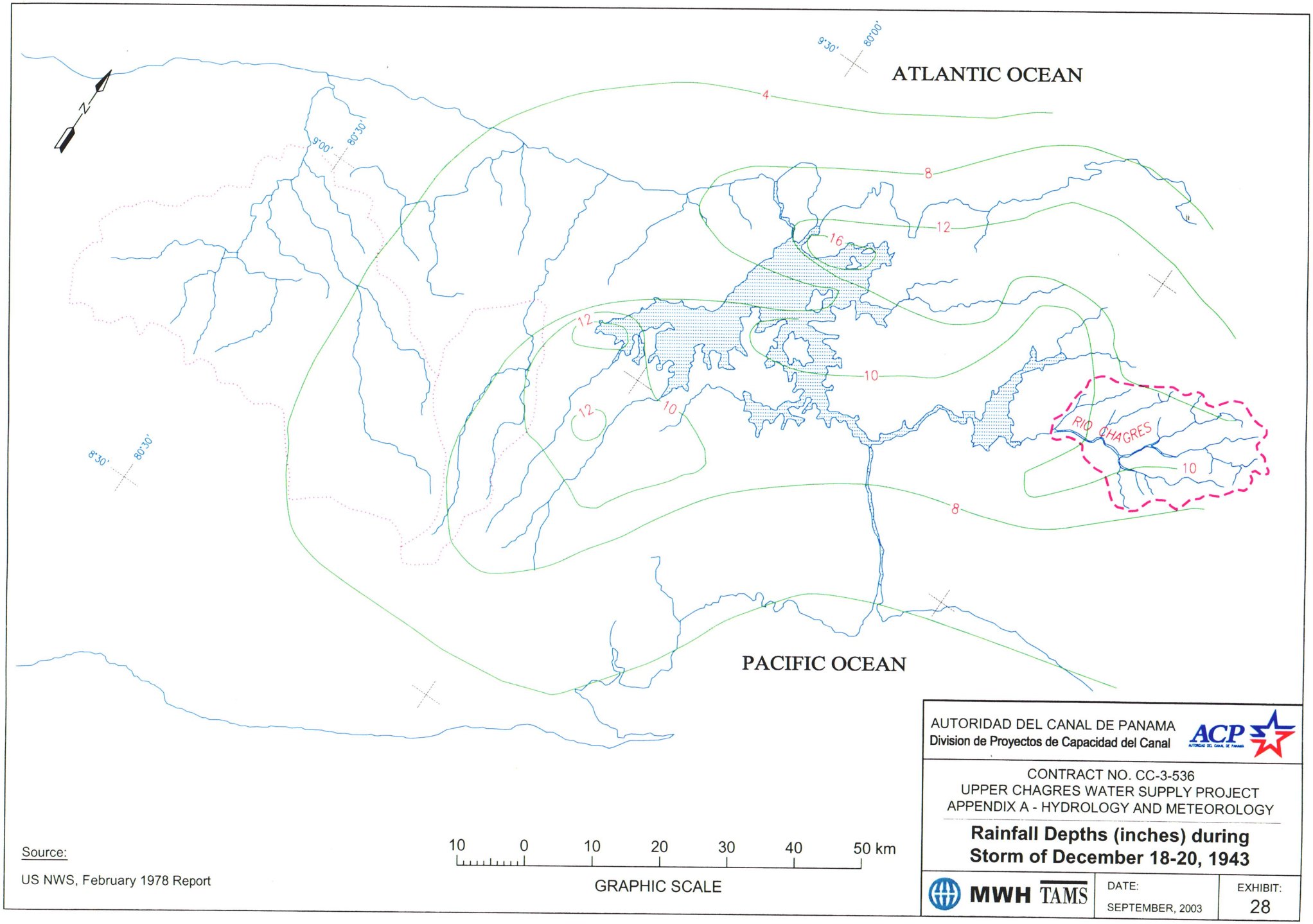
CONTRACT NO. CC-3-536
UPPER CHAGRES WATER SUPPLY PROJECT
APPENDIX A - HYDROLOGY AND METEOROLOGY

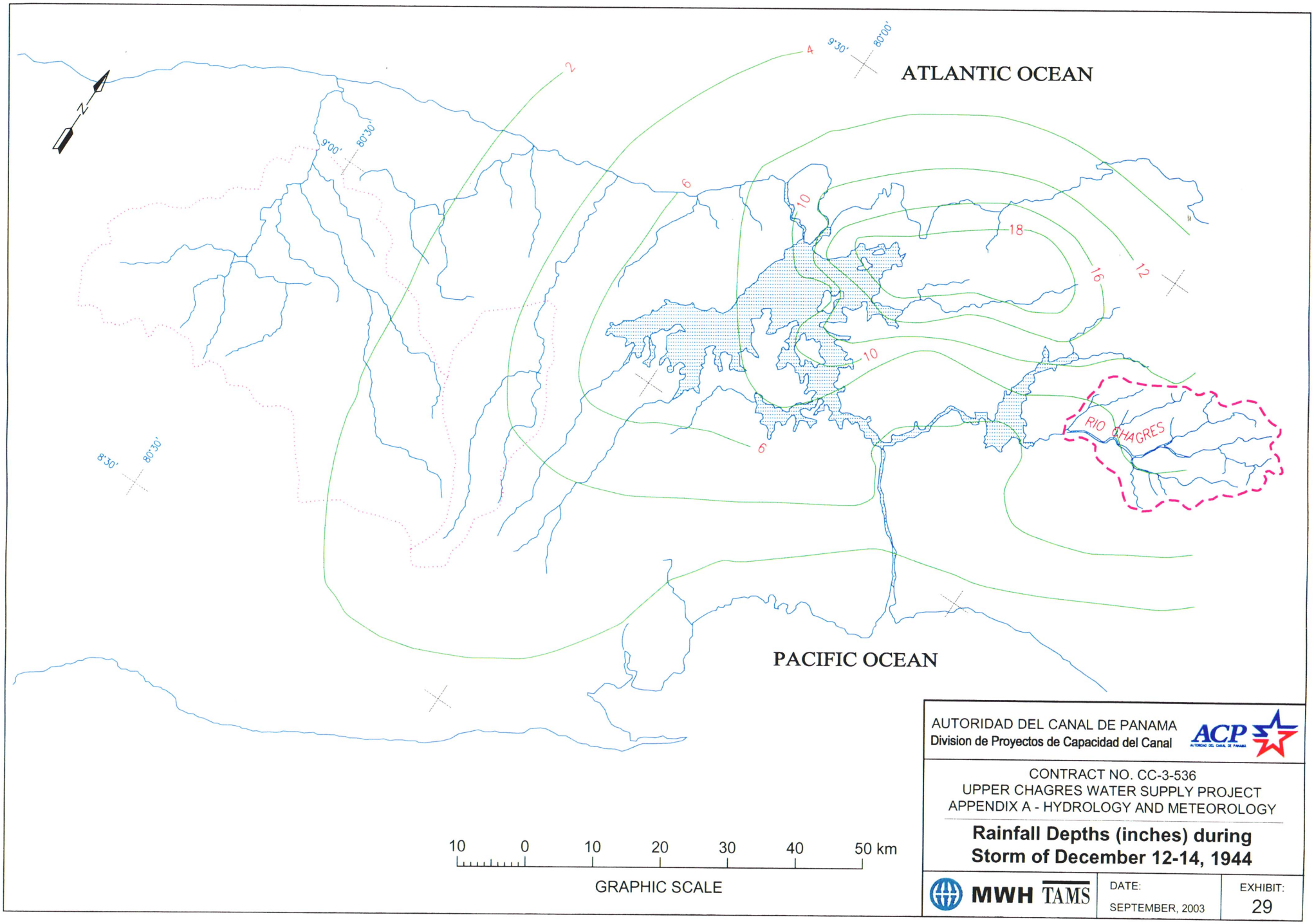
Rainfall Depths (inches) during Storm of October 12-14, 1941

MWH TAMS

DATE: SEPTEMBER, 2003

EXHIBIT: 27


ATLANTIC OCEAN
PACIFIC OCEAN
9°30'
80°00'
9°00'
80°30'
8°30'
80°30'
4
8
12
16
12
10
12
10
8
10
RIO CHAGRES
N
10
0
10
20
30
40
50 km
GRAPHIC SCALE
Source:
US NWS, February 1978 Report
AUTORIDAD DEL CANAL DE PANAMA
Division de Proyectos de Capacidad del Canal
ACP
CONTRACT NO. CC-3-536
UPPER CHAGRES WATER SUPPLY PROJECT
APPENDIX A - HYDROLOGY AND METEOROLOGY
Rainfall Depths (inches) during
Storm of December 18-20, 1943
MWH TAMS
DATE:
SEPTEMBER, 2003
EXHIBIT:
28



AUTORIDAD DEL CANAL DE PANAMA
Division de Proyectos de Capacidad del Canal

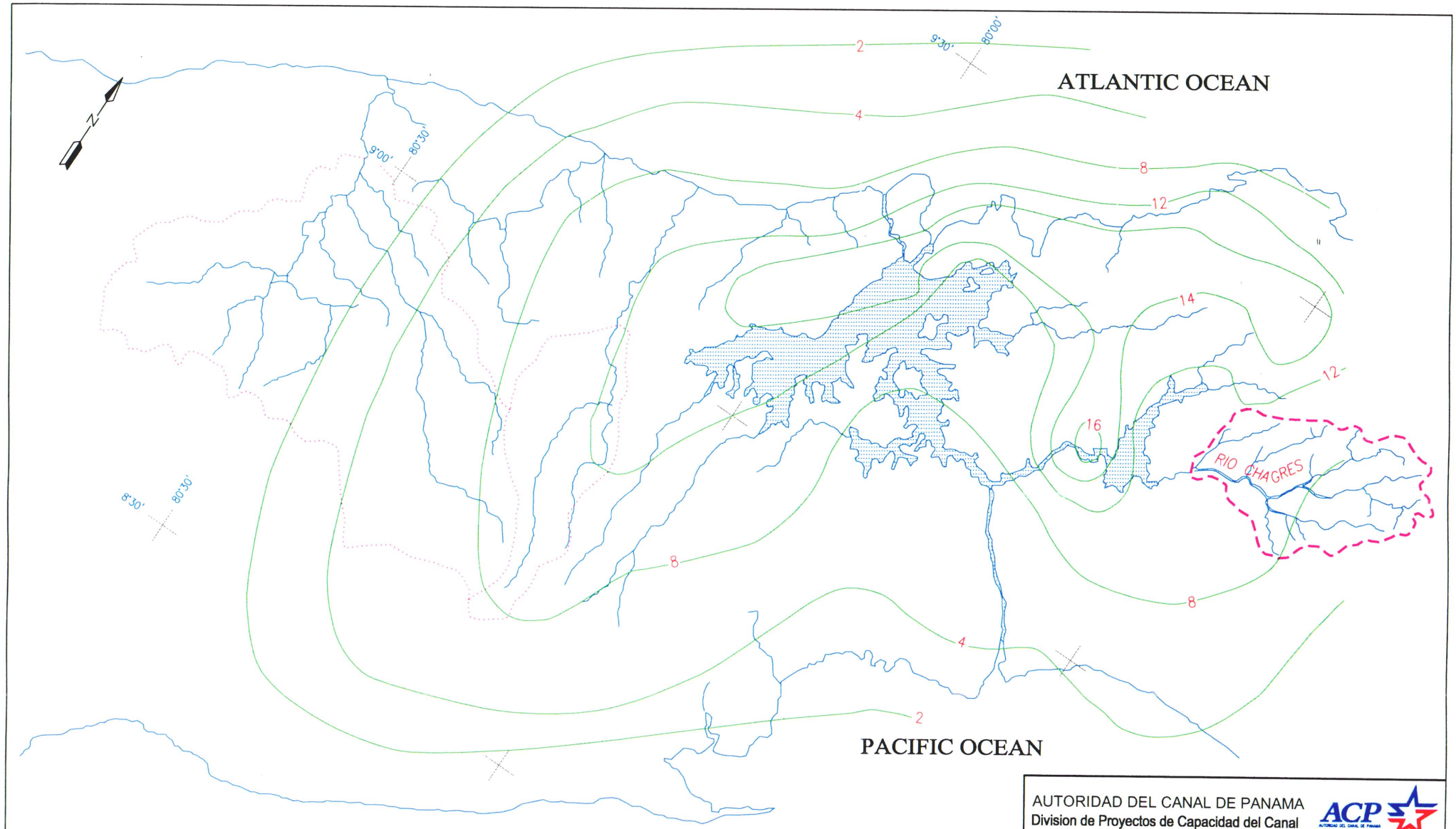
CONTRACT NO. CC-3-536
UPPER CHAGRES WATER SUPPLY PROJECT
APPENDIX A - HYDROLOGY AND METEOROLOGY

Rainfall Depths (inches) during Storm of December 12-14, 1944

MWH TAMS

DATE: SEPTEMBER, 2003

EXHIBIT: 29



Source:

US NWS, February 1978 Report

10 0 10 20 30 40 50 km

GRAPHIC SCALE

AUTORIDAD DEL CANAL DE PANAMA
Division de Proyectos de Capacidad del Canal

ACP

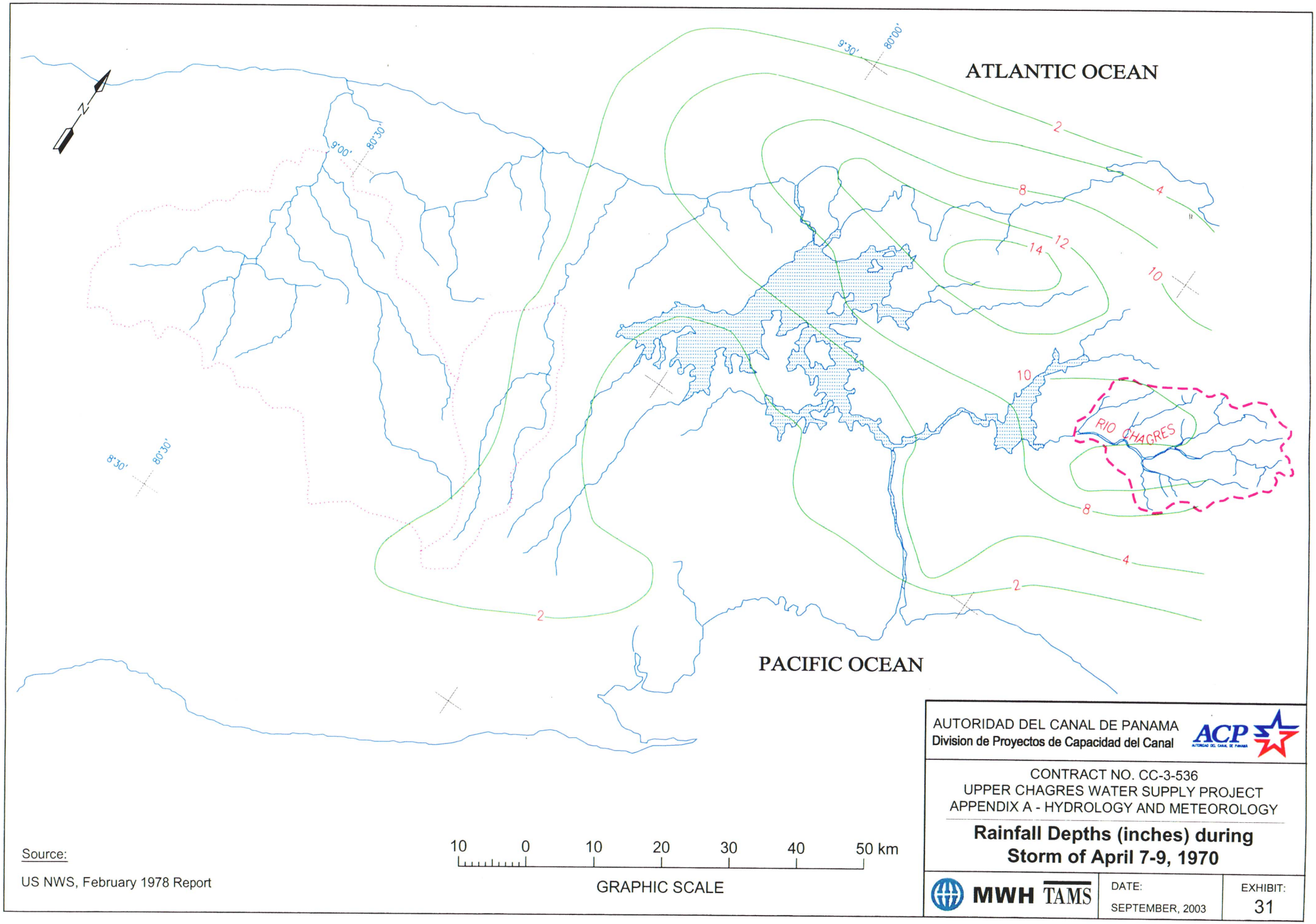
CONTRACT NO. CC-3-536
UPPER CHAGRES WATER SUPPLY PROJECT
APPENDIX A - HYDROLOGY AND METEOROLOGY

Rainfall Depths (inches) during Storm of November 3-5, 1966

MWH TAMS

DATE: SEPTEMBER, 2003

EXHIBIT: 30



Source:

US NWS, February 1978 Report

AUTORIDAD DEL CANAL DE PANAMA
Division de Proyectos de Capacidad del Canal

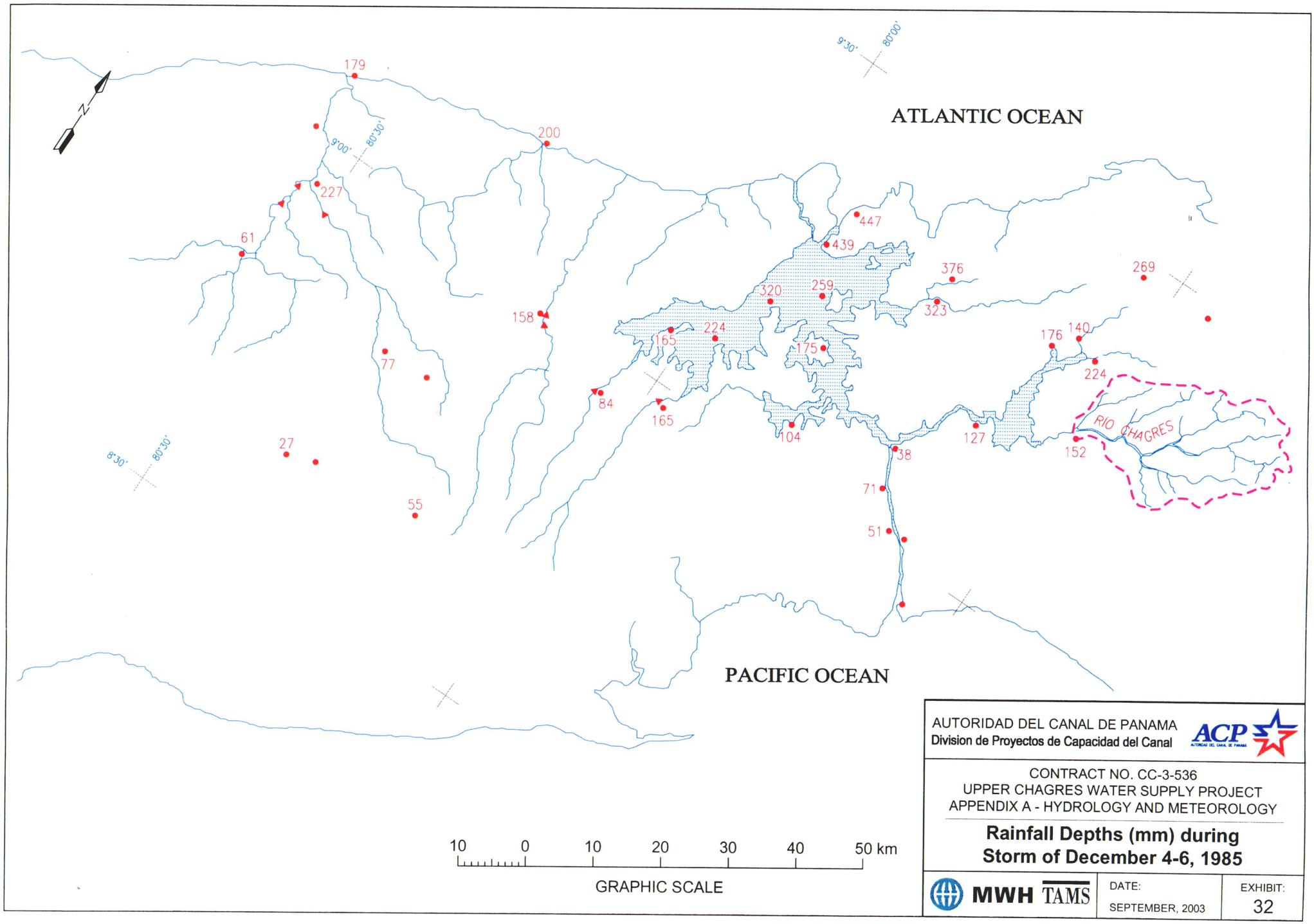
CONTRACT NO. CC-3-536
UPPER CHAGRES WATER SUPPLY PROJECT
APPENDIX A - HYDROLOGY AND METEOROLOGY

Rainfall Depths (inches) during Storm of April 7-9, 1970

MWH TAMS

DATE: SEPTEMBER, 2003

EXHIBIT: 31



AUTORIDAD DEL CANAL DE PANAMA
Division de Proyectos de Capacidad del Canal

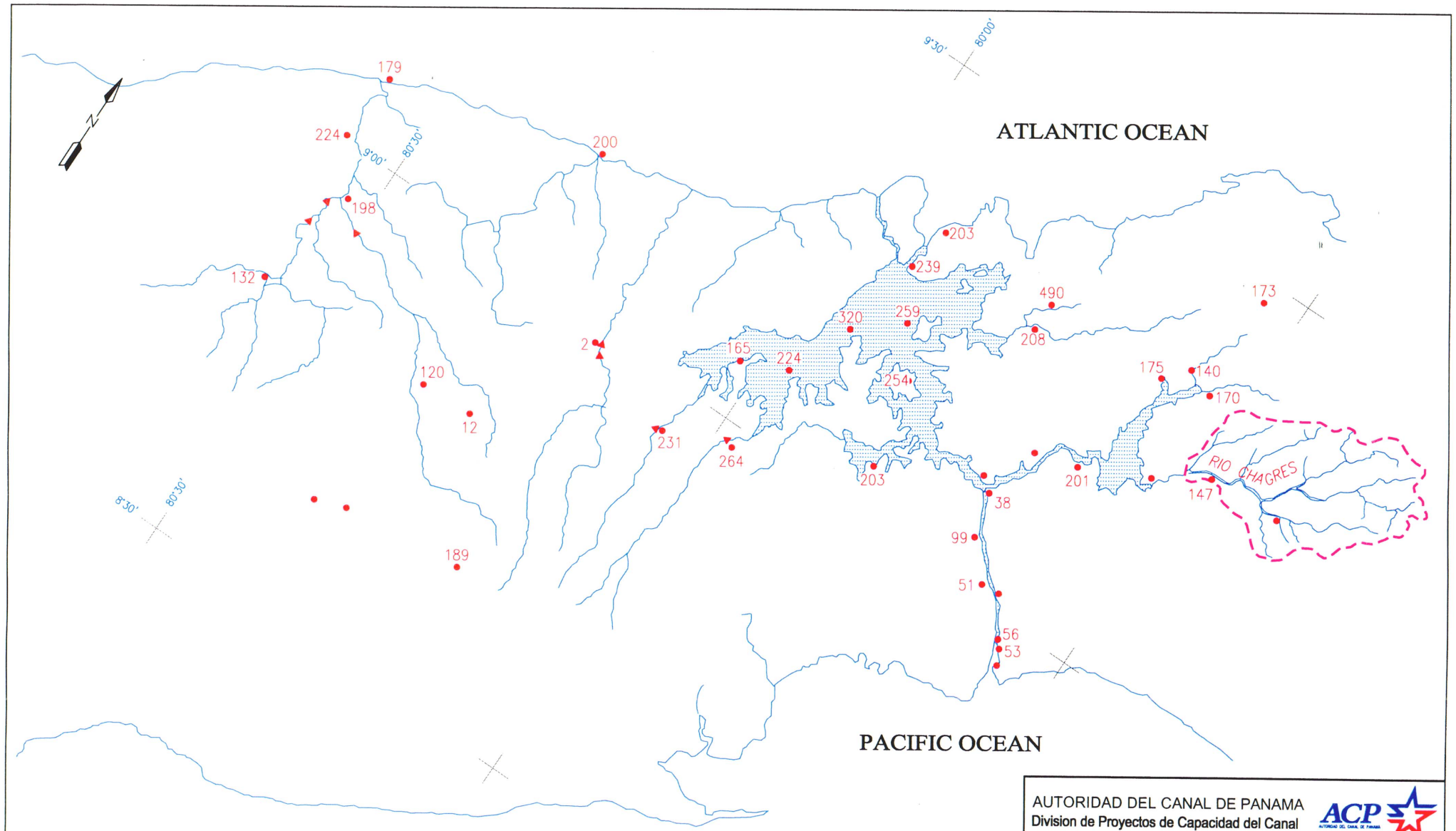
CONTRACT NO. CC-3-536
UPPER CHAGRES WATER SUPPLY PROJECT
APPENDIX A - HYDROLOGY AND METEOROLOGY

Rainfall Depths (mm) during Storm of December 4-6, 1985

MWH TAMS

DATE: SEPTEMBER, 2003

EXHIBIT: 32



AUTORIDAD DEL CANAL DE PANAMA
Division de Proyectos de Capacidad del Canal

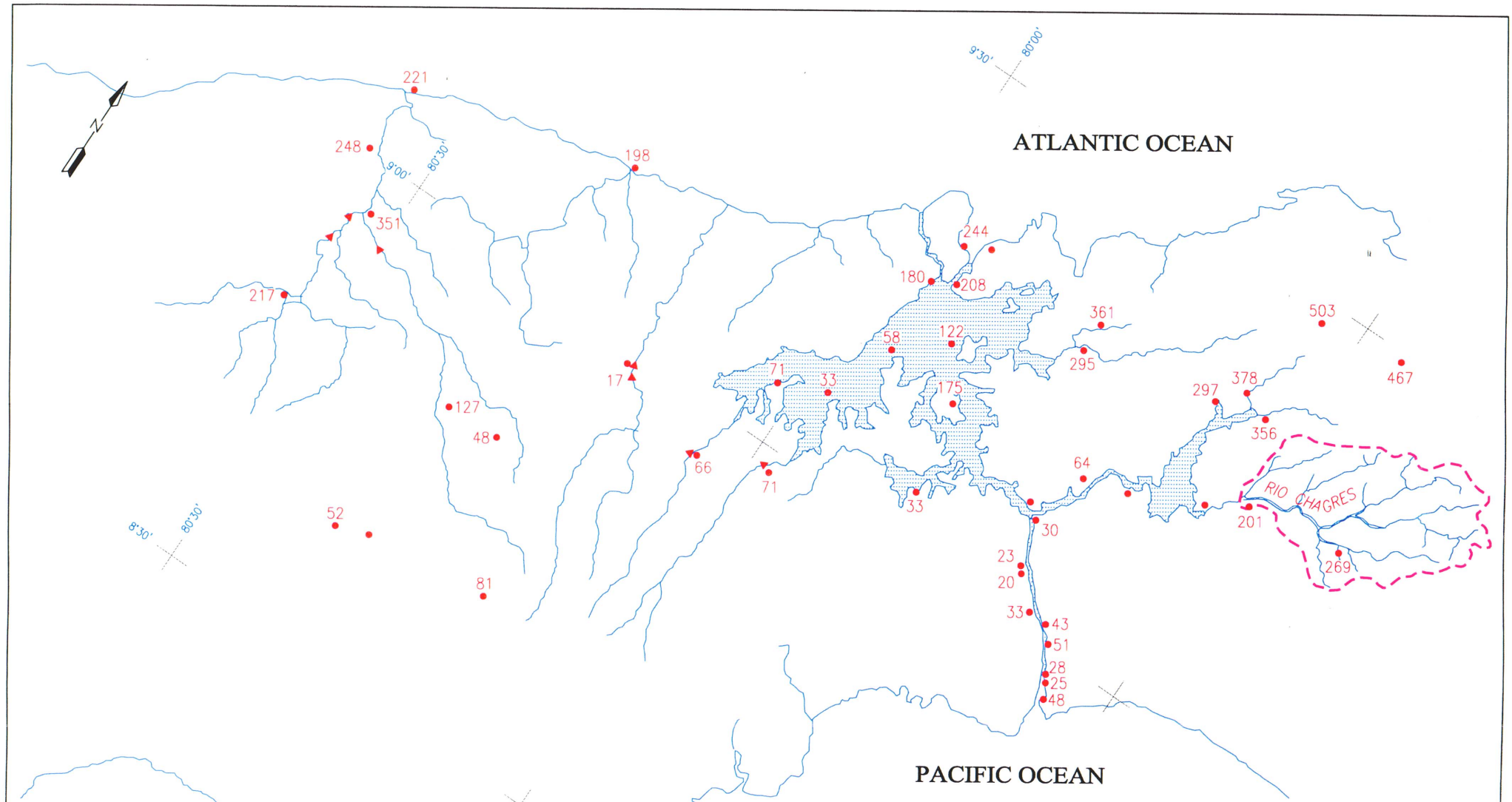
CONTRACT NO. CC-3-536
UPPER CHAGRES WATER SUPPLY PROJECT
APPENDIX A - HYDROLOGY AND METEOROLOGY

Rainfall Depths (mm) during Storm of January 13-15, 1996

MWH TAMS

DATE: SEPTEMBER, 2003

EXHIBIT: 33



AUTORIDAD DEL CANAL DE PANAMA
Division de Proyectos de Capacidad del Canal

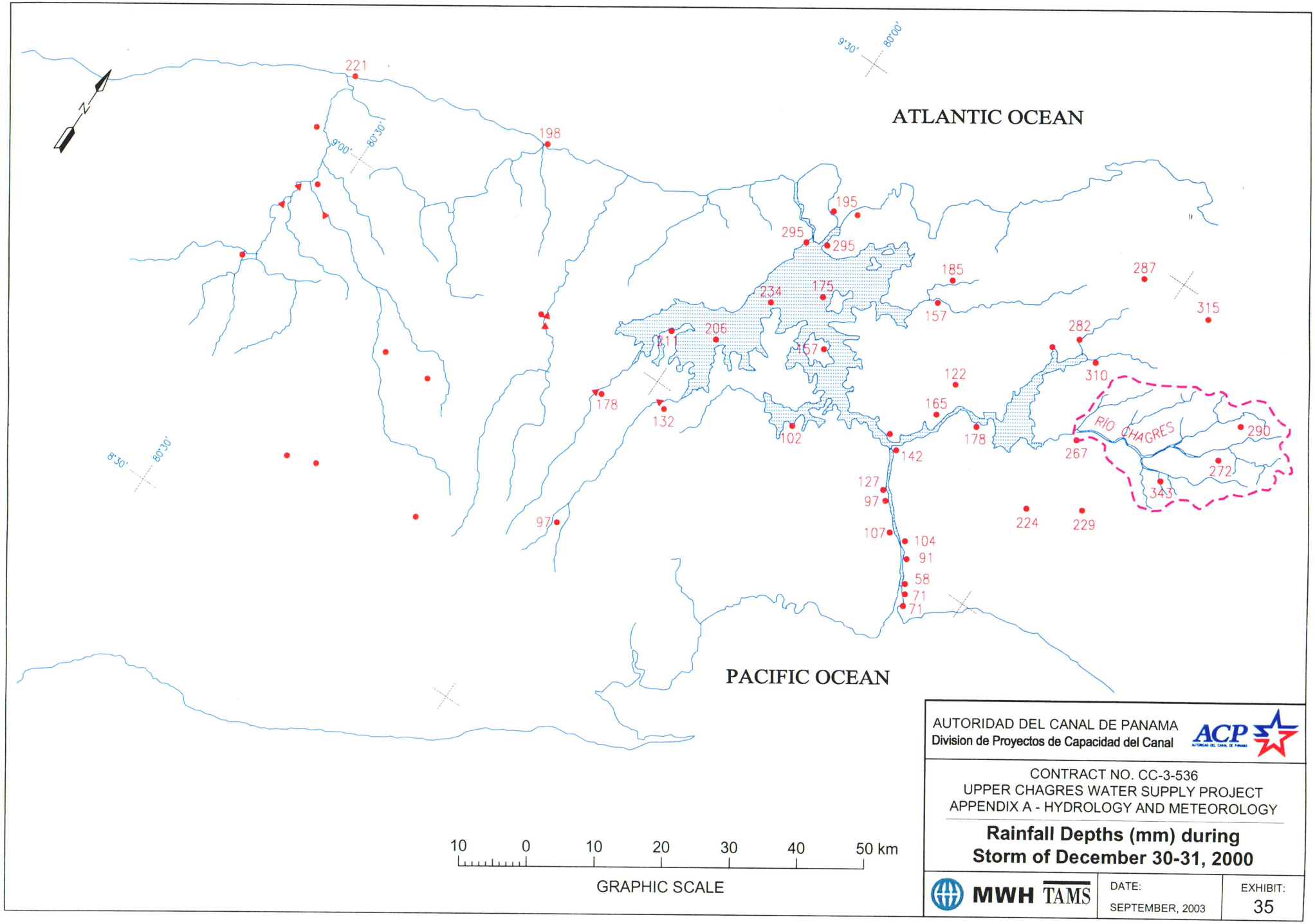
CONTRACT NO. CC-3-536
UPPER CHAGRES WATER SUPPLY PROJECT
APPENDIX A - HYDROLOGY AND METEOROLOGY

Rainfall Depths (mm) during Storm of November 27-29, 1996

MWH TAMS

DATE: SEPTEMBER, 2003

EXHIBIT: 34



AUTORIDAD DEL CANAL DE PANAMA
Division de Proyectos de Capacidad del Canal

ACP

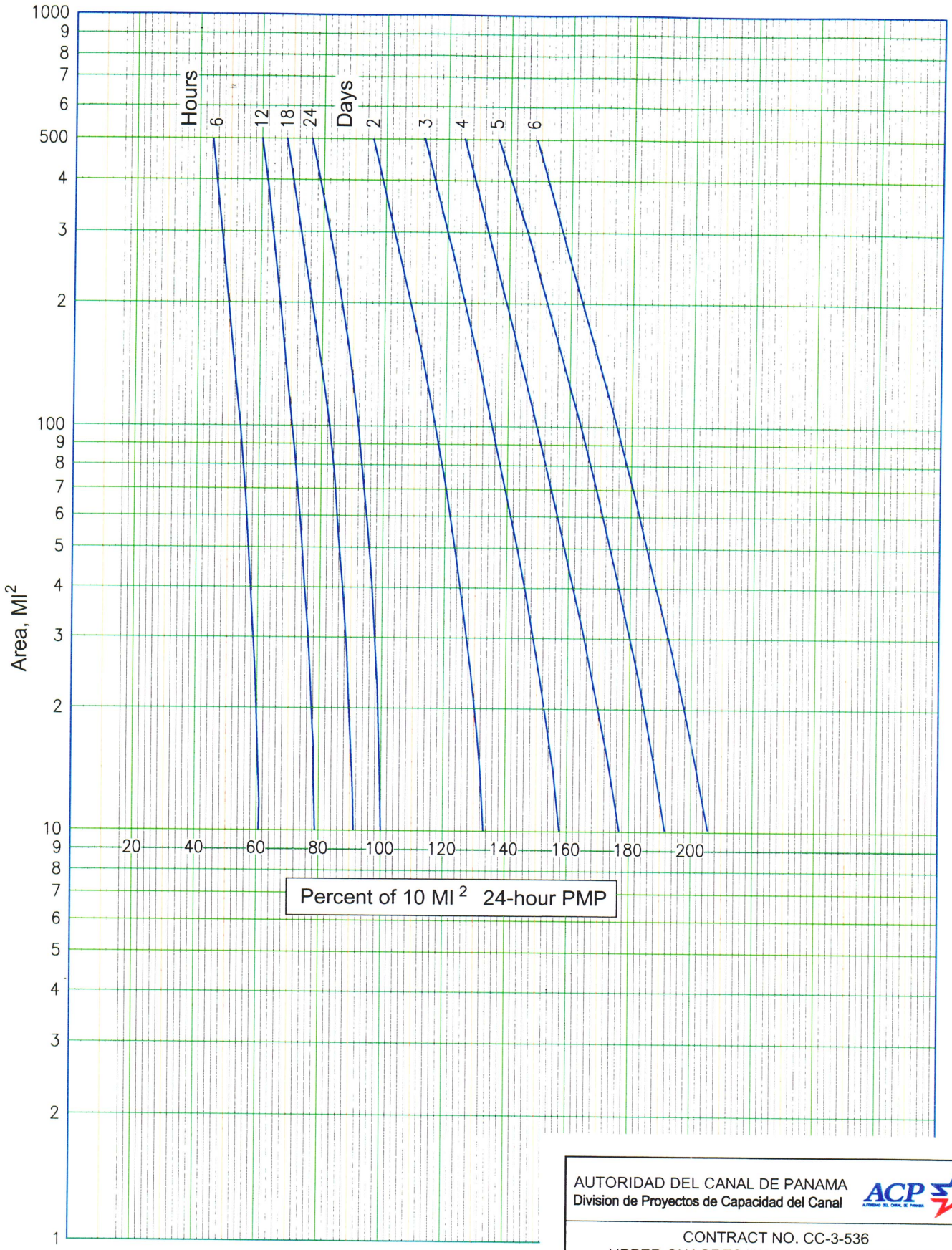
CONTRACT NO. CC-3-536
UPPER CHAGRES WATER SUPPLY PROJECT
APPENDIX A - HYDROLOGY AND METEOROLOGY

Rainfall Depths (mm) during Storm of December 30-31, 2000

MWH TAMS

DATE: SEPTEMBER, 2003

EXHIBIT: 35



Source:

US Weather Bureau, 1965 Report

AUTORIDAD DEL CANAL DE PANAMA
Division de Proyectos de Capacidad del Canal

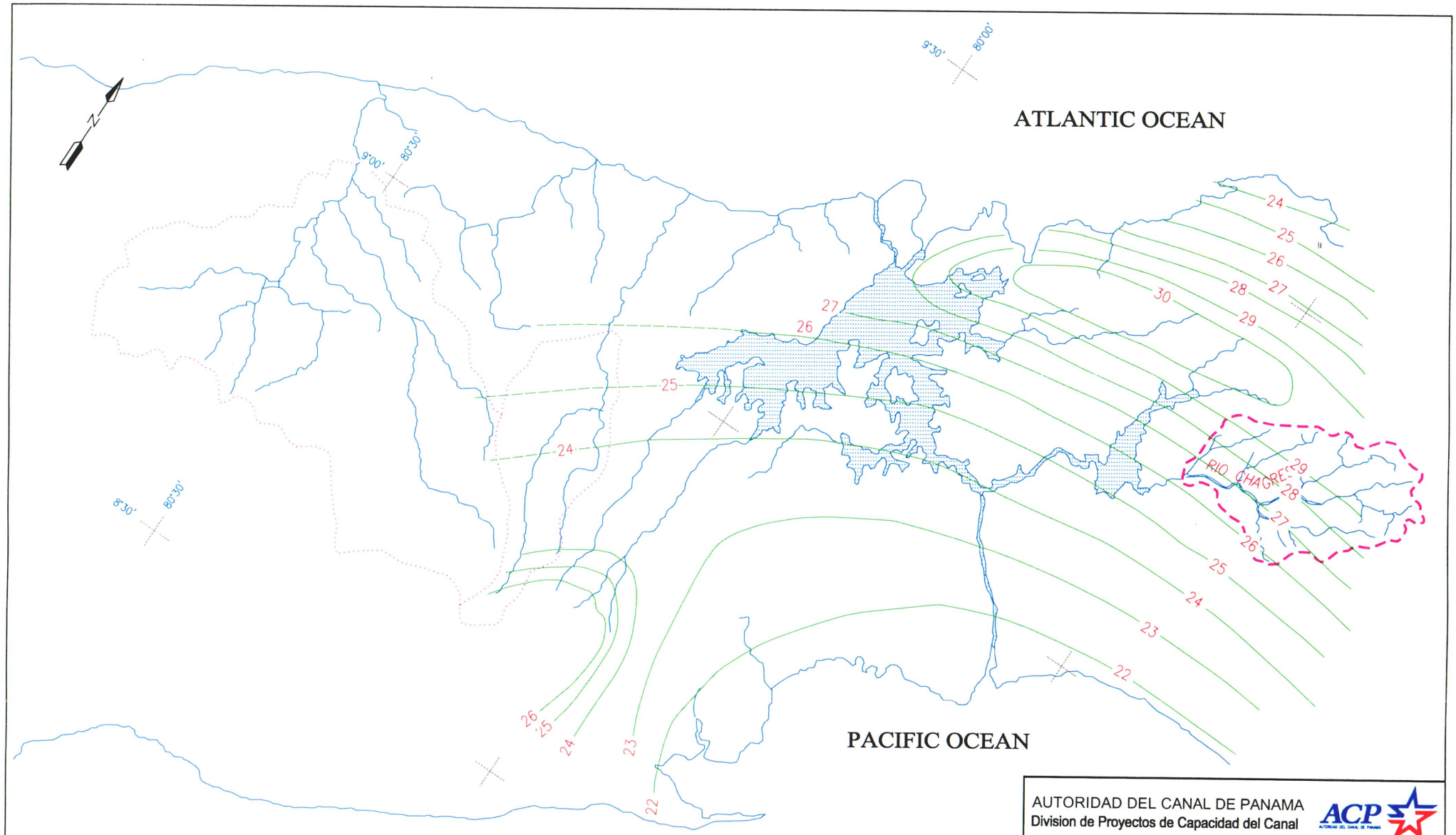
CONTRACT NO. CC-3-536
UPPER CHAGRES WATER SUPPLY PROJECT
APPENDIX A - HYDROLOGY AND METEOROLOGY

Depth-Area-Duration Curves

MWH TAMS

DATE: SEPTEMBER, 2003

EXHIBIT: 36



Source:

US NWS, February 1978 Report

10 0 10 20 30 40 50 km

GRAPHIC SCALE

AUTORIDAD DEL CANAL DE PANAMA
Division de Proyectos de Capacidad del Canal

ACP

CONTRACT NO. CC-3-536
UPPER CHAGRES WATER SUPPLY PROJECT
APPENDIX A - HYDROLOGY AND METEOROLOGY

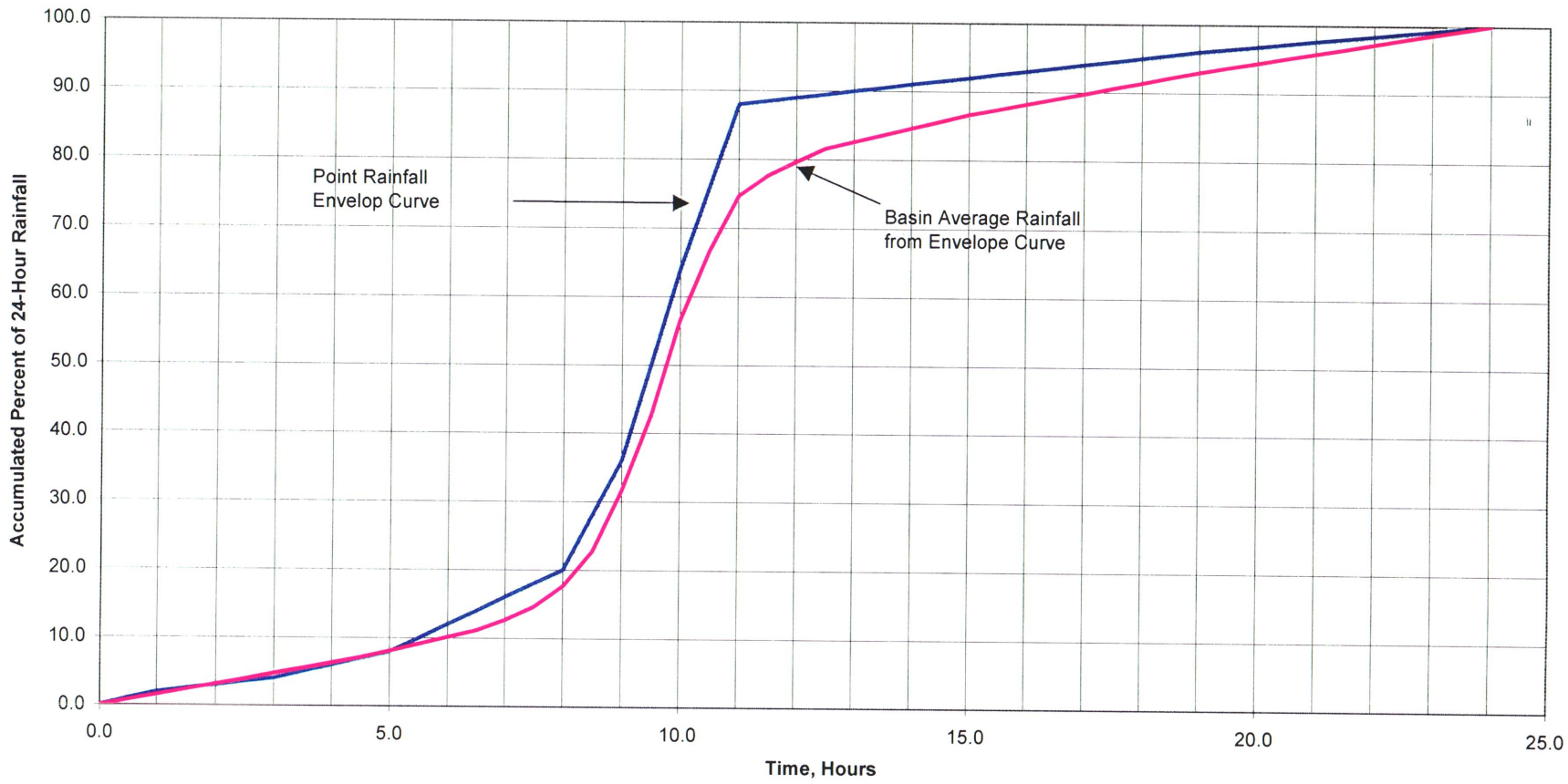
24-Hour, 10-MI^2 PMP
(inches)

MWH TAMS

DATE: SEPTEMBER, 2003

EXHIBIT: 37

MASS RAINFALL CURVES FOR UPPER RIO CHAGRES BASIN



AUTORIDAD DEL CANAL DE PANAMA
Division de Proyectos de Capacidad del Canal

CONTRACT NO. CC-3-536
UPPER CHAGRES WATER SUPPLY PROJECT
APPENDIX A - HYDROLOGY AND METEOROLOGY

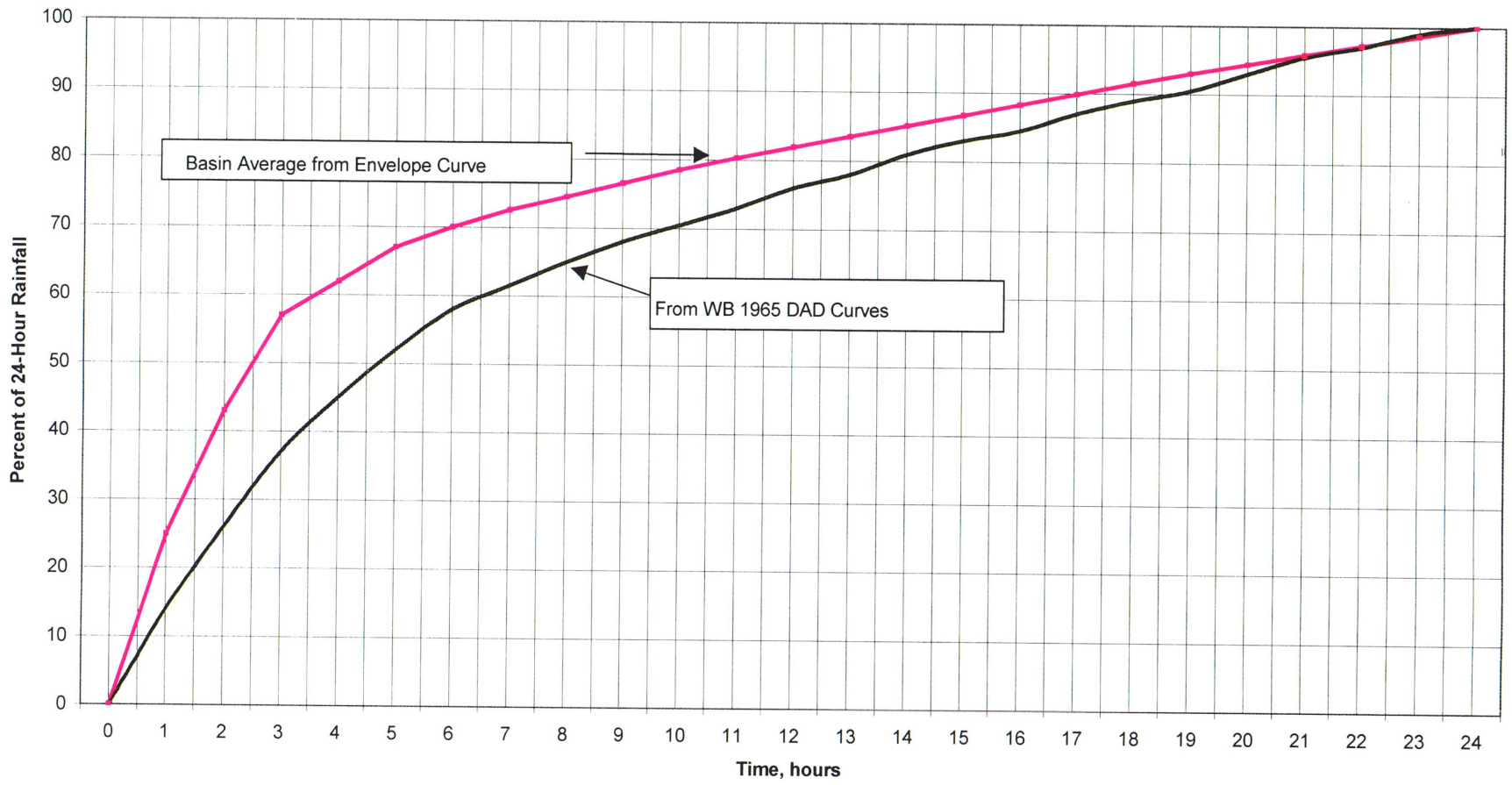
Mass Rainfall Curves for Upper Río Chagres Basin

MWH TAMS

DATE: SEPTEMBER, 2003

EXHIBIT: 38

RIO CHAGRES BASIN - DEPTH DURATION CURVES



AUTORIDAD DEL CANAL DE PANAMA
Division de Proyectos de Capacidad del Canal

CONTRACT NO. CC-3-536
UPPER CHAGRES WATER SUPPLY PROJECT
APPENDIX A - HYDROLOGY AND METEOROLOGY

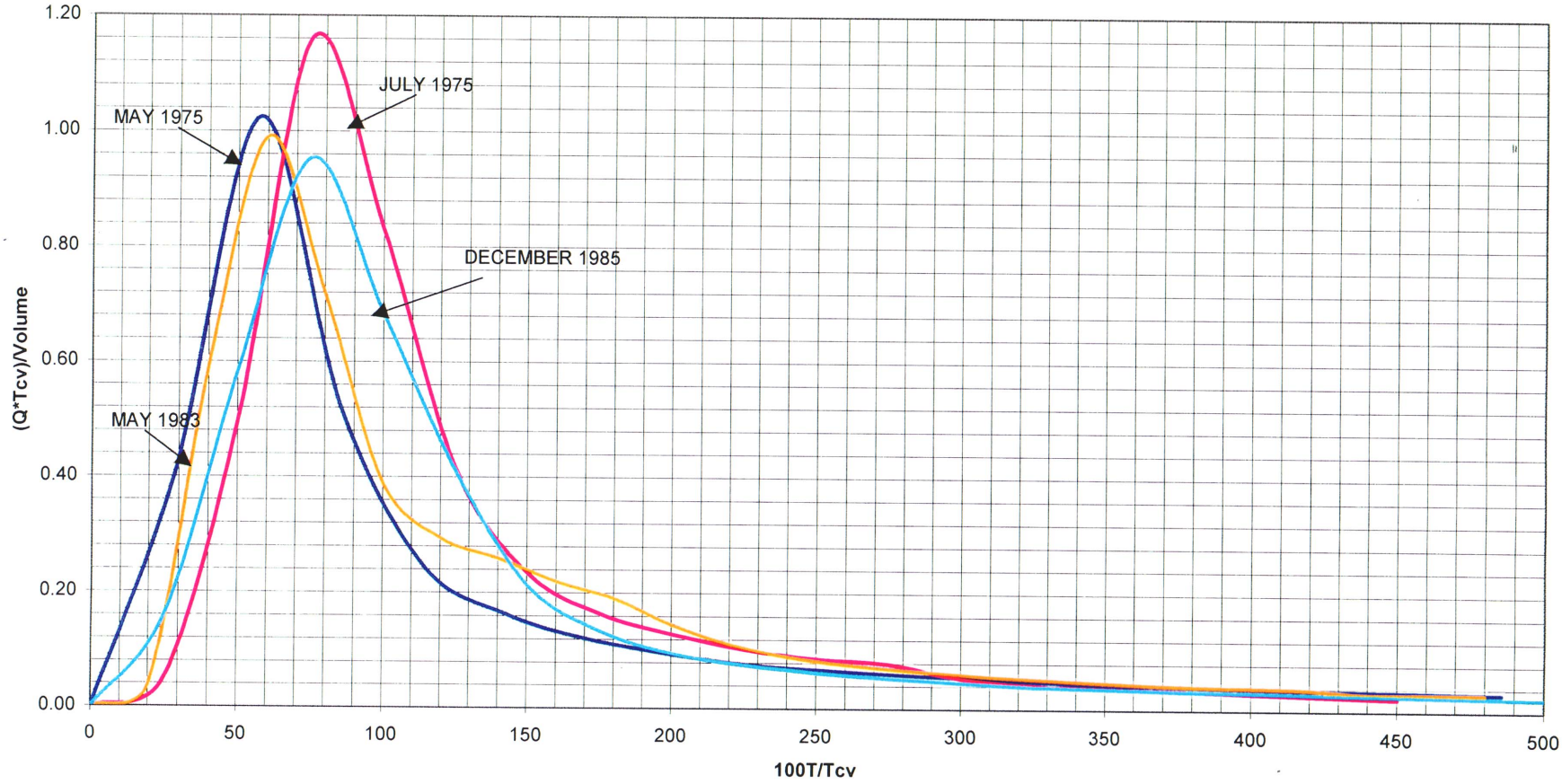
Upper Río Chagres Basin
Depth-Duration Curves

MWH TAMS

DATE: SEPTEMBER, 2003

EXHIBIT: 39

RIO CHAGRES AT CHICO - DIMENSIONLESS UNIT GRAPHS



AUTORIDAD DEL CANAL DE PANAMA
Division de Proyectos de Capacidad del Canal

CONTRACT NO. CC-3-536
UPPER CHAGRES WATER SUPPLY PROJECT
APPENDIX A - HYDROLOGY AND METEOROLOGY

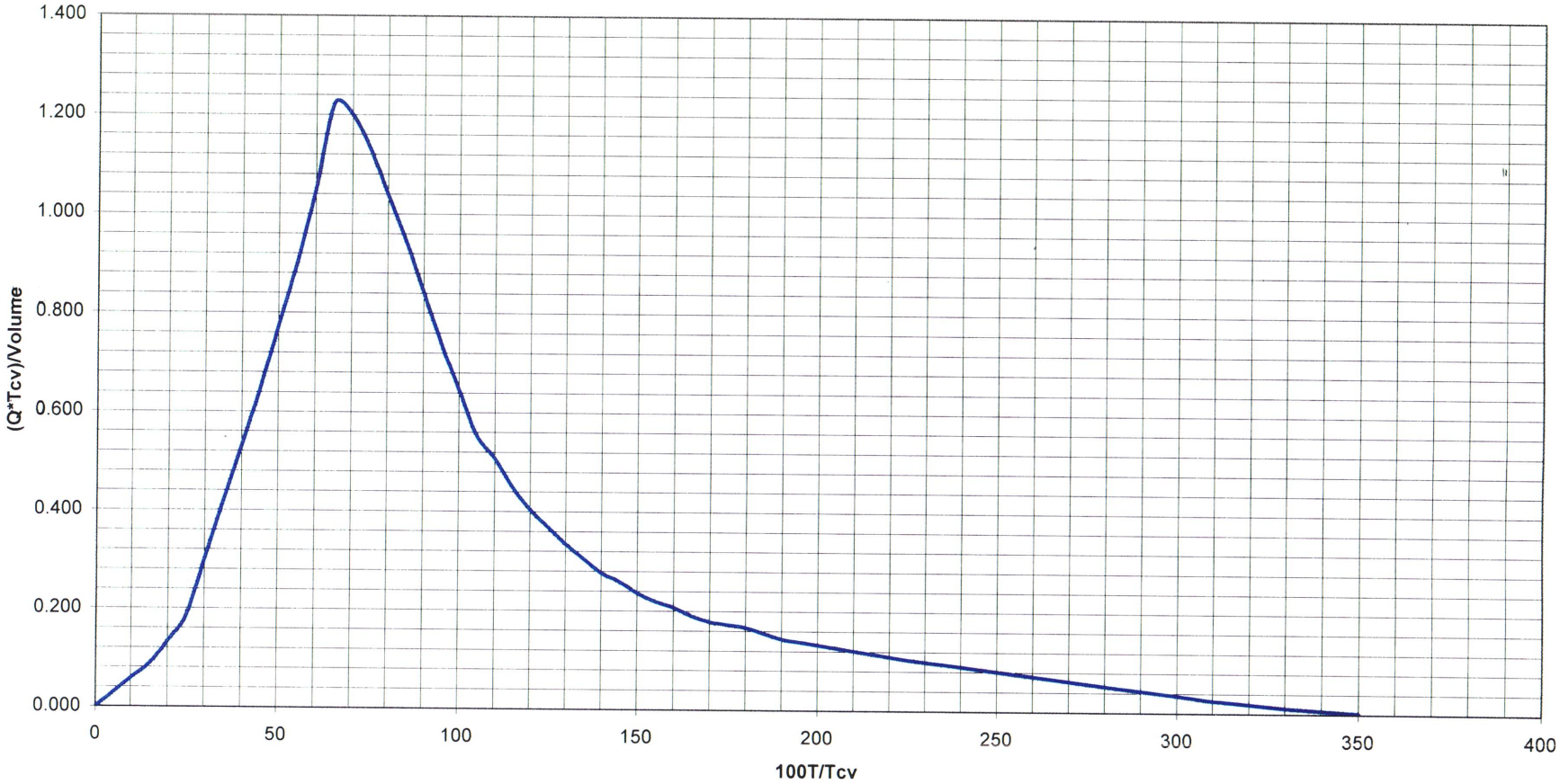
Río Chagres at Chico
Dimensionless Unit Graphs

MWH TAMS

DATE: SEPTEMBER, 2003

EXHIBIT: 40

RIO CHAGRES AT CHICO - AVERAGE DIMENSIONLESS UNIT GRAPH



AUTORIDAD DEL CANAL DE PANAMA
Division de Proyectos de Capacidad del Canal

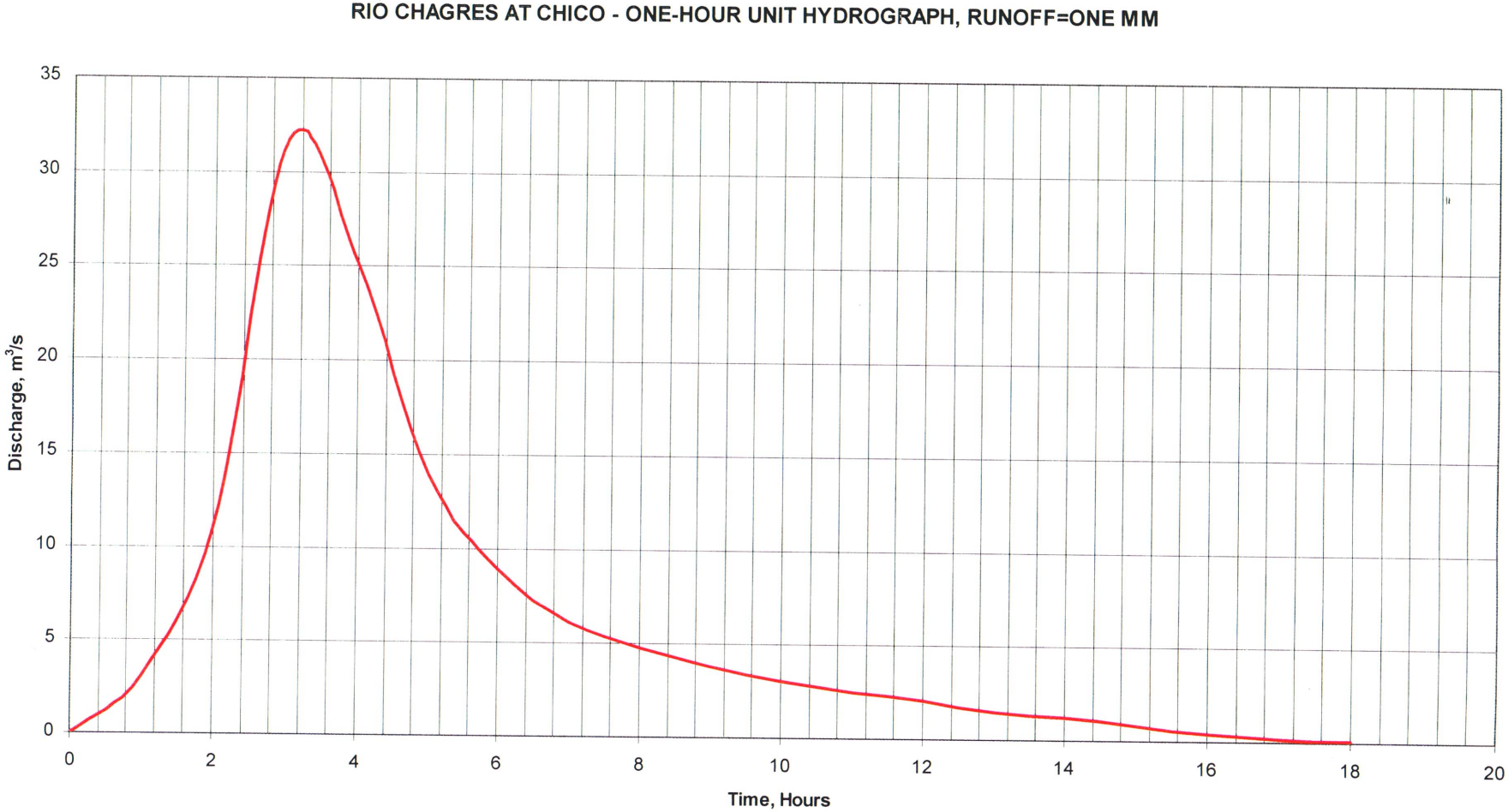
CONTRACT NO. CC-3-536
UPPER CHAGRES WATER SUPPLY PROJECT
APPENDIX A - HYDROLOGY AND METEOROLOGY

Río Chagres at Chico
Average Dimensionless Unit Graph

MWH TAMS

DATE: SEPTEMBER, 2003

EXHIBIT: 41



AUTORIDAD DEL CANAL DE PANAMA
Division de Proyectos de Capacidad del Canal

CONTRACT NO. CC-3-536
UPPER CHAGRES WATER SUPPLY PROJECT
APPENDIX A - HYDROLOGY AND METEOROLOGY

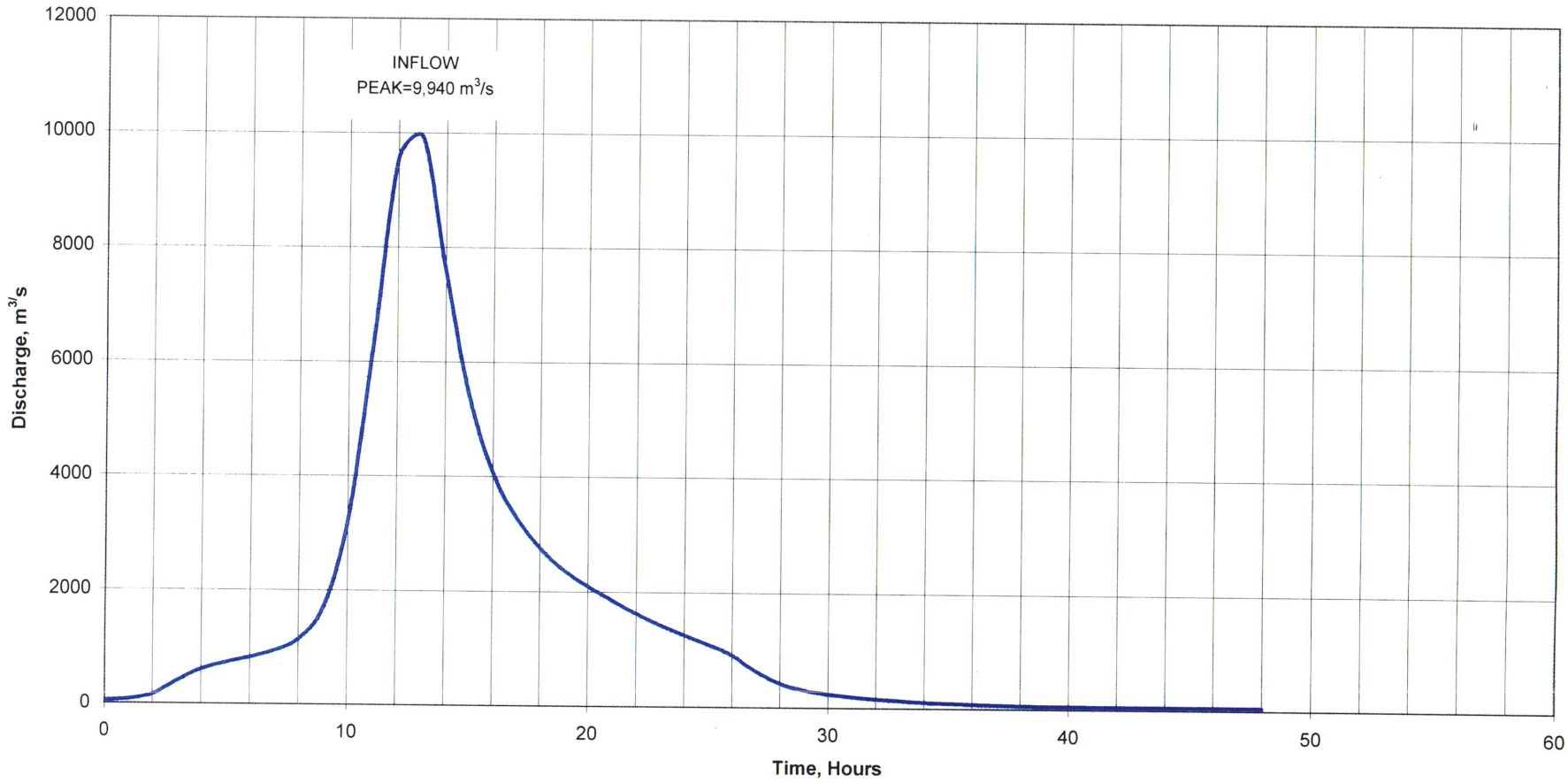
Río Chagres at Chico
One-Hour Unit Hydrograph

MWH TAMS

DATE: SEPTEMBER, 2003

EXHIBIT: 42

INFLOW - PMF HYDROGRAPH



AUTORIDAD DEL CANAL DE PANAMA
Division de Proyectos de Capacidad del Canal

CONTRACT NO. CC-3-536
UPPER CHAGRES WATER SUPPLY PROJECT
APPENDIX A - HYDROLOGY AND METEOROLOGY

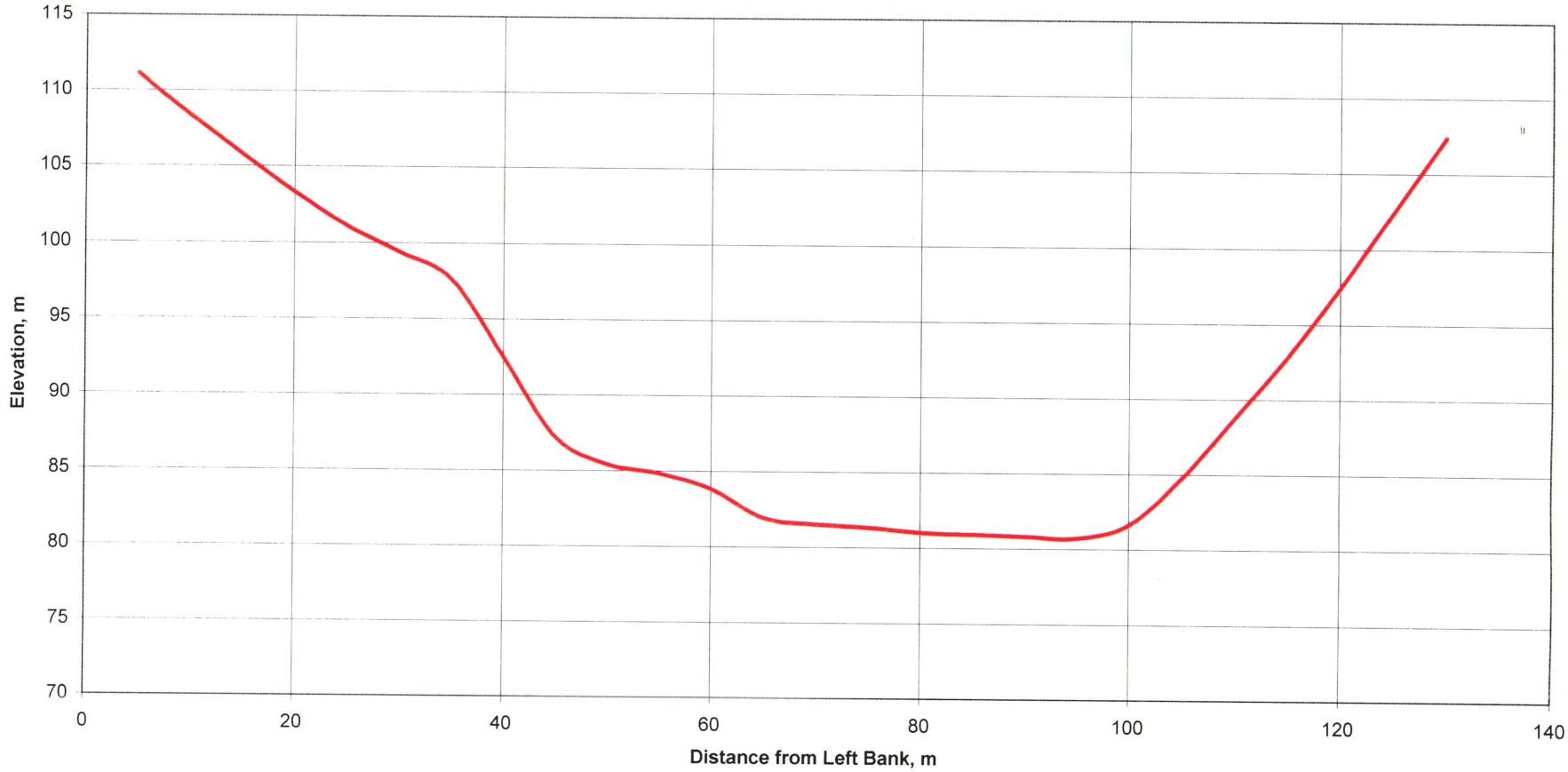
Inflow PMF Hydrograph

MWH TAMS

DATE: SEPTEMBER, 2003

EXHIBIT: 43

RIO CHAGRES - REPRESENTATIVE CROSS SECTION
(SECTION 4)



AUTORIDAD DEL CANAL DE PANAMA
Division de Proyectos de Capacidad del Canal

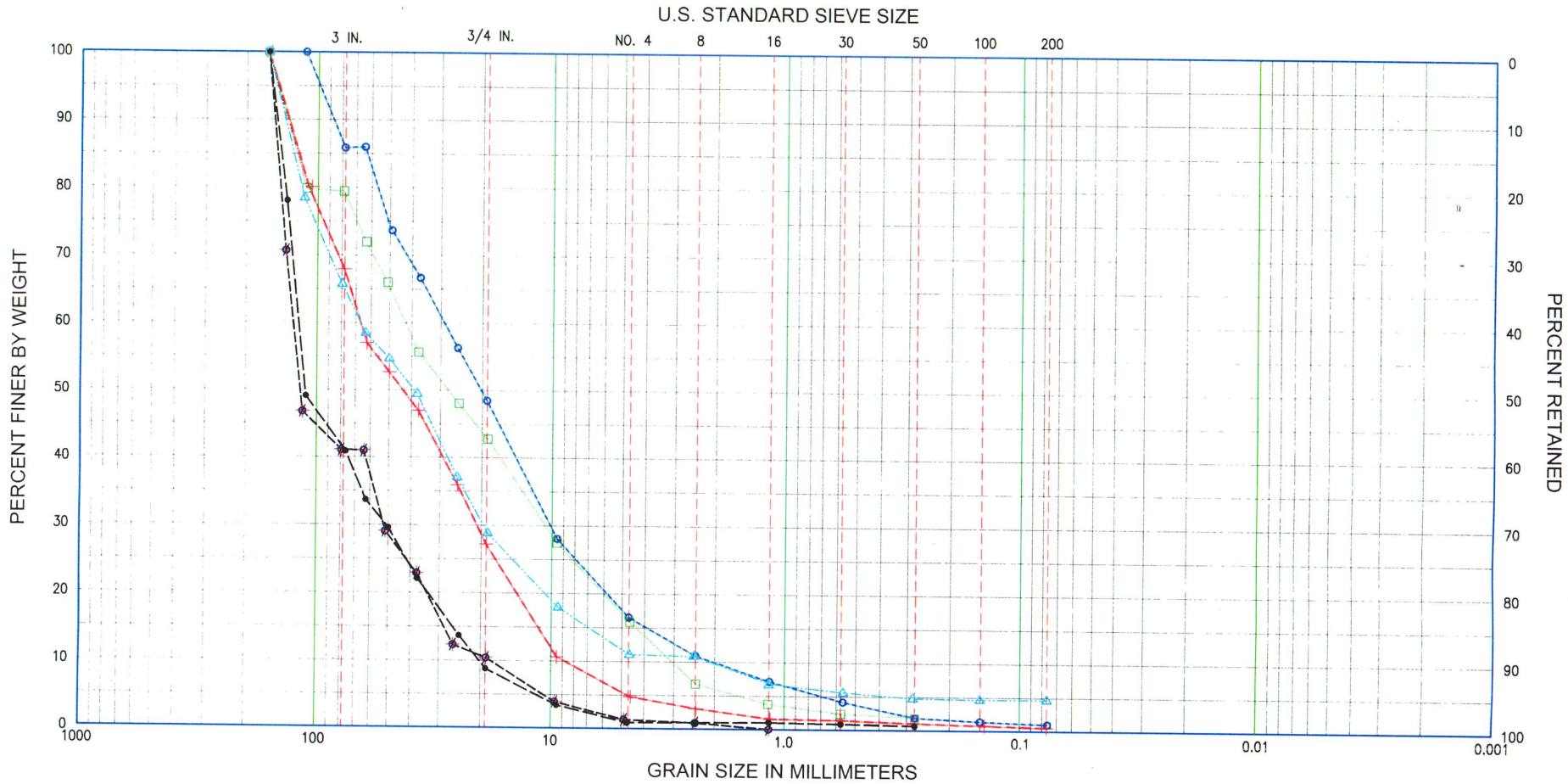
CONTRACT NO. CC-3-536
UPPER CHAGRES WATER SUPPLY PROJECT
APPENDIX A - HYDROLOGY AND METEOROLOGY

Río Chagres
Representative Cross Section

MWH TAMS

DATE: SEPTEMBER, 2003

EXHIBIT: 44



AUTORIDAD DEL CANAL DE PANAMA
Division de Proyectos de Capacidad del Canal

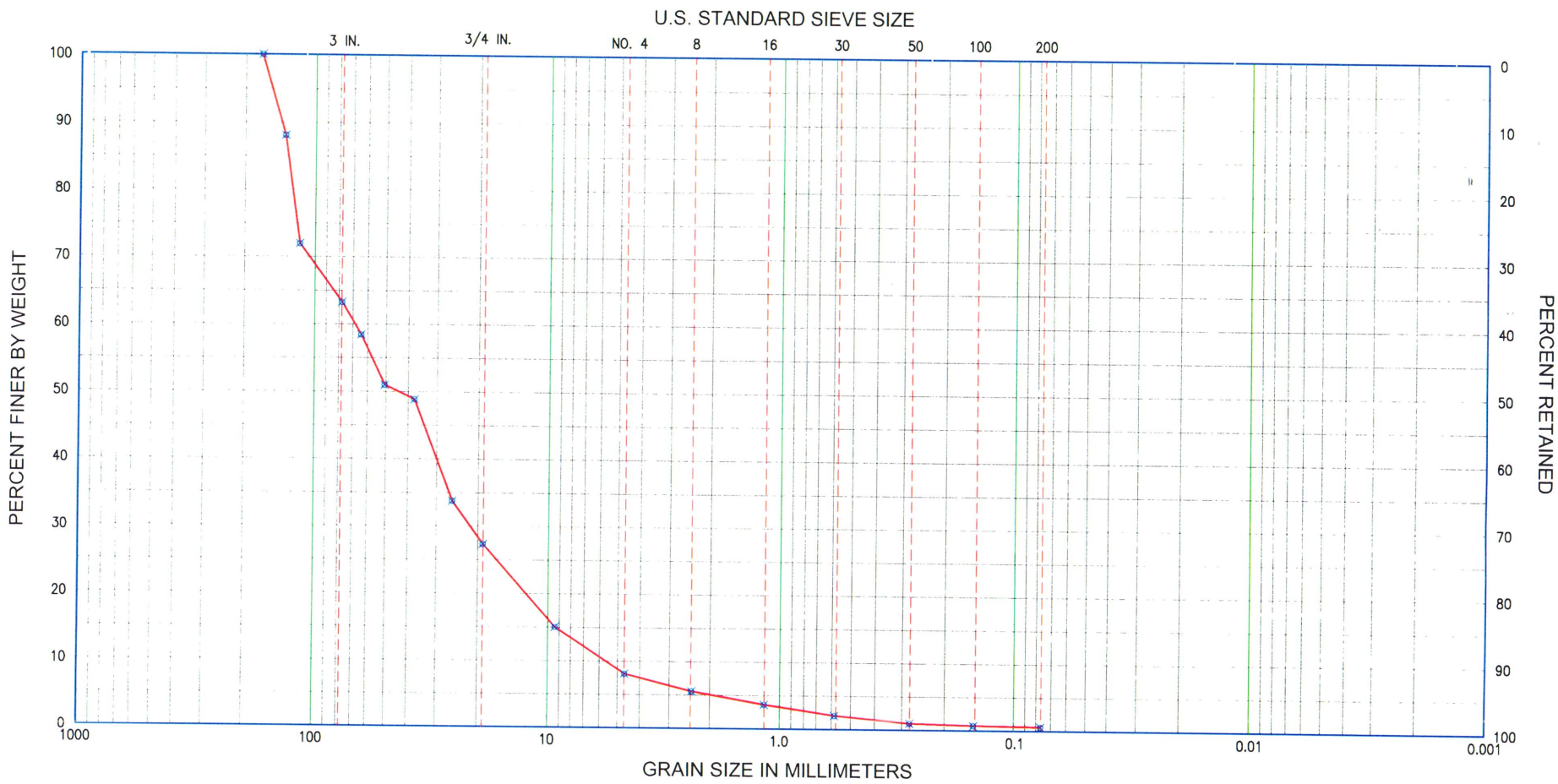
CONTRACT NO. CC-3-536
UPPER CHAGRES WATER SUPPLY PROJECT
APPENDIX A - HYDROLOGY AND METEOROLOGY

Bed Material Samples
Particle Size Distribution

MWH TAMS

DATE: SEPTEMBER, 2003

EXHIBIT: 45



AUTORIDAD DEL CANAL DE PANAMA
Division de Proyectos de Capacidad del Canal

CONTRACT NO. CC-3-536
UPPER CHAGRES WATER SUPPLY PROJECT
APPENDIX A - HYDROLOGY AND METEOROLOGY

Bed Material Average Particle Size Distribution

MWH TAMS

DATE: SEPTEMBER, 2003

EXHIBIT: 46

ATTACHMENTS

Attachment 1 – HEC-1, Calibration Output

```
1****************************************
*                                      *
*   FLOOD HYDROGRAPH PACKAGE  (HEC-1)  *
*            SEPTEMBER 1990            *
*             VERSION 4.0              *
*                                      *
*  RUN DATE  01/30/2002  TIME  14:53:14 *
*                                      *
****************************************
```

```
****************************************
*                                      *
*    U.S. ARMY CORPS OF ENGINEERS      *
*    HYDROLOGIC ENGINEERING CENTER     *
*          609 SECOND STREET           *
*       DAVIS, CALIFORNIA 95616        *
*           (916) 756-1104             *
*                                      *
****************************************
```

```
X     X  XXXXXXX   XXXXX           X
X     X  X        X     X         XX
X     X  X        X                X
XXXXXXX  XXXX     X        XXXXX   X
X     X  X        X                X
X     X  X        X     X          X
X     X  XXXXXXX   XXXXX          XXX
```

THIS PROGRAM REPLACES ALL PREVIOUS VERSIONS OF HEC-1 KNOWN AS HEC1 (JAN 73), HEC1GS, HEC1DB, AND HEC1KW.

THE DEFINITIONS OF VARIABLES -RTIMP- AND -RTIOR- HAVE CHANGED FROM THOSE USED WITH THE 1973-STYLE INPUT STRUCTURE.
THE DEFINITION OF -AMSKK- ON RM-CARD WAS CHANGED WITH REVISIONS DATED 28 SEP 81. THIS IS THE FORTRAN77 VERSION
NEW OPTIONS: DAMBREAK OUTFLOW SUBMERGENCE , SINGLE EVENT DAMAGE CALCULATION, DSS:WRITE STAGE FREQUENCY,
DSS:READ TIME SERIES AT DESIRED CALCULATION INTERVAL LOSS RATE:GREEN AND AMPT INFILTRATION
KINEMATIC WAVE: NEW FINITE DIFFERENCE ALGORITHM

```
1                                          HEC-1 INPUT                                                    PAGE  1

      LINE          ID.......1.......2.......3.......4.......5.......6.......7.......8.......9......10

        1           ID        SIMULATION OF DECEMBER 1985 FLOOD
        2           ID        CHAGRES RIVER AT CHICO
        3           ID        VERIFICATION OF UNIT HYDROGRAPH
        4           IT      60 20NOV01     600         22NOV01     600
        5           IN      60 20NOV01     600
        6           IO       1       2

        7           KK   BASIN
        8           KM        CHAGRES
        9           BA  159.85
       10           BF     800
       11           PB     4.2
       12           PI     0.1     0.9     0.9     1.3     0.6     0.3
```

```
          13          LU     0.0    0.05     0.0
          14          UI    2700   10000   28400   22500   12500    8000    5500    4290    3400    2740
          15          UI    2250    1850    1480    1090     720     370     140      20

          16          KK        OBSERVED HYDROGRAPH
          17          KM        AT CHICO
          18          QO    3441    2974    2624    2743   14174   45453   72635   52962   33018   18438
          19          QO   12631    9801    8314    7322    6633    6103    5646    5414    5154    5005
          20          QO    4825    4701    4524    4390    4310    4231    4074    3996    3957    3970
          21          QO    4152    4035    4087
          22          ZZ
1*****************************************                                    *****************************************
 *                                         *                                    *                                       *
 *   FLOOD HYDROGRAPH PACKAGE  (HEC-1)     *                                    *    U.S. ARMY CORPS OF ENGINEERS       *
 *            SEPTEMBER 1990               *                                    *    HYDROLOGIC ENGINEERING CENTER      *
 *             VERSION 4.0                 *                                    *          609 SECOND STREET            *
 *                                         *                                    *       DAVIS, CALIFORNIA 95616         *
 *  RUN DATE  01/30/2002  TIME  14:53:14   *                                    *           (916) 756-1104              *
 *                                         *                                    *                                       *
 *****************************************                                    *****************************************


                                SIMULATION OF DECEMBER 1985 FLOOD
                                CHAGRES RIVER AT CHICO
                                VERIFICATION OF UNIT HYDROGRAPH

    6 IO          OUTPUT CONTROL VARIABLES
                        IPRNT           1  PRINT CONTROL
                        IPLOT           2  PLOT CONTROL
                        QSCAL          0.  HYDROGRAPH PLOT SCALE

      IT          HYDROGRAPH TIME DATA
                         NMIN          60  MINUTES IN COMPUTATION INTERVAL
                        IDATE     20NOV 1  STARTING DATE
                        ITIME        0600  STARTING TIME
                           NQ          49  NUMBER OF HYDROGRAPH ORDINATES
                       NDDATE     22NOV 1  ENDING DATE
                       NDTIME        0600  ENDING TIME
                       ICENT          19  CENTURY MARK

                  COMPUTATION INTERVAL    1.00 HOURS
                       TOTAL TIME BASE   48.00 HOURS

          ENGLISH UNITS
               DRAINAGE AREA          SQUARE MILES
               PRECIPITATION DEPTH    INCHES
               LENGTH, ELEVATION      FEET
               FLOW                   CUBIC FEET PER SECOND
```

```
STORAGE VOLUME        ACRE-FEET
SURFACE AREA          ACRES
TEMPERATURE           DEGREES FAHRENHEIT

*** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** ***

          **************
          *            *
  7 KK    *     BASIN  *
          *            *
          **************
                          CHAGRES

  5 IN          TIME DATA FOR INPUT TIME SERIES
                      JXMIN          60  TIME INTERVAL IN MINUTES
                     JXDATE     20NOV 1  STARTING DATE
                     JXTIME         600  STARTING TIME

              SUBBASIN RUNOFF DATA

  9 BA          SUBBASIN CHARACTERISTICS
                      TAREA      159.85  SUBBASIN AREA

 10 BF          BASE FLOW CHARACTERISTICS
                      STRTQ      800.00  INITIAL FLOW
                      QRCSN         .00  BEGIN BASE FLOW RECESSION
                      RTIOR     1.00000  RECESSION CONSTANT

                PRECIPITATION DATA

 11 PB                STORM        4.20  BASIN TOTAL PRECIPITATION

 12 PI            INCREMENTAL PRECIPITATION PATTERN
                      .10       .90       .90      1.30       .60       .30

 13 LU          UNIFORM LOSS RATE
                      STRTL         .00  INITIAL LOSS
                      CNSTL         .05  UNIFORM LOSS RATE
                      RTIMP         .00  PERCENT IMPERVIOUS AREA

 13 UI          INPUT UNITGRAPH,  18 ORDINATES,  VOLUME = 1.05
                   2700.0   10000.0   28400.0   22500.0   12500.0    8000.0    5500.0    4290.0    3400.0    2740.0
                   2250.0    1850.0    1480.0    1090.0     720.0     370.0     140.0      20.0
                                                                  ***
*************************************************************************************************************************************
```

HYDROGRAPH AT STATION BASIN

DA MON HRMN	ORD	RAIN	LOSS	EXCESS	COMP Q	DA MON HRMN	ORD	RAIN	LOSS	EXCESS	COMP Q
20 NOV 0600	1	.00	.00	.00	800.	21 NOV 0700	26	.00	.00	.00	800.
20 NOV 0700	2	.10	.05	.05	942.	21 NOV 0800	27	.00	.00	.00	800.
20 NOV 0800	3	.92	.05	.87	3679.	21 NOV 0900	28	.00	.00	.00	800.
20 NOV 0900	4	.92	.05	.87	13363.	21 NOV 1000	29	.00	.00	.00	800.
20 NOV 1000	5	1.33	.05	1.28	38923.	21 NOV 1100	30	.00	.00	.00	800.
20 NOV 1100	6	.61	.05	.56	60179.	21 NOV 1200	31	.00	.00	.00	800.
20 NOV 1200	7	.31	.05	.26	74479.	21 NOV 1300	32	.00	.00	.00	800.
20 NOV 1300	8	.00	.00	.00	66411.	21 NOV 1400	33	.00	.00	.00	800.
20 NOV 1400	9	.00	.00	.00	48830.	21 NOV 1500	34	.00	.00	.00	800.
20 NOV 1500	10	.00	.00	.00	32616.	21 NOV 1600	35	.00	.00	.00	800.
20 NOV 1600	11	.00	.00	.00	22432.	21 NOV 1700	36	.00	.00	.00	800.
20 NOV 1700	12	.00	.00	.00	16934.	21 NOV 1800	37	.00	.00	.00	800.
20 NOV 1800	13	.00	.00	.00	13443.	21 NOV 1900	38	.00	.00	.00	800.
20 NOV 1900	14	.00	.00	.00	10988.	21 NOV 2000	39	.00	.00	.00	800.
20 NOV 2000	15	.00	.00	.00	9067.	21 NOV 2100	40	.00	.00	.00	800.
20 NOV 2100	16	.00	.00	.00	7425.	21 NOV 2200	41	.00	.00	.00	800.
20 NOV 2200	17	.00	.00	.00	5918.	21 NOV 2300	42	.00	.00	.00	800.
20 NOV 2300	18	.00	.00	.00	4467.	22 NOV 0000	43	.00	.00	.00	800.
21 NOV 0000	19	.00	.00	.00	3165.	22 NOV 0100	44	.00	.00	.00	800.
21 NOV 0100	20	.00	.00	.00	2101.	22 NOV 0200	45	.00	.00	.00	800.
21 NOV 0200	21	.00	.00	.00	1391.	22 NOV 0300	46	.00	.00	.00	800.
21 NOV 0300	22	.00	.00	.00	1000.	22 NOV 0400	47	.00	.00	.00	800.
21 NOV 0400	23	.00	.00	.00	847.	22 NOV 0500	48	.00	.00	.00	800.
21 NOV 0500	24	.00	.00	.00	805.	22 NOV 0600	49	.00	.00	.00	800.
21 NOV 0600	25	.00	.00	.00	800.						

TOTAL RAINFALL = 4.20, TOTAL LOSS = .30, TOTAL EXCESS = 3.90

	PEAK FLOW (CFS)	TIME (HR)		MAXIMUM AVERAGE FLOW 6-HR	24-HR	72-HR	48.00-HR
+			(CFS)				
+	74479.	6.00		52199.	18342.	9571.	9571.
			(INCHES)	3.036	4.267	4.453	4.453
			(AC-FT)	25884.	36381.	37967.	37967.

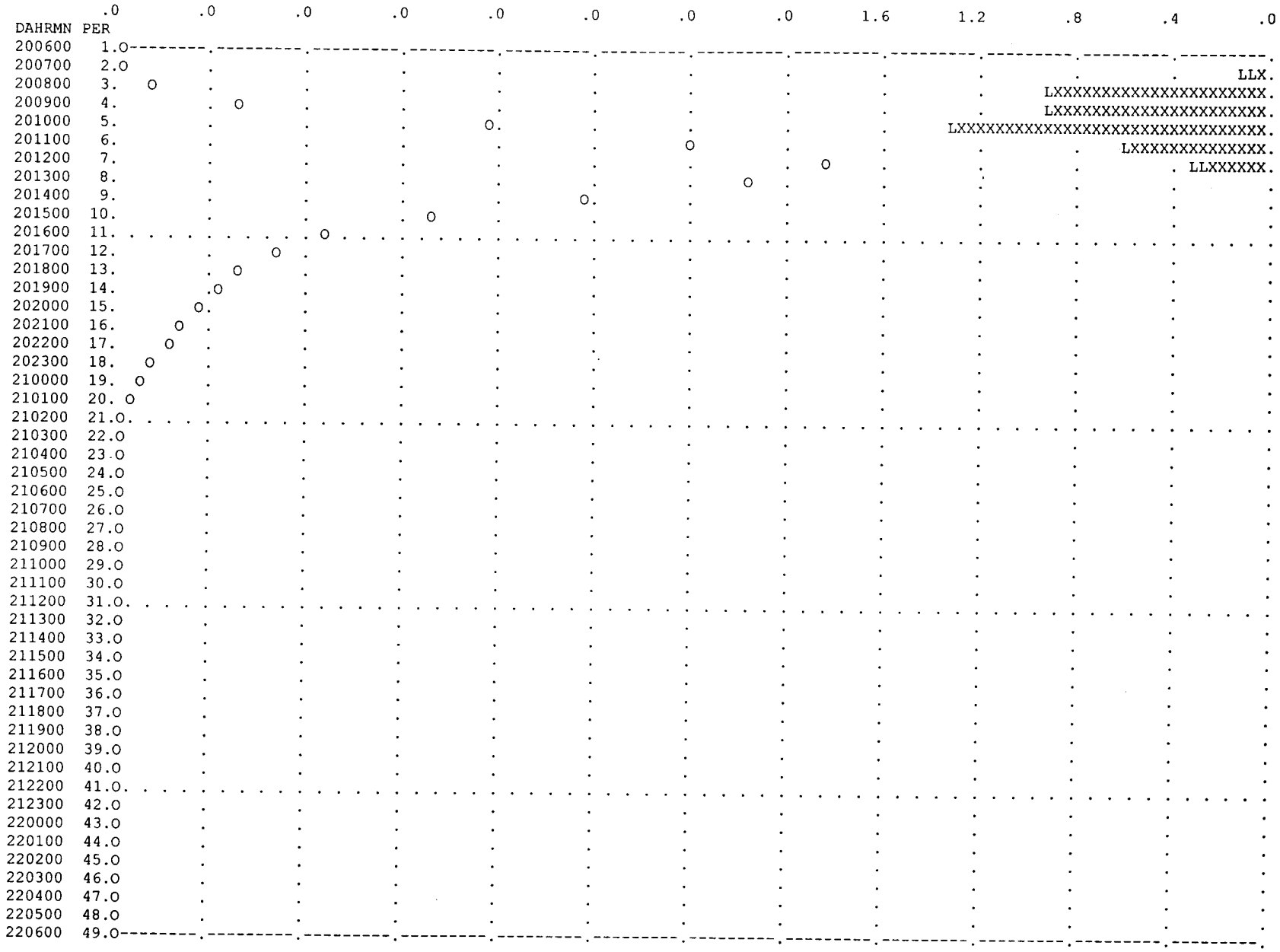
CUMULATIVE AREA = 159.85 SQ MI

1 STATION BASIN

(O) OUTFLOW

0. 10000. 20000. 30000. 40000. 50000. 60000. 70000. 80000. 0. 0. 0. 0.

(L) PRECIP, (X) EXCESS


.0 .0 .0 .0 .0 .0 .0 .0 1.6 1.2 .8 .4 .0
DAHRMN PER
200600 1.0
200700 2.0
200800 3.
200900 4.
201000 5.
201100 6.
201200 7.
201300 8.
201400 9.
201500 10.
201600 11.
201700 12.
201800 13.
201900 14.
202000 15.
202100 16.
202200 17.
202300 18.
210000 19.
210100 20.
210200 21.0
210300 22.0
210400 23.0
210500 24.0
210600 25.0
210700 26.0
210800 27.0
210900 28.0
211000 29.0
211100 30.0
211200 31.0
211300 32.0
211400 33.0
211500 34.0
211600 35.0
211700 36.0
211800 37.0
211900 38.0
212000 39.0
212100 40.0
212200 41.0
212300 42.0
220000 43.0
220100 44.0
220200 45.0
220300 46.0
220400 47.0
220500 48.0
220600 49.0
LLX
LXXXXXXXXXXXXXXXXXXXXXX
LXXXXXXXXXXXXXXXXXXXXXX
LXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
LXXXXXXXXXXXXXXX
LLXXXXXX

1

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*** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** ***

          **************
          *            *
  16 KK   *            *     OBSERVED HYDROGRAPH
          *            *
          **************
                              AT CHICO

   5 IN          TIME DATA FOR INPUT TIME SERIES
                      JXMIN          60  TIME INTERVAL IN MINUTES
                     JXDATE     20NOV 1  STARTING DATE
                     JXTIME         600  STARTING TIME

                                                        ***


    ************************************************************************************************************************
    *                                                                                                                      *
    *                                   COMPARISON OF COMPUTED AND OBSERVED HYDROGRAPHS                                    *
    *                                                                                                                      *
    ************************************************************************************************************************
    *                                                                                                                      *
    *                                                                                TIME TO       LAG                     *
    *                                SUM OF       EQUIV         MEAN       CENTER      C.M. TO       PEAK       TIME OF     *
    *                                 FLOWS       DEPTH         FLOW       OF MASS       C.M.        FLOW        PEAK       *
    *                                                                                                                      *
    *     COMPUTED HYDROGRAPH       460205.       4.461         9392.        9.97        9.97       74479.       6.00      *
    *     OBSERVED HYDROGRAPH       441129.       4.276         9003.       15.95       15.95       72635.       6.00      *
    *                                                                                                                      *
    *     DIFFERENCE                 19076.        .185          389.       -5.98       -5.98        1844.        .00      *
    *     PERCENT DIFFERENCE           4.32                                            -37.49         2.54                 *
    *                                                                                                                      *
    *                       STANDARD ERROR     6577.                        AVERAGE ABSOLUTE ERROR     4761.                *
    *                    OBJECTIVE FUNCTION    8467.                 AVERAGE PERCENT ABSOLUTE ERROR    75.41                *
    *                                                                                                                      *
    ************************************************************************************************************************

*****************************************************************************************************************************

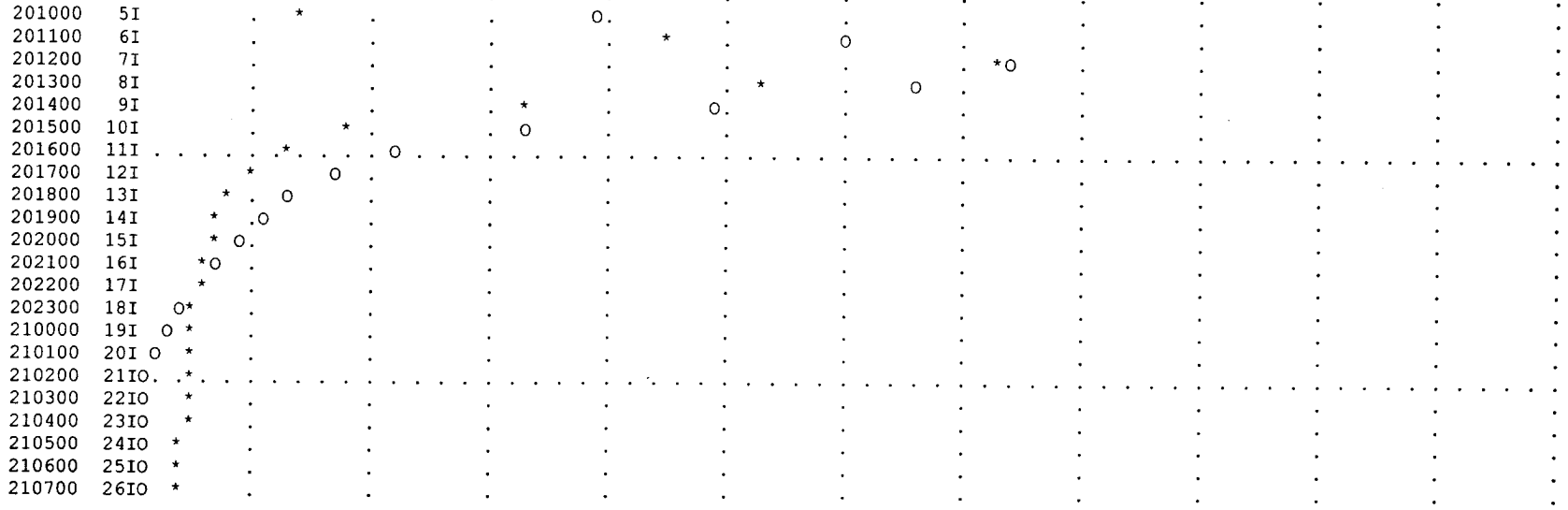
                                                HYDROGRAPH AT STATION

*****************************************************************************************************************************
                                        *                                        *
 DA MON HRMN ORD   COMP Q   OBS Q  RESIDUL * DA MON HRMN ORD   COMP Q   OBS Q  RESIDUL * DA MON HRMN ORD   COMP Q   OBS Q  RESIDUL
```

20 NOV 0600	1	800.	3441.	-2641.	*	20 NOV 2300	18	4467.	5414.	-947.	*	21 NOV 1600	35	800.	4087.	-3287.
20 NOV 0700	2	942.	2974.	-2032.	*	21 NOV 0000	19	3165.	5154.	-1989.	*	21 NOV 1700	36	800.	4087.	-3287.
20 NOV 0800	3	3679.	2624.	1055.	*	21 NOV 0100	20	2101.	5005.	-2904.	*	21 NOV 1800	37	800.	4087.	-3287.
20 NOV 0900	4	13363.	2743.	10620.	*	21 NOV 0200	21	1391.	4825.	-3434.	*	21 NOV 1900	38	800.	4087.	-3287.
20 NOV 1000	5	38923.	14174.	24749.	*	21 NOV 0300	22	1000.	4701.	-3701.	*	21 NOV 2000	39	800.	4087.	-3287.
20 NOV 1100	6	60179.	45453.	14726.	*	21 NOV 0400	23	847.	4524.	-3677.	*	21 NOV 2100	40	800.	4087.	-3287.
20 NOV 1200	7	74479.	72635.	1844.	*	21 NOV 0500	24	805.	4390.	-3585.	*	21 NOV 2200	41	800.	4087.	-3287.
20 NOV 1300	8	66411.	52962.	13449.	*	21 NOV 0600	25	800.	4310.	-3510.	*	21 NOV 2300	42	800.	4087.	-3287.
20 NOV 1400	9	48830.	33018.	15812.	*	21 NOV 0700	26	800.	4231.	-3431.	*	22 NOV 0000	43	800.	4087.	-3287.
20 NOV 1500	10	32616.	18438.	14178.	*	21 NOV 0800	27	800.	4074.	-3274.	*	22 NOV 0100	44	800.	4087.	-3287.
20 NOV 1600	11	22432.	12631.	9801.	*	21 NOV 0900	28	800.	3996.	-3196.	*	22 NOV 0200	45	800.	4087.	-3287.
20 NOV 1700	12	16934.	9801.	7133.	*	21 NOV 1000	29	800.	3957.	-3157.	*	22 NOV 0300	46	800.	4087.	-3287.
20 NOV 1800	13	13443.	8314.	5129.	*	21 NOV 1100	30	800.	3970.	-3170.	*	22 NOV 0400	47	800.	4087.	-3287.
20 NOV 1900	14	10988.	7322.	3666.	*	21 NOV 1200	31	800.	4152.	-3352.	*	22 NOV 0500	48	800.	4087.	-3287.
20 NOV 2000	15	9067.	6633.	2434.	*	21 NOV 1300	32	800.	4035.	-3235.	*	22 NOV 0600	49	800.	4087.	-3287.
20 NOV 2100	16	7425.	6103.	1322.	*	21 NOV 1400	33	800.	4087.	-3287.	*					
20 NOV 2200	17	5918.	5646.	272.	*	21 NOV 1500	34	800.	4087.	-3287.	*					

1 STATION

(I) INFLOW, (O) OUTFLOW, (*) OBSERVED FLOW



```
 210800  27IO  *     .         .         .         .         .         .         .         .         .         .         .         .
 210900  28IO  *     .         .         .         .         .         .         .         .         .         .         .         .
 211000  29IO  *     .         .         .         .         .         .         .         .         .         .         .         .
 211100  30IO  *     .         .         .         .         .         .         .         .         .         .         .         .
 211200  31IO. * . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .
 211300  32IO  *     .         .         .         .         .         .         .         .         .         .         .         .
 211400  33IO  *     .         .         .         .         .         .         .         .         .         .         .         .
 211500  34IO  *     .         .         .         .         .         .         .         .         .         .         .         .
 211600  35IO  *     .         .         .         .         .         .         .         .         .         .         .         .
 211700  36IO  *     .         .         .         .         .         .         .         .         .         .         .         .
 211800  37IO  *     .         .         .         .         .         .         .         .         .         .         .         .
 211900  38IO  *     .         .         .         .         .         .         .         .         .         .         .         .
 212000  39IO  *     .         .         .         .         .         .         .         .         .         .         .         .
 212100  40IO  *     .         .         .         .         .         .         .         .         .         .         .         .
 212200  41IO. * . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .
 212300  42IO  *     .         .         .         .         .         .         .         .         .         .         .         .
 220000  43IO  *     .         .         .         .         .         .         .         .         .         .         .         .
 220100  44IO  *     .         .         .         .         .         .         .         .         .         .         .         .
 220200  45IO  *     .         .         .         .         .         .         .         .         .         .         .         .
 220300  46IO  *     .         .         .         .         .         .         .         .         .         .         .         .
 220400  47IO  *     .         .         .         .         .         .         .         .         .         .         .         .
 220500  48IO  *     .         .         .         .         .         .         .         .         .         .         .         .
 220600  49IO--*-----.---------.---------.---------.---------.---------.---------.---------.---------.---------.---------.---------.
1
1
```

RUNOFF SUMMARY
FLOW IN CUBIC FEET PER SECOND
TIME IN HOURS, AREA IN SQUARE MILES

	OPERATION	STATION	PEAK FLOW	TIME OF PEAK	AVERAGE FLOW FOR MAXIMUM PERIOD 6-HOUR	24-HOUR	72-HOUR	BASIN AREA	MAXIMUM STAGE	TIME OF MAX STAGE
+	HYDROGRAPH AT	BASIN	74479.	6.00	52199.	18342.	9571.	159.85		

*** NORMAL END OF HEC-1 ***

Attachment 2 – HEC-1, Development of PMF

```
1*****************************************
 *                                       *
 *   FLOOD HYDROGRAPH PACKAGE  (HEC-1)   *
 *            SEPTEMBER 1990             *
 *             VERSION 4.0               *
 *                                       *
 *  RUN DATE  02/04/2002  TIME  13:58:11 *
 *                                       *
 *****************************************
```

```
*****************************************
*                                       *
*    U.S. ARMY CORPS OF ENGINEERS       *
*    HYDROLOGIC ENGINEERING CENTER      *
*          609 SECOND STREET            *
*       DAVIS, CALIFORNIA 95616         *
*           (916) 756-1104              *
*                                       *
*****************************************
```

```
X     X  XXXXXXX   XXXXX          X
X     X  X        X     X        XX
X     X  X        X               X
XXXXXXX  XXXX     X        XXXXX  X
X     X  X        X               X
X     X  X        X     X         X
X     X  XXXXXXX   XXXXX         XXX
```

THIS PROGRAM REPLACES ALL PREVIOUS VERSIONS OF HEC-1 KNOWN AS HEC1 (JAN 73), HEC1GS, HEC1DB, AND HEC1KW.

THE DEFINITIONS OF VARIABLES -RTIMP- AND -RTIOR- HAVE CHANGED FROM THOSE USED WITH THE 1973-STYLE INPUT STRUCTURE.
THE DEFINITION OF -AMSKK- ON RM-CARD WAS CHANGED WITH REVISIONS DATED 28 SEP 81. THIS IS THE FORTRAN77 VERSION
NEW OPTIONS: DAMBREAK OUTFLOW SUBMERGENCE , SINGLE EVENT DAMAGE CALCULATION, DSS:WRITE STAGE FREQUENCY,
DSS:READ TIME SERIES AT DESIRED CALCULATION INTERVAL LOSS RATE:GREEN AND AMPT INFILTRATION
KINEMATIC WAVE: NEW FINITE DIFFERENCE ALGORITHM

1 HEC-1 INPUT PAGE 1

```
LINE          ID.......1.......2.......3.......4.......5.......6.......7.......8.......9......10

  1           ID        OMPUTATION OF PMF BASED ON 24-HOUR PMP
  2           ID        CHAGRES RIVER AT CHICO
  3           ID        SPILLWAY 286.5 M, SLUICE 1.22 M * 1.22 M
  4           IT      60 20DEC01     600         25DEC01     600
  5           IN      60 20DEC01     600
  6           IM
  7           IO       1       2

  8           KK   BASIN
  9           KM        CHAGRES
 10           BA   414.0
 11           BF      50
 12           PB     657
 13           PI     1.5     1.6     1.6     1.6     1.8     2.0     2.5     5.0    14.0    25.0
```

```
          14          PI    18.0     5.0     3.0     2.0     2.0     1.6     1.6     1.6     1.5     1.4
          15          PI     1.4     1.4     1.4     1.4
          16          LU     0.0     2.5    0.03
          17          UI     0.0     3.0    11.1    31.7    25.1    13.9     8.9     6.1     4.8     3.8
          18          UI     3.0     2.5     2.1     1.5     1.2     0.8     0.4     0.2     0.1

          19          KK     DAM
          20          KM     ROUTE THROUGH RESERVOIR
          21          RS       1    ELEV     200
          22          SV  436876  449793  462972  476415  490125  504105  578145  748011  766675  785654
          23          SV  804952  824571  844514  949183
          24          SE     200     201     202     203     204     205     210     220     221     222
          25          SE     223     224     225     230
          26          SQ    41.5   595.2  1607.5  2918.4  4270.7  6231.5  7182.7  8178.3  9216.2 10294.9
          27          SQ   11413   12569   13761   14989   16252   17549
          28          SE   200.0   201.0   202.0   203.0   204.0   205.0   205.5   206.0   206.5   207.0
          29          SE   207.5   208.0   208.5   209.0   209.5   210.0
          30          ZZ
1*****************************************                                  *****************************************
*                                         *                                  *                                       *
*   FLOOD HYDROGRAPH PACKAGE  (HEC-1)     *                                  *    U.S. ARMY CORPS OF ENGINEERS       *
*            SEPTEMBER 1990               *                                  *    HYDROLOGIC ENGINEERING CENTER      *
*             VERSION 4.0                 *                                  *          609 SECOND STREET            *
*                                         *                                  *       DAVIS, CALIFORNIA 95616         *
*  RUN DATE  02/04/2002  TIME  13:58:11   *                                  *           (916) 756-1104              *
*                                         *                                  *                                       *
*****************************************                                  *****************************************


                              OMPUTATION OF PMF BASED ON 24-HOUR PMP
                              CHAGRES RIVER AT CHICO
                              SPILLWAY 286.5 M, SLUICE 1.22 M * 1.22 M

    7 IO          OUTPUT CONTROL VARIABLES
                        IPRNT           1  PRINT CONTROL
                        IPLOT           2  PLOT CONTROL
                        QSCAL          0.  HYDROGRAPH PLOT SCALE

      IT          HYDROGRAPH TIME DATA
                         NMIN          60  MINUTES IN COMPUTATION INTERVAL
                        IDATE     20DEC 1  STARTING DATE
                        ITIME        0600  STARTING TIME
                           NQ         121  NUMBER OF HYDROGRAPH ORDINATES
                       NDDATE     25DEC 1  ENDING DATE
                       NDTIME        0600  ENDING TIME
                       ICENT          19  CENTURY MARK

                  COMPUTATION INTERVAL    1.00 HOURS
                       TOTAL TIME BASE  120.00 HOURS
```

```
METRIC UNITS
     DRAINAGE AREA          SQUARE KILOMETERS
     PRECIPITATION DEPTH    MILLIMETERS
     LENGTH, ELEVATION      METERS
     FLOW                   CUBIC METERS PER SECOND
     STORAGE VOLUME         CUBIC METERS
     SURFACE AREA           SQUARE METERS
     TEMPERATURE            DEGREES CELSIUS

*** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** ***

          **************
          *            *
  8 KK    *     BASIN  *
          *            *
          **************
                          CHAGRES

  5 IN          TIME DATA FOR INPUT TIME SERIES
                      JXMIN          60  TIME INTERVAL IN MINUTES
                     JXDATE     20DEC 1  STARTING DATE
                     JXTIME         600  STARTING TIME

              SUBBASIN RUNOFF DATA

 10 BA          SUBBASIN CHARACTERISTICS
                      TAREA      414.00  SUBBASIN AREA

 11 BF          BASE FLOW CHARACTERISTICS
                      STRTQ       50.00  INITIAL FLOW
                      QRCSN         .00  BEGIN BASE FLOW RECESSION
                      RTIOR     1.00000  RECESSION CONSTANT

                PRECIPITATION DATA

 12 PB                STORM      657.00  BASIN TOTAL PRECIPITATION

 13 PI            INCREMENTAL PRECIPITATION PATTERN
                    1.50      1.60      1.60      1.60      1.80      2.00      2.50      5.00     14.00     25.00
                   18.00      5.00      3.00      2.00      2.00      1.60      1.60      1.60      1.50      1.40
                    1.40      1.40      1.40      1.40

 16 LU          UNIFORM LOSS RATE
                      STRTL         .00  INITIAL LOSS
                      CNSTL        2.50  UNIFORM LOSS RATE
                      RTIMP         .03  PERCENT IMPERVIOUS AREA

 16 UI          INPUT UNITGRAPH,  19 ORDINATES,  VOLUME = 1.05
```

.0	3.0	11.1	31.7	25.1	13.9	8.9	6.1	4.8	3.8
3.0	2.5	2.1	1.5	1.2	.8	.4	.2	.1	

***

HYDROGRAPH AT STATION BASIN

DA MON HRMN	ORD	RAIN	LOSS	EXCESS	COMP Q	DA MON HRMN	ORD	RAIN	LOSS	EXCESS	COMP Q
20 DEC 0600	1	.00	.00	.00	50.	22 DEC 1900	62	.00	.00	.00	50.
20 DEC 0700	2	9.86	2.50	7.37	50.	22 DEC 2000	63	.00	.00	.00	50.
20 DEC 0800	3	10.52	2.50	8.02	72.	22 DEC 2100	64	.00	.00	.00	50.
20 DEC 0900	4	10.52	2.50	8.02	156.	22 DEC 2200	65	.00	.00	.00	50.
20 DEC 1000	5	10.52	2.50	8.02	397.	22 DEC 2300	66	.00	.00	.00	50.
20 DEC 1100	6	11.84	2.50	9.34	602.	23 DEC 0000	67	.00	.00	.00	50.
20 DEC 1200	7	13.15	2.50	10.65	725.	23 DEC 0100	68	.00	.00	.00	50.
20 DEC 1300	8	16.44	2.50	13.94	818.	23 DEC 0200	69	.00	.00	.00	50.
20 DEC 1400	9	32.88	2.50	30.38	935.	23 DEC 0300	70	.00	.00	.00	50.
20 DEC 1500	10	92.07	2.50	89.57	1135.	23 DEC 0400	71	.00	.00	.00	50.
20 DEC 1600	11	164.41	2.50	161.92	1682.	23 DEC 0500	72	.00	.00	.00	50.
20 DEC 1700	12	118.38	2.50	115.88	3214.	23 DEC 0600	73	.00	.00	.00	50.
20 DEC 1800	13	32.88	2.50	30.38	6254.	23 DEC 0700	74	.00	.00	.00	50.
20 DEC 1900	14	19.73	2.50	17.23	9555.	23 DEC 0800	75	.00	.00	.00	50.
20 DEC 2000	15	13.15	2.50	10.65	9936.	23 DEC 0900	76	.00	.00	.00	50.
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20 DEC 2200	17	10.52	2.50	8.02	5406.	23 DEC 1100	78	.00	.00	.00	50.
20 DEC 2300	18	10.52	2.50	8.02	4068.	23 DEC 1200	79	.00	.00	.00	50.
21 DEC 0000	19	10.52	2.50	8.02	3286.	23 DEC 1300	80	.00	.00	.00	50.
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21 DEC 0200	21	9.21	2.50	6.71	2371.	23 DEC 1500	82	.00	.00	.00	50.
21 DEC 0300	22	9.21	2.50	6.71	2095.	23 DEC 1600	83	.00	.00	.00	50.
21 DEC 0400	23	9.21	2.50	6.71	1854.	23 DEC 1700	84	.00	.00	.00	50.
21 DEC 0500	24	9.21	2.50	6.71	1620.	23 DEC 1800	85	.00	.00	.00	50.
21 DEC 0600	25	9.21	2.50	6.71	1422.	23 DEC 1900	86	.00	.00	.00	50.
21 DEC 0700	26	.00	.00	.00	1255.	23 DEC 2000	87	.00	.00	.00	50.
21 DEC 0800	27	.00	.00	.00	1086.	23 DEC 2100	88	.00	.00	.00	50.
21 DEC 0900	28	.00	.00	.00	906.	23 DEC 2200	89	.00	.00	.00	50.
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21 DEC 1700	36	.00	.00	.00	110.	24 DEC 0600	97	.00	.00	.00	50.
21 DEC 1800	37	.00	.00	.00	93.	24 DEC 0700	98	.00	.00	.00	50.
21 DEC 1900	38	.00	.00	.00	78.	24 DEC 0800	99	.00	.00	.00	50.
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22 DEC 0000	43	.00	.00	.00	51.	*	24 DEC 1300	104	.00	.00	.00	50.
22 DEC 0100	44	.00	.00	.00	50.	*	24 DEC 1400	105	.00	.00	.00	50.
22 DEC 0200	45	.00	.00	.00	50.	*	24 DEC 1500	106	.00	.00	.00	50.
22 DEC 0300	46	.00	.00	.00	50.	*	24 DEC 1600	107	.00	.00	.00	50.
22 DEC 0400	47	.00	.00	.00	50.	*	24 DEC 1700	108	.00	.00	.00	50.
22 DEC 0500	48	.00	.00	.00	50.	*	24 DEC 1800	109	.00	.00	.00	50.
22 DEC 0600	49	.00	.00	.00	50.	*	24 DEC 1900	110	.00	.00	.00	50.
22 DEC 0700	50	.00	.00	.00	50.	*	24 DEC 2000	111	.00	.00	.00	50.
22 DEC 0800	51	.00	.00	.00	50.	*	24 DEC 2100	112	.00	.00	.00	50.
22 DEC 0900	52	.00	.00	.00	50.	*	24 DEC 2200	113	.00	.00	.00	50.
22 DEC 1000	53	.00	.00	.00	50.	*	24 DEC 2300	114	.00	.00	.00	50.
22 DEC 1100	54	.00	.00	.00	50.	*	25 DEC 0000	115	.00	.00	.00	50.
22 DEC 1200	55	.00	.00	.00	50.	*	25 DEC 0100	116	.00	.00	.00	50.
22 DEC 1300	56	.00	.00	.00	50.	*	25 DEC 0200	117	.00	.00	.00	50.
22 DEC 1400	57	.00	.00	.00	50.	*	25 DEC 0300	118	.00	.00	.00	50.
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22 DEC 1700	60	.00	.00	.00	50.	*	25 DEC 0600	121	.00	.00	.00	50.
22 DEC 1800	61	.00	.00	.00	50.	*						
						*						

****

TOTAL RAINFALL = 657.00, TOTAL LOSS = 59.98, TOTAL EXCESS = 597.02

PEAK FLOW	TIME	MAXIMUM AVERAGE FLOW			
		6-HR	24-HR	72-HR	120.00-HR
+ (CU M/S)	(HR)				
		(CU M/S)			
+ 9936.	14.00	7060.	2962.	1047.	648.
	(MM)	368.372	618.160	655.318	676.187
	(1000 CU M)	152506.	255918.	271302.	279942.

CUMULATIVE AREA = 414.00 SQ KM

1

```
                                                        STATION    BASIN

                    (O) OUTFLOW
        0.     2000.     4000.     6000.     8000.    10000.        0.        0.        0.        0.        0.        0.        0.
                                                                                                   (L) PRECIP,   (X) EXCESS
        0.        0.        0.        0.        0.        0.        0.        0.      200.      150.      100.       50.        0.
DAHRMN PER
200600  1O---------.---------.---------.---------.---------.---------.---------.---------.---------.---------.---------.---------.
200700  2O         .         .         .         .         .         .         .         .         .         .         .       LX.
200800  3O         .         .         .         .         .         .         .         .         .         .         .       XX.
200900  4.O        .         .         .         .         .         .         .         .         .         .         .       XX.
201000  5. O       .         .         .         .         .         .         .         .         .         .         .       XX.
201100  6.  O      .         .         .         .         .         .         .         .         .         .         .       XX.
201200  7.   O     .         .         .         .         .         .         .         .         .         .         .      LXX.
201300  8.   O     .         .         .         .         .         .         .         .         .         .         .      XXX.
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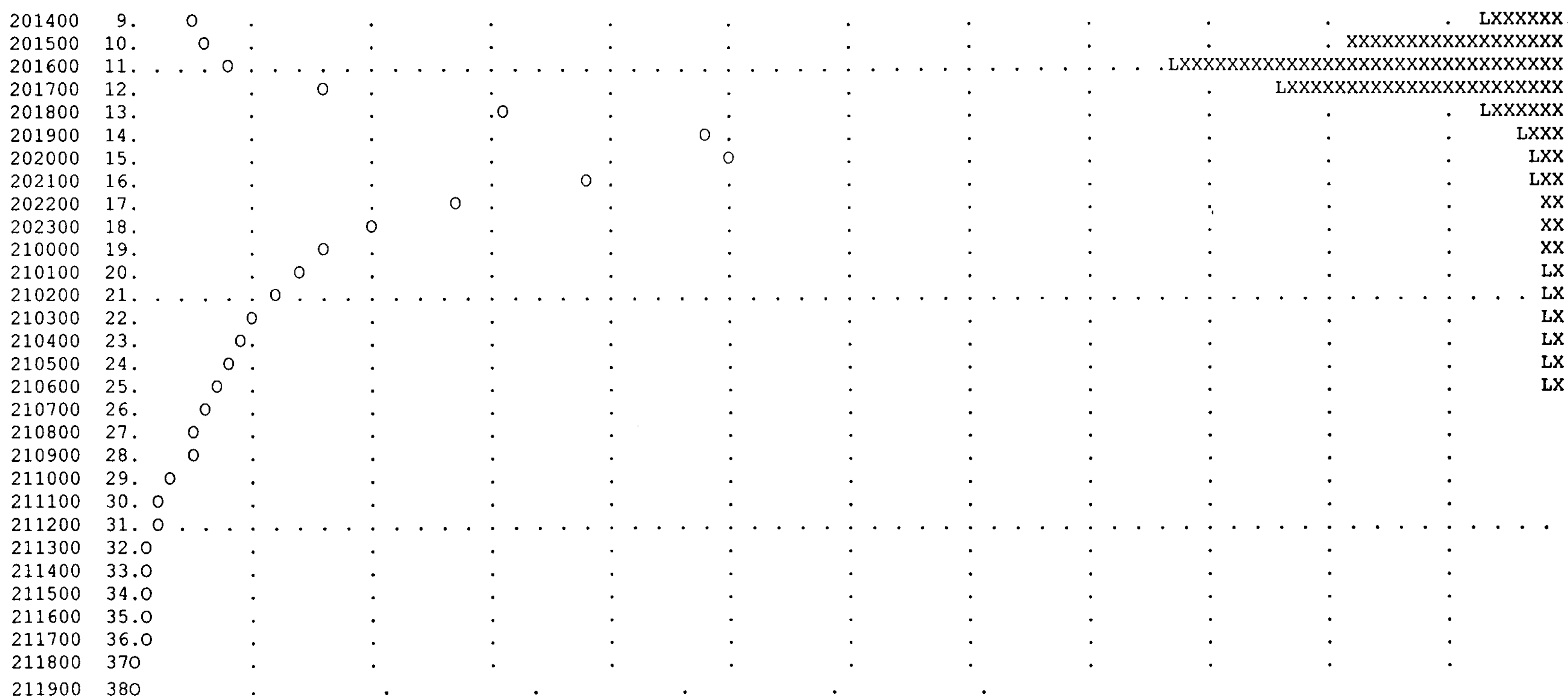
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210000 19.
210100 20.
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210300 22.
210400 23.
210500 24.
210600 25.
210700 26.
210800 27.
210900 28.
211000 29.
211100 30.
211200 31.
211300 32.
211400 33.
211500 34.
211600 35.
211700 36.
211800 37
211900 38

FEASIBILITY DESIGN FOR THE UPPER CHAGRES WATER SUPPLY PROJECT

APPENDIX B

GEOLOGY, GEOTECHNICAL AND SEISMOLOGICAL STUDIES

Prepared by

MWH

In association with

TAMS

AN EARTH TECH COMPANY

FEASIBILITY DESIGN FOR THE UPPER CHAGRES WATER SUPPLY PROJECT

APPENDIX B – GEOLOGY, GEOTECHNICAL AND SEISMOLOGICAL STUDIES

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FOREWORD

The studies described in this appendix have been performed in accordance with the scope of services for Contract CC3-5-536 - Work Order 011, Feasibility Design and Related Services for the Upper Chagres Water Supply Project entered into on September 11, 2001. This appendix presents the results of the investigations and studies related to services addressing Task 5 - Geology, and Task 6 - Geotechnical and Seismological Studies.

Appendix B has been prepared using the following basic information:

- Reconnaissance Study: Identification, Definition, and Evaluation of Water Supply Projects, prepared by the U.S. Army Corps of Engineers, Mobile District, dated August 1999;
- Topographic mapping of the proposed dam site prepared by Ingenieria Avanzada, S.A. under subcontract to MWH. Services were completed and submitted to the ACP under Contract CC-3-536, Task Order 10, Altimetric and Planimetric Surveys of Upper Chagres Dam Site;
- Topographic mapping of the reservoir area using IFSAR aerial survey provided in digital format by ACP;
- Additional topographic mapping of the dam site developed by digitizing 1:50,000 scale maps obtained from Instituto Geografico Nacional (Instituto "Tommy Guardia");
- Aerial photographs of dam site, dated Jaunary 1987, 1:30,000 scale obtained from Instituto Geografico Nacional (Instituto "Tommy Guardia");
- Geological and geotechnical information obtained from a dam site exploration and mapping field program, including subsurface drilling, test pit sampling and laboratory testing; and
- The results of hydrology and meteorology studies presented in the companion Appendix A.

1 INTRODUCTION

1.1 Objectives and Scope of Study

This report presents a summary of the results and interpretations of geologic and geotechnical investigations and studies carried out for the proposed Upper Chagres Water Supply Project, Panama. The purpose of the work was to identify and evaluate geologic conditions of the proposed project and to develop feasibility level geotechnical design criteria and parameters for preparation of layouts and support of cost estimates.

The scope of the work included site investigations involving field geologic mapping, drilling, laboratory testing and technical evaluations. The results of these investigations were used to support the development of feasibility level geotechnical design criteria and cost parameters. On the basis of the limited fieldwork that was performed, technical feasibility is demonstrated through description of site conditions and how these could be dealt with in the layout and design of project features.

Information from the geologic and geotechnical activities was channeled into concurrent planning studies as part of associated tasks, starting with site reconnaissance (Task 2), dam type selection, project optimization and preparation of final costing information for the preferred arrangements. The project features and structures are described in detail in the main volume of the feasibility report and are included herein only to the degree necessary for the geologic evaluations.

1.2 Location and Description of Project

The location of project and sites investigated is shown on Exhibit 1 of this Appendix. The project site is found on Sheet 4243-I of the 1:50,000 scale topographic map series of the Instituto Geografico Nacional "Tommy Guardia".

The ACP identified the Upper Chagres Project as one of several potential projects to provide additional water supply, storage and hydropower generation to augment capacity and capability improvements for the Panama Canal. The project would impound water from the Río Chagres drainage basin upstream of Lake Alajuela and release it to the Lake

Gatun via Lake Alajuela and Madden Dam. Hydropower would be generated at the damsite.

The project area is located in the eastern part of the Canal watershed, approximately 25 km north of Panama City and 30 km east of Lake Gatun (Exhibit 1). The Upper Chagres dam site is located on the Río Chagres about 15 km upstream of Lake Alajuela.

Structures for the project would include a main dam on the Río Chagres (approximately 150 m high), a spillway, hydropower facilities, and other outlet works. The reservoir formed by the dam would have a normal operating level about 220 m above mean sea level with a surface area of approximately 1680 hectares.

2 GEOLOGIC AND GEOTECHNICAL INVESTIGATIONS

This chapter summarizes the sequence and scope of geologic investigations relevant to the proposed Upper Chagres Water Supply Project.

2.1 Scope of Investigations

Geologic investigations had not been previously performed specifically for the Upper Chagres Water Supply Project. A scoping and reconnaissance study which included the Río Chagres project was carried out by the US Army Corps of Engineers (USACE, Mobile District) in 1999, but this initial study did not include any geologic investigation. Regional geologic mapping for this part of the country consists of a 1:75,000 scale map (Woodring, 1955), which provides very limited detail for the project area.

A site visit was made in May 2002 that involved preliminary dam site geologic mapping, construction materials studies, and field locating/adjustment of the exploration program. In addition, MWH provided partial on-site supervision of the field investigations program, carried out during June 2002.

The investigations program incorporated the following activities:

- Reconnaissance of dam site; establish exploration program and investigation requirements;
- Reconnaissance geologic mapping, including geomorphological analysis and photo-geologic studies;
- Outcrop geologic mapping at the dam site;
- Construction materials investigation;
- Supervision of drilling at the damsite;
- Development of preliminary geologic and geotechnical criteria for use in the selection of recommended project concepts and features/structures;
- Seismic hazard assessment of project region;
- Laboratory testing and analyses; and
- Development of geologic and geotechnical parameters for use in design of selected project and estimation of construction costs.

2.1.1 Geologic Mapping

The objectives of geologic mapping performed during these investigations included identifying, interpreting, and documenting the following aspects:

- Geomorphic conditions at the project sites,
- Occurrence and general nature of overburden units,
- Location and conditions of rock outcrops,
- Lithologic and surficial properties of rock units,
- Surficial extent and characteristics of rock weathering, and
- Orientation and condition of joints, shears, and faults.

Particular attention was paid to possible faults identified as photolinears in photogeologic studies and on regional geologic maps (Exhibit 2).

Available topographic maps for the study region were obtained from the Instituto Geografico Nacional. These included maps at 1:50:000 scale (contour interval 20 m). Several of the 1:50:000 scale maps in the vicinity of the project site have not been published, including the map that provides coverage of the reservoir area. Topography for the reservoir area was provided by ACP in digital format. The topography was generated from an aerial survey of the site and reservoir area made using an IFSAR (Interferometric Synthetic Aperture Radar) survey. Additional topographic information at the project site was obtained from a detailed topographic survey made by Ingeniera Avanzada, S.A., in November and December 2001. .

Reconnaissance geologic mapping was performed along the Río Chagres from approximately 1 km upstream of the dam site to Lake Alajuela, located approximately 15 km downstream of the dam site. Geologic mapping was also carried out at selected locations to help identify conditions along prospective tunnel alignments, tunnel portals and intake locations, and possible powerhouse sites. A general reconnaissance of a portion of the proposed reservoir area was performed by helicopter to identify and evaluate any geologic features relevant to reservoir rim stability and watertightness.

2.1.2 Photogeology

Available aerial photographic coverage for the study region was limited in scope and quality. The only source from which aerial photographs are available in Panama is the Instituto Geográfico Nacional, which was able to supply only limited number of older black-and-white photographs for the project area. Photographic coverage for the project area is limited and extends only about 3 km west of the proposed dam site; no aerial photographs are available for the proposed reservoir. The quality, age, and scale of the available aerial photographic coverage was a limiting factor in performing detailed examination of key areas and accurate studies for photogeologic interpretations. Conventional photogeologic methods were followed using a mirror stereoscope and photo-comparator.

2.1.3 Drilling and *In Situ* Testing

ACP contracted with Swissboring Overseas Corporation, Ltd, of Guatemala City, Guatemala, for drilling services. MWH worked in conjunction with ACP to develop the drilling and testing program, including assisting with selection of boring locations and depths, and providing field supervision during the drilling. A total of eight boreholes (six vertical, two inclined) with a combined length of 440 meters were drilled to investigate subsurface conditions in the dam foundation, at a proposed left abutment spillway, and at the proposed right abutment diversion tunnel. *In situ* testing consisted of standard penetration tests and water pressure tests; standard penetration tests were made in all borings, water pressure tests were made in seven of the eight boreholes. The drilling and *in situ* testing program required approximately one month to complete, and was carried out from late May to early July, 2002. The locations of the boreholes are shown on Exhibit 3. The boring logs and *in situ* test results are presented in Attachment 1. Photographs of the core obtained from all but two of the borings are presented in Attachment 5.

Drilling was accomplished with two skid-mounted drill rigs utilizing an HQ wireline system with a double tube core barrel. Water pumped from the Río Chagres was used as the drilling fluid; no additives were used. One rig was located on each abutment; three drillers were on site such that one rig ran 24 hours, while the other rig ran 12 hrs/day. The total time to complete the 440 m of drilling was approximately 33 days.

Core was carried down from the drilling sites to the Río Chagres and transported via canoe approximately 2 km downstream to the village of Embera Drua, where it was logged and photographed by a Swissboring geologist. The core was then transported to Panama City via canoe and then by road.

2.1.4 Laboratory Testing and Analyses

Rock and soil samples from ten test pits and from four rock outcrops were collected for laboratory testing and analysis. MWH contracted Tecnilab, S.A to perform the sampling and testing. Sampling was carried out at the site in early June 2002; testing was performed in Panama City during June and July, 2002. The testing program is summarized below.

Construction Materials Testing: Laboratory tests for gradation, Atterberg limits, specific gravity, compaction, absorption, soundness, abrasion resistance, and reactivity were performed on samples collected from test pits in order to establish their potential use as construction materials. Results are discussed later in this report, under Construction Materials.

Petrographic Analyses: Petrographic analyses were performed on three samples collected from three rock outcrops located along the river channel in the vicinity of the proposed dam site.

Rock Mechanics and Index Testing: Point load index testing was performed on seven rock samples collected from four rock outcrops located along the river channel in the vicinity of the proposed dam site.

The test pit locations are shown on Exhibit 3. Laboratory test results and test pit logs are presented in Attachment 2.

Swissboring and ACP carried out additional laboratory testing on soil and rock samples collected from the drilling program. The testing programs are summarized below.

Soil Testing: Laboratory tests for gradation, Atterberg limits, moisture content and USCS classification were performed on samples collected during from the SPT testing. These tests were carried out by ACP in their Soils and Materials Laboratory. Results are discussed later in this report, under Construction Materials, and are included in Attachment 3.

Rock Mechanics and Index Testing: Unconfined compression tests and unit weight measurements were made on nine samples collected from five boreholes; the tests were performed by ACP in their Soils and Materials Laboratory and are included in Attachment 3. Point load index tests were performed by ACP and Swissboring on samples collected from all eight boreholes. Testing results are discussed later in this report under Engineering Geology. Testing results are presented in Attachments 1, 2 and 3.

3 REGIONAL GEOLOGIC AND TECTONIC SETTING

3.1 General

This chapter presents the basic geologic setting of the region east of Lake Gatún, including the Río Chagres Project area. Information was derived from interpretations made during the course of these studies and from published geologic reports and maps cited in the text and bibliography.

Seismic design criteria developed as part of this study include determination of the hazard rating and associated return periods. Recommendations for design earthquake magnitudes and peak horizontal bedrock accelerations are also made. More detailed analyses may be desired in the future to either update or complement the recommendations provided. Recommendations made in this study are based on a review of existing information on the seismic hazard of the area and its application to the Panama Canal projects.

3.2 General Regional Geology

The proposed Río Chagres project is located in an area underlain by Cretaceous-aged volcanic rocks of the Igneous Basement Complex (Terry, 1956). The Igneous Basement Complex is composed of intrusive and extrusive volcanics, including granites, diorites, basalts, andesites, tuffs and agglomerates. A general stratigraphic column is presented in Table 1 and a regional geologic map is presented as Exhibit 2.

To the east of the project area toward Lake Alajuela, there is a transition from igneous rock types to the sedimentary rock types of the Gatuncillo formation, which includes mudstones, siltstones and limestones (Woodring, 1955). The Lake Alajuela basin itself lies between two major faults striking N 70 E, which are cut by a second fault system striking N 20 E to N 30 E (Terry, 1956). These two fault systems strongly control the drainage pattern of the Río Chagres below Lake Alajuela. They seem to also exert some control in the basin of the Upper Chagres upstream of Lake Alajuela, as the Chagres and several of its main tributaries are oriented N20 E and N 70 E.

At the project site, the bedrock is comprised of andesites and agglomerates deposited as a series of terrestial andesite flows.

The topography in the vicinity of the project area is characterized by steep, V-shaped valleys and can be classified as a mountain region in early maturity. The valley sides are almost entirely covered by vegetation and a well-developed residual soil horizon. Rock outcrops are present at the riverbanks along much of the Río Chagres and its major tributaries.

Although little information on the engineering characteristics of these rocks exists, it is anticipated that they may exhibit a wide variety in quality depending on their depositional history and their degree of weathering.

3.3 Regional Tectonics

The tectonics in the Central American region is predominantly governed by the interaction of the Nazca, Cocos, South American, and Caribbean Plates. Geologic processes in the Republic of Panama, including tectonics, sedimentation, volcanism, seismicity, and epeirogenesis, are all strongly influenced by the relative movements of these plates, Exhibit 5. Although the country is located on the southwest edge of the Caribbean Plate, Panama itself is located on a tectonic microplate called the Panama Block, which is a fairly rigid, yet seismically active segment of crust.

Plate movement in Central America is typically generalized as subduction zone tectonics. However, based on a review of the tectonics, the limit of the strongest influence of the subduction zone appears to cease near the border between Panama and Costa Rica and begins again on the eastern side of Panama and runs along the west coast of South America (Bodare, 2001).

Table 1: Stratigraphic Column

ERA	PERIOD	EPOCH	AGE	FORMATION	DESCRIPTION
CENOZOIC ERA	QUATERNARY	($3x10^6$ to present)			Rio Indio alluvial deposits
				Chagres	Sandstone
	TERTIARY	Pliocene ($3x10^6$)		Toro	Limestone, lime-cemented coquina
		Miocene ($11x10^6$)	Late	Dacite, Andesite & Basalt flows and intrusions	Gatun: Massive sandstone, siltstone, conglomerate and tuff
			Middle	No deposition	
			Early	No deposition	La Boca: Predominantly silty or sandy tuffaceous mudstone with sandstone, limestone and conglomerate
		Oligocene ($26x10^6$)	Late	Caimito	Tuffaceous sandstone, siltstone and agglomeratic tuff
					Tuffaceous sandstone, tuff and thin limestone beds
					Conglomerate and tuffaceous sandstone
			Early	Las Cascadas	Las Cascadas – agglomerate and intercalated lava flows Bohio - conglomerate, tuffaceous sandstone, tuffaceous siltstone with much pyroclastic material, largely non-marine
		Eocene ($38x10^6$)	Late	Gatuncillo	Mudstone, siltstone, impure bentonite and limestone lenses
			Middle		
			Early	No deposition	
		Paleocene ($48x10^6$)			
MESOZOIC		Cretaceous ($71x10^6$)		Pre-Tertiary basement complex	Indurated sedimentary rocks, intrusive and extrusive igneous rocks and metamorphic rocks

Adapted from: Woodring and Thompson, 1949

3.3.1 Tectonic Boundaries

The Panama Block was formed over a period of 12 million years, largely as a result of the north to south spreading at the Galapagos Rift boundary between the Cocos and Nazca plates. Newly created crust at this boundary is being subducted beneath Costa Rica and regions further north. This action contributes to seismic activity extending from Costa Rica all the way to the western coast of Mexico. Four major tectonic regions define the boundaries of the Panama Block (Camacho et al., 1994):

- Panama Block-Caribbean Plate Boundary,
- Panama Block-Nazca Plate Boundary,
- Eastern Panama-Columbia Collision Zone, and
- Panama Block-Cocos Plate Boundary

Most historical seismicity within a 400-km-radius of the Panama Canal area can be attributed to collision and shear deformation at each of these neighboring plate boundaries (Cowan 1995). The junction of the Cocos, Nazca, and Caribbean Plates occurs near is termed Punta Burica, or Burica Peninsula. The junction of the Cocos and Nazca Plates is termed the Panama Fracture Zone (Acres, 1981).

The north edge of the Cocos Plate is being subducted under the Caribbean Plate resulting in a reverse fault structure termed the Middle American Trench. The Nazca plate is being subducted obliquely in the northeast direction beneath the southwest margin of Panama creating the Southern Panama Deformed Belt, while the eastern portion of the Nazca plate is being subducted under South America (Cowan 1995). The thrust of the Caribbean Plate beneath the northern margin of the Panama Block has produced some large earthquakes in the past. The provinces and adjoining offshore regions of Bocas del Toro, Chiriqui, Los Santos in western and southern Panama, and San Blas and Darien in the east are also seismically active regions of Panama located along the margins of the Panama Block (Cowan 1995).

A detailed description of the significant tectonic features of Panama follows.

3.3.1.1 Panama Block-Caribbean Plate Zone

The North Panama Deformed Belt (NPDB) is a wide and shallow belt of folds and thrust faults that extends offshore from the Gulf of Uraba in eastern Panama to near the port of Limon in Costa Rica as seen in Exhibit 4 (Bodare, 2001). The NPDB is the most significant fault zone located in the Panama Block-Caribbean Plate Zone (Cowan 1995) and is one of the two largest seismic sources of engineering interest in the Panama Canal basin. The other source is the interface between the subducted Caribbean plate beneath the Panama Block (Cowan 1995). Some discrepancy exists in identification of the NPDB as a subduction zone. Studies performed by Camacho and Viquez 1993 indicate that the overthrust boundary due to the convergence of the Caribbean Plate and the Panama Block is not a subduction. However, in his report, Joyner addresses the uncertainty in identifying the NPDB as a subduction zone or shallow crustal zone. Subduction earthquakes give significantly larger ground motions for a specified magnitude and distance. Therefore, Joyner recommended that the NPDB, although not a typical subduction zone, should be considered a subduction zone so that ground motions selected to represent this zone are not too small.

3.3.1.2 Panama Block-Cocos Plate Boundary Zone

The Panama Fracture Zone (also known as the Longitudinal Fault Zone) and the Cocos Ridge are the largest faults in the Panama Block-Cocos Plate Boundary Zone (Cowan 1995). The Panama Fracture Zone as seen on Exhibit 4 separates the Cocos and Nazca plates south of the Costa Rica-Panama border (Cowan 1995).

There is evidence of rapid horizontal movement during the last 10,000 years with strong surface expressions that cut through the overriding Panama Block in the Medial Fault Zone and Canoas Fault Zones (Cowan 1995). The Panama Fracture Zone exhibits right lateral strike-slip motion at the rate of 50 to 70 mm/year and is subducted beneath the Panama Block near Cocos Ridge (Cowan 1995). The right-side north-south striking oceanic transform fault that makes the boundary between the Cocos and the Nazca plates extends between 82°W and 83°W and from the equator to 6°N splaying in a series of parallel northwest trending strike-slip faults (Bodare, 2001). The Cocos Ridge, a thickened area of oceanic crust created due to the subduction of the Cocos plate west of the Panama Fracture Zone beneath the southwest margin of the Caribbean plate and the

Panama Block, appears to be moving nearly 90 mm/year (Cowan 1995). The Cocos Ridge can be defined by seismicity depth of nearly 50 km beneath southern Costa Rica (Cowan 1995).

3.3.1.3 Panama Block-Nazca Plate Boundary

The South Panama Deformed Belt (SPDB), along with the Azuero-Sona Fault Zone, and the Southern Panama Fault Zone, are the largest faults in the Panama Block-Nazca Plate Boundary (Cowan 1995). The SPDB is located at the southern border of Panama along the Pacific continental margin where the Nazca plate under-rides the Panama Block at a shallow oblique angle (Exhibit 4). This reverse fault structure may be the cause of volcanic activity in western Panama (Bodare, 2001). The SPDB is a zone of recent subduction of the oceanic plates to a depth of 100-120 km beneath Cordillera Central and represents a slice of the Cocos oceanic lithosphere between Coiba, Balboa, and the PFZ due to the migration of the Cocos-Nazca Boundary. East of the PFZ, the Nazca plate is moving E-NE oblique to the southern margin of Panama. Associated deformation is caused by thrust faulting along the continental margin and oblique normal faulting within the Panama Block west of the Azuero Peninsula and Coiba Island.

The Azuero-Sona peninsula in the southwestern portion of Panama contains a series of active parallel left-lateral strike-slip faults (Exhibit 7). Between 78°50'W and 80°30'W the fault bends landward and continues onshore with a northwest strike as the Azuero-Sona Fault Zone (Exhibit 7). The Azuero-Sona Fault Zone is a large strike-slip fault within the Panama Block that strikes NW-SE, defines a linear valley across the peninsulas and extends offshore to the southeast and merges with the Southern Panama Fault Zone (Camacho et al. 1994). The Southern Panama Fault Zone forms the left-lateral, strike-slip margin of the Nazca plate, offshore of the Azuero Peninsula and extends east across the Gulf of Panama (Exhibits 4 and 5).

3.3.1.4 Central Panama

Within Central Panama lies the Río Gatun Fault, the principal shallow crustal fault in the Canal Basin (Exhibit 7). This tectonic structure, also labeled the Gatun Fracture Zone, bisects Panama in a NNW-SSE direction and bounds the northwest margin of the Madden Basin and the slopes of Sierra Maestra (Schweig et al., 1999). The Río Gatun

Fault is a shallow crustal fault with predominantly dip-slip displacement and is thought to be capable of producing moderate to large earthquakes (Cowan 1995). The fault length is estimated at 30 km with the northeast extent of the fault limited by the Río Boqueron valley and the western extent in Lake Gatun (Schweig et al., 1999).

Mainly intermediate depth earthquakes have been detected beneath Central Panama with a plate interface 35 km beneath Gatun, which deepens farther southeast to 60 km (Schweig et al., 1999). There is also the possibility of an active microseismic zone parallel to Panama Canal (Camacho et al. 1994). The complexity of the Río Gatun Fault and related faults in the Sierra Maestra and the Madden Basin may not be continuous features but small segments, which collectively can produce significant events (Schweig et al., 1999). There is a high density of shallow faults north of Gatun Dam about 250 meters apart and up to 13 km long with varying orientations. In addition to the Río Gatun fault, a system of N-S trending predominantly east-facing normal faults are located west and south of the west end of the Río Gatun fault with no evidence of recent movement (Cowan 1995). Research has determined that all faults in this region are younger than 8.3 million years old and many are more than 6,000 years old based on the results of field studies (Schweig et al., 1999).

Field investigations in the area of the Río Gatun fault also indicate that alluvial deposits that overlie the Río Gatun fault are highly weathered to a depth of at least 5 meters; similar alluvial deposits in Western Panama indicate that these deposits are dated at 10,000 years. Therefore, the rate of deformation has slowed dramatically (Schweig et al., 1999).

3.3.1.5 Eastern Panama – Colombia Collision Zone

Another tectonic region identified on the east coast of Panama along the border with Colombia is the Eastern Panama Deformed Belt, also termed the Eastern Panama-Colombia Collision zone. This structure is located in the eastern portion of Panama and extends to northwestern Colombia between 79°W and the Atrato River Basin. Faults located in this region are shown on Exhibits 7 and 4 and include:

- Chucunaque and Atrato Faults (onshore and offshore normal faults)
- Ungia and Pirre Faults (thrust faults along the Panama-Colombia border)

- Utria Fault (extends from Colombia into Panama along the Pacific Coast)
- Uramita Fault (west-dipping left-lateral strike-slip fault at tectonic boundary between Panama and the North Andes blocks)
- Gulf of Panama and Pearl Islands contain nine NW striking thrust faults that deform the seafloor in the eastern Gulf of Panama
- Sanson Hills Fault Zone (includes active left-lateral strike-slip faults)
- Pirre Hills Fault Zone (includes reverse or thrust faults that bound the northeast side of the Serrania de Pirre and is defined topographically with the most recent movement in 1974)
- Sambu Fault Zone (contains NW striking left-lateral strike-slip faults that bound the southeast margin of the Sambu Basin)
- Jaque River Fault Zone (contains NW striking left-lateral strike-slip that bound the SW margin of the Serrania de Sapo)
- Colombian Trench (zone of westward and eastward verging folded thrust slices with near surface deformation associated with the collision of the Nazca plate subducting beneath South America)

4 SEISMICITY

4.1 Distribution of Earthquakes

4.1.1 Historical Earthquakes

As indicated on Exhibit 5, several major historical earthquakes have occurred in the study region. Most notably, earthquakes occurred in 1822 and 1916 in Northwest Panama along the border of the NPDB, while two earthquakes in 1621 and 1882 occurred nearly 25 km off the northern coast near Colon. An additional earthquake event is noted in 1914 on the northeastern coast in the San Blas region.

4.1.2 Instrumentally Recorded Earthquakes

The Global Hypocenter Database prepared by the U.S. Geological Survey/National Earthquake Information Center (USGS/NEIC) of Denver, CO, was used to search for all historical (non-instrumented) and modern (instrumented) seismicity data within the region bounded by latitudes 5°N and 11°N and longitudes 75°W and 85°W. The database contains over 900,000 earthquakes from 2100 BC through 2002 and draws on information from 53 separate regional and worldwide catalogs. Within the defined region, nearly 2,150 earthquakes were identified. The general distribution of these earthquakes plotted as function of their depth below the surface is presented in Exhibit 6.

A discussion of the overall seismicity of the area in each of the identified principal seismotectonic zones follows.

4.1.3 Panama Block-Caribbean Plate Zone

The North Panama Deformed Belt (NPDB) results from the compression of the Caribbean plate and the Panama Block and is thus the source of several large earthquakes (Schweig et al., 1999). The eastern portion of the NPDB is characterized with thrust-type mechanisms, some strike-slip components, and some normal faulting. This area is the source zone for the largest earthquake on the Caribbean coast of Central America, an 1882 event with M_s = 7.7 (Bodare, 2001). The northwest portion of the NPDB along western Panama has experienced fairly low seismicity recently with some large

earthquake events in the past (Bodare, 2001). The eastern portion of the NPDB exhibits a more regular pattern of thrust deformation than the western portion with variations in sediment thicknesses and crustal structure (Camacho and Viquez 1993). In the western portion, the NPDB reflects a lateral transmission of stress from between the Cocos Ridge collision zone to the area of overthrusting of the Panama Block to the Caribbean Plate. Other earthquakes occurring at greater depths beneath northeast Panama are attributed to the weak southwest dipping zone beneath the Caribbean coast with the Caribbean plate underthrusting the Panama Block (Camacho et al., 1994).

Nearly all of the seismicity seems to occur below the upper plate at crustal depths; thus the area can be described loosely as a dipping subduction zone. The deformed belt can be explained by movement of blocks with dip-slip, mainly thrust-type movements in the Caribbean plate (Camacho and Viquez 1993). The convergence rate between the Caribbean Plate and the Panama Block is nearly 15 mm/year with the Caribbean Plate underthrusting the Panama block (Bodare, 2001). The central portion of the North Panama Deformed Belt between 80° and 81.5°W, near the area of the focus of this report, has no evidence of major seismic activity with hardly any instrumentally recorded seismicity originating from this location (Camacho and Viquez 1993).

4.1.4 Panama Block-Cocos Plate

This area has experienced high seismic activity including earthquake events with magnitudes greater than 7.0 (Bodare, 2001). The epicenter of the 1934 M_s7.5 event in the Gulf of Chiriqui was the largest Panamanian event recorded instrumentally (Camacho et al., 1994). The Panama Fracture Zone is marked by a number of earthquakes west of 83° W (Acres, 1981). Based on evaluations performed by USGS, the highest seismic hazard was found along the west coast of Central America coincident with the subduction of the Cocos Plate under the Caribbean (Shedlock, 2001).

4.1.5 Panama Block – Nazca Boundary

This region has historically experienced several moderate earthquakes between M4.0 and M6.0 (Camacho et al., 1994).

4.1.6 Central Panama

Studies performed at Gatun Dam to develop the seismic hazard of the area included the deployment of a seismic network as well as a search for evidence of prehistoric liquefaction, or paleoliquefaction (Schweig et al., 1999). Over a six-month period, nearly 64 events were recorded with usable data and captured nearly 75% of the seismic events above magnitude 2.5 within 50 km of the network. It was noted that a lack of events were recorded within the network region, while a number of events were recorded at farther distances. Most of the events occurred at depths well below that typical of shallow crustal seismicity and were most likely associated with under-thrusting of the Caribbean Plate beneath Panama. Numerous faulting mechanisms were also identified and a mixture of faulting types for the coastal earthquakes were deep and associated with subduction (Schweig et al., 1999).

4.1.7 Eastern Panama-Colombia Collision Zone

As seen on Exhibit 6, the Eastern Panama-Colombia Collision Zone is a complex zone with diffuse seismicity. Within this region, the Sambu Fault Zone and Jaque River Fault Zone are inferred to be active, while the Colombian Trench is the source of several large historical earthquakes (Cowan 1995).

4.2 Focal Mechanisms

The Panama Canal Basin is characterized by several types of faulting: normal fault, thrust or reverse fault and right-lateral/left-lateral strike slip faulting. This, combined with the observation (and relative lack of information to contradict) that the subduction characteristics prevalent in the rest of Central America are not apparent in the Panama Basin area contributes to the complexity of the region. Results of studies indicate that although recorded events have included shallow crustal earthquakes, many intermediate and deeper events have also been recorded thus classifying the area as not purely a subduction zone.

4.3 Seismic Source Zonation

Seismic source zonation involves the following:

- Identification of individual source zones
- Definition of a maximum magnitude for each zone, and
- Estimation of the rate of seismic activity for each zone

Once these have been determined, the appropriate attenuation relationships for the area can be developed as discussed in subsequent sections.

4.3.1 Identification and Distribution of Seismic Source Zones

Superposition of the seismicity over the seismotectonic provinces discussed earlier permits delineation of seismic source zones of equal activity. Exhibit 6 graphically identifies some of these areas. The highest concentration of seismic activity appears to occur along the west coast of Panama at its boundary with Costa Rica, along the Panama Fracture Zone, as well as on the east coast at Panama's border with Colombia. The North and South Panama Deformed Belts are also areas of high seismic activity. As seen on Exhibit 6, the central portion of Panama near Panama City is a zone of moderate concentration of seismic activity. The Azuero-Sona region can be delineated as an additional seismic source zone. Based on an evaluation of this information, the following seismic source zones are significant source zones:

- North Panama Deformed Belt
- Río Gatun Fault Zone
- Azuero-Sona Fault Zone
- Panama Fracture Zone

4.4 Maximum Magnitudes

Selection of the maximum magnitude, also termed maximum or controlling earthquake, for the area in question depends on the definition of the maximum earthquake for the specific application. Several types of maximum earthquakes exist as follows (Reiter, 1990):

- *Maximum Possible Earthquake*: Defines the upper bound earthquake event related to a specific earthquake source no matter how improbable the event, and is used in probabilistic analyses.

- *Maximum Credible Earthquake (MCE)*: Defines the upper bound earthquake event related to a specific earthquake source that is reasonably expected to occur. This is commonly used in deterministic analyses.
- *Maximum historic earthquake*: Defines the lower bound of the maximum credible earthquake but does not define an earthquake size that will always be exceeded in the future.

Available and accessible historical records have been researched by others and were reviewed to determine maximum historical earthquakes for Panama. History has shown that the largest earthquakes in the Panama Block have occurred at or near the Block boundaries. A review of the research performed and summarized by Camacho et al., Acres Int'l, and Schweig et al. indicates maximum historical magnitudes for each of the main seismotectonic structures presented above as follows:

Table 2: Maximum Historical Earthquake Magnitudes

Structure	**Maximum Magnitude, M_w**
North Panama Deformed Belt	M_w = 7.0 to 7.2 [1](Acres, 1981) M_w = 7.7 (Schweig, 1999)
Río Gatun	M_w=6.8 (Schweig, 1999)
Azuero-Sona	M_w=7.5 (Schweig, 1999)
Panama Fracture Zone	M_w > 6.8 to 7.2 [1](Acres, 1981)
Central Panama	M_w > 5.0 [2] (Acres, 1981)
Eastern Panama Deformed Belt	M_w = 6.8 to 7.0 [1] (Acres, 1981)
Western Panama Block	M_w = 5.0 to 5.7 [2] (Camacho et al., 1994)
Eastern Panama Block	M_w = 6.3 [2] (Camacho et al., 1994)

Notes:

[1] Originally recorded as M_s and converted to M_w using M_w= 2.251+0.655M_s.

[2] Originally recorded as Modified Mercalli Index (MMI) and converted to M_L using M_L= ⅔ (I) +1. M_L converted to M_w using Reiter 1990.

[3] M_w = moment magnitude, M_s = surface wave magnitude, M_L = Richter (local) magnitude, m_b = body wave magnitude

Using this information, the maximum earthquakes selected for this study ranged from M_w=6.8 to 7.7 for the different zones. Maximum magnitudes reported for Central Panama and the Western and Eastern Panama Blocks may be categorized as background seismicity.

5 SEISMIC HAZARD EVALUATION

Determination of the seismic design criteria can be based on deterministic methods that involve evaluation of the affect of ground motions from individual seismic sources attenuated to sites under investigation. Alternatively, seismic design criteria can be based on probabilistic methods involving selection of the allowable risk and associated return period selected for the area. Such methodology typically involves:

1. Selection of the allowable risk, or frequency of exceedance, and associated period of return for the projects.
2. Use of seismic hazard curves and magnitude recurrence relationships to determine the largest magnitude and peak ground acceleration (PGA) based on the associated period of return.

Development of the magnitude-recurrence relationship and the appropriate attenuation relationships are discussed below.

For the water supply projects, seismic design criteria were developed from probabilistic approaches described in the technical literature that were carried out for other projects and civil works in the region. The conclusions drawn from review of such previous work were then compared to results obtained from deterministic methods.

5.1 Earthquake Recurrence Relations

The fundamental relationship characterizing the distribution of earthquakes as a function of magnitude in each source zone described above is the Gutenberg-Richter relationship:

$$\log N = a - bM$$

Earthquake events from the Global Hypocenter Database were evaluated for this study to determine the appropriate magnitude-recurrence relationship. Exhibit 8 presents a plot of the cumulative number of earthquake events of a certain magnitude per year. The apparent drop in number of events recorded below M5.5 may be due to the fact that seismic events below M5.5 are typically difficult to record and therefore records of these

events are limited. A regression analysis was used for the events greater than M 5.5 to develop the *a* and *b* parameters in the Gutenberg-Richter relationship:

$$\log N_c = 7.90 - 1.27M$$

where M is m_b.

The following conversions to standardize magnitude scales for comparison were required to effectively compare magnitudes reported by each of the references (Camacho et al., 1994):

$$M_w = 2.251(\pm 0.19) + 0.655(\pm 0.04) \times M_s$$

$$m_b = 2.64 + 0.50M_s$$

Using these relationships, the magnitude-recurrence relationship can be converted for the M_s and M_w magnitude scales to yield the following equations:

$$\log N_c = 4.63 - 0.63M_s$$

$$\log N_c = 6.79 - 0.96M_w$$

Exhibit 8 presents a preliminary magnitude-recurrence curve developed for this study using the above relationship.

5.2 Ground Motion Attenuation

Attenuation relations are probabilistic descriptions of the level of ground shaking as a function of the earthquake and site parameters including earthquake magnitude (moment magnitude is preferred), type of faulting, site-to-source distance, and local site conditions. Differences in tectonic regimes result in different tectonic relationships: shallow crustal earthquakes in active regions, shallow crustal earthquakes in stable regions, and subduction zone earthquakes. Attenuation relationships for Panama typically recognize subduction zone earthquakes and shallow crustal earthquakes in tectonically active regions.

The most preferable attenuation relationship for use in seismic risk is derived with local data. Although very few seismicity studies have been performed for Panama due to the lack of sufficient strong motion accelerograph data and isoseismal maps, attenuation relationships have been developed by others to describe the seismicity of Panama.

Attenuation relationships developed to describe the seismicity of Panama typically incorporate records from the Guerrero, Mexico earthquake with available Central American data to strengthen the magnitude-distance distribution of the data at larger magnitudes. The differences in the two data sets have been explored and based on comparative plots for soil and rock observations at various magnitudes, no significant differences were observed (Dahle et al., 1995).

Exhibit 9 presents the attenuation curves as prepared by Climent et al. for the Central American sites only and for that including the Mexico earthquake data. Also, the differences between shallow earthquakes and subduction zone earthquakes in the database were explored by Dahle and Climent. Their results indicate that no clear difference exists between the two databases and therefore, their further analyses eliminated the distinction between shallow crustal and subduction zone events.

Exhibit 10 presents the Central American data plotted in comparison with curves developed by Boore et al. (Climent et al, 1994). The relationship developed by Boore et al. depicts the attenuation of events in the Western U. S.; the Western U. S. relations typically appear slightly lower than those for Central America.

Exhibit 11 presents the Central American attenuation curves in comparison with that developed for Japan by Fukushima and Tanaka; such a comparison is made due to the similarity in the geology of Central America and Japan (Bodare, 2001).

The Central American attenuation relationship for rock outcrops as presented in Exhibits 9 through 12 is represented by:

$$\ln a_{\max}(m/s^2) = -1.687 + 0.553M - 0.537\ln R - 0.0032R$$

where R is the hypocentral distance in km (Bodare, 2001).

Exhibit 12 presents a composite comparison of various peak ground acceleration attenuation curves. In addition to the Central American attenuation curve developed by Dahle et al.(referenced in Cowan), the plot presents attenuation curves for subduction zone earthquakes as developed by Kawashima et al., Fukushima and Tanaka, Youngs et al., and Joyner, and for shallow crustal earthquakes by Campbell and Joyner and Boore (Cowan). For this study, this Central American attenuation relationship is used with knowledge that recommendations will be fairly conservative.

5.3 Seismic Risk

Ground motions for analysis are selected based on the assumed risk of the project. Ground motions selected corresponding to a return period of 10,000 years are typically recommended for analysis of high-hazard structures under the maximum design earthquake event (USCOLD, 1999). Return periods between 1,000 years and 10,000 years are typically used for dams where a return period of 10,000 years is approximately equal to a 1 to 2 percent chance of exceedance during a 100-year project life, while a 1,000 year return period is approximately equal to a ten percent chance of exceedance during a 100-year project life.

Design earthquakes representing the assumed risk of the projects must be identified so that seismic design parameters can be developed for each of the design earthquakes identified. Terminology typically used in analyses to define the design earthquakes is presented in USCOLD, 1999. The following paragraphs summarize pertinent information from this document.

5.3.1 Maximum Earthquakes Considered

Maximum Credible Earthquake (MCE). The maximum credible earthquake (MCE) is defined as the "largest reasonable conceivable earthquake that appears possible along a recognized fault or within a geographically defined tectonic province, under the presently known or presumed tectonic framework." In the process of selecting design earthquakes and ground motions, several different MCE's may be selected based on their generating source, fault mechanisms, and

distance from the site. One may be selected as being the controlling event, typically the most severe.

Maximum Design Earthquake (MDE). The maximum design earthquake (MDE) is defined as that which will "produce the maximum level of ground motion for which the dam should be designed or analyzed." Following an MDE event, the project should perform without catastrophic failure, with allowance for severe damage and/or economic loss. Uncontrolled reservoir releases are characterized as a catastrophic failure and would be unacceptable. The MDE can be less than the MCE but, in many cases is taken to be equal to the MCE, in particular for high-hazard, reservoir-retaining structures.

Operating Basis Earthquake (OBE). The operating basis earthquake (OBE) is defined as "the level of ground motion at the dam site with a 50 percent probability of being exceeded in 100 years." Following an OBE event, the structure should function with little to no damage and without interruption towards the true functionality of the project.

5.3.2 Design Earthquakes for the Projects

An evaluation of the project seismicity as well as the economic and life-safety issues associated with the water supply projects indicates that they can most likely be classified as significant rather than high hazard projects. No fault movement, or ground breakage due to tectonic offset, has been recorded in the area over the last 10,000 years and the project region has no potential for the development of seiches or earthquake-triggered tsunamis.

Because the projects will be newly designed and constructed, the most up-to-date seismic design guidelines will be used and seismic resistant design features adopted where needed. The projects will not be constructed of or founded on liquefiable or potentially liquefiable materials and the projects will not be constructed on any known active or potentially active faults.

Based on the density plot of earthquakes (Exhibit 6), it is apparent that the greater percentage of earthquakes occurs on the borders of the Panama Block, away from the

location of the projects. Although the occurrence of a large event affecting the project area is possible, it is more likely to affect the plate boundaries.

On the basis of the above, therefore, it is recommended to analyze the projects with a return period near 2,000 years, *i.e.*, a five percent probability of exceedance over a project life of 100 years. In this respect, it is suggested that a level of motion less than the controlling MCE can be acceptable to represent the MDE for these projects when using probabilistic methods.

The recommended OBE for the projects shall be as recommended by USCOLD at 50 percent probability of exceedance over a project life of 100 years, or a return period of 144 years.

5.3.3 Seismic Hazard Curves

The seismic hazard curve showing the peak ground accelerations (PGA) versus the annual probability of exceedance as developed by others for the Central American attenuation is presented in Exhibit 13 (Bodare, 2001).

In addition, Camacho et al. developed hazard curves for soil conditions using the Central American attenuation for seventeen different localities in Panama. The catalog used for the development of the seismic hazard curves by Camacho et al. was complete from 1910 to 1992 for magnitudes above M_w 5.8 and for magnitudes above M_w 4.7 from 1963 to 1992. The seismic source zones were defined at two depth levels, shallow sources less than 50 km deep and deep sources between 51 and 100 km deep. Sources with depths greater than 100 km were assumed to have minor impact on Panama were not included. Of the hazard curves developed by Camacho et al., the curves for the following cities within the pre-defined boundary of the projects were evaluated for this study and are presented in Attachment 4.

Aguadulce, Cocle	Chitre, Herrera
Chorrera, Panama	Coronado, Panama
Panama City, Panama	Penonome, Cocle
Santiago, Veraguas	Sona, Veraguas

5.4 Results

5.4.1 MDE Event – Probabilistic Basis

The recommended frequency of exceedance (or return period) for the MDE event for these projects is five percent over a 100-year project life, corresponding to a period of return of approximately 2,000 years. Based on the seismic hazard curve for Central America shown in Exhibit 13, the PGA due to this earthquake would be in the range of 0.45g. Such a value is thought to be disproportionately large, possibly because this peak ground acceleration is based on relationships developed from data collected outside Panama and mostly from subduction zone events, which are not characteristic of the project region.

It is noted that the seismic parameters resulting from the referenced studies do not seem to be in keeping with apparent distribution or incidence of earthquakes in the project region as shown on Exhibit 6. Additional study should be made of this seeming paradox but is outside the current scope of work. It is recommended that any future investigations for the water supply projects should include a site-specific seismic hazard analysis with an attenuation model that is more in keeping with the region.

5.4.2 MDE Event – Deterministic Basis

The closest active and most important seismic source zone to the proposed water supply projects is the North Panama Deformed Belt. The maximum magnitude assigned to this source is between $M_w = 7.0$ and 7.7

$M_w = 7.0$ to 7.2 (Acres, 1981).

$M_w = 7.7$ (Schweig, 1999)

With a deterministic approach and applying various Central American attenuation models described above, the resulting peak bedrock acceleration at the Río Chagres water supply projects is as follows:

Table 3: Estimated Peak Bedrock Accelerations at Río Chagres Project Site

Closest Distance to N. Panama Deformed Belt (km)	PGA (g)[1]	PGA (g)[2]	PGA (g)[3]
100	0.20	0.11	0.10

Notes: 1/ based on Joyner (1999) subduction zone earthquakes. 2/ based on Dahle et al. (1995), subduction and shallow crustal earthquakes in Central America and Mexico. Both curves for rock sites. 3/ based on Camacho et al. (1994).

The peak bedrock acceleration value based on Joyner (1999), presented in the first column of the table above, is recommended for use in preliminary design. The values based on the attenuation models of Camacho et al. and Dahle et al. (1995) are considered rather low. In contrast, that calculated based on Joyner (1999) is considered to be appropriate and more in keeping with the regional tectonic framework and known rates of seismicity compared with those developed by probabilistic methods described earlier.

5.4.3 OBE Event

The recommended frequency of exceedance (or return period) for the OBE event for the projects is 50% over 100 years, corresponding to a period of return of approximately 144 years. For the western watershed projects, this hazard is determined from curves developed by Camacho for specific cities within Panama. These were developed for a return period of 1,000 years but can be used to determine the average PGA for the OBE event. The following table presents the maximum peak ground acceleration on soil sites for each of the cities for a return period of 144 years, as defined by the OBE. Equivalent bedrock accelerations are obtained by using a factor of 0.76 (Camacho et al., 1994).

Table 4: Peak Ground Accelerations for Selected Sites

City	Return Period (years)	PGA(1) (m/s^2)	PGA(1) (g)	PGA(2) (g)
Aguadulce, Cocle	144	1.75	0.18	0.14
Chitre, Herrera	144	1.85	0.19	0.14
Chorrera, Panama	144	1.75	0.18	0.14
Coronado, Panama	144	1.65	0.17	0.13

City	Return Period (years)	PGA[1] (m/s^2)	PGA[1] (g)	PGA[2] (g)
Panama City, Panama	144	1.85	0.19	0.14
Penonome, Cocle	144	1.65	0.17	0.13
Santiago, Veraguas	144	2.00	0.20	0.15
Sona, Veraguas	144	2.15	0.22	0.17
Average				**0.14**

Notes:

(1) Peak ground acceleration reported for soil sites.

(2) Peak ground acceleration converted to peak bedrock acceleration by multiplying factor of 0.76

The seismic hazard curves shown in Exhibit 12 and Attachment 4 were used to determine that the PGA (in bedrock) for the OBE event is 0.14g. Further investigation, as recommended above, might result in lower ground accelerations.

5.5 Recommended Seismic Design Parameters

The recommended seismic design parameters for the Río Chagres Project are as follows:

Maximum Design Earthquake (MDE) = 0.20 g
Operating Basis Earthquake (OBE) = 0.14 g

6 GEOLOGY OF RÍO CHAGRES DAM SITE AREA

This chapter provides descriptions of the geology of the Río Chagres dam site and reservoir areas. These descriptions and interpretations are based on the results of site visits and field investigations made during May and June, 2002. Photographs of the site taken during the field investigations are presented in Attachment 5.

6.1 Topographic Conditions and Physiography

The damsite on the Río Chagres is located approximately 500 meters downstream of its confluence with the Río Chico. At the damsite, the Río Chagres flows south in a deeply incised meanders that form an asymmetrically shaped valley exhibiting nearly 300 meters of relief. The meanders seem to be controlled by structural features in the rock mass. Relatively steep slopes on the left abutment contrast with more gradual slopes of the right abutment. The west-facing left abutment slope angle varies between about 35 and 45 degrees. The right abutment is formed by a narrow east-west trending ridge, with the nose of the ridge sloping eastward down to the river at an angle of approximately 20 to 25 degrees; the north and south sides of the ridge are characterized by steeper slopes, with slope angles in the range of 30 to 45 degrees. Both abutments are almost entirely covered with residual soils and colluvium, and are heavily vegetated.

The valley floor in the vicinity of damsite is on the order of 50 meters wide and contains alluvial terraces and gravel and boulder bars. The alluvial terraces are mainly found on the inside of meanders, while the gravel and boulder bars are typically found along straight sections of the river channel. Several boulder bars can be observed at places where apparently more resistant rock controls the river gradient. Bedrock outcrops are exposed almost continuously along the riverbanks, and in several places along the river bed. The outcrops are composed of very hard, resistant andesite and they generally extend about 1 to 5 meters above the river bottom in the vicinity of the project site.

6.2 Unconsolidated Deposits

Overburden at the dam site consists primarily of residual soils and colluvium. In the riverbed and lower 5 to 10 m of the valley sides, overburden consists of alluvial deposits ranging from sand to boulders.

6.2.1 Quaternary Alluvium

Alluvial deposits along the Río Chagres valley consist primarily of sand to boulder-sized material deposited on the inside of meander bends as terraces, and within the river channel as bar deposits. Two different terrace levels are evident, one about 2 m above current river levels, and a second level about 5 m above the current river levels. The higher terraces are generally formed by clean sands while the lower alluvial terrace deposits consist primarily of coarser sands and gravels. Several boulder bars can be observed at places where apparently more resistant rock controls the river gradient.

All of the alluvial material appears to be derived from volcanic rock types – predominantly fine-grained extrusive rocks (andesites, altered and unaltered) and to a lesser extent, granites. No sedimentary rock types were observed among the coarser alluvial material.

6.2.2 Colluvium and Residual Soils

Because of the tropical climate, most bedrock throughout the project area has a moderate to deep weathering profile. Observations made at the site indicate that the depth of residual soil and deeply weathered rock reaches 25 m or more in the upper slopes.

A well-developed layer of residual soil and weathered rock covers most bedrock at the site. Outcrops occur only along the river channel and the largest creeks flowing to it. Smaller creeks and seasonal brooks run on highly weathered rock and deposits of boulder sized corestones. Thin colluvium deposits are identifiable at several locations, and alluvial deposits are visible as terraces in the inside of meanders. Residual soils are medium plastic and with high natural moisture content.

6.3 Rock Units

Bedrock units in the Alto Río Chagres project area consist largely of Cretaceous rocks of volcanic origin. Based upon regional relations and similarities with geologic units observed in the Canal Zone, bedrock units in the Alto Río Chagres project area are thought to belong to the Igneous Basement Complex.

The volcanic rock along the Río Chagres in the vicinity of the dam site has been identified in the field and referred to as andesite. Petrographic analyses performed on several samples collected near the dam site indicate that it is more properly classified as a trachyte. Trachyte is also an intermediate composition extrusive volcanic rock, however it is slightly more mafic than andesite. In keeping with local terminology, however, the rock is referred to as andesite throughout this report.

6.3.1 Andesite and Agglomerate

Bedrock at the dam site and in the immediate vicinity is primarily dark gray to greenish gray andesite. Several zones of agglomerate were also observed in surface exposures and in boreholes. Observations made at during the mapping and drilling program indicate that the stratigraphic relationship between the andesite and agglomerate is highly variable. The agglomerate appears to be an interflow feature of individual andesite flows, with clasts being incorporated from existing surficial deposits and from volcanic activity (explosions, debris flows). Description of the principal rock types follow:

> Andesite: homogeneous, fine-grained; exhibits varying degrees of hydrothermal alteration; hard to very hard, ranging in color from light to dark gray and greenish gray; surface weathering expression results in smooth, rounded appearance in some areas and a more blocky appearance in others. Contains epidote and calcite veins.
>
> Agglomerate: heterogeneous, containing angular to subrounded clasts in a fine to medium-grained gray andesitic matrix; exhibits varying degrees of alteration and hardness, from very soft to hard; color ranges from light greenish-gray to dark gray; clasts range in size from 3 to 200 mm and are of igneous origin, including andesite and granite.

Several andesite dikes cutting through older andesite layers were observed in outcrops along the river. The observed dikes appeared to be concordant with local structural orientations. The andesite is fine-grained, competent and very hard. The thickness of the dikes is on the order of 20 to 40 cm.

6.4 Structural Geology

6.4.1 General

The principal geologic structures recognized at the Río Chagres dam site are fault/shear zones, fracture zones, and joints. A number of lineaments were also identified based on a desk study of aerial photographs and topographic contours available for the project area. The lineaments, shown on Exhibit 2, are predominantly oriented NE-SW, with less prominent orientations being NW-SE and N-S. The NE and NW orientations are similar to the orientation of the major faults forming the Lake Alajuela basin. These lineaments could be representative of faults, shear zones or predominant structure orientations.

6.4.2 Faults and Shear Zones

While no discrete faults were defined at the site, evidence of minor fault/shear zones was observed in several boreholes in the form of gouge zones ranging in length from about 1 to 8 m (downhole length). These zones are indicated on the downhole logs shown on Exhibit 17.

Prior to visiting the site, a north-south lineament was identified from a topographic map of the region. The southern end of the lineament appears to terminate just downstream of the damsite, while the northern end extends several kilometers up the Rio Chico. It was believed that this lineament could potentially be a fault, and in order to explore this possibility, an angled borehole (CH-3) was drilled from the right abutment and oriented such that it penetrated beneath the river channel in the vicinity of the dam axis.

The majority of the rock encountered in CH-3 was agglomerate of medium hardness (R3) and generally highly fractured. Several zones of softer, altered rock were encountered in the hole, along with several shear and fault zones, ranging in width from about 3 to 8 meters. The shear and fault zones are characterized by highly fractured, soft rock containing slickensided surfaces and some clay gouge. The rock core is typically highly

fractured and exhibits some alteration to clay minerals, especially in the shear and fault zones. A downhole summary log of CH-3 is included on Exhibit 17; the detailed log is contained in Attachment 1.

Based on information gained from CH-3 and from observations made during site reconnaissance, this feature is being interpreted as a shear zone rather than a fault. Strong evidence of faulting, including indications of ground offset, changes in lithology, and changes in structural orientations, was not observed in association with this feature. Nonetheless, this feature should be explored more thoroughly in the context of the regional geology and through detailed mapping at the site and additional borings in order to better understand its nature and to determine what, if any, implications there may be with regard to design and construction of a dam at this site.

6.4.3 Rock Joints

Rock joints observed at the site in surface outcrops generally tend to be very tight with little to no infilling. The joints are typically very closely spaced, with spacings on the order of 5 to 40 cm. Rock joints observed in the drill core range from rough, hard joint surfaces with thin calcite, epidote and iron oxide coatings to more altered, softer joint surfaces exhibiting slickensides. Clay minerals were observed in some joints that are usually associated with minor fault and shear zones. The rock core is typically highly fractured, exhibiting very close joint spacings.

Rock joint orientations were measured at outcrops located at the dam site, upstream of the dam site along both the Río Chagres and the Río Chico, downstream of the dam site, and in the right abutment. There are no obvious differences in structural orientations measured from these locations. There are generally three prominent joint sets that seem to control outcrops and influence river channel path; their orientations are listed below

- N-S striking, steeply dipping
- E-W striking, steeply dipping
- N 30° E striking, steeply dipping.

Another less prominent set striking about N 30° E and dipping 15° to 25° to the NW was also observed at several locations. A stereonet showing measured joint orientations is

presented in Exhibit 14. These measurements were collected during the preliminary site visit and they represent the more prominent joints observed at the respective sites – this is in contrast to a more comprehensive, systematic joint mapping program which is normally part of a detailed geologic mapping program.

6.5 Hydrogeology

Groundwater data and hydrogeologic properties of the geologic units at the dam site are not known. It is suspected that groundwater levels are at relatively shallow depths in the abutments.

In general, permeabilities determined from water pressure testing were very low – less than about 2 lugeons – with the exception of a few zones that had lugeon values in the 30 to 90 range; these higher permeability values were usually encountered at the transition zone from the weathered to sound rock. This could be an indication that the rock is very tight, however, it should be noted that in most holes, there was almost no return of the drilling fluid. The drill cuttings therefore could not be confidently washed from the hole, which may have affected the water pressure test results.

7 ENGINEERING GEOLOGY OF RÍO CHAGRES DAM SITE

This chapter presents engineering geologic evaluations of various proposed project elements at the Río Chagres dam site. This is preceded by a brief evaluation of factors influencing selection of the dam type and interim dam axis.

The dam types considered for the proposed project are a concrete faced rockfill dam (CFRD) with an ungated chute spillway located on the right abutment, and a roller-compacted concrete (RCC) dam with a spillway located on top of the dam. Diversion during construction could be achieved by cofferdams and by either diversion tunnels or diversion culverts in the right bank.

7.1 Factors Influencing Dam Type Selection and Preliminary Layouts

Generally, the geologic and geotechnical factors that most influence selection of dam type fall into the following categories:

- General foundation bedrock acceptability;
- Sliding resistance and deformation characteristics of foundation;
- Required excavation depths to achieve acceptable foundation materials;
- Measures required to treat the foundation to improve physical properties and control leakage;
- Long-term performance of the foundation under normal operation conditions and extreme events, especially earthquake; and
- Availability of suitable construction materials.

Such geological and geotechnical factors can have direct influence on the development of comparative construction costs and were taken into consideration during the study of dam type alternatives. The process was based on data obtained from the investigation, as well as on qualitative evaluations involving engineering judgment and previous experience in similar geological environments.

7.1.1 Dam Type Selection

Following layout comparisons based on hydrologic, geologic/geotechnical, and cost considerations, the final recommended arrangement is an RCC (roller compacted concrete) gravity dam with a spillway located on the dam crest (Appendix D-1, Dam Type Selection).

7.2 Geotechnical Design Parameters

Geotechnical design parameters and criteria used for developing preliminary layouts and cost estimates for dam type selection are presented in Table 5 and are described in the following paragraphs.

Table 5: Summary of Geotechnical Design Parameters for Layouts

Parameter	Selected Design Criteria	
Thickness of overburden (top of weathered rock)	Varies; 5 m in river channel to 12.5 m in abutments	
Depth to top of competent rock	Varies; 10 m in river channel to 25 m in abutments	
Rock Excavation Slopes	0.2H : 1V, 3-m-wide benches every 10 m vertically	
Soil Excavation Slopes	Permanent	1.5H : 1V, 3-m-wide benches every 10 m vertically. Bench at soil-rock contact
	Temporary	1H : 1V, 3-m-wide benches every 10 m vertically. Bench at soil-rock contact

7.3 Foundation Bedrock Characteristics

Bedrock at the dam site consists of andesite that is interspersed with zones agglomerate/interflow material. In general, the foundation bedrock is not expected to present any significant constraints on project development that cannot be taken care of with appropriate conventional design details and construction practices. This is in

contrast to some sedimentary rock units and geotechnical conditions known from the Canal Area (e.g. Cucaracha Formation), where sliding and foundation failures have been common and presented serious problems.

- *Bearing Capacity.* The andesite and agglomerate bedrock is expected to provide adequate bearing capacity to support any of the structures being considered. Differential settlements should not be a concern with this type of foundation. Zones of softer rock were encountered in the drilling, particularly in borehole CH-3 drilled beneath the river channel, however, these are not anticipated to be a concern with respect to bearing capacity or differential settlements for the types of dams being considered. Data from additional subsurface investigation and testing will be needed to develop design and construction details for foundation treatment

- *Resistance to Sliding.* The andesite and agglomerate should provide adequate resistance to sliding along jointing or other planes of weakness provided excavation depths are sufficient to achieve fresh sound bedrock.

7.3.1 Material Strength Parameters

The nature of the bedrock at the site spans a wide range of conditions ranging from altered, soft rock to fresh, hard rock (as exposed in the rock outcrops). As a result, two sets of strength parameters were developed to represent an upper and lower bound strength; these upper and lower bounds are designated *Low* and *High* to represent the relative lower (low strength) and upper (high strength) bounds. A description of the rock masses corresponding to these bounds is given below.

Andesite/Agglomerate (Low): Strongly weathered and/or altered; highly fractured with RQD's less than 25 percent; soft rock with a very low unconfined compressive strength in the range of about 5 to 30 MPa; joint surfaces are altered and slickensided and may contain fault gouge. This type of rock was encountered in portions of borehole CH-3 and in the upper portions of several other boreholes.

Andesite/Agglomerate (High): Unaltered or weakly altered; fresh to slightly weathered; moderately fractured with RQD's in the range of 25 to 50 percent; hard rock with unconfined compressive strengths in the range of 80 to 150 MPa;

joint surfaces are rough, tight and have little to no infilling. This type of rock was encountered in the lower sections of several boreholes and was observed in surface outcrops.

No differentiation is being made between the andesite and agglomerate rock types at this time. This is primarily because the relative strengths appear to be more of a function of the state of weathering and/or alteration rather than the lithology.

The estimated range of material strength parameters recommended for use in preliminary stability checks is provided in Table 6.

Table 6: Estimated Material Strength Parameters

Rock Type	Intact Rock		Rock Mass	
	Unit Weight (kg/m^3)	UCS (MPa)	ϕ (deg)	c (MPa)
Andesite/Agglomerate (Low)	2600	5 - 30	29	0.2
Andesite/Agglomerate (High)	2700	80 - 150	61	1.2
Selected Rock Mass Strength Parameters for Design			*45*	*0.5*

The intact rock parameters are based on preliminary rock mechanics testing performed for the present study (Attachments 2 an 3) and on published data and experience with similar materials elsewhere. The unconfined compression strength (UCS) is based on results obtained from uniaxial compression tests and from point load tests. The individual results of the tests are shown on the downhole logs presented in Exhibit 17; the point load test results that are shown have been correlated to the unconfined compression strength.

The rock mass parameters friction angle (ϕ) and cohesion (c) are representative of the *rock mass* strength; the rock mass represents the collection of intact rock blocks and fractures. These parameters were estimated using the Hoek-Brown failure criterion (Hoek, et al., 2002), which is a widely used method for estimating the strength of rock masses.

7.4 Excavation Depths

An estimate of depth to groutable (or foundation-grade), competent rock was made by an MWH geologist upon inspection of the drill core at the ACP offices. The selection was based of the degree of weathering of the rock, and the character of any joint infillings. The depths are summarized below in Table 4.

Table 7: Estimated Depth to Groutable Bedrock

Borehole	Collar Elevation (m)	Selected Depth to Groutable Rock (m)	Location
CH-1	206.3	23	upper right abutment
CH-2	142.5	25	middle right abutment
CH-3*	109.0	16.3 (*8-10*)	river channel
CH-4	184.0	19.1	mid-upper left abutment
CH-6	116.6	27-30	middle left abutment, plinth
CH-7	160.8	22-26	right abutment, diversion tunnel
CH-8*	114.4	23.4 (*18-20*)	middle right abutment, plinth
CH-9	219.7	23.5	upper left abutment, spillway

* inclined hole; (*italics = depth measured vertically from ground surface*)

Based upon information gained from the drilling program and observations made at the site, the estimated depth to competent rock is 10 m in the river channel, increasing to 25 m in the abutments. The depth to top of weathered rock (overburden thickness) was estimated as about half of the depth to competent rock. These values were used in the development of preliminary layouts and in the computation of quantity takeoffs for cost estimates.

Excavation depths used for the preliminary layout of the dam and spillway are indicated below in Table 8.

Table 8: Estimated Excavation Depths

Dam Type	Feature	Estimated Excavation Depth
RCC	Main Dam	Varies from 10 m (river channel) to 25 m (abutments)
CFRD	Plinth and 25m d/s of grout curtain	Varies from 10 m (river channel) to 25 m (abutments)
	Main Dam Body	Varies from 5 m (river channel) to 12.5 m (abutments)

Because of the limited nature of subsurface data, a detailed foundation excavation plan has not been developed. Instead, only a general concept has been reached in which proposed excavation depths are equal to or deeper than the estimated minimum depths indicated on Table 8. It should be understood that in places deeper excavation might be required where localized geologic conditions require. Also, in some places additional excavation may be required just for foundation shaping.

Excavation should go down to uncompressible, sound bedrock that can be readily grouted, if required for strength improvement or to reduce permeability. It should be sufficiently unweathered such that rock strengths are not seriously impaired and joints should be tight, or, if open, should readily accept grout and not be filled with any soft or erodible materials. The rock mass should not be compromised by any pervasive or major through-going discontinuities that could affect sliding stability or uplift of the structure.

The deformation modulus of the foundation should not differ radically from one location to another such that unacceptable stresses may result in the structure itself.

7.5 Foundation Improvement, Treatment, and Long-Term Performance

No special foundation improvement or treatment measures are expected for the Río Chagres site that would strongly influence selection of one dam type over another. Similarly, the andesite and agglomerate bedrock is expected to perform satisfactorily over the lifetime of the project without adverse deterioration.

7.5.1 Foundation Treatment

The proposed treatment programs for the dam foundation will include surface treatment, shallow foundation grouting, curtain grouting, and drainage.

Surface Treatment. For the excavation beneath the dam footprint, dental excavation and concrete will be used to treat local zones of highly weathered, sheared, or otherwise unacceptable rock encountered in the foundation. Required dental treatment should be nominal and only local. However, contingency quantities for backfill concrete should reflect the potential for surprises as found on some other local projects. For example, it is understood that during construction at the Esti Hydroelectric Project in Panama considerable over-excavation and additional treatment were required along parts of the CFRD plinth slab.

Shallow Foundation Grouting (Consolidation). Consolidation grouting is not envisaged except in limited areas (e.g. fault or fracture zones) should they become exposed during excavation. Low pressure cement grouting will be used in such limited zones to fill open cracks or joints in the rock zone immediately beneath the dam foundation. In general, grout takes should be low.

Curtain Grouting. Curtain grouting will be used to reduce seepage through joints and fractures under the dam and in the abutments. Because of the limited extent of the subsurface investigation data it is difficult to estimate depths and extent of grouting. For initial estimating purposes, a single row, staged grout curtain constructed by the split-spacing method is assumed. Final design might require grout holes to be inclined to intercept the maximum number of open joints, fractures, and faults. The initial depth of the grout holes is taken to be half of the height of the PMF above the dam foundation. The initial spacing of primary grout holes is taken to be 10 m and it is assumed that procedures will entail split-spacing down to 2.5 m (tertiary holes) over the entire curtain, and to 1.25 m (quaternary holes) over 75% of the curtain. In some more permeable locations, such as shear zones or faulted areas, grout holes might have to be staggered upstream and downstream.

Grouting will be performed from a gallery constructed within the dam. Grout takes should be low to moderate through most of the curtain. The average grout consumption was assumed for estimating purposes to be about 30 kg/m.

Foundation Drainage. Foundation drainage will be provided from the gallery for the dam to control seepage to reduce pore pressures in the rock mass, and hence uplift. For estimating purposes, a drain hole spacing of 3 m was assumed with depths extending to about half the depth of the grout curtain. Holes would be appropriately inclined in order to maximize the number of joint/fracture interceptions.

7.5.2 Foundation Conditions in the River Channel

While it is not anticipated that shear zones interpreted in the river channel will pose any significant problems with regard to the dam safety, there is a possibility that additional measures may need to be undertaken to improve the foundation and the dam stability in this area. The majority of rock encountered in borehole CH-3, although highly fractured, is of a moderate hardness that does not appear to differ significantly from the rock encountered in the abutments. The rock mass strength is probably lower in this area on account of the fracturing, but it is not expected that there will be a significant difference in the deformation characteristics, such that differential settlement would be of concern.

If, during construction, the rock in the river channel is found to be of questionable or poorer quality than assumed, the traditional foundation treatment measures described above may be difficult to apply in this zone. Typical solutions would be to excavate the weak material or to perform shallow consolidation grouting, however because the shear zone appears to extend fairly deep below the river channel, excavation might not be a feasible or economic option. In addition, consolidation grouting may be difficult due to the extensive nature of the fracturing; water pressure tests performed in CH-3 generally indicated very low permeabilities along much of the borehole.

Additional investigations, including a test grout program, should be made in this area to further assess the foundation conditions in the river channel and to investigate the potential need for special foundation treatment measures. Special measures that can be taken to mitigate any adverse foundation conditions in the river channel discovered prior to or during construction could include addition of an upstream heel block to the RCC cofferdam or construction of a shear key in the zone of questionable material in order to improve the dam stability in this zone.

7.6 Construction Materials

Proposed sources and uses of available materials for construction, included required excavation, are discussed later in this report.

7.7 Plunge Pool Basin

Future assessments should examine rock erosion and stability conditions in areas where spillway discharge will impact. Currently, it is expected that spillway discharge will not result in unfavorable progressive erosion or instability of individual blocks.

For the RCC dam, the spillway is sized and positioned on the dam such that the majority of the discharge is directed into the river channel. Because the proposed spillway is slightly wider than the river channel downstream of the dam, excavation of a spillway plunge pool will be required in the right bank approximately 100 m downstream of the dam toe. The spillway was positioned such that the discharge will not impinge on the left abutment, which is significantly steeper and higher than the right abutment. Any erosion at the base of the left abutment slope could potentially lead to slope instability.

7.8 Diversion and Cofferdams

7.8.1 General

The selected diversion arrangement consists of cofferdams and twin box culverts located on the right abutment. For preliminary design and estimating purposes, a 7m by 7m twin box culvert located on the right abutment has been assumed with a length of about 150 m. The culvert invert elevation will be about 88 m at the upstream end and about 87m at the downstream end.

The upstream cofferdam will have a crest elevation of 121 m and will be about 45 m high. Due to space constraints at the site, the upstream cofferdam is proposed as an RCC structure rather than an earthen structure. The cofferdam will be incorporated into the structure of the main dam. It will be constructed with materials quarried near the dam, or otherwise

imported. The pre-cofferdam and downstream cofferdam will be constructed of random fill material obtained from borrow areas located near the dam site.

Two 7-m diameter, D-shaped diversion tunnels were originally considered for river diversion during the Dam Type Selection Study. The diversion arrangement was later changed to a diversion culvert on the right abutment. There are no geologic features or conditions observed nor anticipated that would impact the selection of one diversion arrangement over the other.

7.8.2 Tunneling Conditions

The alternative diversion scheme involves tunnels that would be excavated through andesite and agglomerate. This bedrock should be of moderate to high strength and unweathered over much of the tunnel length. A cross-section through the right abutment at the approximate location of the diversion tunnels is presented on Exhibit 16. Two boreholes (CH-8 and CH-7) were drilled in vicinity of the proposed tunnel alignments and rock conditions encountered were generally fair to good. Conditions at the tunnel portals are expected to be good, as outcrops of hard, competent andesite were observed at the upstream and downstream portal locations. The andesite and agglomerate should provide favorable tunneling conditions using conventional drill and blast methods. Poor conditions may be encountered locally in the tunnel associated with deeply weathered areas, fracture zones, minor faults, or shear zones. Groundwater is contained almost entirely in open joints. Although local inflows may occur from individual open planes, these flows should be minor and temporary and will not pose any problems during construction. The tunnels, as currently aligned, provide adequate cover below the assumed limits of the dam foundation excavation.

It is assumed that rock support required in diversion tunnel construction would consist of steel sets, pattern bolting, and shotcrete near the portals, and pattern bolts, with or without shotcrete elsewhere. Four tunnel support categories have been identified as indicated on the following table.

Table 9: Diversion Tunnel Rock Support Categories

Tunnel Support Category	Rock Condition	Rock Support
I	Good	0-5 cm shotcrete; spot bolts as required
II	Good to Fair	0-5 cm shotcrete; pattern bolts, 5 per section
III	Poor	5-10 cm shotcrete with wiremesh or fiber reinforced shotcrete; pattern bolts, 7 per section
IV	Poor to Worst	10-15 cm shotcrete; steel sets (lattice girders or shotcrete rebar ribs); bolts as required

For construction cost estimating purposes, the distribution of these rock support categories has been conservatively estimated as indicated on Table 10 below.

Table 10: Estimated Rock Conditions in Construction Diversion Tunnel

Type of Ground	I	II	III	IV
Estimated % of Type Encountered	15	50	30	5

7.8.3 Diversion Cofferdams

Geologic data available for the diversion cofferdam includes surface reconnaissance mapping and information gained from two boreholes drilled in the vicinity of the upstream cofferdam location. Because the RCC cofferdam structure will be incorporated into the main dam, it will need to be founded on competent bedrock. The thickness of the alluvial deposits is estimated to be on the order of about 5 meters thick.

Foundation conditions near the upstream cofferdam were observed during the site visit and were explored via boreholes CH-6 and CH-3. The following observations were made:

- There are rock outcrops of hard, jointed bedrock along both banks of the river.
- Borehole CH-6, drilled in the left abutment just below the cofferdam crest elevation, indicates a depth to weathered rock on the order of about 4 meters and a depth to competent, groutable rock on the order of 25 to 30 meters.
- Borehole CH-3, drilled beneath the river channel along the axis of the main dam, indicates that there is possibly a shear zone located within the river channel. It is not anticipated that this feature will present any problems with respect to cofferdam construction, however this area should be explored with additional borings.

7.9 Reservoir

Small landslips and slumps were observed on slopes located in the vicinity of the proposed dam site, and it is expected that similar features exist throughout the reservoir area. Aerial photo coverage of the reservoir area is not available and therefore the potential for large-scale mass movements within the reservoir could not be assessed.

7.10 Summary and Conclusions on Dam Site Geology

No other potential dam sites were considered during the course of this study. The selected dam site has been well selected from a topographic viewpoint and appears to be a suitable site.

In regard to geological aspects, there do not appear to be any strongly adverse conditions or fatal flaws at the site that would seriously hinder or prevent development or make it too costly to construct. Site conditions are interpreted to be difficult, but can be handled through conventional design and construction practices without having to resort to special or unprecedented methods. Preliminary subsurface investigations indicate that geologic conditions do not impose any significant development impediment.

Factors that appear favorable include:

- No deep alluvium is present at the site that would require deep seepage cutoff;

- Foundation bedrock at the dam site is the same on both sides of the river with no indication of major faulting in the river channel;
- Bedrock consists of andesite and agglomerate which would serve as a suitable foundation for the types of dam and appurtenant structures being considered;
- Given appropriate engineering design and construction methods, the foundation could be readily treated to control seepage, and would not pose hazards with respect to stability or liquefaction;
- A construction scheme can be developed that will permit access to the foundations in the dry, allowing inspection and appropriate treatment;
- Suitable materials for aggregates, rockfill, and other construction requirements are available.

8 GEOLOGY OF POWERHOUSE AREA

Potential locations for a powerhouse facility were not specifically investigated in the field as its size and arrangement were not known at the time of the investigations. Possible locations were anticipated to be immediately downstream of the dam at the dam toe, or at the north side of the 'U' bend in the river at the base of the slope where borehole CH-7 is located (Exhibit 3).

The selected powerhouse location is the latter of the two sites mentioned above, which is approximately 1 km downstream of the dam. Water will be transferred to the powerhouse via a shaft and tunnel arrangement through the right abutment. The power tunnel alignment is approximately the same as that originally considered for the diversion tunnels; Section 7.8.2 should be consulted for a description of the anticipated tunneling conditions.

The powerhouse will be located at the base of a very steep slope. Rock outcrops at this location were observed to extend higher above the river channel than was observed at other locations – on the order of 10 to 15 m above the river level. The rock is strong and competent. The backslope for the powerhouse should be benched and cut to a suitable slope to maintain stability. The exposed surface of the excavation should be rock-bolted and covered with chain-link to control loosening and falling of small blocks. Areas on permanent slopes that are more weathered or closely fractured would require, in addition to the chain-link, a layer of shotcrete provided with drain relief holes. A complete subsurface and surface drainage system would be required to intercept and control surface runoff, and prevent erosion damage.

9 CONSTRUCTION MATERIALS

The construction materials required for the project can be classified as:

- Materials for cofferdams, impervious fill, rockfill and random fill,
- Concrete aggregates,
- Filters and drains,
- Impervious fill,
- Backfill and structural fill,
- Rock fill for the dam, , and
- Rock for riprap and slope protection.

These materials are basically of four types:

- Impervious fill,
- Rockfill,
- Random, backfill and structural fill,
- Concrete aggregates, filters and drains.

9.1 Sources

Three primary construction material sources were identified based on field reconnaissance, aerial photograph analysis and study of topographic maps. Each of the three material sources is discussed below.

9.1.1 Alluvial Deposits

Deposits of clean alluvial sands and gravels were observed along much of the Río Chagres; mainly as terraces and bar deposits on the inside of meander bends and along the sides of the river channel, and as bed load in the river channel. These deposits are locally of small volume and limited in extent. Sufficient quantities of these materials were not identified within reasonable distance of the dam site to warrant their use as a construction material. They are therefore not considered a suitable or economic material resource for the construction of the project, although they may be used for road

construction and construction camp construction. Photographs of sand and alluvial deposits are contained in Appendix 5.

9.1.2 Colluvial and Residual Soils

Most of the bedrock in the project area is covered by well-developed horizons of colluvial and residual soils. These materials were tested in the laboratory and were found to be suitable for use as impervious fill. However, its use as core material in ECRD construction is inconvenient because of its high moisture content.

9.1.3 Andesite

The exploration carried out to date shows that the andesite rock is covered by a thick mantle of residual soil, saprolite, and highly weathered rock. Development of a quarry will require the removal of about 20 m or more of these materials. The andesite rock is hard and durable, and preliminary information indicates it could be used for filters and for conventional concrete and RCC aggregate. Its use as rockfill is questionable, although still feasible, because the rock mass is extremely fractured and its exploitation would result in a large proportion of gravel size particles, or smaller. Potential quarry locations are shown on Exhibit 19.

9.2 Use of Materials

Impervious and Random Fill: Material for construction of diversion cofferdams will be obtained from locally available random fill exploited from the immediate vicinity of the dam site. This would include materials excavated at the site for the diversion culvert and dam foundation as well as materials removed for development of the quarry site.

Coarse and Fine Aggregate and Filters: Materials for coarse and fine concrete aggregates, filters and drains will need to be manufactured from quarried material, or imported from sources off-site. Quarries can be developed in the local andesite.

Rockfill: Rockfill for a CFRD would be obtained from required excavation, and from quarry run material.

Backfill: Materials for backfill will come from the required excavations, including use of tunnel excavation spoil.

Riprap: Riprap for channel and slope protection, where required, will consist of over-sized material obtained from the rock quarries.

10 RECOMMENDED ADDITIONAL INVESTIGATIONS

10.1 Dam Site

In the next phase of study of the Upper Río Chagres Water Supply Project, additional investigations will continue with site characterization activities and development of geologic and engineering parameters required for detailed design and preparation of more accurate construction cost estimates. As engineering studies continue to optimize and finalize structure locations, axes, and alignments, the investigations will focus on developing information on foundation conditions for specific structures and areas.

10.1.1 Dam Site Drilling

As mentioned previously, the exploration program carried out at the site included 8 boreholes comprising about 90 m of soil drilling and 350 m of rock drilling, plus 10 test pits. The following scope of additional exploration drilling is recommended as a minimum, assuming that the type of dam will be an RCC dam. Approximate hole locations are indicated on Exhibit 20.

Table 11: Proposed Drilling for Upper Río Chagres Dam

Location	Number of Drill Holes	Total Depth (m)
Dam foundation, left side	2	150
Dam foundation, right side	2	150
River valley section (angle holes under river)	1	200
Spillway Plunge Pool	2	100
Diversion Culvert	1	50
Upstream Cofferdam	1	100
Powerhouse	1	50

Location	Number of Drill Holes	Total Depth (m)
Power Tunnel/Shaft	1	100
Quarry	5	400
Contingency	3	200
Total	**19**	**1,500**

10.1.2 Dam Site Geologic Mapping

Detailed geologic mapping should be performed for the entire site area. The detailed geologic mapping will be performed to illustrate the detailed surface geology at proposed structure sites, usually in conjunction with subsurface exploration that will be performed in the same area. Detailed maps will be required for all major structure sites. This mapping should include:

- The surface extent and properties of all overburden units;
- Extent and lithology of all rock units including major interbeds or facies;
- All geologic contacts;
- Rock outcrop areas;
- Patterns of jointing, bedding, foliation and schistosity throughout the map area;
- Surface trace, attitude and width of faults and shear zones;
- Evidence of slope instability; and
- Springs, seeps, and any other relevant geologic condition.

The completed detailed geologic maps, in addition, should show the location of major project structures, the location of holes, adits, pits, trenches, seismic lines or other exploration features, and the location of geologic sections used to illustrate the subsurface geology. The maps should illustrate both the general, geology of the site, and the detailed, local geology.

10.1.3 Adits

It is recommended that the next phase of investigation include one or more exploration adits to assist in the evaluation of dam foundation conditions. The total length of adit exploration should be about 100 m per adit. The exploration adits could later be converted to drainage galleries.

10.1.4 *In Situ* Testing and Geophysics

Conventional water pressure testing will be performed in all exploration drill holes. All drill holes, wherever practical, will be converted to permanent groundwater monitoring holes.

Geophysical testing should be performed throughout the dam site to complement and extend the findings of the subsurface exploration. In addition to surface seismic refraction, consideration should be given to downhole seismic (cross hole seismic). Collection of shear wave velocity data in exploration adit(s) and elsewhere is recommended as it is a valuable method of obtaining information on rock mass properties (modulus of deformation).

10.1.5 Construction Materials for Dam

Potential quarries have only been preliminarily identified, without performing any investigation. Investigation of potential quarry sources should include core drilling, sampling, and testing. The number of drill holes and total length of drilling will depend on the location of quarry sites selected for investigation. It is estimated that 5 drill holes will be required for a total of about 400 m. Rock core samples will be collected for laboratory testing which should include compression testing, soundness, LA abrasion, and aggregate petrography, etc. as follows:

Table 12: Recommended Laboratory Testing for Construction Materials

Test Type	Standard
Bulk Specific Gravity of Rock	ASTM C 97
Unconfined Compressive Strength of Rock Core	ASTM D 2938
Petrography	ASTM C 295
Potential Reactivity of Aggregates	ASTM C 1260
LA Abrasion	ASTM C 131 and ASTM C 535

A source of natural sand for blending in the concrete mix might need to be investigated other than using sand processed from quarry rock crushing.

Additional tests required on materials other than rock quarry, would include:

Table 13: Additional Recommended Laboratory Testing

Test Type	Standard
Visual classification of Soils	ASTM D 2488
Water Content	ASTM D 2216
Gradation	ASTM D 422
Specific Gravity	ASTM D 854
Liquid/ Plastic Limits and PI	ASTM D 4318
Unit weight	ASTM D 1188 (applicable sections) and ASTM D 2216
Moisture Density	ASTM D 698
Specific Gravity (rock)	ASTM C 97
Compressive strength	ASTM D 2938
Petrography	ASTM C 295
Sulfate Resistance	ASTM 88
Reactivity	ASTM 1265
LA Abrasion	ASTM C131 and ASTM C 535
Point Load Test	ISRM

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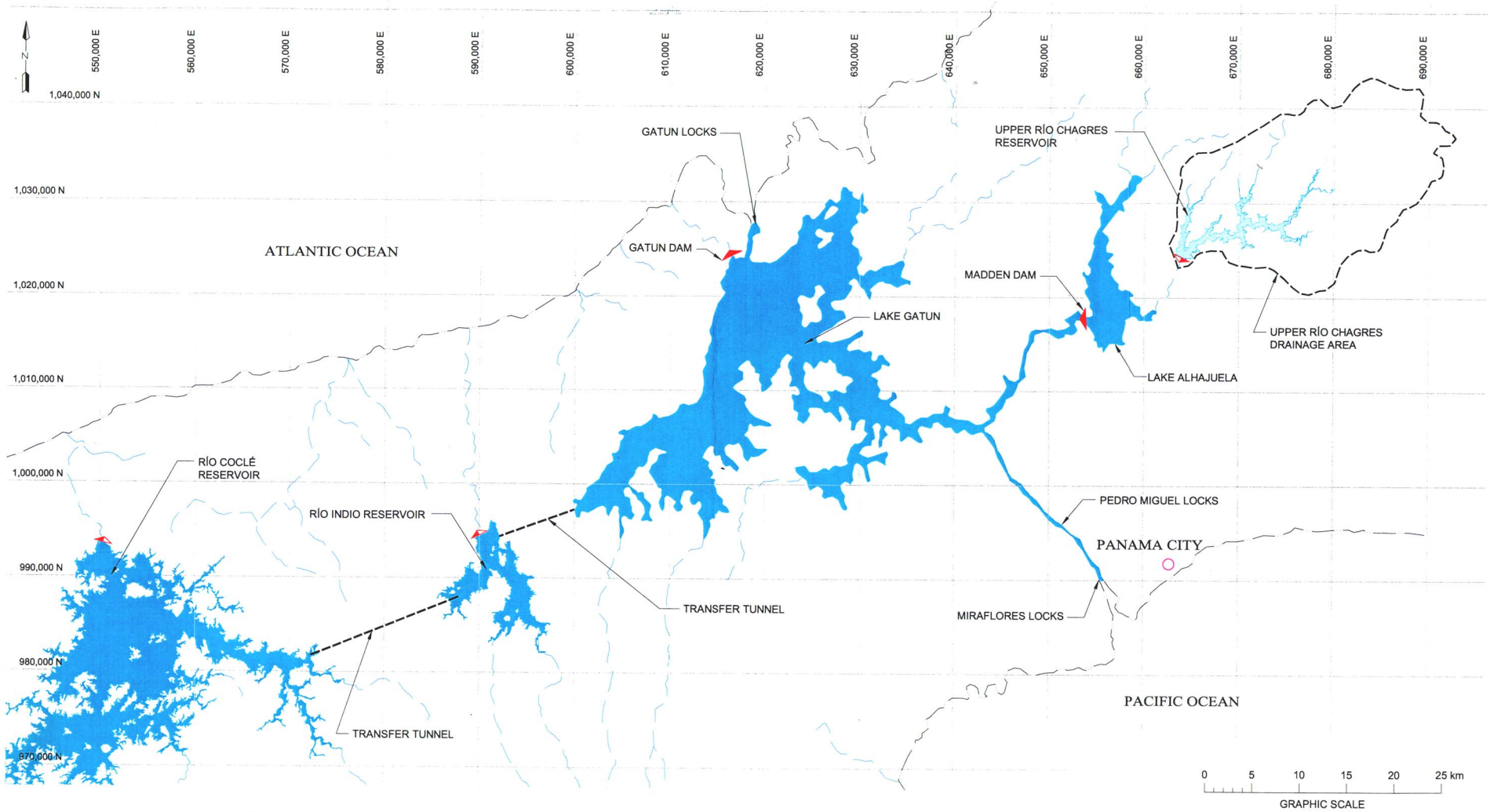
EXHIBITS



AUTORIDAD DEL CANAL DE PANAMA
Division de Proyectos de Capacidad del Canal

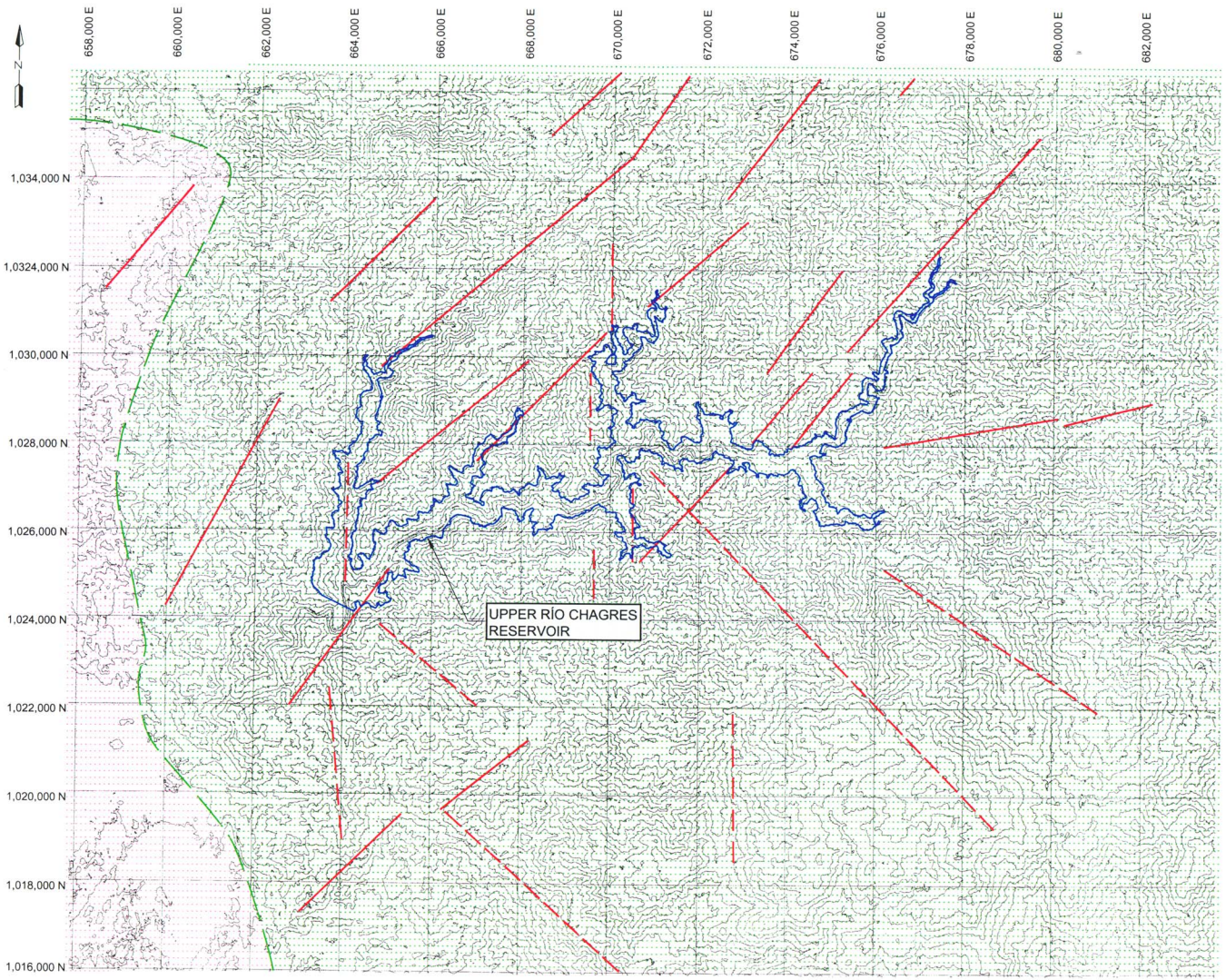
CONTRACT NO. CC-3-536
UPPER CHAGRES WATER SUPPLY PROJECT
APPENDIX B - GEOLOGY, GEOTECHNICAL AND SEISMOLOGICAL STUDIES

LOCATION MAP

MWH TAMS

DATE: SEPTEMBER, 2003

EXHIBIT: 1



LEGEND:

- SEDIMENTARY ROCKS
- IGNEOUS ROCKS
- NE LINEAMENTS
- NW LINEAMENTS
- N-S LINEAMENTS

NOTES:

1. TOPOGRAPHY FROM ACP, CREATED FROM IFSAR AERIAL SURVEY.
2. 50-m CONTOUR INTERVAL.
3. LITHOLOGIC CONTACTS FROM WOODRING, 1955.

0 1 2 3 4 5 km
GRAPHIC SCALE

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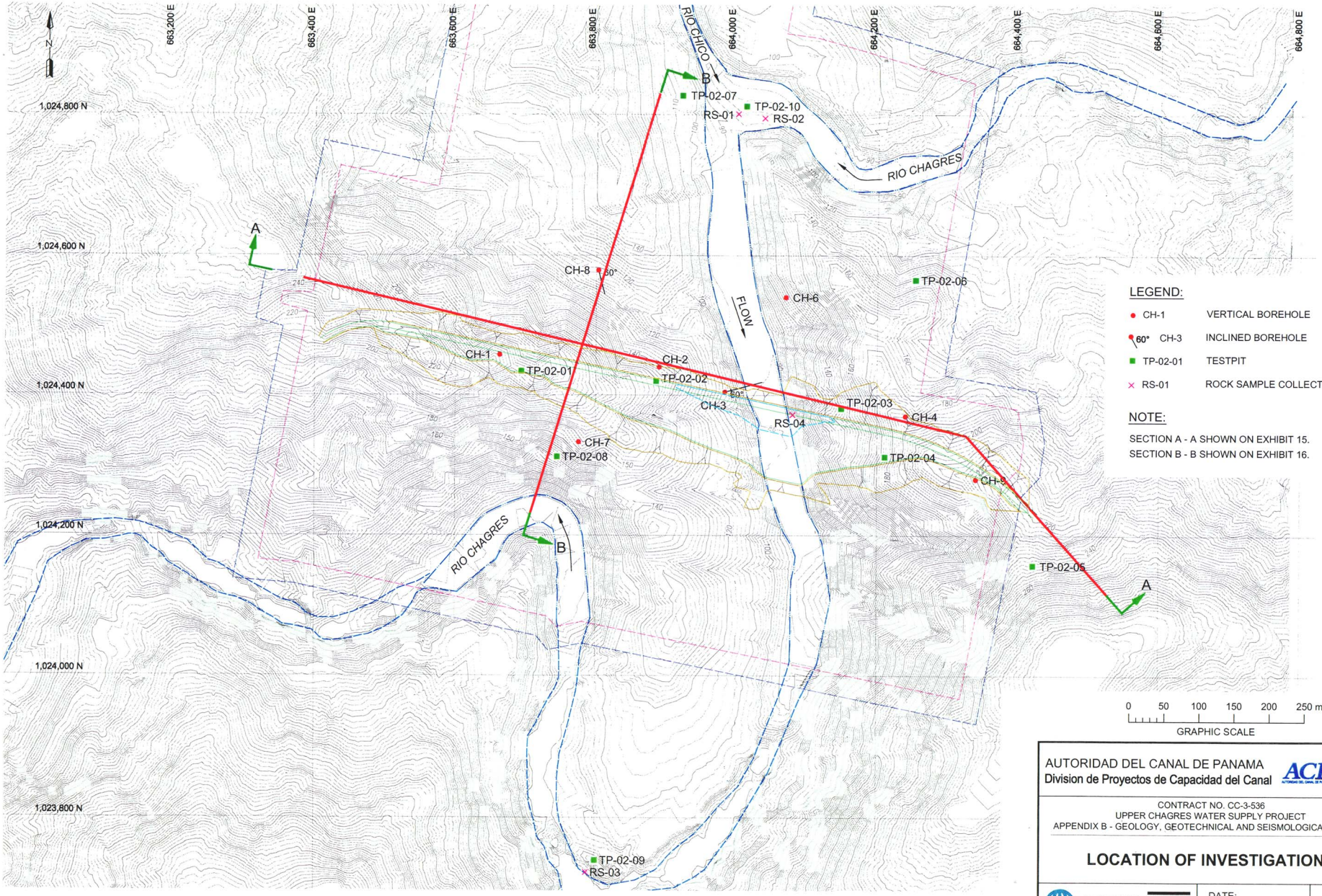
APPENDIX B - GEOLOGY, GEOTECHNICAL AND SEISMOLOGICAL STUDIES

REGIONAL GEOLOGY AND PHOTOLINEARS

MWH TAMS

DATE: SEPTEMBER, 2003

EXHIBIT: 2



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CONTRACT NO. CC-3-536
UPPER CHAGRES WATER SUPPLY PROJECT
APPENDIX B - GEOLOGY, GEOTECHNICAL AND SEISMOLOGICAL STUDIES

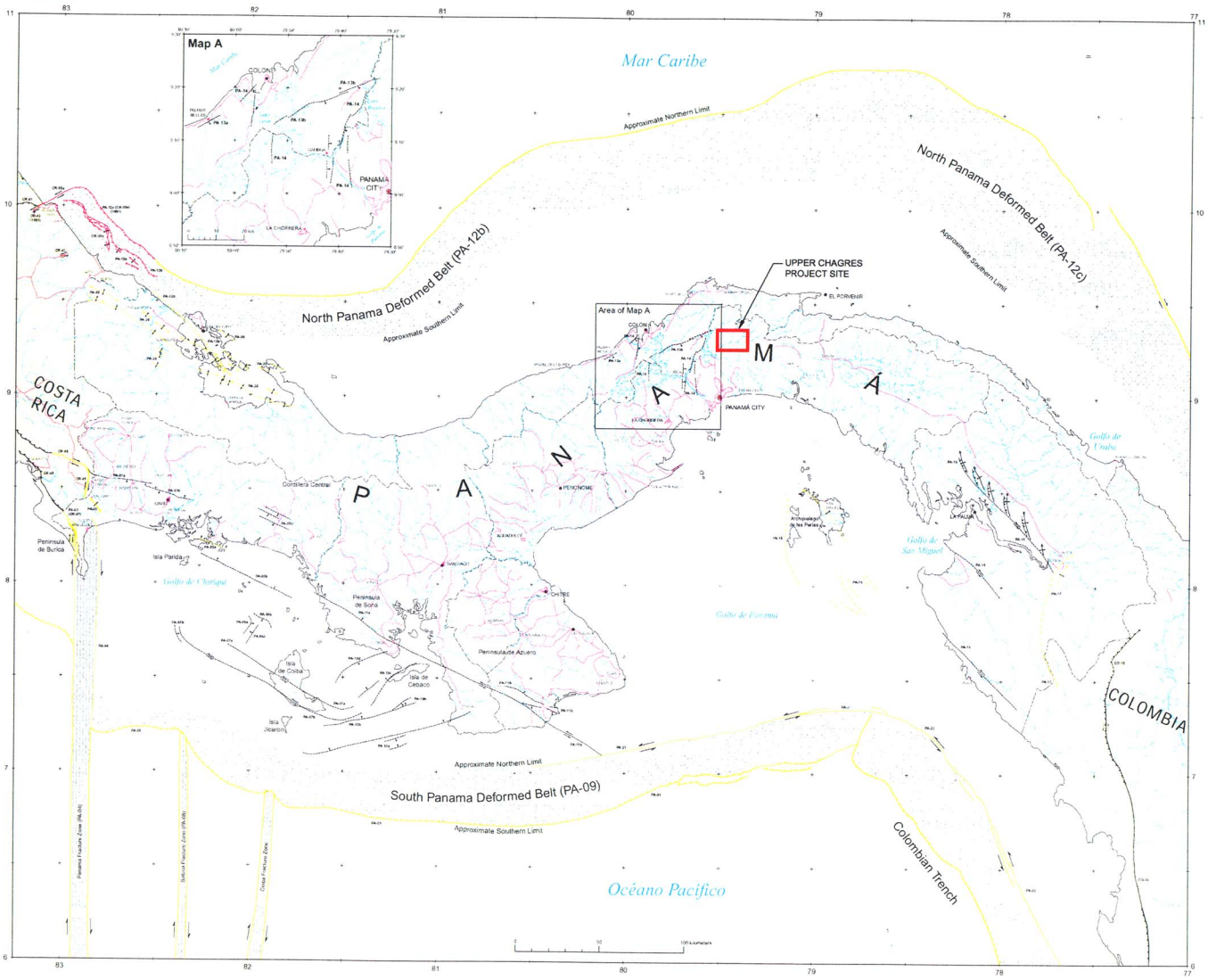
LOCATION OF INVESTIGATIONS

MWH TAMS

DATE: SEPTEMBER, 2003

EXHIBIT: 3

U.S. DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY



QUATERNARY FAULTS AND FOLDS OF PANAMA AND ITS OFFSHORE REGIONS

Number	Name of Structure	* Primary topographic map sheet (number, see map below)	Time of most recent faulting	Slip rate (mm/yr)
PA-01	Longitudinal fault zone			
PA-01A	Unnamed section	David (2)	Probably < 1.6 m.y.	Probably < 1
PA-01B	Unnamed section	David (2)	Probably < 1.6 m.y.	Probably < 1
PA-02	Madre Vieja Anticline	David (2)	Probably historic (1934) < 15 k.y.	Probably > 1 (uplift rate)
PA-03	Medial fault zone	David (2)	Probably < 15 k.y.	Probably > 10
PA-04	Panama fracture zone	Isla de Coiba (3) and offshore	Historic (1934) < 15 k.y. for zone	Probably > 50
PA-05	Unnamed series of faults			
PA-05A	Unnamed section	David (2)	Probably < 15 k.y.	Unknown
PA-05B	Unnamed section	David (2)	Probably < 1.6 m.y.	Unknown
PA-05C	Unnamed section	David (2)	Probably < 1.6 m.y.	Unknown
PA-06	Unnamed faults			
PA-06A	Unnamed section	Isla de Coiba (3)	< 1.6 m.y.	Unknown
PA-06B	Unnamed section	Isla de Coiba (3)	< 1.6 m.y.	Unknown
PA-06C	Unnamed section	Isla de Coiba (3)	< 1.6 m.y.	Unknown
PA-07	Central and South Coiba fault zones			
PA-07A	Central Coiba fault zone	Isla de Coiba (3)	Probably < 1.6 m.y.	Unknown
PA-07B	South Coiba fault zone	Isla de Coiba (3)	Probably < 1.6 m.y.	Unknown
PA-08	Balboa fracture zone	Isla de Coiba (3) and offshore	< 15 k.y. for entire zone	Probably > 5
PA-09	South Panama deformed belt	Isla de Coiba (3) and offshore	Probably < 15 k.y. for entire belt	Probably 1-5
PA-10	Unnamed fault system			
PA-10A	Rio Flores fault zone	Chitre (6)	< 1.6 m.y.	Unknown
PA-10B	Unnamed fault	Chitre (6)	< 1.6 m.y.	Unknown
PA-10C	Unnamed fault	Chitre (6)	< 1.6 m.y.	Unknown
PA-10D	Unnamed fault	Chitre (6)	< 1.6 m.y.	Unknown
PA-11	Azuero-Sona fault zone			
PA-11A	Azuero-Sona fault	Chitre (6)	Probably < 1.6 m.y.	Unknown
PA-11B	Unnamed fault	Chitre (6)	< 1.6 m.y.	Unknown
PA-12	North Panama deformed belt			
PA-12A	Limon fault	Bocas del Toro (1)	Historic (1991)	Unknown
PA-12B	Western section	Bocas del Toro (1) Donoso (4) and offshore	< 15 k.y.	Unknown
PA-12C	Eastern section	Ustupo (10) and offshore	Historic (1882) < 15 k.y. for section	Probably 1-5
PA-13	Unnamed fault system			
PA-13A	Unnamed fault S. of Palmas Bellas	Donoso (4)	Probably < 1.6 m.y.	Unknown
PA-13B	Rio Gatun fault	Panama Norte (7)	Probably < 1.6 m.y.	Probably < 1
PA-14	Unnamed fault system	Panama Norte (7)	Probably < 1.6 m.y.	Unknown
PA-15	Unnamed faults of the East Panama deformed belt	Panama Sur (8) and offshore	Probably < 15 k.y. for entire belt	Unknown
PA-16	Sanson Hills fault zone	La Palma (11)	Probably < 1.6 m.y.	Unknown
PA-17	Pirre Hills fault zone	Jaque (12)	Possibly historic (1974) < 15 k.y. for zone	Unknown
PA-18	Sambu fault zone	La Palma (11)	Probably < 1.6 m.y.	Unknown
PA-19	Jaque River fault zone	Jaque (12)	Probably < 1.6 m.y.	Unknown
PA-20	Unnamed series of folds	Bocas del Toro (1)	Historic (1991) < 15 k.y. for series	Unknown
PA-21	Southern Panama fault zone	Offshore	Probably historic < 15 k.y. for zone	Probably > 5
PA-22	Colombian accretionary complex (deformation zone)	Offshore	Probably historic < 15 k.y. for zone	>5

* From special series of 12 topographic maps at 1:250,000 scale, entitled "Mapa General de la Republica de Panama" (edition 10) by the Instituto Geografico Nacional "Tommy Guardia" (IGNTG), Ministerio de Obras Publicas, Panama

MAP EXPLANATION

TIME OF MOST RECENT SURFACE RUPTURE
- Historic
- Holocene (<10,000 yrs) or post glacial (<15,000 yrs)
- Quaternary, undifferentiated (< 1,600,000 yrs)

SLIP RATE
- > 5 mm/yr
- 1-5 mm/yr
- < 1 mm/yr

QUALITY
- Continuous at map scale
- Poor or discontinuous at map scale
- Inferred or concealed

STRUCTURE TYPE
- Trust or reverse fault (teeth on upper block)
- Right-lateral (dextral) strike-slip fault
- Right-lateral (sinistral) strike-slip fault
- Normal fault
- Anticline
- Syncline
- Plunge direction

PATTERNS
- Broad deformed belts
- Broad fracture zones

REFERENCE: USGS OFR 98-0779

Map of Quaternary Faults and Folds of Panama and Its Offshore Regions

Scale 1:750,000 Mercator Projection
(longitude of central meridian, 80 W; latitude of true scale 0; Clarke 1886 spheroid)

A project of International Lithosphere Program Task Group II-2, Major Active Faults of the World

A cooperative project between the U.S. Geological Survey, the Institute of Geosciences of the University of Panama, the Swedish Agency for Research Cooperation with Developing Countries (SAREC), and NORSAR, Norway
1998

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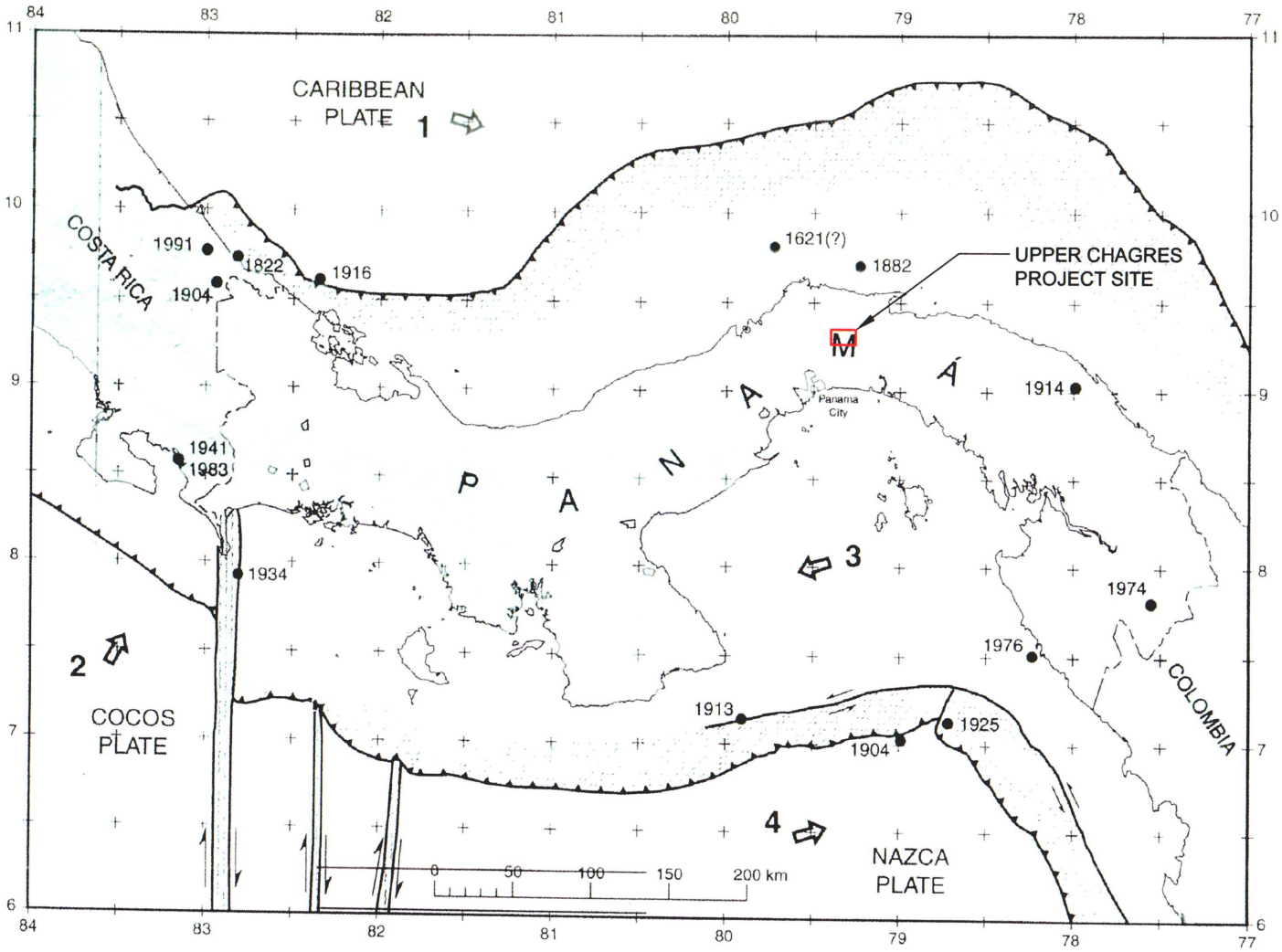
UPPER CHAGRES WATER SUPPLY PROJECT
APPENDIX B - GEOLOGY, GEOTECHNICAL AND SEISMOLOGICAL STUDIES

MAP OF FAULTS AND FOLDS IN PANAMA

MWH TAMS

DATE: SEPTEMBER, 2003

EXHIBIT: 4



RELATIVE PLATE MOTION

No.	Location	Fixed	Moving	Velocity	Direction
1	81.5 W/10.5 N	South America	Caribbean	1.40 cm	105.64
2	83.5 W/7.5 N	Caribbean	Cocos	9.40 cm	29.94
3	79.5 W/8.0 N	Nazca	Panama	5.09 cm	252.60
4	79.0 W/6 5 N	Panama	Nazca	5.19 cm	72.64

Source: Kensaku Tamaki, Ocean Research Institute, University of Tokyo
1-15-1 Minamidai, Nakano-ku, Tokyo, 164, Japan (tamaki@ori.u-tokyo.ac.jp)

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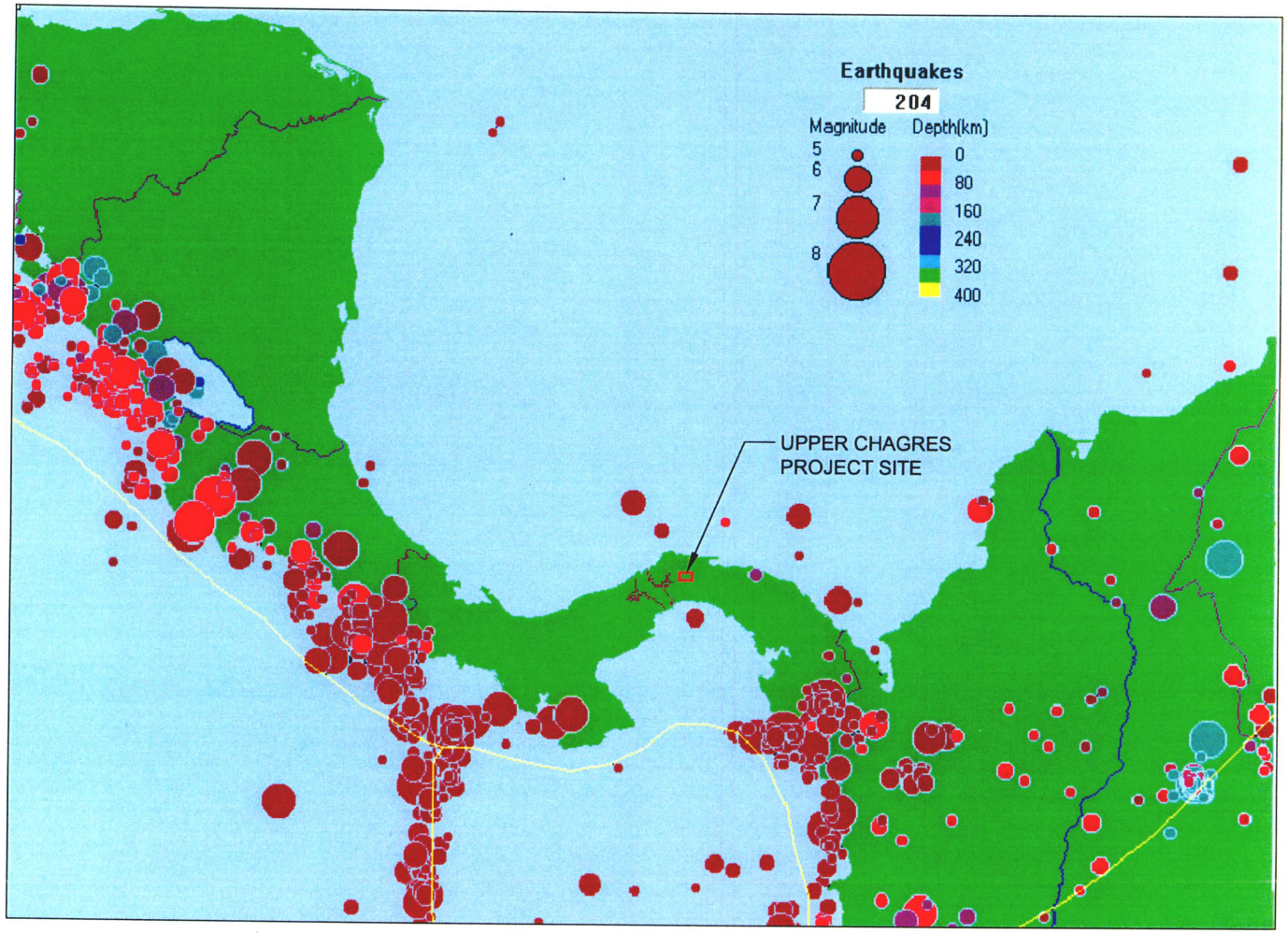
PLATE BOUNDARIES

MWH TAMS

DATE: SEPTEMBER, 2003

EXHIBIT: 5



NOTE:

PLOT OF ALL EARTHQUAKES >M = 3.0 IN 30-YEAR PERIOD JANUARY 1960 TO JANUARY 1990.
YELLOW LINES INDICATE PLATE MARGINS.

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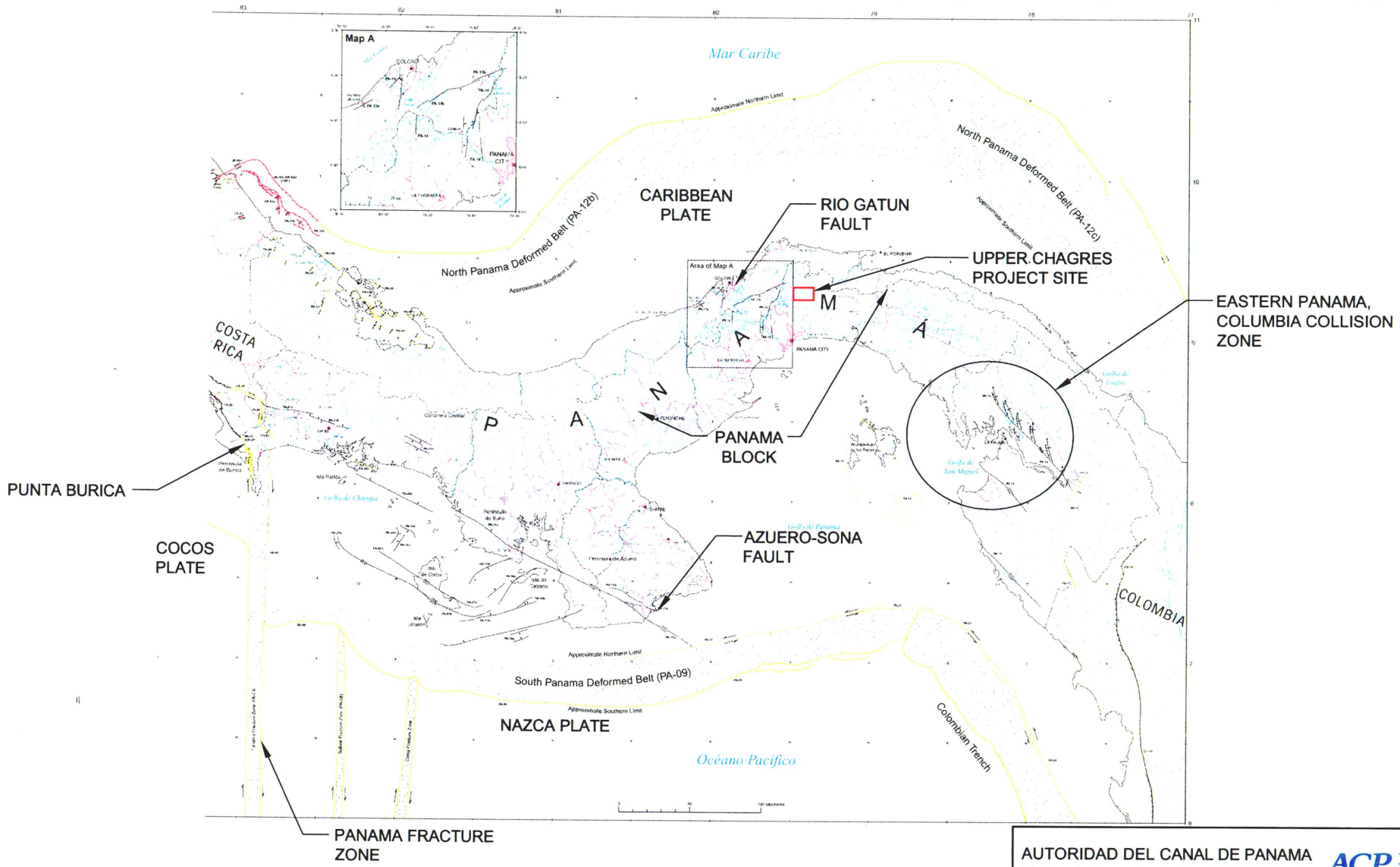
APPENDIX B - GEOLOGY, GEOTECHNICAL AND SEISMOLOGICAL STUDIES

SEISMICITY OF PANAMA

MWH TAMS

DATE: SEPTEMBER, 2003

EXHIBIT: 6



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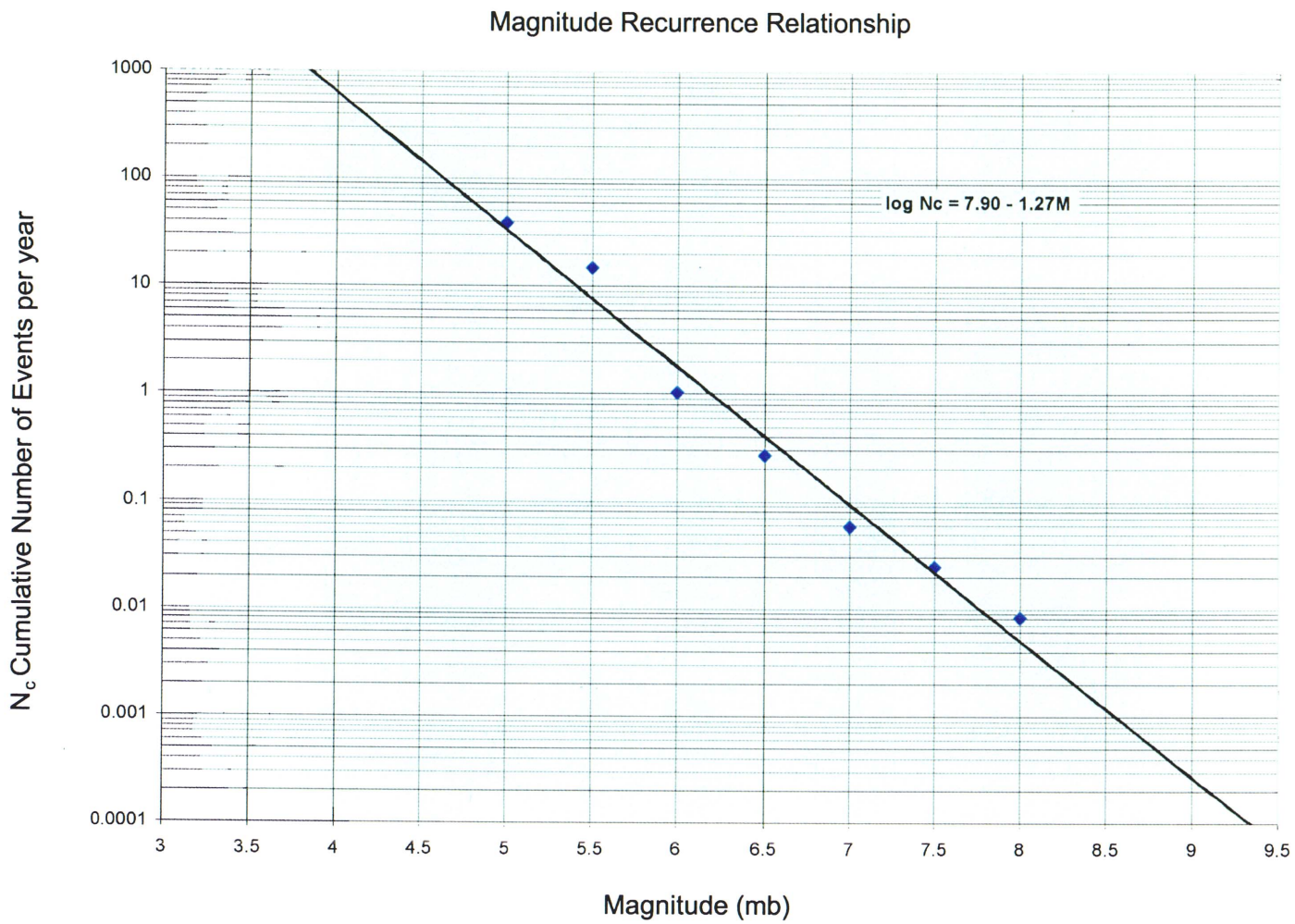
CONTRACT NO. CC-3-536
UPPER CHAGRES WATER SUPPLY PROJECT
APPENDIX B - GEOLOGY, GEOTECHNICAL AND SEISMOLOGICAL STUDIES

SEISMIC SOURCE ZONES

MWH TAMS

DATE: SEPTEMBER, 2003

EXHIBIT: 7



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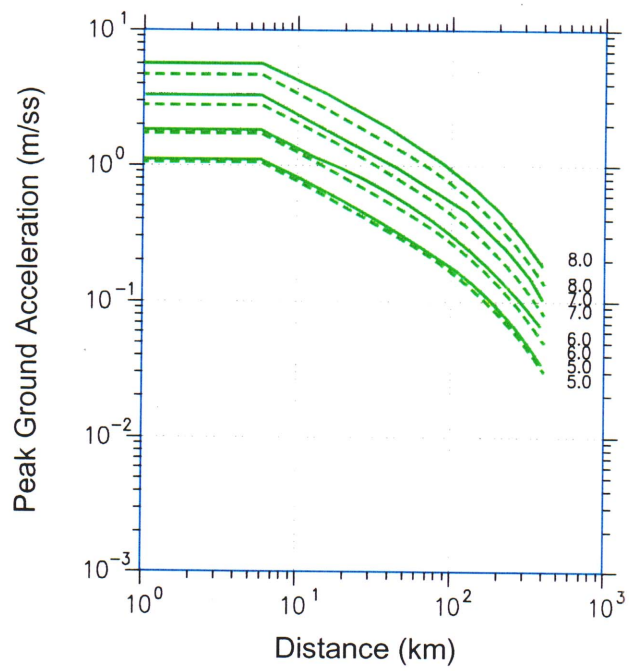
PRELIMINARY MAGNITUDE RECURRENCE CURVE

MWH TAMS

DATE:	EXHIBIT:
SEPTEMBER, 2003	8



Peak Ground Acceleration Curve for Central American Attenuation with (solid line) and without (dashed line) Guerrero Mexico Data (Climent et al., 1994)

AUTORIDAD DEL CANAL DE PANAMA
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CONTRACT NO. CC-3-536
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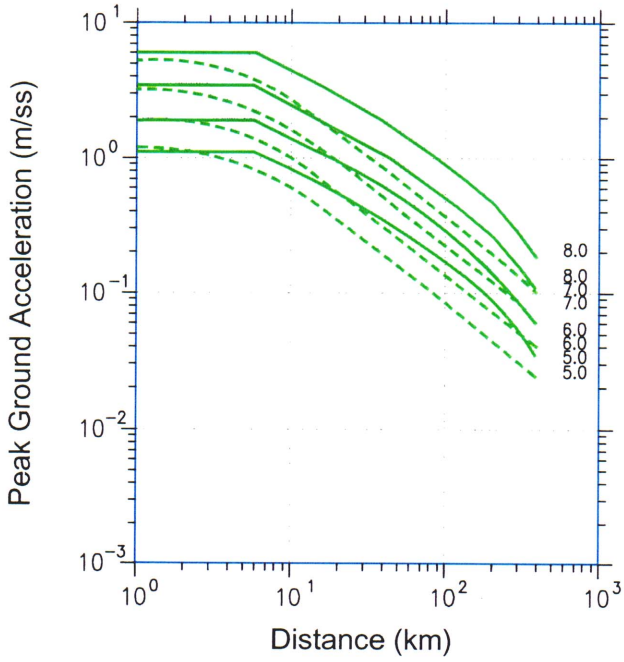
APPENDIX B - GEOLOGY, GEOTECHNICAL AND SEISMOLOGICAL STUDIES

ATTENUATION CURVES
SHEET 1 OF 4

MWH TAMS

DATE:	EXHIBIT:
SEPTEMBER, 2003	9



Peak Ground Acceleration Curve for Central American Attenuation with (solid line) compared to Boore et al. (dashed line) (Climent et al., 1994)

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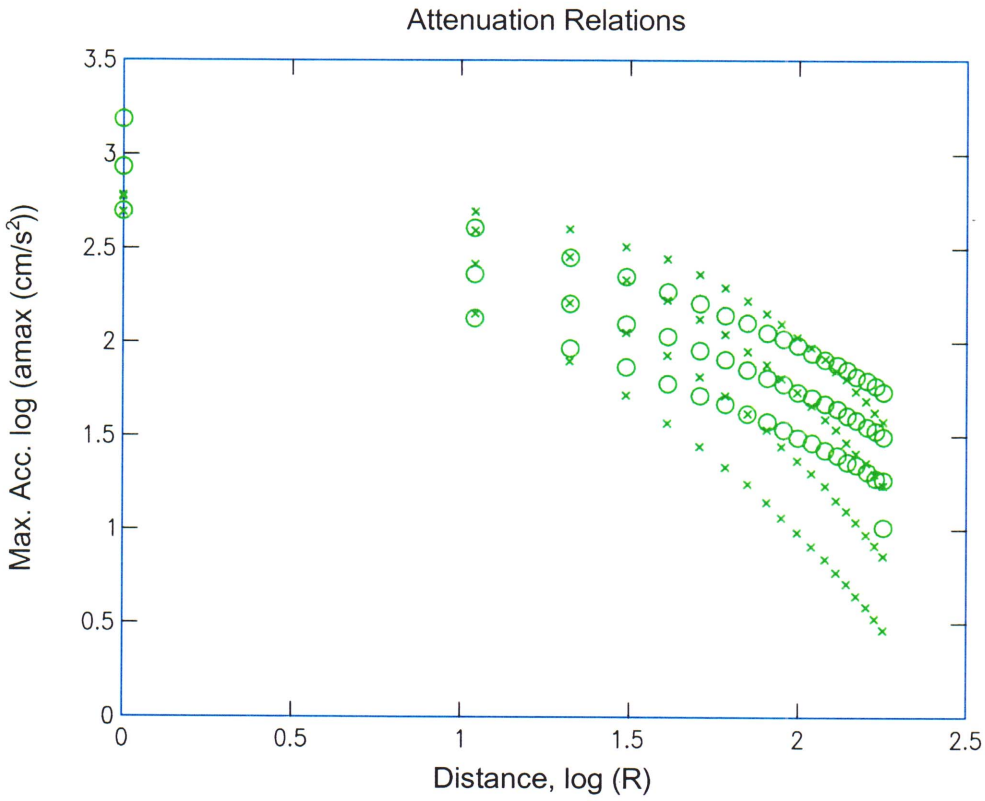
APPENDIX B - GEOLOGY, GEOTECHNICAL AND SEISMOLOGICAL STUDIES

ATTENUATION CURVES
SHEET 2 OF 4

MWH TAMS

DATE: SEPTEMBER, 2003

EXHIBIT: 10



Peak ground Acceleration Curve for Central American Attenuation (circles) compared to Fukushima-Tanaka Attenuation Relationship (plus marks) (Bodare, 2001)

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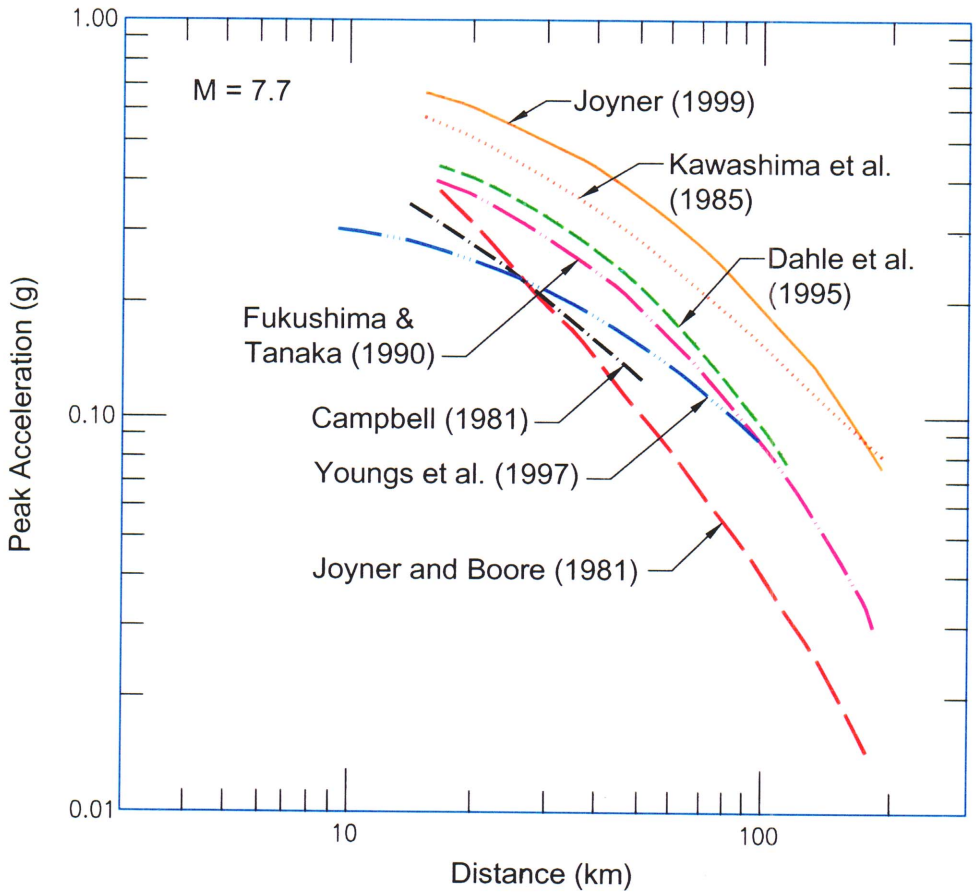
ATTENUATION CURVES
SHEET 3 OF 4

MWH TAMS

DATE: SEPTEMBER, 2003

EXHIBIT: 11



Comparison of Peak Ground Acceleration Attenuation Relationships for Subduction Zone Earthquakes (Kawashima et al, 1985; Fukushima and Tanaka, 1990; Youngs et al. 1997; Joyner, 1999) and Shallow Crustal Earthquakes (Campbell, 1981; Joyner and Boore, 1981) compared to Central American Attenuation Relationship (Dahle et al., 1995) (Exhibit from Cowan)

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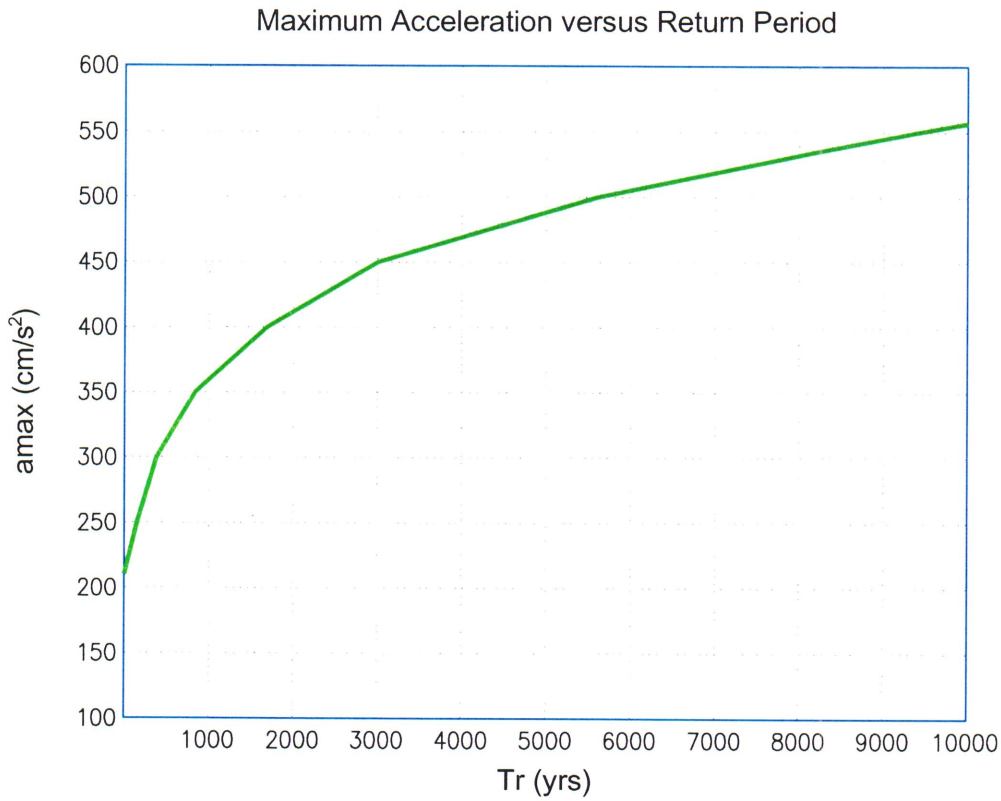
ATTENUATION CURVES
SHEET 4 OF 4

MWH TAMS

DATE: SEPTEMBER, 2003

EXHIBIT: 12



Seismic Hazard Curve based on Central American Attenuation Curve (Bodare, 2001)

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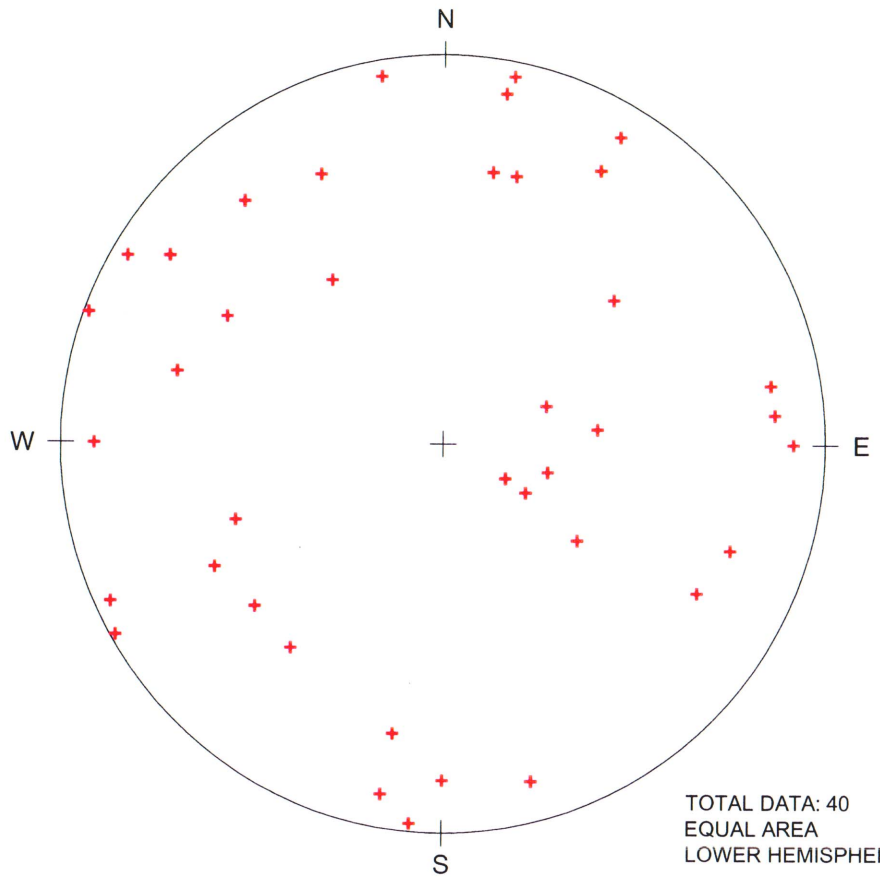
APPENDIX B - GEOLOGY, GEOTECHNICAL AND SEISMOLOGICAL STUDIES

SEISMIC HAZARD CURVE

MWH TAMS

DATE: SEPTEMBER, 2003

EXHIBIT: 13



TOTAL DATA: 40
EQUAL AREA
LOWER HEMISPHERE PROJECTION

AUTORIDAD DEL CANAL DE PANAMA
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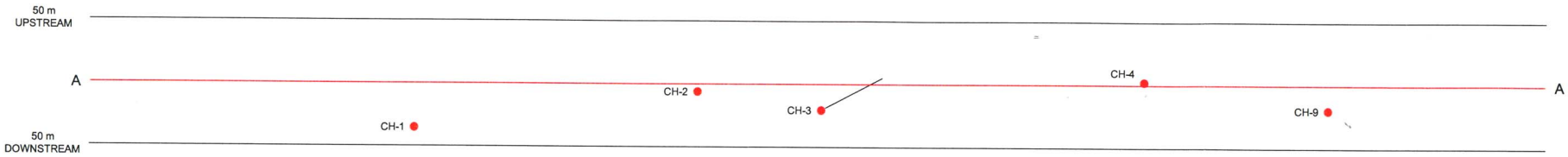
CONTRACT NO. CC-3-536
UPPER CHAGRES WATER SUPPLY PROJECT
APPENDIX B - GEOLOGY, GEOTECHNICAL AND SEISMOLOGICAL STUDIES

STEREONET OF JOINTING AT PROJECT SITE

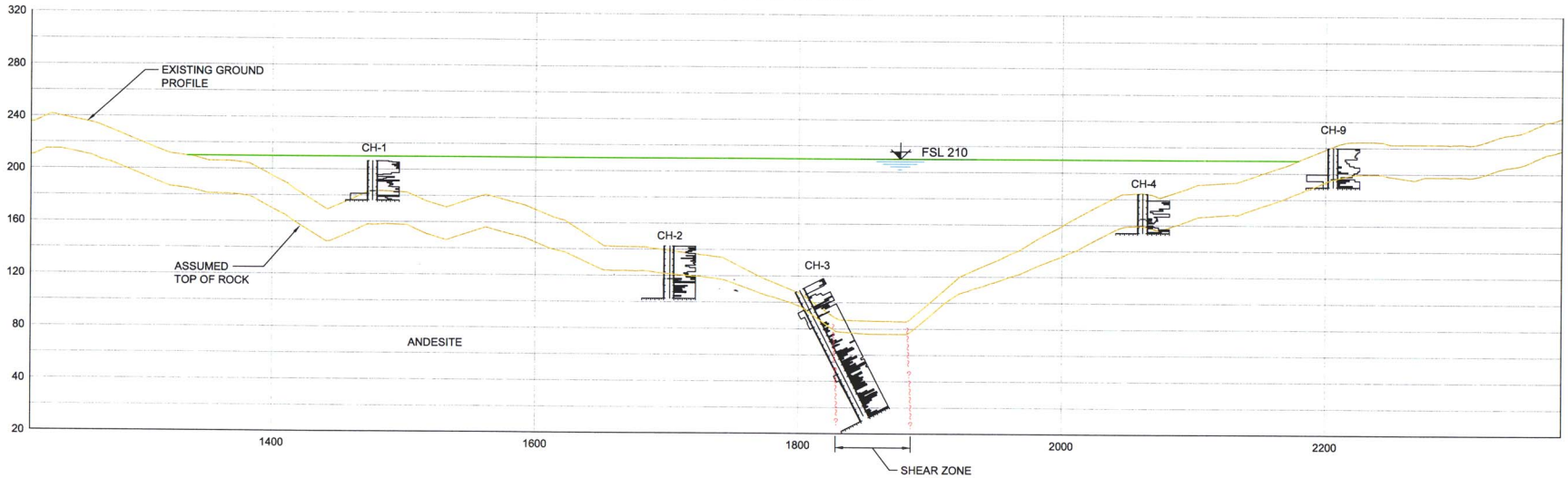
MWH TAMS

DATE: SEPTEMBER, 2003

EXHIBIT: 14



SECTION LOCATION



CROSS SECTION A - A

NOTE:

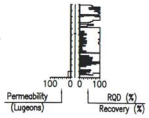
SECTION LOCATION SHOWN ON EXHIBIT 3.
SECTION IS SHOWN APPROXIMATELY ALONG DAM AXIS.

0 40 80 120 160 200 m
GRAPHIC SCALE

LEGEND:

CH-1 VERTICAL BOREHOLE

CH-3,8 HORIZONTAL TRACE OF INCLINED BOREHOLE



BOREHOLE

AUTORIDAD DEL CANAL DE PANAMA
Division de Proyectos de Capacidad del Canal

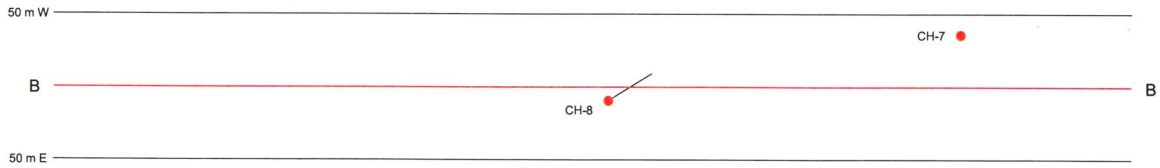
CONTRACT NO. CC-3-536
UPPER CHAGRES WATER SUPPLY PROJECT
APPENDIX B - GEOLOGY, GEOTECHNICAL AND SEISMOLOGICAL STUDIES

CROSS SECTION A-A

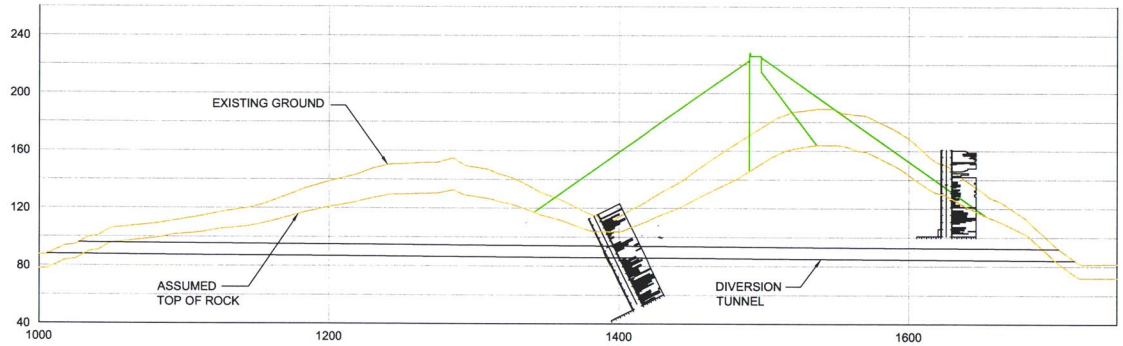
MWH TAMS

DATE: SEPTEMBER, 2003

EXHIBIT: 15



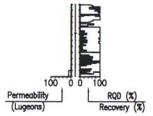
SECTION LOCATION



SECTION B - B
ALONG RIGHT ABUTMENT

LEGEND:

- CH-1 — VERTICAL BOREHOLE
- CH-3,8 — HORIZONTAL TRACE OF INCLINED BOREHOLE



BOREHOLE

NOTE:

1. SECTION LOCATION SHOWN ON EXHIBIT 3.
2. DAM LOCATION IS APPROXIMATE.

0 40 80 120 160 200 m

GRAPHIC SCALE

AUTORIDAD DEL CANAL DE PANAMA
Division de Proyectos de Capacidad del Canal

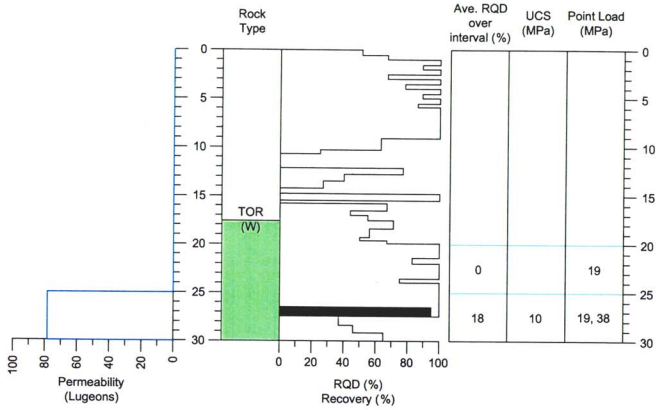
CONTRACT NO. CC-3-536
UPPER CHAGRES WATER SUPPLY PROJECT
APPENDIX B - GEOLOGY, GEOTECHNICAL AND SEISMOLOGICAL STUDIES

CROSS SECTION B-B
THROUGH RIGHT ABUTMENT

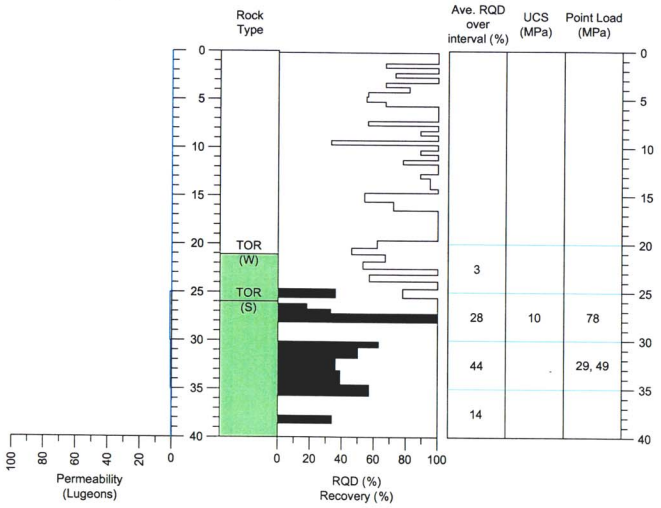
MWH TAMS

DATE: SEPTEMBER, 2003

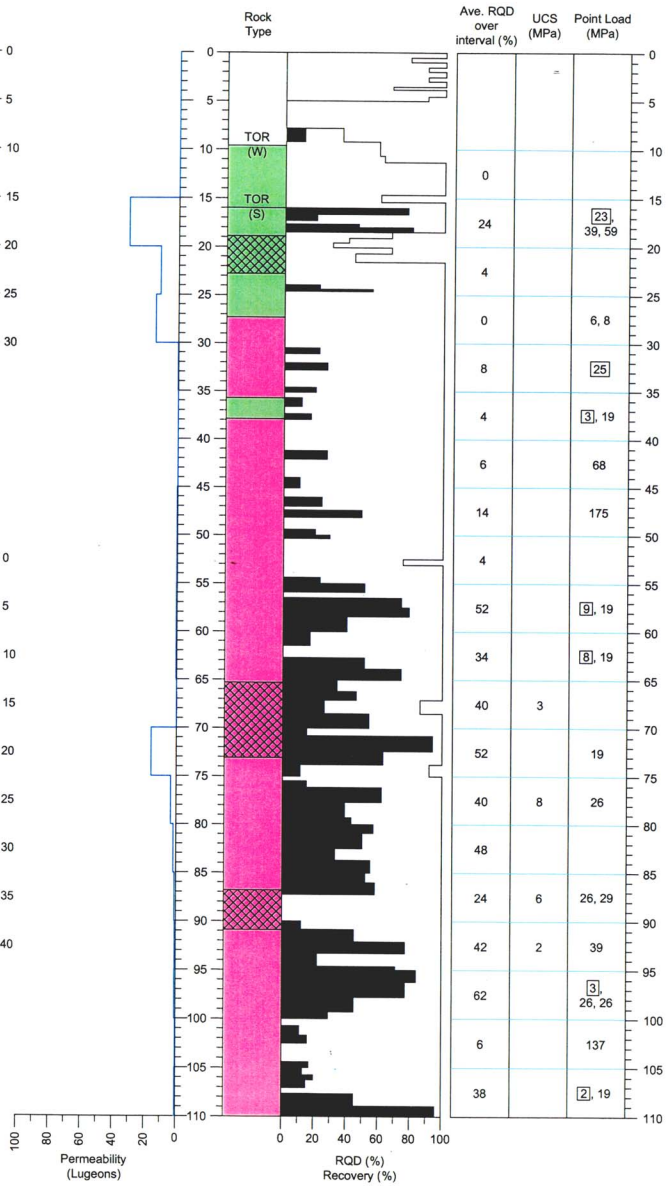
EXHIBIT: 16



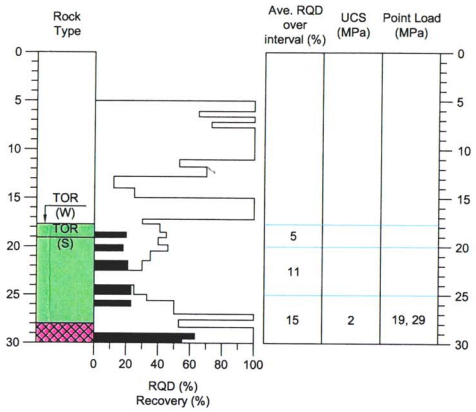
BOREHOLE CH-1



BOREHOLE CH-2



BOREHOLE CH-3



BOREHOLE CH-4

* NO WATER PRESSURE TESTS PERFORMED.

LEGEND:

TOR (W)	TOP OF WEATHERED ROCK
TOR (S)	TOP OF SOUND ROCK
23	ACP - POINT LOAD INDEX TEST; ALL OTHER POINT LOAD DATA FROM SWISSBORING
	ANDESITE
	AGGLOMERATE
	FAULT/SHEAR ZONE

NOTE:

POINT LOAD TEST DATA IS CORRELATED TO UNIAXIAL COMPRESSIVE STRENGTH (UCS).

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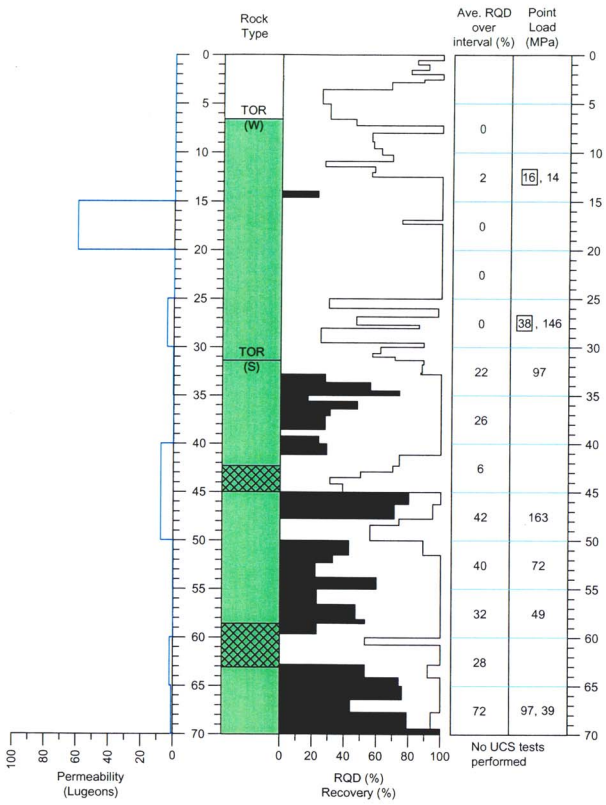
DOWNHOLE PLOTS OF DATA FROM SITE INVESTIGATION PROGRAM SHEET 1 OF 2

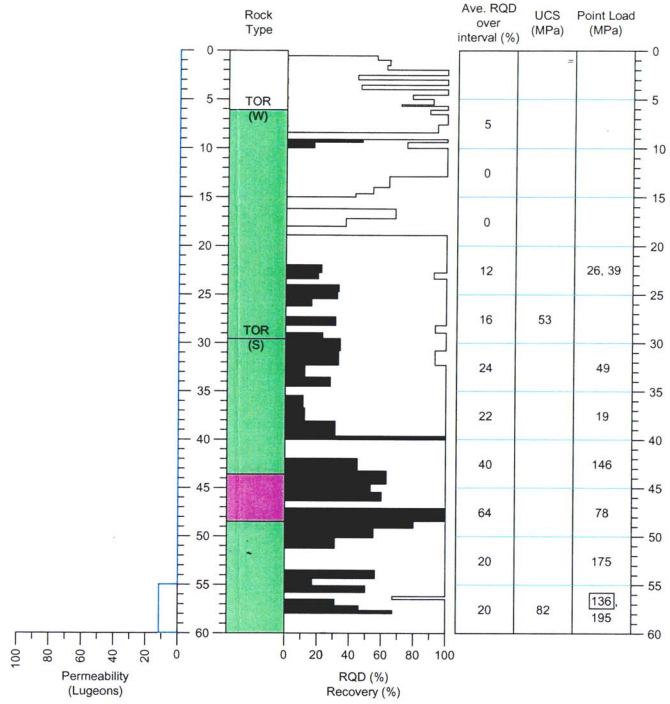
MWH TAMS

DATE: SEPTEMBER, 2003

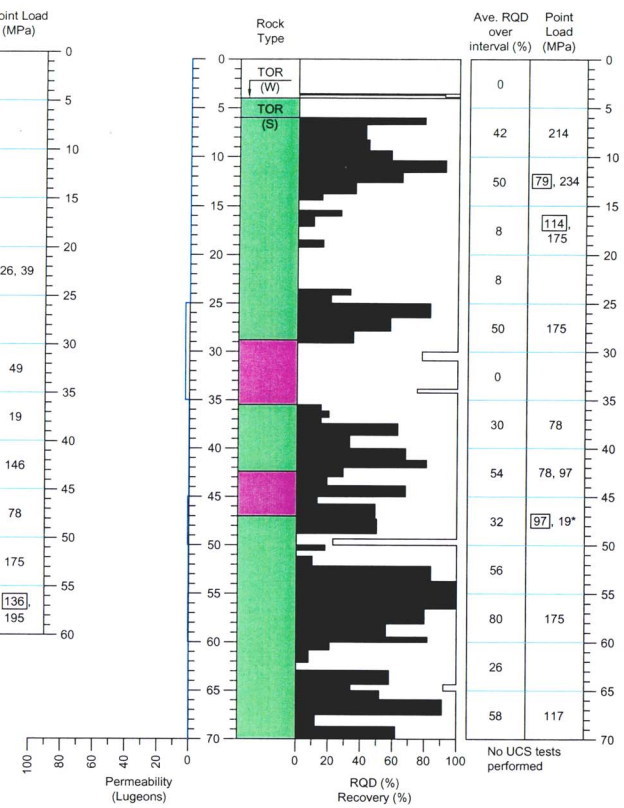
EXHIBIT: 17



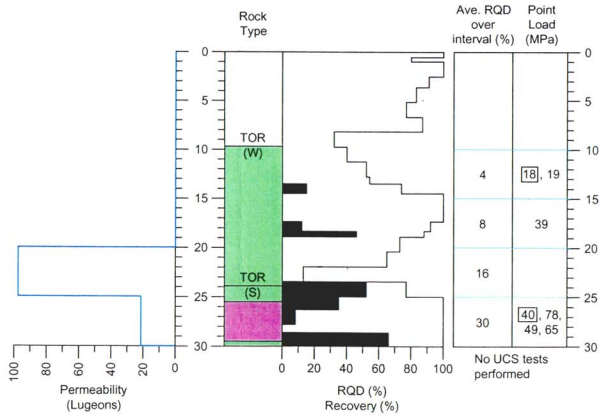
BOREHOLE CH-6



BOREHOLE CH-7



BOREHOLE CH-8



BOREHOLE CH-9

LEGEND:

TOR (W)	TOP OF WEATHERED ROCK
TOR (S)	TOP OF SOUND ROCK
23	ACP - POINT LOAD INDEX TEST; ALL OTHER POINT LOAD DATA FROM SWISSBORING
	ANDESITE
	AGGLOMERATE
	FAULT/SHEAR ZONE

NOTE:

POINT LOAD TEST DATA IS CORRELATED TO UNIAXIAL COMPRESSIVE STRENGTH (UCS).

AUTORIDAD DEL CANAL DE PANAMA
Division de Proyectos de Capacidad del Canal

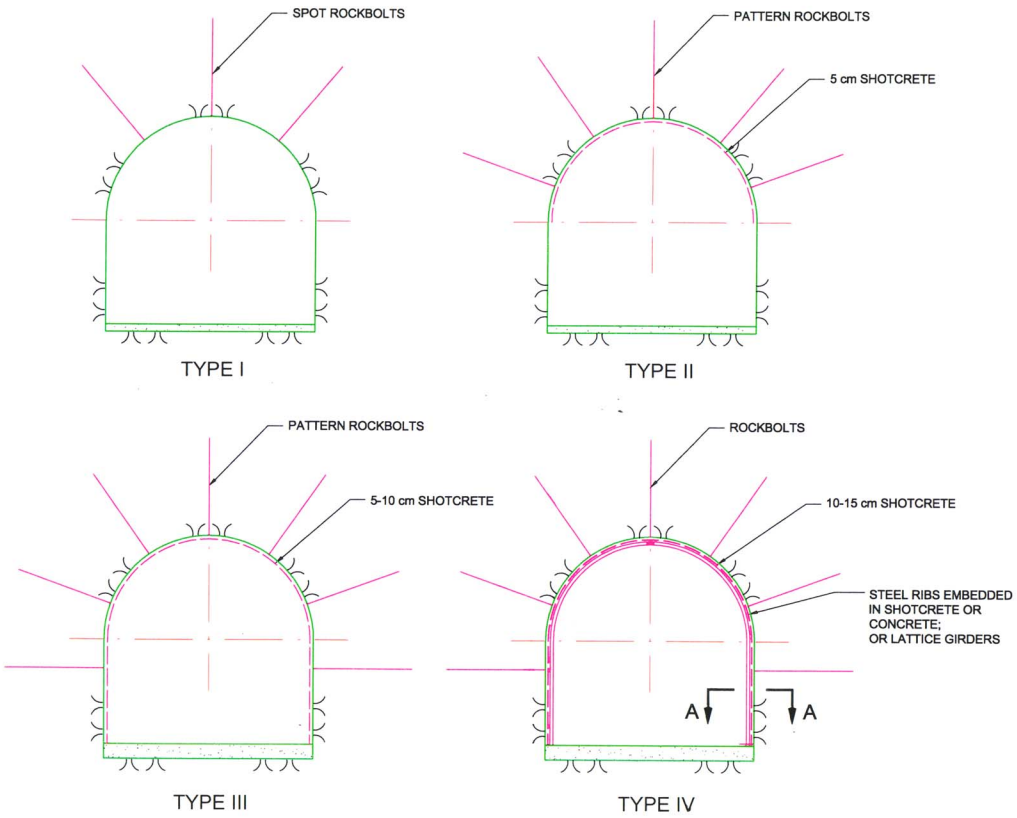
CONTRACT NO. CC-3-536
UPPER CHAGRES WATER SUPPLY PROJECT
APPENDIX B - GEOLOGY, GEOTECHNICAL AND SEISMOLOGICAL STUDIES

DOWNHOLE PLOTS OF DATA FROM SITE INVESTIGATION PROGRAM SHEET 2 OF 2

MWH TAMS

DATE: SEPTEMBER, 2003

EXHIBIT: 17



DRILL & BLAST SECTIONS

ROCK CONDITION CATEGORIES:

TYPE I - BEST ROCK CONDITIONS, MINIMAL OVERBREAK, GENERALLY SELF-SUPPORTING OR REQUIRING MINIMAL SUPPORT WITH SHOTCRETE OR SPOT BOLTING, FULL FACE EXCAVATION WITH NORMAL ADVANCE.

TYPE II - GOOD TO FAIR ROCK CONDITIONS, MODERATE OVERBREAK WITH ROCKBOLTS AND SHOTCRETE; NORMAL ADVANCE POSSIBLE WITH PROPER BOLTING AND SHOTCRETING.

TYPE III - POOR ROCK CONDITIONS, WEATHERED OR WEAK ROCK, LOOSELY JOINTED, FULL FACE EXCAVATION WITH SLOWER SHORT ADVANCE AND LARGE OVERBREAKS. REQUIRES PROMPT SUPPORT WITH PATTERN ROCKBOLTING AND SHOTCRETE.

TYPE IV - VERY POOR ROCK CONDITIONS, FAULT AND SHEAR ZONES HIGHLY WEATHERED; PROMPT SUPPORT WITHIN THE OPEN FACE WITH STEEL RIBS AND LAGGING, BACKPACKING, REINFORCED SHOTCRETE; GROUTING MAY BE NECESSARY TO CONTROL WATER.

SHOTCRETE TO BE STEEL-FIBER REINFORCED OR INSTALLED WITH WIREMESH.

ALL ROCKBOLTS FULLY GROUTED, Ø 25 mm.

0 1 2 3 4 5 m
GRAPHIC SCALE

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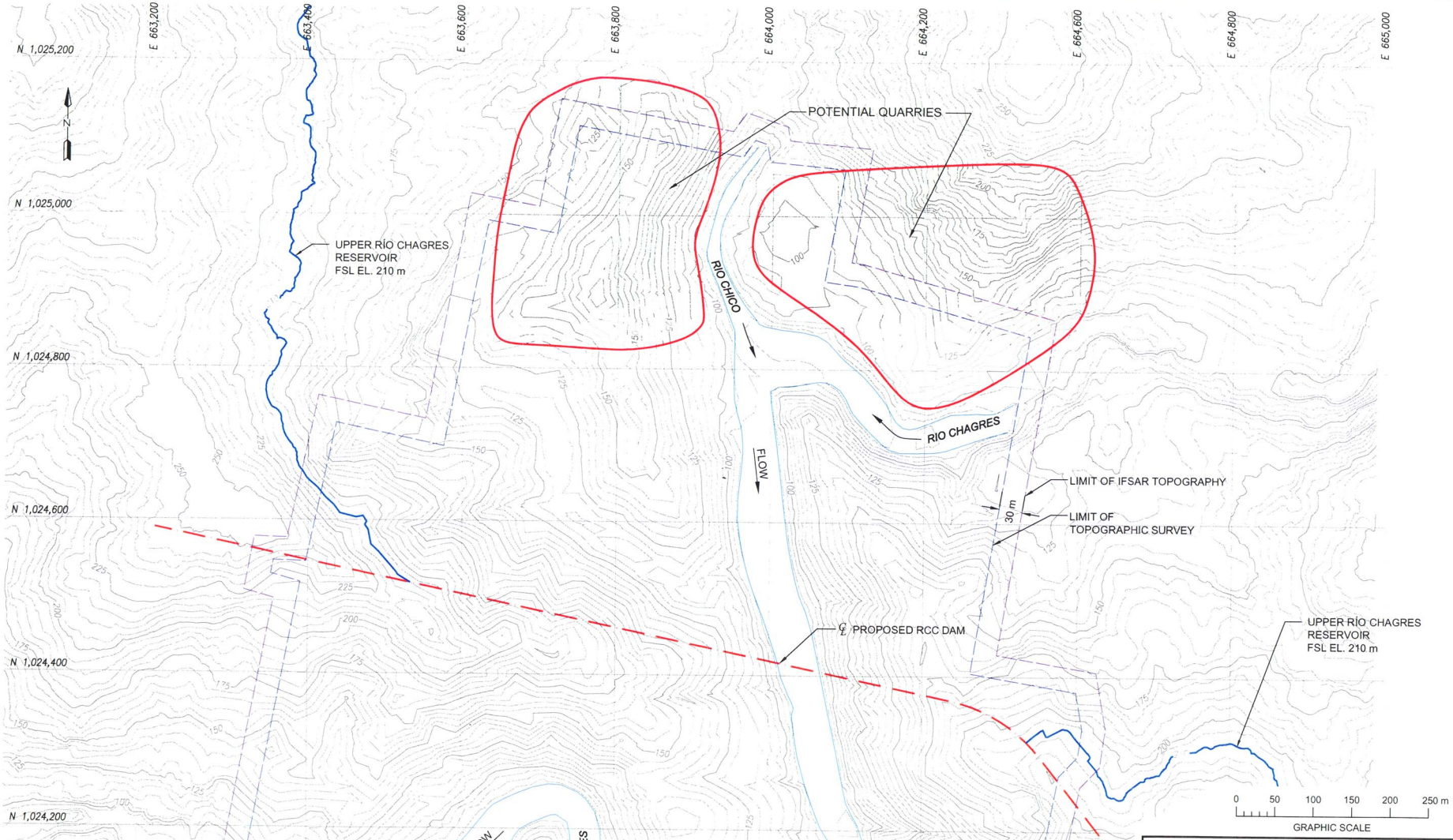
CONTRACT NO. CC-3-536
UPPER CHAGRES WATER SUPPLY PROJECT
APPENDIX B - GEOLOGY, GEOTECHNICAL AND SEISMOLOGICAL STUDIES

TYPICAL TUNNEL CROSS SECTIONS

MWH TAMS

DATE: SEPTEMBER, 2003

EXHIBIT: 18



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Division de Proyectos de Capacidad del Canal

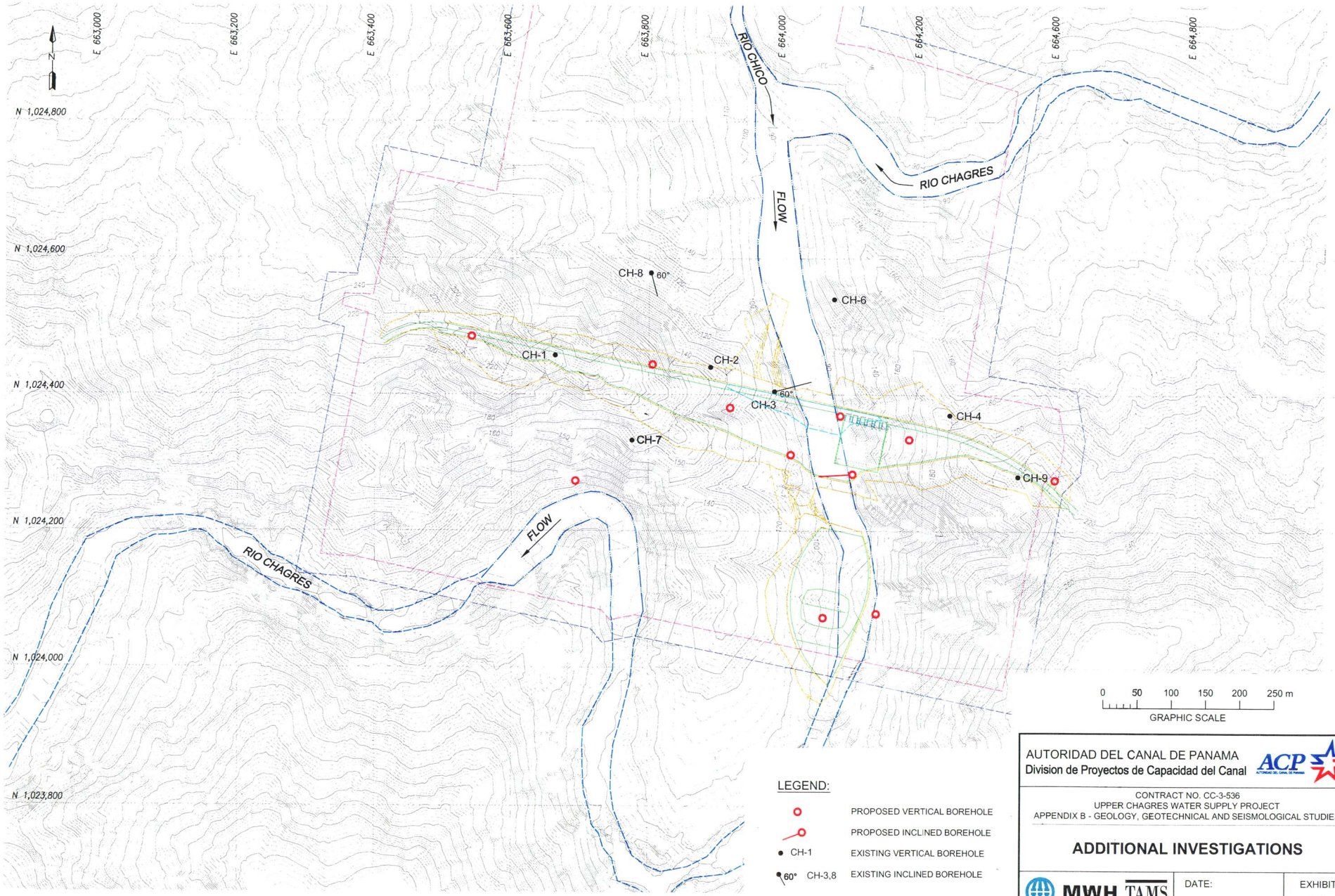
CONTRACT NO. CC-3-536
UPPER CHAGRES WATER SUPPLY PROJECT
APPENDIX B - GEOLOGY, GEOTECHNICAL AND SEISMOLOGICAL STUDIES

POTENTIAL QUARRY SITES

MWH TAMS

DATE: SEPTEMBER, 2003

EXHIBIT: 19



AUTORIDAD DEL CANAL DE PANAMA
Division de Proyectos de Capacidad del Canal

ACP

CONTRACT NO. CC-3-536
UPPER CHAGRES WATER SUPPLY PROJECT
APPENDIX B - GEOLOGY, GEOTECHNICAL AND SEISMOLOGICAL STUDIES

ADDITIONAL INVESTIGATIONS

MWH TAMS

DATE: SEPTEMBER, 2003

EXHIBIT: 20

ATTACHMENTS

UNAUTHORIZED USE OR DUPLICATION IS PROHIBITED
PROHIBIDA LA REPRODUCCION SIN AUTORIZACION
DEL AUTOR

CENTRO DE RECURSOS TECNICOS
AUTORIDAD DEL CANAL DE PANAMA

Attachment 1: Boring Logs and *In-Situ* Test Results

PANAMA CANAL AUTHORITY
ENGINEERING AND INDUSTRIAL SERVICES DEPARTMENT
GEOLOGICAL FIELD LOG
BORING CH-1

PROJECT: ALTO CHAGRES

LOCATION: Right Site
NORTHING: 1024461.503 (1024457.298 ← From ACP)
EASTING: 663662.442 (663662.991)
GROUND ELEVATION: 204.92 (206.305)
CORE RECOVERY:
START DATE: 7/06/02
EQUIPMENT: LONGYEAR 38
TOTAL DEPTH: 30.00
INCLINATION: Vertical
GEOLOGIST: R.Alvarado-Swissboring
COMPLET. DATE: 9/06/02
LOGGER: R.Alvarado-L.Perez
DIR.:
DRILLER: Swissboring

SOIL SYMBOLS, SAMPLERS, FIELD TEST DATA AND CORE RUN	ELEVATION (meters)	DEPTH (meters)	DESCRIPTION OF MATERIAL	DISCONTINUITY	DRILLING CHARACTERISTICS	Permeability Test cm/seg	CORE RECOV (%)	RQD (%)
0.55 0.55 3/15 5/15 6/15 0.30 0.45 0.55	204	0 1	OVERBURDEN, OC-3 to OC-4, medium high to high consistency, moderate water content, moderate plasticity, moderate dry strength, consists of a residual silt and clay derived from andesite by normal weathering processes. Color: reddish brown.		Drilled with 4" single tube sampler, tungstene-carbide bit and dry. SPT #1 All SPT were taken with standard 2", split spoon and a 140 lb hammer dropped 30" for each blow.		100% 51% 67%	
7/15 9/15 10/15 0.40 0.45 0.55	203	2			SPT #2		100% 89%	
7/15 10/15 13/15 0.30 0.45 0.55	202	3	OVERBURDEN, OC-4 to OC-5, high to very high consistency, low to moderate water content, low to moderate plasticity, moderate to high dry strength, consists of a saprolitic clayey silt and sand derived from andesite by normal weathering processes. Color: yellowish brown.		SPT #3		100% 67%	
8/15 17/15 21/15 0.35 0.45 0.55	201	4			SPT #4		100% 78%	
17/15 28/15 40/15 0.40 0.45 0.55	200	5			SPT #5		100% 89%	
47/15 10/15 50/5 0.30 0.35 0.40	199	6			SPT #6		100% 86%	
0.55 0.60	198	7	OVERBURDEN, OC-5, very high consistency, low to moderate water content, low plasticity, moderate to high dry strength, consists of a saprolitic silt and fine sand with clay traces, derived from andesite by normal weathering processes, with iron oxides between fragments. Color: yellowish brown.		Drilled with HQ wire line system double core barrel with diamond bit and water Core recovered in fair condition		100% 100%	
0.75	197	8						

PANAMA CANAL AUTHORITY
ENGINEERING AND INDUSTRIAL SERVICES DEPARTMENT
GEOLOGICAL FIELD LOG
BORING CH-1

PROJECT: ALTO CHAGRES

LOCATION: Right Site

NORTHING: 1024461.503
EASTING: 663662.442
GROUND ELEVATION: 204.92
EQUIPMENT: LONGYEAR 38
TOTAL DEPTH: 30.00
INCLINATION: Vertical
CORE RECOVERY:
START DATE: 7/06/02
COMPLET. DATE: 9/06/02
LOGGER: R.Alvarado-L.Perez
GEOLOGIST: R.Alvarado-Swissboring
DIR.:
DRILLER: Swissboring

SOIL SYMBOLS, SAMPLERS, FIELD TEST DATA AND CORE RUN	ELEVATION (meters)	DEPTH (meters)	DESCRIPTION OF MATERIAL	DISCONTINUITY	DRILLING CHARACTERISTICS	Permeability Test cm/seg	CORE RECOV (%)	RQD (%)
7/06/02							100%	
0.90	196	9					100%	
1.20	195	10			Drilled with HQ wire line system double core barrel with diamond bit and water		54%	
0.40							25%	
0.80	194	11					0%	
0.65 / 1.65	193	12					0%	
							30%	
0.70	192	13	OVERBURDEN, OC-4 to OC-5, high to very high consistency, low water content, low plasticity, low dry strength, consists of a saprolitic silt and highly weathered rock fragments up to 50mm in size, derived from andesite by normal weathering processes. Color: light brown to yellowish brown.				29%	
8/06/02								
0.75	191	14					27%	
0.55							0%	
0.35	190	15					100%	
0.35							100%	
0.30							0%	
0.50 / 0.75	189	16						

PANAMA CANAL AUTHORITY
ENGINEERING AND INDUSTRIAL SERVICES DEPARTMENT
GEOLOGICAL FIELD LOG
BORING CH-1

PROJECT: ALTO CHAGRES

LOCATION: Right Site

NORTHING: 1024461.503 **EASTING:** 663662.442 **GROUND ELEVATION:** 204.92

EQUIPMENT: LONGYEAR 38 **TOTAL DEPTH:** 30.00

CORE RECOVERY: **INCLINATION:** Vertical

START DATE: 7/06/02 **COMPLET. DATE:** 9/06/02 **LOGGER:** R.Alvarado-L.Perez

GEOLOGIST: R.Alvarado-Swissboring **DIR.:** **DRILLER:** Swissboring

SOIL SYMBOLS, SAMPLERS, FIELD TEST DATA AND CORE RUN	ELEVATION (meters)	DEPTH (meters)	DESCRIPTION OF MATERIAL	DISCONTINUITY	DRILLING CHARACTERISTICS	Permeability Test cm/seg	CORE RECOV (%)	RQD (%)
0.45	188	17					100%	
							67%	
0.55					Drilled with HQ wire line system double core barrel with diamond bit and water		44%	
9/06/02							55%	
0.85	187	18	TOP OF WEATHERED ROCK ANDESITE, RH-2, medium soft rock, highly weathered, very weak to weak, consists of silt and fine sand with highly weathered andesite with iron oxides between rock fragments. Color: yellowish brown.				71%	
0.90	186	19					56%	
0.30			ANDESITE, RH-3 to RH-4, medium hard to hard rock, moderate weathered, moderate strength, very close to close jointing, except from 19.30 m to 20.40 m depth, and from 22.00 m to 23.10 m depth, and from 23.50 m to 24.60 m depth, joints cannot be determined, joints are open, rough and most dip 30º, 45º and 90º, contains abundant iron oxides and manganese, andesite is fine grained and igneous. Color: light greenish brown. From 19.30 m to 26.50 m depth; fracture zone				50%	0
0.30							67%	0
0.30	185	20					100%	0
0.70							100%	0
0.50	184	21					100%	0
0.60							83%	0
0.55	183	22					100%	0
0.50							100%	0
0.50	182	23					100%	0
0.40							75%	0
0.65	181	24						

PANAMA CANAL AUTHORITY
ENGINEERING AND INDUSTRIAL SERVICES DEPARTMENT
GEOLOGICAL FIELD LOG
BORING CH-1

PROJECT: ALTO CHAGRES

LOCATION: Right Site

NORTHING: 1024461.503
EASTING: 663662.442
EQUIPMENT: LONGYEAR 38
GROUND ELEVATION: 204.92
TOTAL DEPTH: 30.00
INCLINATION: Vertical
CORE RECOVERY:
START DATE: 7/06/02
COMPLET. DATE: 9/06/02
LOGGER: R.Alvarado-L.Perez
GEOLOGIST: R.Alvarado-Swissboring
DIR.:
DRILLER: Swissboring

SOIL SYMBOLS, SAMPLERS, FIELD TEST DATA AND CORE RUN	ELEVATION (meters)	DEPTH (meters)	DESCRIPTION OF MATERIAL	DISCONTINUITY	DRILLING CHARACTERISTICS	Permeability Test cm/seg	CORE RECOV (%)	RQD (%)
0.50	180	25				9.81E-06	100%	0
0.60							100%	0
0.80	179	26			Drilled with HQ wire line system double core barrel with diamond bit and water		100%	0
0.95	178	27	From 26.50 m to 27.45 m depth; andesite is somewhat brecciated and altered				100%	95
0.95	177	28	FAULT GOUGE, OC-5 to RH-1, very high soil consistency to very soft rock, very weak, no apparent jointing, consists of angular to subangular altered rock fragments up to 30mm in size, contains silt and medium grained sand. Color: gray to yellowish brown.				37%	0
0.75	176	29					40%	0
0.85	175	30	FAULT GOUGE; SILTY SAND, OC-2 to OC-3, medium low to high consistency, moderate water content, low to moderate plasticity, moderate dry strength, consists of silty sand with few and scattered rock fragments up to 10 mm in size. Color: light to yellowish brown.				65%	0
	174	31	Bottom of Hole					
	173	32						

CORE BOX

Box #	From	To
1	0.00	5.55
2	5.55	11.50
3	11.50	19.30
4	19.30	23.50
5	23.50	27.65
6	27.65	30.00

TYPE OF MATERIAL
Elevation: Depth: Description:

PANAMA CANAL AUTHORITY
ENGINEERING AND INDUSTRIAL SERVICES DEPARTMENT
GEOLOGICAL FIELD LOG
BORING CH-1

PROJECT: ALTO CHAGRES

LOCATION: Right Site

NORTHING: 1024461.503

EASTING: 663662.442
EQUIPMENT: LONGYEAR 38

GROUND ELEVATION: 204.92
TOTAL DEPTH: 30.00
INCLINATION: Vertical

CORE RECOVERY:
START DATE: 7/06/02
GEOLOGIST: R.Alvarado-Swissboring

COMPLET. DATE: 9/06/02
DIR.:

LOGGER: R.Alvarado-L.Perez
DRILLER: Swissboring

SOIL SYMBOLS, SAMPLERS, FIELD TEST DATA AND CORE RUN	ELEVATION (meters)	DEPTH (meters)	DESCRIPTION OF MATERIAL	DISCONTINUITY	DRILLING CHARACTERISTICS	Permeability Test cm/seg	CORE RECOV (%)	RQD (%)
			204.9 to 187.3 0.0 to 17.6 OVERBURDEN 187.3 to 177.5 17.6 to 27.5 TOP OF WEATHERED ROCK-ANDESITE 177.5 to 175.8 27.5 to 29.2 FAULT GOUGE 175.8 to 174.9 29.2 to 30.0 FAULT GOUGE: SILTY SAND					
	172	33						
	171	34						
	170	35						
	169	36						
	168	37						
	167	38						
	166	39						
	165	40						

KEY TO SYMBOLS

Symbol Description

Strata symbols

OVERBURDEN

ANDESITE

FAULT ZONE - FAULT GOUGE
(SHEAR ZONE)

Misc. Symbols

Water table during drilling

Boring continues

Core recovery

Water table during
drilling

Casing at depth indicated

Water table during
drilling

Soil Samplers

Rock core

Standard penetration test

PANAMA CANAL AUTHORITY
ENGINEERING AND INDUSTRIAL SERVICES DEPARTMENT
GEOLOGICAL FIELD LOG
BORING CH-2

PROJECT: ALTO CHAGRES

LOCATION: Right Margin

NORTHING: 1024440.003

EASTING: 663890.005
EQUIPMENT: LONGYEAR 38

GROUND ELEVATION: 142.49
TOTAL DEPTH: 40.00
INCLINATION: Vertical

CORE RECOVERY:
START DATE: 21/06/02
GEOLOGIST: R.Alvarado-Swissboring

COMPLET. DATE: 23/06/02
DIR.:

LOGGER: R.Alvarado-L.Perez
DRILLER: Swissboring

SOIL SYMBOLS, SAMPLERS, FIELD TEST DATA AND CORE RUN	ELEVATION (meters)	DEPTH (meters)	DESCRIPTION OF MATERIAL	DISCONTINUITY	DRILLING CHARACTERISTICS	Permeability Test cm/seg	CORE RECOV (%)	RQD (%)
0.55 0.55 2/15 3/15 4/15 0.30 0.45 0.55	142	0 1	OVERBURDEN, OC-2 to OC-3, medium low to medium high consistency, moderate water content, moderate plasticity, moderate to high dry strength, consists of a residual clayey silt with sand traces derived from andesite by normal weathering processes, contains root and decomposed organic debris. Color: reddish brown.		Drilled with 4" single tube sampler, tungstene-carbide bit and dry. SPT #1 All SPT were taken with standard 2", split spoon and a 140 lb hammer dropped 30" for each blow.		100% 100% 67%	
2/15 3/15 3/15 0.33 0.45 0.55	141	2			SPT #2		100% 73%	
3/15 5/15 5/15 0.30 0.45 0.55	140	3			SPT #3		100% 67%	
3/15 3/15 2/15 0.25 0.45 0.55	139	4			SPT #4		82% 56%	
3/15 4/15 6/15 0.30 0.45 0.55	138	5			SPT #5		55% 67%	
8/15 12/15 16/15 0.45 0.45 0.55	137	6	OVERBURDEN, OC-5, very high consistency, low to moderate water content, low to moderate plasticity, moderate to high dry strength, consists of a residual clayey silt with sand traces derived from andesite by normal weathering processes, Color: reddish brown.		SPT #6		100% 100%	
9/15 14/15 17/15 0.25 0.45 0.55	136	7			SPT #7		100% 56%	
5/15 8/15 31/15 0.40	135	8	OVERBURDEN, OC-4, high consistency,		SPT #8 Core was recovered		100% 89%	

PANAMA CANAL AUTHORITY
ENGINEERING AND INDUSTRIAL SERVICES DEPARTMENT
GEOLOGICAL FIELD LOG
BORING CH-2

PROJECT: ALTO CHAGRES

LOCATION: Right Margin

NORTHING: 1024440.003
EASTING: 663890.005
EQUIPMENT: LONGYEAR 38
GROUND ELEVATION: 142.49
TOTAL DEPTH: 40.00
INCLINATION: Vertical
CORE RECOVERY:
START DATE: 21/06/02
COMPLET. DATE: 23/06/02
LOGGER: R.Alvarado-L.Perez
GEOLOGIST: R.Alvarado-Swissboring
DIR.:
DRILLER: Swissboring

SOIL SYMBOLS, SAMPLERS, FIELD TEST DATA AND CORE RUN	ELEVATION (meters)	DEPTH (meters)	DESCRIPTION OF MATERIAL	DISCONTINUITY	DRILLING CHARACTERISTICS	Permeability Test cm/seg	CORE RECOV (%)	RQD (%)
0.45 0.55 4/15 7/15 11/15 0.15 0.45 0.55 5/15 11/15 15/15 0.40 0.45 0.55 6/15 8/15 11/15 0.35 0.45 0.55 0.45 12/15 31/15 49/15 0.40 0.45 1.1 26/15 48/15 50/13 0.43 0.43 22/06/02 0.92 0.90	134 133 132 131 130 129 128 127	9 10 11 12 13 14 15 16	low to moderate water content, moderate plasticity, moderate dry strength, consists of a residual silt with sand traces derived from andesite by normal weathering processes, Color: yellowish brown. OVERBURDEN, OC-5, very high consistency, low water content, low to moderate plasticity, moderate dry strength, consists of a saprolitic silt and clay with sand traces derived from andesite by normal weathering processes, Color: yellowish brown.		in fair condition SPT #9 SPT #10 SPT #11 SPT #12 SPT #13		100% 33% 100% 89% 100% 78% 100% 100% 89% 95% 100% 54% 72%	

PANAMA CANAL AUTHORITY
ENGINEERING AND INDUSTRIAL SERVICES DEPARTMENT
GEOLOGICAL FIELD LOG
BORING CH-2

PROJECT: ALTO CHAGRES

LOCATION: Right Margin

NORTHING: 1024440.003

EASTING: 663890.005
EQUIPMENT: LONGYEAR 38

GROUND ELEVATION: 142.49
TOTAL DEPTH: 40.00
INCLINATION: Vertical

CORE RECOVERY:
START DATE: 21/06/02
GEOLOGIST: R.Alvarado-Swissboring

COMPLET. DATE: 23/06/02
DIR.:

LOGGER: R.Alvarado-L.Perez
DRILLER: Swissboring

SOIL SYMBOLS, SAMPLERS, FIELD TEST DATA AND CORE RUN	ELEVATION (meters)	DEPTH (meters)	DESCRIPTION OF MATERIAL	DISCONTINUITY	DRILLING CHARACTERISTICS	Permeability Test cm/seg	CORE RECOV (%)	RQD (%)
1	126						100%	
0.65		17						
	125						100%	
0.7		18						
							100%	
0.75	124							
		19					100%	
0.80								
	123						62%	
22/06/02		20						
0.65							46%	
	122							
0.75								
23/06/02		21					67%	
0.75	121		TOP OF WEATHERED ROCK ANDESITE, RH-1 to RH-2, soft to medium soft rock, highly weathered, very weak to weak, jointing cannot be determined, core exhibit abundant ochre iron stains, consist of andesite, fine to medium grained and igneous. Color: yellowish brown-yellowish gray.		Drilled with HQ wire line system double core barrel with diamond bit and water			0
		22					53%	
0.60								
	120						100%	0
0.70								0
		23					57%	
0.80	119		ANDESITE, RH-3, medium hard rock, moderate weathered, very close jointing, joints are open, rough and dip 30°, 45° and 60°, contains iron oxides and manganese, andesite is fine to medium grained and igneous. Color: greenish gray.					
		24					100%	0

PANAMA CANAL AUTHORITY
ENGINEERING AND INDUSTRIAL SERVICES DEPARTMENT
GEOLOGICAL FIELD LOG
BORING CH-2

PROJECT: ALTO CHAGRES

LOCATION: Right Margin

NORTHING: 1024440.003

EASTING: 663890.005
EQUIPMENT: LONGYEAR 38

GROUND ELEVATION: 142.49
TOTAL DEPTH: 40.00
INCLINATION: Vertical

CORE RECOVERY:
START DATE: 21/06/02
GEOLOGIST: R.Alvarado-Swissboring

COMPLET. DATE: 23/06/02
DIR.:

LOGGER: R.Alvarado-L.Perez
DRILLER: Swissboring

SOIL SYMBOLS, SAMPLERS, FIELD TEST DATA AND CORE RUN	ELEVATION (meters)	DEPTH (meters)	DESCRIPTION OF MATERIAL	DISCONTINUITY	DRILLING CHARACTERISTICS	Permeability Test cm/seg	CORE RECOV (%)	RQD (%)
0.90	118						78%	36
0.65		25			Drilled with HQ wire line system double core barrel with diamond bit and water	5.96E-06	100%	0
0.55	117		ANDESITE, RH-4, hard rock, sligthly to moderate weathered, moderate strength, very close jointing, joints are open, rough and dip 20°, 30; 45; and 60°, contains abundant iron oxides and manganese, andesite is fine to medium grained and igneous. Color: dark gray to greenish gray.				100%	18
0.45		26			Core was recovered in good condition		100%	33
0.90	116		TOP OF SOUND ROCK					
0.35		27	ANDESITE, RH-4 to RH-5, hard to very hard rock, strong, moderately close jointing, with very close jointing intervals from 27.40m to 27.75m and from 28.60m to 29.05m, joints are open, rough and dip 40°, 50° and 70° and 90°, contains iron oxides, chlorite and calcite films, andesite is fine to medium grained and igneous. Color greenish gray.				100%	100
0.60	115						100%	0
1.05		28	From 27.40 m to 27.75 m depth; fracture zone				100%	0
0.60	114		From 28.60 m to 29.00 m depth; fracture zone					
1.10		29					100%	0
1.30	113						100%	63
		30	ANDESITE, RH-5, very hard rock, strong to very strong, moderately close jointing, joints are close, rough and dip 30°, 45° and 70°, contains epidote and calcite films, andesite is fine to medium grained and igneous. Color: light gray.			2.46E-06		
	112						100%	50
		31						
	111							
		32					100%	36
	110							

PANAMA CANAL AUTHORITY
ENGINEERING AND INDUSTRIAL SERVICES DEPARTMENT
GEOLOGICAL FIELD LOG
BORING CH-2

PROJECT: ALTO CHAGRES

LOCATION: Right Margin

NORTHING: 1024440.003

EASTING: 663890.005
EQUIPMENT: LONGYEAR 38

GROUND ELEVATION: 142.49
TOTAL DEPTH: 40.00
INCLINATION: Vertical

CORE RECOVERY:
START DATE: 21/06/02
GEOLOGIST: R.Alvarado-Swissboring

COMPLET. DATE: 23/06/02
DIR.:

LOGGER: R.Alvarado-L.Perez
DRILLER: Swissboring

SOIL SYMBOLS, SAMPLERS, FIELD TEST DATA AND CORE RUN	ELEVATION (meters)	DEPTH (meters)	DESCRIPTION OF MATERIAL	DISCONTINUITY	DRILLING CHARACTERISTICS	Permeability Test cm/seg	CORE RECOV (%)	RQD (%)
1.45		33						
	109						100%	39
		34						
1.15	108							
		35	From 35.00 m to 36.40 m depth; vertical joints			4.98E-07	100%	57
0.6	107						100%	0
0.80		36						
	106						100%	0
0.65		37					100%	0
0.80	105		ANDESITE, RH-3 to RH-4, medium hard to hard rock, moderate strength, jointing cannot be determined, core exhibit prophylithic alteration, contains epidote and calcite films, this intervals is a highly fractured zone, andesite is fine to medium grained and igneous. Color light gray mottled with yellowish green.		Drilled with HQ wire line system double core barrel with diamond bit and water		100%	34 0
		38						
	104							
0.50		39					100%	0
0.6	103						100%	0
0.3		40					100%	0
40.00 m	102		Bottom of Hole CORE BOX					

PANAMA CANAL AUTHORITY
ENGINEERING AND INDUSTRIAL SERVICES DEPARTMENT
GEOLOGICAL FIELD LOG
BORING CH-2

PROJECT: ALTO CHAGRES

LOCATION: Right Margin

NORTHING: 1024440.003
EASTING: 663890.005
EQUIPMENT: LONGYEAR 38
GROUND ELEVATION: 142.49
TOTAL DEPTH: 40.00
INCLINATION: Vertical
CORE RECOVERY:
START DATE: 21/06/02
COMPLET. DATE: 23/06/02
LOGGER: R.Alvarado-L.Perez
GEOLOGIST: R.Alvarado-Swissboring
DIR.:
DRILLER: Swissboring

SOIL SYMBOLS, SAMPLERS, FIELD TEST DATA AND CORE RUN	ELEVATION (meters)	DEPTH (meters)	DESCRIPTION OF MATERIAL	DISCONTINUITY	DRILLING CHARACTERISTICS	Permeability Test cm/seg	CORE RECOV (%)	RQD (%)
	101	41						
	100	42						
	99	43						
	98	44						
	97	45						
	96	46						
	95	47						
	94	48						

Box #	From	To
1	0.00	5.55
2	5.55	11.00
3	11.00	16.20
4	16.20	21.10
5	21.10	26.05
6	26.05	30.15
7	30.15	34.00
8	34.00	37.85
9	37.85	40.00

TYPE OF MATERIAL

Elevation:	Depth:	Description:
142.5 to 121.4	0.0 to 21.1	OVERBURDEN
121.4 to 116.5	21.1 to 26.0	TOP OF WEATHERED ROCK, ANDESITE
116.5 to 102.5	26.0 to 40.0	TOP OF SOUND ROCK, ANDESITE

KEY TO SYMBOLS

Symbol Description

Strata symbols

OVERBURDEN

ANDESITE

Misc. Symbols

Boring continues

Core recovery

Casing at depth indicated

Water table during drilling

Water table during drilling

Water table during drilling

Casagrande piezometer

Soil Samplers

Rock core

Standard penetration test

PANAMA CANAL AUTHORITY
ENGINEERING AND INDUSTRIAL SERVICES DEPARTMENT
GEOLOGICAL FIELD LOG
BORING CH-3 (v)

PROJECT: ALTO CHAGRES

LOCATION: Right Margin

NORTHING: 1024404.489

EASTING: 663983.543
EQUIPMENT: LONGYEAR 38

GROUND ELEVATION: 108.99
TOTAL DEPTH: 10.25
INCLINATION: Vertical

CORE RECOVERY:
START DATE: 25/06/02
GEOLOGIST: R.Alvarado-Swissboring

COMPLET. DATE: 25/06/02
DIR.:

LOGGER: R.Alvarado-L.Perez
DRILLER: Swissboring

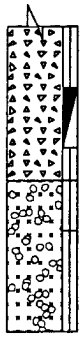
SOIL SYMBOLS, SAMPLERS, FIELD TEST DATA AND CORE RUN	ELEVATION (meters)	DEPTH (meters)	DESCRIPTION OF MATERIAL	DISCONTINUITY	DRILLING CHARACTERISTICS	Permeability Test cm/seg	CORE RECOV (%)	RQD (%)
0.55 5/15 10/15 12/15 0.35 0.45 0.55	108	0 1	RESIDUAL SOIL; OC-4 to OC-5, high to very high consistency, low to moderate water content, low to moderate plasticity, high dry strength, consists of a residual, saprolitic clay with silt and fine sand traces, derived from andesite amd tectonic andesitic breccia by normal weathering processes, upper part contains scattered root and decomposed organic debris. Color: dark brown.		Drilled with 4" single tube sampler, tungstene-carbide bit and dry. SPT #1 All SPT were taken with standard 2", split spoon and a 140 lb hammer dropped 30" for each blow.		100% 78%	
7/15 14/15 21/15 0.40 0.45 0.55	107	2			SPT #2		100% 89%	
8/15 8/15 9/15 0.40 0.45 0.55	106	3			SPT #3		100% 89%	
6/15 50/15 0.20 0.30 0.40	105	4			SPT #4		100% 67%	
0.30 3/15 5/15 7/15 0.40 0.45 0.55	104	5	SAPROLITE, OC-3 to OC-5, medium to very high consistency, low to moderate water content, low to moderate plasticity, high dry strength, consists of saprolitic clay and silt derived from andesite and tectonic andesitic breccia by normal weathering processes, from 3.85m to 3.97 contains one slightly weathered andesite block, and from 6.55m to 8.00m exbibit few andesitic rock fragments up to 80mm in size. Color: yellowish brown and light brown.		SPT #5		100% 100% 89%	
3/15 4/15 4/15 0.40 0.45 0.55	103	6			SPT #6		100% 89%	
5/15 7/15 50/10 0.25 0.40	102	7			SPT #7		100% 62%	
1.05	101	8	TOP OF WEATHERED ROCK.				29%	

PANAMA CANAL AUTHORITY
ENGINEERING AND INDUSTRIAL SERVICES DEPARTMENT
GEOLOGICAL FIELD LOG
BORING CH-3 (v)

PROJECT: ALTO CHAGRES

LOCATION: Right Margin

NORTHING: 1024404.489
EASTING: 663983.543
GROUND ELEVATION: 108.99
EQUIPMENT: LONGYEAR 38
TOTAL DEPTH: 10.25
CORE RECOVERY:
INCLINATION: Vertical
START DATE: 25/06/02
COMPLET. DATE: 25/06/02
LOGGER: R.Alvarado-L.Perez
GEOLOGIST: R.Alvarado-Swissboring
DIR.:
DRILLER: Swissboring

SOIL SYMBOLS, SAMPLERS, FIELD TEST DATA AND CORE RUN	ELEVATION (meters)	DEPTH (meters)	DESCRIPTION OF MATERIAL	DISCONTINUITY	DRILLING CHARACTERISTICS	Permeability Test cm/seg	CORE RECOV (%)	RQD (%)
 0.55 8/15 32/15 50/13 0.40 0.42 0.58 0.70	100 99	9 10	ANDESITE, RH-1 to RH-2, soft to medium soft rock, highly weathered rock, very weak, no apparent jointing, consist of andesite, fine to medium grained and igneous rock. Color: dark brown. AGGLOMERATE, RH-2, medium soft rock, moderate weathered rock, weak, jointing cannot be determined, consists of tectonic andesite breccia, in fine andesitic matrix. Color: greenish gray		SPT #8		55% 95% 100% 100%	
	98 97 96 95 94 93	11 12 13 14 15 16	Bottom of Hole CORE BOX Box # From To 1 0.00 4.55 2 4.55 10.25 TYPE OF MATERIAL Elevation: Depth: Description: 109.0 to 101.0 0.0 to 8.0 RESIDUAL SOIL 101.0 to 99.8 8.0 to 9.2 TOP OF WEATHERED ROCK, ANDESITE 99.8 to 98.7 9.2 to 10.3 AGGLOMERATE					

KEY TO SYMBOLS

Symbol Description

Strata symbols

OVERBURDEN

ANDESITE

AGGLOMERATE

Misc. Symbols

Boring continues

Core recovery

Soil Samplers

Rock core

Standard penetration test

PANAMA CANAL AUTHORITY
ENGINEERING AND INDUSTRIAL SERVICES DEPARTMENT
GEOLOGICAL FIELD LOG
BORING CH-3 (i)

PROJECT: ALTO CHAGRES

LOCATION: Right Margin

NORTHING: 1024404.489
EASTING: 663983.543
GROUND ELEVATION: 108.99
EQUIPMENT: LONGYEAR 38
TOTAL DEPTH: 110
CORE RECOVERY:
INCLINATION: 30°
START DATE: 26/06/02
COMPLET. DATE: 3/07/02
LOGGER: R.Alvarado-L.Perez
GEOLOGIST: R.Alvarado-Swissboring
DIR.: 75°
DRILLER: Swissboring

SOIL SYMBOLS, SAMPLERS, FIELD TEST DATA AND CORE RUN	ELEVATION (meters)	DEPTH (meters)	DESCRIPTION OF MATERIAL	DISCONTINUITY	DRILLING CHARACTERISTICS	Permeability Test cm/seg	CORE RECOV (%)	RQD (%)
		0	From 0.00 to 8.20m; the geology information is presented in the boring log CH-3 (v).		Drilled with tricone rotary bit, no attempt to recover was made.			
	108	1						
	107	2						
	106	3						
	105	4						
	104	5						
	103	6						
	102	7						
	101	8						

PANAMA CANAL AUTHORITY
ENGINEERING AND INDUSTRIAL SERVICES DEPARTMENT
GEOLOGICAL FIELD LOG
BORING CH-3 (i)

PROJECT: ALTO CHAGRES

LOCATION: Right Margin

NORTHING: 1024404.489 **EASTING:** 663983.543 **GROUND ELEVATION:** 108.99

EQUIPMENT: LONGYEAR 38 **TOTAL DEPTH:** 110

CORE RECOVERY: **INCLINATION:** 30°

START DATE: 26/06/02 **COMPLET. DATE:** 3/07/02 **LOGGER:** R.Alvarado-L.Perez

GEOLOGIST: R.Alvarado-Swissboring **DIR.:** 75° **DRILLER:** Swissboring

SOIL SYMBOLS, SAMPLERS, FIELD TEST DATA AND CORE RUN	ELEVATION (meters)	DEPTH (meters)	DESCRIPTION OF MATERIAL	DISCONTINUITY	DRILLING CHARACTERISTICS	Permeability Test cm/seg	CORE RECOV (%)	RQD (%)
28/06/02 1.40	100	9	OVERBURDEN, OC-5 and RH-4, fines material was not recovered, hard rock fragments, moderate to highly weathered, moderate strength to strong, consists of andesite rock fragments up to 170mm in size, fines was not recovered. Color: dark gray.		Drilled with HQ wire line system double core barrel with diamond bit and water		36%	12
1.45	99	10	TOP OF WEATHERED ROCK ANDESITE, RH-1, soft rock, highly weathered, very weak to weak, jointing cannot be determined, core exhibit iron oxides, consists of andesite, fine to medium grained and igneous. Color: dark brown.		From 9.60m to 11.70m core was parcially recovered and washed due to fine material. Core recovered in fair condition		59%	0
0.65	98	11					62%	0
26/06/02 0.9	97	12					100%	0
0.80	96	13					100%	0
0.75	95	14	ANDESITE, RH-2 to RH-3, medium soft to medium hard rock, moderate weathered, very close jointing, joints are open, rough, and contain iron oxides films, consists of andesite, fine to medium grained and igneous. Color: greenish gray.				100%	0
0.50							100%	0
0.4	94	15	ANDESITE, RH-3, medium hard rock, slightly weathered, moderate strength, very close jointing, joints are open, rough, and contain iron oxides films, consists of andesite, fine to medium grained and igneous. Color: greenish gray.			5.77E-04	100%	0
0.75							60%	0
0.6	93	16	TOP OF SOUND ROCK		Drilled with HQ wire line system			

PANAMA CANAL AUTHORITY
ENGINEERING AND INDUSTRIAL SERVICES DEPARTMENT
GEOLOGICAL FIELD LOG
BORING CH-3 (i)

PROJECT: ALTO CHAGRES

LOCATION: Right Margin

NORTHING: 1024404.489
EASTING: 663983.543
GROUND ELEVATION: 108.99
EQUIPMENT: LONGYEAR 38
TOTAL DEPTH: 110
CORE RECOVERY:
INCLINATION: 30°
START DATE: 26/06/02
COMPLET. DATE: 3/07/02
LOGGER: R.Alvarado-L.Perez
GEOLOGIST: R.Alvarado-Swissboring
DIR.: 75°
DRILLER: Swissboring

SOIL SYMBOLS, SAMPLERS, FIELD TEST DATA AND CORE RUN	ELEVATION (meters)	DEPTH (meters)	DESCRIPTION OF MATERIAL	DISCONTINUITY	DRILLING CHARACTERISTICS	Permeability Test cm/seg	CORE RECOV (%)	RQD (%)
0.65			ANDESITE, RH-4, hard rock, strong, close jointing, with a very close jointing interval from 17.70m to 18.30m, joints are open, rough, and dip 20°, 30° and 45°, contains thin calcite films, consists of andesite fine to medium grained and igneous. Color: light gray.		double core barrel with diamond bit and water. Core recovered in good condition		100%	0
	92	17					100%	77
0.65							100%	20
0.35	91	18					100%	0
0.35							100%	46
0.5							100%	80
1/07/02	90	19	FAULT GOUGE-ANDESITE, RH-1 to RH-2, soft to medium soft rock, very weak to weak, no apparent jointing, core exhibit calcite films, from 19.700m to 21.10mm and 21.60 to 22.45m depth core is highly fractured, contain light green gouge, consists of andesite and tectonic andesitic breccia, with volcanic clasts up to 60mm in size. Color: greenish gray.		Core recovered in fair condition		67%	0
0.60							40%	0
0.5	89	20				1.21E-06	30%	0
0.5							67%	0
0.6	88	21					44%	0
0.90							100%	0
0.45	87	22					100%	0
0.35							100%	0
0.4	86	23	ANDESITE, RH-4, hard rock, very close to close jointing, joints are open, rough, mostly dip 20°, 30°, 45°, 60° and 90°, contains thin calcite films and veins, consists of andesite, medium to coarse grained and igneous, and from 25.40m to 25.90m depth consists of tectonic andesitic breccia, contains angular to subangular andesite clasts up to				100%	0
0.55							100%	0
0.60	85	24					100%	0

PANAMA CANAL AUTHORITY
ENGINEERING AND INDUSTRIAL SERVICES DEPARTMENT
GEOLOGICAL FIELD LOG
BORING CH-3 (i)

PROJECT: ALTO CHAGRES

LOCATION: Right Margin

NORTHING: 1024404.489

EASTING: 663983.543
EQUIPMENT: LONGYEAR 38

GROUND ELEVATION: 108.99
TOTAL DEPTH: 110
INCLINATION: 30°

CORE RECOVERY:
START DATE: 26/06/02
GEOLOGIST: R.Alvarado-Swissboring

COMPLET. DATE: 3/07/02
DIR.: 75°

LOGGER: R.Alvarado-L.Perez
DRILLER: Swissboring

SOIL SYMBOLS, SAMPLERS, FIELD TEST DATA AND CORE RUN	ELEVATION (meters)	DEPTH (meters)	DESCRIPTION OF MATERIAL	DISCONTINUITY	DRILLING CHARACTERISTICS	Permeability Test cm/seg	CORE RECOV (%)	RQD (%)
0.45			60mm in fine to medium andesitic matrix. Color: medium gray.				100%	22
0.20							100%	55
0.3	84	25				1.07-04	100%	0
0.4							100%	0
0.8	83	26					100%	0
0.7	82	27					100%	0
0.85			AGGLOMERATE, RH-3, medium hard rock, jointing cannot be determined, all interval is highly fractured, contains propylite alteration with light green gouge and epidote films, from 31.75m to 33.95m depth some core exhibit slickensides, agglomerate rock contains angular andesite clasts up to 60mm in size, in a fine matrix. Color: greenish gray.		Drilled with HQ wire line system double core barrel with diamond bit and water. Core recovered in fair condition		100%	0
1.05	81	28						
0.90	80	29	From 28.80 m to 29.10 m depth; weak due to faulting and hydrothermal alteration				100%	0
0.90	79	30	From 31.75 m to 35.70 m depth; weak due to faulting and hydrothermal alteration			5.54E-07	100%	0
0.6	78	31					100%	0
0.45							100%	22
0.5	77	32					100%	0
							100%	0

PANAMA CANAL AUTHORITY
ENGINEERING AND INDUSTRIAL SERVICES DEPARTMENT
GEOLOGICAL FIELD LOG
BORING CH-3 (i)
PROJECT: ALTO CHAGRES

LOCATION: Right Margin

NORTHING: 1024404.489
EASTING: 663983.543
GROUND ELEVATION: 108.99
EQUIPMENT: LONGYEAR 38
TOTAL DEPTH: 110
CORE RECOVERY:
INCLINATION: 30°
START DATE: 26/06/02
COMPLET. DATE: 3/07/02
LOGGER: R.Alvarado-L.Perez
GEOLOGIST: R.Alvarado-Swissboring
DIR.: 75°
DRILLER: Swissboring

SOIL SYMBOLS, SAMPLERS, FIELD TEST DATA AND CORE RUN	ELEVATION (meters)	DEPTH (meters)	DESCRIPTION OF MATERIAL	DISCONTINUITY	DRILLING CHARACTERISTICS	Permeability Test cm/seg	CORE RECOV (%)	RQD (%)
0.75	76	33					100%	27
0.8	75	34					100%	0
0.7							100%	0
0.3	74	35				0.00E+00	100%	0
0.5							100%	20
0.6	73	36	ANDESITE, RH-3, medium hard rock, moderate strength, very close jointing, joints are open, rough and dip 20°, 30°, 40° and 60°, contains very thin calcite films, andesite is fine to medium grained and igneous. Color: light gray.		Drilled with HQ wire line system double core barrel with diamond bit and water. Core recovered in fair condition		100%	0
0.90	72	37					100%	11
0.85							100%	0
0.6 0.6	71	38	Agglomerate, RH-3, medium hard rock, jointing cannot be determined, with mylonite fault intervals from 40.50m to 40.60m, from 40.80m to 41.10m, from 41.70m to 42.00m and from 44.05m to 44.40m, consists of agglomerate with angular volcanic clasts up to 60mm in size, in a fine to medium grained andesitic matrix. Color: light and dark gray, greenish gray.				100% 100%	0 17
0.60	70	39					100%	0
0.6							100%	0
0.35	69	40				0.00E+00	100%	0
0.6							100%	0

PANAMA CANAL AUTHORITY
ENGINEERING AND INDUSTRIAL SERVICES DEPARTMENT
GEOLOGICAL FIELD LOG
BORING CH-3 (i)

PROJECT: ALTO CHAGRES

LOCATION: Right Margin

NORTHING: 1024404.489 **EASTING:** 663983.543 **GROUND ELEVATION:** 108.99

EQUIPMENT: LONGYEAR 38 **TOTAL DEPTH:** 110

CORE RECOVERY: **INCLINATION:** 30°

START DATE: 26/06/02 **COMPLET. DATE:** 3/07/02 **LOGGER:** R.Alvarado-L.Perez

GEOLOGIST: R.Alvarado-Swissboring **DIR.:** 75° **DRILLER:** Swissboring

SOIL SYMBOLS, SAMPLERS, FIELD TEST DATA AND CORE RUN	ELEVATION (meters)	DEPTH (meters)	DESCRIPTION OF MATERIAL	DISCONTINUITY	DRILLING CHARACTERISTICS	Permeability Test cm/seg	CORE RECOV (%)	RQD (%)
0.5	68	41					100%	0
.90								
	67	42					100%	27
0.65								
							100%	0
0.45	66	43					100%	0
0.8								
	65	44					100%	0
1.1			Agglomerate, RH 3, medium hard rock, moderate strength, very close jointing, joints are open, rough and smooth, but don not exhibit slickensides, dip 30°, 45° and 60°, contains clay minerals, consists of agglomerate, contains angular andesitic clasts up to 70mm, in a fine grained andesitic matrix. Color: light and dark gray.				100%	10
	64	45				8.33E-07		
0.95								
	63	46					100%	0
0.95								
	62	47					100%	24
0.4							100%	0
0.85								
	61	48					100%	49
0.65								

PANAMA CANAL AUTHORITY
ENGINEERING AND INDUSTRIAL SERVICES DEPARTMENT
GEOLOGICAL FIELD LOG
BORING CH-3 (i)

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LOCATION: Right Margin

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INCLINATION: 30°
START DATE: 26/06/02
COMPLET. DATE: 3/07/02
LOGGER: R.Alvarado-L.Perez
GEOLOGIST: R.Alvarado-Swissboring
DIR.: 75°
DRILLER: Swissboring

SOIL SYMBOLS, SAMPLERS, FIELD TEST DATA AND CORE RUN	ELEVATION (meters)	DEPTH (meters)	DESCRIPTION OF MATERIAL	DISCONTINUITY	DRILLING CHARACTERISTICS	Permeability Test cm/seg	CORE RECOV (%)	RQD (%)
0.6	60	49					100%	0
0.6							100%	0
0.35	59	50				7.72E-07	100%	20
0.65							100%	29
0.75	58	51	Agglomerate, RH-1, very soft rock, very weak, jointing cannot be determined, all intervals are highly fractured and exhibit slickensides and calcite films, consists of agglomerate, with angular andesitic clasts up to 20mm in size. Color: light greenish gray.		Drilled with HQ wire line system double core barrel with diamond bit and water. Core recovered in fair condition, some parts was not recovered		100%	0
0.75	57	52					100%	0
0.60	56	53	From 52.50 m to 53.00 m depth; Agglomerate, RH-2, soft rock, due to faulting and hydrothermal alteration (prophilitic)				75%	0
0.65							100%	0
0.65	55	54					100%	0
0.6	54	55	Agglomerate, RH-3 to RH-4, medium hard to hard rock, moderate strength to strong, close to moderate close jointing, with very close intervals from 54.40m to 55.00m, and from 55.50m to 56.50m, joints are open, rough, and dip 20°, 30°, 45°, 60° and 90°, exhibit slickensides, consists of agglomerate, with angular andesitic clasts up to 20mm in length, in a medium to coarse grained matrix. Color: greenish gray to dark gray.		Drilled with HQ wire line system double core barrel with diamond bit and water. Core recovered in good condition	2.13E-06	100%	23
.90							100%	51
0.60	53	56					100%	0

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BORING CH-3 (i)

PROJECT: ALTO CHAGRES

LOCATION: Right Margin

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EASTING: 663983.543
EQUIPMENT: LONGYEAR 38

GROUND ELEVATION: 108.99
TOTAL DEPTH: 110
INCLINATION: 30°

CORE RECOVERY:
START DATE: 26/06/02
GEOLOGIST: R.Alvarado-Swissboring

COMPLET. DATE: 3/07/02
DIR.: 75°

LOGGER: R.Alvarado-L.Perez
DRILLER: Swissboring

SOIL SYMBOLS, SAMPLERS, FIELD TEST DATA AND CORE RUN	ELEVATION (meters)	DEPTH (meters)	DESCRIPTION OF MATERIAL	DISCONTINUITY	DRILLING CHARACTERISTICS	Permeability Test cm/seg	CORE RECOV (%)	RQD (%)
1.0	52	57					100%	74
0.95	51	58					100%	79
1.55	50	59						
	49	60				2.88E-06	100%	40
1.45	48	61	Agglomerate, RH-2 to RH 3, medium soft to medium hard rock, weak to moderately strength, close to moderate close jointing, with highly and altered fractures intervals from 60.40m to 61.50, from 62.00m to 62.70m, from 63.60m to 63.85m, from 64.25m to 64.40 m, from 65.30m to 65.80m, from 67.00m to 67.40m, from 68.00m to 68.35m, and from 70.40m to 70.80m, joints are open, and dip 30°, 45° and 60°, exhibit prophylite alteration and contains abundant slickensides, epidote films and scattered calcite nodules up to 10mm in size, consists of agglomerate, with andesitic clasts up to 40mm, in a coarse grained andesitic matrix. Color: greenish gray		Drilled with HQ wire line system double core barrel with diamond bit and water. Core recovered in far condition		100%	17
1.25	47	62						
	46	63					100%	0
1.15								
	45	64					100%	51
1.15								

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BORING CH-3 (i)

PROJECT: ALTO CHAGRES

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TOTAL DEPTH: 110
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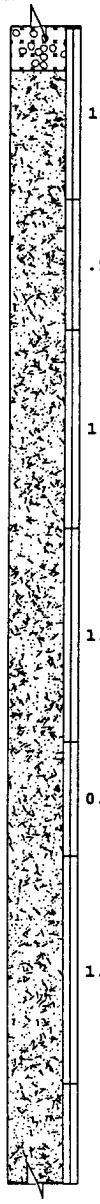
INCLINATION: 30°
START DATE: 26/06/02
COMPLET. DATE: 3/07/02
LOGGER: R.Alvarado-L.Perez
GEOLOGIST: R.Alvarado-Swissboring
DIR.: 75°
DRILLER: Swissboring

SOIL SYMBOLS, SAMPLERS, FIELD TEST DATA AND CORE RUN	ELEVATION (meters)	DEPTH (meters)	DESCRIPTION OF MATERIAL	DISCONTINUITY	DRILLING CHARACTERISTICS	Permeability Test cm/seg	CORE RECOV (%)	RQD (%)
	44	65	From 65.30 m to 68.50 m depth; Agglomerate-Fault gouge (Shear zone), RH-2, medium soft rock, sandy matrix. Color: light gray.			3.38E-07	100%	74
	43	66					100%	34
	42	67					100%	46
	41	68					86%	26
	40	69					100%	54
	39	70				1.74E-04	100%	15
	38	71					100%	94
	37	72						
	36	73						

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NORTHING: 1024404.489 **EASTING:** 663983.543 **GROUND ELEVATION:** 108.99

EQUIPMENT: LONGYEAR 38 **TOTAL DEPTH:** 110

CORE RECOVERY: **INCLINATION:** 30°

START DATE: 26/06/02 **COMPLET. DATE:** 3/07/02 **LOGGER:** R.Alvarado-L.Perez

GEOLOGIST: R.Alvarado-Swissboring **DIR.:** 75° **DRILLER:** Swissboring

SOIL SYMBOLS, SAMPLERS, FIELD TEST DATA AND CORE RUN	ELEVATION (meters)	DEPTH (meters)	DESCRIPTION OF MATERIAL	DISCONTINUITY	DRILLING CHARACTERISTICS	Permeability Test cm/seg	CORE RECOV (%)	RQD (%)
1.4			Agglomerate, RH-2 to RH 3, medium soft to medium hard rock, weak, jointing cannot be determined, core exhibit propylite alteration, slickensides, consists of agglomerate, with angular clasts up to 20mm in size. Color: light gray.		Drilled with HQ wire line system double core barrel with diamond bit and water.		100%	63
1.2	35	74						
.5	34	75				3.46E-05	92%	11
							100%	0
0.65	33	76	Agglomerate, RH-2 to RH 3, medium soft rock to medium hard rock, weak to moderate strength, close to moderately close, with highly fractured intervals from 77.50m to 77.70m, from 80.50m to 80.90m, and from 81.50m to 81.80m, joints are open, rough, and dip 30°, 45° and 60°, contains abundant slickensides and epidote films up to 10mm thick, core exhibit propylite alteration, consists of tectonics andesite breccia, with clasts up to 20mm in size, in fine to medium andesitic grained and igneous, agglomerate is partially altered to clay minerals. Color: greenish gray.				100%	15
1.55	32	77						
							100%	62
	31	78						
1.6								
	30	79					100%	39
0.70								
	29	80				6.67E-06	100%	43
.90								
	28	81					100%	57

PANAMA CANAL AUTHORITY
ENGINEERING AND INDUSTRIAL SERVICES DEPARTMENT
GEOLOGICAL FIELD LOG
BORING CH-3 (i)

PROJECT: ALTO CHAGRES

LOCATION: Right Margin

NORTHING: 1024404.489
EASTING: 663983.543
GROUND ELEVATION: 108.99
EQUIPMENT: LONGYEAR 38
TOTAL DEPTH: 110
CORE RECOVERY:
INCLINATION: 30°
START DATE: 26/06/02
COMPLET. DATE: 3/07/02
LOGGER: R.Alvarado-L.Perez
GEOLOGIST: R.Alvarado-Swissboring
DIR.: 75°
DRILLER: Swissboring

SOIL SYMBOLS, SAMPLERS, FIELD TEST DATA AND CORE RUN	ELEVATION (meters)	DEPTH (meters)	DESCRIPTION OF MATERIAL	DISCONTINUITY	DRILLING CHARACTERISTICS	Permeability Test cm/seg	CORE RECOV (%)	RQD (%)
1.6	27	82					100%	50
1.2	26	83	AGGLOMERATE, RH-3 to RH 4, medium hard to hard rock, moderate strength to strong, close to moderately close jointing, with highly fractured intervals from 84.40m to 84.70m, and from 85.35m to 85.70m, joints are open, rough, and dip 40°, 60° and 90°, contains epidote films, calcite veins up to 5mm thick, and slickensides from 83.05m to 86m, consists of tectonic andesitic breccia, with angular andesitic clasts up to 60mm, in medium to coarse andesitic matrix, contains one large andesite clasts from 86.00m to 86.80m. Color: light green and greenish gray.				100%	33
1.3	25	84						
1.	24	85				1.01E-05	100%	55
1.25	23	86					100%	52
1.1	22	87	FAULT GOUGE-AGGLOMERATE, RH-1 to RH-2, soft to medium soft rock, very weak to weak, jointing cannot be determined, with one very close jointing from 87.30m to 88.00m depth, contain light green gouge, slickensides, epidote and calcite stains, from 88.85m to 89.20m material was not recovered, consists of fault gouge-agglomerate, partially altered to clay minerals. Color: light gray		Drilled with HQ wire line system double core barrel with Drilled with HQ wire line system double core barrel with diamond bit and water. Core recovered in fair condition, some parts was not recovered.		100%	58
	21	88					100%	0
0.85	20	89					100%	0

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EQUIPMENT: LONGYEAR 38 **TOTAL DEPTH:** 110

CORE RECOVERY: **INCLINATION:** 30°

START DATE: 26/06/02 **COMPLET. DATE:** 3/07/02 **LOGGER:** R.Alvarado-L.Perez

GEOLOGIST: R.Alvarado-Swissboring **DIR.:** 75° **DRILLER:** Swissboring

SOIL SYMBOLS, SAMPLERS, FIELD TEST DATA AND CORE RUN	ELEVATION (meters)	DEPTH (meters)	DESCRIPTION OF MATERIAL	DISCONTINUITY	DRILLING CHARACTERISTICS	Permeability Test cm/seg	CORE RECOV (%)	RQD (%)
0.80	19	90				4.53E-06	100%	0
0.85							100%	12
1.25	18	91	AGGLOMERATE, RH-3, medium hard rock, moderate strength, close to moderately closen jointing, with one very close jointing interval from 92.10m to 92.40m, joints are close, rough, and dip 40°, 60° and 90°, core exhibit calcite veins, consists of agglomerate, with angular andesite clasts up to 70mm in size, in a fine grained andesitic matrix. Color: light green		Drilled with HQ wire line system double core barrel with diamond bit and water. Core recovered in fair condition			
1.2	17	92					100%	45
	16	93					100%	77
1.35	15	94	AGGLOMERATE-FAULT GOUGE (SHEAR ZONE), RH-1 to RH 2, soft to medium soft rock, weak, very close to close jointing, joints are close, rough, and dip 20° and 45°, contains abundant slickensides, core exhibit moderate veins of calcite, consists of agglomerate, with angular andesite clasts up to 60mm, in a fine grained andesitic matrix. Color: dark gray.				100%	22
0.35	14	95	AGGLOMERATE, RH-3 to RH 4-, medium hard to hard rock, strong, close to moderately close jointing, joints are close, rough, and dip 45° and 90°, contains slickensides with few scattered pyrite, and calcite veins up to 5mm thick, consists of agglomerate, with angular andesite clasts up to 70mm, in a fine to medium grained matrix. Color: light green.		Drilled with HQ wire line system double core barrel with	9.16E-06	100%	71
1.25	13	96					100%	84
1.55	12	97						

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SOIL SYMBOLS, SAMPLERS, FIELD TEST DATA AND CORE RUN	ELEVATION (meters)	DEPTH (meters)	DESCRIPTION OF MATERIAL	DISCONTINUITY	DRILLING CHARACTERISTICS	Permeability Test cm/seg	CORE RECOV (%)	RQD (%)
			From 97.80 m to 99.25 m depth; dark gray in color with waxy smooth joints, 15º to vertical.				100%	77
1.50	11	98						
	10	99	From 99.25 m to 106.25 m depth; fracture zone, waxy smooth joints				100%	45
0.70								
	9	100				3.00E-06	100%	29
0.75								
							100%	0
	8	101						
.95								
							100%	11
	7	102						
.8								
							100%	16
1.05	6	103						
							100%	0
0.85	5	104						
							100%	0
0.6								
	4	105				4.20E-06	100%	17
0.75								

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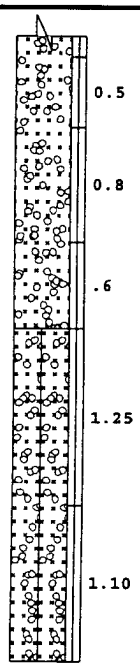
SOIL SYMBOLS, SAMPLERS, FIELD TEST DATA AND CORE RUN	ELEVATION / DEPTH (meters)	DESCRIPTION OF MATERIAL	DISCONTINUITY	DRILLING CHARACTERISTICS	Permeability Test cm/seg	CORE RECOV (%)	RQD (%)
	3 — 106	AGGLOMERATE, RH-2 to RH-3, medium soft to medium hard rock, weak to moderate strength, jointing cannot be determined, with very close jointing intervals from 102.85m to 106.35m, core exhibit abundant slickensides, calcite and epidote films, some core surfaces contains scattered pyrite mineral, consists of agglomerate, in a fine grained matrix, partially altered to clay minerals. Color: dark gray AGGLOMERATE, RH-2 to RH 3-, medium soft to medium hard rock, moderate strength, close to moderately close jointing, with one highly fractured interval from 108.00m to 108.50m, joints are close, rough, mostly dip 45° and 90°, contains slickensides, calcite veins and scattered pyrite crystals, consists of agglomerate, with clasts up to 50mm in size, in a fine to medium grained matrix. Color: light and dark green.		Drilled with HQ wire line system double core barrel with diamond bit and water. Core recovered in fair condition.		100%	13
	2 — 107					100%	20
	1 — 108					100%	15
	0 — 109					100%	0
	-1 — 110					100%	45
	-2 — 111					100%	96
	-3 — 112						
	-4 — 113						

0.5
0.8
.6
1.25
1.10

Bottom of Hole

CORE BOX

Box #	From	to
1	8.20	14.00
2	14.00	18.30
3	18.30	23.75
4	23.75	27.50
5	27.50	31.75
6	31.75	35.95
7	35.95	40.15
8	40.15	44.05
9	44.05	48.10
10	48.10	51.90
11	51.90	56.50
12	56.50	60.95

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SOIL SYMBOLS, SAMPLERS, FIELD TEST DATA AND CORE RUN	ELEVATION (meters)	DEPTH (meters)	DESCRIPTION OF MATERIAL	DISCONTINUITY	DRILLING CHARACTERISTICS	Permeability Test cm/seg	CORE RECOV (%)	RQD (%)
	-5	114						
	-6	115						
	-7	116						
	-8	117						
	-9	118						
	-10	119						
	-11	120						
	-12	121						

13	60.95	65.30
14	65.30	69.90
15	69.90	74.20
16	74.20	78.35
17	78.35	82.25
18	82.25	86.00
19	86.00	90.70
20	90.70	94.90
21	94.90	99.25
22	99.25	102.85
23	102.85	106.35
24	106.35	110.00

TYPE OF MATERIAL

Elevation:	Depth:	Description:
100.8 to 99.4	8.2 to 9.6	OVERBURDEN
99.4 to 93.0	9.6 to 16.0	TOP OF WEATHERED ROCK-ANDESITE
93.0 to 90.1	16.0 to 18.9	TOP OF SOUND ROCK-ANDESITE
90.1 to 86.2	18.9 to 22.8	FAULT GOUGE-ANDESITE
86.2 to 81.7	22.8 to 27.3	ANDESITE
81.7 to 73.3	27.3 to 35.7	AGGLOMERATE
73.3 to 71.1	35.7 to 37.9	ANDESITE
71.1 to 43.7	37.9 to 65.3	AGGLOMERATE
43.7 to 35.9	65.3 to 73.1	AGGLOMERATE - FAULT GOUGE
35.9 to 22.2	73.1 to 86.8	AGGLOMERATE
22.2 to 18.1	86.8 to 90.9	FAUL GOUGE-SHEAR ZONE
18.1 to 15.7	90.9 to 93.3	AGGLOMERATE
15.7 to 14.3	93.3 to 94.7	AGGLOMERATE-FAULT GOUGE
14.3 to -1.0	94.7 to 110.0	AGGLOMERATE

KEY TO SYMBOLS

Symbol Description

Strata symbols

OVERBURDEN

ANDESITE

FAULT ZONE - FAULT GOUGE
(SHEAR ZONE)

AGGLOMERATE

Misc. Symbols

Boring continues

Water table during
drilling

Casing at depth indicated

Water table during drilling

Core recovery

Water table during
drilling

Soil Samplers

Rock core

PANAMA CANAL AUTHORITY
ENGINEERING AND INDUSTRIAL SERVICES DEPARTMENT
GEOLOGICAL FIELD LOG
BORING CH-4

PROJECT: ALTO CHAGRES

LOCATION: LEFT MARGIN

NORTHING: 1024370.006

EASTING: 664240.005
EQUIPMENT: LONGYEAR 38

GROUND ELEVATION: 184.01
TOTAL DEPTH: 30.00 m
INCLINATION: VERTICAL
LOGGER: ING. R.ALVARADO-L.PEREZ
DRILLER: Swissboring

CORE RECOVERY:
START DATE: 1 JUNIO, 2002
GEOLOGIST: R.ALVARADO-L.PEREZ

COMPLET. DATE: 6 JUNIO, 2002
DIR.:

SOIL SYMBOLS, SAMPLERS, FIELD TEST DATA AND CORE RUN	ELEVATION (meters)	DEPTH (meters)	DESCRIPTION OF MATERIAL	DISCONTINUITY	DRILLING CHARACTERISTICS	Permeability Test cm/seg	CORE RECOV (%)	RQD (%)
0.55 4/15 5/15 6/15 0.19 0.55	184 183	0 1	OVERBURDEN, OC-3 to OC-4, medium high to high consistency, moderate to high water content, moderate to high plasticty, low to moderate dry strength, consists of residual clay with lenses of sand, contains little roots, derived from andesite by normal weathering processes. Color: reddish brown		Drilled with 4", single tube, carbide tungstene bit, dry rotary SPT #1 All SPT were taken with standard 2", split spoom and a 140 lb hammer dropped 30" for each blow		100%	
7/15 11/15 15/15 0.30 0.55	182	2			SPT #2		100%	
9/15 12/15 13/15 0.26 0.55	181	3	OVERBURDEN, OC-5, very high consistency, low to moderate water content, low to moderate plasticity, high dry strength, consists of a residual clay and silt and fine sand, contains iron oxides and manganese, material is derived from andesite by normal weathering processes. Color: dark brown.		SPT #3		65%	
7/15 11/15 15/15 0.30 0.55	180	4			SPT #4		100%	
8/15 10/15 17/15 0.32 0.55	179	5			SPT #5		73%	
8/15 14/15 17/15 0.25 0.55	178	6			SPT #6		100%	
18/15 20/15 20/15 0.32 0.55	177	7			SPT #7		100%	
5/15 6/15 6/15 0.30	176	8	OVERBURDEN, OC-4, high consistency, moderate water content, moderate to high plasticity, moderate to high dry strength, consists of residual		SPT #8		100%	

PANAMA CANAL AUTHORITY
ENGINEERING AND INDUSTRIAL SERVICES DEPARTMENT
GEOLOGICAL FIELD LOG
BORING CH-4

PROJECT: ALTO CHAGRES

LOCATION: LEFT MARGIN

NORTHING: 1024370.006

EASTING: 664240.005
EQUIPMENT: LONGYEAR 38

GROUND ELEVATION: 184.01
TOTAL DEPTH: 30.00 m
INCLINATION: VERTICAL

CORE RECOVERY:
START DATE: 1 JUNIO, 2002
GEOLOGIST: R.ALVARADO-L.PEREZ

COMPLET. DATE: 6 JUNIO, 2002
DIR.:

LOGGER: ING. R.ALVARADO-L.PEREZ
DRILLER: Swissboring

SOIL SYMBOLS, SAMPLERS, FIELD TEST DATA AND CORE RUN	ELEVATION (meters)	DEPTH (meters)	DESCRIPTION OF MATERIAL	DISCONTINUITY	DRILLING CHARACTERISTICS	Permeability Test cm/seg	CORE RECOV (%)	RQD (%)
0.55			clay and traces of sand, contains ochre and black iron and manganese oxides, derived from andesite by normal weathering processes. Color: dark brown.				100%	
6/15 8/15 10/15 0.45	175	9			SPT #9			
0.55							100%	
18/15 30/15 50/15 0.45	174	10	OVERBURDEN, OC-5, very high consistency, moderate water content, moderate plasticity, moderate to high dry strength, consists of residual silt and sand, contains scattered iron and manganese oxides, material is derived from andesite by normal weathering processes. Color dark brown and yellowish brown.		SPT #10			
0.55							100%	
30/15 50/10 0.25	173	11			SPT #11			
0.75							53%	
22/15 50/11 0.26	172	12			SPT #12			
1.00								
6/6/02 1.2	171	13	OVERBURDEN, OC-5, very high consistency, low water content, low plasticity, low to moderate dry strength, consists of saprolitic clay, and from 14.00 m to 15.00 m depth, some subangular rock fragments, up to 5 cm in size, contains somendant iroabun oxides, material is derived from andesite and agglomerate by normal weathering processes, fine material was not recovered by drilling operation. Color light to dark brown.		Drilled with HQ wire line system double tube core barrel with diamond bit and water		70%	
	170	14					12%	
0.99								
	169	15					25%	
0.60							100%	
0.40	168	16					100%	

PANAMA CANAL AUTHORITY
ENGINEERING AND INDUSTRIAL SERVICES DEPARTMENT
GEOLOGICAL FIELD LOG
BORING CH-4

PROJECT: ALTO CHAGRES

LOCATION: LEFT MARGIN
NORTHING: 1024370.006
CORE RECOVERY:
START DATE: 1 JUNIO, 2002
GEOLOGIST: R.ALVARADO-L.PEREZ

EASTING: 664240.005
EQUIPMENT: LONGYEAR 38
COMPLET. DATE: 6 JUNIO, 2002
DIR.:

GROUND ELEVATION: 184.01
TOTAL DEPTH: 30.00 m
INCLINATION: VERTICAL
LOGGER: ING. R.ALVARADO-L.PEREZ
DRILLER: Swissboring

SOIL SYMBOLS, SAMPLERS, FIELD TEST DATA AND CORE RUN	ELEVATION (meters)	DEPTH (meters)	DESCRIPTION OF MATERIAL	DISCONTINUITY	DRILLING CHARACTERISTICS	Permeability Test cm/seg	CORE RECOV (%)	RQD (%)
0.55								
0.65	167	17			Drilled with HQ wire line system double tube core barrel with diamond bit and water		100%	
0.50							100%	
0.85	166	18	TOP OF HIGHLY WEATHERED ROCK AGGLOMERATE, RH-1 to RH-2, soft to medium soft rock, highly weathered, weak to moderate strength, no apparent jointing, consists of rock with clay, present prophylitic alteration, clay lost by drilling operations, contains rock fragments, up to 11 in lenght. Color: yellowish greenish gray.				30%	0
0.55	165	19	TOP OF SOUND ROCK AGGLOMERATE, RH-2, medium soft rock, no apparent jointing, except from 27.00 m to 27.60, core exhibit very close to close jointing, joints are open, planar, rough and contains clay minerals, joints dip 30° and 90°, from to 26.20 exhibit highly prophylitic alteration, from 19.10 to 20.50 m and from 26.20 m to 27.00 m exhibit moderaterly prophylitic alteration, from 21.50 m to 22.50 m and from 27.30 m to 27.60 m, andesitic fragments up to 80mm in length, consists of andesite medium to coarse grained and igneous. Color medium gray to greenis h gray.		Core recovered in fair condition		41%	0
0.75							45%	60
0.65	164	20					40%	0
1.00	163	21					46%	33
1	162	22					35%	0
1.50	161	23					30%	70
	160	24					0%	0
								40

PANAMA CANAL AUTHORITY
ENGINEERING AND INDUSTRIAL SERVICES DEPARTMENT
GEOLOGICAL FIELD LOG
BORING CH-4

PROJECT: ALTO CHAGRES

LOCATION: LEFT MARGIN

NORTHING: 1024370.006

EASTING: 664240.005
EQUIPMENT: LONGYEAR 38

GROUND ELEVATION: 184.01
TOTAL DEPTH: 30.00 m
INCLINATION: VERTICAL

CORE RECOVERY:
START DATE: 1 JUNIO, 2002
GEOLOGIST: R.ALVARADO-L.PEREZ

COMPLET. DATE: 6 JUNIO, 2002
DIR.:

LOGGER: ING. R.ALVARADO-L.PEREZ
DRILLER: Swissboring

SOIL SYMBOLS, SAMPLERS, FIELD TEST DATA AND CORE RUN	ELEVATION (meters)	DEPTH (meters)	DESCRIPTION OF MATERIAL	DISCONTINUITY	DRILLING CHARACTERISTICS	Permeability Test cm/seg	CORE RECOV (%)	RQD (%)
1							25%	
0.60	159	25			Drilled with HQ wire line system double tube core barrel with diamond bit and water		33%	0
0.60	158	26					50%	43
0.80							50%	0
0.60	157	27					100%	0
0.75	156	28	SHEAR ZONE-AGGLOMERATE; RH-1 to RH-2, soft to medium soft rock, very weak, no apparent jointing, some joint surfaces contain gouge and calcite, this interval is a highly fractured/jointed zone, matrix is sandy. Color: light gray to dark gray.				53%	0 0
0.65	155	29					100%	0
0.60							100%	63
0.40	154	30					100%	55
	153	31						
	152	32						

Bottom of Hole

CORE BOX

Box #	From	To
1	0.00	5.55
2	5.55	10.80
3	10.80	17.95
4	17.95	27.80
5	27.80	30.00

TYPE OF MATERIAL

Elevation:	Depth:	Description:
184.0 to 166.3	0.0 to 17.7	OVERBURDEN
166.3 to 164.9	17.7 to 19.1	TOP OF HIGHLY WEATHERED ROCK,AGGLOMERATE
164.9 to 156.0	19.1 to 28.0	TOP OF SOUND ROCK, ANDESITE
156.0 to 154.0	28.0 to 30.0	SHEAR ZONE-AGGLOMERATE

KEY TO SYMBOLS

Symbol Description

Strata symbols

OVERBURDEN

AGGLOMERATE

ANDESITE

FAULT ZONE - FAULT GOUGE
(SHEAR ZONE)

Misc. Symbols

Boring continues

Core recovery

Casing at depth indicated

Water table during drilling

oil Samplers

Rock core

Standard penetration test

PANAMA CANAL AUTHORITY
ENGINEERING AND INDUSTRIAL SERVICES DEPARTMENT
GEOLOGICAL FIELD LOG
BORING CH-6

PROJECT: ALTO CHAGRES

LOCATION: Left Margin

NORTHING: 1024539.997

EASTING: 664069.999
EQUIPMENT: LONGYEAR 38

GROUND ELEVATION: 116.593
TOTAL DEPTH: 70.00
INCLINATION: Vertical

CORE RECOVERY:
START DATE: 13/06/02
GEOLOGIST: R.Alvarado-Swissboring

COMPLET. DATE: 17/06/02
DIR.: vert.

LOGGER: R.Alvarado-L.Perez
DRILLER: Swissboring

SOIL SYMBOLS, SAMPLERS, FIELD TEST DATA AND CORE RUN	ELEVATION (meters)	DEPTH (meters)	DESCRIPTION OF MATERIAL	DISCONTINUITY	DRILLING CHARACTERISTICS	Permeability Test cm/seg	CORE RECOV (%)	RQD (%)
0.55 5/15 22/15 36/15 0.38 0.45 0.55 14/15 10/15 16/15 0.36 0.45 0.55 33/15 11/50 0.23 0.26 0.74 1.50 1.55 0.65 0.25 0.50	116 115 114 113 112 111 110 109	0 1 2 3 4 5 6 7 8	OVERBURDEN, OC-4 to OC-5, high to very high consistency, low water consistency, low water content, low plasticity, moderate dry strength, consists of saprolitic silt and clay with traces of sand, contains very little scattered roots and weathered rock fragments derived from andesite by normal weathering processes. Color: yellowish brown.		Drilled with 4" single tube sampler, tungstene-carbide bit and dry. SPT #1 All SPT were taken with standard 2", split spoon and a 140 lb hammer dropped 30" for each blow. Drilled with HQ wire line system double core barrel with diamond bit and water SPT #2 SPT #3		100% 84% 91% 80% 100% 88% 68% 25% 30% 46% 100% 100%	0 0 0 0 0 0
			TOP OF WEATHERED ROCK ANDESITE, RH-2, medium soft rock, highly to completely weathered, very weak to weak, no apparent jointing, consists of angular to subangular andesite fragments, in soil matrix, contains clay materials, core shows red and ochre iron oxide stains. Color: brown to greenish gray.		Drilled with HQ wire line system double tube core barrel with diamond bit and water			

PANAMA CANAL AUTHORITY
ENGINEERING AND INDUSTRIAL SERVICES DEPARTMENT
GEOLOGICAL FIELD LOG
BORING CH-6

PROJECT: ALTO CHAGRES

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NORTHING: 1024539.997
EASTING: 664069.999
GROUND ELEVATION: 116.593
EQUIPMENT: LONGYEAR 38
TOTAL DEPTH: 70.00
CORE RECOVERY:
INCLINATION: Vertical
START DATE: 13/06/02
COMPLET. DATE: 17/06/02
LOGGER: R.Alvarado-L.Perez
GEOLOGIST: R.Alvarado-Swissboring
DIR.: vert.
DRILLER: Swissboring

SOIL SYMBOLS, SAMPLERS, FIELD TEST DATA AND CORE RUN	ELEVATION (meters)	DEPTH (meters)	DESCRIPTION OF MATERIAL	DISCONTINUITY	DRILLING CHARACTERISTICS	Permeability Test cm/seg	CORE RECOV (%)	RQD (%)
14/06/02 0.90	108				Core was recovered in fair condition		56%	0
0.70	107	9			Drilled with HQ wire line system double core barrel with diamond bit and water		57%	0
0.65		10					62%	0
0.65	106						69%	0
0.55		11					27%	0
0.60 15/06/02 16/06/02	105	12					58%	0
0.45	104						56%	0
0.70		13	ANDESITE, RH-3, medium hard rock, moderate weathered, weak to moderate strength, very close jointing, joints are open, rough, and dip 0°, 45, 60 and 90°, contains iron manganese stains, consists of andesite, fine to medium grained and igneous determined, was recovered mostly as loose, subangular rock fragments, contains abundant iron oxides, andesite is fine grained and igneous. Color: light gray to greenish gray.				100%	0
0.75	103						100%	0
0.65		14					100%	23
1.15	102	15				8.64E-04	100%	0
	101	16						

PANAMA CANAL AUTHORITY
ENGINEERING AND INDUSTRIAL SERVICES DEPARTMENT
GEOLOGICAL FIELD LOG
BORING CH-6

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EASTING: 664069.999
EQUIPMENT: LONGYEAR 38

GROUND ELEVATION: 116.593
TOTAL DEPTH: 70.00
INCLINATION: Vertical

CORE RECOVERY:
START DATE: 13/06/02
GEOLOGIST: R.Alvarado-Swissboring

COMPLET. DATE: 17/06/02
DIR.: vert.

LOGGER: R.Alvarado-L.Perez
DRILLER: Swissboring

SOIL SYMBOLS, SAMPLERS, FIELD TEST DATA AND CORE RUN	ELEVATION (meters)	DEPTH (meters)	DESCRIPTION OF MATERIAL	DISCONTINUITY	DRILLING CHARACTERISTICS	Permeability Test cm/seg	CORE RECOV (%)	RQD (%)
1.15	100							
0.40		17			Drilled with HQ wire line system double core barrel with diamond bit and water		100%	0
0.55	99						75%	0
0.35		18					100%	
0.60	98						100%	0
0.60		19	FAULT ZONE-ANDESITE, RH-2 to RH-3, medium soft to medium hard rock, highly to moderate weathered, jointing cannot be determined, contains abundant iron oxides and manganese stains, andesite is fine grained and igneous, parcially altered to clay minerals. Color: dark brown to gray.				100%	0
0.60	97						100%	0
0.80		20				0.00E+00	100%	0
0.85	96						100%	0
0.30		21					100%	0
1.25	95						100%	0
0.40		22					100%	0
0.40	94						100%	0
	93	23					100%	0
		24					100%	0

PANAMA CANAL AUTHORITY
ENGINEERING AND INDUSTRIAL SERVICES DEPARTMENT
GEOLOGICAL FIELD LOG
BORING CH-6

PROJECT: ALTO CHAGRES

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GROUND ELEVATION: 116.593
EQUIPMENT: LONGYEAR 38
TOTAL DEPTH: 70.00
CORE RECOVERY:
INCLINATION: Vertical
START DATE: 13/06/02
COMPLET. DATE: 17/06/02
LOGGER: R.Alvarado-L.Perez
GEOLOGIST: R.Alvarado-Swissboring
DIR.: vert.
DRILLER: Swissboring

SOIL SYMBOLS, SAMPLERS, FIELD TEST DATA AND CORE RUN	ELEVATION (meters)	DEPTH (meters)	DESCRIPTION OF MATERIAL	DISCONTINUITY	DRILLING CHARACTERISTICS	Permeability Test cm/seg	CORE RECOV (%)	RQD (%)
0.70	92						100%	0
0.30		25			Drilled with HQ wire line system double core barrel with diamond bit and water	3.81E-05	100%	0
1.00	91						30%	0
0.85	90	26	ANDESITE, RH-3 to RH-4, medium hard to hard rock, sligthly to moderate weathered, weak to moderate strength, very close jointing, joints are open, rough and dip 0°, 30°, 45° and 90°, contains iron oxides and manganese stains, this interval is a highly fractured/ jointed zone, andesite is fine to medium grained and igneous. Color: greenish gray.				98%	0
0.85	89	27					47%	0
0.35		28					86%	0
1.50	88	29					25%	0
0.45	87	30				3.77E-06	89%	0
0.65	86						62%	0
0.35		31					57%	0
0.35							71%	0
0.45	85	32	TOP OF SOUND ROCK ANDESITE, RH-4, hard rock, moderate streng to strong, close jointing, with very close jointing intervals from 31.40m to 33.05m and from 33.50m to 33.70m, and from 35.60 to 36.00 m, mostly dip 0°, 30°, 45°,				89%	0
0.85								

PANAMA CANAL AUTHORITY
ENGINEERING AND INDUSTRIAL SERVICES DEPARTMENT
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BORING CH-6

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GROUND ELEVATION: 116.593
TOTAL DEPTH: 70.00
INCLINATION: Vertical

CORE RECOVERY:
START DATE: 13/06/02
GEOLOGIST: R.Alvarado-Swissboring

COMPLET. DATE: 17/06/02
DIR.: vert.

LOGGER: R.Alvarado-L.Perez
DRILLER: Swissboring

SOIL SYMBOLS, SAMPLERS, FIELD TEST DATA AND CORE RUN	ELEVATION (meters)	DEPTH (meters)	DESCRIPTION OF MATERIAL	DISCONTINUITY	DRILLING CHARACTERISTICS	Permeability Test cm/seg	CORE RECOV (%)	RQD (%)
0.15	84		60° and 90°, contains abundant light green epidote, iron oxides, manganese stains and calcite veins up to 8mm in size from 33.20 m to 33.50m, and from 34.30m to 34.40m, andesite is fine to medium grained and igneous. Color: greenish gray, dark gray.		Drilled with HQ wire line system double core barrel with diamond bit and water		88%	0
							87%	0
0.85		33						
	83						100%	28
0.85		34						
	82						100%	56
0.50		35					100%	74
0.6						4.38E-07		
	81						100%	17
0.8		36						
							100%	48
	80							
0.7		37					100%	31
	79		ANDESITE-FRACTURE ZONE, RH-4, hard rock, strong, very close jointing, joints are open, and mostly dip 0°, 30° and 45°, contains light green epidote, some joints surfaces contain thin light green gouge and waxy smooth and shiny, and exhibit slickensides and thin calcite veins, andesite is fine to medium grained and igneous. Color: greenish gray.					
1.45		38						
	78						100%	28
0.45								
0.25		39					100%	0
							100%	0
0.75	77							
		40					100%	24
			ANDESITE, RH-4, hard rock, moderate strength to strong, close jointing, joints are open, rough, and dip 0°,			2.04E-05		
1.15	76							

PANAMA CANAL AUTHORITY
ENGINEERING AND INDUSTRIAL SERVICES DEPARTMENT
GEOLOGICAL FIELD LOG
BORING CH-6

PROJECT: ALTO CHAGRES

LOCATION: Left Margin

NORTHING: 1024539.997
EASTING: 664069.999
EQUIPMENT: LONGYEAR 38
GROUND ELEVATION: 116.593
TOTAL DEPTH: 70.00
INCLINATION: Vertical

CORE RECOVERY:
START DATE: 13/06/02
COMPLET. DATE: 17/06/02
LOGGER: R.Alvarado-L.Perez
GEOLOGIST: R.Alvarado-Swissboring
DIR.: vert.
DRILLER: Swissboring

SOIL SYMBOLS, SAMPLERS, FIELD TEST DATA AND CORE RUN	ELEVATION (meters)	DEPTH (meters)	DESCRIPTION OF MATERIAL	DISCONTINUITY	DRILLING CHARACTERISTICS	Permeability Test cm/seg	CORE RECOV (%)	RQD (%)
1.15	75	41	45° and 90°, contains epidote and thin calcite films, andesite is fine to medium grained. Color: dark gray, greenish gray.		Drilled with HQ wire line system double core barrel with diamond bit and water		100%	29
		42					74%	0
0.60	74	43	ANDESITE-fAULT GOUGE, RH-2 to RH-3, medium soft to medium hard rock, weak, jointing cannot be determined, some core surfaces contains light green gouge and epidote, and thin calcite veins, this interval is a highly fractured/jointed zone, andesite is fine to medium grained. Color: greenish gray, gray.				70%	0
0.60							50%	0
0.65	73	44					31%	0
0.85	72						39%	0
1.25	71	45	ANDESITE, RH-4, hard rock, strong to very strong, close to moderately close jointing, joints are open, rough, and dip 45°, 60° and 90°, contain epidote and thin calcite films up to 8mm, andesite is fine to medium grained and igneous. Color: gray, greenish gray.			2.47E-05	100%	80
		46						
1.50	70	47					95%	71
0.65	69	48	ANDESITE-FRACTURE ZONE, RH-3, medium hard rock, weak to moderate strength, very close jointing, joints are open and dip 30°, 45°, 60° and 90°, and contains epidote		Drilled with HQ wire line system		74%	0
	68							

PANAMA CANAL AUTHORITY
ENGINEERING AND INDUSTRIAL SERVICES DEPARTMENT
GEOLOGICAL FIELD LOG
BORING CH-6

PROJECT: ALTO CHAGRES

LOCATION: Left Margin

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EASTING: 664069.999
EQUIPMENT: LONGYEAR 38

GROUND ELEVATION: 116.593
TOTAL DEPTH: 70.00
INCLINATION: Vertical

CORE RECOVERY:
START DATE: 13/06/02
GEOLOGIST: R.Alvarado-Swissboring

COMPLET. DATE: 17/06/02
DIR.: vert.

LOGGER: R.Alvarado-L.Perez
DRILLER: Swissboring

SOIL SYMBOLS, SAMPLERS, FIELD TEST DATA AND CORE RUN	ELEVATION (meters)	DEPTH (meters)	DESCRIPTION OF MATERIAL	DISCONTINUITY	DRILLING CHARACTERISTICS	Permeability Test cm/seg	CORE RECOV (%)	RQD (%)
1.6	67	49	and calcite veins up to 5mm thick, from 50.58m to 50.62m core exhibit very thick epidote and calcite veins, andesite is fine to medium grained and igneous. Color: dark gray and greenish gray.		double core barrel with diamond bit and water			0
		50				1.63E-06	56%	
1.5	66	51	ANDESITE, RH-4 to RH-5, hard to very rock, strong, close jointing, with a very close jointing interval from 53.40m to 53.80m, joints contains epidote, manganese oxides and thin calcite films and vertical calcite veins up to 1cm thick, andesite is fine to medium grained and igneous. Color: dark gray, greenish gray.				89%	43
0.8	65	52					100%	33
1.5	64	53						
	63	54					100%	22
1.2	62	55				6.04E-07	100%	60
1.6	61	56						
	60				Drilled with HQ wire line system		100%	23

PANAMA CANAL AUTHORITY
ENGINEERING AND INDUSTRIAL SERVICES DEPARTMENT
GEOLOGICAL FIELD LOG
BORING CH-6

PROJECT: ALTO CHAGRES

LOCATION: Left Margin

NORTHING: 1024539.997
EASTING: 664069.999
GROUND ELEVATION: 116.593
EQUIPMENT: LONGYEAR 38
TOTAL DEPTH: 70.00
CORE RECOVERY:
INCLINATION: Vertical
START DATE: 13/06/02
COMPLET. DATE: 17/06/02
LOGGER: R.Alvarado-L.Perez
GEOLOGIST: R.Alvarado-Swissboring
DIR.: vert.
DRILLER: Swissboring

SOIL SYMBOLS, SAMPLERS, FIELD TEST DATA AND CORE RUN	ELEVATION (meters)	DEPTH (meters)	DESCRIPTION OF MATERIAL	DISCONTINUITY	DRILLING CHARACTERISTICS	Permeability Test cm/seg	CORE RECOV (%)	RQD (%)
1.55	57				double core barrel with diamond bit and water			
	59							
	58						100%	47
0.40							100%	53
	58		ANDESITE-FAULT ZONE, RH-3, medium hard rock, jointing cannot determined, core shows waxy, smooth and slickensides surfaces, and contains calcite and epidote veins, this intervals is highly fractures/ jointed zone, andesite is fine to medium grained and igneous. Color: greenish gray.					
1.10		59						
	57						100%	23
0.35							100%	0
		60				1.85E-05		0
0.75								
	56						53%	
		61						
0.80							100%	0
	55							
0.50							100%	0
		62						
0.75								
	54						100%	0
		63						
1.30	53		ANDESITE, RH-4 to RH-5, hard to very hard rock, strong to very strong, close to moderate close jointing, joints are close, rough, and dip 45°, 60° and 90°, contains epidote and calcite films, with a chlorite and calcite veins interval from 67.70m to 67.85m, andesite is fine to medium grained and igneous, contains recemented andesitic breccia from 64.15m to 65.00m depth, with clasts up to 7mm in size. Color: dark gray to greenish				92%	53
		64						
.90	52				Drilled with HQ wire line system			

PANAMA CANAL AUTHORITY
ENGINEERING AND INDUSTRIAL SERVICES DEPARTMENT
GEOLOGICAL FIELD LOG
BORING CH-6
PROJECT: ALTO CHAGRES

LOCATION: Left Margin

NORTHING: 1024539.997

EASTING: 664069.999
EQUIPMENT: LONGYEAR 38

GROUND ELEVATION: 116.593
TOTAL DEPTH: 70.00
INCLINATION: Vertical

CORE RECOVERY:
START DATE: 13/06/02
GEOLOGIST: R.Alvarado-Swissboring

COMPLET. DATE: 17/06/02
DIR.: vert.

LOGGER: R.Alvarado-L.Perez
DRILLER: Swissboring

SOIL SYMBOLS, SAMPLERS, FIELD TEST DATA AND CORE RUN	ELEVATION (meters)	DEPTH (meters)	DESCRIPTION OF MATERIAL	DISCONTINUITY	DRILLING CHARACTERISTICS	Permeability Test cm/seg	CORE RECOV (%)	RQD (%)
1.39	51	65	gray.		double tube core barrel with diamond bit and water Drilled with HQ wire line system double core barrel with diamond bit and water	5.40E-06	100%	74
1.31	50	66					100%	76
1.70	49	67					100%	44
0.60	48	68					94%	79
70.00 m	47	69					95%	100
	46	70	**Bottom of Hole**					
	45	71						
	44	72						
		73						

CORE BOX

Box #	From	To
1	0.00	7.50
2	7.50	13.20
3	13.20	17.63
4	17.63	21.80
5	21.80	26.60
6	26.60	33.05
7	33.05	37.10
8	37.10	41.15
9	41.15	46.75
10	46.75	52.30
11	52.30	56.60
12	56.60	61.05
13	61.05	65.25
14	65.25	69.40
15	69.40	70.00

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ENGINEERING AND INDUSTRIAL SERVICES DEPARTMENT
GEOLOGICAL FIELD LOG
BORING CH-6

PROJECT: ALTO CHAGRES

LOCATION: Left Margin

NORTHING: 1024539.997
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GROUND ELEVATION: 116.593
EQUIPMENT: LONGYEAR 38
TOTAL DEPTH: 70.00
INCLINATION: Vertical
CORE RECOVERY:
START DATE: 13/06/02
COMPLET. DATE: 17/06/02
LOGGER: R.Alvarado-L.Perez
GEOLOGIST: R.Alvarado-Swissboring
DIR.: vert.
DRILLER: Swissboring

SOIL SYMBOLS, SAMPLERS, FIELD TEST DATA AND CORE RUN	ELEVATION (meters)	DEPTH (meters)	DESCRIPTION OF MATERIAL	DISCONTINUITY	DRILLING CHARACTERISTICS	Permeability Test cm/seg	CORE RECOV (%)	RQD (%)
	43		TYPE OF MATERIAL					
		74	Elevation: Depth: Description:					
			116.6 to 110.0 0.0 to 6.6 OVERBURDEN					
			110.0 to 98.0 6.6 to 18.6 TOP OF WEATHERED ROCK, ANDESITE					
			98.0 to 85.2 18.6 to 31.4 FRACTURE ZONE-ANDESITE					
			85.2 to 79.0 31.4 to 37.6 TOP OF SOUND ROCK, ANDESITE					
			79.0 to 76.4 37.6 to 40.2 ANDESITE-FRACTURE ZONE					
			76.4 to 74.3 40.2 to 42.3 ANDESITE					
			74.3 to 71.6 42.3 to 45.0 FAULT GOUGE					
			71.6 to 68.6 45.0 to 48.0 ANDESITE					
			68.6 to 65.6 48.0 to 51.0 ANDESITE-FRACTURE ZONE					
	42		65.6 to 58.0 51.0 to 58.6 ANDESITE					
			58.0 to 53.5 58.6 to 63.1 ANDESITE-FAULT ZONE					
			53.5 to 46.6 63.1 to 70.0 ANDESITE					
		75						
	41							
		76						
	40							
		77						
	39							
		78						
	38							
		79						
	37							
		80						
	36							
		81						

KEY TO SYMBOLS

Symbol Description

Strata symbols

OVERBURDEN

ANDESITE

FAULT ZONE - FAULT GOUGE
(SHEAR ZONE)

Misc. Symbols

Water table during drilling

Boring continues

Core recovery

Casing at depth indicated

Water table during
drilling

Water table during
drilling

Casagrande piezometer

Soil Samplers

Rock core

Standard penetration test

PANAMA CANAL AUTHORITY
ENGINEERING AND INDUSTRIAL SERVICES DEPARTMENT
GEOLOGICAL FIELD LOG
BORING CH-7
PROJECT: ALTO CHAGRES

LOCATION: Right Margin

NORTHING: 1024332.780 **EASTING:** 663775.342 **GROUND ELEVATION:** 160.85

EQUIPMENT: LONGYEAR 38 **TOTAL DEPTH:** 60.00

CORE RECOVERY: **INCLINATION:** vertical

START DATE: 7/06/02 **COMPLET. DATE:** 6/06/02 **LOGGER:** R.Alvarado-L.Perez

GEOLOGIST: R.Alvarado-Swissboring **DIR.:** **DRILLER:** Swissboring

SOIL SYMBOLS, SAMPLERS, FIELD TEST DATA AND CORE RUN	ELEVATION (meters)	DEPTH	DESCRIPTION OF MATERIAL	DISCONTINUITY	DRILLING CHARACTERISTICS	Permeability Test cm/seg	CORE RECOV (%)	RQD (%)
0.55 7/15 6/15 8/15 0.25 0.45 0.55	160	0 1	OVERBURDEN, OC-4, high consistency, low to moderate water content, low to moderate plasticity, moderate to high dry strength, consists of a residual clay with traces of sand and silt, contains very little scattered semi-decayed organic material, derived from andesite by normal weathering processes. Color: reddish brown		Drilled with 4" single tube sampler, tungstene - carbide bit and dry SPT # 1 All SPT's were taken with standard 2" split spoon and a 140 lbs hammer dropped 30' for each blow		100% 56%	
6/15 7/15 8/15 0.28 0.45 0.55	159	2			SPT # 2		64% 62%	
5/15 9/15 11/15 0.20 0.45 0.55	158	3	OVERBURDEN, OC-5, very high consistency, low water content, low plasticity, low dry strength, consists of a saprolitic clayey silt with sand traces. Color: yellowish brown		SPT # 3		100% 44%	
25/15 34/15 34/15 0.25 0.45 0.55	157	4			SPT # 4		100% 56%	
17/15 23/15 50/15 0.35 0.45 0.55	156	5			SPT # 5		100% 78%	
50/14 0.10 0.14 0.41	155	6			SPT # 6		91% 71% 100%	
0.45 0.45	154	7	TOP OF WEATHERED ROCK ANDESITE, RH-2, medium soft rock, highly weathered rock, very weak, very close to close jointing, joints are open, planar, and dip 40º and 60º, contain abundant iron oxides and manganese, andesite is fine to medium grained and igneous. Color: light to dark brown.		Drilled with HQ wire line system double tube core barrel with diamond bit and water Core recovered in fair condition		89% 100%	0
	153	8	ANDESITE, RH-3, medium hard rock, moderately weathered, close to very close jointing, contains abundant iron oxide and manganese, andesite is fine to medium grained and					0

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GEOLOGICAL FIELD LOG
BORING CH-7

PROJECT: ALTO CHAGRES

LOCATION: Right Margin

NORTHING: 1024332.780
EASTING: 663775.342
GROUND ELEVATION: 160.85
EQUIPMENT: LONGYEAR 38
TOTAL DEPTH: 60.00
CORE RECOVERY:
INCLINATION: vertical
START DATE: 7/06/02
COMPLET. DATE: 6/06/02
LOGGER: R.Alvarado-L.Perez
GEOLOGIST: R.Alvarado-Swissboring
DIR.:
DRILLER: Swissboring

SOIL SYMBOLS, SAMPLERS, FIELD TEST DATA AND CORE RUN	ELEVATION (meters)	DEPTH (meters)	DESCRIPTION OF MATERIAL	DISCONTINUITY	DRILLING CHARACTERISTICS	Permeability Test cm/seg	CORE RECOV (%)	RQD (%)
1.20			igneous. Color: light brown.					0
			From 8.40 m to 9.10 m depth; core was not recovered					0
0.70	152	9					62%	
							0%	
0.30							100%	47
0.60	151	10					75%	17
0.65					Drilled with HQ wire line system double core barrel with diamond bit and water		100%	0
7.60 0.55	150	11					100%	0
0.90	149	12					100%	0
0.80	148	13					100%	0
1.10	147	14					64%	0
0.65							8%	0
							54%	0
0.35	146	15					43%	0
0.70	145	16	ANDESITE, RH-1 to RH-2, very soft to medium soft rock, highly weathered, very weak to weak, no apparent jointing, consists of fine to medium grained and igneous weathered andesite. Color: light to dark brown. From 15.00 m to 16.20 m depth; core was not recovered				0%	0

PANAMA CANAL AUTHORITY
ENGINEERING AND INDUSTRIAL SERVICES DEPARTMENT
GEOLOGICAL FIELD LOG
BORING CH-7

PROJECT: ALTO CHAGRES

LOCATION: Right Margin

NORTHING: 1024332.780 **EASTING:** 663775.342 **GROUND ELEVATION:** 160.85

EQUIPMENT: LONGYEAR 38 **TOTAL DEPTH:** 60.00

CORE RECOVERY: **INCLINATION:** vertical

START DATE: 7/06/02 **COMPLET. DATE:** 6/06/02 **LOGGER:** R.Alvarado-L.Perez

GEOLOGIST: R.Alvarado-Swissboring **DIR.:** **DRILLER:** Swissboring

SOIL SYMBOLS, SAMPLERS, FIELD TEST DATA AND CORE RUN	ELEVATION (meters)	DEPTH (meters)	DESCRIPTION OF MATERIAL	DISCONTINUITY	DRILLING CHARACTERISTICS	Permeability Test cm/seg	CORE RECOV (%)	RQD (%)
1.50								
1.00	144	17						0
2/06/02					Drilled with HQ wire line system double core barrel with diamond bit and water		0%	
							68%	0
0.80	143	18					37%	
0.90	142	19					100%	0
1.25								
0.50	141	20	ANDESITE, RH-2 to RH-3, medium soft to medium hard rock, moderate weathered, weak, jointing cannot be determined, core exhibit iron oxides and manganese, andesite is fine to medium grained and igneous. Color: dark gray.					0
							68%	
							100%	0
0.60	140	21					100%	0
0.55							100%	0
0.55	139	22	ANDESITE, RH-4, hard rock, slightly weathered, moderate strength to strong, close jointing, most joints are open, rough and dip 10º, 45º, 70º and 90º, joints contain iron oxides and manganese, core exhibit prophylithic alteration, andesite is fine to medium grained and igneous. Color: light greenish gray.				100%	0
0.75							100%	22
0.65	138	23					92%	20
0.60	137	24					100%	0

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GEOLOGICAL FIELD LOG
BORING CH-7

PROJECT: ALTO CHAGRES

LOCATION: Right Margin

NORTHING: 1024332.780
EASTING: 663775.342
GROUND ELEVATION: 160.85
EQUIPMENT: LONGYEAR 38
TOTAL DEPTH: 60.00
CORE RECOVERY:
INCLINATION: vertical
START DATE: 7/06/02
COMPLET. DATE: 6/06/02
LOGGER: R.Alvarado-L.Perez
GEOLOGIST: R.Alvarado-Swissboring
DIR.:
DRILLER: Swissboring

SOIL SYMBOLS, SAMPLERS, FIELD TEST DATA AND CORE RUN	ELEVATION (meters)	DEPTH (meters)	DESCRIPTION OF MATERIAL	DISCONTINUITY	DRILLING CHARACTERISTICS	Permeability Test cm/seg	CORE RECOV (%)	RQD (%)
0.70							100%	33
0.75	136	25			Drilled with HQ wire line system double core barrel with diamond bit and water		100%	32
0.75	135	26					100%	16
1.10	134	27					100%	0
0.90	133	28					100%	31
0.75	132	29					93%	0
0.60							100%	23
1.25	131	30	TOP OF SOUND ROCK ANDESITE, RH-5, very hard rock, strong to very strong, close to moderately close jointing, joints are open, planar and dip 10º, 30º, 45º and 60º, contain iron oxides and manganese, one fracture surface contain light green gouge, consists of andesite, fine to medium grained and igneous. Color: greenish gray mottled with white.				100%	34
1.50	130	31						
3/06/02	129	32					93%	33

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GEOLOGICAL FIELD LOG
BORING CH-7

PROJECT: ALTO CHAGRES

LOCATION: Right Margin

NORTHING: 1024332.780

EASTING: 663775.342
EQUIPMENT: LONGYEAR 38

GROUND ELEVATION: 160.85
TOTAL DEPTH: 60.00
INCLINATION: vertical

CORE RECOVERY:
START DATE: 7/06/02
GEOLOGIST: R.Alvarado-Swissboring

COMPLET. DATE: 6/06/02
DIR.:

LOGGER: R.Alvarado-L.Perez
DRILLER: Swissboring

SOIL SYMBOLS, SAMPLERS, FIELD TEST DATA AND CORE RUN	ELEVATION (meters)	DEPTH (meters)	DESCRIPTION OF MATERIAL	DISCONTINUITY	DRILLING CHARACTERISTICS	Permeability Test cm/seg	CORE RECOV (%)	RQD (%)
1.25	128	33			Drilled with HQ wire line system double core barrel with diamond bit and water		100%	12
0.95	127	34					100%	28
0.95	126	35	ANDESITE, RH-4, hard rock, moderate strength to strong, close jointing, with a very close jointing from 41.60 m to 41.95 m depth, most joints are open and dip 0º, 30º, 45º, and 70º, contain abundant ochre iron oxides and manganese, andesite is fine to medium grained and igneous, contains few and scattered vesicles. Color: greenish gray.				100%	0
1.30	125	36	From 34.70 m to 35.45 m depth, fracture zone					
	124	37	From 36.55 m to 36.75 m depth, highly weathered rock				100%	11
4/06/02 1.35	123	38					101%	12
1.55	122	39						
0.35	121	40	From 41.30 m to 41.95 m depth, fracture zone				100%	31
							100%	100

PANAMA CANAL AUTHORITY
ENGINEERING AND INDUSTRIAL SERVICES DEPARTMENT
GEOLOGICAL FIELD LOG
BORING CH-7

PROJECT: ALTO CHAGRES

LOCATION: Right Margin

NORTHING: 1024332.780
EASTING: 663775.342
GROUND ELEVATION: 160.85
EQUIPMENT: LONGYEAR 38
TOTAL DEPTH: 60.00
CORE RECOVERY:
INCLINATION: vertical
START DATE: 7/06/02
COMPLET. DATE: 6/06/02
LOGGER: R.Alvarado-L.Perez
GEOLOGIST: R.Alvarado-Swissboring
DIR.:
DRILLER: Swissboring

SOIL SYMBOLS, SAMPLERS, FIELD TEST DATA AND CORE RUN	ELEVATION (meters)	DEPTH (meters)	DESCRIPTION OF MATERIAL	DISCONTINUITY	DRILLING CHARACTERISTICS	Permeability Test cm/seg	CORE RECOV (%)	RQD (%)
1.30	120	41			Drilled with HQ wire line system double core barrel with diamond bit and water		100%	26
0.65	119	42					100%	0
1.30	118	43					100%	45
1.35	117	44	AGGLOMERATE, RH-4 to RH-5, hard to very hard rock, strong to very strong, close to very close jointing, most joint are rough and dip 30º, 45º, 60º and 90º, contains abundant iron oxides, consists of angular to subangular andesitic fragments, hard, ranging in size from 2 mm to 120 mm, in a fine to medium grained andesitic matrix. Color: fragments are greenish gray and light to dark gray, matrix is greenish gray.		Core recovered in excellent condition		100%	63
0.85	116	45					100%	53
0.90	115	46					100%	60
0.75	114	47					100%	0
1.35	113	48					100%	100
			ANDESITE, RH-3 to RH-4, medium hard to hard rock, moderate strength,					

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LOCATION: Right Margin

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EASTING: 663775.342
GROUND ELEVATION: 160.85
EQUIPMENT: LONGYEAR 38
TOTAL DEPTH: 60.00
CORE RECOVERY:
INCLINATION: vertical
START DATE: 7/06/02
COMPLET. DATE: 6/06/02
LOGGER: R.Alvarado-L.Perez
GEOLOGIST: R.Alvarado-Swissboring
DIR.:
DRILLER: Swissboring

SOIL SYMBOLS, SAMPLERS, FIELD TEST DATA AND CORE RUN	ELEVATION (meters)	DEPTH (meters)	DESCRIPTION OF MATERIAL	DISCONTINUITY	DRILLING CHARACTERISTICS	Permeability Test cm/seg	CORE RECOV (%)	RQD (%)
0.70	112	49	close jointing, joints are planar, rough and dip 0º, 30º, 45º, 60º, 70º and 90º, contains abundant iron oxides with few scattered pyrite crystals, andesite is fine to medium grained and igneous, core shows some scattered vesicles up to 20 mm in size. Color: light greenish gray.		Drilled with HQ wire line system double core barrel with diamond bit and water		100%	80
1.00	111	50	From 36.25 m to 36.55 m depth; fracture zone				100%	55
1.10	110	51	From 51.25 m to 53.50 m depth; fracture zone, with manganese stains.				100%	31
1.00	109	52					100%	0
0.30							100%	0
0.55	108	53					100%	0
0.40							100%	0
0.85	107	54					100%	56
0.75	106	55				2.75E-04	100%	17
0.70	105	56					100%	50
0.50							50%	0
0.20							100%	0
0.65	104							

PANAMA CANAL AUTHORITY
ENGINEERING AND INDUSTRIAL SERVICES DEPARTMENT
GEOLOGICAL FIELD LOG
BORING CH-7

PROJECT: ALTO CHAGRES

LOCATION: Right Margin

NORTHING: 1024332.780
EASTING: 663775.342
GROUND ELEVATION: 160.85
EQUIPMENT: LONGYEAR 38
TOTAL DEPTH: 60.00
CORE RECOVERY:
INCLINATION: vertical
START DATE: 7/06/02
COMPLET. DATE: 6/06/02
LOGGER: R.Alvarado-L.Perez
GEOLOGIST: R.Alvarado-Swissboring
DIR.:
DRILLER: Swissboring

SOIL SYMBOLS, SAMPLERS, FIELD TEST DATA AND CORE RUN	ELEVATION (meters)	DEPTH (meters)	DESCRIPTION OF MATERIAL	DISCONTINUITY	DRILLING CHARACTERISTICS	Permeability Test cm/seg	CORE RECOV (%)	RQD (%)
0.50		57	ANDESITE, RH-3 to RH-4, medium hard to hard rock, moderate strength to strong, close 0º, 30º, 45º and 90º, contain clay minerals and thin calcite veins, andesite is fine to medium grained and igneous, core exhibit prophylithic alteration. Color: dark gray and greenish gray.		Drilled with HQ wire line system double core barrel with diamond bit and water		100%	31
0.30	103	58					100%	46
0.65							100%	67
0.30	102	59					100%	0
1.10							100%	0
	101	60					100%	0
	100	61						
	99	62						
	98	63						
	97	64						
	96							

Bottom of Hole

CORE BOX

Box #	From	to
1	0.00	5.55
2	5.55	10.65
3	10.65	17.20
4	17.20	21.95
5	21.95	26.20
6	26.20	30.40
7	30.40	34.50
8	34.50	38.45
9	38.45	42.50
10	42.50	46.60
11	46.60	50.65
12	50.65	54.45
13	54.45	58.60
14	58.60	60.00

TYPE OF MATERIAL

Elevation:	Depth:	Description:
160.9 to 154.8	0.0 to 6.1	OVERBURDEN
154.8 to 131.3	6.1 to 29.6	TOP OF WEATHERED ROCK, ANDESITE
131.3 to 117.3	29.6 to 43.6	TOP OF SOUND ROCK, ANDESITE
117.3 to 112.4	43.6 to 48.5	AGGLOMERATE
112.4 to 100.9	48.5 to 60.0	ANDESITE

KEY TO SYMBOLS

Symbol Description

Strata symbols

OVERBURDEN

ANDESITE

AGGLOMERATE

Misc. Symbols

Boring continues

Core recovery

Casing at depth indicated

Water table during drilling

Water table during drilling

Water table during drilling

Soil Samplers

Rock core

Standard penetration test

PANAMA CANAL AUTHORITY
ENGINEERING AND INDUSTRIAL SERVICES DEPARTMENT
GEOLOGICAL FIELD LOG
BORING CH-8 (v)

PROJECT: ALTO CHAGRES

LOCATION: Right Margin

NORTHING: 1024578.475

EASTING: 663802.619
EQUIPMENT: LONGYEAR 38

GROUND ELEVATION: 114.422
TOTAL DEPTH: 4.30
INCLINATION: Vertical

CORE RECOVERY: 98%
START DATE: 11/06/02
GEOLOGIST: R.Alvarado-Swissboring

COMPLET. DATE: 11/06/02
DIR.:

LOGGER: R.Alvarado-L.Perez
DRILLER: Swissboring

SOIL SYMBOLS, SAMPLERS, FIELD TEST DATA AND CORE RUN	ELEVATION (meters)	DEPTH (meters)	DESCRIPTION OF MATERIAL	DISCONTINUITY	DRILLING CHARACTERISTICS	Permeability Test cm/seg	CORE RECOV (%)	RQD (%)
0.55 12/15 20/15 31/15 0.45 0.45 0.55 11/06/02 31/15 31/15 50/11 0.41 0.41 0.59 44/15 50/10 0.25 0.25 0.35 0.40 50/13 0.00 0.13 0.22 0.40	114 113 112 111 110 109 108 107	0 1 2 3 4 5 6 7 8	OVERBURDEN, OC-5, very high consistency, low to moderate water content, low to moderate plasticity, high dry strength, consists of a residual clay with traces of fine sand derived from andesite by normal weathering processes, contains roots. Color: reddish brown to dark brown. OVERBURDEN, OC-5, very high consistency, low water content, low plasticity, low dry strength, consists of a residual silt and weathered rock fragments up to 50 mm in size derived from andesite by normal weathering processes. Color: light brown to greenish gray. TOP OF WEATHERED ROCK, ANDESITE, RH-2 to RH-3, medium hard rock, moderate to highly weathered, weak, no apparent jointing, consists of andesite, fine to medium grained, core shows iron oxides and manganese. Color: gray to greenish gray.		Drilled with 4" single tube sampler tungstene-carbide bit and dry. SPT # 1 All SPT were taken with standard 2", split spoon and a dropped 30" for each blow. SPT # 2 Drilled with HQ wire line system double core barrel with diamond bit and water SPT # 3 SPT # 4		100% 100% 100% 100% 100% 100% 100% 0% 91% 100%	

Bottom of Hole

CORE BOX

Box #	From	To
1	0.00	4.30

TYPE OF MATERIAL

Elevation:	Depth:	Description:
114.4 to 110.7	0.0 to 3.7	OVERBURDEN
110.7 to 110.1	3.7 to 4.3	TOP OF WEATHERED ROCK, ANDESITE

KEY TO SYMBOLS

Symbol Description

Strata symbols

OVERBURDEN

ANDESITE

Misc. Symbols

Water table during drilling

Core recovery

Soil Samplers

Rock core

Standard penetration test

PANAMA CANAL AUTHORITY
ENGINEERING AND INDUSTRIAL SERVICES DEPARTMENT
GEOLOGICAL FIELD LOG
BORING CH-8 (i)

PROJECT: ALTO CHAGRES

LOCATION: Right Margin

NORTHING: 1024578.475 **EASTING:** 663802.619 **GROUND ELEVATION:** 114.42

EQUIPMENT: LONGYEAR 38 **TOTAL DEPTH:** 70.00

CORE RECOVERY: 98% **INCLINATION:** 30 (grados, e.v)

START DATE: 11/06/02 **COMPLET. DATE:** 18/06/02 **LOGGER:** R.Alvarado-L.Perez

GEOLOGIST: R.Alvarado-Swissboring **DIR.:** 165 **DRILLER:** Swissboring

SOIL SYMBOLS, SAMPLERS, FIELD TEST DATA AND CORE RUN	ELEVATION (meters)	DEPTH (meters)	DESCRIPTION OF MATERIAL	DISCONTINUITY	DRILLING CHARACTERISTICS	Permeability Test cm/seg	CORE RECOV (%)	RQD (%)
	114	0	From 0.00 to 4.00 m depth, core was not recovered, drilled to destruction, see CH-8 (v) vertical log		Drilled to destruction with diamond bit and water			
		1						
15/06/02 14/06/02	113							
		2						
17/06/02	112							
		3						
	111							
		4	TOP OF WEATHERED ROCK ANDESITE, RH-2 to RH-3, medium soft to medium hard rock, moderate weathered, very close jointing, most joints are open, rough and dip 15, 0, 45, 60 and 90, contains iron oxides and clay minerals, consists of andesite, fine grained and igneous. Color: dark gray mottled with yellowish brown.		Drilled with HQ wire line system double tube core barrel with diamond bit and water			
0.85	110						100%	
		5						
0.85	109							
0.65							100%	
		6	TOP OF SOUND ROCK ANDESITE, RH-4 to RH-5, hard to very hard rock, strong to very strong, close to moderately close, joints are 45, contains manganese oxides and thin calcite films, white calcite veins up to 8mm thick, some fractures surfaces shows slickenside, consists of andesite fine to medium grained and igneous. Color: dark gray to greenish gray.				100%	
0.70	108						100%	79
		7						
1.55	107							
		8						

PANAMA CANAL AUTHORITY
ENGINEERING AND INDUSTRIAL SERVICES DEPARTMENT
GEOLOGICAL FIELD LOG
BORING CH-8 (i)

PROJECT: ALTO CHAGRES

LOCATION: Right Margin

NORTHING: 1024578.475
EASTING: 663802.619
GROUND ELEVATION: 114.42
EQUIPMENT: LONGYEAR 38
TOTAL DEPTH: 70.00
CORE RECOVERY: 98%
INCLINATION: 30 (grados, e.v)
START DATE: 11/06/02
COMPLET. DATE: 18/06/02
LOGGER: R.Alvarado-L.Perez
GEOLOGIST: R.Alvarado-Swissboring
DIR.: 165
DRILLER: Swissboring

SOIL SYMBOLS, SAMPLERS, FIELD TEST DATA AND CORE RUN	ELEVATION (meters)	DEPTH (meters)	DESCRIPTION OF MATERIAL	DISCONTINUITY	DRILLING CHARACTERISTICS	Permeability Test cm/seg	CORE RECOV (%)	RQD (%)
1.10	106						100%	42
		9						
1.00	105				Drilled with HQ wire line system double core barrel with diamond bit and water		100%	44
		10						
1.20	104						100%	58
		11						
1.05	103						100%	92
		12						
1.15	102						100%	65
		13	ANDESITE, RH-3 to RH-4, medium hard to hard rock, weak to moderate strength, very close to close jointing, mostly joints are open, undulating, rough, contains iron oxide, epidote and calcite films, andesite is fine to medium grained and igneous. Color: dark gray to greenish gray. From 14.00 m to 23.55 m depth; fracture zone				100%	36
0.65	101						100%	15
		14						
1.05	100					0.00E+00	100%	0
		15						
0.60	99						100%	27
		16			Drilled with HQ			

PANAMA CANAL AUTHORITY
ENGINEERING AND INDUSTRIAL SERVICES DEPARTMENT
GEOLOGICAL FIELD LOG
BORING CH-8 (i)

PROJECT: ALTO CHAGRES

LOCATION: Right Margin

NORTHING: 1024578.475 **EASTING:** 663802.619 **GROUND ELEVATION:** 114.42

EQUIPMENT: LONGYEAR 38 **TOTAL DEPTH:** 70.00

CORE RECOVERY: 98% **INCLINATION:** 30 (grados, e.v)

START DATE: 11/06/02 **COMPLET. DATE:** 18/06/02 **LOGGER:** R.Alvarado-L.Perez

GEOLOGIST: R.Alvarado-Swissboring **DIR.:** 165 **DRILLER:** Swissboring

SOIL SYMBOLS, SAMPLERS, FIELD TEST DATA AND CORE RUN	ELEVATION (meters)	DEPTH (meters)	DESCRIPTION OF MATERIAL	DISCONTINUITY	DRILLING CHARACTERISTICS	Permeability Test cm/seg	CORE RECOV (%)	RQD (%)
1.05	98				wire line system double core barrel with diamond bit and water			
		17					100%	10
0.50	97						100%	
0.90		18						
	96						100%	0
0.75		19					100%	16
0.75	95		ANDESITE, RH-2 to RH-3, medium soft to medium hard rock, weak, core is highly fractured, with abundant open, rough joints, contains epidote, quartz, manganese, calcite films and silt, but do not exhibit slickensides, andesite is fine to medium grained and igneous. Color: dark gray to greenish gray.				100%	0
0.50		20				0.00E+00		
	94						100%	0
0.55		21					100%	0
0.70	93						100%	0
0.90		22						
	92						100%	0
0.90		23						
	91						100%	0
0.60		24	ANDESITE, RH-4 to RH-5, hard to very hard rock, strong to very strong, close to moderately close jointing, joints are rough and dip 30º and 45º, contains manganese and				100%	33

PANAMA CANAL AUTHORITY
ENGINEERING AND INDUSTRIAL SERVICES DEPARTMENT
GEOLOGICAL FIELD LOG
BORING CH-8 (i)

PROJECT: ALTO CHAGRES

LOCATION: Right Margin

NORTHING: 1024578.475
EASTING: 663802.619
GROUND ELEVATION: 114.42
EQUIPMENT: LONGYEAR 38
TOTAL DEPTH: 70.00
CORE RECOVERY: 98%
INCLINATION: 30 (grados, e.v)
START DATE: 11/06/02
COMPLET. DATE: 18/06/02
LOGGER: R.Alvarado-L.Perez
GEOLOGIST: R.Alvarado-Swissboring
DIR.: 165
DRILLER: Swissboring

SOIL SYMBOLS, SAMPLERS, FIELD TEST DATA AND CORE RUN	ELEVATION (meters)	DEPTH (meters)	DESCRIPTION OF MATERIAL	DISCONTINUITY	DRILLING CHARACTERISTICS	Permeability Test cm/seg	CORE RECOV (%)	RQD (%)
0.85	90	25	thin calcite films, andesite is fine to medium grained and igneous, core exhibit some amygdales filled with quartz up to 8mm in size. Color: light gray.		Drilled with HQ wire line system double core barrel with diamond bit and water	1.12E-05	100%	21
1.45	89	26					100%	83
1.40	88	27						
1.25	87	28	ANDESITE, RH-3 to RH-4, medium hard to hard rock, weak to moderate strength, very close to close jointing, joints are open, rough and dip 45º and 70º, contains epidote, manganese and calcite films, andesite is fine to medium grained and igneous. Color: dark gray.				100%	58
0.90	86	29	From 28.30 m to 35.50 m depth; fracture zone				100%	35
0.90	85	30	ANDESITE-AGGLOMERATE, RH-2 to RH-3, medium soft to medium hard rock, weak, core is highly fractured, jointing cannot be determined, contains abundant epidote, clay, manganese and calcite films, from 33.30 m to 35.40 m depth, joints surface contains light green gouge, consists mainly of fine to medium grained and igneous andesite, with agglomerate rock from 29.15 m to 30.00 m depth, contains angular to subangular andesitic fragments up to 30mm in size, andesite is partially altered to clay minerals. Color: dark gray and greenish gray.			1.13E-05	100%	0
0.70	84	31					100%	0
0.55	83	32					100%	0
0.60	82				Drilled with HQ wire line system		100%	0

PANAMA CANAL AUTHORITY
ENGINEERING AND INDUSTRIAL SERVICES DEPARTMENT
GEOLOGICAL FIELD LOG
BORING CH-8 (i)

PROJECT: ALTO CHAGRES

LOCATION: Right Margin

NORTHING: 1024578.475 **EASTING:** 663802.619 **GROUND ELEVATION:** 114.42

EQUIPMENT: LONGYEAR 38 **TOTAL DEPTH:** 70.00

CORE RECOVERY: 98% **INCLINATION:** 30 (grados, e.v)

START DATE: 11/06/02 **COMPLET. DATE:** 18/06/02 **LOGGER:** R.Alvarado-L.Perez

GEOLOGIST: R.Alvarado-Swissboring **DIR.:** 165 **DRILLER:** Swissboring

SOIL SYMBOLS, SAMPLERS, FIELD TEST DATA AND CORE RUN	ELEVATION (meters)	DEPTH (meters)	DESCRIPTION OF MATERIAL	DISCONTINUITY	DRILLING CHARACTERISTICS	Permeability Test cm/seg	CORE RECOV (%)	RQD (%)
0.55		33			double core barrel with diamond bit and water		100%	0
0.55	81						100%	0
0.40		34					100%	0
0.75	80						75%	0
0.50		35				6.02E-07	100%	0
0.65	79		ANDESITE, RH-4 to RH-5, hard rock to very hard rock, strong to very strong, close to moderately close jointing, joints are open and dip 30º, 45º, and 90º, contains manganese and thin calcite films, andesite is fine to medium grained and igneous, core exhibit scattered amigdales filled with quartz up to 4 mm in size. Color: dark gray.		Core was recovered in excellent condition		100%	0
0.65		36					100%	15
0.65	78						100%	20
1.20		37			Drilled with HQ wire line system double core barrel with diamond bit and water		100%	15
1.35	77						100%	63
		38						
	76							
		39						
	75						100%	33
		40				6.02E-07		
	74							

PANAMA CANAL AUTHORITY
ENGINEERING AND INDUSTRIAL SERVICES DEPARTMENT
GEOLOGICAL FIELD LOG
BORING CH-8 (i)

PROJECT: ALTO CHAGRES

LOCATION: Right Margin

NORTHING: 1024578.475
EASTING: 663802.619
GROUND ELEVATION: 114.42
EQUIPMENT: LONGYEAR 38
TOTAL DEPTH: 70.00
CORE RECOVERY: 98%
INCLINATION: 30 (grados, e.v)
START DATE: 11/06/02
COMPLET. DATE: 18/06/02
LOGGER: R.Alvarado-L.Perez
GEOLOGIST: R.Alvarado-Swissboring
DIR.: 165
DRILLER: Swissboring

SOIL SYMBOLS, SAMPLERS, FIELD TEST DATA AND CORE RUN	ELEVATION (meters)	DEPTH (meters)	DESCRIPTION OF MATERIAL	DISCONTINUITY	DRILLING CHARACTERISTICS	Permeability Test cm/seg	CORE RECOV (%)	RQD (%)
1.20		41					100%	68
0.80	73				Drilled with HQ wire line system double core barrel with diamond bit and water		100%	81
		42						
0.95	72		From 42.20 m to 42.95 m depth; fracture zone				100%	29
		43	AGGLOMERATE, RH-4, hard rock, moderate strength to strong, close to moderate close jointing, with a very close jointing interval from 42.35 m to 43.00 m depth, joints are rough, undulating, and dip 0º, 15º, 35º, 45º and 60º contains epidote, manganese, thin calcite films and few scattered pyrite crystals, agglomerate contains subangular clasts ranging in size from 5 mm to 100 mm, matrix is fine to medium grained and igneous, core exhibit scattered and little quartz amigdales. Color: greenish gray to dark gray.					
0.90	71						100%	19
		44						
1.15	70						100%	68
		45				3.64E-06		
0.75	69						100%	13
		46						
1.55	68							
		47	ANDESITE, RH-4, medium hard rock, moderate strength, close jointing, joints are rough, and dip 0º, 20º, 45º and 70º, contains epidote veins, filled and cemented some joints, and few scattered pyrite crystals, andesite is fine to medium grained and igneous. Color: dark gray.				100%	49
	67							
1.50		48						
	66							

PANAMA CANAL AUTHORITY
ENGINEERING AND INDUSTRIAL SERVICES DEPARTMENT
GEOLOGICAL FIELD LOG
BORING CH-8 (i)

PROJECT: ALTO CHAGRES

LOCATION: Right Margin

NORTHING: 1024578.475 **EASTING:** 663802.619 **GROUND ELEVATION:** 114.42

EQUIPMENT: LONGYEAR 38 **TOTAL DEPTH:** 70.00

CORE RECOVERY: 98% **INCLINATION:** 30 (grados, e.v)

START DATE: 11/06/02 **COMPLET. DATE:** 18/06/02 **LOGGER:** R.Alvarado-L.Perez

GEOLOGIST: R.Alvarado-Swissboring **DIR.:** 165 **DRILLER:** Swissboring

SOIL SYMBOLS, SAMPLERS, FIELD TEST DATA AND CORE RUN	ELEVATION (meters)	DEPTH (meters)	DESCRIPTION OF MATERIAL	DISCONTINUITY	DRILLING CHARACTERISTICS	Permeability Test cm/seg	CORE RECOV (%)	RQD (%)
0.55		49	From 48.80 m to 50.15 m depth, core is highly fractured, jointing cannot be determined, this intervals is a highly fractured/ jointed zone.		Core recovered in fair condition Drilled with HQ wire line system double core barrel with diamond bit and water		100%	50
	65						100%	0
0.65								0
		50					23%	
0.55			ANDESITE, RH-5, very hard rock, moderate strength to strong, close jointing, joints are rough, and dip 0º, 30º and 45º, contains manganese and thin calcite films, few joint surfaces exhibit slickensides, andesite is fine to medium grained and igneous, core shows scattered and little quartz amigdales. Color: greenish gray to dark gray.			8.66E-07	100%	18
	64							
0.60		51					100%	0
	63							
1.00			ANDESITE, RH-5, very hard rock, strong to very strong, moderate to wide close jointing, joints are close and dip 20º, 45º, 60º, and 90º, contains thin calcite films, andesite is fine to medium grained and igneous. Color: light greenish gray.				100%	10
		52						
	62							
1.55		53						
	61						100%	84
		54						
1.30	60							
		55				1.18E-06	100%	100
	59							
1.55		56						
	58				Drilled with HQ wire line system		100%	100

PANAMA CANAL AUTHORITY
ENGINEERING AND INDUSTRIAL SERVICES DEPARTMENT
GEOLOGICAL FIELD LOG
BORING CH-8 (i)

PROJECT: ALTO CHAGRES

LOCATION: Right Margin

NORTHING: 1024578.475
EASTING: 663802.619
EQUIPMENT: LONGYEAR 38
GROUND ELEVATION: 114.42
TOTAL DEPTH: 70.00
INCLINATION: 30 (grados, e.v)

CORE RECOVERY: 98%
START DATE: 11/06/02
GEOLOGIST: R.Alvarado-Swissboring
COMPLET. DATE: 18/06/02
DIR.: 165
LOGGER: R.Alvarado-L.Perez
DRILLER: Swissboring

SOIL SYMBOLS, SAMPLERS, FIELD TEST DATA AND CORE RUN	ELEVATION (meters)	DEPTH (meters)	DESCRIPTION OF MATERIAL	DISCONTINUITY	DRILLING CHARACTERISTICS	Permeability Test cm/seg	CORE RECOV (%)	RQD (%)
1.55	57	57			double core barrel with diamond bit and water			
		58					100%	80
1.35	56	59						
0.55	55	60	ANDESITE, RH-3, medium hard rock, weak to moderate strength, very close to close jointing, joints are open, rough, and dip 0º, 20º, 45º, 70º and 90º, contains epidote, manganese and thin calcite films, andesite is fine to medium grained and igneous, from 59.18 m to 59.64 m depth, from 60.20 m to 60.60 m depth, and from 61.70 m to 61.80 m depth, contains agglomerate rock, with angular clasts ranging in size from 4mm to 30mm. Color: greenish gray to dark gray.				100%	56
0.80	54	61				3.62E-07	100%	82
1.30	53	62					100%	21
0.80	52	63					100%	8
1.45	51	64	ANDESITE, RH-4 to RH-5, hard to very hard rock, strong to very strong, close to moderately close jointing, contains manganese, epidote and calcite films and dip 20º, 30º, 45º and 60º, andesite is fine to medium grained and igneous, core exhibit few and scattered quartz grains. Color: greenish gray.		Core recovered in excellent condition		100%	0
0.65	50						100%	58
								34

PANAMA CANAL AUTHORITY
ENGINEERING AND INDUSTRIAL SERVICES DEPARTMENT
GEOLOGICAL FIELD LOG
BORING CH-8 (i)
PROJECT: ALTO CHAGRES

LOCATION: Right Margin

NORTHING: 1024578.475
EASTING: 663802.619
GROUND ELEVATION: 114.42
EQUIPMENT: LONGYEAR 38
TOTAL DEPTH: 70.00
CORE RECOVERY: 98%
INCLINATION: 30 (grados, e.v)
START DATE: 11/06/02
COMPLET. DATE: 18/06/02
LOGGER: R.Alvarado-L.Perez
GEOLOGIST: R.Alvarado-Swissboring
DIR.: 165
DRILLER: Swissboring

SOIL SYMBOLS, SAMPLERS, FIELD TEST DATA AND CORE RUN	ELEVATION (meters)	DEPTH (meters)	DESCRIPTION OF MATERIAL	DISCONTINUITY	DRILLING CHARACTERISTICS	Permeability Test cm/seg	CORE RECOV (%)	RQD (%)
0.90	49	65				3.38E-07	92%	
		66					100%	52
1.60	48							
		67						
	47						100%	91
1.20		68						
	46						100%	12
		69						
1.30	45							
		70					100%	62
	44		Bottom of Hole					
		71						
	43							
		72						
	42							
		73						

CORE BOX

Box #	From	To
1	4.00	8.10
2	8.10	12.10
3	12.10	15.80
4	15.80	19.25
5	19.25	23.15
6	23.15	27.25
7	27.25	31.50
8	31.50	35.20
9	35.20	39.15
10	39.15	43.40
11	43.40	47.30
12	47.30	51.80
13	51.80	56.10
14	56.10	60.20
15	60.20	64.40

PANAMA CANAL AUTHORITY
ENGINEERING AND INDUSTRIAL SERVICES DEPARTMENT
GEOLOGICAL FIELD LOG
BORING CH-8 (i)

PROJECT: ALTO CHAGRES

LOCATION: Right Margin

NORTHING: 1024578.475
EASTING: 663802.619
GROUND ELEVATION: 114.42
EQUIPMENT: LONGYEAR 38
TOTAL DEPTH: 70.00
CORE RECOVERY: 98%
INCLINATION: 30 (grados, e.v)
START DATE: 11/06/02
COMPLET. DATE: 18/06/02
LOGGER: R.Alvarado-L.Perez
GEOLOGIST: R.Alvarado-Swissboring
DIR.: 165
DRILLER: Swissboring

SOIL SYMBOLS, SAMPLERS, FIELD TEST DATA AND CORE RUN	ELEVATION (meters)	DEPTH (meters)	DESCRIPTION OF MATERIAL	DISCONTINUITY	DRILLING CHARACTERISTICS	Permeability Test cm/seg	CORE RECOV (%)	RQD (%)
	41		16 64.40 68.70 17 68.70 70.00 TYPE OF MATERIAL Elevation: Depth: Description: 110.4 to 108.4 4.0 to 6.0 TOP OF WEATHERED ROCK, ANDESITE 108.4 to 85.6 6.0 to 28.8 TOP OF SOUND ROCK, ANDESITE 85.6 to 78.9 28.8 to 35.5 ANDESITE WITH AGGLOMERATE 78.9 to 72.0 35.5 to 42.4 ANDESITE 72.0 to 67.4 42.4 to 47.0 AGGLOMERATE 67.4 to 44.4 47.0 to 70.0 ANDESITE					
		74						
	40							
		75						
	39							
		76						
	38							
		77						
	37							
		78						
	36							
		79						
	35							
		80						
	34							
		81						

KEY TO SYMBOLS

Symbol Description

Strata symbols

OVERBURDEN

ANDESITE

AGGLOMERATE

Misc. Symbols

Water table during drilling

Casing at depth indicated

Water table during drilling

Water table during drilling

Boring continues

Core recovery

Soil Samplers

Rock core

PANAMA CANAL AUTHORITY
ENGINEERING AND INDUSTRIAL SERVICES DEPARTMENT
GEOLOGICAL FIELD LOG
BORING CH-9

PROJECT: ALTO CHAGRES

LOCATION: Left Site

NORTHING: 1024280.00 **EASTING:** 664340.005 **GROUND ELEVATION:** 219.66

EQUIPMENT: LONGYEAR 38 **TOTAL DEPTH:** 30.00

CORE RECOVERY: **INCLINATION:** Vertical

START DATE: 7/06/02 **COMPLET. DATE:** 10/06/02 **LOGGER:** R.Alvarado-L.Perez

GEOLOGIST: R.Alvarado-Swissboring **DIR.:** **DRILLER:** Swissboring

SOIL SYMBOLS, SAMPLERS, FIELD TEST DATA AND CORE RUN	ELEVATION (meters)	DEPTH (meters)	DESCRIPTION OF MATERIAL	DISCONTINUITY	DRILLING CHARACTERISTICS	Permeability Test cm/seg	CORE RECOV (%)	RQD (%)
0.55 6/15 12/15 25/15 0.36 0.45 0.55 12/15 50/15 0.30 0.30 0.70	219 218 217	0 1 2	OVERBURDEN, OC-4 to OC-5, high to very high consistency, low to moderate water content, low to moderate plasticity, moderate dry strength, consists of a residual clayey silt with sand, overburden is derived from andesite rock by normal weathering processes. Color: reddish brown.		Drilled with 4" single tube sampler, tungstene-carbide bit and dry. SPT #1 All SPT were taken with standard 2", split spoon and a 140 lb hammer dropped 30" for each blow. SPT #2		100% 80% 100% 100% 100%	
1.10 1.50 1.55 10/06/02 1.50	216 215 214 213 212	3 4 5 6 7 8	OVERBURDEN, OC-5, very high consistency, moderate water content, low plasticity, high dry strength, consists of a saprolitic silt and fine sand, derived from andesite rock by normal weathering processes, contains scattered iron oxides. Color: yellowish brown.		Drilled with HQ wire line system double core barrel with diamond bit and water		91% 83% 77%	

PANAMA CANAL AUTHORITY
ENGINEERING AND INDUSTRIAL SERVICES DEPARTMENT
GEOLOGICAL FIELD LOG
BORING CH-9

PROJECT: ALTO CHAGRES

LOCATION: Left Site

NORTHING: 1024280.00
EASTING: 664340.005
GROUND ELEVATION: 219.66
EQUIPMENT: LONGYEAR 38
TOTAL DEPTH: 30.00
CORE RECOVERY:
INCLINATION: Vertical
START DATE: 7/06/02
COMPLET. DATE: 10/06/02
LOGGER: R.Alvarado-L.Perez
GEOLOGIST: R.Alvarado-Swissboring
DIR.:
DRILLER: Swissboring

SOIL SYMBOLS, SAMPLERS, FIELD TEST DATA AND CORE RUN	ELEVATION (meters)	DEPTH (meters)	DESCRIPTION OF MATERIAL	DISCONTINUITY	DRILLING CHARACTERISTICS	Permeability Test cm/seg	CORE RECOV (%)	RQD (%)
1.55	211	9					87%	
10/06/02								
	210	10	TOP OF WEATHERED ROCK ANDESITE, RH-1 to RH-2, soft to medium soft rock, highly weathered weak, jointing cannot be determined, consists of andesite, core shows iron oxide and manganese, and vesicules up to 5mm in size. Color: yellowish brown to greenish gray.		Drilled with HQ wire line system double core barrel with diamond bit and water		32%	0
1.50	209	11					40%	
1.55	208	12					52%	0
0.70	207	13					54%	0
1.00	206	14	ANDESITE, RH-2 to RH-3, medium soft to medium hard rock, moderate weathered, weak to moderate strength, very close to close jointing, joints are open, rough, and contains iron oxides and manganese and some joints contains clay minerals, andesite is fine to medium grained and igneous, core exhibit vesicles up to 30mm in size. Color: brown and greenish brown.				74%	15
1.35	205	15						
	204	16					100%	0

PANAMA CANAL AUTHORITY
ENGINEERING AND INDUSTRIAL SERVICES DEPARTMENT
GEOLOGICAL FIELD LOG
BORING CH-9

PROJECT: ALTO CHAGRES

LOCATION: Left Site

NORTHING: 1024280.00 **EASTING:** 664340.005 **GROUND ELEVATION:** 219.66

EQUIPMENT: LONGYEAR 38 **TOTAL DEPTH:** 30.00

CORE RECOVERY: **INCLINATION:** Vertical

START DATE: 7/06/02 **COMPLET. DATE:** 10/06/02 **LOGGER:** R.Alvarado-L.Perez

GEOLOGIST: R.Alvarado-Swissboring **DIR.:** **DRILLER:** Swissboring

SOIL SYMBOLS, SAMPLERS, FIELD TEST DATA AND CORE RUN	ELEVATION (meters)	DEPTH	DESCRIPTION OF MATERIAL	DISCONTINUITY	DRILLING CHARACTERISTICS	Permeability Test cm/seg	CORE RECOV (%)	RQD (%)
1.50	203	17					100%	0
0.98	202	18	ANDESITE, RH-3 to RH-4, medium hard rock, slightly weathered, moderate strength, very close jointing, joints are open, rough, some are undulating, and dip 0º, 30º and 45º contains clay minerals, iron oxides and manganese films, consists of vesicular andesite, vesicles ranging in size from 2mm to 20 mm. Color: greenish gray. minerals, andesite is fine to medium grained and igneous, core exhibit vesicles up to 30mm in size. Color: brown and greenish brown.		Drilled with HQ wire line system double core barrel with diamond bit and water		92%	0
0.57	201	19					88%	12
1.50	200	20				7.48E-04	73%	46
1.95	199	21						0
1.50	198	22					51%	0
	197	23					13%	
1.55	196	24	TOP OF SOUND ROCK ANDESITE, RH-5, very hard rock, strong to very strong, moderately					

PANAMA CANAL AUTHORITY
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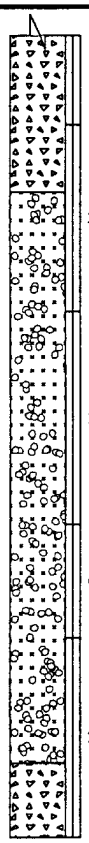
BORING CH-9

PROJECT: ALTO CHAGRES

LOCATION: Left Site

NORTHING: 1024280.00
EASTING: 664340.005
EQUIPMENT: LONGYEAR 38
GROUND ELEVATION: 219.66
TOTAL DEPTH: 30.00
INCLINATION: Vertical
CORE RECOVERY:
START DATE: 7/06/02
COMPLET. DATE: 10/06/02
LOGGER: R.Alvarado-L.Perez
GEOLOGIST: R.Alvarado-Swissboring
DIR.:
DRILLER: Swissboring

SOIL SYMBOLS, SAMPLERS, FIELD TEST DATA AND CORE RUN	ELEVATION (meters)	DEPTH (meters)	DESCRIPTION OF MATERIAL	DISCONTINUITY	DRILLING CHARACTERISTICS	Permeability Test cm/seg	CORE RECOV (%)	RQD (%)
 1.30 1.50 0.80 1.40	195 194 193 192 191 190 189 188	25 26 27 28 29 30 31 32	close jointing, joints are open, rough and dip 25ª and 70ª, andesite is fine to medium grained and igneous, contains some quartz amygdales up to 8mm in size. Color: greenish gray.		Drilled with HQ wire line system double core barrel with diamond bit and water	2.05E-04	77%	52
			AGGLOMERATE-DIKE, RH-2 to RH-3, medium soft to medium hard rock, weak to moderate strength, very close to close jointing, joints are open, rough and dip 0ª, 30ª, 45ª and 90ª, contains epidote, iron oxides and thin calcite films, consists of angular to subangular andesitic clasts from 2mm to 30mm in size, matrix is fine grained and igneous. Color: light greenish.				100%	35
							100%	8
							100%	0
			ANDESITE, RH-5, very hard rock, strong to very strong, moderate close jointing, joints are open, rough, and dip 45ª, 60ª and 90ª, andesite is fine to medium igneous grained, core exhibit vesicles and quartz amygdales up to 10mm in size. Color: greenish gray.				100%	66

Bottom of Hole

CORE BOX

Box #	From	To
1	0.00	4.80
2	4.80	12.80
3	12.80	17.77
4	17.77	24.37
5	24.37	28.85
6	28.85	30.00

TYPE OF MATERIAL

PANAMA CANAL AUTHORITY
ENGINEERING AND INDUSTRIAL SERVICES DEPARTMENT
GEOLOGICAL FIELD LOG
BORING CH-9

PROJECT: ALTO CHAGRES

LOCATION: Left Site

NORTHING: 1024280.00

EASTING: 664340.005
EQUIPMENT: LONGYEAR 38

GROUND ELEVATION: 219.66
TOTAL DEPTH: 30.00
INCLINATION: Vertical

CORE RECOVERY:
START DATE: 7/06/02
GEOLOGIST: R.Alvarado-Swissboring

COMPLET. DATE: 10/06/02
DIR.:

LOGGER: R.Alvarado-L.Perez
DRILLER: Swissboring

SOIL SYMBOLS, SAMPLERS, FIELD TEST DATA AND CORE RUN	ELEVATION (meters)	DEPTH (meters)	DESCRIPTION OF MATERIAL	DISCONTINUITY	DRILLING CHARACTERISTICS	Permeability Test cm/seg	CORE RECOV (%)	RQD (%)
	187		Elevation: Depth: Description:					
			219.7 to 210.0 0.0 to 9.7 OVERBURDEN					
			210.0 to 195.8 9.7 to 23.9 TOP OF WEATHERED ROCK, ANDESITE					
		33	195.8 to 194.2 23.9 to 25.5 TOP OF SOUND ROCK, ANDESITE					
			194.2 to 190.2 25.5 to 29.5 AGGLOMERATE					
			190.2 to 189.7 29.5 to 30.0 ANDESITE					
	186							
		34						
	185							
		35						
	184							
		36						
	183							
		37						
	182							
		38						
	181							
		39						
	180							
		40						

KEY TO SYMBOLS

Symbol Description

Strata symbols

OVERBURDEN

ANDESITE

AGGLOMERATE

Misc. Symbols

Water table during drilling

Boring continues

Core recovery

Water table during drilling

Soil Samplers

Rock core

Standard penetration test

PERMEABILITY TEST

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Swissboring Overseas Corporation Ltd.

CLIENT: AUTORIDAD DEL CANAL DE PANAMA	DATE: 28-June-2001	LUGEON TEST Nº: 6
PROJECT: ALTO CHAGRES DAM SITE	SITE: DAM SITE (right margin)	TESTED BY Geols. L.Peréz- R. Alvarado
BOREHOLE No.: CH-3	ELEVATION: 108.99 m.s.l	CHECKED BY:

Packer type: Neumatic Length (m) = 0.80 Water pump Bean Royal 535 Flood (l/min) =

Test depth (m) from: 40.00 to: 45.00

Test length (cm): L * Cos X º = 499.92 Depth of hole (m): 45.00 Dip X (º)= 30

Swivel H1 (m): H1 = 3.00 Diameter of hole D (cm): 7.57 W.L Before of test (m)= 9.8

Water level Ha (m): 9.8 Ha * Cos X º = 8.49 Hydrostatic load (kg/cm2): Lh= (H1+Ha)/10 = 1.149

Steel pipe:				Plastic Pipe:				Reducciones:		
	Length (m) =	lt	= 5.00		Length (m)	1 m	= 5.00	α	Valv. uniones:	0.2
	Diameter ϕ_1	(m)	= 0.0603		Diameter ϕ_2	(m)	= 0.0254		Packer:	0.12
	Coef. rugosidad	n1	= 0.01		Coef. rugosidad	n2	: 0.008		Codo:	0.008

PRESSURE READING Po (kg/cm²)	LOSS PRESSURE Pto=P1+P2+P3 (kg/cm²)	EFECTIVE PRESSURE ~~Pe=Pm+Ph-Pc~~ (kg/cm²)	INJECTED TIME t (min)	WATER VOLUME Qt (l)	FLOOD Qo=Qt/t (l/min)	FLOOD Q1=Q/60000 (m³/s)	FLOOD Q2=Q*100/6 (cm³/s)	SPECIFIC ABSOPTION Ae = Q / L (l/min/m)	LUGEON UNIT $UL = \frac{10 * Ae}{Pe}$ UL	PERMEABILITY COEFICIENT $K = \frac{Q2}{2\pi Pe L} * \ln\frac{2L}{D}$ (cm/s)
1.54	0.00000	2.69	3	0.00	0.00	0.00E+00	0.00	0.00	0.0	0.00E+00
3.08	0.00000	4.23	3	0.00	0.00	0.00E+00	0.00	0.00	0.0	0.00E+00
4.62	0.00000	5.77	3	0.00	0.00	0.00E+00	0.00	0.00	0.0	0.00E+00
3.08	0.00000	4.23	3	0.00	0.00	0.00E+00	0.00	0.00	0.0	0.00E+00
1.54	0.00000	2.69	3	0.00	0.00	0.00E+00	0.00	0.00	0.0	0.00E+00

TOTAL LOSS LOAD

$$Pc = Pc_1 + Pc_2 + Pc_3$$

$$P_1 = \frac{10.34 * (n_1)^2 * (Q_1^2) * lt}{(\phi_1^{5.33})}$$

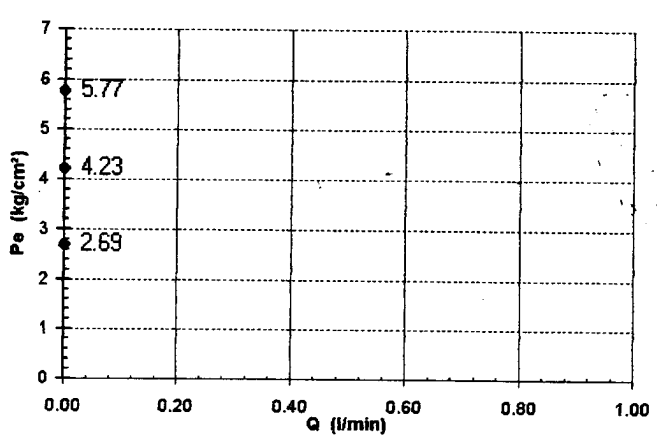
P1= loss load on steel pipe

$$P_2 = \frac{10.34 * (n_2)^2 * (Q_2^2) * lm}{(\phi_2^{5.33})}$$

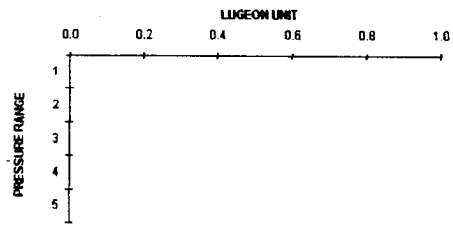
P2= loss load on plastic pipe

$$P_3 = \sum \alpha * (Q_1)$$

P3= loss load on reducciones, valvulas y uniones



VALUES OF LUGEON UNIT



PERMEABILITY (LU) = 0.0

PERMEABILITY TEST

swissboring
Swissboring Overseas Corporation Ltd.

CLIENT: AUTORIDAD DEL CANAL DE PANAMA	DATE: 1-July-2001	LUGEON TEST Nº: 7
PROJECT: ALTO CHAGRES DAM SITE	SITE: DAM SITE (right margin)	TESTED BY Geols. L.Peréz- R. Alvarado
BOREHOLE No.: CH-3	ELEVATION: 108.99 m.s.l	CHECKED BY:

Packer type: Neumatic Length (m) = 0.80 Water pump Bean Royal 535 Flood (l/min) =

Test depth (m) from: 45.00 to: 50.00

Test length (cm): L * Cos X° = 499.92 Depth of hole (m): 50.00 Dip X (°)= 30

Swivel H1 (m): H1 = 1.30 Diameter of hole D (cm): 7.57 W.L. Before of test (m)= 10.5

Water level Ha (m): 10.5 Ha * Cos X° = 9.09 Hydrostatic load (kg/cm2): Lh= (H1+Ha)/10 = 1.039

Steel pipe:			Plastic Pipe:			Reducciones:		
Length (m) =	lt	= 5.00	Length (m)	1 m	= 5.00	Valv. uniones:		0.2
Diameter ϕ_1	(m)	= 0.0603	Diameter ϕ_2	(m)	= 0.0254	α	Packer:	0.12
Coef. rugosidad	n1	= 0.01	Coef. rugosidad	n2	: 0.008		Codo:	0.008

PRESSURE READING	LOSS PRESSURE	EFECTIVE PRESSURE	INJECTED TIME	WATER VOLUME	FLOOD			SPECIFIC ABSOPTION	LUGEON UNIT	PERMEABILITY COEFICIENT
Po	Plo=P1+P2+P3	Pe=Po-Plo-R	t	Qt	Qo=Qt/t	Q1=Q/60000	Q2=Q*100/6	Ae = Q / L	$UL = \frac{10 * Ae}{Pe}$	$K = \frac{Q2}{2\pi Pe\ L} * \ln\frac{2L}{D}$
(kg/cm²)	(kg/cm²)	(kg/cm²)	(min)	(l)	(l/min)	(m³/s)	(cm³/s)	(l/min/m)	UL	(cm/s)
1.75	0.00000	2.79	3	0.00	0.00	0.00E+00	0.00	0.00	0.0	0.00E+00
3.50	0.00000	4.54	3	0.00	0.00	0.00E+00	0.00	0.00	0.0	0.00E+00
5.18	0.00030	6.22	3	3.00	1.00	1.67E-05	16.67	0.20	0.3	4.17E-06
3.50	0.00000	4.54	3	0.00	0.00	0.00E+00	0.00	0.00	0.0	0.00E+00
1.75	0.00000	2.79	3	0.00	0.00	0.00E+00	0.00	0.00	0.0	0.00E+00

TOTAL LOSS LOAD

$$Pc = Pc_1 + Pc_2 + Pc_3$$

$$P_1 = \frac{10.34 * (n_1)^2 * (Q_1^2) * lt}{(\phi_1^{5.33})}$$

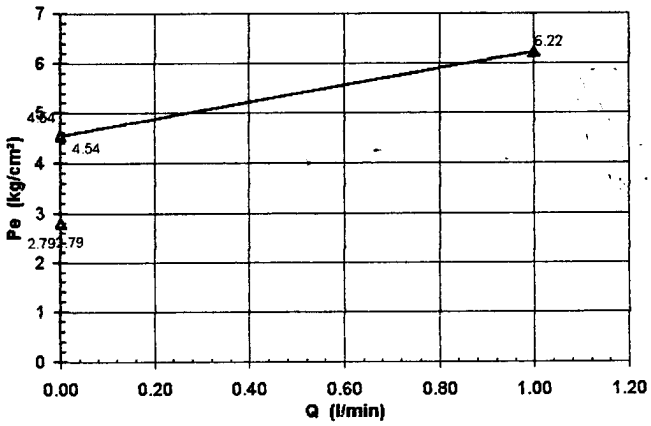
P1= loss load on steel pipe

$$P_2 = \frac{10.34 * (n_2)^2 * (Q_2^2) * lm}{(\phi_2^{5.33})}$$

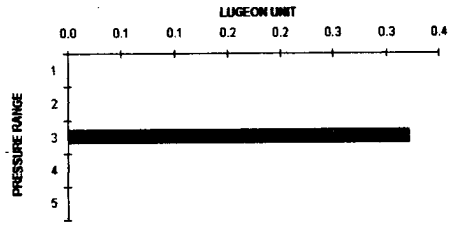
P2= loss load on plastic pipe

$$P_3 = \sum \alpha * (Q_1)$$

P3= loss load on reducciones, valvulas y uniones



VALUES OF LUGEON UNIT



PERMEABILITY (LU) = 0.3

PERMEABILITY TEST

swissboring

Swissboring Overseas Corporation Ltd.

CLIENT: AUTORIDAD DEL CANAL DE PANAMA	DATE: 1-July-2001	LUGEON TEST Nº: 9
PROJECT: ALTO CHAGRES DAM SITE	SITE: DAM SITE (right margin)	TESTED BY Geols. L.Peréz- R. Alvarado
BOREHOLE No.: CH-3	ELEVATION: 108.99 m.s.l	CHECKED BY:

Packer type: Neumatic Length (m) = 0.80 Water pump Bean Royal 535 Flood (l/min) =

Test depth (m) from: 55.00 to: 60.00

Test length (cm): 50 L * Cos X° = 499.92 Depth of hole (m): 60.00 Dip X (°)= 30

Swivel H1 (m): H1 = 1.50 Diameter of hole D (cm): 7.57 W.L. Before of test (m)= 7.4

Water level Ha (m): 7.4 Ha * Cos X° = 6.41 Hydrostatic load (kg/cm2): Lh= (H1+Ha)/10 = 0.791

Steel pipe			Plastic Pipe			Reducciones		
Length (m) =	lt	= 5.00	Length (m)	1 m	= 5.00	Valv. uniones:		0.2
Diameter ϕ_1	(m)	= 0.0603	Diameter ϕ_2	(m)	= 0.0254	α	Packer:	0.12
Coef. rugosidad	n1	= 0.01	Coef. rugosidad	n2	: 0.008		Codo:	0.008

PRESSURE READING Po (kg/cm²)	LOSS PRESSURE Plo=P1+P2+P3 (kg/cm²)	EFECTIVE PRESSURE ~~Pe=Po+Ho-Pc~~ (kg/cm²)	INJECTED TIME t (min)	WATER VOLUME Qt (l)	FLOOD Qo=Qt/t (l/min)	FLOOD Q1=Q/60000 (m³/s)	FLOOD Q2=Q*100/6 (cm³/s)	SPECIFIC ABSORPTION Ae = Q / L (l/min/m)	LUGEON UNIT $UL = \frac{10 * Ae}{Pe}$ UL	PERMEABILITY COEFICIENT $K = \frac{Q2}{2\pi Pe L} * \ln\frac{2L}{D}$ (cm/s)
2.10	0.00000	2.89	3	0.00	0.00	0.00E+00	0.00	0.00	0.0	0.00E+00
4.20	0.00008	4.99	3	1.50	0.50	8.33E-06	8.33	0.10	0.2	2.60E-06
6.30	0.00068	7.09	3	4.50	1.50	2.50E-05	25.00	0.30	0.4	5.48E-06
4.20	0.00008	4.99	3	1.50	0.50	8.33E-06	8.33	0.10	0.2	2.60E-06
2.10	0.00000	2.89	3	0.00	0.00	0.00E+00	0.00	0.00	0.0	0.00E+00

TOTAL LOSS LOAD

$$Pc = Pc_1 + Pc_2 + Pc_3$$

$$P_1 = \frac{10.34 * (n_1)^2 * (Q_1^2) * lt}{(\phi_1^{5.33})}$$

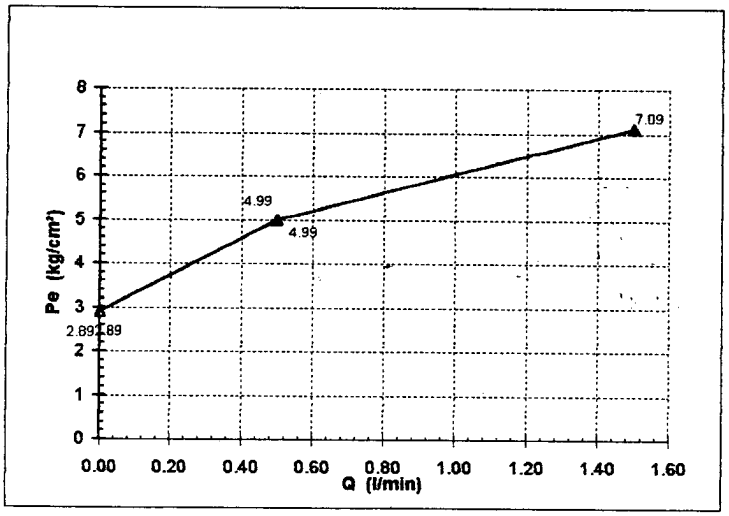
$$P_2 = \frac{10.34 * (n_2)^2 * (Q_2^2) * lm}{(\phi_2^{5.33})}$$

$$P_3 = \sum \alpha * (Q_1)$$

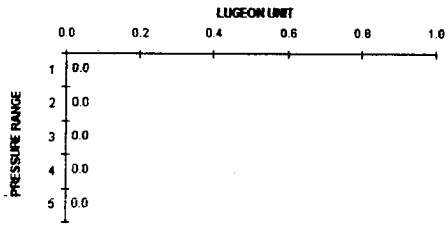
P1= loss load on steel pipe

P2= loss load on plastic pipe

P3= loss load on reducciones, valvulas y uniones



VALUES OF LUGEON UNIT



PERMEABILITY (LU) = 0.4

PERMEABILITY TEST

swissboring
Swissboring Overseas Corporation Ltd.

CLIENT: AUTORIDAD DEL CANAL DE PANAMA	DATE: 1-July-2001	LUGEON TEST Nº: 8
PROJECT: ALTO CHAGRES DAM SITE	SITE: DAM SITE (right margin)	TESTED BY Geols. L.Peréz- R. Alvarado
BOREHOLE No.: CH-3	ELEVATION: 108.99 m.s.l	CHECKED BY:

Packer type: Neumatic Length (m) = 0.80 Water pump Bean Royal 535 Flood (l/min) =

Test depth (m) from: 50.00 to: 55.00

Test length (cm): L * Cos X º = 499.92 Depth of hole (m): 55.00 Dip X (º)= 30

Swivel H1 (m): H1 = 2.05 Diameter of hole D (cm): 7.57 W.L. Before of test (m)= 8.85

Water level Ha (m): 8.85 Ha * Cos X º = 7.66 Hydrostatic load (kg/cm2): Lh= (H1+Ha)/10 = 0.971

Steel pipe:			Plastic Pipe:			Reducciones:		
Length (m) =	lt	= 5.00	Length (m)	1 m	= 5.00	Valv. uniones		0.2
Diameter ϕ_1	(m)	= 0.0603	Diameter ϕ_2	(m)	= 0.0254	α	Packer	0.12
Coef. rugosidad	n1	= 0.01	Coef. rugosidad	n2	: 0.008		Codo	0.008

PRESSURE READING	LOSS PRESSURE	EFECTIVE PRESSURE	INJECTED TIME	WATER VOLUME	FLOOD			SPECIFIC ABSOPTION	LUGEON UNIT	PERMEABILITY COEFICIENT
Po	Plo=P1+P2+P3	~~Pe=Po-Plo-Pc~~	t	Qt	Qo=Qt/t	Q1=Q/60000	Q2=Q*100/6	Ae = Q / L	$UL = \frac{10 * Ae}{Pe}$	$K = \frac{Q2}{2\pi Pe\ L} * \ln\frac{2L}{D}$
(kg/cm²)	(kg/cm²)	(kg/cm²)	(min)	(l)	(l/min)	(m³/s)	(cm³/s)	(l/min/m)	UL	(cm/s)
1.96	0.00000	2.93	3	0.00	0.00	0.00E+00	0.00	0.00	0.0	0.00E+00
3.85	0.00000	4.82	3	0.00	0.00	0.00E+00	0.00	0.00	0.0	0.00E+00
5.74	0.00030	6.71	3	3.00	1.00	1.67E-05	16.67	0.20	0.3	3.86E-06
3.85	0.00000	4.82	3	0.00	0.00	0.00E+00	0.00	0.00	0.0	0.00E+00
1.96	0.00000	2.93	3	0.00	0.00	0.00E+00	0.00	0.00	0.0	0.00E+00

TOTAL LOSS LOAD

$$Pc = Pc_1 + Pc_2 + Pc_3$$

$$P_1 = \frac{10.34 * (n_1)^2 * (Q_1^2) * lt}{(\phi_1^{5.33})}$$

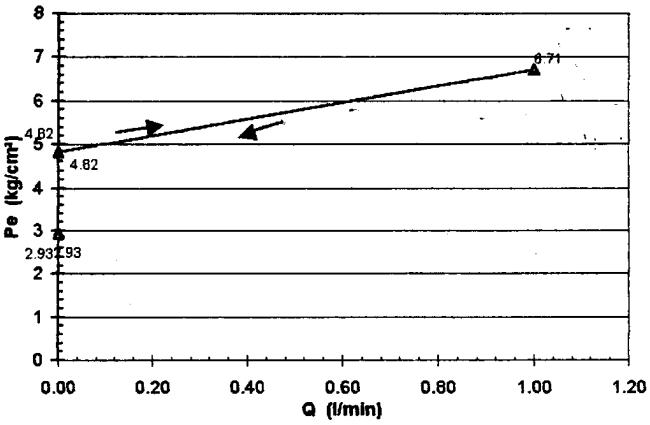
P1= loss load on steel pipe

$$P_2 = \frac{10.34 * (n_2)^2 * (Q_2^2) * lm}{(\phi_2^{5.33})}$$

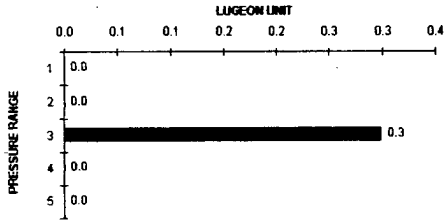
P2= loss load on plastic pipe

$$P_3 = \sum \alpha * (Q_1)$$

P3= loss load on reducciones, *valvulas y uniones*



VALUES OF LUGEON UNIT



PERMEABILITY (LU) = 0.3

PERMEABILITY TEST

swissboring
Swissboring Overseas Corporation Ltd.

CLIENT: AUTORIDAD DEL CANAL DE PANAMA	DATE: 1-July-2001	LUGEON TEST Nº: 10
PROJECT: ALTO CHAGRES DAM SITE	SITE: DAM SITE (right margin)	TESTED BY Geals. L.Perez- R. Alvarado
BOREHOLE No.: CH-3	ELEVATION: 108.99 m.s.l	CHECKED BY:

Packer type: Neumatic Length (m) = 0.80 Water pump: Bean Royal 535 Flood (l/min) =
Test depth (m) from: 60.00 to: 65.00

Test length (cm): L * Cos X º = 499.92 Depth of hole (m): 65.00 Dip X (º)= 30
Swivel H1 (m): H1 = 1.50 Diameter of hole D (cm): 7.57 W.L. Before of test (m)= 5.6
Water level Ha (m): 5.6 Ha * Cos X º = 4.85 Hydrostatic load (kg/cm2): Lh= (H1+Ha)/10 = 0.635

Steel pipe: Length (m) = 1t = 5.00; Diameter ϕ_1 (m) = 0.0603; Coef. rugosidad n1 = 0.01
Plastic Pipe: Length (m) 1 m = 5.00; Diameter ϕ_2 (m) = 0.0254; Coef. rugosidad n2 : 0.008
Reducciones: α — Valv. uniones: 0.2; Packer: 0.12; Codo: 0.008

PRESSURE READING Po (kg/cm²)	LOSS PRESSURE Pio=P1+P2+P3 (kg/cm²)	EFECTIVE PRESSURE ~~Pe=Pm-Pi-Pc~~ (kg/cm²)	INJECTED TIME t (min)	WATER VOLUME Qt (l)	FLOOD Qo=Qt/t (l/min)	FLOOD Q1=Q/60000 (m³/s)	FLOOD Q2=Q*100/6 (cm³/s)	SPECIFIC ABSOPTION Ae = Q / L (l/min/m)	LUGEON UNIT $UL = \frac{10 * Ae}{Pe}$ UL	PERMEABILITY COEFICIENT $K = \frac{Q2}{2\pi Pe L} * \ln\frac{2L}{D}$ (cm/s)
2.28	0.00000	2.91	3	0.00	0.00	0.00E+00	0.00	0.00	0.0	0.00E+00
4.55	0.00008	5.19	3	1.50	0.50	8.33E-06	8.33	0.10	0.2	2.50E-06
6.86	0.00120	7.50	3	6.00	2.00	3.33E-05	33.33	0.40	0.5	6.91E-06
4.55	0.00030	5.19	3	3.00	1.00	1.67E-05	16.67	0.20	0.4	5.00E-06
2.28	0.00000	2.91	3	0.00	0.00	0.00E+00	0.00	0.00	0.0	0.00E+00

TOTAL LOSS LOAD

$$Pc = Pc_1 + Pc_2 + Pc_3$$

$$P_1 = \frac{10.34 * (n_1)^2 * (Q_1^2) * lt}{(\phi_1^{5.33})}$$

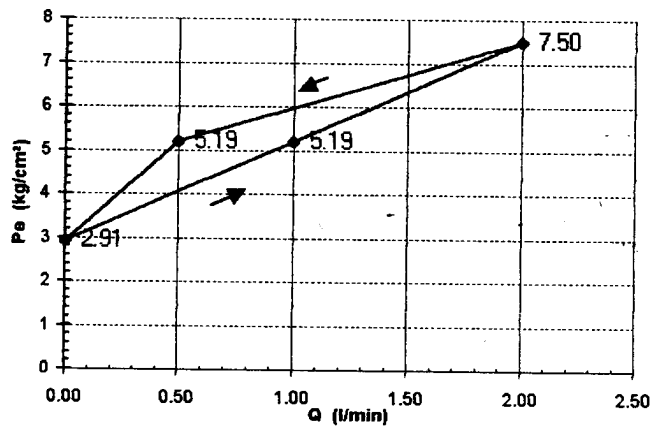
$$P_2 = \frac{10.34 * (n_2)^2 * (Q_2^2) * lm}{(\phi_2^{5.33})}$$

$$P_3 = \sum \alpha * (Q_1)$$

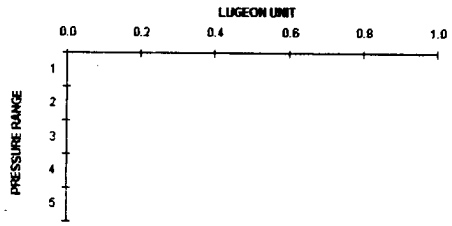
P1= loss load on steel pipe

P2= loss load on plastic pipe

P3= loss load on reducciones, valvulas y uniones



VALUES OF LUGEON UNIT



PERMEABILITY (LU) = 0.5

PERMEABILITY TEST

swissboring

Swissboring Overseas Corporation Ltd.

CLIENT: AUTORIDAD DEL CANAL DE PANAMA	DATE: 2-July-2001	LUGEON TEST Nº: 11
PROJECT: ALTO CHAGRES DAM SITE	SITE: DAM SITE (right margin)	TESTED BY Geols. L.Peréz- R. Alvarado
BOREHOLE No.: CH-3	ELEVATION: 108.99 m.s.l	CHECKED BY:

Packer type: Neumatic Length (m) = 0.80 Water pump Bean Royal 535 Flood (l/min) =

Test depth (m) from: 65.00 to: 70.00

Test length (cm): L * Cos X º = 499.92 Depth of hole (m): 70.00 Dip X (º)= 30

Swivel H1 (m): H1 = 1.80 Diameter of hole D (cm): 7.57 W.L. Before of test (m)= 1.55

Water level Ha (m): 1.55 Ha * Cos X º = 1.34 Hydrostatic load (kg/cm2): Lh= (H1+Ha)/10 = 0.314

Steel pipe:			Plastic Pipe:			Reducciones:		
Length (m) =	1t	= 5.00	Length (m)	1 m	= 5.00	α	Valv. uniones:	0.2
Diameter ϕ_1	(m)	= 0.0603	Diameter ϕ_2	(m)	= 0.0254		Packer:	0.12
Coef. rugosidad	n1	= 0.01	Coef. rugosidad	n2	: 0.008		Codo:	0.008

PRESSURE READING	LOSS PRESSURE	EFECTIVE PRESSURE	INJECTED TIME	WATER VOLUME	FLOOD			SPECIFIC ABSOPTION	LUGEON UNIT	PERMEABILITY COEFICIENT
Po	Pto=P1+P2+P3	Pe=Pm+Pc	t	Qt	Qo=Qt/t	Q1=Q/60000	Q2=Q*100/6	Ae = Q / L	$UL = \frac{10 * Ae}{Pe}$	$K = \frac{Q2}{2\pi Pe\ L} * \ln\frac{2L}{D}$
(kg/cm²)	(kg/cm²)	(kg/cm²)	(min)	(l)	(l/min)	(m³/s)	(cm³/s)	(l/min/m)	UL	(cm/s)
2.45	0.00000	2.77	3	0.00	0.00	0.00E+00	0.00	0.00	0.0	0.00E+00
4.90	0.00000	5.22	3	0.00	0.00	0.00E+00	0.00	0.00	0.0	0.00E+00
7.35	0.00008	7.67	3	1.50	0.50	8.33E-06	8.33	0.10	0.1	1.69E-06
4.90	0.00000	5.22	3	0.00	0.00	0.00E+00	0.00	0.00	0.0	0.00E+00
2.45	0.00000	2.77	3	0.00	0.00	0.00E+00	0.00	0.00	0.0	0.00E+00

TOTAL LOSS LOAD

$$Pc = Pc_1 + Pc_2 + Pc_3$$

$$P_1 = \frac{10.34 * (n_1)^2 * (Q_1^2) * lt}{(\phi_1^{5.33})}$$

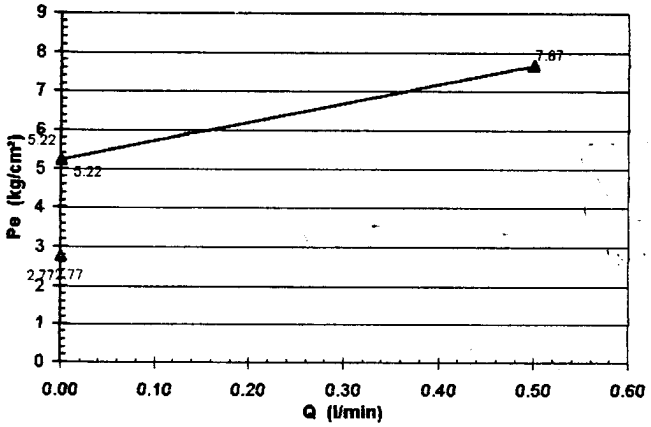
P1= loss load on steel pipe

$$P_2 = \frac{10.34 * (n_2)^2 * (Q_2^2) * lm}{(\phi_2^{5.33})}$$

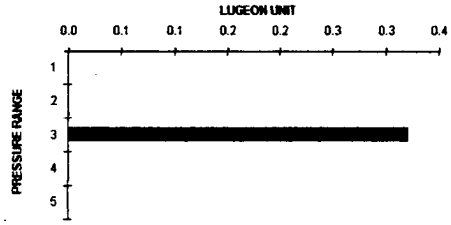
P2= loss load on plastic pipe

$$P_3 = \sum \alpha * (Q_1)$$

P3= loss load on reducciones, valvulas y uniones



VALUES OF LUGEON UNIT



PERMEABILITY (LU) = 0.1

PERMEABILITY TEST

swissboring

Swissboring Overseas Corporation Ltd.

CLIENT: AUTORIDAD DEL CANAL DE PANAMA	DATE: 2-July-2001	LUGEON TEST Nº: 12
PROJECT: ALTO CHAGRES DAM SITE	SITE: DAM SITE (right margin)	TESTED BY Geols. L.Peréz- R. Alvarado
BOREHOLE No.: CH-3	ELEVATION: 108.99 m.s.l	CHECKED BY:

Packer type: Neumatic Length (m) = 0.80 Water pump Bean Royal 535 Flood (l/min) =

Test depth (m) from: 70.00 to: 75.00

Test length (cm): L * Cos X º = 499.92 Depth of hole (m): 75.00 Dip X (º)= 30

Swivel H1 (m): H1 = 1.98 Diameter of hole D (cm): 9.60 W.L. Before of test (m)= 3.78

Water level Ha (m): 3.78 Ha * Cos X º = 3.27 Hydrostatic load (kg/cm2): Lh= (H1+Ha)/10 = 0.525

Steel pipe: Length (m) = 1t = 5.00 Diameter ϕ_1 (m) = 0.0603 Coef. rugosidad n1 = 0.01

Plastic Pipe: Length (m) 1 m = 5.00 Diameter ϕ_2 (m) = 0.0254 Coef. rugosidad n2 : 0.008

Reducciones: α Valv. uniones 0.2 Packer 0.12 Codo 0.008

PRESSURE READING Po (kg/cm²)	LOSS PRESSURE Plo=P1+P2+P3 (kg/cm²)	EFECTIVE PRESSURE ~~Pc=Pm+Ph-Pc~~ (kg/cm²)	INJECTED TIME t (min)	WATER VOLUME Qt (l)	FLOOD Qo=Qt/t (l/min)	FLOOD Q1=Q/60000 (m³/s)	FLOOD Q2=Q*100/6 (cm³/s)	SPECIFIC ABSOPTION Ae = Q / L (l/min/m)	LUGEON UNIT $UL = \frac{10 * Ae}{Pc}$ UL	PERMEABILITY COEFICIENT $K = \frac{Q2}{2\pi Pe L} * \ln\frac{2L}{D}$ (cm/s)
2.66	0.11879	3.07	3	60	20.00	3.33E-04	333.33	4.00	13.0	1.61E-04
5.39	0.49898	5.42	3	123	41.00	6.83E-04	683.33	8.20	15.1	1.87E-04
7.98	1.03313	7.48	3	177	59.00	9.83E-04	983.33	11.80	15.8	1.95E-04
5.39	0.45149	5.47	3	117	39.00	6.50E-04	650.00	7.80	14.3	1.76E-04
2.66	0.10721	3.08	3	57	19.00	3.17E-04	316.67	3.80	12.3	1.52E-04

TOTAL LOSS LOAD

$$Pc = Pc_1 + Pc_2 + Pc_3$$

$$P_1 = \frac{10.34 * (n_1)^2 * (Q_1^2) * lt}{(\phi_1^{5.33})}$$

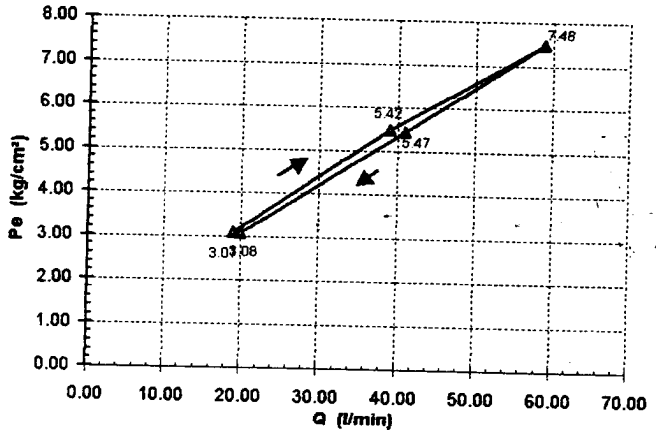
P1= loss load on steel pipe

$$P_2 = \frac{10.34 * (n_2)^2 * (Q_2^2) * lm}{(\phi_2^{5.33})}$$

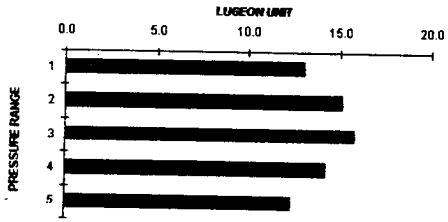
P2= loss load on plastic pipe

$$P_3 = \sum \alpha * (Q_1)$$

P3= loss load on reducciones, valvulas y uniones



VALUES OF LUGEON UNIT



PERMEABILITY (LU) = 15.8

PERMEABILITY TEST

swissboring

Swissboring Overseas Corporation Ltd.

CLIENT: AUTORIDAD DEL CANAL DE PANAMA	DATE: 2-July-2001	LUGEON TEST Nº: 13
PROJECT: ALTO CHAGRES DAM SITE	SITE: DAM SITE (right margin)	TESTED BY Geols. L.Peréz- R. Alvarado
BOREHOLE No.: CH-3	ELEVATION: 108.99 m.s.l	CHECKED BY:

Packer type: Neumatic Length (m) = 0.80 Water pump Bean Royal 535 Flood (l/min) =

Test depth (m) from: 75.00 to: 80.00

Test length (cm): L * Cos X º = 499.92 Depth of hole (m): 80.00 Dip X (º)= 30

Swivel H1 (m): H1 = 1.98 Diameter of hole D (cm): 9.60 W.L. Before of test (m)= 3.75

Water level Ha (m): 3.75 Ha * Cos X º = 3.25 Hydrostatic load (kg/cm2): Lh= (H1+Ha)/10 = 0.523

Steel pipe: Length (m) = lt = 5.00 Diameter ϕ_1 (m) = 0.0603 Coef. rugosidad n1 = 0.01

Plastic Pipe: Length (m) lm = 5.00 Diameter ϕ_2 (m) = 0.0254 Coef. rugosidad n2 : 0.008

Reducciones: α Valv. uniones: 0.2 Packer: 0.12 Codo: 0.008

PRESSURE READING Po (kg/cm²)	LOSS PRESSURE Plo=P1+P2+P3 (kg/cm²)	EFECTIVE PRESSURE ~~Pe=Pm-Ph-Pc~~ (kg/cm²)	INJECTED TIME t (min)	WATER VOLUME Qt (l)	FLOOD Qo=Qt/t (l/min)	FLOOD Q1=Q/60000 (m³/s)	FLOOD Q2=Q*100/6 (cm³/s)	SPECIFIC ABSOPTION Ae = Q / L (l/min/m)	LUGEON UNIT $UL = \frac{10 * Ae}{Pe}$ UL	PERMEABILITY COEFICIENT $K = \frac{Q2}{2\pi Pe L} * \ln\frac{2L}{D}$ (cm/s)
2.87	0.00744	3.39	3	15	5.00	8.33E-05	83.33	1.00	3.0	3.64E-05
5.74	0.03596	6.23	3	33	11.00	1.83E-04	183.33	2.20	3.5	4.35E-05
8.61	0.07604	9.06	3	48	16.00	2.67E-04	266.67	3.20	3.5	4.35E-05
5.74	0.01458	6.25	3	21	7.00	1.17E-04	116.67	1.40	2.2	2.76E-05
2.87	0.00269	3.39	3	9	3.00	5.00E-05	50.00	0.60	1.8	2.18E-05

TOTAL LOSS LOAD

$$Pc = Pc_1 + Pc_2 + Pc_3$$

$$P_1 = \frac{10.34 * (n_1)^2 * (Q_1^2) * lt}{(\phi_1^{5.33})}$$

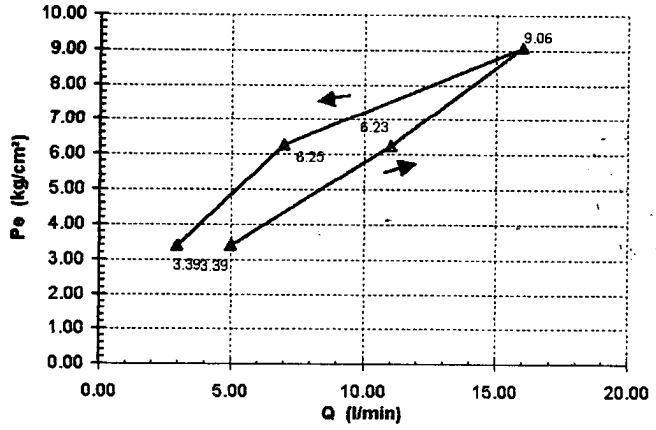
P1= loss load on steel pipe

$$P_2 = \frac{10.34 * (n_2)^2 * (Q_2^2) * lm}{(\phi_2^{5.33})}$$

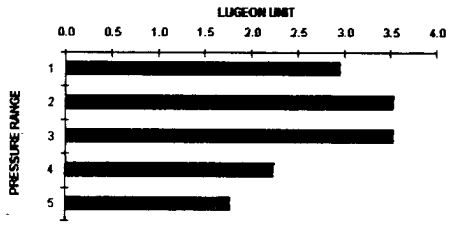
P2= loss load on plastic pipe

$$P_3 = \sum \alpha * (Q_i)$$

P3= loss load on reducciones, valvulas y uniones



VALUES OF LUGEON UNIT



PERMEABILITY (LU) = 3.5

PERMEABILITY TEST

swissboring

Swissboring Overseas Corporation Ltd.

CLIENT: AUTORIDAD DEL CANAL DE PANAMA	DATE: 2-July-2001	LUGEON TEST Nº: 14
PROJECT: ALTO CHAGRES DAM SITE	SITE: DAM SITE (right margin)	TESTED BY Geols. L.Peréz- R. Alvarado
BOREHOLE No.: CH-3	ELEVATION: 108.99 m.s.l	CHECKED BY:

Packer type: Neumatic Length (m) = 0.80 Water pump Bean Royal 535 Flood (l/min) =

Test depth (m) from: 80.00 to: 85.00

Test length (cm): L * Cos X º = 499.92 Depth of hole (m): 85.00 Dip X (º)= 30

Swivel H1 (m): H1 = 3.00 Diameter of hole D (cm): 7.57 W.L. Before of test (m)= 4.2

Water level Ha (m): 4.2 Ha * Cos X º = 3.64 Hydrostatic load (kg/cm2): Lh= (H1+Ha)/10 = 0.664

Steel pipe: Length (m) = lt = 5.00 Diameter ϕ_1 (m) = 0.0603 Coef. rugosidad n1 = 0.01

Plastic Pipe: Length (m) lm = 5.00 Diameter ϕ_2 (m) = 0.0254 Coef. rugosidad n2 : 0.008

Reducciones: α Valv. uniones: 0.2 Packer: 0.12 Codo: 0.008

PRESSURE READING Po (kg/cm²)	LOSS PRESSURE Plo=P1+P2+P3 (kg/cm²)	EFECTIVE PRESSURE ~~Pe=Pm+Ph-Pc~~ (kg/cm²)	INJECTED TIME t (min)	WATER VOLUME Qt (l)	FLOOD Qo=Qt/t (l/min)	FLOOD Q1=Q/60000 (m³/s)	FLOOD Q2=Q*100/6 (cm³/s)	SPECIFIC ABSOPTION Ae = Q / L (l/min/m)	LUGEON UNIT $UL = \frac{10 * Ae}{Pe}$ UL	PERMEABILITY COEFICIENT $K = \frac{Q2}{2\pi Pe\ L} * \ln\frac{2L}{D}$ (cm/s)
3.08	0.00000	3.74	3	0.00	0.00	0.00E+00	0.00	0.00	0.0	0.00E+00
6.09	0.00068	6.76	3	4.50	1.50	2.50E-05	25.00	0.30	0.4	5.75E-06
9.17	0.02408	9.81	3	27.00	9.00	1.50E-04	150.00	1.80	1.8	2.38E-05
6.09	0.00030	6.76	3	3.00	1.00	1.67E-05	16.67	0.20	0.3	3.84E-06
3.08	0.00000	3.74	3	0.00	0.00	0.00E+00	0.00	0.00	0.0	0.00E+00

TOTAL LOSS LOAD

$$Pc = Pc_1 + Pc_2 + Pc_3$$

$$P_1 = \frac{10.34 * (n_1)^2 * (Q_1^2) * lt}{(\phi_1^{5.33})}$$

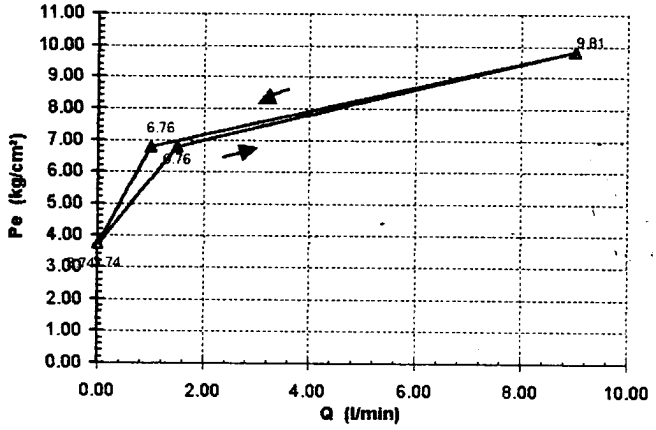
P1= loss load on steel pipe

$$P_2 = \frac{10.34 * (n_2)^2 * (Q_2^2) * lm}{(\phi_2^{5.33})}$$

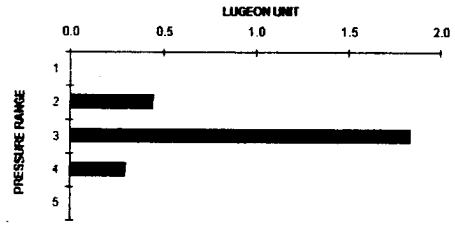
P2= loss load on plastic pipe

$$P_3 = \sum \alpha * (Q_1)$$

P3= loss load on reducciones, valvulas y uniones



VALUES OF LUGEON UNIT



PERMEABILITY (LU) = 1.8

PERMEABILITY TEST

swissboring

Swissboring Overseas Corporation Ltd.

CLIENT: AUTORIDAD DEL CANAL DE PANAMA	DATE: 2-July-2001	LUGEON TEST Nº: 15
PROJECT: ALTO CHAGRES DAM SITE	SITE: DAM SITE (right margin)	TESTED BY Geols. L.Peréz- R. Alvarado
BOREHOLE No.: CH-3	ELEVATION: 108.99 m.s.l	CHECKED BY:

Packer type: Neumatic Length (m) = 0.80 Water pump Bean Royal 535 Flood (l/min) =

Test depth (m) from: 85.00 to: 90.00

Test length (cm): 50 L * Cos X° = 499.92 Depth of hole (m): 90.00 Dip X (°)= 30

Swivel H1 (m): H1 = 2.35 Diameter of hole D (cm): 7.57 W.L. Before of test (m)= 4.95

Water level Ha (m): 4.95 Ha * Cos X° = 4.29 Hydrostatic load (kg/cm2): Lh= (H1+Ha)/10 = 0.664

Steel pipe:			Plastic Pipe:			Reducciones:		
Length (m) =	lt	= 5.00	Length (m)	lm	= 5.00	Valv. uniones:		0.2
Diameter ϕ_1	(m)	= 0.0603	Diameter ϕ_2	(m)	= 0.0254	α	Packer:	0.12
Coef. rugosidad	n1	= 0.01	Coef. rugosidad	n2	: 0.008		Codo:	0.008

PRESSURE READING Po (kg/cm²)	LOSS PRESSURE Plo=P1+P2+P3 (kg/cm²)	EFECTIVE PRESSURE ~~Pe=Pm+Ph-Pc~~ (kg/cm²)	INJECTED TIME t (min)	WATER VOLUME Qt (l)	FLOOD Qo=Qt/t (l/min)	FLOOD Q1=Q/60000 (m³/s)	FLOOD Q2=Q*100/6 (cm³/s)	SPECIFIC ABSOPTION Ae = Q / L (l/min/m)	LUGEON UNIT $UL = \frac{10 * Ae}{Pe}$ UL	PERMEABILITY COEFICIENT $K = \frac{Q2}{2\pi Pe\ L} * \ln\frac{2L}{D}$ (cm/s)
3.22	0.00120	3.88	3	6.00	2.00	3.33E-05	33.33	0.40	1.0	1.33E-05
6.51	0.00269	7.17	3	9.00	3.00	5.00E-05	50.00	0.60	0.8	1.08E-05
9.73	0.00744	10.39	3	15.00	5.00	8.33E-05	83.33	1.00	1.0	1.25E-05
6.51	0.00120	7.16	3	6.00	2.00	3.33E-05	33.33	0.40	0.6	7.22E-06
3.22	0.00030	3.88	3	3.00	1.00	1.67E-05	16.67	0.20	0.5	6.67E-06

TOTAL LOSS LOAD

$$Pc = Pc_1 + Pc_2 + Pc_3$$

$$P_1 = \frac{10.34 * (n_1)^2 * (Q_1^2) * lt}{(\phi_1^{5.33})}$$

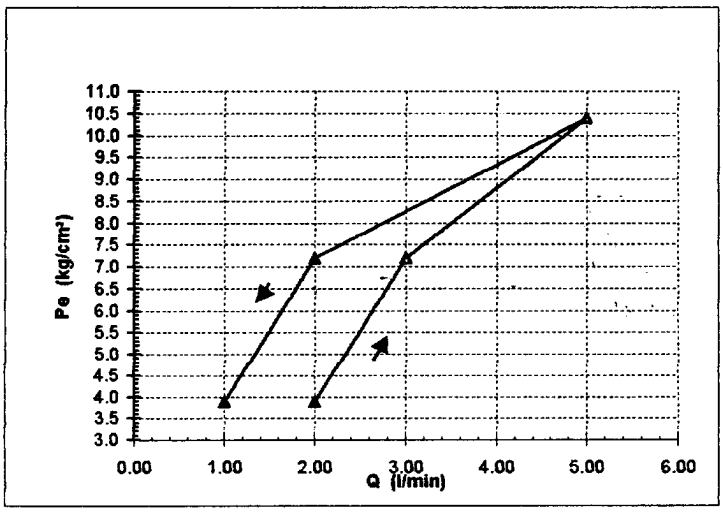
P1= loss load on steel pipe

$$P_2 = \frac{10.34 * (n_2)^2 * (Q_2^2) * lm}{(\phi_2^{5.33})}$$

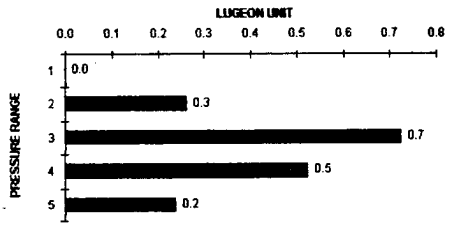
P2= loss load on plastic pipe

$$P_3 = \sum \alpha * (Q_1)$$

P3= loss load on reducciones, valvulas y uniones



VALUES OF LUGEON UNIT



PERMEABILITY (LU) = 1.0

PERMEABILITY TEST

swissboring

Swissboring Overseas Corporation Ltd.

CLIENT: AUTORIDAD DEL CANAL DE PANAMA	DATE: 2-July-2001	LUGEON TEST Nº: 16
PROJECT: ALTO CHAGRES DAM SITE	SITE: DAM SITE (right margin)	TESTED BY Geols. L.Peréz- R. Alvarado
BOREHOLE No.: CH-3	ELEVATION: 108.99 m.s.l	CHECKED BY:

Packer type: Neumatic Length (m) = 0.80 Water pump Bean Royal 535 Flood (l/min) =

Test depth (m) from: 90.00 to: 95.00

Test length (cm): L * Cos X° = 499.92 Depth of hole (m): 95.00 Dip X (°)= 30

Swivel H1 (m): H1 = 2.55 Diameter of hole D (cm): 7.57 W.L. Before of test (m)= 5.9

Water level Ha (m): 5.9 Ha * Cos X° = 5.11 Hydrostatic load (kg/cm2): Lh= (H1+Ha)/10 = 0.766

Steel pipe: Length (m) = lt = 5.00 Diameter ϕ_1 (m) = 0.0603 Coef. rugosidad n1 = 0.01

Plastic Pipe: Length (m) lm = 5.00 Diameter ϕ_2 (m) = 0.0254 Coef. rugosidad n2 : 0.008

Reducciones: α Valv. uniones: 0.2 Packer: 0.12 Codo: 0.008

PRESSURE READING Po (kg/cm²)	LOSS PRESSURE Plo=P1+P2+P3 (kg/cm²)	EFECTIVE PRESSURE ~~Pe=Pm+Ph-Pc~~ (kg/cm²)	INJECTED TIME t (min)	WATER VOLUME Qt (l)	FLOOD Qo=Qt/t (l/min)	FLOOD Q1=Q/60000 (m³/s)	FLOOD Q2=Q*100/6 (cm³/s)	SPECIFIC ABSOPTION Ae = Q / L (l/min/m)	LUGEON UNIT $UL = \frac{10 * Ae}{Pe}$ UL	PERMEABILITY COEFICIENT $K = \frac{Q2}{2\pi Pe L} * \ln\frac{2L}{D}$ (cm/s)
3.43	0.00000	4.20	3	0.00	0.00	0.00E+00	0.00	0.00	0.0	0.00E+00
6.86	0.00030	7.63	3	3.00	1.00	1.67E-05	16.67	0.20	0.3	3.40E-06
10.29	0.00477	11.06	3	12.00	4.00	6.67E-05	66.67	0.80	0.7	9.38E-06
6.86	0.00120	7.63	3	6.00	2.00	3.33E-05	33.33	0.40	0.5	6.79E-06
3.43	0.00008	4.20	3	1.50	0.50	8.33E-06	8.33	0.10	0.2	3.09E-06

TOTAL LOSS LOAD

$$Pc = Pc_1 + Pc_2 + Pc_3$$

$$P_1 = \frac{10.34 * (n_1)^2 * (Q_1^2) * lt}{(\phi_1^{5.33})}$$

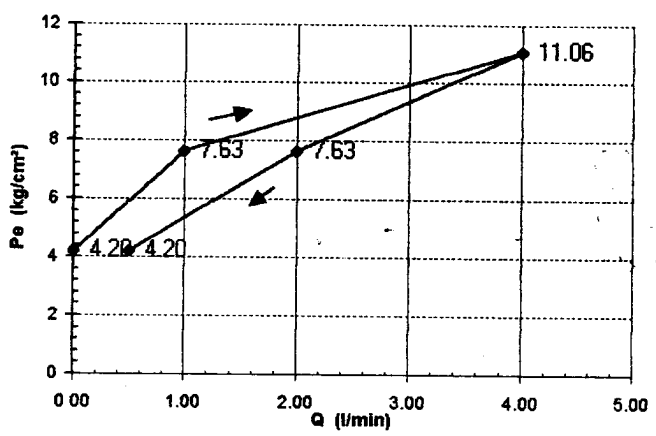
P1= loss load on steel pipe

$$P_2 = \frac{10.34 * (n_2)^2 * (Q_2^2) * lm}{(\phi_2^{5.33})}$$

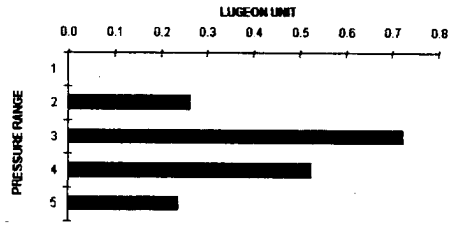
P2= loss load on plastic pipe

$$P_3 = \sum \alpha * (Q_1)$$

P3= loss load on reducciones, valvulas y uniones



VALUES OF LUGEON UNIT



PERMEABILITY (LU) = 0.7

PERMEABILITY TEST

swissboring
Swissboring Overseas Corporation Ltd.

CLIENT: AUTORIDAD DEL CANAL DE PANAMA	DATE: 2-July-2001	LUGEON TEST Nº: 17
PROJECT: ALTO CHAGRES DAM SITE	SITE: DAM SITE (right margin)	TESTED BY Geols. L.Peréz- R. Alvarado
BOREHOLE No.: CH-3	ELEVATION: 108.99 m.s.l	CHECKED BY:

Packer type: Neumatic Length (m) = 0.80 Water pump Bean Royal 535 Flood (l/min) =
Test depth (m) from: 95.00 to: 100.00

Test length (cm): L * Cos X º = 499.92 Depth of hole (m): 100.00 Dip X (º)= 30
Swivel H1 (m): H1 = 1.50 Diameter of hole D (cm): 7.57 W.L. Before of test (m)= 5.9
Water level Ha (m): 5.9 Ha * Cos X º = 5.11 Hydrostatic load (kg/cm2): Lh= (H1+Ha)/10 = 0.661

Steel pipe: Length (m) = lt = 5.00 Diameter ϕ_1 (m) = 0.0603 Coef. rugosidad n1 = 0.01
Plastic Pipe: Length (m) lm = 5.00 Diameter ϕ_2 (m) = 0.0254 Coef. rugosidad n2 : 0.008
Reducciones: α Valv. uniones: 0.2 Packer: 0.12 Codo: 0.008

PRESSURE READING Po (kg/cm²)	LOSS PRESSURE Plo=P1+P2+P3 (kg/cm²)	EFECTIVE PRESSURE ~~Pe=Po-Plo-Lh~~ (kg/cm²)	INJECTED TIME t (min)	WATER VOLUME Qt (l)	FLOOD Qo=Qt/t (l/min)	FLOOD Q1=Q/60000 (m³/s)	FLOOD Q2=Q*100/6 (cm³/s)	SPECIFIC ABSOPTION Ae = Q / L (l/min/m)	LUGEON UNIT $UL = \frac{10 * Ae}{Pe}$ UL	PERMEABILITY COEFICIENT $K = \frac{Q2}{2\pi Pe\ L} * \ln\frac{2L}{D}$ (cm/s)
3.64	0.00120	4.30	3	6.00	2.00	3.33E-05	33.33	0.40	0.93	1.20E-05
7.21	0.00269	7.87	3	9.00	3.00	5.00E-05	50.00	0.60	0.76	9.88E-06
10.85	0.00744	11.51	3	15.00	5.00	8.33E-05	83.33	1.00	0.87	1.13E-05
7.21	0.00120	7.87	3	6.00	2.00	3.33E-05	33.33	0.40	0.51	6.58E-06
3.64	0.00030	4.30	3	3.00	1.00	1.67E-05	16.67	0.20	0.46	6.02E-06

TOTAL LOSS LOAD

$$Pc = Pc_1 + Pc_2 + Pc_3$$

$$P_1 = \frac{10.34 * (n_1)^2 * (Q_1^2) * lt}{(\phi_1^{5.33})}$$

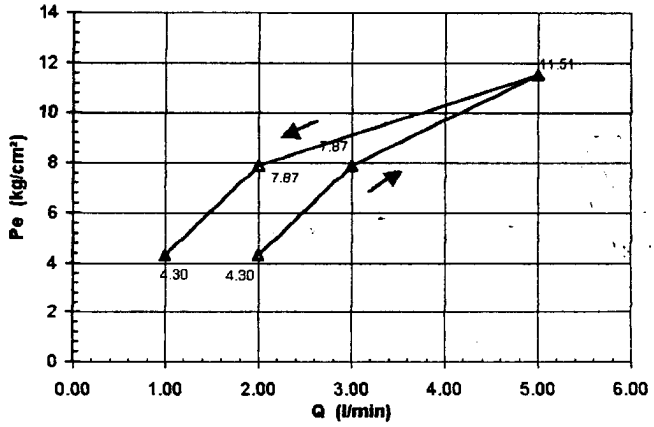
P1= loss load on steel pipe

$$P_2 = \frac{10.34 * (n_2)^2 * (Q_2^2) * lm}{(\phi_2^{5.33})}$$

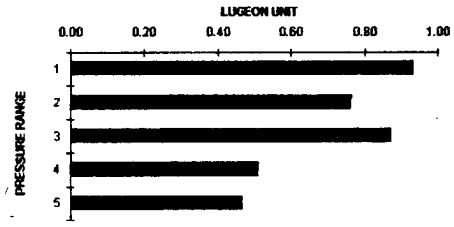
P2= loss load on plastic pipe

$$P_3 = \sum \alpha * (Q_1)$$

P3= loss load on reducciones, valvulas y uniones



VALUES OF LUGEON UNIT



PERMEABILITY (LU) = 0.9

PERMEABILITY TEST

swissboring

Swissboring Overseas Corporation Ltd.

CLIENT: AUTORIDAD DEL CANAL DE PANAMA	DATE: 3-July-2001	LUGEON TEST Nº: 18
PROJECT: ALTO CHAGRES DAM SITE	SITE: DAM SITE (right margin)	TESTED BY Geols. L.Peréz- R. Alvarado
BOREHOLE No.: CH-3	ELEVATION: 108.99 m.s.l	CHECKED BY:

Packer type: Neumatic Length (m) = 0.80 Water pump Bean Royal 535 Flood (l/min) =

Test depth (m) from: 100.00 to: 105.00

Test length (cm): L * Cos X° = 499.92 Depth of hole (m): 105.00 Dip X (°)= 30

Swivel H1 (m): H1 = 1.35 Diameter of hole D (cm): 7.57 W.L. Before of test (m)= 6.3

Water level Ha (m): 6.3 Ha * Cos X° = 5.46 Hydrostatic load (kg/cm2): Lh= (H1+Ha)/10 = 0.681

Steel pipe: Length (m) = lt = 5.00 Plastic Pipe: Length (m) 1 m = 5.00 Reducciones: Valv. uniones: 0.2

Diameter ϕ_1 (m) = 0.0603 Diameter ϕ_2 (m) = 0.0254 α Packer: 0.12

Coef. rugosidad n1 = 0.01 Coef. rugosidad n2 : 0.008 Codo: 0.008

PRESSURE READING Po (kg/cm²)	LOSS PRESSURE Plo=P1+P2+P3 (kg/cm²)	EFECTIVE PRESSURE ~~Pe=Pm+Ph-Pc~~ (kg/cm²)	INJECTED TIME t (min)	WATER VOLUME Qt (l)	FLOOD Qo=Qt/t (l/min)	Q1=Q/60000 (m³/s)	Q2=Q*100/6 (cm³/s)	SPECIFIC ABSOPTION Ae = Q / L (l/min/m)	LUGEON UNIT $UL = \frac{10 * Ae}{Pe}$ UL	PERMEABILITY COEFICIENT $K = \frac{Q2}{2\pi Pe\ L} * \ln \frac{2L}{D}$ (cm/s)
3.78	0.00008	4.46	3	1.50	0.50	8.33E-06	8.33	0.10	0.2	2.90E-06
7.63	0.00068	8.31	3	4.50	1.50	2.50E-05	25.00	0.30	0.4	4.68E-06
11.41	0.00120	12.09	3	6.00	2.00	3.33E-05	33.33	0.40	0.3	4.28E-06
7.63	0.00030	8.31	3	3.00	1.00	1.67E-05	16.67	0.20	0.2	3.12E-06
3.78	0.00000	4.46	3	0.00	0.00	0.00E+00	0.00	0.00	0.0	0.00E+00

TOTAL LOSS LOAD

$$Pc = Pc_1 + Pc_2 + Pc_3$$

$$P_1 = \frac{10.34 * (n_1)^2 * (Q_1^2) * lt}{(\phi_1^{5.33})}$$

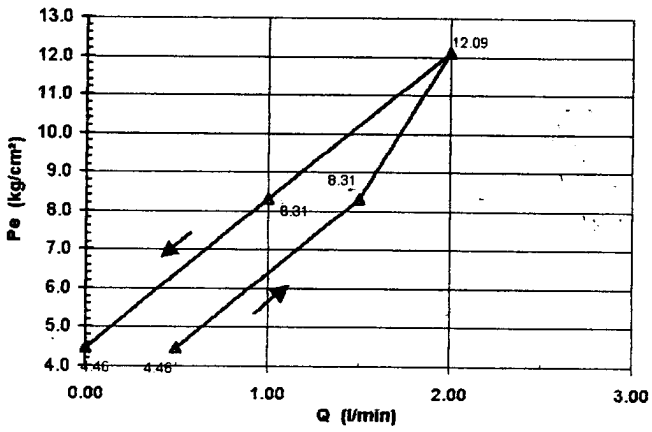
P1= loss load on steel pipe

$$P_2 = \frac{10.34 * (n_2)^2 * (Q_2^2) * lm}{(\phi_2^{5.33})}$$

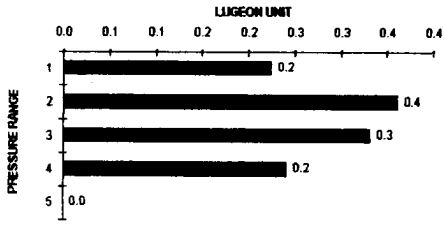
P2= loss load on plastic pipe

$$P_3 = \sum \alpha * (Q_1)$$

P3= loss load on reducciones, valvulas y uniones



VALUES OF LUGEON UNIT



PERMEABILITY (LU) = 0.3

PERMEABILITY TEST

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Swissboring Overseas Corporation Ltd.

CLIENT: AUTORIDAD DEL CANAL DE PANAMA	DATE: 2-July-2001	LUGEON TEST Nº: 19
PROJECT: ALTO CHAGRES DAM SITE	SITE: DAM SITE (right margin)	TESTED BY Geols. L.Peréz- R. Alvarado
BOREHOLE No.: CH-3	ELEVATION: 108.99 m.s.l	CHECKED BY:

Packer type:	Neumatic	Length (m) =	0.80	Water pump	Bean Royal 535	Flood (l/min) =	
				Test depth (m) from:	105.00	to:	110.00
Test length (cm):	50	L * Cos X º =	499.92	Depth of hole (m):	110.00	Dip X (º)=	30
Swivel H1 (m):		H1 =	2.45	Diameter of hole D (cm):	7.57	W.L. Before of test (m)=	5.9
Water level Ha (m):	5.9	Ha * Cos X º =	5.11	Hydrostatic load (kg/cm2):	Lh= (H1+Ha)/10	=	0.756

Steel pipe:	Length (m) =	lt	= 5.00	Plastic Pipe: Length (m)	lm = 5.00	Reducciones: Valv. uniones:	0.2
	Diameter ϕ_1	(m)	= 0.0603	Diameter ϕ_2	(m) = 0.0254	α Packer:	0.12
	Coef. rugosidad	n1	= 0.01	Coef. rugosidad	n2 : 0.008	Codo:	0.008

PRESSURE READING	LOSS PRESSURE	EFECTIVE PRESSURE	INJECTED TIME	WATER VOLUME	FLOOD			SPECIFIC ABSOPTION	LUGEON UNIT	PERMEABILITY COEFICIENT
Po	Plo=P1+P2+P3	~~Pe=Pm+Ph-Pc~~	t	Qt	Qo=Qt/t	Q1=Q/60000	Q2=Q*100/6	Ae = Q / L	$UL = \frac{10 * Ae}{Pe}$	$K = \frac{Q\,2}{2\pi Pe\ L} * \ln\frac{2L}{D}$
(kg/cm²)	(kg/cm²)	(kg/cm²)	(min)	(l)	(l/min)	(m³/s)	(cm³/s)	(l/min/m)	UL	(cm/s)
3.99	0.00030	4.75	3	3.00	1.00	1.67E-05	16.67	0.20	0.4	5.46E-06
7.98	0.00068	8.74	3	4.50	1.50	2.50E-05	25.00	0.30	0.3	4.45E-06
11.97	0.00477	12.73	3	12.00	4.00	6.67E-05	66.67	0.80	0.6	8.14E-06
7.98	0.00030	8.74	3	3.00	1.00	1.67E-05	16.67	0.20	0.2	2.97E-06
3.99	0.00000	4.75	3	0.00	0.00	0.00E+00	0.00	0.00	0.0	0.00E+00

TOTAL LOSS LOAD

$$Pc = Pc_1 + Pc_2 + Pc_3$$

$$P_1 = \frac{10.34 * (n_1)^2 * (Q_1^2) * lt}{(\phi_1^{5.33})}$$

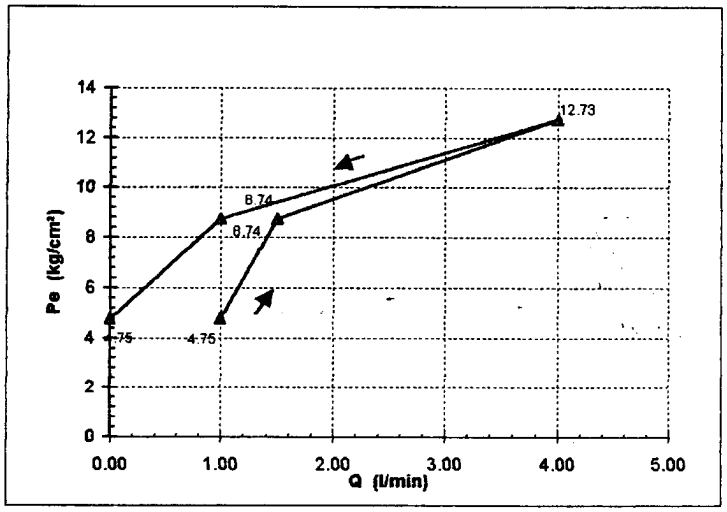
$$P_2 = \frac{10.34 * (n_2)^2 * (Q_2^2) * lm}{(\phi_2^{5.33})}$$

$$P_3 = \sum \alpha * (Q_1)$$

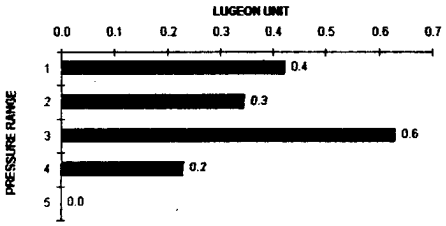
P1= loss load on steel pipe

P2= loss load on plastic pipe

P3= loss load on reducciones, valvulas y uniones



VALUES OF LUGEON UNIT



PERMEABILITY (LU) = 0.6

PERMEABILITY TEST

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Swissboring Overseas Corporation Ltd.

CLIENT: AUTORIDAD DEL CANAL DE PANAMA	DATE: 14-June-2001	LUGEON TEST Nº: 1
PROJECT: ALTO CHAGRES DAM SITE	SITE: DAM SITE (right margin)	TESTED BY Geols. L.Peréz- R. Alvarado
BOREHOLE No.: CH-6	ELEVATION: 116.59 m.s.l	CHECKED BY:

Packer type: Neumatic Length (m) = 0.80 Water pump Bean Royal 535 Flood (l/min) =

Test depth (m) from: 15.00 to: 20.00

Test length (cm): L * Cos X º = 500.00 Depth of hole (m): 20.00 Dip X (º)= 0

Swivel H1 (m): H1 = 1.50 Diameter of hole D (cm): 9.60 W.L. Before of test (m)= 8.7

Water level Ha (m): 8.7 Ha * Cos X º = 8.70 Hydrostatic load (kg/cm2): Lh= (H1+Ha)/10 = 1.020

Steel pipe: Length (m) = - 1t = 5.00 Diameter ϕ_1 (m) = 0.0603 Coef. rugosidad n1 = 0.01

Plastic Pipe: Length (m) 1 m = 5.00 Diameter ϕ_2 (m) = 0.0254 Coef. rugosidad n2 : 0.008

Reducciones: α Valv. uniones: 0.2 Packer: 0.12 Codo: 0.008

PRESSURE READING Po (kg/cm²)	LOSS PRESSURE Plo=P1+P2+P3 (kg/cm²)	EFECTIVE PRESSURE Pe=Pm+Ph-Pc (kg/cm²)	INJECTED TIME t (min)	WATER VOLUME Qt (l)	FLOOD Qo=Qt/t (l/min)	FLOOD Q1=Q/60000 (m³/s)	FLOOD Q2=Q*100/6 (cm³/s)	SPECIFIC ABSOPTION Ae = Q / L (l/min/m)	LUGEON UNIT $UL = \frac{10 * Ae}{Pe}$ UL	PERMEABILITY COEFICIENT $K = \frac{Q2}{2 \pi Pe L} * \ln \frac{2L}{D}$ (cm/s)
0.70	0.01841	1.70	3	189	63.00	1.05E-03	1050.00	12.60	74.0	9.12E-04
1.40	0.02883	2.39	3	237	79.00	1.32E-03	1316.67	15.80	66.1	8.14E-04
2.10	0.03902	3.08	3	276	92.00	1.53E-03	1533.33	18.40	59.7	7.36E-04
1.40	0.00035	2.42	3	195	65.00	1.08E-03	1083.33	13.00	53.7	6.62E-04
0.70	0.03105	1.69	3	246	82.00	1.37E-03	1366.67	16.40	97.1	1.20E-03

TOTAL LOSS LOAD

$$Pc = Pc_1 + Pc_2 + Pc_3$$

$$P_1 = \frac{10.34 * (n_1)^2 * (Q_1^2) * lt}{(\phi_1^{5.33})}$$

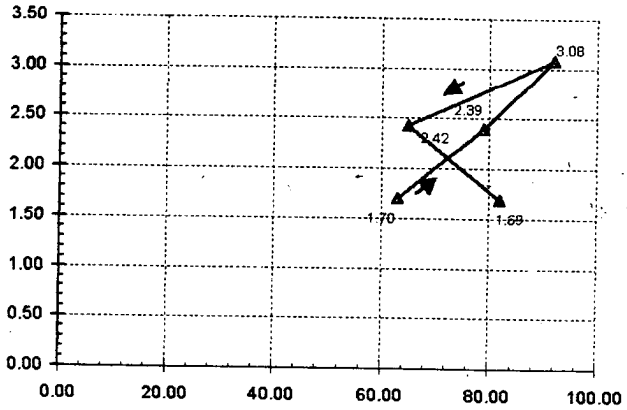
P1= loss load on steel pipe

$$P_2 = \frac{10.34 * (n_2)^2 * (Q_2^2) * lm}{(\phi_2^{5.33})}$$

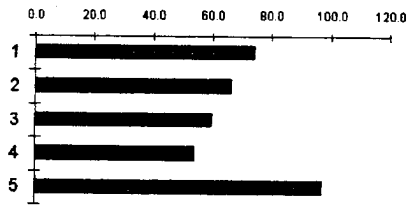
P2= loss load on plastic pipe

$$P_3 = \sum \alpha * (Q_1)$$

P3= loss load on reducciones, valvulas y uniones



VALUES OF LUGEON UNIT



PERMEABILITY (LU) = 59.7

PERMEABILITY TEST

swissboring

Swissboring Overseas Corporation Ltd.

CLIENT: AUTORIDAD DEL CANAL DE PANAMA	DATE: 15-June-2001	LUGEON TEST Nº: 2
PROJECT: ALTO CHAGRES DAM SITE	SITE: DAM SITE (right margin)	TESTED BY Geols. L.Peréz- R. Alvarado
BOREHOLE No.: CH-6	ELEVATION: 116.59 m.s.l	CHECKED BY:

Packer type: Neumatic Length (m) = 0.80 Water pump Bean Royal 535 Flood (l/min) =

Test depth (m) from: 20.00 to: 25.00

Test length (cm): L * Cos X° = 500.00 Depth of hole (m): 25.00 Dip X (°)= 0

Swivel H1 (m): H1 = 1.60 Diameter of hole D (cm): 9.60 W.L. Before of test (m)= 16.32

Water level Ha (m): 16.32 Ha * Cos X° = 16.32 Hydrostatic load (kg/cm2): Lh= (H1+Ha)/10 = 1.792

Steel pipe:			Plastic Pipe:			Reducciones:		
Length (m) =	lt	= 5.00	Length (m)	1 m	= 5.00	α	Valv. uniones:	0.2
Diameter ϕ_1	(m)	= 0.0603	Diameter ϕ_2	(m)	= 0.0254		Packer:	0.12
Coef. rugosidad	n1	= 0.01	Coef. rugosidad	n2	: 0.008		Codo:	0.008

PRESSURE READING	LOSS PRESSURE	EFECTIVE PRESSURE	INJECTED TIME	WATER VOLUME	FLOOD			SPECIFIC ABSOPTION	LUGEON UNIT	PERMEABILITY COEFICIENT
Po	Plo=P1+P2+P3	~~Pe=Pm-Pl-Pc~~	t	Qt	Qo=Qt/t	Q1=Q/60000	Q2=Q*100/6	Ae = Q / L	$UL = \frac{10 * Ae}{Pe}$	$K = \frac{Q2}{2\pi Pe L} * \ln\frac{2L}{D}$
(kg/cm²)	(kg/cm²)	(kg/cm²)	(min)	(l)	(l/min)	(m³/s)	(cm³/s)	(l/min/m)	UL	(cm/s)
0.91										
1.82	PERMEABILITY TEST WAS SUSPENDED BY WATER LEAKAGE									
2.80										
1.82										
0.91										

TOTAL LOSS LOAD

$$Pc = Pc_1 + Pc_2 + Pc_3$$

$$P_1 = \frac{10.34 * (n_1)^2 * (Q_1^2) * lt}{(\phi_1^{5.33})}$$

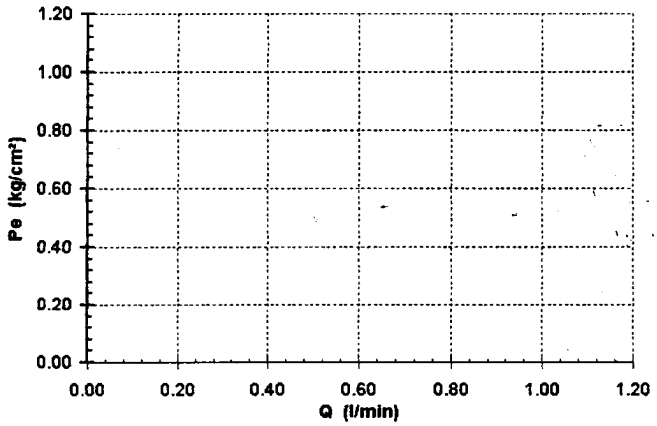
P1= loss load on steel pipe

$$P_2 = \frac{10.34 * (n_2)^2 * (Q_2^2) * lm}{(\phi_2^{5.33})}$$

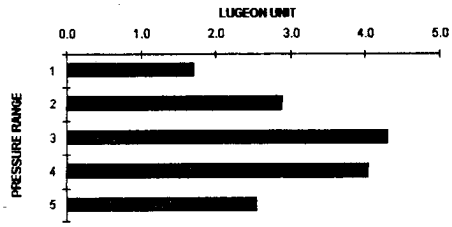
P2= loss load on plastic pipe

$$P_3 = \sum \alpha * (Q_1)$$

P3= loss load on reducciones, valvulas y uniones



VALUES OF LUGEON UNIT



PERMEABILITY (LU) = 0.0

PERMEABILITY TEST

swissboring

Swissboring Overseas Corporation Ltd.

CLIENT: AUTORIDAD DEL CANAL DE PANAMA	DATE: 15-June-2001	LUGEON TEST Nº: 3
PROJECT: ALTO CHAGRES DAM SITE	SITE: DAM SITE (right margin)	TESTED BY Geols. L.Peréz- R. Alvarado
BOREHOLE No.: CH-6	ELEVATION: 116.59 m.s.l	CHECKED BY:

Packer type: Neumatic Length (m) = 0.80 Water pump Bean Royal 535 Flood (l/min) =

Test depth (m) from: 25.00 *to:* 30.00

Test length (cm): L * Cos X° = 500.00 Depth of hole (m): 30.00 Dip X (°)= 0

Swivel H1 (m): H1 = 1.60 Diameter of hole D (cm): 9.60 W.L. Before of test (m)= 10.8

Water level Ha (m): 10.8 Ha * Cos X° = 10.80 Hydrostatic load (kg/cm2): Lh= (H1+Ha)/10 = 1.240

Steel pipe: Length (m) = 1t = 5.00 Diameter ϕ_1 (m) = 0.0603 Coef. rugosidad n1 = 0.01

Plastic Pipe: Length (m) 1 m = 5.00 Diameter ϕ_2 (m) = 0.0254 Coef. rugosidad n2 : 0.008

Reducciones: α Valv. uniones: 0.2 Packer: 0.12 Codo: 0.008

PRESSURE READING Po (kg/cm²)	LOSS PRESSURE Plo=P1+P2+P3 (kg/cm²)	EFECTIVE PRESSURE ~~Pe=Pm+Ph-Pc~~ (kg/cm²)	INJECTED TIME t (min)	WATER VOLUME Qt (l)	FLOOD Qo=Qt/t (l/min)	FLOOD Q1=Q/60000 (m³/s)	FLOOD Q2=Q*100/6 (cm³/s)	SPECIFIC ABSOPTION Ae = Q / L (l/min/m)	LUGEON UNIT $UL = \frac{10 * Ae}{Pe}$ UL	PERMEABILITY COEFICIENT $K = \frac{Q2}{2\pi Pe L} * \ln\frac{2L}{D}$ (cm/s)
1.12	0.00120	2.36	3	6	2.00	3.33E-05	33.33	0.40	1.7	2.09E-05
2.24	0.00744	3.47	3	15	5.00	8.33E-05	83.33	1.00	2.9	3.55E-05
3.43	0.02972	4.64	3	30	10.00	1.67E-04	166.67	2.00	4.3	5.31E-05
2.24	0.01458	3.47	3	21	7.00	1.17E-04	116.67	1.40	4.0	4.98E-05
1.12	0.00269	2.36	3	9	3.00	5.00E-05	50.00	0.60	2.5	3.14E-05

TOTAL LOSS LOAD

$$Pc = Pc_1 + Pc_2 + Pc_3$$

$$P_1 = \frac{10.34 * (n_1)^2 * (Q_1^2) * lt}{(\phi_1^{5.33})}$$

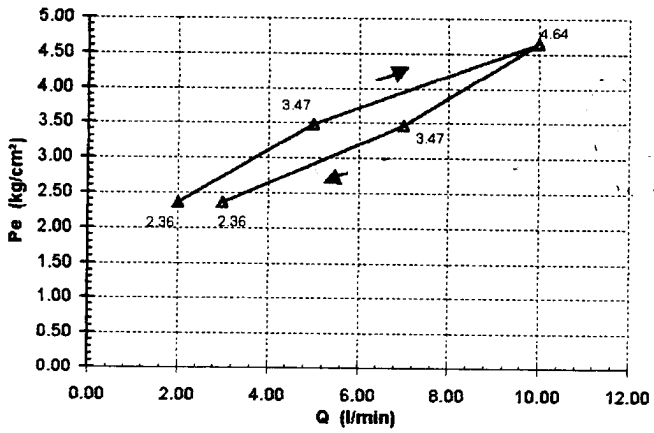
P1= loss load on steel pipe

$$P_2 = \frac{10.34 * (n_2)^2 * (Q_2^2) * lm}{(\phi_2^{5.33})}$$

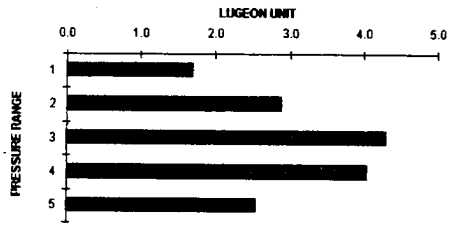
P2= loss load on plastic pipe

$$P_3 = \sum \alpha * (Q_1)$$

P3= loss load on reducciones, valvulas y uniones



VALUES OF LUGEON UNIT



PERMEABILITY (LU) = 4.3

PERMEABILITY TEST

swissboring
Swissboring Overseas Corporation Ltd.

CLIENT: AUTORIDAD DEL CANAL DE PANAMA	DATE: 15-June-2001	LUGEON TEST Nº: 4
PROJECT: ALTO CHAGRES DAM SITE	SITE: DAM SITE (right margin)	TESTED BY Geols. L.Peréz- R. Alvarado
BOREHOLE No.: CH-6	ELEVATION: 116.59 m.s.l	CHECKED BY:

Packer type: Neumatic Length (m) = 0.80 Water pump Bean Royal 535 Flood (l/min) =

Test depth (m) from: 30.00 to: 35.00

Test length (cm): L * Cos X° = 500.00 Depth of hole (m): 35.00 Dip X (°)= 0

Swivel H1 (m): H1 = 15.50 Diameter of hole D (cm): 7.57 W.L. Before of test (m)= 11.9

Water level Ha (m): 11.9 Ha * Cos X° = 11.90 Hydrostatic load (kg/cm2): Lh= (H1+Ha)/10 = 2.740

Steel pipe:				Plastic Pipe:				Reducciones:		
Length (m) =	lt	=	5.00	Length (m)	1 m	=	5.00	Valv. uniones:		0.2
Diameter ϕ_1	(m)	=	0.0603	Diameter ϕ_2	(m)	=	0.0254	α Packer:		0.12
Coef. rugosidad	n1	=	0.01	Coef. rugosidad	n2	=	0.008	Codo:		0.008

PRESSURE READING	LOSS PRESSURE	EFECTIVE PRESSURE	INJECTED TIME	WATER VOLUME	FLOOD			SPECIFIC ABSOPTION	LUGEON UNIT	PERMEABILITY COEFICIENT
Po	Plo=P1+P2+P3	~~Pe Pm Ph Pc~~	t	Qt	Qo=Qt/t	Q1=Q/60000	Q2=Q*100/6	Ae = Q / L	$UL = \frac{10 * Ae}{Pe}$	$K = \frac{Q2}{2\pi Pe\ L} * \ln\frac{2L}{D}$
(kg/cm²)	(kg/cm²)	(kg/cm²)	(min)	(l)	(l/min)	(m³/s)	(cm³/s)	(l/min/m)	UL	(cm/s)
1.40	0.00030	4.14	3	3.00	1.00	1.67E-05	16.67	0.20	0.5	6.26E-06
2.80	0.00030	5.54	3	3.00	1.00	1.67E-05	16.67	0.20	0.4	4.68E-06
4.20	0.00068	6.94	3	4.50	1.50	2.50E-05	25.00	0.30	0.4	5.60E-06
2.80	0.00008	5.54	3	1.50	0.50	8.33E-06	8.33	0.10	0.2	2.34E-06
1.40	0.00000	4.14	3	0.00	0.00	0.00E+00	0.00	0.00	0.0	0.00E+00

TOTAL LOSS LOAD

$$Pc = Pc_1 + Pc_2 + Pc_3$$

$$P_1 = \frac{10.34 * (n_1)^2 * (Q_1^2) * lt}{(\phi_1^{5.33})}$$

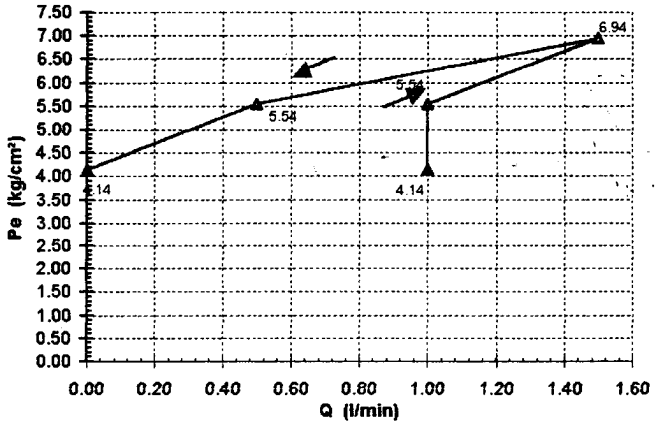
P1= loss load on steel pipe

$$P_2 = \frac{10.34 * (n_2)^2 * (Q_2^2) * lm}{(\phi_2^{5.33})}$$

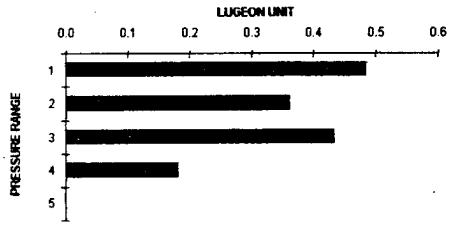
P2= loss load on plastic pipe

$$P_3 = \sum \alpha * (Q_1)$$

P3= loss load on reducciones, valvulas y uniones



VALUES OF LUGEON UNIT



PERMEABILITY (LU) = 0.4

PERMEABILITY TEST

swissboring

Swissboring Overseas Corporation Ltd.

CLIENT: AUTORIDAD DEL CANAL DE PANAMA	DATE: 15-June-2001	LUGEON TEST Nº: 5
PROJECT: ALTO CHAGRES DAM SITE	SITE: DAM SITE (right margin)	TESTED BY Geols. L.Peréz- R. Alvarado
BOREHOLE No.: CH-6	ELEVATION: 116.59 m.s.l	CHECKED BY:

Packer type:	Neumatic	Length (m) =	0.80	Water pump	Bean Royal 535	Flood (l/min) =	
				Test depth (m) from:	35.00	to:	40.00
Test length (cm):	50	L * Cos X° =	500.00	Depth of hole (m):	40.00	Dip X (°)=	0
Swivel H1 (m):		H1 =	1.55	Diameter of hole D (cm):	7.57	W.L. Before of test (m)=	10.75
Water level Ha (m):	10.75	Ha * Cos X° =	10.75	Hydrostatic load (kg/cm2):	Lh= (H1+Ha)/10 =		1.230

Steel pipe:	Length (m) =	1t	=	5.00	Plastic Pipe:	Length (m)	1 m = 5.00	Reducciones:	Valv. uniones: 0.2
	Diameter ϕ_1	(m)	=	0.0603		Diameter ϕ_2	(m) = 0.0254	α	Packer: 0.12
	Coef. rugosidad	n1	=	0.01		Coef. rugosidad	n2 : 0.008		Codo: 0.008

PRESSURE READING Po (kg/cm²)	LOSS PRESSURE Plo=P1+P2+P3 (kg/cm²)	EFECTIVE PRESSURE ~~Pe=Pm+Ph-Pc~~ (kg/cm²)	INJECTED TIME t (min)	WATER VOLUME Qt (l)	FLOOD Qo=Qt/t (l/min)	FLOOD Q1=Q/60000 (m³/s)	FLOOD Q2=Q*100/6 (cm³/s)	SPECIFIC ABSOPTION Ae = Q / L (l/min/m)	LUGEON UNIT $UL = \frac{10 * Ae}{Pe}$ UL	PERMEABILITY COEFICIENT $K = \frac{Q2}{2\pi Pe L} * \ln\frac{2L}{D}$ (cm/s)
1.54	0.00000	2.77	3	0.00	0.00	0.00E+00	0.00	0.00	0.0	0.00E+00
3.08	0.00000	4.31	3	0.00	0.00	0.00E+00	0.00	0.00	0.0	0.00E+00
4.69	0.00008	5.92	3	1.50	0.50	8.33E-06	8.33	0.10	0.2	2.19E-06
3.08	0.00000	4.31	3	0.00	0.00	0.00E+00	0.00	0.00	0.0	0.00E+00
1.54	0.00000	2.77	3	0.00	0.00	0.00E+00	0.00	0.00	0.0	0.00E+00

TOTAL LOSS LOAD

$$Pc = Pc_1 + Pc_2 + Pc_3$$

$$P_1 = \frac{10.34 * (n_1)^2 * (Q_1^2) * lt}{(\phi_1^{5.33})}$$

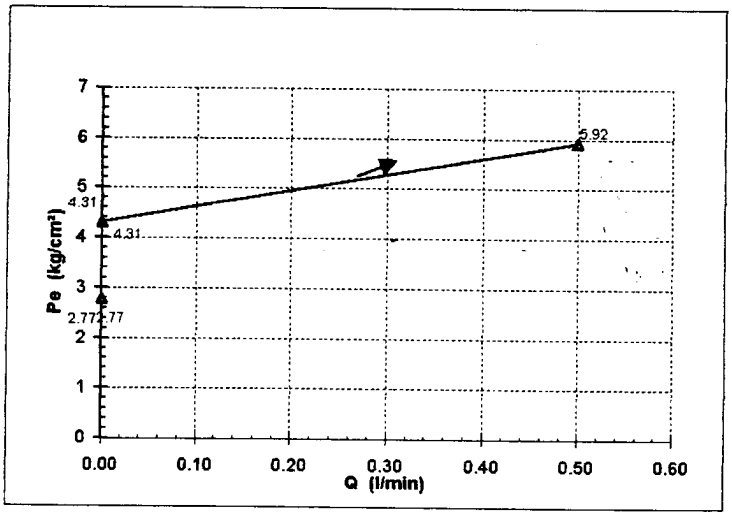
P1= loss load on steel pipe

$$P_2 = \frac{10.34 * (n_2)^2 * (Q_2^2) * lm}{(\phi_2^{5.33})}$$

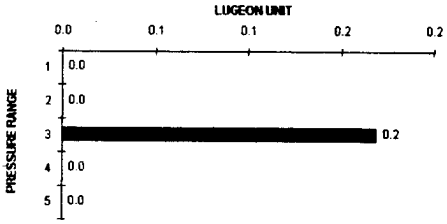
P2= loss load on plastic pipe

$$P_3 = \sum \alpha * (Q_1)$$

P3= loss load on reducciones, valvulas y uniones



VALUES OF LUGEON UNIT



PERMEABILITY (LU) = 0.2

PERMEABILITY TEST

swissboring
Swissboring Overseas Corporation Ltd.

CLIENT: AUTORIDAD DEL CANAL DE PANAMA	DATE: 17-June-2001	LUGEON TEST Nº: 6
PROJECT: ALTO CHAGRES DAM SITE	SITE: DAM SITE (right margin)	TESTED BY Geols. L.Peréz- R. Alvarado
BOREHOLE No.: CH-6	ELEVATION: 116.59 m.s.l	CHECKED BY:

Packer type: Neumatic Length (m) = 0.80 Water pump Bean Royal 535 Flood (l/min) =

Test depth (m) from: 40.00 to: 45.00

Test length (cm): L * Cos X° = 500.00 Depth of hole (m): 45.00 Dip X (°)= 0

Swivel H1 (m): H1 = 1.60 Diameter of hole D (cm): 7.57 W.L. Before of test (m)= 12.54

Water level Ha (m): 12.54 Ha * Cos X° = 12.54 Hydrostatic load (kg/cm2): Lh= (H1+Ha)/10 = 1.414

Steel pipe:			Plastic Pipe:			Reducciones:		
Length (m) =	lt	= 5.00	Length (m)	1 m	= 5.00	Valv. uniones:		0.2
Diameter ϕ_1	(m)	= 0.0603	Diameter ϕ_2	(m)	= 0.0254	α	Packer:	0.12
Coef. rugosidad	n1	= 0.01	Coef. rugosidad	n2	: 0.008		Codo:	0.008

PRESSURE READING	LOSS PRESSURE	EFECTIVE PRESSURE	INJECTED TIME	WATER VOLUME	FLOOD			SPECIFIC ABSOPTION	LUGEON UNIT	PERMEABILITY COEFICIENT
Po	Plo=P1+P2+P3	~~Pe=Pm+Ph-Pc~~	t	Qt	Qo=Qt/t	Q1=Q/60000	Q2=Q*100/6	Ae = Q / L	$UL = \frac{10 * Ae}{Pe}$	$K = \frac{Q2}{2\pi Pe\ L} * \ln\frac{2L}{D}$
(kg/cm²)	(kg/cm²)	(kg/cm²)	(min)	(l)	(l/min)	(m³/s)	(cm³/s)	(l/min/m)	UL	(cm/s)
1.75	0.00000	3.16	3	0.00	0.00	0.00E+00	0.00	0.00	0.0	0.00E+00
3.50	0.00000	4.92	3	0.00	0.00	0.00E+00	0.00	0.00	0.0	0.00E+00
5.39	0.20071	6.61	3	78.00	26.00	4.33E-04	433.33	5.20	7.9	1.02E-04
3.50	0.00000	4.92	3	0.00	0.00	0.00E+00	0.00	0.00	0.0	0.00E+00
1.75	0.00000	3.16	3	0.00	0.00	0.00E+00	0.00	0.00	0.0	0.00E+00

TOTAL LOSS LOAD

$$Pc = Pc_1 + Pc_2 + Pc_3$$

$$P_1 = \frac{10.34 * (n_1)^2 * (Q_1^2) * lt}{(\phi_1^{5.33})}$$

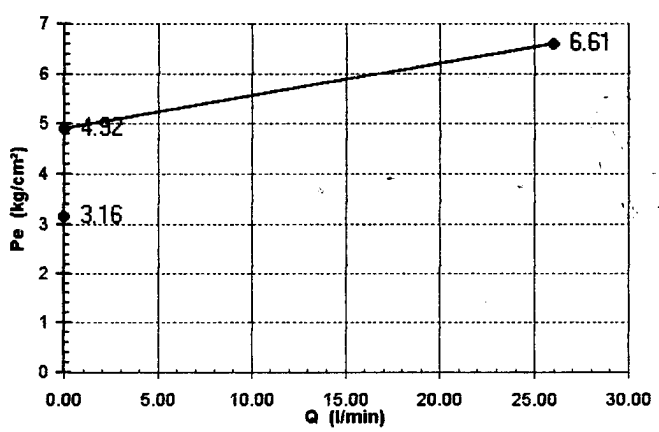
P1= loss load on steel pipe

$$P_2 = \frac{10.34 * (n_2)^2 * (Q_2^2) * lm}{(\phi_2^{5.33})}$$

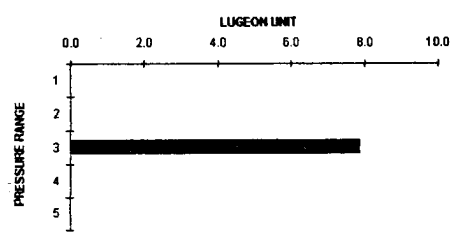
P2= loss load on plastic pipe

$$P_3 = \sum \alpha * (Q_1)$$

P3= loss load on reducciones, valvulas y uniones



VALUES OF LUGEON UNIT



PERMEABILITY (LU) = 7.9

PERMEABILITY TEST

swissboring
Swissboring Overseas Corporation Ltd.

CLIENT: AUTORIDAD DEL CANAL DE PANAMA	DATE: - 16-June-2001	LUGEON TEST Nº: 7
PROJECT: ALTO CHAGRES DAM SITE	SITE: DAM SITE (right margin)	TESTED BY Geols. L.Peréz- R. Alvarado
BOREHOLE No.: CH-6	ELEVATION: 116.59 m.s.l	CHECKED BY:

Packer type: Neumatic Length (m) = 0.80 Water pump Bean Royal 535 Flood (l/min) =

Test depth (m) from: 45.00 to: 50.00

Test length (cm): L * Cos X° = 500.00 Depth of hole (m): 50.00 Dip X (°)= 0

Swivel H1 (m): H1 = 1.60 Diameter of hole D (cm): 7.57 W.L. Before of test (m)= 12.3

Water level Ha (m): 12.3 Ha * Cos X° = 12.30 Hydrostatic load (kg/cm2): Lh= (H1+Ha)/10 = 1.390

Steel pipe:				Plastic Pipe:				Reducciones:		
Length (m) =	1t	=	5.00	Length (m)	1 m	=	5.00	Valv. uniones:		0.2
Diameter ϕ_1	(m)	=	0.0603	Diameter ϕ_2	(m)	=	0.0254	α Packer:		0.12
Coef. rugosidad	n1	=	0.01	Coef. rugosidad	n2	:	0.008	Codo:		0.008

PRESSURE READING	LOSS PRESSURE	EFECTIVE PRESSURE	INJECTED TIME	WATER VOLUME	FLOOD			SPECIFIC ABSOPTION	LUGEON UNIT	PERMEABILITY COEFICIENT
Po	Plo=P1+P2+P3	~~Pe=Po-Plo-R~~	t	Qt	Qo=Qt/t	Q1=Q/60000	Q2=Q*100/6	Ae = Q / L	$UL = \frac{10*Ae}{Pe}$	$K = \frac{Q2}{2\pi Pe\ L} * \ln\frac{2L}{D}$
(kg/cm²)	(kg/cm²)	(kg/cm²)	(min)	(l)	(l/min)	(m³/s)	(cm³/s)	(l/min/m)	UL	(cm/s)
1.96	0.00030	3.35	3	3.00	1.00	1.67E-05	16.67	0.20	0.6	7.73E-06
3.92	0.00120	5.31	3	6.00	2.00	3.33E-05	33.33	0.40	0.8	9.76E-06
6.02	0.23277	7.18	3	84.00	28.00	4.67E-04	466.67	5.60	7.8	1.01E-04
3.92	0.00030	5.31	3	3.00	1.00	1.67E-05	16.67	0.20	0.4	4.88E-06
1.96	0.00000	3.35	3	0.00	0.00	0.00E+00	0.00	0.00	0.0	0.00E+00

TOTAL LOSS LOAD

$$Pc = Pc_1 + Pc_2 + Pc_3$$

$$P_1 = \frac{10.34 * (n_1)^2 * (Q_1^2) * lt}{(\phi_1^{5.33})}$$

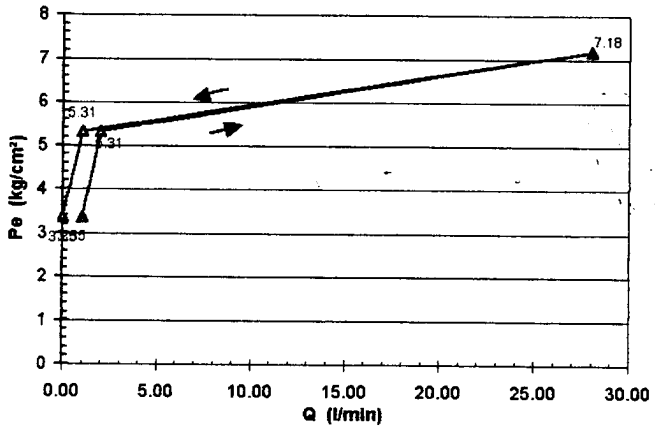
P1= loss load on steel pipe

$$P_2 = \frac{10.34 * (n_2)^2 * (Q_2^2) * lm}{(\phi_2^{5.33})}$$

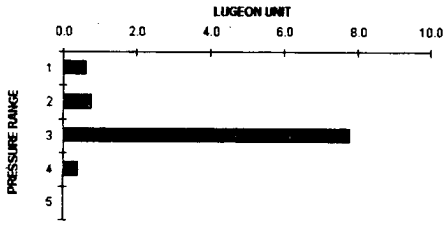
P2= loss load on plastic pipe

$$P_3 = \sum \alpha * (Q_1)$$

P3= loss load on reducciones, valvulas y uniones



VALUES OF LUGEON UNIT



PERMEABILITY (LU) = 7.8

PERMEABILITY TEST

swissboring
Swissboring Overseas Corporation Ltd.

CLIENT: AUTORIDAD DEL CANAL DE PANAMA	DATE: 17-June-2001	LUGEON TEST Nº: 8
PROJECT: ALTO CHAGRES DAM SITE	SITE: DAM SITE (right margin)	TESTED BY Geols. L.Peréz- R. Alvarado
BOREHOLE No.: CH-6	ELEVATION: 116.59 m.s.l	CHECKED BY:

Packer type: Neumatic Length (m) = 0.80 Water pump Bean Royal 535 Flood (l/min) =

Test depth (m) from: 50.00 to: 55.00

Test length (cm): L * Cos X° = 500.00 Depth of hole (m): 55.00 Dip X (°)= 0

Swivel H1 (m): H1 = 1.14 Diameter of hole D (cm): 7.57 W.L. Before of test (m)= 16

Water level Ha (m): 16 Ha * Cos X° = 16.00 Hydrostatic load (kg/cm2): Lh= (H1+Ha)/10 = 1.714

Steel pipe:				Plastic Pipe:				Reducciones:		
Length (m) =	lt	=	5.00	Length (m)	1 m	=	5.00	Valv. uniones:		0.2
Diameter ϕ_1	(m)	=	0.0603	Diameter ϕ_2	(m)	=	0.0254	α	Packer:	0.12
Coef. rugosidad	n1	=	0.01	Coef. rugosidad	n2	=	0.008		Codo:	0.008

PRESSURE READING	LOSS PRESSURE	EFECTIVE PRESSURE	INJECTED TIME	WATER VOLUME	FLOOD			SPECIFIC ABSOPTION	LUGEON UNIT	PERMEABILITY COEFICIENT
Po	Plo=P1+P2+P3	~~Pe=Po-Plo-Pc~~	t	Qt	Qo=Qt/t	Q1=Q/60000	Q2=Q*100/6	Ae = Q / L	$UL = \frac{10 * Ae}{Pe}$	$K = \frac{Q2}{2\pi Pe\ L} * \ln\frac{2L}{D}$
(kg/cm²)	(kg/cm²)	(kg/cm²)	(min)	(l)	(l/min)	(m³/s)	(cm³/s)	(l/min/m)	UL	(cm/s)
1.89	0.00000	3.60	3	0.00	0.00	0.00E+00	0.00	0.00	0.0	0.00E+00
3.85	0.00008	5.57	3	1.50	0.50	8.33E-06	8.33	0.10	0.2	2.33E-06
5.74	0.00030	7.46	3	3.00	1.00	1.67E-05	16.67	0.20	0.3	3.47E-06
3.85	0.00008	5.57	3	1.50	0.50	8.33E-06	8.33	0.10	0.2	2.33E-06
1.89	0.00000	3.60	3	0.00	0.00	0.00E+00	0.00	0.00	0.0	0.00E+00

TOTAL LOSS LOAD

$$Pc = Pc_1 + Pc_2 + Pc_3$$

$$P_1 = \frac{10.34 * (n_1)^2 * (Q_1^2) * lt}{(\phi_1^{5.33})}$$

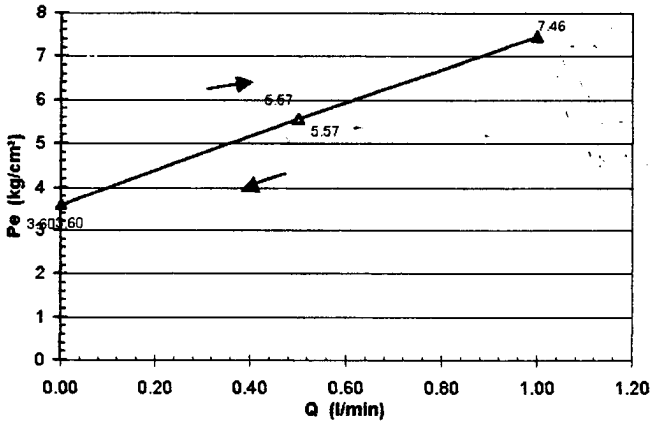
P1= loss load on steel pipe

$$P_2 = \frac{10.34 * (n_2)^2 * (Q_2^2) * lm}{(\phi_2^{5.33})}$$

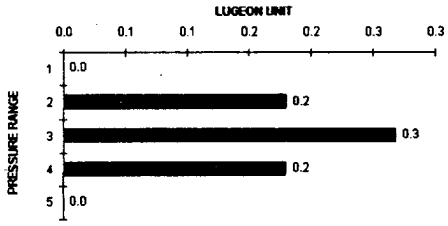
P2= loss load on plastic pipe

$$P_3 = \sum \alpha * (Q_1)$$

P3= loss load on reducciones, valvulas y uniones



VALUES OF LUGEON UNIT



PERMEABILITY (LU) = 0.3

PERMEABILITY TEST

swissboring

Swissboring Overseas Corporation Ltd.

CLIENT: AUTORIDAD DEL CANAL DE PANAMA	DATE: 17-June-2001	LUGEON TEST Nº: 9
PROJECT: ALTO CHAGRES DAM SITE	SITE: DAM SITE (right margin)	TESTED BY Geols. L.Peréz- R. Alvarado
BOREHOLE No.: CH-6	ELEVATION: 116.59 m.s.l	CHECKED BY:

Packer type: Neumatic Length (m) = 0.80 Water pump Bean Royal 535 Flood (l/min) =

Test depth (m) from: 55.00 to: 60.00

Test length (cm): 50 L * Cos X º = 500.00 Depth of hole (m): 60.00 Dip X (º)= 0

Swivel H1 (m): H1 = 1.60 Diameter of hole D (cm): 7.57 W.L. Before of test (m)= 10.7

Water level Ha (m): 10.7 Ha * Cos X º = 10.70 Hydrostatic load (kg/cm2): Lh= (H1+Ha)/10 = 1.230

Steel pipe:			Plastic Pipe:			Reducciones:		
Length (m) =	1t	= 5.00	Length (m)	1 m	= 5.00	Valv. uniones:		0.2
Diameter ϕ_1	(m)	= 0.0603	Diameter ϕ_2	(m)	= 0.0254	α	Packer:	0.12
Coef. rugosidad	n1	= 0.01	Coef. rugosidad	n2	: 0.008		Codo:	0.008

PRESSURE READING Po (kg/cm²)	LOSS PRESSURE Plo=P1+P2+P3 (kg/cm²)	EFECTIVE PRESSURE Pe=Pm+Ph-Pc (kg/cm²)	INJECTED TIME t (min)	WATER VOLUME Qt (l)	FLOOD Qo=Qt/t (l/min)	FLOOD Q1=Q/60000 (m³/s)	FLOOD Q2=Q*100/6 (cm³/s)	SPECIFIC ABSOPTION Ae = Q / L (l/min/m)	LUGEON UNIT $UL = \frac{10 * Ae}{Pe}$ UL	PERMEABILITY COEFICIENT $K = \frac{Q2}{2\pi Pe L} * \ln\frac{2L}{D}$ (cm/s)
2.45	0.00000	3.68	3	0.00	0.00	0.00E+00	0.00	0.00	0.0	0.00E+00
4.90	0.00000	6.13	3	0.00	0.00	0.00E+00	0.00	0.00	0.0	0.00E+00
7.35	0.00030	8.58	3	3.00	1.00	1.67E-05	16.67	0.20	0.2	3.02E-06
4.90	0.00000	6.13	3	0.00	0.00	0.00E+00	0.00	0.00	0.0	0.00E+00
2.45	0.00000	3.68	3	0.00	0.00	0.00E+00	0.00	0.00	0.0	0.00E+00

TOTAL LOSS LOAD

$$Pc = Pc_1 + Pc_2 + Pc_3$$

$$P_1 = \frac{10.34 * (n_1)^2 * (Q_1^2) * lt}{(\phi_1^{5.33})}$$

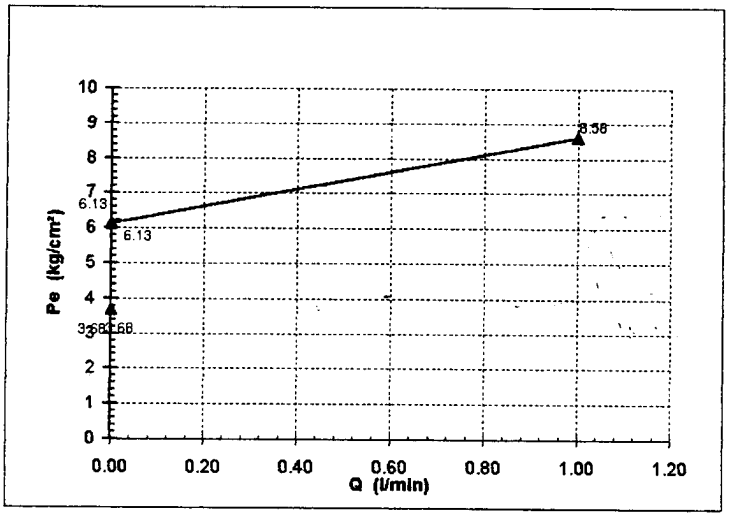
P1= loss load on steel pipe

$$P_2 = \frac{10.34 * (n_2)^2 * (Q_2^2) * lm}{(\phi_2^{5.33})}$$

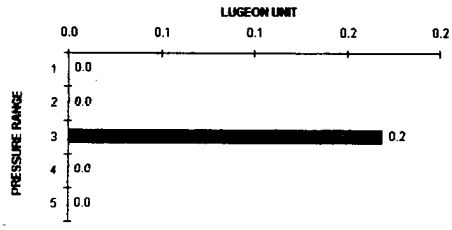
P2= loss load on plastic pipe

$$P_3 = \sum \alpha * (Q_1)$$

P3= loss load on reducciones, valvulas y uniones



VALUES OF LUGEON UNIT



PERMEABILITY (LU) = 0.2

PERMEABILITY TEST

swissboring
Swissboring Overseas Corporation Ltd.

CLIENT: AUTORIDAD DEL CANAL DE PANAMA	DATE: 18-June-2001	LUGEON TEST Nº: 10
PROJECT: ALTO CHAGRES DAM SITE	SITE: DAM SITE (right margin)	TESTED BY Geols. L.Peréz- R. Alvarado
BOREHOLE No.: CH-6	ELEVATION: 116.59 m.s.l	CHECKED BY:

Packer type: Neumatic Length (m) = 0.80 Water pump Bean Royal 535 Flood (l/min) =
Test depth (m) from: 60.00 to: 65.00

Test length (cm): L * Cos X º = 500.00 Depth of hole (m): 65.00 Dip X (º)= 0
Swivel H1 (m): H1 = 1.60 Diameter of hole D (cm): 7.57 W.L. Before of test (m)= 10.06
Water level Ha (m): 10.06 Ha * Cos X º = 10.06 Hydrostatic load (kg/cm2): Lh= (H1+Ha)/10 = 1.166

Steel pipe: Length (m) = lt = 5.00 Diameter ϕ_1 (m) = 0.0603 Coef. rugosidad n1 = 0.01
Plastic Pipe: Length (m) 1 m = 5.00 Diameter ϕ_2 (m) = 0.0254 Coef. rugosidad n2 : 0.008
Reducciones: Valv. uniones: 0.2 α Packer: 0.12 Codo: 0.008

PRESSURE READING Po (kg/cm²)	LOSS PRESSURE Plo=P1+P2+P3 (kg/cm²)	EFECTIVE PRESSURE ~~Pc=Pm+Ph-Pc~~ (kg/cm²)	INJECTED TIME t (min)	WATER VOLUME Qt (l)	FLOOD Qo=Qt/t (l/min)	FLOOD Q1=Q/60000 (m³/s)	FLOOD Q2=Q*100/6 (cm³/s)	SPECIFIC ABSOPTION Ae = Q / L (l/min/m)	LUGEON UNIT $UL = \frac{10 * Ae}{Pe}$ UL	PERMEABILITY COEFICIENT $K = \frac{Q2}{2\pi Pe L} * \ln\frac{2L}{D}$ (cm/s)
2.66	0.00030	3.83	3	3.00	1.00	1.67E-05	16.67	0.20	0.5	6.77E-06
5.32	0.00744	6.48	3	15.00	5.00	8.33E-05	83.33	1.00	1.5	2.00E-05
7.98	0.02972	9.12	3	30.00	10.00	1.67E-04	166.67	2.00	2.2	2.84E-05
5.32	0.01071	6.48	3	18.00	6.00	1.00E-04	100.00	1.20	1.9	2.40E-05
2.66	0.00120	3.83	3	6.00	2.00	3.33E-05	33.33	0.40	1.0	1.35E-05

TOTAL LOSS LOAD

$$Pc = Pc_1 + Pc_2 + Pc_3$$

$$P_1 = \frac{10.34 * (n_1)^2 * (Q_1^2) * lt}{(\phi_1^{5.33})}$$

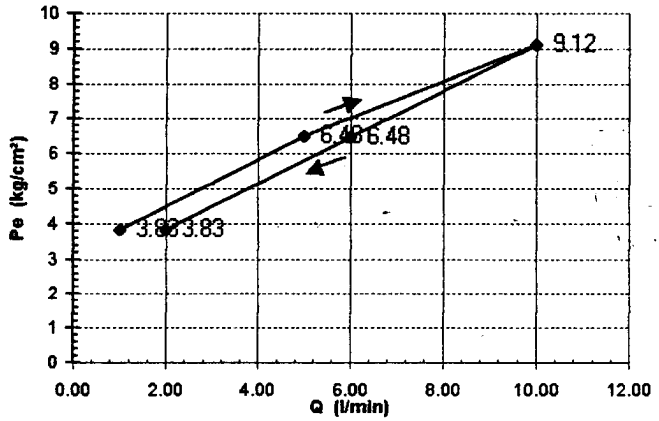
$$P_2 = \frac{10.34 * (n_2)^2 * (Q_2^2) * lm}{(\phi_2^{5.33})}$$

$$P_3 = \sum \alpha * (Q_1)$$

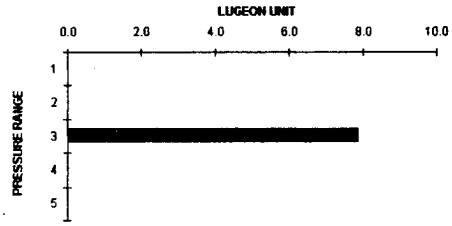
P1= loss load on steel pipe

P2= loss load on plastic pipe

P3= loss load on reducciones, valvulas y uniones



VALUES OF LUGEON UNIT



PERMEABILITY (LU) = 2.2

PERMEABILITY TEST

swissboring

Swissboring Overseas Corporation Ltd.

CLIENT: AUTORIDAD DEL CANAL DE PANAMA	DATE: 17-June-2001	LUGEON TEST Nº: 11
PROJECT: ALTO CHAGRES DAM SITE	SITE: DAM SITE (right margin)	TESTED BY Geols. L.Peréz- R. Alvarado
BOREHOLE No.: CH-6	ELEVATION: 116.59 m.s.l	CHECKED BY:

Packer type: Neumatic Length (m) = 0.80 Water pump Bean Royal 535 Flood (l/min) =

Test depth (m) from: 65.00 to: 70.00

Test length (cm): L * Cos X º = 500.00 Depth of hole (m): 70.00 Dip X (º)= 0

Swivel H1 (m): H1 = 1.60 Diameter of hole D (cm): 7.57 W.L. Before of test (m)= 10.64

Water level Ha (m): 10.64 Ha * Cos X º = 10.64 Hydrostatic load (kg/cm2): Lh= (H1+Ha)/10 = 1.224

Steel pipe:			Plastic Pipe:			Reducciones:		
Length (m) =	1t	= 5.00	Length (m)	1 m	= 5.00	α	Valv. uniones:	0.2
Diameter ϕ_1	(m)	= 0.0603	Diameter ϕ_2	(m)	= 0.0254		Packer:	0.12
Coef. rugosidad	n1	= 0.01	Coef. rugosidad	n2	: 0.008		Codo:	0.008

PRESSURE READING	LOSS PRESSURE	EFECTIVE PRESSURE	INJECTED TIME	WATER VOLUME	FLOOD			SPECIFIC ABSOPTION	LUGEON UNIT	PERMEABILITY COEFICIENT
Po	Pto=P1+P2+P3	Pe=Pm+Pc	t	Qt	Qo=Qt/t	Q1=Q/60000	Q2=Q*100/6	Ae = Q / L	$UL = \frac{10 * Ae}{Pe}$	$K = \frac{Q2}{2\pi Pe\ L} * \ln \frac{2L}{D}$
(kg/cm²)	(kg/cm²)	(kg/cm²)	(min)	(l)	(l/min)	(m³/s)	(cm³/s)	(l/min/m)	UL	(cm/s)
2.87	0.00000	4.10	3	0.00	0.00	0.00E+00	0.00	0.00	0.0	0.00E+00
5.74	0.00030	6.97	3	3.00	1.00	1.67E-05	16.67	0.20	0.3	3.72E-06
8.61	0.01071	9.83	3	18.00	6.00	1.00E-04	100.00	1.20	1.2	1.58E-05
5.74	0.00120	6.97	3	6.00	2.00	3.33E-05	33.33	0.40	0.6	7.44E-06
2.87	0.00000	4.10	3	0.00	0.00	0.00E+00	0.00	0.00	0.0	0.00E+00

TOTAL LOSS LOAD

$$Pc = Pc_1 + Pc_2 + Pc_3$$

$$P_1 = \frac{10.34 * (n_1)^2 * (Q_1^2) * lt}{(\phi_1^{5.33})}$$

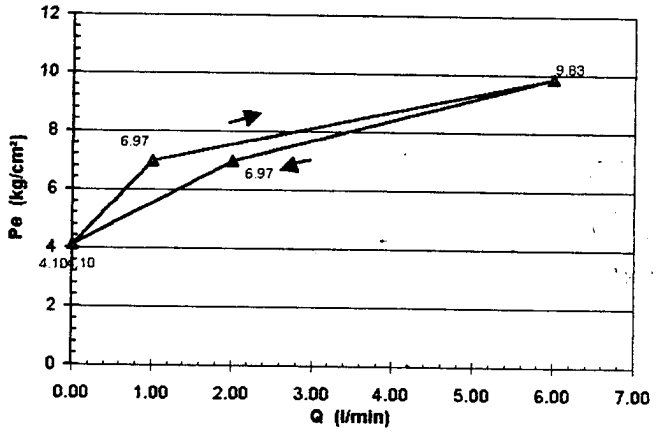
P1= loss load on steel pipe

$$P_2 = \frac{10.34 * (n_2)^2 * (Q_2^2) * lm}{(\phi_2^{5.33})}$$

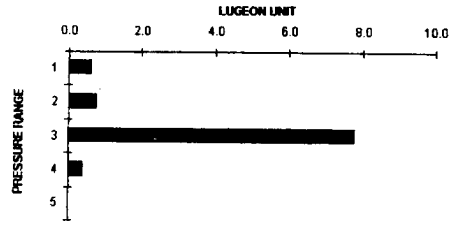
P2= loss load on plastic pipe

$$P_3 = \sum \alpha * (Q_1)$$

P3= loss load on reducciones, valvulas y uniones



VALUES OF LUGEON UNIT



PERMEABILITY (LU) = 1.2

PERMEABILITY TEST

swissboring
Swissboring Overseas Corporation Ltd.

CLIENT: AUTORIDAD DEL CANAL DE PANAMA	DATE: 5-June-2001	LUGEON TEST Nº: 1
PROJECT: ALTO CHAGRES DAM SITE	SITE: DAM SITE (right margin)	TESTED BY Geols. L.Peréz- R. Alvarado
BOREHOLE No.: CH-7	ELEVATION: 141.43 m.s.l	CHECKED BY:

Packer type: Neumatic Length (m) = 0.80 Water pump Bean Royal 535 Flood (l/min) =

Test depth (m) from: 55.00 to: 60.00

Test length (cm): L * Cos X° = 500.00 Depth of hole (m): 60.00 Dip X (°)= 0

Swivel H1 (m): H1 = 1.30 Diameter of hole D (cm): 7.57 W.L. Before of test (m)= 36.9

Water level Ha (m): 36.9 Ha * Cos X° = 36.90 Hydrostatic load (kg/cm2): Lh= (H1+Ha)/10 = 3.820

Steel pipe			Plastic Pipe			Reducciones		
Length (m) =	1t	= 5.00	Length (m)	1 m	= 5.00	Valv. uniones:		0.2
Diameter ϕ_1	(m)	= 0.0603	Diameter ϕ_2	(m)	= 0.0254	α Packer		0.12
Coef. rugosidad	n1	= 0.01	Coef. rugosidad	n2	: 0.008	Codo		0.008

PRESSURE READING Po (kg/cm²)	LOSS PRESSURE Plo=P1+P2+P3 (kg/cm²)	EFECTIVE PRESSURE Pe=Pm+Ph-Pc (kg/cm²)	INJECTED TIME t (min)	WATER VOLUME Qt (l)	FLOOD Qo=Qt/t (l/min)	FLOOD Q1=Q/60000 (m³/s)	FLOOD Q2=Q*100/6 (cm³/s)	SPECIFIC ABSOPTION Ae = Q / L (l/min/m)	LUGEON UNIT $UL = \frac{10 * Ae}{Pe}$ UL	PERMEABILITY COEFICIENT $K = \frac{Q\,2}{2\pi Pe\ L} * \ln\frac{2L}{D}$ (cm/s)
2.80	1.53649	5.08	3	216.00	72.00	1.20E-03	1200.00	14.40	28.3	3.67E-04
4.20	1.26680	6.75	3	196.00	65.33	1.09E-03	1088.89	13.07	19.3	2.51E-04
5.60	0.76194	8.66	3	152.00	50.67	8.44E-04	844.44	10.13	11.7	1.52E-04
4.20	2.01171	6.01	3	247.00	82.33	1.37E-03	1372.22	16.47	27.4	3.55E-04
2.80	0.89782	5.72	3	165.00	55.00	9.17E-04	916.67	11.00	19.2	2.49E-04

TOTAL LOSS LOAD

$$Pc = Pc_1 + Pc_2 + Pc_3$$

$$P_1 = \frac{10.34 * (n_1)^2 * (Q_1^2) * lt}{(\phi_1^{5.33})}$$

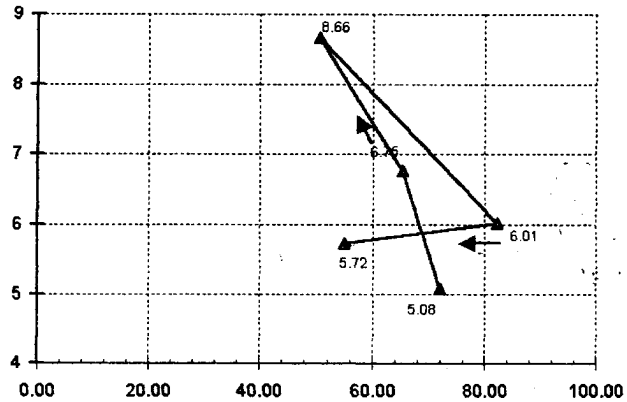
P1= loss load on steel pipe

$$P_2 = \frac{10.34 * (n_2)^2 * (Q_2^2) * lm}{(\phi_2^{5.33})}$$

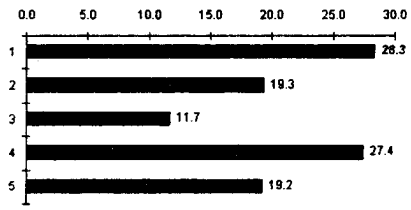
P2= loss load on plastic pipe

$$P_3 = \sum \alpha * (Q_1)$$

P3= loss load on reducciones, valvulas y uniones



VALUES OF LUGEON UNIT



PERMEABILITY (LU) = 11.7

PERMEABILITY TEST

swissboring
Swissboring Overseas Corporation Ltd.

CLIENT: AUTORIDAD DEL CANAL DE PANAMA	DATE: 15-June-2001	LUGEON TEST Nº: 1
PROJECT: ALTO CHAGRES DAM SITE	SITE: DAM SITE (right margin)	TESTED BY Geols. L.Peréz- R. Alvarado
BOREHOLE No.: CH-8	ELEVATION: 119.86 m.s.l	CHECKED BY:

Packer type: Neumatic Length (m) = 0.80 Water pump Bean Royal 535 Flood (l/min) =

Test depth (m) from: 15.00 to: 20.00

Test length (cm): L * Cos X º = 499.92 Depth of hole (m): 20.00 Dip X (º)= 30

Swivel H1 (m): H1 = 0.80 Diameter of hole D (cm): 9.60 W.L. Before of test (m)= 1.53

Water level Ha (m): 1.53 Ha * Cos X º = 1.33 Hydrostatic load (kg/cm2): Lh= (H1+Ha)/10 = 0.213

Steel pipe:				Plastic Pipe:			Reducciones:		
Length (m) =	-1t	=	5.00	Length (m)	1 m	= 5.00	α	Valv. uniones:	0.2
Diameter ϕ_1	(m)	=	0.0603	Diameter ϕ_2	(m)	= 0.0254		Packer:	0.12
Coef. rugosidad	n1	=	0.01	Coef. rugosidad	n2	: 0.008		Codo:	0.008

PRESSURE READING Po (kg/cm²)	LOSS PRESSURE Plo=P1+P2+P3 (kg/cm²)	EFECTIVE PRESSURE Pe=Pm+Ph-Pc (kg/cm²)	INJECTED TIME t (min)	WATER VOLUME Qt (l)	FLOOD Qo=Qt/t (l/min)	FLOOD Q1=Q/60000 (m³/s)	FLOOD Q2=Q*100/6 (cm³/s)	SPECIFIC ABSOPTION Ae = Q / L (l/min/m)	LUGEON UNIT $UL = \frac{10 * Ae}{Pe}$ UL	PERMEABILITY COEFICIENT $K = \frac{Q2}{2\pi Pe L} * \ln\frac{2L}{D}$ (cm/s)
0.60	0.00000	0.81	3	0	0.00	0.00E+00	0.00	0.00	0.0	0.00E+00
1.19	0.00000	1.40	3	0	0.00	0.00E+00	0.00	0.00	0.0	0.00E+00
1.82	0.00000	2.03	3	0	0.00	0.00E+00	0.00	0.00	0.0	0.00E+00
1.19	0.00000	1.40	3	0	0.00	0.00E+00	0.00	0.00	0.0	0.00E+00
0.60	0.00000	0.81	3	0	0.00	0.00E+00	0.00	0.00	0.0	0.00E+00

TOTAL LOSS LOAD

$$Pc = Pc_1 + Pc_2 + Pc_3$$

$$P_1 = \frac{10.34 * (n_1)^2 * (Q_1^2) * lt}{(\phi_1^{5.33})}$$

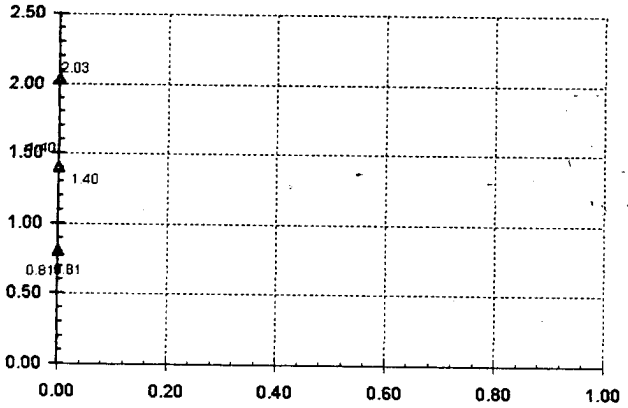
P1= loss load on steel pipe

$$P_2 = \frac{10.34 * (n_2)^2 * (Q_2^2) * lm}{(\phi_2^{5.33})}$$

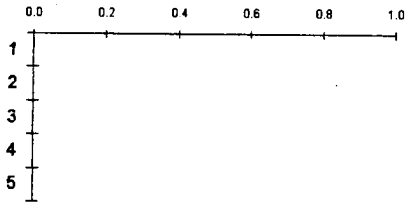
P2= loss load on plastic pipe

$$P_3 = \sum \alpha * (Q_1)$$

P3= loss load on reducciones, valvulas y uniones



VALUES OF LUGEON UNIT



PERMEABILITY (LU) = 0.0

PERMEABILITY TEST

swissboring

Swissboring Overseas Corporation Ltd.

CLIENT: AUTORIDAD DEL CANAL DE PANAMA	DATE: 15-June-2001	LUGEON TEST Nº: 2
PROJECT: ALTO CHAGRES DAM SITE	SITE: DAM SITE (right margin)	TESTED BY Geols. L.Peréz- R. Alvarado
BOREHOLE No.: CH-8	ELEVATION: 119.86 m.s.l	CHECKED BY:

Packer type: Neumatic Length (m) = 0.80 Water pump Bean Royal 535 Flood (l/min) =

Test depth (m) from: 20.00 to: 25.00

Test length (cm): L * Cos X º = 499.92 Depth of hole (m): 25.00 Dip X (º)= 30

Swivel H1 (m): H1 = 0.75 Diameter of hole D (cm): 9.60 W.L. Before of test (m)= 2.25

Water level Ha (m): 2.25 Ha * Cos X º = 1.95 Hydrostatic load (kg/cm2): Lh= (H1+Ha)/10 = 0.270

Steel pipe: Length (m) = 1t = 5.00 Diameter ϕ_1 (m) = 0.0603 Coef. rugosidad n1 = 0.01

Plastic Pipe: Length (m) 1 m = 5.00 Diameter ϕ_2 (m) = 0.0254 Coef. rugosidad n2 0.008

Reducciones: α Valv. uniones: 0.2 Packer: 0.12 Codo: 0.008

PRESSURE READING Po (kg/cm²)	LOSS PRESSURE Plo=P1+P2+P3 (kg/cm²)	EFECTIVE PRESSURE ~~Pe=Pm+Hh-Pc~~ (kg/cm²)	INJECTED TIME t (min)	WATER VOLUME Qt (l)	FLOOD Qo=Qt/t (l/min)	FLOOD Q1=Q/60000 (m³/s)	FLOOD Q2=Q*100/6 (cm³/s)	SPECIFIC ABSOPTION Ae = Q / L (l/min/m)	LUGEON UNIT $UL = \frac{10 * Ae}{Pe}$ UL	PERMEABILITY COEFICIENT $K = \frac{Q2}{2\pi Pe L} * \ln\frac{2L}{D}$ (cm/s)
0.60	0.00000	0.87	3	0	0.00	0.00E+00	0.00	0.00	0.0	0.00E+00
1.19	0.00000	1.46	3	0	0.00	0.00E+00	0.00	0.00	0.0	0.00E+00
1.82	0.00000	2.09	3	0	0.00	0.00E+00	0.00	0.00	0.0	0.00E+00
1.19	0.00000	1.46	3	0	0.00	0.00E+00	0.00	0.00	0.0	0.00E+00
0.60	0.00000	0.87	3	0	0.00	0.00E+00	0.00	0.00	0.0	0.00E+00

TOTAL LOSS LOAD

$$Pc = Pc_1 + Pc_2 + Pc_3$$

$$P_1 = \frac{10.34 * (n_1)^2 * (Q_1^2) * lt}{(\phi_1^{5.33})}$$

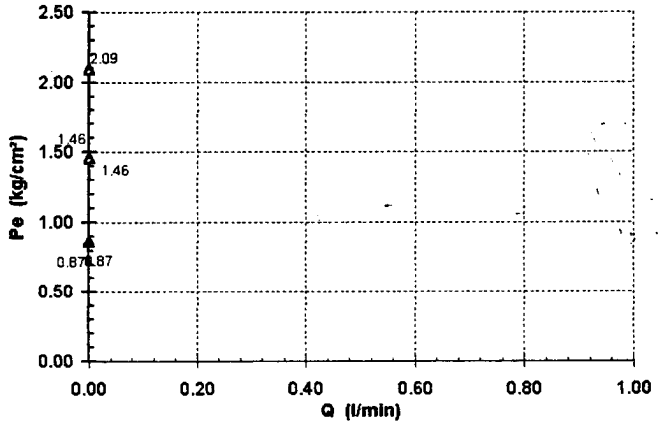
P1= loss load on steel pipe

$$P_2 = \frac{10.34 * (n_2)^2 * (Q_2^2) * lm}{(\phi_2^{5.33})}$$

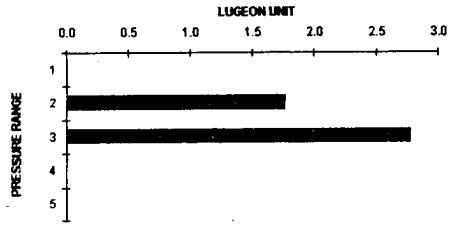
P2= loss load on plastic pipe

$$P_3 = \sum \alpha * (Q_1)$$

P3= loss load on reducciones, valvulas y uniones



VALUES OF LUGEON UNIT



PERMEABILITY (LU) = 0.0

PERMEABILITY TEST

swissboring
Swissboring Overseas Corporation Ltd.

CLIENT: AUTORIDAD DEL CANAL DE PANAMA	DATE: 16-June-2001	LUGEON TEST Nº: 3
PROJECT: ALTO CHAGRES DAM SITE	SITE: DAM SITE (right margin)	TESTED BY Geols. L.Peréz- R. Alvarado
BOREHOLE No.: CH-8	ELEVATION: 119.86 m.s.l	CHECKED BY:

Packer type: Neumatic Length (m) = 0.80 Water pump Bean Royal 535 Flood (l/min) =

Test depth (m) from: 25.00 to: 30.00

Test length (cm): L * Cos X º = 499.92 Depth of hole (m): 30.00 Dip X (º)= 30

Swivel H1 (m): H1 = 2.50 Diameter of hole D (cm): 9.60 W.L. Before of test (m)= 0.75

Water level Ha (m): 0.75 Ha * Cos X º = 0.65 Hydrostatic load (kg/cm2): Lh= (H1+Ha)/10 = 0.315

Steel pipe:			Plastic Pipe:			Reducciones:		
Length (m) =	lt	= 5.00	Length (m)	1 m	= 5.00	α	Valv. uniones:	0.2
Diameter ϕ_1	(m)	= 0.0603	Diameter ϕ_2	(m)	= 0.0254		Packer:	0.12
Coef. rugosidad	n1	= 0.01	Coef. rugosidad	n2	: 0.008		Codo:	0.008

PRESSURE READING Po (kg/cm²)	LOSS PRESSURE Plo=P1+P2+P3 (kg/cm²)	EFECTIVE PRESSURE ~~Pe=Pm+Ph-Pc~~ (kg/cm²)	INJECTED TIME t (min)	WATER VOLUME Qt (l)	FLOOD Qo=Qt/t (l/min)	FLOOD Q1=Q/60000 (m³/s)	FLOOD Q2=Q*100/6 (cm³/s)	SPECIFIC ABSOPTION Ae = Q / L (l/min/m)	LUGEON UNIT $UL = \frac{10 * Ae}{Pe}$ UL	PERMEABILITY COEFICIENT $K = \frac{Q2}{2\pi Pe L} * \ln\frac{2L}{D}$ (cm/s)
0.98	0.00000	1.30	3	0	0.00	0.00E+00	0.00	0.00	0.0	0.00E+00
1.96	0.00120	2.27	3	6	2.00	3.33E-05	33.33	0.40	1.8	2.17E-05
2.94	0.00603	3.25	3	14	4.50	7.50E-05	75.00	0.90	2.8	3.41E-05
1.96	0.00000	2.28	3	0	0.00	0.00E+00	0.00	0.00	0.0	0.00E+00
0.98	0.00000	1.30	3	0	0.00	0.00E+00	0.00	0.00	0.0	0.00E+00

TOTAL LOSS LOAD

$$Pc = Pc_1 + Pc_2 + Pc_3$$

$$P_1 = \frac{10.34 * (n_1)^2 * (Q_1^2) * lt}{(\phi_1^{5.33})}$$

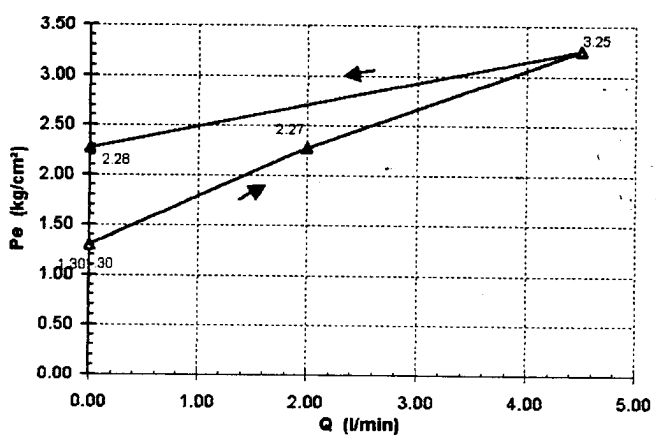
P1= loss load on steel pipe

$$P_2 = \frac{10.34 * (n_2)^2 * (Q_2^2) * lm}{(\phi_2^{5.33})}$$

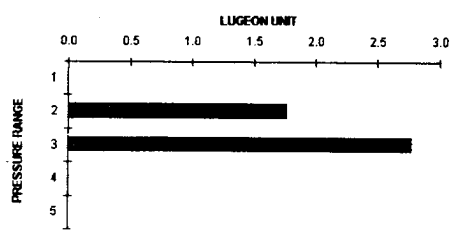
P2= loss load on plastic pipe

$$P_3 = \sum \alpha * (Q_1)$$

P3= loss load on reducciones, valvulas y uniones



VALUES OF LUGEON UNIT



PERMEABILITY (LU) = 2.8

PERMEABILITY TEST

swissboring

Swissboring Overseas Corporation Ltd.

CLIENT: AUTORIDAD DEL CANAL DE PANAMA	DATE: 17-June-2001	LUGEON TEST Nº: 4
PROJECT: ALTO CHAGRES DAM SITE	SITE: DAM SITE (right margin)	TESTED BY Geols. L.Peréz- R. Alvarado
BOREHOLE No.: CH-8	ELEVATION: 119.86 m.s.l	CHECKED BY:

Packer type: Neumatic Length (m) = 0.80 Water pump Bean Royal 535 Flood (l/min) =

Test depth (m) from: 30.00 to: 35.00

Test length (cm): L * Cos X º = 499.92 Depth of hole (m): 35.00 Dip X (º)= 30

Swivel H1 (m): H1 = 0.75 Diameter of hole D (cm): 7.57 W.L. Before of test (m)= 2.05

Water level Ha (m): 2.05 Ha * Cos X º = 1.78 Hydrostatic load (kg/cm2): Lh= (H1+Ha)/10 = 0.253

Steel pipe:			Plastic Pipe:			Reducciones:		
Length (m) =	-1t	= 5.00	Length (m)	1 m	= 5.00	α	Valv. uniones:	0.2
Diameter ϕ_1	(m)	= 0.0603	Diameter ϕ_2	(m)	= 0.0254		Packer:	0.12
Coef. rugosidad	n1	= 0.01	Coef. rugosidad	n2	: 0.008		Codo:	0.008

PRESSURE READING Po (kg/cm²)	LOSS PRESSURE Plo=P1+P2+P3 (kg/cm²)	EFECTIVE PRESSURE ~~Pe=Pm-Pl-Pc~~ (kg/cm²)	INJECTED TIME t (min)	WATER VOLUME Qt (l)	FLOOD Qo=Qt/t (l/min)	FLOOD Q1=Q/60000 (m³/s)	FLOOD Q2=Q*100/6 (cm³/s)	SPECIFIC ABSOPTION Ae = Q / L (l/min/m)	LUGEON UNIT $UL = \frac{10 * Ae}{Pe}$ UL	PERMEABILITY COEFICIENT $K = \frac{Q2}{2\pi Pe L} * \ln\frac{2L}{D}$ (cm/s)
1.16	0.00000	1.41	3	0.00	0.00	0.00E+00	0.00	0.00	0.0	0.00E+00
2.31	0.00140	2.56	3	6.50	2.17	3.61E-05	36.11	0.43	1.7	2.19E-05
3.50	0.00744	3.75	3	15.00	5.00	8.33E-05	83.33	1.00	2.7	3.46E-05
2.31	0.00000	2.56	3	0.00	0.00	0.00E+00	0.00	0.00	0.0	0.00E+00
1.16	0.00000	1.41	3	0.00	0.00	0.00E+00	0.00	0.00	0.0	0.00E+00

TOTAL LOSS LOAD

$$Pc = Pc_1 + Pc_2 + Pc_3$$

$$P_1 = \frac{10.34 * (n_1)^2 * (Q_1^2) * lt}{(\phi_1^{5.33})}$$

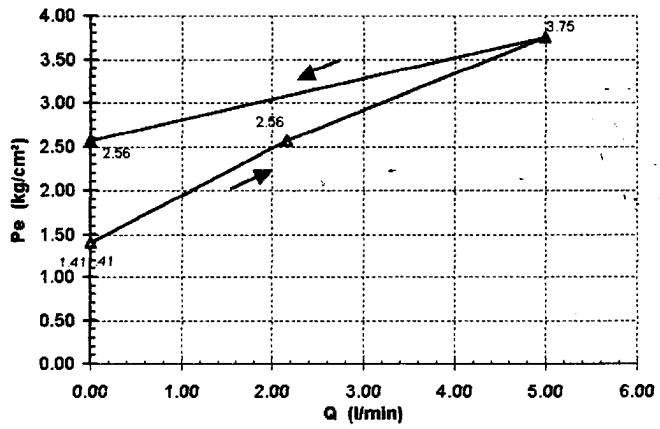
P1= loss load on steel pipe

$$P_2 = \frac{10.34 * (n_2)^2 * (Q_2^2) * lm}{(\phi_2^{5.33})}$$

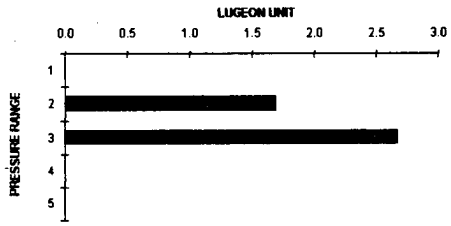
P2= loss load on plastic pipe

$$P_3 = \sum \alpha * (Q_1)$$

P3= loss load on reducciones, valvulas y uniones



VALUES OF LUGEON UNIT



PERMEABILITY (LU) = 2.7

PERMEABILITY TEST

swissboring
Swissboring Overseas Corporation Ltd.

CLIENT: AUTORIDAD DEL CANAL DE PANAMA	DATE: 18-June-2001	LUGEON TEST Nº: 7
PROJECT: ALTO CHAGRES DAM SITE	SITE: DAM SITE (right margin)	TESTED BY Geols. L.Peréz- R. Alvarado
BOREHOLE No.: CH-8	ELEVATION: 119.86 m.s.l	CHECKED BY:

Packer type: Neumatic Length (m) = 0.80 Water pump Bean Royal 535 Flood (l/min) =

Test depth (m) from: 45.00 to: 50.00

Test length (cm): L * Cos X º = 499.92 Depth of hole (m): 50.00 Dip X (º)= 30

Swivel H1 (m): H1 = 1.30 Diameter of hole D (cm): 7.57 W.L. Before of test (m)= 3.6

Water level Ha (m): 3.6 Ha * Cos X º = 3.12 Hydrostatic load (kg/cm2): Lh= (H1+Ha)/10 = 0.442

Steel pipe:			Plastic Pipe:			Reducciones:		
Length (m) =	lt	= 5.00	Length (m)	1 m	= 5.00	α	Valv. uniones:	0.2
Diameter ϕ_1	(m)	= 0.0603	Diameter ϕ_2	(m)	= 0.0254		Packer:	0.12
Coef. rugosidad	n1	= 0.01	Coef. rugosidad	n2	: 0.008		Codo:	0.008

PRESSURE READING	LOSS PRESSURE	EFECTIVE PRESSURE	INJECTED TIME	WATER VOLUME	FLOOD			SPECIFIC ABSOPTION	LUGEON UNIT	PERMEABILITY COEFICIENT
Po	Plo=P1+P2+P3	Pe=Po-Plo-R	t	Qt	Qo=Qt/t	Q1=Q/60000	Q2=Q*100/6	Ae = Q / L	$UL = \frac{10*Ae}{Pe}$	$K = \frac{Q2}{2\pi Pe\ L} * \ln\frac{2L}{D}$
(kg/cm²)	(kg/cm²)	(kg/cm²)	(min)	(l)	(l/min)	(m³/s)	(cm³/s)	(l/min/m)	UL	(cm/s)
1.72	0.00000	2.16	3	0.00	0.00	0.00E+00	0.00	0.00	0.0	0.00E+00
3.43	0.00000	3.87	3	0.00	0.00	0.00E+00	0.00	0.00	0.0	0.00E+00
5.18	0.00187	5.62	3	7.50	2.50	4.17E-05	41.67	0.50	0.9	1.15E-05
3.43	0.00030	3.87	3	3.00	1.00	1.67E-05	16.67	0.20	0.5	6.69E-06
1.72	0.00000	2.16	3	0.00	0.00	0.00E+00	0.00	0.00	0.0	0.00E+00

TOTAL LOSS LOAD

$$Pc = Pc_1 + Pc_2 + Pc_3$$

$$P_1 = \frac{10.34 * (n_1)^2 * (Q_1^2) * lt}{(\phi_1^{5.33})}$$

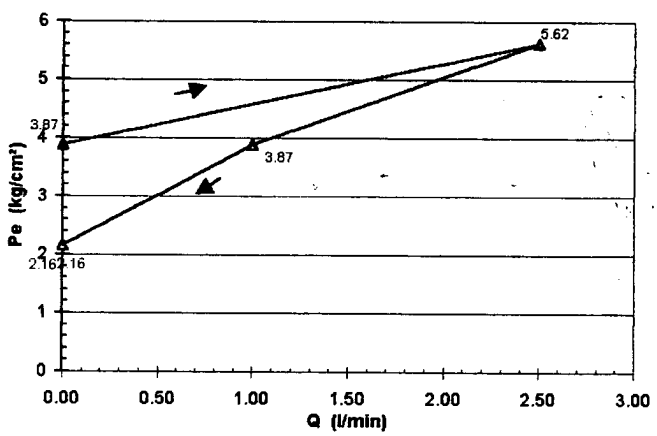
P1= loss load on steel pipe

$$P_2 = \frac{10.34 * (n_2)^2 * (Q_2^2) * lm}{(\phi_2^{5.33})}$$

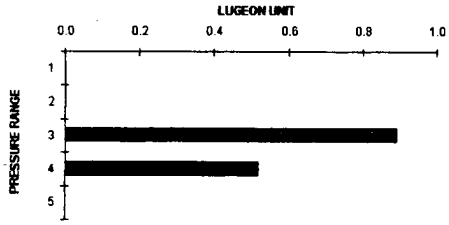
P2= loss load on plastic pipe

$$P_3 = \sum \alpha * (Q_1)$$

P3= loss load on reducciones, valvulas y uniones



VALUES OF LUGEON UNIT



PERMEABILITY (LU) = 0.9

PERMEABILITY TEST

swissboring
Swissboring Overseas Corporation Ltd.

CLIENT: AUTORIDAD DEL CANAL DE PANAMA	DATE: 18-June-2001	LUGEON TEST Nº: 8
PROJECT: ALTO CHAGRES DAM SITE	SITE: DAM SITE (right margin)	TESTED BY Geols. L.Peréz- R. Alvarado
BOREHOLE No.: CH-8	ELEVATION: 119.86 m.s.l	CHECKED BY:

Packer type:	Neumatic	Length (m) =	0.80	Water pump	Bean Royal 535	Flood (l/min) =	
				Test depth (m) from:	50.00	to:	55.00
Test length (cm):		L * Cos X º =	499.92	Depth of hole (m):	55.00	Dip X (º)=	30
Swivel H1 (m):		H1 =	1.40	Diameter of hole D (cm):	7.57	W.L. Before of test (m)=	1.15
Water level Ha (m):	1.15	Ha * Cos X º =	1.00	Hydrostatic load (kg/cm2):	Lh= (H1+Ha)/10 =		0.240

Steel pipe:	Length (m) =	1t =	5.00	Plastic Pipe : Length (m)	1 m = 5.00	Reducciones: Valv. uniones:	0.2
	Diameter ϕ_1	(m) =	0.0603	Diameter ϕ_2	(m) = 0.0254	α Packer:	0.12
	Coef. rugosidad	n1 =	0.01	Coef. rugosidad	n2 : 0.008	Codo:	0.008

PRESSURE READING Po (kg/cm²)	LOSS PRESSURE Plo=P1+P2+P3 (kg/cm²)	EFECTIVE PRESSURE Pe=Po-Ho-Pc (kg/cm²)	INJECTED TIME t (min)	WATER VOLUME Qt (l)	FLOOD Qo=Qt/t (l/min)	FLOOD Q1=Q/60000 (m³/s)	FLOOD Q2=Q*100/6 (cm³/s)	SPECIFIC ABSOPTION Ae = Q / L (l/min/m)	LUGEON UNIT $UL = \frac{10 * Ae}{Pe}$ UL	PERMEABILITY COEFICIENT $K = \frac{Q2}{2\pi Pe\ L} * \ln\frac{2L}{D}$ (cm/s)
1.89	0.00000	2.13	3	0.00	0.00	0.00E+00	0.00	0.00	0.0	0.00E+00
3.85	0.00000	4.09	3	0.00	0.00	0.00E+00	0.00	0.00	0.0	0.00E+00
5.74	0.00030	5.98	3	3.00	1.00	1.67E-05	16.67	0.20	0.3	4.33E-06
3.85	0.00000	4.09	3	0.00	0.00	0.00E+00	0.00	0.00	0.0	0.00E+00
1.89	0.00000	2.13	3	0.00	0.00	0.00E+00	0.00	0.00	0.0	0.00E+00

TOTAL LOSS LOAD

$$Pc = Pc_1 + Pc_2 + Pc_3$$

$$P_1 = \frac{10.34 * (n_1)^2 * (Q_1^2) * lt}{(\phi_1^{5.33})}$$

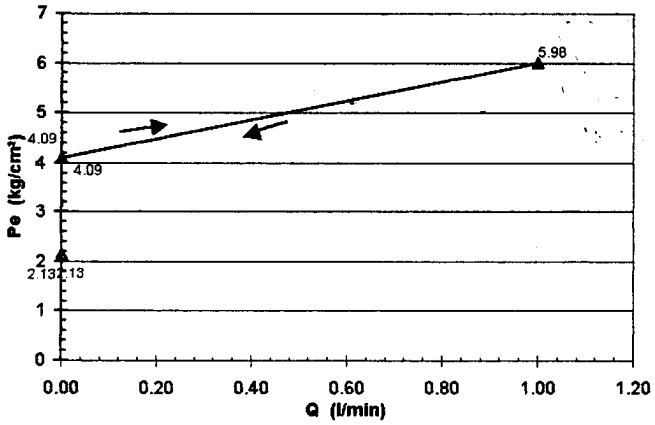
P1= loss load on steel pipe

$$P_2 = \frac{10.34 * (n_2)^2 * (Q_2^2) * lm}{(\phi_2^{5.33})}$$

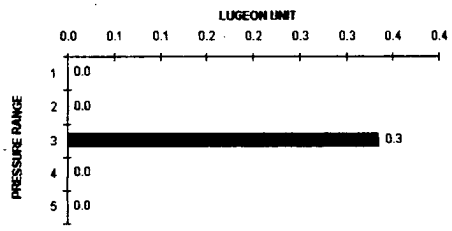
P2= loss load on plastic pipe

$$P_3 = \sum \alpha * (Q_1)$$

P3= loss load on reducciones, valvulas y uniones



VALUES OF LUGEON UNIT



PERMEABILITY (LU) = 0.3

PERMEABILITY TEST

swissboring

Swissboring Overseas Corporation Ltd.

CLIENT: AUTORIDAD DEL CANAL DE PANAMA	DATE: 18-June-2001	LUGEON TEST Nº: 9
PROJECT: ALTO CHAGRES DAM SITE	SITE: DAM SITE (right margin)	TESTED BY Geols. L.Peréz- R. Alvarado
BOREHOLE No.: CH-8	ELEVATION: 119.86 m.s.l	CHECKED BY:

Packer type: Neumatic Length (m) = 0.80 Water pump Bean Royal 535 Flood (l/min) =

Test depth (m) from: 55.00 to: 60.00

Test length (cm): 50 L * Cos X° = 499.92 Depth of hole (m): 60.00 Dip X (°)= 30

Swivel H1 (m): H1 = 1.50 Diameter of hole D (cm): 7.57 W.L. Before of test (m)= 1.35

Water level Ha (m): 1.35 Ha * Cos X° = 1.17 Hydrostatic load (kg/cm2): Lh= (H1+Ha)/10 = 0.267

Steel pipe: Length (m) = 1t = 5.00 Diameter ϕ_1 (m) = 0.0603 Coef. rugosidad n1 = 0.01

Plastic Pipe: Length (m) 1 m = 5.00 Diameter ϕ_2 (m) = 0.0254 Coef. rugosidad n2 : 0.008

Reducciones: α Valv. uniones: 0.2 Packer: 0.12 Codo: 0.008

PRESSURE READING Po (kg/cm²)	LOSS PRESSURE Plo=P1+P2+P3 (kg/cm²)	EFECTIVE PRESSURE ~~Pe=Pm+Ph-Pc~~ (kg/cm²)	INJECTED TIME t (min)	WATER VOLUME Qt (l)	FLOOD Qo=Qt/t (l/min)	FLOOD Q1=Q/60000 (m³/s)	FLOOD Q2=Q*100/6 (cm³/s)	SPECIFIC ABSOPTION Ae = Q / L (l/min/m)	LUGEON UNIT $UL = \frac{10 * Ae}{Pe}$ UL	PERMEABILITY COEFICIENT $K = \frac{Q\,2}{2 \pi Pe\ L} * \ln \frac{2L}{D}$ (cm/s)
2.10	0.00000	2.37	3	0.00	0.00	0.00E+00	0.00	0.00	0.0	0.00E+00
4.20	0.00000	4.47	3	0.00	0.00	0.00E+00	0.00	0.00	0.0	0.00E+00
6.30	0.00068	6.57	3	4.50	1.50	2.50E-05	25.00	0.30	0.5	5.92E-06
4.20	0.00000	4.47	3	0.00	0.00	0.00E+00	0.00	0.00	0.0	0.00E+00
2.10	0.00000	2.37	3	0.00	0.00	0.00E+00	0.00	0.00	0.0	0.00E+00

TOTAL LOSS LOAD

$$Pc = Pc_1 + Pc_2 + Pc_3$$

$$P_1 = \frac{10.34 * (n_1)^2 * (Q_1^2) * lt}{(\phi_1^{5.33})}$$

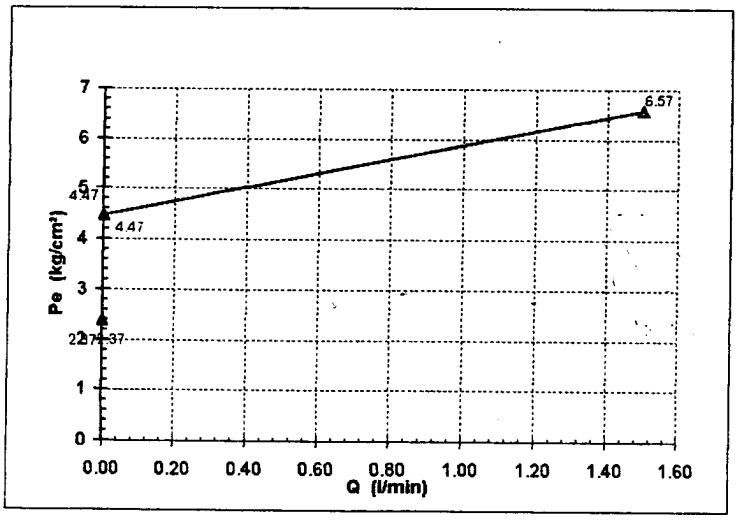
P1= loss load on steel pipe

$$P_2 = \frac{10.34 * (n_2)^2 * (Q_2^2) * lm}{(\phi_2^{5.33})}$$

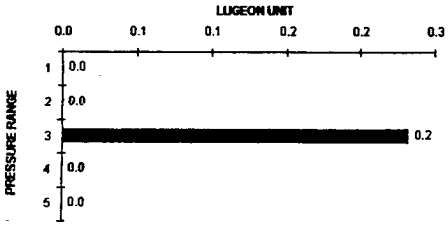
P2= loss load on plastic pipe

$$P_3 = \sum \alpha * (Q_1)$$

P3= loss load on reducciones, valvulas y uniones



VALUES OF LUGEON UNIT



PERMEABILITY (LU) = 0.5

PERMEABILITY TEST

swissboring
Swissboring Overseas Corporation Ltd.

CLIENT: AUTORIDAD DEL CANAL DE PANAMA	DATE: 18-June-2001	LUGEON TEST Nº: 10
PROJECT: ALTO CHAGRES DAM SITE	SITE: DAM SITE (right margin)	TESTED BY Geols. L.Peréz- R. Alvarado
BOREHOLE No.: CH-8	ELEVATION: 119.86 m.s.l	CHECKED BY:

Packer type: Neumatic Length (m) = 0.80 Water pump Bean Royal 535 Flood (l/min) =
Test depth (m) from: 60.00 to: 65.00

Test length (cm): L * Cos X° = 499.92 Depth of hole (m): 65.00 Dip X (°)= 30
Swivel H1 (m): H1 = 1.50 Diameter of hole D (cm): 7.57 W.L. Before of test (m)= 1.65
Water level Ha (m): 1.65 Ha * Cos X° = 1.43 Hydrostatic load (kg/cm2): Lh= (H1+Ha)/10 = 0.293

Steel pipe: Length (m) = lt = 5.00 Diameter ϕ_1 (m) = 0.0603 Coef. rugosidad n1 = 0.01
Plastic Pipe: Length (m) lm = 5.00 Diameter ϕ_2 (m) = 0.0254 Coef. rugosidad n2 : 0.008
Reducciones: α Valv. uniones: 0.2 Packer: 0.12 Codo: 0.008

PRESSURE READING Po (kg/cm²)	LOSS PRESSURE Plo=P1+P2+P3 (kg/cm²)	EFECTIVE PRESSURE ~~Pe=Pm+Ph-Pc~~ (kg/cm²)	INJECTED TIME t (min)	WATER VOLUME Qt (l)	FLOOD Qo=Qt/t (l/min)	FLOOD Q1=Q/60000 (m³/s)	FLOOD Q2=Q*100/6 (cm³/s)	SPECIFIC ABSOPTION Ae = Q / L (l/min/m)	LUGEON UNIT $UL = \frac{10 * Ae}{Pe}$ UL	PERMEABILITY COEFICIENT $K = \frac{Q\,2}{2\pi Pe\ L} * \ln\frac{2L}{D}$ (cm/s)
2.24	0.00000	2.53	3	0.00	0.00	0.00E+00	0.00	0.00	0.0	0.00E+00
4.55	0.00000	4.84	3	0.00	0.00	0.00E+00	0.00	0.00	0.0	0.00E+00
6.86	0.00008	7.16	3	1.50	0.50	8.33E-06	8.33	0.10	0.1	1.81E-06
4.55	0.00000	4.84	3	0.00	0.00	0.00E+00	0.00	0.00	0.0	0.00E+00
2.24	0.00000	2.53	3	0.00	0.00	0.00E+00	0.00	0.00	0.0	0.00E+00

TOTAL LOSS LOAD

$$Pc = Pc_1 + Pc_2 + Pc_3$$

$$P_1 = \frac{10.34 * (n_1)^2 * (Q_1^2) * lt}{(\phi_1^{5.33})}$$

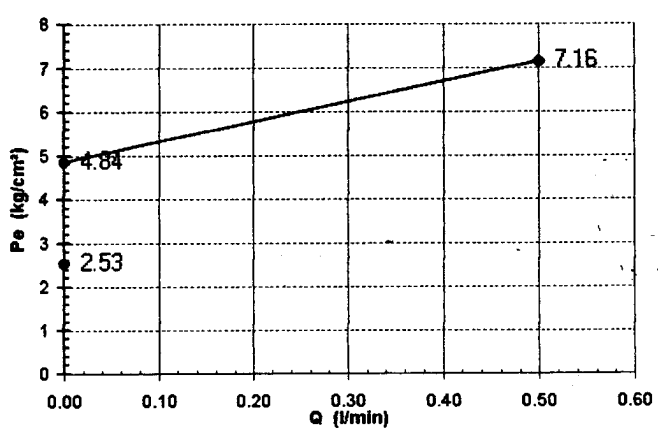
P1= loss load on steel pipe

$$P_2 = \frac{10.34 * (n_2)^2 * (Q_2^2) * lm}{(\phi_2^{5.33})}$$

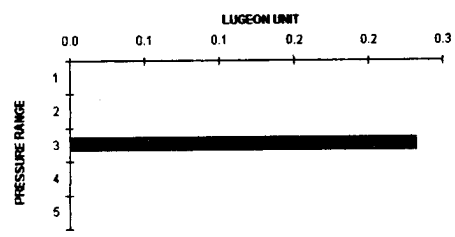
P2= loss load on plastic pipe

$$P_3 = \sum \alpha * (Q_1)$$

P3= loss load on reducciones, valvulas y uniones



VALUES OF LUGEON UNIT



PERMEABILITY (LU) = 0.1

PERMEABILITY TEST

swissboring
Swissboring Overseas Corporation Ltd.

CLIENT: AUTORIDAD DEL CANAL DE PANAMA	DATE: 10-June-2001	LUGEON TEST Nº: 2
PROJECT: ALTO CHAGRES DAM SITE	SITE: DAM SITE (right margin)	TESTED BY Geols. L.Peréz- R. Alvarado
BOREHOLE No.: CH-9	ELEVATION: 219.66 m.s.l	CHECKED BY:

Packer type: Neumatic Length (m) = 0.80 Water pump Bean Royal 535 Flood (l/min) =

Test depth (m) from: 25.00 to: 30.00

Test length (cm): L * Cos X º = 500.00 Depth of hole (m): 30.00 Dip X (º)= 0

Swivel H1 (m): H1 = 1.25 Diameter of hole D (cm): 9.60 W.L. Before of test (m)= 16.4

Water level Ha (m): 16.4 Ha * Cos X º = 16.40 Hydrostatic load (kg/cm2): Lh= (H1+Ha)/10 = 1.765

Steel pipe: Length (m) = 1t = 5.00 Diameter ϕ_1 (m) = 0.0603 Coef. rugosidad n1 = 0.01

Plastic Pipe: Length (m) 1 m = 5.00 Diameter ϕ_2 (m) = 0.0254 Coef. rugosidad n2 : 0.008

Reducciones: α Valv. uniones: 0.2 Packer: 0.12 Codo: 0.008

PRESSURE READING Po (kg/cm²)	LOSS PRESSURE Plo=P1+P2+P3 (kg/cm²)	EFECTIVE PRESSURE Pe=Pm+Ph-Pc (kg/cm²)	INJECTED TIME t (min)	WATER VOLUME Qt (l)	FLOOD Qo=Qt/t (l/min)	FLOOD Q1=Q/60000 (m³/s)	FLOOD Q2=Q*100/6 (cm²/s)	SPECIFIC ABSOPTION Ae = Q / L (l/min/m)	LUGEON UNIT $UL = \frac{10 * Ae}{Pe}$ UL	PERMEABILITY COEFICIENT $K = \frac{Q2}{2\pi Pe L} * \ln\frac{2L}{D}$ (cm/s)
0.70	0.03596	2.43	3	33	11.00	1.83E-04	183.33	2.20	9.1	1.12E-04
1.40	0.13096	3.03	3	63	21.00	3.50E-04	350.00	4.20	13.8	1.71E-04
2.10	0.40638	3.46	3	111	37.00	6.17E-04	616.67	7.40	21.4	2.64E-04
1.40	0.24968	2.92	3	87	29.00	4.83E-04	483.33	5.80	19.9	2.45E-04
0.70	0.14372	2.32	3	66	22.00	3.67E-04	366.67	4.40	19.0	2.34E-04

TOTAL LOSS LOAD

$$Pc = Pc_1 + Pc_2 + Pc_3$$

$$P_1 = \frac{10.34 * (n_1)^2 * (Q_1^2) * lt}{(\phi_1^{5.33})}$$

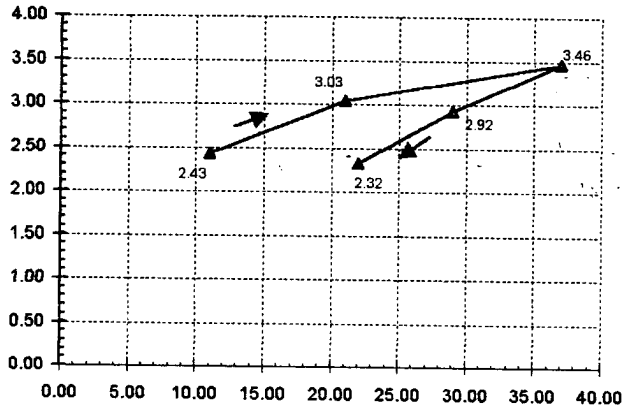
P1= loss load on steel pipe

$$P_2 = \frac{10.34 * (n_2)^2 * (Q_2^2) * lm}{(\phi_2^{5.33})}$$

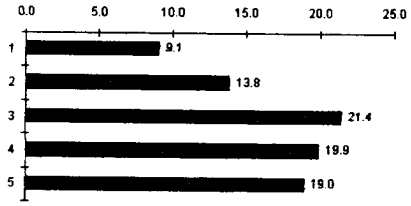
P2= loss load on plastic pipe

$$P_3 = \sum \alpha * (Q_1)$$

P3= loss load on reducciones, valvulas y uniones



VALUES OF LUGEON UNIT



PERMEABILITY (LU) = 21.4

PERMEABILITY TEST

swissboring
Swissboring Overseas Corporation Ltd.

CLIENT: AUTORIDAD DEL CANAL DE PANAMA	DATE: 10-June-2001	LUGEON TEST Nº: 1
PROJECT: ALTO CHAGRES DAM SITE	SITE: DAM SITE (right margin)	TESTED BY Geols. L.Peréz- R. Alvarado
BOREHOLE No.: CH-9	ELEVATION: 219.66 m.s.l	CHECKED BY:

Packer type: Neumatic Length (m) = 0.80 Water pump Bean Royal 535 Flood (l/min) =

Test depth (m) from: 20.00 to: 25.00

Test length (cm): L * Cos X° = 500.00 Depth of hole (m): 25.00 Dip X (°)= 0

Swivel H1 (m): H1 = 1.45 Diameter of hole D (cm): 9.60 W.L. Before of test (m)= 16.4

Water level Ha (m): 16.4 Ha * Cos X° = 16.40 Hydrostatic load (kg/cm2): Lh= (H1+Ha)/10 = 1.785

Steel pipe:	Length (m) =	lt = 5.00	Plastic Pipe:	Length (m)	1 m = 5.00	Reducciones:	Valv. uniones:	0.2
	Diameter ϕ_1	(m) = 0.0603		Diameter ϕ_2	(m) = 0.0254	α	Packer:	0.12
	Coef. rugosidad	n1 = 0.01		Coef. rugosidad	n2 : 0.008		Codo:	0.008

PRESSURE READING Po (kg/cm²)	LOSS PRESSURE Plo=P1+P2+P3 (kg/cm²)	EFECTIVE PRESSURE Pe=Pm+Ph-Pc (kg/cm²)	INJECTED TIME t (min)	WATER VOLUME Qt (l)	FLOOD Qo=Qt/t (l/min)	FLOOD Q1=Q/60000 (m³/s)	FLOOD Q2=Q*100/6 (cm³/s)	SPECIFIC ABSOPTION Ae = Q / L (l/min/m)	LUGEON UNIT $UL = \frac{10 * Ae}{Pe}$ UL	PERMEABILITY COEFICIENT $K = \frac{Q2}{2\pi Pe L} * \ln\frac{2L}{D}$ (cm/s)
0.70	0.52361	1.96	3	126	42.00	7.00E-04	700.00	8.40	42.8	5.28E-04
1.40	0.90873	2.28	3	166	55.33	9.22E-04	922.22	11.07	48.6	5.99E-04
2.10	2.14412	1.74	3	255	85.00	1.42E-03	1416.67	17.00	97.6	1.20E-03
1.40	1.03313	2.15	3	177	59.00	9.83E-04	983.33	11.80	54.8	6.76E-04
0.70	0.77200	1.71	3	153	51.00	8.50E-04	850.00	10.20	59.5	7.34E-04

TOTAL LOSS LOAD

$$Pc = Pc_1 + Pc_2 + Pc_3$$

$$P_1 = \frac{10.34 * (n_1)^2 * (Q_1^2) * lt}{(\phi_1^{5.33})}$$

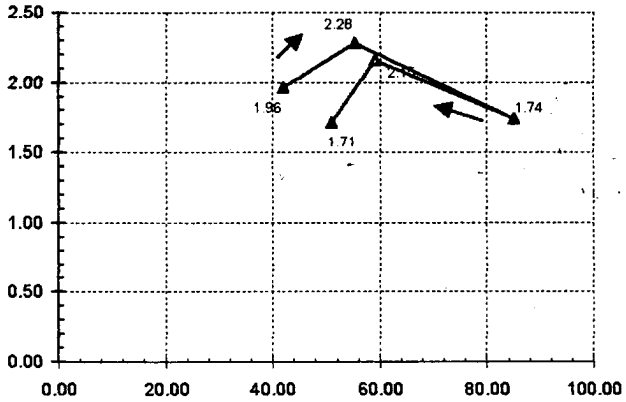
P1= loss load on steel pipe

$$P_2 = \frac{10.34 * (n_2)^2 * (Q_2^2) * lm}{(\phi_2^{5.33})}$$

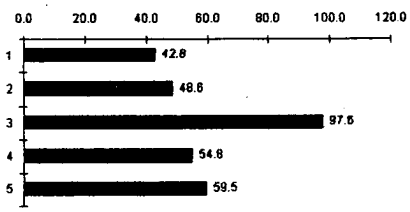
P2= loss load on plastic pipe

$$P_3 = \sum \alpha * (Q_1)$$

P3= loss load on reducciones, valvulas y uniones



VALUES OF LUGEON UNIT



PERMEABILITY (LU) = 97.6

PERMEABILITY TEST

swissboring

Swissboring Overseas Corporation Ltd.

CLIENT: AUTORIDAD DEL CANAL DE PANAMA	DATE: 18-June-2001	LUGEON TEST Nº: 11
PROJECT: ALTO CHAGRES DAM SITE	SITE: DAM SITE (right margin)	TESTED BY Geols. L.Peréz- R. Alvarado
BOREHOLE No.: CH-8	ELEVATION: 119.86 m.s.l	CHECKED BY:

Packer type: Neumatic Length (m) = 0.80 Water pump Bean Royal 535 Flood (l/min) =

Test depth (m) from: 65.00 to: 70.00

Test length (cm): L * Cos X° = 499.92 Depth of hole (m): 70.00 Dip X (°)= 30

Swivel H1 (m): H1 = 1.80 Diameter of hole D (cm): 7.57 W.L. Before of test (m)= 1.55

Water level Ha (m): 1.55 Ha * Cos X° = 1.34 Hydrostatic load (kg/cm2): Lh= (H1+Ha)/10 = 0.314

Steel pipe:			Plastic Pipe:			Reducciones:		
Length (m) =	lt	= 5.00	Length (m)	lm	= 5.00	α	Valv. uniones:	0.2
Diameter ϕ_1	(m)	= 0.0603	Diameter ϕ_2	(m)	= 0.0254		Packer:	0.12
Coef. rugosidad	n1	= 0.01	Coef. rugosidad	n2	: 0.008		Codo:	0.008

PRESSURE READING Po (kg/cm²)	LOSS PRESSURE Plo=P1+P2+P3 (kg/cm²)	EFFECTIVE PRESSURE Pe=Po-Plo-Pc (kg/cm²)	INJECTED TIME t (min)	WATER VOLUME Qt (l)	FLOOD Qo=Qt/t (l/min)	FLOOD Q1=Q/60000 (m³/s)	FLOOD Q2=Q*100/6 (cm²/s)	SPECIFIC ABSOPTION Ae = Q / L (l/min/m)	LUGEON UNIT $UL = \frac{10 * Ae}{Pe}$ UL	PERMEABILITY COEFICIENT $K = \frac{Q2}{2\pi Pe\ L} * \ln\frac{2L}{D}$ (cm/s)
2.45	0.00000	2.77	3	0.00	0.00	0.00E+00	0.00	0.00	0.0	0.00E+00
4.90	0.00000	5.22	3	0.00	0.00	0.00E+00	0.00	0.00	0.0	0.00E+00
7.35	0.00006	7.67	3	1.50	0.50	8.33E-06	8.33	0.10	0.1	1.69E-06
4.90	0.00000	5.22	3	0.00	0.00	0.00E+00	0.00	0.00	0.0	0.00E+00
2.45	0.00000	2.77	3	0.00	0.00	0.00E+00	0.00	0.00	0.0	0.00E+00

TOTAL LOSS LOAD

$$Pc = Pc_1 + Pc_2 + Pc_3$$

$$P_1 = \frac{10.34 * (n_1)^2 * (Q_1^2) * lt}{(\phi_1^{5.33})}$$

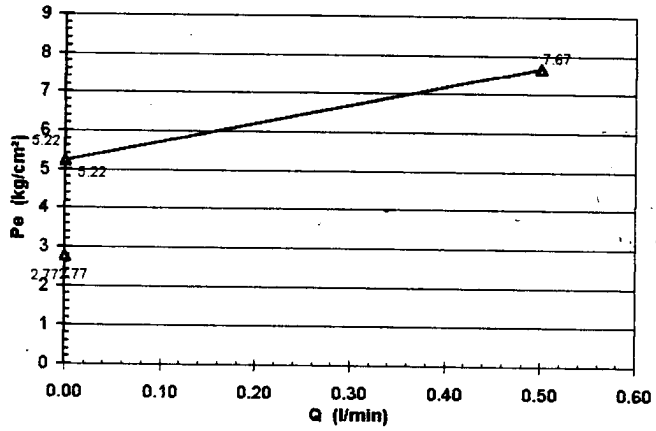
P1= loss load on steel pipe

$$P_2 = \frac{10.34 * (n_2)^2 * (Q_2^2) * lm}{(\phi_2^{5.33})}$$

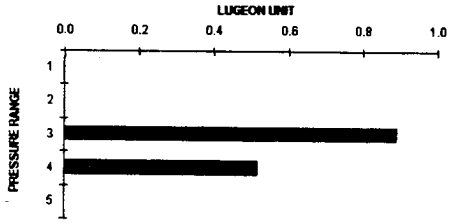
P2= loss load on plastic pipe

$$P_3 = \sum \alpha * (Q_1)$$

P3= loss load on reducciones, valvulas y uniones



VALUES OF LUGEON UNIT



PERMEABILITY (LU) = 0.1

PERMEABILITY TEST

swissboring
Swissboring Overseas Corporation Ltd.

CLIENT: AUTORIDAD DEL CANAL DE PANAMA	DATE: 17-June-2001	LUGEON TEST Nº: 6
PROJECT: ALTO CHAGRES DAM SITE	SITE: DAM SITE (right margin)	TESTED BY Geols. L.Peréz- R. Alvarado
BOREHOLE No.: CH-8	ELEVATION: 119.86 m.s.l	CHECKED BY:

Packer type: Neumatic Length (m) = 0.80 Water pump Bean Royal 535 Flood (l/min) =

Test depth (m) from: 40.00 to: 45.00

Test length (cm): L * Cos X º = 499.92 Depth of hole (m): 45.00 Dip X (º)= 30

Swivel H1 (m): H1 = 1.45 Diameter of hole D (cm): 7.57 W.L. Before of test (m)= 1.1

Water level Ha (m): 1.1 Ha * Cos X º = 0.95 Hydrostatic load (kg/cm2): Lh= (H1+Ha)/10 = 0.240

Steel pipe:	Length (m) =	1t = 5.00	Plastic Pipe:	Length (m)	1 m = 5.00	Reducciones:	Valv. uniones: 0.2
	Diameter ϕ_1	(m) = 0.0603		Diameter ϕ_2	(m) = 0.0254	α	Packer: 0.12
	Coef. rugosidad	n1 = 0.01		Coef. rugosidad	n2 : 0.008		Codo: 0.008

PRESSURE READING Po (kg/cm²)	LOSS PRESSURE Plo=P1+P2+P3 (kg/cm²)	EFECTIVE PRESSURE ~~Pe=Pm+Ph-Pc~~ (kg/cm²)	INJECTED TIME t (min)	WATER VOLUME Qt (l)	FLOOD Qo=Qt/t (l/min)	FLOOD Q1=Q/60000 (m³/s)	FLOOD Q2=Q*100/6 (cm³/s)	SPECIFIC ABSOPTION Ae = Q / L (l/min/m)	LUGEON UNIT $UL = \frac{10 * Ae}{Pe}$ UL	PERMEABILITY COEFICIENT $K = \frac{Q2}{2\pi Pe\ L} * \ln\frac{2L}{D}$ (cm/s)
1.33	0.00000	1.57	3	0.00	0.00	0.00E+00	0.00	0.00	0.0	0.00E+00
2.66	0.00000	2.90	3	0.00	0.00	0.00E+00	0.00	0.00	0.0	0.00E+00
4.06	0.00008	4.30	3	1.50	0.50	8.33E-06	8.33	0.10	0.2	3.01E-06
2.66	0.00000	2.90	3	0.00	0.00	0.00E+00	0.00	0.00	0.0	0.00E+00
1.33	0.00000	1.57	3	0.00	0.00	0.00E+00	0.00	0.00	0.0	0.00E+00

TOTAL LOSS LOAD

$$Pc = Pc_1 + Pc_2 + Pc_3$$

$$P_1 = \frac{10.34 * (n_1)^2 * (Q_1^2) * lt}{(\phi_1^{5.33})}$$

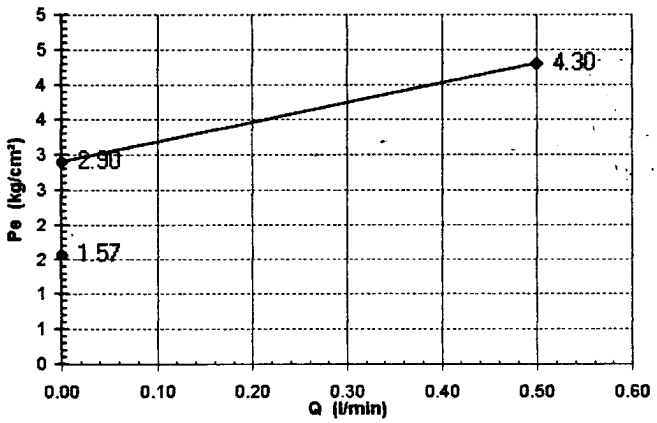
P1= loss load on steel pipe

$$P_2 = \frac{10.34 * (n_2)^2 * (Q_2^2) * lm}{(\phi_2^{5.33})}$$

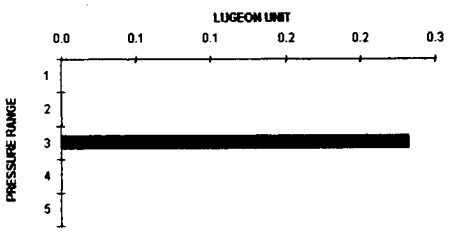
P2= loss load on plastic pipe

$$P_3 = \sum \alpha * (Q_1)$$

P3= loss load on reducciones, valvulas y uniones



VALUES OF LUGEON UNIT



PERMEABILITY (LU) = 0.2

PERMEABILITY TEST

swissboring
Swissboring Overseas Corporation Ltd.

CLIENT: AUTORIDAD DEL CANAL DE PANAMA	DATE: 17-June-2001	LUGEON TEST Nº: 5
PROJECT: ALTO CHAGRES DAM SITE	SITE: DAM SITE (right margin)	TESTED BY Geols. L.Peréz- R. Alvarado
BOREHOLE No.: CH-8	ELEVATION: 119.86 m.s.l	CHECKED BY:

Packer type:	Neumatic	Length (m) =	0.80	Water pump	Bean Royal 535	Flood (l/min) =	
				Test depth (m) from:	35.00	to:	40.00
Test length (cm):	50	L * Cos X º =	499.92	Depth of hole (m):	40.00	Dip X (º)=	30
Swivel H1 (m):		H1 =	1.45	Diameter of hole D (cm):	7.57	W.L. Before of test (m)=	1.1
Water level Ha (m):	1.1	Ha * Cos X º =	0.95	Hydrostatic load (kg/cm2):	Lh= (H1+Ha)/10 =		0.240

Steel pipe:	Length (m) =	1t	= 5.00	Plastic Pipe:	Length (m)	1 m	= 5.00	Reducciones:	Valv. uniones: 0.2
	Diameter ϕ_1	(m)	= 0.0603		Diameter ϕ_2	(m)	= 0.0254	α	Packer: 0.12
	Coef. rugosidad	n1	= 0.01		Coef. rugosidad	n2	: 0.008		Codo: 0.008

PRESSURE READING Po (kg/cm²)	LOSS PRESSURE Plo=P1+P2+P3 (kg/cm²)	EFECTIVE PRESSURE ~~Pe=Pm+Ph-Pc~~ (kg/cm²)	INJECTED TIME t (min)	WATER VOLUME Qt (l)	FLOOD Qo=Qt/t (l/min)	FLOOD Q1=Q/60000 (m³/s)	FLOOD Q2=Q*100/6 (cm³/s)	SPECIFIC ABSOPTION Ae = Q / L (l/min/m)	LUGEON UNIT $UL = \frac{10 * Ae}{Pe}$ UL	PERMEABILITY COEFICIENT $K = \frac{Q2}{2\pi Pe\ L} * \ln\frac{2L}{D}$ (cm/s)
1.33	0.00000	1.57	3	0.00	0.00	0.00E+00	0.00	0.00	0.0	0.00E+00
2.66	0.00000	2.90	3	0.00	0.00	0.00E+00	0.00	0.00	0.0	0.00E+00
4.06	0.00008	4.30	3	1.50	0.50	8.33E-06	8.33	0.10	0.2	3.01E-06
2.66	0.00000	2.90	3	0.00	0.00	0.00E+00	0.00	0.00	0.0	0.00E+00
1.33	0.00000	1.57	3	0.00	0.00	0.00E+00	0.00	0.00	0.0	0.00E+00

TOTAL LOSS LOAD

$$Pc = Pc_1 + Pc_2 + Pc_3$$

$$P_1 = \frac{10.34 * (n_1)^2 * (Q_1^2) * lt}{(\phi_1^{5.33})}$$

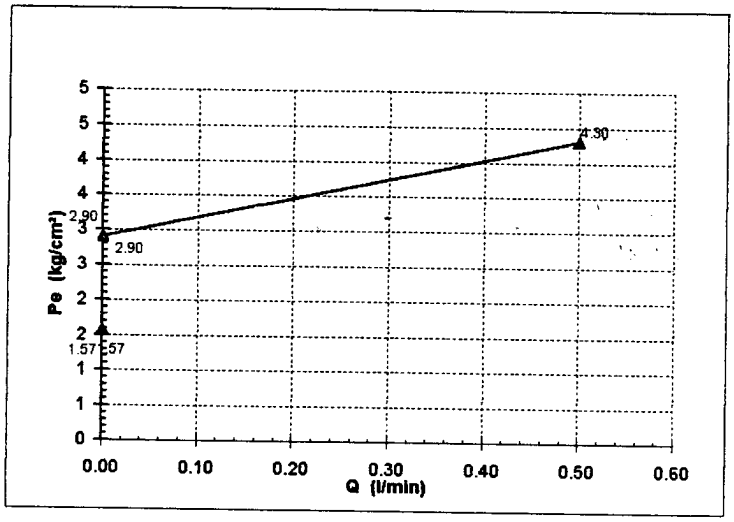
P1= loss load on steel pipe

$$P_2 = \frac{10.34 * (n_2)^2 * (Q_2^2) * lm}{(\phi_2^{5.33})}$$

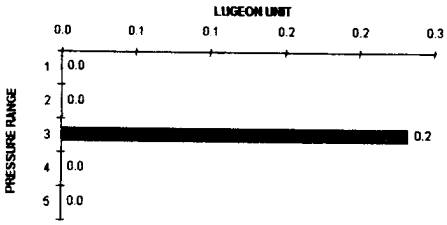
P2= loss load on plastic pipe

$$P_3 = \sum \alpha * (Q_1)$$

P3= loss load on reducciones, valvulas y uniones



VALUES OF LUGEON UNIT



PERMEABILITY (LU) = 0.2

Attachment 2: Laboratory Sampling and Testing Report, Tecnilab, S.A.

MWH GLOBAL, INC.

SITIO DE PRESA DEL PROYECTO ALTO CHAGRES

INVESTIGACIÓN GEOTECNICA

MUESTREO Y PRUEBAS DE LABORATORIO

Presentado por:

TECNILAB, S. A.

FUNDADA EN 1973

UNA EMPRESA E. BARRANCO Y ASOC. S. A.

JULIO DE 2002

TECNILAB, S. A. FUNDADA EN 1973
UNA EMPRESA E. BARRANCO Y ASOC., S. A.
LABORATORIO DE SUELOS Y MATERIALES

19 de julio de 2002.

Señores
MWH GLOBAL, INC.
Ciudad

Asunto: **Investigación Geotécnica, Alto Chagres**

Estimados Señores:

Con la presente tenemos el agrado de adjuntarles el informe de la investigación geotécnica para toma de muestras y pruebas de laboratorio, realizada para el proyectos "Sitio de Presa del Proyecto Alto Chagres", ubicado en el Río Chagres, Provincias de Panamá y Colón.

Indicándoles que estamos a su disposición para cualquier aclaración sobre la información adjunta, nos es grato suscribirnos.

Atentamente,

TECNILAB, S.A.

Ing. Bruno R. Barranco J.
Gerente General

BRBJ/. 02.07-191
Adj.: Informe
c.c.: Archivo 4-220

AVE. PRIMERA PARQUE LEFEVRE APARTADO: 2414. PANAMA 9A, R. DE PANAMA TEL'S.: 224-9137, 224-3567, FAX: 221-6451 e-mail: tecnilab@sinfo.net

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I. DETALLE DE CALICATAS

TECNILAB, S. A.

TECNILAB, S. A. FUNDADA EN 1973

UNA EMPRESA E. BARRANCO Y ASOC., S. A.

LABORATORIO DE SUELOS Y MATERIALES

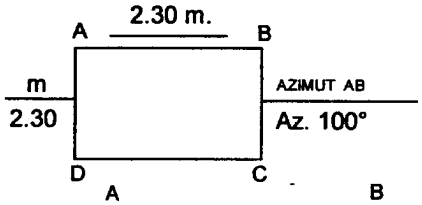
DETALLE DE CALICATA

TRABAJO No. 4-220 CALICATA No 02-01 FECHA: 5 al 6 de junio de 2002

PROYECTO SITIO DE PRESA DEL PROYECTO ALTO CHAGRES

LOCALIZACION RÍO CHAGRES, PROVINCIA DE PANAMÁ

CLIENTE MWH GLOBAL INC.



UBICACIÓN: COORDENADAS APROX.: 664675 E / 102449 N

ALTITUD APROX. DE 220.0 MTS.

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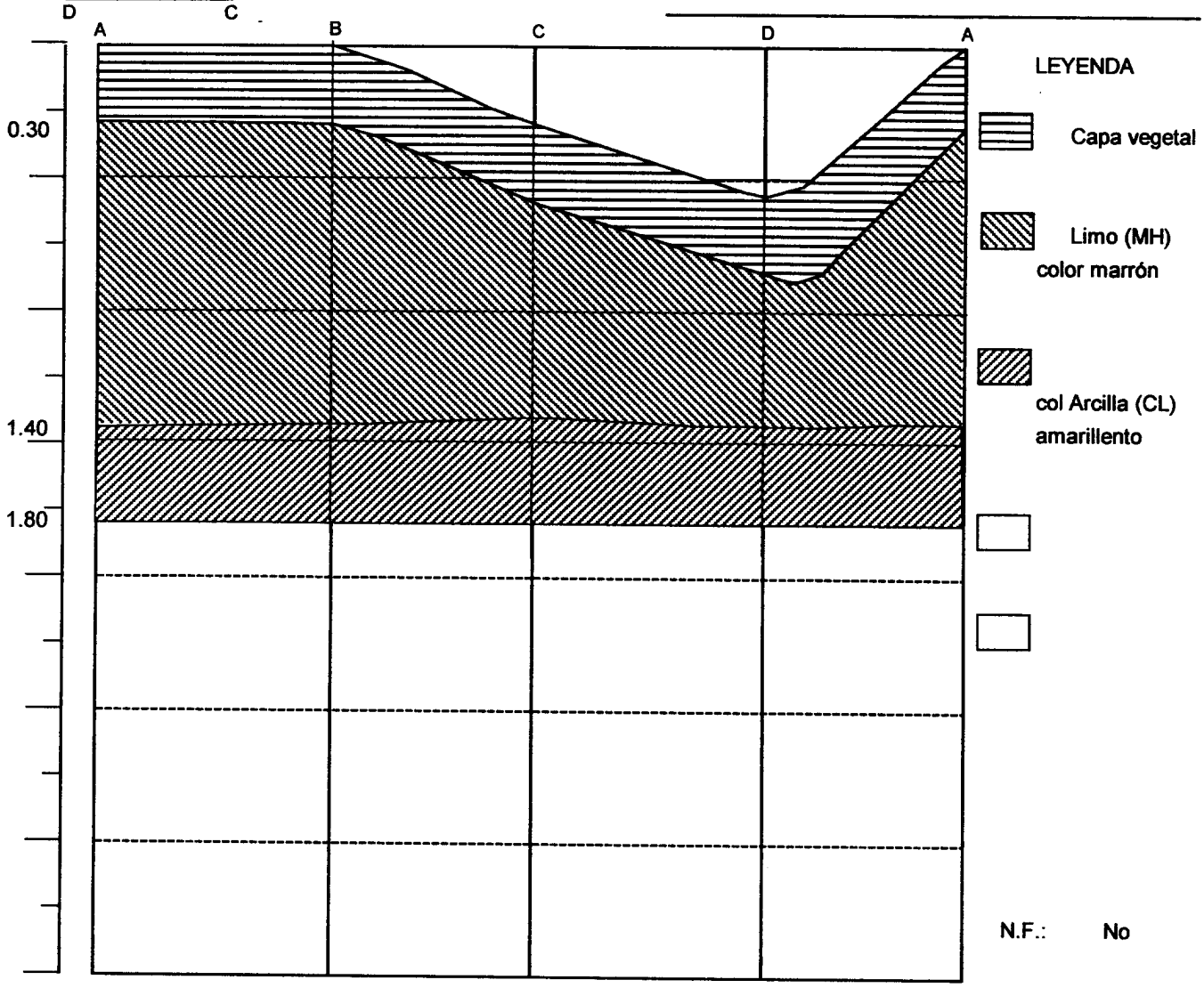


N.F.: No

Observaciones:

FECHA DE INICIO: 5 de junio de 2002 HORA: 09:00

TERMINACIÓN: 6 de junio de 2002 HORA: 10:00

René Sánchez

RESPONSABLE

TECNILAB, S. A. FUNDADA EN 1973

UNA EMPRESA E. BARRANCO Y ASOC., S. A.

LABORATORIO DE SUELOS Y MATERIALES

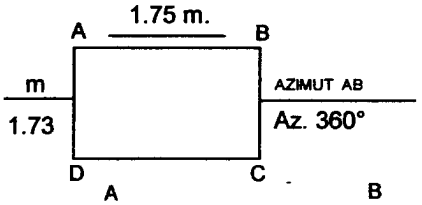
PERFIL DE PERFORACION

TRABAJO No. 4-220 CALICATA No 02-02 FECHA: 4 de junio de 2002

PROYECTO SITIO DE PRESA DEL PROYECTO ALTO CHAGRES

LOCALIZACION RÍO CHAGRES, PROVINCIA DE PANAMÁ

CLIENTE MWH GLOBAL INC.



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ALTITUD APROX. DE 142.0 MTS.

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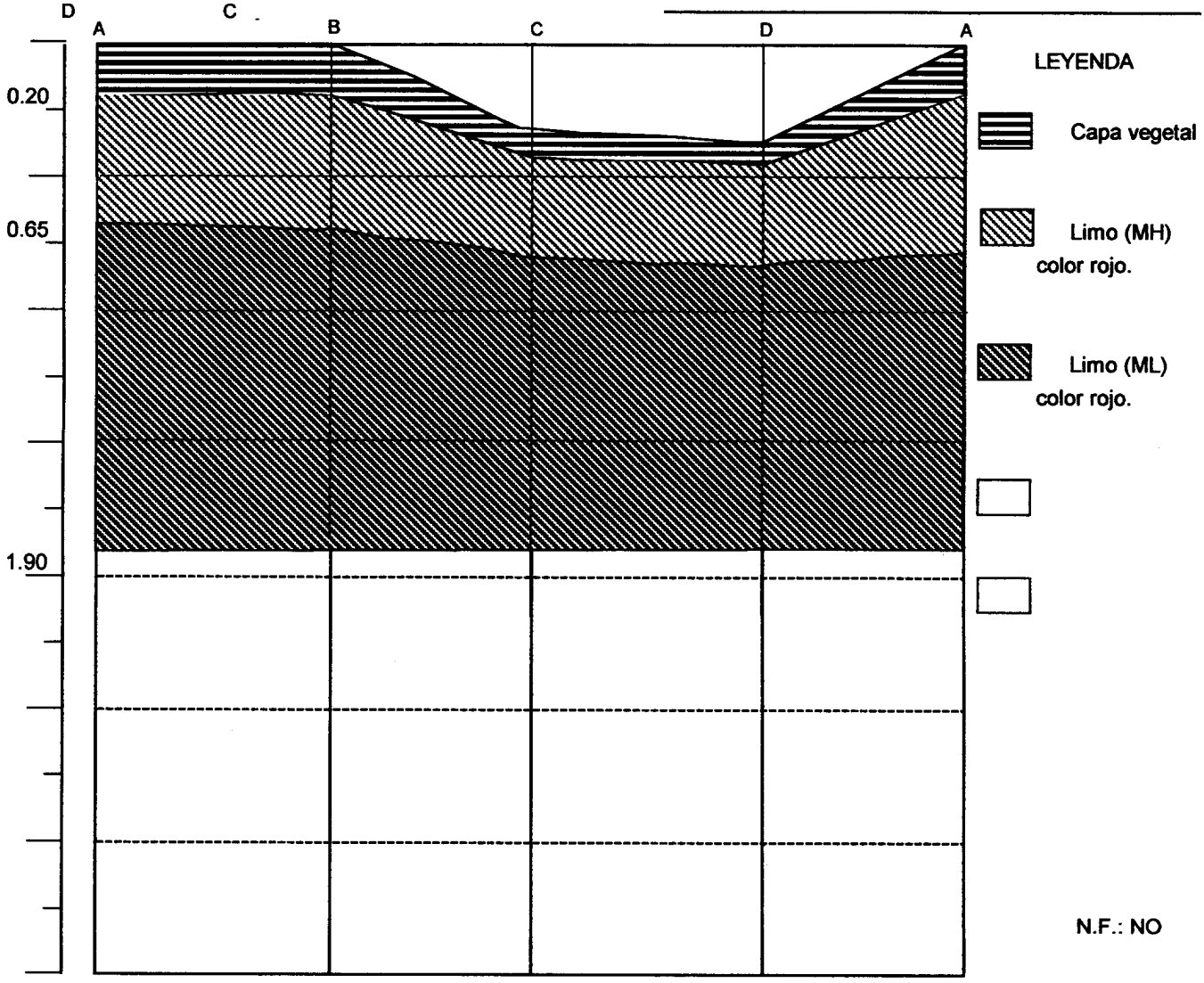


Observaciones: La arcilla roja es de plasticidad media a alta, limo arenoso poco plástico, es un Saprolito andesítico de color rojo con pátinas negras de óxidos de manganeso, la zona continúa.

FECHA DE INICIO: 4 de junio de 2002 HORA: 10:00

TERMINACIÓN: 4 de junio de 2002 HORA: 15:45

René Sánchez

RESPONSABLE

TECNILAB, S. A. FUNDADA EN 1973

UNA EMPRESA E. BARRANCO Y ASOC., S. A.

LABORATORIO DE SUELOS Y MATERIALES

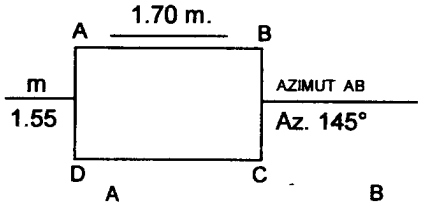
DETALLE DE CALICATA

TRABAJO No. 4-220 CALICATA No 02-03 FECHA: 6 al 7 de junio de 2002

PROYECTO ESTUDIO DE FACTIBILIDAD PARA SITIO DE PRESA EN EL ALTO CHAGRES

LOCALIZACION ALTOS DEL RÍO CHAGRES, PROVINCIA DE PANAMÁ

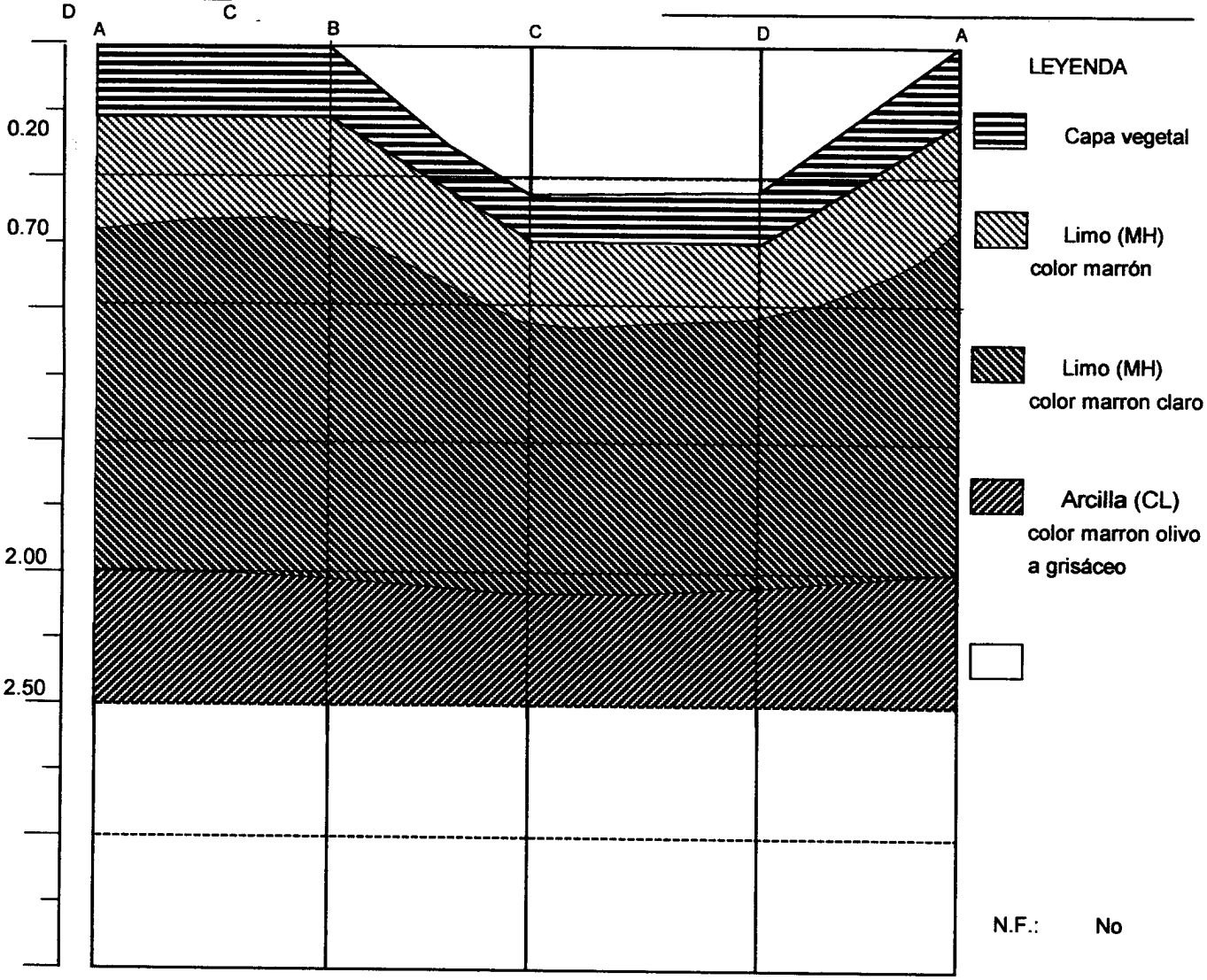
CLIENTE MWH GLOBAL INC.



UBICACIÓN: COORDENADAS APROX.: 664160 E / 102385 N

ALTITUD APROX. DE 146.0 MTS.

REFERENCIA: LADO DERECHO, RIO ARRIBA



N.F.: No

Observaciones: Saprolito tipo andesítico, Limo arenoso sin vestigios de alteración hidrotermal

FECHA DE INICIO 6 de junio de 2002 HORA: 09:00

TERMINACIÓN: 7 de junio de 2002 HORA: 10:00

René Sánchez

RESPONSABLE

TECNILAB, S. A. FUNDADA EN 1973

UNA EMPRESA E. BARRANCO Y ASOC., S. A.

LABORATORIO DE SUELOS Y MATERIALES

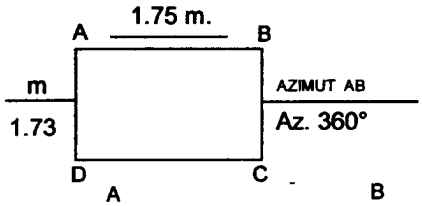
PERFIL DE PERFORACION

TRABAJO No. 4-220 CALICATA No 02-04 FECHA: 6 al 7 de junio de 2002

PROYECTO ESTUDIO DE FACTIBILIDAD PARA SITIO DE PRESA EN EL ALTO CHAGRES

LOCALIZACION ALTOS DEL RÍO CHAGRES, PROVINCIA DE PANAMÁ

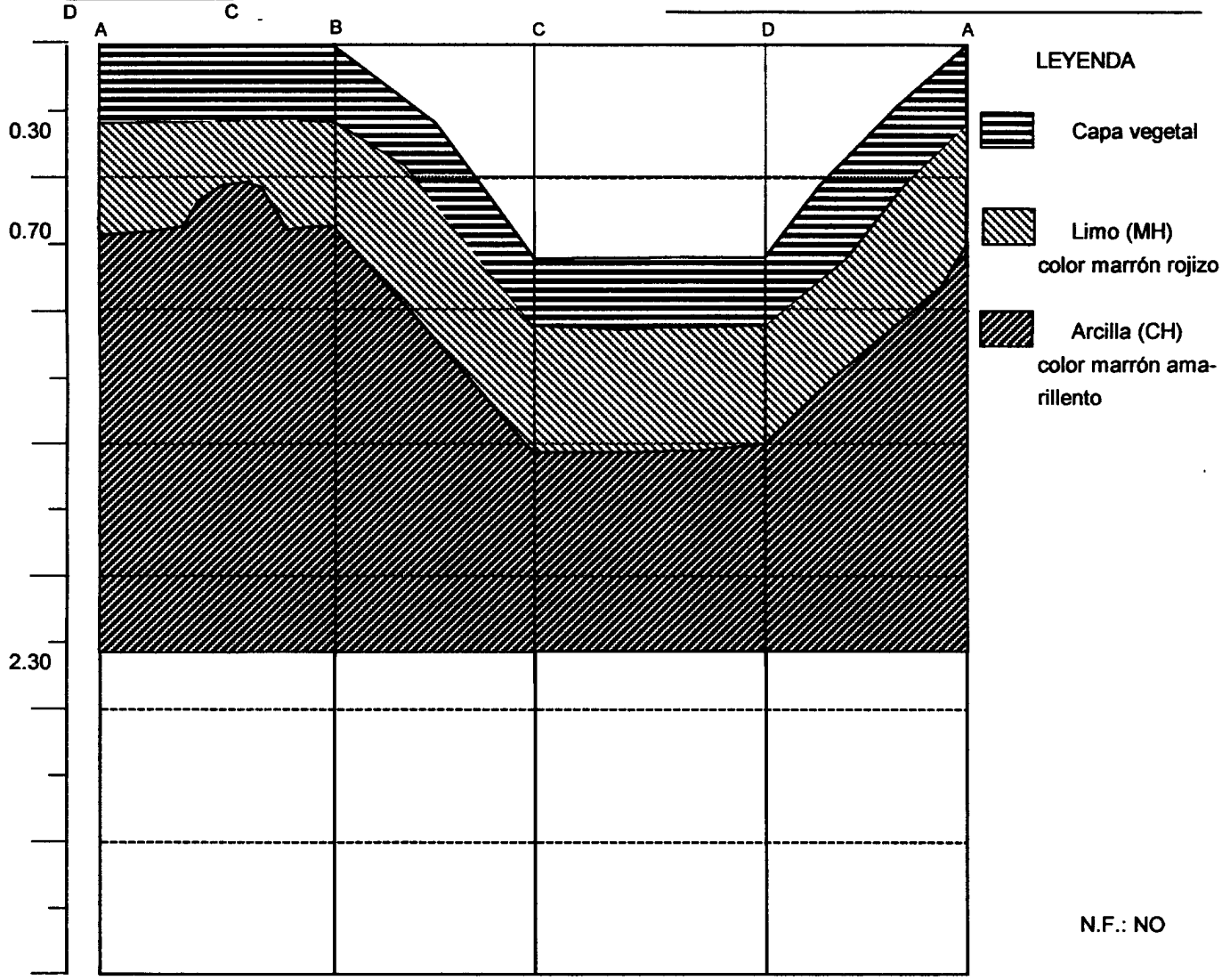
CLIENTE MWH GLOBAL INC.



UBICACIÓN: COORDENADAS APROX.: 664303 E / 1024285 N

ALTITUD APROX. DE 205 MTS.

REFERENCIA: LADO DERECHO RIO ARRIBA



Observaciones: Saprolito: Limo con poca arena, color marrón amarillento, microfracturas con óxidos de mmanganeso, no presenta vestigios de alteración hidrotermal.

FECHA DE INICIO: 6 de junio de 2002 HORA: 09:00

TERMINACIÓN: 7 de junio de 2002 HORA: 10:15

René Sánchez

RESPONSABLE

TECNILAB, S. A. FUNDADA EN 1973

UNA EMPRESA E. BARRANCO Y ASOC., S. A.

LABORATORIO DE SUELOS Y MATERIALES

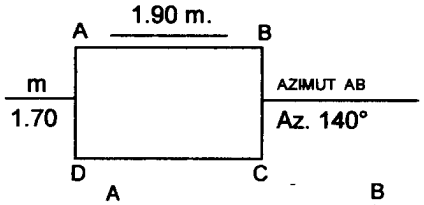
DETALLE DE CALICATA

TRABAJO No. 4-220 CALICATA No 02-05 FECHA: 7 de junio de 2002

PROYECTO SITIO DE PRESA DEL PROYECTO ALTO CHAGRES

LOCALIZACION RÍO CHAGRES, PROVINCIA DE PANAMÁ

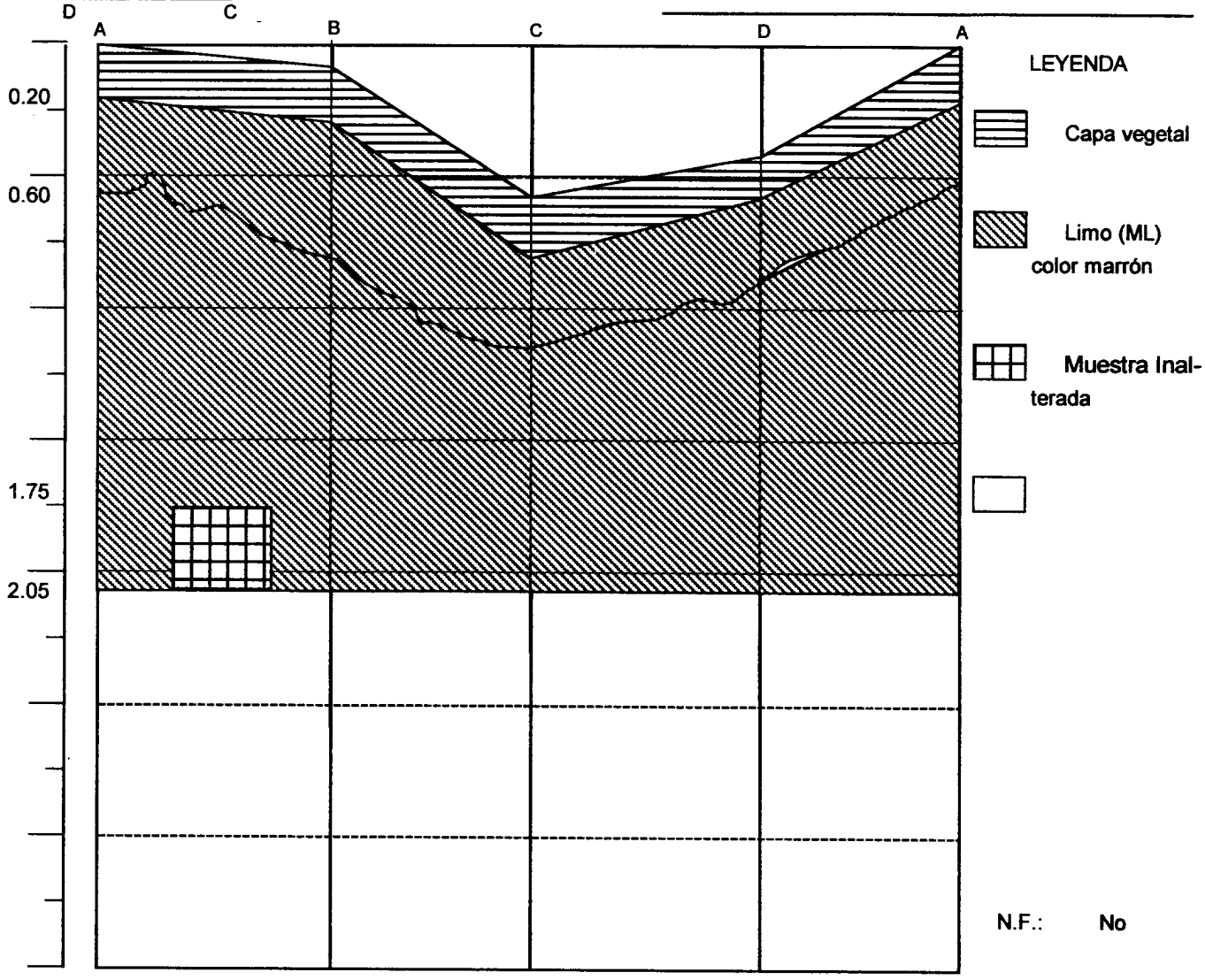
CLIENTE MWH GLOBAL INC.



UBICACIÓN: COORDENADAS APROX.: 664422 E / 1024220 N

ALTITUD APROX. DE 220.0 MTS.

REFERENCIA: LADO DERECHO, RIO ARRIBA



N.F.: No

Observaciones: Saprolito de roca andesítica, sin vestigio de alteración hidrotermal, plano de diaclasas con óxido de manganeso

FECHA DE INICIO: 7 de junio de 2002 HORA: 10:00

TERMINACIÓN: 7 de junio de 2002 HORA: 18:00

René Sánchez

RESPONSABLE

TECNILAB, S. A. FUNDADA EN 1973

UNA EMPRESA E. BARRANCO Y ASOC., S. A.

LABORATORIO DE SUELOS Y MATERIALES

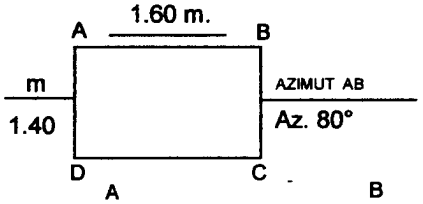
PERFIL DE PERFORACION

TRABAJO No. 4-220 CALICATA No 02-06 FECHA: 5 y 6 de junio de 2002

PROYECTO SITIO DE PRESA DEL PROYECTO ALTO CHAGRES

LOCALIZACION RÍO CHAGRES, PROVINCIA DE PANAMÁ

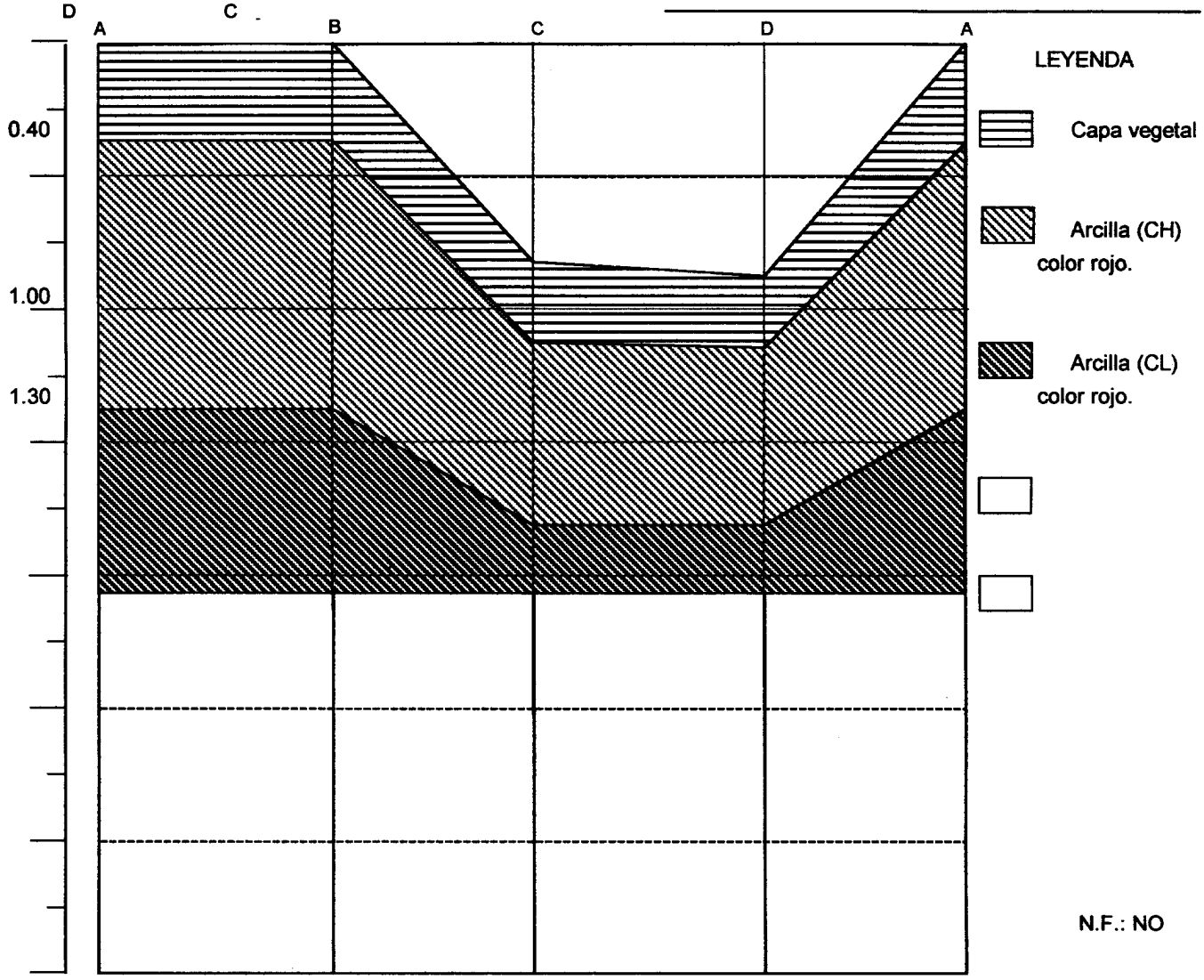
CLIENTE MWH GLOBAL INC.



UBICACIÓN: COORDENADAS APROX.: 664254 E / 1024565 N

ALTITUD APROX. DE 140.0 MTS.

REFERENCIA: LADO DERECHO, RIO ARRIBA



Observaciones: Saprolito, limo arenoso, color marron olivo claro, con óxidos férricos (limolita).

FECHA DE INICIO: 5 de junio de 2002 HORA: 15:00

TERMINACIÓN: 6 de junio de 2002 HORA: 10:00

René Sánchez

RESPONSABLE

TECNILAB, S. A. FUNDADA EN 1973

UNA EMPRESA E. BARRANCO Y ASOC., S. A.

LABORATORIO DE SUELOS Y MATERIALES

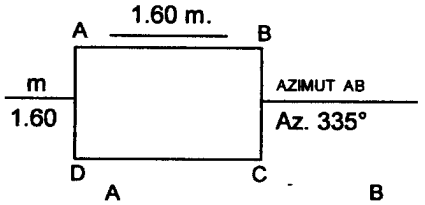
DETALLE DE CALICATA

TRABAJO No. 4-220 CALICATA No 02-07 FECHA: 4 de junio de 2002

PROYECTO SITIO DE PRESA DEL PROYECTO ALTO CHAGRES

LOCALIZACION RÍO CHAGRES, PROVINCIA DE PANAMÁ

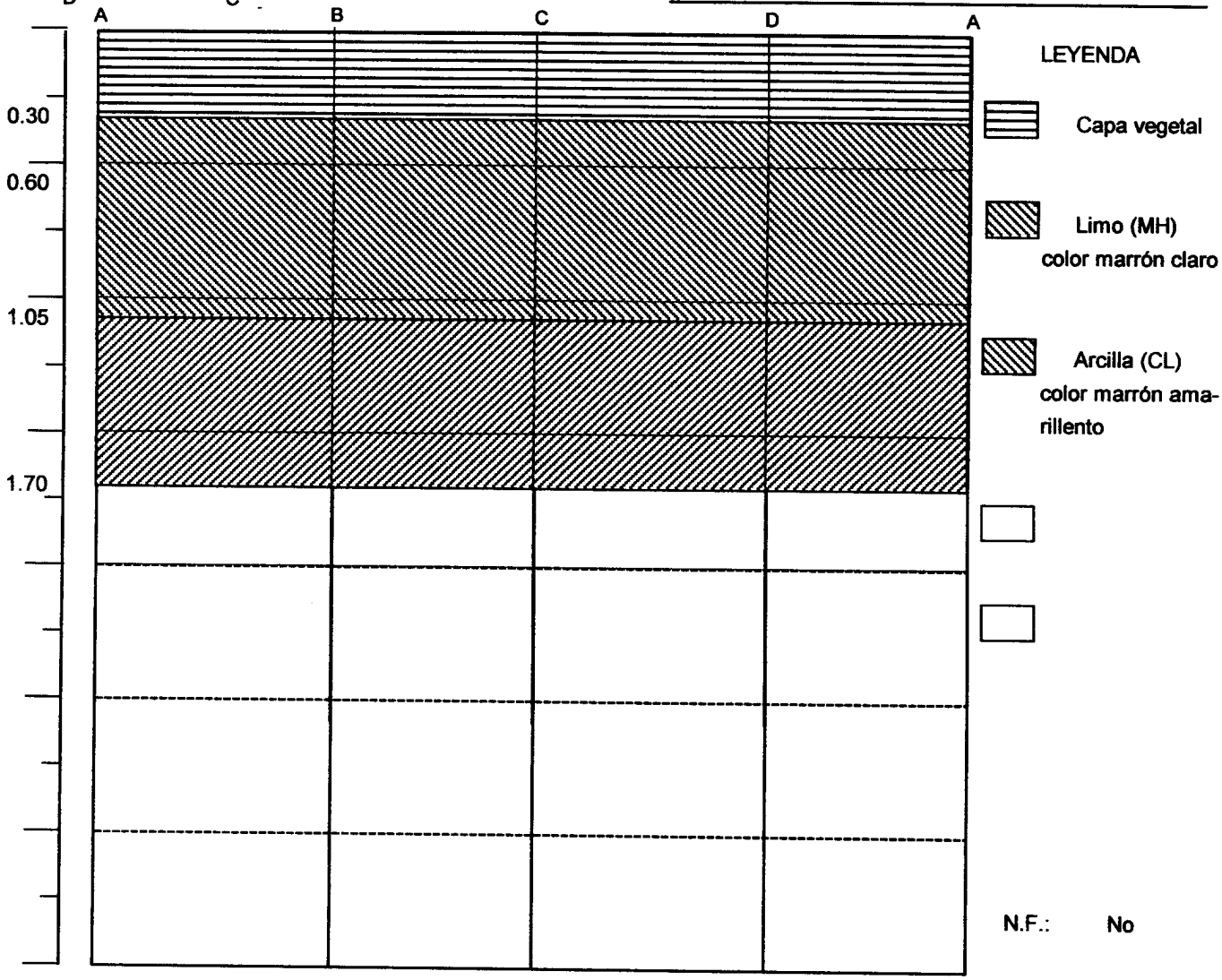
CLIENTE MWH GLOBAL INC.



UBICACIÓN: COORDENADAS APROX.: 663921 E / 1024827 N

ALTITUD APROX. DE 108.0 MTS.

REFERENCIA: ANTES DE LA DESEMBOCADURA DEL RIO CHICO CON RIO CHAGRES ARRIBA



N.F.: No

Observaciones:

FECHA DE INICIO: 4 de junio de 2002 HORA: 14:00

TERMINACIÓN: 5 de junio de 2002 HORA: 13:00

René Sánchez

RESPONSABLE

TECNILAB, S. A. FUNDADA EN 1973

UNA EMPRESA E. BARRANCO Y ASOC., S. A.

LABORATORIO DE SUELOS Y MATERIALES

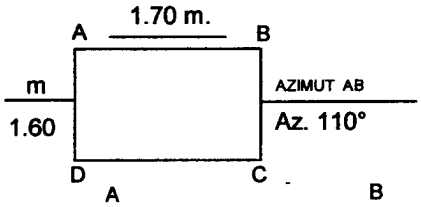
PERFIL DE PERFORACION

TRABAJO No. 4-220 CALICATA No 02-08 FECHA: 5 de junio de 2002

PROYECTO SITIO DE PRESA DEL PROYECTO ALTO CHAGRES

LOCALIZACION RÍO CHAGRES, PROVINCIA DE PANAMÁ

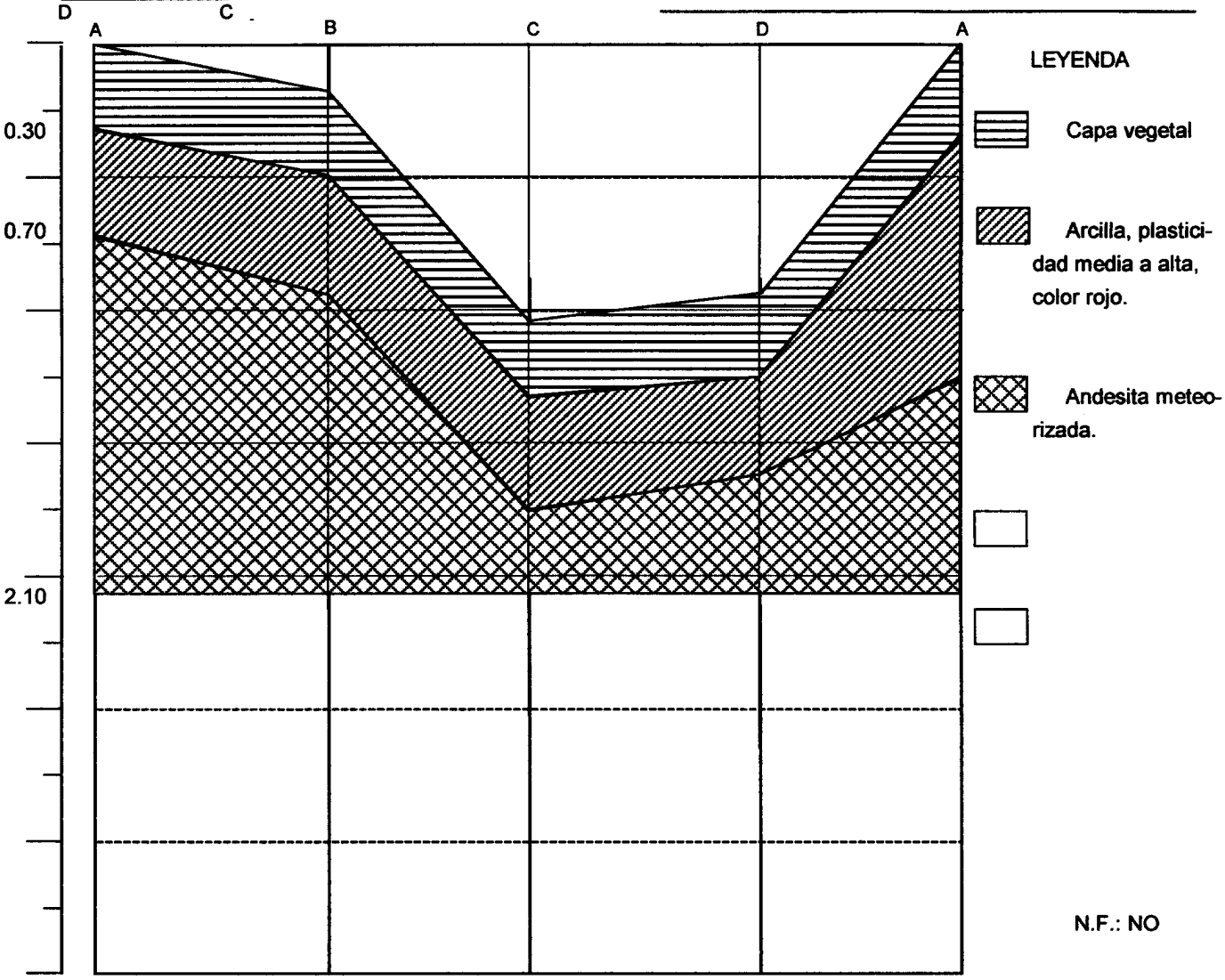
CLIENTE MWH GLOBAL INC.



UBICACIÓN: COORDENADAS APROX.: 664647 E / 1024306 N

ALTITUD APROX. DE 110.0 MTS.

REFERENCIA: LADO IZQUIERDO, RIO ARRIBA



Observaciones: La andesita meteorizada está levemente alterada hidrotermalmente con pirita oxodada (limolita)

FECHA DE INICIO: 5 de junio de 2002 HORA: 09:00

TERMINACIÓN: 5 de junio de 2002 HORA: 15:50

René Sánchez

RESPONSABLE

TECNILAB, S. A. FUNDADA EN 1973

UNA EMPRESA E. BARRANCO Y ASOC., S. A.

LABORATORIO DE SUELOS Y MATERIALES

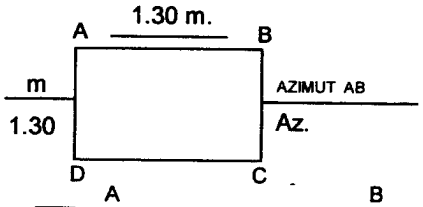
PERFIL DE PERFORACION

TRABAJO No. 4-220 CALICATA No 02-09 FECHA: 3 de junio de 2002

PROYECTO SITIO DE PRESA DEL PROYECTO ALTO CHAGRES

LOCALIZACION RÍO CHAGRES, PROVINCIA DE PANAMÁ

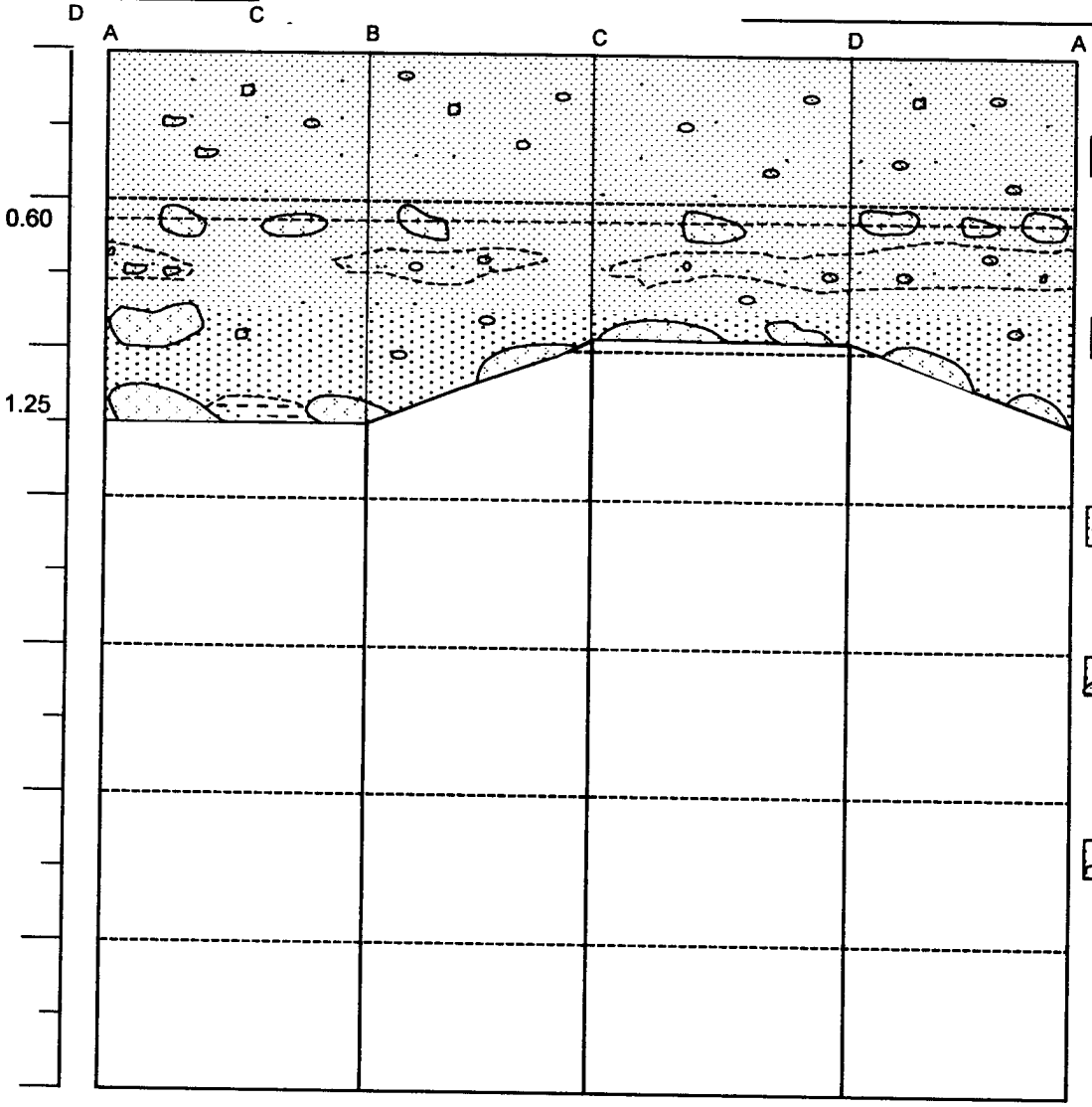
CLIENTE MWH GLOBAL INC.



UBICACIÓN: COORDENADAS APROX.: 664850 E / 1024740 N

ALTITUD APROX. DE 98.0 MTS.

REFERENCIA:



LEYENDA

- Arenas con gravas
- Gravas y guijarros, en arena
- Lente de arena con gravas y poca arcilla roja.
- Rodados de rocas intrusivas y volcánicas
- Lente de arcilla roja con arena

N.F. No

Observaciones:

FECHA DE INICIO: HORA:

TERMINACIÓN: HORA:

René Sánchez

RESPONSABLE

TECNILAB, S. A. FUNDADA EN 1973

UNA EMPRESA E. BARRANCO Y ASOC., S. A.

LABORATORIO DE SUELOS Y MATERIALES

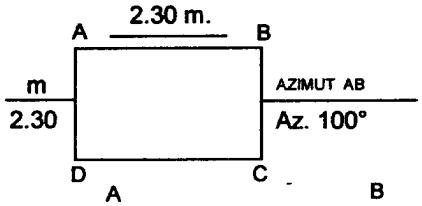
DETALLE DE CALICATA

TRABAJO No. 4-220 CALICATA No 02-10 FECHA: 3 de junio de 2002

PROYECTO SITIO DE PRESA DEL PROYECTO ALTO CHAGRES

LOCALIZACION RÍO CHAGRES, PROVINCIA DE PANAMÁ

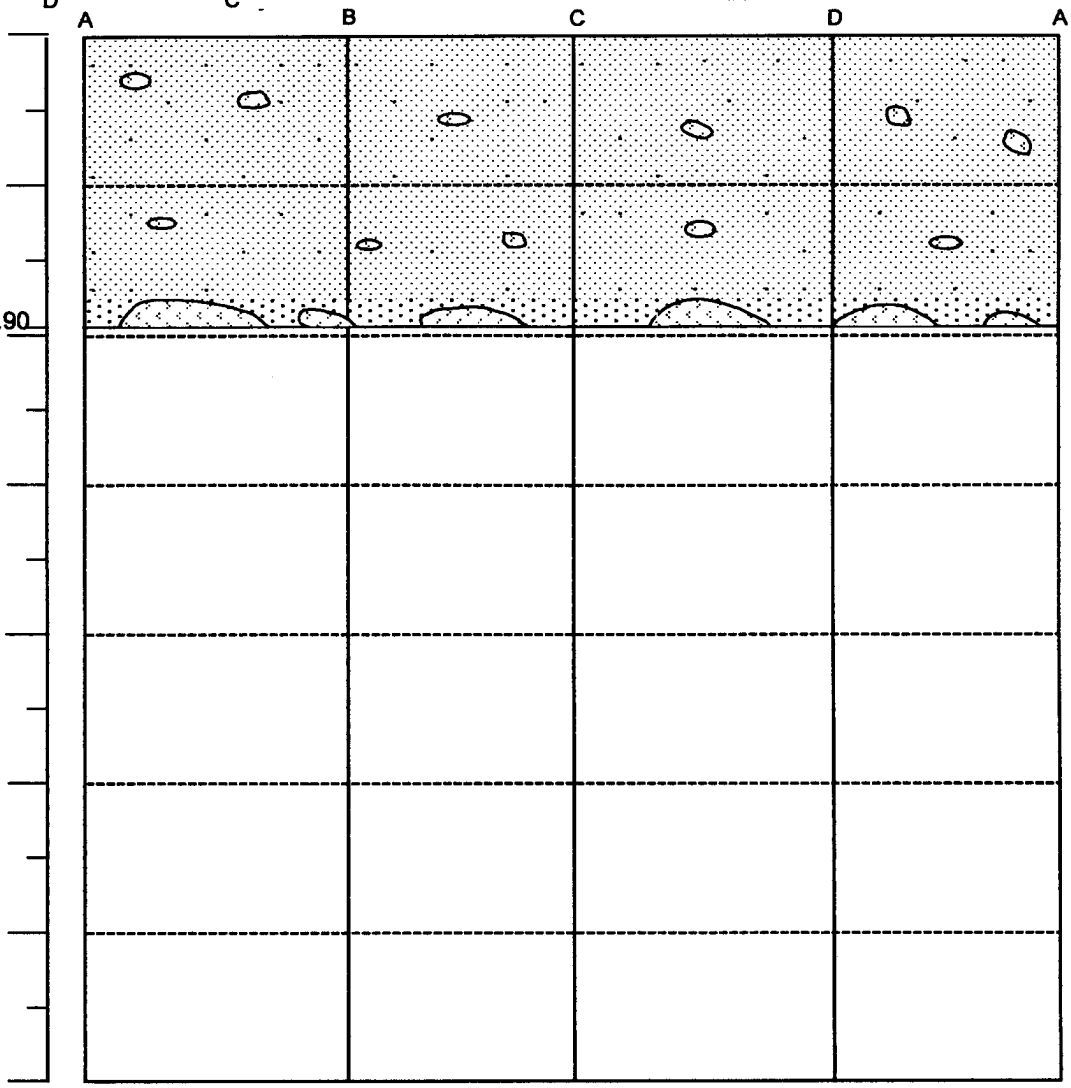
CLIENTE MWH GLOBAL INC.



UBICACIÓN: COORDENADAS APROX.: 664015 E / 1024785 N

ALTITUD APROX. DE 96.0 MTS.

REFERENCIA: TERRAZA CERCANA A LA INTERSECCIÓN DE RÍO CHICO CON EL RÍO CHAGRES.



LEYENDA

Arenas y gravas, menores de 1mm a 60 mm, algunos guijarros

Fondo de rodados de rocas volcánicas e intrusivas.

N.F.: No

Observaciones: :Las gravas, guijarros y rodados son de rocas intrusivas y volcánicas

FECHA DE INICIO: 3 de junio 02 HORA: 13:00

TERMINACIÓN: 3 de junio 02 HORA: 15:00

René Sánchez

RESPONSABLE

II. RESÚMENES

MWH GLOBAL INC

SITIO DE PRESA PROYECTO ALTO CHAGRES

RESUMEN DE PRUEBAS DE LABORATORIO

MUESTRAS DE SUELO

No.	CALICATA (No.)	MUESTRA (No.)	PROFUNDIDAD (m)	CLASIFICACION	ANALISIS GRANULOMETRICO	LIMITES DE ATTERBERG	GRAVEDAD ESPECIFICA	PESO VOLUMETRICO SECO	CONTENIDO NATURAL DE HUMEDAD	PROCTOR ESTANDAR	PINHOLE TEST	ENSAYO TRIAXIAL CU
1	02-01	1	0.30-1.40	x	x	x	x	x	x	X	x	
2	02-01	2	1.40-1.80	x	x	x		x	x		x	
3	02-02	1	0.20-0.65	x	x	x	x	x	x		x	
4	02-02	2	0.65-1.90	x	x	x		x	x	x	x	
5	02-03	1	0.20-0.70	x	x	x		x	x	X	x	
6	02-03	2	0.70-2.00	x	x	x	x	x	x		x	
7	02-03	3	2.00-2.50	x	x	x		x	x	x	x	
8	02-04	1	0.30-0.70	x	x	x	x	x	x	X	x	
9	02-04	2	0.70-2.30	x	x	x		x	x		x	
10	02-05	1	0.60-2.05	x	x	x	x	x	x	x	x	x
11	02-06	1	0.40-1.30	x	x	x		x	x		x	
12	02-06	2	1.30-2.10	x	x	x	x	x	x	x	x	
13	02-07	1	0.70-1.05	x	x	x		x	x	X	x	
14	02-07	2	1.05-1.70	x	x	x	x	x	x		x	

MUESTRAS DE ARENA Y ROCA

				ANALISIS PETROGRAFICO	ANALISIS GRANULOMETRICO	GRAVEDA ESPECIFICA	DESGASTE LOS ANGELES	REACTIVIDAD ALCALINA	POINT LOAD INDEX TEST
11	02-09	1	0.0 - 0.90		x	x	x	x	
12	02-10	1	0.0 - 0.60		x	x	x	x	
13		R1							x
14		R2		x		x			x
15		R3		x		x			x
16		R4		x		x	x	x	x

TECNILAB, S. A.

FUNDADA EN 1973

UNA EMPRESA E. BARRANCO Y ASOC., S. A.

LABORATORIO DE SUELOS Y MATERIALES

MWH GLOBAL, INC

SITIO DE PRESA DEL PROYECTO ALTO CHAGRES

RESUMEN GENERAL DE PRUEBAS DE LABORATORIO A MUESTRAS DE SUELO

No.	Calicata No.	Muestra No.	Profundidad (m)	CLASIFICACION	% w (%)	Análisis Granulométrico % Que Pasa Tamiz No.				LL	LP	IP	G_s	DENSIDAD MAX. (lb/pie^3)	HUMEDAD OPT. (%)	PESO VOL. SECO (g/cm^3)	PINHOLE TEST
						#4	#10	#40	#200								
1	02-01	1	0.30 - 1.40	MH	35.78	100.0	98.90	96.70	84.90	56.10	37.63	18.47	2.77	94.80	27.00	0.830	ND1
2	02-01	2	1.40 - 1.80	CL	20.48	100.0	99.90	98.20	72.10	44.60	21.90	22.70	-			0.846	ND1
3	02-02	1	0.20 - 0.65	MH	21.10	100.0	97.60	90.30	75.90	67.80	38.88	28.92	2.79	-	-	0.847	ND1
4	02-02	2	0.65 - 1.90	ML	33.84	100.0	93.80	80.60	57.10	45.40	32.33	13.07	-	89.20	31.80	0.819	ND1
5	02-03	1	0.20 - 0.70	MH	43.43	100.0	99.70	97.70	83.10	52.60	37.03	15.57	-	85.50	33.20	0.882	ND1
6	02-03	2	0.70 - 2.00	MH	37.48	100.0	99.98	98.38	82.69	58.00	25.10	32.90	2.62			0.779	ND3
7	02-03	3	2.00 - 2.50	CL	20.85	100.0	97.81	91.51	74.52	47.50	26.79	20.71	-	96.70	26.30	0.898	ND1
8	02-04	1	0.30 - 0.70	MH	45.48	100.0	97.81	91.51	80.12	66.80	44.34	22.46	2.66	79.70	36.30	0.774	ND1
9	02-04	2	0.70 - 2.30	CH	33.53	100.0	97.73	93.03	87.52	70.10	32.29	37.81	-			0.839	ND1
10	02-05	1	0.60 - 2.05	ML	21.98	100.0	99.97	92.68	59.74	38.70	30.65	8.05	2.73	102.4	21.30	0.901	ND1
11	02-06	1	0.40 - 1.30	CH	35.10	100.0	99.96	97.89	84.43	53.90	24.26	29.64	-	-	-	0.856	ND1
12	02-06	2	1.30 - 2.10	CL	11.41	100.0	91.12	78.95	56.10	41.00	21.40	19.60	2.84	105.5	21.80	0.997	ND1
13	02-07	1	0.30 - 1.05	MH	30.28	100.0	97.92	89.32	69.14	52.40	30.13	22.27	-	94.00	26.60	0.914	ND1
14	02-07	2	1.05 - 1.70	CL	23.10	100.0	99.92	93.04	67.30	47.40	24.26	23.14	2.72			0.878	ND1

TECNILAB, S. A.
UNA EMPRESA E. BARRANCO Y ASOC., S. A.
LABORATORIO DE SUELOS Y MATERIALES
FUNDADA EN 1973

MWH GLOBAL, INC

SITIO DE PRESA DEL PROYECTO ALTO CHAGRES

RESUMEN GENERAL DE PRUEBAS DE LABORATORIO A MUESTRAS DE ARENA Y ROCA

No.	Calicata No.	Muestra No.	Profundidad (m)	Análisis Granulométrico % Que Pasa Tamiz No.									G_s (Bruta)	DESGASTE LA (%)	REACTIVIDAD ALC (mM/L)	POINT LOAD TEST (MPa) M1	POINT LOAD TEST (MPa) M2
				1 1/2"	1"	3/4"	1/2"	3/8"	#4	#16	#100	#200					
1	02-09	1	0.00 - 0.90	95.60	84.30	74.10	55.00	42.90	22.50	9.99	1.46	0.97	2.90	18.8	47.0	-	-
2	02-10	2	0.00 - 0.60	100.0	87.30	82.20	79.64	68.30	56.60	39.28	1.35	0.91	2.87	22.5	20.0	-	-
3	R1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	2.506	12.03
5	R2	1	-	-	-	-	-	-	-	-	-	-	2.53	-	-	1.502	1.626
8	R3	1	-	-	-	-	-	-	-	-	-	-	2.34	-	-	1.339	-
10	R4	1	-	-	-	-	-	-	-	-	-	-	2.69	17.9	35.0	4.204	11.61

TECNILAB, S. A.
UNA EMPRESA E. BARRANCO Y ASOC., S. A.
LABORATORIO DE SUELOS Y MATERIALES
FUNDADA EN 1973

III. ANÁLISIS GRANULOMETRICO Y LIMITES DE ATTERBERG

TECNILAB, S. A.

TECNILAB, S. A. FUNDADA EN 1973
UNA EMPRESA E. BARRANCO Y ASOC., S. A.
LABORATORIO DE SUELOS Y MATERIALES

ANALISIS MECANICO Y LIMITES DE ATTERBERG ASTM C 136 Y D 4318

TRABAJO No. : 4-220 CLIENTE MWH GLOBAL, INC. Calicata 02-01
PROYECTO: SITIO DE PRESA DEL PROYECTO ALTO CHAGRES LOCALIZACION RIO CHAGRES Muestra 1
MUESTREADO POR TECNILAB, S.A. FECHA 15-Jun-02 PROFUNDIDAD 0.30m a 1.40m
PREPARADO POR TECNILAB, S.A. FECHA 20-Jun-02 LABORATORISTA I. LLERENA

ANALISIS MECANICO

TAMIZ	RETENIDO ACUMULADO	% RETENIDO	% QUE PASA	TAMIZ	RETENIDO ACUMULADO	% RETENIDO	% QUE PASA	CORR QUE PASA
3"				#4	0.00	0.00	100.00	100.00
2½"				#10	2.20	1.17	98.83	98.90
2"				#40	6.20	3.31	96.69	96.70
1½"				#200	28.20	15.06	84.94	84.90
1"				FONDO				
¾"				TOTAL				
½"								
⅜"								
#4								
FONDO								
TOTAL								

AGREGADO FINO

Peso Muestra Total Secada al Aire 214.10 gr
Peso Muestra Total Seca 187.30 gr
Peso Seco Depués de Lavado _____ gr

AGREGADO GRUESO

Peso Muestra Total Secada al Aire _____ gr

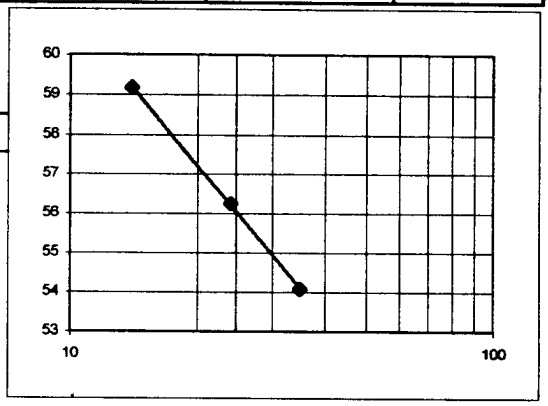
LIMITES DE ATTERBERG

LIMITE LIQUIDO

CAPSULA No.	PESO CAPSULA (gr)	CAPSULA + SUELO HUM. (gr)	CAPSULA + SUELO SECO (gr)	AGUA (gr)	SUELO SECO (gr)	CONTENIDO DE HUMEDAD (%)	NUMERO DE GOLPES
X-9	2.40	17.50	12.20	5.30	9.80	54.08	35
A-11	2.30	17.30	11.90	5.40	9.60	56.25	24
A-5	2.30	17.90	12.10	5.80	9.80	59.18	14

LIMITE PLASTICO

CAPSULA No.	PESO CAPSULA (gr)	CAPSULA + SUELO HUM. (gr)	CAPSULA + SUELO SECO (gr)	AGUA (gr)	SUELO SECO (gr)	CONTENIDO DE HUMEDAD (%)	PROM.
W-3	2.20	8.50	6.80	1.70	4.60	36.96	37.63
W-5	2.30	8.80	7.00	1.80	4.70	38.30	



CLASIFICACION Limo Inorganico de plasticidad baja, color Café rojizo.

CLASIFICACION S.U.C.S (MH)

L.L. = 56.10
L.P. = 37.63
I.p. = 18.47

CLASIFICACION A.A.S.H.T.O.

_____

TECNILAB, S. A. FUNDADA EN 1973
UNA EMPRESA E. BARRANCO Y ASOC., S. A.
LABORATORIO DE SUELOS Y MATERIALES

ANALISIS MECANICO Y LIMITES DE ATTERBERG ASTM C 136 Y D 4318

TRABAJO No. : 4-220 CLIENTE MWH GLOBAL, INC. Calicata 02-01
PROYECTO: SITIO DE PRESA DEL PROYECTO ALTO CHAGRES LOCALIZACION RIO CHAGRES Muestra 2
MUESTREADO POR TECNILAB, S.A. FECHA 15-Jun-02 PROFUNDIDAD 1.40m a 1.80m
PREPARADO POR TECNILAB, S.A. FECHA 20-Jun-02 LABORATORISTA I. LLERENA

ANALISIS MECANICO

TAMIZ	RETENIDO ACUMULADO	% RETENIDO	% QUE PASA	TAMIZ	RETENIDO ACUMULADO	% RETENIDO	% QUE PASA	CORR QUE PASA
3"				#4	0.00	0.00	100.00	100.00
2½"				#10	3.00	1.09	98.91	99.90
2"				#40	5.00	1.81	98.19	98.20
1½"				#200	76.80	27.86	72.14	72.10
1"				FONDO				
¾"				TOTAL				
½"								
⅜"								
#4								
FONDO								
TOTAL								

AGREGADO FINO

Peso Muestra Total Secada al Aire 303.00 gr
Peso Muestra Total Seca 275.70 gr
Peso Seco Depués de Lavado _____ gr

AGREGADO GRUESO

Peso Muestra Total Secada al Aire _____ gr

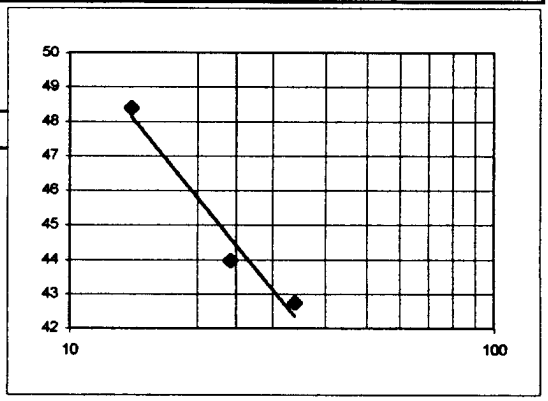
LIMITES DE ATTERBERG

LIMITE LIQUIDO

CAPSULA No.	PESO CAPSULA (gr)	CAPSULA + SUELO HUM. (gr)	CAPSULA + SUELO SECO (gr)	AGUA (gr)	SUELO SECO (gr)	CONTENIDO DE HUMEDAD (%)	NUMERO DE GOLPES
V-4	2.00	18.70	13.70	5.00	11.70	42.74	34
W-5	2.30	19.00	13.90	5.10	11.60	43.97	24
X-2	2.50	16.30	11.80	4.50	9.30	48.39	14

LIMITE PLASTICO

CAPSULA No.	PESO CAPSULA (gr)	CAPSULA + SUELO HUM. (gr)	CAPSULA + SUELO SECO (gr)	AGUA (gr)	SUELO SECO (gr)	CONTENIDO DE HUMEDAD (%)	PROM.
X-12	2.20	4.80	4.30	0.50	2.10	23.81	21.90
W-5	2.20	4.60	4.20	0.40	2.00	20.00	



CLASIFICACION Arcilla Inorganica de plasticidad baja, color Café rojizo.

CLASIFICACION S.U.C.S (CL)

L.L. = 44.60
L.P. = 21.90
I.p. = 22.70

CLASIFICACION A.A.S.H.T.O.

_____

TECNILAB, S. A. FUNDADA EN 1973
UNA EMPRESA E. BARRANCO Y ASOC., S. A.
LABORATORIO DE SUELOS Y MATERIALES

ANALISIS MECANICO Y LIMITES DE ATTERBERG ASTM C 136 Y D 4318

..ABAJO No. : 4-220 CLIENTE MWH GLOBAL, INC. Ca Calicata 02-02
PROYECTO: SITIO DE PRESA DEL PROYECTO ALTO CHAGRES LOCALIZACION RIO CHAGRES Muestra 1
MUESTREADO POR TECNILAB, S.A. FECHA 15-Jun-02 PROFUNDIDAD 0.20m a 0.65m
PREPARADO POR TECNILAB, S.A. FECHA 20-Jun-02 LABORATORISTA I. LLERENA

ANALISIS MECANICO

TAMIZ	RETENIDO ACUMULADO	% RETENIDO	% QUE PASA	TAMIZ	RETENIDO ACUMULADO	% RETENIDO	% QUE PASA	CORR QUE PASA
3"				#4	0.00	0.00	100.00	100.00
2½"				#10	5.50	2.35	97.65	97.60
2"				#40	22.80	9.75	90.25	90.30
1½"				#200	56.30	24.07	75.93	75.90
1"				FONDO				
¾"				TOTAL				
½"								
⅜"								
#4								
FONDO								
TOTAL								

AGREGADO FINO
Peso Muestra Total Secada al Aire 274.20 gr
Peso Muestra Total Seca 233.90 gr
Peso Seco Depués de Lavado _____ gr

AGREGADO GRUESO
Peso Muestra Total Secada al Aire _____ gr

LIMITES DE ATTERBERG

LIMITE LIQUIDO

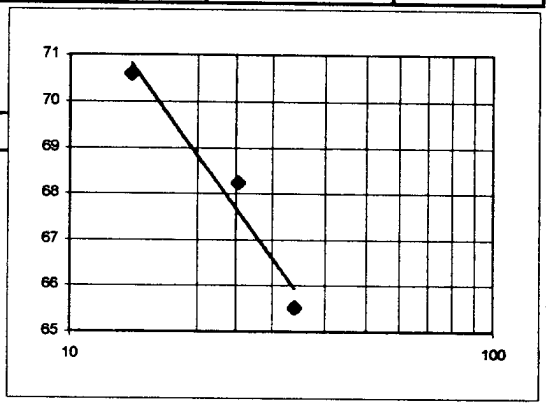
CAPSULA No.	PESO CAPSULA (gr)	CAPSULA + SUELO HUM. (gr)	CAPSULA + SUELO SECO (gr)	AGUA (gr)	SUELO SECO (gr)	CONTENIDO DE HUMEDAD (%)	NUMERO DE GOLPES
X-10	2.50	16.90	11.20	5.70	8.70	65.52	34
X-5	2.30	16.60	10.80	5.80	8.50	68.24	25
X-5	2.40	16.90	10.90	6.00	8.50	70.59	14

LIMITE PLASTICO

CAPSULA No.	PESO CAPSULA (gr)	CAPSULA + SUELO HUM. (gr)	CAPSULA + SUELO SECO (gr)	AGUA (gr)	SUELO SECO (gr)	CONTENIDO DE HUMEDAD (%)	PROM.
V-4	2.00	10.70	8.30	2.40	6.30	38.10	38.88
A-11	2.30	10.40	8.10	2.30	5.80	39.66	

CLASIFICACION Limo Inorganico de plasticidad media, color Café rojizo.
CLASIFICACION S.U.C.S (MH)
L.L. = 67.80
L.P. = 38.88
I.p. = 28.92

CLASIFICACION A.A.S.H.T.O.



TECNILAB, S. A.
UNA EMPRESA E. BARRANCO Y ASOC., S. A.
LABORATORIO DE SUELOS Y MATERIALES

FUNDADA EN 1973

ANALISIS MECANICO Y LIMITES DE ATTERBERG ASTM C 136 Y D 4318

TRABAJO No. : 4-220 CLIENTE MWH GLOBAL, INC. Calicata 02-02
PROYECTO: SITIO DE PRESA DEL PROYECTO ALTO CHAGRES LOCALIZACION RIO CHAGRES Muestra 2
MUESTREADO POR TECNILAB, S.A. FECHA 15-Jun-02 PROFUNDIDAD 0.65m a 1.90m
PREPARADO POR TECNILAB, S.A. FECHA 20-Jun-02 LABORATORISTA I. LLERENA

ANALISIS MECANICO

TAMIZ	RETENIDO ACUMULADO	% RETENIDO	% QUE PASA	TAMIZ	RETENIDO ACUMULADO	% RETENIDO	% QUE PASA	CORR QUE PASA
3"				#4	0.00	0.00	100.00	100.00
2½"				#10	17.70	6.18	93.82	93.80
2"				#40	55.50	19.37	80.63	80.60
1 1/2"				#200	122.90	42.90	57.10	57.10
1"				FONDO				
3/4"				TOTAL				
1/2"								
3/8"								
#4								
FONDO								
TOTAL								

AGREGADO FINO

Peso Muestra Total Secada al Aire 325.60 gr
Peso Muestra Total Seca 286.50 gr
Peso Seco Depués de Lavado _____ gr

AGREGADO GRUESO

Peso Muestra Total Secada al Aire _____ gr

LIMITES DE ATTERBERG

LIMITE LIQUIDO

CAPSULA No.	PESO CAPSULA (gr)	CAPSULA + SUELO HUM. (gr)	CAPSULA + SUELO SECO (gr)	AGUA (gr)	SUELO SECO (gr)	CONTENIDO DE HUMEDAD (%)	NUMERO DE GOLPES
T-9	2.20	21.50	15.70	5.80	13.50	42.96	33
W-3	2.20	20.40	14.70	5.70	12.50	45.60	25
X-12	2.10	18.30	13.00	5.30	10.90	48.62	15

LIMITE PLASTICO

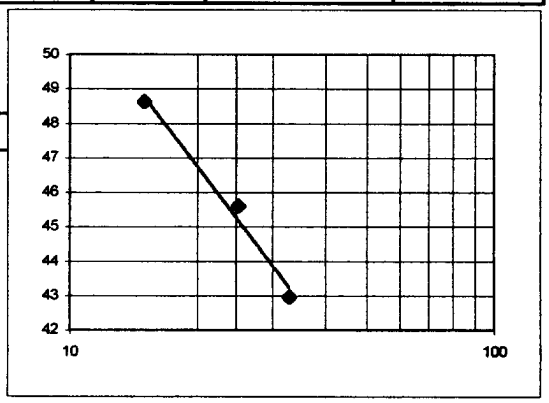
CAPSULA No.	PESO CAPSULA (gr)	CAPSULA + SUELO HUM. (gr)	CAPSULA + SUELO SECO (gr)	AGUA (gr)	SUELO SECO (gr)	CONTENIDO DE HUMEDAD (%)	PROM.
T-9	4.20	14.90	12.30	2.60	8.10	32.10	32.33
T-12	4.30	15.70	12.90	2.80	8.60	32.56	

CLASIFICACION Limo Inorganico de plasticidad baja, color Café rojizo.

CLASIFICACION S.U.C.S (ML)

L.L. = 45.40
L.P. = 32.33
I.p. = 13.07

CLASIFICACION A.A.S.H.T.O.



TECNILAB, S. A.
UNA EMPRESA E. BARRANCO Y ASOC., S. A.
LABORATORIO DE SUELOS Y MATERIALES

FUNDADA EN 1973

ANALISIS MECANICO Y LIMITES DE ATTERBERG ASTM C 136 Y D 4318

TRABAJO No. : 4-220 CLIENTE MWH GLOBAL, INC. Calicata 02-03
PROYECTO: SITIO DE PRESA DEL PROYECTO ALTO CHAGRES LOCALIZACION RIO CHAGRES Muestra 1
MUESTREADO POR TECNILAB, S.A. FECHA 15-Jun-02 PROFUNDIDAD 0.20m a 0.70m
PREPARADO POR TECNILAB, S.A. FECHA 25-Jun-02 LABORATORISTA I. LLERENA

ANALISIS MECANICO

TAMIZ	RETENIDO ACUMULADO	% RETENIDO	% QUE PASA	TAMIZ	RETENIDO ACUMULADO	% RETENIDO	% QUE PASA	CORR QUE PASA
3"				#4	0.00	0.00	100.00	100.00
2½"				#10	0.60	0.29	99.71	99.71
2"				#40	4.30	2.07	97.93	97.93
1 1/2"				#200	35.20	16.91	83.09	83.09
1"				FONDO				
3/4"				TOTAL				
1/2"								
3/8"								
#4								
FONDO								
TOTAL								

AGREGADO FINO

Peso Muestra Total Secada al Aire 227.80 gr
Peso Muestra Total Seca 208.20 gr
Peso Seco Depués de Lavado _____ gr

AGREGADO GRUESO

Peso Muestra Total Secada al Aire _____ gr

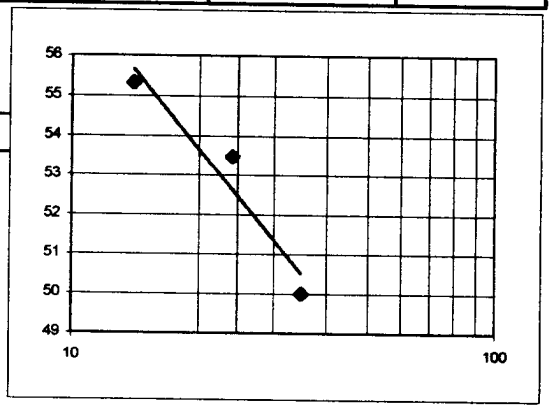
LIMITES DE ATTERBERG

LIMITE LIQUIDO

CAPSULA No.	PESO CAPSULA (gr)	CAPSULA + SUELO HUM. (gr)	CAPSULA + SUELO SECO (gr)	AGUA (gr)	SUELO SECO (gr)	CONTENIDO DE HUMEDAD (%)	NUMERO DE GOLPES
1-5	10.70	23.30	19.10	4.20	8.40	50.00	35
T-9	10.60	23.80	19.20	4.60	8.60	53.49	24
Z-1	10.50	25.10	19.90	5.20	9.40	55.32	14

LIMITE PLASTICO

CAPSULA No.	PESO CAPSULA (gr)	CAPSULA + SUELO HUM. (gr)	CAPSULA + SUELO SECO (gr)	AGUA (gr)	SUELO SECO (gr)	CONTENIDO DE HUMEDAD (%)	PROM.
T-9	4.00	13.60	11.00	2.60	7.00	37.14	37.03
T-12	4.00	12.90	10.50	2.40	6.50	36.92	



CLASIFICACION Limos Inorganicos, Limos Micaceos o Diatomaceos. Limos Elasticos

CLASIFICACION S.U.C.S (MH)

L.L. = 52.60
L.P. = 37.03
I.p. = 15.57

CLASIFICACION A.A.S.H.T.O.

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TECNILAB, S. A.
UNA EMPRESA E. BARRANCO Y ASOC., S. A.
LABORATORIO DE SUELOS Y MATERIALES

FUNDADA EN 1973

ANALISIS MECANICO Y LIMITES DE ATTERBERG ASTM C 136 Y D 4318

TRABAJO No. : 4-220 CLIENTE MWH GLOBAL, INC. Calicata 02-03
PROYECTO: SITIO DE PRESA DEL PROYECTO ALTO CHAGRES LOCALIZACION RIO CHAGRES Muestra 2
MUESTREADO POR TECNILAB, S.A. FECHA 15-Jun-02 PROFUNDIDAD 0.70m A 2.00m
PREPARADO POR TECNILAB, S.A. FECHA 25-Jun-02 LABORATORISTA I. LLERENA

ANALISIS MECANICO

TAMIZ	RETENIDO ACUMULADO	% RETENIDO	% QUE PASA	TAMIZ	RETENIDO ACUMULADO	% RETENIDO	% QUE PASA	CORR QUE PASA
3"				#4	0.00	0.00	100.00	100.00
2½"				#10	0.04	0.02	99.98	99.98
2"				#40	2.90	1.62	98.38	98.38
1 1/2"				#200	30.90	17.31	82.69	82.69
1"				FONDO				
3/4"				TOTAL				
1/2"								
3/8"								
#4								
FONDO								
TOTAL								

AGREGADO FINO

Peso Muestra Total Secada al Aire 228.80 gr
Peso Muestra Total Seca 178.50 gr
Peso Seco Depués de Lavado _____ gr

AGREGADO GRUESO

Peso Muestra Total Secada al Aire _____ gr

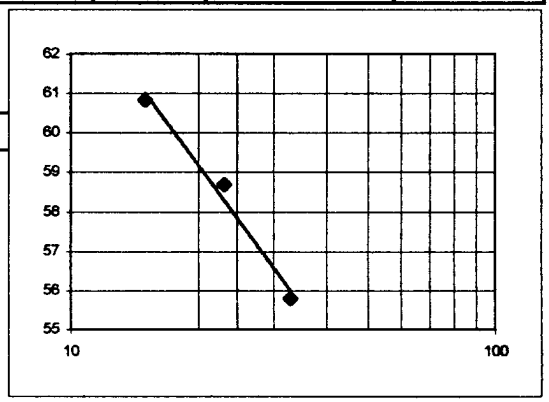
LIMITES DE ATTERBERG

LIMITE LIQUIDO

CAPSULA No.	PESO CAPSULA (gr)	CAPSULA + SUELO HUM. (gr)	CAPSULA + SUELO SECO (gr)	AGUA (gr)	SUELO SECO (gr)	CONTENIDO DE HUMEDAD (%)	NUMERO DE GOLPES
B-3	1.90	16.70	11.40	5.30	9.50	55.79	33
B-4	1.90	16.50	11.10	5.40	9.20	58.70	23
B-1	1.90	17.50	11.60	5.90	9.70	60.82	15

LIMITE PLASTICO

CAPSULA No.	PESO CAPSULA (gr)	CAPSULA + SUELO HUM. (gr)	CAPSULA + SUELO SECO (gr)	AGUA (gr)	SUELO SECO (gr)	CONTENIDO DE HUMEDAD (%)	PROM.
X-9	2.20	4.10	3.70	0.40	1.50	26.67	25.10
X-6	2.10	4.20	3.80	0.40	1.70	23.53	



CLASIFICACION Limo Inorganico de plasticidad media, color Ocre (amarillo).

CLASIFICACION S.U.C.S (MH)

L.L. = 58.00
L.P. = 25.10
I.p. = 32.90

CLASIFICACION A.A.S.H.T.O.

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TECNILAB, S. A. FUNDADA EN 1973
UNA EMPRESA E. BARRANCO Y ASOC., S. A.
LABORATORIO DE SUELOS Y MATERIALES

ANALISIS MECANICO Y LIMITES DE ATTERBERG ASTM C 136 Y D 4318

TRABAJO No. : 4-220 CLIENTE MWH GLOBAL, INC. Calicata 02-03
PROYECTO: SITIO DE PRESA DEL PROYECTO ALTO CHAGRES LOCALIZACION RIO CHAGRES Muestra 3
MUESTREADO POR TECNILAB, S.A. FECHA 15-Jun-02 PROFUNDIDAD 2.00m A 2.50m
PREPARADO POR TECNILAB, S.A. FECHA 25-Jun-02 LABORATORISTA I. LLERENA

ANALISIS MECANICO

TAMIZ	RETENIDO ACUMULADO	% RETENIDO	% QUE PASA	TAMIZ	RETENIDO ACUMULADO	% RETENIDO	% QUE PASA	CORR QUE PASA
3"				#4	0.00	0.00	100.00	100.00
2½"				#10	5.50	2.19	97.81	97.81
2"				#40	21.30	8.49	91.51	91.51
1 1/2"				#200	63.90	25.48	74.52	74.52
1"				FONDO				
3/4"				TOTAL				
1/2"								
3/8"								
#4								
FONDO								
TOTAL								

AGREGADO FINO

Peso Muestra Total Secada al Aire 291.60 gr
Peso Muestra Total Seca 250.80 gr
Peso Seco Depués de Lavado _____ gr

AGREGADO GRUESO

Peso Muestra Total Secada al Aire _____ gr

LIMITES DE ATTERBERG

LIMITE LIQUIDO

CAPSULA No.	PESO CAPSULA (gr)	CAPSULA + SUELO HUM. (gr)	CAPSULA + SUELO SECO (gr)	AGUA (gr)	SUELO SECO (gr)	CONTENIDO DE HUMEDAD (%)	NUMERO DE GOLPES
X-1	2.30	15.30	11.20	4.10	8.90	46.07	33
X-6	2.20	17.00	12.20	4.80	10.00	48.00	23
B-7	2.00	16.50	11.70	4.80	9.70	49.48	15

LIMITE PLASTICO

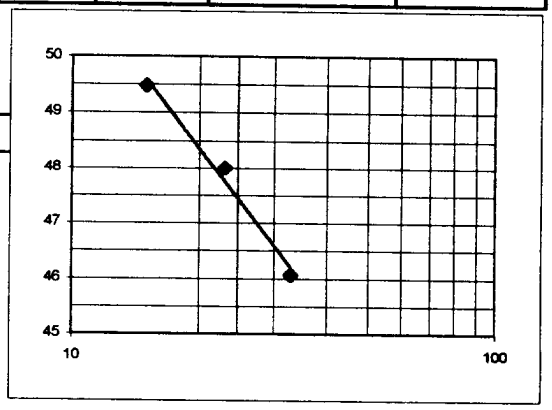
CAPSULA No.	PESO CAPSULA (gr)	CAPSULA + SUELO HUM. (gr)	CAPSULA + SUELO SECO (gr)	AGUA (gr)	SUELO SECO (gr)	CONTENIDO DE HUMEDAD (%)	PROM.
X-4	2.10	4.10	3.70	0.40	1.60	25.00	26.79
X-5	2.20	4.00	3.60	0.40	1.40	28.57	

CLASIFICACION Arcilla Inorganica de plasticidad baja, color Café claro.

CLASIFICACION S.U.C.S (CL)

L.L. = 47.50
L.P. = 26.79
I.p. = 20.71

CLASIFICACION A.A.S.H.T.O.



TECNILAB, S. A. FUNDADA EN 1973
UNA EMPRESA E. BARRANCO Y ASOC., S. A.
LABORATORIO DE SUELOS Y MATERIALES

ANALISIS MECANICO Y LIMITES DE ATTERBERG ASTM C 136 Y D 4318

TRABAJO No. : 4-220 CLIENTE MWH GLOBAL, INC. Calicata 02-04
PROYECTO: SITIO DE PRESA DEL PROYECTO ALTO CHAGRES LOCALIZACION RIO CHAGRES Muestra 1
MUESTREADO POR TECNILAB, S.A. FECHA 15-Jun-02 PROFUNDIDAD 0.30m A 0.70m
PREPARADO POR TECNILAB, S.A. FECHA 25-Jun-02 LABORATORISTA I. LLERENA

ANALISIS MECANICO

TAMIZ	RETENIDO ACUMULADO	% RETENIDO	% QUE PASA	TAMIZ	RETENIDO ACUMULADO	% RETENIDO	% QUE PASA	CORR QUE PASA
3"				#4	0.00	0.00	100.00	100.00
2½"				#10	7.10	3.60	96.40	96.40
2"				#40	16.40	8.32	91.68	91.68
1 1/2"				#200	31.20	15.82	84.18	84.18
1"				FONDO				
3/4"				TOTAL				
1/2"								
3/8"								
#4								
FONDO								
TOTAL								

AGREGADO FINO

Peso Muestra Total Secada al Aire 249.00 gr
Peso Muestra Total Seca 197.20 gr
Peso Seco Depués de Lavado _____ gr

AGREGADO GRUESO

Peso Muestra Total Secada al Aire _____ gr

LIMITES DE ATTERBERG

LIMITE LIQUIDO

CAPSULA No.	PESO CAPSULA (gr)	CAPSULA + SUELO HUM. (gr)	CAPSULA + SUELO SECO (gr)	AGUA (gr)	SUELO SECO (gr)	CONTENIDO DE HUMEDAD (%)	NUMERO DE GOLPES
T-9	2.30	17.30	11.40	5.90	9.10	64.84	33
X-10	2.40	18.10	11.80	6.30	9.40	67.02	23
X-5	2.30	17.10	11.00	6.10	8.70	70.11	15

LIMITE PLASTICO

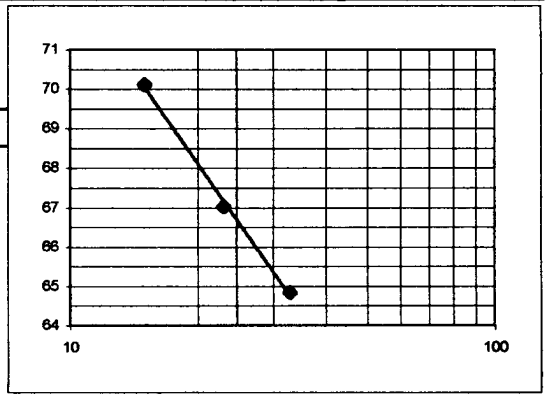
CAPSULA No.	PESO CAPSULA (gr)	CAPSULA + SUELO HUM. (gr)	CAPSULA + SUELO SECO (gr)	AGUA (gr)	SUELO SECO (gr)	CONTENIDO DE HUMEDAD (%)	PROM.
W-5	2.30	11.70	8.80	2.90	6.50	44.62	44.34
X-2	2.50	11.00	8.40	2.60	5.90	44.07	

CLASIFICACION Limos Inorganicos de plasticidad baja, color café rojizo.

CLASIFICACION S.U.C.S (MH)

L.L. = 66.80
L.P. = 44.34
I.p. = 22.46

CLASIFICACION A.A.S.H.T.O.



TECNILAB, S. A. FUNDADA EN 1973
UNA EMPRESA E. BARRANCO Y ASOC., S. A.
LABORATORIO DE SUELOS Y MATERIALES

ANALISIS MECANICO Y LIMITES DE ATTERBERG ASTM C 136 Y D 4318

..ABAJO No. : 4-220 CLIENTE MWH GLOBAL, INC. Calicata 02-04
PROYECTO: SITIO DE PRESA DEL PROYECTO ALTO CHAGRES LOCALIZACION RIO CHAGRES Muestra 2
MUESTREADO POR TECNILAB, S.A. FECHA 15-Jun-02 PROFUNDIDAD 0.70m A 2.30m
PREPARADO POR TECNILAB, S.A. FECHA 25-Jun-02 LABORATORISTA I. LLERENA

ANALISIS MECANICO

TAMIZ	RETENIDO ACUMULADO	% RETENIDO	% QUE PASA	TAMIZ	RETENIDO ACUMULADO	% RETENIDO	% QUE PASA	CORR QUE PASA
3"				#4	0.00	0.00	100.00	100.00
2½"				#10	4.70	2.27	97.73	97.73
2"				#40	14.40	6.97	93.03	93.03
1 1/2"				#200	25.80	12.49	87.51	87.51
1"				FONDO				
3/4"				TOTAL				
1/2"								
3/8"								
#4								
FONDO								
TOTAL								

AGREGADO FINO

Peso Muestra Total Secada al Aire 246.00 gr
Peso Muestra Total Seca 206.60 gr
Peso Seco Depués de Lavado _____ gr

AGREGADO GRUESO

Peso Muestra Total Secada al Aire _____ gr

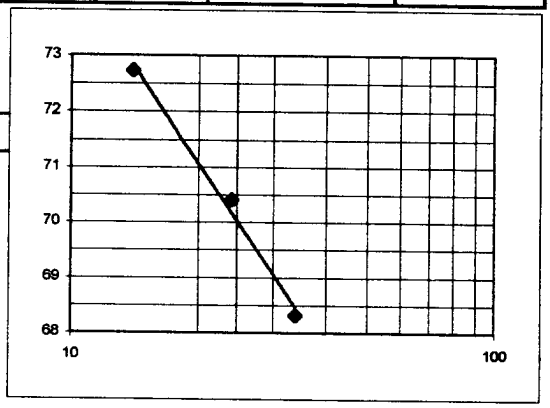
LIMITES DE ATTERBERG

LIMITE LIQUIDO

CAPSULA No.	PESO CAPSULA (gr)	CAPSULA + SUELO HUM. (gr)	CAPSULA + SUELO SECO (gr)	AGUA (gr)	SUELO SECO (gr)	CONTENIDO DE HUMEDAD (%)	NUMERO DE GOLPES
B-6	2.50	19.50	12.60	6.90	10.10	68.32	34
B-5	2.40	19.10	12.20	6.90	9.80	70.41	24
B-4	2.30	19.40	12.20	7.20	9.90	72.73	14

LIMITE PLASTICO

CAPSULA No.	PESO CAPSULA (gr)	CAPSULA + SUELO HUM. (gr)	CAPSULA + SUELO SECO (gr)	AGUA (gr)	SUELO SECO (gr)	CONTENIDO DE HUMEDAD (%)	PROM.
X-2	2.30	4.30	3.80	0.50	1.50	33.33	32.29
X-1	1.80	3.90	3.40	0.50	1.60	31.25	



CLASIFICACION Arcilla Inorganica de plasticidad media, color Café rojizo.

CLASIFICACION S.U.C.S (CH)

L.L. = 70.10
L.P. = 32.29
I.p. = 37.81

CLASIFICACION A.A.S.H.T.O.

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TECNILAB, S. A.
UNA EMPRESA E. BARRANCO Y ASOC., S. A.
LABORATORIO DE SUELOS Y MATERIALES

FUNDADA EN 1973

ANALISIS MECANICO Y LIMITES DE ATTERBERG ASTM C 136 Y D 4318

TRABAJO No. : 4-220 CLIENTE MWH GLOBAL, INC. Calicata 02-05
PROYECTO: SITIO DE PRESA DEL PROYECTO ALTO CHAGRES LOCALIZACION RIO CHAGRES Muestra 1
MUESTREADO POR TECNILAB, S.A. FECHA 15-Jun-02 PROFUNDIDAD 0.60m A 2.05m
PREPARADO POR TECNILAB, S.A. FECHA 25-Jun-02 LABORATORISTA I. LLERENA

ANALISIS MECANICO

TAMIZ	RETENIDO ACUMULADO	% RETENIDO	% QUE PASA	TAMIZ	RETENIDO ACUMULADO	% RETENIDO	% QUE PASA	CORR QUE PASA
3"				#4	0.00	0.00	100.00	100.00
2½"				#10	0.70	0.28	99.72	99.72
2"				#40	18.30	7.32	92.68	92.68
1 1/2"				#200	100.70	40.26	59.74	59.74
1"				FONDO				
3/4"				TOTAL				
1/2"								
3/8"								
#4								
FONDO								
TOTAL								

AGREGADO FINO

Peso Muestra Total Secada al Aire 276.30 gr
Peso Muestra Total Seca 250.10 gr
Peso Seco Depués de Lavado _____ gr

AGREGADO GRUESO

Peso Muestra Total Secada al Aire _____ gr

LIMITES DE ATTERBERG

LIMITE LIQUIDO

CAPSULA No.	PESO CAPSULA (gr)	CAPSULA + SUELO HUM. (gr)	CAPSULA + SUELO SECO (gr)	AGUA (gr)	SUELO SECO (gr)	CONTENIDO DE HUMEDAD (%)	NUMERO DE GOLPES
B-8	1.90	17.60	13.40	4.20	11.50	36.52	35
B-5	1.90	17.40	13.00	4.40	11.10	39.64	24
B-2	1.90	17.00	12.60	4.40	10.70	41.12	14

LIMITE PLASTICO

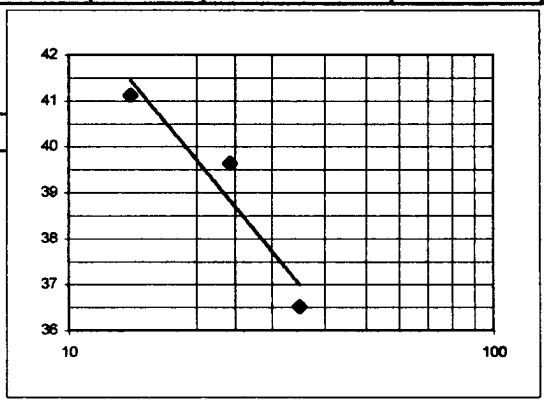
CAPSULA No.	PESO CAPSULA (gr)	CAPSULA + SUELO HUM. (gr)	CAPSULA + SUELO SECO (gr)	AGUA (gr)	SUELO SECO (gr)	CONTENIDO DE HUMEDAD (%)	PROM.
A-8	2.30	10.50	8.60	1.90	6.30	30.16	30.65
A-5	2.40	10.40	8.50	1.90	6.10	31.15	

CLASIFICACION Limo Inorganico de plasticidad baja, color Café claro a ocre.

CLASIFICACION S.U.C.S (ML)

L.L. = 38.70
L.P. = 30.65
I.p. = 8.05

CLASIFICACION A.A.S.H.T.O.



TECNILAB, S. A.
UNA EMPRESA E. BARRANCO Y ASOC., S. A.
LABORATORIO DE SUELOS Y MATERIALES

FUNDADA EN 1973

ANALISIS MECANICO Y LIMITES DE ATTERBERG ASTM C 136 Y D 4318

..ABAJO No. : 4-220 CLIENTE MWH GLOBAL, INC. Calicata 02-06
PROYECTO: SITIO DE PRESA DEL PROYECTO ALTO CHAGRES LOCALIZACION RIO CHAGRES Muestra 1
MUESTREADO POR TECNILAB, S.A. FECHA 15-Jun-02 PROFUNDIDAD 0.40m a 1.30m
PREPARADO POR TECNILAB, S.A. FECHA 25-Jun-02 LABORATORISTA I. LLERENA

ANALISIS MECANICO

TAMIZ	RETENIDO ACUMULADO	% RETENIDO	% QUE PASA	TAMIZ	RETENIDO ACUMULADO	% RETENIDO	% QUE PASA	CORR QUE PASA
3"				#4	0.00	0.00	100.00	100.00
2½"				#10	0.60	0.31	99.69	99.69
2"				#40	4.10	2.11	97.89	97.89
1½"				#200	30.20	15.58	84.42	84.42
1"				FONDO				
¾"				TOTAL				
½"								
⅜"								
#4								
FONDO								
TOTAL								

AGREGADO FINO

Peso Muestra Total Secada al Aire 246.40 gr
Peso Muestra Total Seca 193.90 gr
Peso Seco Depués de Lavado _____ gr

AGREGADO GRUESO

Peso Muestra Total Secada al Aire _____ gr

LIMITES DE ATTERBERG

LIMITE LIQUIDO

CAPSULA No.	PESO CAPSULA (gr)	CAPSULA + SUELO HUM. (gr)	CAPSULA + SUELO SECO (gr)	AGUA (gr)	SUELO SECO (gr)	CONTENIDO DE HUMEDAD (%)	NUMERO DE GOLPES
T-9	10.90	26.80	21.30	5.50	10.40	52.88	32
V-4	2.00	21.00	14.30	6.70	12.30	54.47	24
V-9	2.30	21.70	14.80	6.90	12.50	55.20	14

LIMITE PLASTICO

CAPSULA No.	PESO CAPSULA (gr)	CAPSULA + SUELO HUM. (gr)	CAPSULA + SUELO SECO (gr)	AGUA (gr)	SUELO SECO (gr)	CONTENIDO DE HUMEDAD (%)	PROM.
B-4	1.90	3.90	3.50	0.40	1.60	25.00	24.26
B-8	1.90	4.00	3.60	0.40	1.70	23.53	

CLASIFICACION Arcilla Inorganica de plasticidad media, color Café claro.

CLASIFICACION S.U.C.S (CH)

L.L. = 53.90
L.P. = 24.26
I.p. = 29.64

CLASIFICACION A.A.S.H.T.O.

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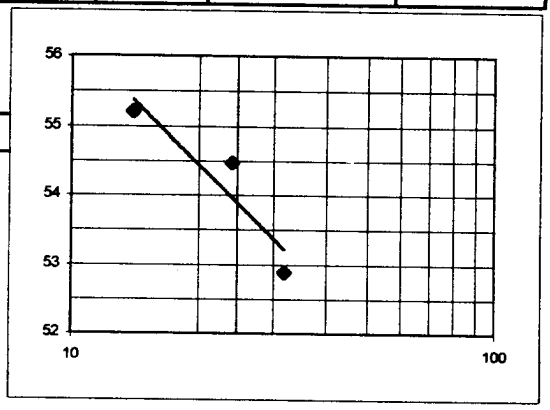


TECNILAB, S. A.
UNA EMPRESA E. BARRANCO Y ASOC., S. A.
LABORATORIO DE SUELOS Y MATERIALES

FUNDADA EN 1973

ANALISIS MECANICO Y LIMITES DE ATTERBERG ASTM C 136 Y D 4318

TRABAJO No. : 4-220 CLIENTE MWH GLOBAL, INC. Calicata 02-06
PROYECTO: SITIO DE PRESA DEL PROYECTO ALTO CHAGRES LOCALIZACION RIO CHAGRES Muestra 2
MUESTREADO POR TECNILAB, S.A. FECHA 15-Jun-02 PROFUNDIDAD 1.30m A 2.10m
PREPARADO POR TECNILAB, S.A. FECHA 25-Jun-02 LABORATORISTA I. LLERENA

ANALISIS MECANICO

TAMIZ	RETENIDO ACUMULADO	% RETENIDO	% QUE PASA	TAMIZ	RETENIDO ACUMULADO	% RETENIDO	% QUE PASA	CORR QUE PASA
3"				#4	0.00	0.00	100.00	100.00
2½"				#10	20.90	8.89	91.11	91.11
2"				#40	49.50	21.05	78.95	78.95
1 1/2"				#200	103.20	43.90	56.10	56.10
1"				FONDO				
3/4"				TOTAL				
1/2"								
3/8"								
#4								
FONDO								
TOTAL								

AGREGADO FINO

Peso Muestra Total Secada al Aire 261.10 gr
Peso Muestra Total Seca 235.10 gr
Peso Seco Depués de Lavado _____ gr

AGREGADO GRUESO

Peso Muestra Total Secada al Aire _____ gr

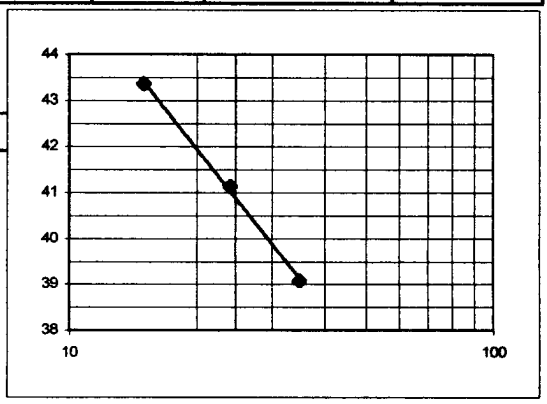
LIMITES DE ATTERBERG

LIMITE LIQUIDO

CAPSULA No.	PESO CAPSULA (gr)	CAPSULA + SUELO HUM. (gr)	CAPSULA + SUELO SECO (gr)	AGUA (gr)	SUELO SECO (gr)	CONTENIDO DE HUMEDAD (%)	NUMERO DE GOLPES
X-2	2.50	23.50	17.60	5.90	15.10	39.07	35
X-12	2.10	19.60	14.50	5.10	12.40	41.13	24
W-5	2.30	22.80	16.60	6.20	14.30	43.36	15

LIMITE PLASTICO

CAPSULA No.	PESO CAPSULA (gr)	CAPSULA + SUELO HUM. (gr)	CAPSULA + SUELO SECO (gr)	AGUA (gr)	SUELO SECO (gr)	CONTENIDO DE HUMEDAD (%)	PROM.
B-2	1.90	4.20	3.80	0.40	1.90	21.05	21.40
B-5	1.90	4.70	4.20	0.50	2.30	21.74	



CLASIFICACION Arcilla inorganica de baja plasticidad, color Café claro con pintas ocre.

CLASIFICACION S.U.C.S (CL)

L.L. = 41.00
L.P. = 21.40
I.p. = 19.60

CLASIFICACION A.A.S.H.T.O.

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TECNILAB, S. A. FUNDADA EN 1973
UNA EMPRESA E. BARRANCO Y ASOC., S. A.
LABORATORIO DE SUELOS Y MATERIALES

ANALISIS MECANICO Y LIMITES DE ATTERBERG ASTM C 136 Y D 4318

TRABAJO No. : 4-220 CLIENTE MWH GLOBAL, INC. Calicata 02-07
PROYECTO: SITIO DE PRESA DEL PROYECTO ALTO CHAGRES LOCALIZACION RIO CHAGRES Muestra 1
MUESTREADO POR TECNILAB, S.A. FECHA 15-Jun-02 PROFUNDIDAD 0.30m a 1.05m
PREPARADO POR TECNILAB, S.A. FECHA 25-Jun-02 LABORATORISTA I. LLERENA

ANALISIS MECANICO

TAMIZ	RETENIDO ACUMULADO	% RETENIDO	% QUE PASA	TAMIZ	RETENIDO ACUMULADO	% RETENIDO	% QUE PASA	CORR QUE PASA
3"				#4	0.00	0.00	100.00	100.00
2½"				#10	4.40	2.09	97.91	97.91
2"				#40	22.50	10.68	89.32	89.32
1 1/2"				#200	65.00	30.86	69.14	69.14
1"				FONDO				
3/4"				TOTAL				
1/2"								
3/8"								
#4								
FONDO								
TOTAL								

AGREGADO FINO

Peso Muestra Total Secada al Aire 250.40 gr
Peso Muestra Total Seca 210.60 gr
Peso Seco Depués de Lavado _____ gr

AGREGADO GRUESO

Peso Muestra Total Secada al Aire _____ gr

LIMITES DE ATTERBERG

LIMITE LIQUIDO

CAPSULA No.	PESO CAPSULA (gr)	CAPSULA + SUELO HUM. (gr)	CAPSULA + SUELO SECO (gr)	AGUA (gr)	SUELO SECO (gr)	CONTENIDO DE HUMEDAD (%)	NUMERO DE GOLPES
B-2	1.90	21.60	14.90	6.70	13.00	51.54	35
B-4	1.90	23.40	16.00	7.40	14.10	52.48	24
B-5	1.90	22.60	15.40	7.20	13.50	53.33	15

LIMITE PLASTICO

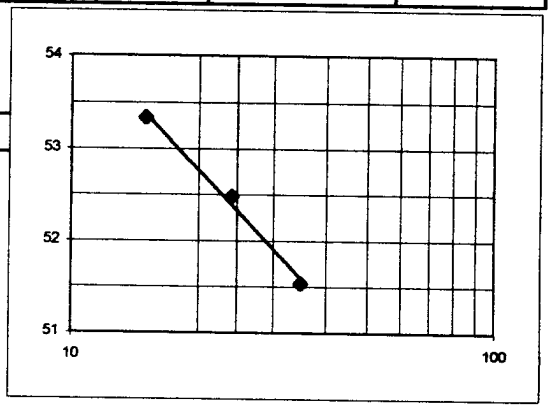
CAPSULA No.	PESO CAPSULA (gr)	CAPSULA + SUELO HUM. (gr)	CAPSULA + SUELO SECO (gr)	AGUA (gr)	SUELO SECO (gr)	CONTENIDO DE HUMEDAD (%)	PROM.
B-4	1.90	12.30	9.90	2.40	8.00	30.00	30.13
B-8	1.90	11.80	9.50	2.30	7.60	30.26	

CLASIFICACION Limos Inorganicos de plasticidad baja, color Café

CLASIFICACION S.U.C.S (MH)

L.L. = 52.40
L.P. = 30.13
I.p. = 22.27

CLASIFICACION A.A.S.H.T.O.



TECNILAB, S. A.
UNA EMPRESA E. BARRANCO Y ASOC., S. A.
LABORATORIO DE SUELOS Y MATERIALES

FUNDADA EN 1973

ANALISIS MECANICO Y LIMITES DE ATTERBERG ASTM C 136 Y D 4318

TRABAJO No. : 4-220 CLIENTE MWH GLOBAL, INC. Calicata 02-07
PROYECTO: SITIO DE PRESA DEL PROYECTO ALTO CHAGRES LOCALIZACION RIO CHAGRES Muestra 2
MUESTREADO POR TECNILAB, S.A. FECHA 15-Jun-02 PROFUNDIDAD 1.05m A 1.70m
PREPARADO POR TECNILAB, S.A. FECHA 25-Jun-02 LABORATORISTA I. LLERENA

ANALISIS MECANICO

TAMIZ	RETENIDO ACUMULADO	% RETENIDO	% QUE PASA	TAMIZ	RETENIDO ACUMULADO	% RETENIDO	% QUE PASA	CORR QUE PASA
3"				#4	0.00	0.00	100.00	100.00
2½"				#10	1.90	0.84	99.16	99.16
2"				#40	15.80	6.96	93.04	93.04
1 1/2"				#200	74.20	32.70	67.30	67.30
1"				FONDO				
3/4"				TOTAL				
1/2"								
3/8"								
#4								
FONDO								
TOTAL								

AGREGADO FINO

Peso Muestra Total Secada al Aire 263.20 gr
Peso Muestra Total Seca 226.90 gr
Peso Seco Depués de Lavado _____ gr

AGREGADO GRUESO

Peso Muestra Total Secada al Aire _____ gr

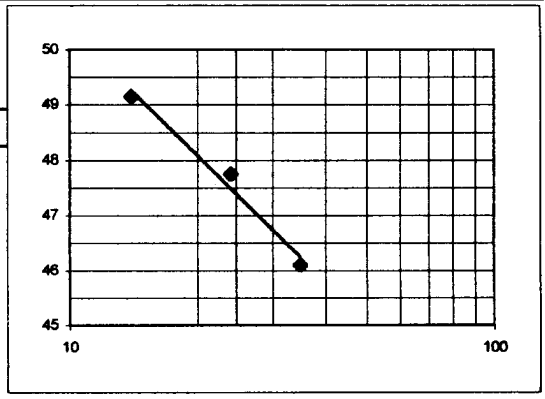
LIMITES DE ATTERBERG

LIMITE LIQUIDO

CAPSULA No.	PESO CAPSULA (gr)	CAPSULA + SUELO HUM. (gr)	CAPSULA + SUELO SECO (gr)	AGUA (gr)	SUELO SECO (gr)	CONTENIDO DE HUMEDAD (%)	NUMERO DE GOLPES
I-5	10.80	29.50	23.60	5.90	12.80	46.09	35
Z-1	10.50	26.90	21.60	5.30	11.10	47.75	24
Z-2	10.60	28.20	22.40	5.80	11.80	49.15	14

LIMITE PLASTICO

CAPSULA No.	PESO CAPSULA (gr)	CAPSULA + SUELO HUM. (gr)	CAPSULA + SUELO SECO (gr)	AGUA (gr)	SUELO SECO (gr)	CONTENIDO DE HUMEDAD (%)	PROM.
A-11	2.20	4.30	3.90	0.40	1.70	23.53	24.26
W-3	2.20	4.70	4.20	0.50	2.00	25.00	



CLASIFICACION Arcilla Inorganica de plasticidad baja a media
Color Café rojizo

CLASIFICACION S.U.C.S (CL)

L.L. = 47.40
L.P. = 24.26
I.p. = 23.14

CLASIFICACION A.A.S.H.T.O.

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IV. GRAVEDAD ESPECIFICA (SUELOS)

TECNILAB, S. A.

TECNILAB, S. A. FUNDADA EN 1973
UNA EMPRESA E. BARRANCO Y ASOC., S. A.
LABORATORIO DE SUELOS Y MATERIALES

GRAVEDAD ESPECIFICA
ASTM D 854

TRABAJO No. : 4-220 CLIENTE MWH GLOBAL, INC. Calicata N°.: 02-01 Muestra N°.: 1
PROYECTO: SITIO DE PRESA DEL PROYECTO ALTO CHAGRES.
PROCEDENCIA DE LA MUESTRA: RIO CHAGRES
MUESTREADO POR: TECNILAB, S.A. FECHA: 15-Jun-02 PROFUNDIDAD: 0.30m a 1.40m
PREPARADO POR: TECNILAB, S.A. FECHA: 27-Jun-02 LABORATORISTA: I. LLERENA.

DETALLE	UNIDAD	NUMERO DE ENSAYO			
		#1			
PROFUNDIDAD	m	0.30 a 1.40			
MUESTRA No.		1			
PICNOMETRO No.		7			
PESO DE LA TARA	g	112.50			
PESO DE LA TARA + SUELO SECO	g	187.70			
PESO DEL SUELO SECO (W_0)	g	75.20			
PICNOMETRO + AGUA + SUELO (W_1)	g	736.20			
PICNOMETRO + AGUA A CAPACIDAD TOTAL (W_2)	g	688.10			
TEMPERATURA DE ENSAYO	^0C	25.00			
GRAVEDAD ESPECIFICA (G_S)		2.77			

$$G_S = \frac{W_0}{W_0 + W_2 - W_1}$$

OBSERVACIONES: _____

REVISADO POR: _____

TECNILAB, S. A. FUNDADA EN 1973
UNA EMPRESA E. BARRANCO Y ASOC., S. A.
LABORATORIO DE SUELOS Y MATERIALES

GRAVEDAD ESPECIFICA
ASTM D 854

TRABAJO No. : 4-220 CLIENTE MWH GLOBAL, INC. Calicata N°.: 02-02 Muestra N°.: 1
PROYECTO: SITIO DE PRESA DEL PROYECTO ALTO CHAGRES.
PROCEDENCIA DE LA MUESTRA: RIO CHAGRES
MUESTREADO POR: TECNILAB, S.A. FECHA: 15-Jun-02 PROFUNDIDAD: 0.20m a 0.65m
PREPARADO POR: TECNILAB, S.A. FECHA: 27-Jun-02 LABORATORISTA: I. LLERENA.

DETALLE	UNIDAD	NUMERO DE ENSAYO			
		#1			
PROFUNDIDAD	m	0.20 a 0.65			
MUESTRA No.		1			
PICNOMETRO No.		7			
PESO DE LA TARA	g	106.30			
PESO DE LA TARA + SUELO SECO	g	179.90			
PESO DEL SUELO SECO (W_0)	g	73.60			
PICNOMETRO + AGUA + SUELO (W_1)	g	735.40			
PICNOMETRO + AGUA A CAPACIDAD TOTAL (W_2)	g	688.10			
TEMPERATURA DE ENSAYO	^0C	25.00			
GRAVEDAD ESPECIFICA (G_S)		2.79			

$$G_S = \frac{W_0}{W_0 + W_2 - W_1}$$

OBSERVACIONES: _____

REVISADO POR: _____

TECNILAB, S. A. FUNDADA EN 1973
UNA EMPRESA E. BARRANCO Y ASOC., S. A.
LABORATORIO DE SUELOS Y MATERIALES

GRAVEDAD ESPECIFICA
ASTM D 854

TRABAJO No. : 4-220 CLIENTE MWH GLOBAL, INC. Calicata N°.: 02-03 Muestra N°.: 2
PROYECTO: SITIO DE PRESA DEL PROYECTO ALTO CHAGRES.
PROCEDENCIA DE LA MUESTRA: RIO CHAGRES
MUESTREADO POR: TECNILAB, S.A. FECHA: 15-Jun-02 PROFUNDIDAD: 0.70m a 2.00m
PREPARADO POR: TECNILAB, S.A. FECHA: 27-Jun-02 LABORATORISTA: I. LLERENA.

DETALLE	UNIDAD	NUMERO DE ENSAYO			
		#1			
PROFUNDIDAD	m	0.70 a 2.00			
MUESTRA No.		2			
PICNOMETRO No.		1			
PESO DE LA TARA	g	106.40			
PESO DE LA TARA + SUELO SECO	g	180.40			
PESO DEL SUELO SECO (W_0)	g	74.00			
PICNOMETRO + AGUA + SUELO (W_1)	g	712.10			
PICNOMETRO + AGUA A CAPACIDAD TOTAL (W_2)	g	666.30			
TEMPERATURA DE ENSAYO	^0C	29.00			
GRAVEDAD ESPECIFICA (G_S)		2.62			

$$G_S = \frac{W_0}{W_0 + W_2 - W_1}$$

OBSERVACIONES:

REVISADO POR:

TECNILAB, S. A. FUNDADA EN 1973
UNA EMPRESA E. BARRANCO Y ASOC., S. A.
LABORATORIO DE SUELOS Y MATERIALES

GRAVEDAD ESPECIFICA
ASTM D 854

TRABAJO No. : 4-220 CLIENTE MWH GLOBAL, INC. Calicata N°.: 02-04 Muestra N°.: 1
PROYECTO: SITIO DE PRESA DEL PROYECTO ALTO CHAGRES.
PROCEDENCIA DE LA MUESTRA: RIO CHAGRES
MUESTREADO POR: TECNILAB, S.A. FECHA: 15-Jun-02 PROFUNDIDAD: 0.30m a 0.70m
PREPARADO POR: TECNILAB, S.A. FECHA: 27-Jun-02 LABORATORISTA: I. LLERENA.

DETALLE	UNIDAD	NUMERO DE ENSAYO			
		#1			
PROFUNDIDAD	m	0.30 a 0.70			
MUESTRA No.		1			
PICNOMETRO No.		3			
PESO DE LA TARA	g	107.20			
PESO DE LA TARA + SUELO SECO	g	178.40			
PESO DEL SUELO SECO (W_0)	g	71.20			
PICNOMETRO + AGUA + SUELO (W_1)	g	716.10			
PICNOMETRO + AGUA A CAPACIDAD TOTAL (W_2)	g	671.70			
TEMPERATURA DE ENSAYO	^0C	28.00			
GRAVEDAD ESPECIFICA (G_S)		2.66			

$$G_S = \frac{W_0}{W_0 + W_2 - W_1}$$

OBSERVACIONES: _____

REVISADO POR: _____

TECNILAB, S. A. FUNDADA EN 1973
UNA EMPRESA E. BARRANCO Y ASOC., S. A.
LABORATORIO DE SUELOS Y MATERIALES

GRAVEDAD ESPECIFICA
ASTM D 854

TRABAJO No. : 4-220 CLIENTE MWH GLOBAL, INC. Calicata N°.: 02-05 Muestra N°.: 1
PROYECTO: SITIO DE PRESA DEL PROYECTO ALTO CHAGRES.
PROCEDENCIA DE LA MUESTRA: RIO CHAGRES
MUESTREADO POR: TECNILAB, S.A. FECHA: 15-Jun-02 PROFUNDIDAD: 0.60m a 2.05m
PREPARADO POR: TECNILAB, S.A. FECHA: 27-Jun-02 LABORATORISTA: I. LLERENA.

DETALLE	UNIDAD	NUMERO DE ENSAYO			
		#1			
PROFUNDIDAD	m	0.60 a 2.05			
MUESTRA No.		1			
PICNOMETRO No.		1			
PESO DE LA TARA	g	105.40			
PESO DE LA TARA + SUELO SECO	g	216.50			
PESO DEL SUELO SECO (W_0)	g	111.10			
PICNOMETRO + AGUA + SUELO (W_1)	g	736.70			
PICNOMETRO + AGUA A CAPACIDAD TOTAL (W_2)	g	666.30			
TEMPERATURA DE ENSAYO	^0C	25.00			
GRAVEDAD ESPECIFICA (G_S)		2.73			

$$G_S = \frac{W_0}{W_0 + W_2 - W_1}$$

OBSERVACIONES: _____

REVISADO POR: _____

TECNILAB, S. A. FUNDADA EN 1973
UNA EMPRESA E. BARRANCO Y ASOC., S. A.
LABORATORIO DE SUELOS Y MATERIALES

GRAVEDAD ESPECIFICA
ASTM D 854

TRABAJO No. : 4-220 CLIENTE MWH GLOBAL, INC. Calicata N°.: 02-06 Muestra N°.: 2
PROYECTO: SITIO DE PRESA DEL PROYECTO ALTO CHAGRES.
PROCEDENCIA DE LA MUESTRA: RIO CHAGRES
MUESTREADO POR: TECNILAB, S.A. FECHA: 15-Jun-02 PROFUNDIDAD: 1.30m a 2.10m
PREPARADO POR: TECNILAB, S.A. FECHA: 27-Jun-02 LABORATORISTA: I. LLERENA.

DETALLE	UNIDAD	NUMERO DE ENSAYO			
		#1			
PROFUNDIDAD	m	1.30 a 2.10			
MUESTRA No.		2			
PICNOMETRO No.		3			
PESO DE LA TARA	g	108.50			
PESO DE LA TARA + SUELO SECO	g	211.30			
PESO DEL SUELO SECO (W_0)	g	102.80			
PICNOMETRO + AGUA + SUELO (W_1)	g	738.30			
PICNOMETRO + AGUA A CAPACIDAD TOTAL (W_2)	g	671.70			
TEMPERATURA DE ENSAYO	^0C	26.00			
GRAVEDAD ESPECIFICA (G_S)		2.84			

$$G_S = \frac{W_0}{W_0 + W_2 - W_1}$$

OBSERVACIONES:

REVISADO POR:

TECNILAB, S. A. FUNDADA EN 1973
UNA EMPRESA E. BARRANCO Y ASOC., S. A.
LABORATORIO DE SUELOS Y MATERIALES

GRAVEDAD ESPECIFICA
ASTM D 854

TRABAJO No. : 4-220 CLIENTE MWH GLOBAL, INC. Calicata N°.: 02-07 Muestra N°.: 2
PROYECTO: SITIO DE PRESA DEL PROYECTO ALTO CHAGRES.
PROCEDENCIA DE LA MUESTRA: RIO CHAGRES
MUESTREADO POR: TECNILAB, S.A. FECHA: 15-Jun-02 PROFUNDIDAD: 1.05m a 1.70m
PREPARADO POR: TECNILAB, S.A. FECHA: 27-Jun-02 LABORATORISTA: I. LLERENA.

DETALLE	UNIDAD	NUMERO DE ENSAYO			
		#1			
PROFUNDIDAD	m	1.05 a 1.70			
MUESTRA No.		2			
PICNOMETRO No.		6			
PESO DE LA TARA	g	107.90			
PESO DE LA TARA + SUELO SECO	g	197.30			
PESO DEL SUELO SECO (W_0)	g	89.40			
PICNOMETRO + AGUA + SUELO (W_1)	g	715.80			
PICNOMETRO + AGUA A CAPACIDAD TOTAL (W_2)	g	659.30			
TEMPERATURA DE ENSAYO	°C	26.00			
GRAVEDAD ESPECIFICA (G_S)		2.72			

$$G_S = \frac{W_0}{W_0 + W_2 - W_1}$$

OBSERVACIONES:

REVISADO POR:

V. PESO VOLUMÉTRICO SECO

TECNILAB, S. A.

TECNILAB, S. A. FUNDADA EN 1973

UNA EMPRESA E. BARRANCO Y ASOC., S. A.

LABORATORIO DE SUELOS Y MATERIALES

PESO VOLUMETRICO SECO

TRABAJO No. : 4-220 CLIENTE : MWH GLOBAL, INC.

PROYECTO : Sitio de Presa Proyecto Alto Chagres

LOCALIZACION: Rio chagres

MUESTREADO POR : Tecnilab, s.a. FECHA : JUNIO, 02

PREPARADO POR : Tecnilab, s.a. FECHA : JUNIO, 02 LABORATORISTA : C.C.

VOLUMEN DEL MOLDE : 73.12 cm^3 PESO DEL MOLDE : 535.3 g

No	PRUEBA	1	2	3	4	5	6	7
1	Calicata No.	02-01	02-01	02-02	02-02	02-03	02-03	02-03
2	Muestra No.	1	2	1	2	1	2	3
3	Profundidad en metro	0.30/1.40	1.40/1.80	0.20/0.65	0.65/1.90	0.20/0.70	0.70/2.00	2.00/2.50
4	Peso Molde + Suelo Seco	596.0	597.2	597.3	595.2	599.8	592.3	601.0
5	Peso del Molde	535.3	535.3	535.3	535.3	535.3	535.3	535.3
6	Peso Suelo Seco	60.7	61.9	62.0	59.9	64.5	57.0	65.7
7	Peso Volumetrico Seco g/cm^3	0.830	0.846	0.847	0.819	0.882	0.779	0.898

No	PRUEBA	8	9	10	11	12	13	14
8	Calicata No.	02-04	02-04	02-05	02-06	02-06	02-07	02-07
9	Muestra No.	1	2	1	1	2	1	2
10	Profundidad en metro	0.30/0.70	0.70/2.30	0.60/1.05	0.40/1.30	1.30/2.70	0.30/1.05	1.05/1.70
11	Peso Molde + Suelo Seco	591.9	596.7	601.2	597.9	608.2	602.2	599.5
12	Peso del Molde	535.3	535.3	535.3	535.3	535.3	535.3	535.3
13	Peso Suelo Seco	56.6	61.4	65.9	62.6	72.9	66.9	64.2
14	Peso Volumetrico Seco g/cm^3	0.774	0.839	0.901	0.856	0.997	0.914	0.878

Observaciones :

VI. CONTENIDO NATURAL DE HUMEDAD

TECNILAB, S. A. FUNDADA EN 1973
UNA EMPRESA E. BARRANCO Y ASOC., S. A.
LABORATORIO DE SUELOS Y MATERIALES

CONTENIDO NATURAL DE HUMEDAD
ASTM D 2216

TRABAJO Nº. 4-220 CLIENTE MWH, ENGINEERING COMPANY HOYO No. _____
PROYECTO: SITIO DE PRESA DEL PROYECTO ALTO CHAGRES
MUESTREADO POR: TECNILAB, S.A. FECHA : 4-7/Junio/02 LOCOLIZACIÓN : RÍO CHAGRES, PROVINCIA DE PANAMÁ
PREPARADO POR: TECNILAB, S.A. FECHA : 10-Jun-02 LABORATORISTA : C. CORDOBA .

1	MUESTRA No.	1	2	1	2	1	2	3	1	2	1
2	HOYO No. (CALICATA No.)	02-01	02-01	02-02	02-02	02-03	02-03	02-03	02-04	02-04	02-05
3	PROFUNDIDAD (m)	0.30 - 1.40	1.40 - 1.80	0.20 - 0.65	0.65 - 1.90	0.20 - 0.70	0.70 - 2.00	2.00 - 2.50	0.30 - 0.70	0.70 - 2.30	0.60 - 2.05
4	TARA No.	05	N-91	03	AB-0	99	E-5	B-21	K-8	NW	G-16
5	TARA + SUELO HÚMEDO	194.40	189.70	179.90	206.00	196.50	186.50	211.30	199.00	216.00	211.00
6	TARA + SUELO SECO (g)	172.00	176.00	167.20	181.40	171.40	164.20	193.70	170.80	187.50	192.80
7	PÉRDIDA DE HUMEDAD	22.40	13.70	12.70	24.60	25.10	22.30	17.60	28.20	28.50	18.20
8	PESO DE LA TARA (g)	109.40	109.10	107.00	108.70	113.60	104.70	109.30	108.80	102.50	110.00
9	PESO DEL SUELO SECO	62.60	66.90	60.20	72.70	57.80	59.50	84.40	62.00	85.00	82.80
10	CONTENIDO DE HUMEDAD %	35.78	20.48	21.10	33.84	43.43	37.48	20.85	45.48	33.53	21.98

OBSERVACIONES: _____

PRESENTADO POR: _____

TECNILAB, S. A. FUNDADA EN 1973
UNA EMPRESA E. BARRANCO Y ASOC., S. A.
LABORATORIO DE SUELOS Y MATERIALES

CONTENIDO NATURAL DE HUMEDAD
ASTM D 2216

TRABAJO Nº. 4-220 CLIENTE MWH, ENGINEERING COMPANY HOYO No. _____
PROYECTO: SITIO DE PRESA DEL PROYECTO ALTO CHAGRES
MUESTREADO POR: TECNILAB, S.A. FECHA : 4-7/Junio/02 LOCOLIZACIÓN : RÍO CHAGRES, PROVINCIA DE PANAMÁ
PREPARADO POR: TECNILAB, S.A. FECHA : 10-Jun-02 LABORATORISTA : C. CORDOBA

1	MUESTRA No.	1	2	1	2						
2	HOYO No. (CALICATA No.)	02-06	02-06	02-07	02-07						
3	PROFUNDIDAD (m)	0.40 - 1.30	1.30 - 2.10	0.30 - 1.05	1.05 - 1.70						
4	TARA No.	P-2	AB-2	AE	B-4						
5	TARA + SUELO HÚMEDO	193.20	221.20	187.00	203.10						
6	TARA + SUELO SECO (g)	170.70	209.60	168.50	185.50						
7	PÉRDIDA DE HUMEDAD	22.50	11.60	18.50	17.60						
8	PESO DE LA TARA (g)	106.60	107.90	107.40	109.30						
9	PESO DEL SUELO SECO	64.10	101.70	61.10	76.20						
10	CONTENIDO DE HUMEDAD %	35.10	11.41	30.28	23.10						

OBSERVACIONES: _____

PRESENTADO POR: _____

VII. PRUEBA DE COMPACTACION
(PROCTOR ESTANDAR)

TECNILAB, S. A. FUNDADA EN 1973
UNA EMPRESA E. BARRANCO Y ASOC., S. A.
LABORATORIO DE SUELOS Y MATERIALES

PRUEBA DE COMPACTACION
ASTM D698

TRABAJO No. : 4-220 CLIENTE: MWH GLOBAL, INC. Calicata : 02-01
PROYECTO: SITIO DE PRESA DEL PROYECTO ALTO CHAGRES. MUESTRA No : 1-2
LOCALIZACION: RIO CHAGRES.
MUESTREADO POR: TECNILAB, S.A. FECHA 15-Jun-02
PREPARADO POR: TECNILAB, S.A. FECHA 28-Jun-02 LABORATORISTA: I. LLERENA

Volumen del Molde 0.03324 pie^3 Peso del Molde 4.31 lb

DETERMINACION DEL CONTENIDO DE HUMEDAD

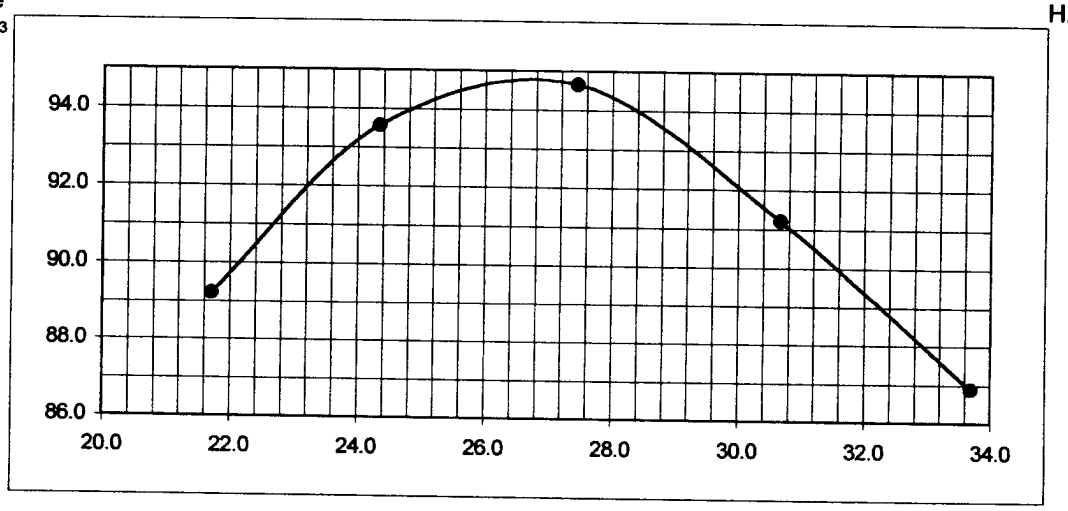
Prueba No.	1		2		3		4		5	
Recipiente No.	K-8	18	R-1	P-16	A-23	A-12	P-11	100	35	44
Peso Recipiente	108.8	108.1	108.6	106.5	113.4	106.9	106.6	108.8	107.2	107.9
Peso Recipiente + Suelo Húmedo	203.4	206.3	204.3	197.3	205.5	204.6	198.8	196.4	197.5	218.0
Peso Recipiente + Suelo Seco	186.6	188.7	185.7	179.4	185.8	183.4	177.3	175.7	174.7	190.3
Peso de Agua	16.8	17.6	18.6	17.9	19.7	21.2	21.5	20.7	22.8	27.7
Peso de Suelo Seco	77.8	80.6	77.1	72.9	72.4	76.5	70.7	66.9	67.5	82.4
% de Humedad	21.6	21.8	24.1	24.6	27.2	27.7	30.4	30.9	33.8	33.6
% Humedad Promedio	21.7		24.3		27.5		30.7		33.7	

DETERMINACION DE LA DENSIDAD

Prueba No.	1	2	3	4	5
% Humedad Promedio	21.7	24.3	27.5	30.7	33.7
Cantidad de Agua Añadida	100	100	100	100	100
Peso del Molde + Agua	7.92	8.18	8.32	8.27	8.17
Peso del Molde	4.31	4.31	4.31	4.31	4.31
Peso del Suelo Húmedo	3.61	3.87	4.01	3.96	3.86
Densidad Húmeda	108.6	116.3	120.6	119.2	116.1
Densidad Seca	89.2	93.6	94.7	91.2	86.9

D.M. 94.8 lb/pie^3
1520.6 kg/m^3

H.O. 27.0 %



TECNILAB, S. A. FUNDADA EN 1973
UNA EMPRESA E. BARRANCO Y ASOC., S. A.
LABORATORIO DE SUELOS Y MATERIALES

PRUEBA DE COMPACTACION
ASTM D698

TRABAJO No. : 4-220 CLIENTE: MWH GLOBAL, INC. Calicata : 02-02
PROYECTO: SITIO DE PRESA DEL PROYECTO ALTO CHAGRES. MUESTRA No : 2
LOCALIZACION: RIO CHAGRES.
MUESTREADO POR: TECNILAB, S.A. FECHA 15-Jun-02
PREPARADO POR: TECNILAB, S.A. FECHA 27-Jun-02 LABORATORISTA: I. LLERENA

Volumen del Molde 0.03324 pie^3 Peso del Molde 4.31 lb

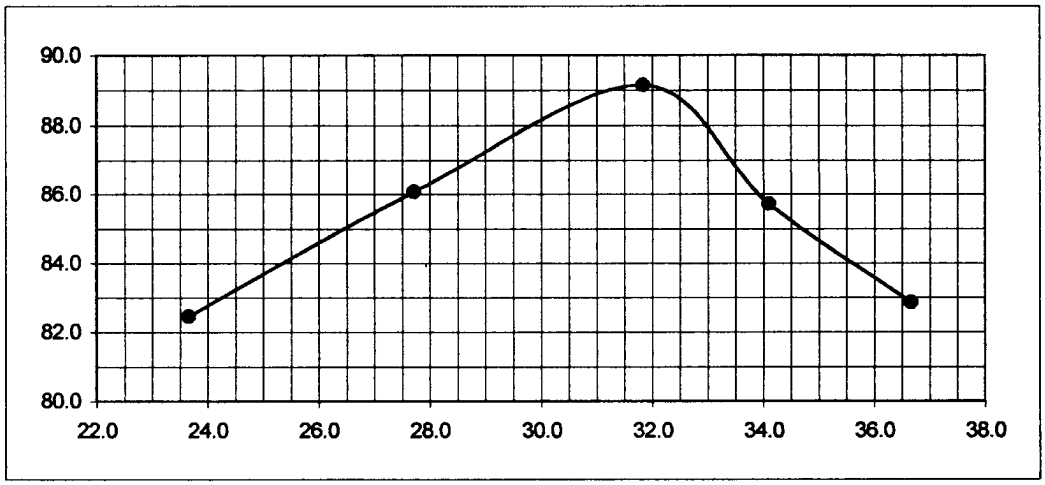
DETERMINACION DEL CONTENIDO DE HUMEDAD

Prueba No.	1		2		3		4		5	
Recipiente No.	40	D-44	12	3	A-8	25	K-25	A-12	R-1	7
Peso Recipiente	103.9	105.7	106.9	104.0	110.8	104.4	107.9	108.3	108.6	105.5
Peso Recipiente + Suelo Húmedo	180.6	180.0	181.1	188.3	189.4	192.5	183.3	183.5	206.7	194.5
Peso Recipiente + Suelo Seco	165.9	165.8	164.4	170.7	170.8	170.8	164.1	164.4	180.4	170.6
Peso de Agua	14.7	14.2	16.7	17.6	18.6	21.7	19.2	19.1	26.3	23.9
Peso de Suelo Seco	62.0	60.1	57.5	66.7	60.0	66.4	56.2	56.1	71.8	65.1
% de Humedad	23.7	23.6	29.0	26.4	31.0	32.7	34.2	34.0	36.6	36.7
% Humedad Promedio	23.7		27.7		31.8		34.1		36.7	

DETERMINACION DE LA DENSIDAD

Prueba No.	1	2	3	4	5
% Humedad Promedio	23.7	27.7	31.8	34.1	36.7
Cantidad de Agua Añadida	100	100	100	100	100
Peso del Molde + Agua	7.70	7.96	8.22	8.13	8.07
Peso del Molde	4.31	4.31	4.31	4.31	4.31
Peso del Suelo Húmedo	3.39	3.65	3.91	3.82	3.76
Densidad Húmeda	102.0	109.9	117.5	115.0	113.2
Densidad Seca	82.5	86.1	89.2	85.7	82.9

D.M. 89.2 lb/pie^3 H.O. 31.8 %
1430.8 kg/m^3



TECNILAB, S. A. FUNDADA EN 1973
UNA EMPRESA E. BARRANCO Y ASOC., S. A.
LABORATORIO DE SUELOS Y MATERIALES

PRUEBA DE COMPACTACION
ASTM D 698

TRABAJO No. : 4-220 CLIENTE: MWH GLOBAL, INC. Calicata : 02-03
PROYECTO: SITIO DE PRESA DEL PROYECTO ALTO CHAGRES. MUESTRA No : 1-2
LOCALIZACION: RIO CHAGRES.
MUESTREADO POR: TECNILAB, S.A. FECHA 15-Jun-02
PREPARADO POR: TECNILAB, S.A. FECHA 28-Jun-02 LABORATORISTA: I. LLERENA

Volumen del Molde 0.03324 pie^3 Peso del Molde 4.31 lb

DETERMINACION DEL CONTENIDO DE HUMEDAD

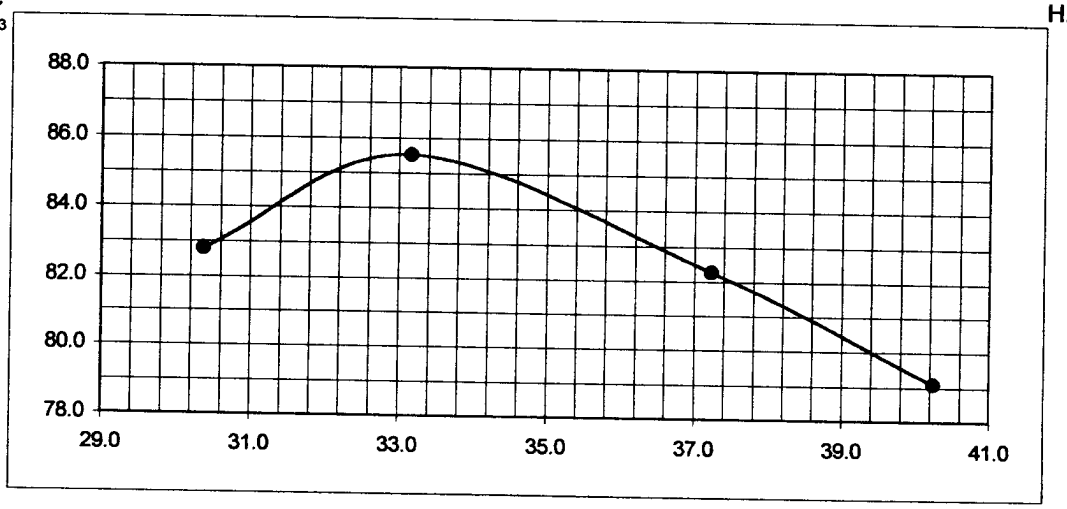
Prueba No.	1		2		3		4		5	
Recipiente No.	145	A-3	Z-9	M	F-30	B-6	Q-6	A-4		
Peso Recipiente	107.5	104.0	105.4	105.7	108.3	106.3	102.4	105.7		
Peso Recipiente + Suelo Húmedo	196.7	194.6	197.7	200.1	196.6	194.9	201.0	207.1		
Peso Recipiente + Suelo Seco	176.1	173.3	174.6	176.7	172.7	170.8	172.7	178.0		
Peso de Agua	20.6	21.3	23.1	23.4	23.9	24.1	28.3	29.1		
Peso de Suelo Seco	68.6	69.3	69.2	71.0	64.4	64.5	70.3	72.3		
% de Humedad	30.0	30.7	33.4	33.0	37.1	37.4	40.3	40.2		
% Humedad Promedio	30.4		33.2		37.2		40.3			

DETERMINACION DE LA DENSIDAD

Prueba No.	1	2	3	4	5
% Humedad Promedio	30.4	33.2	37.2	40.3	
Cantidad de Agua Añadida	100	100	100	100	
Peso del Molde + Agua	7.90	8.10	8.06	8.00	
Peso del Molde	4.31	4.31	4.31	4.31	
Peso del Suelo Húmedo	3.59	3.79	3.75	3.69	
Densidad Húmeda	107.9	113.9	112.9	110.9	
Densidad Seca	82.8	85.5	82.3	79.1	

D.M. 85.5 lb/pie^3
1371.4 kg/m^3

H.O. 33.2 %



TECNILAB, S. A. FUNDADA EN 1973
UNA EMPRESA E. BARRANCO Y ASOC., S. A.
LABORATORIO DE SUELOS Y MATERIALES

PRUEBA DE COMPACTACION
ASTM D 698

TRABAJO No. : 4-220 CLIENTE: MWH GLOBAL, INC. Calicata : 02-03
PROYECTO: SITIO DE PRESA DEL PROYECTO ALTO CHAGRES. MUESTRA No : 3
LOCALIZACION: RIO CHAGRES.
MUESTREADO POR: TECNILAB, S.A. FECHA 15-Jun-02
PREPARADO POR: TECNILAB, S.A. FECHA 27-Jun-02 LABORATORISTA: I. LLERENA

Volumen del Molde 0.03324 pie^3 Peso del Molde 4.31 lb

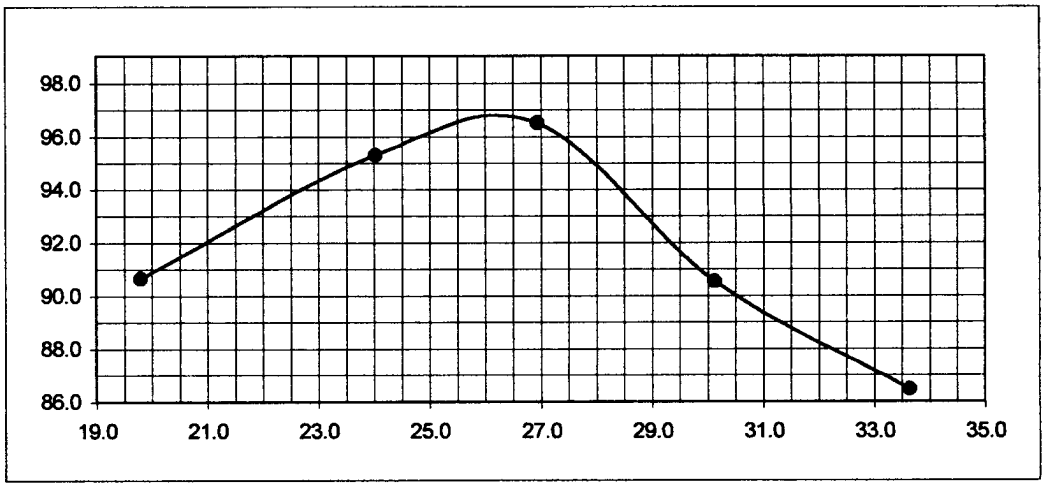
DETERMINACION DEL CONTENIDO DE HUMEDAD

Prueba No.	1		2		3		4		5	
Recipiente No.	35	8	11	113	1	15	34	43	16	K-8
Peso Recipiente	107.2	109.1	106.6	113.4	104.0	109.1	104.1	106.4	106.5	108.8
Peso Recipiente + Suelo Húmedo	179.9	184.6	191.3	197.5	186.0	193.4	183.3	180.5	201.7	197.9
Peso Recipiente + Suelo Seco	167.9	172.1	174.9	181.2	168.5	175.6	164.9	163.4	177.6	175.6
Peso de Agua	12.0	12.5	16.4	16.3	17.5	17.8	18.4	17.1	24.1	22.3
Peso de Suelo Seco	60.7	63.0	68.3	67.8	64.5	66.5	60.8	57.0	71.1	66.8
% de Humedad	19.8	19.8	24.0	24.0	27.1	26.8	30.3	30.0	33.9	33.4
% Humedad Promedio	19.8		24.0		26.9		30.1		33.6	

DETERMINACION DE LA DENSIDAD

Prueba No.	1	2	3	4	5
% Humedad Promedio	19.8	24.0	26.9	30.1	33.6
Cantidad de Agua Añadida	100	100	100	100	100
Peso del Molde + Agua	7.92	8.24	8.38	8.23	8.15
Peso del Molde	4.31	4.31	4.31	4.31	4.31
Peso del Suelo Húmedo	3.61	3.93	4.07	3.92	3.84
Densidad Húmeda	108.6	118.2	122.5	117.8	115.6
Densidad Seca	90.7	95.3	96.5	90.5	86.5

D.M. 96.7 lb/pie^3 H.O. 26.3 %
1551.1 kg/m^3



TECNILAB, S. A. FUNDADA EN 1973
UNA EMPRESA E. BARRANCO Y ASOC., S. A.
LABORATORIO DE SUELOS Y MATERIALES

PRUEBA DE COMPACTACION
ASTM D698

TRABAJO No. : 4-220 CLIENTE: MWH GLOBAL, INC. Calicata : 02-04
PROYECTO: SITIO DE PRESA DEL PROYECTO ALTO CHAGRES. MUESTRA No : 1-2
LOCALIZACION: RIO CHAGRES.
MUESTREADO POR: TECNILAB, S.A. FECHA 15-Jun-02
PREPARADO POR: TECNILAB, S.A. FECHA 28-Jun-02 LABORATORISTA: I. LLERENA

Volumen del Molde 0.03324 pie^3 Peso del Molde 4.31 lb

DETERMINACION DEL CONTENIDO DE HUMEDAD

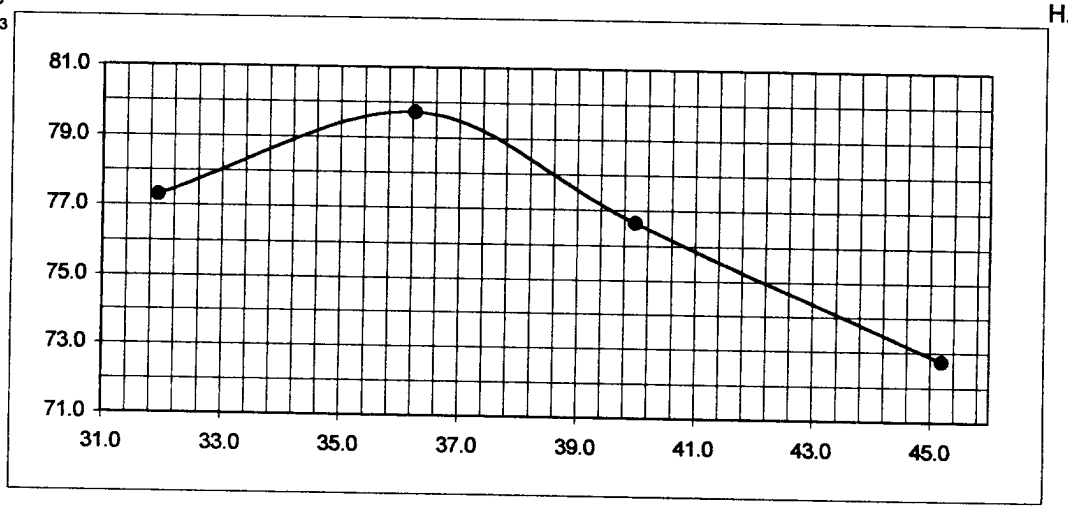
Prueba No.	1		2		3		4		5	
Recipiente No.	25	K-25	190	70	Z-19	R-12	Z	Z-4		
Peso Recipiente	104.4	107.9	104.4	108.0	112.0	108.3	107.0	108.5		
Peso Recipiente + Suelo Húmedo	181.2	188.5	193.1	198.2	206.5	198.3	196.3	196.5		
Peso Recipiente + Suelo Seco	162.6	169.0	169.6	174.1	179.6	172.5	168.2	169.4		
Peso de Agua	18.6	19.5	23.5	24.1	26.9	25.8	28.1	27.1		
Peso de Suelo Seco	58.2	61.1	65.2	66.1	67.6	64.2	61.2	60.9		
% de Humedad	32.0	31.9	36.0	36.5	39.8	40.2	45.9	44.5		
% Humedad Promedio	31.9		36.3		40.0		45.2			

DETERMINACION DE LA DENSIDAD

Prueba No.	1	2	3	4	5
% Humedad Promedio	31.9	36.3	40.0	45.2	
Cantidad de Agua Añadida	100	100	100	100	
Peso del Molde + Agua	7.70	7.92	7.88	7.82	
Peso del Molde	4.31	4.31	4.31	4.31	
Peso del Suelo Húmedo	3.39	3.61	3.57	3.51	
Densidad Húmeda	102.0	108.6	107.3	105.6	
Densidad Seca	77.3	79.7	76.6	72.7	

D.M. 79.7 lb/pie^3
1278.4 kg/m^3

H.O. 36.3 %



TECNILAB, S. A. FUNDADA EN 1973
UNA EMPRESA E. BARRANCO Y ASOC., S. A.
LABORATORIO DE SUELOS Y MATERIALES

PRUEBA DE COMPACTACION
ASTM D698

TRABAJO No. : 4-220 CLIENTE: MWH GLOBAL, INC. Calicata : 02-05
PROYECTO: SITIO DE PRESA DEL PROYECTO ALTO CHAGRES. MUESTRA No : 1
LOCALIZACION: RIO CHAGRES.
MUESTREADO POR: TECNILAB, S.A. FECHA 15-Jun-02
PREPARADO POR: TECNILAB, S.A. FECHA 27-Jun-02 LABORATORISTA: I. LLERENA

Volumen del Molde 0.03324 pie^3 Peso del Molde 4.31 lb

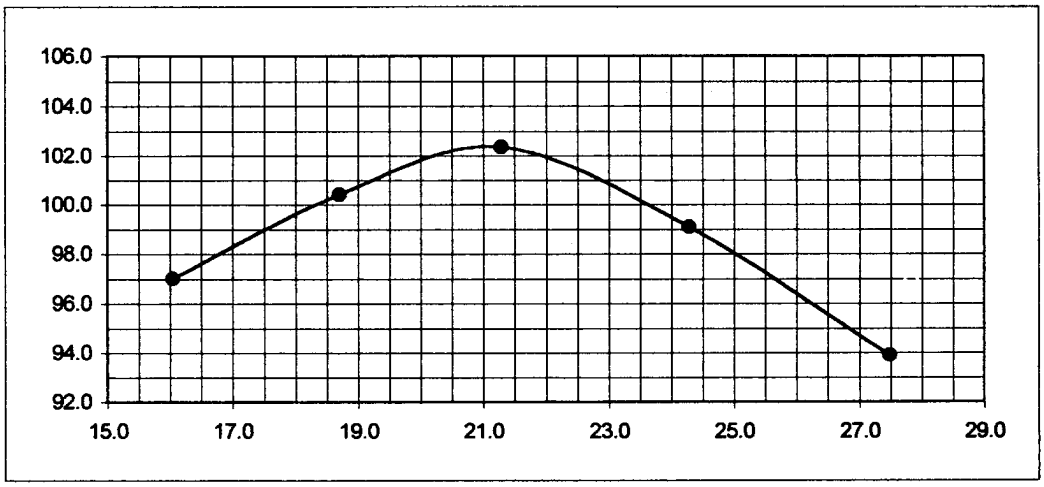
DETERMINACION DEL CONTENIDO DE HUMEDAD

Prueba No.	1		2		3		4		5	
Recipiente No.	100	14	44	63	B-6	21	Z-4	Z	M	28
Peso Recipiente	108.6	107.9	107.9	112.5	106.3	109.3	108.5	105.0	106.7	105.4
Peso Recipiente + Suelo Húmedo	188.3	182.2	197.0	197.3	175.8	180.5	188.9	184.8	186.7	183.5
Peso Recipiente + Suelo Seco	177.2	172.0	183.0	183.9	163.5	168.1	173.2	169.2	169.3	166.8
Peso de Agua	11.1	10.2	14.0	13.4	12.3	12.4	15.7	15.6	17.4	16.7
Peso de Suelo Seco	68.6	64.1	75.1	71.4	57.2	58.8	64.7	64.2	62.6	61.4
% de Humedad	16.2	15.9	18.6	18.8	21.5	21.1	24.3	24.3	27.8	27.2
% Humedad Promedio	16.0		18.7		21.3		24.3		27.5	

DETERMINACION DE LA DENSIDAD

Prueba No.	1	2	3	4	5
% Humedad Promedio	16.0	18.7	21.3	24.3	27.5
Cantidad de Agua Añadida	100	100	100	100	100
Peso del Molde + Agua	8.05	8.27	8.44	8.40	8.29
Peso del Molde	4.31	4.31	4.31	4.31	4.31
Peso del Suelo Húmedo	3.74	3.96	4.13	4.09	3.98
Densidad Húmeda	112.6	119.2	124.2	123.2	119.7
Densidad Seca	97.0	100.4	102.4	99.1	93.9

D.M. 102.4 lb/pie^3 H.O. 21.3 %
1642.5 kg/m^3



TECNILAB, S. A. FUNDADA EN 1973
UNA EMPRESA E. BARRANCO Y ASOC., S. A.
LABORATORIO DE SUELOS Y MATERIALES

PRUEBA DE COMPACTACION
ASTM D698

TRABAJO No. : 4-220 CLIENTE: MWH GLOBAL, INC. Calicata : 02-06
PROYECTO: SITIO DE PRESA DEL PROYECTO ALTO CHAGRES. MUESTRA No : 2
LOCALIZACION: RIO CHAGRES.
MUESTREADO POR: TECNILAB, S.A. FECHA 15-Jun-02
PREPARADO POR: TECNILAB, S.A. FECHA 27-Jun-02 LABORATORISTA: I. LLERENA

Volumen del Molde 0.03324 pie^3 Peso del Molde 4.31 lb

DETERMINACION DEL CONTENIDO DE HUMEDAD

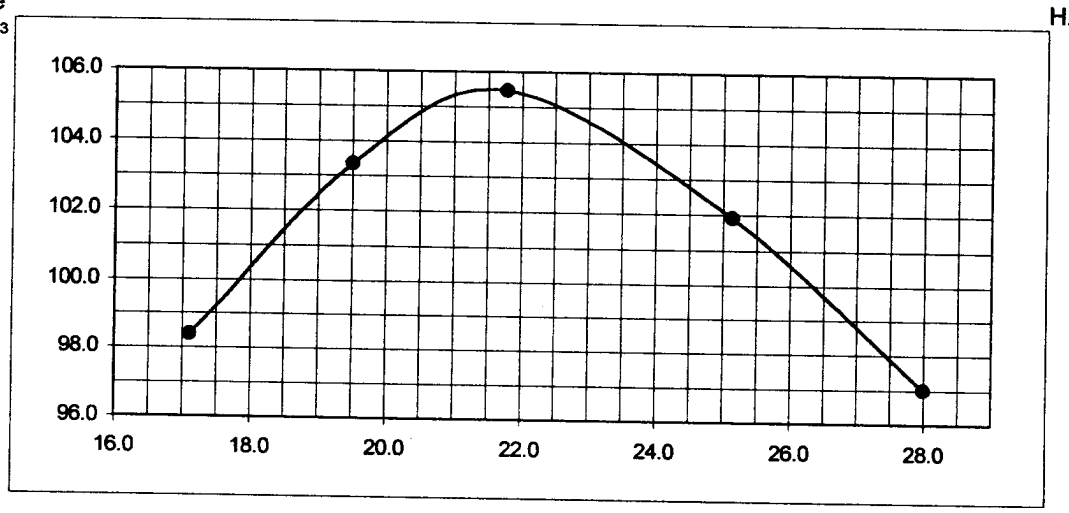
Prueba No.	1		2		3		4		5	
Recipiente No.	C-23	145	Z-9	Q-6	190	E-30	Z-19	A-4	70	B-13
Peso Recipiente	113.8	107.5	105.4	102.4	104.4	108.3	112.0	105.7	108.0	108.1
Peso Recipiente + Suelo Húmedo	201.5	192.2	190.7	197.1	201.2	202.1	201.6	196.3	210.2	210.7
Peso Recipiente + Suelo Seco	188.7	179.8	177.0	181.4	183.8	185.4	183.5	178.2	187.8	188.3
Peso de Agua	12.8	12.4	13.7	15.7	17.4	16.7	18.1	18.1	22.4	22.4
Peso de Suelo Seco	74.9	72.3	71.6	79.0	79.4	77.1	71.5	72.5	79.8	80.2
% de Humedad	17.1	17.2	19.1	19.9	21.9	21.7	25.3	25.0	28.1	27.9
% Humedad Promedio	17.1		19.5		21.8		25.1		28.0	

DETERMINACION DE LA DENSIDAD

Prueba No.	1	2	3	4	5
% Humedad Promedio	17.1	19.5	21.8	25.1	28.0
Cantidad de Agua Añadida	100	100	100	100	100
Peso del Molde + Agua	8.14	8.42	8.58	8.55	8.44
Peso del Molde	4.31	4.31	4.31	4.31	4.31
Peso del Suelo Húmedo	3.83	4.11	4.27	4.24	4.13
Densidad Húmeda	115.2	123.5	128.5	127.5	124.2
Densidad Seca	98.4	103.3	105.5	101.9	97.0

D.M. 105.5 lb/pie^3
1692.2 kg/m^3

H.O. 21.8 %



TECNILAB, S. A. FUNDADA EN 1973
UNA EMPRESA E. BARRANCO Y ASOC., S. A.
LABORATORIO DE SUELOS Y MATERIALES

PRUEBA DE COMPACTACION
ASTM D698

TRABAJO No. : 4-220 CLIENTE: MWH GLOBAL, INC. Calicata : 02-07
PROYECTO: SITIO DE PRESA DEL PROYECTO ALTO CHAGRES. MUESTRA No : 1-2
LOCALIZACION: RIO CHAGRES.
MUESTREADO POR: TECNILAB, S.A. FECHA 15-Jun-02
PREPARADO POR: TECNILAB, S.A. FECHA 28-Jun-02 LABORATORISTA: I. LLERENA

Volumen del Molde 0.03324 pie^3 Peso del Molde 4.31 lb

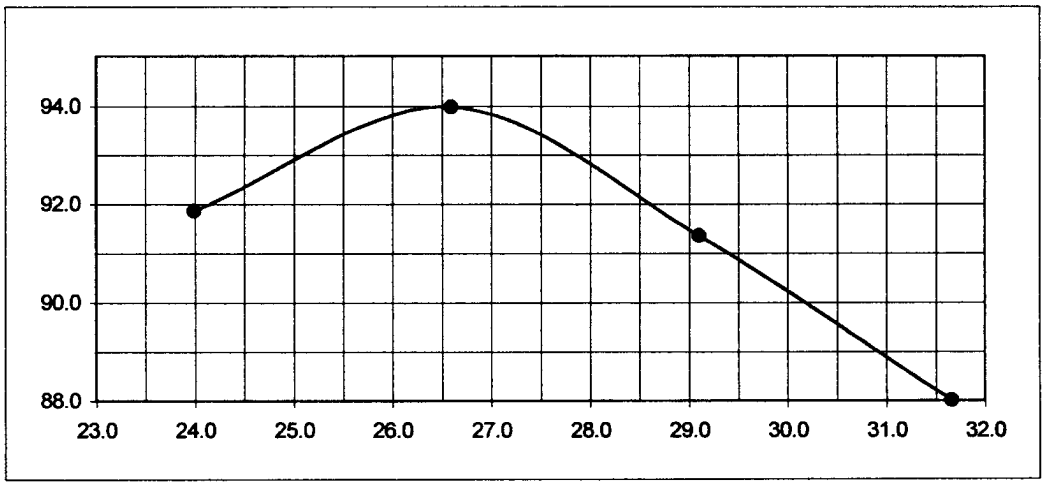
DETERMINACION DEL CONTENIDO DE HUMEDAD

Prueba No.	1		2		3		4		5	
Recipiente No.	63	28	G-15	P-14	8	34	Z-1	43		
Peso Recipiente	112.5	105.4	109.1	107.9	109.1	104.1	109.3	106.4		
Peso Recipiente + Suelo Húmedo	188.1	183.3	195.8	201.1	200.2	180.7	211.7	206.5		
Peso Recipiente + Suelo Seco	173.4	168.3	177.6	181.5	179.7	163.4	187.0	182.5		
Peso de Agua	14.7	15.0	18.2	19.6	20.5	17.3	24.7	24.0		
Peso de Suelo Seco	60.9	62.9	68.5	73.6	70.6	59.3	77.7	76.1		
% de Humedad	24.1	23.8	26.6	26.6	29.0	29.2	31.8	31.5		
% Humedad Promedio	24.0		26.6		29.1		31.7			

DETERMINACION DE LA DENSIDAD

Prueba No.	1	2	3	4	5
% Humedad Promedio	24.0	26.6	29.1	31.7	
Cantidad de Agua Añadida	100	100	100	100	
Peso del Molde + Agua	8.10	8.27	8.23	8.16	
Peso del Molde	4.31	4.31	4.31	4.31	
Peso del Suelo Húmedo	3.79	3.96	3.92	3.85	
Densidad Húmeda	113.9	119.0	117.9	115.9	
Densidad Seca	91.9	94.0	91.3	88.0	

D.M. 94.0 lb/pie^3 H.O. 26.6 %
1507.8 kg/m^3



VIII. PINHOLE TEST

TECNILAB, S. A.

TECNILAB, S. A. FUNDADA EN 1973
UNA EMPRESA E. BARRANCO Y ASOC., S. A.
LABORATORIO DE SUELOS Y MATERIALES

PINHOLE TEST
ASTM D 4647

TRABAJO No. : 4-220 CLIENTE: MWH GLOBAL, INC. CALICATA : 02-01 MUESTRA : 1
PROYECTO: SITIO DE PRESA, PROYECTO AITOS DEL CHAGRES LOCALIZACION: RIO CHAGRES
MUESTREADO POR: TECNILAB, S.A. FECHA: JUNIO, 02 PROFUNDIDAD: 0.30m a 1.40m
PREPARADO POR: TECNILAB, S.A. FECHA: JULIO, 02 LABORATORISTA: JOSE VERGARA

Hora de Inicio	Cabeza mm	Flujo ml.	Flujo seg.	Rata de Flujo	TURBIDEZ Muy Obscura	Obscura	Moderadamente Obscura	Ligeramente Obscura	Apenas Visible	Completamente Claro	Completamente Clara desde el Inicio	OBSERVACIONES
15:24	50	10	38							X		
		20	72							X		
		30	94							X		
		40	125							X		
		50	156							X		
		60	187							X		
16:00	180	25	35							X		
		50	77							X		
		75	125							X		
		100	169							X		
		125	209							X		
		150	250							X		
16:10	380	50	69							X		
		100	155							X		
		150	240							X		
		200	326							X		
		250	411							X		
		300	493							X		**ND1(No Dispersivo)**

OBSERVACIONES:

REVISADO POR:

TECNILAB, S. A. FUNDADA EN 1973
UNA EMPRESA E. BARRANCO Y ASOC., S. A.
LABORATORIO DE SUELOS Y MATERIALES

PINHOLE TEST
ASTM D 4647

TRABAJO No. : 4-220 CLIENTE: MWH GLOBAL, INC. CALICATA : 02-01 MUESTRA : 2
PROYECTO: SITIO DE PRESA, PROYECTO AITOS DEL CHAGRES LOCALIZACION: RIO CHAGRES
MUESTREADO POR: TECNILAB, S.A. FECHA: JUNIO, 02 PROFUNDIDAD: 1.40m a 1.80m
PREPARADO POR: TECNILAB, S.A. FECHA: JULIO, 02 LABORATORISTA: JOSE VERGARA

Hora de Inicio	Cabeza mm	Flujo ml.	Flujo seg.	Rata de Flujo	TURBIDEZ Muy Obscura	Obscura	Moderadamente Obscura	Ligeramente Obscura	Apenas Visible	Completamente Claro	Completamente Clara desde el Inicio	OBSERVACIONES
07:40	50	10	20							X		
		20	46							X		
		30	78							X		
		40	105							X		
		50	130							X		
		60	155							X		
07:45	180	25	21							X		
		50	66							X		
		75	111							X		
		100	155							X		
		125	203							X		
		150	248							X		
07:55	380	50	46							X		
		100	107							X		
		150	180							X		
		200	241							X		
		250	353							X		
		300	428							X		**ND1(No Dispersivo)**

OBSERVACIONES:

REVISADO POR:

TECNILAB, S. A. FUNDADA EN 1973
UNA EMPRESA E. BARRANCO Y ASOC., S. A.
LABORATORIO DE SUELOS Y MATERIALES

PINHOLE TEST
ASTM D 4647

TRABAJO No. : 4-220 CLIENTE: MWH GLOBAL, INC. CALICATA : 02-02 MUESTRA : 1
PROYECTO: SITIO DE PRESA, PROYECTO AITOS DEL CHAGRES LOCALIZACION: RIO CHAGRES
MUESTREADO POR: TECNILAB, S.A. FECHA: JUNIO, 02 PROFUNDIDAD: 0.20m a 0.65m
PREPARADO POR: TECNILAB, S.A. FECHA: JULIO, 02 LABORATORISTA: JOSE VERGARA

Hora de Inicio	Cabeza mm	Flujo ml.	Flujo seg.	Rata de Flujo	TURBIDEZ Muy Obscura	Obscura	Moderadamente Obscura	Ligeramente Obscura	Apenas Visible	Completamente Claro	Completamente Clara desde el Inicio	OBSERVACIONES
08:24	50	10	26							X		
		20	55							X		
		30	88							X		
		40	119							X		
		50	191							X		
		60	236							X		
08:32	180	25	32							X		
		50	85							X		
		75	148							X		
		100	196							X		
		125	259							X		
		150	316							X		
08:35	380	50	59							X		
		100	144							X		
		150	235							X		
		200	325							X		
		250	418							X		
		300	506							X		**ND1(No Dispersivo)**

OBSERVACIONES:

REVISADO POR:

TECNILAB, S. A. FUNDADA EN 1973
UNA EMPRESA E. BARRANCO Y ASOC., S. A.
LABORATORIO DE SUELOS Y MATERIALES

PINHOLE TEST
ASTM D 4647

TRABAJO No. : 4-220 CLIENTE: MWH GLOBAL, INC. CALICATA : 02-02 MUESTRA : 2
PROYECTO: SITIO DE PRESA, PROYECTO AITOS DEL CHAGRES LOCALIZACION: RIO CHAGRES
MUESTREADO POR: TECNILAB, S.A. FECHA: JUNIO, 02 PROFUNDIDAD: 0.65m a 1.90m
PREPARADO POR: TECNILAB, S.A. FECHA: JULIO, 02 LABORATORISTA: JOSE VERGARA

Hora de Inicio	Cabeza mm	Flujo ml.	Flujo seg.	Rata de Flujo	TURBIDEZ Muy Obscura	Obscura	Moderadamente Obscura	Ligeramente Obscura	Apenas Visible	Completamente Claro	Completamente Clara desde el Inicio	OBSERVACIONES
09:00	50	10	8							X		
		20	16							X		
		30	24							X		
		40	32							X		
		50	41							X		
		60	47							X		
09:07	180	25	7							X		
		50	16							X		
		75	31							X		
		100	46							X		
		125	64							X		
		150	78							X		
09:13	380	50	15							X		
		100	47							X		
		150	74							X		
		200	104							X		
		250	129							X		
		300	156							X		**ND1(No Dispersivo)**

OBSERVACIONES:

REVISADO POR:

TECNILAB, S. A. FUNDADA EN 1973
UNA EMPRESA E. BARRANCO Y ASOC., S. A.
LABORATORIO DE SUELOS Y MATERIALES

PINHOLE TEST
ASTM D 4647

TRABAJO No: : 4-220 CLIENTE: MWH GLOBAL, INC. CALICATA : 02-03 MUESTRA : 1
PROYECTO: SITIO DE PRESA, PROYECTO ALTO CHAGRES LOCALIZACION: RIO CHAGRES
MUESTREADO POR: TECNILAB, S.A. FECHA: JUNIO, 02 PROFUNDIDAD: 0.20m a 0.70m
PREPARADO POR: TECNILAB, S.A. FECHA: JULIO, 02 LABORATORISTA: JOSE VERGARA

Hora de Inicio	Cabeza mm	Flujo ml.	Flujo seg.	Rata de Flujo	TURBIDEZ Muy Obscura	Obscura	Moderadamente Obscura	Ligeramente Obscura	Apenas Visible	Completamente Claro	Completamente Clara desde el Inicio	OBSERVACIONES
13:50	50	10	15							X		
		20	33							X		
		30	54							X		
		40	70							X		
		50	89							X		
		60	107							X		
13:57	180	25	47							X		
		50	79							X		
		75	127							X		
		100	178							X		
		125	220							X		
		150	269							X		
14:06	380	50	78							X		
		100	176							X		
		150	280							X		
		200	366							X		
		250	483							X		
		300	605							X		**ND1(No Dispersivo)**

OBSERVACIONES:

REVISADO POR:

TECNILAB, S. A. FUNDADA EN 1973
UNA EMPRESA E. BARRANCO Y ASOC., S. A.
LABORATORIO DE SUELOS Y MATERIALES

PINHOLE TEST
ASTM D 4647

TRABAJO No. : 4-220 CLIENTE: MWH GLOBAL, INC. CALICATA : 02-03 MUESTRA : 2
PROYECTO: SITIO DE PRESA, PROYECTO AITOS DEL CHAGRES LOCALIZACION: RIO CHAGRES
MUESTREADO POR: TECNILAB, S.A. FECHA: JUNIO, 02 PROFUNDIDAD: 0.70m a 2.00m
PREPARADO POR: TECNILAB, S.A. FECHA: JULIO, 02 LABORATORISTA: JOSE VERGARA

Hora de Inicio	Cabeza mm	Flujo ml.	Flujo seg.	Rata de Flujo	TURBIDEZ Muy Obscura	Obscura	Moderadamente Obscura	Ligeramente Obscura	Apenas Visible	Completamente Claro	Completamente Clara desde el Inicio	OBSERVACIONES
09:45	50	10	13							X		**En este ciclo el agua salio completa-**
		20	24							X		**mente clara.**
		30	34							X		
		40	45							X		
		50	55							X		
		60	64							X		
09:52	180	25	10						X			**En este ciclo el agua salio apenas**
		50	29						X			**visible y con muestra de suelo**
		75	52						X			
		100	74						X			
		125	56						X			
		150	120						X			
10:00	380	50	20						X			**En este ciclo el agua salio apenas**
		100	53						X			**visible y con muestra de suelo**
		150	91						X			
		200	140						X			
		250	199						X			
		300	281						X			**ND3(Dispersivo)**

OBSERVACIONES: _____

REVISADO POR: _____

TECNILAB, S. A. FUNDADA EN 1973
UNA EMPRESA E. BARRANCO Y ASOC., S. A.
LABORATORIO DE SUELOS Y MATERIALES

PINHOLE TEST
ASTM D 4647

TRABAJO No. : 4-220 CLIENTE: MWH GLOBAL, INC. CALICATA : 02-03 MUESTRA : 3
PROYECTO: SITIO DE PRESA, PROYECTO AITOS DEL CHAGRES LOCALIZACION: RIO CHAGRES
MUESTREADO POR: TECNILAB, S.A. FECHA: JUNIO, 02 PROFUNDIDAD: 2.00m a 2.50m
PREPARADO POR: TECNILAB, S.A. FECHA: JULIO, 02 LABORATORISTA: JOSE VERGARA

Hora de Inicio	Cabeza mm	Flujo ml.	Flujo seg.	Rata de Flujo	TURBIDEZ Muy Obscura	Obscura	Moderadamente Obscura	Ligeramente Obscura	Apenas Visible	Completamente Claro	Completamente Clara desde el Inicio	OBSERVACIONES
14:10	50	10	24							X		
		20	56							X		
		30	83							X		
		40	170							X		
		50	142							X		
		60	175							X		
14:18	180	25	45							X		
		50	113							X		
		75	185							X		
		100	255							X		
		125	312							X		
		150	379							X		
14:31	380	50	101							X		
		100	237							X		
		150	374							X		
		200	508							X		
		250	624							X		
		300	773							X		**ND1(No Dispersivo)**

OBSERVACIONES:

REVISADO POR:

TECNILAB, S. A. FUNDADA EN 1973
UNA EMPRESA E. BARRANCO Y ASOC., S. A.
LABORATORIO DE SUELOS Y MATERIALES

PINHOLE TEST
ASTM D 4647

TRABAJO No. : 4-220 CLIENTE: MWH GLOBAL, INC. CALICATA : 02-04 MUESTRA : 1
PROYECTO: SITIO DE PRESA, PROYECTO ALTO CHAGRES LOCALIZACION: RIO CHAGRES
MUESTREADO POR: TECNILAB, S.A. FECHA: JUNIO, 02 PROFUNDIDAD: 0.30m a 0.70m
PREPARADO POR: TECNILAB, S.A. FECHA: JULIO, 02 LABORATORISTA: JOSE VERGARA

Hora de Inicio	Cabeza	Flujo		Rata de Flujo	TURBIDEZ							OBSERVACIONES
	mm	ml.	seg.		Muy Obscura	Obscura	Moderadamente Obscura	Ligeramente Obscura	Apenas Visible	Completamente Claro	Completamente Clara desde el Inicio	
14:20	50	10	9							X		
		20	19							X		
		30	28							X		
		40	39							X		
		50	50							X		
		60	61							X		
14:27	180	25	11							X		
		50	28							X		
		75	52							X		
		100	82							X		
		125	114							X		
		150	137							X		
14:35	380	50	42							X		
		100	84							X		
		150	124							X		
		200	155							X		
		250	215							X		
		300	278							X		**ND1(No Dispersivo)**

OBSERVACIONES:

REVISADO POR:

TECNILAB, S. A. FUNDADA EN 1973
UNA EMPRESA E. BARRANCO Y ASOC., S. A.
LABORATORIO DE SUELOS Y MATERIALES

PINHOLE TEST
ASTM D 4647

TRABAJO No. : 4-220 CLIENTE: MWH GLOBAL, INC. CALICATA : 02-04 MUESTRA : 2
PROYECTO: SITIO DE PRESA, PROYECTO AITOS DEL CHAGRES LOCALIZACION: RIO CHAGRES
MUESTREADO POR: TECNILAB, S.A. FECHA: JUNIO, 02 PROFUNDIDAD: 0.70m a 2.30m
PREPARADO POR: TECNILAB, S.A. FECHA: JULIO, 02 LABORATORISTA: JOSE VERGARA

Hora de Inicio	Cabeza mm	Flujo ml.	Flujo seg.	Rata de Flujo	TURBIDEZ Muy Obscura	Obscura	Moderadamente Obscura	Ligeramente Obscura	Apenas Visible	Completamente Claro	Completamente Clara desde el Inicio	OBSERVACIONES
09:45	50	10	45							X		
		20	56							X		
		30	67							X		
		40	76							X		
		50	85							X		
		60	95							X		
09:52	180	25	11							X		
		50	34							X		
		75	63							X		
		100	86							X		
		125	103							X		
		150	125							X		
10:00	380	50	25							X		
		100	61							X		
		150	92							X		
		200	128							X		
		250	164							X		
		300	200							X		**ND1(No Dispersivo)**

OBSERVACIONES:

REVISADO POR:

TECNILAB, S. A. FUNDADA EN 1973
UNA EMPRESA E. BARRANCO Y ASOC., S. A.
LABORATORIO DE SUELOS Y MATERIALES

PINHOLE TEST
ASTM D 4647

TRABAJO No. : 4-220 CLIENTE: MWH GLOBAL, INC. CALICATA : 02-05 MUESTRA : 1
PROYECTO: SITIO DE PRESA, PROYECTO AITOS DEL CHAGRES LOCALIZACION: RIO CHAGRES
MUESTREADO POR: TECNILAB, S.A. FECHA: JUNIO, 02 PROFUNDIDAD: 0.60m a 2.05m
PREPARADO POR: TECNILAB, S.A. FECHA: JULIO, 02 LABORATORISTA: JOSE VERGARA

Hora de Inicio	Cabeza mm	Flujo ml.	Flujo seg.	Rata de Flujo	TURBIDEZ Muy Obscura	Obscura	Moderadamente Obscura	Ligeramente Obscura	Apenas Visible	Completamente Claro	Completamente Clara desde el Inicio	OBSERVACIONES
09:45	50	10	17							X		
		20	40							X		
		30	72							X		
		40	97							X		
		50	126							X		
		60	154							X		
09:52	180	25	19							X		
		50	65							X		
		75	122							X		
		100	187							X		
		125	252							X		
		150	320							X		
10:00	380	50	55							X		
		100	157							X		
		150	245							X		
		200	350							X		
		250	440							X		
		300	539							X		**ND1(No Dispersivo)**

OBSERVACIONES:

REVISADO POR:

TECNILAB, S. A. FUNDADA EN 1973
UNA EMPRESA E. BARRANCO Y ASOC., S. A.
LABORATORIO DE SUELOS Y MATERIALES

PINHOLE TEST
ASTM D 4647

TRABAJO No. : 4-220 CLIENTE: MWH GLOBAL, INC. CALICATA : 02-06 MUESTRA : 1
PROYECTO: SITIO DE PRESA, PROYECTO ALTO CHAGRES LOCALIZACION: RIO CHAGRES
MUESTREADO POR: TECNILAB, S.A. FECHA: JUNIO, 02 PROFUNDIDAD: 0.40m a 1.30m
PREPARADO POR: TECNILAB, S.A. FECHA: JULIO, 02 LABORATORISTA: JOSE VERGARA

Hora de Inicio	Cabeza mm	Flujo ml.	Flujo seg.	Rata de Flujo	TURBIDEZ Muy Obscura	Obscura	Moderadamente Obscura	Ligeramente Obscura	Apenas Visible	Completamente Claro	Completamente Clara desde el Inicio	OBSERVACIONES
13:05	50	10	17							X		
		20	34							X		
		30	53							X		
		40	71							X		
		50	90							X		
		60	110							X		
13:15	180	25	36							X		
		50	99							X		
		75	163							X		
		100	236							X		
		125	316							X		
		150	389							X		
13:30	380	50	85							X		
		100	219							X		
		150	229							X		
		200	476							X		
		250	605							X		
		300	749							X		**ND1(No Dispersivo)**

OBSERVACIONES:

REVISADO POR:

TECNILAB, S. A. FUNDADA EN 1973
UNA EMPRESA E. BARRANCO Y ASOC., S. A.
LABORATORIO DE SUELOS Y MATERIALES

PINHOLE TEST
ASTM D 4647

TRABAJO No. : 4-220 CLIENTE: MWH GLOBAL, INC. CALICATA : 02-06 MUESTRA : 2
PROYECTO: SITIO DE PRESA, PROYECTO ALTO CHAGRES LOCALIZACION: RIO CHAGRES
MUESTREADO POR: TECNILAB, S.A. FECHA: JUNIO, 02 PROFUNDIDAD: 1.30m a 2.10m
PREPARADO POR: TECNILAB, S.A. FECHA: JULIO, 02 LABORATORISTA: JOSE VERGARA

Hora de Inicio	Cabeza mm	Flujo ml.	Flujo seg.	Rata de Flujo	TURBIDEZ Muy Obscura	Obscura	Moderadamente Obscura	Ligeramente Obscura	Apenas Visible	Completamente Claro	Completamente Clara desde el Inicio	OBSERVACIONES
11:00	50	10	12							X		
		20	22							X		
		30	31							X		
		40	41							X		
		50	50							X		
		60	61							X		
11:06	180	25	9							X		
		50	27							X		
		75	46							X		
		100	68							X		
		125	88							X		
		150	108							X		
11:13	380	50	21							X		
		100	58							X		
		150	95							X		
		200	133							X		
		250	171							X		
		300	205							X		**ND1(No Dispersivo)**

OBSERVACIONES:

REVISADO POR:

TECNILAB, S. A. FUNDADA EN 1973
UNA EMPRESA E. BARRANCO Y ASOC., S. A.
LABORATORIO DE SUELOS Y MATERIALES

PINHOLE TEST
ASTM D 4647

TRABAJO No. : 4-220 CLIENTE: MWH GLOBAL, INC. CALICATA : 02-07 MUESTRA : 1
PROYECTO: SITIO DE PRESA, PROYECTO AITOS DEL CHAGRES LOCALIZACION: RIO CHAGRES
MUESTREADO POR: TECNILAB, S.A. FECHA: JUNIO, 02 PROFUNDIDAD: 0.30m a 1.05m
PREPARADO POR: TECNILAB, S.A. FECHA: JULIO, 02 LABORATORISTA: JOSE VERGARA

Hora de Inicio	Cabeza mm	Flujo ml.	Flujo seg.	Rata de Flujo	TURBIDEZ Muy Obscura	Obscura	Moderadamente Obscura	Ligeramente Obscura	Apenas Visible	Completamente Claro	Completamente Clara desde el Inicio	OBSERVACIONES
09:45	50	10	10							X		
		20	20							X		
		30	27							X		
		40	36							X		
		50	45							X		
		60	53							X		
09:52	180	25	12							X		
		50	31							X		
		75	54							X		
		100	74							X		
		125	93							X		
		150	112							X		
10:00	380	50	26							X		
		100	61							X		
		150	153							X		
		200	128							X		
		250	161							X		
		300	196							X		**ND1(No Dispersivo)**

OBSERVACIONES:

REVISADO POR:

TECNILAB, S. A. FUNDADA EN 1973
UNA EMPRESA E. BARRANCO Y ASOC., S. A.
LABORATORIO DE SUELOS Y MATERIALES

PINHOLE TEST
ASTM D 4647

TRABAJO No. : 4-220 CLIENTE: MWH GLOBAL, INC. CALICATA : 02-07 MUESTRA : 2
PROYECTO: SITIO DE PRESA, PROYECTO ALTO CHAGRES LOCALIZACION: RIO CHAGRES
MUESTREADO POR: TECNILAB, S.A. FECHA: JUNIO, 02 PROFUNDIDAD: 1.05m a 1.70m
PREPARADO POR: TECNILAB, S.A. FECHA: JULIO, 02 LABORATORISTA: JOSE VERGARA

Hora de Inicio	Cabeza mm	Flujo ml.	Flujo seg.	Rata de Flujo	TURBIDEZ Muy Obscura	Obscura	Moderadamente Obscura	Ligeramente Obscura	Apenas Visible	Completamente Claro	Completamente Clara desde el Inicio	OBSERVACIONES
11:40	50	10	14							X		
		20	31							X		
		30	51							X		
		40	71							X		
		50	90							X		
		60	108							X		
11:46	180	25	12							X		
		50	37							X		
		75	80							X		
		100	108							X		
		125	141							X		
		150	172							X		
11:53	380	50	30							X		
		100	81							X		
		150	132							X		
		200	192							X		
		250	249							X		
		300	298							X		**ND1(No Dispersivo)**

OBSERVACIONES:

REVISADO POR:

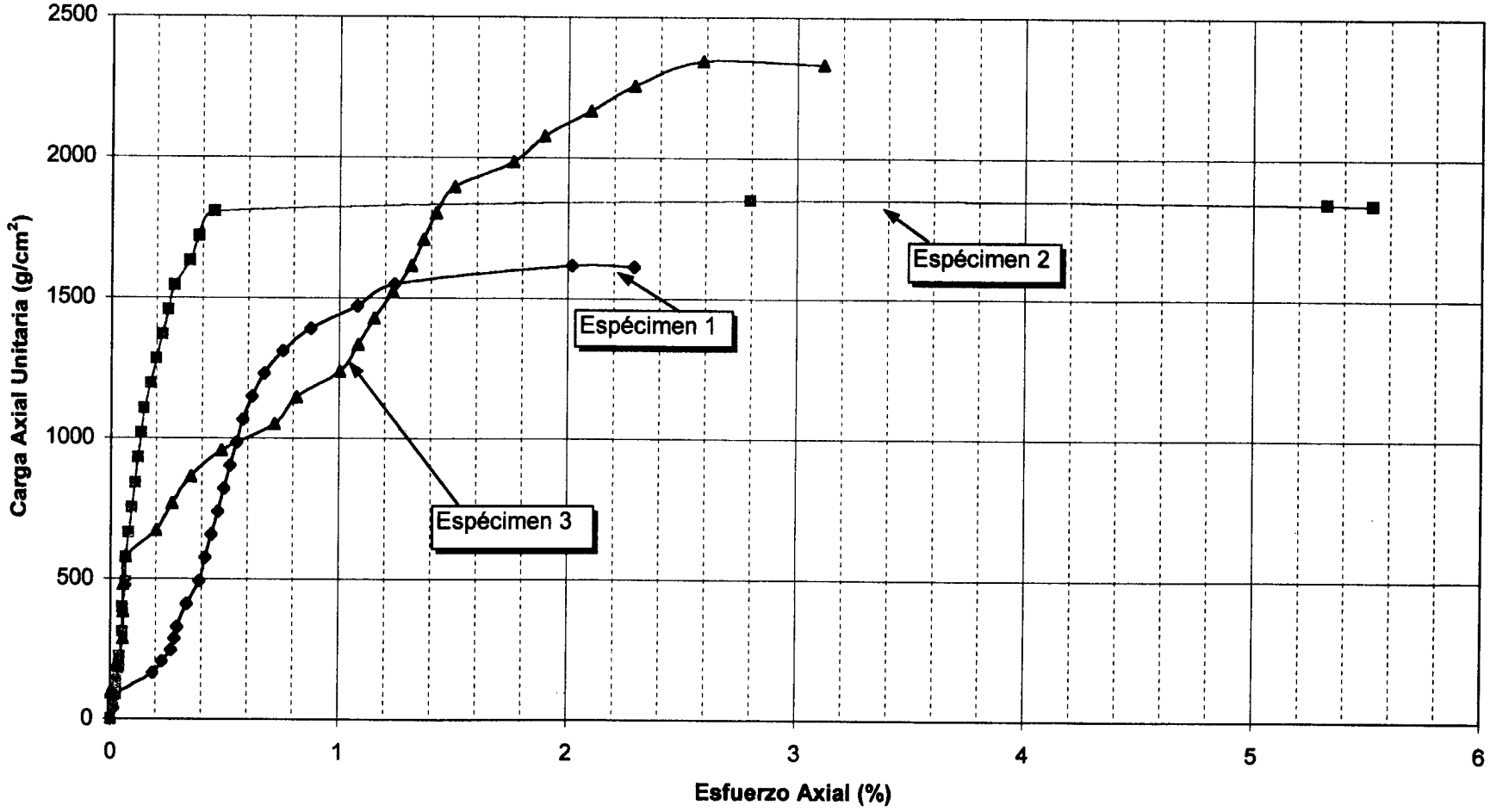
IX. ENSAYO DE COMPRESION TRIAXIAL

SITIO DE PRESA, ALTO CHAGRES

PRUEBA TRIAXIAL CU

MUESTRA 02-05 (Prof. 1.75 - 2.05)

Trabajo No. 4-220 Fecha: Junio de 2002



TECNILAB, S. A.

TECNILAB, S. A. FUNDADA EN 1973

UNA EMPRESA E. BARRANCO Y ASOC., S. A.

LABORATORIO DE SUELOS Y MATERIALES

ENSAYO DE COMPRESION TRIAXIAL CU

TRABAJO No. 4-220 MUESTRA Nº.: 02-05

PROYECTO Sitio de Presa, Alto Chagres

LOCALIZACION Río Chagres, Provincia de Panamá

CLIENTE MWH, Global Inc. FECHA 14 de junio de 2002

DESCRIPCION Profundidad 1.75 - 2.05

PROBADO POR C. Córdoba

[A] Información del Especímen (Antes de la Consolidación)

Espécimen N°. 1 Presión Efectiva 0.49 kg/cm^2

(1) Tipo de prueba realizada	Consolidada - No drenada	
(2) Tipo de Espécimen	[*] Inalterada	[ ] Remoldeada
(3) Diámetro del Espécimen	4.07	cm
(4) Area inicial del espécimen	13.01	cm^2
(5) Altura Inicial del espécimen	7.97	cm
(6) Relación Alto - diámetro	1.96	
(7) Volumen del espécimen	103.69	cm^3
(8) Masa del Espécimen	196.20	g.
(9) Peso unitario húmedo del espécimen	1.89	g/cm^3
(10) Contenido de agua del espécimen	15.14	%
(a.) Tara N°.	23	
(b.) Peso de suelo húmedo + tara	220.60	g.
(c.) Peso de suelo seco + tara	194.80	g.
(d.) Peso de la tara	24.40	g.
(e.) Peso del agua	25.80	g.
(f.) Peso del suelo seco	170.40	g.
(g.) Contenido de agua	15.10	%
(11) Peso unitario seco del espécimen	1.64	g/cm^3

[A] Información del Especímen (Después de la Consolidación)

(1) Presión Efectiva de La Cámara	0.49	kg/cm^2
(2) Presión de La Cámara	2.04	kg/cm^2
(3) Contra Presión	1.55	kg/cm^2
(4) Parámetro B	100.00	
(5) Volúmen Consolidado (V_c)	93.19	cm^3
(6) Area de la Muestra Después de la Consolidadación (A_c)	12.12	cm^2
(7) Altura de la Muestra Después de la Consolidación (L_c)	7.42	cm^2

OBSERVACIONES: DADA LA PRESENCIA DE DIACLASAS EN LAS MUESTRAS ENSAYADAS, NO SE DEBEN CONSIDERAR LOS RESULTADOS DE LAS PRUEBAS COMO CERTEROS.

TECNILAB, S. A.
UNA EMPRESA E. BARRANCO Y ASOC., S. A.
LABORATORIO DE SUELOS Y MATERIALES

FUNDADA EN 1973

COMPRESION TRIAXIAL CU
RESULTADOS

TRABAJO No.: 4-220 Espécimen N°. : 1
PROYECTO Sitio de Presa, Alto Chagres
LOCALIZACION : Río Chagres, Provincia de Panamá
CLIENTE : MWH Global, Inc. FECHA : 14 de junio de 2002
DESCRIPCION : Calicata 02-05
PROBADO POR : Cecilio Cordoba PROFUNDIDAD : 1.75 - 2.05

(1) Presión en la cámara del espécimen probado, σ_3 0.49 kg/cm^2
(2) Esfuerzo axial promedio _____ cm/min
(3) Altura de La Muestra Después de Consolodacion L_c, 7.42 cm.
(4) Area de La Muestra Después de Consolidación A_c 12.12 cm^2

Tiempo (min)	Deformación ΔL (cm)	Esfuerzo axial	Area de la Sección Transversal	Carga Axial Aplicada (g)	Carga Axial Unitaria (esfuerzo desviador) g/cm^2	Presión de Poros (kg/cm^2)
(1)	(2)	(3) = $\frac{\Delta L}{L_c}$	(4) = $\frac{A_c}{1 - \epsilon}$	(5)	(7) = $\frac{(6)}{(4)}$	(8)
0.38	0.0010	0.0001	12.12	503.300	41.53	
0.75	0.0010	0.0001	12.12	1003.300	82.80	
1.13	0.0140	0.0019	12.14	2009.300	165.52	
1.50	0.0170	0.0023	12.14	2511.300	206.79	
1.88	0.0200	0.0027	12.15	3013.300	248.03	
2.25	0.0210	0.0028	12.15	3513.300	289.15	
2.63	0.0220	0.0030	12.15	4011.300	330.09	
3.00	0.0250	0.0034	12.16	5012.300	412.29	
3.36	0.0290	0.0039	12.16	6011.300	494.20	
3.73	0.0310	0.0042	12.17	7016.300	576.66	
4.09	0.0330	0.0044	12.17	8015.300	658.59	
4.45	0.0350	0.0047	12.17	9013.300	740.39	
4.82	0.0370	0.0050	12.18	10013.300	822.32	
5.18	0.0390	0.0053	12.18	11019.300	904.69	
5.55	0.0410	0.0055	12.18	12025.300	987.01	
5.91	0.0430	0.0058	12.19	13027.300	1068.96	
6.27	0.0460	0.0062	12.19	14026.300	1150.47	
6.64	0.0500	0.0067	12.20	15032.300	1232.32	
7.00	0.0560	0.0075	12.21	16031.300	1313.14	
7.20	0.0650	0.0088	12.22	17030.300	1393.27	
7.40	0.0800	0.0108	12.25	18025.300	1471.66	
7.60	0.0920	0.0124	12.27	19024.300	1550.69	
7.80	0.1500	0.0202	12.37	20023.300	1619.20	
8.00	0.1700	0.0229	12.40	20023.300	1614.75	

Esfuerzo principal menor (Presión de confinamiento, $\sigma 3$) 0.49 kg/cm^2
Carga axial unitaria al fallar, Δp 1.619 kg/cm^2
Esfuerzo principal mayor al fallar $\sigma 1 = \sigma 3 + \Delta p$ 2.109 kg/cm^2
Presión de poros al momento de fallar μ_f - kg/cm^2
Esfuerzo principal menor Efectivo $\bar{\sigma}_3 = \sigma_3 - \mu_f$ - kg/cm^2
Esfuerzo principal mayor Efectivo $\bar{\sigma}_1 = \sigma_1 - \mu_f$ - kg/cm^2

OBSERVACIONES: DADA LA PRESENCIA DE DIACLASAS EN LAS MUESTRAS ENSAYADAS, LOS VALORES DE LA PRESION DE POROS NO FUERON CONSIDERADOS PARA LA PRESENTACION DE LOS RESULTADOS

TECNILAB, S. A. FUNDADA EN 1973
UNA EMPRESA E. BARRANCO Y ASOC., S. A.
LABORATORIO DE SUELOS Y MATERIALES

ENSAYO DE COMPRESION TRIAXIAL CU

TRABAJO No. 4-220 MUESTRA Nº.: 02-05
PROYECTO Sitio de Presa, Alto Chagres
LOCALIZACION Río Chagres, Provincia de Panamá
CLIENTE MWH, Global Inc. FECHA 14 de junio de 2002
DESCRIPCION Profundidad 1.75 - 2.05
PROBADO POR C. Córdoba

[A] Información del Especímen (Antes de la Consolidación)

Espécimen N°. 2 Presión Efectiva 0.98 kg/cm^2

(1) Tipo de prueba realizada	Consolidada - No drenada	
(2) Tipo de Espécimen	[*] Inalterada [ ] Remoldeada	
(3) Diámetro del Espécimen	3.94	cm
(4) Area inicial del espécimen	12.19	cm^2
(5) Altura Inicial del espécimen	8.10	cm
(6) Relación Alto - diámetro	2.06	
(7) Volumen del espécimen	98.76	cm^3
(8) Masa del Espécimen	203.60	g.
(9) Peso unitario húmedo del espécimen	2.06	g/cm^3
(10) Contenido de agua del espécimen	15.16	%
(a.) Tara N°.	8	
(b.) Peso de suelo húmedo + tara	230.80	g.
(c.) Peso de suelo seco + tara	204.00	g.
(d.) Peso de la tara	27.20	g.
(e.) Peso del agua	26.80	g.
(f.) Peso del suelo seco	176.80	g.
(g.) Contenido de agua	15.20	%
(11) Peso unitario seco del espécimen	1.79	g/cm^3

[A] Información del Especímen (Después de la Consolidación)

(1) Presión Efectiva de La Cámara	0.98	kg/cm^2
(2) Presión de La Cámara	3.94	kg/cm^2
(3) Contra Presión	2.96	kg/cm^2
(4) Parámetro B	100.00	
(5) Volúmen Consolidado (V_c)	88.26	cm^3
(6) Area de la Muestra Después de la Consolidadación (A_c)	11.31	cm^2
(7) Altura de la Muestra Después de la Consolidación (L_c)	7.52	cm^2

OBSERVACIONES: DADA LA PRESENCIA DE DIACLASAS EN LAS MUESTRAS ENSAYADAS, NO SE DEBEN CONSIDERAR LOS RESULTADOS DE LAS PRUEBAS COMO CERTEROS.

TECNILAB, S. A.
UNA EMPRESA E. BARRANCO Y ASOC., S. A.
LABORATORIO DE SUELOS Y MATERIALES

FUNDADA EN 1973

COMPRESION TRIAXIAL CU
RESULTADOS

TRABAJO No.: 4-220 Espécimen N°. : 1
PROYECTO: Sitio de Presa, Alto Chagres
LOCALIZACION : Río Chagres, Provincia de Panamá
CLIENTE : MWH Global, Inc. FECHA : 14 de junio de 2002
DESCRIPCION : Calicata 02-05
PROBADO POR : Cecilio Cordoba PROFUNDIDAD : 1.75 - 2.05

(1) Presión en la cámara del espécimen probado, σ_3 0.98 kg/cm^2
(2) Esfuerzo axial promedio _____ cm/min
(3) Altura de La Muestra Después de Consolodacion L_c, 7.52 cm.
(4) Area de La Muestra Después de Consolidación A_c 11.31 cm^2

Tiempo (min)	Deformación ΔL (cm)	Esfuerzo axial	Area de la Sección Transversal	Carga Axial Aplicada (g)	Carga Axial Unitaria (esfuerzo desviador) g/cm^2	Presión de Poros (kg/cm^2)
(1)	(2)	(3) = $\frac{\Delta L}{L_c}$	(4) = $\frac{A_c}{1 - \in}$	(5)	(7) = $\frac{(6)}{(4)}$	(8)
0.33	0.0010	0.0001	11.31	503.000	44.46	
0.65	0.0020	0.0003	11.31	1003.000	88.64	
0.98	0.0020	0.0003	11.31	1504.600	132.97	
1.31	0.0030	0.0004	11.32	2005.100	177.18	
1.63	0.0030	0.0004	11.32	2505.100	221.37	
1.96	0.0040	0.0005	11.32	3511.100	310.22	
2.29	0.0040	0.0005	11.32	4510.100	398.49	
2.62	0.0050	0.0007	11.32	5517.100	487.40	
2.94	0.0050	0.0007	11.32	6515.100	575.57	
3.27	0.0060	0.0008	11.32	7513.100	663.64	
3.60	0.0070	0.0009	11.32	8518.100	752.32	
3.92	0.0080	0.0011	11.32	9524.100	841.05	
4.25	0.0090	0.0012	11.33	10530.700	929.82	
4.58	0.0100	0.0013	11.33	11531.700	1018.07	
4.90	0.0110	0.0015	11.33	12536.700	1106.65	
5.23	0.0130	0.0017	11.33	13534.700	1194.43	
5.56	0.0150	0.0020	11.33	14535.700	1282.42	
5.88	0.0170	0.0023	11.34	15529.700	1369.75	
6.21	0.0190	0.0025	11.34	16528.700	1457.48	
6.54	0.0210	0.0028	11.34	17527.700	1545.16	
6.86	0.0260	0.0035	11.35	18526.700	1632.13	
7.19	0.0290	0.0039	11.36	19532.700	1720.07	
7.52	0.0340	0.0045	11.36	20532.700	1806.92	
7.85	0.2100	0.0279	11.64	21531.700	1850.26	
8.17	0.4000	0.0532	11.95	22028.700	1843.73	
8.50	0.4150	0.0552	11.97	22028.700	1839.85	

Esfuerzo principal menor (Presión de confinamiento, $\sigma 3$) 0.98 kg/cm^2
Carga axial unitaria al fallar, Δp 1.843 kg/cm^2
Esfuerzo principal mayor al fallar $\sigma 1 = \sigma 3 + \Delta p$ 2.823 kg/cm^2
Presión de poros al momento de fallar μ_f - kg/cm^2
Esfuerzo principal menor Efectivo $\overline{\sigma}_3 = \sigma_3 - \mu_f$ - kg/cm^2
Esfuerzo principal mayor Efectivo $\overline{\sigma}_1 = \sigma_1 - \mu_f$ - kg/cm^2

OBSERVACIONES: DADA LA PRESENCIA DE DIACLASAS EN LAS MUESTRAS ENSAYADAS, LOS VALORES DE LA PRESION DE POROS NO FUERON CONSIDERADOS PARA LA PRESENTACION DE LOS RESULTADOS

TECNILAB, S. A. FUNDADA EN 1973
UNA EMPRESA E. BARRANCO Y ASOC., S. A.
LABORATORIO DE SUELOS Y MATERIALES

ENSAYO DE COMPRESION TRIAXIAL CU

TRABAJO No. 4-220 MUESTRA Nº.: 02-05
PROYECTO Sitio de Presa, Alto Chagres
LOCALIZACION Río Chagres, Provincia de Panamá
CLIENTE MWH, Global Inc. FECHA 14 de junio de 2002
DESCRIPCION Profundidad 1.75 - 2.05
PROBADO POR C. Córdoba

[A] Información del Especímen (Antes de la Consolidación)

Espécimen N°. 3 Presión Efectiva 1.97 kg/cm^2

(1) Tipo de prueba realizada	Consolidada - No drenada	
(2) Tipo de Espécimen	[*] Inalterada [ ] Remoldeada	
(3) Diámetro del Espécimen	3.79	cm
(4) Area inicial del espécimen	11.28	cm^2
(5) Altura Inicial del espécimen	8.02	cm
(6) Relación Alto - diámetro	2.12	
(7) Volumen del espécimen	90.48	cm^3
(8) Masa del Espécimen	192.10	g.
(9) Peso unitario húmedo del espécimen	2.12	g/cm^3
(10) Contenido de agua del espécimen	14.07	%
(a.) Tara N°.	64	
(b.) Peso de suelo húmedo + tara	218.80	g.
(c.) Peso de suelo seco + tara	195.10	g.
(d.) Peso de la tara	26.70	g.
(e.) Peso del agua	23.70	g.
(f.) Peso del suelo seco	168.40	g.
(g.) Contenido de agua	14.10	%
(11) Peso unitario seco del espécimen	1.86	g/cm^3

[A] Información del Especímen (Después de la Consolidación)

(1) Presión Efectiva de La Cámara	1.97	kg/cm^2
(2) Presión de La Cámara	7.04	kg/cm^2
(3) Contra Presión	5.07	kg/cm^2
(4) Parámetro B	100.00	
(5) Volúmen Consolidado (V_c)	79.98	cm^3
(6) Area de la Muestra Después de la Consolidadación (A_c)	10.39	cm^2
(7) Altura de la Muestra Después de la Consolidación (L_c)	7.39	cm^2

OBSERVACIONES: DADA LA PRESENCIA DE DIACLASAS EN LAS MUESTRAS ENSAYADAS, NO SE DEBEN CONSIDERAR LOS RESULTADOS DE LAS PRUEBAS COMO CERTEROS.

TECNILAB, S. A.
UNA EMPRESA E. BARRANCO Y ASOC., S. A.
LABORATORIO DE SUELOS Y MATERIALES

FUNDADA EN 1973

COMPRESION TRIAXIAL CU
RESULTADOS

TRABAJO No.: 4-220 Espécimen N°. : 1
PROYECTO: Sitio de Presa, Alto Chagres
LOCALIZACION : Río Chagres, Provincia de Panamá
CLIENTE : MWH Global, Inc. FECHA : 14 de junio de 2002
DESCRIPCION : Calicata 02-05
PROBADO POR : Cecilio Cordoba PROFUNDIDAD : 1.75 - 2.05

(1) Presión en la cámara del espécimen probado, σ_3 1.97 kg/cm^2
(2) Esfuerzo axial promedio _____ cm/min
(3) Altura de La Muestra Después de Consolodacion L_c, 7.39 cm.
(4) Area de La Muestra Después de Consolidación A_c 10.39 cm^2

Tiempo (min)	Deformación ΔL (cm)	Esfuerzo axial	Area de la Sección Transversal	Carga Axial Aplicada (g)	Carga Axial Unitaria (esfuerzo desviador) g/cm^2	Presión de Poros (kg/cm^2)
(1)	(2)	(3) = $\frac{\Delta L}{L_c}$	(4) = $\frac{A_c}{1 - \in}$	(5)	(7) = $\frac{(6)}{(4)}$	(8)
0.34	0.0000	0.0000	10.39	999.000	96.14	
0.68	0.0020	0.0003	10.39	1999.000	192.33	
1.02	0.0040	0.0005	10.40	2998.000	288.36	
1.36	0.0040	0.0005	10.40	4004.000	385.13	
1.70	0.0040	0.0005	10.40	5011.000	481.99	
2.04	0.0050	0.0007	10.40	6017.000	578.67	
2.38	0.0150	0.0020	10.41	7023.000	674.51	
2.72	0.0200	0.0027	10.42	8021.000	769.83	
3.06	0.0260	0.0035	10.43	9022.000	865.20	
3.40	0.0360	0.0049	10.44	10021.000	959.70	
3.74	0.0530	0.0072	10.47	11027.000	1053.60	
4.08	0.0600	0.0081	10.48	12027.000	1148.05	
4.42	0.0740	0.0100	10.50	13026.000	1241.04	
4.76	0.0800	0.0108	10.50	14025.000	1335.12	
5.10	0.0850	0.0115	10.51	15024.000	1429.24	
5.44	0.0910	0.0123	10.52	16018.000	1522.55	
5.78	0.0970	0.0131	10.53	17016.000	1616.08	
6.12	0.1010	0.0137	10.53	18016.000	1710.11	
6.46	0.1050	0.0142	10.54	19022.000	1804.61	
6.80	0.1110	0.0150	10.55	20023.000	1898.01	
7.14	0.1300	0.0176	10.58	21025.000	1987.79	
7.48	0.1400	0.0190	10.59	22022.000	2079.18	
7.73	0.1550	0.0210	10.61	23021.100	2169.01	
7.98	0.1690	0.0229	10.63	24020.400	2258.78	
8.23	0.1910	0.0259	10.67	25025.400	2346.12	
8.48	0.2300	0.0311	10.72	25025.400	2333.40	

Esfuerzo principal menor (Presión de confinamiento, $\sigma 3$) 1.97 kg/cm^2
Carga axial unitaria al fallar, Δp 2.346 kg/cm^2
Esfuerzo principal mayor al fallar $\sigma 1 = \sigma 3 + \Delta p$ 4.316 kg/cm^2
Presión de poros al momento de fallar μ_f - kg/cm^2
Esfuerzo principal menor Efectivo $\overline{\sigma}_3 = \sigma_3 - \mu_f$ - kg/cm^2
Esfuerzo principal mayor Efectivo $\overline{\sigma}_1 = \sigma_1 - \mu_f$ - kg/cm^2

OBSERVACIONES: DADA LA PRESENCIA DE DIACLASAS EN LAS MUESTRAS ENSAYADAS, LOS VALORES DE LA PRESION DE POROS NO FUERON CONSIDERADOS PARA LA PRESENTACION DE LOS RESULTADOS

X. ANÁLISIS PETROGRAFICO

TECNILAB, S. A.

ANALISIS PETROGRÁFICO

MUESTRA R2:

Roca de estructura glómero-porfídica, textura traquítica. Pequeños fenocristales de sanidina (feldespato potásico) y de escaso cuarzo, formado por grupos de fenocristales. Pasta de fondo de laminillas de sanidina y escasa plagioclasa (albita-oligoclasa). Epidota y clorita secundarias (de originales fémicos). Cristales y "manchas" de hematita secundaria. Magnetita y rutilo.

- Feltespato potásico +/- 35%
- Plagioclasa +/- 5%
- Cuarzo +/- 5%
- Epidota +/- 20%
- Clorita +/- 15%
- Hematita +/- 10%
- Magnetita +/- 5%
- Rutilo +/- 5%

La roca es una Traquita con alteración hidrotermal de bajo a medio grado.

MUESTRA R3:

Roca de estructura porfídica, textura traquítica un poco granular. Pequeños fenocristales de sanidina (feldespato potásico). Pasta de fondo de laminillas de sanidinia y escasa plagioclasa (albita-oligoclasa). Epidota e illita secundarias. Vetillas de hematita. Lentes de cuarzo en mosaico. Rutilo y magnetita.

- Feldespato potásico +/- 35%
- Cuarzo +/- 10%
- Epidota +/- 20%
- Illita +/- 10%
- Hematita +/- 10%
- Magnetita +/- 10%
- Rutilo +/- 5%

La roca es una Traquita con fuerte alteración hidrotermal. La muestra de mano indica una meteorización notable.

MUESTRA R4:

Roca de estructura clástica. Textura original escoriácea vidriosa. Se observan burbujas originales recristalizadas en sanidina y rellenadas de clorita. Magnetita diseminada, trazas de epidota. Sulfuros (pirita y probable calcopirita). Rutilo y algo de cuarzo.

- Feldespato potásico +/- 40%
- Cuarzo +/- 5%
- Clorita +/- 30%
- Epidota +/- 5%
- Illita +/- 2%
- Sulfuros +/- 10%
- Magnetita +/- 5%
- Rutilo +/- 3%

La roca es una Toba recristalizada de ceniza vidriosa traquítica con alteración hidrotermal de grano medio.

ANÁLISIS REALIZADO POR: Dr. Eric Gutierrez

XI. ANÁLISIS GRANULOMETRICO

TECNILAB, S. A.

TECNILAB, S. A.

FUNDADA EN 1973

UNA EMPRESA E. BARRANCO Y ASOC., S. A.

LABORATORIO DE SUELOS Y MATERIALES

ANALISIS GRANULOMETRICO
ASTM-C136

TRABAJO Nº. 4-220 CLIENTE : MWH GLOBAL, INC. MUESTRA Nº. : 02-09

PROYECTO: SITIO DE PRESA DEL PROYECTO ALTO CHAGRES

MUESTREADO POR: TECNILAB, S.A. FECHA : 15-Jun-02 LOCOLIZACIÓN : RIO CHAGRES

PREPARADO POR: TECNILAB, S.A. FECHA : 18-Jun-02 LABORATORISTA : I. LLERENA

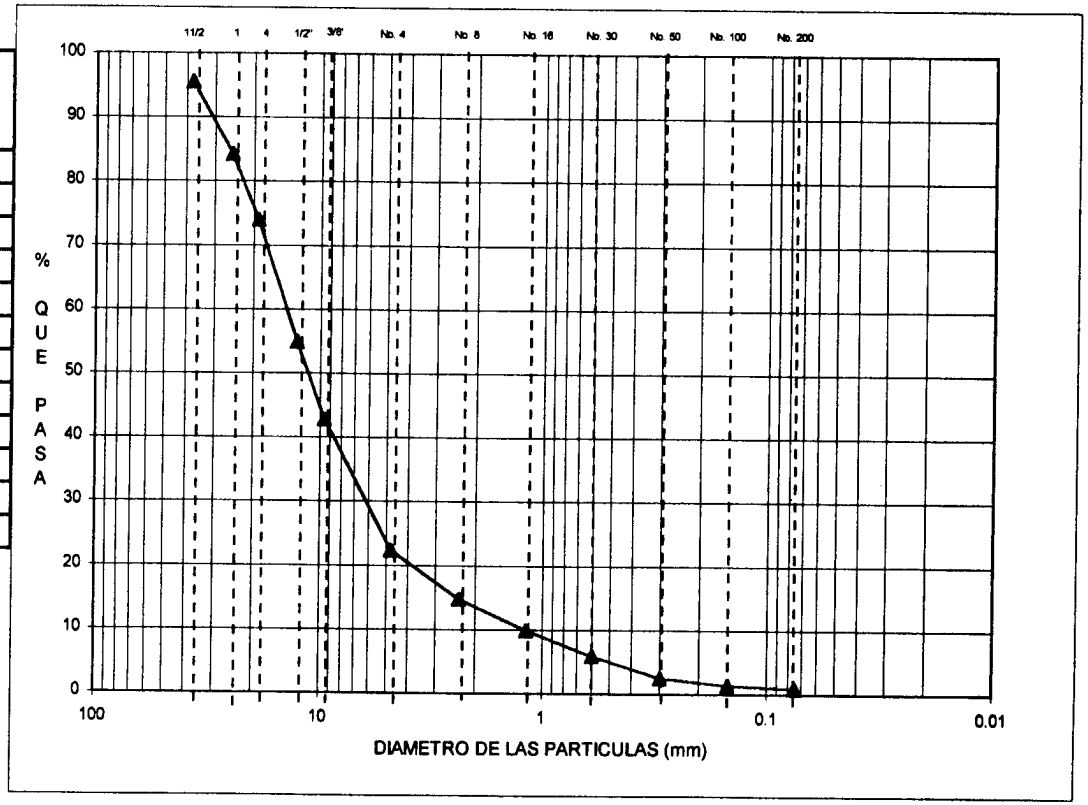
Agregado Grueso

Peso de Muestra Total Secada al aire 11,540.0 g

Agregado Fino

Peso de Muestra Total Secada al aire 396.7 g

TAMIZ	RETENIDO ACUMULADO	% RETENIDO	% QUE PASA	% CORR QUE PASA
1 1/2"	506.00	4.38	95.62	95.60
1"	1813.0	15.71	84.29	84.30
3/4"	2985.0	25.87	74.13	74.10
1/2"	5,192.0	44.99	55.01	55.00
3/8"	6,593.0	57.13	42.87	42.90
No. 4	8,944.0	77.50	22.50	22.50
No. 8	134.1	33.80	66.20	14.89
No. 16	220.4	55.56	44.44	9.99
No. 30	291.80	73.56	26.44	5.94
No. 50	350.50	88.35	11.65	2.61
No.100	371.00	93.52	6.48	1.46
No. 200	379.70	95.71	4.29	0.97



Observaciones: _____

TECNILAB, S. A.

FUNDADA EN 1973

UNA EMPRESA E. BARRANCO Y ASOC., S. A.

LABORATORIO DE SUELOS Y MATERIALES

ANALISIS GRANULOMETRICO
ASTM C136

TRABAJO Nº. 4-220 CLIENTE : MWH GLOBAL, INC. MUESTRA Nº. : 02-10

PROYECTO: SITIO DE PRESA DEL PROYECTO ALTO CHAGRES

MUESTREADO POR: TECNILAB, S.A. FECHA : 15-Jun-02 LOCOLIZACIÓN : RIO CHAGRES

PREPARADO POR: TECNILAB, S.A. FECHA : 18-Jun-02 LABORATORISTA : I. LLERENA

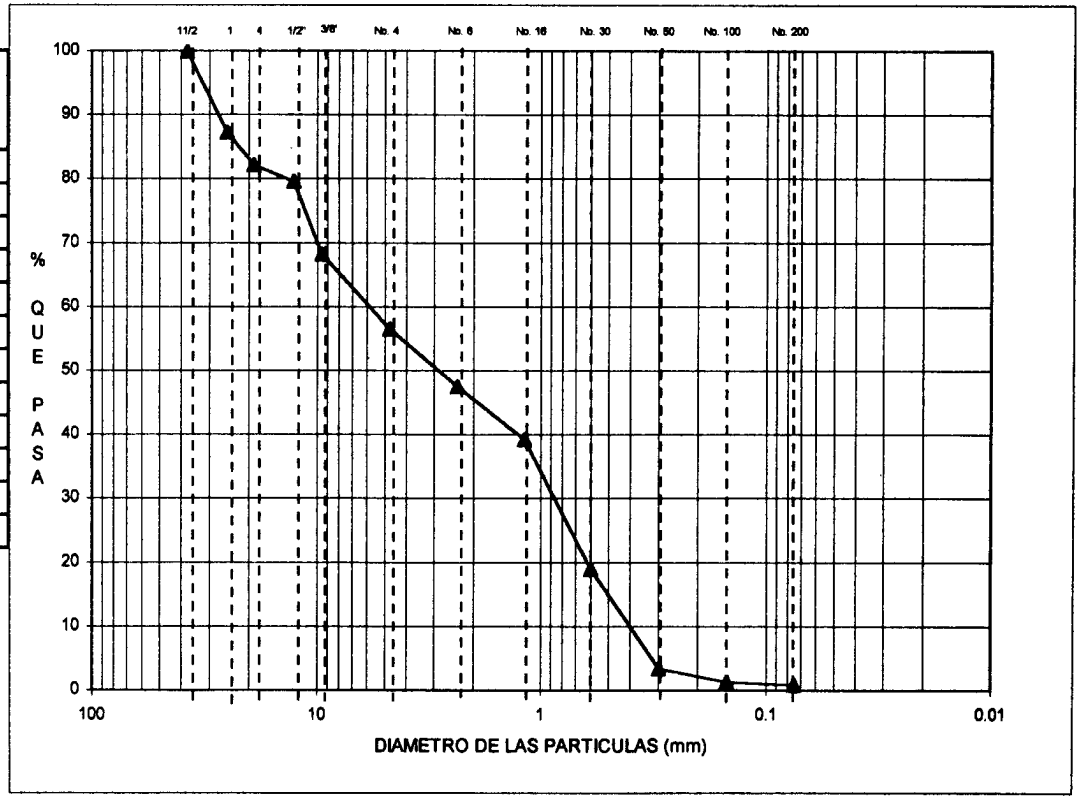
Agregado Grueso

Peso de Muestra Total Secada al aire 9,738.0 g

Agregado Fino

Peso de Muestra Total Secada al aire 304.8 g

TAMIZ	RETENIDO ACUMULADO	% RETENIDO	% QUE PASA	% CORR QUE PASA
1 1/2"	0.00	0.00	100.00	**100.00**
1"	1240.0	12.73	87.27	**87.30**
3/4"	1732.0	17.79	82.21	**82.20**
1/2"	2,498.0	25.65	74.35	**79.64**
3/8"	3,083.0	31.66	68.34	**68.30**
No. 4	4,235.0	43.49	56.51	**56.60**
No. 8	48.5	15.91	84.09	**47.60**
No. 16	93.3	30.61	69.39	**39.28**
No. 30	202.30	66.37	33.63	**19.02**
No. 50	286.30	93.93	6.07	**3.45**
No.100	297.60	97.64	2.36	**1.35**
No. 200	299.80	98.36	1.64	**0.91**



Observaciones:

XII. GRAVEDAD ESPECIFICA Y ABSORCIÓN DE AGREGADOS

TECNILAB, S. A.

TECNILAB, S. A. FUNDADA EN 1973
UNA EMPRESA E: BARRANCO Y ASOC., S. A.
LABORATORIO DE SUELOS Y MATERIALES

GRAVEDAD ESPECIFICA Y ABSORCIÓN DE AGREGADOS GRUESOS ASTM-C 127

TRABAJO No. : 4-220 CLIENTE MWH GLOBAL, INC. Calicata No.: 02-09
PROYECTO: SITIO DE PRESA DEL PROYECTO ALTO CHAGRES LOCALIZACION: RIO CHAGRES
MUESTREADO POR: TECNILAB S.A. FECHA: Jun-02 PROFUNDIDAD : 0.00 A 0.90
PREPARADO POR: TECNILAB S.A. FECHA: Jun-02 LABORATORISTA: I. LLERENA

MATERIAL GRAVA DE RIO

AGREGADO GRUESO

DETALLE	UNIDAD	NUMERO DE ENSAYO			
		1	2	3	4
(A) PESO DE LA GRAVA SECA AL HORNO	g	3061.00			
PESO DE LA GRAVA SATURADA EN AGUA + TARA	g	4430.00			
(B) PESO DE LA GRAVA SATURADA	g	3086.00			
PESO DE LA TARA	g	1344.00			
(C) PESO DE LA GRAVA SATURADA EN AGUA	g	2022.00			
GRAVEDAD ESPECIFICA BRUTA A / B-C		2.88			
GRAVEDAD ESPECIFICA BRUTA (S.S.S.) B / B-C		2.90			
GRAVEDAD ESPECIFICA APARENTE A / A-C		2.95			
PORCENTAJE DE ABSORCIÓN (B-A x 100) / A		0.80			

AGREGADO FINO

DETALLE	UNIDAD	NUMERO DE ENSAYO			
		1	2	3	4
(A) PESO DE LA GRAVA SECA AL HORNO	g				
PESO DE LA GRAVA SATURADA EN AGUA + TARA	g				
(B) PESO DE LA GRAVA SATURADA	g				
PESO DE LA TARA	g				
(C) PESO DE LA GRAVA SATURADA EN AGUA	g				
GRAVEDAD ESPECIFICA BRUTA A / B-C					
GRAVEDAD ESPECIFICA BRUTA (S.S.S.) B / B-C					
GRAVEDAD ESPECIFICA APARENTE A / A-C					
PORCENTAJE DE ABSORCIÓN (B-A x 100) / A					

OBSERVACIONES:

TECNILAB, S. A. FUNDADA EN 1973
UNA EMPRESA E. BARRANCO Y ASOC., S. A.
LABORATORIO DE SUELOS Y MATERIALES

GRAVEDAD ESPECIFICA Y ABSORCIÓN DE AGREGADOS GRUESOS ASTM-C 127

TRABAJO No. : 4-220 CLIENTE MWH GLOBAL, INC. Calicata No.: 02-10
PROYECTO: SITIO DE PRESA DEL PROYECTO ALTO CHAGRES LOCALIZACION: RIO CHAGRES
MUESTREADO POR: TECNILAB, S.A. FECHA: Jun-02 PROFUNDIDAD : 0.00 A 0.60
PREPARADO POR: TECNILAB, S.A. FECHA: Jun-02 LABORATORISTA: I. LLERENA

MATERIAL GRAVA DE RIO

AGREGADO GRUESO

DETALLE	UNIDAD	NUMERO DE ENSAYO			
		1	2	3	4
(A) PESO DE LA GRAVA SECA AL HORNO	g	3079.00			
PESO DE LA GRAVA SATURADA EN AGUA + TARA	g	4452.00			
(B) PESO DE LA GRAVA SATURADA	g	3108.00			
PESO DE LA TARA	g	1344.00			
(C) PESO DE LA GRAVA SATURADA EN AGUA	g	2025.00			
GRAVEDAD ESPECIFICA BRUTA A / B-C		2.84			
GRAVEDAD ESPECIFICA BRUTA (S.S.S.) B / B-C		2.87			
GRAVEDAD ESPECIFICA APARENTE A / A-C		2.92			
PORCENTAJE DE ABSORCIÓN (B-A x 100) / A		0.90			

AGREGADO FINO

DETALLE	UNIDAD	NUMERO DE ENSAYO			
		1	2	3	4
(A) PESO DE LA GRAVA SECA AL HORNO	g				
PESO DE LA GRAVA SATURADA EN AGUA + TARA	g				
(B) PESO DE LA GRAVA SATURADA	g				
PESO DE LA TARA	g				
(C) PESO DE LA GRAVA SATURADA EN AGUA	g				
GRAVEDAD ESPECIFICA BRUTA A / B-C					
GRAVEDAD ESPECIFICA BRUTA (S.S.S.) B / B-C					
GRAVEDAD ESPECIFICA APARENTE A / A-C					
PORCENTAJE DE ABSORCIÓN (B-A x 100) / A					

OBSERVACIONES:

TECNILAB, S. A. FUNDADA EN 1973
UNA EMPRESA E. BARRANCO Y ASOC., S. A.
LABORATORIO DE SUELOS Y MATERIALES

GRAVEDAD ESPECIFICA Y ABSORCIÓN DE AGREGADOS GRUESOS ASTM-C 127

TRABAJO No. : 4-220 CLIENTE MWH GLOBAL, INC. Calicata No.: R-2
PROYECTO: SITIO DE PRESA DEL PROYECTO ALTO CHAGRES LOCALIZACION: RIO CHAGRES
MUESTREADO POR: TECNILAB, S.A. FECHA: Jun-02 PROFUNDIDAD : -
PREPARADO POR: TECNILAB, S.A. FECHA: Jun-02 LABORATORISTA: C.C.

MATERIAL GRAVA DE RIO

AGREGADO GRUESO

DETALLE	UNIDAD	NUMERO DE ENSAYO			
		1	2	3	4
(A) PESO DE LA GRAVA SECA AL HORNO	g	2555.00			
PESO DE LA GRAVA SATURADA EN AGUA + TARA	g	4110.00			
(B) PESO DE LA GRAVA SATURADA	g	2625.00			
PESO DE LA TARA	g	2520.00			
(C) PESO DE LA GRAVA SATURADA EN AGUA	g	1590			
GRAVEDAD ESPECIFICA BRUTA A / B-C		2.46			
GRAVEDAD ESPECIFICA BRUTA (S.S.S.) B / B-C		2.53			
GRAVEDAD ESPECIFICA APARENTE A / A-C		2.65			
PORCENTAJE DE ABSORCIÓN (B-A x 100) / A		2.74			

AGREGADO FINO

DETALLE	UNIDAD	NUMERO DE ENSAYO			
		1	2	3	4
(A) PESO DE LA GRAVA SECA AL HORNO	g				
PESO DE LA GRAVA SATURADA EN AGUA + TARA	g				
(B) PESO DE LA GRAVA SATURADA	g				
PESO DE LA TARA	g				
(C) PESO DE LA GRAVA SATURADA EN AGUA	g				
GRAVEDAD ESPECIFICA BRUTA A / B-C					
GRAVEDAD ESPECIFICA BRUTA (S.S.S.) B / B-C					
GRAVEDAD ESPECIFICA APARENTE A / A-C					
PORCENTAJE DE ABSORCIÓN (B-A x 100) / A					

OBSERVACIONES:

TECNILAB, S. A. FUNDADA EN 1973
UNA EMPRESA E. BARRANCO Y ASOC., S. A.
LABORATORIO DE SUELOS Y MATERIALES

GRAVEDAD ESPECIFICA Y ABSORCIÓN DE AGREGADOS GRUESOS ASTM-C 127

TRABAJO No. : 4-220 CLIENTE MWH GLOBAL, INC. Calicata No.: R-3
PROYECTO: SITIO DE PRESA DEL PROYECTO ALTO CHAGRES LOCALIZACION: RIO CHAGRES
MUESTREADO POR: TECNILAB, S.A. FECHA: Jun-02 PROFUNDIDAD : -
PREPARADO POR: TECNILAB, S.A. FECHA: Jun-02 LABORATORISTA: C.C.

MATERIAL GRAVA DE RIO

AGREGADO GRUESO

DETALLE	UNIDAD	NUMERO DE ENSAYO			
		1	2	3	4
(A) PESO DE LA GRAVA SECA AL HORNO	g	2535.00			
PESO DE LA GRAVA SATURADA EN AGUA + TARA	g	4100.00			
(B) PESO DE LA GRAVA SATURADA	g	2725.00			
PESO DE LA TARA	g	2526.00			
(C) PESO DE LA GRAVA SATURADA EN AGUA	g	1574			
GRAVEDAD ESPECIFICA BRUTA A / B-C		2.20			
GRAVEDAD ESPECIFICA BRUTA (S.S.S.) B / B-C		2.34			
GRAVEDAD ESPECIFICA APARENTE A / A-C		2.64			
PORCENTAJE DE ABSORCIÓN (B-A x 100) / A		7.49			

AGREGADO FINO

DETALLE	UNIDAD	NUMERO DE ENSAYO			
		1	2	3	4
(A) PESO DE LA GRAVA SECA AL HORNO	g				
PESO DE LA GRAVA SATURADA EN AGUA + TARA	g				
(B) PESO DE LA GRAVA SATURADA	g				
PESO DE LA TARA	g				
(C) PESO DE LA GRAVA SATURADA EN AGUA	g				
GRAVEDAD ESPECIFICA BRUTA A / B-C					
GRAVEDAD ESPECIFICA BRUTA (S.S.S.) B / B-C					
GRAVEDAD ESPECIFICA APARENTE A / A-C					
PORCENTAJE DE ABSORCIÓN (B-A x 100) / A					

OBSERVACIONES:

TECNILAB, S. A. FUNDADA EN 1973
UNA EMPRESA E. BARRANCO Y ASOC., S. A.
LABORATORIO DE SUELOS Y MATERIALES

GRAVEDAD ESPECIFICA Y ABSORCIÓN DE AGREGADOS GRUESOS ASTM-C 127

TRABAJO No. : 4-220 CLIENTE MWH GLOBAL, INC. Calicata No.: R-4
PROYECTO: SITIO DE PRESA DEL PROYECTO ALTO CHAGRES LOCALIZACION: RIO CHAGRES
MUESTREADO POR: TECNILAB, S.A. FECHA: Jun-02 PROFUNDIDAD : -
PREPARADO POR: TECNILAB, S.A. FECHA: Jun-02 LABORATORISTA: C.C.

MATERIAL GRAVA DE RIO

AGREGADO GRUESO

DETALLE	UNIDAD	NUMERO DE ENSAYO			
		1	2	3	4
(A) PESO DE LA GRAVA SECA AL HORNO	g	3574.00			
PESO DE LA GRAVA SATURADA EN AGUA + TARA	g	4810.00			
(B) PESO DE LA GRAVA SATURADA	g	3632.00			
PESO DE LA TARA	g	2526.00			
(C) PESO DE LA GRAVA SATURADA EN AGUA	g	2284			
GRAVEDAD ESPECIFICA BRUTA A / B-C		2.65			
GRAVEDAD ESPECIFICA BRUTA (S.S.S.) B / B-C		2.69			
GRAVEDAD ESPECIFICA APARENTE A / A-C		2.77			
PORCENTAJE DE ABSORCIÓN (B-A x 100) / A		1.60			

AGREGADO FINO

DETALLE	UNIDAD	NUMERO DE ENSAYO			
		1	2	3	4
(A) PESO DE LA GRAVA SECA AL HORNO	g				
PESO DE LA GRAVA SATURADA EN AGUA + TARA	g				
(B) PESO DE LA GRAVA SATURADA	g				
PESO DE LA TARA	g				
(C) PESO DE LA GRAVA SATURADA EN AGUA	g				
GRAVEDAD ESPECIFICA BRUTA A / B-C					
GRAVEDAD ESPECIFICA BRUTA (S.S.S.) B / B-C					
GRAVEDAD ESPECIFICA APARENTE A / A-C					
PORCENTAJE DE ABSORCIÓN (B-A x 100) / A					

OBSERVACIONES:

XIV. REACTIVIDAD ALCALINA

TECNILAB, S. A.

TECNILAB, S. A. FUNDADA EN 1973
UNA EMPRESA E. BARRANCO Y ASOC., S. A.
LABORATORIO DE SUELOS Y MATERIALES

REACTIVIDAD ALCALINA
(ASTM C 289)

TRABAJO No. : 4-220 CLIENTE : MWH GLOBAL, INC.
PROYECTO: SITIO DE PRESA PROYECTO ALTO DE CHAGRES LOCALIZACION : RIO CHAGRES
MUESTREADO POR : TECNILAB, S. A. FECHA : JUNIO, 02
PREPARADO POR : TECNILAB, S. A. FECHA : JULIO, 02 LABORATORISTA : LAISA

Calicata	No.	PRUEBA REALIZADA	mM/L	mg/L	TIPO DE MUESTRA
R-4	1	REACTIVIDAD ALCALINA	35.0	1400	ROCA TRITURADA
02-09	1	REACTIVIDAD ALCALINA	47.0	1880	AGREGADO GRUESO
02-10	1	REACTIVIDAD ALCALINA	20.0	800	AGREGADO FINO ARENA

OBSERVACIONES:

PRESENTADO POR:

XIII. ENSAYO DE DESGASTE LOS ANGELES

TECNILAB, S. A. FUNDADA EN 1973
UNA EMPRESA E. BARRANCO Y ASOC., S. A.
LABORATORIO DE SUELOS Y MATERIALES

ENSAYO DE DESGASTE LOS ANGELES (ASTM C 131)

TRABAJO No. : 4-220 CLIENTE MWH GLOBAL, INC. Hoyo N° 02-09
PROYECTO: SITIO DE PRESA DEL PROYECTO ALTO CHAGRES LOCALIZACION RIO CHAGRES
MUESTREADO POR TECNILAB FECHA 18-Jun-02 PROFUNDIDAD 0.00 A 0.90
PREPARADO POR TECNILAB FECHA 19-Jun-02 LABORATORISTA C.CORDOBA
MUESTRA No. 1

No. DE ESFERAS: 12 DIAMETRO: 1 27/32" PESO 44.5 g TIEMPO DE PRUEBA: 15 min

TAMAÑO DE TAMICES		PESO ORIGINAL DE LA MUESTRA (g)
PASA	RETENIDO EN	
1 1/2"	1"	1250.00
1"	3/4"	1250.00
3/4"	1/2"	1250.00
1/2"	3/8"	1250.00
	TOTAL	**5000.00**

a) Peso Original de La Muestra: ..... 5000.00 g

b) Peso del Material Retenido en el Tamiz No. 12: ..... 4060 g

c) Pérdida de Peso (a-b): ..... 940.00 g

d) Porcentaje de Desgaste: ..... 18.8 %

Revoluciones por Minuto: 33 Gradación de Muestra para Pruebas: "A"

Observaciones: _____

Laboratorista: _____ Verificado Por: _____

TECNILAB, S. A. FUNDADA EN 1973
UNA EMPRESA E. BARRANCO Y ASOC., S. A.
LABORATORIO DE SUELOS Y MATERIALES

ENSAYO DE DESGASTE LOS ANGELES (ASTM C 131)

TRABAJO No. : 4-220 CLIENTE MWH GLOBAL, INC. Hoyo N° 02-10
PROYECTO: SITIO DE PRESA DEL PROYECTO ALTO CHAGRES LOCALIZACION RIO CHAGRES
MUESTREADO POR TECNILAB FECHA 18-Jun-02 PROFUNDIDAD 0.00 A 0.60
PREPARADO POR TECNILAB FECHA 19-Jun-02 LABORATORISTA C.CORDOBA
MUESTRA No. 1

No. DE ESFERAS: 12 DIAMETRO: 1 27/32" PESO 44.5 g TIEMPO DE PRUEBA: 15 min

TAMAÑO DE TAMICES		PESO ORIGINAL DE LA MUESTRA
PASA	RETENIDO EN	(g)
1 1/2"	1"	1250.00
1"	3/4"	1250.00
3/4"	1/2"	1250.00
1/2"	3/8"	1250.00
	TOTAL	5000.00

a) Peso Original de La Muestra: ..... 5000.00 g

b) Peso del Material Retenido en el Tamiz No. 12: ..... 3875 g

c) Pérdida de Peso (a-b): ..... 1125.00 g

d) Porcentaje de Desgaste: ..... 22.5 %

Revoluciones por Minuto: 33 Gradación de Muestra para Pruebas: "A"

Observaciones: _____

Laboratorista: _____ Verificado Por: _____

TECNILAB, S. A. FUNDADA EN 1973
UNA EMPRESA E. BARRANCO Y ASOC., S. A.
LABORATORIO DE SUELOS Y MATERIALES

ENSAYO DE DESGASTE LOS ANGELES (ASTM C 131)

TRABAJO No. : 4-220 CLIENTE MWH GLOBAL, INC. Hoyo N° R-4
PROYECTO: SITIO DE PRESA DEL PROYECTO ALTO CHAGRES LOCALIZACION RIO CHAGRES
MUESTREADO POR TECNILAB FECHA Jun-02 PROFUNDIDAD -
PREPARADO POR TECNILAB FECHA Jun-02 LABORATORISTA C.CORDOBA
MUESTRA No. 1

No. DE ESFERAS: 11 DIAMETRO: 1 27/32" PESO 44.5 g TIEMPO DE PRUEBA: 15 min

TAMAÑO DE TAMICES		PESO ORIGINAL DE LA MUESTRA (g)
PASA	RETENIDO EN	
1 1/2"	1"	1250.00
1"	3/4"	1250.00
3/4"	1/2"	1250.00
1/2"	3/8"	1250.00
	TOTAL	**5000.00**

a) Peso Original de La Muestra: ..... 5000.00 g

b) Peso del Material Retenido en el Tamiz No. 12: ..... 4105 g

c) Pérdida de Peso (a-b): ..... 895.00 g

d) Porcentaje de Desgaste: ..... 17.9 %

Revoluciones por Minuto: 33 Gradación de Muestra para Pruebas: "B"

Observaciones: _____

Laboratorista: _____ Verificado Por: _____

XV. POINT LOAD INDEX TEST

TECNILAB, S. A.

TECNILAB, S. A. FUNDADA EN 1973
UNA EMPRESA E. BARRANCO Y ASOC., S. A.
LABORATORIO DE SUELOS Y MATERIALES

POINT LOAD INDEX TEST
ASTM D 5731

TRABAJO : 4-220 CLIENTE : MWH GLOBAL, INC.
PROJECTO : SITIO DE PRESA PROYECTO ALTO CHAGRES
LOCALIZACION : RIO CHAGRES
MUESTREADO POR : TECNILAB, S.A. FECHA : JUNIO,02 LABORATORISTA : J.V./C.C.
PREPARADO POR : TECNILAB, S.A. FECHA : JULIO, 02

POINT LOAD STRENGTH INDEX

HOYO N°	TIPO DE ROCA	ALTITUD m	TIPO PRUEBA	W mm.	D mm.	P kN.	De^2 mm^2.	De mm.	Is MPa.	DESIGNACION (!) ROTURA	TIPO DE ROTURA
R-1,M-1	Andesita	117.60	a	38.00	42.00	4.00	1596.00	39.95	2.506	Alto	Explosiva
R-1, M-2	Andesita	117.60	a	35.00	38.00	16.00	1330.00	36.47	12.030	Muy Alto	
R-2,M-1	Andesita	105.10	a	36.00	37.00	2.00	1332.00	36.50	1.502	Alto	Pasiva
R-2, M-2	Andesita	105.10	a	41.00	42.00	2.80	1722.00	41.50	1.626	Alto	
R-3, M-1	Andesita	111.00	a	32.00	35.00	1.50	1120.00	33.47	1.339	Medio	Pasiva
R-4, M-1	Andesita	92.00	a	40.00	41.00	5.60	1332.00	36.50	4.204	Alto	Explosiva
R-4, M-2	Andesita	92.00	a	40.00	41.00	20.00	1722.00	41.50	11.614	Muy Alto	

REMARKS : (!) Obtained using the Table 1 - Nomogram, source: Point Load Tester Model RM-735 Manual

Type Data
a axial
d diametral
b block
I Irregular lump
D diameter
P Failure Load
Is Point Load Strength Index

Calculation
Obtained the uncorrect point load strength value (Is) as:
P/De^2
Where De^2; the equivalent core diameter, is given by:
$De^2 = D^2$ for diametral test
$De^2 = 4A / 3.1416$ for axial, block and lump test; and
A = WD = minimum cross sectional area for a plane through the platen contact point

REVISADO POR: _____

XVI. FOTOGRAFIAS

PROYECTO: SITIO DE PRESA ALTO CHAGRES
RIO CHAGRES
INVESTIGACIÓN DE SUELOS
TRABAJO N°. 4-220 JUNIO DE 2002

CONDICION EN SITIO DEL MATERIAL R-2

TECNILAB, S. A.

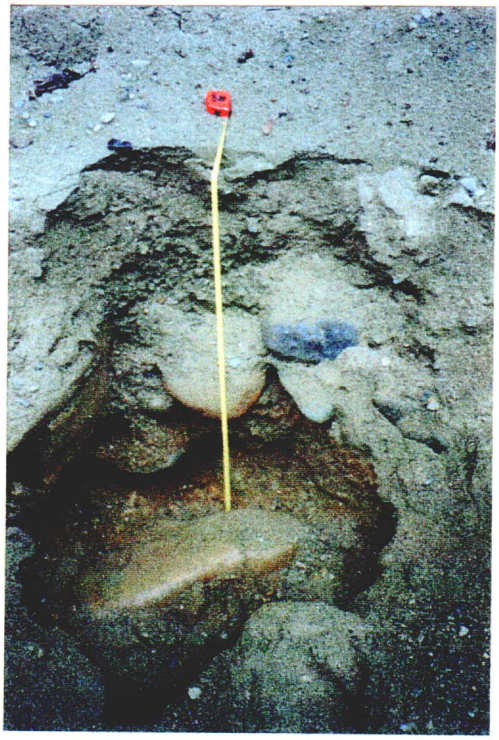
PROYECTO: SITIO DE PRESA ALTO CHAGRES
RIO CHAGRES
INVESTIGACIÓN DE SUELOS
TRABAJO N°. 4-220 JUNIO DE 2002

CONDICION EN SITIO DEL MATERIAL R-1

TECNILAB, S. A.

PROYECTO: SITIO DE PRESA ALTO CHAGRES
RIO CHAGRES
INVESTIGACIÓN DE SUELOS
TRABAJO N°. 4-220 JUNIO DE 2002

CONDICION DEL SITIO 02-09 AL MOMENTO DE EXCAVAR LA CALICATA



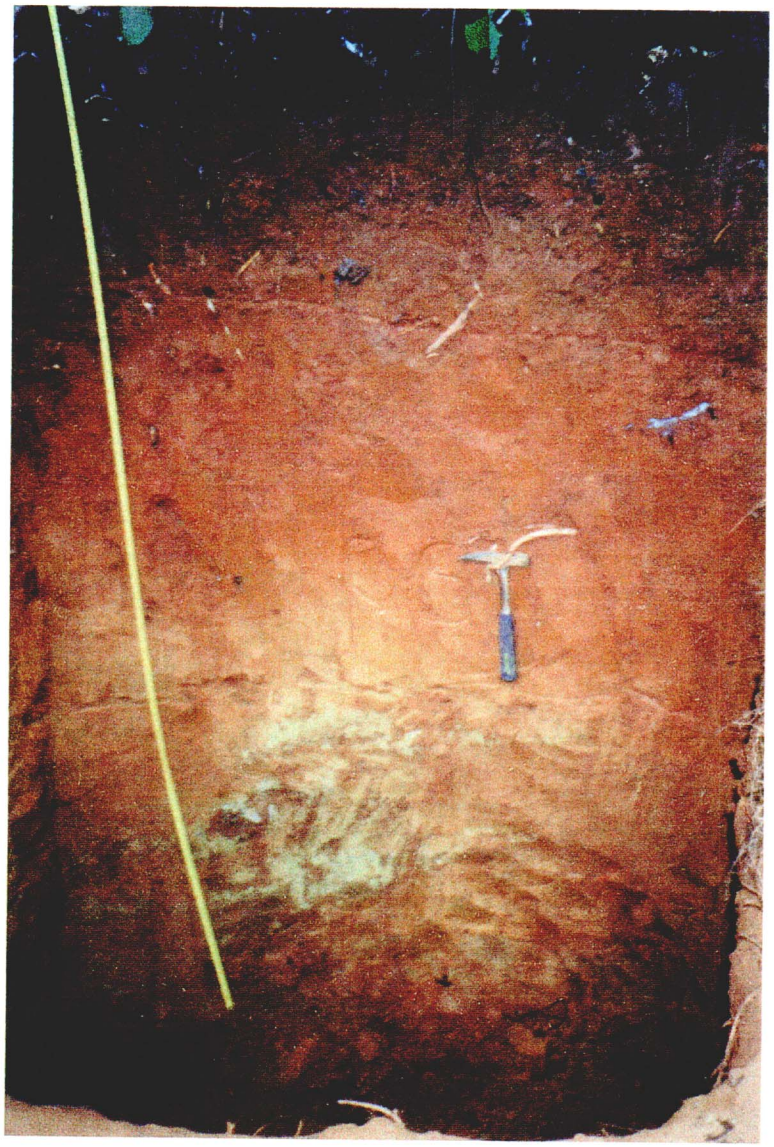
ESTRATIFICACION ENCONTRADA EN LA CALICATA 02-01

PROYECTO: SITIO DE PRESA ALTO CHAGRES
RIO CHAGRES
INVESTIGACIÓN DE SUELOS
TRABAJO N°. 4-220 JUNIO DE 2002

CONDICION DEL SITIO 02-10 AL MOMENTO DE EXCAVAR LA CALICATA

ESTRATIFICACION ENCONTRADA EN LA CALICATA 02-10

PROYECTO: SITIO DE PRESA ALTO CHAGRES
RIO CHAGRES
INVESTIGACIÓN DE SUELOS
TRABAJO N°. 4-220 JUNIO DE 2002



ESTRATIFICACION ENCONTRADA EN LA CALICATA 02-06

TECNILAB, S. A.

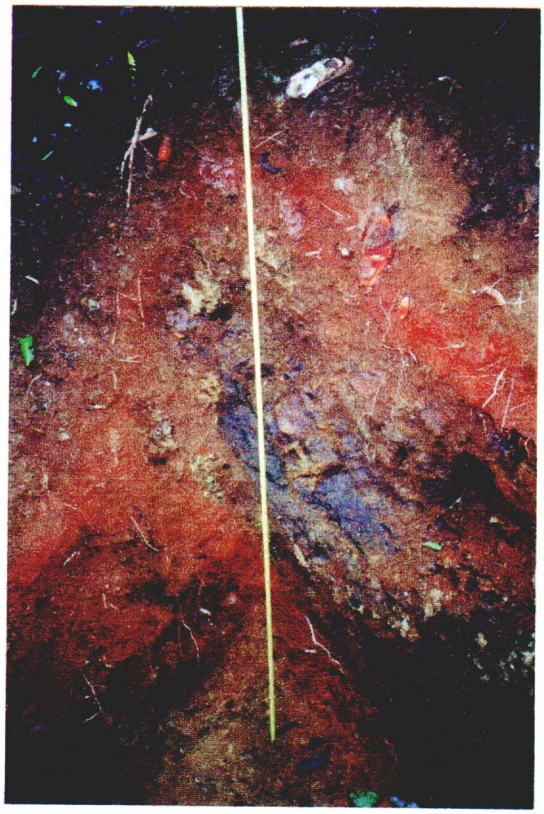
PROYECTO: SITIO DE PRESA ALTO CHAGRES
RIO CHAGRES
INVESTIGACIÓN DE SUELOS
TRABAJO N°. 4-220 JUNIO DE 2002

CONDICION DEL SITIO 02-07 AL MOMENTO DE EXCAVAR LA CALICATA

ESTRATIFICACION ENCONTRADA EN LA CALICATA 02-07

PROYECTO: SITIO DE PRESA ALTO CHAGRES
RIO CHAGRES
INVESTIGACIÓN DE SUELOS
TRABAJO N°. 4-220 JUNIO DE 2002

CONDICION DEL SITIO 02-08 AL MOMENTO DE EXCAVAR LA CALICATA



ESTRATIFICACION ENCONTRADA EN LA CALICATA 02-08

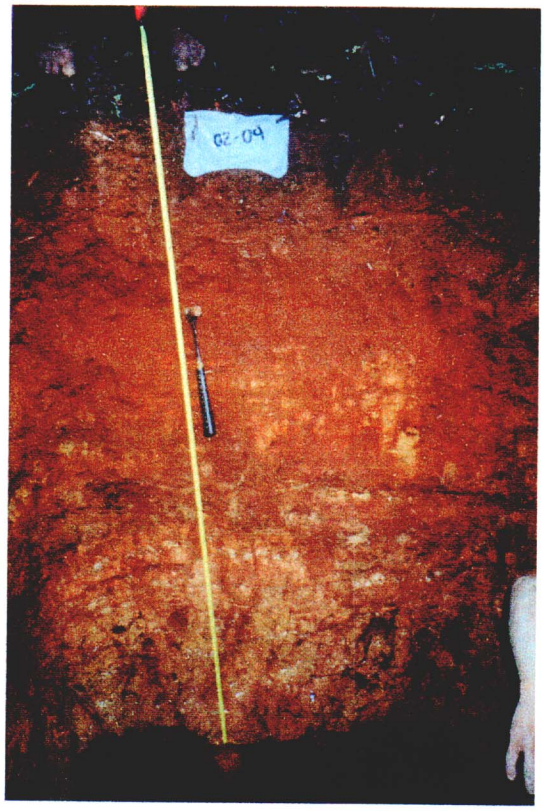
PROYECTO: SITIO DE PRESA ALTO CHAGRES
RIO CHAGRES
INVESTIGACIÓN DE SUELOS
TRABAJO N°. 4-220 JUNIO DE 2002

CONDICION DEL SITIO 02-05 AL MOMENTO DE EXCAVAR LA CALICATA

ESTRATIFICACION ENCONTRADA EN LA CALICATA 02-05

PROYECTO: SITIO DE PRESA ALTO CHAGRES
RIO CHAGRES
INVESTIGACIÓN DE SUELOS
TRABAJO N°. 4-220 JUNIO DE 2002

CONDICION DEL SITIO 02-04 AL MOMENTO DE EXCAVAR LA CALICATA



ESTRATIFICACION ENCONTRADA EN LA CALICATA 02-04

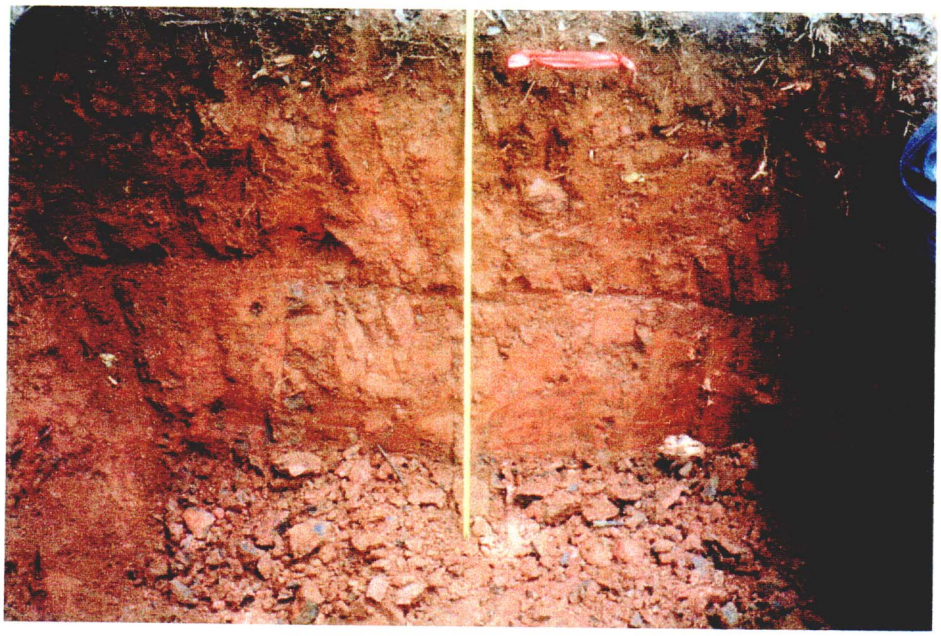
PROYECTO: SITIO DE PRESA ALTO CHAGRES
RIO CHAGRES
INVESTIGACIÓN DE SUELOS
TRABAJO N°. 4-220 JUNIO DE 2002

CONDICION DEL SITIO 02-03 AL MOMENTO DE EXCAVAR LA CALICATA

ESTRATIFICACION ENCONTRADA EN LA CALICATA 02-03

PROYECTO: SITIO DE PRESA ALTO CHAGRES
RIO CHAGRES
INVESTIGACIÓN DE SUELOS
TRABAJO N°. 4-220 JUNIO DE 2002

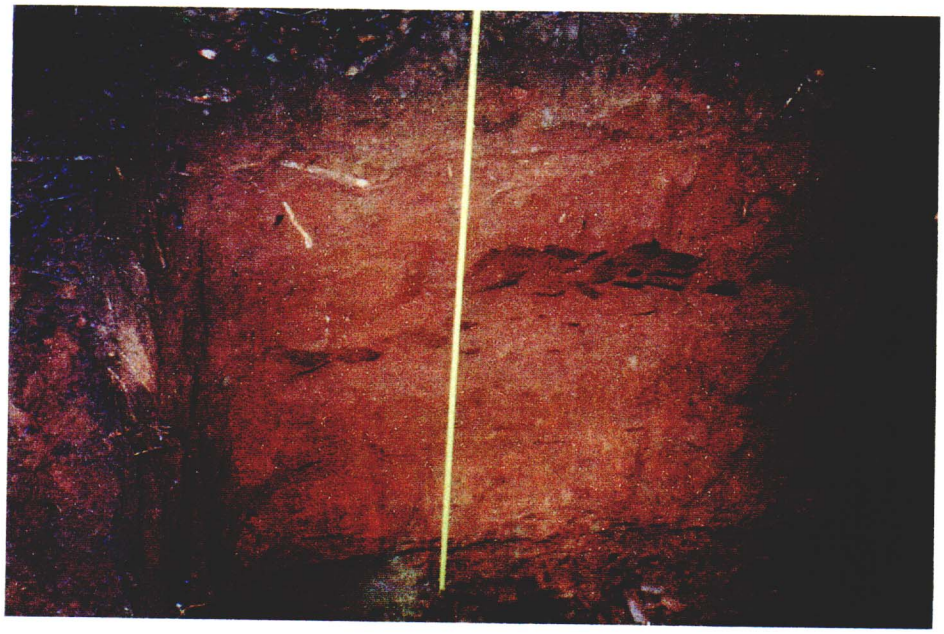
CONDICION DEL SITIO 02-02 AL MOMENTO DE EXCAVAR LA CALICATA



ESTRATIFICACION ENCONTRADA EN LA CALICATA 02-02

PROYECTO: SITIO DE PRESA ALTO CHAGRES
RIO CHAGRES
INVESTIGACIÓN DE SUELOS
TRABAJO N°. 4-220 JUNIO DE 2002

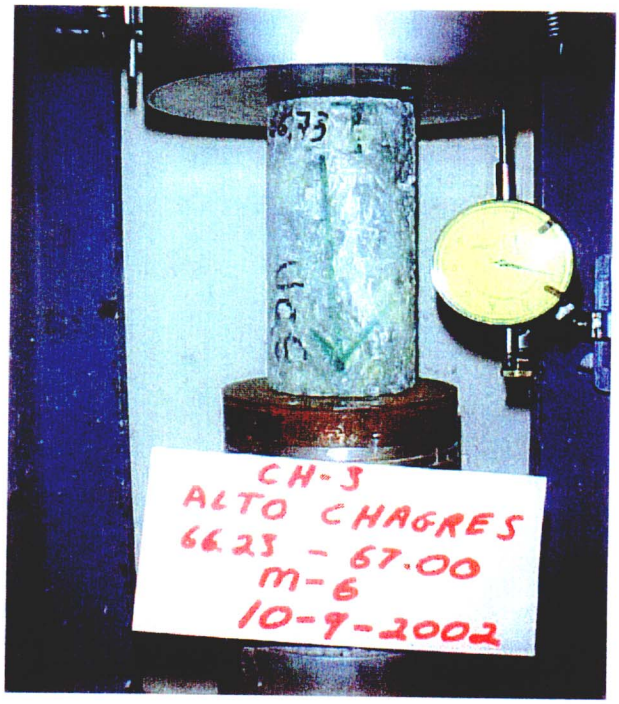
CONDICION DEL SITIO 02-01 AL MOMENTO DE EXCAVAR LA CALICATA



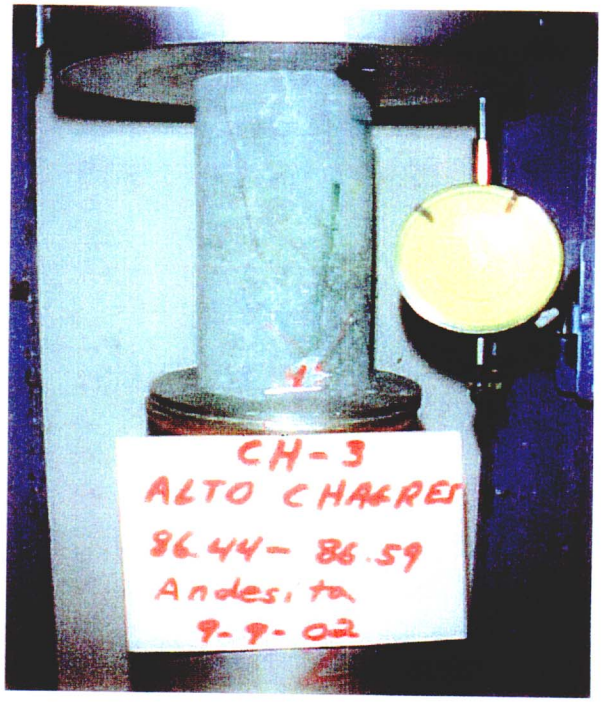
ESTRATIFICACION ENCONTRADA EN LA CALICATA 02-01

Attachment 3: Laboratory Testing Program for Alto Chagres Site Investigation, ACP

CH-1
ALTO CHAGRES
27.03 - 27.30
ANDESITE
#1
10-9-02


CH-3
ALTO CHAGRES
66.23 - 67.00
m-6
10-9-2002

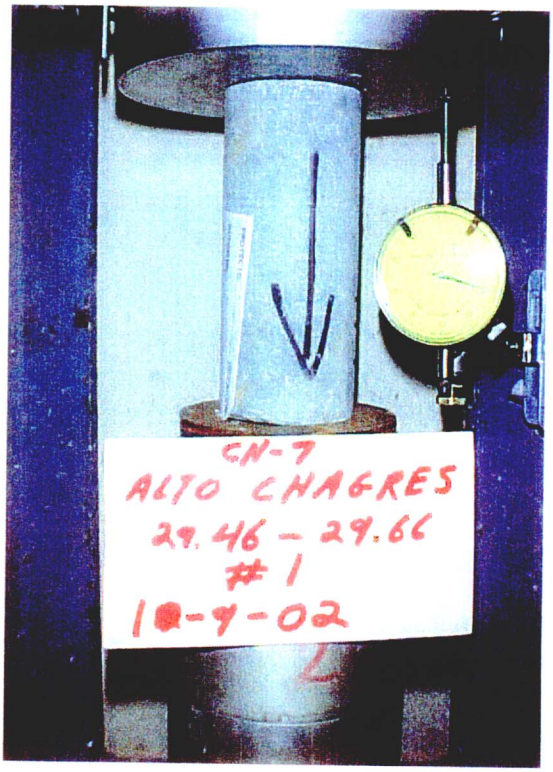
CH-3
ALTOS CHAGRES
77.25 - 77.46
Tectonic Breccia
09-09-02


CH-3
ALTO CHAGRES
86.44 - 86.59
Andesita
9-9-02

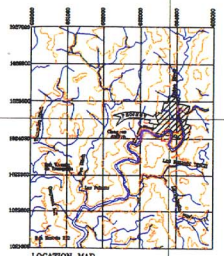
CH-4
ALTO CHAGRES
29.19 - 29.37
TECTONIC BRECCIA
#2
10-9-02

CH-4
ALTO CHAGRES
22.29 - 22.50
TECTONIC BRECCIA
#1
10-9-02

CH-7
ALTO CHAGRES
56.30 - 56.55
ANDESITE
#3
10-9-02


CH-7
ALTO CHAGRES
29.46 - 29.66
#1
10-9-02

APPENDIX E: MAP OF BORING LOCATIONS



LOCATION MAP
SCALE: 1:50,000

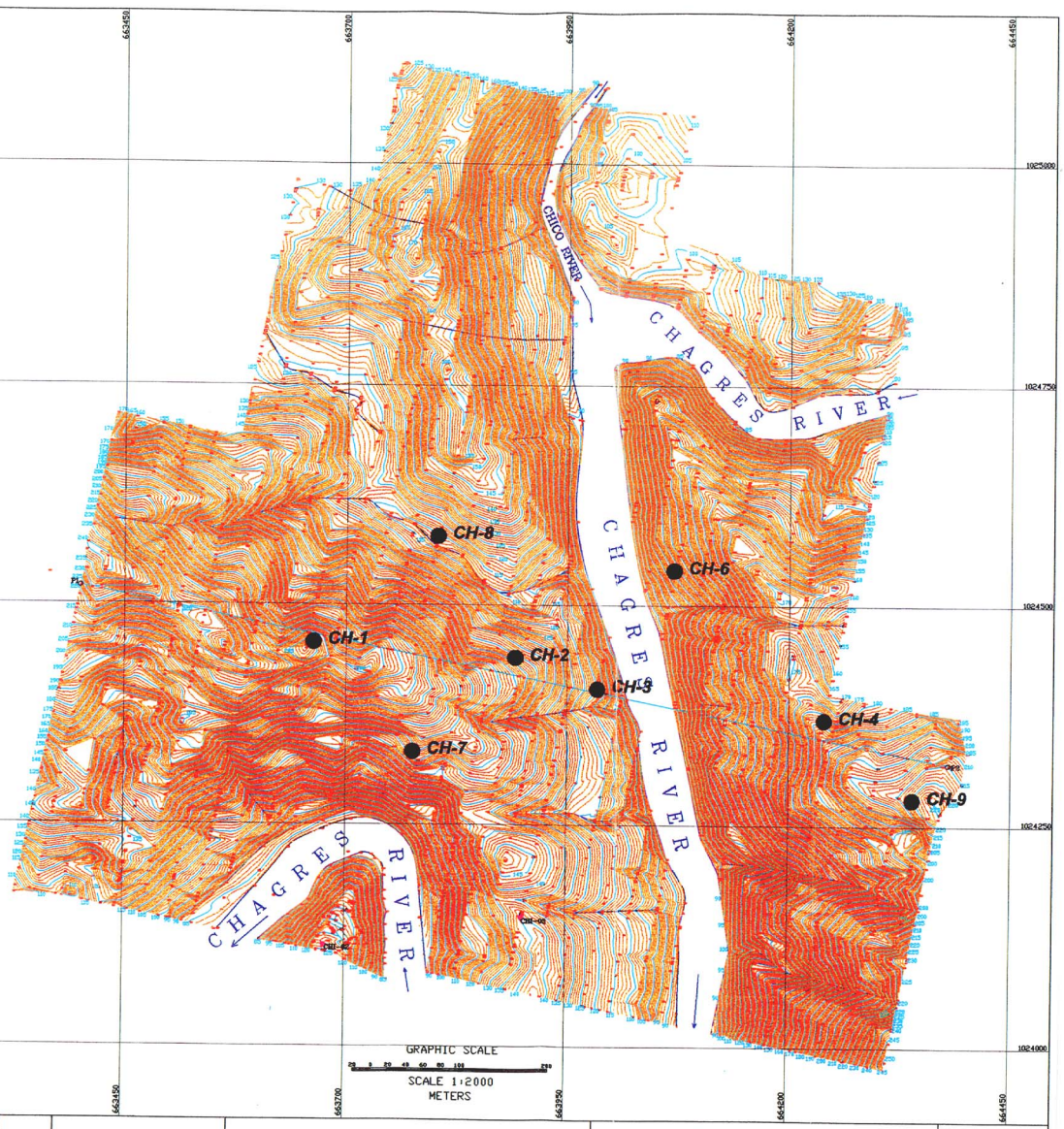
SYMBOLOGY

- MAJOR CONTOUR
- MINOR CONTOUR
- BASE
- RIVERS AND DITCHES
- BASE LINE
- STRUCTURES
- WATER TANK
- SEPTIC TANK

CONTROL POINTS			
POINT	EAST	NORTH	ELEVATION
CHI-02	663676.49	1024112.86	123.25
CHI-03	663898.47	1024145.31	140.23

NOTES

1. HORIZONTAL DATUM NAD27, UTM GRID, SPHEROID CLARKE 1866, ZONE 17
2. VERTICAL DATUM MEAN SEA LEVEL
3. ALL COORDINATES AND ELEVATIONS ARE IN METERS
4. THE INTERVAL OF LEVEL LINES (CONTOURS) IS EVERY 1.00 METERS.
5. THE LINE FROM P1 TO P2 IS THE BASELINE.



REVISION	BY

DESIGNED BY F.J.Z.D.
CHECKED BY I.A.S.A.
DRAWN BY F.J.Z.D.
CHECKED BY P.E.Q.S.

Ingenieria Avanzada, S.A.

PANAMA, REPUBLIC OF PANAMA
PANAMA CANAL AUTHORITY

MAIN DAM (RIO CHICO)
HARZA ENGINEERING COMPANY

DATE 01-19-02
JOB NO 1

SHEET NO
OF 1 SHEETS

AUTORIDAD DEL CANAL DE PANAMÁ

Memorándum

Fecha: 16 de septiembre de 2002

Conteste a: IPIG

Asunto: Reporte de las Pruebas de Laboratorio

Para: Gerente de la División de Proyectos de Capacidad del Canal (IPC)
Por intermedio de: Gerente de la Sección de Ingeniería Geotécnica IPIG)
Gerente de la División de Ingeniería (IPI)

1. Le adjuntamos el informe de las pruebas de laboratorio realizadas en las diferentes muestras de las formaciones geológicas extraídas en las perforaciones del proyecto de investigación de sitio Alto Chagres.

2. En este informe se presentan los resultados de las pruebas de clasificación, compressión no confinada y el índice de resistencia de la roca (point load test.)

3. Para cualquier información adicional favor de contactar al Ing. Gustavo Guerra al teléfono 272-3098.

Gustavo Guerra B.
Ingeniero Civil

Adjunto

c:
IPI

GGB:ckg

Contents

1. Introduction.....2
2. General procedures.....3
2.1 Sample preparation.....3
2.2 Particle size analysis.....3
2.3 Atterberg limits 3
2.4 Specific gravity.....3
2.5 Unconfined Compression Test.....4
2.6 Point load test.....4

3. Appendixes.....
3.1 Appendix A: Index Test
3.2 Appendix B: Unconfined Compression Test
3.3 Appendix C: Point Load Test
3.4 Appendix D: Photos of Materials
3.5 Appendix E: Map of Boring Locations

INTRODUCTION

The purpose of this report is to present the results from tests conducted on samples obtained from the site investigation in Alto Chagres, located at the northeast side of the Canal watershed.

The samples were obtained from 9 holes. The standard penetration tests were made every 1.05 meter. The soils samples taken from holes were covered with plastic and sealed with paraffin, in order to transport them to the laboratory for storage.

In the laboratory all samples were taken out from the bags and dried in the work area. For each sample, we made the following index tests: water content, Atterberg Limits, specific gravity and sieve analysis. All these tests were made on the 53 standard penetration tests, that is 159 tests in order to determine the classification index of the materials.

The two types of strength tests were conducted on rock samples, namely, unconfined compression test, and point load test.

The compression test was performed on intact rock samples having a nominal diameter of 2.36 in. and loading at constant rate until the failure is reached.

All these test have been done according to standards ASTM and performed by the personnel of the Soils and Materials Laboratory of the Geotechnical Branch, Engineering Division.

The results are summarized in tables presented in the appendixes.

2.2 General Procedures

2.1 Sample Preparation

All samples were prepared for index properties requiring for classification soils. The soils as received from the field to air at room temperature until dried thoroughly. We break up the aggregations in the mortar with rubber-covered pestle quartering and selecting portion for different tests.

2.2 Sieving ASTM D422

The soil sample is tested for grain size distribution by passing the sample through number of sieves of different size openings. Mechanical shaker should agitate the sieves, over a period of time. When the sieving operation has been completes, the weight of the soils particles retained on each sieve is determined from and the percentage passing each sieve is calculated. The test results are presented on semi logarithmic scale.

2.3 Atterberg limits ASTM D4318

The sample at its material water content was air dried for 48 hours. The material was then ground in a mortar using a rubber-tipped pestle until a powder was produced that would pass the no. 40 sieve.

We place a sample in the brass cup of the liquid limit device, cut the standard groove, and then count the number of drops of device that are required to close the groove. The liquid limit is that water content of the soil at which the standard groove is closed a distance of ½ in be exactly 25 drops. This is determined by plotting on semilogaritmic graph paper. For determine the plastic limit soil is crumbled by loosing moisture and soil no longer can be rolled into a thread at this point is assumed to have been reached.

2.4 Specific gravity ASTM C-128

The procedure is to put the soil sample (100 gr,) in a pycnometer, which is then filled with water then weight the pycnometer with water and soil and measured the temperature. With these data now known the specific gravity can be calculated by dividing the weight of solid by the weight of an n equal volume of water.

2.5 Unconfined Compresion Test ASTM 2938

Unconfined compression test were performed on the samples on the fields samples (1.86 and 2.5 in. diam) with the ends trimmed provide a length to diameter ratio 2. The specimens were tested under controlled strain conditions; the loading rate was about 50-150 lbs/s. The moisture condition of samples at time of test is as received from the field. To determine the unconfined compressive strength of the specimen this is obtain by dividing the maximum load carried by specimen during the test by cross-sectional area calculated.

2.6 Point load Test ASTM 5731

Point load test is used as an index test for strength classification of rock materials. This method is performed of either core (the diametral and axial test), cut blocks (block test) or irregular lumps (the irregular lump test) by application of concentrated load through of truncated, conical platens. Little or no specimen preparation is required.

The rocks is inserted in the test device and close the platens to make contact along core diameter, record the height of specimens an steadily increase the load such that failures occurs within 10 to 60 s. and record failure load. After the test calculation of point load strength is determined.

APPENDIX A: INDEX TEST

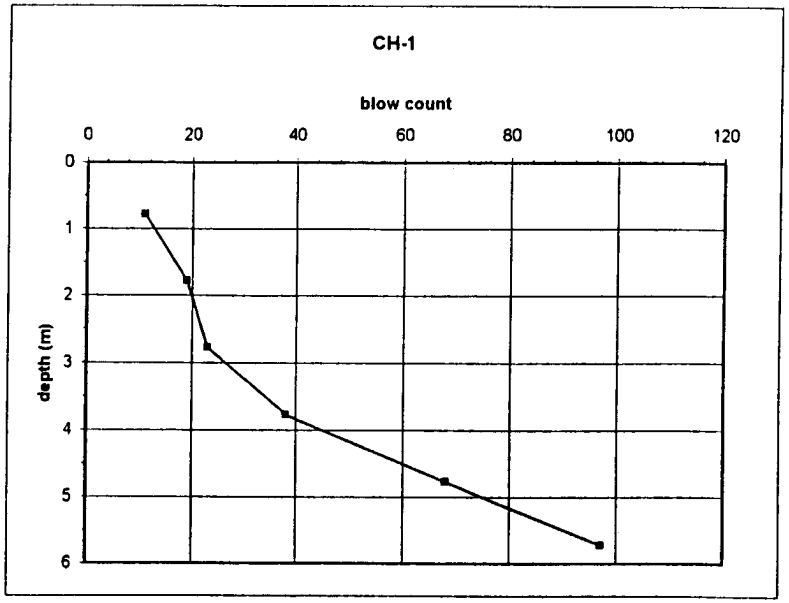
AUTORIDAD DEL CANAL DE PANAMA
DIVISION DE INGENIERIA
SECCION DE GEOTECNIA

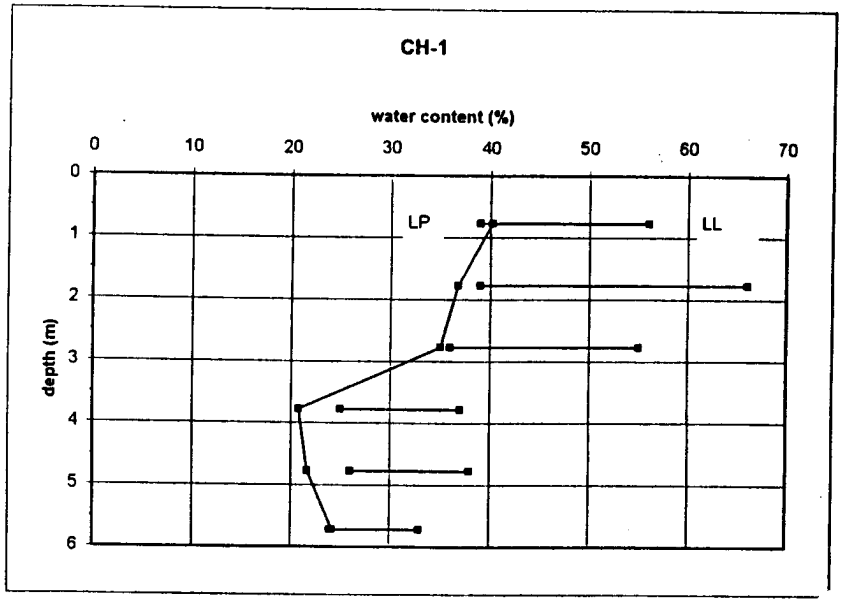
SUMMARY RESULTS OF INDEX TESTS

Project: ALTO CHAGRES
Location: Rio Chagres

Borehole	SPT No.	Depth (m)	Blows (N)	Specific Gravity Gs	Moisture Content (%)	Passing No.200 (%)	Liquid Limit LL	Plastic Limit PL	Plastic Index PI	Classific. U.C.S.	Name	Color
CH-1	1	0.55-1.00	3-5-6		40.19	50.76	56	39	17	MH	Sandy elastic silt	Reddish yellow
CH-1	2	1.55-2.00	7-9-10		36.76	72.20	66	39	27	MH	Elastic silt with sand	Reddish yellow
CH-1	3	2.55-3.00	7-10-13		35.09	78.14	55	36	19	MH	Elastic silt with sand	Light yellowish brown
CH-1	4	3.55-4.00	8-17-21		20.75	68.96	37	25	12	ML	Sandy silt	Light yellowish brown
CH-1	5	4.55-5.00	17-28-40		21.64	61.21	38	26	12	ML	Sandy silt	Very pale brown
CH-1	6	5.55-5.90	28-47-50		24.27	65.78	33	24	9	ML	Sandy silt	Very pale brown

Remarks:(+) means "insufficient material"
Tested By: C. Rodriguez, and X. Rios.
Date: 09/09/2002
File: AltoChagres
Prepared By: Xenia Rios
Checked by: Gustavo Guerra B.





AUTORIDAD DEL CANAL DE PANAMA
DIVISION DE INGENIERIA
SECCION DE GEOTECNIA

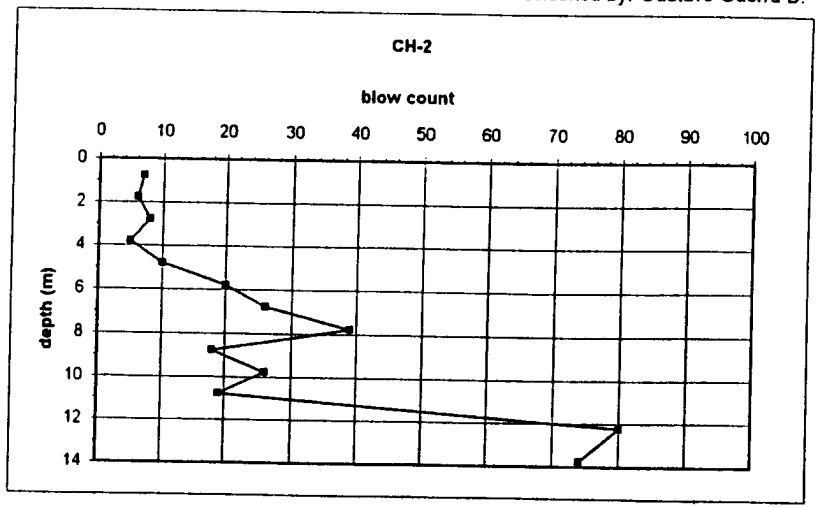
SUMMARY RESULTS OF INDEX TESTS

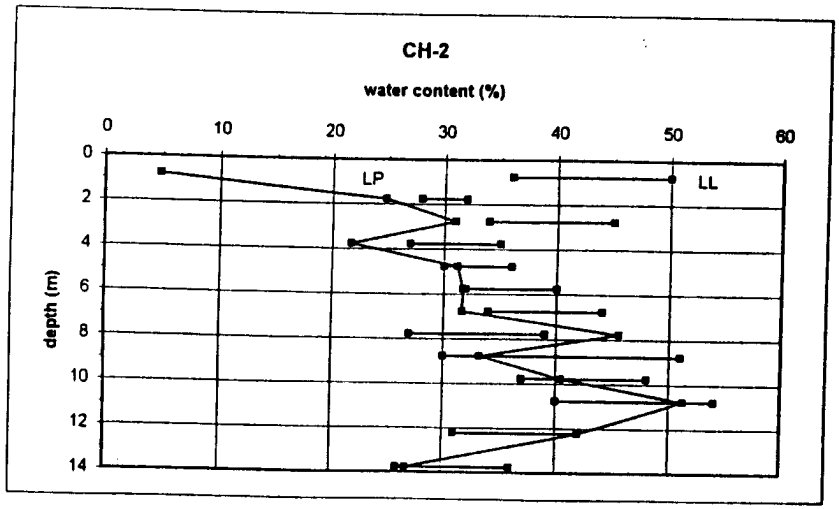
Project: ALTO CHAGRES
Location: Rio Chagres

Borehole	SPT No.	Depth (m)	Blows (N)	Specific Gravity Gs	Moisture Content (%)	Passing No.200 (%)	Liquid Limit LL	Plastic Limit PL	Plastic Index PI	Classific. U.C.S.	Name	Color
CH-2	1	0.55-1.00	2-3-4		4.76	43.36	50	36	14	SM	Silty sand	Light reddish brown
CH-2	2	1.55-2.00	2-3-3		24.77	69.08	32	28	4	ML	Sandy silt	Reddish yellow
CH-2	3	2.55-3.00	2-3-5		31.05	27.54	45	34	11	SM	Silty sand	Light reddish yellow
CH-2	4	3.55-4.00	2-3-2		21.65	73.47	35	27	8	ML	Silt with sand	Reddish yellow
CH-2	5	4.55-5.00	3-4-6		31.23	57.25	36	30	6	ML	Sandy silt	Reddish yellow
CH-2	6	5.55-6.00	8-12		31.75	69.51	40	32	8	ML	Sandy silt	Reddish yellow
CH-2	7	6.55-7.00	14-12		31.68	37.07	44	34	10	SM	Siilty sand	Light reddish yellow
CH-2	8	7.55-8.00	5-8-31		45.5	61.53	39	27	12	ML	Sandy silt	Light yellowish brown
CH-2	9	8.55-9.00	4-7-11		33.28	57.18	51	30	21	MH	Sandy elastic silt	Light brown
CH-2	10	9.55-10.00	5-11-15		40.49	77.42	48	37	11	ML	Silt with sand	Light yellowish brown
CH-2	11	10.55-11.00	6-8-11		51.27	82.70	54	40	14	MH	Elastic silt with sand	Very pale brown
CH-2	12	12.00-12.45	12-31-49		41.95	72.01	42	31	11	ML	Silt with sand	Very pale brown
CH-2	13	13.55-13.98	26-48		26.79	65.91	36	26	10	ML	Sandy silt	Very pale brown

Remarks:(+) means "insufficient material"
Tested By: C. Rodriguez, and X. Rios.
Date: 9/9/02

File: AltoChagres
Prepared By: Xenia Rios
Checked by: Gustavo Guerra B.





AUTORIDAD DEL CANAL DE PANAMA
DIVISION DE INGENIERIA
SECCION DE GEOTECNIA

SUMMARY RESULTS OF INDEX TESTS

Project: ALTO CHAGRES
Location: Rio Chagres

Borehole	SPT No.	Depth (m)	Blows (N)	Specific Gravity Gs	Moisture Content (%)	Passing No.200 (%)	Liquid Limit LL	Plastic Limit PL	Plastic Index PI	Classific. U.C.S.	Name	Color
CH-3	1	0.55-1.00	5-10-12		32.77	51.68	60	35	25	MH	Sandy elastic silt	Reddish brown
CH-3	2	1.55-2.00	7-14-21		32.16	52.49	61	38	23	MH	Sandy elastic silt	Reddish brown
CH-3	3	2.55-3.00	8-8-9		32.12	46.30	50	35	15	SM	Silty sand	Brown
CH-3	4	3.55-4.00	6-50		39.98	33.06	53	36	17	SM	Silty sand	Brown
CH-3	5	4.55-5.00	3-5-7		44.79	58.06	49	35	14	ML	Sandy silt	Brownish yellow
CH-3	6	5.55-6.00	3-4-4		41.18	62.74	44	32	12	ML	Sandy silt	Light yellowish brown
CH-3	7	6.55-7.00	3-7-50		28.91	31.98	32	24	8	SM	Silty sand with gravel	Light yellowish brown
CH-3	8	8.55-8.97	18-32-50		23.32	38.12	26	22	4	SM	Silty sand	Light yellowish brown

Remarks:(+) means "insufficient material"
Tested By: C. Rodriguez, and X. Rios.
Date: 09/09/2002
File: AltoChagres
Prepared By: Xenia Rios
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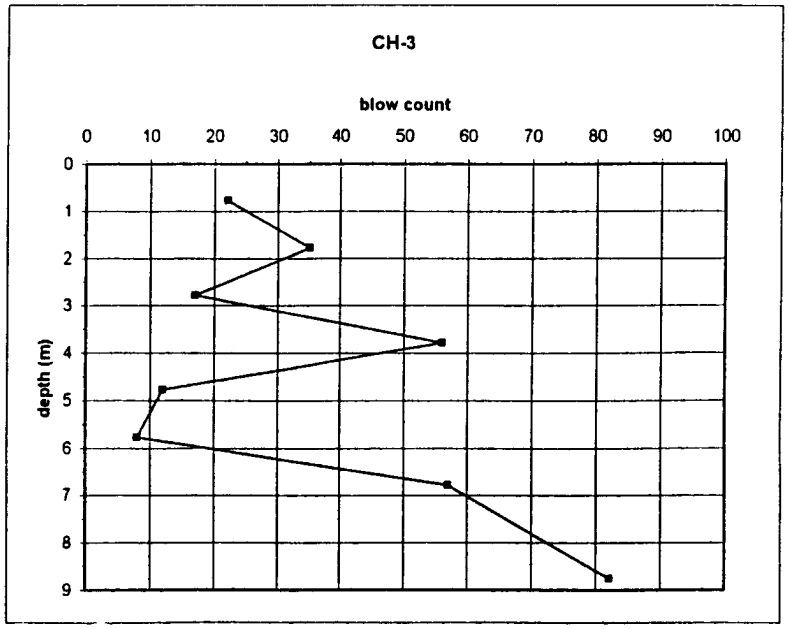
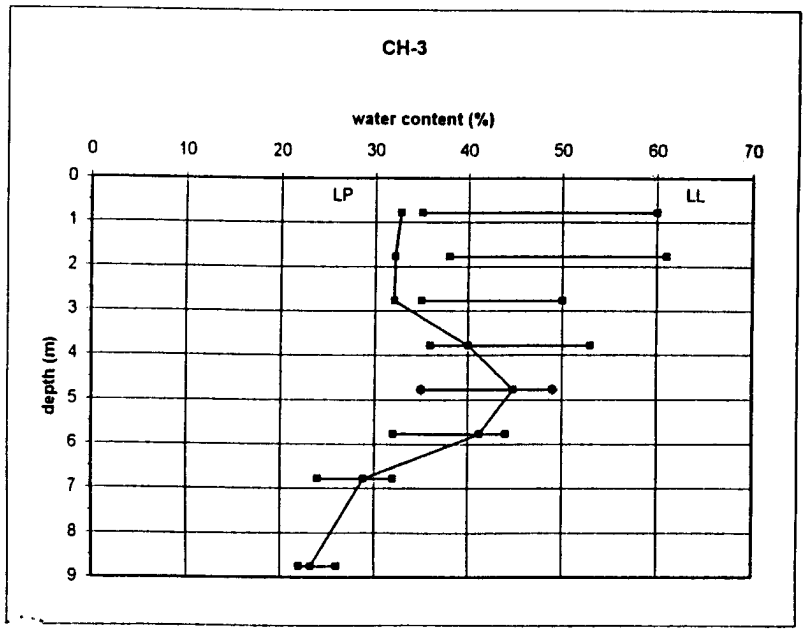




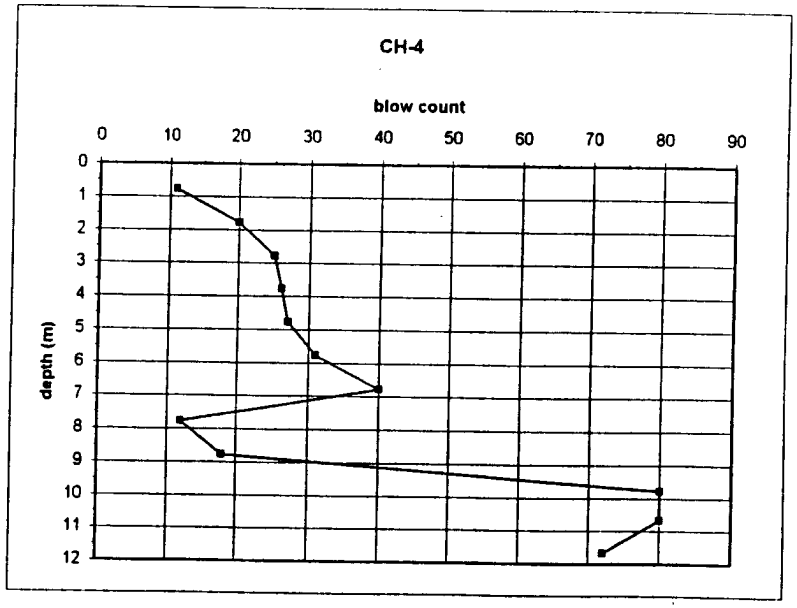
AUTORIDAD DEL CANAL DE PANAMA
DIVISION DE INGENIERIA
SECCION DE GEOTECNIA

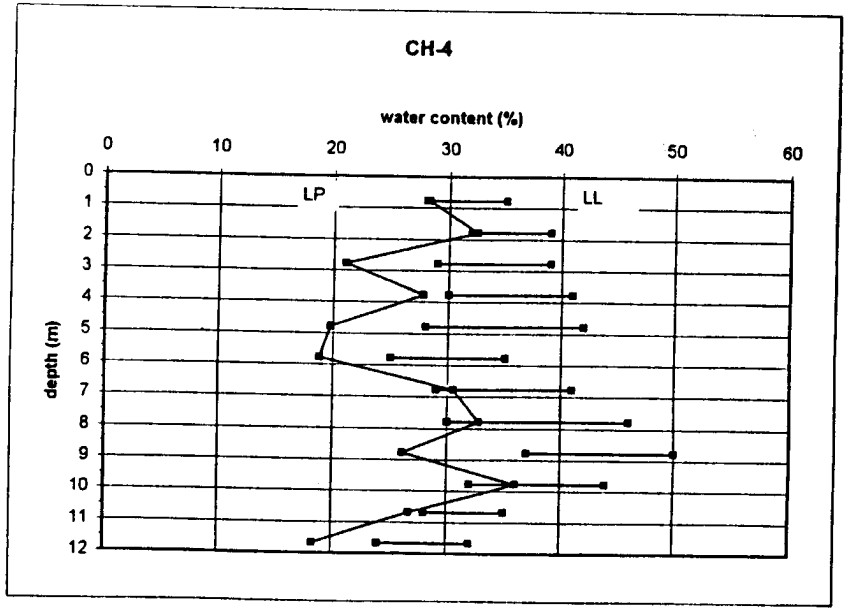
SUMMARY RESULTS OF INDEX TESTS

Project: ALTO CHAGRES
Location: Rio Chagres

Borehole	SPT No.	Depth (m)	Blows (N)	Specific Gravity Gs	Moisture Content (%)	Passing No.200 (%)	Liquid Limit LL	Plastic Limit PL	Plastic Index PI	Classific. U.C.S.	Name	Color
CH-4	1	0.55-1.00	4-5-6		28.26	54.72	35	28	7	ML	Sandy silt	Reddish brown
CH-4	2	1.55-2.00	5-8-12		32.50	34.62	39	32	7	SM	Silty sand	Light brown
CH-4	3	2.55-3.00	9-12-13		21.02	41.50	39	29	10	SM	Silty sand	Yellowish brown
CH-4	4	3.55-4.00	7-11-15		27.80	43.97	41	30	11	SM	Silty sand	Light brown
CH-4	5	4.55-5.00	8-10-17		19.74	53.17	42	28	14	ML	Sandy silt	Light brown
CH-4	6	5.55-6.00	8-14-17		18.82	42.43	35	25	10	SM	Silty sand	Light brown
CH-4	7	6.55-7.00	18-20-20		30.49	39.69	41	29	12	SM	Silty sand	Brown
CH-4	8	7.55-8.00	5-6-6		32.74	63.36	46	30	16	ML	Sandy silt	Brown
CH-4	9	8.55-9.00	6-8-10		26.11	74.28	50	37	13	MH	Elastic silt with sand	Brown
CH-4	10	9.55-10.00	18-30-50		36.00	78.40	44	32	12	ML	Silt with sand	Light brown
CH-4	11	10.55-10.80	30-50		26.69	70.47	35	28	7	ML	Silt with sand	Light yellowish brown
CH-4	12	11.55-11.81	22-50		18.31	30.26	32	24	8	SM	Silty sand	Light yellowish brown

Remarks:(+) means "insufficient material"
Tested By: C. Rodriguez, and X. Rios.
Date: 09/09/2002
File: AltoChagres
Prepared By: Xenia Rios
Checked by: Gustavo Guerra B.





AUTORIDAD DEL CANAL DE PANAMA
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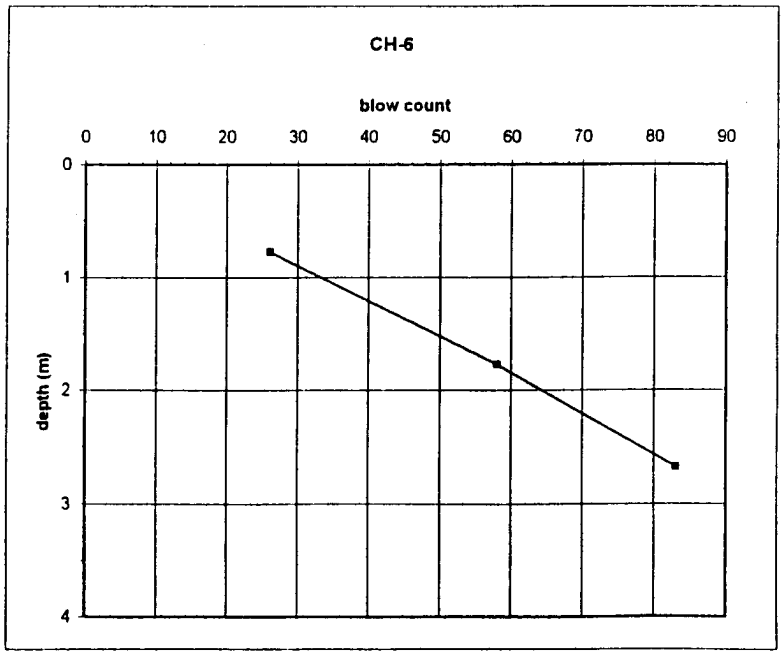
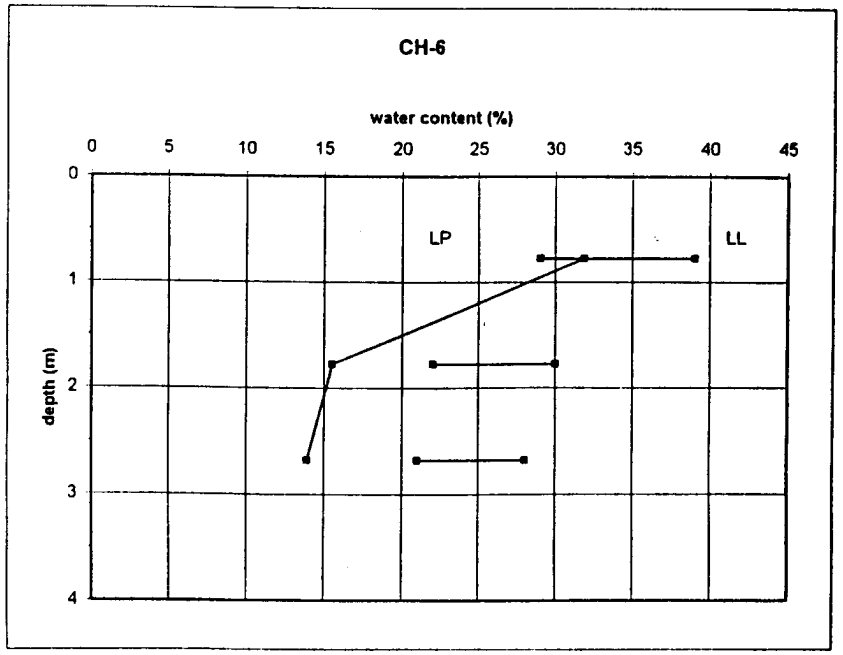
SUMMARY RESULTS OF INDEX TESTS

Project: ALTO CHAGRES
Location: Rio Chagres

Borehole	SPT No.	Depth (m)	Blows (N)	Specific Gravity Gs	Moisture Content (%)	Passing No.200 (%)	Liquid Limit LL	Plastic Limit PL	Plastic Index PI	Classific. U.C.S.	Name	Color
CH-6	1	0.55-1.00	5-10-16		31.84	69.09	39	29	10	ML	Sandy silt	Very pale brown
CH-6	2	1.55-2.00	14-22-36		15.55	51.68	30	22	8	CL	Sandy lean clay	Very pale brown
CH-6	3	2.55-2.81	33-50		13.93	55.37	28	21	7	CL-ML	Sandy silty clay	Light yellowish brown

Remarks:(+) means "insufficient material"
Tested By: C. Rodriguez, and X. Rios.
Date: 09/09/2002
File: AltoChagres
Prepared By: Xenia Rios
Checked by: Gustavo Guerra B.





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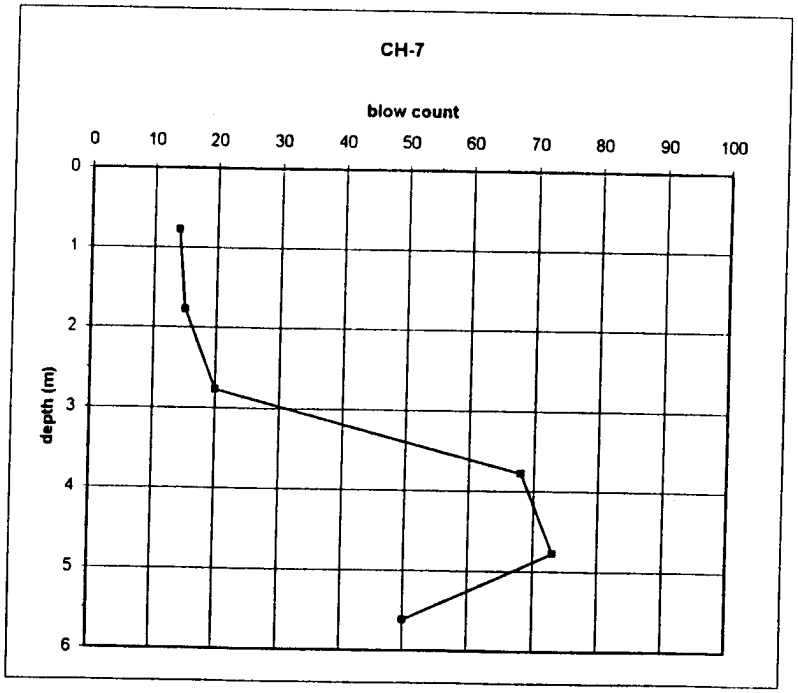
SECCION DE GEOTECNIA

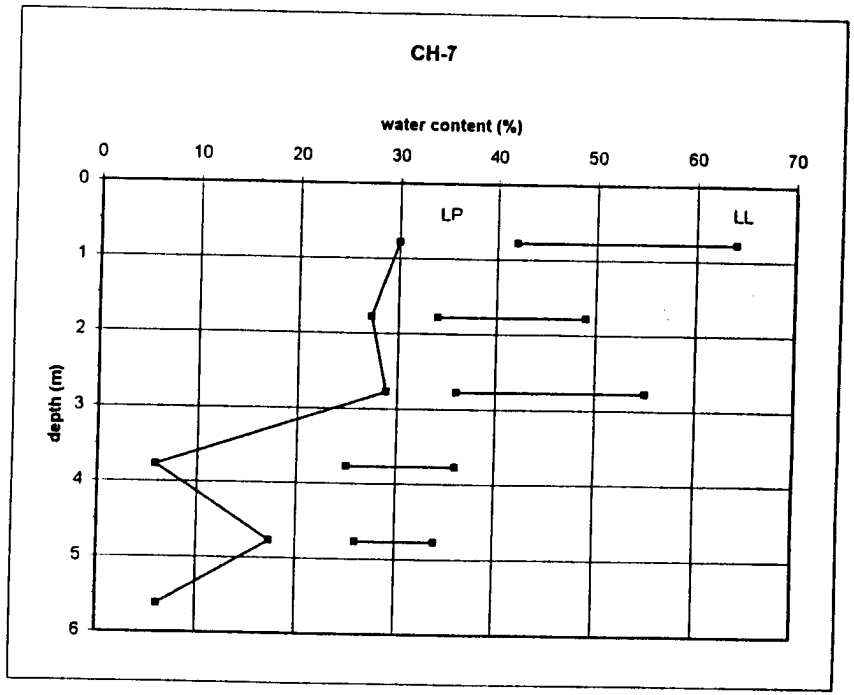
SUMMARY RESULTS OF INDEX TESTS

Project: ALTO CHAGRES
Location: Rio Chagres

Borehole	SPT No.	Depth (m)	Blows (N)	Specific Gravity Gs	Moisture Content (%)	Passing No.200 (%)	Liquid Limit LL	Plastic Limit PL	Plastic Index PI	Classific. U.C.S.	Name	Color
CH-7	1	0.55-1.00	7-6-8		30.01	87.08	64	42	22	MH	Elastic silt	Reddish yellow
CH-7	2	1.55-2.00	6-7-8		27.25	61.27	49	34	15	ML	Sandy silt	Reddish yellow
CH-7	3	2.55-3.00	5-9-11		28.83	48.70	55	36	19	SM	Silty sand	Brownish yellow
CH-7	4	3.55-4.00	25-34-34		5.85	58.95	36	25	11	ML	Sandy silt	Light yellowish brown
CH-7	5	4.55-5.00	17-23-50		17.40	49.43	34	26	8	SM	Silty sand	Light yellowish brown
CH-7	6	5.55-5.69	50		6.11	29.59	+	+	+			

Remarks:(+) means "insufficient material"
Tested By: C. Rodriguez, and X. Rios.
Date: 09/09/2002
File: AltoChagres
Prepared By: Xenia Rios
Checked by: Gustavo Guerra B.





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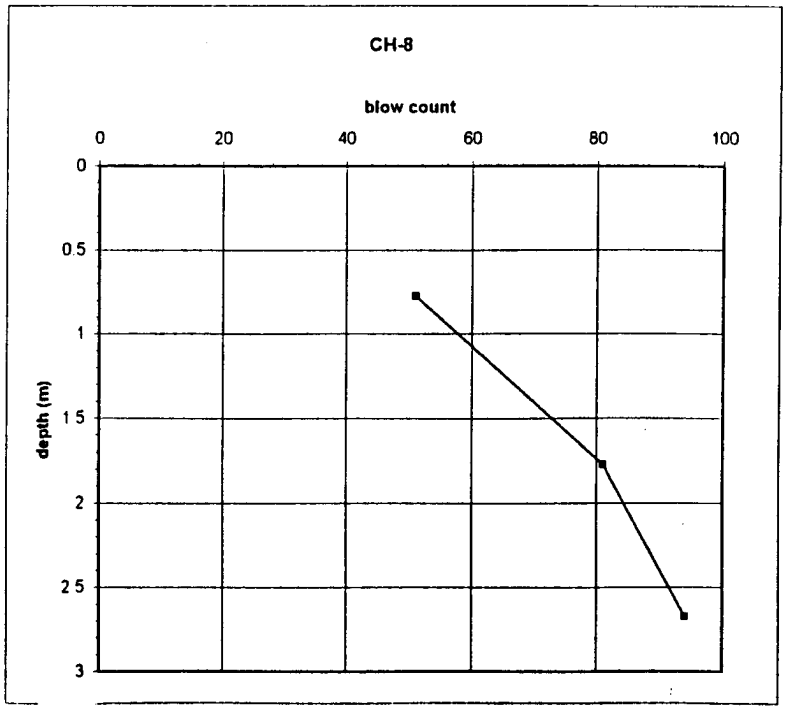
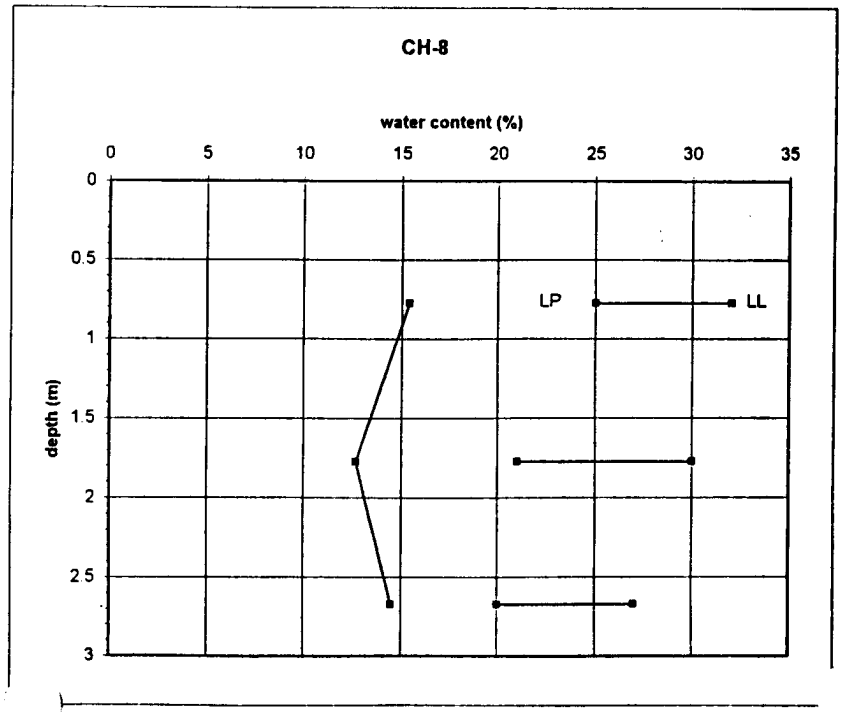
SUMMARY RESULTS OF INDEX TESTS

Project: ALTO CHAGRES
Location: Rio Chagres

Borehole	SPT No.	Depth (m)	Blows (N)	Specific Gravity Gs	Moisture Content (%)	Passing No.200 (%)	Liquid Limit LL	Plastic Limit PL	Plastic Index PI	Classific. U.C.S.	Name	Color
CH-8	1	0.55-1.00	12-20-31		15.39	49.40	32	25	7	SM	Silty sand	Very pale brown
CH-8	2	1.55-1.96	31-31-50		12.68	31.84	30	21	9	SC	Clayey sand	Light yellowish brown
CH-8	3	2.55-2.80	44-50		14.50	36.83	27	20	7	SC-SM	Silty, clayey sand	Light yellowish brown

Remarks:(+) means "insufficient material"
Tested By: C. Rodriguez, and X. Rios.
Date: 09/09/2002
File: AltoChagres
Prepared By: Xenia Rios
Checked by: Gustavo Guerra B.





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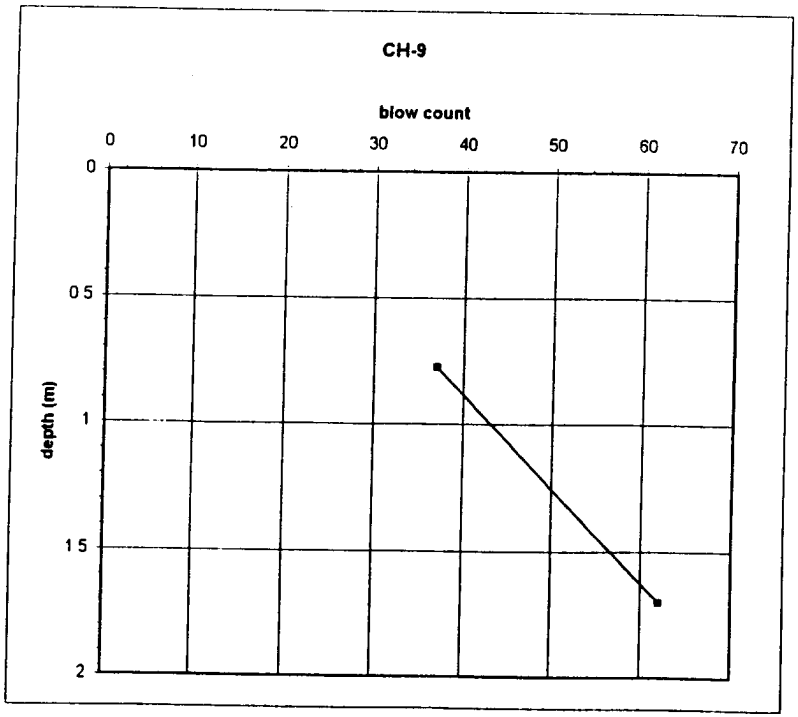
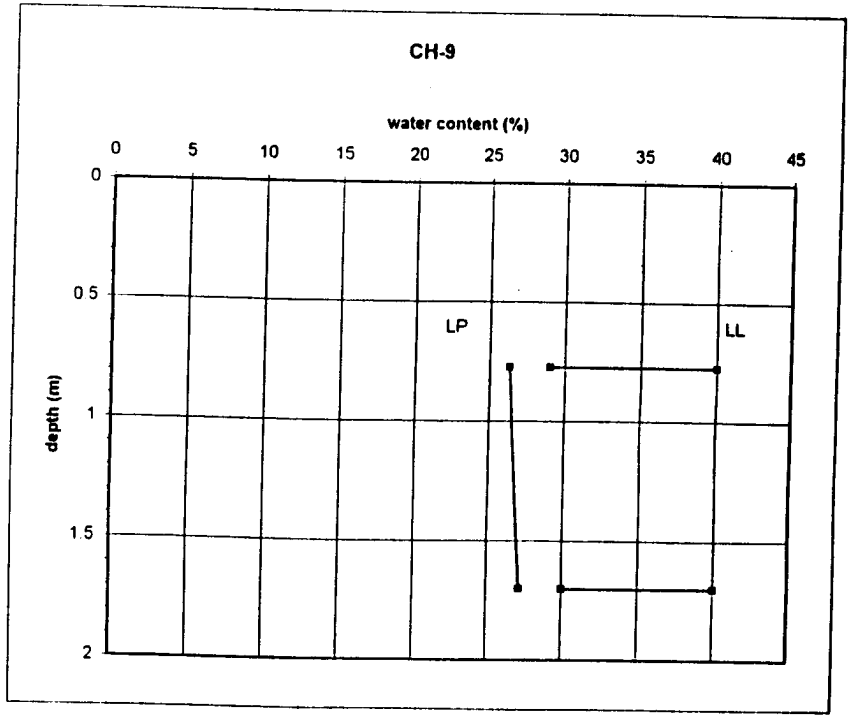
SUMMARY RESULTS OF INDEX TESTS

Project: ALTO CHAGRES
Location: Rio Chagres

Borehole	SPT No.	Depth (m)	Blows (N)	Specific Gravity Gs	Moisture Content (%)	Passing No.200 (%)	Liquid Limit LL	Plastic Limit PL	Plastic Index PI	Classific. U.C.S.	Name	Color
CH-9	1	0.55-1.00	6-12-25		26.34	56.43	40	29	11	ML	Sandy silt	Reddish yellow
CH-9	2	1.55-1.85	12-50		27.14	67.91	40	30	10	ML	Sandy silt	Light yellowish brown

Remarks:(+) means "insufficient material"
Tested By: C. Rodriguez, and X. Rios.
Date: 09/09/2002
File: AltoChagres
Prepared By: Xenia Rios
Checked by: Gustavo Guerra B.





APPENDIX B: UNCONFINED COMPRESSION TEST

AUTORIDAD DEL CANAL DE PANAMA
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SUMMARY RESULTS OF UNCONFINED COMPRESSIVE STRENGTH TESTS ON INTACT ROCK
Project: ALTO CHAGRES
CH

	Boring	Depth (m)	Sample No.	Unit weight Kg/m3	Elastic Modulus E (Mpa)	Unconf. Comp. Gc (Mpa)	Specific gravity	Water %	Type of rock	Formation
1	CH-1	27.03-27.30	m-4	2785		36	2.7	0.8	Andesite	Tb
2	CH-2	26.87-27.7	m-1	2558		10	2.6	3.17	Andesite	Tb
3	CH-3	91.35-91.48	m-9	2799		2	2.6	2.63	Andesite	Tb
4	CH-3	66.23-67.00	m-6	2549		3	2.6	2.25	Tectonic Breccia	Tb
5	CH-3	77.25-77.46	m-7	2661		8	2.6	2.52	Tectonic Breccia	Tb
6	CH-3	86.44-86.37	m-8	2658		6	2.6	4.08	Andesite	Tb
7	CH-4	29.17-29.37	m-6	2367		2	2.3	5.2	Tectonic Breccia	Tb
8	CH-7	29.46-29.66	m-1	2646		53	2.7	1.22	Andesite	Tb
9	CH-7	56.30-56.55	m-3	2700		82	2.7	0.97	Andesite	Tb

Remarks: rock color : Andesite: greenish gray
Tectonic Breccia: grayish green

Tested and prepared By: R. Lam, X. Rios and G. Guerra 09/15/2002

AUTORIDAD DEL CANAL DE PANAMA
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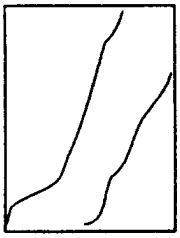
UNCONFINED COMPRESSIVE STRENGTH OF INTACT ROCK CORE SPECIMENS ASTM 2938

Project:	Alto del Chagres	Date:	09/11/2002
Location:	Chagres	No. Sample:	4
Boring:	CH-1	Testing time:	2.15 min
Depth:	27.03-27.30	Tested By:	R. Lam
Description:	Andesite		G. Guerra
	greenish gray		

TEST ESPECIMEN DATA

Avg. Diameter Do(cm):	6.3	Moisture condition:	Air
Avg. Length Lo(cm):	14.00	Porcentage of absorption(%):	
Weight(grs):	1215.5	Water content Wo%:	0.80
Cross-sect. Area(cm2):	4.8	Specific gravity:	2.7
Unit weight(kg/m3):	2785	Type of failure(shape):	shear
Time of failure(lb/seg):	164	Mode:	weak
Lo / Do ratio:	2.22	Angle of failure:	
Factor correction:	1.0121	Deformation rate:	0.60
Elastic modulus E(MPa):		Uniaxial compressive strenght(psi):	5272
Classification Strength:	low	(Kgf/cm2):	371
		(MPa):	36

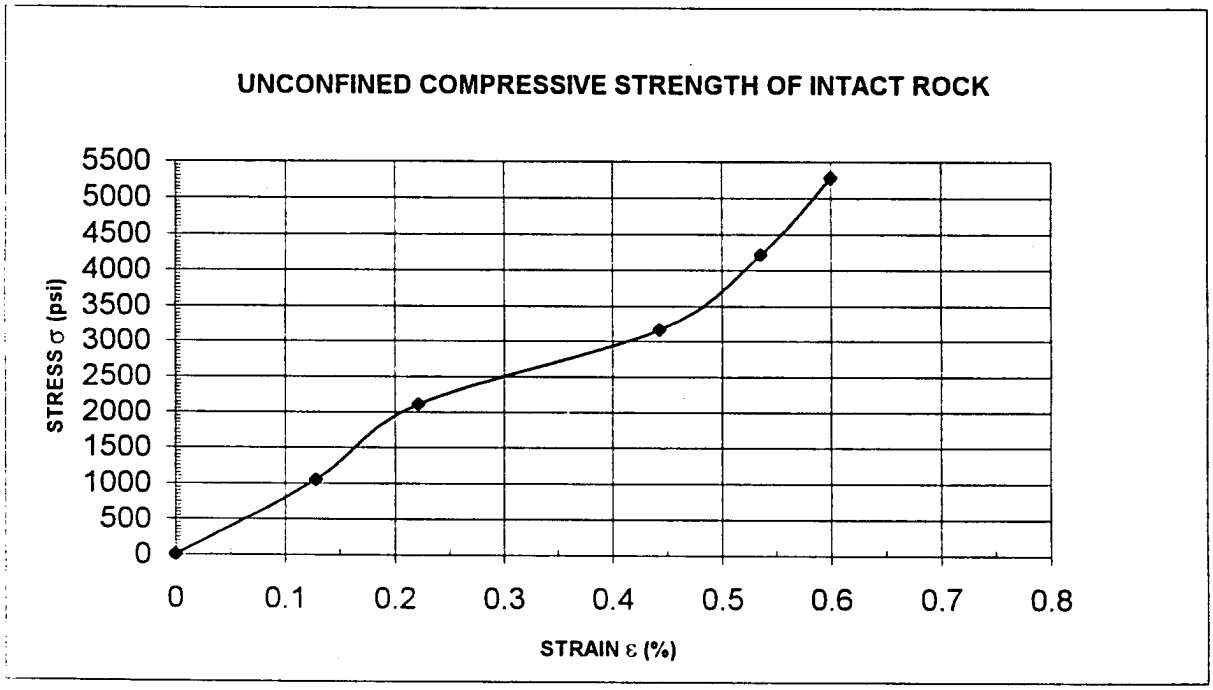
Type of Failure



AXIAL LOADING DATA

Time (min.seg)	Deformation gauge (x10-3)	LOAD GAUGE (lb.)	Cross-sectional area (in.2)	Vertical strain e%	STRESS (psi)
0	0	0	0	0	0
	18	5000	4.8	0.13	1054
	31	10000	4.8	0.22	2109
	62	15000	4.8	0.44	3163
	75	20000	4.8	0.54	4217
	84	25000	4.8	0.60	5272

Tested, prepared and checked by: R. Lam and G. Guerra
File: Unconfchagres



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UNCONFINED COMPRESSIVE STRENGTH OF INTACT ROCK CORE SPECIMENS ASTM 2938

Project: Alto del Chagres
Location: Chagres
Boring: CH-2
Depth: 26.87-27.07 m
Description: Andesite
greenish gray

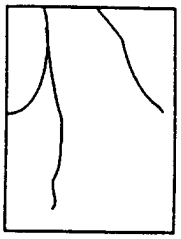
Date: 09/11/2002
No. Sample: 1
Testing time: 2.32 min
Tested By: R. Lam
G. Guerra

TEST ESPECIMEN DATA

Avg. Diameter Do(cm):	6.3
Avg. Length Lo(cm):	13.95
Weight(grs):	1112.5
Cross-sect. Area(cm2):	4.8
Unit weight(kg/m3):	2558
Time of failure(lb/seg):	52
Lo / Do ratio:	2.21
Factor correction:	1.0117
Elastic modulus E(MPa):	
Classification Strength:	very low

Moisture condition:	Air
Porcentage of absorption(%):	
Water content Wo%:	3.17
Specific gravity:	2.6
Type of failure(shape):	shear
Mode:	weak
Angle of failure:	
Deformation rate:	0.32
Uniaxial compressive strenght(psi):	1475
(Kgf/cm2):	104
(MPa):	10

Type of Failure

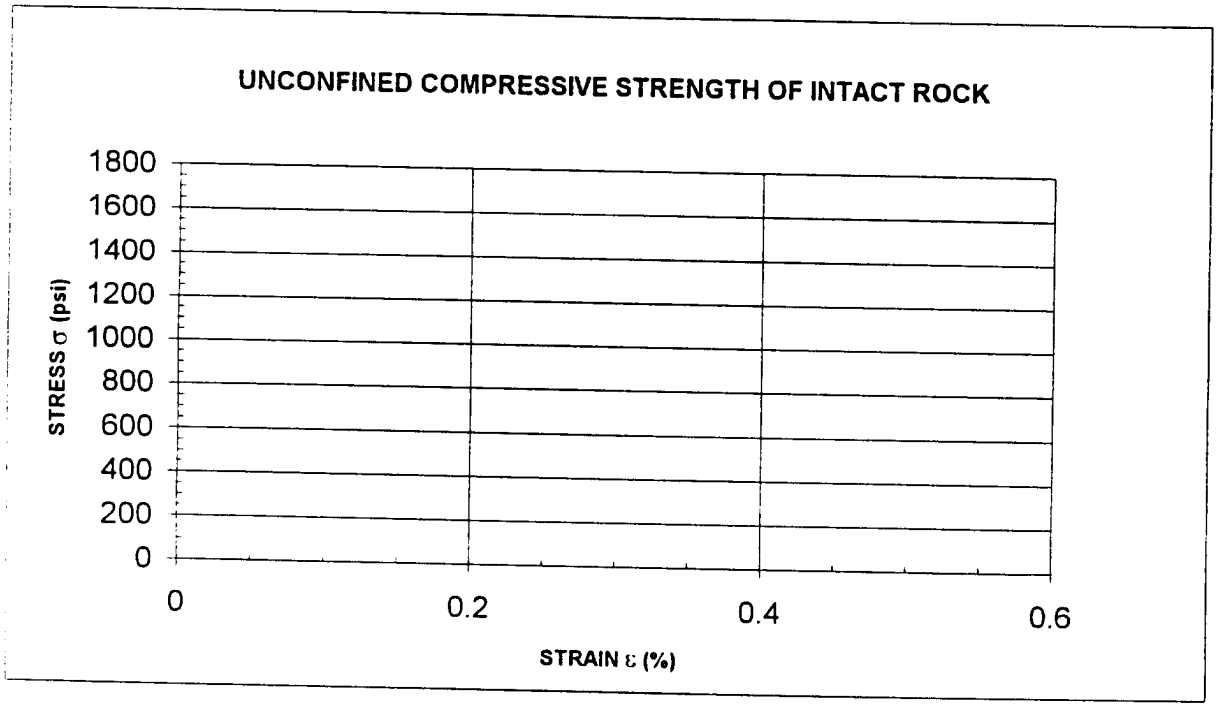


AXIAL LOADING DATA

Time (min.seg)	Deformation gauge (x10-3)	LOAD GAUGE (lb.)	Cross-sectional area (in.2)	Vertical strain e%	STRESS (psi)
0	0	0	0	0	0
	30	5000	4.8	0.22	1054
	45	7000	4.8	0.32	1475

Tested, prepared and checked by: R. Lam and G. Guerra

File: Unconfchagres



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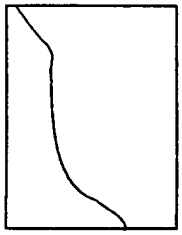
UNCONFINED COMPRESSIVE STRENGTH OF INTACT ROCK CORE SPECIMENS ASTM 2938

Project:	Alto del Chagres	Date:	09/11/2002
Location:	Chagres	No. Sample:	1
Boring:	CH-3	Testing time:	1.24 min
Depth:	91.35-91.48	Tested By:	R. Lam
Description:	Andesite		G. Guerra
	greenish gray		

TEST ESPECIMEN DATA

Avg. Diameter Do(cm):	6.3	Moisture condition:	Air
Avg. Length Lo(cm):	12.50	Porcentage of absorption(%):	
Weight(grs):	1090.7	Water content Wo%:	2.63
Cross-sect. Area(cm2):	4.8	Specific gravity:	2.6
Unit weight(kg/m3):	2799	Type of failure(shape):	shear
Time of failure(lb/seg):	15	Mode:	weak
Lo / Do ratio:	1.98	Angle of failure:	
Factor correction:	0.9990	Deformation rate:	0.34
Elastic modulus E(MPa):		Uniaxial compressive strenght(psi):	260
Classification Strength:	very low	(Kgf/cm2):	18
		(MPa):	2

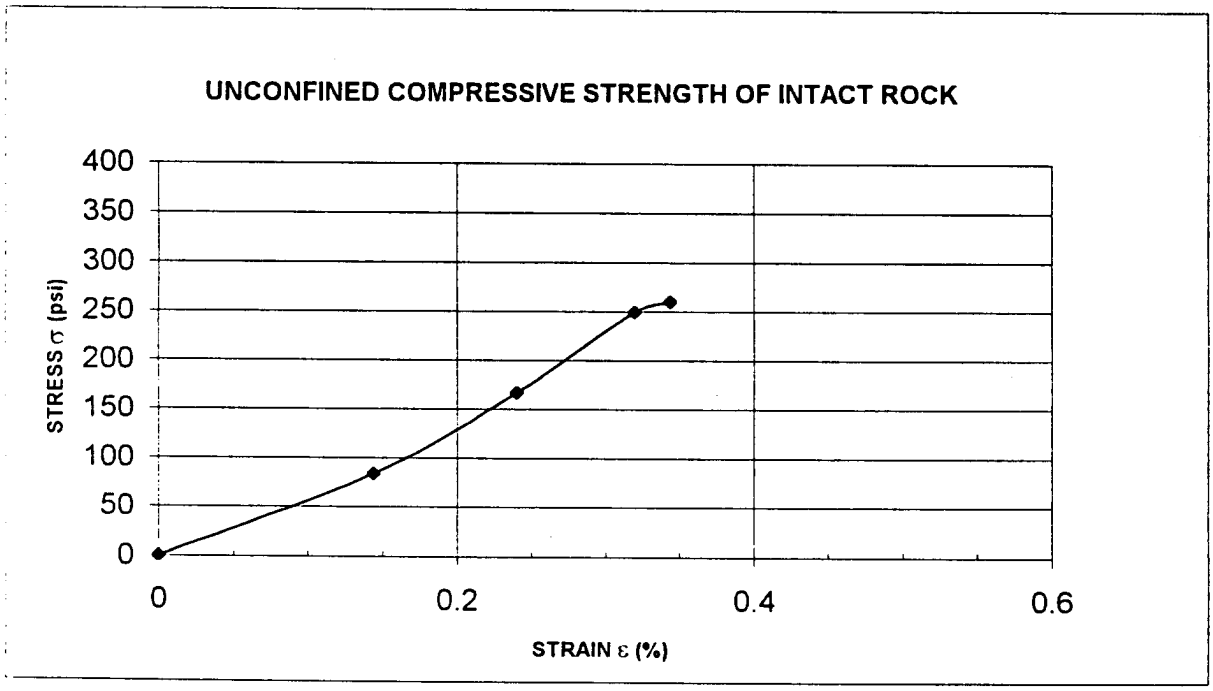
Type of Failure



AXIAL LOADING DATA

Time (min.seg)	Deformation gauge (x10-3)	LOAD GAUGE (lb.)	Cross-sectional area (in.2)	Vertical strain e%	STRESS (psi)
0	0	0	0	0	0
	18	400	4.8	0.14	83
	30	800	4.8	0.24	167
	40	1200	4.8	0.32	250
	43	1250	4.8	0.34	260

Tested, prepared and checked by: R. Lam and G. Guerra
File: Unconfchagres



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UNCONFINED COMPRESSIVE STRENGTH OF INTACT ROCK CORE SPECIMENS ASTM 2938

Project: Alto del Chagres
Location: Chagres
Boring: CH-3
Depth: 66.23-67.00
Description: Tectonic Breccia
grayish green

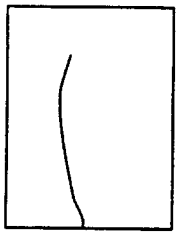
Date: 09/11/2002
No. Sample: m-6
Testing time: 3.42 min
Tested By: R. Lam
G. Guerra

TEST ESPECIMEN DATA

Avg. Diameter Do(cm):	6.3
Avg. Length Lo(cm):	13.85
Weight(grs):	1100.9
Cross-sect. Area(cm2):	4.8
Unit weight(kg/m3):	2549
Time of failure(lb/seg):	71
Lo / Do ratio:	2.20
Factor correction:	1.0109
Elastic modulus E(MPa):	
Classification Strength:	very low

Moisture condition:	Air
Porcentage of absorption(%):	
Water content Wo%:	2.25
Specific gravity:	2.6
Type of failure(shape):	shear
Mode:	weak
Angle of failure:	
Deformation rate:	0.81
Uniaxial compressive strenght(psi):	505
(Kgf/cm2):	36
(MPa):	3

Type of Failure

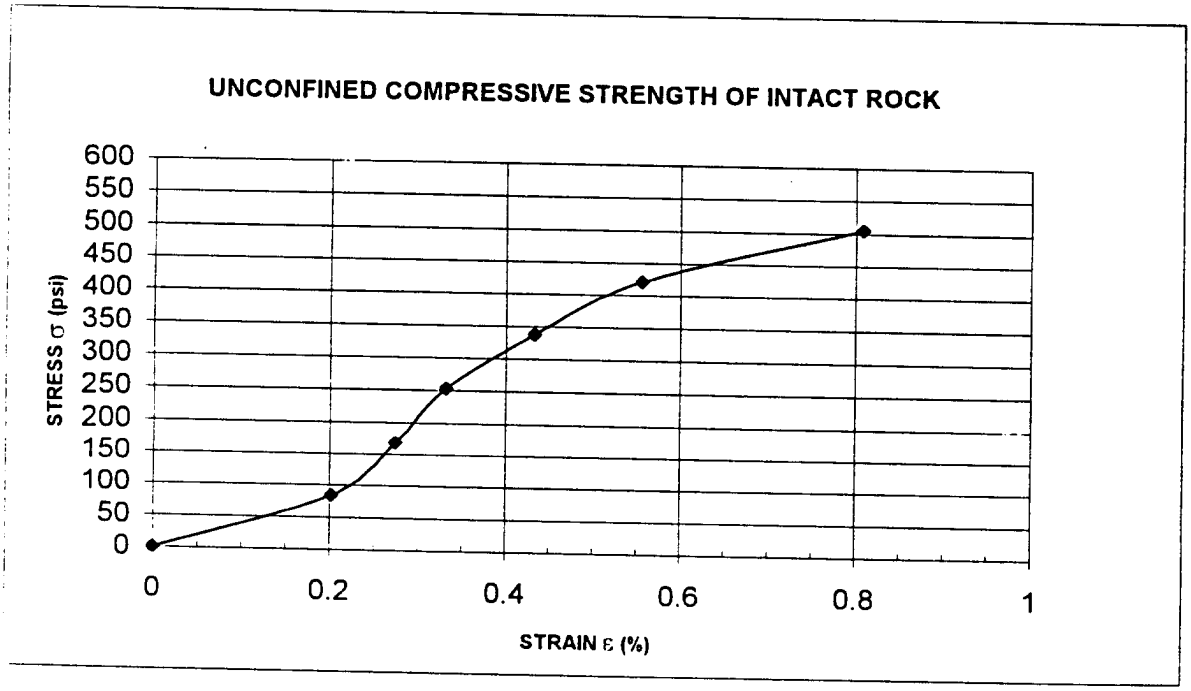


AXIAL LOADING DATA

Time (min.seg)	Deformation gauge (x10-3)	LOAD GAUGE (lb.)	Cross-sectional area (in.2)	Vertical strain e%	STRESS (psi)
0	0	0	0	0	0
	28	400	4.8	0.20	84
	38	800	4.8	0.27	168
	46	1200	4.8	0.33	253
	60	1600	4.8	0.43	337
	77	2000	4.8	0.56	421
	112	2400	4.8	0.81	505

Tested, prepared and checked by: R. Lam and G. Guerra

File: Unconfchagres



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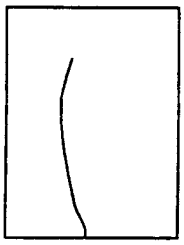
UNCONFINED COMPRESSIVE STRENGTH OF INTACT ROCK CORE SPECIMENS ASTM 2938

Project:	Alto del Chagres	Date:	09/11/2002
Location:	Chagres	No. Sample:	m-6
Boring:	CH-3	Testing time:	3.42 min
Depth:	77.25-77.46	Tested By:	R. Lam
Description:	Tectonic Breccia		G. Guerra
	grayish green		

TEST ESPECIMEN DATA

Avg. Diameter Do(cm):	6.3	Moisture condition:	Air
Avg. Length Lo(cm):	14.90	Porcentage of absorption(%):	
Weight(grs):	1256.3	Water content Wo%:	2.52
Cross-sect. Area(cm2):	4.8	Specific gravity:	2.6
Unit weight(kg/m3):	2661	Type of failure(shape):	shear
Time of failure(lb/seg):	88	Mode:	weak
Lo / Do ratio:	2.37	Angle of failure:	
Factor correction:	1.0189	Deformation rate:	0.26
Elastic modulus E(MPa):		Uniaxial compressive strenght(psi):	1189
Classification Strength:	very low	(Kgf/cm2):	84
		(MPa):	8

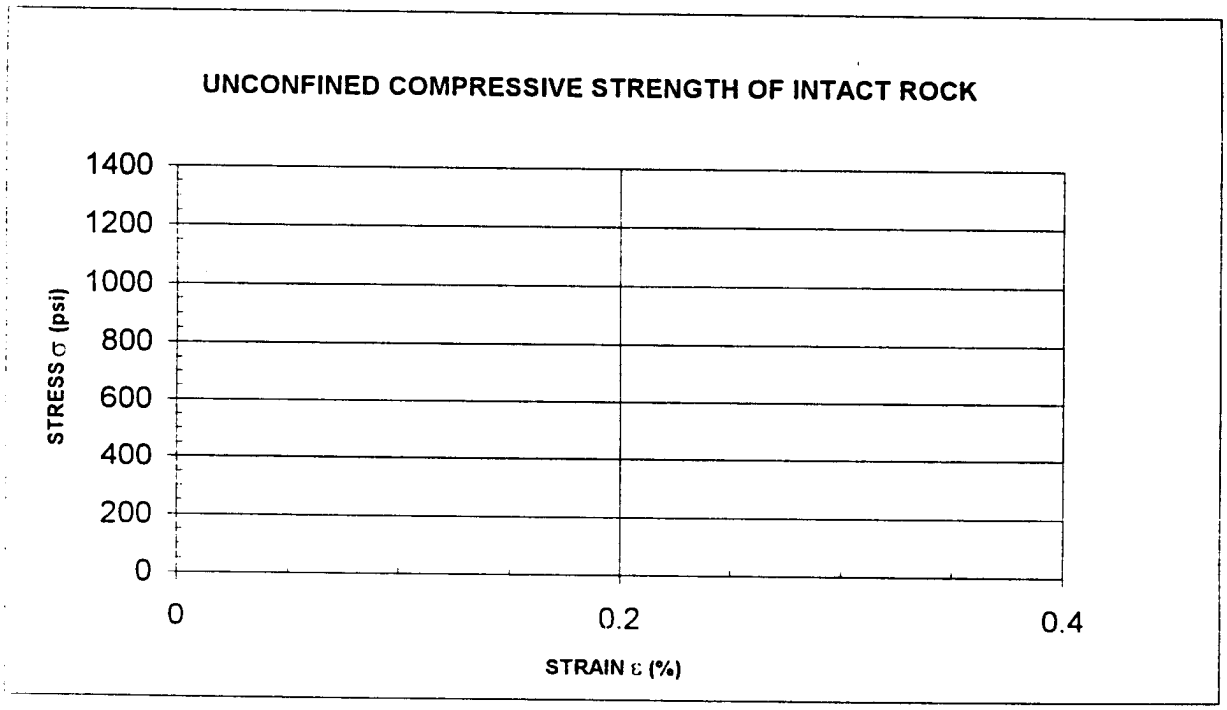
Type of Failure



AXIAL LOADING DATA

Time (min.seg)	Deformation gauge (x10-3)	LOAD GAUGE (lb.)	Cross-sectional area (in.2)	Vertical strain e%	STRESS (psi)
0	0	0	0	0	0
	34	5000	4.8	0.23	1061
	38	5600	4.8	0.26	1189

Tested, prepared and checked by: R. Lam and G. Guerra
File: Unconfchagres



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UNCONFINED COMPRESSIVE STRENGTH OF INTACT ROCK CORE SPECIMENS ASTM 2938

Project: Alto del Chagres
Location: Chagres
Boring: CH-3
Depth: 86.44-86.37
Description: Andesite greenish gray

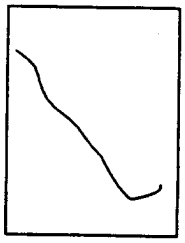
Date: 09/11/2002
No. Sample: 2
Testing time: 1.29 min
Tested By: R. Lam
G. Guerra

TEST ESPECIMEN DATA

Avg. Diameter Do(cm):	6.4
Avg. Length Lo(cm):	12.55
Weight(grs):	1056.7
Cross-sect. Area(cm2):	4.9
Unit weight(kg/m3):	2658
Time of failure(lb/seg):	51
Lo / Do ratio:	1.98
Factor correction:	0.9986
Elastic modulus E(MPa):	
Classification Strength:	very low

Moisture condition:	Air
Porcentage of absorption(%):	
Water content Wo%:	4.08
Specific gravity:	2.6
Type of failure(shape):	shear
Mode:	weak
Angle of failure:	
Deformation rate:	0.68
Uniaxial compressive strenght(psi):	917
(Kgf/cm2):	64
(MPa):	6

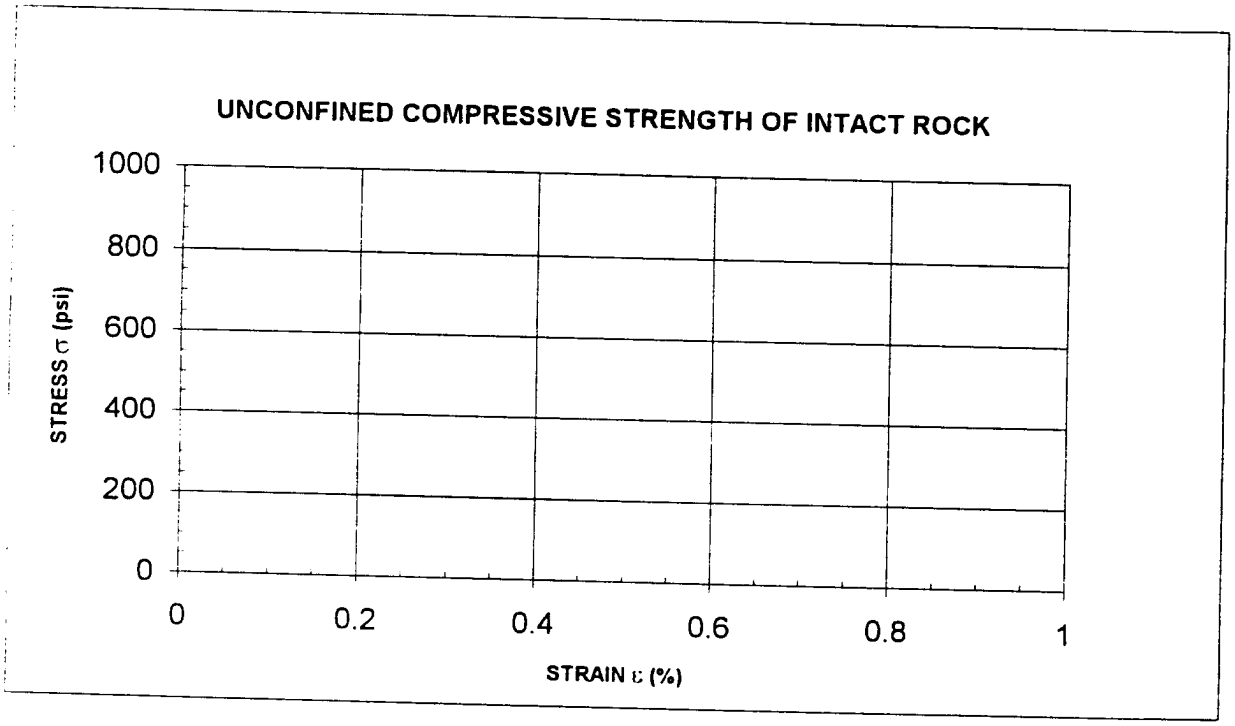
Type of Failure



AXIAL LOADING DATA

Time (min.seg)	Deformation gauge (x10-3)	LOAD GAUGE (lb.)	Cross-sectional area (in.2)	Vertical strain e%	STRESS (psi)
0	0	0	0	0	0
	85	4500	4.9	0.68	917

Tested, prepared and checked by: R. Lam and G. Guerra
File: Unconfchagres



AUTORIDAD DEL CANAL DE PANAMA
DIVISION DE INGENIERIA
SECCION DE GEOTECNIA

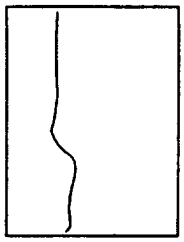
UNCONFINED COMPRESSIVE STRENGTH OF INTACT ROCK CORE SPECIMENS ASTM 2938

Project:	Alto del Chagres	Date:	09/11/2002
Location:	Chagres	No. Sample:	m-6
Boring:	CH-4	Testing time:	1.44 min
Depth:	29.17-20.37	Tested By:	R. Lam
Description:	Tectonic Breccia		G. Guerra
	grayish green		

TEST ESPECIMEN DATA

Avg. Diameter Do(cm):	6.1	Moisture condition:	Air
Avg. Length Lo(cm):	13.70	Porcentage of absorption(%):	
Weight(grs):	948.0	Water content Wo%:	5.20
Cross-sect. Area(cm2):	4.5	Specific gravity:	2.3
Unit weight(kg/m3):	2367	Type of failure(shape):	shear
Time of failure(lb/seg):	12	Mode:	weak
Lo / Do ratio:	2.25	Angle of failure:	
Factor correction:	1.0133	Deformation rate:	0.51
Elastic modulus E(MPa):		Uniaxial compressive strenght(psi):	281
Classification Strength:	very low	(Kgf/cm2):	20
		(MPa):	2

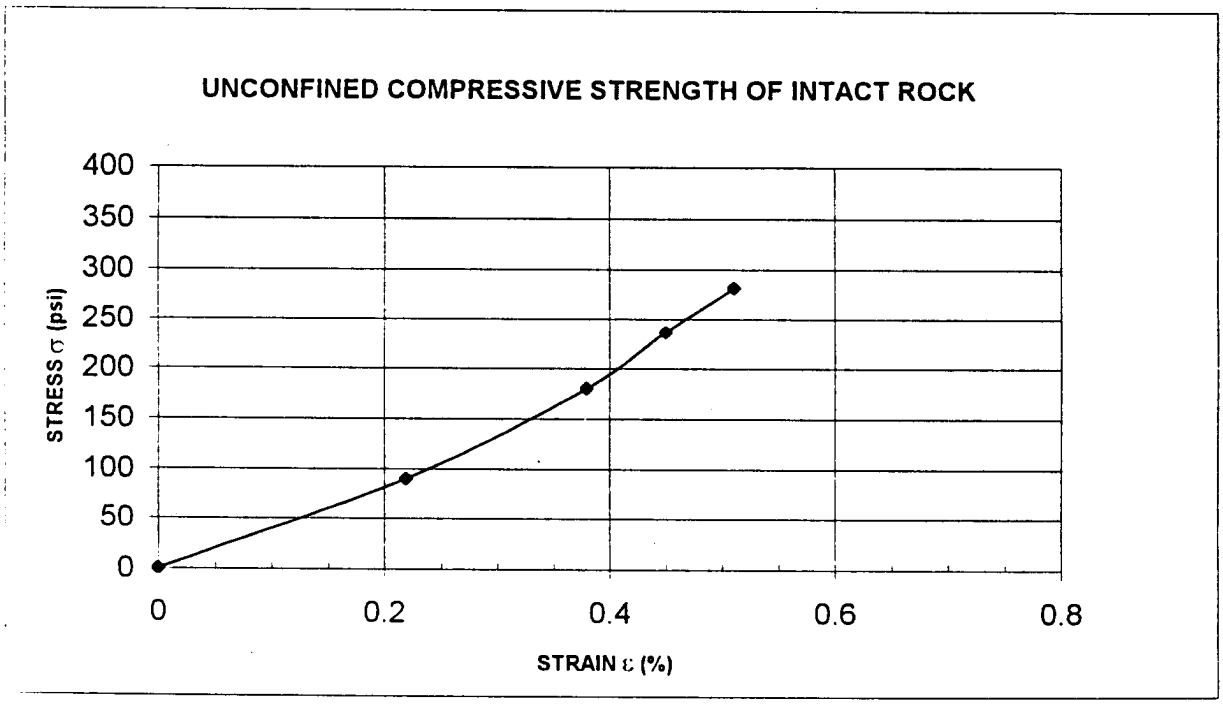
Type of Failure



AXIAL LOADING DATA

Time (min.seg)	Deformation gauge (x10-3)	LOAD GAUGE (lb.)	Cross-sectional area (in.2)	Vertical strain e%	STRESS (psi)
0	0	0	0	0	0
	30	400	4.5	0.22	90
	52	800	4.5	0.38	180
	63	1050	4.5	0.45	236
	70	1250	4.5	0.51	281

Tested, prepared and checked by: R. Lam and G. Guerra
File: Unconfchagres



AUTORIDAD DEL CANAL DE PANAMA
DIVISION DE INGENIERIA
SECCION DE GEOTECNIA

UNCONFINED COMPRESSIVE STRENGTH OF INTACT ROCK CORE SPECIMENS ASTM 2938

Project: Alto del Chagres
Location: Chagres
Boring: CH-7
Depth: 29.46-29.66
Description: Andesite greenish gray

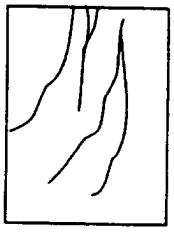
Date: 09/11/2002
No. Sample: 1
Testing time: 3.48 min
Tested By: R. Lam, G. Guerra

TEST ESPECIMEN DATA

Avg. Diameter Do(cm):	6.3
Avg. Length Lo(cm):	14.10
Weight(grs):	1163.1
Cross-sect. Area(cm2):	4.8
Unit weight(kg/m3):	2646
Time of failure(lb/seg):	160
Lo / Do ratio:	2.24
Factor correction:	1.0129
Elastic modulus E(MPa):	
Classification Strength:	low

Moisture condition:	Air
Porcentage of absorption(%):	
Water content Wo%:	1.22
Specific gravity:	2.7
Type of failure(shape):	shear
Mode:	violent
Angle of failure:	
Deformation rate:	1.27
Uniaxial compressive strenght(psi):	7702
(Kgf/cm2):	542
(MPa):	53

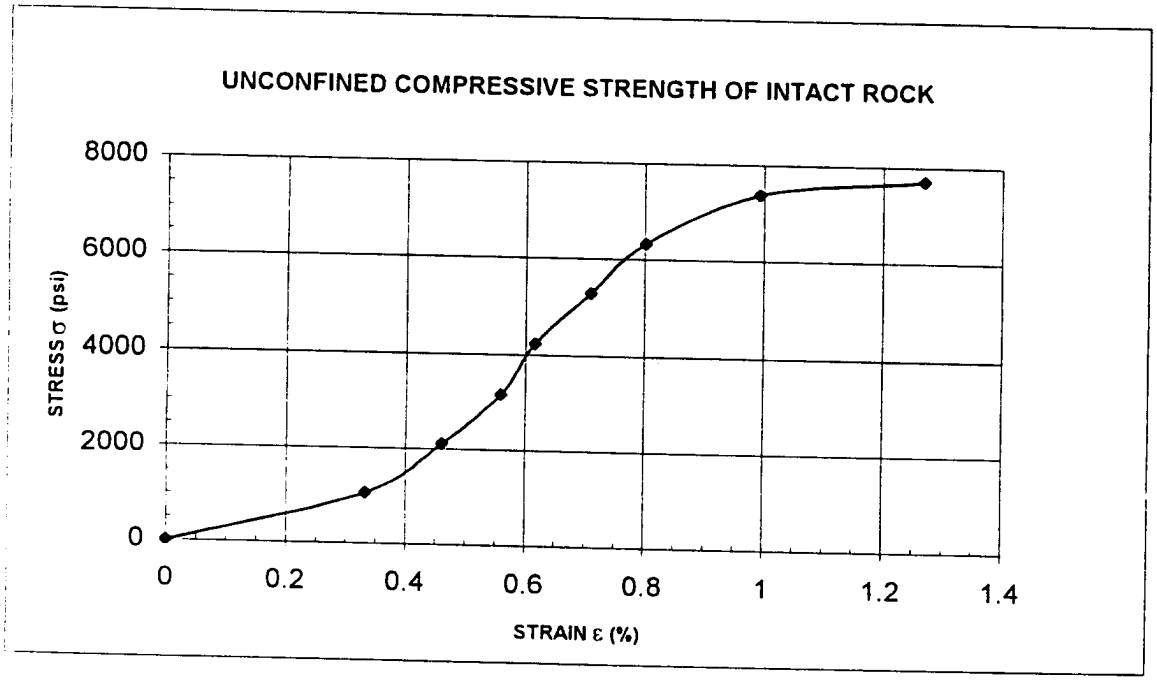
Type of Failure



AXIAL LOADING DATA

Time (min.seg)	Deformation gauge (x10-3)	LOAD GAUGE (lb.)	Cross-sectional area (in.2)	Vertical strain e%	STRESS (psi)
0	0	0	0	0	0
	47	5000	4.8	0.33	1055
	65	10000	4.8	0.46	2110
	79	15000	4.8	0.56	3165
	87	20000	4.8	0.62	4221
	100	25000	4.8	0.71	5276
	113	30000	4.8	0.80	6331
	140	35000	4.8	0.99	7386
	179	36500	4.8	1.27	7702

Tested, prepared and checked by: R. Lam and G. Guerra
File: Unconfchagres



AUTORIDAD DEL CANAL DE PANAMA

DIVISION DE INGENIERIA

SECCION DE GEOTECNIA

UNCONFINED COMPRESSIVE STRENGTH OF INTACT ROCK CORE SPECIMENS ASTM 2938

Project: Alto del Chagres
Location: Chagres
Boring: CH-7
Depth: 56.30-56.55
Description: Andesite
greenish gray

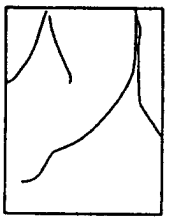
Date: 09/11/2002
No. Sample: 3
Testing time: 4.15 min
Tested By: R. Lam
G. Guerra

TEST ESPECIMEN DATA

Avg. Diameter Do(cm):	6.3
Avg. Length Lo(cm):	13.90
Weight(grs):	1170.0
Cross-sect. Area(cm2):	4.8
Unit weight(kg/m3):	2700
Time of failure(lb/seg):	221
Lo / Do ratio:	2.21
Factor correction:	1.0114
Elastic modulus E(MPa):	
Classification Strength:	medium

Moisture condition:	Air
Porcentage of absorption(%):	
Water content Wo%:	0.97
Specific gravity:	2.7
Type of failure(shape):	shear
Mode:	violent
Angle of failure:	
Deformation rate:	1.15
Uniaxial compressive strenght(psi):	11904
(Kgf/cm2):	837
(MPa):	82

Type of Failure

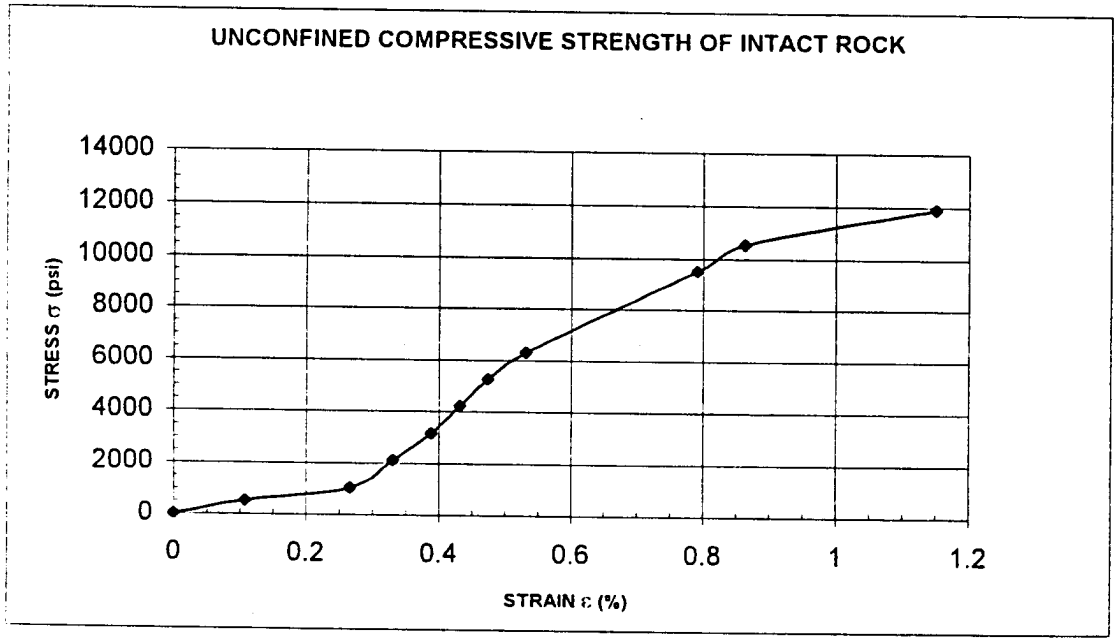


AXIAL LOADING DATA

Time (min.seg)	Deformation gauge (x10-3)	LOAD GAUGE (lb.)	Cross-sectional area (in.2)	Vertical strain e%	STRESS (psi)
0	0	0	0	0	0
	15	2500	4.8	0.11	527
	37	5000	4.8	0.27	1053
	46	10000	4.8	0.33	2107
	54	15000	4.8	0.39	3160
	60	20000	4.8	0.43	4214
	66	25000	4.8	0.47	5267
	74	30000	4.8	0.53	6321
	110	45000	4.8	0.79	9481
	120	50000	4.8	0.86	10535
	160	56500	4.8	1.15	11904

Tested, prepared and checked by: R. Lam and G. Guerra

File: Unconfchagres



APPENDIX C: POINT LOAD TEST

AUTORIDAD DEL CANAL DE PANAMA
DIVISION DE INGENIERIA
SECCION DE GEOTECNIA

SUMMARY RESULTS OF THE POINT LOAD STRENGTH INDEX OF ROCK
Project: Alto Chagres

Location: Northeast of the Canal

	Boring	Depth (m)	Sample No.	Point Load I: Is_{50} (Mpa)	Estimated Unconf. Comp. σc (Mpa)	Type of rock
1	CH-3	16.89-17.05	m-1	1.04	23	Andesite
2	CH-3	31.20-31.31	M-3	1.14	25	Tectonic Breccia
3	CH-3	35.00-35.11	m-3	0.15	3	Tectonic Breccia
4	CH-3	55.00-55.13	m-4	0.43	9	Tectonic Breccia
5	CH-3	62.80-62.95	m-5	0.37	8	Tectonic Breccia
6	CH-3	97.66-97.80	m-10	0.16	3	Tectonic Breccia
7	CH-3	109.49-109.61	m-12	0.08	2	Tectonic Breccia
8	CH-6	14.32-14.50	m-1	0.72	16	Andesite
9	CH-6	26.74-26.85	m-2	1.72	38	Andesite
10	CH-7	55.30-55.44	m-2	6.43	136	Andesite
11	CH-8	11.69-11.83	m-1	3.59	79	Andesite
12	CH-8	15.48-15.61	m-2	5.19	114	Andesite
13	CH-8	45.75-45.87	m-3	5.13	97	Andesite
14	CH-9	13.68-13.83	m-1	0.8	18	Andesite
15	CH-9	28.69-29.20	m-2	1.84	40	Tectonic Breccia

Remarks: rock color :

Andesite: greenish gray
Tectonic Breccia: grayish green

Tested and prepared By: R. Lam, X. Rios and G. Guerra

09/15/2002

AUTORIDAD DEL CANAL DE PANAMA
DIVISION DE INGENIERIA
SECCION DE GEOTECNIA

POINT LOAD TEST

Project: **Altos del Chagres**
Location Chagres
Material: Tectonic Breccia
Boring: **CH-3** **m-3**
Depth: 31.20-31.31 m
Date: 09/11/2002

LOAD (KN)	W1(mm)	W2(mm)	W	d(mm)	AREA	De^2	SQRT De	Is	FACTOR Cc	Is 50(Mpa)	Unc. Compression kg/cm^2
2.4				63.5				0.6	1.11	0.66	149
5				63.5				1.2	1.11	1.38	310
3.1				63.5				0.8	1.11	0.86	192
1.95	42	62	52	45	2340	2980.89	54.60	0.65	1.04	0.68	153
2.95	37	58	47.5	39	1853	2359.87	48.58	1.25	0.99	1.23	
2.5	31	55	43	35	1505	1917.20	43.79	1.30	0.94	1.23	276
3.7	39	58	48.5	28	1358	1729.94	41.59	2.14	0.92	1.97	442
									average	1.14	253
										psi	3604

Tested and prepared By: R. Lam
Date: 09/11/2002
File: altochagresPLT
Checked by: Gustavo Guerra B.

Estimated Unconfined compressive strength
253 kg/cm^2
3604 psi
25 Mpa

AUTORIDAD DEL CANAL DE PANAMA
DIVISION DE INGENIERIA
SECCION DE GEOTECNIA

POINT LOAD TEST

Project: **Altos del Chagres**
Location Chagres
Material: Andesite
Boring: **CH-3** **m-1**
Depth: 16.89-17.05 m
Date: 09/11/2002

LOAD (KN)	W1(mm)	W2(mm)	W	d(mm)	AREA	De^2	SQRT De	Is	FACTOR Cc	Is 50(Mpa)	Unc. Compression kg/cm^2
1.1				60				0.3	1.09	0.33	74
4.7	63.5	84	73.75	45	3319	4227.71	65.02	1.11	1.13	1.25	281
2.2	63	84	73.5	34	2499	3183.44	56.42	0.69	1.06	0.73	164
5.1	61	81.5	71.25	31	2209	2813.69	53.04	1.81	1.03	1.86	418
									average	1.04	234
										psi	3330

Tested and prepared By: R. Lam
Date: 09/11/2002
File: altochagresPLT
Checked by: Gustavo Guerra B.

Estimated Unconfined compressive strength
234 **kg/cm^2**
3330 **psi**
23 **Mpa**

AUTORIDAD DEL CANAL DE PANAMA
DIVISION DE INGENIERIA
SECCION DE GEOTECNIA

POINT LOAD TEST

Project: **Altos del Chagres**
Location Chagres
Material: Tectonic Breccia
Boring: **CH-3** **m-3**
Depth: 35.00-35.11 m
Date: 09/11/2002

LOAD (KN)	W1(mm)	W2(mm)	W	d(mm)	AREA	De^2	SQRT De	Is	FACTOR Cc	Is 50(Mpa)	Unc. Compression kg/cm^2
0.5	63.5	131	97.25	52	5057	6442.04	80.26	0.08	1.24	0.10	22
0.6	63	80	71.5	57	4076	5191.72	72.05	0.12	1.18	0.14	31
0.9	58	72.5	65.25	64	4176	5319.75	72.94	0.17	1.19	0.20	45
0.7	63.5	75	69.25	35	2424	3087.58	55.57	0.23	1.05	0.24	53
0.2	63	62	62.5	45	2813	3582.80	59.86	0.06	1.08	0.06	14
0.1	42.5	62	52.25	26	1359	1730.57	41.60	0.06	0.92	0.05	12
0.5	45	59.5	52.25	33	1724	2196.50	46.87	0.23	0.97	0.22	50
									average	0.15	33
										psi	467

Tested and prepared By: R. Lam
Date: 09/11/2002
File: altochagresPLT
Checked by: Gustavo Guerra B.

Estimated Unconfined compressive strength
33 kg/cm^2
467 psi
3 Mpa

AUTORIDAD DEL CANAL DE PANAMA
DIVISION DE INGENIERIA
SECCION DE GEOTECNIA

POINT LOAD TEST

Project: **Altos del Chagres**
Location Chagres
Material: Tectonic Breccia
Boring: **CH-3** **m-4**
Depth: 55.00-55.13
Date: 09/11/2002

LOAD (KN)	W1(mm)	W2(mm)	W	d(mm)	AREA	De^2	SQRT De	Is	FACTOR Cc	Is 50(Mpa)	Unc. Compression kg/cm^2
0.4				63.5				0.1	1.11	0.11	25
2.2				64				0.5	1.12	0.60	
2.95	63	130	96.5	50	4825	6146.50	78.40	0.48	1.22	0.59	132
1.4	44	76	60	41.5	2490	3171.97	56.32	0.44	1.06	0.47	104
1.1	43	64	53.5	40	2140	2726.11	52.21	0.40	1.02	0.41	92
1.2	52	63.5	57.75	35.5	2050	2611.62	51.10	0.46	1.01	0.46	104
1	40	62.5	51.25	29	1486	1893.31	43.51	0.53	0.94	0.50	111
1.3	55	75.5	65.25	65	4241	5402.87	73.50	0.24	1.19	0.29	64
									average	0.43	90
										psi	1286

Tested and prepared By: R. Lam
Date: 09/11/2002
File: altochagresPLT
Checked by: Gustavo Guerra B.

Estimated Unconfined compressive strength
90 kg/cm^2
1286 psi
9 Mpa

AUTORIDAD DEL CANAL DE PANAMA
DIVISION DE INGENIERIA
SECCION DE GEOTECNIA

POINT LOAD TEST

Project: **Altos del Chagres**
Location Chagres
Material: Tectonic Breccia
Boring: **CH-3** **m-5**
Depth: 62.80-62.95 m
Date: 09/11/2002

LOAD (KN)	W1(mm)	W2(mm)	W	d(mm)	AREA	De^2	SQRT De	Is	FACTOR Cc	Is 50(Mpa)	Unc. Compression kg/cm^2
1.5				63.5				0.4	1.11	0.41	93
2	50	83	66.5	48	3192	4066.24	63.77	0.49	1.12	0.55	123
1.35	44	76	60	30.5	1830	2331.21	48.28	0.58	0.98	0.57	
0.5	34	56	45	31	1395	1777.07	42.16	0.28	0.93	0.26	58
0.2	34.5	31	32.75	28	917	1168.15	34.18	0.17	0.84	0.14	32
0.6	63	114	88.5	25	2213	2818.47	53.09	0.21	1.03	0.22	49
0.8	63	121	92	44	4048	5156.69	71.81	0.16	1.18	0.18	
1.4	63	52	57.5	30.5	1754	2234.08	47.27	0.63	0.98	0.61	137
1.25	62	77	69.5	34	2363	3010.19	54.87	0.42	1.04	0.37	83
									average	0.37	82
										psi	1170

Tested and prepared By: R. Lam
Date: 09/11/2002
File: altochagresPLT
Checked by: Gustavo Guerra B.

Estimated Unconfined compressive strength
82 kg/cm^2
1170 psi
8 Mpa

AUTORIDAD DEL CANAL DE PANAMA
DIVISION DE INGENIERIA
SECCION DE GEOTECNIA

POINT LOAD TEST

Project: **Altos del Chagres**
Location Chagres
Material: Tectonic Breccia
Boring: **CH-3** **m-10**
Depth: 97.66-97.80 m
Date: 09/11/2002

LOAD (KN)	W1(mm)	W2(mm)	W	d(mm)	AREA	De^2	SQRT De	Is	FACTOR Cc	Is 50(Mpa)	Unc. Compression kg/cm^2
0.7				63.5				0.2	1.11	0.19	43
0.7				63.5				0.2	1.11	0.19	43
0.7				63.5				0.2	1.11	0.19	43
0.7	63.5	77.5	70.5	43	3032	3861.78	62.14	0.18	1.10	0.20	45
0.6	61	112	86.5	29	2509	3195.54	56.53	0.19	1.06	0.20	45
0.4	63	99	81	40	3240	4127.39	64.24	0.10	1.12	0.11	24
0.8	60	48	54	37	1998	2545.22	50.45	0.31	1.00	0.32	
0.1	60	66.5	63.25	29	1834	2336.62	48.34	0.04	0.98	0.04	
0.2	55	59	57	35	1995	2541.40	50.41	0.08	1.00	0.08	18
0.1	49	85	67	40	2680	3414.01	58.43	0.03	1.07	0.03	7
									average	0.16	34
										psi	478

Tested and prepared By: R. Lam
Date: 09/11/2002
File: altochagresPLT
Checked by: Gustavo Guerra B.

Estimated Unconfined compressive strength	
34	kg/cm^2
478	psi
3	Mpa

AUTORIDAD DEL CANAL DE PANAMA
DIVISION DE INGENIERIA
SECCION DE GEOTECNIA

POINT LOAD TEST

Project: **Altos del Chagres**
Location Chagres
Material: Tectonic Breccia
Boring: **CH-3** **m-12**
Depth: 109.49-109.61 m
Date: 09/11/2002

LOAD (KN)	W1(mm)	W2(mm)	W	d(mm)	AREA	De^2	SQRT De	Is	FACTOR Cc	Is 50(Mpa)	Unc. Compression kg/cm^2
0.7				63.5				0.2	1.11	0.19	43
0.1	63.5	99.5	81.5	48.5	3953	5035.35	70.96	0.02	1.17	0.02	5
0.1	63.5	53.5	58.5	38	2223	2831.85	53.22	0.04	1.03	0.04	8
0.05	38.5	50	44.25	40	1770	2254.78	47.48	0.02	0.98	0.02	5
0.2	42	99.5	70.75	31	2193	2793.95	52.86	0.07	1.03	0.07	16
0.4	35	58	46.5	29	1349	1717.83	41.45	0.23	0.92	0.21	48
0.2	62	72	67	40	2680	3414.01	58.43	0.06	1.07	0.06	14
0.2	42.5	73	57.75	43	2483	3163.38	56.24	0.06	1.05	0.07	15
0.1	47.5	62	54.75	21	1149.75	1464.65	38.27	0.07	0.89	0.06	14
0.1	40	57	48.5	30	1455	1853.50	43.05	0.05	0.93	0.05	11
									average	0.08	19
										psi	267

Tested and prepared By: R. Lam
Date: 09/11/2002
File: altochagresPLT
Checked by: Gustavo Guerra B.

Estimated Unconfined compressive strength
19 kg/cm^2
267 psi
2 Mpa

AUTORIDAD DEL CANAL DE PANAMA

DIVISION DE INGENIERIA

SECCION DE GEOTECNIA

POINT LOAD TEST

Project: **Altos del Chagres**
Location Chagres
Material: Andesite
Boring: **CH-6** **m-1**
Depth: 14.32-14.50 m
Date: 09/11/2002

LOAD (KN)	W1(mm)	W2(mm)	W	d(mm)	AREA	De^2	SQRT De	Is	FACTOR Cc	Is 50(Mpa)	Unc. Compression kg/cm^2
8				63.5				2.0	1.11	2.21	**496**
2.8				62				0.7	1.10	0.80	**180**
1.9				63.5				0.5	1.11	0.52	**118**
0.2	63.5	86.5	75	64.5	4838	6162.42	78.50	0.03	1.23	0.04	**9**
2.3	62.5	97	79.75	28	2233	2844.59	53.33	0.81	1.03	0.83	**187**
2.7	46	62.5	54.25	63.5	3445	4388.38	66.24	0.62	1.13	0.70	**157**
1	46	62.5	54.25	63	3418	4353.82	65.98	0.23	1.13	0.26	**58**
2.2	63	46	54.5	34	1853	2360.51	48.59	0.93	0.99	0.92	**206**
0.6	61.5	70	65.75	33	2170	2764.01	52.57	0.22	1.02	0.22	**50**
									average	**0.72**	**162**
										psi	**2308**

Tested and prepared By: R. Lam
Date: 09/11/2002
File: altochagresPLT
Checked by: Gustavo Guerra B.

Estimated Unconfined compressive strength

162 kg/cm^2
2308 **psi**
16 **Mpa**

AUTORIDAD DEL ANAL DE PANAMA
DIVISION DE INGENIERIA
SECCION DE GEOTECNIA

POINT LOAD TEST

Project: **Altos del Chagres**
Location Chagres
Material: Andesite
Boring: **CH-6** **m-2**
Depth: 26.74-26.85 m
Date: 09/11/2002

LOAD (KN)	W1(mm)	W2(mm)	W	d(mm)	AREA	De^2	SQRT De	Is	FACTOR Cc	Is 50(Mpa)	Unc. Compression kg/cm^2
4.7				64				I.I	1.12	1.28	288
4.9	63.5	110	86.75	55	4771	6078.03	77.96	0.81	1.22	0.98	221
4.3	60	57	58.5	46	2691	3428.03	58.55	1.25	1.07	1.35	302
4.6	50.5	63	56.75	36	2043	2602.55	51.02	1.77	1.01	1.78	400
4.6	63.5	45	54.25	32.5	1763	2246.02	47.39	2.05	0.98	2.00	449
5:1	57	58	57.5	34	1955	2490.45	49.90	2.05	1.00	2.05	459
4.8	40	97	68.5	25.5	1747	2225.16	47.17	2.16	0.97	2.10	472
3.3	43	44	43.5	23	1001	1274.52	35.70	2.59	0.86	2.23	499
									average	1.72	386
										psi	5492

Tested and prepared By: R. Lam
Date: 09/11/2002
File: altochagresPLT
Checked by: Gustavo Guerra B.

Estimated Unconfined compressive strength
386 kg/cm^2
5492 psi
38 Mpa

AUTORIDAD DEL CANAL DE PANAMA

DIVISION DE INGENIERIA

SECCION DE GEOTECNIA

POINT LOAD TEST

Project: **Altos del Chagres**
Location Chagres
Material: Andesite
Boring: CH-7 m-2
Depth: 55.30-55.44 m
Date: 09/11/2002

LOAD (KN)	W1(mm)	W2(mm)	W	d(mm)	AREA	De^2	SQRT De	Is	FACTOR Cc	Is 50(Mpa)	Unc. Compression kg/cm^2
23	61.5	161.5	111.5	63.5	7080	9019.43	94.97	2.55	1.33	3.40	**764**
32	63.5	123	93.25	42	3917	4989.17	70.63	6.41	1.17	7.49	**1681**
24	62	64	63	42	2646	3370.70	58.06	7.12	1.07	7.62	**1709**
24	66	64	65	35	2275	2898.09	53.83	8.28	1.03	8.56	
15	62	42.5	52.25	37	1933	2462.74	49.63	6.09	1.00	6.07	**1362**
12	34.5	61	47.75	30	1433	1824.84	42.72	6.58	0.93	6.13	**1375**
26	35	68	51.5	40	2060	2624.20	51.23	9.91	1.01	10.02	
14	57	48	52.5	40	2100	2675.16	51.72	5.23	1.02	5.31	**1192**
4.8	41	57	49	28	1372	1747.77	41.81	2.75	0.92	2.53	
10	60	37	48.5	22	1067	1359.24	36.87	7.36	0.87	6.41	**1439**
12	43	61.5	52.25	22.5	1176	1497.61	38.70	8.01	0.89	7.14	**1602**
									average	**6.43**	**1391**
										psi	**19775**

Tested and prepared By: R. Lam
Date: 09/11/2002
File: altochagresPLT
Checked by: Gustavo Guerra B.

Estimated Unconfined compressive strength
1391 kg/cm^2
19775 psi
136 Mpa

AUTORIDAD DEL CANAL DE PANAMA
DIVISION DE INGENIERIA
SECCION DE GEOTECNIA

POINT LOAD TEST

Project: **Altos del Chagres**
Location Chagres
Material: Andesite
Boring: **CH-8** **m-1**
Depth: 11.69-11.83 m
Date: 09/11/2002

LOAD (KN)	W1(mm)	W2(mm)	W	d(mm)	AREA	De^2	SQRT De	Is	FACTOR Cc	Is 50(Mpa)	Unc. Compression kg/cm^2
9	63	138	100.5	57	5729	7297.45	85.43	1.23	1.27	1.57	352
31	63	138	100.5	47	4724	6017.20	77.57	5.15	1.22	6.28	1409
12	63	77	70	53	3710	4726.11	68.75	2.54	1.15	2.93	658
									average	3.59	806
										psi	11463

Tested and prepared By: R. Lam
Date: 09/11/2002
File: altochagresPLT
Checked by: Gustavo Guerra B.

Estimated Unconfined compressive strength
806 kg/cm^2
11463 **psi**
79 **Mpa**

AUTORIDAD DEL CANAL DE PANAMA
DIVISION DE INGENIERIA
SECCION DE GEOTECNIA

POINT LOAD TEST

Project: **Altos del Chagres**
Location Chagres
Material: Andesite
Boring: **CH-8** **m-2**
Depth: 15.48-15.61 m
Date: 09/11/2002

LOAD (KN)	W1(mm)	W2(mm)	W	d(mm)	AREA	De^2	SQRT De	Is	FACTOR Cc	Is 50(Mpa)	Unc. Compression kg/cm^2
24.5	62.5	139	100.75	57	5743	7315.61	85.53	3.35	1.27	4.26	**957**
4.8	62.5	86	74.25	58	4307	5485.99	74.07	0.87	1.19	1.04	**234**
27	63	68	65.5	32	2096	2670.06	51.67	10.11	1.01	10.26	**2303**
									average	**5.19**	**1165**
										psi	**16563**

Tested and prepared By: R. Lam
Date: 09/11/2002
File: altochagresPLT
Checked by: Gustavo Guerra B.

Estimated Unconfined compressive strength
1165 kg/cm^2
16563 **psi**
114 **Mpa**

AUTORIDAD DEL CANAL DE PANAMA
DIVISION DE INGENIERIA
SECCION DE GEOTECNIA

POINT LOAD TEST

Project: **Altos del Chagres**
Location Chagres
Material: Tectonic Breccia
Boring: **CH-9** **m-2**
Depth: 28.96-29.20 m
Date: 09/11/2002

LOAD (KN)	W1(mm)	W2(mm)	W	d(mm)	AREA	De^2	SQRT De	Is	FACTOR Cc	Is 50(Mpa)	Unc. Compression kg/cm^2
4.4				63.5				1.1	1.11	1.22	273
8				63.5				2.0	1.11	2.21	496
4.9				63.5				1.2	1.11	1.35	304
9				63.5				2.2	1.11	2.49	558
10	63.5	93.5	78.5	47	3690	4700.00	68.56	2.13	1.15	2.45	550
5	63	77	70	43	3010	3834.39	61.92	1.30	1.10	1.44	322
4.6	61	95	78	32	2496	3179.62	56.39	1.45	1.06	1.53	343
4.7	62	63.5	62.75	32.5	2039	2597.93	50.97	1.81	1.01	1.82	409
5	77	62.5	69.75	29	2023	2576.75	50.76	1.94	1.01	1.95	438
4.5	63	57	60	27	1620	2063.69	45.43	2.18	0.96	2.09	469
									average	**1.84**	**413**
										psi	**5867**

Tested and prepared By: R. Lam
Date: 09/11/2002
File: altochagresPLT
Checked by: Gustavo Guerra B.

Estimated Unconfined compressive strength
413 kg/cm^2
5867 psi
40 Mpa

AUTORIDAD DEL CANAL DE PANAMA
DIVISION DE INGENIERIA
SECCION DE GEOTECNIA

POINT LOAD TEST

Project: **Altos del Chagres**
Location Chagres
Material: Andesite
Boring: **CH-8** **m-3**
Depth: 45.75-45.87 m
Date: 09/11/2002

LOAD (KN)	W1(mm)	W2(mm)	W	d(mm)	AREA	De^2	SQRT De	Is	FACTOR Cc	Is 50(Mpa)	Unc. Compression kg/cm^2
5.5				64				1.3	1.12	1.50	**337**
20	63	93	78	38	2964	3775.80	61.45	5.30	1.10	5.81	**1304**
12	63	78	70.5	41.5	2926	3727.07	61.05	3.22	1.09	3.52	**790**
13	63	71	67	64	4288	5462.42	73.91	2.38	1.19	2.84	**637**
19.5	63	71	67	46	3082	3926.11	62.66	4.97	1.11	5.50	**1234**
23	63	49	56	42	2352	2996.18	54.74	7.68	1.04	8.00	
14	62	56	59	44	2596	3307.01	57.51	4.23	1.06	4.51	**1012**
									average	**5.13**	**991**
										psi	**14096**

Tested and prepared By: R. Lam
Date: 09/11/2002
File: altochagresPLT
Checked by: Gustavo Guerra B.

Estimated Unconfined compressive strength
991 **kg/cm^2**
14096 **psi**
97 **Mpa**

AUTORIDAD DEL CANAL DE PANAMA
DIVISION DE INGENIERIA
SECCION DE GEOTECNIA

POINT LOAD TEST

Project: **Altos del Chagres**
Location Chagres
Material: Andesite
Boring: **CH-9** **m-1**
Depth: 13.68-13.83 m
Date: 09/11/2002

LOAD (KN)	W1(mm)	W2(mm)	W	d(mm)	AREA	De^2	SQRT De	Is	FACTOR Cc	Is 50(Mpa)	Unc. Compression kg/cm^2
2.5				63.5				0.6	1.11	0.69	**155**
2.6				63.5				0.6	1.11	0.72	**161**
4	60	100	80	50	4000	5095.54	71.38	0.79	1.17	0.92	**207**
4.1	61	97	79	63.5	5017	6390.45	79.94	0.64	1.24	0.79	**178**
4.3	63.5	50	56.75	52	2951	3759.24	61.31	1.14	1.10	1.25	**281**
1.5	62	77	69.5	41.5	2884	3674.20	60.62	0.41	1.09	0.45	**100**
1.2	30	54	42	36	1512	1926.11	43.89	0.62	0.94	0.59	**132**
1.7	51	87	69	32	2208	2812.74	53.04	0.60	1.03	0.62	**139**
2	62.5	48	55.25	25	1381	1759.55	41.95	1.14	0.92	1.05	**236**
1.7	32.5	63.5	48	27	1296	1650.96	40.63	1.03	0.91	0.94	**210**
1.4	63.5	61	62.25	44	2739	3489.17	59.07	0.40	1.08	0.43	**97**
2.4	63	65	64	37.5	2400	3057.32	55.29	0.79	1.05	0.82	**184**
									average	**0.80**	**180**
										psi	**2553**

Tested and prepared By: R. Lam
Date: 09/11/2002
File: altochagresPLT
Checked by: Gustavo Guerra B.

Estimated Unconfined compressive strength
180 kg/cm^2
2553 psi
18 Mpa

APPENDIX D: PHOTOS OF MATERIALS

ACP
AUTORIDAD DEL CANAL DE PANAMA

PANAMA CANAL AUTHORITY
ENGINEERING DIVISON
GEOTECHNICAL BRANCH
SOILS AND MATERIALS LABORATORY

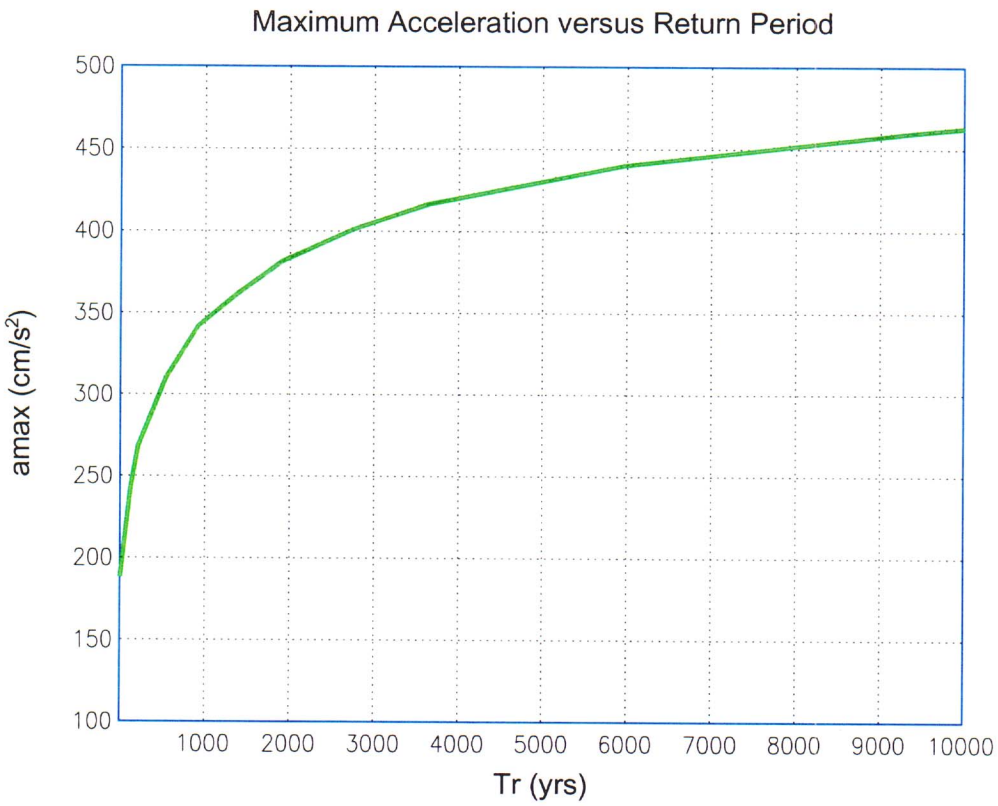
Laboratory Testing Program for ALTO CHAGRES Site Investigation

Prepared By:
Gustavo Guerra B.

Assisted by:
Xenia Ríos
Rodrigo Lam
Adalberto Guzmán
Carlos Rodriguez

September 2002

Attachment 4: Seismic Hazard Curves



Seismic Hazard Curve based on Fukushima-Tanaka Attenuation Curve (Bodare, 2001)

AUTORIDAD DEL CANAL DE PANAMA
Division de Proyectos de Capacidad del Canal

CONTRACT NO. CC-3-536
=UPPER CHAGRES WATER SUPPLY PROJECT
APPENDIX B - GEOLOGY, GEOTECHNICAL AND SEISMOLOGICAL STUDIES

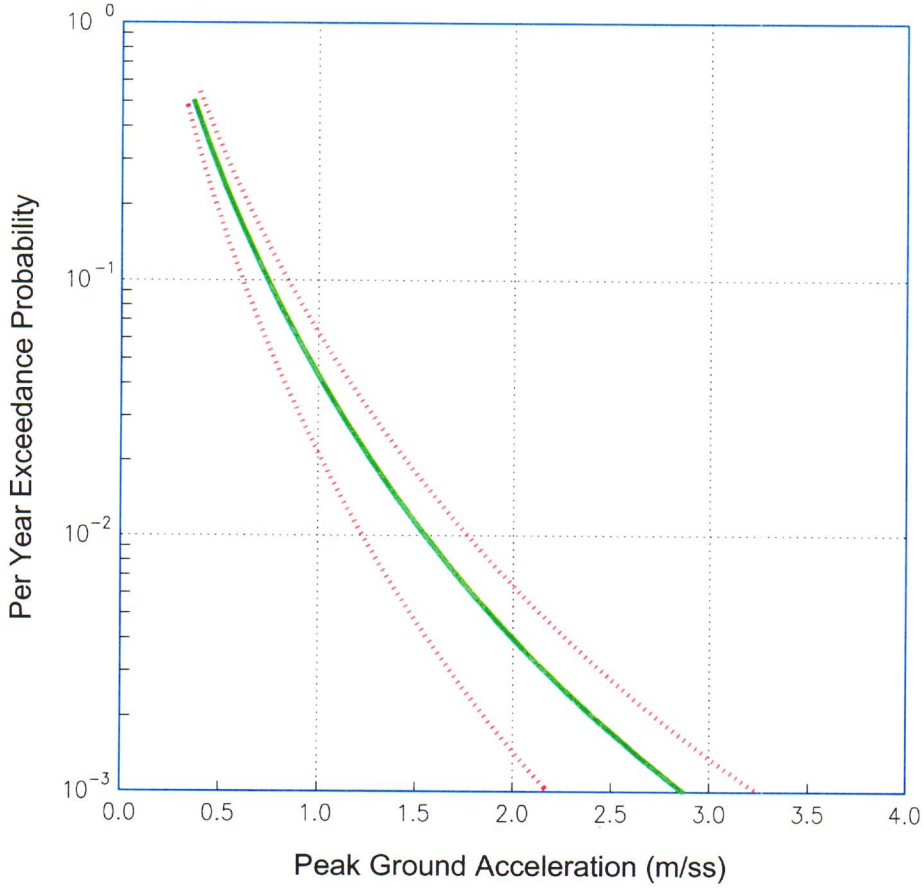
SEISMIC HAZARD CURVE
FUKUSHIMA-TANAKA

MWH TAMS

DATE: JUNE, 2003

EXHIBIT: A-1

Results for Site Location -80.544 8.241



Seismic Hazard Curve for Aguadulce, Cocle (Camacho et al., 1994)

AUTORIDAD DEL CANAL DE PANAMA
Division de Proyectos de Capacidad del Canal

CONTRACT NO. CC-3-536
UPPER CHAGRES WATER SUPPLY PROJECT
APPENDIX B - GEOLOGY, GEOTECHNICAL AND SEISMOLOGICAL STUDIES

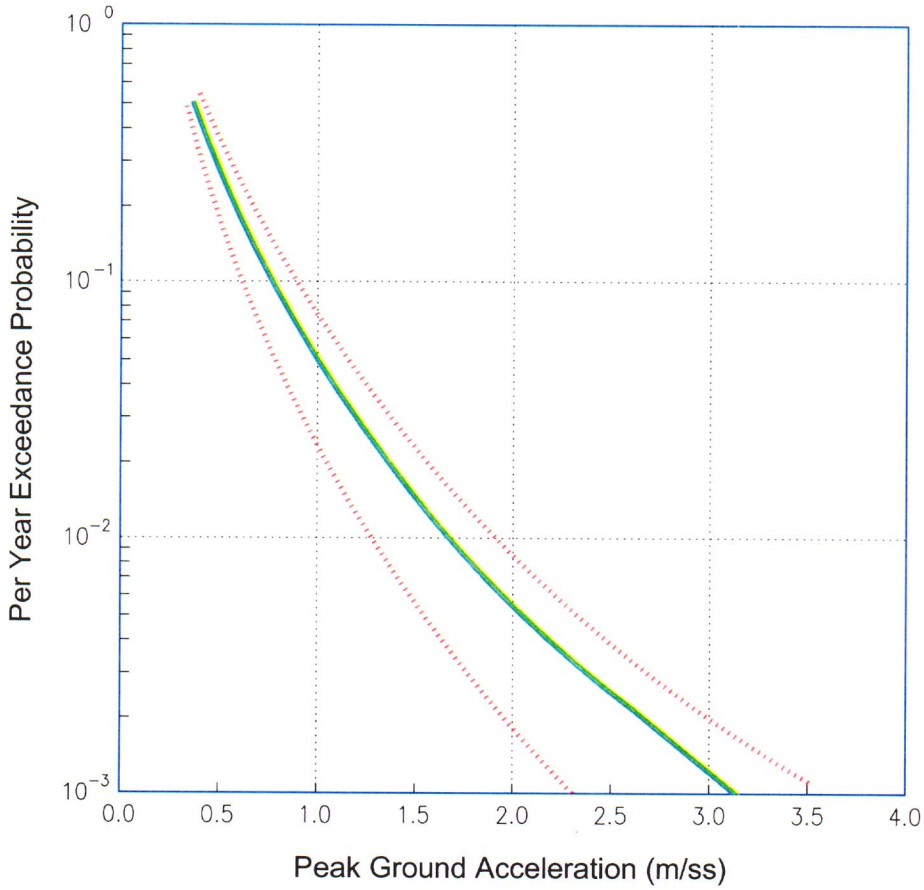
SEISMIC HAZARD CURVE
AGUADULCE, COCLE

MWH TAMS

DATE: JUNE, 2003

EXHIBIT: A-2

Results for Site Location -80.433 7.961



Seismic Hazard Curve for Chitre, Herrera (Camacho et al., 1994)

AUTORIDAD DEL CANAL DE PANAMA
Division de Proyectos de Capacidad del Canal

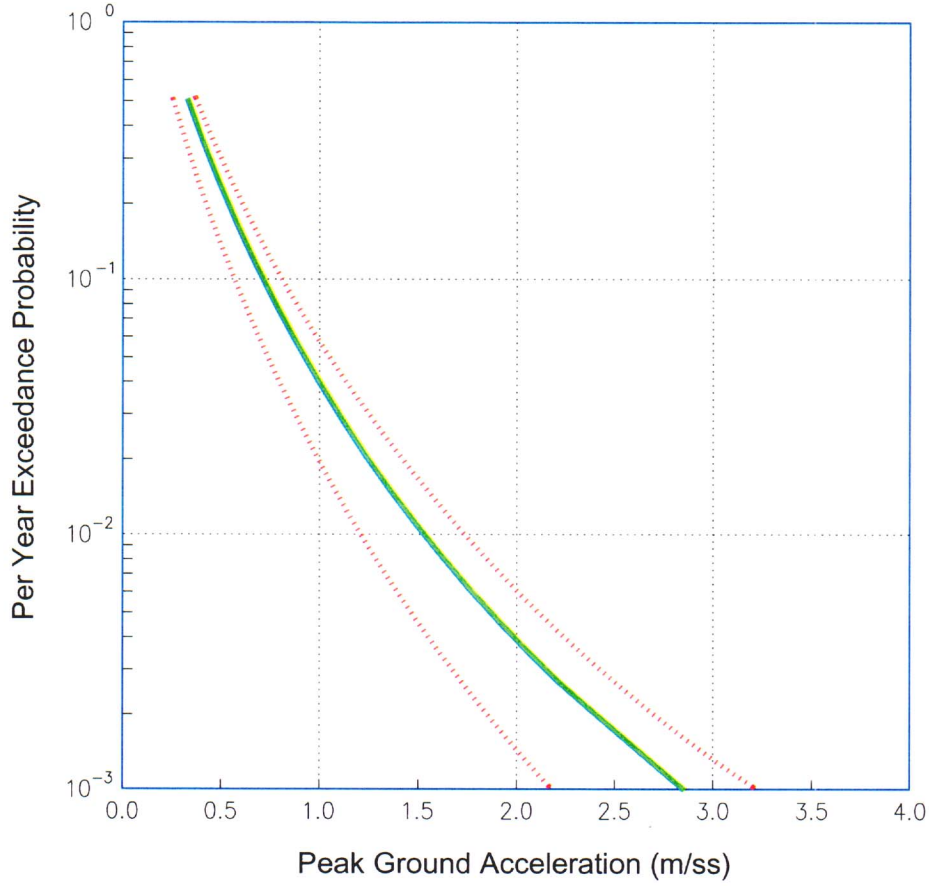
CONTRACT NO. CC-3-536
UPPER CHAGRES WATER SUPPLY PROJECT
APPENDIX B - GEOLOGY, GEOTECHNICAL AND SEISMOLOGICAL STUDIES

SEISMIC HAZARD CURVE
CHITRE, HERRERA

MWH TAMS

DATE:	EXHIBIT:
JUNE, 2003	A-3

Results for Site Location -79.782 8.879



Seismic Hazard Curve for Chorrera, Panama (Camacho et al., 1994)

AUTORIDAD DEL CANAL DE PANAMA
Division de Proyectos de Capacidad del Canal

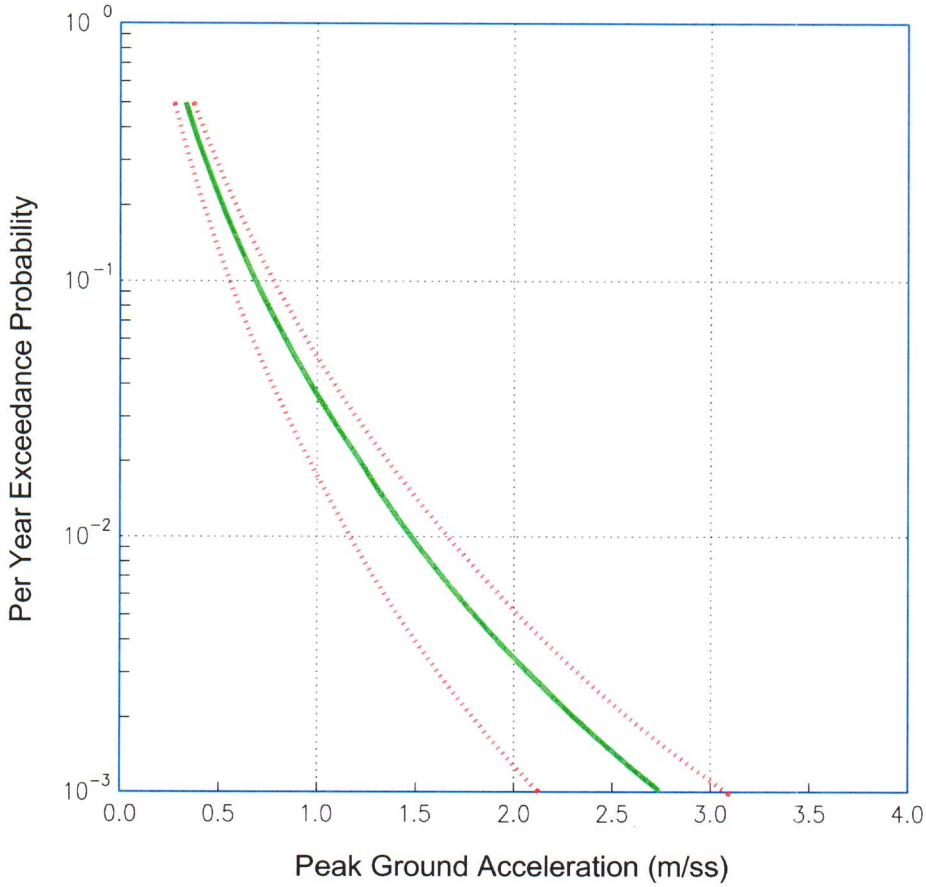
CONTRACT NO. CC-3-536
UPPER CHAGRES WATER SUPPLY PROJECT
APPENDIX B - GEOLOGY, GEOTECHNICAL AND SEISMOLOGICAL STUDIES

SEISMIC HAZARD CURVE
CHORRERA, PANAMA

MWH TAMS

DATE:	EXHIBIT:
JUNE, 2003	A-4

Results for Site Location -79.883 8.525



Seismic Hazard Curve for Coronado, Panama (Camacho et al., 1994)

AUTORIDAD DEL CANAL DE PANAMA
Division de Proyectos de Capacidad del Canal

CONTRACT NO. CC-3-536
UPPER CHAGRES WATER SUPPLY PROJECT
APPENDIX B - GEOLOGY, GEOTECHNICAL AND SEISMOLOGICAL STUDIES

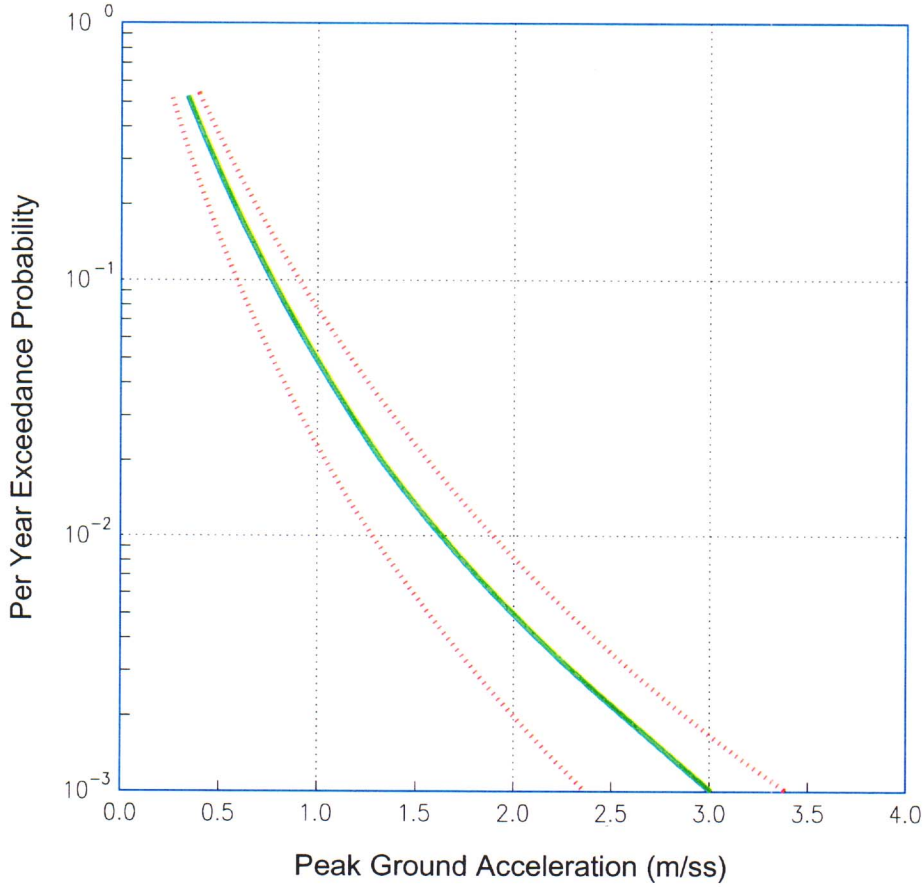
SEISMIC HAZARD CURVE
CORONADO, PANAMA

MWH TAMS

DATE: JUNE, 2003

EXHIBIT: A-5

Results for Site Location -79.534 8.984



Seismic Hazard Curve for Panama City, Panama (Camacho et al., 1994)

AUTORIDAD DEL CANAL DE PANAMA
Division de Proyectos de Capacidad del Canal

CONTRACT NO. CC-3-536
UPPER CHAGRES WATER SUPPLY PROJECT
APPENDIX B - GEOLOGY, GEOTECHNICAL AND SEISMOLOGICAL STUDIES

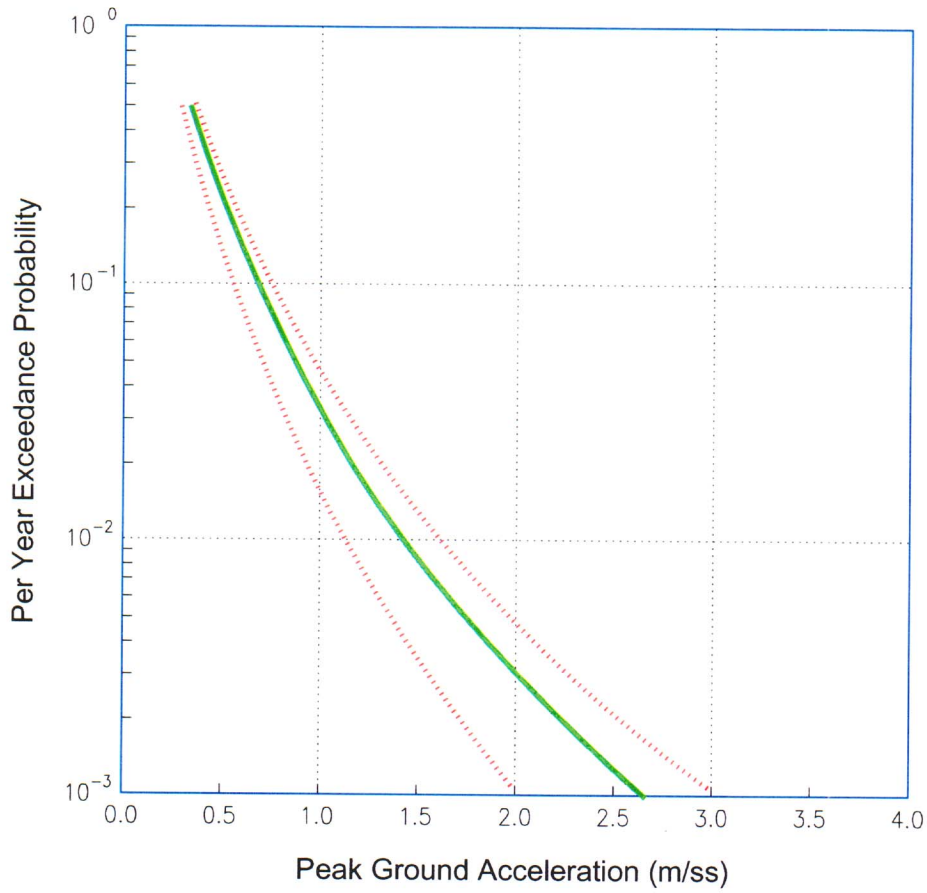
SEISMIC HAZARD CURVE
PANAMA CITY, PANAMA

MWH TAMS

DATE: JUNE, 2003

EXHIBIT: A-6

Results for Site Location -80.358 8.518



Seismic Hazard Curve for Penonome, Cocle (Camacho et al., 1994)

AUTORIDAD DEL CANAL DE PANAMA
Division de Proyectos de Capacidad del Canal

CONTRACT NO. CC-3-536
UPPER CHAGRES WATER SUPPLY PROJECT
APPENDIX B - GEOLOGY, GEOTECHNICAL AND SEISMOLOGICAL STUDIES

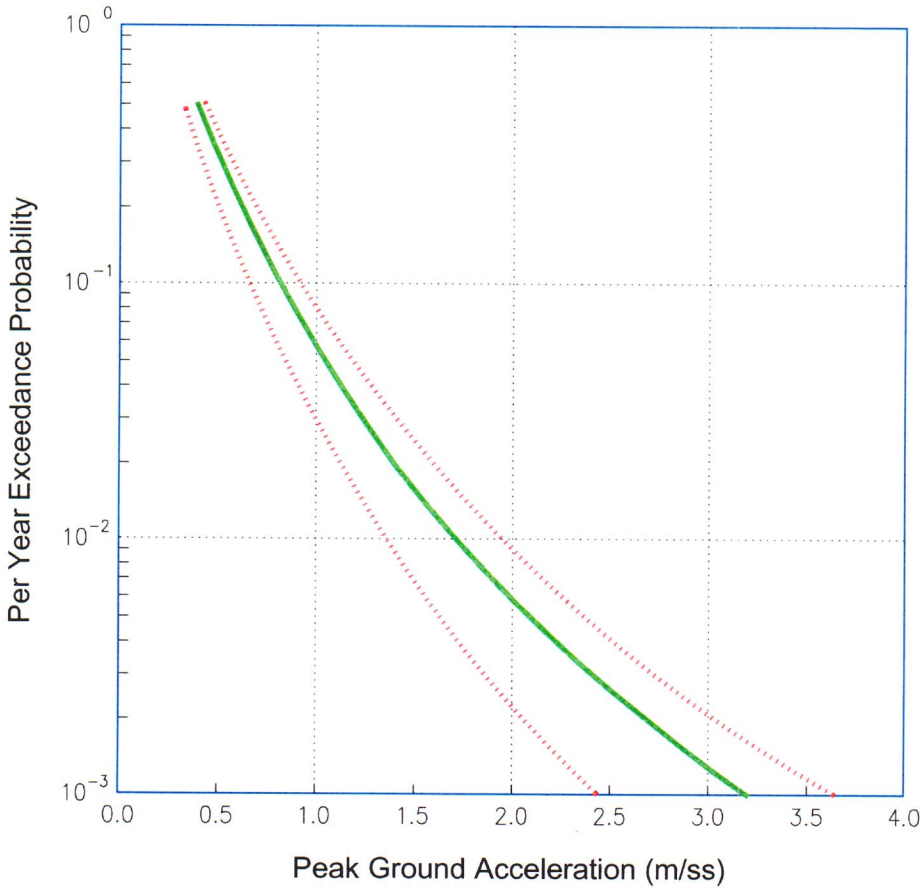
SEISMIC HAZARD CURVE
PENONOME, COCLE

MWH TAMS

DATE: JUNE, 2003

EXHIBIT: A-7

Results for Site Location -80.979 8.101



Seismic Hazard Curve for Santiago, Veraguas (Camacho et al., 1994)

AUTORIDAD DEL CANAL DE PANAMA
Division de Proyectos de Capacidad del Canal

CONTRACT NO. CC-3-536
= UPPER CHAGRES WATER SUPPLY PROJECT
APPENDIX B - GEOLOGY, GEOTECHNICAL AND SEISMOLOGICAL STUDIES

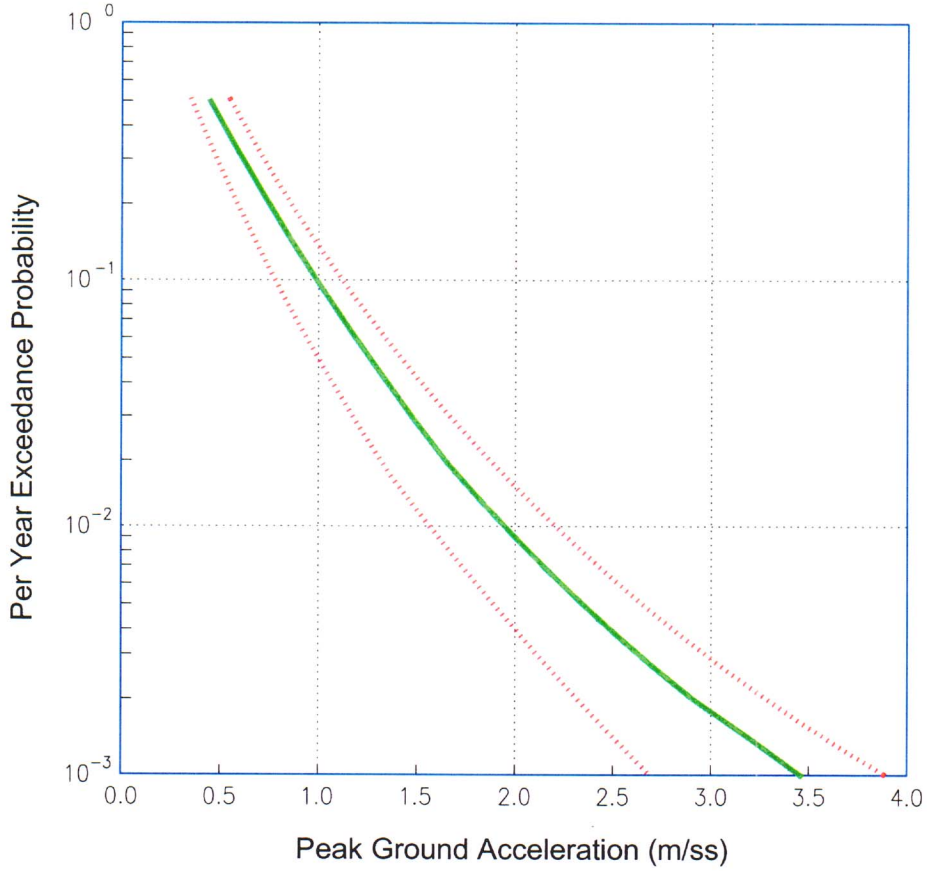
SEISMIC HAZARD CURVE
SANTIAGO, VERAGUAS

MWH TAMS

DATE: JUNE, 2003

EXHIBIT: A-8

Results for Site Location -81.319 8.008



Seismic Hazard Curve for Sona, Veraguas (Camacho et al., 1994)

AUTORIDAD DEL CANAL DE PANAMA
Division de Proyectos de Capacidad del Canal

CONTRACT NO. CC-3-536
UPPER CHAGRES WATER SUPPLY PROJECT
APPENDIX B - GEOLOGY, GEOTECHNICAL AND SEISMOLOGICAL STUDIES

SEISMIC HAZARD CURVE
SONA, VERAGUAS

MWH TAMS

DATE: JUNE, 2003

EXHIBIT: A-9

Attachment 5: Photographs

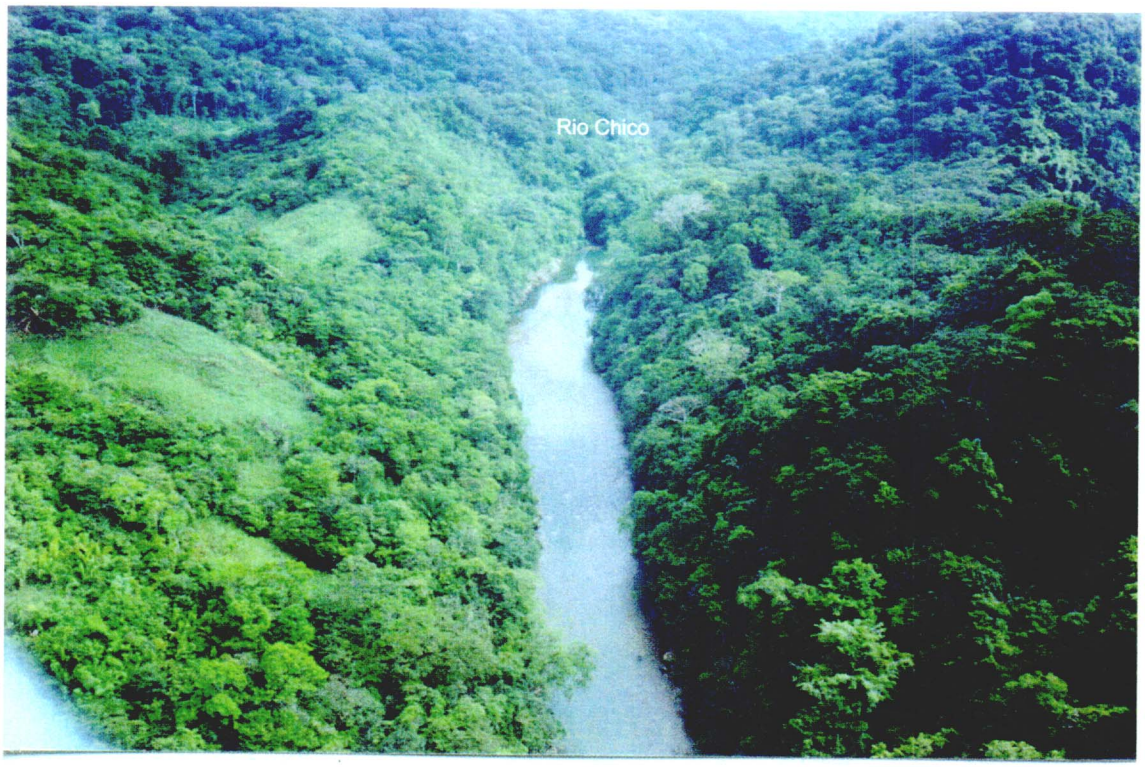


Photo 1: Dam site looking N toward Rio Chico

Photo 2: Dam site looking S from Rio Chico

Photo 3: Dam site looking SW toward right abutment

Photo 4: Looking E toward left abutment; note helicopter landing pads (H) on right (foreground) and left abutments

Photo 5: Right abutment, looking N

Photo 6: Embera Drua village downstream of damsite

Photo 7: Andesite outcrop with andesite dike on Rio Chagres just upstream of confluence with RioChico

Photo 8: Outcrop on right abutment looking down to Rio Chagres

Photo 9: Agglomerate outcrop in quebrada on right bank of Rio Chico

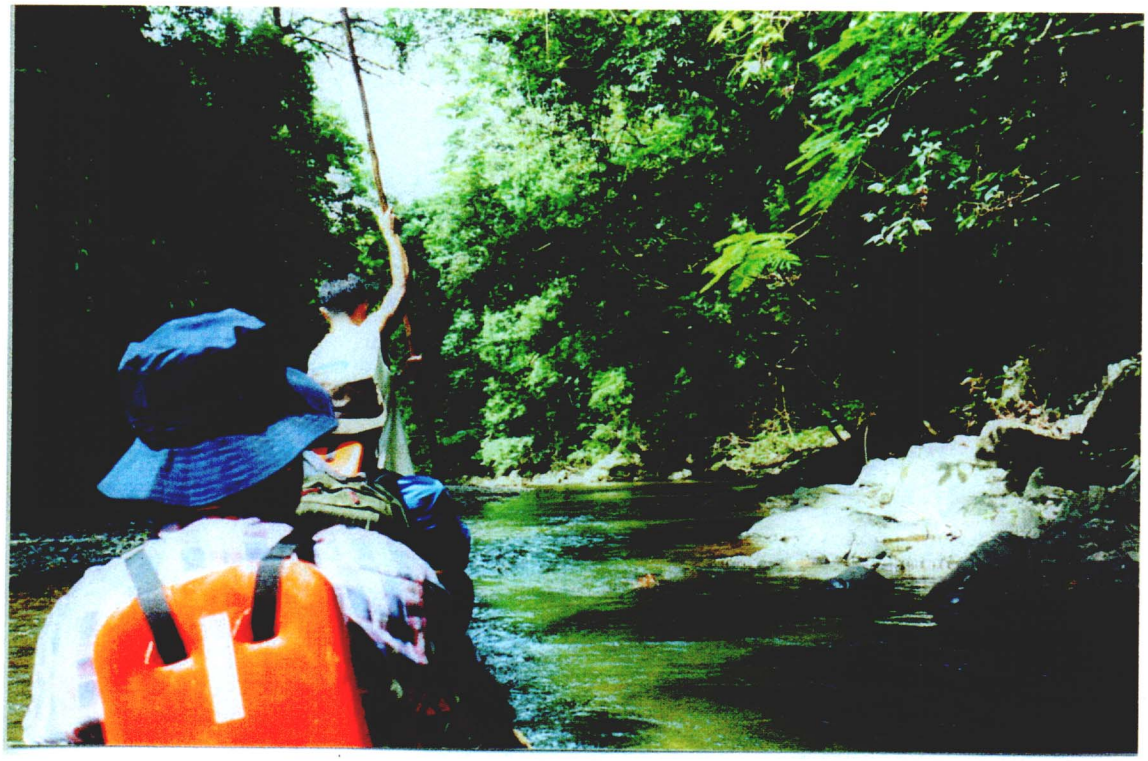


Photo 10: Rio Chico just upstream of confluence with Rio Chagres

Photo 11: Boulder bar deposit a few km upstream of damsite

Photo 12: Helicopter delivering drilling equipment to left abutment

Photo 13: Right abutment powerhouse site, looking N-NE

Photo 14: Rock outcrop and small landslip on Rio Chagres a few km upstream of confluence with Rio Chico

Photo 15: Rock outcrop at mouth of quebrada on right abutment just upstream of dam axis

Photo 16: Rock outcrop further along right abutment quebrada

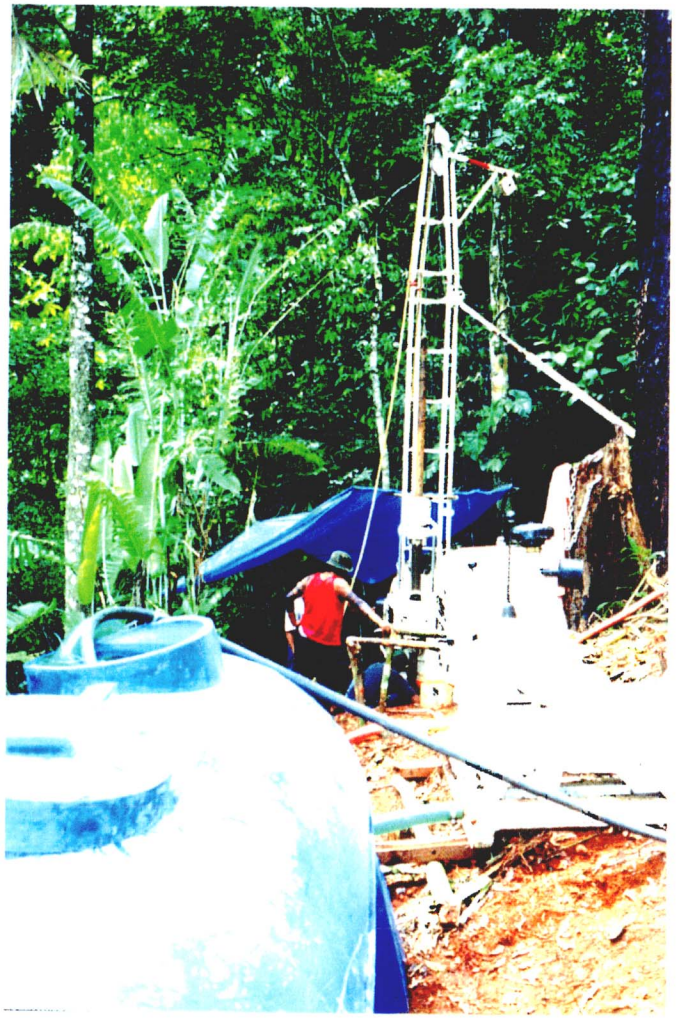


Photo 17: Drilling set-up at CH-4 on left abutment

Photo 18: Delivering drilling equipement to left abutment

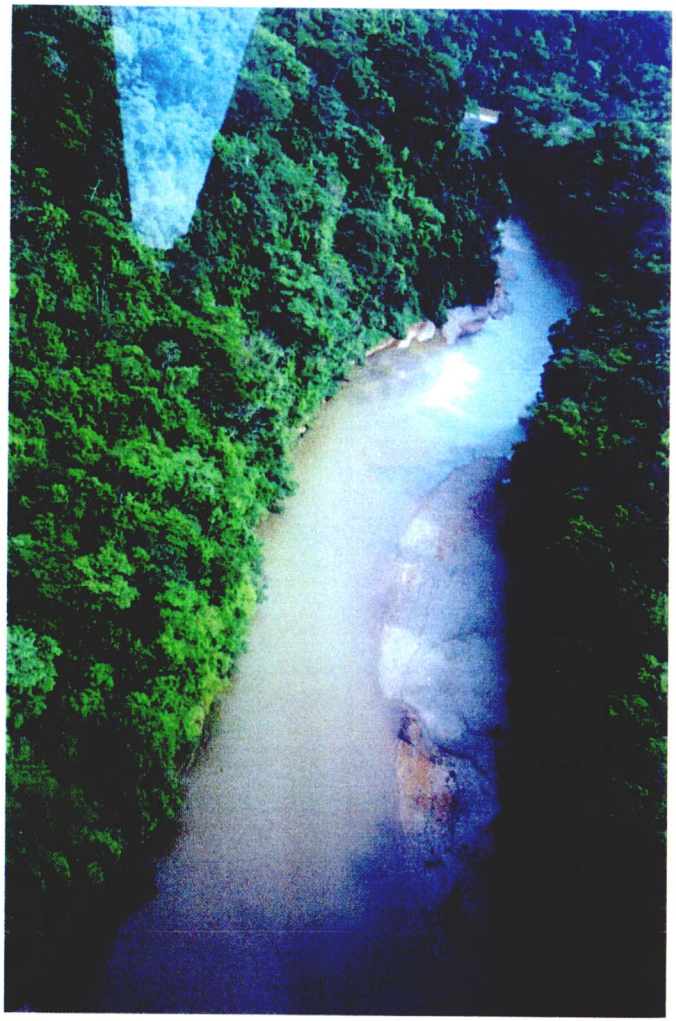
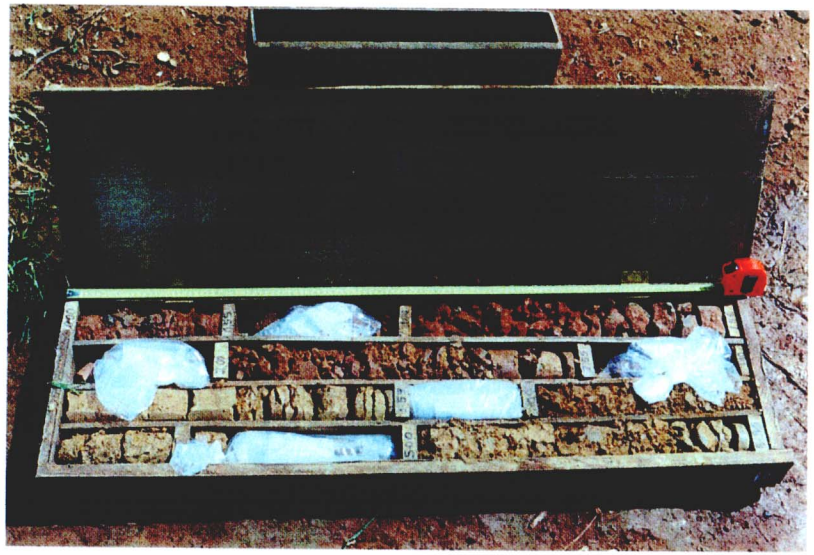
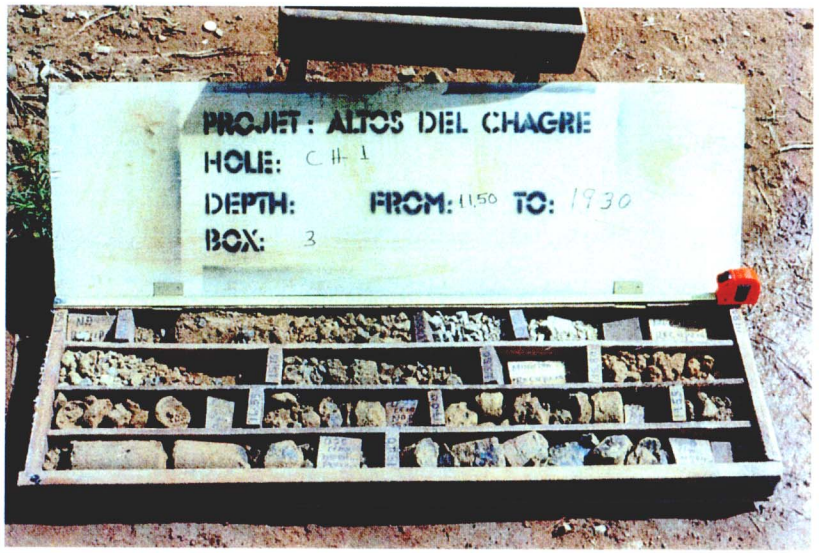


Photo 19: Alluvial deposits on Rio Chagres several km downstream of damsite near Lake Alajuela

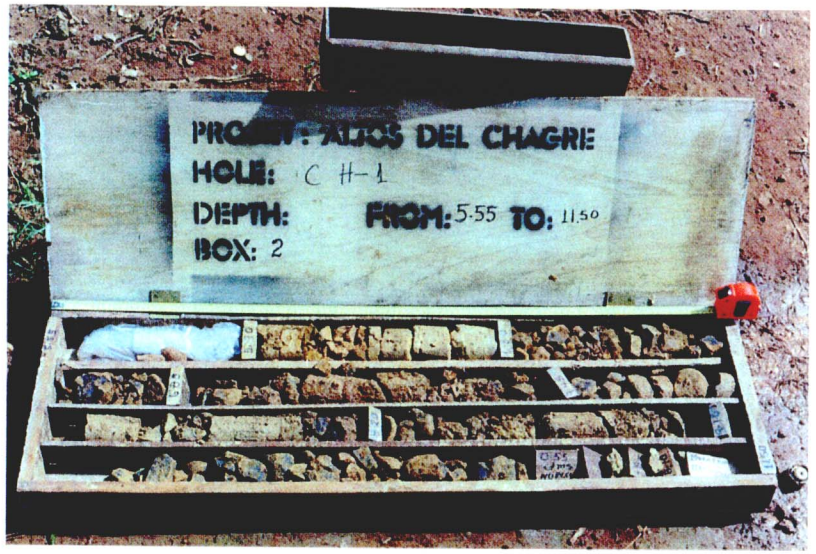
Photo 20: Alluvial deposits on Rio Chagres several km downstream of damsite near Lake Alajuela



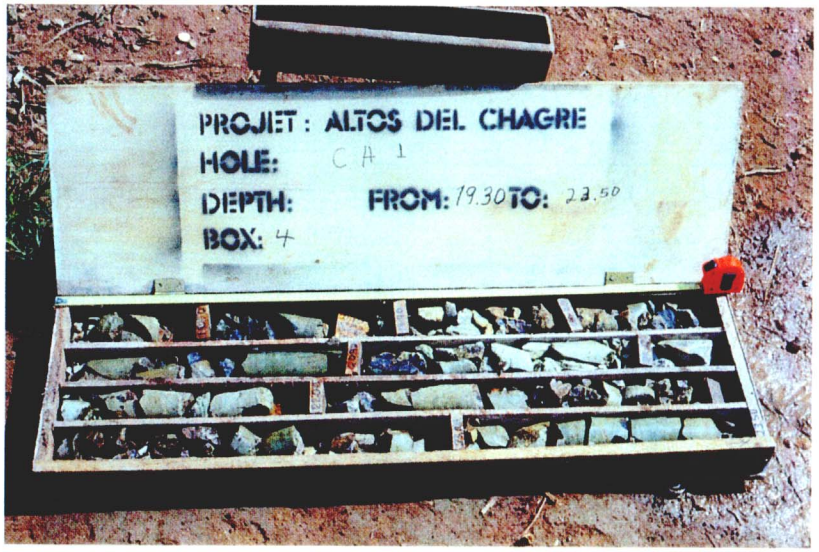
CH-1 Box 1



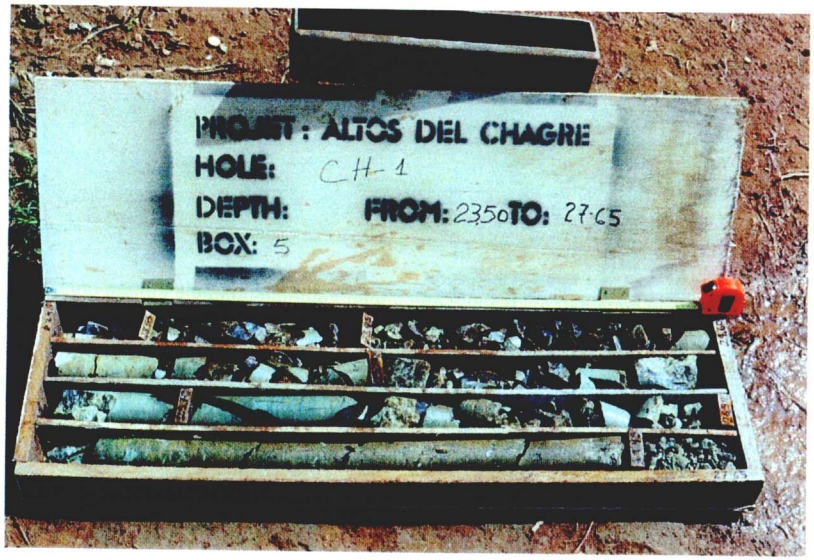
CH-1 Box 3



CH-1 Box 2



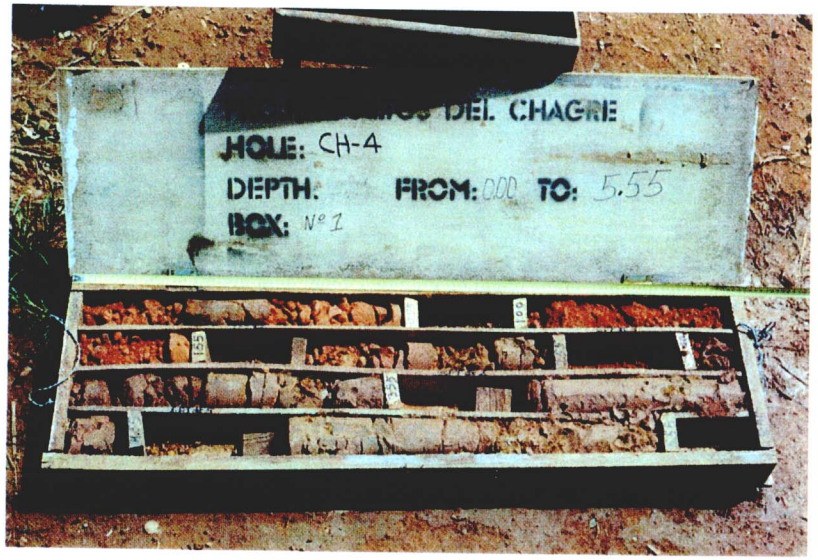
CH-1 Box 4



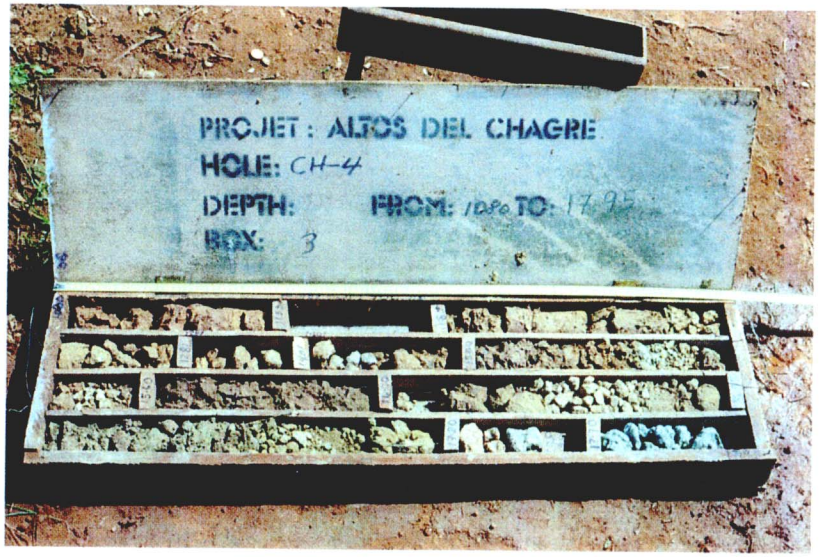
CH-1 Box 5

CH-1 Box 6

No Photographs Available For CH-2 and CH-3

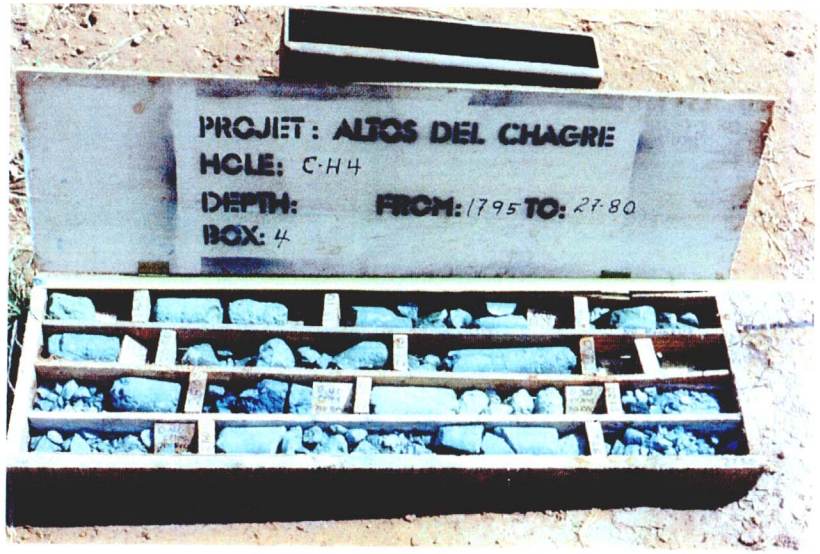


CH-4 Box 1

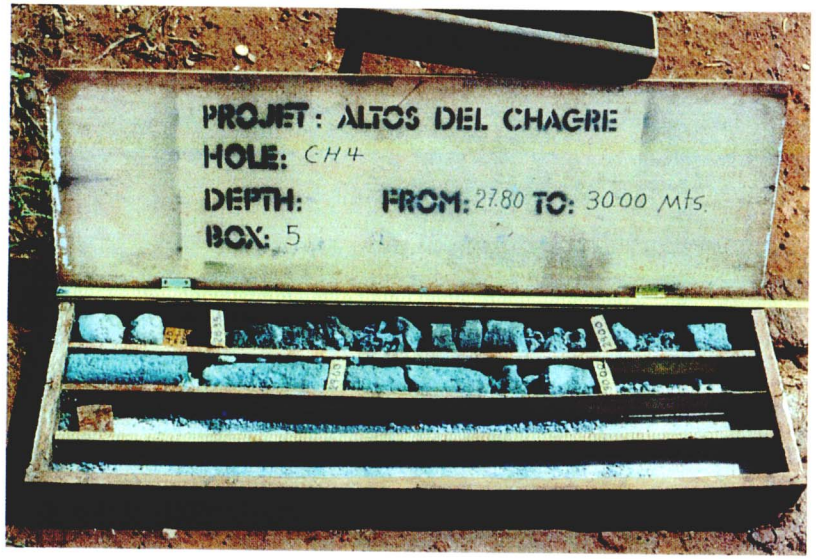


CH-4 Box 3

CH-4 Box 2



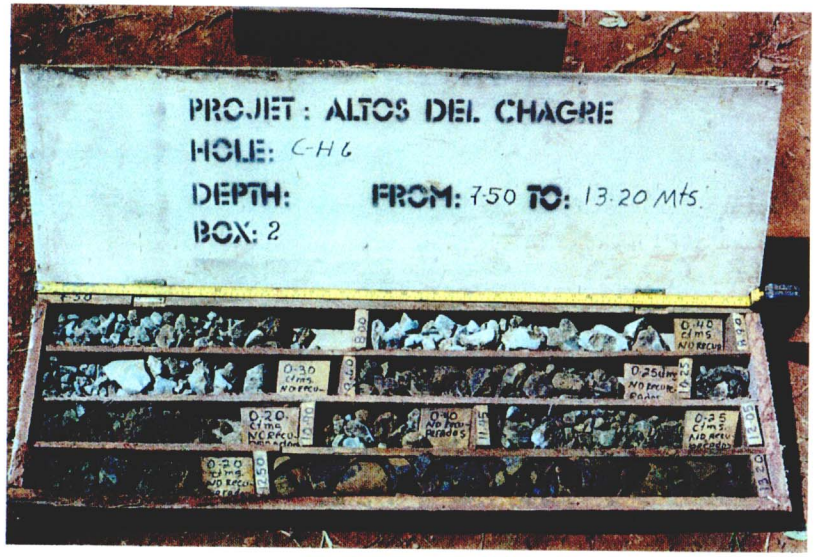
CH-4 Box 4


PROJET: ALTOS DEL CHAGRE
HOLE: CH4
DEPTH: FROM: 27.80 TO: 30.00 Mts.
BOX: 5

CH-4 Box 5

CH-6 Box 1

CH-6 Box 3



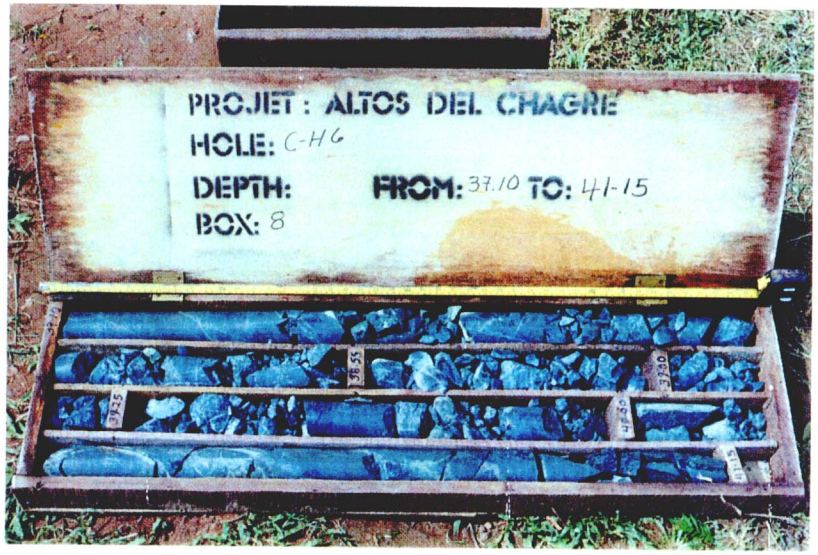
CH-6 Box 2

CH-6 Box 4

CH-6 Box 5

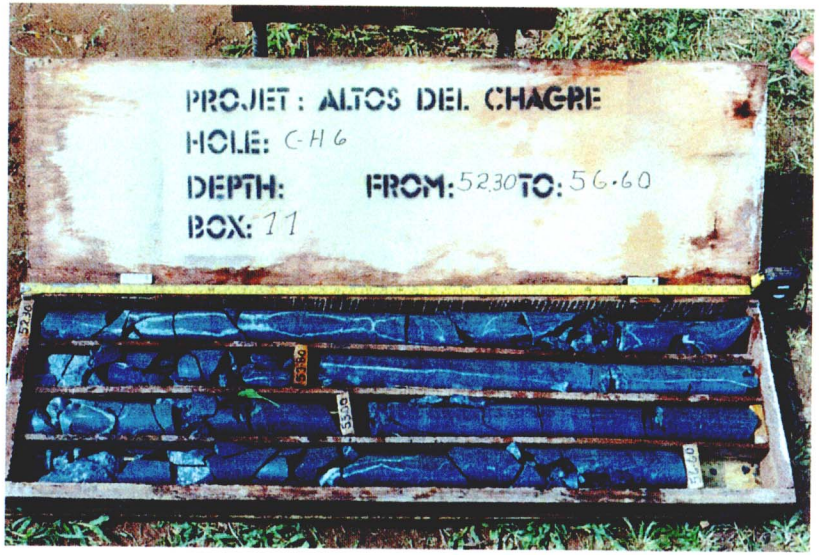
CH-6 Box 7

CH-6 Box 6



CH-6 Box 8

CH-6 Box 9

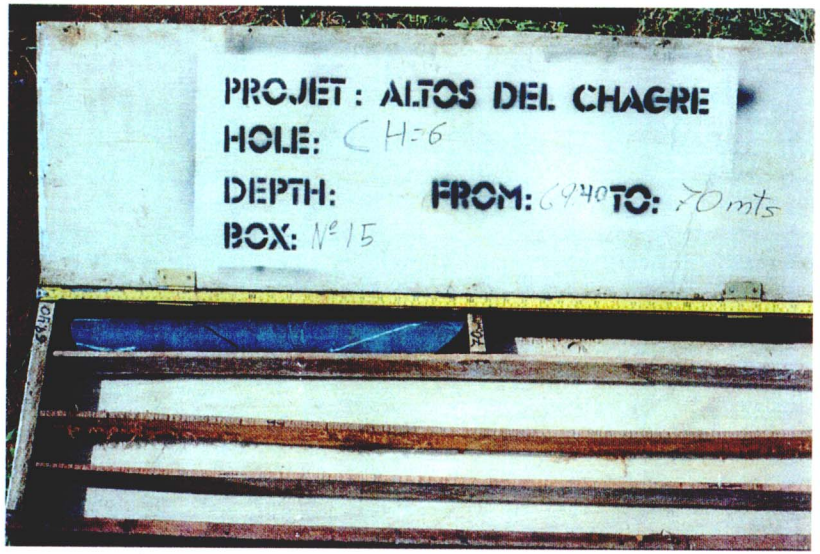


CH-6 Box 11

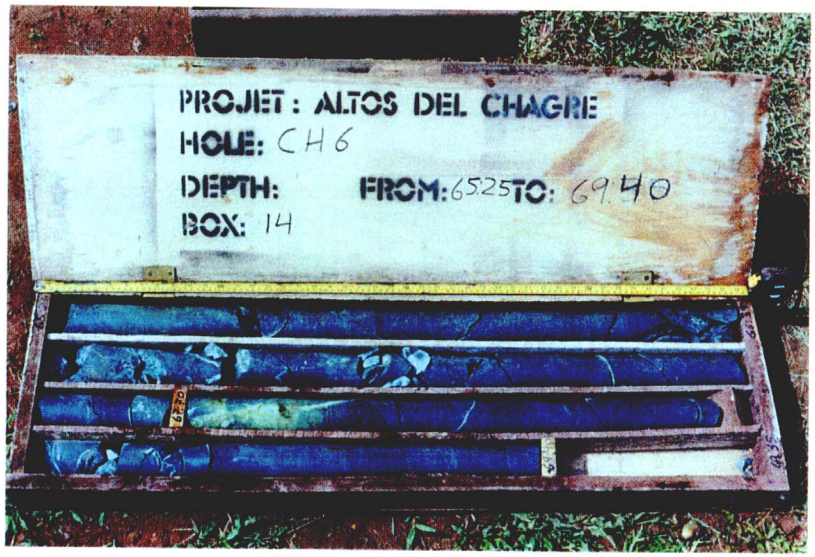
CH-6 Box 10

CH-6 Box 12

CH-6 Box 13



CH-6 Box 15



CH-6 Box 14

CH-7 Box 1

CH-7 Box 3

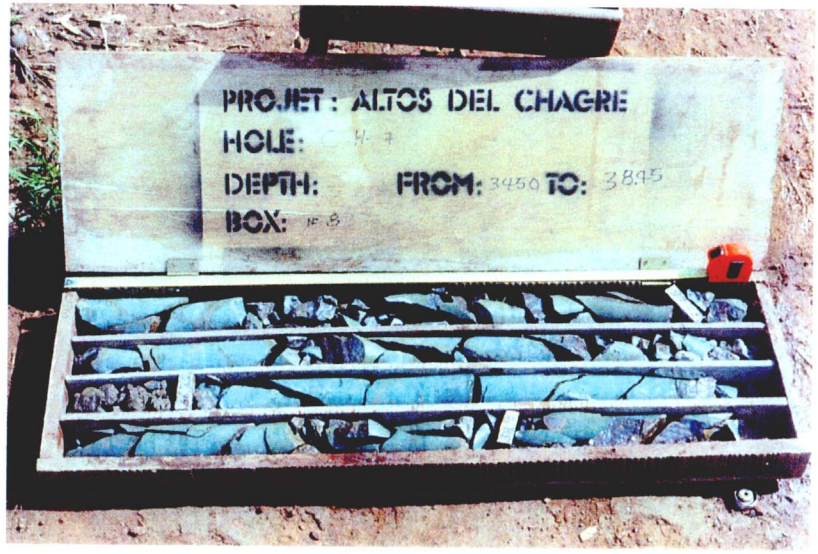
CH-7 Box 2

CH-7 Box 4

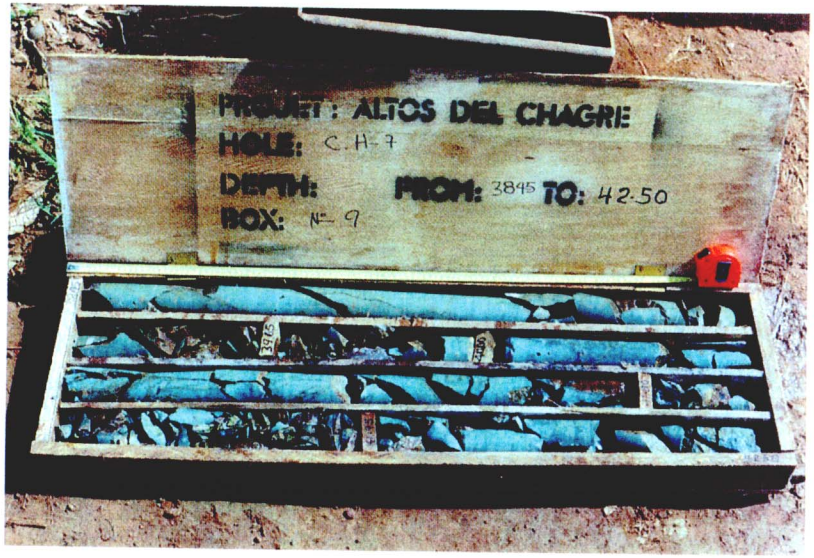
CH-7 Box 5

CH-7 Box 7

CH-7 Box 6



CH-7 Box 8



CH-7 Box 9

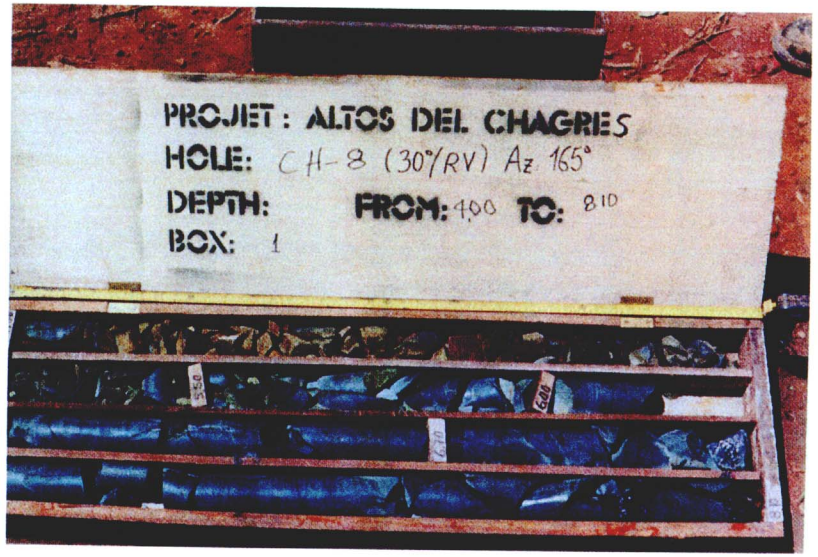
CH-7 Box 11

CH-7 Box 10

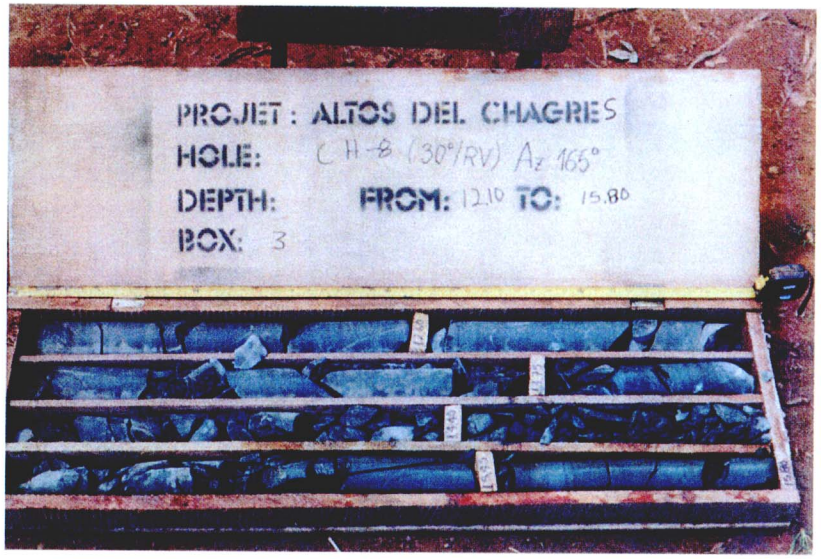
CH-7 Box 12

CH-7 Box 13

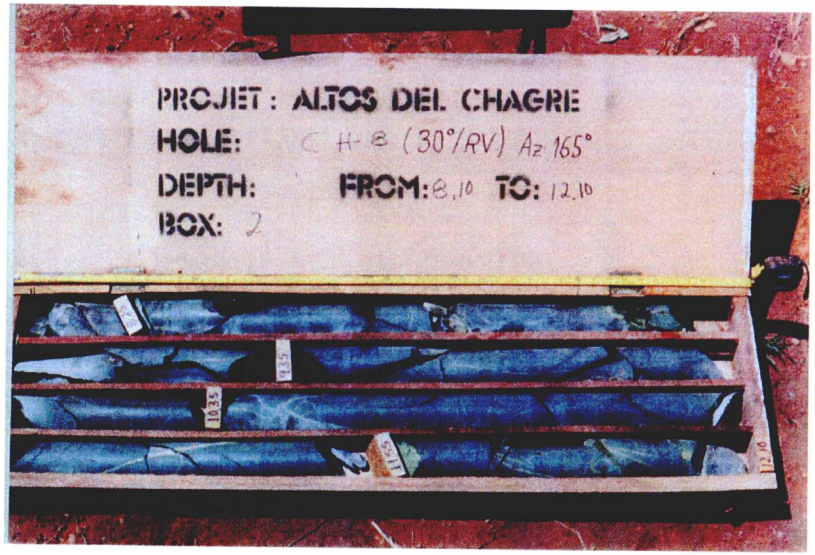
CH-7 Box 14



CH-8 Box 1

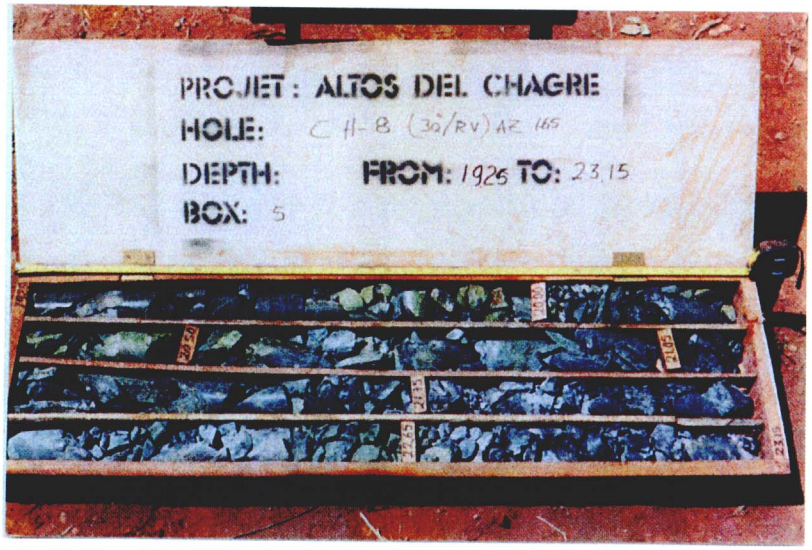


CH-8 Box 3



CH-8 Box 2

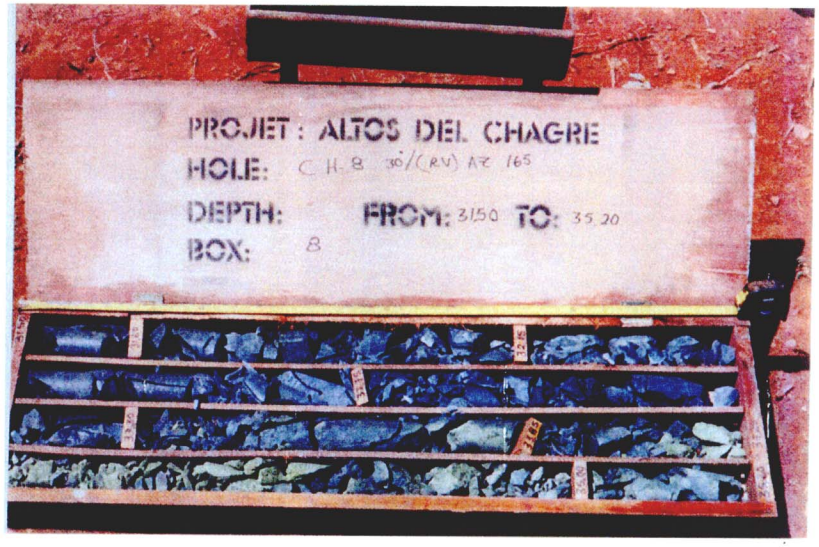
CH-8 Box 4



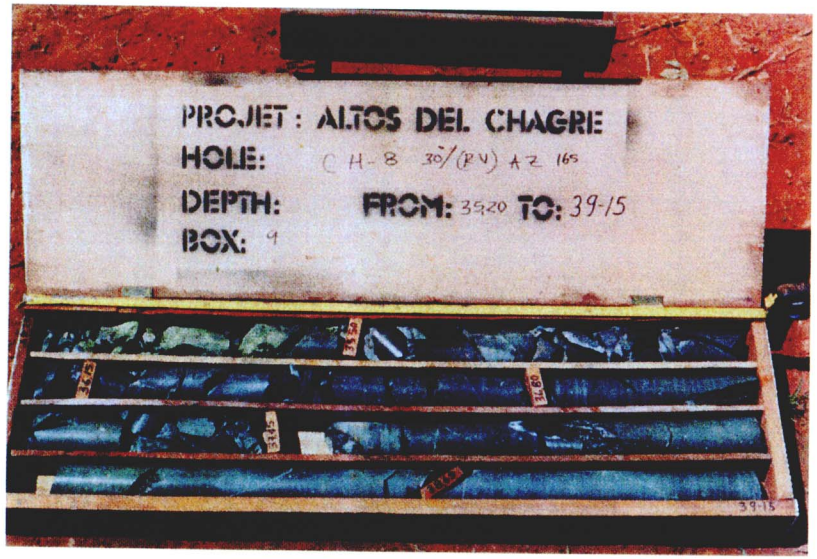
CH-8 Box 5

CH-8 Box 7

CH-8 Box 6



CH-8 Box 8



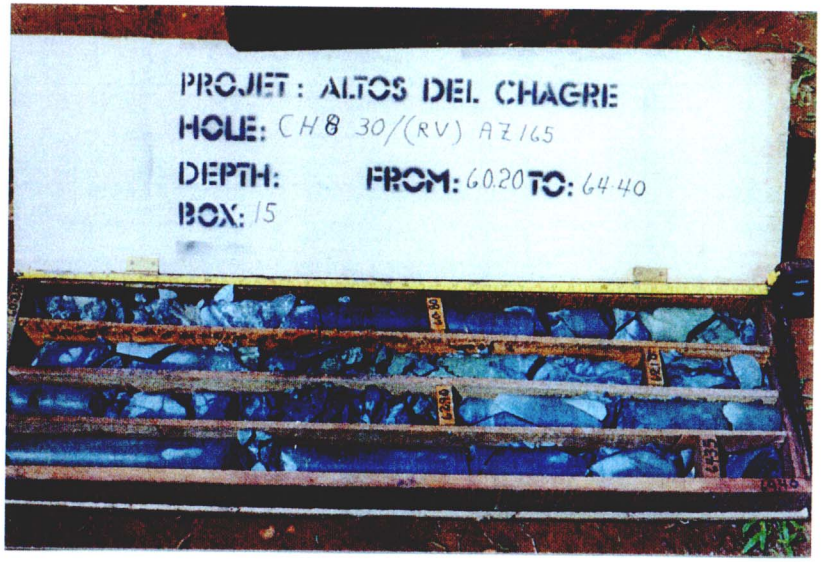
CH-8 Box 9

CH-8 Box 11

CH-8 Box 10

CH-8 Box 12

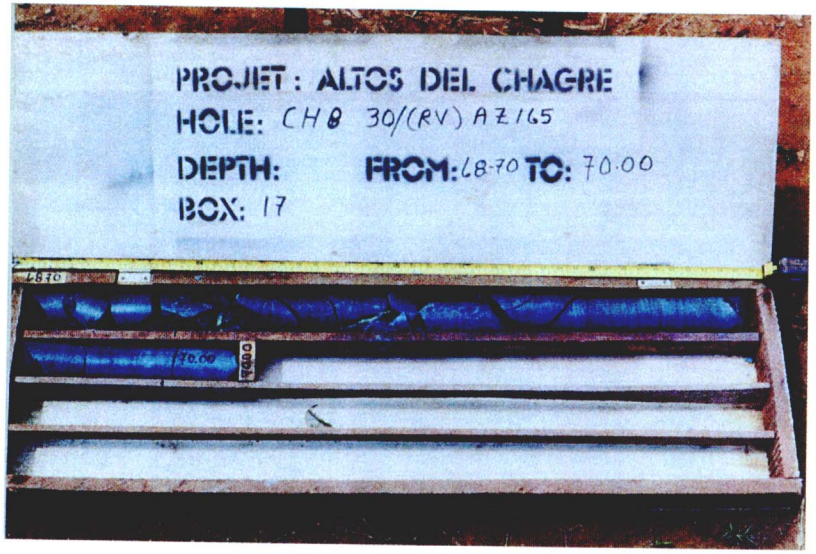
CH-8 Box 13



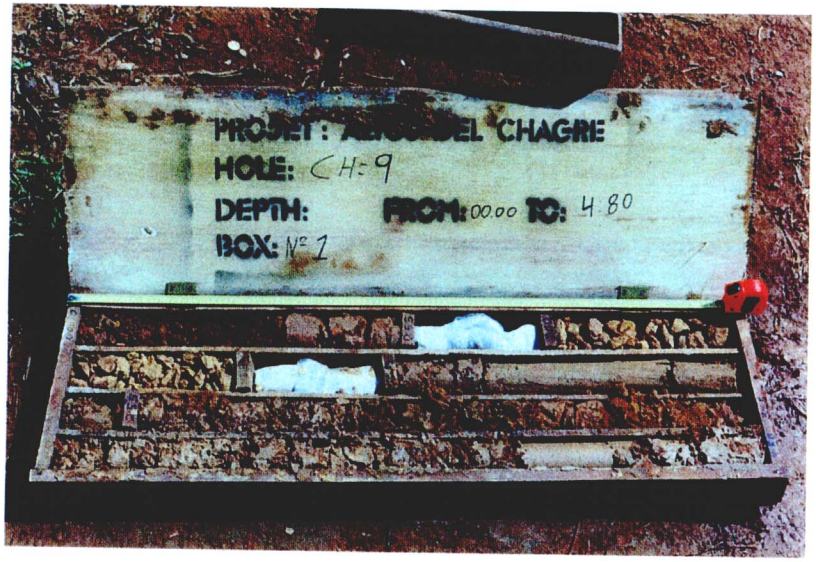
CH-8 Box 15

CH-8 Box 14

CH-8 Box 16


PROJET : ALTOS DEL CHAGRE
HOLE: CH8 30/(RV) AZ165
DEPTH: FROM: 68.70 TO: 70.00
BOX: 17
68.70
70.00

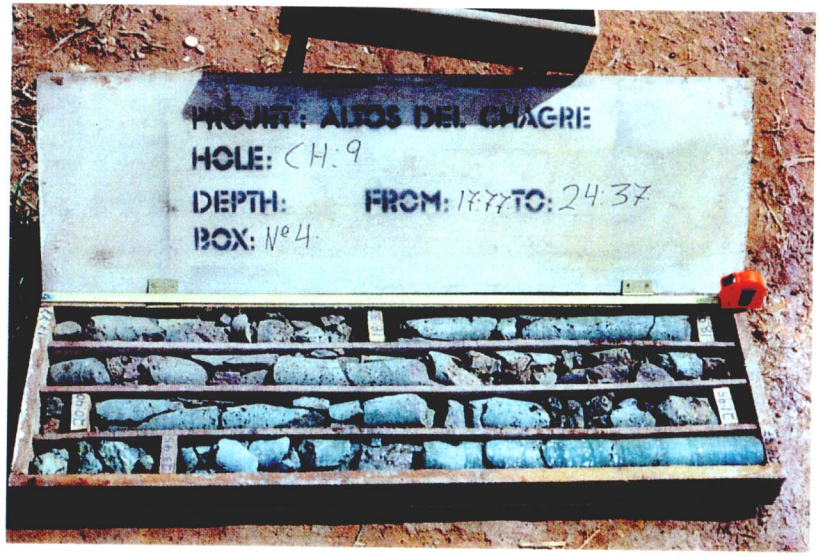
CH-8 Box 17



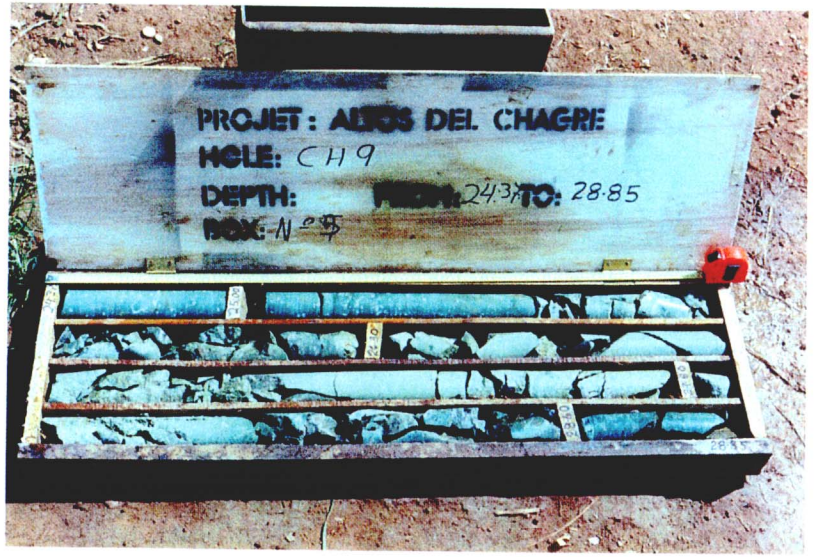
CH-9 Box 1

CH-9 Box 3

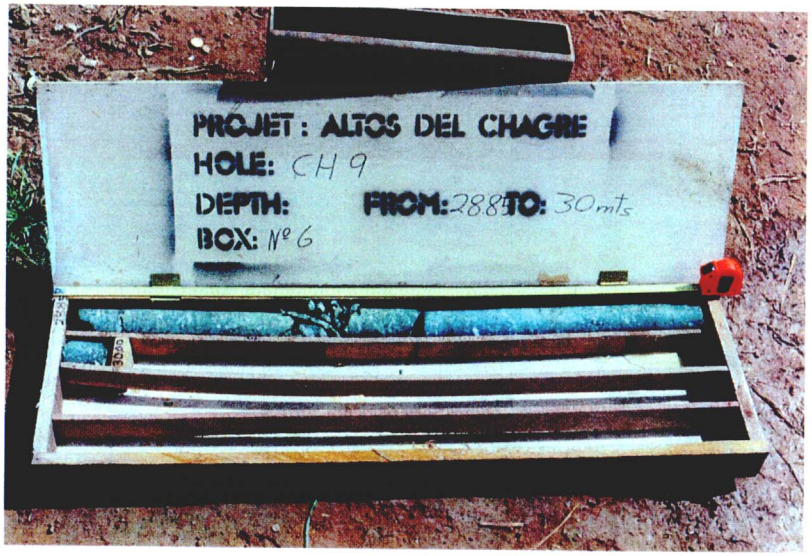
CH-9 Box 2



CH-9 Box 4



CH-9 Box 5



CH-9 Box 6