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ACP

Autoridad Del Canal De Panama
Division de Proyectos de Capacidad del Canal

Work Order No.5 Feasibility Design For The Ríos Coclé Del Norte And Caño Sucio Water Supply Projects

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MWH

In association with

TAMS

AN EARTH TECH COMPANY

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THE PANAMA CANAL

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Work Order No. 5
The Ríos Coclé del Norte and Caño Sucio
Water Supply Projects

Feasibility Study

Volume 3 APPENDICES A-C

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In association with
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FEASIBILITY DESIGN FOR THE RÍOS COCLÉ DEL NORTE AND CAÑO SUCIO WATER SUPPLY PROJECTS

Volume	Title
1	Feasibility Study of the Río Coclé del Norte Reservoir Acting in Full Regulation with the Río Indio Reservoir
2	Feasibility Study of the Río Coclé del Norte Reservoir Acting in Full Regulation with the Río Caño Sucio and Río Indio Reservoirs
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Appendix A
Hydrology

FEASIBILITY DESIGN FOR THE RÍOS COCLÉ DEL NORTE AND CAÑO SUCIO WATER SUPPLY PROJECTS

APPENDIX A

HYDROLOGY, METEOROLOGY AND RIVER HYDRAULICS

Prepared by

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FEASIBILITY DESIGN FOR THE RÍOS COCLÉ DEL NORTE AND CAÑO SUCIO WATER SUPPLY PROJECTS

APPENDIX A – HYDROLOGY, METEOROLOGY AND RIVER HYDRAULICS

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PART 1 – INTRODUCTION AND SUMMARY

1 INTRODUCTION

A project is proposed to deliver water from the Río Coclé del Norte Basin to Lake Gatun. Two primary alternatives are being considered:

- A reservoir on the Río Coclé del Norte acting in regulation with reservoirs on the Río Caño Sucio and the Río Indio, and
- A reservoir on the Río Coclé del Norte acting in regulation with a reservoir on the Río Indio.

1.1 Objective and Scope

This Appendix describes the hydrologic and river hydraulic analyses performed at a feasibility level for the development in the Río Coclé del Norte and the Río Caño Sucio basins. 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 (Coclé del Norte only)
- Impact on Water Quality (Coclé del Norte only)
- Channel Stability Downstream of the Dams (Coclé del Norte only)

A summary of previous reports pertinent to the development on the two basins was also made and review comments are given as Attachment 1.

1.2 Location and Accessibility

The drainage basins of the Río Coclé del Norte and the Río Caño Sucio are located on the west of the Panama Canal Area (see Exhibit 1). As proposed by the U.S. Army Corps of Engineers (USACE) in their Reconnaissance Report, the dam on the Río Coclé del Norte will be located approximately at latitude about 8° 59′ north and longitude about 80° 32′ west. The location is about 15 kilometers (km) inland from the Caribbean Sea (Atlantic Ocean) and about 7 km downstream from the confluence with the Río Toabré, near the mountain named Cerro Pelado. The drainage area at the dam site is about 1,594 km^2 (615.4 mi^2).

The Río Caño Sucio is a tributary of the Río Miguel de la Borda. The damsite, as selected by the USACE, will be located approximately at latitude about 8° 56′ north and longitude about 81° 18′ west. The location will be about 25 km inland from the Caribbean Sea and about 17 km above the point where two major tributaries join to form the Río Miguel de la Borda. The drainage area at the site is about 111.1 km^2 (42.9 mi^2) at the dam site.

Presently, neither dam site is accessible by road. Access is by boat or helicopter.

1.3 Unit of Measurements

The ACP has used both English and SI units in reporting the hydrologic data. Most of the data was reported in English units. These data were used as such and the results are reported in English units and the values in SI units are parenthesized. If the data received was in SI unit, the results are presented in SI units and the values in English units are parenthesized. Similarly, the exhibits and tables taken from previous reports were in mixed units. These were used as such and the sources were identified on the exhibits or tables. Most of the computations made for this study are reported in SI units only. On the exhibits, cubic meters per second and cubic feet per second are abbreviated as cms and cfs, respectively.

2 SUMMARY OF STUDIES

This report presents the hydrologic analyses made for the Río Coclé del Norte and the Río Caño Sucio basins. The analyses included determination of five hydrologic parameters including long-term monthly flow sequence, net reservoir evaporation, construction period floods, spillway design flood and depletion of reservoir storage due to sedimentation.

Two long-term monthly flow sequences were developed at the proposed dam site by Panama Canal Authority (ACP) for the period from January 1948 to December 1998. The data was updated to include the year 1999. The sequences were developed for the Río Coclé del Norte at the dam site (drainage area about 1,594 km^2), the Río Caño Sucio (drainage area about 111 km^2). The sequences was reviewed, checked for consistency and considered to be reasonable for representation of long-term future conditions. The mean annual flow of the Río Coclé del Norte at dam site was about 107.5 m^3/s. The mean annual flow of the Río Caño Sucio is estimated to be about 7.5 m^3/s.

Annual net reservoir evaporation from the reservoirs on the Río Coclé del Norte and the Río Caño Sucio is estimated to be about 1,134 mm based on studies performed by the ACP for the Río Indio reservoir.

Construction period floods at the Río Coclé del Norte dam site were based on the flood frequency analysis made for the Río Coclé del Norte at Cañoas and El Torno, and the Río Toabré at Batatilla. For the Río Caño Sucio, flood peaks were estimated using data from the Río Indio at Boca de Uracillo. The frequency analysis was performed using annual maximum instantaneous flood peaks for the available periods of record.

The transposed flood peaks at the Río Coclé del Norte dam site for the 10-, 20-, 50- and 100-year were about 2430, 2995, 3860 and 4610 m^3/s, respectively. The transposed flood peaks at the Río Caño Sucio damsite for the 10-, 20-, 50- and 100-year return periods were about 358, 385, 417 and 439 m^3/s, respectively.

The probable maximum flood (PMF) was adopted as the design flood for both the Coclé del Norte and the Caño Sucio projects. For the Coclé del Norte Project, two maximum operating pool elevations of 100 and 80 meters were considered as per current planning of the project. For the 100 meters case, the resulting PMF had a peak of about 10,550 m^3/s and 5-day volume of about 1004 million cubic meters. For the 80 meters case, the resulting PMF had a peak of about 10,460 m^3/s and 5-day volume of about 988 million cubic meters. The PMF for the Río Caño Sucio had an estimated peak inflow of 1,690 m^3/s and a 3-day volume of 78 million cubic meters based on a maximum operating pool of 100 meters.

An analysis for the depletion of the live storage of the Coclé del Norte reservoir due to sediment deposition indicated that the depletion would be negligible after 50 and 100 years of operation

Channel Stability analyses were made for "pre-project" and "post-project" conditions on the Coclé del Norte. Under post-project condition, the flood peaks would be significantly reduced. The degradation below the dam would be insignificant. However, the bed material transported by the tributaries might cause aggradation near the mouths of these tributaries because there would not be sufficiently high floods in the main channel to remove these deposits.

3 CLIMATE

3.1 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)

3.2 Average Annual Rainfall

The average annual rainfall over the Coclé del Norte and Caño Sucio basins above the respective damsites is estimated to be 2,800 mm and 3,300 mm respectively. Exhibit 2 shows a mean annual rainfall map taken from *Atlas Nacional de la Republica de Panama*

(7). The map shows that mean annual rainfall is higher in the coastal area and decreases inland.

Estoque (Estoque, *et al.*, 1985) studied the effect of El Niño on the rainfall in Panama. He 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, including the watershed in which the two proposed dam sites are located. The average annual rainfall anomaly, based on all El Niño episodes was about 8 percent below normal. In case of the 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.

Through verbal discussion with the climatologists of ACP, it was determined that in the Canal Area and neighboring basins including the basins of the Río Indio, Río Caño Sucio and Río Coclé del Norte, the effect of El Niño has been a slight to significant decrease in rainfall during the episodes. During the 1976 and 1982 episodes, the annual rainfalls at Boca De Toabré were about 3,260 and 3,891 mm, respectively (about 128.35 and 153.19 inches, respectively), compared to mean annual rainfall of about 4,393 mm (about 172.95 inches). This indicates a decrease of about 26 and 11 percent, respectively. The 1997-98 El Niño significantly decreased the rainfall in the Canal Area and over the basins of the Río Indio and the Río Coclé del Norte. In 1997 the annual rainfall at Boca de Toabré was about 79 percent of the mean annual rainfall (period 1966 to 1995).

3.3 Temperature

Mean monthly temperatures vary within about 2° C throughout the year. Mean annual temperature varies from about 26° C near the dam to about 24° 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.

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PART 2 – HYDROLOGY OF THE RÍO COCLÉ DEL NORTE BASIN

1 TOPOGRAPHY AND DRAINAGE

The Río Coclé del Norte is formed downstream from the confluence of the Río San Juan and the Río Coclecito near the town of Coclecito. Both rivers drain the northern slopes of the Cordillera Central (Continental Divide) and flow northward. The Río San Juan is larger and longer of the two rivers. It rises at an elevation of 1,300 meters above mean sea level (El. 1300). The river is very steep in the head reach, dropping about 900 meters in a distance of about 5 km (about 18 percent slope). The slope decreases downstream to about 6 percent in about 4 km. Further downstream up to the confluence with the Río Toabré, the slope is about 0.3 percent (see Exhibit 3). The drainage area of the Río Coclé del Notre at the confluence is about 674 km^2 (about 260.2 mi^2). The river basin is fan-shaped with a maximum length of about 58 km and a width of about 55 km.

The Río Toabré is the major right bank tributary of the Río Coclé del Norte and drains an area of about 805 km^2 (310.8 mi^2) at the confluence. The Río San Miguel is the major and longest tributary of the Río Toabré. It rises at about El. 900 and flows in a general northwestern direction to join the Río Toabré. Exhibit 4 shows the bed profile of the Río Toabré (including the Río San Miguel). The profile starts from the confluence of the Río Toabré and Río Coclé del Norte. The slope is about 10 percent in the 4-km long head reach, decreases to 3.3 percent in the next 6 km, and flattens to about 0.06 percent near the confluence.

The Río Cuatro Calles is another major right bank tributary, joining the Río Coclé del Norte about 2 km upstream from the dam site. The drainage area, including the area of the Río Coclé del Norte from confluence of the Río Toabré and Coclé del Norte to the dam site, is about 115 km^2 ((about 44.4 mi^2). Exhibit 5 shows the bed profile from confluence with the Río Coclé del Norte. Except for the most upstream distance of about 1.2 km, the river slope is about 0.3 percent.

The drainage area at the dam is 1,594 km^2, the sum of the three components.

2 RAINFALL ON THE COCLÉ DEL NORTE BASIN

There are nine rainfall stations in the Río Coclé del Norte basin for which historic rainfall data are available (see Exhibit 6). Daily rainfall data are available from September 1974 to December 1998. Monthly rainfall data at these stations and the stations in the vicinity towards east were generated for a 30-year period (1966 to 1995) through correlation with nearby stations in the Canal Area. The mean monthly rainfall amounts are given in Attachment 2.

The mean annual rainfall over the contributing watershed is estimated to be about 2,800 mm. Based on extended records for the *Coclecito* station, the mean monthly rainfall is estimated based on a ratio of the basin annual rainfall and the station annual rainfall times the station monthly rainfall. Mean monthly rainfall values are shown below.

Mean Monthly Rainfall, Coclé del Norte Basin (mm)

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
192	128	119	203	287	258	215	279	241	303	265	310	2,800

The mean monthly rainfall varies from a low of 119 mm in March to a high of 310 mm in December.

3 STREAMFLOW ANALYSIS

3.1 Data Sources

Monthly streamflow data for stream gaging stations pertinent to this study were obtained from ACP. The data included: measured flows, estimated flows identified with asterisks, and the flows filled-in through correlation/transposition with other stations. The period of record considered in the analysis was from January 1948 through December 1999. Tables 1 to 6 give measured monthly flows at the stream gaging stations pertinent to this study. Table 7 provides names of the stream gaging stations and the rainfall stations used in this study. Exhibit 7 shows the locations of stream gaging stations. The exhibit also shows the locations of rainfall stations as per list given in Table 7. The rainfall stations were used for the design flood study as discussed under "Spillway Design Flood".

There are three stream gaging stations in the Río Coclé del Norte basin. These include – Río Coclé del Norte at Canoas (drainage area 571 km^2, or about 220.5 mi^2)· Río Coclé del Norte at El Torno (drainage area 672 km^2 or about 259.5 mi^2) and Río Toabré at Batatilla (drainage area 788 km^2) or about 304.2 mi^2). The station at El Torno was discontinued in 1986. The locations of these stations are shown on Exhibit 6. Tables 1 to 3 give the observed monthly discharges. Mean annual flows for the period of record are about 39.5, 53.0 and 41.5 m^3/s, respectively (about 1,95, 1,72 and 1,66 ft^3/s, respectively).

3.2 ACP Analysis

The ACP performed analyses to generate a long-term monthly flow sequence on the Río Coclé del Norte at the dam site for the period from January 1948 to December 1999. The monthly flows were generated as follows:

Monthly flow data for the period from January 1948 to December 1999 (flow missing for a few months) was available for the Río Trinidad at El Chorro (drainage area 172 km^2 or 66.4 mi^2). The data for the missing months was estimated either using gage height data from a staff gage installed at the station or based on the general trend in the monthly flows. A correlation was developed between the monthly flows of the Río Ciri Grande at Los Canones (drainage area 186 km^2 or 71.8 mi^2) and the Río Trinidad at El Chorro using the concurrent period of record. The regression equation is given below:

$$\text{Los Canones} = 1.4075\ (\text{El Chorro})^{0.9983}$$

The above equation was used to fill-in monthly flows at Los Canones for the missing period from January 1959 to July 1978 plus a few other missing months in the remaining period. This resulted in monthly flows for the period from January 1948 to December 1999.

Using concurrent monthly flows of the Río Indio at Boca de Uracillo (drainage area 365 km^2 or 140.9 mi^2) and of the Río Ciri Grande at Los Canones, the following regression equation was developed.

$$\text{Boca de Uracillo} = 2.865\ (\text{Los Canones})^{0.9606}$$

The above equation was used to generate the monthly flow data at Boca de Uracillo for the period from January 1948 to July 1979 and June to December 1999.

Using concurrent monthly flows of the Río Indio at Boca de Uracillo and Río Toabré at Batatilla, the following regression equation was developed.

$$\text{Toabré at Batatilla} = 2.4037\ (\text{Indio at Boca de Uracillo})^{\wedge 0.9029}$$

The above equation was used to extend the monthly flows of the Río Toabré at Batatilla.

Using concurrent monthly flows of the Río Coclé del Norte at El Torno and the Río Toabré at Batatilla, the following regression equation was developed.

$$\text{Coclé del Norte at El Torno} = 6.0965\ (\text{Toabré at Batatilla})^{\wedge 0.5948}$$

The above equation was used to fill-in and extend the monthly flows of the Río Coclé del Norte at El Torno.

Monthly flows at the dam site were developed using the following equation:

$$\text{Dam site flows} = ((\text{Batatilla flows}) + 1.1384(\text{El Torno flows})) * 1.0264$$

The above equation was discussed with the hydrologists of ACP. The above method was used to give more weight to the flows of the Río Coclé del Norte. This is because the Río Coclé del Norte receives more rainfall compared to the rainfall over the Río Toabré basin.

3.3 Review of the APC Analysis

The streamflow analysis performed by ACP for the Coclé del Norte basin was reviewed. The correlation coefficients for the four regression equations shown above varied from about 0.90 to 0.95. ACP performed mass curve and double mass curve analyses using the monthly flow series at various stations to check the consistency of the data. The mass curves of the monthly flows indicated that the data are consistent.

MWH made an independent check of the equation used to compute monthly flows at the damsite. Using conventional procedure of transposing flows by a combined ratio of drainage area and mean annual rainfall, the estimated flows were about 1 to 3 percent less than the flows derived by ACP. This was considered to be an insignificant difference. Therefore, the monthly flows estimated by ACP were adopted.

The ACP procedure to develop a correlation between Los Canones and El Chorro, between Los Canones and Boca de Uracillo, between Batatilla and Boca de Uracillo, and between El Torno and Batatilla, was reasonable. This is because the correlations were developed step by step from a high rainfall area to a lower rainfall area. The Río Trinidad is east of the Río Indio and Río Coclé de Norte is on the west of the Río Indio. The rainfall decreases from east to west. Therefore, the approach is logical and acceptable.

3.4 Annual Streamflow and Monthly Streamflow Sequence

The estimated mean annual flow of the Río Coclé del Norte at the damsite, as determined by the foregoing analysis, is estimated to be 107.5 m^3/s. Long-term monthly discharges (in m^3/s and ft^3/s units) for the Río Coclé del Norte at the dam site are given in Tables 8. Exhibits 8 and 9 show the mass curve and the time series of annual flows for the Río Coclé del Norte at the dam site. These exhibits show that the annual flows are consistent, homogeneous and there is no apparent trend in the data. However, there are significant variations in flows from year to year. The highest flow occurred in 1970 and the lowest in 1997. The low flow was due to the El Niño episode recorded in 1997-1998.

3.5 Streamflow Characteristics

The wet period is generally from October through December but quite often, high flows can occur in the month of January and September. The months of low flows are from February to April.

Generally, floods 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 generally in the months of June through August. The highest floods of record at Canoas (period from 1983 to 1999), El Torno (period from 1958 to 1986) and Batatilla (period from 1958 to 1999) were about 1,356 m^3/s (47,900 ft^3/s) in June 1994, 3,116 m^3/s

(110,000 ft^3/s) in January 1990 and 2,633 m^3/s (93,000 ft^3/s) in January 1970, respectively.

The potential firm yield of the Río Coclé del Norte at the dam site was estimated using mass curve analyses (as a spreadsheet) and the monthly flow data from 1948 to 1999. For selected constant yield rates varying from 17.0 m^3/s to 141.6 m^3/s), the required active storage was determined. The yield curve, which is shown on Exhibit 10, shows that the firm yield at the dam site would be about 99.1 m^3/s, or about 92 percent of the mean annual flow and would require an active storage of about 1,835 million cubic meters (MCM).

3.6 Flow Duration Curves

Daily flow data were available for the Río Toabré at Batatilla (from 1968 to 98) and the Río Coclé del Norte (from 1984 to 98). These data were used to develop flow duration curves for the two stations. The curves are shown on Exhibits 10 and 11, respectively. The minimum observed daily flows were about 0.1 and 3.1 m^3/s, respectively (3.5 and 109.5 ft^3/s, respectively). Flows exceeding 90 and 95 percent of the time were estimated to be 7.3 and 5.4 m^3/s, respectively (257.5 and 190.7 ft^3/s, respectively) at Batatilla, and about 13.7 and 9.9 m^3/s, respectively (483.8 and 349.6 ft^3/s, respectively) at Canoas.

Daily flow data were not generated at the dam site. The flow duration curve based on monthly data does not provide a good indication of low flows. To estimate the flows exceeding 90 and 95 percent of the time at the dam site, the flows corresponding to these percentages were transposed from Canoas and Batatilla and combined. The flows at Canoas were transposed to the dam site using drainage area ratio and to this the flows at Batatilla were added. The resulting flows were about 26.1 and 19.3 m^3/s, respectively (921.7 and 681.6 ft^3/s, respectively). These flows were judged to be reasonable.

3.7 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, the absence of long records, potential long-term variation in rainfall and runoff, and topographic changes brought by man make it rather difficult to make precise forecasts.

For drought analysis, data is selected by one or two methods: either one 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 are chosen, regardless of when they occurred. With the latter method, the number of values chosen need not equal 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 overlapping of data and repeated appearance of extreme values. Thus, in the analysis of droughts lasting 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 Coclé del Norte.

Monthly flows of the Río Coclé del Norte at dam site were arrayed in one column. Running totals of 6-, 12-, 18- and 24-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 selecting or excluding.
- 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 divided by the order", that is, "52/1" (Stall, 1964). The return period for the second lowest value will be "52/2 = 26."

In case of 6-month period, the values were more than 52, the years of record. In this case only 52 lowest values were used. The lowest values for the selected duration are given in

Table 9. The table also shows the recurrence intervals. Exhibits 12 to 15 show the frequency curves.

The 6-, 12-, 18- and 24-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 52/3 = 17.3 years. Thus, it can be said that in any year the probability is 1 in 17.3 for the start of a 12-month period during which the total flow would be as low as 2,220 MCM.

4 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

Since ACP with the help of COE had computed the net reservoir evaporation rates, the above procedure was not used. ACP derived the net reservoir evaporation rates using the historic evaporation data of Gatun Lake. The data was judged to be reasonable. Due to proximity of Gatun Lake to the Río Coclé del Norte reservoir, the net evaporation data derived for Gatun Lake was used for this study. The total net reservoir evaporation is estimated to be 1,134 mm/yr, and the monthly rates are given in Table 10.

5 CONSTRUCTION PERIOD F LOODS

5.1 Previous Regional Flood Analysis

The *Instituto de Recurcos Hidraulicos y Electrificacion* (IRHE) performed a regional flood frequency analysis in June 1986 for the river basins west of about 79° west longitude in the Republic of Panama. This study is discussed in Attachment 1.

Annual maximum instantaneous peaks for the Río Coclé del Norte at El Torno and Cañoas, and the Río Toabré at Batatilla were available for 16 years (1970 to 1985). The data for Cañoas was partly estimated.

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 and return periods were developed. According to these relationships, the Río Coclé del Norte was zone III. The flood peaks corresponding to various return periods listed in this report are shown in Table 11. The flood peaks were estimated up to return period of 10,000 years.

5.2 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 annual largest recorded floods at a representative stream gaging station. For the present analysis, the monthly instantaneous flood peaks for the Río Coclé del Norte at Canoas and El Torno, and Río Toabré at Batatilla were obtained from ACP. The data are given in Table 12 to 14. The data for some months and/or years are missing. The annual peaks derived from these data are for 16 years at Canoas, 26 years at El Torno and 35 years at Batatilla. The maximum instantaneous observed peaks were 1,356 m^3/s or 47,900 ft^3/s (June 1994) at Canoas, about 3,116 m^3/s or 110,000 ft^3/s (January 1907) at El Torno and about 2,633 m^3/s or 93,000 ft^3/s at Batatilla.

5.3 Current Analysis

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 of the Río Coclé del Norte at Canoas. A computer program developed by the United States Army Corps of Engineers, Hydrologic Engineering Center was used. The results are given in Table 11.

The generalized extreme value (GEV) distribution was also fitted to the data to compare the results from this distribution with that obtained by using LP III distribution. A computer program developed by Environment Canada (1994) was used. The results are also given in Table 11. Exhibits 16 and 17 show the frequency curves based on LP III and GEV distributions, respectively.

The skew coefficient of the flood peaks was about 0.52 and that of log-transferred values was about –0.02. The flood peaks estimated by LP III were low compared to those obtained by using GEV. However, based on a visual judgment of Exhibits 16 and 17, both the distributions indicated reasonable goodness of fit. For a conservative estimate of the flood peaks, the values resulting from GEV distribution were adopted.

The above analysis was repeated using the flood peaks of the Río Coclé del Norte at El Torno and Río Toabré at Batatilla. The results are given in Table 11. Exhibits 18 to 21 show the frequency curves. For both the stations, the flood frequency data based on GEV distribution was adopted.

The flood estimates by the IRHE (based on regional analysis) and site-specific estimates discussed above were compared. For the Río Coclé del Norte at Canoas and El Torno, and the Río Toabré at Batatilla, the 20-year flood peaks estimated by the IRHE were 2,144, 2,357, and 2,525 m^3/s respectively, compared to the site-specific estimates of 1,320, 2,160, and1,810 m^3/s respectively. The IRHE estimates are higher for all sites and return periods except for El Torno above a return period of 20 years. It was concluded that the site-specific estimates were a better representation of the construction period floods and MWH's estimates by the GEV distribution were adopted for the subsequent studies.

Realizing that flood protection works might be designed for protection during dry season, flood frequency analysis was also performed for the dry period. From a review of the monthly flood peak data, the dry season was judged to be the months of January, February and March. The flood frequency data based on GEV distribution was estimated and is given in Table 15.

5.4 Transposition of Flood Peaks to Dam Site

The dam site will be located downstream from the confluence of the Río Coclé del Norte and Río Toabré. The rainfall over the Río Coclé del Norte basin is higher than that over the Río Toabré basin. Therefore, flood peaks at the dam site should include effect of the variation of extreme rainfall over both basins. Since the period of record at El Torno was longer than that at Canoas, the flood peak data at El Torno was used. The following procedure was used to derive the flood peaks at dam site using the estimated flood peaks at El Torno and Batatilla.

A general procedure for transposition of flood peaks from a gaged location to an ungaged location is to use coefficients of empirical relationships assuming that these coefficients remain constant for hydrologically and meteorologically similar drainage basins. Commonly used relationships are given below.

Creager's Formula (Creager, 1950)

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

Rodier's Formula

$$K = 10 * (1- ((\log^{Q} - 6) / (\log^{A} - 8))) \quad \text{(Rodier, 1985)}$$

'K' and 'C' are coefficients, A is the drainage area in km^2 and Q is flood peak in m^3/s. The original Creager's relationship was in English units, relating discharge per unit area with the area. The above form in SI units was developed by MWH.

The values of 'K' and 'C' were computed for floods of various return periods. Table 11 shows the values. Both coefficients increased with the increase in flood magnitudes. The values of both coefficients were consistent. Either of the two coefficients could be used for transposition. The values of K were used.

For the El Torno station (draining an area of relatively high rainfall), the values of K were greater than that for Batatilla (draining an area of relatively low rainfall). Considering the rainfall variation, the mean of two values for a given return period was used for transposition. Table 15 shows the mean values of K and the flood peaks derived at the dam site.

5.5 Flood Hydrographs

Flood hydrographs of 20- and 50-year return periods were developed for the Río Coclé del Norte at dam site using the following procedure:

The historic floods (hourly discharge data) of the Río Coclé del Norte at Cañoas and at El Torno, and the Río Toabré at Batatilla were reviewed. The data showed that the duration of floods could vary from about 1 to 2 days.

The annual maximum one- and two-day flood-volumes were determined for the three stations.

A volume-frequency analysis was performed (the results are given in Table 16).

The 1-day and 2-day flood volumes at the dam site were estimated as sum of flood volumes at El Torno and Batatilla adjusted for difference in drainage area. The 20- and 50-year flood volumes for 1-day duration were about 1,490 and 1,950 cubic meters per second - day (cms-day), respectively. The 2-day volumes were about 2,370 and 3,100 cms-day.

The observed hydrographs at the two stations were plotted (see Attachment 3). The shape of the hydrographs was reviewed. Although the peaks and volumes of the hydrographs were quite different yet the shape (rising and falling limbs) had a reasonable similarity. The single peaked historic flood of December 1995 was selected to shape the flood hydrographs of 20- and 50-year return periods.

The historic flood was adjusted to represent flood peaks and volumes equal to the 20- and 50-year floods.

The derived floods are shown on Exhibits 22 and 23. Table 17 gives the ordinates of the hydrographs.

6 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 Coclé del Norte 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 the PMP to a PMF
- Evaluation of the PMF

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

6.1 Probable Maximum Precipitation (PMP)

6.1.1 Rainfall Regime

In Panama, October and November are the heaviest rainfall months. This period of heavy rainfall is associated with the southward traverse of the inter-tropical convergence zone (ITCZ). November dominates 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 hurricanes in Panama. A necessary condition for a hurricane is a coriolis force sufficiently strong to cause the winds to spin around the center of a low-pressure area. On the equator, the Coriolis force is zero and still relatively weak within 10° of the equator. Therefore, only rarely there are hurricanes within 10° 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 the NWS.) However, the influences of 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 200 to 500 mi^2. General storms can cover larger areas. The months of October through December are the season of large-area rainfalls. Nearly all-major storms reported in the 1965 and 1978 reports occurred in this period. 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, 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 mean annual rainfall map shown on Exhibit 2. The pattern is controlled by the local topography. A generalized map of the topography in the Canal Area and in the drainage basins of the Río Indio, Río Coclé del Norte and Río Caño Sucio is shown on Exhibit 24.

6.1.2 Methods for Estimating PMP

Two approaches were used to estimate the PMP for the Río Coclé del Norte basin. These are listed below:

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 Indio and Río Coclé del Norte basins including the Canal Area. Maximize, transpose and locate the most sever storm over the Río Coclé del Norte basin to produce critical flood conditions.

Extend the 24-hour, 10-mi^2 PMP developed in the NWS 1978 Report over the Río Coclé del Norte basin, use depth-area-duration curves of WS 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.

6.1.3 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. Exhibit 25 shows the relationship.

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 the drainage basins of the Río Indio and The Río Coclé del Norte. Exhibit 7 shows the locations of the stations as per Table 7. The new data points when checked with Exhibit 25 did not show 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 exit) for preparing the October-December isohyetal map.

6.1.4 Mean October-December Rainfall Map

The mean October-December rainfall developed by the NWS for their 1978 Report was checked in two steps.

First, 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 zone. Therefore, the isohyetal pattern was not changed. Secondly, the 30-year mean rainfall amounts in the Río Indio and the Río Coclé del Norte were plotted. The data points were used to extend the previous map towards the west. The relationship between elevation and mean October-December rainfall and the general topography map was used to guide this extension. The derived map is shown on Exhibit 26.

6.1.5 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. Storms with more than 6 inches (150 mm) rainfall in a day or 10 inches (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 27 to 36.

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

Exhibits 27 to 36 were reviewed and compared with the general topography (Exhibit 24). The centers of most of the storms were near Lake Madden. The heavy rainfall was caused due high-elevation land masses on the east and north of the lake. Some of the storms had their centers near or at elevations varying from 500 to 1,000 feet (about 150 to 305 meters) near Lake Gatun. These storms were judged to be transposable to the Río Coclé del Norte basin where major part of the basin is at altitudes from 500 to 1,000 feet. The selected storms included:

November 7-9, 1931
November 27-29, 1932
November 5-7, 1939
December 18-20, 1943
December 12-14, 1944

These storms were carefully reviewed and the storm of November 7-9, 1931 was judged to be critical in respect of rainfall amount and aerial extent. This storm was selected and transposed to the middle of the Río Coclé del Norte basin where the elevations vary from about 500 to 1,000 feet (150 to 305 meters). The transposition is discussed under "PMP Estimate".

For the major storms since 1976 that occurred over the Río Coclé del Norte basin, daily rainfall data were obtained for the stations in the Canal Area, Río Indio basin and Río Coclé del Norte basin. The following five storms, centered over the Río Indio and/or the Río Coclé del Norte basins, were selected.

December 4-6, 1981
December 10-12, 1981
December 4-6, 1985
January 13-15, 1996
November 27-29, 1996

The rainfall amounts associated with these storms and recorded at various stations are given on Exhibits 37 to 41. The storm of December 4-6, 1981 had heavy rainfall over the Río Coclé del Norte basin with the storm center at Boca de Toabré (three-day rainfall about 362 mm (about 14.3 inches)). This storm produced the heaviest rainfall over the Río Coclé del Norte basin, of all the storms reported in the NWS 1978 Report. An isohyetal map of this storm was prepared and is shown on Exhibit 42.

6.1.6 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 for the stations at El Chorro and Los Canones, located east of the Río Coclé del Norte basin, indicated that the actual maximum rainfall duration in the major three-day storms (based on daily observations taken at 07-09 hours in the morning) was about 48 hours. For this reason, a duration of 48 hours was considered appropriate for all the storms plotted on Exhibits 31 to 42. This duration was also adopted for the PMP.

6.1.7 PMP Estimate

Following the first approach for estimating the PMP, presented in Section 7.1.2, the isohyetal maps of the November 7-9, 1931 (Exhibit 29, the most critical storm transposable to the Río Coclé del Norte basin from NWS 1978 Report) and the storm of December 4-6, 1981 (Exhibit 42, the critical storm over the Río Coclé del Norte basin) were compared. The December 4-6, 1981 storm was centered over the Río Coclé del Norte basin. The three-day rainfall at the center of the storm was about 350 mm (13.8 inches). The storm center covered a small area. The basin average rainfall was estimated to be 190 mm (about 7.5 inches)

For the November 7-9, 1931 storm, the three-day rainfall at the center of the storm was about 22 inches (559 mm) and the center covered a relatively large area. The next lower isohyet of 20 inches (508 mm) covered significantly large area (Exhibit 29). Thus, the storm of 7-9, 1931 was the most critical and, therefore, was transposed and located over the Río Coclé del Norte basin as shown on Exhibit 43. The storm center was placed approximately at altitude of about 500 feet (150 meters) with nearly same orientation as at the place of occurrence of the storm. This resulted in a basin average rainfall of about 16.3 inches (about 414 mm). This is significantly higher than the 7.5 inches (190 mm) basin average rainfall derived from the December 4-6, 1981 storm.

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 mechanism which 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, the storm of November 7-9, 1931 was maximized in place as discussed below.

The U.S. Weather Bureau (1965) estimated seasonal variation of maximum 12-hour persisting dew points. This variation is given in Table 18. This table was adopted for this study in the absence of any additional data. Thus, the maximum dew point of 77° F was selected for the month of November. The elevation at the place of occurrence is about 500 feet. Using this elevation the 1,000 mb dew point was about 78.1° F. The corresponding precipitable water was estimated to be 3.23 inches (about 82 mm).

Dew point data during the storm is not available. From the dew point data available for the station at FAA in the Canal Area, it was determined that the dew points could vary from 71° to 69° F during November storms. For a conservative estimate of the maximization factor, a dew point of 69° F was adopted. Using an elevation of 500 feet, the 1,000 mb temperature was about 70.2° F. The precipitable water corresponding to this was about 2.18 inches (about 55 mm).

The resulting maximization factor was about 1.5 (3.23/2.18). This factor was used for maximization.

The transposition factor was based on the mean October-December isohyetal map. The basin average October-December rainfall for the Río Coclé del Norte basin, with the basin oriented over the place of occurrence of the storm (see Exhibit 44), was about 42.0 inches (1067 mm). For the Río Coclé del Norte at its own location, the basin average October-December rainfall was about 41.3 inches (1049 mm). This resulted in a transposition ratio of 0.98 (41.3/42.0). Thus the maximized and transposed PMP for the Río Coclé del Norte basin was about 24.0 inches (16.3*1.5*0.98) or 610 mm.

Using the second approach discussed in Section 7.1.2, the 24-hour, 10 mi^2 PMP map given in the NWS 1978 Report (Exhibit 45) was extended towards west to cover the Río Coclé del Norte basin. The following procedure was used for the extension.

For about ten rainfall stations in the Río Coclé del Norte basin and its vicinity, annual maximum daily rainfall data were obtained. The stations included: Boca de Toabré, Chiguiri Arriba, Coclé del Norte, Toabré, San Lucas, Sabanita Verde, Coclecito, Santa Ana, Miguel de la Borda and Boca de Uracillo. The stations are shown on Exhibit 7 with names given in Table 7. The period of record varied from about 18 to 41 years.

Point PMP at each station was determined using Hershfield's method (1963). The values of the point PMP varied from station to station. Some values were quite consistent with the values from the NWS point PMP map. The value at Toabré, located at relatively high altitude, was high compared to other values. The value was retained considering orographic effect due to high altitude of the station.

Keeping in mind the local topography and the trend of the point PMP lines on the NWS map, the point PMP lines were extended over the Río Coclé del Norte basin as shown on Exhibit 52. It should be realized that the extension was based on the trend of the lines on the NWS map, and estimated point PMP values. Some of the values considered to be inconsistent (especially based on 20 years or less data) were given less weight. No meteorological factors were used in the estimation of point PMP.

Exhibit 45 was used to derive the basin average PMP for the Río Coclé del Norte basin. Because of variation in the point PMP, the drainage basin upstream from the dam was divided into three sub-basins as shown on Exhibit 46. The derived 24-hour, 10-mi^2 PMP were about 30.60 (777), 26.25 (667) and 26.89 (683) inches (mm) for sub-basins 1,2 and 3, respectively. To obtain the sub-basin average PMP for duration of 48 hours, the depth-area-duration curves shown on Exhibit 47 were used. For sub-basins 1 (drainage area about 115 km^2 or 44.4 mi^2), 2 (drainage area about 805 km^2 or 310.8 mi^2) and 3 (drainage area about 674 km^2 or 260.2 mi^2), the factors were about 1.23, 1.02 and 1.04, respectively. The sub-basin average PMP were about 37.65 (956), 26.75 (679) and 27.95 (710) inches (mm), respectively. Based on the sub-basin PMPs, the basin 48-hour PMP was about 28.1 inches (714 mm). The 48-hour PMP based on the maximized and transposed storm was about 24 inches (610 mm), which is lower than the PMP based on NWS point PMP map. Therefore, a 48-hour basin average PMP of 28.1 inches (714 mm) was used.

6.1.8 Depth-Duration Curve

Depth-duration data for the size of each sub-basin was obtained from Exhibit 47. There was not much variation of percentages of 48-hour derived for each sub-basin from the exhibit. Therefore, same percentages were used for all sub-basins. The estimated percentages were 45.9, 61.1, 70.5 79.1 and 100.0 for 6, 12, 18, 24 and 48 hours. These were plotted and a smooth curve was drawn as shown on Exhibit 48. This data was for duration of six hours and greater. Because of small sizes of the sub-basins, the PMP amounts for duration less than six hours were required. To extend the depth-duration curve for duration less than 6 hours, guidance was obtained from the hourly rainfall data recorded at El Chorro. The curve on Exhibit 48 also shows extrapolation to a one-hour duration.

6.1.9 Sequential Arrangement of PMP Increments

A unit duration of one hour was selected considering the size of the sub-basins. The hourly PMP increments were obtained from Exhibit 48. There are a number of methods available to sequentially arrange the PMP increments to produce critical flood conditions. For this study, the "alternating block method" (Ven Te Chow, et al 1988) was used. This method provides reasonable critical flood conditions. The highest hourly increment was placed at 28th hour and the remaining increments were arranged in descending order alternately to the right and left of the maximum increment to form PMP hyetograph. Table 19 shows the arrangement of the increments.

6.2 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 Toabré at Batatilla and five major floods recorded on the Río Coclé del Norte at Canoas. Attachment 3 shows the flood hydrographs.

Contacts were made with the Empressa de Transmision Electrica, S.A. (ETESA), and ACP to obtain the daily rainfall data and hourly time distribution of the rainfall corresponding to each of the floods. There is no hourly rainfall data in the Río Coclé del Norte basin. Therefore, the calibration approach was not feasible.

The COE (1981) has discussed four methods – 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. The exponential loss rate and Holtan loss rate require calibration of HEC-1 model, which was not feasible because of any rainfall data. The SCS method also requires either calibration or a detailed knowledge of the soils and land use in the basin. For this study, initial loss and uniform loss rate method was used. The derivation of these losses is discussed below.

6.2.1 Initial Loss

A review of the daily rainfall data at various stations in the basin indicated that during the months of October through December, the rainfall occurred 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. Therefore, the initial retention was considered negligible on the assumption that the soil moisture deficiency and other abstractions would be satisfied by an antecedent storm.

6.2.2 Uniform Loss

This 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 3 mm (0.12 inches) per hour was used. No infiltration loss was considered from the reservoir area.

6.3 Unit Hydrograph

The derivation of the unit hydrograph for the three sub-basin using historic floods was not feasible because the basin average rainfall amounts and their hyetographs could not be determined for the floods given in Attachment 3. Therefore, synthetic unit hydrographs were developed for the three sub-basins as discussed below.

There are a number of methods available to develop a synthetic unit hydrograph. MWH has tested these methods on various projects and determined that Clark's method (Clark, 1945) provides a better definition of watershed characteristics that transform rainfall to runoff. This method was used in this study.

The Clark's method translates incremental runoff from the sub-areas within a basin to the outlet of the basin according to the travel time (time of concentration) and then routes the runoff through a linear reservoir to account for the storage effect of the basin size and channel system. The method requires estimates of time of concentration and storage routing coefficient, and a time-area curve defining the cumulated area of the basin contributing runoff to the outlet of the basin as a function of time, expressed as ratio or percent of the time of concentration.

The time of concentration (Tc) is defined as the travel time of water particles from the most upstream point (time wise) in the basin to the outflow location. This time may be estimated by measuring the time between the end of effective basin average rainfall over the basin and the inflection point on the recession limb of the surface runoff hydrograph resulting from that rainfall. The storage routing coefficient (R), also called the attenuation coefficient has the dimension of time. The coefficient can be defined by the following equation when the inflow into a storage reach has ceased (Muskingum X=0):

$$R = - (Q/(dQ/dt)$$

The magnitude of R can be approximately calculated at the point of inflection of the recession limb of the observed direct runoff hydrograph. The above ratio decreases to a minimum at the point of inflection and, in theory, remains constant thereafter. Therefore, R may be estimated by dividing the ordinate of the surface runoff hydrograph at the point of inflection by the rate of change of discharge (slope) at the same point. An average value of R from a number of hydrographs is adopted.

From the hourly rainfall data at Los Canones and El Chorro, located in the catchment area of Lake Gatun, it was approximated that the duration of rainfall excess for each storm causing the first peak of each of the flood (given in Attachment 3) could be about six hours.

The time from the rise of the hydrograph to half the volume of direct runoff (after separating the base flow) was estimated for the flood hydrographs of July 1974, June 1985 and December 1995 recorded on the Río Toabré at Batatilla. This time represented 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. Half duration of three hours was subtracted from the time from the rise to half the volume. This resulted in lag times varying from about 5.0 to 11.0 hours with an average of about 7.3 hours.

The SCS (1972) presented a relationship between lag time and time of concentration as:

Lag time = 0.6 * Time of concentration

Using the above relationship, the time of concentration for the Río Toabré at Batatilla was about 12.2 hours.

As an alternate approach, Kirpich formula (1940, also presented in the SCS Handbook) was used to compute the time of concentration.

$$Tc = (0.87 * L^3 / H)^{0.385}$$

in which

L = length of main channel, km

H = difference between the elevations at the upstream end of the main channel and that at the outlet of the basin, m

The above formula resulted in a value of about 11.7 hours. For practical use, this value is nearly same as 12.2 hours estimated from analysis of hydrographs.

To compute the value of R, another flood of January 1996 was included. The R value from each of these hydrographs was computed as the ratio between the discharge ordinate at the point of inflection and the rate of change of discharge at the same point. The values ranged from 7.4 to13.4, with an average of 11.2 hour.

An alternate approach for computing the value of R is the use of the following empirical relationship (Clark, 1945):

$$R = C * ((L^{1.5}/H^{0.5})$$

in which L and H are as defined above. The value of C can vary from 0.2 to 0.4. From field reconnaissance, a value of 0.4 was estimated for the Río Toabré watershed. The R value for Batatilla station was about 10.7 using the above relationship. This value is comparable with the value 11.2 hours obtained from the analysis of hydrographs.

The above analysis was repeated for the Río Coclé del Norte at Canoas. The Flood hydrographs of March 1991, November 1996 and December 1996 were used. The resulting values of Tc and R were about 11.7 and 12.4 hours, respectively. These were judged to be too large given the physical condition in the watershed of the Río Coclé del Norte. This could be because the flood hydrographs were the result of multiple rainfall bursts. Using the alternate approach, described above, values of 7.1 and 5.5 hours for Tc and R, were computed respectively. These were considered more reasonable.

The adopted values for Tc and R for the three sub-basins above the dam site were computed using the Kirpich formula and the empirical relationship reported by Clark. Values of L and H for the sub-basins were taken from topographic maps of 1:50,000-scale. The Clark's method also required areas contributing to runoff at the outlet of the sub-basins at equally spaced intervals. These were also calculated from the topographic maps. Table 20 gives the characteristics of the sub-basins including time-area histogram.

6.4 Base Flow

Base flow was estimated from the historic flood hydrographs given in Attachment 3. The base flow prior to the rise of historic floods varied from about 30 to 120 m^3/s. A flow of 110 m^3/s was used at the dam site. This was assigned to the sub-basins as: for sub-basins 1 and 2, a flow of 50 m^3/s was adopted and for sub-basin 3, a flow of 10 m^3/s was assumed.

6.5 Río Coclé del Norte Probable Maximum Flood

The HEC-1 computer model was used to develop flood hydrograph from each sub-basin and the PMF at the dam site resulting from the 48-hour PMP. The input to the model included: drainage area, base flow, 48-hour PMP, time distribution of the PMP, retention losses and the percentage of the drainage area under reservoir at maximum operating pool elevation, values of Tc and R, and the time area curve for each sub-basin. Since two operating levels of 100 and 80 meters were used, the percentages of the drainage areas under reservoir varied. For the 80 meters case, the resulting flood hydrograph at the dam site had a peak of about 10,460 m^3/s and a 5-day volume of about 988 MCM. Attachment 4 provides a sample of the HEC-1 output. If the maximum operating pool will be at 100 meters, the PMF peak would be about 10,550 m^3/s and a 5-day volume of 1,005 MCM. Exhibit 49 shows the PMF inflow hydrograph.

6.6 Evaluation of the Coclé del Norte PMF

Generally, a PMF estimate is compared with the historic floods and 100-year flood at the site. Also, based on the experience of the investigator, the value of coefficient C in the modified Creager's formula given below is computed and compared with the values obtained for PMF's 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 the dam site was estimated to be 4,610 m^3/s (see Table 15). The ratio between the PMF peak and the 100-year flood peak was about 2.3 (80 meters maximum normal pool), which is reasonable for the hydrologic conditions in the basin.

The value of Creager's C was about 116. The value of C for the PMF for the Río Indio dam site was about 99. A higher value of C for the Río Coclé del Norte is reasonable because the shape of the basin is fan type compared to an elongated shape of the Río Indio basin and also the Río Coclé del Norte basin-average PMP was slightly higher (about 714 mm compared to 711 mm). The value is also in the range of the values expected in similar areas. Therefore, the estimated PMF is reasonable.

7 RESERVOIR SEDIMENTATION

7.1 Data Sources

Suspended sediment data were collected by *Empresa De Transmision Electrica, S.A., Departmento de Hidrometeorologia, Sección de Hidrología* (ETESA) for the following gaging stations.

Río Coclé del Notre at Canoas
Río Toabré at Batatilla

At Canoas, a total of 46 suspended samples with corresponding discharge measurements were collected from November 1983 to August 1998 (see Table 21). 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 (see Table 22). 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 the field visit, the methods of collection of suspended sediment samples and sample analysis were discussed with ETESA. The agency is using standard methods of United States Geological Survey (USGS) for the collection and analysis of the samples.

ACP is collecting suspended sediment samples on the streams entering Lake Madden and Lake Gatun. These include:

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

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

Monthly suspended sediment transport data estimated by ACP for the above stations are given in Tables 23 to 28. The methods of sampling and analysis were discussed with the hydrologists of ACP. Daily sampling is performed during low flows and more samples are taken during a flood event. The flows corresponding to the samples 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 also conducted a sedimentation survey of Lake Madden in 1983 when the Lake was at an elevation of 235 feet (PCC 1987). Jack R. Tutzauer of the 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.

7.2 Suspended and Bed Load Material Sampling Protocol

The methods of sampling and analysis were discussed with the hydrologists of the ACP.

7.2.1 Existing Method

ETESA is using standard United States Geological Survey, Water Resources Division (USGS) methods and instruments to collect and analyze the suspended sediment samples. ACP is also using the equipment recommended by the USGS, but the method of sampling is incorrect. Suspended sediment samples are collected from the riverbanks using hand-held USGS DH-48 depth-integrating samplers. However, as per verbal communication with Ing. Jaime Massot, head of the field data collection unit, ACP has started using US D-74 depth-integrating samplers from overhead cableways. One sample is taken in the middle of the stream.

7.2.2 Recommended Method

ACP should revise its suspended sediment sampling and analysis program following the USGS guidelines. These guidelines are given in the following USGS publications.

Techniques of Water Resources Investigations of the USGS
Book 3, Chapter C2, Field Methods for Measurements of Fluvial Discharge
Book 3, Chapter C3, Computations of Fluvial Sediment Discharge
Book 5, Chapter C1, Laboratory Theory and Sediment Analysis

National Handbook of Recommended Methods for Water Data Acquisition, USGS, 1978, "Field Sampling Procedures and Methods for Analyzing Sediment Concentration and Particle Size Distribution, Chapter 3, Sediment."

During low flows, one sample in the middle of the stream is sufficient. But during medium to high flows, three samples should be collected using equal-discharge increment (EDI) or equal-width-increment (EWI), also called equal-transit-rate (ETR). Details of these methods are given in Book 3, Chapter C2 or Chapter 3 – Sediment. The three samples may be combined to form a composite sample, representative for the cross section, or each sample may be analyzed separately and results averaged. All samples with concentration greater than 200 milligram per liter should be analyzed for particle size distributions.

Efforts should be made to collect bed material samples after each major flood. The samples should be collected at ¼, ½ and ¾ of the width from either bank. An appropriate sampler should be used. A description of the bed material samplers with their limitations is given in Chapter 3, Sediment. All bed material samples should be analyzed for particle size distribution.

7.3 Previous Analyses

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 (including bed load) was about 203 cuft/ac/yr or about 1.4 mm/year.

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. As stated before, the samples for these streams were taken near the banks, which provided low suspended sediment concentration.

ETESA prepared sediment rating curves for the Río Coclé del Norte and Río Toabré as shown on Exhibits 50 and 51, respectively. Best-fit curves were drawn from the data points. For the Río Toabré, for all flows greater than 107.2 m^3/s, the suspended sediment concentration was assumed to be the maximum observed concentration (see Table 22). Similarly, for the Río Coclé del Norte, the suspended sediment concentration was assumed to be the observed maximum concentration (see Table 21) for all flows greater than 84.7 m^3/s. Total sediment transports at the two stream gaging stations were not available from ETESA.

7.4 Current Analyses

After a careful review of the analysis performed by ACP, the estimate of 1.4 mm/year was considered to be reasonable. This estimate was also considered applicable for the Río Coclé del Norte watershed because of similar hydrological conditions.

Additional analysis was performed for the Río Coclé del Norte and Río Toabré. The suspended sediment rating curves fitted by ETESA to the observed data points (Exhibits 50 and 51) were judged to be reasonable. However, the use of maximum observed concentration as the limiting concentration for the high discharges was not a correct assumption. The limiting concentration could be significantly higher than the observed value. 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 suspended sediment rating curves for the two rivers were revised for the high flows. The revised curves are shown on Exhibits 52 and 53. The equations for the curves are given below.

Río Coclé del Norte (drainage area 571 km^2)

Qw < or = 24.54 m^3/s	$Qs = 0.2464\ (Qw)^{\wedge 1.301}$
Qw > 24.54 and < or = 84.73 m^3/s	$Qs = 0.0114\ (Qw)^{\wedge 2.2613}$
Qw > 84.73 and < or = 300 m^3/s	$Qs = 0.000025\ (Qw)^{\wedge 3.637}$
Qw > 300 and < or = 2,000 m^3/s	$Qs = 0.0773\ (Qw)^{\wedge 2.228}$
Qw >2,000 m^3/s	Qs = 864.0 Qw

Río Toabré (drainage area 786 km^2)

Qw < or = 38.97 m^3/s	$Qs = 0.3455\ (Qw)^{\wedge 1.3813}$
Qw > 38.97 and < or = 107.23 m^3/s	$Qs = 0.0000448\ (Qw)^{\wedge 3.825}$
Qw > 107.23 and < or = 300 m^3/s	$Qs = 0.0772\ (Qw)^{\wedge 2.231}$
Qw > 300 and < or = 3,000 m^3/s	$Qs = 0.2867\ (Qw)^{\wedge 2.001}$
Qw >3,000 m^3/s	Qs = 864.0 Qw

Flow duration curves were developed for the Río Coclé del Norte and the Río Toabré based on daily flows for the period of record. These curves were used with the suspended sediment rating curves to estimate mean annual suspended sediment load. The estimated loads were about 676,330 and 873,800 metric tons per year (mt/yr), respectively (see Tables 29 and 30). 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. ACP did not provide any explanation on how the specific weight of 1.04 mt/m^3 was computed.

7.5 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 basin of the Río Coclé del Norte. For a conservative estimate of the reservoir sedimentation analysis, a unit yield of 1.4 mm/yr was adopted for the Río Coclé del Norte basin. However, it should be realized that this yield is indicative of the current land use in the 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 dam site is about 1,594 km^2. Using a yield of 1.4 mm/yr, the mean annual total sediment inflow in the reservoir would be about 2,232 MCM. In their computations, ACP used a specific weight of 1.04 mt/m^3. Therefore, the annual yield would be about 2.321 million metric tons.

7.6 Trap Efficiency

The maximum normal pool elevation for the Río Coclé del Norte dam is planned to be about 100 meters (328.1 feet). The reservoir volume at this elevation is about 13,669 MCM. Long-term mean annual flow is about 3,390 MCM. Thus, the capacity-inflow ratio is about 4.03.

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 Coclé del Norte and the general soils in the watershed, it was judged that the sediment entering the reservoir would be of medium sizes. Therefore, Brune's curve for medium sediment sizes was used. For a capacity-inflow ratio of 4.03, the trap efficiency would be about 99 percent. This would result in a mean annual deposit of about 2.21 MCM or 2.298 million metric tons.

7.7 Analysis of Storage Depletion

Depletion in the reservoir storage was estimated using the methods developed by the United States Bureau of Reclamation (USBR, 1987).

7.7.1 Specific Weight of Sediment

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 15 percent clay, 45 percent silt and 40 percent sand based on MWH experience on similar streams. Using the USBR procedure (USBR, 1987), the specific weight of the fresh deposit was about 75 pounds per cubic feet (about 1.2 mt/m^3). The average specific weights for 5-, 10-, 20-, 25-, 50- and 100-year of operation were about 1.21, 1.22, 1.23, 1.23, 1.24 and 1.25 mt/m^3, respectively. These values were used to compute the volume of deposit at the end each period.

7.7.2 Estimate of Storage Depletion

Sediment distribution in the reservoir was determined using a computer program obtained from USBR. Both the area-increment and empirical area-reduction methods were considered. The empirical area-reduction method could not be used because the data and information about the reservoir did not fit any of the sediment distribution design curves developed by the USBR. Therefore, the area-increment method was used to estimate the reduction in storage over time.

As per current investigation of the project, the maximum and minimum operating reservoir elevations would be either 100 and 90 meters or 80 and 50 meters, respectively. The incoming sediment will partly deposit in the dead storage (below elevation of 50 (or 90) meters) and partly in the operating volume (live storage, above elevation of 50 (or 90) 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 31. The table shows that reservoir sedimentation will not be a major problem for the project. Even after 100-year of reservoir operation, loss in live storage capacity would be about 1.4 percent (80 meter case) or 0.5 percent (100 meter case). After 100 years, it is estimated that less than 1 percent of the live storage will be lost to deposition. Using the same model, the deposition at the face of the Río Coclé del Norte dam is estimated to reach to about El 3.

8 PROJECT IMPACT ON WATER QUALITY

8.1 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.

8.1.1 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 Norte and Sucio basins, 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.

8.1.2 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:

- <u>Fit the Activities to Existing Site Conditions</u>
  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.

- <u>Minimize the Extent and Duration of Exposure</u>
  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.

8.2 Potential Long-Term Impact

The project operation may have three longer-term impacts on water quality. First, normal daily fluctuations in the reservoirs may cause reservoir bank erosion or landslides. Second, the flow released from the reservoirs may cause bank and bed erosion in the channel downstream, 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 areas, the reservoir rims are not expected to exhibit much erosion except in very limited areas. It is not expected that this local erosion will have any significant impact. 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 Coclé del Norte 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.

9 STABILITY OF THE RÍO COCLÉ DEL NORTE CHANNEL DOWNSTREAM FROM THE DAM

The assessment of the Río Coclé del Norte channel stability downstream from the dam 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.

9.1 Flood Regime Downstream from the Dam

Pre-project flood peaks and post-project flood peaks with return intervals are presented in Table 32. The post-project peaks were developed for the 20- and 50-year return periods using flood peak, and 1-day and 2-day flood volumes of the selected return periods. The hydrographs were shaped after the historic flood of December 1955 at Río Toabré and adjusted for the flood peak and volumes. The hydrographs for the 2-, 5-, 10- and 20-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.

The seven flood hydrographs were routed through Río Coclé del Norte reservoir and the resulting maximum outflow peaks are given in Table 32. The starting reservoir level was 80 meters, crest of uncontrolled ogee spillway. An effective spillway width of 50 meters was used. Because of relatively small spillway width and large reservoir volume, the inflow peaks were greatly reduced due to reservoir attenuation.

9.2 Hydraulic Characteristics

MWH developed nine river cross sections in the river reach from about 200 to 11,500 meters downstream from the axis of the dam. The first cross section, located about 200 meters downstream from the axis of the dam, was taken from a 1:2,000 scale map. The rest of the cross sections were taken from 1:50,000 scale topographic maps. These cross sections were adjusted using the data of a field survey conducted by a hand-held echo sounder.

The ACP surveyed eight cross sections at locations identified by MWH. A review of the two sets of cross sections indicated that the cross sectional profiles (shapes and bank slopes) were nearly similar at each location. However, the thalweg elevations were much lower for the surveyed cross sections. The surveyed bed profile was significantly undulating. The effective bed slope was judged to be similar to that adopted by MWH. Therefore, the cross sections developed by MWH were judged to be adequate for the purpose of stability analysis of the river channel downstream from the dam.

The FEQ computer model was used to determine the water surface profiles for selected discharges. The cross sections developed by MWH were used in the model. All cross sections were plotted on one sheet. The shapes of the cross sections were compared. Cross section No. 4, located about 4,800 meters downstream, was judged to represent the hydraulic condition of the about six kilometers channel reach downstream from the dam. Therefore, this section was used as a representative cross section to investigate the channel stability. A channel slope of 0.00007 was estimated. Using the computed water surface elevations, the hydraulic characteristics of the cross section for selected discharge rates were computed and are given in Table 33.

9.3 Characteristics of the Bed Material

ACP took four bed material samples at the location of the first, third, fourth and fifth cross sections. The samples were analyzed for particle size distribution. A representative bed material distribution curve was developed from this data. The characteristics of this curve are given in Table 34. The median diameter of the representative curve was determined using the method recommended by United States Bureau of Reclamation Design of Small Dams). The estimated diameter was 7.0 mm.

9.4 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, which is the case for the Coclé del Norte Reservoir, 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.

9.4.1 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 riverbed and suspended sediment in the releases, and flow pattern of the releases. These data are not available for the Río Coclé del Norte. 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 riverbed 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 streambed 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. The low velocities and presence of coarse gravel in the bed of the Río Coclé del Norte suggest that the first approach is more appropriate.

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). This was the case in the Río Coclé del Norte.

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 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.

9.4.2 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:

1. Samples of streambed material in the reach selected for degradation to a depth anticipated to the scour zone.
2. 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).

3. 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, or

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

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 significantly larger than those computed by Meyer-Peter, Muller and Shield methods. However, because of some uncertainty in bed material sampling, the armoring sizes under selected flow conditions were assumed to be average of the sizes derived using the four methods. The estimated armoring sizes are given in Table 35 for both the pre- and post- project flooding conditions.

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.

9.4.3 Potential for Degradation and Aggradation

A comparison of pre-project armoring sizes (Table 35) with the median diameter of 7.0 mm indicates the potential for degradation in the Río Coclé del Norte. Under pre-project conditions, the required armor sizes (average of the sizes computed using four methods) corresponding to the selected flood peaks are larger than the median diameter of the available bed-load material. Therefore, channel degradation would be 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 flood peaks have been greatly reduced and the required armor sizes are much less than the median diameter of the available bed load material. Degradation would not occur. However, because of reduced floods in the river, aggradation would occur at the mouths of the small tributaries downstream from the dam. A special study should be conducted by collecting field data. The data will include: particle size distribution of the bed material transposed by these tributaries, magnitude of flood peaks for various return periods and total sediment transport.

PART 3 – HYDROLOGY OF THE RÍO CAÑO SUCIO BASIN

1 TOPOGRAPHY AND DRAINAGE

The Río Caño Sucio joins with the Río Caño to form the Río Miguel de la Borda, which drains into the Caribbean Sea. The two rivers join about 22 km along the river from the Caribbean Sea over an air distance of about 15 km. The Río Caño Sucio basin drains an area of about 216 square kilometers. The basin is oriented in a northwest/southeast direction and is about 22 km long by 15 km wide.

The Río Caño Sucio is formed by four significant drainage systems. The Río Riecito rises from the southern part of the basin and is joined by the Río Limon from the west before joining the Río Caño Sucio about two kilometers upstream from the damsite. The Quebrada La Guinea de Loma originates on the western side of the basin and joins with the Río Cerro Miguel from the north to form the Río Caño Sucio about five kilometers upstream from the damsite. The drainage configuration of the Río Caño Sucio basin is shown on Exhibit 54.

2 RAINFALL ON THE CAÑO SUCIO BASIN

There are no rainfall stations in the Río Caño Sucio basin

The mean annual rainfall over the contributing watershed is estimated to be about 3,300 mm. Based on extended records for the *Santa Ana* station, which is located in the Río Coclé del Norte basin about 12 km south of the Río Caño Sucio damsite, the mean monthly rainfall is estimated based on a ratio of the basin annual rainfall and the station annual rainfall times the station monthly rainfall. Mean monthly rainfall values are shown below.

Mean Monthly Rainfall, Río Caño Sucio Basin
(mm)

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
158	81	119	158	327	326	347	340	345	473	403	223	3,300

The mean monthly rainfall varies from a low of 81 mm in February to a high of 473 mm in October.

3 STREAMFLOW ANALYSIS

ACP generated the monthly flows of the Río Caño Sucio using the monthly flows of the Río Indio at Boca de Uracillo and drainage area ratio (about 0.304) between the two locations. The method was considered reasonable. A time series and mass curve of the data were prepared to check the consistency of the data. The mass curves of the monthly flows indicated that the data are consistent.

MWH made an independent check of the equation used to compute monthly flows at the damsite. Using conventional procedure of transposing flows by a combined ratio of drainage area and mean annual rainfall, the estimated flows were about 1 to 3 percent less than the flows derived by ACP. This was considered to be an insignificant difference. Therefore, the monthly flows estimated by ACP were adopted.

The monthly flow of the Río Caño Sucio is presented in Table 36. A mass curve and the time series of the annual flows are shown on Exhibits 55 and 56.

The estimated mean annual flow for the Río Caño Sucio at the damsite is 7.5 m^3/s. The highest runoff months are October and November and above average flows occur from June through December. The lowest flow occurs in the months of February, March and April.

Generally, floods 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 generally in the months of June through August.

Flow duration and drought-duration-frequency studies were not performed for the Río Caño Sucio.

4 CONSTRUCTION PERIOD FLOODS

The flood peaks for the Río Caño Sucio were estimated by transposing the flood frequency data developed for the Río Indio dam site.

Analysis of extreme flood events involves the selection of the largest events from a set of flow data. The flood frequency analysis uses the annual largest recorded floods at a representative stream gaging station. For the present analysis, the maximum instantaneous flood peaks for the Río Indio at Boca de Uracillo were obtained from ACP. The data are given in Table 37. The data is available from 1979 to 1998 with the values missing for a number of months in 1988 and from 1996 to 1998. The annual peaks are available for 16 years. The maximum instantaneous peak, which occurred in 1991, is about 772 m^3/s.

The Log-Pearson type III (LP III) distribution, recommended by the Hydrology subcommittee, United States Geological Survey (March 1982) was fitted to the annual peaks from Boca de Uracillo. A computer program developed by the United States Army Corps of Engineers, Hydrologic Engineering Center was used.

The generalized extreme value (GEV) distribution was also fitted to the data to compare the results from this distribution with that obtained by using LP III distribution. A computer program developed by Environment Canada (1994) was used.

Both the distributions indicated reasonable goodness of fit. For a conservative estimate of the flood peaks, the higher values resulting from GEV were adopted.

Realizing that flood protection works could be designed for protection during the dry season, flood frequency analysis was also performed for the dry period. From a preliminary flood frequency analysis of monthly flood peaks, the dry period was determined to be the months of January through March.

The following procedure was used to derive the flood peaks at the Caño Sucio damsite using the estimated flood peaks from the Río Indio at Boca de Uracillo. A general procedure for transposition of flood peaks from a gaged location to an ungaged location is to use coefficients of empirical relationships assuming that these coefficients remain constant for hydrologically and meteorologically similar drainage basins. Commonly used relationships are given below.

Creager's Formula (Creager, 1950)

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

Rodier's Formula

$$K = 10 * (1- ((\log^{Q} - 6) / (\log^{A} - 8))) \quad \text{(Rodier, 1985)}$$

'K' and 'C' are coefficients, A is the drainage area in km^2 and Q is flood peak in m^3/s. The original Creager's relationship was in English units, relating discharge per unit area with the area. The above form in SI units was developed by MWH.

Based on computations for the Coclé del Norte studies, the values of both coefficients were consistent and either of the two coefficients could be used for transposition. The values of K were used for the Coclé del Norte studies and for Caño Sucio.

The values of "K", computed for the flood peaks of selected return periods for the Río Indio, were used with the drainage area of the Río Caño Sucio at the damsite to estimate flood peaks of selected return intervals. The values are presented in Table 38.

5 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 Caño Sucio 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 the PMP to a PMF
- Evaluation of the PMF

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

5.1 Probable Maximum Precipitation (PMP)

5.1.1 Rainfall Regime

In Panama, October and November are the heaviest rainfall months. This period of heavy rainfall is associated with the southward traverse of the inter-tropical convergence zone (ITCZ). November dominates 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 hurricanes in Panama. A necessary condition for a hurricane is a coriolis force sufficiently strong to cause the winds to spin around the center of a low-pressure area. On the equator, the Coriolis force is zero and still relatively weak within 10° of the equator. Therefore, only rarely there are hurricanes within 10° 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 the NWS.) However, the influences of 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 200 to 500 mi^2. General storms can cover larger areas. The months of October through December are the season of large-area rainfalls. Nearly all-major storms reported in the 1965 and 1978 reports occurred in this period. 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, 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 mean annual rainfall map shown on Exhibit 2. The pattern is controlled by the local topography. A generalized map of the topography in the Canal Area and in the drainage basins of the Río Indio, Río Coclé del Norte and Río Caño Sucio is shown on Exhibit 24.

5.1.2 Methods for Estimating PMP

Two approaches were considered to estimate the PMP. These are listed below:

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 Indio and Río Coclé del Norte basins including the Canal Area. Maximize, transpose and locate the most sever storm over the Río Coclé del Norte basin to produce critical flood conditions.

Extend the 24-hour, 10-mi^2 PMP developed in the NWS 1978 Report over the Río Coclé del Norte basin, use depth-area-duration curves of WS 1965 Report and estimate basin average PMP.

Based on a rigorous assessment of the patterns of the major storms for the Coclé del Norte basin, it was concluded that the most severe PMP would result from using the 24-hour, 10-mi^2 PMP developed by the U.S. National Weather Service in 1978.

The 24-hour, 10 mi^2 PMP map given in the NWS 1978 Report (Exhibit 45) was extended towards west to cover the Río Caño Sucio basin. The following procedure was used for the extension.

For about ten rainfall stations in the Río Coclé del Norte basin and its vicinity, annual maximum daily rainfall data were obtained. The stations included: Boca de Toabré, Chiguiri Arriba, Coclé del Norte, Toabré, San Lucas, Sabanita Verde, Coclecito, Santa Ana, Miguel de la Borda and Boca de Uracillo. The stations are shown on Exhibit 7 with names given in Table 7. The period of record varied from about 18 to 41 years.

Point PMP at each station was determined using Hershfield's method (1963). The values of the point PMP varied from station to station. Some values were quite consistent with the values from the NWS point PMP map. The value at Toabré, located at relatively high altitude, was high compared to other values. The value was retained considering orographic effect due to high altitude of the station.

Keeping in mind the local topography and the trend of the point PMP lines on the NWS map, the point PMP lines were extended over the Río Caño Sucio and Río Coclé del Norte basins as shown on Exhibit 45. It should be realized that the extension was based on the trend of the lines on the NWS map, and estimated point PMP values. Some of the values considered to be inconsistent (especially based on 20 years or less data) were given less weight. No meteorological factors were used in the estimation of point PMP. The 24-hour, 10-mi^2 PMP for the basin was estimated to be about 25.7 inches (about 653 mm) from Exhibit 45.

The proposed dam on the Río Caño Sucio will control a drainage area of about 111 km^2 (42.90 mi^2). The estimate of the 48-hour PMP was based on depth-area-duration data for a basin the size of the Caño Sucio basin derived from Exhibit 57. The 48-hour PMP was estimated to be about 31.9 inches (about 810 mm).

5.1.3 Depth-Duration Curve

Depth-duration data for the size of the Caño Sucio basin was obtained from Exhibit 57 and plotted as a smooth curve shown on Exhibit 58. This data was for duration of six hours and greater. Because of small sizes of the Caño Sucio basin, the PMP amounts for durations less than six hours were required. To extend the depth-duration curve for duration less than 6 hours, guidance was obtained from the hourly rainfall data recorded at El Chorro. The curve on Exhibit 58 also shows extrapolation to one-hour duration.

5.1.4 Sequential Arrangement of PMP Increments

A unit duration of one hour was selected considering the size of the basin. The hourly PMP increments, as a percent of the rainfall, were obtained from Exhibit 58. There are a number of methods available to sequentially arrange the PMP increments to produce critical flood conditions. For this study, the "alternating block method" (Ven Te Chow, et al 1988) was adopted. This method provides reasonable critical flood conditions. The highest hourly increment was placed at the 28th hour and the remaining increments were arranged in descending order alternately to the right and left of the maximum increment to form PMP hyetograph. Table 39 shows the arrangement of the increments.

5.1.5 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. There is no hourly rainfall data in the region, therefore the calibration approach was not feasible.

The COE (1981) has discussed four methods – 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. The exponential loss rate and Holtan loss rate require calibration of HEC-1 model, which was not feasible because of any rainfall data. The SCS method also requires either calibration or a detailed knowledge of the soils and land use in the basin. For this study, initial loss and uniform loss rate method was selected.

A review of the daily rainfall data at various stations in the basin indicated that during the months of October through December, the rainfall occurred 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. Therefore, the initial retention was considered negligible on the assumption that the soil moisture deficiency and other abstractions would be satisfied by an antecedent storm.

This 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 3 mm per hour was adopted. No infiltration loss was considered from the reservoir area.

5.2 Unit Hydrograph

Because of insufficient data, a synthetic unit hydrographs was developed for the basin. There are a number of methods available to develop a synthetic unit hydrograph. MWH has tested these methods on various projects and determined that Clark's method (Clark, 1945) provides a better definition of watershed characteristics that transform rainfall to runoff. This method was used in this study.

The Clark's method translates incremental runoff from the sub-areas within a basin to the outlet of the basin according to the travel time (time of concentration) and then routes the runoff through a linear reservoir to account for the storage effect of the basin size and channel system. The method requires estimates of time of concentration and storage routing coefficient, and a time-area curve defining the cumulated area of the basin contributing runoff to the outlet of the basin as a function of time, expressed as ratio or percent of the time of concentration.

The watershed parameters, length of main stream, overall stream slope and time-area histogram were calculated from the topographic maps of 1:50,000 scale. The time of concentration and routing coefficient were estimated to be 4.5 and 3.0 hours, respectively.

5.3 Base Flow

Base flow was estimated as 50 m^3/s from the studies done for a similar size subbasin in the Coclé del Norte studies.

5.4 Probable Maximum Flood

The HEC-1 computer model was used to transform PMP to PMF. The resulting PMF hydrograph had a peak of about 1,690 m^3/s and a 3-day volume of about 80 MCM. Exhibit 59 shows the PMF inflow hydrograph.

TABLES

Table 1

MONTHLY MEAN DISCHARGES IN CUBIC METERS PER SECOND
COCLE DEL NORTE AT CANOAS

Drainage Area: 571 km^2
Latitude: 08 - 53 N Longitude: 80 - 34 W Elevation: 20 m

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	AVG
1983										41.1	39.2	51.2	
1984	51.2	54.7	36.3	10.4	32.3	44.7	53.1	79.5	53.4	48.9	56.5	41.1	**46.8**
1985	47.2	23.9	23.5	13.0	21.1	47.7	29.6	34.0	30.3	39.4	36.4		
1986	57.2	31.3	17.9	47.5	39.3	37.9	32.9	38.2	55.3	75.6	76.7	25.4	**44.6**
1987	24.9	17.8	8.1	58.6	46.0	29.2	31.3	32.3	33.3	89.4	43.8	30.9	**37.1**
1988	23.2	32.7	13.9	8.7	28.3	29.0					40.5	41.0	
1989	38.2	28.4	20.8	15.3	38.8	51.8	50.9	47.9	44.5			48.8	
1990	51.0	28.7	31.3	18.9	43.6	30.1						64.7	
1991	28.3	23.0	50.1				24.9	42.7	66.6	50.1	47.2	64.8	
1992	30.7	20.2	14.2	46.9	50.7	31.7	29.5	34.5	46.4	40.3	32.7	40.4	**34.9**
1993	52.1	31.6	35.2	22.2	32.2	38.8	32.2	29.2	68.8	49.6	46.4		
1994				41.8	63.6	64.0	31.5	37.4	42.0	54.0	50.2	43.2	
1995	23.5	16.8	13.0	27.0	30.2	34.9	36.8	46.3	44.5	33.4	38.7	68.4	**34.5**
1996			73.2	42.4	73.9		46.0					160.0	
1997	36.8			10.5	56.6	26.3	29.8	31.1	31.2	29.6	33.0	17.6	
1998	14.8	15.7	10.9	50.2	48.2	50.0	22.1						

Period of record

From October, 1983 to current year

Gage

Water-stage recorder: Stilling well float system coupled with Stevens A-71 recorder.
A Sutron shaft encoder and telemetry equipment for transmiting
gage height and precipitation were instaled on November 18+A15, 1999.

MWH / TAMS

Table 2

MONTHLY MEAN DISCHARGES IN CUBIC METERS PER SECOND
COCLE DEL NORTE AT EL TORNO

Drainage Area 672 km^2
Latitude: 08 - 56 N Longitude: 80 - 33 W Elevation: 15 M

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	AVG
1958							38.8	63.6	51.9	51.9	45.4	59.7	
1959	36.7	18.2	8.7			58.5	58.5	68.5	56.3	72.2	70.2	157.0	
1960	76.5	39.1	34.1	49.6	34.7	48.0	33.8						
1961					43.7	46.4	48.4	82.6	51.7	70.8	101.0	119.0	
1962	48.0	28.0	18.0	29.5	41.4	47.3	44.6	54.2	46.9	61.6	95.4	74.9	**49.2**
1963	34.5	32.1	25.7	103.0	67.7	51.6	49.7	51.0	44.9	49.1	102.0	51.9	**55.3**
1964	43.9	13.0	12.9	84.2	64.9	83.2	64.8	58.7	54.2	83.6	63.9	27.2	**54.5**
1965	82.9	27.9	12.6	7.2	68.0	34.3	39.0	38.9	41.9	60.4	65.9	86.6	**47.1**
1966	41.4	22.4	18.1	25.1	57.9	67.0	53.1	54.6	45.6	60.8	144.0	116.0	**58.8**
1967	54.7	37.8	17.0	61.1	80.8	85.8	55.7	73.6	60.8	64.7	68.5	66.2	**60.6**
1968	37.4	43.2	47.5	31.6	60.3	66.1	47.8	48.3	59.1	55.9	41.9	83.9	**51.9**
1969	19.9	23.5	9.9	14.6	29.6	44.5	27.3	51.8	49.7	85.8	89.8	90.0	**44.7**
1970						44.5	53.0	80.6	108.0	81.9			
1971					63.7	65.9	61.6	65.8	80.5	83.0	52.7	30.7	
1972	56.5	33.3	24.4	53.6	59.2	32.2	43.0	37.9	62.8	57.6	50.9	40.8	**46.0**
1973	41.1	27.1	12.4	13.2	53.4	60.3				86.0			
1974	54.4				66.5	48.3	50.4	58.9	51.4	101.0	79.0	50.8	
1975	39.1	23.1	11.6	10.7	43.4	37.7	49.0	87.6	102.0	100.0	149.0	143.0	**66.4**
1976	55.0	39.0	25.3	16.8	26.1	21.5	23.8	35.7			53.3	21.7	
1977	23.8	18.3	10.6	16.1	26.0	40.0	41.3	82.8	64.0	70.5	60.2	37.3	**40.9**
1978	27.7	27.2	16.6	109.0	113.0	53.7	27.1	29.3	62.6	67.8	65.8	51.7	**54.3**
1979	15.4	17.3	14.5	67.9								84.9	
1980	82.8	28.8	13.7		28.3	42.8	39.0	64.5	49.5	59.6	73.8	95.9	
1981	77.0	53.7	39.3	115.0	90.3	71.5	51.2				122.0	183.0	
1982	38.4	25.8	18.5	20.2	35.9	39.5	58.1	43.9	45.6	62.1	57.9	35.9	**40.2**
1983	33.9	14.7	10.6	12.2	76.4	37.3	24.2	34.2	69.8				
1984		61.3	43.9	15.6	39.9	54.1	64.6	109.0	72.5	69.6	76.4	43.9	
1985	50.7	26.5	26.2	16.3	23.0	69.0	36.5	40.5	37.4	57.8	59.9	98.2	**45.2**
1986	69.4	37.0	25.1	67.8	67.4	54.3							

Period of record
From July, 1958 to July, 1986

Gage
Water-stage recorder: Stilling well float system coupled with Stevens A-71 recorder.

MWH / TAMS

Table 3

MONTHLY MEAN DISCHARGES IN CUBIC METERS PER SECOND
RIO TOABRE AT BATATILLA

Drainage Area 788 km^2

Latitude: 08 - 55 N   Longitude: 80 - 30 W   Elevation: 20 M

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	AVG
1958							34.6	59.9	59.7	61.5	53.5	37.7	
1959	21.2	9.7	5.1	5.9				50.5	52.3	65.6	62.4	85.3	
1960	38.5	15.5	10.7	18.9	30.3	43.4	42.9						
1961					18.8	37.1	45.3	73.8					
1962	19.6	9.3	5.7		18.9	36.0	32.2	50.9	49.5	63.6	70.0	42.5	
1963	23.1	14.4	6.8	34.9	44.6	52.8	53.4	59.3	46.6	56.7	73.3	35.7	**41.8**
1964	20.9	9.3	4.8	30.3	44.8	58.5	67.1	71.7	75.9				
1965													
1966													
1967													
1968													
1969						32.0	27.0	44.8	55.5	61.8	69.2	57.5	
1970					75.9		53.1	75.6			94.9	142.0	
1971	44.0			9.5	31.5	61.3	60.3	66.3	72.6	78.0	51.3	22.6	
1972	38.3	15.4	10.3	26.7		31.7	24.7	21.9	48.4	45.0	47.3	22.8	
1973	14.0	8.7		5.1	21.9	53.3	59.6	62.0	84.8			74.5	
1974	27.3	14.4	9.0				46.4	44.9	43.4	94.0	61.7	42.9	
1975	16.5			3.8	17.7					116.0	147.0	113.0	
1976	36.3	14.8	8.1	6.4	13.9	18.7	17.7	34.8	58.6	61.9	53.9	23.3	**29.0**
1977	12.0	7.6	4.9	4.6	12.2	33.3	35.9	73.5	54.2	80.1	52.2	28.5	**33.3**
1978	14.3	9.7	8.4	50.5	90.2	42.4	34.1	39.7	63.0	68.5	80.5	31.7	**44.4**
1979	13.0	7.9	4.8	17.7		51.8	48.4	81.8		50.1	46.8	57.2	
1980	46.8	15.3	8.2	9.5	22.8	35.4	37.6	69.7	50.6	75.2	67.9		
1981					71.3	64.3	78.9	81.3	49.5	65.7	99.3	124.0	
1982	32.1	15.0	9.3	8.9	17.3	38.0	42.5	37.6	45.9	70.8	52.3	18.8	**32.4**
1983	11.4	6.0	3.6	3.8	41.2	36.9	23.0	29.1	71.4	56.5	47.6	51.6	**31.8**
1984	23.9	22.5	16.6	6.1	21.1	47.5	67.9	77.5	77.9	80.3	73.3	27.2	**45.2**
1985	19.8	10.9	7.9	4.9	9.2	59.4	40.9	54.4	54.0	59.4	75.5	53.1	**37.5**
1986	20.9	11.6	7.6	27.1	33.6	49.3	55.8	49.4	55.2	114.0	108.0	29.2	**46.8**
1987	13.8	8.9	5.2	18.5	22.4	21.1	30.6	38.3	45.3	110.0	60.2	35.7	**34.2**
1988	15.1	13.0	5.0	3.9	33.0	32.5	51.7				78.2	35.6	
1989	23.7	12.2	8.7	5.9	29.4	40.7	56.9	62.6	56.9			51.2	
1990	26.3	12.6	7.1	5.4	20.6	21.6						95.4	
1991	17.3	9.4	27.6							91.5	58.1	54.5	
1992	14.0	7.3	4.2	23.7	46.9	50.5	38.8	49.1	79.0	58.7	46.8	30.2	**37.4**
1993	27.0	11.4	13.4	14.0	20.3	52.4	41.8	29.5	95.2	64.7	118.0	72.5	**46.7**
1994	18.4	10.9	8.9	13.3	35.8	64.1	34.7	54.7	70.7	72.0	63.7	25.6	**39.4**
1995	14.5	9.6	7.1	11.9	44.5	41.6		57.5	71.3	40.8	54.6	80.9	
1996	152.0				75.1	73.5	83.9	98.7	112.0	81.5	102.0	166.0	
1997	26.4	17.7	9.2	7.3	25.7	20.3	23.6	31.1	28.4	50.8	39.2	16.0	**24.6**
1998	10.0			22.0									

Period of record

From July 1958 to current year

Gage

Water-stage recorder: Stilling well float system coupled with Stevens A-71 recorder.

Table 4

MONTHLY MEAN DISCHARGES IN CUBIC METERS PER SECOND
RIO INDIO AT BOCA DE URACILLO

Drainage Area: 365 km^2

Latitude: 08 - 58 N   Longitude: 80 - 11 W   Elevation: 8 M

YEAR	JAN	FEB	MAR	APRIL	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	ANNUAL
1979								34.9	37.3	35.1	25.9	24.9	
1980	23.2	8.4	3.9	2.7	13.5	18.3	20.1	47.2	23.7	36.0	32.4	27.8	**21.4**
1981	20.1	13.0	11.8	28.9	29.6			37.6	28.7	48.0	58.6	75.6	
1982	18.6	5.8	3.8	5.2			27.0	17.3	27.8	50.6	26.1	8.9	
1983	5.8	3.0	1.8	1.5	15.6	23.3	16.5	18.5	45.1	35.2	29.9	38.4	**19.6**
1984	15.7	10.0		3.6	16.9	27.4	30.8	48.5	39.8	44.6	37.7	12.8	
1985	8.6	5.3	4.1	2.7	8.4	30.2	17.3	39.0	37.6	35.0	40.5	26.5	**21.3**
1986	9.4	4.9	3.0	16.0	19.0				27.5	56.1	61.3	15.0	
1987	7.4	5.0	2.9				25.7	31.1	40.0	72.1	32.0	17.7	
1988	7.5	5.1	2.9	2.6							40.9	22.1	
1989	12.6			2.8	13.2	18.5	27.8	35.7	34.6	36.4	53.8	30.0	
1990	15.2	6.8	4.7	3.2	24.7							62.0	
1991	10.3	5.8	7.0	3.1	14.0	19.9	14.7	18.2	38.6	48.8	33.3	44.1	**21.5**
1992	9.1	3.4	3.7	5.5	26.7	27.9	26.8	46.1	43.1	37.5	31.6	19.4	**23.4**
1993	11.7	6.7	5.4	8.7	11.1	29.9	21.8	16.9	35.4	49.3	62.9	33.1	**24.4**
1994	12.1	7.0	5.7	6.2	13.4	21.0	15.6	12.1	25.5	36.0	36.9	13.3	**17.1**
1995			2.9	4.0	23.0	35.9	31.5		36.6	30.8	41.8	29.5	
1996		26.7			40.3	41.7			41.0	71.3	55.6	51.5	
1997	11.3	7.1				6.9							
1998	5.1	4.2	2.9	3.9	13.6								

Period of record

From August 1979 to current year

Gage

Water-stage recorder: Stilling well float system coupled with Stevens A-71 recorder.
A Sutron shaft encoder and telemetry equipment for transmiting
gage height and precipitation were instaled on November 1, 1999.

Table 5
MONTHLY MEAN DISCHARGES IN CUBIC METERS PER SECOND
CIRI GRANDE AT LOS CANONES

Drainage Area: 186 km^2
Latitude: 08 - 57 N Longitude: 80 - 04 W Elevation: 87 M

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	AVG
1948	4.3	1.6	1.2	0.9	1.9	2.7	10.5	12.3	11.7	10.8	22.1	5.9	**7.2**
1949	2.4	1.4	0.9	0.8	2.6	15.0	10.4	13.1	18.7	17.7	31.2	24.5	**11.6**
1950	4.0	2.2	1.3	0.9	7.0	13.2	13.7	20.3	13.3	18.3	23.9	24.0	**11.8**
1951	7.3	4.0	2.2	1.4	7.2	8.9	8.2	9.0	15.5	13.1	19.9	11.3	**9.0**
1952	4.8	2.2	1.2	1.0	4.0	10.6	8.1	8.6	14.8	21.5	13.3	19.0	**9.1**
1953	14.1	5.3	2.7	1.9	8.6	7.7	7.4	6.1	7.6	22.5	22.6	12.1	**9.9**
1954	6.0	2.7	1.7	1.4	6.8	7.2	17.5	13.1	18.0	15.2	29.3	15.2	**11.2**
1955	16.4	4.9	2.4	1.9	3.8	15.3	10.8	18.1	22.2	19.1	29.6	16.8	**13.4**
1956	17.0	5.1	2.9	2.7	10.5	15.4	14.5	10.7	17.4	26.4	18.5	10.5	**12.6**
1957	4.1	2.0	1.3	0.9	4.2	4.2	4.1	8.3	9.1	21.4	13.9	11.1	**7.0**
1958	6.8	5.2	2.7	1.9	6.2	7.5	10.5	14.2	13.8	18.2	14.7	7.6	**9.1**
1959		2.0	1.4	1.2	1.9								
1960													
1961													
1962													
1963													
1964													
1965													
1966													
1967													
1968													
1969													
1970													
1971													
1972													
1973													
1974													
1975													
1976													
1977													
1978								16.0	16.7	19.2	16.3	9.4	
1979	5.1	3.9	3.5	4.0	6.5	10.7	10.6	15.9	19.4	19.0	6.3	5.5	**9.2**
1980	10.7	3.7	2.0	1.4	5.4	10.9	8.0	19.2	9.0	15.4	15.6	12.6	**9.5**
1981	11.4	9.2	7.4	13.1	21.2	22.8	20.7	14.8	14.6	21.9	21.0	19.8	**16.5**
1982	7.9	3.5	2.3	2.6	4.6	7.5	6.3	4.7	8.7	17.1	12.6	3.8	**6.8**
1983	2.4	1.5	0.9	0.5	4.4	5.7	4.1	5.3	17.2	12.7	12.4	15.7	**6.9**
1984			2.3	1.4	6.4	12.2	10.9	17.1	16.7	17.4		11.4	
1985			1.3	0.9	2.5	7.1	3.1	12.6	20.8	14.9			
1986	4.0	2.1	1.4	4.1	5.9	12.7	8.4	6.7	9.8	25.8			
1987	2.8	1.9	1.1	1.7	5.3	5.4	7.7	12.8	14.0	24.3	10.1	8.0	**7.9**
1988	2.8	1.7	0.9	0.9	4.1	8.0	8.6	15.1	17.0	21.3	16.5	9.5	**8.9**
1989	6.7	3.5	2.3	1.2	4.8	5.5	10.1	14.7	13.7	16.0	16.2	10.5	**8.8**
1990	5.8	3.0	2.2	1.3	5.2	7.7	10.1	10.5	19.4	29.2	18.8	16.2	**10.8**
1991	3.8	1.9	2.4	1.2	4.6	6.1	4.7	5.6	11.0	18.0	14.2	11.3	**7.0**
1992	3.3	1.7	1.2	1.6	6.5	11.6	8.3	13.2	15.1	12.3	11.3	7.3	**7.8**
1993	4.4	2.9	2.1	2.0	4.9	10.3	7.5	6.3	13.8	14.6	22.0	12.6	**8.6**
1994	4.6	2.2	1.6	1.4	5.0	8.0	5.8	4.5	9.7	13.9	14.3	5.0	**6.3**
1995	2.9	1.6	1.0	1.3	7.8	12.8	10.3	11.2	11.6	13.0	12.6	8.6	**7.9**
1996	22.6	6.9	5.1	2.7	7.9	12.0	18.0	22.3	17.5	23.0	15.5	14.7	**14.0**
1997	5.6	3.3	1.7	1.2	2.0	3.6	2.9	2.4	6.0	7.9	9.6	4.1	**4.2**
1998	2.3	1.6	0.7	0.9	2.6	4.7	8.4	6.8	9.6	15.3	8.8	13.3	**6.3**

Period of record: From July 1947 to 1959 and from July 1978 to current year.

Gage: Water-stage recorder: Stilling well float System coupled with Stevens A-71 recorder, Handar shaft encoder and Sutron shaft encoder.
Gage -height and precipitation telemetry at station

Table 6
MONTHLY MEAN DISCHARGES IN CUBIC METERS PER SECOND
RIO TRINIDAD AT CHORRO

Drainage Area: 172 km^2
Latitude: 08 - 59 N Longitude: 79 - 59 W Elevation: 43 M

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	AVG
1948	3.5	1.9	1.0	0.6	1.6	2.0	6.3	7.6	6.7	7.3	16.6	5.7	**5.1**
1949	2.3	1.0	0.6	0.5	1.8	10.3	9.7	10.5	15.9	13.0	23.0	17.1	**8.8**
1950	4.4	2.6	1.4	0.7	6.3	9.8	10.1	13.5	8.6	13.3	19.2	15.8	**8.8**
1951	5.0	3.4	1.7	1.2	5.7	6.2	7.1	9.0	11.2	9.7	12.0	7.8	**6.7**
1952	3.2	2.0	1.0	0.8	2.0	5.4	4.9	5.8	9.9	14.1	9.7	18.8	**6.5**
1953	7.5	3.4	1.7	1.2	6.7	6.2	5.7	4.2	5.9	11.5	11.9	6.4	**6.0**
1954	3.0	1.7	1.0	0.9	8.2	7.1	17.8	14.4	14.3	13.9	21.5	9.7	**9.5**
1955	10.1	3.2	1.6	1.1	2.1	8.2	7.0	11.0	13.0	15.2	21.9	10.9	**8.8**
1956	9.2	3.1	2.0	1.5	5.0	8.4	10.3	6.4	11.7	19.3	11.6	5.9	**7.9**
1957	2.6	1.5	0.9	0.5	2.2	2.6	2.5	5.2	5.4	13.7	9.9	5.4	**4.4**
1958	3.5	3.3	1.6	1.0	3.6	4.4	6.5	9.4	9.2	10.5	8.0	4.5	**5.5**
1959	2.4	1.3	0.7	0.6	1.1	2.7	2.8	3.6	4.3	13.4	9.2	11.7	**4.5**
1960	5.4	2.2	2.3	2.8	6.9	7.4	7.3	7.5	6.6	10.7	15.0	25.6	**8.3**
1961	4.0	2.0	1.1	1.2	2.1	5.4	4.7	5.3	8.6	13.5	11.8	9.5	**5.8**
1962	3.3	1.8	1.0	0.9	1.4	2.2	3.0	7.8	6.7	9.1	9.5	7.1	**4.5**
1963	2.8	1.8	1.0	2.1	4.6	5.6	6.8	8.9	9.0	12.9	14.6	4.6	**6.2**
1964	2.3	1.2	0.8	0.9	3.4	11.4	11.3	11.5	13.9	15.0	17.7	5.2	**7.9**
1965	4.0	1.9	1.1	0.6	1.0	2.0	1.8	4.2	3.3	7.0	8.8	9.4	**3.8**
1966	3.2	1.5	1.0	1.1	6.7	9.2	7.4			14.2	19.2	14.6	**7.8**
1967	4.5	2.2	1.1	1.8	5.5	13.4	10.0	11.0	14.8	17.2	11.3	5.2	**8.2**
1968	2.4	1.7	1.1	1.0	2.7	8.0	5.9	8.4	8.9	15.2	14.7	6.9	**6.4**
1969	2.9	1.6	0.8	1.3	2.7	5.6				11.7	12.8	7.7	**5.2**
1970	6.2	2.7	2.3	2.4	7.5	4.9	5.6	12.4	10.4	15.8	12.4	26.4	**9.1**
1971	11.1	3.8	2.1	1.6	6.5	9.8	8.3	12.2	13.5	15.0	17.9	5.0	**8.9**
1972	3.3	2.2	1.3	3.7	3.1	5.8	2.5	3.6	8.6	8.7		3.6	**4.2**
1973	2.0	1.2	0.6	0.6	2.4	10.3	10.7	8.5	15.5	17.3	20.7	9.9	**8.3**
1974	4.3	2.6	1.9	1.1	2.2	4.9	6.0	6.9	8.2	24.0	13.4	6.9	**6.9**
1975	3.0	1.7	1.1	0.7	2.0	4.0	5.9	11.6	16.3	18.1	28.1	14.6	**8.9**
1976	5.5	2.9	1.7	1.5	3.5	3.2	1.6	2.0	6.2	15.0	10.3	3.9	**4.8**
1977	2.4	1.5	0.9	0.7	2.0	3.0	2.9	6.7	7.7	14.8	10.9	5.9	**4.9**
1978	2.8	1.8	1.2	7.0	6.1	8.6	8.3	13.6	11.8	16.2	17.7	8.2	**8.6**
1979	3.6	2.1	1.4	2.4	3.7	6.4	6.9	9.9	11.2	13.5	8.2	7.0	**6.4**
1980	6.1	2.8	1.5	1.0	3.6	7.2	5.2	8.8	6.7	13.3	13.4	8.8	**6.5**
1981	5.8	4.0	3.2	7.3	12.4	13.9	12.9	13.5	11.3	15.3	18.1	13.7	**10.9**
1982	6.6	3.2	2.1	2.1	2.7	4.0	2.7	2.8	6.3	11.4	8.4	2.4	**4.6**
1983	1.7	1.1	0.7	0.5	2.3	3.3	2.1	2.9	10.4	8.2	7.7	8.0	**4.1**
1984	3.7	2.7	1.7	1.2	6.1	7.9	8.5	10.8	16.2	23.9	15.7	6.3	**8.7**
1985	3.5	2.1	1.4	1.0	2.6	4.5	3.3		12.8	9.5	8.4	7.4	**5.1**
1986	3.3	1.9	1.3	2.7	2.9	5.9	4.6	4.4	5.3	16.9	14.4	5.4	**5.7**
1987	2.8	2.0	1.2	1.3	3.5	3.6	4.4	7.6	11.9	16.8	8.2	5.9	**5.8**
1988	2.5	1.5	0.9	0.9	4.7	4.7	6.5	10.1	13.5	14.1	11.6	8.0	**6.6**
1989	4.5	2.5	1.6	0.9	2.4	3.6	6.5	10.4	9.5	10.1	10.5	10.4	**6.1**
1990	4.6	2.5	1.6	1.1	3.2	7.2	7.4	7.7	15.0	17.6	13.6	11.3	**7.7**
1991	3.6	2.0	2.0	1.0	3.9	4.7	4.3	4.6	7.4	10.6	10.2	7.5	**5.2**
1992	3.0	1.7	1.0	1.2	3.4	7.2	5.2	6.7	14.5	10.5	9.5	6.4	**5.8**
1993	3.6	2.1	1.4	1.6	3.1	6.3	5.1	4.6	11.2	9.5	16.1	9.2	**6.2**
1994	3.5	2.2	1.5	1.0	3.3	4.3	3.4	3.3	7.7	12.7	11.0	4.8	**4.9**
1995	2.6	1.4	0.9	1.0	5.0	7.9	7.5	9.4	8.9	10.6	9.8	5.8	**5.9**
1996	15.6	4.6	3.6	2.1	6.3	10.0	11.6	15.2	15.0	16.9	12.8	10.5	**10.4**
1997	3.5	2.2	1.4	1.1	1.3	2.5	1.6	1.4	2.6	6.0	6.0	2.1	**2.6**
1998	1.2	0.8	0.5	0.5	1.5	2.0	4.8	5.1	5.5	10.4	8.6	10.4	**4.3**

Period of record: From April 1947 to current year.
Gage: Water-stage recorder: Stilling well float System coupled with Stevens A-71 recorder,
Handar shaft encoder and Sutron shaft encoder.
Gage -height and precipitation telemetry at station

MWH / TAMS

Table 7

LIST OF RAINFALL AND STREAM GAGING STATIONS
(shown on Exhibit 8)

Rainfall Station

01. San Miguel
02. Escandalosa
03. Rio 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. Boro 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. Cocle del Norte
40. San Lucas
41. Boca de Toabre
42. Coclesito
43. Tambo
44. Toabre

Stream Gaging Stations

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

Table 8

MONTHLY MEAN DISCHARGES IN CUBIC METERS PER SECOND COCLE DEL NORTE AT DAM SITE

Drainage Area 1594 km^2

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
1948	67.5	37.1	30.1	25.0	40.2	50.3	120.0	133.4	128.8	122.3	198.1	82.5	**86.3**
1949	46.6	33.9	25.9	24.5	49.0	152.0	119.4	139.4	176.5	169.9	250.9	212.4	**116.7**
1950	64.7	44.5	32.3	26.4	92.2	139.6	143.6	186.5	140.4	173.9	208.8	209.3	**121.9**
1951	95.0	64.1	44.5	34.3	93.8	107.5	102.3	108.2	155.8	138.8	184.4	126.1	**104.6**
1952	72.5	44.9	30.1	27.8	64.7	120.9	101.6	105.7	151.0	193.9	140.2	178.6	**102.7**
1953	145.8	76.8	50.9	40.9	105.0	97.6	95.7	84.5	97.4	200.5	200.6	132.1	**110.7**
1954	83.2	50.9	37.9	33.1	90.2	93.6	168.8	139.0	172.1	153.9	240.1	153.7	**118.1**
1955	161.3	73.6	46.6	40.2	62.6	154.5	122.1	172.5	198.4	179.0	241.6	164.5	**134.7**
1956	165.8	74.9	52.6	49.9	120.2	155.1	148.5	121.5	168.0	223.4	175.2	120.2	**131.3**
1957	65.0	42.4	32.3	26.4	66.1	66.4	65.8	103.0	109.3	193.7	144.4	124.5	**86.6**
1958	90.7	76.3	50.6	40.9	85.5	96.5	80.9	135.8	121.9	123.8	108.0	108.5	**93.3**
1959	64.6	31.2	15.4	39.9	40.2	197.5	211.1	131.9	119.5	151.7	146.1	271.0	**118.3**
1960	128.9	61.6	50.8	77.4	71.7	100.6	83.5	79.8	110.3	152.0	191.5	275.9	**115.3**
1961	80.3	52.3	36.4	37.0	70.4	92.3	103.1	172.3	115.7	164.6	191.0	199.3	**109.5**
1962	76.2	42.2	26.9	42.6	67.8	92.2	85.2	115.6	105.6	137.3	183.3	131.2	**92.2**
1963	64.0	52.3	37.0	156.2	124.9	114.5	112.9	120.5	100.3	115.6	194.4	97.3	**107.5**
1964	72.8	24.8	20.0	129.5	121.8	157.3	144.6	142.2	141.2	187.3	178.2	67.8	**115.6**
1965	125.4	47.8	23.9	14.1	88.0	55.8	59.8	75.2	73.2	117.0	133.4	160.7	**81.2**
1966	71.7	38.6	29.9	38.5	112.0	137.2	110.6	106.8	86.2	156.6	279.2	223.0	**115.9**
1967	95.5	60.9	29.2	85.4	132.1	181.5	128.1	154.6	159.8	176.6	150.3	113.1	**122.3**
1968	61.9	64.1	64.7	45.2	90.9	129.0	95.9	110.9	125.9	156.0	136.9	143.8	**102.1**
1969	44.6	40.7	18.8	27.7	54.6	84.8	59.6	106.5	115.0	163.7	176.0	164.2	**88.0**
1970	313.0	114.8	55.9	149.3	249.7	86.2	116.4	171.8	191.6	189.4	268.0	353.8	**188.3**
1971	138.2	68.6	96.8	56.7	106.8	139.9	133.9	144.9	168.6	177.1	114.2	59.1	**117.1**
1972	105.3	54.7	39.1	90.0	92.2	70.2	75.6	66.8	123.1	113.5	108.0	71.1	**84.1**
1973	62.4	40.6	19.9	20.7	84.9	125.2	123.6	130.8	176.4	201.9	245.5	200.3	**119.4**
1974	91.6	73.9	46.7	55.8	94.7	90.3	106.5	114.9	104.6	214.5	155.7	103.4	**104.4**
1975	62.6	40.7	23.2	16.4	68.9	72.4	97.3	174.0	215.5	235.9	325.0	283.1	**134.6**
1976	101.5	60.8	37.9	26.2	44.8	44.3	46.0	77.4	137.4	127.5	117.6	49.3	**72.5**
1977	40.1	29.2	17.5	23.5	42.9	80.9	85.1	172.2	130.4	164.6	123.9	72.8	**81.9**
1978	47.0	41.8	28.0	179.2	224.6	106.3	66.7	75.0	137.8	149.5	159.5	93.0	**109.0**
1979	31.3	28.3	21.9	97.5	89.8	143.5	110.3	177.5	144.0	106.2	108.1	157.9	**101.4**
1980	144.8	49.4	24.5	38.8	56.5	86.4	84.2	146.9	109.8	146.8	155.9	161.7	**100.5**
1981	127.0	87.8	68.8	185.8	178.7	149.6	140.8	146.6	95.3	132.2	244.5	341.1	**158.2**
1982	77.8	45.5	31.1	32.8	59.7	85.2	111.5	89.9	100.4	145.2	121.3	61.2	**80.2**
1983	51.3	23.3	16.1	18.2	131.6	81.5	51.9	69.8	154.9	116.3	106.0	131.0	**79.3**
1984	90.2	94.7	68.3	24.5	68.3	112.0	145.2	206.9	164.7	163.8	164.5	79.2	**115.2**
1985	79.6	42.2	38.7	24.1	36.4	141.6	84.6	103.2	99.1	128.5	147.5	169.3	**91.2**
1986	102.6	55.1	37.1	107.0	113.3	114.1	117.3	123.2	134.1	236.2	226.3	83.0	**120.8**
1987	48.1	35.4	24.5	59.4	68.3	65.4	85.9	101.6	115.3	229.6	143.3	96.4	**89.4**
1988	51.3	46.1	23.6	19.9	90.9	89.9	127.5	136.8	137.3	189.1	175.5	96.2	**98.7**
1989	71.1	44.1	34.6	26.6	83.4	106.4	137.2	147.7	137.2	146.1	192.2	126.6	**104.4**
1990	76.8	45.1	30.2	25.1	64.2	66.5	106.2	109.1	160.0	207.1	156.6	205.1	**104.3**
1991	56.6	36.6	79.6	29.0	76.1	96.6	78.7	91.0	152.2	198.5	139.5	132.8	**97.3**
1992	48.6	30.8	21.0	71.1	118.4	125.3	102.6	122.6	176.9	140.6	118.2	85.1	**96.8**
1993	78.3	42.0	47.1	48.6	63.5	128.8	108.5	83.6	204.8	151.5	242.8	165.5	**113.8**
1994	59.2	40.7	35.1	46.9	96.6	150.4	94.4	133.1	162.3	164.6	149.7	75.3	**100.7**
1995	49.8	37.2	30.0	43.3	113.8	108.1	132.2	138.3	163.3	106.6	133.0	180.2	**103.0**
1996	297.4	118.0	74.9	50.0	170.1	167.2	185.4	210.7	232.9	181.3	216.2	319.4	**185.3**
1997	77.0	57.5	36.1	30.6	75.5	63.5	70.9	87.0	81.3	125.8	103.4	53.5	**71.8**
1998	38.2	35.1	27.5	67.4	74.8	71.3	104.0	90.8	113.4	154.3	107.2	140.4	**85.4**
1999	89.5	55.2	38.1	53.4	92.3	110.4	108.8	127.8	141.2	162.8	172.9	149.2	**108.5**
Mean	**89.5**	**52.1**	**37.7**	**53.5**	**91.8**	**108.8**	**107.7**	**125.3**	**139.2**	**162.7**	**173.0**	**149.2**	**107.5**
Maximum	**313.0**	**118.0**	**96.8**	**185.8**	**249.7**	**197.5**	**211.1**	**210.7**	**232.9**	**236.2**	**325.0**	**353.8**	**188.3**
Minimum	**31.3**	**23.3**	**15.4**	**14.1**	**36.4**	**44.3**	**46.0**	**66.8**	**73.2**	**106.2**	**103.4**	**49.3**	**71.8**

MWH / TAMS

Table 9

RIO COCLE DEL NORTE AT DAM SITE
DROUGHT-DURATION-FREQUENCY ANALYSIS

ACCUMULATED 6-MONTH FLOWS

Rank of Event	Return Period (Years)	6-Month Flow (MCM)	Date of Occurrence	
			From	To
1	52.00	525	Dec 76	May 77
2	26.00	648	Jan 48	Jun 48
3	17.33	674	Feb 76	Jul 76
4	13.00	680	Dec 48	May 49
5	10.40	703	Jan 69	Jun 69
6	8.67	737	Jan 75	Jun 75
7	7.43	750	Feb 65	Jul 65
8	6.50	756	Nov 82	Apr 83
9	5.78	768	Dec 97	May 98
10	5.20	774	Jan 57	Jun 57
11	4.73	776	Dec 72	May 73
12	4.33	777	Dec 58	May 59
13	4.00	778	Dec 84	May 85
14	3.71	780	Jan 87	Jun 87
15	3.47	798	Jan 90	Jun 90
16	3.25	834	Jan 88	Jun 88
17	3.06	861	Jan 82	Jun 82
18	2.89	866	Feb 97	May 97
19	2.74	880	Feb 80	Jul 80
20	2.60	902	Jan 62	Jun 62
21	2.48	906	Dec 94	May 95
22	2.36	923	Dec 88	May 89
23	2.26	935	Jan 52	Jun 52
24	2.17	938	Dec 78	May 79
25	2.08	945	Dec 92	May 93
26	2.00	956	Jan 61	Jun 61
27	1.93	971	Jan 91	Jun 91
28	1.86	1,008	Jan 54	Jun 54
29	1.79	1,036	Jan 50	Jun 50
30	1.73	1,076	Jan 92	Jun 92
31	1.68	1,093	Feb 72	Jul 72
32	1.63	1,109	Jan 66	Jun 66
33	1.58	1,111	Jan 94	Jun 94
34	1.53	1,116	Feb 58	Jul 58
35	1.49	1,138	Jan 99	Jun 99
36	1.44	1,139	Jan 51	Jun 51
37	1.41	1,140	Dec 67	May 68
38	1.37	1,155	Feb 60	Jul 60
39	1.33	1,174	Jan 74	Jun 74
40	1.30	1,187	Jan 84	Jun 84
41	1.27	1,208	Dec 63	May 64
42	1.24	1,210	Feb 52	Jul 53
43	1.21	1,239	Oct 77	Mar 78
44	1.18	1,295	Feb 55	Jul 55
45	1.16	1,371	Jan 86	Jun 86
46	1.13	1,423	Jan 63	Jun 63
47	1.11	1,504	Jun 83	Nov 83
48	1.08	1,515	Jan 67	Jun 67
49	1.06	1,558	Feb 56	Jul 56
50	1.04	1,562	Feb 71	Jul 71
51	1.02	1,661	Jun 98	Nov 98
52	1.00	1,801	Jun 78	Nov 78

Table 9, cont.

ACCUMULATED 12-MONTH FLOWS

Rank of Event	Return Period (Years)	12-Month Flow (MCM)	Date of Occurrence	
			From	To
1	52.00	1,951	Jun 76	May 77
2	26.00	2,054	Apr 97	Mar 98
3	17.33	2,220	Jun 72	May 73
4	13.00	2,260	Sep 82	Aug 83
5	10.40	2,284	Dec 64	Nov 65
6	8.67	2,505	Jul 58	Jun 59
7	7.43	2,564	Oct 68	Sep 69
8	6.50	2,604	Dec 84	Nov 85
9	5.78	2,609	Jun 48	May 49
10	5.20	2,682	Dec 56	Nov 57
11	4.73	2,713	May 87	Apr 88
12	4.33	2,739	Jun 78	May 79
13	4.00	2,785	Aug 74	Jul 75
14	3.71	2,831	May 98	Apr 99
15	3.47	2,835	Feb 62	Jan 63
16	3.25	2,837	Apr 91	Mar 92
17	3.06	2,886	Oct 79	Sep 80
18	2.89	2,906	Sep 92	Aug 93
19	2.74	2,917	Sep 89	Aug 90
20	2.60	2,931	Dec 94	Nov 95
21	2.48	3,015	Jun 51	May 52
22	2.36	3,110	Jul 53	Jun 54
23	2.26	3,141	Jun 88	May 89
24	2.17	3,173	Jun 63	May 64
25	2.08	3,184	Oct 67	Sep 68
26	2.00	3,270	Jul 60	Jun 61
27	1.93	3,365	Dec 93	Nov 94
28	1.86	3,370	Apr 71	Mar 72
29	1.79	3,407	May 86	Apr 87
30	1.73	3,417	Sep 83	Aug 84
31	1.68	3,442	Dec 65	Nov 66
32	1.63	3,490	Sep 81	Aug 82
33	1.58	3,501	Jun 77	May 78
34	1.53	3,598	Jul 52	Jun 53
35	1.49	3,725	May 49	Apr 50
36	1.44	3,925	Aug 73	Jul 74
37	1.41	3,939	Aug 54	Jul 55
38	1.37	3,945	Jul 59	Jun 60
39	1.33	3,972	May 50	Apr 51
40	1.30	4,198	Dec 55	Nov 56
41	1.27	4,934	Apr 96	Mar 97
42	1.24	5,060	Oct 69	Sep 70

ACCUMULATED 18-MONTH FLOWS

Rank of Event	Return Period (Years)	18-Month Flow (MCM)	Date of Occurrence	
			From	To
1	52.00	2,821	Feb 76	Jul 77
2	26.00	3,049	Jan 97	Jun 98
3	17.33	3,260	Feb 82	May 83
4	13.00	3,362	Dec 71	May 73
5	10.40	3,454	Dec 64	May 66
6	8.67	3,543	Jan 48	Jun 49
7	7.43	3,597	Dec 86	May 88
8	6.50	3,719	Dec 57	May 59
9	5.78	3,872	Feb 68	Jul 69
10	5.20	3,983	Jan 74	Jun 75
11	4.73	4,046	Jan 89	Jun 90
12	4.33	4,068	Jan 92	Jun 93
13	4.00	4,118	Dec 84	May 86
14	3.71	4,122	Jan 94	Jun 95
15	3.47	4,188	Jul 51	Jun 52
16	3.25	4,190	Jan 79	Jun 80
17	3.06	4,289	Jan 62	Jun 63
18	2.89	4,450	Jan 53	Jun 54
19	2.74	4,476	Feb 60	Jul 61
20	2.60	4,598	Feb 56	Jul 57
21	2.48	5,214	Jul 98	Dec 99
22	2.36	5,472	Jul 90	Dec 91
23	2.26	6,171	Aug 66	Jan 68
24	2.17	6,559	Jul 49	Dec 50
25	2.08	6,847	Aug 54	Jan 56
26	2.00	6,966	Feb 70	Jul 71
27	1.93	6,991	Aug 80	Jan 82
28	1.86	7,975	Jul 95	Dec 96

Table 9, cont.

ACCUMULATED 24-MONTH FLOWS

Rank of Event	Return Period (Years)	24-Month Flow (MCM)	Date of Occurrence	
			From	To
1	52.00	4,589	Apr 76	Mar 78
2	26.00	4,890	Jan 97	Dec 98
3	17.33	4,960	Jan 82	Dec 83
4	13.00	5,464	Nov 64	Oct 66
5	10.40	5,488	Jun 57	May 59
6	8.67	5,538	Sep 71	Aug 73
7	7.43	5,714	Nov 67	Oct 69
8	6.50	5,816	Dec 86	Nov 88
9	5.78	5,956	Jul 78	Jun 80
10	5.20	6,021	Apr 91	Mar 93
11	4.73	6,138	Apr 62	Mar 64
12	4.33	6,211	Dec 88	Nov 90
13	4.00	6,236	Oct 84	Sep 86
14	3.71	6,296	Dec 93	Nov 95
15	3.47	6,305	Feb 48	Jan 50
16	3.25	6,417	Oct 51	Sep 53
17	3.06	6,746	Apr 60	Mar 62
18	2.89	6,823	Sep 73	Aug 75
19	2.74	7,672	Nov 53	Oct 55

Table 10

MEAN MONTHLY NET RESERVOIR EVAPORATION
RIO COCLE DEL NORTE AND RIO CANO SUCIO RESERVOIRS

Month	Evaporation	
	(mm)	(inches)
January	112	4.41
February	117	4.62
March	133	5.23
April	123	4.86
May	91	3.59
June	80	3.13
July	84	3.29
August	80	3.15
September	78	3.08
October	80	3.13
November	72	2.83
December	84	3.31
Annual	**1,134**	**44.63**

Table 11

FLOOD PEAKS FOR SELECTED RETURN PERIODS
(based on annual series)

Estimate by Institudo de Recursos Hidraulicos y Electrificacion, Departamento de Hidrometeorologia, Seccion Hidrologia

Return Period	Rio Cocle Del Norte		Rio Toabre
	at Canoas	at El Torno	at Batatilla
(years)	(m^3/s)	(m^3/s)	(m^3/s)
2	586	1,084	1,189
5	1,479	1,628	1,783
10	1,801	1,979	2,171
20	2,144	2,357	2,585
25	2,251	2,474	2,714
50	2,573	2,828	3,101
100	2,948	3,240	3,554
1000	4,235	4,654	5,104
10000	5,682	6,245	6,849

Estimate by Harza
Rio Cocle Del Norte at Canoas

Return Period	LP III	Generalized Extreme Value		
	Flood Peak	Flood Peak	Value of K	Value of C
(years)	(m^3/s)	(m^3/s)		
2	833	827	4.12	15
5	1,030	1,060	4.33	20
10	1,150	1,200	4.43	22
20	1,260	1,320	4.51	24
50	1,400	1,480	4.60	27
100	1,490	1,590	4.66	29
200	1,590	1,690	4.71	31
500	1,710	1,820	4.77	34

Table 11, cont.

Rio Cocle Del Norte at El Torno

Return Period (years)	LP III Flood Peak (m^3/s)	Generalized Extreme Value Flood Peak (m^3/s)	Value of K	Value of C
2	793	776	3.99	13
5	1,260	1,220	4.37	22
10	1,670	1,640	4.62	28
20	2,160	2,160	4.85	37
50	2,950	3,070	5.14	52
100	3,700	3,990	5.36	68
200	4,590	5,170	5.58	88
500	6,060	7,270	5.87	124

Rio Toabre at Batatilla

Return Period (years)	LP III Flood Peak (m^3/s)	Generalized Extreme Value Flood Peak (m^3/s)	Value of K	Value of C
2	820	826	3.96	13
5	1,240	1,240	4.30	20
10	1,530	1,530	4.48	24
20	1,810	1,810	4.63	29
50	2,190	2,200	4.79	35
100	2,470	2,490	4.90	39
200	2,770	2,800	5.00	44
500	3,160	3,220	5.12	51

Table 12

RIO COCLE DEL NORTE AT CANOAS
MAXIMUM INSTANTANEOUS FLOOD PEAKS (m^3/s)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1983										218	475	392	
1984	398	532	354	36.9	462	366	551	658	315	396	524	179	**658**
1985	468	81	121	82.1	157	625	256	180	131	347	416	1,073	**1,073**
1986	199	123	99	350	546	235	155	458	617	721	815	65.2	**815**
1987	179	128	22	610	343	280	217	238	215	843	200	228	**843**
1988	105	151	38	47.8	617	311					200	145	**617**
1989	152	121	122	59.2	378	503	401	357	283			519	**519**
1990	309	104	223	87.2	561	179						604	**604**
1991	94.5	62.1	1,013	447	435	259	177	430	931	476	258	322	**1,013**
1992	74.7	46.4	37	798	419	285	146	463	229	351	224	139	**798**
1993	451	255	202	338	298	443	296	239	692	527	359		**692**
1994				479	389	1,356	239	473	317	519	442	302	**1,356**
1995	99	42.2	93	569	91.8	268	723	443	272	138	352	940	**940**
1996			908	470	429		147				899	1,019	**1,019**
1997	225	142		176	1,109	156	265	268	430	205	154	60.3	**1,109**
1998	133	113	181	822	713	374	166	168	374	779	475	287	**822**
1999	156	120	515	449	446	731	867						**867**

Table 13

RIO COCLE DEL NORTE AT EL TORNO
MAXIMUM INSTANTANEOUS FLOOD PEAKS (m^3/s)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1958							256	186	251	157	120	150	
1959	133	35.7	16.1	318		151	401	177	203	157	197	662	**662**
1960	299	233	271	145	99.3	138	116	84.7					
1961				108	282	111	115	531	150	236	526	659	**659**
1962	168	114	37.7	146	267	204	154	206	168	225	319	372	**372**
1963	118	139	51.7	581	312	157	320	171	274	226	299	338	**581**
1964	263	48.9	104	482	237	277	213	247	183	566	220	57.4	**566**
1965	424	60	22	16.2	461	231	139	167	83.7	326	161	643	**643**
1966	85.7	45.6	110	136	200	176	197	150	135	266	482	437	**482**
1967	277	165	29.2	226	255	367	259	233	214	264	362	294	**367**
1968	43.5	266	507	340	627	366	575	143	276	201	123	439	**627**
1969	63.8	326	115	72.9	381	556	152	325	457	1070	657	1150	**1150**
1970	3116	782	157	2357	782	689	651	601	787	601	690	542	**3116**
1971	491	45.6	826	105	631	478	548	478	778	636	258	83.9	**826**
1972	264	129	100	379	599	274	627	287	581	439	399	179	**627**
1973	714	42.7	38.1	67.2	395	158	338	303	652	537	590	343	**714**
1974	174	117	87.9	534	442	358	800	415	350	560	392	255	**800**
1975	182	64.7	16.5	36.1	299	251	474	643	1090	548	893	770	**1090**
1976	171	114	55.2	116	85.8	85.8	113	264	943	298	291	79.4	**943**
1977	196	34.4	18.2	96.2	663	1019	291	726	532	511	396	150	**1019**
1978	109	100	198	2599	1645	577	234	176	531	659	495	366	**2599**
1979	36.4	133	41.9	1164	368	638	259	445	443	216	271	1170	**1170**
1980	867	97	26.4	925	433	770	517	793	588	375	261	704	**925**
1981	415	168	227	1072	677	593	576	428	194	461	753	1645	**1645**
1982	364	99	56	219	622	293	357	408	177	524	439	100	**622**
1983	263	47.1	29.3	158	699	354	67.9	402	503	212	537	447	**699**
1984	443	608	474	34.9	566	548	599	890	502	593	572	171	**890**
1985	579	65.6	94.9	59.8	128	1030	242	284	147	355	773	1752	**1752**
1986	487	126	114	445	864	624	234						

Table 14

RIO TOABRE AT BATATILLA
MAXIMUM INSTANTANEOUS FLOOD PEAKS (m^3/s)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1958							101	139	422	151	144	121	**422**
1959	42.3	17.7	10.3	26.3	120	139		152	153	153	164	422	**422**
1960	114	33.8	43	153	106	136	104						
1961					82.2	78.7	96.5	152					
1962	132	61.7	57.2		187	523	139	167	209	209	371	185	**523**
1963	62.6	59.9	54.5	267	161	142	136	155	146	150	251	78.1	**267**
1964	69.8	12.8	9.65	375	192	203	150	323	230	357			**375**
1965													
1966													
1967													
1968													
1969					216	462	168	224	751	775	747	442	**775**
1970	2633			929	806	229	414	636	808		1025	1368	**2633**
1971	687		251	22.9	367	557	378	498	842	465	263	105	**842**
1972	751	57.5			141	184	207	175	367	237	329	131	**751**
1973	149	13.7	11.9	11.9	213	369	597	354	765	536		424	**765**
1974	86.7	39.8	20.7				1230	370	232	628	386	312	**1230**
1975	33.2			4.44	75.3					504	842	1044	**1044**
1976	35.3	24	11.9	43	77.9	99.2	88.4	275	403	257	231	79.6	**403**
1977	16.2	9.7	5.82	12.8	166	296	315	393	331	306	185	108	**393**
1978	24.8	18.6	70.9	1817	727	155	247	206	296	522	469	84	**1817**
1979	18.6	11.6	9.59	308	231	293	286	806			108	1108	**1108**
1980	450	24	11.9	308	132	222	299	954	414	398	511		**954**
1981				474	632	523	737	794	412	397	800	1390	**1390**
1982	57.4	26.3	12.9	43	178	511	296	296	328	422	544	36.8	**544**
1983	27.8	8.05	6.04	42.3	437	224	87.6	149	612	555	203	232	**612**
1984	84	136	117	9.39	255	819	389	507	583	1111	386	50.1	**1111**
1985	186	15.8	11.4	8.47	78.9	1276	372	829	247	397	840	757	**1276**
1986	89.9	19.5	26	218	608	1266	261	608	414	943	894	72.6	**1266**
1987	22.4	12.4	6.77	255	218	203	369	363	422	618	236	145	**618**
1988	20.9	18.4	9.24	9.24	804	188	311				354	120	**804**
1989	52.4	14.3	12.4	6.77	570	255	1053	231	306			376	**1053**
1990	72.6	14.6	11.9	11.4	326	168						1080	**1080**
1991	30.5	12.4	920							794	211	381	**920**
1992	20.9	16.4	6.47	513	568	360	392	375	638	369	367	90.9	**638**
1993	153	24.6	274	363	121	585	450	160	727	361	1116	703	**1116**
1994	31.1	17	51.3	242	422	802	108	593	664	424	810	72.2	**810**
1995	17.5	9.5	40.9	349	311	313		603	429	142	369	1355	**1355**
1996	2438	577	568	149	859	723	767	1253	1133	1077	755	898	**2438**
1997	60.7	274	69.7	79	429	145	147	123	236	488	120	31.1	**488**
1998	14.5			488	384	559	422	442	486	759	731	672	**759**
1999		36.6	182	173	392	634	1382	777	429				

Table 15

FLOOD PEAKS FOR SELECTED RETURN PERIODS AT COCLE DEL NORTE DAM SITE

Drainage Area: 1,594 sq.km

All Season

Return Period (years)	Values of K Factor: El Torno	Values of K Factor: Batatilla	Mean Value	Flood Peak (m^3/s)
2	3.99	3.96	3.98	1,295
5	4.37	4.30	4.34	1,925
10	4.62	4.48	4.55	2,430
20	4.85	4.63	4.74	2,995
50	5.14	4.79	4.97	3,860
100	5.36	4.90	5.13	4,610

Dry Season (February and March)

Return Period (years)	Values of K Factor: El Torno	Values of K Factor: Batatilla	Mean Value	Flood Peak (m^3/s)
2	2.46	1.33	1.90	130
5	3.04	2.20	2.62	288
10	3.38	2.69	3.04	458
20	3.69	3.14	3.42	697
50	4.08	3.69	3.89	1,171
100	4.35	4.10	4.23	1,705

Table 16

FLOOD VOLUMES FOR SELECTED RETURN PERIODS
(based on Generalized Extreme Value Distribution)

Rio Cocle Del Norte at Canoas

Period (years)	1-Day	2-Day
2	396	538
5	534	740
10	609	863
20	670	973
50	737	1110
100	779	1200
200	815	1290
500	856	1400

Rio Cocle Del Norte at El Torno

Return Period (years)	Volumes in cms-day	
	1-Day	2-Day
2	316	513
5	482	783
10	613	1000
20	758	1250
50	977	1650
100	1170	2000
200	1390	2410
500	1720	3060

Rio Toabre at Batatilla

Return Period (years)	Volumes in cms-day	
	1-Day	2-Day
2	251	402
5	379	595
10	486	750
20	610	922
50	808	1190
100	990	1420
200	1210	1690
500	1560	2110

Table 17

FLOODS HYDROGRAPHS
RIO COCLE DEL NORTE DAM SITE

Time	20-Year Return Period	50-Year Return Period
(hr)	(m^3/s)	(m^3/s)
1	98	128
2	103	135
3	187	244
4	304	396
5	408	532
6	568	742
7	831	900
8	1,230	1,500
9	1,630	2,000
10	2,100	2,600
11	2,600	3,200
12	2,995	3,860
13	2,750	3,700
14	2,550	3,400
15	2,350	3,100
16	2,250	2,800
17	2,050	2,600
18	1,900	2,500
19	1,750	2,400
20	1,650	2,300
21	1,550	2,200
22	1,500	2,100
23	1,450	2,000
24	1,400	1,900

Time	20-Year Return Period	50-Year Return Period
(hr)	(m^3/s)	(m^3/s)
25	1,350	1,800
26	1,250	1,700
27	1,200	1,600
28	1,150	1,500
29	1,100	1,450
30	1,070	1,400
31	1,040	1,350
32	1,010	1,300
33	980	1,250
34	950	1,200
35	920	1,150
36	890	1,100
37	860	1,070
38	830	1,040
39	800	1,010
40	770	980
41	740	950
42	710	920
43	690	890
44	660	860
45	630	830
46	600	800
47	570	770
48	540	740

Table 18

SEASONAL VARIATION OF ESTIMATED MAXIMUM 12-HOUR PERSISTING DEW POINTS IN PANAMA

Month	12-Hour Dew Point (F^0)
November- February	77
March	77.5
April – August	78
September – October	79

Table 19

SEQUENTIAL ARRANGEMENT OF PMP INCREMENTS
(Increments as percentages of 48-hour PMP)

Hour	Increment	Hour	Incremen
1	0.7	25	3.0
2	0.7	26	4.0
3	0.7	27	4.0
4	0.7	28	13.5
5	0.8	29	14.0
6	0.8	30	6.5
7	0.8	31	4.0
8	0.8	32	3.0
9	0.8	33	3.0
10	0.8	34	2.0
11	0.8	35	2.0
12	0.9	36	1.5
13	0.9	37	1.5
14	1.0	38	1.5
15	1.0	39	1.5
16	1.0	40	1.5
17	1.0	41	1.0
18	1.5	42	1.0
19	1.5	43	1.0
20	1.5	44	0.9
21	1.5	45	0.9
22	2.0	46	0.9
23	2.0	47	0.8
24	2.0	48	0.8

Table 20

WATERSHED CHARACTERISTICS AND TIME-AREA HISTOGRAM
COCLE DEL NORTE BASIN

Basin	Area (sq km)	Length (km)	Difference in Eleva. (m)	Tc (hr)	R (hr)
Rio Toabre at Batatilla	788	68.3	465	11.7	10.7
Cocle del Norte at Canoas	571	41.5	380	7.1	5.5
Sub-basin 1	115	32.9	135	8.1	6.7
Sub-basin 2	805	74.9	470	13.0	12.3
Sub-basin 3	674	52.8	390	9.3	8.0

Sub-Basin Histogram

Interval	Percentage of Area Contributing		
	Sub-Basins		
(hours)	1	2	3
1	23.5	2.3	4.0
2	32.6	5.2	9.6
3	43.5	7.6	15.5
4	54.3	11.3	37.3
5	70.0	18.5	58.4
6	80.0	30.4	79.7
7	92.6	44.7	93.2
8	100.0	61.6	100.0
9		71.1	
10		81.5	
11		90.2	
12		100.0	

L = effective length of main stream neglecting the steep slope in the head reach
H = elevation difference between the ends of the adopted length L
Tc = time concentration for Clarks's method
R = linear reservoir routing parameter for Clark's method

$$Tc = (0.87 * (L^3)/H)^{0.385}$$

$$R = 0.40 * (L^{1.5})/(H^{0.5})$$

Table 21

MUESTROS DE SEDIMENTOS, COCLE DEL NORTE, CANOAS, 105-0102

Número de muestra	Fecha (Date)	Q. Liquido (Streamflow) m^3/s	Concentración (Concentration) mg/l	Q. Sólido (Sediment Discharge) ton/dia (tons/day)	Temperatura (Temperature) °C
1	23-11-83	18.98	11.14	18.30	26
2	28-1-84	27.10	5.40	12.60	25.5
3	1-4-84	11.58	5.16	5.16	25.5
4	20-5-84	27.50	28.55	67.83	26
5	9-7-84	38.45	8.07	26.81	23
6	29-8-84	42.77	17.30	63.90	24
7	21-10-84	33.01	7.94	22.60	
8	1-3-85	19.42	10.40	17.40	
9	21-6-85	26.71	12.50	28.80	
10	20-9-85	20.91	6.50	11.70	
11	12-12-85	56.85	7.77	38.20	
12	14-3-86	12.60	4.85	5.28	
13	9-10-86	43.45	22.40	84.10	
14	9-10-86	43.45	22.40	84.10	
15	27-11-86	38.99	4.12	13.90	
16	25-2-87	8.36	8.43	6.09	26
17	20-5-87	25.77	9.97	22.20	25
18	12-8-87	24.96	8.52	18.40	24
19	7-10-87	28.32	10.30	25.20	27
20	24-2-88	28.88	9.74	24.31	24
21	26-10-88	29.94	8.09	20.90	25
22	16-3-89	14.96	2.64	3.41	25
23	30-6-89	19.81	3.49	5.97	
24	23-11-89	53.52	19.50	90.20	
25	21-11-90	15.64	6.51	8.79	
26	15-11-90	40.49	7.66	26.80	
27	4-9-91	25.94	33.56	75.22	
28	2-9-92	20.16	1.72	3.00	
29	17-12-92	24.52	3.25	6.89	
30	19-8-93	42.29	20.66	75.48	
31	17-3-94	8.14	10.77	7.57	27
32	8-6-94	29.48	11.26	28.68	28
33	8-sep-94	19.96	6.64	11.45	27
34	30-nov-94	31.51	6.89	18.75	27
35	17-2-95	10.60	17.73	16.24	26
36	1-may-95	17.41	8.50	12.76	
37	08-jul-95	18.78	10.10	1.78	
38	29-sep-95	38.89	32.18	108.13	
39	01-dic-95	22.20	17.80	34.13	
40	22-AGP-96	51.28	16.50	73.13	
41	16-nov.96	58.53	9.73	49.19	26
42	14 MAR. 97	16.95	3.79	5.55	--
43	30 jul. 97	30.41	10.47	27.51	--
44	13 nov. 97	32.65	8.19	23.04	--
45	21 abr. 98	5.56	5.89	2.83	--
46	11 ag0. 98	16.92	2.52	3.68	--

Table 22

MUESTROS DE SEDIMENTOS, TOABRE, BATATILLA, 105-0201

Número de muestra	Fecha (Date)	Q. Liquido (Streamflow) m^3/s	Concentración (Concentration) mg/l	Q. Sólido (Sediment Discharge) ton/dia (tons/day)	Temperatura (Temperature) ° C
1	3-2-82	18.44	6.60	10.50	
2	10-3-82	10.50	6.02	5.46	28.0
3	28-4-82	7.53	6.27	4.08	28.0
4	29-7-82	46.30	38.50	154	26.0
5	8-9-82	42.40	15.60	57.1	27.0
6	27-10-82	82.3	46.80	33.3	26.0
7	24-11-82	26.40	19.10	43.6	
8	26-1-83	7.96	10.27	7.06	26.0
9	6-4-83	2.72	6.44	1.51	26.0
10	26-5-83	26.28	8.04	18.25	27.0
11	24-8-83	38.54	22.4	74.59	26.0
12	23-11-83	43.79	19.81	75	
13	26-1-84	17.15	6.91	10.25	24.5
14	30-3-84	14.78	11.71	15	27.0
15	18-5-84	10.21	7.15	6.31	26.0
16	6-7-84	94.89	120.06	984.3	24.0
17	30-8-84	50.61	19.10	83.5	26.0
18	19-10-84	66.70	78.80	454	25.0
19	29-11-84	49.87	13.12	56.6	
20	5-3-85	10.41	10.10	9.08	
21	23-6-85	25.28	25.00	54.6	
22	21-9-85	43.20	24.70	92.2	
23	11-12-85	46.70	26.00	105	
24	13-3-86	7.06	6.34	3.87	
25	3-6-86	9.97	5.84	5.03	
26	8-10-86	86.20	239.30	1782	
27	26-11-86	65.20	9.54	53.7	
28	24-2-87	7.04	10.73	6.53	
29	19-5-87	19.20	9.55	15.8	26.0
30	11-8-87	39.10	18.58	62.8	25.0
31	6-10-87	73.60	282.10	1794	25.0
32	23-2-88	6.32	3.57	1.95	24.0
33	27-10-88	55.55	66.86	320.87	25.0
34	17-3-89	7.97	7.91	5.45	26.5
35	1-7-89	31.12	5.27	14.17	
36	24-11-89	53.11	5.56	25.5	
37	18-11-90	56.42	12.00	58.5	
38	5-9-91	25.90	10.11	22.62	
39	1-9-92	40.79	16.90	59.5	
40	15-12-92	31.56	5.53	15.08	
41	17-8-93	21.50	7.59	14.1	
42	19-3-94	6.89	23.10	13.75	27.0
43	10-6-94	19.61	28.70	48.63	
44	9-sep-94	42.43	29.98	109.92	27.0
45	1-dic-94	35.89	8.83	27.38	--

Table 22, cont.

Número de muestra	Fecha (Date)	Q. Liquido (Streamflow) m^3/s	Concentración (Concentration) mg/l	Q. Sólido (Sediment Discharge) ton/dia (tons/day)	Temperatura (Temperature) ° C
46	19-2-95	7.63	7.67	5.05	27.0
47	09-may-95	16.40	5.78	8.18	28.0
48	10-jul-95	28.09	4.57	11.08	
49	28-sep-95	49.22	35.61	151.44	27.0
50	04-dic-95	69.23	55.99	334.92	
51	19-nov-96	44.04	10.82	41.17	26
52	15-mar-97	9.99	36.47	31.47	--
53	31-jul.	20.93	20.79	37.6	--
54	14-	38.13	9.8	32.29	--
55	22-	2.7	5.78	1.35	--
56	12	27.46	20.83	49.415	--

Table 23

SUSPENDED SEDIMENT DISCHARGE
RIO CHAGRES AT CHICO

Drainage Area: 160 sq.mi (414 sq. km)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1981	761.8	981.4	367.5	73458.1	16517.2	7687.2	31683.1	44578.1	18955.7	26299.4	27001.4	51197.9	**299488.6**
1982	677.0	125.5	73.3	225.9	525.5	280.3	8606.6	3723.8	4326.4	9456.6	2207.0	992.7	**31220.5**
1983	439.4	160.9	100.7	2147.7	34182.0	5040.2	4618.4	10473.6	8859.3	10158.4	12552.5	41636.8	**130369.8**
1984	270.6	31.6	30.0	42.1	9510.4	11155.7	6865.7	27779.3	8747.2	42322.8	14020.4	2932.2	**123708.0**
1985	279.6	223.6	238.6	148.6	3831.9	16072.3	4919.3	5636.4	14475.2	6222.7	885.6	47053.1	**99986.8**
1986	216.4	86.3	1364.5	3067.5	55168.7	3471.0	2759.0	4505.1	11289.5	10918.3	24436.5	1036.6	**118319.4**
1987	72.0	55.0	49.1	13452.1	60093.2	3160.1	14173.1	16009.8	52045.3	10314.3	65068.0	2285.5	**236777.5**
1988	47.8	92.1	40.0	26.6	7116.8	1601.8	12057.3	7762.2	3428.7	5426.7	8530.1	1324.1	**47454.2**
1989	352.7	1847.4	194.3	377.3	3516.8	6146.3	9139.7	2768.6	2853.6	20495.6	9413.2	2893.8	**59999.3**
1990	550.4	301.8	274.7	1519.7	41259.6	1222.5	1963.8	5540.8	5884.8	12230.0	11296.0	18556.9	**100601.0**
1991	168.1	155.1	3270.3	1541.5	7167.7	1891.6	2948.2	1885.0	11397.2	4639.4	24619.3	790.2	**60473.6**
1992	131.9	227.0	82.1	1247.2	5033.3	9745.2	5090.1	16957.3	9539.4	2485.8	14108.0	374.4	**65021.7**
1993	1388.4	57.4	3067.3	6364.9	6094.3	18593.8	2825.5	1745.4	5599.8	13872.0	1641.8	591.3	**61841.9**
1994	126.3	155.2	183.4	52.9	4712.5	9303.0	7583.2	3051.3	3100.2	6390.8	16728.3	716.3	**52103.4**
1995	272.5	12.4	0.0	438.5	24706.4	12491.9	12881.2	7547.2	1994.3	2789.6	7227.2	23238.1	**93599.3**
1996	13781.2	357.3	1078.1	1210.2	11776.0	3756.3	2371.4	8819.1	3234.2	9251.7	119677.8	23109.4	**198422.7**
1997	69.0	43.2	1.9	207.6	19841.4	1893.5	761.7	1825.3	1046.0	1393.5	1032.5	768.3	**28883.9**
1998													
Mean	**1153.2**	**289.0**	**612.7**	**6207.6**	**18297.3**	**6677.2**	**7720.4**	**10035.8**	**9810.4**	**11451.0**	**21202.7**	**12911.6**	**106368.9**

Table 24

SUSPENDED SEDIMENT DISCHARGE
RIO PEQUENI AT CANDELARIA

Drainage Area: 52 sq.mi (135 sq. km)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1987	49	52.5	16.6	4095.1	38665.9	17912.4	5839.2	12932.8	12805.8	6163.8	13174.7	2228.3	**113936**
1988	46.1	117.7	71.4	74	2356.6	1757.8	17268.8	9568.3	799.5	7790.3	1827.6	1456.1	**43134.2**
1989	237.3	1881.3	49.1	24.5	5250.9	5988.2	14774.1	5744.6	2693.1	19415.9	11613.6	8469.7	**76142.3**
1990	667.6	38.4	103	202.2	7188.3	1318.2	1833.5	8066.5	2994	7788.2	3396.6	1901.4	**35497.9**
1991	94.8	37.9	473.1	463.6	6036.8	1330.6	1069.3	3340.1	18429	1432	17751.4	479	**50937.6**
1992	98.7	31.1	65.4	1893.7	11770.3	1955.9	3066.7	10770	3730.5	539.1	6083.8	2196	**42201.2**
1993	823.9	26.2	392.5	10433	1768.1	3193	1172.8	832.5	3236.4	8436.1	1718.8	5650.9	**37684.2**
1994	73.6	50.6	77.4	42.8	2386.2	8828.1	1269.8	9706.4	971.7	2510.3	7899.5	185.9	**34002.3**
1995	447.9	26.2	17.2	838.1	2490.9	1729.8	1835.1	697.6	682.6	1019.7	2421.1	21626.5	**33832.7**
1996	10534	52	1325.1	737.7	6652.1	4433.5	1123.1	2816.4	2035	1248.1	65551.1	4510.2	**101018**
1997	67.5	417.4	14.7	122.1	5900.9	1754.1	1332.2	4804.1	2176.7	1543.4	439.8	23.8	**18596.7**
1998													
Mean	**1194.6**	**248.3**	**236.9**	**1720.6**	**8224.3**	**4563.8**	**4598.6**	**6298.1**	**4595.8**	**5262.4**	**11988.9**	**4429.8**	**53362.1**

Table 25

SUSPENDED SEDIMENT DISCHARGE
RIO BOQUERON AT PELUCA

Drainage Area: 35 sq.mi (91 sq. km)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1987	21.3	78.7	25.4	14669.8	51759.7	5174.3	2522.9	6098.5	8830	3610.7	5770.7	830.8	**99392.8**
1988	45.1	126.8	48.9	41.1	2465.3	741.9	18946.5	8217.4	890.6	8931.9	1598	1679.2	**43732.7**
1989	84	452.6	17.4	5	6337.3	2430.2	5447	4516.7	1089.5	6605.7	4347.9	2741.4	**34074.7**
1990	99.2	69.1	204.5	171.1	5345.5	891.7	1171.1	5573.2	2067	4020.9	2459.1	883.2	**22955.6**
1991	87	15.2	493.2	440.8	8881.2	665.9	606	1433.6	13659.7	563.2	14592.7	410.2	**41848.7**
1992	3.4	3.2	3	1462.7	6889.7	1421.1	2048.5	13483.6	2730.7	711.5	5174.9	1715.3	**35647.6**
1993	547.1	0.7	210.9	7175.5	707.8	3923.9	3295.3	2097.8	3394.5	5144.3	2644.7	3688.3	**32830.8**
1994	13.8	5.6	45	4.2	2514	3644.8	1405.5	6266.9	1633.1	599.3	8384.7	824.9	**25341.8**
1995	1284.4	0.2	0.1	173.1	519	3543.6	4102.7	166.1	1255	403	3652.8	19395.1	**34495.1**
1996	5324.1	122.6	819.4	1014.3	7598.6	1058.2	1034.5	1764.2	1262.3	1794.7	73898.2	20589.3	**116280**
1997	18.7	364.6	6.8	2.9	5421.7	5024.2	865.1	3167.7	1791.5	1660.1	198	1.8	**18523.1**
1998													
Mean	**684.4**	**112.7**	**170.4**	**2287.3**	**8949.1**	**2592.7**	**3767.7**	**4798.7**	**3509.4**	**3095.0**	**11156.5**	**4796.3**	**45920.3**

Table 26

SUSPENDED SEDIMENT DISCHARGE
RIO GATUN AT CIENTO

Drainage Area: 45 sq.mi (117 sq. km)

Year	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Annual**
1987	22.5	24.8	12.9	14193.2	2666.4	906.1	1465.9	2251	5316.9	24423.4	20392.2	1904.6	**73579.9**
1988	39.4	20	10.6	10.8	604	315.5	8357.8	10995.2	6246.1	32805.8	3526.1	2642.1	**65573.4**
1989	40.8	123.6	15.3	17	844.9	430.3	3809.5	1695.2	1206.3	4737.4	17508.2	2224.2	**32652.7**
1990	67.3	5.9	18.8	6.1	1808.2	309.4	838.7	4049.4	3612.4	6540.9	2637.8	809.2	**20704.1**
1991	15.3	3.5	14.7	80.9	1866.3	115.9	478.5	553.5	4052.6	2286.6	12454.2	303.7	**22225.7**
1992	21.8	25.5	13.2	137.8	7458.4	2297.7	743.3	4854.6	3821.3	2280.6	1386.9	1177.1	**24218.2**
1993	328.7	10.9	79.9	651.7	600.7	1338.7	3624.3	968.3	4091.2	4244.7	4102.5	484	**20525.6**
1994	688.1	0	3.7	3	188.1	2061.4	1051.7	1040	424.9	2269.9	7502.1	67.5	**15300.4**
1995	343.8	23.1	5.4	20.7	333	1783.4	1761.5	2802.6	1007.2	1501.7	6872.4	3863.1	**20317.9**
1996	7422.6	21.7	42.8	151.3	2377.2	2095.7	1087.2	1697.4	901.3	1295.7	39635.9	4236.8	**60965.6**
1997	46.2	32.2	5.7	9.1	790.3	873.6	267.5	94.9	1562	763.1	2083.6	60.7	**6588.9**
1998													
Mean	**821.5**	**26.5**	**20.3**	**1389.2**	**1776.1**	**1138.9**	**2135.1**	**2818.4**	**2931.1**	**7559.1**	**10736.5**	**1615.7**	**32968.4**

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Table 27

SUSPENDED SEDIMENT DISCHARGE
RIO TRINIDAD AT CHORRO

Drainage Area: 67 sq.mi (174 sq. km)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1987	16	25.1	27.5	98.8	696	502.1	1085.3	2774.1	4042.4	5327.5	792.8	838	**16225.6**
1988	134.9	6	1.3	77.1	2220.8	924.3	1366.2	4755.8	4638.6	2915.6	1707.3	1721.8	**20469.7**
1989	198.5	36.9	19.4	8.4	967.5	727.4	2053	2935.1	3047	2529.1	1486.8	3377.4	**17386.5**
1990	179.8	20.7	5.1	5	449.9	1828.8	2491.8	1667.3	9022.5	7461.8	4318.2	895.8	**28346.7**
1991	31.8	6.4	29.3	5.8	766.5	645.5	197	390.8	1386.4	2246	1688.5	794.6	**8188.6**
1992	13.8	4.6	1.7	91.2	500.8	1794.1	352.3	1232.1	3740.6	1342.7	2009	462.2	**11545.1**
1993	41.1	11.5	11.1	184.4	714.2	2242.5	467.2	563.4	3306.8	2162.7	4233.6	940.5	**14879**
1994	3	0	22	9.7	789.5	504.8	225.8	176.1	3109.7	3164.7	1714.6	181.8	**9901.7**
1995	9.3	1	0	19.8	1179.3	2344.7	1938.9	3319.5	2831.7	5817.5	2342.1	470.4	**20274.2**
1996	13474.7	63.1	134.4	12.5	2896.2	5388	3351.9	5366.5	4533.5	6585.9	3373.8	1997.1	**47177.6**
1997	415.7	1.1	0	21.6	13.4	389.3	66.7	28.4	284.9	1556.9	839.9	6.7	**3624.6**
1998													
Mean	**1319.9**	**16.0**	**22.9**	**48.6**	**1017.6**	**1572.0**	**1236.0**	**2109.9**	**3631.3**	**3737.3**	**2227.9**	**1062.4**	**18001.8**

Table 28

SUSPENDED SEDIMENT DISCHARGE
RIO CIRI GRANDE AT LOS CANONES

Drainage Area: 72 sq.mi (186 sq. km)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1987	47.1	31.5	11.9	57	2812	1093.5	1436.8	4411.9	6186.5	8752.5	3254.8	3758.1	**31853.6**
1988	49.1	21.9	6.6	28.7	727.9	1551	1468.8	4645.1	4173.3	5039.6	3938.8	1800.5	**23451.3**
1989	363.5	87.2	20.4	5.4	1135.1	844.4	2179.9	4607.1	4737	9667.2	2845.8	2094.8	**28587.8**
1990	596.1	12.2	26	7.4	1042.4	1062.3	1493.7	1073.5	7587.8	5774.3	2739.9	2929.1	**24344.7**
1991	109.2	47.5	184.4	30.8	590.6	536.8	157.6	427.7	1836.3	3041.4	1454.6	876	**9292.9**
1992	45.8	13.4	5.6	286.1	1046.8	1266.8	1267.6	4005.2	3686.3	1974.4	2977.4	356.9	**16932.3**
1993	154.4	46.4	39.1	271.6	485.3	2460.7	466.6	581.6	3883.3	3448.8	8734.5	1634	**22206.3**
1994	14.9	7.5	39.4	32.5	859.2	1347.8	390.6	140.9	1956.6	3960	3224.3	224.1	**12197.8**
1995	27.3	0.4	18	163.2	4297	3246.3	2298.7	3216.8	3896.3	4583.8	2339.4	1892.4	**25979.6**
1996	93184.1	149.7	216.3	30.6	3694.7	6064.4	9619.6	14254.5	8190.3	13263.5	7510.9	7213.5	**163392.1**
1997	26.8	33.2	0	44	118.8	533.2	252.6	93.7	1164.7	1551.1	2172.1	66.6	**6056.8**
1998													
Mean	**8601.66**	**40.99**	**51.61**	**87.03**	**1528.16**	**1818.84**	**1912.05**	**3405.27**	**4299.85**	**5550.60**	**3744.77**	**2076.91**	**33117.75**

Table 29

SUSPENDED SEDIMENT DISCHARGE, COCLE DEL NORTE AT CANOAS USING SEDIMENT RATING AND FLOW DURATION CURVES

Limits	Interval	Middle Ordinate	Qw	qs	Qs
(%)	(%)	(%)	(m3/s)	(mt/day)	(mt/day)
('1)	('2)	('3)	('4)	('5)	('6) (col.2*col.5)
0.0.01	0.01	0.005	1350.0	728724.1	7287.2
0.01-0.02	0.01	0.015	1300.0	669954.5	6699.5
0.02-0.05	0.03	0.035	1200.0	560525.4	16815.8
0.05-0.1	0.05	0.075	1100.0	461745.2	23087.3
0.1-0.5	0.4	0.3	800.0	227124.5	90849.8
0.5-1.0	0.5	0.75	450.0	63028.5	31514.3
1.0-2.0	1	1.5	145.0	1814.8	1814.8
2.0-5.0	3	3.5	115.0	781.1	2343.3
5-10	5	7.5	87.0	283.1	1415.6
10-15	5	12.5	68.0	158.8	793.8
15-20	5	17.5	57.0	106.5	532.6
20-25	5	22.5	50.0	79.2	396.1
25-30	5	27.5	45.0	62.4	312.1
30-35	5	32.5	41.5	52.0	259.9
35-40	5	37.5	38.0	42.6	212.9
40-45	5	42.5	35.0	35.4	176.8
45-50	5	47.5	32.0	28.9	144.4
50-55	5	52.5	30.0	25.0	124.8
55-60	5	57.5	27.0	19.7	98.3
60-65	5	62.5	25.5	17.3	86.4
65-70	5	67.5	23.0	14.6	72.8
70-75	5	72.5	21.0	12.9	64.7
75-80	5	77.5	19.0	11.4	56.8
80-85	5	82.5	17.0	9.8	49.1
85-90	5	87.5	15.0	8.4	41.8
90-95	5	92.5	12.0	6.2	31.2
95-97	2	96	8.8	4.2	8.3
97-99	2	98	5.6	2.3	4.6
99-100	1	99.5	3.5	1.3	1.3
				Sum =	**185296.3**
					676331.4 mt/yr

Qw = discharge at mid-ordinate of the interval
qs = sediment discharge corresponding to Qw
Qs = qs* interval

Table 30

SUSPENDED SEDIMENT DISCHARGE, RIO TOABRE AT BATATILLA USING SEDIMENT RATING AND FLOW DURATION CURVES

Limits	Interval	Middle Ordinate	Qw	qs	Qs
(%)	(%)	(%)	(m3/s)	(mt/day)	(mt/day)
('1)	('2)	('3)	('4)	('5)	('6)
					(col.2*col.5)
0-0.01	0.01	0.005	2400.0	1664295.3	16643.0
0.01-0.02	0.01	0.015	2100.0	1274056.0	12740.6
0.02-0.05	0.03	0.035	1900.0	1042830.3	31284.9
0.05-0.1	0.05	0.075	1400.0	566017.5	28300.9
0.1-0.5	0.4	0.3	900.0	233812.1	93524.8
0.5-1.0	0.5	0.75	300.0	25946.3	12973.1
1.0-2.0	1	1.5	180.0	8301.0	8301.0
2.0-5.0	3	3.5	135.0	4369.1	13107.3
5-10	5	7.5	104.0	2441.3	12206.4
10-15	5	12.5	80.0	852.3	4261.5
15-20	5	17.5	66.0	408.4	2041.8
20-25	5	22.5	58.0	249.1	1245.5
25-30	5	27.5	51.0	152.3	761.6
30-35	5	32.5	45.0	94.4	471.8
35-40	5	37.5	40.5	63.1	315.3
40-45	5	42.5	37.0	50.7	253.3
45-50	5	47.5	32.5	42.3	211.7
50-55	5	52.5	28.5	35.3	176.6
55-60	5	57.5	24.0	27.9	139.3
60-65	5	62.5	20.5	22.4	112.0
65-70	5	67.5	17.5	18.0	90.0
70-75	5	72.5	14.5	13.9	69.4
75-80	5	77.5	12.4	11.2	55.9
80-85	5	82.5	10.3	8.7	43.3
85-90	5	87.5	8.4	6.5	32.7
90-95	5	92.5	6.4	4.5	22.4
95-97	2	96	4.6	2.8	5.7
97-99	2	98	3.6	2.0	4.1
99-100	1	99.5	2.9	1.5	1.5
				Sum =	**239397.5**
					873801.0 mt/yr

Qw = discharge at mid-ordinate of the interval
qs = sediment discharge corresponding to Qw
Qs = qs* interval

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Table 31

RIO COCLE DEL NORTE RESERVOIR
LOSS IN LIVE STORAGE

Period of Operation (years)	Live Reservoir Volume (MCM)	Loss (MCM	Loss (%)
Reservoir Operation between 80 m and 50 m			
0	5,394.1		
5	5,390.3	3.8	0.07
10	5386.7	7.4	0.14
20	5379.3	14.8	0.27
25	5375.6	18.5	0.34
50	5357.3	36.8	0.68
100	5320.7	73.4	1.36
Reservoir Operation between 100m and 90 m			
0	3616.2		
5	3615.2	1.0	0.03
10	3614.3	1.9	0.05
20	3612.3	3.9	0.11
25	3611.4	4.8	0.13
50	3606.5	9.7	0.27
100	3596.9	19.3	0.53

Table 32

FLOOD FREQUENCY DATA
RIO COCLE DEL NORTE AT DAM SITE

Return Period	Pre-Project Flood Peak	Post-Project Flood Peak
(year)	(m^3/s)	(m^3/s)
2	1,295	17
5	1,925	25
10	2,430	34
20	2,995	50
50	3,860	75
100	4,610	98

Table 33

HYDRAULIC CHARACTERISTICS OF REPRESENTATIVE CROSS SECTION

Discharge	Water Surface Elevation	Top Width	Maximum Depth	Average Depth	Area	Mean Velocity
(m^3/s)	(m)	(m)	(m)	(m)	(m^2)	(m/s)
1,295	4.72	172	7.82	6.19	1,065	1.22
1,925	6.12	183	9.22	7.05	1,291	1.49
2,430	7.06	193	10.16	7.66	1,479	1.64
2,995	7.98	202	11.08	8.30	1,677	1.79
3,860	9.20	212	12.30	9.10	1,929	2.00
17	0.01	112	3.11	2.46	276	0.06
25	0.02	113	3.12	2.45	277	0.09
34	0.03	114	3.13	2.44	278	0.12
50	0.07	115	3.17	2.46	283	0.18
75	0.14	117	3.24	2.49	291	0.26
98	0.23	120	3.33	2.51	301	0.33

Table 34

CHARCTERICTICS OF AVERAGE BED MATERIAL CURVE

Size Designation	Particle Size
	(mm)
D35	0.45
D50	0.65
D65	3.50
D90	29.00
Median	**7.00**

Table 35

ARMORING SIZES – RIO COCLE DEL NORTE DOWNSTREAM FROM DAM

	Armoring Size (mm) for Indicated Flood					
Method of Estimation	**2-Yr**	**5-Yr**	**10-Yr**	**20-Yr**	**50-Yr**	**100-Yr**
Pre-Project						
Meyer-Peter, Muller	3	4	4	4	5	6
Competent Bottom Velocity	30	45	55	65	82	92
Shield	6	7	7	8	9	13
Yang	32	48	58	69	86	96
Average	**18**	**26**	**31**	**37**	**45**	**52**
Post-Project						
Meyer-Peter, Muller	1	1	1	1	1	1
Competent Bottom Velocity	0	0	0	1	1	2
Shield	2	2	2	2	2	2
Yang	0	0	0	1	1	2
Average	**1**	**1**	**1**	**1**	**1**	**2**

Table 36

MONTHLY MEAN DISCHARGES IN CUBIC METERS PER SECOND
RIO CAÑO SUCIO

Drainage Area 42.90 mi^2

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
1948	125.2	49.6	35.6	26.4	56.2	79.7	294	343	326	303	603	169	**201**
1949	70.8	43.0	28.0	25.5	76.5	414.2	292	366	512	486	840	666	**318**
1950	117.3	66.0	39.7	28.9	199.7	366.6	382	554	370	502	650	652	**327**
1951	209.0	115.7	66.0	43.9	205.1	250.7	233	253	429	364	545	316	**253**
1952	139.5	66.8	35.6	31.4	117.3	297.4	231	245	410	585	369	521	**254**
1953	390.1	152.0	81.3	57.8	242.2	217.5	211	176	217	614	614	339	**276**
1954	171.6	81.3	51.3	41.4	193.4	204.3	481	364	495	422	790	421	**310**
1955	451.1	142.6	70.8	56.2	111.8	424.0	302	496	605	523	797	464	**370**
1956	469.1	146.5	85.4	78.9	295.1	426.3	401	300	478	714	507	295	**350**
1967	118.1	61.1	39.7	28.9	121.3	122.1	120	235	257	585	385	310	**199**
1958	195.0	150.5	80.5	57.8	178.6	213.6	294	395	383	500	406	216	**256**
1959	97.0	59.5	42.2	37.2	56.2	861.3	962	146	171	516	357	452	**313**
1960	216.9	90.3	93.7	116.1	274.1	290.2	287	296	260	414	575	958	**323**
1961	162.5	84.7	48.2	49.4	85.9	214.9	190	211	336	520	458	370	**227**
1962	136.1	73.4	43.6	40.1	59.7	90.4	124	308	266	356	370	282	**179**
1963	113.9	76.8	42.4	85.9	185.5	222.5	268	347	351	499	558	187	**245**
1964	93.8	50.5	33.1	37.8	137.2	443.0	437	445	534	575	674	209	**306**
1965	161.4	80.2	45.9	27.2	42.4	83.6	75	169	135	277	344	365	**150**
1966	129.5	64.3	43.6	45.9	263.5	360.6	291	260	190	546	728	559	**290**
1967	181.2	89.3	47.1	73.4	220.3	515.3	389	427	569	656	439	207	**318**
1968	98.2	71.2	45.9	41.3	111.7	312.8	235	331	347	582	562	273	**251**
1969	117.2	68.9	35.4	54.0	109.4	222.5	572	907	531	454	494	301	**322**
1970	247.3	110.6	93.8	99.4	293.5	197.5	221	478	405	604	477	986	**351**
1971	429.3	153.7	87.0	65.5	257.0	380.8	324	472	520	576	681	200	**346**
1972	136.1	90.5	56.0	149.3	127.2	230.1	102	147	336	339	356	146	**185**
1973	84.1	52.6	25.6	28.0	99.9	401.9	416	334	592	659	780	385	**322**
1974	174.6	107.6	78.5	47.2	91.1	195.3	238	274	322	900	516	273	**26**
1975	121.7	71.9	48.8	30.8	81.5	160.3	235	448	623	688	1047	559	**343**
1976	219.2	117.2	69.9	61.3	142.7	131.7	69	84	246	574	399	159	**189**
1977	97.6	61.6	38.6	30.6	83.5	123.9	118	265	304	565	422	233	**195**
1978	114.9	75.8	50.7	277.5	241.9	338.3	327	441	462	527	449	264	**297**
1979	147.3	114.1	103.8	117.3	187.2	301.2	298	375	401	377	278	268	**247**
1980	249.4	89.8	42.2	28.6	145.1	196.7	216	507	255	387	348	299	**230**
1981	216.1	139.7	126.8	310.6	318.2	355.8	428	404	308	516	630	813	**381**
1982	199.9	62.0	41.0	56.2	98.0	227.9	290	186	299	544	281	95	**198**
1983	62.6	32.6	19.5	16.3	167.7	250.5	177	199	485	378	321	413	**210**
1984	168.8	107.0	69.3	38.2	181.7	294.5	331	521	428	479	405	138	**263**
1985	92.1	57.4	44.4	28.5	90.2	324.6	186	419	404	376	435	285	**229**
1986	101.1	52.8	32.2	172.0	204.2	319.2	239	202	296	603	659	161	**253**
1987	79.4	53.5	31.1	53.7	153.7	246.2	276	334	430	775	344	190	**247**
1988	80.6	54.6	30.8	27.9	126.8	253.7	271	356	358	565	440	238	**233**
1989	135.4	75.0	51.6	30.2	141.9	198.9	299	384	372	391	578	322	**248**
1990	163.4	73.0	50.0	34.0	265.4	192.5	246	256	446	642	432	667	**289**
1991	110.6	62.0	75.4	33.5	150.2	214.1	158	196	415	525	358	474	**231**
1992	98.2	36.4	39.7	59.1	287.1	299.4	288	496	463	404	339	208	**251**
1993	126.1	71.7	58.5	93.4	119.6	321.2	235	182	380	529	676	356	**262**
1994	129.8	75.5	61.5	66.8	144.2	226.0	168	130	274	387	397	143	**184**
1995	88.2	47.0	31.1	43.2	247.1	386.2	339	310	393	331	450	318	**249**
1996	616.7	287.1	146.5	79.1	225.2	447.9	494	608	441	766	598	554	**439**
1997	121.5	75.9	50.0	36.6	60.5	73.7	86	71	171	223	270	119	**113**
1998	54.9	45.5	30.8	42.2	146.2	136.1	239	195	271	423	249	370	**184**
Mean	**169**	**85**	**55**	**64**	**161**	**276**	**282**	**330**	**378**	**511**	**504**	**356**	**264**
Maximum	**616.7**	**287.1**	**146.5**	**310.6**	**318.2**	**861.3**	**962.1**	**907.5**	**622.5**	**900.0**	**1047.4**	**985.5**	**438.5**
Minimum	**54.9**	**32.6**	**19.5**	**16.3**	**42.4**	**73.7**	**68.8**	**70.6**	**135.0**	**223.3**	**249.4**	**95.1**	**113.2**

Table 37

MAXIMUM INSTANTANEOUS FLOOD PEAKS (CMS), RIO INDIO AT BOCA DE URACILLO

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1979							107.0	515.0	166.0	178.0	82.2	186.0	515.0
1980	225.0	20.1	5.3	7.2	146.0	176.0	58.4	610.0	67.5	325.0	166.0	89.2	610.0
1981	32.4	28.8	49.8	316.0	162.0	301.0		213.0	96.8	324.0	489.0	583.0	583.0
1982	80.9	10.0	7.1	49.1	43.9	169.0	386.0	68.3	198.0	445.0	213.0	13.9	445.0
1983	9.0	3.8	3.5	9.8	132.0	427.0	81.7	190.0	404.0	581.0	195.0	270.0	581.0
1984	49.1	22.9		4.7	167.0	197.0	186.0	375.0	237.0	526.0	190.0	20.1	526.0
1985	43.5	6.7	6.7	5.3	145.0	256.0	51.2	603.0	210.0	229.0	401.0	253.0	603.0
1986	15.9	8.2	4.7	242.0	380.0	375.0		182.0	171.0	261.0	504.0	25.2	504.0
1987	11.4	9.0	3.8			319.0	247.0	227.0	443.0	709.0	151.0	89.2	709.0
1988	10.3	8.2	4.1	14.9							187.0	97.6	
1989	25.2			4.7	481.0	346.0	474.0	289.0	360.0	156.0	459.0	297.0	481.0
1990	80.9	9.0	9.4	6.0	595.0	122.0				435.0	345.0	597.0	597.0
1991	22.6	9.0	99.3	10.7	138.0	128.0	54.8	115.0	316.0	336.0	207.0	772.0	772.0
1992	15.1	8.2	6.7	114.0	269.0	199.0	131.0	619.0	286.0	546.0	230.0	41.5	619.0
1993	28.8	9.8	27.0	229.0	48.3	352.0	165.0	57.0	337.0	337.0	391.0	233.0	546.0
1994	22.5	9.4	33.7	25.8	390.0	521.0	124.0	83.4	632.0	133.0	626.0	193.0	632.0
1995	38.8	6.7	5.3	13.4	355.0	296.0	289.0	198.0	366.0	550.0	372.0	153.0	372.0
1996	20.1	34.3			194.0	522.0			515.0		372.0	512.0	
1997	20.1	34.3				126.0							
1998	10.3	6.7	6.0	39.5	256.0								

Table 38

FLOOD PEAKS AT CANO SUCIO FOR SELECTED RETURN PERIODS

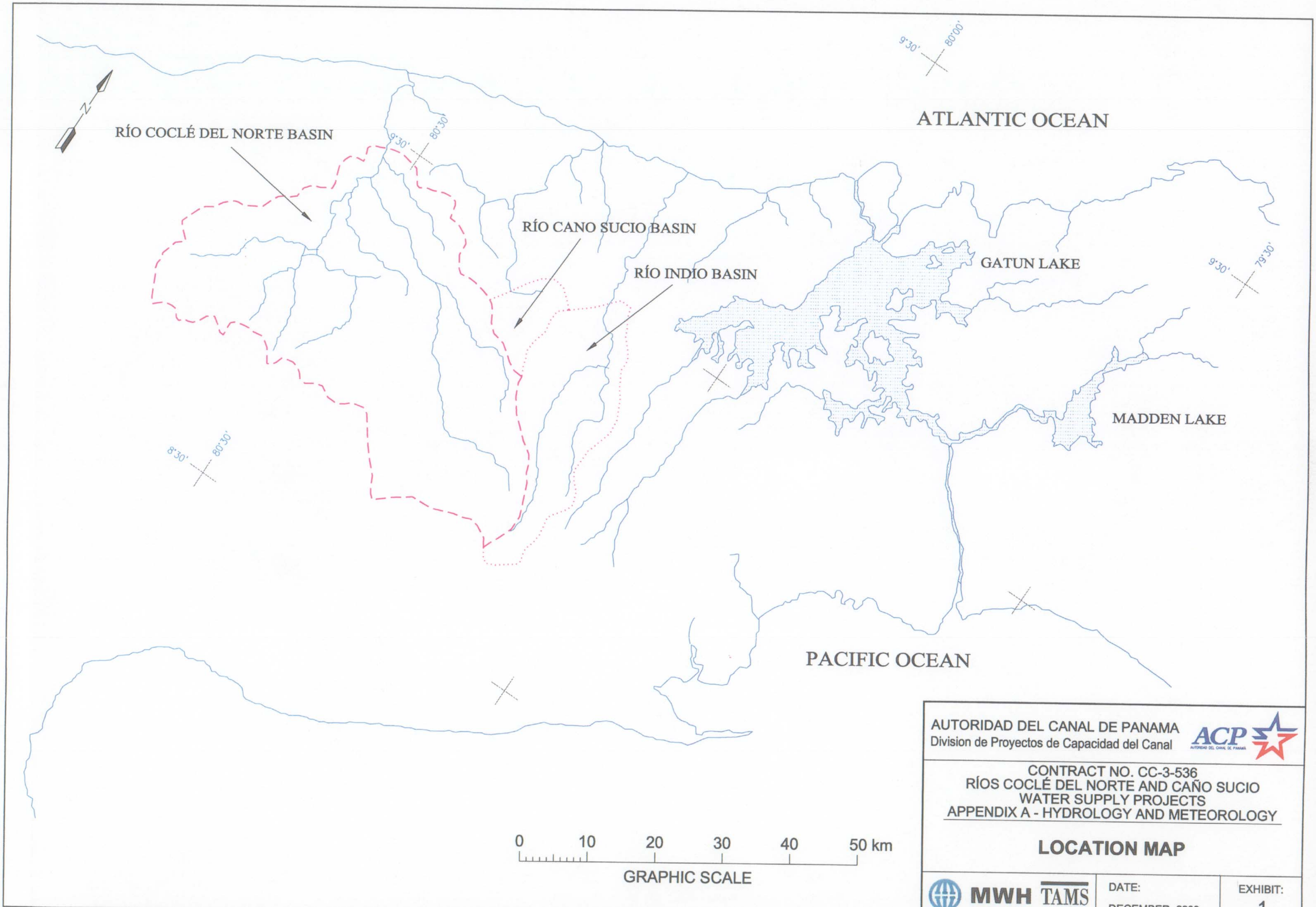
Return Period (years)	Flood Peak (m^3/s)	Dry Period Flood Peak (m^3/s)
5	327	25
10	358	39
20	385	57
50	417	90
100	439	126

Table 39

SEQUENTIAL ARRANGEMENT OF PMP INCREMENTS
(Increments as percentages of 48-hour PMP)

Hour	Increment	Hour	Increment
1	0.7	25	3.0
2	0.7	26	4.0
3	0.7	27	4.0
4	0.7	28	13.5
5	0.8	29	14.0
6	0.8	30	6.5
7	0.8	31	4.0
8	0.8	32	3.0
9	0.8	33	3.0
10	0.8	34	2.0
11	0.8	35	2.0
12	0.9	36	1.5
13	0.9	37	1.5
14	1.0	38	1.5
15	1.0	39	1.5
16	1.0	40	1.5
17	1.0	41	1.0
18	1.5	42	1.0
19	1.5	43	1.0
20	1.5	44	0.9
21	1.5	45	0.9
22	2.0	46	0.9
23	2.0	47	0.8
24	2.0	48	0.8

EXHIBITS



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Division de Proyectos de Capacidad del Canal

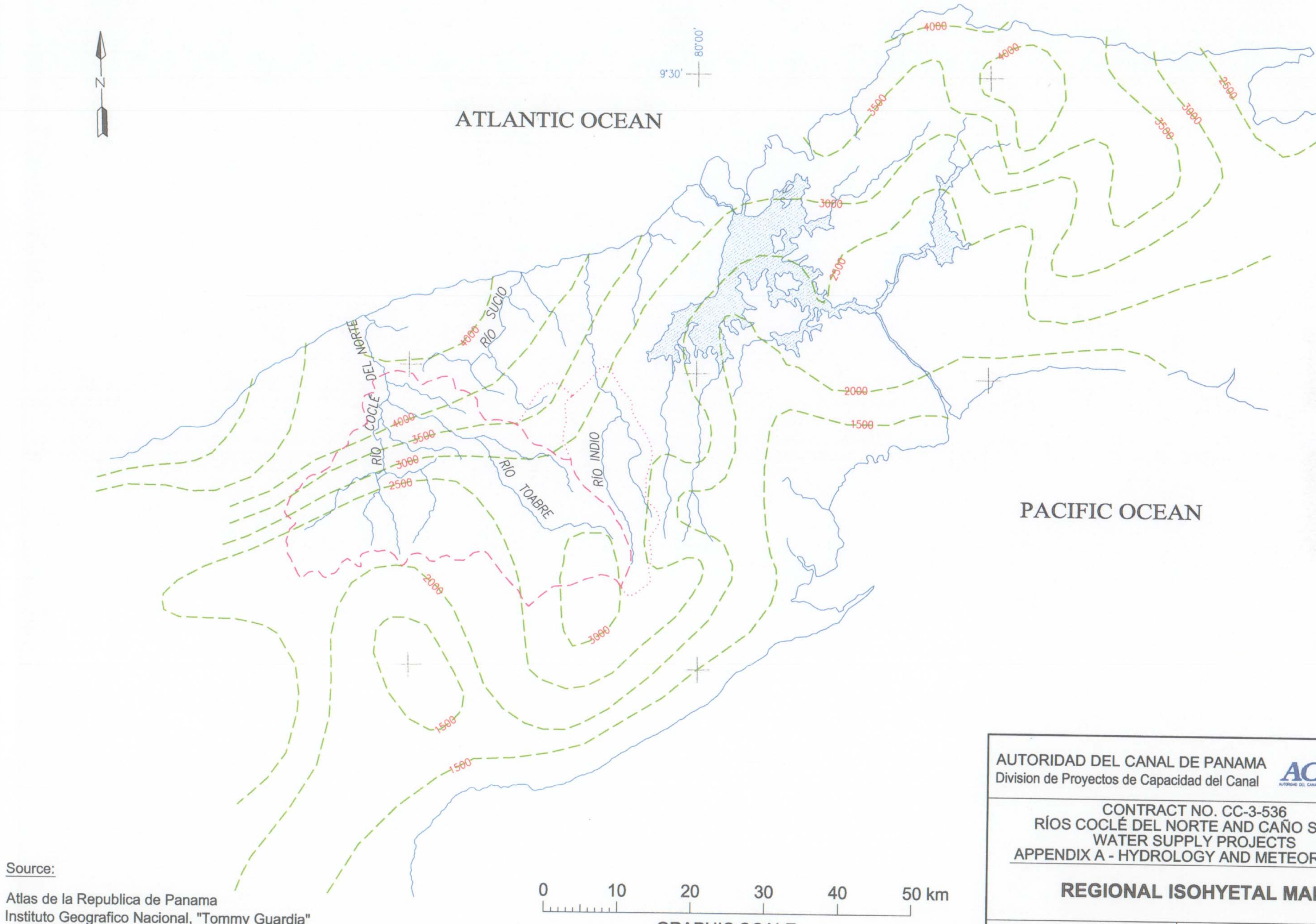
CONTRACT NO. CC-3-536
RÍOS COCLÉ DEL NORTE AND CAÑO SUCIO
WATER SUPPLY PROJECTS
APPENDIX A - HYDROLOGY AND METEOROLOGY

LOCATION MAP

MWH TAMS

DATE: DECEMBER, 2003

EXHIBIT: 1



Source:

Atlas de la Republica de Panama
Instituto Geografico Nacional, "Tommy Guardia"

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CONTRACT NO. CC-3-536
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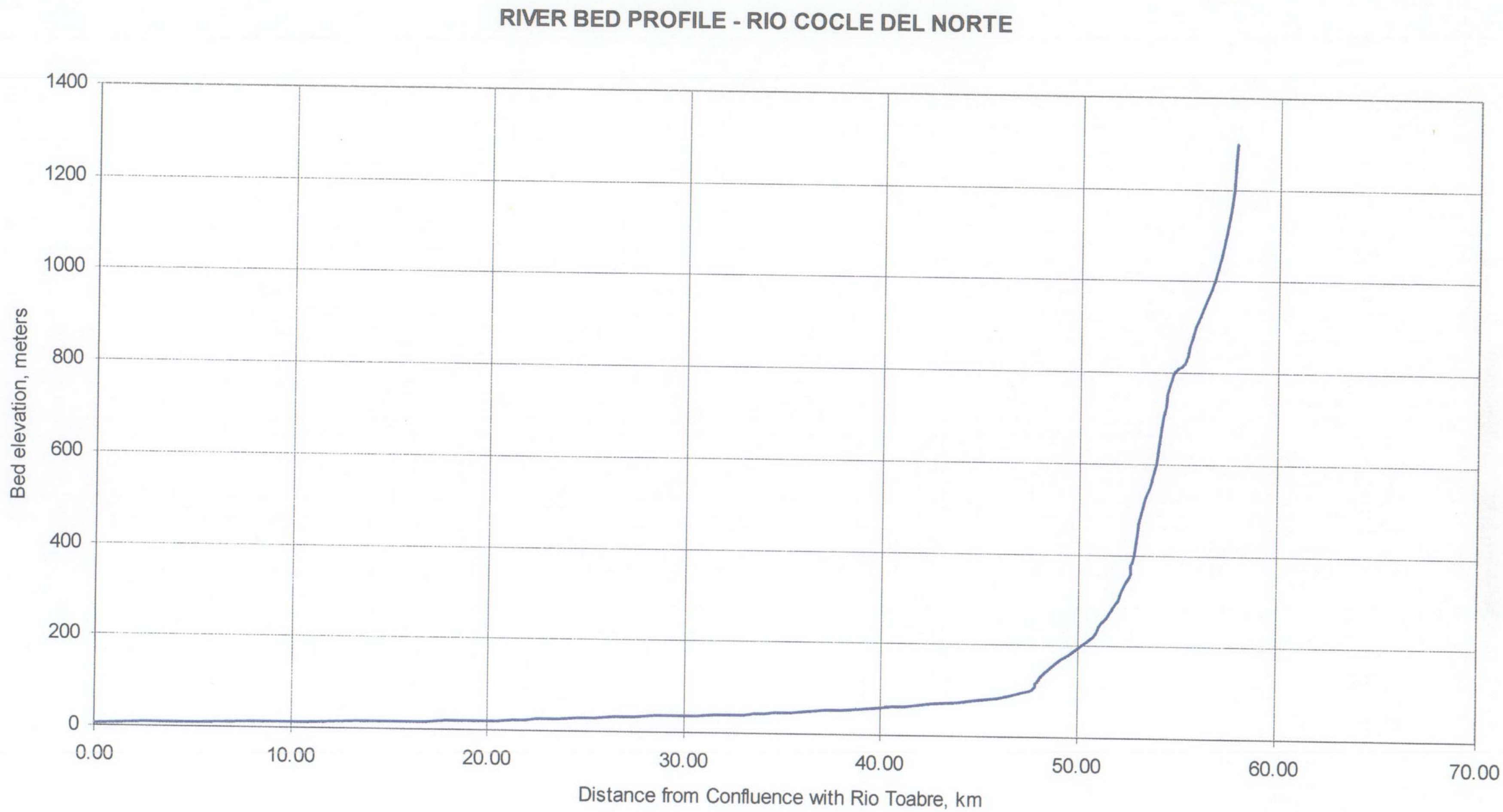
WATER SUPPLY PROJECTS
APPENDIX A - HYDROLOGY AND METEOROLOGY

REGIONAL ISOHYETAL MAP

MWH TAMS

DATE: DECEMBER, 2003

EXHIBIT: 2



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CONTRACT NO. CC-3-536
RÍOS COCLÉ DEL NORTE AND CAÑO SUCIO
WATER SUPPLY PROJECTS
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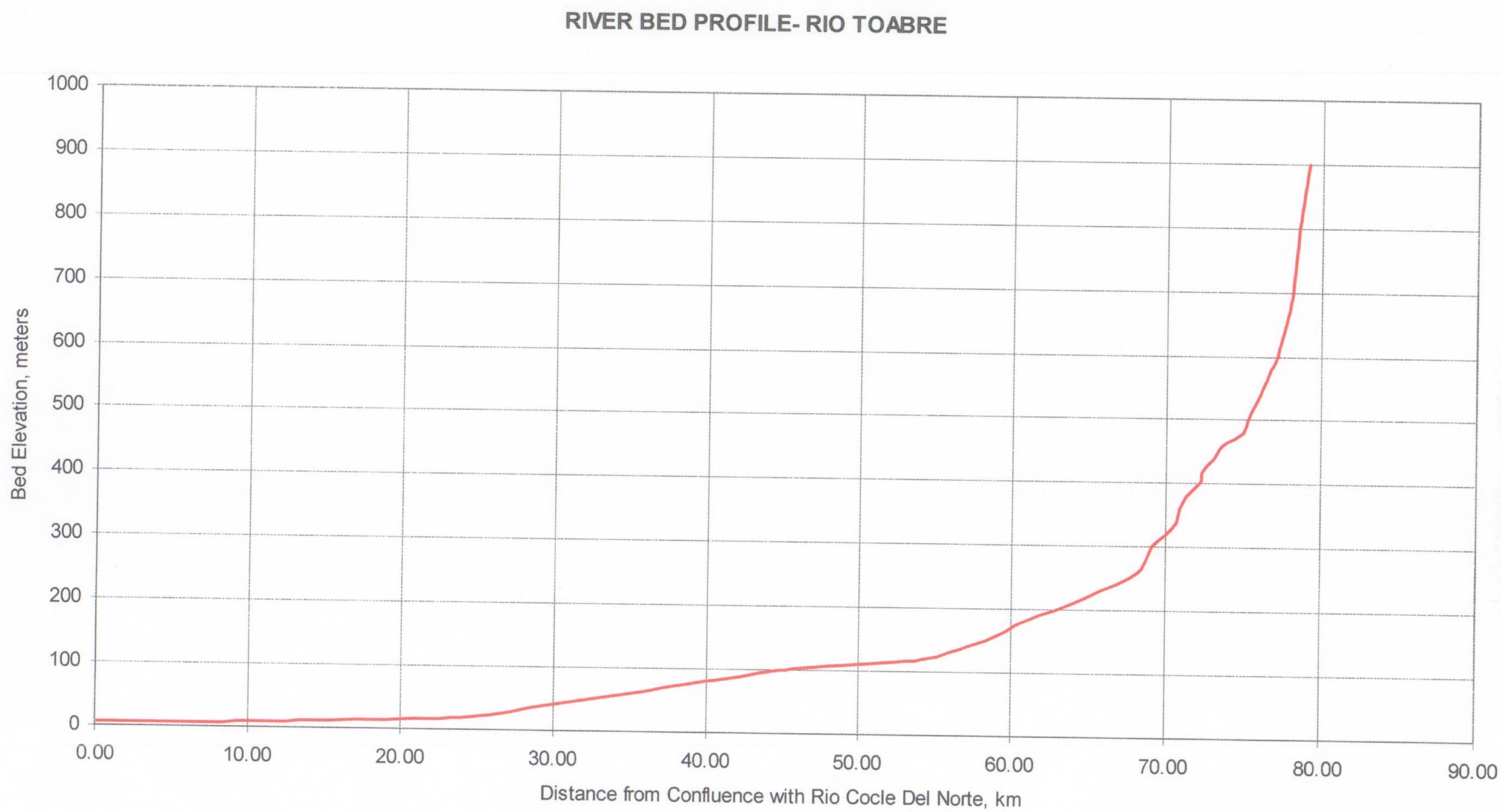
RIVER BED PROFILE
RÍO COCLÉ DEL NORTE

MWH TAMS

DATE: DECEMBER, 2003

EXHIBIT: 3



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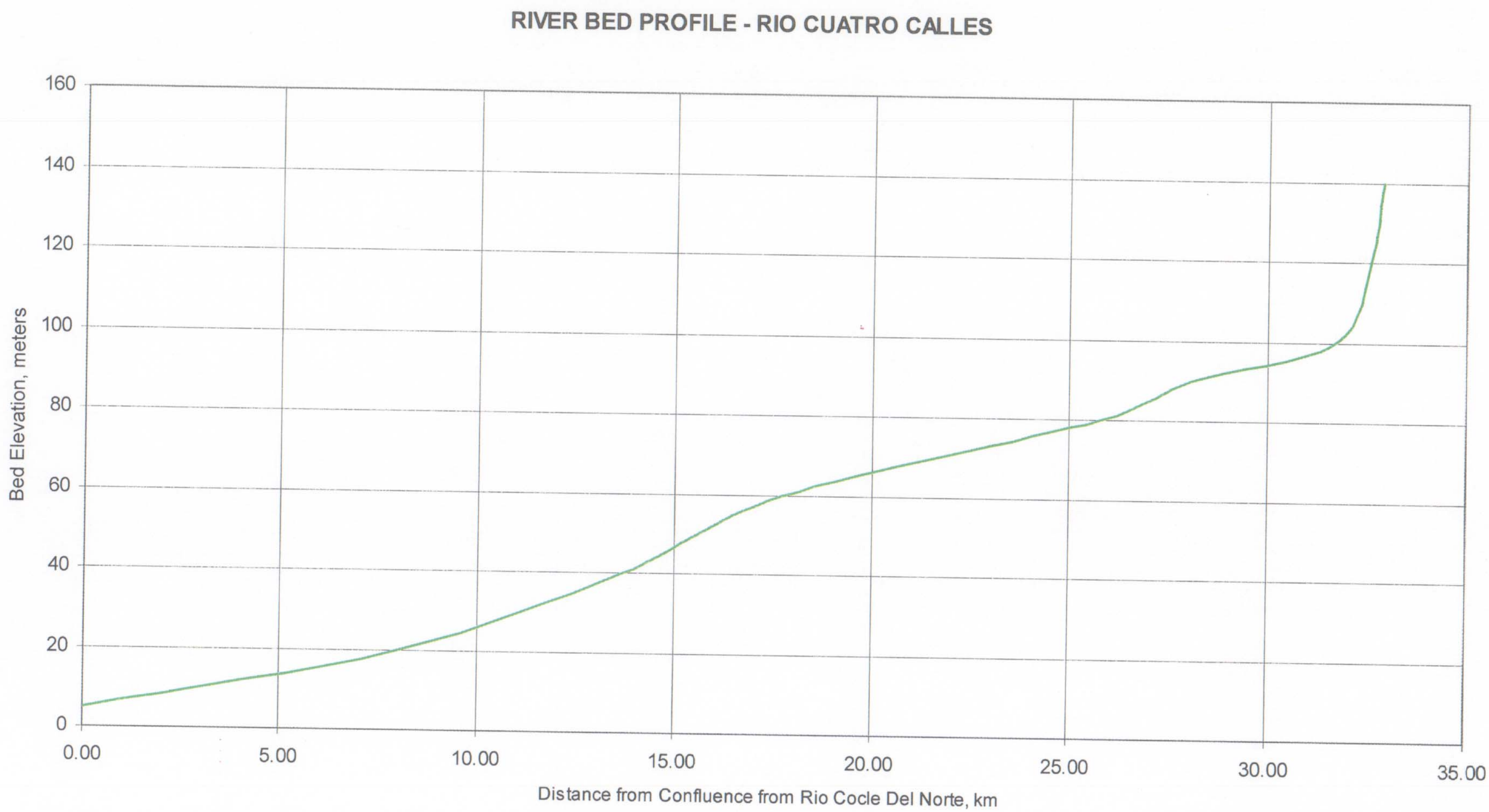
Division de Proyectos de Capacidad del Canal

CONTRACT NO. CC-3-536
RÍOS COCLÉ DEL NORTE AND CAÑO SUCIO
WATER SUPPLY PROJECTS
APPENDIX A - HYDROLOGY AND METEOROLOGY

RIVER BED PROFILE
RÍO TOABRE

MWH TAMS

DATE:	EXHIBIT:
DECEMBER, 2003	4



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Division de Proyectos de Capacidad del Canal

CONTRACT NO. CC-3-536
RÍOS COCLÉ DEL NORTE AND CAÑO SUCIO
WATER SUPPLY PROJECTS
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RIVER BED PROFILE
RÍO CUATRO CALLES

MWH TAMS

DATE: DECEMBER, 2003

EXHIBIT: 5

LEGEND:

- ▲ RAIN GAGE
- ⊙ STREAM GAGE
- DRAINAGE BASIN BOUNDARY
- ■ VILLAGE

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WATER SUPPLY PROJECTS
APPENDIX A - HYDROLOGY AND METEOROLOGY

RÍO COCLÉ DEL NORTE BASIN

MWH TAMS

DATE: DECEMBER, 2003

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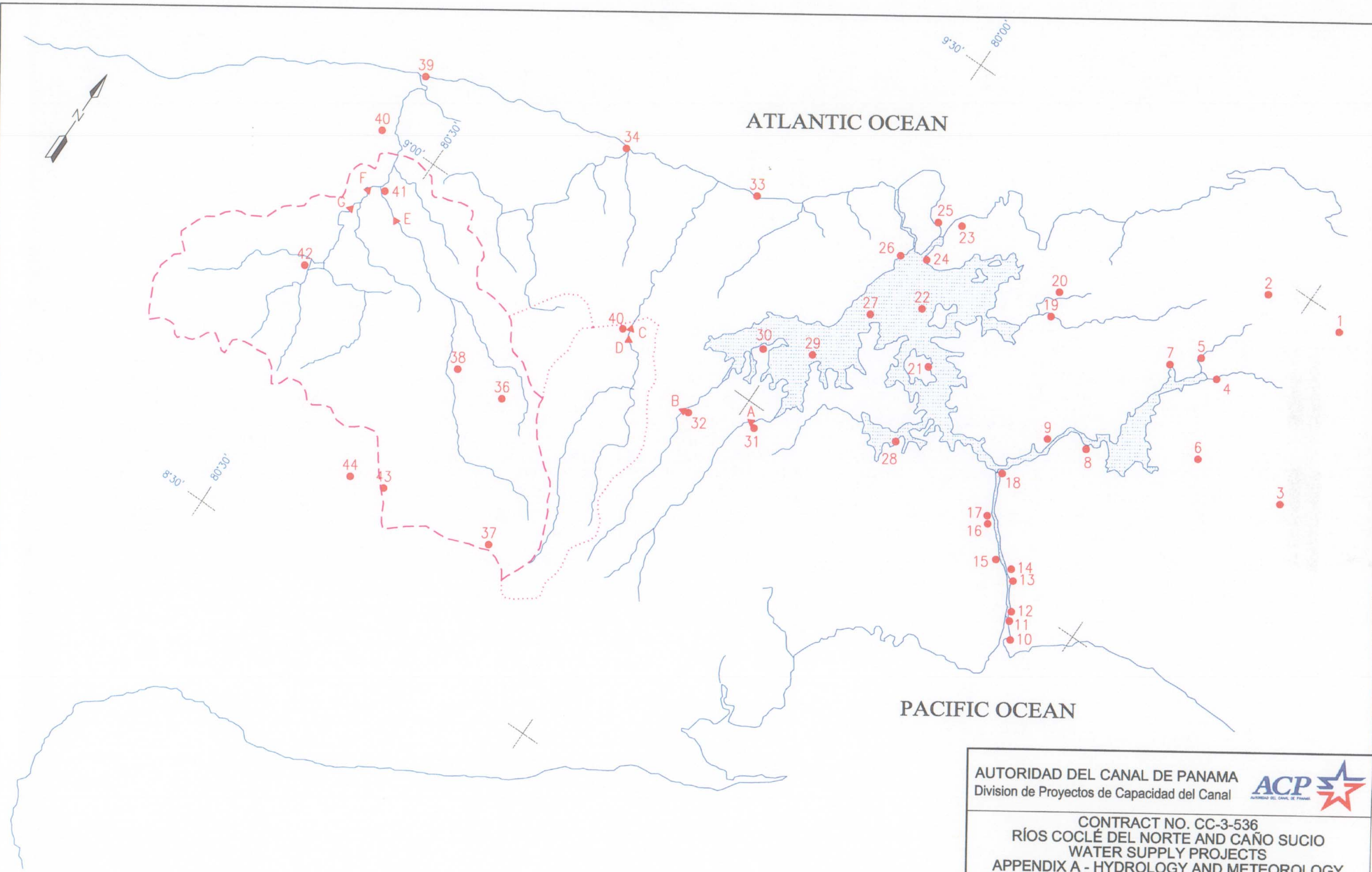

0 10 20 30 40 50 km

GRAPHIC SCALE

Note:

See Table 7 for Names of Stations

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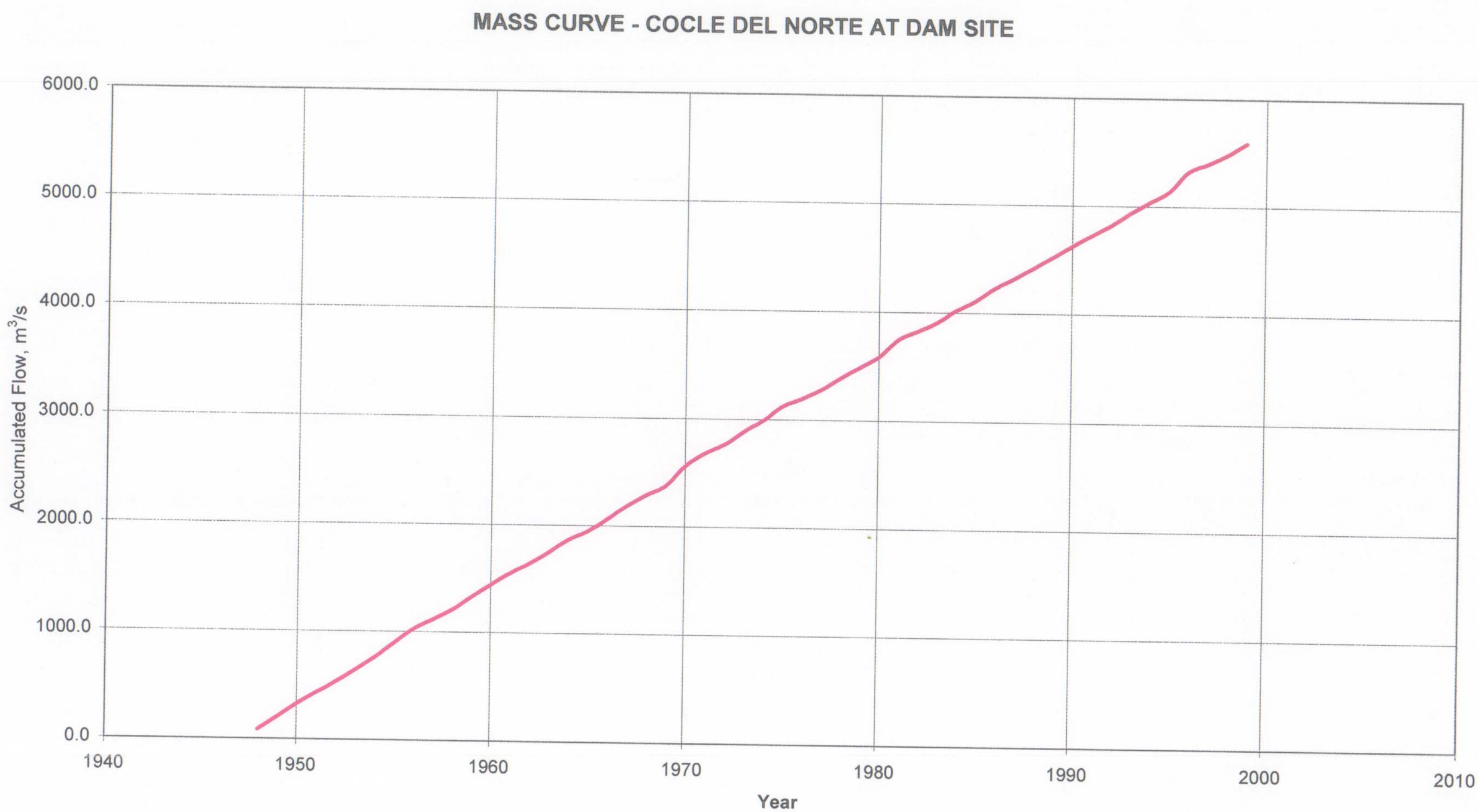
APPENDIX A - HYDROLOGY AND METEOROLOGY

LOCATIONS OF STREAM GAGING AND RAINFALL STATIONS

MWH TAMS

DATE: DECEMBER, 2003

EXHIBIT: 7



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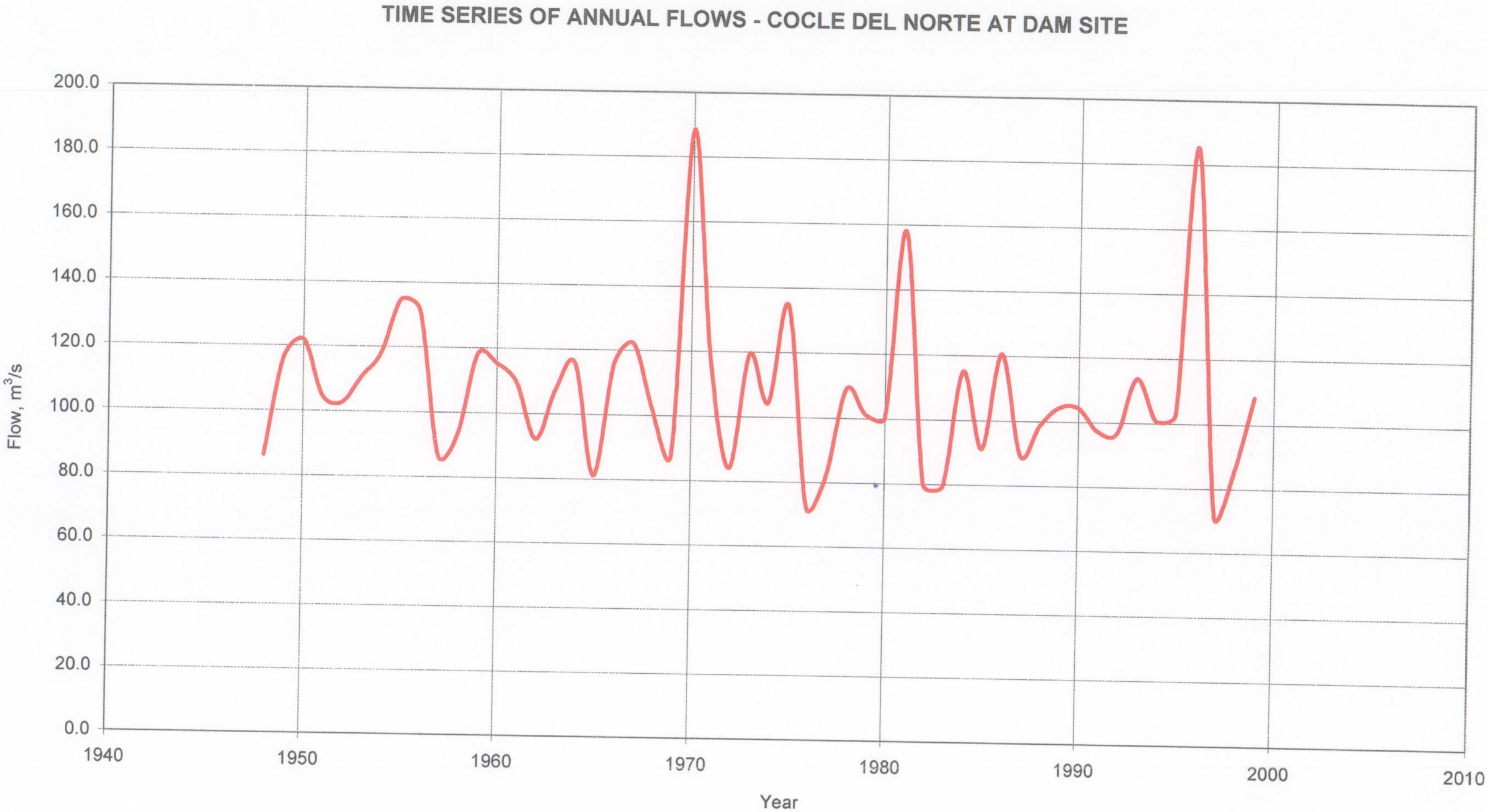
CONTRACT NO. CC-3-536
RÍOS COCLÉ DEL NORTE AND CAÑO SUCIO
WATER SUPPLY PROJECTS
APPENDIX A - HYDROLOGY AND METEOROLOGY

MASS CURVE
RÍO COCLÉ DEL NORTE AT DAM SITE

MWH TAMS

DATE: DECEMBER, 2003

EXHIBIT: 8



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CONTRACT NO. CC-3-536
RÍOS COCLÉ DEL NORTE AND CAÑO SUCIO
WATER SUPPLY PROJECTS
APPENDIX A - HYDROLOGY AND METEOROLOGY

TIME SERIES OF ANNUAL FLOW
RÍO COCLÉ DEL NORTE AT DAM SITE

MWH TAMS

DATE: DECEMBER, 2003

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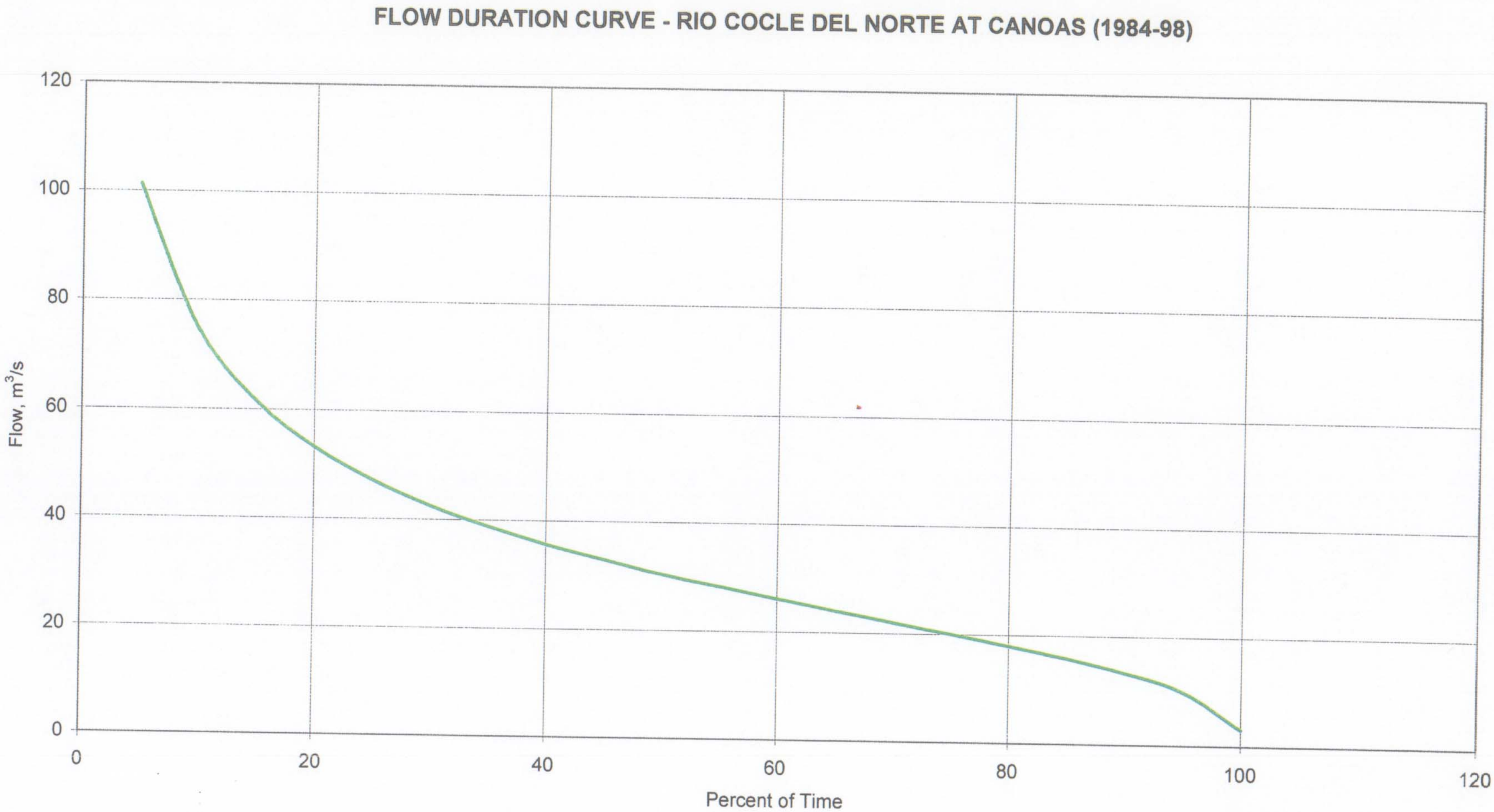

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RÍOS COCLÉ DEL NORTE AND CAÑO SUCIO
WATER SUPPLY PROJECTS
APPENDIX A - HYDROLOGY AND METEOROLOGY

FLOW DURATION CURVE
RÍO COCLÉ DEL NORTE AT CAÑOAS

MWH TAMS

DATE: DECEMBER, 2003

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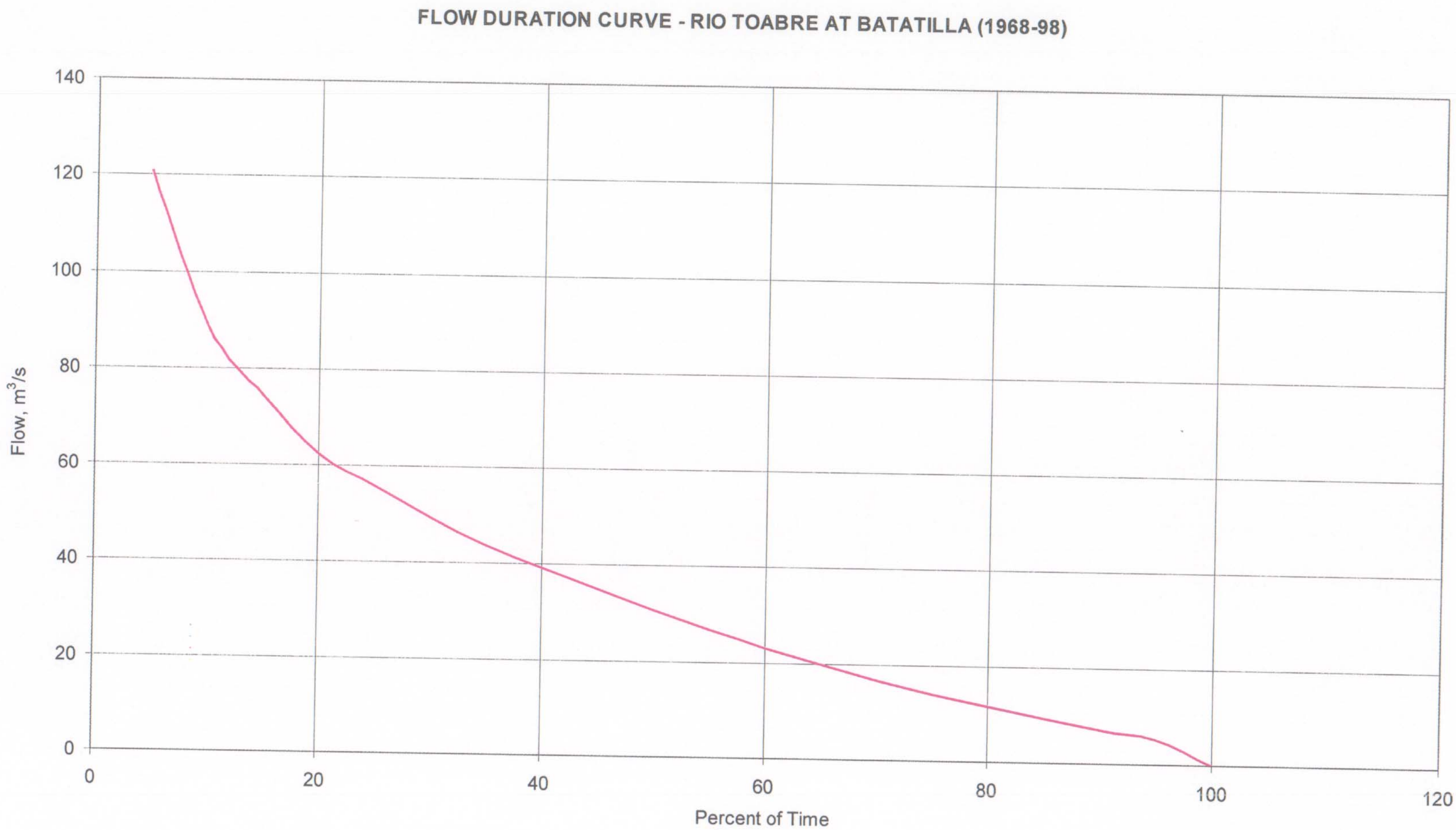

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RÍOS COCLÉ DEL NORTE AND CAÑO SUCIO
WATER SUPPLY PROJECTS
APPENDIX A - HYDROLOGY AND METEOROLOGY

FLOW DURATION CURVE
RÍO TOABRE AT BATATILLA

MWH TAMS

DATE: DECEMBER, 2003

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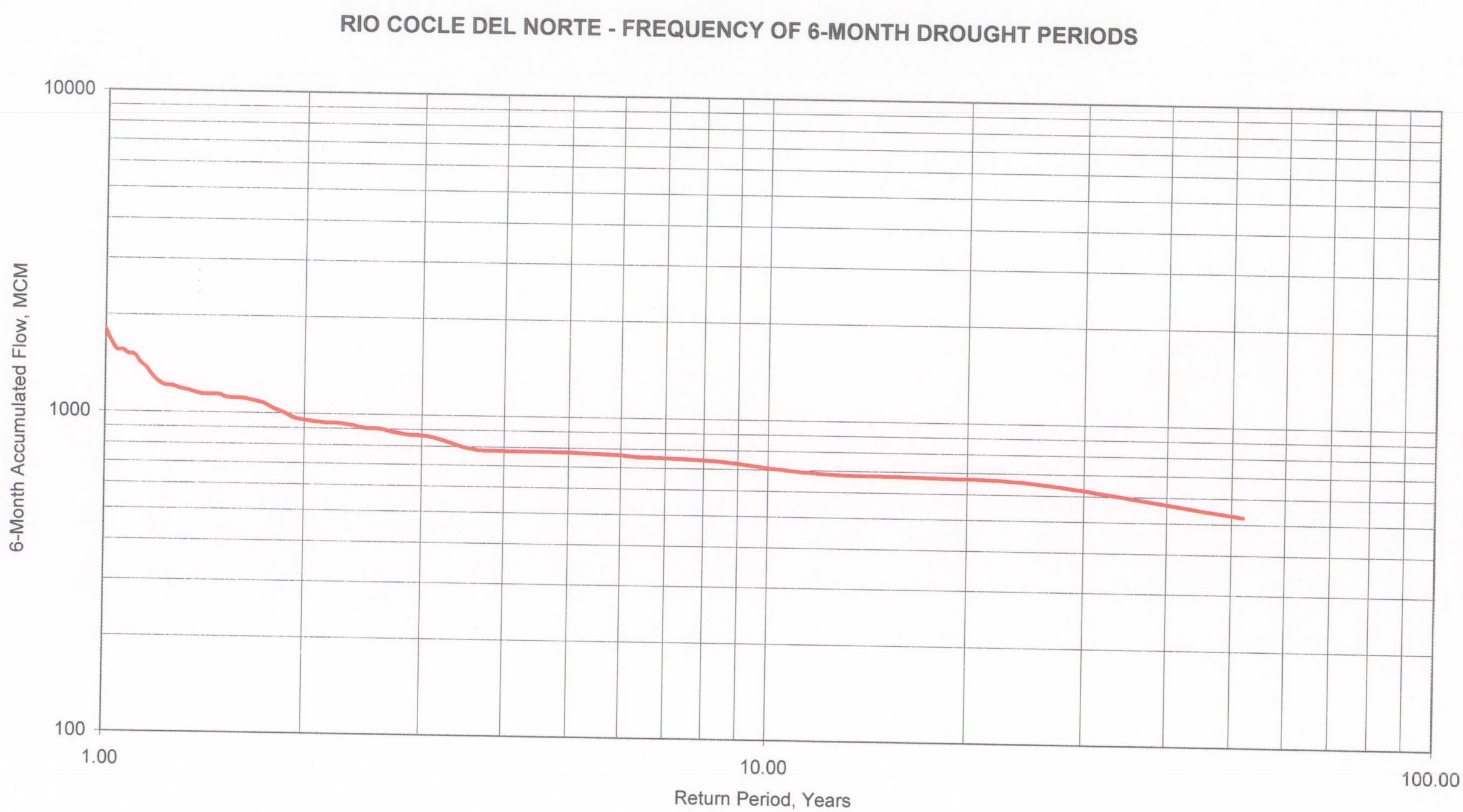

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RÍOS COCLÉ DEL NORTE AND CAÑO SUCIO
WATER SUPPLY PROJECTS
APPENDIX A - HYDROLOGY AND METEOROLOGY

RÍO COCLÉ DEL NORTE FREQUENCY OF 6-MONTH DROUGHT PERIODS

MWH TAMS

DATE: DECEMBER, 2003

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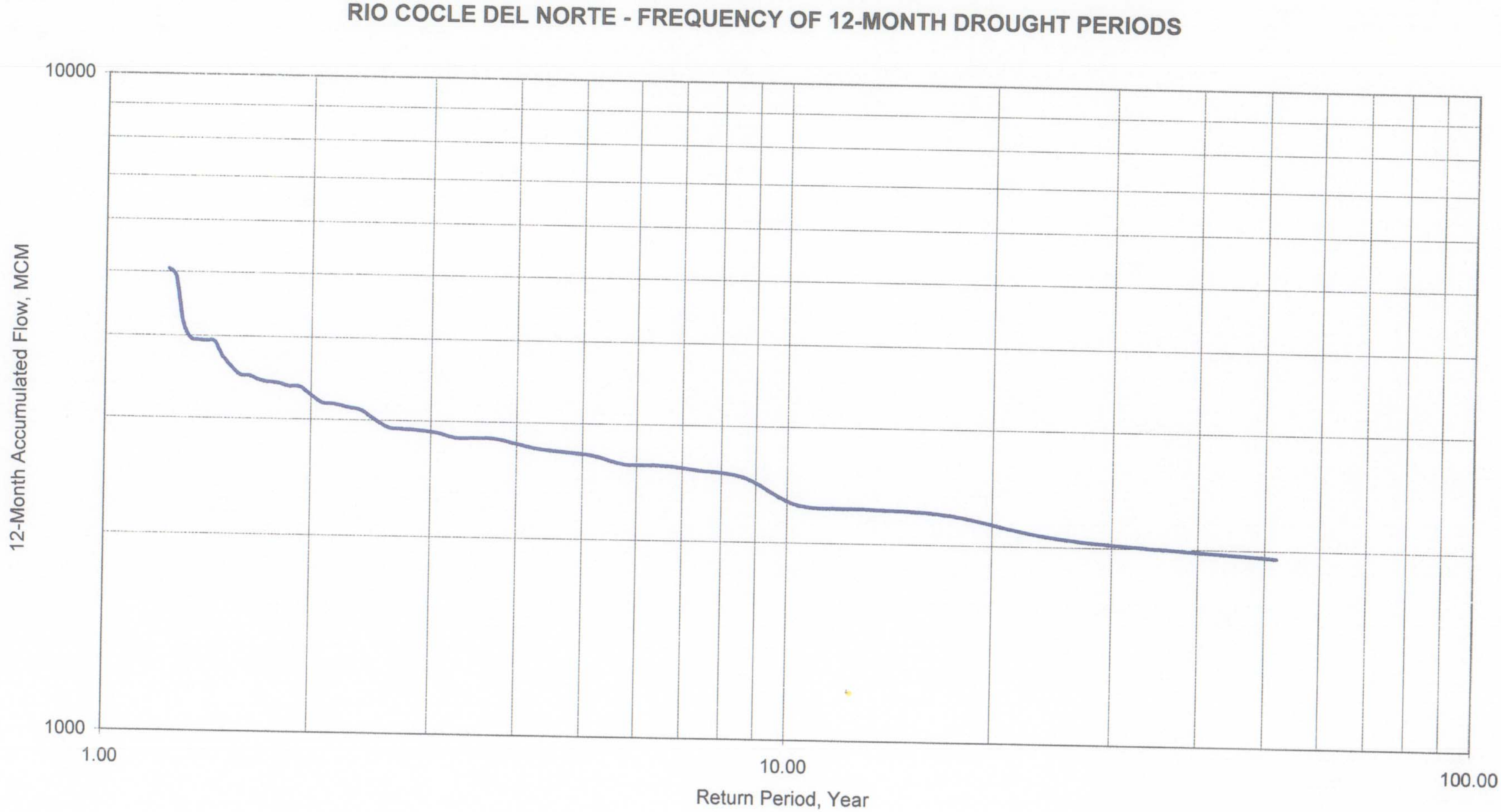

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RÍOS COCLÉ DEL NORTE AND CAÑO SUCIO
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RÍO COCLÉ DEL NORTE
FREQUENCY OF 12-MONTH DROUGHT PERIODS

MWH TAMS

DATE: DECEMBER, 2003

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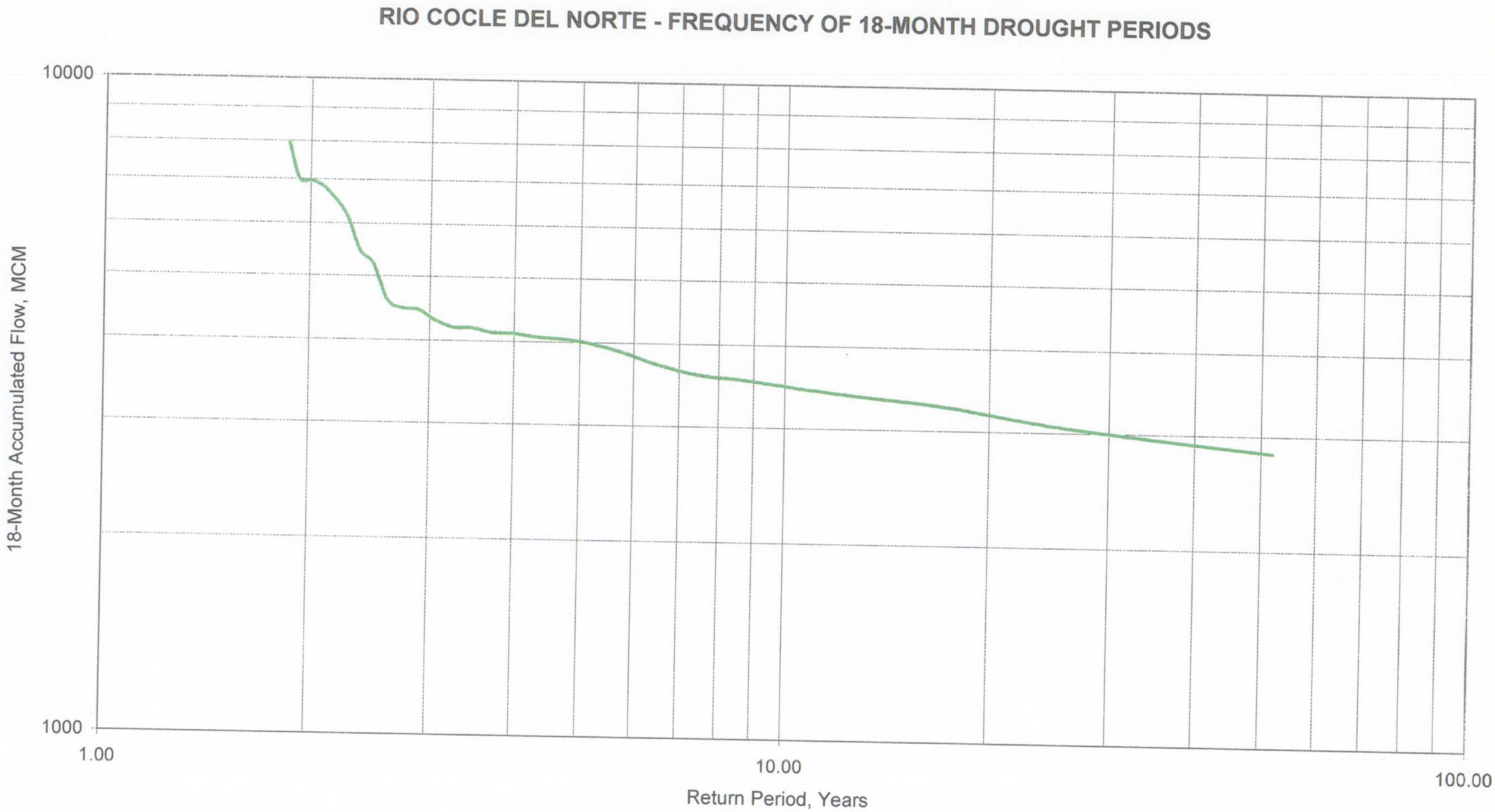

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WATER SUPPLY PROJECTS
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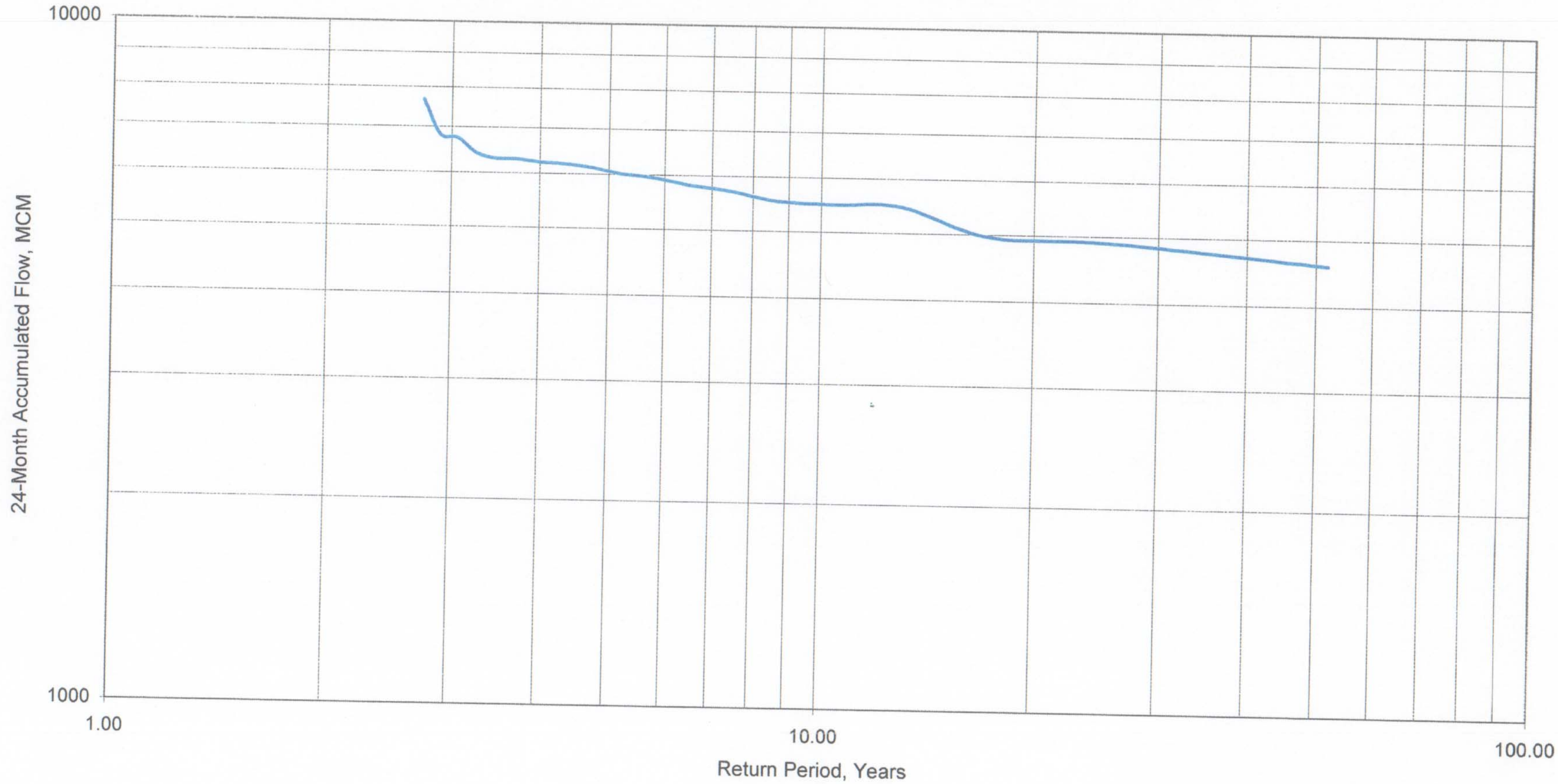
RÍO COCLÉ DEL NORTE
FREQUENCY OF 18-MONTH DROUGHT PERIODS

MWH TAMS

DATE:	EXHIBIT:
DECEMBER, 2003	14

RIO COCLE DEL NORTE - FREQUENCY OF 24-MONTH DROUGHT PERIODS



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RÍO COCLÉ DEL NORTE
FREQUENCY OF 24-MONTH DROUGHT PERIODS

MWH TAMS

DATE: DECEMBER, 2003

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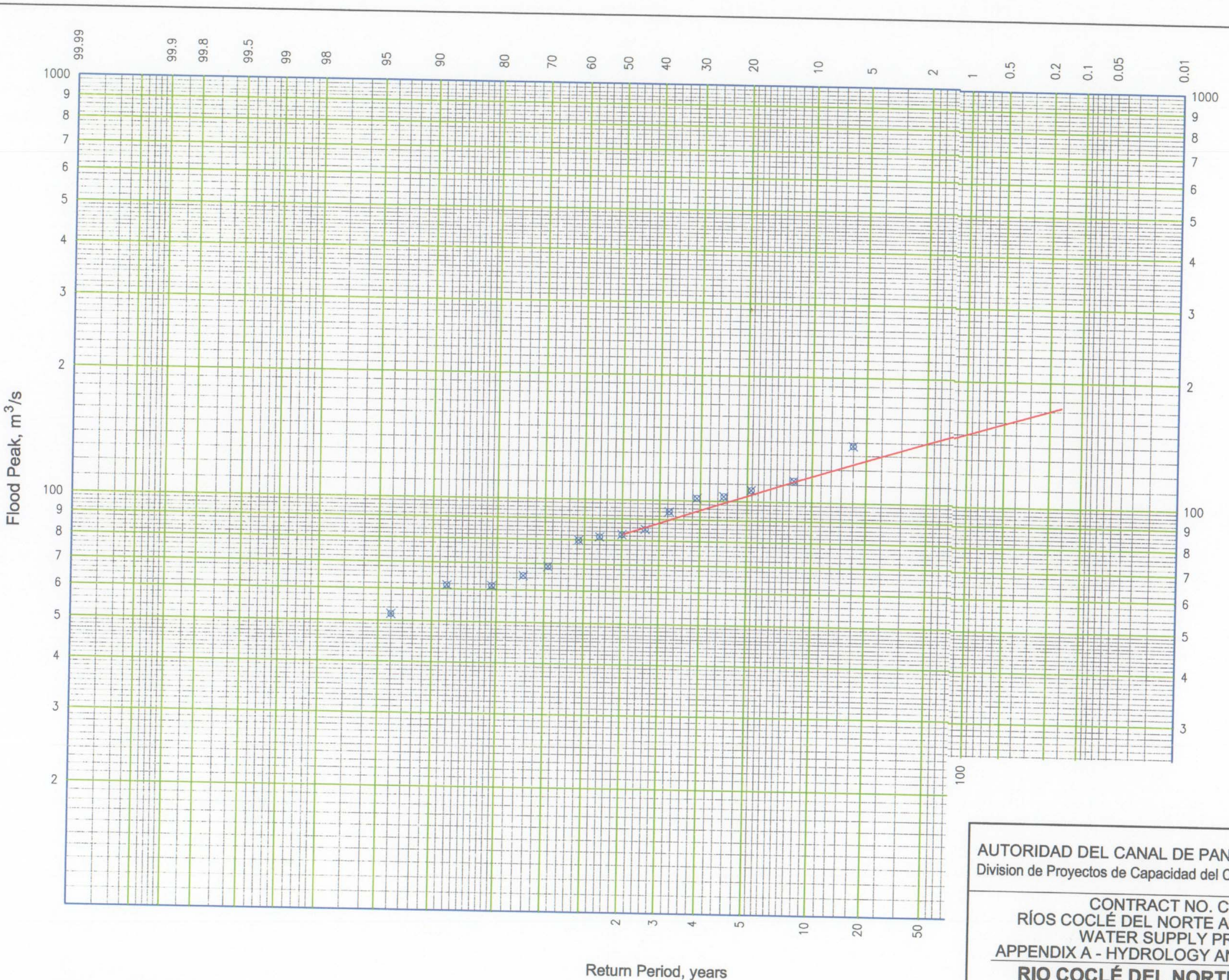

Period: 1984-98 (15 years)

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RÍOS COCLÉ DEL NORTE AND CAÑO SUCIO
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RIO COCLÉ DEL NORTE AT CANOAS
FLOOD FREQUENCY CURVE
LOG PEARSON TYPE III DISTRIBUTION

MWH TAMS

DATE: DECEMBER, 2003

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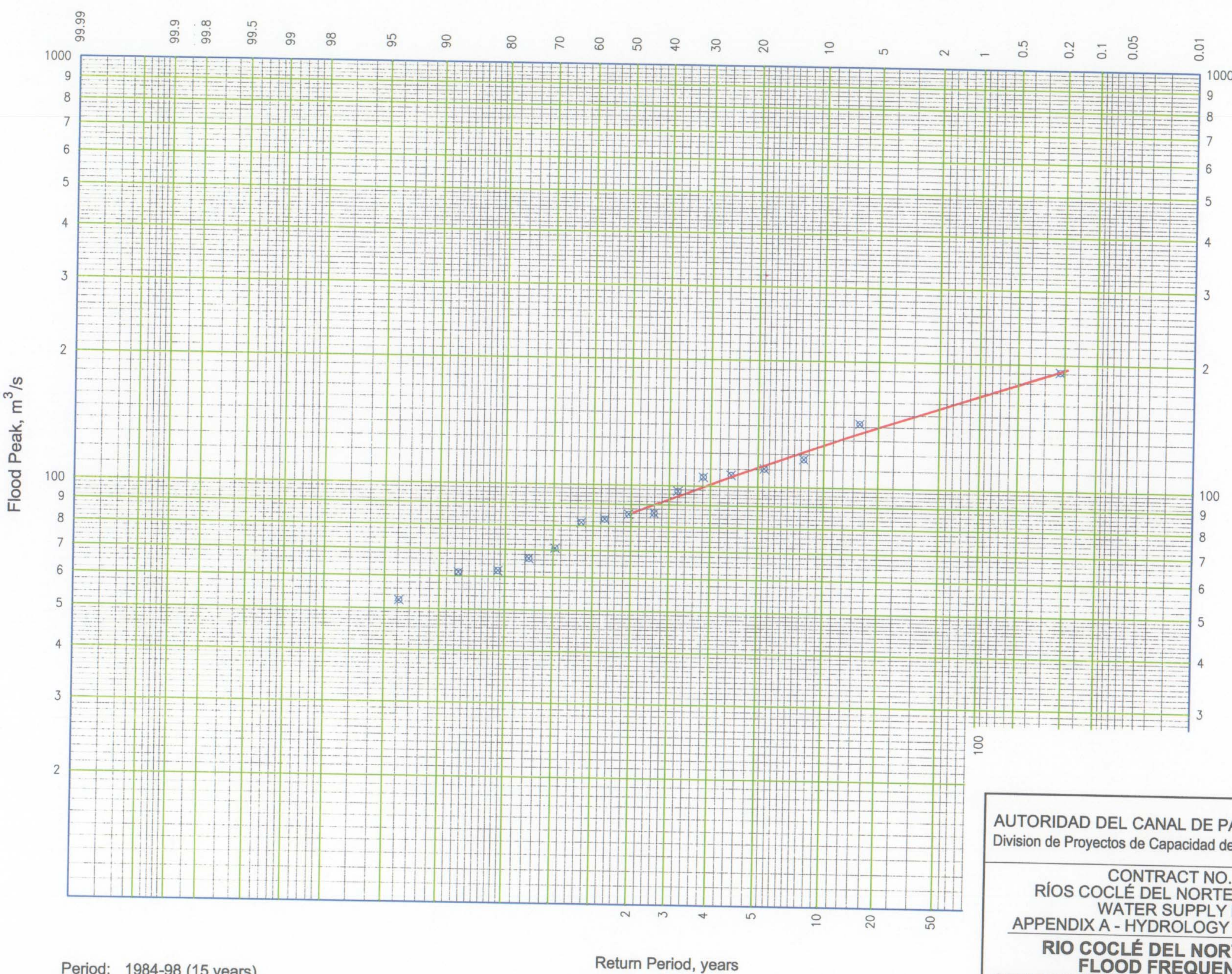

Period: 1984-98 (15 years)

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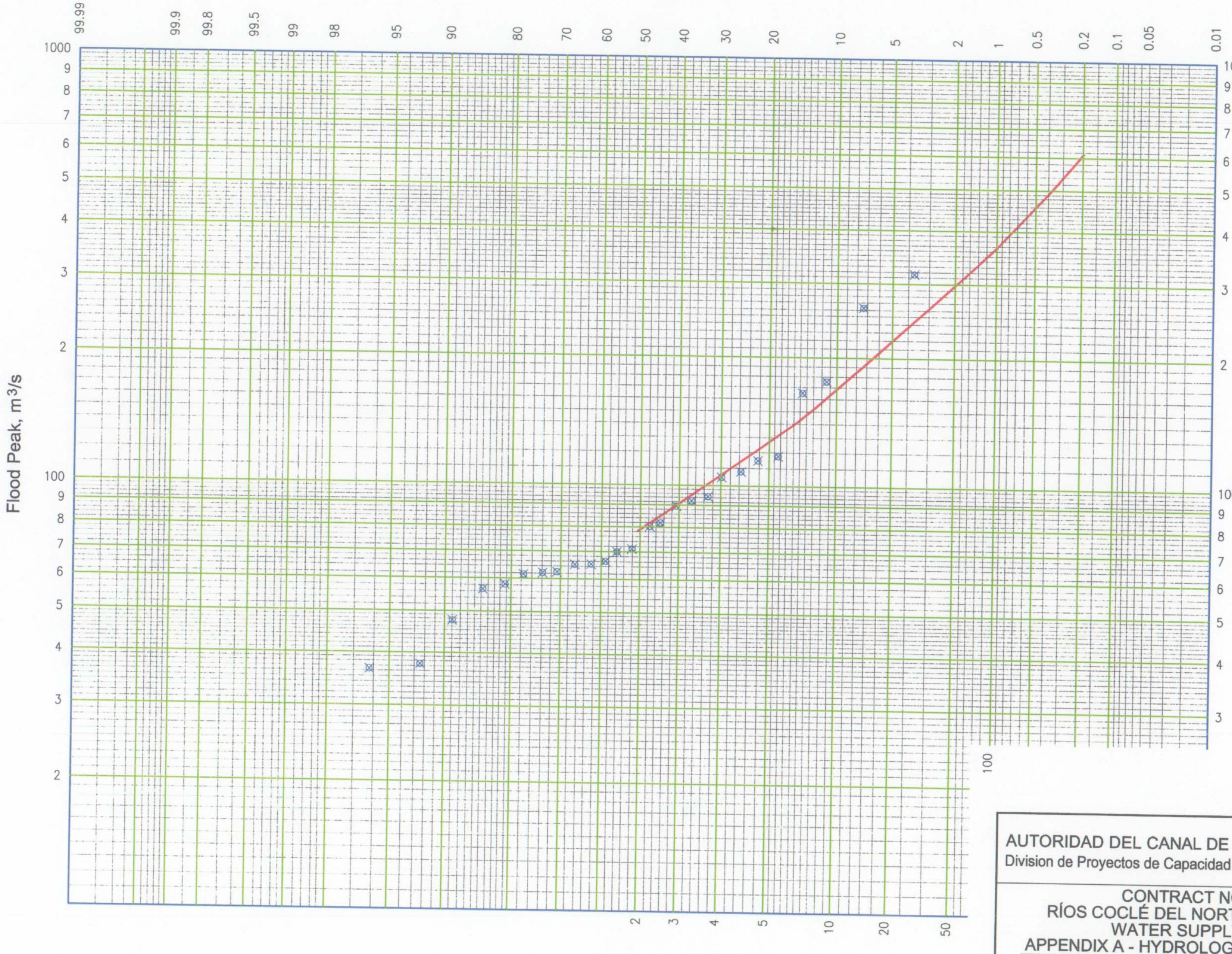
RIO COCLÉ DEL NORTE AT CANOAS
FLOOD FREQUENCY CURVE
GENERALIZED EXTREME VALUE DISTRIBUTION

MWH TAMS

DATE: DECEMBER, 2003

EXHIBIT: 17



Period: 1959, 1961-85 (26 years)

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CONTRACT NO. CC-3-536
RÍOS COCLÉ DEL NORTE AND CAÑO SUCIO
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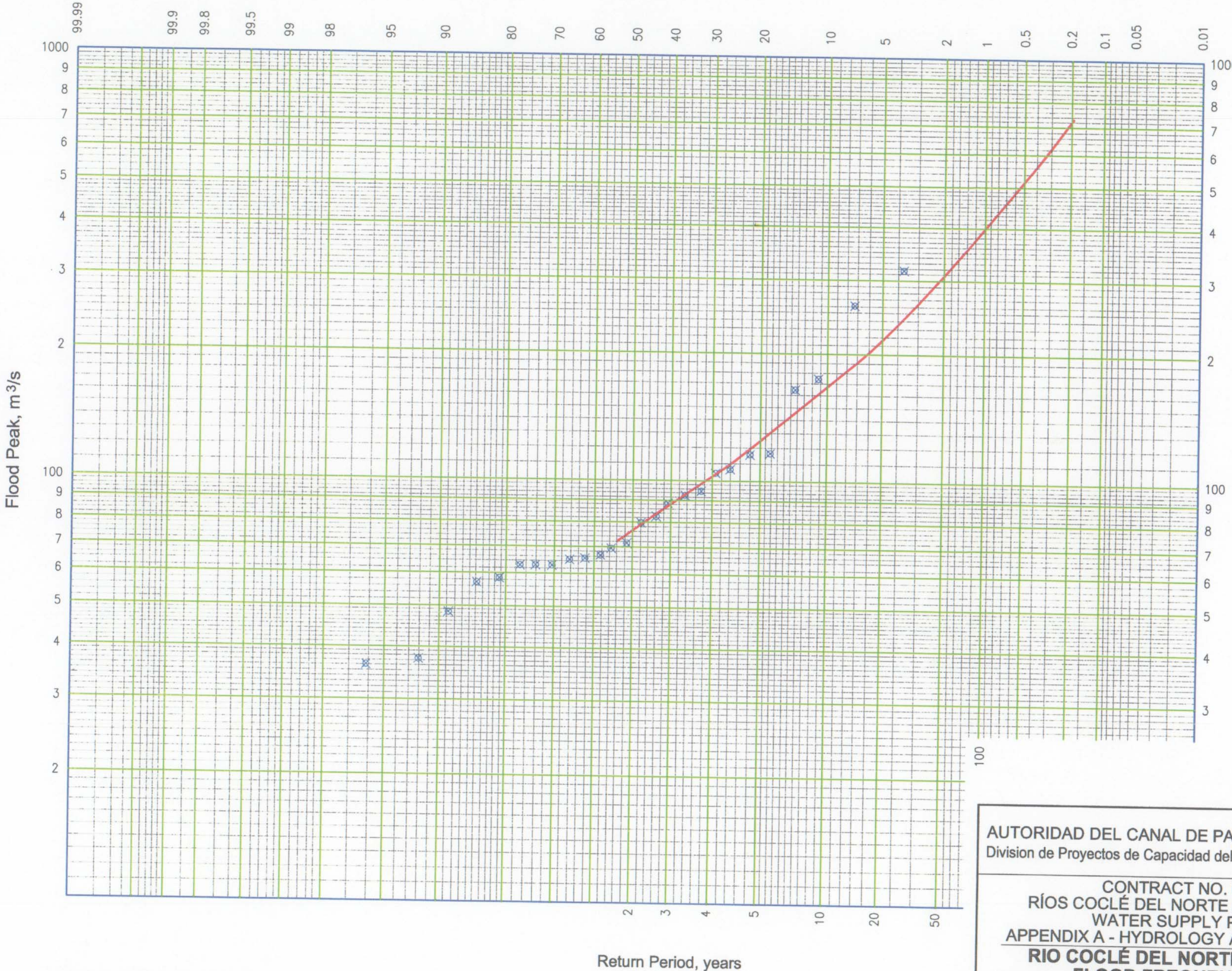
APPENDIX A - HYDROLOGY AND METEOROLOGY

RIO COCLÉ DEL NORTE AT EL TORNO
FLOOD FREQUENCY CURVE
LOG PEARSON TYPE III DISTRIBUTION

MWH TAMS	DATE: DECEMBER, 2003	EXHIBIT: 18



Period: 1959, 1961-85 (26 years)

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CONTRACT NO. CC-3-536
RÍOS COCLÉ DEL NORTE AND CAÑO SUCIO
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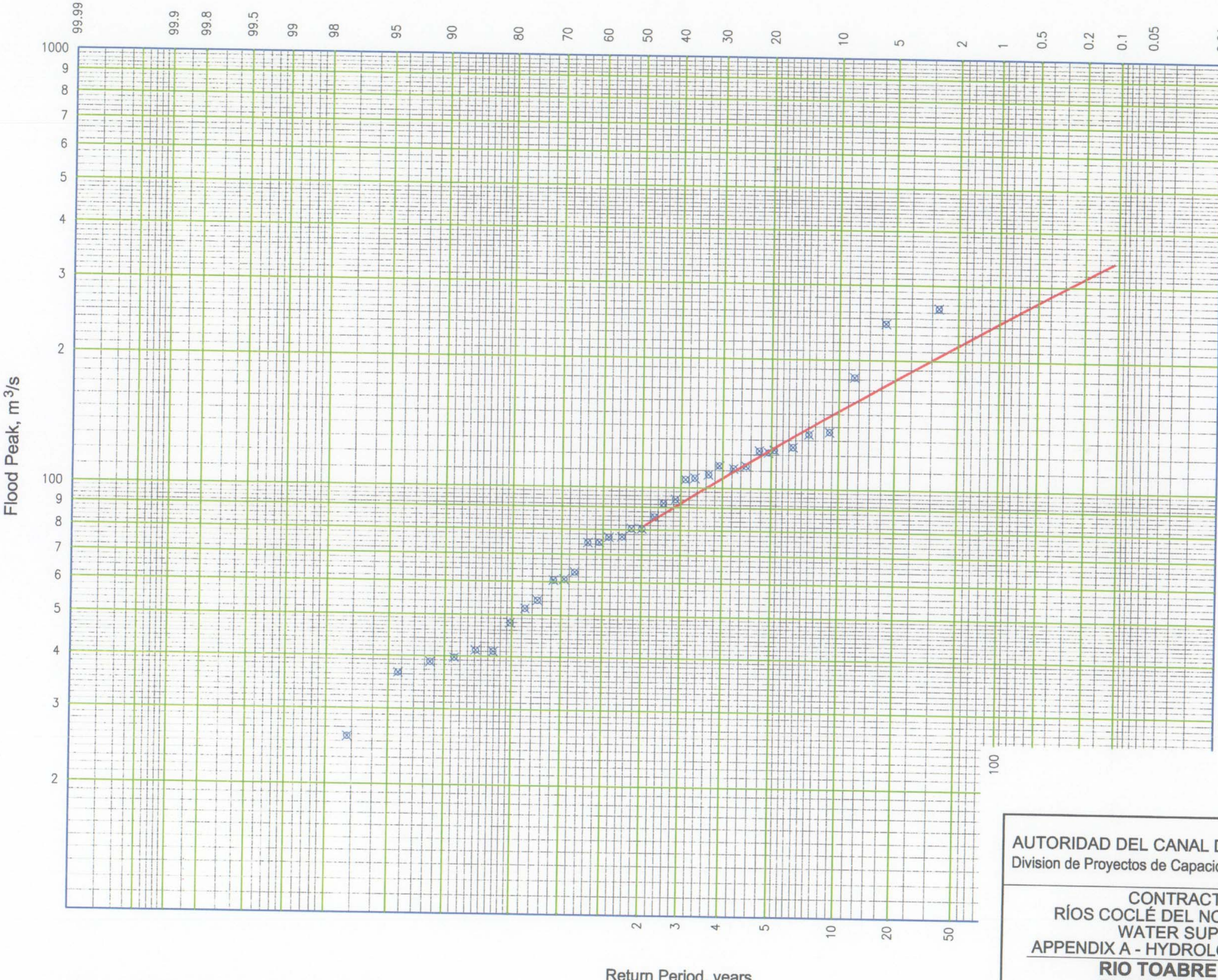
APPENDIX A - HYDROLOGY AND METEOROLOGY

RIO COCLÉ DEL NORTE AT EL TORNO
FLOOD FREQUENCY CURVE
GENERALIZED EXTREME VALUE DISTRIBUTION

MWH TAMS

DATE:	EXHIBIT:
DECEMBER, 2003	19



Period: 1958-59, 1962-64, 1969-98 (35 years)

AUTORIDAD DEL CANAL DE PANAMA
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ACP

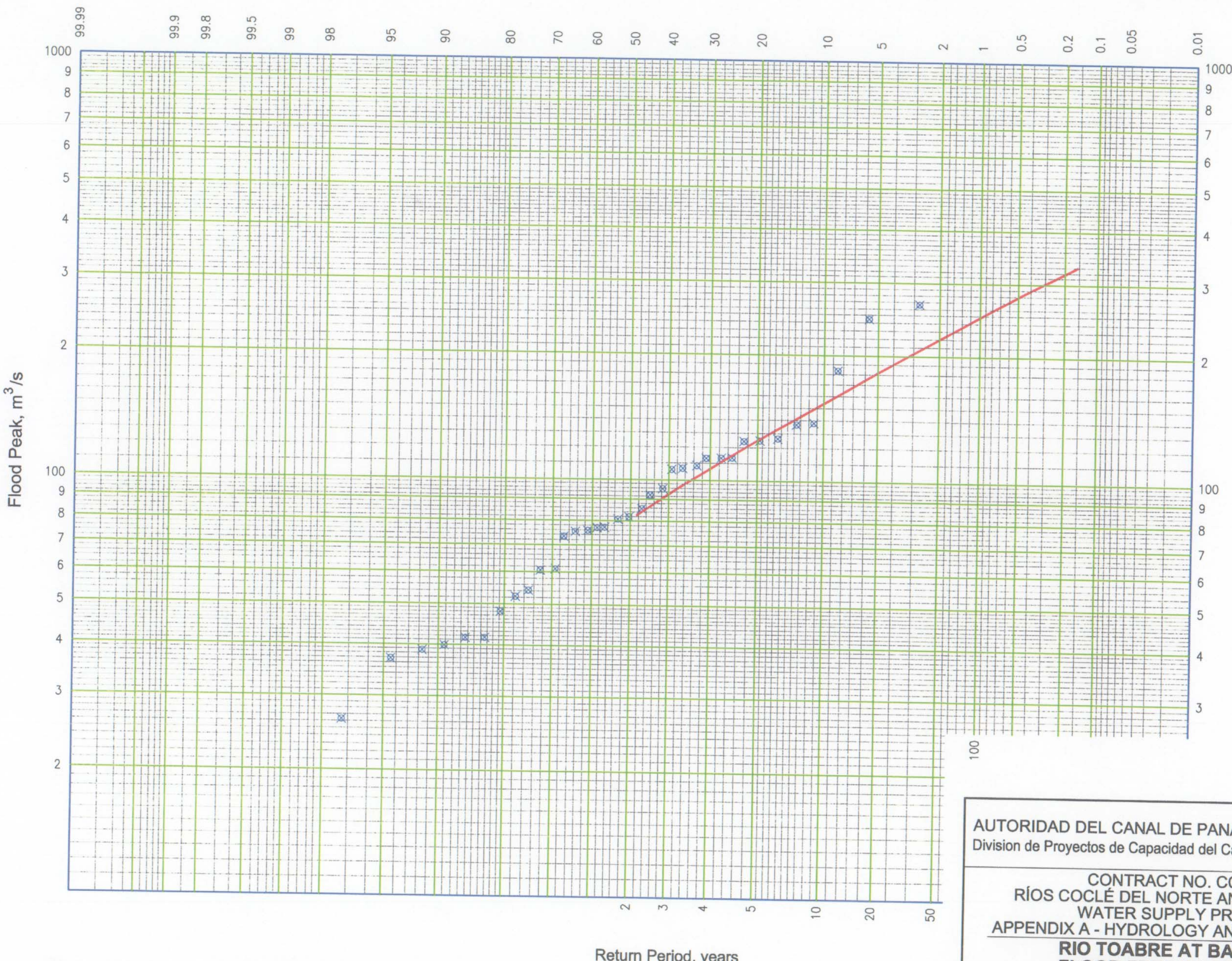
CONTRACT NO. CC-3-536
RÍOS COCLÉ DEL NORTE AND CAÑO SUCIO
WATER SUPPLY PROJECTS
APPENDIX A - HYDROLOGY AND METEOROLOGY

RIO TOABRE AT BATATILLA
FLOOD FREQUENCY CURVE
LOG PEARSON TYPE III DISTRIBUTION

MWH TAMS

DATE: DECEMBER, 2003

EXHIBIT: 20



Period: 1958-59, 1962-64, 1969-98 (35 years)

AUTORIDAD DEL CANAL DE PANAMA
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CONTRACT NO. CC-3-536
RÍOS COCLÉ DEL NORTE AND CAÑO SUCIO
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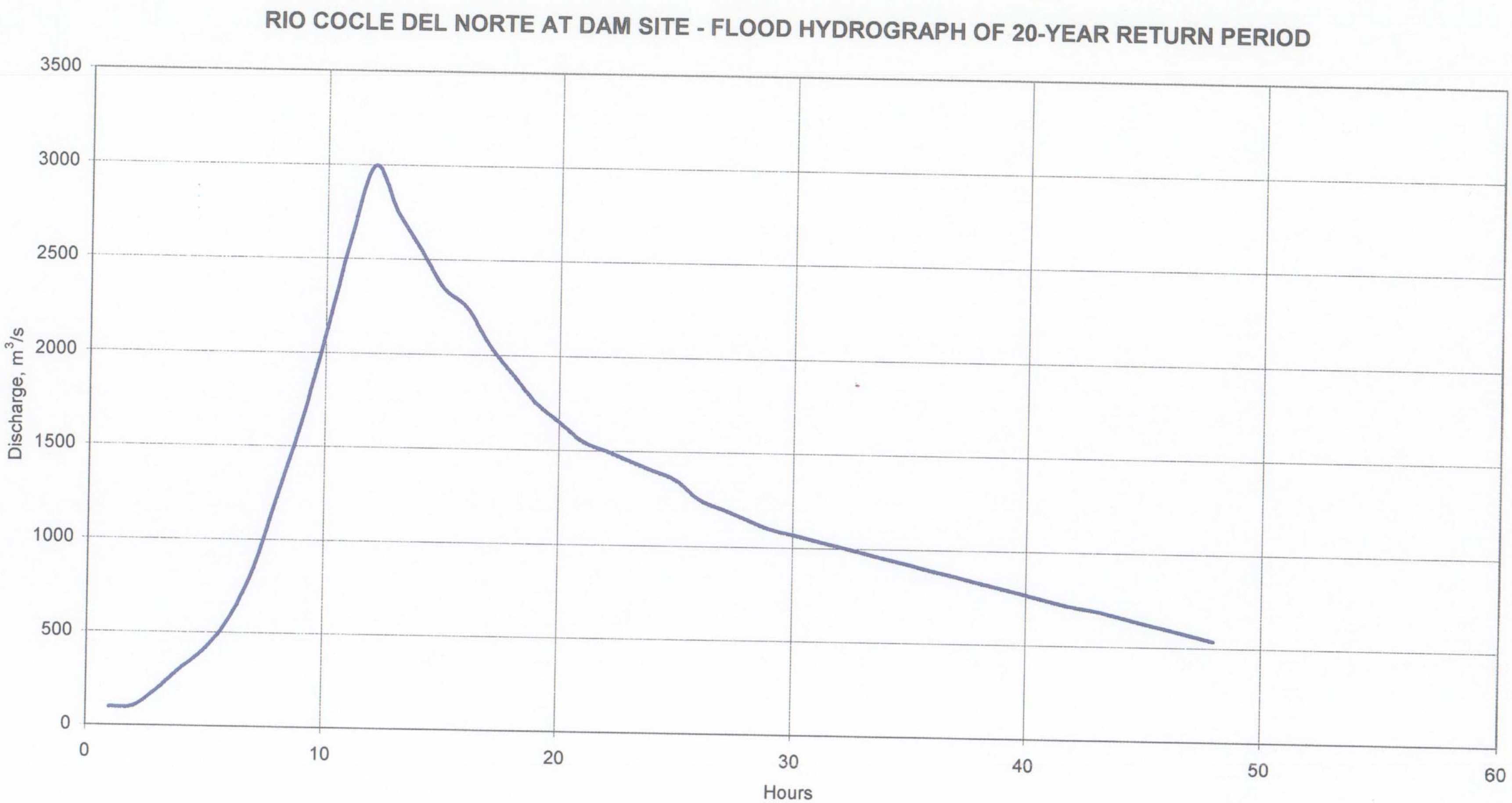
APPENDIX A - HYDROLOGY AND METEOROLOGY

RIO TOABRE AT BATATILLA
FLOOD FREQUENCY CURVE
GENERALIZED EXTREME VALUE DISTRIBUTION

MWH TAMS

DATE:	EXHIBIT:
DECEMBER, 2003	21



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CONTRACT NO. CC-3-536
RÍOS COCLÉ DEL NORTE AND CAÑO SUCIO
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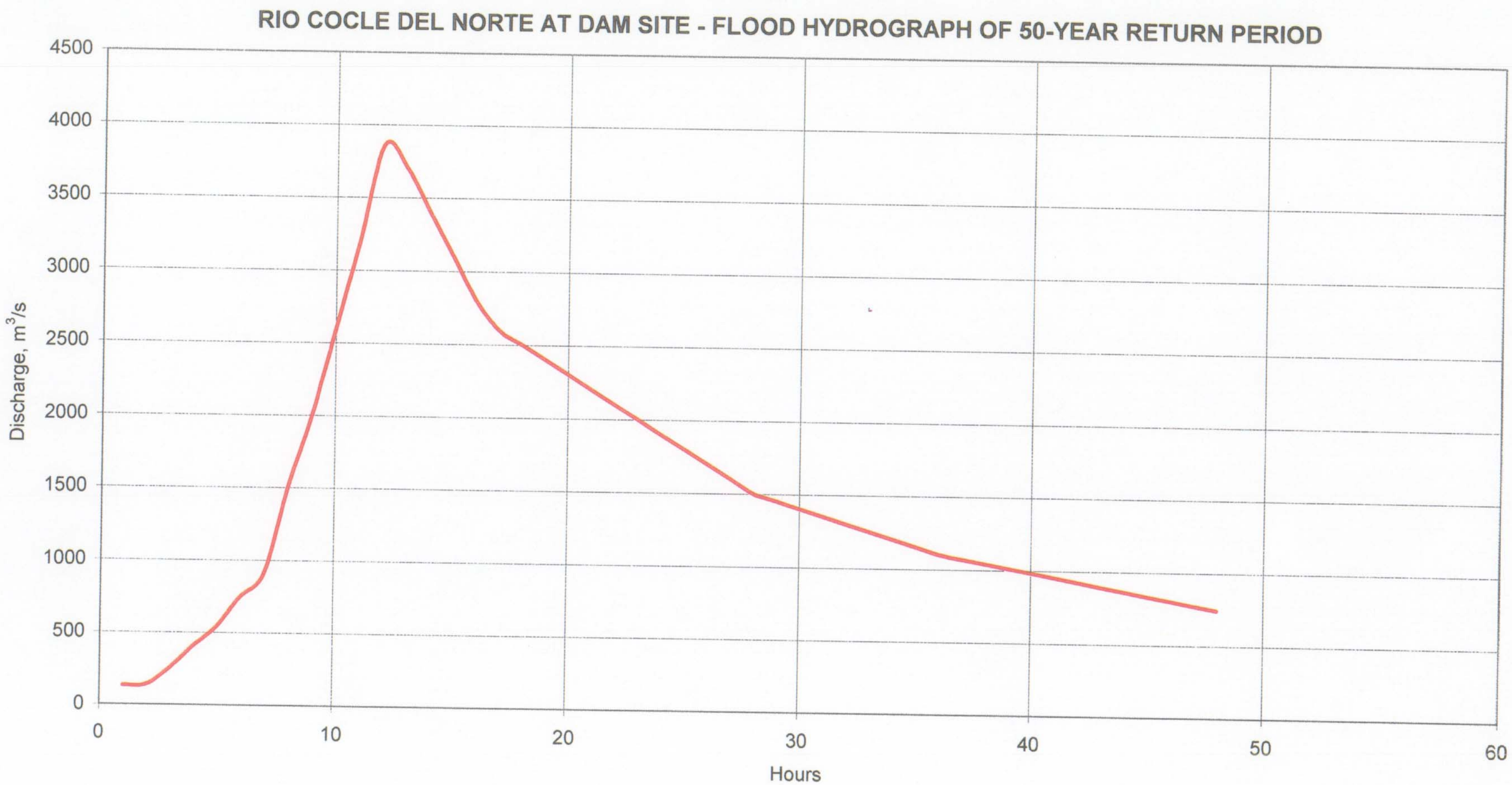
APPENDIX A - HYDROLOGY AND METEOROLOGY

RÍO COCLÉ DEL NORTE AT DAM SITE FLOOD HYDROGRAPH FOR 20-YEAR RETURN PERIOD

MWH TAMS

DATE: DECEMBER, 2003

EXHIBIT: 22



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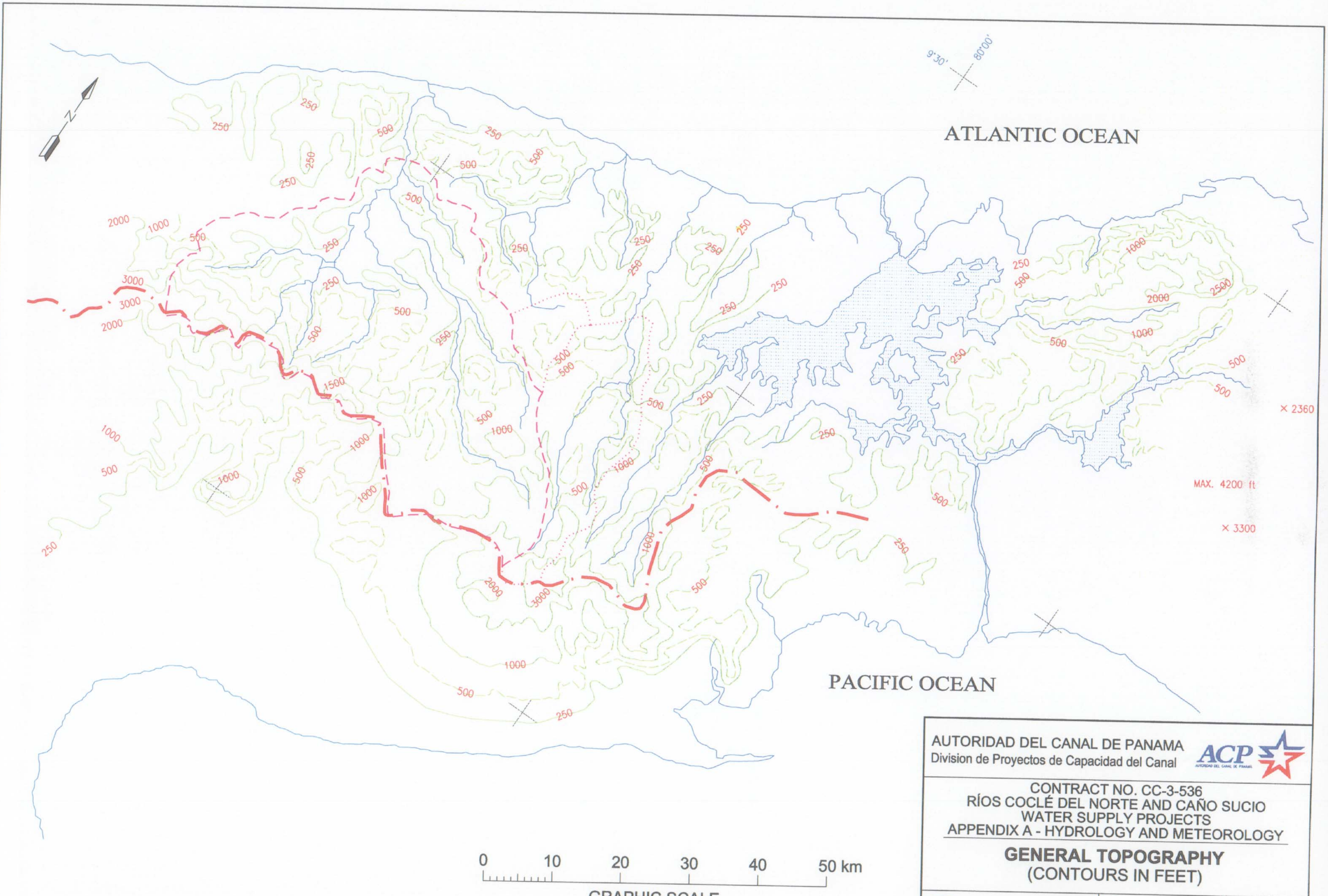
APPENDIX A - HYDROLOGY AND METEOROLOGY

RÍO COCLÉ DEL NORTE AT DAM SITE FLOOD HYDROGRAPH FOR 50-YEAR RETURN PERIOD

MWH TAMS

DATE: DECEMBER, 2003

EXHIBIT: 23



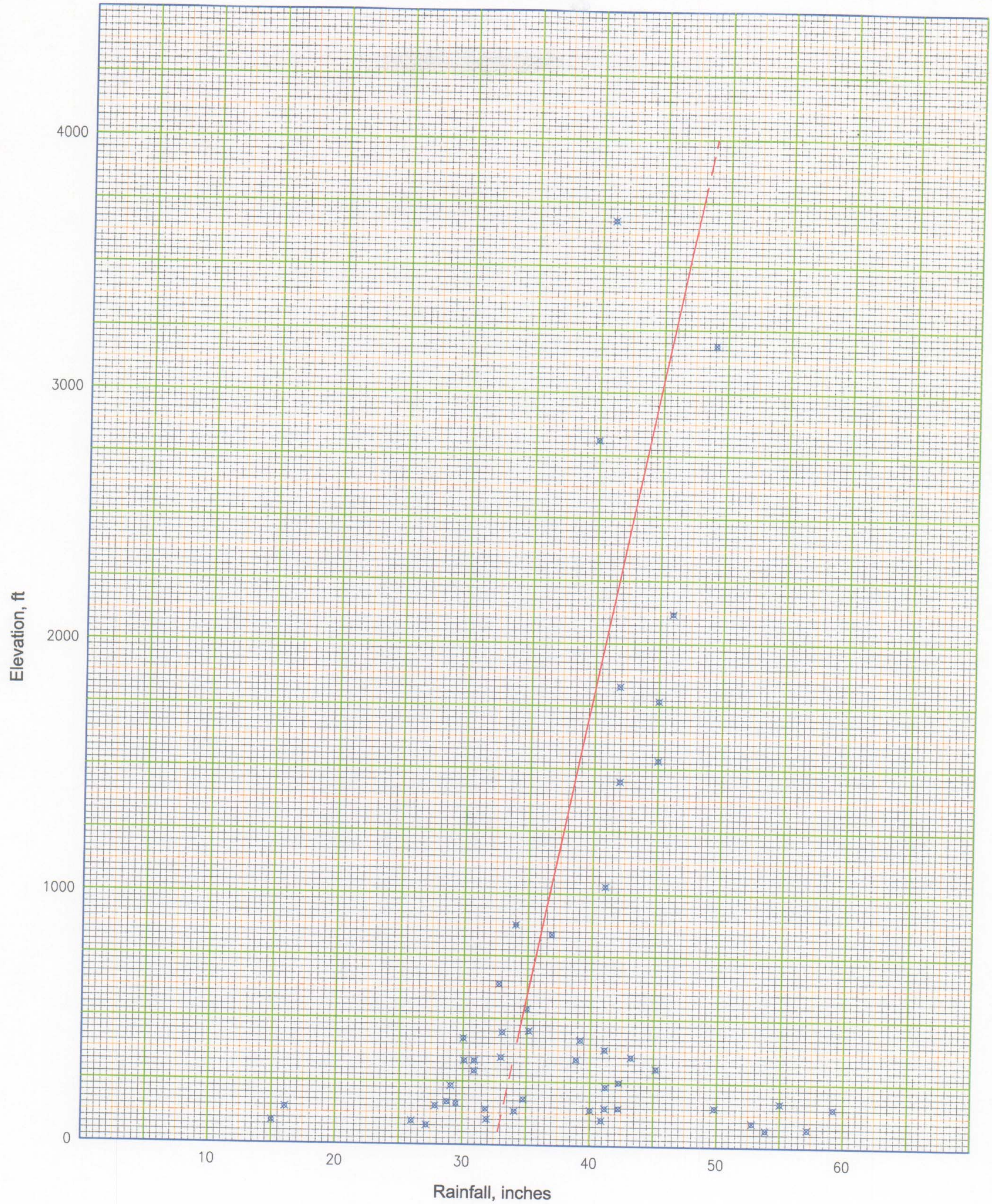
AUTORIDAD DEL CANAL DE PANAMA
Division de Proyectos de Capacidad del Canal

CONTRACT NO. CC-3-536
RÍOS COCLÉ DEL NORTE AND CAÑO SUCIO
WATER SUPPLY PROJECTS
APPENDIX A - HYDROLOGY AND METEOROLOGY

GENERAL TOPOGRAPHY
(CONTOURS IN FEET)

MWH TAMS

DATE:	EXHIBIT:
DECEMBER, 2003	24



Source:

US NWS, February 1978 Report

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

ACP

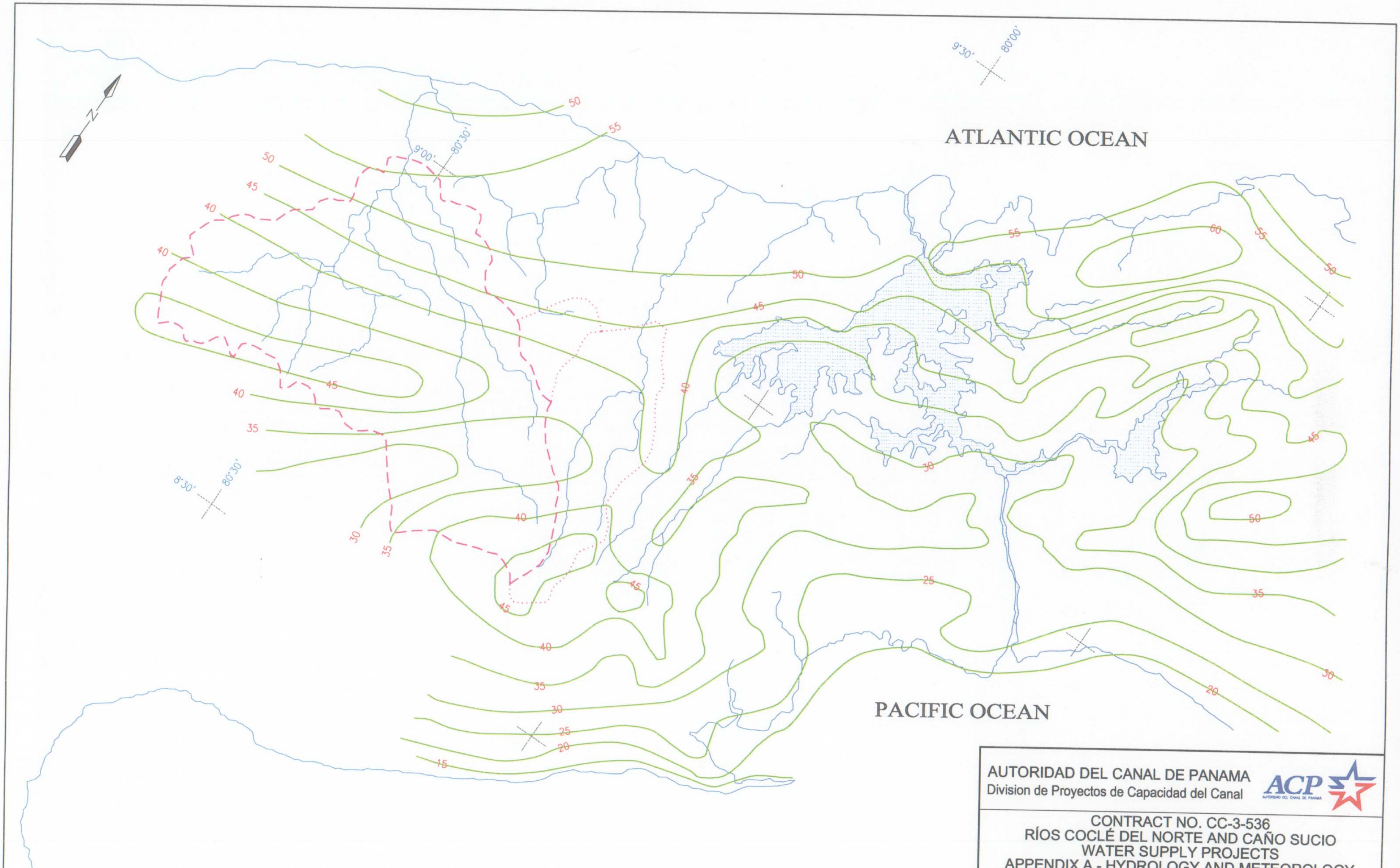
CONTRACT NO. CC-3-536
RÍOS COCLÉ DEL NORTE AND CAÑO SUCIO
WATER SUPPLY PROJECTS
APPENDIX A - HYDROLOGY AND METEOROLOGY

ELEVATION VS. MEAN OCT-DEC RAINFALL

MWH TAMS

DATE: DECEMBER, 2003

EXHIBIT: 25



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

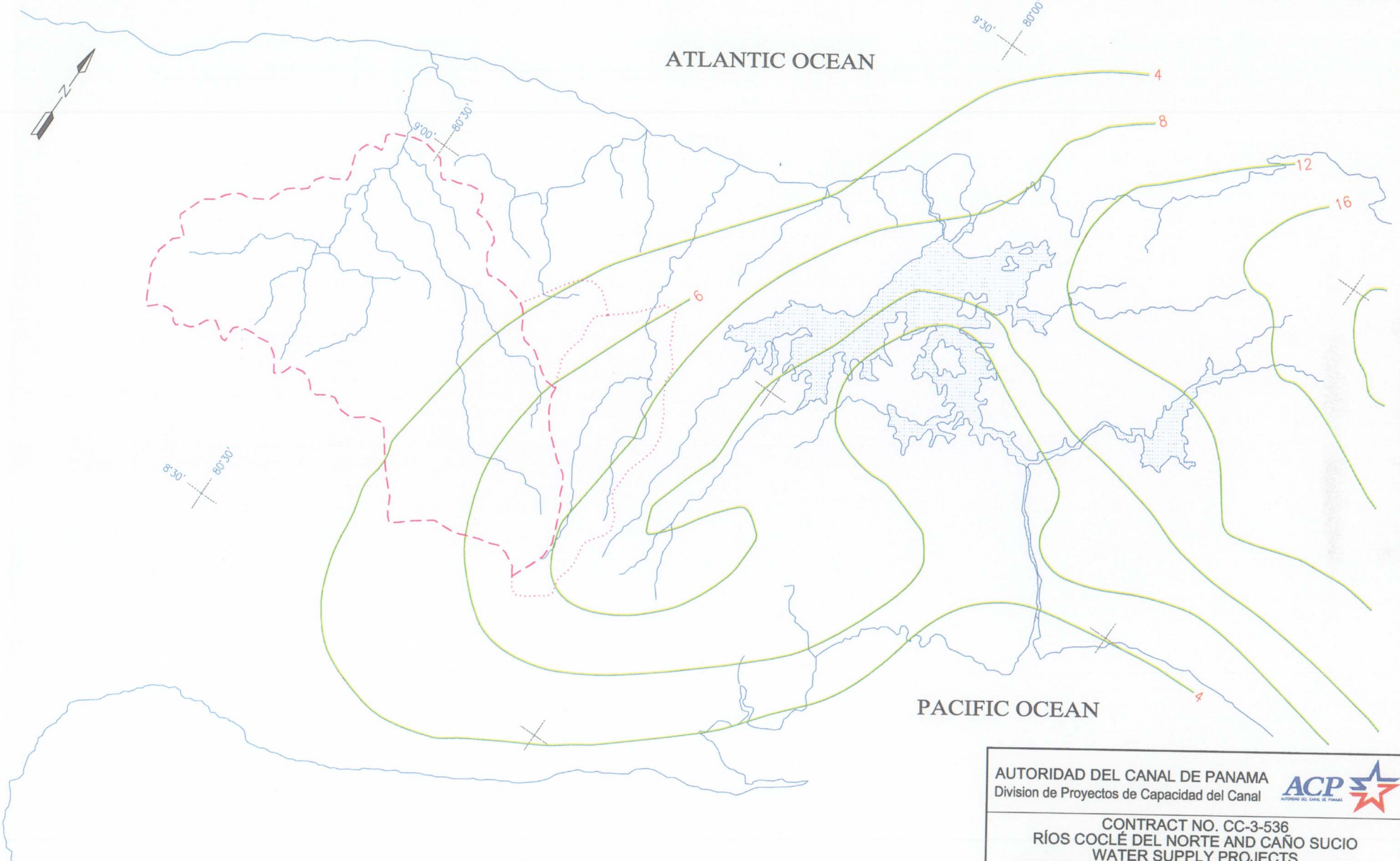
CONTRACT NO. CC-3-536
RÍOS COCLÉ DEL NORTE AND CAÑO SUCIO
WATER SUPPLY PROJECTS
APPENDIX A - HYDROLOGY AND METEOROLOGY

MEAN OCTOBER - DECEMBER RAINFALL
(INCHES)

MWH TAMS

DATE: DECEMBER, 2003

EXHIBIT: 26



Source:

US NWS, February 1978 Report

0 10 20 30 40 50 km

GRAPHIC SCALE

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

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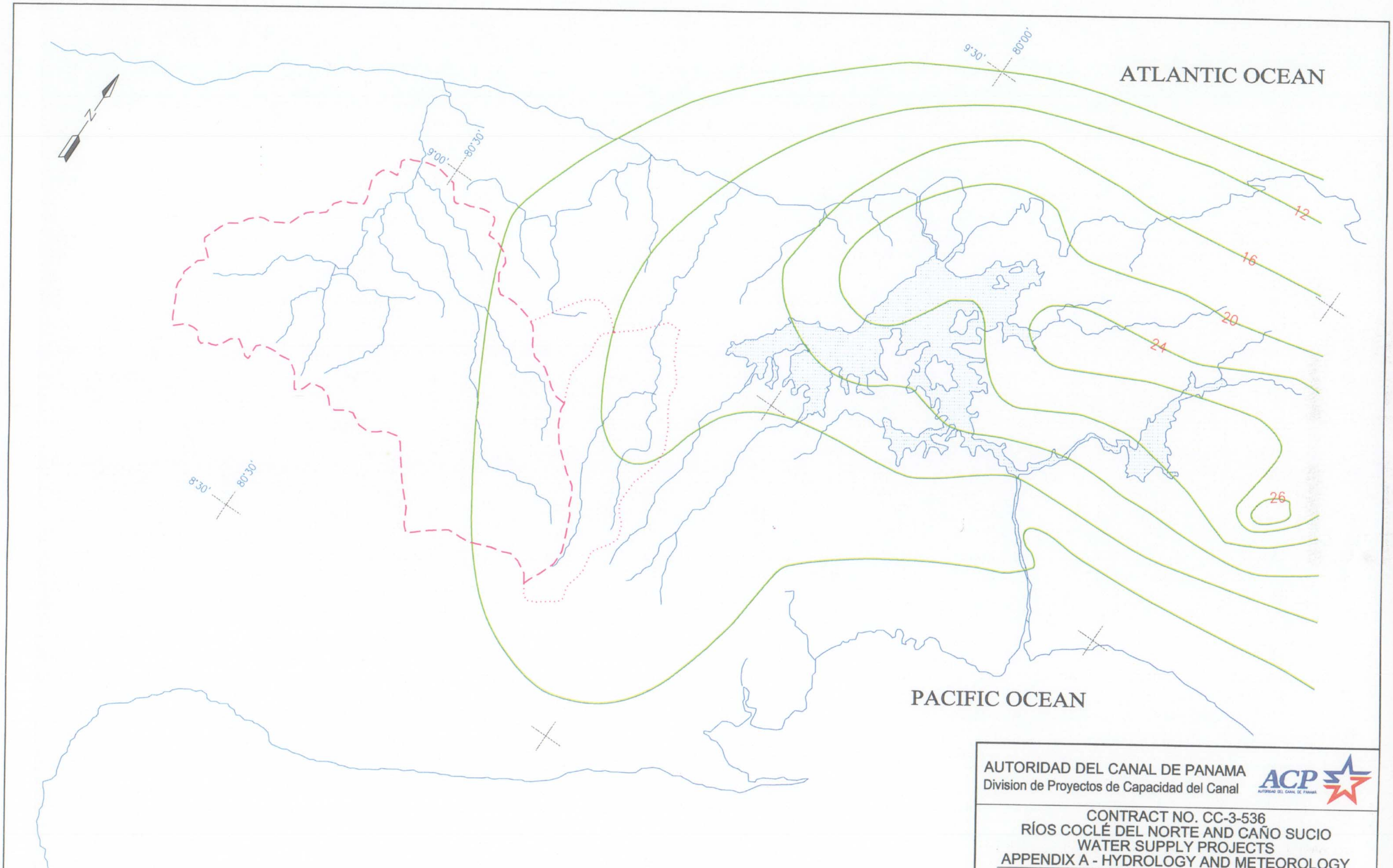
CONTRACT NO. CC-3-536
RÍOS COCLÉ DEL NORTE AND CAÑO SUCIO
WATER SUPPLY PROJECTS
APPENDIX A - HYDROLOGY AND METEOROLOGY

RAINFALL DEPTHS (INCHES) DURING STORM OF NOVEMBER 17-19, 1909

MWH TAMS

DATE:	EXHIBIT:
DECEMBER, 2003	27



Source:

US NWS, February 1978 Report

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

CONTRACT NO. CC-3-536
RÍOS COCLÉ DEL NORTE AND CAÑO SUCIO
WATER SUPPLY PROJECTS
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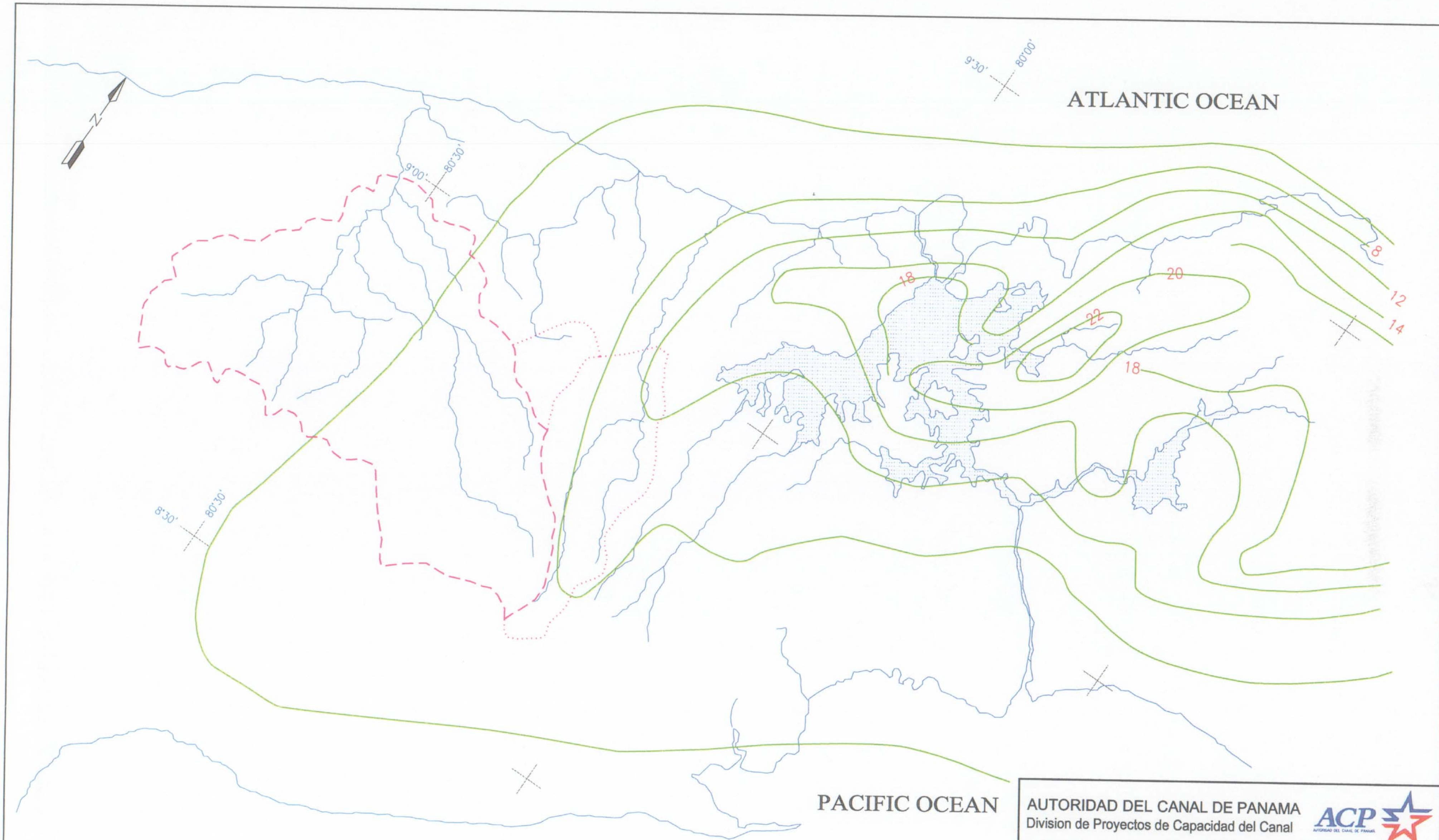
RAINFALL DEPTHS (INCHES) DURING STORM OF OCTOBER 22-24, 1923

MWH TAMS

DATE: DECEMBER, 2003

EXHIBIT: 28



Source:

US NWS, February 1978 Report

0 10 20 30 40 50 km

GRAPHIC SCALE

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

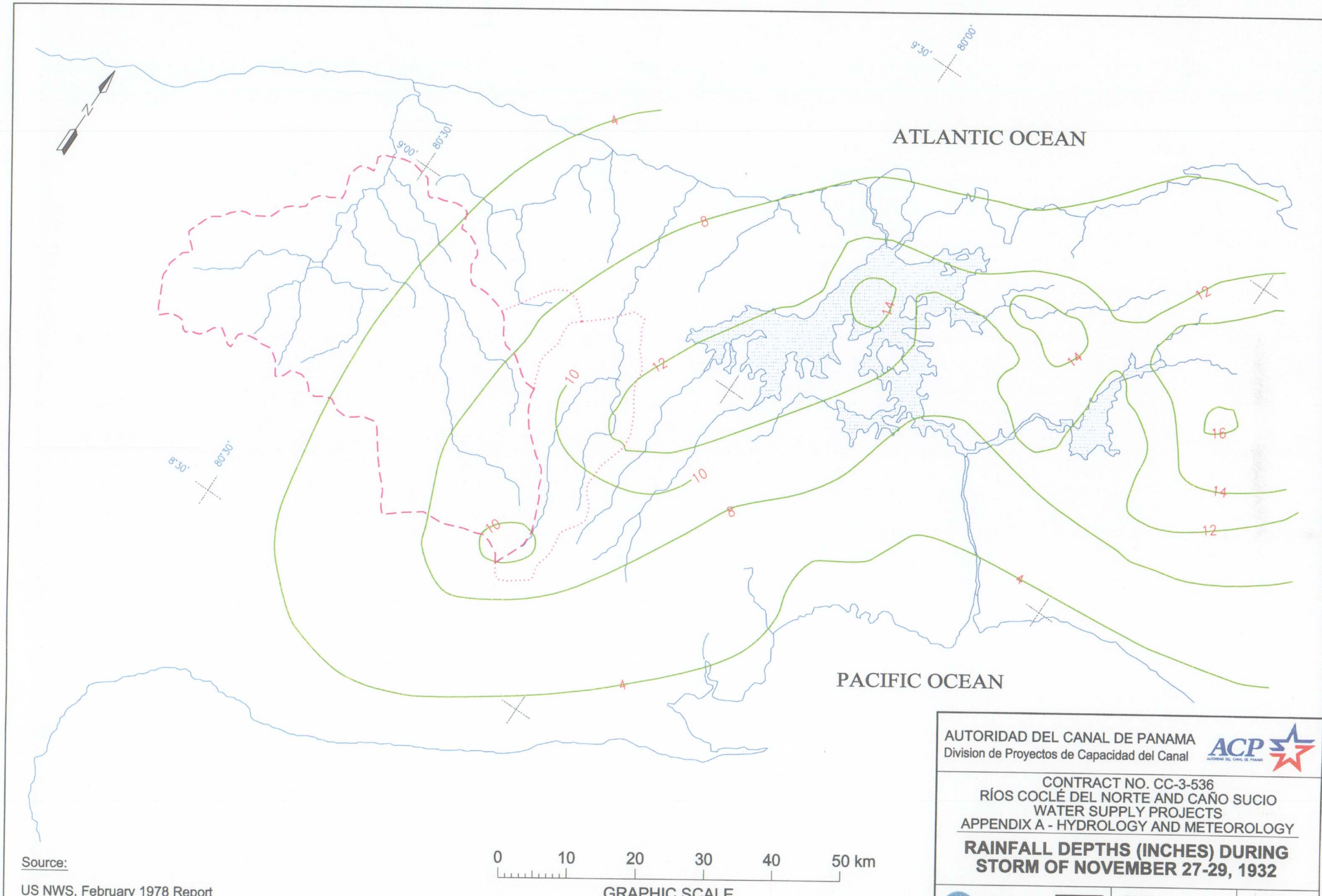
CONTRACT NO. CC-3-536
RÍOS COCLÉ DEL NORTE AND CAÑO SUCIO
WATER SUPPLY PROJECTS
APPENDIX A - HYDROLOGY AND METEOROLOGY

RAINFALL DEPTHS (INCHES) DURING STORM OF NOVEMBER 7-9, 1931

MWH TAMS

DATE: DECEMBER, 2003

EXHIBIT: 29



Source:

US NWS, February 1978 Report

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

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CONTRACT NO. CC-3-536
RÍOS COCLÉ DEL NORTE AND CAÑO SUCIO
WATER SUPPLY PROJECTS
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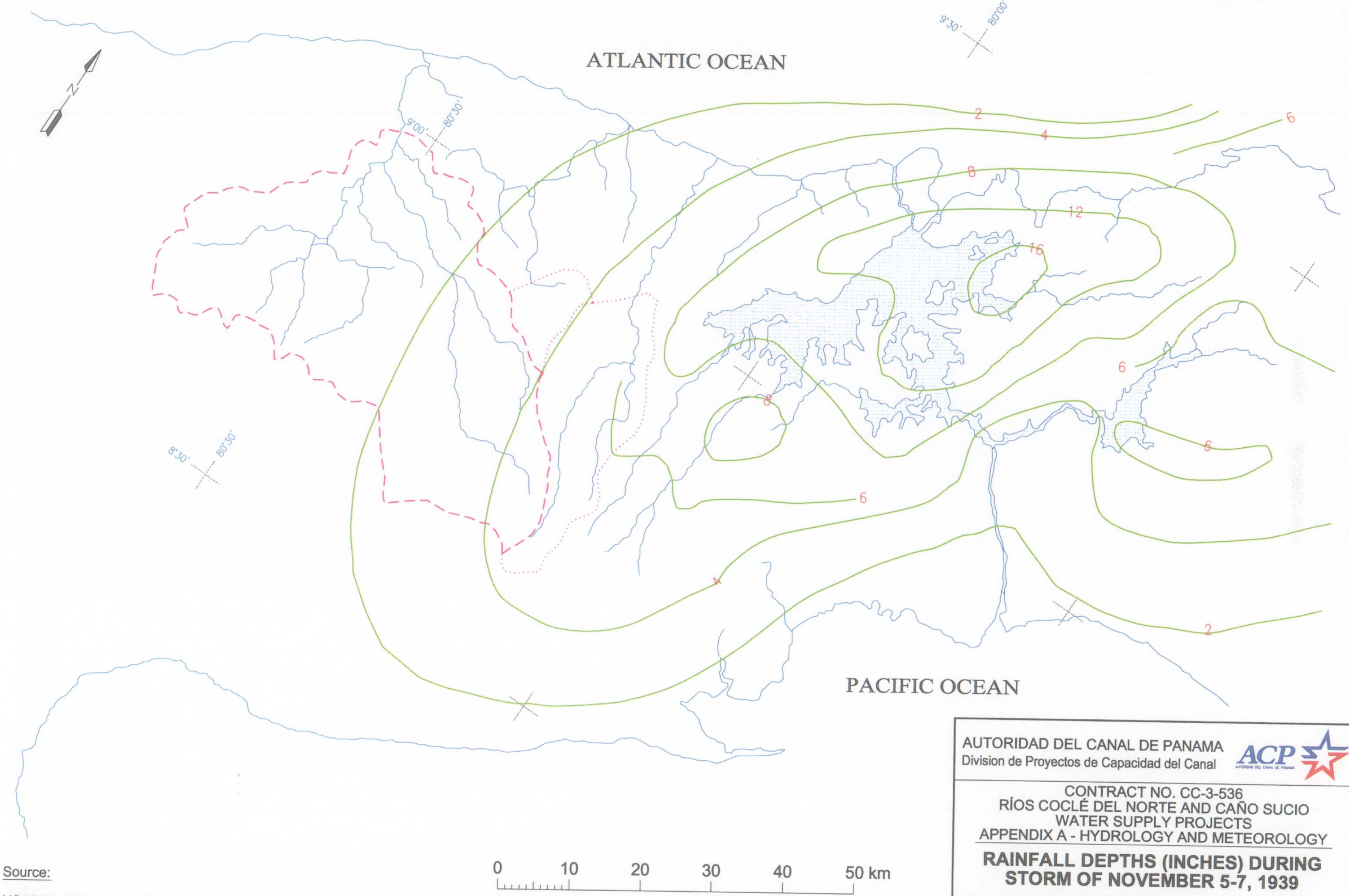
RAINFALL DEPTHS (INCHES) DURING STORM OF NOVEMBER 27-29, 1932

MWH TAMS

DATE: DECEMBER, 2003

EXHIBIT: 30



Source:

US NWS, February 1978 Report

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

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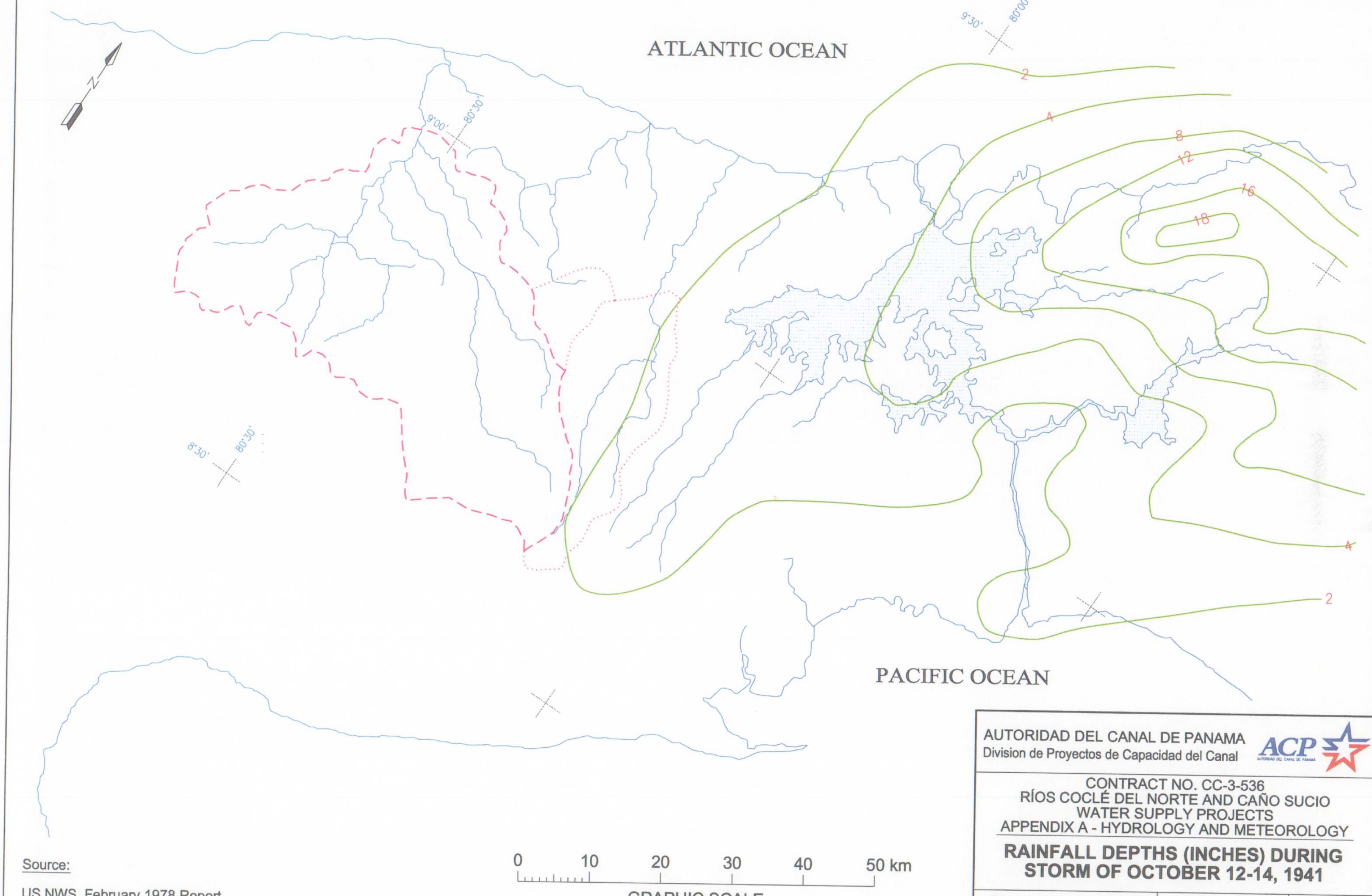
CONTRACT NO. CC-3-536
RÍOS COCLÉ DEL NORTE AND CAÑO SUCIO
WATER SUPPLY PROJECTS
APPENDIX A - HYDROLOGY AND METEOROLOGY

RAINFALL DEPTHS (INCHES) DURING STORM OF NOVEMBER 5-7, 1939

MWH TAMS

DATE: DECEMBER, 2003

EXHIBIT: 31



Source:

US NWS, February 1978 Report

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

CONTRACT NO. CC-3-536
RÍOS COCLÉ DEL NORTE AND CAÑO SUCIO
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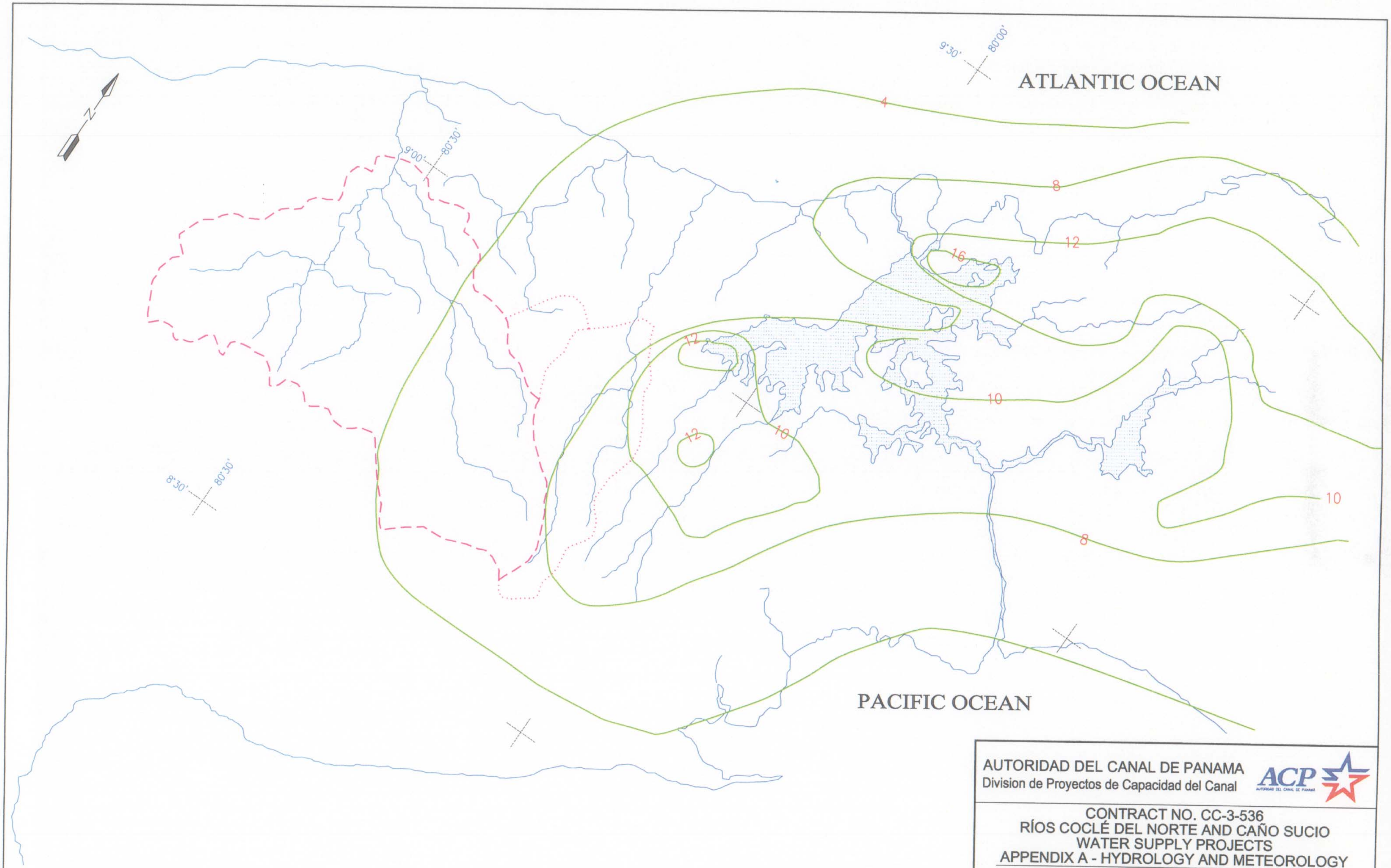
RAINFALL DEPTHS (INCHES) DURING STORM OF OCTOBER 12-14, 1941

MWH TAMS

DATE: DECEMBER, 2003

EXHIBIT: 32



Source:

US NWS, February 1978 Report

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
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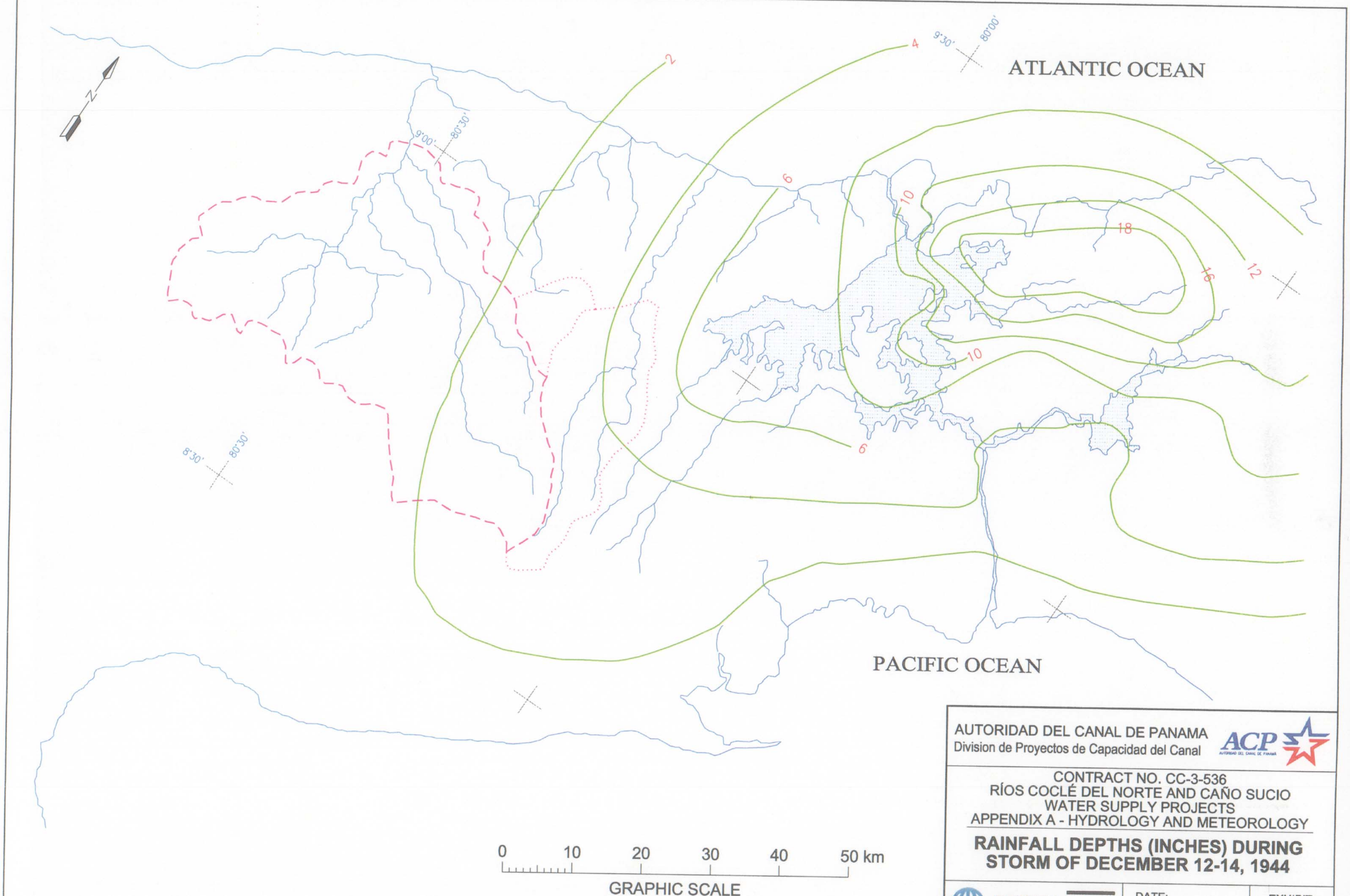
WATER SUPPLY PROJECTS
APPENDIX A - HYDROLOGY AND METEOROLOGY

RAINFALL DEPTHS (INCHES) DURING STORM OF DECEMBER 18-20, 1943

MWH TAMS

DATE: DECEMBER, 2003

EXHIBIT: 33



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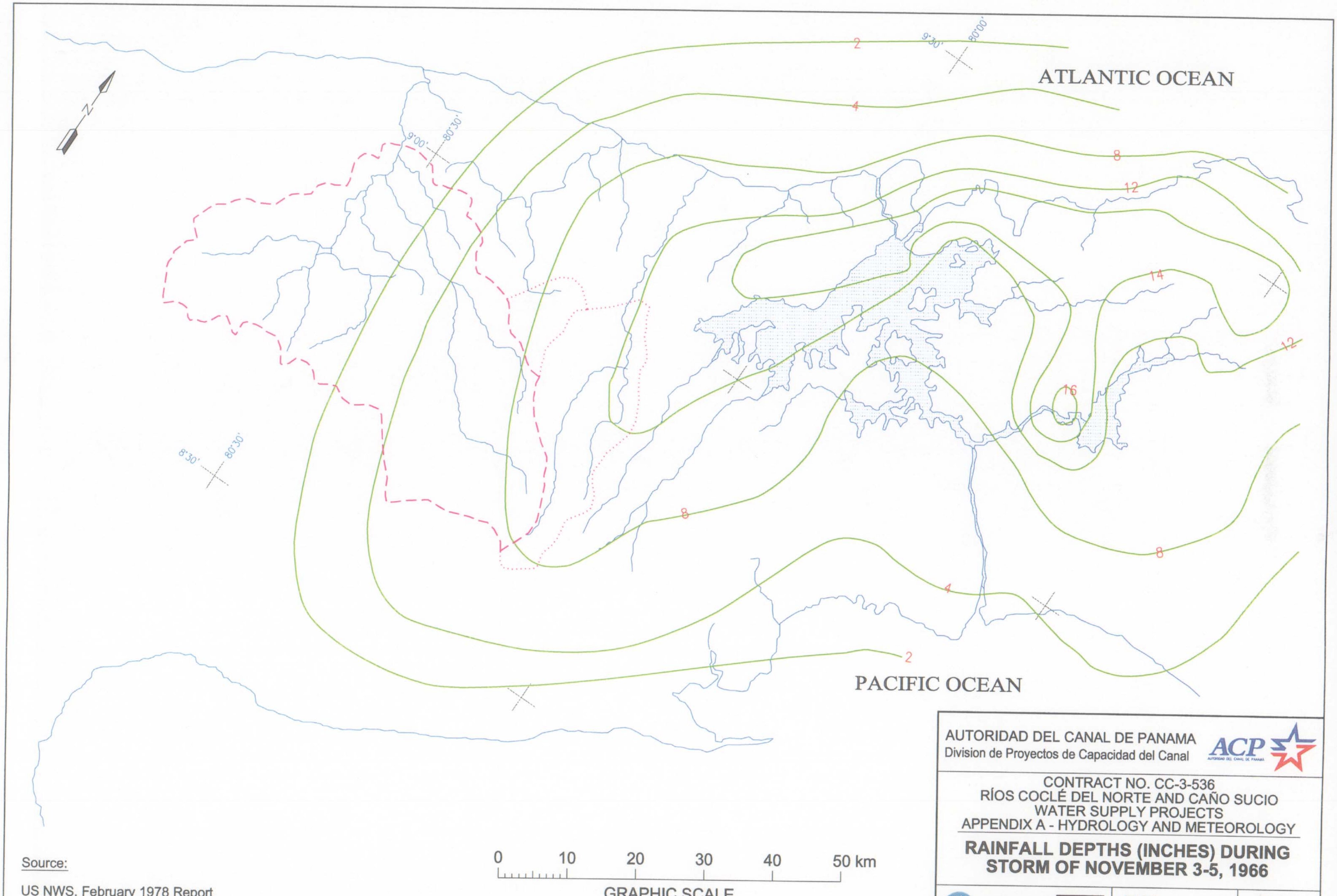
CONTRACT NO. CC-3-536
RÍOS COCLÉ DEL NORTE AND CAÑO SUCIO
WATER SUPPLY PROJECTS
APPENDIX A - HYDROLOGY AND METEOROLOGY

RAINFALL DEPTHS (INCHES) DURING STORM OF DECEMBER 12-14, 1944

MWH TAMS

DATE:	EXHIBIT:
DECEMBER, 2003	34



Source:

US NWS, February 1978 Report

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

CONTRACT NO. CC-3-536
RÍOS COCLÉ DEL NORTE AND CAÑO SUCIO
WATER SUPPLY PROJECTS
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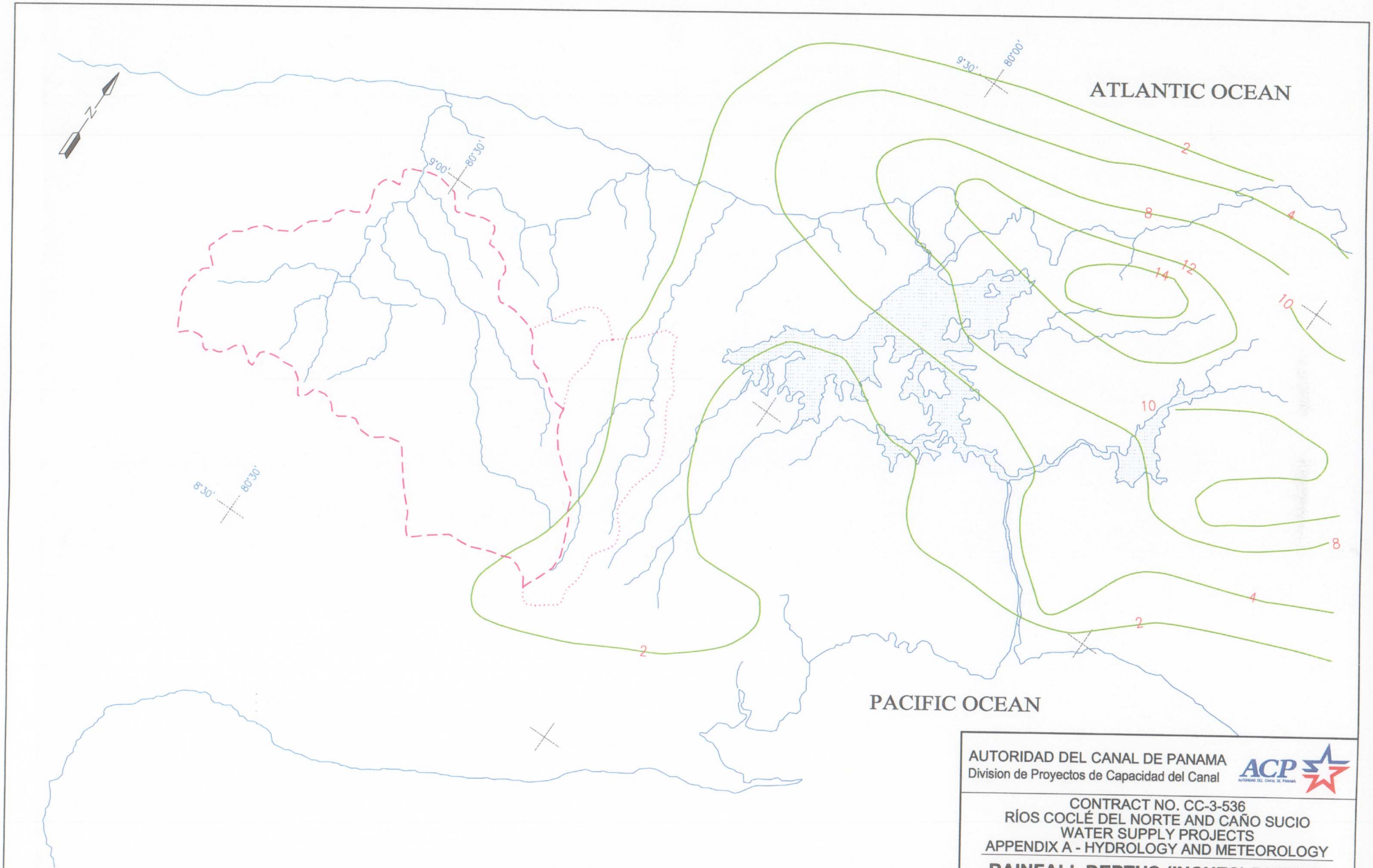
RAINFALL DEPTHS (INCHES) DURING STORM OF NOVEMBER 3-5, 1966

MWH TAMS

DATE: DECEMBER, 2003

EXHIBIT: 35



Source:
US NWS, February 1978 Report

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
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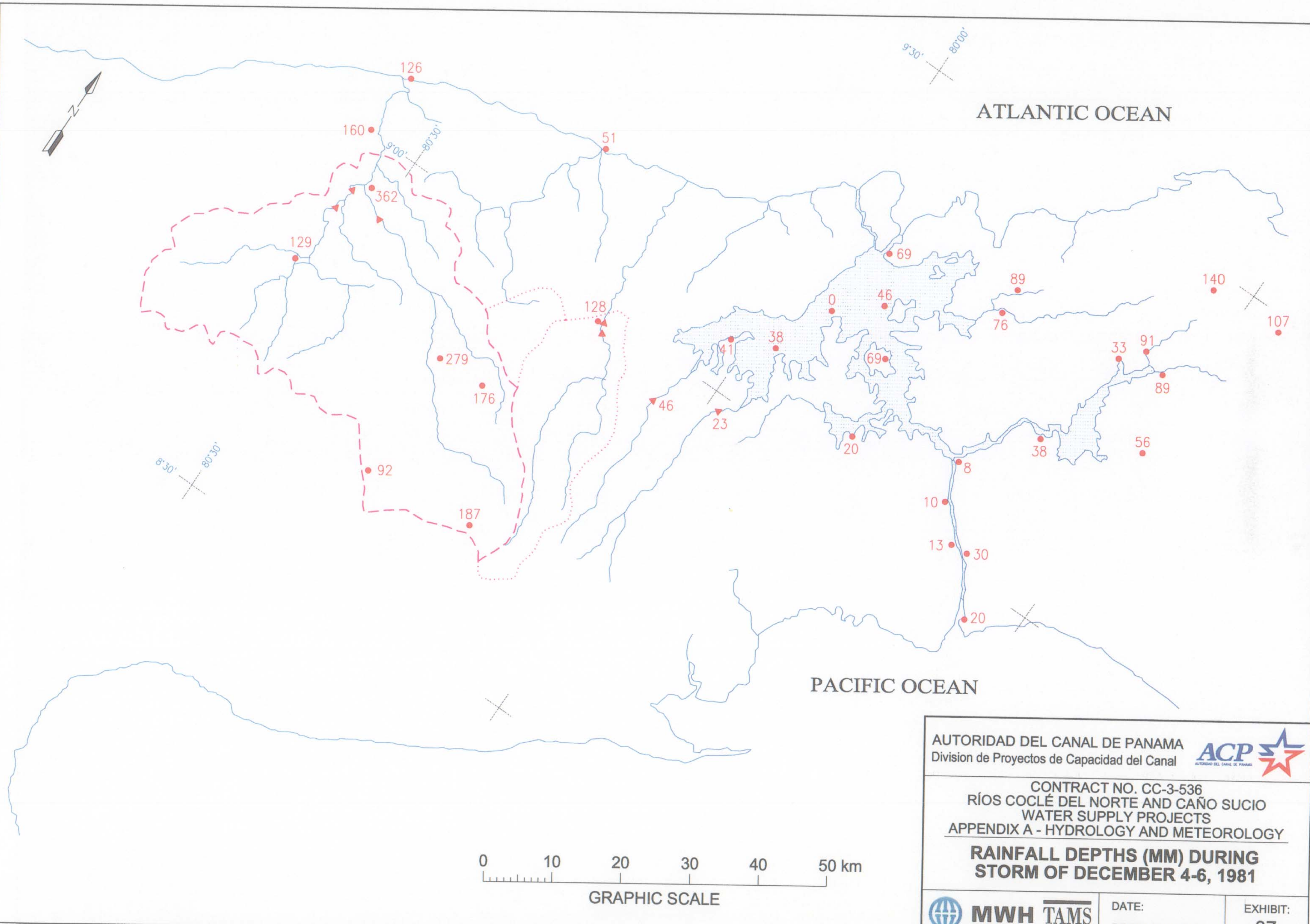
RAINFALL DEPTHS (INCHES) DURING STORM OF APRIL 7-9, 1970

MWH TAMS

DATE: DECEMBER, 2003

EXHIBIT: 36



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CONTRACT NO. CC-3-536
RÍOS COCLÉ DEL NORTE AND CAÑO SUCIO
WATER SUPPLY PROJECTS
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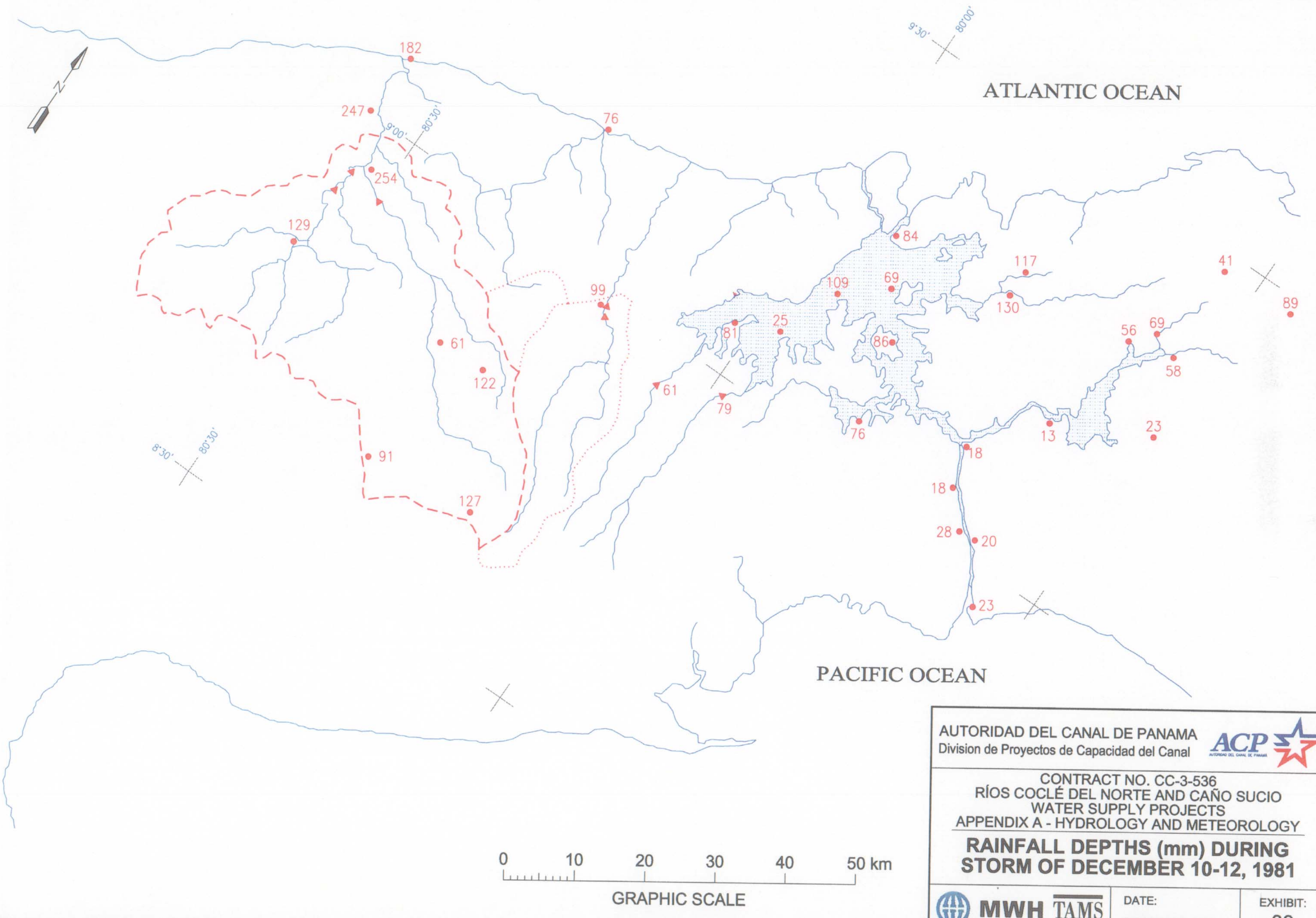
RAINFALL DEPTHS (MM) DURING STORM OF DECEMBER 4-6, 1981

MWH TAMS

DATE: DECEMBER, 2003

EXHIBIT: 37



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CONTRACT NO. CC-3-536
RÍOS COCLÉ DEL NORTE AND CAÑO SUCIO
WATER SUPPLY PROJECTS
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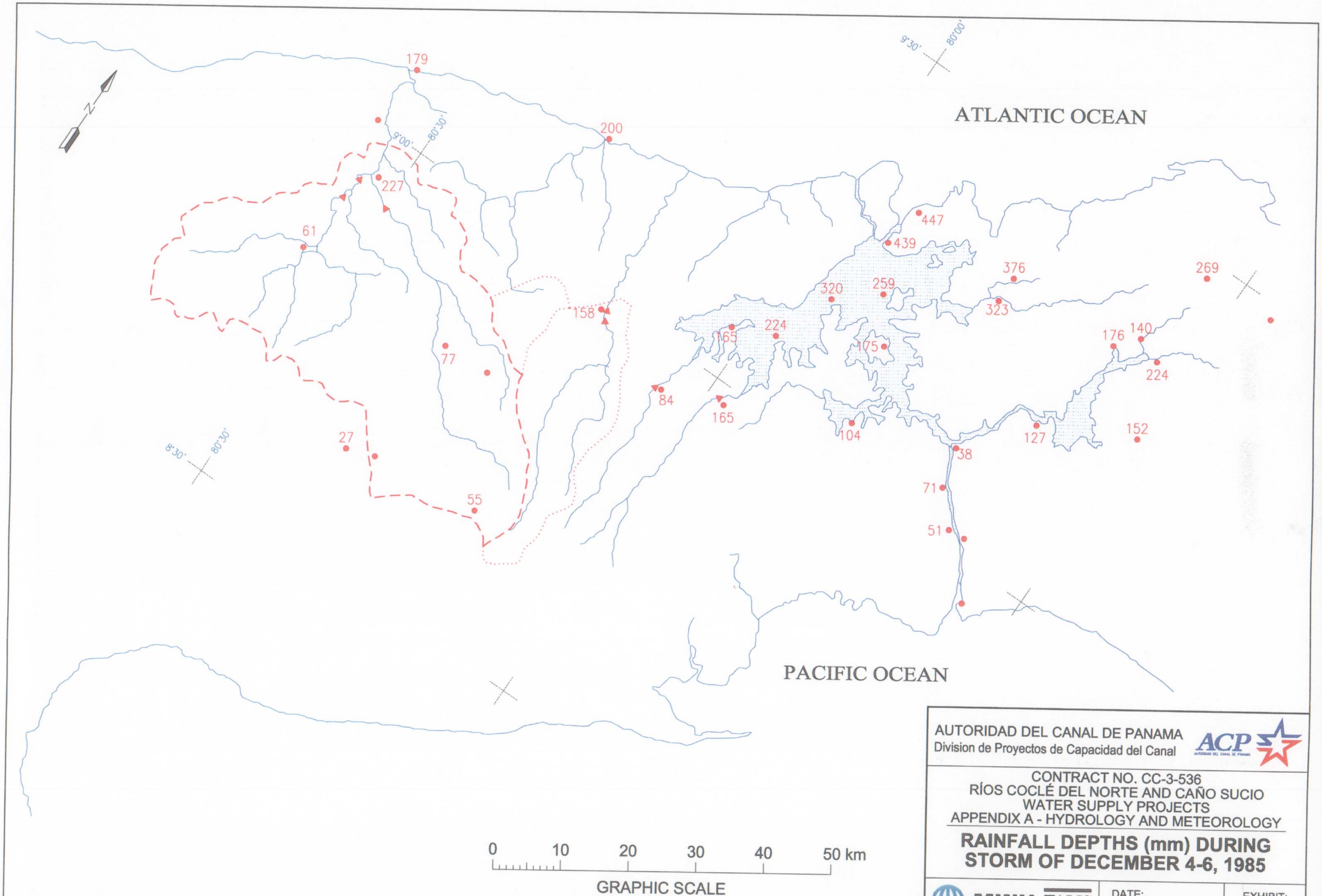
RAINFALL DEPTHS (mm) DURING STORM OF DECEMBER 10-12, 1981

MWH TAMS

DATE:	EXHIBIT:
DECEMBER, 2003	38



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CONTRACT NO. CC-3-536
RÍOS COCLÉ DEL NORTE AND CAÑO SUCIO
WATER SUPPLY PROJECTS
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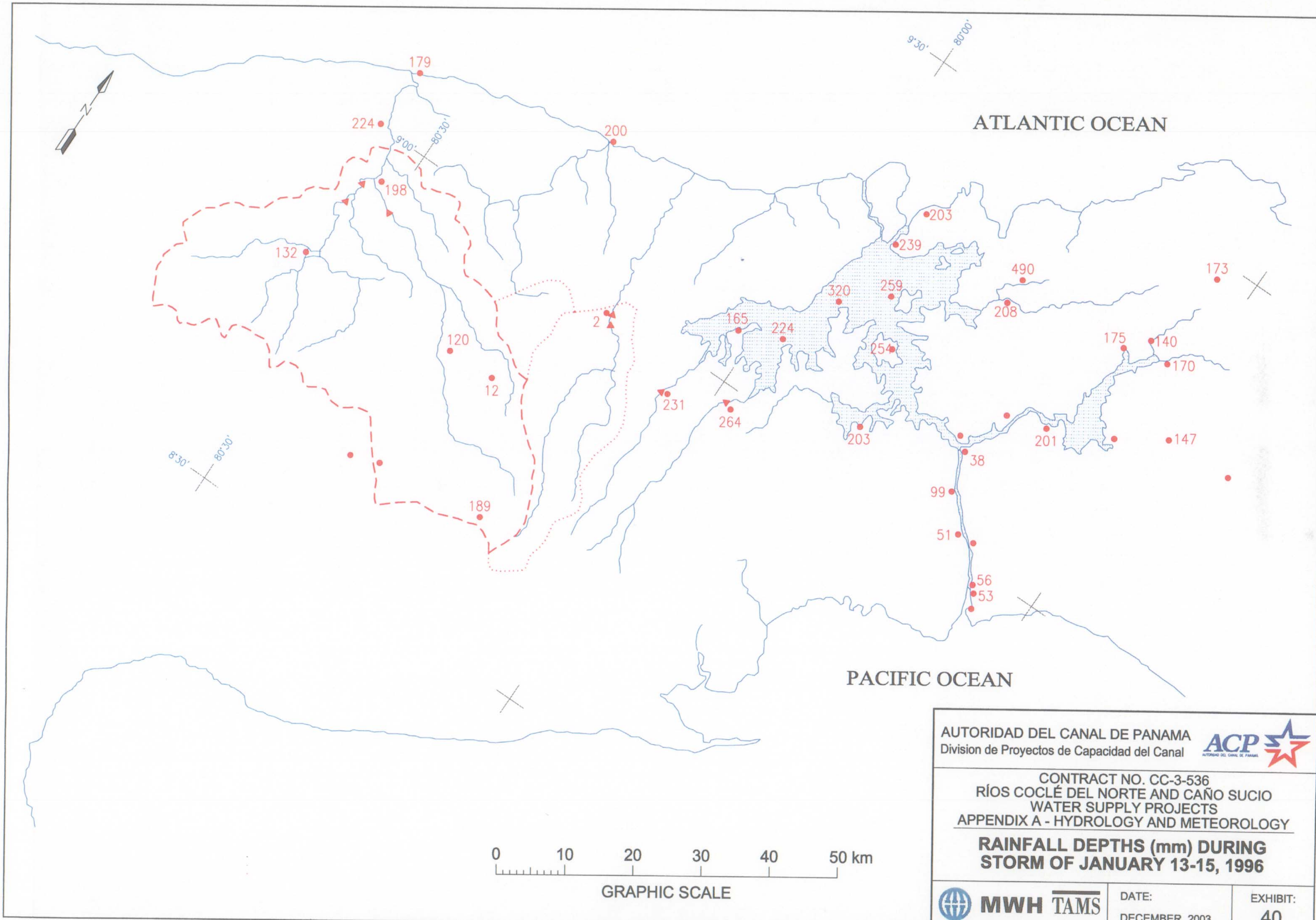
RAINFALL DEPTHS (mm) DURING STORM OF DECEMBER 4-6, 1985

MWH TAMS

DATE: DECEMBER, 2003

EXHIBIT: 39



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

CONTRACT NO. CC-3-536
RÍOS COCLÉ DEL NORTE AND CAÑO SUCIO
WATER SUPPLY PROJECTS
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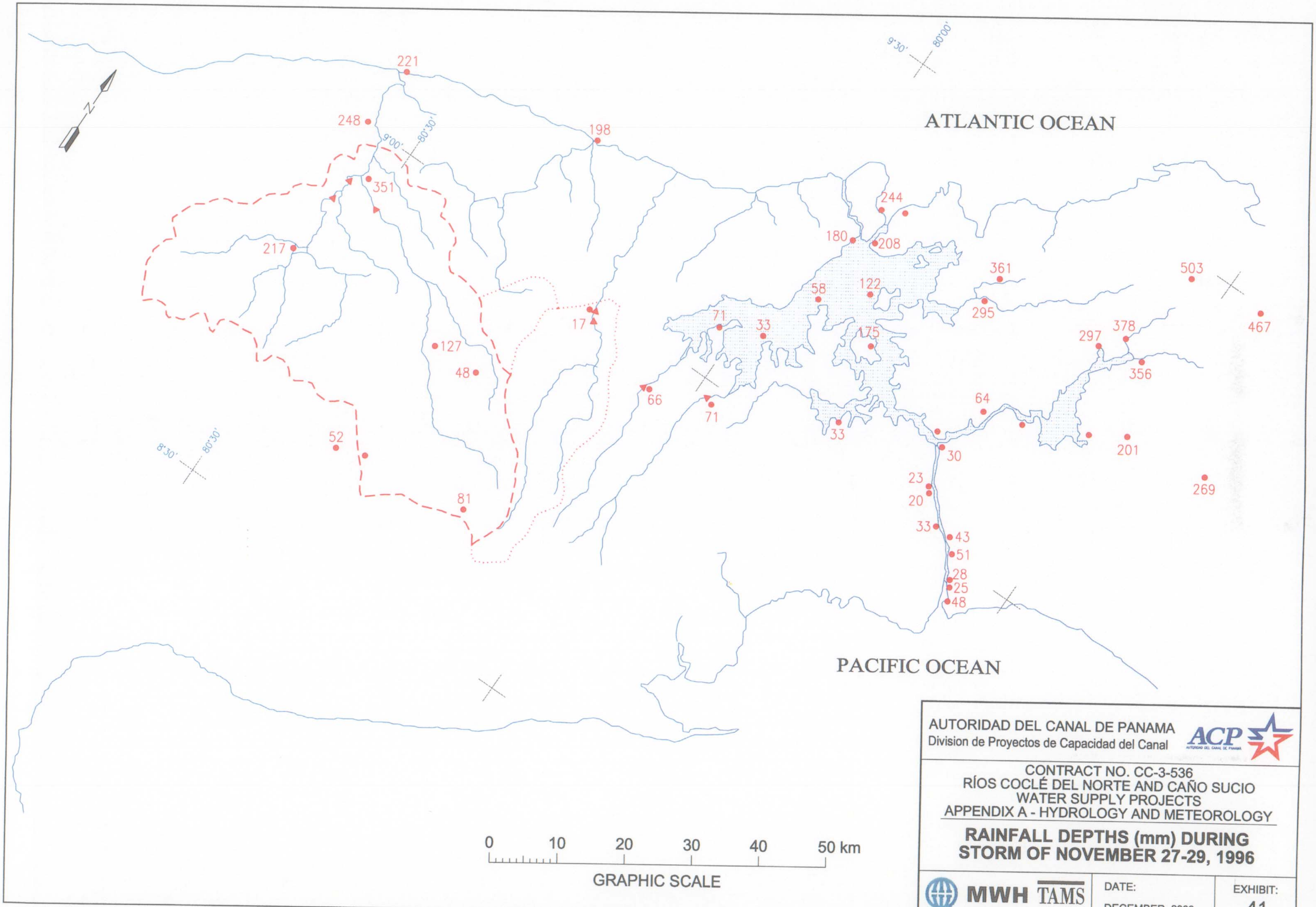
RAINFALL DEPTHS (mm) DURING STORM OF JANUARY 13-15, 1996

MWH TAMS

DATE: DECEMBER, 2003

EXHIBIT: 40



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AUTORIDAD DEL CANAL DE PANAMA

CONTRACT NO. CC-3-536
RÍOS COCLÉ DEL NORTE AND CAÑO SUCIO
WATER SUPPLY PROJECTS
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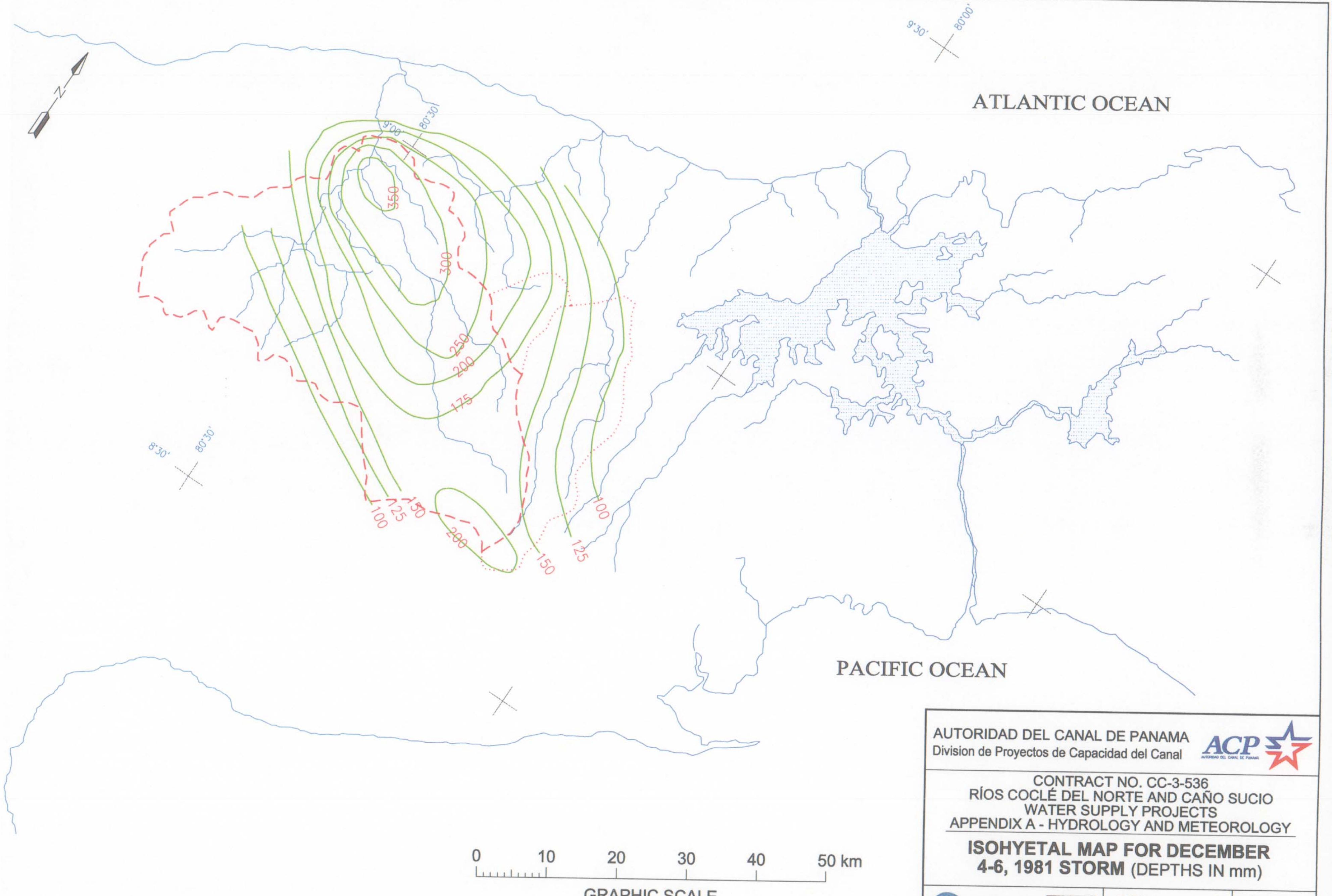
RAINFALL DEPTHS (mm) DURING STORM OF NOVEMBER 27-29, 1996

MWH TAMS

DATE: DECEMBER, 2003

EXHIBIT: 41



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Division de Proyectos de Capacidad del Canal

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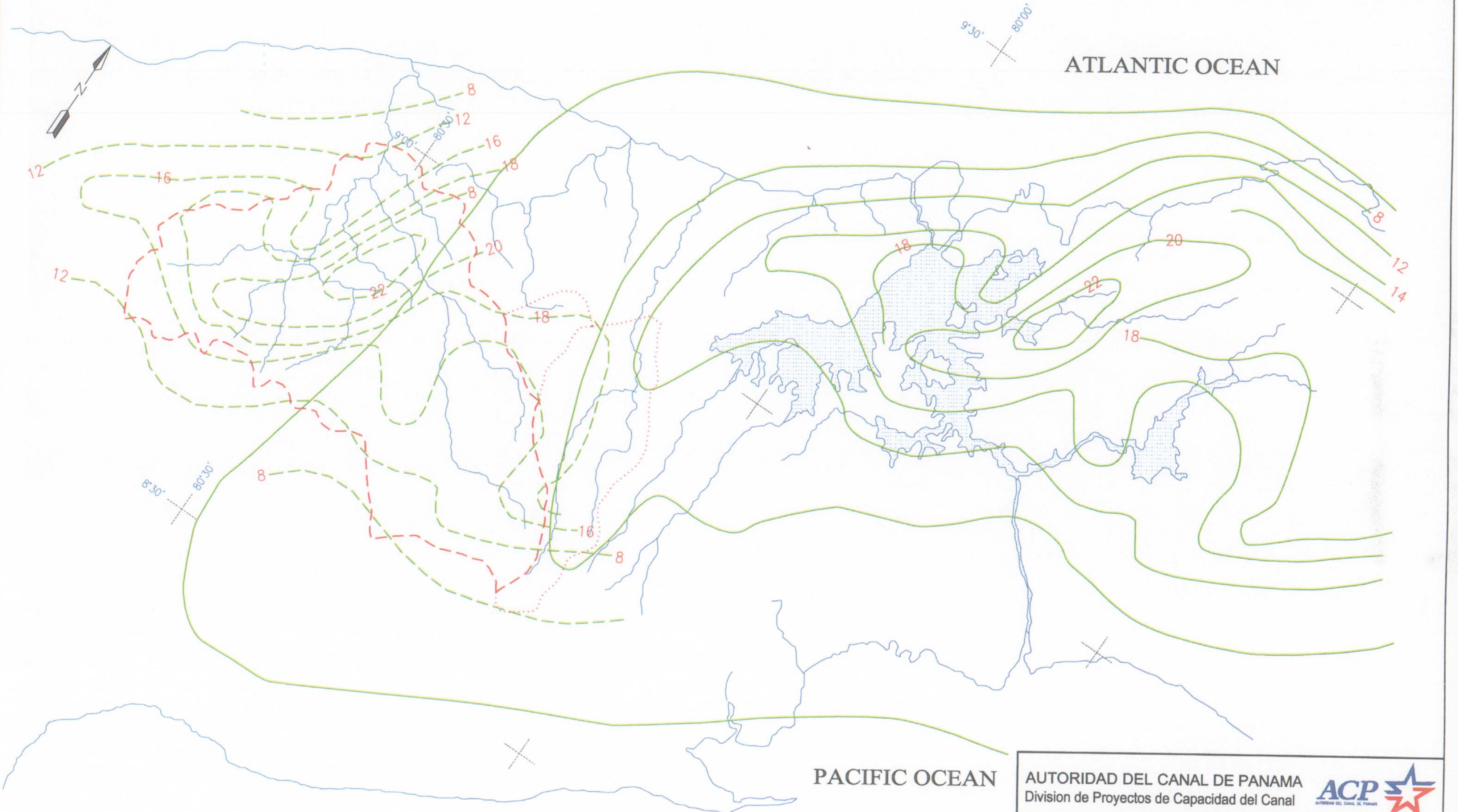
CONTRACT NO. CC-3-536
RÍOS COCLÉ DEL NORTE AND CAÑO SUCIO
WATER SUPPLY PROJECTS
APPENDIX A - HYDROLOGY AND METEOROLOGY

ISOHYETAL MAP FOR DECEMBER 4-6, 1981 STORM (DEPTHS IN mm)

MWH TAMS

DATE: DECEMBER, 2003

EXHIBIT: 42



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

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CONTRACT NO. CC-3-536
RÍOS COCLÉ DEL NORTE AND CAÑO SUCIO
WATER SUPPLY PROJECTS
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RAINFALL DEPTHS (INCHES) DURING NOVEMBER 7-9, 1931 STORM TRANSPOSED TO RÍO COCLÉ DEL NORTE BASIN

MWH TAMS

DATE: DECEMBER, 2003

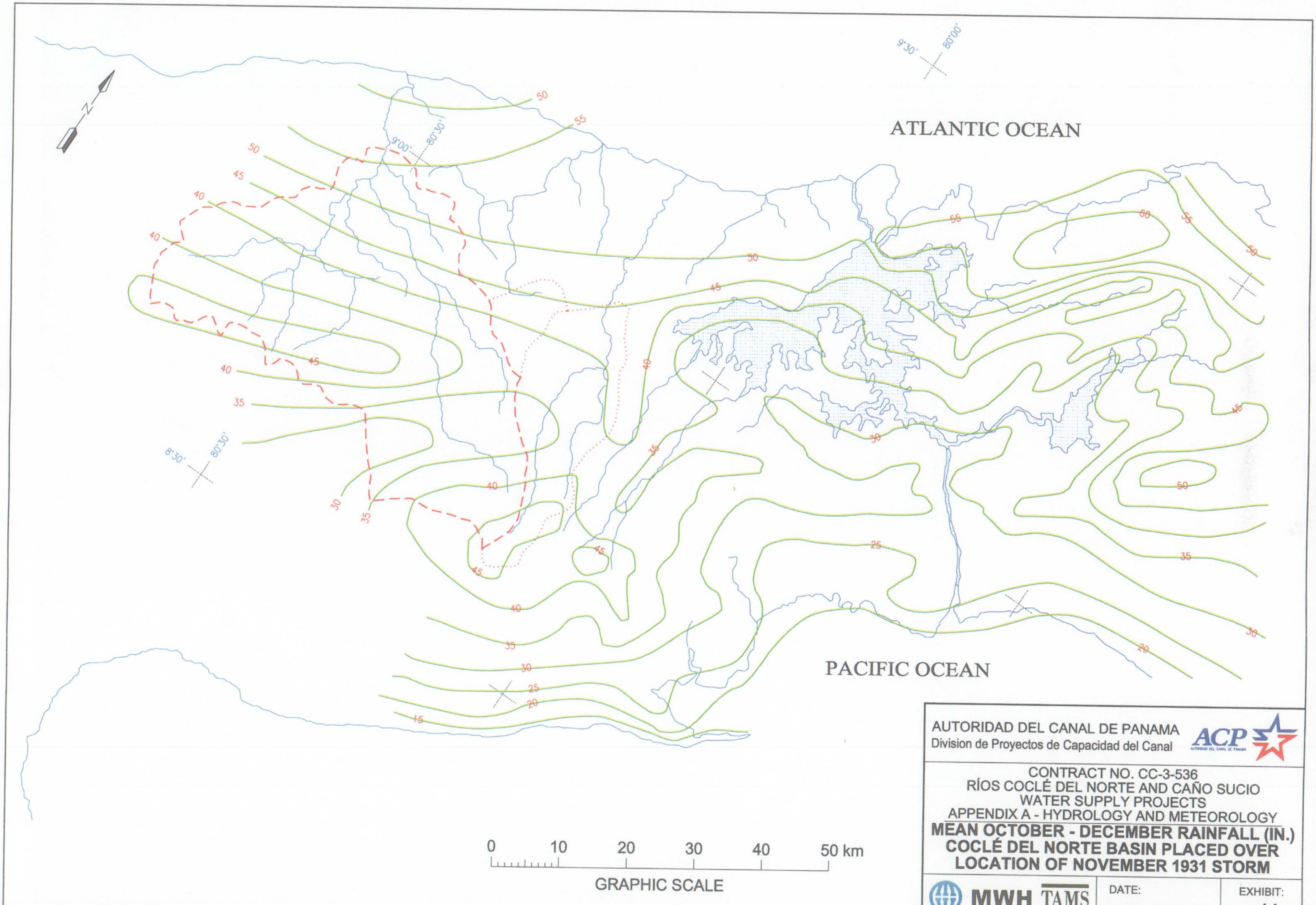
EXHIBIT: 43

Source:

US NWS, February 1978 Report

0 10 20 30 40 50 km

GRAPHIC SCALE



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

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CONTRACT NO. CC-3-536
RÍOS COCLÉ DEL NORTE AND CAÑO SUCIO
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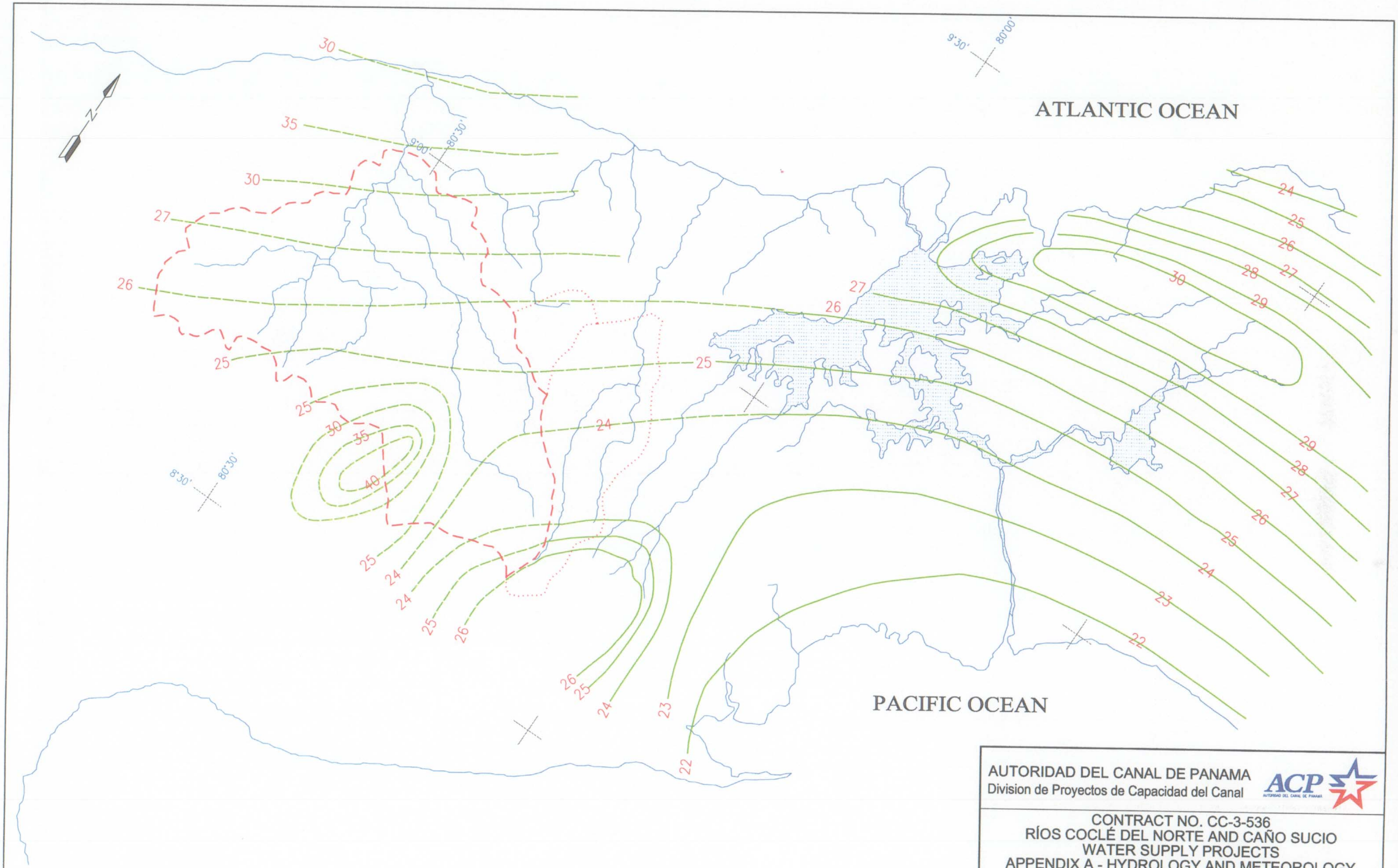
MEAN OCTOBER - DECEMBER RAINFALL (IN.)
COCLÉ DEL NORTE BASIN PLACED OVER
LOCATION OF NOVEMBER 1931 STORM

MWH TAMS

DATE: DECEMBER, 2003

EXHIBIT: 44



Source:

US NWS, February 1978 Report

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
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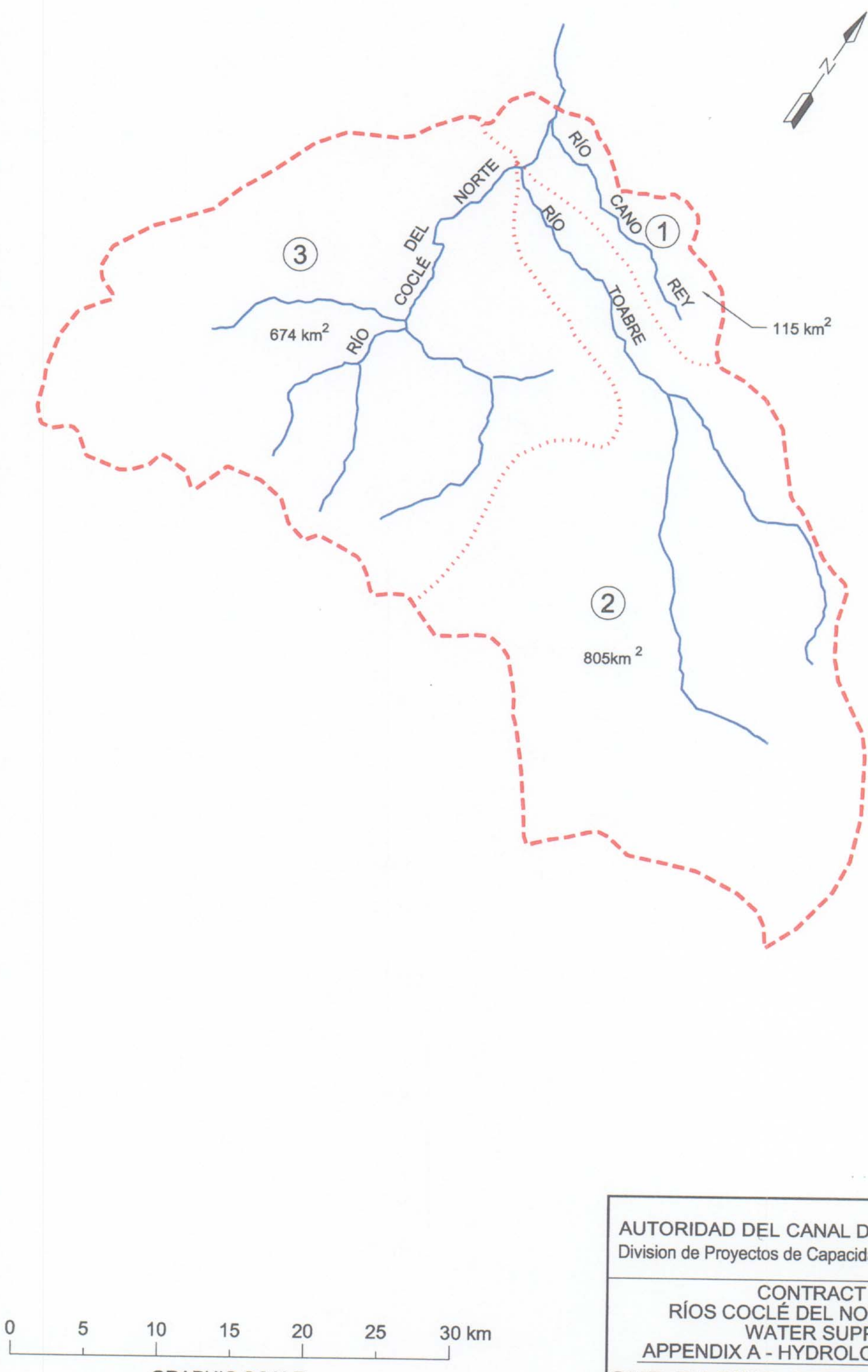
WATER SUPPLY PROJECTS
APPENDIX A - HYDROLOGY AND METEOROLOGY

24-HOUR, 10-MI² PMP
(INCHES)

MWH TAMS

DATE:
DECEMBER, 2003

EXHIBIT:
45



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

CONTRACT NO. CC-3-536
RÍOS COCLÉ DEL NORTE AND CAÑO SUCIO
WATER SUPPLY PROJECTS
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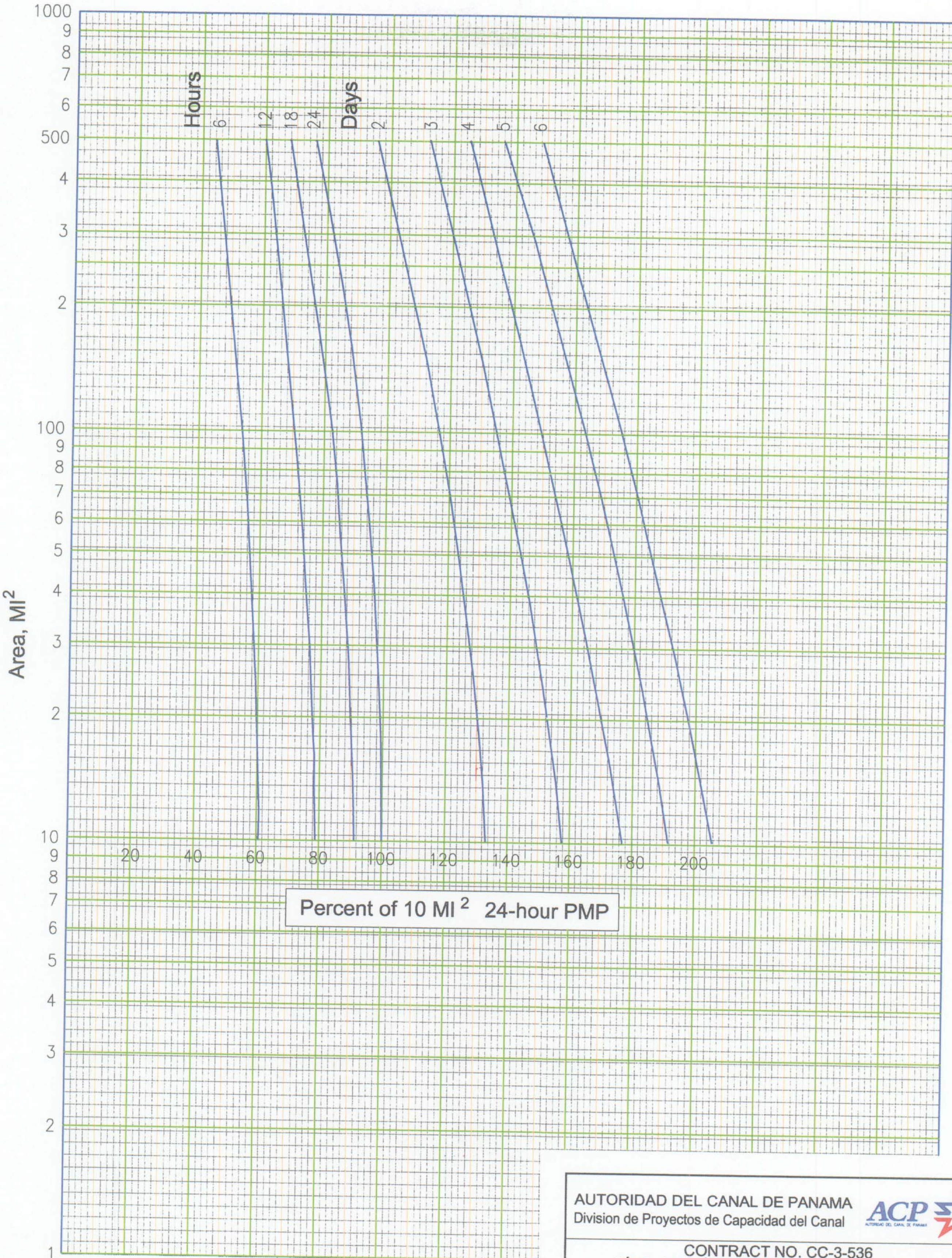
SUB-BASINS OF RIO COCLÉ DEL NORTE BASIN ABOVE THE DAM SITE

MWH TAMS

DATE:	EXHIBIT:
DECEMBER, 2003	46



Source:

US Weather Bureau, 1965 Report

AUTORIDAD DEL CANAL DE PANAMA
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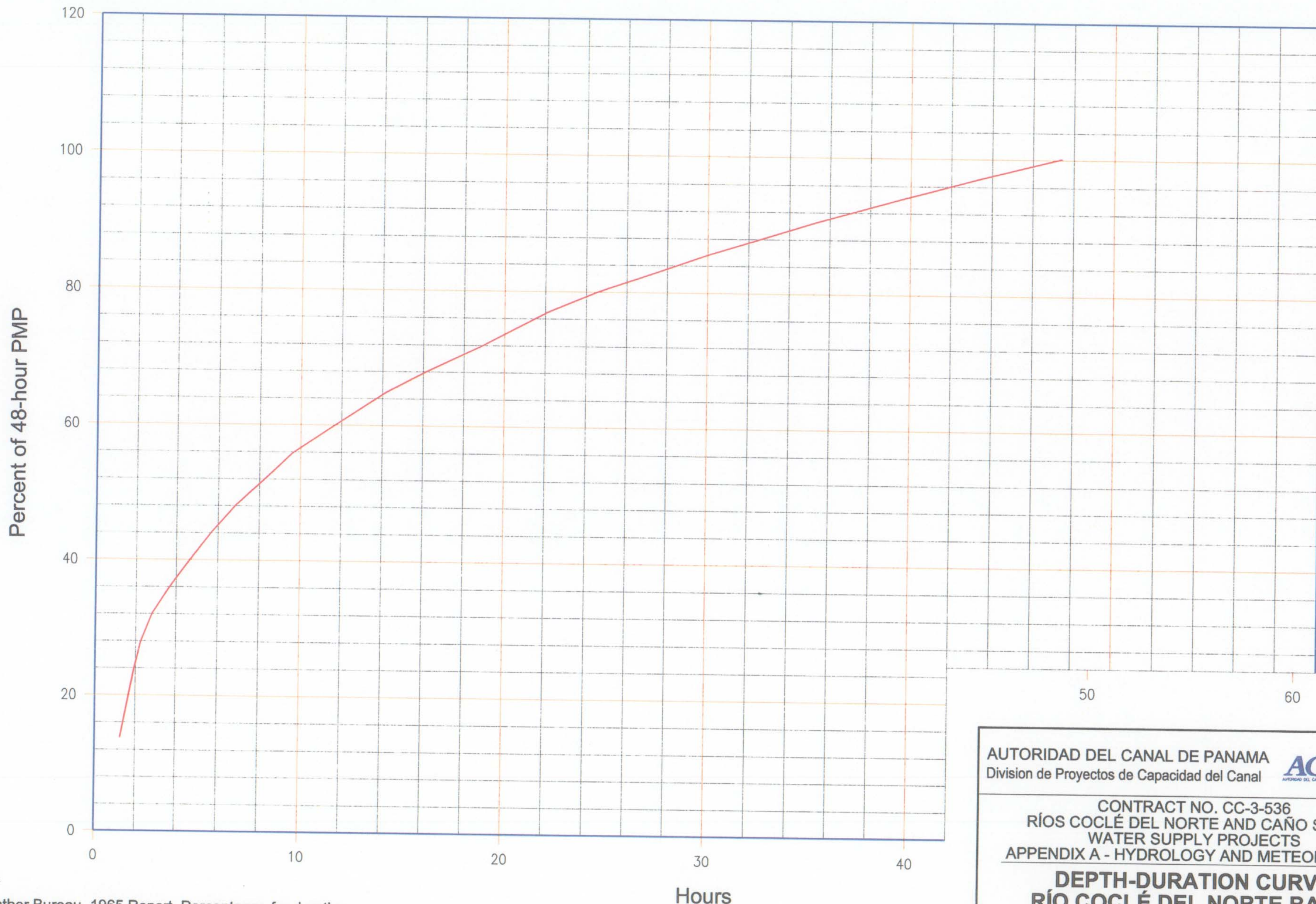
CONTRACT NO. CC-3-536
RÍOS COCLÉ DEL NORTE AND CAÑO SUCIO
WATER SUPPLY PROJECTS
APPENDIX A - HYDROLOGY AND METEOROLOGY

DEPTH-AREA-DURATION CURVES

MWH TAMS

DATE:	EXHIBIT:
DECEMBER, 2003	47



Source:

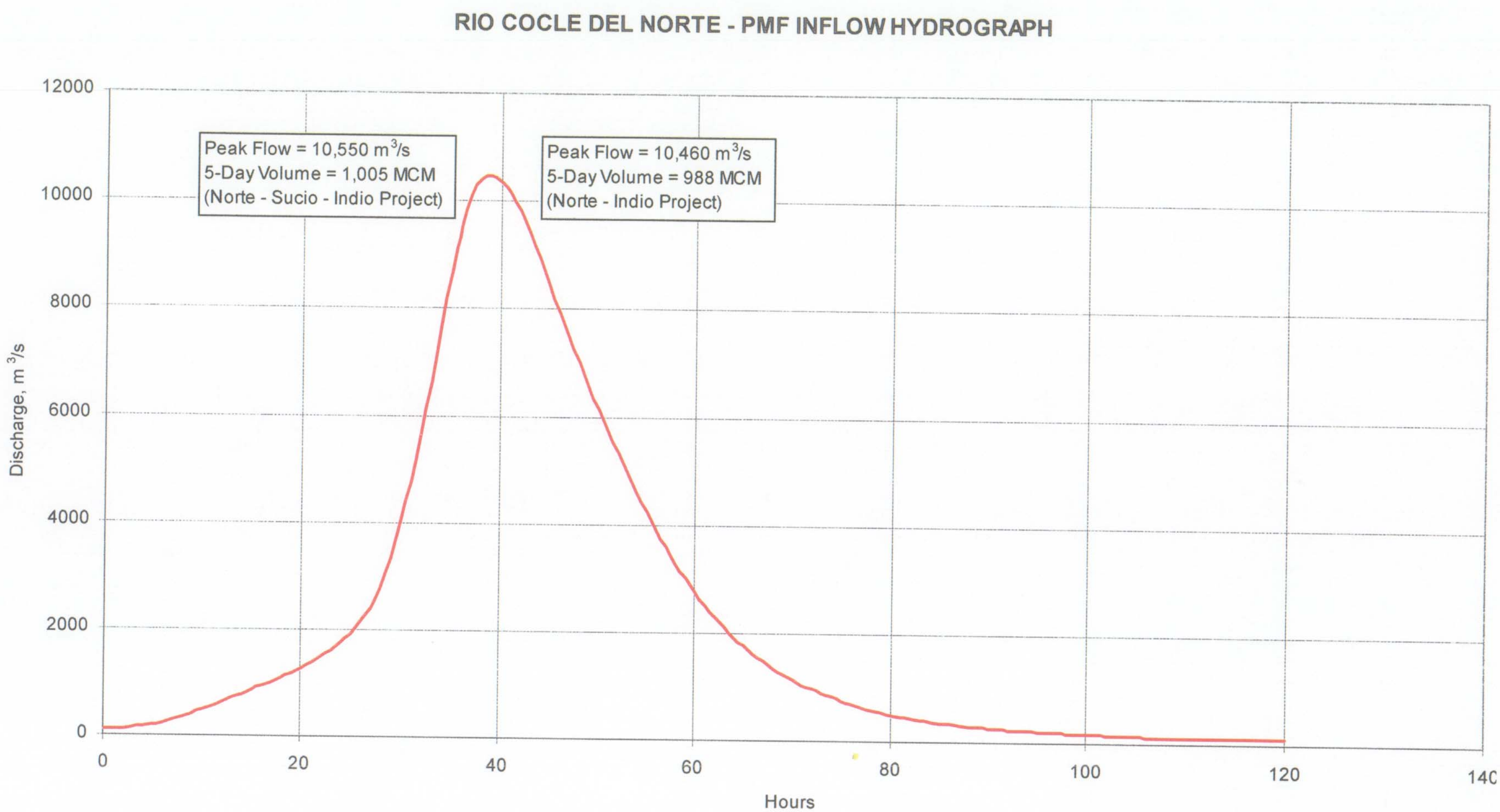
US Weather Bureau, 1965 Report, Percentages for duration less than 6 hours from hourly data

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

CONTRACT NO. CC-3-536
RÍOS COCLÉ DEL NORTE AND CAÑO SUCIO
WATER SUPPLY PROJECTS
APPENDIX A - HYDROLOGY AND METEOROLOGY

DEPTH-DURATION CURVE
RÍO COCLÉ DEL NORTE BASIN

MWH TAMS | DATE: DECEMBER, 2003 | EXHIBIT: 48



AUTORIDAD DEL CANAL DE PANAMA
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CONTRACT NO. CC-3-536
RÍOS COCLÉ DEL NORTE AND CAÑO SUCIO
WATER SUPPLY PROJECTS
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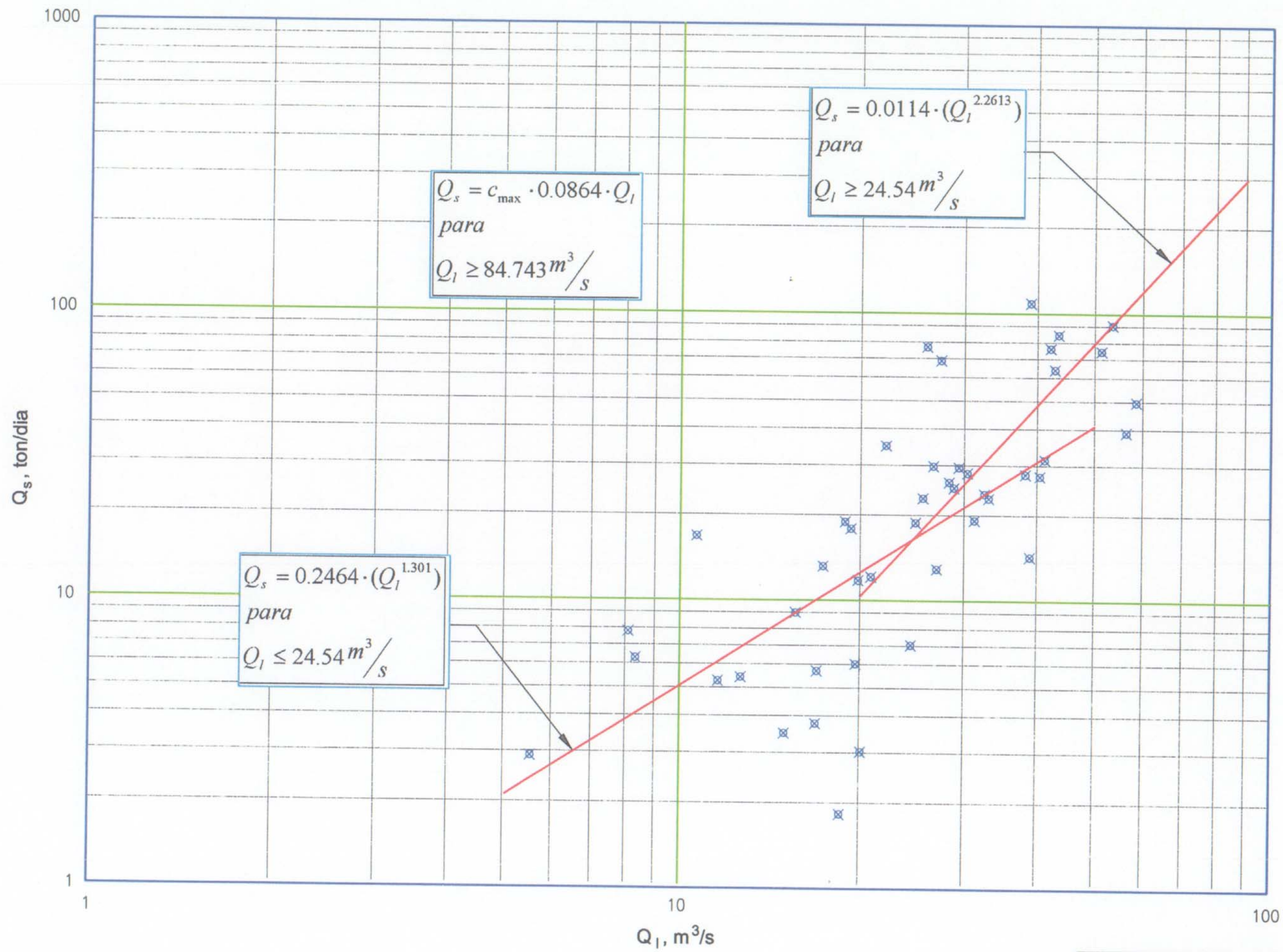
RÍO COCLÉ DEL NORTE
PMF INFLOW HYDROGRAPH

MWH TAMS

DATE:	EXHIBIT:
DECEMBER, 2003	49



Source:

Departamento de Hidrometeorologia

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

CONTRACT NO. CC-3-536
RÍOS COCLÉ DEL NORTE AND CAÑO SUCIO
WATER SUPPLY PROJECTS
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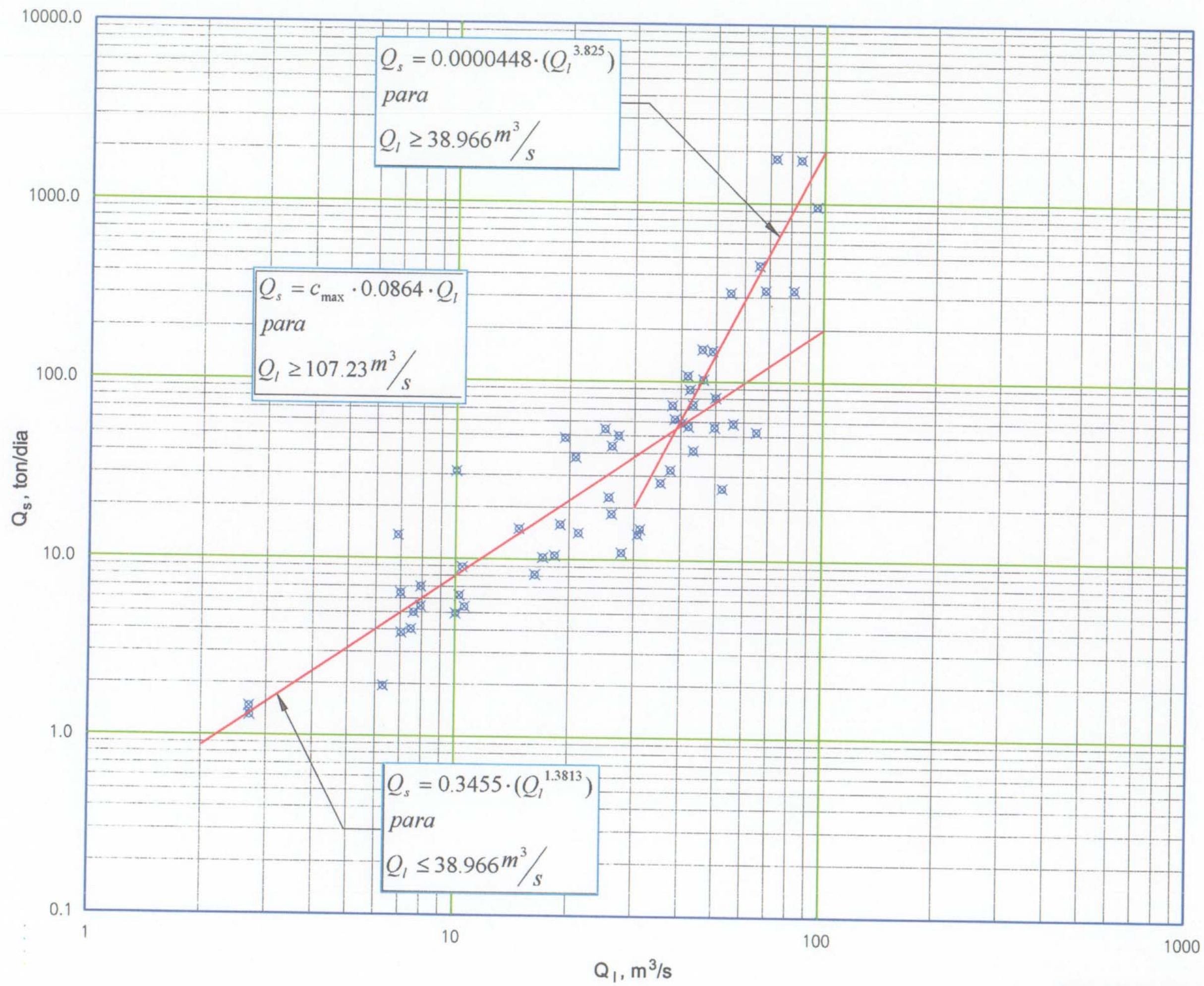
SUSPENDED SEDIMENT RATING CURVE
RÍO COCLÉ DEL NORTE, CANOAS

MWH TAMS

DATE:	EXHIBIT:
DECEMBER, 2003	50



Source:

Departamento de Hidrometeorologia

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

ACP

CONTRACT NO. CC-3-536
RÍOS COCLÉ DEL NORTE AND CAÑO SUCIO
WATER SUPPLY PROJECTS
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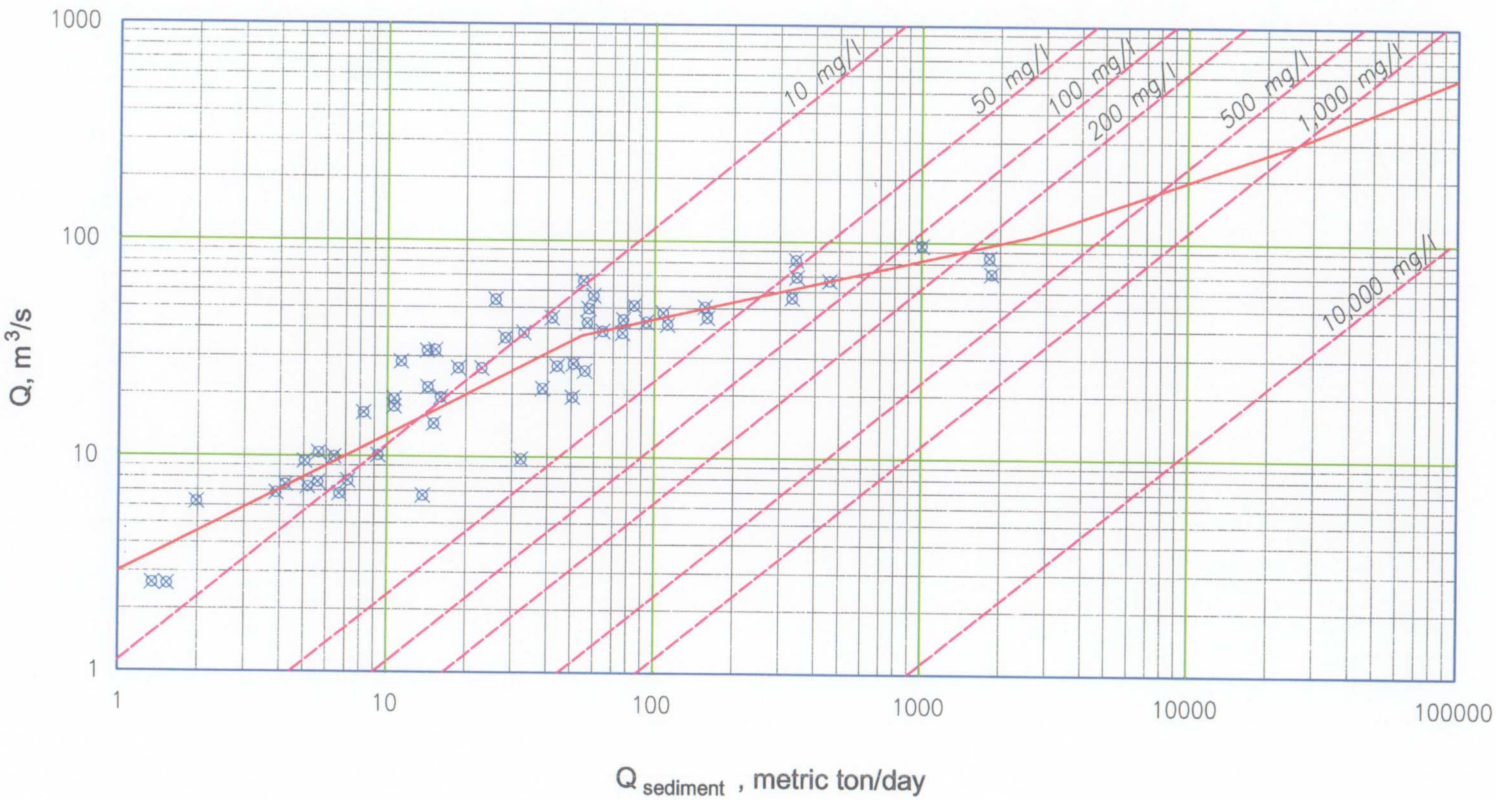
SUSPENDED SEDIMENT RATING CURVE
RÍO TOABRE, BATATILLA

MWH TAMS

DATE:	EXHIBIT:
DECEMBER, 2003	51



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

CONTRACT NO. CC-3-536
RÍOS COCLÉ DEL NORTE AND CAÑO SUCIO
WATER SUPPLY PROJECTS
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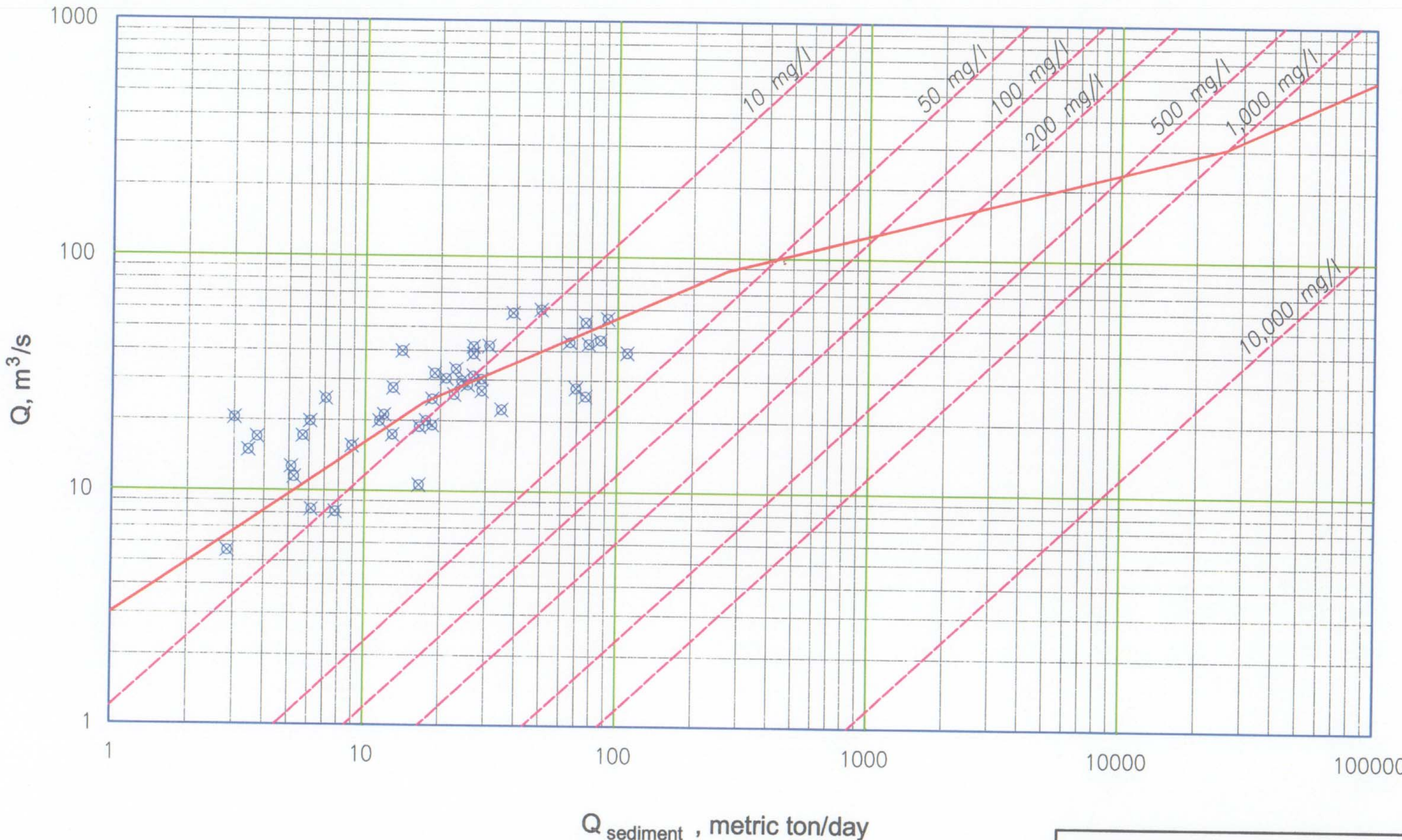
SUSPENDED SEDIMENT RATING CURVE
RÍO TOABRE

MWH TAMS

DATE: DECEMBER, 2003

EXHIBIT: 52



AUTORIDAD DEL CANAL DE PANAMA
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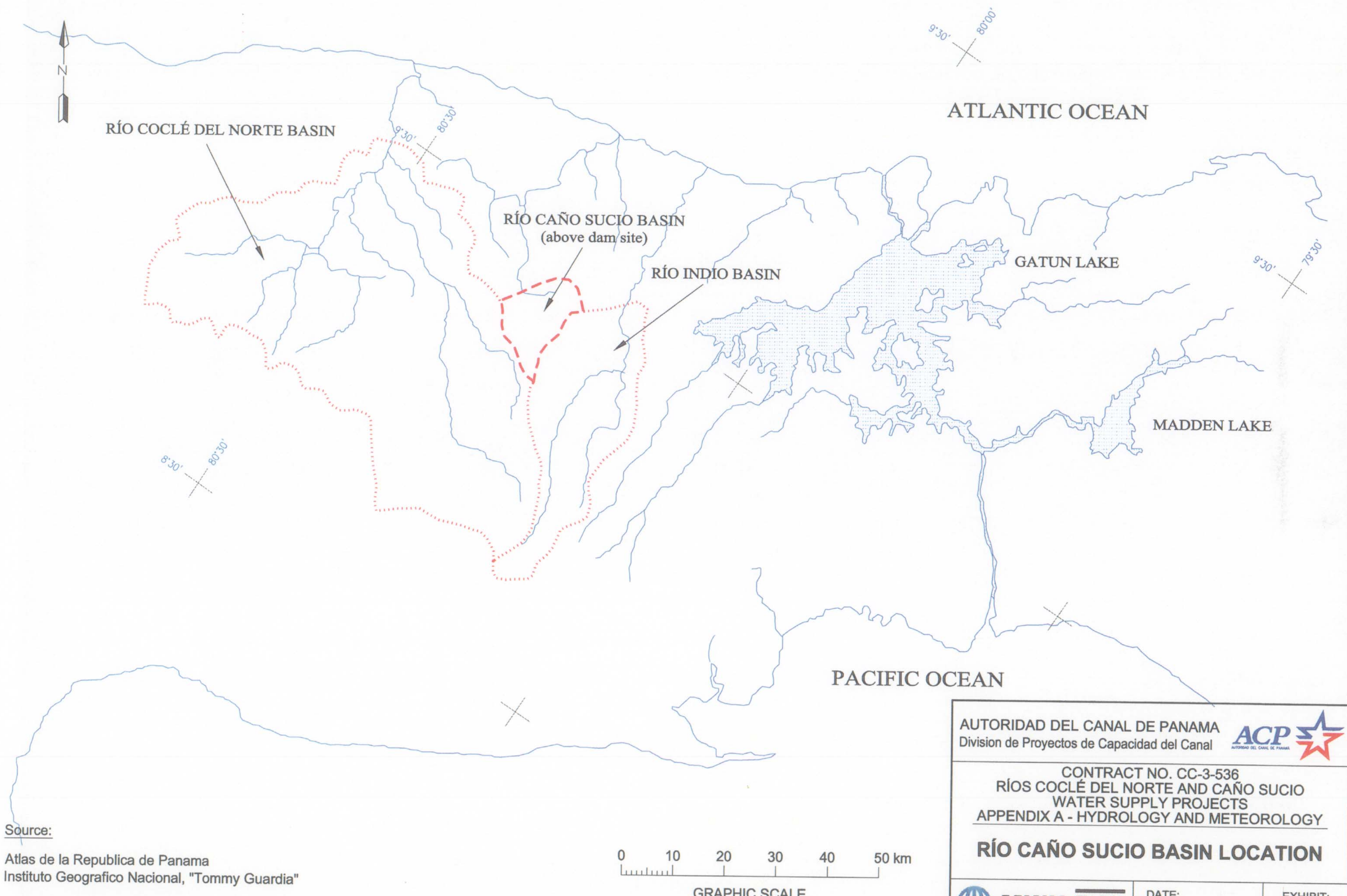
CONTRACT NO. CC-3-536
RÍOS COCLÉ DEL NORTE AND CAÑO SUCIO
WATER SUPPLY PROJECTS
APPENDIX A - HYDROLOGY AND METEOROLOGY

SUSPENDED SEDIMENT RATING CURVE
RÍO COCLÉ DEL NORTE

MWH TAMS	DATE: DECEMBER, 2003	EXHIBIT: 53



Source:

Atlas de la Republica de Panama
Instituto Geografico Nacional, "Tommy Guardia"

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

CONTRACT NO. CC-3-536
RÍOS COCLÉ DEL NORTE AND CAÑO SUCIO
WATER SUPPLY PROJECTS
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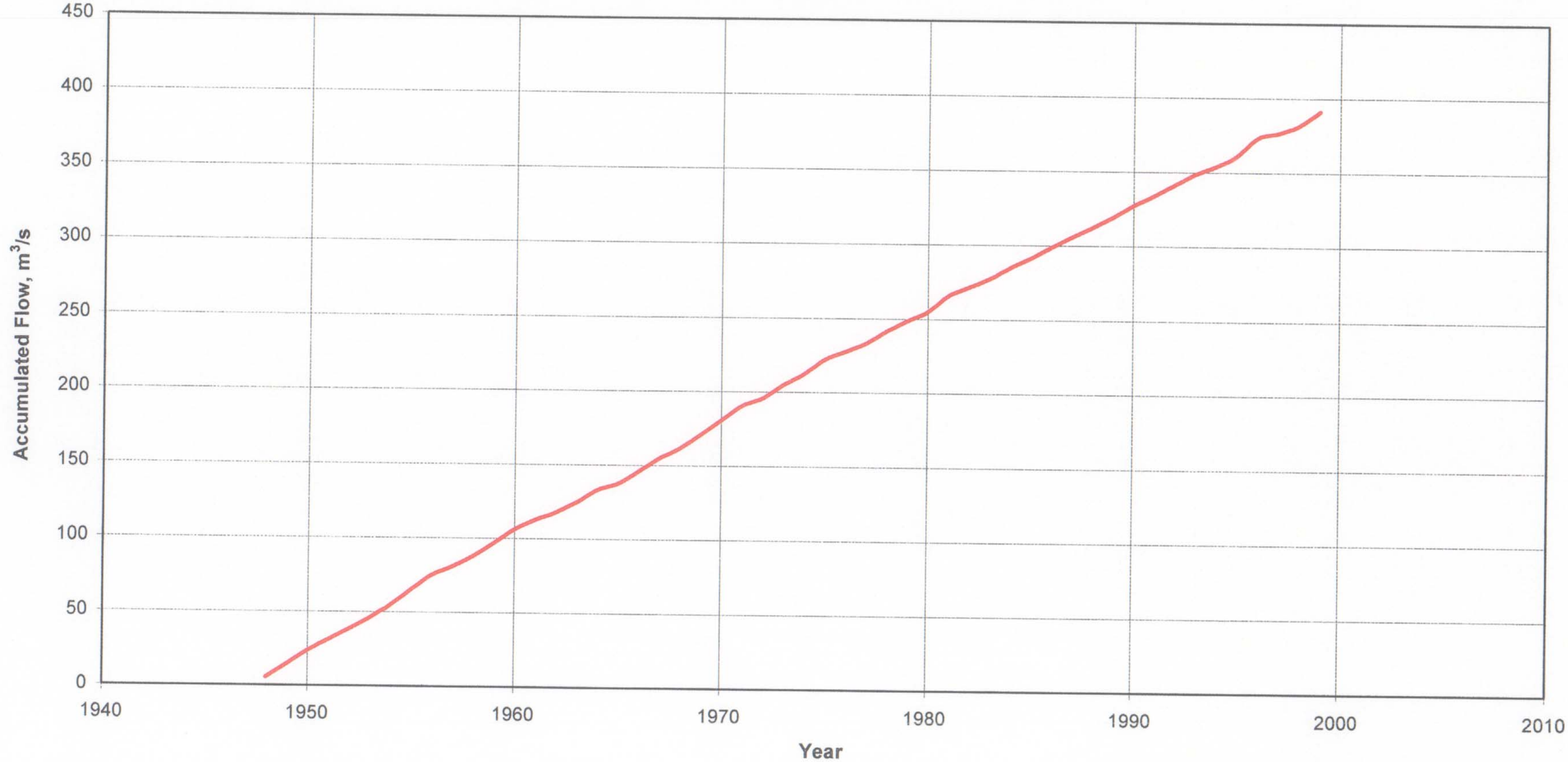
RÍO CAÑO SUCIO BASIN LOCATION

MWH TAMS

DATE: DECEMBER, 2003

EXHIBIT: 54

MASS CURVE - RIO CANO SUCIO AT DAM SITE



AUTORIDAD DEL CANAL DE PANAMA
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CONTRACT NO. CC-3-536
RÍOS COCLÉ DEL NORTE AND CAÑO SUCIO
WATER SUPPLY PROJECTS
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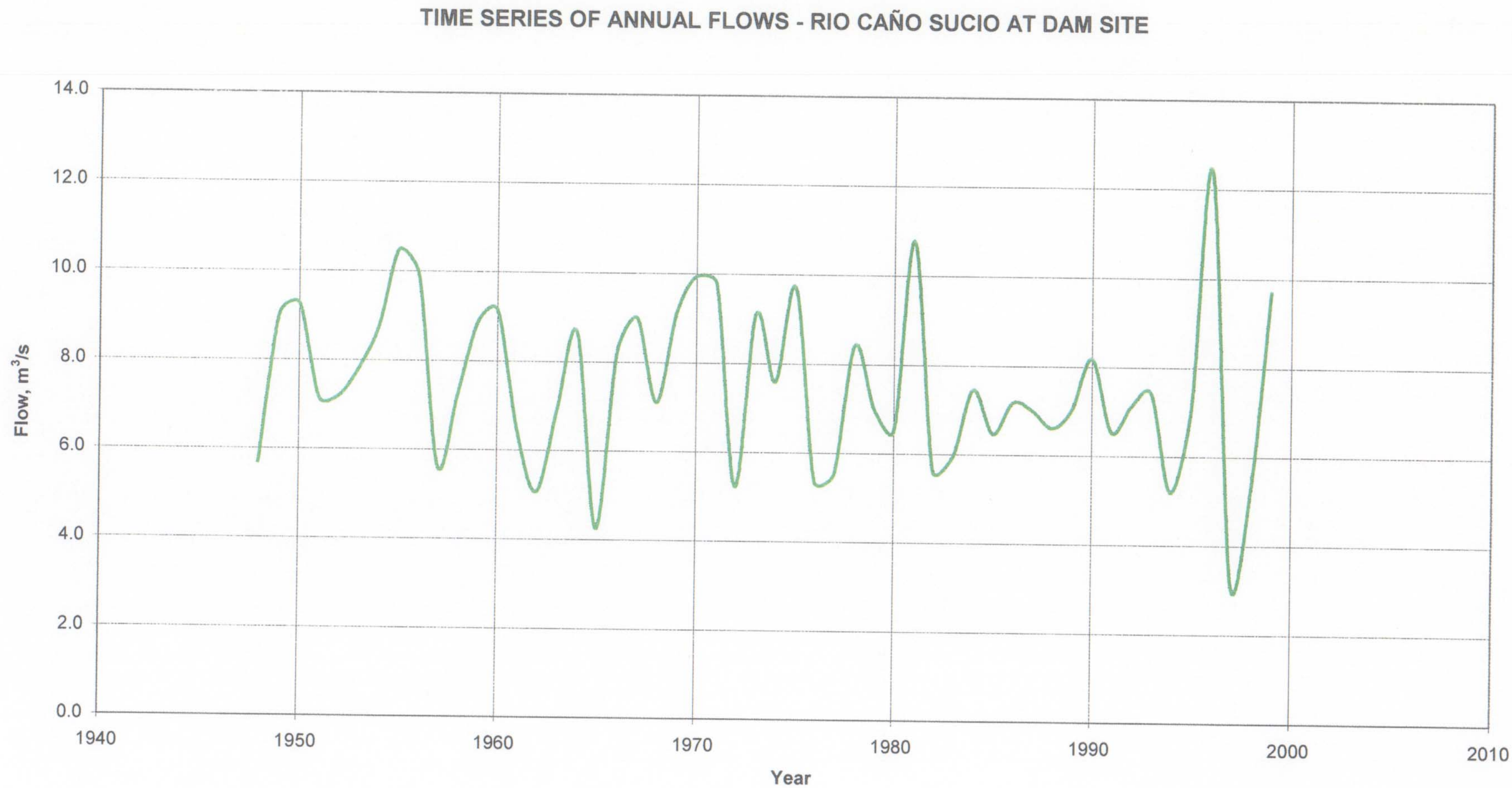
MASS CURVE
RÍO CAÑO SUCIO AT DAM SITE

MWH TAMS

DATE:	EXHIBIT:
DECEMBER, 2003	55



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

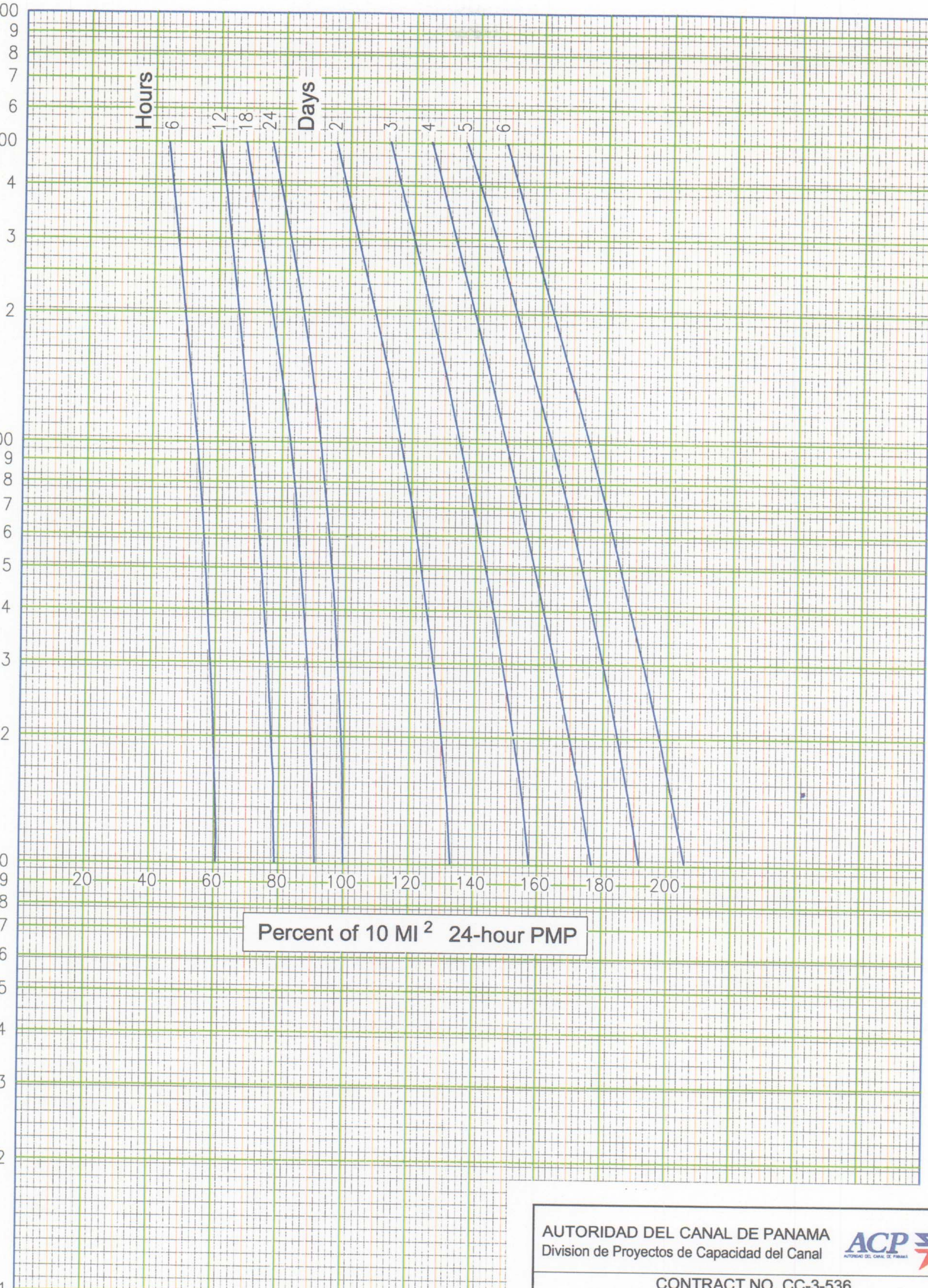
CONTRACT NO. CC-3-536
RÍOS COCLÉ DEL NORTE AND CAÑO SUCIO
WATER SUPPLY PROJECTS
APPENDIX A - HYDROLOGY AND METEOROLOGY

TIME SERIES OF ANNUAL FLOWS
RÍO CAÑO SUCIO AT DAM SITE

MWH TAMS

DATE: DECEMBER, 2003

EXHIBIT: 56



Source:

US Weather Bureau, 1965 Report

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

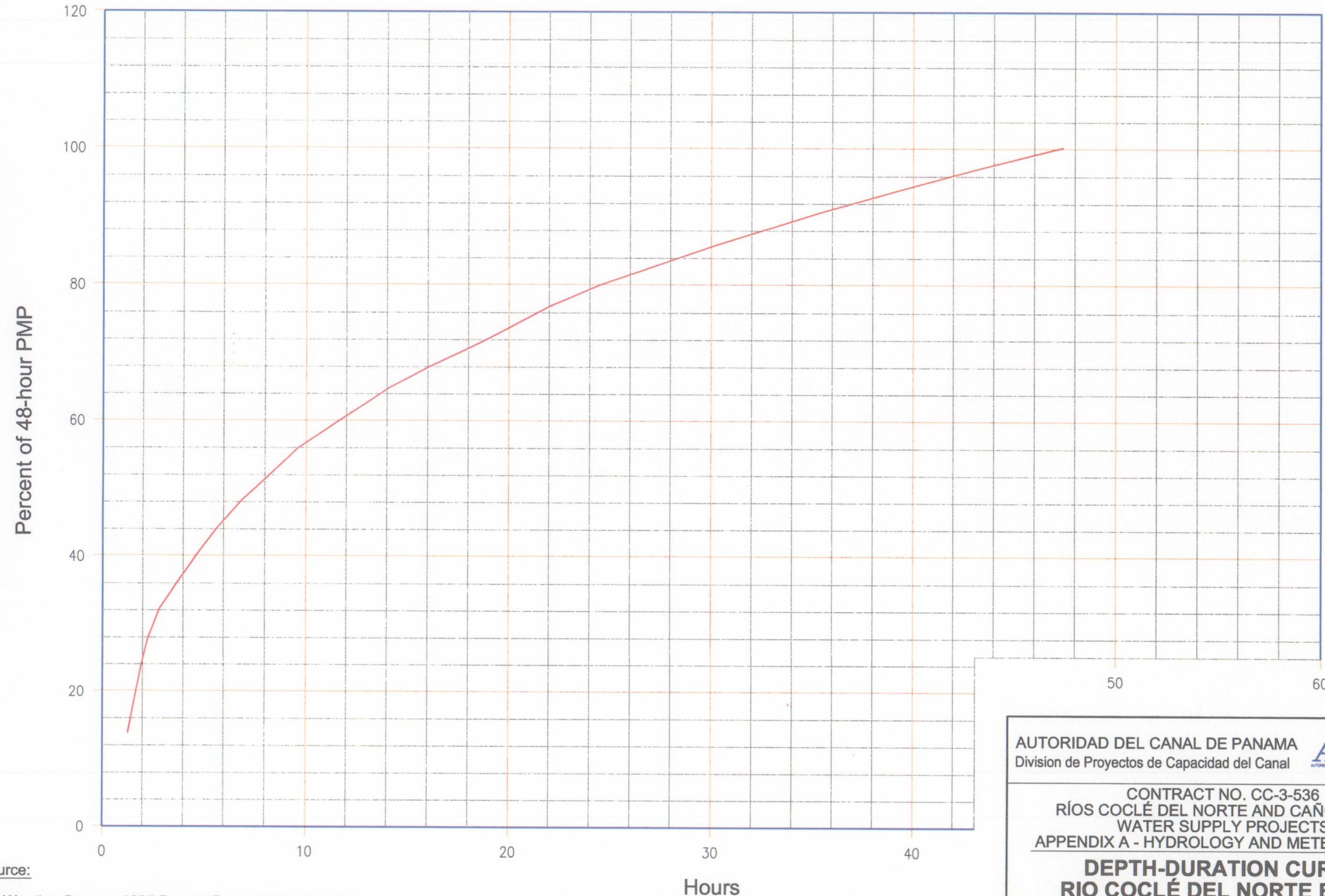
CONTRACT NO. CC-3-536
RÍOS COCLÉ DEL NORTE AND CAÑO SUCIO
WATER SUPPLY PROJECTS
APPENDIX A - HYDROLOGY AND METEOROLOGY

DEPTH-AREA-DURATION CURVES

MWH TAMS

DATE: DECEMBER, 2003

EXHIBIT: 57



Source:

US Weather Bureau, 1965 Report, Percentages for duration less than 6 hours from hourly data

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

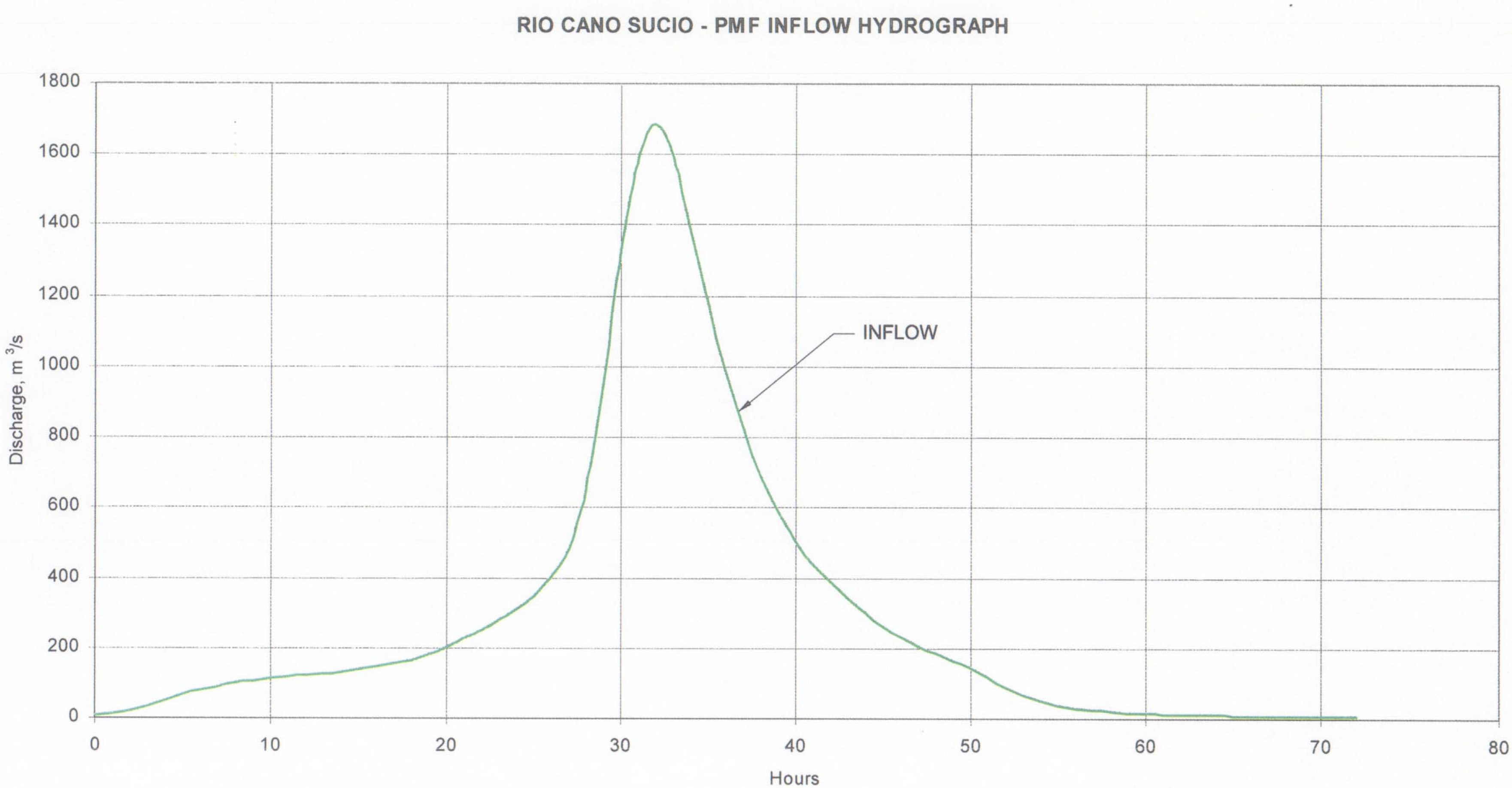
CONTRACT NO. CC-3-536
RÍOS COCLÉ DEL NORTE AND CAÑO SUCIO
WATER SUPPLY PROJECTS
APPENDIX A - HYDROLOGY AND METEOROLOGY

DEPTH-DURATION CURVE
RIO COCLÉ DEL NORTE BASIN

MWH TAMS

DATE: DECEMBER, 2003

EXHIBIT: 58



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

CONTRACT NO. CC-3-536
RÍOS COCLÉ DEL NORTE AND CAÑO SUCIO
WATER SUPPLY PROJECTS
APPENDIX A - HYDROLOGY AND METEOROLOGY

RÍO CAÑO SUCIO
PMF INFLOW HYDROGRAPH
MAXIMUM NORMAL POOL EL. 100 METERS

MWH TAMS

DATE: DECEMBER, 2003

EXHIBIT: 59

ATTACHMENTS

Attachment 1 – Review of Previous Hydrologic Reports and Analyses and List of Hydrologic Data Obtained from PCC

ATTACHMENT I

INVENTORY OF HYDROLOGIC DATA OBTAINED FROM THE ACP AND REVIEW OF PREVIOUS HYDROLOGIC REPORTS AND ANALYSES

Introduction

This report presents an inventory of hydrologic data and previous reports on hydrologic analysis obtained through the ACP. The previous reports were reviewed and the analyses presented in the reports are summarized.

Basic Data Inventory

Streamflows

Streamflow data, historic and extended using statistical techniques, was obtained from the ACP. The period of record included a few months of missing data for each station. Some of the months with asterisk marks were estimated from general monthly trend in the data or from staff gage readings. A list of stream gaging stations operated by *Instituto de Recursos Hidraulicos y Electrificacion* (IRHE) was also provided by the ACP. The list showed station numbers, river names, locations of gages, names of provinces, type of stations, drainage areas and elevations at the gages, latitudes and longitudes, and dates of installation and suspension. The data supplied by the ACP are summarized below.

- Summary of Discharge Measurements (from IRHE)
  Río Coclé del Norte at El Torno:
  272 measurements from April 1958 to June 1986
  Río Toabré at Batatilla:
  267 measurements from September 1968 to February 1995
  Río Coclé del Norte at Canoas:
  124 measurements from November 1983 to February 1995

- Measured Daily Flow Data (from IRHE)
  Río Toabré at Batatilla, July 1958 to April 1999
  Río Coclé del Norte at Canoas, October 1983 to July 1999
  Río Indio at Boca de Uracillo, August 1979 to May 1998

- Measured Monthly Flow Data (from IRHE)
  Río Toabré at Batatilla, July 1958 to April 1999
  Río Coclé del Norte at Canoas, October 1983 to July 1999
  Río Indio at Boca de Uracillo, August 1979 to May 1998
  Río Trinidad at El Chorro, January 1948 to December 1998

Río Coclé del Norte at El Torno, July 1958 to June 1986
Río Ciri Grande at Los Canones, January 1948 to May 1959, August 1978 to December 1998
Río Toabré at Batatilla, July 1958 to September 1964, June 1969 to April 1998

- Filled-in and Extended Monthly Flows (the ACP), January 1948 to December 1998
  Río Coclé del Norte at Dam site plus Río Caño Sucio
  Río Caño Sucio
  Río Coclé del Norte at Dam site
  Río Coclé del Norte at El Torno
  Río Toabré at Batatilla
  Río Coclé del Norte at Canoas
  Río Indio at Boca de Uracillo
  Río Ciri Grande at Los Canones
  Río Trinidad at El Chorro
  Río Indio at Dam Site

- Miscellaneous Data
  1. Exhibits showing double mass curves for Río Trinidad at Chorro versus Río Ciri Grande at Los Canones, Río Toabré at Batatilla versus Río Indio at Boca de Uracillo, Río Coclé del Norte at Canoas versus Río Coclé del Norte at El Torno, Río Indio at Boca de Uracillo versus Río Ciri Grande at Los Canones, and Coclé del Norte at El Torno versus Río Toabré at Batatilla.

  2. Exhibits showing correlation between Río Indio at Boca de Uracillo and Río Ciri Grande at Los Canones, Río Coclé del Norte at Canoas and Río Coclé del Norte at El Torno, and Río Coclé del Norte and Río Toabré at Batatilla.

  3. Río Indio at Limon: monthly maximum and minimum daily observed discharges, May 1958 to October 1980.

  4. Río Indio at Boca de Uracillo: monthly minimum observed discharges, August 1979 to April 1990, and monthly maximum instantaneous discharge July 1979 to April 1990.

  5. Map showing hydrologic units in Panama

  6. Maps showing locations of stream gaging and meteorological stations in the Río Indio and Río Coclé del Norte basins.

Rainfall

Historic rainfall data were obtained for the following stations from the ACP. A list of meteorological stations, showing station numbers, names, provinces, latitudes and longitudes, elevations, type of stations, and date of installation, was also provided by the ACP. The data with period of record are listed below. The indicated period includes a few months of missing data for some stations.

Monthly Rainfall

111001 Boca de Uracillo	September 1974 – September 1998
109001 Miguel de la Borda	February 1975 – October 1998
105010 Santa Ana	November 1980 – August 1998
105009 Coclecito	January 1980 – February 1998
105008 Sabanita Verde	January 1979 – August 1998
105007 San Lucas	February 1974 – April 1998
105005 Toabré	June 1970 – September 1998
105004 Tambo	February 1970 – October 1998
105003 Coclé del Norte	May 1969 – August 1998
105002 Chiguiri Arriba	July 1958 – October 1998
105001 Boca de Toabré	May 1958 – August 1998

Daily Rainfall

105001 Boca de Toabré	May 1958 – July 1999
105002 Chiguiri Arriba	July 1958 – July 1999
105003 Coclé del Norte	May 1969 – July 1999
105005 Toabré	June 1970 – January 1999
105007 San Lucas	January 1974 – July 1999
105008 Sabanita Verde	January 1979 – June 1999
105009 Coclecito	January 1980 – December 1998
105010 Santa Ana (Obre)	November 1980 – June 1999
109001 Miguel de la Borda	February 1975 – January 1999
111001 Boca de Uracillo	September 1974 – June 1999

Daily Rainfall for all station in Canal Zone for the following storms (from the ACP)

December 13, 1981
December 4 to 7, 1985
May 8 to 9, 1987
January 7 to 8, 1996
January 13 to 15, 1996
November 27 to 29, 1996

Hourly Rainfall Data for the above storms for all stations in the Canal Zone from the ACP.

Meteorological Data

These data included: wind speed – average, maximum and minimum; average wind direction; air temperatures – average, maximum and minimum; dew points – average, maximum and minimum; barometric pressure – average, maximum and minimum; and total solar radiation.

Station No	Station ID	Station Name
55	ALH	Alhajuela
50	ACL	Agua Clara
60	BHT	Balboa Heights
04	BCI	Barro Colorado
59	CNO	Cano
53	CHI	Chico
51	CDL	Candelaria
52	CNT	Ciento
48	CHR	Chorro
21	CAN	Canones
30	CAS	Cascadas
65	CSO	Coco Solo
06	DHT	Diablo Heights
14	ESC	Escandalosa
64	EMH	Empire
63	FAA	FAA (Balboa)
54	GAT	Gatun
46	GUA	Guacha
16	GAM	Gamboa
09	GTW	Gatun West
43	HUM	Humedad
41	HHI	Hodges Hill
70	LMB	Limon Bax
42	MLR	Monte Lirio
58	MIR	Miraflores
45	PEL	Peluca
61	PMG	Pedro Miguel
44	RAI	Raices
66	RPD	Río Piedras
47	SAL	Salamanca
49	SMG	San Miguel
08	SRO	Santa Rosa

Floods

Monthly maximum instantaneous flood peaks for the Río Indio at Boca de Uracillo, Río Toabré at Batatilla and Río Coclé del Norte at Canoas for the available period of record.

Sediment

Suspended sediment sampling results including: date of sampling, water discharge in cubic meters per second, sediment concentration in milligram per liter, suspended sediment load in tons per day and water temperature. The data was made available by IRHE for the following sites.

- Río Toabré at Batatilla, 56 samples taken during the period from March 1982 through August 1998.
- Río Coclé del Norte at Canoas, 46 samples taken during the period from November 1983 through August 1998.
- Suspended sediment loads on monthly basis were obtained from the ACP for three rivers (Río Chagres, Río Pequeni and Río Boqueron) entering Madden Lake and three rivers (Río Gatun, Río Trinidad and Río Ciri Grande) entering Gatun Lake. the ACP also provided two reports on sedimentation survey of Lake Madden.

Water Quality

The water quality parameters included: physical quality (conductivity, temperature, turbidity, dissolved solids, total solids), inorganic metals (Ca, Mg, total hardness as CaCo3, Fe, Mn, K, Na), inorganic non-metal (pH, alkalinity, OH, CO_3, HCO_3, NH_3, B, Cl, F, PO_4, NO_3, NO_2, SiO_2, SO_4) and organic matter. The data for the following stations were obtained.

105000102 Coclé del Norte at Canoas

One sample in each 1991, 1992 and 1993, and four samples in 1994.

115000802 Ciri Grande at Los Canones

Three samples in 1990, four in 1991, three in 1992, and three in 1993.

105000201 Toabré at Batatilla

One sample in 1990, one in 1991, two in 1992 one in 1993 and four in 1994.

Previous Reports

Atlas Nacional de la Republica de Panama by Instituto Geografico Nacional "Tommy Guardia," 1988.

The Atlas has a number of maps showing topographical, hydrological, meteorological, soil, land use, etc., features of Panama. The following information was obtained from the Atlas.

About 10 percent of the Río Indio Basin (mostly in the head reach) is covered with forest and the land is subjected to inundation. The remaining downstream area is covered with tropical forest with perennial foliage.

Mean monthly temperature varies within about 2° C through the year. Mean annual temperature varies from about 26° C at the dam site to about 24° C in the head reach. At lower elevations, the lowest temperatures occur in the months of September-October where as the months of March-April have highest temperatures. High temperatures occur during the month of June at relatively higher locations (above about 2,300 meters) in the basin. Generally, temperatures during cold months are less than about 18° C.

The Río Indio basin is humid, with a tropical climate. Mean annual precipitation is higher near the coastal area of the Río Indio (about 4,000 mm) and decreases inland (about 3,000 mm). A few months could be significantly dry. There is a slight increase in precipitation near the watershed divide.

"Development of Probable Maximum Flood (PMF) and Review of Flood Routing Procedures, Phase III and Phase IV Studies," by U.S. Army District, Mobile, Alabama, February 1979.

This report presents methodology and results of studies of the probable maximum floods for Madden and Gatun dams, PMF routings, flood control operation, canal surges, wave run-up, and wind setup.

The PMF for each dam is based on the probable maximum precipitation (PMP). The PMP, and its areal and temporal distributions were derived using the February 1978 study by F.K. Schwarz and J.T. Riedel entitled, "Probable Maximum Precipitation Estimates for Drainages above Gatun and Madden Dams."

The drainage area above Gatun Dam was divided into 12 sub-basins, mostly small streams directly entering Gatun Reservoir. A detailed study was made to derive unit hydrographs using Snyder's method. The following equations were developed:

$$t_p = 0.21\ (AL)^{0.38}$$

$$q_p = 450/t_p$$

where

L = length of main stream, mi
t_p = time to peak, hours
q_p = rate of runoff cubic feet per second per square mile (cfs/sq mi)
A = drainage area in square miles

For the two major tributaries, Río Ciri Grande and Río Trinidad, the unit hydrographs were taken from a 1968 study entitled, "Climatology and Hydrology of the Panama Canal Watershed, 1968, IOCS Memorandum Jax – 50 prepared by Jacksonville District, Corps of Engineers." The equations used were:

$$t_p = 0.21\ (LLc)^{0.50}$$

$$q_p = 2200\ (1/AL)^{0.38}$$

The parameters are as defined above except that Lc is the main stream length from the outlet of the basin to a point opposite to the centroid of the area.

The estimated times to peak for all sub-basins were reduced by 20 percent to obtain conservatively high unit hydrograph peaks. A uniform infiltration rate of 0.05 inches per hour was used for the duration of the PMP. Channel routing was performed using Muskingum method. The coefficient K was assumed equal to travel time through the reach and the coefficient X was set equal to 0.2. The report does not clearly show the estimated PMF peak inflows for Madden and Gatun reservoirs.

"Análisis Regional De Crecidas Maximas," by Instituto de Recursos Hidraulicos y Electrificacion, Departamento de Hidrometeorologia, Seccion de Hidrologia, June 1986.

This study presents basic data, methodology and results of a regional flood frequency analysis for the river basins in the Republic of Panama west of about 79° west longitude. The area was divided into seven zones based on the characteristics of maximum floods observed in the various river basins. The analysis included:

1. Selection of common period for sets of groups of stations: Missing peaks in each common period were estimated using either drainage area ratio raised to an exponent, exponential correlation or adjustment factor. The

parameters for each method were developed from the concurrent instantaneous flood peaks.

2. Estimation of mean annual flood: Mean annual flood was considered to be the mean of selected flood peak series (including estimated flood peaks, that is, for the selected common period of record). Computations were not made to derive mean annual flood with a return period of 2.3 years. However, it was mentioned in the report that the mean of the annual peaks was assumed equivalent to the flood of 2.3-year return period.

3. Development of relationship between mean annual floods and drainage areas: Exponential relationships were developed as given below.

$Q_{mean\ annual} = 34\ A^{0.58}$ equation 1, for zones I and II
$Q_{mean\ annual} = 27\ A^{0.58}$ equation 2, for zones III and IV
$Q_{mean\ annual} = 13\ A^{0.58}$ equation 3, for zones V and VI
$Q_{mean\ annual} = 10\ A^{0.58}$ equation 4, for zone VII

4. Development of dimensionless flood frequency curves: Dimensionless ratios "maximum instantaneous peak divided by mean annual flood" were computed for all stations. These ratios were plotted on a probability paper using the Weibull plotting position formula. The stations with similar flood characteristics, were grouped. The best fit through the plotted points was achieved by eye-ball fitting. A set of four curves was developed. The ratios corresponding to select return periods for each curve are given below.

Return Period	**A**	**B**	**C**	**D**
	Ratios (Qmax/Qmean annual)			
2	0.92	0.93	0.95	0.93
5	1.38	1.35	1.32	1.20
10	1.68	1.62	1.57	1.45
20	2.00	1.90	1.57	1.65
25	2.10	2.00	1.80	1.75
50	2.40	2.25	1.90	1.95
100	2.75	2.55	2.15	2.10
1,000	3.95	3.55	3.25	2.75
10,000	5.3	4.60	4.10	3.40

5. The following table was recommended for estimating flood frequency data.

Zone	Applicable Equation	Ratio (Qmax/Qmean annual)
I	1	A
II	1	C
III	2	A
IV	2	D
V	3	B
VI	3	A
VII	4	C

The drainage area of the Río Indio at Boca de Uracillo is about 365 km^2 and is located in zone III. The report showed the following flood frequency data for this station.

Return Period (years)	Flood Peak (m^3/s)
2	761
5	1,141
10	1,389
20	1,654
25	1,737
50	1,985
100	2,274
1,000	3,267
10,000	4,383

"Probable Maximum Precipitation over Eastern Panama and Northwest Colombia," prepared by Hydrometeorological Branch, Office of Hydrology, Weather Bureau, and September, 1965.

This study presented a good description of the meteorology of the major storms in the canal zone area. A 10-mi^2, 24-hour PMP map was prepared for the canal zone and northwest Colombia. The starting point for the estimation of the PMP was five storms: October 21-24, 1923; November 6-9, 1931; November 26-29, 1932; November 2-4, 1935; and December 2-4, 1937. A range of estimates was made which involved:

1. Moisture maximization of maximum 24-hour rainfall.

2. Adaptation of 1-hour rainfall amount.

3. Adjustment of the value from HMR 4 to 10-mi^2 PMP (U.S Weather Bureau, Possible Precipitation over the Panama Canal Basin, Hydrometeorological Report No. 4, 1943)

4. Adjustment of the canal zone stations 100-year values to the PMP by appropriate ratios from other "similar climatic region where comprehensive PMP studies have been made.

Conclusions drawn from these four approaches as to the magnitude of 24-hour PMP in the canal zone indicated that a value of 28 inches applies to the sea level Atlantic side. Extracts of the reasoning presented in the report are presented below.

"Moisture maximization of the largest storm rainfall in Panama is less meaningful in estimating the PMP because the variation in precipitation intensity from storm to storm depends mostly on the variation in the mechanism which lifts the moist air in cloud masses and less on the availability of the moisture. However, the factor was computed. Based on observed dew points and sea surface temperature (U.S. Navy Hydrographic Office, "World Atlas of Sea Surface Temperatures, H.O. No. 225, 1944), an estimated upper limit to the 12-hour dew point for Panama in November or December was 77° F. The maximum 12-hour persisting dew point on the Gulf of Mexico Coast of the United States ranges about 3° F to 4° F below sea temperatures within a few hundred miles." "Based on the seasonal variation of sea surface temperature and a dew point 3° F below the sea surface temperature, the seasonal variation of the maximum 12-hour persisting dew point was estimated as:

November – February	77° F
March	77.5° F
April – August	78° F
September – October	79° F

The 12-hour dew point for the December 14-15, 1944 storm was estimated to be 72° F based on prevailing dew points on the Northern Hemisphere surface maps (U.S. Weather Bureau, "Daily Series Synoptic Weather Maps"). The December 1944 observed 24-hour rainfall could occur as early as October. Hence, the sea level value of 13.5 inches was adjusted a the dew point of 79° F, resulting in a value of 19.0 inches (factor 19/13.5 = 1.407)."

"Maximum 1-hour observed rainfall of 7.54 inches was adopted to be that of October 7, 1957 at Moran on the Pacific side of Panama during a local storm typical of the summer season in its aerial extent. An upward adjustment of this observed value for moisture and for small sampling area suggested an adopted 1-hour all season PMP of 11.5 inches or a 3-hour value of 15.0 inches, based on the depth-duration relationship typical for the Northwest United States."

"Giving some reasons on the observation and experience basis, the observed 7.54 inches value on the Pacific side, was adopted as 1-hour point PMP on the Atlantic side (near Cristobal). This value was extrapolated to 24-hour 10-mi^2 PMP using the following ratios:

	Ratio 1-hour to 24-hour
Hawaiian	0.25
TP 40 for Gulf Coast	0.33
100-year rainfall (4.4/13.7)	0.32
Design Storm Panama	0.24

(Brod, Howard, W., "Hydrology of the Panama Canal," Part I, Flood Control, Department of Operation and Maintenance, Balboa Heights, Canal Zone, 1941)

The above ratios resulted in a range of 23 to 31 inches for the 24-hour 10-mi^2 PMP. Adjustment to HMR 4 values resulted in a range of 25.3 to 32.1 inches. For adjustment of 100-year rainfall to PMP, ratios were derived for Hawaii and Gulf Coast. The ratio was estimated to range from 1.7 to 2.3. This range multiplied with the 100-year value of 13.2 at Cristobal, resulted into a PMP range of 22.4 to 30.4 inches."

"Based on the above analyses, a value of 28 inches was adopted for the 24-hour 10-mi^2 PMP on the Atlantic side of the canal zone. For extension of this point rainfall to other area, four factors were considered.

1. Latitude trends
2. Atlantic to Pacific trends
3. Terrain relationships
4. Comparison with equatorial rain data."

"100-year daily rainfall values were assumed to represent latitudinal trend. Representative sea level values in the Canal Zone were 11.7 inches at Cristobal, 7.9 inches at Balboa Heights and 9.6 inches at La Palma. However, these values were affected by unequal period of record."

"There are variations from Atlantic to Pacific. In the Canal Zone, rains were extreme for one day and longer duration on the Atlantic side than on the Pacific side. This was based on the observed maximum and 100-year values."

"Experience of extreme events at coastal relative to foothill or mountain ridge locations suggests that the manner in which the 24-hour PMP index map should vary with terrain. There are apparent topographic effects in the highest observed and 100-year rainfall values. The data suggested that 100-year values are highest on slopes near to the coasts and on windward foothill areas but decrease on higher slopes and on the lee slopes in response to decreasing moisture. Compared to mean annual values, the 100-year values of daily rainfall show less aerial variation in areas where data are available, because of greater effect of rain frequency on the mean annual values than on 100-year values."

"The 100-year data suggest a triggering effect along coast lines and in foothills areas which readily stimulates instability release with less lifting required than in middle altitudes. Thus, light on shore winds and diurnal heating (or both) can trigger extreme convective moisture release when the temperature lapse rate and moisture conditions are right. Early release thus robs unstable air of rain that otherwise would fall further inland or on higher slopes. Combined with this, the effect of distance from the coast is that of decrease of moisture with elevation. With little orographic lifting involved, the net effect is considered to be a decrease in rain potential above low elevations in general long-duration storms. Trends in lee areas evident from the mean annual maps are considered valid in a limited sense to PMP."

After all the above discussion, the report does not say how the 24-hour 10-mi² isohyetal map was developed. Probably, it was sketched as the best judgment.

"About 10 storms from 1923 to 1959 were initially selected to develop depth-duration-area relationships. Separate isohyetal maps were plotted for the day of heaviest rain in five of the ten selected storms. Areal average rainfall for each storm was expressed in percent of 10-mi² values. Values with least decrease with increasing area were adopted as:

Area (mi^2)	**Percent of 10-mi^2 Rain**
10	100
50	95.2
100	91.5
150	88.5
200	86.0
250	84.0
300	82.0
350	80.0
400	78.5
450	77.0
500	75.2"

"Station rainfalls for locations in Panama and Colombia were analyzed to define the durational variation of 10-mi² PMP for 1 to 6 days. Highest ratios (ratio to one-day rainfall) adopted were 100, 133, 157, 175, 190 and 204 percent for 1, 2, 3, 4, 5, and 6 days, respectively."

"Using the depth-area and depth-duration data, smooth depth-area duration curves were drawn. These curves were evaluated and judged to be applicable for the Canal Zone area."

"Estimates of local storm PMP were made for the areas up to 100 mi². The values are given in the table below:

Hours	Point PMP (inches)	Hour	Point PMP (inches)
.25	6.5	3.0	15.0
.50	9.0	3.5	15.4
11.5	4.0	15.8	
12.9	5.0	16.2	
13.8	6.0	16.5	
2.5	14.5		

"Probable Maximum Precipitation Estimates for Drainages above Gatun and Madden Dams, Panama Canal Zone," by F.K. Schwarz and J.T. Riedel, Hydrometeorological Branch, Office of Hydrology, National Weather Service, February 1978.

This study was an extension of the 1965 study by Weather Bureau. The report presented additional storm data since 1965. The following analyses were made and presented:

1. From the tracks of major hurricanes, it was concluded that hurricanes do not affect canal-zone watershed. The track of hurricane Martha that affected Panama was also given.

2. Mean October to December isohyetal map was developed using data for the period of 1941 to 1970. The map was based on the rainfall data at the stations and extrapolated data for higher elevations using a relationship between the mean October to December rainfalls and station elevations.

3. Three-day rainfall isohyetal maps were drawn for the selected storms of November 17-19, 1909; October 22-24, 1923; November 7-9, 1931; November 27-29, 1932; November 5-7, 1939; November 12-14, 1941; December 18-20, 1943; December 12-14, 1944; November 3-5, 1966 and April 7-9, 1970.

4. The procedure for developing the isohyetal maps included the following steps:

   i. Plot three-day rainfall at each station
   ii. Express station rainfall as percent of October-December rainfall
   iii. Draw smooth lines to cover Gatun catchment
   iv. Put back the percentage map on the October-December map
   v. Multiply the percentage with October-December rainfall and draw smooth isohyetal

5. Depth-area relationship was developed for each storm as percent of 3-day, 10-mi^2 rainfall

6. Depth area curves were not enveloped. 75 percentile values were determined at 1,285 mi^2 (area draining into Gatun Lake) and 393 mi^2 (area draining into Madden Lake). The area reduction factor for Gatun Lake was about 0.65.

7. One-day 10-mi^2 PMP map developed in 1965 was extended over the catchment for Gatun Lake. The difference was a 2-inch increase in the PMP in the extreme southwest portion of the drainage area.

8. For the Gatun drainage area, the one-day, 10-mi^2 was about 26.1 inches from the PMP isohyetal map. The ratio of 3-day to one-day rainfall was 1.56. This resulted into 3-day, 10-mi^2 rainfall of 40.7 inches.

9. The depth duration data (inches) for Madden and Gatun was reported as:

Hrs	Madden	Gatun
6	12.6	10.0
12	17.0	13.8
18	19.8	16.4
24	22.0	18.6
36	25.0	21.1
48	27.6	23.0
60	29.8	24.9
72	31.8	26.4
84	33.8	27.9
96	35.6	29.4
108	37.3	30.7
120	39.0	32.0
132	40.5	33.2
144	42.0	34.3

10. With sixth increment being the lowest and first as the highest, the time distribution of six-hour increments was suggested as 6, 4, 2, 1, 3, and 5.

"Sedimentation in Madden Reservoir," Meteorological and Hydrographic Branch, Engineering Division, Engineering and Construction Bureau, Panama Canal Commission, Balboa, Panama, June 1985, Revised January 1987.

The drainage area contributing to the Madden Lake is about 376.6 mi^2. Of this, the most important and basically unaltered is the Chagres forest reserve with about 301.3-mi^2 area. The first detailed survey of the lake was made in 1983 at lake elevation of 235 feet. As of December 1983, the volume of accumulated sediment in Madden Lake since impoundment was estimated to be 30,700 acre-feet (49,469,319 cubic yards). This is about 4.7 percent of the total storage capacity of about 648,000 acre-feet. Active storage of about 470,000 acre-feet is between elevation 200 and 252 feet. The inactive storage below elevation 200 feet is about 178,000 acre-feet.

Using the total drainage of 376.6 mi^2 as erosion-susceptible, the sediment deposition rate would be about 113.11 cubic feet/acre/year during the 49 years of operation. With trap efficiency of 93 percent (Brune's diagram), the average sediment yield would be about 121.03 cubic feet/acre/year. However, the major erosion in the watershed started in about 1958 when farmers and cattlemen became more active in the watershed. Using a weighted calculation, a more accurate yield was considered to be about 177.56 cubic feet/acre/year.

A comparison was made of the suspended sediment measured on the three rivers and the measured deposit in the lake. This did not consider the sediment contributed by about 15 small tributaries directly entering the lake. A bed load of about 15 percent was added to the measured suspended loads. To obtain a volumetric estimate, a specific weight of 65 pounds/cubic feet was used. The three-year sediment inflow was about 454 acre-feet/year compared to 49-year deposit of 628 acre-feet/year.

"Madden Reservoir Sedimentation, 1984-1986," by Jack R. Tutzauer, Meteorological and Hydrographic Branch, Engineering Division, Engineering and Construction Bureau, Panama Canal Commission, Balboa, Panama, March 1990.

In this report, the sediment volumes measured by the hydrographic survey of 1983 were adjusted for sediment volumes contained between 235 feet and 252 feet, which were not measured by the survey.

The 1981-86 suspended sediment data measured at the three tributaries were used to establish a correlation between rainfall and suspended sediment. The relationship is:

$Ss = 296.66\ Rm^2 - 50516.23\ Rm + 22383608$
Se = estimated total annual suspended sediment in tons transported by three rivers
Rm = annual Madden watershed rainfall in inches

Based on the above relationship and 51 annual Madden watershed rainfall values from 1933 to 1983, the estimated total amount of suspended sediment transported by three rivers was 736 million cubic feet (mcf). Increasing this by 15 percent for bed load, the yield was 866 mcf. Using a trap efficiency of 99 percent, the deposition in the lake Madden based on inflow was about 857 mcf.

The drainage area of the three rivers at the gaging stations is about 247 mi^2. The total area contributing to the lake is about 393 mi^2 minus an area of about 11 mi^2 covered by the lake. This gave an adjusted deposit of 1,328 mcf (1.55*857). The factor of 1.55 was computed as (857)*((393-11)/247). This volume was about 15 percent less than the 1,572 mcf estimate based on the 1983 hydrographic survey.

The amount of sediment in Madden Lake at the end of 1983, below elevation 235 was about 1,353 mcf. The maximum usable elevation is about 252 feet. The lake area between 235 and 252 feet is about 3 mi. Adjusting for this area, the total sediment deposit was 1,572 (1353+219) mcf.

Based on the adjusted hydrographic survey of Madden Lake, a correlation was developed between Madden watershed rainfall and sediment deposited in the lake.

$$Sd = (296.66\ Rm^2 - 50516.23\ Rm + 22383608)\ 65.723 * 10^6$$

Sd = estimated total annual sediment in mcf deposited in the lake,
Rm = annual Madden watershed rainfall in inches

To develop the relationship, the annual sediment deposit rates were computed as 3-river suspended sediment volume multiplied by a factor of 2.136. The factor was estimated to compensate for unmeasured area, bed load, trap efficiency, land use, etc.

Reconnaissance Report, Section 5 – Río Indio

This section provides the development plan for the Río Indio. The plan would include a dam and lake on the Río Indio connected by a tunnel to the Panama Canal watershed above Gatun Lake. There would be two power plants, one of 5 MW at the end of the diversion tunnel and the second of 25 MW on the Río Indio downstream from the dam.

The section includes brief discussion on hydrology, geology, lake operation, project features, construction material and development sequences. Hydrologic reliability and project cost-benefit are also discussed.

Hydrologic reliability was derived by simulating the lake operation using HEC-5 computer model. Two operating options for transfer of water from the Río Indio Lake to Panama Canal were considered. Under first option, the lake would fluctuate from normal operating level of 80 meters to a minimum of 70 meters, with 359 MCM of usable storage. For the second option, the lake would fluctuate between 50 and 80 meters with a usable storage of 993 MCM. The maximum flood level would be about 82.5 meters.

An uncontrolled spillway with a crest elevation at 80 meters is provided. The maximum surcharge level is 82.5 meters. The spillway is designed for a maximum discharge of about 920 m^3/s, estimated to be a flood of 1,000-year return period.

Attachment 2 – Monthly Rainfall Data

MONTHLY RAINFALL DATA
BOCA DE TOABRE
(mm)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1966	293	66	147	286	383	465	435	253	236	403	950	723	4635
1967	326	136	163	454	722	425	315	510	221	450	363	513	4594
1968	147	206	483	147	383	381	408	396	329	259	348	434	3919
1969	185	191	98	265	268	176	237	457	365	296	424	609	3567
1970	491	245	166	668	970	407	400	496	297	371	914	817	6239
1971	433	270	430	115	595	530	360	499	260	316	299	236	4341
1972	680	264	197	600	419	294	503	231	480	364	359	367	4756
1973	273	131	61	185	538	257	299	366	234	382	920	504	4148
1974	431	242	212	215	417	296	414	451	343	515	639	321	4493
1975	338	109	109	73	777	260	362	419	387	468	622	598	4518
1976	285	227	55	284	206	269	280	454	328	320	345	211	3260
1977	113	117	130	317	245	233	437	651	322	447	340	251	3600
1978	190	123	264	650	568	323	280	295	364	249	532	231	4067
1979	77	202	102	518	429	495	382	431	327	417	433	548	4360
1980	369	245	78	303	274	366	429	365	307	354	450	628	4166
1981	379	372	174	889	526	338	526	484	211	394	862	955	6108
1982	355	213	158	303	252	238	536	526	362	325	368	257	3891
1983	221	59	89	236	720	254	330	444	395	219	485	574	4026
1984	393	649	128	90	526	428	292	403	315	345	373	303	4244
1985	350	118	193	109	319	383	357	281	180	412	348	476	3525
1986	517	150	274	707	485	397	451	636	389	467	713	237	5420
1987	184	130	73	868	295	241	364	345	298	361	528	485	4171
1988	193	233	105	150	602	345	282	452	409	348	453	428	3998
1989	246	225	217	171	516	344	473	606	327	395	588	361	4467
1990	403	137	250	357	506	242	306	553	397	636	486	567	4840
1991	189	206	316	242	550	433	434	360	701	400	584	661	5075
1992	154	215	66	633	657	283	439	574	400	417	375	305	4517
1993	314	129	200	411	281	271	327	267	462	353	816	710	4540
1994	200	168	201	382	526	475	383	451	244	396	511	373	4308
1995	213	102	186	297	304	353	371	308	264	309	422	872	4001
Mean	298	196	177	364	475	340	380	432	338	379	528	485	4393
Maximum	680	649	483	889	970	530	536	651	701	636	950	955	6239
Minium	77	59	55	73	206	176	237	231	180	219	299	211	3260

MONTHLY RAINFALL DATA
CHIGUIRI ARRIBA
(mm)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1966	123	34	32	196	489	507	614	412	519	430	545	516	4414
1967	96	48	25	193	298	623	417	430	536	554	475	308	4001
1968	13	105	102	85	350	489	454	255	399	540	418	241	3448
1969	85	41	23	84	310	370	351	364	503	290	506	196	3120
1970	215	85	137	198	551	271	619	353	493	475	343	577	4315
1971	145	160	264	72	492	520	600	668	412	485	453	94	4363
1972	193	49	34	348	287	377	290	261	370	370	185	87	2847
1973	30	38	14	79	390	635	380	469	400	526	689	176	3824
1974	116	32	30	48	264	285	342	334	432	613	365	54	2912
1975	40	20	22	25	336	436	290	591	343	491	807	384	3782
1976	82	35	12	81	318	247	172	382	348	426	189	66	2355
1977	28	29	19	78	408	394	356	409	344	504	211	102	2878
1978	68	61	215	203	486	349	317	422	293	458	624	68	3562
1979	16	32	15	289	311	303	324	442	390	338	263	405	3125
1980	119	51	12	52	415	362	373	482	315	517	319	171	3186
1981	131	99	82	303	557	328	462	510	459	407	536	462	4335
1982	113	18	25	270	372	363	321	361	207	426	306	69	2848
1983	41	10	15	148	744	566	278	509	670	402	242	350	3975
1984	78	229	32	2	302	382	405	424	497	487	238	66	3142
1985	69	22	18	14	142	487	194	412	353	488	353	203	2754
1986	30	4	15	158	124	525	345	386	318	427	393	59	2784
1987	56	48	6	159	168	237	215	241	556	479	145	96	2407
1988	31	64	13	113	409	421	434	396	430	485	354	226	3376
1989	72	57	40	24	424	328	428	574	314	374	447	176	3259
1990	120	93	55	37	398	261	354	395	468	467	308	241	3196
1991	31	35	125	58	382	311	326	464	412	442	208	144	2938
1992	35	33	11	191	379	423	293	324	482	349	306	153	2978
1993	125	31	126	101	164	517	350	359	413	435	716	244	3580
1994	32	23	26	182	636	520	612	433	605	685	378	172	4304
1995	60	15	87	218	750	700	488	724	368	606	693	414	5122
Mean	80	53	54	133	388	418	380	426	421	466	400	217	3438
Maximum	215	229	264	348	750	700	619	724	670	685	807	577	5122
Minimum	13	4	6	2	124	237	172	241	207	290	145	54	2355

MONTHLY RAINFALL DATA
COCLE DEL NORTE
(mm)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1966	214	22	36	298	576	615	696	563	201	427	740	459	4847
1967	322	205	46	839	284	435	519	693	483	443	1238	1116	6623
1968	126	56	98	160	215	384	1319	701	400	560	530	217	4766
1969	621	249	19	114	37	721	746	549	330	637	675	669	5367
1970	340	426	935	895	1098	642	791	536	463	511	1288	911	8836
1971	472	253	467	134	558	745	632	518	175	252	299	241	4746
1972	496	133	100	286	357	351	453	398	718	462	520	396	4670
1973	814	139	38	104	754	468	668	303	217	362	1065	777	5709
1974	423	131	144	171	583	674	937	404	100	370	563	273	4771
1975	320	146	190	78	762	620	656	353	109	410	440	811	4894
1976	283	160	39	226	512	325	535	421	578	485	598	456	4617
1977	86	114	65	232	328	450	804	501	193	563	558	318	4211
1978	114	103	393	808	576	304	567	372	276	182	603	213	4510
1979	90	204	77	252	198	267	420	400	217	274	290	475	3164
1980	200	226	60	104	223	391	390	287	305	380	556	625	3745
1981	226	234	135	775	372	395	519	322	173	473	973	880	5476
1982	526	171	191	298	334	465	836	615	286	486	488	260	4955
1983	176	49	50	245	563	646	744	464	736	616	506	1004	5799
1984	361	624	72	113	609	576	371	476	323	495	654	262	4935
1985	173	95	95	18	561	551	660	520	434	465	772	396	4741
1986	390	245	130	518	308	554	511	458	408	625	1101	227	5473
1987	127	20	52	422	438	331	771	517	370	820	517	336	4721
1988	91	88	59	162	427	248	306	324	244	413	560	544	3465
1989	150	142	291	214	589	558	518	503	219	596	519	256	4553
1990	307	28	66	146	552	380	567	528	393	504	535	491	4496
1991	157	90	68	226	731	460	672	340	528	484	717	402	4875
1992	184	239	60	335	646	284	862	499	436	602	539	316	5001
1993	153	44	259	391	331	549	638	434	425	398	1313	887	5822
1994	167	95	290	433	567	709	897	796	413	240	799	538	5944
1995	312	91	218	434	492	507	647	302	305	211	638	891	5049
Mean	281	161	158	314	486	487	655	470	349	458	686	522	5026
Maximum	814	624	935	895	1098	745	1319	796	736	820	1313	1116	8836
Minimum	86	20	19	18	37	248	306	287	100	182	290	213	3164

MONTHLY RAINFALL DATA
TAMBO
(mm)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1966	70	6	30	62	311	152	211	213	174	212	126	48	1615
1967	62	8	24	49	69	117	195	321	265	311	296	130	1847
1968	19	22	31	27	186	214	228	174	193	436	171	13	1714
1969	40	7	1	96	84	157	279	108	184	150	18	48	1172
1970	69	197	258	380	765	478	230	141	244	545	261	224	3792
1971	90	26	34	13	65	218	224	228	299	192	217	79	1682
1972	58	25	32	98	81	78	141	201	227	164	77	45	1227
1973	8	11	2	29	191	272	329	261	351	403	292	85	2233
1974	15	32	21	31	125	211	254	222	299	359	164	22	1755
1975	8	5	1	3	221	160	244	373	382	445	513	267	2621
1976	24	9	0	66	95	145	152	230	261	266	24	29	1302
1977	3	6	0	8	185	209	168	354	181	161	160	49	1484
1978	27	10	1	122	313	238	292	265	396	303	300	124	2392
1979	22	15	6	142	211	261	186	333	280	287	190	84	2017
1980	42	18	4	17	323	279	116	229	169	384	358	124	2063
1981	78	34	51	125	252	116	224	287	169	222	254	189	1999
1982	69	4	13	100	252	208	361	207	204	376	40	19	1850
1983	11	1	15	66	299	172	145	102	248	283	124	151	1616
1984	24	66	30	33	242	356	387	454	201	322	210	51	2376
1985	64	12	24	4	161	445	194	365	252	249	326	118	2213
1986	49	5	16	128	86	316	279	191	234	332	309	24	1969
1987	16	14	2	62	104	173	212	184	285	386	146	46	1628
1988	5	18	0	71	322	280	255	350	449	406	304	110	2571
1989	43	32	23	11	266	272	238	172	117	166	263	138	1740
1990	53	0	41	18	159	98	212	353	366	317	158	160	1935
1991	7	20	87	0	206	173	199	148	363	214	95	138	1649
1992	5	16	1	53	229	334	233	130	208	350	84	35	1677
1993	82	4	64	38	117	255	81	169	232	232	321	101	1695
1994	0	0	72	365	357	160	231	227	235	396	117	24	2182
1995	16	6	10	86	269	180	180	343	426	205	157	151	2028
Mean	36	21	30	77	218	224	223	244	263	302	202	94	1935
Maximum	90	197	258	380	765	478	387	454	449	545	513	267	3792
Minimum	0	0	0	0	65	78	81	102	117	150	18	13	1172

MONTHLY RAINFALL DATA
TOABRE
(mm)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1966	123	17	52	96	265	167	183	154	142	261	163	61	1684
1967	52	12	2	45	106	169	387	376	206	375	221	293	2244
1968	42	23	22	36	222	169	144	154	176	236	265	11	1500
1969	37	9	9	49	155	162	178	66	183	157	13	85	1103
1970	88	61	144	176	689	215	224	179	395	439	213	289	3112
1971	166	11	56	14	188	245	187	252	325	290	288	36	2060
1972	105	27	63	176	113	76	133	195	203	135	107	74	1408
1973	6	33	1	46	181	266	370	299	399	501	338	100	2540
1974	22	28	14	36	100	269	231	190	356	266	170	30	1711
1975	10	6	7	10	203	186	178	413	246	454	551	164	2426
1976	42	15	12	73	86	94	139	222	266	246	46	34	1273
1977	17	13	3	11	331	219	174	371	146	256	194	106	1839
1978	30	15	100	171	243	190	181	247	296	408	339	72	2292
1979	10	17	4	247	303	253	361	338	186	257	137	168	2281
1980	59	29	3	24	264	306	158	302	214	416	307	119	2201
1981	76	26	44	173	391	213	271	419	252	335	310	234	2744
1982	78	6	14	125	307	164	215	173	148	330	38	10	1607
1983	19	0	8	41	146	132	153	91	267	267	140	174	1439
1984	22	48	42	34	210	315	436	398	316	304	300	82	2506
1985	70	10	18	12	170	376	145	373	282	250	233	81	2021
1986	52	6	28	103	130	335	210	210	291	381	305	12	2062
1987	19	11	2	91	54	129	260	124	224	364	110	47	1435
1988	11	20	4	52	285	235	294	438	368	384	303	96	2490
1989	28	29	9	8	259	243	226	156	143	160	309	150	1719
1990	32	11	44	17	213	133	179	228	361	276	197	149	1840
1991	7	12	81	2	216	165	173	134	338	140	73	64	1407
1992	10	3	0	72	153	346	126	218	187	230	92	61	1497
1993	133	14	65	31	160	263	63	155	295	289	240	90	1799
1994	11	10	37	63	358	185	116	134	141	251	111	15	1431
1995	7	5	6	76	186	161	136	126	347	153	133	128	1465
Mean	46	18	30	70	223	213	208	238	257	294	208	101	1904
Maximum	166	61	144	247	689	376	436	438	399	501	551	293	3112
Minimum	6	0	0	2	54	76	63	66	141	135	13	10	1103

MONTHLY RAINFALL DATA
SAN LUCAS
(mm)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1966	485	38	130	138	353	460	272	331	273	495	607	508	4090
1967	307	154	48	240	268	384	533	544	189	361	850	629	4507
1968	252	244	184	139	274	286	463	368	372	396	448	132	3558
1969	566	173	101	147	197	259	215	226	196	488	525	944	4037
1970	233	199	231	389	451	316	289	276	363	621	796	851	5015
1971	302	205	200	315	458	386	414	495	190	329	344	297	3935
1972	1235	297	142	341	255	202	240	297	313	379	457	305	4463
1973	651	93	97	132	408	457	380	398	484	412	779	1077	5368
1974	188	59	239	250	439	425	549	576	265	401	845	408	4644
1975	510	172	139	65	854	466	450	448	208	453	590	758	5111
1976	311	217	45	376	398	255	429	564	347	354	476	413	4184
1977	122	161	96	387	295	467	610	615	392	585	501	274	4504
1978	139	179	286	756	610	372	350	367	387	235	632	299	4610
1979	143	206	199	380	397	505	346	556	192	439	517	724	4605
1980	394	264	78	213	292	487	449	396	211	365	529	853	4532
1981	340	383	201	1117	415	327	537	427	131	516	841	824	6058
1982	437	211	237	262	356	322	717	406	321	323	349	347	4288
1983	209	72	119	104	599	220	427	477	433	263	382	774	4079
1984	400	678	135	126	549	490	291	429	335	395	402	270	4500
1985	283	106	196	84	466	449	273	272	309	323	352	324	3434
1986	152	87	129	308	385	438	220	320	295	426	687	103	3550
1987	145	57	44	81	285	230	254	246	415	441	334	297	2829
1988	88	108	45	97	430	302	328	286	318	482	567	250	3301
1989	165	138	134	94	366	294	308	372	258	293	373	291	3084
1990	175	83	153	182	347	209	294	314	208	526	353	286	3129
1991	110	93	75	154	294	253	237	282	406	310	352	581	3146
1992	107	182	69	263	325	244	261	300	331	233	335	227	2876
1993	305	78	134	225	263	330	274	275	499	349	440	274	3446
1994	139	93	229	292	367	419	256	274	286	263	429	171	3218
1995	143	109	163	256	240	244	246	290	331	319	411	336	3088
Mean	301	171	143	264	388	350	364	381	309	393	517	461	4040
Maximum	1235	678	286	1117	854	505	717	615	499	621	850	1077	6058
Minimum	88	38	44	65	197	202	215	226	131	233	334	103	2829

MONTHLY RAINFALL DATA
SABANITA VERDE
(mm)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1966	496	70	192	211	311	325	241	282	247	473	447	298	3593
1967	187	103	37	407	303	336	352	466	214	285	482	698	3870
1968	125	181	181	95	248	160	252	265	272	339	439	88	2645
1969	289	101	61	146	261	262	255	207	176	344	351	612	3065
1970	169	164	225	322	345	432	294	234	320	520	509	776	4310
1971	316	140	155	214	421	325	332	465	273	356	324	254	3575
1972	873	187	75	332	263	177	241	248	330	312	325	171	3534
1973	455	103	43	116	354	291	307	311	348	366	417	671	3782
1974	110	34	176	407	416	344	319	302	236	320	520	166	3350
1975	185	115	95	38	550	393	269	409	231	336	416	441	3478
1976	394	305	35	194	306	244	264	371	342	287	461	506	3709
1977	121	198	112	190	279	369	287	452	303	595	443	287	3636
1978	97	110	172	358	465	383	411	358	379	235	370	219	3557
1979	44	127	111	303	337	558	263	442	174	377	330	448	3512
1980	211	120	12	144	397	447	342	293	294	429	351	548	3586
1981	336	183	148	650	364	296	387	452	152	361	458	620	4406
1982	262	97	87	245	359	245	504	329	278	392	289	176	3264
1983	209	36	22	184	597	240	275	320	319	211	394	398	3204
1984	229	339	101	49	370	268	228	471	274	291	402	171	3192
1985	219	70	135	52	222	413	293	160	271	479	374	220	2909
1986	248	48	144	452	335	318	251	421	267	361	489	145	3479
1987	105	198	65	399	244	194	250	292	260	175	371	288	2841
1988	88	108	45	97	430	302	328	286	318	482	567	250	3301
1989	165	138	134	94	366	294	308	372	258	293	373	291	3084
1990	175	83	153	182	347	209	294	314	208	526	353	286	3129
1991	110	93	75	154	294	253	237	282	406	310	352	581	3146
1992	107	182	69	263	325	244	261	300	331	233	335	227	2876
1993	305	78	134	225	263	330	274	275	499	349	440	274	3446
1994	139	93	229	292	367	419	256	274	286	320	478	171	3324
1995	143	109	163	256	240	244	246	290	331	319	411	336	3088
Mean	230	130	113	236	346	311	294	331	286	356	409	354	3396
Maximum	873	339	229	650	597	558	504	471	499	595	567	776	4406
Minimum	44	34	12	38	222	160	228	160	152	175	289	88	2645

MONTHLY RAINFALL DATA
COCLECITO
(mm)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1966	322	92	114	105	314	292	210	222	261	293	326	486	3037
1967	198	136	33	172	200	285	245	444	257	330	277	564	3141
1968	175	118	185	37	217	198	275	325	336	573	257	181	2877
1969	196	91	63	83	231	447	189	206	272	312	216	438	2744
1970	210	245	366	1003	413	379	320	299	343	528	393	696	5195
1971	420	295	279	50	248	444	209	485	233	201	243	257	3364
1972	356	178	152	288	221	153	145	206	285	146	221	261	2612
1973	336	110	71	107	263	248	272	216	304	399	459	523	3308
1974	129	135	176	240	350	378	371	281	192	314	399	235	3200
1975	255	107	128	57	518	349	215	283	190	343	366	559	3370
1976	272	141	18	188	351	233	161	343	315	300	245	255	2822
1977	128	173	110	248	316	255	237	330	253	329	247	189	2815
1978	147	165	174	412	413	216	235	364	290	372	311	308	3407
1979	130	170	184	157	279	263	189	416	142	219	191	266	2606
1980	197	188	44	131	259	166	205	292	325	404	387	406	3002
1981	346	253	143	653	378	296	233	308	194	332	456	503	4095
1982	193	147	106	261	266	334	439	240	167	293	224	194	2862
1983	176	36	61	166	527	163	152	371	177	353	224	344	2747
1984	301	395	87	78	396	280	190	437	296	303	370	202	3336
1985	262	98	111	62	265	411	205	198	250	286	239	232	2619
1986	262	98	111	64	265	411	205	198	250	286	239	232	2621
1987	122	47	35	573	223	201	311	166	391	625	247	238	3179
1988	105	160	50	74	323	262	207	454	347	379	235	275	2871
1989	208	69	120	137	400	397	425	370	243	153	325	262	3109
1990	254	101	248	150	354	185	302	446	227	436	326	371	3399
1991	93	134	252	144	380	295	246	327	380	341	310	495	3396
1992	143	127	37	399	374	263	211	272	269	217	238	275	2823
1993	253	123	188	163	308	244	192	221	437	354	360	559	3402
1994	122	71	178	388	381	392	191	307	197	529	291	245	3292
1995	131	102	152	216	209	217	221	320	240	207	256	332	2604
Mean	215	143	133	227	321	289	240	312	269	339	296	346	3129
Maximum	420	395	366	1003	527	447	439	485	437	625	459	696	5195
Minimum	93	36	18	37	200	153	145	166	142	146	191	181	2604

MONTHLY RAINFALL DATA
SANTA ANA
(mm)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1966	192	33	33	108	201	207	257	159	162	359	351	114	2176
1967	123	48	34	55	156	169	217	324	182	346	492	401	2547
1968	132	182	135	54	160	134	233	246	358	379	251	45	2309
1969	80	46	42	174	214	187	290	131	200	248	137	258	2007
1970	130	114	227	222	341	364	458	205	253	433	306	323	3376
1971	332	52	71	19	148	298	235	288	239	327	246	77	2332
1972	313	129	183	207	112	156	101	163	189	193	174	123	2043
1973	99	57	33	48	346	299	449	378	419	457	482	166	3233
1974	114	56	293	146	135	252	338	167	201	321	396	74	2493
1975	57	39	31	47	315	321	242	452	250	539	558	411	3262
1976	159	63	23	104	157	198	140	211	398	340	192	78	2063
1977	58	41	13	61	277	242	246	327	205	545	292	92	2399
1978	177	74	241	219	294	175	404	277	302	246	335	122	2866
1979	76	51	71	265	320	342	329	316	208	323	286	137	2724
1980	146	86	30	38	312	234	339	276	215	294	381	377	2728
1981	188	115	95	261	457	245	402	412	119	414	438	404	3549
1982	174	35	38	153	161	258	249	203	208	424	107	95	2103
1983	60	12	28	87	381	178	104	255	311	316	250	251	2233
1984	70	149	47	21	305	345	359	349	358	339	238	77	2655
1985	142	32	72	41	215	308	192	348	199	228	287	98	2162
1986	103	15	70	301	132	415	277	273	207	489	403	50	2733
1987	49	37	12	187	189	147	249	137	233	418	184	120	1961
1988	46	62	12	89	319	180	292	303	188	356	309	109	2265
1989	67	51	79	51	248	350	296	248	220	280	349	139	2376
1990	67	23	84	71	207	192	133	158	387	442	408	225	2397
1991	56	47	332	62	309	227	234	209	369	424	266	133	2668
1992	43	51	16	123	308	238	157	200	313	225	229	117	2021
1993	162	36	88	91	80	151	108	163	200	321	274	168	1843
1994	62	29	133	133	266	205	210	236	345	291	185	71	2165
1995	71	23	95	111	256	275	243	214	258	264	224	136	2170
Mean	118	60	89	118	244	243	259	254	257	353	301	166	2462
Maximum	332	182	332	301	457	415	458	452	419	545	558	411	3549
Minimum	43	12	12	19	80	134	101	131	119	193	107	45	1843

MONTHLY RAINFALL DATA
MIGUEL DE LA BORDA
(mm)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1966	358	25	49	79	519	381	482	604	289	667	697	345	4495
1967	372	76	70	207	426	319	390	487	418	342	801	739	4647
1968	89	254	160	79	271	175	601	427	403	464	500	97	3520
1969	122	137	16	111	239	183	421	348	206	397	422	768	3370
1970	188	112	216	533	474	261	335	363	426	465	860	1379	5612
1971	147	167	227	67	284	510	315	450	305	268	331	331	3402
1972	489	151	103	171	381	135	233	401	473	576	380	476	3969
1973	157	77	14	50	264	445	368	411	192	299	489	572	3338
1974	210	14	133	313	518	340	468	556	62	277	481	182	3554
1975	290	151	148	28	398	576	402	481	194	316	461	643	4090
1976	126	91	11	299	351	128	325	542	743	561	555	491	4223
1977	52	95	47	44	484	490	356	562	357	737	733	442	4400
1978	118	39	218	415	200	393	698	532	395	472	473	125	4077
1979	47	162	45	174	478	467	235	314	286	309	492	462	3471
1980	188	143	19	37	335	388	336	423	430	425	290	524	3536
1981	261	244	118	750	415	237	377	397	272	456	746	747	5019
1982	171	100	114	184	168	432	496	537	423	536	421	201	3782
1983	93	24	17	215	433	311	477	350	588	341	362	711	3921
1984	314	219	79	79	444	459	366	380	255	310	432	176	3513
1985	145	67	96	39	420	279	402	309	537	491	556	408	3749
1986	102	29	81	491	337	317	487	401	229	327	321	80	3202
1987	44	31	27	226	279	242	298	261	256	501	407	334	2906
1988	46	25	19	116	236	304	360	523	422	244	478	381	3154
1989	54	60	82	115	340	463	373	504	246	658	439	184	3519
1990	126	55	48	185	430	255	327	500	297	422	338	462	3444
1991	158	52	183	99	474	511	456	341	559	391	867	196	4285
1992	134	112	20	460	324	119	572	436	283	310	504	168	3442
1993	104	68	138	475	122	405	260	516	259	334	536	438	3653
1994	165	65	113	203	496	418	358	647	145	269	421	142	3441
1995	129	6	111	308	330	328	322	264	328	265	523	588	3503
Mean	167	95	91	218	362	342	397	442	343	414	510	426	3808
Maximum	489	254	227	750	519	576	698	647	743	737	867	1379	5612
Minimum	44	6	11	28	122	119	233	261	62	244	290	80	2906

MONTHLY RAINFALL DATA
BOCA DE URACILLO
(mm)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1966	168	34	169	432	432	338	215	269	207	513	492	203	3472
1967	226	47	80	282	397	306	477	502	175	488	482	530	3992
1968	49	108	160	92	207	180	311	343	346	457	383	100	2736
1969	159	103	21	76	336	262	227	218	223	316	225	245	2411
1970	137	207	289	326	493	567	357	237	391	431	453	523	4411
1971	138	74	187	34	276	399	192	310	347	329	281	133	2700
1972	513	93	57	325	303	217	172	193	321	294	276	231	2995
1973	227	86	12	56	314	281	375	319	272	364	414	395	3115
1974	83	62	53	51	456	373	316	170	196	354	536	120	2770
1975	65	35	60	27	418	247	241	451	364	567	610	616	3700
1976	101	74	32	126	310	243	142	198	431	365	303	166	2490
1977	59	64	25	77	318	309	229	337	166	477	337	222	2618
1978	196	110	185	388	404	222	374	287	306	380	363	97	3309
1979	36	134	31	216	416	433	471	533	327	323	258	219	3396
1980	195	125	19	68	438	371	391	246	170	291	329	310	2954
1981	222	122	169	396	352	386	407	378	190	330	520	466	3939
1982	163	41	56	139	183	216	347	366	244	514	197	74	2540
1983	58	23	10	105	413	313	251	248	395	411	314	320	2860
1984	144	126	73	63	608	358	263	431	323	406	358	111	3263
1985	201	44	79	37	306	435	315	311	286	411	349	248	3021
1986	105	21	54	517	257	297	196	249	288	462	405	77	2928
1987	74	61	14	234	319	253	353	287	338	473	307	187	2900
1988	38	87	20	126	325	250	313	495	390	472	446	154	3114
1989	55	103	40	77	232	258	236	438	193	475	391	168	2665
1990	160	22	115	116	561	235	235	305	566	587	282	408	3591
1991	60	60	140	106	295	225	180	131	440	355	288	268	2547
1992	70	56	22	200	396	328	301	303	254	315	327	164	2734
1993	109	59	122	323	212	332	181	173	343	432	397	282	2964
1994	78	39	161	148	526	389	212	186	394	366	368	128	2995
1995	151	28	79	257	319	509	345	257	320	312	344	260	3181
Mean	135	75	84	181	361	318	287	306	307	409	368	247	3077
Maximum	513	207	289	517	608	567	477	533	566	587	610	616	4411
Minimum	36	21	10	27	183	180	142	131	166	291	197	74	2411

MONTHLY RAINFALL DATA
ICACAL
(mm)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1966	75	7	70	225	665	286	461	652	290	615	1081	468	4896
1967	167	35	71	160	338	527	497	671	257	272	620	304	3919
1968	10	205	115	48	409	266	580	510	308	668	515	83	3717
1969	133	107	36	156	516	222	493	327	313	421	384	612	3720
1970	284	51	134	509	572	278	380	252	311	423	1005	757	4956
1971	156	112	146	9	457	602	587	367	227	315	398	167	3543
1972	408	73	112	627	454	196	341	393	325	673	273	236	4112
1973	46	29	20	104	424	412	376	466	292	343	516	417	3445
1974	63	67	72	40	461	348	699	484	117	284	955	130	3719
1975	43	37	137	34	418	770	669	342	353	438	451	668	4359
1976	64	60	9	155	355	290	343	393	502	502	329	207	3210
1977	23	31	8	40	339	426	313	568	416	728	601	480	3972
1978	102	72	147	369	250	556	464	375	269	401	473	109	3586
1979	22	137	7	214	565	512	364	358	354	359	550	399	3839
1980	206	79	18	14	431	144	374	323	457	548	283	449	3324
1981	158	96	81	677	553	334	534	389	352	416	926	656	5171
1982	271	52	220	114	106	291	565	373	418	490	560	167	3627
1983	63	30	74	240	551	299	410	473	346	199	237	547	3468
1984	115	125	78	71	423	386	405	339	229	346	547	142	3206
1985	183	56	52	25	439	393	444	171	367	407	500	353	3389
1986	115	40	89	413	403	478	783	546	455	575	505	185	4587
1987	73	47	33	522	608	324	510	373	572	840	366	423	4689
1988	48	67	32	77	411	295	446	356	218	373	590	314	3227
1989	28	55	70	18	207	425	288	740	481	677	484	220	3693
1990	79	10	59	170	412	246	432	425	496	587	433	467	3816
1991	119	60	126	190	816	442	395	309	435	552	755	196	4394
1992	49	61	82	195	249	374	454	472	366	343	524	278	3447
1993	94	32	203	278	290	30	86	226	236	354	582	373	2785
1994	72	46	62	78	322	565	439	364	405	288	597	149	3386
1995	178	34	93	93	498	528	490	137	152	227	707	645	3781
Mean	115	64	82	195	431	375	454	406	344	455	558	353	3833
Maximum	408	205	220	677	816	770	783	740	572	840	1081	757	5171
Minimum	10	7	7	9	106	30	86	137	117	199	237	83	2785

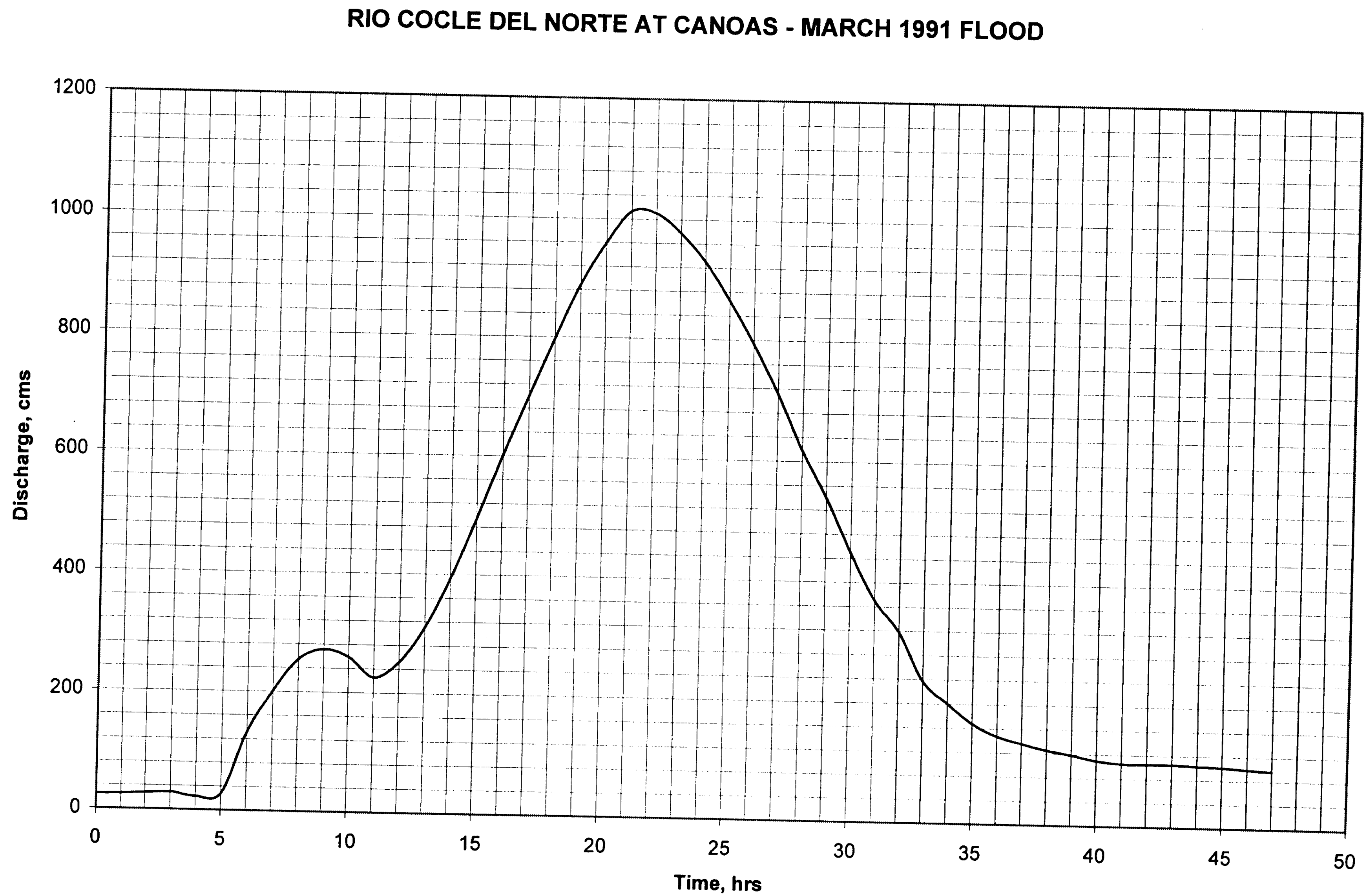
MONTHLY RAINFALL DATA
CIRI GRANDE
(mm)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1966	79	10	30	65	201	168	299	339	297	184	292	51	2015
1967	46	30	66	171	185	378	189	747	428	372	241	100	2953
1968	40	41	10	30	260	120	195	244	348	321	286	48	1943
1969	129	32	0	36	237	244	101	400	233	367	317	124	2220
1970	357	93	137	350	305	302	210	435	240	302	270	148	3149
1971	39	25	18	83	295	350	178	140	143	286	286	97	1940
1972	149	52	35	180	270	298	132	205	350	250	171	39	2131
1973	74	16	0	89	192	190	228	125	217	555	198	102	1986
1974	0	0	2	56	240	136	238	88	147	399	279	178	1763
1975	38	46	16	31	267	250	241	494	228	813	290	173	2887
1976	20	62	29	164	342	334	134	33	270	314	154	67	1923
1977	220	62	20	59	219	124	352	342	161	388	272	228	2447
1978	35	0	84	300	300	145	368	391	345	282	277	36	2562
1979	20	41	5	274	231	239	325	269	251	165	206	193	2220
1980	165	64	10	51	318	351	315	310	119	358	277	224	2560
1981	160	69	163	312	323	358	302	251	198	533	361	249	3279
1982	160	30	20	84	191	259	145	196	206	409	147	36	1882
1983	20	8	5	46	231	180	249	224	351	231	338	262	2144
1984	81	137	20	56	231	279	145	422	401	452	221	71	2517
1985	127	20	25	15	173	267	203	259	300	170	193	124	1877
1986	28	8	10	196	231	86	155	36	277	213	173	23	1435
1987	13	13	5	102	257	81	127	188	671	668	343	345	2812
1988	10	30	3	43	310	277	226	386	368	310	264	178	2405
1989	15	66	51	36	175	203	310	356	330	376	259	208	2385
1990	130	8	58	79	318	198	191	208	422	371	264	229	2474
1991	20	30	86	56	343	168	208	122	297	224	282	147	1984
1992	48	23	10	155	409	244	163	305	231	244	358	140	2329
1993	76	20	89	201	384	343	114	130	401	378	378	155	2670
1994	15	3	5	0	150	335	69	206	180	376	312	41	1692
1995	109	15	23	137	315	394	221	373	290	269	290	267	2703
Mean	81	35	35	115	263	243	211	274	290	353	267	143	2310
Maximum	357	137	163	350	409	394	368	747	671	813	378	345	3279
Minimum	0	0	0	0	150	81	69	33	119	165	147	23	1435

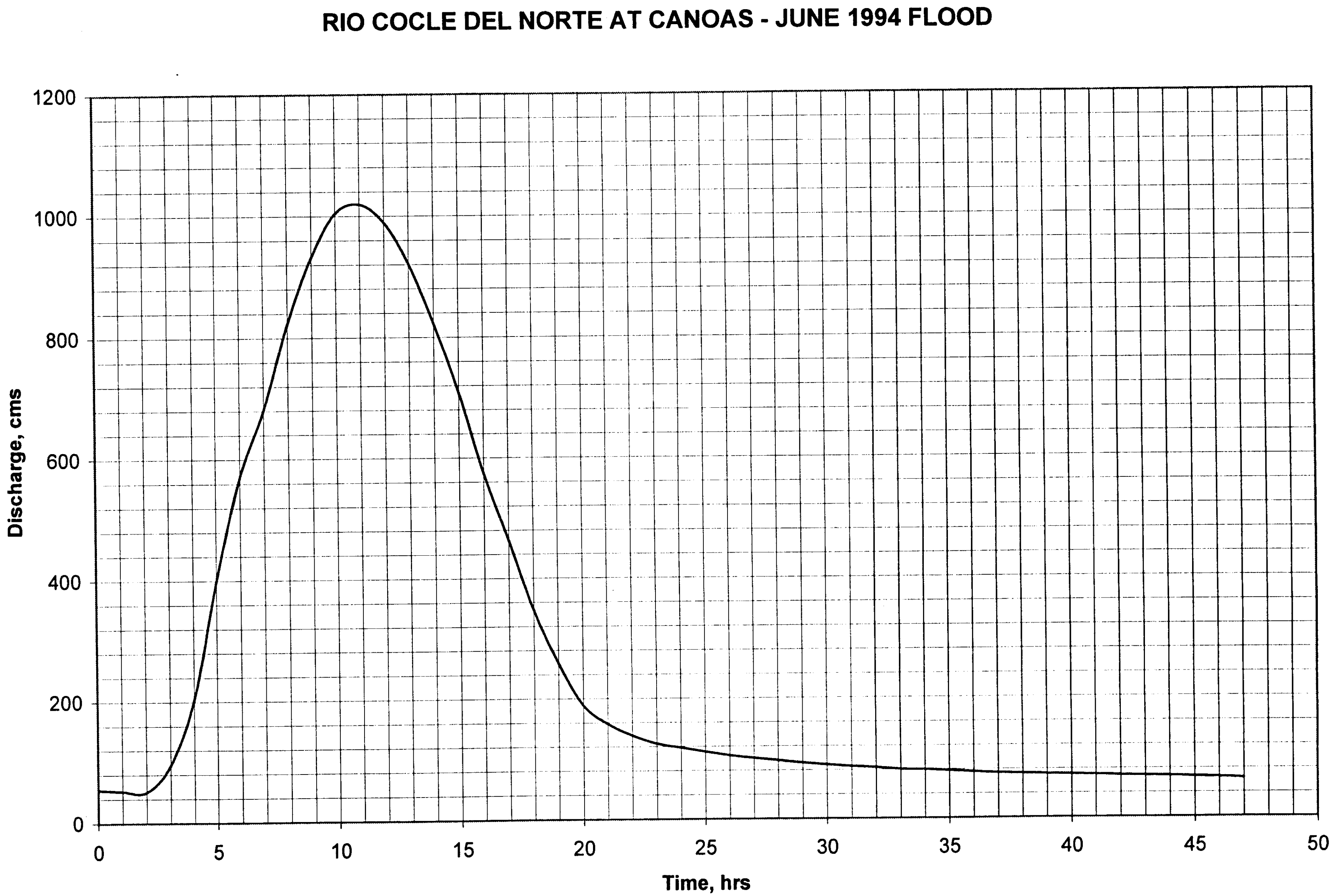
MONTHLY RAINFALL DATA
TRINIDAD
(mm)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1966	47	1	22	62	271	271	201	328	279	135	300	309	2226
1967	37	10	54	112	214	259	185	316	270	385	269	49	2160
1968	5	129	66	13	389	468	80	288	386	399	268	39	2530
1969	63	36	4	174	229	245	132	307	173	421	383	176	2343
1970	155	53	108	115	325	217	163	306	330	269	398	430	2869
1971	108	55	68	5	449	323	153	323	196	264	310	41	2295
1972	160	51	28	257	211	305	102	173	295	267	198	51	2096
1973	23	3	0	69	229	284	124	132	269	480	495	206	2314
1974	8	25	18	30	122	165	246	183	183	457	394	43	1875
1975	8	30	25	18	315	320	201	318	312	681	472	373	3073
1976	33	23	0	119	213	119	89	102	315	358	124	61	1557
1977	18	10	3	23	251	109	165	272	211	409	305	91	1867
1978	84	13	79	302	356	356	246	272	198	373	173	25	2477
1979	13	0	3	132	203	305	335	206	259	216	155	102	1928
1980	86	48	3	43	376	244	389	226	198	310	429	178	2530
1981	170	30	38	307	373	262	262	325	145	211	373	246	2743
1982	147	13	20	69	267	191	132	264	218	384	140	15	1859
1983	28	10	18	28	218	137	165	259	277	246	249	152	1788
1984	91	97	20	25	274	30	122	417	381	318	399	43	2217
1985	74	23	18	38	163	325	191	163	221	107	180	203	1704
1986	58	10	10	211	269	180	117	241	191	366	386	61	2101
1987	33	20	3	91	330	155	226	234	538	231	64	99	2024
1988	5	20	5	53	259	290	272	234	279	213	295	160	2085
1989	33	36	13	28	173	206	218	257	239	236	318	165	1920
1990	15	3	33	58	483	175	221	254	404	414	335	84	2479
1991	33	8	208	5	381	140	130	132	333	216	287	117	1989
1992	0	10	3	163	274	249	178	231	429	183	236	122	2078
1993	38	18	79	183	231	284	124	130	399	358	427	142	2413
1994	56	8	71	38	196	180	89	157	183	404	409	3	1793
1995	102	3	10	109	272	234	221	320	239	300	249	249	2306
Mean	58	26	34	96	277	234	183	246	278	320	301	135	2188
Maximum	170	129	208	307	483	468	389	417	538	681	495	430	3073
Minimum	0	0	0	5	122	30	80	102	145	107	64	3	1557

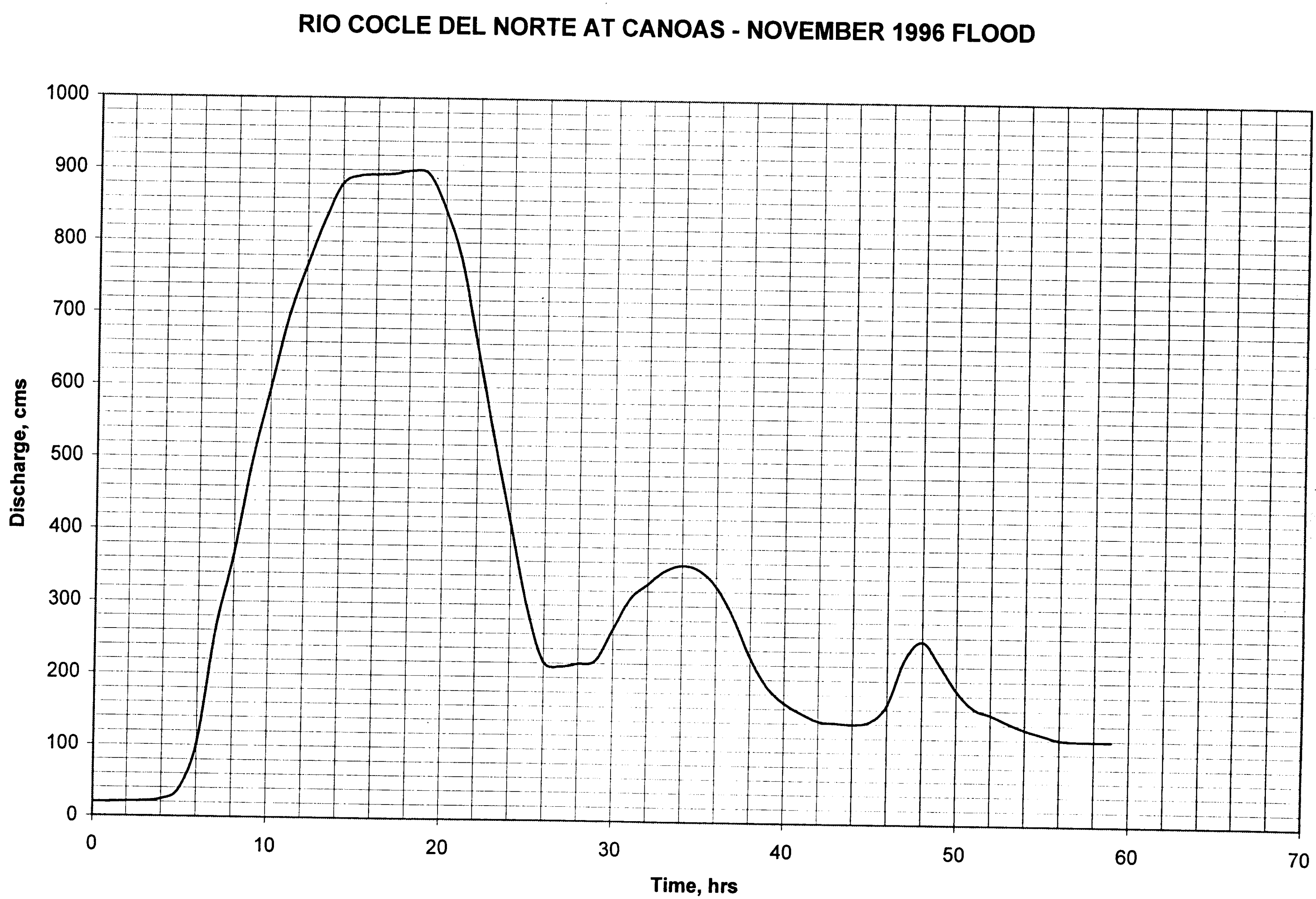
Attachment 3 – Flood Hydrographs



Attachment 3
Flood Hydrographs

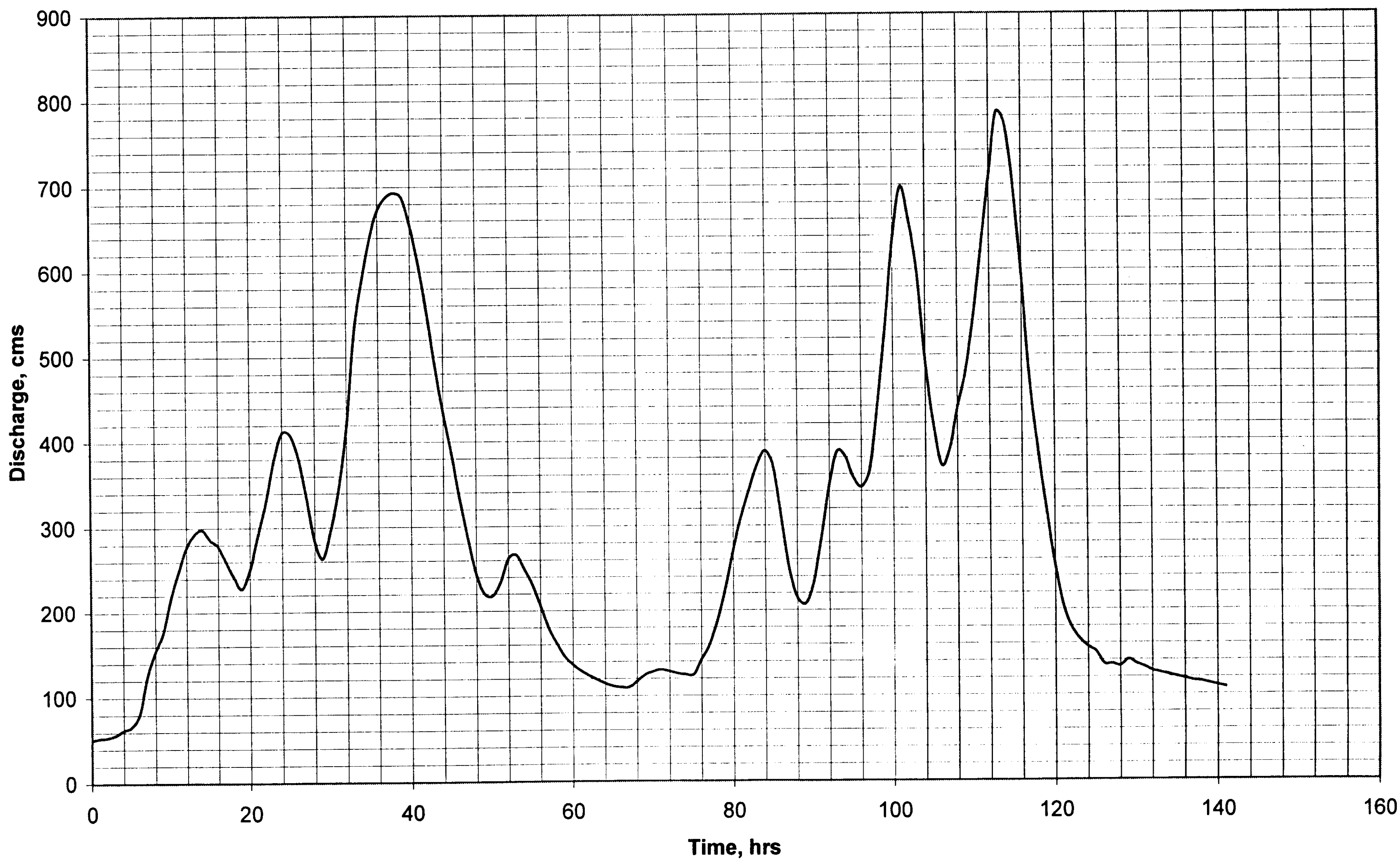


Att nent 3
Flood Hy graphs

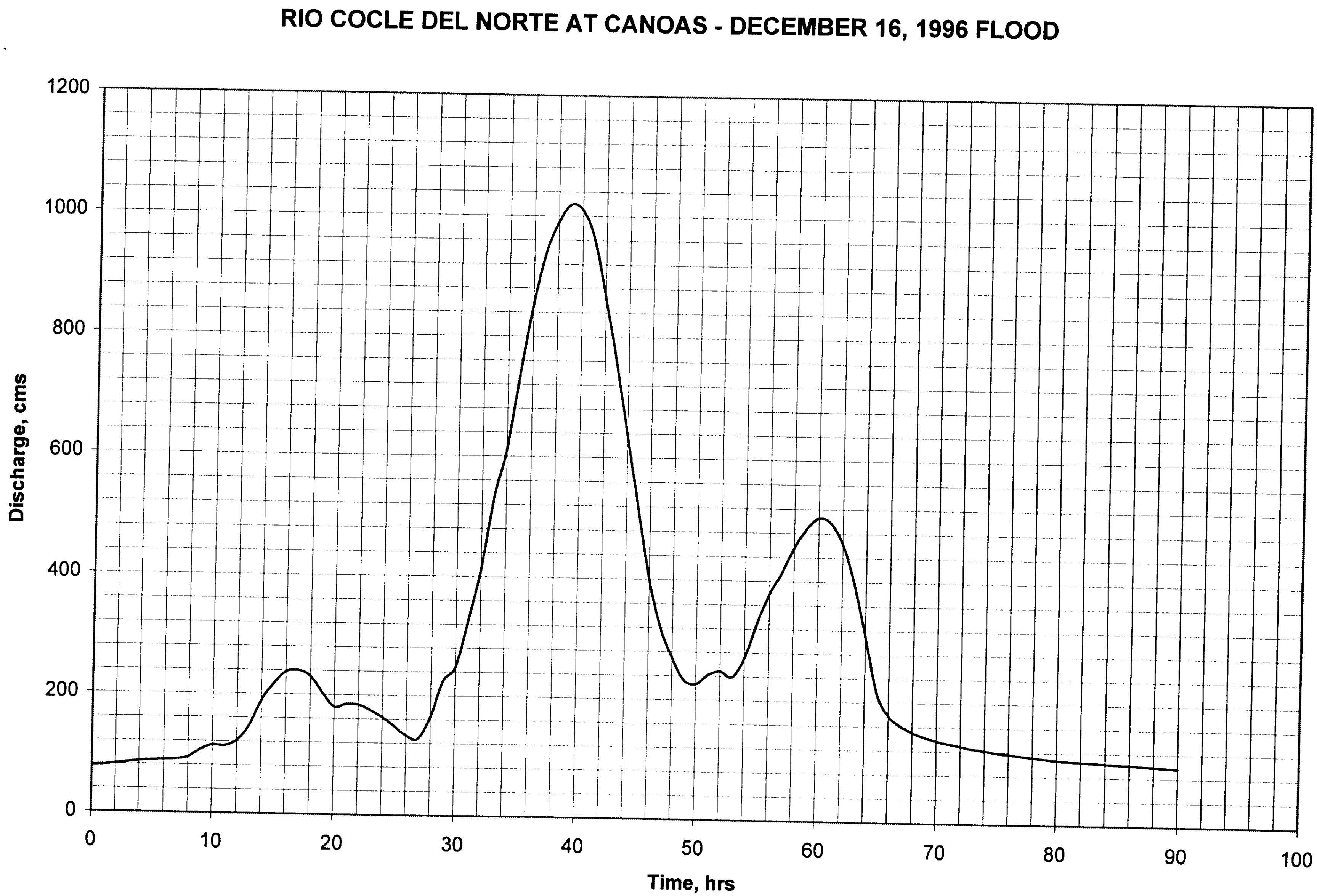


Attachment 3
Flood Hydrographs

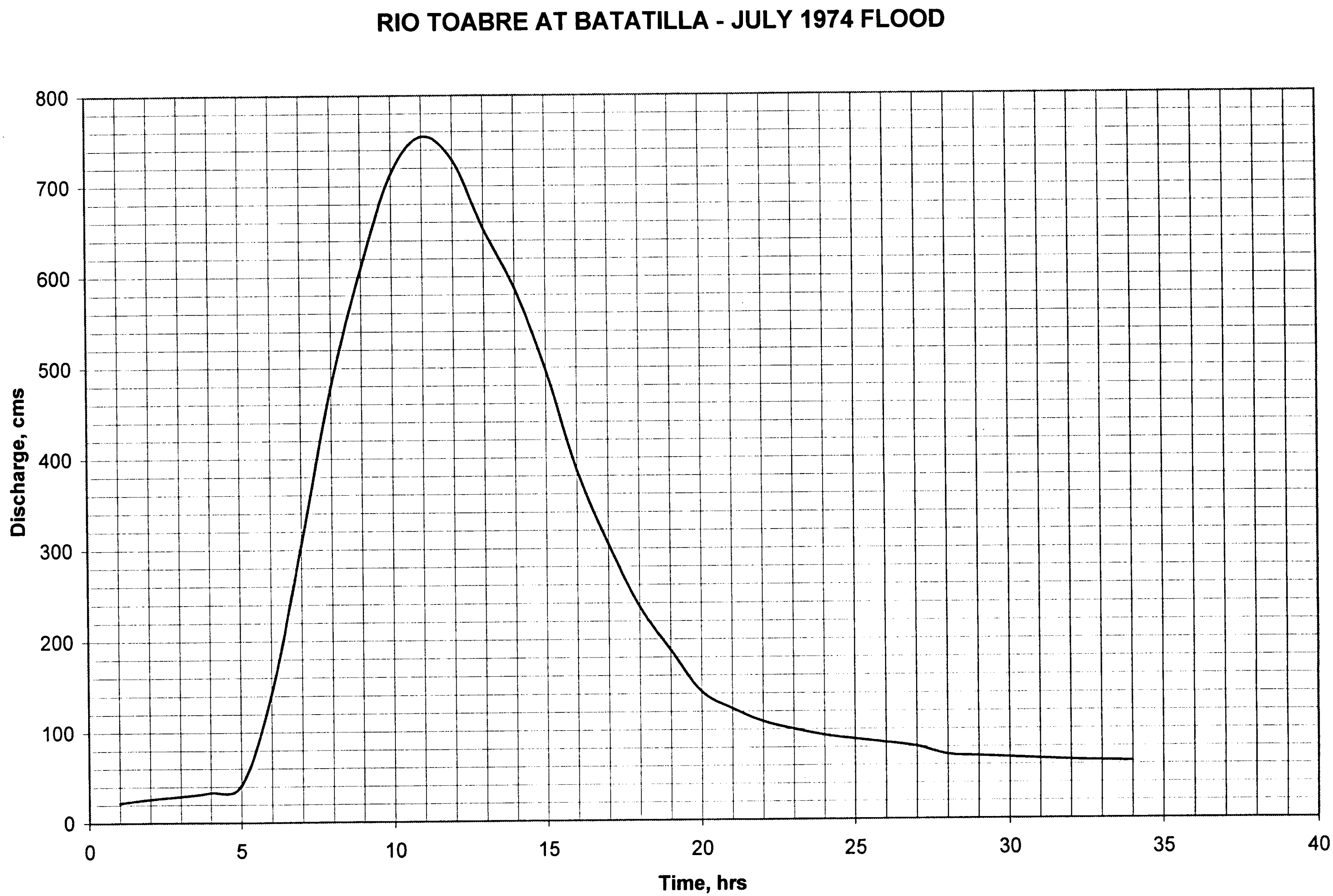
RIO COCLE DEL NORTE AT CANOAS - DECEMBER 08, 1996 FLOOD

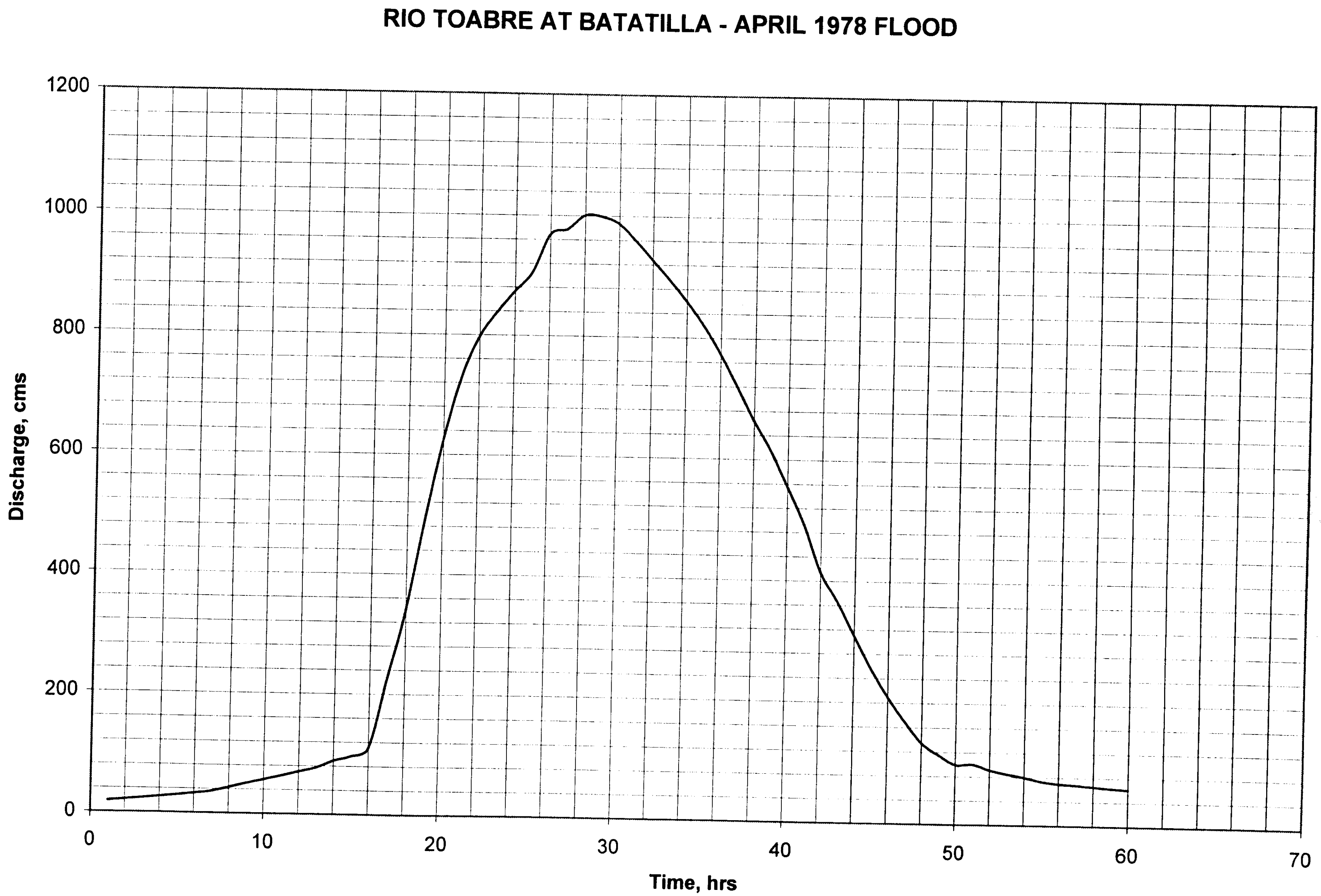


Att· ·ment 3
Flood Hy· ·graphs



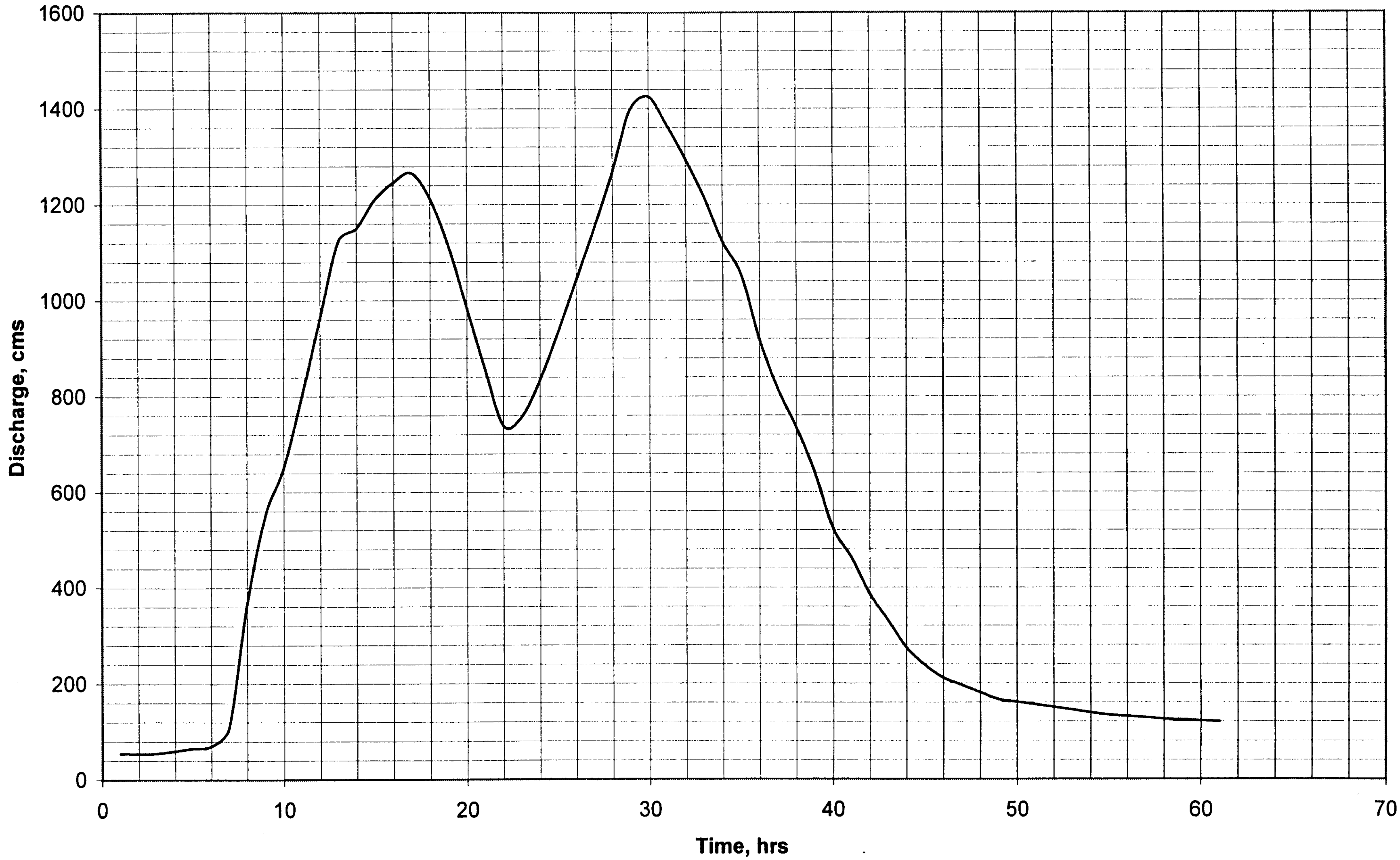
Attachment 3
Flood Hydrographs

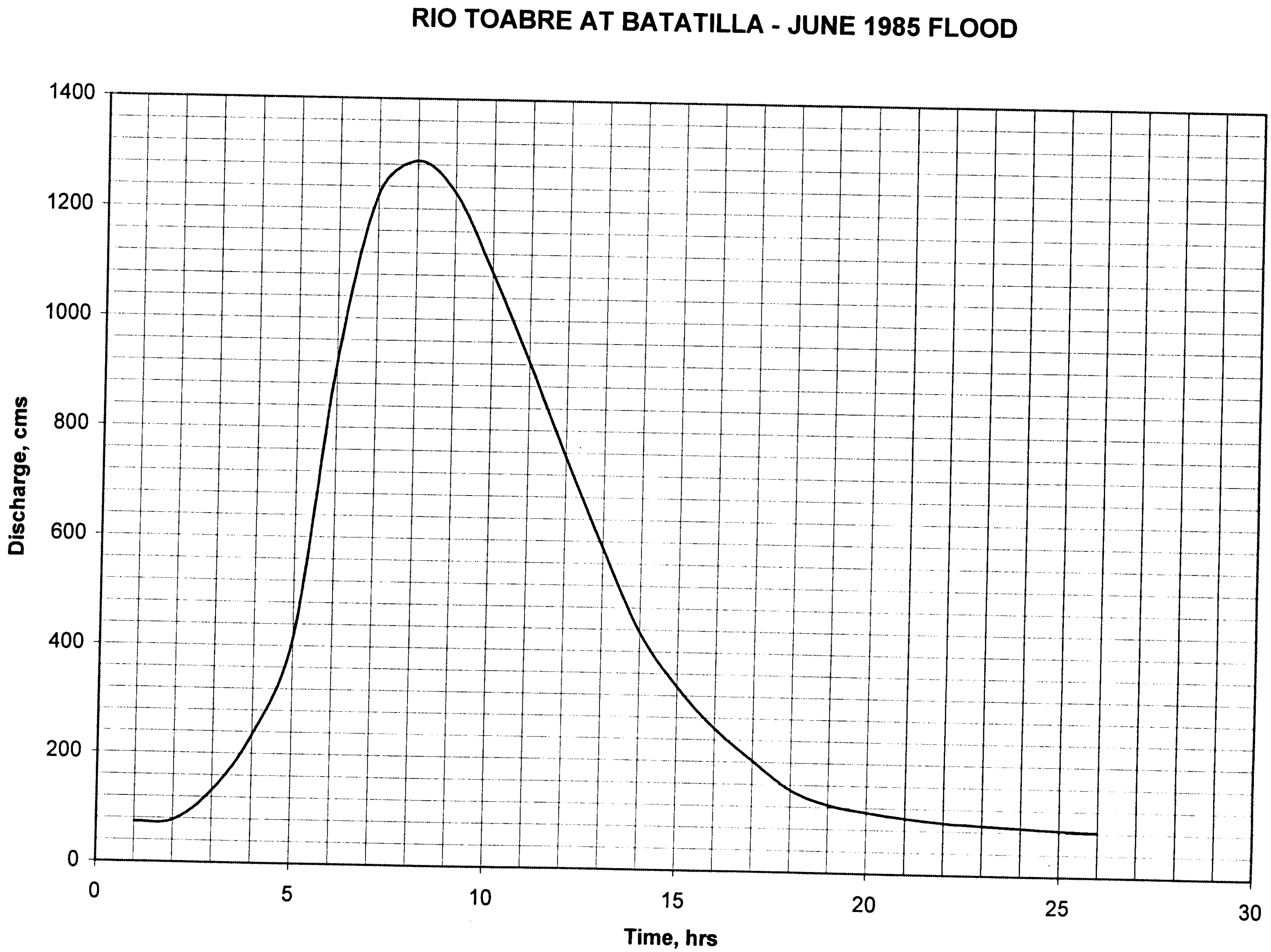

RIO TOABRE AT BATATILLA - JULY 1974 FLOOD
Discharge, cms
Time, hrs
0
100
200
300
400
500
600
700
800
5
10
15
20
25
30
35
40



Attachment 3
Flood Hydrographs

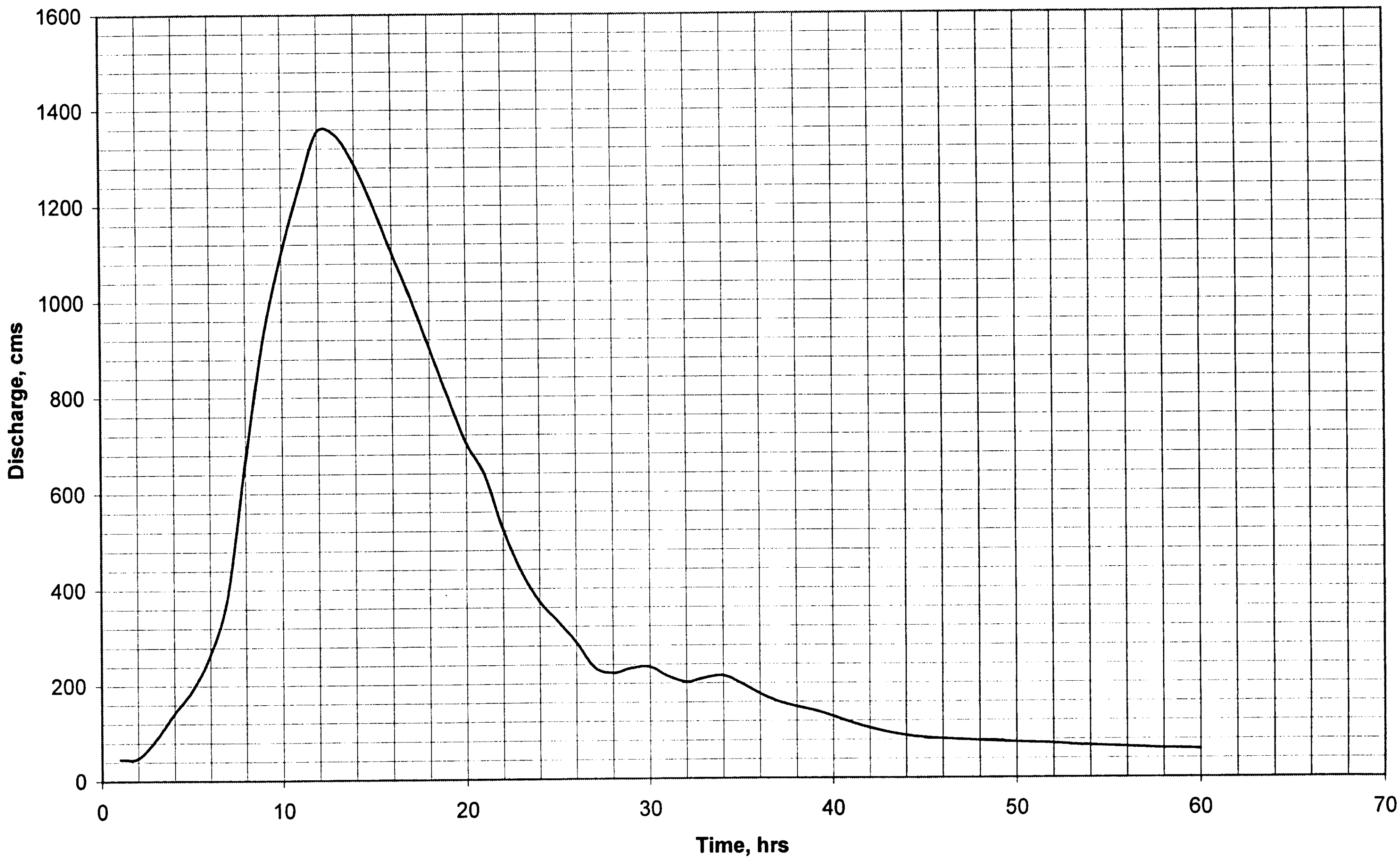
RIO TOABRE AT BATATILLA - DECEMBER 1981 FLOOD





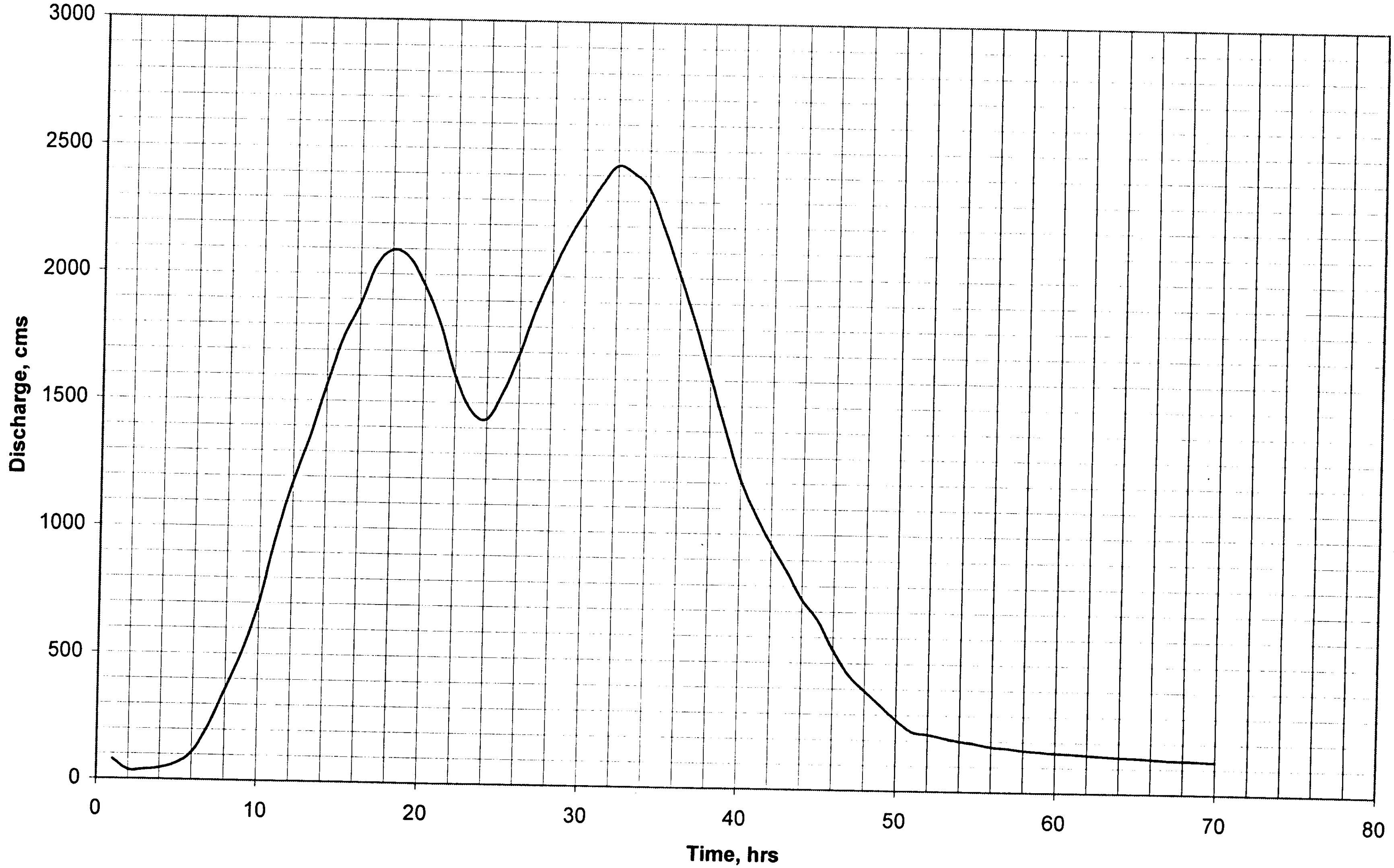
Attachment 3
Flood Hydrographs

RIO TOABRE AT BATATILLA - DECEMBER 1995 FLOOD



Atta ent 3
Flood Hy graphs

RIO TOABRE AT BATATILLA - JANUARY 1996 FLOOD



Attachment 3
Flood Hydrographs

Attachment 4 – HEC-1 Output, Río Coclé del Norte

```
1***************************************
*                                     *
*   FLOOD HYDROGRAPH PACKAGE  (HEC-1) *
*           SEPTEMBER 1990            *
*             VERSION 4.0             *
*                                     *
* RUN DATE  10/30/2002  TIME  12:50:04 *
*                                     *
***************************************
```

```
***************************************
*                                     *
*   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        PROBABLE MAXIMUM FLOOD - RIO COCLE DEL NORTE AT DAM SITE
   2         ID        MAXIMUM NORMAL POOL ELEVATION 80 METERS, NO FLOW THROUGH TUNNEL
   3         ID        48-HOUR PMP, TIME DISTRIBUTION FROM PREVIOUS REPORTS
   4         IT      60 30NOV02      600            05DEC02      600
   5         IN      60 30NOV02      600
   6         IM
   7         IO       1        2

   8         KK     SB03
   9         KM        RUNOFF FROM SUB-BASIN 03
  10         BA      674
  11         BF       50
  12         PB      710
  13         PI      0.7     0.7     0.7     0.7     0.8     0.8     0.8     0.8     0.8     0.8
```

```
 14        PI     0.8     0.9     0.9     1.0     1.0     1.0     1.0     1.5     1.5     1.5
 15        PI     1.5     2.0     2.0     2.0     3.0     4.0     4.0    13.5    14.0     6.5
 16        PI     4.0     3.0     3.0     2.0     2.0     1.5     1.5     1.5     1.5     1.5
 17        PI     1.0     1.0     1.0     0.9     0.9     0.9     0.8     0.8
 18        LU     0.0     3.0    17.0
 19        UC     9.3     8.0
 20        UA     4.0     9.6    15.5    37.3    58.4    79.7    93.2   100.0

 21        KK    SB02
 22        KM        RUNOFF FROM SUB-BASIN 02
 23        BA     805
 24        BF      50
 25        PB     679
 26        PI     0.7     0.7     0.7     0.7     0.8     0.8     0.8     0.8     0.8     0.8
 27        PI     0.8     0.9     0.9     1.0     1.0     1.0     1.0     1.5     1.5     1.5
 28        PI     1.5     2.0     2.0     2.0     3.0     4.0     4.0    13.5    14.0     6.5
 29        PI     4.0     3.0     3.0     2.0     2.0     1.5     1.5     1.5     1.5     1.5
 30        PI     1.0     1.0     1.0     0.9     0.9     0.9     0.8     0.8
 31        LU     0.0     3.0    17.0
 32        UC    13.0    12.3
 33        UA     2.3     5.2     7.6    11.3    18.5    30.4    44.7    61.6    71.1    81.5
 34        UA    90.2   100.0

 35        KK    SB02
 36        KM        COMBINE TWO HYDROGRAPHS
 37        HC       2

 38        KK    SB01
 39        KM        ROUTE COMBINED HYDROGRAPH TO SB01
 40        RM       1     1.0     0.2

 41        KK    SB01
 42        KM        RUNOFF FROM SUB-BASIN 01
 43        BA     115
 44        BF      10
 45        PB     956
 46        PI     0.7     0.7     0.7     0.7     0.8     0.8     0.8     0.8     0.8     0.8
 47        PI     0.8     0.9     0.9     1.0     1.0     1.0     1.0     1.5     1.5     1.5
 48        PI     1.5     2.0     2.0     2.0     3.0     4.0     4.0    13.5    14.0     6.5
 49        PI     4.0     3.0     3.0     2.0     2.0     1.5     1.5     1.5     1.5     1.5
 50        PI     1.0     1.0     1.0     0.9     0.9     0.9     0.8     0.8
1                                     HEC-1 INPUT                                        PAGE  2

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

 51        LU     0.0     3.0    17.0
 52        UC     8.1     6.7
 53        UA    23.5    32.6    43.5    54.3    70.0    80.0    92.6   100.0

 54        KK     DAM
 55        KM        COMBINE TWO HYDROGRAPHS
 56        HC       2
```

```
 57            KK     DAM
 58            KM        ROUTE THROUGH RESERVOIR
 59            RS        1     ELEV    80.0
 60            SV   6.21E6 7.514E6 7.809E6 8.103E6 8.398E6 8.692E6 8.987E6 9.309E6 9.631E6 9.954E6
 61            SE     75.0    80.0    81.0    82.0    83.0    84.0    85.0    86.0    87.0    88.0
 62            SQ        0      30      94     184     288     429     579     912    1275
 63            SE     80.0    80.5    81.0    81.5    82.0    82.5    83.0    84.0    85.0
 64            ZZ
```

```
1*****************************************
*                                         *
*   FLOOD HYDROGRAPH PACKAGE  (HEC-1)    *
*           SEPTEMBER 1990                *
*             VERSION 4.0                 *
*                                         *
* RUN DATE  10/30/2002  TIME  12:50:04   *
*                                         *
*****************************************
```

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

```
                    PROBABLE MAXIMUM FLOOD - RIO COCLE DEL NORTE AT DAM SITE
                    MAXIMUM NORMAL POOL ELEVATION 80 METERS, NO FLOW THROUGH TUNNEL
                    48-HOUR PMP, TIME DISTRIBUTION FROM PREVIOUS REPORTS

  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     30NOV 2  STARTING DATE
                   ITIME        0600  STARTING TIME
                      NQ         121  NUMBER OF HYDROGRAPH ORDINATES
                  NDDATE      5DEC 2  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      *     SB03   *
             *            *
             **************
                              RUNOFF FROM SUB-BASIN 03

   5 IN           TIME DATA FOR INPUT TIME SERIES
                        JXMIN          60  TIME INTERVAL IN MINUTES
                       JXDATE    30NOV 2   STARTING DATE
                       JXTIME         600  STARTING TIME

                SUBBASIN RUNOFF DATA

  10 BA           SUBBASIN CHARACTERISTICS
                        TAREA      674.00  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      710.00  BASIN TOTAL PRECIPITATION

  13 PI             INCREMENTAL PRECIPITATION PATTERN
                      .70        .70        .70        .70        .80        .80        .80        .80        .80        .80
                      .80        .90        .90       1.00       1.00       1.00       1.00       1.50       1.50       1.50
                     1.50       2.00       2.00       2.00       3.00       4.00       4.00      13.50      14.00       6.50
                     4.00       3.00       3.00       2.00       2.00       1.50       1.50       1.50       1.50       1.50
                     1.00       1.00       1.00        .90        .90        .90        .80        .80

  18 LU           UNIFORM LOSS RATE
                        STRTL         .00  INITIAL LOSS
                        CNSTL        3.00  UNIFORM LOSS RATE
                        RTIMP       17.00  PERCENT IMPERVIOUS AREA

  19 UC           CLARK UNITGRAPH
                           TC        9.30  TIME OF CONCENTRATION
                            R        8.00  STORAGE COEFFICIENT

  20 UA           ACCUMULATED-AREA VS. TIME,    8 ORDINATES
                      4.0        9.6       15.5       37.3       58.4       79.7       93.2      100.0
                                                        ***
```

UNIT HYDROGRAPH PARAMETERS

CLARK TC= 9.30 HR, R= 8.00 HR

SNYDER TP= 8.12 HR, CP= .61

UNIT HYDROGRAPH

48 END-OF-PERIOD ORDINATES

1.	2.	3.	6.	9.	11.	13.	14.	14.	13.
12.	10.	9.	8.	7.	6.	6.	5.	4.	4.
3.	3.	3.	2.	2.	2.	2.	1.	1.	1.
1.	1.	1.	1.	1.	1.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.		

****

HYDROGRAPH AT STATION SB03

****

DA MON HRMN	ORD	RAIN	LOSS	EXCESS	COMP Q
30 NOV 0600	1	.00	.00	.00	50.
30 NOV 0700	2	4.97	2.49	2.48	52.
30 NOV 0800	3	4.97	2.49	2.48	58.
30 NOV 0900	4	4.97	2.49	2.48	66.
30 NOV 1000	5	4.97	2.49	2.48	80.
30 NOV 1100	6	5.68	2.49	3.19	102.
30 NOV 1200	7	5.68	2.49	3.19	131.
30 NOV 1300	8	5.68	2.49	3.19	166.
30 NOV 1400	9	5.68	2.49	3.19	205.
30 NOV 1500	10	5.68	2.49	3.19	246.
30 NOV 1600	11	5.68	2.49	3.19	287.
30 NOV 1700	12	5.68	2.49	3.19	326.
30 NOV 1800	13	6.39	2.49	3.90	362.
30 NOV 1900	14	6.39	2.49	3.90	397.
30 NOV 2000	15	7.10	2.49	4.61	429.
30 NOV 2100	16	7.10	2.49	4.61	461.
30 NOV 2200	17	7.10	2.49	4.61	493.
30 NOV 2300	18	7.10	2.49	4.61	525.
1 DEC 0000	19	10.65	2.49	8.16	562.
1 DEC 0100	20	10.65	2.49	8.16	603.
1 DEC 0200	21	10.65	2.49	8.16	649.
1 DEC 0300	22	10.65	2.49	8.16	701.
1 DEC 0400	23	14.20	2.49	11.71	764.
1 DEC 0500	24	14.20	2.49	11.71	838.
1 DEC 0600	25	14.20	2.49	11.71	919.
1 DEC 0700	26	21.30	2.49	18.81	1017.
1 DEC 0800	27	28.40	2.49	25.91	1138.
1 DEC 0900	28	28.40	2.49	25.91	1280.
1 DEC 1000	29	95.85	2.49	93.36	1508.
1 DEC 1100	30	99.40	2.49	96.91	1860.
1 DEC 1200	31	46.15	2.49	43.66	2279.

DA MON HRMN	ORD	RAIN	LOSS	EXCESS	COMP Q
2 DEC 1900	62	.00	.00	.00	652.
2 DEC 2000	63	.00	.00	.00	581.
2 DEC 2100	64	.00	.00	.00	518.
2 DEC 2200	65	.00	.00	.00	462.
2 DEC 2300	66	.00	.00	.00	413.
3 DEC 0000	67	.00	.00	.00	370.
3 DEC 0100	68	.00	.00	.00	331.
3 DEC 0200	69	.00	.00	.00	297.
3 DEC 0300	70	.00	.00	.00	267.
3 DEC 0400	71	.00	.00	.00	241.
3 DEC 0500	72	.00	.00	.00	217.
3 DEC 0600	73	.00	.00	.00	196.
3 DEC 0700	74	.00	.00	.00	177.
3 DEC 0800	75	.00	.00	.00	159.
3 DEC 0900	76	.00	.00	.00	144.
3 DEC 1000	77	.00	.00	.00	123.
3 DEC 1100	78	.00	.00	.00	105.
3 DEC 1200	79	.00	.00	.00	94.
3 DEC 1300	80	.00	.00	.00	86.
3 DEC 1400	81	.00	.00	.00	80.
3 DEC 1500	82	.00	.00	.00	75.
3 DEC 1600	83	.00	.00	.00	70.
3 DEC 1700	84	.00	.00	.00	67.
3 DEC 1800	85	.00	.00	.00	64.
3 DEC 1900	86	.00	.00	.00	62.
3 DEC 2000	87	.00	.00	.00	59.
3 DEC 2100	88	.00	.00	.00	57.
3 DEC 2200	89	.00	.00	.00	56.
3 DEC 2300	90	.00	.00	.00	55.
4 DEC 0000	91	.00	.00	.00	54.
4 DEC 0100	92	.00	.00	.00	53.

1 DEC 1300	32	28.40	2.49	25.91	2800.	*	4 DEC 0200	93	.00	.00	.00	52.
1 DEC 1400	33	21.30	2.49	18.81	3446.	*	4 DEC 0300	94	.00	.00	.00	51.
1 DEC 1500	34	21.30	2.49	18.81	4114.	*	4 DEC 0400	95	.00	.00	.00	51.
1 DEC 1600	35	14.20	2.49	11.71	4701.	*	4 DEC 0500	96	.00	.00	.00	50.
1 DEC 1700	36	14.20	2.49	11.71	5135.	*	4 DEC 0600	97	.00	.00	.00	50.
1 DEC 1800	37	10.65	2.49	8.16	5365.	*	4 DEC 0700	98	.00	.00	.00	50.
1 DEC 1900	38	10.65	2.49	8.16	5375.	*	4 DEC 0800	99	.00	.00	.00	50.
1 DEC 2000	39	10.65	2.49	8.16	5209.	*	4 DEC 0900	100	.00	.00	.00	50.
1 DEC 2100	40	10.65	2.49	8.16	4940.	*	4 DEC 1000	101	.00	.00	.00	50.
1 DEC 2200	41	10.65	2.49	8.16	4634.	*	4 DEC 1100	102	.00	.00	.00	50.
1 DEC 2300	42	7.10	2.49	4.61	4321.	*	4 DEC 1200	103	.00	.00	.00	50.
2 DEC 0000	43	7.10	2.49	4.61	4015.	*	4 DEC 1300	104	.00	.00	.00	50.
2 DEC 0100	44	7.10	2.49	4.61	3725.	*	4 DEC 1400	105	.00	.00	.00	50.
2 DEC 0200	45	6.39	2.49	3.90	3452.	*	4 DEC 1500	106	.00	.00	.00	50.
2 DEC 0300	46	6.39	2.49	3.90	3195.	*	4 DEC 1600	107	.00	.00	.00	50.
2 DEC 0400	47	6.39	2.49	3.90	2954.	*	4 DEC 1700	108	.00	.00	.00	50.
2 DEC 0500	48	5.68	2.49	3.19	2727.	*	4 DEC 1800	109	.00	.00	.00	50.
2 DEC 0600	49	5.68	2.49	3.19	2514.	*	4 DEC 1900	110	.00	.00	.00	50.
2 DEC 0700	50	.00	.00	.00	2314.	*	4 DEC 2000	111	.00	.00	.00	50.
2 DEC 0800	51	.00	.00	.00	2125.	*	4 DEC 2100	112	.00	.00	.00	50.
2 DEC 0900	52	.00	.00	.00	1950.	*	4 DEC 2200	113	.00	.00	.00	50.
2 DEC 1000	53	.00	.00	.00	1782.	*	4 DEC 2300	114	.00	.00	.00	50.
2 DEC 1100	54	.00	.00	.00	1620.	*	5 DEC 0000	115	.00	.00	.00	50.
2 DEC 1200	55	.00	.00	.00	1464.	*	5 DEC 0100	116	.00	.00	.00	50.
2 DEC 1300	56	.00	.00	.00	1315.	*	5 DEC 0200	117	.00	.00	.00	50.
2 DEC 1400	57	.00	.00	.00	1174.	*	5 DEC 0300	118	.00	.00	.00	50.
2 DEC 1500	58	.00	.00	.00	1044.	*	5 DEC 0400	119	.00	.00	.00	50.
2 DEC 1600	59	.00	.00	.00	928.	*	5 DEC 0500	120	.00	.00	.00	50.
2 DEC 1700	60	.00	.00	.00	824.	*	5 DEC 0600	121	.00	.00	.00	50.
2 DEC 1800	61	.00	.00	.00	733.	*						
						*						

```
*****************************************************************************************************************

   TOTAL RAINFALL =  710.00, TOTAL LOSS =  119.52, TOTAL EXCESS =  590.48

  PEAK FLOW     TIME                        MAXIMUM AVERAGE FLOW
                                    6-HR        24-HR        72-HR     120.00-HR
+  (CU M/S)     (HR)
                          (CU M/S)
+    5375.     37.00              5115.        3534.        1574.         967.
                              (MM)  163.934      453.012      605.135      619.796
                       (1000 CU M)  110492.      305330.      407861.      417742.

                         CUMULATIVE AREA =  674.00 SQ KM

1                                                  STATION      SB03

                           (O) OUTFLOW
         0.      1000.     2000.     3000.     4000.     5000.     6000.        0.        0.        0.        0.        0.        0.
                                                                                              (L) PRECIP,    (X) EXCESS
         0.         0.        0.        0.        0.        0.        0.        0.        0.      120.       80.       40.        0.
DAHRMN PER
```

```
300600   1.O------------------------------------------------------------------------------------------------------.
300700   2.O                                                                                                       .
300800   3.O                                                                                                     X.
300900   4.O                                                                                                     X.
301000   5.O                                                                                                     X.
301100   6.O                                                                                                     X.
301200   7.O                                                                                                     X.
301300   8. O                                                                                                    X.
301400   9. O                                                                                                    X.
301500  10. O                                                                                                    X.
301600  11. .O. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . X.
301700  12.  O . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .X.
301800  13.   O                                                                                                  X.
301900  14.   O                                                                                                 LX.
302000  15.   O                                                                                                 LX.
302100  16.    O                                                                                                LX.
302200  17.    O                                                                                                LX.
302300  18.    O                                                                                                LX.
 10000  19.     O                                                                                               LX.
 10100  20.     O                                                                                              LXX.
 10200  21. . . O . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . LXX.
 10300  22.      O . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .LXX.
 10400  23.       O                                                                                            LXX.
 10500  24.       O                                                                                           LXXX.
 10600  25.        O.                                                                                         LXXX.
 10700  26.         O                                                                                         LXXX.
 10800  27.         .O                                                                                       XXXXX.
 10900  28.           O                                                                                    LXXXXXX.
 11000  29.             O                                                                                  LXXXXXX.
 11100  30.                 O.                                                      LXXXXXXXXXXXXXXXXXXXXXXXX.
 11200  31. . . . . . . . . . . .O. . . . . . . . . . . . . . . . . . . . . . . .  LXXXXXXXXXXXXXXXXXXXXXXXXX.
 11300  32.                          O . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . LXXXXXXXXXXX.
 11400  33.                                 O                                                          LXXXXXXX.
 11500  34.                                        .O                                                    XXXXX.
 11600  35.                                              O                                               XXXXX.
 11700  36.                                                  .O                                           LXXXX.
 11800  37.                                                     O                                         LXXXX.
 11900  38.                                                     O                                          LXX.
 12000  39.                                                   O                                            LXX.
 12100  40.                                                O.                                              LXX.
 12200  41. . . . . . . . . . . . . . . . . . . . . . . O . . . . . . . . . . . . . . . . . . . . . . . . LXX.
 12300  42.                                          O . . . . . . . . . . . . . . . . . . . . . . . . . . .LXX.
 20000  43.                                      O                                                          LX.
 20100  44.                                   O                                                             LX.
 20200  45.                                 O                                                               LX.
 20300  46.                              .O                                                                 LX.
 20400  47.                            O                                                                    LX.
 20500  48.                        O                                                                        LX.
 20600  49.                      O                                                                           X.
 20700  50.                    O                                                                             X.
 20800  51. . . . . . . . . .O. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .
 20900  52.                O.                                                                                 .
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21000  53.         .       O .         .         .         .         .         .         .         .         .         .         .
21100  54.         .     O   .         .         .         .         .         .         .         .         .         .         .
21200  55.         .    O    .         .         .         .         .         .         .         .         .         .         .
21300  56.         .  O      .         .         .         .         .         .         .         .         .         .         .
21400  57.         . O       .         .         .         .         .         .         .         .         .         .         .
21500  58.         O         .         .         .         .         .         .         .         .         .         .         .
21600  59.        O.         .         .         .         .         .         .         .         .         .         .         .
21700  60.       O .         .         .         .         .         .         .         .         .         .         .         .
21800  61. . . .O. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .
21900  62.      O  .         .         .         .         .         .         .         .         .         .         .         .
22000  63.     O   .         .         .         .         .         .         .         .         .         .         .         .
22100  64.    O    .         .         .         .         .         .         .         .         .         .         .         .
22200  65.    O    .         .         .         .         .         .         .         .         .         .         .         .
22300  66.   O     .         .         .         .         .         .         .         .         .         .         .         .
30000  67.   O     .         .         .         .         .         .         .         .         .         .         .         .
30100  68.  O      .         .         .         .         .         .         .         .         .         .         .         .
30200  69.  O      .         .         .         .         .         .         .         .         .         .         .         .
30300  70.  O      .         .         .         .         .         .         .         .         .         .         .         .
30400  71. O . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .
30500  72. O       .         .         .         .         .         .         .         .         .         .         .         .
30600  73. O       .         .         .         .         .         .         .         .         .         .         .         .
30700  74. O       .         .         .         .         .         .         .         .         .         .         .         .
30800  75. O       .         .         .         .         .         .         .         .         .         .         .         .
30900  76.O        .         .         .         .         .         .         .         .         .         .         .         .
31000  77.O        .         .         .         .         .         .         .         .         .         .         .         .
31100  78.O        .         .         .         .         .         .         .         .         .         .         .         .
31200  79.O        .         .         .         .         .         .         .         .         .         .         .         .
31300  80.O        .         .         .         .         .         .         .         .         .         .         .         .
31400  81.O. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .
31500  82.O        .         .         .         .         .         .         .         .         .         .         .         .
31600  83.O        .         .         .         .         .         .         .         .         .         .         .         .
31700  84.O        :         .         .         .         .         .         .         .         .         .         .         .
31800  85.O        .         .         .         .         .         .         .         .         .         .         .         .
31900  86.O        .         .         .         .         .         .         .         .         .         .         .         .
32000  87.O        .         .         .         .         .         .         .         .         .         .         .         .
32100  88.O        .         .         .         .         .         .         .         .         .         .         .         .
32200  89.O        .         .         .         .         .         .         .         .         .         .         .         .
32300  90.O        .         .         .         .         .         .         .         .         .         .         .         .
40000  91.O. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .
40100  92.O        .         .         .         .         .         .         .         .         .         .         .         .
40200  93.O        .         .         .         .         .         .         .         .         .         .         .         .
40300  94.O        .         .         .         .         .         .         .         .         .         .         .         .
40400  95.O        .         .         .         .         .         .         .         .         .         .         .         .
40500  96.O        .         .         .         .         .         .         .         .         .         .         .         .
40600  97.O        .         .         .         .         .         .         .         .         .         .         .         .
40700  98.O        .         .         .         .         .         .         .         .         .         .         .         .
40800  99.O        .         .         .         .         .         .         .         .         .         .         .         .
40900 100.O        .         .         .         .         .         .         .         .         .         .         .         .
41000 101.O. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .
41100 102.O        .         .         .         .         .         .         .         .         .         .         .         .
41200 103.O        .         .         .         .         .         .         .         .         .         .         .         .
41300 104.O        .         .         .         .         .         .         .         .         .         .         .         .
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 41400 105.0         .         .         .         .         .         .         .         .         .         .         .          .
 41500 106.0         .         .         .         .         .         .         .         .         .         .         .          .
 41600 107.0         .         .         .         .         .         .         .         .         .         .         .          .
 41700 108.0         .         .         .         .         .         .         .         .         .         .         .          .
 41800 109.0         .         .         .         .         .         .         .         .         .         .         .          .
 41900 110.0         .         .         .         .         .         .         .         .         .         .         .          .
 42000 111.0. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .
 42100 112.0         .         .         .         .         .         .         .         .         .         .         .          .
 42200 113.0         .         .         .         .         .         .         .         .         .         .         .          .
 42300 114.0         .         .         .         .         .         .         .         .         .         .         .          .
 50000 115.0         .         .         .         .         .         .         .         .         .         .         .          .
 50100 116.0         .         .         .         .         .         .         .         .         .         .         .          .
 50200 117.0         .         .         .         .         .         .         .         .         .         .         .          .
 50300 118.0         .         .         .         .         .         .         .         .         .         .         .          .
 50400 119.0         .         .         .         .         .         .         .         .         .         .         .          .
 50500 120.0         .         .         .         .         .         .         .         .         .         .         .          .
 50600 121.0---------.---------.---------.---------.---------.---------.---------.---------.---------.---------.---------.----------.
1


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             *            *
  21 KK      *     SB02   *
             *            *
             **************
                             RUNOFF FROM SUB-BASIN 02

   5 IN              TIME DATA FOR INPUT TIME SERIES
                          JXMIN          60  TIME INTERVAL IN MINUTES
                         JXDATE     30NOV 2  STARTING DATE
                         JXTIME         600  STARTING TIME

                   SUBBASIN RUNOFF DATA

  23 BA              SUBBASIN CHARACTERISTICS
                          TAREA      805.00  SUBBASIN AREA

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

                   PRECIPITATION DATA

  25 PB                   STORM      679.00  BASIN TOTAL PRECIPITATION

  26 PI                 INCREMENTAL PRECIPITATION PATTERN
                          .70       .70       .70       .70       .80       .80       .80       .80       .80       .80
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.80	.90	.90	1.00	1.00	1.00	1.00	1.50	1.50	1.50
1.50	2.00	2.00	2.00	3.00	4.00	4.00	13.50	14.00	6.50
4.00	3.00	3.00	2.00	2.00	1.50	1.50	1.50	1.50	1.50
1.00	1.00	1.00	.90	.90	.90	.80	.80		

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31 LU          UNIFORM LOSS RATE
                    STRTL          .00  INITIAL LOSS
                    CNSTL         3.00  UNIFORM LOSS RATE
                    RTIMP        17.00  PERCENT IMPERVIOUS AREA

32 UC          CLARK UNITGRAPH
                       TC        13.00  TIME OF CONCENTRATION
                        R        12.30  STORAGE COEFFICIENT

33 UA          ACCUMULATED-AREA VS. TIME,  12 ORDINATES
                    2.3      5.2      7.6     11.3     18.5     30.4     44.7     61.6     71.1     81.5
                   90.2    100.0
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UNIT HYDROGRAPH PARAMETERS

CLARK TC= 13.00 HR, R= 12.30 HR

SNYDER TP= 13.17 HR, CP= .67

UNIT HYDROGRAPH

73 END-OF-PERIOD ORDINATES

0.	1.	1.	2.	3.	4.	6.	8.	9.	10.
11.	11.	12.	11.	11.	10.	9.	8.	8.	7.
6.	6.	6.	5.	5.	4.	4.	4.	3.	3.
3.	3.	2.	2.	2.	2.	2.	2.	2.	1.
1.	1.	1.	1.	1.	1.	1.	1.	1.	1.
1.	1.	0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.							

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HYDROGRAPH AT STATION SB02

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DA MON HRMN	ORD	RAIN	LOSS	EXCESS	COMP Q	*	DA MON HRMN	ORD	RAIN	LOSS	EXCESS	COMP Q
30 NOV 0600	1	.00	.00	.00	50.	*	2 DEC 1900	62	.00	.00	.00	1556.
30 NOV 0700	2	4.75	2.49	2.26	51.	*	2 DEC 2000	63	.00	.00	.00	1438.
30 NOV 0800	3	4.75	2.49	2.26	53.	*	2 DEC 2100	64	.00	.00	.00	1330.
30 NOV 0900	4	4.75	2.49	2.26	56.	*	2 DEC 2200	65	.00	.00	.00	1230.
30 NOV 1000	5	4.75	2.49	2.26	60.	*	2 DEC 2300	66	.00	.00	.00	1138.
30 NOV 1100	6	5.43	2.49	2.94	67.	*	3 DEC 0000	67	.00	.00	.00	1053.
30 NOV 1200	7	5.43	2.49	2.94	77.	*	3 DEC 0100	68	.00	.00	.00	974.
30 NOV 1300	8	5.43	2.49	2.94	90.	*	3 DEC 0200	69	.00	.00	.00	902.
30 NOV 1400	9	5.43	2.49	2.94	109.	*	3 DEC 0300	70	.00	.00	.00	836.

30 NOV 1500	10	5.43	2.49	2.94	131.	*
30 NOV 1600	11	5.43	2.49	2.94	156.	*
30 NOV 1700	12	5.43	2.49	2.94	184.	*
30 NOV 1800	13	6.11	2.49	3.62	214.	*
30 NOV 1900	14	6.11	2.49	3.62	248.	*
30 NOV 2000	15	6.79	2.49	4.30	281.	*
30 NOV 2100	16	6.79	2.49	4.30	314.	*
30 NOV 2200	17	6.79	2.49	4.30	347.	*
30 NOV 2300	18	6.79	2.49	4.30	379.	*
1 DEC 0000	19	10.18	2.49	7.69	413.	*
1 DEC 0100	20	10.19	2.49	7.70	448.	*
1 DEC 0200	21	10.18	2.49	7.69	485.	*
1 DEC 0300	22	10.18	2.49	7.69	524.	*
1 DEC 0400	23	13.58	2.49	11.09	567.	*
1 DEC 0500	24	13.58	2.49	11.09	616.	*
1 DEC 0600	25	13.58	2.49	11.09	672.	*
1 DEC 0700	26	20.37	2.49	17.88	737.	*
1 DEC 0800	27	27.16	2.49	24.67	815.	*
1 DEC 0900	28	27.16	2.49	24.67	905.	*
1 DEC 1000	29	91.66	2.49	89.17	1034.	*
1 DEC 1100	30	95.06	2.49	92.57	1216.	*
1 DEC 1200	31	44.13	2.49	41.64	1421.	*
1 DEC 1300	32	27.16	2.49	24.67	1646.	*
1 DEC 1400	33	20.37	2.49	17.88	1921.	*
1 DEC 1500	34	20.37	2.49	17.88	2267.	*
1 DEC 1600	35	13.58	2.49	11.09	2678.	*
1 DEC 1700	36	13.58	2.49	11.09	3132.	*
1 DEC 1800	37	10.18	2.49	7.69	3575.	*
1 DEC 1900	38	10.18	2.49	7.69	3945.	*
1 DEC 2000	39	10.18	2.49	7.69	4234.	*
1 DEC 2100	40	10.18	2.49	7.69	4455.	*
1 DEC 2200	41	10.18	2.49	7.69	4620.	*
1 DEC 2300	42	6.79	2.49	4.30	4696.	*
2 DEC 0000	43	6.79	2.49	4.30	4642.	*
2 DEC 0100	44	6.79	2.49	4.30	4502.	*
2 DEC 0200	45	6.11	2.49	3.62	4332.	*
2 DEC 0300	46	6.11	2.49	3.62	4152.	*
2 DEC 0400	47	6.11	2.49	3.62	3966.	*
2 DEC 0500	48	5.43	2.49	2.94	3778.	*
2 DEC 0600	49	5.43	2.49	2.94	3591.	*
2 DEC 0700	50	.00	.00	.00	3406.	*
2 DEC 0800	51	.00	.00	.00	3227.	*
2 DEC 0900	52	.00	.00	.00	3053.	*
2 DEC 1000	53	.00	.00	.00	2884.	*
2 DEC 1100	54	.00	.00	.00	2718.	*
2 DEC 1200	55	.00	.00	.00	2556.	*
2 DEC 1300	56	.00	.00	.00	2398.	*
2 DEC 1400	57	.00	.00	.00	2244.	*
2 DEC 1500	58	.00	.00	.00	2094.	*
2 DEC 1600	59	.00	.00	.00	1950.	*
2 DEC 1700	60	.00	.00	.00	1813.	*
2 DEC 1800	61	.00	.00	.00	1681.	*

3 DEC 0400	71	.00	.00	.00	774.
3 DEC 0500	72	.00	.00	.00	718.
3 DEC 0600	73	.00	.00	.00	665.
3 DEC 0700	74	.00	.00	.00	617.
3 DEC 0800	75	.00	.00	.00	573.
3 DEC 0900	76	.00	.00	.00	532.
3 DEC 1000	77	.00	.00	.00	494.
3 DEC 1100	78	.00	.00	.00	459.
3 DEC 1200	79	.00	.00	.00	427.
3 DEC 1300	80	.00	.00	.00	397.
3 DEC 1400	81	.00	.00	.00	370.
3 DEC 1500	82	.00	.00	.00	345.
3 DEC 1600	83	.00	.00	.00	321.
3 DEC 1700	84	.00	.00	.00	300.
3 DEC 1800	85	.00	.00	.00	280.
3 DEC 1900	86	.00	.00	.00	262.
3 DEC 2000	87	.00	.00	.00	245.
3 DEC 2100	88	.00	.00	.00	229.
3 DEC 2200	89	.00	.00	.00	215.
3 DEC 2300	90	.00	.00	.00	202.
4 DEC 0000	91	.00	.00	.00	189.
4 DEC 0100	92	.00	.00	.00	178.
4 DEC 0200	93	.00	.00	.00	167.
4 DEC 0300	94	.00	.00	.00	157.
4 DEC 0400	95	.00	.00	.00	148.
4 DEC 0500	96	.00	.00	.00	140.
4 DEC 0600	97	.00	.00	.00	132.
4 DEC 0700	98	.00	.00	.00	124.
4 DEC 0800	99	.00	.00	.00	117.
4 DEC 0900	100	.00	.00	.00	110.
4 DEC 1000	101	.00	.00	.00	103.
4 DEC 1100	102	.00	.00	.00	91.
4 DEC 1200	103	.00	.00	.00	80.
4 DEC 1300	104	.00	.00	.00	74.
4 DEC 1400	105	.00	.00	.00	70.
4 DEC 1500	106	.00	.00	.00	67.
4 DEC 1600	107	.00	.00	.00	64.
4 DEC 1700	108	.00	.00	.00	62.
4 DEC 1800	109	.00	.00	.00	60.
4 DEC 1900	110	.00	.00	.00	58.
4 DEC 2000	111	.00	.00	.00	57.
4 DEC 2100	112	.00	.00	.00	56.
4 DEC 2200	113	.00	.00	.00	55.
4 DEC 2300	114	.00	.00	.00	54.
5 DEC 0000	115	.00	.00	.00	53.
5 DEC 0100	116	.00	.00	.00	52.
5 DEC 0200	117	.00	.00	.00	52.
5 DEC 0300	118	.00	.00	.00	51.
5 DEC 0400	119	.00	.00	.00	51.
5 DEC 0500	120	.00	.00	.00	51.
5 DEC 0600	121	.00	.00	.00	50.

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    TOTAL RAINFALL =  679.00, TOTAL LOSS =  119.52, TOTAL EXCESS =  559.48

  PEAK FLOW     TIME                              MAXIMUM AVERAGE FLOW
                                         6-HR         24-HR        72-HR      120.00-HR
+  (CU M/S)     (HR)
                                (CU M/S)
+    4696.     41.00                    4533.         3540.        1741.         1087.
                                    (MM)  121.634       379.973      560.424       583.524
                               (1000 CU M)  97916.       305878.      451141.       469737.

                                  CUMULATIVE AREA =  805.00 SQ KM

1                                                                              STATION     SB02

                                  (O) OUTFLOW
          0.      1000.      2000.      3000.      4000.      5000.         0.         0.         0.         0.         0.         0.         0.
                                                                                                                (L) PRECIP,    (X) EXCESS
          0.         0.         0.         0.         0.         0.         0.         0.         0.       120.        80.        40.         0.
DAHRMN PER
300600   1.O---------.---------.---------.---------.---------.---------.---------.---------.---------.---------.---------.---------.
300700   2.O         .         .         .         .         .         .         .         .         .         .         .        X.
300800   3.O         .         .         .         .         .         .         .         .         .         .         .        X.
300900   4.O         .         .         .         .         .         .         .         .         .         .         .        X.
301000   5.O         .         .         .         .         .         .         .         .         .         .         .        X.
301100   6.O         .         .         .         .         .         .         .         .         .         .         .        X.
301200   7.O         .         .         .         .         .         .         .         .         .         .         .        X.
301300   8.O         .         .         .         .         .         .         .         .         .         .         .        X.
301400   9.O         .         .         .         .         .         .         .         .         .         .         .        X.
301500  10.O         .         .         .         .         .         .         .         .         .         .         .        X.
301600  11. O . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .X.
301700  12. O        .         .         .         .         .         .         .         .         .         .         .        X.
301800  13. O        .         .         .         .         .         .         .         .         .         .         .       LX.
301900  14. O        .         .         .         .         .         .         .         .         .         .         .       LX.
302000  15.  O       .         .         .         .         .         .         .         .         .         .         .       LX.
302100  16.  O       .         .         .         .         .         .         .         .         .         .         .       LX.
302200  17.  O       .         .         .         .         .         .         .         .         .         .         .       LX.
302300  18.   O      .         .         .         .         .         .         .         .         .         .         .       LX.
 10000  19.   O      .         .         .         .         .         .         .         .         .         .         .      LXX.
 10100  20.   O      .         .         .         .         .         .         .         .         .         .         .      LXX.
 10200  21. . .O. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .LXX.
 10300  22.    O     .         .         .         .         .         .         .         .         .         .         .      LXX.
 10400  23.     O    .         .         .         .         .         .         .         .         .         .         .      XXX.
 10500  24.     O    .         .         .         .         .         .         .         .         .         .         .      XXX.
 10600  25.      O   .         .         .         .         .         .         .         .         .         .         .      XXX.
 10700  26.      O   .         .         .         .         .         .         .         .         .         .         .    LXXXX.
 10800  27.       O  .         .         .         .         .         .         .         .         .         .         .  LXXXXXX.
 10900  28.        O.          .         .         .         .         .         .         .         .         .         .  LXXXXXX.
 11000  29.         O          .         .         .         .         .         .         .         .         .  LXXXXXXXXXXXXXXXXXXXXXX.
 11100  30.         . O        .         .         .         .         .         .         .         .         . LXXXXXXXXXXXXXXXXXXXXXXX.
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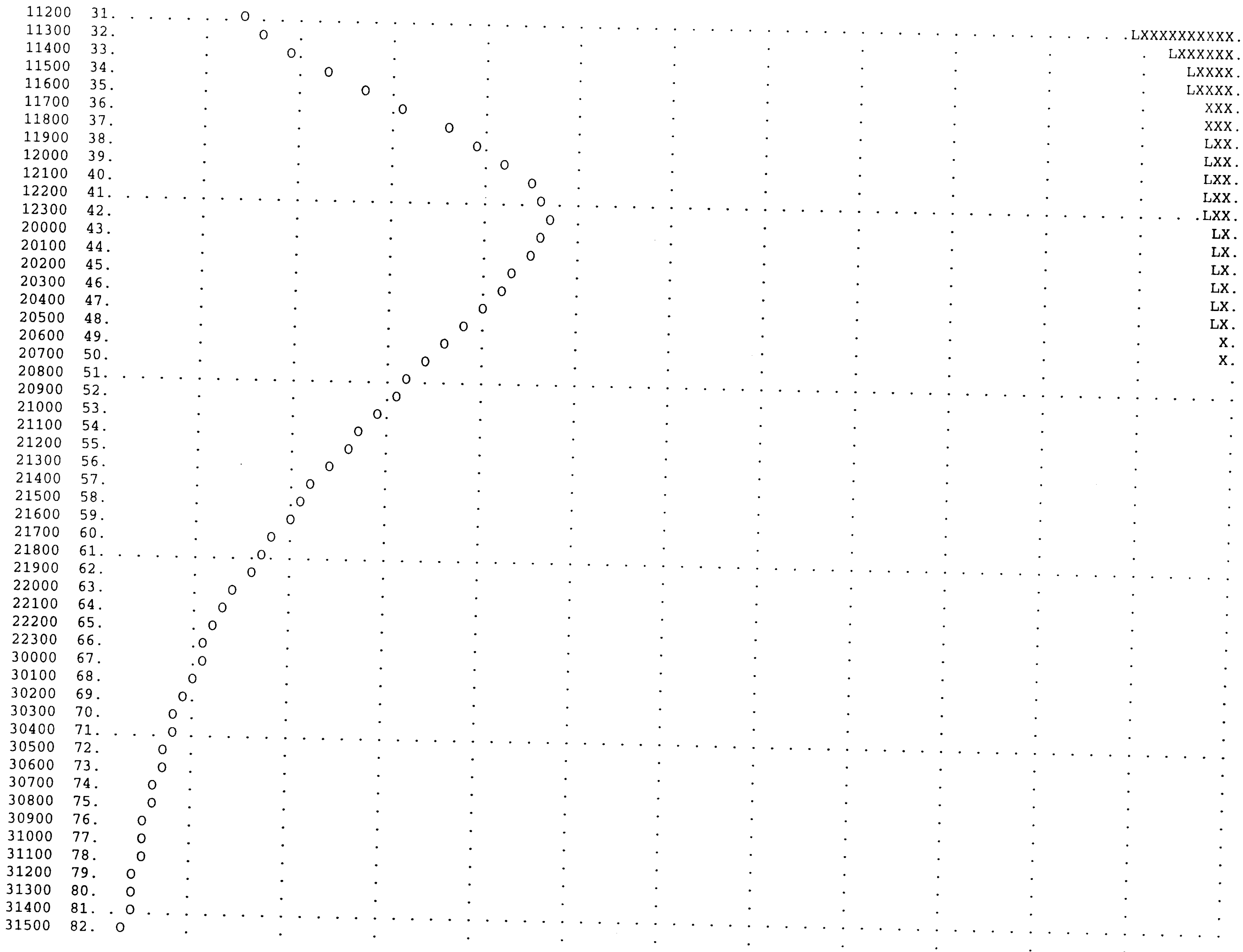
11200 31.
11300 32.
11400 33.
11500 34.
11600 35.
11700 36.
11800 37.
11900 38.
12000 39.
12100 40.
12200 41.
12300 42.
20000 43.
20100 44.
20200 45.
20300 46.
20400 47.
20500 48.
20600 49.
20700 50.
20800 51.
20900 52.
21000 53.
21100 54.
21200 55.
21300 56.
21400 57.
21500 58.
21600 59.
21700 60.
21800 61.
21900 62.
22000 63.
22100 64.
22200 65.
22300 66.
30000 67.
30100 68.
30200 69.
30300 70.
30400 71.
30500 72.
30600 73.
30700 74.
30800 75.
30900 76.
31000 77.
31100 78.
31200 79.
31300 80.
31400 81.
31500 82.

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31600  83.  O      .         .         .         .         .         .         .         .         .         .         .         .
31700  84.  O      .         .         .         .         .         .         .         .         .         .         .         .
31800  85.  O      .         .         .         .         .         .         .         .         .         .         .         .
31900  86.  O      .         .         .         .         .         .         .         .         .         .         .         .
32000  87. O       .         .         .         .         .         .         .         .         .         .         .         .
32100  88. O       .         .         .         .         .         .         .         .         .         .         .         .
32200  89. O       .         .         .         .         .         .         .         .         .         .         .         .
32300  90. O       .         .         .         .         .         .         .         .         .         .         .         .
40000  91. O . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .
40100  92. O       .         .         .         .         .         .         .         .         .         .         .         .
40200  93. O       .         .         .         .         .         .         .         .         .         .         .         .
40300  94. O       .         .         .         .         .         .         .         .         .         .         .         .
40400  95.O        .         .         .         .         .         .         .         .         .         .         .         .
40500  96.O        .         .         .         .         .         .         .         .         .         .         .         .
40600  97.O        .         .         .         .         .         .         .         .         .         .         .         .
40700  98.O        .         .         .         .         .         .         .         .         .         .         .         .
40800  99.O        .         .         .         .         .         .         .         .         .         .         .         .
40900 100.O        .         .         .         .         .         .         .         .         .         .         .         .
41000 101.O. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .
41100 102.O        .         .         .         .         .         .         .         .         .         .         .         .
41200 103.O        .         .         .         .         .         .         .         .         .         .         .         .
41300 104.O        .         .         .         .         .         .         .         .         .         .         .         .
41400 105.O        .         .         .         .         .         .         .         .         .         .         .         .
41500 106.O        .         .         .         .         .         .         .         .         .         .         .         .
41600 107.O        .         .         .         .         .         .         .         .         .         .         .         .
41700 108.O        .         .         .         .         .         .         .         .         .         .         .         .
41800 109.O        .         .         .         .         .         .         .         .         .         .         .         .
41900 110.O        .         .         .         .         .         .         .         .         .         .         .         .
42000 111.O. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .
42100 112.O        .         .         .         .         .         .         .         .         .         .         .         .
42200 113.O        .         .         .         .         .         .         .         .         .         .         .         .
42300 114.O        .         .         .         .         .         .         .         .         .         .         .         .
50000 115.O        .         .         .         .         .         .         .         .         .         .         .         .
50100 116.O        .         .         .         .         .         .         .         .         .         .         .         .
50200 117.O        .         .         .         .         .         .         .         .         .         .         .         .
50300 118.O        .         .         .         .         .         .         .         .         .         .         .         .
50400 119.O        .         .         .         .         .         .         .         .         .         .         .         .
50500 120.O        .         .         .         .         .         .         .         .         .         .         .         .
50600 121.O--------.---------.---------.---------.---------.---------.---------.---------.---------.---------.---------.---------.
1


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


              **************
              *            *
  35 KK       *      SB02  *
              *            *
              **************
                                 COMBINE TWO HYDROGRAPHS
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37 HC HYDROGRAPH COMBINATION

ICOMP 2 NUMBER OF HYDROGRAPHS TO COMBINE

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HYDROGRAPH AT STATION SB02

SUM OF 2 HYDROGRAPHS

DA MON HRMN	ORD	FLOW	DA MON HRMN	ORD	FLOW	DA MON HRMN	ORD	FLOW	DA MON HRMN	ORD	FLOW
30 NOV 0600	1	100.	1 DEC 1300	32	4447.	2 DEC 2000	63	2019.	4 DEC 0300	94	209.
30 NOV 0700	2	103.	1 DEC 1400	33	5367.	2 DEC 2100	64	1847.	4 DEC 0400	95	199.
30 NOV 0800	3	111.	1 DEC 1500	34	6381.	2 DEC 2200	65	1692.	4 DEC 0500	96	190.
30 NOV 0900	4	122.	1 DEC 1600	35	7379.	2 DEC 2300	66	1551.	4 DEC 0600	97	182.
30 NOV 1000	5	140.	1 DEC 1700	36	8267.	3 DEC 0000	67	1422.	4 DEC 0700	98	174.
30 NOV 1100	6	169.	1 DEC 1800	37	8940.	3 DEC 0100	68	1306.	4 DEC 0800	99	167.
30 NOV 1200	7	208.	1 DEC 1900	38	9320.	3 DEC 0200	69	1199.	4 DEC 0900	100	160.
30 NOV 1300	8	256.	1 DEC 2000	39	9443.	3 DEC 0300	70	1103.	4 DEC 1000	101	153.
30 NOV 1400	9	314.	1 DEC 2100	40	9395.	3 DEC 0400	71	1015.	4 DEC 1100	102	141.
30 NOV 1500	10	377.	1 DEC 2200	41	9254.	3 DEC 0500	72	935.	4 DEC 1200	103	130.
30 NOV 1600	11	443.	1 DEC 2300	42	9017.	3 DEC 0600	73	862.	4 DEC 1300	104	124.
30 NOV 1700	12	510.	2 DEC 0000	43	8657.	3 DEC 0700	74	794.	4 DEC 1400	105	120.
30 NOV 1800	13	577.	2 DEC 0100	44	8227.	3 DEC 0800	75	732.	4 DEC 1500	106	117.
30 NOV 1900	14	644.	2 DEC 0200	45	7784.	3 DEC 0900	76	676.	4 DEC 1600	107	114.
30 NOV 2000	15	711.	2 DEC 0300	46	7347.	3 DEC 1000	77	617.	4 DEC 1700	108	112.
30 NOV 2100	16	776.	2 DEC 0400	47	6920.	3 DEC 1100	78	564.	4 DEC 1800	109	110.
30 NOV 2200	17	840.	2 DEC 0500	48	6505.	3 DEC 1200	79	521.	4 DEC 1900	110	108.
30 NOV 2300	18	904.	2 DEC 0600	49	6105.	3 DEC 1300	80	483.	4 DEC 2000	111	107.
1 DEC 0000	19	975.	2 DEC 0700	50	5720.	3 DEC 1400	81	450.	4 DEC 2100	112	106.
1 DEC 0100	20	1052.	2 DEC 0800	51	5352.	3 DEC 1500	82	419.	4 DEC 2200	113	105.
1 DEC 0200	21	1134.	2 DEC 0900	52	5003.	3 DEC 1600	83	392.	4 DEC 2300	114	104.
1 DEC 0300	22	1225.	2 DEC 1000	53	4667.	3 DEC 1700	84	367.	5 DEC 0000	115	103.
1 DEC 0400	23	1331.	2 DEC 1100	54	4339.	3 DEC 1800	85	344.	5 DEC 0100	116	102.
1 DEC 0500	24	1454.	2 DEC 1200	55	4020.	3 DEC 1900	86	323.	5 DEC 0200	117	102.
1 DEC 0600	25	1591.	2 DEC 1300	56	3713.	3 DEC 2000	87	304.	5 DEC 0300	118	101.
1 DEC 0700	26	1754.	2 DEC 1400	57	3418.	3 DEC 2100	88	287.	5 DEC 0400	119	101.
1 DEC 0800	27	1953.	2 DEC 1500	58	3138.	3 DEC 2200	89	271.	5 DEC 0500	120	101.
1 DEC 0900	28	2185.	2 DEC 1600	59	2878.	3 DEC 2300	90	256.	5 DEC 0600	121	100.
1 DEC 1000	29	2541.	2 DEC 1700	60	2637.	4 DEC 0000	91	243.			
1 DEC 1100	30	3076.	2 DEC 1800	61	2414.	4 DEC 0100	92	231.			
1 DEC 1200	31	3700.	2 DEC 1900	62	2208.	4 DEC 0200	93	219.			

PEAK FLOW	TIME	MAXIMUM AVERAGE FLOW			
		6-HR	24-HR	72-HR	120.00-HR
+ (CU M/S)	(HR)				

```
                                   (CU M/S)
 +     9443.      38.00                      9205.        6987.        3303.        2054.
                                  (MM)    134.429      408.187      578.883      600.053
                           (1000 CU M)    198820.      603708.      856168.      887479.

                           CUMULATIVE AREA = 1479.00 SQ KM

1                                                                       STATION     SB02

                         (O) OUTFLOW
          0.      1000.     2000.     3000.     4000.     5000.     6000.     7000.     8000.     9000.    10000.        0.        0.
DAHRMN PER
300600    1.O---------.---------.---------.---------.---------.---------.---------.---------.---------.---------.---------.---------.
300700    2.O         .         .         .         .         .         .         .         .         .         .         .         .
300800    3.O         .         .         .         .         .         .         .         .         .         .         .         .
300900    4.O         .         .         .         .         .         .         .         .         .         .         .         .
301000    5.O         .         .         .         .         .         .         .         .         .         .         .         .
301100    6. O        .         .         .         .         .         .         .         .         .         .         .         .
301200    7. O        .         .         .         .         .         .         .         .         .         .         .         .
301300    8.  O       .         .         .         .         .         .         .         .         .         .         .         .
301400    9.  O       .         .         .         .         .         .         .         .         .         .         .         .
301500   10.   O      .         .         .         .         .         .         .         .         .         .         .         .
301600   11. . O . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .
301700   12.    O     .         .         .         .         .         .         .         .         .         .         .         .
301800   13.     O    .         .         .         .         .         .         .         .         .         .         .         .
301900   14.     O    .         .         .         .         .         .         .         .         .         .         .         .
302000   15.      O   .         .         .         .         .         .         .         .         .         .         .         .
302100   16.       O  .         .         .         .         .         .         .         .         .         .         .         .
302200   17.       O  .         .         .         .         .         .         .         .         .         .         .         .
302300   18.        O .         .         .         .         .         .         .         .         .         .         .         .
 10000   19.          O         .         .         .         .         .         .         .         .         .         .         .
 10100   20.          .O        .         .         .         .         .         .         .         .         .         .         .
 10200   21. . . . . . .O. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .
 10300   22.          . O       .         .         .         .         .         .         .         .         .         .         .
 10400   23.          .  O      .         .         .         .         .         .         .         .         .         .         .
 10500   24.          .    O    .         .         .         .         .         .         .         .         .         .         .
 10600   25.          .     O   .         .         .         .         .         .         .         .         .         .         .
 10700   26.          .       O .         .         .         .         .         .         .         .         .         .         .
 10800   27.          .         O         .         .         .         .         .         .         .         .         .         .
 10900   28.          .         . O       .         .         .         .         .         .         .         .         .         .
 11000   29.          .         .    O    .         .         .         .         .         .         .         .         .         .
 11100   30.          .         .         .O        .         .         .         .         .         .         .         .         .
 11200   31. . . . . . . . . . . . . . . . . . .O. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .
 11300   32.          .         .         .         .   O     .         .         .         .         .         .         .         .
 11400   33.          .         .         .         .         .   O     .         .         .         .         .         .         .
 11500   34.          .         .         .         .         .         .   O     .         .         .         .         .         .
 11600   35.          .         .         .         .         .         .         .   O     .         .         .         .         .
 11700   36.          .         .         .         .         .         .         .         .  O      .         .         .         .
 11800   37.          .         .         .         .         .         .         .         .        O.         .         .         .
 11900   38.          .         .         .         .         .         .         .         .         .  O      .         .         .
 12000   39.          .         .         .         .         .         .         .         .         .   O     .         .         .
 12100   40.          .         .         .         .         .         .         .         .         .   O     .         .         .
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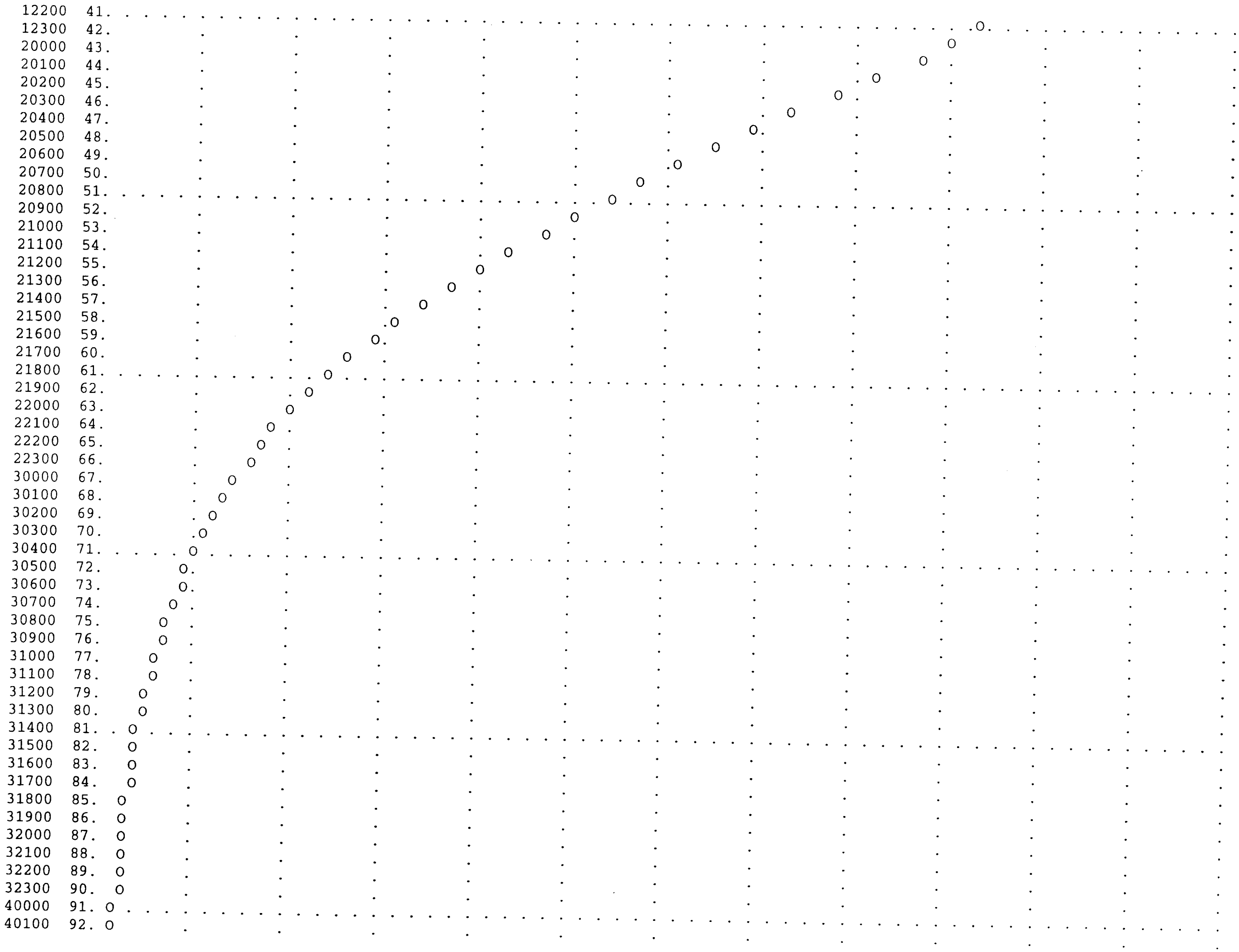
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12300 42.
20000 43.
20100 44.
20200 45.
20300 46.
20400 47.
20500 48.
20600 49.
20700 50.
20800 51.
20900 52.
21000 53.
21100 54.
21200 55.
21300 56.
21400 57.
21500 58.
21600 59.
21700 60.
21800 61.
21900 62.
22000 63.
22100 64.
22200 65.
22300 66.
30000 67.
30100 68.
30200 69.
30300 70.
30400 71.
30500 72.
30600 73.
30700 74.
30800 75.
30900 76.
31000 77.
31100 78.
31200 79.
31300 80.
31400 81.
31500 82.
31600 83.
31700 84.
31800 85.
31900 86.
32000 87.
32100 88.
32200 89.
32300 90.
40000 91.
40100 92.

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 40200  93. O       .         .         .         .         .         .         .         .         .         .         .         .
 40300  94. O       .         .         .         .         .         .         .         .         .         .         .         .
 40400  95. O       .         .         .         .         .         .         .         .         .         .         .         .
 40500  96. O       .         .         .         .         .         .         .         .         .         .         .         .
 40600  97. O       .         .         .         .         .         .         .         .         .         .         .         .
 40700  98. O       .         .         .         .         .         .         .         .         .         .         .         .
 40800  99. O       .         .         .         .         .         .         .         .         .         .         .         .
 40900 100. O       .         .         .         .         .         .         .         .         .         .         .         .
 41000 101. O . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .
 41100 102.O        .         .         .         .         .         .         .         .         .         .         .         .
 41200 103.O        .         .         .         .         .         .         .         .         .         .         .         .
 41300 104.O        .         .         .         .         .         .         .         .         .         .         .         .
 41400 105.O        .         .         .         .         .         .         .         .         .         .         .         .
 41500 106.O        .         .         .         .         .         .         .         .         .         .         .         .
 41600 107.O        .         .         .         .         .         .         .         .         .         .         .         .
 41700 108.O        .         .         .         .         .         .         .         .         .         .         .         .
 41800 109.O        .         .         .         .         .         .         .         .         .         .         .         .
 41900 110.O        .         .         .         .         .         .         .         .         .         .         .         .
 42000 111.O. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .
 42100 112.O        .         .         .         .         .         .         .         .         .         .         .         .
 42200 113.O        .         .         .         .         .         .         .         .         .         .         .         .
 42300 114.O        .         .         .         .         .         .         .         .         .         .         .         .
 50000 115.O        .         .         .         .         .         .         .         .         .         .         .         .
 50100 116.O        .         .         .         .         .         .         .         .         .         .         .         .
 50200 117.O        .         .         .         .         .         .         .         .         .         .         .         .
 50300 118.O        .         .         .         .         .         .         .         .         .         .         .         .
 50400 119.O        .         .         .         .         .         .         .         .         .         .         .         .
 50500 120.O        .         .         .         .         .         .         .         .         .         .         .         .
 50600 121.O--------.---------.---------.---------.---------.---------.---------.---------.---------.---------.---------.---------.
1


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            *            *
  38 KK     *     SB01   *
            *            *
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                                ROUTE COMBINED HYDROGRAPH TO SB01

               HYDROGRAPH ROUTING DATA

  40 RM          MUSKINGUM ROUTING
                       NSTPS          1 NUMBER OF SUBREACHES
                       AMSKK       1.00 MUSKINGUM K
                           X        .20 MUSKINGUM X

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HYDROGRAPH AT STATION SB01

DA MON HRMN	ORD	FLOW	DA MON HRMN	ORD	FLOW	DA MON HRMN	ORD	FLOW	DA MON HRMN	ORD	FLOW
30 NOV 0600	1	100.	1 DEC 1300	32	3736.	2 DEC 2000	63	2213.	4 DEC 0300	94	219.
30 NOV 0700	2	101.	1 DEC 1400	33	4495.	2 DEC 2100	64	2024.	4 DEC 0400	95	209.
30 NOV 0800	3	104.	1 DEC 1500	34	5400.	2 DEC 2200	65	1852.	4 DEC 0500	96	199.
30 NOV 0900	4	112.	1 DEC 1600	35	6385.	2 DEC 2300	66	1696.	4 DEC 0600	97	190.
30 NOV 1000	5	124.	1 DEC 1700	36	7354.	3 DEC 0000	67	1555.	4 DEC 0700	98	182.
30 NOV 1100	6	143.	1 DEC 1800	37	8212.	3 DEC 0100	68	1426.	4 DEC 0800	99	174.
30 NOV 1200	7	172.	1 DEC 1900	38	8860.	3 DEC 0200	69	1309.	4 DEC 0900	100	167.
30 NOV 1300	8	211.	1 DEC 2000	39	9242.	3 DEC 0300	70	1202.	4 DEC 1000	101	160.
30 NOV 1400	9	259.	1 DEC 2100	40	9386.	3 DEC 0400	71	1106.	4 DEC 1100	102	152.
30 NOV 1500	10	316.	1 DEC 2200	41	9361.	3 DEC 0500	72	1017.	4 DEC 1200	103	141.
30 NOV 1600	11	378.	1 DEC 2300	42	9224.	3 DEC 0600	73	937.	4 DEC 1300	104	131.
30 NOV 1700	12	443.	2 DEC 0000	43	8982.	3 DEC 0700	74	863.	4 DEC 1400	105	124.
30 NOV 1800	13	510.	2 DEC 0100	44	8633.	3 DEC 0800	75	796.	4 DEC 1500	106	120.
30 NOV 1900	14	577.	2 DEC 0200	45	8219.	3 DEC 0900	76	734.	4 DEC 1600	107	117.
30 NOV 2000	15	644.	2 DEC 0300	46	7784.	3 DEC 1000	77	676.	4 DEC 1700	108	114.
30 NOV 2100	16	711.	2 DEC 0400	47	7349.	3 DEC 1100	78	618.	4 DEC 1800	109	112.
30 NOV 2200	17	776.	2 DEC 0500	48	6924.	3 DEC 1200	79	567.	4 DEC 1900	110	110.
30 NOV 2300	18	840.	2 DEC 0600	49	6509.	3 DEC 1300	80	523.	4 DEC 2000	111	108.
1 DEC 0000	19	906.	2 DEC 0700	50	6109.	3 DEC 1400	81	485.	4 DEC 2100	112	107.
1 DEC 0100	20	977.	2 DEC 0800	51	5725.	3 DEC 1500	82	451.	4 DEC 2200	113	106.
1 DEC 0200	21	1053.	2 DEC 0900	52	5358.	3 DEC 1600	83	420.	4 DEC 2300	114	105.
1 DEC 0300	22	1137.	2 DEC 1000	53	5007.	3 DEC 1700	84	392.	5 DEC 0000	115	104.
1 DEC 0400	23	1229.	2 DEC 1100	54	4670.	3 DEC 1800	85	367.	5 DEC 0100	116	103.
1 DEC 0500	24	1336.	2 DEC 1200	55	4342.	3 DEC 1900	86	345.	5 DEC 0200	117	102.
1 DEC 0600	25	1458.	2 DEC 1300	56	4024.	3 DEC 2000	87	324.	5 DEC 0300	118	102.
1 DEC 0700	26	1598.	2 DEC 1400	57	3717.	3 DEC 2100	88	305.	5 DEC 0400	119	101.
1 DEC 0800	27	1764.	2 DEC 1500	58	3422.	3 DEC 2200	89	287.	5 DEC 0500	120	101.
1 DEC 0900	28	1963.	2 DEC 1600	59	3144.	3 DEC 2300	90	271.	5 DEC 0600	121	101.
1 DEC 1000	29	2216.	2 DEC 1700	60	2884.	4 DEC 0000	91	257.			
1 DEC 1100	30	2590.	2 DEC 1800	61	2642.	4 DEC 0100	92	243.			
1 DEC 1200	31	3108.	2 DEC 1900	62	2419.	4 DEC 0200	93	231.			

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PEAK FLOW	TIME		MAXIMUM AVERAGE FLOW			
			6-HR	24-HR	72-HR	120.00-HR
+ (CU M/S)	(HR)					
		(CU M/S)				
+ 9386.	39.00		9157.	6975.	3303.	2054.
		(MM)	133.728	407.480	578.815	600.052
		(1000 CU M)	197784.	602663.	856068.	887477.

CUMULATIVE AREA = 1479.00 SQ KM

```
1                                                         STATION     SB01

                         (I) INFLOW,   (O) OUTFLOW
         0.     2000.     4000.     6000.     8000.    10000.        0.        0.        0.        0.        0.        0.        0.
DAHRMN PER
300600   1.I--------.---------.---------.---------.---------.---------.---------.---------.---------.---------.---------.---------.
300700   2.I        .         .         .         .         .         .         .         .         .         .         .         .
300800   3.I        .         .         .         .         .         .         .         .         .         .         .         .
300900   4.I        .         .         .         .         .         .         .         .         .         .         .         .
301000   5.I        .         .         .         .         .         .         .         .         .         .         .         .
301100   6.I        .         .         .         .         .         .         .         .         .         .         .         .
301200   7.I        .         .         .         .         .         .         .         .         .         .         .         .
301300   8.I        .         .         .         .         .         .         .         .         .         .         .         .
301400   9.OI       .         .         .         .         .         .         .         .         .         .         .         .
301500  10. I       .         .         .         .         .         .         .         .         .         .         .         .
301600  11. I . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .
301700  12. OI      .         .         .         .         .         .         .         .         .         .         .         .
301800  13.  I      .         .         .         .         .         .         .         .         .         .         .         .
301900  14.  I      .         .         .         .         .         .         .         .         .         .         .         .
302000  15.  OI     .         .         .         .         .         .         .         .         .         .         .         .
302100  16.   I     .         .         .         .         .         .         .         .         .         .         .         .
302200  17.   I     .         .         .         .         .         .         .         .         .         .         .         .
302300  18.   OI    .         .         .         .         .         .         .         .         .         .         .         .
 10000  19.    I    .         .         .         .         .         .         .         .         .         .         .         .
 10100  20.    I    .         .         .         .         .         .         .         .         .         .         .         .
 10200  21. . .OI . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .
 10300  22.     I   .         .         .         .         .         .         .         .         .         .         .         .
 10400  23.     OI  .         .         .         .         .         .         .         .         .         .         .         .
 10500  24.      I  .         .         .         .         .         .         .         .         .         .         .         .
 10600  25.      OI .         .         .         .         .         .         .         .         .         .         .         .
 10700  26.       OI.         .         .         .         .         .         .         .         .         .         .         .
 10800  27.        OI         .         .         .         .         .         .         .         .         .         .         .
 10900  28.         OI        .         .         .         .         .         .         .         .         .         .         .
 11000  29.         .O I      .         .         .         .         .         .         .         .         .         .         .
 11100  30.         .  O I    .         .         .         .         .         .         .         .         .         .         .
 11200  31. . . . . . . . O .I. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .
 11300  32.         .        O. I       .         .         .         .         .         .         .         .         .         .
 11400  33.         .         . O    I  .         .         .         .         .         .         .         .         .         .
 11500  34.         .         .      O  . I       .         .         .         .         .         .         .         .         .
 11600  35.         .         .         . O    I  .         .         .         .         .         .         .         .         .
 11700  36.         .         .         .      O  .I        .         .         .         .         .         .         .         .
 11800  37.         .         .         .         .O   I    .         .         .         .         .         .         .         .
 11900  38.         .         .         .         .   O  I  .         .         .         .         .         .         .         .
 12000  39.         .         .         .         .     OI  .         .         .         .         .         .         .         .
 12100  40.         .         .         .         .      I  .         .         .         .         .         .         .         .
 12200  41. . . . . . . . . . . . . . . . . . . . . . . IO. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .
 12300  42.         .         .         .         .    IO   .         .         .         .         .         .         .         .
 20000  43.         .         .         .         .  I O    .         .         .         .         .         .         .         .
 20100  44.         .         .         .         .I O      .         .         .         .         .         .         .         .
 20200  45.         .         .         .        I.O        .         .         .         .         .         .         .         .
 20300  46.         .         .         .      I O.         .         .         .         .         .         .         .         .
 20400  47.         .         .         .    I O  .         .         .         .         .         .         .         .         .
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 20500  48.        .         .         .  I O    .         .         .         .         .         .         .         .         .
 20600  49.        .         .         .I O      .         .         .         .         .         .         .         .         .
 20700  50.        .         .        I.O        .         .         .         .         .         .         .         .         .
 20800  51. . . . . . . . . . . . . .I.O. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .
 20900  52.        .         .     I O .         .         .         .         .         .         .         .         .         .
 21000  53.        .         .   I O   .         .         .         .         .         .         .         .         .         .
 21100  54.        .         . IO      .         .         .         .         .         .         .         .         .         .
 21200  55.        .         I O       .         .         .         .         .         .         .         .         .         .
 21300  56.        .        IO         .         .         .         .         .         .         .         .         .         .
 21400  57.        .      I O.         .         .         .         .         .         .         .         .         .         .
 21500  58.        .     IO  .         .         .         .         .         .         .         .         .         .         .
 21600  59.        .  I O    .         .         .         .         .         .         .         .         .         .         .
 21700  60.        . IO      .         .         .         .         .         .         .         .         .         .         .
 21800  61. . . . . IO. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .
 21900  62.        .IO       .         .         .         .         .         .         .         .         .         .         .
 22000  63.        IO        .         .         .         .         .         .         .         .         .         .         .
 22100  64.       IO         .         .         .         .         .         .         .         .         .         .         .
 22200  65.      IO.         .         .         .         .         .         .         .         .         .         .         .
 22300  66.      I .         .         .         .         .         .         .         .         .         .         .         .
 30000  67.     IO .         .         .         .         .         .         .         .         .         .         .         .
 30100  68.     I  .         .         .         .         .         .         .         .         .         .         .         .
 30200  69.    IO  .         .         .         .         .         .         .         .         .         .         .         .
 30300  70.    I   .         .         .         .         .         .         .         .         .         .         .         .
 30400  71. . .IO . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .
 30500  72.   I    .         .         .         .         .         .         .         .         .         .         .         .
 30600  73.  IO    .         .         .         .         .         .         .         .         .         .         .         .
 30700  74.  I     .         .         .         .         .         .         .         .         .         .         .         .
 30800  75.  I     .         .         .         .         .         .         .         .         .         .         .         .
 30900  76. IO     .         .         .         .         .         .         .         .         .         .         .         .
 31000  77. I      .         .         .         .         .         .         .         .         .         .         .         .
 31100  78. I      .         .         .         .         .         .         .         .         .         .         .         .
 31200  79. I      .         .         .         .         .         .         .         .         .         .         .         .
 31300  80.IO      .         .         .         .         .         .         .         .         .         .         .         .
 31400  81.I . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .
 31500  82.I       .         .         .         .         .         .         .         .         .         .         .         .
 31600  83.I       .         .         .         .         .         .         .         .         .         .         .         .
 31700  84.I       .         .         .         .         .         .         .         .         .         .         .         .
 31800  85.I       .         .         .         .         .         .         .         .         .         .         .         .
 31900  86.I       .         .         .         .         .         .         .         .         .         .         .         .
 32000  87.I       .         .         .         .         .         .         .         .         .         .         .         .
 32100  88.IO      .         .         .         .         .         .         .         .         .         .         .         .
 32200  89.I       .         .         .         .         .         .         .         .         .         .         .         .
 32300  90.I       .         .         .         .         .         .         .         .         .         .         .         .
 40000  91.I. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .
 40100  92.I       .         .         .         .         .         .         .         .         .         .         .         .
 40200  93.I       .         .         .         .         .         .         .         .         .         .         .         .
 40300  94.I       .         .         .         .         .         .         .         .         .         .         .         .
 40400  95.I       .         .         .         .         .         .         .         .         .         .         .         .
 40500  96.I       .         .         .         .         .         .         .         .         .         .         .         .
 40600  97.I       .         .         .         .         .         .         .         .         .         .         .         .
 40700  98.I       .         .         .         .         .         .         .         .         .         .         .         .
 40800  99.I       .         .         .         .         .         .         .         .         .         .         .         .
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40900 100.I       .         .         .         .         .         .         .         .         .         .         .         .
41000 101.I. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .
41100 102.I       .         .         .         .         .         .         .         .         .         .         .         .
41200 103.I       .         .         .         .         .         .         .         .         .         .         .         .
41300 104.I       .         .         .         .         .         .         .         .         .         .         .         .
41400 105.I       .         .         .         .         .         .         .         .         .         .         .         .
41500 106.I       .         .         .         .         .         .         .         .         .         .         .         .
41600 107.I       .         .         .         .         .         .         .         .         .         .         .         .
41700 108.I       .         .         .         .         .         .         .         .         .         .         .         .
41800 109.I       .         .         .         .         .         .         .         .         .         .         .         .
41900 110.I       .         .         .         .         .         .         .         .         .         .         .         .
42000 111.I. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .
42100 112.I       .         .         .         .         .         .         .         .         .         .         .         .
42200 113.I       .         .         .         .         .         .         .         .         .         .         .         .
42300 114.I       .         .         .         .         .         .         .         .         .         .         .         .
50000 115.I       .         .         .         .         .         .         .         .         .         .         .         .
50100 116.I       .         .         .         .         .         .         .         .         .         .         .         .
50200 117.I       .         .         .         .         .         .         .         .         .         .         .         .
50300 118.I       .         .         .         .         .         .         .         .         .         .         .         .
50400 119.I       .         .         .         .         .         .         .         .         .         .         .         .
50500 120.I       .         .         .         .         .         .         .         .         .         .         .         .
50600 121.I--------.---------.---------.---------.---------.---------.---------.---------.---------.---------.---------.---------.
1


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


           **************
           *            *
  41 KK    *     SB01   *
           *            *
           **************
                          RUNOFF FROM SUB-BASIN O1

   5 IN         TIME DATA FOR INPUT TIME SERIES
                      JXMIN          60  TIME INTERVAL IN MINUTES
                     JXDATE     30NOV 2  STARTING DATE
                     JXTIME         600  STARTING TIME

              SUBBASIN RUNOFF DATA

  43 BA         SUBBASIN CHARACTERISTICS
                      TAREA      115.00  SUBBASIN AREA

  44 BF         BASE FLOW CHARACTERISTICS
                     STRTQ        10.00  INITIAL FLOW
                     QRCSN          .00  BEGIN BASE FLOW RECESSION
                     RTIOR      1.00000  RECESSION CONSTANT

                PRECIPITATION DATA
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45 PB            STORM       956.00  BASIN TOTAL PRECIPITATION

46 PI          INCREMENTAL PRECIPITATION PATTERN
                  .70        .70        .70        .70        .80        .80        .80        .80        .80        .80
                  .80        .90        .90       1.00       1.00       1.00       1.00       1.50       1.50       1.50
                 1.50       2.00       2.00       2.00       3.00       4.00       4.00      13.50      14.00       6.50
                 4.00       3.00       3.00       2.00       2.00       1.50       1.50       1.50       1.50       1.50
                 1.00       1.00       1.00        .90        .90        .90        .80        .80

51 LU          UNIFORM LOSS RATE
                 STRTL          .00  INITIAL LOSS
                 CNSTL         3.00  UNIFORM LOSS RATE
                 RTIMP        17.00  PERCENT IMPERVIOUS AREA

52 UC          CLARK UNITGRAPH
                    TC         8.10  TIME OF CONCENTRATION
                     R         6.70  STORAGE COEFFICIENT

53 UA          ACCUMULATED-AREA VS. TIME,   8 ORDINATES
                 23.5       32.6       43.5       54.3       70.0       80.0       92.6      100.0

                                                   ***

                                          UNIT HYDROGRAPH PARAMETERS
                                   CLARK   TC=  8.10 HR,        R=  6.70 HR
                                  SNYDER   TP=  7.18 HR,       CP=   .55

                                              UNIT HYDROGRAPH
                                          40 END-OF-PERIOD ORDINATES
              1.         1.         2.         2.         2.         2.         2.         2.         2.         2.
              2.         1.         1.         1.         1.         1.         1.         1.         1.         0.
              0.         0.         0.         0.         0.         0.         0.         0.         0.         0.
              0.         0.         0.         0.         0.         0.         0.         0.         0.         0.
*****************************************************************************************************************

                                 HYDROGRAPH AT STATION       SB01

*****************************************************************************************************************
                                                                  *
   DA MON HRMN  ORD     RAIN    LOSS  EXCESS      COMP Q          *    DA MON HRMN  ORD     RAIN    LOSS  EXCESS      COMP Q
                                                                  *
   30 NOV 0600    1      .00     .00     .00         10.          *     2 DEC 1900   62      .00     .00     .00         97.
   30 NOV 0700    2     6.69    2.49    4.20         13.          *     2 DEC 2000   63      .00     .00     .00         84.
   30 NOV 0800    3     6.69    2.49    4.20         19.          *     2 DEC 2100   64      .00     .00     .00         74.
   30 NOV 0900    4     6.69    2.49    4.20         26.          *     2 DEC 2200   65      .00     .00     .00         65.
   30 NOV 1000    5     6.69    2.49    4.20         34.          *     2 DEC 2300   66      .00     .00     .00         56.
   30 NOV 1100    6     7.65    2.49    5.16         44.          *     3 DEC 0000   67      .00     .00     .00         49.
   30 NOV 1200    7     7.65    2.49    5.16         56.          *     3 DEC 0100   68      .00     .00     .00         43.
   30 NOV 1300    8     7.65    2.49    5.16         67.          *     3 DEC 0200   69      .00     .00     .00         36.
   30 NOV 1400    9     7.65    2.49    5.16         80.          *     3 DEC 0300   70      .00     .00     .00         30.
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30	NOV	1500	10	7.65	2.49	5.16	92.	*
30	NOV	1600	11	7.65	2.49	5.16	102.	*
30	NOV	1700	12	7.65	2.49	5.16	112.	*
30	NOV	1800	13	8.60	2.49	6.11	121.	*
30	NOV	1900	14	8.60	2.49	6.11	130.	*
30	NOV	2000	15	9.56	2.49	7.07	139.	*
30	NOV	2100	16	9.56	2.49	7.07	148.	*
30	NOV	2200	17	9.56	2.49	7.07	156.	*
30	NOV	2300	18	9.56	2.49	7.07	164.	*
1	DEC	0000	19	14.34	2.49	11.85	176.	*
1	DEC	0100	20	14.34	2.49	11.85	191.	*
1	DEC	0200	21	14.34	2.49	11.85	206.	*
1	DEC	0300	22	14.34	2.49	11.85	222.	*
1	DEC	0400	23	19.12	2.49	16.63	241.	*
1	DEC	0500	24	19.12	2.49	16.63	265.	*
1	DEC	0600	25	19.12	2.49	16.63	289.	*
1	DEC	0700	26	28.68	2.49	26.19	320.	*
1	DEC	0800	27	38.24	2.49	35.75	366.	*
1	DEC	0900	28	38.24	2.49	35.75	420.	*
1	DEC	1000	29	129.06	2.49	126.57	540.	*
1	DEC	1100	30	133.84	2.49	131.35	740.	*
1	DEC	1200	31	62.14	2.49	59.65	914.	*
1	DEC	1300	32	38.24	2.49	35.75	1035.	*
1	DEC	1400	33	28.68	2.49	26.19	1139.	*
1	DEC	1500	34	28.68	2.49	26.19	1226.	*
1	DEC	1600	35	19.12	2.49	16.63	1286.	*
1	DEC	1700	36	19.12	2.49	16.63	1316.	*
1	DEC	1800	37	14.34	2.49	11.85	1303.	*
1	DEC	1900	38	14.34	2.49	11.85	1243.	*
1	DEC	2000	39	14.34	2.49	11.85	1160.	*
1	DEC	2100	40	14.34	2.49	11.85	1074.	*
1	DEC	2200	41	14.34	2.49	11.85	991.	*
1	DEC	2300	42	9.56	2.49	7.07	910.	*
2	DEC	0000	43	9.56	2.49	7.07	833.	*
2	DEC	0100	44	9.56	2.49	7.07	762.	*
2	DEC	0200	45	8.60	2.49	6.11	698.	*
2	DEC	0300	46	8.60	2.49	6.11	639.	*
2	DEC	0400	47	8.60	2.49	6.11	586.	*
2	DEC	0500	48	7.65	2.49	5.16	537.	*
2	DEC	0600	49	7.65	2.49	5.16	491.	*
2	DEC	0700	50	.00	.00	.00	447.	*
2	DEC	0800	51	.00	.00	.00	403.	*
2	DEC	0900	52	.00	.00	.00	363.	*
2	DEC	1000	53	.00	.00	.00	325.	*
2	DEC	1100	54	.00	.00	.00	289.	*
2	DEC	1200	55	.00	.00	.00	255.	*
2	DEC	1300	56	.00	.00	.00	224.	*
2	DEC	1400	57	.00	.00	.00	195.	*
2	DEC	1500	58	.00	.00	.00	169.	*
2	DEC	1600	59	.00	.00	.00	147.	*
2	DEC	1700	60	.00	.00	.00	128.	*
2	DEC	1800	61	.00	.00	.00	111.	*

3	DEC	0400	71	.00	.00	.00	26.
3	DEC	0500	72	.00	.00	.00	23.
3	DEC	0600	73	.00	.00	.00	21.
3	DEC	0700	74	.00	.00	.00	19.
3	DEC	0800	75	.00	.00	.00	17.
3	DEC	0900	76	.00	.00	.00	16.
3	DEC	1000	77	.00	.00	.00	15.
3	DEC	1100	78	.00	.00	.00	14.
3	DEC	1200	79	.00	.00	.00	13.
3	DEC	1300	80	.00	.00	.00	13.
3	DEC	1400	81	.00	.00	.00	12.
3	DEC	1500	82	.00	.00	.00	12.
3	DEC	1600	83	.00	.00	.00	11.
3	DEC	1700	84	.00	.00	.00	11.
3	DEC	1800	85	.00	.00	.00	11.
3	DEC	1900	86	.00	.00	.00	10.
3	DEC	2000	87	.00	.00	.00	10.
3	DEC	2100	88	.00	.00	.00	10.
3	DEC	2200	89	.00	.00	.00	10.
3	DEC	2300	90	.00	.00	.00	10.
4	DEC	0000	91	.00	.00	.00	10.
4	DEC	0100	92	.00	.00	.00	10.
4	DEC	0200	93	.00	.00	.00	10.
4	DEC	0300	94	.00	.00	.00	10.
4	DEC	0400	95	.00	.00	.00	10.
4	DEC	0500	96	.00	.00	.00	10.
4	DEC	0600	97	.00	.00	.00	10.
4	DEC	0700	98	.00	.00	.00	10.
4	DEC	0800	99	.00	.00	.00	10.
4	DEC	0900	100	.00	.00	.00	10.
4	DEC	1000	101	.00	.00	.00	10.
4	DEC	1100	102	.00	.00	.00	10.
4	DEC	1200	103	.00	.00	.00	10.
4	DEC	1300	104	.00	.00	.00	10.
4	DEC	1400	105	.00	.00	.00	10.
4	DEC	1500	106	.00	.00	.00	10.
4	DEC	1600	107	.00	.00	.00	10.
4	DEC	1700	108	.00	.00	.00	10.
4	DEC	1800	109	.00	.00	.00	10.
4	DEC	1900	110	.00	.00	.00	10.
4	DEC	2000	111	.00	.00	.00	10.
4	DEC	2100	112	.00	.00	.00	10.
4	DEC	2200	113	.00	.00	.00	10.
4	DEC	2300	114	.00	.00	.00	10.
5	DEC	0000	115	.00	.00	.00	10.
5	DEC	0100	116	.00	.00	.00	10.
5	DEC	0200	117	.00	.00	.00	10.
5	DEC	0300	118	.00	.00	.00	10.
5	DEC	0400	119	.00	.00	.00	10.
5	DEC	0500	120	.00	.00	.00	10.
5	DEC	0600	121	.00	.00	.00	10.

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

    TOTAL RAINFALL =  956.00, TOTAL LOSS =  119.52, TOTAL EXCESS =  836.48

  PEAK FLOW      TIME                              MAXIMUM AVERAGE FLOW
                                        6-HR        24-HR        72-HR      120.00-HR
+  (CU M/S)      (HR)
                              (CU M/S)
+    1316.      35.00                  1254.         861.         379.         232.
                                 (MM) 235.564      647.229      854.167      870.397
                          (1000 CU M)  27090.       74431.       98229.      100096.

                           CUMULATIVE AREA =  115.00 SQ KM

1
                                                              STATION     SB01

                              (O) OUTFLOW
          0.        200.       400.       600.       800.      1000.      1200.      1400.       0.         0.         0.         0.         0.
          0.         0.         0.         0.         0.         0.         0.         0.       160.       120.   (L) PRECIP,  (X) EXCESS
DAHRMN PER                                                                                                             80.        40.         0.
300600   1.O---------.---------.---------.---------.---------.---------.---------.---------.---------.---------.---------.---------.
300700   2.O         .         .         .         .         .         .         .         .         .         .         .
300800   3.O         .         .         .         .         .         .         .         .         .         .         .      LX.
300900   4.O         .         .         .         .         .         .         .         .         .         .         .      LX.
301000   5. O        .         .         .         .         .         .         .         .         .         .         .      LX.
301100   6. O        .         .         .         .         .         .         .         .         .         .         .      LX.
301200   7.  O       .         .         .         .         .         .         .         .         .         .         .      LX.
301300   8.  O       .         .         .         .         .         .         .         .         .         .         .      LX.
301400   9.   O      .         .         .         .         .         .         .         .         .         .         .      LX.
301500  10.    O     .         .         .         .         .         .         .         .         .         .         .      LX.
301600  11. . .O. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .      LX.
301700  12.     O    .         .         .         .         .         .         .         .         .         .         . . . .LX.
301800  13.     O    .         .         .         .         .         .         .         .         .         .         .      LX.
301900  14.     O    .         .         .         .         .         .         .         .         .         .         .      XX.
302000  15.      O   .         .         .         .         .         .         .         .         .         .         .      XX.
302100  16.      O   .         .         .         .         .         .         .         .         .         .         .      XX.
302200  17.       O  .         .         .         .         .         .         .         .         .         .         .      XX.
302300  18.       O  .         .         .         .         .         .         .         .         .         .         .      XX.
 10000  19.        O.          .         .         .         .         .         .         .         .         .         .      XX.
 10100  20.         O          .         .         .         .         .         .         .         .         .         .    LXXX.
 10200  21. . . . . O . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .    LXXX.
 10300  22.         .O         .         .         .         .         .         .         .         .         .         . . LXXX.
 10400  23.         . O        .         .         .         .         .         .         .         .         .         .    LXXX.
 10500  24.         .  O       .         .         .         .         .         .         .         .         .         .   LXXXX.
 10600  25.         .   O      .         .         .         .         .         .         .         .         .         .   LXXXX.
 10700  26.         .     O    .         .         .         .         .         .         .         .         .         .   LXXXX.
 10800  27.         .       O  .         .         .         .         .         .         .         .         .         . XXXXXXX.
 10900  28.         .          .O        .         .         .         .         .         .         .         .         LXXXXXXXXX.
 11000  29.         .          .       O .         .         .         .         .         .         .         .         LXXXXXXXXX.
 11100  30.         .          .         .         O .       .         .         .         .         XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX.
                                                                                                      XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX.
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11200  31. . . . . . . . . . . . . . . . . . . . . . . O . . . . . . . . . . . . . . . . . . . . . . . . . . . . . LXXXXXXXXXXXXXXX.
11300  32.         .         .         .         .         . O       .         .         .         .         .         LXXXXXXXXX.
11400  33.         .         .         .         .         .      O  .         .         .         .         .         .  XXXXXXX.
11500  34.         .         .         .         .         .         .O        .         .         .         .         .  XXXXXXX.
11600  35.         .         .         .         .         .         .   O     .         .         .         .         .    LXXXX.
11700  36.         .         .         .         .         .         .     O   .         .         .         .         .    LXXXX.
11800  37.         .         .         .         .         .         .    O    .         .         .         .         .     LXXX.
11900  38.         .         .         .         .         .         . O       .         .         .         .         .     LXXX.
12000  39.         .         .         .         .         .       O .         .         .         .         .         .     LXXX.
12100  40.         .         .         .         .         .   O     .         .         .         .         .         .     LXXX.
12200  41. . . . . . . . . . . . . . . . . . . . . . . . . O . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . LXXX.
12300  42.         .         .         .         .     O   .         .         .         .         .         .         .       XX.
20000  43.         .         .         .         . O       .         .         .         .         .         .         .       XX.
20100  44.         .         .         .       O .         .         .         .         .         .         .         .       XX.
20200  45.         .         .         .    O    .         .         .         .         .         .         .         .       XX.
20300  46.         .         .         . O       .         .         .         .         .         .         .         .       XX.
20400  47.         .         .        O.         .         .         .         .         .         .         .         .       XX.
20500  48.         .         .      O  .         .         .         .         .         .         .         .         .       LX.
20600  49.         .         .    O    .         .         .         .         .         .         .         .         .       LX.
20700  50.         .         . O       .         .         .         .         .         .         .         .         .         .
20800  51. . . . . . . . . . O . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .
20900  52.         .       O .         .         .         .         .         .         .         .         .         .         .
21000  53.         .     O   .         .         .         .         .         .         .         .         .         .         .
21100  54.         .   O     .         .         .         .         .         .         .         .         .         .         .
21200  55.         .  O      .         .         .         .         .         .         .         .         .         .         .
21300  56.         .O        .         .         .         .         .         .         .         .         .         .         .
21400  57.         O         .         .         .         .         .         .         .         .         .         .         .
21500  58.       O .         .         .         .         .         .         .         .         .         .         .         .
21600  59.      O  .         .         .         .         .         .         .         .         .         .         .         .
21700  60.     O   .         .         .         .         .         .         .         .         .         .         .         .
21800  61. . . O . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .
21900  62.    O    .         .         .         .         .         .         .         .         .         .         .         .
22000  63.   O     .         .         .         .         .         .         .         .         .         .         .         .
22100  64.   O     .         .         .         .         .         .         .         .         .         .         .         .
22200  65.  O      .         .         .         .         .         .         .         .         .         .         .         .
22300  66.  O      .         .         .         .         .         .         .         .         .         .         .         .
30000  67. O       .         .         .         .         .         .         .         .         .         .         .         .
30100  68. O       .         .         .         .         .         .         .         .         .         .         .         .
30200  69. O       .         .         .         .         .         .         .         .         .         .         .         .
30300  70.O        .         .         .         .         .         .         .         .         .         .         .         .
30400  71.O. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .
30500  72.O        .         .         .         .         .         .         .         .         .         .         .         .
30600  73.O        .         .         .         .         .         .         .         .         .         .         .         .
30700  74.O        .         .         .         .         .         .         .         .         .         .         .         .
30800  75.O        .         .         .         .         .         .         .         .         .         .         .         .
30900  76.O        .         .         .         .         .         .         .         .         .         .         .         .
31000  77.O        .         .         .         .         .         .         .         .         .         .         .         .
31100  78.O        .         .         .         .         .         .         .         .         .         .         .         .
31200  79.O        .         .         .         .         .         .         .         .         .         .         .         .
31300  80.O        .         .         .         .         .         .         .         .         .         .         .         .
31400  81.O. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .
31500  82.O        .         .         .         .         .         .         .         .         .         .         .         .
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 31600  83.O         .         .         .         .         .         .         .         .         .         .         .         .
 31700  84.O         .         .         .         .         .         .         .         .         .         .         .         .
 31800  85.O         .         .         .         .         .         .         .         .         .         .         .         .
 31900  86.O         .         .         .         .         .         .         .         .         .         .         .         .
 32000  87.O         .         .         .         .         .         .         .         .         .         .         .         .
 32100  88.O         .         .         .         .         .         .         .         .         .         .         .         .
 32200  89.O         .         .         .         .         .         .         .         .         .         .         .         .
 32300  90.O         .         .         .         .         .         .         .         .         .         .         .         .
 40000  91.O. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .
 40100  92.O         .         .         .         .         .         .         .         .         .         .         .         .
 40200  93.O         .         .         .         .         .         .         .         .         .         .         .         .
 40300  94.O         .         .         .         .         .         .         .         .         .         .         .         .
 40400  95.O         .         .         .         .         .         .         .         .         .         .         .         .
 40500  96.O         .         .         .         .         .         .         .         .         .         .         .         .
 40600  97.O         .         .         .         .         .         .         .         .         .         .         .         .
 40700  98.O         .         .         .         .         .         .         .         .         .         .         .         .
 40800  99.O         .         .         .         .         .         .         .         .         .         .         .         .
 40900 100.O         .         .         .         .         .         .         .         .         .         .         .         .
 41000 101.O. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .
 41100 102.O         .         .         .         .         .         .         .         .         .         .         .         .
 41200 103.O         .         .         .         .         .         .         .         .         .         .         .         .
 41300 104.O         .         .         .         .         .         .         .         .         .         .         .         .
 41400 105.O         .         .         .         .         .         .         .         .         .         .         .         .
 41500 106.O         .         .         .         .         .         .         .         .         .         .         .         .
 41600 107.O         .         .         .         .         .         .         .         .         .         .         .         .
 41700 108.O         .         .         .         .         .         .         .         .         .         .         .         .
 41800 109.O         .         .         .         .         .         .         .         .         .         .         .         .
 41900 110.O         .         .         .         .         .         .         .         .         .         .         .         .
 42000 111.O. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .
 42100 112.O         .         .         .         .         .         .         .         .         .         .         .         .
 42200 113.O         .         .         .         .         .         .         .         .         .         .         .         .
 42300 114.O         .         .         .         .         .         .         .         .         .         .         .         .
 50000 115.O         .         .         .         .         .         .         .         .         .         .         .         .
 50100 116.O         .         .         .         .         .         .         .         .         .         .         .         .
 50200 117.O         .         .         .         .         .         .         .         .         .         .         .         .
 50300 118.O         .         .         .         .         .         .         .         .         .         .         .         .
 50400 119.O         .         .         .         .         .         .         .         .         .         .         .         .
 50500 120.O         .         .         .         .         .         .         .         .         .         .         .         .
 50600 121.O---------.---------.---------.---------.---------.---------.---------.---------.---------.---------.---------.---------.
1


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

            **************
            *            *
   54 KK    *     DAM    *
            *            *
            **************

                           COMBINE TWO HYDROGRAPHS
```

56 HC HYDROGRAPH COMBINATION

ICOMP 2 NUMBER OF HYDROGRAPHS TO COMBINE

***

HYDROGRAPH AT STATION DAM

SUM OF 2 HYDROGRAPHS

DA MON HRMN	ORD	FLOW	DA MON HRMN	ORD	FLOW	DA MON HRMN	ORD	FLOW	DA MON HRMN	ORD	FLOW
30 NOV 0600	1	110.	1 DEC 1300	32	4771.	2 DEC 2000	63	2297.	4 DEC 0300	94	229.
30 NOV 0700	2	114.	1 DEC 1400	33	5634.	2 DEC 2100	64	2098.	4 DEC 0400	95	219.
30 NOV 0800	3	124.	1 DEC 1500	34	6626.	2 DEC 2200	65	1917.	4 DEC 0500	96	209.
30 NOV 0900	4	138.	1 DEC 1600	35	7671.	2 DEC 2300	66	1753.	4 DEC 0600	97	200.
30 NOV 1000	5	158.	1 DEC 1700	36	8671.	3 DEC 0000	67	1604.	4 DEC 0700	98	192.
30 NOV 1100	6	188.	1 DEC 1800	37	9515.	3 DEC 0100	68	1469.	4 DEC 0800	99	184.
30 NOV 1200	7	227.	1 DEC 1900	38	10103.	3 DEC 0200	69	1345.	4 DEC 0900	100	177.
30 NOV 1300	8	278.	1 DEC 2000	39	10402.	3 DEC 0300	70	1232.	4 DEC 1000	101	170.
30 NOV 1400	9	339.	1 DEC 2100	40	10459.	3 DEC 0400	71	1132.	4 DEC 1100	102	162.
30 NOV 1500	10	407.	1 DEC 2200	41	10352.	3 DEC 0500	72	1040.	4 DEC 1200	103	151.
30 NOV 1600	11	480.	1 DEC 2300	42	10134.	3 DEC 0600	73	958.	4 DEC 1300	104	141.
30 NOV 1700	12	555.	2 DEC 0000	43	9814.	3 DEC 0700	74	882.	4 DEC 1400	105	134.
30 NOV 1800	13	631.	2 DEC 0100	44	9395.	3 DEC 0800	75	813.	4 DEC 1500	106	130.
30 NOV 1900	14	707.	2 DEC 0200	45	8917.	3 DEC 0900	76	750.	4 DEC 1600	107	127.
30 NOV 2000	15	783.	2 DEC 0300	46	8423.	3 DEC 1000	77	691.	4 DEC 1700	108	124.
30 NOV 2100	16	858.	2 DEC 0400	47	7935.	3 DEC 1100	78	632.	4 DEC 1800	109	122.
30 NOV 2200	17	932.	2 DEC 0500	48	7460.	3 DEC 1200	79	580.	4 DEC 1900	110	120.
30 NOV 2300	18	1004.	2 DEC 0600	49	7000.	3 DEC 1300	80	535.	4 DEC 2000	111	118.
1 DEC 0000	19	1081.	2 DEC 0700	50	6556.	3 DEC 1400	81	497.	4 DEC 2100	112	117.
1 DEC 0100	20	1167.	2 DEC 0800	51	6128.	3 DEC 1500	82	462.	4 DEC 2200	113	116.
1 DEC 0200	21	1259.	2 DEC 0900	52	5720.	3 DEC 1600	83	431.	4 DEC 2300	114	115.
1 DEC 0300	22	1358.	2 DEC 1000	53	5332.	3 DEC 1700	84	403.	5 DEC 0000	115	114.
1 DEC 0400	23	1471.	2 DEC 1100	54	4958.	3 DEC 1800	85	378.	5 DEC 0100	116	113.
1 DEC 0500	24	1601.	2 DEC 1200	55	4597.	3 DEC 1900	86	355.	5 DEC 0200	117	112.
1 DEC 0600	25	1747.	2 DEC 1300	56	4247.	3 DEC 2000	87	334.	5 DEC 0300	118	112.
1 DEC 0700	26	1918.	2 DEC 1400	57	3911.	3 DEC 2100	88	315.	5 DEC 0400	119	111.
1 DEC 0800	27	2130.	2 DEC 1500	58	3591.	3 DEC 2200	89	297.	5 DEC 0500	120	111.
1 DEC 0900	28	2383.	2 DEC 1600	59	3291.	3 DEC 2300	90	281.	5 DEC 0600	121	111.
1 DEC 1000	29	2756.	2 DEC 1700	60	3011.	4 DEC 0000	91	267.			
1 DEC 1100	30	3330.	2 DEC 1800	61	2753.	4 DEC 0100	92	253.			
1 DEC 1200	31	4021.	2 DEC 1900	62	2516.	4 DEC 0200	93	241.			

PEAK FLOW	TIME		MAXIMUM AVERAGE FLOW		
		6-HR	24-HR	72-HR	120.00-HR
+ (CU M/S)	(HR)				

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                                 (CU M/S)
+   10459.      39.00                       10186.       7763.       3677.       2286.
                                    (MM)   138.026     420.780     597.885     619.556
                              (1000 CU M)  220013.     670723.     953029.     987573.

                                   CUMULATIVE AREA = 1594.00 SQ KM

1
                                                                STATION      DAM

                                   (O) OUTFLOW
          0.       1000.      2000.      3000.      4000.      5000.      6000.      7000.      8000.      9000.     10000.     11000.         0.
DAHRMN PER
300600   1.O---------.---------.---------.---------.---------.---------.---------.---------.---------.---------.---------.---------.
300700   2.O         .         .         .         .         .         .         .         .         .         .         .         .
300800   3.O         .         .         .         .         .         .         .         .         .         .         .         .
300900   4.O         .         .         .         .         .         .         .         .         .         .         .         .
301000   5. O        .         .         .         .         .         .         .         .         .         .         .         .
301100   6. O        .         .         .         .         .         .         .         .         .         .         .         .
301200   7. O        .         .         .         .         .         .         .         .         .         .         .         .
301300   8.  O       .         .         .         .         .         .         .         .         .         .         .         .
301400   9.  O       .         .         .         .         .         .         .         .         .         .         .         .
301500  10.   O      .         .         .         .         .         .         .         .         .         .         .         .
301600  11. . .O. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .
301700  12.    O     .         .         .         .         .         .         .         .         .         .         .         .
301800  13.    O     .         .         .         .         .         .         .         .         .         .         .         .
301900  14.     O    .         .         .         .         .         .         .         .         .         .         .         .
302000  15.      O   .         .         .         .         .         .         .         .         .         .         .         .
302100  16.       O. .         .         .         .         .         .         .         .         .         .         .         .
302200  17.       O. .         .         .         .         .         .         .         .         .         .         .         .
302300  18.        O           .         .         .         .         .         .         .         .         .         .         .
 10000  19.         .O         .         .         .         .         .         .         .         .         .         .         .
 10100  20.         . O        .         .         .         .         .         .         .         .         .         .         .
 10200  21. . . . . . .O. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .
 10300  22.         .   O      .         .         .         .         .         .         .         .         .         .         .
 10400  23.         .    O     .         .         .         .         .         .         .         .         .         .         .
 10500  24.         .     O    .         .         .         .         .         .         .         .         .         .         .
 10600  25.         .      O   .         .         .         .         .         .         .         .         .         .         .
 10700  26.         .        O.          .         .         .         .         .         .         .         .         .         .
 10800  27.         .          .O        .         .         .         .         .         .         .         .         .         .
 10900  28.         .          .   O     .         .         .         .         .         .         .         .         .         .
 11000  29.         .          .       O .         .         .         .         .         .         .         .         .         .
 11100  30.         .          .         .  O      .         .         .         .         .         .         .         .         .
 11200  31. . . . . . . . . . . . . . . . . . . . .O. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .
 11300  32.         .          .         .         .       O .         .         .         .         .         .         .         .
 11400  33.         .          .         .         .         .      O  .         .         .         .         .         .         .
 11500  34.         .          .         .         .         .         .      O  .         .         .         .         .         .
 11600  35.         .          .         .         .         .         .         .         O .         .         .         .         .
 11700  36.         .          .         .         .         .         .         .         .        O  .         .         .         .
 11800  37.         .          .         .         .         .         .         .         .         .      O  .         .         .
 11900  38.         .          .         .         .         .         .         .         .         .         .         .         .
 12000  39.         .          .         .         .         .         .         .         .         .         .O        .         .
 12100  40.         .          .         .         .         .         .         .         .         .         .    O    .         .
                                                                                                                           O
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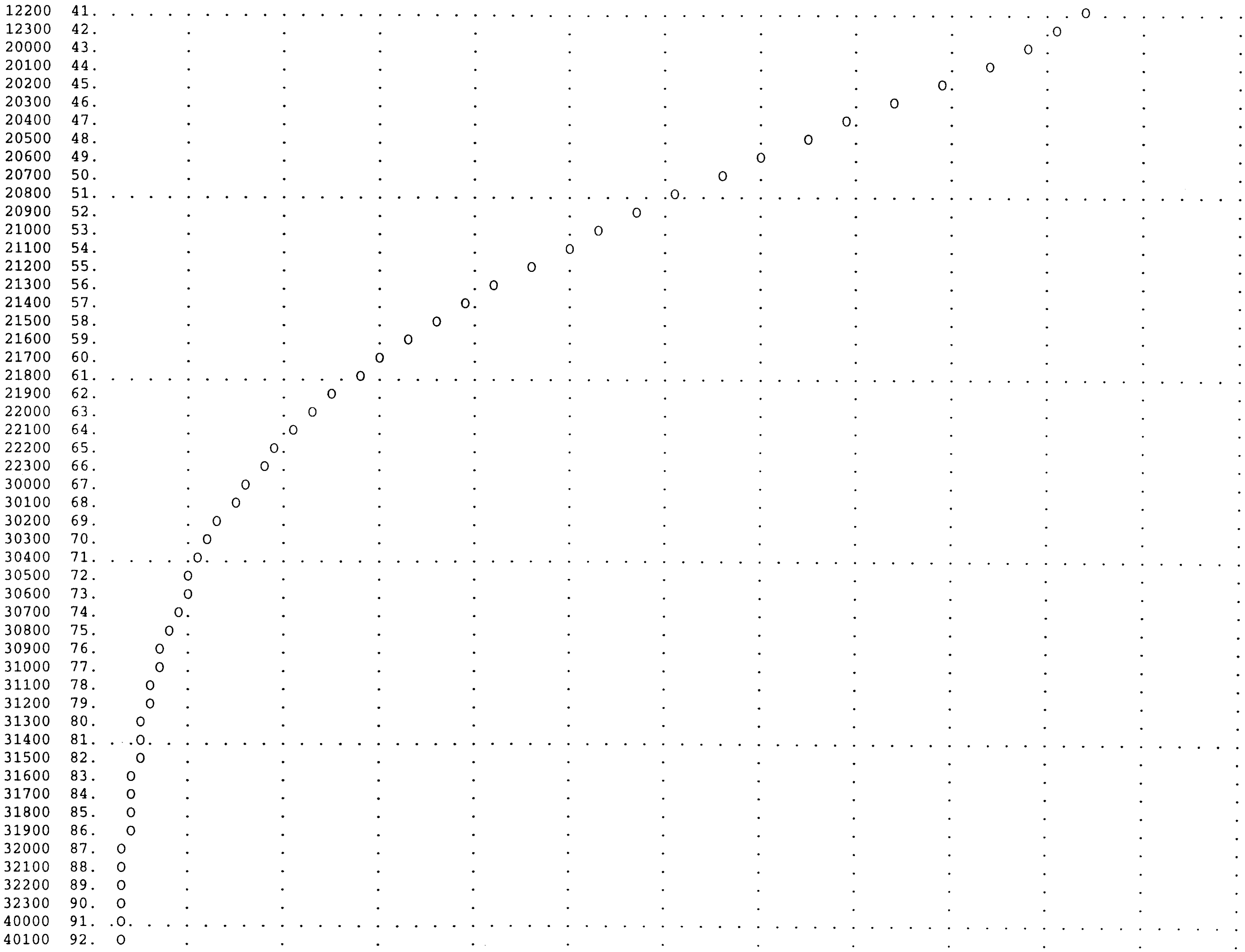
12200 41.
12300 42.
20000 43.
20100 44.
20200 45.
20300 46.
20400 47.
20500 48.
20600 49.
20700 50.
20800 51.
20900 52.
21000 53.
21100 54.
21200 55.
21300 56.
21400 57.
21500 58.
21600 59.
21700 60.
21800 61.
21900 62.
22000 63.
22100 64.
22200 65.
22300 66.
30000 67.
30100 68.
30200 69.
30300 70.
30400 71.
30500 72.
30600 73.
30700 74.
30800 75.
30900 76.
31000 77.
31100 78.
31200 79.
31300 80.
31400 81.
31500 82.
31600 83.
31700 84.
31800 85.
31900 86.
32000 87.
32100 88.
32200 89.
32300 90.
40000 91.
40100 92.

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40200   93. O
40300   94. O
40400   95. O
40500   96. O
40600   97. O
40700   98. O
40800   99. O
40900  100. O
41000  101. O . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .
41100  102. O
41200  103. O
41300  104.O
41400  105.O
41500  106.O
41600  107.O
41700  108.O
41800  109.O
41900  110.O
42000  111.O. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .
42100  112.O
42200  113.O
42300  114.O
50000  115.O
50100  116.O
50200  117.O
50300  118.O
50400  119.O
50500  120.O
50600  121.O--------.---------.---------.---------.---------.---------.---------.---------.---------.---------.---------.---------.
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             *            *
   57 KK     *     DAM    *
             *            *
             **************
                              ROUTE THROUGH RESERVOIR

               HYDROGRAPH ROUTING DATA

   59 RS         STORAGE ROUTING
                      NSTPS          1  NUMBER OF SUBREACHES
                       ITYP       ELEV  TYPE OF INITIAL CONDITION
                     RSVRIC      80.00  INITIAL CONDITION
                          X        .00  WORKING R AND D COEFFICIENT

   60 SV           STORAGE   6210000.0 7514000.0 7809000.0 8103000.0 8398000.0 8692000.0 8987000.0 9309000.0 9631000.0 9954000.0
```

61 SE	ELEVATION	75.00	80.00	81.00	82.00	83.00	84.00	85.00	86.00	87.00	88.00
62 SQ	DISCHARGE	0.	30.	94.	184.	288.	429.	579.	912.	1275.	
63 SE	ELEVATION	80.00	80.50	81.00	81.50	82.00	82.50	83.00	84.00	85.00	

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COMPUTED STORAGE-OUTFLOW-ELEVATION DATA

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  STORAGE 6210000.007514000.007661500.007809000.007956000.008103000.008250500.008398000.008692000.008987000.00
  OUTFLOW       .00       .00     30.00     94.00    184.00    288.00    429.00    579.00    912.00   1275.00
ELEVATION     75.00     80.00     80.50     81.00     81.50     82.00     82.50     83.00     84.00     85.00

  STORAGE 9309000.009631000.009954000.00
  OUTFLOW   1638.00   2001.00   2364.00
ELEVATION     86.00     87.00     88.00
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HYDROGRAPH AT STATION DAM

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DA	MON	HRMN	ORD	OUTFLOW STORAGE	STAGE	*	DA	MON	HRMN	ORD	OUTFLOW STORAGE	STAGE	*	DA	MON	HRMN	ORD	OUTFLOW STORAGE	STAGE
30	NOV	0600	1	0.7514000.0	80.0	*	1	DEC	2300	42	183.7954559.0	81.5	*	3	DEC	1600	83	581.8399878.0	83.0
30	NOV	0700	2	0.7514403.0	80.0	*	2	DEC	0000	43	208.7989763.0	81.6	*	3	DEC	1700	84	580.8399289.0	83.0
30	NOV	0800	3	0.7514829.0	80.0	*	2	DEC	0100	44	232.8023548.0	81.7	*	3	DEC	1800	85	580.8398608.0	83.0
30	NOV	0900	4	0.7515300.0	80.0	*	2	DEC	0200	45	254.8055633.0	81.8	*	3	DEC	1900	86	579.8397842.0	83.0
30	NOV	1000	5	0.7515833.0	80.0	*	2	DEC	0300	46	276.8085888.0	81.9	*	3	DEC	2000	87	578.8397001.0	83.0
30	NOV	1100	6	0.7516454.0	80.0	*	2	DEC	0400	47	299.8114298.0	82.0	*	3	DEC	2100	88	577.8396090.0	83.0
30	NOV	1200	7	1.7517199.0	80.0	*	2	DEC	0500	48	324.8140887.0	82.1	*	3	DEC	2200	89	576.8395116.0	83.0
30	NOV	1300	8	1.7518107.0	80.0	*	2	DEC	0600	49	348.8165706.0	82.2	*	3	DEC	2300	90	575.8394084.0	83.0
30	NOV	1400	9	1.7519214.0	80.0	*	2	DEC	0700	50	370.8188816.0	82.3	*	4	DEC	0000	91	574.8393002.0	83.0
30	NOV	1500	10	1.7520552.0	80.0	*	2	DEC	0800	51	391.8210279.0	82.4	*	4	DEC	0100	92	573.8391874.0	83.0
30	NOV	1600	11	2.7522145.0	80.0	*	2	DEC	0900	52	410.8230165.0	82.4	*	4	DEC	0200	93	572.8390703.0	83.0
30	NOV	1700	12	2.7524002.0	80.0	*	2	DEC	1000	53	427.8248553.0	82.5	*	4	DEC	0300	94	570.8389494.0	83.0
30	NOV	1800	13	2.7526129.0	80.0	*	2	DEC	1100	54	444.8265507.0	82.6	*	4	DEC	0400	95	569.8388251.0	83.0
30	NOV	1900	14	3.7528527.0	80.0	*	2	DEC	1200	55	460.8281078.0	82.6	*	4	DEC	0500	96	568.8386975.0	83.0
30	NOV	2000	15	3.7531197.0	80.1	*	2	DEC	1300	56	475.8295315.0	82.7	*	4	DEC	0600	97	566.8385671.0	83.0
30	NOV	2100	16	4.7534138.0	80.1	*	2	DEC	1400	57	488.8308268.0	82.7	*	4	DEC	0700	98	565.8384340.0	83.0
30	NOV	2200	17	5.7537344.0	80.1	*	2	DEC	1500	58	500.8319996.0	82.7	*	4	DEC	0800	99	564.8382986.0	82.9
30	NOV	2300	18	5.7540810.0	80.1	*	2	DEC	1600	59	510.8330566.0	82.8	*	4	DEC	0900	100	562.8381609.0	82.9
1	DEC	0000	19	6.7544544.0	80.1	*	2	DEC	1700	60	520.8340055.0	82.8	*	4	DEC	1000	101	561.8380211.0	82.9
1	DEC	0100	20	7.7548568.0	80.1	*	2	DEC	1800	61	529.8348543.0	82.8	*	4	DEC	1100	102	559.8378791.0	82.9
1	DEC	0200	21	8.7552909.0	80.1	*	2	DEC	1900	62	536.8356110.0	82.9	*	4	DEC	1200	103	558.8377342.0	82.9
1	DEC	0300	22	9.7557591.0	80.1	*	2	DEC	2000	63	543.8362830.0	82.9	*	4	DEC	1300	104	556.8375861.0	82.9
1	DEC	0400	23	10.7562649.0	80.2	*	2	DEC	2100	64	549.8368774.0	82.9	*	4	DEC	1400	105	555.8374356.0	82.9

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  1 DEC 0500  24      11.7568139.0     80.2 *  2 DEC 2200  65      555.8374014.0     82.9 *  4 DEC 1500 106      553.8372837.0     82.9
  1 DEC 0600  25      12.7574124.0     80.2 *  2 DEC 2300  66      559.8378614.0     82.9 *  4 DEC 1600 107      552.8371310.0     82.9
  1 DEC 0700  26      14.7580675.0     80.2 *  3 DEC 0000  67      563.8382636.0     82.9 *  4 DEC 1700 108      550.8369777.0     82.9
  1 DEC 0800  27      15.7587910.0     80.3 *  3 DEC 0100  68      567.8386133.0     83.0 *  4 DEC 1800 109      549.8368241.0     82.9
  1 DEC 0900  28      17.7595974.0     80.3 *  3 DEC 0200  69      570.8389152.0     83.0 *  4 DEC 1900 110      547.8366704.0     82.9
  1 DEC 1000  29      19.7605161.0     80.3 *  3 DEC 0300  70      573.8391734.0     83.0 *  4 DEC 2000 111      546.8365166.0     82.9
  1 DEC 1100  30      21.7616044.0     80.3 *  3 DEC 0400  71      575.8393924.0     83.0 *  4 DEC 2100 112      544.8363629.0     82.9
  1 DEC 1200  31      23.7629197.0     80.4 *  3 DEC 0500  72      577.8395760.0     83.0 *  4 DEC 2200 113      542.8362092.0     82.9
  1 DEC 1300  32      27.7644933.0     80.4 *  3 DEC 0600  73      578.8397277.0     83.0 *  4 DEC 2300 114      541.8360557.0     82.9
  1 DEC 1400  33      31.7663558.0     80.5 *  3 DEC 0700  74      580.8398505.0     83.0 *  5 DEC 0000 115      539.8359024.0     82.9
  1 DEC 1500  34      40.7685498.0     80.6 *  3 DEC 0800  75      581.8399469.0     83.0 *  5 DEC 0100 116      538.8357493.0     82.9
  1 DEC 1600  35      52.7711068.0     80.7 *  3 DEC 0900  76      581.8400191.0     83.0 *  5 DEC 0200 117      536.8355966.0     82.9
  1 DEC 1700  36      64.7740275.0     80.8 *  3 DEC 1000  77      582.8400690.0     83.0 *  5 DEC 0300 118      535.8354442.0     82.9
  1 DEC 1800  37      78.7772752.0     80.9 *  3 DEC 1100  78      582.8400975.0     83.0 *  5 DEC 0400 119      533.8352922.0     82.8
  1 DEC 1900  38      93.7807755.0     81.0 *  3 DEC 1200  79      582.8401060.0     83.0 *  5 DEC 0500 120      532.8351406.0     82.8
  1 DEC 2000  39     116.7844288.0     81.1 *  3 DEC 1300  80      582.8400971.0     83.0 *  5 DEC 0600 121      530.8349894.0     82.8
  1 DEC 2100  40     138.7881382.0     81.2 *  3 DEC 1400  81      582.8400732.0     83.0 *
  1 DEC 2200  41     161.7918304.0     81.4 *  3 DEC 1500  82      582.8400363.0     83.0 *
                                            *                                              *
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   PEAK FLOW      TIME                                    MAXIMUM AVERAGE FLOW
                                             6-HR         24-HR          72-HR      120.00-HR
 +   (CU M/S)      (HR)
                             (CU M/S)
 +       582.     78.00                       582.         578.           544.         351.
                                   (MM)      7.889       31.350         88.484       95.155
                           (1000 CU M)      12575.       49971.        141043.      151677.

  PEAK STORAGE     TIME                                   MAXIMUM AVERAGE STORAGE
                                             6-HR         24-HR          72-HR      120.00-HR
 + (1000 CU M)     (HR)
   8401060.       78.00                   8400780.     8397264.       8363552.      8087248.

   PEAK STAGE      TIME                                   MAXIMUM AVERAGE STAGE
                                             6-HR         24-HR          72-HR      120.00-HR
 +  (METERS)       (HR)
      83.01       78.00                      83.01        83.00          82.88        81.95

                              CUMULATIVE AREA = 1594.00 SQ KM

1                                                                  STATION       DAM

                                  (I) INFLOW,    (O) OUTFLOW
          0.        2000.       4000.       6000.       8000.      10000.      12000.          0.          0.          0.          0.          0.          0.
                                                                                           (S) STORAGE
          0.           0.          0.          0.          0.          0.    7200000.    7600000.    8000000.    8400000.          0.          0.          0.
DAHRMN PER
300600   1OI--------.---------.---------.---------.---------.---------.-------S-.---------.---------.---------.---------.---------.
300700   2OI         .         .         .         .         .         .       S .         .         .         .         .         .
300800   3OI         .         .         .         .         .         .       S .         .         .         .         .         .
300900   4OI         .         .         .         .         .         .       S .         .         .         .         .         .
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301000   5OI        .         .         .         .         .         .       S .         .         .         .         .         .
301100   6OI        .         .         .         .         .         .       S .         .         .         .         .         .
301200   7OI        .         .         .         .         .         .       S .         .         .         .         .         .
301300   8OI        .         .         .         .         .         .       S .         .         .         .         .         .
301400   9O I       .         .         .         .         .         .       S .         .         .         .         .         .
301500  10O I       .         .         .         .         .         .       S .         .         .         .         .         .
301600  11O I . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . S . . . . . . . . . . . . . . . . . . . . . . . . . .
301700  12O  I      .         .         .         .         .         .       S .         .         .         .         .         .
301800  13O  I      .         .         .         .         .         .       S .         .         .         .         .         .
301900  14O   I     .         .         .         .         .         .       S .         .         .         .         .         .
302000  15O   I     .         .         .         .         .         .       S .         .         .         .         .         .
302100  16O   I     .         .         .         .         .         .       S .         .         .         .         .         .
302200  17O    I    .         .         .         .         .         .       S .         .         .         .         .         .
302300  18O    I    .         .         .         .         .         .        S.         .         .         .         .         .
 10000  19O    I    .         .         .         .         .         .        S.         .         .         .         .         .
 10100  20O     I   .         .         .         .         .         .        S.         .         .         .         .         .
 10200  21O . . I . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .S. . . . . . . . . . . . . . . . . . . . . . . . .
 10300  22O      I  .         .         .         .         .         .        S.         .         .         .         .         .
 10400  23O      I  .         .         .         .         .         .        S.         .         .         .         .         .
 10500  24O       I .         .         .         .         .         .        S.         .         .         .         .         .
 10600  25O        I.         .         .         .         .         .        S.         .         .         .         .         .
 10700  26O         I         .         .         .         .         .         S         .         .         .         .         .
 10800  27O         .I        .         .         .         .         .         S         .         .         .         .         .
 10900  28O         . I       .         .         .         .         .         S         .         .         .         .         .
 11000  29O         .   I     .         .         .         .         .         S         .         .         .         .         .
 11100  30O         .      I  .         .         .         .         .         S         .         .         .         .         .
 11200  31O . . . . . . . . . I . . . . . . . . . . . . . . . . . . . . . . . . .S. . . . . . . . . . . . . . . . . . . . . . . .
 11300  32O         .         .   I     .         .         .         .         .S        .         .         .         .         .
 11400  33O         .         .       I .         .         .         .         . S       .         .         .         .         .
 11500  34O         .         .         .  I      .         .         .         . S       .         .         .         .         .
 11600  35O         .         .         .       I .         .         .         .  S      .         .         .         .         .
 11700  36O         .         .         .         .  I      .         .         .   S     .         .         .         .         .
 11800  37O         .         .         .         .       I .         .         .   S     .         .         .         .         .
 11900  38O         .         .         .         .         .I        .         .    S    .         .         .         .         .
 12000  39.O        .         .         .         .         . I       .         .     S   .         .         .         .         .
 12100  40.O        .         .         .         .         . I       .         .      S  .         .         .         .         .
 12200  41.O. . . . . . . . . . . . . . . . . . . . . . . . . I . . . . . . . . . . . . S . . . . . . . . . . . . . . . . . . . . .
 12300  42.O        .         .         .         .         .I        .         .        S.         .         .         .         .
 20000  43.O        .         .         .         .        I.         .         .         S         .         .         .         .
 20100  44.O        .         .         .         .      I  .         .         .         .S        .         .         .         .
 20200  45.O        .         .         .         .    I    .         .         .         .S        .         .         .         .
 20300  46.O        .         .         .         . I       .         .         .         . S       .         .         .         .
 20400  47.O        .         .         .         I         .         .         .         .  S      .         .         .         .
 20500  48. O       .         .         .      I  .         .         .         .         .   S     .         .         .         .
 20600  49. O       .         .         .    I    .         .         .         .         .   S     .         .         .         .
 20700  50. O       .         .         .  I      .         .         .         .         .    S    .         .         .         .
 20800  51. O . . . . . . . . . . . . . .I. . . . . . . . . . . . . . . . . . . . . . . . . .S. . . . . . . . . . . . . . . . .
 20900  52. O       .         .        I.         .         .         .         .         .     S   .         .         .         .
 21000  53. O       .         .      I  .         .         .         .         .         .     S   .         .         .         .
 21100  54. O       .         .    I    .         .         .         .         .         .      S  .         .         .         .
 21200  55. O       .         .  I      .         .         .         .         .         .      S  .         .         .         .
 21300  56. O       .         .I        .         .         .         .         .         .      S  .         .         .         .
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21400  57. O       .         I         .         .         .         .         .         .       S .         .         .         .
21500  58. O       .       I .         .         .         .         .         .         .       S .         .         .         .
21600  59.  O      .     I   .         .         .         .         .         .         .       S .         .         .         .
21700  60.  O      .    I    .         .         .         .         .         .         .        S.         .         .         .
21800  61. .O. . . . . I . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .S. . . . . . . . . . . . . . . .
21900  62.  O      .  I      .         .         .         .         .         .         .        S.         .         .         .
22000  63.  O      .I        .         .         .         .         .         .         .        S.         .         .         .
22100  64.  O      I         .         .         .         .         .         .         .        S.         .         .         .
22200  65.  O      I         .         .         .         .         .         .         .        S.         .         .         .
22300  66.  O     I.         .         .         .         .         .         .         .        S.         .         .         .
30000  67.  O    I .         .         .         .         .         .         .         .         S         .         .         .
30100  68.  O   I  .         .         .         .         .         .         .         .         S         .         .         .
30200  69.  O   I  .         .         .         .         .         .         .         .         S         .         .         .
30300  70.  O  I   .         .         .         .         .         .         .         .         S         .         .         .
30400  71. .O. I . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . S . . . . . . . . . . . . . . .
30500  72.  O I    .         .         .         .         .         .         .         .         S         .         .         .
30600  73.  O I    .         .         .         .         .         .         .         .         S         .         .         .
30700  74.  OI     .         .         .         .         .         .         .         .         S         .         .         .
30800  75.  OI     .         .         .         .         .         .         .         .         S         .         .         .
30900  76.  OI     .         .         .         .         .         .         .         .         S         .         .         .
31000  77.  I      .         .         .         .         .         .         .         .         S         .         .         .
31100  78.  I      .         .         .         .         .         .         .         .         S         .         .         .
31200  79.  I      .         .         .         .         .         .         .         .         S         .         .         .
31300  80.  I      .         .         .         .         .         .         .         .         S         .         .         .
31400  81. IO. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . S . . . . . . . . . . . . . . .
31500  82. IO      .         .         .         .         .         .         .         .         S         .         .         .
31600  83. IO      .         .         .         .         .         .         .         .         S         .         .         .
31700  84. IO      .         .         .         .         .         .         .         .         S         .         .         .
31800  85. IO      .         .         .         .         .         .         .         .         S         .         .         .
31900  86. IO      .         .         .         .         .         .         .         .         S         .         .         .
32000  87. IO      .         .         .         .         .         .         .         .         S         .         .         .
32100  88. IO      .         .         .         .         .         .         .         .         S         .         .         .
32200  89.I O      .         .         .         .         .         .         .         .         S         .         .         .
32300  90.I O      .         .         .         .         .         .         .         .         S         .         .         .
40000  91.I.O. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . S . . . . . . . . . . . . . . .
40100  92.I O      .         .         .         .         .         .         .         .         S         .         .         .
40200  93.I O      .         .         .         .         .         .         .         .         S         .         .         .
40300  94.I O      .         .         .         .         .         .         .         .         S         .         .         .
40400  95.I O      .         .         .         .         .         .         .         .         S         .         .         .
40500  96.I O      .         .         .         .         .         .         .         .         S         .         .         .
40600  97.I O      .         .         .         .         .         .         .         .         S         .         .         .
40700  98.I O      .         .         .         .         .         .         .         .         S         .         .         .
40800  99.I O      .         .         .         .         .         .         .         .         S         .         .         .
40900 100.I O      .         .         .         .         .         .         .         .         S         .         .         .
41000 101.I.O. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . S . . . . . . . . . . . . . . .
41100 102.I O      .         .         .         .         .         .         .         .        S.         .         .         .
41200 103.I O      .         .         .         .         .         .         .         .        S.         .         .         .
41300 104.I O      .         .         .         .         .         .         .         .        S.         .         .         .
41400 105.I O      .         .         .         .         .         .         .         .        S.         .         .         .
41500 106.I O      .         .         .         .         .         .         .         .        S.         .         .         .
41600 107.I O      .         .         .         .         .         .         .         .        S.         .         .         .
41700 108.I O      .         .         .         .         .         .         .         .        S.         .         .         .
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41800 109.I O      .         .         .         .         .         .         .         .        S.         .         .         .
41900 110.I O      .         .         .         .         .         .         .         .        S.         .         .         .
42000 111.I.O. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .S. . . . . . . . . . . . . . . .
42100 112.I O      .         .         .         .         .         .         .         .        S.         .         .         .
42200 113.I O      .         .         .         .         .         .         .         .        S.         .         .         .
42300 114.I O      .         .         .         .         .         .         .         .        S.         .         .         .
50000 115.I O      .         .         .         .         .         .         .         .        S.         .         .         .
50100 116.I O      .         .         .         .         .         .         .         .        S.         .         .         .
50200 117.I O      .         .         .         .         .         .         .         .        S.         .         .         .
50300 118.I O      .         .         .         .         .         .         .         .        S.         .         .         .
50400 119.I O      .         .         .         .         .         .         .         .        S.         .         .         .
50500 120.I O      .         .         .         .         .         .         .         .        S.         .         .         .
50600 121.I-O------.---------.---------.---------.---------.---------.---------.---------.--------S.---------.---------.---------.
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RUNOFF SUMMARY, AVERAGE FLOW IN CUBIC METERS PER SECOND
AREA IN SQUARE KILOMETERS

	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	SB03	5375.19	37.00	5115.36	3533.91	1573.54	674.00		
+	HYDROGRAPH AT	SB02	4696.13	41.00	4533.13	3540.26	1740.51	805.00		
+	2 COMBINED AT	SB02	9442.77	38.00	9204.63	6987.37	3303.12	1479.00		
+	ROUTED TO	SB01	9385.58	39.00	9156.66	6975.27	3302.73	1479.00		
+	HYDROGRAPH AT	SB01	1316.21	35.00	1254.16	861.47	378.97	115.00		
+	2 COMBINED AT	DAM	10459.41	39.00	10185.81	7762.99	3676.81	1594.00		
+	ROUTED TO	DAM	582.47	78.00	582.15	578.37	544.15	1594.00		
+									83.01	78.00

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

Appendix B
Geology

FEASIBILITY DESIGN FOR THE RÍOS COCLÉ DEL NORTE AND CAÑO SUCIO WATER SUPPLY PROJECTS

APPENDIX B

GEOLOGY, GEOTECHNICAL AND SEISMOLOGICAL STUDIES

Prepared by

MWH

In association with

TAMS

AN EARTH TECH COMPANY

FEASIBILITY DESIGN FOR THE RÍOS COCLÉ DEL NORTE AND CAÑO SUCIO WATER SUPPLY PROJECTS

APPENDIX B – GEOLOGY, GEOTECHNICAL AND SEISMOLOGICAL STUDIES

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1. Laboratory Sampling and Testing Report for Coclé del Norte Site, Tecnilab, S.A.

FOREWORD

The studies described in this appendix have been performed in accordance with the scope of services for Contract CC3-5-536 - Work Order 005, Feasibility Design and Related Services for the Río Coclé del Norte and Caño Sucio Water Supply Projects entered into on June 19, 2000. This appendix presents the results of the investigations and studies related to services addressing **Task 5 - Geology**, and **Task 6 - Geotechnical and Seismological Studies**. The original scope of work anticipated that access to the sites for drilling and other site investigations would be available. However, except for site reconnaissance, access has not been obtained.

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 areas 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 2, Altimetric and Planimetric Surveys of 13 sites located on the Western Side of Lake Gatun;
- Additional topographic mapping of the two dam sites developed by digitizing 1:50,000 scale maps obtained from Instituto Geografico Nacional (Instituto "Tommy Guardia");
- Geological and geotechnical information obtained from a site visit and a construction materials investigation program, including both test pit sampling and laboratory testing;
- 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 Ríos Coclé del Norte and Caño Sucio Water Supply Projects, Panama. The purpose of the work was to identify and evaluate geologic conditions of the proposed projects and to develop feasibility level geotechnical design criteria and parameters for preparation of layouts and support of cost estimates.

The original scope of the work included substantial site investigations involving field geologic mapping, drilling, geophysical exploration, laboratory testing and technical evaluations. The results of these investigations were to be used to support the development of feasibility level geotechnical design criteria and cost parameters. Because access for site exploration could not be obtained, as explained in the next chapter, the present feasibility study is supported by data that is not as extensive as originally anticipated. On the basis of the limited fieldwork that was permitted, 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, water transfer tunnel alignment 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 locations of projects and sites investigated are shown on Exhibit 1 of this Appendix. The project and zone of study is found on Sheets 4042-I and 4043-II (Coclé del Norte) and 4142-IV (Caño Sucio) of the 1:50,000 scale topographic map series.

The ACP identified the Río Coclé del Norte and Caño Sucio Projects among several other potential projects to provide additional water supply, storage and hydropower generation to augment capacity and capability improvements for the Panama Canal. The Río Coclé del Norte Project is located west of the Canal within the Río Coclé del Norte watershed, approximately 12 km inland from the Caribbean Sea and 50 km west of Lake Gatun (Exhibit 1). The project would impound water from the Río Coclé del Norte and Río Toabré drainage basins. The proposed dam site is located about 7 km downstream from the confluence of the Río Toabré with the Río Coclé del Norte and about 3 km upstream from the community of San Lucas.

The Caño Sucio Project is located between the Coclé del Norte and the Panama Canal, approximately 25 km inland from the Caribbean Sea and 25 km west of Lake Gatun (Exhibit 1).

Two schemes are presently being considered for the water supply projects. Structures for either project would include a main dam on the Río Coclé del Norte, a smaller dam on the Caño Sucio, spillways, one or more saddle dams, inter-basin transfer tunnels (or canals), hydropower facilities, and other outlet works. Under one scheme, a lower dam (approximately 85 m high) would be constructed on the Río Coclé del Norte. Water would be diverted from the Coclé del Norte project to the Panama Canal through a long inter-basin transfer tunnel to the Río Indio basin and then through the Río Indio Water Supply Project tunnel to Lake Gatun. Alternatively, a higher dam could be constructed on the Río Coclé del Norte (approximately 105 m high); the water could be conveyed by canal into the Caño Sucio basin through the narrow ridge separating the two basins, routed through the Caño Sucio reservoir, and then the water would be transferred through a channel and tunnel or canal to the Río Indio basin and thence to Lake Gatun.

The reservoir formed by the Río Coclé del Norte dam would have a normal operating level about 80 m above mean sea level under the first scheme and about 100 m under the second scheme. The respective surface areas would be approximately 28,200 and 41,400 hectares. The Caño Sucio reservoir would have a normal operating level of about 100 m above mean sea level with a surface area of approximately 1,240 hectares.

2 GEOLOGIC AND GEOTECHNICAL INVESTIGATIONS

This chapter summarizes the sequence and scope of geologic investigations relevant to the proposed Ríos Coclé del Norte and Caño Sucio Water Supply Projects.

2.1 Scope of Investigations

Geologic investigations have not been performed previously specifically for the Ríos Coclé del Norte and Caño Sucio Water Supply Projects. A scoping and reconnaissance study, which included these projects as well as other western watershed projects, 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 the 1:1,000,000 scale national map and limited coverage at 1:250,000 and 1:75,000 scales. Although very informative for the immediate area of the Canal, these maps provide insufficient detail for project engineering purposes within the project area.

As part of the present scope of work, reconnaissance visits were made to the proposed dam sites in September 1999 that included identification and examination of bedrock types at various project locations. In December 2001, visits were made to carry out dam site geologic mapping and construction materials studies. These later trips were abbreviated due to problems in obtaining access to required areas. An additional site visit was carried out in April 2003 to reconnoiter potential intake and outlet portals and canal sections of the water transfer tunnel system.

The original scope of the feasibility investigation program for both project sites was quite extensive and included reconnaissance geologic mapping, core drilling at locations of principal project elements, geophysical surveys, test pit excavation, and laboratory testing. Because there were problems in obtaining access to the project sites, the drilling program and associated activities (sampling, permeability testing) have been indefinitely postponed. The proposed seismic refraction program and more detailed mapping were also postponed.

The final program incorporated the following activities:

- Reconnaissance of proposed dam sites; establish exploration program and investigation requirements;
- Reconnaissance preliminary geologic mapping, including geomorphological analysis and photo-geologic studies;
- Outcrop geologic mapping at the dam site;
- Construction materials reconnaissance investigation;
- Identification of principal geologic factors governing alternative dam types and tunnel routes;
- 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;
- Preliminary 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.

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). During the course of the work, some new more detailed topographic maps became available for selected areas at the dam site.

Reconnaissance geologic mapping was performed along the Río Coclé del Norte from the reservoir area to immediately downstream of the dam site. Geologic reconnaissance was also carried out at selected locations to help identify conditions along prospective tunnel alignments, tunnel portals and intake locations, and canal sections. A general reconnaissance of some of the proposed reservoir area (up to the confluence with the Río Toabré) was performed by helicopter to identify and evaluate any geologic features relevant to reservoir rim stability and watertightness.

A limited program of reconnaissance geologic mapping was performed at the Caño Sucio Project dam site and in the reservoir area immediately upstream. A general reconnaissance of the proposed reservoir area was performed by helicopter to identify and evaluate any geologic features relevant to reservoir rim stability and watertightness, construction materials, and potential water conveyance canal alignments.

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. A limited number of black-and-white photographs are available for the project area. 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 but the work was indefinitely postponed before it even started. The scope of the drilling program was formulated by the USACE Pittsburgh District and would have included core drilling and *in situ* testing at the dam site, at saddle dam locations, and at proposed tunnel intake/outlet locations.

2.1.4 Geophysical Profiling

A program of seismic refraction profiling was developed by MWH to be performed in conjunction with and as an adjunct to the drilling program. This too has been postponed in view of difficulties in obtaining access to the sites.

2.1.5 Laboratory Testing and Analyses

Samples of rock and soil samples from test pits were collected for subsequent laboratory testing and analysis through the services of Tecnilab in Panama City.

- Construction Materials Testing. Laboratory tests for gradation, specific gravity, absorption, soundness, and abrasion resistance 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, Section 12, Construction Materials.
- Petrographic Analyses. These were to have been performed on selected core samples. Since the drilling was cancelled, only preliminary petrologic determinations were made from hand samples collected during geologic mapping.
- Rock Mechanics and Index Testing. No rock testing was performed because of the cancellation of the drilling work.

Laboratory test results and test pit logs are presented in Attachment 1.

3 REGIONAL GEOLOGIC AND TECTONIC SETTING

3.1 General

This chapter presents the basic geologic and tectonic setting of the Panamá Canal western watershed water supply projects including Río Coclé del Norte and Río Caño Sucio project areas. Information on this basic setting was derived from interpretations made during the course of these studies and from published geologic reports and maps cited in the text and in the 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.

Due to the relative proximity of the water supply projects currently under investigation in the western watershed region (namely the Río Indio, Río Coclé del Norte, and the Río Caño Sucio sites), the study was expanded to cover an area encompassing all three sites. These projects lie in the area bounded by 80.1°W and 80.6°W and 8.6°N and 9°N.

3.2 General Regional Geology of Western Watershed Projects

The proposed Río Indio and Caño Sucio projects are located in an area underlain by Oligocene-aged sedimentary rocks of the three-membered Caimito Formation of Oligocene age (Woodring, 1982 a, 1982 b). A general stratigraphic column is presented as Table 1 and a regional geologic maps are presented as Exhibit 2 and 3. The lower member of the Caimito Formation is composed of conglomerate, greywacke, and tuffaceous sandstone while the middle member consists of tuffaceous sandstone, greywacke, and lenticular foraminiferal limestone. The upper principal member consists of tuff, agglomeratic tuff, tuffaceous siltstone, and discontinuous sandy tuffaceous foraminiferal limestone. The deposits are primarily marine, but lithologically heterogeneous and the rocks of all members are hard, thinly to thickly bedded, and closely to moderately jointed.

The sedimentary units at the Río Indio and Caño Sucio sites comprise tuffaceous siltstones and sandstones, conglomerates and agglomerates. These are interbedded with lavas and, in some parts of the reservoir area, the sedimentary rocks are stratigraphically overlain or are intruded by andesite and basalt flows, sills, and dikes. The volcanic units form many of the steep hills and high plateaus that are readily apparent on topographic maps and aerial photographs. Some of the volcanic formations might represent older units cropping out as erosional inliers. More recent volcanic sequences are found south of the project area.

Bedrock in the region of the proposed Río Coclé del Norte project consists mostly of volcanic igneous rocks belonging to the Tucue Formation. These include basic and intermediate (basaltic and andesitic) lava flows, breccias, tuffs, and agglomerates. Reportedly, other rock types are intrusive igneous rocks classified as granodiorites, quartzmonzonites, gabrodiorites, diorites, or dacites. The published regional geologic map indicates bedrock in the site area to be of an intrusive igneous nature, possibly granodiorite or quartz monzonite (Tertiary age Petaquilla Formation). These rock types were not found during reconnaissance visits to the dam site and surrounding areas. Parts of the reservoir area are underlain by the Tertiary age Cañazas Formation, which consists of andesitic and basaltic lava flows, volcanic breccia, and tuffs, as well as sequences belonging to the Caimito Formation.

Although little information on the engineering characteristics of these rocks exists, it is anticipated that they may exhibit a wide variety in quality (ranging from high quality intrusive rocks and extrusive lava flows to weathered and lesser quality volcanic tuffs and epiclastics).

The general pattern and distribution of major faulting in the region is depicted on Exhibit 4.

Table 1: Stratigraphic Column

Adapted from: Woodring and Thompson, 1949

ERA	PERIOD	EPOCH	AGE	FORMATION	DESCRIPTION
CENOZOIC ERA	QUATERNARY	($3x10^6$ to present)			Río 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 / Bohio	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 ($48x10^6$)		No deposition	
MESOZOIC		Cretaceous ($71x10^6$)		Pre-Tertiary basement complex	Indurated sedimentary rocks, intrusive and extrusive igneous rocks and metamorphic rocks

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).

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 watershed 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 what 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 watershed. The other source is the interface between the subducted Caribbean plate and 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 (Joyner, 1999). 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 5). 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 4). 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 4). 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 4). 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 the 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 Exhibit 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 6, 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 B.C. 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 tectonic 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 5, 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 watershed region is characterized by several types of faulting including 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. Studies have been performed which 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 7 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 Historic 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 $M_L = \frac{2}{3}$ (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:

$$\log N_c = 7.90 - 1.27M \text{ , where M is } m_b$$

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 Camacho et al., 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 (Camacho et al., 1994). 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 western watershed projects indicates that these projects 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 and 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 Exhibits 14 through 22:

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 is 0.42g. 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 various water supply projects is as follows:

Table 3: Peak Bedrock Accelerations for Water Supply Projects

Name of Project	Closest Distance to N. Panama Deformed Belt (km)	PGA (g)[1]	PGA (g)[2]	PGA (g)[3]
Río Coclé del Norte	75	**0.27**	0.16	0.13
Caño Sucio	90	**0.21**	0.11	0.12
Río Indio	95	**0.21**	0.11	0.11

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 values based on Joyner (1999), presented in the first column of the table above, are recommended for use in preliminary design. The values based on the attenuation model of Camacho et al. and those calculated based on Dahle et al. (1995) are considered rather low. In contrast, those calculated by Joyner (1999) are 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: Maximum Peak Ground Acceleration for Selected Sites

City	Return Period	PGA(1) (m/s^2)	PGA(1) (g)	PGA(2) (g)
Aguadulce, Coclé	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
Panama City, Panama	144	1.85	0.19	0.14
Penonome, Coclé	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 Exhibits 13 through 22 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 Coclé del Norte Project are as follows:

Maximum Design Earthquake (MDE) = 0.27 g
Operating Basis Earthquake (OBE) = 0.14 g

The recommended seismic design parameters for the Caño Sucio Project are as follows:

Maximum Design Earthquake (MDE) = 0.21 g
Operating Basis Earthquake (OBE) = 0.14 g

6 GEOLOGY OF RÍO COCLÉ DEL NORTE DAM SITE AREA

This chapter provides descriptions of the geology of the Río Coclé del Norte dam site and reservoir areas and of the region through which the water transfer tunnel would pass. These descriptions and interpretations are based on the results of studies and investigations described above.

6.1 Topographic Conditions and Physiography

The Coclé del Norte dam site has been well-selected from a topographic viewpoint and is probably the only suitable site in the area that would provide the desired storage volume. The site is about 15 km from the mouth of the river on the Atlantic coast and about 7 km downstream from the confluence of the Coclé del Norte and Río Toabré, its main tributary.

At the dam site, the Río Coclé del Norte flows north forming an asymmetrical, relatively steep-sided valley. The river is only slightly above sea level at the site and minor tidal fluctuations (reportedly up to 30 cm) are evident. The sides of the river rise steeply to a little over 100 m on the left side and to above 140 m on the right side. The width of the valley bottom at the site varies, but averages about 100 m with the streambed occupying about 50-80 m.

Both abutments are heavily vegetated and are almost entirely covered with talus, colluvial, and residual soils. Small, scattered rock outcrops can be observed throughout the site area on both abutments, especially in gullies. Most of the dam site area is characterized by a moderately deep weathered profile with locally thick soil cover typical of the sub-tropical climate.

The sides of the river valley are in most places densely vegetated with primary and secondary forest growth. Upstream of the axis on the left side the forest has been cleared for a short distance and the area is used for pasture. Parts of the upper slopes on the left side are used for coffee plantation.

River terrace deposits are found along the valley at many locations, mostly at about 5-10 m above present river level, on the inside of meanders, and at the confluence of tributaries. The terrace deposits appear to be largely silty-sand and clayey-silt. No significant gravel deposits have been found.

Bedrock at the dam site is found to consist mostly of porphyritic basalt and, less commonly of basic agglomerate. Regional geologic maps indicate bedrock at the site to be of an intrusive igneous nature, possibly granodiorite or quartz monzonite (Tertiary age Petaquilla formation). Such rock types were not observed in the site area.

Rock float and large boulder talus indicate the presence of *in situ* bedrock at relatively shallow depths, but severe weathering is evident. Basalt float was observed all the way up the left abutment to above el. 100 m. Rock outcrop was observed at river level on the left side, at several other locations on the left abutment and is widespread on the right side.

The area under which the water transfer tunnel would pass is characterized by a rolling topography and pronounced dendritic drainage with several small streams. The region is densely forested with only local clearings. Rock outcrops are rare and difficult to locate. A few isolated hills rise above the others, presumably formed by more resistant rock than surrounding areas.

6.2 Unconsolidated Deposits

Overburden at the dam site mostly consists deposits of talus, colluvium, and residual soils above river level on the valley slopes and alluvial deposits found in the riverbed or as terraces on the valley sides.

6.2.1 Quaternary Alluvium

Alluvial deposits of the Río Coclé del Norte valley are not extensive compared to many rivers and drainage basin of comparable size elsewhere in Central America. Sand and gravel deposits in the river bed are thin and only localized in occurrence and found as lag deposits on the inside of meanders and as occasional bar deposits. The gravel-sized fractions originate from nearby outcrops of basalt.

The most significant sources of alluvial deposits located in the vicinity of the dam site form 3- to 5-m-high terraces along the banks of the river both upstream and downstream of the dam site. These, however, are also localized in occurrence and consist predominantly of clayey silt (MH) with some layers of clayey and silty fine sand (SC) and inorganic clay (CH). At bends in the river where the terraces are located, at least two terrace levels can be observed. Visual observation of slumps and cuts in the lower terraces indicate the presence of orange, clayey or silty overburden. No deposits of clean alluvial sands and gravels have yet been observed.

6.2.2 Colluvium and Residual Soils

Most of the bedrock in the project area is mantled by variably developed horizons of talus, colluvial, and residual soils.

In the dam site area, the upper layers (0.5 m thick) were found to consist of organic loam, orange-brown silty clay with sand and trace gravel. Gravel pieces are sub-angular decomposed basalt fragments increasing in size with depth from 8-10 mm near the surface to pieces increase in size to 50-75 mm and larger. In test pits, highly weathered rock was encountered at relatively shallow depths (1.0 to 1.5 m) with interlocked angular basalt blocks. Laborers had difficulty prying the blocks apart by hand, and could not excavate the pit any deeper. Large boulders are also present at the surface and within the first meter of depth in the test pits. Generally, overburden contains an increasing number of boulders below 0.75 m of depth to the point where the overburden can be described as having an equal composition of boulders and gravely soil. Boulders can be up to about 1 m in dimension. The soil component of the overburden is generally stiff to very stiff in consistency, and laborers have to use both picks and shovels to excavate test pits to depth.

6.3 Rock Units

Bedrock in the Río Coclé del Norte dam site area has been visually identified as porphyritic basalt. Outcrops of bedrock can be observed at many locations on both sides of the river, though these are difficult to find because of the dense jungle overgrowth.

Surface outcrops and boulders exhibit to varying degrees the spheroidal weathering characteristics typical of basalt.

The basalt consists of non-vesicular to slightly vesicular material that is bedded but not columnar and is hard and strong where fresh or relatively unweathered. Rock outcrops on both sides of the valley indicate that bedrock can be described as thick-bedded (or widely jointed) to locally massive. The much less common agglomerate contains fragments of basalt in a well-cemented epiclastic matrix. There are indications of the possible presence of thin tuffs that might have been deposited as interflow materials, but these have to be confirmed by drilling.

6.4 Rock Properties for Preliminary Design

Table 6 lists typical ranges for compressive strengths and unit weights for the different rock types that may be encountered at the dam site and in construction of the water transfer tunnel. In the absence of data from subsurface investigations performed specifically for this project, these data are from published bibliographic sources and experience with similar rock types.

6.5 Structural Geology

6.5.1 General

The principal geologic structures at the Río Coclé del Norte dam site are joints and bedding. Until subsurface investigations are performed, the existence and extent of other features, such as shear zones and faults, are unknown.

6.5.2 Faults and Shear Zones

Based upon experience with geological investigations and construction in the Canal Zone, it is likely that several small faults and shear zones could exist at the dam site. Such structures can locally influence the pattern and degree of weathering in the rock mass, and probably have exerted a minor control over the morphological development of the site, and either singly or in combination significantly affect the strength and deformation modulus of the rock in local areas.

From regional geologic mapping and photogeologic studies, the presence of major faults is not expected at the dam site. Some photogeologic linears have been interpreted in the dam site area but these are not thought to be caused by significant faulting.

6.5.3 Rock Joints and Bedding (Flow Contacts)

Based on limited observations at rock outcrops in the dam site area, discontinuities exhibit a wide range of orientations and characteristics. Contacts between different basalt flow units were not actually observed in the field but probably will be identified and explored by drilling. It is thought that the flow units at the dam site are relatively thick and comprise mostly sound, widely jointed rock. However, it is probable that weaker, more closely jointed rock, or scoriaceous zones could exist at the top or bottom of individual lava flows. The presence of such features, as well as possible interflow clay, ash deposits, epiclastics, or soil-like materials would have to be explored during drilling.

Columnar jointing in the basalt units was not observed during reconnaissance but cannot be ruled out. Most joints observed in outcrops were variably inclined, mostly steeper than 45° and seemingly in all directions. A systematic joint survey was not performed during the initial mapping studies and currently there are insufficient data to develop typical stereographic plots. At this time, few details have been gathered on the characteristics and properties of such jointing though most joints appeared to be planar to curving, short in persistence, and intersecting. Joint fillings or coatings are probably common up to the limits of weathering. Clay infillings should be expected in the upper part of the weathering profile.

6.6 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. During reconnaissance, springs were observed in the thalweg of gullies on both banks of the river, indicating shallow groundwater conditions.

7 GEOLOGY OF CAÑO SUCIO DAM SITE AREA

This chapter provides descriptions of the geology of the Caño Sucio dam site and reservoir areas and of the region through which the water transfer tunnel (or canals) would pass. These descriptions and interpretations are based on the results of studies and investigations described above.

7.1 Topographic Conditions and Physiography

At the proposed dam site, the Río Caño Sucio flows northwest forming a moderate-sloped valley that exhibits nearly 100 m of relief. Like Río Coclé del Norte, the Río Caño Sucio dam site has been well-selected from a topographic viewpoint and it appears to be the most suitable site in the area. The dam site is located at the top of an approximately 250 m long waterfalls section in the river. The main drop at the falls is about 10 m, but several smaller falls and cataracts exist downstream over a horizontal distance of about 200 m. At the proposed dam site, the river is at about El. 85 m. Upstream of the upper section of the falls, the valley broadens out and the river flows very gently with a low gradient.

The topography is favorable for a dam site at the top of the falls. In addition, there is potential for siting a small hydroelectric facility at this site to take advantage of the head drop at the waterfalls.

Both abutments are almost entirely covered with colluvial and residual soils, and were moderately heavily vegetated in 1999 but are now stripped of trees and partially cultivated. In the reservoir area, large tracts have been cleared for pasture and local arable cultivation.

Although rock outcrop is evident in the river bottom and at the waterfalls, most of the project area is characterized by absence of outcrop and a moderate to deep weathered profile and thick soil cover typical of the sub-tropical climate.

Bedrock at the proposed dam site is a medium-grained sandstone. The sandstone is locally strong, moderately hard, and erosionally resistant, as evidenced by the formation of the waterfalls. Interbeds of shaley (or tuffaceous) materials are also present.

7.2 Unconsolidated Deposits

7.2.1 Quaternary Alluvium

Negligible amounts of alluvium are present in the riverbed at the dam site but are thought to increase in thickness upstream in the reservoir area. Because of the low gradient of the river, any present-day alluvial deposits probably are only fine-grained clayey silt (MH) with some layers of clayey sand (SC) and inorganic clay (CH). No sand or gravel deposits were observed upstream of the dam site and if present at all are assumed to be thin and only localized in occurrence.

During a geomorphological study of the proposed reservoir area, it was noted that the stream gradient of the Río Caño Sucio and its tributaries is exceptionally flat and large parts of the valley bottoms are characterized by flat, almost swampy terrain. These characteristics are quite different from neighboring drainage basins, suggesting either very different bedrock geology or that the valleys have been partially infilled at some time in the recent geologic past, probably late Pleistocene or even early Holocene. The nature of such deposits, their origin and history can only be conjectured at this time since it was not possible to conduct proper field investigations.

7.2.2 Colluvium and Residual Soils

Overburden at the dam site consists of thick deposits of colluvium and residual soils above the river level. Most of the bedrock in the project area is mantled by well-developed horizons of colluvial and residual soils. In the dam site area, these materials were found to consist of clayey and sandy silt (MH, SC), ranging in depth from one or two meters near river level to several meters higher up the abutments.

During reconnaissance, it was noted that on some steeper slopes, the colluvium tends to contain rock float (fragments of weathered bedrock) in a soil matrix. Nowhere is the content of rock fragments sufficient for the deposit to be called talus. Most of the overburden in the project site area has a moderate to high clay content due to the probably volcanic epiclastics origin of the sedimentary bedrock.

7.3 Rock Units

Bedrock at the proposed dam site is a medium to locally coarse-grained sandstone. The sandstone is locally strong, and moderately hard. The sandstone exhibits variable degrees of case-hardening. Examination of float up the left abutment indicates that this is locally calcareous and probably has a calcareous cementation. Interbeds of shaley (or tuffaceous) materials are also present. Bedding is very evident with bedding unit thicknesses on the order of 0.25 to 1.0 m.

Stratigraphically, the bedrock units are thought to belong to the Caimito Formation or its age equivalent (Table 1: Regional Stratigraphic Column).

Volcanic units (lavas) are not thought to be interbedded with the sandstone and are not noted anywhere in the immediate vicinity of the dam site. However, volcanic units are found in outcrop in prominent hills less than 6 km kilometers away, such as at Cerro Miguel and Cerro Loma Alta, where basalt and intermediate acid lavas are observed as float and outcrop.

7.4 Structural Geology

The principal geologic structures at the Caño Sucio dam site are joints and bedding. Until subsurface investigations are performed, the existence and extent of other features, such as shear zones and faults, are unknown.

At the falls, the sandstone strata strike about N32°E and dip about 10° to the southeast, i.e. in an upstream direction.

Based upon experience with geological investigations and construction in the Canal area, it is likely that several small faults and shear zones could exist at the dam site. Such structures can locally influence the pattern and degree of weathering in the rock mass, and probably have exerted a minor control over the morphological development of the site, and either singly or in combination significantly affect the strength and deformation modulus of the rock in local areas.

From regional geologic mapping and photogeologic studies, the presence of major faults is not expected at the dam site. Some photogeologic linears have been interpreted parallel to the river valley at the site and trending northwest but these are not thought to be caused by significant faulting in this direction, rather are more likely related to fold structures in the sedimentary rock cover.

8 ENGINEERING GEOLOGY OF RÍO COCLÉ DEL NORTE DAM SITE

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

The proposed project will consist of a concrete faced rockfill dam with an ungated chute spillway located on the right abutment. Diversion during construction will be achieved by a diversion tunnel in the right bank and cofferdams.

8.1 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. However, in the absence of subsurface investigation data, the process had to be based on qualitative evaluations involving engineering judgment and previous experience in similar geological environments.

8.1.1 Dam Type Selection

Following layout comparisons based on hydrologic, geologic/geotechnical, and cost considerations, the final recommended arrangement involves a concrete faced rock fill dam (CFRD) with an ungated spillway located on the right abutment (Appendix D-1, Dam Type Selection).

8.2 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. In the absence of additional field data these have been used for the remainder of the feasibility design.

Table 5: Summary of Geotechnical Design Parameters - Coclé del Norte

Parameter	Selected Design Criteria
Thickness of overburden (top of weathered rock)	3 m
Depth to top of competent rock	6 m
Rock Excavation Slopes	1H : 5V, 3-m-wide benches every 10 m vertically
Soil Excavation Slopes	
Permanent	2H : 1V, 3-m-wide benches every 10 m vertically. Bench at soil-rock contact
Temporary	1.5H : 1V, 3-m-wide benches every 10 m vertically. Bench at soil-rock contact

8.3 Foundation Bedrock Characteristics

In general, the basaltic foundation bedrock at the site should provide a suitable foundation for all types of structures being considered. This type of foundation material is not expected to present any significant constraints on project development that cannot be taken care of with appropriate design details and construction practices. This is in contrast to some sedimentary rock units and geotechnical conditions known from the Panama Canal (e.g. Cucaracha Formation), where sliding and foundation failures have been common and presented serious problems. Rather, the bedrock geology should be closer to what has been encountered in the basalt formations in the Miraflores Locks area.

- *Bearing Capacity.* The basaltic bedrock units at the site are strong and are expected to present adequate bearing capacity to support any of the structures being considered. Differential settlements should not be a concern with this type of foundation. Data from subsurface investigation and testing will be needed to develop design and construction details for foundation treatment.

- *Resistance to Sliding.* The basalt should provide adequate resistance to sliding along discontinuities and at foundation-structure interfaces, provided excavation depths are sufficient to achieve fresh sound bedrock.

- *Material Strength Parameters.* The estimated range of material strength parameters recommended for use in preliminary stability checks are provided in Table 6. These are based on published data for the respective lithologies and experience with similar materials elsewhere.

Table 6: Estimated Material Strength Parameters – Coclé del Norte

Rock Type	UCS (MPa)	ϕ (degrees)	c (MPa)	Unit Weight (kN/m^3)
Fresh basalt	125-250	50°	10	26
Weathered basalt	75-125	40°	1	25
Tuffaceous, scoriaceous zones	50-100	35°	1	24

8.4 Excavation Depths

Based upon observations made at the site and comparison with rock types elsewhere in similar environments, an average overburden thickness of 3 m was assumed, i.e. depth to top of weathered rock. An average depth to the top of competent rock was assumed to be about 6 m. These values were used in the development of preliminary layouts and in the computation of quantity takeoffs for cost estimates. Actual depths and characteristics of weathering need to be investigated by drilling and geophysical exploration since these can have significant impact on the cost estimates.

Excavation for the dam and spillway was estimated as indicated in Table 7.

Table 7: Estimated Excavation Depths – Coclé del Norte

Feature	Estimated Excavation Depth* (m)
Plinth and 25 m downstream of grout curtain	6
Under main dam body	3
Spillway headworks and chute	6

* to reach bedrock of acceptable quality

Test pits could not penetrate deep into the talus and residual soils covering bedrock at the site, but a fully developed weathering profile up to a few meters thick is expected.

Because of the absence 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 7. 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.

The foundation excavation depth requirements for the dam plinth and spillway are similar. In both cases the excavation should go down to uncompressible, sound bedrock that can be readily grouted. 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.

8.5 Foundation Improvement, Treatment, and Long-Term Performance

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

Although small landslips and slumps are evident at some locations along the river valley, no large mass movements are expected to affect the reservoir, but the effect of saturation, say after intense rainfall, on the stability of residual soils and talus slopes needs to be properly evaluated. This could be significant in design of safe spillway cuts.

8.5.1 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 plinth slab excavation at the dam toe and under the spillway headworks, 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 should reflect the potential for surprises. For example, it is understood that during construction at the Esti Hydroelectric Project in Panama considerable overexcavation and additional treatment were required along parts of the 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 for the plinth slab and under the spillway headworks. 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 lack of 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 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 the toe slab of the CFRD and through the spillway concrete (or from a grout slab prior to placing first stage spillway concrete). 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 below the plinth and spillway headworks 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 along the plinth 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.

8.6 Construction Materials

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

8.7 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.

8.8 Diversion and Cofferdams

8.8.1 General

River diversion during construction will be accomplished by a diversion tunnel and cofferdams. The optimum size and location of these structures will be established during later phases of design with the benefit of subsurface investigations.

For preliminary design and estimating purposes, a tunnel located on the left side has been assumed with a length of about 550 m and finished diameter of 8.0 m. The tunnel invert elevation at the upstream and downstream portals will be about 0 m. The tunnel will be modified horse-shoe (or horseshoe) in shape and will be concrete-lined.

The upstream cofferdam will have a crest elevation of 22.5 m and will be about 27 m high. It is proposed as zoned fill structure constructed with materials excavated at the dam site. In the weathered state, these would be relatively impermeable upon compaction. The downstream cofferdam will have a crest elevation of 4 m and will be about 9 m high. It is proposed as a random fill structure constructed with materials excavated from the site.

8.8.2 Diversion Tunnel Conditions

The diversion tunnel for construction of a CFRD dam will be excavated entirely in basalt. This bedrock should be of moderate to high strength and unweathered over most of the tunnel length except at the tunnel portals. Basalt 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 will be 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 tunnel, as currently aligned, provides adequate cover below the assumed limits of the dam foundation excavation.

It is assumed that rock support required in the construction of the diversion tunnel 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 8: 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 with wiremesh; pattern bolts, 5 per section
III	Poor	5 cm shotcrete with wiremesh; pattern bolts, 7 per section
IV	Poor to Worst	5-10 cm shotcrete; steel sets (or lattice girders); bolts as required

For construction cost estimating purposes, the distribution of these rock support categories has been conservatively estimated as indicated on Table 9 below.

Table 9: Estimated Rock Conditions in Construction Diversion Tunnel

Type of Rock	I	II	III	IV
Estimated % of Type encountered	20	40	30	10

8.8.3 Diversion Cofferdams

Geologic data currently available for the diversion cofferdam areas are limited to surface mapping and the foundation areas are underlain by an unknown thickness of overburden. Construction of the upstream cofferdam may present some problems. The structure will be founded only partly on bedrock; the majority will be on channel fill and terrace deposits. Cut-off will involve excavation through varied overburden materials of unknown thickness (possibly 3-6 m to top of rock).

8.9 Summary and Conclusions on Dam Site Geology

The Río Coclé del Norte dam site has been well-selected from a topographic viewpoint and appears to be probably the most suitable site in the area.

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 generally favorable and can be readily handled through conventional design and construction practices, without having to resort to special or unprecedented methods. Subsurface investigations have yet to be done to confirm technical feasibility, but at this stage it is thought 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 strong basalt that would serve as a suitable foundation for the types of dam and appurtenant structures being considered;
- Based on outcrop data, a competent foundation for the dam can be obtained at reasonable depths;
- 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.

9 ENGINEERING GEOLOGY OF CAÑO SUCIO DAM SITE

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

The proposed project will consist of a conventional concrete or RCC gravity dam ungated ogee spillway located on top of the dam. Diversion during construction will be achieved by a diversion culvert and cofferdams.

9.1 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. However, in the absence of subsurface investigation data, the process was based on qualitative evaluations involving engineering judgment and previous experience in similar geological environments including comparisons with other projects in Panama, such as the Esti Project currently under construction.

9.1.1 Dam Type Selection

Following layout comparisons based on hydrologic, geologic/geotechnical, and cost considerations, the final recommended arrangement involves a conventional concrete or RCC gravity dam with an ungated spillway located on top of the dam (Appendix D-1, Dam Type Selection.

9.2 Geotechnical Design Parameters

Geotechnical design parameters and criteria used for developing preliminary layouts and cost estimates for dam type selection are presented below in Table 10 and are described in the following paragraphs. In the absence of additional field data these were used for the remainder of the feasibility design.

Table 10: Summary of Geotechnical Design Parameters for Layouts – Caño Sucio

Parameter	Selected Design Criteria
Thickness of overburden (top of weathered rock)	Varies from 0 m in the river channel to 2 m in the abutments
Depth to top of competent rock	Varies from 2 m in the river channel to 6 m in the abutments
Rock Excavation Slopes	1H : 5V, 3-m-wide benches every 10 m vertically
Soil Excavation Slopes	
Permanent	2H : 1V, 3-m-wide benches every 10 m vertically. Bench at soil-rock contact
Temporary	1.5H : 1V, 3-m-wide benches every 10 m vertically. Bench at soil-rock contact

A specific seismic design criterion was not used in the dam type selection stage since it was assumed that whatever dam type was selected would be designed to include seismic design features appropriate for the site. It was already understood that the project is located in a region known to be subject to earthquake activity.

9.3 Foundation Bedrock Characteristics

In general, the foundation bedrock at the site 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 immediate area of the Canal (e.g. Cucaracha Formation), where sliding and foundation failures have been common and presented serious problems.

- *Bearing Capacity.* The sandstones and shales are relatively soft rocks but are expected to present adequate bearing capacity to support any of the structures being considered. However, their moderately low modulus of deformation may result in settlement and/or displacements between adjacent structures of different size and weight. Data from subsurface investigation and testing will be needed to develop design and construction details to deal with such behavior.

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

- *Material Strength Parameters.* The estimated range of material strength parameters recommended for use in preliminary stability checks are provided in Table 11. These are based on published data for the respective lithologies and experience with similar materials elsewhere.

Table 11: Estimated Material Strength Parameters – Caño Sucio

Rock Type	**UCS (MPa)**	**ϕ (degrees)**	**c (MPa)**	**Unit Weight (kN/m^3)**
Fresh sandstone	35-120	45°	5	22
Weathered sandstone	20-70	30°	1	21
Basalt (quarry)	150-250	50°	10	26

9.4 Excavation Depths

Based upon observations made at the site and comparison with rock types elsewhere in similar environments, an average overburden thickness of 2 m was assumed, i.e. depth to top of weathered rock. The average depth to the top of competent rock was assumed to vary from about 2 m in the river channel where bedrock is exposed to about 6 m in the abutments. These values were used in the development of layouts and in the computation of quantity takeoffs for cost estimates. Actual depths and characteristics of weathering need to be investigated by drilling and geophysical exploration since these can have significant impact on the cost estimates.

Excavation for the dam was estimated as the following:

River channel:	2 m
Abutments:	6 m

Because of the absence of subsurface data, a detailed foundation excavation plan has not been developed. Instead, a general concept has been reached in which proposed excavation depths are equal to or deeper than the estimated minimum depths indicated above. 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.

The foundation excavation should go down to uncompressible, sound bedrock that can be readily grouted. 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.

9.5 Foundation Improvement, Treatment, and Long-Term Performance

No special foundation improvement or treatment measures are expected for the Caño Sucio site that would influence selection of one dam type over another. Similarly, the sandstone bedrock is expected to perform satisfactorily over the lifetime of the project without adverse deterioration. During subsequent investigations, the potential for internal erosion of the sandstone under high seepage pressures and flows should be studied to determine appropriate design and construction details.

Although small landslip and slumps are evident within the reservoir, no large mass movements are expected to affect the reservoir, but the effect of saturation, say after intense rainfall, on the stability of residual soils and saprolites needs to be properly evaluated.

9.5.1 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 foundation excavation under the dam, 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 plinth slab. Geologic conditions at this project are similar to what is interpreted for the Caño Sucio area with sedimentary and volcanic rock types.

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 for the dam foundation and under the spillway headworks. 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 lack of 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 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 either the crest of the dam or from a slab constructed at the upstream toe of 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 for the dam and spillway 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.

9.6 Foundation Stability Analysis

The proposed project layout has the dam located between 40 and 50 meters upstream of the crest of the waterfall. A preliminary analysis was performed to assess the stability of rock blocks forming the waterfall with respect to a potential increase in water pressure loads that could be introduced by impounding of the reservoir. The concern is that the dam foundation could be undermined by a progressive failure of the rock ledge downstream of the dam. The analysis indicates that the waterfall will be stable, however a more in-depth analysis incorporating information gained from the subsurface exploration program should be undertaken at the detailed design stage.

9.7 Construction Materials

Proposed sources and uses of available materials for construction, included required excavation, are discussed later in this report, Section 12, Construction Materials.

9.8 Plunge Pool Basin

Future assessments should examine rock erosion and stability conditions in areas where spillway discharge will impact. The stability of rock blocks forming the waterfall downstream of the dam should be considered with respect to the possibility of progressive erosion that could potentially impact foundation stability. Currently, it is expected that spillway discharge will not result in unfavorable progressive erosion or instability of individual blocks.

9.9 Diversion and Cofferdams

River diversion during construction will be accomplished by a diversion culvert and upstream cofferdam. The optimum size and location of these structures will be established during later phases of design with the benefit of subsurface investigations.

For preliminary design and estimating purposes, a culvert located on the left side of the river channel has been assumed with a length of about 50 m. The river elevation at the upstream entrance will about 83m and at the downstream exit, about 81m. The culvert will be a single box culvert with interior dimensions of 2 m by 2 m.

The upstream cofferdam will have a crest elevation of 87 m and will be about 5 m high. The cofferdam is proposed as an RCC structure.

9.10 Summary and Conclusions on Dam Site Geology

The Río Caño Sucio dam site has been well selected from a topographic viewpoint and appears to be the most suitable site in the area.

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 generally favorable and can be readily handled through conventional design and construction practices, without having to resort to special or unprecedented methods. Subsurface investigations have yet to be done to confirm technical feasibility, but at this stage it is thought 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 medium to fine-grained sandstone that would serve as a suitable foundation for the types of dam and appurtenant structures being considered;
- Based on outcrop data, a competent foundation for the dam can be obtained at reasonable depths;
- 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.

10 ENGINEERING GEOLOGY OF WATER TRANSFER SYSTEM

Construction of a project on the Río Coclé del Norte would involve transfer of the impounded water from the Río Coclé del Norte basin to Lake Gatun via the Río Indio basin. It has been presumed that a project in the Coclé del Norte basin would *not* be constructed unless the Río Indio project was first constructed. Therefore, the following discussion of the water transfer systems presumes that the Río Indio project has been constructed and is operational. The Río Indio project is described in the report "Feasibility Design of the Río Indio Water Supply Project" (MWH, April 2003). Details of the Río Indio project that pertain to the water transfer system include reservoir full and low supply levels of 80 m and 40 m, and an 8,350 m-long, 4.5 m diameter transfer tunnel between the Río Indio reservoir and Lake Gatun.

10.1 Water Transfer System Alternatives

As part of these studies, two alternatives are being evaluated for transferring water from the Río Coclé del Norte basin to the Río Indio basin. Selection of one of these alternatives will depend on the final selection of the project on the Río Coclé del Norte. The projects presently being considered are:

- A reservoir full supply level of 71 m
- A reservoir full supply level of 100 m.

For a reservoir elevation of 71 m, water would be transferred via a 15.8 km-long tunnel that would extend from an intake in the Río Coclé del Norte reservoir to a construction and control shaft close to the Río Indio reservoir. This is described in Section 10.2. An 0.8 km long drill and blast tunnel will be constructed from the shaft under Río Indio Reservoir, and connection to the reservoir would be by lake-tap; this is described in Appendix D5 and in the Main Report. The general arrangements are shown in plan view and in profile on Exhibits 24 to 27.

For a reservoir elevation of 100 m, water would be transferred to the Río Indio basin via the Río Caño Sucio reservoir (El. 100 m) using a 15 km-long canal and a 2.6 km-long tunnel. This is described in Section 10.3.

Selection of either project on the Río Coclé del Norte would require construction of a second transfer tunnel between the Río Indio basin and Lake Gatun. The tunnel alignment and profile are shown on Exhibits 28 and 29. A discussion of the second transfer tunnel is presented in Section 10.4.

10.2 Río Coclé del Norte to Río Indio Tunnel Alternative

Only one principal tunnel alignment was investigated for the Río Coclé del Norte Project. This alignment is indicated on Exhibit 24, with a total length of about 16,600 m, including the 0.8 km-long connection for the lake tap.

Very little is known of the geologic conditions in the area that would affect selection of a recommended alignment. Typically, the principal concern during preparation of initial layouts is to avoid or minimize areas where geologic conditions would be suspected to be unfavorable for the construction of long tunnels. Such areas would include zones of faulted rock, exceptionally weak rock, or where the tunnel alignment could parallel fracture zones. Ideally, it would be most favorable to maintain the tunnel excavation in uniform rock type and conditions. At this stage of study, information on such aspects is incomplete or speculative.

All other features and considerations of the Río Coclé del Norte - Río Indio water transfer tunnel being equal, the length and diameter of the tunnel can have the most direct impact on construction schedule and construction costs. Potential geologic factors influencing design and construction are described below.

10.2.1 Principal Lithologies along Tunnel Alignment

Existing geologic maps of the region show bedrock in the region as belonging to 'undifferentiated Tertiary volcanics' or alternatively as belonging to the Tertiary age Caimito Formation (tuffaceous sandstone, tuffaceous siltstone, tuffs, dacitic agglomerate, conglomerate, sandstone, and limestone). It is assumed that rock units that could be encountered in excavation of the tunnel alternative could include any of those identified during investigation of the Río Toabré and Río Indio sites and reservoir areas.

Geologic investigations at the Río Toabré dam site revealed a sedimentary sequence on both banks consisting of dark gray marls, marly limestones, siltstones, coarse-grained sandstones, and conglomerates. Various types of limestone units occur in the proposed reservoir area, ranging from thin-bedded silty limestones (calcilutites and calcwackes) to thick-bedded, hard, strong calcarenites, some of which contain significant layers and nodules of chert.

At the Río Indio dam site, geologic investigations indicate that bedrock units in the Río Indio project area consist of Tertiary sedimentary and volcanic rocks, assumed to be Caimito Formation units of tuffaceous siltstones and sandstones, conglomerates and agglomerates. These are interbedded with lavas and in some parts of the reservoir area, the sedimentary rocks are stratigraphically overlain by andesite and basalt flows. The volcanic units form many of the steep hills and high plateaus that are readily apparent on topographic maps and aerial photographs, while the sedimentary units tend to occur in the lower ground. Some of the volcanic formations might represent older units cropping out as erosional inliers.

In April 2003, geologic reconnaissance was carried out at the proposed intake and outlet portal locations for the proposed water transfer tunnel route. Observations indicated that the outlet works into the Río Indio reservoir would be constructed in rolling subdued topography with possibly little cover over tunnel grade and deeply weathered sedimentary units (sandstones and shales). Recommendations were made to locate the proposed outlet works sufficiently far back to ensure adequate rock cover and to attain relatively sound bedrock.

At the intake end, reconnaissance revealed that the topography in the portal area is complicated with deeply incised drainages. Nevertheless, it was considered that a favorable portal location could be found with a range of options for detailed design, i.e. flexibility in vertical and horizontal location. The bedrock geology in this area (possibly Cañazas Formation) consists of a variable sedimentary sequence of thick-bedded calcareous pebbly sandstone units (conglomerates), calcareous sandstone and siltstone (calcilutes), sandy tuffaceous limestone, and hard cherty limestone (calcarenite). Based on the presence of abundant basalt float in the area, an igneous unit could also occur in the area, possibly a local dike, sill, or isolated lava flow, but its exact location with respect to the portal is not known.

It is probable that tunnel construction for the inter-basin transfer will encounter a wide range of rock types and tunneling conditions. The range and relative persistence of various conditions will depend on final alignment selection. Rock types could include sandstone and softer epiclastics of the Caimito Formation as well as hard, strong lavas (andesites, dacites, and basalts), limestones, and agglomerates. Based on air-photo interpretation and map studies, there is a strong probability of encountering karstic limestone conditions within the first third of the tunnel length – as evidenced by enclosed surface depressions and doline-like features. Associated with karstic conditions could be the potential for significant water inflows and poor tunneling conditions. There will also be transition over short distances from very hard strong rock (such as andesite or basalt) to soft, weak almost clay-like materials. Such aspects would need to be examined in more detail to establish their impact on construction method as well as cost parameters, including support and lining requirements.

10.2.2 Major Regional Structures Affecting Tunnel Alignment

There are no known major features that would seriously impact tunnel alignment selection. As interpreted from field reconnaissance, aerial photographs and topographic maps, there is the potential of encountering a wide range of rock types and conditions, none of which would be completely unfavorable to tunneling. The potential of encountering very hard and resistant igneous lithologies in a volcanic neck or plug should be examined in a later phase. At this time, it is thought that the proposed alignment does not encounter such conditions. The number and orientation of major faults or other discontinuities is not known at this time.

Review of the regional geology with respect to tunnel alignments has also taken into consideration the depth of cover, depth of overburden and weathered bedrock under stream crossings, potential for faults or shear zones under stream crossings, and stability of hillsides and slopes over or adjacent to the tunnel alignment.

10.2.3 Local Geologic Structures Affecting Tunnels

The stability of the underground openings (tunnels and shafts) will depend on the orientation, frequency, and characteristics of rock discontinuities, rock stresses, and on groundwater conditions encountered during construction. At this stage of study, it is not possible to predict the location or accurately estimate the extent of local geologic conditions that will impact tunnel stability. Anticipated tunneling conditions are described below based on interpretation of available geologic information, review of other tunnel projects, and experience from elsewhere.

Geologic factors affecting the design and construction costs of the Río Coclé del Norte - Río Indio water transfer tunnel involve two basic areas:

- Anticipated tunneling (excavation) conditions along selected alignments, including potential for water inflow during construction, potential for hazardous gases and hydrothermal water, and potential for squeezing ground, slabbing rock and rock bursts, and
- Anticipated support requirements

Generally, it is desirable to locate tunnels in as geologically competent material as possible to minimize lengths requiring heavy tunnel support, especially near to the portals. Since there is little information on geologic conditions along the proposed alignment and at the tunnel portal locations, evaluation relied on the estimated geologic conditions interpreted from topographic and photogeologic features. Preference was given to portals located where relatively steep topographic rises indicate the potential to encounter comparatively competent bedrock within a short distance.

Approximate estimates were made of anticipated tunneling conditions and support requirements along potential alignments under consideration. Geologic criteria and their impacts upon the development and design of various tunnel features are discussed below.

10.2.4 Cover Criteria

The tunnel cover criterion (the minimum vertical distance between the ground surface and the crown of the tunnel excavation) used in developing a potential alignment was:

$$H = 2D + 10 \text{ meters}$$

Where H equals the distance between the ground surface and the crown of the excavated tunnel and D equals the tunnel diameter. The requirement for two effective tunnel diameters between the top of ground and the crown of the tunnel is based on previous experience with the construction of tunnels of this type in similar environments. Ten meters was added to this value to account for topographic uncertainty (including the 20-m-contour interval of the topography available for this study).

In addition to influencing factors relating to excavation and support, ground cover becomes an important consideration for selection of tunnel lining requirements.

10.2.5 Tunnel Diameter

For the initial tunnel alignment studies an effective finished tunnel diameter of 9.0 meters was used, based on hydraulic criteria. The excavated diameter would be larger to take into account lining thickness (0.3 to 0.5 m).

10.2.6 Tunnel Excavation Methods

Alternative methods of excavation can be considered for the water transfer tunnel, involving either conventional drill-and-blast or mechanical excavation by tunnel boring machine (TBM), or both. These methods would entail different excavation and finished tunnel profiles, as well as differing construction schedules and associated risks and costs. Selection of a preferred method would involve consideration of various factors, including geologic conditions, construction schedule, risk, and cost.

For drill-and-blast methods, the excavated shape for the tunnel will be of a horseshoe, or modified horseshoe. The finished tunnel profile would be in shape of a horseshoe or possibly circular, depending on internal design pressures. For mechanical excavation by TBM, the excavated shape for the tunnel will be circular. The finished tunnel profile would also be circular.

For costing and scheduling purposes, it was assumed that tunnel construction would utilize TBM for the bulk of excavation with drill-and-blast techniques in limited lengths at the main portals. A typical tunnel cross-section is shown in Exhibit 23.

The most compelling reason for selection of the TBM method of excavation concerns the total length of the tunnel and the necessity for intermediate access locations with a drill-and-blast approach. At least three construction access points would be needed for drill-and-blast, and because of the relatively subdued topography, access adits would have to be very long. Construction shafts could be used as an alternative to access adits but they would be relatively deep. In addition, intermediate access points, either adits or shafts, would require construction of long access roads. It is considered that, using a TBM approach, it would be possible to eliminate the need for intermediate access, though small diameter utility shafts might be needed.

10.2.7 Estimated Tunnel Excavation Conditions

Conditions at Contacts and in other Geologic Structures (Faults, Shear Zones, etc.). Most of the principal rock formations are expected to be in normal contact with one another. In some places lithologic contacts could be faulted and in such areas there will be zones of highly fractured rock, breccia, gouge, and probable water inflow. These conditions will pose special problems for excavation and support. The width of contact zones and faults will vary and range up to one tunnel diameter (<1 m to > 5 m).

Most faults are interpreted to be more or less vertical, or steeply inclined, and therefore the tunnels should be affected over only relatively short distances by such features. Lithologic contacts, however, could be gently inclined or horizontal. Any conditions or characteristics associated with them would be experienced over longer distances. These would have the most severity where mixed ground or lithologies of strongly contrasting character could be encountered.

Potential for Water Inflow. Experience indicates that groundwater inflow should be expected at various points along the proposed tunnel alignment. However, the location and quantity of water inflow are not known and cannot be predicted with any certainty. It should be assumed that inflow potential will be greatest in zones of faulted or highly fractured rock, in zones of deep weathering, and in low cover zones at stream crossings (which are probably characterized anyway by faulted, fractured, or weathered bedrock). Water inflow potential should also be assumed at contacts between formations, especially at contacts with igneous units. Water inflow potential should also be assumed within the zone of limestone that could be karstic. Water encountered in the tunnel excavations should not be at high very pressures, only up to the head equivalent of the overlying ground cover.

Because of the uncertainty in predicting rock conditions ahead of the tunnel face, probe hole drilling is recommended, especially in zones where faults are anticipated, and maintained at least 20 m ahead of the face to detect changes in rock conditions or potentially high water inflows.

Potential for Hazardous Gases and Hydrothermal Water. The potential for encountering hazardous gases is considered remote. Ventilation and shotcrete have been used successfully to control gas occurrences, should they occur.

Potential for Squeezing Ground, Slabbing Rock, Rock Bursts. The tunnels are not likely to encounter stress-related problems (popping rock, slabbing rock, or rock burst in competent rock, squeezing ground in weak/fractured rock) because the rock cover is not that great.

10.2.8 Rock Support Classification

Rock support requirements estimated to be encountered in the tunnel during construction are listed in Tables 12 and 13. Geology and rock support requirements have a direct impact on the tunnel excavation, and therefore directly impact construction costs and scheduling. Rock support requirements are determined based upon rock conditions encountered along the tunnel alignment, which are typically divided into four different types. The four rock conditions types used for this study are listed in Table 12 below.

Table 12: Estimated Rock Support Classes for Río Cocle del Norte-Rio Indio Transfer Tunnel

Rock Type	Description	Drill-and-Blast	TBM*
Type I	**Excellent** - Best Rock Conditions	Typically minimal overbreak and generally self-supporting or requiring minimal support with shotcrete and spot rock bolting of localized rock wedges, full face excavation with normal advance.	No systematic support required
Type II	**Good to Fair** - Good to Fair Rock Conditions	Moderate overbreak, generally requiring systematic support with shotcrete and rock bolts to within 10-20 m of face. Full-face excavation with normal advance. Prompt, systematic rock bolting with shotcrete (fiber-reinforced shotcrete) to within 2-5 m of the face required to control loosening of rock.	One pass shotcrete locally, split sets, mine straps as required.*
Type III	**Fair to Poor** - Fair to Poor Rock Conditions; weathered or weak rock, fractured rock, contacts between different rock units, closely jointed rock. Possible local inflows of groundwater.	Full-face excavation, with slower, shorter advance and larger amounts of overbreak. Requires prompt support with shotcrete after excavation, with systematic pattern rock bolting.	One pass shotcrete, locally, systematic split sets, mine straps as required.*
Type IV	**Very Poor** – Worst Conditions; fault zones and shear zones containing crushed, altered rock, or at shallow depths, highly weathered, disaggregated rock, potentially squeezing or running/ flowing ground. High inflows of groundwater possible.	Requires shortened excavation rounds, possibly top heading and bench in worst areas. Prompt support to within 1-2 m of the face with steel ribs (or lattice girders or shotcrete-encased rebar ribs) with steel lagging and rock backpacking or shotcrete (fiber-reinforced, or with welded wire mesh). Grouting may be necessary to reduce water inflows.	Shotcrete with mesh, systematic split sets, mine straps as required.*

* Note: It is assumed that if a segmental liner system is used in combination with TBM excavation method that temporary rock support requirements would be minimal provided prompt installation of the liner takes place. It is also assumed that probe drilling ahead of the face will be carried out with provisions for pre-excavation grouting.

Tunnel lengths associated with the rock support classes, I - IV, listed in Table 12, were estimated for the proposed alignment. These were based on the general knowledge of the geology of the area, geologic mapping, and judgment to account for:

- Lithology and the extent to which a tunnel alignment could encounter mixed face conditions or rock types of markedly different character (strength, fracture type, etc.) alternating over short distances (Type III condition).
- Potential widths and degree of rock fracturing in faults,
- Depth of cover and potential for development of weathered ground,
- Effects of tectonic shears commonly associated with folding of rocks, and
- Other factors, such as presence of water or proximity to a major stream crossing.

For the proposed tunnel alignment, the proportional distribution of the different rock support classes are estimated as shown in Table 13. On Table 13 is also shown a suggested comparison, based on experience, between rock support classification and conventional rock mass classifications, Q-system and RMR.

Table 13: Estimated Rock Conditions for Cocle del Norte-Rio Indio Transfer Tunnel Route

Rock Support Class	Symbol	Q Values	RMR Values	Estimated Percent of Total Tunnel Length
Excellent	I	> 7.0	> 60	20%
Good to Fair	II	1.0 - 7.0	40 – 60	40%
Fair to Poor	III	0.4 - 1.0	35 – 40	30%
Very Poor	IV	< 0.4	< 35	10%

10.2.9 Tunnel Lining

For this study, it is assumed that the tunnel will be fully lined from portal to portal. The lining will be required mostly for hydraulic reasons, but will also be to control water loss in low cover zones and areas of severely fractured rock and to prevent erosion and deterioration of the rock in areas of soft or highly fractured rock.

A pre-cast concrete, segmental lining has been assumed in all rock conditions (I-IV) described above. The thickness of the liner is expected to be between 0.3 and 0.5 m. A thickness of 0.4 m has been assumed for estimating purposes.

The segmental lining will be designed for various loading conditions, including construction (grouting and rock wedge loads), operation (external and internal hydrostatic pressures, rock relaxation loads), and inspection/de-watering condition (external water and rock pressures). The design will take into account areas of low cover (inadequate confinement) or poor ground. A simple expanded liner would be used in good ground, while a stronger reinforced liner will be provided for lining in Types III and IV rock. In areas where the rock cover is low and there is inadequate confinement (estimated to be where the hydraulic grade line exceeds 40 m of total cover), a more heavily reinforced liner will be designed to accept internal tunnel pressures with some interaction with the surrounding rock.

A segmental lining system typically has the disadvantage of greater hydraulic roughness compared to a cast-in-place concrete lining. However, it has significant scheduling and production advantages in that rock support and tunnel lining are installed in one pass. With a cast-in-place concrete lining, the lining operation could not begin until mining has been completed.

A cast-in-place concrete lining (reinforced as required) will be included in the drill-and-blast sections of the tunnel, such as at the portals, and in other areas as needed.

Final design of the tunnel lining will require information on geologic and groundwater conditions obtained from appropriate investigations. External pressures acting on the concrete-lined sections should not be a concern since the cover depth is not large and groundwater pressures would rapidly dissipate through cracks in the concrete.

Concrete lining (segmental, cast-in-place concrete, or fiber-reinforced shotcrete) would be required in fault zones and in areas where the rock mass is severely fractured or deeply weathered. The potential for substituting steel-fiber reinforced shotcrete lining for segmental or cast-in-place concrete should be investigated in a later phase. For cost estimating purposes, it was assumed in this study that shotcrete with rock bolts would constitute the primary method of support. It might be possible to optimize use of shotcrete as permanent lining.

10.2.10 Tunnel Muck

It is estimated that about 1,250,000 m^3 of excavated material (un-bulked tunnel muck; approximately 1.94 million m^3 bulked) will be removed from the underground works. Initially, some of the material (such as the muck from excavation of the portals and starter tunnels) might be used immediately for other construction purposes (e.g. road bedding, fills, etc.) though the majority will probably be hauled to disposal areas. These have not yet been identified but would probably be within 5 km of the tunnel exit point.

10.2.11 Tunnel Excavation Advance Rate

The anticipated geologic and tunneling conditions strongly influenced the estimate of excavation advance rate and construction cost.

A detailed estimate of the advance rate including lining that could be achieved by a TBM-mined alternative has not been made at this stage of design. In general, it is estimated that the mining advance rate could be in the range of 12-15 m per day (net penetration rate of about 1.75 m/h and 42% utilization). Provisions would need to be made for adjustments in the cutter system to account for changes in rock type (hardness and abrasivity) along the length of the tunnel. Design of a TBM system for the Río Coclé del Norte project would probably be able to address most, if not all the rock mass parameters that influence TBM excavation advance rate. Nevertheless, there can remain important risk elements associated with certain geologic conditions, such as potential for water inflow or squeezing conditions, though for this project squeezing ground is considered to be only a remote possibility because of relatively low cover.

The estimated daily advance rate estimates per excavation face for drill-and-blast excavation sections of the headrace tunnel range from about 1 m/day in the Type IV ground to about 5 m/day in the best ground. The average may be under 4 m/day. Limiting factors on the production rates will probably not be geologic but rather other aspects, such as resource availability and intermediate access.

10.3 Río Coclé del Norte to Río Indio Canal-Tunnel Alternative

For a reservoir elevation of 100 m, water would be transferred to the Río Indio basin via the Río Caño Sucio reservoir (El. 100 m) using a canal and a tunnel as indicated on Exhibit 24. Water transfer from the Río Coclé del Norte Reservoir to the Río Indio Reservoir will be through a 15,100-m long channel with a base width of 5 m and side slopes of 2H:1V, and through a 2,550-m long 5.5-m diameter tunnel.

10.3.1 Geology along Canal-Tunnel Alignment

Existing geologic maps of the region show bedrock in the region as belonging to 'undifferentiated Tertiary volcanics'. In fact, no regional geologic mapping has yet been carried out in this area. It is assumed that rock units that could be encountered in excavation of the canal alternative could include any of those identified during investigation of the Río Toabré and Río Indio sites and reservoir areas.

The first part of the canal from the Río Coclé drainage to the Caño Sucio drainage would involve excavation through a saddle area (at Quebrada Encantada). This will encounter varied sedimentary rock units belonging to the upper Cañazas Formation and lower Caimito Formation, ranging from marls, limestones, siltstones, coarse-grained sandstones, to conglomerates. Based on the presence of abundant basalt float in the area, igneous units could also occur in the area, possibly local dikes, sills, or isolated lava flows.

The bulk of the proposed canal alignment through the Caño Sucio Reservoir would encounter various soil or overburden units rather than rock formations. The nature and origin of these are unknown at this time but are thought to include fine-grained alluvium (silty sand), possibly lacustrine sand and silt deposits, and severely weathered to decomposed sedimentary bedrock. The groundwater table can be expected to be close to the surface or at shallow depths along about one third to half of this reach. Locally in the canal reach leading up to the Río Indio tunnel, excavation might encounter bouldery basalt talus originating from basalt outcrops on the flanks of Cerro Miguel.

It is probable that excavation of the 2,550-m-long tunnel from the Caño Sucio Reservoir to the Río Indio drainage will encounter a wide range of rock types and tunneling conditions. Rock types could include sandstone and softer epiclastics of the Caimito Formation as well as hard, strong lavas (andesites, dacites, and basalts) and agglomerates. Because of the relatively low cover, various degrees of weathering of the rock formations should be expected over much of the tunnel length.

10.3.2 Canal and Tunnel Excavation Conditions

Without the benefit of subsurface investigations, the following general conditions are estimated:

Table 14: Estimated Excavation Conditions for the Canal Alignment

Canal Station	Excavation Conditions	Canal Length
0+000 to 2+700	• Decomposed rock, talus, alluvium, and soil; common excavation • Weathered bedrock; rippable • Fresh bedrock; requires blasting	20% 40% 40%
2+700 to 12+000	• Fine-grained alluvium (silty sand), possible lacustrine sand and silt deposits, severely weathered to decomposed sedimentary bedrock; groundwater close to surface; common excavation	100%
12+000 to 17+000	• Alluvium, weathered/decomposed rock, bouldery basalt talus; common excavation, possible light blasting locally or use of hydraulic breakers • Weathered to fresh bedrock; requires blasting	90% 10%

10.3.3 Canal Stability and Lining

Canal slopes in soil and soil-like decomposed materials would be 2H:1V. A 3-m wide bench will be excavated for every 10 m of vertical cut. Slopes in deeper sections in fresh rock could be steeper. The canal would have a base width of 5 m. It is assumed that the canal would be unlined and that water velocities would be low and less than 1.5 m/s.

10.3.4 Canal Construction Approach

Excavation of the eastern branch of the transfer canal will be initiated from the tunnel intake end as soon as access is gained at that location. In this upper reach small cofferdams and diversion channels will be used to perform the work in the dry, as river flows are not expected to be excessive. It is however anticipated that the bulk of the effort will be transferred to Las Maravillas as soon as the construction access has reached that location. The work there will progress in the upstream direction and consist of the following sequences:

- Construction (excavation) of an initial channel, possibly part of the final canal, to be used as diversion;
- Construction of a cofferdam\diversion dam to direct the flows into the diversion channel;
- Excavation of the main canal to the final grade;
- Dredging as necessary of the existing river bed;
- Breaching of diversion into the completed segment.

Depending on the detail of the river configuration, these segments could be as long as one kilometer. Temporary berms, river crossings and roads may be required. Detailed topographic maps will be required for the planning of the operation.

A similar operation will be initiated for the western branch of the canal on the Río Limon. Both operations will progress in parallel. Overall the excavation of the canal is expected to take approximately 34 months, including possible disruptions during the periods of large flows.

10.3.5 Tunnel from Río Caño Sucio Reservoir to Río Indio Reservoir

Bedrock outcrops in the tunnel area consist of a sequence of interbedded tuffs, epiclastics, sandstone, and dark andesitic lava. The commonest lithology appears be the sandstone, which in many outcrops is seen to be thick-bedded and relatively strong. The volcanic units form many of the steep hills and high plateaus that are readily apparent on topographic maps and aerial photographs, while the sedimentary units tend to occur in the lower ground.

Estimated rock support class and support requirements for the Caño Sucio to Río Indio tunnel are as follows:

Table 15: Estimated Tunneling Conditions for the Caño Sucio-Río Indio Tunnel

Rock Support Class	Support Requirements	Tunnel Length
Excellent	Minimal support and spot rock bolting	20%
Good to Fair	Systematic support with shotcrete and rock bolts to within 10-20 m of the face	35%
Fair to Poor	Prompt support with shotcrete after excavation with systematic pattern rock bolting	35%
Very Poor	Steel ribs with steel lagging and rock backpacking or shotcrete, or rebar ribs encased in shotcrete; possible spiling and grouting	10%

10.3.6 Tunnel Construction Method

It is assumed that the 2.5-km-long tunnel will be excavated using the drill-and-blast method. The advance rate of excavation greatly depends on the rock quality: it can vary from approximately one meter per day in Type IV ground to five meters per day in the best ground. An average advance rate of 3.5 to 4.0 meters per day has been recommended as a realistic estimate for the Caño Sucio to Río Indio transfer tunnel. Excavation of the tunnel will be initiated from both ends. Intermediate access would not be required.

The selected tunnel shape is a 5.5-meter diameter modified horseshoe (D-shape) section. It is estimated that approximately 61,000 m^3 of material (un-bulked) will be excavated from the tunnel. Taking into account the portal excavation and construction of the access road from the western to the eastern portal it is anticipated that the tunnel excavation will be completed in approximately 24 months.

It is also assumed that the tunnel will be fully lined with cast-in-place concrete throughout to prevent erosion and deterioration of the rock in areas of soft or highly fractured rock. The concrete lining of the tunnel will follow the excavation and it is anticipated to take approximately six months.

10.4 Río Indio to Lake Gatun Transfer Tunnel

With construction of either one of the proposed water supply projects on the Río Coclé del Norte, a second transfer tunnel between the Río Indio reservoir and Lake Gatun would be required to transfer the increased supply of water.

Only one tunnel alignment was examined for the second transfer tunnel; it is located about 120 m to the south of the first tunnel in an approximately parallel alignment. The alignment was selected with the idea that facilities that would be developed for the Río Indio project, such as access roads, power facilities and intermediate tunnel access adits, would be utilized for construction of the second transfer tunnel. Additionally, experience gained during construction of the first transfer tunnel, especially knowledge of ground conditions, would be directly applicable to the second tunnel. The selected tunnel alignment for the second transfer tunnel is about 8250 m long and is shown in plan and profile on Exhibits 28 and 29.

Tunneling conditions (lithology, geologic structure, groundwater inflow) for the second transfer tunnel are assumed to be the same as those anticipated for the first transfer tunnel. The reader is referred to Río Indio report Appendices B (Geology, Geotechnical and Seismological Studies) and D4 (Indio-Gatun Water Transfer Tunnel) (MWH, April 2003) for a more detailed discussion of the studies carried out in support of the first Río Indio to Lake Gatun transfer tunnel. These studies include a tunnel alignment selection study, as well as two site visits made in the area of the tunnel intake and outlet portals.

Prior to construction of the Coclé del Norte project, the first Río Indio-Lake Gatun tunnel will have been constructed. All of the experience and knowledge gained during construction will be used in the design of the second Indio-Gatun tunnel, including final tunnel alignment, construction method, rock support and tunnel liner design.

10.4.1 Geologic Conditions along Tunnel Alignment

Existing geologic maps of the region show bedrock in the region as belonging to 'undifferentiated Tertiary volcanics' or alternatively as belonging to the Tertiary age Caimito Formation (tuffaceous sandstone, tuffaceous siltstone, tuffs, dacitic agglomerate, conglomerate, sandstone, and limestone). There is debate as to whether the rock sequence found in this region is the same as the Caimito Formation best known in the immediate area of the Canal. Based on discussions with ACP geologists in the field, it is conjectured that the sandstone and tuffaceous sequence observed in the Río Indio area could in fact be younger than the Caimito known from elsewhere and overlay older, possibly pre-Tertiary volcanics.

Geologic investigations at the Río Indio dam site indicate that bedrock units in the Río Indio project area consist of Tertiary sedimentary and volcanic rocks. The sedimentary formations comprise tuffaceous siltstones and sandstones, conglomerates and agglomerates. These are interbedded with lavas and in some parts of the reservoir area, the sedimentary rocks are stratigraphically overlain by andesite and basalt flows. The volcanic units form many of the steep hills and high plateaus that are readily apparent on topographic maps and aerial photographs, while the sedimentary units tend to occur in the lower ground. Some of the volcanic formations might represent older units cropping out as erosional inliers.

Two reconnaissance visits were made to the area of the proposed tunnel intake and outlet portals in 1999 and 2002 as part of the studies for the Río Indio Project. Outcrops of a very hard and strong andesite and basalt were found in the vicinity a potential location for the tunnel outlet works was visited close to Isla Pablon on Lake Gatun. These materials are quarried locally and would provide useful sources of construction material for the project. Sedimentary rocks, possibly tuffaceous and foraminiferal sandstone belonging to the marine phase of the Caimito Formation, were found nearby. It was confirmed that the Gatun outlet works could be founded on sound igneous bedrock, however, design details, such as the extent of tailrace channel excavation and the extent of tunnel steel lining would depend on final arrangements with respect to local topography.

At the intake end, reconnaissance revealed that the topography in the portal area is favorable and provides a range of options for detailed design, i.e. flexibility in vertical and horizontal location. The bedrock geology consists of thick-bedded sandstone units, such as found at the dam site, which crop out or are mantled with a thin layer of cobbly/bouldery colluvium. Based on the presence of basalt float in the area, an igneous unit also occurs in the area, probably a local sill or dike, but its exact location with respect to the portal is not known.

It is probable that tunnel construction for the inter-basin transfer will encounter a wide range of rock types and tunneling conditions. The range and relative persistence of various conditions will depend on final alignment selection. Rock types could include sandstone and softer epiclastics of the Caimito Formation as well as hard, strong lavas (andesites, dacites, and basalts) and agglomerates. There is potential for transition over short distances from very hard strong rock (such as andesite or basalt) to soft, weak almost clay-like materials. Differing ground conditions can be expected for any of the tunnel alignments considered in this study. Such aspects would need to be examined in more detail to establish their impact on construction method as well as cost parameters, including support and lining requirements.

There are no known major features that would seriously impact tunnel alignment selection. As interpreted from aerial photographs and topographic maps, the general trend of the principal structures, including faults and principal lithologic contacts, is northwest-southeast. Local northeast-southwest lineaments are also observed. In this regard, the overall alignment of the alternative tunnel alignments is favorable with respect to the strike of features that will be intercepted by underground construction. Most of the significant discontinuities and contacts will be intersected more or less at favorable angles that will reduce the amount of rock support required. The alignment of some smaller sections of the tunnel system may be less favorable with respect to the orientation of the major geologic features.

10.4.2 Tunnel Diameter

The final finished tunnel diameter of the selected tunnel arrangement is 6.5 meters. Depending on rock conditions, the excavated diameter will range from 7.0 to 7.5 meters.

10.4.3 Excavation Methods

Alternative methods of excavation can be considered for the water transfer tunnel, involving either conventional drill-and-blast or mechanical excavation by tunnel boring machine (TBM), or both. For cost estimating purposes, it was assumed that tunnel construction would utilize drill-and-blast techniques from multiple headings. A typical tunnel cross-section is shown in Exhibit 23.

It is assumed that intermediate access adits developed for the first transfer tunnel would be rehabilitated and utilized for construction of the second transfer tunnel.

10.4.4 Anticipated Tunneling Conditions

Tunnel lengths associated with the rock support classes, I - IV, listed in Table 7, were estimated for the different alignments considered. These were based on the general knowledge of the geology of the area, geologic mapping, and judgment to account for 1) potential widths and degree of rock fracturing in faults, 2) depth of cover and potential for development of weathered ground, 3) effects of tectonic shears commonly associated with folding of rocks, and 4) other factors, such as presence of water or proximity to a major stream crossing. Also taken into consideration was the extent to which a tunnel alignment could encounter mixed face conditions or rock types of markedly different character (strength, fracture type, etc.) alternating over short distances (Type III condition).

For the selected tunnel alignment, the proportional distribution of the different rock support classes is estimated as shown in Table 16. On Table 16 is also shown a suggested comparison, based on experience, between rock support classification and conventional rock mass classifications, Q-system and RMR.

Table 16: Estimated Rock Conditions for the Río Indio-Lake Gatun Transfer Tunnel

Rock Support Class	Symbol	Q Values	RMR Values	Estimated Percent of Total Tunnel Length
Excellent	I	> 7.0	> 60	25%
Good to Fair	II	1.0 - 7.0	40 - 60	40%
Fair to Poor	III	0.4 - 1.0	35 - 40	30%
Very Poor	IV	< 0.4	< 35	5%

10.4.5 Tunnel Lining

For this study, it is assumed that the tunnel will be fully lined from portal to portal. The lining will be required mostly for hydraulic reasons, but will also be to control water loss in low cover zones and areas of severely fractured rock and to prevent erosion and deterioration of the rock in areas of soft or highly fractured rock.

A cast-in-place concrete lining has been assumed in all rock conditions (I-IV) described above. Minimum lining thickness will be 25 cm but will be thicker, 50 cm, in areas of low cover (inadequate confinement) or poor ground.

Nominal reinforcement (for temperature/shrinkage crack control) will be provided for lining in Types III and IV rock. In areas where the rock cover is low and there is inadequate confinement (estimated to be where the hydraulic grade line exceeds 40 m of total cover), more heavily reinforced concrete linings will be designed to accept internal tunnel pressures with some interaction with the surrounding rock.

Reinforced concrete lining and a steel-lined section are included in the tunnel at the downstream end approaching Lake Gatun where internal pressures would be greatest. Currently it is assumed that steel lining is necessary because the rock cover over and around the pressure tunnels along the present alignment does not provide adequate confinement for the tunnels.

Final design of the tunnel lining will require information on geologic and groundwater conditions. The steel-lined sections for the tunnel should be designed to withstand, when empty, an external hydrostatic pressure equal to the groundwater table in the surrounding rock mass. External pressures acting on the concrete -lined sections should not be a concern since the cover depth is not large and groundwater pressures would rapidly dissipate through cracks in the concrete. Final design optimizations might consider benefits offered by alternative tunnel shapes (horseshoe or circular) with respect to savings in concrete volumes and structural stability of the lining.

The design of steel lining for internal pressures, as well as reinforced concrete-lined sections, should consider some interaction and participation with the rock mass surrounding the lining. The extent of such interaction is a function of the quality and properties of the surrounding rock mass and the ability to perform and effectiveness of consolidation grouting.

Concrete lining, consisting of cast-in-place concrete or fiber-reinforced shotcrete, would be required in fault zones and in areas where the rock mass is severely fractured or deeply weathered. The potential for substituting steel-fiber reinforced shotcrete lining for cast-in-place concrete should be investigated in a later phase. For cost estimating purposes, it was assumed in this study that fiber-reinforced shotcrete would constitute the primary method of support. It might be possible to optimize its use as permanent lining.

Since proportionally more tunnel concrete-lining quantities would be required in a drill-and-blast excavation than with TBM, the tunneling construction method should be re-evaluated during the next phase of study following site investigations.

10.4.6 Tunnel Muck

It is estimated that about 385,000 m^3 of excavated material (unbulked tunnel muck) will be removed from the underground works. Initially, some of the material (such as the muck from excavation of the construction adits) might be used immediately or for other construction purposes (e.g. road bedding, fills, etc.) though the majority will probably be hauled to disposal areas.

10.4.7 Excavation Advance Rate

The daily advance rate estimates per excavation face for drill-and-blast excavation sections of the headrace tunnel range from about 1 m/day in the Type IV ground to about 5 m/day in the best ground. The average is just under 4 m/day, which is considered realistic. Limiting factors on the production rates will probably not be geologic but rather other aspects such as resource availability and intermediate access.

11 GEOLOGY OF POWERHOUSE AREAS

Locations for powerhouse facilities immediately downstream of the Río Coclé del Norte and Río Caño Sucio dams were not specifically investigated in the field as their respective sizes and arrangements were not known at the time of the investigations. However, no unusual or exceptional problems are envisaged with respect to geology or geotechnical conditions that would strongly impact such developments.

12 CONSTRUCTION MATERIALS

The types of required construction materials for the project are:

- Materials for cofferdams,
- Concrete aggregates,
- Filters and drains,
- Rock fill for the dam, backfill materials and other structural fills, and
- Rock for riprap and slope protection.

12.1 Río Coclé del Norte Project Area

12.1.1 Available Materials

Materials available in the vicinity of the proposed Río Coclé del Norte dam site include alluvial deposits in terraces and along the river bottom, overburden, and rockfill from quarry operations. Each of the material types is discussed below; their locations are indicated on Exhibit 30.

Alluvial Deposits. Small alluvial terraces are found at various locations along the river and are found to consist of clayey and sandy silt with fragments of weathered basalt. These are limited in size and volume and do not provide a suitable resource for construction materials. Gravel deposits in the river bottom are used as a source of materials by local inhabitants but are also thought to be limited in quantity for use in dam construction as zone material in fill dams or as concrete aggregate.

Colluvial and Residual Soils. Based on current interpretations of overburden conditions in the vicinity of the proposed dam site, the overburden in this area can be classified as a bouldery and gravely silty clay or clayey silt with sand. Such overburden could be suitable for use in random fills for access roads, ramps or in cofferdams, and also as random fill zones for a zoned earthfill dam type. However, it is considered that the predominance of boulder-sized, weathered basalt blocks precludes the overburden from use as a core material, or as either coarse or fine filter zones in a zoned fill dam alternative. Removing boulder-sized blocks from the overburden could potentially produce core material, but alteration of the remaining cobble sized fragments due to breakage could lead to a gap-graded or open graded material in-place. Although most of the bedrock in the project area is covered by horizons of talus, colluvial, and residual soils, it is thought that the relatively shallow depth of overburden at the dam site would necessitate opening other additional borrow sources.

Basalt. Bedrock throughout the dam site area consists of basalt rock units. Rockfill could be obtained from materials removed from the required excavations (e.g. spillway and diversion tunnel excavation). However, the quantities of rockfill required for a fill dam type would most likely require opening of one or more rock quarries in the area in addition to use of materials from required excavation. The area downstream of the proposed dam site on the right side of the Río Coclé del Norte contains high hills that could be stripped and opened as quarries. This currently seems to be the most attractive location for quarry operations to supply not only rockfill for dam construction, but also coarse aggregate for concrete and filters.

No suitable natural sand deposits were identified in the vicinity of the Project site for potential use as fine aggregate for concrete during the site investigations. Investigations of terrace deposits along the sides of the river indicated that these materials may be sandy or contain some quantity of sand, but further exploration of these features could not be carried out due to suspension of site investigation activities in December, 2001. Due to the low ground surface elevation of the lower terraces above the river level, excavation of suitable quantities of materials from these terraces, if found to contain suitable materials, would be difficult.

Helicopter reconnaissance of the Caribbean shoreline on either side of the mouth of the Río Coclé del Norte was carried out. The shoreline in both directions can be described as rocky with many outcrops of basalt bedrock. Small sand beaches were identified, and local people have reportedly used the beach sand for construction purposes in the area; however, it is doubtful that these beaches could successfully yield adequate quantities of sand suitable for construction. There may be offshore sources of sand that could be mined and transported to the Project site via the Río Coclé del Norte; but the existence and adequacy of such sources is purely speculative, and could not be confirmed during the site investigations activities.

Given the above observations, the most promising source of fine concrete aggregate may come from quarry operations such as those described for use in producing coarse aggregates.

12.1.2 Use of Materials

Diversion cofferdams will consist of temporary dikes designed to divert the river, in combination with channel excavation. Currently, it is assumed that these could be constructed from locally available random fill obtained from the immediate area of the dam site.

All aggregates (including coarse and fine aggregates for concrete, filters, drains, and riprap) need to be manufactured from quarried sources. Coarse and fine aggregates for concrete will be processed from quarried igneous rock materials, i.e. basalt or andesite. Aggregates for filters and drains will be obtained by processing of the same quarry sources as exploited for concrete aggregates.

A portion of the rockfill for the dam could be obtained from required excavation, provided that it is not too decomposed. The majority of the rockfill will need to be obtained from quarries opened near the site. Materials for backfill will come from the required excavations, including use of tunnel excavation spoil.

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

12.2 Caño Sucio Project Area

12.2.1 Available Materials

Various construction material sources were examined during field reconnaissance and study of topographic maps. These are discussed below and their locations are indicated on Exhibit 31.

Alluvial deposits. Deposits of alluvial materials that could be used for construction are not found in the project area. The nearest significant sources of natural sands and gravel materials are located outside of the drainage basin.

Residual soils. It is assumed that most of the bedrock along the sides of the river valley in the project area is covered by well-developed horizons of residual soils. No test pits or close inspection of these soils were conducted in either of the two reconnaissance visits. However, the sedimentary bedrock found in this area is similar to the tuffaceous sandstone and siltstone bedrock found at the Río Indio dam site. The overlying residual soils are also thought to bear strong similarities. Residual soils in a test pit excavated at the Río Indio dam site were found to consist of clayey silt. It is interpreted that most of the overburden in the project area is clay-rich due to the calcareous and tuffaceous nature of the bedrock. Samples of this material from the Río Indio investigations were tested in the laboratory and found to be suitable for use as impervious fill. Sufficient quantities of residual soil are available at or near the dam site for use as impervious fill material for the earthfill dam types being considered for the Caño Sucio site.

Sandstone. Tuffaceous sandstones and siltstones form the uppermost bedrock units at the site and are thought to be widespread throughout the project area. As stated earlier, bedrock is covered by overburden to some thickness throughout the project area, except where it is exposed at the river channel and the waterfall. Sandstone and siltstone can be obtained from required excavations in rock at the dam site; however, no other potential quarry sites containing significant quantities of these materials were confirmed during the reconnaissance visits. Furthermore, the results of laboratory testing conducted on tuffaceous sandstones and siltstones for the Río Indio project indicate that the material may be of sufficient strength to be used as random rockfill; however, its durability is such that it most likely would not be suitable for use as concrete aggregate or for select processed fills (i.e. filters, drains, riprap).

Andesite and Basalt. Andesite and basalt rock units suitable for development as construction material sources are found in the area around Cerro Miguel. A potential quarry site for obtaining these materials was identified near Cerro Loma Alta, located approximately 5-6 km to the southeast of the site. Samples from this site were compared with samples collected and tested for Río Indio and were found to be petrologically similar. Results indicate that the material would be suitable for use as rockfill, processed select fills, and concrete aggregate.

12.2.2 Use of Materials

The diversion dam will consist of a temporary dike designed to divert the river, in combination with the culvert excavation. This would be constructed from locally available random fill obtained from the immediate area of the dam site.

All aggregates (including coarse and fine aggregates for concrete, filters, drains, and riprap) need to be manufactured from quarried sources of andesite and basalt located about six kilometers away from the damsite. To decrease the cement requirements for RCC, some mixing with imported sands and silts will be necessary, impacting the cost of production. The nearest significant sources on natural sands and gravel material are located outside of the drainage basin

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

13 RECOMMENDED ADDITIONAL INVESTIGATIONS

13.1 Coclé del Norte and Caño Sucio Dam Sites

In the next phase of study for the Ríos Coclé del Norte and Caño Sucio Water Supply Projects, 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. These will have to include the types of subsurface investigations that were postponed for the present study. 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.

13.1.1 Coclé del Norte Dam Site Drilling

The additional exploration drilling shown in Table 17 is recommended as a minimum, assuming that the type of dam will be a concrete faced rockfill dam. Another program of investigations will be required to support detailed design. Approximate hole locations are indicated on Exhibit 32.

Table 17: Proposed Drilling for the Coclé del Norte Dam

Location	Number of Drill Holes	Total Depth (m)
Plinth foundation, left side	2	100
Plinth foundation, right side	3	150
Dam foundation, downstream left side	1	50
Dam foundation, downstream right side	1	50
Spillway	4	200
Diversion tunnel	3	250
Diversion tunnel exit channel	1	30

Location	Number of Drill Holes	Total Depth (m)
Upstream cofferdam	3	100
Saddle dam	1	50
Powerhouse and power tunnel	2	120
Quarry	4	200
Contingency	3	200
Total	**28**	**1,500**

13.1.2 Caño Sucio Dam Site Drilling

The additional exploration drilling shown in Table 18 is recommended as a minimum, assuming that the type of dam will be an RCC or conventional concrete gravity dam. Another program of investigations may be required to support detailed design. Approximate hole locations are indicated on Exhibit 33.

Table 18: Proposed Drilling for the Caño Sucio Dam

Location	Number of Drill Holes	Total Depth (m)
Dam foundation, left side	2	100
Dam foundation, right side	3	150
Spillway	2	100
Quarry	4	200
Contingency	1	100
Total	**12**	**650**

13.1.3 Dam Site Geologic Mapping

Detailed geologic mapping would be performed for the entire site area. The detailed geologic mapping will be performed to illustrate the detailed surface geology of 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.

13.1.4 Adits

It is recommended that the next phase of investigation include an exploration adit at the Coclé del Norte dam site to assist in the evaluation of dam foundation conditions. The total length of adit excavation should be about 100 m.

13.1.5 *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.

The possible need for and practicality of performing dilatometer tests in selected drill holes should be also examined in order to obtain additional information on the range of rock mechanics properties of *in situ* bedrock.

Geophysical testing should be conducted throughout the dam site. In addition to surface seismic refraction, consideration should be given to downhole seismic (cross hole seismic) and possibly resistivity surveys. 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).

13.1.6 Construction Materials for Dam

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. For a basalt rock quarry, it is estimated that 4 drill holes will be required for a total of about 300 m. If a sandstone rock quarry is needed as well, additional drilling will be required. Rock core samples will be collected for laboratory testing which should include compression testing, soundness, LA abrasion, and concrete petrography, etc. as follows:

Table 19: Recommended Testing for Rock Quarry Materials

Test	ASTM Designation
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
Potential Alkali Reactivity	ASTM C 227
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 20: Recommended Testing for Construction Materials

Test	ASTM Designation
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 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 289 ASTM C 227
LA Abrasion	ASTM C131 and ASTM C 535
Point Load Test	ISRM

13.2 Water Transfer System

In the next phase, investigations for the water transfer tunnel alternative and/or canal alternative will focus on a specific alignment and locations for the transfer system and other structures (e.g. intake and outlet portals). Activities will cover the following features:

- **Water conveyance tunnel, intake, and outlet portals**; information will be required to develop new or confirm previous data for estimating excavation and support requirements, construction technology, portal stabilization, groundwater inflows, etc.
- **Canal**; information will be required to develop an appropriate design for the canal and to develop cost parameters for construction, including rock and soil

characteristics and groundwater depths. This will provide data needed to estimate excavation methods, lining requirements and support (if needed), groundwater control requirements, excavation stability, and other construction parameters.

Investigation activities will include geologic mapping, core drilling, and testing.

13.2.1 Core Drilling Investigation for Tunnel

The approximate scope of recommended core drilling would probably involve about 4 to 6 drillholes in proposed portal areas, totaling about 300 m. Depending on the number and location of intermediate points of access for construction, additional drilling may be advisable at points along the transfer tunnel route.

13.2.2 Geologic Mapping

Detailed geologic mapping will be performed at the locations of tunnel portals and detailed geologic reconnaissance will be performed along the entire length of the tunnel corridor. The latter will be combined with revised photogeologic interpretations carried out on new aerial photography that should be flown as part of the next phase of study. The primary objective will be to revise and improve the current estimate of conditions that would be encountered during construction of the proposed tunnel.

13.2.3 *In Situ* Testing

Permeability testing will be performed in all exploration drill holes (Lugeon testing in rock, Lefranc testing in soil and overburden). Dilatometer and pressuremeter tests might be considered.

13.2.4 Construction Materials

Construction materials investigation for the water transfer tunnel facilities will be linked to those being carried out for the dam and other structures.

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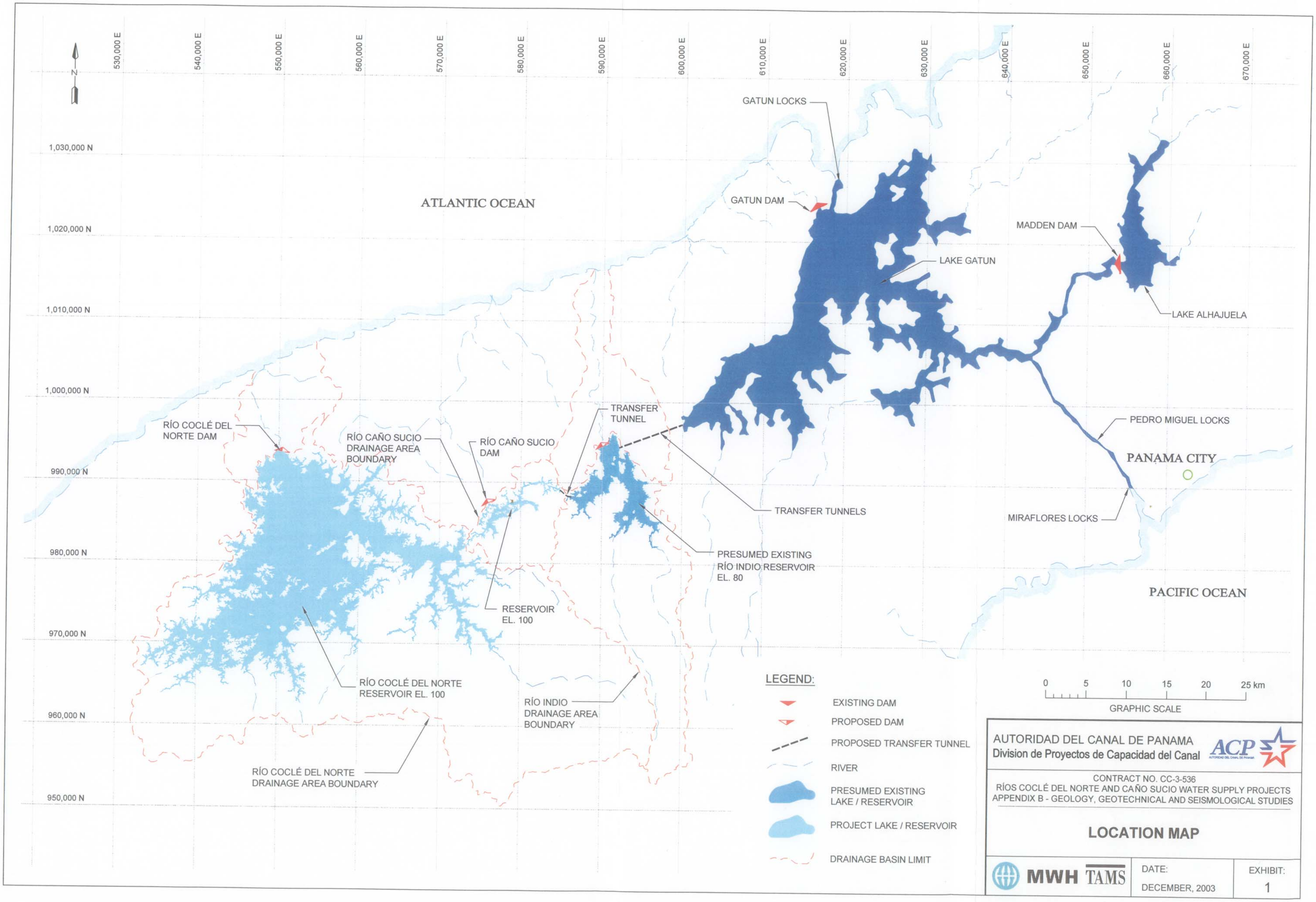
EXHIBITS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LAKE ALHAJUELA
PEDRO MIGUEL LOCKS
MIRAFLORES LOCKS
TRANSFER TUNNEL
TRANSFER TUNNELS
RÍO COCLÉ DEL NORTE DAM
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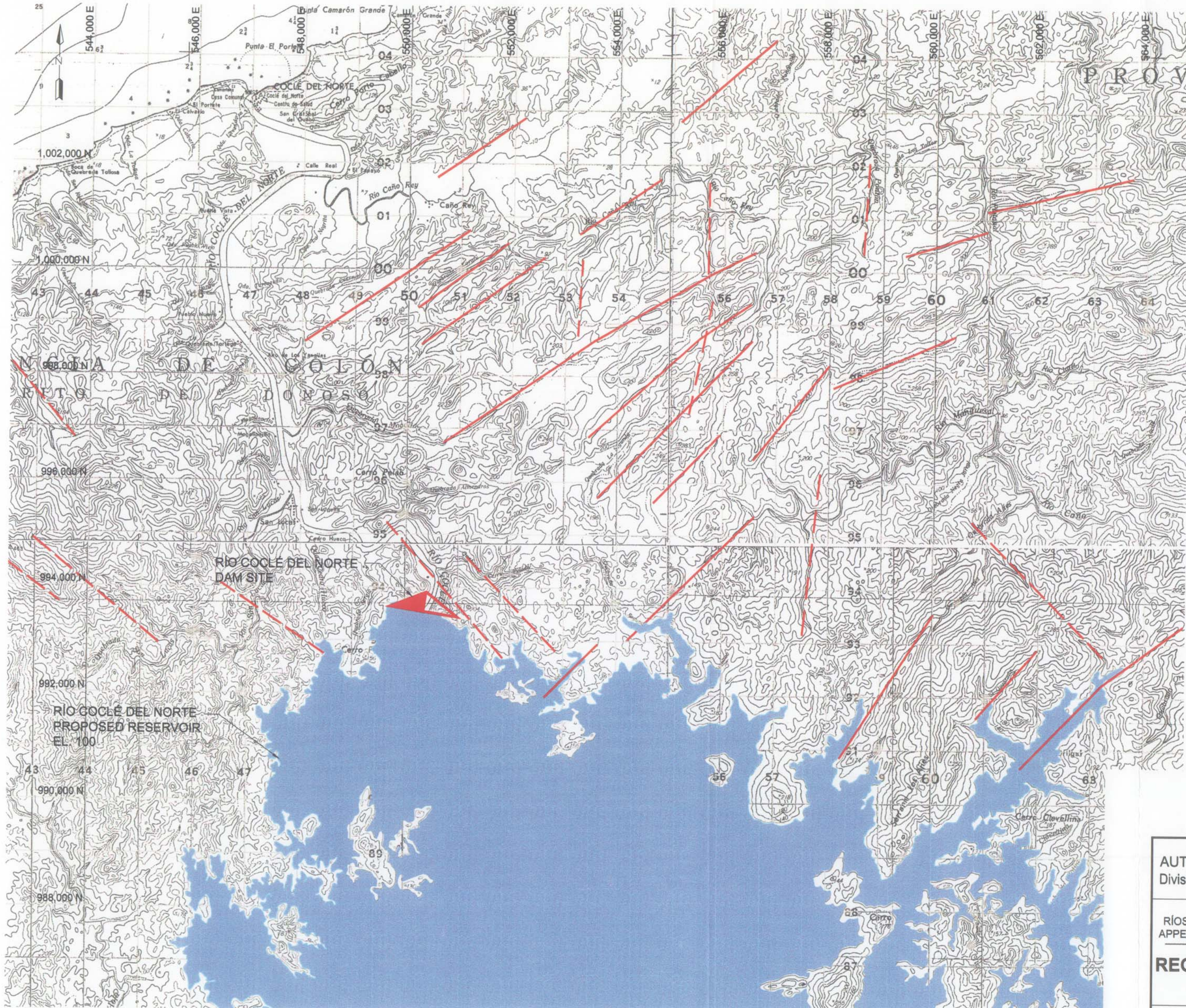
LEGEND:
EXISTING DAM
PROPOSED DAM
PROPOSED TRANSFER TUNNEL
RIVER
PRESUMED EXISTING LAKE / RESERVOIR
PROJECT LAKE / RESERVOIR
DRAINAGE BASIN LIMIT
0
5
10
15
20
25 km
GRAPHIC SCALE
AUTORIDAD DEL CANAL DE PANAMA
Division de Proyectos de Capacidad del Canal
ACP
CONTRACT NO. CC-3-536
RÍOS COCLÉ DEL NORTE AND CAÑO SUCIO WATER SUPPLY PROJECTS
APPENDIX B - GEOLOGY, GEOTECHNICAL AND SEISMOLOGICAL STUDIES
LOCATION MAP
MWH TAMS
DATE:
DECEMBER, 2003
EXHIBIT:
1



LEGEND:

NE LINEAMENTS

NW LINEAMENTS

N-S LINEAMENTS

NOTES:

1. GEOLOGIC CONTACTS INFERRED BASED ON MAP STUDY, AERIAL RECONNAISSANCE AND SITE VISITS TO DAM SITE AND CERRO LOMA ALTA.

0 1 2 3 4 5 km

GRAPHIC SCALE

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

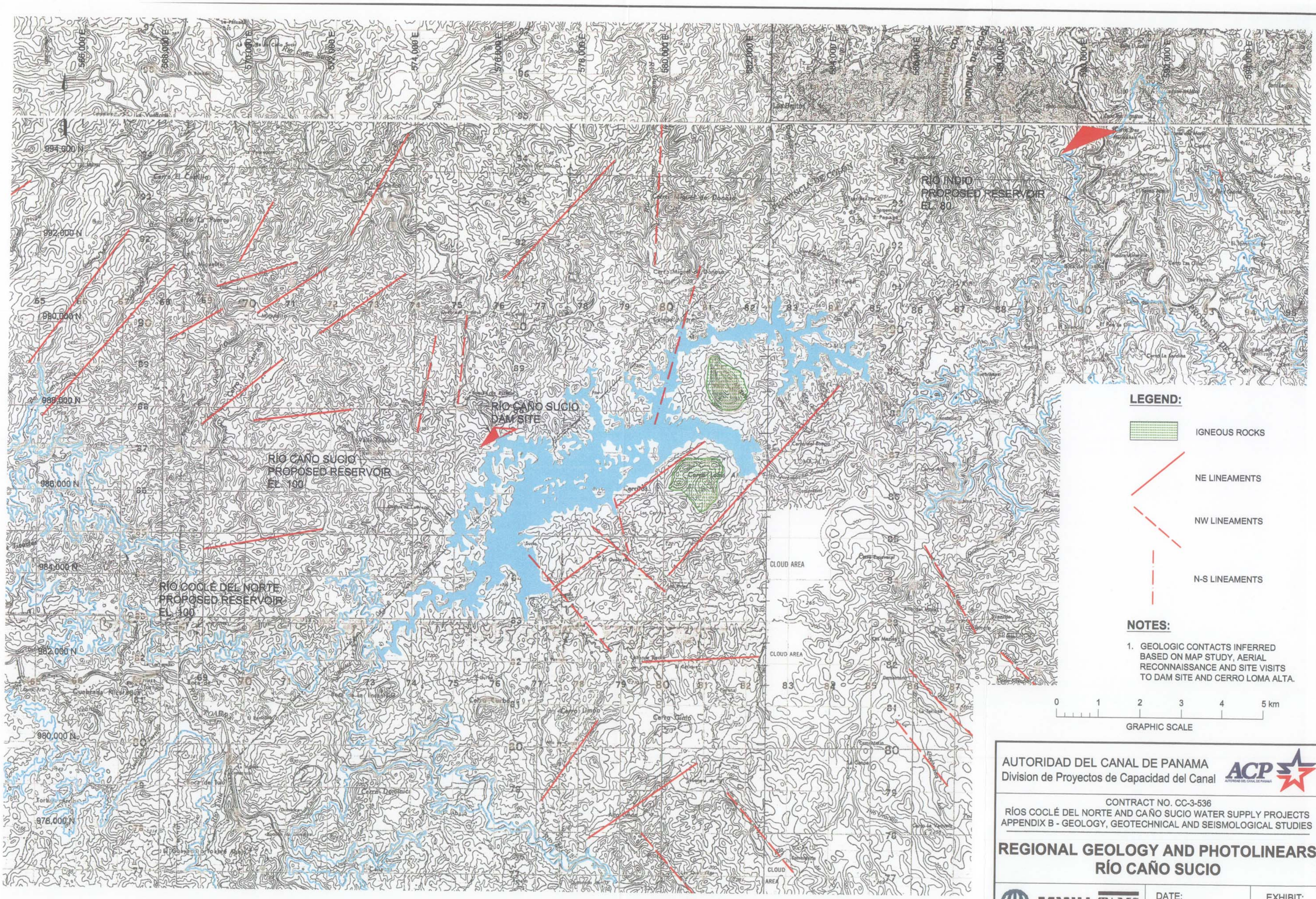
CONTRACT NO. CC-3-536
RÍOS COCLÉ DEL NORTE AND CAÑO SUCIO WATER SUPPLY PROJECTS
APPENDIX B - GEOLOGY, GEOTECHNICAL AND SEISMOLOGICAL STUDIES

REGIONAL GEOLOGY AND PHOTOLINEARS
RÍO COCLÉ DEL NORTE

MWH TAMS

DATE: DECEMBER, 2003

EXHIBIT: 2



NOTES:

1. GEOLOGIC CONTACTS INFERRED BASED ON MAP STUDY, AERIAL RECONNAISSANCE AND SITE VISITS TO DAM SITE AND CERRO LOMA ALTA.

AUTORIDAD DEL CANAL DE PANAMA
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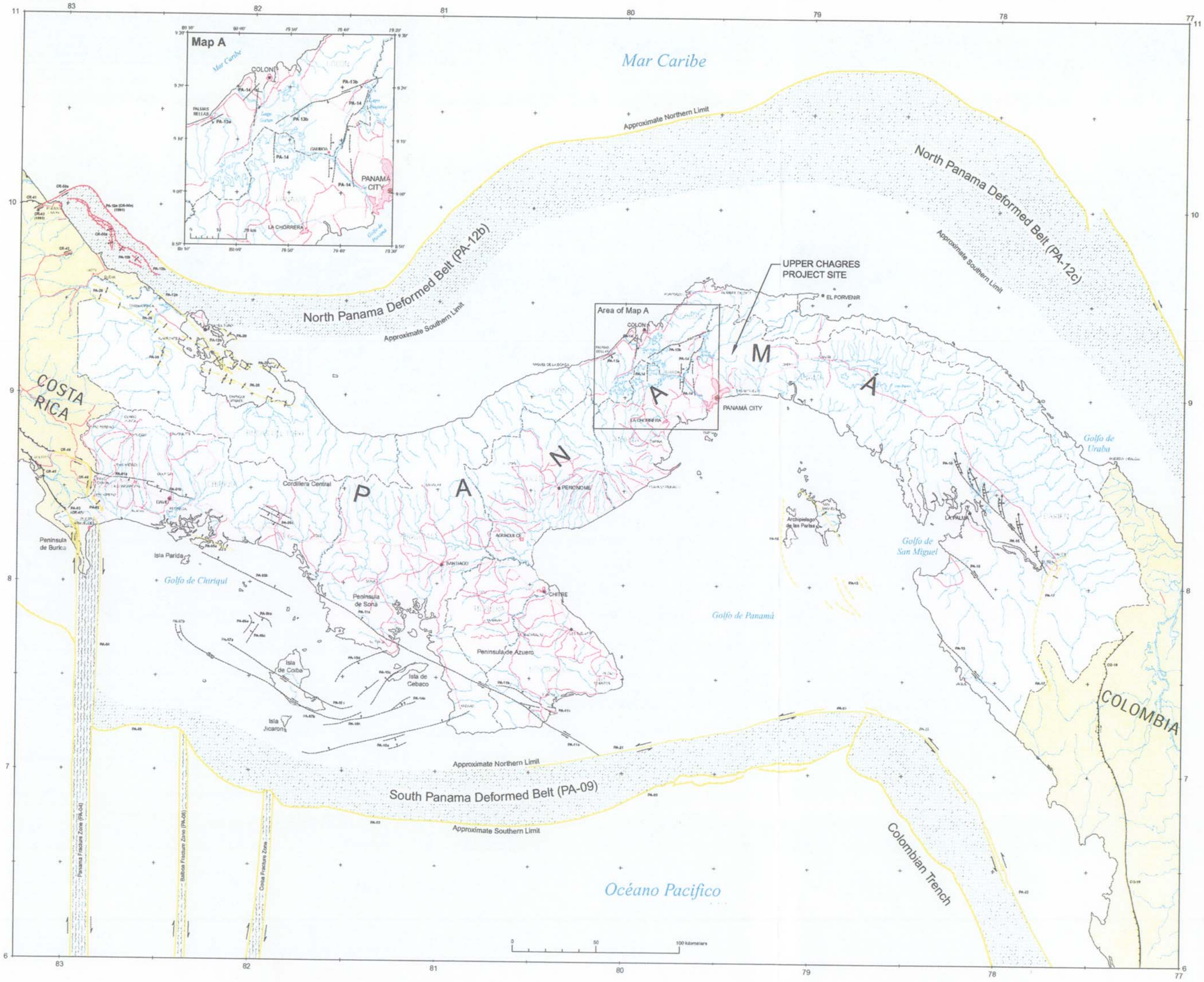
CONTRACT NO. CC-3-536
RÍOS COCLÉ DEL NORTE AND CAÑO SUCIO WATER SUPPLY PROJECTS
APPENDIX B - GEOLOGY, GEOTECHNICAL AND SEISMOLOGICAL STUDIES

REGIONAL GEOLOGY AND PHOTOLINEARS
RÍO CAÑO SUCIO

MWH TAMS

DATE:	EXHIBIT:
DECEMBER, 2003	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

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

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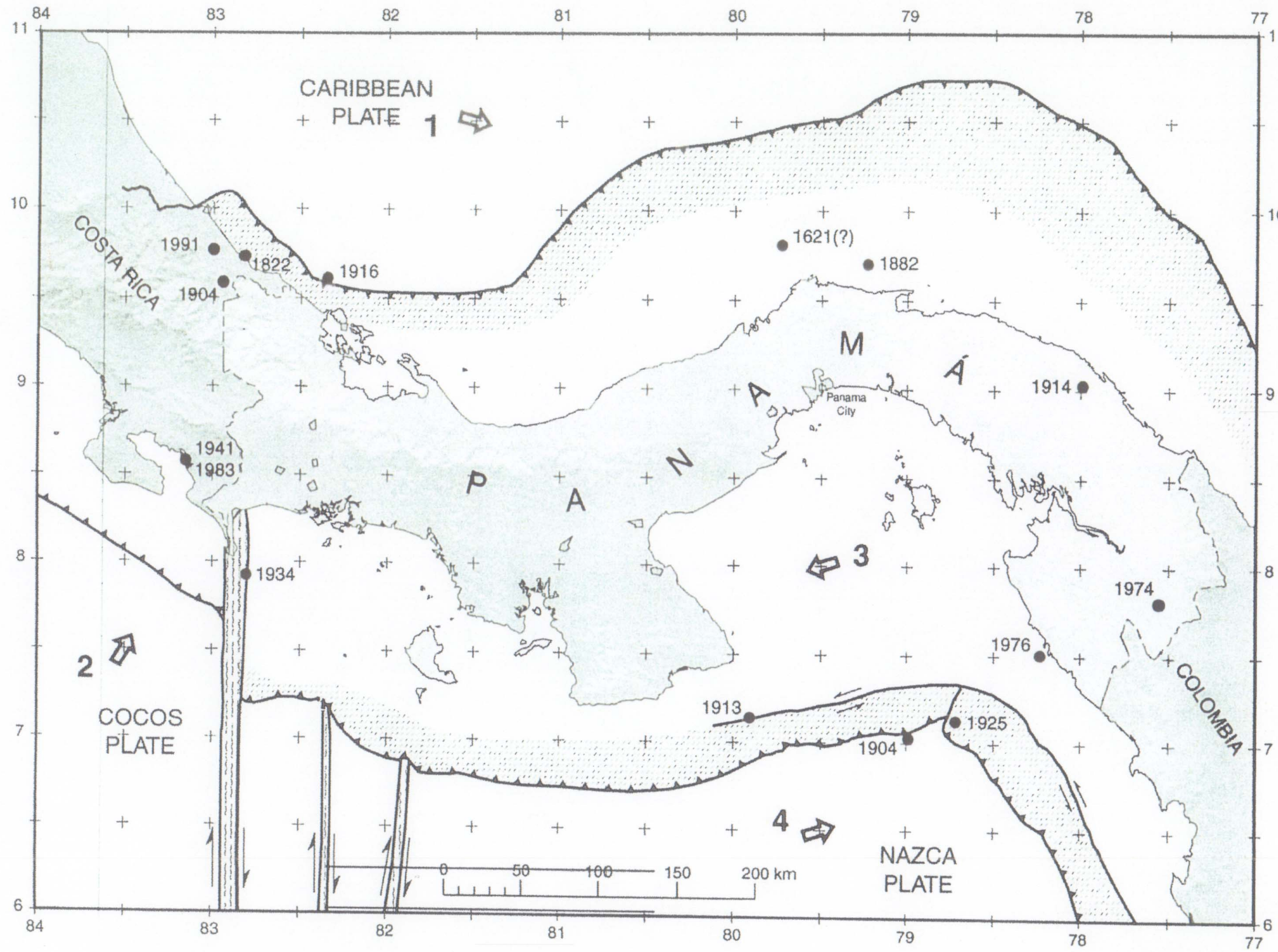
APPENDIX B - GEOLOGY, GEOTECHNICAL AND SEISMOLOGICAL STUDIES

MAP OF FAULTS AND FOLDS IN PANAMA

MWH TAMS	DATE: DECEMBER, 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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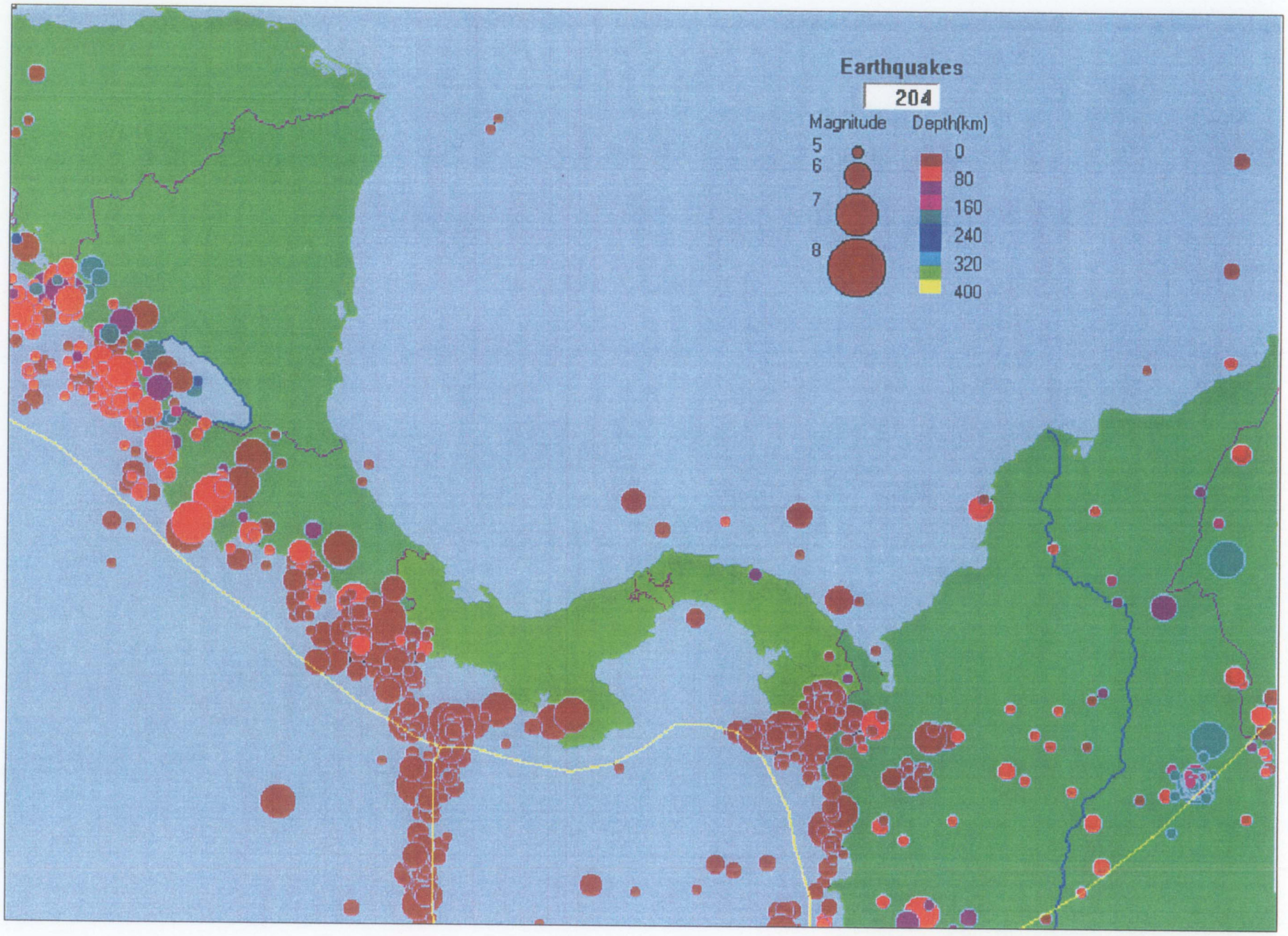
APPENDIX B - GEOLOGY, GEOTECHNICAL AND SEISMOLOGICAL STUDIES

PLATE BOUNDARIES

MWH TAMS

DATE: DECEMBER, 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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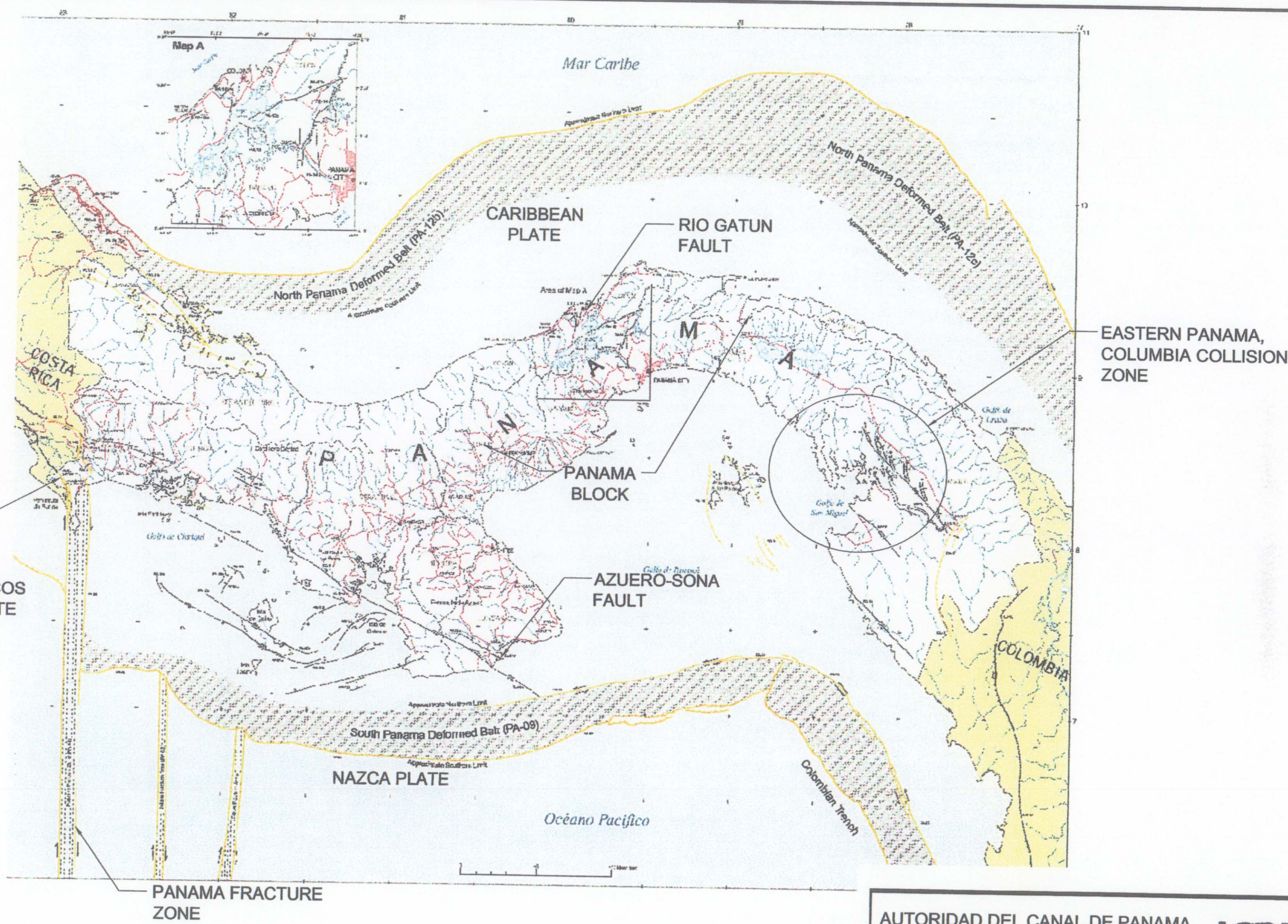
SEISMICITY OF PANAMA

MWH TAMS

DATE: DECEMBER, 2003

EXHIBIT: 6



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

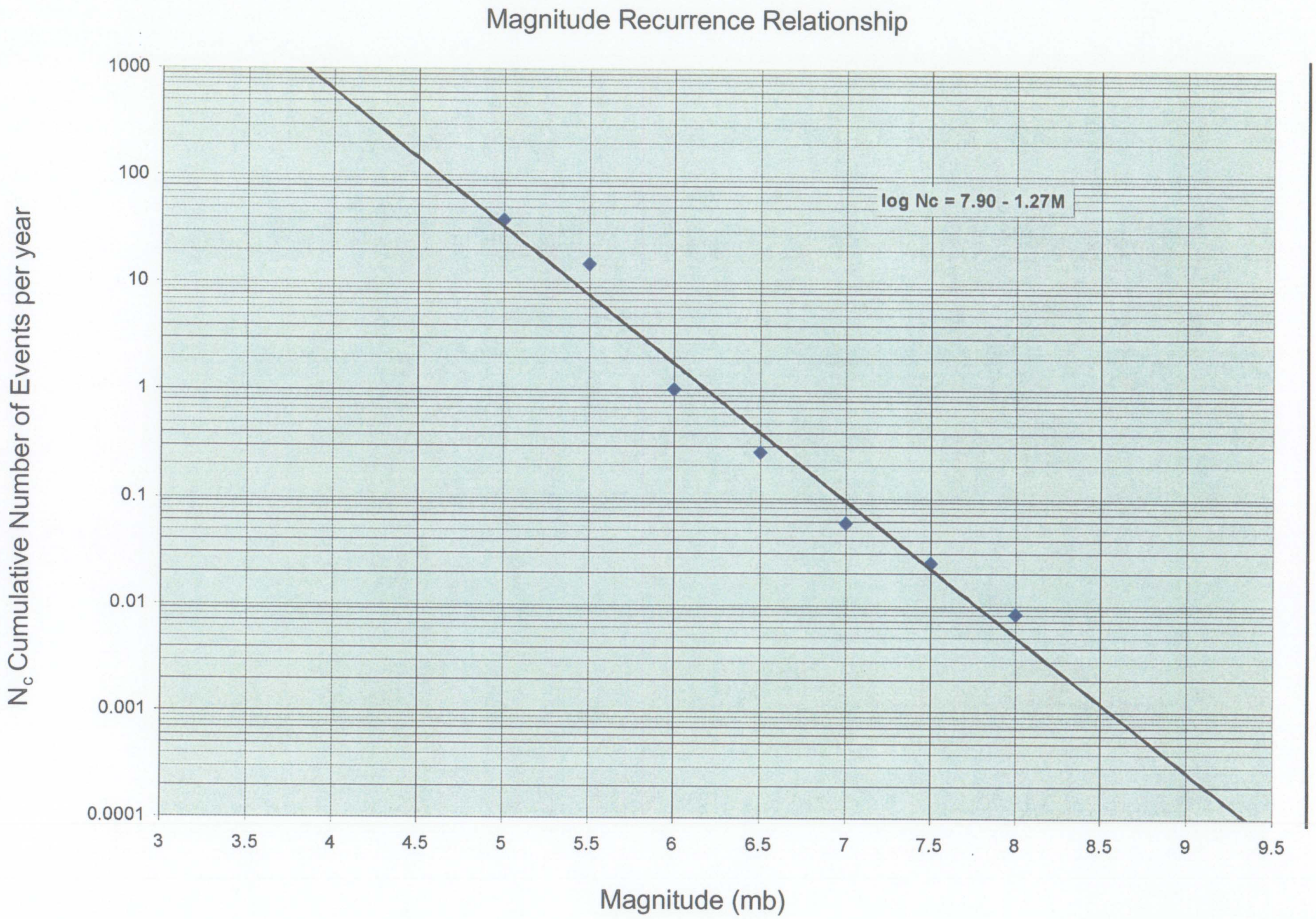
ACP

CONTRACT NO. CC-3-536
RÍOS COCLÉ DEL NORTE AND CAÑO SUCIO WATER SUPPLY PROJECTS
APPENDIX B - GEOLOGY, GEOTECHNICAL AND SEISMOLOGICAL STUDIES

SEISMIC SOURCE ZONES

MWH TAMS

DATE:	EXHIBIT:
DECEMBER, 2003	7



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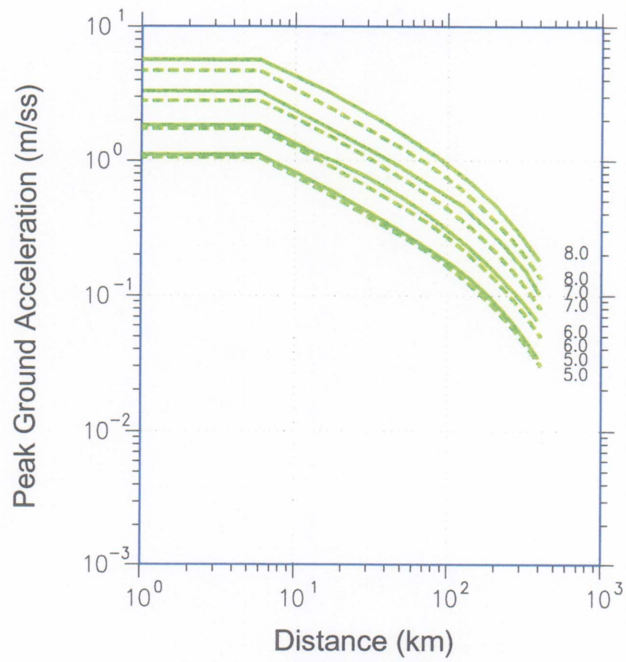
APPENDIX B - GEOLOGY, GEOTECHNICAL AND SEISMOLOGICAL STUDIES

PRELIMINARY MAGNITUDE RECURRENCE CURVE

MWH TAMS	DATE: DECEMBER, 2003	EXHIBIT: 8



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

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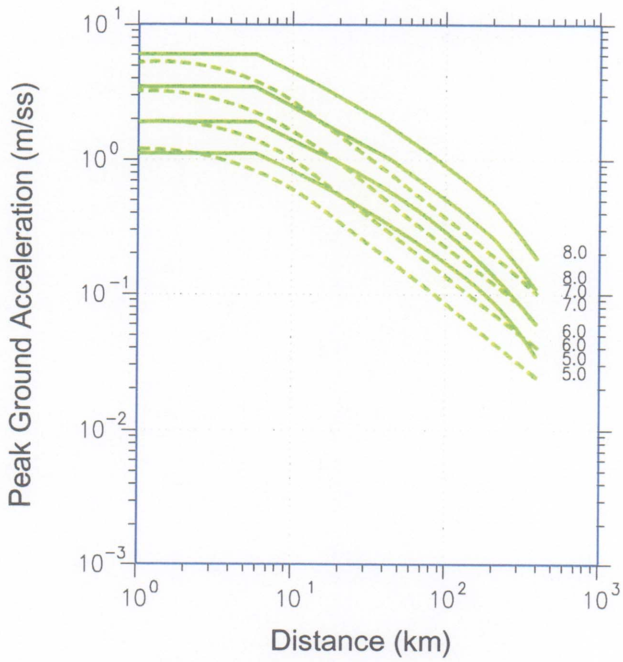
ATTENUATION CURVES
SHEET 1 OF 4

MWH TAMS	DATE: DECEMBER, 2003	EXHIBIT: 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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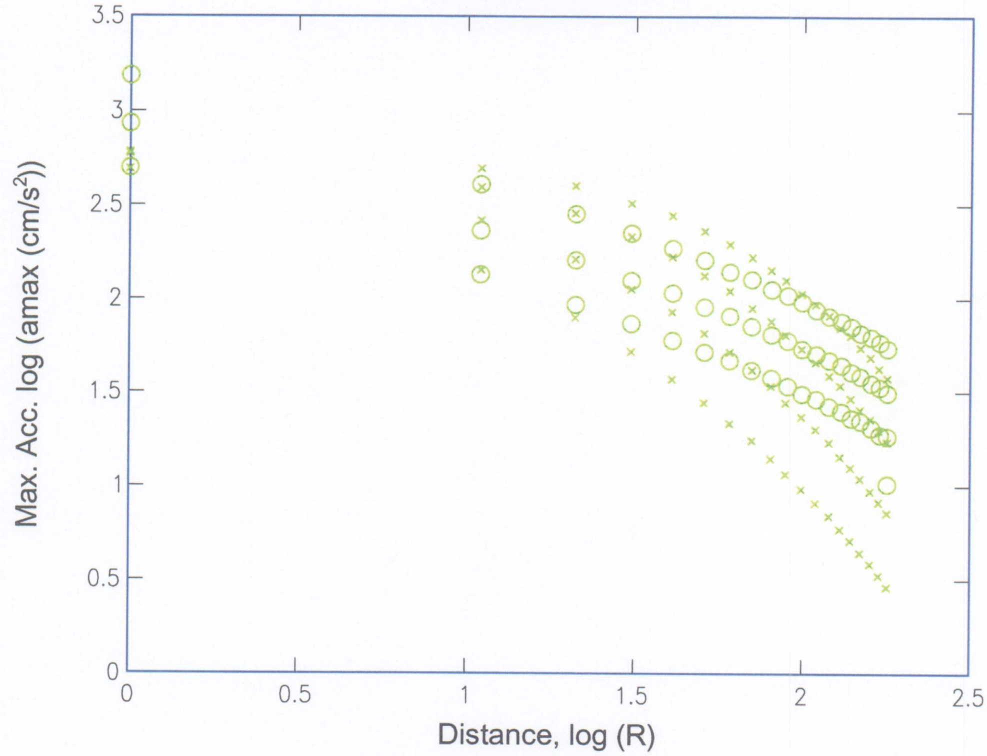
ATTENUATION CURVES
SHEET 2 OF 4

MWH TAMS

DATE:	EXHIBIT:
DECEMBER, 2003	10

Attenuation Relations



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

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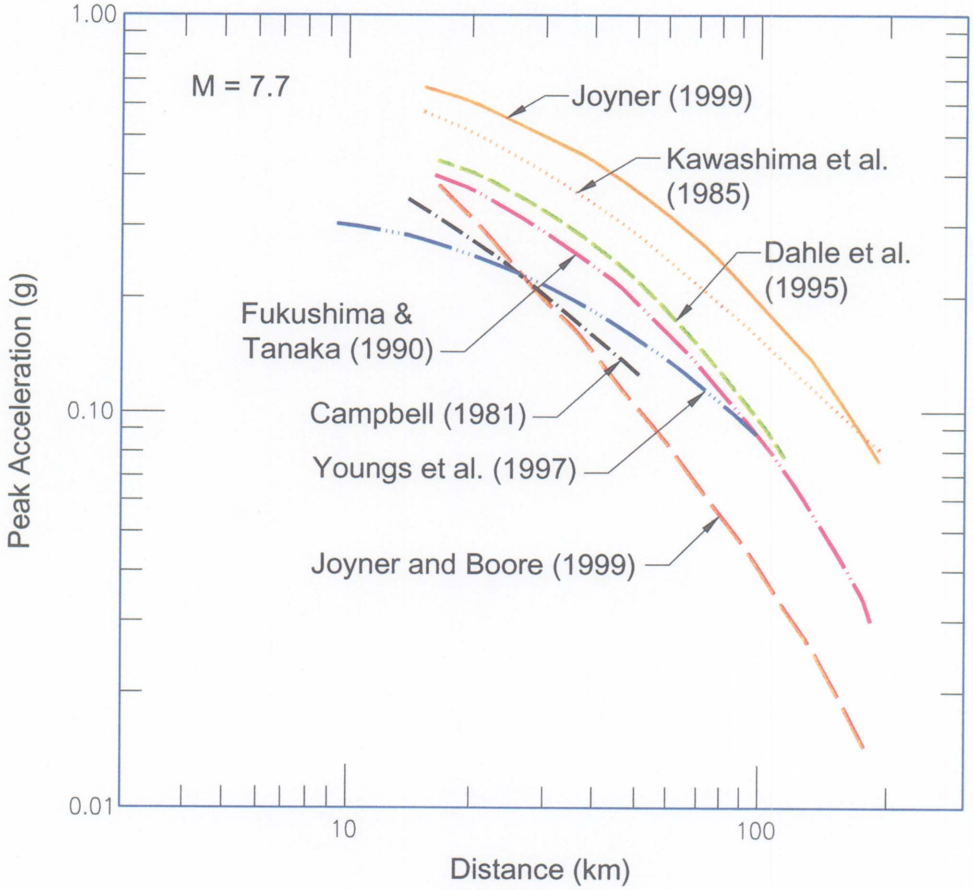
ATTENUATION CURVES **SHEET 3 OF 4**		
MWH TAMS	DATE: DECEMBER, 2003	EXHIBIT: 11



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 (Cowan)

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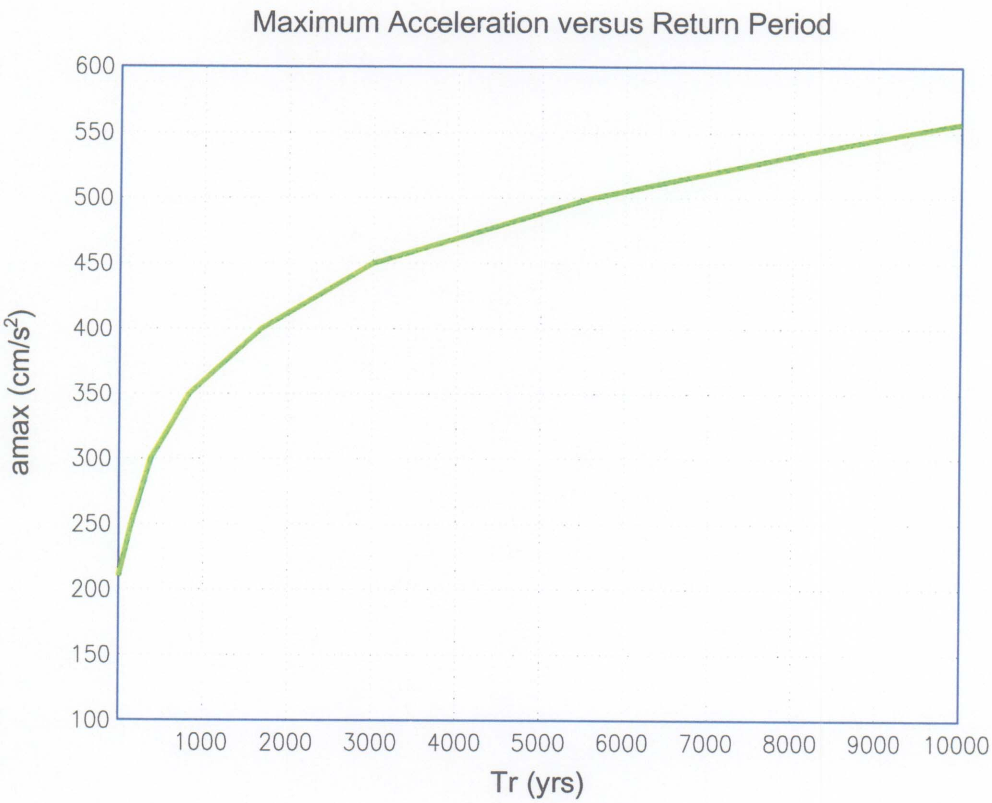
ATTENUATION CURVES **SHEET 4 OF 4**	
MWH TAMS	DATE: DECEMBER, 2003 | EXHIBIT: 12



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

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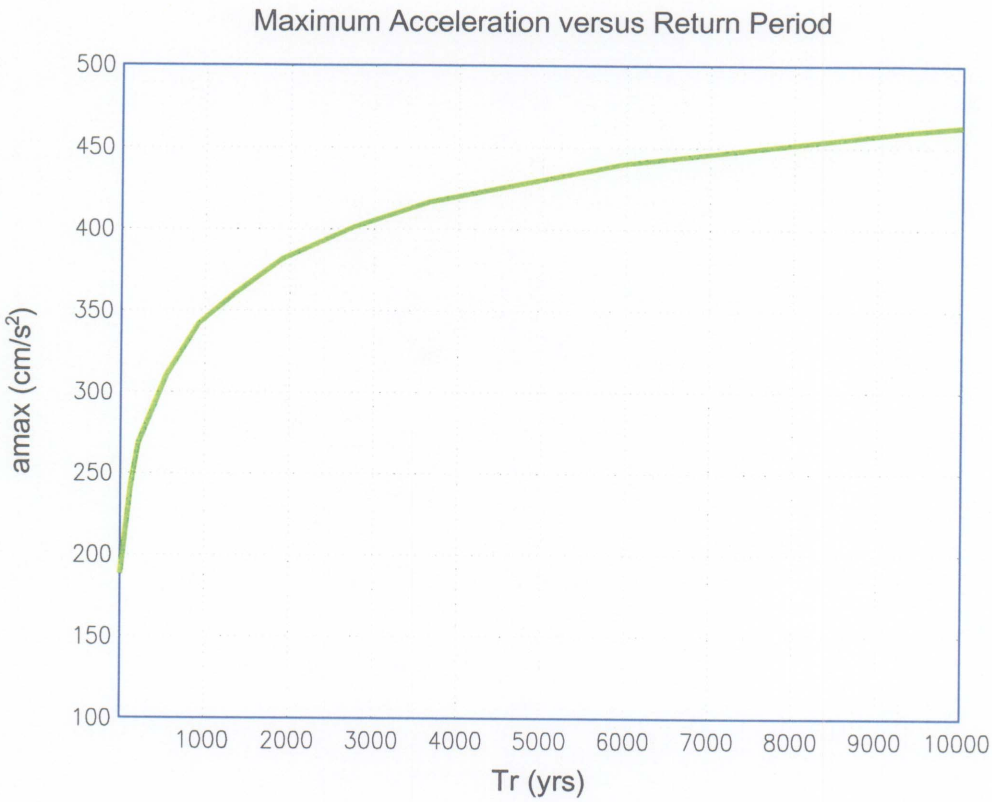
SEISMIC HAZARD CURVES **SHEET 1 OF 10**		
MWH TAMS	DATE: DECEMBER, 2003	EXHIBIT: 13



Seismic Hazard Curve based on Fukushima-Tanaka Attenuation Curve (Bodare, 2001)

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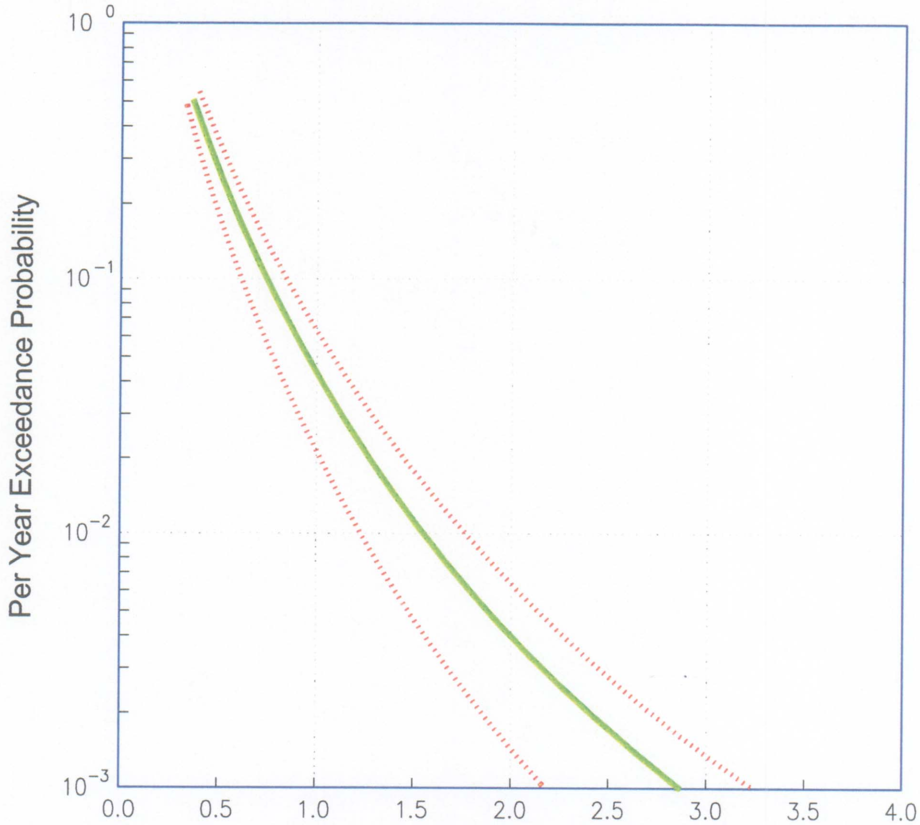
SEISMIC HAZARD CURVES
SHEET 2 OF 10

MWH TAMS

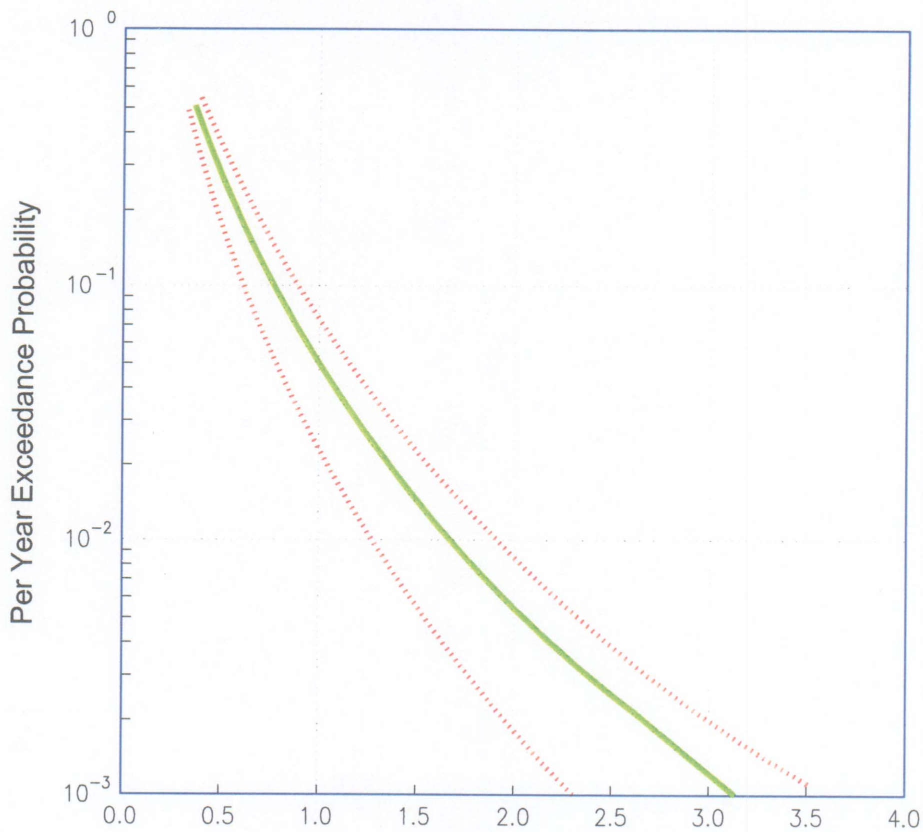
DATE:	EXHIBIT:
DECEMBER, 2003	14

Results for Site Location -80.544 8.241



Seismic Hazard Curve for Aguadulce, Cocle (Camacho et al., 1994)

Results for Site Location -80.433 7.961



Seismic Hazard Curve for Chitre, Herrera (Camacho et al., 1994)

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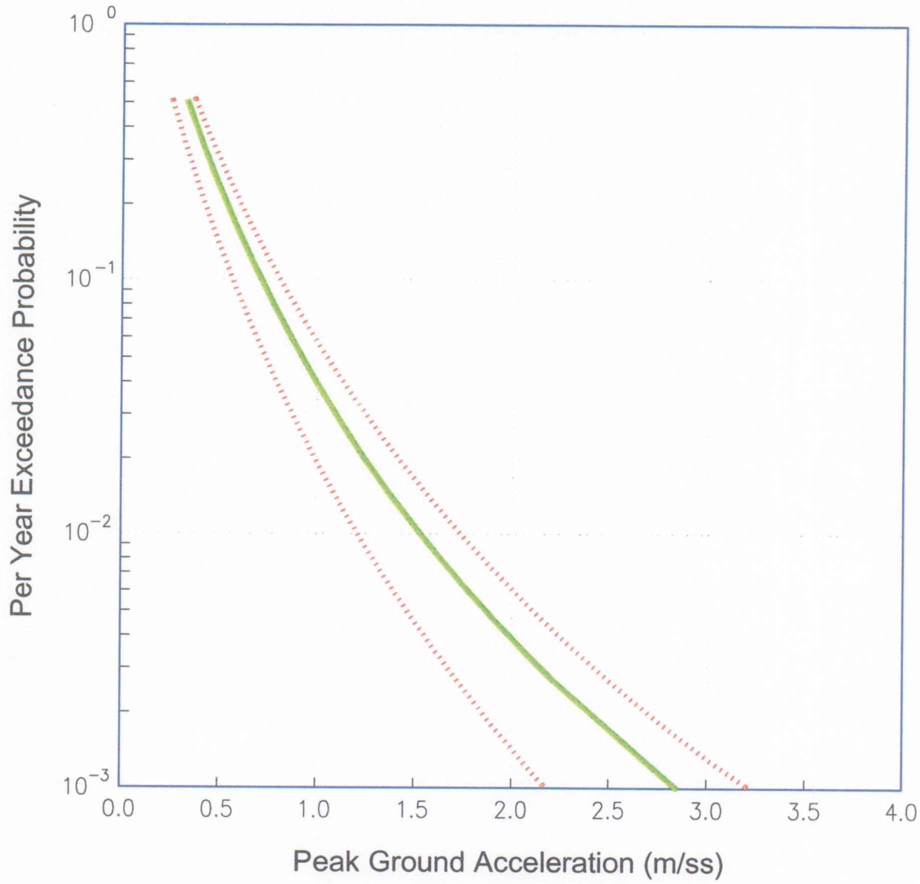
SEISMIC HAZARD CURVES
SHEET 4 OF 10

MWH TAMS	DATE: DECEMBER, 2003	EXHIBIT: 16

Results for Site Location -79.782 8.879



Seismic Hazard Curve for Chorrera, Panama (Camacho et al., 1994)

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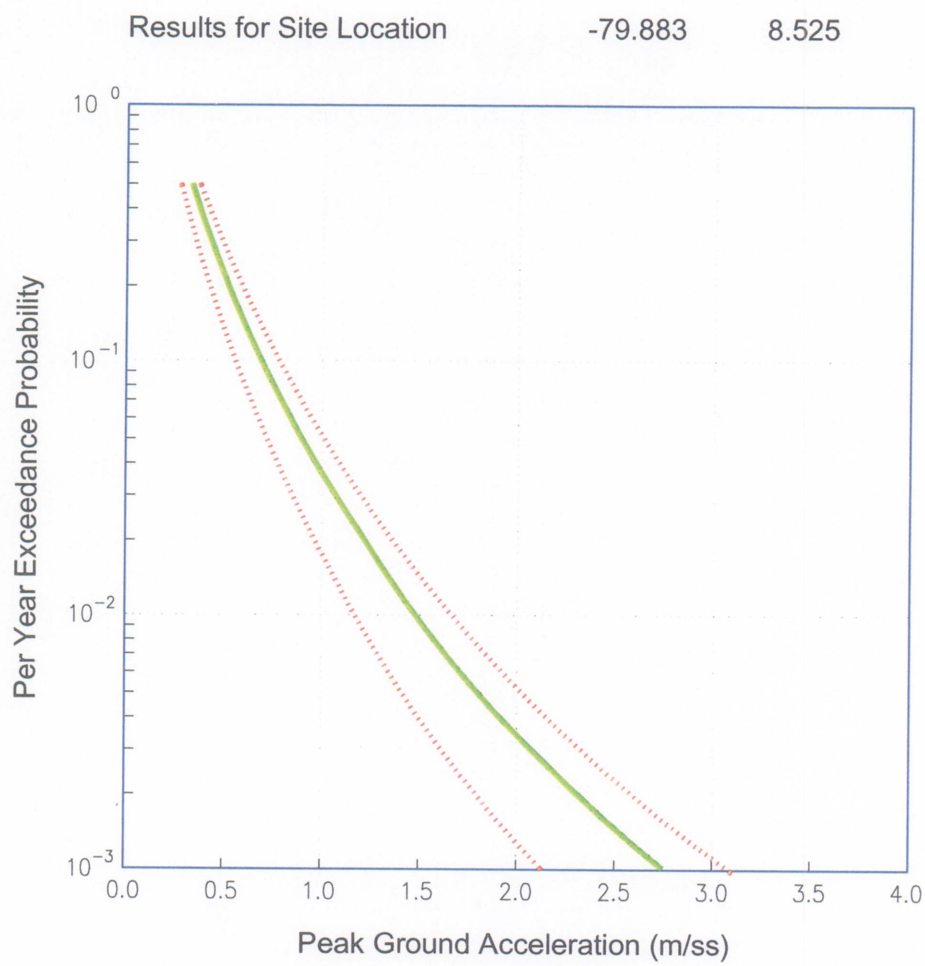
SEISMIC HAZARD CURVES
SHEET 5 OF 10

MWH TAMS

DATE:	EXHIBIT:
DECEMBER, 2003	17



Seismic Hazard Curve for Coronado, Panama (Camacho et al., 1994)

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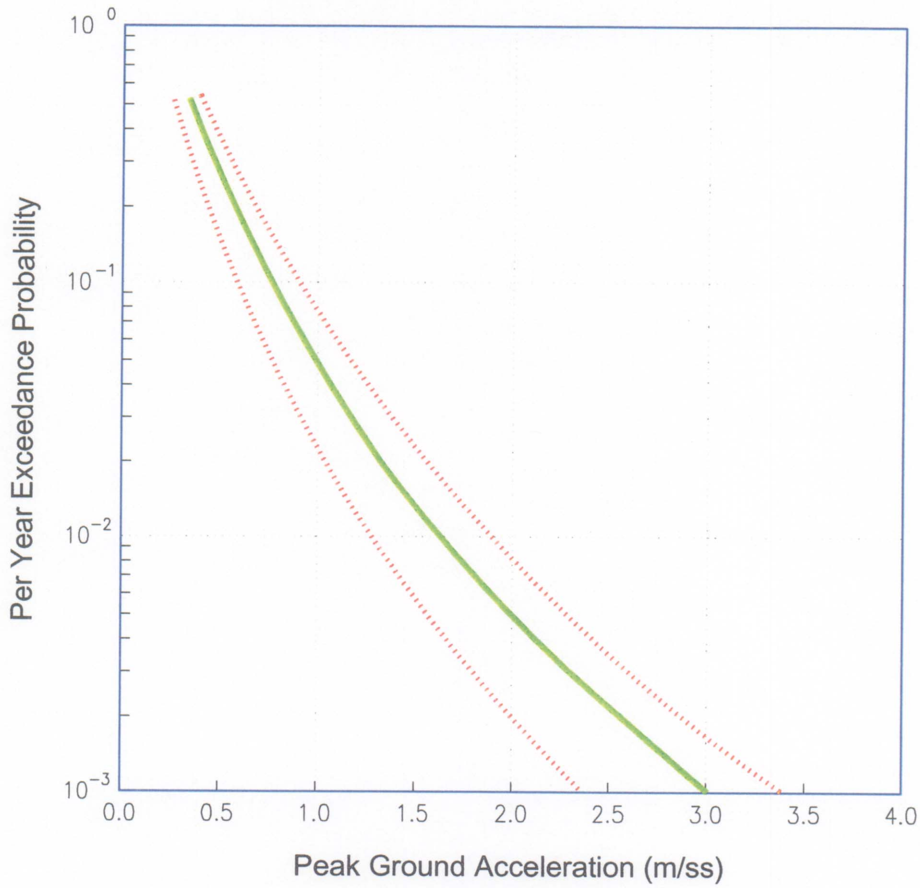
SEISMIC HAZARD CURVES
SHEET 6 OF 10

MWH TAMS

DATE:	EXHIBIT:
DECEMBER, 2003	18

Results for Site Location -79.534 8.984



Seismic Hazard Curve for Panama City, Panama (Camacho et al., 1994)

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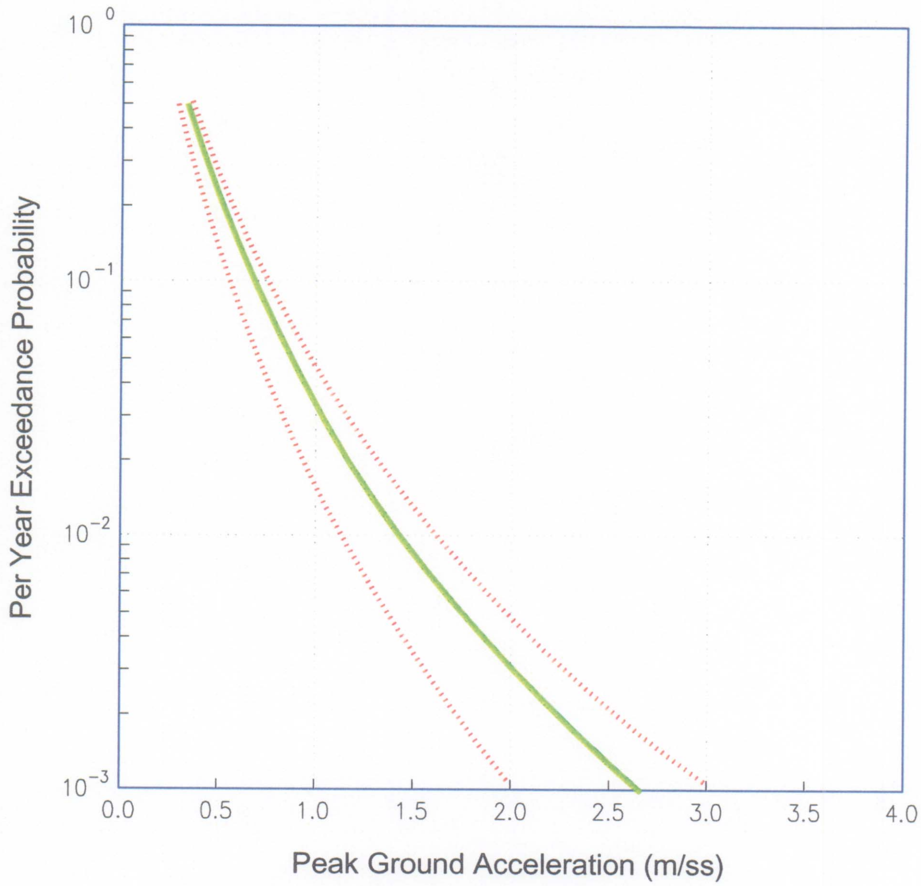
SEISMIC HAZARD CURVES
SHEET 7 OF 10

MWH TAMS

DATE:	EXHIBIT:
DECEMBER, 2003	19

Results for Site Location -80.358 8.518



Seismic Hazard Curve for Penonome, Cocle (Camacho et al., 1994)

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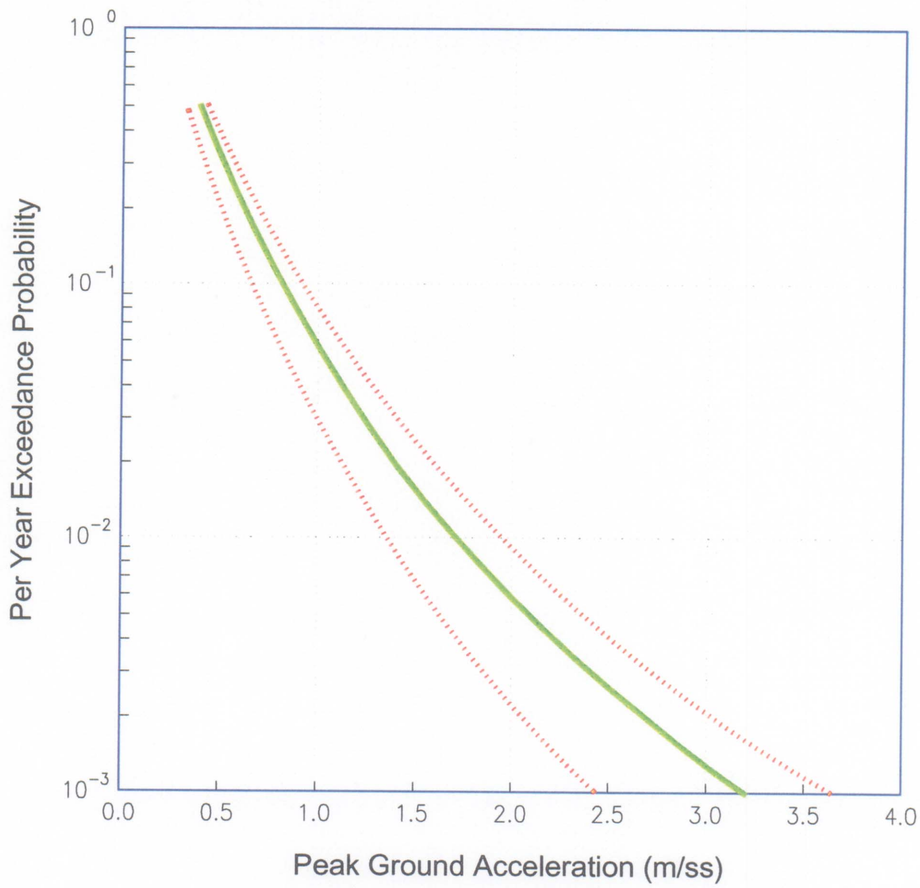
SEISMIC HAZARD CURVES
SHEET 8 OF 10

MWH TAMS

DATE: DECEMBER, 2003

EXHIBIT: 20

Results for Site Location -80.979 8.101



Seismic Hazard Curve for Santiago, Veraguas (Camacho et al., 1994)

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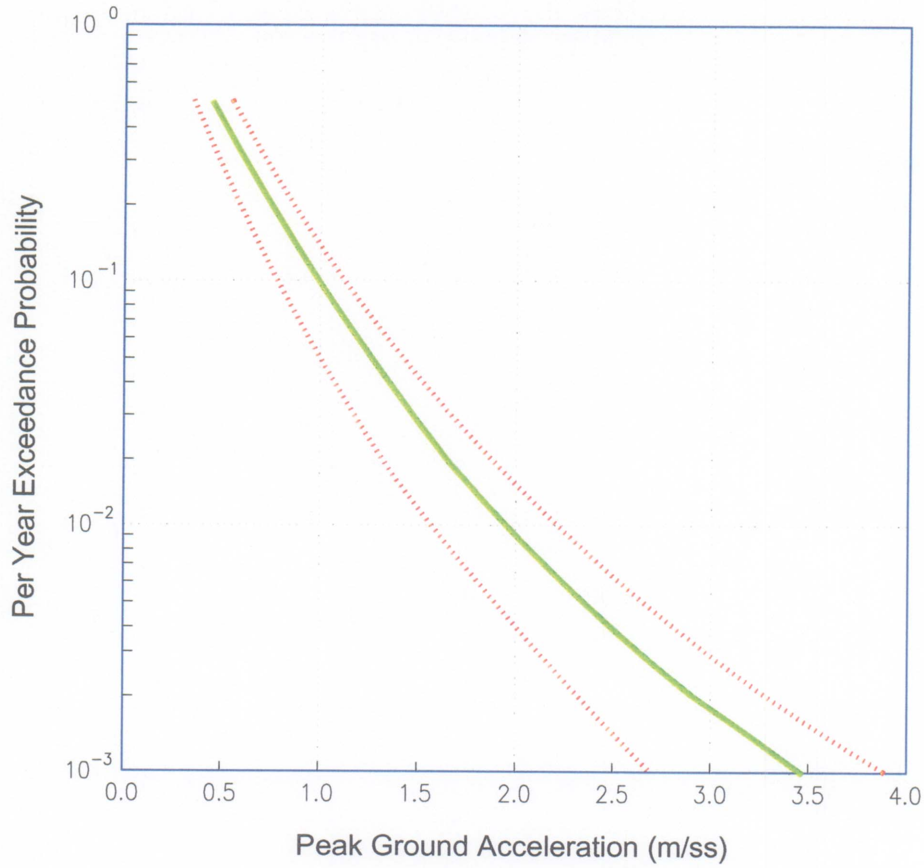
SEISMIC HAZARD CURVES
SHEET 9 OF 10

MWH TAMS	DATE: DECEMBER, 2003	EXHIBIT: 21

Results for Site Location -81.319 8.008



Seismic Hazard Curve for Sona, Veraguas (Camacho et al., 1994)

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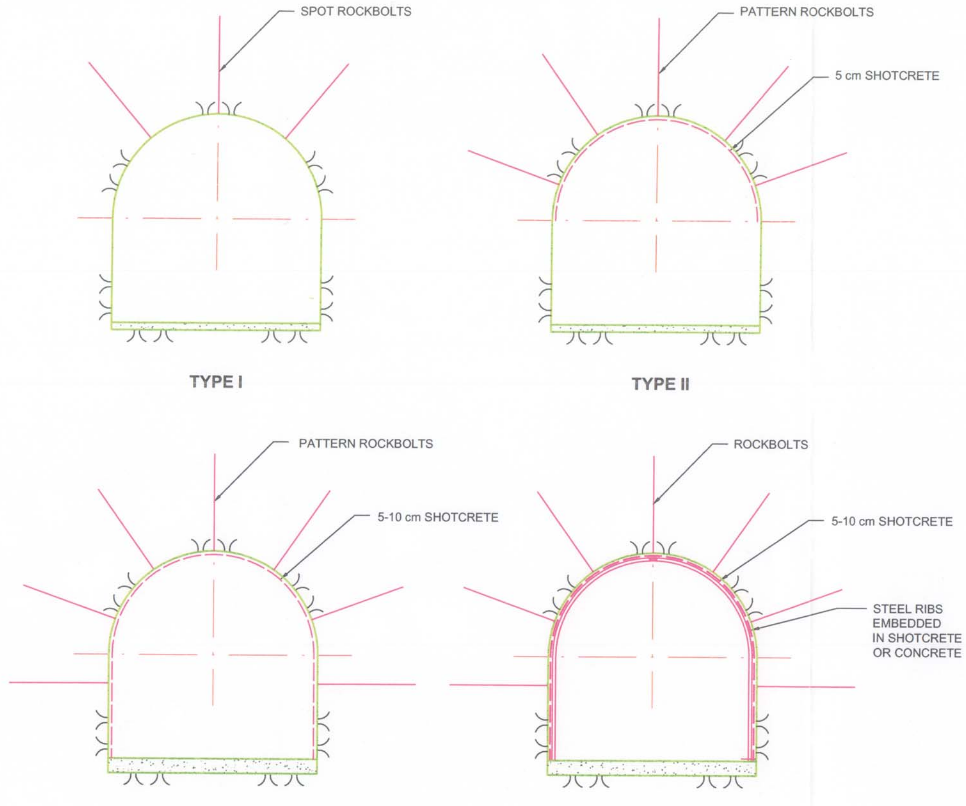
APPENDIX B - GEOLOGY, GEOTECHNICAL AND SEISMOLOGICAL STUDIES

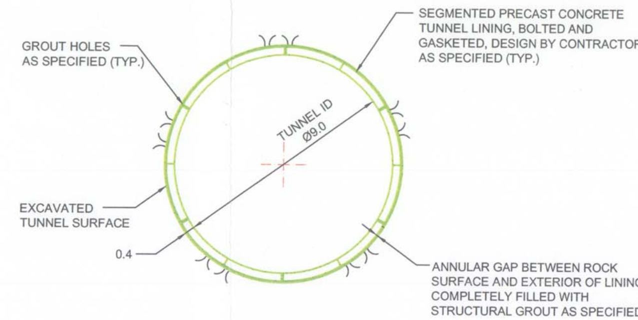
SEISMIC HAZARD CURVES
SHEET 10 OF 10

MWH TAMS

DATE:	EXHIBIT:
DECEMBER, 2003	22



DRILL & BLAST SECTIONS
(N.T.S.)



TBM SECTION
TYPICAL SEGMENTED TUNNEL LINING
(N.T.S.)

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.

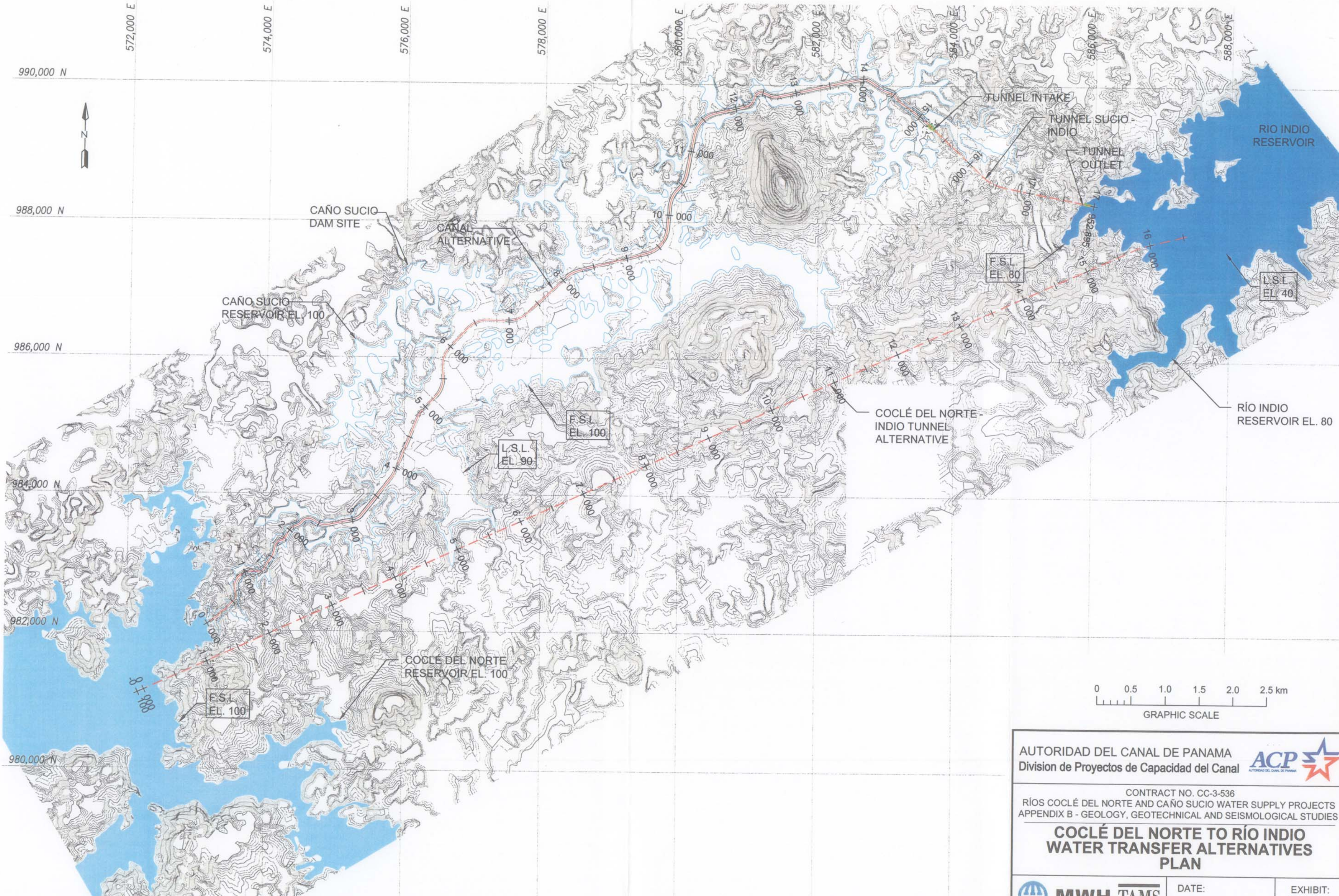
AUTORIDAD DEL CANAL DE PANAMA
División de Proyectos de Capacidad del Canal

CONTRACT NO. CC-3-536
RÍOS COCLÉ DEL NORTE AND CAÑO SUCIO WATER SUPPLY PROJECTS
APPENDIX B - GEOLOGY, GEOTECHNICAL AND SEISMOLOGICAL STUDIES

TYPICAL TUNNEL CROSS SECTIONS

MWH TAMS

DATE:	EXHIBIT:
DECEMBER, 2003	23



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

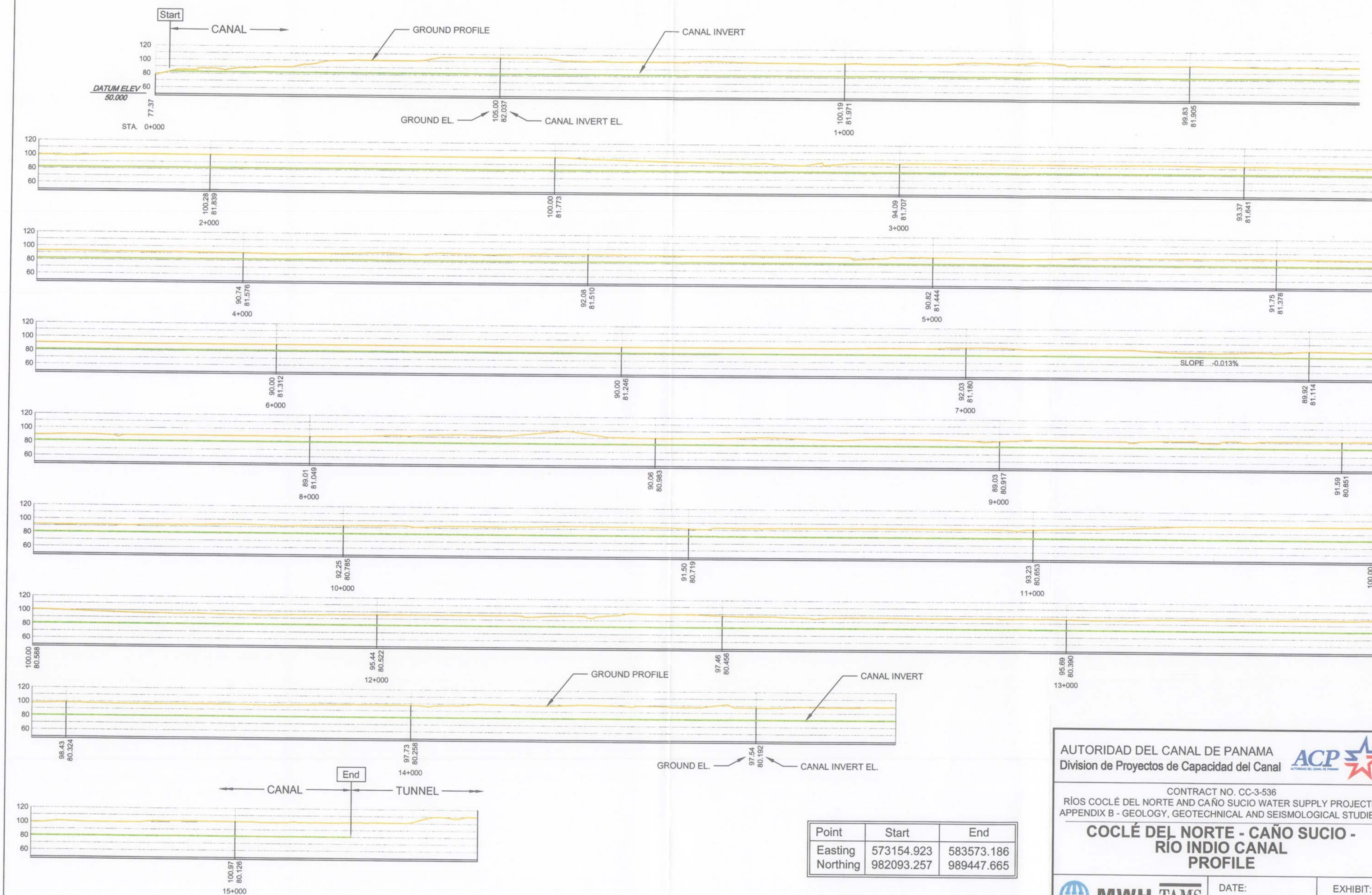
ACP

CONTRACT NO. CC-3-536
RÍOS COCLÉ DEL NORTE AND CAÑO SUCIO WATER SUPPLY PROJECTS
APPENDIX B - GEOLOGY, GEOTECHNICAL AND SEISMOLOGICAL STUDIES

COCLÉ DEL NORTE TO RÍO INDIO WATER TRANSFER ALTERNATIVES PLAN

MWH TAMS

DATE:	EXHIBIT:
DECEMBER, 2003	24



Point	Start	End
Easting	573154.923	583573.186
Northing	982093.257	989447.665

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

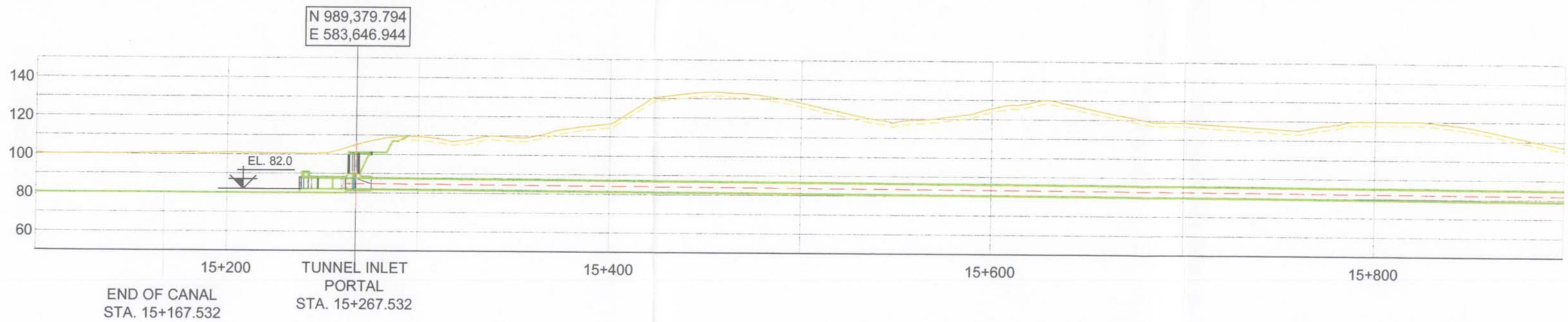
ACP

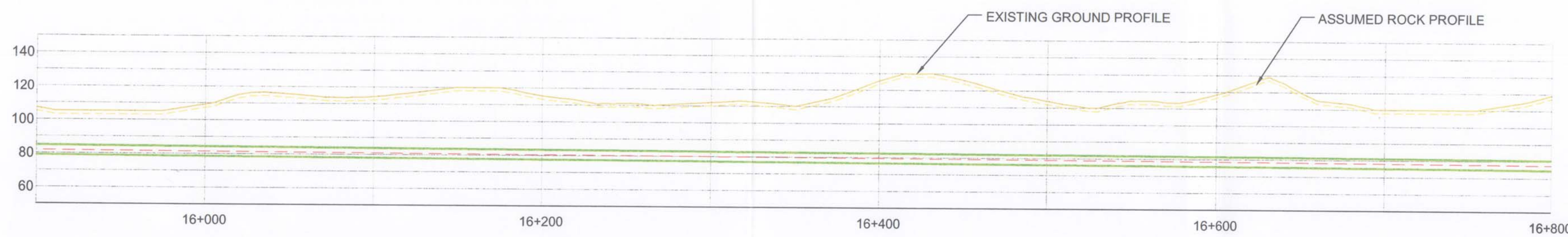
CONTRACT NO. CC-3-536
RÍOS COCLÉ DEL NORTE AND CAÑO SUCIO WATER SUPPLY PROJECTS
APPENDIX B - GEOLOGY, GEOTECHNICAL AND SEISMOLOGICAL STUDIES

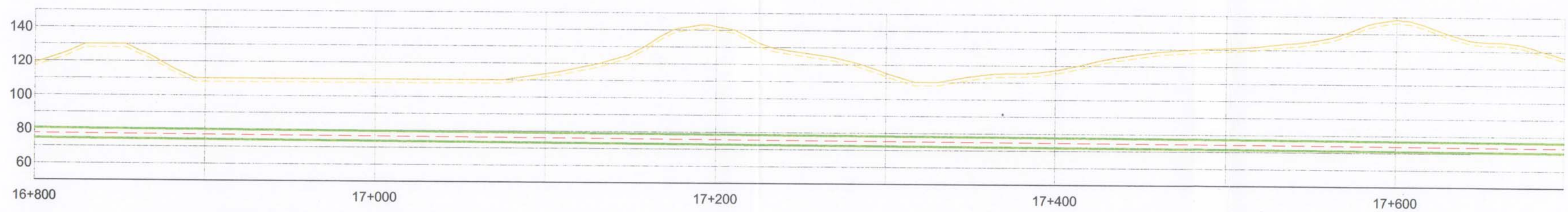
COCLÉ DEL NORTE - CAÑO SUCIO - RÍO INDIO CANAL PROFILE

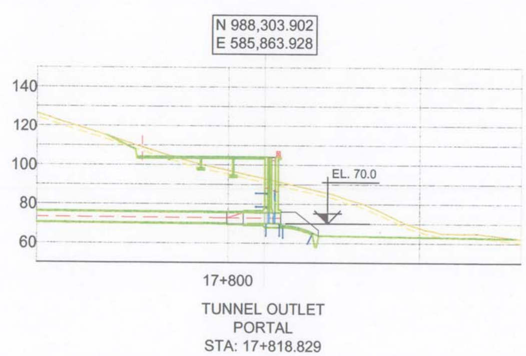
MWH TAMS

DATE:	EXHIBIT:
DECEMBER, 2003	25









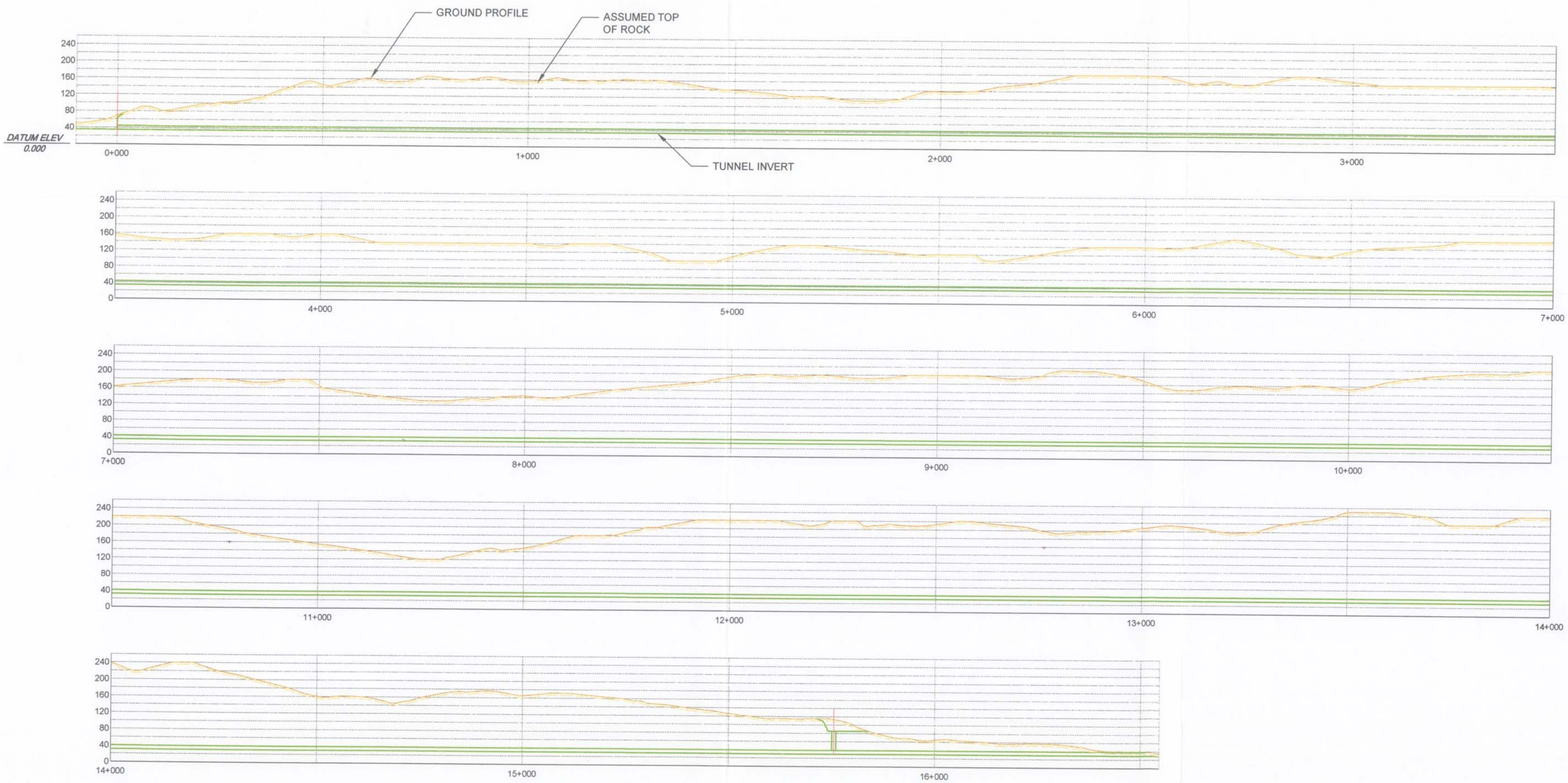
AUTORIDAD DEL CANAL DE PANAMA
División de Proyectos de Capacidad del Canal

CONTRACT NO. CC-3-536
RÍOS COCLÉ DEL NORTE AND CAÑO SUCIO WATER SUPPLY PROJECTS
APPENDIX B - GEOLOGY, GEOTECHNICAL AND SEISMOLOGICAL STUDIES

COCLÉ DEL NORTE - CAÑO SUCIO - RÍO INDIO TUNNEL PROFILE

MWH TAMS

DATE:	EXHIBIT:
DECEMBER, 2003	26



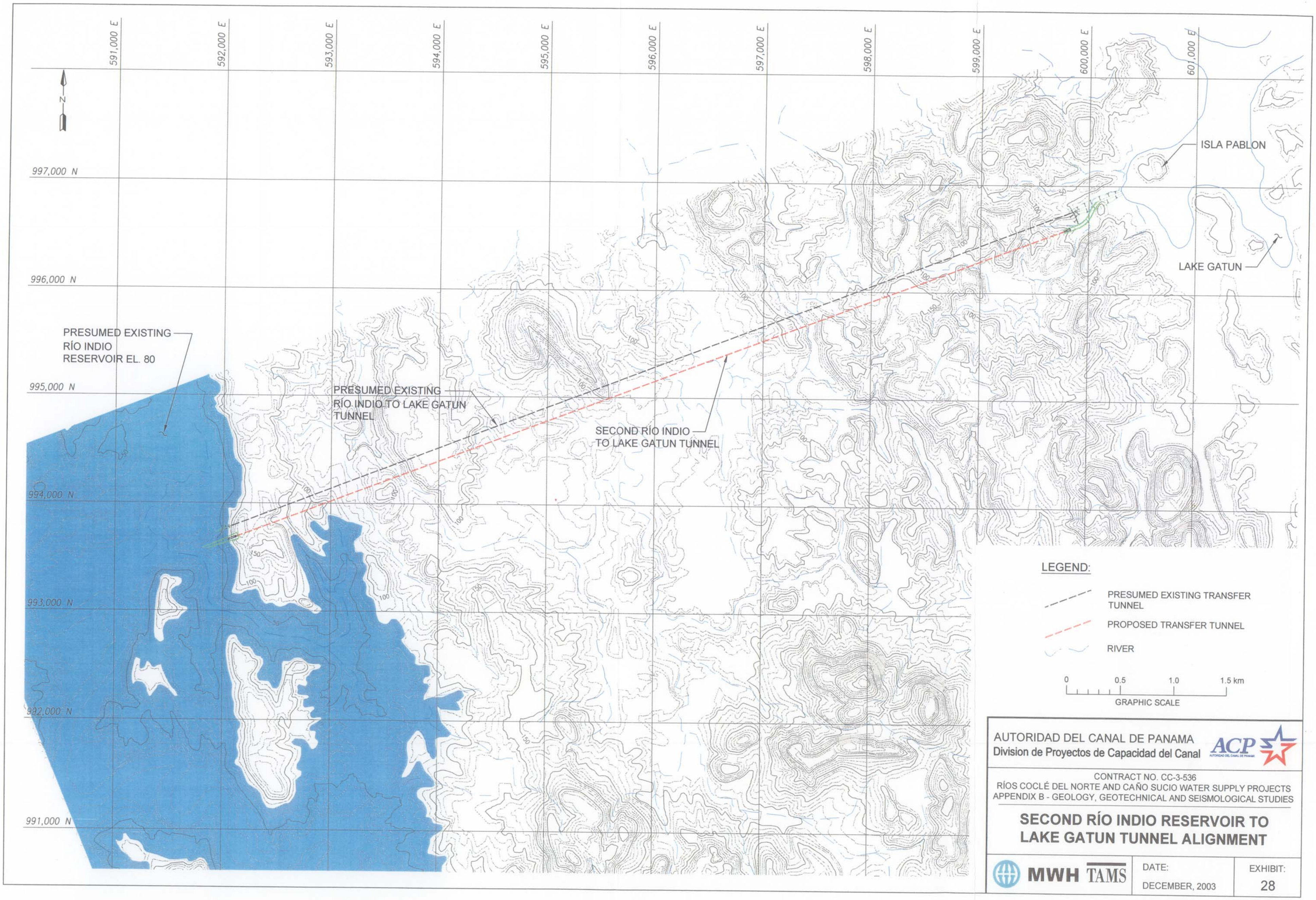
AUTORIDAD DEL CANAL DE PANAMA
Division de Proyectos de Capacidad del Canal

CONTRACT NO. CC-3-536
RÍOS COCLÉ DEL NORTE AND CAÑO SUCIO WATER SUPPLY PROJECTS
APPENDIX B - GEOLOGY, GEOTECHNICAL AND SEISMOLOGICAL STUDIES

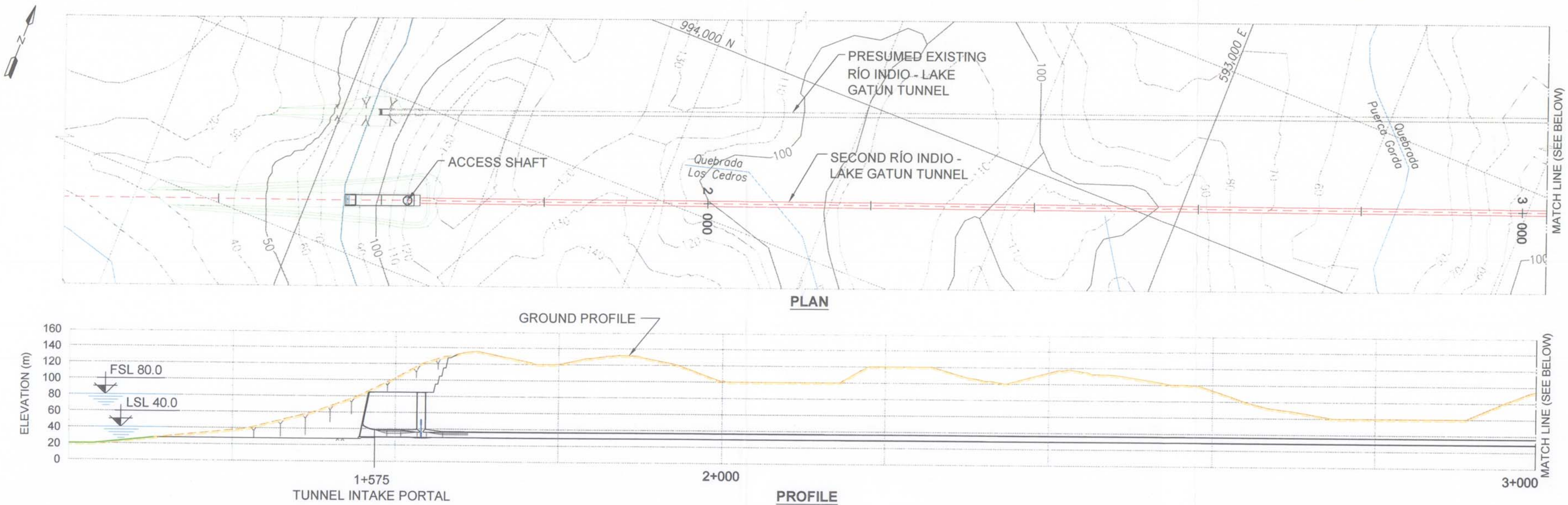
RÍO COCLÉ DEL NORTE TO RÍO INDIO TUNNEL PROFILE

MWH TAMS

DATE:	EXHIBIT:
DECEMBER, 2003	27



591,000 E
592,000 E
593,000 E
594,000 E
595,000 E
596,000 E
597,000 E
598,000 E
599,000 E
600,000 E
601,000 E
N
997,000 N
996,000 N
995,000 N
994,000 N
993,000 N
992,000 N
991,000 N
ISLA PABLON
LAKE GATUN
PRESUMED EXISTING RÍO INDIO RESERVOIR EL. 80
PRESUMED EXISTING RÍO INDIO TO LAKE GATUN TUNNEL
SECOND RÍO INDIO TO LAKE GATUN TUNNEL
LEGEND:
PRESUMED EXISTING TRANSFER TUNNEL
PROPOSED TRANSFER TUNNEL
RIVER
0
0.5
1.0
1.5 km
GRAPHIC SCALE
AUTORIDAD DEL CANAL DE PANAMA
Division de Proyectos de Capacidad del Canal
ACP
CONTRACT NO. CC-3-536
RÍOS COCLÉ DEL NORTE AND CAÑO SUCIO WATER SUPPLY PROJECTS
APPENDIX B - GEOLOGY, GEOTECHNICAL AND SEISMOLOGICAL STUDIES
SECOND RÍO INDIO RESERVOIR TO LAKE GATUN TUNNEL ALIGNMENT
MWH TAMS
DATE:
DECEMBER, 2003
EXHIBIT:
28



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

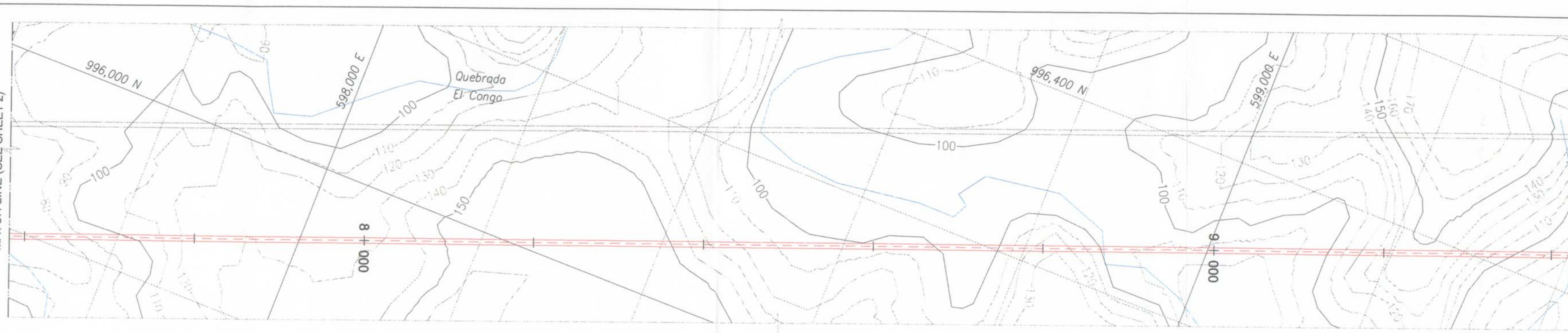
ACP

CONTRACT NO. CC-3-536
RÍOS COCLÉ DEL NORTE AND CAÑO SUCIO WATER SUPPLY PROJECTS
APPENDIX B - GEOLOGY, GEOTECHNICAL AND SEISMOLOGICAL STUDIES

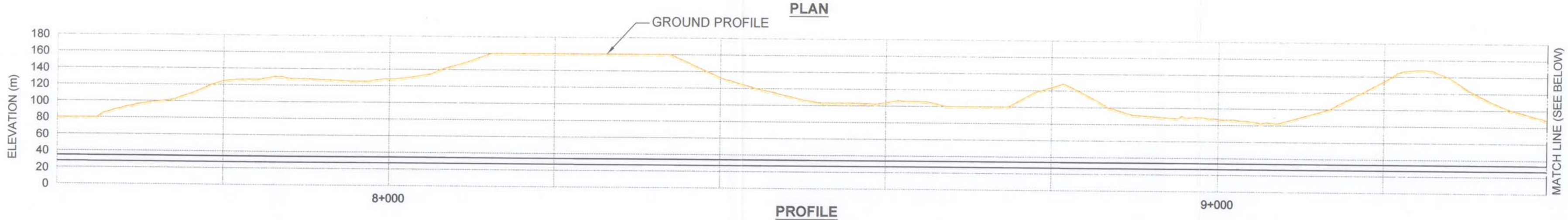
SECOND RÍO INDIO - LAKE GATUN TUNNEL PLAN AND PROFILE - SHEET 1 OF 3

MWH TAMS

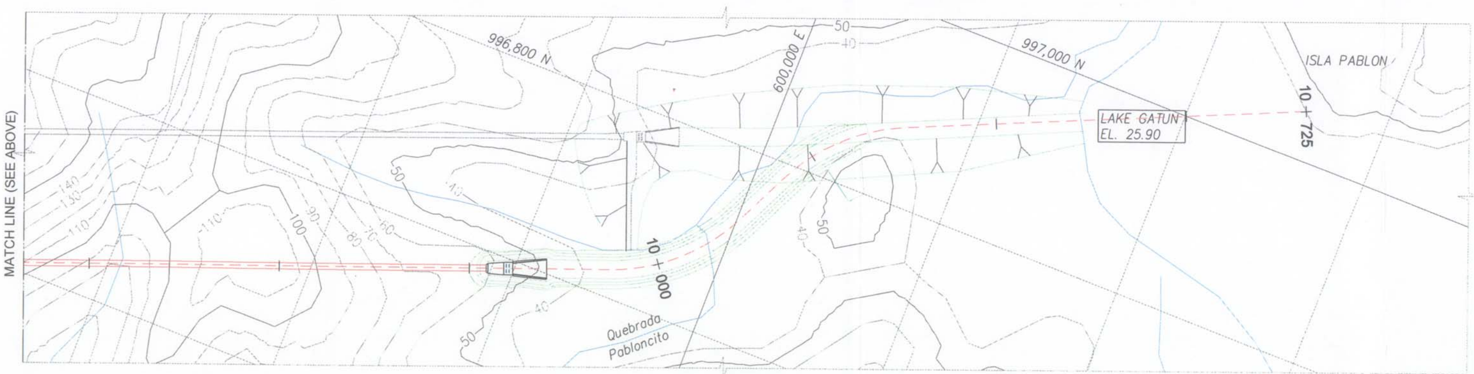
DATE:	EXHIBIT:
DECEMBER, 2003	29



PLAN



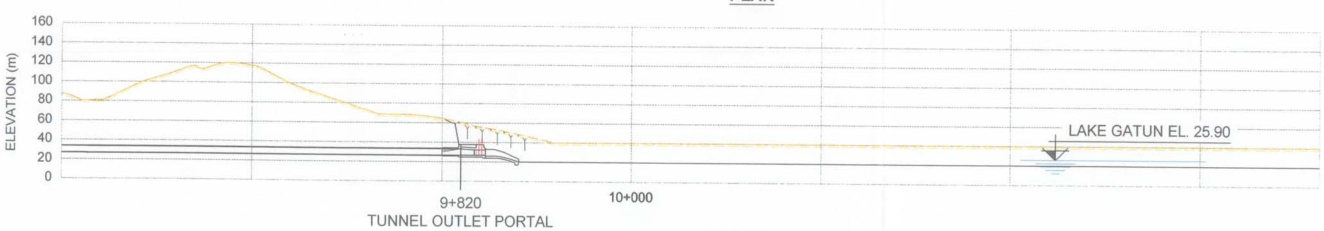
PROFILE



0 50 100 150 200 250 m

GRAPHIC SCALE

PLAN



PROFILE

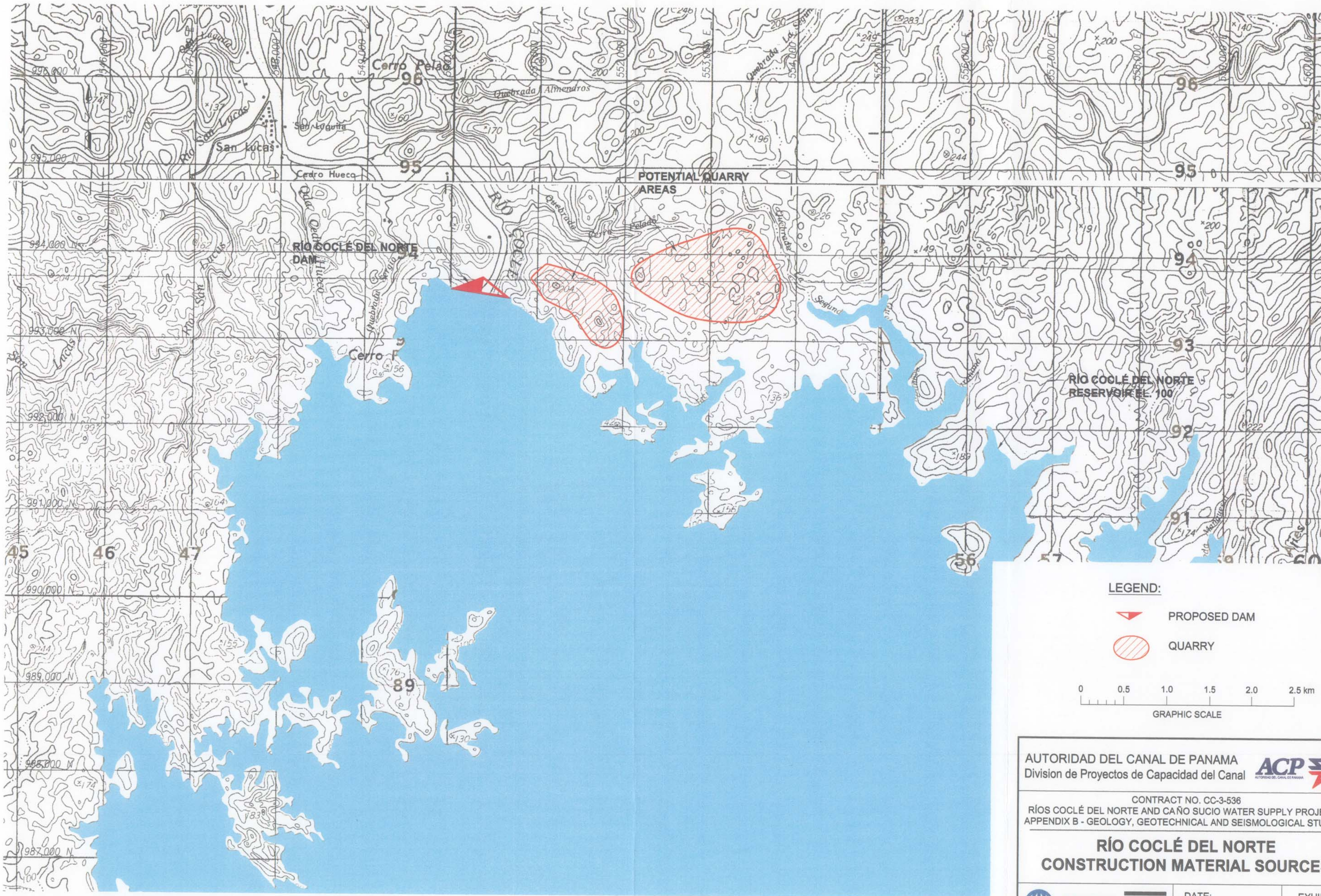
AUTORIDAD DEL CANAL DE PANAMA
Division de Proyectos de Capacidad del Canal

ACP

CONTRACT NO. CC-3-536
RÍOS COCLÉ DEL NORTE AND CAÑO SUCIO WATER SUPPLY PROJECTS
APPENDIX B - GEOLOGY, GEOTECHNICAL AND SEISMOLOGICAL STUDIES

SECOND RÍO INDIO - LAKE GATUN TUNNEL
PLAN AND PROFILE - SHEET 3 OF 3

MWH TAMS	DATE: DECEMBER, 2003	EXHIBIT: 29



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

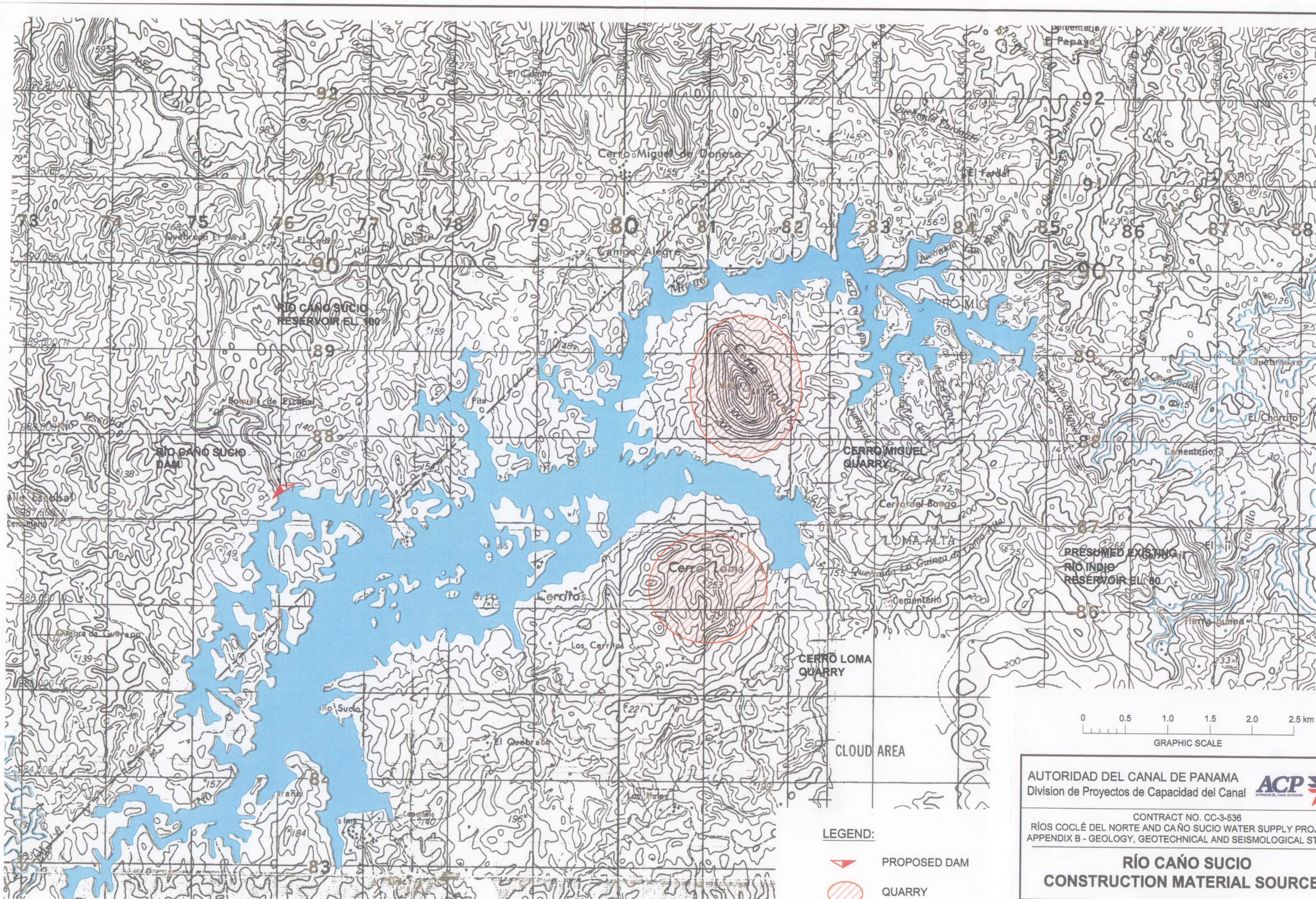
ACP

CONTRACT NO. CC-3-536
RÍOS COCLÉ DEL NORTE AND CAÑO SUCIO WATER SUPPLY PROJECTS
APPENDIX B - GEOLOGY, GEOTECHNICAL AND SEISMOLOGICAL STUDIES

RÍO COCLÉ DEL NORTE CONSTRUCTION MATERIAL SOURCES

MWH TAMS

DATE:	EXHIBIT:
DECEMBER, 2003	30



0 0.5 1.0 1.5 2.0 2.5 km

GRAPHIC SCALE

LEGEND:

PROPOSED DAM

QUARRY

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

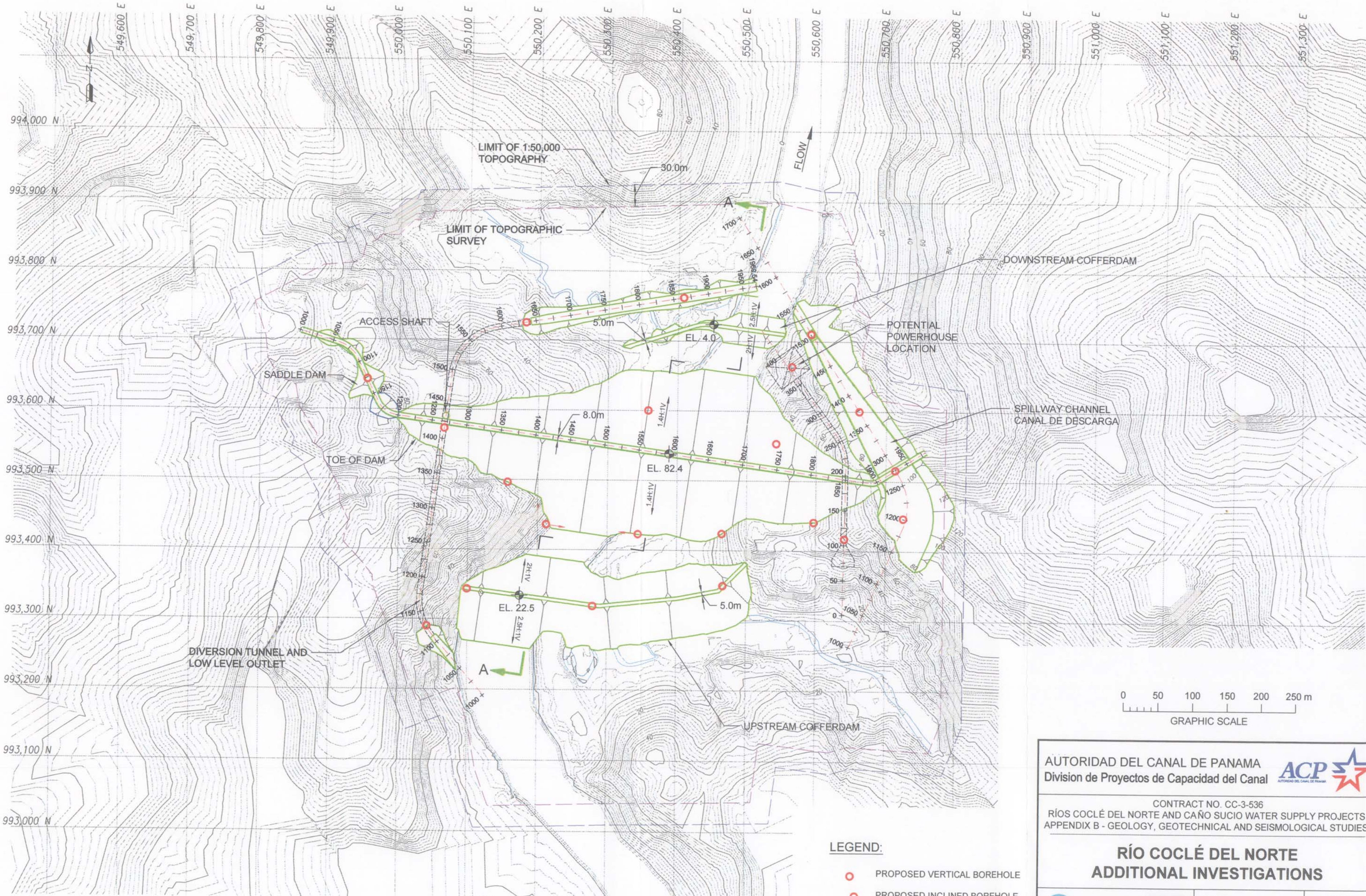
ACP

CONTRACT NO. CC-3-536
RÍOS COCLÉ DEL NORTE AND CAÑO SUCIO WATER SUPPLY PROJECTS
APPENDIX B - GEOLOGY, GEOTECHNICAL AND SEISMOLOGICAL STUDIES

RÍO CAÑO SUCIO
CONSTRUCTION MATERIAL SOURCES

MWH TAMS

DATE:	EXHIBIT:
DECEMBER, 2003	31



LEGEND:

- PROPOSED VERTICAL BOREHOLE
- PROPOSED INCLINED BOREHOLE

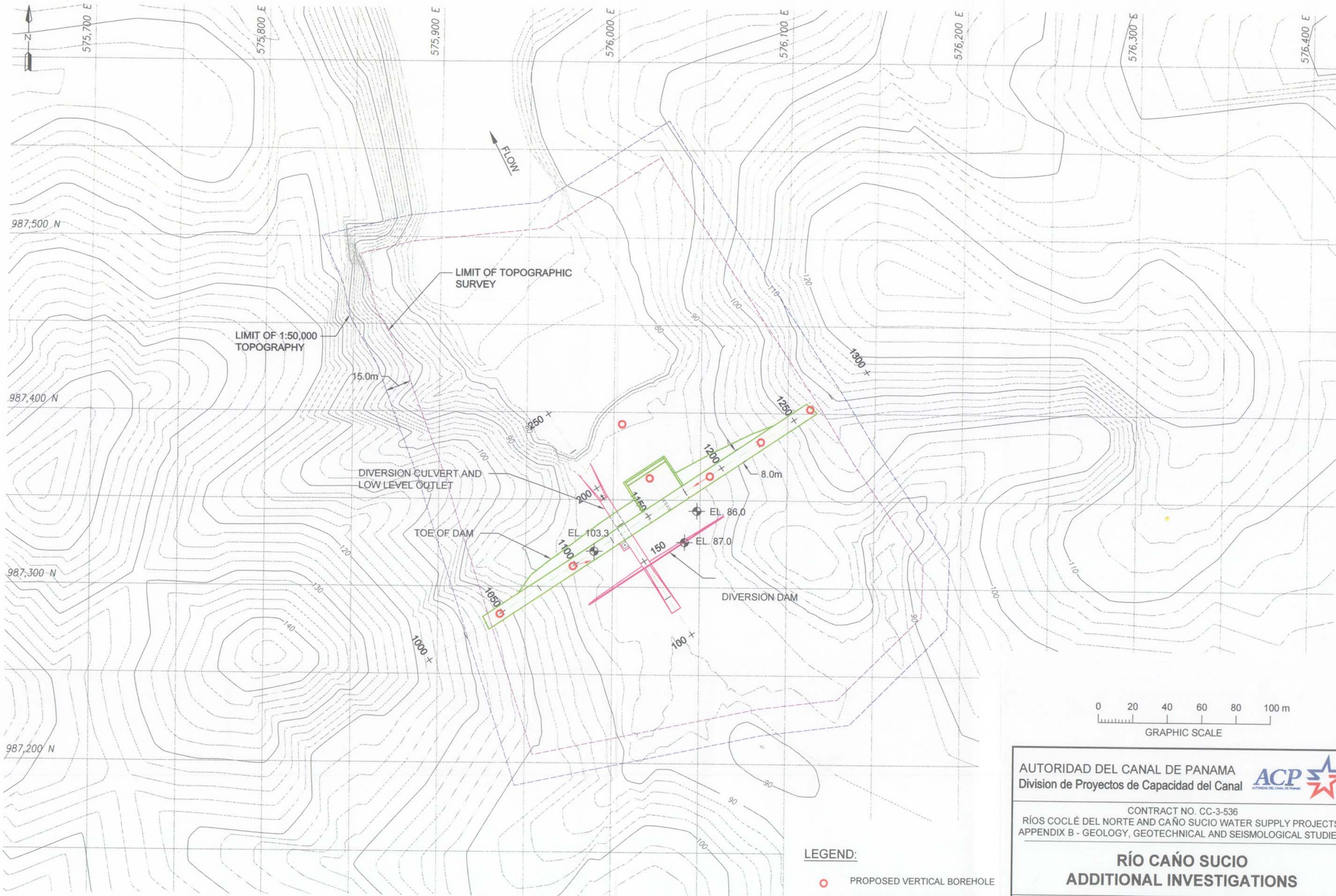
AUTORIDAD DEL CANAL DE PANAMA
División de Proyectos de Capacidad del Canal

CONTRACT NO. CC-3-536
RÍOS COCLÉ DEL NORTE AND CAÑO SUCIO WATER SUPPLY PROJECTS
APPENDIX B - GEOLOGY, GEOTECHNICAL AND SEISMOLOGICAL STUDIES

RÍO COCLÉ DEL NORTE ADDITIONAL INVESTIGATIONS

MWH TAMS

DATE:	EXHIBIT:
DECEMBER, 2003	32



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

CONTRACT NO. CC-3-536
RÍOS COCLÉ DEL NORTE AND CAÑO SUCIO WATER SUPPLY PROJECTS
APPENDIX B - GEOLOGY, GEOTECHNICAL AND SEISMOLOGICAL STUDIES

RÍO CAÑO SUCIO
ADDITIONAL INVESTIGATIONS

MWH TAMS

DATE: DECEMBER, 2003

EXHIBIT: 33

ATTACHMENTS

Attachment 1 – Laboratory Sampling and Testing Report for Coclé del Norte Site, Tecnilab, S.A.

TECNILAB, S. A.

FUNDADA EN 1973

UNA EMPRESA E. BARRANCO Y ASOC., S. A.

LABORATORIO DE SUELOS Y MATERIALES

AMPLIACION DE LA CUENCA DEL CANAL DE PANAMA

MUESTREO Y PRUEBAS DE LABORATORIO

SITIO
COCLE DEL NORTE

CLIENTE
MONTGOMERY WATSON HARZA

PRESENTADO POR:

TECNILAB, S. A.

ENERO 2002

INDICE

X. FOTOGRAFIAS

- Calicata No. C-1 Condición del Sitio
- Calicata No. C-1 (Prof. 0.00 – 0.20 m)
- Calicata No. C-1 (Prof. 0.20 – 0.40 m)
- Calicata No. C-1 (Prof. 0.40 – 1.20 m)
- Calicata No. C-1 (Prof. 1.20 – 1.80 m)
- Calicata No. C-1 Muestra 1 (Prof. 0.50 – 1.00 m)
- Calicata No. C-1 Muestra 2 (Prof. 1.50 – 1.80 m)
- Calicata No. C-2 Condición del Sitio
- Calicata No. C-2 (Prof. 0.20 – 0.90 m)
- Calicata No. C-2 (Prof. 1.60 – 1.75 m)
- Calicata No. C-2 Muestra 1 (Prof. 0.40 – 0.60 m)
- Calicata No. C-2 Muestra 2 (Prof. 0.90 – 1.20 m)
- Calicata No. C-2 Muestra 3 (Prof. 1.60 – 1.75 m)
- Calicata No. C-6 Condición del Sitio
- Calicata No. C-6 (Prof. 0.15 – 1.25 m)
- Calicata No. C-6 (Prof. 1.25 – 1.60 m)

I. RESUMEN DE MUESTREO Y PRUEBAS DE LABORATORIO

II. DETALLES DE CALICATAS

TECNILAB, S. A.

FUNDADA EN 1973

UNA EMPRESA E. BARRANCO Y ASOC. S. A.

LABORATORIO DE SUELOS Y MATERIALES

RESUMEN DE PRUEBAS REALIZADAS

TRABAJO No. 4-214

PROYECTO AMPLIACION DE LA CUENCA DEL CANAL DE PANAMÁ

LOCALIZACION RIO COCLÉ DEL NORTE, PROVINCIA DE COLÓN.

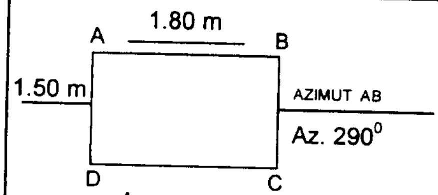
CLIENTE MONTGOMERY WATSON HARZA FECHA DICIEMBRE DE 2001

No.	CALICATA No.	MUESTRA No.	PROFUNDIDAD (m)	PRUEBA REALIZADA						
				% W	G_S	ANALISIS MECANICO	HIDROMETRO	LIMITES DE ATTERBERG	PROCTOR ESTANDAR	CLASIFICASION
1	C-1	1	0.50 - 1.00	✓	✓	✓	✓	✓	✓	✓
2	C-1	2	1.50 - 1.80	✓	✓	✓	✓	✓	✓	✓
3	C-2	1	0.40 - 0.60	✓	✓	✓	✓	✓	✓	✓
4	C-2	2	0.90 - 1.20	✓	✓	✓	✓	✓	✓	✓
5	C-2	3	1.60 - 1.75	✓	✓	✓	✓	✓	✓	✓
6	C-6	1	0.20 - 1.20	✓						
7	C-6	2	1.20 - 1.60	✓						

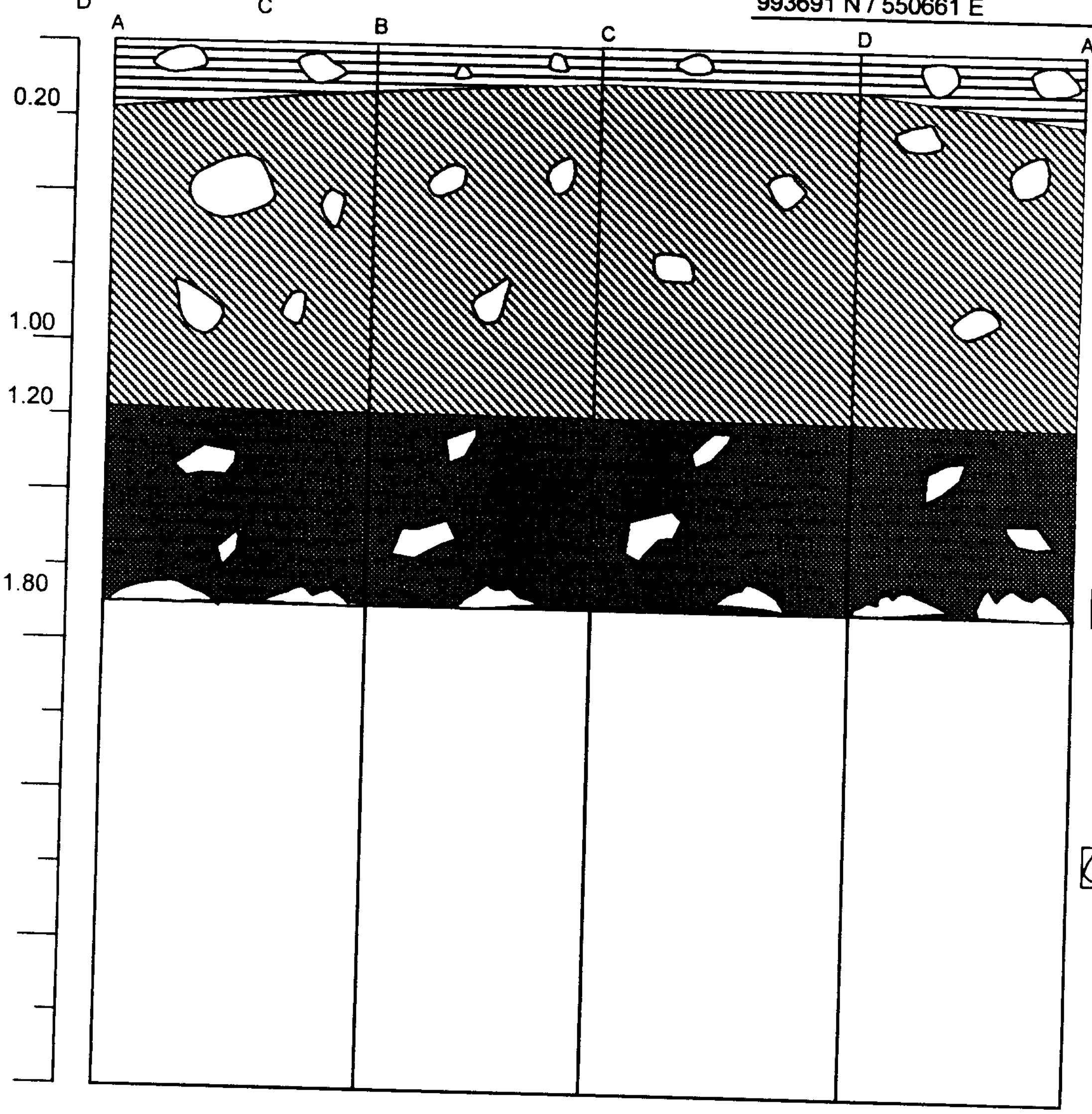
TECNILAB, S. A. FUNDADA EN 1973
UNA EMPRESA E. BARRANCO Y ASOC., S. A.
LABORATORIO DE SUELOS Y MATERIALES

DETALLE DE CALICATA

TRABAJO No. 4-214 CALICATA No C-1 FECHA: 5 de diciembre de 2001
PROYECTO AMPLIACION DE LA CUENCA DEL CANAL DE PANAMÁ
LOCALIZACION COCLÉ DEL NORTE
CLIENTE MONTGOMERY WATSON HARZA



UBICACIÓN: LADERA DEL CERRO CASTILLO, LADO EXTREMO DEL CERRO PELADO.
REFERENCIA: COORDENADAS APROXIMADAS
993691 N / 550661 E



LEYENDA

Capa Vegetal con boulders redondeados de 30 cm; color café oscuro.

Limo arcilloso, con boulders subredondeados de 40cm, ó más, plasticidad me-dia, color café claro.

Limo arenoso con boulders subangulosos y angulosos meteorizados de 30-50cm, plasticidad media, color café claro.

Boulders de roca basáltica

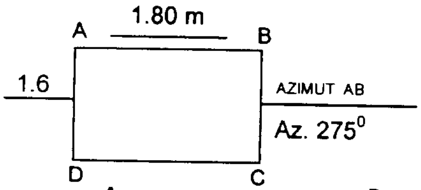
N.F. ________

Observaciones: DESDE 0.20 A 1.20 LIMO ARCILLOSO, CON BOULDERS SUBREDONDEADOS, 40CM DE PROMEDIO. DE 1.20 A 1.80 BOULDERS SUBANGULARES, MATERIAL TOSCOSO, METERIZACION DE RODADOS SUPERFICIALMENTE, EN INTERIOR ROCA SANA DE COMPOSICIÓN BASÁLTICA.

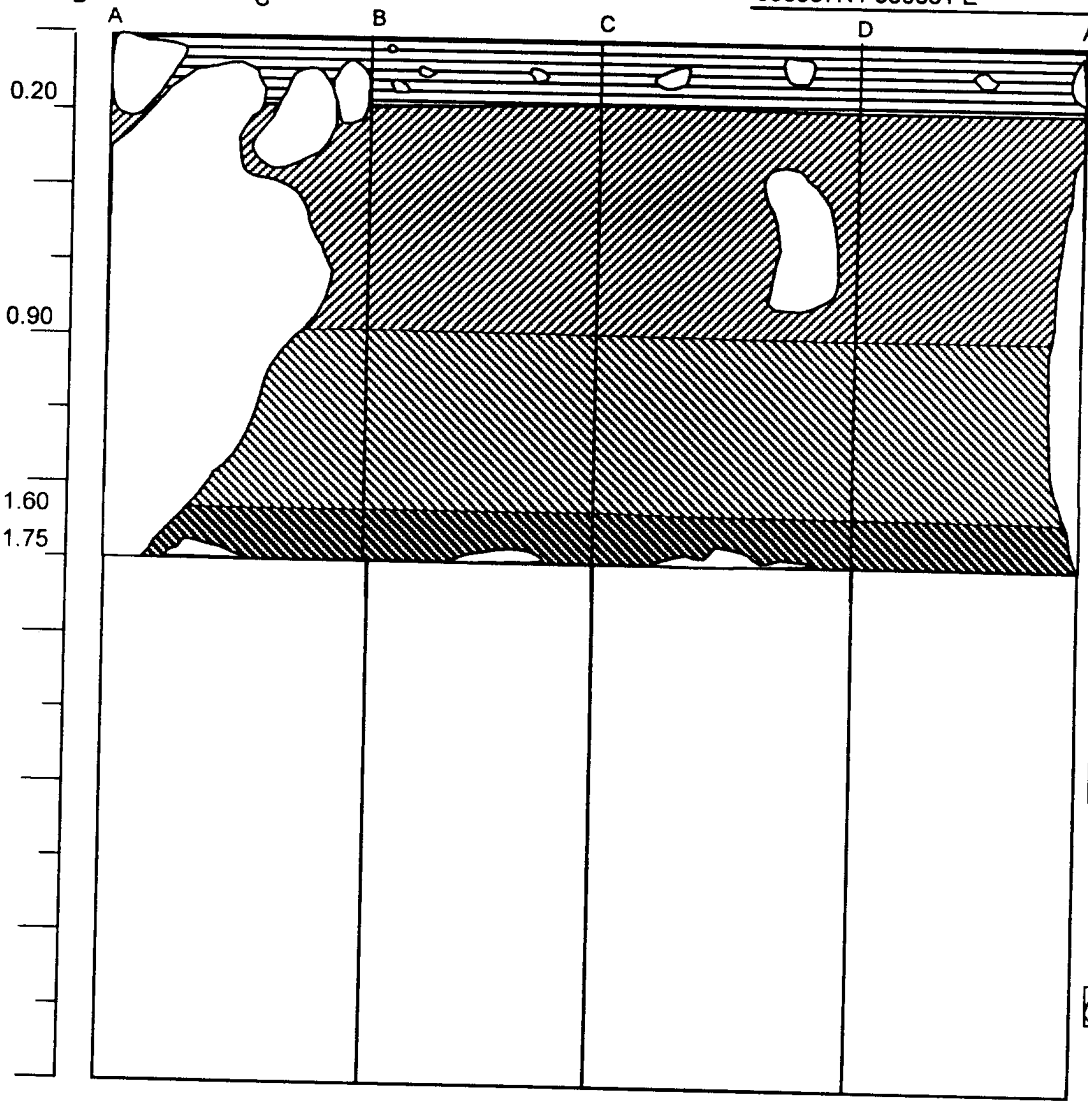
TECNILAB, S. A. FUNDADA EN 1973
UNA EMPRESA E. BARRANCO Y ASOC., S. A.
LABORATORIO DE SUELOS Y MATERIALES

DETALLE DE CALICATA

TRABAJO No. 4-214 CALICATA No C-2 FECHA: 5 de diciembre de 2001
PROYECTO AMPLIACION DE LA CUENCA DEL CANAL DE PANAMÁ
LOCALIZACION COCLÉ DEL NORTE
CLIENTE MONTGOMERY WATSON HARZA



UBICACIÓN: LADERA DEL CERRO CASTILLO, LADO EXTREMO DEL CERRO PELADO.
REFERENCIA: COORDENADAS APROXIMADAS 993557N / 550651 E



LEYENDA

Capa Vegetal con boulders redondeados de 30 cm; color café oscuro.

Arcilla Limosa, con boulders subredondeados de 60cm, ó más, plasticidad alta, color marrón rojizo.

Limo arcilloso con boulders subangulosos y angulosos meteorizados de 40cm ó más, plasticidad alta, color café claro.

Limo con boulders subangulosos de 30-50cm, plasticidad media, color café claro.

Boulders de roca basáltica.

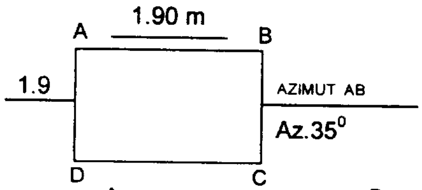
N.F. ________

Observaciones: DESDE 0.20 A 0.90 ARCILLAS LIMOSAS, CON BOULDERS SUBREDONDEADOS, 50-60CM DE PROMEDIO. DE 0.90-1.60 LIMO ARCILLOSO, CON BOULDERS SUBANGULARES. DE 1.60 -1.75 LIMO CON FRAGMENTOS DE ROCA METEORIZADA, INTERIOR DE BOULDERS ROCA SANA BASÁLTICA.

TECNILAB, S. A. FUNDADA EN 1973
UNA EMPRESA E. BARRANCO Y ASOC., S. A.
LABORATORIO DE SUELOS Y MATERIALES

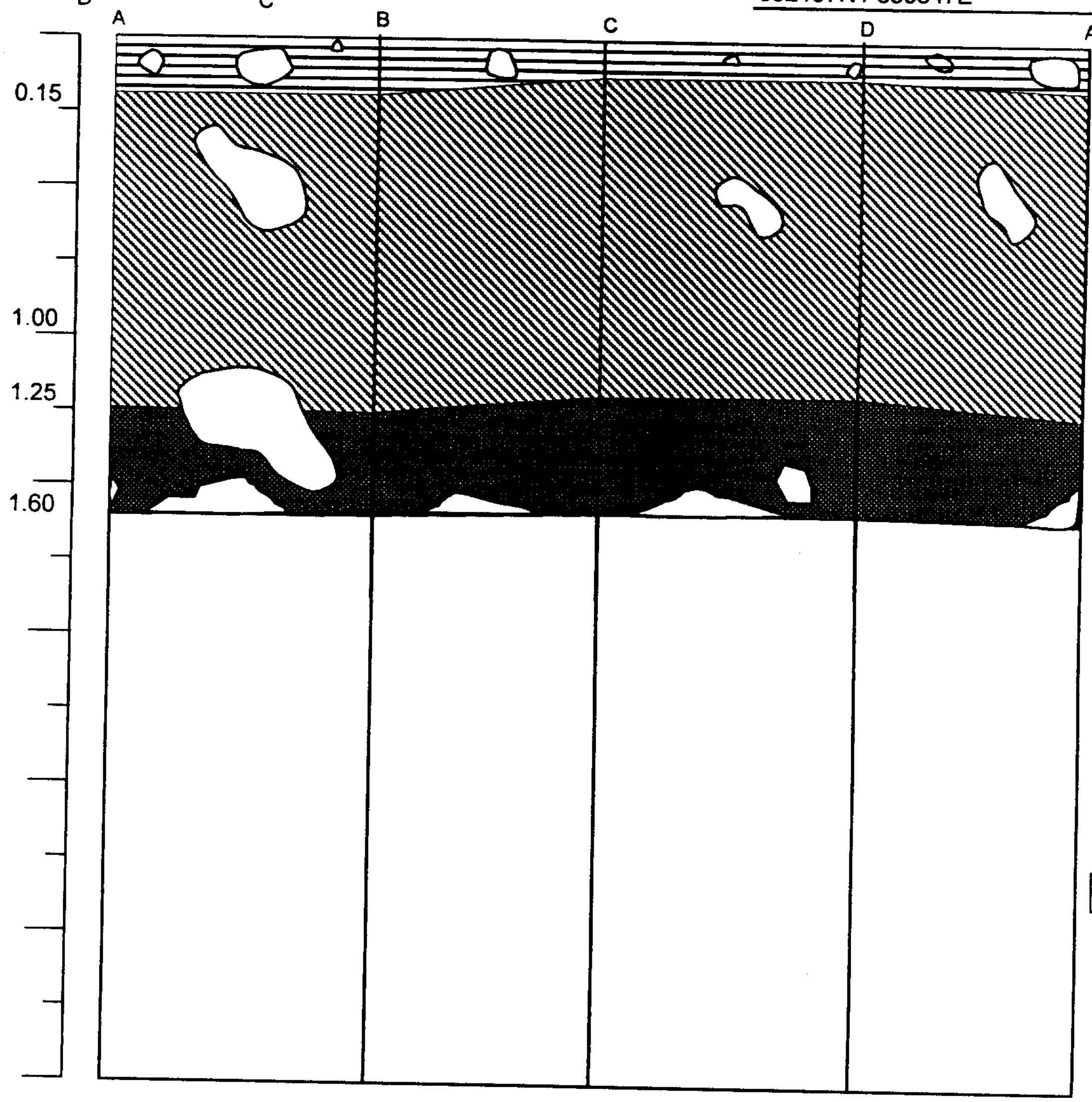
DETALLE DE CALICATA

TRABAJO No. 4-214 CALICATA No C-6 FECHA: 6 de diciembre de 2001
PROYECTO AMPLIACION DE LA CUENCA DEL CANAL DE PANAMÁ
LOCALIZACION COCLÉ DEL NORTE
CLIENTE MONTGOMERY WATSON HARZA



UBICACIÓN: EL GUABO, AL OESTE DE CUATRO CALLITAS

REFERENCIA: COORDENADAS APROXIMADAS
992197N / 550647E



LEYENDA

Capa Vegetal con boulders redondeados de 30 cm; color café oscuro.

Limo arcilloso con boulders subredondeados de 0.20-40cm ó más, plasticidad media, color café claro con tono gris.

Limo arenoso con boulders subangulosos meteoriza-dos de 0.40-0.70cm, plasticidad baja, color café claro con tono gris verdoso.

Boulders de roca basáltica

N.F. __________

Observaciones: DE 0.15 A 1.25 LIMO ARCILLOSO, CON BOULDERS METEORIZADOS SUBREDONDEADOS DE ROCA BASÁLTICA. DE 1.25 A 1.60 LIMO ARENOSO CON BOULDERS SUBANGULARES, DE 0.50 A 1.00 M, DE LA MISMA COMPOSICIÓN.

III. CONTENIDO NATURAL DE HUMEDAD (%W)

IV. DESCRIPCION VISUAL DE LAS MUESTRAS

TECNILAB, S. A. FUNDADA EN 1973

UNA EMPRESA E. BARRANCO Y ASOC., S. A.

LABORATORIO DE SUELOS Y MATERIALES

DESCRIPCIÒN VISUAL DE LAS MUESTRAS

TRABAJO No. 4-214

PROYECTO AMPLIACION DE LA CUENCA DEL CANAL DE PANAMÁ

LOCALIZACION COCLÉ DEL NORTE

CLIENTE MONTGOMERY WATSON HARZA

FECHA 5-6 DE DICIEMBRE DE 2001

No. DE CALICATA	No. DE MUESTRA	PROFUNDIDAD (m)	DESCRIPCIÓN VISUAL
C-1	1	0.20 A 1.20	LIMO INORGÁNICO DE PLASTICIDAD ALTA, COLOR CAFÉ CLARO CON TONO OCRE.
C-1	2	1.20 A 1.80	ARENA LIMOSA DE PLASTICIDAD BAJA, COLOR CAFÉ CLARO CON TONO OCRE.
C-2	1	0.20 A 0.90	LIMO INORGÀNICO DE PLASTICIDADALTA, COLOR MARRÓN ROJIZO.
C-2	2	0.90 A 1.60	LIMO INORGÀNICO DE PLASTICIDAD ALTA, COLOR OCRE CON VETAS ROJAS.
C-2	3	1.60 A 1.75	LIMO INORGÀNICO ARENOSO, DE PLASTICIDAD MEDIA, COLOR CAFÉ CLARO CON PINTAS OCRE.
C-6	1	0.20 A 1.20	LIMO ARCILLOSO, DE PLASTICIDAD MEDIA, COLOR CAFÉ CLARO .
C-6	2	1.20 A 1.60	LIMO ARENOSO, DE PLASTICIDAD BAJA, COLOR CAFÉ CLARO CON TONO GRIS VERDOSO .

V. GRAVEDAD ESPECIFICA (G_S)

TECNILAB, S. A.

FUNDADA EN 1973

UNA EMPRESA E. BARRANCO Y ASOC., S. A.

LABORATORIO DE SUELOS Y MATERIALES

RESUMEN DE PRUEBA DE GRAVEDAD ESPECIFICA

TRABAJO No. 4-214

PROYECTO AMPLIACION DE LA CUENCA DEL CANAL DE PANAMÁ

LOCALIZACION RIO COCLÉ DEL NORTE, PROVINCIA DE COLÓN.

CLIENTE MONTGOMERY WATSON HARZA FECHA DICIEMBRE DE 2001

No.	CALICATA No.	MUESTRA No.	PROFUNDIDAD (m)	G_S
1	C-1	1	0.50 - 1.00	2.74
2	C-1	2	1.50 - 1.80	2.80
3	C-2	1	0.40 - 0.60	2.63
4	C-2	2	0.90 - 1.20	2.61
5	C-2	3	1.60 - 1.75	2.66

TECNILAB, S. A. FUNDADA EN 1973
UNA EMPRESA E. BARRANCO Y ASOC., S. A.
LABORATORIO DE SUELOS Y MATERIALES

GRAVEDAD ESPECIFICA EN LOS SUELOS
ASTM D 854

TRABAJO No. : 4-214 CLIENTE MONTGOMERY WATSON HARZA HUECO No. C-1 MUESTRA No. 1
PROYECTO: AMPLIACION DE LA CUENCA DEL CANAL DE PANAMA LOCALIZACION COCLE DEL NORTE
MUESTREADO POR TECNILAB, S.A. FECHA 5-DIC.-01 PROFUNDIDAD 0.50 A 1.00
PREPARADO POR TECNILAB, S.A. FECHA 13-DIC.-01 LABORATORISTA J. Vergara

MATERIAL LIMO INORGANICO DE ALTA PLASTICIDAD, CAFÉ CLARO CON TONO OCRE (MH)

DETALLE	UNIDAD	NUMERO DE ENSAYO			
		1	2	3	4
PROFUNDIDAD	m	0.50 A 1.00			
MUESTRA No.		1			
PICNOMETRO No.		7			
TARA + MUESTRA HUMEDA	g	271.80			
PESO DE LA TARA	g	151.80			
PESO DE LA TARA + SUELO SECO	g	271.00			
PESO DEL SUELO SECO (W_0)	g	119.20			
PICNOMETRO + AGUA + SUELO (W_1)	g	767.10			
PICNOMETRO + AGUA A CAPACIDAD TOTAL (W_2)	g	691.40			
TEMPERATURA DE ENSAYO	^{0}C	22			
GRAVEDAD ESPECIFICA (G_S)		2.74			

$$G_S = \frac{W_0}{W_0 + W_2 - W_1}$$

OBSERVACIONES:

REVISADO POR:

TECNILAB, S. A. FUNDADA EN 1973
UNA EMPRESA E. BARRANCO Y ASOC., S. A.
LABORATORIO DE SUELOS Y MATERIALES

GRAVEDAD ESPECIFICA EN LOS SUELOS
ASTM D 854

TRABAJO No. : 4-214 CLIENTE MONTGOMERY WATSON HARZA HUECO No. C-1 MUESTRA No. 2
PROYECTO: AMPLIACION DE LA CUENCA DEL CANAL DE PANAMA LOCALIZACION COCLE DEL NORTE
MUESTREADO POR TECNILAB, S.A. FECHA 5-DIC.-01 PROFUNDIDAD 1.50 A 1.80
PREPARADO POR TECNILAB, S.A. FECHA 13-DIC.-01 LABORATORISTA J. Vergara

MATERIAL ARENA LIMOSA DE BAJA PLASTICIDAD, CAFÉ CLARO CON TONO OCRE (SM)

DETALLE	UNIDAD	NUMERO DE ENSAYO			
		1	2	3	4
PROFUNDIDAD	m	1.50 A 1.80			
MUESTRA No.		2			
PICNOMETRO No.		C			
TARA + MUESTRA HUMEDA	g	274.50			
PESO DE LA TARA	g	154.50			
PESO DE LA TARA + SUELO SECO	g	273.00			
PESO DEL SUELO SECO (W_0)	g	118.50			
PICNOMETRO + AGUA + SUELO (W_1)	g	737.70			
PICNOMETRO + AGUA A CAPACIDAD TOTAL (W_2)	g	661.48			
TEMPERATURA DE ENSAYO	^0C	22			
GRAVEDAD ESPECIFICA (G_S)		2.80			

$$G_S = \frac{W_0}{W_0 + W_2 - W_1}$$

OBSERVACIONES:

REVISADO POR:

TECNILAB, S. A. FUNDADA EN 1973
UNA EMPRESA E. BARRANCO Y ASOC., S. A.
LABORATORIO DE SUELOS Y MATERIALES

GRAVEDAD ESPECIFICA EN LOS SUELOS
ASTM D 854

TRABAJO No. : 4-214 CLIENTE MONTGOMERY WATSON HARZA HUECO No. C-2 MUESTRA No. 1
PROYECTO: AMPLIACION DE LA CUENCA DEL CANAL DE PANAMA LOCALIZACION COCLE DEL NORTE
MUESTREADO POR TECNILAB, S.A. FECHA 5-DIC.-01 PROFUNDIDAD 0.40 A 0.60
PREPARADO POR TECNILAB, S.A. FECHA 13-DIC.-01 LABORATORISTA J. Vergara

MATERIAL LIMO INORGANICO DE ALTA PLASTICIDAD, MARRON ROJIZO (MH)

DETALLE	UNIDAD	NUMERO DE ENSAYO			
		1	2	3	4
PROFUNDIDAD	m	0.40 A 0.60			
MUESTRA No.		1			
PICNOMETRO No.		6			
TARA + MUESTRA HUMEDA	g	274.60			
PESO DE LA TARA	g	154.60			
PESO DE LA TARA + SUELO SECO	g	272.50			
PESO DEL SUELO SECO (W_0)	g	117.90			
PICNOMETRO + AGUA + SUELO (W_1)	g	766.90			
PICNOMETRO + AGUA A CAPACIDAD TOTAL (W_2)	g	693.85			
TEMPERATURA DE ENSAYO	^0C	22			
GRAVEDAD ESPECIFICA (G_S)		2.63			

$$G_S = \frac{W_0}{W_0 + W_2 - W_1}$$

OBSERVACIONES:

REVISADO POR:

TECNILAB, S. A. FUNDADA EN 1973
UNA EMPRESA E. BARRANCO Y ASOC., S. A.
LABORATORIO DE SUELOS Y MATERIALES

GRAVEDAD ESPECIFICA EN LOS SUELOS
ASTM D 854

TRABAJO No. : 4-214 CLIENTE MONTGOMERY WATSON HARZA HUECO No. C-2 MUESTRA No. 2
PROYECTO: AMPLIACION DE LA CUENCA DEL CANAL DE PANAMA LOCALIZACION COCLE DEL NORTE
MUESTREADO POR TECNILAB, S.A. FECHA 5-DIC.-01 PROFUNDIDAD 0.90 A 1.20
PREPARADO POR TECNILAB, S.A. FECHA 13-DIC.-01 LABORATORISTA J. Vergara

MATERIAL LIMO INORGANICO DE ALTA PLASTICIDAD, OCRE CON VETAS ROJAS (MH)

DETALLE	UNIDAD	NUMERO DE ENSAYO			
		1	2	3	4
PROFUNDIDAD	m	0.90 A 1.20			
MUESTRA No.		2			
PICNOMETRO No.		3			
TARA + MUESTRA HUMEDA	g	275.90			
PESO DE LA TARA	g	155.90			
PESO DE LA TARA + SUELO SECO	g	275.40			
PESO DEL SUELO SECO (W_0)	g	119.50			
PICNOMETRO + AGUA + SUELO (W_1)	g	750.60			
PICNOMETRO + AGUA A CAPACIDAD TOTAL (W_2)	g	676.80			
TEMPERATURA DE ENSAYO	^0C	22			
GRAVEDAD ESPECIFICA (G_S)		2.61			

$$G_S = \frac{W_0}{W_0 + W_2 - W_1}$$

OBSERVACIONES:

REVISADO POR:

TECNILAB, S. A.
UNA EMPRESA E. BARRANCO Y ASOC., S. A.
LABORATORIO DE SUELOS Y MATERIALES
FUNDADA EN 1973

GRAVEDAD ESPECIFICA EN LOS SUELOS
ASTM D 854

TRABAJO No. : 4-214 CLIENTE MONTGOMERY WATSON HARZA HUECO No. C-2 MUESTRA No. 3
PROYECTO: AMPLIACION DE LA CUENCA DEL CANAL DE PANAMA LOCALIZACION COCLE DEL NORTE
MUESTREADO POR TECNILAB, S.A. FECHA 5-DIC.-01 PROFUNDIDAD 1.60 A 1.75
PREPARADO POR TECNILAB, S.A. FECHA 13-DIC.-01 LABORATORISTA J. Vergara

MATERIAL LIMO INORGANICO ARENOSO DE PLASTICIDAD MEDIA, CAFÉ CLARO CON PINTAS OCRE

DETALLE	UNIDAD	NUMERO DE ENSAYO			
		1	2	3	4
PROFUNDIDAD	m	1.60 A 1.75			
MUESTRA No.		3			
PICNOMETRO No.		1			
TARA + MUESTRA HUMEDA	g	292.30			
PESO DE LA TARA	g	172.30			
PESO DE LA TARA + SUELO SECO	g	292.00			
PESO DEL SUELO SECO (W_0)	g	119.70			
PICNOMETRO + AGUA + SUELO (W_1)	g	745.60			
PICNOMETRO + AGUA A CAPACIDAD TOTAL (W_2)	g	670.82			
TEMPERATURA DE ENSAYO	^0C	22			
GRAVEDAD ESPECIFICA (G_S)		2.66			

$$G_S = \frac{W_0}{W_0 + W_2 - W_1}$$

OBSERVACIONES:

REVISADO POR:

VI. ANALISIS GRANULOMETRICO MECANICO Y LIMITES DE ATTERBERG

TECNILAB, S. A.

FUNDADA EN 1973

UNA EMPRESA E BARRANCO Y ASOC. S. A

LABORATORIO DE SUELOS Y MATERIALES

RESUMEN DE PRUEBAS DE ANALISIS GRANULOMETRICO MECANICO Y LIMITES DE ATTERBERG

TRABAJO No. 4-214

PROYECTO AMPLIACION DE LA CUENCA DEL CANAL DE PANAMÁ

LOCALIZACION RIO COCLÉ DEL NORTE, PROVINCIA DE COLÓN.

CLIENTE MONTGOMERY WATSON HARZA FECHA DICIEMBRE DE 2001

No.	CALICATA No.	MUESTRA No.	PROFUNDIDAD (m)	ANALISIS GRANULOMETRICO % QUE PASA TAMIZ						LIMITES DE ATTERBERG			CLASIFICACION (S. U. C. S.)
				1/2	3/8	#4	#10	#40	#200	LL	LP	IP	
1	C-1	1	0.50 - 1.00	100.00	98.99	97.56	93.74	87.07	75.61	69.90	39.80	30.10	MH
2	C-1	2	1.50 - 1.80	100.00	100.00	84.87	78.07	65.68	48.93	47.90	42.90	5.00	SM
3	C-2	1	0.40 - 0.60	100.00	100.00	99.12	97.47	93.77	86.90	69.90	37.50	28.40	MH
4	C-2	2	0.90 - 1.20	100.00	100.00	99.09	97.35	92.93	84.69	61.20	36.80	24.40	MH
5	C-2	3	1.60 - 1.75	100.00	100.00	97.31	92.74	83.51	68.91	51.00	36.60	14.40	MH

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 / ASTM D 421)

:ABAJO No. : 4-214	CLIENTE: MONTGOMERY WATSON HARZA			Hoyo N°: C-1	Muestra N°: 1
PROYECTO: AMPLIACION DE LA CUENCA DEL CANAL		LOCALIZACION	COCLÉ DEL NORTE		
MUESTREADO POR	TECNILAB, S.A.	FECHA	5-dic.-01	PROFUNDIDAD	0.50 A 1.00 m
PREPARADO POR	TECNILAB, S.A.	FECHA	12-Dic-01	LABORATORISTA	M. GONZALEZ

ANALISIS MECANICO

TAMIZ	RETENIDO ACUMULADO	% RETENIDO	% QUE PASA
2½"			
2"			
1½"			
1"			
¾"			
½"			
⅜"	2.70	1.01	98.99
#4	6.50	2.44	97.56
FONDO			
TOTAL			

TAMIZ	RETENIDO ACUMULADO	% RETENIDO	% QUE PASA	CORR QUE PASA
#4	6.50	2.44	97.56	
#10	16.70	6.26	93.74	
#40	34.50	12.93	87.07	
#200	65.10	24.39	75.61	
FONDO				
TOTAL				

AGREGADO FINO

Peso Muestra Total Secada al Aire 361.90 gr

Peso Muestra Total Seca 266.90 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	2.40	12.10	8.20	3.90	5.80	67.20	34
X-5	2.50	12.00	8.10	3.90	5.60	69.60	24
X-10	2.50	12.40	8.20	4.20	5.70	73.70	15

LIMITE PLASTICO

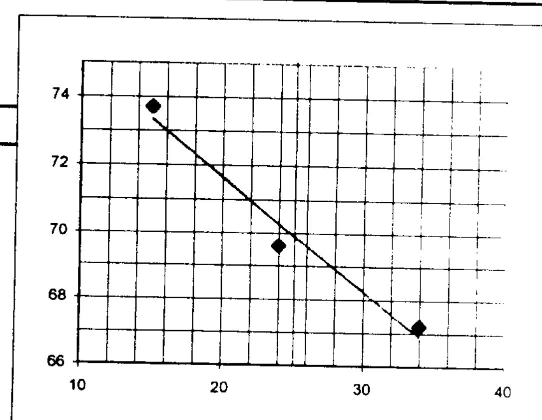
CAPSULA No.	PESO CAPSULA (gr)	CAPSULA + SUELO HUM. (gr)	CAPSULA + SUELO SECO (gr)	AGUA (gr)	SUELO SECO (gr)	CONTENIDO DE HUMEDAD (%)	PROM.
T-9	2.40	6.40	5.20	1.20	2.80	42.90	39.8
X-12	2.30	6.40	5.30	1.10	3.00	36.70	

CLASIFICACION LIMO INORGANICO DE ALTA PLASTICIDAD
COLOR CAFÉ CLARO CON TONO OCRE

CLASIFICACION S.U.C.S. MH

L.L. = 69.90
L.P. = 39.80
I.p. = 30.10

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 / ASTM D 421)

TRABAJO No. : 4-214 CLIENTE: MONTGOMERY WATSON HARZA Hoyo N°: C-1 Muestra N° 2
PROYECTO: AMPLIACION DE LA CUENCA DEL CANAL LOCALIZACION COCLÉ DEL NORTE
MUESTREADO POR TECNILAB, S.A. FECHA 5-dic.-01 PROFUNDIDAD 1.50 A 1.80 m.
PREPARADO POR TECNILAB, S.A. FECHA 12-Dic-01 LABORATORISTA M. GONZALEZ

ANALISIS MECANICO

TAMIZ	RETENIDO ACUMULADO	% RETENIDO	% QUE PASA
2½"			
2"			
1½"			
1"			
¾"			
½"			
⅜"			
#4			
FONDO			
TOTAL			

AGREGADO GRUESO
Peso Muestra Total Secada al Aire ______ gr

TAMIZ	RETENIDO ACUMULADO	% RETENIDO	% QUE PASA	CORR QUE PASA
#4	52.90	15.13	84.87	
#10	76.70	21.93	78.07	
#40	120.00	34.32	65.68	
#200	178.60	51.07	48.93	
FONDO				
TOTAL				

AGREGADO FINO
Peso Muestra Total Secada al Aire 455.30 gr
Peso Muestra Total Seca 349.70 gr
Peso Seco Depués de Lavado - 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
94	10.90	20.50	17.60	2.90	6.70	43.30	32
75	11.90	22.00	18.70	3.30	6.80	48.50	24
83	11.80	21.70	18.10	3.60	6.30	57.10	12

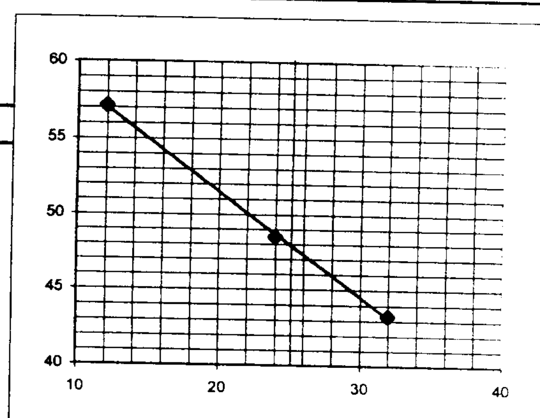
LIMITE PLASTICO

CAPSULA No.	PESO CAPSULA (gr)	CAPSULA + SUELO HUM. (gr)	CAPSULA + SUELO SECO (gr)	AGUA (gr)	SUELO SECO (gr)	CONTENIDO DE HUMEDAD (%)	PROM.
W-3	2.30	6.30	5.10	1.20	2.80	42.90	42.90
A-5	2.50	6.50	5.30	1.20	2.80	42.90	

CLASIFICACION ARENA LIMOSA DE PLASTICIDAD BAJA
COLOR CAFÉ CLARO CON TONO OCRE
CLASIFICACION S.U.C.S. SM

L.L. = 47.90
L.P. = 42.90
I.p. = 5.00

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 / ASTM D 421)

RABAJO No. : 4-214 CLIENTE: MONTGOMERY WATSON HARZA Hoyo N°: C-2 Muestra N°: 1
PROYECTO: AMPLIACION DE LA CUENCA DEL CANAL LOCALIZACION COCLÉ DEL NORTE
MUESTREADO POR TECNILAB, S.A. FECHA 5 -dic.-01 PROFUNDIDAD 0.40 A 0.60 m
PREPARADO POR TECNILAB, S.A. FECHA 12-Dic-01 LABORATORISTA M. GONZALEZ

ANALISIS MECANICO

TAMIZ	RETENIDO ACUMULADO	% RETENIDO	% QUE PASA
2½"			
2"			
1½"			
1"			
¾"			
½"			
⅜"			
#4			
FONDO			
TOTAL			

TAMIZ	RETENIDO ACUMULADO	% RETENIDO	% QUE PASA	CORR QUE PASA
#4	2.60	0.88	99.12	
#10	7.50	2.53	97.47	
#40	18.50	6.23	93.77	
#200	38.90	13.10	86.90	
FONDO				
TOTAL				

AGREGADO FINO
Peso Muestra Total Secada al Aire 407.80 gr
Peso Muestra Total Seca 297.00 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
33	11.10	20.70	17.00	3.70	5.90	62.70	38
71	11.70	21.60	17.70	3.90	6.00	65.00	26
A8	11.00	22.80	18.00	4.80	7.00	68.60	16

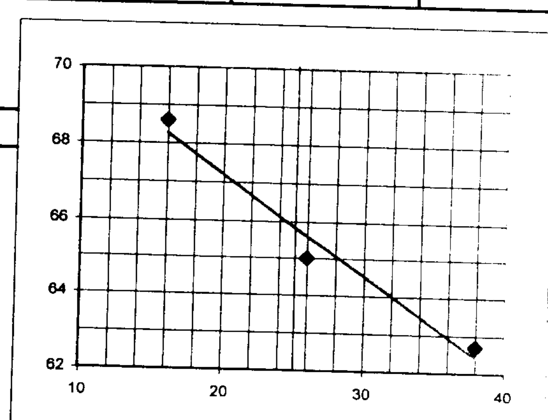
LIMITE PLASTICO

CAPSULA No.	PESO CAPSULA (gr)	CAPSULA + SUELO HUM. (gr)	CAPSULA + SUELO SECO (gr)	AGUA (gr)	SUELO SECO (gr)	CONTENIDO DE HUMEDAD (%)	PROM.
A-11	2.40	5.80	4.90	0.90	2.50	36.00	[illegible]
X-1	2.50	5.00	4.30	0.70	1.80	38.90	

CLASIFICACION LIMO INORGÁNICO DE ALTA PLASTICIDAD
COLOR MARRÓN ROJIZO
CLASIFICACION S.U.C.S. MH

L.L. = 65.90
L.P. = 37.50
I.p. = 28.40

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 / ASTM D 421)

ᵢBAJO No. : 4-214 CLIENTE: MONTGOMERY WATSON HARZA Hoyo N°: C-2 Muestra N°: 2
PROYECTO: AMPLIACION DE LA CUENCA DEL CANAL LOCALIZACION COCLÉ DEL NORTE
MUESTREADO POR TECNILAB, S.A. FECHA 5-dic.-01 PROFUNDIDAD 0.90 A 1.20
PREPARADO POR TECNILAB, S.A. FECHA 12-Dic-01 LABORATORISTA M. GONZALEZ

ANALISIS MECANICO

TAMIZ	RETENIDO ACUMULADO	% RETENIDO	% QUE PASA
2½"			
2"			
1½"			
1"			
¾"			
½"			
⅜"			
#4			
FONDO			
TOTAL			

TAMIZ	RETENIDO ACUMULADO	% RETENIDO	% QUE PASA	CORR QUE PASA
#4	2.40	0.91	99.09	
#10	7.00	2.65	97.35	
#40	18.70	7.07	92.93	
#200	40.50	15.31	84.69	
FONDO				
TOTAL				

AGREGADO FINO
Peso Muestra Total Secada al Aire 353.00 gr
Peso Muestra Total Seca 264.60 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
1.1	10.60	23.70	18.90	4.80	8.30	57.80	33
2.1	10.60	22.10	17.70	4.40	7.10	62.00	22
1.3	10.60	24.00	18.70	5.30	8.10	65.40	13

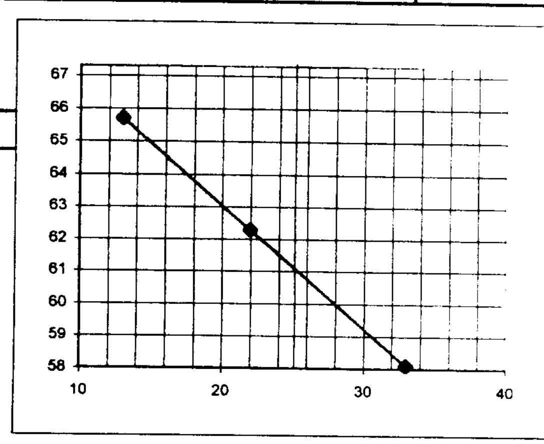
LIMITE PLASTICO

CAPSULA No.	PESO CAPSULA (gr)	CAPSULA + SUELO HUM. (gr)	CAPSULA + SUELO SECO (gr)	AGUA (gr)	SUELO SECO (gr)	CONTENIDO DE HUMEDAD (%)	PROM.
B-3	1.80	6.60	5.30	1.30	3.50	37.10	36.80
B-5	2.00	5.00	4.20	0.80	2.20	36.40	

CLASIFICACION LIMO INORGÁNICO DE ALTA PLASTICIDAD
COLOR OCRE CON VETAS ROJAS
CLASIFICACION S.U.C.S. MH

L.L. = 61.20
L.P. = 36.80
I.p. = 24.40

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 / ASTM D 421)

TRABAJO No. : 4-214 CLIENTE: MONTGOMERY WATSON HARZA Hoyo N°: C-2 Muestra N°: 3
PROYECTO: AMPLIACION DE LA CUENCA DEL CANAL LOCALIZACION COCLÉ DEL NORTE
MUESTREADO POR TECNILAB, S.A. FECHA 5- dic.-01 PROFUNDIDAD 1.60 A 1.75 m
PREPARADO POR TECNILAB, S.A. FECHA 12-Dic-01 LABORATORISTA M. GONZALEZ

ANALISIS MECANICO

TAMIZ	RETENIDO ACUMULADO	% RETENIDO	% QUE PASA
2½"			
2"			
1½"			
1"			
¾"			
½"			
⅜"			
#4			
FONDO			
TOTAL			

TAMIZ	RETENIDO ACUMULADO	% RETENIDO	% QUE PASA	CORR QUE PASA
#4	7.40	2.69	97.31	
#10	20.00	7.26	92.74	
#40	45.40	16.49	83.51	
#200	85.60	31.09	68.91	
FONDO				
TOTAL				

AGREGADO FINO
Peso Muestra Total Secada al Aire 360.60 gr
Peso Muestra Total Seca 275.30 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
A-4	10.60	22.40	18.80	3.60	8.20	43.90	39
T-1	10.70	25.50	20.50	5.00	9.80	51.00	28
A-5	10.60	21.70	17.80	3.90	7.20	54.20	17

LIMITE PLASTICO

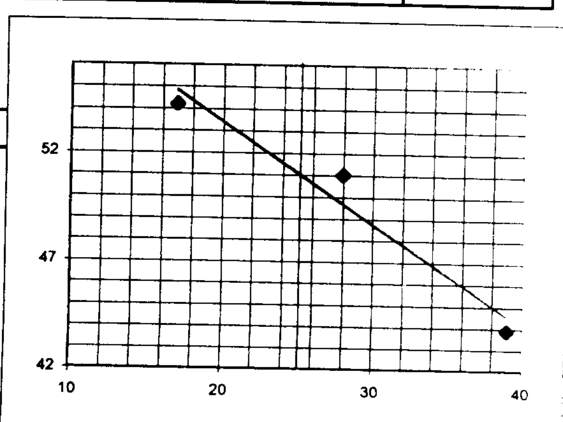
CAPSULA No.	PESO CAPSULA (gr)	CAPSULA + SUELO HUM. (gr)	CAPSULA + SUELO SECO (gr)	AGUA (gr)	SUELO SECO (gr)	CONTENIDO DE HUMEDAD (%)	PROM.
B-8	1.90	6.80	5.50	1.30	3.60	36.10	36.60
B4	1.90	6.70	5.40	1.30	3.50	37.10	

CLASIFICACION LIMO INORGANICO ARENOSO DE PLASTICIDAD MEDIA. COLOR CAFÉ CLARO CON PINTAS OCRE

CLASIFICACION S.U.C.S. MH

L.L. = 51.00
L.P. = 36.60
I.p. = 14.40

CLASIFICACION A.A.S.H.T.O. ______



VII. ANALISIS GRANULOMETRICO POR HIDROMETRO

TECNILAB, S.A.

FUNDADA EN 1973

UNA EMPRESA E. BARRANCO Y ASOC., S. A
LABORATORIO DE SUELOS Y MATERIALES

ANALISIS DE HIDROMETRO
ASTM D421 Y D422

TRABAJO No : 4.214 CLIENTE : MONTGOMERY W. HARZA HOYO No : C-1 MUESTRA No : 1

PROJECTO : AMPLIACION DE LA CUENCA DEL CANAL LOCALIZACIÓN : COCLE DEL NORTE

MUESTREADO POR : TECNILAB, S.A. FECHA 5-DIC.-01 PROFUNDIDAD : 0.50 A 1.00

PREPARADO POR: TECNILAB, S.A. FECHA 14-Dic-01 LABORATORISTA : JOSE VERGARA

ANALISIS DEL HIDROMETRO

HIDROMETRO No.: 151 H G_S DE LOS SOLIDOS : 2.74 a : 0.98 PESO DEL SUELO $_{WS}$: 50.0 g

AGENTE DISPERSANTE : Silicato de sodio CANTIDAD : 40%

CORRECCIÓN DE CERO : 1.0 CORRECCIÓN DE MENISCO : 1.0

FECHA	HORA DE LECTURA	TIEMPO min.	TEMP. °C	LECTURA R	LECTURA R_C	% MAS FINO	HIDROMETRO CORREGIDO POR MENISCO	L	L/t	K	D mm
14-Dic-01	10:50	0	22	25.0	24.40	49.00	26.0	9.40	12.700	0.0129	0.07500
14-Dic-01	10:51	1	22	23.0	22.40	45.08	24.0	10.00	10.000	0.0129	0.04079
14-Dic-01	10:52	2	22	22.0	21.40	43.12	23.0	10.20	5.100	0.0129	0.02913
14-Dic-01	10:53	3	22	22.0	21.40	43.12	23.0	10.20	3.400	0.0129	0.02379
14-Dic-01	10:54	4	22	21.0	20.40	41.16	22.0	10.50	2.625	0.0129	0.02090
14-Dic-01	10:58	8	22	20.0	19.40	39.20	21.0	10.70	1.338	0.0129	0.01492
14-Dic-01	11:06	16	22	20.0	19.40	39.20	21.0	10.70	0.669	0.0129	0.01055
14-Dic-01	11:20	30	22	18.0	17.40	35.28	19.0	11.30	0.377	0.0129	0.00792
14-Dic-01	11:50	60	22	17.0	16.40	33.32	18.0	11.50	0.192	0.0129	0.00565
14-Dic-01	12:50	120	21	15.0	14.40	29.40	16.0	12.10	0.101	0.0131	0.00416
14-Dic-01	03:50	300	20	14.0	13.40	27.44	15.0	12.30	0.041	0.0133	0.00269
15-Dic-01	06:30	960	20	10.0	9.40	19.60	11.0	13.40	0.014	0.0133	0.00157
15-Dic-01	10:50	1440	22	10.0	9.4	19.60	11.0	13.40	0.009	0.0129	0.00124

REVISADO POR ____________________

TECNILAB, S.A. FUNDADA EN 1973
UNA EMPRESA E. BARRANCO Y ASOC., S. A
LABORATORIO DE SUELOS Y MATERIALES

ANALISIS DE HIDROMETRO
ASTM D421 Y D422

TRABAJO No : 4.214 CLIENTE : MONTGOMERY W. HARZA HOYO No : C-1 MUESTRA No : 2
PROJECTO : AMPLIACION DE LA CUENCA DEL CANAL LOCALIZACIÓN : COCLE DEL NORTE
MUESTREADO POR : TECNILAB, S.A. FECHA: 5 -DIC.-01 PROFUNDIDAD: 1.50 A 1.80
PREPARADO POR: TECNILAB, S.A. FECHA 14-Dic-01 LABORATORISTA: JOSE VERGARA

ANALISIS DEL HIDROMETRO

HIDROMETRO No.: 151 H G_S DE LOS SOLIDOS : 2.8 a : 0.98 PESO DEL SUELO $_{WS}$: 50.0 g
AGENTE DISPERSANTE : Silicato de sodio CANTIDAD : 40%
CORRECCIÓN DE CERO : 1.0 CORRECCIÓN DE MENISCO : 1.0

FECHA	HORA DE LECTURA	TIEMPO min.	TEMP. °C	LECTURA R	LECTURA R_c	% MAS FINO	HIDROMETRO CORREGIDO POR MENISCO	L	L/t	K	D mm
14-Dic-01	10:40	0	22	23.0	22.40	44.62	24.0	10.00	12.700	0.0129	0.07500
14-Dic-01	10:41	1	22	20.0	19.40	38.80	21.0	10.70	10.700	0.0129	0.04220
14-Dic-01	10:42	2	22	19.0	18.40	36.86	20.0	11.00	5.500	0.0129	0.03025
14-Dic-01	10:43	3	22	18.0	17.40	34.92	19.0	11.30	3.767	0.0129	0.02504
14-Dic-01	10:44	4	22	18.0	17.40	34.92	19.0	11.30	2.825	0.0129	0.02168
14-Dic-01	10:48	8	22	17.0	16.40	32.98	18.0	11.50	1.438	0.0129	0.01547
14-Dic-01	10:56	16	22	15.0	14.40	29.10	16.0	12.10	0.756	0.0129	0.01122
14-Dic-01	11:10	30	22	14.0	13.40	27.16	15.0	12.30	0.410	0.0129	0.00826
14-Dic-01	11:40	60	22	12.0	11.40	23.28	13.0	12.90	0.215	0.0129	0.00598
14-Dic-01	12:40	120	21	11.0	10.40	21.34	12.0	13.10	0.109	0.0131	0.00433
14-Dic-01	03:40	300	20	9.0	8.40	17.46	10.0	13.70	0.046	0.0133	0.00284
15-Dic-01	06:30	960	20	6.0	5.40	11.64	7.0	14.40	0.015	0.0133	0.00163
15-Dic-01	10:40	1440	22	6.0	5.4	11.64	7.0	14.40	0.010	0.0129	0.00129

REVISADO POR ____________________

TECNILAB, S.A. FUNDADA EN 1973
UNA EMPRESA E. BARRANCO Y ASOC., S. A.
LABORATORIO DE SUELOS Y MATERIALES

ANALISIS DE HIDROMETRO
ASTM D421 Y D422

TRABAJO No : 4.214 CLIENTE : MONTGOMERY W. HARZA HOYO No : C-2 MUESTRA No : 1
PROJECTO : AMPLIACION DE LA CUENCA DEL CANAL LOCALIZACIÓN : COCLE DEL NORTE
MUESTREADO POR : TECNILAB, S.A. FECHA: 5 -DIC.-01 PROFUNDIDAD: 0.40 A 0.60
PREPARADO POR: TECNILAB, S.A. FECHA 14-Dic-01 LABORATORISTA : JOSE VERGARA

ANALISIS DEL HIDROMETRO

HIDROMETRO No.: 152 H G_S DE LOS SOLIDOS : 2.63 a : 0.98 PESO DEL SUELO $_{WS}$: 50.0 g
AGENTE DISPERSANTE : Silicato de sodio CANTIDAD : 40%
CORRECCIÓN DE CERO : 1.0 CORRECCIÓN DE MENISCO : 1.0

FECHA	HORA DE LECTURA	TIEMPO min.	TEMP. °C	LECTURA R	LECTURA R_c	% MAS FINO	HIDROMETRO CORREGIDO POR MENISCO	L	L/t	K	D mm
14-Dic-01	10:30	0	22	25.0	24.40	49.00	26.0	12.00	12.700	0.0129	0.07500
14-Dic-01	10:31	1	22	23.0	22.40	45.08	24.0	12.40	12.400	0.0129	0.04543
14-Dic-01	10:32	2	22	22.0	21.40	43.12	23.0	12.50	6.250	0.0129	0.03225
14-Dic-01	10:33	3	22	21.0	20.40	41.16	22.0	12.70	4.233	0.0129	0.02654
14-Dic-01	10:34	4	22	21.0	20.40	41.16	22.0	12.70	3.175	0.0129	0.02299
14-Dic-01	10:38	8	22	20.0	19.40	39.20	21.0	12.90	1.613	0.0129	0.01638
14-Dic-01	10:46	16	22	19.0	18.40	37.24	20.0	13.00	0.813	0.0129	0.01163
14-Dic-01	11:00	30	22	18.0	17.40	35.28	19.0	13.20	0.440	0.0129	0.00856
14-Dic-01	11:30	60	22	16.0	15.40	31.36	17.0	13.50	0.225	0.0129	0.00612
14-Dic-01	12:30	120	21	15.0	14.40	29.40	16.0	13.70	0.114	0.0131	0.00443
14-Dic-01	03:30	300	20	12.0	11.40	23.52	13.0	14.20	0.047	0.0133	0.00289
15-Dic-01	6:30	960	20	9.0	8.40	17.64	10.0	14.70	0.015	0.0133	0.00165
15-Dic-01	10:30	1440	22	8.0	7.4	15.68	9.0	14.80	0.010	0.0129	0.00131

REVISADO POR ____________

TECNILAB, S.A. FUNDADA EN 1973
UNA EMPRESA E. BARRANCO Y ASOC., S. A.
LABORATORIO DE SUELOS Y MATERIALES

ANALISIS DE HIDROMETRO
ASTM D421 Y D422

TRABAJO No : 4.214 CLIENTE : MONTGOMERY W. HARZA HOYO No : C-2 MUESTRA No : 2
PROJECTO : AMPLIACION DE LA CUENCA DEL CANAL LOCALIZACIÓN : COCLE DEL NORTE
MUESTREADO POR : TECNILAB, S.A. FECHA: 5 -DIC.-01 PROFUNDIDAD : 0.90 A 1.20
PREPARADO POR: TECNILAB, S.A. FECHA 14-Dic-01 LABORATORISTA : JOSE VERGARA

ANALISIS DEL HIDROMETRO

HIDROMETRO No.: 152 H G_S DE LOS SOLIDOS : 2.61 a : 1.01 PESO DEL SUELO $_{WS}$: 50.0 g
AGENTE DISPERSANTE : Silicato de sodio CANTIDAD : 40%
CORRECCIÓN DE CERO : 1.0 CORRECCIÓN DE MENISCO : 1.0

FECHA	HORA DE LECTURA	TIEMPO min.	TEMP. °C	LECTURA R	LECTURA R_C	% MAS FINO	HIDROMETRO CORREGIDO POR MENISCO	L	L/t	K	D mm
14-Dic-01	10:20	0	22	42.0	41.40	84.84	43.0	9.20	12.700	0.0129	0.07500
14-Dic-01	10:21	1	22	38.0	37.40	76.76	39.0	9.90	9.900	0.0129	0.04059
14-Dic-01	10:22	2	22	36.0	35.40	72.72	37.0	10.20	5.100	0.0129	0.02913
14-Dic-01	10:23	3	22	35.0	34.40	70.70	36.0	10.40	3.467	0.0129	0.02402
14-Dic-01	10:24	4	22	34.0	33.40	68.68	35.0	10.60	2.650	0.0129	0.02100
14-Dic-01	10:28	8	22	32.0	31.40	64.64	33.0	10.90	1.363	0.0129	0.01506
14-Dic-01	10:36	16	22	30.0	29.40	60.60	31.0	11.20	0.700	0.0129	0.01079
14-Dic-01	10:50	30	22	28.0	27.40	56.56	29.0	11.50	0.383	0.0129	0.00799
14-Dic-01	11:20	60	22	25.0	24.40	50.50	26.0	12.00	0.200	0.0129	0.00577
14-Dic-01	12:20	120	21	23.0	22.40	46.46	24.0	12.40	0.103	0.0131	0.00421
14-Dic-01	03:20	300	20	19.0	18.40	38.38	20.0	13.00	0.043	0.0133	0.00277
15-Dic-01	6:30	960	20	12.0	11.40	24.24	13.0	14.20	0.015	0.0133	0.00162
15-Dic-01	10:20	1440	22	12.0	11.4	24.24	13.0	14.20	0.010	0.0129	0.00128

REVISADO POR ______________________

TECNILAB, S.A. FUNDADA EN 1973

UNA EMPRESA E BARRANCO Y ASOC., S. A.
LABORATORIO DE SUELOS Y MATERIALES

ANALISIS DE HIDROMETRO
ASTM D421 Y D422

TRABAJO No : 4.214 CLIENTE : MONTGOMERY W. HARZA HOYO No : C-2 MUESTRA No : 3
PROJECTO : AMPLIACION DE LA CUENCA DEL CANAL LOCALIZACIÓN : COCLE DEL NORTE
MUESTREADO POR : TECNILAB, S.A. FECHA: 5 -DIC.-01 PROFUNDIDAD: 1.60 A 1.75
PREPARADO POR: TECNILAB, S.A. FECHA 14-Dic-01 LABORATORISTA : JOSE VERGARA

ANALISIS DEL HIDROMETRO

HIDROMETRO No.: 151 H G_S DE LOS SOLIDOS : 2.66 a : 1.00 PESO DEL SUELO $_{WS}$: 50.0 g
AGENTE DISPERSANTE : Silicato de sodio CANTIDAD : 40%
CORRECCIÓN DE CERO : 1.0 CORRECCIÓN DE MENISCO : 1.0

FECHA	HORA DE LECTURA	TIEMPO min.	TEMP. °C	LECTURA R	LECTURA R_C	% MAS FINO	HIDROMETRO CORREGIDO POR MENISCO	L	L/t	K	D mm
14-Dic-01	10:10	0	22	27.0	26.40	54.00	28.0	8.90	12.700	0.0129	0.07500
14-Dic-01	10:11	1	22	22.0	21.40	44.00	23.0	10.20	10.200	0.0129	0.04120
14-Dic-01	10:12	2	22	21.0	20.40	42.00	22.0	10.50	5.250	0.0129	0.02956
14-Dic-01	10:13	3	22	21.0	20.40	42.00	22.0	10.50	3.500	0.0129	0.02413
14-Dic-01	10:14	4	22	20.0	19.40	40.00	21.0	10.70	2.675	0.0129	0.02110
14-Dic-01	10:18	8	22	19.0	18.40	38.00	20.0	11.00	1.375	0.0129	0.01513
14-Dic-01	10:26	16	22	17.0	16.40	34.00	18.0	11.50	0.719	0.0129	0.01094
14-Dic-01	10:40	30	22	15.0	14.40	30.00	16.0	12.10	0.403	0.0129	0.00819
14-Dic-01	11:10	60	22	13.0	12.40	26.00	14.0	12.60	0.210	0.0129	0.00591
14-Dic-01	12:10	120	21	11.0	10.40	22.00	12.0	13.10	0.109	0.0131	0.00433
14-Dic-01	03:10	300	20	10.0	9.40	20.00	11.0	13.40	0.045	0.0133	0.00281
15-Dic-01	02:10	960	20	6.0	5.40	12.00	7.0	14.40	0.015	0.0133	0.00163
15-Dic-01	10:10	1440	22	6.0	5.4	12.00	7.0	14.40	0.010	0.0123	0.00123

REVISADO POR ____________________

VIII. GRAFICOS GRANULOMETRICOS

TECNILAB, S. A.

UNA EMPRESA E. BARRANCO Y ASOC., S. A.

LABORATORIO DE SUELOS Y MATERIALES

FUNDADA EN 1973

ANALISIS GRANULOMETRICO MECANICO Y POR HIDROMETRO ASTM C 136 Y D 422

TRABAJO No.: 4-214 CLIENTE: MONTGOMERY WATSON HARZA

PROYECTO: AMPLIACION DE LA CUENCA DEL CANAL DE PANAMA

MUESTREADO POR: TECNILAB, S.A. FECHA: 05-Dic-01

PREPARADO POR: TECNILAB, S.A. FECHA: 12 y 14-Dic-01

LOCALIZACION: COCLE DEL NORTE

CALICATA No.: C-1 MUESTRA No.: 1

PROFUNDIDAD: 0.50 - 1.00 m

LABORATORISTA: J. Vergara / M. González

DIAM. PART. (mm)	% QUE PASA CORREGIDO
ANALISIS MECANICO	
37.50	100.0
25.00	100.0
19.00	100.0
12.50	100.0
9.50	99.0
4.75	97.6
2.00	93.7
0.425	87.1
0.075	75.6
HIDROMETRO	
0.040790	69.56
0.029130	66.54
0.023790	66.54
0.020900	63.51
0.014920	60.49
0.010550	60.49
0.007920	54.44
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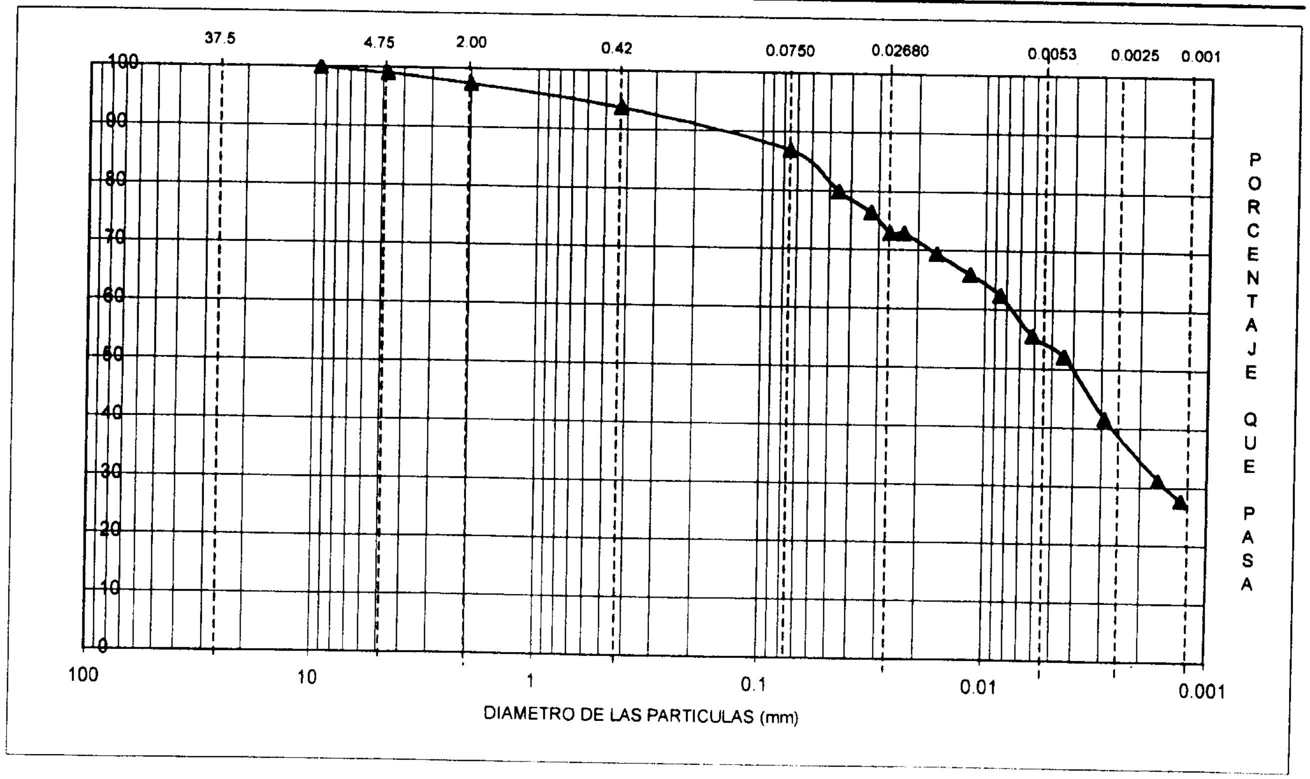

REVISADO POR: ____________________

TECNILAB, S. A.

UNA EMPRESA E. BARRANCO Y ASOC., S. A.

LABORATORIO DE SUELOS Y MATERIALES

FUNDADA EN 1973

ANALISIS GRANULOMETRICO MECANICO Y POR HIDROMETRO ASTM C 136 Y D 422

TRABAJO No.: 4-214 CLIENTE: MONTGOMERY WATSON HARZA

PROYECTO: AMPLIACION DE LA CUENCA DEL CANAL DE PANAMA

MUESTREADO POR: TECNILAB, S.A. FECHA: 05-Dic-01

PREPARADO POR: TECNILAB, S.A. FECHA: 12 y 14-Dic-01

LOCALIZACION: COCLE DEL NORTE

CALICATA No.: C-1 MUESTRA No.: 2

PROFUNDIDAD: 1.50 - 1.80 m

LABORATORISTA: J. Vergara / M. González

DIAM. PART. (mm)	% QUE PASA CORREGIDO
ANALISIS MECANICO	
37.50	100.0
25.00	100.0
19.00	100.0
12.50	100.0
9.50	100.0
4.75	84.9
2.00	8.1
0.425	65.7
0.075	48.9
HIDROMETRO	
0.042200	42.55
0.030250	40.42
0.025040	38.29
0.021680	38.29
0.015470	36.17
0.011220	31.91
0.008260	29.78
0.005980	25.53
0.004330	23.40
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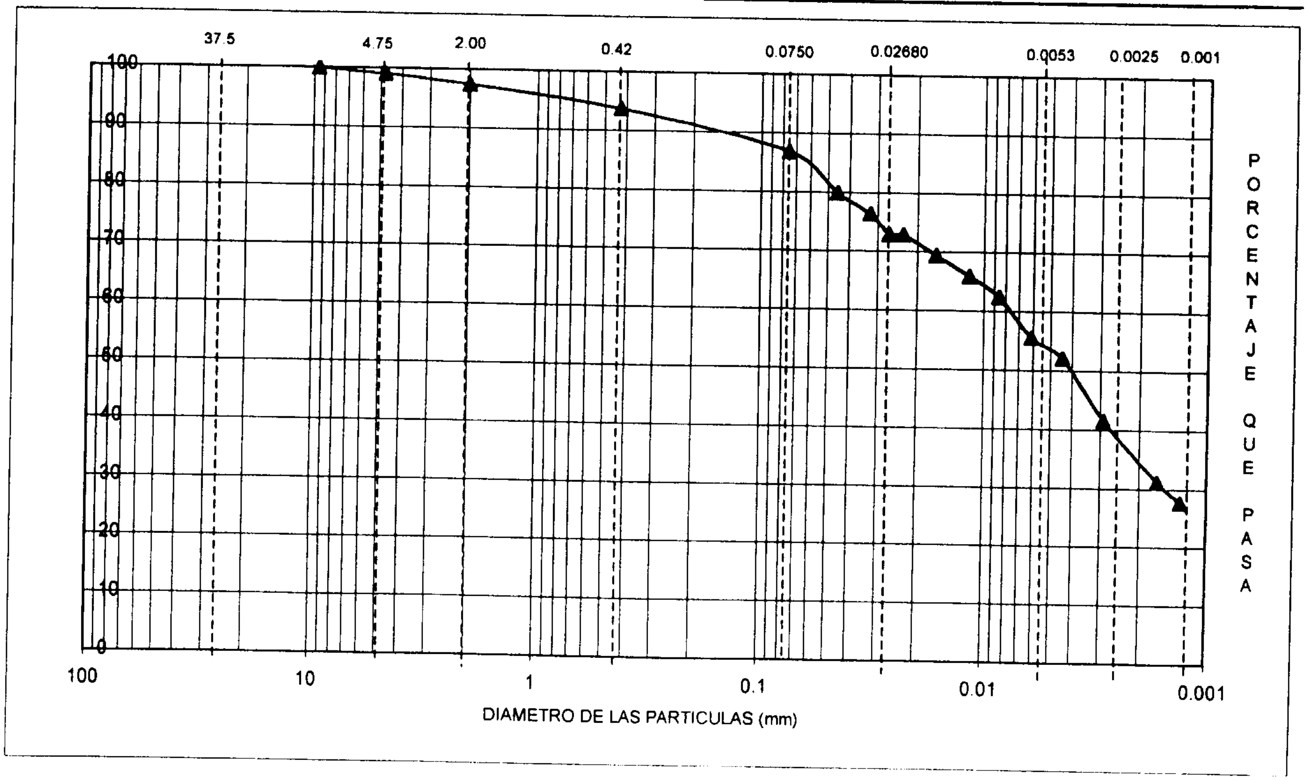

REVISADO POR: ____________________

TECNILAB, S. A.

UNA EMPRESA E. BARRANCO Y ASOC., S. A.

LABORATORIO DE SUELOS Y MATERIALES

FUNDADA EN 1973

ANALISIS GRANULOMETRICO MECANICO Y POR HIDROMETRO ASTM C 136 Y D 422

TRABAJO No.: 4-214 CLIENTE: MONTGOMERY WATSON HARZA

PROYECTO: AMPLIACION DE LA CUENCA DEL CANAL DE PANAMA

MUESTREADO POR: TECNILAB, S.A. FECHA: 05-Dic-01

PREPARADO POR: TECNILAB, S.A. FECHA: 12 y 14-Dic-01

LOCALIZACION: COCLE DEL NORTE

CALICATA No.: C-2 MUESTRA No.: 1

PROFUNDIDAD: 0.40 - 0.60 m

LABORATORISTA: J. Vergara / M. González

DIAM. PART. (mm)	% QUE PASA CORREGIDO
ANALISIS MECANICO	
37.50	100.0
25.00	100.0
19.00	100.0
12.50	100.0
9.50	100.0
4.75	99.1
2.00	97.5
0.425	93.8
0.075	86.9
HIDROMETRO	
0.045430	79.95
0.032250	76.47
0.026540	73.00
0.022990	73.00
0.016380	69.52
0.011630	66.04
0.008560	62.57
0.006120	55.62
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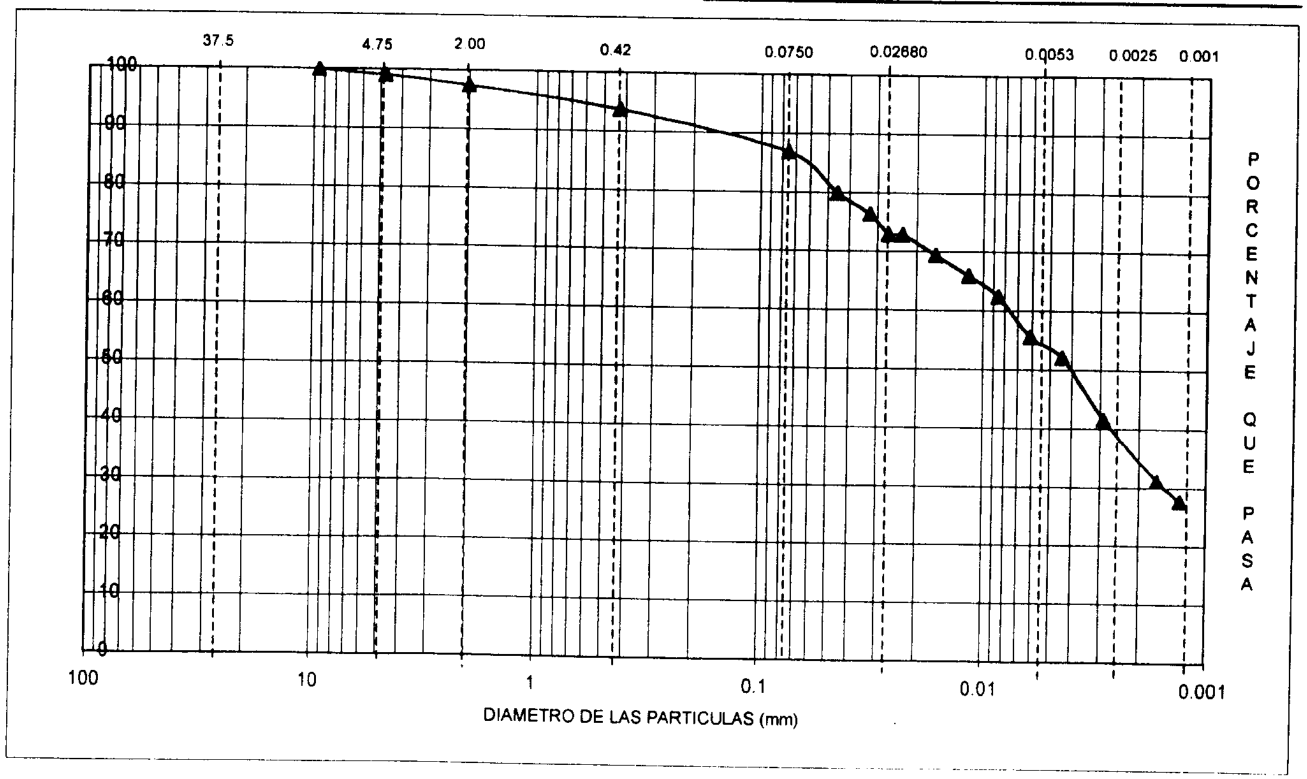

REVISADO POR: ____________________

TECNILAB, S. A.

UNA EMPRESA E. BARRANCO Y ASOC., S. A.

LABORATORIO DE SUELOS Y MATERIALES

FUNDADA EN 1973

ANALISIS GRANULOMETRICO MECANICO Y POR HIDROMETRO ASTM C 136 Y D 422

TRABAJO No.: 4-214 CLIENTE: MONTGOMERY WATSON HARZA

PROYECTO: AMPLIACION DE LA CUENCA DEL CANAL DE PANAMA

MUESTREADO POR: TECNILAB, S.A. FECHA: 05-Dic-01

PREPARADO POR: TECNILAB, S.A. FECHA: 12 y 14-Dic-01

LOCALIZACION: COCLE DEL NORTE

CALICATA No.: C-2 MUESTRA No.: 2

PROFUNDIDAD: 0.90 - 1.20 m

LABORATORISTA: J. Vergara / M. González

DIAM. PART. (mm)	% QUE PASA CORREGIDO
ANALISIS MECANICO	
37.50	100.0
25.00	100.0
19.00	100.0
12.50	100.0
9.50	100.0
4.75	99.1
2.00	97.4
0.425	92.9
0.075	84.7
HIDROMETRO	
0.040590	76.62
0.029130	72.59
0.024020	70.58
0.021000	68.56
0.015060	64.53
0.010790	60.49
0.007990	56.46
0.005770	50.41
0.004210	46.38
0.002770	38.31
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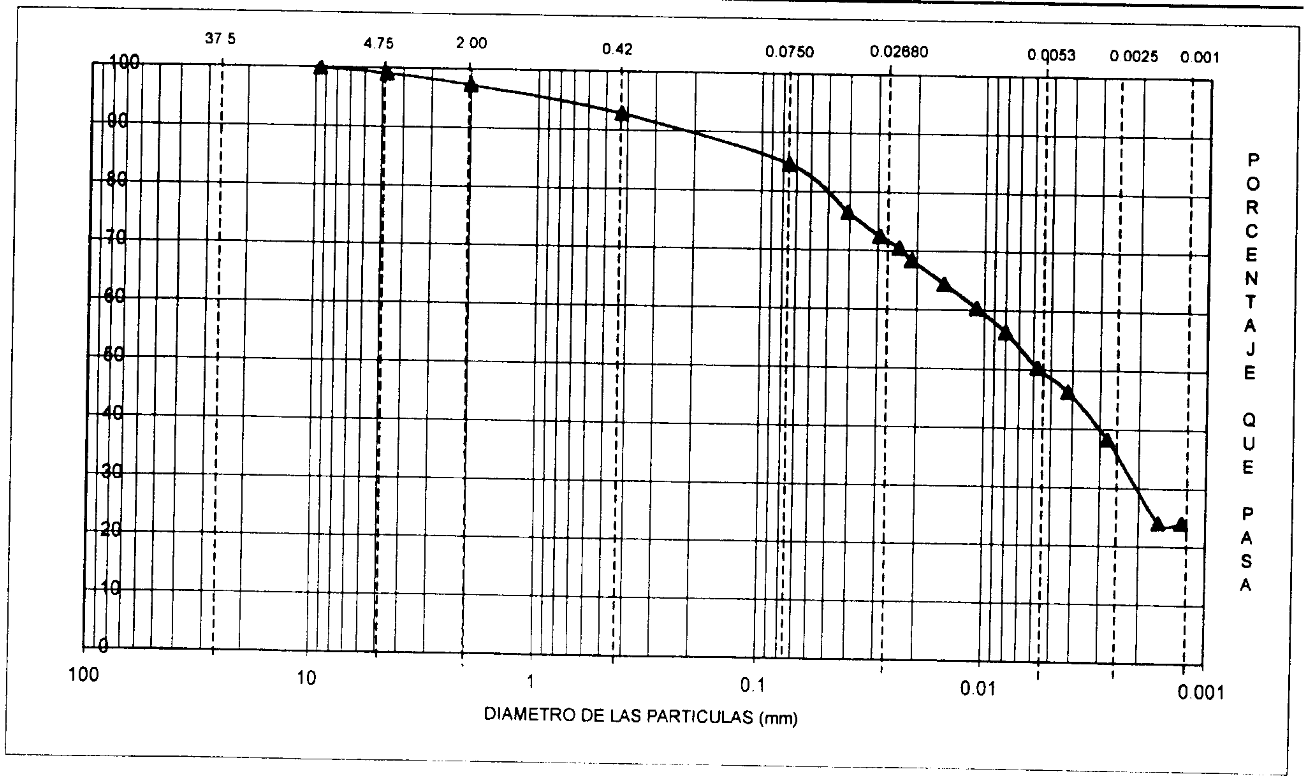

REVISADO POR: ____________________

TECNILAB, S. A.

UNA EMPRESA E. BARRANCO Y ASOC., S. A

LABORATORIO DE SUELOS Y MATERIALES

FUNDADA EN 1973

ANALISIS GRANULOMETRICO MECANICO Y POR HIDROMETRO ASTM C 136 Y D 422

TRABAJO No.: 4-214 CLIENTE: MONTGOMERY WATSON HARZA

PROYECTO: AMPLIACION DE LA CUENCA DEL CANAL DE PANAMA

MUESTREADO POR: TECNILAB, S.A. FECHA: 05-Dic-01

PREPARADO POR: TECNILAB, S.A. FECHA: 12 y 14-Dic-01

LOCALIZACION: COCLE DEL NORTE

CALICATA No.: C-2 MUESTRA No.: 3

PROFUNDIDAD: 1.60 - 1.75 m

LABORATORISTA: J. Vergara / M. González

DIAM. PART. (mm)	% QUE PASA CORREGIDO
ANALISIS MECANICO	
37.50	100.0
25.00	100.0
19.00	100.0
12.50	100.0
9.50	100.0
4.75	97.3
2.00	92.7
0.425	83.5
0.075	68.9
HIDROMETRO	
0.041200	56.15
0.029560	53.60
0.024130	53.60
0.021100	51.04
0.015130	48.49
0.010940	43.39
0.008190	38.28
0.005910	33.18
0.004330	28.07
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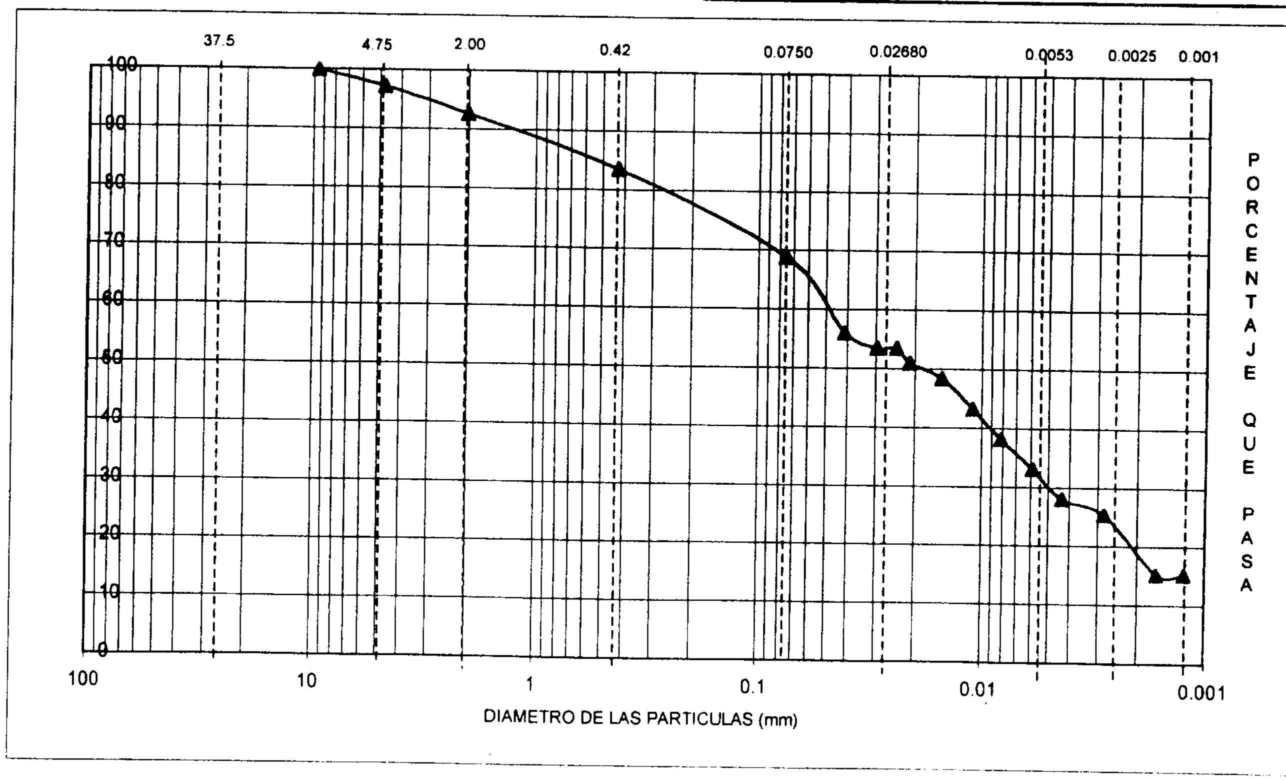
0.001230	



REVISADO POR: ____________________

IX. PRUEBA DE COMPACTACION
(PROCTOR ESTANDAR)

TECNILAB, S. A.

FUNDADA EN 1973

UNA EMPRESA E. BARRANCO Y ASOC., S. A.

LABORATORIO DE SUELOS Y MATERIALES

RESUMEN DE PRUEBA DE COMPACTACION (PROCTOR ESTANDAR)

TRABAJO No. 4-214

PROYECTO AMPLIACION DE LA CUENCA DEL CANAL DE PANAMÁ

LOCALIZACION RIO COCLÉ DEL NORTE, PROVINCIA DE COLÓN.

CLIENTE MONTGOMERY WATSON HARZA FECHA DICIEMBRE DE 2001

No.	CALICATA No.	MUESTRA No.	PROFUNDIDAD (m)	DENSIDAD MAXIMA	HUMEDAD OPTIMA
1	C-1	1	0.50 - 1.00	76.9	39.3
2	C-1	2	1.50 - 1.80	77.0	39.4
3	C-2	1	0.40 - 0.60	80.1	35.5
4	C-2	2	0.90 - 1.20	77.8	41.0
5	C-2	3	1.60 - 1.75	81.9	34.0

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. : 4-214 CLIENTE MONTGOMERY WATSON HARZA HOYO No : C-1
PROYECTO: AMPLIACION DE LA CUENCA DEL CANAL DE PANAMA MUESTRA : 1
LOCALIZACION: COCLE DEL NORTE PROFUNDIDAD : 0.50 A 1.00
MUESTREADO POR TECNILAB, S. A. FECHA 5-DIC.-01
PREPARADO POR TECNILAB, S.A. FECHA 12-Dic-01 LABORATORISTA C. CORDOBA

Volumen del Molde 0.03363 pie^3 Peso del Molde 5.42 lb

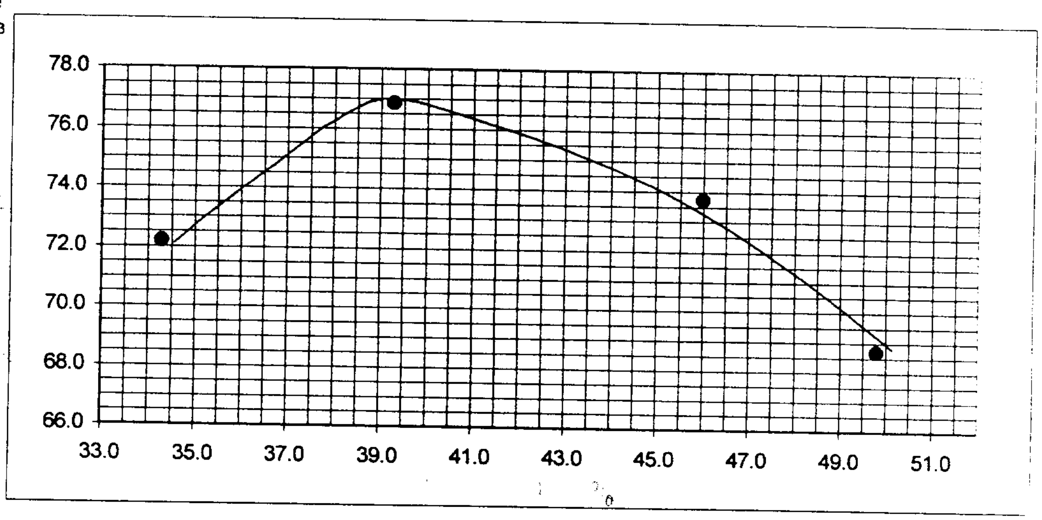
DETERMINACION DEL CONTENIDO DE HUMEDAD

Prueba No.	1		2		3		4		5			
Recipiente No.	T-4	E-3	P-20	P-21	P-11	A-30	A-8	M				
Peso Recipiente	104.8	108.2	104.6	109.1	106.6	108.6	107.9	105.7				
Peso Recipiente + Suelo Húmedo	198.5	204.0	210.2	199.9	197.1	203.4	220.1	206.2				
Peso Recipiente + Suelo Seco	174.5	179.6	180.4	174.3	169.1	173.0	182.9	172.7				
Peso de Agua	24.0	24.4	29.8	25.6	28.0	30.4	37.2	33.5				
Peso de Suelo Seco	69.7	71.4	75.8	65.2	62.5	64.4	75.0	67.0				
% de Humedad	34.4	34.2	39.3	39.3	44.8	47.2	49.6	50.0				
% Humedad Promedio	34.3		39.3		46.0		49.8					

DETERMINACION DE LA DENSIDAD

Prueba No.	1	2	3	4		
% Humedad Promedio	34.3	39.3	46.0	49.8		
Cantidad de Agua Añadida	100	100	100	100		
Peso del Molde + Agua	8.68	9.02	9.04	8.88		
Peso del Molde	5.42	5.42	5.42	5.42		
Peso del Suelo Húmedo	3.26	3.60	3.62	3.46		
Densidad Húmeda	96.9	107.0	107.6	102.9		
Densidad Seca	72.2	76.9	73.7	68.7		

D.M. 76.9 lb/pie^3 H.O. ____ %
1231.9 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. : 4-214 CLIENTE MONTGOMERY WATSON HARZA HOYO No : C-1
PROYECTO: AMPLIACION DE LA CUENCA DEL CANAL DE PANAMA MUESTRA : 2
LOCALIZACION: COCLE DEL NORTE PROFUNDIDAD : 0.40 A 0.60
MUESTREADO POR TECNILAB, S. A. FECHA 5-DIC.-01
PREPARADO POR TECNILAB, S.A. FECHA 12-Dic-01 LABORATORISTA C. CORDOBA

Volumen del Molde 0.03363 pie^3 Peso del Molde 5.42 lb

DETERMINACION DEL CONTENIDO DE HUMEDAD

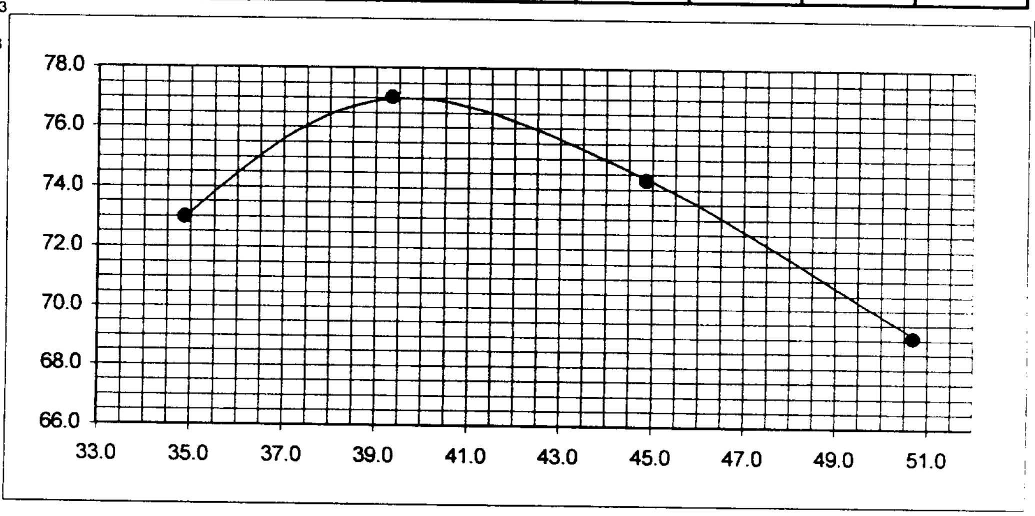
Prueba No.	1		2		3		4		5			
Recipiente No.	D-25	A	R-43	37	D-14	D-24	R-6	27				
Peso Recipiente	109.6	105.4	106.3	105.5	108.4	104.7	108.0	108.4				
Peso Recipiente + Suelo Húmedo	210.8	211.9	188.4	199.9	193.0	207.8	195.0	212.8				
Peso Recipiente + Suelo Seco	184.5	184.5	165.6	172.8	166.6	176.1	165.7	177.7				
Peso de Agua	26.3	27.4	22.8	27.1	26.4	31.7	29.3	35.1				
Peso de Suelo Seco	74.9	79.1	59.3	67.3	58.2	71.4	57.7	69.3				
% de Humedad	35.1	34.6	38.4	40.3	45.4	44.4	50.8	50.6				
% Humedad Promedio	34.9		39.4		44.9		50.7					

DETERMINACION DE LA DENSIDAD

Prueba No.	1	2	3	4		
% Humedad Promedio	34.9	39.4	44.9	50.7		
Cantidad de Agua Añadida	100	100	100	100		
Peso del Molde + Agua	8.73	9.03	9.04	8.92		
Peso del Molde	5.42	5.42	5.42	5.42		
Peso del Suelo Húmedo	3.31	3.61	3.62	3.50		
Densidad Húmeda	98.4	107.3	107.6	104.1		
Densidad Seca	73.0	77.0	74.3	69.1		

D.M. 77.0 lb/pie^3
1233.5 kg/m^3

H.O. ______ %



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. : 4-214 CLIENTE MONTGOMERY WATSON HARZA HOYO No : C-2
PROYECTO: AMPLIACION DE LA CUENCA DEL CANAL DE PANAMA MUESTRA : 1
LOCALIZACION: COCLE DEL NORTE PROFUNDIDAD : 0.40 A 0.60
MUESTREADO POR TECNILAB, S. A. FECHA 5-DIC.-01
PREPARADO POR TECNILAB, S.A. FECHA 12-Dic-01 LABORATORISTA C. CORDOBA

Volumen del Molde 0.03363 pie^3 Peso del Molde 5.42 lb

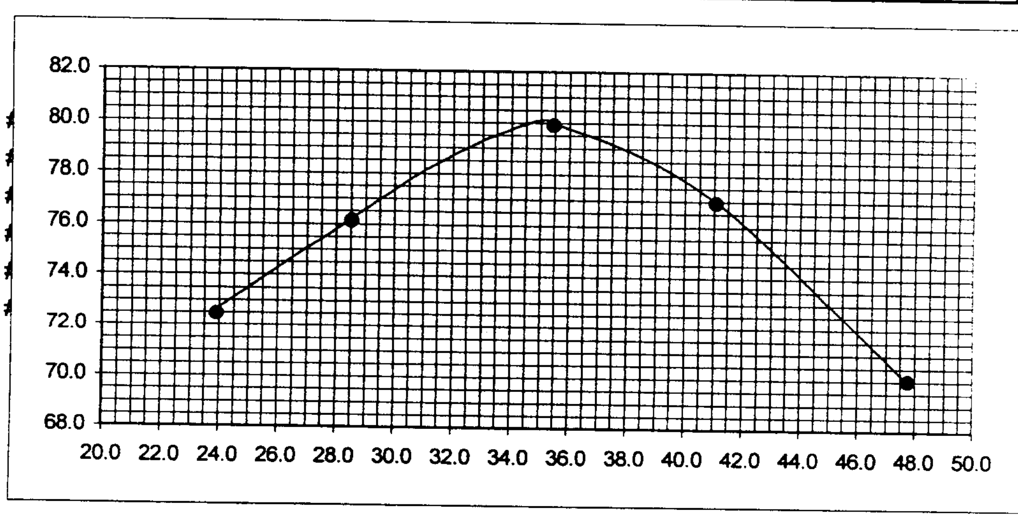
DETERMINACION DEL CONTENIDO DE HUMEDAD

Prueba No.	1		2		3		4		5			
Recipiente No.	R-28	AB.B	D-41	B-6	T-22	P-3	K-12	P-10	P-14			
Peso Recipiente	108.1	106.2	106.4	106.3	109.5	106.3	105.8	107.4	107.9	108.6		
Peso Recipiente + Suelo Húmedo	208.1	202.9	216.4	217.4	215.0	217.0	194.1	204.2	228.4	227.2		
Peso Recipiente + Suelo Seco	188.7	184.3	192.2	192.5	187.0	188.4	168.3	176.1	189.4	188.9		
Peso de Agua	19.4	18.6	24.2	24.9	28.0	28.6	25.8	28.1	39.0	38.3		
Peso de Suelo Seco	80.6	78.1	85.8	86.2	77.5	82.1	62.5	68.7	81.5	80.3		
% de Humedad	24.1	23.8	28.2	28.9	36.1	34.8	41.3	40.9	47.9	47.7		
% Humedad Promedio	23.9		28.5		35.5		41.1		47.8			

DETERMINACION DE LA DENSIDAD

Prueba No.	1	2	3	4	5	
% Humedad Promedio	23.9	28.5	35.5	41.1	47.8	
Cantidad de Agua Añadida	100	100	100	100	100	
Peso del Molde + Agua	8.44	8.71	9.06	9.07	8.90	
Peso del Molde	5.42	5.42	5.42	5.42	5.42	
Peso del Suelo Húmedo	3.02	3.29	3.64	3.65	3.48	
Densidad Húmeda	89.8	97.8	108.2	108.5	1.04	
Densidad Seca	72.5	76.1	79.9	76.9	70.0	

D.M. [illegible] lb/pie^3 H.O. ____ %
1283.2 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. : 4-214 CLIENTE MONTGOMERY WATSON HARZA HOYO No : C-2

PROYECTO: AMPLIACION DE LA CUENCA DEL CANAL DE PANAMA MUESTRA : 2

LOCALIZACION: COCLE DEL NORTE PROFUNDIDAD : 0.90 A 1.20 m

MUESTREADO POR TECNILAB, S. A. FECHA 5-DIC.-01

PREPARADO POR TECNILAB, S.A. FECHA 12-Dic-01 LABORATORISTA C. CORDOBA

Volumen del Molde 0.03363 pie^3 Peso del Molde 5.42 lb

DETERMINACION DEL CONTENIDO DE HUMEDAD

Prueba No.	1		2		3		4		5			
Recipiente No.	67	X	A-19	83	ABM	68	X-11	A-2	95	D-50		
Peso Recipiente	109.3	114.7	109.3	108.9	108.4	106.5	110.0	105.5	108.3	104.6		
Peso Recipiente + Suelo Húmedo	208.2	216.3	217.7	204.3	210.8	209.7	227.5	219.0	234.7	227.7		
Peso Recipiente + Suelo Seco	183.3	191.7	188.1	178.5	180.7	179.4	189.2	181.4	191.5	184.9		
Peso de Agua	24.9	24.6	29.6	25.8	30.1	30.3	38.3	37.6	43.2	42.8		
Peso de Suelo Seco	74.0	77.0	78.8	69.6	72.3	72.9	79.2	75.9	83.2	80.3		
% de Humedad	33.6	31.9	37.6	37.1	41.6	41.6	48.4	49.5	51.9	53.3		
% Humedad Promedio	32.8		37.3		41.6		48.9		52.6			

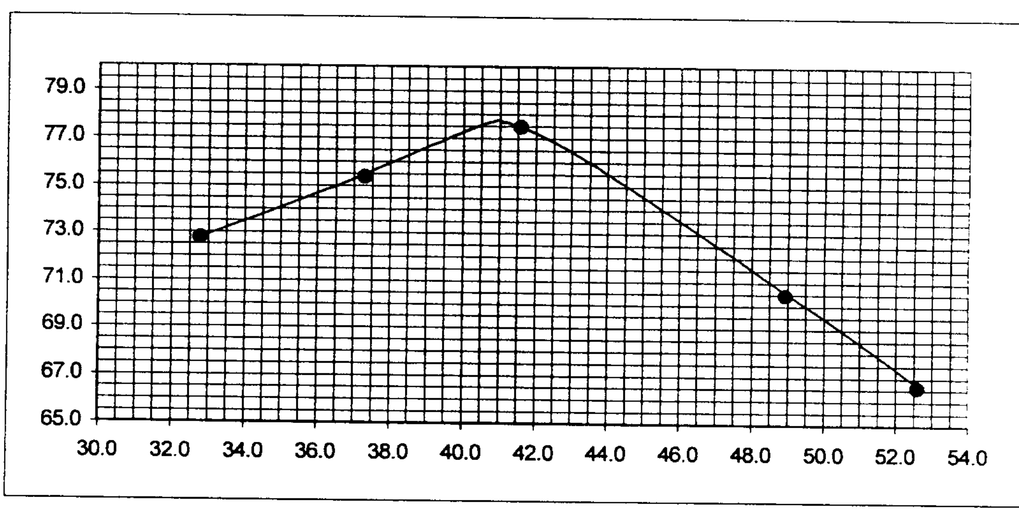
DETERMINACION DE LA DENSIDAD

Prueba No.	1	2	3	4	5	
% Humedad Promedio	32.8	37.3	41.6	48.9	52.6	
Cantidad de Agua Añadida	100	100	100	100	100	
Peso del Molde + Agua	8.67	8.90	9.11	8.95	8.84	
Peso del Molde	5.42	5.42	5.42	5.42	5.42	
Peso del Suelo Húmedo	3.25	3.48	3.69	3.53	3.42	
Densidad Húmeda	96.6	103.5	109.7	105.0	101.70	
Densidad Seca	72.8	75.4	77.5	70.5	66.6	

D.M. [illegible] lb/pie^3

[illegible] kg/m^3

H.O. ______ %



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. : 4-214 CLIENTE MONTGOMERY WATSON HARZA HOYO No : C-2
PROYECTO: AMPLIACION DE LA CUENCA DEL CANAL DE PANAMA MUESTRA : 3
LOCALIZACION: COCLE DEL NORTE PROFUNDIDAD : 1.60 A 1.75
MUESTREADO POR TECNILAB, S. A. FECHA 5-DIC.-01
PREPARADO POR TECNILAB, S.A. FECHA 12-Dic-01 LABORATORISTA C. CORDOBA

Volumen del Molde 0.03363 pie^3 Peso del Molde 5.42 lb

DETERMINACION DEL CONTENIDO DE HUMEDAD

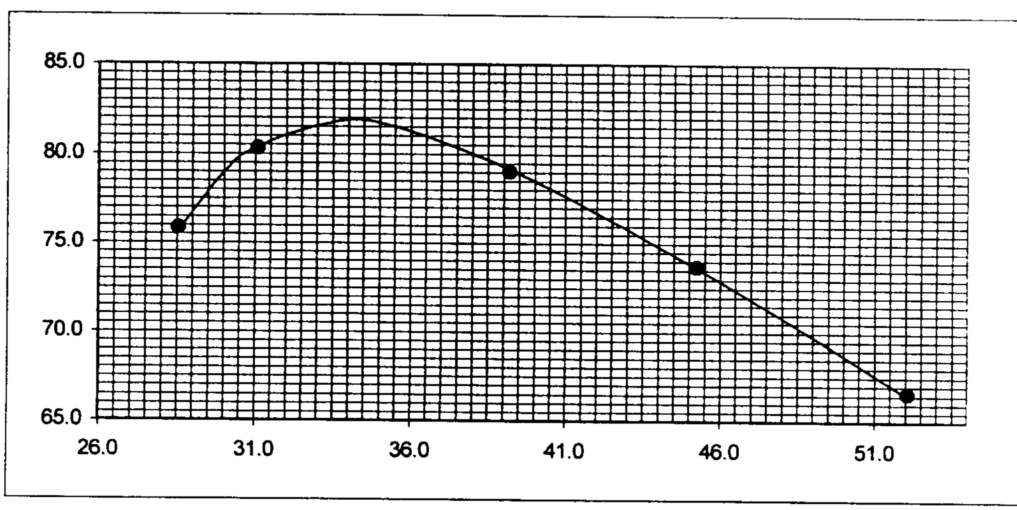
Prueba No.	1		2		3		4		5			
Recipiente No.	P-21	CL	C-13	P-22	33	D-15	75	X-10	63	X-11		
Peso Recipiente	104.8	109.1	110.8	112.0	109.0	112.2	108.6	109.1	112.5	105.8		
Peso Recipiente + Suelo Húmedo	220.0	205.0	187.5	181.8	212.7	229.8	229.6	244.5	253.3	262.0		
Peso Recipiente + Suelo Seco	193.8	184.2	169.8	164.8	183.2	197.0	191.9	202.3	204.8	208.8		
Peso de Agua	26.2	20.8	17.7	17.0	29.5	32.8	37.7	42.2	48.5	53.2		
Peso de Suelo Seco	89.0	75.1	59.0	52.8	74.2	84.8	83.3	93.2	92.3	103.0		
% de Humedad	29.4	27.7	30.0	32.2	39.8	38.7	45.3	45.3	52.5	51.7		
% Humedad Promedio	28.6		31.1		39.2		45.3		52.1			

DETERMINACION DE LA DENSIDAD

Prueba No.	1	2	3	4	5	
% Humedad Promedio	28.6	31.1	39.2	45.3	52.6	
Cantidad de Agua Añadida	100	100	100	100	100	
Peso del Molde + Agua	8.70	8.96	9.12	9.02	8.84	
Peso del Molde	5.42	5.42	5.42	5.42	5.42	
Peso del Suelo Húmedo	3.28	3.54	3.70	3.60	3.42	
Densidad Húmeda	97.5	105.3	110.0	107.0	101.70	
Densidad Seca	75.9	80.3	79.0	73.7	66.6	

D.M. 81.9 lb/pie^3
1313.7 kg/m^3

H.O. %



X. FOTOGRAFIAS

AMPLIACION DE LA CUENCA DEL CANAL DE PANAMA
COCLE DEL NORTE
INVESTIGACION DE SUELOS
TRABAJO No. 4-214 DICIEMBRE DE 2001

CONDICION DEL SITIO C-1 AL MOMENTO DE LA INVESTIGACION

CALICATA C-1 (PROF. 0.00 – 0.20 m)

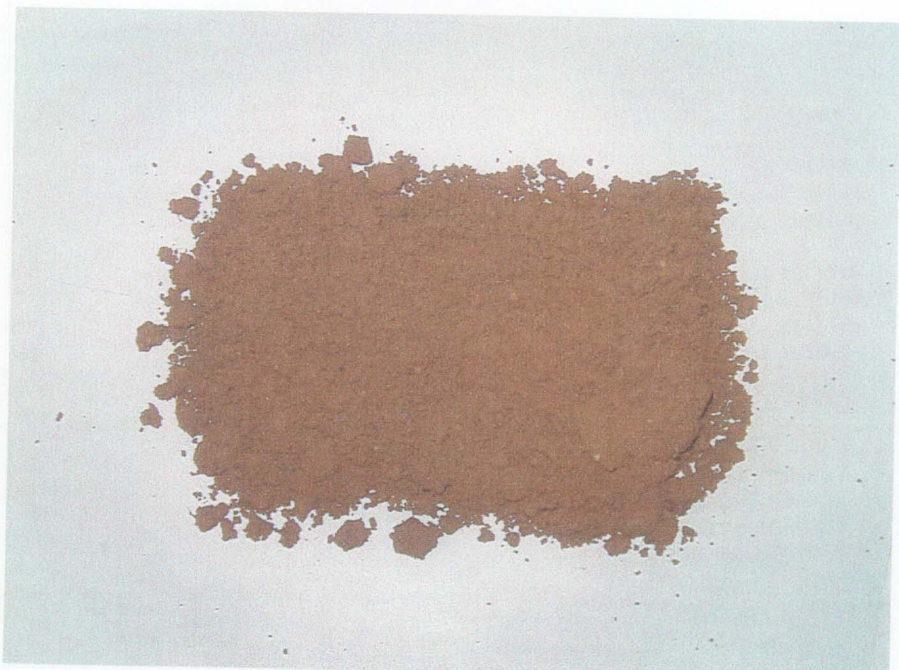
AMPLIACION DE LA CUENCA DEL CANAL DE PANAMA
COCLE DEL NORTE
INVESTIGACION DE SUELOS
TRABAJO No. 4-214 DICIEMBRE DE 2001

CALICATA C-1 (PROF. 0.20 – 0.40 m)

CALICATA C-1 (PROF. 0.40 – 1.20 m)

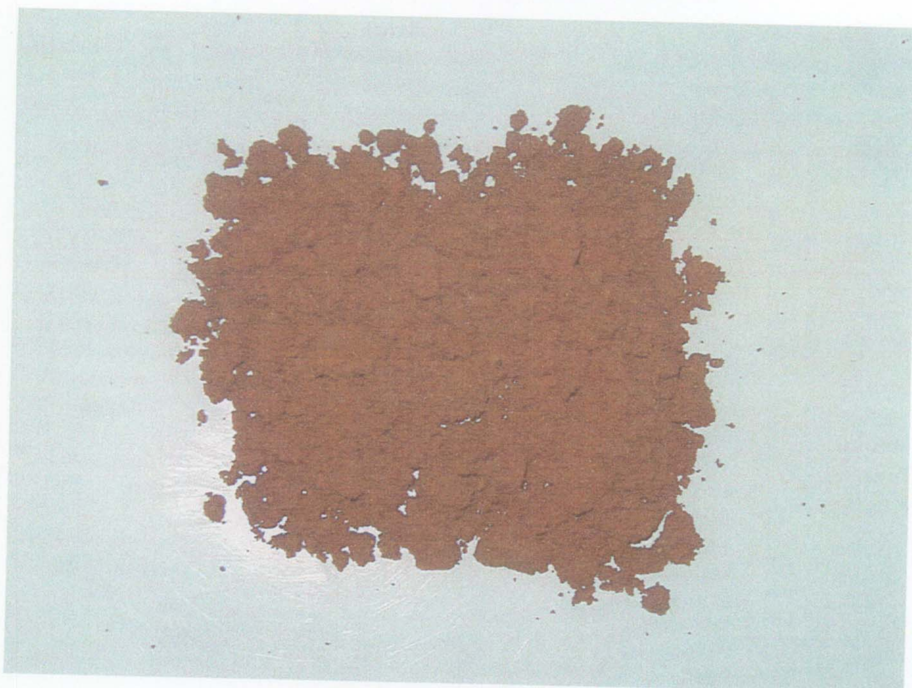
AMPLIACION DE LA CUENCA DEL CANAL DE PANAMA
COCLE DEL NORTE
INVESTIGACION DE SUELOS
TRABAJO No. 4-214 DICIEMBRE DE 2001

CALICATA C-1 (PROF. 1.20 – 1.80 m)



CALICATA C-1 MUESTRA 1 (PROF. 0.50 – 1.00 m)

AMPLIACION DE LA CUENCA DEL CANAL DE PANAMA
COCLE DEL NORTE
INVESTIGACION DE SUELOS
TRABAJO No. 4-214 DICIEMBRE DE 2001



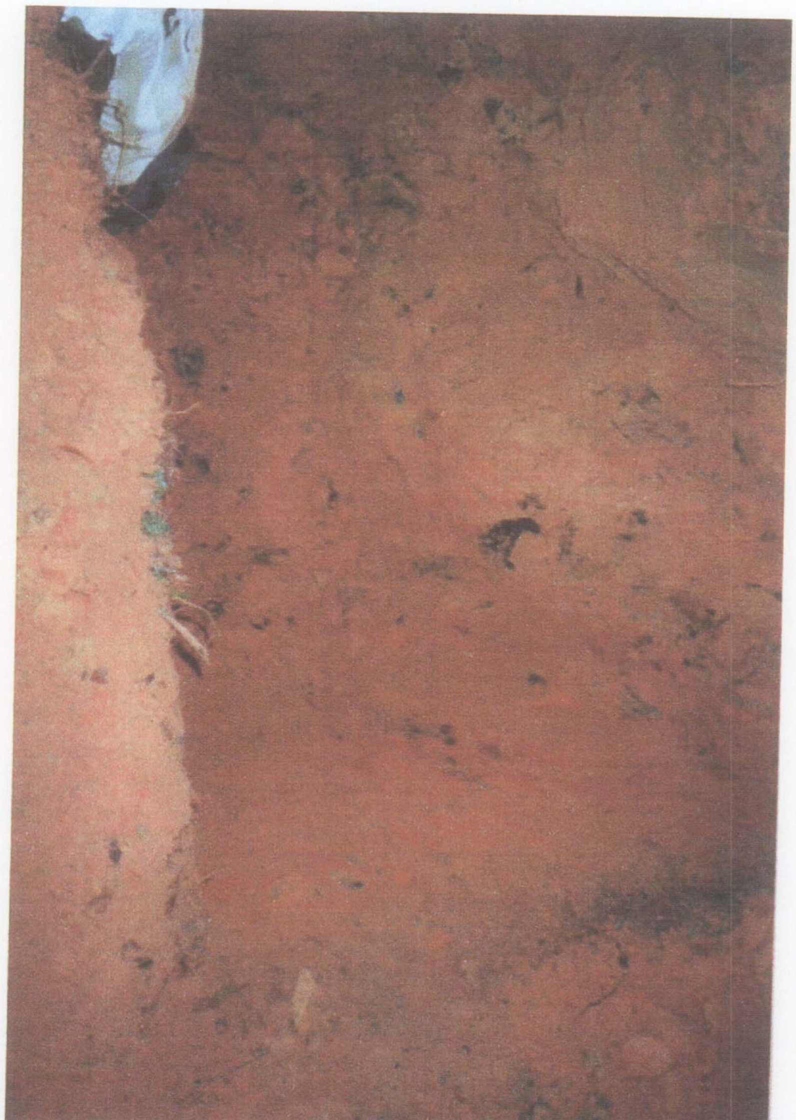
CALICATA C-1 MUESTRA 2 (PROF. 1.50 – 1.80 m)

AMPLIACION DE LA CUENCA DEL CANAL DE PANAMA
COCLE DEL NORTE
INVESTIGACION DE SUELOS
TRABAJO No. 4-214 DICIEMBRE DE 2001

CONDICION DEL SITIO C-2 AL MOMENTO DE LA INVESTIGACION

CALICATA C-2 (PROF. 0.20 – 0.90 m)

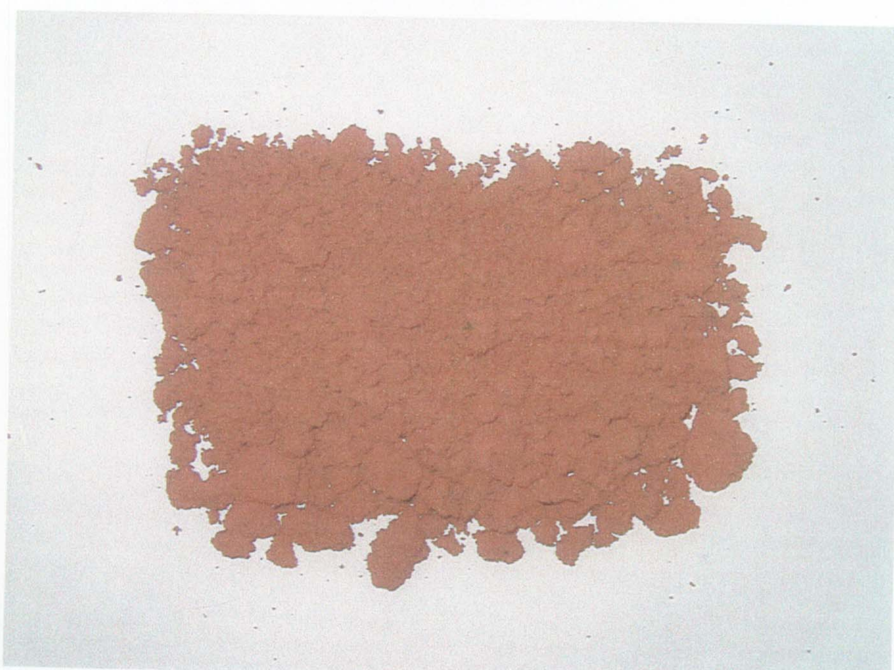
AMPLIACION DE LA CUENCA DEL CANAL DE PANAMA
COCLE DEL NORTE
INVESTIGACION DE SUELOS
TRABAJO No. 4-214 DICIEMBRE DE 2001



CALICATA C-2 (PROF. 1.60 – 1.75 m)

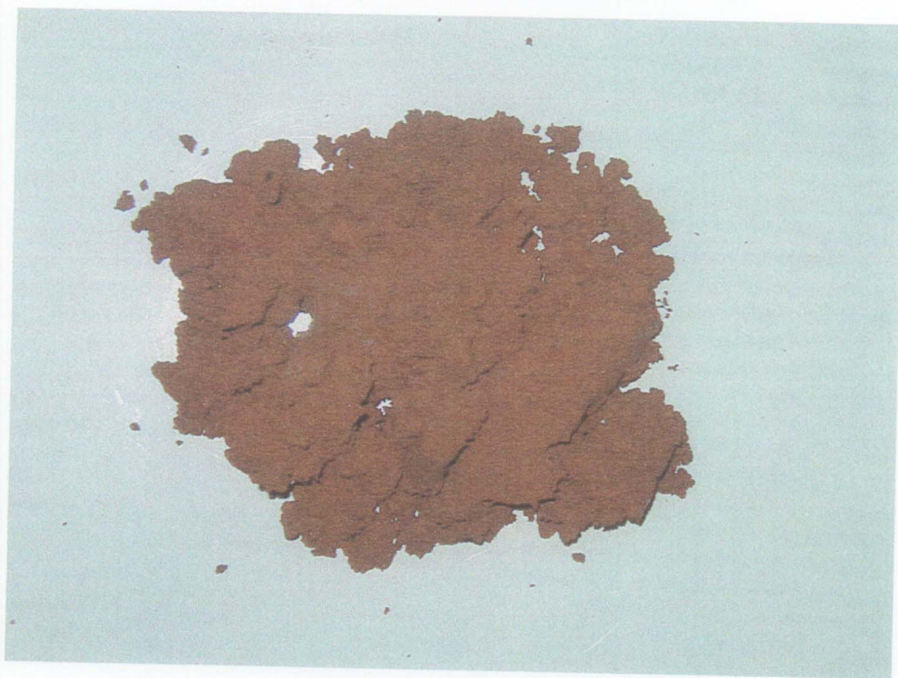
AMPLIACION DE LA CUENCA DEL CANAL DE PANAMA
COCLE DEL NORTE
INVESTIGACION DE SUELOS
TRABAJO No. 4-214 DICIEMBRE DE 2001

CALCICATA C-2 MUESTRA 1 (PROF. 0.40 – 0.60 m)



CALICATA C-2 MUESTRA 2 (PROF. 0.90 – 1.20 m)

AMPLIACION DE LA CUENCA DEL CANAL DE PANAMA
COCLE DEL NORTE
INVESTIGACION DE SUELOS
TRABAJO No. 4-214 DICIEMBRE DE 2001



CALICATA C-2 MUESTRA 3 (PROF. 1.60 – 1.75 m)

AMPLIACION DE LA CUENCA DEL CANAL DE PANAMA
COCLE DEL NORTE
INVESTIGACION DE SUELOS
TRABAJO No. 4-214 DICIEMBRE DE 2001

CONDICION DEL SITIO C-6 AL MOMENTO DE LA INVESTIGACION

CALICATA C-6 (PROF. 0.15 – 1.25 m)

AMPLIACION DE LA CUENCA DEL CANAL DE PANAMA
COCLE DEL NORTE
INVESTIGACION DE SUELOS
TRABAJO No. 4-214 DICIEMBRE DE 2001

CALICATA C-6 (PROF. 1.25 – 1.60 m)

Appendix C
Operation Simulation

FEASIBILITY DESIGN FOR THE RÍOS COCLÉ DEL NORTE AND CAÑO SUCIO WATER SUPPLY PROJECTS

APPENDIX C

OPERATION SIMULATION STUDIES

Prepared by

MWH

In association with

TAMS

AN EARTH TECH COMPANY

FEASIBILITY DESIGN FOR THE RÍOS COCLÉ DEL NORTE AND CAÑO SUCIO WATER SUPPLY PROJECTS

APPENDIX C – OPERATION SIMULATION STUDIES

TABLE OF CONTENTS

ATTACHMENTS

INTRODUCTION

The evaluation of the production of the Río Coclé del Norte storage project acting in full regulation with the Río Caño Sucio and Río Indio Reservoirs and with only the Río Indio Reservoir was established by simulating the operation of the existing system and the existing system plus the proposed new facilities. The U.S. Army Corps of Engineers, Hydrologic Engineering Center's HEC-5 model, "Simulation of Flood Control and Water Conservation Systems Computer Program" was used as the basis for the operation simulations. The simulations were performed using English units.

The operation simulation studies were performed by:

Ms. T. Atencio – Operations Specialist, ACP
Mr. R. Lee – Water Resource Engineer, ACP

Under the directions of:

Mr. J. Pascal, Task Order Manager, and
Mr. J. de la Guardia, Manager, Canal Capacity Projects Division

The basic input requirements of the model consist of physical data, operational data, and hydrologic time-series data consisting primarily of flow data. The physical and operational data were either developed by the ACP or carried over from the Reconnaissance Study. The hydrologic data were confirmed or re-developed by MWH and are presented in Appendix A.

In the Reconnaissance Report, the concept of hydrologic reliability was introduced. Hydrologic reliability was defined as the ability of the Panama Canal system to provide sufficient water for unrestricted operation. It is represented by a ratio of the volume of water provided to the volume of water demanded for canal operations during the designated period with no draft restrictions. The base level of reliability was taken as 99.6%, which was derived by operating the existing system (without improvements to Lake Gatun) over the period from 1919 to 1999 with a demand equal to an average of the lockages provided over the 5-year period from 1993-1997. This reliability was adopted as representing the yield of the projects under study.

The same model was used to assess the potential for adding hydropower. In addition to the base case runs, operation rules to favor hydropower also were evaluated. The results of the hydropower operation studies are presented in Appendix E, Part 2.

In the attachments to this appendix, we have presented the ACP synopsis of the operation simulation studies, a sample output from the HEC-5 mode, and MWH's review of the studies together with some representative graphs of the output data.

ATTACHMENTS

ATTACHMENT 1

ACP SYNOPSIS OF THE OPERATION SIMULATION STUDIES

HEC-5, Simulation of Flood Control and Water Conservation System

INTRODUCTION

The HEC-5 reservoir system model was developed by the U.S. Army Corps of Engineers' Hydrologic Engineering Center in Davis, California. The existing system model (base system model) was developed in order to evaluate the capability of the present ACP system, which consists of Lake Madden and Lake Gatun, and to evaluate the effectiveness of proposed alternatives to improve the system capability and reliability.

This model performs a sequential simulation of reservoir operations given a time-series of flow. The reservoirs are defined by their storage and outflow capability. The reservoir storage is allocated to operational zones (levels) that define their usage (rule curves). The flood control zone is only used to store excess inflow, the conservation zone is used to store water to meet future demands, and the inactive zone (dead storage) is where no releases can be made. Water demands include minimum flow goals, diversions, and hydroelectric power generation. Reservoirs are linked to other reservoirs and control points (non-reservoir locations) using routing reaches. A combination of reservoirs, control points and connecting routing reaches then define a reservoir model system.

BASE SYSTEM MODEL

The base system model represents the existing ACP water supply system. Madden and Gatun reservoirs are the primary elements of the system. HEC-5 can only process one diversion from each reservoir. The municipal water supply and the lockages for Gatun and Pedro Miguel were combined into one diversion from Gatun.

All data are in foot-pound units. The simulation time-interval is one month. However, this model could operate at time steps as small as one-hour. Given the monthly time-step, the seasonally varying data are all defined over the 12 months. There is no river-reach routing data required for the monthly time step.

The average-monthly flow data are input to Madden and Gatun. The inflow is assigned as incremental-local flow, which means that the inflow to Gatun only represents the catchment not controlled by Madden.

<u>Madden Reservoir</u>

The model begins with a Madden Reservoir (location 50) that receives basin inflow, provides M&I water supply, and releases flow to Gatun. Reservoir releases are assumed to pass through the hydroelectric facility and energy generation is computed up to the limits of power capacity. The outflow from Madden is "routed" to Gatun reservoir. The channel capacity was set to 1,415 m^3/s (50,000cfs) based on operation manual information; however, that value should not be a controlling factor in the monthly simulation.

Elevation-Storage: HEC-5 defines the reservoir with a set of storage-based relationships. Reservoir outflow capacity, elevation, and area are defined as a function of storage. The data between elevations 57.9m and 82.3 m (190 and 270 feet) were input on a 0.60m (two-foot interval), except for the 60.9m to 67.1 m (200 to 220 feet) range where data input is on 0.30 m (one-foot) interval. Data below elevation 57.9 m (190 feet) and above 80.5m (264 feet) were estimated by extrapolation. There are two reasons for this: one is that the reservoir operating range is between elev. 57.9m and 76.8m (190 and 252 ft), so that information within this range should be more accurate. The other reason is that the program interpolates on a straight line between points, and in order to be more precise in the part of the curve where the slope changes more rapidly, closer points will be needed.

Outflow Capacity. The outflow capacity is a constraint on releases in HEC-5. The program does not simulate gate openings; it only ensures that the release does not exceed the maximum outflow capacity of the reservoir.

Reservoir guide-curve. The guide curve for the top-of-conservation is defined by the target storage at the end of each month. The reservoir guide curve has changed over the years. Since this analysis is for the existing system, the current guide-curve was used in the model. The guide curve is a data input supplied by ACP; more information will be given on its development in following sections.

Reservoir evaporation. The evaporation for Madden is the computed reservoir evaporation, in inches, provided by ACP.

Hydropower data: The total installed capacity is 36 MW comprised of three 12 MW units. No overload is assumed. The tailwater was set at 27.1 m (89 feet). The efficiency was set at 83%, based on turbine testing data and an assumed generator efficiency of 96%. No hydropower requirements were specified. A leakage value of 0.6 m^3/s (20 cfs) was used, as determined by the Meteorological & Hydrographic Branch (Met & Hyd) of ACP. The program will pass that value as a minimum and that flow will not be used for energy computation.

M&I Diversions: The municipal and industrial water supply is diverted from Madden to nowhere, i.e. the diverted flow leaves the system. Average monthly values for the 5-year period 1993-1997 were used. These were the last 5 complete years of information available when the base model was set in late 1998.

Gatun Reservoir

Gatun (location 40) is the next location below Madden. The input flow data to Gatun is the uncontrolled flow downstream from Madden. The total inflow is the sum of Madden releases and input flow data. The release from Gatun routes to the Caribbean Sea. As with Madden, the reservoir releases will be used to generate electrical energy. Flow diversion from Gatun includes municipal water supply and the combined lockages for Gatun and Pedro Miguel Locks.

Elevation-Storage. HEC-5 defines the reservoir same as with Madden. The data between elevations 23.5m and 27.4m (77 and 90 feet) were input on 0.30m (one-foot) interval. The data were not defined below elevation 23.5 and above elevation 27.4m, so that data was estimated by extrapolating the given curves. Reasoning for this same as that for the Madden reservoir storage data.

Outflow capacity: Criteria are the same as that for Madden. The outflow capacity was taken from information by ACP for all 14 gates open from an elevation of 23.8m to 28.0m (78 to 92 feet). Outflow capacity for elevations 21.3m and 23.5m (70 and 77 feet) were estimated using the weir equation and a coefficient of 3.0.

Reservoir Guide-Curves and Reservoir evaporation. Same considerations as those for Madden.

Hydropower data. The total installed capacity is 24 MW, 3 x 3 MW units and 3 x 5 MW units. No overload is assumed. The tailwater elevation was set at 2.7m (9 feet), based on tailwater data from unit testing. The efficiency was set at 85%, based on turbine testing data and an assumed generator efficiency of 96%. No hydropower requirements were specified. A leakage value of $0.8m^3/s$ (27 cfs) is used, information provided by ACP's Met & Hyd Branch.

Gatun and Pedro Miguel Locks: The diversions from Gatun include the combined flow for lockages.

M&I Diversions: The diversion from Gatun for municipal and industrial water supplies is included with the flow for locks as the diversion from Gatun. Average monthly values for the 5-year period 1993 to 1997 were used. These were the last 5 years of complete information available since the base model was set in late 1998.

Flow data:

It is a requirement of the model to define the starting storage values and the corresponding date for each reservoir.

BASE SYSTEM MODEL VALIDATION

To validate the model configuration and data, a simulation was performed with the outflow and the inflow defined. With all the inflow and outflow defined, the simulation should yield the same results as historically recorded. A simulation run was made for the period of January 1970 to December 1997. For both reservoirs, the validation model elevations are essentially the same as the observed elevations, therefore, the model configuration is consistently accounting for the water in the system.

BASE SYSTEM RESERVOIR GUIDE CURVES (RULE CURVES)

ACP has developed rule curves for the tandem operation of Gatun and Madden Lakes. The purpose of the curves is to provide a minimum draft for ships with a maximum level of reliability. Several curves have been in use throughout the more than 85 years of operation of the Canal, the existing set was implemented in the late 1970`s. The development of the curves has been based on the experience with the hydrology in the Panama Canal Watershed, with a dry season extending from January through April and the rainy season from May through December. In general the intent of the curves is to use in the dry season the water stored during the rainy season and to fill both lakes by the end of the year.

Though the current set of curves was mostly developed on an empirical base, a study was conducted on April 1999 by Manuel B. Vilar from the Met & Hyd Branch of ACP to validate them. The study consisted on two distinctive approaches in simulating lake operations with the daily data from 1965 to 1994. They are a historical analysis and a stochastical analysis. The study concluded that "...it was verified that the existing rule curve has about a lower decile probability of requiring draft restrictions. That is, that about 10% of the historical events....will produce draft restrictions..."

YIELD OF THE BASE SYSTEM

The yield of the base system is estimated to be about 2,930 MCM/year or the equivalent of about 38.7 lockages/day (L/d). The yields are presented in terms of a hydrologic reliability, which is computed as the total water delivered divided by the total requirement. The target reliability, based on historic records, is 99.6%.

PRESUMED DEVELOPMENT

At present, the ACP is in the process of deepening channel in Lake Gatun by 3.0 feet. This deepening can serve to permit passage of vessels with a deeper draft and can also be used to increase the yield of the base system. In the estimation of the yield from projects in the Río Coclé del Norte basin, it is assumed that this deepening has been completed.

Under this assumption, the yield of the base system increases from 2,930 MCM/year (38.7 L/d) to 3,380 MCM (44.5 L/d).

In addition, in order for the projects in the Río Coclé del Norte basin to contribute to the Panama Canal System, it is necessary that the Río Indio Reservoir is operational. Water from the Río Coclé del Norte will be regulated in a reservoir and conveyed to Lake Gatun through tunnels leading into and out of the Río Indio Reservoir.

A rule curve for the operation of the Río Indio Reservoir was developed by trial and error to maximize the yield of the Río Indio basin while maintaining the Lake Gatun elevations according to its rule curve. The operating rules consist of a mandatory release 2.6 m^3/s into the Rio Indio, 43 m^3/s for the four-month period from February through May to Lake Gatun, and operating the reservoir to bring the water level to the rule-curve elevations during the other months. More information in the Río Indio Reservoir operation is presented in the feasibility study of the Río Indio Water Supply Project (April 2003).

Operation simulations were made for a demand identified in terms of daily lockage requirements (Lockages per day, L/d) using the live storage in Río Indio reservoir between El. 80 and El. 40. One lockage was assumed to equal 55 million gallons or 208,000 m^3. The system yield (Gatun after deepening, Madden, and Indio) is estimated to be 4,580 MCM/year (60.3 L/d). This water is available at the volumetric reliability of 99.6%.

COCLÉ DEL NORTE RESERVOIR

A series of operation cases were performed to assess the relationship between yield and active storage at a reliability of 99.6%. On the basis of these operation studies, an operating range was selected and the system yield, augmented by a reservoir in the

Basic Data for the Río Coclé del Norte Storage Project Operations

Inflow/Outflow: The Río Coclé del Norte Reservoir would receive an annual average runoff of about 107.5 m^3/s from approximately 1,594 km^2 of the watershed. The calculated discharge at the Río Coclé del Norte dam site is obtained from streamflow data of the Río Toabre at Batatilla and the Río Coclé del Norte Reservoir at El Torno.

A minimum desired flow of 10.7 m^3/s (10% of the average flow) is released from the reservoir releases are assumed to pass through the hydroelectric facility located at the downstream toe of the dam. The energy generation is computed up to the limits of power capacity.

The Río Caño Sucio Reservoir would receive an annual average runoff of about 7.5 m^3/s from approximately 111 km^2 of the watershed. The calculated discharge at the Río Caño Sucio dam site is obtained from streamflow data of the Río Indio at Uracillo.

A minimum release of 10.7 m^3/s (10% of the average flow) is released from the Río Coclé del Norte Reservoir. This release are assumed to pass through the hydroelectric facility located at the downstream toe of the dam. The energy generation is computed up to the limits of power capacity. At the Río Caño Sucio Reservoir, a minimum release of 0.7 m^3/s will be discharged through the low-level outlet into the stream channel.

Elevation-Storage: HEC-5 defines the reservoir with a set of storage-based relationships. Reservoir outflow capacity, elevation, and area are defined as a function of storage.

Outflow Capacity. The outflow capacity is a constraint on releases in HEC-5. The program does not simulate gate openings, it only ensures that the release does not exceed the maximum outflow capacity of the reservoir.

Reservoir evaporation. Because of the absence of site-specific information, the monthly evaporation rates established for Madden Lake were considered appropriate for the evaporation rates from the released from the Río Coclé del Norte and the Río Caño Sucio Reservoirs.

Flood flow. An uncontrolled ogee spillway was considered to the release of flood events. It was designed assuming a maximum water level of 1.8 m and 3.6 m above the spillway crest for the Río Coclé del Norte and the Río Caño Sucio Reservoirs respectively, a C value of 3.5 and a design flow for a return period of one thousand years.

Hydropower data: HEC-5 runs were executed considering a 60 MW and a 75 MW hydropower plant at the Río Coclé del Norte dam for full supply levels at El. 71 and El. 100 respectively. The only limitation of power output was the powerplant rated capacity. No overload was assumed. A tailwater elevation of 3 m. was assumed. The power peaking capability function was not used. The efficiency was set at 86%. A fixed head loss of 1 ft was assumed.

Results of the Reservoir Operation Studies

To evaluate the relationship between yield and active storage and the impact of the location of the active storage within the bounds of the development, the following operation runs were performed.

Río Coclé del Norte Reservoir Operating Range	Active Storage MCM	System Yield Locks/day
100-60	11,300	110.4
80-50	5,680	109.1
75-50	4,380	108.6
70-50	3,210	107.3
65-50	2,180	101.0

Inspection of these results suggests a significant point of diminishing returns between an active storage of 3,200 MCM and 4,000 MCM (see Exhibit 1). Storage within these bounds is, therefore, considered to represent a near-optimum development. (Note that subsequent minor modifications to the model resulted in yields from 2% to 3% lower than indicated above. These modifications would not result in a different conclusion regarding the level of development.)

For the Río Coclé del Norte storage project acting in full regulation with the Río Caño Sucio and Río Indio Reservoirs, the operating range was established between El. 100 and El. 90 (3,840 MCM). This is the same range that was used in the U.S. Army Corps of Engineers' Reconnaissance Report and, since it appears to be within the adopted range, it was carried forward.

The operation procedure was to combine the Río Coclé del Norte and the Río Caño Sucio Reservoirs to form one large reservoir and operate the system. The resultant active storage was 3,910 MCM and the system yield was estimated to be about 8,150 MCM/year (107.3 L/d). Subtracting the system yield without the Río Coclé del Norte and Río Caño Sucio Reservoirs (4,580 MCM/year or 60.3 L/d) results in an incremental yield due to the addition of the two reservoirs of 3,570 MCM/year (47 L/d). Earlier studies for a project at the Río Caño Sucio site indicated that the yield of the Río Caño Sucio Reservoir was 190 MCM/year (2.5 L/d). Therefore, the yield allocated to the Río Coclé del Norte Reservoir is estimated to be 3,380 MCM/year (44.5 L/d).

For the Río Coclé del Norte storage project acting in full regulation with the Río Indio Reservoirs, the operating range was set as low as possible. For hydraulic reasons and to provide an active storage equal to the point of maximum curvature on Figure 1, an operating range between El. 71 and El. 50, which provides an active storage of about 3,445 MCM, was adopted. The yield of the system with the Río Coclé del Norte reservoir operating between El. 71 and El. 50 is estimated to be 8,030 MCM/year (105.7 L/d). Therefore, the yield allocated to the Río Coclé del Norte Reservoir is estimated to be 3,450 MCM/year (45.4 L/d).

ATTACHMENT 2

TYPICAL HEC-5 OUTPUT FILE

Río Coclé del Norte storage project acting in full regulation with the Río Caño Sucio and Río Indio Reservoirs
(Operation Range El. 100 – 90)

The following has been extracted from file Final 71_50 (2.733&99.6%).out

```
*************************************************************
* HEC-5 SIMULATION OF FLOOD CONTROL AND CONSERVATION SYSTEMS *
*                                                           *
*              Version  8.0.18;  Sep 18, SPK2000            *
*                                                           *
*       Run Date: 17 DEC 03       Time: 08:14:11            *
*************************************************************
```

```
*******************************************************
*             U.S. ARMY CORPS OF ENGINEERS            *
*             Hydrologic Engineering Center           *
*             609 Second Street, Suite A              *
*             Davis, California  95616-4687           *
*  (530) 756-1104   http://www.hec.usace.army.mil     *
*******************************************************
```

```
X     X  XXXXXXX   XXXXX          XXXXXX
X     X  X     X  X     X         X
X     X  X        X               X
XXXXXXX  XXXXX    X         XXXXX XXXXXX
X     X  X        X                     X
X     X  X     X  X     X         X     X
X     X  XXXXXXX   XXXXX          XXXXXX
```

```
**************************************************************************************************
*                                                                                                *
*                                                                                                *
*                          MODELING CAPABILITIES OF THIS VERSION ARE:                            *
*                                                                                                *
*                        Flood Control,  Water Supply,  and  Hydropower                          *
*                                                                                                *
*                                                                                                *
*                           MAXIMUM LIMITS FOR THIS VERSION ARE:                                 *
*                                                                                                *
*          Reservoirs = 40,   Control Points =150,   Diversions = 40,   Power Plants = 35        *
*                                                                                                *
*   Model Data Records (T1-ED)  =1000    Reservoir Levels    = 40    Flow Sequence Sets (BF-EJ)=     80   *
*   J8+JZ Output/DSS Records    =  80    Seasonal Storages   = 36    Periods per Flow Sequence =   9000   *
*   Res Physical Values (RS-RE) =  60    Seasons (CS Record) = 36    Dynamic Dimen. (DM array) =2000000   *
*                                                                                                *
*                                                                                                *
**************************************************************************************************
```

```
1
      HEC-5 SIMULATION OF FLOOD CONTROL AND CONSERVATION SYSTEMS

                   Version  8.0.18;  Sep 18, SPK2000
```

```
T1    Panama Canal Capacity Study:   (COCL8050.DAT)
T2    Model: Cocle del Norte to Gatun with Average Lockage & Municipal Qs
T3
C  RIO INDIO AT LIMON, PANAMA CANAL
C  NORMAL POOL=80M MIN POOL=40M; 1 TUNNELS OF 4.5 & 6.5 METER OF DIAMETER
C  COCLE DEL NORTE DAM, PANAMA CANAL
C  NORMAL POOL=70M MIN POOL=50M
C  HYDROPOWER, EVAPORATION AND 4 M3/S MINIMUM FLOW INCLUDED; 9 meter tunnel
C
J1     0       1       5       3       4       2
J2    24     1.0             132                               0
J3     5                                      -1
C
C Annual Statistic Table -----------------------------------------------------
C J840.313  40.033  40.303  40.222 200.222  50.222 400.222  40.103
C J840.314  40.132  50.132 200.132 400.132
C ---------------------------------------------------------------------------
JZ 40.03   40.30   40.31   40.22   50.22  300.22  200.22  301.10  199.10
JZ300.21  300.03  290.10  200.21  200.03
JZ300.16  290.16   40.16   50.16
JZ300.24  300.10  300.12  300.32  301.03  200.24  200.10  200.12  199.03
JZ 40.24   40.09   40.10   40.21   40.32   50.24   50.09   50.10   50.21   50.32
C  DATA SAVED TO DSS
C   .03=FLOW-DIV          .04=FLOW-REG         .12=CASE         .13=LEVEL
C   .09=FLOW-RES IN       .10=FLOW-RES OUT     .22=ELEV         .30=DIV REQUIRE
C   .32=FLOW-SPILL        .16=ENERGY-GEN       .35=PLANT FACTOR .33=POWER HEAD
C   .21=EVAPORATION       .32=FLOW-POWER SPILL .31=DIV SHORTAGE .11=STORGE
C +++++++ Write Diversion Shortages To DSS File (Madden and Gatun Sum) +++++++++
C JZ-40.03   40.10   40.11   40.13   40.16   40.21   40.22   40.30   40.31   40.
C JZ 50.03   50.10   50.13   50.16   50.21   50.22   50.30   50.31   50.33   50.
C  INDIO DAM AND POWER PLANT
C JZ200.01  200.03  200.09  200.10  200.11  200.33  200.13  200.16  200.22  200.
C JZ 20.09   20.10   20.12   20.16   20.22   20.32   20.33   20.35  200.35  200.
C  TOABRE DAM AND POWER PLANT
C JZ400.03  400.09  400.10  400.12  400.13  400.21  400.22  400.30  400.33  400.
C JZ390.09  390.10  390.12  390.13  390.16  390.22  390.32  390.33  390.35  400.
C  SUCIO DAM AND SPILLWAY
C JZ290.09  290.10  290.12  290.13  290.22
C ============= Lake Madden ================================================
C  5.  Top-of-dam      = Elev. 270
C  4.  Top-of-flood    = Monthly varying, Based on Spill Curve
C  3.  Top-of-conserv. = Monthly varying, Elevations from Fig 5.1
C  2.  Top-of-buffer   = Elev. 190 (M&I only)
C  1.  Top-of-inactive = Elev. 190

RL    50 -252.00
RL     1      50      -1          127250
RL     2      50      -1          127250
```

```
C        ELEV:                             249      243      233      221      217      215
RL     3      50        0               611478   541116   434890   324950   292650   277430
C        ELEV:                             217      222      228      236      247      252
RL                                      292650   333360   386640   465290   587580   648140
C   Madden Spill Curve from PCC OPERDATA.BAS dated 6-23-94
RL     4      50        0               648140   648140   648140   564096   564096   564096
RL                                      564096   564096   564096   599470   635790   648140
RL     5      50       -1               886754
RO     1      40
C  Reservoir storage from path = /PCC/MAD/ELEV-CAPAC(ACFT)///OBS/
C  Reservoir areas from path =  /PCC/MAD/ELEV-AREA(ACRES)///OBS/
C  Storage & area values below Elev. = 190 are extrapolated
C  Areas above Elev = 264.0 are extrapolated
C  Reservoir maximum outflow from Tables 5-2 + 5-3 + 6-2 PCC FC MANUAL (9/1992)
RS   -54        0     16.0     54.4   127.25   136.89   146.51   156.70   167.29   178.35
RS184.07  189.992  195.914  202.066  208.356  214.761  221.281  227.916  234.665  241.529
RS248.51  255.579  262.764  270.041  277.433  284.963  292.654  300.505  308.517  316.667
RS333.36  350.573  368.297  386.639  405.556  425.000  444.904  465.289  486.226  507.782
RS529.87  552.525  575.781  599.472  623.577  648.140  673.255  698.852  724.908  751.400
RS778.33  805.624  832.668  859.711  886.754
RQ    54     1000    10000    15000    20000    22000    23000    24000    25000    26000
RQ 26150    26300    26400    26500    26750    27000    27150    27300    27400    27500
RQ 27650    27800    27900    28000    28150    28300    28400    28500    28650    28800
RQ 29000    29300    29500    29800    30000    30100    34100    41100    50400    60700
RQ 74000    88000   103700   120800   139300   159200   180600   203500   227700   253600
RQ281000   310000   340700   373100   407100
RA    54        0     1600     3840     4608     4800     4992     5184     5376     5568
RA  5792     6016     6144     6272     6400     6528     6624     6720     6784     6848
RA  6976     7104     7168     7296     7488     7616     7744     7936     8064   8198.4
RA  8480   8761.6   9043.2   9318.4   9587.2     9856  10124.8  10393.6  10630.4    10912
RA 11168    11424    11680    11936  12179.2  12422.4  12665.6  12908.8  13145.6    13376
RA 13606    13837    14080    14304    14528
RE    54      140      160      180      190      192      194      196      198      200
RE   201      202      203      204      205      206      207      208      209      210
RE   211      212      213      214      215      216      217      218      219      220
RE   222      224      226      228      230      232      234      236      238      240
RE   242      244      246      248      250      252      254      256      258      260
RE   262      264      266      268      270
C   Evaporation rates are 5 yr. average for Madden
C R2                1.08
C  4.944    5.135    5.850    5.031    3.369    2.878    3.244    3.214    2.889    2.997
C  2.583    3.673
C   Evaporation rates are read from DSS file for Madden ======================
P1    50    36000     1.05               89              .83
C   Penstock Capacity Based on Hydro-Met data for Maximum Discharge @ elev = 252
P2    20     3624
PR
PR
C  = Channel Capacity Based on Limiting Non-spill Releases to Power Operation ==
C  = Minimum flow set to 500 cfs based on historic minimum ====================
```

```
CP    50    3624      500
IDMAD
RT    50      40
C ============== Municipal Diversion from Lake Madden =========================
C   Diversions are M&I 5 yr average (1993 - 1997)
DR    50                                                  1           2.733
C                                                                   =======
QD    12      185      188      190      190      191      188      188      187      187
QD   180      182      183
C   *************  COCLE DEL NORTE DAM AT EL TORNO  **************
C  RESERVOIR LEVELS
C  LEVEL 1 = INACTIVE STORAGE     (BELOW ELEV 50M)
C  LEVEL 2 = MINIMUM POOL ELEV    (ELEV 50M)
C  LEVEL 3 = TOP OF CONSERVATION  (ELEV 71M)
C  LEVEL 4 = MAXIMUM POOL ELEV    (ELEV 72.5M)
C  LEVEL 5 = TOP OF DAM           (ELEV 75M)

RL   300 -232.95 1483860 1483860 4275330 4559543 5033231
RO     1      200
RS   -18  772.37 1086.25 1483.86 1677.05 1870.23 2082.73 2314.55 2546.37 2828.60
RS3110.8 3418.73 3752.29 4085.86 4464.80 4843.76 5244.90 5668.24 6091.57
C Multiple outlet capacity from a tunnel of 9 Meters diameter and 16.5kms length
QQ   200        7  262.48
RQ131.24        0        0     5866     6426     6941     7420     7870     7296     8701
RQ  9087     9459     9816    10160    10493    10816    11130    11435    11732
RQ147.65        0        0      386      386      386     6152     6688     7184     7648
RQ  8086     8501     8896     9275     9639     9989    10328    10656    10974
RQ164.05        0        0      386      386      386      386      386     5866     6426
RQ  6941     7420     7870     8296     8701     9087     9459     9816    10160
RQ180.46        0        0      386      386      386      386      386      386      386
RQ   386     6152     6688     7184     7648     8086     8501     8896     9275
RQ196.86        0        0      386      386      386      386      386      386      386
RQ   386      386      386     5866     6426     6941     7420     7870     8296
RQ213.26        0        0      386      386      386      386      386      386      386
RQ   386      386      386      386      386      386     6152     6688     7184
RQ229.67        0        0      386      386      386      386      386      386      386
RQ   386      386      386      386      386      386      386      386     5866
RA    18    16128    20680    26185    28765    31345    34044    36862    39681    42609
RA 45537    48495    51483    54471    57505    60540    63602    66693    69783
C Elev (m)     40       45       50       52       54       56       58       60       62
RE    18  131.24  147.65  164.05  170.61  177.17  183.74  190.30  196.86  203.42
C     64       66       68       70       72       74       76       78       80
RE209.98  216.55  223.11  229.67  236.23  242.79  249.36  255.92  262.48
C Divert all flood waters to power plant and spillway, values from spillway rati
RD    -1      .01      .01      .01      .01      .01      .01      .01      .01      .01
RD   .01      .01      .01      .01    66745   188784   346818   533961   746233
C  AVERAGE EVAPORATION RATES PROVIDED BY PCC, BASED ON GATUN AVERAGE FROM 1993-1
R3 4.406    4.615    5.226    4.858    3.586    3.128    3.293    3.148    3.075    3.133
R3 2.827    3.307
C   **************  POWER RECORDS **************
C Indio pool elevation to compute head
```

```
 P1   300   20000     1.0       0       0     200    0.86       1
 P2   386       0
 PR
 PR
 C    *******************************************

 CP   300   15000     386     386
 IDCOCLE DAM
 RT   300     301
 DR   300     290                                   -2
 C QM  1500    1500    1500    1500    1500    1500    1500    1500    1500    15
 C QM  1500    1500

 CP   301   99999     386     386
 ID CP301
 RT   301     200
 DR   301     290                                             386
 C ================ COCLE DAM & POWER PLANT (THIRD of 3 Parts) =============
 C  ============= COCLE Hydro Power Reservoir ================================

 RL   290 -246.08 1483860 1483865 5033231 5562402 6091573
 RO
 RS   -18  723.91 1037.36 1428.97 1608.33 1801.37 2008.55 2230.34 2432.90 2719.58
 RS2988.0 3272.80 3574.56 3893.71 4230.71 4586.02 4960.10 5353.42 5798.67
 RQ    18      -1      -1      -1      -1      -1      -1      -1      -1      -1
 RQ    -1      -1      -1      -1      -1      -1      -1      -1      -1
 RA    18   15488   21419   26516   28680   30914   33214   35578   38347   40493
 RA 43040   45642   48299   51008   53767   56573   59426   62323   65539
 RE    18  131.24  147.65  164.05  170.61  177.17  183.74  190.30  196.86  203.42
 RE209.98  216.55  223.11  229.67  236.23  242.79  249.36  255.92  262.48
 C    ************** POWER RECORDS **************
 C Tailwater block loading at 20 m (65.6 ft)
 P1   290    7500     1.0       0       0       0    0. 6       1
 C No leakage; minimum flow pass thru small unit, ? MW
 P2     0       0
 PR
 PR
 C    *******************************************

 CP   290  999999
 IDCOCLE PP          POWER PLANT
 RT   290     999
 C  ============= RIO INDIO DAM AT LIMON  ===================================
 C  RESERVOIR LEVELS
 C  LEVEL 1 = INACTIVE STORAGE      (BELOW ELEV 40M)
 C  LEVEL 2 = MINIMUM POOL ELEV     (ELEV 40.01M)
 C  LEVEL 3 = TOP OF CONSERVATION   (ELEV 80M)
 C  LEVEL 4 = MAXIMUM POOL ELEV     (ELEV 82.5M)
 C  LEVEL 5 = TOP OF DAM            (ELEV 85M)

 RL   200 -262.48
```

```
RL     1     200      -1          229600
RL     2     200      -1          229649
RL     3     200      -1         1278900
C RL     3     200       0          1278900 1226400 1174000 1121500 1069100 10166
C RL                                1016600 1069100 1121500 1174000 1226400 12789
RL     4     200      -1         1384200
RL     5     200      -1         1489530
RO     1      40
RS   -19   33.544 229.649 318.191 406.733 528.932 651.131 708.070 765.009 821.947
RS878.89 935.825 1004.44 1073.04 1141.66 1210.27 1278.88 1384.20 1489.53 1700.19
C Discharges for 1 tunnel of 4.5m and 1 tunnel of 6.5M of diameter (HORSESHOE)
RQ    19       0    7038    8200    9215   10130   10967   11287   11596   11897
RQ 12191   12476   12758   13032   13302   13565   13823   14139   14449   15049
RA    19    1573    4371    5401    6425    7026    7624    8014    8404    8794
RA  9185    9575    9915   10255   10595   10935   11275   11671   12059   12842
RE    19   65.62  131.24  147.65  164.05  180.46  196.86  203.42  209.98  216.55
RE223.11  229.67  236.23  242.79  249.36  255.92  262.48  270.68  278.88  295.29
RD    -1    0.01    0.01    0.01    0.01    0.01    0.01    0.01    0.01    0.01
RD  0.01    0.01    0.01    0.01    0.01    0.01    0.01   32362   91535  258900
C  AVERAGE EVAPORATION RATES PROVIDED BY PCC, BASED ON GATUN AVERAGE FROM 1993-1
R3 4.406   4.615   5.226   4.858   3.586   3.128   3.293   3.148   3.075   3.133
R3 2.827   3.307
C ****************** POWER CARDS ***********************
C P1   200   25000     1.0       0       0      40    0.86       1
C Set leakage to 91.2 cfs which will be diverted from 199 to 20
C P2  91.2       0
C PR
C PR
C  ******************************************************

CP   200   15000    91.2    91.2
ID INDIO DAM       NR LIMON
RT   200     199
DR   200     999                                        -2
C QM  2050    2050    2050    2050    2050    2050       0       0       0
C QM     0       0       0       0

CP   199  999999    91.2    91.2
ID CP199
RT   199      40
DR   199     999                                         0    91.2
C ============= Lake Gatun ===============================================
C  5.  Top-of-dam      = Elev. 105.0
C  4.  Top-of-flood    = Monthly varying, Based on Spill Curve
C  3.  Top-of-conserv. = Monthly varying, Elevaions from Fig 5.1
C  2.  Top-of-buffer   = Elev.  785
C  1.  Top-of-inactive = Elev.  785 to determine DIV Shortages

RL    40  -87.75
C                          Elev= 78.5ft
RL     1      40      -1         3536150
```

```
RL      2       40      -1          3536150
RL      3       40      -1          4475260
RL      4       40      -1          4480570
C        ELEV:                          87.0    86.3    85.4    84.7    84.7    84.7
C RL     3       40       0         4399800 4325160 4230070 4156820 4156820 41568
C        ELEV:                          84.7    84.7    85.0    85.9    87.3    87.5
C RL                                4156820 4156820 4188100 4282800 4432050 44535
C   Gatun Spill Curve from PCC OPERDATA.BAS dated 6-23-94
C        ELEV:                          87.75   87.75   87.75   87.75   86.5    86.5
C RL     4       40       0         4480570 4480570 4480570 4480570 4346420 43464
C        ELEV:                          86.5    86.5    86.5    86.8    87.4    87.75
C RL                                4346420 4346420 4346420 4378440 4442800 44805
RL     5       40      -1          6384700
RO
C   Reservoir storage from path = /PCC/GAT/ELEV-CAPAC(ACFT)///OBS/
C   Reservoir maximum outflow from StoneyGAT.xls, data for 14 gates ELEV=78'-92'
C   Reservoir areas from path =   /PCC/GAT/ELEV-AREA(ACRES)///OBS/
C   data below elev. 77 and above 90 was extrapolated
RS   -21       0   833.7  1781.7  2729.7  3393.3  3488.1  3584.2  3681.6  3780.3
RS3880.2  3981.6  4084.2  4188.1  4293.3  4399.8  4507.6  4616.7  4727.2  5279.7
RS5832.2  6384.7
RQ    21       0       0       0    1890   42790   58878   69463   80672   92479
RQ104860  117796  131268  145260  159756  174743  190208  206139  222525  300000
RQ350000  400000
RA    21       0   56544   70404   84264   93966   95353   96740   98127   99414
RA100702  101990  103277  104566  105853  107141  108382  109670  110957  117392
RA123827  130262
RE    21      40      50      60      70      77      78      79      80      81
RE    82      83      84      85      86      87      88      89      90      95
RE   100     105
C   Evaporation rates are 5 yr. average for Gatun
C R2                1.10
C  4.240   4.589   5.372   5.251   3.304   2.896   3.037   3.132   2.882   2.869
C  2.666   3.349
P1    40   24000       1               9               .85
C   Penstock Capacity Estimated from Operation Data Sheets
P2    27    4550
PR
PR
C    Channel Capacity Based on Limiting Non-spill Releases to Power Operation

CP    40    4550
IDGAT
RT    40     999
C ============= Divert Lockage + Municipal Water Supply Flows ================
C  Current Ave Demands:  A=PCC B=GAT C=FLOW-DIV F=AVE CURRENT DEMANDS
C                                                                  ======
DR    40                                                  -5        2.733
C                                                                  ======

CP   999  999999
```

IDEND

****

Summary by Period Flood= 1

Location No=		40.	40.	40.	40.	50.	300.	200.	301.	199.
		GAT	GAT	GAT	GAT	MAD	COCLE DAM	INDIO DA	CP301	CP199
Period	Date:	Diversio	Div Requ	Div Shor	EOP Elev	EOP Elev	EOP Elev	EOP Elev	Outflow	Outflow
2653	31Oct 1998	8450.44	8450.44	0.00	80.32	203.93	184.79	162.38	934.27	1938.80
2654	7Nov 1998	8103.35	8103.35	0.00	80.28	205.41	186.36	161.69	394.33	1538.80
2655	14Nov 1998	8103.35	8103.35	0.00	80.40	204.53	187.79	161.36	741.74	1548.80
2656	21Nov 1998	8103.35	8103.35	0.00	80.18	207.37	189.15	163.15	946.19	888.80
2657	28Nov 1998	8103.35	8103.35	0.00	80.45	205.42	190.55	161.69	801.41	2188.80
2658	5Dec 1998	8329.80	8329.80	0.00	80.46	208.73	192.13	166.44	1446.14	0.00
2659	12Dec 1998	8420.37	8420.37	0.00	80.98	211.37	193.62	170.13	2135.20	2218.80
2660	19Dec 1998	8420.37	8420.37	0.00	81.19	214.26	194.96	176.58	2493.06	254.80
2661	26Dec 1998	8420.37	8420.37	0.00	81.57	216.20	196.50	179.74	1976.75	1028.80
2662	2Jan 1999	8611.68	8611.68	0.00	81.67	216.12	197.92	181.46	753.56	608.80
2663	9Jan 1999	9089.96	9089.96	0.00	81.59	212.02	198.80	175.88	0.00	3818.80
2664	16Jan 1999	9089.96	9089.96	0.00	81.39	208.06	199.48	172.04	619.41	3188.80
2665	23Jan 1999	9089.96	9089.96	0.00	81.06	205.06	199.63	171.81	2263.03	2758.80
2666	30Jan 1999	9089.96	9089.96	0.00	80.88	202.09	199.56	170.31	2973.86	4008.80
2667	6Feb 1999	9087.61	9087.61	0.00	80.68	198.28	199.04	167.43	3260.45	5008.80
2668	13Feb 1999	9087.23	9087.23	0.00	80.33	197.85	198.24	164.71	3979.87	5608.80
2669	20Feb 1999	9087.23	9087.23	0.00	80.51	190.22	197.15	160.61	4870.94	6808.80
2670	27Feb 1999	9087.23	9087.23	0.00	80.02	191.12	195.76	161.58	5205.21	5108.80
2671	6Mar 1999	9105.97	9105.97	0.00	79.83	191.07	194.52	155.15	4556.33	7208.80
2672	13Mar 1999	9109.09	9109.09	0.00	79.58	190.01	193.38	149.69	4306.75	6508.80
2673	20Mar 1999	9109.09	9109.09	0.00	79.37	190.00	191.90	145.15	5180.37	7108.80
2674	27Mar 1999	9109.09	9109.09	0.00	79.21	190.00	189.96	142.52	6367.60	7508.80
2675	3Apr 1999	8980.26	8980.26	0.00	79.13	190.02	187.97	140.09	6475.21	7608.80
2676	10Apr 1999	8808.46	8808.46	0.00	79.09	190.00	185.95	138.28	6506.53	7308.80
2677	17Apr 1999	8808.46	8808.46	0.00	79.00	190.02	183.93	137.68	6513.35	6908.80
2678	24Apr 1999	8808.46	8808.46	0.00	78.97	190.03	181.89	135.06	6166.55	7308.80
2679	1May 1999	8755.74	8755.74	0.00	78.85	190.01	180.17	135.23	5769.39	6308.80
2680	8May 1999	8439.50	8439.50	0.00	78.95	190.01	179.28	138.37	5679.99	5108.80
2681	15May 1999	8439.50	8439.50	0.00	79.11	190.02	178.69	138.86	4974.20	5508.80
2682	22May 1999	8439.50	8439.50	0.00	79.15	190.02	178.43	140.40	4228.23	4648.80
2683	29May 1999	8439.50	8439.50	0.00	79.18	190.17	178.34	139.66	3809.02	4658.80
2684	5Jun 1999	8156.45	8156.45	0.00	79.22	192.23	179.10	144.80	3842.05	2398.80
2685	12Jun 1999	8043.22	8043.22	0.00	79.75	192.37	180.25	147.63	3716.31	3888.80
2686	19Jun 1999	8043.22	8043.22	0.00	79.83	194.22	181.46	156.22	3569.93	1398.80
2687	26Jun 1999	8043.22	8043.22	0.00	80.28	194.54	182.81	158.84	3238.50	3498.80
2688	3Jul 1999	8040.87	8040.87	0.00	80.22	196.20	184.35	164.22	2140.08	878.80
2689	10Jul 1999	8037.75	8037.75	0.00	80.45	195.30	186.03	161.40	893.06	2678.80
2690	17Jul 1999	8037.75	8037.75	0.00	80.34	197.36	187.89	160.01	443.54	1428.80
2691	24Jul 1999	8037.75	8037.75	0.00	80.43	196.49	189.43	160.52	1257.03	1698.80
2692	31Jul 1999	8037.75	8037.75	0.00	80.33	197.95	190.81	164.18	1637.35	1248.80

2693	7Aug 1999	8152.54	8152.54	0.00	80.85	199.79	193.26	167.73	1984.35	2458.80
2694	14Aug 1999	8152.54	8152.54	0.00	81.04	201.83	195.31	174.69	2967.28	212.80
2695	21Aug 1999	8152.54	8152.54	0.00	81.55	203.31	197.35	178.12	2738.21	2368.80
2696	28Aug 1999	8152.54	8152.54	0.00	81.69	205.46	199.55	184.95	1388.78	0.00
2697	4Sep 1999	8021.35	8021.35	0.00	81.93	206.50	202.15	186.26	0.00	808.80
2698	11Sep 1999	7922.97	7922.97	0.00	81.98	207.81	204.72	189.35	0.00	0.00
2699	18Sep 1999	7922.97	7922.97	0.00	82.25	209.05	207.29	191.58	0.00	1628.80
2700	25Sep 1999	7922.97	7922.97	0.00	82.25	211.03	209.86	195.23	0.00	0.00
2701	2Oct 1999	8073.66	8073.66	0.00	82.59	212.03	211.95	195.92	187.51	2448.80
2702	9Oct 1999	8450.44	8450.44	0.00	82.45	215.03	213.47	196.48	189.93	1088.80
2703	16Oct 1999	8450.44	8450.44	0.00	82.56	215.55	215.01	195.54	151.34	1648.80
2704	23Oct 1999	8450.44	8450.44	0.00	82.46	217.90	216.50	196.02	263.95	1118.80

1

Location No=		40.	40.	40.	40.	50.	300.	200.	301.	199.
Period	Date:	GAT Diversio	GAT Div Requ	GAT Div Shor	GAT EOP Elev	MAD EOP Elev	COCLE DAM EOP Elev	INDIO DA EOP Elev	CP301 Outflow	CP199 Outflow
2705	30Oct 1999	8450.44	8450.44	0.00	82.56	218.58	217.86	195.73	382.76	1648.80
2706	6Nov 1999	8152.92	8152.92	0.00	82.83	222.59	219.60	198.52	392.28	0.00
2707	13Nov 1999	8103.35	8103.35	0.00	83.24	226.01	221.51	202.13	0.00	0.00
2708	20Nov 1999	8103.35	8103.35	0.00	83.66	229.16	223.39	205.69	111.64	0.00
2709	27Nov 1999	8103.35	8103.35	0.00	84.07	232.24	225.15	208.30	566.74	0.00
2710	4Dec 1999	8284.52	8284.52	0.00	84.81	237.84	227.21	213.67	989.66	0.00
2711	11Dec 1999	8420.37	8420.37	0.00	85.69	245.69	229.68	217.99	618.72	0.00
2712	18Dec 1999	8420.37	8420.37	0.00	86.67	252.00	232.00	221.60	0.00	0.00
2713	25Dec 1999	8420.37	8420.37	0.00	87.75	252.00	232.95	224.67	0.00	0.00
2714	1Jan 2000	8516.03	8516.03	0.00	87.75	252.00	232.95	228.04	0.00	0.00
	Sum =	22901912.00	22993956.00	92026.64	222970.41	567763.50	578694.69	508670.88	6739283.50	8896441.00
	Max =	9109.09	9109.09	5759.04	87.75	252.00	232.95	262.48	7139.09	8408.80
	Min =	3076.75	7922.97	0.00	78.50	190.00	164.05	131.24	0.00	0.00
	PMax=	11.00	11.00	2625.00	102.00	103.00	1.00	1.00	1840.00	1525.00
	Avg =	8438.43	8472.35	33.91	82.16	209.20	213.23	187.42	2483.16	3277.98
	PMin=	2625.00	37.00	1.00	1530.00	68.00	2624.00	1897.00	1.00	49.00

1

*USERS. 2 User Designed Output (Dates shown are for END-of-Period)

1

Location No=		300.	300.	290.	200.	200.
Period	Date:	COCLE DAM Evaporat	COCLE DAM Diversio	COCLE PP Outflow	INDIO DA Evaporat	INDIO DA Diversio
2653	31Oct 1998	149.71	0.00	386.00	27.89	0.00
2654	7Nov 1998	137.90	0.00	386.00	24.94	0.00

2655	14Nov 1998	140.46	0.00	386.00	24.81	0.00
2656	21Nov 1998	142.83	0.00	386.00	24.99	0.00
2657	28Nov 1998	145.17	0.00	386.00	25.03	0.00
2658	5Dec 1998	172.80	0.00	386.00	29.81	0.00
2659	12Dec 1998	175.84	0.00	386.00	30.47	0.00
2660	19Dec 1998	178.65	0.00	386.00	31.33	0.00
2661	26Dec 1998	181.52	0.00	386.00	32.15	0.00
2662	2Jan 1999	245.90	0.00	386.00	43.38	0.00
2663	9Jan 1999	248.98	0.00	386.00	42.95	0.00
2664	16Jan 1999	251.13	0.00	386.00	41.88	0.00
2665	23Jan 1999	252.28	0.00	386.00	41.42	0.00
2666	30Jan 1999	252.38	0.00	386.00	41.23	0.00
2667	6Feb 1999	263.49	0.00	386.00	42.67	0.00
2668	13Feb 1999	261.60	0.00	386.00	42.00	0.00
2669	20Feb 1999	258.87	0.00	386.00	41.01	0.00
2670	27Feb 1999	255.42	0.00	386.00	40.33	0.00
2671	6Mar 1999	285.01	0.00	386.00	44.42	0.00
2672	13Mar 1999	281.27	0.00	386.00	41.71	0.00
2673	20Mar 1999	277.15	0.00	386.00	39.42	0.00
2674	27Mar 1999	271.77	0.00	386.00	37.78	0.00
2675	3Apr 1999	246.88	0.00	386.00	34.04	0.00
2676	10Apr 1999	241.02	0.00	386.00	33.13	0.00
2677	17Apr 1999	235.12	0.00	386.00	32.62	0.00
2678	24Apr 1999	229.32	0.00	386.00	31.93	0.00
2679	1May 1999	165.37	0.00	386.00	23.18	0.00
2680	8May 1999	162.68	0.00	386.00	23.70	0.00
2681	15May 1999	161.16	0.00	386.00	24.28	0.00
2682	22May 1999	160.28	0.00	386.00	24.60	0.00
2683	29May 1999	159.92	0.00	386.00	24.72	0.00
2684	5Jun 1999	140.10	0.00	386.00	22.17	0.00
2685	12Jun 1999	141.81	0.00	386.00	23.26	0.00
2686	19Jun 1999	143.93	0.00	386.00	24.83	0.00
2687	26Jun 1999	146.24	0.00	386.00	26.36	0.00
2688	3Jul 1999	156.74	0.00	386.00	28.91	0.00
2689	10Jul 1999	159.87	0.00	386.00	29.28	0.00
2690	17Jul 1999	163.38	0.00	386.00	28.67	0.00
2691	24Jul 1999	166.74	0.00	386.00	28.54	0.00
2692	31Jul 1999	169.64	0.00	386.00	29.15	0.00
2693	7Aug 1999	165.80	0.00	386.00	28.63	0.00
2694	14Aug 1999	170.06	0.00	386.00	29.48	0.00
2695	21Aug 1999	174.04	0.00	386.00	30.32	0.00
2696	28Aug 1999	178.06	0.00	386.00	31.15	0.00
2697	4Sep 1999	178.55	0.00	386.00	31.06	0.00
2698	11Sep 1999	183.52	0.00	386.00	31.41	0.00
2699	18Sep 1999	188.46	0.00	386.00	31.83	0.00
2700	25Sep 1999	193.40	0.00	386.00	32.29	0.00
2701	2Oct 1999	201.64	0.00	386.00	33.25	0.00
2702	9Oct 1999	205.19	0.00	386.00	33.35	0.00
2703	16Oct 1999	208.21	0.00	386.00	33.31	0.00
2704	23Oct 1999	211.21	0.00	386.00	33.28	0.00

Location No=	300.	300.	290.	200.	200.
Period Date:	COCLE DAM Evaporat	COCLE DAM Diversio	COCLE PP Outflow	INDIO DA Evaporat	INDIO DA Diversio
2705 30Oct 1999	214.04	0.00	386.00	33.29	0.00
2706 6Nov 1999	195.92	0.00	386.00	30.26	0.00
2707 13Nov 1999	199.22	0.00	386.00	31.00	0.00
2708 20Nov 1999	202.64	0.00	386.00	31.84	0.00
2709 27Nov 1999	205.92	0.00	386.00	32.57	0.00
2710 4Dec 1999	244.90	0.00	386.00	39.20	0.00
2711 11Dec 1999	249.68	0.00	386.00	40.53	0.00
2712 18Dec 1999	254.78	0.00	386.00	41.62	0.00
2713 25Dec 1999	258.28	5733.92	6119.92	42.54	0.00
2714 1Jan 2000	345.47	8979.53	9365.53	57.86	0.00
Sum =	669043.88	2050027.25	3078915.75	103560.80	18.50
Max =	409.76	12706.53	13092.53	73.80	6.16
Min =	114.71	0.00	0.00	19.15	0.00
PMax=	10.00	1153.00	1153.00	375.00	2.00
Avg =	246.52	755.35	1134.46	38.16	0.01
PMin=	2632.00	14.00	1.00	2632.00	4.00

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*USERS. 3 User Designed Output (Dates shown are for END-of-Period)

Summary by Period Flood= 1

Location No=	300.	290.	40.	50.
J8/JZ Codes=	300.160	290.160	40.160	50.160
Period Date:	COCLE DAM Energy G	COCLE PP Energy G	GAT Energy G	MAD Energy G
2653 31Oct 1998	247.42	821.54	0.00	3050.91
2654 7Nov 1998	104.19	821.54	0.00	2688.24
2655 14Nov 1998	217.96	821.54	0.00	4172.70
2656 21Nov 1998	300.01	821.54	0.00	1821.40
2657 28Nov 1998	260.51	821.54	0.00	4930.55
2658 5Dec 1998	493.63	821.54	0.00	3176.40
2659 12Dec 1998	717.32	821.54	0.00	4298.79
2660 19Dec 1998	761.88	821.54	0.00	4134.11
2661 26Dec 1998	516.45	821.54	0.00	4884.69
2662 2Jan 1999	166.55	821.54	0.00	5310.37
2663 9Jan 1999	0.00	821.54	0.00	5312.90
2664 16Jan 1999	147.43	821.54	0.00	4855.95
2665 23Jan 1999	680.41	821.54	0.00	3939.14

2666	30Jan 1999	969.48	821.54	0.00	3704.37
2667	6Feb 1999	1085.53	821.54	0.00	3201.83
2668	13Feb 1999	1399.50	821.54	0.00	1235.19
2669	20Feb 1999	1823.31	821.54	0.00	4392.05
2670	27Feb 1999	2080.73	821.54	0.00	575.69
2671	6Mar 1999	1840.61	821.54	0.00	578.11
2672	13Mar 1999	1820.96	821.54	0.00	934.34
2673	20Mar 1999	2483.65	821.54	0.00	496.38
2674	27Mar 1999	3308.46	821.54	0.00	490.85
2675	3Apr 1999	3360.00	821.54	0.00	857.92
2676	10Apr 1999	3360.00	821.54	0.00	1370.31
2677	17Apr 1999	3360.00	821.54	0.00	1358.38
2678	24Apr 1999	3311.52	821.54	0.00	1358.56
2679	1May 1999	3078.81	821.54	0.00	1501.52
2680	8May 1999	3025.62	821.54	0.00	2287.87
2681	15May 1999	2504.23	821.54	0.00	2287.98
2682	22May 1999	2012.77	821.54	0.00	2288.09
2683	29May 1999	1757.80	821.54	0.00	2230.20
2684	5Jun 1999	1770.21	821.54	0.00	2411.27
2685	12Jun 1999	1655.59	821.54	0.00	3631.39
2686	19Jun 1999	1467.74	821.54	0.00	2928.41
2687	26Jun 1999	1155.98	821.54	0.00	3617.63
2688	3Jul 1999	655.90	821.54	0.00	3162.23
2689	10Jul 1999	246.99	821.54	0.00	4533.52
2690	17Jul 1999	125.32	821.54	0.00	3153.07
2691	24Jul 1999	414.06	821.54	0.00	4583.38
2692	31Jul 1999	577.47	821.54	0.00	3459.64
2693	7Aug 1999	695.23	821.54	0.00	4303.01
2694	14Aug 1999	991.23	821.54	0.00	4221.35
2695	21Aug 1999	809.16	821.54	0.00	4568.83
2696	28Aug 1999	357.24	821.54	0.00	4192.81
2697	4Sep 1999	0.00	821.54	0.00	4029.59
2698	11Sep 1999	0.00	821.54	0.00	3205.88
2699	18Sep 1999	0.00	821.54	0.00	3268.57
2700	25Sep 1999	0.00	821.54	0.00	2755.97
2701	2Oct 1999	37.83	821.54	0.00	3541.33
2702	9Oct 1999	37.46	821.54	0.00	2086.22
2703	16Oct 1999	31.52	821.54	0.00	4037.36
2704	23Oct 1999	60.48	821.54	0.00	2546.64

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Location No=		300.	290.	40.	50.
		COCLE DAM	COCLE PP	GAT	MAD
Period	Date:	Energy G	Energy G	Energy G	Energy G
2705	30Oct 1999	95.46	821.54	0.00	3963.93
2706	6Nov 1999	104.78	821.54	0.00	2654.93
2707	13Nov 1999	0.00	821.54	0.00	3400.21
2708	20Nov 1999	28.83	821.54	0.00	3580.79
2709	27Nov 1999	134.13	821.54	0.00	3577.55
2710	4Dec 1999	219.95	821.54	0.00	5842.07

2711	11Dec 1999	124.49	821.54	0.00	6350.40
2712	18Dec 1999	0.00	821.54	0.00	6350.40
2713	25Dec 1999	0.00	1260.00	4032.00	6350.40
2714	1Jan 2000	0.00	1260.00	4032.00	6350.40
	Sum =	2890411.25	2453638.50	146190.97	7978090.50
	Max =	3360.00	1260.00	4032.00	6350.40
	Min =	0.00	0.00	0.00	0.00
	PMax=	67.00	13.00	102.00	1.00
	Avg =	1065.00	904.07	53.87	2939.61
	PMin=	1.00	1.00	2.00	69.00

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Location No=		300.	300.	300.	300.	301.	200.	200.	200.	199.
Period	Date:	COCLE DAM Loc Incr	COCLE DAM Outflow	COCLE DAM Case	COCLE DAM Q-Spill	CP301 Diversio	INDIO DA Loc Incr	INDIO DA Outflow	INDIO DA Case	CP199 Diversio
2653	31Oct 1998	5881.00	1320.27	0.06	0.00	386.00	674.00	2030.00	0.05	91.20
2654	7Nov 1998	4917.00	780.33	0.06	0.00	386.00	994.00	1630.00	0.05	91.20
2655	14Nov 1998	4917.00	1127.74	0.06	0.00	386.00	795.00	1640.00	0.05	91.20
2656	21Nov 1998	4917.00	1332.19	0.06	0.00	386.00	752.00	980.00	0.05	91.20
2657	28Nov 1998	4917.00	1187.41	0.06	0.00	386.00	937.00	2280.00	0.05	91.20
2658	5Dec 1998	6027.00	1832.14	0.06	387.96	386.00	876.00	91.20	0.00	91.20
2659	12Dec 1998	6471.00	2521.20	0.06	1088.55	386.00	2182.00	2310.00	0.05	91.20
2660	19Dec 1998	6471.00	2879.06	0.06	1456.87	386.00	1345.00	346.00	0.05	91.20
2661	26Dec 1998	6471.00	2362.75	0.06	951.10	386.00	870.00	1120.00	0.05	91.20
2662	2Jan 1999	5584.43	1139.56	0.06	0.00	386.00	910.00	700.00	0.05	91.20
2663	9Jan 1999	3368.00	386.00	0.13	0.00	386.00	964.00	3910.00	0.05	91.20
2664	16Jan 1999	3368.00	1005.41	0.06	0.00	386.00	640.00	3280.00	0.05	91.20
2665	23Jan 1999	3368.00	2649.03	0.06	1264.60	386.00	506.00	2850.00	0.05	91.20
2666	30Jan 1999	3368.00	3359.86	0.06	1975.68	386.00	363.00	4100.00	0.05	91.20
2667	6Feb 1999	2317.14	3646.45	0.06	2260.20	386.00	339.00	5100.00	0.05	91.20
2668	13Feb 1999	2142.00	4365.87	0.06	2975.00	386.00	301.00	5700.00	0.05	91.20
2669	20Feb 1999	2142.00	5256.94	0.06	3859.39	386.00	378.00	6900.00	0.05	91.20
2670	27Feb 1999	2142.00	5591.21	0.06	4185.02	386.00	412.00	5200.00	0.05	91.20
2671	6Mar 1999	2084.57	4942.33	0.06	3526.40	386.00	289.00	7300.00	0.05	91.20
2672	13Mar 1999	2075.00	4692.75	0.06	3268.10	386.00	213.00	6600.00	0.05	91.20
2673	20Mar 1999	2075.00	5566.37	0.06	4131.98	386.00	295.00	7200.00	0.05	91.20
2674	27Mar 1999	2075.00	6753.60	0.06	5306.28	386.00	248.00	7600.00	0.05	91.20
2675	3Apr 1999	2040.29	6861.21	0.06	5398.74	386.00	312.00	7700.00	0.05	91.20
2676	10Apr 1999	1994.00	6892.53	0.06	5414.29	386.00	226.00	7400.00	0.05	91.20
2677	17Apr 1999	1994.00	6899.35	0.06	5404.88	386.00	286.00	7000.00	0.05	91.20
2678	24Apr 1999	1994.00	6552.55	0.06	5041.48	386.00	244.00	7400.00	0.05	91.20
2679	1May 1999	2303.29	6155.39	0.06	4628.46	386.00	721.00	6400.00	0.05	91.20

2680	8May 1999	4159.00	6065.99	0.06	4527.90	386.00	763.00	5200.00	0.05	91.20
2681	15May 1999	4159.00	5360.20	0.06	3815.73	386.00	844.00	5600.00	0.05	91.20
2682	22May 1999	4159.00	4614.23	0.06	3066.08	386.00	1132.00	4740.00	0.05	91.20
2683	29May 1999	4159.00	4195.02	0.06	2645.34	386.00	678.00	4750.00	0.05	91.20
2684	5Jun 1999	6128.29	4228.05	0.06	2681.31	386.00	667.00	2490.00	0.05	91.20
2685	12Jun 1999	6916.00	4102.31	0.06	2563.80	386.00	1390.00	3980.00	0.05	91.20
2686	19Jun 1999	6916.00	3955.93	0.06	2427.49	386.00	1284.00	1490.00	0.05	91.20
2687	26Jun 1999	6916.00	3624.50	0.06	2106.86	386.00	1396.00	3590.00	0.05	91.20
2688	3Jul 1999	6404.71	2526.08	0.06	1020.69	386.00	976.00	970.00	0.05	91.20
2689	10Jul 1999	5723.00	1279.06	0.06	0.00	386.00	786.00	2770.00	0.05	91.20
2690	17Jul 1999	5723.00	829.54	0.06	0.00	386.00	565.00	1520.00	0.05	91.20
2691	24Jul 1999	5723.00	1643.03	0.06	178.18	386.00	757.00	1790.00	0.05	91.20
2692	31Jul 1999	5723.00	2023.35	0.06	569.82	386.00	1174.00	1340.00	0.05	91.20
2693	7Aug 1999	8756.00	2370.35	0.06	931.40	386.00	2501.00	2550.00	0.05	91.20
2694	14Aug 1999	8756.00	3353.28	0.06	1931.07	386.00	1095.00	304.00	0.05	91.20
2695	21Aug 1999	8756.00	3124.21	0.06	1717.29	386.00	1595.00	2460.00	0.05	91.20
2696	28Aug 1999	8756.00	1774.78	0.06	382.56	386.00	2398.00	91.20	0.00	91.20
2697	4Sep 1999	8632.00	386.00	0.13	0.00	386.00	1632.00	900.00	0.05	91.20
2698	11Sep 1999	8539.00	386.00	0.13	0.00	386.00	1781.00	91.20	0.00	91.20
2699	18Sep 1999	8539.00	386.00	0.13	0.00	386.00	2951.00	1720.00	0.05	91.20
2700	25Sep 1999	8539.00	386.00	0.13	0.00	386.00	2082.00	91.20	0.00	91.20
2701	2Oct 1999	7791.00	573.51	0.06	0.00	386.00	2754.00	2540.00	0.05	91.20
2702	9Oct 1999	5921.00	575.93	0.06	0.00	386.00	1327.00	1180.00	0.05	91.20
2703	16Oct 1999	5921.00	537.34	0.06	0.00	386.00	1113.00	1740.00	0.05	91.20
2704	23Oct 1999	5921.00	649.95	0.06	0.00	386.00	1240.00	1210.00	0.05	91.20

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Location No=		300.	300.	300.	300.	301.	200.	200.	200.	199.
Period	Date:	COCLE DAM Loc Incr	COCLE DAM Outflow	COCLE DAM Case	COCLE DAM Q-Spill	CP301 Diversio	INDIO DA Loc Incr	INDIO DA Outflow	INDIO DA Case	CP199 Diversio
2705	30Oct 1999	5921.00	768.76	0.06	0.00	386.00	1234.00	1740.00	0.05	91.20
2706	6Nov 1999	7353.29	778.28	0.06	0.00	386.00	1373.00	91.20	0.00	91.20
2707	13Nov 1999	7592.00	386.00	0.13	0.00	386.00	2379.00	91.20	0.00	91.20
2708	20Nov 1999	7592.00	497.64	0.06	0.00	386.00	2238.00	91.20	0.00	91.20
2709	27Nov 1999	7592.00	952.74	0.06	0.00	386.00	1188.00	91.20	0.00	91.20
2710	4Dec 1999	9148.00	1375.66	0.06	154.89	386.00	2492.00	91.20	0.00	91.20
2711	11Dec 1999	10315.00	1004.72	0.06	0.00	386.00	2211.00	91.20	0.00	91.20
2712	18Dec 1999	10315.00	386.00	0.13	0.00	386.00	2390.00	91.20	0.00	91.20
2713	25Dec 1999	10315.00	386.00	0.13	0.00	386.00	2052.00	91.20	0.00	91.20
2714	1Jan 2000	9711.00	386.00	0.13	0.00	386.00	2257.00	91.20	0.00	91.20
	Sum =	10505953.00	7786882.50	211.69	4973394.50	1047604.00	2482358.00	9143762.00	114.80	247522.64
	Max =	13438.00	7525.09	0.13	6160.51	386.00	6355.00	8500.00	0.06	91.20
	Min =	478.00	386.00	0.05	0.00	386.00	32.00	91.20	0.00	91.20
	PMax=	1150.00	1840.00	1.00	1840.00	1.00	676.00	1525.00	1529.00	1.00
	Avg =	3871.02	2869.15	0.08	1832.50	386.00	914.65	3369.11	0.04	91.20

	PMin=	902.00	1.00	1546.00	1.00	1.00	1843.00	49.00	49.00	1.00

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*USERS. 5 User Designed Output (Dates shown are for END-of-Period)

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Location No=		40.	40.	40.	40.	40.	50.	50.	50.	50.	50.
Period	Date:	GAT Loc Incr	GAT Inflow	GAT Outflow	GAT Evaporat	GAT Q-Spill	MAD Loc Incr	MAD Inflow	MAD Outflow	MAD Evaporat	MAD Q-Spill
2653	31Oct 1998	5867.93	1636.29	27.00	441.29	0.00	3236.55	2744.61	2280.00	27.05	0.00
2654	7Nov 1998	4704.04	129.49	27.00	365.98	0.00	3185.01	2687.60	1990.00	22.82	0.00
2655	14Nov 1998	4704.04	1219.49	27.00	366.17	0.00	3185.01	2687.60	3070.00	22.96	0.00
2656	21Nov 1998	4704.04	-1170.51	27.00	365.92	0.00	3185.01	2687.60	1340.00	23.42	0.00
2657	28Nov 1998	4704.04	2369.49	27.00	366.06	0.00	3185.01	2687.60	3580.00	23.57	0.00
2658	5Dec 1998	6469.30	439.50	27.00	334.17	0.00	4389.91	3889.77	2300.00	21.38	0.00
2659	12Dec 1998	7175.41	4003.84	27.00	322.82	0.00	4871.88	4371.74	3030.00	21.11	0.00
2660	19Dec 1998	7175.41	1859.84	27.00	324.34	0.00	4871.88	4371.74	2850.00	22.04	0.00
2661	26Dec 1998	7175.41	3083.84	27.00	325.58	0.00	4871.88	4371.74	3300.00	23.15	0.00
2662	2Jan 1999	5581.82	1138.94	27.00	377.11	0.00	4047.05	3541.45	3560.00	26.95	0.00
2663	9Jan 1999	1597.83	-53.33	27.00	503.49	0.00	1985.00	1479.40	3620.00	34.03	0.00
2664	16Jan 1999	1597.83	-883.33	27.00	502.59	0.00	1985.00	1479.40	3420.00	31.90	0.00
2665	23Jan 1999	1597.83	-1873.33	27.00	500.87	0.00	1985.00	1479.40	2860.00	30.62	0.00
2666	30Jan 1999	1597.83	-723.33	27.00	499.23	0.00	1985.00	1479.40	2760.00	28.94	0.00
2667	6Feb 1999	686.66	-932.15	27.00	508.70	0.00	1440.71	926.91	2460.00	28.61	0.00
2668	13Feb 1999	534.80	-1963.63	27.00	508.64	0.00	1350.00	836.20	980.00	27.78	0.00
2669	20Feb 1999	534.80	1816.37	27.00	508.07	0.00	1350.00	836.20	3560.00	25.85	0.00
2670	27Feb 1999	534.80	-2943.63	27.00	507.05	0.00	1350.00	836.20	500.00	24.12	0.00
2671	6Mar 1999	648.92	-748.25	27.00	565.94	0.00	1033.71	514.44	500.00	29.56	0.00
2672	13Mar 1999	667.94	-1132.35	27.00	574.74	0.00	981.00	461.73	800.00	30.10	0.00
2673	20Mar 1999	667.94	-895.76	27.00	572.86	0.00	981.00	461.73	436.58	29.76	0.00
2674	27Mar 1999	667.94	-500.38	27.00	571.35	0.00	981.00	461.73	431.97	29.76	0.00
2675	3Apr 1999	603.69	-27.77	27.00	499.38	0.00	1291.71	772.44	740.00	26.47	0.00
2676	10Apr 1999	518.02	188.36	27.00	404.18	0.00	1706.00	1186.73	1170.00	22.07	0.00
2677	17Apr 1999	518.02	-221.64	27.00	403.81	0.00	1706.00	1186.73	1160.00	22.07	0.00
2678	24Apr 1999	518.02	178.36	27.00	403.44	0.00	1706.00	1186.73	1160.00	22.08	0.00
2679	1May 1999	809.81	-357.13	27.00	407.06	0.00	1817.00	1295.00	1280.00	21.69	0.00
2680	8May 1999	2560.54	1169.84	27.00	433.12	0.00	2483.00	1961.00	1940.00	19.28	0.00
2681	15May 1999	2560.54	1569.84	27.00	433.93	0.00	2483.00	1961.00	1940.00	19.28	0.00
2682	22May 1999	2560.54	709.84	27.00	434.54	0.00	2483.00	1961.00	1940.00	19.29	0.00
2683	29May 1999	2560.54	669.84	27.00	434.74	0.00	2483.00	1961.00	1890.00	19.32	0.00
2684	5Jun 1999	4445.20	707.55	27.00	370.33	0.00	3265.14	2751.34	2020.00	17.15	0.00
2685	12Jun 1999	5199.06	4044.64	27.00	345.53	0.00	3578.00	3064.20	3000.00	16.46	0.00
2686	19Jun 1999	5199.06	954.64	27.00	347.02	0.00	3578.00	3064.20	2400.00	16.79	0.00
2687	26Jun 1999	5199.06	3584.64	27.00	348.32	0.00	3578.00	3064.20	2930.00	17.14	0.00
2688	3Jul 1999	4577.90	-44.17	27.00	361.03	0.00	3682.14	3168.34	2540.00	18.45	0.00
2689	10Jul 1999	3749.68	2010.73	27.00	376.80	0.00	3821.00	3307.20	3620.00	19.88	0.00
2690	17Jul 1999	3749.68	-349.27	27.00	377.10	0.00	3821.00	3307.20	2510.00	20.10	0.00
2691	24Jul 1999	3749.68	1030.73	27.00	377.05	0.00	3821.00	3307.20	3620.00	20.32	0.00
2692	31Jul 1999	3749.68	-309.27	27.00	377.02	0.00	3821.00	3307.20	2730.00	20.43	0.00

2693	7Aug 1999	6461.38	4107.64	27.00	373.91	0.00	4604.00	4092.93	3340.00	21.63	0.00
2694	14Aug 1999	6461.38	1741.64	27.00	375.63	0.00	4604.00	4092.93	3220.00	22.79	0.00
2695	21Aug 1999	6461.38	4107.64	27.00	377.34	0.00	4604.00	4092.93	3430.00	24.12	0.00
2696	28Aug 1999	6461.38	1408.84	27.00	378.94	0.00	4604.00	4092.93	3100.00	25.05	0.00
2697	4Sep 1999	6419.39	2146.84	27.00	399.15	0.00	3961.71	3450.64	2940.00	26.36	0.00
2698	11Sep 1999	6387.89	784.92	27.00	413.78	0.00	3480.00	2968.93	2320.00	27.22	0.00
2699	18Sep 1999	6387.89	2433.72	27.00	414.63	0.00	3480.00	2968.93	2340.00	27.66	0.00
2700	25Sep 1999	6387.89	414.92	27.00	415.34	0.00	3480.00	2968.93	1950.00	28.10	0.00
2701	2Oct 1999	6089.44	2934.57	27.00	419.88	0.00	3496.57	3004.63	2470.00	29.09	0.00
2702	9Oct 1999	5343.32	-578.32	27.00	428.32	0.00	3538.00	3046.06	1440.00	30.36	0.00
2703	16Oct 1999	5343.32	1271.68	27.00	428.24	0.00	3538.00	3046.06	2730.00	31.57	0.00
2704	23Oct 1999	5343.32	-278.32	27.00	428.27	0.00	3538.00	3046.06	1710.00	32.35	0.00

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Location No=		40.	40.	40.	40.	40.	50.	50.	50.	50.	50.
Period	Date:	GAT Loc Incr	GAT Inflow	GAT Outflow	GAT Evaporat	GAT Q-Spill	MAD Loc Incr	MAD Inflow	MAD Outflow	MAD Evaporat	MAD Q-Spill
2705	30Oct 1999	5343.32	1161.68	27.00	428.26	0.00	3538.00	3046.06	2620.00	33.42	0.00
2706	6Nov 1999	8798.57	2375.65	27.00	361.58	0.00	4654.00	4156.59	1730.00	30.08	0.00
2707	13Nov 1999	9374.45	3421.10	27.00	352.14	0.00	4840.00	4342.59	2150.00	31.13	0.00
2708	20Nov 1999	9374.45	3481.10	27.00	353.98	0.00	4840.00	4342.59	2210.00	32.75	0.00
2709	27Nov 1999	9374.45	3431.10	27.00	355.83	0.00	4840.00	4342.59	2160.00	34.23	0.00
2710	4Dec 1999	10757.73	5883.21	27.00	329.09	0.00	8057.71	7557.57	3410.00	33.84	0.00
2711	11Dec 1999	11795.19	6994.82	27.00	309.74	0.00	10471.00	9970.86	3620.00	34.80	98.44
2712	18Dec 1999	11795.19	7840.79	27.00	313.28	0.00	10471.00	9970.86	4465.98	37.59	1099.11
2713	25Dec 1999	11795.19	13306.91	4671.23	317.16	404.06	10471.00	9970.86	9932.09	38.77	6629.49
2714	1Jan 2000	11795.19	13205.79	12886.66	319.13	8648.52	10471.00	9965.39	9926.63	38.77	6624.03
	Sum =	10347378.00	1906004.50	349372.91	1556636.50	124457.89	7047526.00	5675373.50	5564221.50	111145.23	67752.23
	Max =	18071.00	14984.48	14311.20	1007.87	10073.06	10471.00	9970.86	9932.09	119.33	6629.49
	Min =	-398.32	-6547.96	0.00	294.73	0.00	108.34	-284.27	0.00	13.80	0.00
	PMax=	989.00	989.00	989.00	1472.00	989.00	2711.00	2711.00	2713.00	106.00	2713.00
	Avg =	3812.59	702.29	128.73	573.56	45.86	2596.73	2091.15	2050.19	40.95	24.96
	PMin=	2154.00	837.00	1530.00	2024.00	1.00	1628.00	485.00	69.00	2473.00	4.00

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ATTACHMENT 3

REVIEW OF ACP OPERATION STUDIES

Date: August 05, 2003

To: Michael Newbery

From: Khalid Jawed

Subject: Review of HEC-5 Simulation Run

I have reviewed the input and output files of HEC-5 simulation run # COC 10090 (2.775 & 99.6%). My understanding and findings of this run are discussed below.

Cocle Del Norte Reservoir

1. Cocle reservoir (designated as 300) was operated for a control point (CP) 301 and Indio reservoir (designated as 200). The flow from Cocle was first routed to CP 301 and then to Indio reservoir.
2. Capacity of the tunnel between Cocle and Indio was affected by the reservoir levels in Indio. Nine sets of capacity curves were provided as input, with the Indio reservoir levels at 40, 45, 50, 55, 60, 65, 70, 75 and 80 meters.
3. A power plant, installed capacity 20,000 kW, was considered on the tunnel.
4. A second power plant, designated as CP 290 (Cocle hydropower reservoir) was also operated. The CP 290 received flow from Cocle reservoir when the level was above 100 meters and also received flow from CP 301, when flow exceeded the tunnel capacity.
5. No rule curve was used for the operation of Cocle reservoir. Probably, the criterion used was to minimize the shortages at Gatun.
6. About 12 cms flow was released for in-stream flow requirements.
7. Shortages in Gatun occurred in 1987 to 1990, 1995 and 1998. During the weeks of shortages, Cocle reservoir was at its minimum elevation of 90 meters.
8. Spills from the reservoir are properly accounted for, and are routed to CP 290.

Cocle reservoir elevations, inflows from the drainage area, outflows to Indio reservoir and outflows to power plant (power spills) for the period from 1948 to 1999 are plotted on Exhibit 1. The four sets of data appear to be consistent.

Rio Indio Reservoir

1. The inflows from drainage basin, inflows from Cocle del Norte and outflow to Gatun appear to be consistent. However, the operation of Indio shows significant variations (see Exhibit 2). For the period from 1948 to about 1972, releases of about 380 cms were made during a number of weeks. During these weeks, the reservoir elevation in Indio was near 80 meters and the elevations in Cocle reservoirs were above about 95 meters. During this period, the Indio reservoir reached the maximum level of 80 meters quite frequently. After about 1976, the Indio reservoir reached the maximum level of 80 meters only two times and there were no releases of more than about 230 cms. A review of the local inflows to the

reservoir showed that during the period from 1948 to 1972, there were a number of wet years. The releases of about 380 cms occurred during these wet years. There is no wet year of previous magnitude during the period from about 1976 to 2000. Therefore, it was concluded that the operation of Indio reservoir was consistent with that of Cocle.

2. Spills from the reservoir above elevation 80 meters, are not printed. This should be printed to approximately check the water balance in the reservoir.
3. Shortages in Gatun occurred in 1987 to 1990, 1995 and 1998. During the weeks of shortages, Indio reservoir was at its minimum level of 40 meters.

Indio elevations, inflows from the drainage area, inflows from Cocle reservoir and outflows to Gatun for the period from 1948 to 1999 are plotted on Exhibit 2. The four sets of data appear to be consistent.

The operation of Gatun and Madden reservoirs also are consistent with logic adopted for this simulation run, that is, minimize shortages at Gatun.

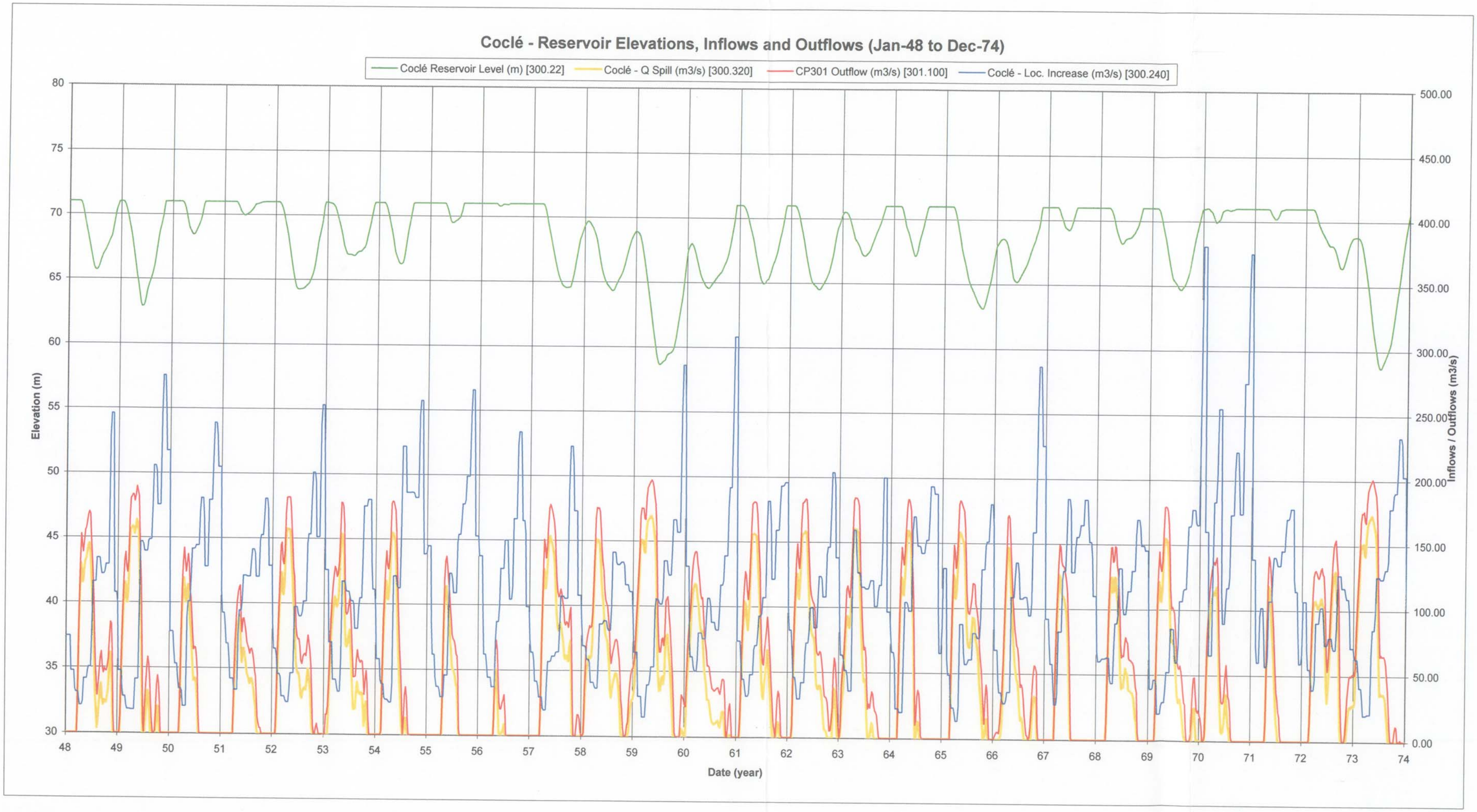
NOTE

The exhibits are presented for final operation study runs selected for the feasibility study. Additional exhibits for the final operation study runs for the Cocle del Norte acting in full regulation with Rio Indio are also provided here for information only.

Exhibits

1	Coclé Reservoir Elevations, Inflows and Outflows
2	Río Indio Reservoir Elevations, Inflows and Outflows
3	Coclé – Indio Elevation v. Outflow
4	Indio – Gatun Elevation v. Outflow
5	Coclé Reservoir Elevations, Inflows and Outflows
6	Río Indio Reservoir Elevations, Inflows and Outflows
7	Coclé – Indio Elevation v. Outflow
8	Indio – Gatun Elevation v. Outflow

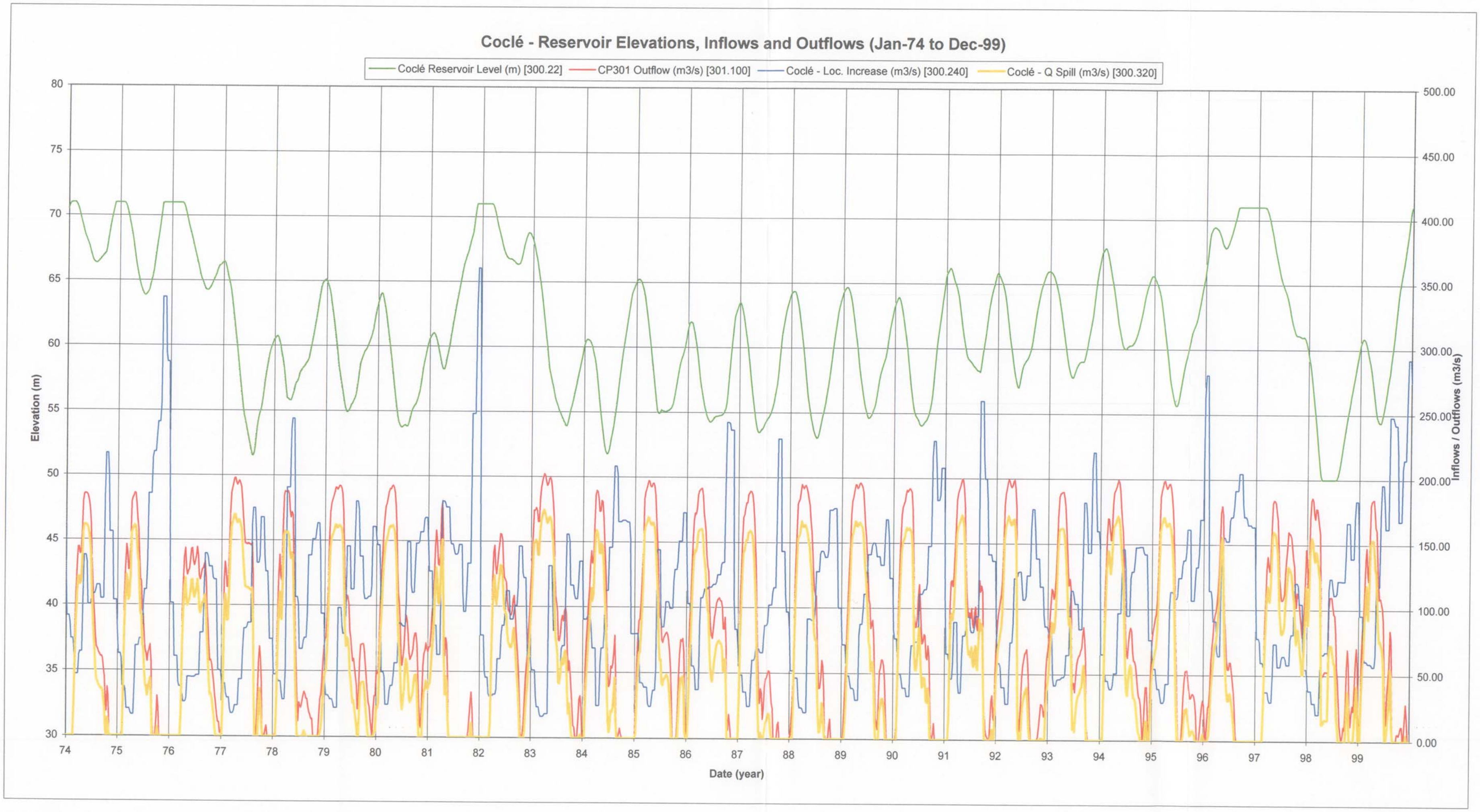
Panamá Canal Authority
Cocle del Norte



5-Aug-03
CO7150NW(tun=9m&16.5km((2.733&99.6%).OUT

MWH

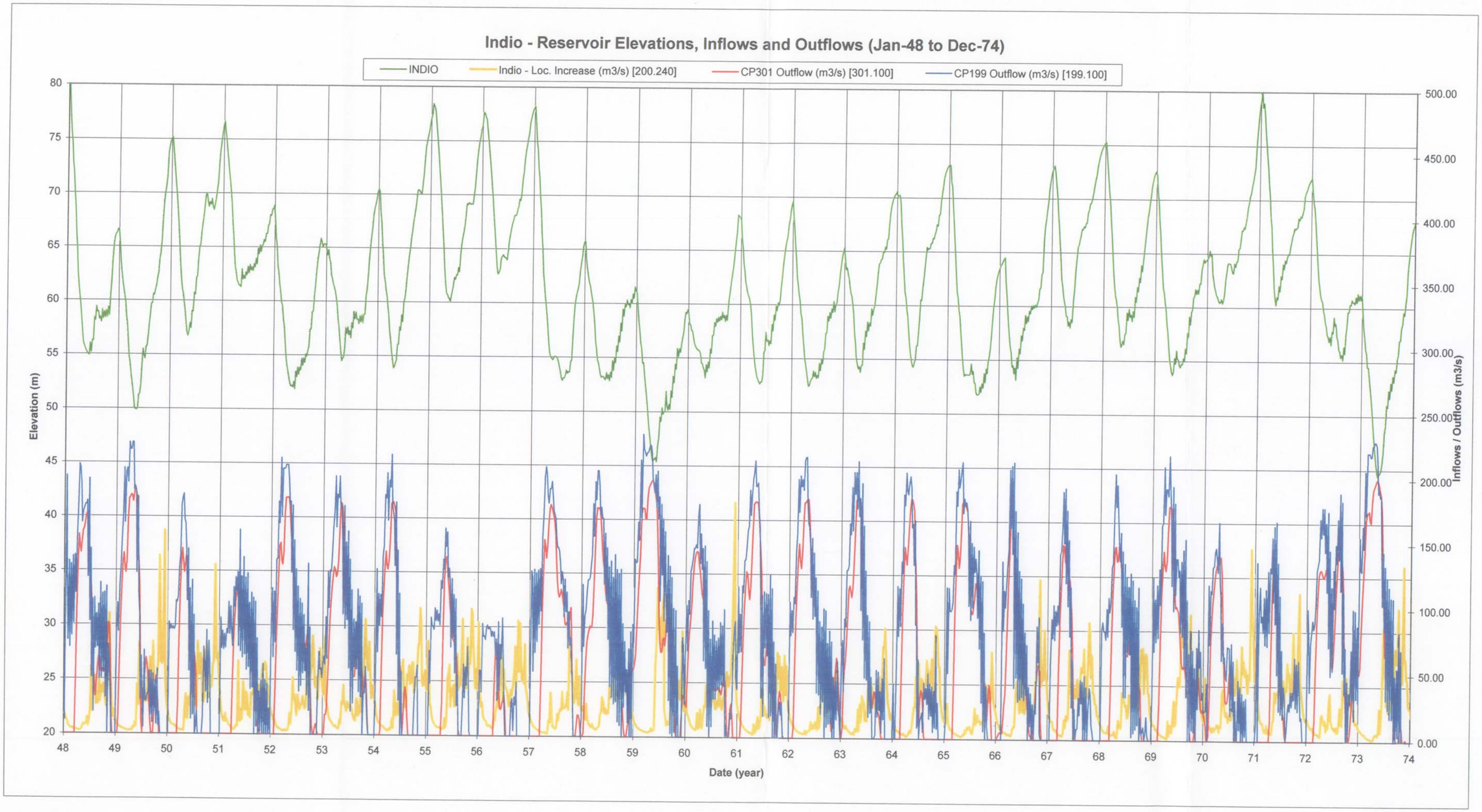
Panamá Canal Authority
Coclé del Norte



5-Aug-03
CO7150NW(tun=9m&16.5km((2.733&99.6%).OUT

MWH

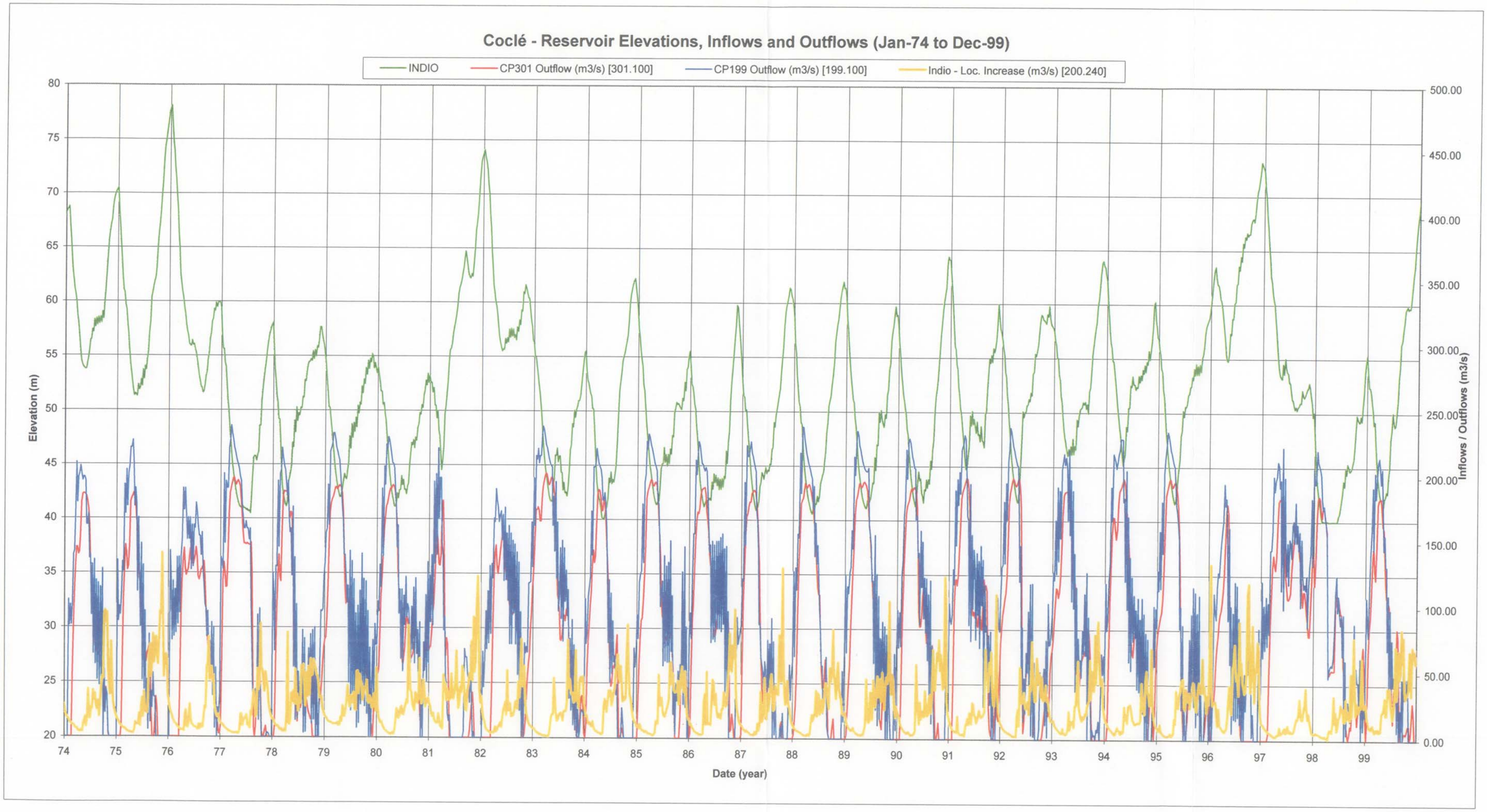
Panamá Canal Authority
Río Indio



5-Aug-03
CO7150NW(tun=9m&16.5km((2.733&99.6%).OUT

MWH

Panamá Canal Authority
Río Indio



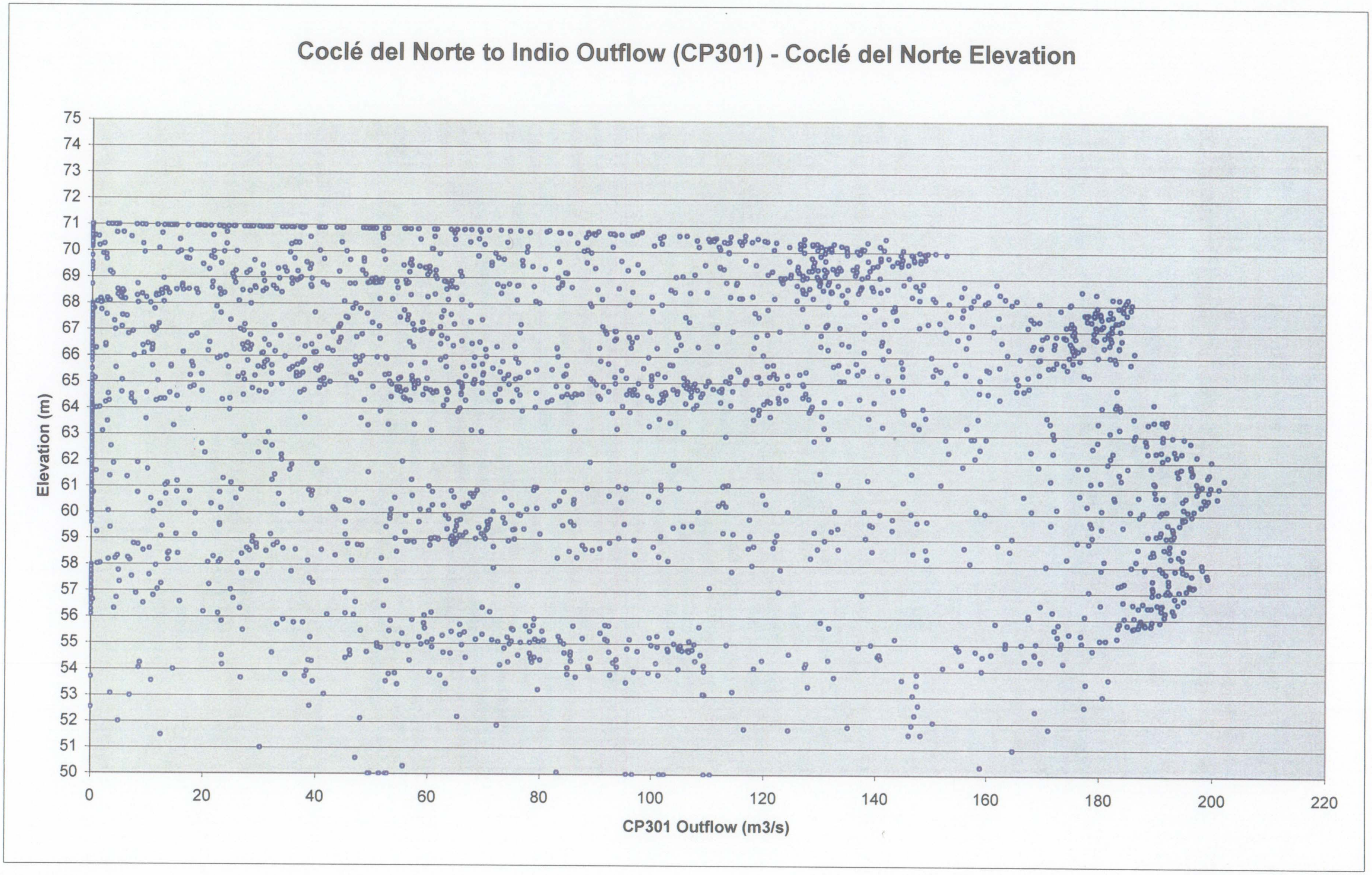
5-Aug-03
CO7150NW(tun=9m&16.5km((2.733&99.6%).OUT

MWH

Panamá Canal Authority

Coclé del Norte - Indio

Exhibit 3



5-Aug-03

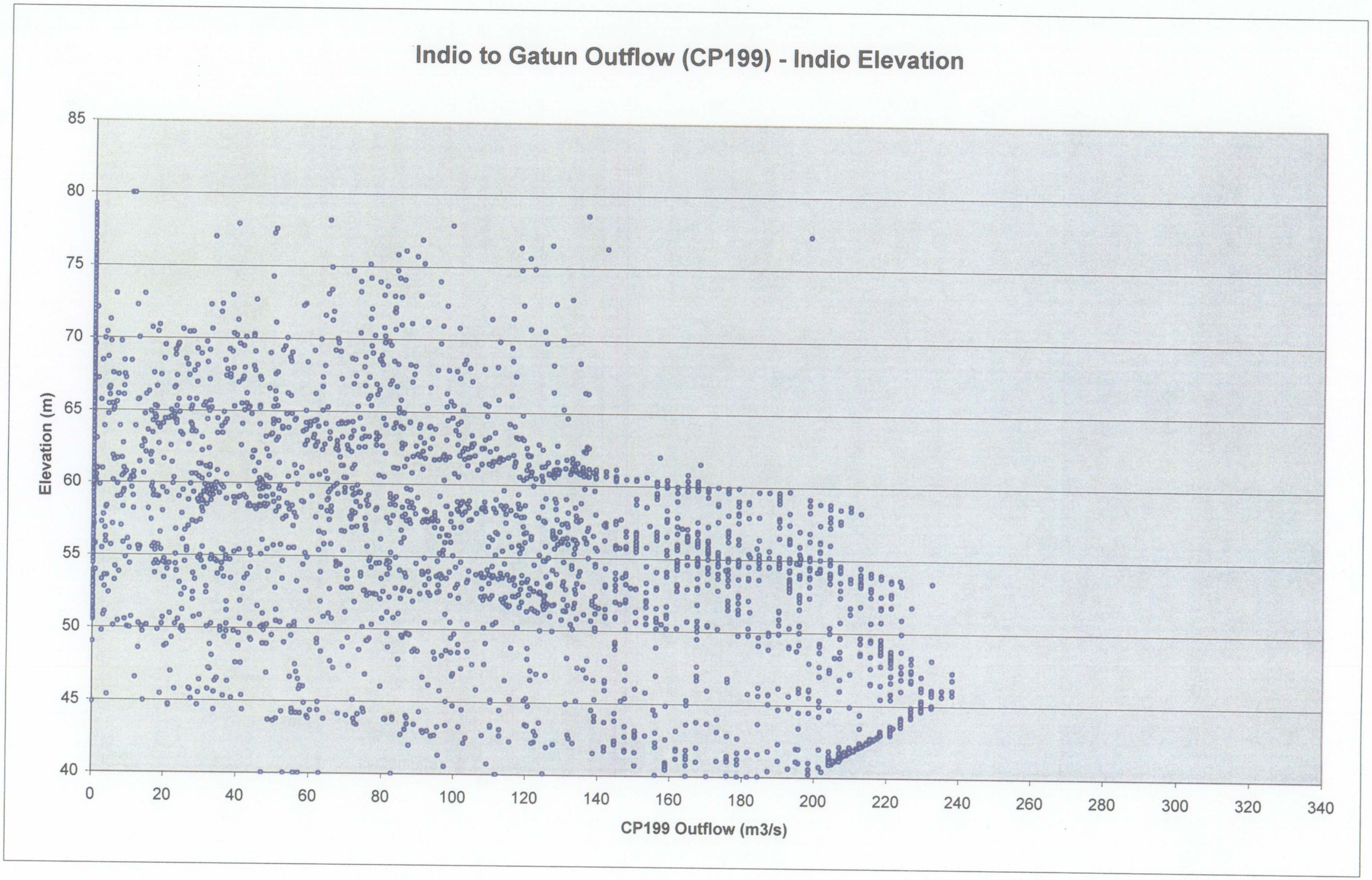
CO7150NW(tun=9m&16.5km((2.733&99.6%).OUT

MWH

Panamá Canal Authority

Indio - Gatun

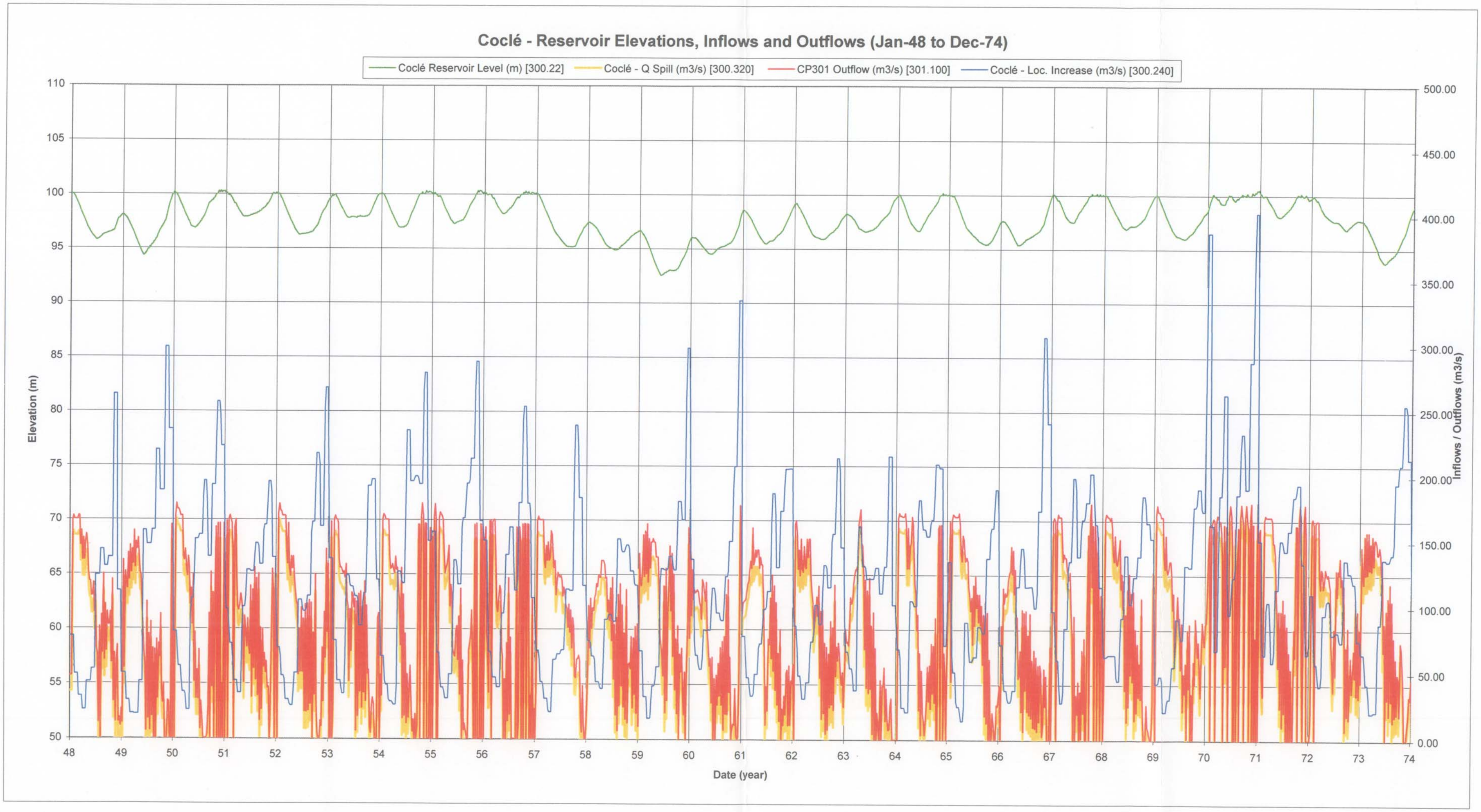
Exhibit 4



5-Aug-03
CO7150NW(tun=9m&16.5km((2.733&99.6%).OUT

MWH

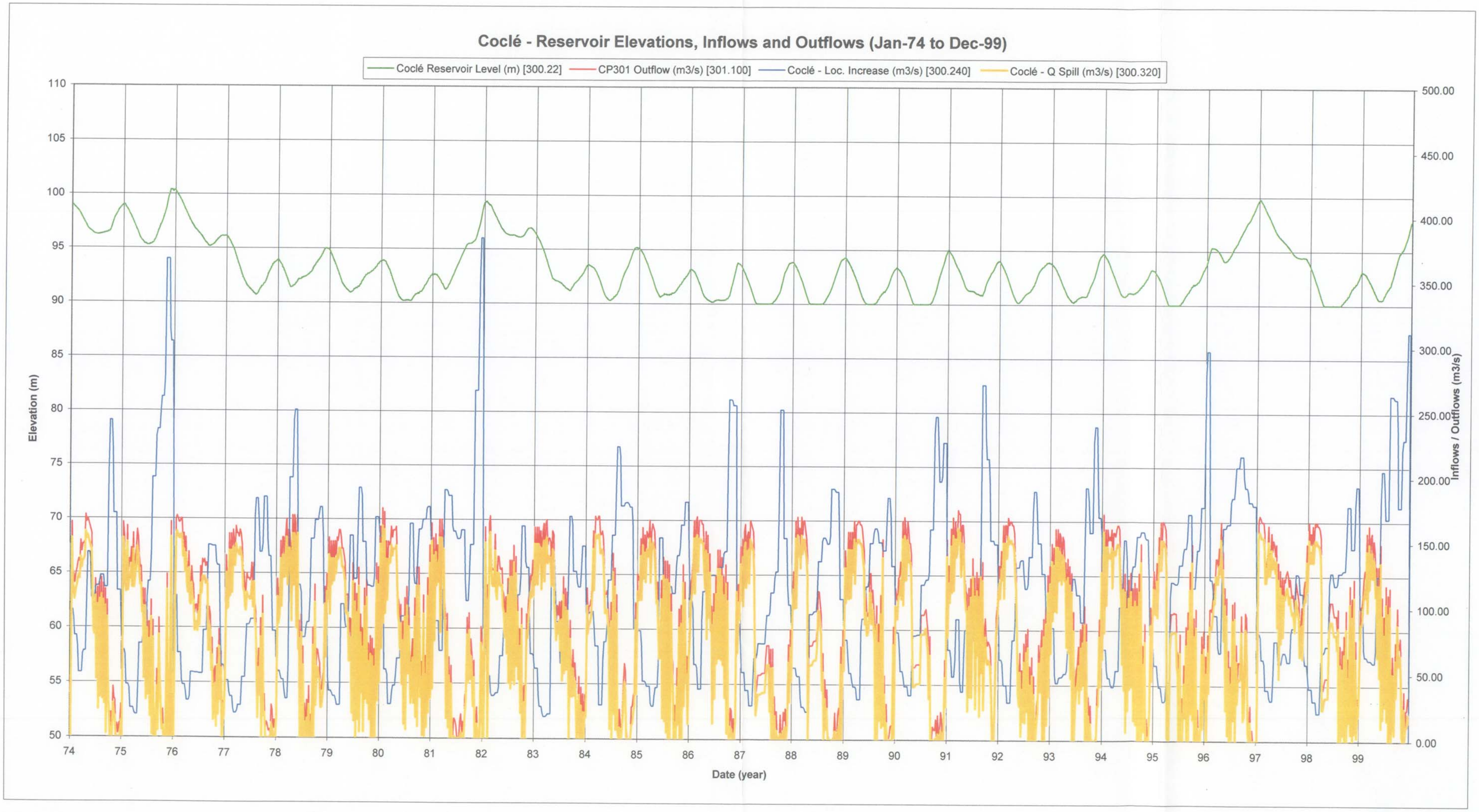
Panamá Canal Authority
Coclé del Norte



Aug-5-03
COC10090(2.775&99.6%).OUT

MWH

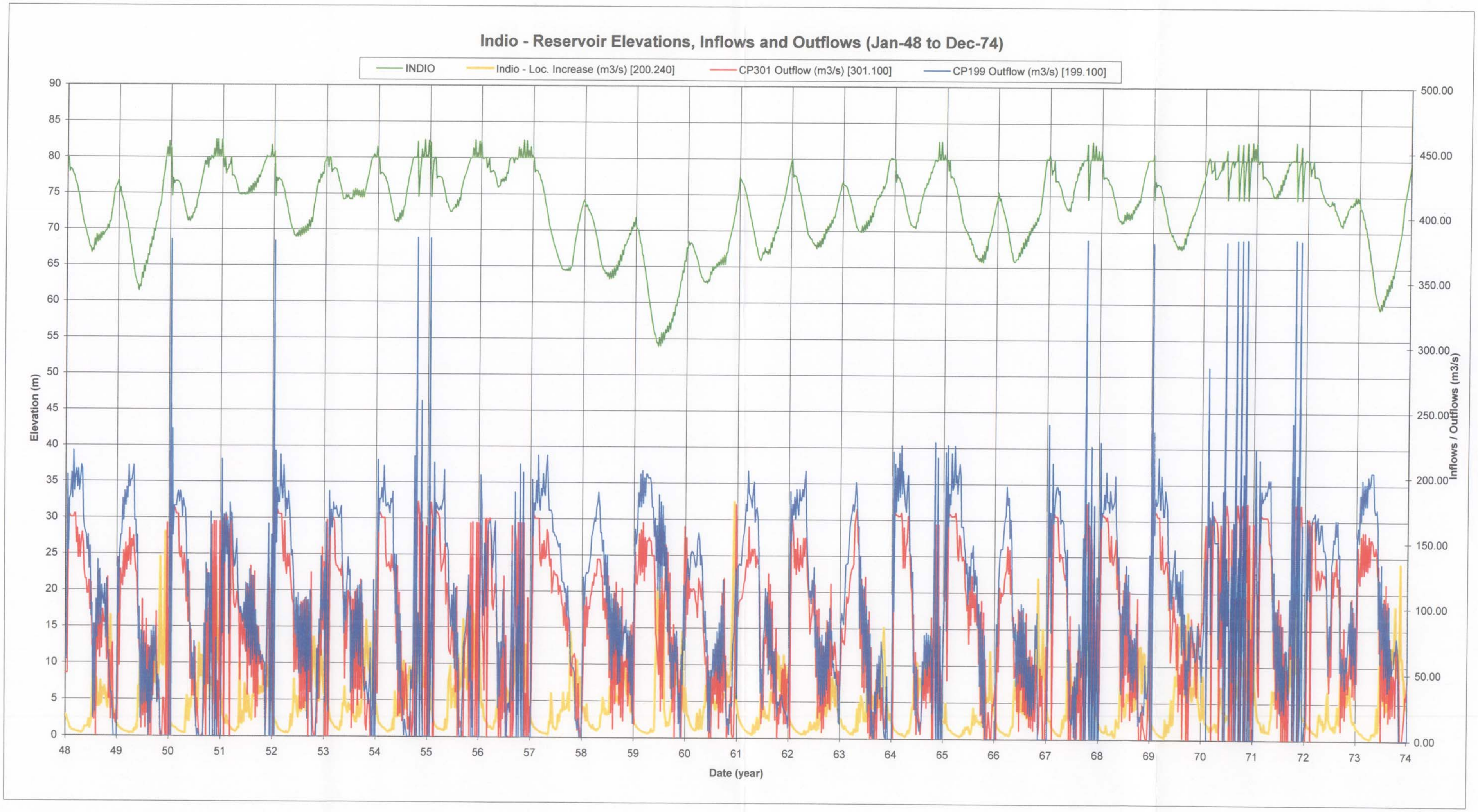
Panamá Canal Authority
Cocle del Norte



Aug-5-03
COC10090(2.775&99.6%).OUT

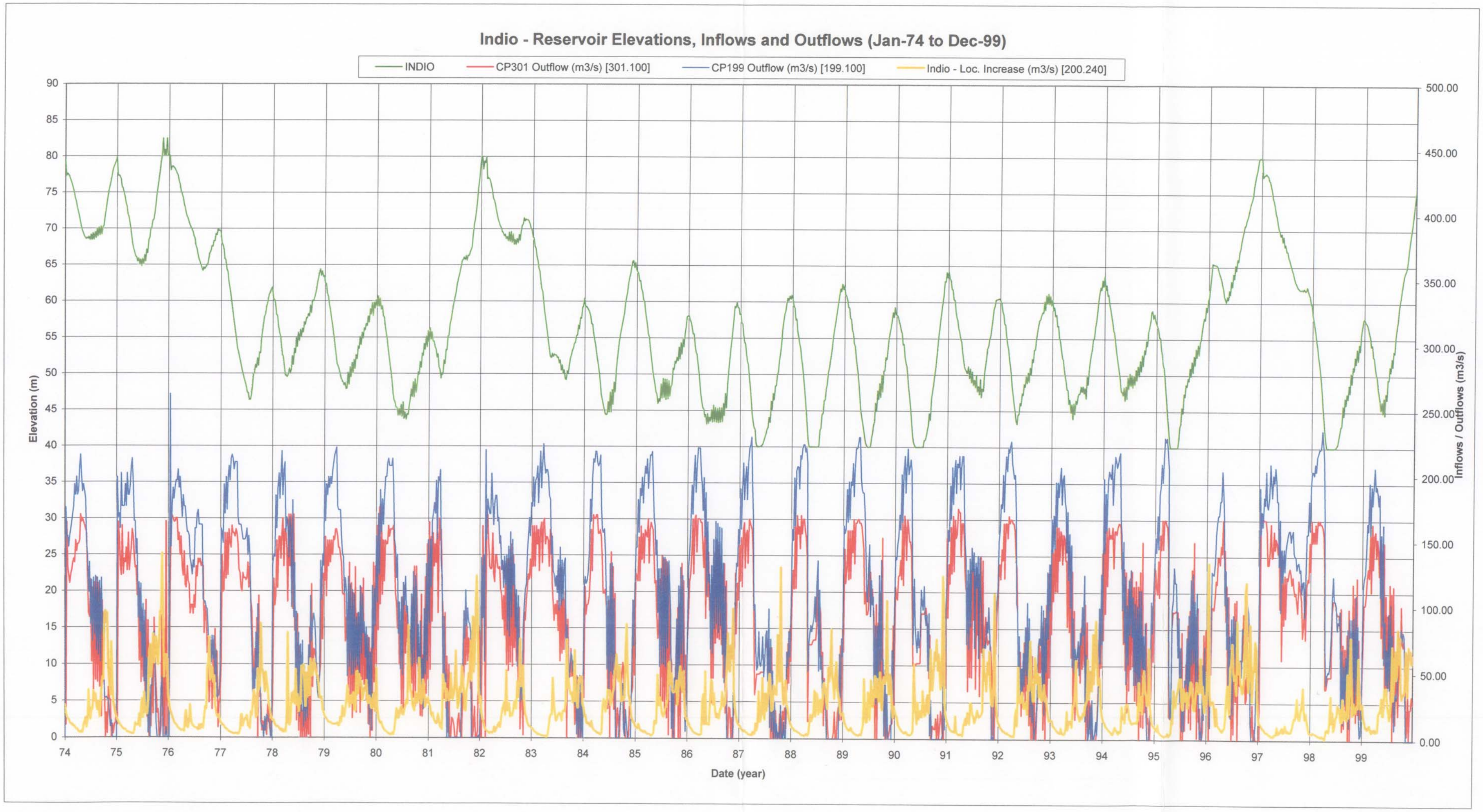
MWH

Panamá Canal Authority
Río Indio



Aug-5-03
COC10090(2.775&99.6%).OUT

MWH


Indio - Reservoir Elevations, Inflows and Outflows (Jan-74 to Dec-99)
INDIO
CP301 Outflow (m3/s) [301.100]
CP199 Outflow (m3/s) [199.100]
Indio - Loc. Increase (m3/s) [200.240]
Elevation (m)
Inflows / Outflows (m3/s)
Date (year)
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
85
90
0.00
50.00
100.00
150.00
200.00
250.00
300.00
350.00
400.00
450.00
500.00
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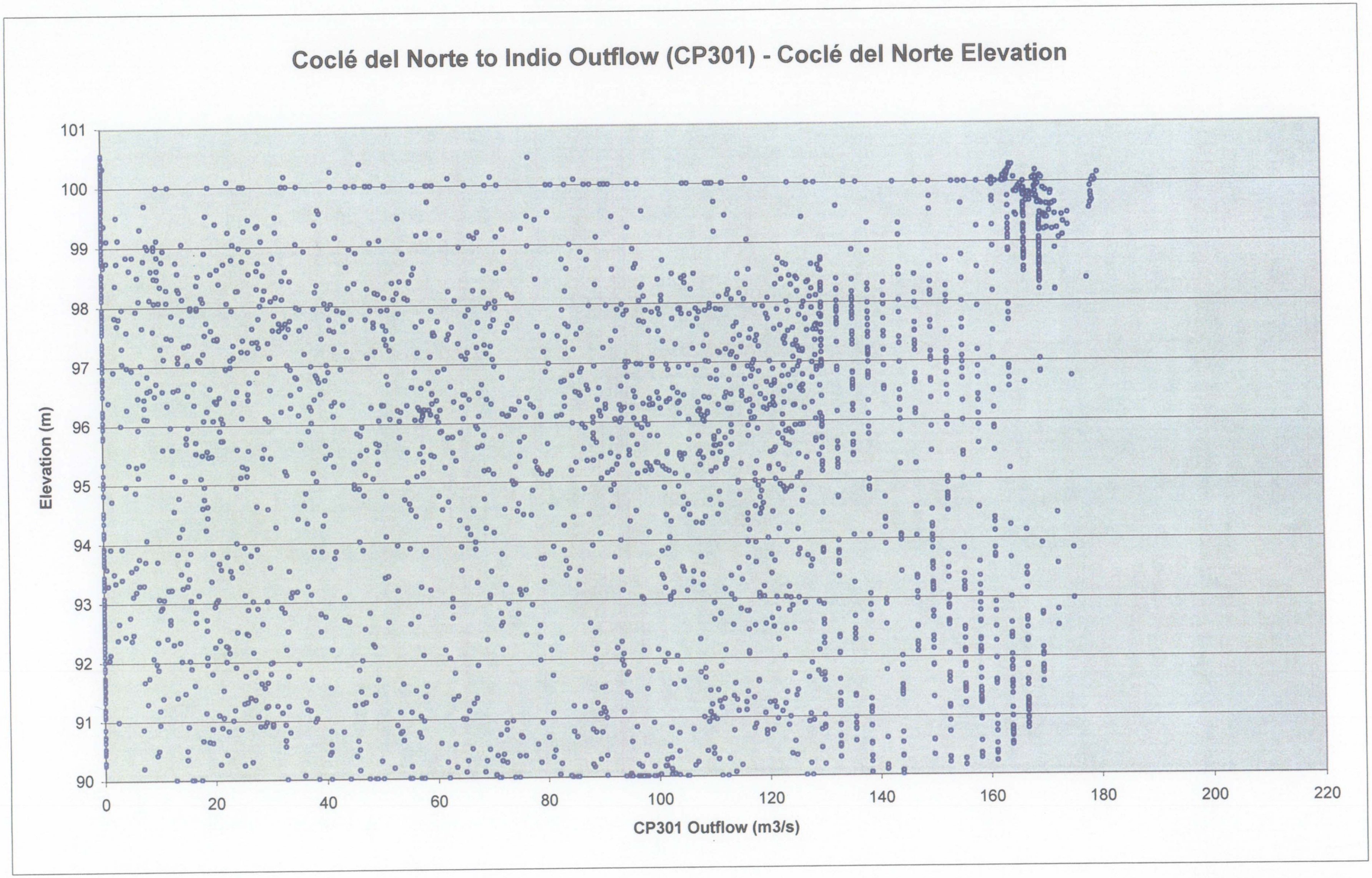
Panamá Canal Authority

Exhibit 7

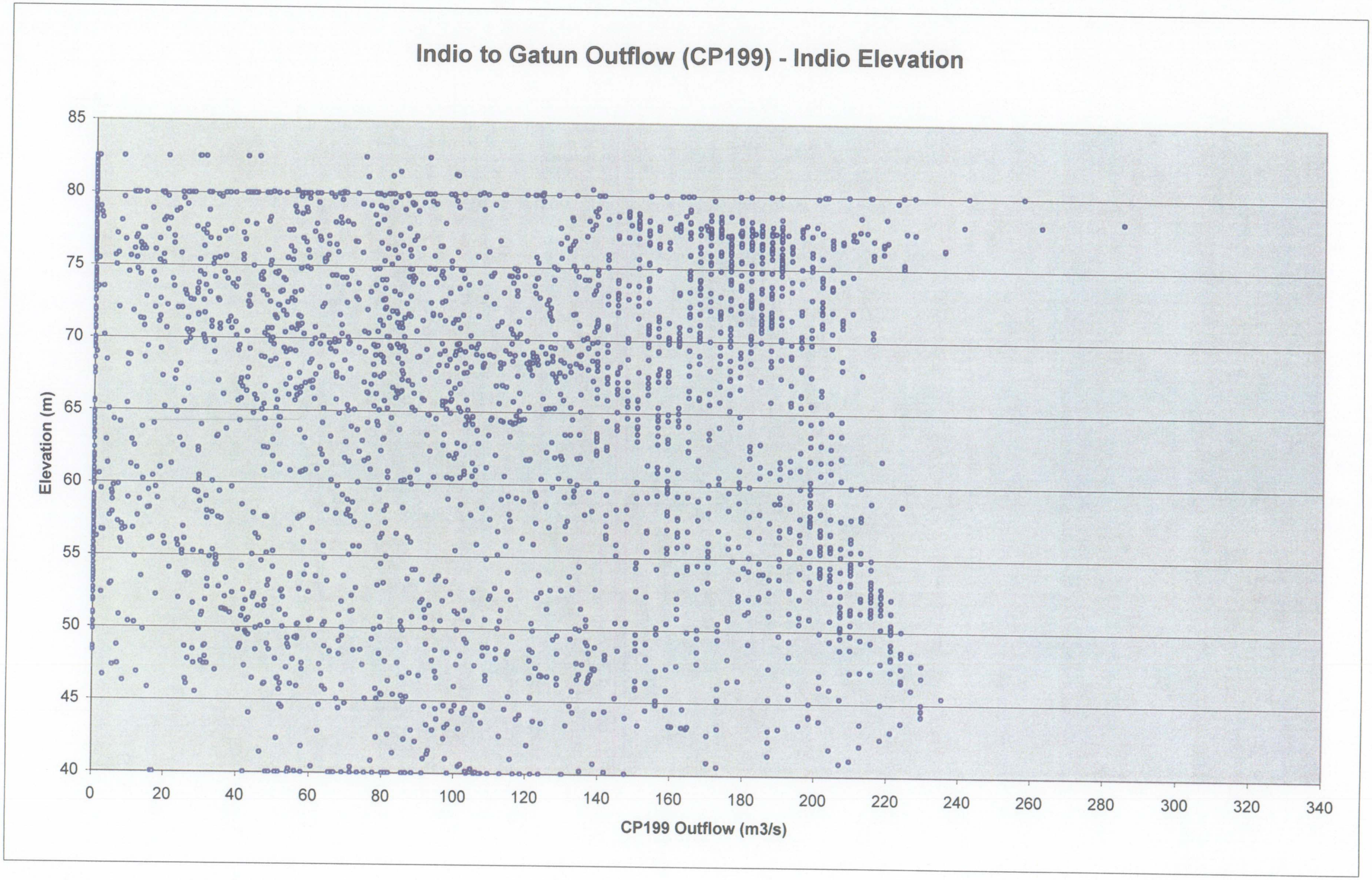


Aug-5-03
COC10090(2.775&99.6%).OUT

MWH

Panamá Canal Authority

Exhibit 8



Aug-5-03
COC10090(2.775&99.6%).OUT

MWH