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

Panama Canal

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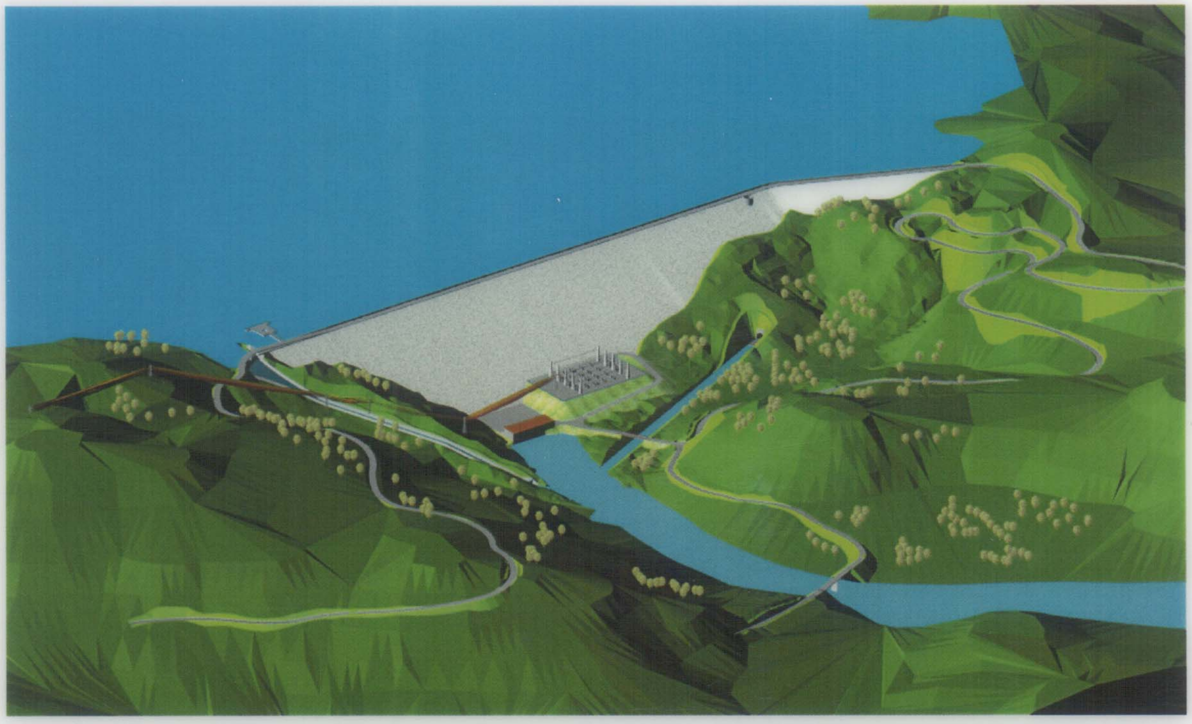
The Ríos Coc
Norte And Caño
Water Supply Pr

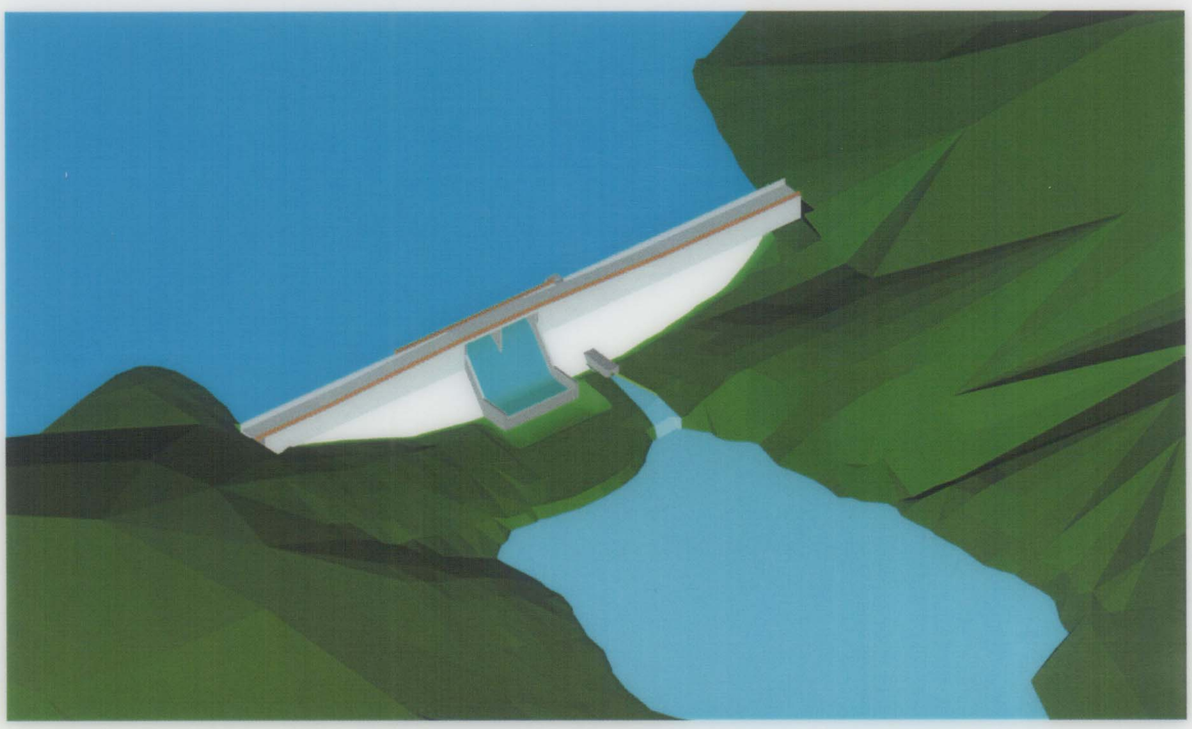
Contract Number C

VOLUME 2: MAIN R
Coclé Del Norte-Caño
Río Indio

December 2003

Coclé del Norte with Caño Sucio and Río Indio





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

THE PANAMA CANAL

ENGINEERING SERVICES

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

Volume 2

150.00

Feasibility Study Of The
Río Coclé del Norte Reservoir Acting in Full Regulation
With The
Río Caño Sucio and Río Indio Reservoirs

DECEMBER 2003

MWH
In association with
TAMS Consultants, Inc.
Ingenieria Avanzada, S.A.
Tecnilab, S.A.

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**
3	Appendix A – Hydrology, Meteorology and River Hydraulics Appendix B – Geology, Geotechnical and Seismological Studies Appendix C – Operation Simulation Studies
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Executive Summary

EXECUTIVE SUMMARY

INTRODUCTION

The ACP is undertaking a canal capacity study, which includes the evaluation of additional sources of water to augment Canal capacity. The transit of ships through the Panama Canal is dependent upon the availability of the fresh water stored in Madden and Gatun reservoirs. Water availability is limited and, even at present traffic levels, is not sufficient to meet traffic demand during prolonged dry periods. Therefore, new sources of water must be identified, defined, and evaluated.

The US Army Corps of Engineers (USACE) performed a reconnaissance study for the Panama Canal Commission to identify and evaluate potential water supply projects. A reservoir on the Río Coclé del Norte, operating between elevations 90 m and 100 m and in conjunction with reservoirs on the Río Caño Sucio and Río Indio, was recommended as a feasible alternative for further consideration to develop a long-term water supply plan.

The Autoridad del Canal de Panama (ACP), formerly the Panama Canal Commission, has authorized Montgomery Watson Harza, formerly Harza Engineering Company, to perform an engineering feasibility study of this project under Contract CC-3-536, Work Order 005, dated June 19, 2000.

OBJECTIVE OF THE STUDY

The original objective of this study was to determine the technical and economic feasibility of the project. An assessment of the environmental feasibility was to have been performed separately under the direction of the ACP.

During the course of the study, it was decided by the ACP that water resources development in the Río Coclé del Norte basin would only occur in conjunction with a plan to add new locks to the Panama Canal System. Under this assumption, the demand for and benefits from developing the Río Coclé del Norte Project could not be assessed at this time. Therefore, a determination of economic feasibility was not possible. The objective of the study was changed to an assessment of technical feasibility.

HYDROLOGY AND RIVER HYDRAULICS

Studies were performed to confirm the long-term streamflow sequences at the Río Coclé del Norte and Río Caño Sucio damsites, to estimate the spillway design floods at each site, and to estimate the impact of reservoir sedimentation.

A long-term flow sequence (1948-1999) at the Río Coclé del Norte damsite was generated by adding the data from El Torno and Batatilla, adjusted for drainage area and rainfall. The flows at El Torno and Batatilla were completed using correlations with El Chorro, Los Canones and Boca de Uracillo. The mean annual flow at the Río Coclé del Norte damsite is estimated to be 107.5 m^3/s and the monthly distribution of flow is shown below

MONTHLY MEAN STREAMFLOW AT THE RÍO COCLÉ DEL NORTE DAMSITE
(m^3/s)

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
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

There are no flow data available for the Río Caño Sucio. The long-term flow sequence was generated using the monthly flows of the Río Indio at Boca de Uracillo and a drainage area ratio (about 0.304) between the two locations.

The mean annual flow at the damsite is estimated to be 7.5 m^3/s and the monthly distribution of flow is shown below:

MONTHLY MEAN STREAMFLOW AT THE RÍO CAÑO SUCIO DAMSITE
(m^3/s)

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
4.8	2.4	1.6	1.8	4.6	7.8	8.0	9.5	10.9	14.4	14.3	10.3	7.5

The probable maximum floods (PMF), based on probable maximum precipitation (PMP) were adopted as the spillway design flood for both dams. PMP estimates of 714 mm and 679 mm were adopted for the Río Coclé del Norte and Río Caño Sucio basins respectively based on information presented in the National Weather Service publication of PMP dated 1978. Using the HEC-1 computer model and allowing for a based flow estimated from an analysis of major historic floods, the PMF for each dam was estimated as follows:

Dam	Peak Inflow (m^3/s)	Flood Volume (MCM)
Río Coclé del Norte	10,550	1,005 (5-day)
Río Caño Sucio	1,690	80 (3-day)

The impact of sediment deposition on storage in the reservoir was evaluated using data from the Río Coclé del Norte basin, Lake Madden and other sources. After 100 years, it is expected that sediment deposition will reduce the live storage of the Río Coclé del Norte reservoir by about 1 percent and, therefore, presents no problem. The impact of the project on the Río Caño Sucio and Río Indio reservoirs cannot be estimated without modeling. The transfer of large volumes of water from the Río Coclé del Norte to these reservoirs will impact sediment deposition. In the Caño Sucio Reservoir, an allowance will be included for continuous dredging. No allowance has been included for the Indio Reservoir.

GEOLOGIC CONDITIONS

The geologic conditions were established on the basis of geologic mapping, geomorphological analysis, photogeologic studies, a moderate subsurface investigation program, and construction materials investigations.

Río Coclé del Norte Damsite

Bedrock at the dam site is found to consist mostly of porphyritic basalt and, less commonly of basic agglomerate. 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.

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.

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. From regional geologic mapping and photogeologic studies, the presence of major faults, however, is not expected. Some photogeologic linears, shown on Exhibit 2-5, have been interpreted in the dam site area but these are not thought to be caused by significant faulting.

In general, the basaltic foundation bedrock at the site should provide a suitable foundation for all types of structures being considered.

Río Caño Sucio Damsite

The Río Caño Sucio dam site is located at the upstream end of an approximately 250-m long waterfalls section. The main drop at the falls is about 7 m high, but several smaller falls and cataracts are located downstream over a horizontal distance of about 200 m.

Bedrock units in the Río Caño Sucio project area consist of Tertiary sedimentary rocks. A medium to coarse-grained sandstone occurs at the proposed dam site, cropping out at the waterfalls and in the riverbed. Abutments at the damsite are covered by residual soils and weathered sandstone float. In outcrop, the sandstone is locally strong, moderately hard, and erosionally resistant, as evidenced by the formation of the waterfalls. The shape of the river valley and absence of rock exposure above the valley floor suggest that the slopes forming either side of the river valley consist of residual overburden to some depth.

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. In regard to other 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 Río Caño Sucio Dam.

Water Transfer Facilities

The water transfer facilities will consist of a combination of canals and tunnels. 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.

The first part of the water transfer facilities, from the Río Coclé drainage to the Río Caño Sucio drainage, will require excavation through the saddle area at Quebrada Encantada. The excavation will be through 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 Río 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.

It is probable that excavation of the 2,550-m long tunnel from the Río 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.

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.

For the Río Caño Sucio project, most of the facilities are comprised of concrete or roller compacted concrete and, therefore, the required construction material is concrete aggregate. All coarse and fine aggregate for concrete needs to be manufactured from quarried igneous rock materials, *i.e.* basalt or andesite. Quarry sites for obtaining this material were identified 5-6 km southeast of the damsite at Cerro Miguel and Cerro Loma Alta.

At the Río Coclé del Norte site, the 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.

The majority of the rockfill and all aggregates (including coarse and fine aggregates for concrete, filters, drains, and riprap) for the Río Coclé del Norte Project 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. The area one to three kilometers to the east of the damsite consists of high hills that could be stripped and opened as quarries.

Materials for backfill will come from the required excavations, including use of tunnel excavation spoil. A portion of the rockfill for the dam also could be obtained from required excavation, provided that it is not too decomposed.

It is anticipated that some mixing with imported sands and silts will be necessary.

DESCRIPTION OF THE PROJECT

Implementation of a project to result in the impoundment of the Río Coclé del Norte Reservoir that will operate in full regulation with the Río Caño Sucio and Río Indio Reservoirs will require the construction of:

- A dam on the Río Coclé del Norte,
- A dam on the Río Caño Sucio,
- A combination of canal and tunnel to transfer water from the Río Coclé del Norte Reservoir through the Río Caño Sucio Reservoir to the Río Indio Reservoir, and
- A second tunnel between the Río Indio Reservoir and Lake Gatun.

In addition, it has been determined that a power plant at the base of the Río Coclé del Norte dam is feasible. Commercial agriculture associated with the development of the project is not warranted at this time. A general plan of the project is shown on Exhibit 1.

Río Coclé del Norte Dam and Reservoir

The major elements that comprise the storage facility on the Río Coclé del Norte include:

- A 113-m high concrete-face rockfill dam with its crest at El. 101 and top-of-structure at El. 103,
- A 50-m wide spillway in the right abutment with a capacity at full surcharge of 250 m^3/s,
- An 8-m diameter, D-shaped tunnel in the left abutment sized to pass the 50-year flood and provide for drawdown in the case of emergency,
- A 75 MW powerplant at the base of the dam, incorporating a minimum release facility.

The dam will impound a reservoir with a gross storage capacity of about 14,440 MCM and operate between El. 100, the full supply level, and El. 90. Live storage between El. 100 and El. 90 will be about 3,840 MCM. The reservoir area at the full supply level is 414 square kilometers.

Of the total project yield of 3,570 MCM/year, the yield resulting from the addition of the Río Coclé del Norte reservoir is 3,380 MCM/year or 44.5 lockages/day. The 75 MW powerplant will contain three equal-sized units and generate an average of 410 GWh/year ranging from 538 GWh/year in the initial years of operation to 76 GWh/year at the end of its economic life.

A general site plan of the Río Coclé del Norte Project, showing the location of the dam and appurtenant works is shown on Exhibit 2.

Río Caño Sucio Dam and Reservoir

The major elements that comprise the storage facility on the Río Caño Sucio include:

- A 22-m high roller compacted concrete (RCC) dam at the waterfall site with its crest at El. 103 and top-of-structure at El. 105,
- A 25-m wide spillway over the face of the dam with a capacity at full surcharge of 430 m^3/s
- A diversion conduit to pass the 50-year dry-season flood
- A minimum release facility

The dam will impound a reservoir with a gross storage capacity of about 73 MCM and operate between El. 100, the full supply level, and El. 90. Live storage between El. 100 and El. 90 will be 68.5 MCM. The reservoir area at the full supply level is 12.4 square kilometers. The system yield allocated to the project is estimated to be 190 MCM/year or 2.5 lockages/day.

A general site plan of the development, showing the arrangement of the dam and its appurtenant works is shown on Exhibit 3.

Water Transfer Facilities to Río Indio Reservoir

To transfer water from the Río Coclé del Norte reservoir to the Río Indio basin, it is necessary to construct:

- An 6,500-m long west branch of canal through the divide between the Río de U and the Río Limon to the Río Caño Sucio
- A 8,650-m long canal east branch along the Río Caño Sucio and Río Cerro Miguel to the headrace of a tunnel to the Río Indio basin, and
- A 2,550-m long, 5.5-m diameter tunnel.

The dimensions of the facilities are controlled by the requirement to pass about 160 m3/s when the Río Coclé del Norte reservoir is at its minimum level (El. 90). A plan showing the canal and tunnel alignment is presented on Exhibit 4.

Second Tunnel from Río Indio Reservoir to Lake Gatun

According to the present concept, the Río Indio Project will have been constructed about 20 to 30 years prior to any Río Coclé del Norte Project configuration. As described in the Río Indio Water Supply Project Report (2), a 4.5-m diameter tunnel is required to convey

Río Indio water to Lake Gatun. With the connection of the Río Coclé del Norte Project to the system, a second tunnel, 8250-m long with a diameter of 6.5 m, will be required. The tunnel will be aligned parallel and next to the presumed existing tunnel. A plan of the alignment is shown on Exhibit 5.

COST OF THE PROJECT

The estimated cost of the Project has been developed on the basis of the present feasibility design and construction schedule, plus a compensation and mitigation cost estimated by the ACP. The construction cost estimates represent the prevailing rates and prices in January 2003 and are based on the assumption that an international contractor will construct the water supply and hydropower facilities without restriction on sources of supplies and equipment. The unit prices have been estimated at feasibility level.

A summary of the project cost is shown below.

Item	Estimated Cost
Mitigation and Compensation Costs	**$238,000,000**
Access Roads and Construction Camp	$16,490,000
Río Coclé del Norte Storage Facilities	$190,710,000
Río Caño Sucio Storage Facilities	$6,500,000
Water Transfer Facilities	$79,750,000
Second Río Indio-Lake Gatun Tunnel	$85,520,000
Reservoir Clearing	$42,110,000
Subtotal Direct Cost	**$421,080,000**
Contingency	$77,120,000
Direct Cost	**$498,200,000**
Engineering and Administration	$74,800,000
Construction Cost (Jan 2003 price level)	**$573,000,000**
TOTAL COST	**$811,000,000**

The annual operating costs include the costs of operation and maintenance (O&M), for the various features, the cost of replacing short-life equipment, administration by the Owner, and insurance. In addition, an annual cost associated with watershed management, implementation of the environmental mitigation plan and the relocation activities is included. The annual operation and maintenance costs are summarized below:

Item	Annual Cost
O&M	$2,600,000
Replacement	$150,000
Admin and General Expenses	$700,000
Insurance	$575,000
Resettlement Administration	$150,000
Watershed Management	$150,000
Mitigation Plan Implementation	$100,000
Total (rounded)	**$4,425,000**

PROJECT IMPLEMENTATION

The durations of the construction of each component are estimated at 2.5 years for the access roads, 2 years for the Río Caño Sucio Project, 6 years for the Río Coclé del Norte Project, 3 years for the Water Transfer Facilities, and 3 years for the second Tunnel from Río Indio Reservoir to Lake Gatun. Overall the construction, including the filling of the reservoirs to levels sufficient for the project to be operational, will require nearly 8 years, with full operation achieved in under 12 years.

It is estimated that full implementation of the Project could be achieved within 17 years, with additional water being supplied within 13 years. However, the Reconnaissance Report (1) water demand schedule shows the project will not be required until about 2032, assuming that the Río Indio Water Supply Project is in operation. Therefore, the project can be initiated as late as 2019 to meet that demand schedule. If the project is selected, environmental studies, funding, design, contractor selection, can all be accommodated within this overall implementation schedule. The implementation schedule is shown on Exhibit 5.

CONCLUSIONS AND RECOMMENDATIONS

Without the information required to perform and economic and financial evaluations (for reasons given in Section 1.3.2), it is not possible to make a recommendation concerning the implementation of the project. The economic cost of water is higher than what might normally be expected for a commercial supply and approaches what might be expected for an M&I supply. However, the current benefits accruing to water supply from the Panama Canal operation also are high and may continue at this level. Therefore, development of the project cannot be ruled out, but the recommendations, at this time, can relate only to the relative attractiveness of the possible alternative developments in the basin.

Conclusions

As a result of the studies described in this report and its appendices, it is concluded that:

- The Project is technically feasible.
- The dam sites selected in the Reconnaissance Report are suitable sites for the development of the water resources of the Río Coclé del Norte and Río Caño Sucio Basins.
- A concrete-faced rockfill dam at the Río Coclé del Norte site and an RCC dam at the Río Caño Sucio sites are the most appropriate types of dam for the sites based on the available information, estimates of cost, and preferences of the ACP.
- It is our considered opinion that there are no geologic or geotechnical problems associated with the sites that cannot be accommodated using conventional solutions although the lack of subsurface investigations has increased the potential for inaccuracies in the estimate of cost.
- The yield of the Panama Canal system will increase by about 3,570 MCM/yr (about 47 L/d) with the addition of the Project.
- For the rates of growth of demand considered, the full yield of the Project is not used within 50-years and, therefore, the project is too large.
- There is no way to significantly lower both the yield and the cost of the Project (Lowering the yield will not significantly lower the cost because the minimum supply level must stay at El. 90 so that the Río Coclé del Norte Reservoir can act in full regulation with the Río Caño Sucio Reservoir. Lowering the cost can be accomplished by lowering the Coclé del Norte dam, but that would preclude operation with the Río Caño Sucio Reservoir).
- The addition of a 75 MW hydropower plant at Río Coclé del Norte dam is economically attractive.
- The inclusion of a commercial agricultural endeavor is technically feasible, but is not economically viable at this time and development should not be initiated at this time.
- Construction of the project is estimated to cost about $573 million in 2003 dollars. An addition $238 million have been allowed for compensation and mitigation for a total cost of $811 million.
- The economic cost does not compare favorably with any of the other Western Watershed Projects studied to date.

Recommendations

As a result of these conclusions, development of the Río Coclé del Norte Reservoir at a full supply level of El. 100 and acting in full regulation with the Río Caño Sucio and Río Indio Reservoirs is not recommended.

TABLE OF SIGNIFICANT DATA

Project Setting

The project is located in three adjoining watersheds identified as the "Western Watersheds". All three projects drain into the Atlantic Ocean and are located from 30km to 80 km to the west of Colon.

Hydrology		
Río Coclé del Norte		
Average Annual Precipitation	2,800	mm
Average Annual Streamflow	107.5	m^3/s
Río Caño Sucio		
Average Annual Precipitation	3,500	mm
Average Annual Streamflow	7.5	m^3/s

Río Coclé del Norte Storage Facilities		
Reservoir		
Drainage Area	1,594	km^2
Normal Maximum Water Level	El. 100	msl
Volume (rounded)	14,440	MCM
Surface Area	414	km^2
Minimum Pool Level	El. 90	msl
Volume	10,600	MCM
Surface Area	347	km^2
Live Storage	3,840	MCM
Dam		
Type of Dam	Concrete-face rockfill	
Crest Length	1,020	m
Parapet/Crest Elevation	103/101	m
Minimum Foundation Elevation	-10	m
Maximum Height	113	m
Upstream and Downstream Slope	1.4H:1.0V	
Fill Volume	6,090,000	m^3
Upstream and Downstream Slope	1.4H:1.0V	
Spillway		
Type of Spillway	Ungated ogee	
Spillway Crest Elevation	100	m
Crest width (clear)	50	m
Excavation Volume	221,000	m^3
Concrete volume	2,300	m^3

TABLE OF SIGNIFICANT DATA, cont.

Río Coclé del Norte Storage Facilities, cont.		
Spillway, cont.		
Spillway Design Flood		
Peak Inflow	10,550	m^3/s
5-day Volume	1,005	MCM
Peak Outflow	250	m^3/s
Surcharged Reservoir Level	El. 101.8	msl
Diversion During Construction		
Section Shape	modified horseshoe; vertical sides; horizontal invert	
Diameter	8.0	m
Length	550	m
Diversion Flood	3,860	m^3/s
Discharge Capacity	636	m^3/s
Upstream Cofferdam Height (maximum)	29.5	m
Downstream Cofferdam Height (maximum)	8	m
Cofferdam Fill Volume	614,000	m^3
Minimum Release Facility		
Type	Bypass in hydropower plant	
Capacity	10.7	m^3/s
Río Caño Sucio Storage Facilities		
Reservoir		
Drainage Area	111	km^2
Normal Maximum Water Level	El. 100	msl
Volume	74	MCM
Surface Area	12.4	km^2
Minimum Pool Level	El. 90	msl
Volume	5	MCM
Surface Area	2.5	km^2
Live Storage	69	MCM
Sediment (Dead) Storage	8	MCM
Dam		
Type of Dam	RCC	
Crest Length	220	m
Crest Elevation	El. 105	msl
Minimum Foundation Elevation	83	m
Maximum Height	22	m
Upstream and Downstream Slope	Vertical and 0.75H:1V	
RCC Volume	27,900	m^3

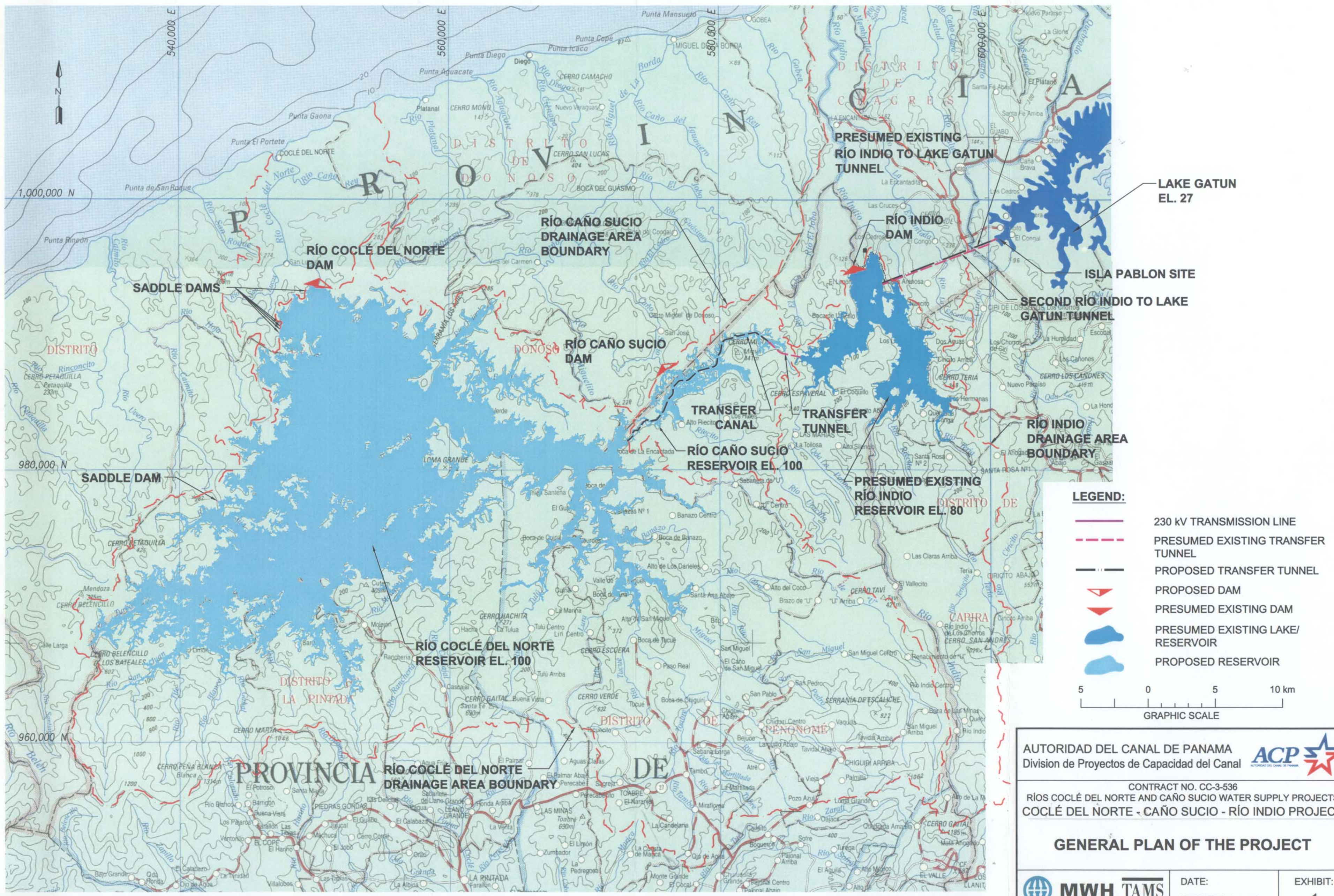
TABLE OF SIGNIFICANT DATA, cont.

Río Caño Sucio Storage Facilities, cont.		
Spillway		
Type of Spillway	Ungated ogee	
Spillway Crest Elevation	El. 100	msl
Spillway Width	25	m
Spillway Design Flood (initial operation)		
Peak Inflow	1,690	m^3/s
3-day Volume	78	MCM
Peak Outflow	393	m^3/s
Surcharged Reservoir Level	El. 103.6	msl
Diversion During Construction		
Type	Box culvert	
Dimensions	2.0 x 2.0	m
Length	48	m
Diversion Flood	90	m^3/s
Discharge Capacity	47	m^3/s
Upstream Cofferdam Height (hydraulic)	4.5	m
Downstream Cofferdam Height (hydraulic)	None required	
Cofferdam fill Volume	1,210	m^3
Minimum Release Facility		
Type	Steel pipeline in diversion conduit	
Capacity	0.75	m^3/s
Water Transfer Facilities		
Coclé del Norte to Río Indio Canal		
Length	15,150	m
Base width	5.0	m
Side slopes	2H:1V	
Coclé del Norte to Río Indio Tunnel		
Length of tunnel	2,550	m
Diameter	5.5	m
Shape	Modified horseshoe	
Capacity at Maximum Pool	220	m^3/s
Capacity at Minimum Pool	180	m^3/s
Río Indio to Lake Gatun Tunnel		
Length	8,250	m
Diameter	6.5	m
Shape	Modified horseshoe	

TABLE OF SIGNIFICANT DATA, cont.

Power Facilities		
Power and Energy		
Installed Capacity	75	MW
Firm Capacity	75	MW
Average Annual Energy Production	410	GWh/year
Peak Annual Energy Production	538	GWh/year
Minimum Annual Energy Production	76	GWh/year
Unit Information		
Number of Units and Capacity	3-25	MW
Design Head	95	m
Discharge	30	m^3/s
Rotational Speed	360	rpm
Generator Rating	27,800	kVA
Generator Frequency	60	Hz
Power Factor	0.9	
Physical Data		
Powerplant Type	Surface	
Power Tunnel Length	260	m
Power Tunnel Diameter	5.0	m
Estimated Project Cost		
Construction Cost (January 2003)	$573,000,000	
Mitigation and Compensation Cost	$238,000,000	
Total Project Cost	$811,000,000	
Annual Cost	$4,425,000	
Estimated Project Schedule		
Implementation Period (Operational)	12.5	years
Implementation Period (Full Operation)	16.5	years
Construction Period (Operational)	8	years
Construction Period (Full Operation)	12	years
Estimated Project Yield		
Volumetric Reliability	99.6	%
System Yield w/ Norte/Sucio/Indio Project	107.3 L/d	8,150 MCM
Yield allocated to the Norte/Sucio Project	**47.0 L/d**	**3,570 MCM**
Yield allocated to Río Caño Sucio Reservoir	**2.5 L/d**	**190 MCM**
Yield allocated to Río Coclé del Norte Reservoir	**44.5 L/d**	**3,380 MCM**

EXHIBITS



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

ACP

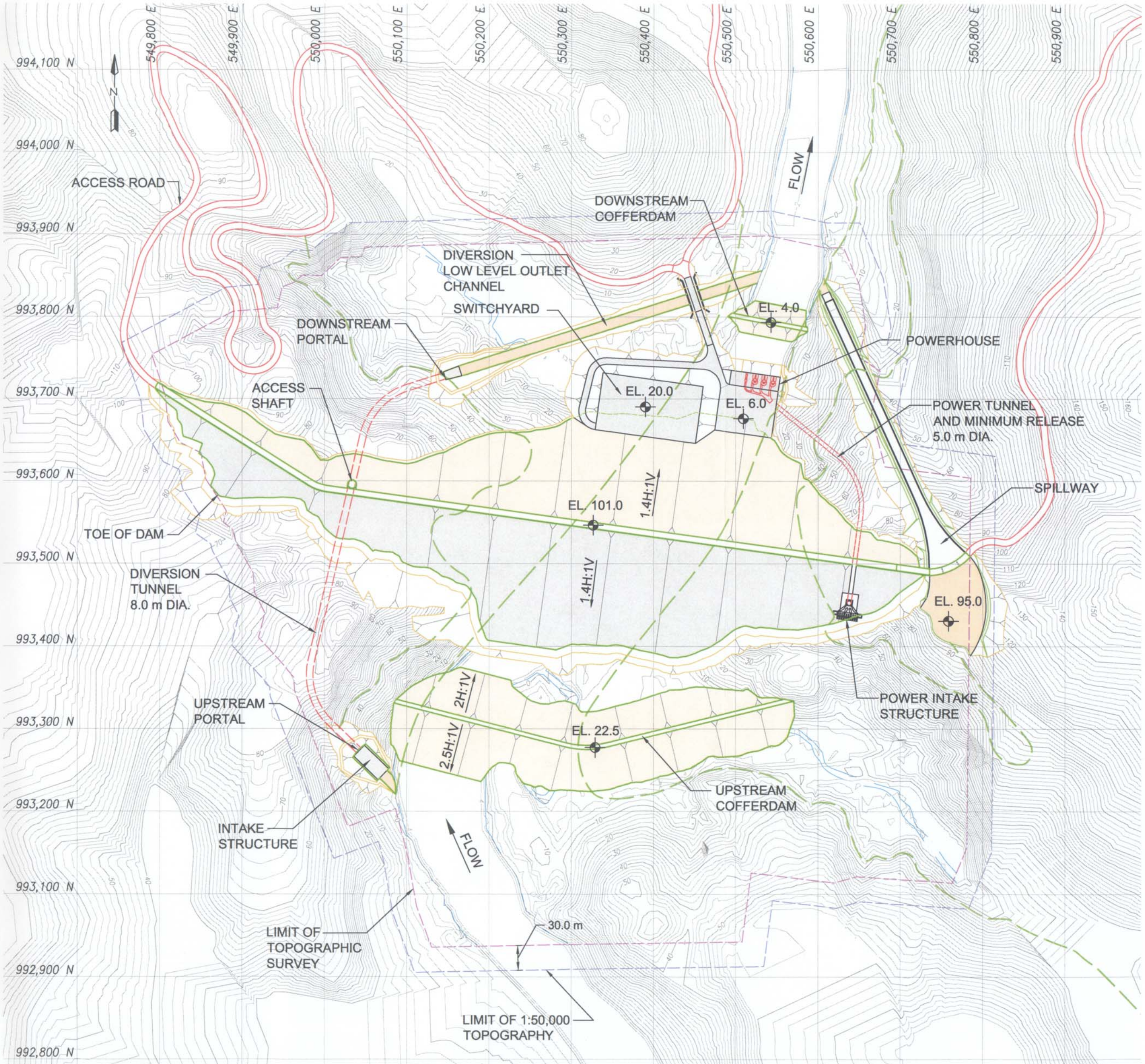
CONTRACT NO. CC-3-536
RÍOS COCLÉ DEL NORTE AND CAÑO SUCIO WATER SUPPLY PROJECTS
COCLÉ DEL NORTE - CAÑO SUCIO - RÍO INDIO PROJECT

GENERAL PLAN OF THE PROJECT

MWH TAMS

DATE: DECEMBER, 2003

EXHIBIT: 1



SITE PLAN

LEGEND:

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CONSTRUCTION ACCESS ROAD

0 50 100 150 200 250 m

GRAPHIC SCALE

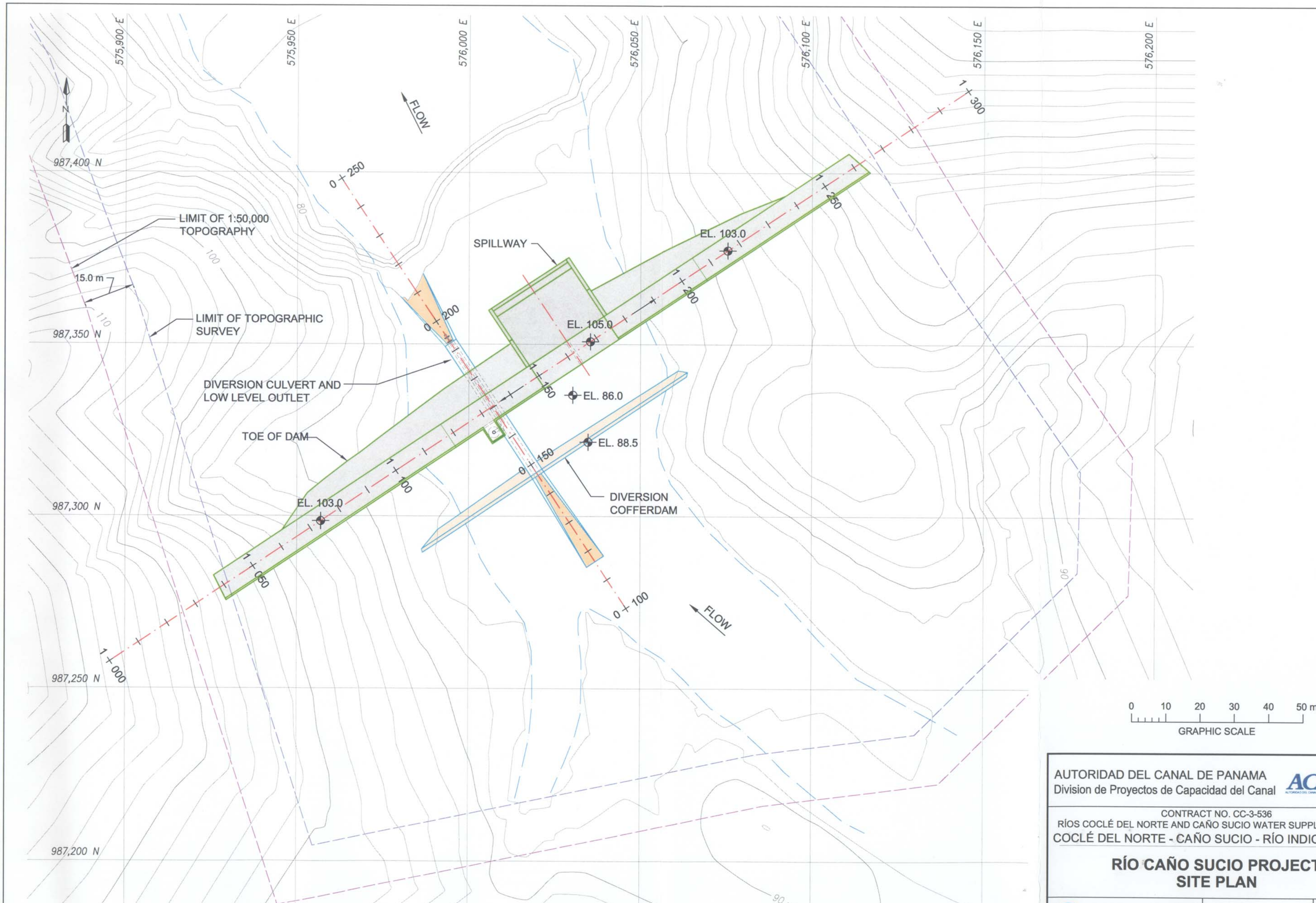
AUTORIDAD DEL CANAL DE PANAMA
Division de Proyectos de Capacidad del Canal

ACP

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

RÍO COCLÉ DEL NORTE PROJECT
SITE PLAN

MWH TAMS	DATE: DECEMBER, 2003	EXHIBIT: 2



SITE PLAN

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

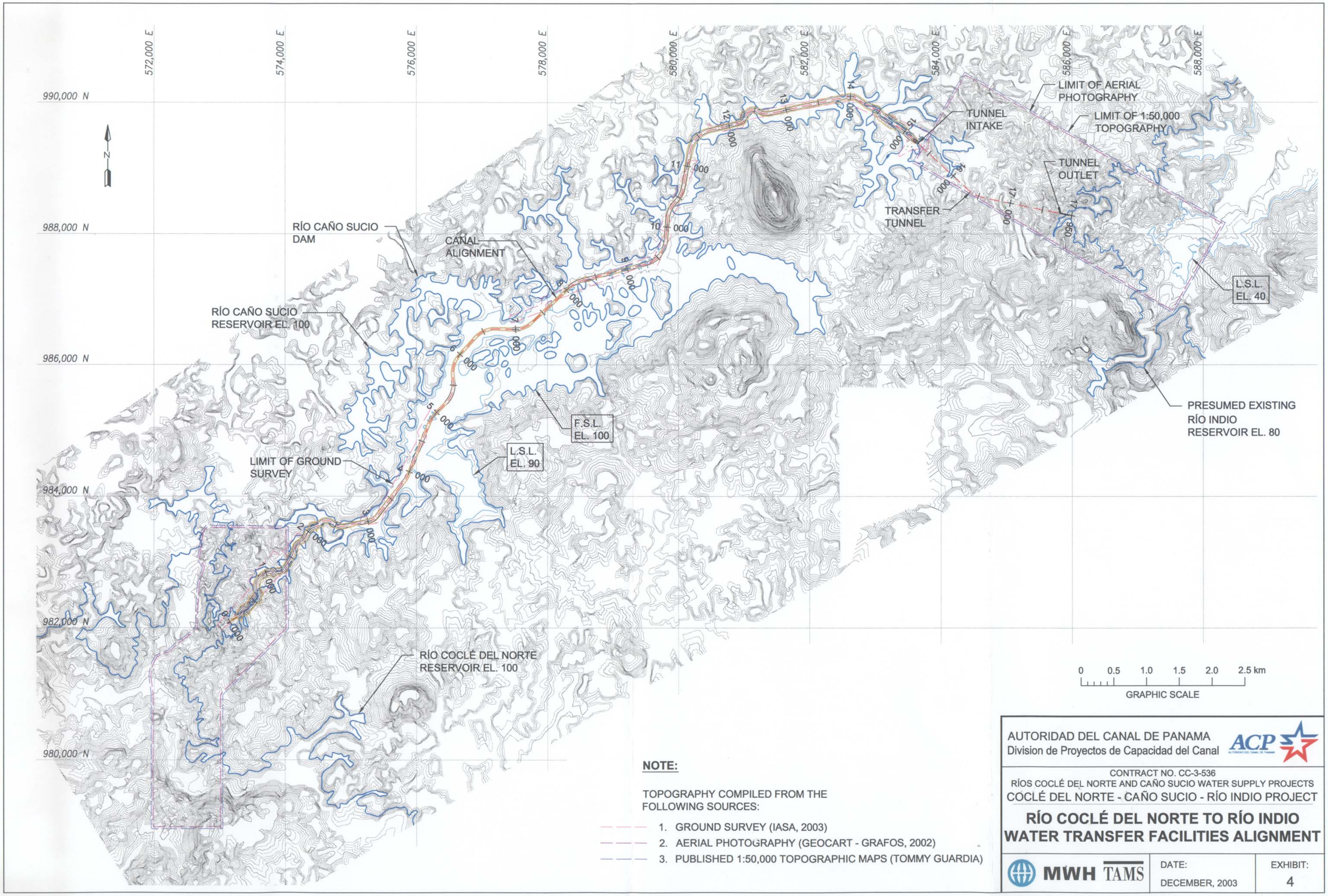
ACP

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

RÍO CAÑO SUCIO PROJECT
SITE PLAN

MWH TAMS

DATE:	EXHIBIT:
DECEMBER, 2003	3



NOTE:

TOPOGRAPHY COMPILED FROM THE FOLLOWING SOURCES:

1. GROUND SURVEY (IASA, 2003)
2. AERIAL PHOTOGRAPHY (GEOCART - GRAFOS, 2002)
3. PUBLISHED 1:50,000 TOPOGRAPHIC MAPS (TOMMY GUARDIA)

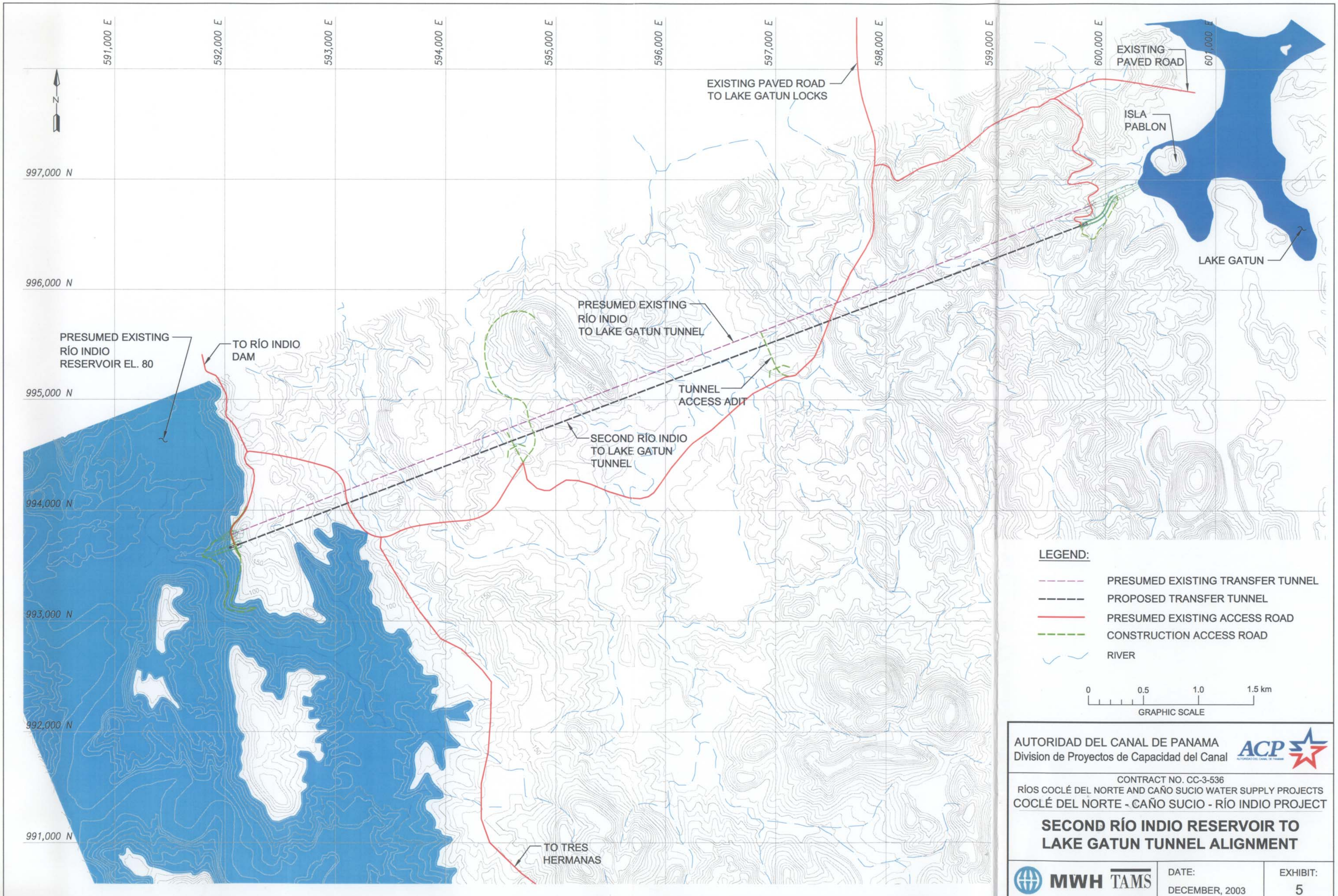
AUTORIDAD DEL CANAL DE PANAMA
Division de Proyectos de Capacidad del Canal

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

RÍO COCLÉ DEL NORTE TO RÍO INDIO WATER TRANSFER FACILITIES ALIGNMENT

MWH TAMS

DATE:	EXHIBIT:
DECEMBER, 2003	4



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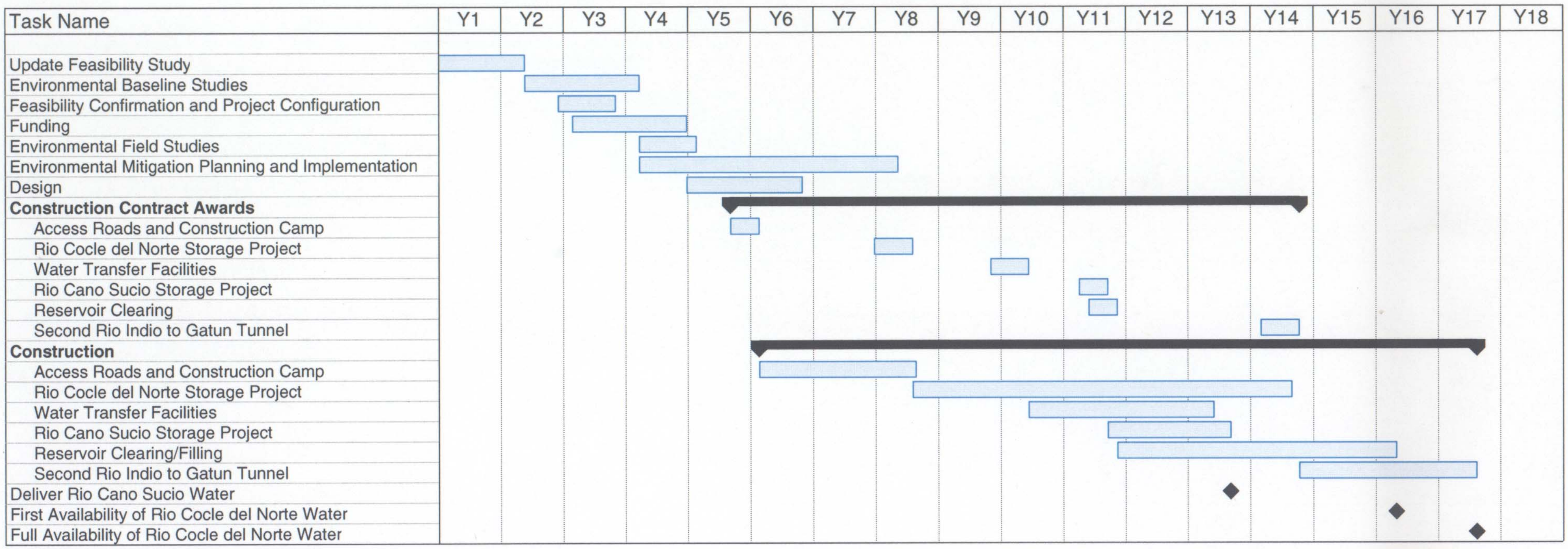
GRAPHIC SCALE
AUTORIDAD DEL CANAL DE PANAMA
Division de Proyectos de Capacidad del Canal
ACP
CONTRACT NO. CC-3-536
RÍOS COCLÉ DEL NORTE AND CAÑO SUCIO WATER SUPPLY PROJECTS
COCLÉ DEL NORTE - CAÑO SUCIO - RÍO INDIO PROJECT
SECOND RÍO INDIO RESERVOIR TO LAKE GATUN TUNNEL ALIGNMENT
MWH TAMS
DATE:
DECEMBER, 2003
EXHIBIT:
5

Cocle del Norte - Cano Sucio - Rio Indio Project

Implementation Schedule



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
COCLÉ DEL NORTE - CAÑO SUCIO - RÍO INDIO PROJECT

IMPLEMENTATION SCHEDULE

MWH TAMS

DATE: DECEMBER, 2003

EXHIBIT: 6

Main Report

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EXHIBITS, cont.

APPENDICES

1. INTRODUCTION

1.1 Authorization

The Autoridad del Canal de Panama (ACP), formerly the Panama Canal Commission, has authorized Montgomery Watson Harza (MWH), formerly Harza Engineering Company, to perform an engineering feasibility study of the Río Coclé del Norte and Río Caño Sucio Water Supply Project under Contract CC-3-536, Work Order 0005, dated June 19, 2000.

1.2 Background

In 1998, the ACP established the Canal Capacity Projects Office to study options for improving the Panama Canal (Canal) operating systems to provide efficient and competitive services for the next 50 years.

The ACP is undertaking a canal capacity study, which includes the evaluation of additional sources of water to augment Canal capacity. The transit of ships through the Panama Canal is dependent upon the availability of the fresh water stored in Lake Gatun and *Lago Alajuela* (Lake Madden). Water availability is limited and, even at present traffic levels, is not sufficient to meet traffic demand during prolonged dry periods. Therefore, new sources of water must be identified, defined, and evaluated.

The US Army Corps of Engineers (USACE) performed a reconnaissance study to identify and evaluate potential water supply projects (1). A project in the Río Coclé del Norte basin was identified as having significant potential to augment the existing water supply to the Canal.

Two concepts were identified in the Reconnaissance Report for transferring water from the Río Coclé del Norte basin to the Canal:

- The Río Coclé del Norte Reservoir acting in full regulation with the Río Indio Reservoir (Norte/Indio Project), and
- The Río Coclé del Norte Reservoir acting in full regulation with the Río Caño Sucio and Río Indio Reservoirs (Norte/Sucio/Indio Project).

The Norte/Sucio/Indio Project is the subject of this volume.

1.3 Objectives

1.3.1 Original Objective

The original objective of this study was to determine the technical and economic feasibility of the Project. An assessment of the environmental feasibility will be performed separately under the direction of the ACP.

1.3.2 Modified Objectives

During the course of the study, it was not possible to implement the subsurface investigation program or the refraction surveys. Also, during the course of the study, it was determined by the ACP that development in the Río Coclé del Norte basin would not be considered without a plan to add new locks to the Panama Canal System. Under this condition, the demand for and benefits from a project in the Río Coclé del Norte watershed could not be assessed at this time. The dam-height optimization and the economic analysis were, therefore, suspended pending the further study of the additional locks.

As a result of these events, the scope of the technical and economic feasibility study was modified to result in an engineering study with the following objectives:

- Assess the technical feasibility of the Project to the extent possible without subsurface information,
- Estimate the economic cost of water for a range of developments at the site identified in the Reconnaissance Report,
- Evaluate the potential for adding hydropower to the water supply Project, and
- Evaluate the potential for developing an agricultural component to the Project.

1.4 Original Scope of Services

Relying on readily available data, information, literature, mapping, photographs, *etc.*, and ground topographic surveys at each of the project features and geological/geotechnical investigations performed under separate contract actions by the ACP, the services are described as a series of tasks, paraphrased from the Terms of Reference as follows:

Task 1 Work Plan and Quality Control Plan. Present final plans with milestones in Panama within two weeks of notification of award.

Task 2 Selection of Dam Location and Field Investigations. Visit both sites to provide preliminary confirmation of dam location, review ground survey, geology, and geotechnical field program proposals.

Task 3 Hydrology and Meteorology. Task 3 included a series of subtasks that apply to both basins:

- Develop a long-term streamflow sequence
- Using a HEC-5 simulation model provided by the ACP, operate the Canal water supply system to determine the contribution from the Río Coclé del Norte basin and to optimize the features of the Project.
- Estimate the probable maximum flood for spillway design and lower frequency floods for the determination of diversion facilities during construction for both damsites.
- Estimate evaporation and reservoir sediment deposition for both reservoirs.

Task 4 River Hydraulics. Assess the impact of construction on the water quality downstream from the reservoirs and the stability of the river channels as a result of the development of the reservoirs. If necessary, perform a feasibility-level assessment of required remedial works.

Task 5 Geology. Based on reports, field visits, and the geologic investigations being performed by the ACP, describe the regional, reservoir, and site geology, the nature of the foundation materials, and the location and characteristics of construction materials in both basins.

Task 6 Geotechnical and Seismological Studies. Using information supplied by the ACP and collected during field visits, characterize foundation conditions, estimate excavation slope requirements, assist in the location of construction materials, and assess seismotectonic movement and risk.

Task 7 Agricultural Development. Assess the potential for small-scale agricultural development in and around the Río Coclé del Norte Reservoir area and downstream of the reservoir area. Estimate water demand, costs, and benefits of potential irrigation systems.

Task 8 Power and Energy Studies. Using estimates of power generation from the HEC-5 simulation model, estimate the costs and benefits of installing hydro plants at the base of the Río Coclé del Norte dam and at the downstream end of the tunnel transferring water from Río Indio to Lake Gatun. In addition, perform a power market study to determine the competitiveness of the project power production as it relates to the national power system.

Task 9 Design of Main Features. Select the most suitable type of dam at each site and provide feasibility-level designs and drawings for the Project features.

Task 10 Construction Planning. To support a detailed engineering and construction schedule, a construction plan will be developed that identifies construction and management components, construction methods, characteristics of the work force, access of materials and equipment, and a construction sequence.

Task 11 Cost Estimate. Prepare a cost estimate to a feasibility-level of detail.

Task 12 Canal Operation Benefits. Define benefits for Canal operation, municipal and industrial water supply, hydropower generation, and agricultural development.

Task 13 Economic Evaluation. Define evaluation methods in coordination with the ACP and calculate the cost-benefit ratio for the project.

A draft feasibility report is to be presented 10 months after issuance of the Task Order. In addition, interim meetings will be held with the ACP to review work progress, hands-on training will be provided in the Consultants home office, and a series of seminars will be presented for the purpose of technology transfer.

1.5 Revised Scope of Services

As a result of the modification to the objectives mentioned earlier:

- The drilling program and the refraction surveys were eliminated from the services.
- The canal benefit and economic analysis subtasks were suspended.
- The schedule to complete the report was extended.

1.6 Organization of Report

This volume titled "Feasibility Study of the Río Coclé del Norte Reservoir Acting in Full Regulation with the Río Caño Sucio and Río Indio Reservoirs" contains a summary of the studies done in connection with the project and the conclusions and recommendations. The details of the studies are presented in seven appendices that are contained in an additional three volumes. The report organization is shown below:

Volume	Title
1	Feasibility Study of the Río Coclé del Norte Reservoir Acting in Full Regulation with the Río Indio Reservoirs
2	Feasibility Study of the Río Coclé del Norte Reservoir Acting in Full Regulation with the Río Caño Sucio and Río Indio Reservoirs
3	Appendix A – Hydrology, Meteorology and River Hydraulics Appendix B – Geology, Geotechnical and Seismological Studies Appendix C – Operation Simulation Studies
4	Appendix D – Project Facilities Studies Appendix E – Power and Energy Studies
5	Appendix F – Agriculture and Irrigation Potential Appendix G – Cost Estimates

1.7 Acknowledgements

MWH gratefully acknowledges the assistance that has been provided during the course of the studies. In particular, the following persons and organizations have provided invaluable assistance.

- Agustín A. Arias, Division Director, Canal Capacity Projects Division, Autoridad del Canal de Panama;
- Jorge de la Guardia, Manager, Canal Capacity Projects Division, Autoridad del Canal de Panama;
- José Pascal, Water Projects Team Leader, Canal Capacity Projects Division, Autoridad del Canal de Panama;
- John Gribar, Special Consultant
- The Supporting Staff of the Canal Capacity Projects Division;
- The Environmental and Safety Group;

- The Department of Meteorology and Hydrology, Autoridad del Canal de Panama, and;
- The Electrical Division, Autoridad del Canal de Panama.

1.8 Subcontracts

The Río Coclé del Norte and Río Caño Sucio Water Supply Project studies were performed by MWH in association with:

TAMS Consultants, Inc., New York USA, an Earth Tech Company

In addition, assistance was provided for data collection in support of this study by:

Ingenieria Avanzada, S.A., Panama, and
Tecnilab, S.A., Panama.

2. PROJECT SETTING

The Norte/Sucio/Indio Water Supply Project consists of a storage facility in the Río Coclé del Norte basin, a storage facility in the Río Caño Sucio basin, water transfer facilities between the Río Coclé del Norte and Río Caño Sucio basins, and a tunnel between the presumed existing Río Indio Reservoir and Lake Gatun. It is located essentially in the middle of the Republic of Panama in the Districts of Donoso, Penonome, and Pintada, in the three contiguous watersheds immediately to the west of the Panama Canal Watershed. A location map is presented on Exhibit 2-1. Descriptive information for the Río Indio Basin is contained in the Feasibility Study of the Río Indio Water Supply Project (2). The Norte/Sucio/Indio Project will be used to augment the existing supply of water to the Panama Canal, provide for increases in municipal and industrial water in and around the Panama Canal Watershed, and as a source of electricity in the local and regional market.

2.1 Climate

The general climate of Panama is tropical with distinct wet and dry seasons induced by the movement of the inter-tropical convergence zone (ITCZ). When the ITCZ is located to the south of Panama, it causes a dry season in Panama. When it travels over Panama either moving northward or southward, its passage results in heavy rainfall; and when it is to the north, the strength of the rainy season decreases somewhat. This movement generally results in a dry season from January through April, a moderated wet season from May to mid-September, and a wet season for the rest of the year.

The average annual rainfall over the Río Coclé del Norte and Río Caño Sucio basins above the respective dam sites is estimated to be 2,800 mm and 3,300 mm respectively. A map of mean annual rainfall, taken from *Atlas Nacional de la República de Panamá* (3), is presented on Exhibit 2-2. The map shows that mean annual rainfall is higher in the coastal area and decreases inland.

Based on extended records for the *Coclecito* station, the mean monthly rainfall over the Río Coclé del Norte basin is estimated as the ratio of the basin annual rainfall and the station annual rainfall times the station monthly rainfall. Mean monthly rainfall values are shown in Table 2-1

TABLE 2-1 MEAN MONTHLY RAINFALL, RÍO 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.

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 over the Río Caño Sucio basin is presented in Table 2-2.

TABLE 2-2 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.

Literature studies and discussions with ACP staff indicate that the occurrence of the El Niño phenomenon causes below normal rainfall in almost all regions of Panama (Appendix A). The studies indicate that the average annual rainfall anomaly based on the El Niño was about 8% below normal. In the case of the strong episodes of 1976 and 1982, the corresponding anomalies were about 28% and 24%.

Mean monthly temperatures vary about 2° C throughout the year around a basin average of 26.9° C. The temperature averages about 26° C near the dam and about 24° C in the head reach. The lowest temperature occurs in September and October, and the highest occurs in March and April at lower altitudes and in June at higher altitudes.

2.2 Description of the Río Coclé del Norte Basin

The drainage configuration of the Río Coclé del Norte basin is presented on Exhibit 2-3. The Río Coclé del Norte is formed downstream from the confluence of the Río San Juan, Río Coclecito, and Río Cascajal near the town of Coclecito. The three rivers drain the northern slopes of the Cordillera Central (Continental Divide) and flow northward to the Atlantic Ocean. About halfway to the damsite, the Río Coclé del Norte is joined by the major basin tributary, the Río Toabré. At the mouth, the drainage area of the Río Coclé del Norte is about 1,730 km^2. The damsite is located about 15 km upstream from the Atlantic Ocean. Above the damsite, the river drains an area of about 1,594 km^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 drains an area of about 810 km^2 at the confluence. The Toabré system is comprised of the main stem of the Río Toabré, the Río San Miguel and the Río de U on the right bank, and the Río Lura and Río Tulu on the left bank. 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 northwesterly direction to join the Río Toabré. The slope of the Río San Miguel/Río Toabré is about 10 percent in the 4-km long head reach, decreases to 3.3 percent in the next 6 km, and gradually flattens to about 0.06 percent near the confluence. The Río de U is the closest connection to the Río Caño Sucio watershed.

The three rivers above Coclecito drain an area of about 520 km^2. The Río San Juan is the larger and longer of the three rivers. It drains an area of 270 km^2, and 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. From Coclecito, the Río Coclé del Norte flattens to a slope of 0.3 percent to the damsite.

The Río Cuatro Calles is another right bank tributary, joining the Río Coclé del Norte about 2 km upstream from the dam site. The drainage area is about 140 km^2. Except for the most upstream 1,200 m, the river slope is about 0.3 percent.

Profiles of the mainstream and main tributaries are presented in Appendix A. The drainage areas of the basins are presented below:

Basin	**Drainage Area (km^2)**	**Accumulated Drainage Area (km^2)**
Río San Juan	270	
Río Coclecito	110	
Río Cascajal	140	
Area above Coclecito		*520*
Intervening local drainage	260	
Río Cuatro Calles	140	
Río Toabré	700	
Area above damsite		*1,600*
Intervening local drainage	130	
Total Basin Area		**1,730**

There is no access to the basin in the vicinity of the dam.

Slightly less than 40% of the basin is in forest. The remaining area has been deforested and is now comprised of shrubs, pasture, and annual crops. Within the inundated area, there are about 183 towns and about 7,300 persons. Agriculture and cattle ranching are the main economic activities. There are also mineral and ore resources reported in the area.

2.3 Description of the Río Caño Sucio Basin

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 drainage configuration of the Río Caño Sucio basin is shown on Exhibit 2-3.

The damsite is located about 42 km along the river upstream from the Caribbean Sea over an air distance of about 25 km. The basin above the damsite covers about 111 square kilometers and is about 12 km long and 14 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.

Access to the basin is very limited. There is no access from the south. From the north, there is an unpaved road from *Boca de Río Indio* to *Miguel de la Borda* at the mouth of the Río Miguel de la Borda. Travel up the river by boat is possible to the falls just below the damsite.

Only about 8% of the basin is still in lowland forest and the remaining area has been deforested and is now comprised of shrubs, pasture, and annual crops. Within the inundated area, there are about 13 towns and nearly 500 persons. As for the Río Coclé del Norte basin, agriculture and cattle ranching are the main economic activities.

2.4 Panama Canal Operations

The Panama Canal operation is dynamic and has a significant macroeconomic impact. Panama has transformed the Canal from a government-run entity into a commercial venture. The Canal has been transformed from a transport route for ships into a commercial supplier of a broad range of services (4). Although these services have been provided in the past, treaty limitations curtailed the full exploitations of this potential. Currently, the government plan is to make the Canal an autonomous enterprise and to permit increased activity in the areas of electricity generation, municipal and industrial (M&I) water supply, and the provision of marine services.

The United States is the most important user in terms of cargo tonnage. The US East Coast to Asia is the dominant trade route for the Canal and the US West Coast and Canada comprise the second major trade route of the waterway. Trade along the north-south axis is also increasing especially between the west coast of South America and the east coast of the United States (4). Ships carrying coal from the east coast of the United States to Japan save 3,000 miles versus the shortest alternative all-water route and ships sailing from Ecuador to Europe save 5,000 miles. Grain is the largest commodity (by tonnage) shipped through the Canal followed by crude oil and petroleum products, and phosphates and fertilizers. There is significant variation in direction – over 90 percent of the grain and phosphates and fertilizers, and over 62 percent of the crude oil and petroleum are shipped from the Atlantic to the Pacific. The largest commodity shipped through the Canal from the Pacific to the Atlantic is mining products and specifically coal or ores and metal (5).

2.4.1 Description of the Canal Facilities

As reported in the Reconnaissance Report (1), the principal features of the 80-km long Canal system, from the Atlantic Ocean to the Pacific Ocean, are:

- The Cristobal Terminal in Colon
- A short section of sea-level channel
- The Gatun Locks, which can raise or lower a ship 26 meters in three steps
- Gatun Lake, which develops 37.6 km of the Canal passage
- The Gaillard Cut, which is 13.7 km long
- The Pedro Miguel Lock, which can raise or lower a ship 9.4 meters
- Miraflores Lake
- The Miraflores Locks, which can raise or lower a ship up to 16.6 meters
- A 9.6-km long sea level channel
- The Balboa Terminal in Panama City
- Madden Lake, which serves as a source of water for the Canal

Gatun Lake is impounded by the Gatun Dam, an earth embankment with a gated spillway across the Río Chagres. Madden Lake is impounded by Madden Dam, a concrete structure also on the Río Chagres about 19 km east of the Canal. Miraflores Lake is formed by an earthfill dam located on either side of the high end of Miraflores Locks. Electricity is generated at both Gatun and Madden dams, and municipal and industrial water is supplied from both Gatun and Madden Lakes.

The ACP is currently improving the efficiency of the Canal through the purchase of new locomotives and tugboats, installing a traffic management system, improving lock chamber door operating machinery, and widening the Gaillard Cut. The Cut is being widened from 152 meters to about 192 meters in the straight sections and 222 meters in the curves. The improvements will shorten the time needed to move vessels through the locks and allow larger ships to use the Canal at the same time.

In addition, the ACP is currently deepening the navigation channel through Lake Gatun by three feet (0.91 m).

2.4.2 Canal Traffic

The ACP operates the twin-lane locks continuously on a 24-hour per day, 365 days per year basis. In 1997 and 1998, oceangoing vessel transits totaled slightly more than 13,000 or an average of just less than 36 vessels per day. In 1997, more than 29 percent of the vessels were classified as PANAMAX vessels (beams of 30.5 m) and this percentage was estimated to increase to about 33 percent by Year 2010 (6). Actual use of the canal by PANAMAX ships is already at 40 percent according to the ACP. At the completion of the improvements described above, the APC estimates that the sustainable transit capacity of the Canal will increase to 43 vessels per day or 15,695 per year.

In 1993, the following actual and projected estimates of traffic were reported (7):

Maximum Design Vessel Size	Cargo Tonnage			Vessel Transits		
	1990	2020	2060	1990	2020	2060
Present Canal (65,000 dwt)	157,472	265,962	276,529	11,162	17,359	18,078
150,000 dwt	NA	360,990	490,647	NA	17,796	23,934
200,000 dwt	NA	363,312	494,726	NA	17,844	24,074
250,000 dwt	NA	369,883	508,527	NA	17,856	24,053

With the currently anticipated limit of about 16,000 vessel transits per year, it becomes apparent that significant improvements to the Canal will be required to meet the anticipated demand.

2.4.3 Water Availability

Currently, the supply of water for the operation of the Canal and the provision of M&I water comes from regulation provided on the Río Chagres. Historically, the supply of water has been adequate to provide a reliable operation of the Canal. The reliability of supply, measured as the ratio of the volume of water provided and the volume of water required, was computed to be 99.6% for a demand equal to the average of the lockage and M&I demands from 1993 to 1997. This value has been used as an indicator of the systems' reliability and, currently, as a goal to which all future developments are compared.

The impact of providing less than the required water supply is severe. At the current time, there are no auxiliary sources of water for M&I supply and, therefore, the entire impact of any shortage is absorbed by the canal operation. There are two actions that can be taken during water shortages: 1) maintain the level of Gatun Lake but restrict the transits, or 2) allow the lake level to drop and impose draft restrictions. The ACP has taken the option of allowing passage to all requesting vessels and imposing draft restrictions on large vessels.

Using the 50-year period of hydrologic data and simulating the operation of the Canal system for multiples of the current demand (taken as the average demand from 1993 to 1998), the reliability of the system as reported in the Reconnaissance Report (1) would have been:

Demand Multiple	Reliability
Current Demand	99.6 %
1.2	98.8 %
1.4	96.4 %
1.6	92.0%
1.8	86.3%

These reliability values indicate that, on the average, current shortages amount to about 11 MCM/yr and shortages for the increased multiples range from 44 MCM/yr for 1.2 times the current demand to 725 MCM/yr for the 1.8 multiple. The situation is worse than suggested by the averages. For the 1.2 multiple, shortages occur in only 20 of the 50 years, which indicates a shortage that averages about 100 MCM/yr in the short years, but as many of the years have only minimal shortages, the shortage in the most severe year would be much larger than the average.

2.4.4 Municipal and Industrial Water Supply

Historically, the Panama Canal Authority has provided municipal and industrial (M&I) water to the Panama Canal Watershed and the immediate vicinity. In year 2000, that supply equaled about 244 million gallons per day (mgd), which is equivalent to about 4.4 lockages per day in the Canal operations. Based on a study performed in 2000 (8), the M&I demand is forecast to increase from 244 mgd to about 500 mgd (about 9.1 lockages per day) in year 2060. It is anticipated that the ACP will retain the responsibility to supply this water.

2.5 Socio-Economic Conditions

The population of both basins, Río Coclé del Norte and Río Caño Sucio, was estimated in year 2000 to be about 28,000 of which about 94% were in the Norte basin. However, there are no indigenous populations reported in the area.

Agriculture and cattle ranching are the main economic activities, but per capita income falls below the extreme poverty level. Cattle ranching occupies about 22% and 45% of the Río Coclé del Norte and Río Caño Sucio basins respectively and, based on a count of animals, low productivity and mismanagement is indicated. Basic crops are rice, corn, and beans, and production rates of these staples are considered to be low when compared to national averages. There are mining metallic concession contracts and requests in both reservoir areas according to the Ministry of Industry and Commerce.

The literacy rate is around 90 percent, although this is slightly lower than the national average. Most homes do not have access to potable water and over 90 percent of the homes do not have electricity. Except for the roads into Coclecito, there is a lack of infrastructure in both basins. Medical services are more than an hour away for a high percentage of the population. The Río Caño Sucio basin is considered to be the least developed of the three watersheds in the Panama Canal Western Region.

About 5,300 persons reside in the Río Coclé del Norte reservoir in 183 towns. The average family size is estimated to be about 4.7 persons. The six largest towns in the Río Coclé del Norte Reservoir are Coclecito (population 683), Villa de Carmen (495), Cutevilla (372), Valle de San Miguel (256), Boca de la Encantada (193), and Sabanita Verde (193) and they contain 30 % of the total reservoir population. About 465 persons reside in the Río Caño Sucio Reservoir in 13 towns. About 75% of the reservoir population resides in five towns, Los Elegidos, Loma Alta, La Puente, Las Maravillas, and Santa Maria.

According to the Reconnaissance Report (1) there are few public services. The town of Coclecito is the most developed and the largest of the towns in either basin. It has several schools and a hospital as well as access by road to La Pintada and Penonome. There is essentially no power except from small, local generating sources and telephone coverage is limited. All of the towns obtain water from the rivers or from groundwater. There is no treatment of community waste and most finds its way into the environment. As a result, there are known health problems such as hepatitis, dysentery, dermatitis, intestinal parasites, and respiratory illnesses associated with the waste disposal methods. A lack of good quality all-weather roads is probably one of the most pressing needs. The only roads are rarely graded and receive little attention from the Ministry of Public Works or local government.

2.6 Power Sector

In 1998, the power sector of Panama was restructured. Prior to 1998, the Panama National Integrated System (PNIS) was operated by the *Instituto de Recursos Hidraulicos y Electrification* (IRHE), responsible for generation, transmission, distribution, and sales. As a part of the restructuring, the generation and distribution facilities were privatized while the transmission system was assigned to a new government agency, the *Empresa de Transmission Electrica, S. A.* (ETESA).

After the restructuring, there were ten generation companies and three distribution companies providing electricity to the national grid. Currently, there are six companies generating a total of 1,060 MW that are providing the bulk of the electricity to Panama. (9).

Two of the original ten companies, EGE Bayano and EGE Chiriqui were bought by the AES Corporation and merged into AES Panama. As reported in a 1999 plan of expansion (10), two additional generation companies, Petroterminales and Hidro Panama operated 15 MW and 1.5 MW respectively. It is not known whether these units were retired or just not considered as major producers for the 2002 operation plan (11).

In the 1999 expansion plan, it was also reported that the distribution companies operated a series of thermal plants. EDE Metro Oeste operated five plants totaling 35 MW that were connected to the Panama National Integrated System (PNIS) and 3.4 MW that were isolated from the grid. EDE Elektra Noreste operated 14 plants with a total capacity of 10.8 MW that were also isolated from the grid.

The Panama Canal Authority owns and operates three power plants: the Gatun and Madden Hydroelectric plants and the Miraflores Thermal Plant. The three plants have installed capacities of 24 MW, 36 MW, and 115 MW respectively for a total of 175 MW. The generation is used to meet the electricity needs of Canal operation. The ACP load is estimated by the Electricity Department of the ACP to be about 60 MW. The Miraflores plant serves as a backup to the hydro plants when there is sufficient water in the Canal System to generate hydropower and supplies electricity when there is not sufficient water. The ACP can sell surplus energy in the energy spot market of the PNIS.

The 2002 Operation Plan indicates that an additional installed capacity of 344 MW will be on line by the end of 2003, consisting of 224 MW of hydro and 120 MW of thermal (although the tabulated expansion plan only shows 206 MW of hydro). Therefore, the major generation companies will have an installed capacity of about 1,404 MW by the end of 2003.

The total installed capacity and distribution between thermal and hydro is presented in Table 2-3

TABLE 2-3 GENERATION FACILITIES
(MW)

Company	Hydro Capacity	Thermal Capacity	Total Capacity	Connected to PNIS
Major Generation Companies				
AES Panama	240.0	40.0	280.0	Yes
EGE Fortuna	300.0	0.0	300.0	Yes
EGE Bahia Las Minas	0.0	280.0	280.0	Yes
Petroelectrica de Panama	0.0	60.0	60.0	Yes
COPESA	0.0	44.0	44.0	Yes
PanAm	0.0	96.0	96.0	Yes
Subtotal	540.0	520.0	1,060	
Planned Expansion				
2002	86.0	0.0	86.0	Yes
2003	120.0	120.0	240.0	Yes
Other Generation (may or may not be still available)				
ACP	60.0	93.0	153.0	Yes
Petroterminales	0.0	15.0	15.0	Yes
Hidro Panama	1.5	0.0	1.5	Yes
EDE Metro Oeste	0.0	34.9	34.9	Yes
EDE Metro Oeste	0.0	3.4	3.4	No
EDE Elektra Noreste	0.0	10.8	10.8	No

The major generation companies, including their planned expansions, have a total installed capacity of 1,386 MW.

In 1998, 2000, and 2002, the total net energy production, which is defined as gross generation less station use, amounted to about 4,192 GWh, 4,511 GWh, and 4,686 GWh respectively.

The existing transmission system consists of 578 km of 230 kV lines, 134 km of 115 kV lines, and ten 230-kV substations with a total capacity of 885 MVA (11). Transmission line losses were estimated at about 3.4 percent of the total energy supply and distribution system losses were estimated at about 17.6 percent of purchased energy. In 1998, energy consumption, as reported by the distribution companies, amounted to about 3,393 GWh to about 452,000 consumers. Aggregate distribution by consumer category for 1998 is shown in Table 2-4.

TABLE 2-4 1998 ENERGY CONSUMPTION BY CONSUMER CATEGORY

Consumer Category	Energy Consumption (GWh)	Percent of Total
Residential	1,005	30
Commercial	1,342	40
Industrial	488	14
Governmental	477	14
Public Lighting	64	2
Own Uses	17	<1
Total	**3,393**	**100**

In 1999, the energy consumption was 3,521 GWH, an increase of 5.8%. The customer base increased by 5.2% to about 476,000 consumers.

Each of the three distribution companies has established a tariff structure including capacity and energy charges for the various types of consumers. The average unit energy sale price in 1998 for each of the consumer categories is presented in Table 2-5 Average Unit Energy Sales Price in 1988.

TABLE 2-5 AVERAGE UNIT ENERGY SALES PRICE IN 1988 ($/MWh)

Sector	Residential	Commercial	Industrial	Government	System
Sale Price	119.00	115.60	97.40	111.20	111.20

The unit energy sales prices in Panama have been decreasing slightly over the last decade. Including the estimated unit sales price of $103/MWh for 1999, the sales price has decreased at an average rate of 1.6 %/year.

2.7 Agricultural Sector

The Río Coclé del Norte and Río Caño Sucio basins are largely undeveloped. The vegetation consists mostly of shrubs, forest, and pasture. Croplands are included within the shrub category, mostly because of the nature of the area under cultivation, the landscape position, and the size of the farm holdings. The distribution of vegetation is shown in Table 2-6:

TABLE 2-6 VEGETATION DISTRIBUTION

Habitat	Río Coclé del Norte Basin		Río Caño Sucio Basin	
	Ha (rounded)	% of Total	Ha (rounded)	% of Total
Shrub	65,000	40	5,400	46
Forest	63,000	39	1,000	8
Pasture	35,000	21	5,400	46
Total	**163,000**	**100**	**11,800**	**100**

Farms and ranches of various sizes occupy approximately 60% of the land in the project area. Farm crops include mandioc, maize, rice, beans, sugar, coffee, and tobacco. Ranchers raise cows, horses, chickens, and hogs. Most of the farmers and ranchers are small commercial enterprises although there is also some cash crop and subsistence farming (1).

2.8 Geologic Setting

Regional geologic maps for each of the basins are presented as Exhibits 2-4 and 2-5. The general pattern and distribution of major faulting in Panama is depicted on Exhibit 2-6.

2.8.1 Regional Geology

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.

The proposed Río Caño Sucio project is located in an area underlain by Oligocene-aged sedimentary rocks of the three-membered Caimito Formation of Oligocene age (12). 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 Caño Sucio site 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.

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).

2.8.2 Regional Tectonics

The tectonics in the Central American region are 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, the boundaries of which are shown on Exhibit 2-7. 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 (13).

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 (14):

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

Most historical seismicity within a 400-km-radius of the Panama Canal area can be attributed to collision and shear deformation at each of these neighboring plate boundaries (15). 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 (16).

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 Eastern Panama-Columbia Collision Zone, while the eastern portion of the Nazca plate is being subducted under South America (15). 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 (15).

A detailed description of the significant tectonic features of Panama is presented in Appendix B.

2.9 Environmental Setting

The information presented has been supplied by the ACP or was taken from the Reconnaissance Report (1).

2.9.1 Terrestrial Habitat

Forests cover about 37% of the land in both basins and about 40% of the reservoir area. The remaining areas are categorized as shrub and pasture.

2.9.2 Fish and Wildlife

Both the Río Coclé del Norte and the Río Caño Sucio are typical of a stream in mountainous country. The water is clear and cool and the river bottom ranges from sand to boulders with numerous riffles, rapids, and pools. The river and its tributaries support some fish and benthic communities. Currently, no fish species information is available. The snail *Melanoides tuburculata* is present in both basins and is considered a vector of some parasites. *Corbicula fluminea* (clam) are abundant in the Río Coclé del Norte.

The biological diversity of the Río Coclé del Norte basin includes 317 species of birds, 71 species of amphibians, 46 species of reptiles, and 75 species of mammals. The endangered species include 143 species of birds, 32 species of amphibians, 22 species of reptiles, and 35 species of mammals or about one-half of all species.

In the Río Caño Sucio basin, the biological diversity includes 188 species of birds, 57 species of amphibians, 35 species of reptiles, and 22 species of mammals. The endangered species include 62 species of birds, 24 species of amphibians, 16 species of reptiles, and 8 species of mammals.

2.9.3 Wetlands

According to the Reconnaissance Report (1), the wetlands in the project area consist of forested riparian habitat along the immediate stream bank area. The width of the riparian habitat within the impoundments varies from 10 m to 75 m. About 80% to 90% of the streams above the dam sites are bordered by forested riparian habitat.

2.9.4 Air Quality

Air quality in the project area is generally good except during the slash and burn period. At the end of the dry season, during March and early April, sizable areas of forest and secondary growth are burned and cleared to prepare the land for agricultural use.

2.9.5 Cultural and Historic Resources

In the Río Coclé del Norte impoundment area, there are more than 80 reported archaeological sites. These sites are located and consist of indigenous villages, hamlets, funeral sites, mines, and miscellaneous sites. Within the Río Caño Sucio reservoir there are 13 reported sites, all indigenous villages.

3. DESCRIPTION OF THE NORTE/SUCIO/INDIO PROJECT

Implementation of a project to result in the impoundment of the Río Coclé del Norte Reservoir that will operate in conjunction with the Río Caño Sucio and Río Indio Reservoirs will require the construction of:

- A dam on the Río Coclé del Norte,
- A dam on the Río Caño Sucio,
- A combination of canal and tunnel to transfer water from the Río Coclé del Norte Reservoir through the Río Caño Sucio Reservoir to the Río Indio Reservoir, and
- A second tunnel between the Río Indio Reservoir and Lake Gatun.

In addition, it has been determined that a power plant at the base of the Río Coclé del Norte dam is feasible. Commercial agriculture associated with the development of the project is not warranted at this time. A general plan of the project is shown on Exhibit 3-1.

3.1 Río Coclé del Norte Dam and Reservoir

The major elements that comprise the storage facility of the Río Coclé del Norte include:

- A 113-m high concrete-face rockfill dam with its crest at El. 101 and top-of-structure at El. 103,
- A 50-m wide spillway in the right abutment with a capacity at full surcharge of 250 m^3/s,
- An 8-m diameter, D-shaped tunnel in the left abutment sized to pass the 50-year flood and provide for drawdown in the case of emergency,
- A 75 MW powerplant at the base of the dam incorporating a minimum release facility.

The dam will impound a reservoir with a gross storage capacity of about 14,440 MCM and operate between El. 100, the full supply level, and El. 90. Live storage between El. 100 and El. 90 will be about 3,840 MCM. The reservoir area at the full supply level is 414 square kilometers.

Of the total project yield of 3570 MCM/year, the yield resulting from the addition of the Río Coclé del Norte reservoir is 3,380 MCM/year or 44.5 lockages/day. The 75 MW powerplant will contain three equal-sized units and generate an average of 410 GWh/year ranging from 538 GWh/year in the initial years of operation to 76 GWh/year at the end of the economic life.

A general site plan of the Río Coclé del Norte Project, showing the location of the dam and appurtenant works is shown on Exhibit 3-2.

3.2 Río Caño Sucio Dam and Reservoir

The major elements that comprise the storage facility on the Río Caño Sucio include:

- A 22-m high roller compacted concrete (RCC) dam at the waterfall site with its crest at El. 103 and top-of-structure at El. 105,
- A 25-m wide spillway over the face of the dam with a capacity at full surcharge of 434 m^3/s
- A diversion conduit to pass the 50-year dry-season flood
- A minimum release facility

The dam will impound a reservoir with a gross storage capacity of about 73 MCM and operate between El. 100, the full supply level, and El. 90. Live storage between El. 100 and El. 90 will be 68.5 MCM. The reservoir area at the full supply level is 12.4 square kilometers. The system yield allocated to the project is estimated to be 190 MCM/year or 2.5 lockages/day

A general site plan of the development, showing the arrangement of the dam and its appurtenant works is shown on Exhibit 3-3.

3.3 Water Transfer Facilities to Río Indio

To transfer water from the Río Coclé del Norte reservoir to the Río Indio basin, it is necessary to construct:

- A 6,500-m long canal through the divide between the Río de U and the Río Limon
- A 8,650-m long canal along the Río Caño Sucio and Río Cerro Miguel to the headrace of a tunnel to the Río Indio basin, and
- A 2,550-m long, 5.5-m diameter tunnel.

The dimensions of the facilities are controlled by the requirement to pass about 160 m^3/s when the Río Coclé del Norte reservoir is at its minimum level (El. 90). A plan showing the canal and tunnel alignment is presented on Exhibit 3-4.

3.4 Second Tunnel from Río Indio to Lake Gatun

According to the present concept, the Río Indio Project will have been constructed about 20 to 30 years prior to any Río Coclé del Norte Project configuration. As described in the

Río Indio Water Supply Project Report (2), a 4.5-m diameter tunnel is required to convey Río Indio water to Lake Gatun. With the connection of the Río Coclé del Norte Project to the system, a second tunnel, 8,250-m long with a diameter of 6.5 m, will be required. The tunnel will be aligned parallel and next to the presumed existing tunnel. A plan of the alignment is shown on Exhibit 3-5.

3.5 Estimate Cost of the Project

The Norte/Sucio/Indio Project is estimated to cost $811 million as shown in Table 3-1.

TABLE 3-1 SUMMARY COST OF THE PROJECT

Item	Estimated Cost
Mitigation and Compensation Costs	**$238,000,000**
Access Roads and Construction Camp	$16,490,000
Río Coclé del Norte Storage Facilities	$190,710,000
Río Caño Sucio Storage Facilities	$6,500,000
Water Transfer Facilities	$79,750,000
Second Río Indio-Lake Gatun Tunnel	$85,520,000
Reservoir Clearing	$42,110,000
Subtotal Direct Cost	**$421,080,000**
Contingency	$77,120,000
Direct Cost	**$498,200,000**
Engineering and Administration	$74,800,000
Construction Cost (Jan 2003 price level)	**$573,000,000**
TOTAL COST	**$811,000,000**

4. PROJECT SUPPORT STUDIES

The project support studies are the basic studies that support the selection of the project facilities and the final project arrangement. These studies include topography, hydrology, geology and geotechnical investigations, and project operation studies.

4.1 Topography

Ingenieria Avanzada, S.A. prepared topographic mapping of the proposed dam site areas, the water transfer tunnel portals, and parts of the water transfer canal through the Río Caño Sucio Reservoir under subcontract to MWH. The services were completed and submitted to the ACP under Contract CC-3-536, Task Orders 2 and 8. The extent of the topographic coverage is shown on the plan views of the proposed project facilities. In some instances, there are project features that are not totally covered by the large-scale mapping. For these features, and for other data requirements such as the area and volume curves, additional topographic mapping of the dam site and basin were developed by digitizing 1:50,000 scale maps obtained from Instituto Geografico Nacional (Tommy Guardia).

4.2 Hydrology Studies

Hydrologic analyses were performed to estimate reservoir evaporation, to confirm the long-term streamflow sequence adopted for the Reconnaissance Study (1), and to estimate construction-period floods, the spillway design flood, and sediment deposition in the reservoir. The studies and their results are presented in more detail in Appendix A, Hydrology and River Hydraulics.

4.2.1 Net Reservoir Evaporation

Net reservoir evaporation is estimated to total 1,134 mm/year and is based on historic reservoir evaporation data from Gatun Lake over the period 1993 to 1998. The estimate, developed by the ACP, was judged to be reasonable and was used for both reservoirs in this study. The monthly distribution of net reservoir evaporation is presented in Table 4-1.

TABLE 4-1 MEAN MONTHLY NET RESERVOIR EVAPORATION (MM)

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
112	117	133	123	91	80	84	80	78	80	72	84	1,134

4.2.2 Long-Term Streamflow at the Río Coclé del Norte Damsite

The long-term flow sequence was developed by the APC and reviewed by Harza. There are three gages located in the Río Coclé del Norte basin. Two stations, Batatilla and El Torno were used with three other gages located outside the basin to derive the long-term streamflow. The location of these gages is shown on Exhibit 2-3 and pertinent data for each gage is presented in Table 4-2.

TABLE 4-2 STREAM GAGES USED IN ANALYSIS OF LONG TERM FLOW RECORD

Station	Watershed	Location	Period of Record	Drainage Area
Río Coclé del Norte at Canoas	Río Coclé del Norte	Half-way between Coclecito and the Río Toabré	1983-date	571 km^2
Río Coclé del Norte at El Torno	Río Coclé del Norte	Slightly upstream from Río Toabré confluence	1958-1986	672 km^2
Río Toabré at Batatilla	Río Coclé del Norte	5 km upstream from the mouth	1958-date	788 km^2
Río Trinidad at El Chorro	Gatun	3 km upstream from Lake Gatun	1948-date	172 km^2
Río Ciri Grande at Los Canones	Gatun	9 km upstream from Lake Gatun	1948-date	186 km^2
Boca de Uracillo	Río Indio	5 km upstream from Río Indio damsite	1979-date	376 km^2

The long-term flow sequence (1948-1999) at the damsite was generated by adding the data from El Torno and Batatilla, adjusted for drainage area and rainfall. The flows at El Torno and Batatilla were completed using correlations with El Chorro, Los Canones and Boca de Uracillo. MWH reviewed the correlation and double mass curve analyses and determined that the approach is logical and results are acceptable.

The mean annual flow at the Río Coclé del Norte damsite is estimated to be 107.5 m^3/s and the monthly distribution of flow is shown in Table 4-3. The complete monthly flow at the damsite is presented in Table 1 (note tables numbered without the section number are located at the end of the report text).

TABLE 4-3 MONTHLY MEAN STREAMFLOW AT THE RÍO COCLÉ DEL NORTE DAMSITE
(m^3/s)

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
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

Mass curve and time series analyses indicate that the annual flows are consistent, homogeneous, and that there are no apparent trends. The annual flows exhibit significant variations in flow from year to year. The highest mean annual flow, 188 m^3/s, occurred in 1970 and the lowest, 72 m^3/s occurred in 1997.

On an annual basis, the lowest 1, 2, 3, and 4 calendar year flow sequences occurred in 1997, 1976-77, 1976-1978, and 1976-79, respectively. The 2, 3, and 4-year flows over the period including 1997 and 1998 were very close. The average runoff in these periods amounted to 67%, 72%, 82%, and 85% of normal, respectively. This would suggest that carryover storage of about one-half year would permit a yield on the order of the mean annual flow. For reference, drought-frequency curves for sequential 6-month, 12-month, 18-month and 24-month periods are presented Appendix A.

4.2.3 Long-Term Streamflow at the Río Caño Sucio Damsite

There are no flow data available for the Río Caño Sucio. The long-term flow sequence was developed by the APC, and reviewed and accepted by MWH. The monthly flows were generated using the monthly flows of the Río Indio at Boca de Uracillo and a drainage area ratio (about 0.304) between the two locations.

The mean annual flow at the damsite is estimated to be 7.5 m^3/s and the monthly distribution of flow is shown in Table 4-4. The complete monthly flow at the damsite is presented in Table 2.

TABLE 4-4 MONTHLY MEAN STREAMFLOW AT THE RÍO CAÑO SUCIO DAMSITE
(m^3/s)

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
4.8	2.4	1.6	1.8	4.6	7.8	8.0	9.5	10.9	14.4	14.3	10.3	7.5

Mass curve and time series analyses indicate that the annual flows are consistent.

4.2.4 Construction Period Floods

Construction period floods were evaluated using both available regional flood frequency data and annual maximum instantaneous flood peaks at representative stations. For both sites, use of the site-specific instantaneous peak data was considered more appropriate than using the regional analysis.

Instantaneous flood peak data are available at the three gages in the Río Coclé del Norte basin, at Canoas, at El Torno, and on the Río Toabré at Batatilla. Both Canoas and El Torno measure essentially the same contributing watershed and, since the record at El Torno is longer, the flood peak data for El Torno was used to represent the Río Coclé del Norte basin above Río Toabré. The Generalized Extreme Value (GEV) distribution was adopted to estimate the relationship between return period and flood peak for the two stations.

The flood peaks for the Río Caño Sucio were estimated by transposing the flood frequency data developed for the Río Indio at dam site. The return periods for the flood peaks at the Río Indio site were based on fitting the GEV distribution to the instantaneous peaks from the Boca de Uracillo gage (2).

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.

The adopted relationship is given below.

Rodier's Formula

$$K = 10 * (1 - ((\log^{Q} - 6) / (\log^{A} - 8))) \quad (17)$$

Where 'K' is a coefficient, A is the drainage area in km^2 and Q is flood peak in m^3/s.

The values of K were computed for the flood peaks of selected return periods for El Torno, Batatilla, and Boca de Uracillo. For the Río Coclé del Norte damsite, the mean of the K values for El Torn and Batatilla were used with the drainage area behind the dam to estimate flood peaks of selected return periods. For Río Caño Sucio, the K values for Boca de Uracillo were used with the drainage area of the Río Caño Sucio damsite to estimate flood peaks of selected return periods. The flood peaks are presented in Table 4-5.

TABLE 4-5 FLOOD PEAKS FOR SELECTED RETURN PERIODS

Return Period (years)	Río Coclé del Norte		Río Caño Sucio	
	Flood Peak (m^3/s)	Dry Period Flood Peak (m^3/s)	Flood Peak (m^3/s)	Dry Period Flood Peak (m^3/s)
5	1,925	288	327	25
10	2,430	458	358	39
20	2,995	697	385	57
50	3,860	1,171	417	90
100	4,610	1,705	439	126

4.2.5 Spillway Design Flood

The probable maximum flood (PMF), based on probable maximum precipitation (PMP), was adopted as the spillway design flood for the both the Río Coclé del Norte and Río Caño Sucio dams.

4.2.5.1 Probable Maximum Precipitation

Three procedures were used to evaluate and select the PMP.

1. The first consisted of transposing the most severe storms listed in the 1965 US Weather Bureau (WB1965) and 1978 National Weather Service (1978NWS) reports (18, 19). These reports covered storms up to 1976.
2. The second procedure was to develop and evaluate storm isohyetal patterns of major storms that occurred over the basins since 1976, and
3. The third was to use the PMP estimates and depth-area duration curves developed as a part of the NWS1978 and WB1965 reports.

A total of 15 storms were evaluated under the first and second procedures, and the storm of November 7-9, 1931 was judged to be critical in terms of rainfall amount and aerial extent over the Río Coclé del Norte Basin. This storm was maximized in-place, and transposed to the basin using a factor based on a ratio of October-December rainfall for the Río Indio basin and the place of occurrence of the storm. This resulted in a maximized and transposed storm with a 48-hour rainfall of 610 mm. For the third procedure, the PMP was estimated to be 714 mm. The higher value was adopted for the Río Coclé del Norte basin.

The PMP for the Río Caño Sucio basin was derived using the same procedure selected for the Río Coclé del Norte basin. The estimated 48-hour PMP, taken from the NWS 1978 Report, was estimated to be 810 mm.

4.2.5.2 Probable Maximum Flood

The PMP was transformed to a PMF using the HEC-1 computer model. The PMP was distributed into one-hour increments using the depth duration curve of the US Weather Bureau (WB1964) extended for durations of less than 6 hours using hourly rainfall data recorded at Chorro. The one-hour increments were arranged sequentially using the "alternating block method" (20), adjusted for retention losses, and applied to a unit hydrograph developed using the Clark Method (21).

Río Coclé del Norte Dam Probable Maximum Flood. The total excess rainfall amounted to 590 mm and the maximum one-hour increment was 97 mm. For a base flow of 110 m^3/s, estimated from an analysis of major historic floods, the probable maximum flood hydrograph has a peak of 10,550 m^3/s and a 5-day volume of 1,005 MCM. The PMF inflow hydrograph is shown on Exhibit 4-1.

Río Caño Sucio Dam Probable Maximum Flood. The total excess rainfall amounted to 679 mm and the maximum one-hour increment was 111 mm. For a base flow of 10 m^3/s, estimated from an analysis of major historic floods, the probable maximum flood hydrograph has a peak of 1,690 m^3/s and a 3-day volume of 80 MCM. The PMF inflow and outflow hydrographs are shown on Exhibit 4-2.

4.2.6 Tailwater Rating

A tailwater rating curve was developed for the Río Coclé del Norte at the damsite. The analysis was based on 10 river sections located from 200 to 13,000 m downstream from the dam. The analysis was performed using the Full Equations (FEQ) modeling system developed by Delbert Franz of Linsley, Kraiger Associates Ltd. The resulting tailwater data at the damsite are shown in Table 4-6.

TABLE 4-6 TAILWATER RATING, RÍO COCLÉ DEL NORTE

Flow Rate (m^3/s)	Tailwater Elevation (m)
0	0.0
200	1.1
500	2.9
1,000	5.0
2,000	7.8
3,000	9.8
4,000	11.4

No tailwater curve was developed for the Río Caño Sucio site. The waterfall immediately downstream from the dam effectively eliminates a tailwater response at the dam.

4.2.7 Reservoir Sedimentation

The analysis of reservoir sedimentation consisted of the collection of available data, a review of existing analyses, estimation of the anticipated sediment yield in the Río Coclé del Norte and Río Caño Sucio basins, and estimation of storage depletion in the reservoirs after periods up to 100 years.

ETESA collected 46 samples on the Río Coclé del Norte at Canoas and 56 samples from the Río Toabré at Batatilla and developed a suspended sediment rating curve, which was limited to a maximum concentration equivalent to the observed maximum. The suspended sediment rating curves for Río Coclé del Norte and Toabré fitted by ETESA were revised upward by MWH to reflect a limiting concentration of 10,000 mg/l rather than the maximum observed concentration. This increase was based on a field visit to the basin and MWH experience. As a result, the unit yields of the Río Coclé del Norte and Toabré basins areas above the sampling locations were estimated to be 1.3 mm/yr and 1.2 mm/yr, including 15% for base load, respectively.

The ACP has collected samples at three stations on streams flowing to Lake Madden and three stations on steams flowing to Lake Gatun. The ACP has also conducted a sediment survey of Lake Madden in 1983, which was revised in 1990. The sediment survey of Lake Madden indicated a sediment yield of about 1.4 mm per year.

These analyses indicate that the sediment yield, including base load, could vary from 1.2 mm/yr to 1.4 mm. For a conservative estimate of the reservoir sedimentation, a unit yield of 1.4 mm/yr was adopted for the Río Coclé del Norte Basin. The same value was adopted for the Río Caño Sucio basin. This yield is considered to be indicative of the current land use and could increase significantly in the future if deforestation and agricultural development continue to expand.

Sediment distribution in the Río Coclé del Norte reservoir was estimated using the US Bureau of Reclamation's alternate area increment method. The method is used to estimate the new zero capacity elevation at the dam as well as sediment distribution in the reservoir. The analysis indicates that reservoir sedimentation will not be a problem for the project. 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.

At the Río Caño Sucio dam, the sediment level after 100 years was estimated at El. 90, the minimum operating level. Deposition in the Río Caño Sucio reservoir resulting from the transfer of the Río Coclé del Norte through the reservoir in an amount equivalent to about 50 times the reservoir volume cannot be evaluated without model studies.

4.2.8 Stability of the River Channel Downstream from the Dam

Studies were performed to assess the stability of the Río Coclé del Norte channel downstream from the dam to determine if channel-stabilizing measures would be needed to maintain the system in its pre-project condition. No analysis was performed for the Río Caño Sucio.

The analysis consisted of an estimation of flood peaks in the channel downstream from the dam under pre- and post-project conditions, a determination of the hydraulic and bed material characteristics of the channel, and an evaluation of channel stability.

4.2.8.1 Flood Regime Downstream from the Dam

Pre-project floods were based on the flood frequency data presented in Table 4-5, 1 and 2-day volumes for the selected return periods, and a hydrograph shape based on the December 1955 flood on the Río Toabré. The post-project floods were estimated by routing the pre-project floods through the reservoir. The flood peaks are shown in Table 4-7.

TABLE 4-7 FLOOD FREQUENCY DATA IN RÍO COCLÉ DEL NORTE CHANNEL DOWNSTREAM FROM THE DAM

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

4.2.8.2 Hydraulic and Bed Material Characteristics

The hydraulic characteristics of the channel downstream from the dam were based on 9 cross sections. It was determined that a representative cross section could be used, which was sketched visually from an overlay of all six sections. The bed load characteristics were based on six bed material samples taken at four of the cross sections. These characteristics are presented in Table 4-8.

TABLE 4-8 CHARACTERISTICS OF THE RÍO COCLÉ DEL NORTE BED MATERIAL

Size Designation	Particle Size (mm)
D35	0.45
D50	0.65
D65	3.50
D90	29.0
Median D	**0.7**

4.2.8.3 Channel Stability

Channel stability was assessed on the basis of an evaluation of degradation potential and the availability of sufficient armoring in the existing bed material. A reduction in the sediment load occurs as the sediment is trapped in the reservoir. The downstream effects are generally an increase in 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 of the channel is reduced to a value that prevents further removal of sediment from the bed.

It was determined that under pre-project conditions, degradation will (and does) occur. Under post-project conditions, the required armoring size is less than the size of the existing bed material. Therefore, no stabilizing measures will be needed. Further, aggradations will likely occur at the mouths of the tributaries because the reduced flood peaks will not be able to transport the bed load material deposited by the tributaries.

4.3 Engineering Geology

This section summarizes the significant results and conclusions of the site investigation program, laboratory tests, and other analyses. More detail is presented in Appendix B, Geology, Geotechnical & Seismological Studies.

4.3.1 Geologic and Geotechnical Investigations

Geologic and geotechnical information was obtained during two visits to the proposed dam sites, one in September 1999 and another in December 2001. Investigations were limited to general reconnaissance of the project area, and descriptions of site geology provided here are taken from observations made during the reconnaissance site visits and literature studies conducted by the USACE for development of the August 1999 Reconnaissance Report.

The original scope of the feasibility investigation program was quite extensive and also included core drilling at locations of principal project elements and geophysical surveys. Because there were problems in obtaining access to the project site, the drilling program and associated activities (sampling, permeability testing) and the seismic refraction program have been indefinitely postponed.

The final program incorporated the following activities:

- Reconnaissance of dam and powerhouse sites; establish exploration program and investigation requirements,
- Reconnaissance geologic mapping, including geomorphological analysis and photo-geologic studies,
- Outcrop geologic mapping at the dam site,
- Construction materials investigation,
- Identification of principal geologic factors governing alternative 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,

- Laboratory testing and analyses of test pit samples, and
- Development of geologic and geotechnical parameters for use in design of selected project and estimation of construction costs.

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.

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 Río 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.

Available aerial photographic coverage was obtained from *Instituto Geográfico Nacional.* The quality, age, and scale of the basin 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.

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. The testing included:

- 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, and
- Preliminary petrologic determinations were made from hand samples collected during geologic mapping.

4.3.2 Geology of the Río Coclé del Norte Damsite

The Río Coclé del Norte dam 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 Río Coclé del Norte and Río Toabré, its main tributary.

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.

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.

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 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.

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. From regional geologic mapping and photogeologic studies, the presence of major faults, however, is not expected. Some photogeologic linears, shown on Exhibit 2-5, have been interpreted in the dam site area but these are not thought to be caused by significant faulting.

4.3.3 Engineering Geology of the Río Coclé del Norte Project

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.

4.3.3.1 Geotechnical Design Parameters

Geotechnical design parameters and criteria used for developing project layouts and cost estimates are presented in Table 4-9.

TABLE 4-9 SUMMARY OF GEOTECHNICAL DESIGN PARAMETERS FOR THE RÍO COCLÉ DEL NORTE DAM

Parameter	Selected Design Criteria
Thickness of overburden (top of weathered rock)	3 m
Depth to top of competent work	6 m
Excavation depth under plinth and 25 m downstream of main dam body	6 m
Excavation depth under main dam body	3 m
Excavation depth under spillway headworks and chute	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
Soil Excavation Slopes, Temporary	1.5H:1V, 3-m-wide benches every 10 m vertically. Bench at soil-rock contact

4.3.3.2 Foundation Treatment

Dental excavation and concrete will be used to treat local zones of highly weathered, sheared, or otherwise unacceptable rock encountered in the foundation under the plinth slab and under the spillway headworks. Required dental treatment should be nominal and only local. Consolidation grouting is not envisaged except in limited areas (e.g. fault or fracture zones) should they become exposed during excavation.

Curtain grouting will be used to reduce seepage through joints and fractures under the dam and in the abutments. For estimating purposes, a single row, staged grout curtain constructed by the split-spacing method is assumed.

4.3.3.3 Diversion and Cofferdams

River diversion during construction will be accomplished through a diversion tunnel and the work site will be protected by cofferdams. The diversion tunnel will be excavated entirely in basalt. Basalt should provide favorable tunneling conditions using conventional drill and blast methods. Poor conditions may be encountered locally. 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).

4.3.4 Geology of the Río Caño Sucio Damsite

The Río Caño Sucio dam site is located at the upstream end of an approximately 250-m long waterfalls section. The main drop at the falls is about 7 m high, but several smaller falls and cataracts are located 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 river flows very gently with a low gradient

Bedrock units in the Río Caño Sucio project area consist of Tertiary sedimentary rocks. A medium to coarse-grained sandstone occurs at the proposed dam site, cropping out at the waterfalls and in the riverbed. Abutments at the damsite are covered by residual soils and weathered sandstone float. In outcrop, the sandstone is locally strong, moderately hard, and erosionally resistant, as evidenced by the formation of the waterfalls. At the top of the falls, strata strike about N32°E and dip about 10° to the southeast. Examination of outcrops on the left abutment indicates that the units are thin to medium-bedded (5 - 80 cm) and are intersected by joints. The sandstone is locally calcareous and probably tuffaceous. Interbeds of shaley (or tuffaceous) materials are also present. A similar rock sequence exists on the right side as observed on the left.

The waterfall itself is presumably formed by the offsetting of bedding layers along nearly vertical joints perpendicular to the bedding planes. The steep, stair-stepped pattern of the waterfall suggests that these joints, at least in the vicinity of the waterfall, have a predominate spacing of from one to more than two meters. Thus, the combination of bedding layers and perpendicular joints break the rock mass into blocks or slabs at this location. Investigation of bedrock conditions away from the riverbed and waterfall was not performed in either of the two reconnaissance visits to the site.

At the damsite, the Río Caño Sucio flows to the northwest, cutting into a relatively flat lying flood plain that is about 50 m in width at the dam site, but considerably widens upstream. The sides of the river valley at the dam site rise up at a slope of approximately 3H:1V on either side of the river, creating a trapezoidal shape to the valley. There is approximately 60 m of vertical relief between the valley floor and the tops of the abutments on either side of the river.

Although bedrock is well exposed in the river bottom at the dam site and at the waterfall, few other bedrock exposures were observed in the vicinity of the dam site. The shape of the river valley and absence of rock exposure above the valley floor suggest that the slopes forming either side of the river valley consist of residual overburden to some depth. It assumed that alluvial deposits cover the wider flood plain upstream of the dam site; however, their extent and composition is not known at this time. Further investigation of these areas is required in the future.

Some photogeologic linears, shown on Exhibit 2-5, have been interpreted in the dam site area.

4.3.5 Engineering Geology of the Río Caño Sucio Project

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. In regard to other 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 Río Caño Sucio Dam.

4.3.5.1 Geotechnical Design Parameters

The most prominent geologic feature at the Río Caño Sucio dam site is the waterfall located downstream of the proposed location of the dam. The height of this is estimated to be about 7 m. Studies were performed to examine the stability of foundation rock blocks and their influence on stability at the toe of the dam. Basic assumptions were made for the geometry and joint strengths for potentially unstable rock blocks, and a simplified stability analysis was conducted. The results of this analysis indicate that the downstream toe of the dam should be located approximately 15 m upstream from the edge of the waterfall.

Geotechnical design parameters and criteria used for developing project layouts and cost estimates are presented in Table 4-10.

TABLE 4-10 SUMMARY OF GEOTECHNICAL DESIGN PARAMETERS FOR THE RÍO CAÑO SUCIO DAM

Parameter	Selected Design Criteria
Thickness of overburden (top of weathered rock)	Varies from valley floor to dam crest
Excavation depth under dam	2 m at valley floor to 6 m at 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
Soil Excavation Slopes, Temporary	1.5H:1V, 3-m-wide benches every 10 m vertically. Bench at soil-rock contact

4.3.5.2 Foundation Treatment

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. Consolidation grouting is not envisaged except in limited areas (e.g. fault or fracture zones) should they become exposed during excavation.

Curtain grouting will be used to reduce seepage through joints and fractures under the dam and in the abutments. For estimating purposes, a single row, staged grout curtain constructed by the split-spacing method is assumed.

4.3.5.3 Diversion and Cofferdams

River diversion during construction will be accomplished through a culvert located under the dam in a trench excavated in bedrock. This bedrock should be of moderate strength and unweathered over most of the culvert length. The upstream cofferdam will be founded on bedrock and consist of an RCC section or masonry wall about 4 m high.

4.3.6 Seismicity

As indicated on Exhibit 2-7 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 North Panama Deformed Belt, while two earthquakes occurred nearly 25 km off the northern coast near Colon in 1621 and 1882. An additional earthquake event is noted in 1914 on the northeastern coast in the San Blas region. 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.

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, 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 maximum credible earthquake (MCE) can be acceptable to represent the maximum design earthquake (MDE), when using probabilistic methods.

The recommended operating basis earthquake (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.

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

For the Río Caño Sucio project, the recommended seismic design parameters are as follows:

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

Both dams were analyzed for stability under MDE conditions.

4.3.7 Geology of the Water Transfer Facilities

The water transfer facilities between the Río Coclé del Norte and Río Indio reservoirs (Exhibit 3-4) will consist of a combination of canal and tunnel. The canal will be excavated, for the most part, in overburden. In some of the deeper cuts, excavation will be in rock. A tunnel will be required over a distance currently estimated to be about 2,550 meters.

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. Based on the limited investigations carried out for this study, it is probable that tunnel and canal construction for the inter-basin transfer would encounter a wide range of rock types and tunneling conditions and could include any of those identified during investigation of the Río Toabré and Río Indio sites and reservoir areas.

The first part of the water transfer facilities consists of a canal from the Río Coclé drainage to the Río Caño Sucio drainage. This part of the canal will require excavation through the saddle area at Quebrada Encantada. The excavation will be through 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 Río 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 Río 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.

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.

Bedrock outcrops in the tunnel outlet 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. Some of the volcanic formations might represent older units cropping out as erosional inliers.

The tunnel cover criterion (the vertical distance between the ground surface and the crown of the tunnel excavation) used in developing various potential alignments was:

$$H = 2D + 10 \text{ meters}$$

Where H equals the distance between the top of ground and the crown of the excavated tunnel and D equals the tunnel diameter. Ten meters was added to the experience estimate for cover to account for topographic uncertainty.

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). For estimating costs, it was assumed that tunnel construction would utilize drill-and-blast techniques from both portals. Intermediate access locations probably will not be used due to the short distance of the tunnel.

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. The potential for encountering hazardous gases is considered remote. Ventilation and shotcrete have been used successfully to control gas occurrences, should they occur. 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.

Anticipated rock condition type and support requirements for the water transfer tunnel during construction are listed in Table 4-11. Tunnel lengths associated with the rock support classes, I - IV were estimated based on the general knowledge of the geology of the area, geologic mapping, and judgment.

TABLE 4-11 ROCK SUPPORT CLASS & SUPPORT REQUIREMENTS FOR THE WATER TRANSFER PROJECT 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, perhaps grouting	10%

It is assumed that the tunnel will be fully lined from portal to portal. The lining will be required 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 with an average lining thickness of 40 cm.

The anticipated geologic and tunneling conditions strongly influenced the estimate of excavation advance rate and of course construction cost. The daily advance rate assumed for estimating costs was 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.

4.3.8 Construction Materials

For the Río Coclé del Norte Project, 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.

The 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.

The majority of the rockfill and 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. The area downstream from the damsite on the right side of the river consists of high hills that could be stripped and opened as quarries. The location of these sources is shown on Exhibit 4-3.

Materials for backfill will come from the required excavations, including use of tunnel excavation spoil. A portion of the rockfill for the dam also could be obtained from required excavation, provided that it is not too decomposed.

For the Río Caño Sucio project, most of the facilities are comprised of concrete or roller compacted concrete and, therefore, the required construction material is concrete aggregate. All coarse and fine aggregate for concrete needs to be manufactured from quarried igneous rock materials, *i.e.* basalt or andesite. Quarry sites for obtaining this material were identified 5-6 km southeast of the damsite at Cerro Miguel and Cerro Loma Alta. It is anticipated that some mixing with imported sands and silts will be necessary. Materials located closer to the dam are not considered to be acceptable. The location of these quarries is shown on Exhibit 4-4.

4.4 Power Market

The ACP owns and operates three powerplants; two hydro plants at Lake Gatun and Lake Madden, and a thermal powerplant at Miraflores that includes 3 diesel-burning gas turbines and 2 steam units that are fired with Bunker C oil. The ACP system is shown in Table 4-12.

TABLE 4-12 ACP ELECTRIC GENERATING SYSTEM

Plant	No. of Units	On-line Date	Actual/Planned Installed Capacity (MW)
Gatun	6	1916(3), '18,'46, '47	24
Madden	3	1935(2), '42	36
Miraflores	6	1963(2),'66,'71(2)	115

As a part of the reconnaissance studies performed by the USACE (1), the potential for adding hydropower to the Río Coclé del Norte Project was considered. The analysis indicated that, at a benefit of $0.07/kWh, the addition of hydropower was very attractive. The USACE went on to say that the estimated value of energy might understate its true value and that modifications to the operating regime of the system might improve the production of energy over that reported in the Reconnaissance Report. It was recommended that additional effort should be expended in any future planning studies to determine the economic value of added hydroelectric power generation and that further study be performed to optimize the (hydro) operation of the project.

As reported by the USACE, the power features of the Río Coclé del Norte Project consisted of a 21.3 MW installation at the base of the dam, 6.2 MW at the end of the Caño Sucio-Río Indio Tunnel, and 9.7 MW at the end of the Río Indio-Lake Gatun tunnel.

A power market study was performed to confirm the need for additional generation in Panama, and the potential for adding hydro to the Río Coclé del Norte Project was evaluated. The results of these studies are summarized below and are presented in detail in Appendix E.

4.4.1 Existing Power Market

The power generated at the Gatun and Madden power plants is used to meet the electricity needs of the canal operation, and the commercial, residential, and governmental sectors in the ACP area. Any surplus can be sold into the Panama national electrical system. A power market survey of Panama was conducted to determine the future power needs of the national system to evaluate the opportunities for such a sale.

4.4.1.1 ACP Internal Market

Over the period from 1992 to 1999, the overall trend in sales by the ACP has been down reflecting a downward trend in sales to its internal customers and a varying but relatively constant sale to IRHE. Historically, the largest user of ACP electricity, accounting for about 65% of the total usage, has been the industrial components of the U.S. Army, Air force, and Navy. This use held constant through 1995 and then began a rapid decline as the plans for the turnover of the canal progressed. In 1999, the demand had dropped 40 percent from the average 4-year usage between 1992 and 1995. The second largest group of users, accounting for 25% to 35% of the sales, consisted of the lock operation, drinking and cooling water, and other miscellaneous uses. This use group has shown an upward trend over the 8-year period of slightly more than one percent per year. The final user group consists of various agencies, employees of the ACP, and other residential and commercial users in the canal area. This group, accounting for about 10% of the sales, has generally trended downwards. The sales to IRHE averaged about 70 GWh/year and have varied from a low of 8 GWh in 1997 to a high of 104 in 1992. These historic data are presented in Table 4-13. Generation has generally been about five percent higher than usage and the average peak load over the period has been 80 MW and trending downward.

TABLE 4-13 HISTORIC SALES AND GENERATION OF ELECTRICITY BY THE ACP
(GWh)

Year	U.S. Military	Locks, Water, etc.	Other Agencies	IRHE	Total Sales	Generation
1992	342	117	52	104	615	643
1993	342	117	51	84	593	624
1994	343	119	50	50	562	599
1995	341	120	49	89	599	635
1996	316	119	44	58	536	570
1997	318	120	43	8	488	502
1998	257	127	36	94	514	548
1999	206	129	26	71	431	450
Avg.	**308**	**121**	**44**	**71**	**544**	**571**

It is difficult to forecast the firm generation demand on the ACP system, especially over the near-term. It is assumed that the industrial demand formerly required by the U.S. military will recur as the facilities are taken over by others. What is not sure is whether or not the required demand will be purchased from the ACP or another generation company. Therefore, it is assumed that the ACP will have an internal demand of about 180 GWh in the first year of operation of Project and that all other demands occurring in the Panama Canal Watershed will be subject to competition.

4.4.1.2 National Market

Historic energy demand and peak load for the Panama National Integrated System (PNIS) is presented in Table 4-14.

TABLE 4-14 ENERGY DEMAND AND PEAK LOAD IN THE PNIS

Year	Energy Demand (GWh)	Peak Load (MW)	Load Factor (%)
1990	2746.1	464	68
1991	2896.6	488	68
1992	3011.6	518	66
1993	3199.1	541	68

Year	Energy Demand (GWh)	Peak Load (MW)	Load Factor (%)
1994	3400.0	592	66
1995	3619.4	619	67
1996	3795.8	640	68
1997	4254.4	707	69
1998	4295.8	726	68
1999	4456.8	754	67
2002[1]	4998.5	857	67

[1] Source: ETESA's web page

Energy demand and peak load grew at a rate of about 5% per year over the 12-year period from 1990 to 2002. The annual system load factor has been constant at about 68%. There are only minor variations among monthly energy demands and peak loads, as monthly temperatures remain relatively constant throughout the year. The monthly peak loads in terms of percent of annual peak load and the monthly energy demand in terms of percentage of total annual energy demand for year 2002 are shown in Table 4-15.

TABLE 4-15 MONTHLY PEAK LOADS AND ENERGY DEMANDS OF THE PNIS FOR 2002

Month	Peak Load (% of Annual Peak Load)	Energy Demands (% of Total Demand)
January	93.2	8.1
February	94.2	7.5
March	96.8	8.6
April	97.9	8.5
May	100.0	8.9
June	96.2	8.3
July	99.2	8.5
August	96.2	8.3
September	97.4	8.1
October	96.6	8.4
November	98.6	8.0
December	99.7	8.8
Total	-	**100.00**

Daily peak loads of the PNIS occur during the period from 11 AM to 3 PM on weekdays and Saturdays and at 7 PM or 8 PM on Sundays. The distribution of typical hourly loads is presented in the Appendix E, Part 1, Power Market Study.

4.4.2 Power Market Forecast

Three demand forecasts are available for each of two economic assumptions, moderate growth and high growth. One forecast was developed in 1998, one in 1999, and the third in November 2000. The earlier estimates were developed using a multiple regression analysis to define the relationship between energy consumption and economic parameters for each consumer sector including residential, commercial, industrial, government, and public lighting. A regression equation was defined for each sector. The economic parameters included population, Gross Domestic Product (GDP) per capita, unit energy sale price for each sector, and energy efficiency. The energy efficiency is the unit energy consumption rate for producing the GDP of the industry sector, and is computed by dividing the GDP by total energy consumption of the sector. The peak load demands were estimated on the basis of the forecasted energy demand and a system load factor at 67.9 %.

The more recent demand estimate was developed using a simplified relation of total energy sales as a function of gross national product (GNP). The coefficient of determination for the two samples (total energy and GNP) was highest using a polynomial function. The simplified approach was used for the recent estimate due to the difficulty in obtaining accurate economic information needed for the earlier estimates.

The estimated energy losses of the transmission and distribution systems, in terms of percentage of the total energy consumption, for the two scenarios was estimated to decrease from about 22% in 1997 to about 14% in 2015. The most recent estimated total energy demands of the PNIS developed in 2000 for the medium and high growth scenarios are shown in Table 4-16.

TABLE 4-16 DEMAND FORECAST DEVELOPED IN 2000 FOR THE PNIS

Year	Medium Growth Scenario		High Growth Scenario	
	Capacity (MW)	Energy (GWh)	Capacity (MW)	Energy (GWh)
2000(Actual)	790	4,732		
2002(Actual)	857	4,998		
2005	1,107	5,304	1,777	5,655
2010	1,608	7,616	1,832	8,691

For comparison, the energy production estimates for the medium growth scenario are shown below for all three estimates:

Year	Medium Growth Scenario – GWh			
	1998 Estimate	1999 Estimate	2000 Estimate	Actual
2001	4,981	4,907	4,028	4,823
2005	6,280	6,431	5,304	
2010	8,154	8,435	7,616	

Average annual growth rates of the most recent forecasted energy demands of the PNIS for the period of 2001-2010 were 7.3 % for the medium scenario forecast, and 8.8 % for the high scenario. These compare with the historical average annual growth rate of the energy demand at 5.5 % for the period of 1990-1999 and 5.6% and 7.0% for the corresponding period and scenario of the 1998 estimate. The comparison indicates a reduction in the forecast of about 18% in the early years and about 10% in 2010.

The average annual load factor of the PNIS was 67.2 % for the period of 1990-1999. In recent years, the system load factor has increased from 65.6 % in 1994 to 68.5 % in 1997, and decreased to 67.4% in 1999. The PNIS has forecasted that the annual system factor will be in the low 50th percentile through year 2010.

4.4.3 Market Opportunity for Río Coclé del Norte Generation

The existing PNIS had an installed capacity of 1,058 MW in 2000. The total generation from the PNIS facilities in 1999 was 4,457 GWh. It appears that the Esti Hydropower project, consisting of two plants, Guasquitas and Canjilones, are committed and will be on line prior to the Río Coclé del Norte project. These two plants have an aggregate capacity of 119 MW and are expected to generate an average of 627 GWh each year. However, from the 1999 expansion plan (10), there are plans to retire two plants by January 1, 2010, which currently have an aggregate capacity of 80 MW.

On the basis of the peak load and energy requirements, the existing, committed, and scheduled retirement available from the 1999 expansion plan, the power balance in year 2010 should be about as follows:

TABLE 4-17 POWER BALANCE IN 2010

	Capacity Demand
Available Capacity (2000)	1,058 MW
Committed Capacity	119 MW
Planned Retirement	80 MW
Net Capacity	*1,097 MW*
Year 2010	**1,608 MW**
Required Capacity	**>500 MW**

According to ETESA's web site, the PNIS installed capacity in 2002 was 1,079 MW and the total generation was 4,998.5 GWh, which is within the range of the estimate for 2010. Therefore, it can be concluded that there is a substantial market for additional power in the future and that the Río Coclé del Norte hydropower project will be easily absorbed into the PNIS.

4.5 Project Operation Studies

The HEC-5 Reservoir System Model, developed by the U.S. Army Corps of Engineers' Hydrologic Engineering Center in Davis, California was used to evaluate the capability of the present ACP system 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). 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 the reservoir model system.

4.5.1 Area/Volume Relationships

Area and volume data versus elevation were developed for both the Río Coclé del Norte and Río Caño Sucio Reservoirs based on the 1:50,000 scale maps. The "zero" area and volume point was taken from topographic mapping of the dam sites. For the Río Caño Sucio site, additional points were based on a partial contour at El. 90 and an estimate for El. 105 based on a contour generated by an LDD Terrain model. Land acquisition was based on an extension of these data. A curve of area and volume versus elevation is shown on Exhibit 4-5 and 4-6 for Río Coclé del Norte and Río Caño Sucio respectively.

4.5.2 Reservoir Operating Level in Río Coclé del Norte Reservoir

The minimum operating level at Río Coclé del Norte is constrained by the minimum level at Río Caño Sucio, which is El. 90. The minimum operating level at Río Caño Sucio is limited by topography.

A series of operation studies were performed to assess the variability of yield versus active storage at various levels in the operating range. Although no economic studies were possible, based on experience and a storage/yield curve, discussed and presented in Appendix D, it was determined that an active storage between 3,000 MCM and 4,000 MCM provides a development level near to the optimum. The active storage available between El. 90 and El. 100 in the Río Coclé del Norte Reservoir is about 3,840 MCM and, therefore, this operating range was adopted. The active storage between El. 90 and El. 105 is more than 6,000 MCM and is probably outside the optimum range.

4.5.3 Reservoir Operating Levels in Río Caño Sucio Reservoir

The reservoir operating level is established to permit the transfer of water to the proposed Río Indio Reservoir from a project in the Río Coclé del Norte basin. At this time, the maximum development contemplated for the Río Coclé del Norte dam results in a full supply level at El. 100 and the full supply level at Río Caño Sucio was established at the same level. Current studies on the Río Toabré may result in a higher level. The available damsite mapping suggests that the dam could be constructed to a higher level, but it is not possible to determine the impact on the reservoir using the available 1:50,000 mapping.

The minimum supply level is estimated to be El. 90, which results in a live storage of 68.5 MCM.

4.5.4 System and Project Yield

Operation simulations were made for a demand identified in terms of daily lockage requirements (Lockages per day, L/d) using the live storage in the Río Caño Sucio reservoir between El. 100 and El. 90 and the live storage in both reservoirs between El. 100 and El. 90. One lockage was assumed to equal 55 million gallons or 208,000 m^3. The yield allocated to the Project was estimated as the total yield of the existing system, (Gatun after deepening, Madden, Río Indio) plus Norte/Sucio less the yield of the system without Norte/Sucio. 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%.

The yield of the Norte/Sucio Project under these conditions is estimated to be 3,570 MCM/year or 47 L/d as shown in Table 4-18. Although it is not the intent to construct the Río Caño Sucio Project as a stand-alone water supply project, the yield from the basin will have an impact on the construction sequencing of the Río Coclé del Norte Project. Therefore, the proportion of the system yield allocated to each of the reservoirs is also shown in Table 4-18.

TABLE 4-18 PROJECT YIELD

	Yield		
	L/d	**Mgd**	**MCM/yr (rounded)**
Existing System Yield (as defined) at reliability of 99.6%	60.3	3,316	4,580
System Yield w/ Río Caño Sucio Reservoir	62.8	3,454	4,770
System Yield w/ Norte and Sucio Reservoirs	107.3	5,900	8,150
Yield allocated to the Norte/Sucio Project	47.0	2,586	3,570
Yield allocated to Río Caño Sucio Reservoir	2.5	138	190
Yield allocated to Río Coclé del Norte Reservoir	44.5	2,448	3,380

Additional information on the operation studies is presented in Appendix C.

5. THE RÍO COCLÉ DEL NORTE DAM AND APPURTENANT WORKS

In the development of an arrangement for the Río Coclé del Norte Dam and its appurtenant works, studies were done to confirm the dam site, to select the type of dam, to size the spillway and diversion works, and to finalize the arrangement of the dam and appurtenant works. The studies were performed for a dam with its full supply level at El. 100 and its minimum operating level at El. 90.

5.1 Río Coclé del Norte Dam Site and Dam Type Selection Studies

A consideration of alternative damsites was made and no better site was identified. Studies were then performed to select the type of dam most appropriate for the selected site. A concrete-face rockfill dam (CFRD) was selected.

5.1.1 Dam Site Selection

In their Reconnaissance Report (1), the USACE selected a dam site with a view toward maximizing the water development potential while maintaining the reservoir high enough to allow for easy outflow through the Río Caño Sucio Reservoir to the Río Indio Reservoir.

Selection of a site was fairly straightforward. To maximize the water development potential in the basin, it is necessary to regulate the flow of the Río Toabré, which accounts for about one-half of the catchment area. It is desirable to locate the dam as far upstream as possible below the confluence to limit the height of dam. The selected site is an acceptable alternative.

The dam site is located about 1 km downstream of Cerro Pelado, and approximately 4km upstream of the village of San Lucas. It is about 6 km downstream of the confluence with the Río Toabré, and 15 km from the mouth of the Río Coclé del Norte with the Atlantic Ocean. The axis used for this study was selected primarily to maximize storage and for topographical considerations. It takes advantage of a relatively narrow reach of river valley to reduce the volume of fill, provides adequate space for cofferdam and diversion facilities, and does not present any adverse access difficulties. The final alignment of the dam will be confirmed following the site investigation program during final design.

5.1.2 Dam Type Selection

The detailed studies of the selection of the type of dam for the Río Coclé del Norte Project are presented in Appendix D, Part 1.

The dam type selected in the Reconnaissance Study (1) was a center core rockfill dam. An ungated spillway was located on the right abutment. The proposed spillway had a crest width of 346 m and the spillway chute was proposed as a sloped and stepped natural rock cut channel.

Four types of dam were identified for evaluation as a part of the current dam type study:

Alternative	Dam Types	Abbreviation
1	Concrete Faced Rockfill Dam	CRFD
2	Roller Compacted Concrete Dam	RCC
3	Conventional Gravity Concrete Dam	CGCD
4	Earth Core Rockfill Dam	ECRD

Alternatives 3 and 4 were rejected in the preliminary screening. The CGCD was rejected because it will be more expensive than the RCC dam primarily owing to the higher cement content (and therefore cost), the need for more formwork, and the longer construction period. The ECRD was rejected because suitable quantities of impervious material were not located in the vicinity of the dam site and the wet climate is less favorable for the construction of an ECRD.

5.1.2.1 Concrete Face Rockfill Dam

For the dam type selection study, the slopes of both the upstream and downstream faces of the CFRD were 1.4H:1.0V. The dam would be constructed of selected rockfill obtained from adjacent or nearby rock quarries. An upstream parapet wall extending 2 m above the fill, and a downstream retaining wall of 1 m, would form the top-of-structure.

An 8-m diameter 530-m long diversion tunnel would be located in the left abutment. It was sized to pass the 50-year event.

An ungated spillway will be located in the right abutment. As configured, the spillway would have a crest width of 50 m and a 250-m long tapered chute.

5.1.2.2 Roller Compacted Concrete Dam

The RCC dam was configured for a vertical upstream face and a downstream slope of 0.75H:1V. The crest would be 8-m-wide and a parapet wall would be constructed to two meters above the crest.

The diversion was also sized for a 50-year flood. The tunnel would be about 450 m long and have a diameter of 8 m.

An ungated spillway was adopted for the dam-type studies with the same hydraulic capacity as the CFRD ungated spillway. It was be located on the RCC dam to discharge directly by means of a chute and flip bucket into the existing Río Coclé del Norte channel. The spillway would be constructed of conventional reinforced concrete.

5.1.2.3 Dam-Type Selection

The two alternatives were evaluated on the basis of cost and construction, foundation, and operation and maintenance considerations.

The CFRD alternative resulted in a cost about 9% lower than the RCC alternative.

Construction considerations do not necessarily favor either type of dam. The RCC dam can be constructed in a shorter time, but the CFRD takes more advantage of local materials.

The known foundation characteristics are equally suitable for either dam type. The rock formation found in outcrop, and found to extend throughout the site is suitable for both types of dam.

Operation and maintenance considerations tend to favor the RCC dam. Leakage through either type of dam should be minimal.

As a result of the analysis, an ungated concrete-face rockfill dam was selected for further study for the following reasons:

1. Changes to the current available foundation information would have less impact on this dam type and cost;
2. The CFRD cost estimate is less sensitive to variation in unit cost, and;
3. The total cost of the CFRD alternative is projected to be lower than the total cost of the RCC alternative.

The selection of the CFRD alternative should be confirmed following the completion of site investigation programs if the investigations show foundation conditions that are highly favorable for RCC dams.

5.2 Río Coclé del Norte Project Configuration Studies

5.2.1 Spillway and Diversion Flood

The spillway is designed to pass the probable maximum flood without overtopping the dam or causing any damage to the spillway facilities. For a project whose failure could result in loss of human life and economic endeavor, such as the Río Coclé del Norte Project, it is customary to design the project for the worst conditions that could reasonably be postulated. The maximum peak inflow of the PMF is estimated to be 10,550 m^3/s and the 5-day volume is about 1,005 MCM.

A flood with a return period of 50 years was selected for the construction diversion flood. This flood would have a peak discharge of 3,860 m^3/s and a 1-day volume of about 167 MCM.

5.2.2 Diversion Facilities

River diversion will be accomplished by an 8.0 m diameter, 550-m long diversion tunnel in the left abutment. The tunnel will be modified horseshoe (D-shaped) in shape and will be concrete lined.

The size of diversion tunnel was selected to limit the height and size of the upstream cofferdam and to be converted into the low level outlet facilities for use in controlling filling and for emergency drawdown. The selected tunnel diameter results in upstream and downstream water surface elevations of 22.1 m and 2.7 m. The upstream and downstream cofferdams crest elevations were set at El. 22.5 and El. 4.0 m respectively.

5.2.3 Emergency Drawdown

The original studies demonstrated that meeting the selected drawdown requirements governed the minimum size of diversion tunnel that would subsequently be used as the low-level outlet facility. The adopted drawdown requirements were taken from the USBR guidelines (ACER Technical Memorandum No. 3 dated January 1982 entitled Criteria and Guidelines for Evacuating Storage Reservoirs and Sizing Low-level Outlet Works).

Preliminary hydraulic analysis showed that a 10.5 m D shaped tunnel would meet draw down the reservoir to El. 75 in 34 days, less than the 40-days recommended in the USBR guidelines. However, the peak flow of 3,100 m^3/s results in peak velocities in the tunnel of over 30 m/s, which is not acceptable. The adopted limiting peak velocities are 20 m/s in the tunnel and 30 m/s through the outlet gates (which would have steel-lined transition sections). For these velocities, the required tunnel diameter to draw down the reservoir by 25% elevation of the hydraulic head (*i.e.* from E. 100 to El. 75) is 12 m. The peak discharge would be 2,500 m^3/s.

At the higher discharge rates, the flow depth will reach El. 8 at very high velocities, which will inundate and possibly cause damage to the powerhouse, flip bucket and downstream infrastructure. It was decided that energy dissipation would be required to eliminate or reduce damage, as the tailwater elevations are insufficient to reduce flow velocities to sub-critical. Because of the cost and the fact that the emergency drawdown facility will be used rarely, if ever, the viability of the arrangement was called into question and further study was performed.

The adopted guidelines were carried over from the studies of the Río Indio and Upper Chagres Water Supply Projects. These smaller reservoirs could be drawn down through diversion facilities sized to pass the selected diversion floods (50 and 25 year return periods, respectively). For the very large reservoir that would be impounded by the Río Coclé del Norte Dam with a FSL at El. 100, meeting the drawdown criteria will result in significant additional diversion and low level outlet cost (estimated at $20 million).

The USBR guidelines state that relaxation of criteria and guidelines because of site-specific conditions should be considered on a case-by-case basis after the consequences and costs of different alternatives have been evaluated and quantified. The guidelines also suggest other criteria including:

- For large reservoirs requiring 5 years to fill might require outlets sized to pass a 25-year flood in addition to mean inflow at specified filling rates. The reservoir requires 5 years to fill, and the diversion tunnel will be sized to pass the 50-year flood, so this criterion is met.
- Low level outlet works should be located and sized to provide discharge capacity sufficient to maintain reservoir filling rates specified by initial filling criteria and to hold reservoir levels reasonably constant for elevations above 50% of the hydraulic height of the dam.

The second criterion was evaluated at the 50 % hydraulic height. Diversion studies had shown that an 8 m diameter tunnel would result in an acceptable cofferdam size and height and pass the selected 50-year return period construction flood. The 50-year return period flood was routed through the reservoir at El. 50 and the low level outlet used to control filling with a maximum discharge of 20 m/s. The resulting rise in reservoir elevation was 0.9 m. This is judged to be reasonably constant. With a likelihood of exceedance of 8% in the 4-year filling period (over El. 50), this is considered an acceptable risk, and the emergency drawdown capacity resulting from an 8-m diameter tunnel was accepted.

Drawdown times with this the 8-m diameter tunnel are:

TABLE 5-1 DRAWDOWN TIME FOR 8 M DIVERSION TUNNEL

Drawdown Elevation (and % of hydraulic head)	Time, days
El 75 (75%)	91
El. 50 (50%)	141
El. 25 (25%)	163

The drawdown estimates do not include using the Río Caño Sucio to Río Indio tunnel for reservoir evacuation, which would decrease the drawdown time from El. 100 to El. 90.

5.3 Preliminary Design of Río Coclé del Norte Dam and Appurtenant Works

This section presents a more complete description of the project features and the design assumptions that were adopted. The project hydrology, engineering geology, and geotechnical assumptions have been summarized in Section 3 and are presented in detail in Appendixes A and B.

5.3.1 Río Coclé del Norte Dam and Saddle Dams

Río Coclé del Norte Dam will be a concrete-face rockfill dam (CFRD) constructed of durable, free-draining compacted rockfill obtained from nearby quarries. The slopes of the upstream and downstream faces will be conservatively set at 1.4H:1.0V based on precedent for this dam type, foundation, and seismicity at the site. The main body of the dam will be comprised of rockfill and the downstream shell will be coarse rockfill. The rockfill shells and filters of the dam have an in-place volume of about 6.1 million cubic meters.

The axis of the dam will be slightly concave downstream and will cross the main channel of the Río Coclé del Norte at about 993540N, 550430E (UTM Coordinate System). The crest of the dam will be at El. 101 and the width of the crest will be 8.0 m. A 5-m high parapet wall will extend 2 m above the crest to El. 103. The dam will be about 114 m high from the deepest foundation excavation to the top of the parapet wall. A plan of the dam is shown on Exhibit 3-2 and a section, and details of the dam are shown on Exhibit 5-1.

A reinforced concrete facing will act as the impermeable membrane. It will be designed to have low permeability, durability against weathering, and sufficient flexibility to tolerate small, expected embankment settling. A 3-m wide zone of filter material and a 3-m wide zone of fine rockfill will underlay the concrete face to provide continuous support. The filter material will be manufactured from the igneous quarry material. The average thickness of the concrete face will be 0.4 m. Reinforcing steel will be included at a rate of 30 kg/m^3. The facing will be placed in individual slabs, up to 15 m wide, and horizontal joints will be inserted as needed.

With reservoir full supply level at El. 100, a series of up to five saddle dams will be required along the western edge of the reservoir over a distance of about 15 km from the dam. A typical section of the saddle dams is shown on Exhibit 5-1. The saddle dams will be embankment fills both with upstream and downstream slopes of 2.75H:1.0V and 2.5H:1.0V respectively. A 3-m wide chimney drain will connect to a 1-m thick blanket drain in all saddle dams. The crest of the saddle dams at El. 103 will be 8.0 m wide and riprap processed from the igneous quarry will be placed on the upstream slopes. Estimates of cost are based on dimensions estimated from 1:50,000 scale mapping.

5.3.2 Foundation Treatment

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

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.

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 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). It is assumed that the spacing of the primary grout holes will be 10 m and it is further 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. The grouting will be to a depth of one-half the height of the PMF above the dam foundation or to a maximum depth of about 55 m below the structural foundation level. Final design might require grout holes to be inclined to intercept the maximum number of open joints, fractures, and faults. The average grout consumption was assumed for estimating purposes to be about 30 kg/m.

Foundation drainage will be provided for the 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.

5.3.3 Spillway

An ungated chute spillway will be located in the right abutment. The spillway has been designed to pass the PMF without overtopping the dam. The discharge under PMF conditions will be 250 m^3/s using a surcharge of 1.8 m above the full supply level. An outflow hydrograph is shown on Exhibit 4-2. The resulting freeboard under this flooding condition will be 1.2 m.

The spillway will consist of an approach channel, an ogee control section, a tapered chute, a flip bucket, and an excavated channel to direct the water back to the natural river channel. A plan and sections of the spillway are shown on Exhibit 5-2 and 5-3.

The approach channel will be about 40 m long and will be excavated to El. 95. The channel will be curved and widen from about 55 m at the control structure to about 80 m at the end of the channel.

The ogee-type control section will be concave downstream and consist of three bays with a total clear opening of 50 m. Two piers will support an 8-m wide bridge to connect the dam crest to the right abutment access road.

The chute will be about 260 m long from the downstream end of the control structure to the beginning of the flip bucket. The width of the spillway chute will taper from 52 m to 10 m at the upstream end of the flip bucket. An aeration ramp will be installed about El. 50. The chute is sloped to follow the rock line. The maximum water depth will vary from 1.8 m at the crest to 3.0 m at the upstream end of the chute to 1.7 m at the upstream end of the flip bucket. A constant wall height of 4.0 m was selected.

The flip bucket is located so that the plunge pool will not impact on any of the proposed project structures. The lip of the bucket will be 10 m wide and will be at El. 4 about 2.0 m above the anticipated tailwater elevation under PMF conditions. A reinforced concrete slab about 10.0 m long will extend downstream from the bucket to provide foundation protection for small discharges.

5.3.4 River Diversion During Construction

The facilities for the temporary diversion of the Río Coclé del Norte during construction consist of cofferdams upstream and downstream from the damsite and a tunnel in the left abutment. The river diversion facilities plan, profile, sections, and details are presented on Exhibits 5-4 and 5-5. The tunnel will serve to:

- Pass the 50-year flood;
- Control the rate of initial reservoir filling, and;
- Assist in the evacuation the reservoir.

The criteria presented in Appendix D4, Section 4 were adopted for determining the drawdown capability. It was determined that controlling the rate of filling determines the selection of the capacity of the diversion tunnel. Provision of drawdown capability will be achieved by a combination of converting the diversion tunnel to a low-level outlet and utilizing the water transfer tunnel.

The diversion tunnel will be an 8.0-m diameter, modified horseshoe with vertical sides and a horizontal invert, approximately 550 m long. The diversion tunnel will be constructed entirely in basalt. Under the 50-year flood event, the tunnel will discharge about 636 m^3/s with the upstream water surface at El. 22.2 and the downstream water surface at about El. 3.

An approach channel 120 m long will lead to the intake portal. The approach channel will be horizontal and approximately at El. 0. The upstream portal will be excavated into a rock face to provide cover of about 10 m at the beginning of the tunnel. The excavation will be at a slope of 1H:5V in the rock and 2H:1V in the overburden. Rockbolts and shotcrete will be applied as needed. A 360-m long discharge channel will extend from the downstream portal to the river channel.

The upstream and downstream cofferdams will be approximately 25-m high and 9-m high respectively. The wet-side slopes will be 2.5H:1V and the dry-side slopes will be 2H:1V. The upstream cofferdam will have its crest at El. 22.5 and is proposed as a zoned-fill structure constructed with materials excavated at the damsite. The structure will only be partially founded on rock and a cutoff of 3 m to 6 m may be required. The downstream cofferdam will have its crest at El. 4 and will be constructed of random fill excavated from the site. The total volume of both cofferdams will be about 614,000 m^3.

5.3.5 Emergency Drawdown

Emergency drawdown will be through the diversion tunnel. The emergency drawdown facilities will consist of a low-level intake structure constructed at the intake portal, a gate shaft constructed under the crest of the dam to facilitate its use for reservoir evacuation and passing the minimum release, high-strength concrete lining, and hydro-mechanical equipment. Profiles and sections of these facilities are shown on Exhibit 5-5.

The intake structure will be constructed to El. 14 to permit continuous operation over the life of the project without interference from sediment buildup. The gate shaft will house two 3.6-m wide by 6-m high wheel gates and two similar sized bulkhead gates. The diversion tunnel opening in the low-level intake will be plugged when the gate shaft is completed. Water can then rise to El. 14 and flow through the low-level intake and be controlled at the gate shaft.

At high reservoir elevations, flow through the diversion tunnel will be controlled by the wheel gates. Control is required to limit the velocity in the tunnel to 20 m/s, to prevent cavitation damage to the tunnel lining by providing aeration, and to control the downstream tailwater elevations. The tunnel lining will be constructed using high strength concrete, and a 20 m long anchored apron will be constructed downstream of the tunnel outlet portal to prevent foundation erosion. At high discharge flows, some erosion damage can be expected in the downstream channel.

5.3.6 Minimum Release Facility

The minimum release has been assumed to equal 10% of the average flow or about 10.7 m^3/s. The minimum release will be discharged through the powerhouse, or through a bypass valve in the powerhouse.

6. THE RÍO CAÑO SUCIO DAM AND APPURTENANT WORKS

In the development of the arrangement for the Río Caño Sucio dam and its appurtenant facilities, studies were done to confirm the dam site, to select the type of dam, to size the spillway and diversion works, and to finalize the arrangement of the dam and appurtenant works.

6.1 Río Caño Sucio Dam Site and Dam Type Selection Studies

A consideration of alternative damsites was made and no better site was identified. Studies were then performed to select the type of dam most appropriate for the selected site. A roller compacted concrete dam was selected.

6.1.1 Dam Site Selection

In their Reconnaissance Report (1), the USACE selected a dam site with a view toward maximizing the water development potential while maintaining the reservoir high enough to facilitate the transfer of water from the Río Coclé del Norte basin to the Río Indio Reservoir.

The selected site permits the transfer of water from the Río Coclé del Norte basin down to El. 90. The site results in a low-cost dam and low cost water transfer facilities. It also leaves intact a waterfall.

Storage could be provided downstream as far as just below the confluence of the Río Caño with the Río Caño Sucio. The dam would be significantly more expensive and be more suitable for a storage facility with the objective of providing significant yield to the system rather than the stated objective of this project, which is to provide for easy transfer of water from the Río Coclé del Norte. The advantage of storage downstream is that it would permit operating any storage in the Río Coclé del Norte basin down to El. 80 thus either reducing the height of dam or increasing the system yield.

The selected site is considered to be the most suitable because of its relatively low cost and the ease with which water can be transferred into the Río Indio basin. Any increase in yield provided by the downstream storage would not be needed until well into the future. Reducing the dam height in the Río Coclé del Norte basin by 10 m or so will do almost nothing to alleviate the environmental concerns associated with the higher dam. Upstream of the selected site, the morphology does not lend itself to the construction of an economical dam.

Although the cost of any facility on the Río Caño Sucio would be insignificant in the development scheme for the third set of locks, there is no better site to maintain the water level at about El. 100 and facilitate the transfer of water from the Río Coclé del Norte basin.

6.1.2 Dam Type Study

Four types of dam were identified for evaluation as a part of a dam type study as follows

Alternative	Dam Type	Abbreviation
1	Concrete Face Rockfill	CFRD
2	Roller Compacted Concrete	RCC
3	Conventional Concrete Gravity	CCGD
4	Earthfill Dam	ED

The general development criteria were:

- An 25-m wide ungated spillway passing the PMF and resulting in a maximum water surface at El. 104.3
- A full-supply level at El. 100
- A parapet wall to El. 105.3
- The diversion flood for all except the RCC dam has a return period of 50 years and the RCC dam diversion is sized for a dry-season 50-year flood.

Additional details for the dam type selection study are presented in Appendix D2.

6.1.2.1 Concrete Face Rockfill Dam

The slope of the upstream and downstream faces of the CFRD was 1.4H:1V. The rockfill will be obtained from nearby quarries developed in the same sandstone unit found at the damsite. The concrete face was sized for an average of 30 cm thick with a plinth placed along the upstream toe. A zone of fine-grained rock would be placed beneath the concrete face to provide continuous support. Grouting would be accomplished through the plinth.

The diversion conduit would be trenched into competent rock on the left side of the river. It would consist of a 3 m by 3 m conduit about 140 m long.

The ungated spillway was located in the right abutment because of the favorable topographic conditions. It would consist of an approach channel, an ogee-shaped control structure, a tapered chute, and a flip bucket. As configured, the spillway would have a capacity of 434 m^3/s.

6.1.2.2 Earthfill Dam

The earthfill dam axis would have upstream and downstream slopes of 2.5H:1V, an 8-m wide crest, and riprap slope protection on the upstream face.

The diversion conduit would be trenched into competent rock on the left side of the river. It would consist of a 3 m by 3 m conduit about 140 m long. The upstream cofferdam would be incorporated into the main dam section.

The ungated spillway was located in the right abutment because of the favorable topographic conditions. It would consist of an approach channel, an ogee-shaped control structure, a tapered chute, and a flip bucket. As configured, the spillway would have a capacity of 434 m^3/s.

6.1.2.3 Concrete Gravity Dams

The CCGD and the RCC dam were configured for a vertical upstream slope and a downstream slope of 0.75H:1V. The crest would be 8-m wide at El. 103.3 and a parapet wall would be constructed to El. 105.3. The estimates were based on a low-cement content concrete conventional concrete dam and a low-paste concrete mix and bedding mixes for the RCC dam. A drainage system would be installed from a gallery situated in the upstream toe.

The diversion arrangement would consist of a 3 m by 3 m culvert, 40 m long, located to the left of the river channel and founded on competent rock. The conduit will have a capacity of 47 m^3/s with the cofferdam at El. 87.

The ungated spillway would be located in the center of the dam and aligned to discharge directly into the Río Caño Sucio. It would be 25 m wide and have a capacity of 434 m^3/s with a surcharge of 4.3 m.

6.1.2.4 Dam Type Selection

The four alternatives were evaluated on the basis of cost, and construction, foundation, and operation and maintenance conditions.

Based on comparative costs, the ED is the least expensive with a cost about 5% lower than the RCC dam, the next least costly alternative and 7.5% and 10% lower than the CFRD and CGCD respectively. The ED probably should be selected over the CFRD and the CCGD; however, there is no significant cost difference between the ED and the RCC dam.

Construction considerations slightly favor the ED as it takes most advantage of local materials. The RCC dam can be constructed in a shorter time, but the feature is not expected to be on the critical path for any development. The known characteristics of the site tend to favor the ED, which does not need to be founded on competent rock. Operation and maintenance will be relatively minor for all types considered; however, minimal maintenance tends to favor the RCC dam.

The dam of choice is an RCC dam for the following reasons:

- The cost of RCC, which is, by far, the major cost item is estimated on the basis that it is a stand-alone project and the unit price is high. If the project were built as a part of the implementation of the Río Toabré or Río Coclé del Norte projects, it would be less. A slight reduction is the unit price of the RCC would bring the estimated cost down to that of the ED or lower.
- It is expected that a local contractor would be better able to construct an RCC dam than an ED.
- The aesthetics of the waterfall would be less impacted by the construction of an RCC dam, with the spillway in the dam, than by and ED, which would require a significant spillway on one abutment.

6.2 Río Caño Sucio Project Configuration Studies

Based on the confirmation of the Reconnaissance Report site and the selection of a RCC-type dam, as described above, alternative development criteria and project configurations were evaluated to confirm or revise the project arrangement identified in dam-type study.

These project configuration studies considered the stability of the waterfall located immediately downstream from the dam, the spillway and diversion flood, the spillway size, the diversion arrangement, and the water transfer facilities. The studies are summarized below.

6.2.1 Waterfall

The waterfall, located just downstream from the dam axis, is formed by an approximately 7-m drop in the bedrock surface at that location. Due to its close proximity to the dam axis, the waterfall was evaluated to determine if it would affect the dam geometry. Potential effects include the stability of rock blocks at the edge of the waterfall and dam foundation performance issues. Based on a block stability analysis, it is concluded that rock-block stability is not a concern beyond a distance of 15 m upstream from the edge of the waterfall. For the selected dam type, it was further concluded that the downstream toe of the dam should be located at least 15 m upstream from the edge of the waterfall.

At this location upstream from the falls, no foundation performance issues related to the waterfall are anticipated.

6.2.2 Spillway and Diversion Flood

The spillway is designed for the probable maximum flood. For a project whose failure could result in loss of human life and economic endeavor, such as the Río Caño Sucio project, it is customary to design the project for the worst conditions that could reasonably be postulated. In addition, the Río Caño Sucio dam is critical to the transfer of water from the Río Coclé del Norte basin and it should be designed for the same flood as the Río Indio dam and the dam in the Río Coclé del Norte basin. The maximum peak inflow of the PMF is estimated to be 1,690 m^3/s and the 3-day volume is about 78 MCM.

A flood with a dry-season return period of 50 years was selected for the construction diversion flood. This flood would have a peak discharge of 90 m^3/s and a 1-day volume of about 3.4 MCM.

6.2.3 Diversion Facilities

The size of the diversion conduit was selected on the basis of a least cost combination of conduit and cofferdam. There is no need to consider emergency drawdown in this case as the water transfer facilities to the Río Indio Reservoir will be more than adequate. It was assumed that the diversion conduit would be a reinforced concrete conduit founded on competent rock about in the center of the river.

The 50-year dry-season flood was routed through the reservoir to determine upstream and downstream water levels. Preliminary estimates of cost were developed for three arrangements an it was determined that a conduit 2 m by 2 m combined with a cofferdam 4 m high would result in the lease-cost combination.

6.3 Preliminary Design of Project Features

This section presents a more complete description of the project features and the design assumptions that were adopted. The project hydrology, engineering geology, and geotechnical assumptions have been summarized in Section 3 and are presented in detail in Appendixes A and B.

6.3.1 Río Caño Sucio Dam

Río Caño Sucio Dam will be constructed from roller compacted concrete (RCC). A plan, profile, and sections of the dam are shown on Exhibit 6-1. The slope of the upstream face will be vertical and the downstream face will be conservatively set at 0.75H:1V based on precedent for this dam type, foundation, and seismicity at the site. The main body of the dam will be comprised of low-cementious materials with minimally processed aggregate. The aggregate will be quarried from the Cerro Loma Alta site, about 5 km away. A 0.5-m thick conventional concrete facing will be placed on the upstream face as an impervious membrane, on the vertical section of the downstream face that supports the crest road, and on the downstream face that forms the spillway.

The axis of the dam will cross the main channel of the Río Caño Sucio at about 987340N, 576015E (UTM Coordinate System). The crest of the dam will be at El. 103 and the width of the crest will be 8.0 m. A 5.0-m high parapet wall, extending 2.0 m above the crest, will provide protection from overtopping during the last stages of PMF operation. The dam will be about 22 m high from the deepest foundation excavation to the top of the parapet wall. A gallery may be provided for access to the interior of the dam for inspections, a collector of seepage, access for instrumentation, a terminal point for drain holes, and for curtain grouting. Because it is a low dam, the grouting may be performed using angled holes drilled from the upstream heel and drain holes may be installed from the downstream face. This would eliminate the need for a gallery to facilitate clean, efficient placement of the RCC mix.

6.3.2 Foundation Treatment

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

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.

Consolidation grouting is not envisaged. Curtain grouting will be performed from a gallery of from the upstream heel. Grouting depths will be sufficient to eliminate the hydrostatic pressure caused by the dam on the waterfall rock blocks. 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 will be provided for the spillway to control seepage to reduce pore pressures in the rock mass, and hence uplift. For estimating purposes, a drain hole spacing of 5 m was assumed with depths extending to about half the depth of the grout curtain. The drain holes would be appropriately inclined in order to maximize the number of joint/fracture interceptions.

6.3.3 Spillway

An ungated chute spillway will be located in the center of the dam and aligned to discharge down the streambed and over the waterfall. The spillway has been designed to pass the PMF without overtopping the dam. The discharge under PMF conditions will be 393 m^3/s using a surcharge of 3.6 m above the full supply level. An outflow hydrograph is shown on Exhibit 4-2.

The spillway will consist of an ogee control section, a chute, and a concrete apron with an end sill. A plan, section, and elevation of the spillway are shown on Exhibit 6-2.

The uncontrolled ogee section will consist of two bays with a total clear opening of 25 m. A pier will support an 8-m wide bridge.

The chute will be located on the downstream face of the dam and will be 26 m wide. The maximum water depth in the chute will be about 2.5 m. For estimating purposes, a constant wall height of 3.0 m was assumed.

A reinforced concrete apron slab about 10.0 m long will extend downstream from the end of the chute to provide foundation protection. The apron will terminate in a concrete sill. The lip of the sill will be at El. 86.8, 2 m above the apron slab.

6.3.4 Diversion During Construction

The facilities for the diversion of the Río Caño Sucio during construction consist of an upstream cofferdam and a conduit in the river channel. The river diversion facilities plan and sections are presented on Exhibit 6-2. The conduit will serve to pass the 50-year dry-season flood.

The diversion conduit will be a 2 m by 2 m square conduit, 48 m long. Under the 50-year dry season flood event, the tunnel will discharge about 47 m^3/s with the upstream water surface at El. 88.3 and the downstream water surface at El. 79.9 (downstream of the waterfall).

The upstream cofferdam will be a 130 m long RCC or cyclopean concrete structure, with a one-meter wide crest at El. 88.5. The upstream slope will be vertical and the downstream slope will be 0.8H:1V.

6.3.5 Minimum Release Facility

A minimum release facility is required to maintain flow in Río Caño Sucio downstream of the project. The minimum release has been assumed to equal 10% of the average flow or about 0.75 m^3/s.

A small intake structure will be located at the face of the dam adjacent to the diversion flood culvert. It will consist of a 2 m by 1 m reinforced concrete tower to the crest of the dam. A single opening in the upstream face of the tower will be protected by a trashrack and include a 1 m by 1 m guard gate with its invert at El. 89.

The intake will connect through the diversion culvert by means of a 0.5 m diameter penstock. A flow control valve will be provided at the outlet of the culvert. A plan and section of the minimum release facility is shown on Exhibit 6-2. With this arrangement, a small hydropower unit can be incorporated into the minimum release facility if desired. It may be determined that a larger release is necessary to maintain the aesthetics of the waterfall. Any change can be easily accommodated in the size of the flow control valve.

7. THE WATER TRANSFER FACILITIES

The three-part water transfer facilities convey water from the Río Coclé del Norte basin into the Río Caño Sucio Reservoir, from the Río Caño Sucio Reservoir to the Río Indio Reservoir, and from the Río Indio Reservoir to Lake Gatun.

7.1 Water Transfer Facilities and Alignment

The alignment of the water transfer facilities was determined from an inspection of the 1:50,000 scale maps and field visits. It was determined that the water transfer facilities will consist of a canal section and two tunnels. The west branch of the canal will convey Río Coclé del Norte water from the Quebrada La Encantada, which flows into the Río de U, along the Río Limon in the Río Caño Sucio basin. The second branch of canal conveys water from the Río Caño Sucio Reservoir along the Río Cerro Miguel to a tunnel headrace. The tunnel will convey water through the divide between the Río Caño Sucio basin and the Río Indio basin to a small tributary of the Río Uracillo in the Río Indio basin. A general plan of the facilities to transfer water to the Río Indio Reservoir is presented on Exhibit 7-1.

The tunnel from the Río Indio Reservoir to Lake Gatun is assumed to be located adjacent to the tunnel that would have been constructed as a part of the Río Indio Water Supply Project. This alignment is presented on Exhibit 7-2.

The size of the water transfer facilities is based on flow data computed as a part of the operation studies performed by the ACP. The maximum flow from Sucio Reservoir to the Río Indio Reservoir is estimated to be 180 m^3/s when the Río Coclé del Norte Project is at El. 100 and the minimum is estimated to be 160 m^3/s at El. 90. The water transfer facilities are designed to pass the water from the Río de U to the Río Caño Sucio Reservoir, to the Río Indio Reservoir, and on to Lake Gatun.

Hydraulic studies, supported by preliminary estimates, were performed to determine the canal dimensions and the tunnel diameter required to provide the required maximum and minimum transfer capacity. The lengths of the water transfer facilities is shown below:

Water Transfer Facility Reach	**Length (m)**
West Branch of the Río Caño Sucio Canal	6,500
East Branch of the Río Caño Sucio Canal	8,650
Río Caño Sucio Tunnel	2,550
Río Indio second Tunnel	8,250
Total Length of Water Transfer Facilities	**25,950**

The diameter of the tunnel from the Río Caño Sucio basin to the Río Indio Reservoir was determined to be 5.5 m based on HEC-5 model studies of system operation performed by the ACP.

Similarly, the diameter for the second tunnel from Río Indio was determined to be 6.5 m.

7.2 Preliminary Design of the Water Transfer Facilities

The reservoir in the Río Coclé del Norte basin is planned for operation between El. 100 and El. 90. The full supply level in the Río Indio Reservoir was presumed to be at El. 80 and the full supply level for Lake Gatun is at El. 26. Topography for the canal and tunnel alignments was developed over some of the length under a subcontract with *Ingenieria Avanzada, S.A.*, taken from aerial photography provided by ACP, and 1:50,000 scale maps with a 20 m contour interval for the remainder.

It was assumed that tunnel construction would utilize drill and blast techniques from two portals. It is also assumed that the tunnel will be fully lined throughout to control water loss in low cover zones and areas of severely fractured rock, to prevent erosion and deterioration of the rock in areas on soft or highly fractured rock, and for hydraulic reasons. The lining will be cast-in-place concrete with an average thickness of 0.25 m. Reinforcement, thicker concrete, and steel lining will be included as required.

7.2.1 Canal Section

Water from the Río de U in the Río Coclé del Norte basin through the Río Caño Sucio Reservoir will be conveyed in a 15,150-m long channel with a base width of 5.0 m and side slopes of 2H:1V. The canal will be unlined and designed to pass the canal discharge of 160 m^3/s at a velocity of about 1.0 m/s. A typical section of the canal is shown on Exhibit 7-3. An embankment dike, similar in design to the upstream cofferdam, will be located at the upstream end of the canal until the Coclé del Norte project is completed and comes on line.

7.2.2 Tunnel

The plan, profile, intake and outlet of the tunnel are shown on Exhibits 7-4 through 7-7. The tunnel will have a diameter of 5.5 m and a modified horseshoe shape. The sides of the section will be vertical and the invert will vary from El. 82.0 at the intake to El. 70.0 at the outlet. The tunnel will be lined throughout its length with concrete.

The intake to the tunnel consists of a transition from the end of the canal that widens out to accommodate the intake structure. The intake is a reinforced concrete structure, shown on Exhibit 7-6, with be a 6-bay entrance, each bay dimensioned at 5.5-m high by 4.9-m wide to limit the velocity through the trashracks to 1.5 m/s. The 6-bay entrance transitions over a distance of 24.5 m to the entrance of the tunnel, which will house a 5.5 m square bulkhead. The section then transitions from a square opening to the modified horseshoe shape over a distance of 8.1 m.

The outlet will discharge at El. 70, slightly below the full supply water surface elevation for the Río Indio Reservoir. The tunnel outlet structure will house a gate chamber containing two 2.5 m by 5.5 m bulkheads and two 2.5 m by 5.5 m slide gates. The water will discharge from the gate chamber on to a concrete sill, which will be about 20 m long. The sill ends at El. 64. The sill widens from 7 m wide at the outlet structure to 12 m wide at the downstream channel. The outlet structure will be founded on sound rock. Power and control equipment will be housed in a small structure adjacent to the gates. A road will be provided for a mobile crane to access the gates when maintenance is required.

7.2.3 Río Indio to Lake Gatun

The water transfer tunnel will consist of an approach channel, an intake structure, the tunnel, and an outlet structure. It will be parallel and adjacent to the presumed existing tunnel that would have been constructed as a part of the Río Indio Water Supply Project. A plan and profile are shown on Exhibit 7-8 and typical sections for the types of rock expected are shown on Exhibit 7-3. More detail on the selection of the alignment is given in the Río Indio Feasibility Report (2)

The approach channel will be 220 m long and has its invert at El. 30. The channel will be excavated as a trapezoidal section with a bottom width of 14 m and side slopes averaging 1H:2V. The intake structure will be a reinforced concrete structure with an opening of 12 m by 15 m. Trash racks will protect the openings. Intake flow velocities at maximum discharge will be limited to 1.5 m/s. The invert of the intake will be at El. 32 to allow for proper hydraulic conditions at minimum pool operation. The intake structure will extend up to El. 85, 1 m above the design flood elevation to provide access to the trash racks. A trash rake will be provided to clean the trash racks. A plan and section of the intake is shown on Exhibit 7-9.

The intake transitions to the tunnel, which will be an 8,250-m long modified horseshoe shaped tunnel with vertical sides and a horizontal invert. The finished diameter of the tunnel is 6.5 m and the capacity is 277 m^3/s and 137 m^3/s at the full supply level, El. 80, and at the minimum pool level, El. 40, respectively.

A gate shaft and gate will be provided at the upstream end of the tunnel for dewatering. It is located 70 m from the intake structure housing two gates, each 3.4 m wide by 6.0 m high. The gate will be raised and lowered by means of a hydraulic cylinder hoist that will be powered and operated from a surface control structure.

At the downstream end of the tunnel, an outlet structure will house two 3.5 m wide by 5.4 m high, bonneted guard gates and bonneted control gates in series. This will provide redundancy for reliable operation and maintenance, and additional flow control. The outlet structure will be founded on sound rock. Power and control equipment will be housed in a small structure adjacent to the gates. A road will be provided for a mobile crane to access the gates when maintenance is required. Details of the outlet facility are shown on Exhibit 7-10 and 7-11.

The outlet will discharge at El. 27, slightly above the maximum water surface elevation for Lake Gatun, onto a concrete sill about 35 m long. The sill will end at El. 20, slightly below the minimum level of Lake Gatun. The sill will widen from 11 m at the outlet structure to 19 m at the downstream channel.

The outlet structure will discharge into a 400 m long channel, which will discharge into the presumed existing discharge channel for the first tunnel. The channel will be excavated as a trapezoidal section with a bottom width of 22 m and side slopes of 2H:1V. It will direct the flow from the Río Indio transfer tunnel into Lake Gatun adjacent to Isla Pablon.

8. POWER DEVELOPMENT

Studies were performed to determine if the addition of hydropower to the Río Coclé del Norte Water Supply 100-90 Project was viable. The studies consisted of estimating the potential energy production under a variety of conditions that nearly reflect the water supply operation and that reflect significant changes to that operation.

8.1 Hydropower Potential

The water supply system for the Canal, including the Río Coclé del Norte Project, will not be required to supply its full yield for a long period after the completion of the Project. To estimate the duration of the period during which the system yield is more than what is required, the projection for unconstrained water demand for navigation presented in the Reconnaissance Study (1) plus the municipal, industrial (M&I) and tourism water demand presented in the report entitled "Long Term Forecast for M&I Demand" (8) prepared by MWH, January 2001. Due to anticipated future development at the Canal, the navigation demand is not considered to be accurate enough to be used in economic studies of the Río Coclé del Norte Project; however, it is the only estimate available at this time and was used for this analysis. First, the total demand was used as a basis for an assumption that the Río Coclé del Norte Project would be required in 2028 based on a comparison of the demand and the yield of the Gatun/Madden/Indio system. A comparison between the system yield with Río Coclé del Norte and the total navigation and M&I demand, extrapolated from 2060 to 2090 on a straight-line basis, indicates that the total yield of the system including Río Coclé del Norte will not be utilized until about 2082. The details of the power and energy studies are presented in Appendix E Part 2 and are summarized below.

In the period prior to the need for the full yield of the system including Río Coclé del Norte, operating the system for hydropower results in more favorable hydropower developments, even if these potential developments had a limited economic life. For the purpose of selecting the best hydropower development associated with the reservoir scheme, three strategies were investigated:

- Strategy 1 would consist of discharging the maximum possible flow into the Río Coclé del Norte to favor hydropower development at that site.
- Strategy 2 would consist of discharging the maximum flow into the Río Indio to favor hydropower development at that site.
- Strategy 3 would consist of discharging the maximum flow through the transfer tunnel between Río Indio and Lake Gatun to favor the development of a power plant at the Isla Pablon site. Strategy 3 also was evaluated for a limited Río Indio operating range (3A).

Strategies 3 and 3A favor energy production at the Gatun 24-MW hydroelectric plant and also can be considered essentially representative of the water supply project operation.

The yield of the system under water supply conditions (Base Case) and under conditions that favor hydropower operations, and the estimated year when the water demand will reach that yield are shown on Table 8-1.

TABLE 8-1 RESERVOIR SYSTEM YIELD MODIFIED FOR HYDRO OPERATION

	Coclé & Río Caño Constant Release (m^3/s)	Indio Constant Release (m^3/s)	Río Indio Operating Range	Constant Transferred Discharge into Gatun (m^3/s)	System Yield (L/d)	Year
Base Case	11.7	2.6	40 – 80	No Rule	107.2	2082
Strategy 1	20.0	2.6	40 – 80	No Rule	103.7	2078
	40.0	2.6	40 – 80	No Rule	95.2	2071
	60.0	2.6	40 – 80	No Rule	86.5	2062
	80.0	2.6	40 – 80	No Rule	77.6	2048
Strategy 2	11.7	20.0	40 – 80	No Rule	99.8	2075
	11.7	40.0	40 – 80	No Rule	91.3	2067
	11.7	60.0	40 – 80	No Rule	82.6	2055
	11.7	80.0	40 – 80	No Rule	73.9	2044
Strategy 3	11.7	2.6	40 – 80	20.0	106.9	2081
	11.7	2.6	40 – 80	40.0	106.8	2081
	11.7	2.6	40 – 80	60.0	106.5	2081
	11.7	2.6	40 – 80	80.0	105.9	2080
Strategy 3A	11.7	2.6	60 - 80	80.0	105.2	2079

The operating rules for strategies 1 and 2 would significantly reduce the overall yield of system, and therefore they would have a limited life.

For all three strategies, energy production and firm capacity at the four potential hydropower sites were calculated for a range of hydropower plant capacities. In order to estimate the energy production for any given scheme, it was assumed that operating rules would apply until the water demand reaches the yield achieved under these conditions. Rules would be progressively relaxed to increase the yield of the system. For example under Strategy 1, the Río Coclé del Norte reservoir would release a constant 80 m^3/s downstream of the dam through a power plant until 2048; this discharge would be progressively reduced to 60 m^3/s in 2062, and 40 m^3/s in 2071, and so on, until the full yield of the system is reached and only the minimum release is discharged through the

Río Coclé del Norte powerplant. Similar rationale was applied to Strategy 2 and Strategy 3.

8.1.1 Evaluation of Power Plant Locations

For the purpose of calculating the energy production and firm capacity of the individual powerplants, a spreadsheet-type model was developed: the model uses the weekly output of the HEC-5 simulation performed by the ACP. The project water released were those determined by the HEC-5 simulation. The tailwater rating curve established under the hydraulics studies was used for the purpose of calculating the gross head on the project at the Río Coclé and Río Indio dam sites.

The energy production at each potential plant was calculated for a range of installed capacity depending on the strategy contemplated:

- At Río Coclé del Norte from 10 MW to 135 MW;
- At Río Caño Sucio from 20 MW to 60 MW;
- At Río Indio from 2.5 MW to 60 MW;
- At Isla Pablon from 20 MW to 50 MW.

The input parameters of the computation and the results are presented in Attachment 3 of Part 2 of Appendix E.

Cost estimates were developed for representative powerplant developments at each of the sites and compared with the present value of the revenue from the site. The size of the powerplant selected for estimating costs was varied depending on the strategy. Table 8-2 presents the results of these studies. In Table 8-2:

- Plant size range is the range of installed capacities considered to be reasonable for the type of strategy adopted
- Present value of revenue is shown for the lower and upper plant size and consists of the value of energy generated, which varies over the life of the installation, estimated at $45/MWh; and the value of firm capacity, estimated at $60/kW-year. In strategy 3A, the firm capacity is greatly increased by operating the Río Indio reservoir between El. 60 and El. 80 rather than between El. 40 and El. 80.
- The representative powerplant size was selected to be appropriate for the plant and the strategy.
- The energy range is the estimated energy at year 1 of the operating period and year and at the end of the plants economic life.
- The cost of the representative powerplant is the economic cost at the beginning of construction.

TABLE 8-2 EVALUATION OF POWER PLANT SITES

	Plant Size Range (MW)	PV of Revenues ($million)	Representative Powerplant Size (MW)	Energy Range Representative Project (GWh)	Cost of Representative Powerplant ($million)
Strategy 1					
Coclé del Norte	25-135	89-267	90	524-76	86.9
Isla Pablon	20-50	26-42	40	104-156	64.1
Río Caño Sucio	20-35	18-23	20	47-68	37.2
Strategy 2					
Coclé del Norte	10-25	33-41	16	76-76	23.7
Isla Pablon	20-50	19-28	30	63-131	55.0
Río Caño Sucio	20-35	18-23	20	89-68	37.2
Río Indio	30-50	79-113	40	286-10	60.1
Strategy 3					
Coclé del Norte	10-25	33-41	16	76-76	23.7
Isla Pablon	20-50	35-53	40	286-156	64.1
Río Caño Sucio	20-60	17-49	20	67-40	37.2
Strategy 3A					
Coclé del Norte	10-25	33-41	16	76-76	23.7
Isla Pablon	20-50	68-129	40	286-156	64.1
Río Caño Sucio	20	25	20	67-40	37.2

From an inspection of the table, it can be concluded that a plant at Río Coclé del Norte is viable for any of the strategies. A plant at Isla Pablon is only viable for Strategy 3 and 3A (for all other strategies, the cost of the plant is more than the maximum of the revenues). A plant at Río Caño Sucio is not viable. Finally, a plant at Río Indio is viable under Strategy 2.

8.1.2 Selection of Strategy

Viable installations exist in all four strategies. However, Strategy 3 can be eliminated as Strategy 3A, which has the same arrangement but only a different operating level regime in Río Indio Reservoir, results in higher revenues for the same cost.

The remaining three strategies were compared utilizing the viable options from Table 8-2 plus the incremental impact on generation at Madden and Gatun, which vary according to the adopted strategy. The results of this comparison are shown in Table 8-3 and the details of the costs and revenue are presented in Appendix E, Part 2.

TABLE 8-3 COMPARISON OF HYDROPOWER STRATEGIES

	Installed Capacity (MW)	Construction Cost ($1000)	O&M Cost ($1000/year)	Annualized PV (12%) of Revenue ($1000)	Rate of Return
Strategy 1					
Coclé del Norte	90	86,900	1,575	29,087	
Río Indio	2.5	Assumed Exist.	No change	468	
Gatun	24	Existing	No change	2,004	
Madden	36	Existing	No change	8,114	
Total		**86,900**	**1,575**	**39,673**	**26**
Strategy 2					
Río Indio	40	60,100	1,037	12,410	
Coclé del Norte	16	23,700	439	4,367	
Gatun	24	Existing	No change	1,630	
Madden	36	Existing	No change	8,038	
Total		**83,800**	**1,476**	**26,445**	**16**
Strategy 3A					
Coclé del Norte	16	23,700	439	4,367	
Río Indio	2.5	Assumed Exist.	No change	727	
Isla Pablon	40	64,100	1,070	14,455	
Gatun	24	Existing	No change	4,736	
Madden	36	Existing	No change	8,276	
Total		**87,800**	**1,509**	**32,561**	**20**

From Table 8-3, it is apparent that all strategies are viable and that Strategy 1 results in the best rate of return. The advantages of Strategy 1 are that it will produce significant funds during the early years of the project that can be used to offset the cost of the water supply project, it will help to stabilize the national grid, and it will provide a major source of firm electricity in an underdeveloped region. Its disadvantage is that 50 years after construction, it will only be generating with the minimum release. Strategy 3A also produces a significant but slightly lower return. Its advantages are that it will continue to produce the revenue even after the economic life of the project, it will provide a small but significant source of firm power for the Río Coclé del Norte basin area, and its revenue, once built, does not depend on an arbitrary demand. For the purpose of this study, Strategy 1 was selected.

8.1.3 Hydropower Level of Development

Estimates of cost and energy generation were developed for a plant at the Río Coclé del Norte dam to select the level of development. The capacity of the plants evaluated and the rate of return based on the estimated costs and benefits are shown in Table 8-4.

TABLE 8-4 LEVEL OF HYDROPOWER DEVELOPMENT AT RÍO COCLÉ DEL NORTE

Plant Capacity	3 x 20-MW units	3 x 25-MW Units	3 x 30-MW Units
Internal Rate of Return	27	28	27

On the basis of this analysis, an installed capacity of 75 MW was selected for the hydropower installation at the Río Coclé del Norte dam.

8.2 Preliminary Design of the Hydro Facilities

The proposed hydroelectric development associated with the Río Coclé del Norte reservoir operating between El.90 and El.100 consists of a 75-MW power plant located at the toe of the dam. The plant will contain 3 25-MW units and will generate an average of 410 GWh/year over the first 50 years of operation, varying from 538 GWh/year in the first years to 76 GWh/year at the end of the period. A plan of the power facilities is shown on Exhibit 3-2. A profile of the hydroelectric scheme is shown on Exhibit 8-1.

8.2.1 Intake and Powerhouse

The power intake will be located on the right abutment, approximately 40 meters west of the spillway. It will consist of a reinforced concrete tower, 35 meters high with foundation at approximately El. 68 and the access platform level with the crest of the dam. A plan and section of the intake are shown on Exhibit 8-2. A 6-m wide bridge will be built to access the intake tower. The invert of the intake will be located at El.84. The intake will have three openings, each 6-m wide by 8-m high. The openings will be protected by a trashrack, and controlled by a 2.2-m wide by 3.3-m high wheel gate. One set of stoplogs, sufficient to close one bay under a balanced head also will be provided. The intake openings join and transition into the 5-m diameter vertical shaft. The vertical shaft extends in the tower all the way up to the crest of the dam. A trash rake will be provided to clean the trash racks.

The vertical shaft will be excavated 50 m deep in rock, and concrete lined. It will connect the power intake with the 260-m long, 5.0-m diameter steel-lined tunnel. The tunnel diameter will be reduced to 4.6 m immediately upstream of a four-branch manifold. The manifold, located in the back of the powerhouse, consists of three 2.8-m diameter steel branches and one 1.7-m diameter steel branch. A spherical valve will be provided at the end of each manifold branch to permit isolation of one unit for maintenance or in case of emergency without interfering with the operation of the other units.

The powerhouse will be a conventional 57-m long by 16.5-m wide reinforced concrete structure located on the right bank of the Río Coclé del Norte. It will contain three unit bays and one service bay. The foundation will be excavated in sound rock to El. –10 approximately 15 m to 20 m below ground surface. The centerline of the units will be at El. –3, below the minimum tailwater level. The powerhouse downstream deck and surrounding ground and access will be at El. 4 to protect the area against flooding during the probable maximum flood. The superstructure will be structural steel with metal cladding. A plan and section of the powerhouse is shown on Exhibits 8-3 and 8-4.

To serve the power intake area equipment, lighting, and dam roadway lighting a 480-V line from the powerhouse will be provided. Provision will also be made for easy connection of a portable emergency generator for use during power outage.

The turbines will be vertical-shaft Francis units with steel spiral cases. The turbines will be direct connected to synchronous generators. The general characteristics of the 25 MW units are described below.

Turbine

Runner diameter:	1.78 meters
Design net head:	95 meters
Discharge:	30 m^3/s
Rated output:	34,000 hp
Setting:	3 meters below minimum tailwater level
Speed:	360 RPM

Generator

Type:	Synchronous / direct coupled
Rated output:	27,800 kVA
Terminal voltage:	13.8 kV
Frequency:	60 Hz
Power factor:	0.90

Each unit will be provided with the necessary auxiliaries such as bearings, servomotor, hydraulic power unit, digital governor, cooling water system for turbine bearing, shaft seal and generator bearings and coolers, lubricating oil system, excitation system, voltage regulator, automatic synchronizer, brakes, SCADA and protection system.

Each unit will have two welded-steel slide gates, 2.8-m wide by 1.7-m high gates to allow for unit and tunnel dewatering. An 80-ton semi-gantry crane spanning the powerhouse and the draft tube deck will be provided to handle turbine and generator components, inlet valves and draft tube gates during erection and maintenance.

The minimum release will be made through the one of the units or through a bypass line. A polyjet valve will be provided to control the flow releases through the bypass.

The generating voltage will be 13.8-kV. Generators will have individual main power transformers directly connected to the generators. Generator breakers will be on the 230kV side of the transformers and will be located in the switchyard.

A 480/277-V station service power distribution switchboard will be provided to feed the outlaying areas, the station auxiliaries and the three unit auxiliary motor control centers (MCC). Each unit MCC will also be fed from the unit auxiliary transformer providing power for its own auxiliaries when the unit is in operation.

A three-phase, oil-filled, 13.8/230 kV step up transformer rated at 30 MVA, 60 Hz, and 0.9 pf will be connected to each generator.

Station service power will be provided at 480/277-V thru service power and station service transformers. A Service Power Transformer with standard rating of 5MVA, Class OA, located in the switchyard, will be used to step down the voltage from 230-kV to 13.8-kV. A Station Service Transformer, located at the powerhouse, will serve all utilization level power requirements at the site. This transformer will be a three phase, oil filled step down transformer from 13.8-kV to 480-V, 60-Hz rated 2 MVA, Class OA. The station service transformer will be fed from the service power transformer by an overhead 15kV line. Each unit will have a 150kVA dry type transformer directly connected to the generator terminals stepping down the voltage from 13.8-kV to 480/277-V to feed the unit auxiliary MCC.

Other station auxiliaries will include a 500-kW stand-by diesel generator, station battery, lighting system, heating, ventilation and air conditioning, fire alarm and protection system, communication system, and grounding and lightning protection.

8.2.2 Switchyard and Transmission

A 230-kV switchyard will be located at approximately El. 20 on a 130-m by 65-m leveled area about 100 m west of the powerhouse at the toe of the dam. The location of the switchyard is shown on Exhibit 3-2 and a plan is shown on Exhibit 8-5. Connection from the powerhouse to the switchyard will be by high voltage cables in conduit. The switchyard will be a conventional open air design yard utilizing the 'breaker and a half' switching scheme. The switchyard will have three fully equipped bays serving the three generator units, a single circuit 230-kV transmission line and the service power transformer. It will be fenced in and served by access and boundary roads. A suitably sized control building will also be provided to house the control, protection, metering and communication equipment.

A 109-km long, single circuit 230-kV transmission line will connect to national grid at ETESA's La Chorrera Substation. The transmission line will be conveyed on steel towers and have three 750 kcmil ACAR conductors. The proposed line will cross the Río Coclé del Norte near the project site, proceed in an easterly direction, and pass the Río Indio Dam to the vicinity of Isla Pablon. It will then continue in the east-southeast direction to La Chorrera Substation. A schematic diagram of the transmission line route is shown on Exhibit 8-6. One of the two empty 230-kV bays at La Chorrera Substation will be fully equipped to handle the new incoming line from Río Coclé del Norte project.

A simplified one-line diagram of the powerhouse, including station services, substation, and transmission-line interconnection is depicted on Exhibit 8-7.

9. OPERATION FACILITIES

The operation facilities for the Río Coclé del Norte Project will be an extension of the facilities presumed already installed at the Río Indio Project. With a major hydro facility at the base of Río Coclé del Norte Dam and the canal reaches of the water transfer facilities potentially subject to sedimentation that could affect project performance, operation is expected to be a combination of remote and in-place operation. The in-place operation and maintenance is covered under the annual operating costs in Section 11. The facilities for remote operation are covered in this section.

The operation facilities will include a SCADA system to remotely operate the tunnel gates and hydropower valves, and to monitor water levels, flow, gate operations, and safety instrumentation. The new SCADA system will include a communications package. As for the Río Indio facilities, it will be monitored and operated by the ACP Meteorology and Hydrology Division as an extension to their existing system. Power for project operation will be supplied through 22 kilometers of 13.8 kV transmission line from the Río Indio dam and from the hydropower plant at Río Coclé del Norte dam.

Instrumentation will be installed in each of the dams to monitor behavior during construction and subsequent operation. Embedded instruments will be used to determine temperature, strain, stress, and hydrostatic pore pressure, and to measure cracks in the RCC dam at Río Caño Sucio. For the CFRD dam at Río Coclé del Norte, the instrumentation will also be used to measure pore pressures in the foundation and embankment and include ocillograph measurements at the crest and foundation levels. Surface monuments will be installed in both dams to monitor deformation.

Additional project facilities will include security and lighting at the dams and spillways, and intakes and outlets of the transfer tunnels. Landscaping and drainage will also be provided at these project features. Limited maintenance facilities will be retained from the temporary construction facilities.

10. AGRICULTURAL DEVELOPMENT

A study was performed to assess the potential for commercial irrigated agriculture on the lands around the reservoir. The details of this study are presented in Appendix F and summarized below. The major components of the study consisted of:

- a land use survey;
- a land capability determination;
- the identification of potentially irrigable areas in the basin;
- the definition of potential crop patterns and their water requirements, and;
- an economic analysis to assess feasibility.

The study area was generally limited to the lands around the reservoir areas and to the east of the Río Coclé del Norte. In an initial study, the area was further limited to seven areas that appeared to provide the best opportunity for agricultural development. These seven areas are shown on Exhibit 10-1.

10.1 Land Use

The land use was identified initially by reviewing available aerial photographs, information provided by the Remote Sensing Unit, and the existing soils map, and verified by a field reconnaissance. The aerial photographs were dated June 1983. The land use categories adopted for this study were forest, slash and burn lands, bush/thicket lands, pasture lands, and miscellaneous, which includes stubble, small sparse farm lands, villages, marshland, and wetlands. The field adjustments were based on transects and random observations. A land use map is shown on Exhibit 10-2.

The land use in the 7 main areas within the study area, which totals about 95,000 hectares consists of 47% forest, 2% slash and burn, 26% bush/thicket, 16% pasture, and 9% miscellaneous lands. According to the 2001 Agricultural Census, almost 100% of the farms exceed one hectare and, based on conversations with farmers in the field, the average size is on the order of 4-5 hectares.

The main annual crops grown in the Project Area are rice, maize, beans, cassava, vegetables, melon, watermelon, cucumber, name, otoe, squash and sugar cane. The perennial crops are coffee, cocoa, fruit trees including avocado, guava, mango, maracuya, marañon, papaya, orange, grapefruit, lime, anona, plantains, banana, pineapple, and coconut.

10.2 Land Capability and Potentially Irrigable Areas

Land capability for irrigation in the basin was based on a semi-detailed soil study accomplished as a part of a National Rural Cadastre Project in 1970 and supplementary field observations and soil sampling. It was determined that about there are about 30,000 ha of arable land in the seven areas and, referencing the US Bureau of Reclamation Land Classification Specifications for Irrigated Land Use, 17,000 ha are Class 2 lands and 13,000 ha are Class 3 lands. Class 1 lands were not found in the areas. The soils are clayey and clayey loams, acidic, high in calcium and magnesium, medium in organic matter and potassium, medium to low in nitrogen, and low in phosphorous, aluminum, copper, and zinc. The results from three water sample analyses suggest that the surface waters can be used for irrigation with little risk of salt accumulation that cannot be mitigated.

10.3 Potential Development Areas

Thirteen areas were identified as being potential development areas in the seven main areas. Based on the land classification, position with respect to potential water sources, and the potential for using the water sources economically, the thirteen areas were reduced to nine. The areas, arable areas based on amount of Class 2 and Class 3 land, and gross and net areas that practically can be developed for irrigated agriculture are presented in Table 10-1 as follows:

TABLE 10-1 POTENTIAL DEVELOPMENT AREAS

Main Area	Development Area	Arable Lands (ha)	Area Suitable for Development	
			Gross Area (ha)	Net Area (ha)
Lower Río Coclé del Norte Valley	Lower Río Coclé del Norte Valley	8,300	2,760	2,200
Costa Platanal – Punta Diego	Costa Platanal – Punta Diego	2,500	1,400	900
Lower Río Miguel de la Borda Valley	Lower Río Miguel de la Borda Valley	6,000	3,600	2,220
Río Caño Sucio Valley	Río Miguelito Valley	500	-0-	-0-
	Río Caño Sucio Valley at El Cedro	1,200	-0-	-0-
	Río Caño Sucio Valley at Las Maravillas	4,000	800	500

Main Area	Development Area	Arable Lands (ha)	Area Suitable for Development	
			Gross Area (ha)	Net Area (ha)
Valleys of the Ríos Tulu and Curia	Río Curia Valley	200	-0-	-0-
	Río Tulu Valley	1,100	740	580
Valleys of the Ríos Lura and Tucue	Río Lura Valley	550	200	160
	Río Tucue and Toabré Valleys	1,000	750	600
Valleys of the Ríos San Miguel and Chiguiri	Río San Miguel Valley	2,900	1,040	830
	Río Chiguiri Valley	2,200	640	500
TOTAL				**8,490**

The net areas are estimated as the gross area less allowances for off-farm hydraulic and other infrastructure, on-farm infrastructure, unusable land, unusable micro relief, and areas with poor drainage or soils conditions.

Water availability for the potential areas was estimated from data available at four gages in the Río Coclé del Norte basin; the Río Coclé del Norte at Canoas, and El Torno, the Río Toabré at Batatilla, and the Río San Juan at Los Higuerones. The available water is estimated as the monthly flow exceeded 80% of the time, on streams other than those regulated by the reservoir, converted to monthly discharge per unit of area. Flows were transposed to ungaged locations using drainage area. The minimum flows available at the streams supplying the potential areas, after deduction a minimum flow, were estimated to be 7-8 liters per second.

The source and estimated available flows for all of the areas are shown in Table 10-2:

TABLE 10-2 WATER AVAILABLE FOR IRRIGATION

Area	Source of Water	Catchment Area (km^2)	Available Minimum Flow (l/s)
Lower Río Coclé del Norte Valley	Río Coclé del Norte at El. 0	1,600	12,800
Costa Platanal – Punta Diego	Platanal, Majagual, Aguacate and Diego Rivers at El. 40	60	450
Lower Río Miguel de la Borda Valley	Miguel de la Borda River	520	4,200

Area	Source of Water	Catchment Area (km^2)	Available Minimum Flow (l/s)
Río Caño Sucio Valley at Las Maravillas	Riecito river at el. 100	42	300
Río Tulu Valley	Tulu River at El. 140 Tulu River at El. 100, proposed reservoir	23 75 75	160 600 600
Río Lura Valley	Lura River At El. 120	20	150
Río Tucue and Toabré Valleys	Toabré River at El. 110 Toabré River at El. 110	26 174	110 1,200
Río San Miguel Valley	San Miguel River at El. 300 San Miguel River at El. 110 San Miguel River at El. 100	32 40 92	250 320 700
Río Chiguiri Valley	Chiguiri River at El. 160	50 54	350 380

10.4 Cropping Patterns and Water Requirements

Cropping patterns were selected on the basis of monthly rainfall distribution, potential evapotranspiration, radiation, mean temperature, land capability, and predominant production environments. The crops included in the suggested pattern are dry-seeded and transplanted rice, maize, plantain, cassava, vegetables, yams, pasture, and nursery crops.

The proposed crops are based on the presently cultivated annual and perennial crops. Cropping patterns were developed for the coastal and inland areas. Generally, the cropping pattern calls for double cropping rice and maize and planting single crops of vegetables. The perennial crops were applied on about 45% of the land. The resultant cropping intensity was computed at 130%. Details of the cropping pattern and schedule are provided in Appendix F, Agricultural Development.

Supplementary irrigation requirements for the food crops, pasture, and perennials were estimated from potential evapotranspiration adjusted by an appropriate crop coefficient, dependable rainfall, and appropriate irrigation-system efficiency. The system efficiencies were estimated to be 50%. The water requirements varied widely depending on the potential area under consideration. Detailed estimates of the water requirements are presented as an attachment to Appendix F.

A rigorous analysis was performed in an attempt to identify the design flows for irrigation of the potential areas. A series of up to three crop conditions were considered for each of the landscape positions to provide a system capacity that would allow the farmer some flexibility in his choice of crops or system operation. The design flow rates varied from a low of 0.2 l/s/ha in the lower Río Coclé del Norte Valley to 0.9 l/s/ha in the Tucue Valley. All of the other areas were either 0.5 or 0.6 l/s/ha.

10.5 Potential for Economically Feasible Development

The assessment of feasible development consisted of developing irrigation schemes for each of the areas capable of delivering the design flow, estimating the construction and annual operating cost of the system, estimating the net benefits, and assessing economic viability of each area.

Each irrigation scheme consists of a main hydraulic system consisting of a water intake, a pumping station if required, a main canal, one or more branch canals, canal structures, a water distribution system between the canal and the farm gate, off farm drainage and roads, and on-farm irrigation and drainage systems. Layouts of each of the irrigation systems are presented in Appendix F.

Based on cropping pattern options for each area, average net benefits were estimated by hectare and for each potential area as the difference between net incomes without and with the reservoir development. The net benefits were computed using data from the Ministry of Agriculture Extension Service and consist of a cost for transport, materials, and labor subtracted from revenue estimated as yield times current price. The costs, benefits, and returns for each area are presented in Table 10-3.

TABLE 10-3 ECONOMIC ANALYSIS OF AGRICULTURAL DEVELOPMENT IN POTENTIAL AREAS

Potential Area	Construction Cost ($1,000)	Annual Cost ($1,000)	Benefits ($1,000)	Rate of Return
Lower Río Coclé del Norte Valley	19,086	251	1,842	8%
Costa Platanal – Punta Diego	11,644	110	754	5%
Lower Río Miguel de la Borda Valley	20,579	311	1,859	7%
Río Caño Sucio Valley at Las Maravillas	4,057	49	521	11%
Río Tulu Valley	7,222	117	604	6%
Río Lura Valley	1,580	29	167	8%
Río Tucue and Toabré Valleys	5,835	103	625	8%

Potential Area	Construction Cost ($1,000)	Annual Cost ($1,000)	Benefits ($1,000)	Rate of Return
Río San Miguel Valley	9,698	133	865	7%
Río Chiguiri Valley	5,849	94	521	7%

To assess the viability of a commercial development, all of the areas were considered as one development. If all potential areas are considered as one development, the rate of return will be about seven percent.

Therefore, it is concluded that the potential for irrigated agriculture marginal, and implementation of the development should not be initiated at this time.

11. CONSTRUCTION PLAN AND COST ESTIMATE

A project implementation schedule, a detailed construction schedule, and cost estimate have been prepared for the project as described in Section 3. Additional details of the construction cost estimate are presented in Appendix G.

11.1 Implementation

The major steps required for project implementation following this engineering study are as follows:

- Master Plan
- Water Demand Assessments
- Environmental Studies
- Feasibility Confirmation and Project Configuration
- Funding
- Environmental Mitigation Planning and Implementation
- Environmental Field Studies
- Design and Contractor Procurement
- Construction Contract Awards
- Construction

The implementation schedule is presented on Exhibit 11-1.

ACP is preparing a Master Plan for the development of the Panama Canal. This will examine a wide range of options, including improvements to the existing facilities, new locks of various configurations, water management plans and alternative water supply projects. The Master Plan will also include shipping forecasts under various scenarios and toll structures. Therefore, the decision to implement the Project will not be made until the conclusion of studies for the Master Plan, and likely will not be made until some time in the future when other higher priority projects are in place that will impact the need for and benefit of this project. If this project is considered for implementation, it will be the subject of a series of updated assessments on the need for additional water and the timing for commencing this project. These studies are assumed to take place in the years prior to the earliest projected need for this project to meet water demands.

Some limited basic environmental studies have been performed in the Río Coclé del Norte and Río Caño Sucio watersheds; however, if the project moves forward, substantial additional environmental base-line studies will be required. In addition, prior to seeking funding, it will be necessary to confirm the feasibility of the project, which will include subsurface investigations to evaluate the foundation conditions, economic studies to optimize the project facilities and establish the economic justification, and financial analyses to determine the viability of the project and the cost of water

Once the decision to obtain funding has been taken, a mitigation plan will be required. This can be prepared while funding is being secured. This plan may cover resettlement of people, habitat mitigation, evaluation of cultural resources, development of a construction plan, and any other mitigation activities identified during the base-line studies. The field studies may include protection or removal of significant archaeological sites, habitat replacement, or additional detailed studies of the flora and fauna in the reservoir area.

With funding in place, the design-level investigation program and final designs can commence along with the procurement of contactors.

Construction of the project is envisaged to consist of six general contracts that would provide local contractors an opportunity to participate significantly. The six contracts would be:

1. Access Roads and the Construction Camp (local contractor),
2. The Water Transfer Facilities (international contractor),
3. The Río Coclé del Norte Storage and Hydropower Facilities (international contractor),
4. The Río Caño Sucio Storage Facilities (local contractor),
5. The Second Río Indio to Gatun Tunnel (international contractor) and,
6. Reservoir Clearing (local contractor).

The operation facilities might be a part of each of the contracts or the responsibility of the contractor for the Río Coclé del Norte Storage Facilities. ACP has also identified substantial compensation and mitigation costs, and implementation of the required mitigation plans could be managed by ACP internally, or also contracted out.

It is assumed that the ACP will develop the capability to manage the construction contracts and also to perform the operation and maintenance. Although it will be a complicated and difficult task, the experience the ACP will get implementing the third set of locks should put them in good stead to manage the development of this water source. It is expected that the ACP will hire a Project Management Team responsible for the consulting engineering services relating to the works required for implementation. Operation and maintenance of the development can be accomplished by adding staff to the ACP's existing organization. Operation and maintenance of the facilities required for the water supply project, including the hydro facilities, are well within the existing capability of the current O&M organization.

11.2 Construction Plan and Schedule

A detailed construction schedule, presented in Exhibit 11-2, has been developed for the implementation of the Norte/Sucio/Indio Project. The project has been divided into six major components:

- Access Roads and Construction Camps,
- Río Coclé del Norte Storage and Hydropower Facilities,
- Water Transfer Facilities,
- Río Caño Sucio Storage Facilities,
- Second Río Indio Reservoir to Lake Gatun Transfer Tunnel, and
- Reservoir Clearing.

The durations of the construction of each component are estimated as 2.5 years for the access roads, 2 years for the Río Caño Sucio Project, 6 years for the Río Coclé del Norte Project, 3 years for the Water Transfer Facilities, and 3 years for the second tunnel from Río Indio Reservoir to Lake Gatun. Overall the construction, including the filling of the reservoirs to levels sufficient for the project to be operational will require nearly 8 years, with full operation achieved in under 12 years.

The overall concept of the project implementation is to delay construction (and therefore expenditures) as long as possible while meeting the water demand of the system. The size of the project, particularly the large size of the reservoir dead storage, requires judicious staging of the construction to maintain the construction period to a reasonable duration. As an indication of the implementation duration it should be noted that the filling of the reservoir dead storage alone, i.e., to El. 90 will take an absolute minimum of three years, and there is a 5% chance that it will not reach that level in four years. Also the placement of rockfill material for the Río Coclé del Norte Dam is anticipated to take approximately 2.5 years.

It is estimated that the Río Caño Sucio reservoir alone can contribute 2.5 lockages per day (L/d) to the yield of the system of reservoirs in place at the time of its implementation. Based on the expected water demand growth, the Río Caño Sucio reservoir would be sufficient to delay the construction of the next project by 3 years. Therefore the implementation of the project can be staged such that the filling of the Río Coclé del Norte Reservoir may be completed three years after the completion of the rest of the project features.

It is estimated that the Río Coclé del Norte reservoir filled to approximately El. 93 will provide sufficient storage for the system to permit drawdown of the Río Indio Reservoir to El. 40 for the first few years after completion of the storage and water transfer facilities while maintaining the required system yield. Therefore, it is planned to lower the Río

Indio Reservoir when the Río Coclé del Norte Reservoir is at El. 93 and construct the intake of the second Río Indio to Gatun tunnel behind a reasonably sized cofferdam. Assuming that the transfer tunnel would have been built at the same time as the other components of the Río Coclé-Río Caño project, the last component of the project, i.e., the tunnel intake would be completed approximately 12 months after the project is operational.

The water level at El. 93 in the Río Coclé del Norte reservoir is also sufficient to commission and operate the hydroelectric power plant, and in general to perform in-situ testing of all mechanical and electrical equipment.

11.3 Contract 1 – Access Roads and Construction Camps

11.3.1 Access Roads

The anticipated contract for construction of access roads will include the construction of 72 kilometers of permanent roads and 21 kilometers of temporary roads. It will also include the construction of three bridges: one immediately downstream of the Río Caño Sucio dam, one across the Río Miguelito and a third bridge across the Río Coclé del Norte downstream of the dam. The location of access roads and bridges is shown on Exhibit 11-3.

The construction of access roads is on the critical path of the project schedule, in particular to reach the Río Coclé del Norte dam site. For the purpose of scheduling it is estimated the construction of permanent road progresses at a rate of 3 kilometers per month. It is therefore necessary to consider several fronts. For the purpose of planning, it has been estimated that the access construction will required approximately 4.5 years including the permanent and temporary roads, and three bridges.

11.3.1.1 Access to the Water Transfer Facilities and the Río Caño Sucio Damsite

Access to the Río Caño Sucio Project will be provided from the Río Indio dam site. The western portal of the transfer tunnel is located at approximately 12 km from the Río Indio dam site. The eastern portal will be accessed through a 2 km long road off the main access road. The Río Caño Sucio dam site is located another 10 km from the western portal. Midway between the tunnel and the dam site a temporary road approximately 2.5 km long will be built to provide access to the source of aggregate for the dam: the Cerro Miguel quarry. About one kilometer before the dam site, a 4.5 km temporary road will provide access to the western branch of the transfer canal.

From the Río Caño Sucio damsite, a 7 km long permanent road will be built to provide access to the western end of the Río Caño Sucio reservoir where a temporary embankment will be built. A bridge crossing the Río Caño Sucio will be built downstream of the dam to provide access to the western end of the reservoir prior to the completion of the dam. The crossing will also be necessary to provide access to the Río Coclé del Norte Project. For the Río Caño Sucio Project, overall 31 kilometers of permanent access road and 7 kilometers of temporary road are anticipated.

11.3.1.2 Access to the Río Coclé del Norte Project

Access to the Río Coclé del Norte project facilities will be gained from the Río Caño Sucio dam site. Approximately 2.5 km southeast of the dam site, the permanent access road will follow the existing trail going in a northwestern direction to Valle Escobal and Miguelito. The Río Miguelito will be crossed at that location. The access road will then take a western direction to the Río Coclé del Norte dam site. Overall 35 km of new road is required to access the Río Coclé del Norte dam site. Short temporary access roads off the main access will be required to access the construction camp and the quarry areas. Quarries for aggregate and rockfill material are located east of the dam and immediately south of the proposed permanent access.

A bridge, approximately 800 meters downstream of the dam axis, is considered necessary to provide access to the left bank of the Río Coclé del Norte for the construction of the diversion tunnel and cofferdam. The bridge construction will be initiated immediately following the completion of the main access road in parallel with the construction of the camp and other access roads.

From the dam site, on the left bank, a six-kilometer long road will be built to access the construction site of several saddle dams in the northern and western part of the reservoir. This permanent road will follow the rim of the reservoir.

Access for the construction of the most southern saddle dam will be gained from Coclecito, which is currently accessible by road. Approximately 4 km west of Coclecito, the existing trail going northwest towards Botija will be improved over approximately 9 km. An additional 5 km of new road will be required to access the site of the saddle dam. These roads will be temporary construction as they will submerged by the filling of the reservoir. There is no permanent road access planned for this saddle dam; access for the purpose of inspection will be gained using small boats on the reservoir.

For the Río Coclé del Norte Project, 41 kilometers of permanent access road and 14 kilometers of temporary road are anticipated.

11.3.1.3 Access to the Second Río Indio- Lake Gatun Transfer tunnel

Access to the second Río Indio-Lake Gatun transfer tunnel will coincide with the previously built access to the first transfer tunnel. It is also anticipated that the same access adits will be used for construction. No new road is anticipated for that purpose.

11.3.2 Construction Camps

It is anticipated that two construction camps will be required: one for the construction of the Río Caño Sucio project, and one for the Río Coclé del Norte project.

The camp for the Río Coclé Project would be located in an area of 10 hectares approximately 3 kilometers east of the dam site, off the main access road. The construction will be started so that its substantial completion coincides with the completion of the Main Access and the beginning of the construction of the main features of the project. Six months of construction will be sufficient to provide housing for the initial crews working at the dam site.

The Río Caño Sucio camp will be made a part of the Water Transfer Facilities contract because the camp is not needed for several years after completion of Contract 1.

No new construction camp is anticipated for the construction of the second transfer tunnel as part of the camp built for the construction of the Río Indio project could be refurbished for that purpose.

11.4 Contract 2 – The Río Coclé del Norte Storage and Hydropower Facilities

11.4.1 Rockfill and Aggregate Quarries

For the Río Coclé del Norte Project, the quarry areas are located less than 3 km from the dam site. The quarry will be used to produce approximately 5,800,000 m^3 of rockfill, 330,000 m^3 of drain and filter material and 130,000 m^3 of aggregate. The establishment of the quarries and installation of the crushing plant will take approximately 6 months.

11.4.2 Power Supply

Electrical power needs for construction at the Río Coclé del Norte dam site is estimated to be approximately 1.5 MW. There is no source for such demand currently available at a reasonable distance from the dam site. The contractor will generate the required power by providing small size diesel generators at appropriate locations.

11.4.3 Diversion

A diversion tunnel approximately 550 meters long will be used to pass the river flows during the dam construction. As this tunnel will be ultimately used as the reservoir low-level outlet, its construction will need to be completed including concrete lining, intake works, gates and operating equipment, prior to start the construction of the cofferdam. Based on the river diversion requirements and the selected cofferdam height, the tunnel will have an 8-meter diameter. As the construction of the feature is one of the critical activities, the tunnel excavation will be initiated at both end of the tunnel, followed immediately by the gate shaft excavation and concreting. The low-level outlet construction is estimated to take approximately 15 months including gate installation and testing, and tailrace channel excavation.

Clearing and preparation of the cofferdam foundation will be initiated prior to completion of the low-level outlet. Materials for construction of cofferdam will be obtained from the overburden excavation of the dam foundation. Overall construction of the cofferdam is estimated to take 6 months, of which 2 months are on the critical path.

11.4.4 Main Dam and Spillway

The dam construction requires the placement of approximately 6,100,000 m^3 of materials including 5,800,000 m^3 of rockfill. Approximately 1,510,000 m^3 of rockfill are expected to be obtained from the spillway and dam rock excavation; the remaining rockfill will be extracted from two possible quarry areas located less than 3.0 km east of the dam site.

Excavations for the dam and foundation preparation are expected to take 11 months. Priority will be given to the locations of grout curtain and consolidation grouting, so as to enable parallel operation as necessary to minimize overall construction period as the dam construction represents the bulk of the critical path of the project construction.

Placement of the rockfill obtained is expected to be take 27 months after initiating construction of the dam; another 10 months are anticipated to complete the construction of the embankment, the concrete face and the crest with parapets.

The excavation for the spillway will be performed at a time when the materials can be directly placed in the dam. Concrete construction will be coordinated with the construction of the face of the dam to make efficient use of the concrete plant capacity.

11.4.5 Hydroelectric Power Plant

11.4.5.1 Intake and Conveyance System

The intake structure for the hydropower facility will consist of a tower located on the dam right abutment approximately 40 meters west of spillway. A 35-meter long bridge will provide access from the crest of the dam. The construction of the hydropower component will start with the excavation of the powerhouse and tunnel portal followed by the tunnel excavation, 260-meter long with a 5-meter finished diameter. The vertical shaft also 5-meter diameter, 80 meter deep will then be excavated, immediately followed by concreting. Upon completion of the shaft, the tunnel steel liner will be installed and backfilled with concrete. Field fabrication of the steel liner may be performed at the location of the proposed switchyard, between the toe of the dam and the low-level outlet tailrace channel, approximately 200 meter from the portal. Overall the tunnel and shaft construction will take approximately 10 months.

11.4.5.2 Powerhouse and Equipment

The powerhouse construction will take approximately 2 years after completion of the tunnel liner. The first twelve months will be essentially dedicated to the civil work while the second will the installation of the three units and the ancillary mechanical and electrical equipment.

11.4.5.3 Transmission System

The engineering and construction of the 230-kV switchyard at the toe of the Río Coclé del Norte dam, the 109 km of 230-kV transmission line and the connection to La Chorrera substation are not critical activities of the project schedule. They will be scheduled in parallel with other construction activities. The duration of this activity is estimated at 4.5 years beginning with preliminary engineering and route survey, followed by detailed design, material procurement and construction.

11.4.6 Reservoir Filling

As indicated previously, the project will only be operational when it is capable of delivering water into the Río Indio reservoir, i.e., with Río Coclé del Norte Reservoir level above El. 90. For this reason, it is recommended to start filling the reservoir prior to completion of the project. When the dam construction reaches a reasonable height, it is anticipated that the low level outlet will be used to control the release from the reservoir.

For the purpose of determining the required time to fill the reservoir, the monthly flow sequence of 52 years from 1948 to 1999 were analyzed. It was also assumed that a minimum release of 10.7 m^3/sec would be continuously released during the filling period. The results of this analysis are presented on Table 11-1.

TABLE 11-1 RÍO COCLÉ DEL NORTE RESERVOIR FILLING

Filling Period	Reached Levels		
	At 90% probability	At 50% Probability	At 10% Probability
1 year	El. 53	El. 59	El. 64
2 years	El. 71	El. 74	El. 80
3 years	El. 82	El. 85	El. 90
4 years	El. 91	El. 94	El. 98
5 years	El. 99	El. 100	El. 100

Based on the results presented above, it is recommended that the reservoir filling be started one year prior to completion. Based on the median hydrologic conditions, the reservoir would reach El. 59 at the completion of construction. There is a 90% probability that water could be transferred to Río Indio and onto Lake Gatun in just under 4 years.

11.5 Contract 3 – Water Transfer Facilities

11.5.1 Camp and Power Supply

The construction camp for the Water Transfer Facilities, which will also serve for the construction of the Río Caño Sucio Project, will be located in a central location, for example, near the village of Cerro Miguel de Doñoso.

The electrical power needs at the Water Supply Facilities and the Río Caño Sucio storage facilities are estimated to be approximately 1.0 MW. It is anticipated that the contractor will generate the required power by providing small size diesel generators (300-kW to 500-kW) at appropriate locations.

11.5.2 Transfer Tunnel

The 2,550-meter long tunnel will be built 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 meters per day has been used.

The selected tunnel shape is a 5.5-meter diameter D-shaped section. It is estimated that approximately 170,000 m^3 of loose material will be excavated from the 2,550-meter long transfer tunnel. Excavation of the tunnel will be initiated from both ends. Taking into account the portal excavation it is anticipated that the tunnel excavation will be completed in approximately 70 weeks. The concrete lining of the tunnel will follow the excavation and it is anticipated to take approximately six months. As the invert of the tunnel outlet is at approximately El. 70, below the normal operating level of the Río Indio reservoir, a cofferdam will be built in the Río Indio reservoir to allow for unrestricted operation of the reservoir during the construction of the Río Caño Sucio transfer tunnel. As the cofferdam may have to be built in the water, it is anticipated that a cellular cofferdam will be required. The cofferdam will have a maximum height of approximately 15 meters to about El. 81, and it will be approximately 150 meters long. It will be removed upon completion of the transfer tunnel outlet structure.

The proposed schedule shows the sequencing of the activities including the construction of the intake and outlet works and the installation of the gates. Overall the tunnel construction, including the intake and outlet works is expected to take 33 months. The last activity to be completed prior to the initial filling of the reservoir is the installation and testing of the intake gate at the upstream end of the tunnel.

11.5.3 Transfer Canal

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 both directions 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, and
- 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 33 months, including possible disruptions during the periods of large flows.

11.6 Contract 4 – The Río Caño Sucio Storage Facilities

11.6.1 Rockfill and Aggregate Quarries

For the Río Caño Sucio Project, two quarries have been identified for use in this project: one located on Cerro Miguel, East of the dam site at 8.5 km by road, and the second located on Cerro Loma approximately 7.0 km by road also East of the dam site. The Cerro Miguel quarry would be preferred for its proximity to the proposed main access. The quarry will be used for the manufacturing of concrete and RCC aggregates (70,000 m^3).

A crushing plant and an aggregate stockpile area will also be established near Cerro Miguel. The establishment of the quarries is anticipated to take approximately 7 months including geotechnical investigations and it is not on the schedule critical path as investigations can be initiated at any time during the first year of activities before aggregates are needed.

11.6.2 Diversion

A diversion culvert approximately 70 meters long will be used to pass the river flows during the dam construction. As this culvert will be ultimately used as the reservoir low-level outlet, its construction will need to be completed including intake works, gates and operating equipment, and outlet works prior to start the construction of the dam. The low-level outlet construction is estimated to take approximately 6 months including gate installation.

11.6.3 Main Dam and Spillway

The dam construction requires the placement of approximately 27,900 m^3 of roller-compacted concrete and 7,300 m^3 of conventional concrete. Aggregates will be obtained from the quarry at Cerro Miguel, located at about 8.5 km from the dam site. A rapid placement of the RCC will be followed by the construction of the spillway with conventional concrete. Overall construction of the dam, including the gravity section and the overflow spillway is expected to take approximately 10 months.

11.6.4 Reservoir Filling

The Río Caño Sucio reservoir will require less than four months from September to December to fill using its own inflow and maintaining a 0.75 m^3/s minimum release at the dam site.

11.7 Contract 5 – Second Transfer Tunnel from Río Indio to Lake Gatun

11.7.1 Excavation Methods

Based on the available geologic information and the relatively shallow topography along the alignment of the transfer tunnel it is anticipated that the tunnel construction will meet a broad range of working conditions and required supports. It is also probable that rock type changes from hard volcanic rock to weaker sedimentary rock may be frequent, resulting in numerous difficult transition zones. On that basis, the drill-and-blast method was selected for the purpose of scheduling, as tunnel boring machines (TBM) are more appropriate for uniform rock formation. Further geologic investigations will be required to finalize the selection of the tunneling 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 advance rate of 3.5 meters per day has been selected as a realistic estimate for the second Río Indio transfer tunnel.

11.7.2 Tunnel Construction

The selected tunnel shape is a 6.5-meter diameter D-shape section. Based on an average over-break of 0.10 meter, it is estimated that a minimum of 445,000 m^3 of material will be excavated from the 8,250-meter long transfer tunnel. The two adits excavated for the construction of the first transfer tunnel will be used as intermediate access. Based on the excavation rate of 3.5 meters per day and the six excavation fronts anticipated, it is estimated that the excavation of the tunnel will take approximately 2 years, 3 months. For that purpose, the most western excavation front will be started from a vertical shaft, to be used as the intake gate shaft.

The upstream end of the tunnel is lower than the Río Indio minimum operating pool, and therefore the construction of the intake will require a cofferdam. As the Río Indio reservoir needs to remain operational during the construction, the level will be maintained at approximately El. 40. A cellular cofferdam 15 to 20 meters high, 200 meters long, will be built around the tunnel intake area.

The proposed schedule shows the sequencing of the activities including the excavation of the gate shaft at the intake and the outlet work. Overall the tunnel construction, including the intake and outlet works is expected to take 39 months. The last activity to be completed prior to the filling of the reservoir is the installation and testing of the intake gate at the upstream end of the tunnel. This is anticipated to take place prior to the completion of the outlet work.

The tunnel excavation can be initiated prior to the completion of the Río Coclé del Norte dam and reservoir, however, as the system of reservoir must remain operational, the Río Indio reservoir will only be lowered to El 40 after the Río Coclé del Norte reservoir is filled and can supply the needed water to maintain the required yield. The Río Coclé del Norte reservoir at El.93 will have sufficient storage to substitute for Río Indio. It is only when Río Coclé del Norte reaches this level that the cofferdam can be built and the intake construction can be initiated.

11.8 Contract 6 – Reservoir Clearing

It is assumed that reservoir clearing will be performed for the forested areas and not for the pastures and shrub land. Further studies will be required to establish the clearing strategy including the economics of timber recovery. The reservoir areas will also need to be surveyed to determine the initial reservoir volume and to permit monitoring of the sediment deposition.

In the Río Coclé del Norte Reservoir, the land will be cleared to about El. 105. Based on the environmental studies, approximately 42% of the land below El. 100 is covered in low land forest. Using that percentage on the area at El. 105 results in a clearing requirement of about 19,000 ha. The clearing is expected to take a minimum of two years; however, to minimize regrowth, the clearing will essentially be done along with the reservoir filling. Clearing will be started from the lower level working towards the higher elevations.

For the Río Caño Sucio Reservoir, about 7% of the land is still in forest. Clearing the reservoir to El. 105 would result in the removal of about 140 ha of forest. The vegetation clearing is expected to take approximately 3 months.

11.9 Cost Estimate

The cost estimate for the construction of the Norte/Sucio/Indio Water Supply Project has been developed on the basis of the present design and the construction schedule presented in Section 11.2. This estimate includes the direct costs of labor, equipment and material, the Contractor indirect costs and engineering and administration costs. The costs were estimated in US Dollars at a January 2003 level. It is assumed that the project will be implemented with six contracts. Local contractors will construct the access roads and construction camp, the Río Caño Sucio dam, and clear the forest lands in the reservoir. International contractors will perform the work associated with the Río Coclé del Norte dam, and the water transfer facilities located within and adjacent to the reservoir, and the second Río Indio to Lake Gatun tunnel. All contracts would be awarded on the basis of competitive bidding.

For each project feature, quantities were calculated from the feasibility-level design drawings and exhibits. The unit costs for major items of dam, appurtenant work and tunnel construction were developed using cost of labor, equipment and material. These items include: excavation (common and rock), fill placement, quarrying, concrete fabrication and placement, formwork, steel reinforcement and tunnel excavation and lining. Other unit costs were estimated from experience on other projects of similar nature.

11.9.1 Cost of Labor and Materials

The cost of local labor was estimated based on the "Convención Colectiva de Trabajo de Panamá" dated July 1998. This document indicates the minimum applicable wages to be paid to workers in the construction industry by profession and region, for every year from July 1998 to June 2002. Beyond that date, labor rates were adjusted according to the local CPI. These rates were increased by 30% to reflect the fact they are mandatory minimum wages. An average across the professions was taken to derive four main categories: unskilled labor, skilled labor, equipment operator and truck driver. The wages were also increased to reflect the expected 60-hour workweek: an overtime premium of 16.7% was assumed. Labor rates were then calculated by adding 50% for social costs. This resulted in the following hourly cost of salary.

TABLE 11-2 LOCAL LABOR COST OF SALARY

Category	Labor Rate
Unskilled labor	$5.60/hr
Skilled labor	$6.70/hr
Equipment operator	$8.00/hr
Truck driver	$6.30/hr

In addition to the local labor a crew leader was generally included at the rate of $10.00/hr.

Equipment rates were generally obtained from the publication of the US Army Corps of Engineers entitled "Construction Equipment Ownership and Operating Expense" (EP 1110-1-8), dated August 31, 2001. These rates have been increased at a 0.8% p.a. factor, reflecting the construction equipment cost escalation for the period. Equipment requirements and production rates were developed based on experience in similar type of project in tropical countries.

It is anticipated that materials including explosives, cement, and reinforcement steel will be imported for the most part. International unit prices were used: Table 11-3 below shows estimated unit costs of materials delivered at the site.

TABLE 11-3 MATERIAL UNIT COST

Material	Unit	Cost
Cement	MT	$122
Explosive	kg	$1.50
Reinforcing Steel	MT	$725

The operational costs for the international contractor were also itemized for the purpose of this estimate. These costs include a management and engineering crew of eight, including a project manager, a superintendent, three staff engineers, a purchasing agent, a scheduler (coordinator) and an accountant. The crew will be fully mobilized on site for the duration of construction, after completion of the preliminary works such as access road, construction camp, establishing quarries, etc. A supporting crew of administrative personnel and drivers was also itemized. Other operational costs accounted for include items such as a maintenance crew, vehicles for staff transportation and telephone.

Overall the contractor operating costs were estimated at approximately 7% of the total direct construction cost. In addition, the following indirect costs were also added:

Contractor home office charges	7.0%
Bond	1.5%
Insurance	2.5%
Margin for risk	2.0%
Margin for profit	10.0%

As a result, unit rates calculated on the basis of the costs of labor, equipment and materials have been increased by a margin of 30% to reflect these items.

The resulting unit prices were compared with those obtained through the bidding process on other international water resources projects in Central and South America and appeared to be reasonable estimate for this type of construction. The unit prices shown in Table 11-4 were used.

TABLE 11-4 ESTIMATED UNIT PRICES (JAN-2003 LEVEL)

Material	Unit	Cost
Clearing	ha	$2,200
Clearing and Grubbing	m^2	$0.55
Overburden Excavation	m^3	$3.20
Bulk Rock Excavation	m^3	$8.80
Structural Rock Excavation	m^3	$14.80
Transfer Tunnel Excavation	m^3	$91-$97
Shotcrete	m^2	$46.0
Rock-bolts	l.m.	$59.50-$67.50
Steel Ribs	kg	$6.00
Rockfill	m^3	$12.50
Backfill	m^3	$7.20
Aggregate/Filters/Drains	m^3	$16.10
Mass RCC	m^3	$72.00
Mass Concrete	m^3	$116.00
Structural Concrete	m^3	$145.00
Tunnel/Shaft Concrete Lining	m^3	$110-$180
Formwork	m^2	$46.50
Reinforcing Steel	kg	$1.32
Temporary Access Road	km	$115,200
Permanent Access Road	km	$147,600

A summary of the construction cost is shown in Table 11-6 below.

TABLE 11-6 SUMMARY COST OF THE RÍO COCLÉ DEL NORTE PROJECT

Item	Estimated Cost
Mitigation and Compensation Costs	**$238,000,000**
Access Roads and Construction Camp	$16,490,000
Río Coclé del Norte Storage Facilities	$190,710,000
Río Caño Sucio Storage Facilities	$6,500,000
Water Transfer Facilities	$79,750,000
Second Río Indio-Lake Gatun Tunnel	$85,520,000
Reservoir Clearing	$42,110,000
Subtotal Direct Cost	**$421,080,000**
Contingency	$77,120,000
Direct Cost	**$498,200,000**
Engineering and Administration	$74,800,000
Construction Cost (Jan 2003 price level)	**$573,000,000**
TOTAL COST	**$811,000,000**

11.9.2 Social, Economic and Environmental Mitigation and Compensation Costs

In the Río Coclé del Norte and Río Caño Sucio Reservoirs, there are estimated to be about 7,300 persons and about 47,000 ha will be acquired. Compensation costs for relocation were estimated by the ACP in the amount of $5,000 per person. Land acquisition was estimated as $5,000/ha of forest, $1,500/ha of shrub land, and $1,000/ha of pasture. Mitigation for habitat loss was estimated on the basis of the current land use and averaged about $1,200/ha over all of the soil uses. Finally, a cost for the replacement of the infrastructure was included, which covered clinics, cemeteries, water supply, commercial agriculture enterprises, parks, generating facilities, transmission lines, and public buildings.

The total mitigation and compensation costs, which are assumed to include contingencies, are estimated to be $230.5 million and $7.5 million for the Río Coclé del Norte and Río Caño Sucio basins respectively.

11.9.3 General Costs

The general costs include mobilization, construction camps and other temporary facilities, access roads and bridges.

The allocation for land acquisition has been included in the compensation and mitigation costs.

The lengths and location of the required access is presented in Section 11.3. It is expected that the access to the area will be to Panama highway standards. The ACP will maintain all permanent roads required for operation of the project.

Reservoir clearing will be done on all forested lands within the reservoir below El. 105. Lowland forest is estimated to cover about 19,140 ha or about 43% of the reservoir area. The full cost of clearing has been included in the estimate. However, it is likely that this cost will be significantly reduced or eliminated if the clearing is contracted out to a commercial logging company.

11.9.4 Contingencies

A contingency allowance is included in the cost estimate for unforeseen site conditions, approximations, and the potential for future design changes. For these estimates, an allowance of 25% was used for the dam and tunnel excavation to reflect the uncertainties associated with foundation unknowns and the conditions that could be encountered in the long tunnel, 15% was used for all civil items and 10% for all equipment. Overall, the contingency is approximately 13% of the project construction cost or about 18% of the subtotal of the direct costs.

11.9.5 Engineering and Administration

Indirect costs for final design, engineering services during construction, and for administration costs of the APC chargeable to the project are based on previous experience for similar projects. It has been estimated that about 15 percent of the total direct costs will be adequate for engineering and administration.

11.9.6 Capital Cost

An estimate of the capital cost is not provided. The problems associated with an assumption of a long-term inflation rate and escalation and interest rates for a period 20-odd years in the future, precludes any kind of a useful result. For discussion purposes, it is estimated that the capital costs will be between $3 billion and $5 billion.

11.9.7 Disbursement Schedule

A disbursement schedule has been estimated beginning in 2019, the point in time when funding is secured according to the implementation schedule. The disbursement schedule has been estimated on the basis of the cost estimate, the implementation schedule, and the detailed construction schedule. The disbursement schedule, presented in Table 11-6 shows a distribution for the construction cost.

TABLE 11-6 DISBURSEMENT SCHEDULE
(x $1,000)

Year	Disbursement of Construction Costs
1 (2021)	35,000
2 (2022)	35,000
3 (2023)	53,000
4 (2024)	64,000
5(2025)	81,000
6(2026)	88,000
7(2027)	103,000
8(2028)	101,000
9(2029)	81,000
10(2030)	75,000
11(2031)	63,000
12(2032)	32,000
Total	**$811,000**

11.10 Annual Operating Cost

The annual operating costs include the costs of operation and maintenance (O&M), for the various features, the cost of replacing short-life equipment, administration by the Owner, and insurance.

The O&M for the two dams, the hydro plant, and the water transfer facilities will be performed by three O&M groups that will be a part of the ACP's much larger Canal Operation Group. As the personnel are part of a larger group, the management duties will required only part time input from existing staff. A summary estimate of the personnel and equipment requirements and the cost are shown below in Table 11-7.

TABLE 11-8 ANNUAL OPERATION AND MAINTENANCE STAFFING COST

	Number	Annual Unit Cost	Total Annual O&M Cost
Personnel			
Manager	0.4	$100,000	$40,000
Assistant Manager	1.5	$60,000	$60,000
Operation Personnel	10	$35,000	$350,000
Maintenance Personnel	15	$30,000	$450,000
Electrical Foreman	0.1	$50,000	$5,000
Electrician	2	$40,000	$80,000
Mechanical Foreman	0.1	$50,000	$5,000
Hydroelectric Mechanical	2	$40,000	$80,000
Heavy Duty mechanical	2	$35,000	$70,000
Laborers	30	$15,000	$450,000
Dredge Crew	1	$150,000	150,000
Subtotal			*$1,900,000*
Equipment			
Vehicles	10	$40,000	$400,000
Spare Parts	LS		$150,000
Maintenance Equipment	LS		$150,000
Total O&M Cost			**$2,600,000**

The cost of replacing short-life equipment is included in the annual cost as a sinking fund. The cost is computed as the amount to replace all equipment in 25 years at an interest rate of 10% and an inflation rate of 3% per year. The sinking fund amount is estimated to be $900,000 per year.

Administration and general expenses of the owner is for salaries, outside services, injuries and damages, welfare, pensions and miscellaneous expenses. These costs were assumed to equal 40% of the labor cost of the O&M personnel.

The annual cost of insurance was estimated as about 0.1% of the construction cost.

In addition, an annual cost associated with watershed management, implementation of the environmental mitigation plan and the relocation activities is included.

The annual operation and maintenance costs are summarized in Table 11-8.

TABLE 11-9 ANNUAL OPERATION AND MAINTENANCE COST

Item	Annual Cost
O&M	$2,600,000
Replacement	$150,000
Admin and General Expenses	$700,000
Insurance	$575,000
Resettlement Administration	$150,000
Watershed Management	$150,000
Mitigation Plan Implementation	$100,000
Total (rounded)	**$4,425,000**

12. ECONOMIC COST OF WATER

The original scope of services for the economic evaluation of the Río Coclé del Norte Project consisted of a series of economic studies that were to include:

- Optimization of the dam height and spillway width,
- Assessment of the economic viability of the combined navigation/M&I project, and
- Evaluation of the addition of hydropower.

During the study, it was determined that no supplemental water supply project would be implemented unless it was a part of a much bigger project to construct a third and even a fourth set of locks. Under these conditions, the existing demand and toll revenues are not valid and any economic justification using these values would be irrelevant. This determination prevented the optimization of the dam height and any assessment of economic feasibility. The evaluation of hydropower was possible and is discussed in Section 8.

Although no economic analysis is possible at this time, it is possible to analyze a series of demand conditions and compare them to the cost of the project to estimate the economic cost of water.

If conditions existed where the full amount of the system yield attributable to the implementation of the Norte/Sucio/Indio Project could be beneficially used immediately upon the completion of construction, the economic cost of water would be about $0.03/m^3. This estimate is derived by dividing the present worth of the total project cost (construction excluding the power facilities, compensation and mitigation cost) and annual costs by the present worth of the supply, which is 47 L/d. In all estimates, a discount rate of 12% was used. This condition is highly unlikely and only serves to indicate a minimum cost of water.

A more likely condition assumes that only a portion of the yield can be used when the project comes on line and that the usable yield increase at some reasonable rate. For example, if the year 2000 demand were assumed to be 38 L/d, the demand increased at 0.75 L/d/yr, the existing system, which is presumed to include the Río Indio Reservoir, could yield 60.3 L/d, and the project came on line in the first year that there was a system deficit (year 2030), the economic cost of water would be about $0.23/m^3. Under these conditions, the full yield of the project is not used within the 50-year period of operation. If the project were delayed for ten years, which would result in the potential for severe shortages during those ten years, the economic cost of water would be reduced to $0.11/m^3.

Under the same assumptions and a rate of increase of 0.6 L/d/yr, the cost of water would be about $0.27/m^3 and $0.13/m^3 for the same two conditions.

For comparison purposes, the following table presents historic demands with a range of growth rates assuming that the current demand for navigation and M&I water is about 38 L/d.

TABLE 12-1 COMPARISON OF DEMANDS AND COST OF WATER

Year	On-Line Year	Recon Report Navigation Demand + MWH M&I Demand	Base Demand Increased by 0.75 L/d/yr	Base Demand Increased by 0.6 L/d/yr
2000		38.0 L/d	38.0 L/d	38.0 L/d
2020		52.5 L/d	53.0 L/d	50.0 L/d
2040		70.8 L/d	68.0 L/d	62.0 L/d
2060		85.1 L/d	83.0 L/d	74.0 L/d
Cost of Water	**First year of deficit**	**$0.18/m^3**	**$0.23/m^3**	**$0.27/m^3**
Cost of Water	**10 yrs after first year of deficit**	**$0.09/m^3**	**$0.11/m^3**	**$0.13/m^3**

The economic cost of water for the Project is substantially more than any of the other projects in the Western Watersheds. The primary reason is that the yield is so large that there is a very long period before the yield is completely used by the Panama Canal. A comparison of five of the projects in the Western Watersheds studied to date is shown below.

TABLE 12-2 COMPARISON OF PROJECTS AND COST OF WATER

Project	Yield	Base Demand Increased by 0.75 L/d/yr	Base Demand Increased by 0.6 L/d/yr
Coclé del Norte, FSL @ El. 100, with Caño Sucio and Río Indio	47 L/d	$0.23/m^3$	$0.27/m^3$
Coclé del Norte, FSL @ El. 71, with Río Indio	45.4 L/d	$0.19/m^3$	$0.22/m^3$
Upper Chagres	5.3 L/d	$0.12/m^3$	$0.12/m^3$
Río Indio	15.8 L/d	$0.07/m^3$	$0.10/m^3$
Río Caño Sucio	2.5 L/d	$0.09/m^3$	$0.12/m^3$

Including hydropower costs and benefits would reduce the cost of water for the Project by about $0.06/ m^3.

13. CONCLUSIONS AND RECOMMENDATIONS

Without the information required to perform and economic and financial evaluations (for reasons given in Section 1.3.2), it is not possible to make a recommendation concerning the implementation of the project. The economic cost of water is higher than what might normally be expected for a commercial supply and approaches what might be expected for an M&I supply. However, the current benefits accruing to water supply from the Panama Canal operation also are high and may continue at this level. Therefore, development of the project cannot be ruled out, but the recommendations, at this time, can relate only to the relative attractiveness of the possible alternative developments in the basin.

13.1 Conclusions

As a result of the studies described in this report and its appendices, it is concluded that:

- The Project is technically feasible.
- The dam sites selected in the Reconnaissance Report are suitable sites for the development of the water resources of the Río Coclé del Norte and Río Caño Sucio Basins.
- A concrete-faced rockfill dam at the Río Coclé del Norte site and an RCC dam at the Río Caño Sucio sites are the most appropriate types of dam for the sites based on the available information, estimates of cost, and preferences of the ACP.
- It is our considered opinion that there are no geologic or geotechnical problems associated with the sites that cannot be accommodated using conventional solutions although the lack of subsurface investigations has increased the potential for inaccuracies in the estimate of cost.
- The yield of the Panama Canal system will increase by about 3,570 MCM/yr (about 47 L/d) with the addition of the Project.
- For the rates of growth of demand considered, the full yield of the Project is not used within 50-years and, therefore, the project is too large.
- There is no way to significantly lower both the yield and the cost of the Project (Lowering the yield will not significantly lower the cost because the minimum supply level must stay at El. 90 so that the Río Coclé del Norte Reservoir can act in full regulation with the Río Caño Sucio Reservoir. Lowering the cost can be accomplished by lowering the Río Coclé del Norte dam, but that would preclude operation with the Río Caño Sucio Reservoir).
- The addition of a 75 MW hydropower plant at Río Coclé del Norte dam is economically attractive.
- The inclusion of a commercial agricultural endeavor is technically feasible, but is not economically viable at this time and development should not be initiated at this time.

- Construction of the project is estimated to cost about $573 million in 2003 dollars. An addition $238 million have been allowed for compensation and mitigation for a total cost of $811 million.
- The economic cost does not compare favorably with any of the other Western Watershed Projects studied to date.

13.2 Recommendations

As a result of these conclusions, development of the Río Coclé del Norte Reservoir at a full supply level of El. 100 and acting in full regulation with the Río Caño Sucio and Río Indio Reservoirs is not recommended.

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Tables

TABLES

Table 1

LONG-TERM MONTHLY STREAMFLOW AT THE RÍO COCLÉ DEL NORTE 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**

Table 2

LONG-TERM MONTHLY STREAMFLOW AT THE RÍO CAÑO SUCIO DAM SITE

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	**268**
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	[illegible]	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**

MWH / TAMS

Table 3

RIO COCLE DEL NORTE RESERVOIR ACTING IN FULL REGULATION WITH RIO CAÑO SUCIO AND RIO INDIO RESERVOIRS

SUMMARY COST ESTIMATE

	US$ million
ACCESS ROADS AND CONSTRUCTION CAMP	$ 16.5
RIO COCLE DEL NORTE STORAGE PROJECT	$ 190.7
RIO CANO SUCIO STORAGE PROJECT	$ 6.5
WATER TRANSFER FACILITIES	$ 79.8
SECOND RIO INDIO TO LAKE GATUN TUNNEL	$ 85.5
RESERVOIR CLEARING	$ 42.1
SUBTOTAL DIRECT COSTS	$ 421.1
Contingency	$ 77.1
DIRECT COST	$ 498.2
Engineering and Administration	$ 74.8
CONSTRUCTION COST (Jan 2003 price level)	$ 573.0
Compensation and Mitigation Cost	$ 238.0
TOTAL COST	$ 811.0

RIO COCLE DEL NORTE RESERVOIR ACTING IN FULL REGULATION WITH RIO CAÑO SUCIO AND RIO INDIO RESERVOIRS

CONSTRUCTION COST ESTIMATE SUMMARY

ACCESS ROADS AND CONSTRUCTION CAMP		
1 General	$	420,000
2 Access Road to Cano Sucio	$	5,730,000
3 Access Road to Cocle del Norte	$	8,760,000
4 Construction Camps	$	1,580,000
Subtotal	***$***	***16,490,000***
RIO COCLE DEL NORTE STORAGE PROJECT		
1 General	$	3,040,000
2 Diversion	$	12,600,000
3 Dam	$	101,660,000
4 Spillway	$	4,470,000
5 Low Level Outlet Structure	$	9,170,000
6 Saddle Dams	$	1,060,000
7 75-Mw Hydroelectric Power Plant	$	36,370,000
8 Transmission System	$	21,170,000
9 Operation Facilities	$	1,170,000
Subtotal	***$***	***190,710,000***
RIO CANO SUCIO STORAGE PROJECT		
1 General	$	1,020,000
2 Diversion	$	250,000
3 Dam	$	3,590,000
4 Spillway	$	570,000
5 Low Level Outlet	$	170,000
6 Operation Facilities	$	900,000
Subtotal	***$***	***6,500,000***
WATER TRANSFER FACILITIES		
1 General	$	2,720,000
2 Canal	$	53,380,000
3 Tunnel	$	18,570,000
4 Cofferdam	$	5,080,000
Subtotal	***$***	***79,750,000***
SECOND RIO INDIO TO LAKE GATUN TUNNEL		
1 General	$	1,770,000
2 Cofferdam	$	6,570,000
3 Access Adit Rehabilitation	$	750,000
4 Tunnel Portals	$	3,150,000
5 Tunnel	$	62,370,000
6 Intake Structure	$	430,000
7 Intake Gate Shaft	$	2,320,000
8 Outlet Structure	$	1,340,000
9 Discharge Channel	$	2,600,000
10 Hydromechanical Equipment	$	4,220,000
Subtotal	***$***	***85,520,000***
RESERVOIR CLEARING	**$**	**42,110,000**
SUBTOTAL DIRECT COSTS	**$**	**421,080,000**
Contingency	$	77,120,000
DIRECT COST	**$**	**498,200,000**
Engineering and Administration	$	74,800,000
CONSTRUCTION COST (Jan 2003 price level)	**$**	**573,000,000**

RIO COCLE DEL NORTE RESERVOIR ACTING IN FULL REGULATION WITH RIO CAÑO SUCIO AND RIO INDIO RESERVOIRS

ACCESS ROADS AND CONSTRUCTION CAMPS

Description	Unit	Unit Cost	Quantity	Amount
1 GENERAL				
1.1 Mobilization and Demobilization	LS	$250,000	1	$250,000
1.2 Temporary Facilities Maintenance	mth	$1,000	48	$48,000
1.3 Access Roads Maintenance	mth	$2,500	48	$120,000
Subtotal 1				***$418,000***
2 ACCESS ROADS TO CANO SUCIO				
2.1 Permanent Access to Dam Site	km	$147,600	24	$3,542,400
2.2 Temporary Roads	km	$115,200	7	$806,400
2.3 Permanent Access to Structure	km	$147,600	7	$1,033,200
2.4 Bridge over Rio Cano Sucio	LS	$350,000	1	$350,000
Subtotal 2				***$5,732,000***
3 ACCESS ROADS TO COCLE DEL NORTE				
3.1 Permanent Access to Dam Site	km	$147,600	35	$5,166,000
3.2 Temporary Road to Southern Saddle Dam	km	$115,200	14	$1,612,800
3.3 Permanent Access to Northern Saddle Dam	km	$147,600	6	$885,600
3.4 Bridge over Rio Miguelito	LS	$350,000	1	$350,000
3.5 Bridge over Rio Cocle del Norte	LS	$750,000	1	$750,000
Subtotal 3				***$8,764,400***
4 CONSTRUCTION CAMPS				
4.1 Cano Sucio Construction Camp	Included with the water transfer facilities			
4.2 Cocle del Norte Construction Camp	LS	$1,575,000	1	$1,575,000
Subtotal 4				***$1,575,000***
Subtotal Direct Cost (rounded)				**$16,490,000**
Contingency				**$2,470,000**
Direct Cost				**$18,960,000**

RIO COCLE DEL NORTE RESERVOIR ACTING IN FULL REGULATION WITH RIO CAÑO SUCIO AND RIO INDIO RESERVOIRS

RIO COCLE DEL NORTE STORAGE PROJECT

Description	Unit	Unit Cost	Quantity	Amount
1 GENERAL				
1.1 Mobilization and Demobilization	LS	$2,500,000	1	$2,500,000
1.2 Temporary Facilities Maintenance	mth	$5,000	72	$360,000
1.3 Access Roads Maintenance	mth	$2,500	72	$180,000
Subtotal 1				***$3,040,000***
2 DIVERSION				
2.1 Site Preparation	m^2	$0.55	80,000	$44,000
2.2 Approach/Discharge Channels				
2.2.1 Overburden Excavation	m^3	$3.20	included in 2.3.1	
2.2.2 Rock Excavation	m^3	$8.80	included in 2.3.2	
2.3 Diversion Tunnel Intake and Outlet Portals				
2.3.1 Overburden Excavation	m^3	$3.20	44,900	$143,680
2.3.2 Rock Excavation	m^3	$8.80	51,700	$454,960
2.3.3 Shotcrete	m^2	$46.00	4,600	$211,600
2.3.4 Rockbolts	l.m.	$59.50	2,300	$136,850
2.3.5 Concrete	m^3	$145.00	1,415	$205,175
2.3.6 Formwork	m^2	$46.50	1,300	$60,450
2.3.7 Reinforcement	kg	$1.32	44,500	$58,740
2.4 Diversion Tunnel				
2.4.1 Tunnel Excavation	m^3	$125.00	39,518	$4,939,750
2.4.2 Shotcrete	m^2	$46.00	7,380	$339,480
2.4.3 Rockbolts	l.m.	$67.50	7,779	$525,083
2.4.4 Steel Ribs	kg	$6.00	33,720	$202,320
2.4.5 Closure Bulkhead	Each	$95,000	2	$190,000
2.5 Cofferdams				
2.5.1 Overburden Excavation	m^3	$3.20	104,397	$334,070
2.5.2 Fill	m^3	$7.30	583,545	$4,259,879
2.5.3 Filter/Drain	m^3	$16.10	30,713	$494,479
Subtotal 2				***$12,600,516***
3 DAM				
3.1 Site Preparation	m^2	$0.55	240,000	$132,000
3.2 Excavation				
3.2.1 Overburden Excavation	m^3	$3.20	475,500	$1,521,600
3.2.2 Rock Excavation	m^3	$8.80	237,800	$2,092,640
3.3 Grouting				
3.3.1 Cut-off	m^2	$46.00	39,528	$1,818,289
3.3.2 Consolidation	m	$69.20	2,750	$190,300
3.4 Rockfill				
3.4.1 Mass	m^3	$12.50	5,761,032	$72,012,902
3.4.2 Filter	m^3	$16.10	296,878	$4,779,730
3.4.3 Drain	m^3	$16.10	32,000	$515,200
3.4.4 Backfill	m^3	$7.20	207,400	$1,493,280
3.5 Concrete				
3.5.1 Dental Concrete	m^3	$116.00	10,078	$1,168,990
3.5.2 Plinth	m^3	$172.00	10,078	$1,733,330
3.5.3 Facing	m^2	$80.00	98,959	$7,916,737
3.5.4 Parapet -US	m^3	$252.00	4,608	$1,161,216
3.5.5 Parapet -DS	m^3	$252.00	870	$219,341
3.5.6 Crest Road	m^2	$9.60	6,144	$58,982
3.6 Miscellaneous Site Work	LS	5%	1	$4,840,727
Subtotal 3				***$101,655,263***

RIO COCLE DEL NORTE RESERVOIR ACTING IN FULL REGULATION WITH RIO CAÑO SUCIO AND RIO INDIO RESERVOIRS

CONSTRUCTION COST ESTIMATE SUMMARY

ACCESS ROADS AND CONSTRUCTION CAMP		
1 General	$	420,000
2 Access Road to Cano Sucio	$	5,730,000
3 Access Road to Cocle del Norte	$	8,760,000
4 Construction Camps	$	1,580,000
Subtotal	***$***	***16,490,000***
RIO COCLE DEL NORTE STORAGE PROJECT		
1 General	$	3,040,000
2 Diversion	$	12,600,000
3 Dam	$	101,660,000
4 Spillway	$	4,470,000
5 Low Level Outlet Structure	$	9,170,000
6 Saddle Dams	$	1,060,000
7 75-Mw Hydroelectric Power Plant	$	36,370,000
8 Transmission System	$	21,170,000
9 Operation Facilities	$	1,170,000
Subtotal	***$***	***190,710,000***
RIO CANO SUCIO STORAGE PROJECT		
1 General	$	1,020,000
2 Diversion	$	250,000
3 Dam	$	3,590,000
4 Spillway	$	570,000
5 Low Level Outlet	$	170,000
6 Operation Facilities	$	900,000
Subtotal	***$***	***6,500,000***
WATER TRANSFER FACILITIES		
1 General	$	2,720,000
2 Canal	$	53,380,000
3 Tunnel	$	18,570,000
4 Cofferdam	$	5,080,000
Subtotal	***$***	***79,750,000***
SECOND RIO INDIO TO LAKE GATUN TUNNEL		
1 General	$	1,770,000
2 Cofferdam	$	6,570,000
3 Access Adit Rehabilitation	$	750,000
4 Tunnel Portals	$	3,150,000
5 Tunnel	$	62,370,000
6 Intake Structure	$	430,000
7 Intake Gate Shaft	$	2,320,000
8 Outlet Structure	$	1,340,000
9 Discharge Channel	$	2,600,000
10 Hydromechanical Equipment	$	4,220,000
Subtotal	***$***	***85,520,000***
RESERVOIR CLEARING	**$**	**42,110,000**
SUBTOTAL DIRECT COSTS	**$**	**421,080,000**
Contingency	$	77,120,000
DIRECT COST	**$**	**498,200,000**
Engineering and Administration	$	74,800,000
CONSTRUCTION COST (Jan 2003 price level)	**$**	**573,000,000**

RIO COCLE DEL NORTE RESERVOIR ACTING IN FULL REGULATION WITH RIO CAÑO SUCIO AND RIO INDIO RESERVOIRS

ACCESS ROADS AND CONSTRUCTION CAMPS

Description	Unit	Unit Cost	Quantity	Amount
1 GENERAL				
1.1 Mobilization and Demobilization	LS	$250,000	1	$250,000
1.2 Temporary Facilities Maintenance	mth	$1,000	48	$48,000
1.3 Access Roads Maintenance	mth	$2,500	48	$120,000
Subtotal 1				***$418,000***
2 ACCESS ROADS TO CANO SUCIO				
2.1 Permanent Access to Dam Site	km	$147,600	24	$3,542,400
2.2 Temporary Roads	km	$115,200	7	$806,400
2.3 Permanent Access to Structure	km	$147,600	7	$1,033,200
2.4 Bridge over Rio Cano Sucio	LS	$350,000	1	$350,000
Subtotal 2				***$5,732,000***
3 ACCESS ROADS TO COCLE DEL NORTE				
3.1 Permanent Access to Dam Site	km	$147,600	35	$5,166,000
3.2 Temporary Road to Southern Saddle Dam	km	$115,200	14	$1,612,800
3.3 Permanent Access to Northern Saddle Dan	km	$147,600	6	$885,600
3.4 Bridge over Rio Miguelito	LS	$350,000	1	$350,000
3.5 Bridge over Rio Cocle del Norte	LS	$750,000	1	$750,000
Subtotal 3				***$8,764,400***
4 CONSTRUCTION CAMPS				
4.1 Cano Sucio Construction Camp	Included with the water transfer facilities			
4.2 Cocle del Norte Construction Camp	LS	$1,575,000	1	$1,575,000
Subtotal 4				***$1,575,000***
Subtotal Direct Cost (rounded)				**$16,490,000**
Contingency				**$2,470,000**
Direct Cost				**$18,960,000**

RIO COCLE DEL NORTE RESERVOIR ACTING IN FULL REGULATION WITH RIO CAÑO SUCIO AND RIO INDIO RESERVOIRS

RIO COCLE DEL NORTE STORAGE PROJECT

Description	Unit	Unit Cost	Quantity	Amount
1 GENERAL				
1.1 Mobilization and Demobilization	LS	$2,500,000	1	$2,500,000
1.2 Temporary Facilities Maintenance	mth	$5,000	72	$360,000
1.3 Access Roads Maintenance	mth	$2,500	72	$180,000
Subtotal 1				***$3,040,000***
2 DIVERSION				
2.1 Site Preparation	m²	$0.55	80,000	$44,000
2.2 Approach/Discharge Channels				
2.2.1 Overburden Excavation	m³	$3.20	included in 2.3.1	
2.2.2 Rock Excavation	m³	$8.80	included in 2.3.2	
2.3 Diversion Tunnel Intake and Outlet Portals				
2.3.1 Overburden Excavation	m³	$3.20	44,900	$143,680
2.3.2 Rock Excavation	m³	$8.80	51,700	$454,960
2.3.3 Shotcrete	m²	$46.00	4,600	$211,600
2.3.4 Rockbolts	l.m.	$59.50	2,300	$136,850
2.3.5 Concrete	m³	$145.00	1,415	$205,175
2.3.6 Formwork	m²	$46.50	1,300	$60,450
2.3.7 Reinforcement	kg	$1.32	44,500	$58,740
2.4 Diversion Tunnel				
2.4.1 Tunnel Excavation	m³	$125.00	39,518	$4,939,750
2.4.2 Shotcrete	m²	$46.00	7,380	$339,480
2.4.3 Rockbolts	l.m.	$67.50	7,779	$525,083
2.4.4 Steel Ribs	kg	$6.00	33,720	$202,320
2.4.5 Closure Bulkhead	Each	$95,000	2	$190,000
2.5 Cofferdams				
2.5.1 Overburden Excavation	m³	$3.20	104,397	$334,070
2.5.2 Fill	m³	$7.30	583,545	$4,259,879
2.5.3 Filter/Drain	m³	$16.10	30,713	$494,479
Subtotal 2				***$12,600,516***
3 DAM				
3.1 Site Preparation	m²	$0.55	240,000	$132,000
3.2 Excavation				
3.2.1 Overburden Excavation	m³	$3.20	475,500	$1,521,600
3.2.2 Rock Excavation	m³	$8.80	237,800	$2,092,640
3.3 Grouting				
3.3.1 Cut-off	m²	$46.00	39,528	$1,818,289
3.3.2 Consolidation	m	$69.20	2,750	$190,300
3.4 Rockfill				
3.4.1 Mass	m³	$12.50	5,761,032	$72,012,902
3.4.2 Filter	m³	$16.10	296,878	$4,779,730
3.4.3 Drain	m³	$16.10	32,000	$515,200
3.4.4 Backfill	m³	$7.20	207,400	$1,493,280
3.5 Concrete				
3.5.1 Dental Concrete	m³	$116.00	10,078	$1,168,990
3.5.2 Plinth	m³	$172.00	10,078	$1,733,330
3.5.3 Facing	m²	$80.00	98,959	$7,916,737
3.5.4 Parapet -US	m³	$252.00	4,608	$1,161,216
3.5.5 Parapet -DS	m³	$252.00	870	$219,341
3.5.6 Crest Road	m²	$9.60	6,144	$58,982
3.6 Miscellaneous Site Work	LS	5%	1	$4,840,727
Subtotal 3				***$101,655,263***

RIO COCLE DEL NORTE RESERVOIR ACTING IN FULL REGULATION WITH RIO CAÑO SUCIO AND RIO INDIO RESERVOIRS

RIO COCLE DEL NORTE STORAGE PROJECT

Description	Unit	Unit Cost	Quantity	Amount
4 SPILLWAY				
4.1 Site Preparation	m^2	$0.55	40,000	$22,000
4.2 Excavation				
4.2.1 Overburden Excavation	m^3	$3.20	120,644	$386,061
4.2.2 Rock Excavation	m^3	$8.80	100,627	$885,519
4.2.3 Backfill	m^3	$7.30	12,000	$87,600
4.3 Headworks				
4.3.1 Concrete	m^3	$145.00	2,970	$430,650
4.3.2 Formwork	m^2	$46.50	2,000	$93,000
4.3.3 Reinforcement	kg	$1.32	60,300	$79,596
4.4 Chute and Flip Bucket				
4.4.1 Concrete	m^3	$145.00	8,240	$1,194,800
4.4.2 Formwork	m^2	$46.50	11,912	$553,908
4.4.3 Reinforcement	kg	$1.32	330,200	$435,864
4.4.4 Drains	l.m.	$9.00	2,380	$21,423
4.4.5 Anchors	l.m.	$37.00	2,707	$100,150
4.5 Bridge				
4.5.1 Concrete	m^3	$145.00	440	$63,800
4.5.2 Formwork	m^2	$46.50	550	$25,575
4.5.3 Reinforcement	kg	$1.32	68,992	$91,069
Subtotal 4				***$4,471,015***
5 LOW LEVEL OUTLET STRUCTURE				
5.1 Shaft				
5.1.1 Shaft Excavation	m^3	$295.00	5,818	$1,716,313
5.1.2 Shotcrete	m^2	$46.00	2,041	$93,905
5.1.3 Rockbolts	l.m.	$59.50	2,052	$122,094
5.1.4 Concrete	m^3	$180.00	5,463	$983,340
5.1.5 Formwork	m^2	$46.50	7,178	$333,777
5.1.6 Reinforcement	kg	$1.32	214,154	$282,683
5.2 Intake Structure				
5.2.1 Concrete, High Strength	m^3	$160.00	7,710	$1,233,600
5.2.2 Formwork	m^2	$46.50	5,620	$261,330
5.2.3 Reinforcement	kg	$1.32	376,400	$496,848
5.2.4 Concrete Plug	m^3	$116.00	480	$55,680
5.3 Tunnel Lining				
5.3.1 Concrete, High Strength	m^3	$125.00	8,295	$1,036,875
5.3.2 Formwork	m^2	$46.00	11,240	$517,040
5.3.3 Reinforcement	kg	$1.32	325,200	$429,264
5.3.4 Anchors	l.m.	$37.00	4,919	$182,003
5.3.5 Steel Lining	LS	$50,000	1	$50,000
5.4 Hydromechanical Equipment				
5.4.1 Control Gate (3.6m x 6m)	Each	$295,000	2	$590,000
5.4.2 Bulkhead (3.6m x 6m)	Each	$195,000	2	$390,000
5.4.3 Operator	Each	$100,000	2	$200,000
5.4.3 Surface Structure	LS	$100,000	1	$100,000
5.4.3 Power and Controls	LS	$100,000	1	$100,000
Subtotal 5				***$9,174,752***
6 SADDLE DAMS				
6.1 Site Preparation	m^2	$0.55	120,000	$66,000
6.2 Additonal Saddle Dikes				
6.2.1 Dike Fill	m^3	$7.30	136,750	$998,275
Subtotal 6				***$1,064,275***

RIO COCLE DEL NORTE RESERVOIR ACTING IN FULL REGULATION WITH RIO CAÑO SUCIO AND RIO INDIO RESERVOIRS

RIO COCLE DEL NORTE STORAGE PROJECT

Description	Unit	Unit Cost	Quantity	Amount
7 75-MW HYDROELECTRIC POWER PLANT				
7.1 Power Intake				
7.1.1 Civil Work				
Site Preparation	m^2	$0.55	4,800	$2,640
Overburden Excavation	m^3	$3.70	23,000	$85,100
Rock Excavation	m^3	$9.20	2,200	$20,240
Portal Excavation	m^3	$14.80	4,430	$65,564
Structural Concrete	m^3	$145.00	15,290	$2,217,050
Formwork	m^2	$46.80	42,800	$2,003,040
Steel Reinforcement	Ton	$1,320	688.0	$908,160
Steel Liner	Ton	$3,200	38.6	$123,520
Miscellaneous Metal Works	%	5%		$271,266
7.1.2 Equipment				
Wheeled Intake Gate (3.60 x 3.40) and Ho	Each	$312,500	3	$937,500
Stoplogs	Each	$87,500	3	$262,500
Trash Screen Bays	Each	$275,000	3	$825,000
Trash Rake	Each	$106,500	2	$213,000
Emergency Diesel Generator (50 kW)	Each	$62,500	1	$62,500
Power and Control Equipment	LS	$50,000	1	$50,000
Cabling, MV & LV Power, Cont/Comm	LS	$37,500	1	$37,500
7.2 Shaft Tunnel and Manifold				
7.2.1 Portal Excavation	m^3	$14.80	1,770	$26,196
7.2.2 Shaft Excavation	m^3	$310.00	1,630	$505,300
7.2.3 Tunnel Excavation	m^3	$185.00	7,220	$1,335,700
7.2.4 Shotcrete	m^2	$45.90	6,090	$279,531
7.2.5 Rockbolts	l.m.	$67.00	4,770	$319,590
7.2.6 Steel Ribs	kg	$6.00	18,250	$109,500
7.2.7 Tunnel Concrete Lining	m^3	$172.00	2,310	$397,320
7.2.8 Shaft Concrete Lining	m^3	$180.00	490	$88,200
7.2.9 Formwork (shaft)	m^2	$46.80	890	$41,652
7.2.10 Steel Reinforcement (shaft)	Ton	$1,320	24.5	$32,340
7.2.11 Structural Concrete (manifold)	m^3	$145.00	520	$75,400
7.2.12 Formwork (manifold)	m^2	$46.80	570	$26,676
7.2.13 Steel Reinforcement (manifold)	Ton	$1,320	26.0	$34,320
7.2.14 Steel Liner and Manifold	Ton	$3,200	1,029.0	$3,292,800
7.2.15 Miscellaneous	%	5%		$328,226
7.3 Tailrace				
7.3.1 Overburden Excavation	m^3	$3.70	10,500	$38,850
7.3.2 Rock Excavation	m^3	$9.20	3,500	$32,200
7.4 Powerhouse				
7.4.1 Civil Work				
Overburden Excavation	m^3	$3.70	32,900	$121,730
Rock Excavation	m^3	$9.20	4,710	$43,332
Mass Concrete	m^3	$116.00	1,850	$214,600
Structural Concrete	m^3	$145.00	4,855	$703,975
Formwork	m^2	$46.80	16,350	$765,180
Steel Reinforcement	Ton	$1,320	264.7	$349,404
Roof, siding, windows, doors, etc	m^2	$310	970	$300,700
Miscellaneous	%	5%		$124,946

RIO COCLE DEL NORTE RESERVOIR ACTING IN FULL REGULATION WITH RIO CAÑO SUCIO AND RIO INDIO RESERVOIRS

RIO COCLE DEL NORTE STORAGE PROJECT

Description	Unit	Unit Cost	Quantity	Amount
7.4.2 Equipment				
Power Generating				
Main Inlet Valve (2.50 m dia)	Each	$437,500	3	$1,312,500
Turbine/Generator Unit (25 MW)	Each	$3,500,000	3	$10,500,000
25-MW Unit Auxiliaries	Each	$500,000	3	$1,500,000
Draft Tube Gates	Each	$62,500	6	$375,000
Tunnel Release				
Main Inlet Valves (1.50 m dia)	Each	$218,750	1	$218,750
Pressure Reducing Control Valves (1.50 m	Each	$437,500	1	$437,500
Draft Tube Gates	Each	$62,500	1	$62,500
Miscellaneous Mechanical				
Dewatering System	LS	$112,500	1	$112,500
Semi-Gantry Crane	LS	$500,000	1	$500,000
Miscellaneous Electrical				
Main Power Transformer -30 MVA	Each	$437,500	3	$1,312,500
Take-off Structures & OH lines to Switchy	LS	$100,000	1	$100,000
Switchgear - 13.8 kV	LS	$125,000	1	$125,000
Station Service Transformer	Each	$50,000	1	$50,000
Stand-by Diesel Generator	Each	$250,000	1	$250,000
Station Auxiliaries (light, HVAC, etc.)	LS	$468,750	1	$468,750
Control and Communication Equip	LS	$375,000	1	$375,000
Cabling, MV & LV Power, Cont/Comm	LS	$1,000,000	1	$1,000,000
Subtotal 7				***$36,372,248***
8 TRANSMISSION SYSTEM				
8.1 Switchyard				
8.1.1 230-kV Equipment Bays	Each	$312,500	3	$937,500
8.1.2 Service Power Transformer - 5MV	Each	$112,500	1	$112,500
8.1.3 Protection, Control and Comm. Equip	LS	$562,500	1	$562,500
8.1.4 Cabling, MV & LV Power, Cont/Comm	LS	$312,500	1	$312,500
8.1.5 Control Building Auxiliaries	LS	$44,000	1	$44,000
8.1.6 Steel structures	LS	$600,000	1	$600,000
8.1.7 Civil Work	LS	$350,000	1	$350,000
8.2 La Chorrera Substation				
8.2.1 230-kV Equipment Bays	Each	$312,500	1	$312,500
8.2.2 Protection, Control and Comm. Equip	LS	$125,000	1	$125,000
8.2.3 Cabling, MV & LV Power, Cont/Comm	LS	$100,000	1	$100,000
8.3 230-kV Transmission Line				
8.3.1 Civil Works (Survey, Found., Struc.)	km	$62,500	109	$6,812,500
8.3.2 Conductors and Shield Wire	km	$62,500	109	$6,812,500
8.3.3 Insulators and Accessories	km	$31,250	109	$3,406,250
8.3.4 Grounding and Miscellaneous	%	4.00%		$681,250
Subtotal 8				***$21,169,000***
9 OPERATION FACILITIES				
9.1 Diesel Generators	Each	$35,000	2	$70,000
9.2 SCADA	LS	$200,000	1	$200,000
9.3 Communication	LS	$100,000	1	$100,000
9.4 Security and Lighting	LS	$146,000	1	$146,000
9.5 Landscaping and Drainage	LS	$150,000	1	$150,000
9.6 Instrumentation	LS	$500,000	1	$500,000
Subtotal 9				***$1,166,000***
Subtotal Direct Cost (rounded)				**$190,710,000**
Contingency				**$34,810,000**
Direct Cost				**$225,520,000**

RIO COCLE DEL NORTE RESERVOIR ACTING IN FULL REGULATION WITH RIO CAÑO SUCIO AND RIO INDIO RESERVOIRS

RIO CANO SUCIO STORAGE PROJECT

Description	Unit	Unit Cost	Quantity	Amount
1 GENERAL				
1.1 Mobilization and Demobilization	LS	$750,000	1	$750,000
1.2 Temporary Facilities Maintenance	mth	$5,000	36	$180,000
1.3 Access Roads Maintenance	mth	$2,500	36	$90,000
Subtotal 1				***$1,020,000***
2 DIVERSION				
2.1 Site Preparation	m^2	$0.55	5,000	$2,750
2.2 Diversion Culvert				
2.2.1 Overburden Excavation	m^3	Included in 3.1.1		
2.2.2 Rock Excavation	m^3	$14.80	1,560	$23,088
2.2.3 Concrete	m^3	$116.00	650	$75,400
2.2.4 Formwork	m^2	$46.50	700	$32,550
2.2.5 Reinforcement	kg	$1.32	25,200	$33,264
2.3 Cofferdam				
2.3.1 Overburden Excavation	m^3	$3.20	210	$672
2.3.2 RCC fill	m^3	$72.00	1,210	$87,120
Subtotal 2				***$254,844***
3 DAM				
3.1 Excavation				
3.1.1 Overburden Excavation	m^3	$3.20	8,150	$26,080
3.1.2 Rock Excavation	m^3	$14.80	8,150	$120,620
3.2 Grouting				
3.2.1 Cut-off	m^2	$46.00	2,500	$115,000
3.2.2 Roller Compacted Concrete				
3.2.3 Mass RCC	m^3	$72.00	27,900	$2,008,800
3.2.4 Uncompacted	m^3	$72.00	500	$36,000
3.3 Conventional Concrete				
3.3.1 Upstream Face	m^3	$280.00	3,000	$840,000
3.3.2 Foundation	m^3	$116.00	1,600	$185,600
3.3.3 Gallery	m^3	$280.00	900	$252,000
Subtotal 3				***$3,584,100***
4 SPILLWAY				
4.1 Headworks,Chute and Flip Bucket				
4.1.1 Concrete	m^3	$145.00	1,682	$243,890
4.1.2 Formwork	m^2	$46.50	1,382	$64,263
4.1.3 Reinforcement	kg	$1.32	131,885	$174,088
4.2 Bridge				
4.2.1 Concrete	m^3	$145.00	224	$32,480
4.2.2 Formwork	m^2	$46.50	280	$13,020
4.2.3 Reinforcement	kg	$1.32	35,123	$46,362
Subtotal 4				***$574,104***

RIO COCLE DEL NORTE RESERVOIR ACTING IN FULL REGULATION WITH RIO CAÑO SUCIO AND RIO INDIO RESERVOIRS

RIO CANO SUCIO STORAGE PROJECT

Description	Unit	Unit Cost	Quantity	Amount
5 LOW LEVEL OUTLET				
5.1 Gate Structure				
5.1.1 Concrete	m^3	$116.00	170	$19,720
5.1.2 Formwork	m^2	$46.50	900	$41,850
5.1.3 Reinforcement	kg	$1.32	11,500	$15,180
5.2 Pipe				
5.2.1 Concrete	m^3	$116.00	100	$11,600
5.2.2 Pipe	l.m.	$850.00	50	$42,500
5.3 Hydromechanical Equipment				
5.3.1 Valve	kg	$9.70	1,000	$9,700
5.3.2 Control Gate	Each	$10,000	1	$10,000
5.3.3 Operator	Each	$5,000	1	$5,000
5.3.4 Power and Controls	LS	$10,000	1	$10,000
Subtotal 5				***$165,550***
6 OPERATION FACILITIES				
6.1 13.8-kV Transmission Line	km	$17,000.00	22	$374,000
6.2 Diesel Generators				
6.2.1 Standby Generators	Each	$25,000	2	$50,000
6.2.2 Control Panels and other Equipment	LS	$50,000	1	$50,000
6.3 SCADA	LS	$200,000	1	$200,000
6.4 Communication	LS	$100,000	1	$100,000
6.5 Security and Lighting	LS	$50,000	1	$50,000
6.6 Landscaping and Drainage	LS	$50,000	1	$50,000
6.7 Instrumentation	LS	$25,000	1	$25,000
Subtotal 6				***$899,000***
Subtotal Direct Cost (rounded)				**$6,500,000**
Contingency				**$1,120,000**
Direct Cost				**$7,620,000**

RIO COCLE DEL NORTE RESERVOIR ACTING IN FULL REGULATION WITH RIO CAÑO SUCIO AND RIO INDIO RESERVOIRS

WATER TRANSFER FACILITIES

Description	Unit	Unit Cost	Quantity	Amount
1 GENERAL				
1.1 Mobilization and Demobilization	LS	$750,000	1	$750,000
1.2 Construction Camp	LS	$950,000	1	$950,000
1.3 Dredge	LS	$750,000	1	$750,000
1.3 Temporary Facilities Maintenance	mth	$5,000	36	$180,000
1.4 Access Roads Maintenance	mth	$2,500	36	$90,000
Subtotal 1				***$2,720,000***
2 CANAL				
2.1 Site Preparation	m^2	$0.55	1,000,000	$550,000
2.2 Excavation				
2.2.1 Care of water	LS	$700,000	1	$700,000
2.2.2 Overburden	m^3	$3.20	4,502,000	$14,406,400
2.2.3 Overburden, wet excavation	m^3	$7.60	500,000	$3,800,000
2.2.4 Weathered Rock (rippable)	m^3	$6.00	1,443,000	$8,658,000
2.2.5 Weathered Rock, wet excavation	m^3	$10.00	361,000	$3,610,000
2.2.6 Rock	m^3	$14.80	1,017,000	$15,051,600
2.2.7 Rock, wet excavation	m^3	$25.00	254,000	$6,350,000
2.3 Trash Booms	Each	$100,000	2	$200,000
2.4 Temporary U/S closure dike	LS	$50,000	1	$50,000
Subtotal 2				***$53,376,000***
3 TRANS-BASIN TRANSFER TUNNEL				
3.1 Site Preparation	m^2	$0.55	40,000	$22,000
3.3 Tunnel Portals				
3.3.1 Overburden Excavation	m^3	$3.20	61,500	$196,800
3.3.2 Rock Excavation	m^3	$8.80	75,400	$663,520
3.3.3 Shotcrete	m^2	$46.00	7,890	$362,940
3.3.4 Rockbolts	l.m.	$59.50	3,940	$234,430
3.3.5 Concrete	m^3	$116.00	901	$104,516
3.3.6 Formwork	m^2	$46.50	1,052	$48,918
3.3.7 Reinforcement	kg	$1.32	35,335	$46,642
3.4 Tunnel				
3.4.1 Rock Excavation	m^3	$102.00	81,940	$8,357,880
3.4.2 Shotcrete	m^2	$46.00	26,110	$1,201,060
3.4.3 Rockbolts	l.m.	$67.50	13,720	$926,100
3.4.4 Steel Ribs	kg	$6.00	185,800	$1,114,800
3.4.5 Concrete	m^3	$110.00	19,924	$2,191,640
3.4.6 Formwork	m^2	$10.00	36,055	$360,550
3.4.7 Reinforcement	kg	$1.32	390,510	$515,473
3.5 Intake Structure				
3.5.1 Concrete	m^3	$116.00	2,896	$335,936
3.5.2 Formwork	m^2	$46.50	2,491	$115,832
3.5.3 Reinforcement	kg	$1.32	165,479	$218,432

RIO COCLE DEL NORTE RESERVOIR ACTING IN FULL REGULATION WITH RIO CAÑO SUCIO AND RIO INDIO RESERVOIRS

3.6 Outlet Structure				
3.6.1 Concrete	m^3	$116.00	2,160	$250,543
3.6.2 Formwork	m^2	$46.50	2,092	$97,259
3.6.3 Reinforcement	kg	$1.32	88,530	$116,859
3.6.4 Anchors	l.m.	$59.50	536	$31,862
3.7 Discharge Channel				
3.7.1 Excavation	m^3	$3.20	included in 7.3	
3.8 Hydromechanical Equipment				
3.8.1 Trashracks and Embeds	kg	$4.40	27,000	$118,800
3.8.2 U/S Bulkhead (5.5 x 5.5 m)	Each	$140,000	1	$140,000
3.8.3 U/S Operator	Each	$50,000	1	$50,000
3.8.4 U/S Surface Structure	LS	$50,000	1	$50,000
3.8.5 U/S Power and Controls	LS	$50,000	1	$50,000
3.8.6 D/S Control Gates (2.5 x 5.5 m)	Each	$100,000	2	$200,000
3.8.7 D/S Bulkheads (2.5 x 5.5 m)	Each	$75,000	2	$150,000
3.8.8 D/S Operator	Each	$25,000	4	$100,000
3.8.9 D/S Surface Structure	LS	$50,000	1	$50,000
3.8.10 D/S Power and Controls	LS	$100,000	1	$100,000
3.8.11 Miscellaneous	LS	5%	1	$50,440
Subtotal 3				***$18,573,233***
4 COFFERDAM				
4.1 Sheetpiles	kg	$2.50	1,710,000	$4,275,000
4.2 Fill material	m^3	$7.30	35,000	$255,500
4.3 Clearing	LS	$50,000	1	$50,000
4.4 Care of water	LS	$500,000	1	$500,000
Subtotal 4				***$5,080,500***
Subtotal Direct Cost (rounded)				**$79,750,000**
Contingency				**$13,280,000**
Direct Cost				**$93,030,000**

RIO COCLE DEL NORTE RESERVOIR ACTING IN FULL REGULATION WITH RIO CAÑO SUCIO AND RIO INDIO RESERVOIRS

SECOND RIO INDIO TO LAKE GATUN TRANSFER TUNNEL

Description	Unit	Unit Cost	Quantity	Amount
1 GENERAL				
1.1 Mobilization and Demobilization	LS	$1,500,000	1	$1,500,000
1.2 Temporary Facilities Maintenance	mth	$5,000	36	$180,000
1.3 Access Roads Maintenance	mth	$2,500	36	$90,000
Subtotal 1				***$1,770,000***
2 COFFERDAM				
2.1 Sheetpiles	kg	$2.50	2,275,000	$5,687,500
2.2 Fill material	m^3	$7.30	46,000	$335,800
2.3 Clearing	LS	$50,000	1	$50,000
2.4 Care of water	LS	$500,000	1	$500,000
Subtotal 2				***$6,573,300***
3 ACCESS ADIT REHABILITATION (2)				
3.1 Clearing	m^3	$3.20	24,500	$78,400
3.2 Tunnel Excavation	m^3	$91.00	1,850	$168,350
3.3 Shotcrete	m^2	$46.00	7,200	$331,200
3.4 Rockbolts	l.m.	$67.50	1,500	$101,250
3.5 Miscellaneous	LS	10%	1	$67,920
Subtotal 3				***$747,120***
4 TUNNEL INTAKE PORTAL & CHANNEL				
4.1 Overburden Excavation	m^3	$3.20	27,560	$88,192
4.2 Rock Excavation	m^3	$8.80	305,189	$2,685,663
4.3 Shotcrete	m^2	$46.00	3,833	$176,318
4.4 Rockbolts	l.m.	$59.50	1,917	$114,062
4.5 Concrete	m^3	$116.00	426	$49,416
4.6 Formwork	m^2	$46.50	282	$13,113
4.7 Reinforcement	kg	$1.32	16,560	$21,859
Subtotal 4				***$3,148,623***
5 TUNNEL				
5.1 Rock Excavation	m^3	$95.00	384,300	$36,508,500
5.2 Shotcrete	m^2	$46.00	90,770	$4,175,420
5.3 Rockbolts	l.m.	$67.50	42,070	$2,839,725
5.4 Steel Ribs	kg	$6.00	357,900	$2,147,400
5.5 Concrete	m^3	$110.00	95,975	$10,557,250
5.6 Formwork	m^2	$10.00	142,872	$1,428,720
5.7 Reinforcement	kg	$1.32	3,574,109	$4,717,824
Subtotal 5				***$62,374,839***
6 INTAKE STRUCTURE				
6.1 Concrete	m^3	$116.00	1,598	$185,368
6.2 Formwork	m^2	$46.50	1,837	$85,421
6.3 Reinforcement	kg	$1.32	123,291	$162,744
Subtotal 6				***$433,533***
7 INTAKE GATE SHAFT				
7.1 Shaft Excavation	m^3	$295.00	4,181	$1,233,395
7.2 Shotcrete	m^2	$46.00	1,521	$69,966
7.3 Rockbolts	l.m.	$67.50	1,496	$100,980
7.4 Concrete	m^3	$145.00	3,052	$442,540
7.5 Formwork	m^2	$46.50	2,772	$128,898
7.6 Reinforcement	kg	$1.32	259,752	$342,873
Subtotal 7				***$2,318,652***

RIO COCLE DEL NORTE RESERVOIR ACTING IN FULL REGULATION WITH RIO CAÑO SUCIO AND RIO INDIO RESERVOIRS

SECOND RIO INDIO TO LAKE GATUN TRANSFER TUNNEL

Description	Unit	Unit Cost	Quantity	Amount
8 OUTLET STRUCTURE				
8.1 Concrete	m^3	$145.00	4,481	$649,745
8.2 Formwork	m^2	$46.50	2,734	$127,131
8.3 Reinforcement	kg	$1.32	331,458	$437,525
8.4 Steel Lining	LS	$64,000	1	$64,000
8.5 Anchors	l.m.	$59.50	1,020	$60,690
Subtotal 8				***$1,339,091***
9 TUNNEL OUTLET PORTAL & CHANNEL				
9.1 Overburden Excavation	m^3	$3.20	39,427	$126,166
9.2 Rock Excavation	m^3	$8.80	198,360	$1,745,568
9.3 Shotcrete	m^2	$46.00	8,488	$390,448
9.4 Rockbolts	l.m.	$59.50	4,244	$252,518
9.5 Concrete	m^3	$116.00	426	$49,416
9.6 Formwork	m^2	$46.50	282	$13,113
9.7 Reinforcement	kg	$1.32	16,560	$21,859
Subtotal 9				***$2,599,089***
10 HYDROMECHANICAL EQUIPMENT				
10.1 Trashracks and Embeds	kg	$4.50	40,000	$180,000
10.2 U/S Bulkhead	Each	$145,000	2	$290,000
10.3 U/S Operator	Each	$50,000	2	$100,000
10.4 U/S Surface Stucture	LS	$50,000	1	$50,000
10.5 U/S Power and Controls	LS	$50,000	1	$50,000
10.6 D/S Control Gates (3.5 x 5.4 m, bonneted)	Each	$700,000	4	$2,800,000
10.7 D/S Operator	Each	$150,000	4	$600,000
10.8 D/S Surface Stucture	LS	$50,000	1	$50,000
10.9 D/S Power and Controls	LS	$100,000	1	$100,000
Subtotal 10				***$4,220,000***
Subtotal Direct Cost (rounded)				**$85,520,000**
Contingency				**$19,120,000**
Direct Cost				**$104,640,000**

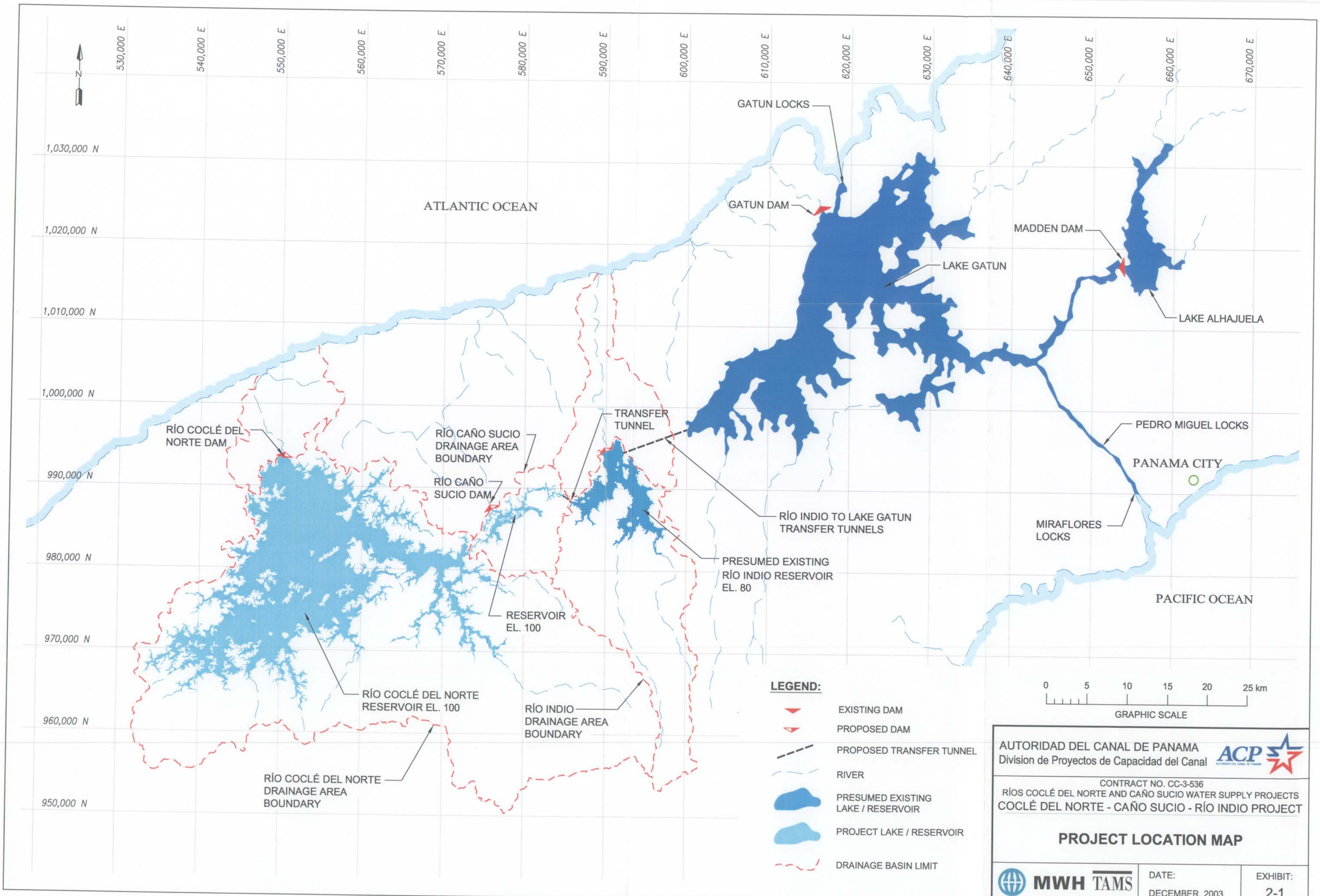
RIO COCLE DEL NORTE RESERVOIR ACTING IN FULL REGULATION WITH RIO CAÑO SUCIO AND RIO INDIO RESERVOIRS

RESERVOIR CLEARING

Description	Unit	Unit Cost	Quantity	Amount
1 RESERVOIR CLEARING				
1.1 Cocle del Norte Reservoir	ha	$2,200	19,000	$41,800,000
1.2 Caño Sucio Reservoir	ha	$2,200	140	$308,000
Subtotal Direct Cost (rounded)				**$42,110,000**
Contingency				**$6,320,000**
Direct Cost				**$48,430,000**

Exhibits

EXHIBITS


530,000 E
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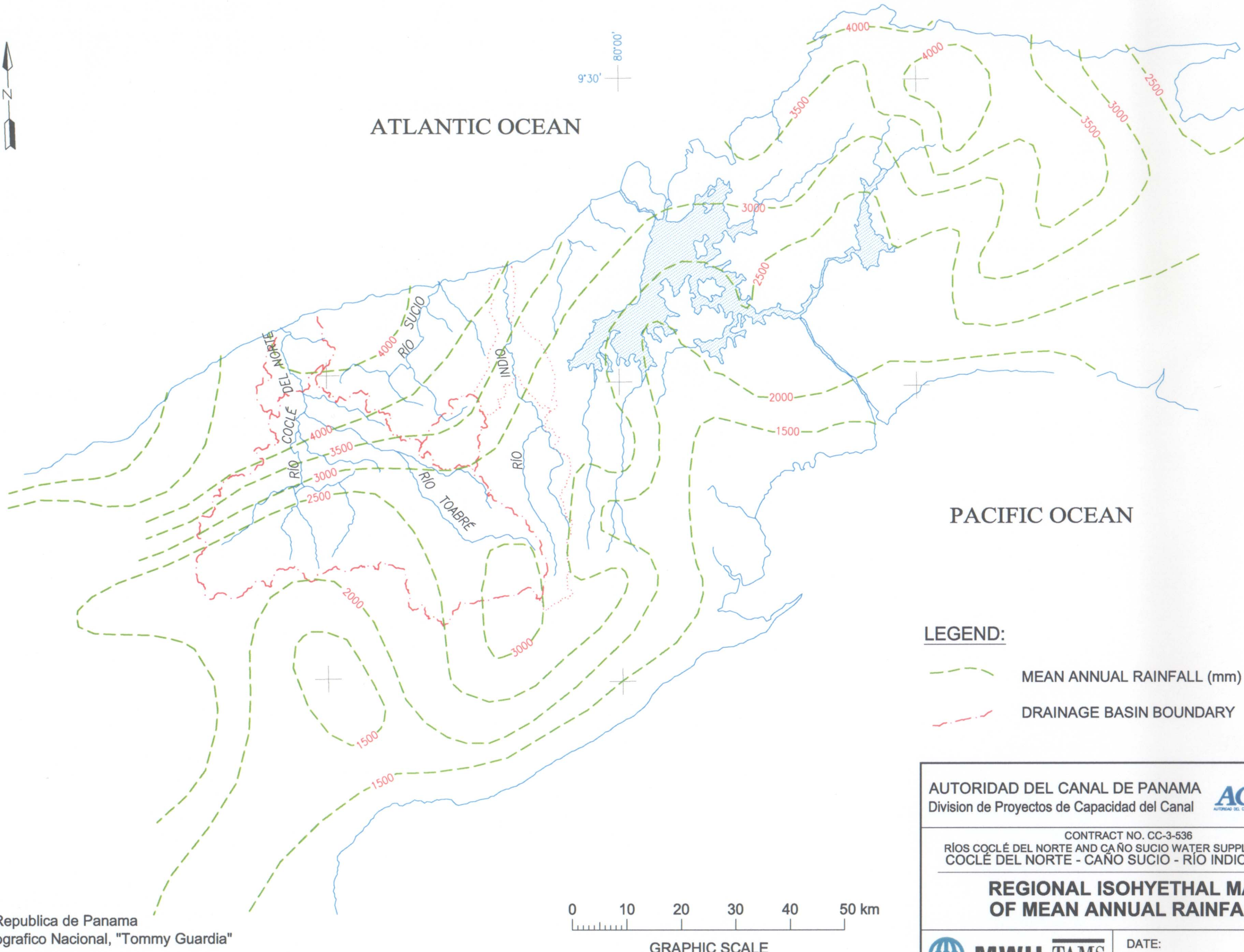
1,030,000 N
1,020,000 N
1,010,000 N
1,000,000 N
990,000 N
980,000 N
970,000 N
960,000 N
950,000 N
ATLANTIC OCEAN
GATUN LOCKS
GATUN DAM
LAKE GATUN
MADDEN DAM
LAKE ALHAJUELA
PEDRO MIGUEL LOCKS
PANAMA CITY
MIRAFLORES LOCKS
PACIFIC OCEAN
TRANSFER TUNNEL
RÍO COCLÉ DEL NORTE DAM
RÍO CAÑO SUCIO DRAINAGE AREA BOUNDARY
RÍO CAÑO SUCIO DAM
RÍO INDIO TO LAKE GATUN TRANSFER TUNNELS
PRESUMED EXISTING RÍO INDIO RESERVOIR EL. 80
RESERVOIR EL. 100
RÍO COCLÉ DEL NORTE RESERVOIR EL. 100
RÍO INDIO DRAINAGE AREA BOUNDARY
RÍO COCLÉ DEL NORTE DRAINAGE AREA BOUNDARY
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
COCLÉ DEL NORTE - CAÑO SUCIO - RÍO INDIO PROJECT
PROJECT LOCATION MAP
MWH TAMS
DATE:
DECEMBER, 2003
EXHIBIT:
2-1



LEGEND:

- MEAN ANNUAL RAINFALL (mm)
- DRAINAGE BASIN BOUNDARY

SOURCE:

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

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

REGIONAL ISOHYETHAL MAP OF MEAN ANNUAL RAINFALL

MWH TAMS

DATE: DECEMBER, 2003

EXHIBIT: 2-2

LEGEND:

- PRESUMED EXISTING DAM SITE
- PROPOSED DAM SITE

0 5 10 15 20 25 km

GRAPHIC SCALE

SOURCE:

IRHE, Departamento De Hidrometeorologia

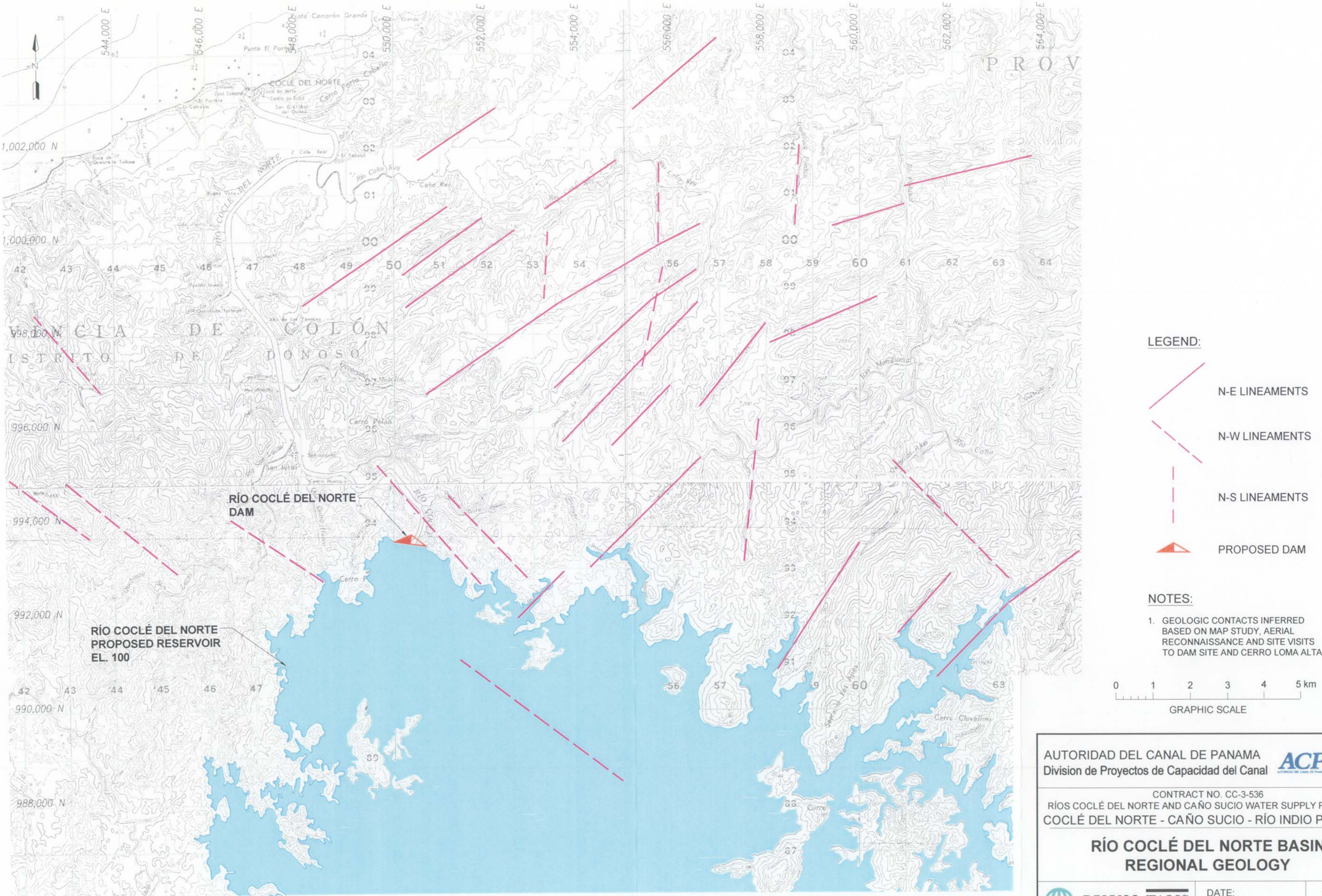
AUTORIDAD DEL CANAL DE PANAMA
Division de Proyectos de Capacidad del Canal

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

RÍO COCLÉ DEL NORTE AND RÍO CAÑO SUCIO BASIN DRAINAGE CONFIGURATIONS

MWH TAMS

DATE:	EXHIBIT:
DECEMBER, 2003	2-3



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

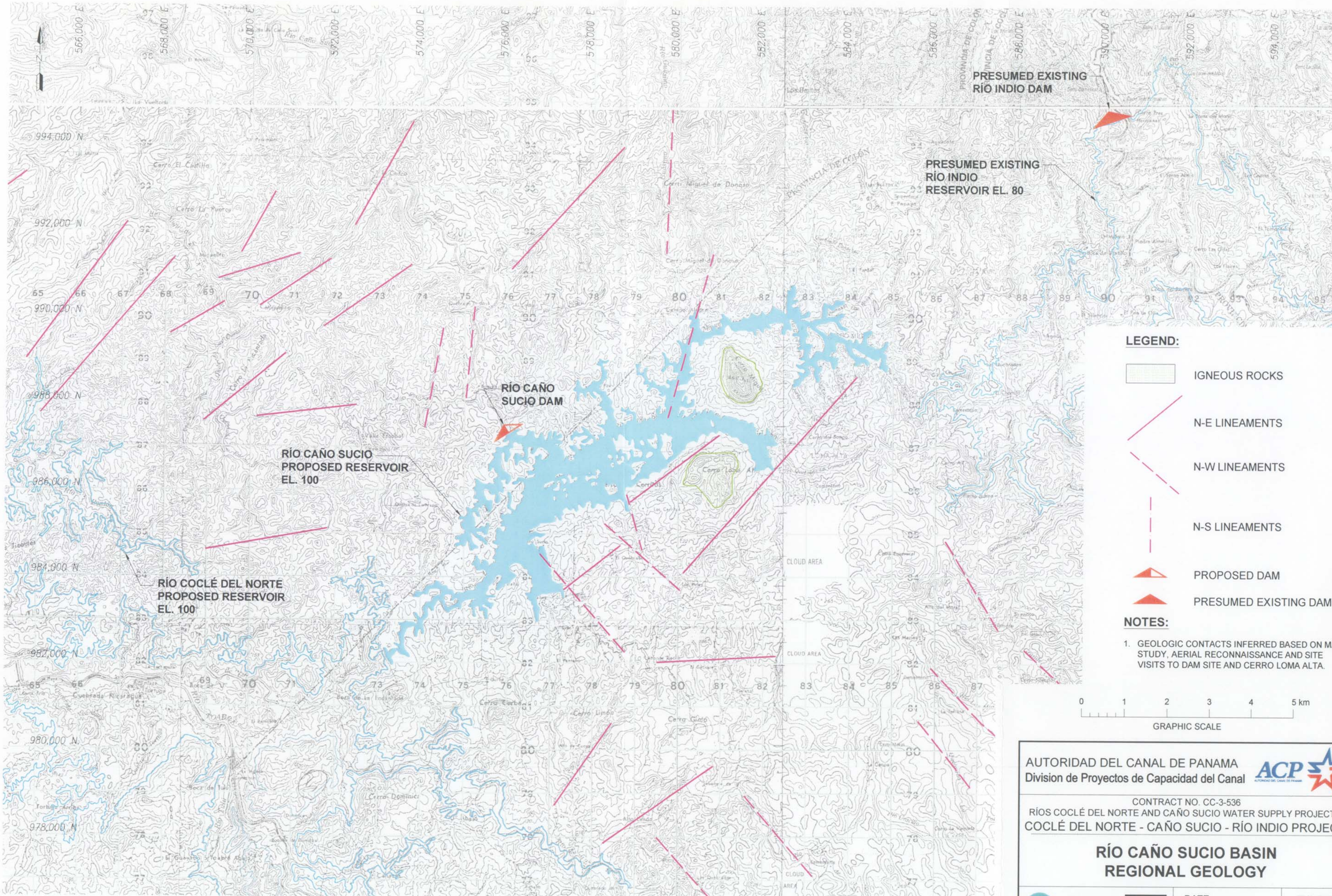
ACP

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

RÍO COCLÉ DEL NORTE BASIN REGIONAL GEOLOGY

MWH TAMS

DATE:	EXHIBIT:
DECEMBER, 2003	2-4



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

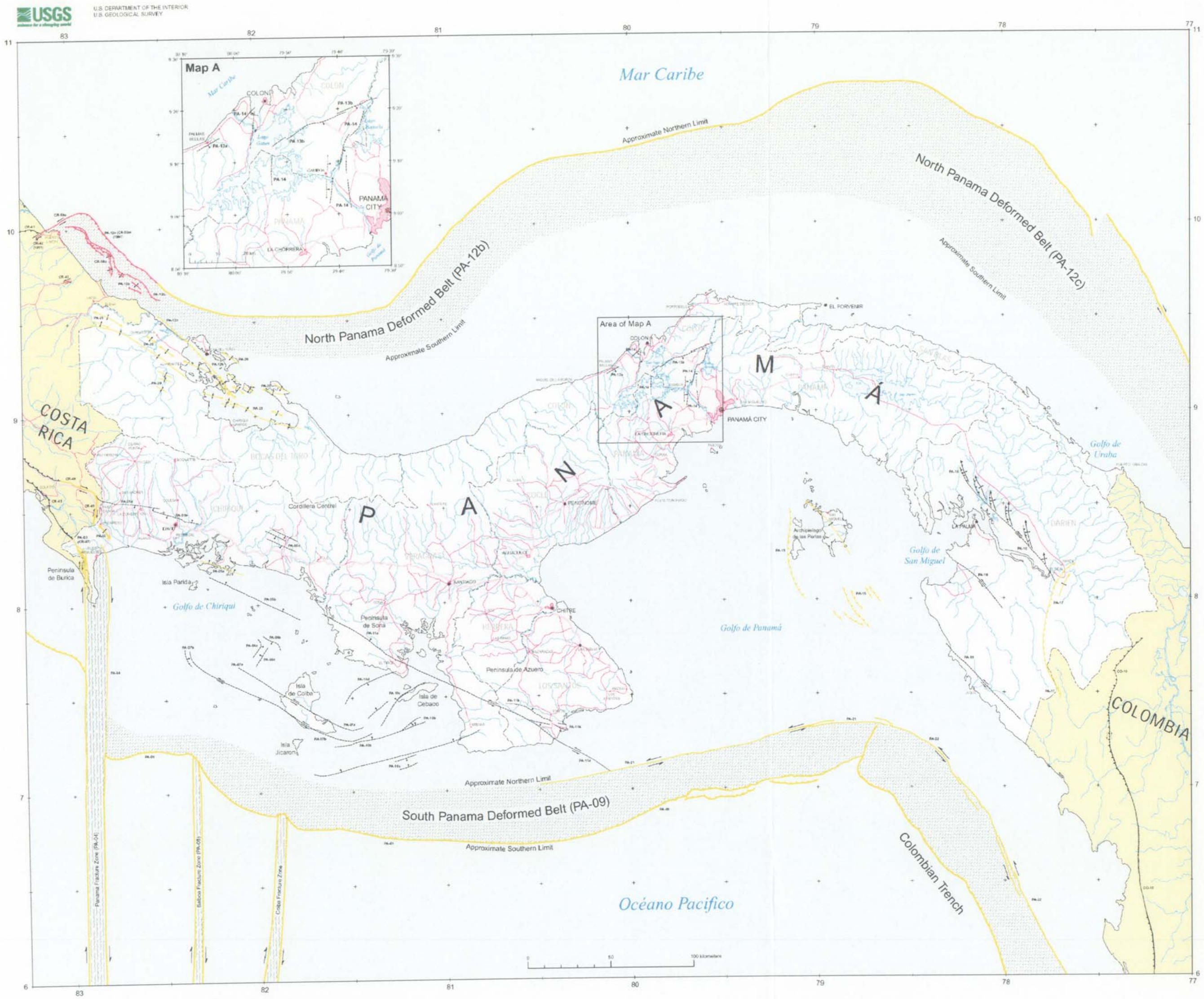
CONTRACT NO. CC-3-536
RÍOS COCLÉ DEL NORTE AND CAÑO SUCIO WATER SUPPLY PROJECTS
COCLÉ DEL NORTE - CAÑO SUCIO - RÍO INDIO PROJECT

RÍO CAÑO SUCIO BASIN
REGIONAL GEOLOGY

MWH TAMS

DATE: DECEMBER, 2003

EXHIBIT: 2-5



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

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

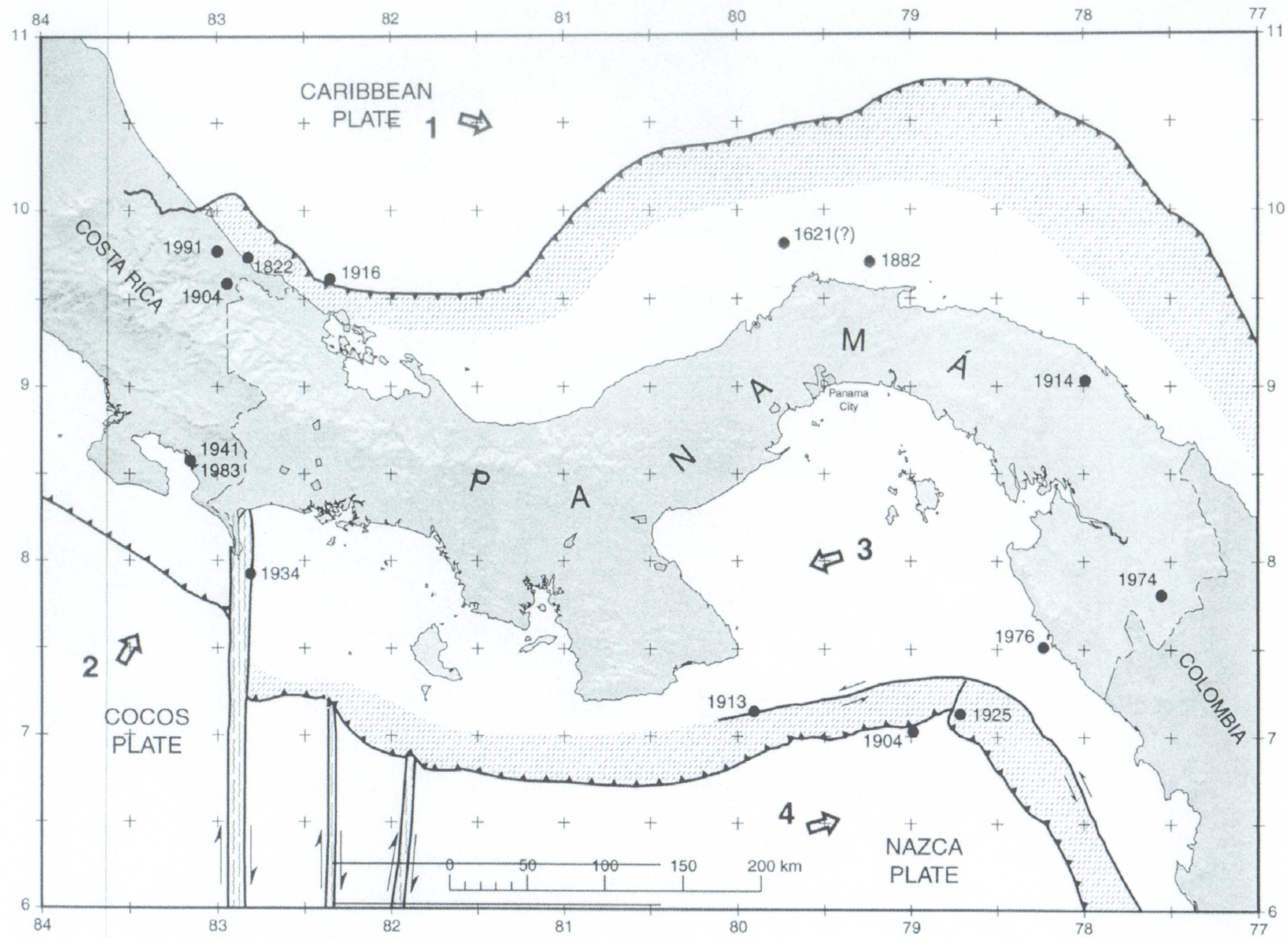
AUTORIDAD DEL CANAL DE PANAMA
Division de Proyectos de Capacidad del Canal

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

MAP OF FAULTS AND FOLDS IN PANAMA

MWH TAMS

DATE:	EXHIBIT:
DECEMBER, 2003	2-6



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)

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

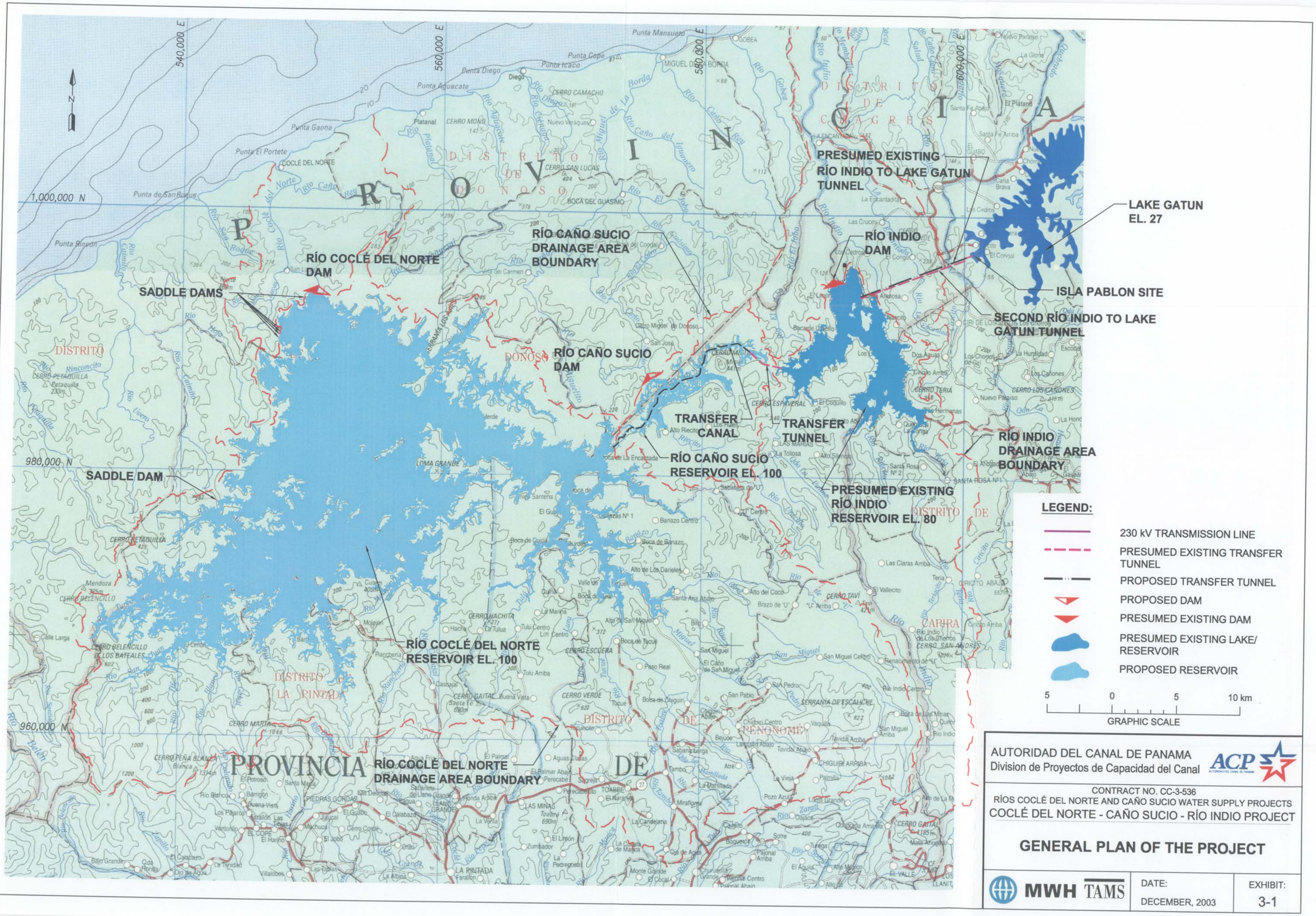
CONTRACT NO. CC-3-536
RÍOS COCLÉ DEL NORTE AND CAÑO SUCIO WATER SUPPLY PROJECTS
COCLÉ DEL NORTE - CAÑO SUCIO - RÍO INDIO PROJECT

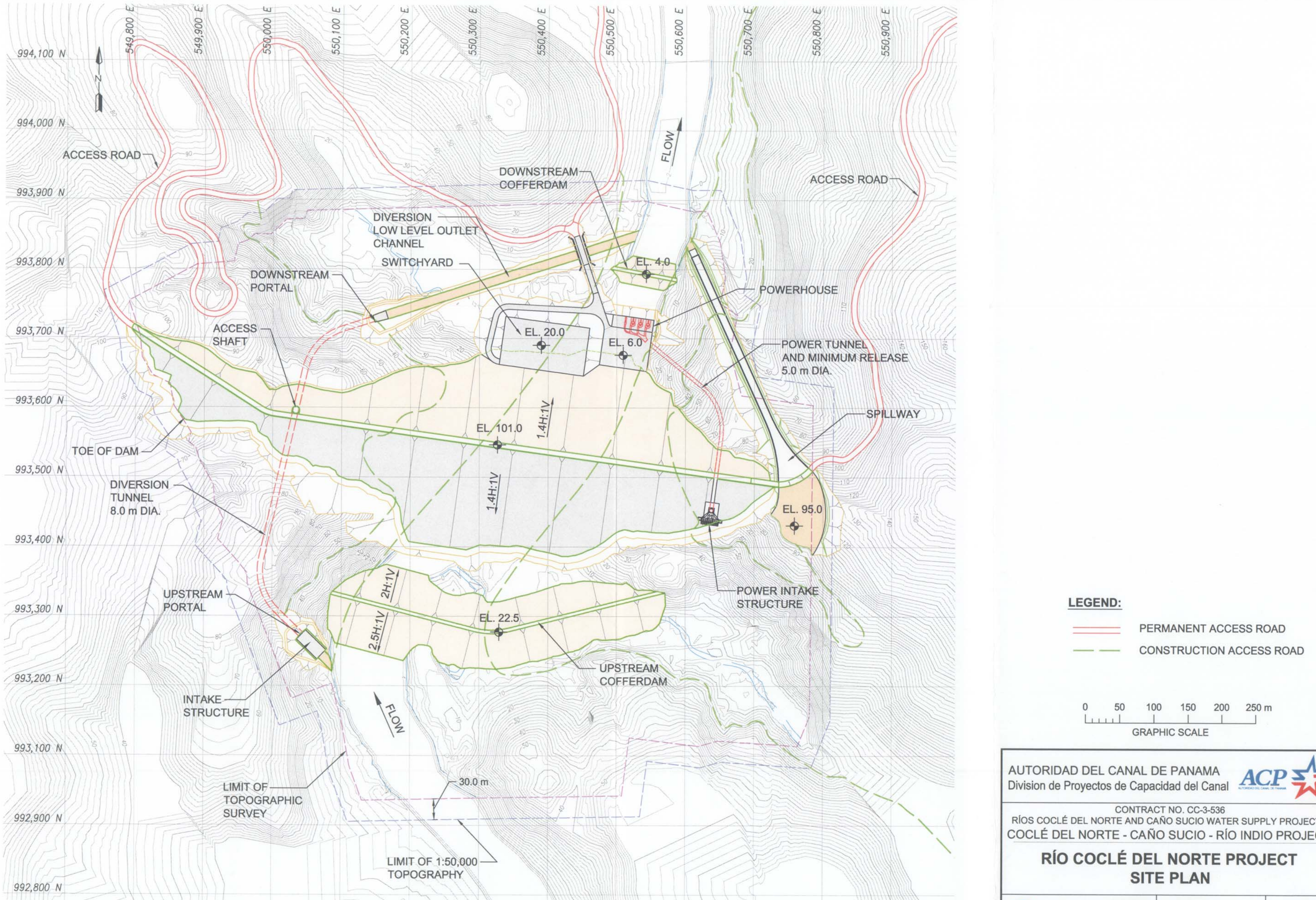
PLATE BOUNDARIES

MWH TAMS

DATE: DECEMBER, 2003

EXHIBIT: 2-7


PRESUMED EXISTING RÍO INDIO TO LAKE GATUN TUNNEL
LAKE GATUN EL. 27
RÍO INDIO DAM
ISLA PABLON SITE
SECOND RÍO INDIO TO LAKE GATUN TUNNEL
RÍO CAÑO SUCIO DRAINAGE AREA BOUNDARY
RÍO COCLÉ DEL NORTE DAM
SADDLE DAMS
RÍO CAÑO SUCIO DAM
TRANSFER CANAL
TRANSFER TUNNEL
RÍO CAÑO SUCIO RESERVOIR EL. 100
RÍO INDIO DRAINAGE AREA BOUNDARY
SADDLE DAM
PRESUMED EXISTING RÍO INDIO RESERVOIR EL. 80
RÍO COCLÉ DEL NORTE RESERVOIR EL. 100
RÍO COCLÉ DEL NORTE DRAINAGE AREA BOUNDARY
PROVINCIA
DISTRITO DE DONOSO
DISTRITO DE CHAGRES
DISTRITO LA PINTADA
DISTRITO DE PENONOMÉ
1,000,000 N
980,000 N
960,000 N
540,000 E
560,000 E
580,000 E
600,000 E
N
LEGEND:
230 kV TRANSMISSION LINE
PRESUMED EXISTING TRANSFER TUNNEL
PROPOSED TRANSFER TUNNEL
PROPOSED DAM
PRESUMED EXISTING DAM
PRESUMED EXISTING LAKE/ RESERVOIR
PROPOSED RESERVOIR
5 0 5 10 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
COCLÉ DEL NORTE - CAÑO SUCIO - RÍO INDIO PROJECT
GENERAL PLAN OF THE PROJECT
MWH TAMS
DATE: DECEMBER, 2003
EXHIBIT: 3-1



SITE PLAN

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

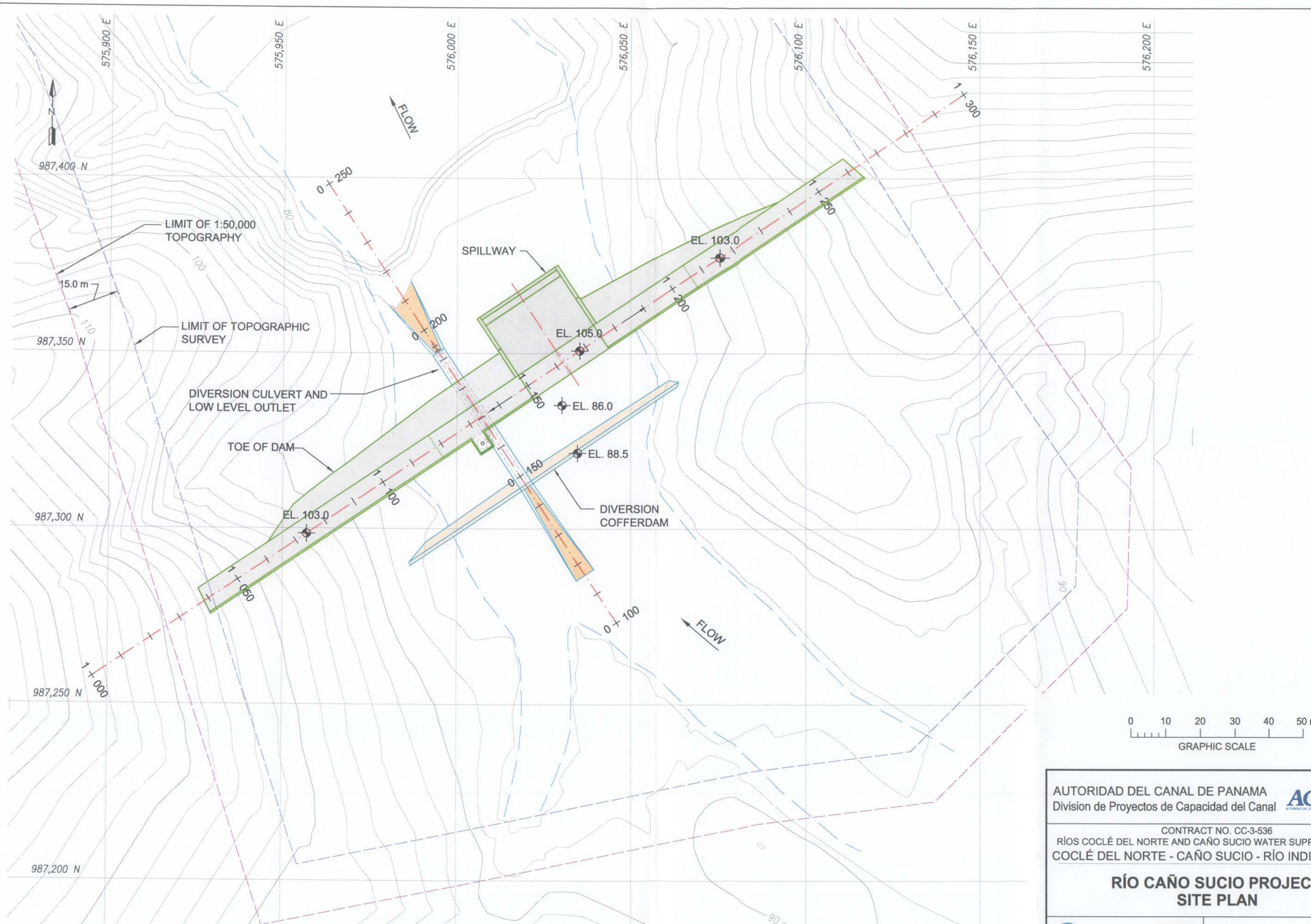
CONTRACT NO. CC-3-536
RÍOS COCLÉ DEL NORTE AND CAÑO SUCIO WATER SUPPLY PROJECTS
COCLÉ DEL NORTE - CAÑO SUCIO - RÍO INDIO PROJECT

RÍO COCLÉ DEL NORTE PROJECT
SITE PLAN

MWH TAMS

DATE: DECEMBER, 2003

EXHIBIT: 3-2



SITE PLAN

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

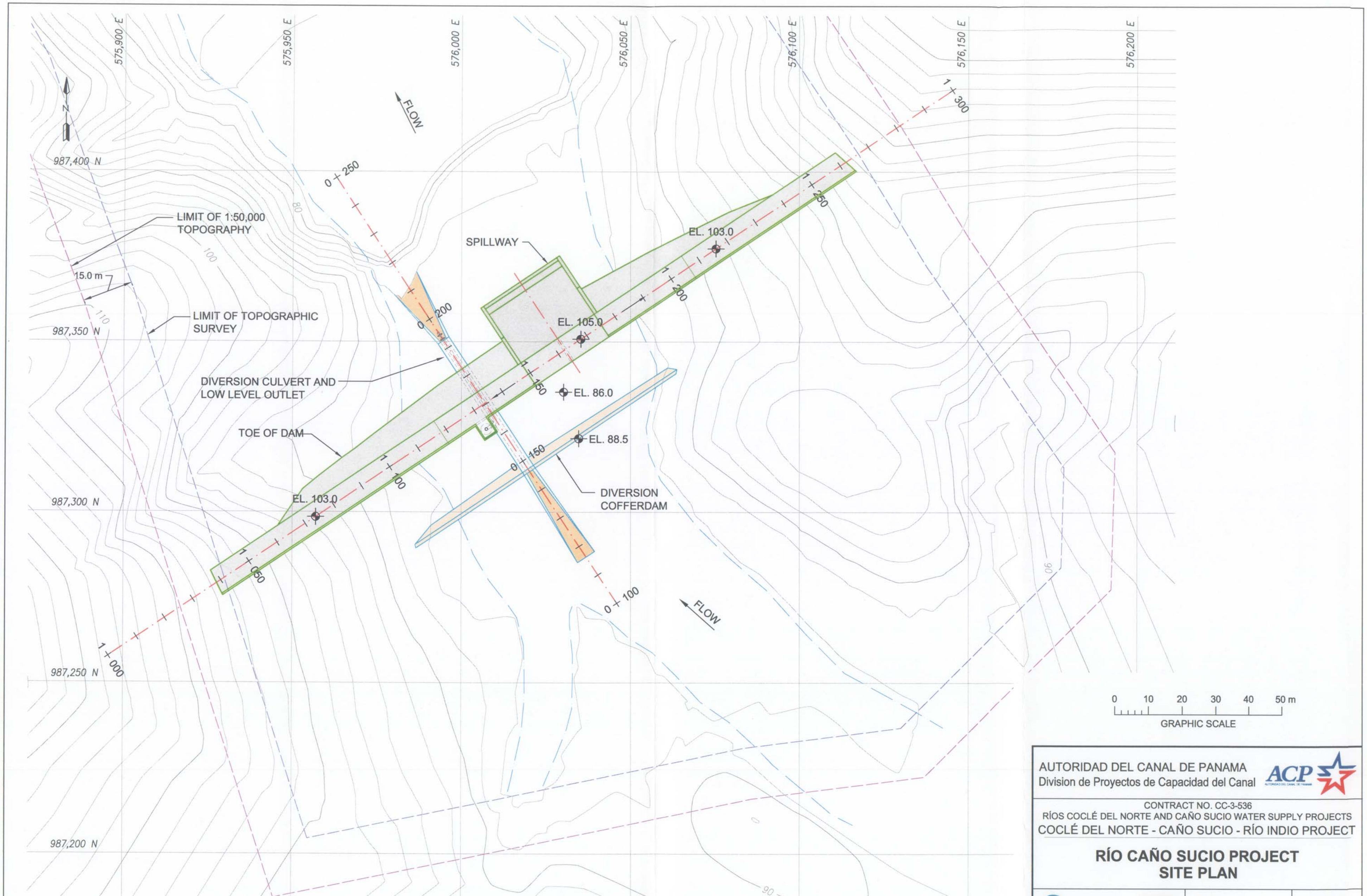
ACP

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

RÍO CAÑO SUCIO PROJECT
SITE PLAN

MWH TAMS

DATE:	EXHIBIT:
DECEMBER, 2003	3-3



SITE PLAN

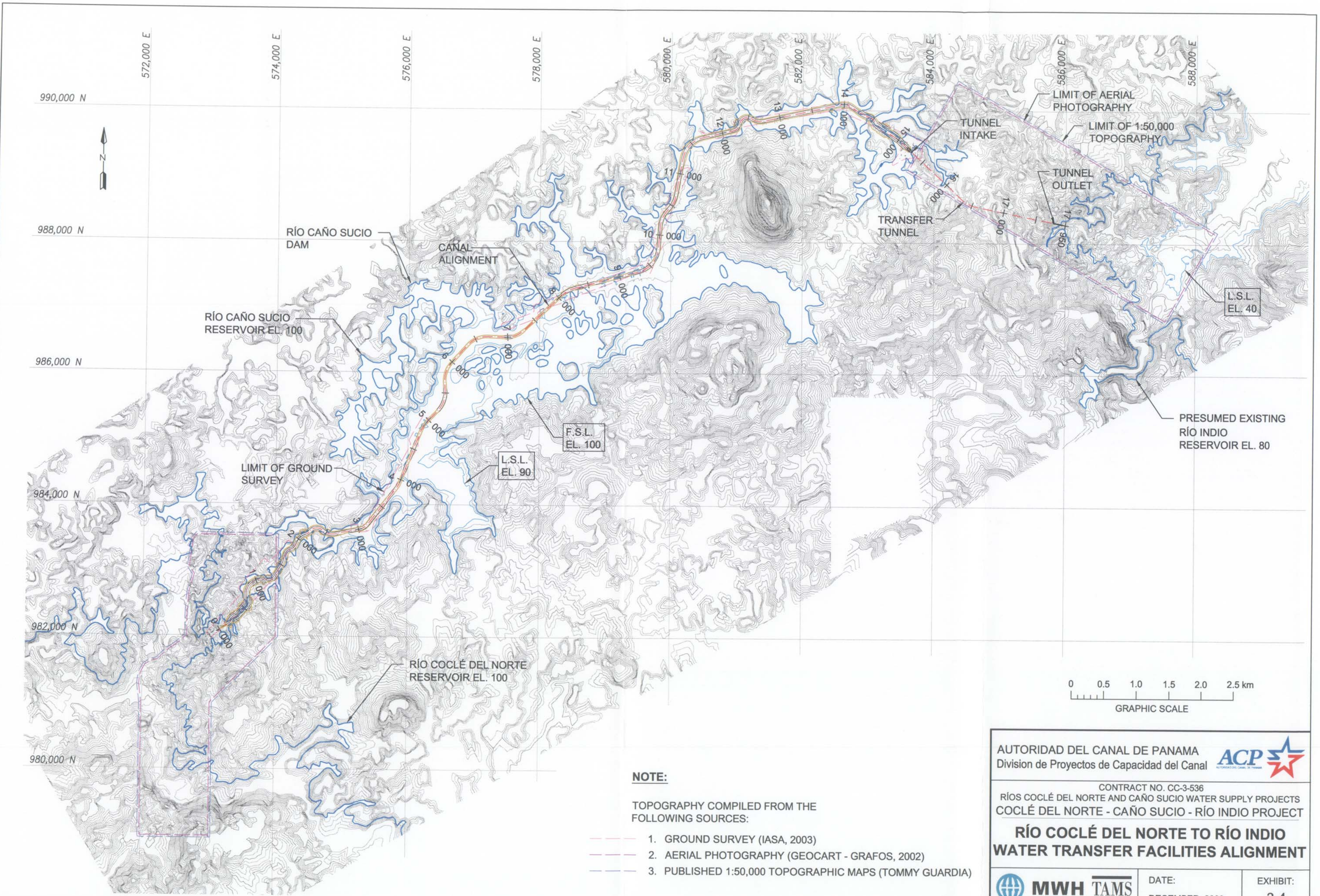
AUTORIDAD DEL CANAL DE PANAMA
Division de Proyectos de Capacidad del Canal

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

RÍO CAÑO SUCIO PROJECT
SITE PLAN

MWH TAMS

DATE:	EXHIBIT:
DECEMBER, 2003	3-3



NOTE:

TOPOGRAPHY COMPILED FROM THE FOLLOWING SOURCES:

1. GROUND SURVEY (IASA, 2003)
2. AERIAL PHOTOGRAPHY (GEOCART - GRAFOS, 2002)
3. PUBLISHED 1:50,000 TOPOGRAPHIC MAPS (TOMMY GUARDIA)

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

ACP

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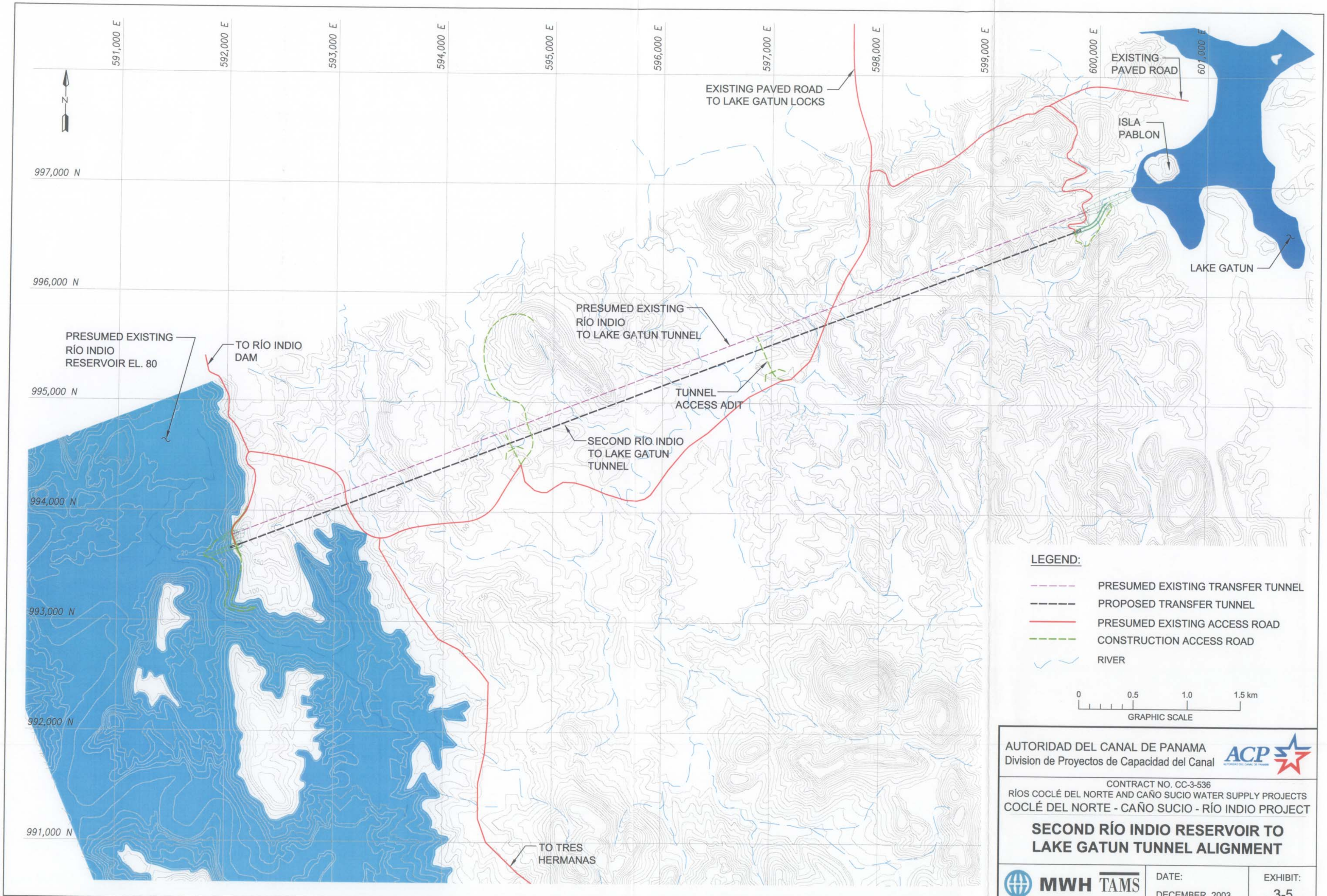
RÍOS COCLÉ DEL NORTE AND CAÑO SUCIO WATER SUPPLY PROJECTS
COCLÉ DEL NORTE - CAÑO SUCIO - RÍO INDIO PROJECT

RÍO COCLÉ DEL NORTE TO RÍO INDIO WATER TRANSFER FACILITIES ALIGNMENT

MWH TAMS

DATE: DECEMBER, 2003

EXHIBIT: 3-4



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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
EXISTING PAVED ROAD TO LAKE GATUN LOCKS
EXISTING PAVED ROAD
ISLA PABLON
LAKE GATUN
PRESUMED EXISTING RÍO INDIO TO LAKE GATUN TUNNEL
PRESUMED EXISTING RÍO INDIO RESERVOIR EL. 80
TO RÍO INDIO DAM
TUNNEL ACCESS ADIT
SECOND RÍO INDIO TO LAKE GATUN TUNNEL
TO TRES HERMANAS
LEGEND:
PRESUMED EXISTING TRANSFER TUNNEL
PROPOSED TRANSFER TUNNEL
PRESUMED EXISTING ACCESS ROAD
CONSTRUCTION ACCESS ROAD
RIVER
0
0.5
1.0
1.5 km
GRAPHIC SCALE
AUTORIDAD DEL CANAL DE PANAMA
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ACP
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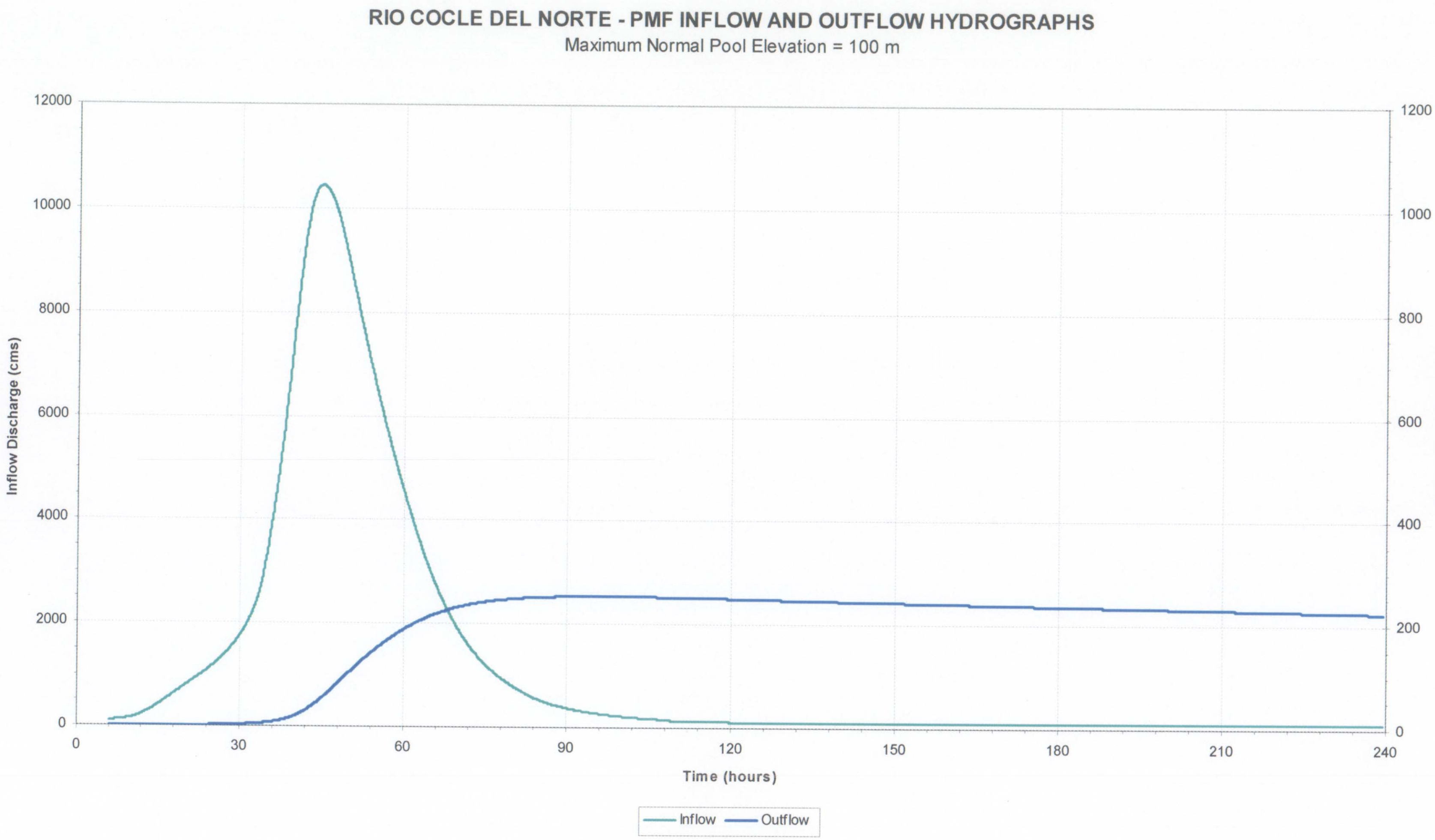
RÍOS COCLÉ DEL NORTE AND CAÑO SUCIO WATER SUPPLY PROJECTS
COCLÉ DEL NORTE - CAÑO SUCIO - RÍO INDIO PROJECT
SECOND RÍO INDIO RESERVOIR TO LAKE GATUN TUNNEL ALIGNMENT
MWH TAMS
DATE:
DECEMBER, 2003
EXHIBIT:
3-5



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

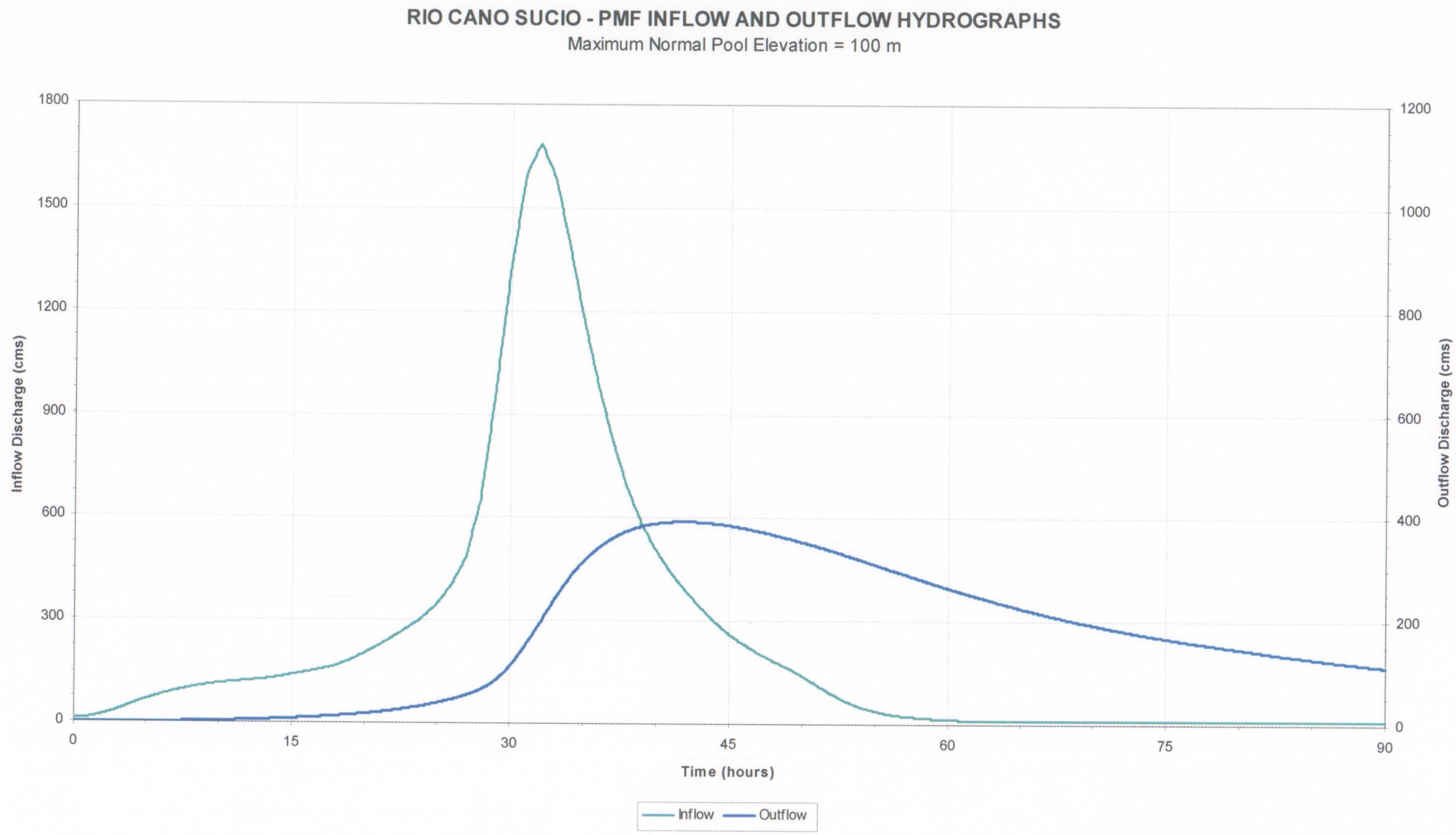
CONTRACT NO. CC-3-536
RÍOS COCLÉ DEL NORTE AND CAÑO SUCIO WATER SUPPLY PROJECTS
COCLÉ DEL NORTE - CAÑO SUCIO - RÍO INDIO PROJECT

RÍO COCLÉ DEL NORTE - PMF INFLOW AND OUTFLOW HYDROGRAPHS

MWH TAMS

DATE: DECEMBER, 2003

EXHIBIT: 4-1



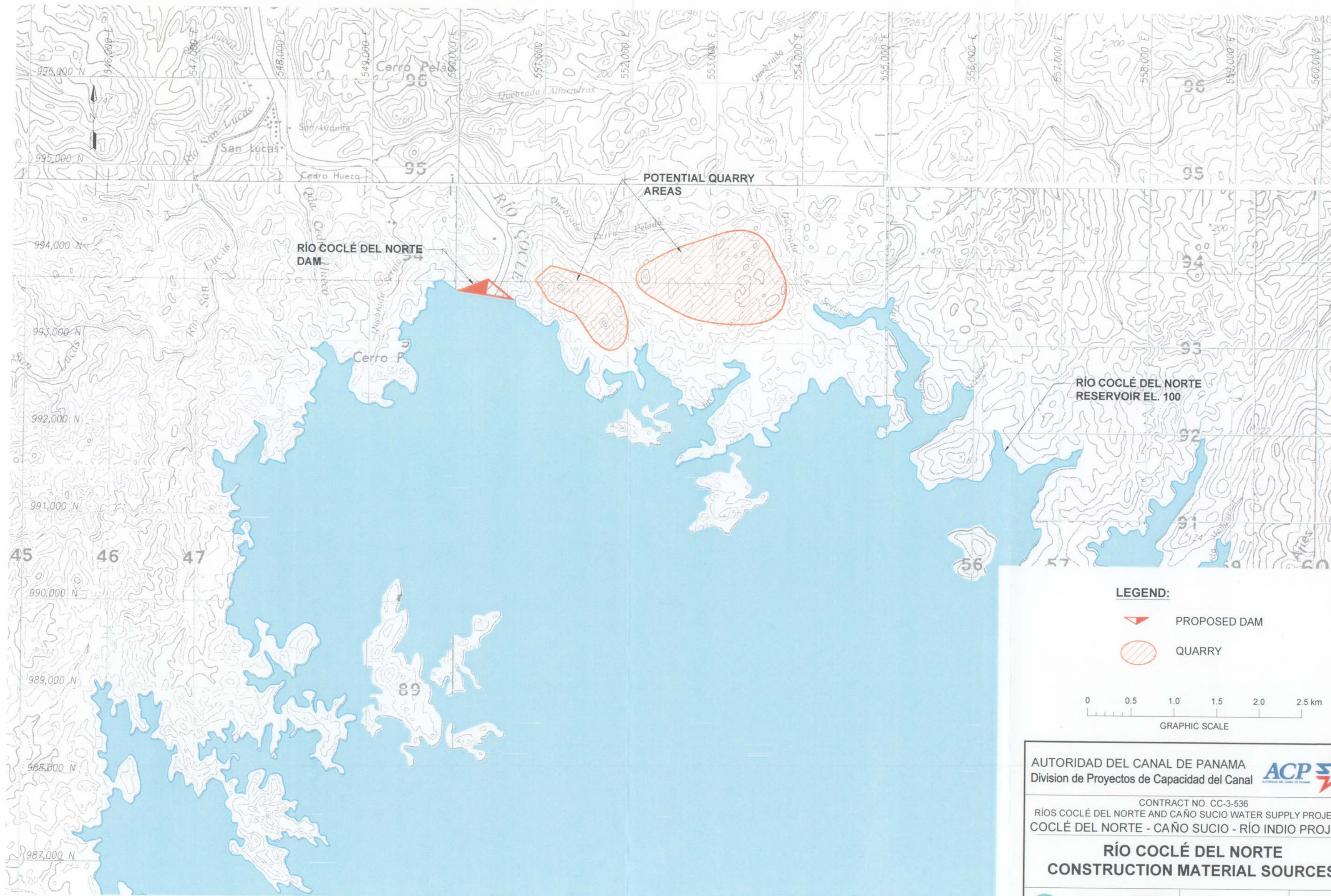
AUTORIDAD DEL CANAL DE PANAMA
Division de Proyectos de Capacidad del Canal

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

RÍO CAÑO SUCIO - PMF INFLOW AND OUTFLOW HYDROGRAPHS

MWH TAMS

DATE:	EXHIBIT:
DECEMBER, 2003	4-2



AUTORIDAD DEL CANAL DE PANAMA
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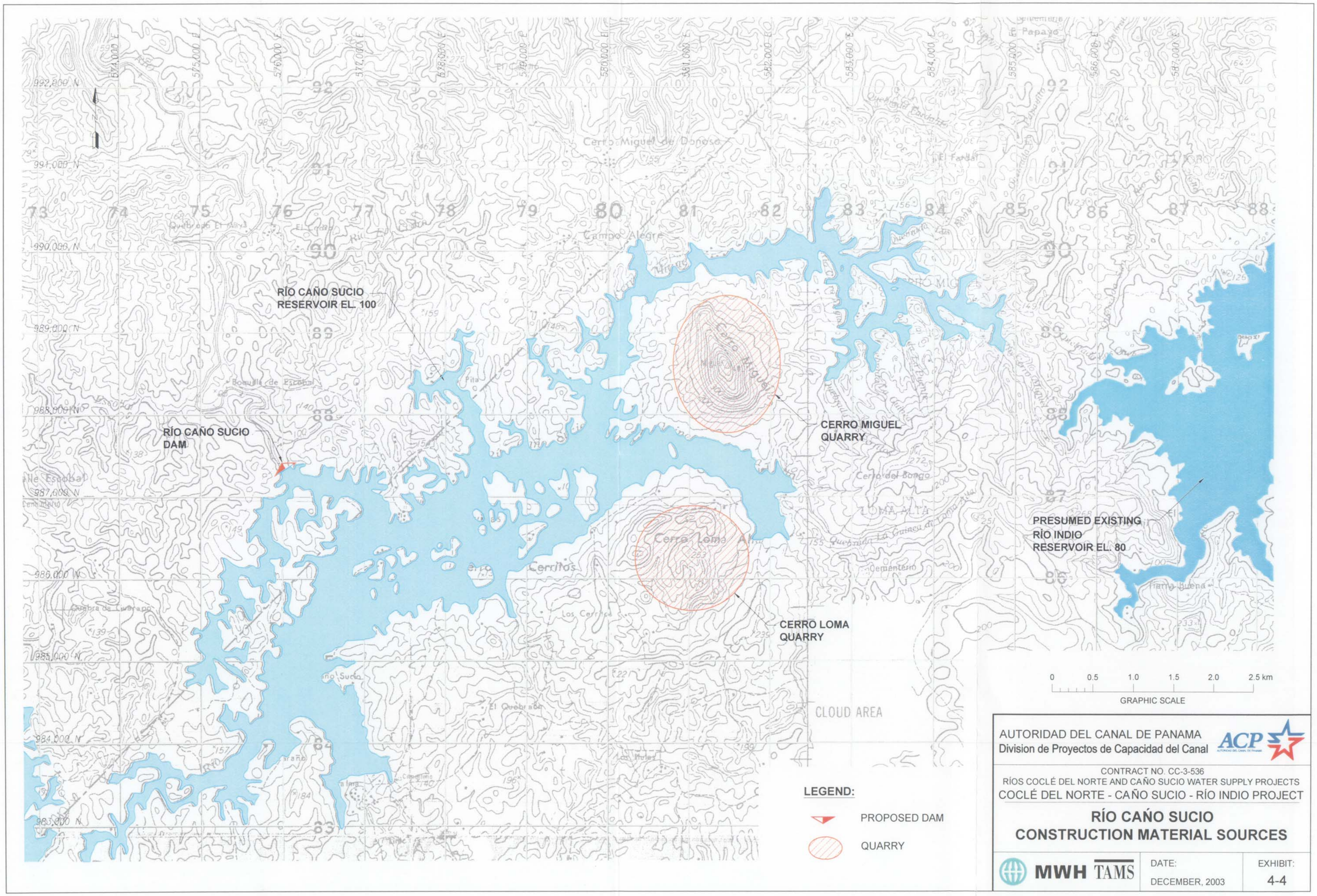
RÍOS COCLÉ DEL NORTE AND CAÑO SUCIO WATER SUPPLY PROJECTS
COCLÉ DEL NORTE - CAÑO SUCIO - RÍO INDIO PROJECT

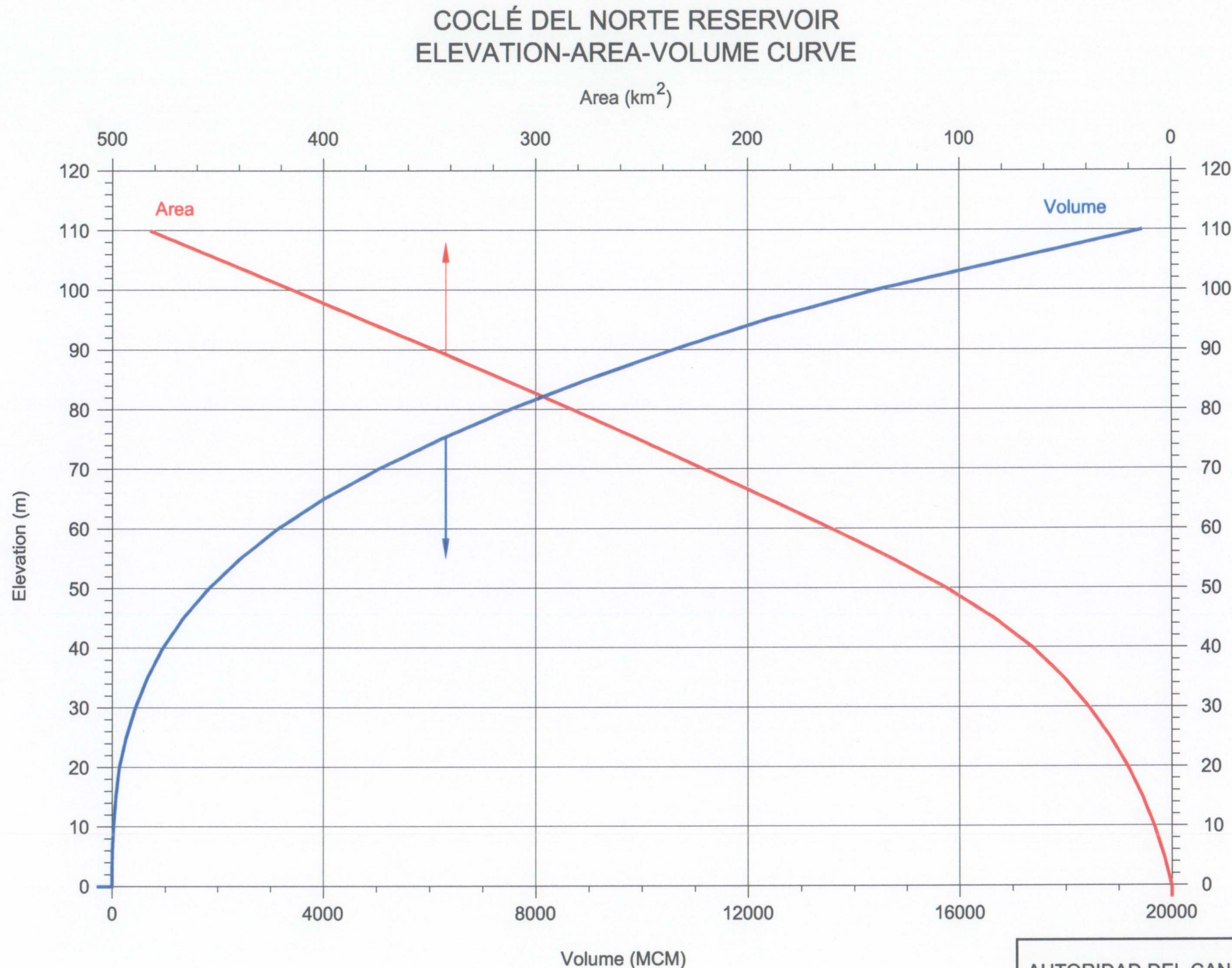
RÍO COCLÉ DEL NORTE
CONSTRUCTION MATERIAL SOURCES

MWH TAMS

DATE:	EXHIBIT:
DECEMBER, 2003	4-3



RÍO CAÑO SUCIO
RESERVOIR EL. 100
RÍO CAÑO SUCIO
DAM
CERRO MIGUEL
QUARRY
CERRO LOMA
QUARRY
PRESUMED EXISTING
RÍO INDIO
RESERVOIR EL. 80
CLOUD AREA
Cerro Miguel de Donoso
Campo Alegre
Cerro del Bongo
LOMA ALTA
Cerritos
Cementerio
Tierra Buena
992,000 N
991,000 N
990,000 N
989,000 N
988,000 N
987,000 N
986,000 N
985,000 N
984,000 N
983,000 N
574,000 E
575,000 E
576,000 E
577,000 E
578,000 E
579,000 E
580,000 E
581,000 E
582,000 E
583,000 E
584,000 E
585,000 E
586,000 E
587,000 E
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
COCLÉ DEL NORTE - CAÑO SUCIO - RÍO INDIO PROJECT
RÍO CAÑO SUCIO
CONSTRUCTION MATERIAL SOURCES
MWH TAMS
DATE:
DECEMBER, 2003
EXHIBIT:
4-4



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
COCLÉ DEL NORTE - CAÑO SUCIO - RÍO INDIO PROJECT

COCLÉ DEL NORTE RESERVOIR
AREA AND VOLUME VS. ELEVATION

MWH TAMS

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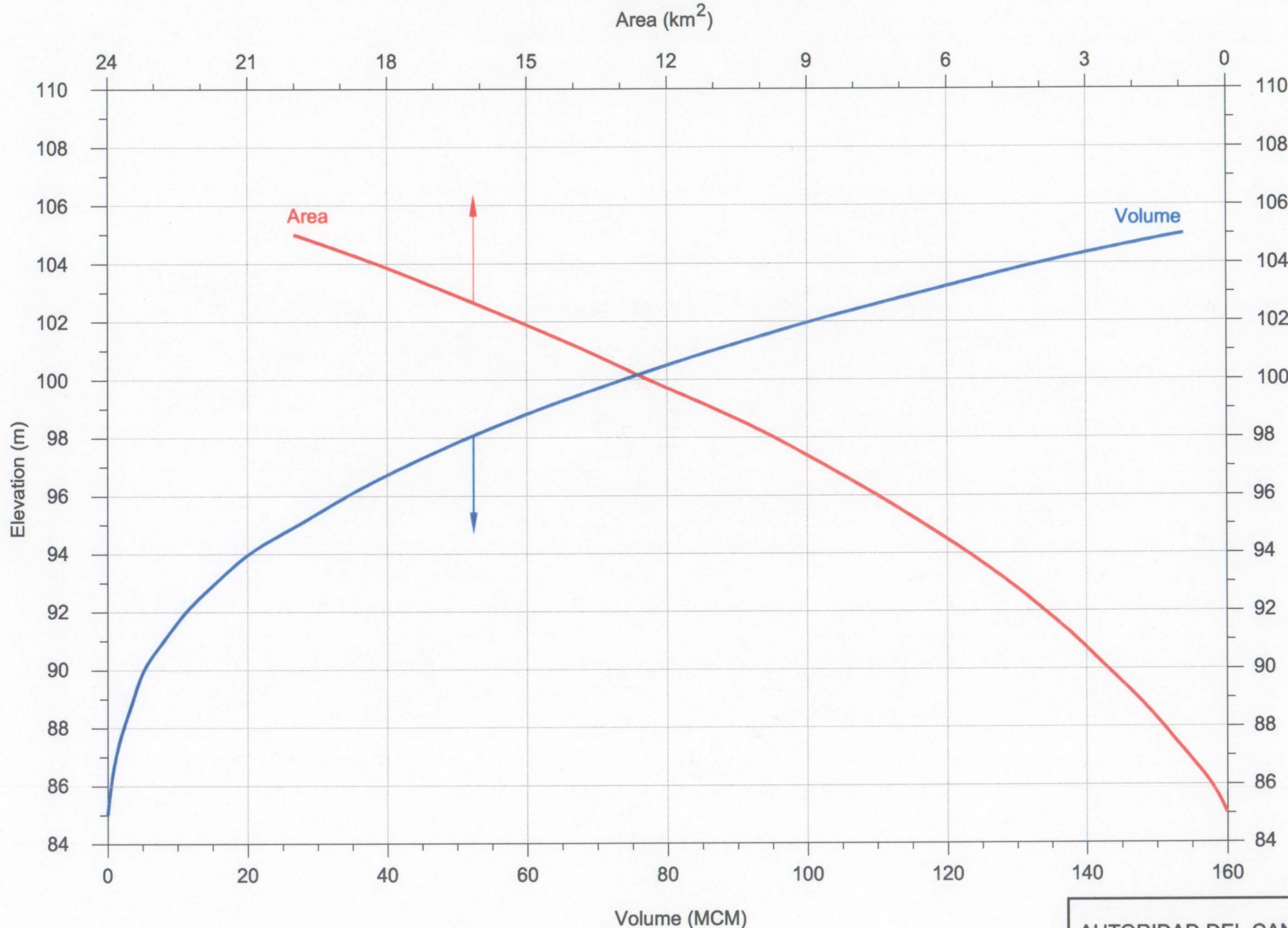
CAÑO SUCIO RESERVOIR
ELEVATION-AREA-VOLUME CURVE



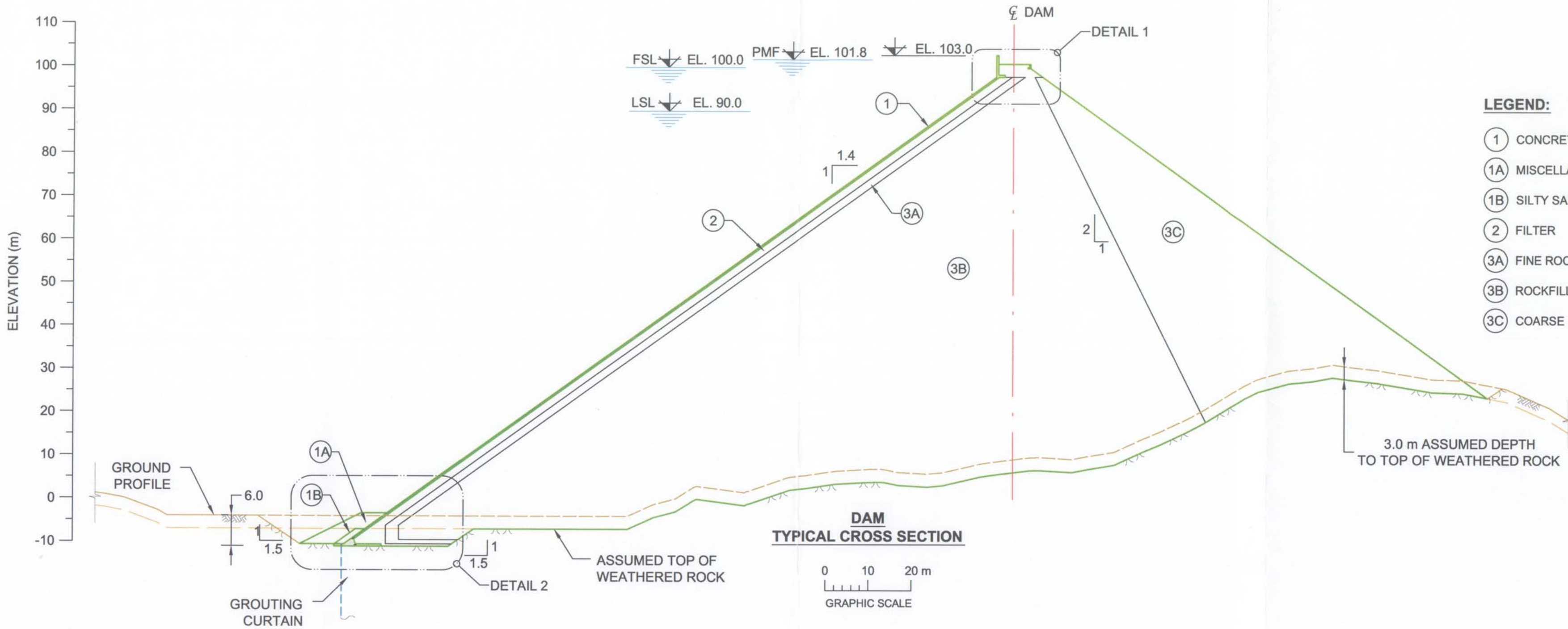
AUTORIDAD DEL CANAL DE PANAMA
Division de Proyectos de Capacidad del Canal

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

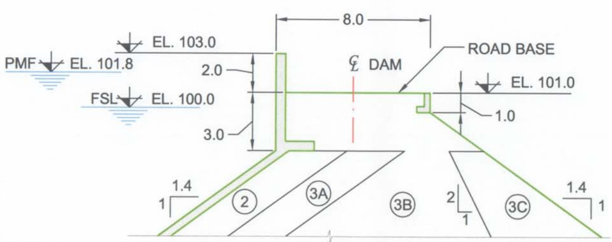
CAÑO SUCIO RESERVOIR
AREA AND VOLUME VS. ELEVATION

MWH TAMS

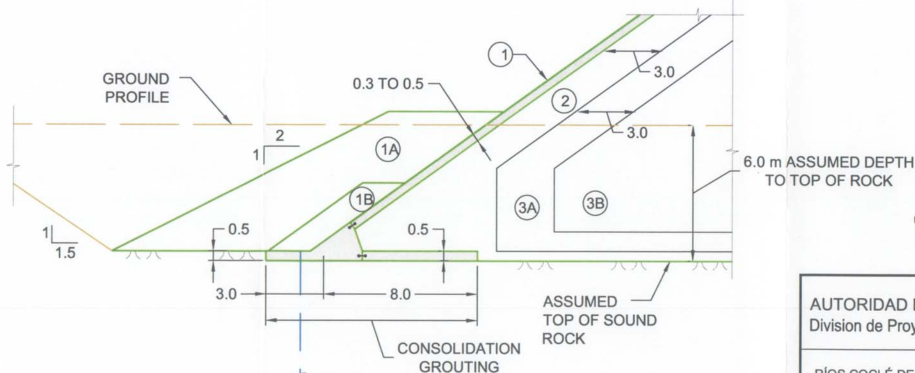
DATE:	EXHIBIT:
DECEMBER, 2003	4-6



DAM TYPICAL CROSS SECTION



DETAIL 1



DETAIL 2

0 50 100 150 200 250 m
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
COCLÉ DEL NORTE - CAÑO SUCIO - RÍO INDIO PROJECT

RÍO COCLÉ DEL NORTE DAM
SECTION AND DETAILS

MWH TAMS

DATE:	EXHIBIT:
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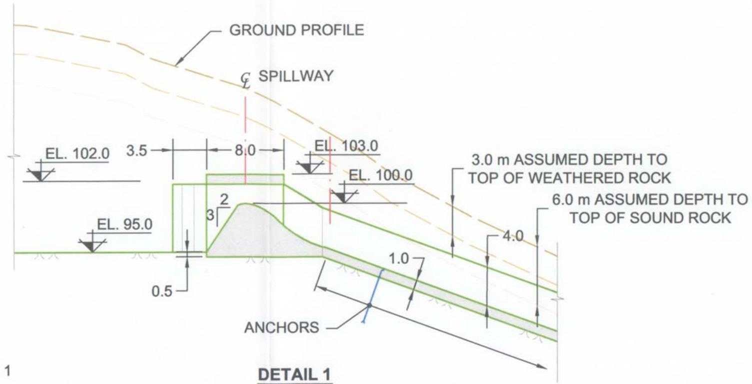
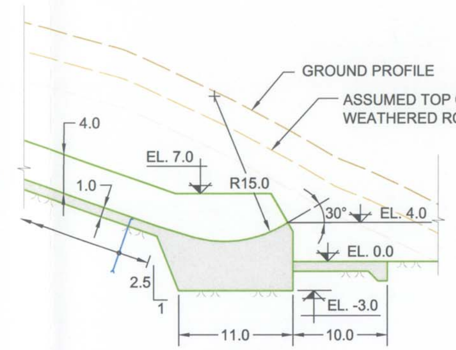


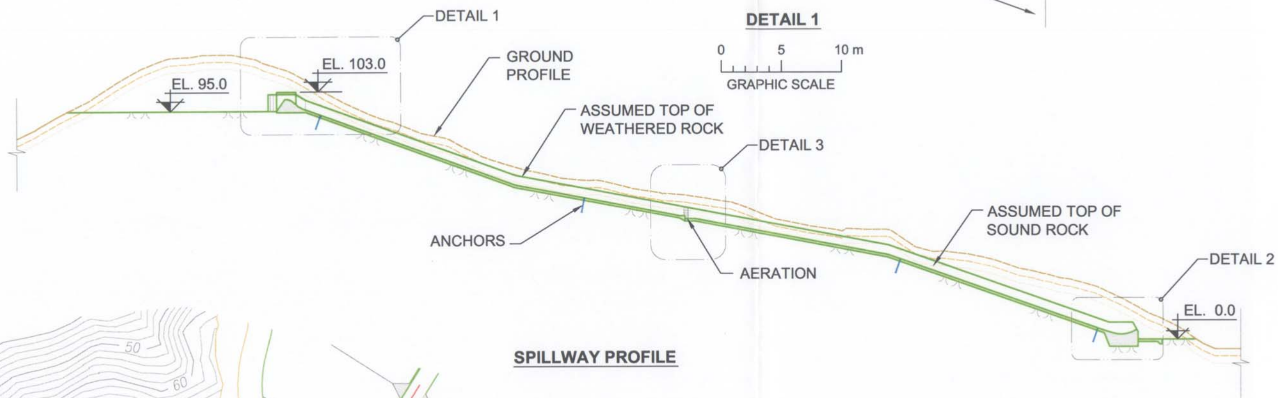
DETAIL 1

0 5 10 m
GRAPHIC SCALE

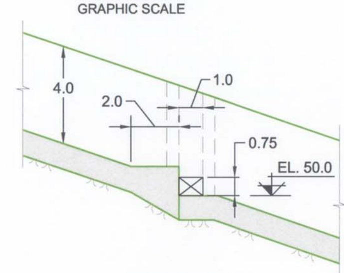


DETAIL 2

0 5 10 m
GRAPHIC SCALE

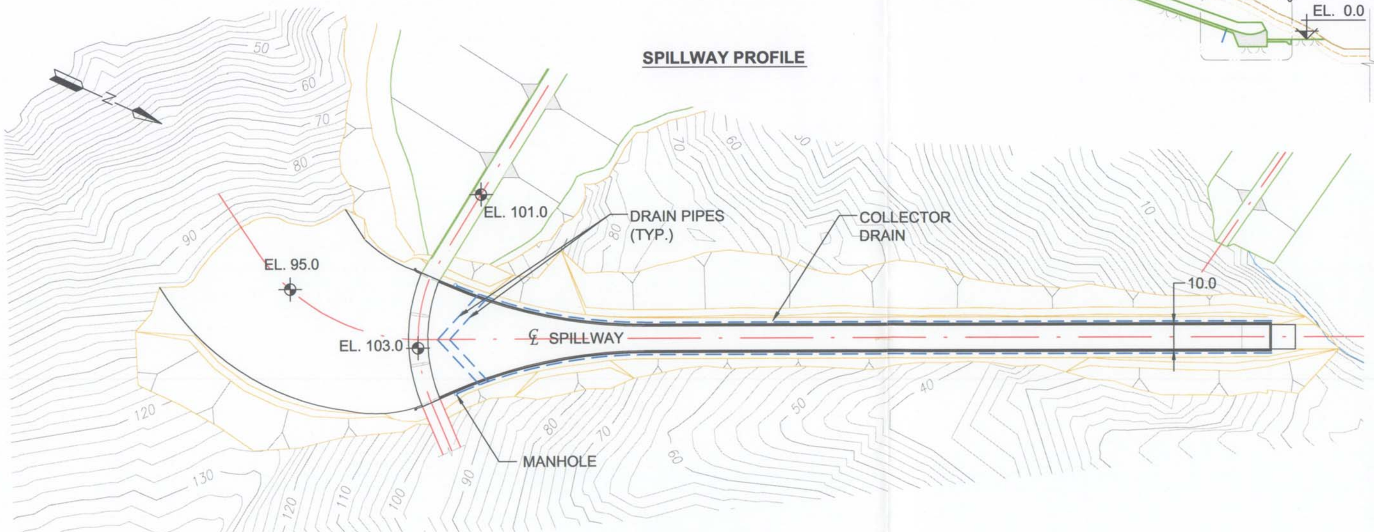


SPILLWAY PROFILE



DETAIL 3

0 2 4 m
GRAPHIC SCALE



0 10 20 30 40 50 m
GRAPHIC SCALE

SPILLWAY PLAN

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
COCLÉ DEL NORTE - CAÑO SUCIO - RÍO INDIO PROJECT

RÍO COCLÉ DEL NORTE SPILLWAY PLAN, PROFILE AND DETAILS

MWH TAMS

DATE:	EXHIBIT:
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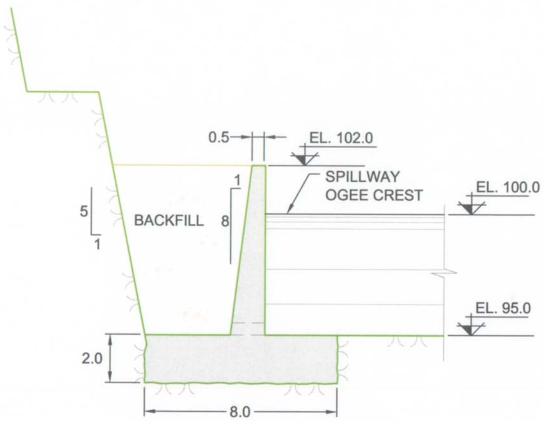
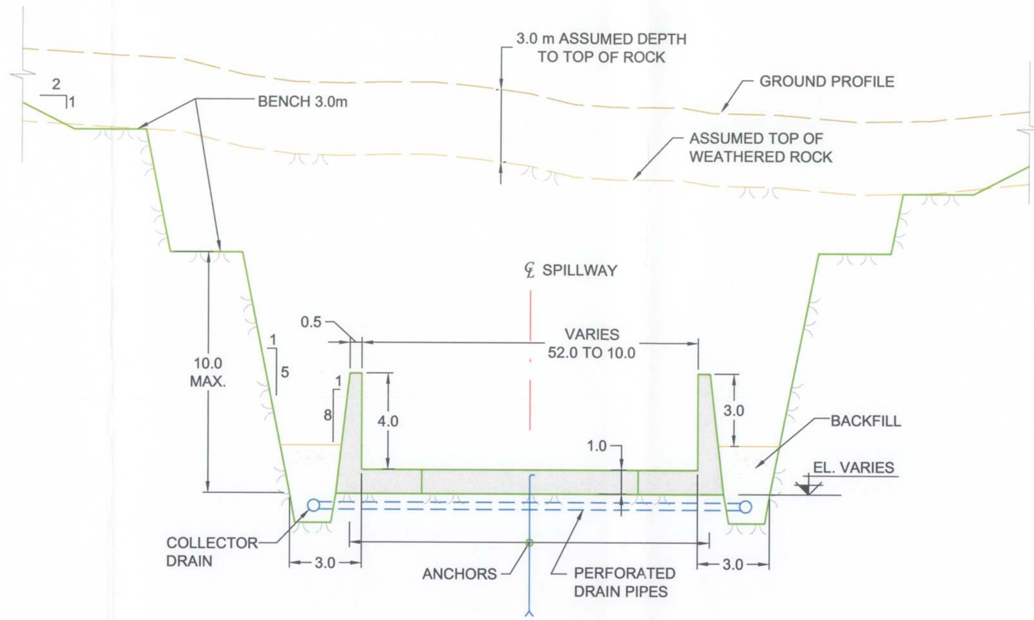
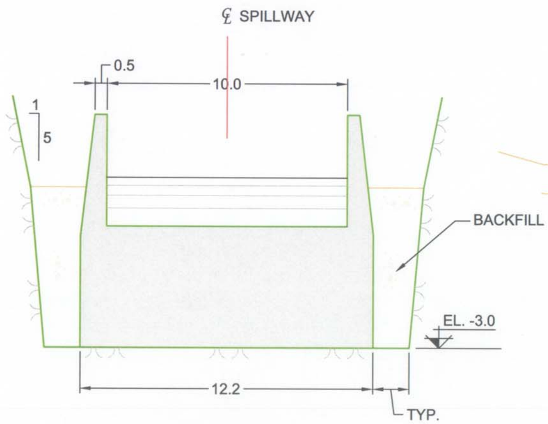


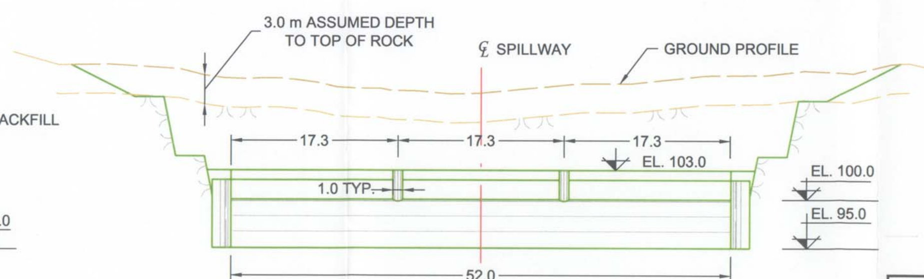
SPILLWAY APPROACH WALL SECTION



SPILLWAY CHUTE TYPICAL CROSS-SECTION



FLIP BUCKET TYPICAL CROSS-SECTION



SPILLWAY CONTROL STRUCTURE UPSTREAM VIEW

0 5 10 m
GRAPHIC SCALE

0 10 20 30 40 50 m
GRAPHIC SCALE

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

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RÍOS COCLÉ DEL NORTE AND CAÑO SUCIO WATER SUPPLY PROJECTS
COCLÉ DEL NORTE - CAÑO SUCIO - RÍO INDIO PROJECT

RÍO COCLÉ DEL NORTE SPILLWAY SECTIONS AND ELEVATION

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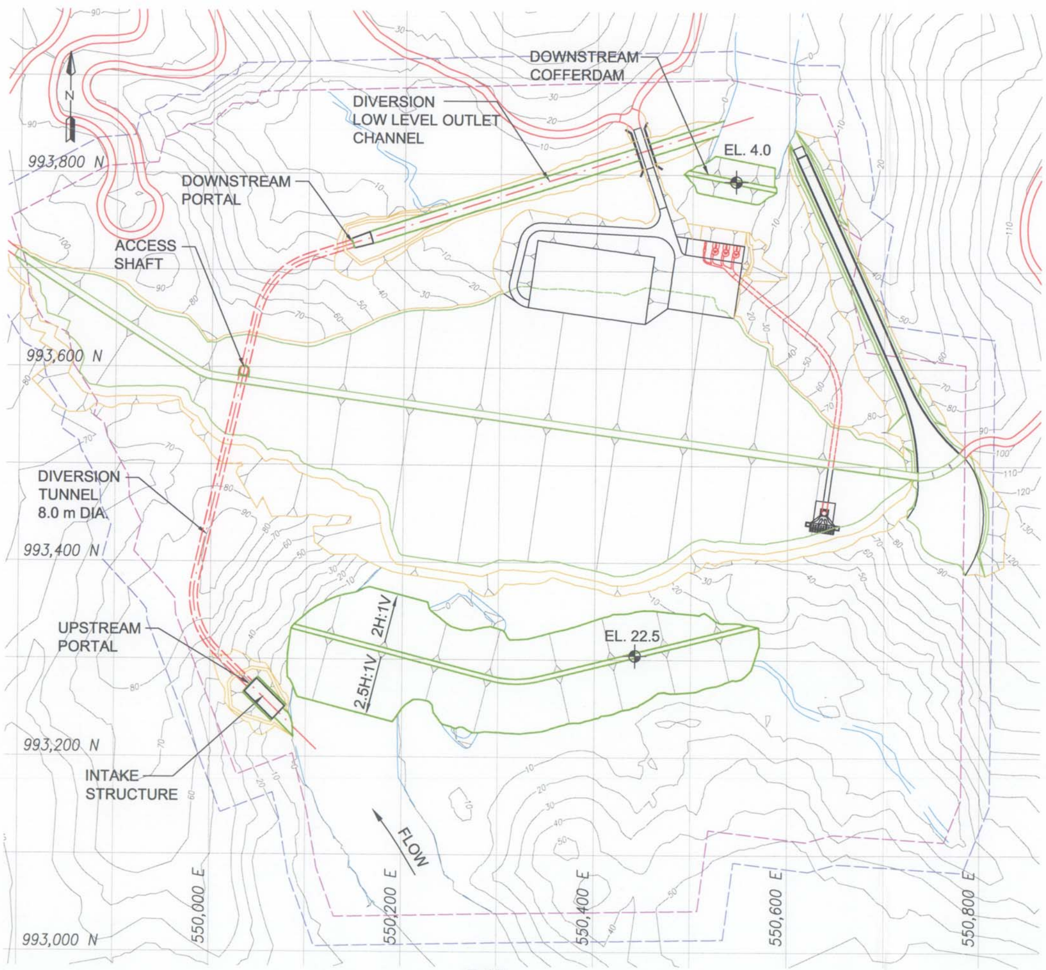
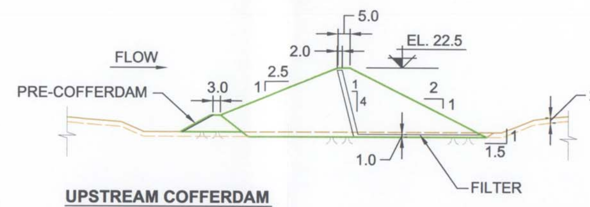
PROFILE
DIVERSION TUNNEL AND LOW LEVEL OUTLET

0 25 50 m
GRAPHIC SCALE

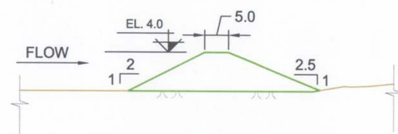


PLAN



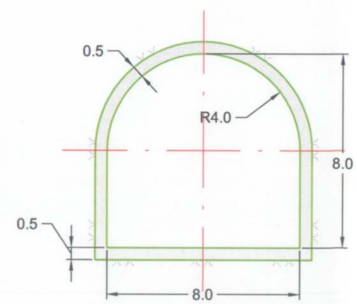
UPSTREAM COFFERDAM TYPICAL CROSS SECTION

0 20 40 m
GRAPHIC SCALE



DOWNSTREAM COFFERDAM TYPICAL CROSS SECTION

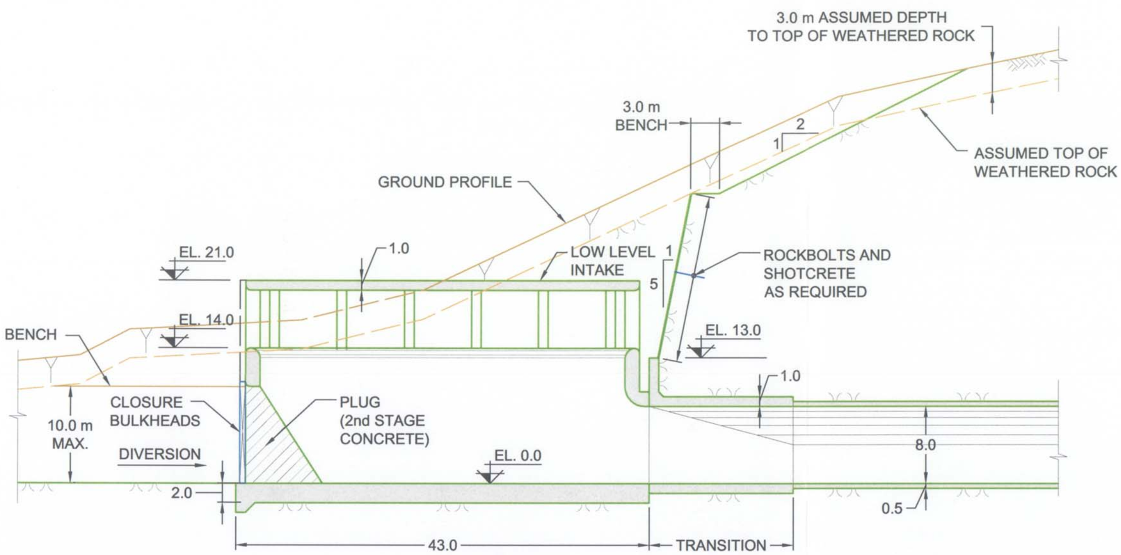
0 50 100 150 200 250 m
GRAPHIC SCALE



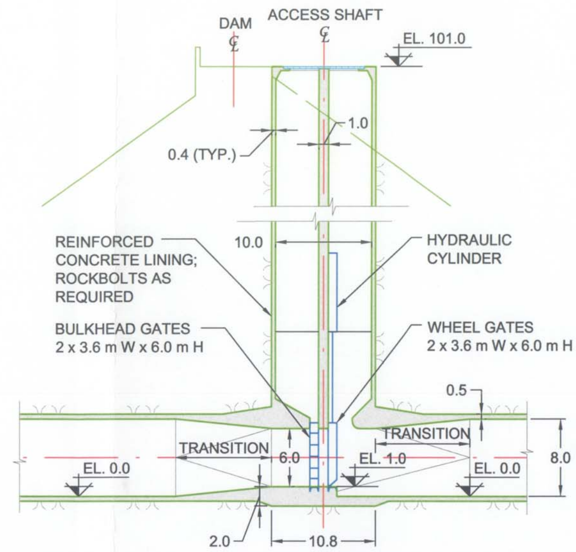
TYPICAL DIVERSION TUNNEL CROSS SECTION

0 2 4 m
GRAPHIC SCALE

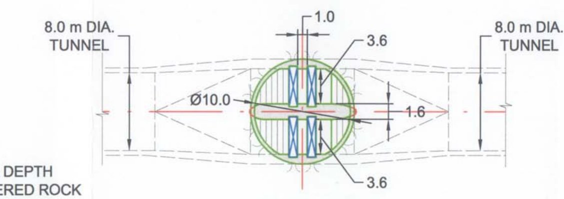
AUTORIDAD DEL CANAL DE PANAMA Division de Proyectos de Capacidad del Canal	ACP
CONTRACT NO. CC-3-536 RÍOS COCLÉ DEL NORTE AND CAÑO SUCIO WATER SUPPLY PROJECTS COCLÉ DEL NORTE - CAÑO SUCIO - RÍO INDIO PROJECT	
RÍO COCLÉ DEL NORTE RIVER DIVERSION FACILITIES PLAN, PROFILE AND SECTIONS	
MWH TAMS	DATE: DECEMBER, 2003 — EXHIBIT: 5-4



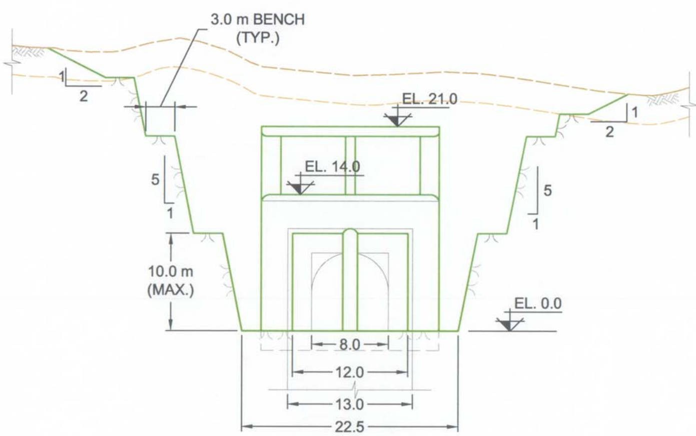
TUNNEL INLET PROFILE



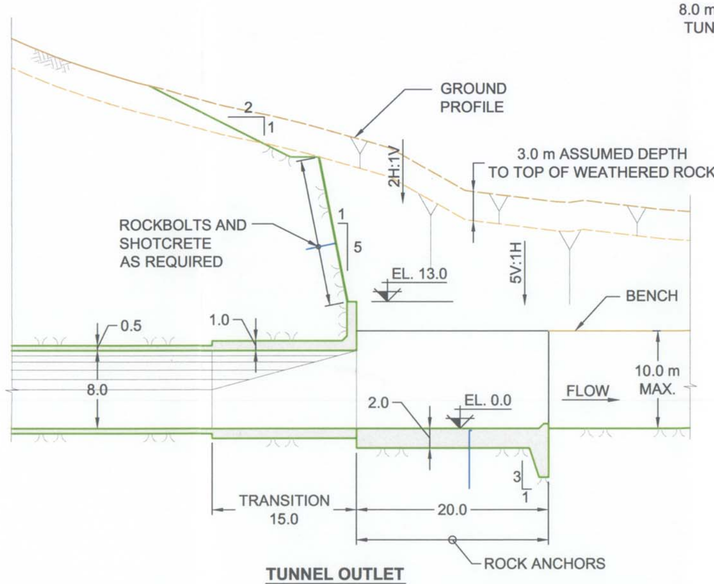
ACCESS SHAFT PROFILE



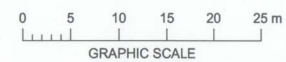
ACCESS SHAFT PLAN



TUNNEL INLET UPSTREAM VIEW



TUNNEL OUTLET PROFILE



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
COCLÉ DEL NORTE - CAÑO SUCIO - RÍO INDIO PROJECT

RÍO COCLÉ DEL NORTE EMERGENCY DRAWDOWN FACILITIES DETAILS

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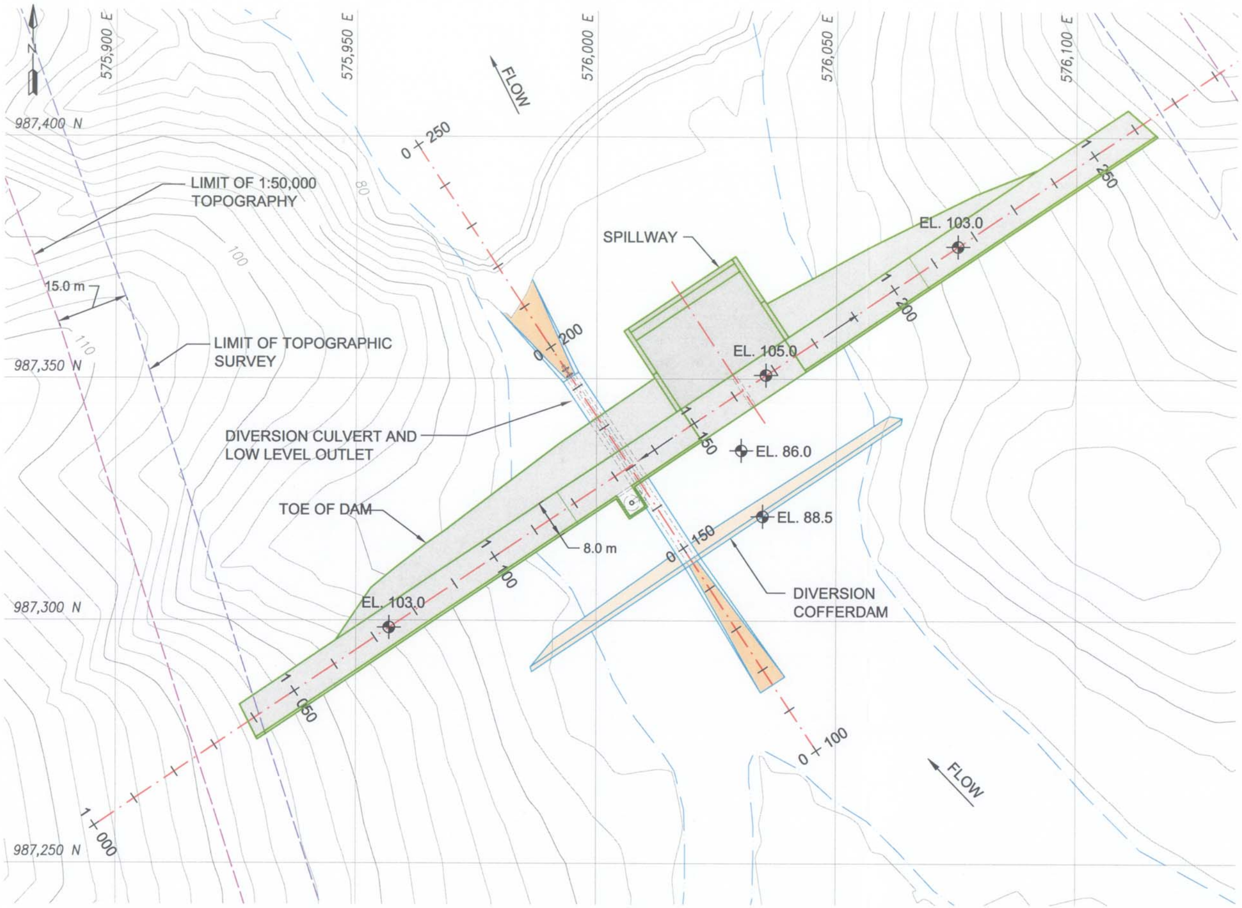
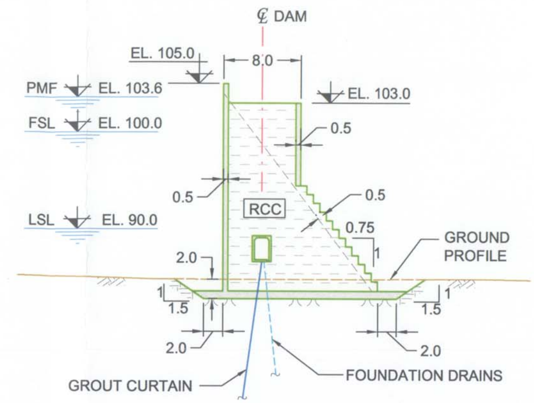
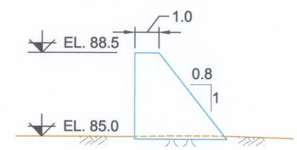


PLAN



RCC - TYPICAL SECTION

0 5 10 m

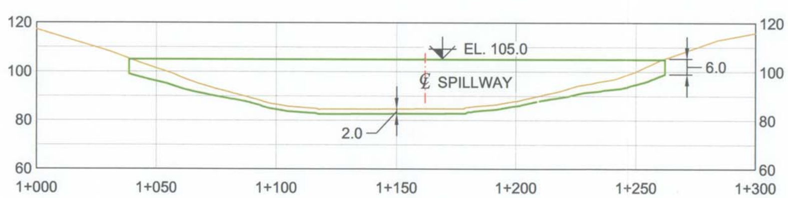


DIVERSION DAM

0 1 2 m

0 10 20 30 40 50 m

GRAPHIC SCALE



DAM 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
COCLÉ DEL NORTE - CAÑO SUCIO - RÍO INDIO PROJECT

RÍO CAÑO SUCIO DAM
PLAN, PROFILE AND SECTIONS

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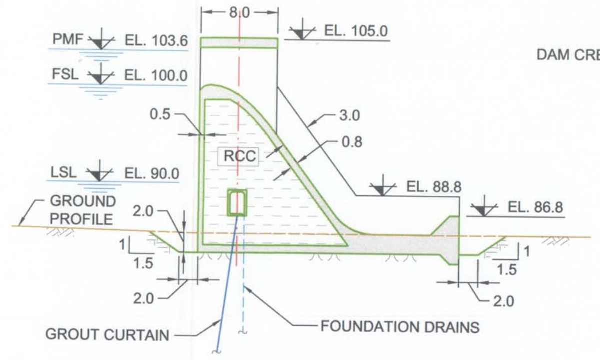
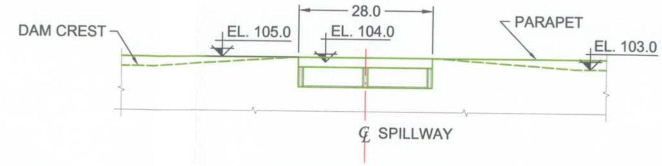
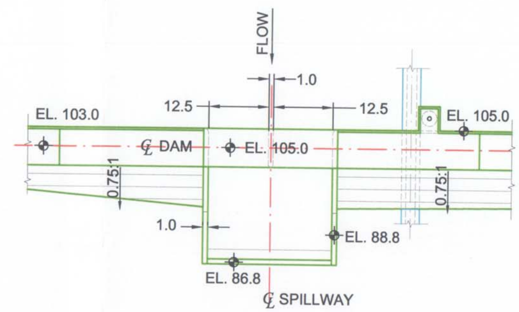
MINIMUM RELEASE OUTLET DURING OPERATION



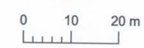
SPILLWAY - TYPICAL SECTION

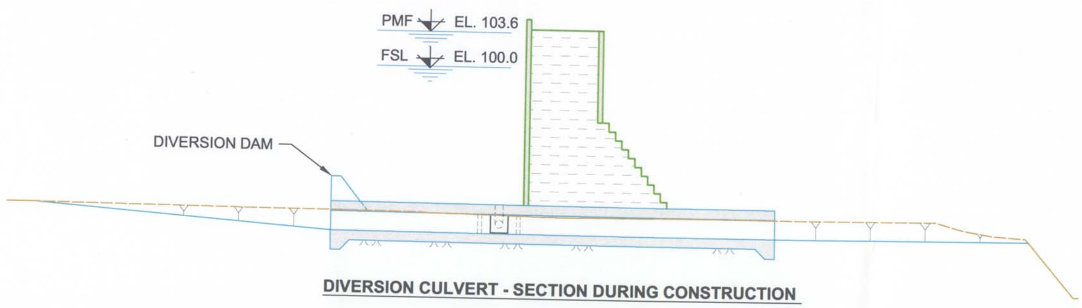


UPSTREAM ELEVATION

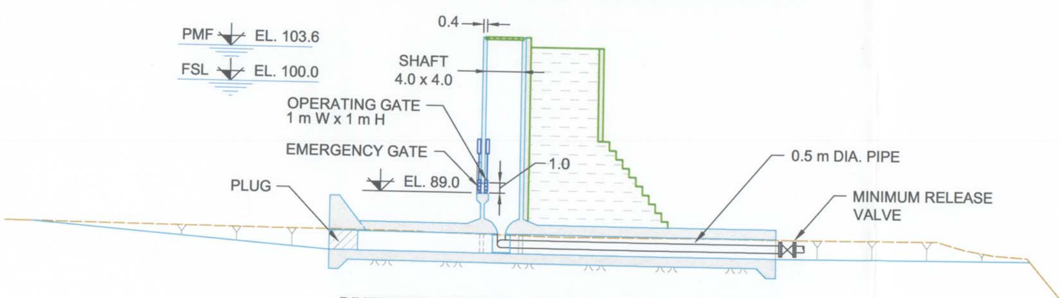


PLAN





DIVERSION CULVERT - SECTION DURING CONSTRUCTION



DIVERSION CULVERT - SECTION DURING OPERATION

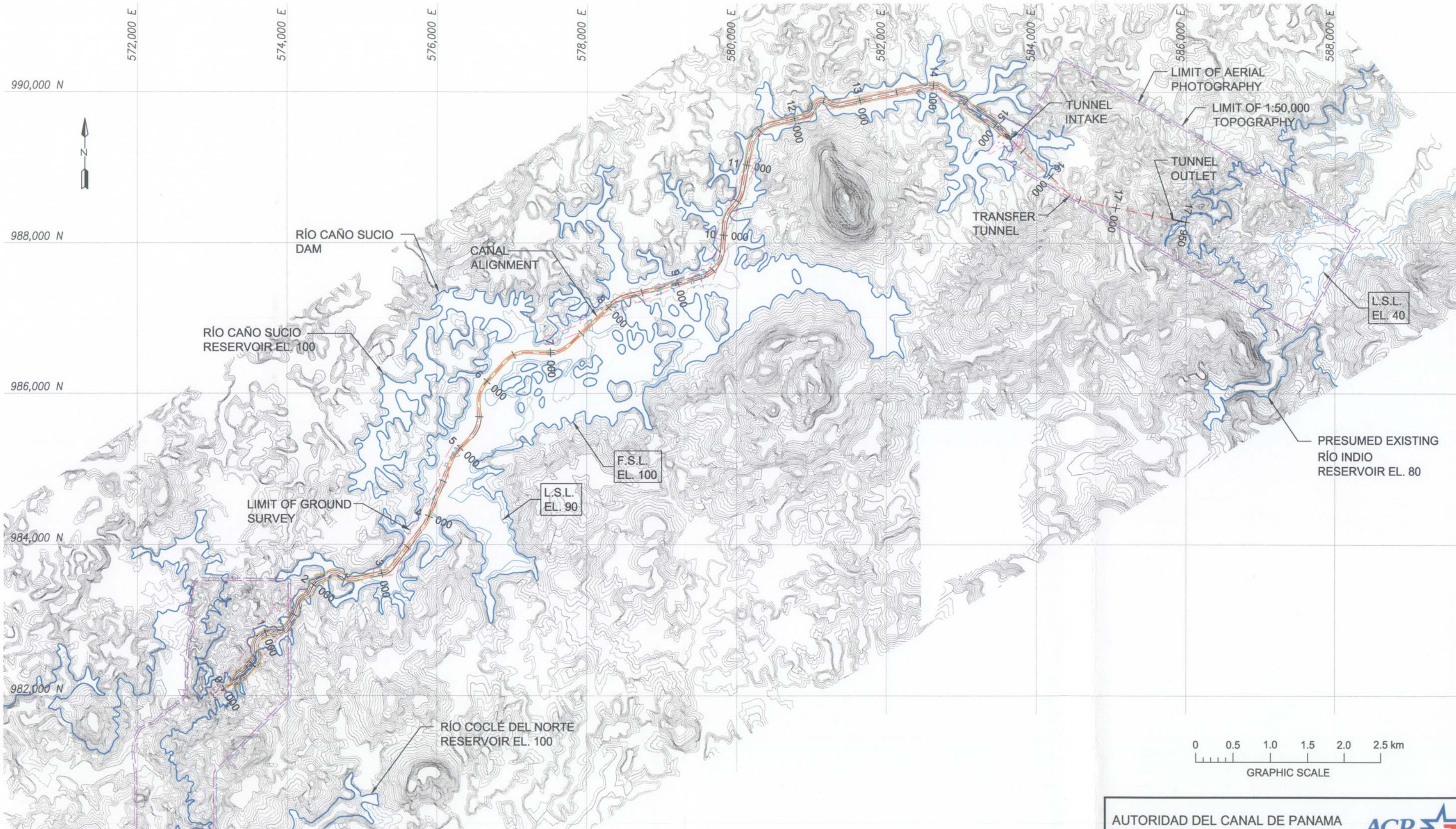
AUTORIDAD DEL CANAL DE PANAMA
Division de Proyectos de Capacidad del Canal

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

RÍO CAÑO SUCIO
SPILLWAY, DIVERSION AND MINIMUM RELEASE PLANS AND SECTIONS

MWH TAMS

DATE:	EXHIBIT:
DECEMBER, 2003	6-2



NOTE:

TOPOGRAPHY COMPILED FROM THE FOLLOWING SOURCES:

1. GROUND SURVEY (IASA, 2003)
2. AERIAL PHOTOGRAPHY (GEOCART - GRAFOS, 2002)
3. PUBLISHED 1:50,000 TOPOGRAPHIC MAPS (TOMMY GUARDIA)

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

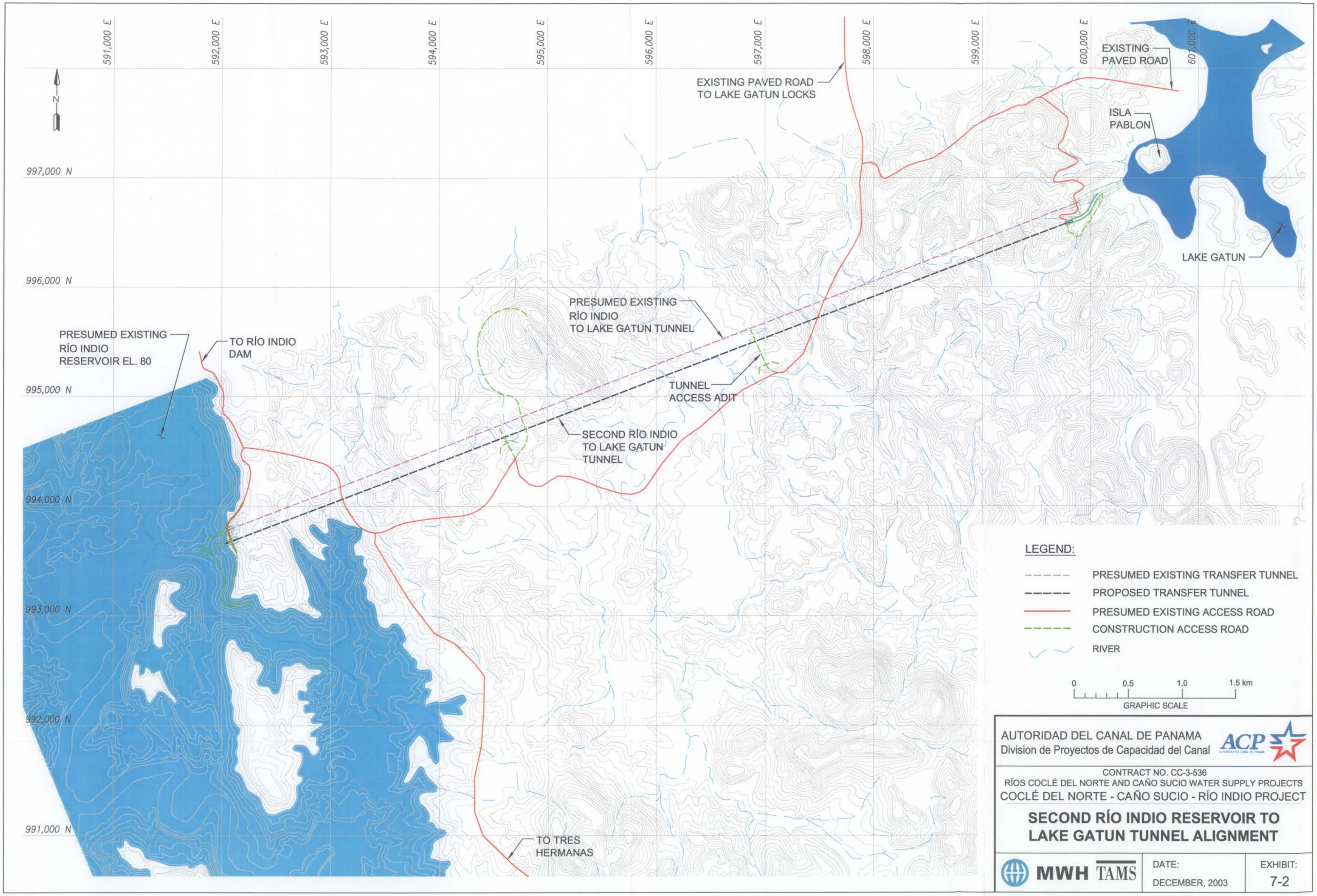
CONTRACT NO. CC-3-536
RÍOS COCLÉ DEL NORTE AND CAÑO SUCIO WATER SUPPLY PROJECTS
COCLÉ DEL NORTE - CAÑO SUCIO - RÍO INDIO PROJECT

RÍO COCLÉ DEL NORTE TO RÍO INDIO GENERAL PLAN OF THE WATER TRANSFER FACILITIES

MWH TAMS

DATE: DECEMBER, 2003

EXHIBIT: 7-1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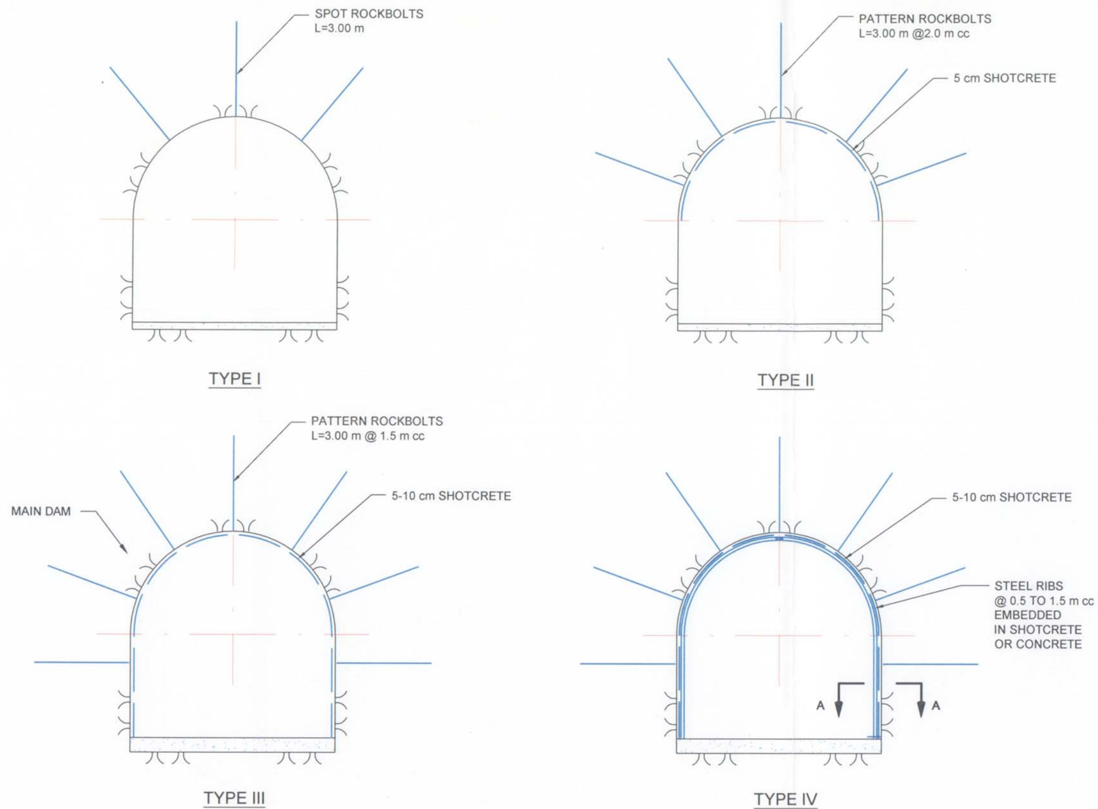
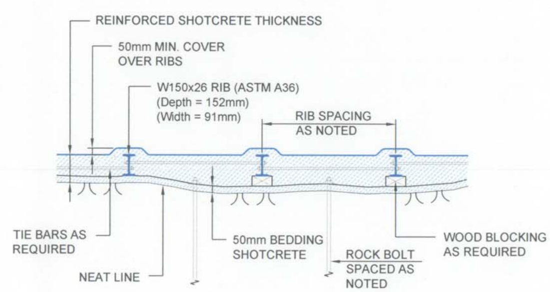
601,000 E
997,000 N
996,000 N
995,000 N
994,000 N
993,000 N
992,000 N
991,000 N
N
EXISTING PAVED ROAD TO LAKE GATUN LOCKS
EXISTING PAVED ROAD
ISLA PABLON
LAKE GATUN
PRESUMED EXISTING RÍO INDIO TO LAKE GATUN TUNNEL
PRESUMED EXISTING RÍO INDIO RESERVOIR EL. 80
TO RÍO INDIO DAM
TUNNEL ACCESS ADIT
SECOND RÍO INDIO TO LAKE GATUN TUNNEL
TO TRES HERMANAS
LEGEND:
PRESUMED EXISTING TRANSFER TUNNEL
PROPOSED TRANSFER TUNNEL
PRESUMED EXISTING ACCESS ROAD
CONSTRUCTION ACCESS ROAD
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
COCLÉ DEL NORTE - CAÑO SUCIO - RÍO INDIO PROJECT
SECOND RÍO INDIO RESERVOIR TO LAKE GATUN TUNNEL ALIGNMENT
MWH
TAMS
DATE:
DECEMBER, 2003
EXHIBIT:
7-2



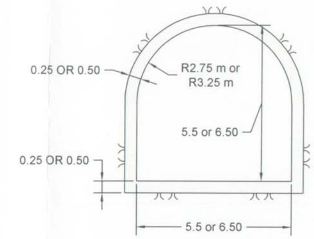
DRILL & BLAST SECTIONS

N.T.S.



SECTION A - A

N.T.S.



FINISHED TUNNEL DIMENSIONS

0 2 m

GRAPHIC SCALE

NOTE:

LINING THICKNESS VARIES TO MEET GROUND COVER CRITERIA.

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
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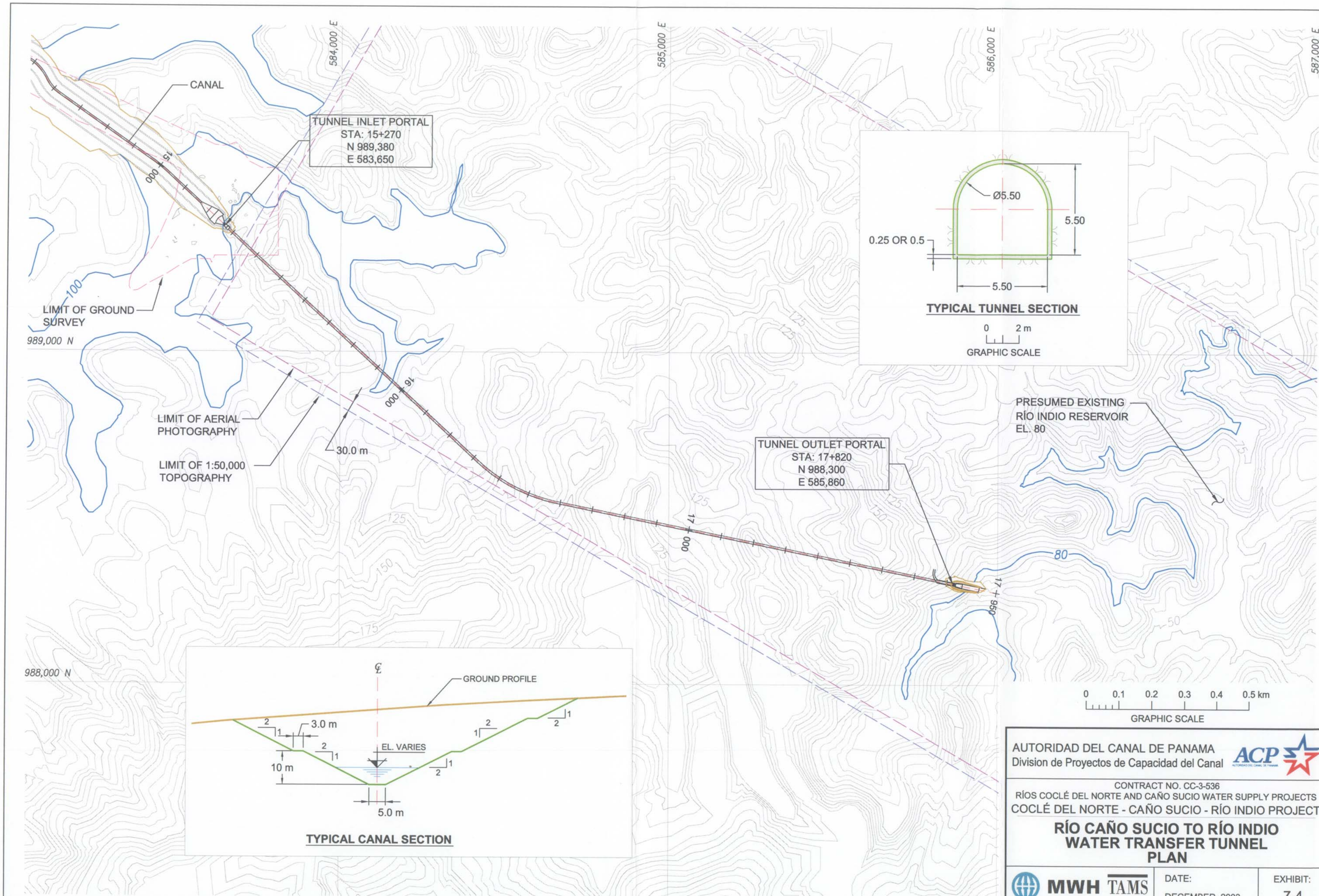
RÍOS COCLÉ DEL NORTE AND CAÑO SUCIO WATER SUPPLY PROJECTS
COCLÉ DEL NORTE - CAÑO SUCIO - RÍO INDIO PROJECT

TYPICAL TUNNEL CROSS SECTIONS

MWH TAMS	DATE: DECEMBER, 2003	EXHIBIT: 7-3



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
COCLÉ DEL NORTE - CAÑO SUCIO - RÍO INDIO PROJECT

RÍO CAÑO SUCIO TO RÍO INDIO WATER TRANSFER TUNNEL PLAN

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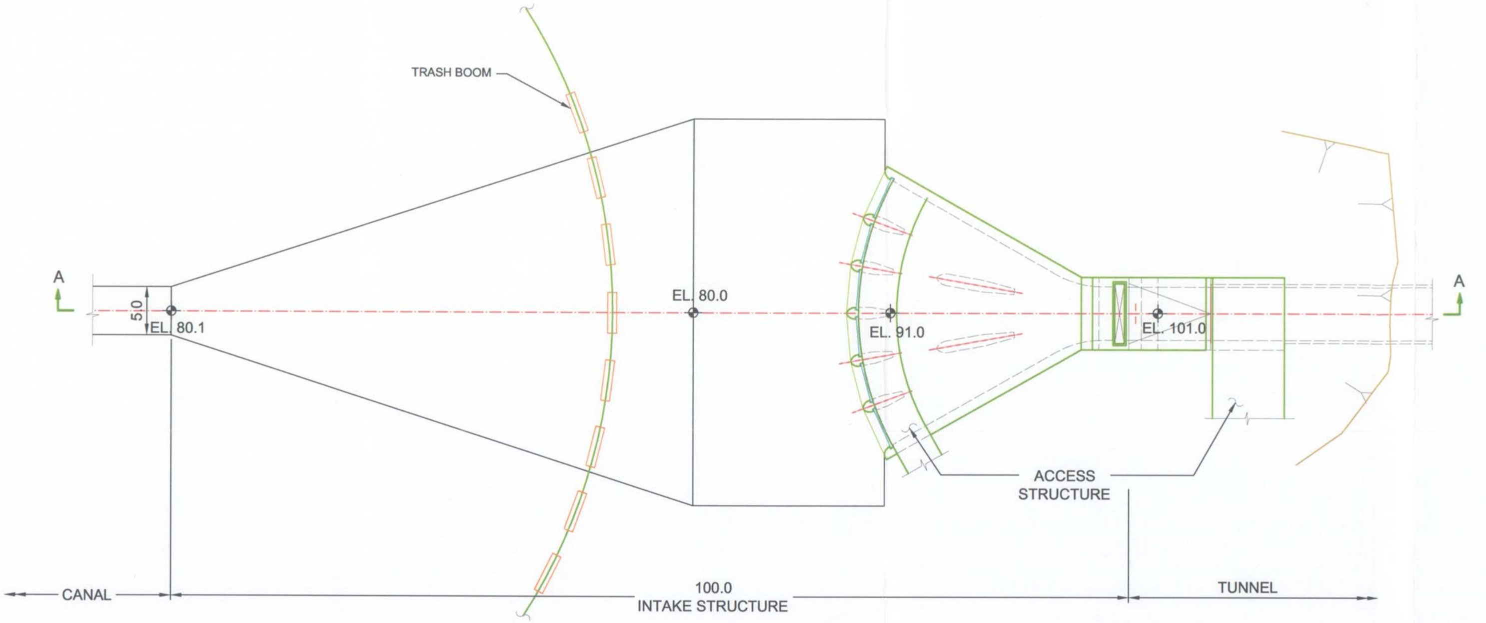
CONTRACT NO. CC-3-536
RÍOS COCLÉ DEL NORTE AND CAÑO SUCIO WATER SUPPLY PROJECTS
COCLÉ DEL NORTE - CAÑO SUCIO - RÍO INDIO PROJECT

RÍO CAÑO SUCIO TO RÍO INDIO WATER TRANSFER TUNNEL PROFILE

MWH TAMS

DATE: DECEMBER, 2003

EXHIBIT: 7-5



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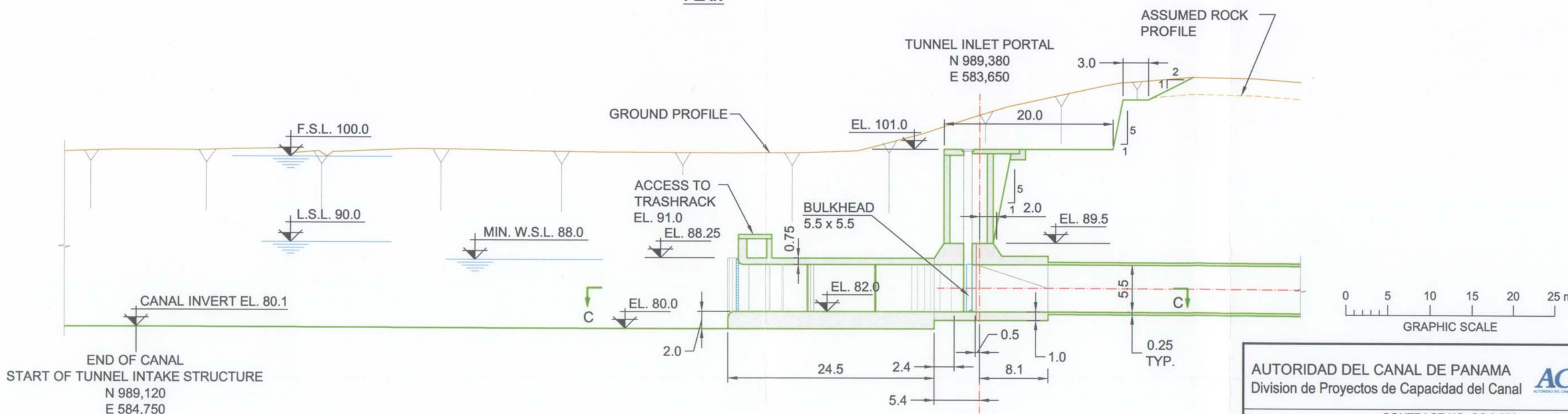


SECTION A - A

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

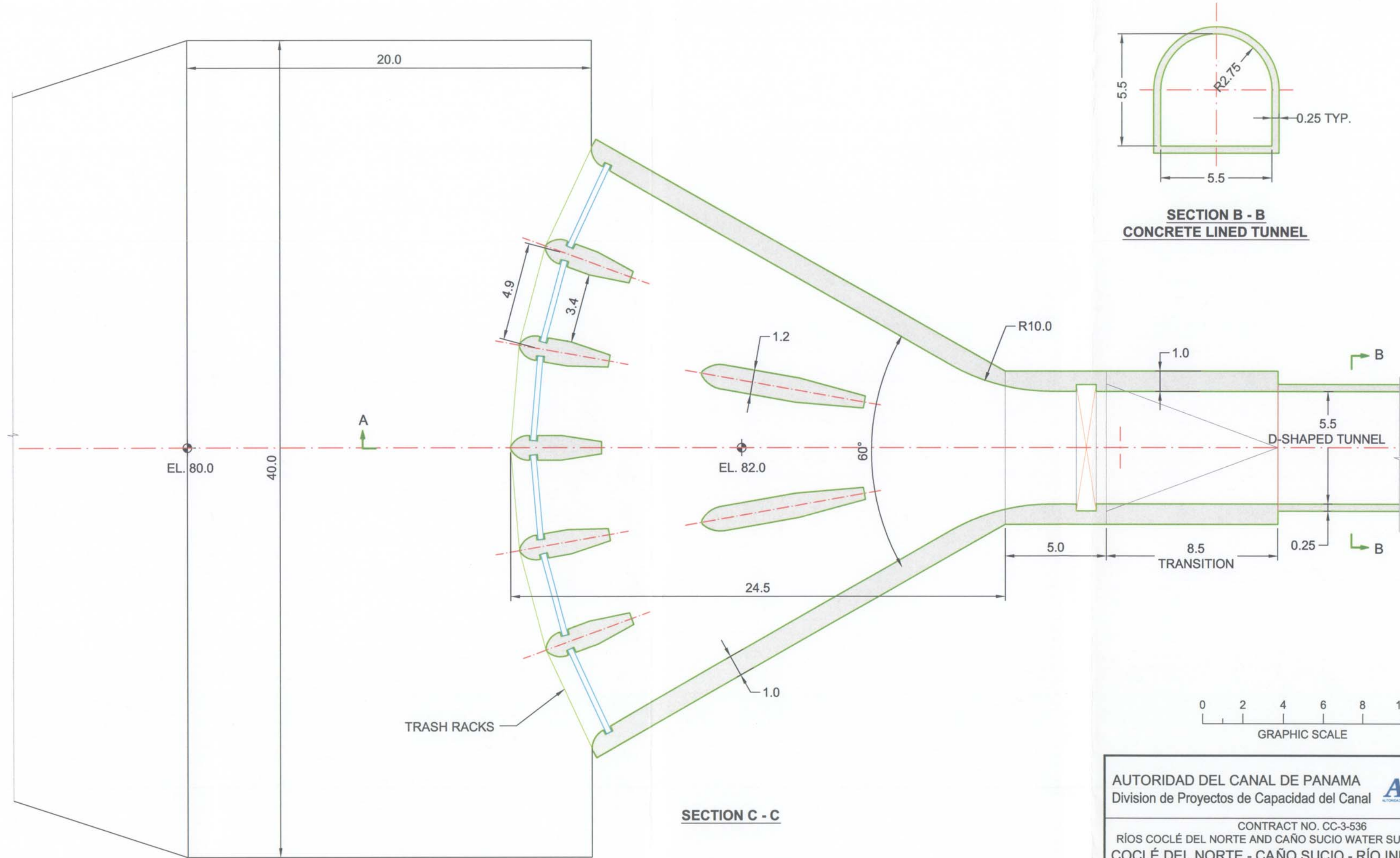
ACP

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

RÍO CAÑO SUCIO TO RÍO INDIO WATER TRANSFER TUNNEL - INTAKE STRUCTURE, PLAN, PROFILE AND SECTIONS - SHEET 1 OF 2

MWH TAMS

DATE:	EXHIBIT:
DECEMBER, 2003	7-6



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

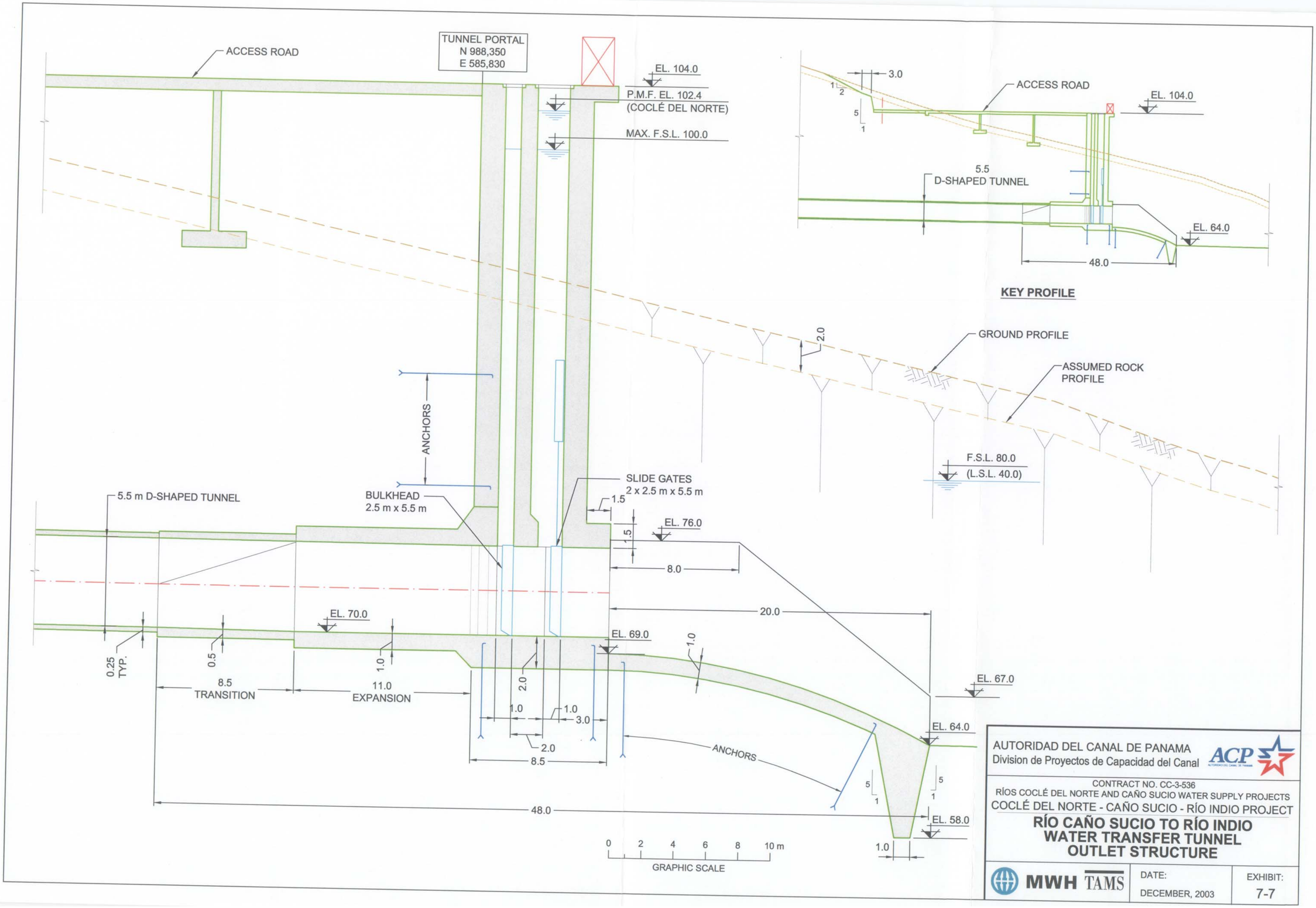
ACP

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

RÍO CAÑO SUCIO TO RÍO INDIO WATER TRANSFER TUNNEL - INTAKE STRUCTURE, PLAN, PROFILE AND SECTIONS - SHEET 2 OF 2

MWH TAMS

DATE:	EXHIBIT:
DECEMBER, 2003	7-6



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

ACP

CONTRACT NO. CC-3-536

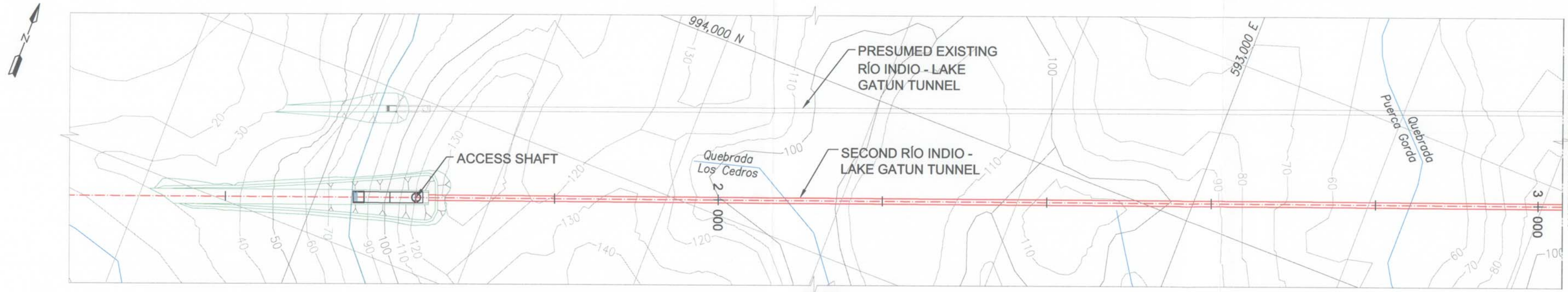
RÍOS COCLÉ DEL NORTE AND CAÑO SUCIO WATER SUPPLY PROJECTS

COCLÉ DEL NORTE - CAÑO SUCIO - RÍO INDIO PROJECT

RÍO CAÑO SUCIO TO RÍO INDIO WATER TRANSFER TUNNEL OUTLET STRUCTURE

MWH TAMS

DATE:	EXHIBIT:
DECEMBER, 2003	7-7



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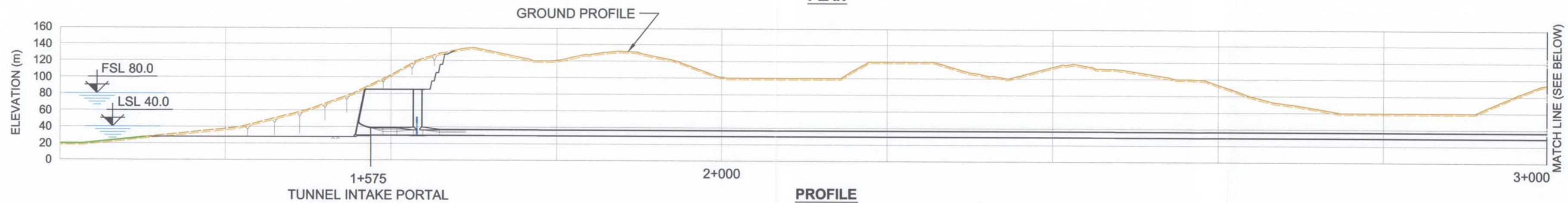
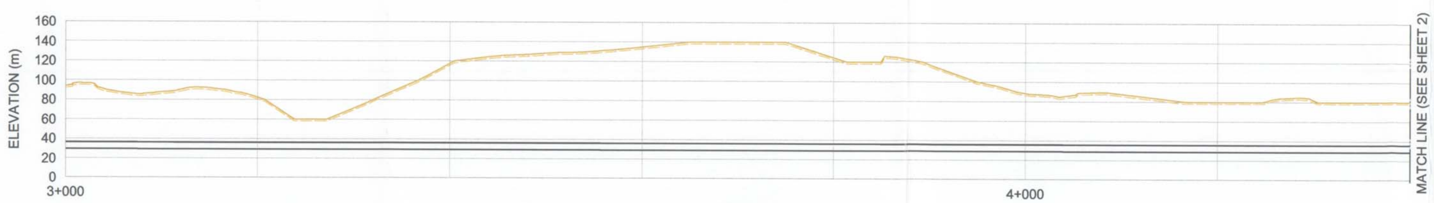


PROFILE

PLAN

0 50 100 150 200 250 m

GRAPHIC SCALE



PROFILE

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

ACP

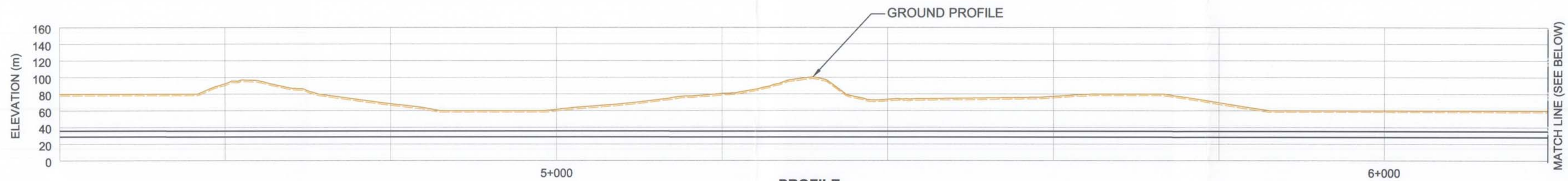
CONTRACT NO. CC-3-536
RÍOS COCLÉ DEL NORTE AND CAÑO SUCIO WATER SUPPLY PROJECTS
COCLÉ DEL NORTE - CAÑO SUCIO - RÍO INDIO PROJECT

SECOND RÍO INDIO - LAKE GATUN TUNNEL
PLAN AND PROFILE - SHEET 1 OF 3

MWH TAMS

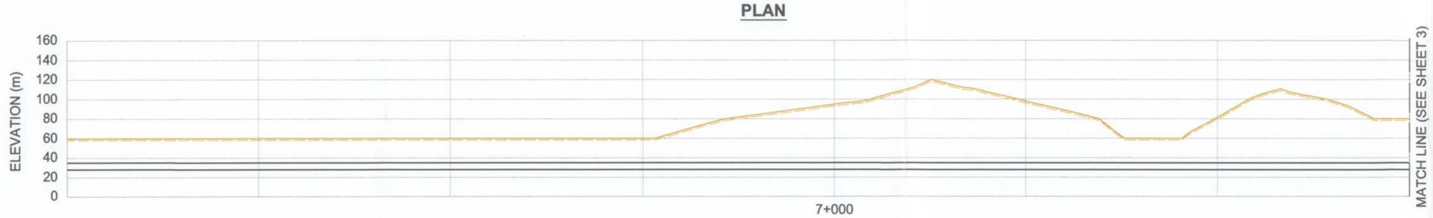
DATE:	EXHIBIT:
DECEMBER, 2003	7-8

PLAN



PROFILE

PLAN



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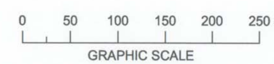


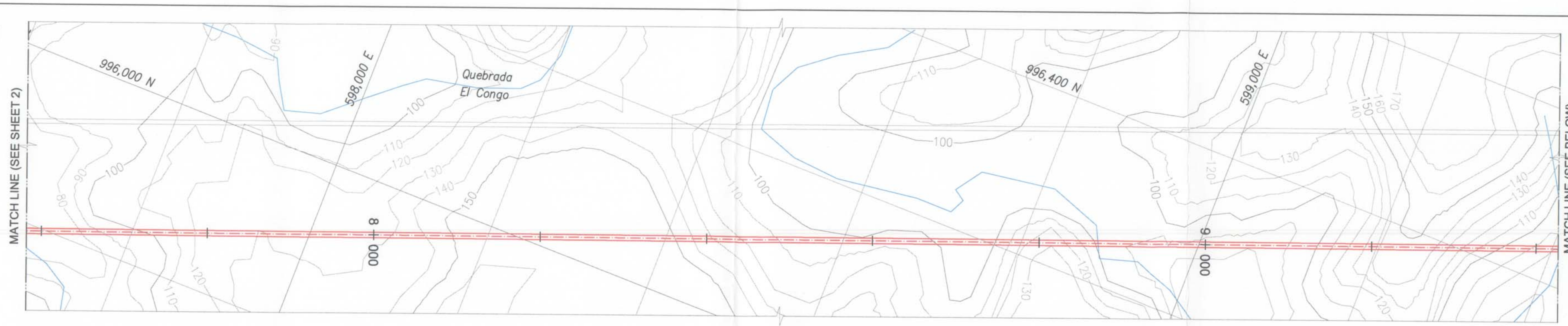
AUTORIDAD DEL CANAL DE PANAMA
Division de Proyectos de Capacidad del Canal

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

SECOND RÍO INDIO - LAKE GATUN TUNNEL
PLAN AND PROFILE - SHEET 2 OF 3

MWH TAMS

DATE:	EXHIBIT:
DECEMBER, 2003	7-8



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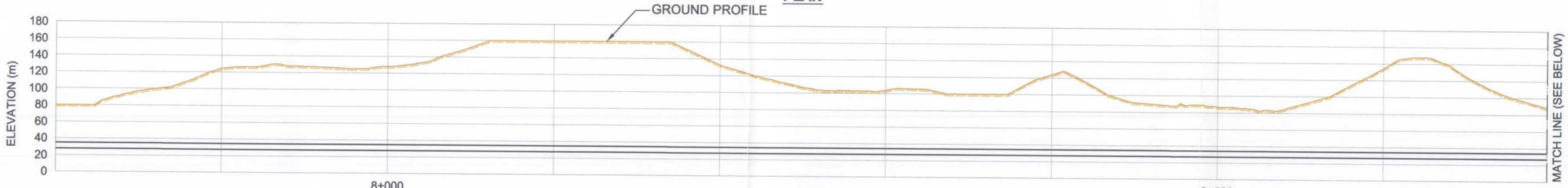

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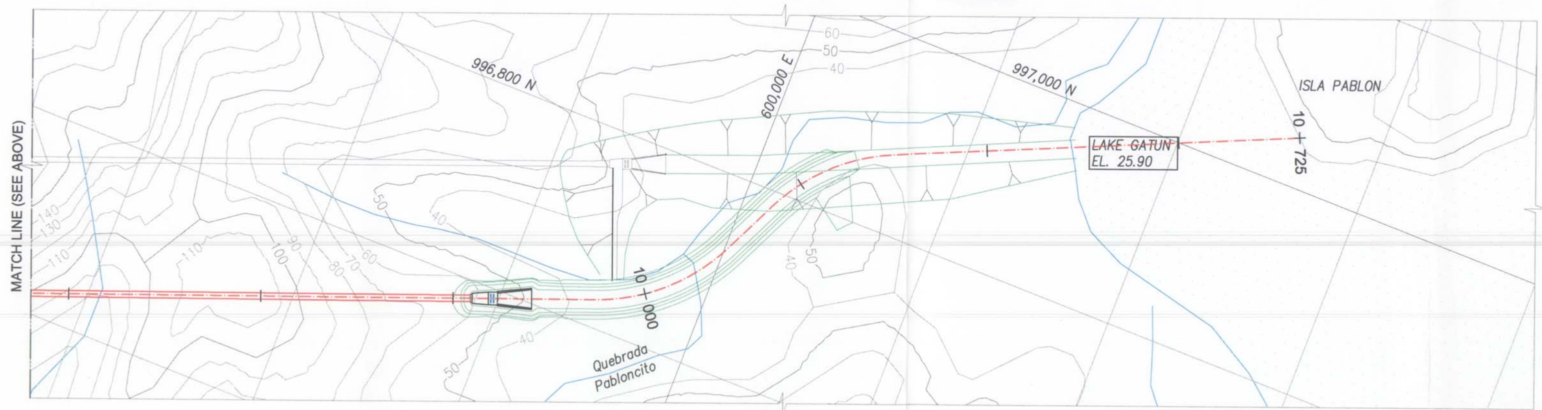
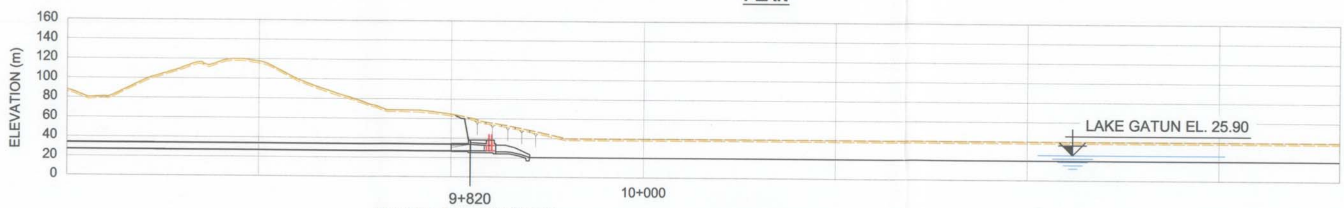


0 50 100 150 200 250 m

GRAPHIC SCALE

PLAN



PROFILE

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

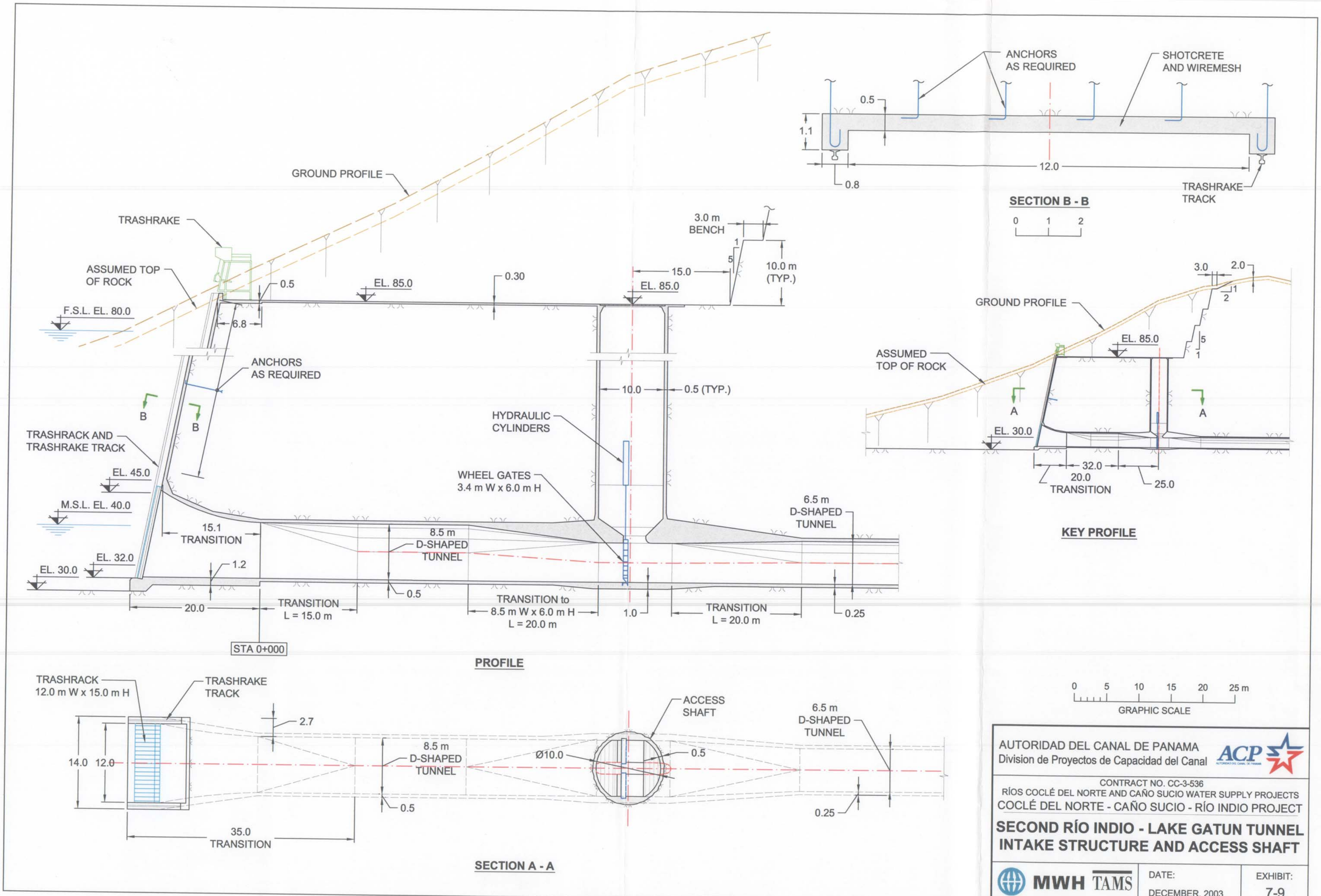
COCLÉ DEL NORTE - CAÑO SUCIO - RÍO INDIO PROJECT

SECOND RÍO INDIO - LAKE GATUN TUNNEL PLAN AND PROFILE - SHEET 3 OF 3

MWH TAMS

DATE: DECEMBER, 2003

EXHIBIT: 7-8



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

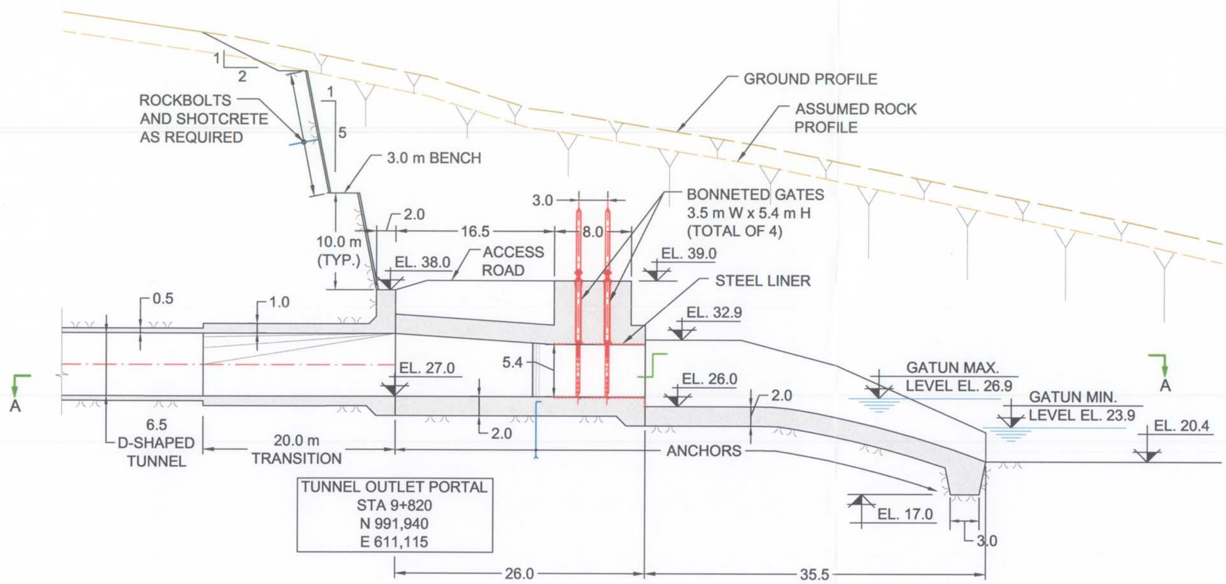
CONTRACT NO. CC-3-536
RÍOS COCLÉ DEL NORTE AND CAÑO SUCIO WATER SUPPLY PROJECTS
COCLÉ DEL NORTE - CAÑO SUCIO - RÍO INDIO PROJECT

SECOND RÍO INDIO - LAKE GATUN TUNNEL
INTAKE STRUCTURE AND ACCESS SHAFT

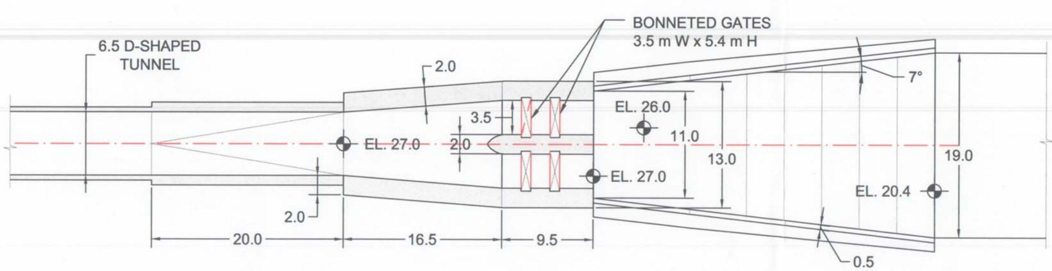
MWH TAMS

DATE: DECEMBER, 2003

EXHIBIT: 7-9



PROFILE



SECTION A - A

0 5 10 15 20 25 m
GRAPHIC SCALE

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

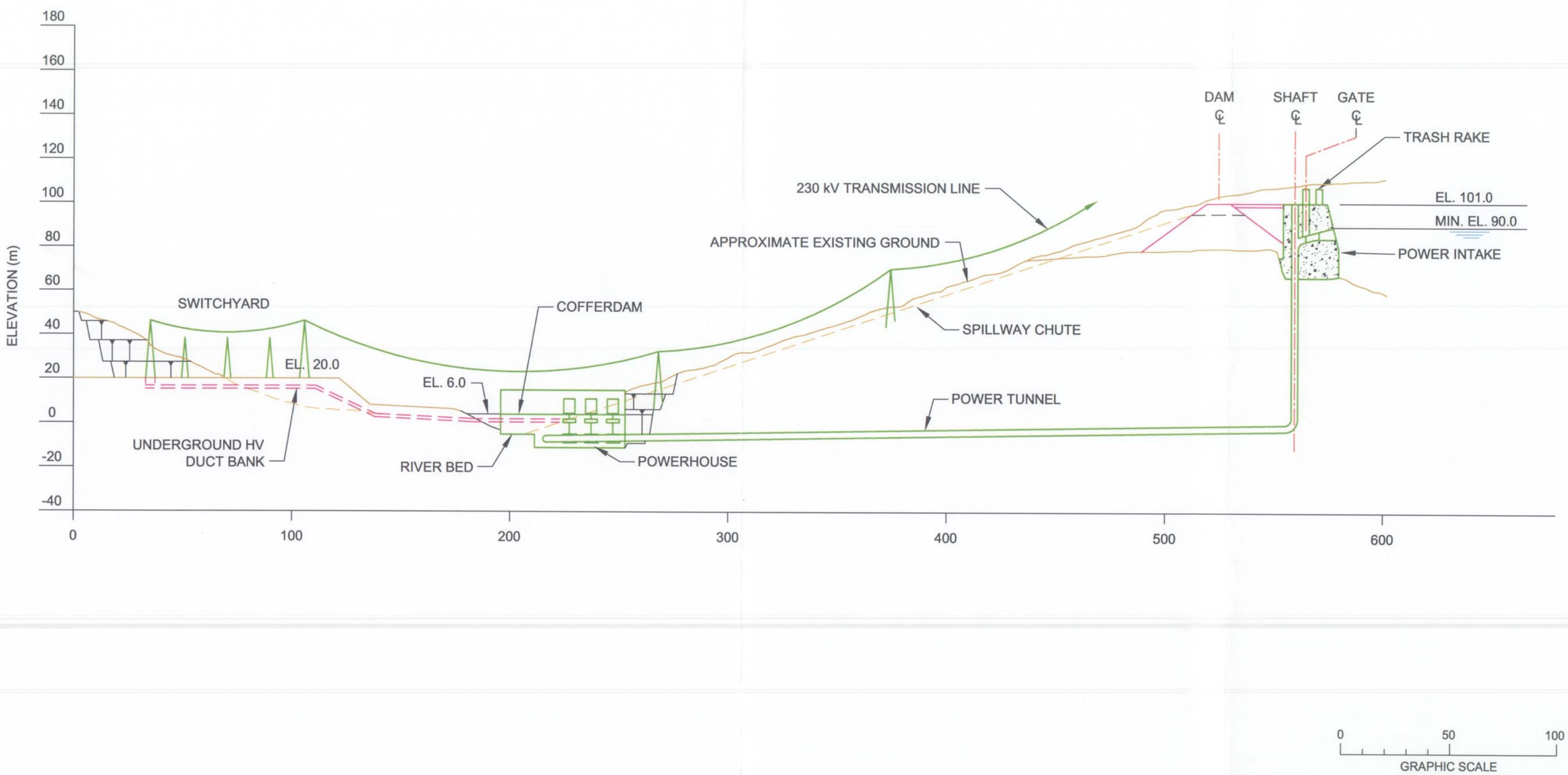
ACP

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

SECOND RÍO INDIO - LAKE GATUN TUNNEL OUTLET STRUCTURE PROFILE AND SECTION

MWH TAMS

DATE:	EXHIBIT:
DECEMBER, 2003	7-10



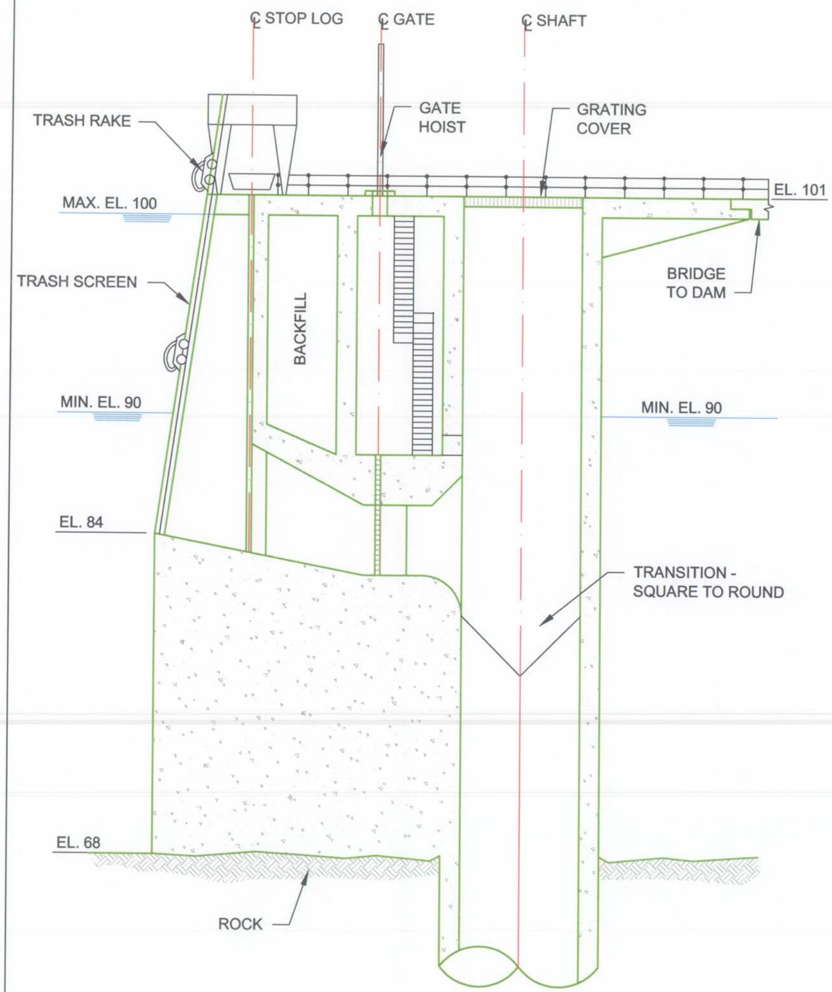
AUTORIDAD DEL CANAL DE PANAMA
Division de Proyectos de Capacidad del Canal

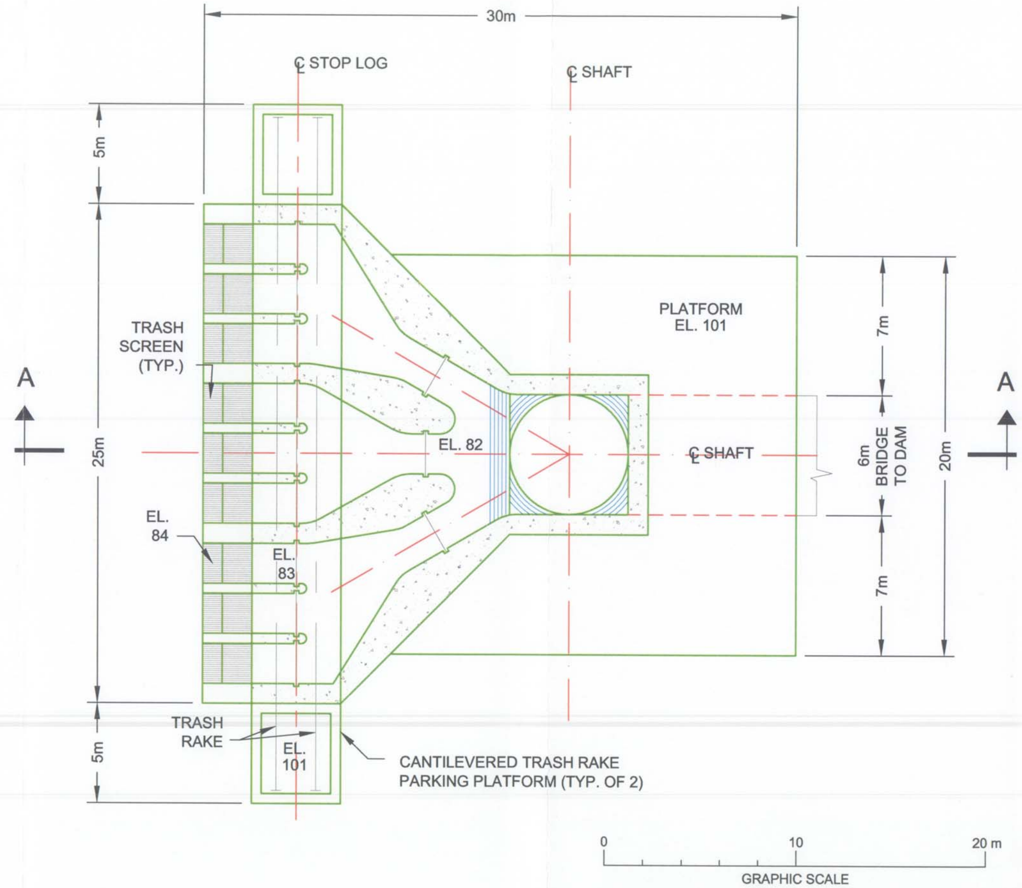
CONTRACT NO. CC-3-536
RÍOS COCLÉ DEL NORTE AND CAÑO SUCIO WATER SUPPLY PROJECTS
COCLÉ DEL NORTE - CAÑO SUCIO - RÍO INDIO PROJECT

RÍO COCLÉ DEL NORTE HYDROELECTRIC POWER SCHEME PROFILE

MWH TAMS

DATE:	EXHIBIT:
DECEMBER, 2003	8-1





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

ACP

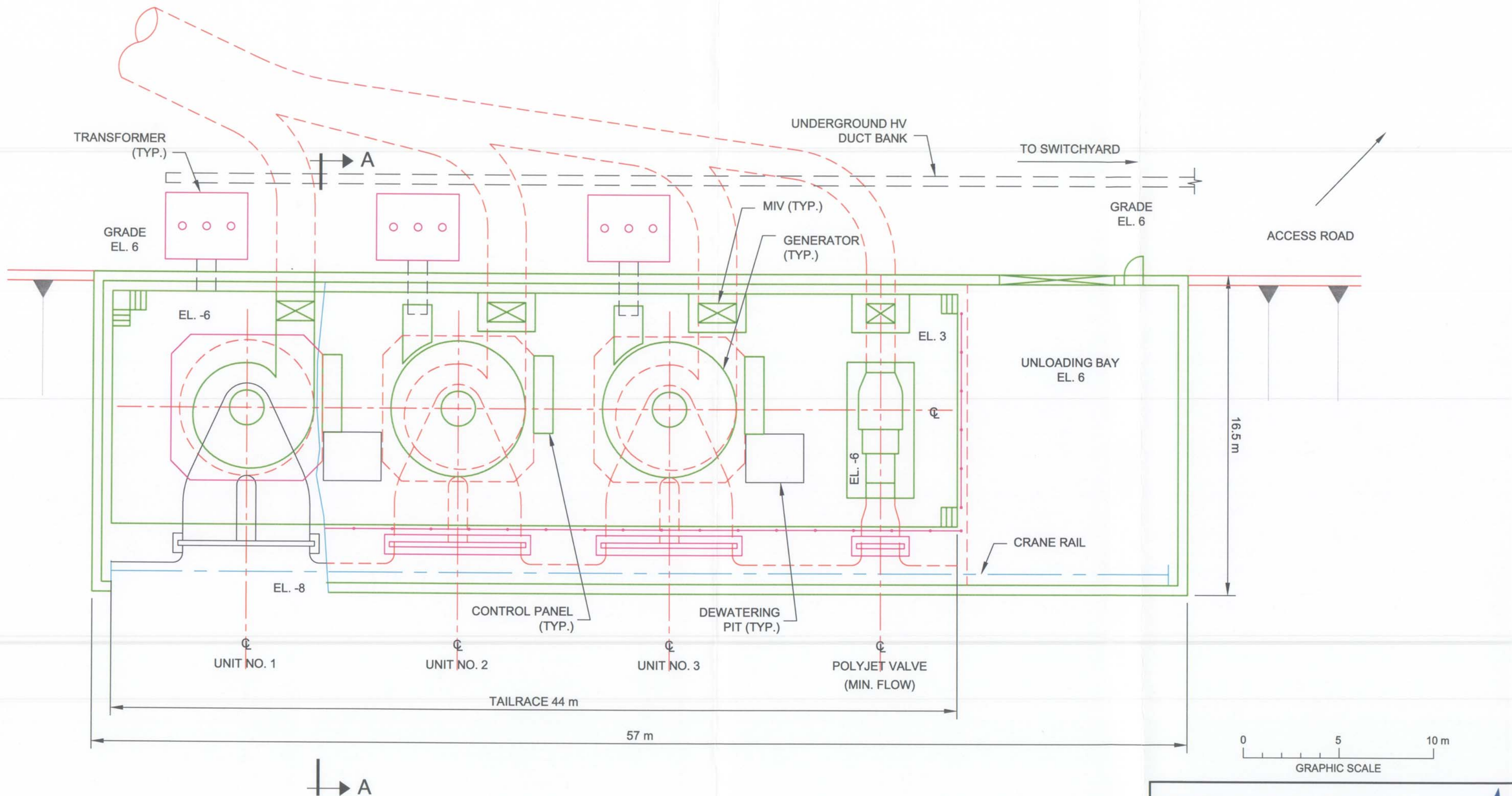
CONTRACT NO. CC-3-536
RÍOS COCLÉ DEL NORTE AND CAÑO SUCIO WATER SUPPLY PROJECTS
COCLÉ DEL NORTE - CAÑO SUCIO - RÍO INDIO PROJECT

RÍO COCLÉ DEL NORTE
POWER INTAKE - PLAN AND SECTIONS

MWH TAMS

DATE: DECEMBER, 2003

EXHIBIT: 8-2



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

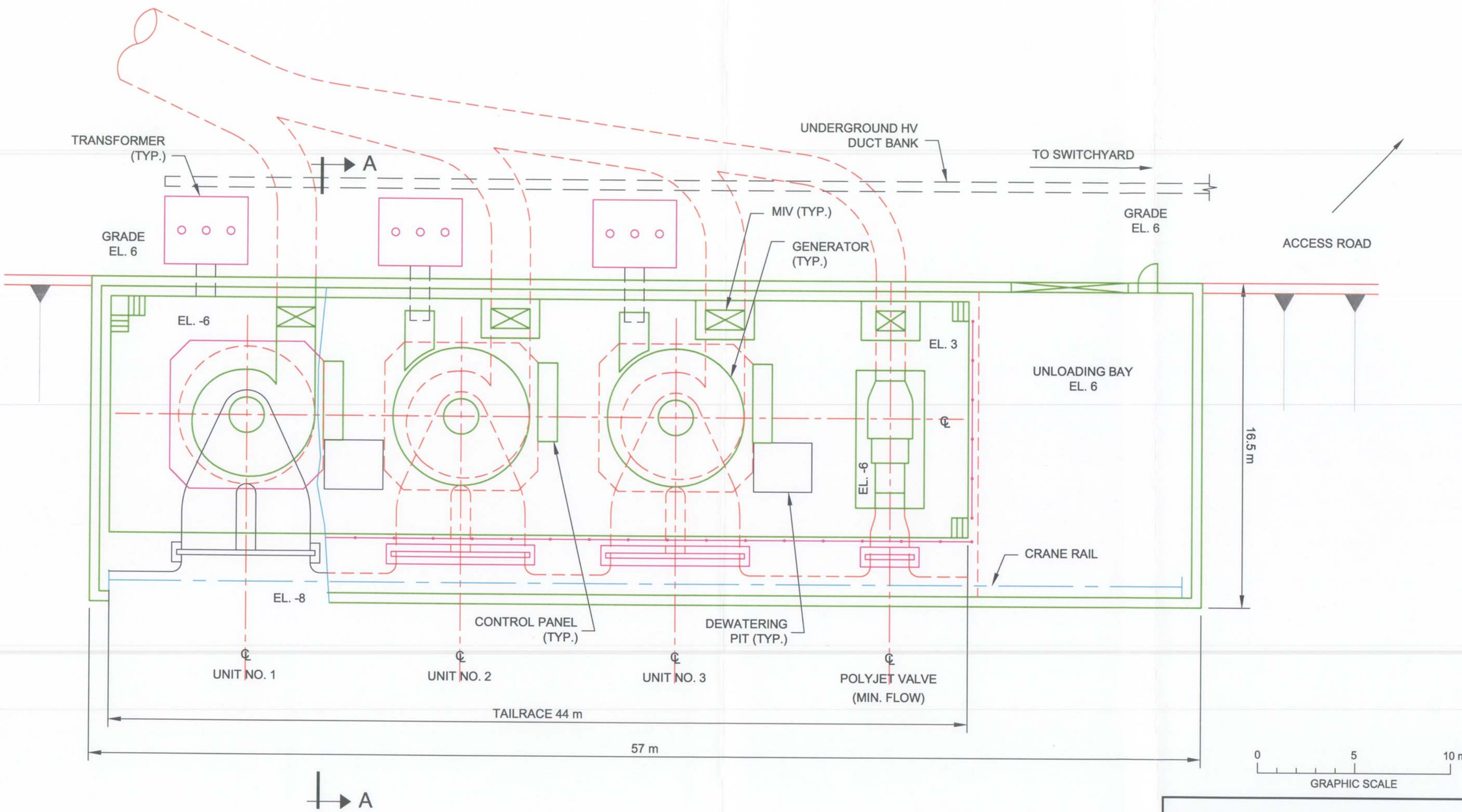
CONTRACT NO. CC-3-536
RÍOS COCLÉ DEL NORTE AND CAÑO SUCIO WATER SUPPLY PROJECTS
COCLÉ DEL NORTE - CAÑO SUCIO - RÍO INDIO PROJECT

RÍO COCLÉ DEL NORTE POWERHOUSE - PLAN

MWH TAMS

DATE: DECEMBER, 2003

EXHIBIT: 8-3



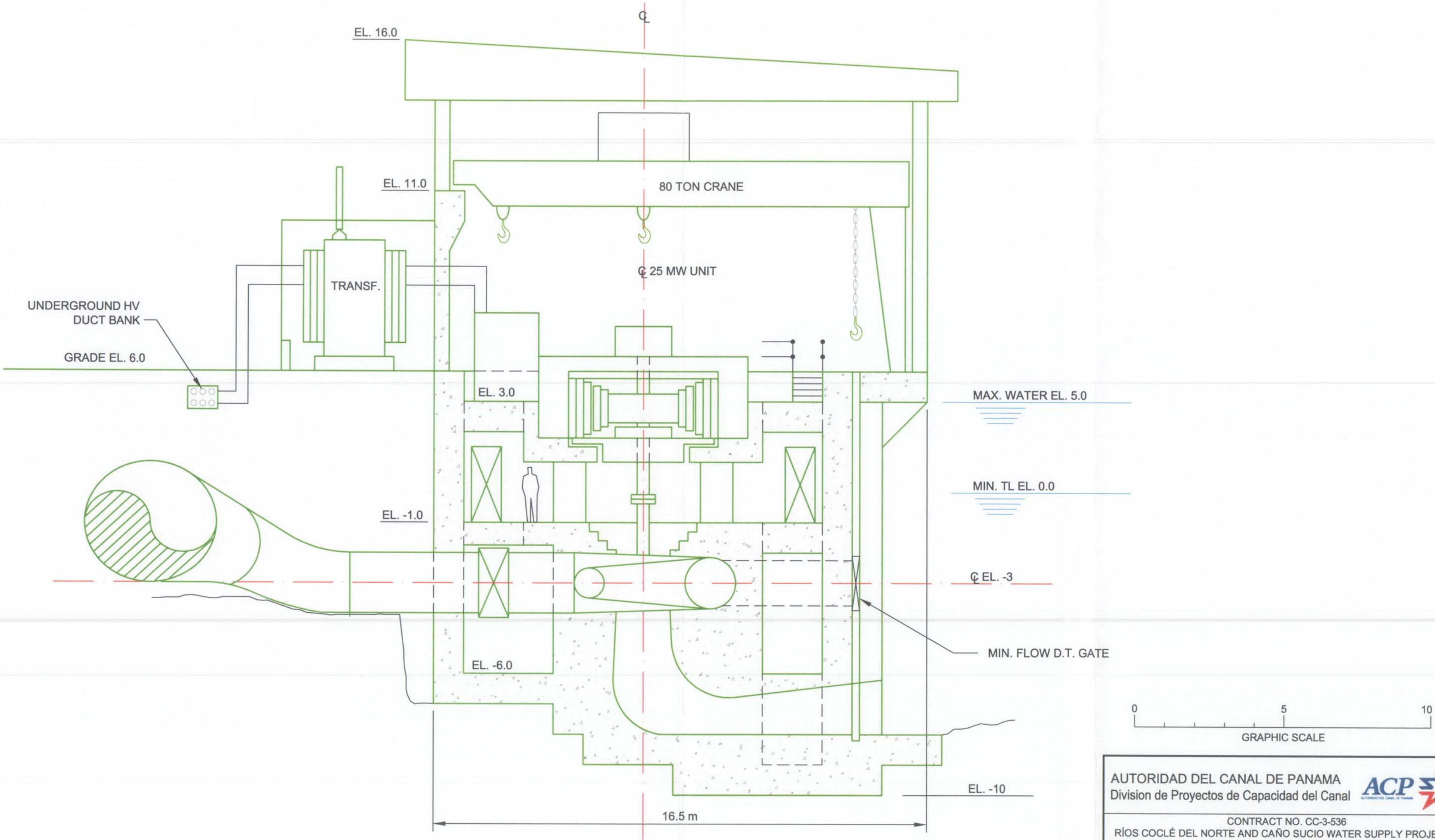
AUTORIDAD DEL CANAL DE PANAMA
Division de Proyectos de Capacidad del Canal

ACP

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

RÍO COCLÉ DEL NORTE
POWERHOUSE - PLAN

MWH TAMS	DATE: DECEMBER, 2003	EXHIBIT: 8-3



SECTION A - A

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

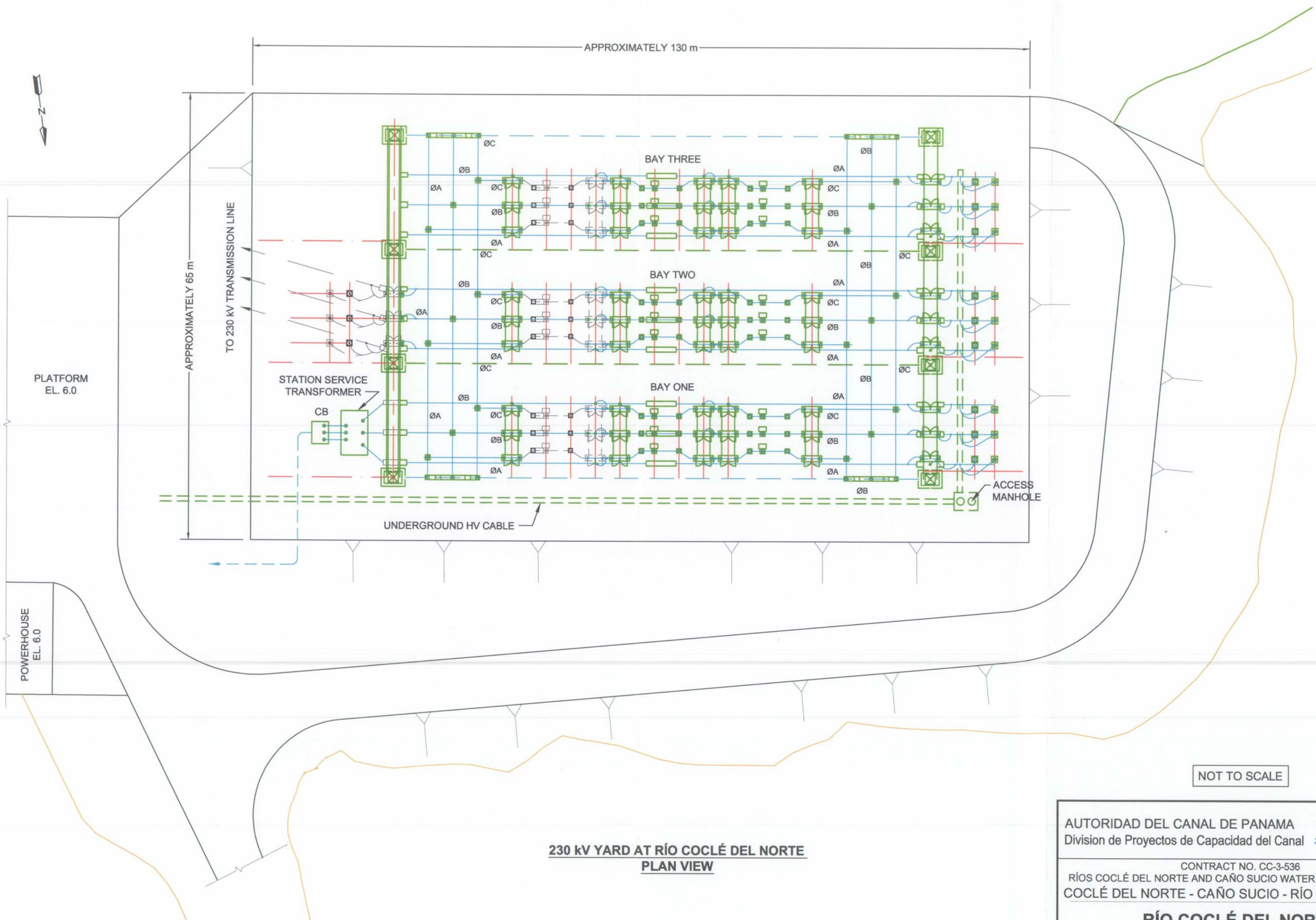
CONTRACT NO. CC-3-536
RÍOS COCLÉ DEL NORTE AND CAÑO SUCIO WATER SUPPLY PROJECTS
COCLÉ DEL NORTE - CAÑO SUCIO - RÍO INDIO PROJECT

RÍO COCLÉ DEL NORTE
POWERHOUSE - SECTION

MWH TAMS

DATE: DECEMBER, 2003

EXHIBIT: 8-4



NOT TO SCALE

230 kV YARD AT RÍO COCLÉ DEL NORTE
PLAN VIEW

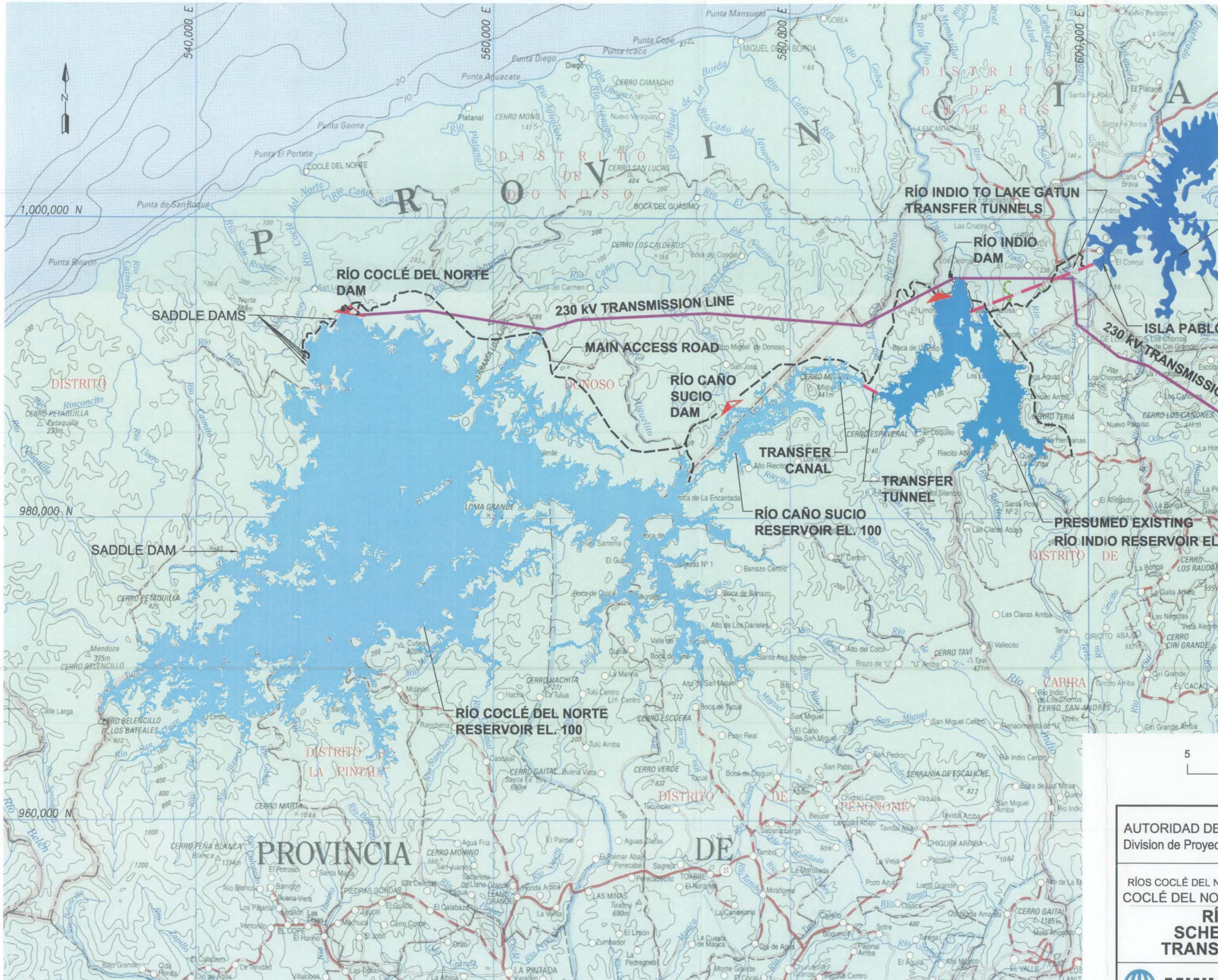
AUTORIDAD DEL CANAL DE PANAMA
Division de Proyectos de Capacidad del Canal

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

RÍO COCLÉ DEL NORTE
230 kV SWITCHYARD - PLAN

MWH TAMS

DATE:	EXHIBIT:
DECEMBER, 2003	8-5



AUTORIDAD DEL CANAL DE PANAMA

Division de Proyectos de Capacidad del Canal

ACP

CONTRACT NO. CC-3-536

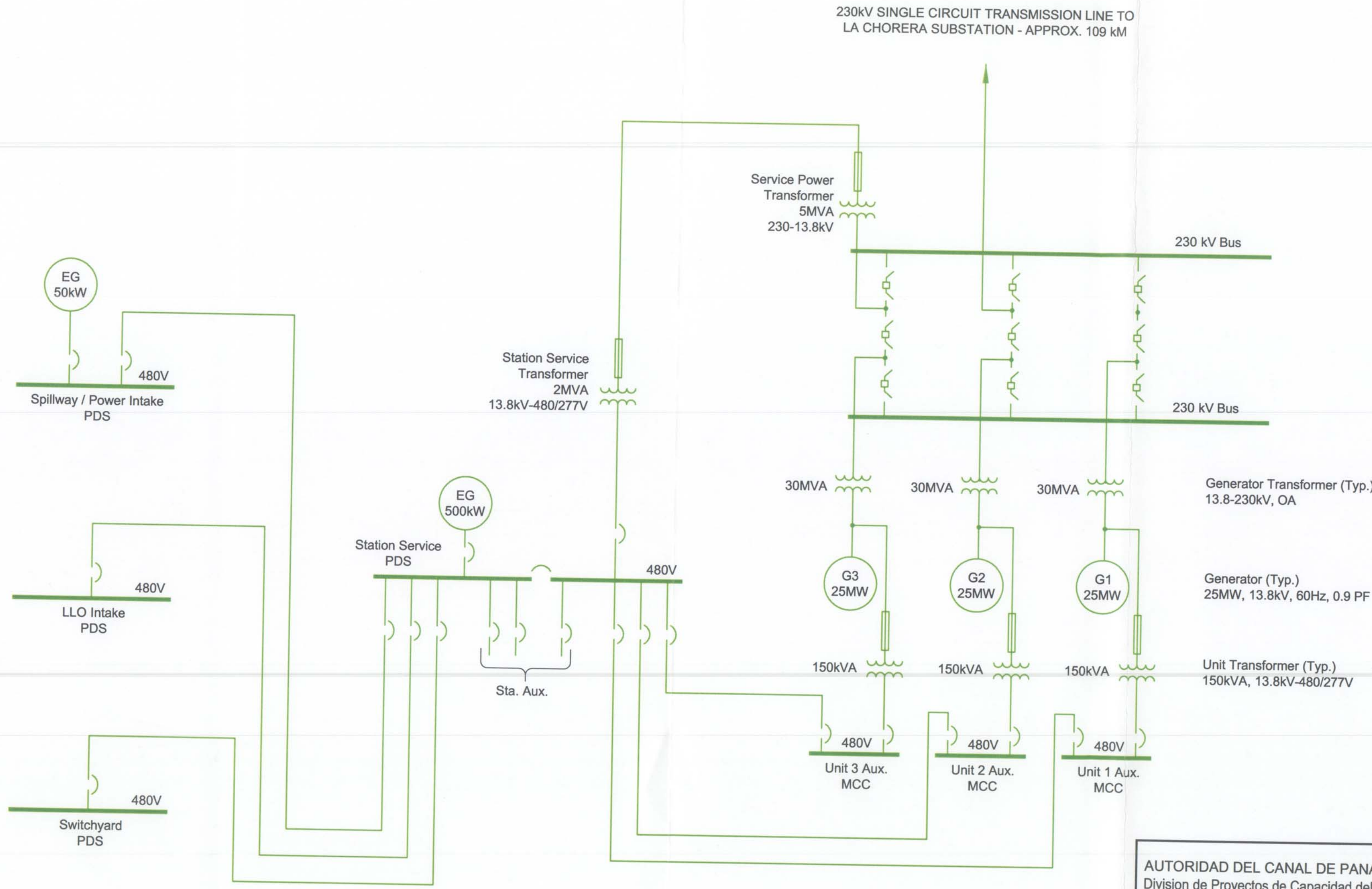
RÍOS COCLÉ DEL NORTE AND CAÑO SUCIO WATER SUPPLY PROJECTS

COCLÉ DEL NORTE - CAÑO SUCIO - RÍO INDIO PROJECT

RÍO COCLÉ DEL NORTE SCHEMATIC DIAGRAM OF THE TRANSMISSION LINE ALIGNMENT

MWH TAMS

DATE:	EXHIBIT:
DECEMBER, 2003	8-6



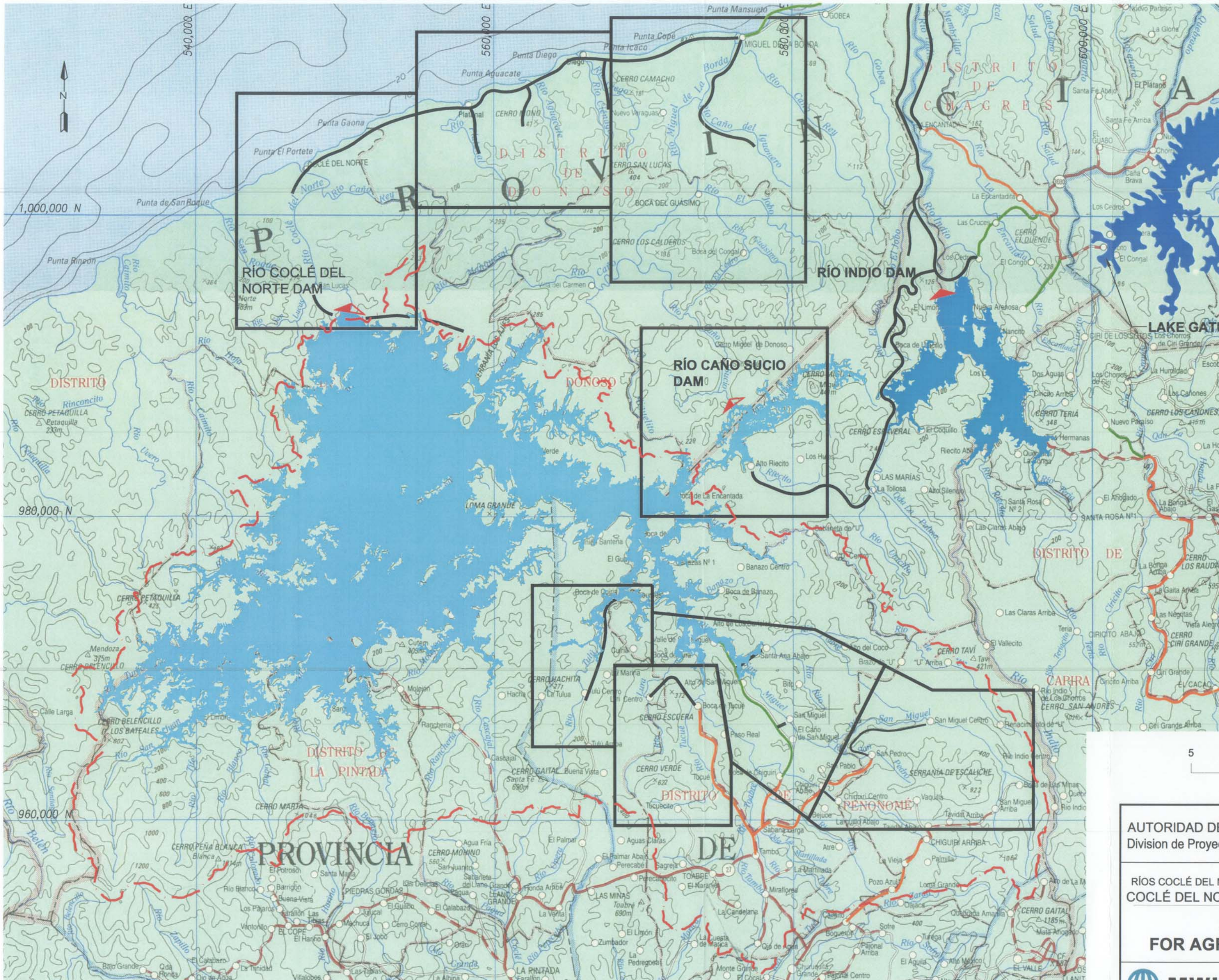
AUTORIDAD DEL CANAL DE PANAMA
División de Proyectos de Capacidad del Canal

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

RÍO COCLÉ DEL NORTE ONE-LINE DIAGRAM

MWH TAMS

DATE:	EXHIBIT:
DECEMBER, 2003	8-7



LEGEND:

- EXISTING PAVED ROAD
- EXISTING EARTH ROAD (DRY WEATHER) NEEDS UPGRADE
- EXISTING GRAVEL ROAD NEEDS REHABILITATION
- PROPOSED UPGRADE TO EXISTING EARTH ROAD (GRAVEL SURFACING, BASE, DRAINAGE, STRUCTURES
- PROPOSED REHABILITATION OF EXISTING GRAVEL ROAD
- PROPOSED NEW ROAD CONSTRUCTION.
- DRAINAGE BOUNDARY
- AREA CONSIDERED FOR AGRICULTURAL DEVELOPMENT

NOTES:

1. THE PROPOSED PROJECT ACCESS ROADS SHOWN ON THIS MAP INCLUDE ACCESS TO THE RIO INDIO PROJECT AS IT WILL HAVE BEEN DEVELOPED PRIOR TO THE IMPLEMENTATION OF THE RIO COCLE DEL NORTE PROJECT.

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

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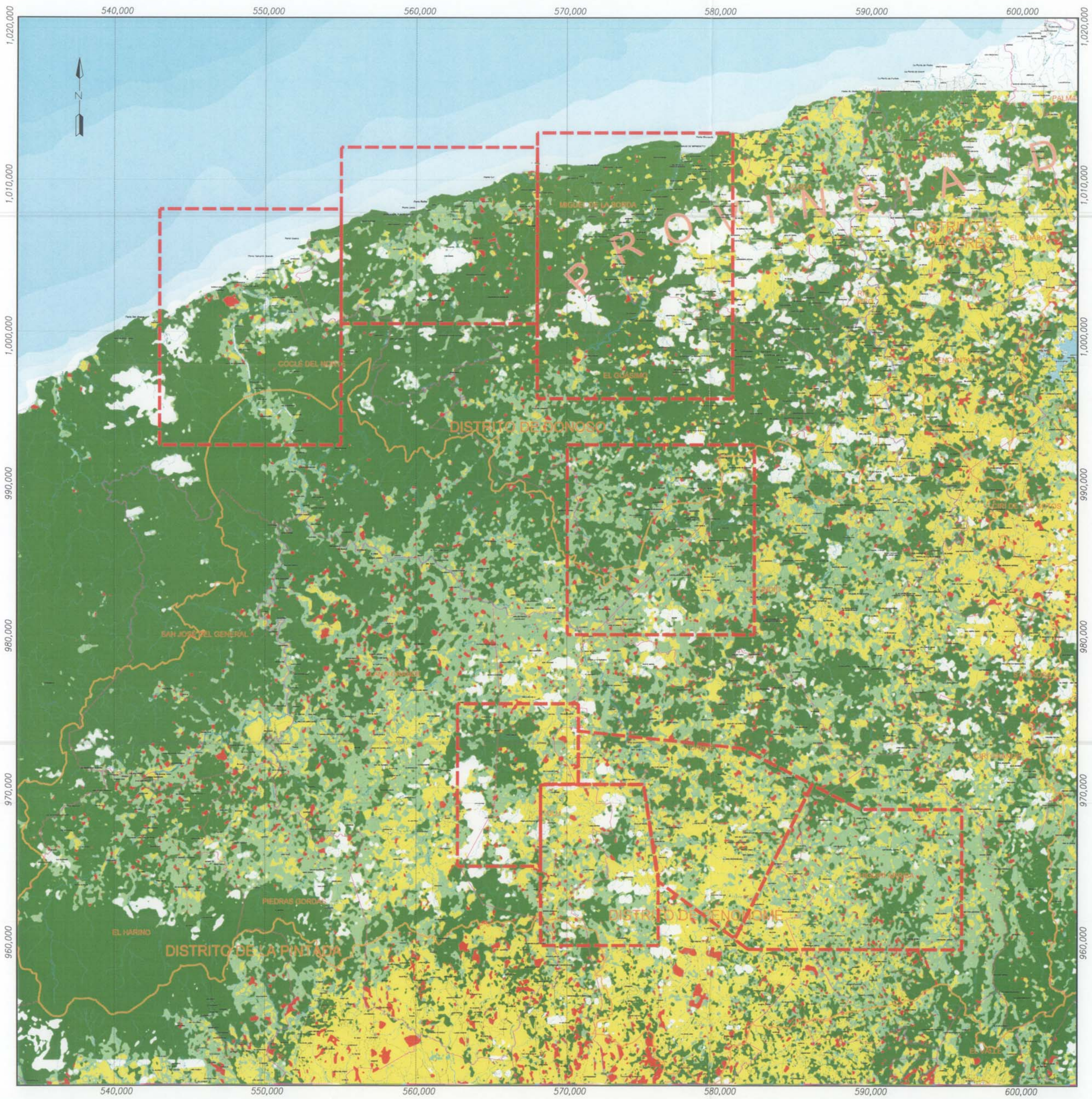
RÍOS COCLÉ DEL NORTE AND CAÑO SUCIO WATER SUPPLY PROJECTS
COCLÉ DEL NORTE - CAÑO SUCIO - RÍO INDIO PROJECT

AREA CONSIDERED FOR AGRICULTURAL DEVELOPMENT

MWH TAMS

DATE: DECEMBER, 2003

EXHIBIT: 10-1



LEGENDS:

- FOREST COVER
- SLASH AND BURN AREAS
- BUSH / THICKET
- PASTURE
- WATER BODIES
- MISCELLANEOUS (INCLUDES AREAS *Lacking Information,* SMALL CULTIVATED AREA, STUBBLE)
- AREAS CONSIDERED FOR AGRICULTURAL DEVELOPMENT SEE APPENDIX F FOR ADDITIONAL INFORMATION

NOTE:

THE LAND USE MAP HAS BEEN PREPARED BY THE ACP DIVISION DE ADMINISTRACION DEL MEDIO AMBIENTAL.

5 0 5 10 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
COCLÉ DEL NORTE - CAÑO SUCIO - RÍO INDIO PROJECT

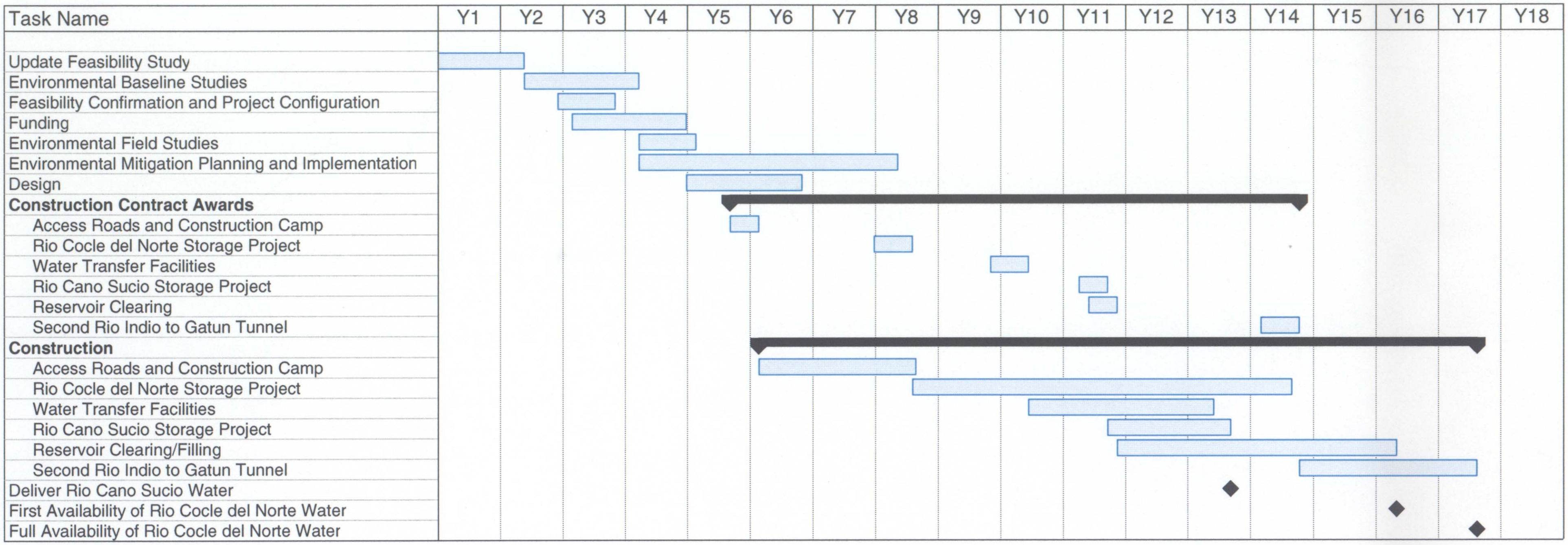
LAND USE MAP

MWH TAMS

DATE:	EXHIBIT:
DECEMBER, 2003	10-2

Cocle del Norte - Cano Sucio - Rio Indio Project

Implementation Schedule



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
COCLÉ DEL NORTE - CAÑO SUCIO - RÍO INDIO PROJECT

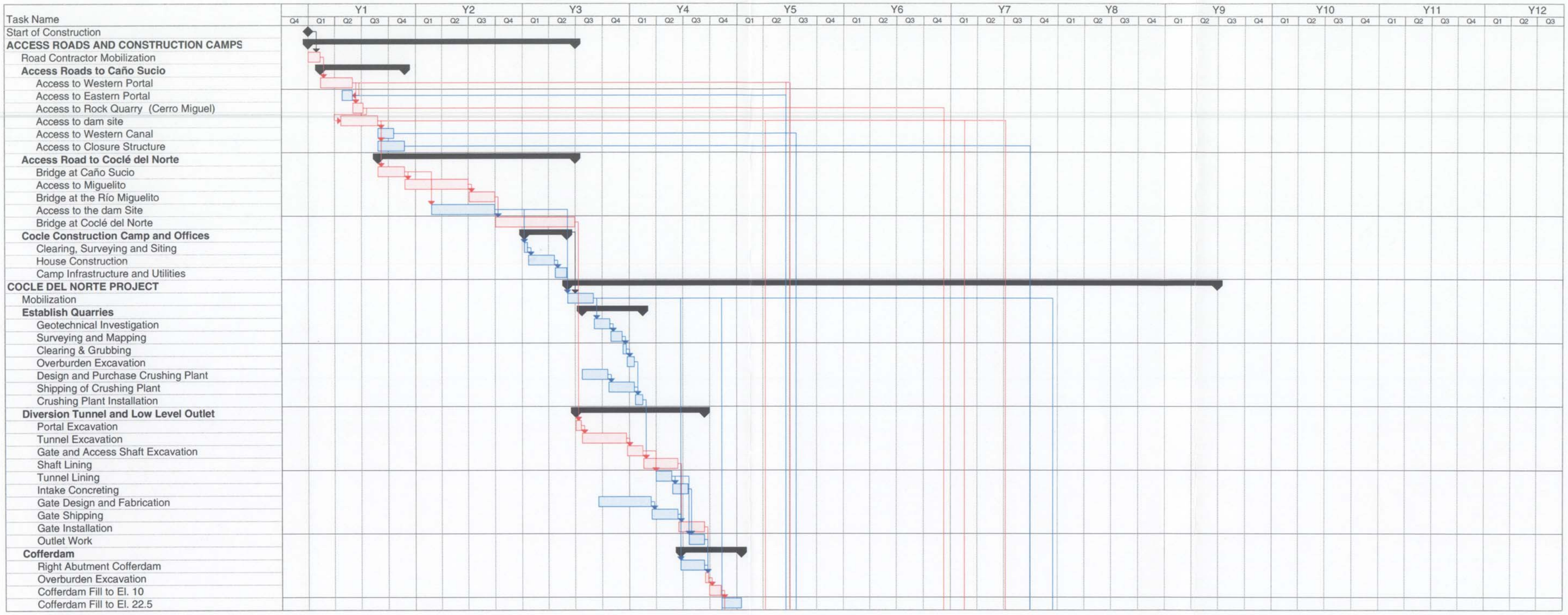
IMPLEMENTATION SCHEDULE

MWH TAMS

DATE: DECEMBER, 2003

EXHIBIT: 11-1

Coclé del Norte - Caño Sucio - Rio Indio Project
Construction Schedule



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

ACP

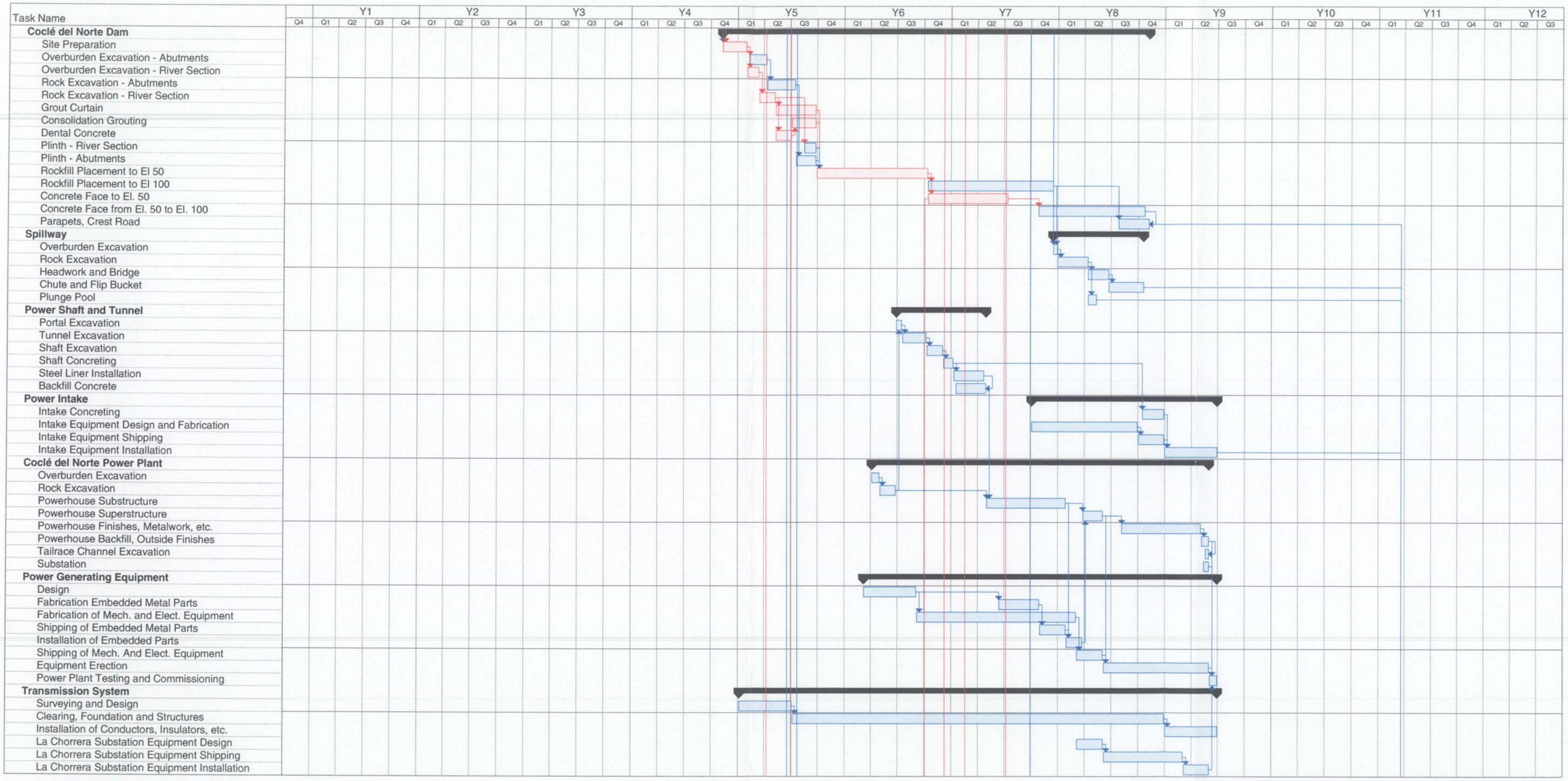
CONTRACT NO. CC-3-536
RÍOS COCLÉ DEL NORTE AND CAÑO SUCIO WATER SUPPLY PROJECTS
COCLÉ DEL NORTE - CAÑO SUCIO - RÍO INDIO PROJECT

CONSTRUCTION SCHEDULE
SHEET 1 OF 4

MWH TAMS

DATE:	EXHIBIT:
DECEMBER, 2003	11-2

Coclé del Norte - Caño Sucio - Rio Indio Project
Construction Schedule



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
COCLÉ DEL NORTE - CAÑO SUCIO - RÍO INDIO PROJECT

CONSTRUCTION SCHEDULE
SHEET 2 OF 4

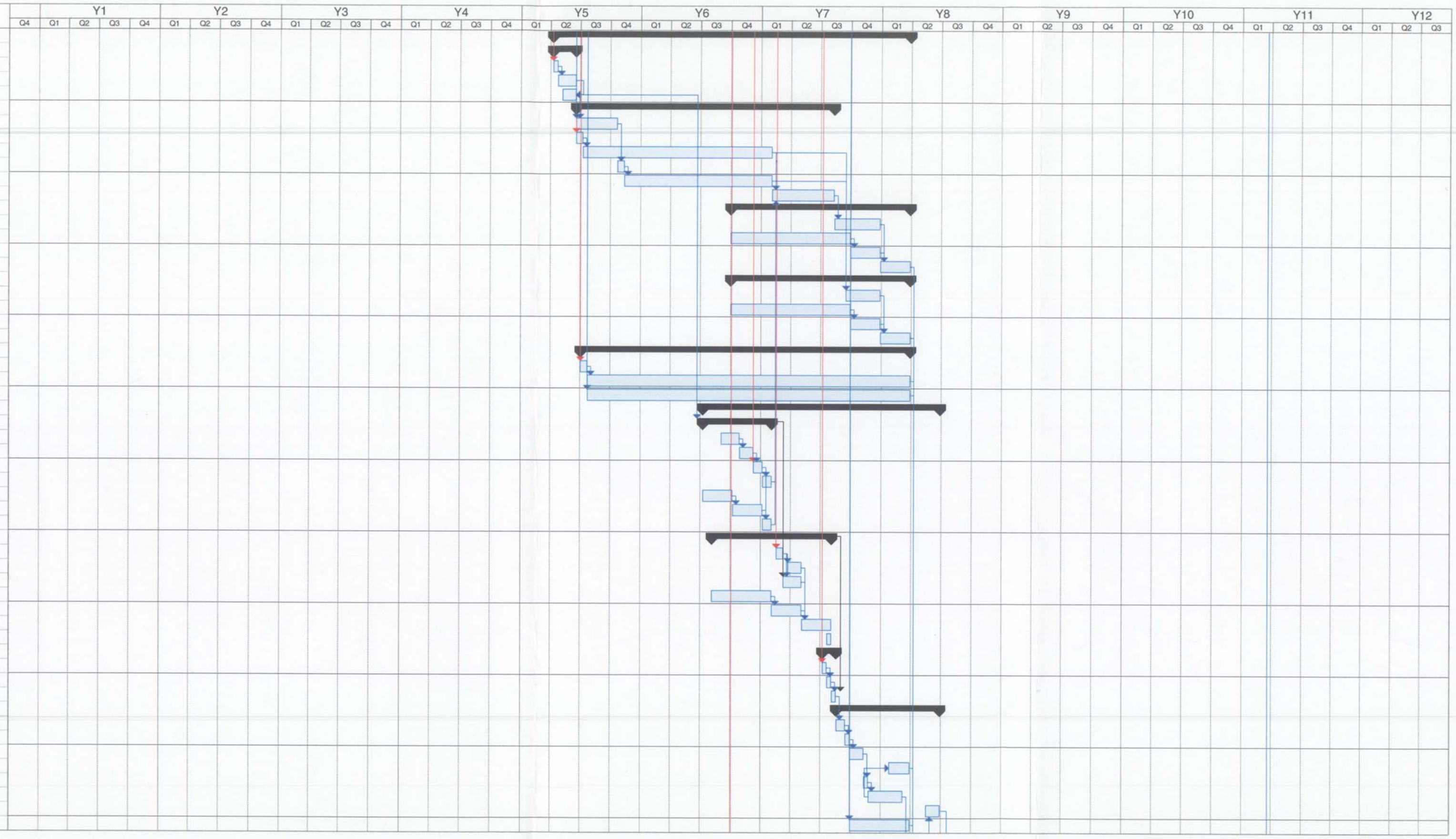
MWH TAMS

DATE: DECEMBER, 2003

EXHIBIT: 11-2

Coclé del Norte - Caño Sucio - Rio Indio Project
Construction Schedule

Task Name
WATER TRANSFER FACILITIES
Caño Sucio Construction Camp and Offices
Clearing, Surveying and Siting
House Construction
Camp Infrastructure and Utilities
Transfer Tunnel Excavation and Lining
Cofferdam Construction
Western Portal Excavation
Excavation from Western Portal
Eastern Portal
Excavation from Eastern Portal
Transfer Tunnel Lining
Transfer Tunnel Intake
Intake Concreting
Intake Equipment Design and Fabrication
Intake Equipment Shipping
Intake Equipment Installation
Transfer Tunnel Outlet Work
Outlet Concreting
Outlet Equipment Design and Fabrication
Outlet Equipment Shipping
Outlet Equipment Installation
Transfer Canal
Site Preparation
Eastern Branch Excavation
Western Branch Excavation
CANO SUCIO PROJECT
Establish Quarries
Geotechnical Investigation
Surveying and Mapping
Clearing & Grubbing
Overburden Excavation
Design and Purchase Crushing Plant
Shipping of Crushing Plant
Crushing Plant Installation
Diversion Culvert and Low Level Outlet
Rock Excavation
Culvert Concreting
Intake Concreting
Gate Design and Fabrication
Gate Shipping
Gate Installation
Outlet Work
Cofferdams
Site Preparation
Overburden Excavation
Fill Material
Caño Sucio Dam
Site Preparation
Overburden Excavation
Rock Excavation
Grouting Curtain
Dental Concrete
RCC Mass
Crest Road and Finishes
Closure Structure



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

ACP

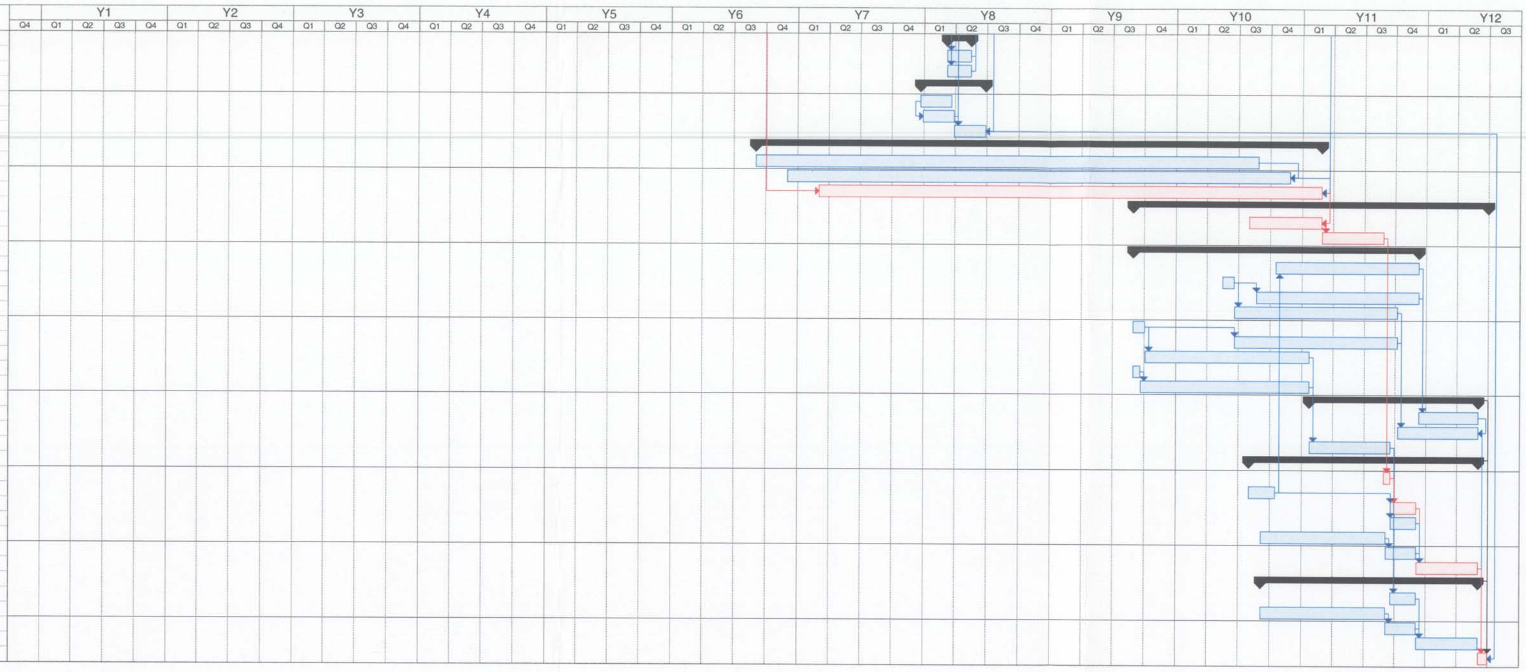
CONTRACT NO. CC-3-536
RÍOS COCLÉ DEL NORTE AND CAÑO SUCIO WATER SUPPLY PROJECTS
COCLÉ DEL NORTE - CAÑO SUCIO - RÍO INDIO PROJECT

CONSTRUCTION SCHEDULE
SHEET 3 OF 4

MWH TAMS	DATE: DECEMBER, 2003	EXHIBIT: 11-2

Coclé del Norte - Caño Sucio - Rio Indio Project
Construction Schedule

Task Name
Spillway
Headwork and Bridge
Chute and Flip Bucket
Caño Sucio Reservoir Area
Reservoir Clearing
Reservoir Mapping
Reservoir Filling
COCLE DEL NORTE RESERVOIR AREA
Reservoir Clearing
Reservoir Mapping
Reservoir Filling to El 93
SECOND RIO INDIO-GATUN TRANSFER TUNNEL
Lowering of Indio Reservoir to El 40
Cofferdam Construction
Transfer Tunnel Excavation
Excavation from Intake Shaft
Adit No.1 Modification
Excavation West from Adit No.1
Excavation East From Adit No.1
Adit No.2 Modification
Excavation West from Adit No.2
Excavation East from Adit No.2
Eastern Portal
Excavation from Eastern Portal
Transfer Tunnel Lining
Lining between Western Portal and Adit No.1
Lining between Adit No.1 and Adit No.2
Lining between Eastern Portal and Adit No.2
Transfer Tunnel Intake
Western Portal Excavation
Gate Shaft Excavation
Gate Shaft Concreting
Intake Concreting
Intake Equipment Design and Fabrication
Intake Equipment Shipping
Intake Equipment Installation
Transfer Tunnel Outlet
Outlet Concreting
Equipment Design and Fabrication
Equipment Shipping
Equipment Installation
Transfer Tunnel Commissioning



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

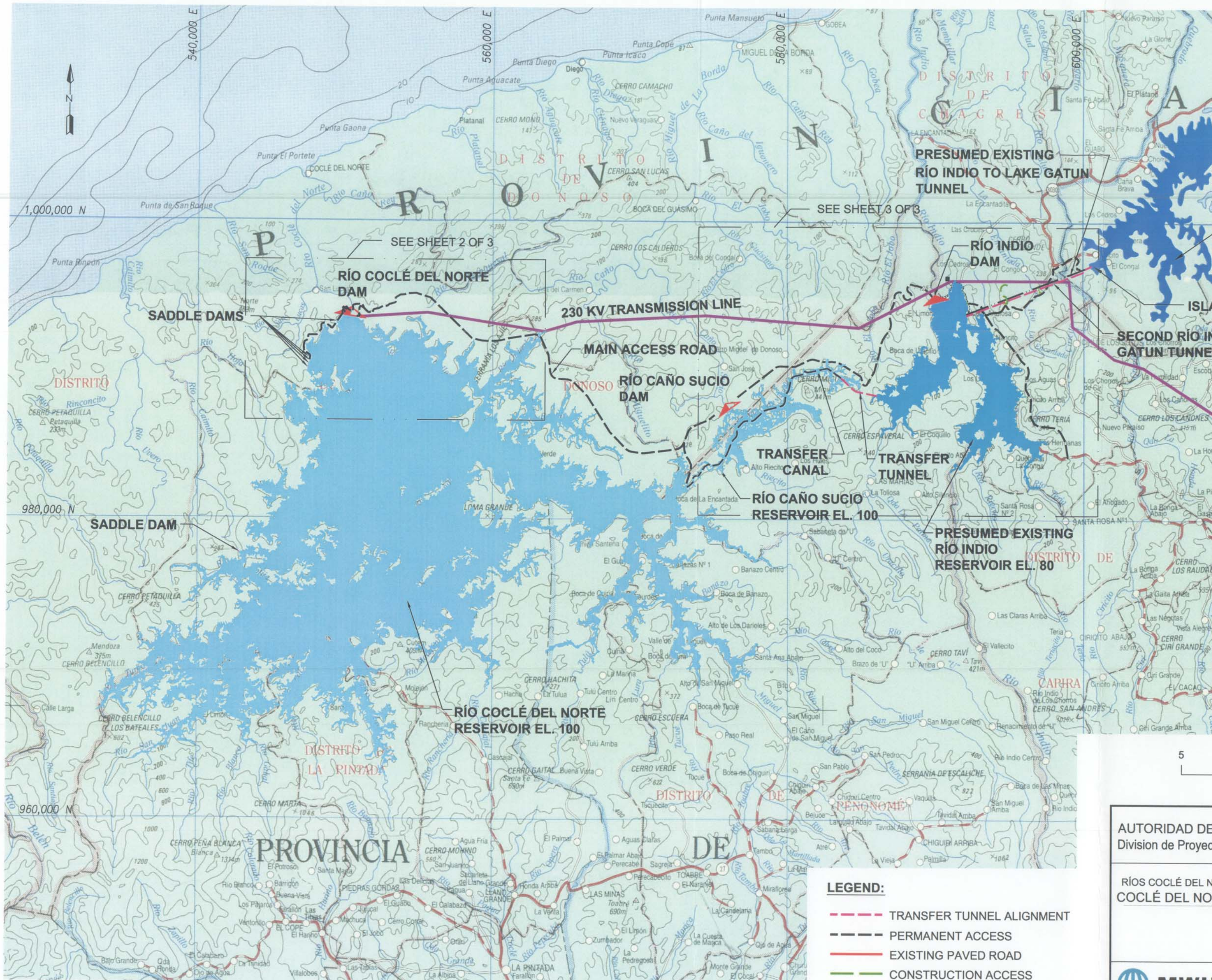
CONTRACT NO. CC-3-536
RÍOS COCLÉ DEL NORTE AND CAÑO SUCIO WATER SUPPLY PROJECTS
COCLÉ DEL NORTE - CAÑO SUCIO - RÍO INDIO PROJECT

CONSTRUCTION SCHEDULE
SHEET 4 OF 4

MWH TAMS

DATE: DECEMBER, 2003

EXHIBIT: 11-2



LEGEND:

- TRANSFER TUNNEL ALIGNMENT
- PERMANENT ACCESS
- EXISTING PAVED ROAD
- CONSTRUCTION ACCESS

5 0 5 10 km

GRAPHIC SCALE

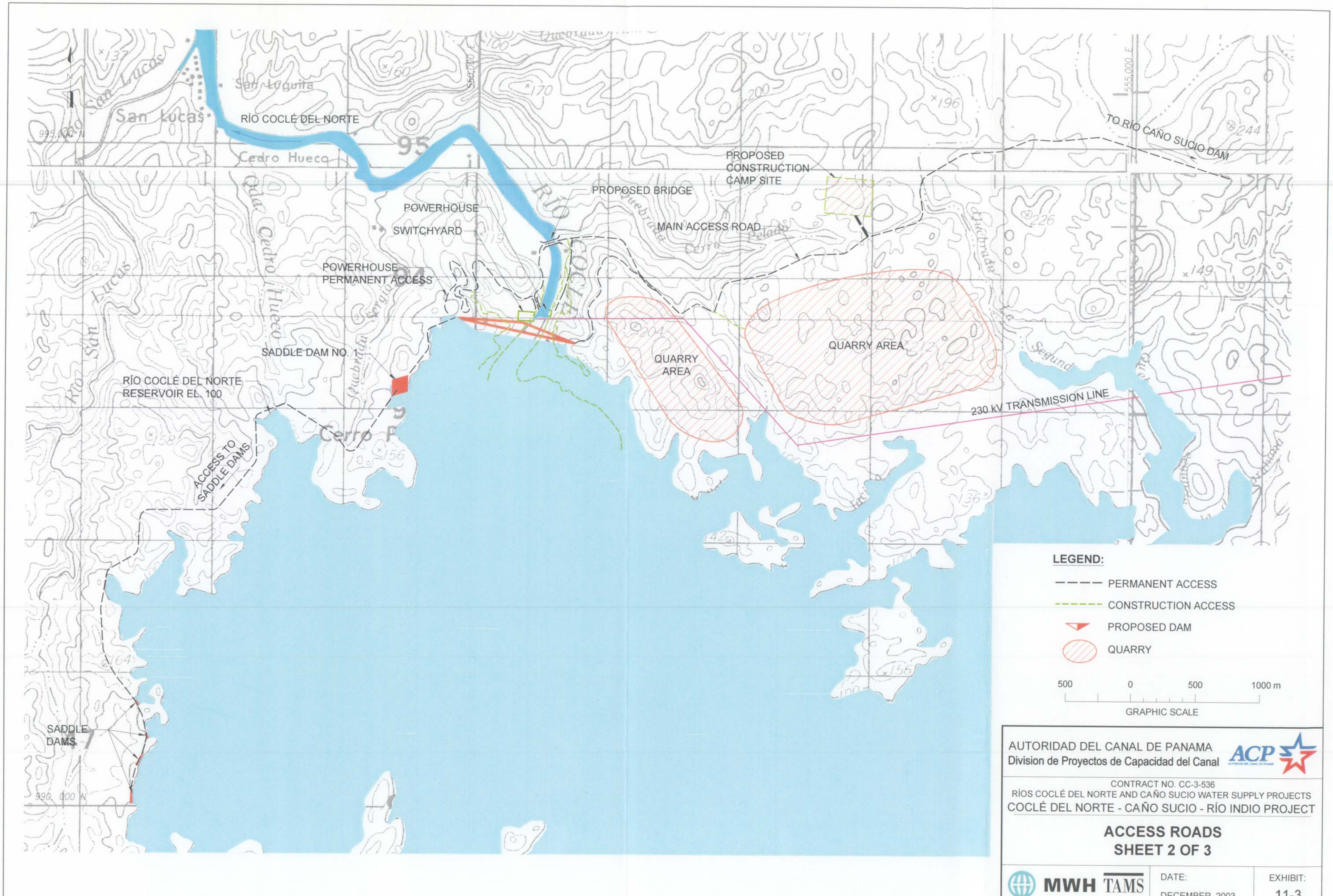
AUTORIDAD DEL CANAL DE PANAMA
Division de Proyectos de Capacidad del Canal

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

ACCESS ROADS
SHEET 1 OF 3

MWH TAMS

DATE:	EXHIBIT:
DECEMBER, 2003	11-3



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

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RÍOS COCLÉ DEL NORTE AND CAÑO SUCIO WATER SUPPLY PROJECTS
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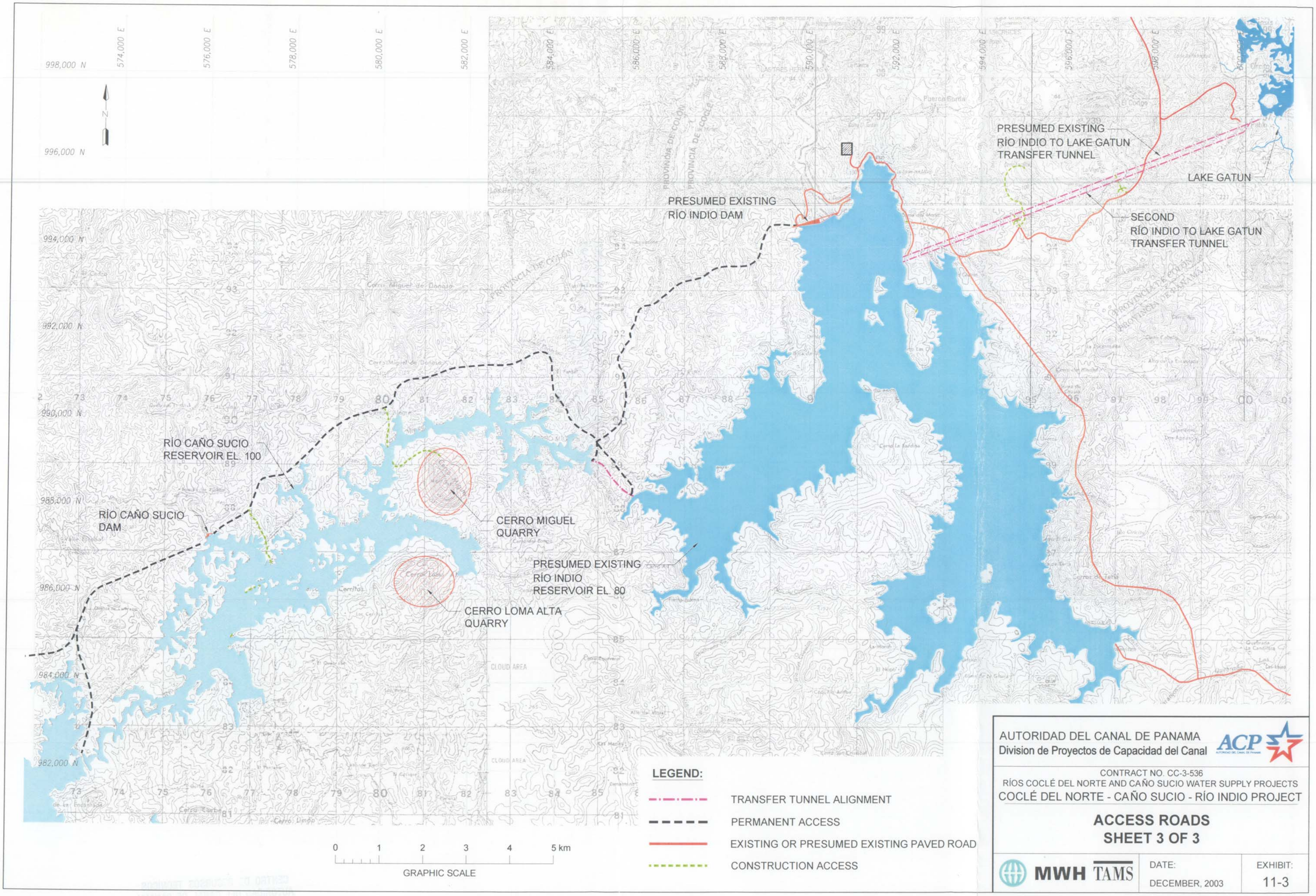
ACCESS ROADS
SHEET 2 OF 3

MWH TAMS

DATE:	EXHIBIT:
DECEMBER, 2003	11-3



PRESUMED EXISTING RÍO INDIO TO LAKE GATUN TRANSFER TUNNEL
LAKE GATUN
SECOND RÍO INDIO TO LAKE GATUN TRANSFER TUNNEL
PRESUMED EXISTING RÍO INDIO DAM
RÍO CAÑO SUCIO RESERVOIR EL. 100
RÍO CAÑO SUCIO DAM
CERRO MIGUEL QUARRY
PRESUMED EXISTING RÍO INDIO RESERVOIR EL. 80
CERRO LOMA ALTA QUARRY
PROVINCIA DE COLÓN
PROVINCIA DE COCLÉ
PROVINCIA DE PANAMA
998,000 N
996,000 N
994,000 N
992,000 N
990,000 N
988,000 N
986,000 N
984,000 N
982,000 N
574,000 E
576,000 E
578,000 E
580,000 E
582,000 E
584,000 E
586,000 E
588,000 E
590,000 E
592,000 E
594,000 E
596,000 E
598,000 E
N
LEGEND:
TRANSFER TUNNEL ALIGNMENT
PERMANENT ACCESS
EXISTING OR PRESUMED EXISTING PAVED ROAD
CONSTRUCTION ACCESS
0 1 2 3 4 5 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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COCLÉ DEL NORTE - CAÑO SUCIO - RÍO INDIO PROJECT
ACCESS ROADS
SHEET 3 OF 3
MWH TAMS
DATE:
DECEMBER, 2003
EXHIBIT:
11-3