ACP

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

Panama Canal

Work Order No.3 Feasibility Design For The Río Indio Water Supply Project

Contract Number CC-3-536

VOLUME 1: MAIN REPORT

MWH

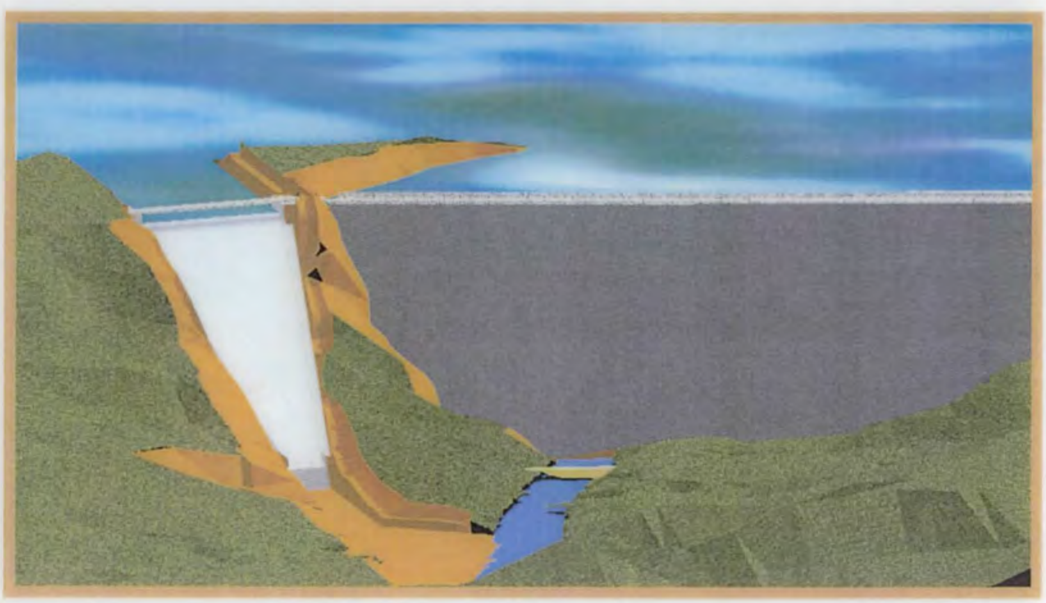
In association with

TAMS

AN EARTH TECH COMPANY

April 2003

The Río Indio Water Supply Project



MWH in association with TAMS
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AUTORIDAD DEL CANAL DE PANAMA
Division de Proyectos de Capacidad del Canal

THE PANAMA CANAL

ENGINEERING SERVICES

Work Order No. 3
Río Indio Water Supply Project

Feasibility Study

Volume 1 MAIN REPORT

APRIL 2003

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

Contract No. 20075 [CC-5-536]
Work Order No. 3
RÍO INDIO WATER SUPPLY PROJECT

Prepared for

AUTORIDAD DEL CANAL DE PANAMA

Division de Proyectos de Capacidad del Canal

By

MWH

In association with

TAMS Consultants, Inc.

Ingenieria Avanzada, S.A.

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April 2003

Executive Summary

EXECUTIVE SUMMARY

INTRODUCTION

The US Army Corps of Engineers (USACE) performed a reconnaissance study to identify and evaluate potential water supply projects to augment the supply of water to the Panama Canal. Three projects were identified as having significant potential. One of the three, the Río Indio Water Supply Project, is the subject of this study. A location map is shown on Exhibit 1. A table of significant data is presented at the end of this summary.

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 the Río Indio Water Supply Project (Project) under Contract CC-3-536, Work Order 0003, dated September 1, 1999.

OBJECTIVE OF THE STUDY

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

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 decided by the ACP to implement the Río Indio Project in conjunction with a plan to add new locks to the Panama Canal System. Under this condition, the demand for and benefits from developing the Río Indio Project could not be assessed at this time. Therefore, a determination of technical and 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 sequence adopted for the reconnaissance study, and to estimate the spillway design flood and anticipated reservoir sedimentation.

The ACP developed the long-term streamflow sequence. MWH reviewed the approach and concluded that it was logical and that the results are acceptable. The mean annual flow at the damsite is estimated to be 25.8 m^3/s. The monthly distribution of flow is shown below in m^3/s.

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
16.5	8.3	5.4	6.2	15.8	26.9	27.3	32.5	37.3	49.3	48.9	35.2	25.8

The probable maximum flood (PMF), based on probable maximum precipitation (PMP) was adopted as the spillway design flood for the Río Indio Water Supply Project. Based on information presented in the National Weather Service publication of PMP dated 1978 and the Weather Bureau publication of depth-area-duration dated 1965, the PMP was estimated to be 711 mm. The results of storm transposition and maximization procedures resulted in a slightly lower estimate.

The PMP was transformed to a PMF using the HEC-1 computer model. For a base flow of 50 m^3/s, estimated from an analysis of five major floods at the Boca de Uracillo gage, the probable maximum flood hydrograph has a peak of 4,345 m^3/s and a 5-day volume of 243 MCM.

GEOLOGIC CONDITIONS

Although originally scheduled, neither subsurface investigations nor refraction surveys were performed. All geologic interpretation is the result of several field visits, photo-interpretation, and construction materials testing.

Geology of the Damsite and Transfer Tunnel

Both abutments are almost entirely covered with colluvial and residual soils, and are moderately heavily vegetated. Although a few small, scattered rock outcrops can be observed, a moderate to deep weathered profile and thick soil cover typical of the sub-tropical climate characterizes most of the project area. Bedrock at the dam site and along the headrace tunnel route consists almost entirely of Tertiary sedimentary and volcanic rocks. The sedimentary formations are comprised of tuffaceous siltstones and sandstones, conglomerates and agglomerates thought to belong to the Caimito Formation or its age equivalent.

The valley floor at the damsite is approximately 200 m wide and is filled with alluvial terrace deposits consisting primarily of silts and clays. Bedrock is exposed in parts of the riverbed and along the cut banks of the lower right abutment.

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

Seismicity

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 Río Indio project is classified as a significant project. The project was analyzed for a return period near 2,000 years. The recommended seismic design parameters for the Río Indio Project are as follows:

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

The Río Indio dam was analyzed for deformation of the rockfill due to the MDE.

Engineering Geology

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.

It is probable that tunnel construction for the inter-basin transfer will be 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. For estimating costs, it was assumed that tunnel construction would utilize drill-and-blast techniques from six headings.

Experience indicates that groundwater inflow should be expected. The potential for encountering hazardous gases and stress-related problems is considered remote.

Construction Materials

The types of required construction materials and the anticipated source of these materials is as follows:

The diversion cofferdams will be constructed from locally available random fill obtained from the immediate area of the dam site. The most significant source is the right abutment excavation for the spillway. Another source is located two to three kilometers upstream from the dam in the terraces along the banks of the river.

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. Several quarry areas were identified within nine kilometers

Rockfill for the dam will be obtained from required excavation, mostly sandstone units from the right bank spillway excavation, and from quarry run material. Since the local sandstone appears to be suitable for rockfill, there is a possibility of opening a sandstone quarry closer to the site than the igneous rock quarry indicated above. Materials for backfill will come from the required excavations, including use of tunnel excavation spoil.

DESCRIPTION OF RÍO INDIO WATER SUPPLY PROJECT

The major elements that comprise the Río Indio Water Supply project include:

- A concrete face rockfill dam at the Tres Hermanas site with its crest at El. 83.
- A 4.5 m diameter, 8,350-m long water transfer tunnel from the Río Indio Reservoir to Lake Gatun.
- A minimum release facility, which will include a 1.6 MW power plant

A general plan of development and a plan of the dam and appurtenant works are shown on Exhibits 2 and 3.

The location of the dam was selected on the basis of a dam site study that evaluated 7 locations between the mouth of the river and the confluence of the Indio and Uracillo rivers. The type of dam was selected after consideration of roller compacted concrete, convention gravity, earth-core rockfill, and concrete faced rockfill dams. The roller compacted concrete dam is a viable alternative.

The dam will impound a reservoir with a gross storage capacity of 1,577 MCM at El. 80, the full supply level. Live storage between El. 80 and El. 40 will be 1,294 MCM. Sediment deposition is not expected to be a problem. The reservoir area at the full supply level, El. 80, is 45.6 square kilometers.

Upon completion of the dam and transfer tunnel, the yield of the water supply system for the Panama Canal with be increased by about 1,200 million cubic meters per year with a reliability of 99.6%. This is about equivalent to about 15.8 additional lockages per day in the canal system.

Rio Indio Dam will be constructed of durable, free-draining compacted rockfill obtained from required excavation of the right abutment and from nearby quarries. The slopes of the upstream and downstream faces will be conservatively set at 1.4H:1.0V. The main body of the dam will be comprised of rockfill and the downstream shell will be coarse rockfill. The rockfill shells of the dam have an in-place volume of about 2.7 million cubic meters. A reinforced concrete facing will act as the impermeable membrane. The average thickness of the concrete face will be 0.4 m.

With reservoir full supply level at El. 80, two saddle dams will be required, one on the north side of the right abutment and the second about 4 km south-east of the main dam. The saddle dams will contain a volume of about 860,000 m^3 of material.

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 950 m^3/s using a surcharge of 4.0 m above the full supply level.

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.

The facilities for the diversion of the Río Indio during construction consist of cofferdams upstream and downstream from the damsite and a tunnel in the right abutment. The tunnel will serve to:

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

The diversion tunnel will be a 4.0-m diameter, modified horseshoe with vertical sides and a horizontal invert, 635 m long. Under the 50-year flood event, the tunnel will discharge about 113 m^3/s with the upstream water surface at El. 21.6 and the downstream water surface at El. 7.8. The upstream and downstream cofferdams will be at E. 22.5 m and El. 8.5 respectively. The total volume of both cofferdams will be about 107,500 m^3.

A low-level intake structure will be constructed at the intake portal and a gate shaft will be constructed at about the mid-point of the tunnel to facilitate its use as a low level outlet for reservoir evacuation.

A minimum release facility, sized to pass 2.6 m^3/s, will be located in the right abutment. The intake structure will be located on the face of the CFRD just below El. 40.0, the minimum operating level of the reservoir. The intake will connect through the face of the dam to a steel penstock, nominally sized at 1.0 m. A 1.6 MW turbine/generator will be included in the minimum release facility to provide power to the resettlement area and for project operation.

The water transfer tunnel consists of an approach channel, an intake structure, the tunnel, and an outlet structure. The approach channel is 100 m long and has its invert at El. 30. The channel is excavated as a trapezoidal section. The intake structure is a reinforced concrete structure with an opening of 5 m by 10 m protected by trash racks. Intake flow velocities at maximum discharge are limited to 1.5 m/s. The intake transitions to the tunnel, which is an 8,350-m long modified horseshoe shaped tunnel with vertical sides and a horizontal invert. The finished diameter of the tunnel is 4.5 m and the capacity is 94 m^3/s and 43 m^3/s at full supply level, El. 80 and minimum pool level, El. 40, respectively. A gate shaft and gate will be provided at the upstream end of the tunnel for dewatering. At the downstream end of the tunnel, an outlet structure will house two 2.5-m wide by 3.6-m high bonneted guard gates and bonneted control gates in series. This will provide redundancy for reliable operation and maintenance, and additional flow control.

Operation facilities will include a SCADA system for monitoring and operation of the project remotely, security and lighting at the dam, spillway, and at the intake, and outlet of the transfer tunnel. Landscaping and drainage will also be provided at these project features. Limited maintenance facilities will be retained from the temporary construction facilities.

It is estimated that the project will require about 8 years for implementation and 5 years (58 months) for construction. The first 16 months of the 5-year construction period are required to mobilize, complete most of the access roads, and establish the construction camp. Construction of the dam and appurtenant works and the water transfer tunnel will require about 42 months. An implementation schedule is shown on Exhibit 4.

POTENTIAL FOR ADDING HYDROPOWER

As a part of these studies, a power market study was performed to confirm the need for additional generation and the potential for adding hydro to the Río Indio Project was evaluated.

The Existing Power Market

The most recent estimated total energy demands of the Panama National Integrated System (PNIS), developed in 2000 for the medium and high growth scenarios, are shown below:

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

The existing PNIS has an installed capacity of 1,079 MW (year 2002). On the basis of the peak load and energy requirements, the existing, committed, and scheduled retirement, the power balance in year 2010 should be about as follows:

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

Therefore, it can be concluded that there is a substantial market for additional power in the near future and that the Indio hydro will be easily absorbed into the PNIS.

Potential for Adding Hydropower to the Río Indio Project

Studies were performed to determine if the addition of hydropower to the water supply project was viable. The studies consisted of estimating the potential energy production under a variety of conditions, evaluating the alternative locations for generating electricity, and determining the viability of the most attractive alternatives.

Three alternatives to generate power as a part of the Río Indio Project were evaluated:

1. Maximize production at the tunnel powerplant
2. Maximize the power production at the Gatun Powerplant.
3. Maximize the power production at Río Indio Dam.

The economic value of the development was based on information provided by the ACP Power Department. It was suggested that the benefits be computed on the basis of the current value of energy and capacity, which are $45/MWh and $60/kW-year respectively.

On the basis of a comparison, Alternative 1, maximizing generation at the tunnel powerplant is selected as providing the best opportunity for the development of hydropower as it produces nearly 2.5 times the energy and, during the period when demand is less than yield, the excess water transferred from Indio to Gatun would be used to generate at the Gatun Power Plant.

The major facilities associated with the selected power generation alternative include:

- A 2.5 MW powerplant at the Río Indio Dam
- A 14 MW powerplant at the end of the water transfer tunnel
- An increase the diameter of the water transfer tunnel from 4.5 m to 5.0 m for hydraulic reasons
- A 47-km long, 115 kV transmission line from the tunnel powerplant to the La Chorrera substation and a 12.6-km long, 13.8 kV line from the dam to the tunnel powerplant.

The cost of this alternative is estimated to be about $35 million. The project would generate an average of 55 GWh per year. Based on a life-cycle analysis, the economic internal rate of return for this configuration is 9.1%. As this return is significantly less than the opportunity cost of capital for ACP (12%), the addition of power to the Río Indio Project is not recommended at this time.

Although power generation is not recommended as a project purpose, the ACP will install a powerplant at the base of the dam to generate with the minimum environmental release. The electricity from this plant will be used for social benefits, both for irrigation and household needs in the resettlement area, and to operate the project facilities.

POTENTIAL FOR ADDING COMMERCIAL AGRICULTURE

A study was performed to assess the potential for commercial irrigated agriculture on the lands around the reservoir. 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 land use was initially identified by reviewing available aerial photographs and verified by a field reconnaissance. 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. As a result of the land resources investigations, eight potential development areas were identified having a gross area of approximately 5,500 ha and a net area for farming of about 3,500 ha.

Crops included in a suggested pattern are dry-seeded and transplanted rice, maize, plantain, cassava, vegetables, yams, pasture, and nursery crops. These crops were selected to match the current farmer preferences while allowing for the production of a marketable surplus as well as farm-family requirements.

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.

Costs were estimated to average about $16,000/ha over the eight areas. Based on cropping pattern options for each area, average net benefits were estimated by hectare and for each potential area using data from the Ministry of Agriculture Extension Service.

The economic returns of the agricultural development ranged from 7% to 12%. Therefore, it is concluded that the potential for irrigated agriculture exists, however, implementation of the development is not warranted at this time.

COST OF THE PROJECT

The cost estimate for the construction of the Río Indio Water Supply Project has been developed on the basis of the present feasibility design and construction schedule. The estimates represent the prevailing rates during the middle of 2001. The estimates are based on the assumption that an international contractor will construct the storage facilities and the water transfer tunnel without restriction on sources of supplies and equipment. The unit prices have been estimated at feasibility level. The quantities have been estimated with the constraint of no subsurface investigations. A summary of the construction cost is shown in the following table.

SUMMARY COST OF THE RÍO INDIO PROJECT

Item	Estimated Cost
Land Acquisition and Resettlement	$26,100,000
General Costs including Construction and Permanent Access	$23,839,000
Diversion	$3,603,000
Main Dam	$52,704,000
Spillway	$6,043,000
Low-Level Outlet	$3,049,000
Saddle Dams	$7,427,000
Interbasin Water Transfer Tunnel	$46,765,000
Minimum Release Facility	$837,000
Operation Facilities	$1,139,000
Subtotal Direct Cost	**$171,506,000**
Contingency	$28,868,000
Direct Cost	**$200,374,000**
Engineering and Administration	$30,056,000
Construction Cost (mid-2001 price level)	**$230,430,000**

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, insurance, and annual allowances for resettlement, watershed management, and the implementation of a mitigation plan.

The annual operation and maintenance costs are summarized below:

ANNUAL OPERATION AND MAINTENANCE COST

Item	Annual Cost
O&M	$1,020,000
Replacement	$114,000
Admin and General Expenses	$228,000
Insurance	$230,000
Resettlement Administration	$100,000
Watershed Management	$150,000
Mitigation Plan Implementation	$100,000
Total	**$1,940,000**

CONCLUSIONS AND RECOMMENDATIONS

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

- The Río Indio Water Supply Project is technically feasible;
- The dam site selected in the Reconnaissance Report is the most suitable site for the development of the water resources of the Río Indio Basin;
- Either a concrete-face rockfill dam or a roller compacted concrete dam is suitable for the site and cost effective. A concrete-faced rockfill dam was selected based on a preliminary analysis and discussions with the ACP;
- The lack of subsurface investigations has increased the potential for inaccuracies in the estimate of cost. However, it is our considered opinion that there are no geologic or geotechnical problems associated with the site that cannot be accommodated using conventional solutions;
- The yield of the Panama Canal system will increase by about 1,200 MCM/yr (about 15.8 L/d) with the addition of the Río Indio Project;
- The addition of hydropower to the Project is not warranted at this time. However, a 1.6 MW plant has been included to generate electricity from the minimum release for project operation and to serve the needs of the resettled population. Any plans to implement any other project to the west of the Río Indio Project will improve the economics of the hydropower addition and should cause the issue to be revisited;
- The inclusion of a commercial agricultural endeavor is technically feasible, but is not warranted at this time due to a lack of government services, infrastructure, and an adequate labor pool;
- The project is estimated to cost about $230 million in 2001 dollars. Allowing for inflation at 3% per year, escalation during construction at 3% per year, and interest during construction at 10% per year, the capital cost of the project in current dollars would be about $303 million.
- A project that delivers about 1,200 MCM/yr for a cost on the order of $300 million is a very attractive proposition.

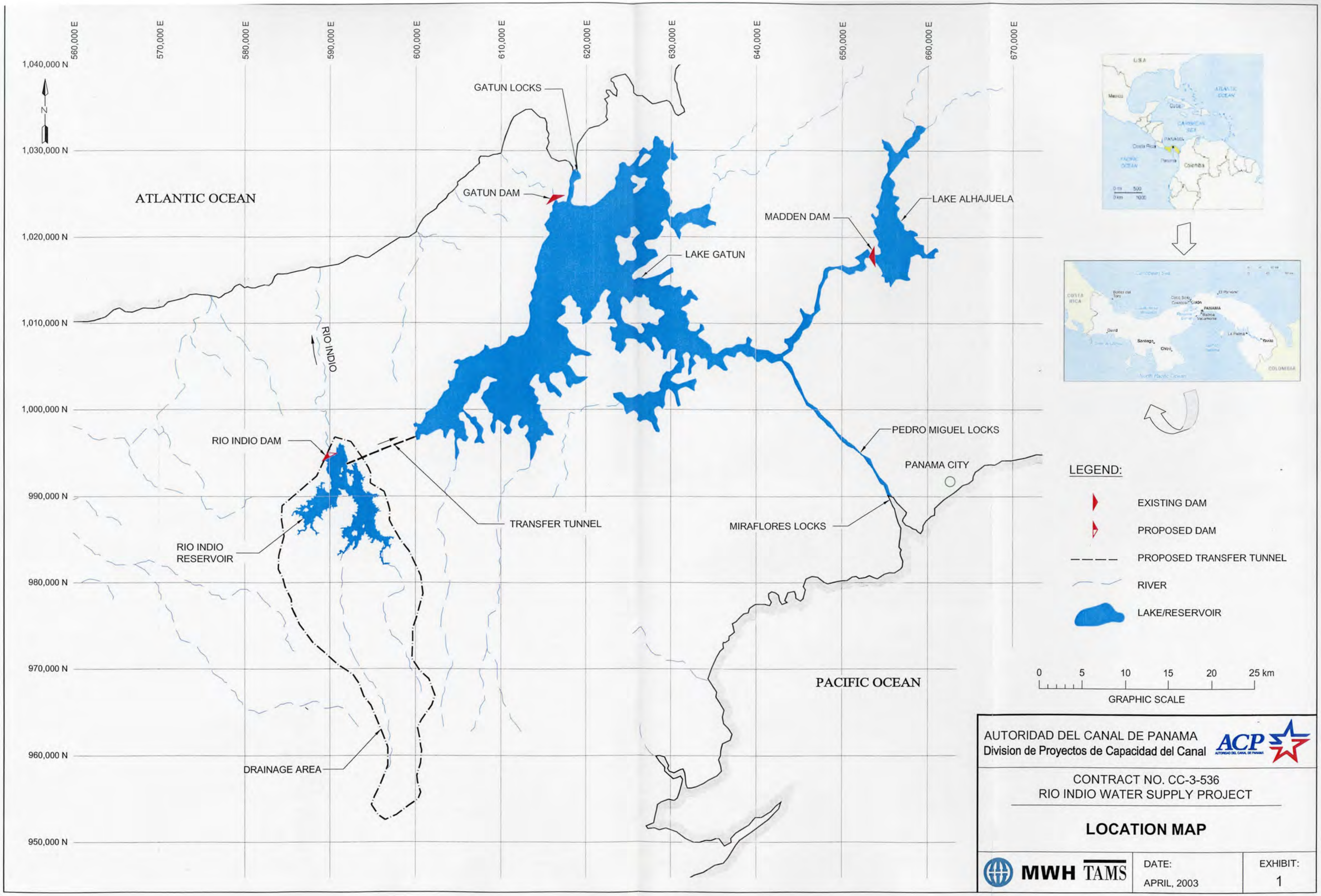
As a result of these conclusions, it is recommended that:

1. The Río Indio Project is considered as a suitable source of water for any canal expansion.
2. Concurrent with the evaluation of new-lock schemes and alternative sources of water, subsurface investigations and environmental studies of the Río Indio Project should continue without hiatus.

TABLE OF SIGNIFICANT DATA

Project Setting	Río Indio Basin; NW of Panama City and SW of Colon	
Hydrology		
Average Annual Precipitation	3,078	mm
Average Annual Streamflow	25.8	m^3/s
Storage Facilities		
Reservoir		
Drainage Area	381	km^2
Normal Maximum Water Level	El. 80	msl
Volume	1,577	MCM
Surface Area	45.6	km^2
Minimum Pool Level	El. 40	msl
Volume	283	MCM
Surface Area	17.7	km^2
Live Storage	1,294	MCM
Sediment (Dead) Storage	283	MCM
Dam		
Type of Dam	Concrete-face rockfill	
Crest Elevation	83	m
River Bed Elevation	5	m
Hydraulic Height	78	m
Upstream and Downstream Slope	1.4H:1.0V	
Fill Volume	3,078,000	m^3
Upstream and Downstream Slope	1.4H:1.0V	
Spillway		
Type of Spillway	Ungated ogee	
Spillway Crest	80	m
Excavation Volume	402,000	m^3
Concrete volume	13,700	m^3
Spillway Design Flood		
Peak Inflow	4,345	m^3/s
5-day Volume	243	MCM
Peak Outflow	950	m^3/s
Surcharged Reservoir Level	El. 84	Msl

Diversion During Construction		
Section Shape	modified horseshoe; vertical sides; horizontal invert	
Diameter	4.0	m
Length	635	m
Diversion Flood	820	m^3/s
Discharge Capacity	113	m^3/s
Upstream Cofferdam Height (hydraulic)	18	m
Downstream Cofferdam Height (hydraulic)	3	m
Cofferdam fill Volume	107,500	m^3
Minimum Release Facility		
Type	Concrete encased steel pipeline under dam	
Capacity	2.6	m^3/s
Water Transfer Tunnel		
Intake		
Type of structure	Reinforced concrete	
Invert Elevation	El. 32	msl
Tunnel		
Shape	Modified horseshoe	
Length	8,350	m
Diameter	4.5	m
Capacity at Maximum Pool	94	m^3/s
Capacity at Minimum Pool	43	m^3/s
Outlet		
Type of Structure	Reinforced concrete	
Invert Elevation	El. 27	msl
Estimated Project Cost		
Construction Cost	$230,430,000	
Annual Cost	$1,940,000	
Estimated Project Yield		
Volumetric Reliability	99.6	%
Yield L/d	15.8	L/d
Yield MCM/year	1,200	MCM/yr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ATLANTIC OCEAN
PACIFIC OCEAN
GATUN LOCKS
GATUN DAM
LAKE GATUN
MADDEN DAM
LAKE ALHAJUELA
RIO INDIO
RIO INDIO DAM
RIO INDIO RESERVOIR
TRANSFER TUNNEL
PEDRO MIGUEL LOCKS
PANAMA CITY
MIRAFLORES LOCKS
DRAINAGE AREA
LEGEND:
EXISTING DAM
PROPOSED DAM
PROPOSED TRANSFER TUNNEL
RIVER
LAKE/RESERVOIR
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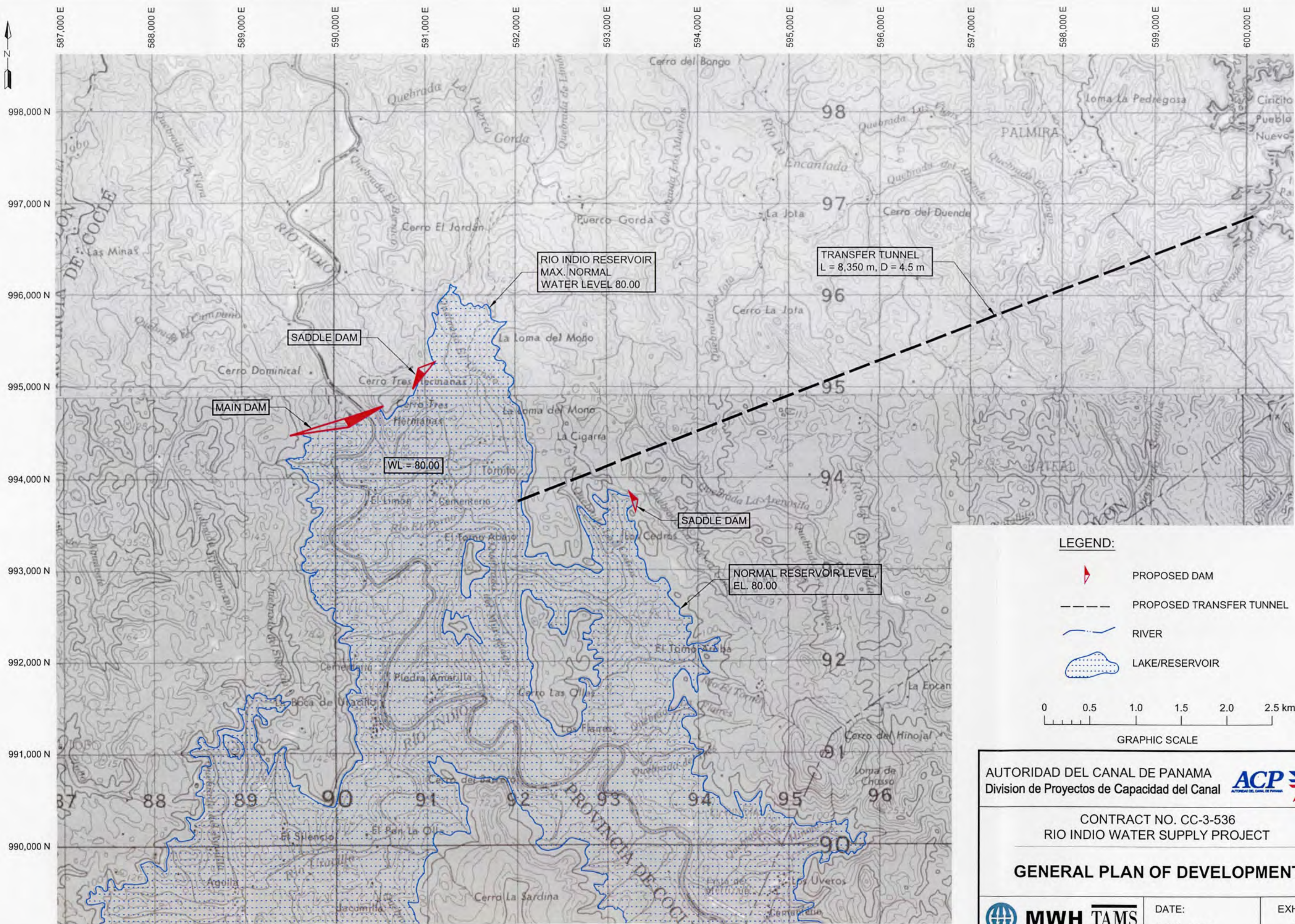
GRAPHIC SCALE
AUTORIDAD DEL CANAL DE PANAMA
Division de Proyectos de Capacidad del Canal
ACP
CONTRACT NO. CC-3-536
RIO INDIO WATER SUPPLY PROJECT
LOCATION MAP
MWH TAMS
DATE:
APRIL, 2003
EXHIBIT:
1



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

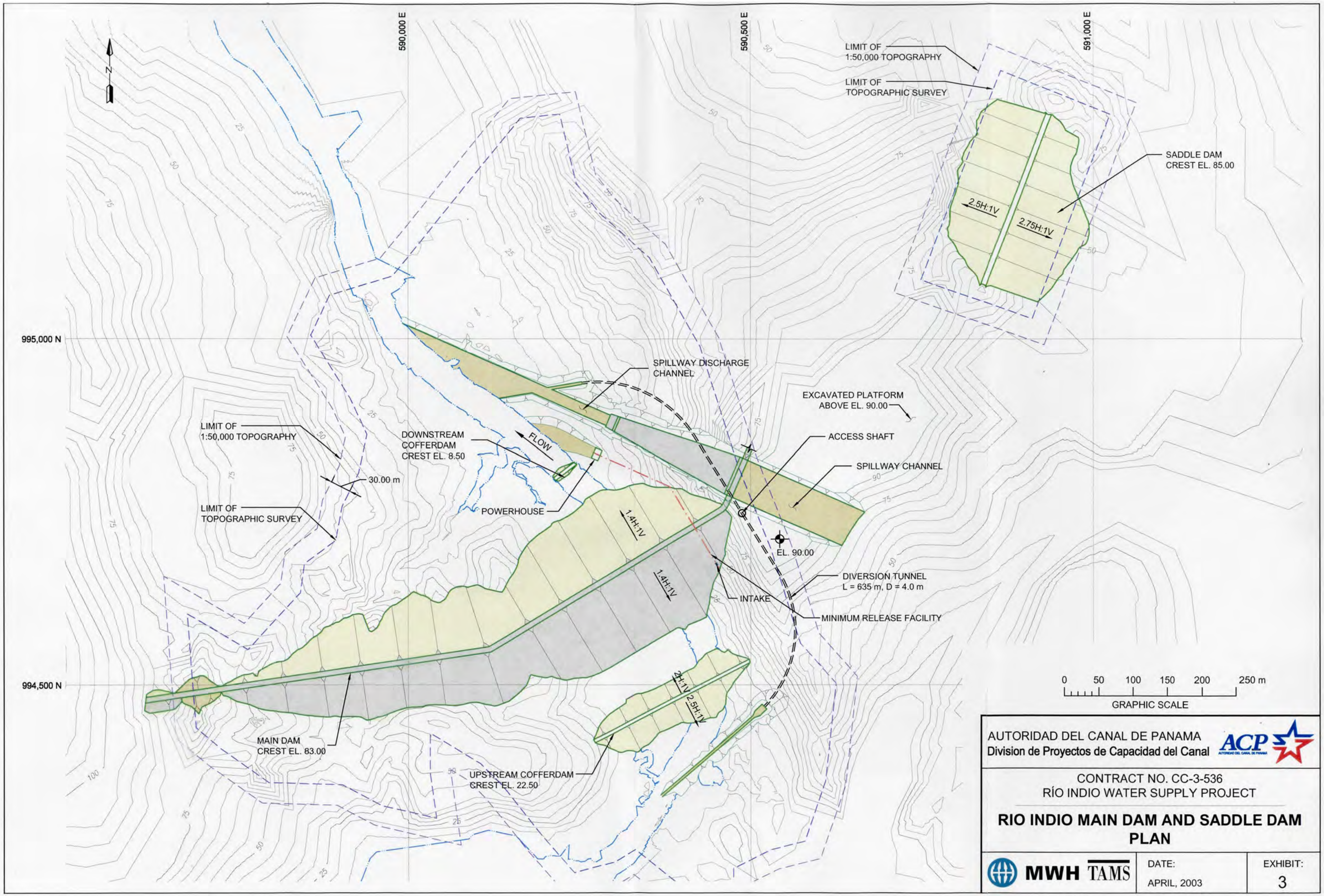
ACP

CONTRACT NO. CC-3-536
RIO INDIO WATER SUPPLY PROJECT

GENERAL PLAN OF DEVELOPMENT

MWH TAMS

DATE:	EXHIBIT:
APRIL, 2003	2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2.75H:1V
SPILLWAY DISCHARGE CHANNEL
EXCAVATED PLATFORM ABOVE EL. 90.00
ACCESS SHAFT
SPILLWAY CHANNEL
DOWNSTREAM COFFERDAM CREST EL. 8.50
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POWERHOUSE
1.4H:1V
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DIVERSION TUNNEL L = 635 m, D = 4.0 m
INTAKE
MINIMUM RELEASE FACILITY
2H:1V
2.5H:1V
MAIN DAM CREST EL. 83.00
UPSTREAM COFFERDAM CREST EL. 22.50
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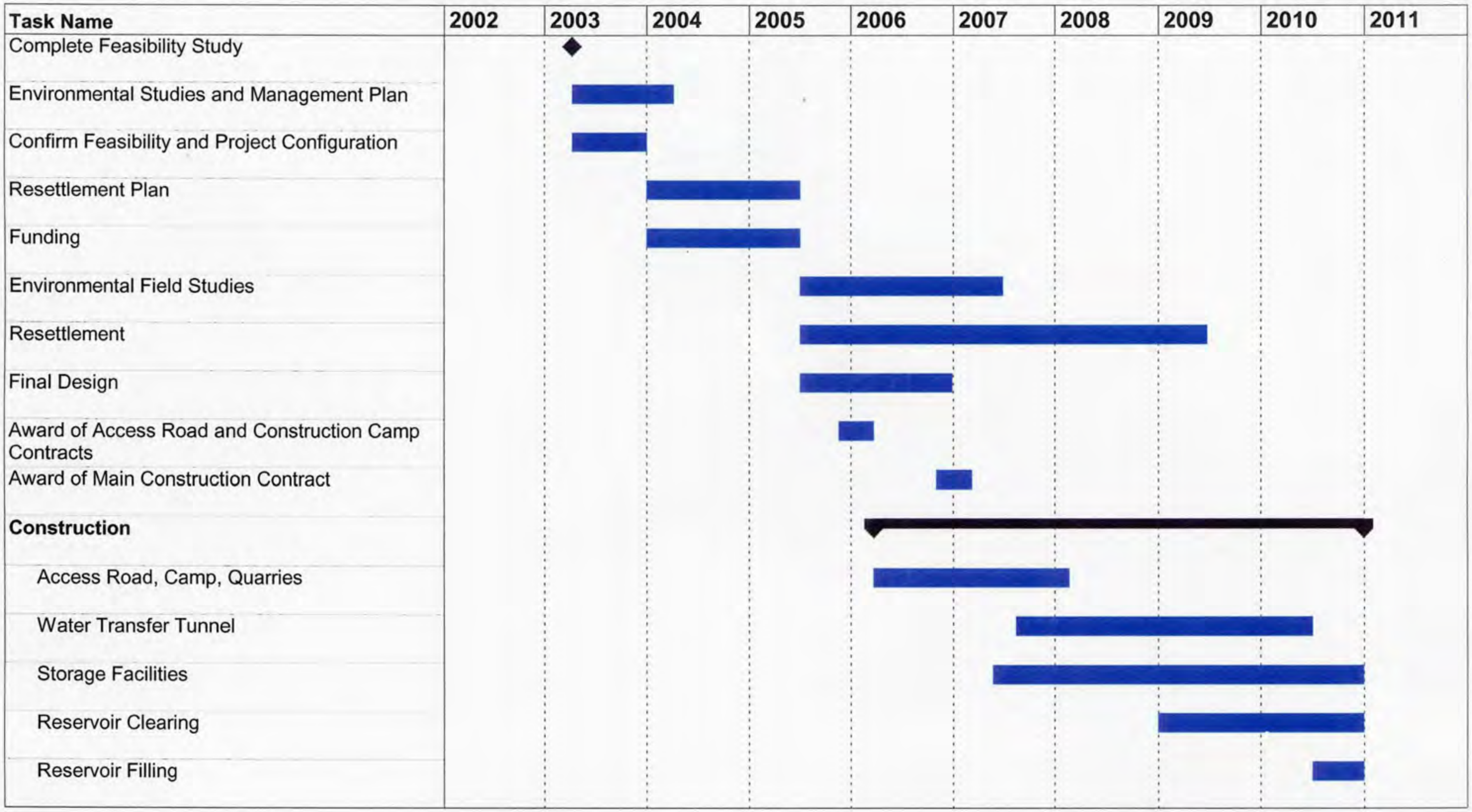
GRAPHIC SCALE
AUTORIDAD DEL CANAL DE PANAMA
Division de Proyectos de Capacidad del Canal
ACP
CONTRACT NO. CC-3-536
RÍO INDIO WATER SUPPLY PROJECT
RIO INDIO MAIN DAM AND SADDLE DAM PLAN
MWH TAMS
DATE: APRIL, 2003
EXHIBIT: 3



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

CONTRACT NO. CC-3-536
RÍO INDIO WATER SUPPLY PROJECT

IMPLEMENTATION SCHEDULE

MWH TAMS

DATE: APRIL, 2003

EXHIBIT: 4

Main Report

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APPENDICES

1. INTRODUCTION

1.1 Authorization

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 the Río Indio Water Supply Project (Project) under Contract CC-3-536, Work Order 0003, dated September 1, 1999.

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.

Recent climatological phenomena have shown that the existing water supplies for the Canal would not be sufficient to meet the anticipated future demand. A recent long-term traffic demand forecast indicates that, over the next 50 years, the number of transits per year will almost double and the tonnage passed will increase at a greater rate (1)[1]. In addition, the municipal and industrial water demand in Panama is expected to increase substantially over the near term and, as this demand must be met first, the availability of water for Canal operations will be further constrained. As a result, a major component of the study of the operating systems is the formulation and development of additional water supplies.

The US Army Corps of Engineers (USACE) performed a reconnaissance study to identify and evaluate potential water supply projects (1). Three projects were identified as having significant potential to augment the existing water supply to the Canal. One of the three, the Río Indio Water Supply Project, is the subject of this study.

1.3 Objectives

1.3.1 Original Objective

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

[1] All references are located at the end of the text.

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. Therefore, a determination of technical feasibility was not possible. The objective was changed to an assessment of technical feasibility.

Also, during the course of the study, it was decided by the ACP to implement the Río Indio Project in conjunction with a plan to add new locks to the Panama Canal System. Under this condition, the demand for and benefits from developing the Río Indio Project 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 that has, as its objectives, to:

- Assess the technical feasibility of the Río Indio Water Supply Project
- 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.
- 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 13 tasks, paraphrased from the Terms of Reference as follows:

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

<u>Task 2 Selection of Dam Location and Field Investigations.</u> Visit site to provide preliminary confirmation of dam location, review ground survey, geology, and geotechnical field program proposals.

<u>Task 3 Hydrology and Meteorology.</u> Task 3 included a series of subtasks:

- 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 and to optimize the features of the Río Indio Project.
- Estimate the probable maximum flood for spillway design and lower frequency floods for the determination of diversion facilities during construction.

- Estimate evaporation and reservoir sediment deposition

Task 4 River Hydraulics. Assess the impact of construction on the water quality downstream from the dam and the stability of the river channel as a result of the project's development. 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.

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 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 dam and at the downstream end of the tunnel transferring water from Indio to Gatun Lakes. 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 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 detailed 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

Over the course of the investigation, there were two significant changes to the geologic/ geotechnical and economic tasks:

- It was determined to be inappropriate to perform the drilling program and the refraction surveys due to the concerns of the local inhabitants,. As a results, these two subtasks were eliminated from the services.
- Mid-way through the studies, the ACP decided that the channel through Lake Gatun would be deepened and that a third and possibly a fourth set of locks would be constructed. As a result, the historic navigation demand, toll structure, and operating costs were not a suitable basis for the estimation of navigation benefits and the canal benefit and economic analysis subtasks were suspended.

1.6 Organization of Report

This volume titled "Main Report" 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 six appendices that are contained in an additional two volumes. The report organization is shown below:

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

- Augustin 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;
- Jose 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 Indio 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.

PÁGINA EN BLANCO

2. PROJECT SETTING

The Río Indio Water Supply Project is located essentially in the middle of the Republic of Panama, immediately to the west of the Panama Canal Watershed and about 75 km northwest of Panama City. A location map is presented on Exhibit 2-1. The production from the Project will be used to augment the existing supply of water to the Canal, provide for increases in municipal and industrial water in and around the Panama Canal Watershed, and possibly 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 (ITZ). When the ITZ is located to the south of Panama, the effect is to cause a dry season; 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 results in a dry season from January through April, a moderated wet season from mid-June to mid-September, and a wet season for the rest of the year. Based on extended records for the *Boca de Uracillo* station, the single rainfall station in the Río Indio basin, the mean annual rainfall is 3,078 mm and the mean monthly rainfall varies from a low of 75 mm in February to a high of 409 mm in October. Mean monthly rainfall values are shown in Table 2-1.

TABLE 2-1 MEAN MONTHLY RAINFALL, BOCA DE URACILLO

Month	Dry Season Rainfall (mm)	Month	Wet Season Rainfall (mm)
January	135	May	361
February	75	June	318
March	84	July	287
April	181	August	306
		September	307
		October	409
		November	368
		December	247
Mean Annual Rainfall 3,078 mm			

The months of October through December are the season of large-area rainfalls. During this period, strong air outflows come from the northern latitudes. These northerly winds, coming from the Atlantic Ocean, cause convergence when they encounter the coastal hills and heavy rainfall occurs. The rainfall and intensity decrease farther inland, but increase again near the Continental Divide. The mean annual rainfall varies from about 4,000 mm at the coast to about 2,500 mm in the upper reaches of the basin. There is a slight increase in rainfall with elevation in the head reach of Río Indio. An isohyetal map of mean annual rainfall, taken from the *Atlas Nacional de la Republica de Panama,* (7) is presented as Exhibit 2.2.

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. The studies indicated that the average annual rainfall anomaly based on the El Niño episodes was about 8 % below normal. In the case of the strong episodes of 1976 and 1982, the corresponding anomalies were about 28% and 24%. The 1997-98 El Niño significantly decreased the rainfall in the Panama Canal Watershed and the 1977 annual rainfall at *Boca de Uracillo* rainfall station was about 50% of the mean annual rainfall.

Mean monthly temperatures vary about 2° C throughout the year around 26° C near the dam to 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 Location and Description of the Río Indio Basin

The Río Indio Basin covers an area of about 570 square kilometers or less than one percent of the land area of Panama. The lower one-third and the upper one-third of the basin are narrow with an east-west extent of about five kilometers. The middle third of the basin extends out to a width averaging about 16 kilometers. The proposed reservoir is located on the Río Indio, about 21 kilometers (29.8 kilometers along the river as measured on 1:50,000 scale maps) upstream from the Atlantic Ocean, about where the basin starts to widen out. The basin area upstream from the proposed damsite is about 381 km^2.

The Río Indio rises at the Continental Divide about 1,100 meters above sea level (El. 1100) and flows in a northerly direction for about 100 kilometers over an air-distance of 63 kilometers. The river flows down off of the Divide at a gradient of about 6.5 percent, flows through the relatively narrow upstream third of the basin at a gradient of about 2.5 percent and then flattens to an average gradient of about 0.4 percent through the reservoir area and to 0.25 Percent to the Atlantic Ocean. At its upstream end, the river almost immediately becomes the boundary between the Provinces of Panama and Coclé. The river width varies from 3 m (in the dry season) to 50 m at its mouth, and its depth varies up to 15 m (1). Exhibit 2-3 shows the basin and the location of the Río Indio Reservoir.

There are two major tributary systems to the Río Indio, both flow parallel to the river in the wide middle part of the basin. On the east (right) bank, the Río Teria system, which drains an area of about 96 km^2 flows into the Río Indio at kilometer 48 or about 19 kilometers upstream from the damsite. On the west (left) bank, the Río Uracillo system, which drains an area of about 103 km^2 flows into the Río Indio at kilometer 38. The two major river systems cover slightly more than one-half of the drainage area above the dam. In addition, there are two other sizable tributaries, Río El Torno and Río Riacito plus about 20 smaller creeks that flow into the Río Indio.

There are no significant features in the basin. The topography is characterized by strongly dissected and moderately steep terrain with irregularly spaced conical-shaped hills and a dendritic drainage pattern. The landforms appear to be the result of high rainfall-caused runoff and well-developed stream erosion. Although a majority of the basin is forested, significant amounts of clearing and subsistence farming have occurred, especially in the proposed reservoir area.

Access to the basin is very limited. From the south, several asphalt roads approach the basin but access is only by gravel-surfaced roads and even this access is only to limited areas. The favored access route is by paved road from Santa Rita to La Trinidad and then by a dry-weather road to the middle of the basin. When the drilling program is implemented, dry-season, access to the site will be possible due to the planned improvements for the existing road system. From the Atlantic Ocean side, there is an all-weather road from Colon to the mouth of the river and then motor-driven canoes can be used to reach the site. As a part of the Project, permanent access to the site has been planned.

According to the Reconnaissance Report (1), the reservoir area is devoted to subsistence farming and ranching. There are 6 towns and villages in the reservoir area that will need to be relocated; *El Limon, Los Uveros, La Boca de Uracillo, Los Cedros, El Coquillo, and Tres Hermanas*, and approximately 30 other small settlements.

2.3 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 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 at the waterway. Trade along the north-south axis is also increasing especially between the west cost 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).

2.3.1 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 gravity 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.

The ACP also is currently deepening the navigation channel through Lake Gatun by three feet (0.91 m).

2.3.2 Canal Traffic

The Canal 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 (2). Actual use of the canal by PANAMAX ships already is 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 (3):

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.

2.3.3 Water Availability

Currently, the supply of water for the operation of the Canal and the provision of M&I water comes from the regulation of 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 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 shortages: 1) maintain the level of Gatun Lake so that all vessels can pass and reduce the number of passages 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 (4) 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, the shortages occur in only 20 of the 50 years, which indicates a shortage that averages about 100 MCM/yr in the short years and as many of the years have only minimal shortages, the shortage in the most severe year would be much larger.

2.3.4 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 locks per day in the Canal operations. Based on a study performed in 2000 (17), 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.

2.4 Socio-Economic Conditions

The Reconnaissance Report (1) and other sources report that the socio-economic conditions in the Río Indio basin are poor. The basin is estimated to contain about 10,000 persons of whom 2,300 reside in the reservoir area. There are six towns in the project area; *El Limon, Los Uveros, Uveros, La Boca de Uracillo, Los Cedros, El Coquillo, and Tres Hermanas*, with a combined total population of about 900. It is estimated that about 600 persons reside in 14 communities in the area downstream of the dam site with about 150 in *La Boca del Río Indio.* Residential developments consist of scattered groupings of houses with few amenities.

An extensive compilation of the socio-economic data for the basin is presented in the March 2002 report *Recopilacion y Presentacion de Datos Socioeconomicos de la Region Occidental de la Cuenca del Canal de Panama.*

Slash and burn farming is the major economic activity and it is only at the subsistence level. The farmer draws a major portion of his subsistence from his own crops or livestock and the family is the main source of labor. There is no access to farm machinery and little access to work animals. There are no major industries or beef or poultry processing plants in the area.

In general, the level of education in the basin is relatively low. *El Limon* in the basin, and *El Silencio, San Cristobal,* and *Piedra Amarilla* have elementary schools

There are few public services. Several towns have cemeteries, churches, and medical centers. 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.

2.5 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. (14).

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 (12), 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 (14).

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 not connected. EDE Elektra Noreste operated 14 plants with a total capacity of 10.8 MW that were not connected to 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 24MW, 36 MW, and 93 MW respectively for a total of 153 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 30 MW. The Miraflores plant serves as a backup to the hydro plants in times of high water and supplies electricity in times of low 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 2-2.

TABLE 2-2 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 line, 134 km of 115 kV line, and ten 230-kV substations with a total capacity of 885 MVA (16). 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 MWh to about 452,000 consumers. Aggregate distribution by consumer category is shown in Table 2-3.

TABLE 2-3 1998 ENERGY CONSUMPTION BY CONSUMER CATEGORY

Consumer Category	Energy Consumption (MWh)	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**

Each of the three distribution companies has established a tariff structure including capacity and energy charges for the various types of consumers. In 1998, the average unit energy sale price for each of the consumer categories is presented in Table 2-4.

TABLE 2-4 AVERAGE UNIT ENERGY SALES PRICE IN 1998
($/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.

2.6 Agricultural Sector

The basin is a largely undeveloped rural area. Mature forests are generally non-existent in the basin. The vegetation consists mostly of pasture, secondary forest, and stubble. Croplands are included within the stubble category, mostly because of the nature of the area under cultivation, the landscape position, and the size of the farm holdings.

Approximately 60% of the land in the project area is occupied by farms and ranches of various sizes (4). The main crops are rice and maize, and ancillary crops include cassava, yams, plantains, and beans. Coffee is grown in the low and intermediate basin on small, dispersed farm holdings and there are some teak tree plantations in the area.

Small farms are predominant; the prevailing size of the holdings is about 0.5 ha. The small size appears to be the result of difficulties in obtaining labor. The farmer draws a major portion of his subsistence from his own crops or livestock and the family is the main source of labor. There is no access to farm machinery and little access to work animals.

2.7 Geologic Setting

The proposed Río Indio Project is located in an area underlain by Oligocene-aged sedimentary rocks of the three-membered Caimito Formation of Oligocene age (Woodring, 1982 a, 1982 b). A general stratigraphic column is presented as Table 2-5 and a regional geologic map is presented as Exhibit 2-4. The general pattern and distribution of major faulting in the region is depicted on Exhibit 2-5.

2.7.1 Regional Geology

Regional geologic mapping for this part of the country consists only of the 1:1,000,000 scale national map, which provides negligible detail for the project area. The following descriptions are derived from interpretations made during the course of the geologic studies, from published reports, and this map.

The lower member of the Caimito Formation is composed of conglomerate, greywacke, and tuffaceous sandstone while the middle member consists of tuffaceous sandstone, greywacke, and lenticular foraminiferal limestone. The upper principal member consists of tuff, agglomeratic tuff, tuffaceous siltstone, and discontinuous sandy tuffaceous foraminiferal limestone. The deposits are primarily marine, but lithologically heterogeneous and the rocks of all members are hard, thinly to thickly bedded, and closely to moderately jointed.

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

TABLE 2-5 RÍO INDIO AREA STRATIGRAPHIC COLUMN

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

Adapted from: Woodring and Thompson, 1949

2.7.2 Regional Tectonics

The tectonics in the Central American region is predominantly governed by the interaction of the Nazca, Cocos, South American, and Caribbean Plates. Geologic processes in the Republic of Panama, including tectonics, sedimentation, volcanism, seismicity, and epeirogenesis, are all strongly influenced by the relative movements of these plates, which are shown on Exhibit 2-6. Although the country is located on the southwest edge of the Caribbean Plate, Panama itself is located on a tectonic microplate called the Panama Block, which is a fairly rigid, yet seismically active segment of crust.

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

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

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

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

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

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

2.8 Environmental Setting

The scope of work states that *the environmental evaluation efforts will be separately accomplished by the PCC (sic) and the information will be furnished to the contractor as it is available and necessary.* These studies have not yet been performed and, therefore, the environmental comment is taken directly from the Reconnaissance Report (1).

2.8.1 Terrestrial Habitat

Forests along the river that could support diverse wildlife populations cover about 90 percent of the areas along the Río Indio and its tributaries. The forests also extend to the upper mountainous areas above the Río Indio impoundment area. As a result of slash and burn activities, there are no large continuous tracts of forests at lower elevations in the impoundment area.

2.8.2 Fish and Wildlife

The Río Indio and its tributaries appear to support some fish communities; however, information about the fish communities in the project area is limited.

The *Autoridad Nacional del Ambiente* declared 33 mammals, 39 birds, and 11 reptiles and amphibians as being in danger of becoming extinct in Panama. Although it has not been determined, some of the listed species might be found in the project area.

2.8.3 Wetlands

The wetlands in the project area consist of forested riparian habitat and are limited by the relatively steep topography of the project area to the immediate vicinity of the stream banks. The width of the riparian habitat within the impoundment area varies from approximately 5 m to 50 m. Approximately 90 percent of the streams above and below the dam site along the Río Indio and its tributaries are bordered by forested riparian habitat.

2.8.4 Air Quality

Air quality in the project area is generally good, except during the periods of slash and burn activities. At the end of the dry season in March or early April, sizable areas of established forests and secondary growth are burned and cleared to prepare the land for agricultural use. Based on observations in the Río Indio project area, approximately 10 percent (or 400 ha) of forested land is burned annually.

2.8.5 Cultural and Historic Resources

No parks or other government-protected lands are known to be located in the Río Indio impoundment area. In the pre-Columbian period, the Río Indio constituted a language frontier; that is, the inhabitants on each side of the river spoke a different native language. During the Spanish colonial period, the river served as a political boundary; therefore, the project area has a high potential to be rich in archaeological and historical remains. A potentially significant archaeological site has been identified in Boca de Uracillo, about nine kilometers above the damsite. It should also be noted that most of the Atlantic region of Panama is within the interest and objectives of the Mesoamerican Biological Corridor, an international project to conserve biodiversity.

PÁGINA EN BLANCO

3. PROJECT DEFINITION STUDIES

The project definition studies are the basic studies that preceded the selection of the final project arrangement. For many of the studies, an appendix is attached.

3.1 Topography

Ingenieria Avanzada, S.A. prepared topographic mapping of the proposed dam site area under subcontract to MWH. The services were completed and submitted to the ACP under Contract CC-3-536, Task Order 2, Altimetric and Planimetric Surveys of 13 sites located on the Western Side of Lake Gatun. The extent of the topographic coverage is shown on the plan views of the proposed project. 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).

3.2 Hydrology Studies

Hydrologic analyses were performed to confirm the long-term streamflow sequence adopted for the Reconnaissance Study (1), to estimate reservoir evaporation, 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.

3.2.1 Long-Term Streamflow

The long-term flow sequence was developed by the APC and reviewed by Harza. Four gages, identified in Table 3-1, were considered in the development of the long-term streamflow record.

TABLE 3-1 STREAM GAGES USED IN ANALYSIS OF LONG TERM FLOW RECORD

Station	Location	Period of Record	Drainage Area	Type of Gage	Missing Data
Rio Indio at Limon	Slightly upstream from the dam site	1958 - 1980	376 km^2	Non-recording	
Rio Indio at Boca de Uracillo	5 km upstream from the damsite	1979 - date	365 km^2	Recording	28 months

Station	Location	Period of Record	Drainage Area	Type of Gage	Missing Data
Rio Ciri Grande at Los Canones	Basin east of Río Indio	1948 - date	186 km^2	Recording	1959-1978 misc. months
Rio Trinidad at El Chorro	Basin east of Río Ciri Grande	1948 – date	172 km^2	Recording	

The long-term flow sequence (1948-1999) at the damsite was generated by transposing the data from Boca de Uracillo using a drainage area ratio of 1.044. The data at Boca de Uracillo was completed and extended using data from Los Canones. The data at Los Canones was completed by a correlation with El Chorro. Limon was not used because of the limited overlap of data and because the data were based on only two readings per day. A subsequent check of the generated data at Boca de Uracillo with the Limon data resulted in a good correlation. The two step correlation process (El Chorro to Los Canones to Boca de Uracillo was chosen over a one-one-one-step correlation process (El Chorro to Boca de Uracillo) because of the decreasing rainfall from east to west and the relative locations of each of the basins. 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 damsite is 25.8 m^3/s and the monthly distribution of flow is shown in Table 3-2. 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 3-2 MONTHLY MEAN STREAMFLOW AT THE RÍO INDIO DAMSITE
(m^3/s)

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
16.5	8.3	5.4	6.2	15.8	26.9	27.3	32.5	37.3	49.3	48.9	35.2	25.8

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, 42.6 m^3/s, occurred in 1996 and the lowest, 11.0 m^3/s occurred in 1997. A flow duration curve derived from monthly data is presented as Exhibit 3-1.

On an annual basis, the lowest 1, 2, 3, and 4 calendar year flow sequences occurred in 1997, 1997-98, 1997-1999, and 1962-65, respectively. The average runoff in these periods amounted to 42%, 56%, 80%, and 83% of normal, respectively. This would suggest that a carryover storage of about one year would permit a yield on the order of the mean annual flow. For reference, a drought-frequency curve for sequential 6-month, 12-month, 18-month and 24-month periods is presented in Exhibit 3-2.

3.2.2 Net Reservoir Evaporation

Net reservoir evaporation is estimated to total 1,134 mm 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 this study. The estimate is presented in Table 3-3.

TABLE 3-3 MEAN MONTHLY NET RESERVOIR EVAPORATION, RÍO INDIO RESERVOIR
(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

3.2.3 Construction Period Floods

Construction period floods were estimated using both available regional flood frequency data and annual maximum instantaneous flood peaks at the Boca de Uracillo gage. The maximum instantaneous peak of 16 annual peaks available for the Boca de Uracillo gage was 772 m^3/s. On this basis, the estimate for the 10-year flood of 1,390 m^3/s from the regional data was considered to be too high and not probable for the Indio basin.

Both Log-Pearson Type III (LPIII) and the Generalized Extreme Value (GEV) distributions were fitted to the annual peaks. The flood peaks estimated using the GEV distribution ranged up to about 8% higher than the flood peaks estimated using the LPIII distribution. However, both distributions indicated a good fit with the data. The values resulting from the GEV distribution were adopted as a conservative (high) estimate. To account for the possibility that flood protection works could also be designed for protection during the dry season, a flood frequency analysis was performed for monthly flood peaks occurring during the period January through March. The construction period flood information is presented in Table 3-4.

TABLE 3-4 FLOOD PEAKS FOR SELECTED RETURN PERIODS, RÍO INDIO AT BOCA URACILLO

Return Period (years)	Flood Peak (m^3/s)	Dry Period Flood Peak (m^3/s)
5	657	63
10	713	94
20	762	133
50	820	202
100	859	274

3.2.4 Spillway Design Flood

The probable maximum flood (PMF), based on probable maximum precipitation (PMP) was adopted as the spillway design flood for the Río Indio Water Supply Project.

3.2.4.1 Probable Maximum Precipitation

Three procedures were used to evaluate and select the PMP. The first consisted of transposing the most severe storms listed in the 1965 US Weather Bureau (WB1965) and 1978 National Weather Service (1978NWS) reports (8, 9). These reports covered storms up to 1976. The second procedures was to develop and evaluate storm isohyetal patterns of major storms that occurred over the Río Indio since 1976, and 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 Indio Basin. This storm was maximized in-place, and transposed to the Indio Basin using a factor based on a ratio of October-December rainfall for the Indio basin and the place of occurrence of the storm. This resulted in a maximized and transposed storm with a 48-hour rainfall of 607 mm. For the third procedure, the PMP was estimated to be 711 mm. The higher value was adopted for the Río Indio basin.

3.2.4.2 Probable Maximum Flood

The PMP was transformed to a PMF using the HEC-1 computer model. A one-hour duration of PMP increments was selected based on the lag time of the Río Indio basin above the damsite. 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 (10), adjusted for losses, and applied to a unit hydrograph developed using the Clark Method (11). The total excess rainfall amounted to 583 mm and the maximum one-hour increment was 104 mm. For a base flow of 50 m^3/s, estimated from an analysis of five major floods at the Boca de Uracillo gage, the probable maximum flood hydrograph has a peak of 4,345 m^3/s and a 5-day volume of 243 MCM. The PMF and excess rainfall are shown on Exhibit 3-3.

3.2.5 Tailwater Rating

A tailwater rating curve was developed for the Río Indio at the damsite. The analysis was based on 20 river sections spaced over 16 km 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 are shown in Table 3-5.

TABLE 3-5 TAILWATER RATING INFORMATION

Flow Rate (m^3/s)	Tailwater Elevation (m)
0	5.3
200	8.7
400	10.5
600	11.6
800	12.4
1,000	13.2

3.2.6 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 Indio basin, and estimation of storage depletion after periods up to 100 years.

Suspended sediment data are not available for the Río Indio. However, significant amounts of data are available. ETESA has collected 46 samples on the Río Coclé del Norte at Canoas and 56 samples from the Río Toabre at Batatilla. 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. The suspended sediment rating curves for Norte and Toabre fitted by ETESA were revised 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 Coclé del Norte and Toabre 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.

Based on the estimates for Lake Madden and for the neighboring basins, a value of 1.4 mm/yr was adopted for the Río Indio basin. This yield is 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 reservoir was estimated using a computer program obtained from the US Bureau of Reclamation. Due to a lack of data, the empirical area-reduction method could not be used and estimates were made using the area-increment method. The analysis indicates that reservoir sedimentation will not be a problem for the project. After 100 years, it is estimated that less than 2 percent of the live storage will be lost to deposition. The loss in live storage for a range of operating periods, assuming that the reservoir is relatively full for most of the year, is shown in Table 3-6. If it is assumed, for example, that the reservoir is always low at the onset of the flood season, which is the period when most of the sediment might be expected, the loss in live storage would be significantly less and the loss in dead storage would be more.

TABLE 3-6 LOSS IN LIVE STORAGE DUE TO SEDIMENT DEPOSITION

Operating Period (years)	Sediment Deposition		Loss of Live Storage (%)
	In Dead Storage (MCM)	In Live Storage (MCM)	
5	1.1	1.2	0.1
10	2.1	2.4	0.2
20	4.2	4.9	0.4
25	5.3	6.1	0.5
50	11.9	10.8	0.9
100	22.2	23.2	1.9

3.2.7 Stability of the River Channel Downstream from the Dam

Studies were performed to assess the stability of the Río Indio channel downstream from the dam to determine if channel-stabilizing measures would be needed to maintain the system in its pre-project condition. 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.

3.2.7.1 Flood Regime Downstream from the Dam

Pre-project floods were based on the flood frequency data presented in Table 3-4, 1 and 2 day volumes for the selected return periods, and a hydrograph shape based on the Dec 4-6, 1991 storm. The post-project floods were estimated by routing the pre-project floods through the reservoir. The flood peaks are shown in Table 3-7.

TABLE 3-7 FLOOD FREQUENCY DATA IN RÍO INDIO CHANNEL DOWNSTREAM FROM THE DAM

Return Period (years)	Pre-Project Flood Peak (m^3/s)	Post-Project Flood Peak (m^3/s)
2	562	57
5	657	71
10	713	79
25	780	89
50	820	100
100	859	108

3.2.7.2 Hydraulic and Bed Material Characteristics

The hydraulic characteristics of the channel downstream from the dam were based on a survey of 6 cross sections and the HEC-2 computer model. 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 the six cross sections. These characteristics are presented in Table 3-8.

TABLE 3-8 CHARACTERISTICS OF THE RÍO INDIO BED MATERIAL

Size Designation	Particle Size (mm)
D35	1.6
D50	6.0
D65	14.0
D90	50.0
Median D	**16.5**

3.2.7.3 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.

3.3 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.

3.3.1 Geologic and Geotechnical Investigations

A reconnaissance visit was made in September 1999 that included identification and examination of bedrock types at various project locations. This was followed in January 2000 by a visit that involved dam site geologic mapping and construction materials studies. In August 2002, another field visit was made to carry out reconnaissance in the intake and outlet portal areas of the water transfer tunnel.

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.

Particular attention was paid to possible faults identified as photolinears in photogeologic studies and on regional geologic maps (shown on Exhibit 2-5).

Reconnaissance geologic mapping was performed along the Río Indio from the upstream end of the reservoir area to immediately downstream of the dam site (Cerro Tres Hermanas). Geologic mapping was also carried out at selected locations to help identify conditions along prospective water transfer tunnel alignments, tunnel portals and intake locations, and possible powerhouse sites. 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.

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

3.3.2 Geology of the Damsite and Transfer Tunnel

At the damsite, the Río Indio flows northwest forming an asymmetrically shaped valley that exhibits nearly 100 m of relief. The relatively steep slopes on the right abutment are formed by Cerro Tres Hermanas, while the slopes on the left abutment have a more gradual slope. Both abutments are almost entirely covered with colluvial and residual soils, and are moderately heavily vegetated. Although a few small, scattered rock outcrops can be observed, a moderate to deep weathered profile and thick soil cover typical of the sub-tropical climate characterizes most of the project area.

The valley floor at the damsite is approximately 200 m wide and is filled with alluvial terrace deposits consisting primarily of silts and clays. The river, which is about 20-50 m wide at the site, has eroded steep banks up to 5 m high. Terraces are seen on both sides about 3 to 4 m above the present river elevation. Bedrock is exposed in parts of the riverbed and along the cut banks of the lower right abutment.

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

3.3.2.1 Unconsolidated Deposits

Overburden at the dam site mostly consists of deposits of talus, colluvium, and residual soils above about elevation 15m on the valley slopes and alluvial deposits found in the riverbed or as terraces on the valley sides.

Alluvial deposits of the Río Indio valley are not extensive compared to many rivers and drainage basins of comparable size elsewhere in Central America. Sand and gravel deposits in the riverbed are thin and only localized in occurrence and found as lag deposits on the inside of meanders and as occasional bar deposits. The gravel-sized fractions originate from nearby outcrops of tuffaceous sandstone, andesite, basalt, and a few fragments of slabby siltstone.

3.3.2.2 Rock Units

Bedrock at the dam site and along the headrace tunnel route consists almost entirely of Tertiary sedimentary and volcanic rocks. Based on observation made during geologic reconnaissance mapping, the sedimentary formations are found to be comprised of tuffaceous siltstones and sandstones, conglomerates and agglomerates thought to belong to the Caimito Formation or its age equivalent (see Table 2-5: Regional Stratigraphic Column).

It is suspected these units are interbedded with lavas in the vicinity of the larger (eastern) saddle dam. In some parts of the reservoir area, and in the area of the village of Limon, the sedimentary rocks are stratigraphically overlain by andesite and basalt flows. The volcanic units form many of the steep hills and high plateaus that are readily apparent on topographic maps and aerial photographs. 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.

Tuffaceous sandstones and siltstones form the uppermost bedrock unit at the dam site and are widespread throughout the project area. Most of the bedrock is covered by overburden, however in some areas shallow landslides/slumps have removed the overburden to expose underlying *in situ* bedrock. Residual soils developed from the weathering of the sandstones and siltstones at the dam site tend to be clay-silts, as described in previous paragraphs. Andesite and basalt rock units form many of the steep hills and high plateaus in the project area.

3.3.2.3 Structural Geology

The principal geologic structures at the Río Indio 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 Panama Canal Watershed, it is likely that several small faults and shear zones could exist at the dam site. Such structures can locally influence the pattern and degree of weathering in the rock mass, and probably have exerted a minor control over the morphological development of the site, and either singly or in combination significantly affect the strength and deformation modulus of the rock in local areas.

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

Based on limited observations at rock outcrops in the dam site area, bedding in the tuffaceous sandstone is found to more or less horizontal to slightly inclined. The strata are intersected by a well-developed pattern of systematic, near-vertical joints. At this time, few details have been gathered on the characteristics and properties of such jointing but two distinct sets are thought to present, one trending northwest and the other northeast. Currently, there are insufficient data to develop typical stereographic plots. Joints of the major sets are probably mostly planar. Joint fillings or coatings are probably common up to the limits of weathering. Clay infillings should be expected in the upper part of the weathering profile.

3.3.2.4 Hydrogeology

Groundwater data and hydrogeologic properties of the geologic units at the dam site are not known. It is suspected that groundwater levels are at relatively shallow depths in the abutments. During reconnaissance, a small spring was observed in the thalweg close to the western saddle dam, indicating shallow groundwater conditions.

3.3.3 Seismicity

As indicated on Exhibit 3-4 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 5ºN and 11°N and longitudes 75°W and 85°W. The database contains over 900,000 earthquakes from 2100 B.C. through 2002 and draws on information from 53 separate regional and worldwide catalogs. Within the defined region, nearly 2,150 earthquakes were identified. The general distribution of these earthquakes plotted as function of their depth below the surface also is presented on Exhibit 3-4.

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

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

Based on the density plot of earthquakes (Exhibit 3-4), 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 Indio Project are as follows:

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

The Río Indio dam was analyzed for deformation of the rockfill due to the MDE.

3.3.4 Engineering Geology

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 Indio Dam.

3.3.4.1 Geotechnical Design Parameters

Geotechnical design parameters and criteria used for developing project layouts and cost estimates for dam type selection are presented in Table 3-9.

TABLE 3-9 SUMMARY OF GEOTECHNICAL DESIGN PARAMETERS

Parameter	Selected Design Criteria
Thickness of overburden (top of weathered rock)	4 m
Depth to top of competent rock	8 m
Rock Excavation Slopes	1H : 5V, 3-m-wide benches every 10 m vertically
Soil Excavation Slopes	
Permanent	2H : 1V, 3-m-wide benches every 10 m vertically. Bench at soil-rock contact
Temporary	1.5H : 1V, 3-m-wide benches every 10 m vertically. Bench at soil-rock contact

Based upon these estimates, excavation depths for the dam and spillway were estimated as follows:

TABLE 3-10 ESTIMATED EXCAVATION DEPTHS

Feature	Estimated Excavation Depth (m)
Plinth and 25 m downstream of grout curtain	8
Under main dam body	4
Spillway headworks and chute	8

3.3.4.2 Foundation Treatment

For the plinth slab excavation at the dam toe and under the spillway headworks, dental excavation and concrete will be used to treat local zones of highly weathered, sheared, or otherwise unacceptable rock encountered in the foundation. Required dental treatment should be nominal and only local. 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. 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. The initial spacing of primary grout holes is taken to be 10 m and it is assumed that procedures will entail split-spacing down to 2.5 m (tertiary holes) over the entire curtain, and to 1.25 m (quaternary holes) over 75% of the curtain. In some more permeable locations, such as shear zones or faulted areas, grout holes might have to be staggered upstream and downstream.

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.

3.3.4.3 Diversion and Cofferdams

River diversion during construction will be accomplished by a 4.0-m diameter, 635-m long diversion tunnel in the right abutment. The tunnel will be horse-shoe (or modified horseshoe) in shape and will be concrete-lined.

The diversion tunnel will be excavated entirely in tuffaceous sandstone. This bedrock should be of moderate strength and unweathered over most of the tunnel length except at the tunnel portals. Sandstone should provide favorable tunneling conditions using conventional drill and blast methods.

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 3-5 m to top of rock).

3.3.4.4 Water Transfer Tunnel

The tunnel outlet at Lake Gatun will be founded on sound igneous bedrock, however, design details, such as the extent of tailrace channel excavation and the extent of tunnel steel lining will depend on final arrangements with respect to local topography. At the intake end, reconnaissance revealed that the topography in the portal area is favorable and provides a range of options for detailed design, i.e. flexibility in vertical and horizontal location. The bedrock geology consists of thick-bedded sandstone units, such as found at the dam site, which crop out or are mantled with a thin layer of cobbly/bouldery colluvium.

It is probable that tunnel construction for the inter-basin transfer will be encounter a wide range of rock types and tunneling conditions. The range and relative persistence of various conditions will depend on alignment selection. Rock types could include sandstone and softer epiclastics of the Caimito Formation as well as hard, strong lavas (andesites, dacites, and basalts) and agglomerates. There is potential for transition over short distances from very hard strong rock (such as andesite or basalt) to soft, weak almost clay-like materials. Differing ground conditions can be expected for any of the tunnel alignments considered in this study. Such aspects would need to be examined in more detail to establish their impact on construction method as well as cost parameters, including support and lining requirements.

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 multiple headings. Intermediate access locations have yet to be fixed but at this time, it is assumed that two construction adits or shafts would be used along the alignment.

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 3-11. 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 3-11 ROCK SUPPORT CLASS & SUPPORT REQUIREMENTS FOR THE WATER TRANSFER TUNNEL

Rock Support Class	Support Requirements	Tunnel Length
Excellent	Minimal support and spot rock bolting	25%
Good to Fair	Systematic support with shotcrete and rock bolts to within 10-20 m of the face	40%
Fair to Poor	Prompt support with shotcrete after excavation with systematic pattern rock bolting	30%
Very Poor	Steel ribs with steel lagging and rock backpacking or shotcrete, perhaps grouting	5%

It is assumed that the tunnel will be fully lined throughout mostly to prevent erosion and deterioration of the rock in areas of soft or highly fractured rock, to control water loss in low cover zones and areas of severely fractured rock and, to a lesser intent, for hydraulic reasons. With additional subsurface investigations, a better understanding of the rock structure may enable a reduction in the length on lined tunnel. A cast-in-place concrete lining has been assumed in all rock conditions with a minimum lining thickness of 25 cm except in reaches of low cover where it will be 50 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 and intermediate access.

3.3.4.5 Water Transfer Tunnel Outlet Area

Geologic investigation at the end of the water transfer tunnel, where any power development would occur (i.e. Lake Gatun end) was limited to reconnaissance visits only. Based on observations made during this reconnaissance, the powerhouse will be entirely located on bedrock consisting of relatively strong, sound igneous rock units that are probably andesitic in composition.

The backslope for the powerhouse will be benched and cut to a suitable slope to maintain stability. The exposed surface of the excavation will be rock-bolted and covered with chain-link to control loosening and falling of small blocks. Shotcrete and drain-relief holes will be included in areas on permanent slopes that are more weathered or closely fractured. A complete subsurface and surface drainage system will be installed to intercept and control surface runoff and prevent erosion damage.

3.3.5 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.

3.3.5.1 Diversion Cofferdams

The diversion cofferdams will be constructed from locally available random fill obtained from the immediate area of the dam site. The most significant source is the right abutment excavation for the spillway. Another source is located two to three kilometers upstream from the dam in the terraces along the banks of the river.

3.3.5.2 Aggregate, Filter and Drain Material, Riprap

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. Several quarry areas were identified at *Cerro del Barrero*, located about four kilometers south southeast of the damsite and at *Cerro La Jota, Cerro del Duende, and Palmira*, located between four and nine kilometers east northeast of the damsite. The borrow area locations are shown on Exhibit 3-5.

3.3.5.3 Rockfill

Rockfill for the dam will be obtained from required excavation, mostly sandstone units from the right bank spillway excavation, and from quarry run material. Since the local sandstone appears to be suitable for rockfill, there is a possibility of opening a sandstone quarry closer to the site than the igneous rock quarry indicated above. Materials for backfill will come from the required excavations, including use of tunnel excavation spoil.

3.4 Dam Site and Dam Type Selection Studies

A study of alternative dam sites was performed followed by studies to select the type of dam most appropriate for the selected site.

3.4.1 Dam Site Selection

In their Reconnaissance Report (1), the USACE selected a dam site with a view toward maximizing the water development potential of the project at a minimum cost. They selected a site that minimized the size of the dam and saddle dams and could contain a reservoir that would regulate, to a large extent, the entire runoff of the Río Indio. The disadvantage of the site is that it floods a large area including the two minor but significant population centers of Limon and Uracillo and a potentially significant archaeological site.

As little documentation was provided for the selection, a site selection study was performed and documented to serve as the basis of an alternatives analysis in the environmental impact assessment. A series of alternative sites were identified and compared to confirm the site selected in the Reconnaissance Report or to identify other reasonable alternatives that might be compared at feasibility level.

3.4.1.1 Identification of Sites

Six alternative dam sites were identified during a map study using the best available mapping, which consisted of 1:50,000 scale topographic maps. The sites were located over a reach of river from about 17 km downstream of the Reconnaissance site to 10 km upstream of the site. The sites and a legend giving the distance upstream form the mouth in river miles and the coordinates of the axes are presented on Exhibit 3-6. The most downstream site was selected as the farthest downstream site that could impound a significant reservoir. The most upstream site is immediately upstream from the confluence of the Río Indio and the Río Uracillo. Moving farther upstream would significantly lessen the project yield.

In a meeting with the ACP, the six alternatives were reduced to four as follows:

Site	Distance above mouth (river miles)	Comment
Alt. 1	12.5	Accepted. Most downstream site
Alt. 2	15.2	Rejected in favor of Alt. 3. Alt 2 would be more costly with no additional benefits to offset the cost.
Alt. 3	16.0	Accepted.
Alt. 4	28.1	Rejected. Can be considered in final design as an alternative axis to the Reconnaissance site
Recon Site	29.8	USACE site
Alt.5	33.5	Accepted. Site is upstream from Limon
Alt. 6	40.1	Accepted. Site is upstream of Uracillo and is the last site that can fully develop the full basin yield.

3.4.1.2 Site Inspection

In preparation for the site inspection, a dam footprint and alignments for the diversion and spillway were developed. With this information, MWH and ACP staff performed a reconnaissance of the reach of the Río Indio river valley within which the sites were located. The field reconnaissance consisted of two parts, a helicopter flyover and a traverse of the river from Boca del Río Indio to Alternative 6, which is just upstream from Boca de Uracillo. As a result of this site inspection, it was concluded that:

- The reconnaissance site is the only location where the morphology is clearly favorable for the placement of a dam.
- Dams of different heights and widths could be constructed at all of the sites.

- Geologically and technically there are no advantages favoring one site over the other or disadvantages that would eliminate any of the sites.
- The bedrock units are essentially the same for all sites and the construction materials sources would probably be the same for all sites.

3.4.1.3 Screening Phase

Cost curves based on comparative-level cost estimates were prepared for the accepted sites. The cost estimates for each site were developed using the basis of the relatively detailed estimate for the Recon site and the total volume of fill as estimated from 1:50,000 scale maps. The estimates were refined to account for differences in spillway flood surcharge, diversion tunnel length and spillway length. A curve indicating the ratio of the comparative costs of all levels of all alternatives to the detailed estimated of cost at the Reconnaissance site is presented on Exhibit 3-7. This type of presentation (ratio rather than absolute cost) was selected to eliminate the confusion of presenting comparative costs and because the screening evaluation is based primarily of the relative merits of each alternative site. The construction cost for the reconnaissance site is estimated to equal about $200 million for this analysis.

System yield was estimated at each site using a HEC-5 model developed during the Reconnaissance Report and modified during these studies. The yields are represented as a multiple of the current demand in lockages/day with a volumetric reliability of 99.6 %. In addition, additional runs were made to assess the system yields for a range of reliabilities.

The economic cost is presented as the discounted construction and annual cost divided by the discounted yield. The analysis was done for a 50-year period from the beginning of construction and using a 12% discount rate. The annual cost was estimated to equal 1% of the construction cost.

The area inundated was estimated at the crest elevation. It is likely that a buffer zone will be required around the reservoir that will increase this value. The population impacted was based on information supplied by the ACP. The supplied values were increased at a rate of 2% per year to account for net population gains.

Based on the comparative-level costs and yields, a best supply level was selected for each site except for Alternative 5. The best supply level is an approximation of the optimum development and was selected based on estimates of the economic cost of water and the yield/storage relationships indicated by the yield curve. No value was estimated for Alternative 5 because, over the range investigated, the economic cost of water was about the same regardless of the yield.

Relative cost, yield and social information are presented for each alternative in Table 3-12. Additional social information developed by the ACP is presented in Appendix D.

TABLE 3-12 DAM SITE EVALUATION CRITERIA

Criterion	Alt 1	Alt 3	Recon	Alt 5	Alt 6
Comparison at live storage equivalent to near-optimum development at the Recon Site (1,294 MCM)					
Crest Elevation (m)	60	60	85	90	101
Relative Cost to Recon Site	1.2	1.2	1.0	2.1	3.4
Yield (L/d)	15.7	13.7	15.8	16.2	13.7
Economic Cost	\$.027	\$.031	\$.022	\$.046	\$.089
Area Inundated (km^2)	101	92	47	44	40
No of persons directly impacted	3,900	3,500	2,000	1,600	1,500
Comparison at "Best supply level"					
Crest Elevation (m)	68	62	85	(1)	129
Relative Cost to Recon Site	1.6	1.3	1.0		5.9
Yield (l/d)	22.7	15.7	15.8		25.7
Economic Cost	\$.025	\$.030	\$.022		\$.082
Area Inundated (km^2)	117	96	47		57
No of persons directly impacted	4,200	3,600	2,000		2,000
Archaeological impacts	Major	Major	Major	Major	Minor

(1) Indeterminate as yield and cost increase in a straight line over range of values studied and no best supply level could be determined.

3.4.1.4 Conclusions

On the basis of these criteria, it is concluded that the site identified in the reconnaissance report is the most suitable site for the development of the Río Indio basin for the following reasons:

1. The sites downstream from the reconnaissance site, Alternatives 1 and 3, provide about the same yield for a slightly greater cost; however, the social impact is significantly greater. Both sites 1 and 3 inundate approximately twice the area and impact almost twice the number of people. In addition, neither 1 nor 3 eliminates the major archaeological impact and neither site has more favorable morphology or geology.

2. Alternative 5 would provide the same yield as the reconnaissance site for about twice the cost. The major advantage of Alternative 5 is that is would not inundate

the town of Limon. However, the dam would be very close to the town and the inhabitants may not be willing to stay in the town.

3. Alternative 6 inundates the least amount of land (with storage equivalent to the Recon site level of development), impacts the fewest people, and would be constructed upstream from the potential archaeological site. However, the cost of the development would be on the order of three times the reconnaissance site and, therefore, was rejected.

3.4.2 Dam Type Study

Four types of dam and six alternative arrangements were identified for evaluation as a part of the dam type study as follows:

Alternative	Dam Type	Abbreviation	Spillway Configurations
1a	Concrete Face Rockfill	CFRD	Gated
1b	Concrete Face Rockfill	CFRD	Ungated
2a	Roller Compacted Concrete	RCC	Gated
2b	Roller Compacted Concrete	RCC	Ungated
3	Conventional Concrete Gravity	CCGD	N/A
4	Earth Core Rockfill	ECRD	N/A

The CCGD and the ECRD were rejected in the preliminary screening and, therefore, no spillway configurations were assumed. The CCGD will be more expensive than the RCC dam because of the higher cement ratio and the need for extensive formwork. In addition, the construction period will be substantially longer. The ECRD was rejected in favor of the CFRD because a suitable source of impervious material for the core was not readily available and the climate was much less favorable for the construction of an ECRD.

Both of the remaining dam types were arranged to provide a full supply level at El. 80, a dam crest at El. 83, a maximum flood level at El. 84, and an upstream parapet wall to El. 85.

3.4.2.1 Concrete Face Rockfill Dam

The slopes of both the upstream and downstream faces were 1.4H:1.V. The rockfill will be obtained from the right abutment excavation and nearby rock quarries. The concrete face was sized for an average of 0.4 m 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 tunnel was located in the right abutment and consisted of a 5.0-m diameter D-shaped tunnel, 635 m long.

The ungated spillway was located in the right abutment because of the favorable topographic conditions and to take advantage of the right abutment excavation as a source of construction materials. To minimize additional excavation, a side-channel spillway arrangement was selected discharging over an ogee-shaped control structure into a tapering chute and terminating in a flip bucket. As configured, the spillway would have a capacity of 770 m^3/s for a control structure length of 50 m and the chute would taper from 20 m to 10 m over a length of 250 m.

The gated spillway was also located in the right abutment. To develop the assumed flood surcharge, it consisted of a two-bay gated control structure, with 5.0-m wide by 7.0-m high radial gates, a 13-m wide chute and a flip bucket. The capacity of the spillway at full-gate would be 300 m^3/s.

3.4.2.2 Roller Compacted Concrete Dam

The RCC dam was configured for a vertical upstream slope and a downstream slope of 0.75H:1V. The crest would be 8-m wide at El. 83 and a parapet wall would be constructed to El. 85. The estimate was based on a low-paste concrete mix and bedding mixes as required. A drainage system would be installed from a gallery situated in the upstream toe.

The diversion arrangement would include two 2.0-m wide by 3.0-m high culverts located to the left of the river channel. The culverts would be founded on rock and be about 250 m long.

The ungated spillway would have the same hydraulic capacity as for the CFRD. It was located on the RCC dam to discharge directly into the channel by means of a chute and flip bucket.

The gated spillway also will be placed on the RCC dam and will have the same hydraulic capacity as for the CFRD alternative. It also will discharge directly into the Río Indio by means of a chute and flip bucket.

3.4.2.3 Dam Type Selection

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

The RCC alternatives resulted in a cost about 6% lower than the CFRD alternatives and the ungated and gated configurations were equal in cost.

Construction considerations do not necessarily favor either type of dam. The RCC dam can be constructed in a shorter time, but since the water transfer tunnel to Lake Gatun will strongly influence, if not control the implementation schedule, the shorter construction period associated with an RCC is not a factor. The CFRD takes more advantage of local materials while the RCC will require the importation of cement from an offsite factory or even from outside of the country. There is local experience with CFRD construction (Fortuna and Barrigon dams), which may provide some advantage in the oversight of the construction contract; however, this is not of major importance as a well qualified international contractor will likely construct the selected dam.

As mentioned earlier, no subsurface investigations have been performed. Therefore the greatest concern is that the foundation conditions will be more adverse than assumed. The known characteristics of the site tend to favor the CFRD, which does not have to be completely founded on competent rock. Additionally, fill dams are more capable of accommodating the differential deformations associated with low modulus of deformation.

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

As a result of the analysis, an ungated CFRD was selected for further study for the following reasons:

- Changes to the current available foundation information would have less impact on this type of dam and its cost;
- There is no advantage to the shorter construction period for the RCC dam;
- The CFRD is less sensitive to upward variation in unit cost; and
- The ungated spillway has a lower O&M cost and risk.

Additional information concerning the selection of the dam type is presented in Appendix D, Part 2.

3.5 Reservoir Operation Simulation

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.

A simulation run of the operation of Lake Madden and Lake Gatun was made for the period of January 1970 to December 1997. For both reservoirs, the validation model results in terms of reservoir elevations were essentially the same as the observed elevations. Therefore, the model configuration was assumed to be consistently accounting for the water in the system.

3.5.1 Reservoir Rule Curves

The ACP has developed rule curves for the tandem operation of Gatun and Madden Lakes. The purpose of the curves is to provide a minimum draft for ships with a maximum level of reliability. Several curves have been in use throughout the more than 85 years of operation of the Canal, the existing set was implemented in the late 1970`s. The development of the curves has been based on the experience with the hydrology in the Panama Canal Watershed, with a dry season extending from January through April and the rainy season from May through December. In general the intent of the curves is to use in the dry season the water stored during the rainy season and to fill both lakes by the end of the year.

The Indio Rule curve was developed by trial and error to maximize the yield of the Río Indio basin while maintaining the Lake Gatun elevations according to its rule curve. The operating rules consist of a mandatory release 2.6 m^3/s into the Rio Indio, 43 m^3/s for the four-month period from February through May to Lake Gatun, and operating the reservoir to bring the water level to the rule-curve elevations during the other months. The Río Indio rule curve is presented as Exhibit 3-8.

3.5.2 Results of the Operation Simulations

Operation simulations were made for a demand identified in terms of daily lockage requirements (Lockages per day, L/d) using the live storage in Río Indio reservoir between El. 80 and El. 40. One lockage was assumed to equal 55 million gallons or 208,000 m^3. The yield allocated to the Río Indio Project was estimated as the total system yield, (Gatun after deepening, Madden, and Indio) less the yield of the system without Indio. 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 estimated yield of the Rio Indio under these conditions is shown in Table 3-13.

TABLE 3-13 YIELD OF RIO INDIO PROJECT

	Yield		
	L/d	**Mgd**	**MCM/yr**
System Yield at reliability of 99.6%	60.3	3,316	4,578
System Yield w/o Rio Indio	44.5	2,447	3,378
Yield attributed to the Rio Indio {Project	15.8	869	1,200

The increase in system yield attributed to the Rio Indio Project is larger than the mean annual runoff of the river. This phenomenon occurs because the addition of Rio Indio storage provides for a more efficient use of the water in Lake Madden and Lake Gatun. This would be evidenced by a reduction in spill from Lake Gatun.

3.6 Project Configuration Studies

Based on the confirmation of the Reconnaissance Report site and the selection of a CFRD type dam, as described above, alternative development criteria and project configurations were evaluated to confirm or revise the project arrangement identified in the Reconnaissance Report (1). These configuration studies are oriented toward a water supply project arrangement. In subsequent sections of the report, the potential for adding hydropower and developing a commercial agricultural component are discussed.

A center-core rockfill dam was selected by the USACE with a crest at El. 83.5, providing a full supply level at El. 80.0. An ungated spillway with a capacity of 920 m^3/s was located on the left abutment. The spillway chute was proposed as a sloped and/or stepped natural rock cut channel of about 1,100 m length. The project also included a hydropower facility at the dam, transmission line, inter-basin transfer tunnel with associated power facility, as well as access roads and other facilities required for this remote location.

These project configuration studies considered the spillway and diversion flood, the spillway type and size, the diversion arrangement, and water transfer tunnel size. The studies are presented in Appendix D and summarized below.

3.6.1 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, 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 4,345 m^3/s and the 5-day volume if about 243 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 820 m^3/s and a 2-day volume of about 55 MCM.

3.6.2 Reservoir Operating Levels and Live Storage

The reservoir operating level is determined as a part of the project optimization studies. Normally, the reservoir live storage would be increased until the value of the yield from that storage just equals the cost of providing the storage (maximizing net benefits). As mentioned earlier, the ACP decided that the channel through Lake Gatun would be deepened and that a third and possibly a fourth set of locks would be constructed. As a result, the historic navigation demand, toll structure, and operating costs were not a suitable basis for the estimation of navigation benefits and the canal benefit and economic analysis subtasks were suspended. This decision precluded the determination of an optimum level of development. However, in our analysis of optimum dam height, which was performed before the decision was made, several developmental assumptions were determined. First, based on an analysis of the hydraulics of the transfer tunnel, it was determined that the minimum pool of the reservoir could be lowered to El 40. Second, although not verifiable by an economic analysis, it is apparent that a reasonable level of development can be obtained with the full supply level at El. 80. On the basis of these unused dam-height optimization studies and the results of the Reconnaissance Report, it was decided to complete the Río Indio studies with a live storage between El. 80 and El. 40. This results in a live storage of approximately 1,294 MCM.

3.6.3 Spillway Type

As a part of the dam-type selection studies, a concrete-face rockfill dam was selected. In the selection analysis, a side-channel spillway was assumed. The configuration studies include a review of the type of ungated spillway and optimization of the size of the spillway.

A side-channel spillway configuration is usually considered when the abutment topography results in massive quantities of excavation for a conventional spillway (considered to be when the crest is parallel to the dam axis). Based on the spillway width suggested by the USACE in their Reconnaissance Report and the right-abutment topography, it was decided to use a side-channel spillway for the dam-type study. Further inspection of the abutment material and the selection of a CFRD led to the conclusion that most of the abutment excavation could be used in the dam at a lower cost than the next best material source. Therefore, it was decided to revisit the type of spillway to determine if a conventional spillway might be less expensive. A cost comparison was performed, assigning most of the abutment excavation cost to the dam. The conventional chute spillway was determined to be less expensive and was selected.

Optimization of the spillway size was performed assuming an ungated conventional ogee spillway configuration. The optimum size is defined as the lowest cost combination of spillway and surcharge storage.

Spillway costs and surcharge were estimated for spillway widths of 25 m, 50 m, 75 m, and 100 m. Reservoir surcharge was determined by routing the PMF through the reservoir using the HEC-1 computer model. A tailwater rating curve, up to a river flow of 1,000 m^3/s, was developed from 20 river sections located between 200 m and 16,500 m downstream from the dam centerline. The cost of surcharge storage was taken from a cost-height curve developed for the optimization study. It was determined that the entire PMF could be contained within a surcharge of 5 m and this configuration results in the lowest cost. However, there is little precedent for constructing a project of this size without a spillway and the no-spillway alternative was rejected. Spillway widths of 25 m and 50 m, within the accuracy of the estimate, provide the lowest cost combination of spillway and surcharge storage. To reduce the unit flow over the spillway, a 50 m wide spillway was selected.

3.6.4 Diversion Facilities

The size of the diversion tunnel was selected in a two-step study. In the first step, the least-cost total of the diversion tunnel and the cofferdams, both upstream and downstream was estimated. It was assumed that the minimum tunnel diameter would be 2.5 m and that the tunnel would be 635 m long. The second step consisted of evaluating the diversion tunnel diameter needed to meet the reservoir drawdown criteria when operated in conjunction with the water transfer tunnel.

The 50-year flood was routed through the reservoir for three tunnel diameters to determine the upstream and downstream water surface elevations. The results are tabulated below:

Tunnel Diameter (m)	Upstream Water Surface Elevation (m)	Downstream Water Surface Elevation (m)
2.5	23.2	6.6
5.0	20.9	8.7
7.0	19.3	10.2

Based on this operation study and the relative costs of the indicated cofferdams, it is concluded that, for an initial determination of diversion tunnel size, the minimum tunnel diameter would be the most economic arrangement. The upstream cofferdam height would be about 19 m and this is considered reasonable.

For reservoir drawn, the Río Indio is assumed to be a significant hazard, significant risk project as classified by the U.S. Bureau of Reclamation in ACER Technical Memorandum No. 3 dated 1982. The guidelines for reservoir drawdown are as follows:

Drawdown to	Time (days)
75% of full supply volume	30-40
50% of full supply volume	50-60
25% of full supply volume	80-100

As discussed in the following section, the water transfer tunnel diameter for a single-purpose water supply project is 4.5 m (actually computed at 4.35 m but rounded up). In addition, in Section 5, Power Development, it is concluded that the optimum water transfer tunnel diameter for a project that includes power is 5.0 m. Based on a hydraulic analysis and routing studies, for a water transfer tunnel diameter of 4.5 m and 5.0 m, the reservoir drawdown criteria can be met with a diversion tunnel of 4.0 m and 3.5 m respectively.

Therefore, a diameter of 4.0 m is selected for the diversion tunnel. The upstream water surface would rise to El. 21.6 for a 50-year flood and the downstream water surface would rise to El. 7.8.

3.6.5 Water Transfer Tunnel Size and Alignment

The diameter of the Indio to Gatun water transfer tunnel was determined as a part of the HEC-5 runs, which were used to estimate system yield as discussed above. The tunnel was sized to allow a near-maximum development of the Indio basin while minimizing the diameter of the tunnel. After extensive analyses of the system operation, it was determined that a tunnel with a diameter of 4.5 m would provide sufficient capacity to maximize the yield of the Gatun-Madden-Indio system. At this diameter, the tunnel will have a design capacity of 94 m^3/s at a gross head of 53 m and a capacity of about 43 m^3/s at the low supply pool level in the Río Indio Reservoir, El. 40.0 m. If power is added to the project, as discussed in Section 5, the diameter would increase to 5.0 m to improve the transient conditions in the tunnel.

Reservoir and tunnel operating criteria adopted for these studies included the following:

- The maximum reservoir water level will be at El. 80.
- The minimum reservoir water level will be at El. 40.
- The invert of the tunnel intake will be at El. 32.
- The invert of the tunnel at its outlet will be at El. 28.

The tunnel alignment was based on a consideration of the inlet approach and portal topography, the tunnel cover, and the outlet portal and channel topography and the social impact on the outlet location.

Seven inlet portal and three outlet portal locations were identified using information supplied by the USACE prepared for their Reconnaissance Report and map studies by ACP and MWH. The inlet portals IP-1 through IP-7, the three outlet portals OP-1 through OP-3, and the various alignments studies are shown on Exhibit 3-9.

Based on a preliminary screening, alignments from inlet portals IP-2 and IP-3 to outlet portal OP-2 were eliminated because the alignments encountered significant lengths of tunnel that did not meet the cover criterion. In addition, alignment utilizing outlet portal OP-3 were not considered because of difficulties achieving acceptable hydraulic conditions at the outlet, environmental impacts as a result of changes to river flows, and because the local inhabitants indicated a reluctance to have such a structure located in that area.

The anticipated geologic conditions along the tunnel route are summarized in Section 3.3.4.4 and are presented in more detail in Appendix B. The ground cover was assumed to be two diameters over the crown plus 10 m to account for the small scale mapping inaccuracies. Groundwater inflow should be expected during construction; however, there is assumed to be little potential for hazardous gases, hydrothermal water or squeezing ground conditions.

The tunnel alignments were laid out to be as short (straight) as possible between two portals while maintaining appropriate cover to minimize tunnel costs. However, some longer alignments were considered to avoid potentially questionable geologic conditions, provide adequate cover, and to reduce excavation costs and rock support costs. The original eight alignments were reviewed and compared leading to the three tunnel alignments being taken forward:

Alignment Alternative	Inlet Portal	Outlet Portal	Selected	Basis
1	IP-1	OP-1	Yes	Shorter tunnel, good cover
2	IP-2	OP-1	No	Similar to Alt. 1 but longer
3	IP-3	OP-1	Yes	Shortest tunnel, but nominal ground cover
4	IP-3	OP-1	No	Longer tunnel to provide ground cover
5	IP-4	OP-1	No	Similar to Alt. 6
6	IP-5	OP-1	Yes	Representative of Alts. 4-7
7	IP-6	OP-1	No	Similar to Alt. 6
8	IP-7	OP-2	No	Longer tunnel, no cover/geologic advantage

Each of the alignments was finalized on the basis of profiles to ensure, to the extent possible, that adequate cover is available.

Tunnel profiles were then prepared with tunnel rock types for Alignments 1, 3 and 6. The extent of rock support classes were estimated for the different alignments based on the general knowledge of the geology of the area, geologic mapping, and judgment to account for:

- Potential widths and degree of rock fracturing in faults,
- Depth of cover and potential for development of weathered ground,
- Effects of tectonic shears commonly associated with folding of rocks,
- Other factors such as the presence of water or proximity to a major stream crossing, and
- The extent to which a tunnel alignment could encounter mixed face conditions or rock types of markedly different character alternating over short distances.

Tunnel lining, consisting of cast-in-place concrete from 25 cm to 50 cm, was assumed for the entire length. Heavier lining was included in tunnel reaches with minimum ground cover to provide containment. Approach channels were estimated to the inlet portals to reflect the topographic conditions in the vicinity of the inlet and to allow for adequate submergence and velocity through the trashracks.

The estimated costs for each of the tunnel alignments is presented in Table 3-14.

TABLE 3-14 TUNNEL ALIGNMENT ALTERNATIVE COSTS

Alignment Alternative	Estimated Cost (4.5 m Diameter)
1	$31,700,000
3	$31,000,000
6	$36,700,000

The water transfer tunnel is a significant component of the overall cost of the Río Indio development. Selection of the alignment for the water transfer tunnel is based on a best value approach – one that minimizes the construction cost and also the construction risks.

The effect of minimizing tunnel lengths and poor ground conditions is reflected in the cost of the alternatives. In addition, when the estimated costs of alignments are within the limits of the estimate accuracy, it is also necessary to consider minimizing geologic risk. A rigorous evaluation of risk is not possible due to the limited availability of geologic and topographic information. Assessing incremental risk also is made more difficult due to the fact that the three alignments are similar, even to the relative locations of the intake and outlet portals.

However, it is our opinion that Alternative 6 can be eliminated from further consideration as, compared to Alternatives 1 and 3, its length imposes a significant cost penalty that is not offset by any known geological advantages. Alternatives 1 and 3 are essentially the same cost, however, substantial lengths of Alternative 3 would be constructed with close to minimum ground cover. While this is reflected in the higher cost of tunneling to some degree, there is a greater risk that this alternative alignment could be substantially higher in cost than Alternative 1 due to the uncertainty in the available topographical mapping. Therefore, Alternative 1 is selected as the proposed tunnel alignment. Nevertheless, since it is the shortest alignment, Alternative 3 should be reconsidered if additional geologic and topographic mapping show adequate ground cover and ground conditions that result in a lower tunnel cost and acceptable tunneling risk.

4. DESCRIPTION OF THE RIO INDIO WATER SUPPLY PROJECT

The major elements that comprise the Río Indio Water Supply project include:

- A concrete face rockfill dam and appurtenant works at the Tres Hermanas site with its crest at El. 83.
- A 4.5 m diameter, 8,400-m long water transfer tunnel from the Río Indio Reservoir to Lake Gatun.
- A minimum release facility, which will include a 1.6 MW power plant.

The dam will impound a reservoir with a gross storage capacity of 1,577 MCM at El. 80, the full supply level. Live storage between El. 80 and El. 40 will be 1,294 MCM. The resultant dead storage is far more than needed for the estimated sediment deposition although after 100 years it is estimated that the live storage will be reduced by about two percent. The reservoir area at the full supply level, El. 80, is 45.6 square kilometers.

A general plan of the development, showing the location of the dam, the reservoir boundary, and the water transfer tunnel alignment is shown on Exhibit 4-1. A plan of the dam and appurtenant works is shown on Exhibit 4-2, and profile along the centerline of the dam and several typical sections are shown on Exhibit 4-3.

Upon completion of the dam and transfer tunnel, the yield of the water supply system for the Panama Canal with be increased by about 1,200 million cubic meters per year with a reliability of 99.6%. This is about equivalent to 15.8 additional lockages per day in the canal system. The demand on the water supply system of the Canal will depend on the future configuration of the Canal system, the adopted reliability of supply, and the continued supply of M&I water from the system to the Panama Canal Watershed through IDAAN. The implementation of the Río Indio Project will greatly assist the ACP in meeting whatever needs arise. As an example, using the unconstrained navigation demand schedule presented in the Reconnaissance Report and the most current M&I demand estimate, Río Indio Project will be able to supply the additional requirements at a 99.6% reliability through year 2028.

4.1 Description and 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.

4.1.1 Rio Indio Dam and Saddle Dams

Rio Indio Dam will be a concrete-face rockfill dam (CFRD) constructed of durable, free-draining compacted rockfill obtained from required excavation of the right abutment and 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 of the dam have an in-place volume of about 2.7 million cubic meters.

The axis of the dam will be slightly concave downstream and will cross the main channel of the Río Indio at about 994700N, 590300E (UTM Coordinate System). The crest of the dam will be at El. 83 and the width of the crest will be 8.0 m. A 5-m high parapet wall will extend 2.0 m above the crest to El. 85. The dam will be about 91 m high from the deepest foundation excavation to the top of the parapet wall.

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. 80, two saddle dams will be required, one on the north side of the right abutment, and the second about 4 km south-east of the main dam. A profile and cross section of the largest saddle dam is shown on Exhibit 4-4. 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 both saddle dams. The crest of the saddle dams at El. 85 will be 8.0 m wide and riprap processed from the igneous quarry will be placed on the upstream slopes.

4.1.2 Foundation Treatment

The proposed treatment programs for the dam foundation will include surface treatment, shallow foundation (consolidation) 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. Contingency quantities for backfill concrete have been included to reflect the potential for unforeseen conditions.

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 concrete face and through the spillway concrete (or from a grout slab prior to placing first stage spillway concrete). Grout takes should be low to moderate through most of the curtain. The average grout consumption was assumed for estimating purposes to be about 30 kg/m.

Foundation drainage 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. holes would be appropriately inclined in order to maximize the number of joint/fracture interceptions.

4.1.3 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 950 m^3/s using a surcharge of 4.0 m above the full supply level.

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 4-5 and 4-6.

The approach channel will be 52 m wide and will be excavated to El.75. The channel will be straight and approximately 150 m long.

The uncontrolled ogee section will consist of three bays with a total 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 180 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 12 m at the upstream end of the flip bucket. An aeration ramp will be installed about two-thirds of the way down the chute. The chute is sloped at about 33% to facilitate founding the entire structure on competent rock. At this slope the discharge will be supercritical. The maximum water depth will vary from 4.0 m at the crest to 1.5 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 3.0 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 14 m wide and will be at El. 14 m about 1.0 m above the anticipated tailwater elevation under PMF conditions. The plunge pool will be formed in pre-excavated competent rock. A reinforced concrete slab about 8.0 m long will extend downstream from the bucket to provide foundation protection for small discharges.

4.1.4 Diversion During Construction

The facilities for the diversion of the Río Indio during construction consist of cofferdams upstream and downstream from the damsite and a tunnel in the right abutment. The river diversion facilities plan, profile, sections, and details are presented on Exhibits 4-7 and 4-8. The tunnel will serve to:

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

It was determined that the evacuation of the reservoir controls the selection of the capacity of the diversion tunnel. The criteria presented in Section 3.6.4 were adopted for determining the drawdown capability. Provision of the 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 a 4.0-m diameter, modified horseshoe with vertical sides and a horizontal invert, 635 m long. Under the 50-year flood event, the tunnel will discharge about 113 m^3/s with the upstream water surface at El. 21.6 and the downstream water surface at El. 7.8.

An approach channel 250 m long will lead to the intake portal. The approach channel will be horizontal and approximately at El. 5. 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 120-m long discharge channel will extend from the downstream portal to the river channel. It will be formed as a part of the spillway discharge channel.

The diversion tunnel will be excavated in tuffaceous sandstone, which should be of moderate strength and unweathered over most of the tunnel length. Drill and blast methods will be used for excavation and tunnel support will vary from steel sets at the portals to shotcrete in the better sections.

The upstream and downstream cofferdams will be 18-m high and 3.0-m high respectively. The upstream and downstream slopes of the cofferdams will be 2.5H:1V and 2H:1V respectively (the upstream slope of the downstream cofferdam is on the downstream side). Although not yet designed, it is expected that the upstream section will be relatively finer impervious material and the downstream shell will be courser material. A chimney and blanket filter will be provided. The total volume of both cofferdams will be about 107,500 m^3.

A low-level intake structure will be constructed at the intake portal and a gate shaft will be constructed at about the mid-point of the tunnel to facilitate its use as a low level outlet for reservoir evacuation. The intake structure will be constructed to El. 12 to permit continuous operation over the life of the project without interference from sediment buildup. The gate shaft will house a 4-m wide by 4-m high wheel gate and a similar sized bulkhead gate. The diversion tunnel opening in the low-level intake will be plugged when the gate shaft is completed. Water can then rise to El. 12 and flow through the low-level intake and be controlled at the gate shaft.

4.1.5 Minimum Release Facility

A minimum release facility is required to maintain flow in Río Indio downstream of the project. The minimum release has been assumed to equal 10% of the average flow or about 2.6 m^3/s. Computer modeling studies have been performed of the water quality expected in the Río Indio Reservoir (20). While the studies generally indicate that the quality of water in or released from the Río Indio Reservoir should not present any problems that require mitigation, the model did predict low dissolved oxygen levels under some operation scenarios at lower reservoir elevations. There are no water quality concerns discharging through the transfer tunnel into Lake Gatun. When making minimum releases downstream of the Río Indio dam, aeration would likely raise dissolved oxygen levels above minimum acceptable levels. However, to avoid any potential for discharging reservoir water with low levels of dissolved oxygen, the minimum release facility intake will be located at elevations above the projected low oxygen content water, or above El. 30.0.

An intake structure will be located on the face of the CFRD just below El. 40.0, the minimum operating level of the reservoir. The 1.0 m wide x 2.0 m high intake will be equipped with a trashrack and slide gate housed in an inclined structure located on the concrete facing of the dam. Both will be operated from the crest of the CFRD. The intake will connect through the face of the dam to a steel penstock, nominally sized at 1.0 m to provide more than sufficient capacity for the assumed minimum release. The penstock will transfer the minimum release flow 150 m through the dam then 100 m down the downstream right abutment back to the Río Indio. The penstock will be placed in a trench excavated in rock. The trench will be backfilled with concrete under the dam, and conventional granular backfill downstream of the dam. The penstock will terminate at a valve/power house containing a turbine/generator unit and a Howell-Bunger flow regulating valve. Releases will discharge into a channel that directs flow back into the Río Indio immediately downstream of the dam. A guard valve will be provided upstream of the control valve. A plan and section of the minimum release facility is shown on Exhibit 4-9.

Studies were performed of utilizing the minimum release for hydropower generation (see section 5 of this report). The studies show that the addition of hydropower is currently not warranted. However, it has been decided to include a power plant attached to the minimum release facility to provide electricity to the resettlement area and as the primary source of power for project operation. The unit will consist of a horizontal-shaft Francis turbine direct connected to a synchronous generator. The unit will have a capacity of 1.6 MW and be designed to pass the minimum release at the minimum reservoir operating level (El. 40).

4.1.6 Water Transfer Tunnel

The water transfer tunnel consists of an approach channel, an intake structure, the tunnel, and an outlet structure. A plan and profile is shown on Exhibit 4-10 and typical cross sections are shown on Exhibit 4-11.

The approach channel is 100 m long and has its invert at El. 30. The channel is excavated as a trapezoidal section with a bottom width of 20 m and side slopes of 2H:1V. The intake structure is a reinforced concrete structure with an opening of 5 m by 10 m. Trash racks protect the openings. Intake flow velocities at maximum discharge are limited to 1.5 m/s. The invert of the intake is at El. 32 to allow for proper hydraulic conditions at minimum pool operation. The intake structure extends up to El. 85, 1 m above the design flood elevation to provide access to the trash racks. A trash rake is provided to clean the trash racks. A plan and sections of the intake are shown on Exhibit 4-12.

The intake transitions to the tunnel, which is an 8,350-m long modified horseshoe shaped tunnel with vertical sides and a horizontal invert. The finished diameter of the tunnel is 4.5 m and the capacity is 94 m^3/s and 43 m^3/s at full supply level, El. 80 and minimum pool level, El. 40, respectively.

It was assumed that the tunnel construction would utilize drill and blast techniques from multiple headings. For the selected alignment, the estimated proportional distribution of the different rock support classes are shown below:

Tunnel Length (%)	Approximate Length (m)	Rock Support Class	
25	2,100	Excellent	I
40	3,400	Good to Fair	II
30	2,500	Fair to poor	III
5	400	Poor	IV

It is assumed that the tunnel will be fully lined. The lining is included to prevent erosion and deterioration of the rock in areas of soft or highly fractured rock. The lining will be cast-in-place concrete with a minimum thickness of 0.25 m. Reinforcement, thicker concrete, and steel lining will be included as required. For the cost estimate, it is assumed that the concrete lining will be increased to 0.5 m and nominal reinforcement will be provided where the rock cover is relatively low to provide containment.

A gate shaft and gate will be provided at the upstream end of the tunnel for dewatering. It is located 50 m from the intake structure. The gate will be 3.8 m wide by 4.5 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 2.5 m wide by 4.5 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 is provided for a mobile crane to access the gates when maintenance is required. Details of the outlet facility are shown on Exhibit 4-13 and 4-14.

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 ends at El. 20, slightly below the minimum level of Lake Gatun. The sill widens from 9 m wide at the outlet structure to 19 m wide at the downstream channel.

The outlet structure discharges into a 240 m long channel. The channel is excavated as a trapezoidal section with a bottom width of 20 m and side slopes of 2H:1V. It directs the flow from the Río Indio transfer tunnel into Lake Gatun adjacent to Isla Pablon.

4.1.7 Operation Facilities

Operation facilities are required for the Río Indio Water Supply Project. Without the addition of hydropower, and with only the Indio to Gatun transfer tunnel gates requiring daily adjustment, the project lends itself to remote operation. Operation facilities will include a SCADA system for monitoring and operation of the project remotely. The system will monitor water levels, flow measurements, gate operation and project safety instrumentation. The new SCADA system will include a communications package. It will be monitored and operated by the ACP Meteorology and Hydrology Division as an extension to their existing system.

Additional project facilities will include security and lighting at the dam and spillway, and intake and outlet of the transfer tunnel. Landscaping and drainage will also be provided at these project features. Limited maintenance facilities will be retained from the temporary construction facilities.

5. POWER DEVELOPMENT

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 5-1.

TABLE 5-1 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	5	1963(2),'66,'71(2)	93

As a part of the reconnaissance studies performed by the USACE (1), the potential for adding hydropower to the Río Indio Project was considered. The analysis indicated that, at a benefit of $0.07/kWh, the addition of hydropower was marginally 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 Indio Project consisted of a 25 MW installation at the base of the dam, operating at a plant factor of 0.5, and a 5.0 MW installation at the downstream end of the transfer tunnel to Lake Gatun. The facilities also included substations at each powerhouse, and a 115 kV transmission line from the dam to the tunnel powerhouse and on to the La Chorrera substation (estimated in the current studies to be about 47 km long from the transfer tunnel powerhouse).

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

5.1 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.

5.1.1 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 use, 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 have averages about 70 GWh 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 5-2. 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 5-2 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 the Río Indio Project and that all other demands occurring in the Panama Canal Watershed will be subject to competition.

5.1.2 National Market

Historic energy demand and peak load for the Panama National Integrated System (PNIS) is presented in Table 5-3:

TABLE 5-3 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
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 10-year period. 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 1999 are shown in Table 5-4:

TABLE 5-4 MONTHLY PEAK LOADS AND ENERGY DEMANDS OF THE PNIS FOR 1999

Month	Peak Load (% of Annual Peak Load)	Energy Demands (% of Total Demand)
January	93.5	7.98
February	93.6	7.35
March	97.2	8.79
April	99.7	8.72
May	98.6	8.61
June	98.9	8.18
July	96.4	8.24
August	98.9	8.35
September	97.9	8.15
October	97.8	8.55
November	96.4	8.30
December	100.0	8.78
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 Power Market Appendix.

5.2 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, 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 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. 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 5-5:

TABLE 5-5 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 for all three estimates below:

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.

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The average annual load factor of the PNIS was at 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.

5.3 Opportunity for Río Indio Generation

The existing PNIS had an installed capacity of 1,058 MW in 2000. The total generation from the PNIS facilities in 1995 was 4,4457 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 Indio 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 (12), there are plans to retire two plants with an aggregate capacity of 80 MW by January 1, 2010.

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 5-6 POWER BALANCE IN 2010

	Capacity Demand
Year 2010	1,608 MW
Available Capacity (2000)	1,058 MW
Committed Capacity	119 MW
Planned Retirement	80 MW
Net Capacity	1,097 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 near future and that the Indio hydro will be easily absorbed into the PNIS.

5.4 Potential for Adding Hydropower to the Río Indio Project

The Project as described in sections 3 and 4 is configured to supply water to the Panama Canal for navigation and M&I water supply. Studies were performed to determine if the addition of hydropower to the water supply project was viable. The studies consisted of estimating the potential energy production under a variety of conditions, evaluating the alternative locations for generating electricity, and determining the viability of the most attractive alternatives. In summary the addition of hydropower was found to be not viable under current conditions. However, if subsequent development is implemented in other watersheds that use the Indio Reservoir for transfer to Lake Gatun, hydropower may be attractive. The details of the power and energy studies for the Río Indio Water Supply Project are presented in Appendix E.

5.4.1 Alternatives for Power Development

The potential for power development was made within the constraints of the operating criteria for the water supply project. Based on a series of operation simulations using the HEC-5 model, it was determined that the opportunity exists to alter the operation and water transfer schedule from the Río Indio reservoir to Lake Gatun to favor the production of energy while satisfying the navigation and M&I water demands. As mentioned previously, the navigation demands are not well defined and, therefore, for these studies of potential energy demand, the navigation demands presented in the Reconnaissance Report (1) are used to assess the timing of the partial yields.

5.4.1.1 Power Development Alternatives When the Demand is Equal to or Greater than the Indio Yield

Potential energy production was estimated for the following operating conditions:

- For discharge through the water transfer tunnel under maximum yield conditions with the tunnel sized for water supply (4.35 m).
- For discharge through the water transfer tunnel under maximum yield conditions with the tunnel diameter increased to 5.0 m.
- For discharge through the water transfer tunnel under maximum yield conditions with the tunnel diameter increased to 6.0 m.
- For the same three conditions above, but with the operating regime changed to allow a constant monthly water transfer rather than the 4-month transfer that resulted from the operation studies.

Under the reservoir operating criteria described in Section 3.5, three distinct patterns of release occur through the tunnel. Referring to Exhibit 5-1, the patterns are as follows:

- For 56% of the time, the discharge in the tunnel is 43 m^3/s. This discharge occurs with the reservoir level between El. 80 and El. 40 and corresponds to the months of February to May when the discharge is governed by the Río Indio rule curve established in the operation studies.
- For 17% of the time, the discharge varies between 0 and 55 m^3/s while the reservoir is at or near El. 80. These discharges are made to satisfy the demand at Lake Gatun. Under these conditions, the tunnel is not discharging at full capacity.
- The final pattern occurs when the tunnel is operated at maximum capacity.

For the water supply project configuration and this discharge pattern, it was determined that the maximum energy production would be about 22.5 GWh and that this energy would be developed with a 16.3 MW plant operating at a plant factor of 15.8%. For the same maximum turbine discharge and tunnel diameters increased to 5.0 m and 6.0 m, the energy production increased to 30.1 GWh and 42.9 GWh respectively. Increasing the capacity of the units had essentially no effect on generation for the 4.35 m and 5.0 m tunnels and only a nominal impact on the production with a 6.0 m tunnel.

As a part of the energy production studies, additional reservoir operation simulations were performed to determine if energy production could be increased with little or no penalty to the water supply requirements. It was determined that if the four-month discharge were delivered at a reduced rate over 12 months and all other operation rules remained the same, the same yield could be provided at the same volumetric reliability and the energy production could be substantially improved. With a 4.35 m tunnel, the energy production would increase from 22.5 GWh to 33.0 GWh while the required plant capacity would be reduced from 16.3 MW to 9.0 MW. For the 5.0 m tunnel, production was increased from 30.4 GWh to 33.7 GWh

As a result, it is concluded that if power is included as a project purpose, additional operation rules should be tested to maximize power production while maintaining the volumetric reliability of the water supply project.

5.4.1.2 Power Development Alternatives When Demand is Less Than the Río Indio Yield

When the demand on the Río Indio Reservoir is less than the full yield of the reservoir, there are three primary alternatives to generate power:

1. Water could be transferred to Gatun according to a schedule to meet the demand on Gatun while maintaining the water level in Indio as high as possible. This would maximize production at the tunnel powerplant (Isla Pablon Powerplant) The powerplant at the dam (Indio Dam Powerplant) would be sized for a minimal release.
2. Water could be transferred to Gatun to maximize the power production at the Gatun Powerplant. Indio would be maintained between El. 55 and El. 80 for as long as this storage can provide the required yield to the system.
3. Water could be transferred to Gatun to just meet the navigation and M&I demands and the generation at the dam site would be maximized. Two sub-alternatives were considered; a) the minimum water level at Indio reservoir would be set at El. 55 and b) the minimum water level at Indio reservoir would be set at El. 50.

The existing system complemented with the (on-going) deepening of Lake Gatun by about 1.0 m will yield 44.5 lockages per day (L/d), which will be sufficient to meet the assumed demand until 2010. By 2029, using the demand schedule described above, the full yield of the existing system plus Río Indio operating between El. 80 and El. 40 will be required. Over this 19-year period, the opportunity exists to operate under one of the three alternatives.

Based on an assessment of the total system generation, at Gatun, Madden, Isla Pablon, and the damsite, it was determined that Alternatives 1 and 3a warranted further study. Alternatives 2 and 3b were rejected as having a similar cost to Alternatives 1 and 3 respectively and generating less electricity.

5.4.1.3 Comparison of Selected Alternatives and Definition of Potential for Development

The comparison of alternatives consisted of selecting an optimum or appropriate level of development for each power plant for each alternative and performing an economic evaluation of the two alternatives.

The economic value of the development was based on information provided by the ACP Power Department. It was suggested that the benefits be computed on the basis of the current value of energy and capacity, which are \$45/MWh and \$60/kW-year respectively. The capacity benefit was based on firm capacity. Firm capacity is computed as the energy provided 95% of the time over an 8-hour period. The energy benefit is based on average annual energy produced at the power plant.

The economic costs were estimated as the cost of the project with power less the cost of the project without power. Annual costs were estimated as 0.5% of the civil cost plus 1.25% of the equipment costs plus 1% of the transmission line cost. The major cost components of the power facilities were as follows:

- The powerhouse and powerhouse intake associated with the Isla Pablon plant;
- The powerhouse and powerhouse intake associated with the Río Indio Dam power plant;
- Adjustments to the water transfer tunnel;
- The transmission system to link the development to the national grid, and;
- Elimination of the water supply transfer tunnel intake and energy dissipation features. and the Río Indio Dam low-level outlet facilities.

As a result of a hydraulic analysis of the water transfer tunnel for power operation, two major requirements were identified to provide acceptable transient conditions. First, it was determined that a surge tank is necessary. Second, in order for the surge tank to operate correctly under all conditions, it is necessary to have a larger diameter tunnel or to lower the invert elevation of the tunnel. As it is not feasible to lower the tunnel invert because of the tailwater elevation developed at Lake Gatun, the tunnel diameter was increased from 4.5 m to 5.0 m. Further analysis was performed to determine if a larger tunnel would provide any additional benefits to the project. Based on an incremental cost and benefit evaluation, it was determined that increasing the tunnel diameter above 5.0 m did not improve the economics of the power development.

Each of the two remaining alternatives was optimized. Alternative 1, which maximizes power production at the Isla Pablon Power Plant, was evaluated with a 2.5 MW plant at the dam and variable installations at Isla Pablon, and Alternative 3, which maximizes power production at the dam, with a 5.4 MW plant at Isla Pablon and variable installations at the Río Indio Dam. It was determined that for Alternative 1, the optimum installation at Isla Pablon would be about 14 MW and for Alternative 3, the optimum installation at the dam would be 15.9 MW. As a part of the optimization of Alternative 3, it was also concluded that no hydropower development would be recommended at the end of the transfer tunnel as the return would be much too low.

5.4.1.4 Comparison of Alternatives 1 and 3

The results of the comparison between Alternatives 1 and 3 are presented in Table 5-7:

TABLE 5-7 COMPARISON OF HYDROPOWER ALTERNATIVES

Alternative	Hydropower Component	Construction Cost	O&M Annual Cost	Average Annual Energy	Internal Rate of Return
1	Indio – 2.5 MW	$6,816,000	$57,000	12.2 GWh	9.1%
	Pablon – 14 MW	$23,482,000	$200,000	43.0GWh	
	Transmission	$4,588,000	$45,000	-	
3	Indio – 15.9 MW	$19,438,000	$181,000	22.7GWh	9.0%
	Transmission	4,588,000	$45,000	-	

On the basis of this comparison, Alternative 1 is selected as providing the best opportunity for the development of hydropower as it produces nearly 2.5 times the energy and, during the period when demand is less than yield, the excess water transferred from Indio to Gatun would be used to generate at the Gatun Power Plant. It could be argued that this additional generation, estimated to be about 190 GWh per year over the period from 2011 through 2028, could be used to justify the power development; however, the generation also could be produced with the water supply project facilities. Therefore, it is not considered to be a benefit of the hydropower facilities.

5.4.1.5 Description of the Potential Hydropower Facilities

The facilities associated with Alternative 1 are as follows:

Isla Pablon Power Plant Facilities

- An intake located adjacent to the transfer tunnel gate chamber with facilities for raking and removing trash;
- Increasing the diameter of the 8,400-m long, 4.5 m diameter modified horseshoe shaped tunnel to 5.0 m and installing a steel liner over the last 250 m;
- A surge tank located 250 m upstream from the powerhouse;
- A powerhouse located at the end of the water transfer tunnel;
- Two vertical-shaft Francis turbines each rated at 7.0 MW direct connected to synchronous generators rated at 7,800 kVA with a power factor of 0.9 and a rotational speed of 360 rpm;
- Appropriate gates, valves, and a 30-ton crane;
- Switchyard and switchgear, and;
- A 47-km long, 115 kV, single circuit transmission line to the existing La Chorrera substation.

Rio Indio Power Plant Facilities

- A 250-m long 2.5 m diameter power tunnel in the right abutment of the dam;
- A power intake with trash screening and raking facilities;
- A powerhouse at the downstream end of the tunnel;
- A horizontal-shaft Francis turbine rated at 2.5 MW direct connected to a 2,777 kVA synchronous generator with a 0.9 power factor and an rotational speed of 600 rpm;
- Appropriate gates, valves and a 12-ton crane;
- Switchyard and switchgear, and;
- A 12.6-km long, 13.8 kV, single circuit transmission line to the Isla Pablon site.

5.4.2 Evaluation of the Hydropower Potential

A summary estimate of cost for the hydropower facilities described above is presented in Table 5-8.

TABLE 5-8 COST OF POTENTIAL HYDROPOWER FACILITIES

Item	Estimated Cost
Isla Pablon Power House	
Civil Works	$6,996.000
Electrical and Mechanical Equipment	$10,793,000
Subtotal Isla Pablon	$17,789,000
Rio Indio Power House	
Civil Works	$2,234,000
Electrical and Mechanical Equipment	$2,932,000
Subtotal Río Indio	$5,166,000
Transmission System	$3,476,000
Subtotal Direct Cost	$26,431,000
Contingency	$5,289,000
Total Direct Cost	$31,720,000
Engineering and Administration	$3,180,000
Total Construction Cost	**$34,900,000**

Based on a life-cycle analysis, the economic internal rate of return for this configuration is 9.1%. As this return is significantly less than the opportunity cost of capital for ACP (12%), the addition of power to the Río Indio Project is not recommended at this time.

5.4.3 Other Considerations for Hydropower Development

Although hydropower development is not recommended at this time, there are other considerations that should be taken into account:

- Additional development at the Río Toabre or Río Coclé del Norte damsites, which would deliver water to Lake Gatun through the Río Indio reservoir, would change the economics of hydropower development at Indio. For example, the transmission line included in the Indio costs would have enough capacity for Toabre and the incremental sizing of the transfer tunnel to handle the additional flow from Toabre would be very cost effective.
- It is possible that powerplant at the dam may be feasible under some future conditions. For example, it may be feasible to use the plant as a local supply for the project and for any resettlement in the area. While the economic return will still be low, it still may be the best solution for an isolated system.

6. 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.

6.1 Land Use

The land use was initially identified by reviewing available aerial photographs and verified by a field reconnaissance. The aerial photographs were dated from 1979 through 1993. The land use categories adopted for this study were forest, pasture, and stubble and combinations of these categories. These elements have been subjected to the most drastic changes in terms of use over time and it was assumed that they are indicative of present land use. The field adjustments were based on transects and random observations over the course of two field visits.

In the area, mature forests generally do not exist. The vegetation consists mostly of pasture, secondary forest, and stubble. Farming is nearly exclusively at a subsistence level. Crops are not discretely differentiated from stubble. The farming systems found consist mainly of two cropping cycles:

- First cycle
    - Main crop – rice and maize
    - Ancillary crop – root crops, plantains

- Second cropping cycle
    - Main crop – maize
    - Ancillary crops – beans in association with maize

Coffee is also grown on small, dispersed farm holdings. Most of the cleared holdings are covered with native pasture that has evolved from the process of slash and burn farming. The present land use is shown on Exhibit 6-1 for four primary and five mixed-use categories.

6.2 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. A land capability map is shown on Exhibit 6-2. Referencing the US Bureau of Reclamation Land Classification Specifications for Irrigated Land Use, it was determined that the best land in the basin is Class 2 and that this land lies along the river. There are also significant amounts of Class 3 land. The soils are moderate to fine and include loam, silty loam, silty clay loam, clay loam, and clay textured horizons. The chemical analysis indicates that some of the land may be highly acidic. 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.

As a result of the land resources investigations, eight potential development areas were identified having a gross area of approximately 5,500 ha. These areas are shown on Exhibit 6-3. The potential development areas are generally located on Class 2 and Class 3 lands identified as arable land. The areas, and the gross and net surface areas are presented in Table 6-1 as follows:

TABLE 6-1 POTENTIAL DEVELOPMENT AREAS

Area	Area Location	Gross Area (ha)	Net Area (ha)
1	Mouth of Río Indio	377	300
2	Río Indio Valley	1,249	1,025
3A	La Encantada	445	250
3B	La Encantada	2,263	1,000
4	El Papayo	307	200
5	Nuevo Paraiso	878	450
6	Las Marias	118	100
7	Río Indio Abajo	63	50
8	Tierra Buena	266	150

The net surface 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 Boca de Uracillo. The available water is estimated as the monthly flow exceeded 80% of the time converted to monthly discharge per unit of area. The minimum flows available at the streams supplying the potential areas, after deduction a minimum flow, was estimated to be 6.6 liters per second.

The source and estimated available flows for all of the areas are shown in Table 6-2:

TABLE 6-2 – WATER AVAILABLE FOR IRRIGATION

Area	Source of Water	Catchment Area (km^2)	Available Minimum Flow (l/s)
1	Release from reservoir	-	-
2	Release from reservoir	-	-
3A	Release from reservoir	-	-
3B	Reservoir	-	-
4	Río Jobo at El. 65	7	46
5	Río Teria at El/ 80	70	460
6	Río Uracillo at El. 125	23	152
7	Río Indio at El. 220	40	264
8	Río Indio at El. 120	50	330

6.3 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 identified crops were selected to match the current farmer preferences while allowing for the production of a marketable surplus as well as farm-family requirements. Cropping patterns were developed that match these crops to three general landscape positions as follows:

TABLE 6-3 CROP PATTERN DESIGN

	Landscape Position		
	Fluvial Terraces	Side Slopes and Bench/Terraces	Side Slopes and Mini Plains
Dry seeded and transplanted rice	X		
Transplanted rice		X	X

	Landscape Position		
	Fluvial Terraces	**Side Slopes and Bench/Terraces**	**Side Slopes and Mini Plains**
Maize, root crops, or maize and beans		X	X
Pasture	X	X	
Plantain	X		
Coffee		X	X
Agroforestry		X	X

The suggested pattern for these crops is shown on Exhibit 6-4. Nursery crops are included because the rainfall in the area is not dependable and not well distributed throughout the proposed growing season.

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 varied form 50% for flood irrigation to 60% and 65% for sprinkler systems and micro sprinkler and drip systems respectively. 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. For areas 1-4, the peak design flow was estimated as 1.0 l/s/ha and for areas 5-8, the peak design flow is 0.8 l/s/ha.

6.4 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. 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 6-4.

TABLE 6-4 ECONOMIC ANALYSIS OF AGRICULTURAL DEVELOPMENT IN POTENTIAL AREAS

Potential Area	Construction Cost ($1,000)	Annual Cost ($1,000)	Benefits ($1,000)	Rate of Return
1 Mouth of Río Indio	3,171	45	380	10
2 Río Indio Valley	17,895	156	2,608	12
3A La Encantada	4,442	44	509	10
3B La Encantada	16,107	155	2,035	10
4 El Papayo	4,065	55	356	7
5 Nuevo Paraiso	6,451	97	822	10
6 Las Marias	1,847	22	183	8
7 Río Indio Abajo	814	6	91	10
8 Tierra Buena	2,135	30	274	10

The construction costs in Table 6-4 exclude the cost of land, power supply, and marketing infrastructure such as access roads, farm support and marketing facilities. With these exclusions, the economic results suggest that each of the areas is marginally suitable for agricultural development.

To assess the viability of a commercial development, all of the areas were considered as one development and the cost of power and access was included. The total cost associated with power supply for irrigation development is estimated to be $1,200,000. An allocation of the cost of such supply for each of the proposed area is presented in Appendix F. The road development program for the Rio Indio Study Area, which is presented in Appendix F, has been estimated at approximately $12,800,000. The cost specifically associated to the agriculture and irrigation development is estimated to be $6,600,000. If all potential areas are considered as one development and the cost of power and access is added, the rate of return will be about nine percent.

Therefore, it is concluded that the potential for irrigated agriculture exists; however, implementation of the development is not warranted at this time.

PÁGINA EN BLANCO

7. CONSTRUCTION PLAN AND ESTIMATE OF COST

As a result of the analyses of the potential for adding hydropower and irrigated agriculture to the project, it is concluded that only water supply facilities are warranted at this time. Therefore, an implementation schedule, a detailed construction schedule and cost estimate have been prepared for the project as described in Section 4 Additional details of the construction plan and cost estimate are presented in Appendix G.

7.1 Implementation

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

- Completion of the Environmental Studies
- Confirmation of Feasibility and Project Configuration
- Funding
- Resettlement Plan
- Environmental Field Studies
- Resettlement
- Final Design
- Award of Construction Contracts
- Construction

An implementation schedule is presented on Exhibit 7-1.

The environmental base line studies are underway. Prior to securing funding for the project, it will be necessary to confirm feasibility and probably to develop an acceptable resettlement plan. The confirmation studies will include a feasibility-level drilling program and an economic analysis, and finally, the confirmation of the project arrangement.

Once the decision to obtain funding has been taken, a resettlement program will be required. This can be prepared while funding is being secured. With funding in place, the design-level investigation program and final designs can commence along with the implementation of the resettlement program and any environmental field studies.

Construction of the project has been scheduled for two separate general contracts: 1) Access Roads and the Construction Camp, and; 2) The storage facilities and the transfer tunnel. It is anticipated that the access road contract will be let to a local contractor and an international contractor will handle the dam and tunnel contract.

It is assumed that the ACP has the capability to manage the construction contracts and also to perform the operation and maintenance. It is suggested that the ACP hire a team responsible for the consulting engineering services relating to the works required for implementation. The operation and maintenance can be accomplished by adding staff to the ACP's existing organization. The facilities required for the water supply project are well within the existing capability of the current O&M organization.

The completion of the environmental studies and environmental field studies relate to the development and implementation of a resettlement plan and, if necessary, the excavation of the archaeological site, identified on a preliminary basis, at Boca de Uracillo.

Procurement of contractors can be accomplished as soon as funding is assured and should be completed after design so that construction can start immediately.

7.2 Construction Plan

A detailed construction plan and schedule has been developed for the implementation of the Río Indio Water Supply Project. For the purpose of this study it was assumed that the project is to be completed prior to the dry season of 2011 when the demand for navigation and M&I water is expected to exceed the yield of the existing system complemented by the deepening of Lake Gatun.

The construction of the project including the construction of the access roads, the dam and appurtenant works and the transfer tunnel is anticipated to take approximately 66 months. At the end of that period the Indio reservoir would have a 50%-probability to be filled to El.59, which would be sufficient to transfer water to Lake Gatun and respond to a significant drought. Filling the reservoir to its maximum operating level, i.e., El 80 will require at least an additional wet season. The implementation of such a schedule would require the start of the preliminary design work, including detailed topography and geotechnical investigations, by mid-2005. The construction schedule is presented on Exhibit 7-2.

The project construction has been divided into four major groups of activities, namely:

1. The preliminary works.
2. The transfer tunnel.
3. The Río Indio dam and appurtenant works, including diversion tunnel, low level outlet, cofferdam, concrete faced rockfill dam (CFRD), spillway, saddle dam.
4. The clearing of the Río Indio reservoir area and the filling of the reservoir.

7.2.1 Preliminary Works

The preliminary works include mobilization, access road construction, construction camp, power supply and other services, establishing quarries, crushing and concrete plants, etc.

7.2.1.1 Mobilization

Upon receiving Notice to Proceed, the contractor will initiate mobilization of staff and equipment. The effort is anticipated to extend over nearly one year as the contractor's effort will built-up during the execution to the preliminary works including access road, establishing construction camp and power supply, establishing quarries and installing crushing plant and concrete plant. Most of the heavier pieces of equipment will be mobilized towards the end of the first year when the main access road has been completed and when the construction of the main features of the project starts.

The mobilization of personnel and equipment for road construction is expected to be rapid as it is entirely available locally.

7.2.1.2 Access Roads

Construction of the project requires both temporary and permanent access improvements. No attempt has been made to locate the regional access that will be necessary as a part of the resettlement program. However, to the extent possible, the permanent access described herein will be used. The temporary and permanent access is presented on Exhibit 7-3.

The Río Indio dam site is located at approximately 66 km by road from the Cristobal Harbor (Colon) and approximately 88 km from the Balboa Harbor (Panama City).

From Cristobal Harbor, a paved road (No. 3030) reaches the western end of Lake Gatun near the upper reaches of the Río Salud and Quebrada La Encantadita. A dry weather road approximately 12 km long joins Route No. 3030 to El Limòn in the vicinity of the dam site.

From Balboa Harbor, a paved road passes through La Chorrera and reaches El Cigual approximately 18 km West of La Chorrera. The following 27 km from El Cigual to Tres Hermanas in the Río Teria valley consists of a gravel road; another 13 km of dry-weather road joins Tres Hermanas to El Limòn.

Although access from Colon is shorter, the crossing of the Gatun Locks through the existing moveable bridge may represent a major disruption to the flow of supply for the contractor. It is also estimated that construction of a temporary docking facility on the western shore of Lake Gatun may not be a practical solution to transport equipment and supply to the dam site. For these reasons it is anticipated that access to the dam site will be gained from Panama City and the Balboa Harbor.

A total of 60 km of roads will need to be built to access the various location of construction. These include:

- Improvement of 27 km of all weather gravel road from El Cigual to Tres Hermanas to the same highway standards as Rte 3030.
- Improvement of 9 km of dry weather road from Tres Hermanas to the junction of the connection with Rte 3030 and the construction access to the dam to the same highway standards as Rte 3030.
- 6 km of new road from the junction to Rte 3030 to the same highway standards as Rt. 3030.

Upon completion of these three segments, this permanent access will also provide the second transisthmian highway by connecting El Cigual to Rte 3030 and the Colon area.

- From the Junction to the construction camp, the saddle dams, the dam crest, the tailrace, and the tunnel intake: 10.0 km of new, permanent access;
- From Rte No. 3030 to the tunnel outlet (Isla Pablon): improvement of 2.5 km of all weather gravel road;
- From the permanent road between the junction and the construction camp to El Limòn and the cofferdam, the diversion tunnel, the minimum release conduit and Quarry No. 2 (Cerro Las Ollas): 3.5 km of new temporary road;
- From the 6 km of new road between the junction and Rt. 303, 1.5 km of new temporary road to Quarry No.1 (Cerro La Jota): 1.5 km;
- From 6km of road between the junction and Rt. 3030, 0.5 km of new temporary road to adits Nos.1 and 2.

Construction of the access roads is expected to take about 12 months.

7.2.1.3 Construction Camp

The camp will be located North of the community named El Jordan on a relatively flat area above El.100. The area of approximately 7 to 8 hectares, located at about 1.5 km from the dam site is sufficient to accommodate the large labor force needed during construction, and at an appropriate location for residential use after completion of the work. The camp construction will be started so that its substantial completion coincides with the completion of access and the beginning of the construction of the main features of the project. Eight months of construction will be sufficient to provide housing for the initial crews working at the dam site and at the transfer tunnel.

7.2.1.4 Power Supply

Construction needs for electrical power 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. 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.

7.2.1.5 Rock and Aggregate Quarries

Two quarries have been identified for use in this project: one located on Cerro La Jota, East of the dam site at 6.5 km by road from El Limòn, and the second located on Cerro Las Ollas approximately 3.0 km by road South of the dam site. The Cerro La Jota quarry is anticipated to be mainly used for the manufacturing of concrete aggregates (290,000 m^3) and an estimated 270,000 m^3 of rockfill for the dam. Approximately 920,000 m^3 of rockfill will be extracted from Cerro Las Ollas.

A crushing plant and an aggregate stockpile area will also be established near Cerro La Jota. The establishment of the quarries is anticipated to take approximately 6 months including geotechnical investigations and it is not on the critical path as investigations can be initiated at any time during the first year of activities well before aggregates are needed.

7.2.2 Transfer Tunnel

The drill-and-blast method was selected for the purpose of scheduling, as tunnel boring machine (TBM) are most 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 three to four meters per day has been adopted as a realistic estimate for the Río Indio transfer tunnel.

In order to complete the project in a reasonable construction period it is anticipated that additional adits are required. It is recommended to build the tunnel with two adits.

Overall the tunnel construction, including the intake and outlet works, is expected to take about 32 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.

7.2.3 Rio Indio Dam and Appurtenant Work

A diversion tunnel approximately 750 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 emergency drawdown criteria selected the low-level outlet will consist of a 4.5-m diameter D-shaped tunnel. As the construction of the feature is one of the critical activities, the tunnel excavation will be initiated at both ends of the tunnel, followed immediately by the gate shaft excavation and concreting. The low-level outlet construction is estimated to take approximately 13 months including gate installation and testing.

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 8 weeks.

The dam construction requires the placement of approximately 3,080,000 m^3 of materials including 2,700,000 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, 1,190,000 m^3, will be extracted from two quarries, Cerro La Jota and Cerro Las Ollas, located at about 6.5 km and 3.0 km from the dam site respectively.

Excavations for the dam foundation and right abutment of approximately 1,970,000 m^3 are expected to take 13 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 from the dam central section and the spillway, will be sufficient to raise the dam to El. 24; this activity will be initiated in parallel with the construction of the plinth. The remaining rockfill from required excavation will be sufficient to raise the dam to El. 45. This is expected to occur 27 months after initiating construction of the dam; another 14 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 most efficient use to the capacity concrete plants.

7.2.4 Reservoir Clearing and Filling

Approximately 47 km^2 (4,700 hectares) of land needs to be cleared to reach El.85. The reservoir area will also need to be surveyed to determine the initial reservoir volume and also to be used as the base survey to monitor sedimentation. The vegetation clearing is expected to take a minimum of two years and will be started from the lower level working towards the higher elevations.

The project will only be operational when it is capable of delivering water into the Lake Gatun. Also it is important to be capable to be able to test the hydraulic turbine at the dam and all mechanical and electrical equipment. For these reasons, 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. At that time the power intake and the transfer tunnel intake will be completed with all equipment, power supply and controls.

For the purpose of determining the required time to fill the reservoir, the monthly flow sequence of 52 years from 1948 to 1999 was used. It was also assumed that a minimum release of 2.6 m^3/sec would be continuously released during the filling period. The results of this analysis are presented in Table 7-1:

TABLE 7-1 RESERVOIR FILLING

Filling Period	Duration	Reached Levels		
		At 90% probability	At 50% Probability	At 10% Probability
Jul – Dec	6 months	El.43	El.51	El.59
Jan – Dec	12 months	El.49	El.57	El.66
Jan – Jun	18 months	El.54	El.62	El.70
Jul – Dec	18 months	El.67	El.72	El.80 (15%)
Jan – Dec	24 months	El.70	El.77	El.80 (35%)

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.57. This level is sufficient to transfer water to the Lake Gatun and to test the Río Indio unit near its design condition. From this table it can also be seen that at least two rainy seasons are needed to fill the reservoir to its maximum operating level.

7.3 Cost Estimate

The cost estimate for the construction of the Río Indio Water Supply Project has been developed on the basis of the present feasibility design and the construction schedule presented in Section 7.2. The estimates represent the prevailing rates during the middle of 2001. The estimates are based on the assumption that an international contractor will construct the storage facilities and the water transfer tunnel without restriction on sources of supplies and equipment. The unit prices have been estimated at feasibility level. The quantities have been estimated with the constraint of no subsurface investigations. The project construction cost is comprised of general costs, which includes land acquisition and resettlement, access; civil works; equipment; contingencies; engineering and owner's administrative costs.

7.3.1 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. 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. The costs of salary were then calculated by adding 50% for social cost. This resulted in the following hourly cost of salary:

TABLE 7-2 LOCAL LABOR COST OF SALARY

Type	Cost
Unskilled labor	\$5.50/hr
Skilled labor	\$6.60/hr
Equipment operator	\$7.90/hr
Truck driver	\$6.20/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. Equipment requirements and production rates were developed based on experience in similar types of projects 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 7-3 below shows estimated unit costs of materials delivered at the site:

TABLE 7-3 MATERIAL UNIT COST

Material	Unit	Cost
Cement	Kg	$0.12
Explosive	Kg	$1.50
Reinforcement Steel	Kg	$0.76

The Contractor operational costs 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 42 months 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 to these costs, the following additional costs were assumed:

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 appear to be reasonable estimate for this type of construction.

The unit prices shown in Table 7-4 were used:

TABLE 7-4 ESTIMATED UNIT PRICES (MID-2001 LEVEL)

Material	Unit	Cost
Vegetation Clearing	ha	$2,200
Clearing and Grubbing	m^2	$0.55
Overburden Excavation	m^3	$3.20
Bulk Rock Excavation	m^3	$8.75
Structural Rock Excavation	m^3	$14.70
Transfer Tunnel Excavation	m^3	$72.30
Shaft Excavation	m^3	$295.00
Shotcrete	m^2	$45.90
Rock-bolt	m	$60.50
Steel Ribs	kg	$2.90
Selected Fill	m^3	$7.20
Aggregate	m^3	$15.90
Rockfill Placement	m^3	$3.75
Fill Transportation	m^3 x km	$0.30
Mass Concrete	m^3	$115.00
Structural Concrete	m^3	$140.00
Tunnel Concrete Lining	m^3	$118.00
Formwork	m^2	$46.20
Reinforcing Steel	kg	$1.36
Temporary Access Road	km	$114,000
Permanent Access Road	km	$146,000

7.3.2 Construction Costs

A summary of the construction cost is shown in Table 7-5 and a detailed cost estimate is presented in Table 2 at the end of the report text.

TABLE 7-5 SUMMARY COST OF THE RÍO INDIO PROJECT

Item	Estimated Cost
Land Acquisition and Resettlement	$26,100,000
General Costs including Construction and Permanent Access	$23,839,000
Diversion	$3,603,000
Main Dam	$52,704,000
Spillway	$6,043,000
Low-Level Outlet	$3,049,000
Saddle Dams	$7,427,000
Interbasin Water Transfer Tunnel	$46,765,000
Minimum Release Facility	$837,000
Operation Facilities	$1,139,000
Subtotal Direct Cost	**$171,506,000**
Contingency	$28,868,000
Direct Cost	**$200,374,000**
Engineering and Administration	$30,056,000
Construction Cost (mid-2001 price level)	**$230,430,000**

7.3.3 General Costs

The General Costs include mobilization, land acquisition and resettlement, temporary facilities, access roads, a bridge across the Rio Indio, watershed management, mitigation plan implementation, and reservoir clearing. Certain of these costs are discussed in more detail below.

7.3.3.1 Land Acquisition and Resettlement Costs

The allocation for land acquisition will include all land in and around the reservoir up to El. 90, plus land for structures, borrow areas, construction roads, construction camp, other temporary structures, and disposal areas. These areas comprise a total area estimated to be about 55 sq. km. The value of these lands has been estimated to average $1,000/ha based on information supplied by the ACP.

Implementation of the Río Indio Project will require resettling the people living in the reservoir area and the natural increase in this population. In many instances, it is expected that the resettlement will be involuntary. It is the intention of the ACP to follow the guidelines of multilateral and bilateral donors, which can be summarized as compensation for all losses, and, to the extent feasible, improvement of the economic situation of the people affected.

The ACP guidelines for resettlement might include:

- Replace land by other land.
- Provide all-weather access and dependable communication to the resettlement areas.
- Provide public services (hospitals, schools, potable water, electricity, etc.) to the resettlement areas.

It is estimated that about 2,215 persons reside within the 100-m contour in 453 homesteads. It is expected that the population within this contour will increase to about 2,500 by the time of project implementation. It is further estimated that this population will be equivalent to about 500 families.

The resettlement cost includes am allowance for homes and related facilities, agricultural development for 1.0 ha per family, a power plant at the base of the dam and a transmission line to the resettlement area, local roads, and other infrastructure including a school, clinic, a potable water supply, and waste disposal. The cost is based on recent experience in Panama and is estimated to equal about $20.6 million.

Each of the resettled families will receive $1,000 per ha of land owned in the reservoir. They will be expected to use this money to purchase land in the resettlement area and, therefore, no land cost is included in the resettlement cost.

7.3.3.2 Access Roads and Bridges

The lengths and location of the required access is presented in Section 7.2.1.2. 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. A major road bridge will be installed downstream from the dam to provide access to the resettlement areas and to provide access to the western areas.

7.3.3.3 Mitigation Plan Implementation

Although an environmental mitigation plan has not been developed, an allowance has been included in the estimate for the implementation of the mitigation plan. In addition, in anticipation of the necessity to protect or remove a potentially significant archaeological site in Boca de Uracillo, an allowance has been included.

7.3.4 Contingencies

A contingency allowance is included in the cost estimate for unforeseen site conditions, approximations, and the chance of future design changes. For these estimates, an allowance of 25% was used for dam and tunnel excavation to reflect the uncertainties associated with foundation unknowns and the conditions that could be encountered in the long water-transfer tunnel, 10% for all equipment, and 15% for all other categories. Overall, the contingency is approximately 12.5% of the project construction cost or about 17% of the subtotal of the direct costs.

7.3.5 Engineering and Administration

Indirect costs for 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 15 percent of the total direct costs will be adequate for engineering and administration.

7.3.6 Capital Cost

An estimate of the capital cost is provided to indicate the anticipated financial cost of the project if it is implemented according to the schedules shown on Exhibits 7.1 and 7.2. The capital cost provides for inflation from the price level date to the beginning of construction, escalation for each of the features according to the construction schedule, and interest during construction.

For estimating purposes, it was assumed that inflation and escalation would occur at a rate of 3% per year and that interest would accrue at a rate of 10% per year.

It was further assumed that construction of the storage facilities and water transfer tunnel will require about five years and that the earliest required on-line date for the water supply will be January 2011. Therefore the construction cost, priced at the mid 2001 level, was inflated at 3% per year for 4.5 years and then escalated at 3% according to an expenditure schedule derived form the construction schedule. For the interest computation, it was assumed that the year's disbursement would be borrowed in January and July and that the interest would accrue.

The estimated capital cost is shown below:

Item	Estimated Cost
Construction Cost mid-2001 price level	**$230,430,000**
Inflation to beginning of construction	$32,780,000
Escalation during construction	$20,510,000
Construction Cost (current dollars)	**$283,720,000**
Interest during construction	$19,260,000
CAPITAL COST	**$302,980,000**

7.3.7 Disbursement Schedule

A disbursement schedule has been estimated over the implementation period on the basis of the cost estimate, the implementation schedule, and the detailed construction schedule. The disbursement schedule, presented in Table 7-6 shows a distribution for the construction cost and for the capital cost, which consists of the construction cost plus inflation and escalation during construction, and interest during construction.

TABLE 7-6 DISBURSEMENT SCHEDULE
($1,000)

Year	Disbursement of Construction Costs	Disbursement of Capital Costs
1 (2006)	$25,800	$31,900
2 (2007)	$47,130	$59,390
3 (2008)	$62,940	$82,300
4 (2009)	$61,540	$82,300
5 (2010)	$33,010	$47,090
Total	**$283,720**	**$302,980**

7.4 Annual 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 dam and water transfer tunnel will be performed by a single O&M group 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. An estimate of the personnel and equipment requirements and the cost are shown below:

	Number	Annual Unit Cost	Total Annual O&M Cost
Personnel			
Manager	.25	$80,000	$20,000
Assistant Managers	1	$50,000	$50,000
Operation Personnel	5	$30,000	$150,000
Maintenance Personnel	8	$25,000	$200,000
Laborers	15	$10,000	$150,000
Equipment			
Vehicles	5	$40,000	$200,000
Spare Parts	LS	$100,000	$100,000
Maintenance Equipment	LS	$150,000	$150,000
Total O&M Cost			**$1,020,000**

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 for an interest rate of 10% and an inflation rate of 3%per year. The sinking fund amount is estimated to be $114,000 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 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 7-7:

TABLE 7-7 ANNUAL OPERATION AND MAINTENANCE COST

Item	Annual Cost
O&M	$1,020,000
Replacement	$114,000
Admin and General Expenses	$228,000
Insurance	$230,000
Resettlement Administration	$100,000
Watershed Management	$150,000
Mitigation Plan Implementation	$100,000
Total (rounded)	**$1,940,000**

8. ECONOMIC COST OF WATER

The original scope of services for the economic evaluation of the Río Indio 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 the Río Indio Project would probably not 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 5.

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 Río Indio Project could be beneficially used, the economic cost of water would be about $0.03/m^3. This estimate is derived by dividing the present worth of the construction and annual costs by the present worth of the supply, which is 15.8 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 without Indio could yield 44.5 L/d, and the project came on line in year 2011, the economic cost of water would be about $0.07/m^3. Under these conditions, it would take about 20 years for the full yield of the project to be utilized. In other words, if the benefit of water was $0.07/m^3, which would be about $5.3 million/year for one lockage, the benefit cost ratio under the condition described above would be 1.0 for an interest rate of 12%.

Under the same assumptions and a rate of increase of 0.6 L/d/yr, the cost of water would be about $0.10.

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 8-1 COMPARISON OF DEMANDS AND COST OF WATER

Year	Recon Report Constrained Demand	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	38.0 L/d
2020	47.6 L/d	52.5 L/d	53.0 L/d	50.0 L/d
2040	52.0 L/d	70.8 L/d	68.0 L/d	62.0 L/d
2060	59.0 L/d	85.1 L/d	83.0 L/d	74.0 L/d
Cost of Water	**$0.25/m^3**	**$0.07/m^3**	**$0.07/m^3**	**$0.10/m^3**

For the Reconnaissance Report constrained demand, the system cannot use the entire yield of the project within the 50-years period of analysis and, therefore, the cost of water is very high. In reality, the project is sized too large for this demand. For the other three demand conditions, it takes 23 years, 24 years, and 31 years to fully utilize the water from the Río Indio basin.

9. CONCLUSIONS AND RECOMMENDATIONS

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

- The Río Indio Water Supply Project is technically feasible.
- The dam site selected in the Reconnaissance Report is the most suitable site for the development of the water resources of the Río Indio Basin.
- Either a concrete-face rockfill dam or a roller compacted concrete dam is suitable for the site and cost effective. A concrete-faced rockfill dam was selected based on a preliminary analysis and discussions with the ACP.
- The lack of subsurface investigations has increased the potential for inaccuracies in the estimate of cost. However, it is our considered opinion that there are no geologic or geotechnical problems associated with the site that cannot be accommodated using conventional solutions.
- The yield of the Panama Canal system will increase by about 1,200 MCM/yr (about 15.8 L/d) with the addition of the Río Indio Project.
- The addition of hydropower to the Project is not warranted at this time. However, a 1.6 MW plant has been included to generate electricity from the minimum release for project operation and to serve the needs of the resettled population. Any plans to implement any other project to the west of the Río Indio Project will improve the economics of the hydropower addition and should cause the issue to be revisited.
- The inclusion of a commercial agricultural endeavor is technically feasible, but is not warranted at this time due to a lack of government services, infrastructure, and an adequate labor pool.
- The project is estimated to cost about $230 million in 2001 dollars. Allowing for inflation at 3% per year, escalation during construction at 3% per year, and interest during construction at 10% per year, the capital cost of the project in current dollars would be about $303 million.
- A project that delivers 1,200 MCM/yr for a capital cost on the order of $300 million is a very attractive proposition.

As a result of these conclusions, it is recommended that:

1. The Río Indio Project is considered as a suitable source of water for any canal expansion.

2. Concurrent with the evaluation of new-lock schemes and alternative sources of water, subsurface investigations and environmental studies of the Río Indio Project should continue without hiatus.

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TABLES

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Table 1

LONG TERM MONTHLY STREAMFLOW AT THE DAM SITE
(cubic meters per second)

Drainage Area: 381.1 km^2

YEAR	JAN	FEB	MAR	APRIL	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	AVE
1948	12.16	4.82	3.46	2.56	5.46	7.75	28.59	33.33	31.70	29.41	58.60	16.44	19.52
1949	6.88	4.18	2.72	2.48	7.43	40.23	28.37	35.54	49.78	47.16	81.57	64.64	30.92
1950	11.40	6.41	3.86	2.80	19.39	35.61	37.08	53.84	35.91	48.76	63.14	63.35	31.80
1951	20.30	11.24	6.41	4.26	19.92	24.35	22.63	24.57	41.70	35.32	52.97	30.74	24.53
1952	13.55	6.49	3.46	3.05	11.40	28.89	22.40	23.75	39.87	56.87	35.83	50.65	24.68
1953	37.89	14.77	7.90	5.62	23.52	21.13	20.52	17.05	21.05	59.61	59.68	32.88	26.80
1954	16.67	7.90	4.98	4.02	18.79	19.85	46.73	35.39	48.04	40.97	76.73	40.89	30.08
1955	43.81	13.85	6.88	5.46	10.85	41.18	29.33	48.18	58.75	50.80	77.37	45.05	35.96
1956	45.56	14.23	8.29	7.67	28.67	41.40	38.92	29.11	46.44	69.37	49.27	28.67	33.97
1967	11.47	5.93	3.86	2.80	11.78	11.86	11.70	22.85	24.94	56.80	37.37	30.15	19.29
1958	18.94	14.62	7.82	5.62	17.35	20.75	28.52	38.33	37.15	48.55	39.43	20.97	24.84
1959	9.43	5.78	4.10	3.62	5.46	83.66	93.45	14.19	16.64	50.15	34.71	43.94	30.43
1960	21.07	8.77	9.10	11.27	26.62	28.18	27.87	28.70	25.27	40.25	55.90	93.01	31.34
1961	15.79	8.23	4.68	4.80	8.34	20.87	18.44	20.45	32.66	50.46	44.46	35.96	22.10
1962	13.22	7.13	4.23	3.90	5.80	8.78	12.04	29.96	25.80	34.62	35.96	27.37	17.40
1963	11.06	7.46	4.12	8.34	18.02	21.61	26.01	33.69	34.10	48.43	54.21	18.13	23.77
1964	9.11	4.91	3.21	3.67	13.33	43.03	42.42	43.24	51.88	55.83	65.49	20.35	29.70
1965	15.68	7.79	4.46	2.64	4.12	8.12	7.24	16.43	13.11	26.95	33.38	35.44	14.61
1966	12.57	6.25	4.23	4.46	25.59	35.03	28.30	25.22	18.41	53.00	70.70	54.31	28.17
1967	17.60	8.67	4.57	7.13	21.40	50.06	37.81	41.50	55.22	63.68	42.62	20.14	30.87
1968	9.54	6.91	4.46	4.01	10.85	30.38	22.87	32.14	33.69	56.53	54.61	26.53	24.38
1969	11.39	6.69	3.44	5.24	10.63	21.61	55.55	88.14	51.62	44.05	48.02	29.24	31.30
1970	24.02	10.74	9.11	9.65	28.51	19.19	21.51	46.40	39.35	58.65	46.30	95.73	34.10
1971	41.70	14.93	8.45	6.36	24.97	36.99	31.52	45.87	50.46	55.93	66.19	19.40	33.56
1972	13.22	8.79	5.43	14.51	12.36	22.35	9.93	14.29	32.66	32.97	34.57	14.19	17.94
1973	8.17	5.11	2.49	2.72	9.71	39.04	40.37	32.45	57.54	63.98	75.79	37.40	31.23
1974	16.96	10.46	7.63	4.58	8.84	18.97	23.08	26.64	31.31	87.42	50.16	26.53	26.05
1975	11.82	6.99	4.74	3.00	7.91	15.57	22.87	43.54	60.47	66.79	101.74	54.31	33.31
1976	21.30	11.39	6.79	5.96	13.86	12.79	6.68	8.18	23.92	55.73	38.73	15.47	18.40
1977	9.48	5.98	3.75	2.97	8.11	12.04	11.50	25.70	29.55	54.92	40.99	22.66	18.97
1978	11.16	7.36	4.92	26.95	23.50	32.86	31.73	42.79	44.83	51.16	43.60	25.62	28.87
1979	14.31	11.09	10.08	11.40	18.19	29.26	28.96	36.44	38.94	36.65	27.04	26.00	24.03
1980	24.22	8.72	4.10	2.78	14.10	19.11	20.99	49.28	24.74	37.59	33.83	29.03	22.37
1981	20.99	13.57	12.32	30.17	30.90	34.56	41.55	39.26	29.97	50.12	61.18	78.93	36.96
1982	19.42	6.02	3.98	5.46	9.52	22.13	28.19	18.06	29.03	52.83	27.25	9.24	19.26
1983	6.08	3.16	1.89	1.59	16.29	24.33	17.23	19.32	47.09	36.75	31.22	40.09	20.42
1984	16.39	10.39	6.73	3.71	17.64	28.61	32.16	50.64	41.55	46.57	39.36	13.36	25.59
1985	8.95	5.58	4.31	2.77	8.76	31.53	18.06	40.72	39.26	36.54	42.29	27.67	22.20
1986	9.82	5.13	3.13	16.71	19.84	31.01	23.18	19.63	28.71	58.57	64.00	15.66	24.62
1987	7.72	5.20	3.02	5.22	14.93	23.91	26.83	32.47	41.76	75.28	33.41	18.48	24.02
1988	7.83	5.30	3.00	2.71	12.32	24.64	26.31	34.56	34.77	54.92	42.70	23.07	22.68
1989	13.16	7.29	5.01	2.93	13.78	19.32	29.03	37.27	36.13	38.00	56.17	31.32	24.12
1990	15.87	7.09	4.85	3.30	25.78	18.70	23.92	24.89	43.30	62.38	41.99	64.74	28.07
1991	10.74	6.02	7.32	3.26	14.59	20.80	15.33	19.02	40.32	50.98	34.79	46.08	22.44
1992	9.54	3.54	3.85	5.74	27.89	29.08	27.98	48.16	44.98	39.19	32.94	20.22	24.43
1993	12.25	6.96	5.68	9.07	11.62	31.20	22.78	17.64	36.91	51.43	65.62	34.56	25.48
1994	12.61	7.33	5.97	6.48	14.00	21.95	16.29	12.63	26.58	37.60	38.55	13.93	17.83
1995	8.57	4.56	3.02	4.20	24.00	37.51	32.90	30.10	38.21	32.13	43.66	30.84	24.14
1996	59.90	27.89	14.23	7.68	21.88	43.51	47.96	59.03	42.80	74.41	58.04	53.80	42.59
1997	11.80	7.37	4.85	3.55	5.88	7.16	8.36	6.86	16.64	21.69	26.24	11.53	10.99
1998	5.34	4.42	3.00	4.10	14.20	13.22	23.18	18.98	26.31	41.11	24.23	35.91	17.83
1999	18.55	10.14	7.67	8.75	24.55	33.81	23.79	53.26	66.15	35.06	50.38	67.28	33.28
AVE	16.48	8.30	5.42	6.22	15.83	26.91	27.33	32.49	37.27	49.33	48.94	35.23	25.81

(Monthly flows for Indio at Damsite were obtained from flows of Indio at Uracillo adjusted with the ratio of the drainage areas of Indio at Damsite = 381.1 Km^2 and Indio at Uracillo = 365 Km)

Indio Damsite = Indio at Uracillo * (381.1/365)

TABLE 2
RIO INDIO WATER SUPPLY PROJECT
CONSTRUCTION COST ESTIMATE SUMMARY
(mid-2001 price level)

DESCRIPTION	AMOUNT
1 GENERAL	$49,939,000
2 DIVERSION	$3,603,000
3 DAM	$52,704,000
4 SPILLWAY	$6,043,000
5 LOW LEVEL OUTLET STRUCTURE	$3,049,000
6 SADDLE DAMS	$7,427,000
7 INTERBASIN TRANSFER TUNNEL	$46,765,000
8 MINIMUM RELEASE FACILITY	$837,000
9 OPERATION FACILITIES	$1,139,000
SUBTOTAL	$171,506,000
CONTINGENCIES	$28,868,000
ENGINEERING AND ADMINISTRATION (15%)	$30,056,000
TOTAL PROJECT COST	**$230,430,000**

PÁGINA EN BLANCO

TABLE 2
RIO INDIO WATER SUPPLY PROJECT
CONSTRUCTION COST ESTIMATE
(mid-2001 price level)

Description	Unit	Unit Cost	Quantity	Amount
1 GENERAL				
1.1 Mobilization and Demobilization	LS		1	$3,000,000
1.2 Land Acquisition and Resettlement				
1.2.1 Land Acquisition	ha	1000	5,500	$5,500,000
1.2.2 Home and Facilities	fam	17000	500	$8,500,000
1.2.3 Ag Development Facilities	ha	500	10,800	$5,400,000
1.2.4 Local Roads	LS			$800,000
1.2.5 Power Supply and Transmission	LS			$1,780,000
1.2.6 Other Infrastructure	LS			$4,120,000
1.3 Temporary Facilities	LS		1	$3,055,000
1.4 Access Roads				
1.4.1 Road Improvements (Permanent/Temporary)	Km	$66,000	38.5	$2,541,000
1.4.2 Permanent Roads	Km	$146,000	16.0	$2,336,000
1.4.3 Temporary Roads	Km	$114,000	5.5	$627,000
1.5 Rio Indio Bridge	LS	$495,800	1	$495,800
1.6 Watershed Management	LS			$2,000,000
1.7 Mitigation Plan Implementation/Archaeological	LS			$2,000,000
1.7 Reservoir Clearing	ha	$2,200	3,538	$7,784,000
Subtotal 1				**$49,938,800**
2 DIVERSION				
2.1 Site Preparation	m^2	$0.55	40,000	$22,000
2.2 Approach/Discharge Channels				
2.2.1 Overburden Excavation	m^3	$3.20	9,400	$30,080
2.2.2 Rock Excavation	m^3	$8.75	7,700	$67,375
2.3 Diversion Tunnel Intake and Outlet Portals				
2.3.1 Overburden Excavation	m^3	$3.20	4,700	$15,040
2.3.2 Rock Excavation	m^3	$8.75	15,500	$135,625
2.3.3 Shotcrete	m^2	$45.90	3,330	$152,847
2.3.4 Rockbolts	l.m.	$60.50	1,670	$101,035
2.3.5 Concrete	m^3	$115.00	220	$25,300
2.3.6 Formwork	m^2	$46.20	220	$10,164
2.3.7 Reinforcement	kg	$1.36	8,300	$11,288
2.4 Diversion Tunnel				
2.4.1 Tunnel Excavation	m^3	$103.20	13,950	$1,439,640
2.4.2 Shotcrete	m^2	$45.90	5,700	$261,630
2.4.3 Rockbolts	l.m.	$60.50	3,200	$193,600
2.4.4 Steel Ribs	kg	$2.90	59,200	$171,680
2.5 Cofferdams				
2.5.1 Overburden Excavation	m^3	$3.20	30,700	$98,240
2.5.2 Fill	m^3	$7.20	96,750	$696,600
2.5.3 Filter/Drain	m^3	$15.90	10,750	$170,925
Subtotal 2				**$3,603,069**
3 DAM				
3.1 Site Preparation	m^2	$0.55	300,000	$165,000
3.2 Excavation				
3.2.1 Overburden Excavation	m^3	$3.20	454,600	$1,454,720
3.2.2 Rock Excavation	m^3	$8.75	271,500	$2,375,625
3.2.3 Overburden Excavation (Right Abutment)	m^3	$3.20	309,000	$988,800
3.2.4 Rock Excavation (Right Abutment)	m^3	$8.75	933,600	$8,169,000
3.3 Grouting				
3.3.1 Cut-off	m^2	$46.00	27,300	$1,255,800
3.3.2 Consolidation	m	$69.20	2,250	$155,700
3.4 Rockfill				
3.4.1 Mass from Site Excavation	m^3	$3.75	1,509,500	$5,660,625
3.4.2 Mass from Quarry 1	m^3	$13.70	269,600	$3,693,520
3.4.3 Mass from Quarry 2	m^3	$13.70	916,500	$12,556,050
3.4.4 Filter	m^3	$15.90	216,000	$3,434,400
3.4.5 Drain	m^3	$15.90	19,600	$311,640
3.4.6 Backfill	m^3	$7.20	145,800	$1,049,760
3.5 Concrete				
3.5.1 Dental Concrete	m^3	$115.00	8,400	$966,000
3.5.2 Plinth	m^3	$172.00	8,400	$1,444,800
3.5.3 Facing	m^2	$80.00	66,100	$5,288,000
3.5.4 Parapet -US	m^3	$252.00	3,850	$970,200
3.5.5 Parapet -DS	m^3	$252.00	750	$189,000
3.5.6 Crest Road	m^2	$9.60	6,800	$65,280
3.6 Miscellaneous Site Work	LS	5%	1	$2,509,696
Subtotal 3				**$52,703,616**

TABLE 2
RIO INDIO WATER SUPPLY PROJECT
CONSTRUCTION COST ESTIMATE
(mid-2001 price level)

Description	Unit	Unit Cost	Quantity	Amount
4 SPILLWAY				
4.1 Site Preparation	m^2	$0.55	60,000	$33,000
4.2 Excavation				
4.2.1 Overburden Excavation	m^3	$3.20	40,030	$128,096
4.2.2 Rock Excavation	m^3	$8.75	288,750	$2,526,563
4.3 Headworks				
4.3.1 Concrete	m^3	$115.00	3,200	$368,000
4.3.2 Formwork	m^2	$46.20	2,000	$92,400
4.3.3 Reinforcement	kg	$1.36	123,700	$168,232
4.3.4 Backfill	m^3	$7.20	2,850	$20,520
4.4 Chute and Flip Bucket				
4.4.1 Concrete	m^3	$115.00	10,200	$1,173,000
4.4.2 Formwork	m^2	$46.20	4,350	$200,970
4.4.3 Reinforcement	kg	$1.36	425,700	$578,952
4.4.4 Backfill	m^3	$7.20	1,290	$9,288
4.4.5 Drains	l.m.	$9.00	2,200	$19,800
4.4.6 Anchors	l.m.	$37.00	4,270	$157,990
4.5 Bridge				
4.5.1 Concrete	m^3	$140.00	440	$61,600
4.5.2 Formwork	m^2	$46.20	1,100	$50,820
4.5.3 Reinforcement	kg	$1.36	67,800	$92,208
4.6 Tailrace Channel				
4.6.1 Overburden Excavation	m^3	$3.20	51,400	$164,480
4.6.2 Rock Excavation	m^3	$8.75	22,500	$196,875
Subtotal 4				**$6,042,794**
5 LOW LEVEL OUTLET STRUCTURE				
5.1 Shaft				
5.1.1 Shaft Excavation	m^3	$295.00	2,180	$643,100
5.1.2 Shotcrete	m^2	$45.90	1,500	$68,850
5.1.3 Rockbolts	l.m.	$60.50	1,230	$74,415
5.1.4 Concrete	m^3	$140.00	1,560	$218,400
5.1.5 Formwork	m^2	$46.20	2,400	$110,880
5.1.6 Reinforcement	kg	$1.36	61,000	$82,960
5.2 Intake Structure				
5.2.1 Concrete	m^3	$115.00	720	$82,800
5.2.2 Formwork	m^2	$46.20	630	$29,106
5.2.3 Reinforcement	kg	$1.36	28,200	$38,352
5.3 Tunnel Lining				
5.3.1 Concrete	m^3	$118.00	4,810	$567,580
5.3.2 Formwork	m^2	$10.00	6,600	$66,000
5.3.3 Reinforcement	kg	$1.36	192,100	$261,256
5.4 Hydromechanical Equipment				
5.4.1 Gate	kg	$10.00	18,000	$180,000
5.4.2 Bulkhead	kg	$10.00	14,000	$140,000
5.4.3 Embedded Metals	kg	$4.50	7,750	$34,875
5.4.4 Operator	LS	$300,000	1	$300,000
5.4.5 Surface Structure	LS	$100,000	1	$100,000
5.4.6 Power and Controls	LS	$50,000	1	$50,000
Subtotal 5				**$3,048,574**
6 SADDLE DAMS				
6.1 Site Preparation	m^2	$0.55	120,000	$66,000
6.2 Dam				
6.2.1 Overburden	m^3	$3.20	200,500	$641,600
6.2.2 Cut-off	m^2	$46.00	4,150	$190,900
6.2.3 Embankment Fill	m^3	$7.20	806,400	$5,806,080
6.2.4 Filter/Drain	m^3	$15.90	22,600	$359,340
6.2.5 Riprap	m^3	$15.00	14,400	$216,000
6.2.6 Roadbase	m^2	$9.80	2,100	$20,580
6.3 Additonal Saddle Dikes				
6.3.1 Dike Fill	m^3	$7.20	17,500	$126,000
Subtotal 6				**$7,426,500**

TABLE 2
RIO INDIO WATER SUPPLY PROJECT
CONSTRUCTION COST ESTIMATE
(mid-2001 price level)

Description	Unit	Unit Cost	Quantity	Amount
7 INTERBASIN TRANSFER TUNNEL				
7.1 Site Preparation	m^2	$0.55	180,000	$99,000
7.2 Construction Access Adits (2)				
7.2.1 Overburden Excavation	m^3	$3.20	24,500	$78,400
7.2.2 Bulk Rock Excavation	m^3	$8.75	6,400	$56,000
7.2.3 Portal Excavation	m^3	$14.70	850	$12,495
7.2.4 Tunnel Excavation	m^3	$105.00	12,900	$1,354,500
7.2.5 Shotcrete	m^2	$45.90	5,600	$257,040
7.2.6 Rockbolts	lm	$60.50	3,400	$205,700
7.2.7 Steel Ribs	kg	$2.90	55,000	$159,500
7.2.8 Portal Concrete	m^3	$140.00	1,250	$175,000
7.2.9 Formwork	m^2	$46.20	650	$30,030
7.2.10 Invert Concrete	m^3	$115.00	600	$69,000
7.2.11 Miscellaneous	L.S.	5%	1	$119,883
7.3 Tunnel Portals				
7.3.1 Excavation	m^3	$8.75	76,600	$670,250
7.3.2 Shotcrete	m^2	$45.90	5,800	$266,220
7.3.3 Rockbolts	l.m.	$60.50	2,900	$175,450
7.3.4 Concrete	m^3	$115.00	710	$81,650
7.3.5 Formwork	m^2	$46.20	470	$21,714
7.3.6 Reinforcement	kg	$1.36	27,600	$37,536
7.4 Tunnel				
7.4.1 Rock Excavation	m^3	$72.30	225,200	$16,281,960
7.4.2 Shotcrete	m^2	$45.90	72,700	$3,336,930
7.4.3 Rockbolts	l.m.	$60.50	43,400	$2,625,700
7.4.4 Steel Ribs	kg	$2.90	437,300	$1,268,170
7.4.5 Concrete	m^3	$118.00	73,400	$8,661,200
7.4.6 Formwork	m^2	$10.00	97,200	$972,000
7.4.7 Reinforcement	kg	$1.36	2,934,300	$3,990,648
7.5 Intake Structure				
7.5.1 Concrete	m^3	$115.00	780	$89,700
7.5.2 Formwork	m^2	$46.30	920	$42,596
7.5.3 Reinforcement	kg	$1.36	51,200	$69,632
7.6 Intake Gate/Access Shaft				
7.6.1 Shaft Excavation	m^3	$295.00	1,620	$477,900
7.6.2 Shotcrete	m^2	$45.90	1,000	$45,900
7.6.3 Rockbolts	l.m.	$60.50	740	$44,770
7.6.4 Concrete	m^3	$140.00	1,140	$159,600
7.6.5 Formwork	m^2	$46.20	1,200	$55,440
7.6.6 Reinforcement	kg	$1.36	51,200	$69,632
7.7 Outlet Structure				
7.7.1 Concrete	m^3	$140.00	3,420	$478,800
7.7.2 Formwork	m^2	$46.20	4,320	$199,584
7.7.3 Reinforcement	kg	$1.36	178,200	$242,352
7.7.4 Steel Lining	kg	$3.20	25,000	$80,000
7.7.5 Anchors	l.m.	$60.50	900	$54,450
7.8 Discharge Channel				
7.8.1 Excavation	m^3	$3.20	326,600	$1,045,120
7.9 Hydromechanical Equipment				
7.9.1 Trashracks and Embeds (8 x 10)	kg	$4.50	27,000	$121,500
7.9.2 U/S Gates (3.8 x 4.5 m)	kg	$10.00	13,100	$131,000
7.9.3 Embedded Metals	kg	$4.50	7,500	$33,750
7.9.4 U/S Operator	L.S.	$50,000	1	$50,000
7.9.5 U/S Surface Structure	L.S.	$50,000	1	$50,000
7.9.6 U/S Power and Controls	L.S.	$50,000	1	$50,000
7.9.7 D/S Gates 4 - 2.5 x 3.6	kg	$10.00	148,800	$1,488,000
7.9.8 D/S Operators	L.S.	$125,000	4	$500,000
7.9.9 D/S Surface Structure	L.S.	$50,000	1	$50,000
7.9.10 D/S Power and Controls	L.S.	$100,000	1	$100,000
7.9.11 Miscellaneous	L.S.	5%	1	$128,713
Subtotal 7				**$46,765,415**

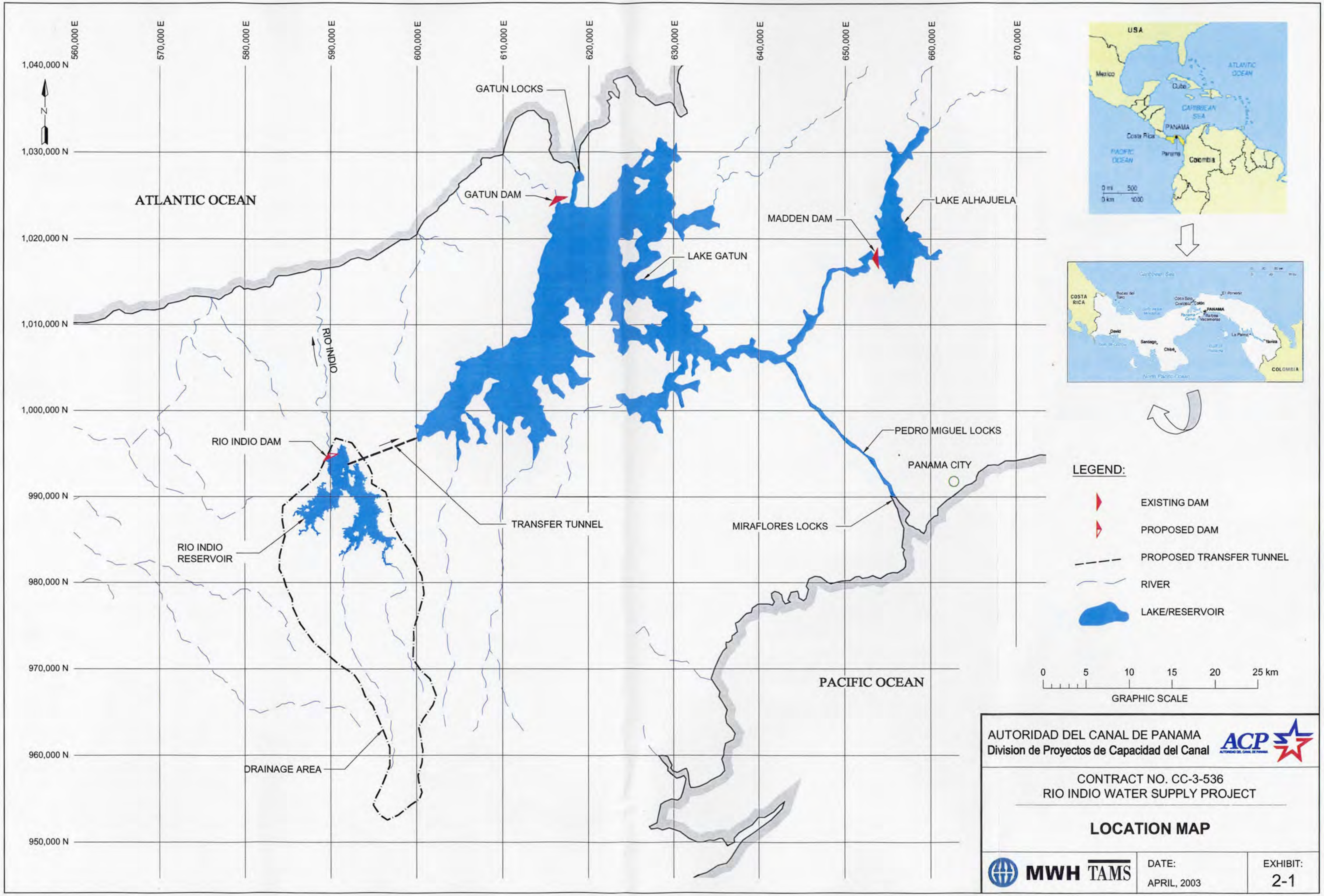
TABLE 2
RIO INDIO WATER SUPPLY PROJECT
CONSTRUCTION COST ESTIMATE
(mid-2001 price level)

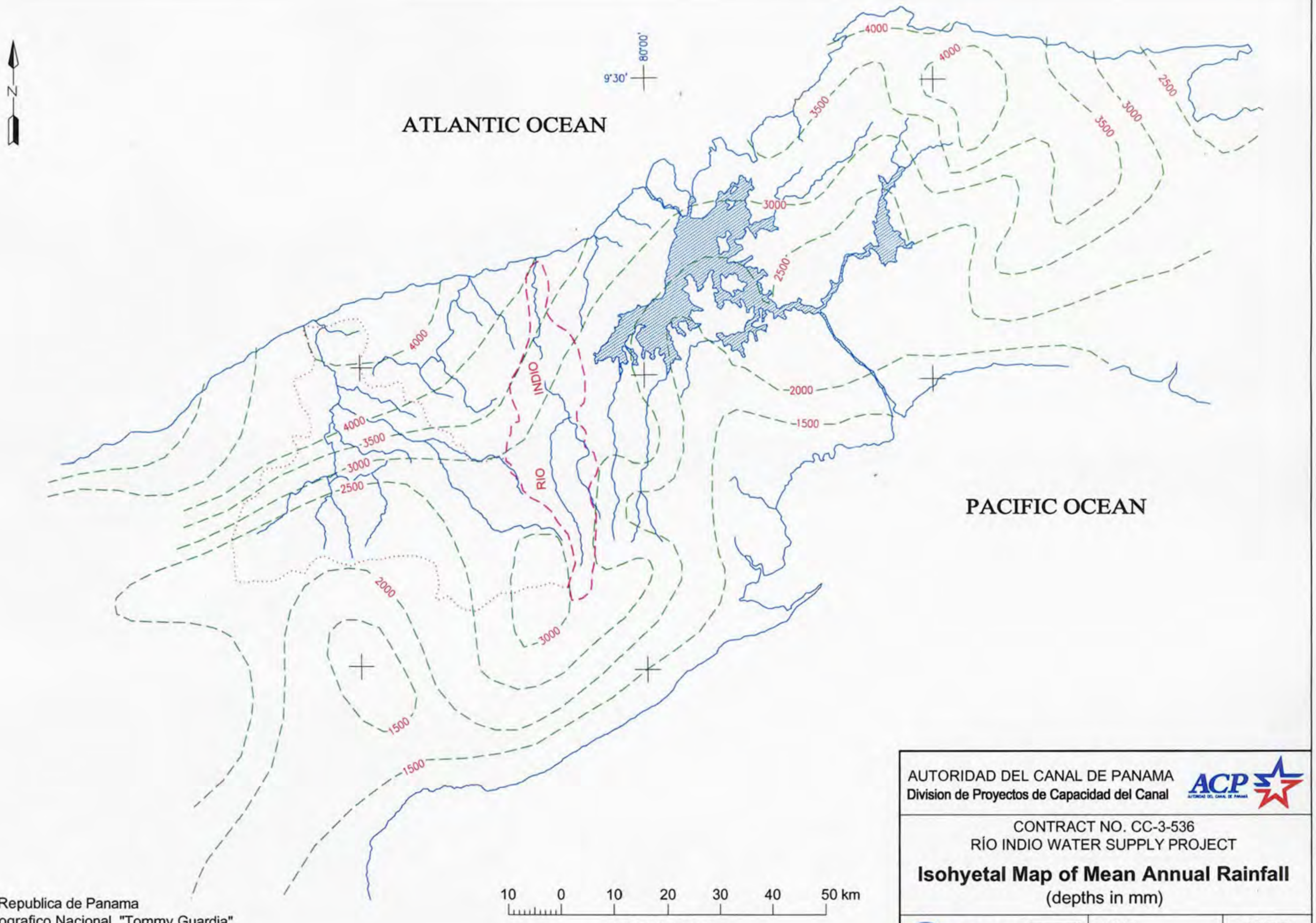
Description	Unit	Unit Cost	Quantity	Amount
8 MINIMUM RELEASE FACILITY				
8.1 Intake				
8.1.1 Structural Concrete	m^3	$140.00	400	$56,000
8.1.2 Formwork	m^2	$46.20	1,000	$46,200
8.1.3 Steel Reinforcement	kg	$1.36	32,000	$43,520
8.1.4 Miscellaneous	%	5%		$7,286
8.2 Equipment				
8.2.1 Intake Gate and Hoist	L.S.	$10,000	1	$10,000
8.2.2 Trashracks	kg	4.5	450	$2,025
8.2.3 Power and Control Equipment	L.S.	$40,000	1	$40,000
8.3 Conduit				
8.3.1 Rock Excavation	m^3	$14.70	520	$7,644
8.3.2 Steel Conduit	kg	$3.20	49,000	$156,800
8.3.3 Concrete Backfill	m^3	$115.00	420	$48,300
8.3.4 Granular Backfill	m^3	$15.90	360	$5,724
8.4 Valve and Power House				
8.4.1 Civil Works	L.S.	$200,000.00	1	$200,000
8.4.2 Control Valve and Operator	L.S.	$80,000.00	1	$80,000
8.4.3 Guard Valve and Operator	L.S.	$40,000.00	1	$40,000
8.4.4 Operating Equipment	L.S.	$60,000.00	1	$60,000
8.4.5 Powerhouse Equipment	Included in Resettlement Cost			
8.5 Tailrace				
8.5.1 Overburden Excavation	m^3	$3.20	9,800	$31,360
8.5.2 Rock Excavation	m^3	$14.70	150	$2,205
Subtotal 8				**$837,064**
9 OPERATION FACILITIES				
9.1 13.8-kV Transmission Line				
9.1.1 Civil Works (survey, Found., Struc.)	km	$10,500	16	$168,000
9.1.2 Conductors and Shield Wire	km	$3,500	16	$56,000
9.1.3 Insulators and Accessories	km	$2,000	16	$32,000
9.1.4 Grounding and Miscellaneous	%	5.00%		$12,800
9.2 Diesel Generators				
9.2.1 Standby Generators	Each	$35,000	2	$70,000
9.2.2 Control Panels and other Equipment	LS	$200,000	1	$200,000
9.3 SCADA	LS	$200,000	1	$200,000
9.4 Communication System	LS	$100,000	1	$100,000
9.5 Security and Lighting	LS	$100,000	1	$100,000
9.6 Landscaping and Drainage	LS	$100,000	1	$100,000
9.7 Instrumentation	LS	$100,000	1	$100,000
Subtotal 9				**$1,138,800**

Exhibits

EXHIBITS

No.	Title
5-1	Transferred Discharge
6-1	Land Use Map
6-2	Land Capability Map
6-3	Potential Irrigation Development Areas
6-4	Cropping Pattern Diagram
7-1	Implementation Schedule
7-2	Construction Schedule
7-3	Access Roads (2 sheets)


560,000 E
570,000 E
580,000 E
590,000 E
600,000 E
610,000 E
620,000 E
630,000 E
640,000 E
650,000 E
660,000 E
670,000 E
1,040,000 N
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
N
ATLANTIC OCEAN
GATUN LOCKS
GATUN DAM
LAKE GATUN
MADDEN DAM
LAKE ALHAJUELA
RIO INDIO
RIO INDIO DAM
RIO INDIO RESERVOIR
TRANSFER TUNNEL
DRAINAGE AREA
PEDRO MIGUEL LOCKS
PANAMA CITY
MIRAFLORES LOCKS
PACIFIC OCEAN
USA
Mexico
Cuba
ATLANTIC OCEAN
CARIBBEAN SEA
PANAMA
Costa Rica
PACIFIC OCEAN
Colombia
0 mi 500
0 km 1000
COSTA RICA
COLOMBIA
LEGEND:
EXISTING DAM
PROPOSED DAM
PROPOSED TRANSFER TUNNEL
RIVER
LAKE/RESERVOIR
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
RIO INDIO WATER SUPPLY PROJECT
LOCATION MAP
MWH TAMS
DATE:
APRIL, 2003
EXHIBIT:
2-1



Source:

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

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

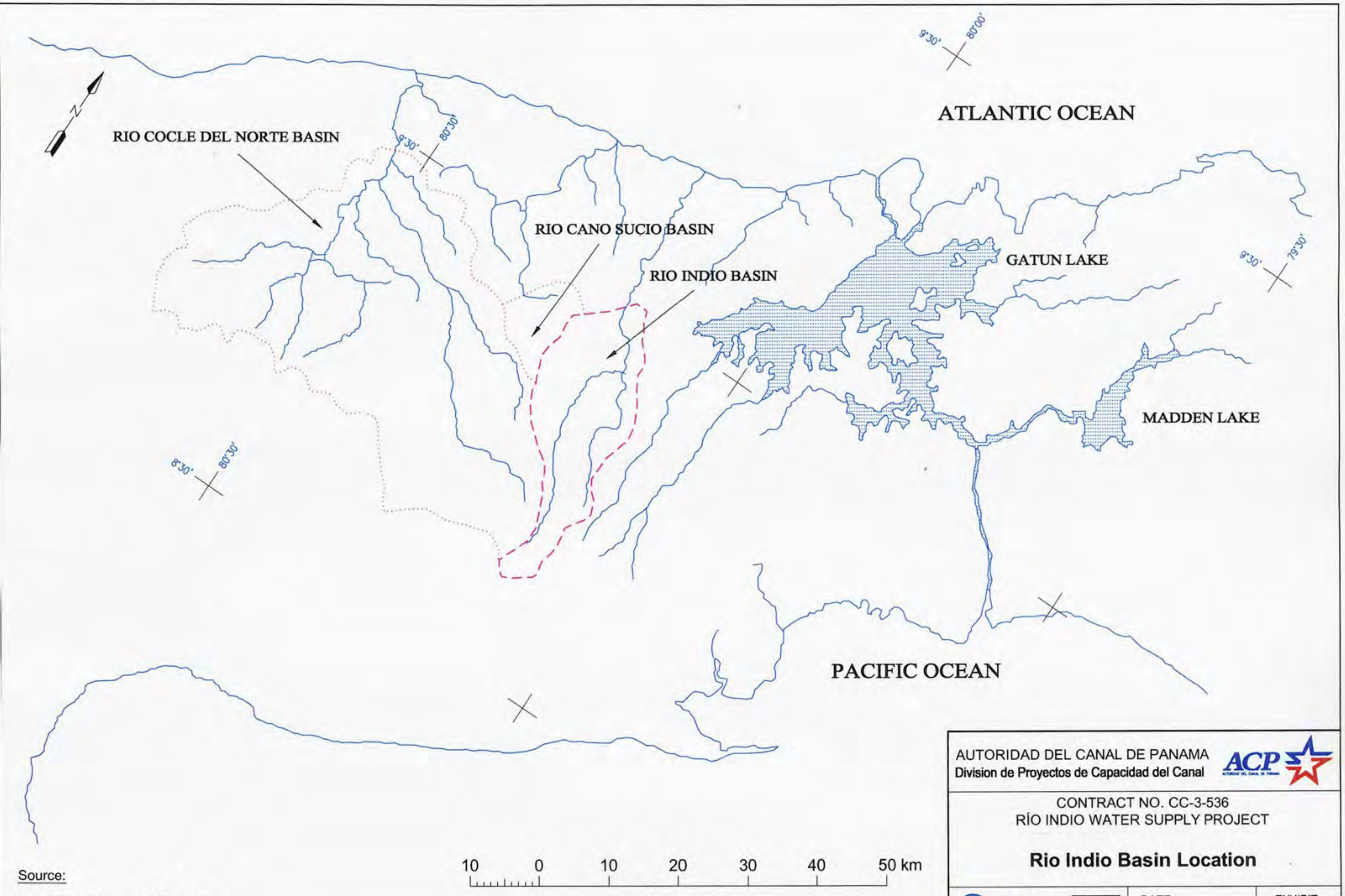
CONTRACT NO. CC-3-536
RÍO INDIO WATER SUPPLY PROJECT

Isohyetal Map of Mean Annual Rainfall
(depths in mm)

MWH TAMS

DATE: APRIL, 2003

EXHIBIT: 2-2



Source:
US NWS, February 1978 Report

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

ACP

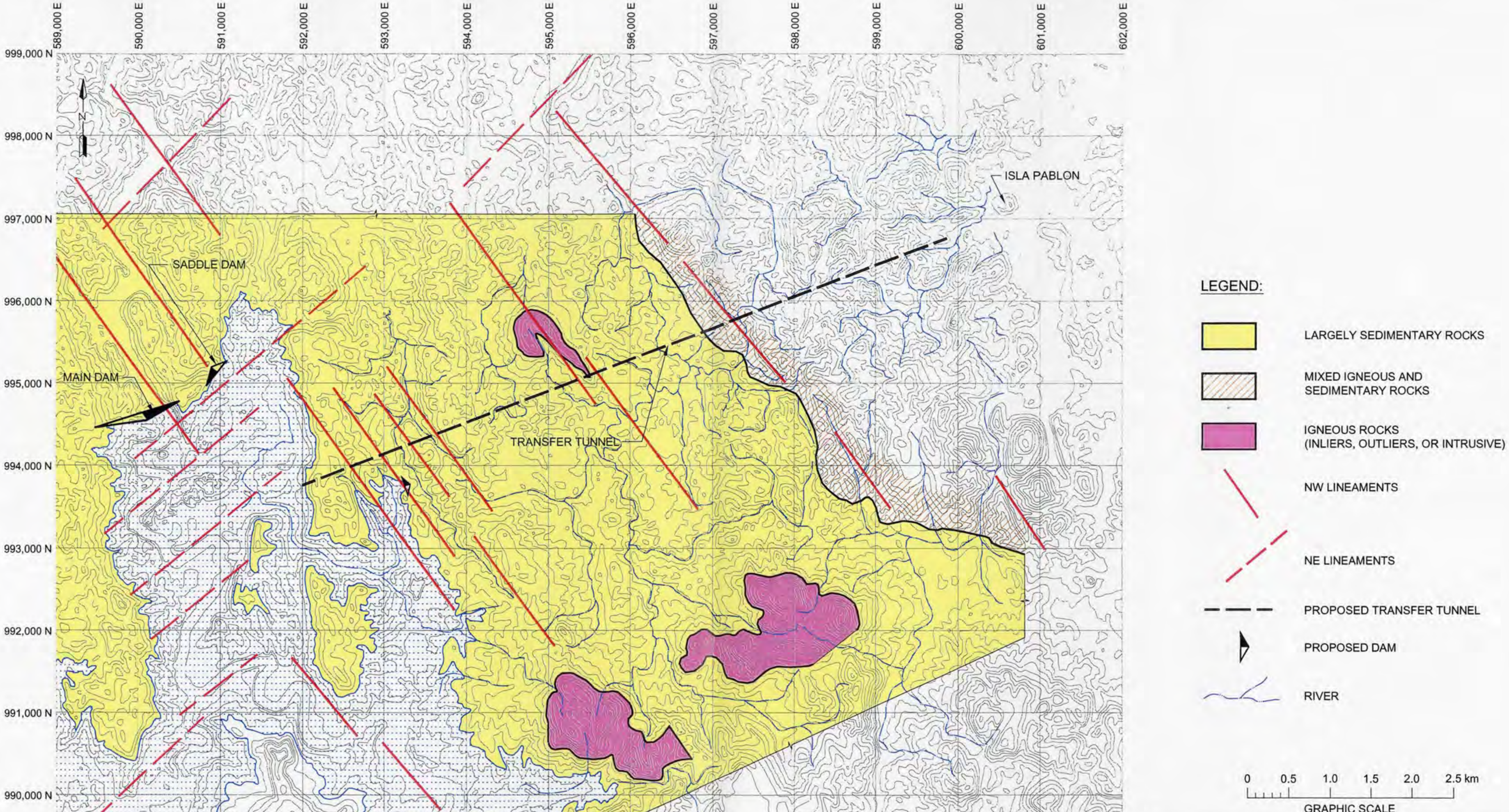
CONTRACT NO. CC-3-536
RÍO INDIO WATER SUPPLY PROJECT

Rio Indio Basin Location

MWH TAMS

DATE: APRIL, 2003

EXHIBIT: 2-3



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

CONTRACT NO. CC-3-536
RIO INDIO WATER SUPPLY PROJECT

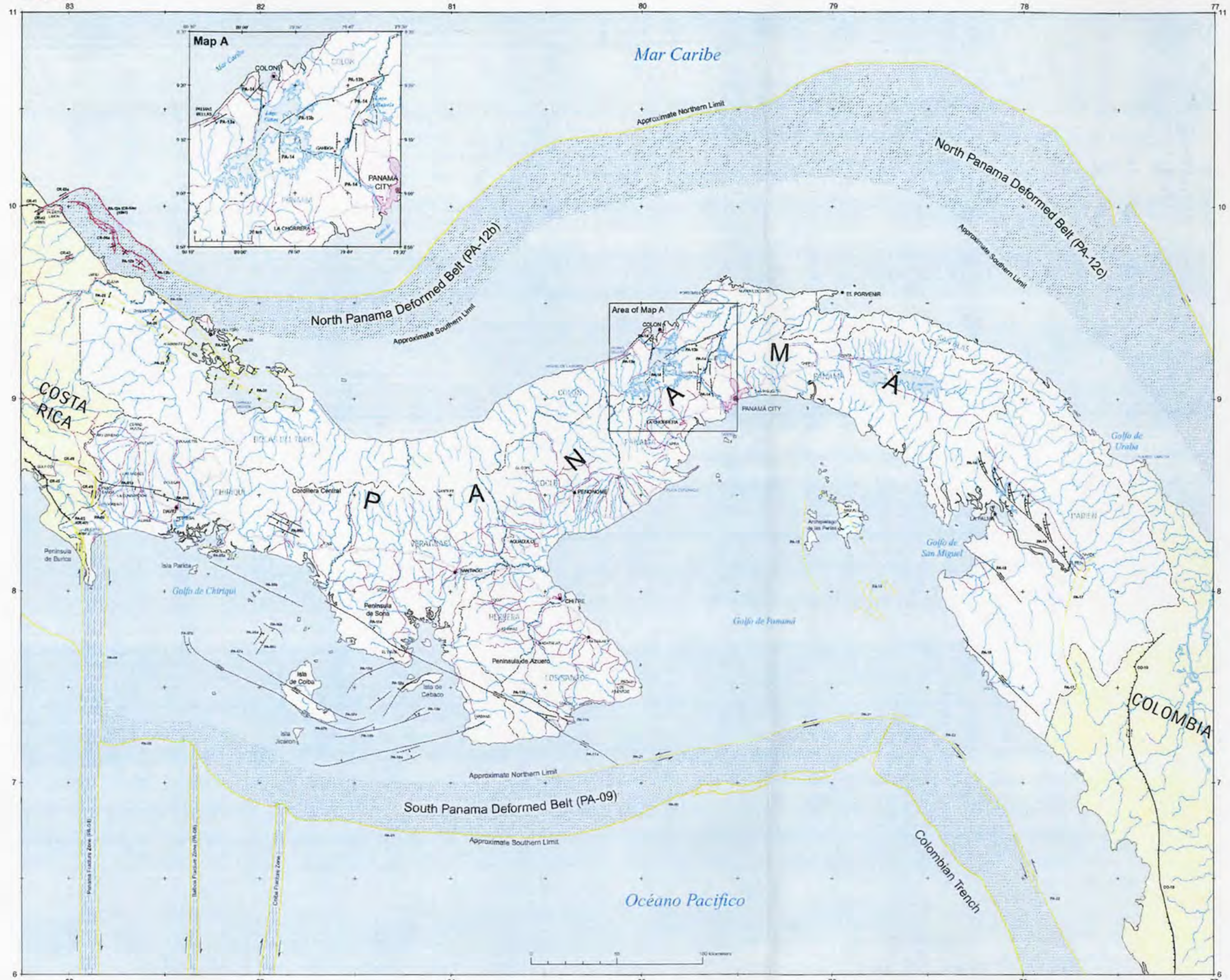
REGIONAL GEOLOGY

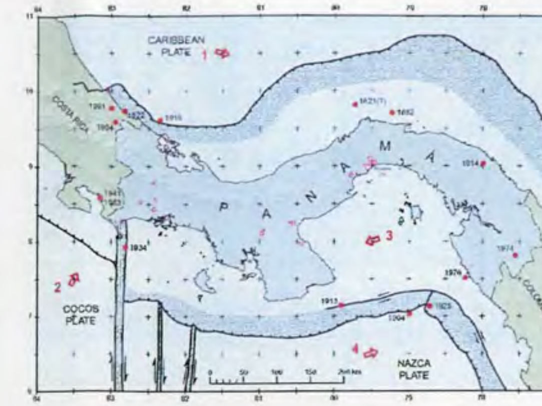
MWH TAMS

DATE:	EXHIBIT:
APRIL, 2003	2-4

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

OPEN FILE REPORT
OFR 98-779
Text accompanies map





RELATIVE PLATE MOTION

No.	Location	Fixed	Moving	Velocity	Direction
1	[illegible]	South America	Caribbean	1.40 cm	[illegible]
2	[illegible]	Caribbean	Cocos	9.40 cm	[illegible]
3	[illegible]	Nazca	Panama	[illegible]	[illegible]
4	[illegible]	Panama	Nazca	[illegible]	[illegible]

Diagram of plate boundaries and major historical earthquakes for Panama

Esquema de límites de placas y terremotos históricos de major importancia para Panamá

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)
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

MAP EXPLANATION

SIMBOLOGIA DEL MAPA

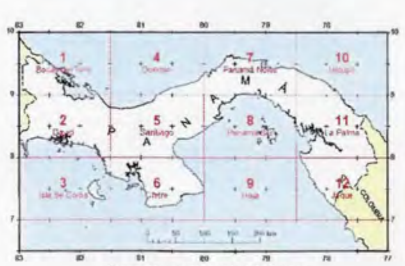


Diagram of topographic map sheets for Panama
Esquema de hojas topográficas para Panamá

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

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

Data compiled by Hugh Cowan, digital representation by Richard L. Dart, and project coordinated by Michael N. Machette (Co-chairman, ILP Task Group II-2)

1998

Scale 1:750,000 Mercator Projection
(longitude of central meridian, 80 W; latitude of true scale 0 ; Clarke 1866 spheroid)

Mapa de Fallas y Pliegues Cuaternarios de Panamá y Regiones Oceanicas Adyacentes

Proyecto Internacional de la Litosfera, Grupo de Trabajo II-2,
Principales Fallas Activas del Mundo

Un proyecto de cooperación entre el U.S. Geological Survey, el Instituto de Geociencias de la Universidad de Panamá la Agencia Sueca para Investigaciones Cooperativas con Naciones en Desarrollo (SAREC), y NORSAR, Norway

Datos compilados por Hugh Cowan, representacion digital por Richard L. Dart, y proyecto coordinado por Michael N. Machette (Co-chairman, ILP Grupo de Trabajo II-2)

1998

Escala 1:750,000 Proyección de Mercator
(longitud de meridiano central, 80 W; latitud de escala verdadera 0 , con base en el esferoide de Clarke 1866)

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

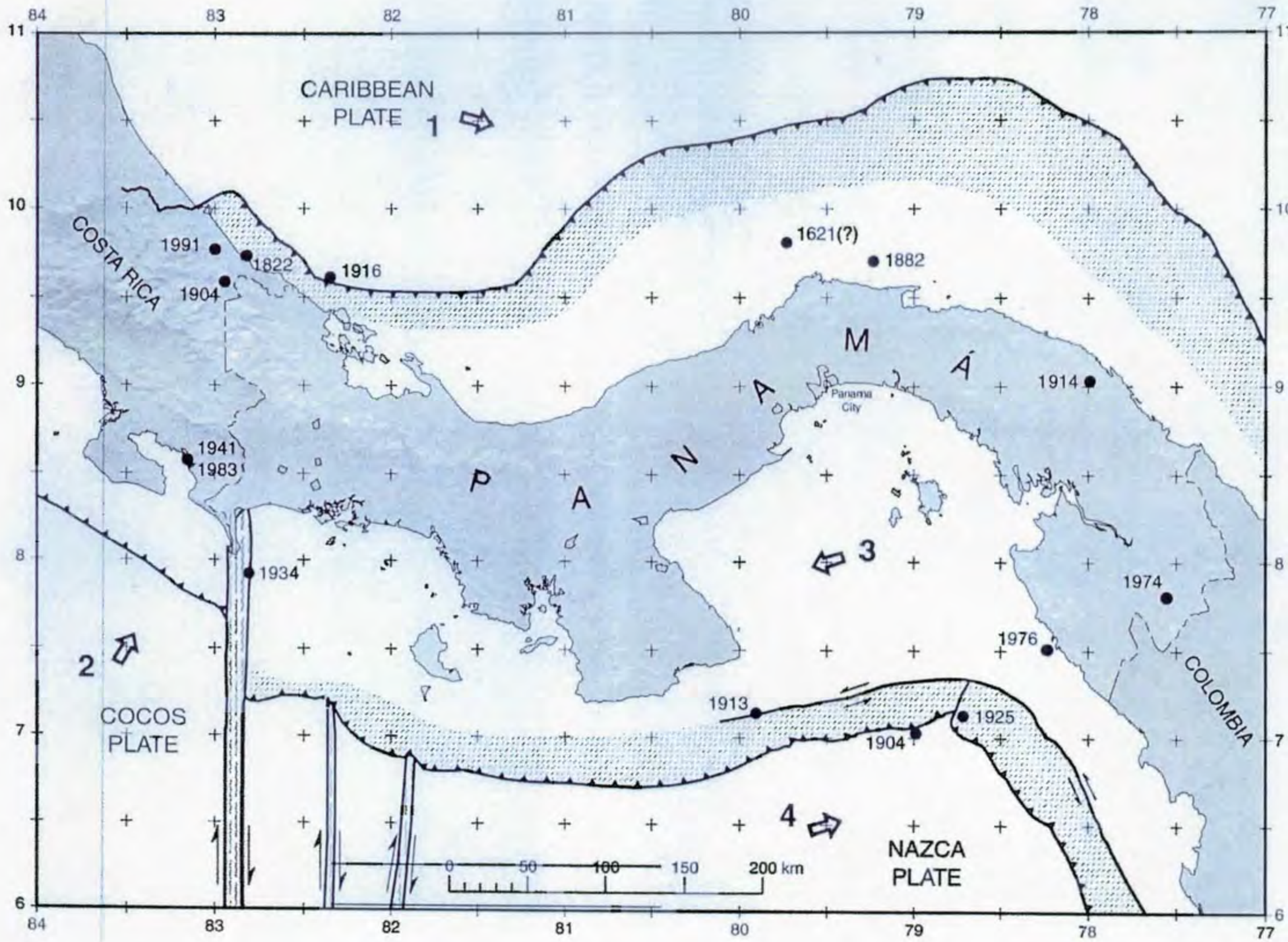
ACP

CONTRACT NO. CC-3-536
RIO INDIO WATER SUPPLY PROJECT

MAP OF FAULTS AND FOLDS IN PANAMA

MWH TAMS

DATE:	EXHIBIT:
APRIL, 2003	2-5



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

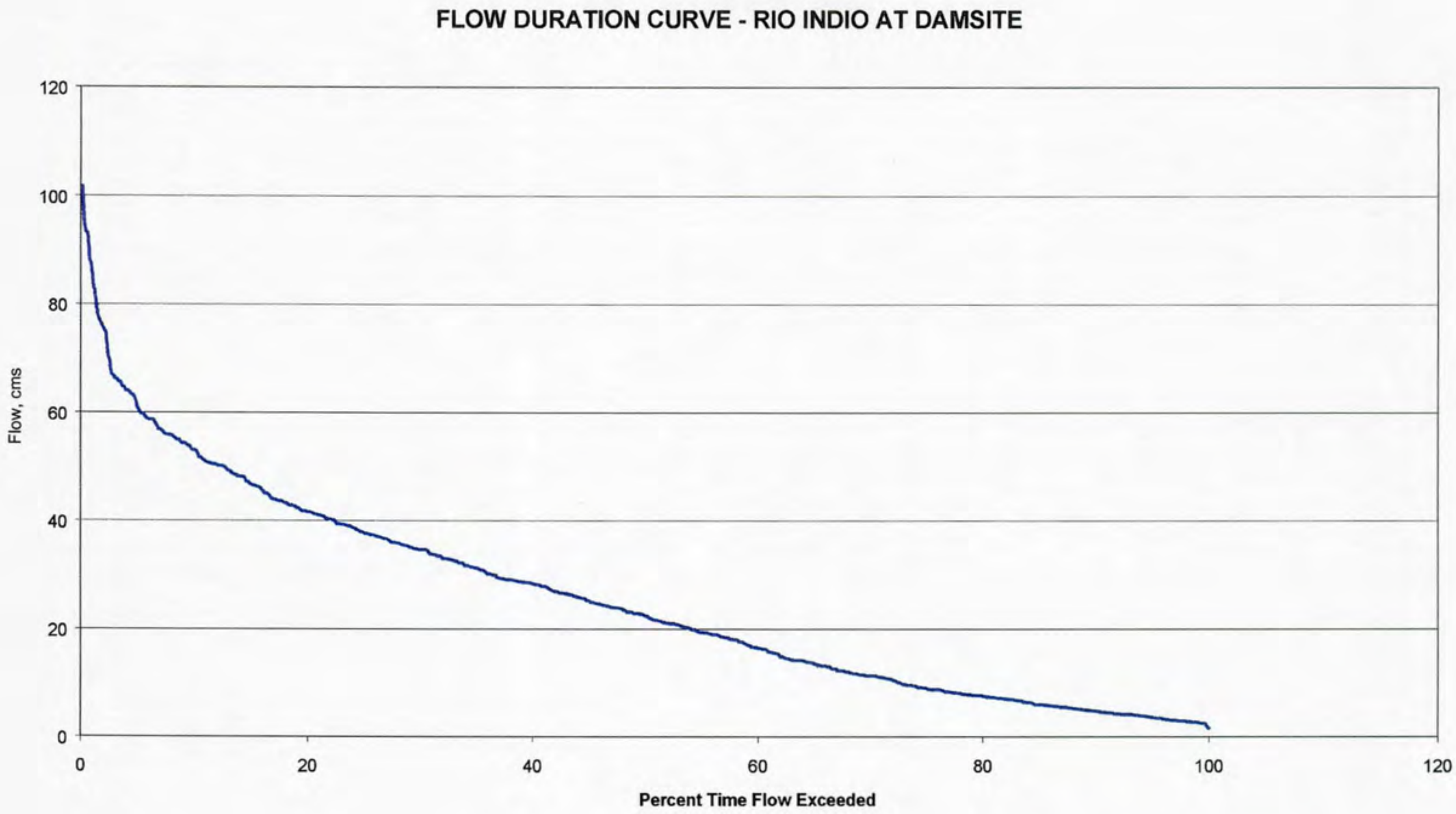
CONTRACT NO. CC-3-536
RÍO INDIO WATER SUPPLY PROJECT

Tectonic Plate Boundaries

MWH TAMS

DATE: APRIL, 2003

EXHIBIT: 2-6



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

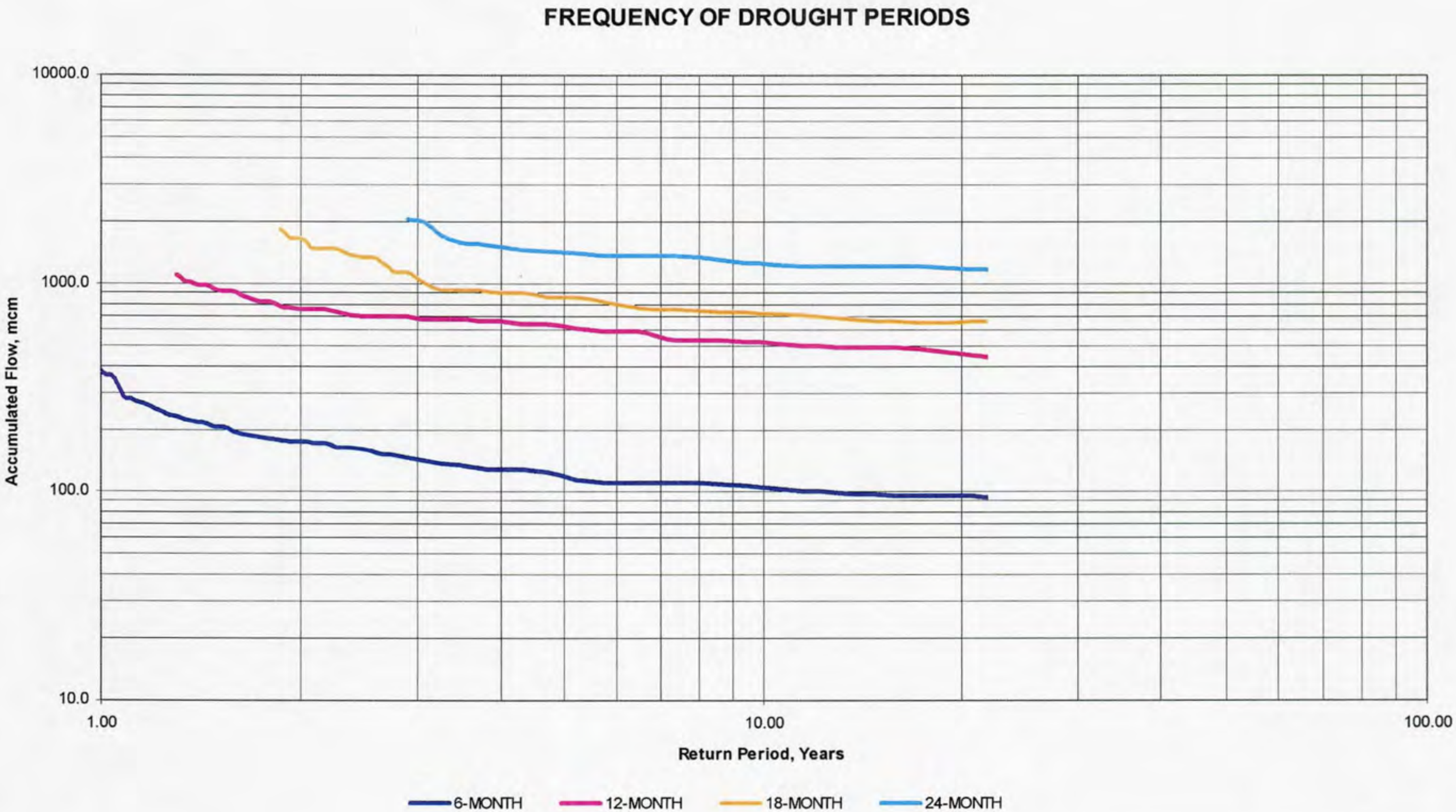
CONTRACT NO. CC-3-536
RÍO INDIO WATER SUPPLY PROJECT

Flow Duration at the Rio Indio Dam Site

MWH TAMS

DATE: APRIL, 2003

EXHIBIT: 3-1



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

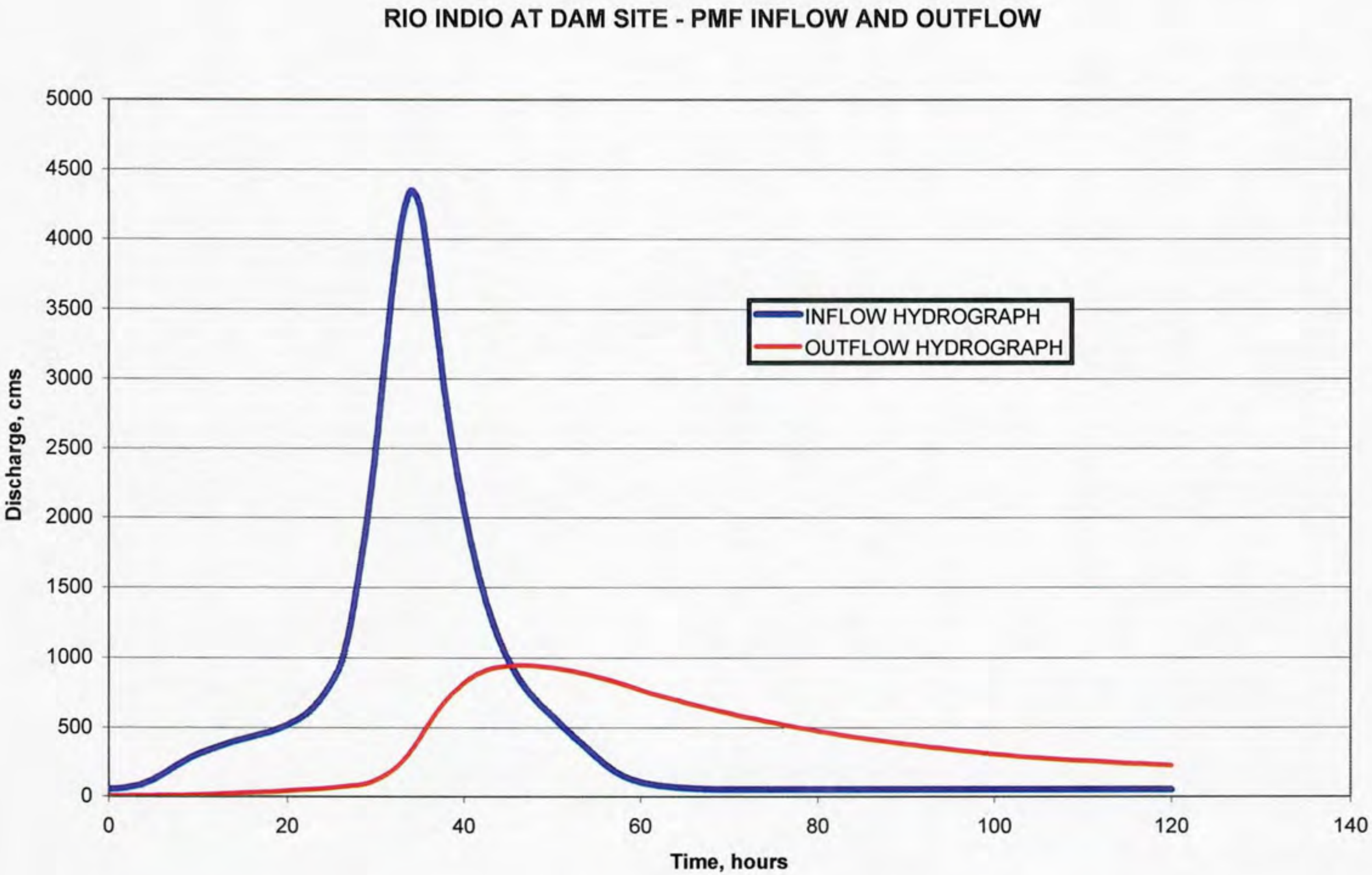
CONTRACT NO. CC-3-536
RÍO INDIO WATER SUPPLY PROJECT

Drought Frequency at the Rio Indio Dam Site

MWH TAMS

DATE: APRIL, 2003

EXHIBIT: 3-2



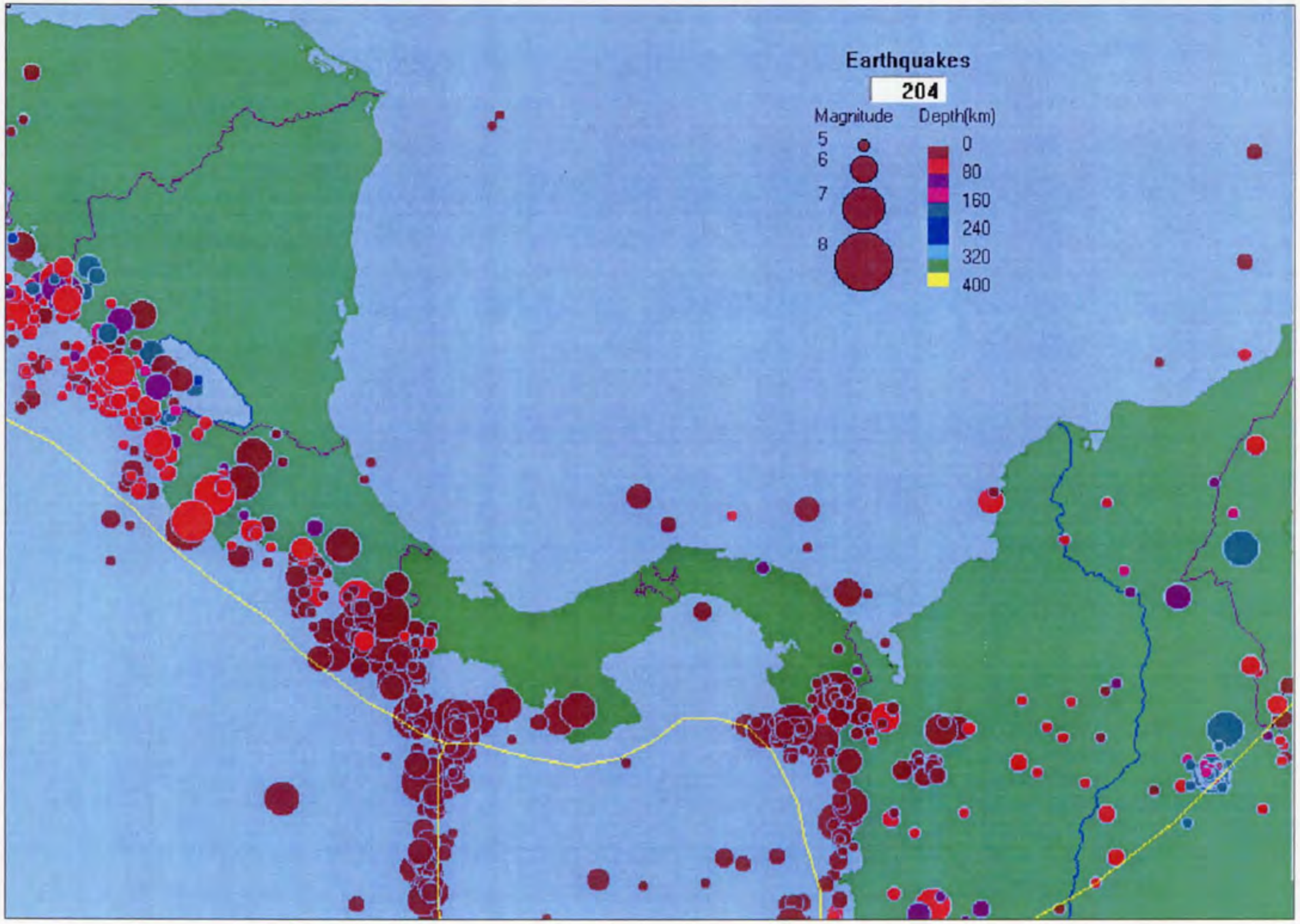
AUTORIDAD DEL CANAL DE PANAMA
Division de Proyectos de Capacidad del Canal

CONTRACT NO. CC-3-536
RÍO INDIO WATER SUPPLY PROJECT

Probable Maximum Flood at the Rio Indio Dam Site

MWH TAMS

DATE:	EXHIBIT:
APRIL, 2003	3-3



NOTE:

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

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

ACP

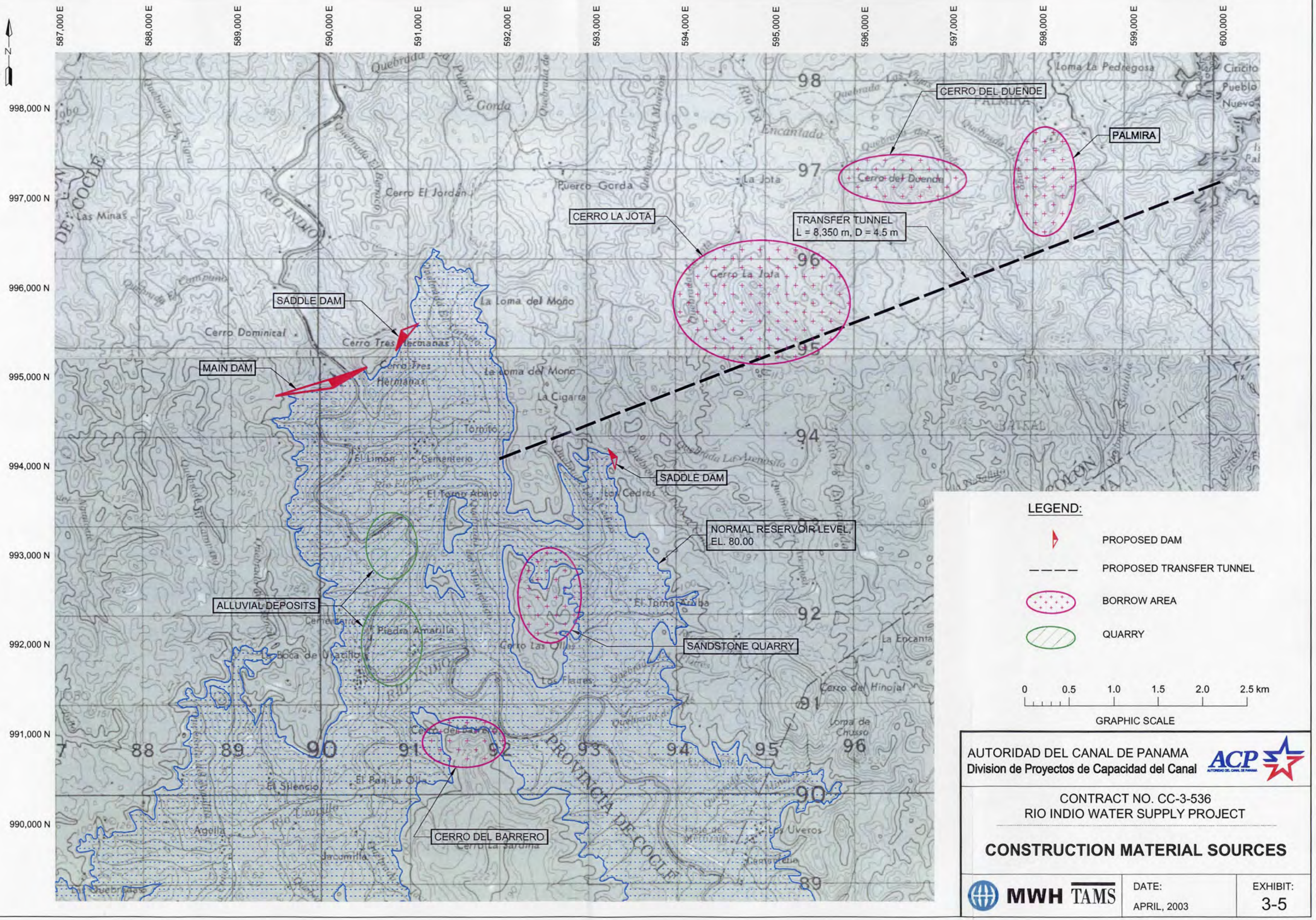
CONTRACT NO. CC-3-536
RÍO INDIO WATER SUPPLY PROJECT

Seismicity of Panama

MWH TAMS

DATE:
APRIL, 2003

EXHIBIT:
3-4



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

ACP

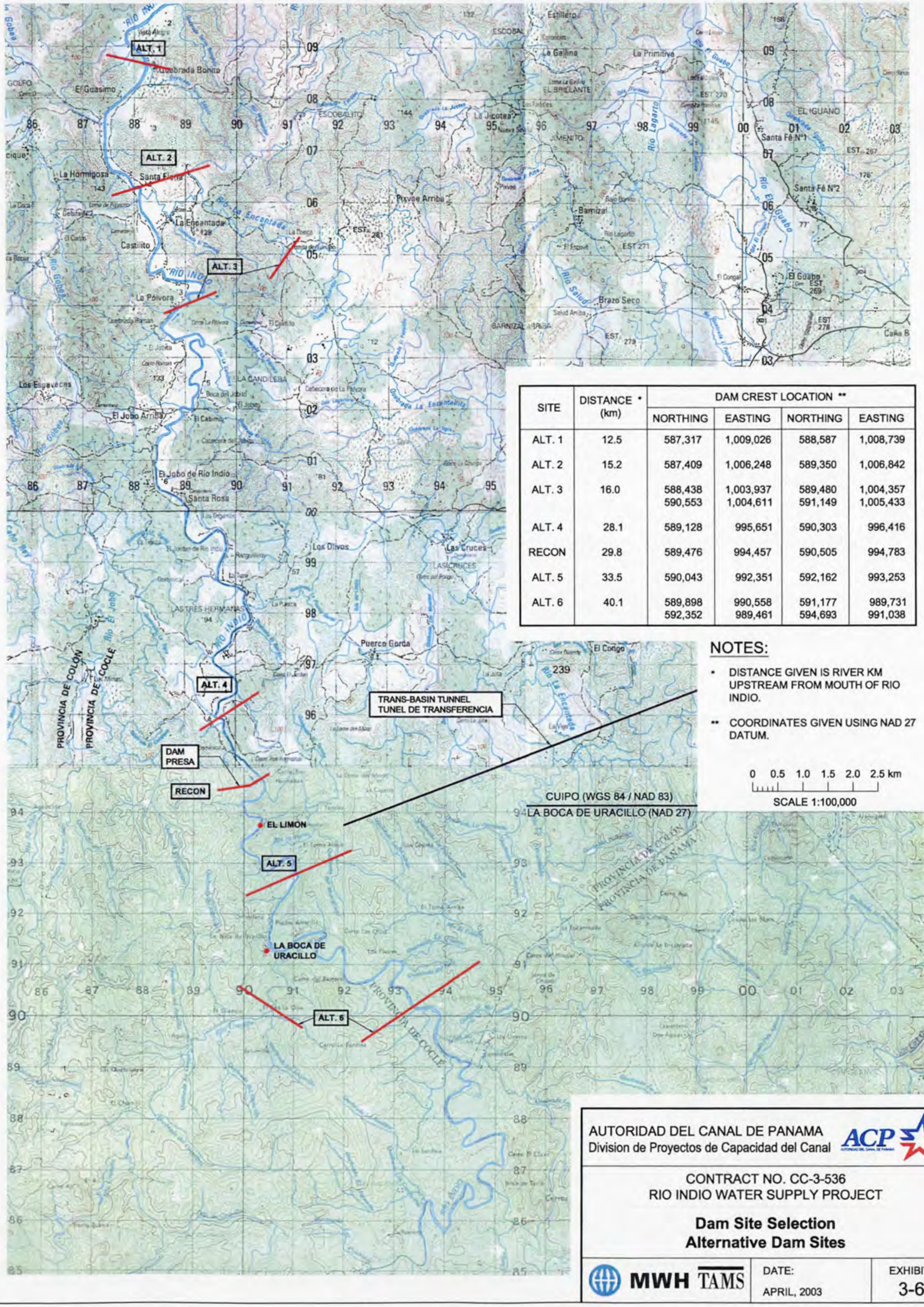
CONTRACT NO. CC-3-536
RIO INDIO WATER SUPPLY PROJECT

CONSTRUCTION MATERIAL SOURCES

MWH TAMS

DATE: APRIL, 2003

EXHIBIT: 3-5



SITE	DISTANCE * (km)	DAM CREST LOCATION **			
		NORTHING	EASTING	NORTHING	EASTING
ALT. 1	12.5	587,317	1,009,026	588,587	1,008,739
ALT. 2	15.2	587,409	1,006,248	589,350	1,006,842
ALT. 3	16.0	588,438 590,553	1,003,937 1,004,611	589,480 591,149	1,004,357 1,005,433
ALT. 4	28.1	589,128	995,651	590,303	996,416
RECON	29.8	589,476	994,457	590,505	994,783
ALT. 5	33.5	590,043	992,351	592,162	993,253
ALT. 6	40.1	589,898 592,352	990,558 989,461	591,177 594,693	989,731 991,038

NOTES:

- * DISTANCE GIVEN IS RIVER KM UPSTREAM FROM MOUTH OF RIO INDIO.
- ** COORDINATES GIVEN USING NAD 27 DATUM.

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

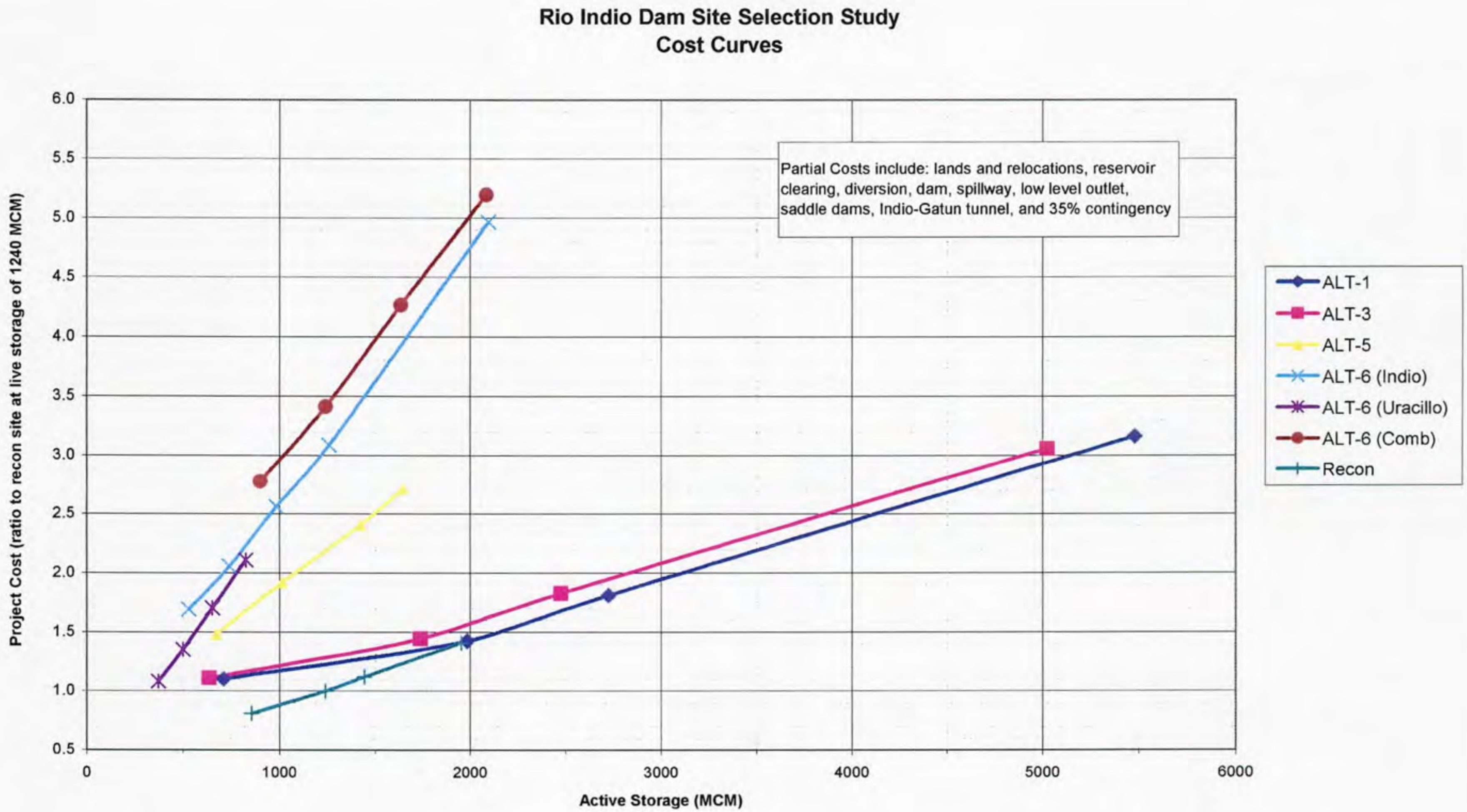
CONTRACT NO. CC-3-536
RIO INDIO WATER SUPPLY PROJECT

Dam Site Selection
Alternative Dam Sites

MWH TAMS

DATE: APRIL, 2003

EXHIBIT: 3-6

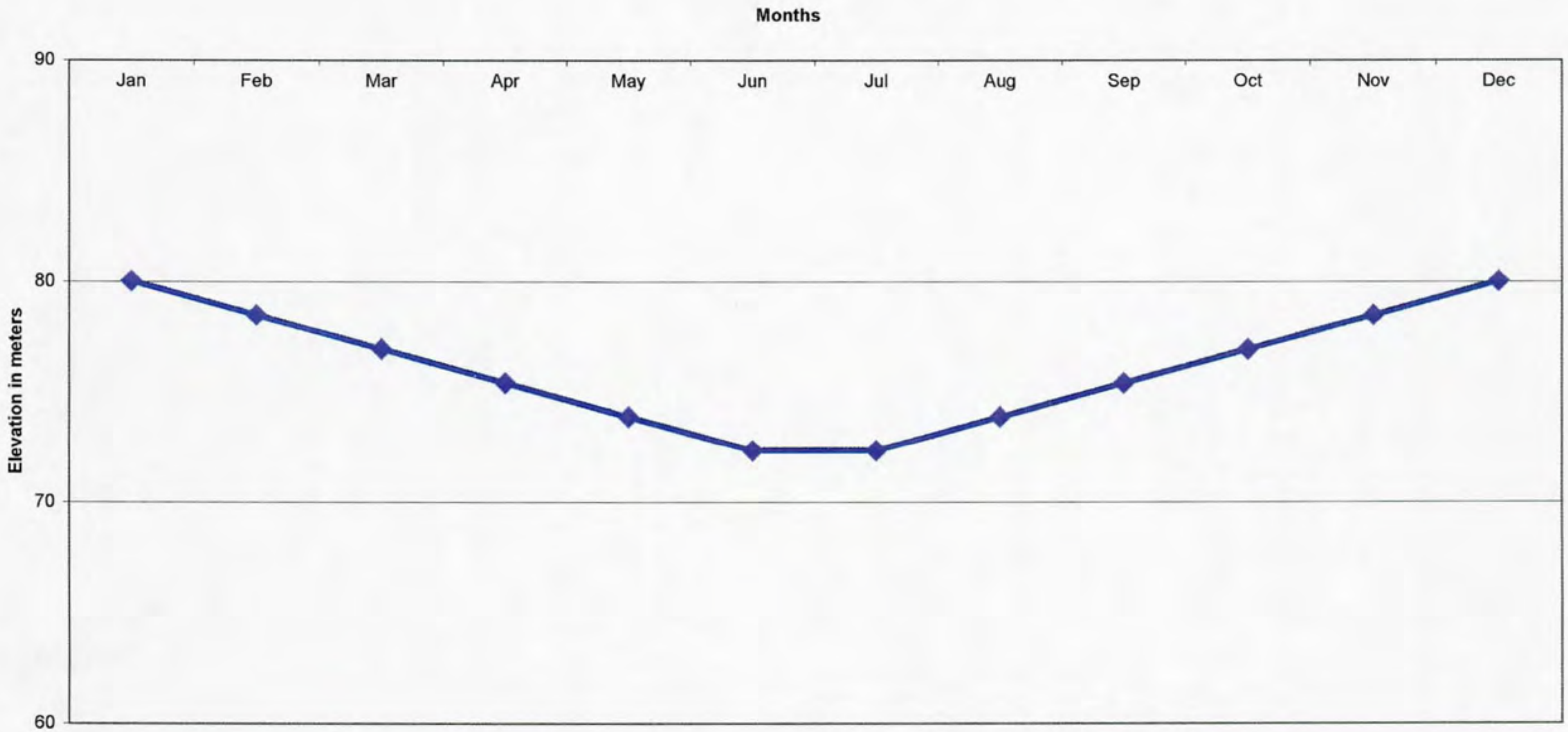


AUTORIDAD DEL CANAL DE PANAMA
Division de Proyectos de Capacidad del Canal

CONTRACT NO. CC-3-536
RÍO INDIO WATER SUPPLY PROJECT

Comparative costs of Alternative Dam Sites

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



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

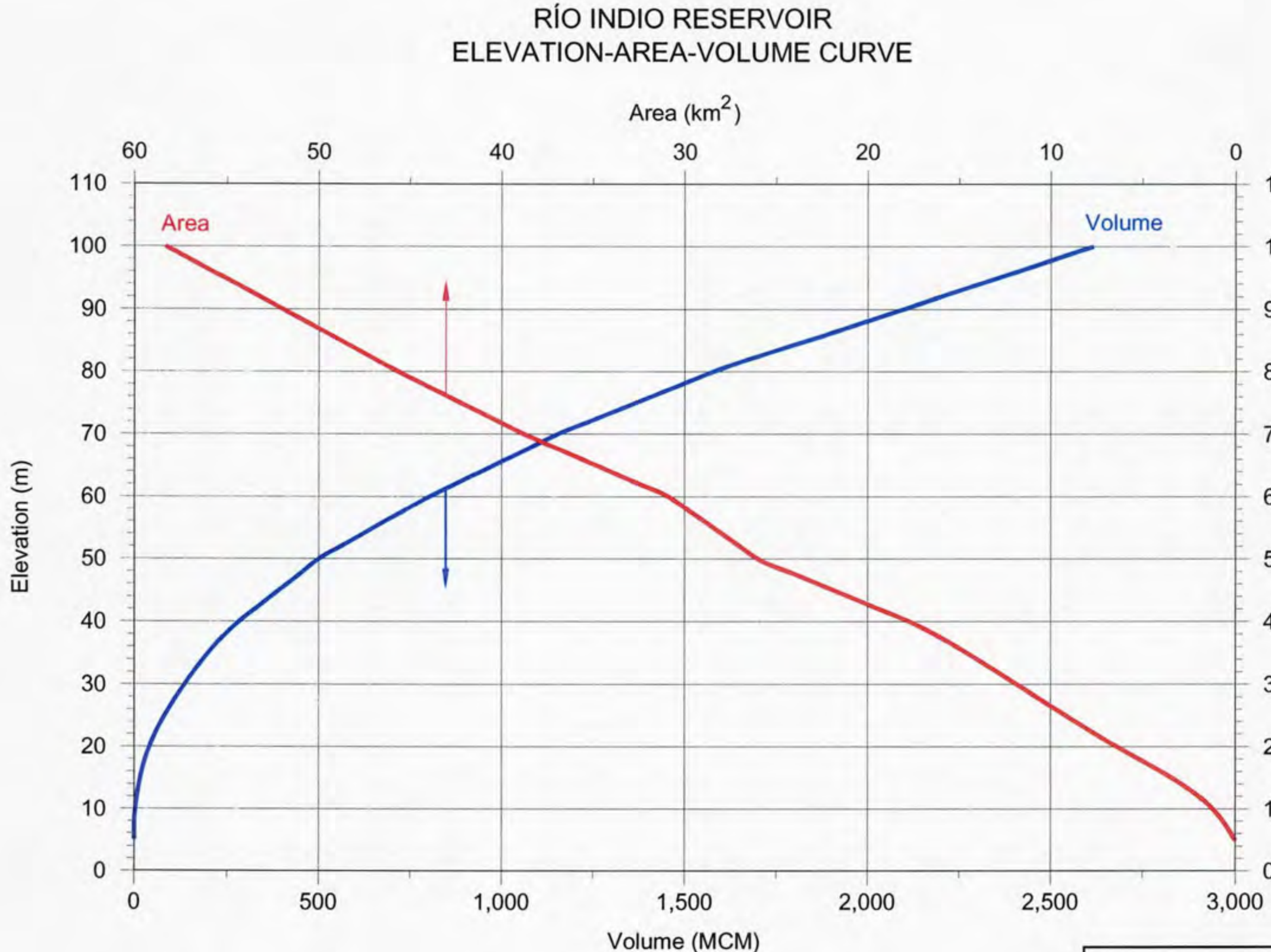
CONTRACT NO. CC-3-536
RÍO INDIO WATER SUPPLY PROJECT

Rio Indio Rule Curve

MWH TAMS

DATE: APRIL, 2003

EXHIBIT: 3-8



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

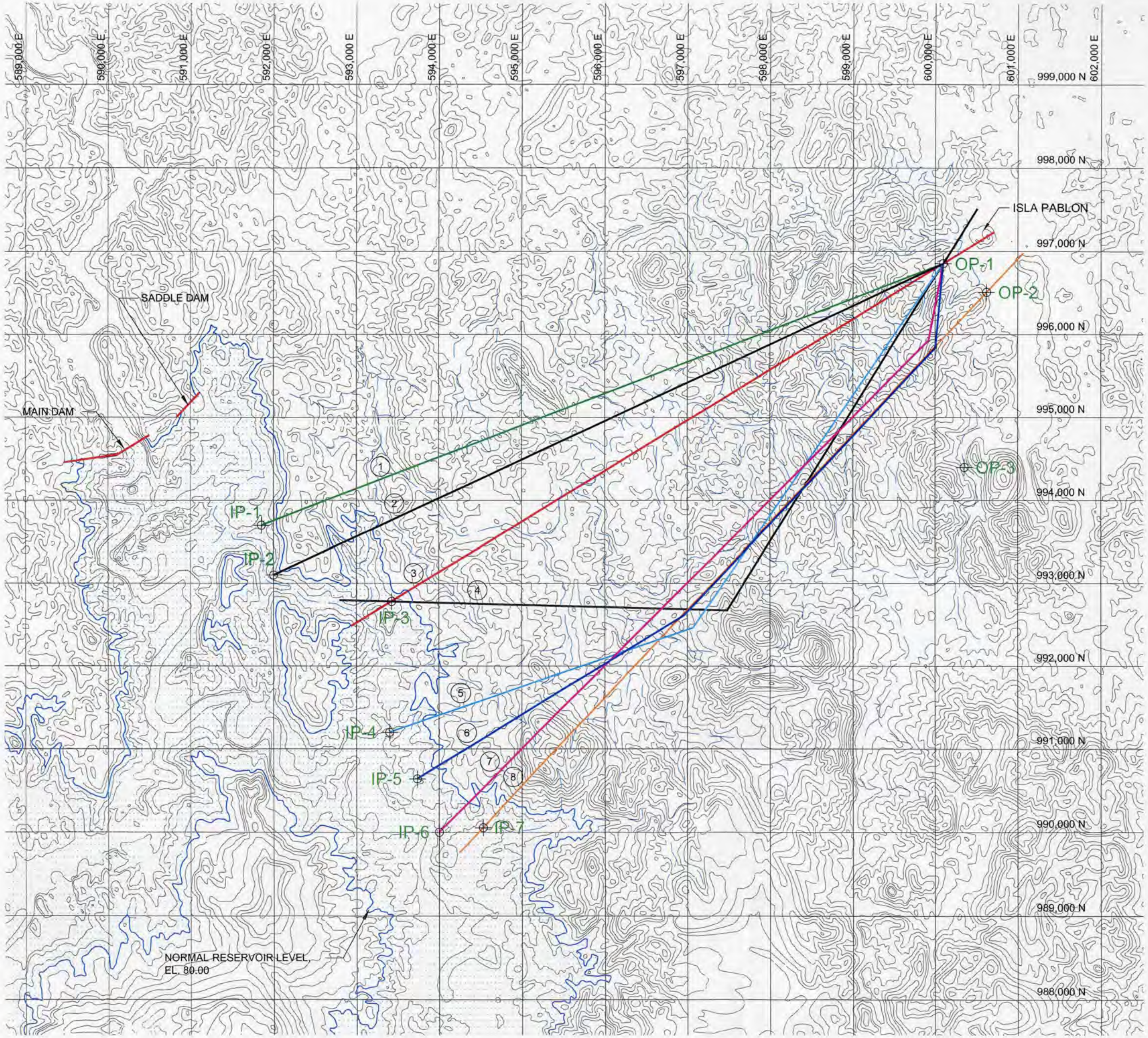
CONTRACT NO. CC-3-536
RÍO INDIO WATER SUPPLY PROJECT

AREA AND VOLUME CURVE

MWH TAMS

DATE: APRIL, 2003

EXHIBIT: 3-9



ALIGNMENT ALTERNATIVE	INLET PORTAL	OUTLET PORTAL
1	IP-1	OP-1
2	IP-2	OP-1
3	IP-3	OP-1
4	IP-3	OP-1
5	IP-4	OP-1
6	IP-5	OP-1
7	IP-6	OP-1
8	IP-7	OP-2

LEGEND:

QUEBRADAS

IP-1 OP-1 TUNNEL ALIGNMENT

TRANS-BASIN TRANSFER TUNNEL

0 0.5 1.0 1.5 2.0 2.5 km

GRAPHIC SCALE

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

ACP

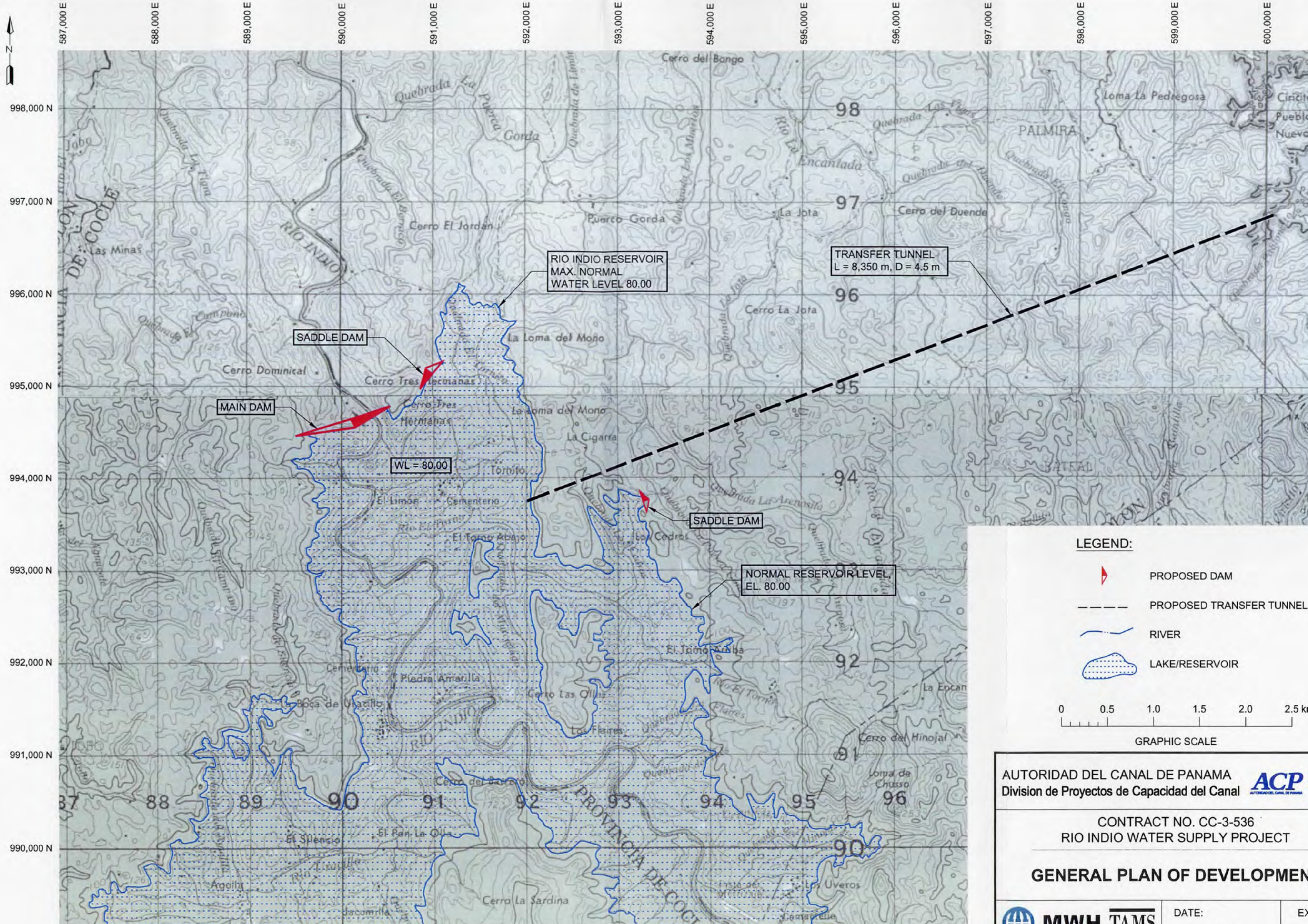
CONTRACT NO. CC-3-536
RIO INDIO WATER SUPPLY PROJECT

POTENTIAL WATER TRANSFER ALIGNMENTS

MWH TAMS

DATE: APRIL, 2003

EXHIBIT: 3-10



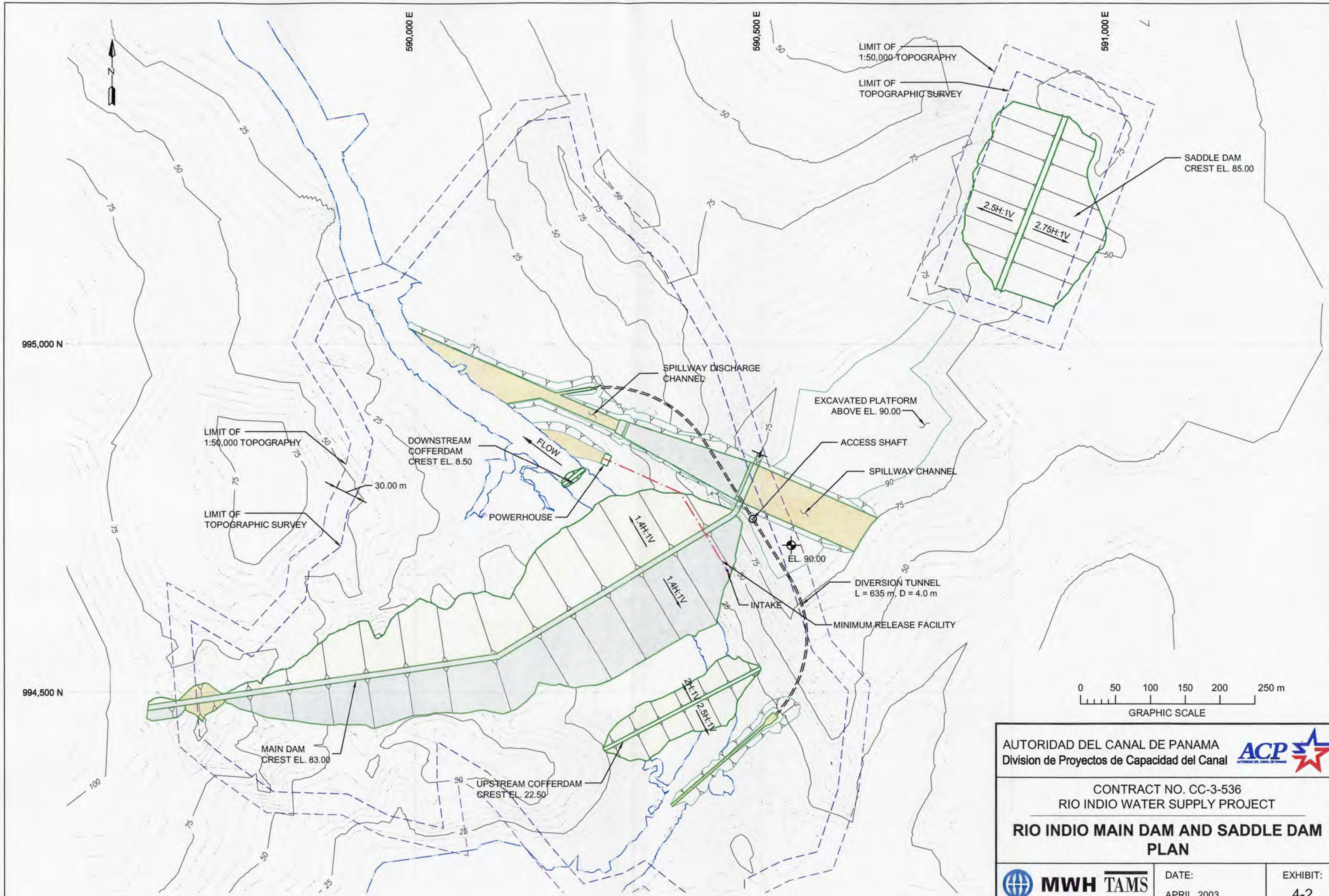
AUTORIDAD DEL CANAL DE PANAMA
Division de Proyectos de Capacidad del Canal

CONTRACT NO. CC-3-536
RIO INDIO WATER SUPPLY PROJECT

GENERAL PLAN OF DEVELOPMENT

MWH TAMS

DATE:	EXHIBIT:
APRIL, 2003	4-1



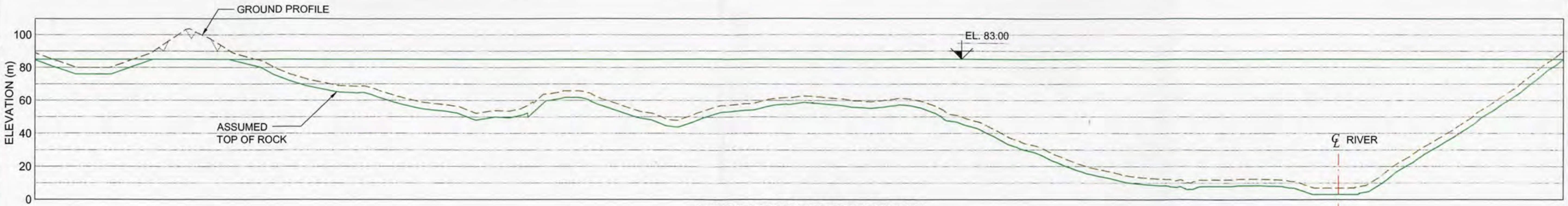
AUTORIDAD DEL CANAL DE PANAMA
Division de Proyectos de Capacidad del Canal

CONTRACT NO. CC-3-536
RIO INDIO WATER SUPPLY PROJECT

RIO INDIO MAIN DAM AND SADDLE DAM PLAN

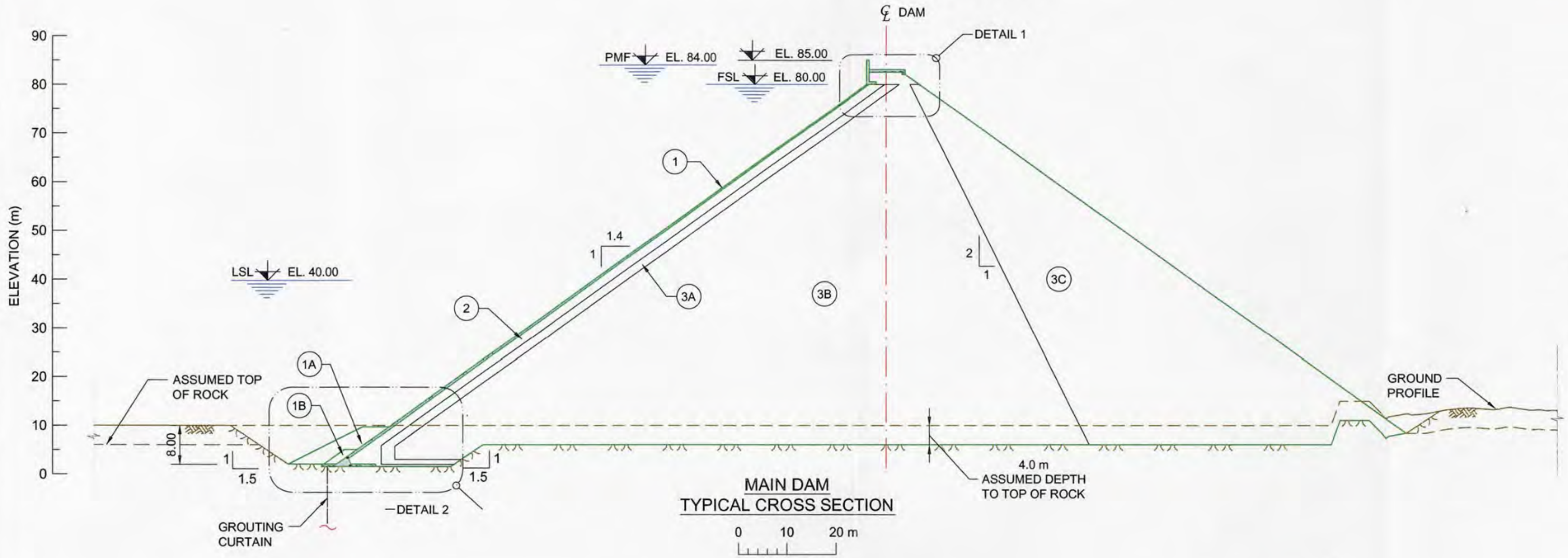
MWH TAMS

DATE:	EXHIBIT:
APRIL, 2003	4-2



LONGITUDINAL PROFILE OF DAM

(LOOKING DOWNSTREAM)



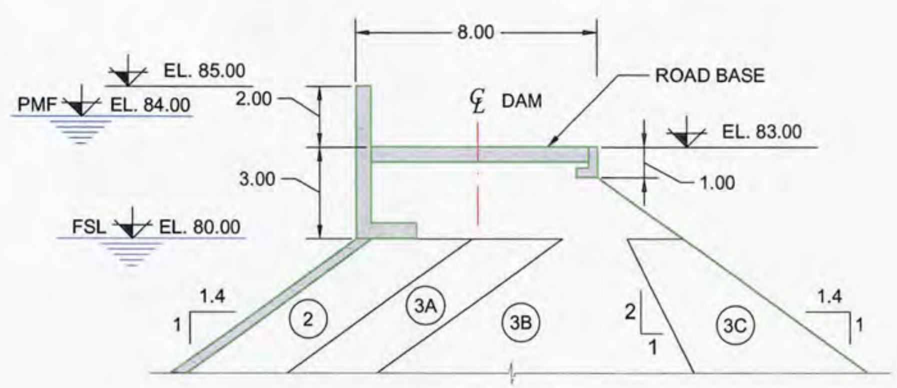
MAIN DAM TYPICAL CROSS SECTION

0 10 20 m
GRAPHIC SCALE

LEGEND:

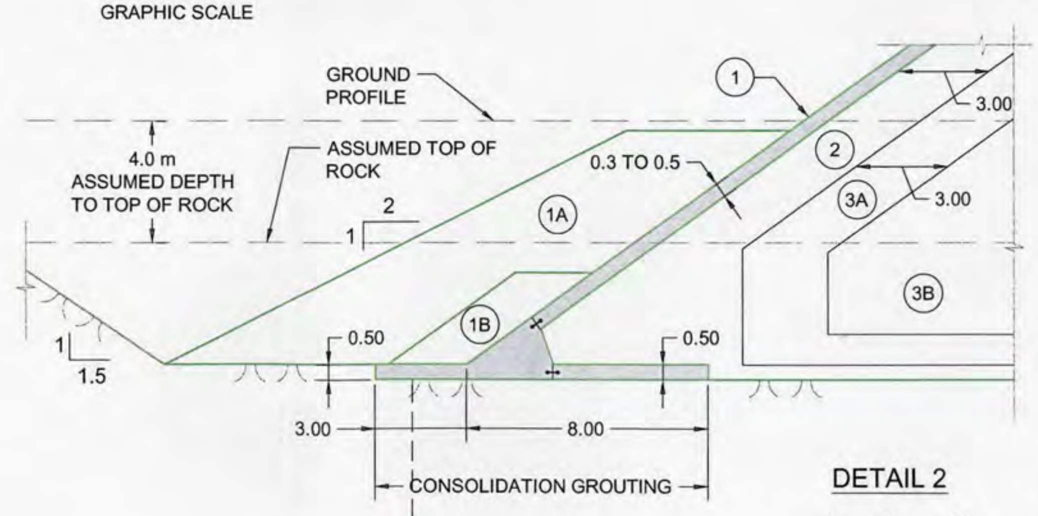
- (1) CONCRETE FACE SLAB
- (1A) MISCELLANEOUS FILL
- (1B) SILTY SAND
- (2) FILTER
- (3A) FINE ROCKFILL
- (3B) ROCKFILL
- (3C) COARSE ROCKFILL

0 50 100 150 200 250 m
GRAPHIC SCALE



DETAIL 1

0 2 4 m
GRAPHIC SCALE



DETAIL 2

0 2 4 m
GRAPHIC SCALE

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

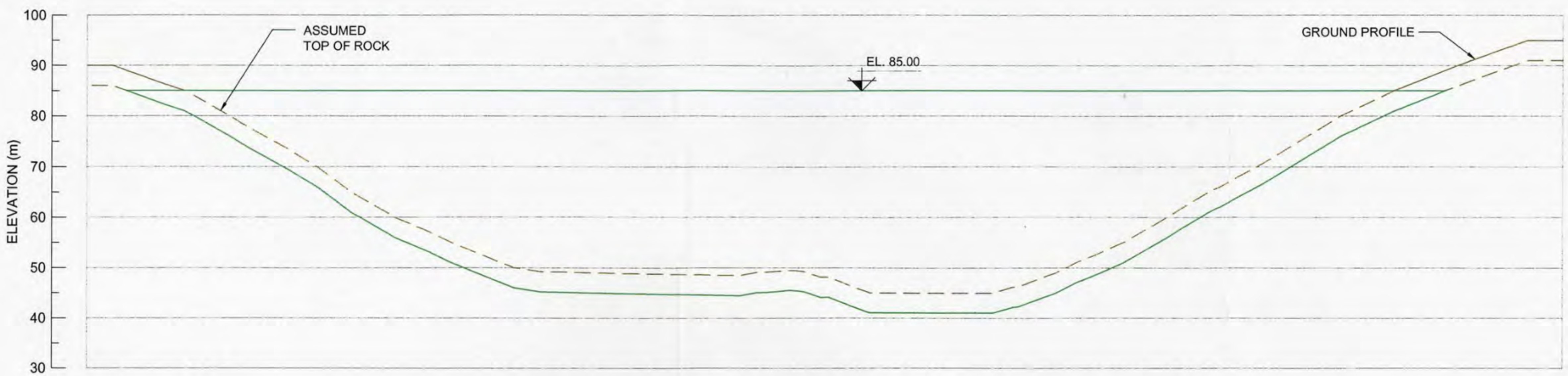
ACP

CONTRACT NO. CC-3-536
RIO INDIO WATER SUPPLY PROJECT

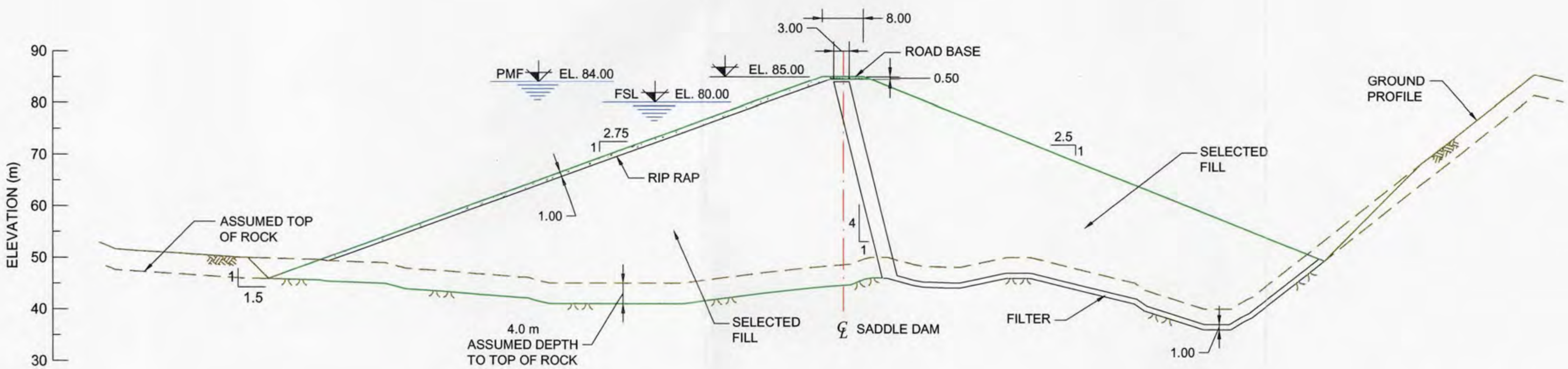
RIO INDIO MAIN DAM PROFILE AND TYPICAL CROSS SECTION

MWH TAMS

DATE:	EXHIBIT:
APRIL, 2003	4-3



LONGITUDINAL PROFILE OF SADDLE DAM
(LOOKING DOWNSTREAM)



SADDLE DAM
TYPICAL CROSS SECTION

0 10 20 m
GRAPHIC SCALE

0 25 50 75 100 125 m
GRAPHIC SCALE

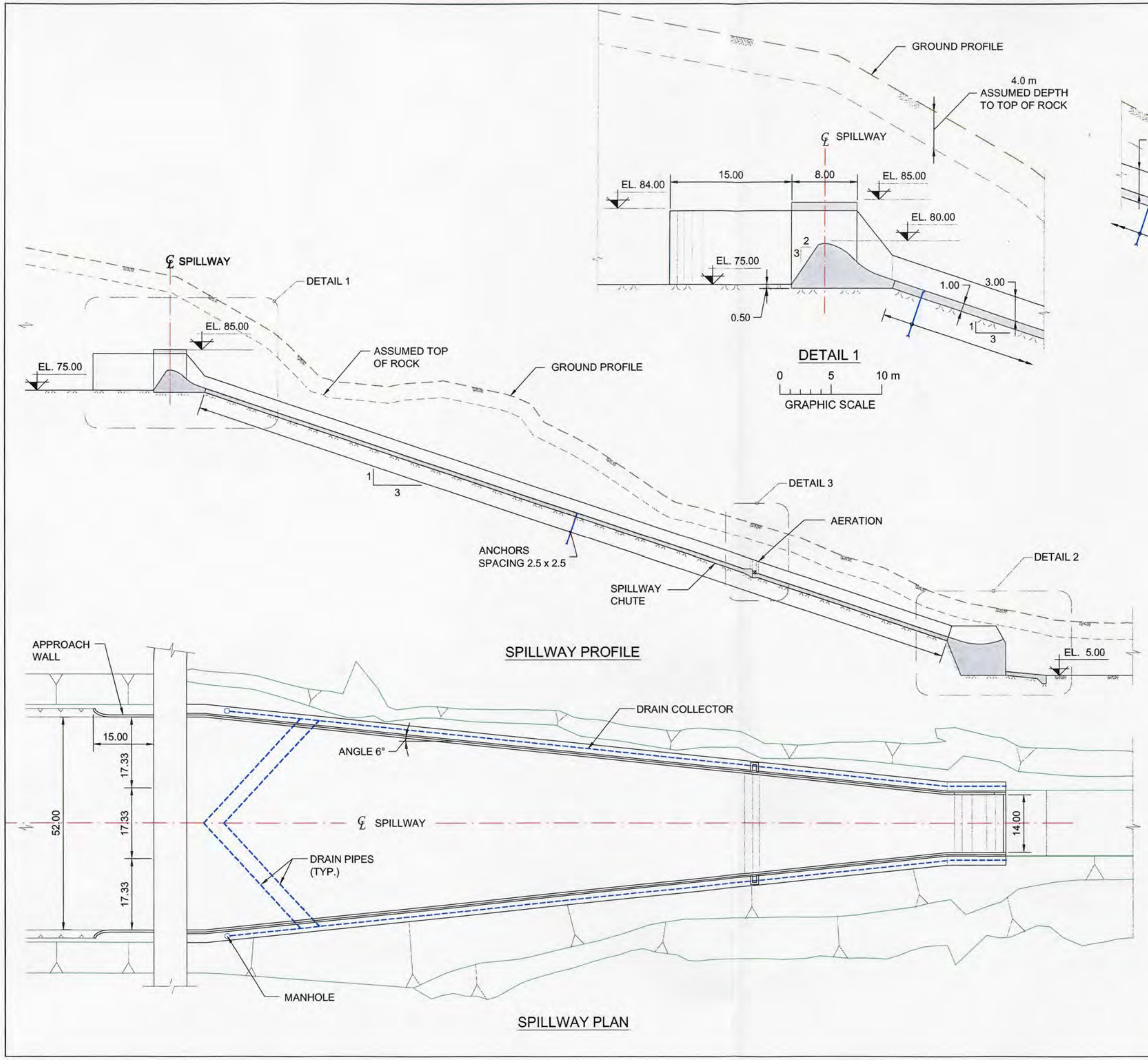
AUTORIDAD DEL CANAL DE PANAMA
Division de Proyectos de Capacidad del Canal

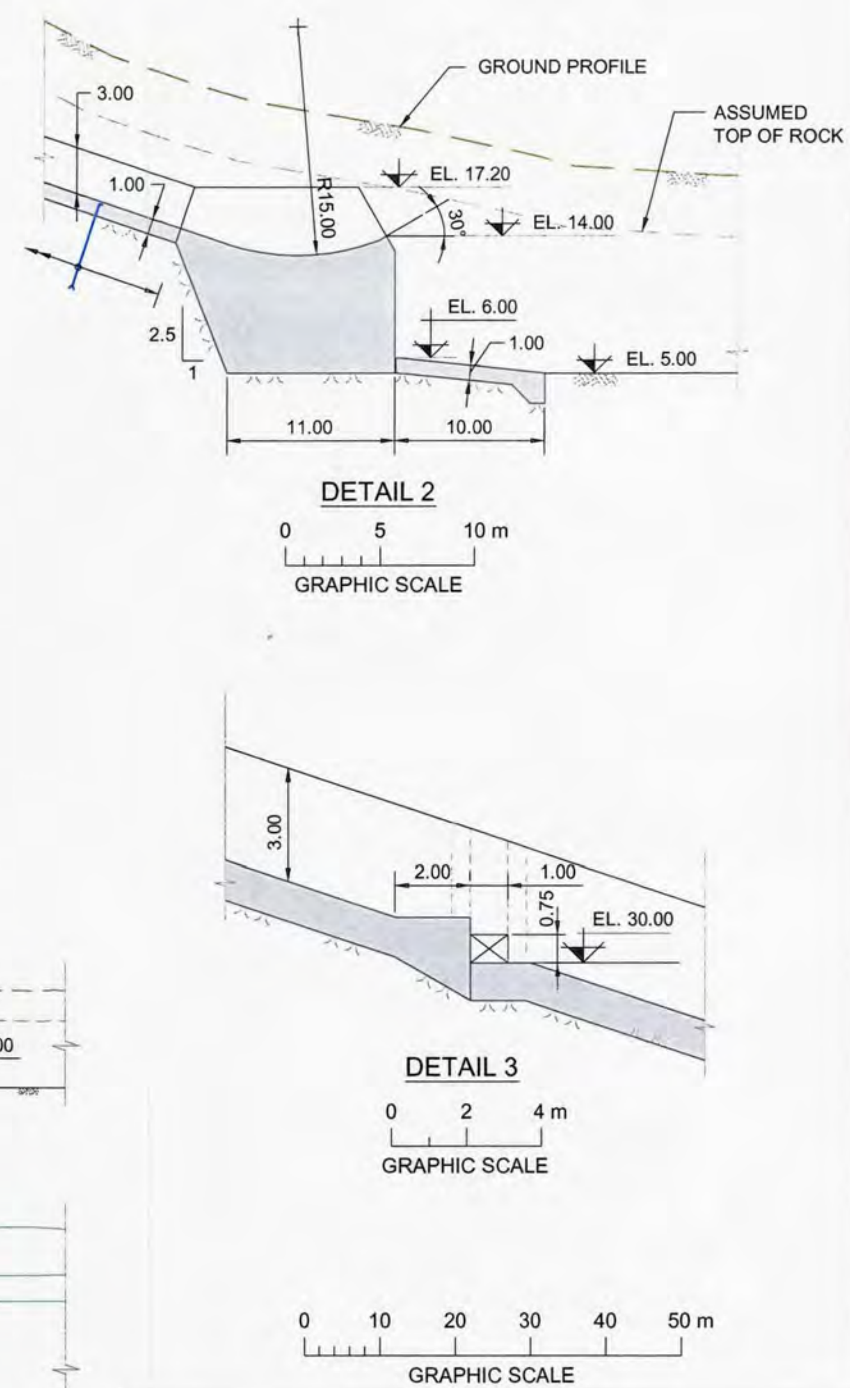
CONTRACT NO. CC-3-536
RIO INDIO WATER SUPPLY PROJECT

RIO INDIO SADDLE DAM
PROFILE AND TYPICAL CROSS SECTION

MWH TAMS

DATE:	EXHIBIT:
APRIL, 2003	4-4





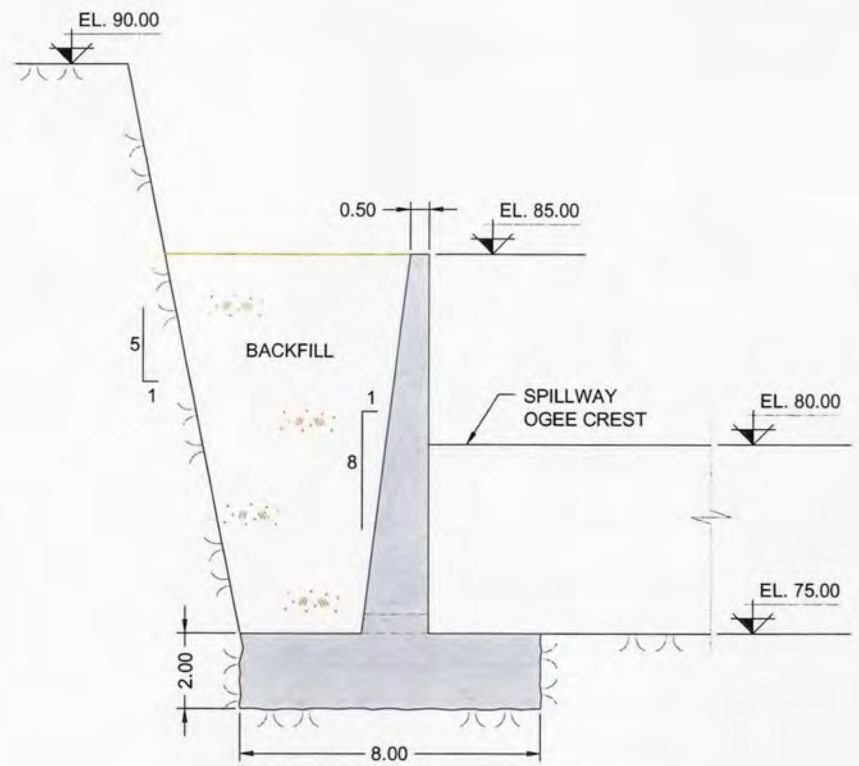
AUTORIDAD DEL CANAL DE PANAMA
Division de Proyectos de Capacidad del Canal

CONTRACT NO. CC-3-536
RIO INDIO WATER SUPPLY PROJECT

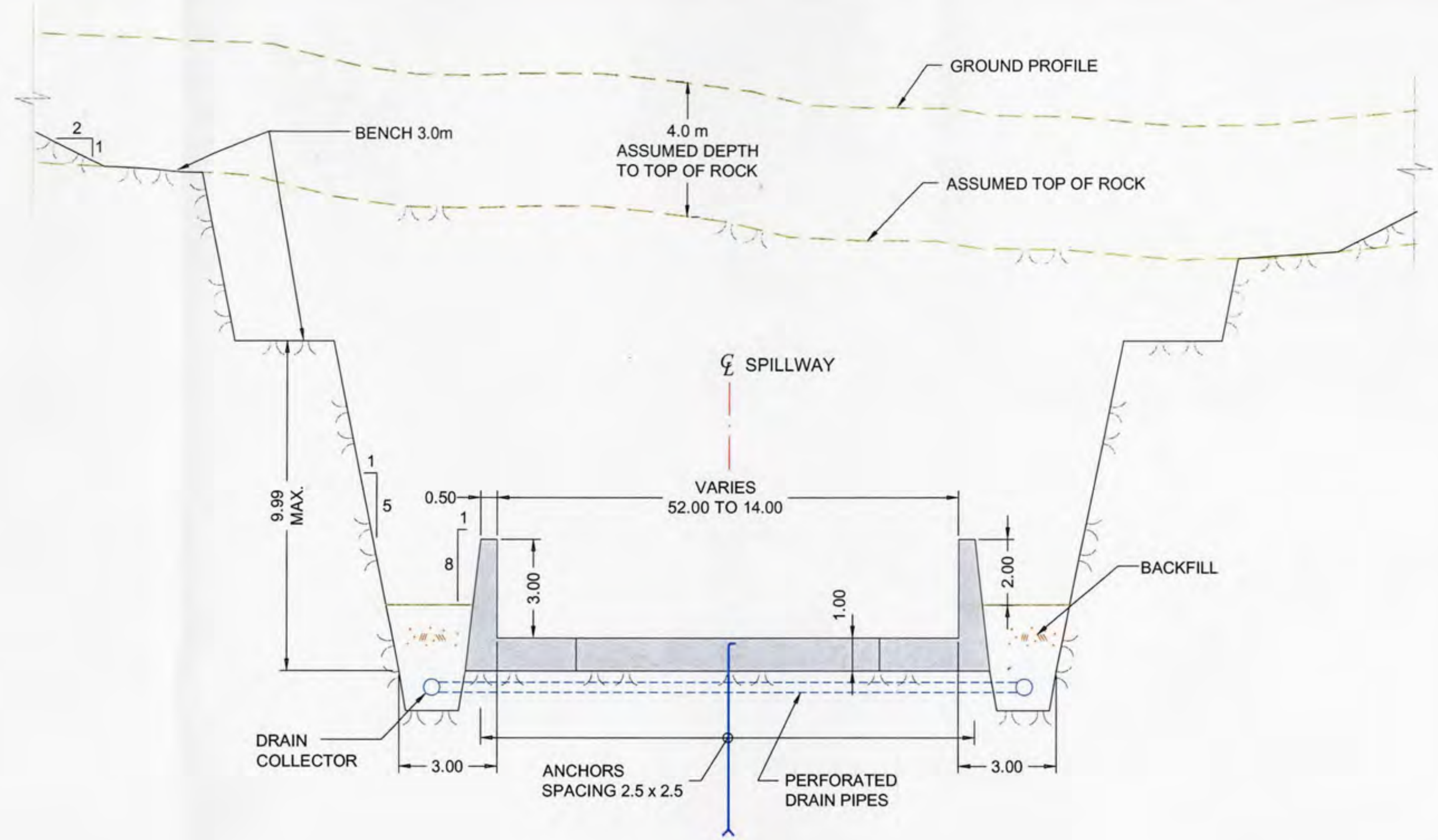
SPILLWAY
PLAN, PROFILE AND DETAILS

MWH TAMS

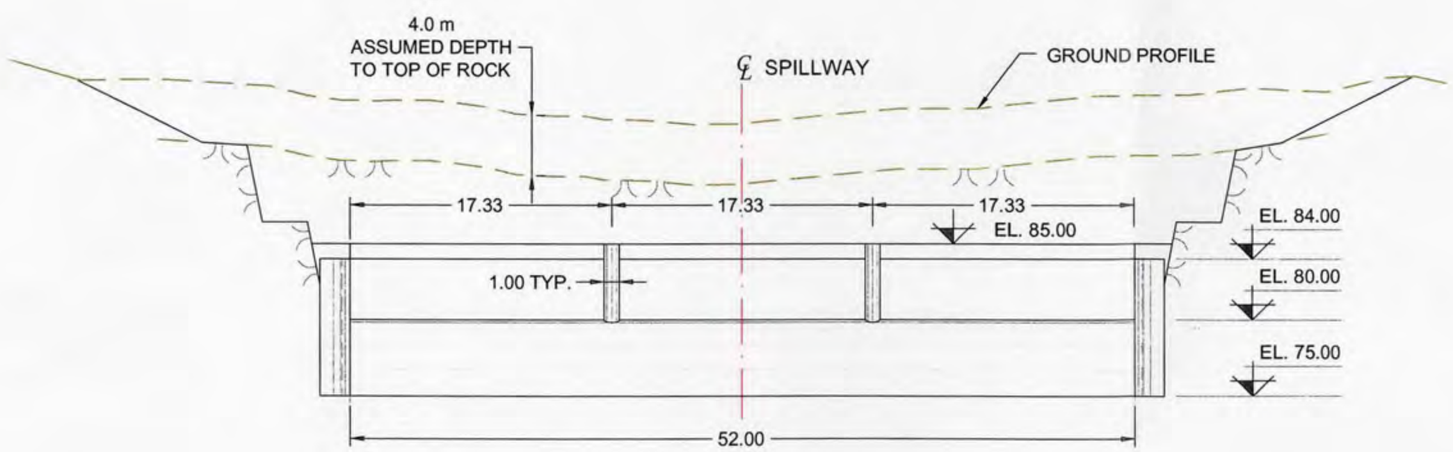
DATE:	EXHIBIT:
APRIL, 2003	4-5



SPILLWAY APPROACH WALL
SECTION



SPILLWAY CHUTE
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

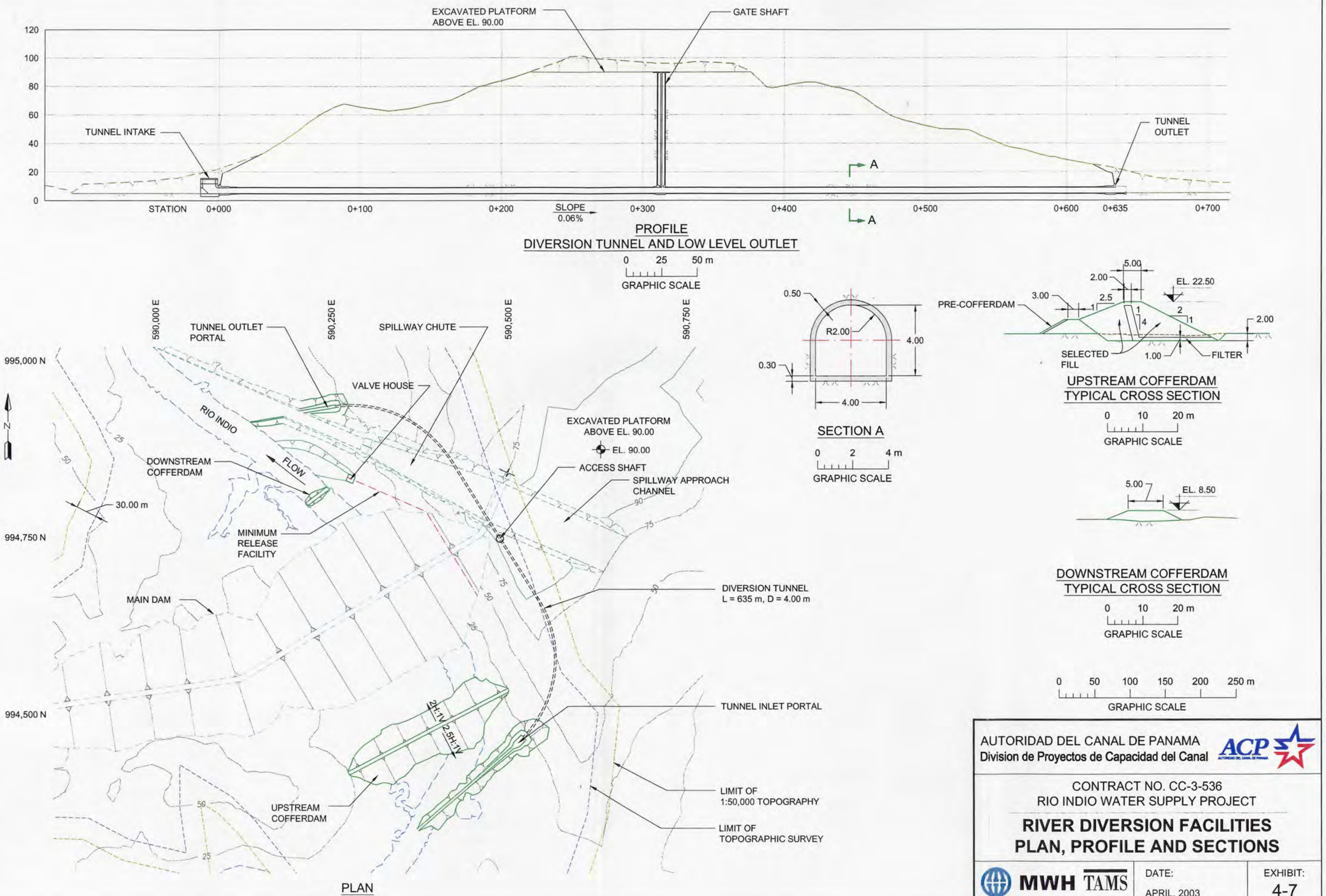
CONTRACT NO. CC-3-536
RIO INDIO WATER SUPPLY PROJECT

SPILLWAY
SECTIONS AND UPSTREAM VIEW

MWH TAMS

DATE: APRIL, 2003

EXHIBIT: 4-6



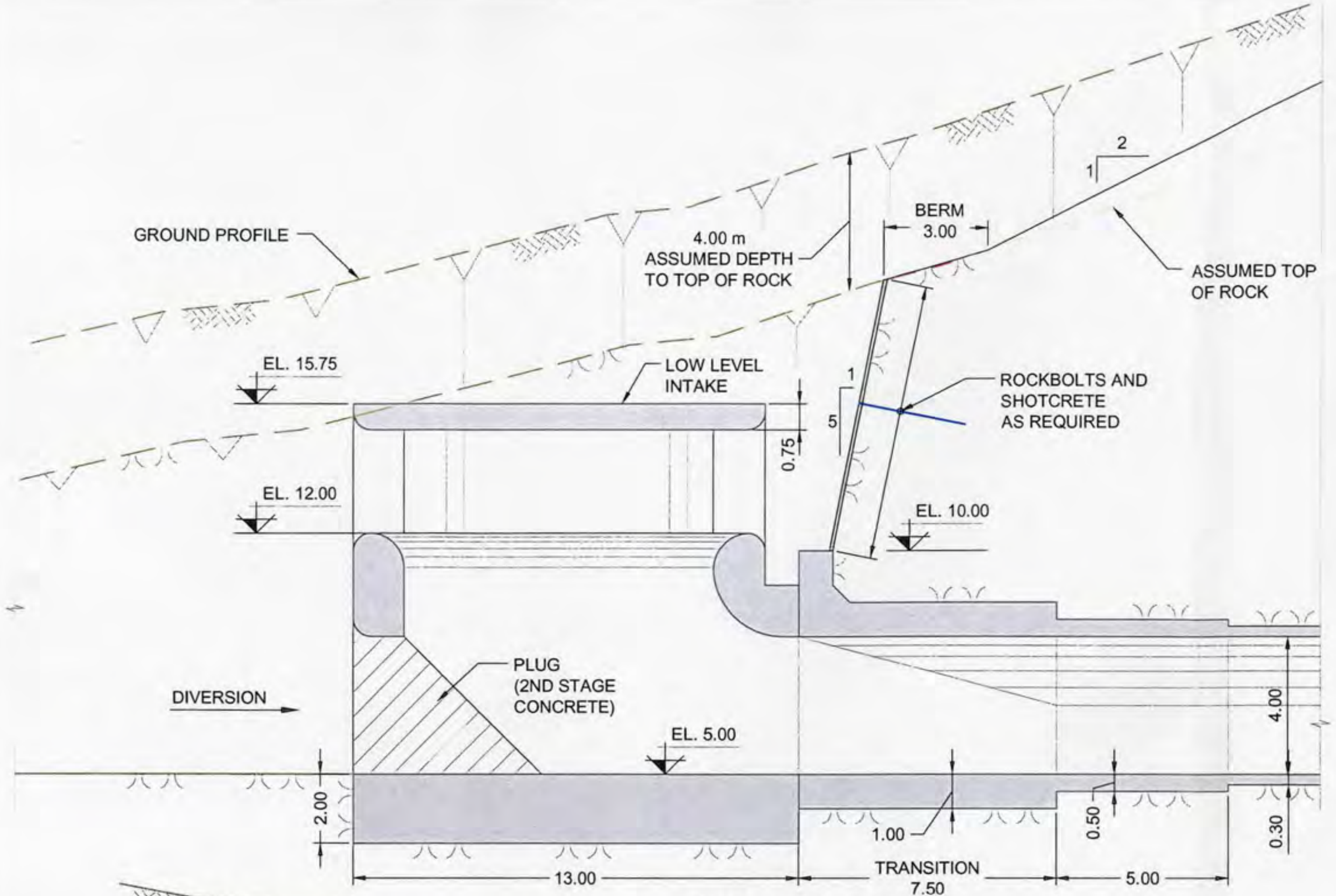
AUTORIDAD DEL CANAL DE PANAMA
Division de Proyectos de Capacidad del Canal

CONTRACT NO. CC-3-536
RIO INDIO WATER SUPPLY PROJECT

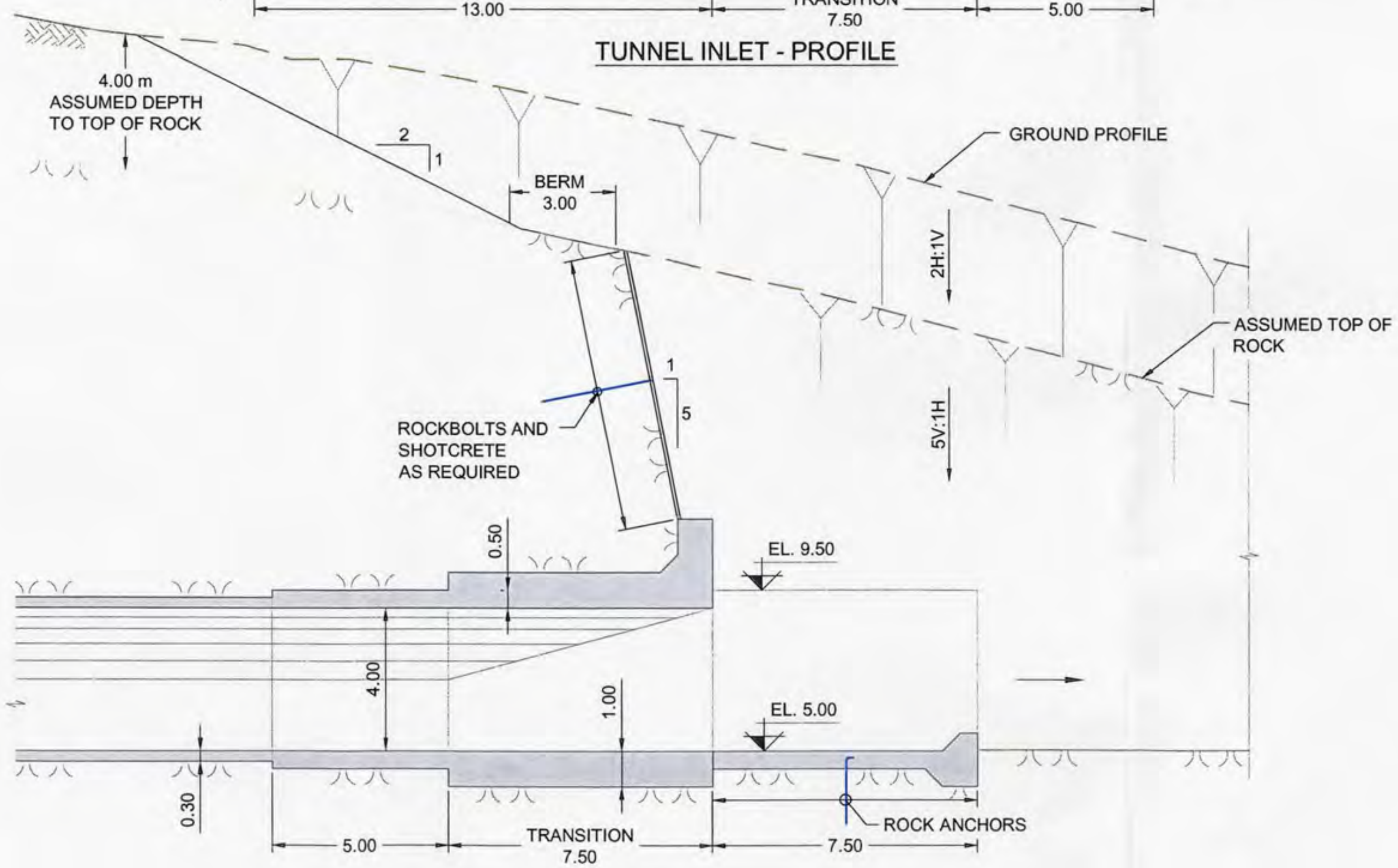
RIVER DIVERSION FACILITIES
PLAN, PROFILE AND SECTIONS

MWH TAMS

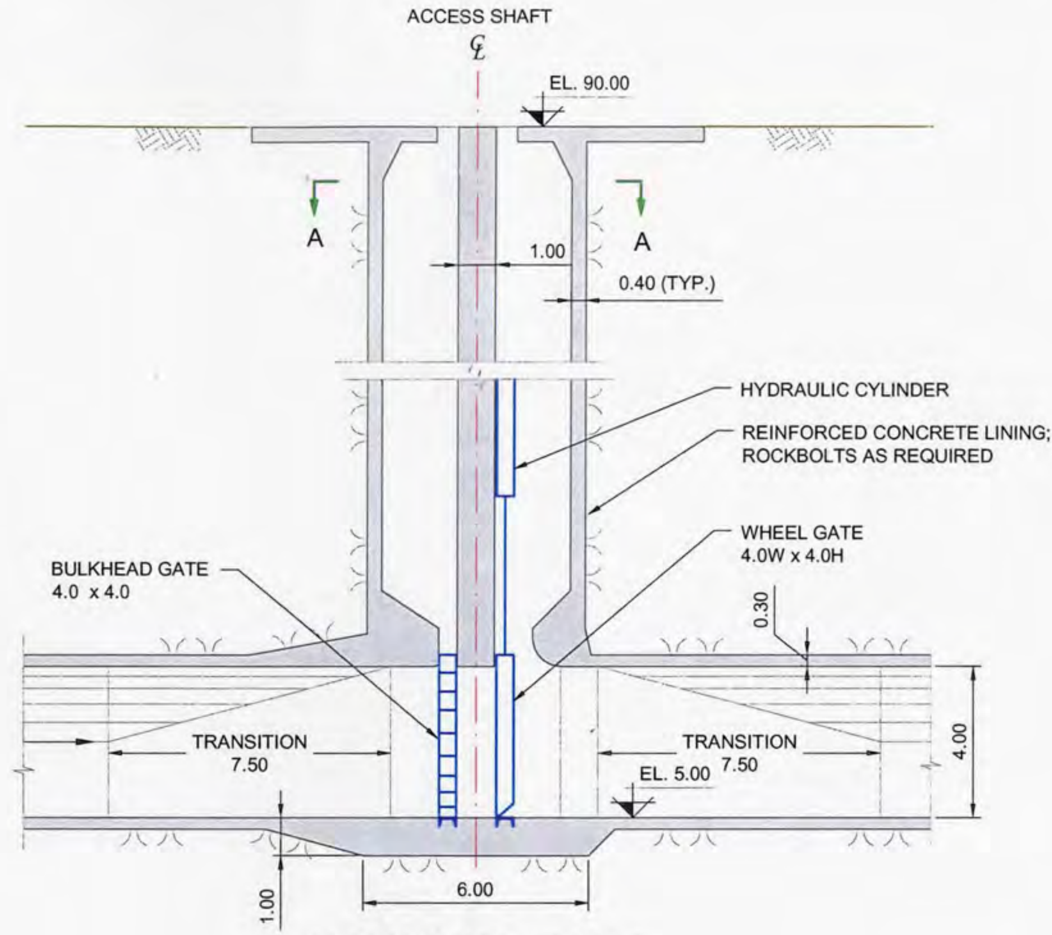
DATE:	EXHIBIT:
APRIL, 2003	4-7



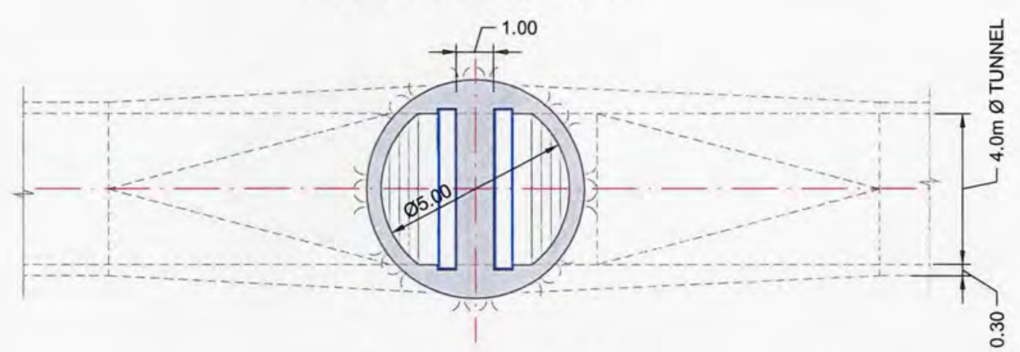
TUNNEL INLET - PROFILE



TUNNEL OUTLET - PROFILE



ACCESS SHAFT - PROFILE



ACCESS SHAFT - PLAN

0 2 4 6 8 10 m

GRAPHIC SCALE

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

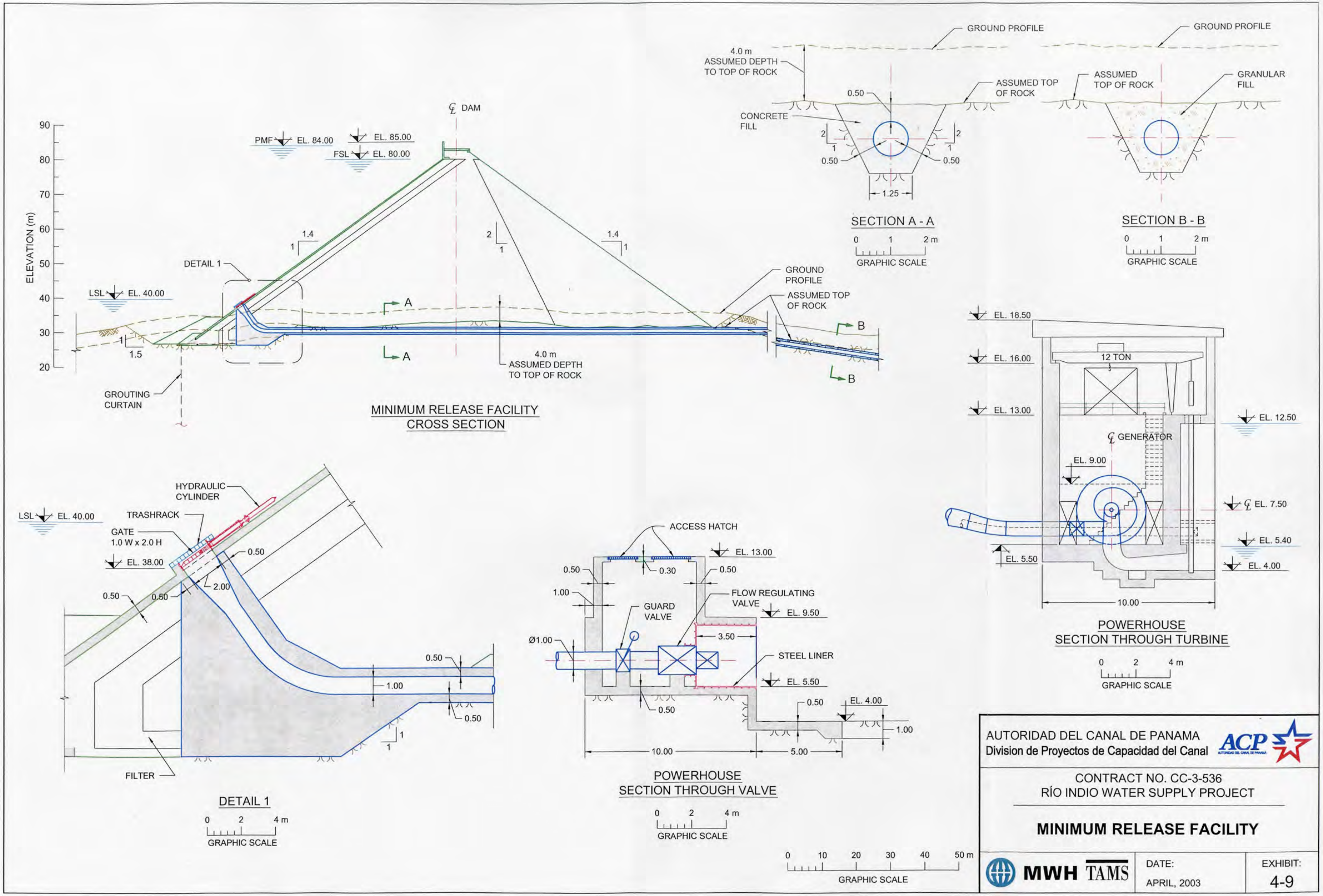
ACP

CONTRACT NO. CC-3-536
RIO INDIO WATER SUPPLY PROJECT

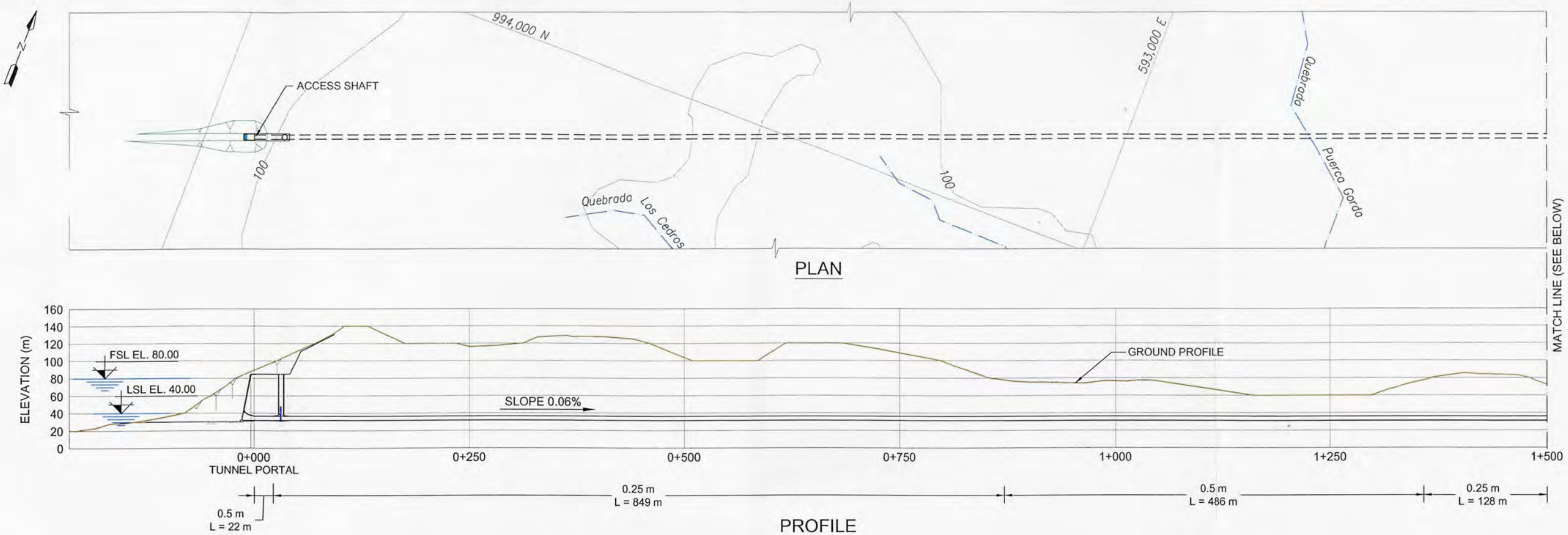
RIVER DIVERSION FACILITIES DETAILS

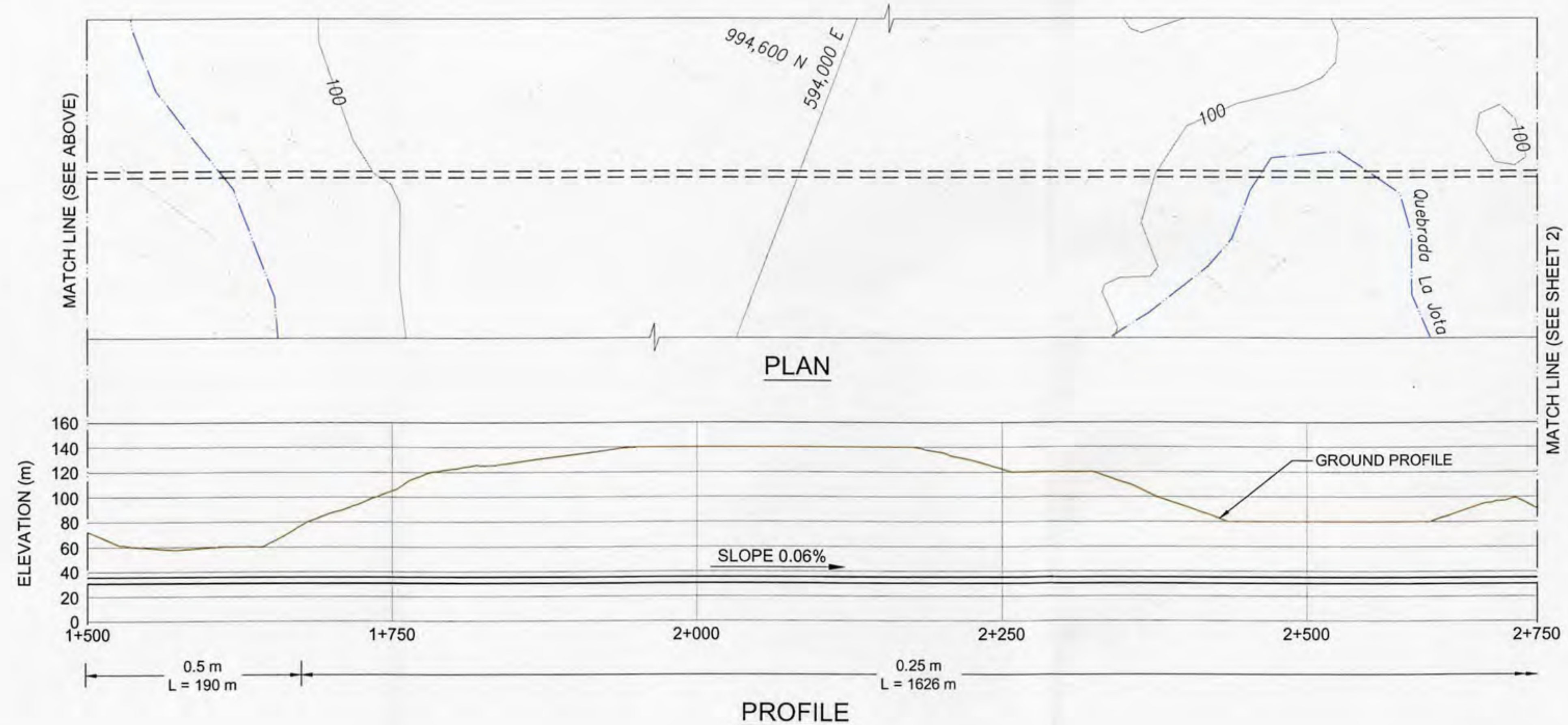
MWH TAMS

DATE:	EXHIBIT:
APRIL, 2003	4-8



MINIMUM RELEASE FACILITY CROSS SECTION
ELEVATION (m)
90
80
70
60
50
40
30
20
℄ DAM
PMF EL. 84.00
EL. 85.00
FSL EL. 80.00
LSL EL. 40.00
DETAIL 1
1.4
1
2
1
1.4
1
1
1.5
GROUTING CURTAIN
A
A
4.0 m ASSUMED DEPTH TO TOP OF ROCK
GROUND PROFILE
ASSUMED TOP OF ROCK
B
B
SECTION A - A
GROUND PROFILE
4.0 m ASSUMED DEPTH TO TOP OF ROCK
ASSUMED TOP OF ROCK
CONCRETE FILL
0.50
2
1
0.50
2
1
0.50
1.25
0 1 2 m
GRAPHIC SCALE
SECTION B - B
GROUND PROFILE
ASSUMED TOP OF ROCK
GRANULAR FILL
0 1 2 m
GRAPHIC SCALE
DETAIL 1
HYDRAULIC CYLINDER
TRASHRACK
GATE 1.0 W x 2.0 H
LSL EL. 40.00
EL. 38.00
0.50
2.00
0.50
0.50
0.50
1.00
0.50
1
1
FILTER
0 2 4 m
GRAPHIC SCALE
POWERHOUSE SECTION THROUGH VALVE
ACCESS HATCH
EL. 13.00
0.50
0.30
0.50
1.00
GUARD VALVE
FLOW REGULATING VALVE
EL. 9.50
Ø1.00
3.50
STEEL LINER
EL. 5.50
0.50
0.50
EL. 4.00
1.00
10.00
5.00
0 2 4 m
GRAPHIC SCALE
0 10 20 30 40 50 m
GRAPHIC SCALE
POWERHOUSE SECTION THROUGH TURBINE
EL. 18.50
EL. 16.00
12 TON
EL. 13.00
EL. 12.50
℄ GENERATOR
EL. 9.00
℄ EL. 7.50
EL. 5.40
EL. 5.50
EL. 4.00
10.00
0 2 4 m
GRAPHIC SCALE
AUTORIDAD DEL CANAL DE PANAMA
Division de Proyectos de Capacidad del Canal
ACP
CONTRACT NO. CC-3-536
RÍO INDIO WATER SUPPLY PROJECT
MINIMUM RELEASE FACILITY
MWH TAMS
DATE: APRIL, 2003
EXHIBIT: 4-9





NOTE:

0.25 m - LINING THICKNESS
L = 856 m - LENGTH OF INDICATED TUNNEL LINING THICKNESS

0 50 100 150 200 250 m
GRAPHIC SCALE

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

ACP

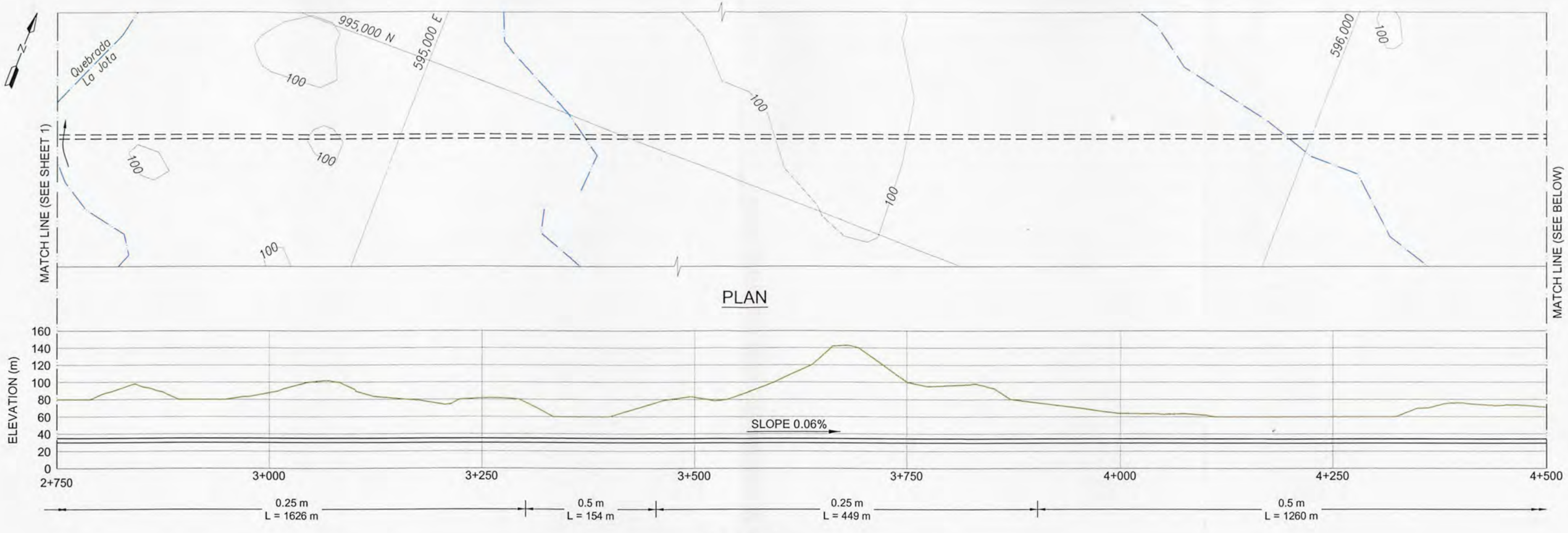
CONTRACT NO. CC-3-536
RIO INDIO WATER SUPPLY PROJECT

WATER TRANSFER TUNNEL
PLAN AND PROFILE - SHEET 1 OF 3

MWH TAMS

DATE: APRIL, 2003

EXHIBIT: 4-10



NOTE:

0.25 m - LINING THICKNESS
L = 856 m - LENGTH OF INDICATED TUNNEL LINING THICKNESS

0 50 100 150 200 250 m
GRAPHIC SCALE

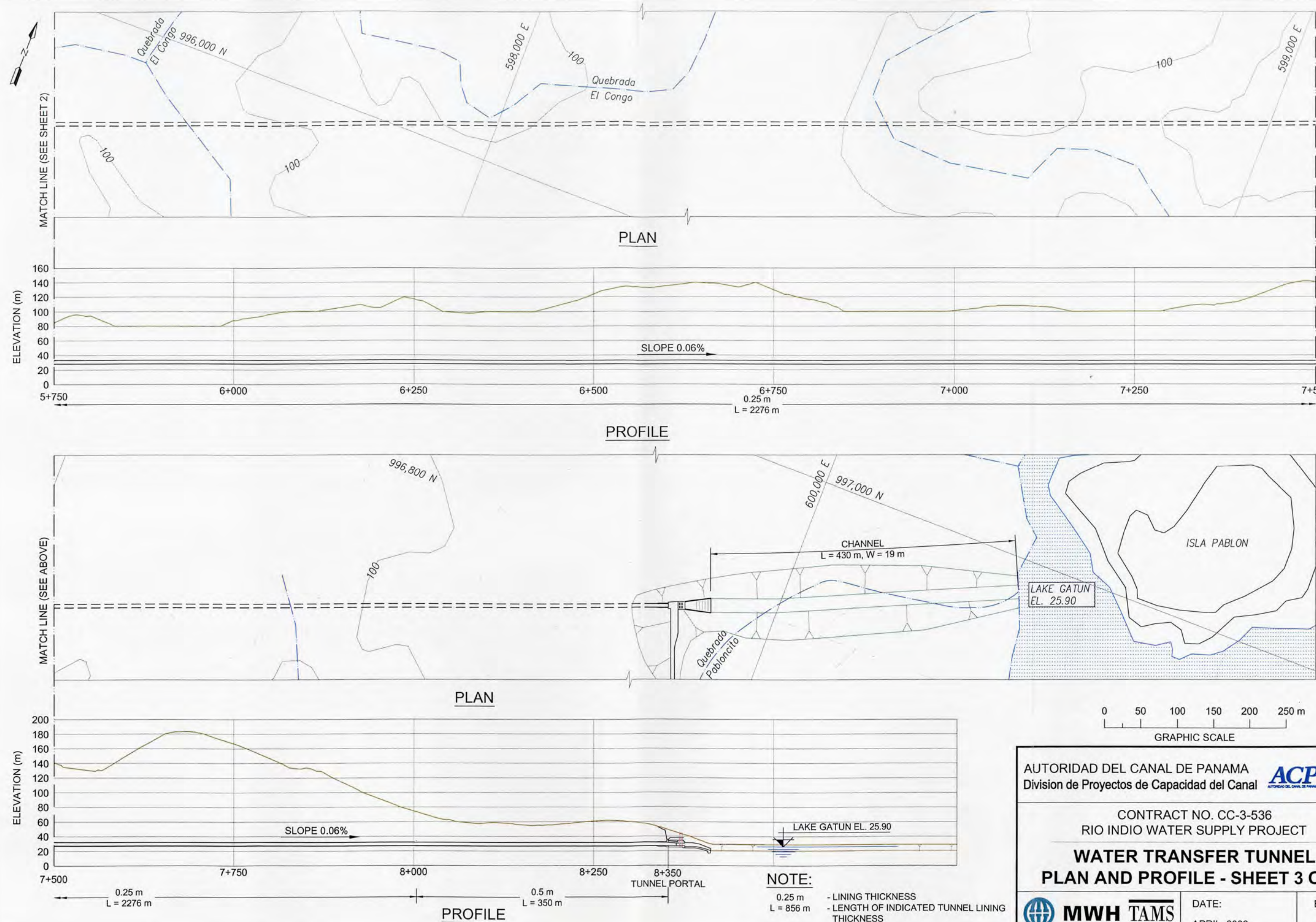
AUTORIDAD DEL CANAL DE PANAMA
Division de Proyectos de Capacidad del Canal

CONTRACT NO. CC-3-536
RIO INDIO WATER SUPPLY PROJECT

WATER TRANSFER TUNNEL
PLAN AND PROFILE - SHEET 2 OF 3

MWH TAMS

DATE:	EXHIBIT:
APRIL, 2003	4-10



NOTE:

0.25 m - LINING THICKNESS

L = 856 m - LENGTH OF INDICATED TUNNEL LINING THICKNESS

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

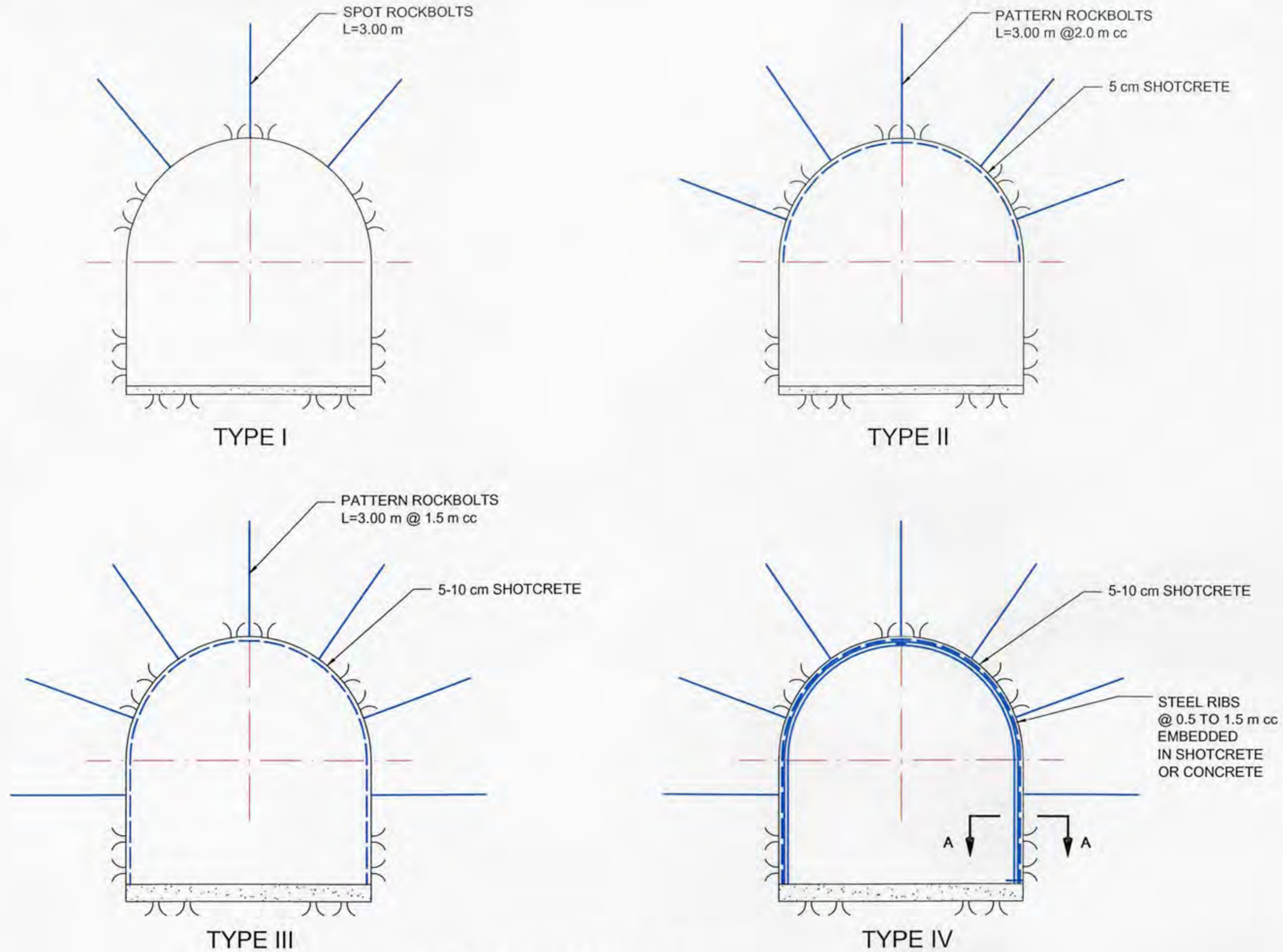
CONTRACT NO. CC-3-536
RIO INDIO WATER SUPPLY PROJECT

WATER TRANSFER TUNNEL
PLAN AND PROFILE - SHEET 3 OF 3

MWH TAMS

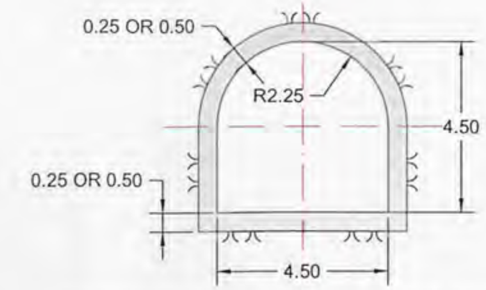
DATE: APRIL, 2003

EXHIBIT: 4-10



DRILL & BLAST SECTIONS

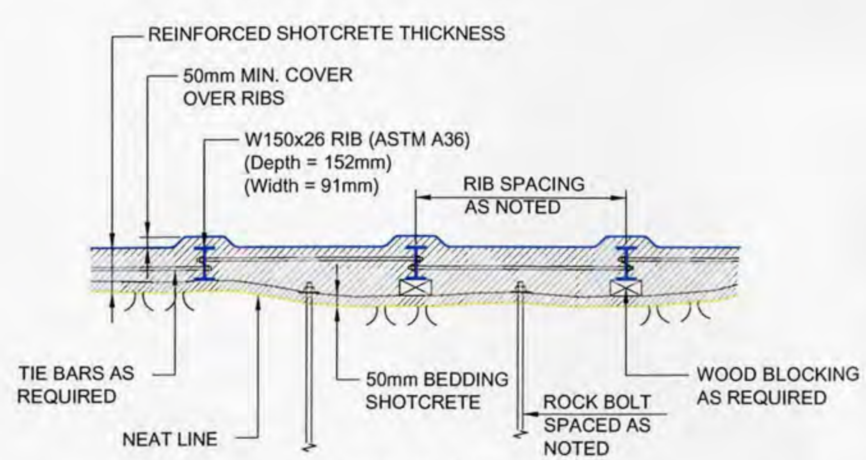
N.T.S.



FINISHED TUNNEL DIMENSIONS

0 2 m

GRAPHIC SCALE



SECTION A-A

N.T.S.

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

Division de Proyectos de Capacidad del Canal

ACP

CONTRACT NO. CC-3-536

RIO INDIO WATER SUPPLY PROJECT

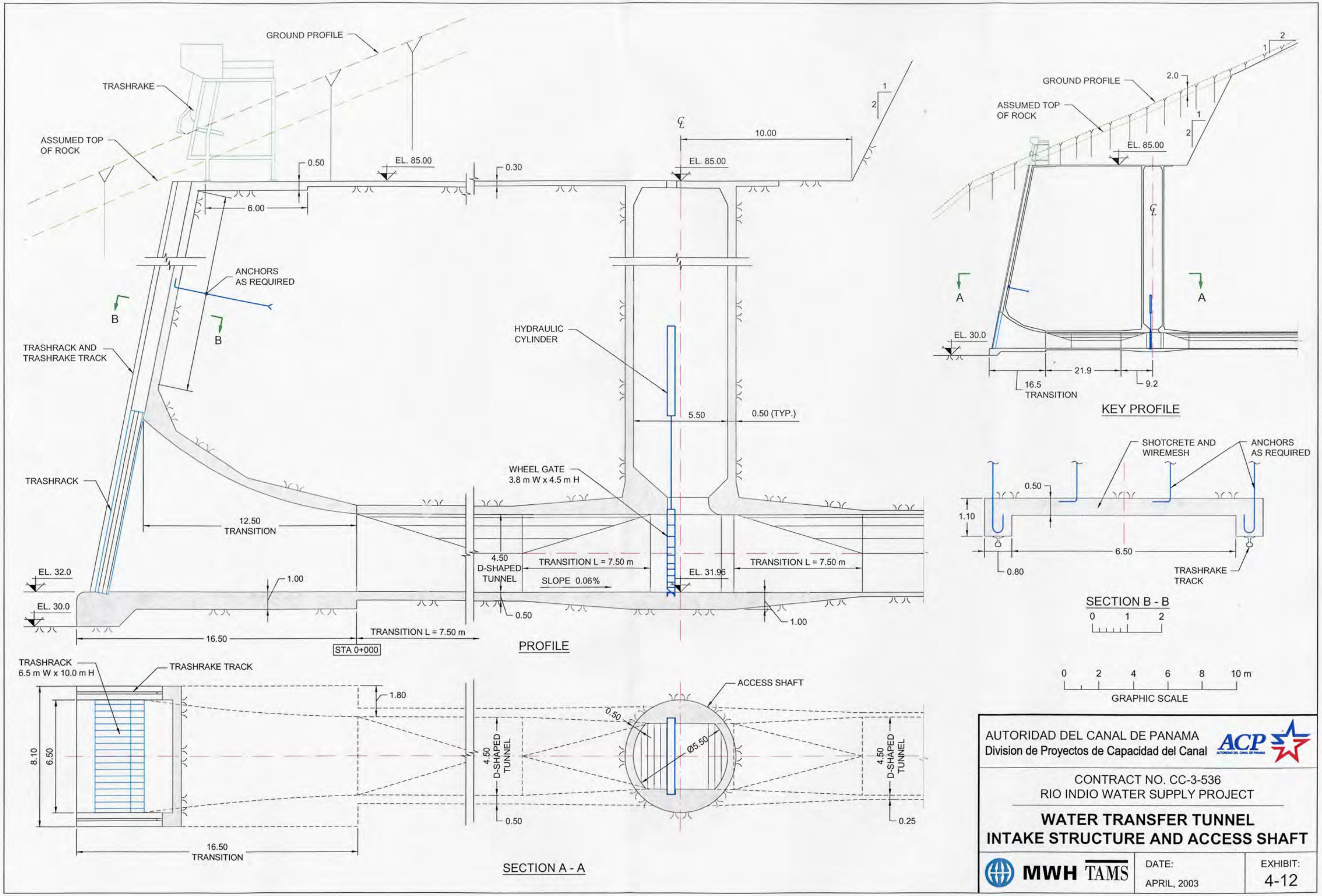
WATER TRANSFER TUNNEL

TYPICAL CROSS SECTIONS

MWH TAMS

DATE: APRIL, 2003

EXHIBIT: 4-11



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

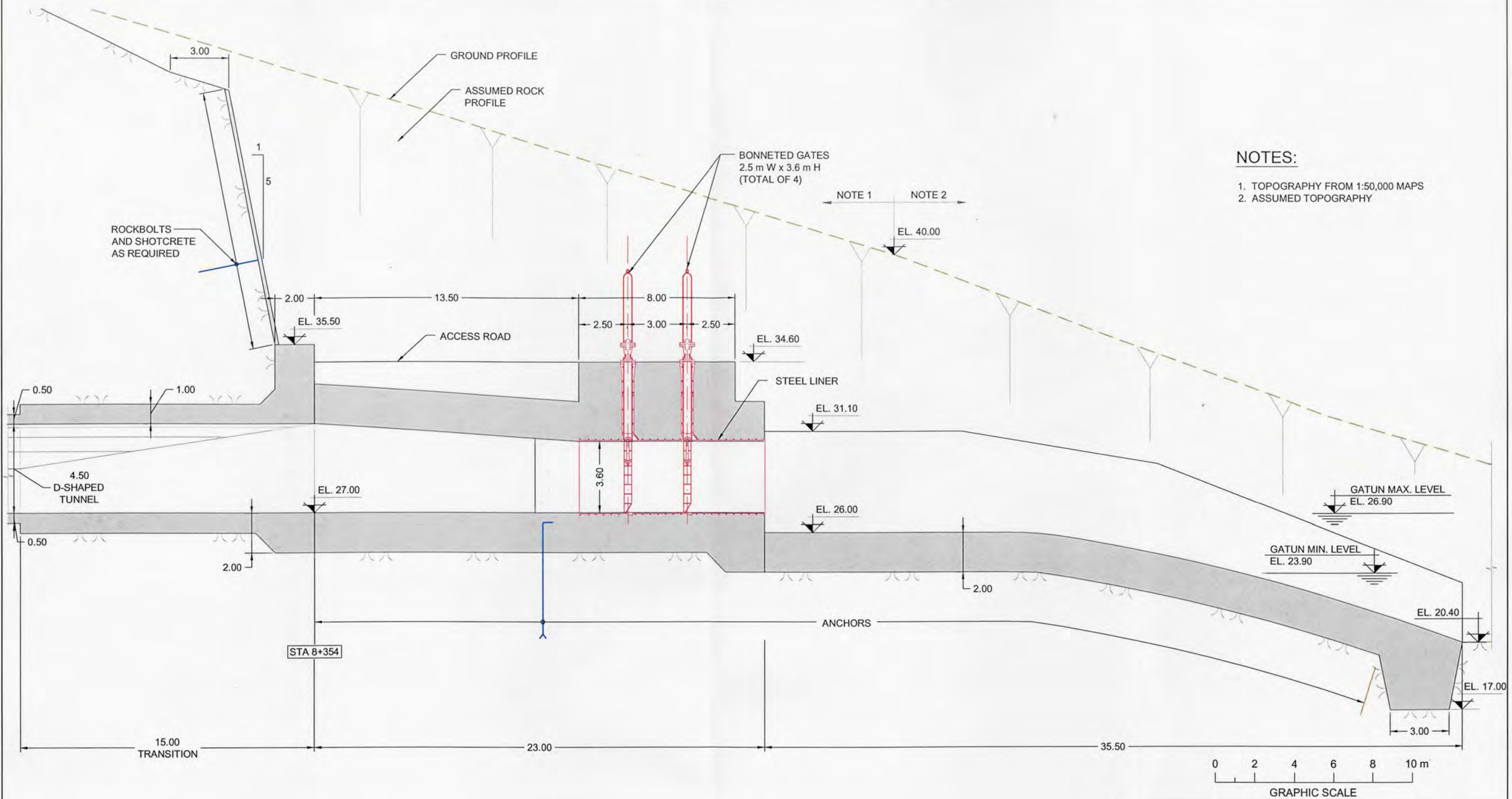
CONTRACT NO. CC-3-536
RIO INDIO WATER SUPPLY PROJECT

WATER TRANSFER TUNNEL
INTAKE STRUCTURE AND ACCESS SHAFT

MWH TAMS

DATE: APRIL, 2003

EXHIBIT: 4-12



NOTES:

1. TOPOGRAPHY FROM 1:50,000 MAPS
2. ASSUMED TOPOGRAPHY

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

ACP

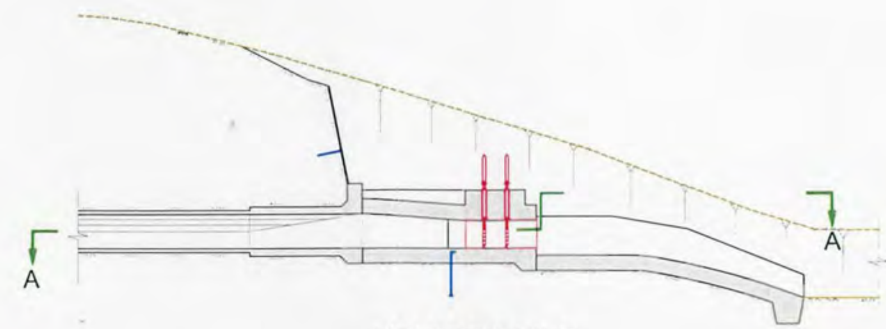
CONTRACT NO. CC-3-536
RIO INDIO WATER SUPPLY PROJECT

WATER TRANSFER TUNNEL
OUTLET STRUCTURE - PROFILE

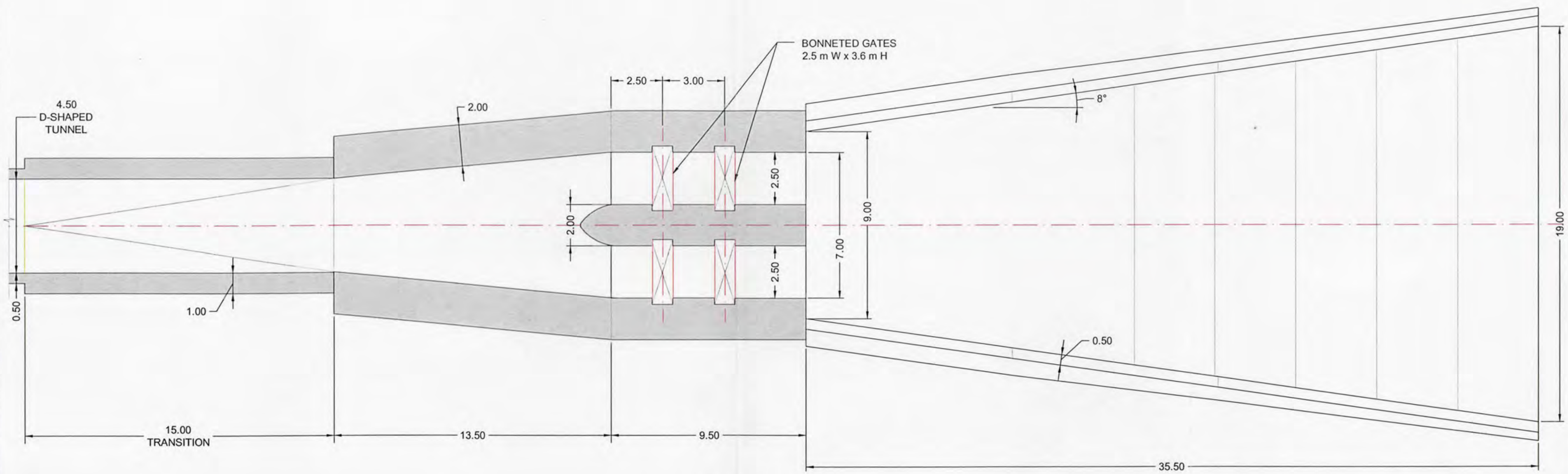
MWH TAMS

DATE: APRIL, 2003

EXHIBIT: 4-13



KEY PROFILE



SECTION A - A

0 2 4 6 8 10 m
GRAPHIC SCALE

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

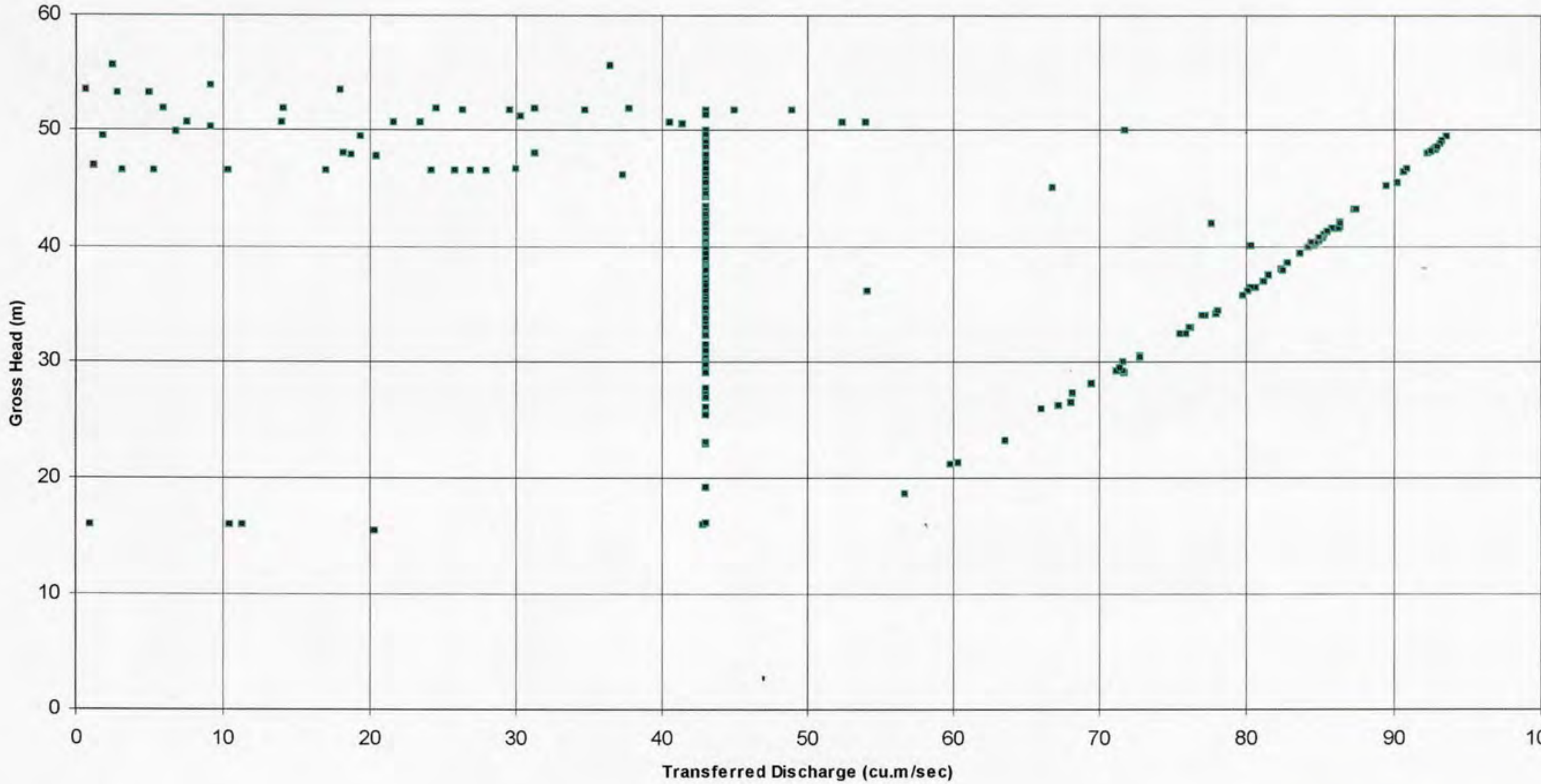
CONTRACT NO. CC-3-536
RIO INDIO WATER SUPPLY PROJECT

WATER TRANSFER TUNNEL
OUTLET STRUCTURE - SECTION

MWH TAMS

DATE:	EXHIBIT:
APRIL, 2003	4-14

Rio Indio Reservoir Operation



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

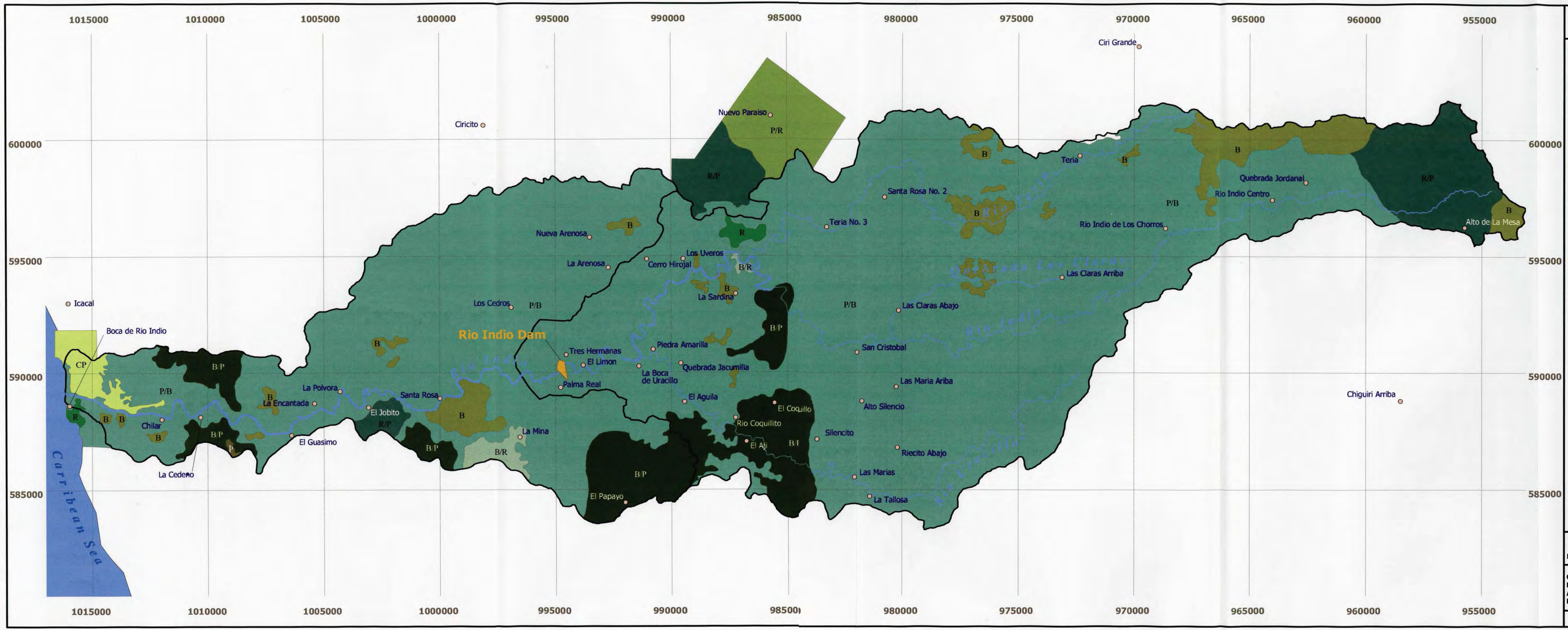
CONTRACT NO. CC-3-536
RÍO INDIO WATER SUPPLY PROJECT

Transferred Discharge

MWH TAMS

DATE: APRIL, 2003

EXHIBIT: 5-1



Land Use Map

Legend:

Symbol	Code	Description
	B	Forest
	B/P	Forest/Natural Pasture Lands
	B/R	Forest/Stubble
	P	Natural Pasture Lands
	P/B	Natural Pasture Lands/Forest
	P/R	Natural Pasture Lands/Stubble
	CP	Oil Palm
	R	Stubble
	R/P	Stubble/Natural Pasture Lands
		Watershed
		River
		Village/Hamlet

B - Forest
P - Pasture
R - Stubble
CP - Oil Palm Plantation

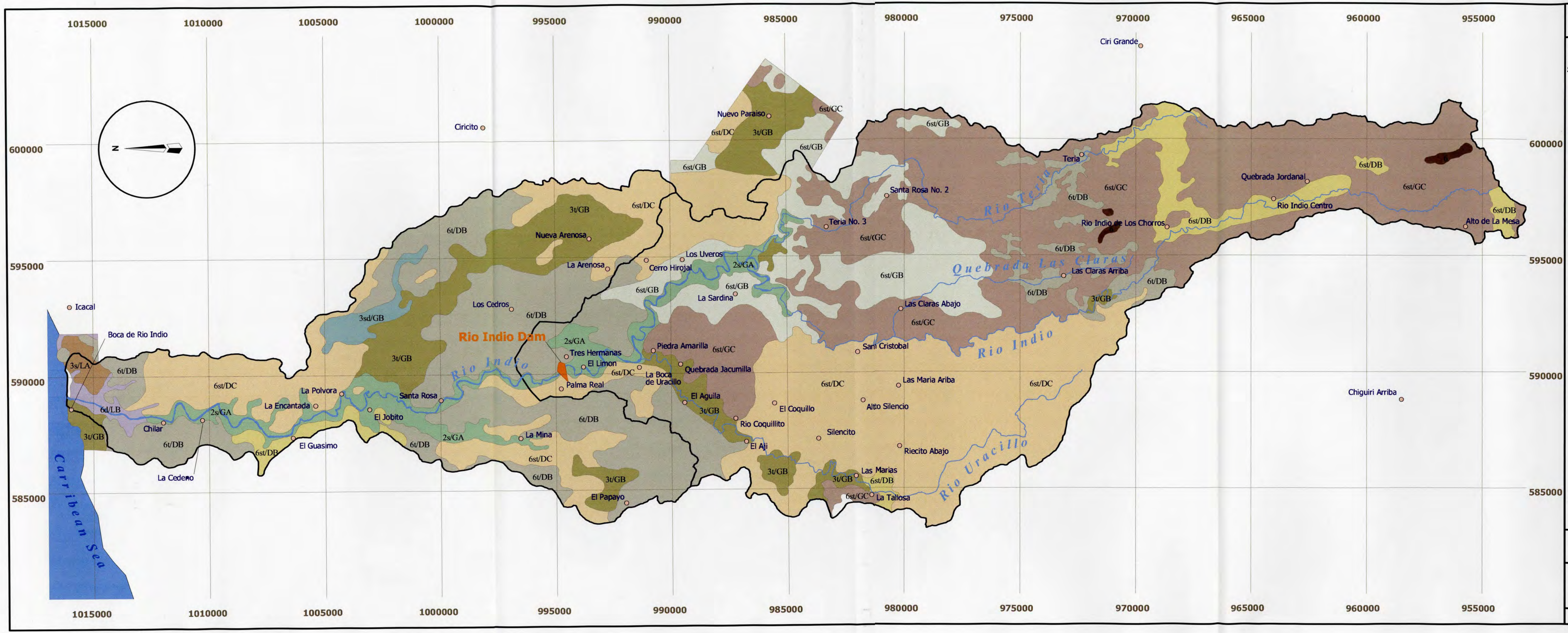
Notes: 1. The existing Agricultural Areas are located in the stubble areas and in the vicinity of the villages/hamlets.
2. A more detailed description is given in the report.
3. When two letters are present in a code, the first one indicates the predominant use.

3 0 5
Scale in Kilometers

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

CONTRACT NO. CC-5-536
Feasibility Design for the Rio Indio Water Supply Project
Agricultural and Irrigation Potential
Land Use Map

MWH TAMS | **April 2003** | **Exhibit 6-1**



Land Capability for Irrigation Map

Legend:

Symbol	Class	Description / Limiting Factors
	2s/GA	Texture - moderately fine
	3s/LA	Texture - very fine
	3sd/GB	Texture - very fine, Internal Drainage - high water table
	3t/GB	Slope
	6	Bedrock
	6d/LB	External Drainage - inundation, Internal Drainage - high water table
	6st/DB	Soil Depth - shallow, slope
	6st/DC	Soil Depth - shallow, Slope & Stoniness
	6st/GB	Texture - very fine, Slope & Stoniness
	6st/GC	Soil Depth - shallow, Texture - very fine, Slope & Stoniness
	6t/DB	Texture - very fine
		Watershed
		River
		Village/Hamlet

2,3,6 - Land Class
t,s,d - Limiting Factors (Topography; Soil; Drainage)
L,D,G - Land Use (Cultivated, Non-irrigated; Stubble and Forest; Permanent Pasture, Non-irrigated)
A,B,C - Potential Productivity (High; Moderate; Low)

Note: Further description of land classes is given in the report.

3 0 5
Scale in Kilometers

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

CONTRACT NO. CC-5-536
Feasibility Design for the Rio Indio Water Supply Project
Agricultural and Irrigation Potential
Land Capability for Irrigation Map

MWH | TAMS | **April 2003** | **Exhibit 6-2**


Potential Development Areas Location Map
Legend:
Symbol Description
Potential Development Area
Watershed
River
Existing Paved Road
Existing Gravel Road to be Rehabilitated
Dry Weather Road to be Upgraded
Proposed New Road
Village/Hamlet
3 0 5
Scale in Kilometers
AUTORIDAD DEL CANAL DE PANAMA
Division de Proyectos de Capacidad del Canal
CONTRACT NO. CC-5-536
Feasibility Design for the Rio Indio Water Supply Project
Agricultural and Irrigation Potential
Potential Development Areas Location Map
MWH
TAMS
April 2003
Exhibit 6-3
1015000
1010000
1005000
1000000
995000
990000
985000
980000
975000
970000
965000
960000
955000
600000
595000
590000
585000
Escobal & Gatun
Rte 3030
El Cigual
Ciri Grande
Area 5
Nuevo Paraiso on 3t/GB Land
Nueva Paraiso
Area 3B
La Encantada Larger Option 3B on 3sd/GB Plus 3t/GB Lands
Ciricito
Nueva Arenosa
Area 3A
La Encantada Smaller Option 3A on 3sd/GB Land
Icacal
Area 1
Mouth of Rio Indio Right Bank
Rio Indio Dam
Los Cedros
Los Uveros
Cerro Hirojal
La Sardina
Proposed Reservoir at el. 80
Teria No. 3
Santa Rosa No. 2
Teria
Rio Teria
Quebrada Jordanal
Rio Indio Centro
Rio Indio de Los Chorros
Alto de La Mesa
Quebrada Las Claras
Las Claras Arriba
Las Claras Abajo
Rio Indio
San Cristobal
Area 7
Rio Indio Abajo on 3t/GB Land
Tres Hermanas
El Limon
Piedra Amarilla
La Boca de Uracillo
Quebrada Jacumilla
Palma Real
El Aguila
Las Maria Ariba
Alto Silencio
El Coquillo
Rio Coquillito
Silencito
El Aji
Riecito Abajo
Chiguiri Arriba
Boca de Rio Indio
La Encantada
La Polvora
Santa Rosa
El Jobito
Chilar
La Cedero
El Guasimo
La Mina
El Papayo
Las Marias
La Tallosa
Rio Uracillo
Carribean Sea
Area 1
Mouth of Rio Indio Left Bank
Area 2
Rio Indio Valley on 2s/GA Lands Downstream of Proposed Dam
Area 4
El Papayo on 3t/GB Land
Area 8
Tierra Buena on 3t/GB Land
Area 6
Las Marias on 3t/GB Land

Table 1 - Cropping Pattern Diagram

Crop	Month											
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Rice DSR – TPR												
Rice TPR – TRP												
Beans												
Maize												
Plantain yr. 1												
Plantain yr. 2												
Cassava yr. 1												
Cassava yr. 2												
Vegetables (blend)												
Yams												
Pasture - Field												
SEEDBED Pasture												
NURSERY Organic Coffee;												
Pinus caribaea;												
Acacia mangium;												
Byrsonima cras.;												
Anacardium occ.;												

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

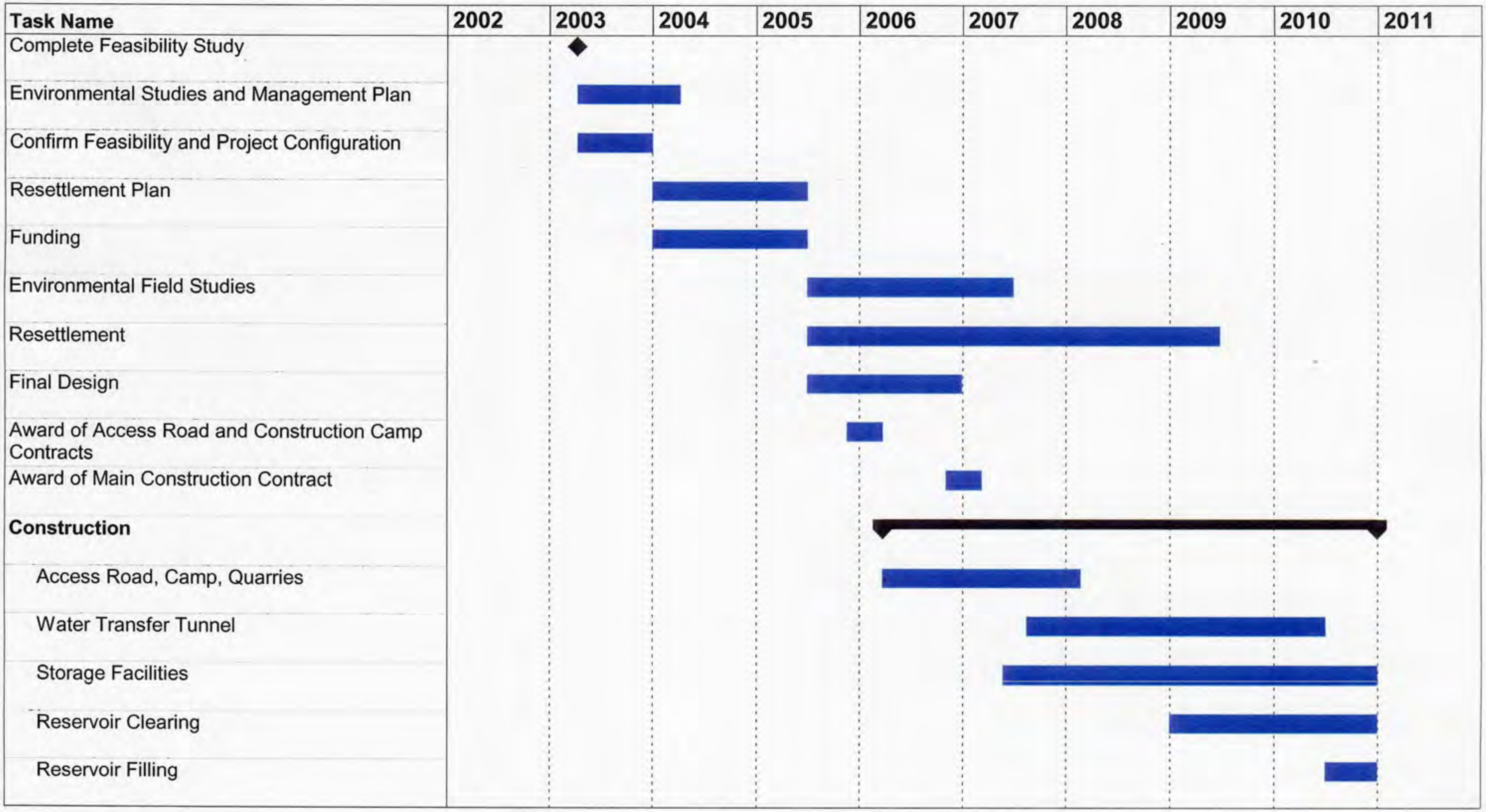
CONTRACT NO. CC-3-536
RÍO INDIO WATER SUPPLY PROJECT

Cropping Pattern Diagram

MWH TAMS

DATE: APRIL, 2003

EXHIBIT: 6-4



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

CONTRACT NO. CC-3-536
RÍO INDIO WATER SUPPLY PROJECT

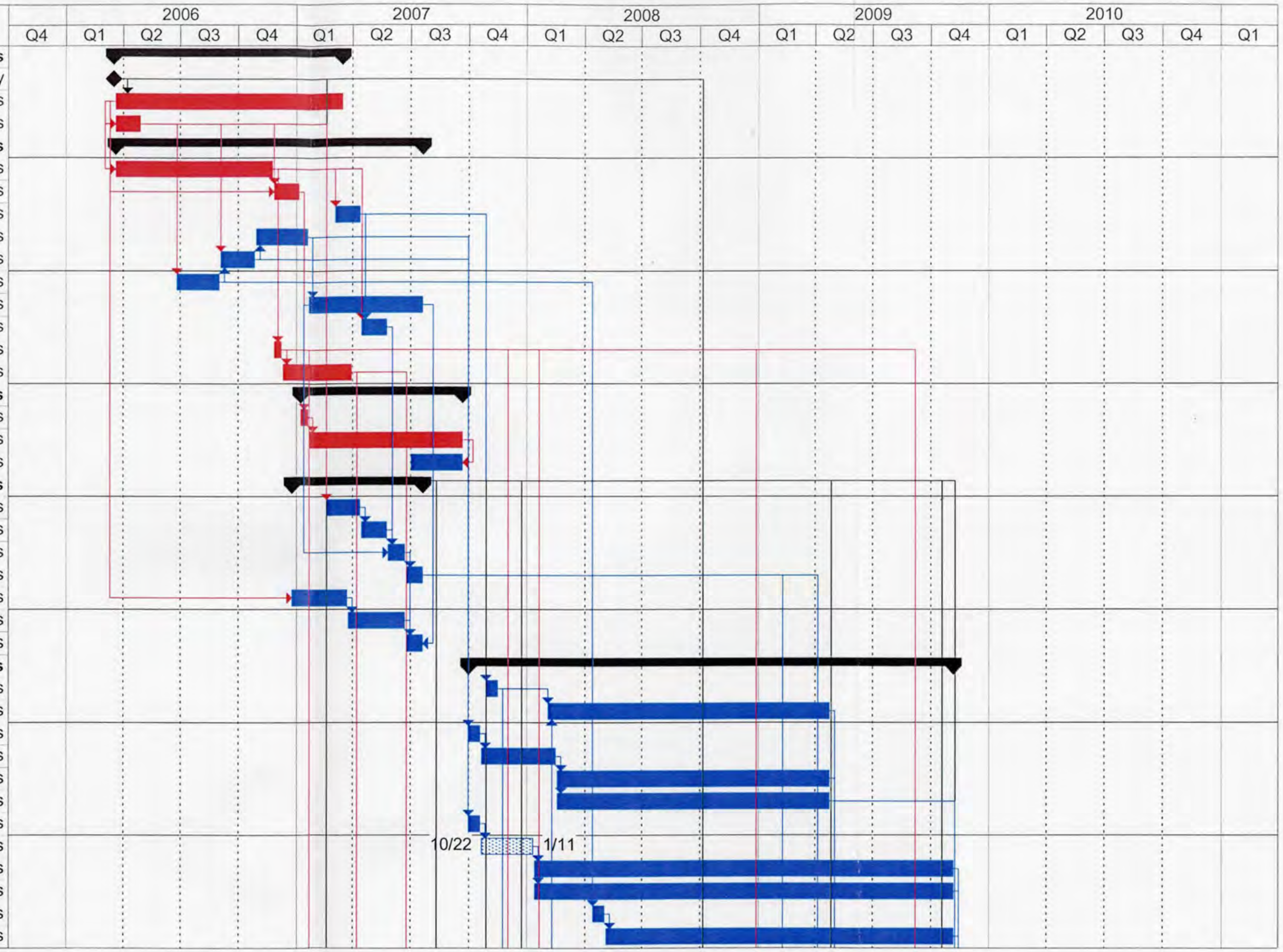
IMPLEMENTATION SCHEDULE

MWH TAMS

DATE: APRIL, 2003

EXHIBIT: 7-1

Task Name	Duration
Mobilization	**52.2 wks**
Notice to Proceed	1 day
Staffing and Personnel Mobilization	52 wks
Road Subcontractor Mobilization	6 wks
Access Roads	**70 wks**
Improve Access from Tres Hermanas to Junction	36 wks
Access to Construction Camp	6 wks
Access to Western Portal	6 wks
Access to Adit No.1	12 wks
Access to Adit No.2	8 wks
Access to Eastern Portal	10 wks
Access to Rock Quarry No.1 (Cerro La Jota)	26 wks
Access to Rock Quarry No.2 (Cerro Las Ollas)	6 wks
Access to dam site	2 wks
Bridge to Rio Indio Left Bank	16 wks
Construction Camp and Offices	**37 wks**
Clearing, Surveying and Siting	2 wks
House Construction	35 wks
Camp Infrastructures and Utilities	12 wks
Establish Quarries	**30 wks**
Geotechnical Investigation	8 wks
Surveying and Mapping	6 wks
Clearing & Grubbing	4 wks
Overburden Excavation	4 wks
Design and Purchase Crushing Plant	13 wks
Shipping of Crushing Plant	13 wks
Crushing Plant Installation	4 wks
Transfer Tunnel Excavation	**110 wks**
Western Portal Excavation	3 wks
Excavation from Western Portal	64 wks
Adit No.1 Portal	3 wks
Adit No.1 Excavation	17 wks
Excavation West from Adit No.1	62 wks
Excavation East From Adit No.1	62 wks
Adit No.2 Portal	3 wks
Adit No.2 Excavation	12 wks
Excavation West from Adit No.2	95 wks
Excavation East from Adit No.2	95 wks
Eastern Portal	3 wks
Excavation from Eastern Portal	79 wks



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

CONTRACT NO. CC-3-536
RIO INDIO WATER SUPPLY PROJECT

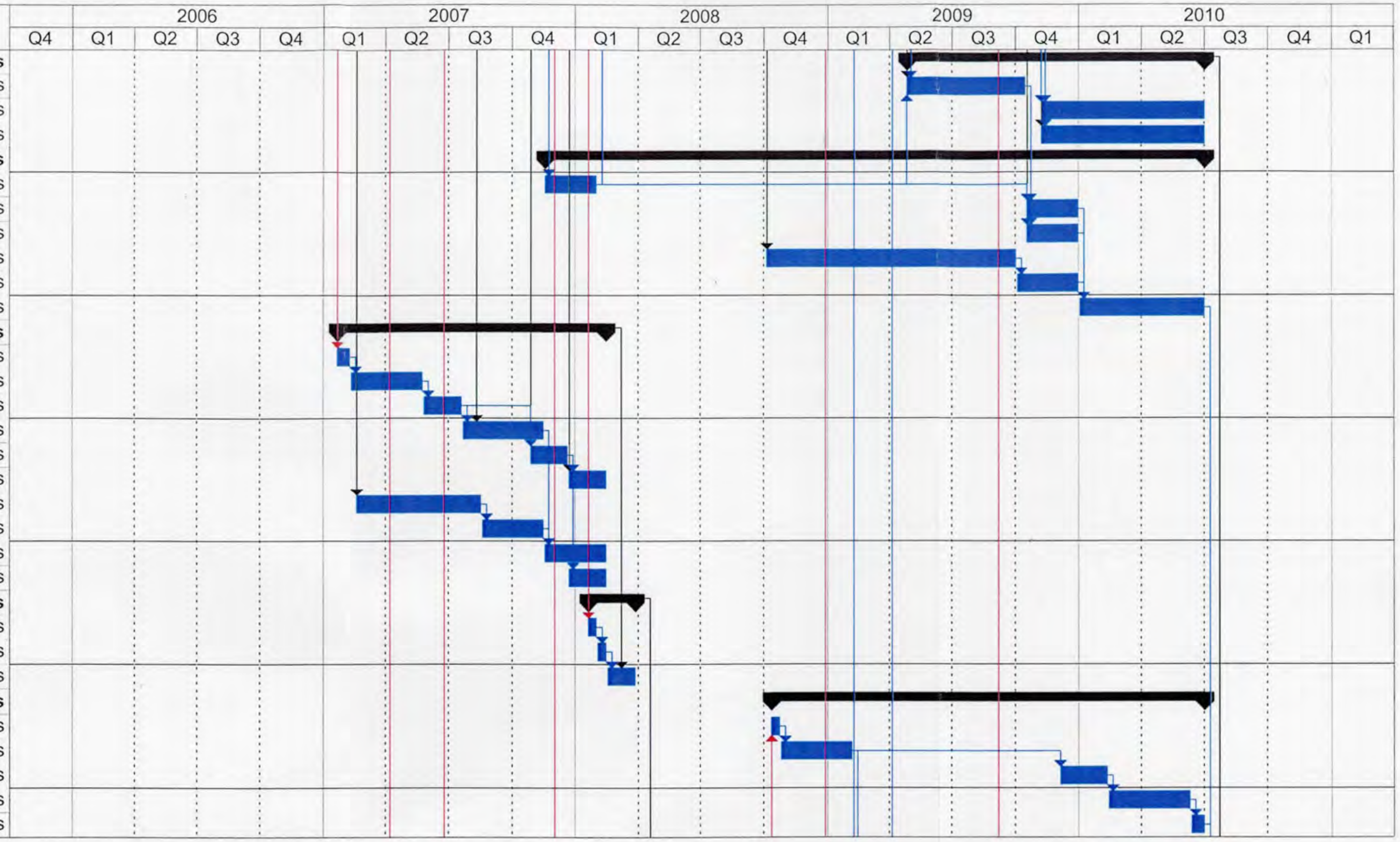
CONSTRUCTION SCHEDULE
SHEET 1 OF 3

MWH TAMS

DATE: APRIL, 2003

EXHIBIT: 7-2

Task Name	Duration
Transfer Tunnel Lining	**62 wks**
Lining between Western Portal and Adit No.1	25 wks
Lining between Adit No.1 and Adit No.2	34 wks
Lining between Eastern Portal and Adit No.2	34 wks
Transfer Tunnel Intake	**137 wks**
Gate Shaft Excavation	11 wks
Gate Shaft Concreting	11 wks
Intake Concreting	11 wks
Intake Equipment Design and Fabrication	52 wks
Intake Equipment Shipping	13 wks
Intake Equipment Installation	26 wks
Diversion Tunnel and Low Level Outlet	**56 wks**
Portal Excavation	3 wks
Tunnel Excavation	15 wks
Gate and Access Shaft Excavation	8 wks
Shaft Lining	17 wks
Tunnel Lining	8 wks
Intake Concreting	8 wks
Gate Design and Fabrication	26 wks
Gate Shipping	13 wks
Gate Installation	13 wks
Outlet Work	8 wks
Cofferdams	**10 wks**
Site Preparation	2 wks
Overburden Excavation	2 wks
Fill Material	6 wks
Spillway	**90 wks**
Overburden Excavation	2 wks
Rock Excavation	15 wks
Headworks and Bridge	10 wks
Chute and Flip Bucket	17 wks
Tailrace Channel	3 wks



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

CONTRACT NO. CC-3-536
RIO INDIO WATER SUPPLY PROJECT

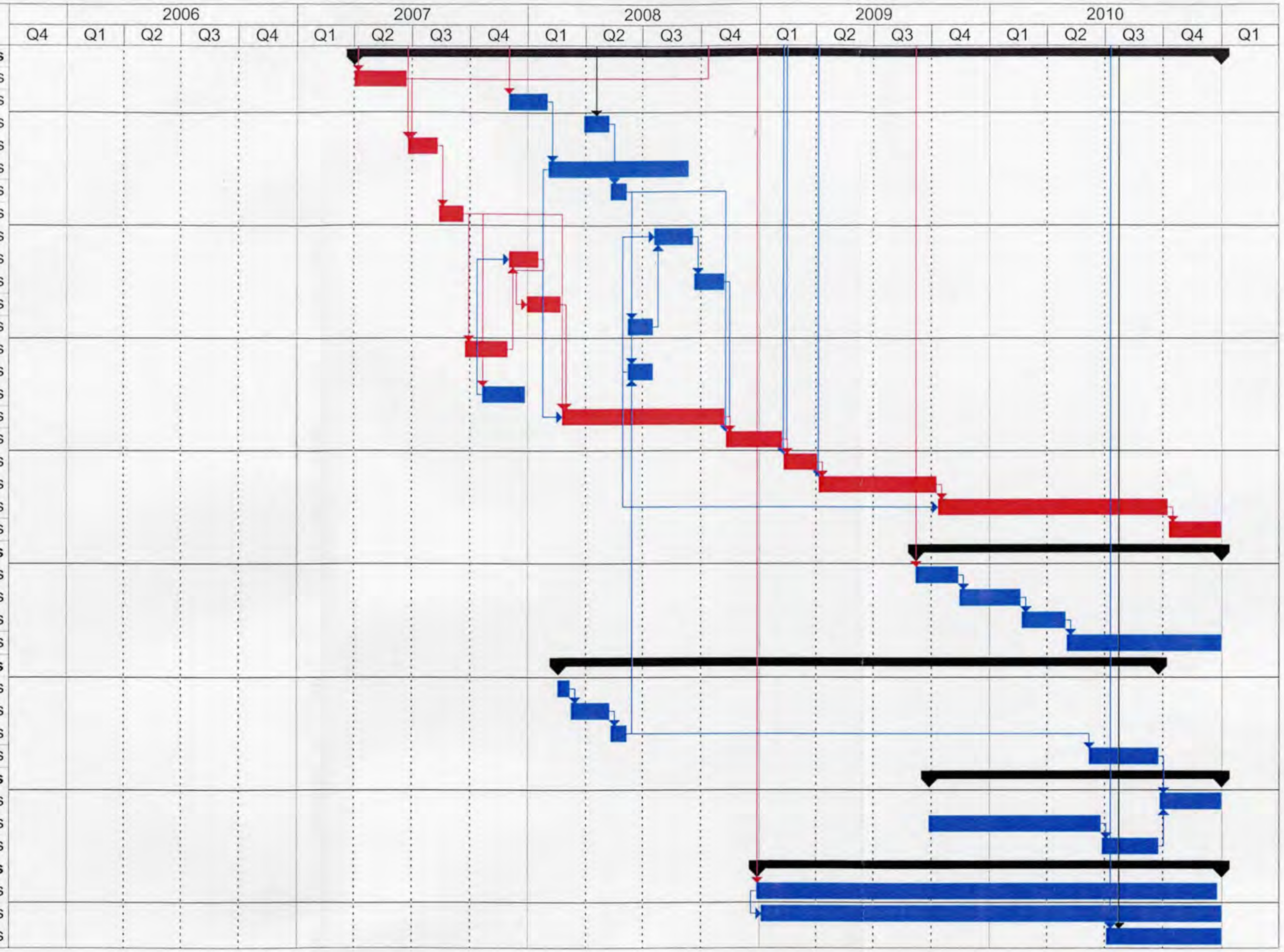
CONSTRUCTION SCHEDULE
SHEET 2 OF 3

MWH TAMS

DATE: APRIL, 2003

EXHIBIT: 7-2

Task Name	Duration
Rio Indio Dam	**196 wks**
Site Preparation	12 wks
Overburden Excavation - Abutment	9 wks
Overburden Excavation - River Section	6 wks
Overburden Excavation - Left Bank	7 wks
Rock Excavation - Abutment	32 wks
Rock Excavation - River Section	4 wks
Rock Excavation - Left Bank	6 wks
Grouting Curtain - River Section	9 wks
Grouting Curtain - Left Bank	7 wks
Consolidation Grouting - River Section	7 wks
Consolidation Grouting - Left Bank	8 wks
Dental Concrete - River Section	6 wks
Dental Concrete - Left Bank	10 wks
Plinth - River Section	6 wks
Plinth - Left Bank	10 wks
Rockfill Placement Left Bank	37 wks
Rockfill Placement River Section from Excav	13 wks
Rockfill Placement from Quarrie No.1	8 wks
Rockfill Placement from Quarrie No.2	27 wks
Concrete Face	52 wks
Parapets, Crest Road	12 wks
Saddle Dams	**69 wks**
Site Preparation	10 wks
Overburden Excavation, Foundation Preparation	14 wks
Cut-off Curtain	10 wks
Embankment Fill (incl. Filter, Riprap and Road)	35 wks
Rio Indio Minimum Release/Hydropower Facilities	**136 wks**
Trench Excavation	3 wks
Conduit Installation	9 wks
Conduit Concrete	4 wks
Powerhouse	16 wks
Rio Indio Minimum Release/Hydropower	**66 wks**
Equipment Installation	14 wks
Equipment Design and Fabrication	39 wks
Equipment Shipping	13 wks
Reservoir Area	**105 wks**
Reservoir Clearing	104 wks
Reservoir Mapping	104 wks
Reservoir Filling	26 wks



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

ACP

CONTRACT NO. CC-3-536
RIO INDIO WATER SUPPLY PROJECT

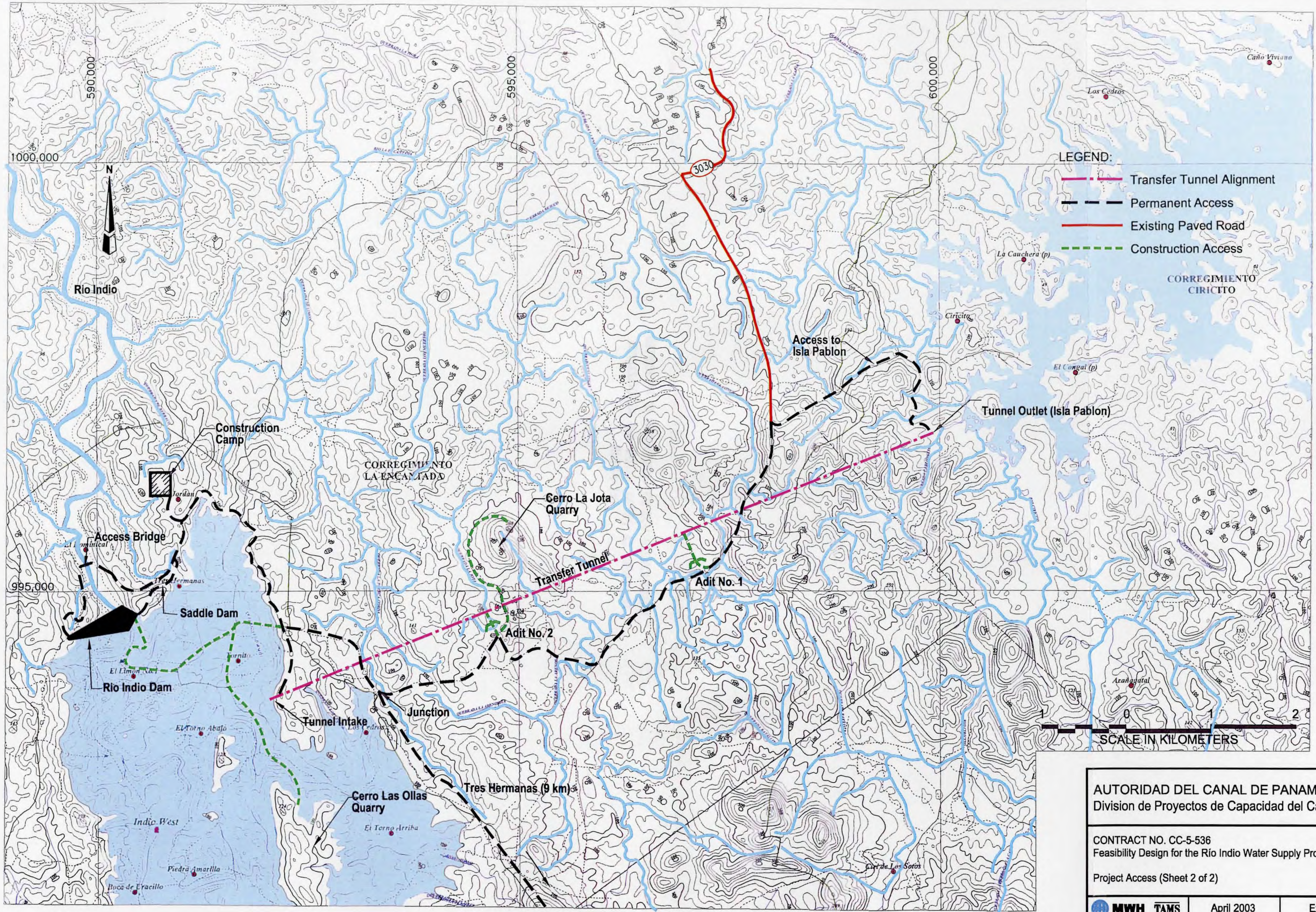
CONSTRUCTION SCHEDULE
SHEET 3 OF 3

MWH TAMS

DATE: APRIL, 2003

EXHIBIT: 7-2


LEGEND:
Paved Road
All Weather Gravel Road
Dry Weather Road
Cristobal
Colón
Gatun Locks
Lago Gatún
Supply Project
See Sheet 2 of 2
Isla Pablon
Rio Indio Dam Site
El Limon
Tres Hermanas
El Cigual
La Chorrera
Balboa
Panamá
580,000
600,000
620,000
640,000
660,000
1020,000
1000,000
980,000
0 5 10
SCALE IN KILOMETERS
AUTORIDAD DEL CANAL DE PANAMA
Division de Proyectos de Capacidad del Canal
CONTRACT NO. CC-5-536
Feasibility Design for the Río Indio Water Supply Project
Project Access (Sheet 1 of 2)
MWH TAMS
April 2003
Exhibit 7-3



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

CONTRACT NO. CC-5-536
Feasibility Design for the Río Indio Water Supply Project

Project Access (Sheet 2 of 2)

MWH TAMS	April 2003	Exhibit 7-3