Feasibility design for the Rio Indio Water Supply Project

Diseño de factibilidad para el Proyecto de Suministro de Agua de Río Indio

Montgomery Watson Harza

Abril del 2003

Contrato No. 30817

Resumen Ejecutivo

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

Executive Summary

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.
Tecnilab, S.A.

April 2003

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~~40~~ 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.

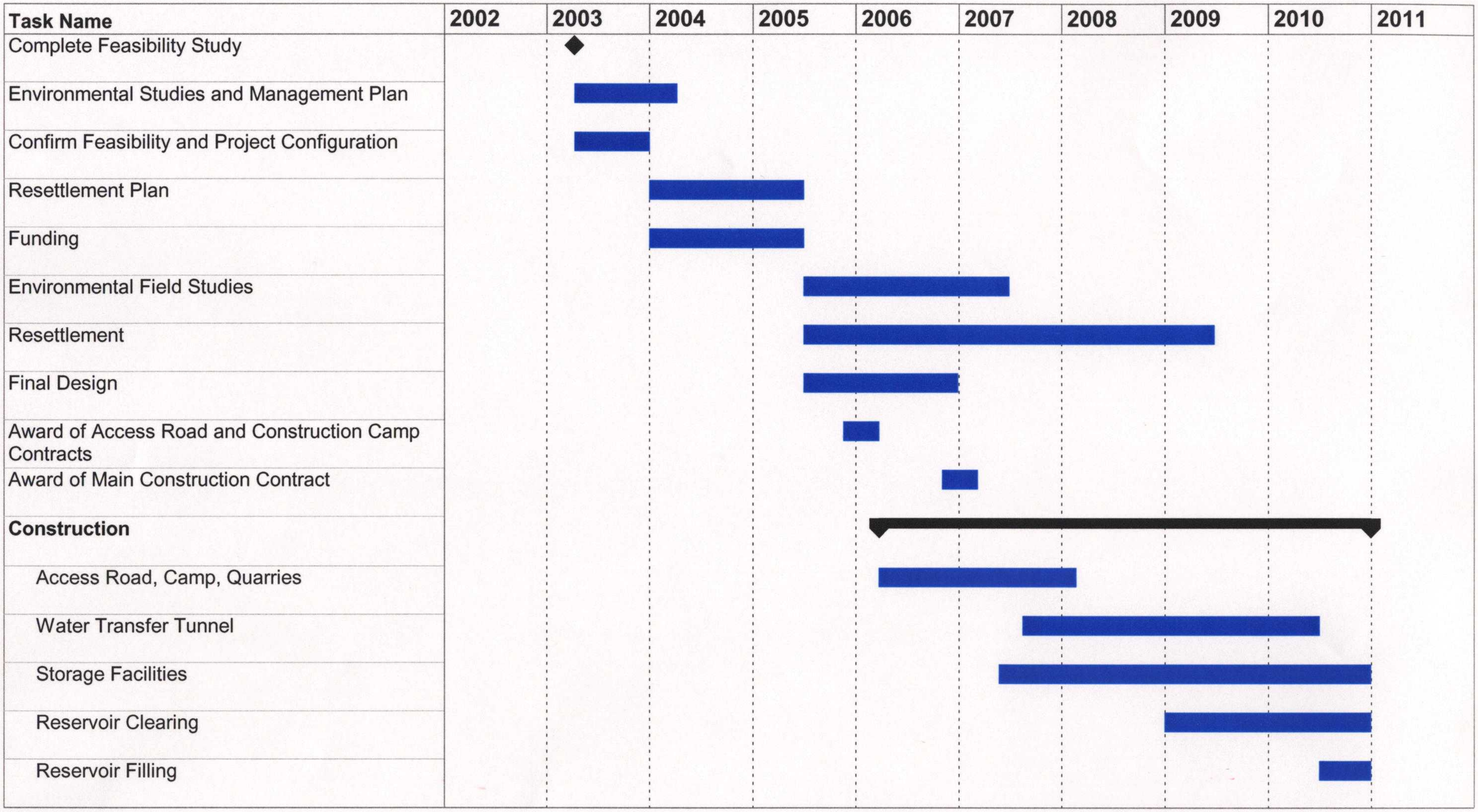
As a result of these conclusions, it is recommended that:

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



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

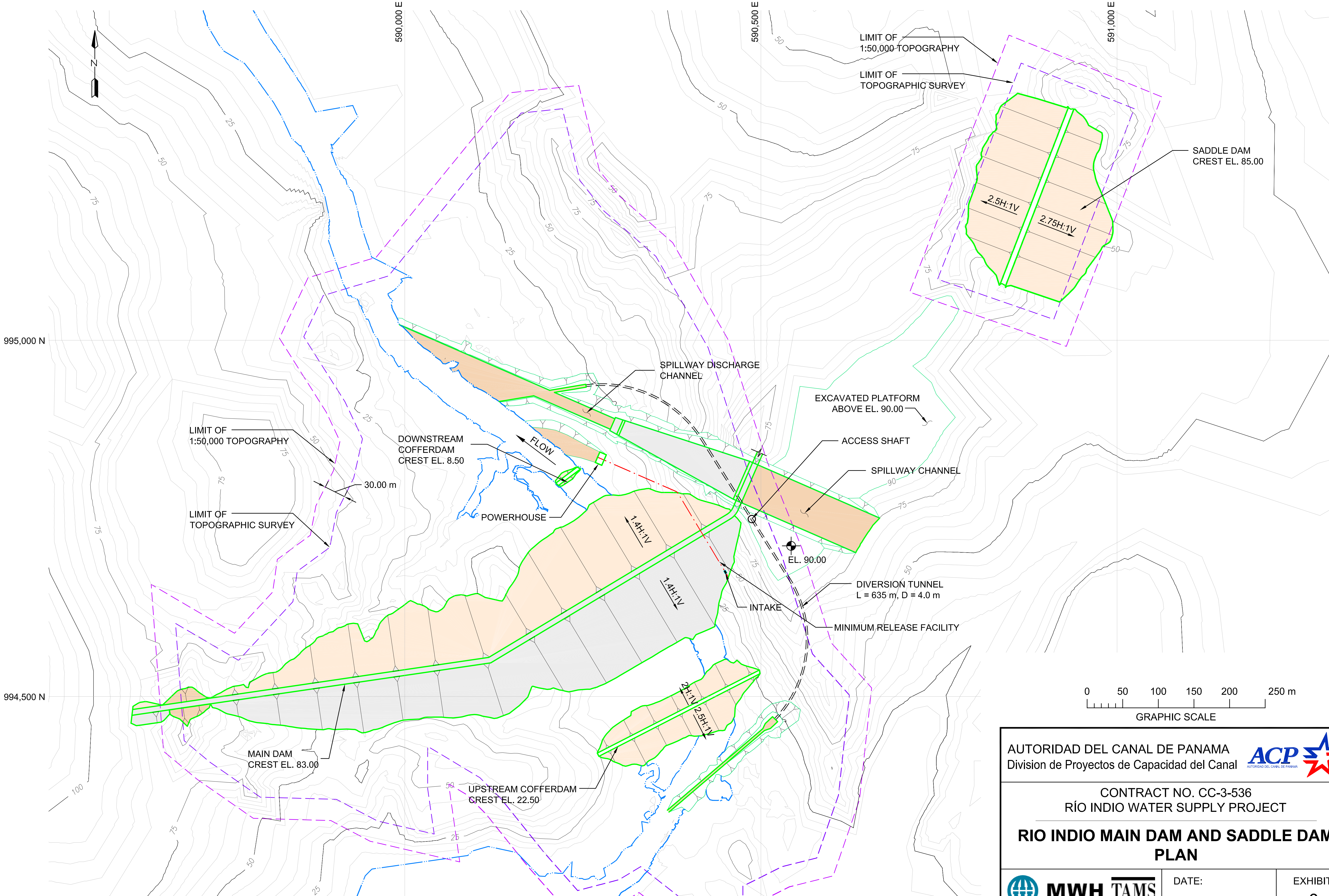
CONTRACT NO. CC-3-536
RÍO INDIO WATER SUPPLY PROJECT

IMPLEMENTATION SCHEDULE

MWH TAMS

DATE: APRIL, 2003

EXHIBIT: 4



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

ACP

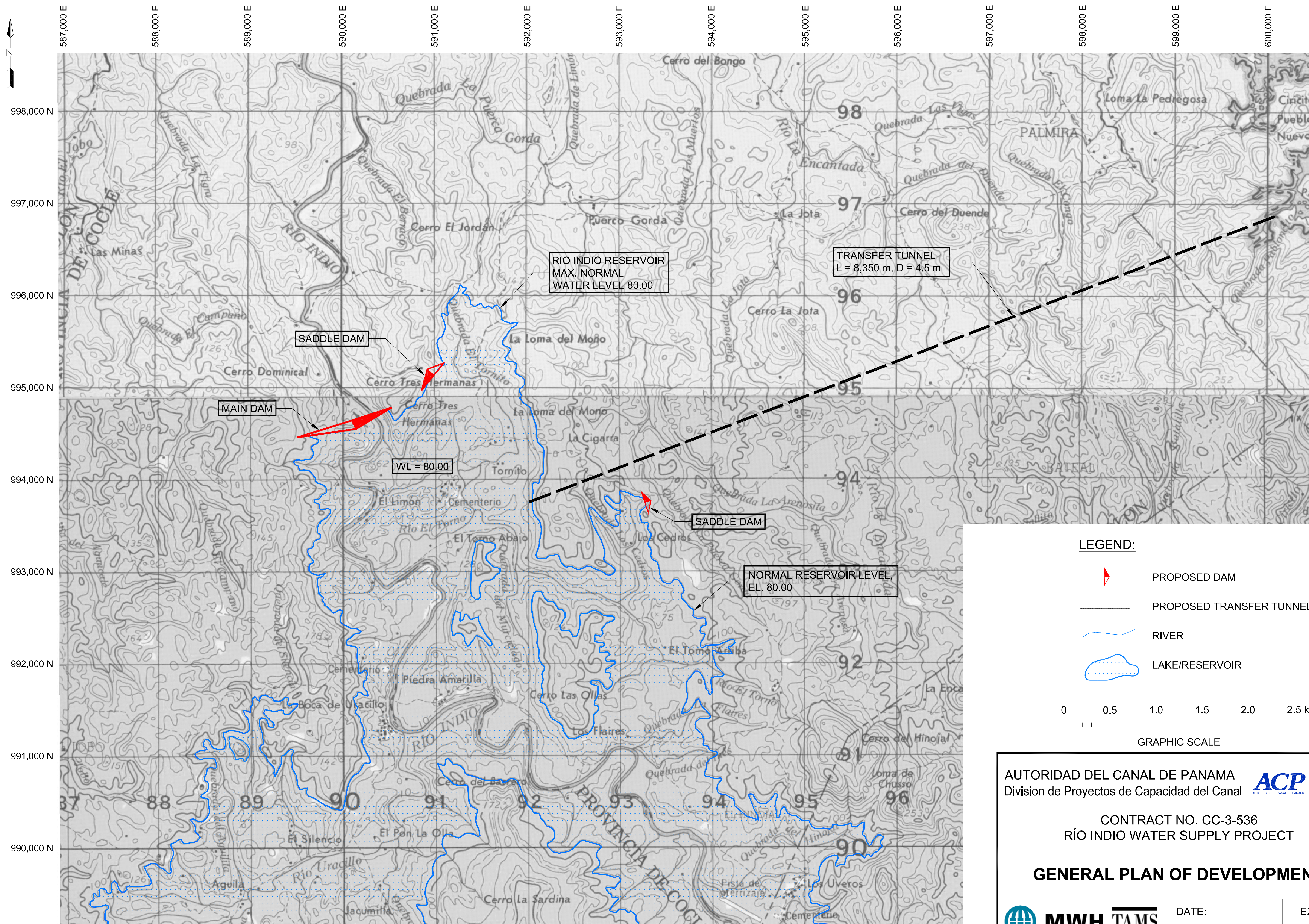
CONTRACT NO. CC-3-536
RÍO INDIO WATER SUPPLY PROJECT

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

ACP

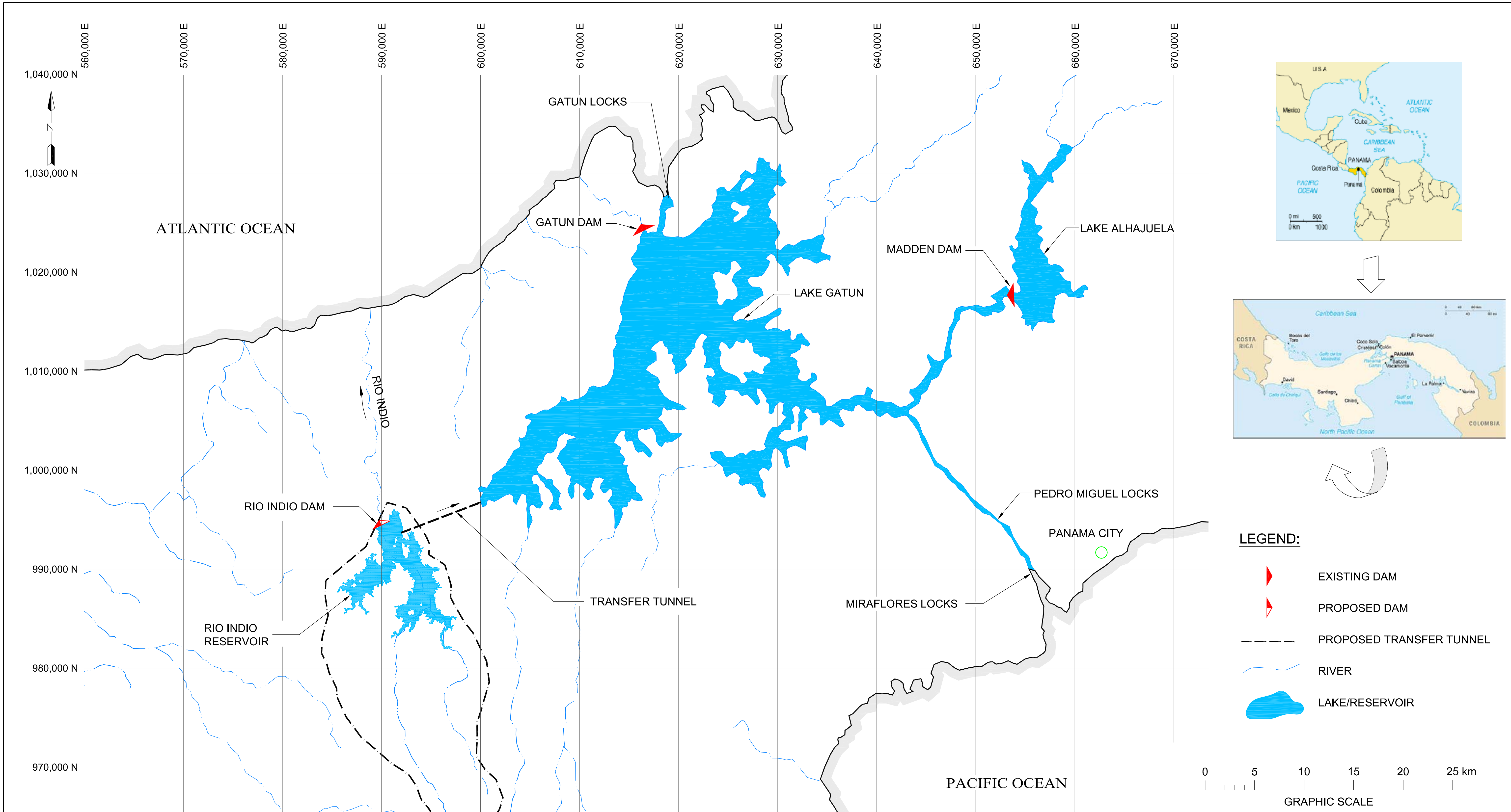
CONTRACT NO. CC-3-536
RÍO INDIO WATER SUPPLY PROJECT

GENERAL PLAN OF DEVELOPMENT

MWH TAMS

DATE: APRIL, 2003

EXHIBIT: 2



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

ACP

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

LOCATION MAP

MWH TAMS

DATE:	EXHIBIT:
APRIL, 2003	1