Rio Toabre Water Transfer Project
Feasibility Study

Proyecto de Transferencia de Aguas del Río Toabré
Estudio de Factibilidad

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Resumen Ejecutivo

EXECUTIVE SUMMARY

1. SYNOPSIS OF PROJECT

The Feasibility Study of Rio Toabre Water Transfer Project was initially launched to determine the technical and economic development of the Project as part of a general Panama Canal Infrastructures Development. The present lack of possibilities to assess the benefits of such project in the general context of upgrading current Canal infrastructures turned this primary aim into the establishment of technical (yield) - economical (cost) characteristics of the Project at 3 different Normal Water Level : 90, 95 and 100 masl.

The Feasibility Report focuses on the reservoir elevation alternative of NWL 95 masl, but also presents the specific characteristics of the two other alternatives for reservoir elevation. A data sheet is presented at the end of the present Volume I.

The studies define the development of the Rio Toabre Project by means of the following works:

- a large Roller-Compacted Concrete (RCC) dam. For the envisaged reservoir levels the dam heights and volumes varies respectively from 80 to 90 m and from 1.8 MCMto 2.4 MCM.
- a 16 km long, 5 m diameter transfer tunnel to link the Toabre reservoir to the Indio reservoir, this last Project being implemented prior to the Toabre Project.

The yield (at 99.6% reliability) and costs of the Rio Toabre Water Transfer Project are as follows:

TOABRE NWL	**90**	**95**	**100**
Yield of Global Canal System : Gatun deepened, Madden, Indio and Toabre Reservoirs (MCM/y)	**5 685**	**5 820**	**5 970**
Increase rate from Current Yield	*1.920*	*1.975*	*1.997*
Yield attributed to Toabre Project (MCM/y)	**1 043**	**1 204**	**1 269**
equivalent additional lockages / day	*13.73*	*15.86*	*16.71*
Total Rio Toabre Project Cost (MUSD)	**362**	**391**	**419**
Cost / Yield Index (USD / m^3)	*0.347*	*0.325*	*0.330*

2. GENERAL CONTEXT AND OBJECTIVE OF THE STUDY

The Panama Canal Authority (ACP) is undertaking a Canal Capacity Study to evaluate the feasibility of upgrading current Canal infrastructures. A Reconnaissance Study of potential projects to augment the supply of water to the Panama Canal was accomplished in 1999 by the US Army Corps of Engineers.

Among the identified projects, the **Rio Toabre Water Transfer Project** included a reservoir dam on the Rio Toabre and a reservoir dam on the nearby Rio Cano Sucio, connected by an open channel. The development of this project required the parallel development of the Rio Indio Project in which the water from the Toabre/Cano Sucio reservoir would be transferred by means of a tunnel connecting the two reservoirs. The Rio Toabre project would then function in conjunction with the Rio Indio project to transfer water into Gatun Lake via the transfer tunnel linking these two lakes. The Rio Indio project has been studied in parallel at feasibility stage by the US firm MWH in 2002-2003.

Under a contract signed February 2002 supported by a grant from French Government, the Panama Canal Authority (ACP), assigned the firm Coyne et Bellier to carry out the engineering feasibility studies for the Rio Toabre water project, but considering a direct transfer from the Toabre Lake to the Indio Lake through an approximately 16 km long inter-basin transfer tunnel connecting the two reservoirs.

As the benefits for a standard feasibility economical study could not be assessed at this time, the Scope of the Services of the initial Feasibility Study have been modified during the study. The final Feasibility Study comprises four main tasks:

- Basic Data assessment,
- Site Identification and Selection Study (task added during the course of the study),
- Water Management & Power Study, performed with the HEC-5 model from ACP,
- Technical Design Studies to define the optimum design of the structures at feasibility stage and the corresponding construction planning and cost estimate for three different Normal Water Level.

3. NATURAL CHARACTERISTICS

3.1. Location - Topography

A location map is shown on **Figure 1**. The selected dam site is located in the vicinity of the village of San Vicente, about 100 km West, as the crow flies, of Panama City. It is on the downstream part of the Toabre river, 16 km upstream of the confluence with the Cocle del Norte river which empties 14 km farther in the Caribbean Sea.

The major available topographical documents included: 1:50 000 scale maps with 20 m contour lines (by IGN 1965-1999), map of the Toabre dam site from a ground survey done in 2002 with 1 m contour lines, local maps from recent photorestitution works (February 2003) and 1/20 000 aerial photo (2000).

These available documents show several local topographical limits of the Toabre reservoir between El. 100 masl and El. 108 masl.

A Height / Surface / Volume (H/S/V) relationship for the Toabre reservoir has been established on the basis of measurement of surface areas delimited with the contours of the available 1/50 000 topographic maps.

Between El. 90 masl and El. 100 masl, the reservoir capacity increase from 740 MCM to 1 130 MCM with respective surfaces from 32 km^2 to 46 km^2.

3.2. Geology & Geotechnics

As the conflictive local social conditions reported by ACP were not appropriate for the implementation of a full, standard feasibility reconnaissance program including boreholes, pits, trenches, field tests and adits, all geologic interpretation is based on a minimum programme of preliminary investigations, restricted to field visits and mapping, geophysical survey, auger holes excavation, soil sampling and laboratory tests.

The minimum borehole program recommended by Coyne et Bellier, as the only consistent mean to validate the seismic refraction campaign results and to supply additional information of the subsurface foundation of the dam, could not finally be executed.

i) Regional geological features

The Tertiary Cañazas Formation is inferred to prevail in the reservoir area, consisting of andesitic and basaltic lava flows, volcanic breccia and tuffs. This volcanic formation is underlain by the Oligocene sedimentary rocks of the Caimito Formation, a bedded marine sequence composed of tuffaceous sandstone, tuffaceous siltstone and limestone. These rocks are generally hard and less altered than the volcanic tuffs but some siltstone horizons appear to be strongly weakened by weathering.

ii) Local geological features

The geomorphological conditions of the dam site are rather irregular, with apparently thick soil overburden composed of silty-clayey latosoil widely extended over the whole project area with dense vegetation and very few rock exposures along some sections of the river course and deep gullies.

A sedimentary sequence was identified on both banks, comprising sub-horizontal, decimetric to metric layers of dark-gray marls, marly limestones, siltstones, coarse-grained sandstones and conglomerates.

The main joint systems at the dam site are bedding, N 90-100°E and N 130-140°. Subordinary, a sub-meridian joint set was mapped in the Right Bank.

iii) Engineering geology

Owing to the relatively low amount and quality of the data currently available (cf. reliability of seismic refraction campaign data and the lack of boreholes), it must be stated that the following assumptions need to be carefully reconsidered and confirmed by further reconnaissance surveys.

• *Dam Foundation*

Basically, the depth models derived from the seismic refraction data distinguished 2 main layers:

- a superficial horizon corresponding to the latosoils (altered rock) or to colluvial and local alluvial, unconsolidated deposits, about 5-10 m thick, up to 15-20 m thick (top Right Bank), characterised by velocities of about 350 – 550 m/s in both banks,
- a second layer, probably corresponding to the altered and fractured bedrock, which according to the interpretation of the seismic data supplied by Bachy-Fundaciones, would have a thickness in excess of 25 m and is characterised by velocities ranging between 1 900 and 3 000 m/s (some values of 1 500 m/s locally).

The interpretative engineering cross sections shows two main foundation levels:

- a foundation level for rockfill embankment, basically designed at the contact between soil (300 to 500 m/s layer) and bedrock (> 1 500-1 900 m/s layer). Depth to this foundation level increases from the river and stream channels, where only the alluvial deposits (2-5 m max) would have to be removed, to a maximum 10 m in the left bank and about 15 m in the top of the right bank.
- a foundation level for the concrete structures (RCC or CFRD plinth), assumed 5 m below the rockfill foundation level. The average depth to found the concrete structures would be 10-15 m to about 20 m maximum at the top of the right bank.

The possible presence of clayey or silty layers/interbeds of poor geomechanical condition, which could lower the overall strength of the foundation, can not be ruled out at this stage, while the structural configuration, featuring sub-horizontal, closely spaced bedding, is relatively unfavourable.

- ***Transfer Tunnel***

The major length of the transfer tunnel is inferred to be excavated in the sedimentary sequence of the Caimito Formation. The main upper member of this formation, which consists of tuff, agglomeratic tuff, tuffaceous siltstone, and discontinuous sandy tuffaceous limestone, should be the dominant moderately hard rock foundation of the transfer tunnel. The inlet and the first part of the tunnel will be excavated in the Cañazas volcanic tuff.

The sub-horizontal bedding observed in the Rio Toabre riverbed, if confirmed, would obviously be an unfavourable configuration, taking into account that bedding represents the main joint set affecting the rock mass.

Further development of this project requires general mapping to identify the lithological and structural features regarding the tunnel alignment. It shall also require core drilling to determine the conditions of underground excavation, both along the alignment and in the proposed tunnel inlet and outlet areas.

- ***Construction Materials***

All aggregates for both RCC and conventional vibrated concrete (CVC) should be manufactured from quarried sources. Several quarry areas were identified within 6 km of the dam site. Preliminary site investigations indicate that large volumes (5 millions of m^3) of andesite, featuring sound massive texture considered to be an appropriate source of concrete aggregate, would be available. The use of the limestone as possible concrete aggregate source can also be considered but it should be subject to additional tests.

In addition some limited amounts of sand and gravel material were observed in alluvial deposits in the vicinity of the dam site along the riverbed. Where present, these alluvial deposits, generally related with andesite or basalt bedrock outcropping in the riverbed, consist mainly of 5 to 40 cm wide, angular to sub-rounded andesitic blocks.

iv) Seismic Hazard Analysis

The Toabre dam project is located in the Panama Block along the Pacific coast in a very complex tectonic zone where the South American, Central American, Caribbean, Nazca and Cocos plates interact, giving rise to significant seismicity. The recommended seismic design parameters for the Rio Toabre Project are:

	MCE	MDE	OBE
Recommended PGA (in g) (for rock conditions)	0.31	0.25	0.20
	ICOLD		

3.3. Hydrology

i) *Climate*

On the basis of existing data about nearby raingauges, the average yearly rainfall over the future Toabre Lake has been found to be 3,411 mm/year. Similarly, the catchment rainfall is 2 761 mm/year. The dry season corresponds to the period January to April. The other months appear to be equally wet.

Maximum Daily Rainfall has been computed according to a regional approach. The daily Probable Maximum Precipitation (PMP) is 650 mm/day.

ii) *Inflows*

ACP reviewed in depth the record of Batatilla gauging station (catchment area 788 km²). A 53-year monthly record has been developed for Toabre damsite (catchment area 727 km²).

The average runoff amounts to 40.8 m^3/s (i.e. 1 290 MCM/y):

Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec	**Year**	***Annual***
27.9	14.0	9.1	12.2	28.6	41.6	42.4	52.4	59.2	70.4	74.2	56.7	**40.8**	***1 290 hm3***

Units: m^3/s.

As for the rainfall, the dry season is from January to April, although heavy runoff could occur during this season.

iii) *Floods*

Using flood statistics at Batatilla station and after a synthesis about flood hydrographs, the following flood estimates were developed for Toabre damsite:

Return Period	**Shape single peak**		**Shape double peak**	
(year)	**V** (10^6 m^3)	**Qp** (m^3/s)	**V** (10^6 m^3)	**Qp** (m^3/s)
20	98	1 870	131	1 280
50	124	2 370	167	1 630
100	145	2 780	194	1 900
1 000	214	4 100	286	2 800
10 000	277	5 310	371	3 630
PMF	497	9 510	664	6 490

iv) *Sediment Transport*

The sediment inflow can vary between about 200 000 m^3/year and 970 000 m^3/year. Even for the worst case, the loss of storage does not appear to be a problem.

3.4. River hydraulics

The recently installed gauging station at the dam site is not yet operational. On the basis of topographical river cross sections waterline calculations have been performed to establish maximum and minimum limits of the rating curve of the Toabre river at the site.

This rating curve should be precised during the next phase of the study with the data collected at the dam site gauging station which must be operated without delays.

4. WATER MANAGEMENT & POWER STUDY

At the start of the present Feasibility Study the result of the Rio Indio Feasibility Study were not available, especially considerations about Indio reservoir sizing and simulations details. To avoid any delay the study of Rio Toabre, it was decided to perform, in a preliminary phase, some simulations with the Rio Toabre Reservoir alone in order to roughly quantify the performance of this reservoir in terms of yield potential.

In a later second phase of the study, detailed simulations with the Rio Toabre Reservoir integrated into the Panama Canal System with Gatun + Madden + Indio reservoirs have been performed.

For practical reasons the simulations of the above mentioned preliminary phase have been performed with the SIM software developed by Coyne et Bellier, while the second phase simulations have been run with the HEC-5 program used by ACP for the previous studies.

i) Preliminary Simulations with Toabre reservoir alone

For the probable optimal operation of the future reservoir of Toabre in the Canal System, two different scenario of Regulation Demand have been envisaged: annual or semestral constant operation. In addition the maximum energy potential of the Project has been established, considering only hydroelectric use of the reservoir capacity.

The corresponding potentials are:

	Yield Potential with reliability 99%						**Energy Potential**
	Scenario D1 – Constant all the year			Scenario D2 – Constant 6 months (January to June)			Installed Capacity
NWL/MOL	MCM/y	m^3/s	lockage/d	MCM/y	m^3/s	lockage/d	MW
El. 90/50	1 060	33.6	14.0	775	49.6	20.6	31
El. 95/50	1 105	35.0	14.5	880	56.3	23.4	35
El. 100/50	1 125	35.7	14.8	990	63.3	26.3	37

Note : Installed Capacity based on the 95% reliability Firm Energy Production with load factor of 0.6

ii) Simulations with HEC-5 Canal System Modeling

ACP was in charge of this part of the Water Management & Power Study, with the utilization of their HEC-5 Canal System Model developed as part of a global Canal Capacity Study to evaluate the feasibility of upgrading current Canal infrastructures.

The current Hydrologic Volumetric Reliability, represented by a ratio of the volume of water provided to the volume of water demanded for canal operations with no draft restrictions at Gatún Lake, was calculated as 99.6%, using the historic flows from January 1948 to July 1998. The yield associated with this current reliability is the 1993-1997 five-year average demand of 2 940 MCM/year or equivalent 38.7 lockages/day.

The Feasibility Study of Rio Indio recommended the development of a reservoir at NWL 80 masl and MOL 40 masl, associated with a transfer tunnel of 4.5 m diameter to Gatun Lake. The yield of the Canal System including Gatun (deepened), Madden and Indio reservoirs at the historic 99.6% reliability has been estimated to 4 593 MCM/year, equivalent to 60.5 lockages/day, i.e. 1.56 time the current system yield.

With the current available results, a preliminary analysis based on Cost / Yield Index for several combinations 'NWL/MOL/Tunnel diameter' allowed to retain a common 5 m diameter tunnel for the three alternatives of the Toabre Project, associated with a single 4.5 m diameter tunnel from Indio to Gatun, with the corresponding yield:

TOABRE NWL	**90**	**95**	**100**
Yield of Global Canal System: Gatun deepened, Madden, Indio and Toabre Reservoirs			
expressed in MCM/ year	5 685	5 820	5 970
expressed in equivalent lockages / day	74.85	76.60	78.6
increase rate from Current Yield	1.920	1.975	1.997
Yield attributed to Toabre Project			
expressed in MCM/ year	1 043	1 204	1 269
expressed in equivalent additional lockages / day	13.73	15.86	16.71

iii) Power and Energy

By analogy with Rio Indio Feasibility Study, the recommended scheme for Rio Toabre Feasibility will maximize energy produced at the end of Rio Indio / Gatun Lake Isla Pablon Power Plant.

The recommended scheme is:

- a Rio Toabre 2 x 2 MW mini hydropower plant producing 18 GWh/year,
- a supplementary 9 MW unit at Isla Pablon Power Plant.

During the intermediate period, starting 2029, as long as Rio Toabre yield will exceed Canal navigation demand, energy can be produced at Gatun Power Plant.

5. DESCRIPTION OF RIO TOABRE WATER SUPPLY PROJECT

5.1. Preliminary Site and Dam Type Selection Studies

i) Site location

A specific "Site Identification and Selection Study" was added to the Scope of the Services with the intent to compare alternative dam and reservoir sites on the Rio Toabre that would provide quantities of water of similar order of magnitude than for the dam site selected during the Reconnaissance Study.

This study, which considered up to 11 additional dam sites identified over a distance of 11.5 km on the Rio Toabre, has confirmed the original location of the dam at the San Vicente site.

ii) Dam type

A RCC dam type was selected to proceed with the feasibility design after a preliminary comparative evaluation of RCC and CFRD alternatives with the following conclusions:

- the RCC alternative is cheaper than the CFRD alternative, even if the difference is not strongly significant and likely within the accuracy of the evaluation (5% to 15%).
- the RCC alternative presents a number of advantages, especially fewer imponderables associated mainly with underground works and the easy integration of simple appurtenant works structures.
- the CFRD remains a viable alternative in case the conclusions of this dam type selection phase should be eventually reviewed in the light of the results of the recommended boreholes campaign.

5.2. Feasibility Design

The technical feasibility studies consider:

- a **RCC Dam** designed for a Normal Water Level at El. 95 masl (reference),
- a **Transfer Tunnel** to Indio reservoir, 16 km long and 5 m diameter.
- the characteristics of the scheme for NWL at El. 90 masl and El. 100 masl, according to the modification of the scope of the works introduced by ACP.

The project associated with all the necessary appurtenant works and related operations: spillway, outlets, access roads, camp, environmental measures and resettlement of populations living in the reservoir area, impact on Indio / Gatun transfer tunnel etc.

The general plan of development is shown on **Figure 2**.

5.2.1. Dam and appurtenant structures

The general layout, presented on **Figures 3**, includes:

- a 1 150 m long RCC dam with a crest at El. 99.5 masl,
- a spillway located on the RCC cross section in the centre of the valley, with an ungated sill 330 m long and supporting a bridge at the dam crest elevation,
- diversion temporary openings located in the Resumidero streambed on the left bank, converted at the final stage into river and bottom outlets,
- an optional hydropower plant of 4 MW with local distribution, easily integrated into one of the temporary openings mentioned hereabove (see § 5.2.3).

i) RCC dam

The typical section is presented on **Figure 4**.

The structure is entirely founded on slightly weathered or sound rock supposed to be at 10-15 m depth in average from the natural ground. The crest is 8 m wide at El. 99.5 masl; the upstream face is sloped at 1 V / 0.2 H and the downstream face at 1 V / 0.7 H, for adequate seismic stability behaviour,

The 2 MCM of the dam body are made of Rolled Compacted Concrete (RCC). The aggregates will be produced by crushing the rock available from the identified quarries and the excavation material. The cement and flyash (or equivalent fine material) contents could be respectively around 80-100 kg/m^3 and 50-70 kg/m^3.

The upstream face has an impervious slab of Conventional Vibrated Concrete (CVC) and the downstream face is protected from weather effects by steps of CVC.

One perimetral gallery along the upstream toe of the dam and two horizontal galleries will be arranged in the RCC body near the upstream face. These galleries will serve all necessary access, inspection, monitoring, and maintenance functions.

A drainage curtain in the upstream part of the dam body will intersect the circulation of any water leakage and will control uplift pressures. In addition a grout curtain and a drainage curtain are foreseen in the foundation at the upstream toe of the dam.

ii) Spillway

The spillway is advantageously located on the downstream face of the RCC dam in the centre of the valley and support a bridge at the dam crest elevation.

A typical cross section is shown on **Figure 4**. The ungated sill is at the NWL El. 95 masl. It is divided by the 21 piers of the bridge for an effective length of 300 m for flood control.

Taking account of the flood routing capacity of the reservoir, the 4 100 m^3/s of the design flood (T = 1 000 years) are handled with spillway discharge of practically 2 200 m^3/s under a Maximum Water Level (MWL) at El. 97.35 masl, leaving a freeboard of about 2.15 m under the crest elevation.

The 9 500 m^3/s of the PMF are routed to 5 800 m^3/s with a reservoir level at the dam crest elevation.

From the sill, water will flow down the spillway chute sloped at 1 V: 0.7 H. This chute is designed as steps of reinforced vibrated concrete which guarantees an important dissipation of the energy of the water at the downstream toe of the dam were a simple concrete slab is foreseen before the restitution to the river.

Excavation of the downstream hills is necessary for a good restitution of the flows to the river over the whole width of the spillway.

iii) Diversion Works and Outlets

During dam construction the Toabre river will be routed through four openings in a concrete structure built within the dam footprint, in the Resumidero stream bed on the left bank. The water will be controlled by upstream (crest at El. 36 masl) and downstream (crest at El. 31 masl) cofferdams and lateral concrete walls. The 4 openings have a total section of 250 m^2, or enough to control the construction flood peak (2 000 m^3/s) under El. 35.5 masl.

The location of this diversion structure some 350 m from the river bed on the left bank requires important excavations through the hills (10 to 20 m high) which separate the Toabre and Resumidero beds to open a 500 m long inlet channel.

In the final phase of construction, two of the openings will be plugged, and the two others will be converted into outlets, shown on **Figure 4**:

- a **minimum release outlet** to maintain a permanent release of the ecological flow (4 m^3/s = 10% of the mean flow) in the river downstream of the dam : installation of an 700 mm steel pipe with the standard control equipment (ϕ 700 mm Butterfly Valve coupled with a ϕ 600 mm Hollow Jet) operated from a control room installed at the downstream toe of the dam.

- a **bottom outlet**, required to control the reservoir (during the initial filling for example) and to secure drawdown of the reservoir if necessary, designed to discharge a maximum of 150 m^3/s under NWL 95 masl: installation of a 17 m long steel lined opening of 2.7 x 2.0 at El. 22 masl controlled by an upstream fixed-wheel guard gate (3.0 x 2.0) and a downstream radial control gate (2.7 x 2.0) operated from a control room reserved in the RCC dam body. The initial sizes of the temporary opening allow sufficient air volume to guarantee a free-surface flow regime downstream of the radial gate.

5.2.2. Transfer Tunnel

The tunnel allows the transfer of water from Toabre reservoir to Indio reservoir (operated between NWL 80 and MOL 40), from where this flow can be transferred to Gatun lake for Canal operations by the transfer tunnel from Indio reservoir to Gatun lake.

Despite the present poor geological knowledge which conducts to select a straight-line alignment as the base of the implementation, the location of the inlet and outlet of the tunnel have been optimised in order to minimise the length of the tunnel, while guarantying an adequate topographical cover along its whole length and minimise the approach and outlet open channels.

The water transfer tunnel consists of an approach channel, an intake structure, an upstream access shaft, the tunnel, a downstream access shaft and an outlet structure. **Figure 1 and Figure 5** present the location and the design of these different structures.

The approach channel, which consists of large excavations along the Rio de U streambed, will lead to the intake portal. The intake structure is a reinforced concrete structure with an invert at El. 35 masl to allow proper hydraulic conditions at MOL 50 and guarantee to the entire length of the tunnel will always be under pressure.

The intake structure incorporates the transition to the tunnel, which is a 16 km long horseshoe shaped tunnel (pressure flow). The finished diameter of the tunnel is 5 m (concrete lining) with a capacity of 42 m^3/s with a gross head of 10 m minimum (60 m^3/s under a 20 m head) between Toabre and Indio reservoirs (velocity around 2 m/s). With the present poor knowledge of the geological conditions it is assumed that the tunnel construction would utilise drill and blast technique from multiple headings. The tunnel is designed as fully lined by cast-in-place concrete with a minimum thickness of 40 cm. Steel reinforcement, thicker concrete and steel lining will be included as required, depending on the rock quality.

An upstream shaft including a gate room with two bonneted gates 4.0 m x 3.0 m is designed for operation control. A downstream shaft allows tunnel dewatering by pumping and additional flow control with one 4.0 m x 3.0 m bonneted gate. These two shafts with their equipment allow all the access, aeration and dewatering facilities for inspection and maintenance of the whole length of the tunnel between these two shafts.

At the downstream end of the tunnel, a reinforced concrete outlet structure with an invert at the El. 31 masl, followed by an excavated outlet channel, allows the good restitution of the flow into the Indio reservoir.

5.2.3. Hydropower Facilities

i) Potential for adding Hydropower facilities in the Toabre Project

The generation of hydroelectric power was assumed to be a possible secondary benefit for the Toabre Project. Studies were performed to determine if the addition of hydropower to the water supply project was viable.

Two alternatives to generate power as a part of the Rio Toabre Project were initially envisaged:

- power production at Toabre Dam site.
- maximize production at the Indio-Gatun tunnel powerplant (Isla Pablon).

ii) Mini Hydropower plant at the dam site

The design of the mini powerplant for local distribution is based on the turbining the 4 m^3/s of the ecological flow with a local load factor of 0.5. With a rated head of 60 m, the installed capacity will be around 4 MW. The project would generate an average of 18 GWh/y for an estimated cost of 4 MUSD.

Due to the small size of the mini hydropower plant (for both civil works and equipment) it can be economically located in one of the temporary diversion opening, to be optimized with the parallel equipment into river and bottom outlets.

The power generation conversion works includes an intake similar to the one designed for the minimum release facility, a ϕ 1 600 mm penstock and a surface powerhouse built at the downstream end of the diversion opening which houses two generating sets of 2MW each.

iii) Indio Gatun tunnel powerplant, Isla Pablon

The Feasibility Report of the Rio Indio Project, available during the course of the present study, reveals that the cost of the optional hydropower facilities associated with this project make such development non economic and didn't recommend any hydroelectric development at this time.

Should Isla Pablon 14 MW hydropower plant be installed, as part of Rio Indio project works, Rio Toabre project brings a new energy potential, allowing for a 9 MW supplementary unit installation. Economic rate of return is increased by (+2%).

5.2.4. Access road and camp

The proposed access to the project is provided from Panama City on the Pacific Coast via the Pan-American highway until Penonome and then by the existing permanent access, 24 km long, to the village of Tambo. To reach the dam site the project requires the improvement of 12 km of the existing dry-weather road from Tambo to the vicinity of San Miguel and the construction of 29 km of new road through mountainous terrain.

In addition, a 16 km long service road will serve the two shafts of the transfer tunnel from this main access road.

The owner's camp will be built on the right bank of the Toabre future reservoir, on a relatively flat area around El. 120 masl.

5.2.5. Impact on transfer tunnel Indio - Gatun

The yield of Toabre Project transferred to Indio reservoir should be then transferred to Gatun lake for Canal operation. The Rio Indio Feasibility Study performed by MWH includes an 8.5 km, 4.5 m diameter transfer tunnel from Indio to Gatun; these transfer structures should be adequate to transfer the additional yield brought by the Toabre reservoir.

At the present stage of the study the ACP's HEC-5 simulations studies didn't included optimisation on the size of this tunnel. As a preliminary design it has been agreed with ACP to simply keep the tunnel developed in the Rio Indio Feasibility Report by MWH.

6. ENVIRONMENTAL IMPACTS

The Environmental Impacts Study has been established by ACP. It includes the evaluation, with the corresponding cost estimate, of:

- population affected: number of people and villages
- infrastructures affected: roads, electric lines, public building, houses, water distribution, cemetery, etc.
- inundated areas of terrestrial and aquatic cover/habitat
- inundated areas of each land use type.

Among the major impacts, the affected population varies with the project alternatives: 1 405 persons for alternative NWL 90, 1 345 persons for NWL 95 and 1 601 persons for NWL 100: the highest alternative (NWL 100) requires the displacement of the important village of Valle de San Miguel with a total population of 256 people. On the opposite, the lowest alternative (NWL 90) can avoid the displacement of 200 people, living in the villages of Banacito, Lubre and Tulu Abajo.

7. IMPLEMENTATION SCHEDULE

Without economic analysis, it is not possible to determine the optimum date of implementation of the Toabre Project in the long-range master plan to augment Canal capacity and capability with other developments such as Indio Project, new sets of locks etc. But it can be stated that completion should be planned only after the completion of the Rio Indio Project, forecast at the earliest in 2011.

The future optimisation of the integrated Canal System Development will establish the date to launch the major successive steps of the implementation schedule to guarantee the completion of the Toabre Project at the desired date, as presented on **Figure 6** with an estimated minimum period of 8 years:

The construction works including the Preparatory Works (Access Road and Owner's Camp) and the construction of the Dam with its appurtenant works and the Transfer Tunnels are anticipated to take 7 years: 2 years for the preparatory works and 5 additional years for the main works.

8. COST ESTIMATE

The Project construction cost includes civil works, equipment, access, camp, environmental costs (resettlement and mitigation costs), contingencies, engineering and administration costs.

The cost of the civil works has been estimated on the basis of a series of aggregated unit prices for major construction elements adapted to the conditions of this study. Application of these unit prices to the various quantities estimated from the feasibility engineering drawings (with a NWL at El. 95 masl) gives the project construction costs.

The integration of the cost of the others structures (Transfer Tunnel Indio-Gatun, Access Road) or items (Environmental Impacts, Contingencies, Engineering & Administration) gives the Total Cost of the Project. The following table sum up all the investment costs for the Rio Toabre Water Transfer Project for the three envisaged reservoir alternatives:

Items	NWL 90	NWL 95	NWL 100
Dam & Appurtenant Works	132	146	162
Transfer Tunnel Toabre – Indio	103	103	103
Access Road & Owner's Camp	10	10	10
Environmental Costs	19	27	31
Sub Total Direct Cost (MUSD)	***264***	***286***	***306***
Contingencies	51	54	58
Total Direct Cost (MUSD)	***315***	***340***	***364***
Engineering & Administration Cost	47	51	55
TOTAL (MUSD)	**362**	**391**	**419**

9. OPERATION AND MAINTENANCE

The annual cost estimate of Operation and Maintenance, Administration and Insurance is USD 2,340,000 per year.

10. CONCLUSIONS

The following fundamental results were obtained from the technical feasibility studies of the Rio Toabre Project:

- the Rio Toabre Water Supply Project is technically feasible;
- the site selected in the Reconnaissance Report is the most suitable site for the development of the water resources of the Rio Toabre basin; a viable alternative dam axis exists 1 km upstream and should be investigated in parallel;
- either a Rolled Compacted Concrete (RCC) dam or a Concrete Faced Rockfill Dam (CFRD) is suitable for the site and cost effective. The RCC dam was selected based on a preliminary analysis;
- the lack of sufficient subsurface investigations has increased the potential for inaccuracies in the cost estimate. However it is considered that there are no geologic or geotechnical problems associated with the site that cannot be accommodated using conventional solutions. The level of contingencies included in the cost estimate is sufficient to cover any uncertainties related to this absence of sub-surface information;

- the yield of the Panama Canal System will increase by about 1 204 to 1 269 MCM/y (about 15.86 to 16.71) with the addition of the Rio Toabre Project, depending of the reservoir sizing (NWL 95 or NWL 100 masl);
- the addition of hydropower to the Project is limited to an optional mini powerplant of 2 x 2 MW at the dam site for local distribution and reservoir operation;
- the Project is estimated to cost about 391 to 419 MUSD depending of the reservoir sizing (NWL 95 or NWL 100 masl);
- a Cost / Yield Index lower than 0.33 USD/m^3.

DATA SHEET OF THE PROJECT

Normal Water Level	**masl**	**90**	**95**	**100**
• Location				
		Rio Toabre Basin ; 100 km West of Panama City, 60 km SW of Colon		
• Hydrology				
Mean annual rainfall	mm	2 800		
Mean inflow	MCM	1 290		
Mean streamflow	m^3/s	41		
Peak flow of 25-y flood (construction)	m^3/s	2 000		
Peak flow of 1 000-y flood (design)	m^3/s	4 100		
Peak flow of PMF	m^3/s	9 500		
• Reservoir				
Catchment area	km^2	727	727	727
Normal Water Level (NWL)	masl	90	95	100
Maximum Water Level (MWL)	masl	92.5	97.35	102.2
Minimum Operating Level (MOL)	masl	50	50	50
River bed elevation	masl	20	20	20
Reservoir area at NWL	km^2	32	39	46
Total reservoir capacity at NWL	MCM	741	918	1 131
Dead storage at MOL	MCM	68	68	68
Active storage	MCM	673	850	1 063
• Dam				
Type		RCC dam		
Upstream face		0.2 H / 1 V		
Downstream face		0.7 H / 1 V		
Crest Elevation	masl	94.75	99.5	104.3
Crest length	m	1 140	1 150	1 250
Maximum height above foundation	m	80	85	90
Total volume	MCM	1.8	2.1	2.5
• Spillway				
Spillway type		ungated sill - stepped chute		
Crest elevation	masl	90	95	100
Crest length	m	330	330	330
Maximum discharge for design flood	m^3/s	2 400	2 200	2 000
Maximum discharge for PMF	m^3/s	6 350	5 900	5 450
Head for PMF	m	4.75	4.5	4.3
• Diversion Works				
Type		concrete culvert through dam		
Number of openings	unit	4		
Size of openings	m	9 h x 7 w		
Discharge capacity	m^3/s	2 000		
Upstream cofferdam crest elevation	masl	36		
Downstream cofferdam crest elevation	masl	31		
Cofferdams fill volume	m^3	120 000		

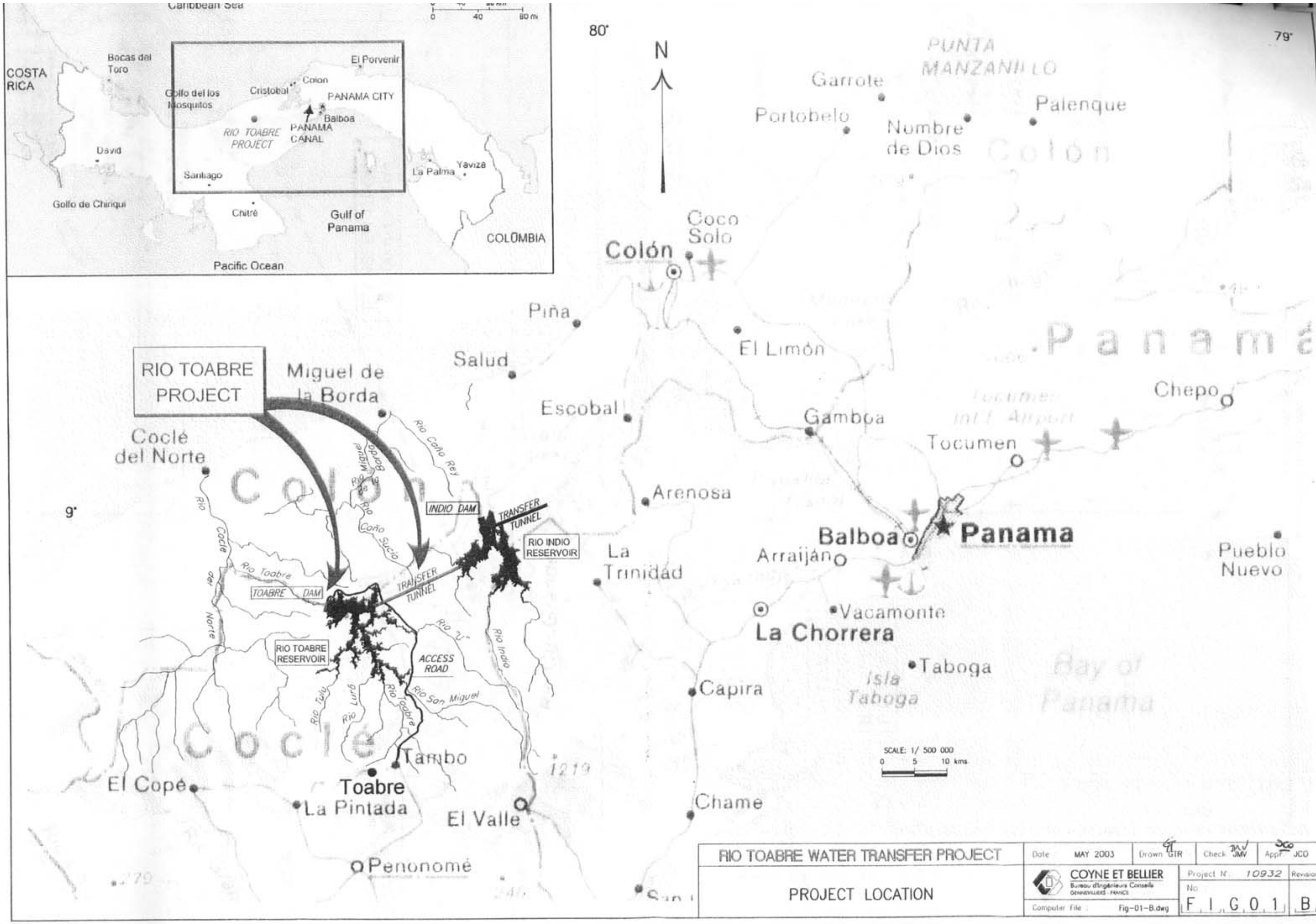
Normal Water Level	**masl**	**90**	**95**	**100**
• Minimum Release Facility				
Type		steel pipe located in diversion temporary opening		
Maximum Capacity at NWL	m^3/s	7		
Minimum Capacity at MOL	m^3/s	4		
Sill elevation	masl	37		
Steel pipe diameter	m	700		
Butterfly valve	mm	700		
Hollow Jet	mm	600		
• Bottom Outlet				
Type		conversion of diversion temporary opening		
Number of outlets		1	1	1
Capacity at NWL	m^3/s	125	150	185
Sill elevation	masl	22	22	22
Fixed-wheel gate	m	2.7 x 1.9	3 x 2	3.2 x 2.2
Radial gate	m	2.4 x 1.9	2.7 x 2	2.9 x 2.2
• Mini Hydropower Plant				
Type		surface powerhouse; conversion of diversion temporary opening		
Number of generating sets		1		
Installed capacity	MW	4		
Average energy	GWh/yr	18		
Penstock diameter	mm	1 600		
Horizontal Francis turbines				
Rated power	MW	4		
Rated discharge	m^3/s	8		
Nominal net head	m	60		
Speed	rpm	600		
• Transfer Tunnel Toabre – Indio				
Intake structures				
Type		reinforced concrete + vertical shaft		
Invert Elevation	masl	35		
Bonneted gates (2 units)	m	4.0 h x 3.0 w		
Tunnel				
Shape		horseshoe		
Length	km	16		
Diameter (finished)	m	5		
Minimum capacity (10 m net head)	m^3/s	40		
Maximum capacity	m^3/s	100		
Outlet structures				
Type		reinforced concrete + vertical shaft		
Invert Elevation	masl	31		
Bonneted gate (1 unit)	m	4.0 h x 3.0 w		

Normal Water Level	**masl**	**90**	**95**	**100**
• Saddle dams				
Cano Sucio saddle dam Maximum height above foundation **Left bank saddle dam**	m	NO NO	NO NO	YES 5 Limit
• Access Road				
Type / Length		improvement of existing track (12 km) + new road (29 km) + service road (16 km)		
• Environmental Impacts				
inundated area affected population	ha people	3 425 1 145	5 350 1 345	6 000 1 601
• Estimated Yield	MCM/y	1 043	1 204	1 269
• Estimated Project Cost	MUSD	362	391	419

VOLUME I – FIGURES

(this part has 7 pages)

FIGURES



RIO TOABRE WATER TRANSFER PROJECT	Date MAY 2003	Drawn GTR	Check JMV	Appr JCO	
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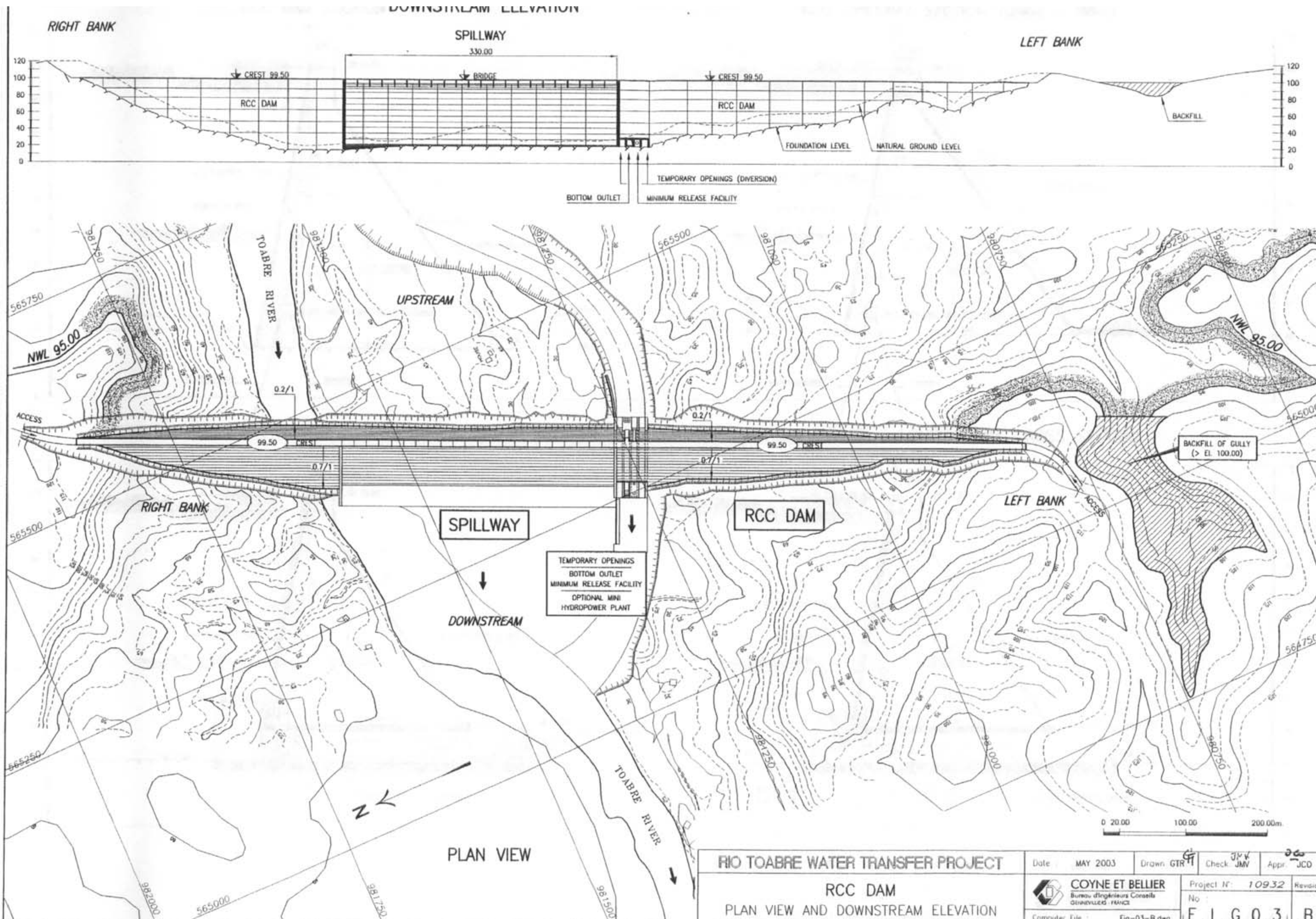
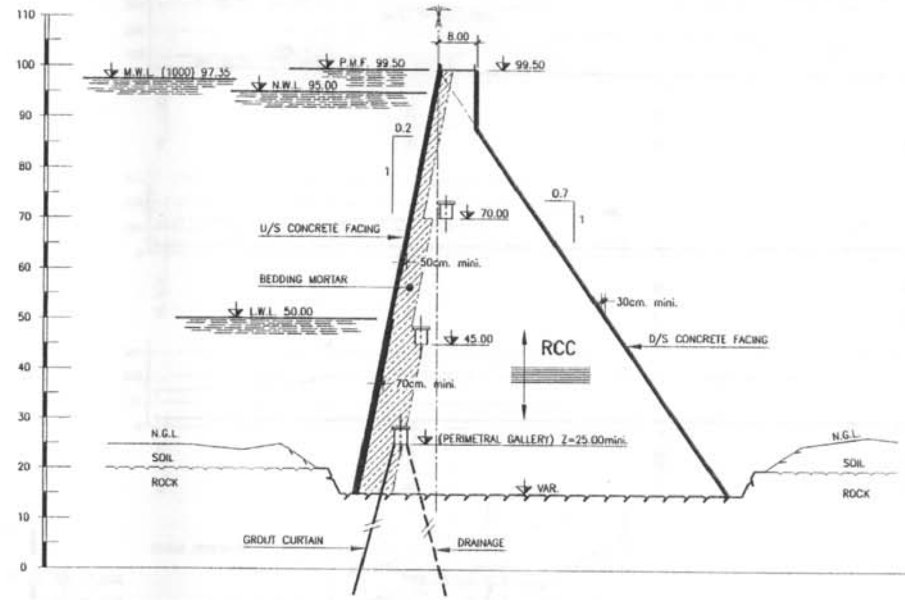
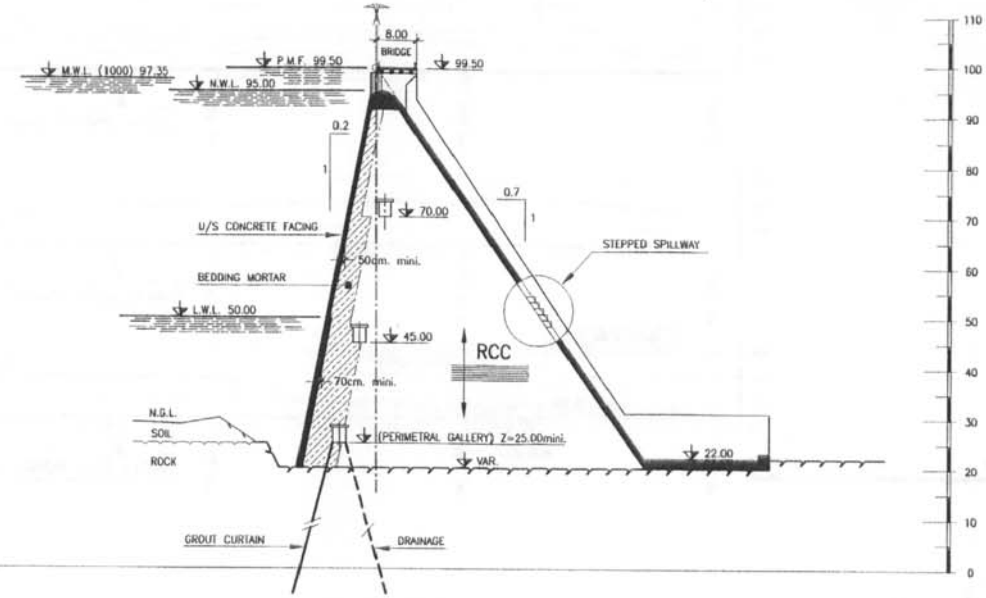

DOWNSTREAM ELEVATION
RIGHT BANK
SPILLWAY
330.00
LEFT BANK
CREST 99.50
BRIDGE
RCC DAM
BACKFILL
FOUNDATION LEVEL
NATURAL GROUND LEVEL
TEMPORARY OPENINGS (DIVERSION)
BOTTOM OUTLET
MINIMUM RELEASE FACILITY
TOABRE RIVER
UPSTREAM
NWL 95.00
ACCESS
0.2/1
0.7/1
99.50
CREST
BACKFILL OF GULLY (> EL 100.00)
RIGHT BANK
SPILLWAY
RCC DAM
LEFT BANK
TEMPORARY OPENINGS
BOTTOM OUTLET
MINIMUM RELEASE FACILITY
OPTIONAL MINI HYDROPOWER PLANT
DOWNSTREAM
N
PLAN VIEW
0 20.00 100.00 200.00m
RIO TOABRE WATER TRANSFER PROJECT
RCC DAM
PLAN VIEW AND DOWNSTREAM ELEVATION
Date MAY 2003
Drawn GTR
Check JMV
Appr. JCD
COYNE ET BELLIER
Bureau d'Ingénieurs Conseils
GENNEVILLIERS - FRANCE
Project N° 10932
No F I G 0 3
Revision B
Computer File Fig-03-B.dwg

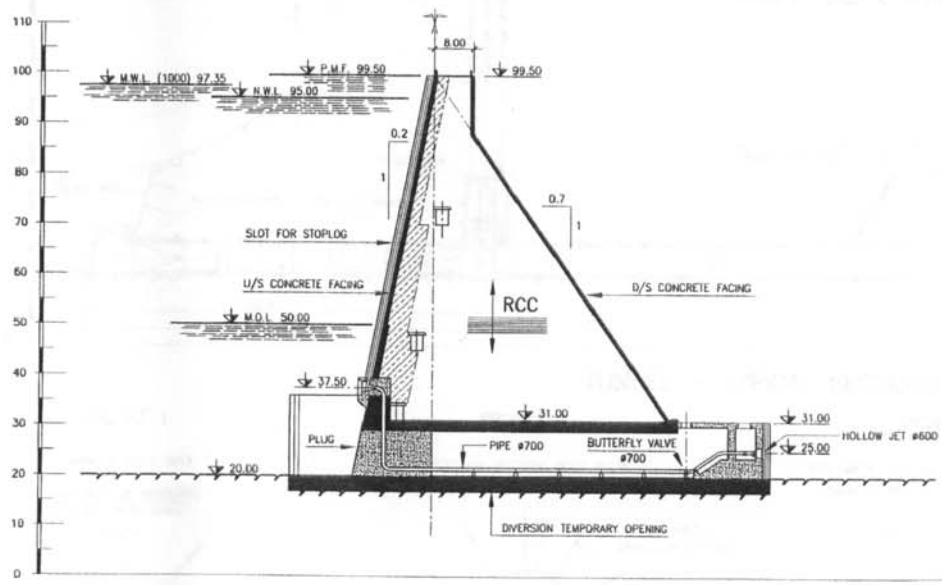
RCC DAM SECTION



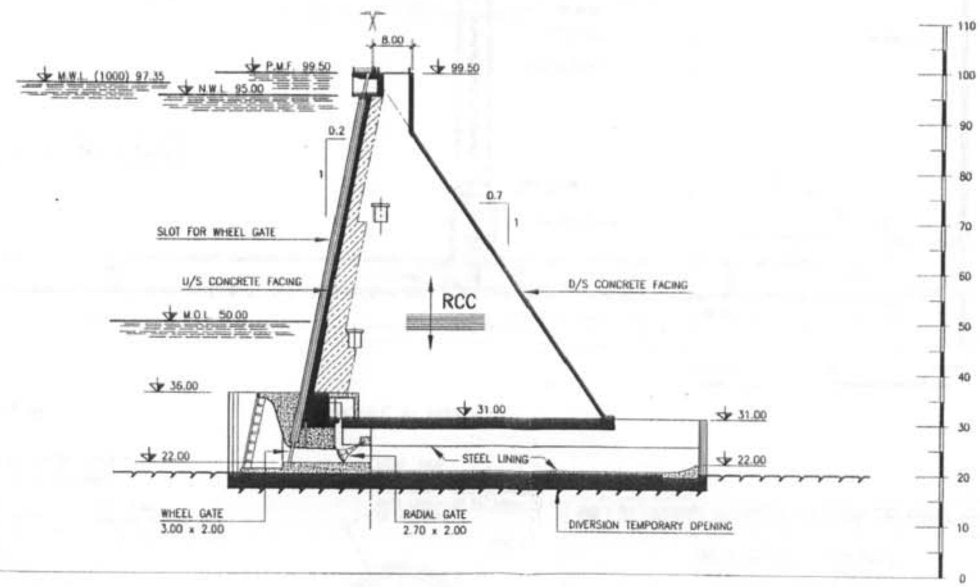
RCC SPILLWAY SECTION (LENGHT = 330m.)



MINIMUM RELEASE FACILITY – LONGITUDINAL CROSS SECTION



BOTTOM OUTLET – LONGITUDINAL CROSS SECTION



RIO TOABRE WATER TRANSFER PROJECT	Date : MAY 2003	Drawn GTR	Check JMV	Appr. JCO
RCC DAM TYPICAL CROSS SECTIONS	COYNE ET BELLIER Bureau d'Ingénieurs Conseils GENNEVILLIERS - FRANCE	Project N°: 10932		Revision
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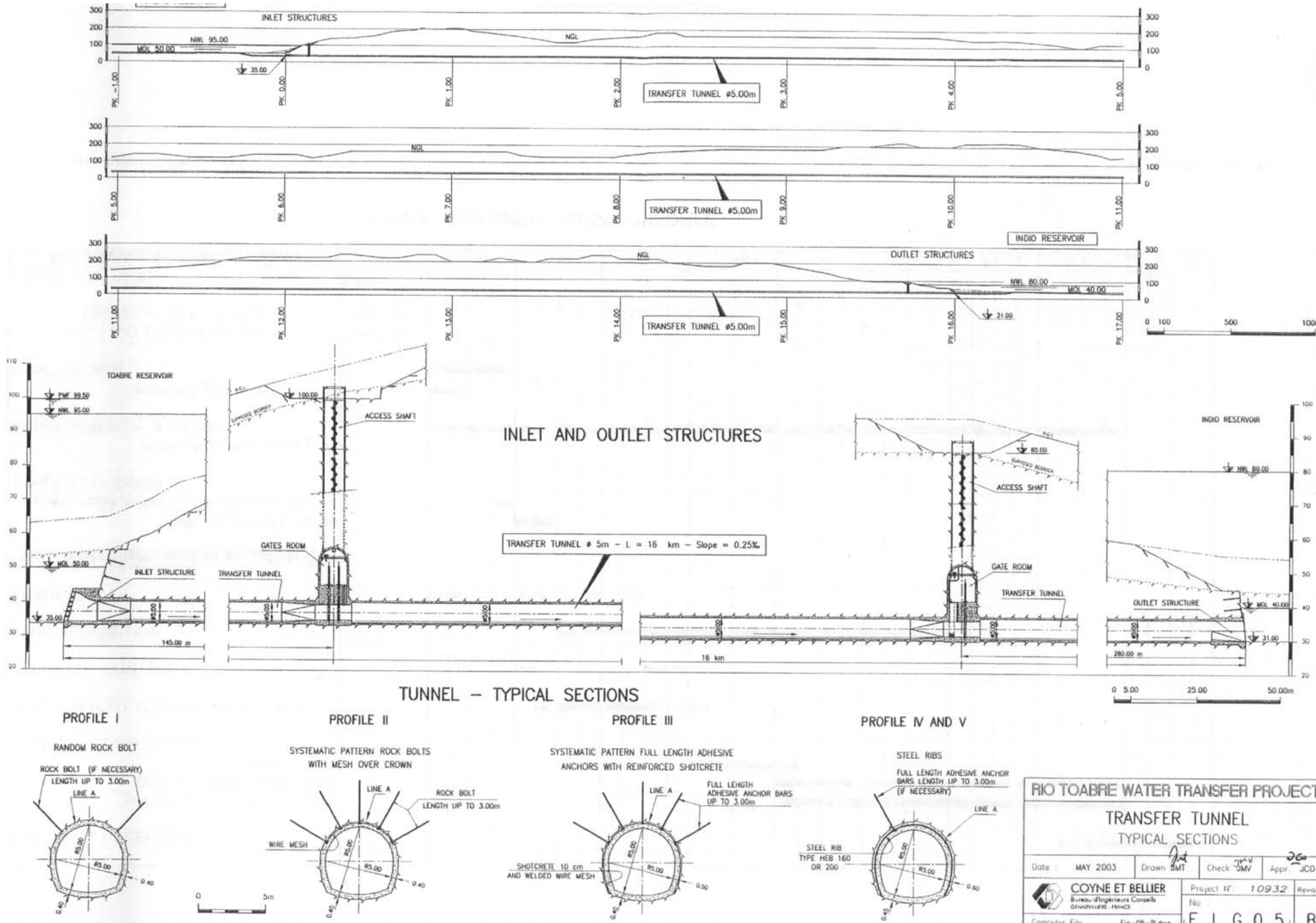

RIO TOABRE WATER TRANSFER PROJECT

TRANSFER TUNNEL

TYPICAL SECTIONS

Date : MAY 2003	Drawn SMT	Check JMV	Appr. JCO
COYNE ET BELLIER Bureau d'Ingénieurs Conseils GENNEVILLIERS - FRANCE	Project N°: 10932		Revision
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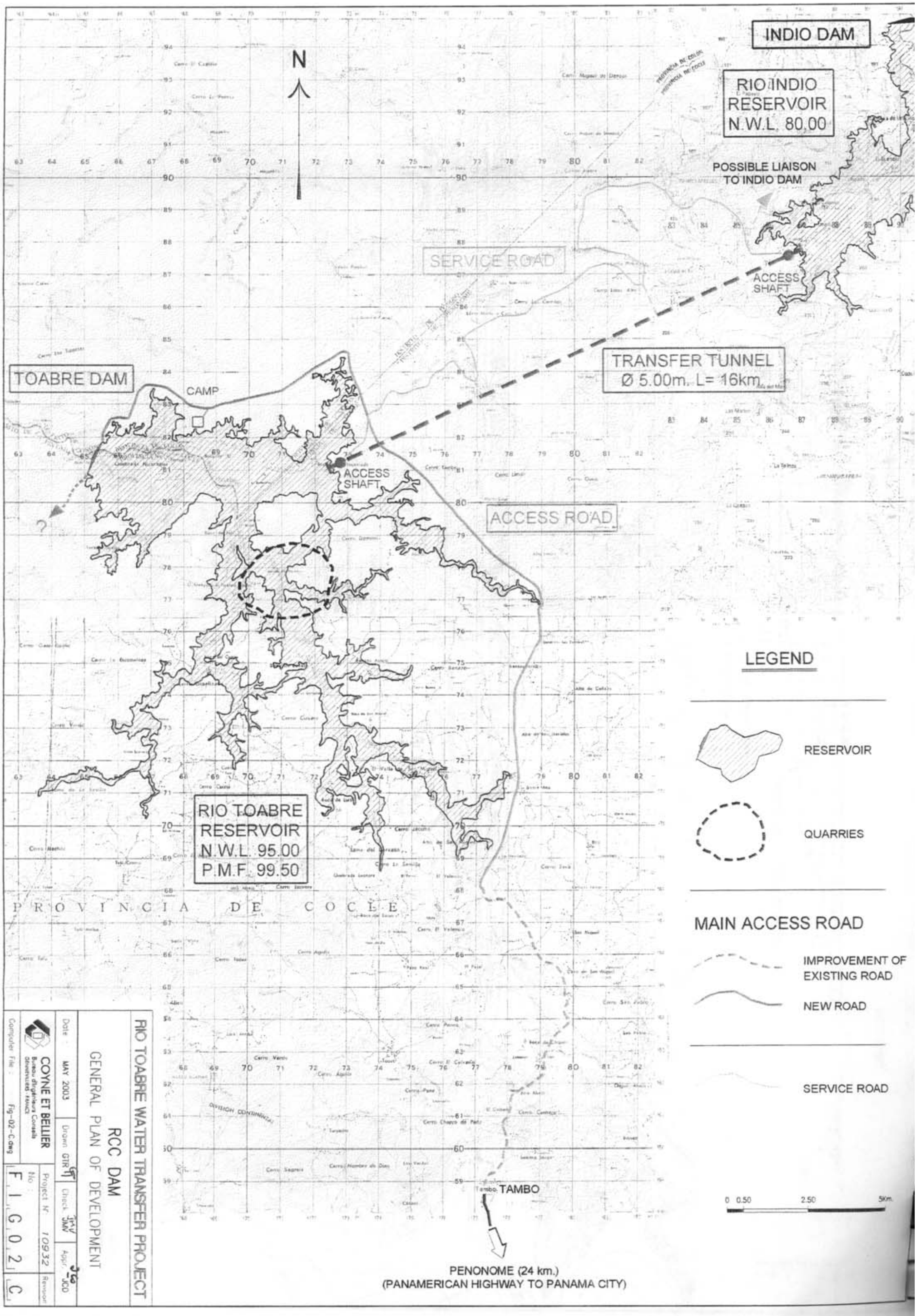
INDIO DAM
RIO INDIO RESERVOIR N.W.L. 80.00
POSSIBLE LIAISON TO INDIO DAM
N
SERVICE ROAD
ACCESS SHAFT
TRANSFER TUNNEL Ø 5.00m. L= 16km.
TOABRE DAM
CAMP
ACCESS SHAFT
ACCESS ROAD
RIO TOABRE RESERVOIR N.W.L. 95.00 P.M.F. 99.50
PROVINCIA DE COCLE
TAMBO
PENONOME (24 km.)
(PANAMERICAN HIGHWAY TO PANAMA CITY)
LEGEND
RESERVOIR
QUARRIES
MAIN ACCESS ROAD
IMPROVEMENT OF EXISTING ROAD
NEW ROAD
SERVICE ROAD
0 0.50 2.50 5Km.
RIO TOABRE WATER TRANSFER PROJECT
RCC DAM
GENERAL PLAN OF DEVELOPMENT
Date: MAY 2003
Drawn: GTR
Check: JMV
Appr.: JCO
COYNE ET BELLIER
Bureau d'Ingénieurs Conseils
GENNEVILLIERS - FRANCE
Project N°: 10932
No: F I G 0 2
Revision: C
Computer File: Fig-02-C.dwg

FIGURE 6 - IMPLEMENTATION SCHEDULE