ACP
AUTORIDAD DEL CANAL DE PANAMÁ

RIO TOABRE WATER TRANSFER PROJECT

Feasibility Study

FEASIBILITY REPORT

COYNE ET BELLIER
Bureau d'Ingénieurs Conseils
PARIS - FRANCE

Ref 10932 RP 06 - June 2003

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VOLUME I - EXECUTIVE SUMMARY

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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 km² to 46 km².

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);

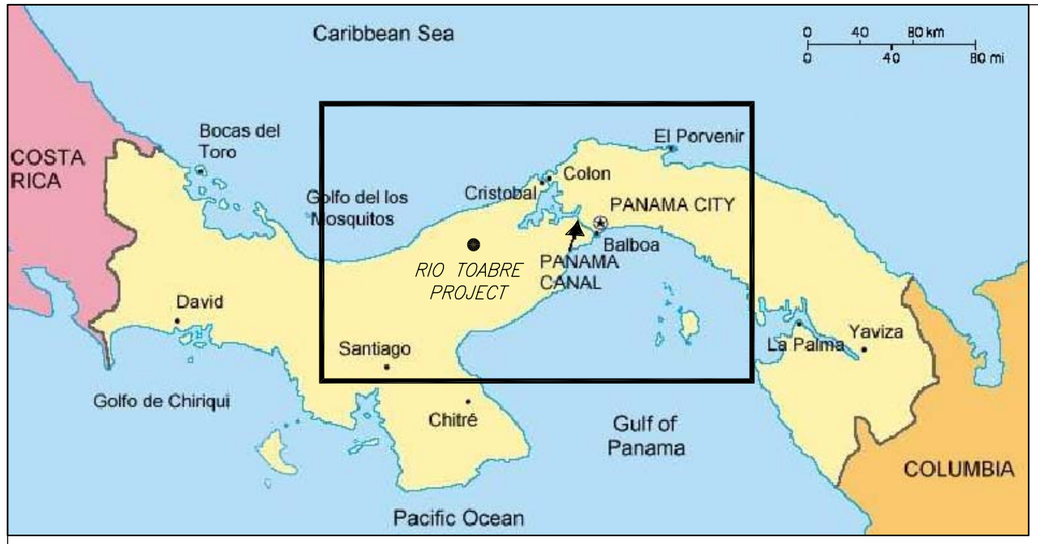
. a Cost / Yield Index lower than 0.33 USD/m^3.

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	km²	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	km²	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



RIO TOABRE WATER TRANSFER PROJECT	Date : MAY 2003	Drawn GTR	Check. JMV	Appr. JCO
PROJECT LOCATION	COYNE ET BELLIER Bureau d'Ingénieurs Conseils GENNEVILLIERS - FRANCE	Project N°: 10932		Revision
	Computer File : Fig-01-B.dwg	No : F I G 0 1		B

INDIO DAM

RIO INDIO
RESERVOIR
N.W.L. 80.00

POSSIBLE LIAISON
TO INDIO DAM

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 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.

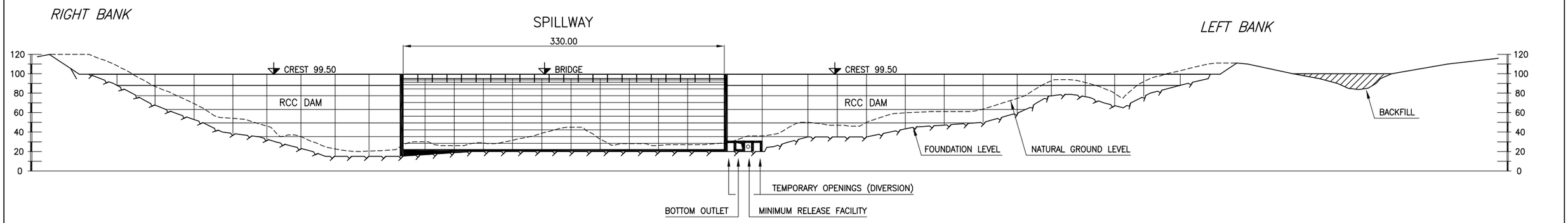
RIO TOABRE WATER TRANSFER PROJECT

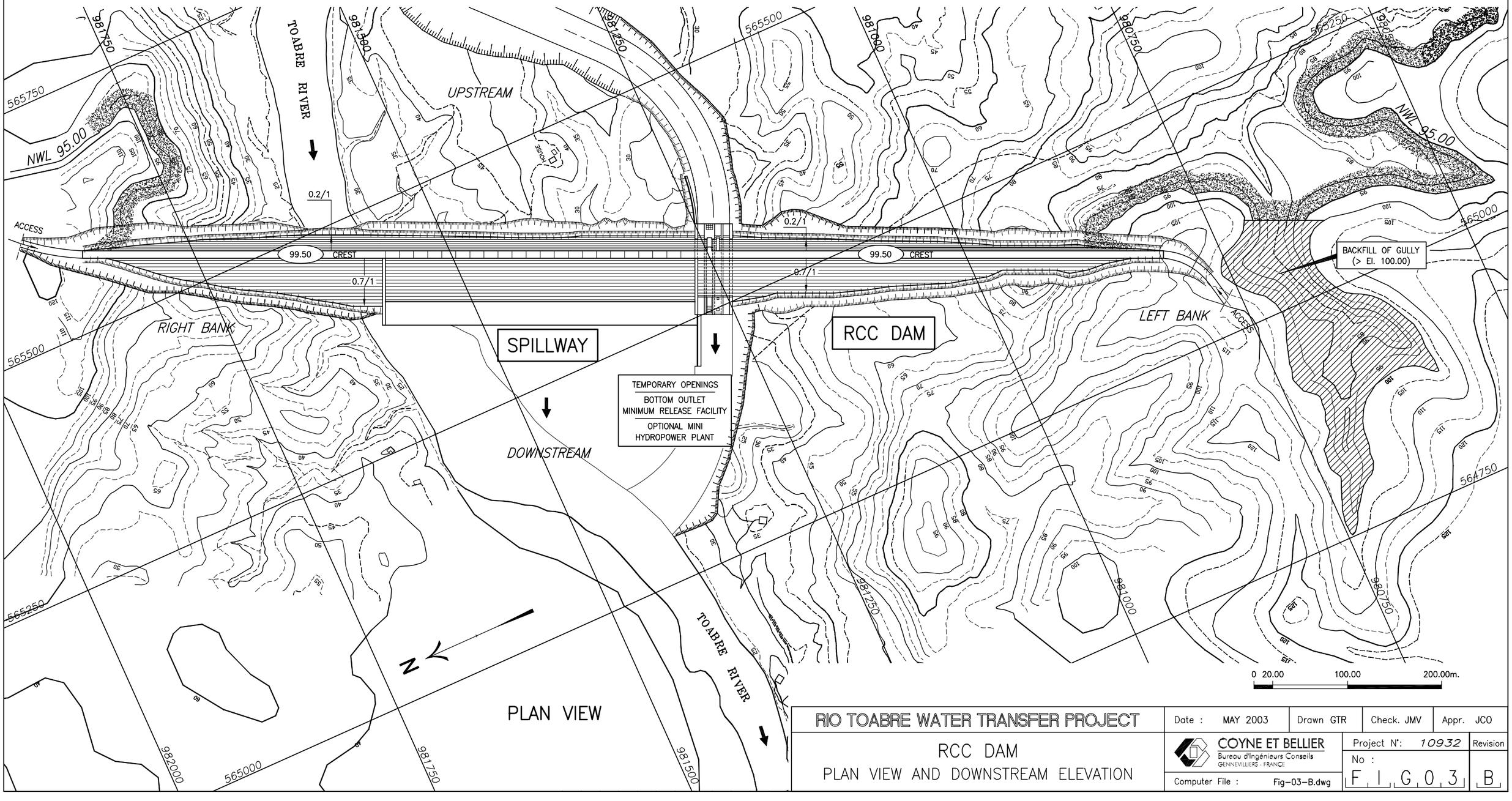
RCC DAM
GENERAL PLAN OF DEVELOPMENT

COYNE ET BELLIER
Bureau d'Ingénieurs Conseils
GENTILLY-LES-FRANCE

Date : MAY 2003	Drawn GTR	Check JMV	Appr. JCO
Computer File : Fig-02-C.dwg	Project N°: 10932	No : F1G02	Revision C

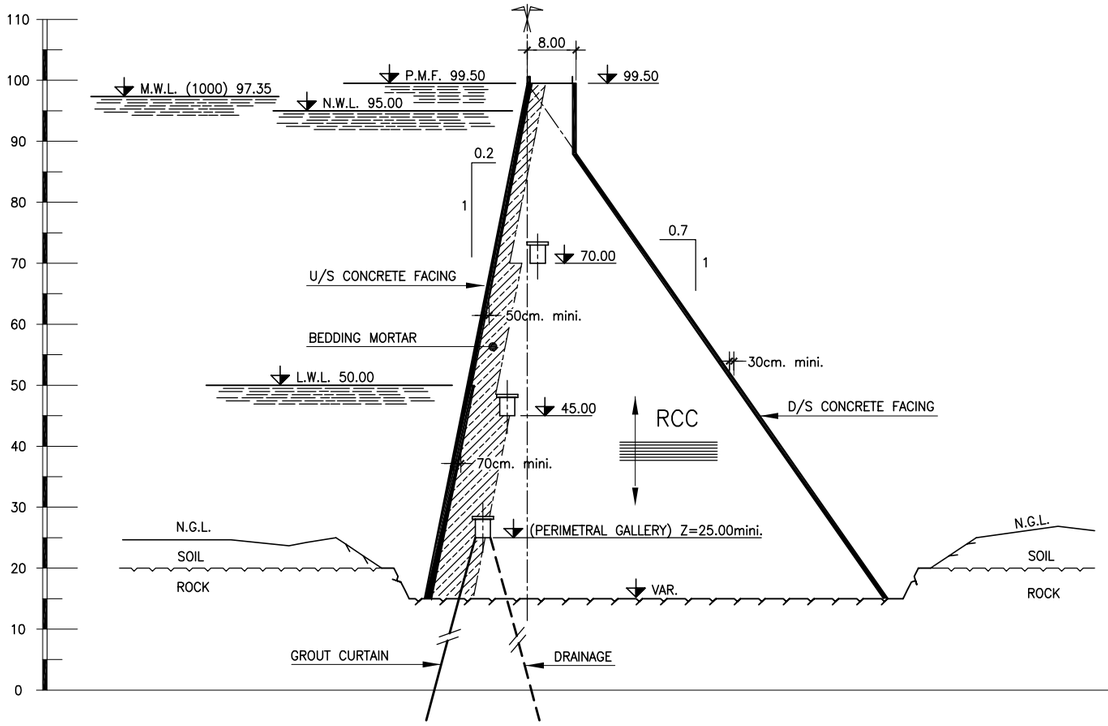
DOWNSTREAM ELEVATION





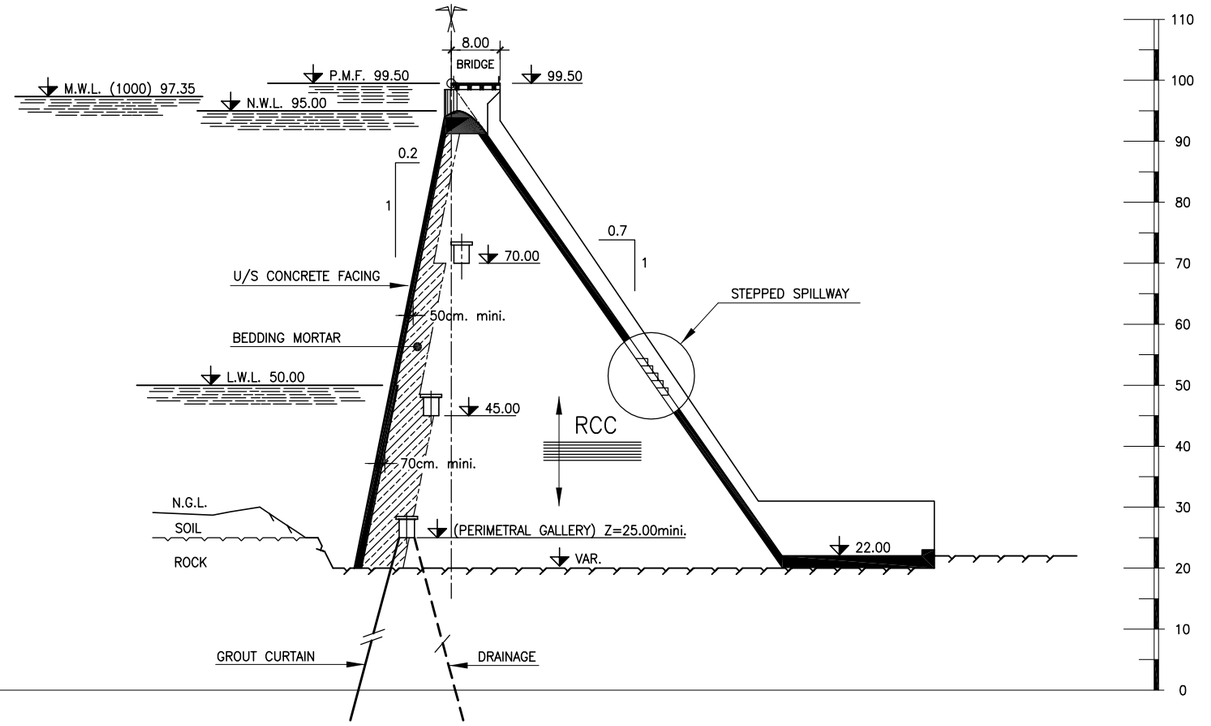
RIO TOABRE WATER TRANSFER PROJECT	Date : MAY 2003	Drawn GTR	Check. JMV	Appr. JCO
RCC DAM PLAN VIEW AND DOWNSTREAM ELEVATION	COYNE ET BELLIER Bureau d'Ingénieurs Conseils GENNEVILLIERS - FRANCE	Project N°: 10932		Revision
	Computer File : Fig-03-B.dwg	No : F I G 0 3		B

RCC DAM SECTION

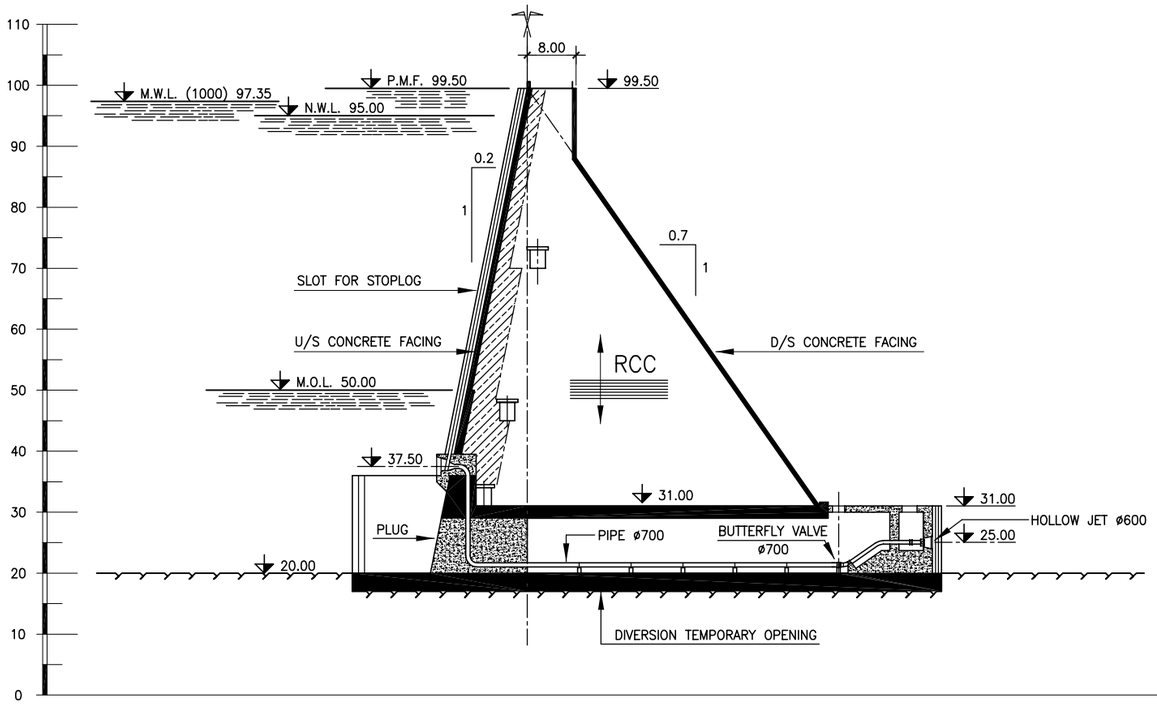


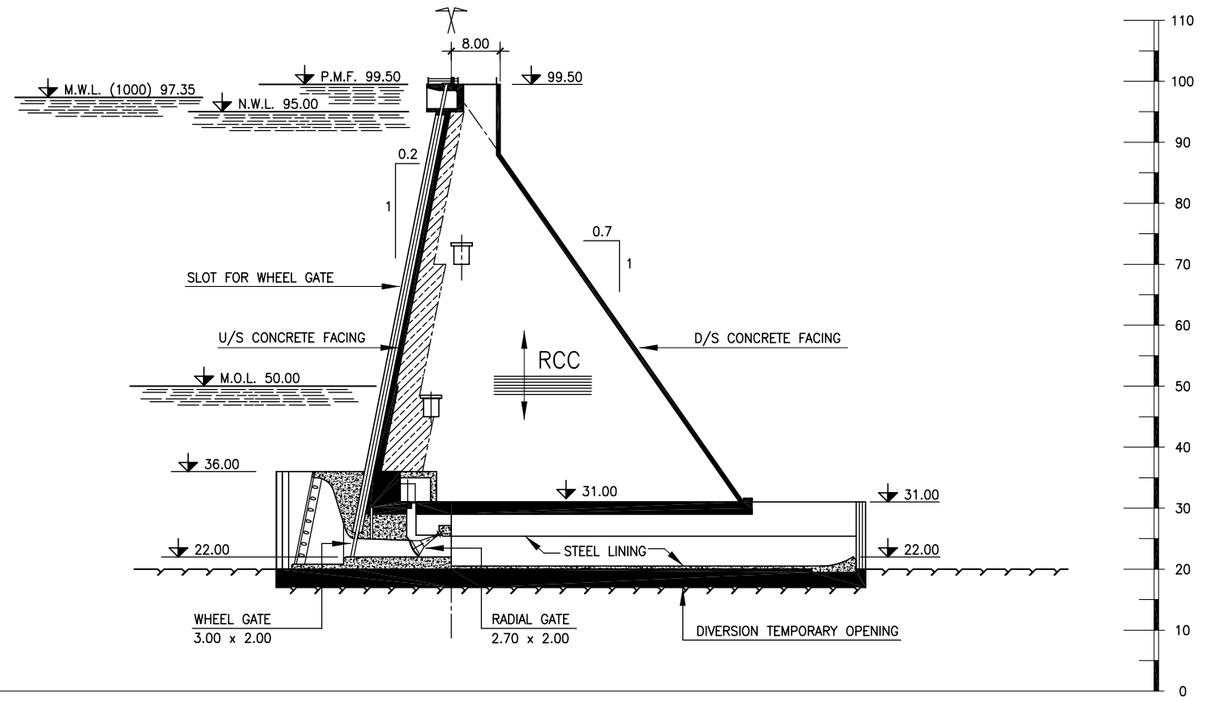
MINIMUM RELEASE FACILITY – LONGITUDINAL CROSS SECTION

RCC SPILLWAY SECTION (LENGHT = 330m.)



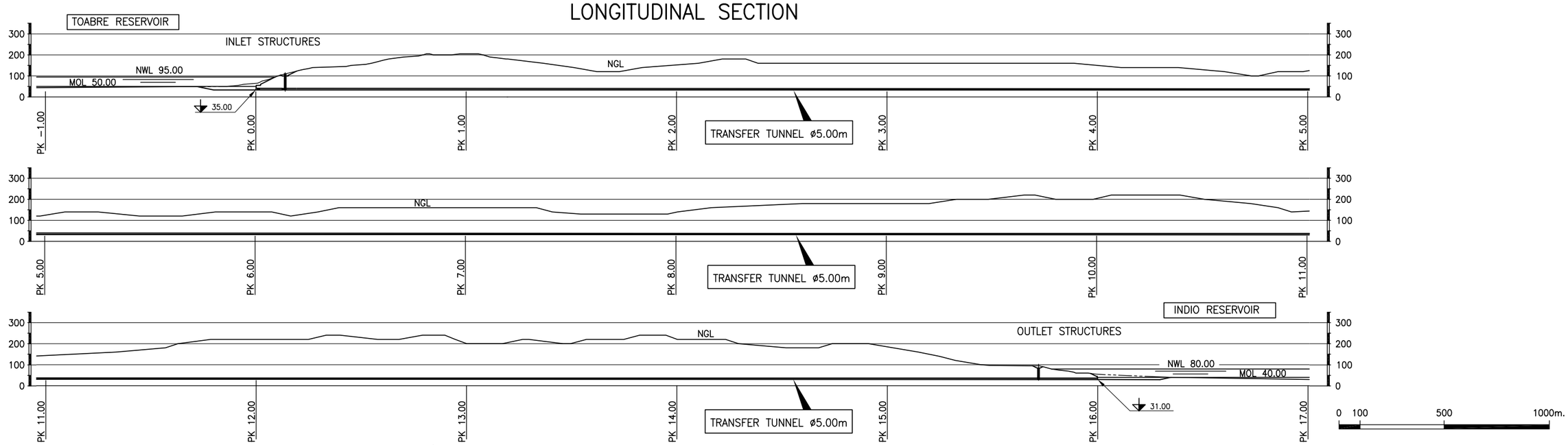
BOTTOM OUTLET – LONGITUDINAL CROSS SECTION



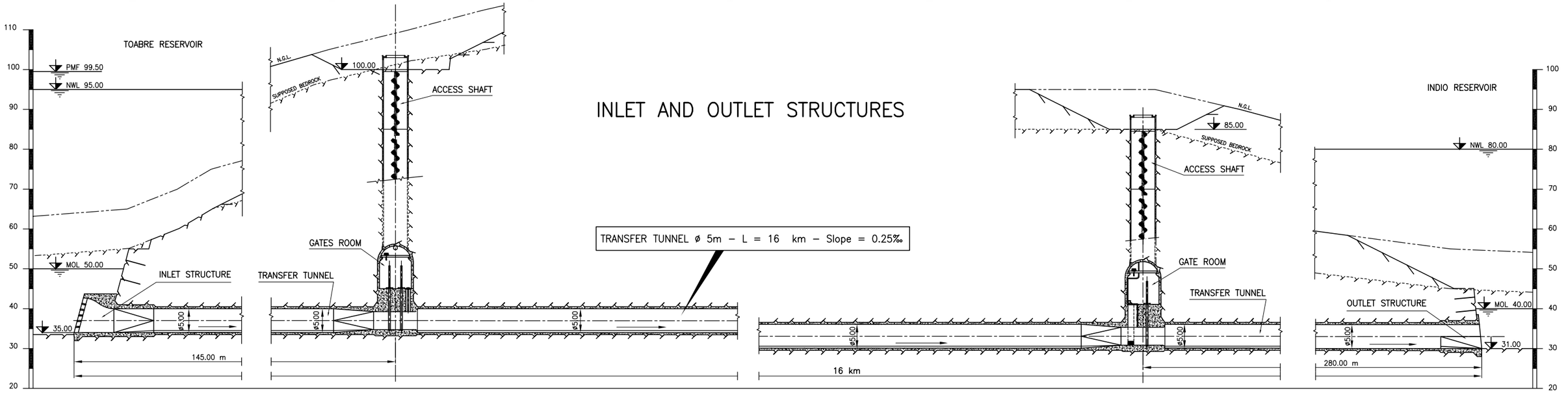


RIO TOABRE WATER TRANSFER PROJECT	Date : MAY 2003	Drawn GTR	Check. JMV	Appr. JCO
RCC DAM TYPICAL CROSS SECTIONS	COYNE ET BELLIER Bureau d'Ingénieurs Conseils GENNEVILLIERS - FRANCE	Project N°: 10932		Revision
	Computer File : Fig-04-B.dwg	No : F I G 0 4		B

LONGITUDINAL SECTION



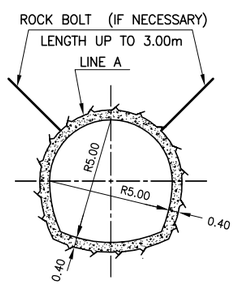
INLET AND OUTLET STRUCTURES



TUNNEL – TYPICAL SECTIONS

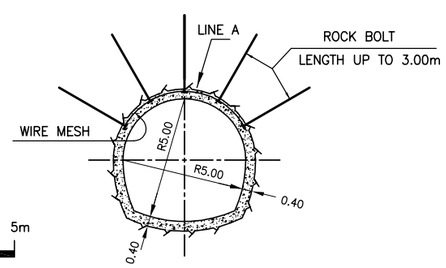
PROFILE I

RANDOM ROCK BOLT



PROFILE II

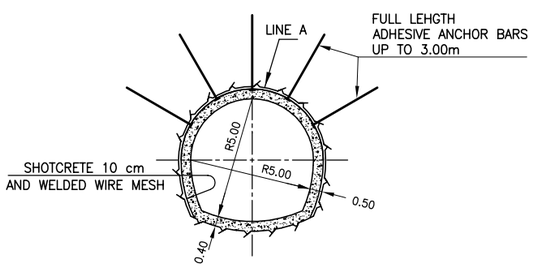
SYSTEMATIC PATTERN ROCK BOLTS
WITH MESH OVER CROWN



0 5m

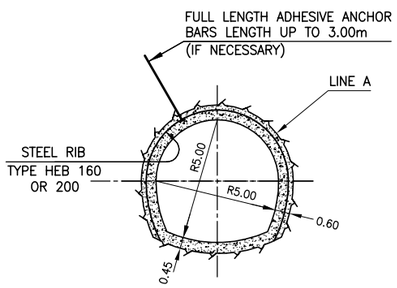
PROFILE III

SYSTEMATIC PATTERN FULL LENGTH ADHESIVE
ANCHORS WITH REINFORCED SHOTCRETE



PROFILE IV AND V

STEEL RIBS



RIO TOABRE WATER TRANSFER PROJECT

TRANSFER TUNNEL
TYPICAL SECTIONS

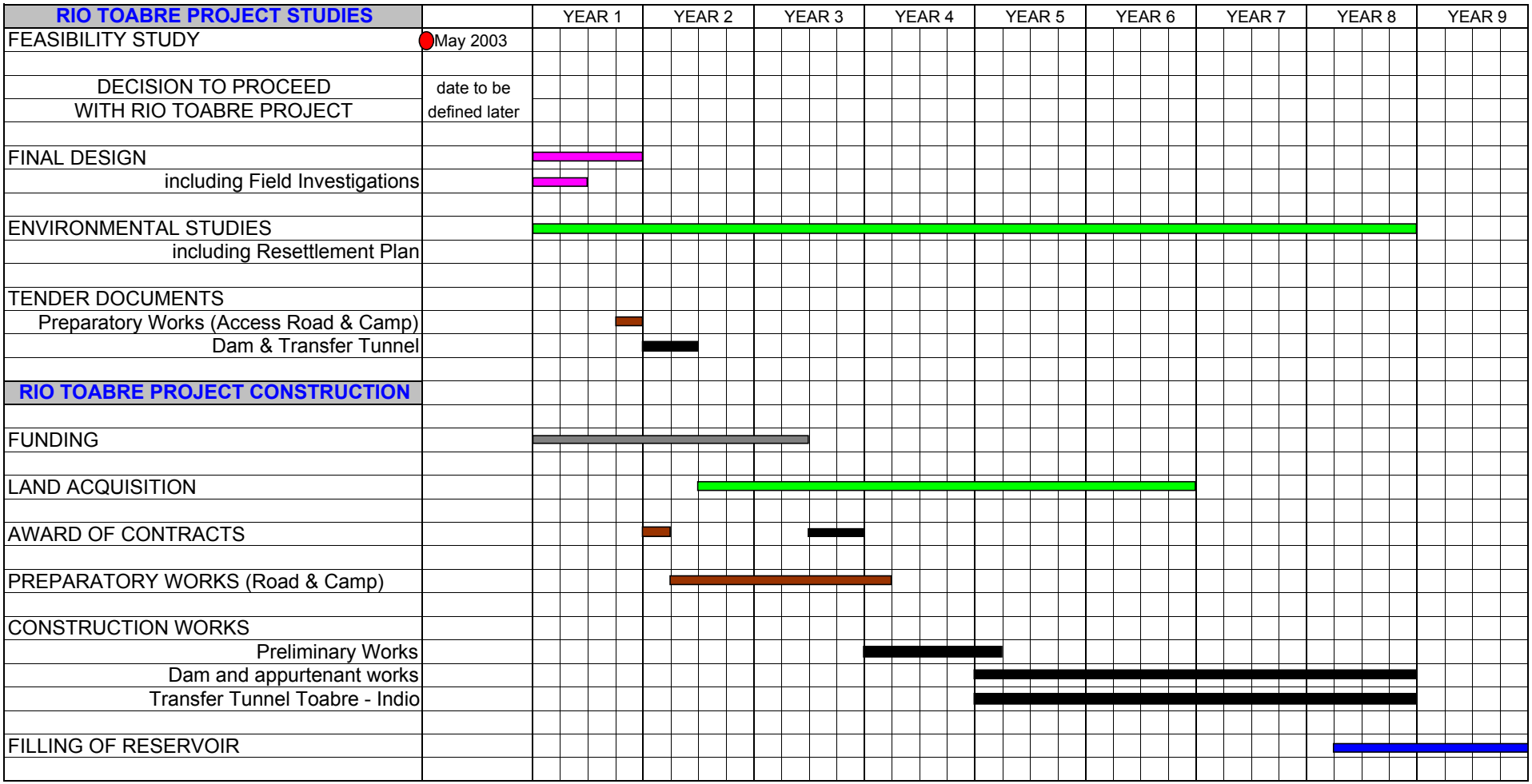
Date : MAY 2003	Drawn JMT	Check. JMV	Appr. JCO

COYNE ET BELLIER
Bureau d'Ingénieurs Conseils
GENNEVILLIERS - FRANCE

Project N°: 10932	Revision
No : F I G 0 5	B

Computer File : Fig-05-B.dwg

FIGURE 6 - IMPLEMENTATION SCHEDULE



ACP
AUTORIDAD DEL CANAL DE PANAMÁ

RIO TOABRE WATER TRANSFER PROJECT

Feasibility Study

FEASIBILITY REPORT

VOLUME IIA - TECHNICAL REPORT

SITE IDENTIFICATION AND SELECTION STUDY

COYNE ET BELLIER
Bureau d'Ingénieurs Conseils
PARIS - FRANCE

Ref 10932 RP 06 - June 2003

RIO TOABRE WATER TRANSFER PROJECT

Feasibility Study

FEASIBILITY REPORT

VOLUME II A

TECHNICAL REPORT
SITE IDENTIFICATION AND SELECTION

Report n° 10932 RP 06

C	June 2003	Final edition	JMV	JCO	JCO
B	May 2003	Pre-final edition	JMV	JCO	JCO
A	March 2003	First emission	JMV	JCO	JCO
Revision	**Date**	**Revision object**	**Redaction**	**Control**	**Approbation**

COYNE ET BELLIER
Bureau d'Ingénieurs Conseils

INTRODUCTION

INTRODUCTION

1. GENERAL CONTEXT OF THE STUDY

The Panama Canal Authority (ACP) is undertaking a Canal Capacity Study to evaluate the feasibility of upgrading current Canal infrastructures.

The **Rio Toabre Water Transfer Project** falls within this Canal infrastructures development with the purpose to increase sources of water supply for meeting the Post Panamax locks operation and the growing municipal and industrial water uses of the Metropolitan Area.

Under a contract signed February 2002, ACP assigned the firm Coyne et Bellier (COB) to carry out the engineering feasibility studies for the Rio Toabre water project as proposed by the Division of Canal Capacity Projects (IPC) and based on the Reconnaissance Study of this project accomplished in 1999 by the US Army Corps of Engineers.

Recently , ACP's Program Management and Technical Advisory Services (PMTAS) team, as part of an overall review of ACP's studies performed to date, has reviewed this Reconnaissance Report. The report states that the present Toabre site was selected to maximise reservoir size but does not document a site selection study.

ACP is completing data collection studies to serve as baselines for environmental and social impact assessments of the project, and to identify required mitigation. As part of the environmental impact assessment, a comparison of alternative courses of action will be performed. The PMTAS team has recommended that a site selection study is performed and documented as part of the feasibility study and to serve as the basis of an alternative analysis in the environmental impact analysis.

Under an additional contract signed December 2002, this Site Identification and Selection Study has been integrated in the current Feasibility Study performed by Coyne et Bellier, as proposed by the PMTAS.

2. SCOPE OF THE STUDY

According to the Terms of Reference established by ACP (Request for Quote n°SAA-28187, November 2002), the objective of the Site Identification & Selection Study is "to compare alternative dam and reservoir sites on the Rio Toabre that would provide quantities of water of similar order of magnitude to the dam site selected during the Reconnaissance Study".

This study comprises two main phases:

- **Part I : Screening Phase** including the following tasks:
  - identification and evaluation of sites alternatives
  - sites visit / technical meeting with ACP
  - selection of potential dam sites

- **Part II : Analysis Phase** : Prefeasibility Study on Selected Sites
  - preliminary layout / cost estimate
  - technical / cost comparison

This Volume II.A presents the contents and the conclusions of this Site Identification and Selection Study.

PART I – SCREENING PHASE

PART I – SCREENING PHASE

1. IDENTIFICATION & PRELIMINARY EVALUATION OF SITES ALTERNATIVES

1.1. Identification of sites alternatives

The “feasibility dam site” which is used as the reference site is the ACP’s site selected during the Reconnaissance study, with approximate geographical coordinates : 982 000 / 565 600 – 980 500 / 565 000. This site is named 'Site n°0' in the present study.

On the base of the best available 1/50 000 scale topographic maps, up to 11 additional dam sites have been identified. **Figure 1** presents the location of the 12 dam site alternatives, including the present reference site n°0.

The identified sites extent over 11.5 km on the Rio Toabre, from 4.5 km downstream (n°11) of the reference site n°0, to 7 km upstream (n°7). Four of the alternative sites (n°11, 10, 1 and 2) are located on Rio Toabre. Sites n°3, 4 and 5 encompass both Rio Toabre and Rio de “U”, while sites n°6 and n°7, both concerning Rio Toabre and Rio Tulù, are to be considered either separately or in conjunction with sites n°8 or 9 on Rio de “U”.

The most downstream site was selected as the farthest downstream site that could impound a economical reservoir linked to Indio Reservoir with a NWL at El. 80 masl. The most upstream site, already located upstream of the confluence with Rio de U allow to keep the control of the Rio Tulu catchment area. Moving farther upstream would significantly lessen the project yield.

Table 1 gives the coordinates of each sites and points out some particularities as 'location on two main rivers' or 'topographical limit above elevation Z' (need of saddles dams) etc.

1.2. Preliminary evaluation of sites alternatives

1.2.1. Yield of identified sites

The yield of each alternative sites (or combination of sites) has been evaluated with simulation calculations.

The simulations have been made with the COB software SIM, modelling the Toabre reservoir alone with two scenarios of water regulation, considering for each site the variation in storage capacity and for the inflows. This methodology is convenient for yield comparison at this stage of the study:

Period of simulation	1948-1999
Calculation step	Monthly
Inflows	1948-1999 Series *(Report ref. 10932 RP 04)* adjusted to the corresponding catchment area
Evaporation	Monthly Average Rate *(Report ref. 10932 RP 04)*
Height / Volume Reservoir curves	established for each site on the base of the 1/50 000 maps (planimetry of surfaces) - see **Figure 2**
Ecological flow	10% of annual average flow
Minimum Operating Level (MOL)	max of the criteria : El. 50 minimum (=+10 m / MOL Indio) Dead storage = 50 MCM (for 50 y to 100 y sedimentation)
Yield scenario D1 scenario D2	reliability of 99% (in volume) curve of Yield (Qr) vs. Reservoir NWL (*) for two scenarios: Annual Demand = Qr constant all the year Seasonal Demand= Qr constant from January to June

Note (*): the range of studied NWL starts from El. 80 masl, the NWL of Indio reservoir.

The data and the results are presented on **Table 2** and **Figures 3 and 4**.

It can be noticed that the more upstream identified sites n°6 or n°7 alone, i.e. without the corresponding inflow and storage capacity contribution of the Rio de U valley, cannot provide the same yield that the reference site n°0, even with high reservoir NWL.

1.2.2. Sites visit – Geological conditions

The project manager and the geologist of Coyne et Bellier visited the alternative sites with ACP's specialists on December 2002.

These visits, including the reference dam site n°0, allow to better appraise both technical and geological conditions of each site. A field mission memorandum, detailing the geological conditions of each alternative sites, is presented on **Appendix 1**.

The main conclusion of these visits is that both geological and technical conditions do not allow operating a clear discrimination between all the alternative sites, which will favour or eliminate any of the sites:

. no site appears to be significantly better than the others; dams of different heights and widths could be constructed at all of the alternative sites; only specific local topographical conditions should have a minor impact on the simple definition and integration of the spillway or the diversion works for particular sites.

. all the sites seem acceptable at this stage, but doubts persist as to the water tightness, abutment stability and overall foundation quality, which may result in more or less significant treatment for particular sites.

1.2.3. Preliminary estimation and comparison

On the base of the 1/50 000 scale topographic maps, preliminary estimation of the volume of a RCC dam (with total slope of 0.9H/1V and theoretically founded 10 m below the natural ground level, not significant at this stage) have been established for each sites.

A RCC dam, technically possible at all the identified sites, presents the advantage of a simple integration of the spillway and the diversion structures on its body, making the evaluation of the volume of the dam representative of the project works. The variations in the design of these structures from one site to another is then of minor importance.

RCC Dam volume of all the identified alternatives sites are presented on **Figure 5** for NWL 95, 105 and 115. For the sites n°3, 4, 5, 6 and 7 two different possible axis have been evaluated : downstream location (D) and upstream location (U).

Based on the analysis of these preliminary volumes it has been decided to retain only the eight following alternatives sites (or combination) for the more detailed screening phase: sites n°10, 0 (reference), 1, 2, 6D (alone), 7D (alone), 6D+8 (combination), 7D+8 (combination).

Indeed all the others sites appear to be significantly more expensive (higher volume) than the closer ones with quite similar yield: n°11 compare to n°10, n°3-4-5 compared to n°2, n°6U compared to n°6D, n°6+9 or n°7+9 compared to n°6+8 or n°7+8.

2. SELECTION OF SITES ALTERNATIVES

2.1. Screening criteria

The Feasibility Study, developed in parallel with the present Site Selection Study, shows that the optimal size of the Toabre reference reservoir would likely be between El. 95 masl and El. 100 masl with respective total volume of reservoir of 920 MCM and 1 130 MCM.

The reference reservoir sizing for the present screening phase has then been chosen at NWL 95 for site n°0. The corresponding reference yield are respectively 1 100 MCM/y for scenario D1 and 886 MCM/y scenario D2 (or respectively 14.5 additional lockages per day all the year and 23.5 additional lockages per day during 6 months).

Screening criteria has been developed in collaboration with ACP. The aim of these criteria is to guide the screening process in order to select the best site alternatives on the basis of the most favourable combination of technical, economical and environmental features for further comparison.

These criteria included:

- **Yield** comparison by the way of the Index : Site Yield / Reference Yield

  ➔ *as a first screening step it was decided to discard sites with index below 90% (i.e. priority to keep the same order of magnitude for the site yield)*

- **Cost** : evaluation of the Total Cost of each alternatives sites and comparison of the two following index : 'Total Cost / Yield Index ' and Total Cost / Reference Total Cost'

  the total cost includes construction cost and environmental costs and is considered with an accuracy around 15%

  ➔ *selection of sites alternatives with lower index within the accuracy of evaluation*

- **Environmental Impacts,** furnished by ACP

  ➔ *selection of site alternatives with lower impacts (both quantitative and qualitative)*

- **Technical consideration** (geological risk, construction constraints, etc)

  ➔ *selection of site alternatives with lowers risk or constraints*

Note : for each alternative sites, four different Normal Water Level has been screened.

In addition, ACP introduced a particular criteria related to the possible connection of the Toabre reservoir with the Cano Sucio reservoir, as designed in the Reconnaissance Study, and presently studied by others.

Indeed ACP is thinking about a possible development of Toabre reservoir into two steps:

- first stage: create the Toabre reservoir linked with the Cano Sucio reservoir, both reservoirs being linked by an open channel and operated above El. 90 masl. Such exploitation involves a shorter tunnel transfer to Indio reservoir (with a lower initial investment cost) but also a lower yield.

- second stage: according to the water demand increase, use of the lower part of the Toabre reservoir (under El. 90 masl), with the maximum yield, which requires the construction of the 17 km long transfer tunnel to Indio, this important investment cost being postponed until the date of the need of such yield.

This particular criteria, introduced during the study, is not satisfied for all alternatives with a NWL under El. 95 masl (or more probably El. 100 masl) and upstream sites (n°6 or 7, combined or not with n°8) with no easy topographical connection (open channel) between the two reservoirs.

2.2. Evaluation of sites alternatives

2.2.1. Technical considerations

➢ *Dam volume*

Based on the geological conditions established after the site visit, a rough estimation of the rock foundation level for a RCC dam has been drawn for each site alternatives. The general principle assumes a foundation 10 m below the natural ground level in the central part of the valley, and 15 m in the banks. But particular higher local foundation level has been considered in the central abutment of sites n°6 and 7.

As a result, more precise RCC dam volume has been estimated for each site alternatives at different NWL. The design of the RCC has a classical gravity section with a total slope of 0.9 H / 1 V founded on the above mentioned level and an 8 m wide crest at the elevation NWL + 5 m [(1)].

Tables 3 and Figure 6 present the evolution of the RCC dam volume vs. NWL for each alternative sites.

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(1) assuming a PMF control with a maximum of 5 m head, i.e. a free spillway around 250-300 m wide at NWL. Such a spillway wide is more difficult to locate in narrow sites as n°6 or n°7.

➢ ***Topographical and geological constraints***

Topographical limits or constraints of each alternative sites have been identified in § 1 and reported in **Table 1**. The following comments consider the impact of such features on the evaluation of the alternatives :

- in the range of the envisaged NWL for alternatives sites n°6 or 7 alone, saddle dams of significant volume will be required for NWL above El. 100 masl and must therefore be considered in the evaluation of these alternatives.

  an economical earthfill dam type has been selected to estimate the total volume of such saddle dam, as presented in **Table 3**.

- the alternative combination of sites n°6 or 7 with site n°8 requires some excavation works to connect the two valleys of Rio Toabre and Rio de U through the saddle at the El. 95 masl approximately (coordinates 979 500 / 572 300). This can be realised by the way of a wide open channel or a short tunnel.

- the alternative sites n°6 or 7 combined or not with site n°8 go across Rio Toabre, Rio Tulu (only n°7) and Rio de U (if combined with site n°8) in a narrow valley and will require multi diversion works which could represent a disadvantage in terms of organisation complexity, construction planning extension and civil works extra-cost.

Geological conditions of each alternative sites have been described in § 1 and reported in **Appendix A1**. The following comments consider the impact of such conditions on the evaluation of the alternatives :

- some doubts persist as to the watertightness of the central abutment of sites n°6 and 7, which may result in particular significant grouting treatment.

- in addition, an important reserve should be made about the long spur which form the left abutment of site n°6 (downstream axis) and which make the volume of the dam attractive : it could be not as favourable as expected and considered for the present evaluation. But it is proposed to continue with this optimistic assumption, keeping in mind that this site should be selected only if it allows a significant saving compared to the others alternatives.

➢ ***Transfer tunnel***

The transfer tunnel to Indio reservoir represents an important part of the total cost of the project. As the design of this transfer tunnel can differ from one site (with one NWL) to another it must be considered accordingly in the present site selection:

. the tunnel layout is identical for alternatives sites n°10, 0, 1 and 2; the alternative combination of sites n°6 or 7 with n°8 required a slight rotation of this layout to locate the inlet in the reservoir, but with the resulting same length of 17 km, while an adequate tunnel layout for sites n°6 or 7 alone involves the increase of the tunnel length of about 2 km (i.e. a total length of 19 km).

. the size (diameter) of this transfer tunnel is a function of the flow to transfer, i.e. the yield of the reservoir; as a preliminary design the concrete lined transfer tunnel is sized

to pass the flow corresponding to the yield obtained with the scenario demand D2 (highest flow) under a minimum head between the two reservoirs, variable upon the alternatives considered:

10 m minimum for sites n°10, 0 and 1 with a MOL at El. 50 masl;

for the others sites : head calculated as the minimum difference between the NWL or the MOL of Toabre and Indio reservoirs, and therefore variable with the considered alternatives, from 13 m (site n°2) to 26 m (site n°7).

The resulting tunnel length and diameter for each site alternatives are presented in **Table 3**.

2.2.2. Construction cost estimate

The RCC dam type has the advantage to concentrate all the appurtenant works within its body, making the total volume of RCC representative of the construction cost of the project.

Based on the cost estimate recently performed during the Dam Type Selection phase of the Feasibility study, a global overall unit price of 60 USD / m^3 of RCC dam (2) is considered to be representative of the construction cost of the project including the RCC itself, but also the excavations and all the conventional concrete structures.

Construction cost of the dam for each alternative sites have then been estimated by applying this rate to the above mentioned total volume of RCC dam.

The construction cost of the transfer tunnel has been calculated with a unit price of 50 USD/m^3 for the tunnelling excavations and 350 USD/m^3 of concrete lining (50 cm thick) applied to the estimated quantities.

In addition, the following particular items has been considered in the total project cost:

. saddle dam required for the alternatives with sites n°6 and 7 alone, estimated with a global unit price of 10 USD/m^3 of fill,

. contingency of 10% of the dam cost for constraints of diversion works for alternatives sites n°6 and 7 combined or not with site n°8,

. contingency of 5% of the dam cost for particular significant grouting treatment anticipated for alternatives sites n°6 and 7,

. contingency of 5% of the dam cost for connection works of site reservoir n°8 with site reservoirs n°6 or 7,

The resulting global project costs are detailed in **Table 4**.

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(2) recall : with a unit price of 40 USD/m3 of RCC itself

2.2.3. Environmental Impacts

As needed for this study, ACP performed an environmental impacts study and provided information for 6 different elevations at each site alternatives, within the range of envisaged NWL [3]. 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

The informations are issued from 'Estudios Socioeconomicos Irg-Dames – Moore', 'Estudios Socioambiantales – Consultora Louis Berger' and ACP 'Unidad de Sensores Remotos'. Units prices used for the cost estimate have been established by ACP (ESM & IPC).

These informations focus on the negative impacts, which differ from one site (with one NWL) to another. Positive impacts (as social and technical development of these remote and isolated areas, opening up etc) have not been considered to be significantly different for each site and were not considered for this site comparison phase.

The rough data tables provided by ACP (quantities and corresponding costs) are given in **Appendix 2** (in Spanish) while the main elements of this environmental impacts evaluation for each site alternatives [4] are resumed and discussed in § 2.3.

It is worthwhile to notice that the population is more concentrated in the upper upstream part of the reservoir. This situation is likely historically linked to the fact that the only access of this region is from the Pacific side, increased by the poor development of access down to the Caribbean side from Tambo (or San Miguel).

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(3) the elevation considered for the impacts evaluation of each alternative (site / NWL) is NWL + 5 m (considering the flood storage capacity)

(4) the evaluation for sites (6+8) and (7+8) at El. 125 and sites n°6 and 7 alone have been issued by Coyne et Bellier from the available information provided by ACP

2.3. Screening of sites alternatives

Table 5 synthesises all the pertinent data and main results of each alternative sites for comparison in terms of yield, costs, environmental impacts and technical considerations.

All the main parameter (yield, costs, population, etc.) are compared with the reference site n°0 with NWL 95 in the form of a ratio expressed in percentage (100% for reference site). The Total Cost considered in this table includes the Project cost (cf. § 2.2.2) and the Environmental cost (cf. § 2.2.3).

In addition, **Figures 7 to 11** illustrate some of these results.

The following Table focus on sites n°10, 0, 1 and 6+8 at selected NWL:

Alternative Site		**n°10**		**n°0 (ref)**		**n°1**		**n°6+8**	
Normal Water Level (NWL)	**masl**	**90**	**95**	**95**	**100**	**95**	**100**	**110**	**115**
Yield D1	**MCM/y**	**1115**	**1149**	**1100**	**1131**	**1071**	**1105**	**1022**	**1061**
Yield D1 Ratio / n°0 NWL 95		101%	104%	**100%**	103%	97%	101%	93%	96%
Yield D2	**MCM/y**	**881**	**990**	**886**	**991**	**841**	**948**	**794**	**913**
Yield D2 Ratio / n°0 NWL 95		99%	112%	**100%**	112%	95%	107%	90%	103%
Affected Population	**people**	**1248**	**1448**	**1345**	**1601**	**1324**	**1580**	**1717**	**2612**
ratio / n°0 NWL 95		93%	108%	**100%**	119%	98%	117%	128%	194%
Affected Area	**ha**	**6010**	**6700**	**5350**	**6000**	**5080**	**5650**	**4546**	**6325**
ratio / n°0 NWL 95		112%	125%	**100%**	112%	95%	106%	85%	118%
Total Cost (Project + Environment)	**MUSD**	**266**	**306**	**254**	**284**	**263**	**298**	**234**	**278**
Total Cost Ratio / n°0 NWL 95		105%	121%	**100%**	112%	103%	117%	92%	109%
Total Cost / Yield D1 Index		239	266	**231**	251	245	270	229	262
Total Cost / Yield D2 Index		302	309	**286**	286	312	314	295	304
Connexion with Cano Sucio Reservoir 90	**Y/N**	**N**	**Y**	**Y**	**Y**	**Y**	**Y**	**N**	**N**

The analysis of the ratio and index presented in these synthetic tables and shown on the figures provides the following comments:

- for all the alternatives sites, the optimum sizing (optimal NWL) of the reservoir depends on the choice of the scenario D1 or D2 for the definition of the yield : with D2 it appears that the minimum of the cost / yield (D2) index (i.e. the optimal sizing or development of the project) falls within the range of envisaged NWL (see Figure 8), while the minimum of this index with D1 is for lower (not envisaged) NWL (see Figure 7).

  for the present screening process, preference is given to the yield corresponding to the scenario D2 for the comparison of the alternative sites.

  in addition it can be stated from Figure 8 that the cost / yield (D2) index of the reference site n°0 at NWL 95 is always below the index of all the others alternative sites, making this site probably the best one, even before considering any environmental qualitative impacts.

- none alternative sites can be considered as significantly competitive with the reference site n°0 to provide the same yield (curve of site n°0 always below the others curves in Figures 9 and 10).

  nevertheless, within the range of accuracy of the evaluations, it can be considered that alternative sites n°10 (at NWL 90) and n°1 (at NWL 98) could represent some competitive alternative to the reference site (at NWL 95): similar yield (specially D2) with slightly greater total cost (and cost / yield index) and quite similar environmental impacts and technical conditions;

- site n°2 (at NWL 103) is judged not competitive because of its higher cost (curve above the upper line of equivalence of Figures 9 and 10), cost/yield index and environmental impacts for similar yield;

- in the range of the acceptable yield (D2) ratio (above 90%) the upstream combination of sites n°6+8 should be designed with a NWL above El. 115 masl approximately which presents quite the same cost (increase inferior to +10%) but affects a significantly larger number of population (nearly double, see Figure 11); this point, in addition of the technical reserves pointed out for the site n°6, make this alternative not competitive.

  the alternative combination with site n°7 is more expansive with more or less the same drawback in terms of population affected and technical constraints.

- the alternative sites n°6 or 7 alone don't allow to provide the same yield than the reference site n°0 (max = 80% of yield D1 and 95% of yield D2) and should then be designed with a NWL above El. 120 masl associated with significantly more important qualitative environmental impacts for quite the same total cost.

3. CONCLUSIONS AND RECOMMENDATIONS FOR ANALYSIS PHASE

The screening process performed with the yield, cost, environmental and technical criteria agreed with ACP shows that none alternative sites appears to be better that the reference site. Nevertheless it can be stated that the sites n°10 (downstream) and n°1 (just upstream) present quite similar value or characteristic for the main concerns to be considered as competitive with the reference site.

In addition it must be considered that the geological conditions which may be revealed during the additional survey of any of these three sites could reverse (or reduce) this favourable comparison for the reference site.

Taken into account the possible future development of the Toabre reservoir linked with the initial development of the Cano Sucio reservoir operated above El. 90 masl, it is proposed to **select only the alternative site n°1 for the analysis phase**, with a design given the same yield as the reference site at NWL 95.

TABLE 1 – Identified Alternatives Sites

Alternative site	coordinates (river) village name	Location on river	Topographical Limit Saddles
11	982 700 - 562 200	Rio Toabre	saddle between basins of Rio de U and Cano Sucio at El. 100 masl + saddle in Toabre reservoir on Left bank at El. 105 masl approx.
10	982 400563 100 Los Ticocles	Rio Toabre	
0 reference	**981 600 – 565 500 San Vicente**	Rio Toabre	
1	981 600 – 566 600 Santa Elena	Rio Toabre	saddle between basins of Rio de U and Cano Sucio at El. 100 masl
2	981 600 – 567 900 San Isidro	Rio Toabre	
3	981 100 - 568 700 San Isidro E	Rio Toabre + Rio de U	
4	980 700 – 568 900 La Tomasa N	Rio Toabre + Rio de U	
5	980 500 – 569 400 La Tomasa S	Rio Toabre + Rio de U	
6	979 500 - 569 600 Boca de Tulu	Rio Toabre (+ Rio Tulu)	saddles between basins of Rio Toabre and Rio de U at El. 100 masl and El. 120 approx.
7	978 500 - 569 700 El Guayabo	Rio Toabre + Rio Tulu	
8	980 100 - 572 400	Rio de U	saddle between basins of Rio de U and Cano Sucio above El. 120 masl approx.
9	981 000 – 571 600 Boca de la Entradata	Rio de U	saddle between basins of Rio de U and Cano Sucio at El. 100 masl and El. 120 masl approx.

TABLE 2 – Hydrological Data and Yield of Alternatives Sites

	Site	n°10_11	n°0	n°1	n°2	n°3_4_5	n°6_7+8	n°6_7
Catchment area	km²	737	**727**	720	710	708	700	595
Annual inflow	MCM/y	1315	**1288**	1267	1237	1230	1214	994
MOL	masl	50	**50**	50	53	66	66	67
Yield with scenario D1 (constant all the year) : Qr (MCM/y) with volumetric reliability 99%								
NWL								
80		1000	**912**	871	768	709		
85		1067	**996**	959	858	800	594	499
90		1115	**1058**	1025	941	892	682	575
95		1149	**1100**	1071	1004	971	781	659
100		1166	**1131**	1105	1049	1025	883	741
105		1168	**1144**	1123	1082	1064	967	805
110		1168	**1144**	1125	1097	1088	1022	846
115		1168	**1144**	1125	1098	1092	1061	874
120					1098	1092	1078	883
125							1078	883
Yield with scenario D2 (constant 6 months) : Qr (MCM/y) with volumetric reliability 99%								
NWL								
80		648	**551**	515	421	370		
85		764	**659**	618	510	454	276	237
90		881	**772**	728	610	551	349	301
95		990	**886**	841	718	659	439	379
100		1077	**991**	948	831	775	547	470
105		1130	**1067**	1034	937	889	667	572
110		1151	**1115**	1086	1020	986	794	677
115		1151	**1127**	1109	1067	1047	913	771
120		1151	**1127**	1109	1082	1076	1000	834
125							1052	867

Note : Theoretical yield with saddles dams as required

TABLE 3 – Project main quantities of alternatives sites

I. RCC Dam Volume in m3 (founded on assumed bedrock)

NWL / Site Crest El.	n°10	n°0	n°1	n°2	n°6+8	n°7+8	n°6	n°7
80	85	1 802 830	1 435 699	1 383 316	1 319 855	514 241	736 132	349 108	570 998
85	90	2 164 391	1 692 017	1 702 670	1 637 531	664 571	936 309	442 683	714 421
90	95	2 576 014	1 979 565	2 064 623	2 000 860	845 184	1 166 773	555 066	876 656
95	100	3 039 388	**2 300 458**	2 480 014	2 411 123	1 066 381	1 431 799	695 929	1 061 346
100	105	3 556 199	2 656 540	2 951 407	2 868 727	1 337 205	1 759 804	851 290	1 273 889
105	110	4 139 265	3 064 451	3 504 396	3 382 868	1 635 833	2 111 274	1 033 650	1 509 091
110	115				3 944 937	1 988 461	2 515 505	1 244 136	1 771 180
115	120					2 397 338	2 974 637	1 483 872	2 061 170
120	125					2 864 716	3 490 806	1 753 983	2 380 072

II. Saddle Dam (earthfill section) required for alternatives sites n°6 and 7 alone

NWL	Crest Elevation	Volume (m^3)
100	105	150 000
105	110	250 000
110	115	450 000
115	120	700 000
120	125	1 050 000

III. Transfer Tunnel to Indio reservoir

Site	n°10	n°0	n°1	n°2	n°6_7+8	n°6_7
Length (km)	17	**17**	17	17	17	19
Diameter of concrete lined tunnel (m) (calculated on the basis on the Yield with scenario D2)						
NWL						
85	6.20					
90	5.75	5.50	5.35			
95	6.00	**5.75**	5.65	5.10		
100	6.20	6.00	5.90	5.35	4.25	4.10
105		6.20	6.10	5.60	4.45	4.30
110				5.80	4.65	4.50
115					4.90	4.60
120					5.05	4.85

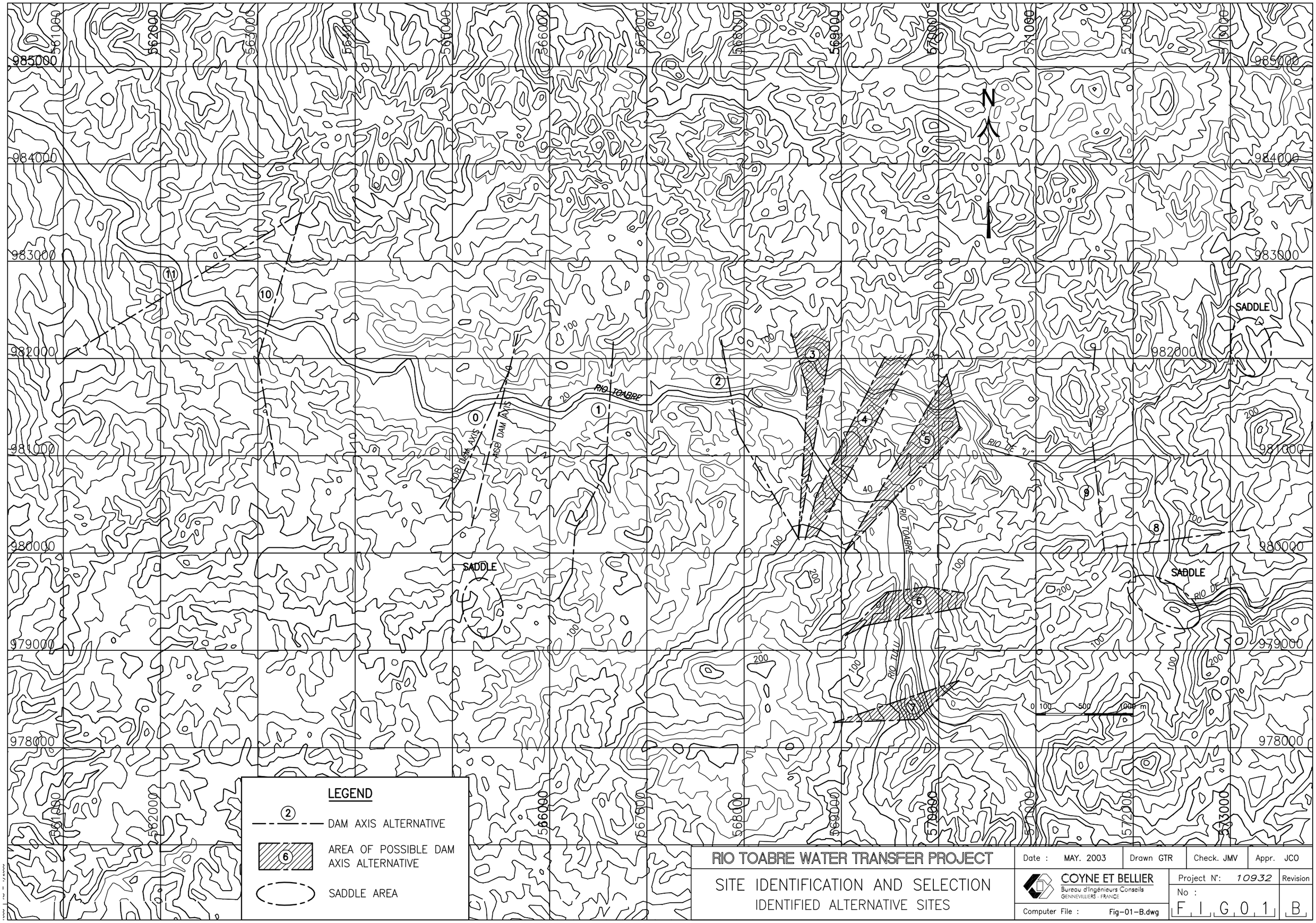
TABLE 4 – Project cost of alternatives sites

		DAM SITE	n°0				n°10				n°1				n°2			
NWL	**masl**		**90**	**95**	**100**	**105**	**85**	**90**	**95**	**100**	**90**	**95**	**100**	**105**	**95**	**100**	**105**	**110**
Crest elevation	masl		95	**100**	105	110	90	95	100	105	95	100	105	110	100	105	110	115
Volume of dam (RCC)	MCM		2,00	**2,30**	2,65	3,05	2,15	2,60	3,05	3,55	2,05	2,50	2,95	3,50	2,40	2,90	3,40	3,95
Volume of saddle dam (earthfill)	MCM																	
Tunnel length	km		17	**17**	17	17	17	17	17	17	17	17	17	17	17	17	17	17
Tunnel diameter	m		5,50	**5,75**	6,00	6,20	6,20	5,75	6,00	6,20	5,35	5,65	5,90	6,10	5,10	5,35	5,60	5,80
COST		unit cost USD/m3																
DAM																		
Dam	MUSD	60	120	**138**	159	183	129	156	183	213	123	150	177	210	144	174	204	237
Contingencies	MUSD																	
Diversion works (sites n° 6, 7, 8)		10%																
Grouting treatment (sites n° 6 & 7)		5%																
Reservoir connection works (site n° 8)		5%																
Saddle dams (sites n° 6 & 7)	MUSD	10																
Total dams	***MUSD***		***120***	***138***	***159***	***183***	***129***	***156***	***183***	***213***	***123***	***150***	***177***	***210***	***144***	***174***	***204***	***237***
TRANSFER TUNNEL																		
Tunnelling	MUSD	50	28	**30**	33	35	35	30	33	35	27	30	32	34	25	27	29	31
Concrete	MUSD	350	56	**58**	61	63	63	58	61	63	55	57	60	62	52	55	57	59
Total tunnel	***MUSD***		***84***	***89***	***93***	***97***	***97***	***89***	***93***	***97***	***82***	***87***	***92***	***95***	***77***	***82***	***86***	***90***
TOTAL PROJECT	**MUSD**		**204**	**227**	**252**	**280**	**226**	**245**	**276**	**310**	**205**	**237**	**269**	**305**	**221**	**256**	**290**	**327**

		DAM SITE	n°6+8				n°7+8				n°6				n°7			
NWL	**masl**		**100**	**110**	**115**	**120**	**100**	**110**	**115**	**120**	**100**	**110**	**115**	**120**	**100**	**110**	**115**	**120**
Crest elevation	masl		105	115	120	125	105	115	120	125	105	115	120	125	105	115	120	125
Volume of dam (RCC)	MCM		1,35	2,00	2,40	2,90	1,75	2,50	3,00	3,50	0,85	1,25	1,50	1,75	1,30	1,80	2,10	2,40
Volume of saddle dam (earthfill)	MCM										0,15	0,45	0,70	1,05	0,15	0,45	0,70	1,05
Tunnel length	km		17	17	17	17	17	17	17	17	19	19	19	19	19	19	19	19
Tunnel diameter	m		4,25	4,65	4,90	5,05	4,25	4,65	4,90	5,05	4,10	4,50	4,60	4,85	4,10	4,50	4,60	4,85
COST		unit cost USD/m3																
DAM																		
Dam	MUSD	60	81	120	144	174	105	150	180	210	51	75	90	105	78	108	126	144
Contingencies	MUSD																	
Diversion works (sites n° 6, 7, 8)		10%	8	12	14	17	11	15	18	21	5	8	9	11	8	11	13	14
Grouting treatment (sites n° 6 & 7)		5%	3	4	5	5	4	5	6	7	3	4	5	5	4	5	6	7
Reservoir connection works (site n° 8)		5%	2	2	3	3	1	2	3	3								
Saddle dams (sites n° 6 & 7)	MUSD	10									1,5	4,5	7,0	10,5	1,5	4,5	7,0	10,5
Total dams	***MUSD***		***93***	***138***	***166***	***200***	***121***	***173***	***207***	***242***	***60***	***91***	***111***	***131***	***91***	***129***	***152***	***176***
TRANSFER TUNNEL																		
Tunnelling	MUSD	50	18	21	23	24	18	21	23	24	19	23	23	26	19	23	23	26
Concrete	MUSD	350	44	48	50	52	44	48	50	52	48	52	53	56	48	52	53	56
Total tunnel	***MUSD***		***63***	***69***	***74***	***76***	***63***	***69***	***74***	***76***	***67***	***75***	***77***	***81***	***67***	***75***	***77***	***81***
TOTAL PROJECT	**MUSD**		**156**	**207**	**239**	**276**	**184**	**242**	**281**	**318**	**128**	**166**	**187**	**213**	**159**	**203**	**229**	**257**

TABLE 5 - SYNTHETIC TABLE FOR SCREENING PROCESS

DAM SITE		**n°0 (reference)**				**n°10**				**n°1**				**n°2**				**n°6+8**				**n°7+8**				**n°6**				**n°7**			
Catchment Area	km²		**727**			737				720				710				700				700				595				595			
Annual Inflow (AI)	MCM/y		**1 288**			1 315				1 267				1 237				1 214				1 214				994				994			
Ratio Inflow / site n°0			**100%**			102%				98%				96%				94%				94%				77%				77%			
PMF	m3/s		**9 510**			9 560				9 475				9 420				9 370				9 370				8 790				8 790			
River Elevation	masl		**18**			16				19				20				30				35				30				35			
Normal Water Level (NWL)	**masl**	**90**	**95**	**100**	**105**	**85**	**90**	**95**	**100**	**90**	**95**	**100**	**105**	**95**	**100**	**105**	**110**	**100**	**110**	**115**	**120**	**100**	**110**	**115**	**120**	**100**	**110**	**115**	**120**	**100**	**110**	**115**	**120**
Maximum Water Level (MWL)	masl	95	**100**	105	110	90	95	100	105	95	100	105	110	100	105	110	115	105	115	120	125	105	115	120	125	105	115	120	125	105	115	120	125
Minimum Operating Level (MOL)	masl	50	**50**	50	50	50	50	50	50	50	50	50	50	53	53	53	53	66	66	66	66	66	66	66	66	67	67	67	67	67	67	67	67
Reservoir Surface at NWL	km²	32	**39**	46	55	32	38	45	53	30	36	43	51	30	37	45	53	26	40	48	58	26	40	48	58	22	35	42	50	22	35	42	50
Reservoir Capacity at NWL	MCM	740	**920**	1 130	1 385	780	950	1 160	1 400	675	840	1 040	1 275	665	835	1 035	1 280	460	785	1 000	1 270	460	785	1 000	1 270	410	695	885	1 115	410	695	885	1 115
Active Storage (AC)	MCM	675	**850**	1 065	1 315	655	830	1 035	1 280	620	785	985	1 220	615	785	985	1 230	410	735	950	1 220	410	735	950	1 220	360	645	835	1 065	360	645	835	1 065
AC/AI		0,5	**0,7**	0,8	1,0	0,5	0,6	0,8	1,0	0,5	0,6	0,8	1,0	0,5	0,6	0,8	1,0	0,3	0,6	0,8	1,0	0,3	0,6	0,8	1,0	0,4	0,6	0,8	1,1	0,4	0,6	0,8	1,1
Height of dam (above river bed)	m	77	**82**	87	92	74	79	84	89	76	81	86	91	80	85	90	95	75	85	90	95	70	80	85	90	75	85	90	95	70	80	85	90
Length of dam crest	m	1 460	**1 520**	1 600	2 000	2 225	2 300	2 375	2 450	2 375	2 500	2 620	3 000	2 115	2 150	2 350	2 450	2 300	2 500	2 600	2 700	2 250	2 440	2 535	2 630	1 200	1 300	1 350	1 400	1 150	1 240	1 285	1 330
Volume of dams (RCC)	MCM	2,00	**2,30**	2,65	3,05	2,15	2,60	3,05	3,55	2,05	2,50	2,95	3,50	2,40	2,90	3,40	3,95	1,35	2,00	2,40	2,90	1,75	2,50	3,00	3,50	0,85	1,25	1,50	1,75	1,30	1,80	2,10	2,40
Transfer Tunnel length	km	17	**17**	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	19	19	19	19	19	19	19	19
Transfer Tunnel diameter (base D2)	m	5,50	**5,75**	6,00	6,20	6,20	5,75	6,00	6,20	5,35	5,65	5,90	6,10	5,10	5,35	5,60	5,80	4,25	4,65	4,90	5,05	4,25	4,65	4,90	5,05	4,10	4,50	4,60	4,85	4,10	4,50	4,60	4,85
Project Cost (dams + tunnel)	**MUSD**	**204**	**227**	**252**	**280**	**226**	**245**	**276**	**310**	**205**	**237**	**269**	**305**	**221**	**256**	**290**	**327**	**156**	**207**	**239**	**276**	**184**	**242**	**281**	**318**	**128**	**166**	**187**	**213**	**159**	**203**	**229**	**257**
Project Cost ratio / n°0 NWL 95		90%	**100%**	111%	124%	100%	108%	122%	137%	90%	104%	118%	135%	98%	113%	128%	144%	69%	91%	106%	122%	81%	107%	124%	140%	56%	73%	83%	94%	70%	90%	101%	114%
Yield D1	**MCM/y**	**1058**	**1100**	**1131**	**1144**	**1067**	**1115**	**1149**	**1166**	**1025**	**1071**	**1105**	**1123**	**1004**	**1049**	**1082**	**1097**	**883**	**1022**	**1061**	**1078**	**883**	**1022**	**1061**	**1078**	**741**	**846**	**874**	**883**	**741**	**846**	**874**	**883**
Yield D1 Ratio / n°0 NWL 95		96%	**100%**	103%	104%	97%	101%	104%	106%	93%	97%	101%	102%	91%	95%	98%	100%	80%	93%	96%	98%	80%	93%	96%	98%	67%	77%	79%	80%	67%	77%	79%	80%
Yield D2	**MCM/y**	**772**	**886**	**991**	**1 067**	**764**	**881**	**990**	**1 077**	**728**	**841**	**948**	**1 034**	**718**	**831**	**937**	**1 020**	**547**	**794**	**913**	**1 000**	**547**	**794**	**913**	**1 000**	**470**	**677**	**771**	**834**	**470**	**677**	**771**	**834**
Yield D2 Ratio / n°0 NWL 95		87%	**100%**	112%	120%	86%	99%	112%	122%	82%	95%	107%	117%	81%	94%	106%	115%	62%	90%	103%	113%	62%	90%	103%	113%	53%	76%	87%	94%	53%	76%	87%	94%
Environmental Impacts (negative)																																	
affected population	people	1145	**1345**	1601	1918	1248	1248	1448	1704	1131	1324	1580	1897	1218	1474	1791	2098	1109	1717	2612	*2612*	994	1602	2497	*2497*	1109	1717	2529	2529	994	1602	2414	2414
ratio / n°0 NWL 95		85%	**100%**	119%	143%	93%	93%	108%	127%	84%	98%	117%	141%	91%	110%	133%	156%	82%	128%	194%	194%	74%	119%	186%	186%	82%	128%	188%	188%	74%	119%	179%	179%
affected village	unit	15	**21**	21	25	16	18	24	27	14	19	19	23	18	18	22	24	12	17	21	21	11	16	20	20	12	17	19	19	11	16	18	18
ratio / n°0 NWL 95		71%	**100%**	100%	119%	76%	86%	114%	129%	67%	90%	90%	110%	86%	86%	105%	114%	57%	81%	100%	100%	52%	76%	95%	95%	57%	81%	90%	90%	52%	76%	86%	86%
affected area	ha	3425	**5350**	6000	6620	4010	6010	6700	7350	3190	5080	5650	6260	4430	4940	5520	5965	3650	4546	6325	7465	3490	4380	6155	7265	3175	3955	5500	6500	3040	3810	5355	6320
ratio / n°0 NWL 95		64%	**100%**	112%	124%	75%	112%	125%	137%	60%	95%	106%	117%	83%	92%	103%	111%	68%	85%	118%	140%	65%	82%	115%	136%	59%	74%	103%	121%	57%	71%	100%	118%
Environmental Cost	**MUSD**	**19**	**27**	**31**	**35**	**20**	**22**	**30**	**34**	**18**	**26**	**29**	**34**	**23**	**27**	**31**	**34**	**20**	**27**	**38**	**42**	**19**	**26**	**38**	**42**	**19**	**25**	**35**	**38**	**18**	**24**	**35**	**38**
Environmental Cost ratio / n°0 NWL 95		70%	**100%**	115%	130%	73%	80%	109%	126%	66%	95%	109%	126%	86%	99%	115%	126%	74%	100%	142%	156%	70%	96%	141%	154%	70%	93%	130%	142%	67%	89%	129%	140%
Total Cost (Project+Environment)	**MUSD**	**223**	**254**	**284**	**315**	**246**	**266**	**306**	**344**	**222**	**263**	**298**	**339**	**244**	**282**	**321**	**361**	**176**	**234**	**278**	**318**	**203**	**268**	**319**	**359**	**147**	**191**	**222**	**251**	**177**	**227**	**263**	**295**
Total Cost Ratio / n°0 NWL 95		88%	**100%**	112%	124%	97%	105%	121%	136%	88%	103%	117%	134%	96%	111%	127%	142%	69%	92%	109%	125%	80%	106%	126%	142%	58%	75%	88%	99%	70%	90%	104%	116%
Total Cost / Yield D1 Index		211	**231**	251	276	230	239	266	295	217	245	270	302	243	269	297	329	199	229	262	295	229	262	300	333	198	225	254	284	238	269	301	335
Total Cost/Yield D1 Index Ratio / n°0 NWL 95		91%	**100%**	109%	119%	100%	104%	115%	128%	94%	106%	117%	131%	105%	117%	129%	143%	86%	99%	113%	128%	99%	114%	130%	144%	86%	98%	110%	123%	103%	116%	131%	145%
Total Cost / Yield D2 Index		289	**286**	286	295	322	302	309	320	306	312	314	328	340	340	343	354	322	295	304	318	370	337	349	359	312	281	288	301	376	336	342	354
Total Cost/Yield D2 Index Ratio / n°0 NWL 95		101%	**100%**	100%	103%	112%	106%	108%	112%	107%	109%	110%	115%	119%	119%	120%	123%	112%	103%	106%	111%	129%	118%	122%	125%	109%	98%	101%	105%	131%	117%	119%	124%
Technical Comments (negative)																		multi diversion works topographical & geological reserve on left abutment n°6 grouting treatment site n°6 reservoirs connexion works				multi diversion works grouting treatment site n°7 reservoirs connexion works				topographical & geological reserve on left abutment n°6 grouting treatment saddle dams				multi diversion works grouting treatment saddle dams			
Connexion with Cano Sucio Reservoir 90	Y/N	N	**Y**	Y	Y	N	N	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
DECISION for Analysis Phase	Y/N	N	**Y**	**Y**	N	N	N	N	N	N	**Y**	**Y**	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N

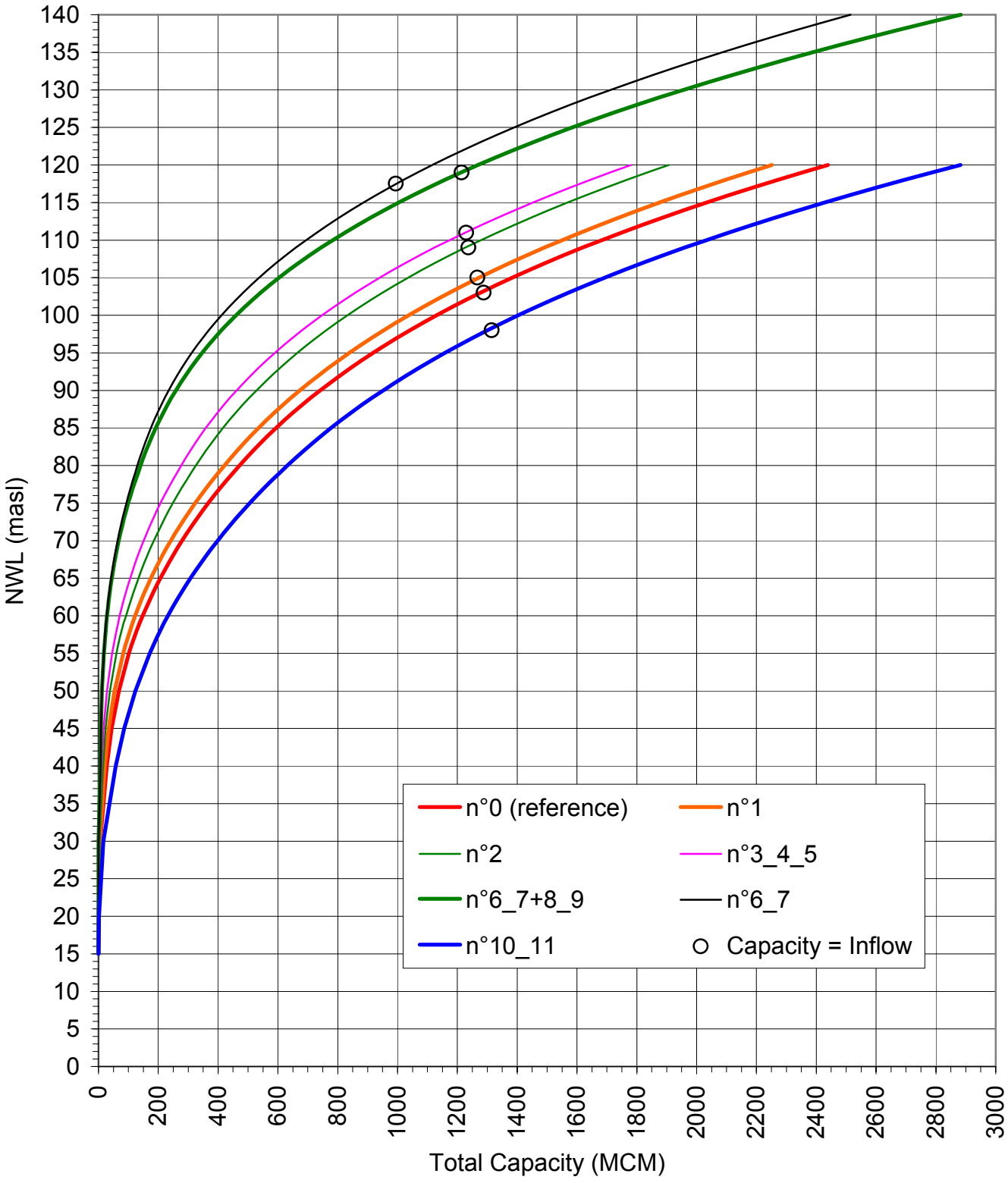


RIO TOABRE WATER TRANSFER PROJECT

SITE IDENTIFICATION AND SELECTION
IDENTIFIED ALTERNATIVE SITES

Date : MAY. 2003	Drawn GTR	Check. JMV	Appr. JCO
COYNE ET BELLIER Bureau d'Ingénieurs Conseils GENNEVILLIERS - FRANCE	Project N°: 10932		Revision
Computer File : Fig-01-B.dwg	No : FIG01		B

FIGURE 2 - Height / Volume Reservoir of Alternatives Sites



Note : Capacity established with saddle dams as required

FIGURE 3 - Yield (Scenario D1) of Alternatives Sites vs. NWL

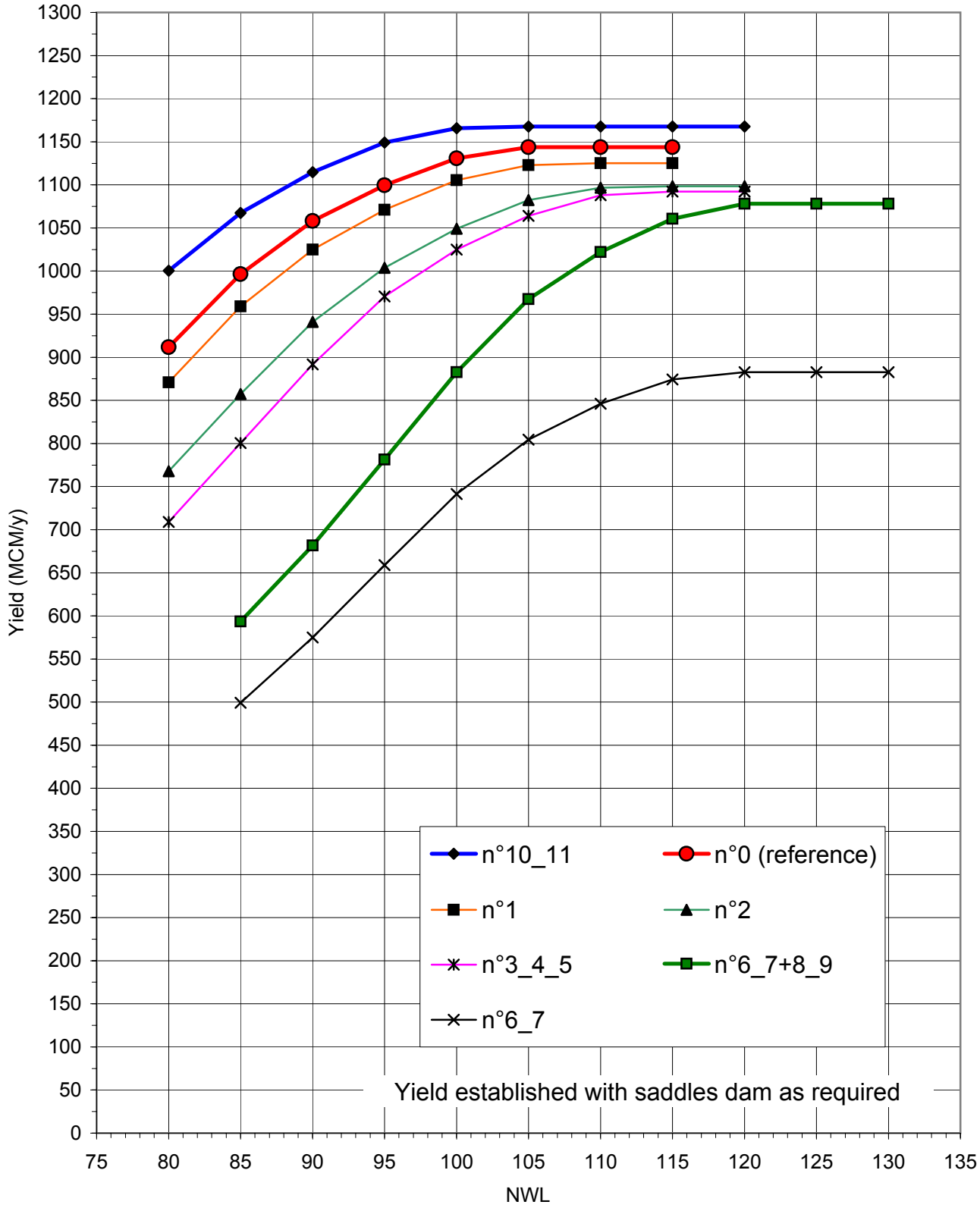


FIGURE 4 - Yield (Scenario D2) of Alternatives Sites vs. NWL

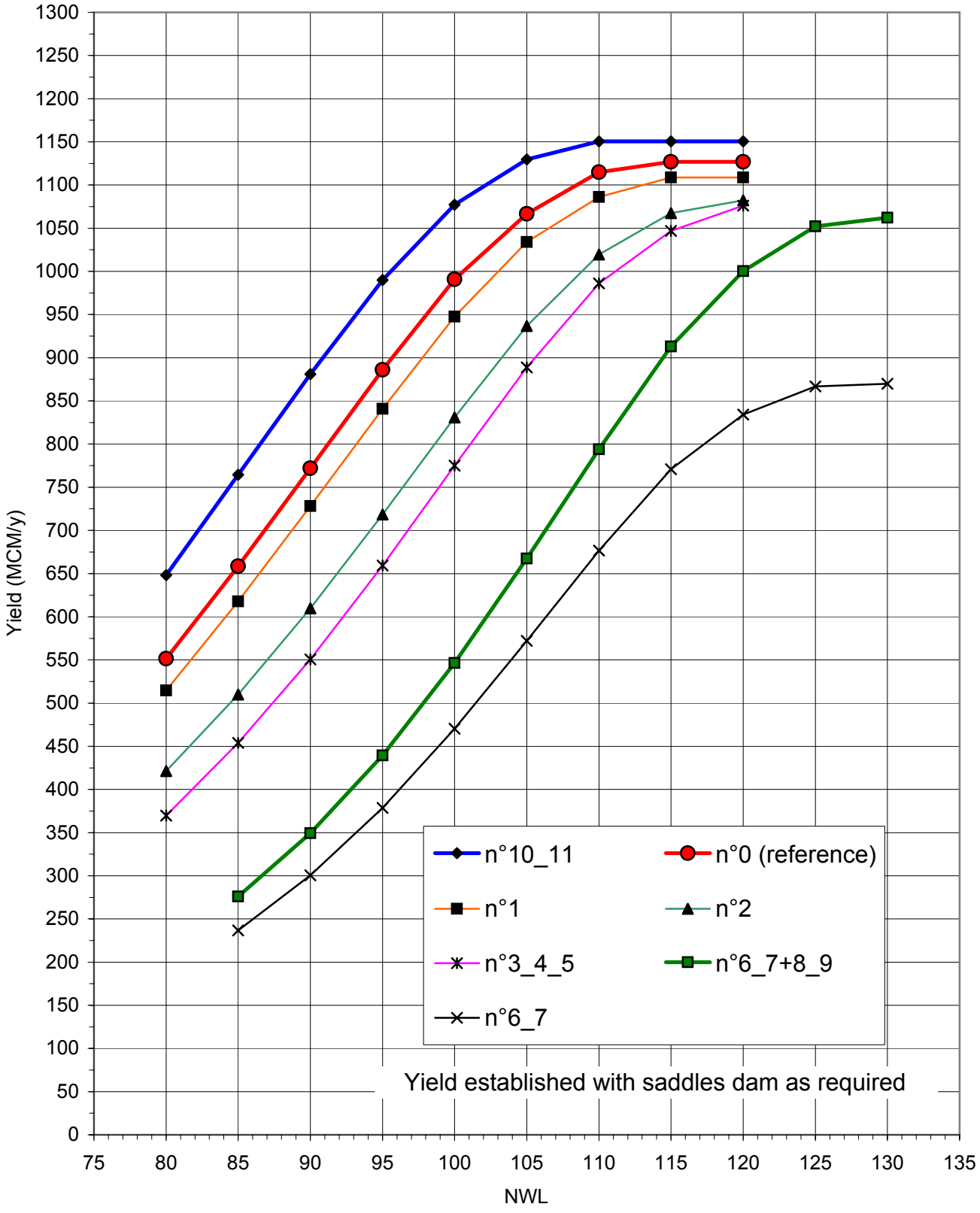
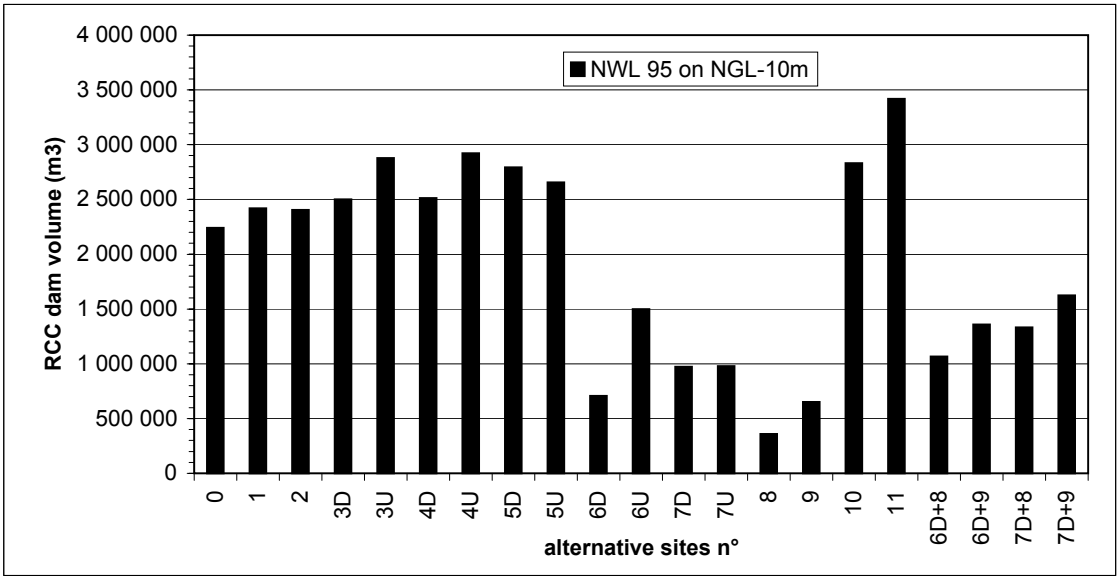
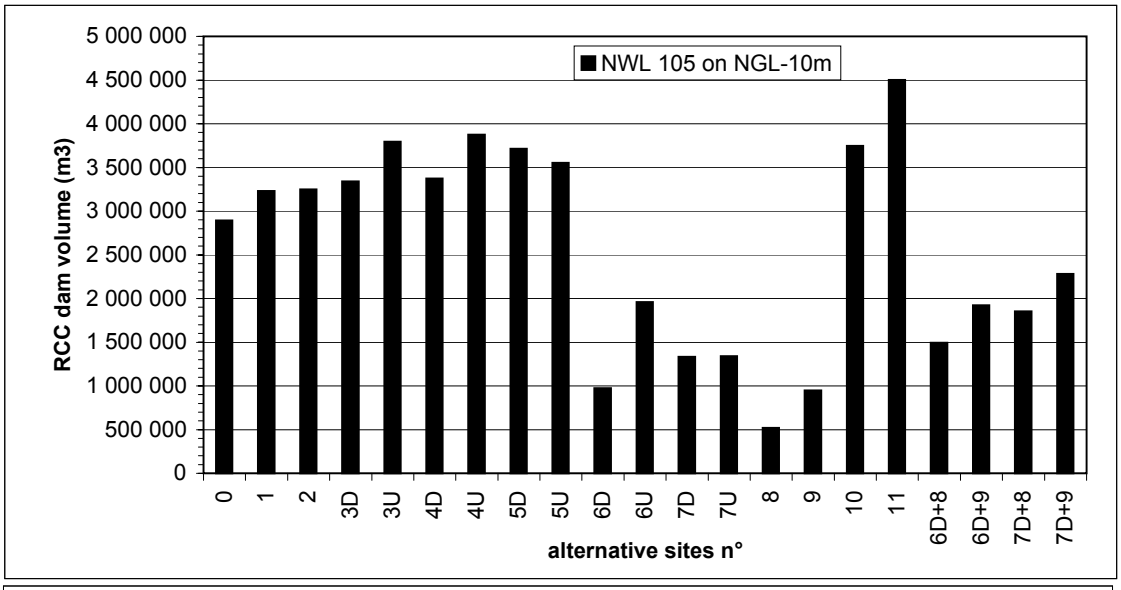


FIGURE 5 - Preliminary Dam Volume (RCC) for alternatives sites





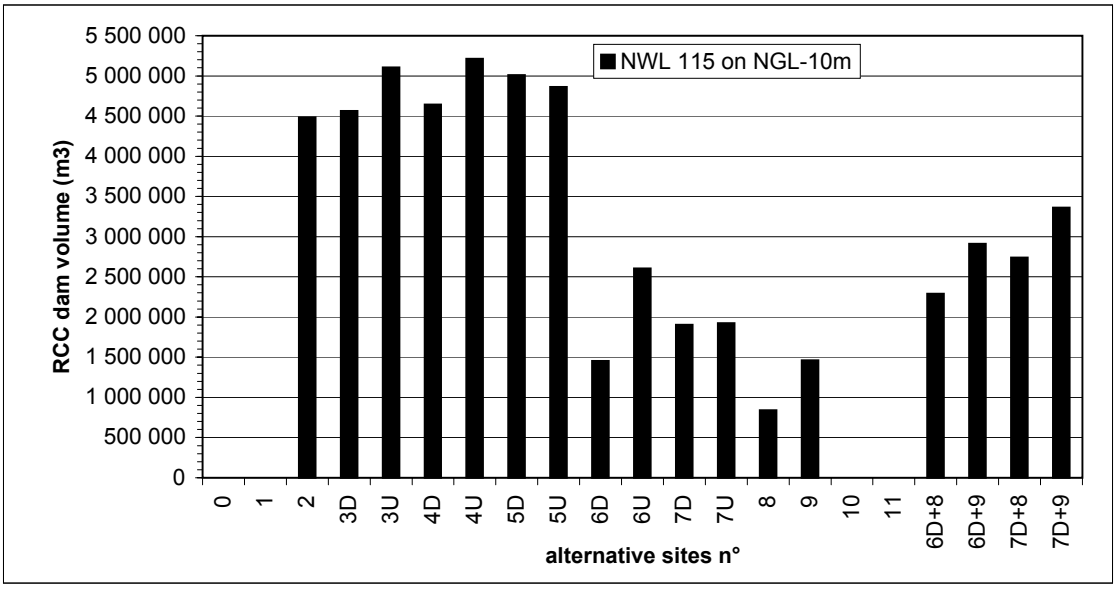


FIGURE 6 - RCC Dam Volumes of Alternatives Sites (without saddles dam)

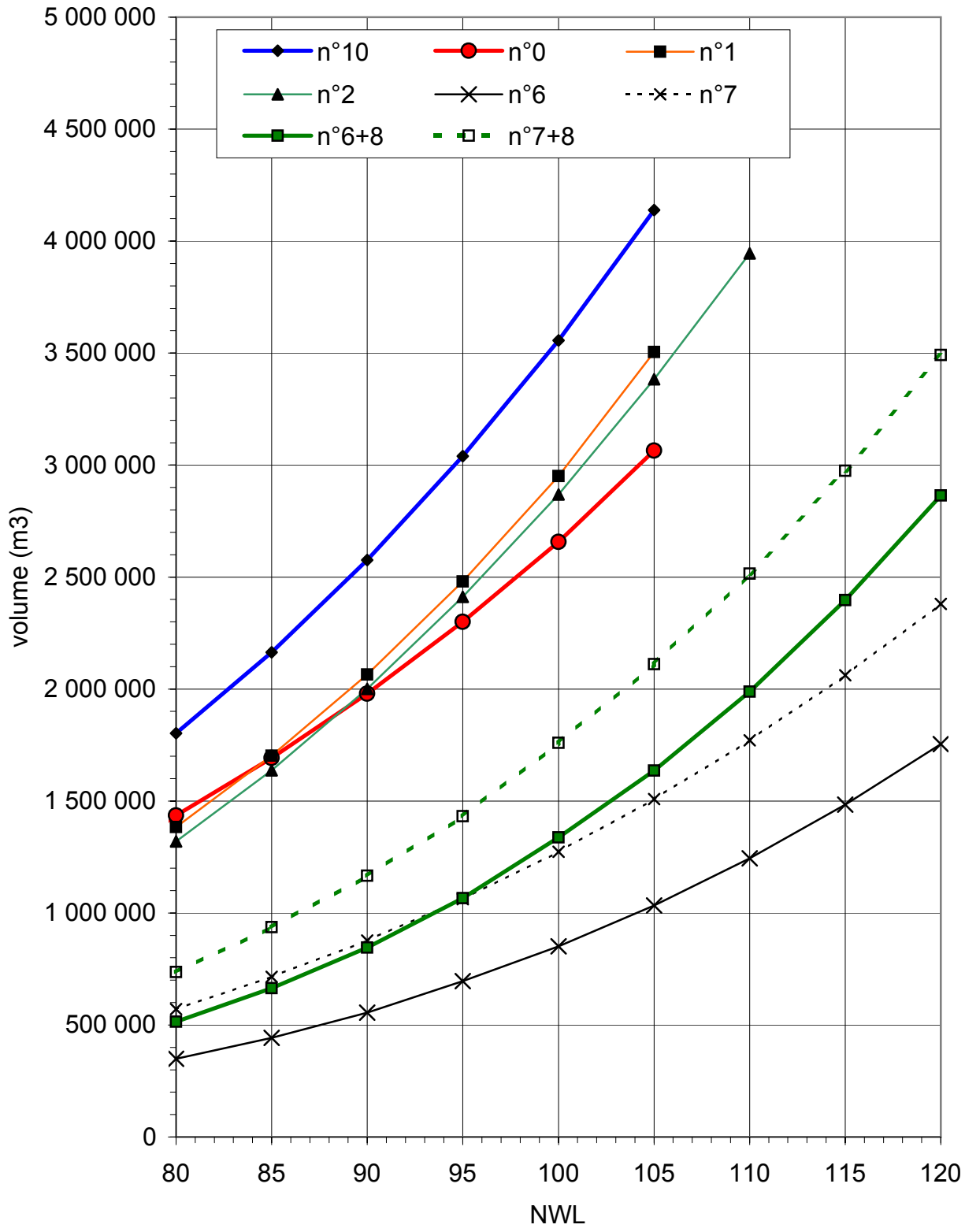


FIGURE 7 - Total Cost / Yield (D1) Index vs. NWL of Alternative Sites

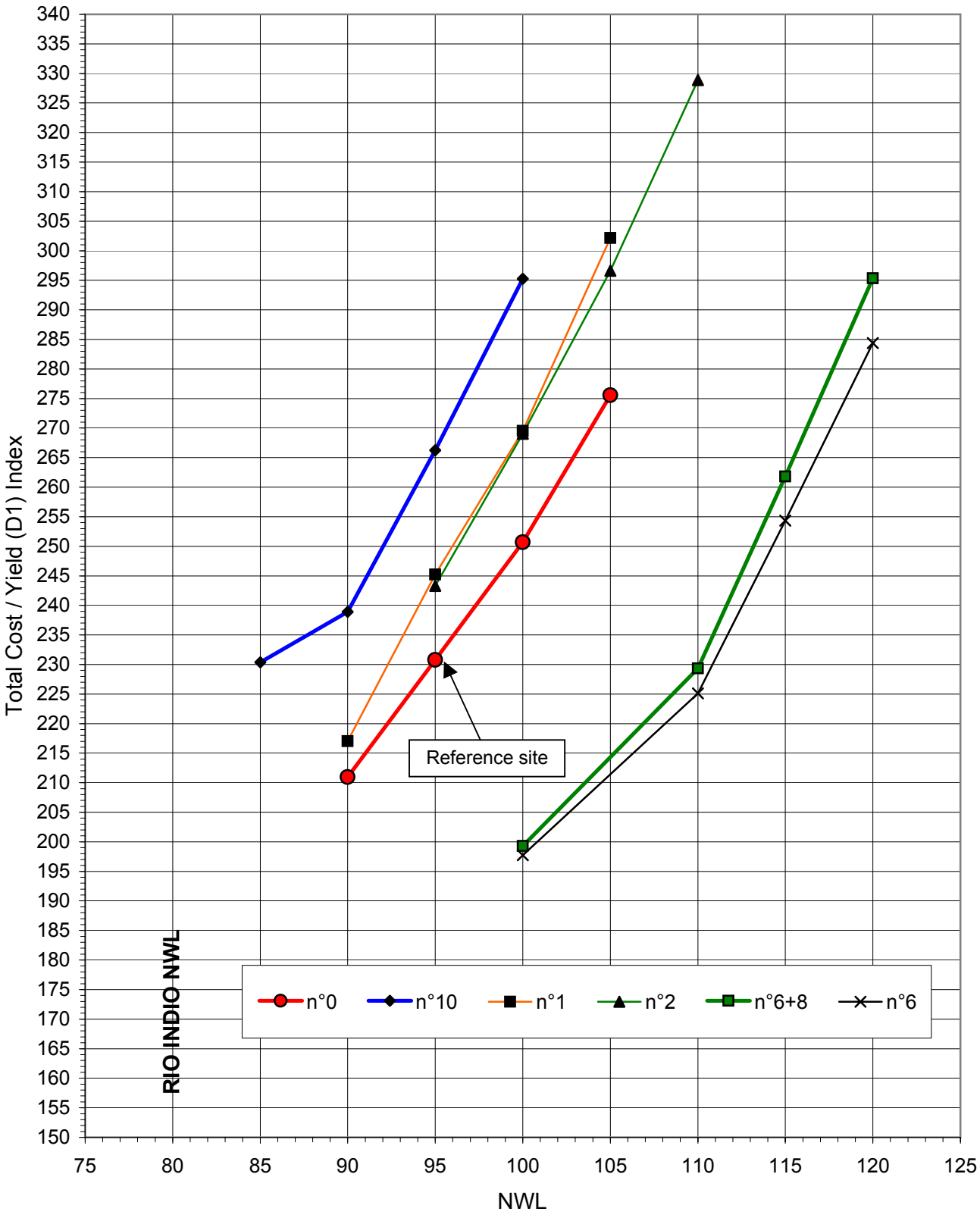


FIGURE 8 - Total Cost / Yield (D2) Index vs. NWL of Alternative Sites

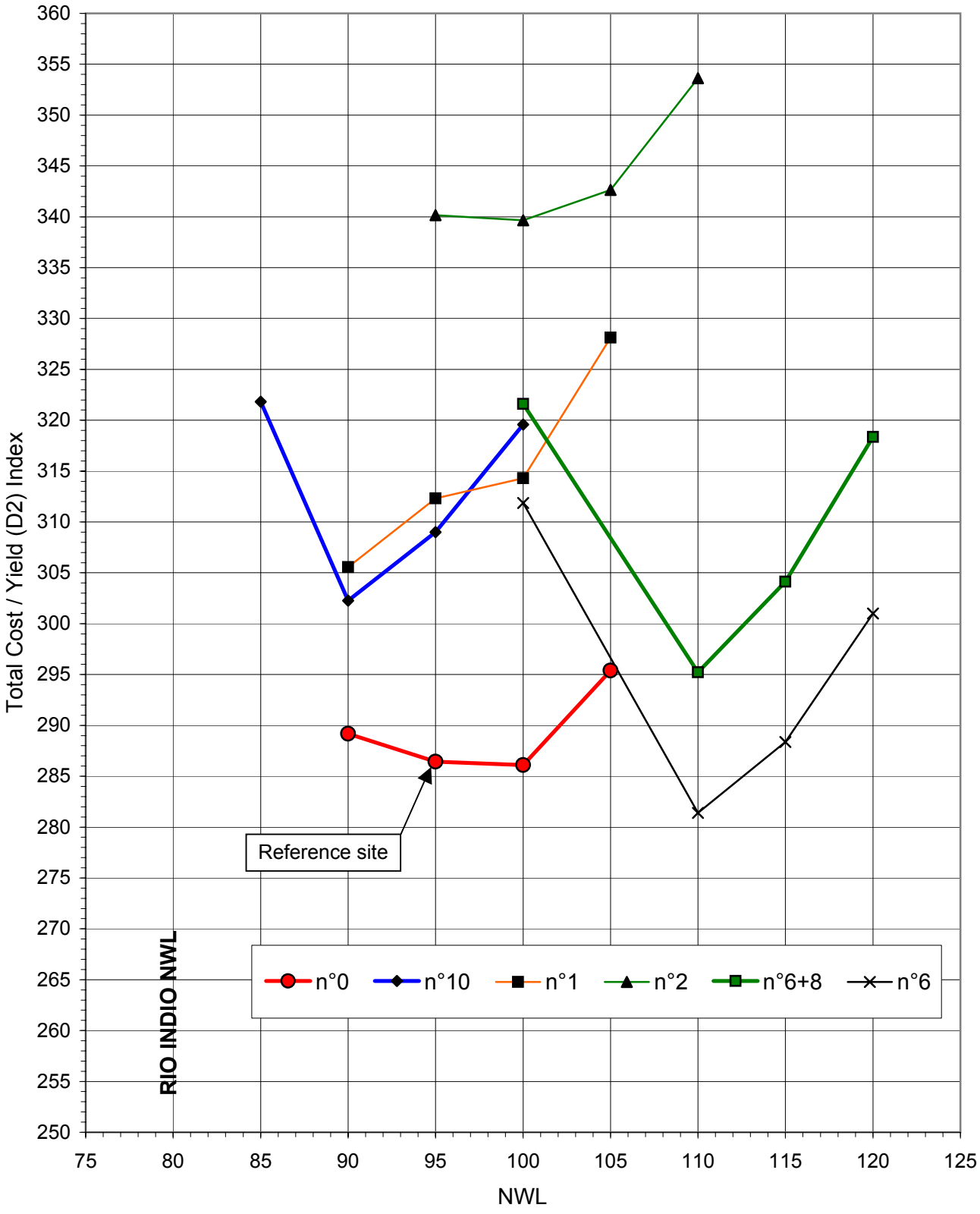


FIGURE 9 - Screening process
Total Cost Ratio vs. Yield (D1) Ratio

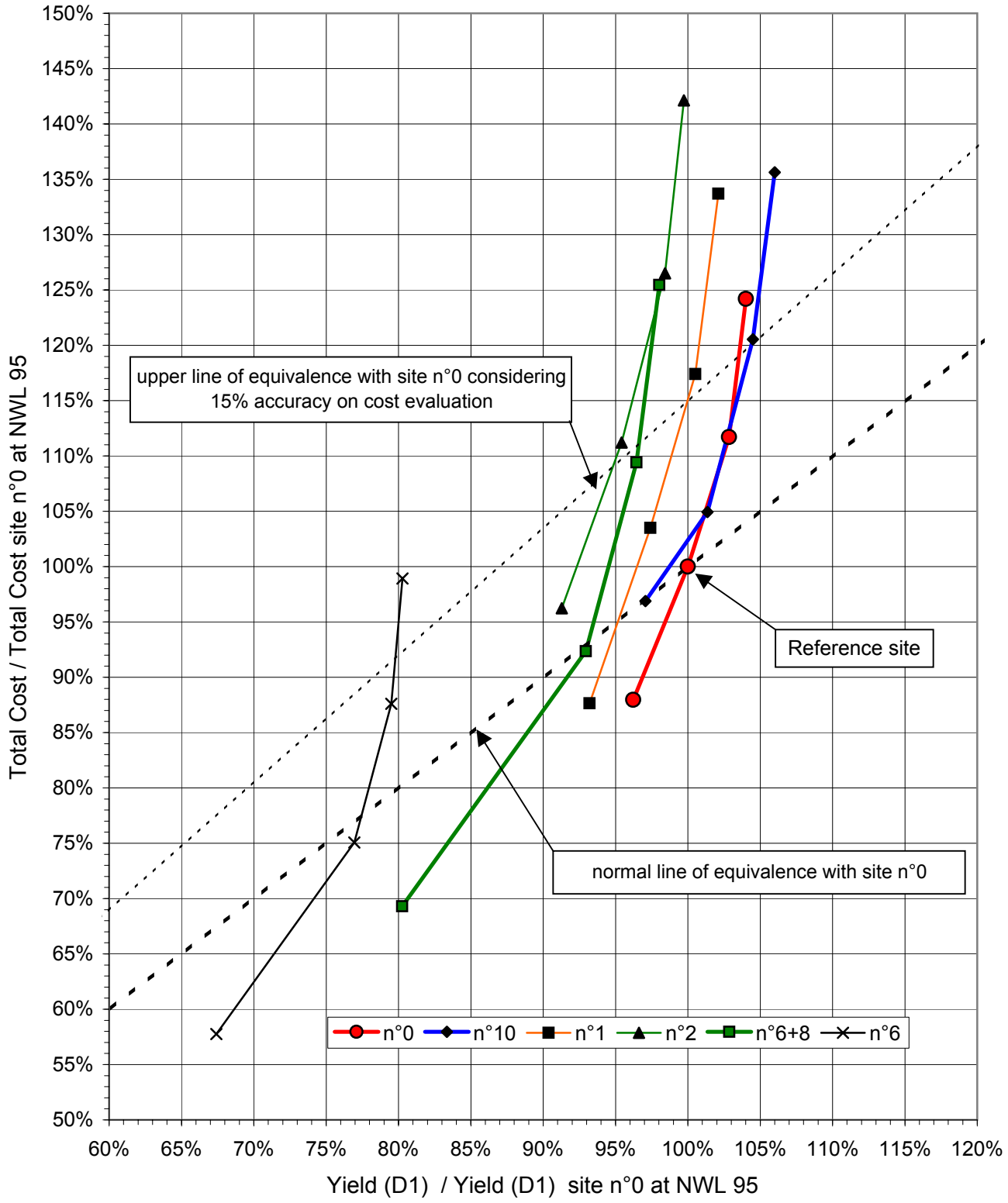


FIGURE 10 - Screening process
Total Cost Ratio vs. Yield (D2) Ratio

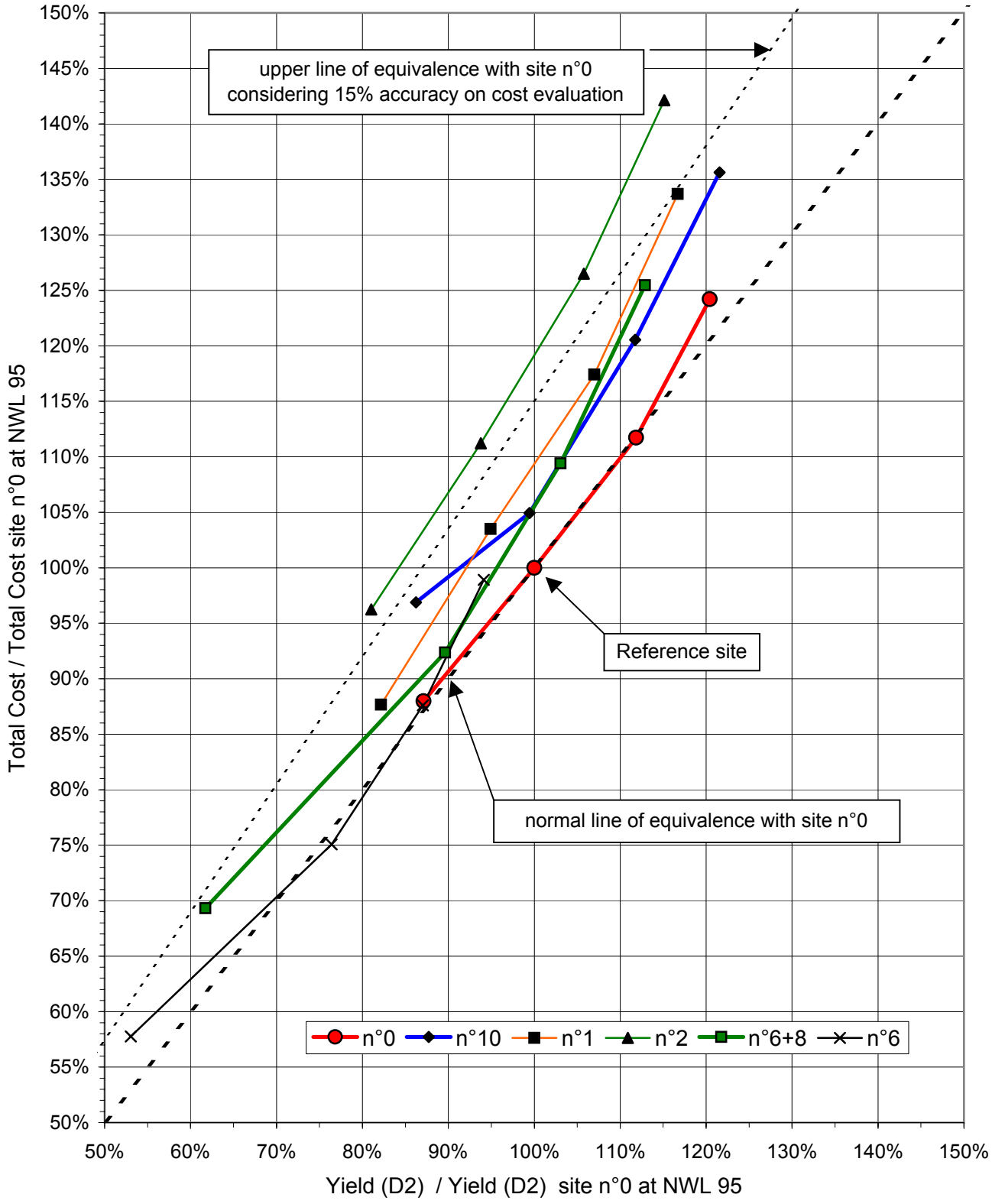
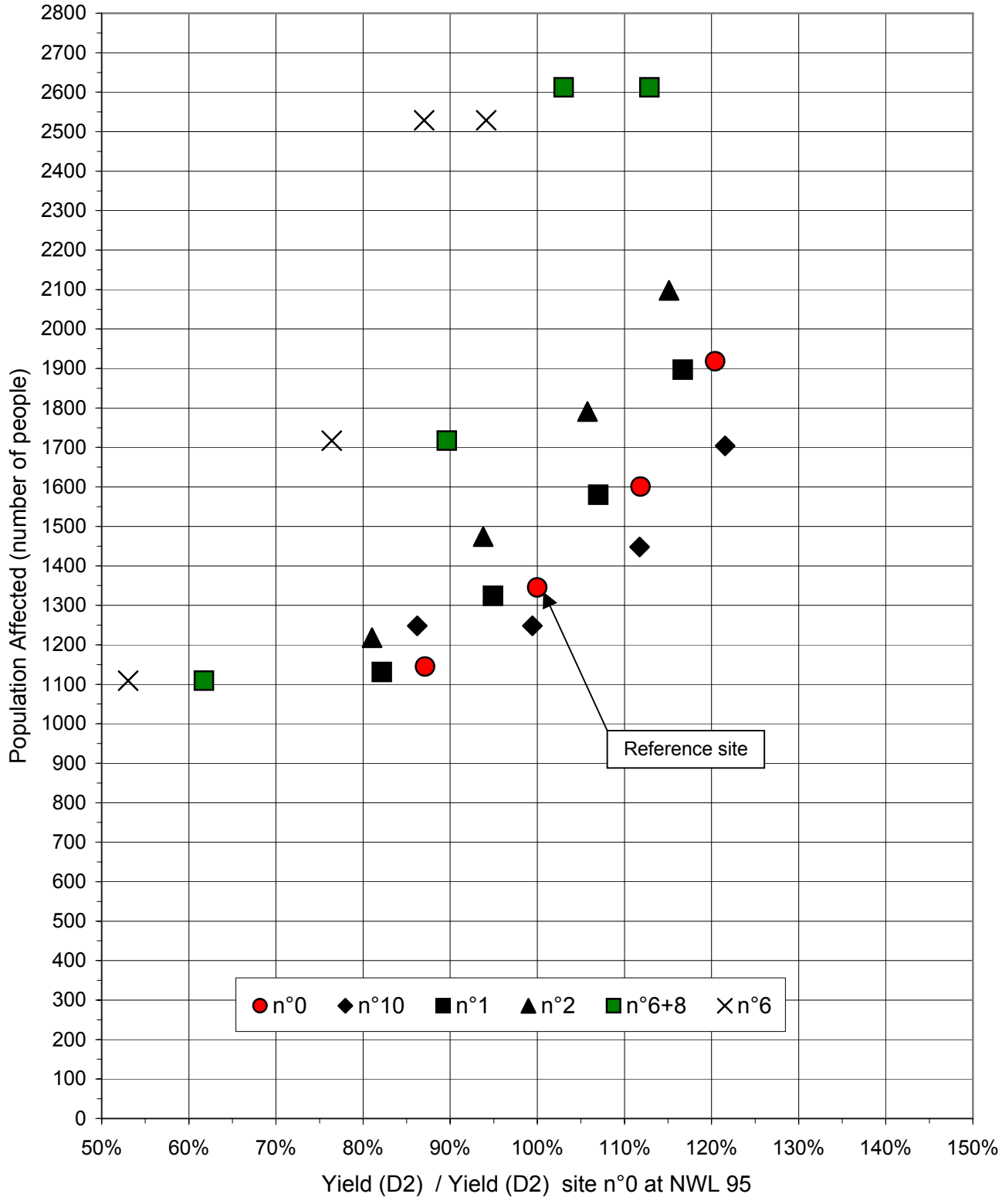


FIGURE 11 - Screening process
Population Affected vs. Yield (D2) Ratio



PART II – ANALYSIS PHASE

PART II – ANALYSIS PHASE

1. PRELIMINARY DESIGN

1.1. Design Criteria

The Screening Phase performed on 11 alternatives sites revealed the site n°1, located about 1 km upstream of reference site n°0, as the only potentially competitive with this reference site and proposed to perform a preliminary design of the structures on these two sites for a more precise evaluation and comparison.

The Feasibility Study of the Project was developed in parallel to this analysis phase, given some precious indications about the optimal design of such structures on the reference site n°0. It is obvious that these informations have been directly integrated in this analysis phase carried out with permanent reference with the Dam Type Selection Phase of the Feasibility Study (Ref. [1] : Vol. II.B - Part IX), performed at the same required stage of detail.

This preliminary design is then based on the following criteria:

- use of the best available topographical maps common to both sites, i.e. the new photorestitution map (2003). Nevertheless, as a preliminary design on site n°0 was already completed (Ref. [1]) on a more accurate topography (ground survey 2002), this design has been kept, after verification that this accurate topography didn't present any significant difference which may change the results of the comparison with the design made on site n°1 on the base of the photorestitution map (favourable design for alternative site n°1).

- reference reservoir sizing for site n°0 : Normal Water Level (NWL) at El. 95 masl and Minimum Operating Level (MOL) at El. 50 masl. The corresponding reference yield are respectively 1 100 MCM/y (or 14.5 l/d) for scenario D1 (constant transfer all the year) and 886 MCM/y (or 11.7 l/d) for scenario D2 (transfer constant on 6 months January to June).

  the reservoir of the alternative site n°1 is sized to provide an equivalent yield (with a similar dead storage) : respectively NWL 99.5 / MOL 52.5 for scenario D1 and NWL 97.5 / MOL 52.5 for scenario D2.

  the comparative reservoir for the site n°1 is proposed at NWL 98.5 and MOL 52.5 for a comparison with an estimated precision around +/- 5%.

- with the present poor knowledge of the geological conditions of the two sites (even very poor at site n°1) they are considered quite similar for the present comparison. At this time there is not (yet) identified elements susceptible to modify significantly the conclusion of this comparison performed with the same assumption on bedrock level and suitability at both sites (see Feasibility Report, Volume II B - Part IV-Geology for site n°0).

- selected dam type, according to the recommendation of the RCC / CFRD comparative study already performed on site n°0 (**Ref. [1])** : a RCC dam which, in addition of a slightly lower cost [(1)], allows the simple integration of the spillway and the diversion structures; this alternative presents then the advantage to minimise the higher geological risk of underground works for diversion works and uncertainties for a separated spillway associated with the CFRD alternative, subject to the same poor knowledge of geological conditions.

  it should be focused that further recommended reconnaissance to precise the geological conditions could modify the conclusion of such economic development of a RCC dam alternative, presently considered technically possible at the two selected sites.

- flood protection based on the 1/1 000 years design flood and consideration of the PMF with spillway performance, security and efficiency as same as possible for the two sites.
- diversion works during construction designed to control the 1/25 years flood.
- transfer tunnel designed for the similar yield but with respective minimum head between Toabre and Indio NWL 80 / MOL 40 reservoirs (at simultaneous MOL): 10 m for site n°0 (MOL 50) and 12.5 m for site n°1 (MOL 52.5).
- all the others minor or common features such as saddles dam, bottom outlet, hydroelectric powerplant, monitoring, access road, engineering etc are not considered or included in the comparison process.

1.2. Preliminary Selection of Dam Axis

Based of the new photorestitution map, **Drawing 10-501** presents the location of different alternative dam axis on the two selected sites :

. at reference site n°0 : the ACP dam axis rotated downstream on an obvious better Left Bank abutment, definitely adopted;

. at alternative site n°1 which present a wide area on the left bank with two deep gullies (El. 70 masl approx.) after a first left abutment at El. 130 masl, necessitating the development of the dam axis along some 1 000 additional meters : two axis, 200 m distant on the riverbed (n°1A downstream and n°1B upstream) joined on a common layout on this left bank gullies area.

It is also recalled that these two sites present the following reservoir topographical limits :

Reference Site n°0	saddle between basins of Rio de U and Cano Sucio at El. 100 masl + saddle on Left Bank (near dam) at El. 104 masl. + saddle on Right Bank (near dam) at El. 108 masl.
Alternative Site n°1	saddle between basins of Rio de U and Cano Sucio at El. 100 masl + saddle on Right Bank (near dam) at El. 103 masl

(1) except in case of significantly lower (or inappropriate) foundation which could increase the volume (and then the cost) of the RCC dam,

On the base of this map, preliminary layout for estimation of the volume of a RCC dam have been established for the two axis alternatives at site n°1, based on the following principles:

. ungated spillway located on the central part of the RCC dam, with maximum length adapted to the topography on the flat left riverbank, with following characteristics:

		Axis n°1A	Axis n°1B
Spillway length	m	230	190
NWL	masl	98.5	98.5
PMF control (= dam crest elevation)	masl	103.35	103.8
Specific flow for PMF routing	$m^3/s/m$	21.3	24.4 (+ 15%)

note : the axis n°1A allows a more favourable design for an ungated spillway (longer length with better energy dissipation of the flow on a stepped spillway chute) with a resulting lower dam crest elevation.

in addition, the diversion works are easier to implement for this axis n°1A;

. RCC Dam with total slope of 0.9H/1V theoretically founded 10-15 m below the natural ground level (not significant at this stage), divided in two sections, with the following respective volumes:

		Axis n°1A	Axis n°1B
RCC Dam 1 (on specific axis)	MCM	1.75	1.71
RCC Dam 2 (on common left bank axis)	MCM	0.60	0.62
TOTAL RCC DAMS (1 + 2)	**MCM**	**2.35**	**2.33 (-0.9%)**

Based on the analysis of these preliminary volumes and spillway efficiency considerations it has been decided to **select the downstream axis (n°1A)** in alternative site n°1 for the more detailed analysis phase.

1.3 Technical Design of the Project

The design of the structures is similar to the one developed and detailed for the Dam Type Selection Phase of the Feasibility (Ref. [1]). **Drawings 10-502 to 10-504** show the general layout and typical sections of these structures at the two selected sites, presented hereafter :

➢ ***RCC dam***

. dam divide in two sections on the alternative site n°1, separated by the first left bank abutment at El. 130 masl.

. structures entirely founded on slightly weathered or sound rock supposed to be at 10-15 m depth in average from the natural ground on both sites; consolidation grouting of the upper part of the foundation is foreseen.

. preliminary conservative design : crest 8 m wide, upstream face sloped at 1 V : 0.2 H and downstream face sloped at 1 V : 0.7 H.

. dam body made of RCC; the upstream face has an impervious slab of conventional concrete, 0.5 to 0.75 m (average) thick, and built in successive layers at the same time as RCC. The downstream face is protected from weather effects by steps of conventional concrete (0.3 m minimum thickness).

. a drainage curtain in the upstream part of the dam will check the circulation of any water and will control uplift pressures. It will consist of boreholes intersecting the horizontal galleries in the dam which will serve all necessary access, inspection, monitoring, and maintenance functions.

a grout curtain and a drainage curtain are foreseen in the foundation at the upstream toe of the dam. The drainage should be extended into the first left bank abutment which divide the dam of the alternative site n°1.

➢ *Spillway*

The spillway is advantageously located on the downstream face of the RCC dam in the centre of the valley. The length of its ungated concrete sill at the respective NWL is adapted to the local topographical constraint for restitution : 300 m at site n°0 and 230 m at site n°1.

Taking account of the flood routing capacity of the reservoirs, the 4 100 m^3/s of the design flood (T = 1 000 years) and the 9 500 m^3/s of the PMF are handled under the following levels and outflows:

	unit	Reference site n°0	Alternative site n°1
Spillway length	m	300	230
Sill at NWL	masl	95	98.5
Dam crest elevation (for PMF)	masl	99.5	103.35
MWL with design flood (1/1000)	masl	97.35	101.10
Freeboard with design flood	m	2.15	2.25
Outflow (for design flood)	m3/s	2 200	1 910
Specific outflow (for design flood)	m3/s/m	7.5	8.3
MWL with PMF	m	99.5	103.35
Outflow (for PMF)	m3/s	5 800	4 900
Specific outflow (for PMF)	m3/s/m	19.5	21.3

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 (0.6 m height) cast and anchored onto the sloped downstream RCC face. With a specific flow around 8 $m^3/s/m$ for the design flood (and still acceptable 20-21 $m^3/s/m$ for PMF) this design 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.

➢ *Diversion works and Outlet*

The two selected sites present quite similar topographical conditions to manage with the control of the river during the dam construction : Rio Toabre routed through four openings in a concrete structure built within the dam footprint on the flat left riverbank. This concrete structure can be built while the Toabre river flow in its natural bed.

The water will be controlled by upstream and downstream 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 respective level presented on **Drawing 10-504**.

This principle also requires the excavations of important inlet and outlet open channels, especially at site n°0.

In the final phase of construction, two of the openings will be plugged, and the other two will be easily converted into bottom outlet (not detailed at this stage of the study).

➢ *Power generation works*

If economically justified, a surface powerplant can be easily located at the toe of the dam, on the right of the spillway in the river bed. The intake structure will consist of adequate openings within the RCC dam continued with penstocks routed down the downstream face of the dam until the powerplant.

The design of these structures is not detailed for this analysis phase.

➢ *Transfer Tunnel*

Due to the similar shape of their respective reservoirs, the optimum alignment of the transfer tunnel between Toabre and Indio reservoirs, as well as the location and the details of the inlet and outlet structures, considering the local geological conditions, will be exactly the same for the two alternatives sites.

The inlet is located in the upstream part of the reservoir along the Rio de U valley, in the vicinity of Boca de la Encantada. The tunnel, around 16 km long, comes out into the western upstream part of the Rio Indio reservoir.

The tunnel will differs only by the diameter required to pass the same design flow (from same yield, i.e. respectively 35 m3/s with scenario D1 or 56.5 m3/s with scenario D2), under the respective minimum head between Toabre and Indio reservoirs (10 m for site n°0 and 12.5 m for site n°1): respectively 4.7 m or 5.65 m for the tunnel associated with site n°0 and 4.5 m or 5.4 m for the tunnel of site n°1. The comparative design diameter have been fixed at 5.2 m for site n°0 and 5.0 m for site n°1.

At this stage of the study this preliminary design of an horseshoe-shaped concrete-lined (0.5 m) tunnel (pressure flow) will be sufficient for comparison.

➢ ***Quantities***

The main quantities are as follows :

Designation	Reference site n°0	Alternative site n°1
Overburden	1 500 000 m3	1 500 000 m3
Rock Excavation	800 000 m3	750 000 m3
Tunnel excavation	510 000 m3	480 000 m3
RCC	2 000 000 m3	2 175 000 m3
Concrete	175 000 m3	200 000 m3
Tunnel concrete	150 000 m3	145 000 m3
Grouting & Drainage	70 000 ml	90 000 ml

2. COMPARISON OF ALTERNATIVES SITES

2.1. Methodology

The choice of the best site should be based on the evaluation and comparison of the following factors :

. construction cost

. technical and environmental considerations

For the purpose of this comparison, design details and cost estimates were concentrated on those elements which differ for the two alternatives. Then common features to both sites such as the access road, the hydroelectric powerplant and the bottom outlet main components were not considered and included in the comparison process.

By the same, considering the transfer tunnel, the cost estimate focus only on the two main comparative components : tunnel excavation and concrete tunnel, the only items function of the tunnel diameter and anyway representative of the more significant part of the total cost.

For the construction cost estimate the list of aggregate unit prices developed during the Dam Type Selection Phase of the Feasibility Study **[Ref. 1]** has been adapted:

Item	Unit	Unit Price (USD)
Clearing	m^2	1
Overburden Excavation	m^3	3
Rock Excavation	m^3	10
Tunnel Excavation (including supports)	m^3	100
Cofferdam fill	m^3	5
Rolled Compacted Concrete (RCC)	m^3	40
Conventional Vibrated Concrete (CVC)		
CVC for RCC Dam Faces	m^3	200
CVC for Spillway	m^3	200
Levelling CVC	m^3	150
Mass CVC	m^3	100
CVC for Structures	m^3	200 to 300
CVC Tunnel	m^3	300
Grout Curtain	ml	135
Consolidation Grouting	ml	120
Drainage	ml	100

In addition the Environmental Impacts, as provided by ACP and presented in the Part I has been considered. They 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

2.2. Cost Estimate

Construction cost for each alternative sites have been estimated by applying the above rates to the corresponding quantities of the dam, appurtenant works and transfer tunnel estimated from the engineering drawings.

Tables 1 and 2 present this cost estimate for the two selected sites.

The consideration of the additional Environmental Impacts gives the comparative project costs summarised as follows :

Structures	**Reference site n°0 Cost (MUSD)**	**Alternative site n°1 Cost (MUSD)**
Dam	103.0	119.5
Spillway	8.0	6.0
Diversion Works	12.0	10.5
Grouting and Drainage	8.5	10.5
Bottom Outlet & Power Plant	common	common
Saddles Dams	negligible (-)	negligible (+)
Transfer Tunnel	96.0	91.5
Environmental Impacts	27.0	29.0
Infrastructures	common	common
Engineering	common	common
Total (comparative)	**255**	**267 (+ 5%)**

2.3. Comparison of alternatives

The difference in cost of only 5% in the advantage of the reference site n°0 is negligible compared to the accuracy of the evaluation. Then, on the base of the present available data it can be stated that the cost of the Toabre Project will be very similar at any of the two alternative sites n°0 or n°1.

It is worthwhile to recall here that no boreholes have yet been performed on any of the alternatives sites. As a consequence the above conclusion may change if the geological conditions presently assumed turned out to be radically different at one site compared to the other, with for example a significantly lower or inappropriate bedrock. Further appropriate reconnaissances to confirm or refute the present assumptions become of major importance to definitively stated this conclusion.

In addition of the cost comparison the following comments are pointed out, all favourable for the reference site n°0:

. for equivalent yield the site n°0 requires lower reservoir levels, with respective lower 'qualitative' environmental impacts; among these impacts, the possible preservation of the village 'Valle de San Miguel' with a population of 256 people can be a major 'qualitative' argument in favour of the site n°0 at NWL 95 masl; and there is very few population (21 people) between the two sites which could be 'saved' with the site n°1.

. for the same reasons the eventual saddle dams will be lower (or even not necessary) with a development on site n°0;

. the closure of the reservoir on the left bank of the site n°1 requires a long secondary RCC dam which will present small construction area with the associated disadvantages for planning construction;

. the possible longer spillway at site n°0 allows a better energy dissipation along a stepped chute;

3. CONCLUSIONS

Based on the above comments it is recommended **to continue with the Feasibility Study of the Toabre Dam located on the reference site n°0.**

Nevertheless it is also recommended to proceed during the next phase of the development study with **appropriate geological survey in both sites n°0 and n°1**, in order to match with any unexpected conditions at the recommended site n°0 which may conduct to prefer the alternative site n°1, if revealed better by this common reconnaissance survey. This eventual necessary change of site (or dam axis, 1 km upstream) should not significantly modify the global cost of the Toabre Project evaluated at the Feasibility Stage with the present assumption at site n°0.

TABLE 1 REFERENCE SITE N°0 - CONSTRUCTION COST

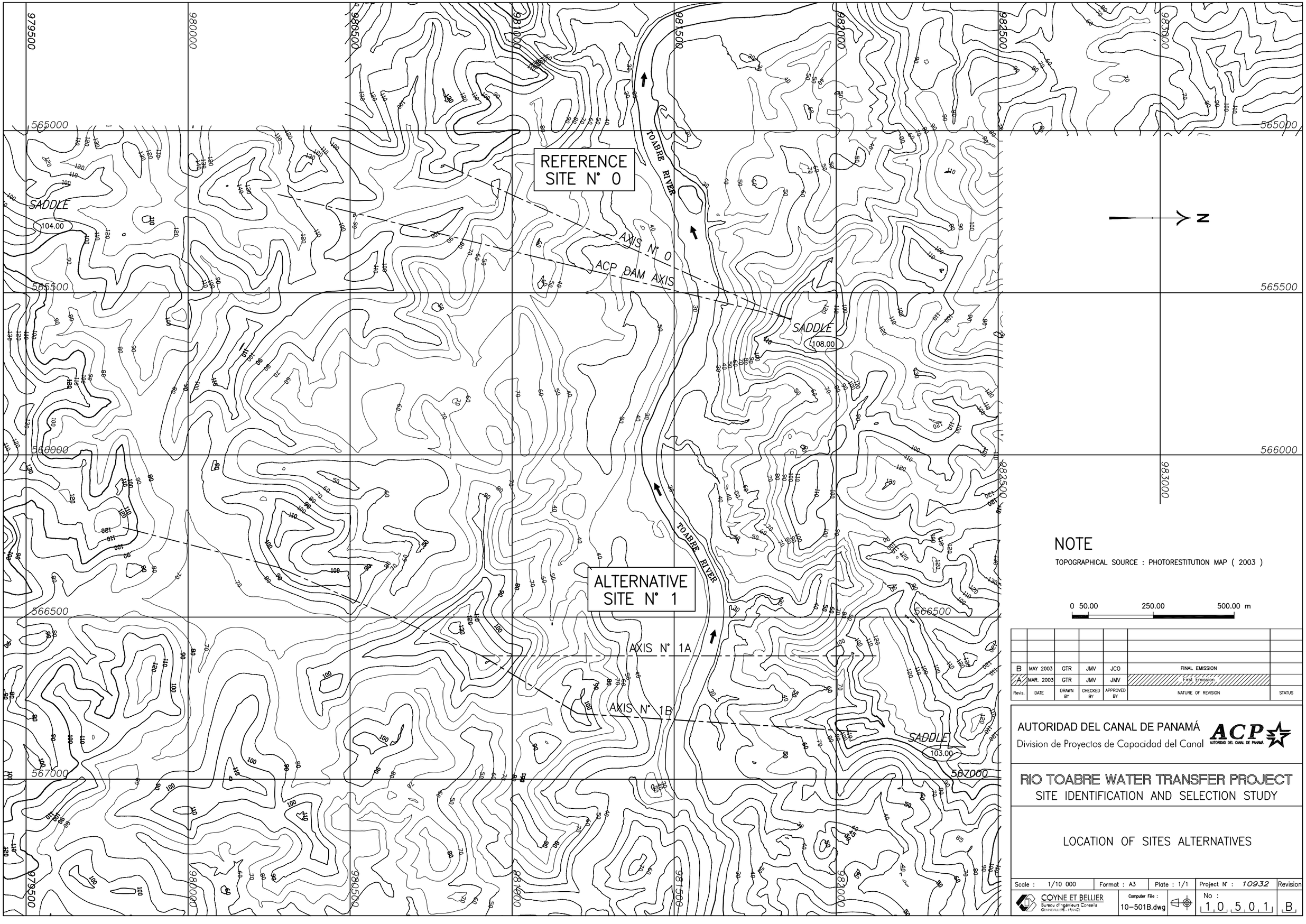
Designation	unit	Quantity	Unit price USD/unit	Cost USD
Dam & Spillway				
Clearing	m2	200 000	1	200 000
Overburden Excavations	m3	1 000 000	3	3 000 000
Rock Excavations	m3	500 000	10	5 000 000
RCC	m3	1 950 000	40	78 000 000
CVC U/S facing	m3	50 000	200	10 000 000
CVC D/S facing	m3	20 000	200	4 000 000
CVC Spillway	m3	40 000	200	8 000 000
Levelling CVC	m3	20 000	150	3 000 000
Consolidation grouting	ml	50 000	120	6 000 000
Grout curtain	ml	10 000	135	1 350 000
Drainage curtain	ml	9 500	100	950 000
sub total Dam				*119 500 000*
Diversion works				
Overburden Excavations	m3	500 000	3	1 500 000
Rock Excavations	m3	300 000	10	3 000 000
Cofferdam fill	m3	120 000	5	600 000
Mass CVC	m3	20 000	100	2 000 000
CVC structures	m3	25 000	200	5 000 000
sub total Diversion Works				*12 100 000*
Transfer Tunnel				
Tunnel Excavations	m3	510 000	100	51 000 000
Tunnel Concrete	m3	150 000	300	45 000 000
sub total Transfer Tunnel				*96 000 000*
TOTAL			**USD**	**227 600 000**

Note : these costs are only comparative costs, not total. Moreover they don't include contingencies on either quantities or unit costs.

TABLE 2 ALTERNATIVE SITE N°1 - CONSTRUCTION COST

Designation	unit	Quantity	Unit price USD/unit	Cost USD
Dam & Spillway				
Clearing	m2	200 000	1	200 000
Overburden Excavations	m3	1 125 000	3	3 375 000
Rock Excavations	m3	550 000	10	5 500 000
RCC	m3	2 175 000	40	87 000 000
CVC U/S facing	m3	65 000	200	13 000 000
CVC D/S facing	m3	33 000	200	6 600 000
CVC Spillway	m3	30 000	200	6 000 000
Levelling CVC	m3	25 000	150	3 750 000
Consolidation grouting	ml	60 000	120	7 200 000
Grout curtain	ml	15 000	135	2 025 000
Drainage curtain	ml	15 000	100	1 500 000
sub total Dam				*136 150 000*
			ratio / n°0	*1.15*
Diversion works				
Overburden Excavations	m3	350 000	3	1 050 000
Rock Excavations	m3	200 000	10	2 000 000
Cofferdam fill	m3	110 000	5	550 000
Mass CVC	m3	20 000	100	2 000 000
CVC structures	m3	25 000	200	5 000 000
sub total Diversion Works				*10 600 000*
			ratio / n°0	*0.90*
Transfer Tunnel				
Tunnel Excavations	m3	480 000	100	48 000 000
Tunnel Concrete	m3	145 000	300	43 500 000
sub total Transfer Tunnel				*91 500 000*
			ratio / n°0	*0.95*
TOTAL			**USD**	**238 250 000**
			ratio / n°0	**1.05**

Note : these costs are only comparative costs, not total. Moreover they don't include contingencies on either quantities or unit costs.



NOTE

TOPOGRAPHICAL SOURCE : PHOTORESTITUTION MAP (2003)

0 50.00 250.00 500.00 m

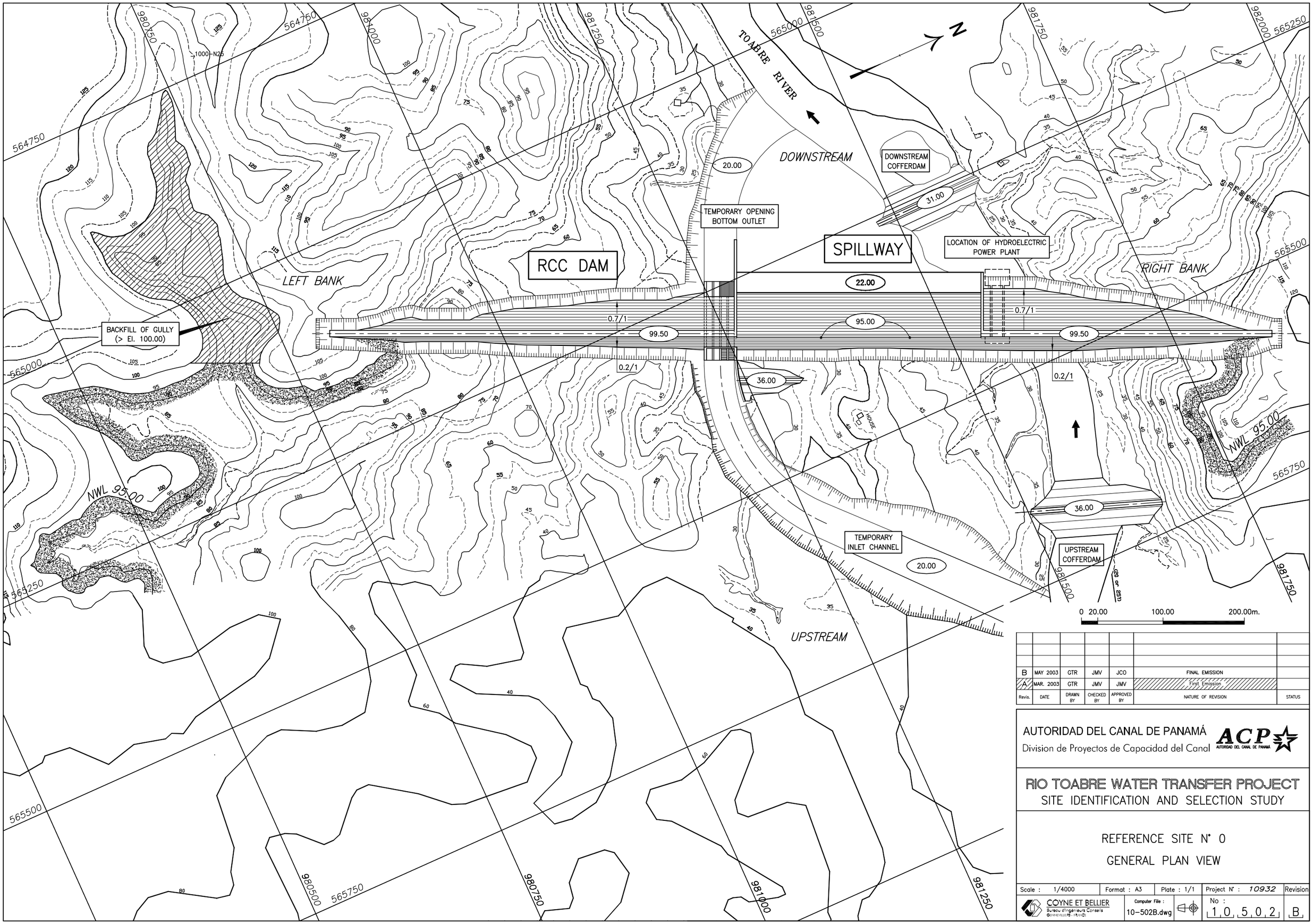
Revis.	DATE	DRAWN BY	CHECKED BY	APPROVED BY	NATURE OF REVISION	STATUS
B	MAY 2003	GTR	JMV	JCO	FINAL EMISSION	
A	MAR. 2003	GTR	JMV	JMV	First Emission	

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

RIO TOABRE WATER TRANSFER PROJECT
SITE IDENTIFICATION AND SELECTION STUDY

LOCATION OF SITES ALTERNATIVES

Scale : 1/10 000	Format : A3	Plate : 1/1	Project N° : 10932	Revision
COYNE ET BELLIER Bureau d'Ingénieurs Conseils	Computer File : 10-501B.dwg		No : 10501	B



Revis.	DATE	DRAWN BY	CHECKED BY	APPROVED BY	NATURE OF REVISION	STATUS
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A	MAR. 2003	GTR	JMV	JMV	First Emission	

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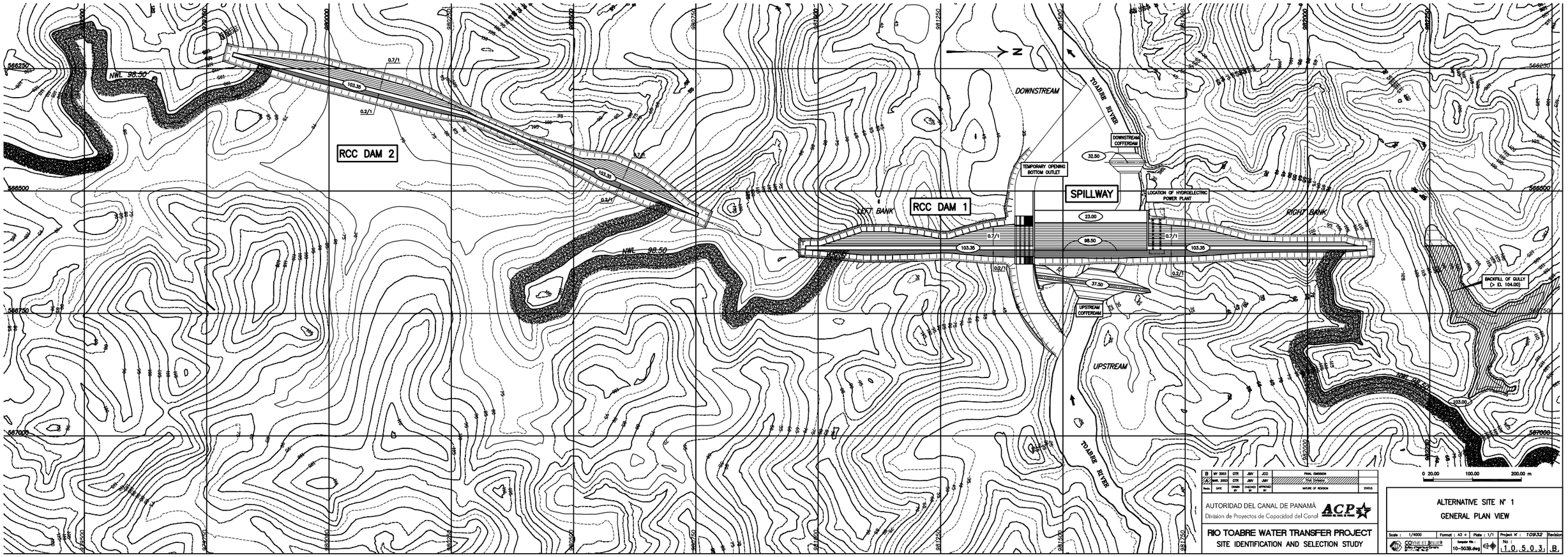
RIO TOABRE WATER TRANSFER PROJECT
SITE IDENTIFICATION AND SELECTION STUDY

REFERENCE SITE N° 0
GENERAL PLAN VIEW

Scale : 1/4000	Format : A3	Plate : 1/1	Project N° : 10932	Revision
COYNE ET BELLIER Bureau d'Ingénieurs Conseils GENNEVILLIERS - FRANCE	Computer File : 10-502B.dwg		No : 10502	B



B	MY 2003	GTR	JMV	JCO	FINAL EMISSION
A	MAR. 2003	GTR	JMV	JMV	
Rev.	DATE	DRAWN BY	CHECKED BY	APPROVED BY	NATURE OF REVISION

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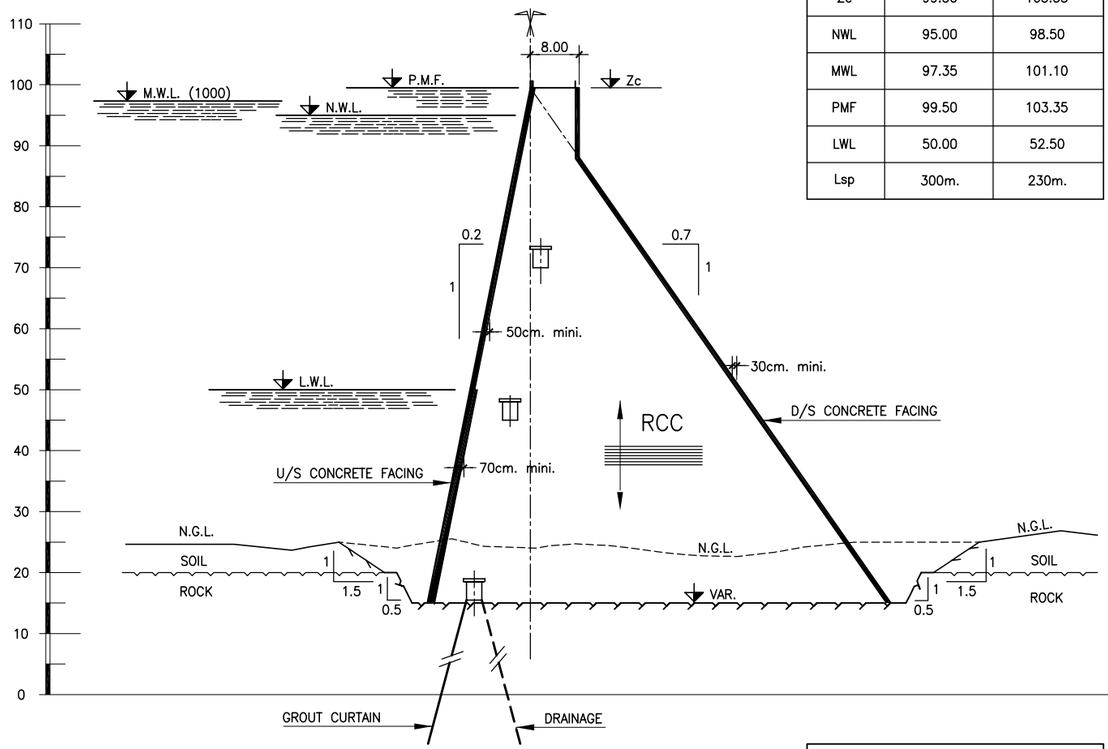
RIO TOABRE WATER TRANSFER PROJECT
SITE IDENTIFICATION AND SELECTION STUDY

ALTERNATIVE SITE N° 1
GENERAL PLAN VIEW

Scale : 1/4000	Format : A3 +	Plate : 1/1	Project N° : 10932	Revision
Consultant	Drawing File : 10-5038.dwg		No : 10.5.03	B

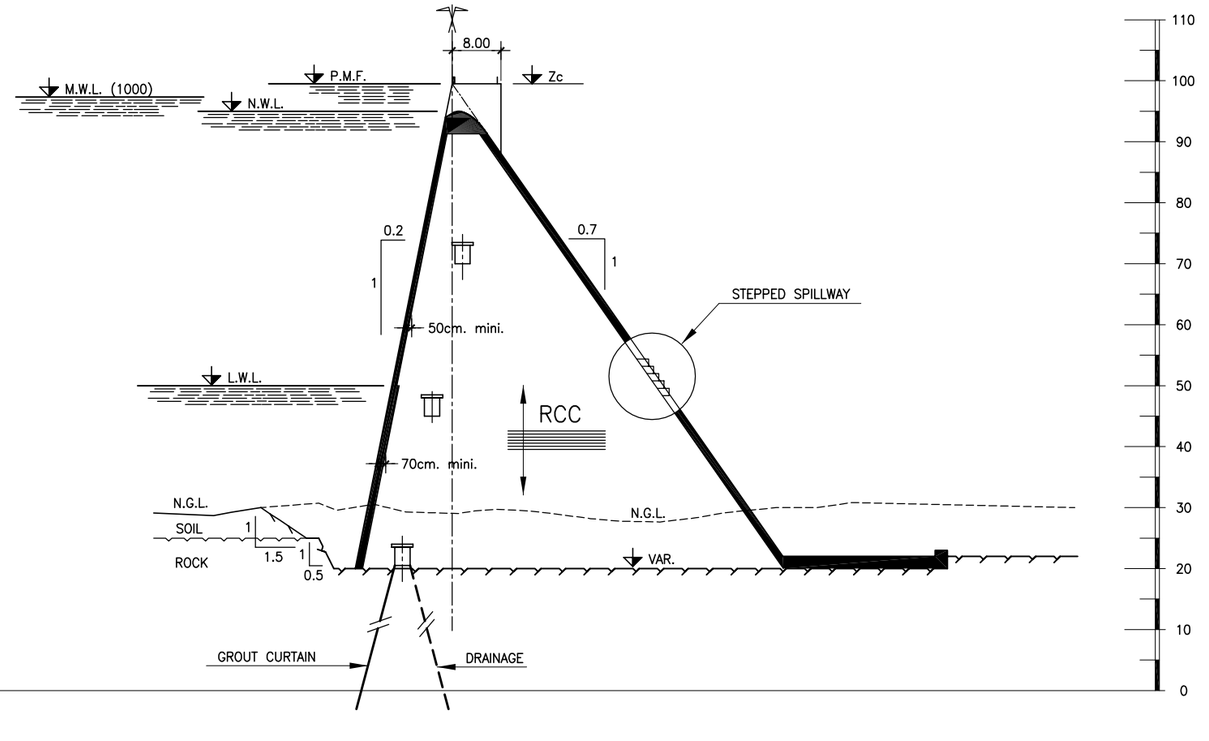
RCC DAM SECTION



RCC DAM AND SPILLWAY		
SITE	REFERENCE SITE N° 0	ALTERNATIVE SITE N° 1
Zc	99.50	103.35
NWL	95.00	98.50
MWL	97.35	101.10
PMF	99.50	103.35
LWL	50.00	52.50
Lsp	300m.	230m.

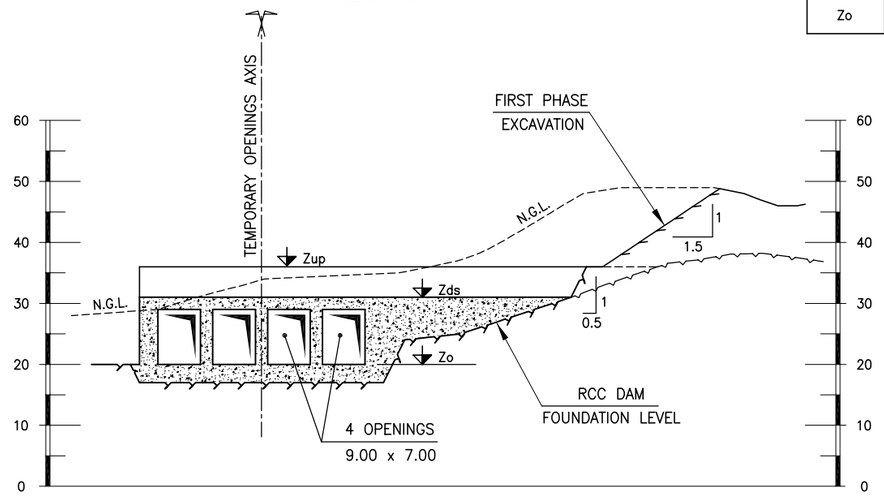
RCC SPILLWAY SECTION

(LENGHT = Lsp)

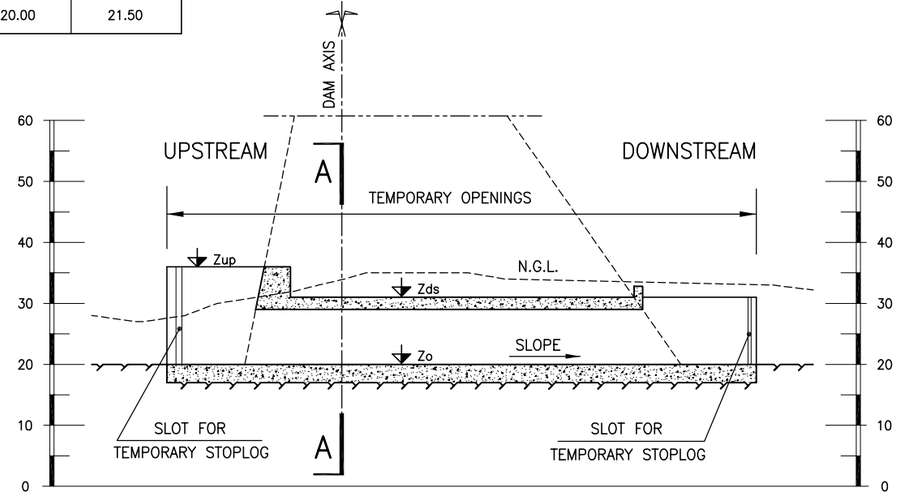


DIVERSION STRUCTURES		
SITE	REFERENCE SITE N° 0	ALTERNATIVE SITE N° 1
Zup	36.00	37.50
Zds	31.00	32.50
Zo	20.00	21.50

SECTION A–A



DIVERSION STRUCTURES



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ACP AUTORIDAD DEL CANAL DE PANAMÁ

RIO TOABRE WATER TRANSFER PROJECT

SITE IDENTIFICATION AND SELECTION STUDY

RCC DAM

TYPICAL CROSS SECTIONS

Scale : 1/1000	Format : A3	Plate : 1/1	Project N° : 10932	Revision
COYNE ET BELLIER Bureau d'Ingénieurs Conseils GENNEVILLIERS - FRANCE	Computer File : 10-504B.dwg		No : 10504	B

PART III – APPENDICES

(this part III has 2 appendices)

APPENDICES

APPENDIX 1 Site Selection – Field Mission Report – December, 2002
(18 pages)

APPENDIX 2 Environmental Impacts (from ACP)
(40 pages)

SITE SELECTION: FIELD MISSION REPORT – 10 - 12 December, 2002

1. Introduction

As a part of the site selection process, a field visit was organized from December 10 to 12, 2002 for the assessment of 11 alternative sites (n°0 – reference - to n°10 (1) on the Figure 1 of main text) previously proposed by the Consultant's engineers. The attendants were:

- ACP
  - Roderick Lee (on Dec. 12) — Project Manager
  - Derek Irving — Geologist
- Coyne et Bellier
  - J.M. Vuillot — Project Manager
  - S. Ianos — Geologist

A very efficient organization provided by ACP's engineers, including the use of helicopter and motor boats, allowed quick access to the pre-selected sites, located in relatively remote areas. Camping facilities in the area (Santa Elena village) also contributed to the successful completion of this 3 days field visit.

Three of the alternative sites, namely no. 1, 2 and 10 are located on Rio Toabre. Sites number 3, 4 and 5 encompass both Rio Toabre and Rio de "U", while sites no. 6 and number 7, both concerning Rio Toabre and Rio Tulù, are to be considered either separately or in conjunction with sites no. 8 or 9 on Rio de "U".

Helicopter survey around each site, appropriate for the overall estimation of the topographic setting, inventory of outcrops and of possible structural features, was completed by ground investigations starting from helicopter and boat stops.

Considering the notorious lack of outcrops in the study area, particularly comprehensive and helpful, through the amount and quality of rock exposures, were the walks in the following areas:

- Site 0, quebrada Nicaragua in the left bank
- Site 0, right abutment
- Site 6, both abutments
- The interfluve between Rio Toabre and Rio Tulù, in the central section of site 7
- Site 10, left abutment

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(1) site n°11 has been discarded during preliminary office evaluation before the field mission

On the contrary, sites no. 8 and 9, as well as the sections located on Rio de "U" of sites no. 3, 4 and 5, involving longer approach trips, were not investigated on the ground, in order to optimize the time spent in the field on potentially higher priority sites.

In addition, all major outcrops in the Rio Toabre and Rio Tulù riverbeds between site no. 7, upstream, and site no. 10, downstream, were subject to geological observation.

2. Main results of the field geologic investigations

General setting

The sediments of the Caimito Formation were found to be more extended than anticipated in the previous studies. Considering the outcrops at the riverbed level, 3 sections can be distinguished in the study area:

- Basalts / basaltic andesites, upstream from site no.6
- Sediments, downstream from Rio Toabre / Rio de "U" confluence
- An intermediate zone, where volcanic and sedimentary rocks are alternatively exposed in small outcrops

Site no. 7

- Outcrops on the interfluve between the Toabre and Tulù rivers indicate that basalts / basaltic andesites, exposed in the riverbeds and in the lower slopes, are overlain by moderately welded, pyroclastic andesitic tuff. The tuff is moderately to strongly weathered, as opposed to the basalts / basaltic andesites.

- Faults may be inferred from local strong fracturing and brecciation observed at several locations but their orientations could not be clearly determined. The best exposure, in the right bank of the Rio Tulù, showed N10° and N60° sub-vertical joints, local brecciation, silicification and silica veinlets. The N10° joint set, parallel to the riverbed, would account for the structural control of Rio Tulù in this section.

Site no. 6

- Calcarenites and limestones, both including bioclasts, outcrop within a SW-NE strip in the area of site 6. The main outcrops of calcareous sediments were identified in the left bank of the Rio Tulù, just upstream from the confluence with Rio Toabre, and in the right bank of Rio Toabre, downstream from the confluence.

  The latter is composed of massive limestone featuring rare, sub-horizontal or slightly northward dipping bedding planes (**photo 1**) and constitutes an outstanding hill with steep western and south-eastern slopes, referred to as Cerro Tulù [Ref 6]. On the other hand, calcarenites and limestones in the Rio Tulù show NE strike and low to moderate dip to the SE. The dipping seems to increase towards SE, from about 10° (outcrop in a minor, left-hand tributary of the Rio Tulù at approximately 100 m upstream from its confluence with Rio Toabre) to 40° (right bank and riverbed of Rio Tulù at the confluence with Rio Toabre).

  Dissolution of calcarenites and limestones resulted in dm to metric karstic cavities (**photo 2**). Greater cavities were also reported by locals.

- Fracturing adds to the complexity of this site. Brecciation related with a vertical fault plane striking SW-NE (**photos 3 and 4**) was observed on the NE trending ridge corresponding with the left abutment of the downstream proposed dam axis. This field observation confirmed the anticipation based on topography and aero-photographs, which suggested the existence of the fault. Small, shallow landslides are visible on both slopes of this narrow, fault-bordered ridge.

  In addition, the western and southeastern steep slopes of the Cerro Tulù could also reflect the presence of sub-vertical faults. The one limiting the hill to the W, roughly oriented N-S, would coincide with the relatively linear trend of Rio Toabre in this section. As previously mentioned, fault evidence with a similar orientation (N10°) was found in the riverbed of Rio Tulù. The NE trending fault, assumed to border the Cerro Tulù to the SW, would be actually parallel to the fault mapped in the left bank, as described above. It would also be consistent with the abrupt lithological change from massive limestone and calcarenite in the NW to basalts in the SE.

Sites no. 3, 4, 5 – intermediate zone

- The lack of outcrops along Rio Toabre between site no. 6 and the confluence with Rio de "U" does not allow to refine the geological setting of this section, which includes **sites no. 3, 4 and 5.**

- Rapids at **site no. 5** exposed moderately welded, crystal-fragment and matrix supported tuff, featuring scarce euhedral biotite. Two sub-vertical joint sets, N100° and, subordinately, N5° affect these rocks.

- About 250 m downstream, finely interbedded marls, siltstones and sandstones outcrop in the left bank of Rio Toabre. Bedding trends ENE and dips 10 – 15° SSE.

- The relationship between sediments and volcanic rocks is not clear in this intermediate zone, owing to the lack of outcrops. It can be assumed that locally, in areas of deposition close to volcanic centers, volcanic rocks can be interbedded with sediments.

Sites no. 0, 1 and 2 – sub-horizontal sediments

- The outcrop in the right bank at the confluence with Rio de "U", less than **200 m upstream from site no.2**, is mainly composed of calcareous sandstones, including a 10 cm thick bioclastic limestone layer and finely laminated siltstones. They feature NE trending, 15° SE dipping bedding, consistent with measurements at **sites no.5 and 6**, but downstream from this point all outcrops show sub-horizontal bedding. Visible fracturing pattern at this location consists of two vertical, closed and non-persistent joint sets, trending N45° and N140°, respectively.

- A fresh cut in the **right bank at Santa Elena** shows horizontal, finely bedded, light brown-yellowish siltstones and fine-grained sandstones. Strong weathering and moisturizing might explain the relatively loosened condition of these rocks.

- **About 250 m downstream from site no.1**, sub-horizontal, decimetric layers of micritic, slightly marly limestones and rare, centimetric marl interlayers, form a 3 m high cliff in the right bank (**photo 5**). Local joint system includes two vertical, planar, closed joint sets, trending ESE and NE, respectively.

- One of the best-exposed fault zones in the whole study area was identified in the left bank, half way **between sites 0 and 1** (**photos 6 and 7**). The fresh cut, exposing locally microfolded and strongly fractured marls and marly limestone layers, coincides with a recent minor slide, obviously related to the fragility of the materials along the fault. Several vertical planar joints, NNW trending, indicate the orientation of the fault (**photo 8**). The extension of this fault in both directions along the same NNW-SSE trend is suggested by the alignment of topographical features such as creeks and saddles, over several kilometers. It's worth noticing that the prolongation of the fault to the NNW would intersect the extremity of the ACP dam axis' right abutment.

- Very good outcrops were mapped **at site n°0,** along the quebrada Nicaragua in the left bank (**photo 9**), at elevations ranging between 25 and 40 m, and in a small stream running almost parallel to the axis in the right bank (**photo 10**), between elevations 25 and 65.

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

- Previous investigations had reported the presence of volcanic tuff fragments, particularly in exploration pits excavated in the top layers of the overburden, while a thick sedimentary sequence was explored during this field visit in the lower part of the banks. It can be inferred that volcanic rocks, not yet exposed in outcrops in this area, might overtop the sediments or that the rock fragments represent transported material.

- Few discontinuities could be mapped in the left bank, where the main vertical joint set shows a N90° (E-W) to N100° trend. In the right bank, the fracturing pattern is dominated by several discontinuities, N130-140° trending, featuring decimetric to metric zones of intense jointing and local argillic alteration. In addition, a recent, local and shallow landslide exposed an E-W trending, 50-70° S dipping, undulating slide surface, about 100 m downstream from the axis and 30 m N of the riverbed. This discontinuity is part of the joint set of similar trend mapped on the opposite river and coincides with the overall E-W orientation of the riverbed in this section. Locally, a minor joint set, N175° trending was also mapped in the right bank.

- Slope instability in the right bank is attested by the presence of small scale, shallow recent slides, debris flow deposits and deeply incised topography in the downstream half of the right abutment. This local instability can be related to fracturing and steep slopes on prominent topography, which, in turn, would indicate more resistant rocks.

➢ The outcrop in the **left bank of Rio Toabre at San Vicente** shows coarse sandstone, featuring 1 to 3 mm quartz and feldspars fragments, mainly sub-rounded and subordinately sub-angular, in a fine-grained matrix. Rare and discontinuous sub-horizontal surfaces could be interpreted as bedding, but the overall aspect is rather massive. Vertical joint system comprises N175° and N90° joint sets, with dm to metric spacing, both already mapped upstream, at site n°0.

Site 10

➢ The particularity of this site is the presence, in the lower part of the left bank, of silicified andesite and volcanic breccia. The latter seems alternatively fragment- and matrix supported. Vugs resulting from alteration and washout of mafic or feldspar phenocrystals are also locally present. The upper part of the left bank was investigated starting from a helicopter stop. Sporadic outcrops exposed sub-horizontal, strongly weathered marls and siltstones and argillic altered +/- silicified volcanic tuffs and breccias. Volcanic rocks also appear as boulders in a secondary stream, along with argillic altered and sheared tectonic breccia boulders.

➢ The actual relative position of volcanic rocks and sediments is not yet clear and the fracturing pattern could not be determined, but the proximity of a tectonic accident can be inferred from the presence of volcanic and tectonic breccia, locally featuring silicification and argillic alteration.

3. Geological screening criteria

Based on lithology and structural setting, engineering judgement was used to assess the geological conditions at the pre-selected sites. The geological screening criteria are summarized in **Table 1.**

The following items were considered:

- site geology – quality and level of foundation, abutment stability, water tightness
- reservoir geology – siltation, slope stability, water tightness
- availability of construction materials
- reconnaissance program

Where the distinction was appropriate, the influence of the lithology, on one hand, and of structures and fracturing, on the other, was considered separately.

3.1 Site geology

Foundation

Basically, two main Tertiary lithological units are involved in the foundation of the pre-selected dam sites: sediments and volcanics. The geomechanical properties of these rocks are assumed to be appropriate for the foundation of the dam. Good exposures allowed refining the estimation and defining sections with relatively thinner soil overburden at sites 1, 6, 7 and 10. Elsewhere, the rough estimation of foundation level can not lead to significant discrimination between the alternative sites.

The possibility of finding clayey or silty layers or interbeds of poor geomechanical condition within the sedimentary sequence can not be ruled out at this stage. This potentially unfavorable configuration, which could lower the overall condition of the foundation, may concern any of the **sites 0 to 5 and possibly site 10.**

The sub-horizontal bedding of the sedimentary sequence at **sites 0, 1 and 2** can turn out to be unfavorable in local configurations involving soft, clayey layers and slight but consistent downstream-wards dipping.

On the contrary, the upstream-ward dipping at **sites 3, 4 and 5** constitutes a favorable setting.

Structural complexity, including presence of faults, folding and downstream-ward dipping bedding joints would justify the unfavorable rating of **site 6**.

The presence of brittle volcanic lavas in conjunction with intense fracturing, as well as possible local superposition of flows with different lithologies and geomechanical characteristics may be unfavorable. Nevertheless, only further reconnaissance can determine the actual existence of such configurations at sites **7, 8 and 9.**

At **site 10,** the inferred major tectonic accident might involve complex contacts between formations with different geomechanical properties, such as marls and silicified volcanics.

Abutments stability

Potential instability can be related to the relatively intense fracturing / faulting, evidenced or inferred at **site 10** (particularly the left abutment), **site 0** (especially in the right abutment) and **site 7**. These assumptions need to be confirmed by further reconnaissance. A careful use should be made of these work hypotheses, considering that better outcrops in the respective areas, commonly corresponding to more resistant rocks, allowed the mapping of the faults, while the lack of outcrops at the other sites does not necessarily indicate the absence of tectonic accidents.

The faults mapped or inferred in both abutments at **site 6,** as well as recent shallow slides observed in the left abutment are definitely unfavorable aspects for this site.

Water tightness

The presence of karstified limestone and calcarenites was ascertained at **site 6** and an inferred N-S (upstream-downstream) fault would increase the risk of leakage at the same site.

No limestone layers featuring karstic dissolution could be mapped so far within the sedimentary sequence at **sites 1 to 5**. In addition, all calcareous layers exposed downstream from Rio Toabre / Rio de “U” confluence include a marly component, which strengthens their resistance to dissolution. Nevertheless, the absence of this risk would need to be confirmed during further reconnaissance surveys, since the available outcrops only give a discontinuous log of the sedimentary series.

It is worth noticing that the presence of such layers would not be very critical **for sites 3, 4 and 5**, due to the upstream dipping of the bedding at those locations.

The foundation at **sites 7, 8 and 9** includes interlayered mafic volcanic units. Although not pervious rocks, they are traditionally considered unfavorable with respect to leakage because of their brittle character.

Sub-horizontal bedding at **sites 0, 1 and 2** may be an unfavorable structural setting but the influence on water tightness will be precisely evaluated only by water tests. On the contrary, the upstream dipping bedding at **sites 3, 4 and 5** is definitely a favorable setting.

Inferred strong fracturing might have a negative impact on leakage in the foundation at **site no. 10**, but the silicification could have sealed the fractures. Further reconnaissance is needed for an accurate judgment on this site. Likewise, although local fault evidence was identified, doubts persist as to the intensity of fracturing and of its possible influence on leakage at **site 6**.

3.2 Reservoir geology

Owing to the sporadic information at reservoir scale, the following considerations are only rough estimates.

Siltation

The possible presence of potentially more erodible layers within the sedimentary sequence, such as loose silts, may lead to a greater sedimentation yield downstream from site no 6. Upstream reservoirs, involving mainly volcanics, would be consequently slightly advantaged, accepting that yield from relatively erodible volcanic tuffs would supply all reservoirs.

Slope stability

Instability phenomena, mainly shallow, involving residual soil and colluvial deposits, are widespread throughout the whole study area. Assuming a similar impact, no significant discrimination can be accurately performed between the alternative sites at this stage.

Water tightness

Most of the sedimentary layers (marls, marly limestones, siltstones and sandstones) as well as volcanic units (basalts / andesites and tuffs) are basically impervious.

The only pervious formation known so far would be the karstic massive limestone and calcarenites mapped at **site 6**. The lack of continuity and the limited extension of this formation, as suggested by field investigations, do not support the hypothesis of a significant impact.

In addition, the fracturing pattern at the reservoir scale does not seem to affect in particular any of the alternatives.

For these reasons, no distinction could be operated in this respect.

3.3 Construction materials

Preliminary surveys [Ref 6] indicated the general lack of fines in the entire area and this can not be used as a discriminating item.

Same surveys showed that the most prospective sources of appropriate rockfill material and concrete aggregates were the andesite units in the proximity of **sites 7, 8 and 9**. The farthest sites (**10, 0, 1 and 2**) would therefor be less favorable.

3.4 Reconnaissance program

Work hypotheses were done at this stage for all alternative sites, requiring confirmation through further reconnaissance.

Site 0 appears as the only alternative having been subject to reconnaissance surveys, including a refraction seismic campaign, and thus a step forward with respect to all the other sites.

4. Conclusions

Lithology, structural setting and fracturing pattern were used to assess and to compare the alternative dam sites.

The geological conditions do not allow operating a clear discrimination:

- no site appears to be significantly better than the others
- all the sites seem acceptable at this stage, but doubts persist as to the water tightness, abutment stability and overall foundation quality, which may result in more or less significant treatment for particular sites.

TABLE 5 - SYNTHETIC TABLE FOR SCREENING PROCESS

DAM SITE		n°0 (reference)				n°10				n°1				n°2				n°6+8				n°7+8				n°6				n°7			
Catchment Area	km²	727				737				720				710				700				700				595				595			
Annual Inflow (AI)	MCM/y	1 288				1 315				1 267				1 237				1 214				1 214				994				994			
Ratio Inflow / site n°0		100%				102%				98%				96%				94%				94%				77%				77%			
PMF	m3/s	9 510				9 560				9 475				9 420				9 370				9 370				8 790				8 790			
River Elevation	masl	18				16				19				20				30				35				30				35			
Normal Water Level (NWL)	**masl**	**90**	**95**	**100**	**105**	**85**	**90**	**95**	**100**	**90**	**95**	**100**	**105**	**95**	**100**	**105**	**110**	**100**	**110**	**115**	**120**	**100**	**110**	**115**	**120**	**100**	**110**	**115**	**120**	**100**	**110**	**115**	**120**
Maximum Water Level (MWL)	masl	95	100	105	110	90	95	100	105	95	100	105	110	100	105	110	115	105	115	120	125	105	115	120	125	105	115	120	125	105	115	120	125
Minimum Operating Level (MOL)	masl	50	50	50	50	50	50	50	50	50	50	50	50	53	53	53	53	66	66	66	66	66	66	66	66	67	67	67	67	67	67	67	67
Reservoir Surface at NWL	km²	32	39	46	55	32	38	45	53	30	36	43	51	30	37	45	53	26	40	48	58	26	40	48	58	22	35	42	50	22	35	42	50
Reservoir Capacity at NWL	MCM	740	920	1 130	1 385	780	950	1 160	1 400	675	840	1 040	1 275	665	835	1 035	1 280	460	785	1 000	1 270	460	785	1 000	1 270	410	695	885	1 115	410	695	885	1 115
Active Storage (AC)	MCM	675	850	1 065	1 315	655	830	1 035	1 280	620	785	985	1 220	615	785	985	1 230	410	735	950	1 220	410	735	950	1 220	360	645	835	1 065	360	645	835	1 065
AC/AI		0,5	0,7	0,8	1,0	0,5	0,6	0,8	1,0	0,5	0,6	0,8	1,0	0,5	0,6	0,8	1,0	0,3	0,6	0,8	1,0	0,3	0,6	0,8	1,0	0,4	0,6	0,8	1,1	0,4	0,6	0,8	1,1
Height of dam (above river bed)	m	77	82	87	92	74	79	84	89	76	81	86	91	80	85	90	95	75	85	90	95	70	80	85	90	75	85	90	95	70	80	85	90
Length of dam crest	m	1 460	1 520	1 600	2 000	2 225	2 300	2 375	2 450	2 375	2 500	2 620	3 000	2 115	2 150	2 350	2 450	2 300	2 500	2 600	2 700	2 250	2 440	2 535	2 630	1 200	1 300	1 350	1 400	1 150	1 240	1 285	1 330
Volume of dams (RCC)	MCM	2,00	2,30	2,65	3,05	2,15	2,60	3,05	3,55	2,05	2,50	2,95	3,50	2,40	2,90	3,40	3,95	1,35	2,00	2,40	2,90	1,75	2,50	3,00	3,50	0,85	1,25	1,50	1,75	1,30	1,80	2,10	2,40
Transfer Tunnel length	km	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	19	19	19	19	19	19	19	19
Transfer Tunnel diameter (base D2)	m	5,50	5,75	6,00	6,20	6,20	5,75	6,00	6,20	5,35	5,65	5,90	6,10	5,10	5,35	5,60	5,80	4,25	4,65	4,90	5,05	4,25	4,65	4,90	5,05	4,10	4,50	4,60	4,85	4,10	4,50	4,60	4,85
Project Cost (dams + tunnel)	**MUSD**	**204**	**227**	**252**	**280**	**226**	**245**	**276**	**310**	**205**	**237**	**269**	**305**	**221**	**256**	**290**	**327**	**156**	**207**	**239**	**276**	**184**	**242**	**281**	**318**	**128**	**166**	**187**	**213**	**159**	**203**	**229**	**257**
Project Cost ratio / n°0 NWL 95		90%	100%	111%	124%	100%	108%	122%	137%	90%	104%	118%	135%	98%	113%	128%	144%	69%	91%	106%	122%	81%	107%	124%	140%	56%	73%	83%	94%	70%	90%	101%	114%
Yield D1	**MCM/y**	**1058**	**1100**	**1131**	**1144**	**1067**	**1115**	**1149**	**1166**	**1025**	**1071**	**1105**	**1123**	**1004**	**1049**	**1082**	**1097**	**883**	**1022**	**1061**	**1078**	**883**	**1022**	**1061**	**1078**	**741**	**846**	**874**	**883**	**741**	**846**	**874**	**883**
Yield D1 Ratio / n°0 NWL 95		96%	100%	103%	104%	97%	101%	104%	106%	93%	97%	101%	102%	91%	95%	98%	100%	80%	93%	96%	98%	80%	93%	96%	98%	67%	77%	79%	80%	67%	77%	79%	80%
Yield D2	**MCM/y**	**772**	**886**	**991**	**1 067**	**764**	**881**	**990**	**1 077**	**728**	**841**	**948**	**1 034**	**718**	**831**	**937**	**1 020**	**547**	**794**	**913**	**1 000**	**547**	**794**	**913**	**1 000**	**470**	**677**	**771**	**834**	**470**	**677**	**771**	**834**
Yield D2 Ratio / n°0 NWL 95		87%	100%	112%	120%	86%	99%	112%	122%	82%	95%	107%	117%	81%	94%	106%	115%	62%	90%	103%	113%	62%	90%	103%	113%	53%	76%	87%	94%	53%	76%	87%	94%
Environmental Impacts (negative)																																	
affected population	people	1145	1345	1601	1918	1248	1248	1448	1704	1131	1324	1580	1897	1218	1474	1791	2098	1109	1717	2612	*2612*	994	1602	2497	*2497*	1109	1717	2529	2529	994	1602	2414	2414
ratio / n°0 NWL 95		85%	100%	119%	143%	93%	93%	108%	127%	84%	98%	117%	141%	91%	110%	133%	156%	82%	128%	194%	194%	74%	119%	186%	186%	82%	128%	188%	188%	74%	119%	179%	179%
affected village	unit	15	21	21	25	16	18	24	27	14	19	19	23	18	18	22	24	12	17	21	21	11	16	20	20	12	17	19	19	11	16	18	18
ratio / n°0 NWL 95		71%	100%	100%	119%	76%	86%	114%	129%	67%	90%	90%	110%	86%	86%	105%	114%	57%	81%	100%	100%	52%	76%	95%	95%	57%	81%	90%	90%	52%	76%	86%	86%
affected area	ha	3425	5350	6000	6620	4010	6010	6700	7350	3190	5080	5650	6260	4430	4940	5520	5965	3650	4546	6325	7465	3490	4380	6155	7265	3175	3955	5500	6500	3040	3810	5355	6320
ratio / n°0 NWL 95		64%	100%	112%	124%	75%	112%	125%	137%	60%	95%	106%	117%	83%	92%	103%	111%	68%	85%	118%	140%	65%	82%	115%	136%	59%	74%	103%	121%	57%	71%	100%	118%
Environmental Cost	**MUSD**	**19**	**27**	**31**	**35**	**20**	**22**	**30**	**34**	**18**	**26**	**29**	**34**	**23**	**27**	**31**	**34**	**20**	**27**	**38**	**42**	**19**	**26**	**38**	**42**	**19**	**25**	**35**	**38**	**18**	**24**	**35**	**38**
Environmental Cost ratio / n°0 NWL 95		70%	100%	115%	130%	73%	80%	109%	126%	66%	95%	109%	126%	86%	99%	115%	126%	74%	100%	142%	156%	70%	96%	141%	154%	70%	93%	130%	142%	67%	89%	129%	140%
Total Cost (Project+Environment)	**MUSD**	**223**	**254**	**284**	**315**	**246**	**266**	**306**	**344**	**222**	**263**	**298**	**339**	**244**	**282**	**321**	**361**	**176**	**234**	**278**	**318**	**203**	**268**	**319**	**359**	**147**	**191**	**222**	**251**	**177**	**227**	**263**	**295**
Total Cost Ratio / n°0 NWL 95		88%	100%	112%	124%	97%	105%	121%	136%	88%	103%	117%	134%	96%	111%	127%	142%	69%	92%	109%	125%	80%	106%	126%	142%	58%	75%	88%	99%	70%	90%	104%	116%
Total Cost / Yield D1 Index		211	231	251	276	230	239	266	295	217	245	270	302	243	269	297	329	199	229	262	295	229	262	300	333	198	225	254	284	238	269	301	335
Total Cost/Yield D1 Index Ratio / n°0 NWL 95		91%	100%	109%	119%	100%	104%	115%	128%	94%	106%	117%	131%	105%	117%	129%	143%	86%	99%	113%	128%	99%	114%	130%	144%	86%	98%	110%	123%	103%	116%	131%	145%
Total Cost / Yield D2 Index		289	286	286	295	322	302	309	320	306	312	314	328	340	340	343	354	322	295	304	318	370	337	349	359	312	281	288	301	376	336	342	354
Total Cost/Yield D2 Index Ratio / n°0 NWL 95		101%	100%	100%	103%	112%	106%	108%	112%	107%	109%	110%	115%	119%	119%	120%	123%	112%	103%	106%	111%	129%	118%	122%	125%	109%	98%	101%	105%	131%	117%	119%	124%
Technical Comments (negative)																		multi diversion works topographical & geological reserve on left abutment n°6 grouting treatment site n°6 reservoirs connexion works				multi diversion works grouting treatment site n°7 reservoirs connexion works				topographical & geological reserve on left abutment n°6 grouting treatment saddle dams				multi diversion works grouting treatment saddle dams			
Connexion with Cano Sucio Reservoir 90	Y/N	N	Y	Y	Y	N	N	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
DECISION for Analysis Phase	Y/N	N	Y	Y	N	N	N	N	N	N	Y	Y	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N

LIST OF DOCUMENTS

Ref 1 Reconnaissance Study – US Army Corps of Engineers - Dec. 1999
Section 5 - Rio Indio

Ref 2 Reconnaissance Study – US Army Corps of Engineers - Dec. 1999
Section 9 – Rio Toabre and Rio Cano Sucio.

Ref 3 Mapa geologico Republica de Panama scale 1/250000 Ministerio de Comercio e Industrios; hojas 3, 4, 5 y 6.

Ref 4 Field Mission Report - Coyne et Bellier, April 2002.

Ref 5 Reporte prospeccion sismica – Bachy-Fundaciones, S.A., Oct. 2002.

Ref 6 Informe de gira de campo 8 – 12 Julio 2002 – Consultores Asociados de Ingenieria, Aug. 2002

Ref 7 Laboratory testing results from Toabre Project – ACP, Oct. 2002

Ref 8 Basic Data Report – Coyne et Bellier, Dec. 2002

Photo 1. Site 6, right bank, lower part of Cerro Tulù. Massive limestone with vertical joints reworked by dissolution and slightly downstream-ward dipping bedding joint.

Photo 2. Site 6, left bank of Rio Tulù, about 100 m upstream of confluence with Rio Toabré. Karst dissolution in bioclastic calcarenite.

Photo 3. Site 6, left abutment. SW-NE planar joint / fault.

Photo 4. Site 6, left abutment. Detail from fault zone, showing brecciated rocks with iron oxides.

Photo 5. Right bank of Rio Toabré, 250 m downstream from site 1. Sub-horizontal marly limestone and rare, cm marl interlayers.

Photo 6. Fault zone in the left bank of Rio Toabre, between sites 0 and 1, coinciding with recent slide.

Photo 7. Fault in the left bank of Rio Toabre, between sites 0 and 1. Detail showing brecciation and intense fracturing.

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Photo 8. Fault zone in the left bank of Rio Toabre, between sites 0 and 1. Several sub-vertical planar joints indicate the trend of the fault.

Photo 9. Site 0, left bank, 'chorro' in quebrada Nicaragua. Sub-horizontal coarse grained sandstone with marly interbeds.

Photo 10. Site O, right bank. Sub-horizontal marly limestones and marls.

APPENDIX 2 – ENVIRONMENTAL IMPACTS (FROM ACP)

COSTOS DE IMPACTO AMBIENTAL DE ALTERNATIVAS ANALIZADAS POR ELEVACION :								
ALTERNATIVA	ELEV 80	ELEV 90	ELEV 95	ELEV 100	ELEV 105	ELEV 110	ELEV 115	ELEV 120
SITIO 10 - Los Ticocles								
a. Población	B/. 4 385 000	B/. 6 240 000	B/. 6 240 000	B/. 7 240 000	B/. 8 520 000	B/. 10 105 000	XXXXXXXXX	XXXXXXXXX
b. Habitat	B/. 4 037 068	B/. 5 190 254	B/. 5 742 089	B/. 8 535 724	B/. 9 563 662	B/. 10 559 521	XXXXXXXXX	XXXXXXXXX
c. Uso de Suelo	B/. 4 090 882	B/. 5 476 095	B/. 6 170 710	B/. 9 434 760	B/. 10 583 686	B/. 11 713 511	XXXXXXXXX	XXXXXXXXX
d. Infraestructura	B/. 1 912 494	B/. 2 826 705	B/. 3 319 000	B/. 4 312 794	B/. 5 318 132	B/. 5 959 986	XXXXXXXXX	XXXXXXXXX
TOTAL =	**B/. 14 425 443**	**B/. 19 733 054**	**B/. 21 471 798**	**B/. 29 523 278**	**B/. 33 985 480**	**B/. 38 338 017**	XXXXXXXXX	XXXXXXXXX
	MB/. 14.4	MB/. 19.7	MB/. 21.5	MB/. 29.5	MB/. 34.0	MB/. 38.3		
SITIO 0 - San Vicente								
a. Población	B/. 3 870 000	B/. 5 725 000	B/. 5 725 000	B/. 6 725 000	B/. 8 005 000	B/. 9 590 000	XXXXXXXXX	XXXXXXXXX
b. Habitat	B/. 3 286 087	B/. 4 262 045	B/. 4 757 165	B/. 7 362 255	B/. 8 259 018	B/. 9 148 452	XXXXXXXXX	XXXXXXXXX
c. Uso de Suelo	B/. 3 530 210	B/. 4 800 454	B/. 5 462 465	B/. 8 650 079	B/. 9 773 630	B/. 10 881 975	XXXXXXXXX	XXXXXXXXX
d. Infraestructura	B/. 1 668 539	B/. 2 573 989	B/. 3 065 052	B/. 4 304 411	B/. 5 037 142	B/. 5 678 086	XXXXXXXXX	XXXXXXXXX
TOTAL =	**B/. 12 354 835**	**B/. 17 361 488**	**B/. 19 009 682**	**B/. 27 041 745**	**B/. 31 074 789**	**B/. 35 298 513**	XXXXXXXXX	XXXXXXXXX
	MB/. 12.4	MB/. 17.4	MB/. 19.0	MB/. 27.0	MB/. 31.1	MB/. 35.3		
SITIO 1 -Santa Elena								
a. Población	B/. 3 800 000	B/. 5 655 000	B/. 5 655 000	B/. 6 620 000	B/. 7 900 000	B/. 9 485 000	XXXXXXXXX	XXXXXXXXX
b. Habitat	B/. 2 998 166	B/. 3 948 987	B/. 4 412 942	B/. 6 977 625	B/. 7 757 717	B/. 8 629 434	XXXXXXXXX	XXXXXXXXX
c. Uso de Suelo	B/. 3 271 962	B/. 4 508 049	B/. 5 138 129	B/. 8 280 813	B/. 9 283 305	B/. 10 375 155	XXXXXXXXX	XXXXXXXXX
d. Infraestructura	B/. 1 389 495	B/. 2 291 185	B/. 2 694 686	B/. 3 783 161	B/. 4 475 139	B/. 5 006 923	XXXXXXXXX	XXXXXXXXX
TOTAL =	**B/. 11 459 622**	**B/. 16 403 220**	**B/. 17 900 757**	**B/. 25 661 599**	**B/. 29 416 160**	**B/. 33 496 511**	XXXXXXXXX	XXXXXXXXX
	MB/. 11.5	MB/. 16.4	MB/. 17.9	MB/. 25.7	MB/. 29.4	MB/. 33.5		
SITIO 2 - San Isidro								
a. Población	B/. 2 825 000	XXXXXXXXX	B/. 5 125 000	B/. 6 090 000	B/. 7 370 000	B/. 8 955 000	B/. 10 490 000	XXXXXXXXX
b. Habitat	B/. 2 406 804	XXXXXXXXX	B/. 3 641 667	B/. 6 083 822	B/. 6 788 839	B/. 7 621 955	B/. 8 309 947	XXXXXXXXX
c. Uso de Suelo	B/. 2 610 082	XXXXXXXXX	B/. 4 244 996	B/. 7 196 725	B/. 8 084 619	B/. 9 129 514	B/. 9 940 331	XXXXXXXXX
d. Infraestructura	B/. 1 183 103	XXXXXXXXX	B/. 2 449 686	B/. 3 711 148	B/. 4 422 715	B/. 5 060 719	B/. 5 416 232	XXXXXXXXX
TOTAL =	**B/. 9 024 988**	XXXXXXXXX	**B/. 15 461 348**	**B/. 23 081 694**	**B/. 26 666 173**	**B/. 30 767 188**	**B/. 34 156 510**	XXXXXXXXX
	MB/. 9.0		MB/. 15.5	MB/. 23.1	MB/. 26.7	MB/. 30.8	MB/. 34.2	
SITIO 4 -La Tomasa Norte								
a. Población	B/. 2 825 000	XXXXXXXXX	B/. 4 480 000	B/. 5 445 000	B/. 6 725 000	B/. 8 310 000	B/. 9 845 000	XXXXXXXXX
b. Habitat	B/. 2 072 241	XXXXXXXXX	B/. 3 235 696	B/. 5 643 784	B/. 6 312 126	B/. 7 133 681	B/. 7 807 014	XXXXXXXXX
c. Uso de Suelo	B/. 2 341 027	XXXXXXXXX	B/. 3 899 218	B/. 6 835 050	B/. 7 712 021	B/. 8 752 526	B/. 9 552 869	XXXXXXXXX
d. Infraestructura	B/. 1 151 166	XXXXXXXXX	B/. 2 212 685	B/. 3 418 281	B/. 4 128 516	B/. 4 765 178	B/. 5 119 220	XXXXXXXXX
TOTAL =	**B/. 8 389 434**	XXXXXXXXX	**B/. 13 827 598**	**B/. 21 342 114**	**B/. 24 877 663**	**B/. 28 961 385**	**B/. 32 324 103**	XXXXXXXXX
	MB/. 8.4		MB/. 13.8	MB/. 21.3	MB/. 24.9	MB/. 29.0	MB/. 32.3	
SITIO 6- Boca de Tulú (+8)								
a. Población	B/. 1 525 000	XXXXXXXXX	XXXXXXXXX	B/. 4 265 000	B/. 5 545 000	B/. 7 050 000	B/. 8 585 000	B/. 13 060 000
b. Habitat	B/. 1 246 225	XXXXXXXXX	XXXXXXXXX	B/. 4 222 492	B/. 4 753 774	B/. 5 441 576	B/. 6 023 919	B/. 8 660 383
c. Uso de Suelo	B/. 1 482 105	XXXXXXXXX	XXXXXXXXX	B/. 5 539 673	B/. 6 341 161	B/. 7 295 424	B/. 8 041 874	B/. 11 536 155
d. Infraestructura	B/. 724 444	XXXXXXXXX	XXXXXXXXX	B/. 1 769 762	B/. 3 381 490	B/. 3 881 339	B/. 4 370 791	B/. 5 128 859
TOTAL =	**B/. 4 977 775**	XXXXXXXXX	XXXXXXXXX	**B/. 15 796 927**	**B/. 20 021 425**	**B/. 23 668 339**	**B/. 27 021 583**	**B/. 38 385 397**
	MB/. 5.0			MB/. 15.8	MB/. 20.0	MB/. 23.7	MB/. 27.0	MB/. 38.4
SITIO 7 - El Guayabo (+8)								
a. Población	B/. 1 000 000	XXXXXXXXX	XXXXXXXXX	B/. 3 690 000	B/. 4 970 000	B/. 6 475 000	B/. 8 010 000	B/. 12 485 000
b. Habitat	B/. 1 164 828	XXXXXXXXX	XXXXXXXXX	B/. 4 005 740	B/. 4 528 677	B/. 5 212 469	B/. 5 788 149	B/. 8 418 291
c. Uso de Suelo	B/. 1 372 521	XXXXXXXXX	XXXXXXXXX	B/. 5 325 289	B/. 6 117 436	B/. 7 067 616	B/. 7 808 472	B/. 11 296 171
d. Infraestructura	B/. 487 349	XXXXXXXXX	XXXXXXXXX	B/. 2 589 736	B/. 3 276 391	B/. 3 904 287	B/. 4 248 666	B/. 5 803 759
TOTAL =	**B/. 4 024 698**	XXXXXXXXX	XXXXXXXXX	**B/. 15 610 764**	**B/. 18 892 503**	**B/. 22 659 372**	**B/. 25 855 287**	**B/. 38 003 220**
	MB/. 4.0			MB/. 15.6	MB/. 18.9	MB/. 22.7	MB/. 25.9	MB/. 38.0

ALTERNATIVAS DE SITIO DE PRESA PARA EL PROYECTO DE RIO TOABRE

AREAS INUNDADAS POR ELEVACION EN HECTAREAS								
ALTERNATIVA	ELEV 80	ELEV 90	ELEV 95	ELEV 100	ELEV 105	ELEV 110	ELEV 115	ELEV 120
SITIO 10	2707	3569	3988	5197	5981	6704	xxxxxxxxxxx	xxxxxxxx
ISLAS 0	73	32	23	814	716	648		
SITIO 10	2247	3012	3404	4536	5284	5973	xxxxxxxxxxx	xxxxxxxx
ISLAS 0	70	31	21	809	712	645		
SITIO 1	2063	2800	3172	4275	4957	5626	xxxxxxxxxxx	xxxxxxxx
ISLAS 1	55	27	16	805	690	630		
SITIO 2	1665	xxxxxxxxx	2628	3648	4263	4900	5407	xxxxxxxx
ISLAS 2	28		3	784	679	622	558	
SITIO 4	1478	xxxxxxxxx	2391	3391	3990	4619	5117	xxxxxxxx
ISLAS 4	22		3	784	679	622	558	
SITIO 6 Y 8	924	xxxxxxxxx	xxxxxxxxx	2562	3072	3628	4074	5838
ISLAS 6 Y 8	4			668	577	528	472	487
SITIO 7 Y 8	865	xxxxxxxxx	xxxxxxxxx	2480	2982	3533	3973	5728
ISLAS 7 Y 8	4			598	509	463	408	426

POBLACION AFECTADA POR DEBAJO DE :								
ALTERNATIVA	ELEV 80	ELEV 90	ELEV 95	ELEV 100	ELEV 105	ELEV 110	ELEV 115	ELEV 120
SITIO 10	877	1248	1248	1448	1704	2021	xxxxxxxxxxx	xxxxxxxxxx
SITIO 0	774	1145	1145	1345	1601	1918	xxxxxxxxxxx	xxxxxxxxxx
SITIO 1	760	1131	1131	1324	1580	1897	xxxxxxxxxxx	xxxxxxxxxx
SITIO 2	565	xxxxxxxxx	1025	1218	1474	1791	2098	xxxxxxxxxx
SITIO 4	565	xxxxxxxxx	896	1089	1345	1662	1969	xxxxxxxxxx
SITIO 6 Y 8	305	xxxxxxxxx	xxxxxxxxx	853	1109	1410	1717	2612
SITIO 7 Y 8	200	xxxxxxxxx	xxxxxxxxx	738	994	1295	1602	2497

COSTOS DE INDEMNIZACIÓN PARA POBLACION AFECTADA POR DEBAJO DE :								
ALTERNATIVA	ELEV 80	ELEV 90	ELEV 95	ELEV 100	ELEV 105	ELEV 110	ELEV 115	ELEV 120
SITIO 10	B/. 4 385 000	B/. 6 240 000	B/. 6 240 000	B/. 7 240 000	B/. 8 520 000	B/. 10 105 000	xxxxxxxxxxx	xxxxxxxxxx
SITIO 0	B/. 3 870 000	B/. 5 725 000	B/. 5 725 000	B/. 6 725 000	B/. 8 005 000	B/. 9 590 000	xxxxxxxxxxx	xxxxxxxxxx
SITIO 1	B/. 3 800 000	B/. 5 655 000	B/. 5 655 000	B/. 6 620 000	B/. 7 900 000	B/. 9 485 000	xxxxxxxxxxx	xxxxxxxxxx
SITIO 2	B/. 2 825 000	xxxxxxxxx	B/. 5 125 000	B/. 6 090 000	B/. 7 370 000	B/. 8 955 000	B/. 10 490 000	xxxxxxxxxx
SITIO 4	B/. 2 825 000	xxxxxxxxx	B/. 4 480 000	B/. 5 445 000	B/. 6 725 000	B/. 8 310 000	B/. 9 845 000	xxxxxxxxxx
SITIO 6 Y 8	B/. 1 525 000	xxxxxxxxx	xxxxxxxxx	B/. 4 265 000	B/. 5 545 000	B/. 7 050 000	B/. 8 585 000	B/. 13 060 000
SITIO 7 Y 8	B/. 1 000 000	xxxxxxxxx	xxxxxxxxx	B/. 3 690 000	B/. 4 970 000	B/. 6 475 000	B/. 8 010 000	B/. 12 485 000

Indemnización = B/. 5 000 estimación por persona afectada

ALTERNATIVAS DE SITIO DE PRESA PARA EL PROYECTO DE RIO TOABRE

AREAS DIRECTAMENE AFECTADAS POR ELEVACION EN HECTAREAS								
ALTERNATIVA	ELEV 80	ELEV 90	ELEV 95	ELEV 100	ELEV 105	ELEV 110	ELEV 115	ELEV 120
SITIO 10 Los Ticocles	2780	3601	4011	6011	6697	7352	xxxxxxxxxxx	xxxxxxxx
SITIO 0 San Vicente	2317	3043	3425	5345	5996	6618	xxxxxxxxxxx	xxxxxxxx
SITIO 1 Santa Elena	2118	2827	3188	5080	5647	6256	xxxxxxxxxxx	xxxxxxxx
SITIO 2 San Isidro	1694	xxxxxxxxx	2631	4432	4942	5522	5966	xxxxxxxx
SITIO 4 La Tomasa Norte	1500	xxxxxxxxx	2393	4175	4669	5241	5675	xxxxxxxx
SITIO 6 Y 8 Boca de Tulú	928	xxxxxxxxx	xxxxxxxxx	3230	3649	4156	4546	6324
SITIO 7 Y 8 El Guayabo	869	xxxxxxxxx	xxxxxxxxx	3078	3492	3996	4381	6154

COSTOS DE TERRENOS DIRECTAMENE AFECTADOS								
ALTERNATIVA	ELEV 80	ELEV 90	ELEV 95	ELEV 100	ELEV 105	ELEV 110	ELEV 115	ELEV 120
SITIO 10	B/. 556 031	B/. 720 214	B/. 802 170	B/. 1 202 161	B/. 1 339 450	B/. 1 470 426	xxxxxxxxxx	xxxxxxxxx
SITIO 0	B/. 463 342	B/. 608 579	B/. 685 022	B/. 1 068 976	B/. 1 199 130	B/. 1 323 506	xxxxxxxxxx	xxxxxxxxx
SITIO 1	B/. 423 633	B/. 565 416	B/. 637 627	B/. 1 016 083	B/. 1 129 333	B/. 1 251 241	xxxxxxxxxx	xxxxxxxxx
SITIO 2	B/. 338 710	xxxxxxxxx	B/. 526 158	B/. 886 342	B/. 988 356	B/. 1 104 364	B/. 1 193 130	xxxxxxxxx
SITIO 4	B/. 300 025	xxxxxxxxx	B/. 478 679	B/. 835 037	B/. 933 756	B/. 1 048 251	B/. 1 135 050	xxxxxxxxx
SITIO 6 Y 8	B/. 185 588	xxxxxxxxx	xxxxxxxxx	B/. 645 911	B/. 729 859	B/. 831 257	B/. 909 197	B/. 1 264 876
SITIO 7 Y 8	B/. 173 739	xxxxxxxxx	xxxxxxxxx	B/. 615 599	B/. 698 365	B/. 799 163	B/. 876 132	B/. 1 230 897

Valor de la Tierra = B/. 200 $/Hectárea de acuerdo a valorización de la Reforma Agraria

URS-Dames & Moore / IRG 7 GEA

ALTERNATIVAS DE SITIO DE PRESA PARA EL PROYECTO DE RIO TOABRE

	NUMERO DE POBLADOS AFECTADOS POR DEBAJO DE :							
ALTERNATIVA	ELEV 80	ELEV 90	ELEV 95	ELEV 100	ELEV 105	ELEV 110	ELEV 115	ELEV 120
SITIO 10 (A-C)	15	16	18	24	27	28	xxxxxxxxxxx	xxxxxxxxxxx
SITIO 0 (A - B)	12	13	15	21	21	25	xxxxxxxxxxx	xxxxxxxxxxx
SITIO 1 (A-E)	11	12	14	19	19	23	xxxxxxxxxxx	xxxxxxxxxxx
SITIO 2 (A-C)	9	XXXXXXXX	13	18	18	22	24	xxxxxxxxxxx
SITIO 4 (A-B)	9	XXXXXXXX	12	17	17	21	23	xxxxxxxxxxx
SITIO 6 Y 8 (A-B)	5	XXXXXXXX	XXXXXXXXX	12	12	15	17	21
SITIO 7 Y 8 (A-B)	4	XXXXXXXX	XXXXXXXXX	11	11	14	16	20

Fuente: Estudios Socioeconomicos Irg-Dames -Moore

Infraestructuras TOABRE	Cantidad de Infraestructuras en Sitio 10 (Los Ticocles)							
Estructura	Nivel 80	Nivel 90	Nivel 95	Nivel 100	Nivel 105	Nivel 110	Nivel 115	Nivel 120
Agua Potable Distribucion	4	5	5	6	7	7	xxxxxxx	xxxxxxx
Almacenamiento de Agua	4	4	4	5	6	6	xxxxxxx	xxxxxxx
Areas Recreativas	0	0	0	0	0	0	xxxxxxx	xxxxxxx
Caminos	4	4	5	6	8	12	xxxxxxx	xxxxxxx
Cementerio	2	2	4	8	10	10	xxxxxxx	xxxxxxx
Clinica o Centro de Salud	1	2	2	3	3	3	xxxxxxx	xxxxxxx
Comercio/Industrial/Agroindustrial	3	6	6	7	8	9	xxxxxxx	xxxxxxx
Escuela	4	6	9	10	16	17	xxxxxxx	xxxxxxx
Fuente de Agua Potable	1	1	1	3	4	4	xxxxxxx	xxxxxxx
Generación De Energía Eléctrica	0	1	1	1	1	2	xxxxxxx	xxxxxxx
Gubernamental	3	3	3	3	4	5	xxxxxxx	xxxxxxx
Iglesia/Capilla	3	7	7	8	10	13	xxxxxxx	xxxxxxx
Parque Publico o Area Recreativas	3	5	5	7	7	8	xxxxxxx	xxxxxxx
Postes Electricos	0	0	0	0	0	0	xxxxxxx	xxxxxxx
Puente	6	7	10	14	15	16	xxxxxxx	xxxxxxx
Telecomunicaciones	1	3	3	4	5	7	xxxxxxx	xxxxxxx
Vivienda	157	223	247	313	362	416	xxxxxxx	xxxxxxx

	Cantidad de Infraestructuras en Sitio 0 (San Vicente)							
Estructura	Nivel 80	Nivel 90	Nivel 95	Nivel 100	Nivel 105	Nivel 110	Nivel 115	Nivel 120
Agua Potable Distribucion	3	4	4	6	6	6	xxxxxxx	xxxxxxx
Almacenamiento de Agua	3	3	3	5	5	5	xxxxxxx	xxxxxxx
Areas Recreativas	0	0	0	0	0	0	xxxxxxx	xxxxxxx
Caminos	4	4	5	6	8	12	xxxxxxx	xxxxxxx
Cementerio	2	2	4	9	10	10	xxxxxxx	xxxxxxx
Clinica o Centro de Salud	1	2	2	3	3	3	xxxxxxx	xxxxxxx
Comercio/Industrial/Agroindustrial	3	6	6	7	8	9	xxxxxxx	xxxxxxx
Escuela	3	5	8	10	15	16	xxxxxxx	xxxxxxx
Fuente de Agua Potable	1	1	1	3	4	4	xxxxxxx	xxxxxxx
Generación de Energía Eléctrica	0	1	1	1	1	2	xxxxxxx	xxxxxxx
Gubernamental	3	3	3	3	3	4	xxxxxxx	xxxxxxx
Iglesia/Capilla	2	6	6	8	9	12	xxxxxxx	xxxxxxx
Parque Publico o Area Recreativas	3	5	5	7	7	8	xxxxxxx	xxxxxxx
Postes Electricos	0	0	0	0	0	0	xxxxxxx	xxxxxxx
Puente	5	6	9	14	14	15	xxxxxxx	xxxxxxx
Telecomunicaciones	1	3	3	4	5	7	xxxxxxx	xxxxxxx
Vivienda	146	211	235	316	349	403	xxxxxxx	xxxxxxx

	Cantidad de Infraestructuras en Sitio 1 (Santa Elena)							
Estructura	Nivel 80	Nivel 90	Nivel 95	Nivel 100	Nivel 105	Nivel 110	Nivel 115	Nivel 120
Agua Potable Distribucion	3	4	4	6	6	6	xxxxxxx	xxxxxxx
Almacenamiento de Agua	3	3	3	5	5	5	xxxxxxx	xxxxxxx
Areas Recreativas	0	0	0	0	0	0	xxxxxxx	xxxxxxx
Caminos	4	4	5	6	8	12	xxxxxxx	xxxxxxx
Cementerio	2	2	3	8	9	9	xxxxxxx	xxxxxxx
Clinica o Centro de Salud	1	2	2	3	3	3	xxxxxxx	xxxxxxx
Comercio/Industrial/Agroindustrial	3	6	6	7	8	9	xxxxxxx	xxxxxxx
Escuela	3	5	8	10	15	16	xxxxxxx	xxxxxxx
Fuente de Agua Potable	1	1	1	3	4	4	xxxxxxx	xxxxxxx
Generación de Energía Eléctrica	0	1	1	1	1	2	xxxxxxx	xxxxxxx
Gubernamental	2	3	3	3	3	4	xxxxxxx	xxxxxxx
Iglesia/Capilla	0	5	5	7	7	8	xxxxxxx	xxxxxxx
Parque Publico o Area Recreativas	0	0	0	0	0	0	xxxxxxx	xxxxxxx
Postes Electricos	5	6	9	14	14	15	xxxxxxx	xxxxxxx
Puente	0	0	0	0	0	0	xxxxxxx	xxxxxxx
Telecomunicaciones	1	3	3	4	5	7	xxxxxxx	xxxxxxx
Vivienda	143	208	232	313	345	399	xxxxxxx	xxxxxxx

	Cantidad de Infraestructuras en Sitio 2 (San Isidro)							
Estructura	Nivel 80	Nivel 90	Nivel 95	Nivel 100	Nivel 105	Nivel 110	Nivel 115	Nivel 120
Agua Potable Distribucion	2	xxxxxxx	3	5	5	5	5	xxxxxxx
Almacenamiento de Agua	2	xxxxxxx	2	4	4	4	5	xxxxxxx
Areas Recreativas	0	xxxxxxx	0	0	0	0	0	xxxxxxx
Caminos	3	xxxxxxx	4	5	7	11	14	xxxxxxx
Cementerio	2	xxxxxxx	3	8	9	9	9	xxxxxxx
Clinica o Centro de Salud	1	xxxxxxx	2	3	3	3	3	xxxxxxx
Comercio/Industrial/Agroindustrial	1	xxxxxxx	4	5	6	7	8	xxxxxxx
Escuela	2	xxxxxxx	6	8	13	14	14	xxxxxxx

Fuente de Agua Potable	0	xxxxxxx	0	2	3	3	3	xxxxxxx
Generación de Energía Eléctrica	0	xxxxxxx	1	1	1	2	2	xxxxxxx
Gubernamental	1	xxxxxxx	2	2	2	3	3	xxxxxxx
Iglesia/Capilla	1	xxxxxxx	5	7	8	11	13	xxxxxxx
Parque Publico o Area Recreativas	2	xxxxxxx	4	6	6	7	7	xxxxxxx
Postes Electricos	0	xxxxxxx	0	0	0	0	0	xxxxxxx
Puente	3	xxxxxxx	7	12	12	13	14	xxxxxxx
Telecomunicaciones		xxxxxxx	2	3	4	6	6	xxxxxxx
Vivienda	120	xxxxxxx	200	287	317	371	396	xxxxxxx
	Cantidad de Infraestructuras en Sitio 4 (La Tomasa Norte)							
Estructura	Nivel 80	Nivel 90	Nivel 95	Nivel 100	Nivel 105	Nivel 110	Nivel 115	Nivel 120
Agua Potable Distribucion	2	xxxxxxx	3	5	5	5	5	xxxxxxx
Almacenamiento de Agua	2	xxxxxxx	2	4	4	4	5	xxxxxxx
Areas Recreativas	0	xxxxxxx	0	0	0	0	0	xxxxxxx
Caminos	3	xxxxxxx	4	5	7	11	14	xxxxxxx
Cementerio	2	xxxxxxx	3	8	9	9	9	xxxxxxx
Clinica o Centro de Salud	1	xxxxxxx	1	2	2	2	2	xxxxxxx
Comercio/Industrial/Agroindustrial	1	xxxxxxx	4	5	6	7	8	xxxxxxx
Escuela	2	xxxxxxx	5	7	12	13	13	xxxxxxx
Fuente de Agua Potable	0	xxxxxxx	0	2	3	3	3	xxxxxxx
Generación de Energía Eléctrica	0	xxxxxxx	0	0	0	1	1	xxxxxxx
Gubernamental	1	xxxxxxx	1	1	1	2	2	xxxxxxx
Iglesia/Capilla	1	xxxxxxx	4	6	7	10	12	xxxxxxx
Parque Publico o Area Recreativas	2	xxxxxxx	3	5	5	6	6	xxxxxxx
Postes Electricos	0	xxxxxxx	0	0	0	0	0	xxxxxxx
Puente	3	xxxxxxx	7	12	12	13	14	xxxxxxx
Telecomunicaciones	0	xxxxxxx	1	2	3	5	5	xxxxxxx
Vivienda	116	xxxxxxx	194	270	300	354	379	xxxxxxx
	Cantidad de Infraestructura Sitio 6 (Boca de Tulú)							
Estructura	Nivel 80	Nivel 90	Nivel 95	Nivel 100	Nivel 105	Nivel 110	Nivel 115	Nivel 120
Agua Potable Distribucion	1	xxxxxxx	xxxxxxx	3	3	3	3	3
Almacenamiento de Agua	1	xxxxxxx	xxxxxxx	2	2	2	3	3
Areas Recreativas	0	xxxxxxx	xxxxxxx	0	0	0	0	0
Caminos	1	xxxxxxx	xxxxxxx	3	5	9	12	14
Cementerio	2	xxxxxxx	xxxxxxx	8	9	9	9	10
Clinica o Centro De Salud	1	xxxxxxx	xxxxxxx	2	2	2	2	3
Comercio/Industrial/Agroindustrial	1	xxxxxxx	xxxxxxx	5	6	7	8	9
Escuela	1	xxxxxxx	xxxxxxx	6	11	12	12	12
Fuente de Agua Potable	0	xxxxxxx	xxxxxxx	0	1	2	2	2
Generación de Energía Eléctrica	0	xxxxxxx	xxxxxxx	0	0	1	1	1
Gubernamental	0	xxxxxxx	xxxxxxx	0	0	1	1	3
Iglesia/Capilla	1	xxxxxxx	xxxxxxx	5	6	9	11	11
Parque Publico o Area Recreativas	1	xxxxxxx	xxxxxxx	4	4	5	5	5
Postes Electricos	0	xxxxxxx	xxxxxxx	0	0	0	0	0
Puente	2	xxxxxxx	xxxxxxx	10	10	11	12	19
Telecomunicaciones	0	xxxxxxx	xxxxxxx	2	3	5	5	5
Vivienda	69	xxxxxxx	xxxxxxx	0	212	239	292	316
	Cantidad de Infraestructura Sitio 7 (El Guayabo)							
Estructura	Nivel 80	Nivel 90	Nivel 95	Nivel 100	Nivel 105	Nivel 110	Nivel 115	Nivel 120
Agua Potable Distribucion	1	xxxxxxx	xxxxxxx	3	3	3	3	3
Almacenamiento de Agua	1	xxxxxxx	xxxxxxx	2	2	2	3	4
Areas Recreativas	0	xxxxxxx	xxxxxxx	0	0	0	0	1
Caminos	0	xxxxxxx	xxxxxxx	2	4	8	11	18
Cementerio	1	xxxxxxx	xxxxxxx	7	8	8	8	14
Clinica o Centro de Salud	1	xxxxxxx	xxxxxxx	2	2	2	2	5
Comercio/Industrial/Agroindustrial	1	xxxxxxx	xxxxxxx	5	6	7	8	12
Escuela	0	xxxxxxx	xxxxxxx	5	10	11	11	12
Fuente de Agua Potable	0	xxxxxxx	xxxxxxx	1	2	2	2	2
Generación de Energía Eléctrica	0	xxxxxxx	xxxxxxx	0	0	1	1	1
Gubernamental	0	xxxxxxx	xxxxxxx	0	0	1	1	3
Iglesia/Capilla	0	xxxxxxx	xxxxxxx	4	5	8	10	13
Parque Publico o Area Recreativas	1	xxxxxxx	xxxxxxx	4	4	5	5	5
Postes Electricos	0	xxxxxxx	xxxxxxx	0	0	0	0	0
Puente	1	xxxxxxx	xxxxxxx	9	9	10	11	21
Telecomunicaciones	0	xxxxxxx	xxxxxxx	2	3	5	5	7
Vivienda	53	xxxxxxx	xxxxxxx	196	223	276	300	380

Fuente: Estudios Socioeconomicos Irg-Dames -Moore

Infraestructuras TOABRE — Cantidad de Infraestructuras en Sitio 10 (Los Ticocles)

Estructura	Nivel 80	Nivel 90	Nivel 95	Nivel 100	Nivel 105	Nivel 110	Nivel 115	Nivel 120
Agua Potable Distribucion	80000	100000	100000	120000	140000	140000	xxxxxxx	xxxxxxx
Almacenamiento de Agua	20000	20000	20000	25000	30000	30000	xxxxxxx	xxxxxxx
Areas Recreativas	0	0	0	0	0	0	xxxxxxx	xxxxxxx
Caminos	233994	322705	368000	634294	746132	842486	xxxxxxx	xxxxxxx
Cementerio	30000	30000	60000	120000	150000	150000	xxxxxxx	xxxxxxx
Clinica o Centro de Salud	40000	80000	80000	120000	120000	120000	xxxxxxx	xxxxxxx
Comercio/Industrial/Agroindustrial	75000	150000	150000	175000	200000	225000	xxxxxxx	xxxxxxx
Escuela	300000	450000	675000	750000	1200000	1275000	xxxxxxx	xxxxxxx
Fuente de Agua Potable	2000	2000	2000	6000	8000	8000	xxxxxxx	xxxxxxx
Generación De Energía Eléctrica	0	1500	1500	1500	1500	3000	xxxxxxx	xxxxxxx
Gubernamental	45000	45000	45000	45000	60000	75000	xxxxxxx	xxxxxxx
Iglesia/Capilla	105000	245000	245000	280000	350000	455000	xxxxxxx	xxxxxxx
Parque Publico o Area Recreativas	45000	75000	75000	105000	105000	120000	xxxxxxx	xxxxxxx
Postes Electricos	0	0	0	0	0	0	xxxxxxx	xxxxxxx
Puente	144000	168000	240000	336000	360000	384000	xxxxxxx	xxxxxxx
Telecomunicaciones	7500	22500	22500	30000	37500	52500	xxxxxxx	xxxxxxx
Vivienda	785000	1115000	1235000	1565000	1810000	2080000	xxxxxxx	xxxxxxx
	B/. 1 912 494	**B/. 2 826 705**	**B/. 3 319 000**	**B/. 4 312 794**	**B/. 5 318 132**	**B/. 5 959 986**		

Cantidad de Infraestructuras en Sitio 0 (San Vicente)

Estructura	Nivel 80	Nivel 90	Nivel 95	Nivel 100	Nivel 105	Nivel 110	Nivel 115	Nivel 120
Agua Potable Distribucion	60000	80000	80000	120000	120000	120000	xxxxxxx	xxxxxxx
Almacenamiento de Agua	15000	15000	15000	25000	25000	25000	xxxxxxx	xxxxxxx
Areas Recreativas	0	0	0	0	0	0	xxxxxxx	xxxxxxx
Caminos	204039	288989	333052	595911	704142	799586	xxxxxxx	xxxxxxx
Cementerio	30000	30000	60000	135000	150000	150000	xxxxxxx	xxxxxxx
Clinica o Centro de Salud	40000	80000	80000	120000	120000	120000	xxxxxxx	xxxxxxx
Comercio/Industrial/Agroindustrial	75000	150000	150000	175000	200000	225000	xxxxxxx	xxxxxxx
Escuela	225000	375000	600000	750000	1125000	1200000	xxxxxxx	xxxxxxx
Fuente de Agua Potable	2000	2000	2000	6000	8000	8000	xxxxxxx	xxxxxxx
Generación de Energía Eléctrica	0	1500	1500	1500	1500	3000	xxxxxxx	xxxxxxx
Gubernamental	45000	45000	45000	45000	45000	60000	xxxxxxx	xxxxxxx
Iglesia/Capilla	70000	210000	210000	280000	315000	420000	xxxxxxx	xxxxxxx
Parque Publico o Area Recreativas	45000	75000	75000	105000	105000	120000	xxxxxxx	xxxxxxx
Postes Electricos	0	0	0	0	0	0	xxxxxxx	xxxxxxx
Puente	120000	144000	216000	336000	336000	360000	xxxxxxx	xxxxxxx
Telecomunicaciones	7500	22500	22500	30000	37500	52500	xxxxxxx	xxxxxxx
Vivienda	730000	1055000	1175000	1580000	1745000	2015000	xxxxxxx	xxxxxxx
	B/. 1 668 539	**B/. 2 573 989**	**B/. 3 065 052**	**B/. 4 304 411**	**B/. 5 037 142**	**B/. 5 678 086**		

Cantidad de Infraestructuras en Sitio 1 (Santa Elena)

Estructura	Nivel 80	Nivel 90	Nivel 95	Nivel 100	Nivel 105	Nivel 110	Nivel 115	Nivel 120
Agua Potable Distribucion	60000	80000	80000	120000	120000	120000	xxxxxxx	xxxxxxx
Almacenamiento de Agua	15000	15000	15000	25000	25000	25000	xxxxxxx	xxxxxxx
Areas Recreativas	0	0	0	0	0	0	xxxxxxx	xxxxxxx
Caminos	188745	273685	316436	577161	684639	779673	xxxxxxx	xxxxxxx
Cementerio	30000	30000	45000	120000	135000	135000	xxxxxxx	xxxxxxx
Clinica o Centro de Salud	40000	80000	80000	120000	120000	120000	xxxxxxx	xxxxxxx
Comercio/Industrial/Agroindustrial	75000	150000	150000	175000	200000	225000	xxxxxxx	xxxxxxx
Escuela	225000	375000	600000	750000	1125000	1200000	xxxxxxx	xxxxxxx
Fuente de Agua Potable	2000	2000	2000	6000	8000	8000	xxxxxxx	xxxxxxx
Generación de Energía Eléctrica	0	1500	1500	1500	1500	3000	xxxxxxx	xxxxxxx
Gubernamental	30000	45000	45000	45000	45000	60000	xxxxxxx	xxxxxxx
Iglesia/Capilla	0	175000	175000	245000	245000	280000	xxxxxxx	xxxxxxx
Parque Publico o Area Recreativas	0	0	0	0	0	0	xxxxxxx	xxxxxxx
Postes Electricos	1250	1500	2250	3500	3500	3750	xxxxxxx	xxxxxxx
Puente	0	0	0	0	0	0	xxxxxxx	xxxxxxx
Telecomunicaciones	7500	22500	22500	30000	37500	52500	xxxxxxx	xxxxxxx
Vivienda	715000	1040000	1160000	1565000	1725000	1995000	xxxxxxx	xxxxxxx
	B/. 1 389 495	**B/. 2 291 185**	**B/. 2 694 686**	**B/. 3 783 161**	**B/. 4 475 139**	**B/. 5 006 923**		

Cantidad de Infraestructuras en Sitio 2 (San Isidro)

Estructura	Nivel 80	Nivel 90	Nivel 95	Nivel 100	Nivel 105	Nivel 110	Nivel 115	Nivel 120
Agua Potable Distribucion	40000	xxxxxxx	60000	100000	100000	100000	100000	xxxxxxx
Almacenamiento de Agua	10000	xxxxxxx	10000	20000	20000	20000	25000	xxxxxxx
Areas Recreativas	0	xxxxxxx	0	0	0	0	0	xxxxxxx
Caminos	136103	xxxxxxx	255186	510148	612215	704719	811232	xxxxxxx
Cementerio	30000	xxxxxxx	45000	120000	135000	135000	135000	xxxxxxx
Clinica o Centro de Salud	40000	xxxxxxx	80000	120000	120000	120000	120000	xxxxxxx
Comercio/Industrial/Agroindustrial	25000	xxxxxxx	100000	125000	150000	175000	200000	xxxxxxx
Escuela	150000	xxxxxxx	450000	600000	975000	1050000	1050000	xxxxxxx
Fuente de Agua Potable	0	xxxxxxx	0	4000	6000	6000	6000	xxxxxxx
Generación de Energía Eléctrica	0	xxxxxxx	1500	1500	1500	3000	3000	xxxxxxx
Gubernamental	15000	xxxxxxx	30000	30000	30000	45000	45000	xxxxxxx
Iglesia/Capilla	35000	xxxxxxx	175000	245000	280000	385000	455000	xxxxxxx
Parque Publico o Area Recreativas	30000	xxxxxxx	60000	90000	90000	105000	105000	xxxxxxx
Postes Electricos	0	xxxxxxx	0	0	0	0	0	xxxxxxx
Puente	72000	xxxxxxx	168000	288000	288000	312000	336000	xxxxxxx
Telecomunicaciones	0	xxxxxxx	15000	22500	30000	45000	45000	xxxxxxx
Vivienda	600000	xxxxxxx	1000000	1435000	1585000	1855000	1980000	xxxxxxx
	B/. 1 183 103		**B/. 2 449 686**	**B/. 3 711 148**	**B/. 4 422 715**	**B/. 5 060 719**	**B/. 5 416 232**	

Cantidad de Infraestructuras en Sitio 4 (La Tomasa Norte)

Estructura	Nivel 80	Nivel 90	Nivel 95	Nivel 100	Nivel 105	Nivel 110	Nivel 115	Nivel 120
Agua Potable Distribucion	40000	xxxxxxx	60000	100000	100000	100000	100000	xxxxxxx
Almacenamiento de Agua	10000	xxxxxxx	10000	20000	20000	20000	25000	xxxxxxx
Areas Recreativas	0	xxxxxxx	0	0	0	0	0	xxxxxxx
Caminos	124166	xxxxxxx	237185	491281	592016	683178	788220	xxxxxxx

Cementerio	30000	xxxxxxx	45000	120000	135000	135000	135000	xxxxxxx
Clinica o Centro de Salud	40000	xxxxxxx	40000	80000	80000	80000	80000	xxxxxxx
Comercio/Industrial/Agroindustrial	25000	xxxxxxx	100000	125000	150000	175000	200000	xxxxxxx
Escuela	150000	xxxxxxx	375000	525000	900000	975000	975000	xxxxxxx
Fuente de Agua Potable	0	xxxxxxx	0	4000	6000	6000	6000	xxxxxxx
Generación de Energía Eléctrica	0	xxxxxxx	0	0	0	1500	1500	xxxxxxx
Gubernamental	15000	xxxxxxx	15000	15000	15000	30000	30000	xxxxxxx
Iglesia/Capilla	35000	xxxxxxx	140000	210000	245000	350000	420000	xxxxxxx
Parque Publico o Area Recreativas	30000	xxxxxxx	45000	75000	75000	90000	90000	xxxxxxx
Postes Electricos	0	xxxxxxx	0	0	0	0	0	xxxxxxx
Puente	72000	xxxxxxx	168000	288000	288000	312000	336000	xxxxxxx
Telecomunicaciones	0	xxxxxxx	7500	15000	22500	37500	37500	xxxxxxx
Vivienda	580000	xxxxxxx	970000	1350000	1500000	1770000	1895000	xxxxxxx
	B/. 1 151 166		**B/. 2 212 685**	**B/. 3 418 281**	**B/. 4 128 516**	**B/. 4 765 178**	**B/. 5 119 220**	

Cantidad de Infraestructura Sitio 6 (Boca de Tulú)

Estructura	Nivel 80	Nivel 90	Nivel 95	Nivel 100	Nivel 105	Nivel 110	Nivel 115	Nivel 120
Agua Potable Distribucion	20000	xxxxxxx	xxxxxxx	60000	60000	60000	60000	60000
Almacenamiento de Agua	5000	xxxxxxx	xxxxxxx	10000	10000	10000	15000	15000
Areas Recreativas	0	xxxxxxx	xxxxxxx	0	0	0	0	0
Caminos	86444	xxxxxxx	xxxxxxx	434762	526990	614339	714791	1074859
Cementerio	30000	xxxxxxx	xxxxxxx	120000	135000	135000	135000	150000
Clinica o Centro De Salud	40000	xxxxxxx	xxxxxxx	80000	80000	80000	80000	120000
Comercio/Industrial/Agroindustrial	25000	xxxxxxx	xxxxxxx	125000	150000	175000	200000	225000
Escuela	75000	xxxxxxx	xxxxxxx	450000	825000	900000	900000	900000
Fuente de Agua Potable	0	xxxxxxx	xxxxxxx	0	2000	4000	4000	4000
Generación de Energía Eléctrica	0	xxxxxxx	xxxxxxx	0	0	1500	1500	1500
Gubernamental	0	xxxxxxx	xxxxxxx	0	0	15000	15000	45000
Iglesia/Capilla	35000	xxxxxxx	xxxxxxx	175000	210000	315000	385000	385000
Parque Publico o Area Recreativas	15000	xxxxxxx	xxxxxxx	60000	60000	75000	75000	75000
Postes Electricos	0	xxxxxxx	xxxxxxx	0	0	0	0	0
Puente	48000	xxxxxxx	xxxxxxx	240000	240000	264000	288000	456000
Telecomunicaciones	0	xxxxxxx	xxxxxxx	15000	22500	37500	37500	37500
Vivienda	345000	xxxxxxx	xxxxxxx	0	1060000	1195000	1460000	1580000
	B/. 724 444			**B/. 1 769 762**	**B/. 3 381 490**	**B/. 3 881 339**	**B/. 4 370 791**	**B/. 5 128 859**

Cantidad de Infraestructura Sitio 7 (El Guayabo)

Estructura	**Nivel 80**	**Nivel 90**	**Nivel 95**	**Nivel 100**	**Nivel 105**	**Nivel 110**	**Nivel 115**	**Nivel 120**
Agua Potable Distribucion	20000	xxxxxxx	xxxxxxx	60000	60000	60000	60000	60000
Almacenamiento de Agua	5000	xxxxxxx	xxxxxxx	10000	10000	10000	15000	20000
Areas Recreativas	0	xxxxxxx	xxxxxxx	0	0	0	0	15000
Caminos	78349	xxxxxxx	xxxxxxx	421736	513891	601287	701666	1061759
Cementerio	15000	xxxxxxx	xxxxxxx	105000	120000	120000	120000	210000
Clinica o Centro de Salud	40000	xxxxxxx	xxxxxxx	80000	80000	80000	80000	200000
Comercio/Industrial/Agroindustrial	25000	xxxxxxx	xxxxxxx	125000	150000	175000	200000	300000
Escuela	0	xxxxxxx	xxxxxxx	375000	750000	825000	825000	900000
Fuente de Agua Potable	0	xxxxxxx	xxxxxxx	2000	4000	4000	4000	4000
Generación de Energía Eléctrica	0	xxxxxxx	xxxxxxx	0	0	1500	1500	1500
Gubernamental	0	xxxxxxx	xxxxxxx	0	0	15000	15000	45000
Iglesia/Capilla	0	xxxxxxx	xxxxxxx	140000	175000	280000	350000	455000
Parque Publico o Area Recreativas	15000	xxxxxxx	xxxxxxx	60000	60000	75000	75000	75000
Postes Electricos	0	xxxxxxx	xxxxxxx	0	0	0	0	0
Puente	24000	xxxxxxx	xxxxxxx	216000	216000	240000	264000	504000
Telecomunicaciones	0	xxxxxxx	xxxxxxx	15000	22500	37500	37500	52500
Vivienda	265000	xxxxxxx	xxxxxxx	980000	1115000	1380000	1500000	1900000
	B/. 487 349			**B/. 2 589 736**	**B/. 3 276 391**	**B/. 3 904 287**	**B/. 4 248 666**	**B/. 5 803 759**

Precio Unitario por Estructura		
Agua Potable Distribucion	20000	Sistema de conducción de agua con línea principal de 2 pulgadas para conectar entre
Almacenamiento de Agua	5000	Almacenamiento para tanque máximo de 5000 galones
Areas Recreativas	15000	Cancha de beisball o de baloncesto con pavimento
Caminos	Nota :	Ver cuadro resumen con costos de acuerdo a tipos de caminos
Cementerio	15000	$/cementerio tomando como referencia 65 tumbas por cementerio (230 $/tumba relocalizada)
Clinica o Centro de Salud	40000	Construcción de bloques de concreto de 70 a 80 mts2
Comercio/Industrial/Agroindustrial	25000	
Escuela	75000	construcción en mampostería con 3 aulas promedio de 60 mts2 c/u más instalaciones para cocina y cuarto de maestra
Fuente de Agua Potable	2000	Toma de agua directamente de quebradas con noria para aplicación de cloro o con bomba de succión de hasta 7 mts prof.
Generación De Energía Eléctrica	1500	Planta solares de generación o plantas portátiles
Gubernamental	15000	considerando las instalaciones para Junta Comunal o Juntas Locales de 60 mts2 a 250 $/mt2
Iglesia/Capilla	35000	Uso actual de 8000 fieles distribuído entre 100 estructuras. Aprox 80 personas/estructura. Considerar 140 mts2 * 250$/mt2
Parque Publico o Area Recreativas	15000	Cancha de beisball o de baloncesto con pavimento
Postes Electricos	250	Poste de madera instalado
Puente	24000	Puente de una vía de concreto a 4000$/mt lineal y de 6 mts de vano promedio según cuadro 4.3.5
Telecomunicaciones	7500	
Vivienda	5000	

Estructuras de Caminos
ver sección 4.3.2.1 a)
y cuadro No. 4.3.3

125000 Camino permanentes de 6 mts de ancho con revestimiento de carpeta asfáltica de 5 cms
100000 Caminos permanente de 5.60 mts con revestimiento de imprimación y doble sello asfaltico de 5 cms
75000 Caminos permanentescon capabase y material selecto de 5.60 mts de ancho
44000 Camino de Verano con superficie con tosca con 5.00 de ancho
22000 Caminos de Verano, corte y nivelación con tierra

Solo existen 8 puentes de doble vía según el MOP y de acuerdo al cuadro 4.3.5 el resto son puentes de madera o acero

1.25 - 1.50 $/m2 Conformación de caminos y nivelación
15.00-18.00 $/m3 Material Selecto
25.00-28.00 $/m3 Capabase
50.00 $/Ton Carpeta asfáltica

Precios estándares del Ministerio de Obras Públicas

Fuente: Estudios Socioeconomicos IRG-Dames -More

TOABRE/Vías

Longitudes en metros

Vías Sitio 10

Tipo	Nivel 80	Nivel 90	Nivel 95	Nivel 100	Nivel 105	Nivel 110	Nive4l 115	Nivel 120
Camino Herradura	46 799	63 486	71 772	114 515	128 627	142 964	xxxxxxxxx	xxxxxxxxx
Camino Permanente		42	73	494	824	1 019	xxxxxxxxx	xxxxxxxxx
Camino Verano						6	xxxxxxxxx	xxxxxxxxx

Vías Sitio 0

Tipo	Nivel 80	Nivel 90	Nivel 95	Nivel 100	Nivel 105	Nivel 110	Nivel 115	Nivel 120
Camino Herradura	40 808	56 743	64 782	106 838	120 229	134 384	xxxxxxxxx	xxxxxxxxx
Camino Permanente		42	73	494	824	1 019	xxxxxxxxx	xxxxxxxxx
Camino Verano						6	xxxxxxxxx	xxxxxxxxx

Vías Sitio 1

Tipo	Nivel 80	Nivel 90	Nivel 95	Nivel 100	Nivel 105	Nivel 110	Nivel 115	Nivel 120
Camino Herradura	37 749	53 682	61 459	103 088	116 328	130 401	xxxxxxxxx	xxxxxxxxx
Camino Permanente		42	73	494	824	1 019	xxxxxxxxx	xxxxxxxxx
Camino Verano						6	xxxxxxxxx	xxxxxxxxx

Vías Sitio 2

Tipo	Nivel 80	Nivel 90	Nivel 95	Nivel 100	Nivel 105	Nivel 110	Nivel 115	Nivel 120
Camino Herradura	27 221	xxxxxxxxxx	49 209	89 686	101 844	115 410	127 057	xxxxxxxxx
Camino Permanente		xxxxxxxxxx	73	494	824	1 019	1 388	xxxxxxxxx
Camino Verano		xxxxxxxxxx				6	56	xxxxxxxxx

Vías Sitio 4

Tipo	Nivel 80	Nivel 90	Nivel 95	Nivel 100	Nivel 105	Nivel 110	Nivel 115	Nivel 120
Camino Herradura	24 833	xxxxxxxxxx	45 609	85 912	97 804	111 102	122 454	xxxxxxxxx
Camino Permanente		xxxxxxxxxx	73	494	824	1 019	1 388	xxxxxxxxx
Camino Verano		xxxxxxxxxx				6	56	xxxxxxxxx

Vías Sitio 6

Tipo	Nivel 80	Nivel 90	Nivel 95	Nivel 100	Nivel 105	Nivel 110	Nivel 115	Nivel 120
Camino Herradura	17 289	xxxxxxxxxx	xxxxxxxxxx	74 608	84 799	97 334	107 768	151 213
Camino Permanente		xxxxxxxxxx	xxxxxxxxxx	494	824	1 019	1 388	2 271
Camino Verano		xxxxxxxxxx	xxxxxxxxxx			6	56	794

Vías Sitio 7

Tipo	Nivel 80	Nivel 90	Nivel 95	Nivel 100	Nivel 105	Nivel 110	Nivel 115	Nivel 120
Camino Herradura	15 670	xxxxxxxxxx	xxxxxxxxxx	72 003	82 179	94 724	105 143	148 593
Camino Permanente		xxxxxxxxxx	xxxxxxxxxx	494	824	1 019	1 388	2 271
Camino Verano		xxxxxxxxxx	xxxxxxxxxx			6	56	794

Fuente: Estudios Socioeconomicos IRG-Dames -More

TOABRE/Vías

Longitudes en metros

Vías Sitio 10

Tipo	Nivel 80	Nivel 90	Nivel 95	Nivel 100	Nivel 105	Nivel 110	Nive4l 115	Nivel 120
Camino Herradura	B/. 233 994	B/. 317 430	B/. 358 859	B/. 572 574	B/. 643 135	B/. 714 819	xxxxxxxxx	xxxxxxxxx
Camino Permanente	B/. 0	B/. 5 275	B/. 9 141	B/. 61 720	B/. 102 997	B/. 127 421	xxxxxxxxx	xxxxxxxxx
Camino Verano	B/. 0	B/. 0	B/. 0	B/. 0	B/. 0	B/. 246	xxxxxxxxx	xxxxxxxxx
	B/. 233 994	**B/. 322 705**	**B/. 368 000**	**B/. 634 294**	**B/. 746 132**	**B/. 842 486**		

Vías Sitio 0

Tipo	Nivel 80	Nivel 90	Nivel 95	Nivel 100	Nivel 105	Nivel 110	Nivel 115	Nivel 120
Camino Herradura	B/. 204 039	B/. 283 714	B/. 323 911	B/. 534 191	B/. 601 145	B/. 671 919	xxxxxxxxx	xxxxxxxxx
Camino Permanente	B/. 0	B/. 5 275	B/. 9 141	B/. 61 720	B/. 102 997	B/. 127 421	xxxxxxxxx	xxxxxxxxx
Camino Verano	B/. 0	B/. 0	B/. 0	B/. 0	B/. 0	B/. 246	xxxxxxxxx	xxxxxxxxx
	B/. 204 039	**B/. 288 989**	**B/. 333 052**	**B/. 595 911**	**B/. 704 142**	**B/. 799 586**		

Vías Sitio 1

Tipo	Nivel 80	Nivel 90	Nivel 95	Nivel 100	Nivel 105	Nivel 110	Nivel 115	Nivel 120
Camino Herradura	B/. 188 745	B/. 268 410	B/. 307 295	B/. 515 441	B/. 581 642	B/. 652 006	xxxxxxxxx	xxxxxxxxx
Camino Permanente	B/. 0	B/. 5 275	B/. 9 141	B/. 61 720	B/. 102 997	B/. 127 421	xxxxxxxxx	xxxxxxxxx
Camino Verano	B/. 0	B/. 0	B/. 0	B/. 0	B/. 0	B/. 246	xxxxxxxxx	xxxxxxxxx
	B/. 188 745	**B/. 273 685**	**B/. 316 436**	**B/. 577 161**	**B/. 684 639**	**B/. 779 673**		

Vías Sitio 2

Tipo	Nivel 80	Nivel 90	Nivel 95	Nivel 100	Nivel 105	Nivel 110	Nivel 115	Nivel 120
Camino Herradura	B/. 136 103	xxxxxxxxxx	B/. 246 045	B/. 448 428	B/. 509 218	B/. 577 052	B/. 635 283	xxxxxxxxx
Camino Permanente	B/. 0	xxxxxxxxxx	B/. 9 141	B/. 61 720	B/. 102 997	B/. 127 421	B/. 173 495	xxxxxxxxx
Camino Verano	B/. 0	xxxxxxxxxx	B/. 0	B/. 0	B/. 0	B/. 246	B/. 2 453	xxxxxxxxx
	B/. 136 103		**B/. 255 186**	**B/. 510 148**	**B/. 612 215**	**B/. 704 719**	**B/. 811 232**	

Vías Sitio 4

Tipo	Nivel 80	Nivel 90	Nivel 95	Nivel 100	Nivel 105	Nivel 110	Nivel 115	Nivel 120
Camino Herradura	B/. 124 166	xxxxxxxxxx	B/. 228 043	B/. 429 560	B/. 489 020	B/. 555 511	B/. 612 272	xxxxxxxxx
Camino Permanente	B/. 0	xxxxxxxxxx	B/. 9 141	B/. 61 720	B/. 102 997	B/. 127 421	B/. 173 495	xxxxxxxxx
Camino Verano	B/. 0	xxxxxxxxxx	B/. 0	B/. 0	B/. 0	B/. 246	B/. 2 453	xxxxxxxxx
	B/. 124 166		**B/. 237 185**	**B/. 491 281**	**B/. 592 016**	**B/. 683 178**	**B/. 788 220**	

Vías Sitio 6

Tipo	Nivel 80	Nivel 90	Nivel 95	Nivel 100	Nivel 105	Nivel 110	Nivel 115	Nivel 120
Camino Herradura	B/. 86 444	xxxxxxxxxx	xxxxxxxxxx	B/. 373 042	B/. 423 994	B/. 486 672	B/. 538 842	B/. 756 067
Camino Permanente	B/. 0	xxxxxxxxxx	xxxxxxxxxx	B/. 61 720	B/. 102 997	B/. 127 421	B/. 173 495	B/. 283 851
Camino Verano	B/. 0	xxxxxxxxxx	xxxxxxxxxx	B/. 0	B/. 0	B/. 246	B/. 2 453	B/. 34 941
	B/. 86 444			**B/. 434 762**	**B/. 526 990**	**B/. 614 339**	**B/. 714 791**	**B/. 1 074 859**

Vías Sitio 7

Tipo	Nivel 80	Nivel 90	Nivel 95	Nivel 100	Nivel 105	Nivel 110	Nivel 115	Nivel 120
Camino Herradura	B/. 78 349	xxxxxxxxxx	xxxxxxxxxx	B/. 360 015	B/. 410 894	B/. 473 620	B/. 525 717	B/. 742 967
Camino Permanente	B/. 0	xxxxxxxxxx	xxxxxxxxxx	B/. 61 720	B/. 102 997	B/. 127 421	B/. 173 495	B/. 283 851
Camino Verano	B/. 0	xxxxxxxxxx	xxxxxxxxxx	B/. 0	B/. 0	B/. 246	B/. 2 453	B/. 34 941
	B/. 78 349			**B/. 421 736**	**B/. 513 891**	**B/. 601 287**	**B/. 701 666**	**B/. 1 061 759**

Costos Unitarios de Vías Impactadas

Camino Herradura	B/. 5 000 $/km	B/. 5 $/mt
Camino Permanente	B/. 125 000 $/km	B/. 125 $/mt
Camino Verano	B/. 44 000 $/km	B/. 44 $/mt

Dirección Nacional de Mantenimientos del MOP

Fuente: Estudios Socioambientales - Consultora Louis Berger

CLASIFICACION POR COVERTURA VEGETAL

Habitat Sitio 10

HABITAT	Nivel 80	Nivel 90	Nivel 95	Nivel 100	Nivel 105	Nivel 110
Bosque peremnifolio ombrófilo tropical de tierras bajas	47	63	69	106	141	190
Bosque peremnifolio ombrófilo tropical submontano	0	0	0	0	0	0
Bosque peremnifolio ombrófilo tropical montano	0	0	0	0	0	0
Bosque nuboso	0	0	0	0	0	0
Pastizales y cultivos	593	863	1033	1701	1955	2268
Rastrojos	2141	2675	2909	4204	4601	4894
Total	2780	3601	4011	6011	6697	7352

Habitat Sitio 0

HABITAT	Nivel 80	Nivel 90	Nivel 95	Nivel 100	Nivel 105	Nivel 110
Bosque peremnifolio ombrófilo tropical de tierras bajas	23	28	29	46	60	93
Bosque peremnifolio ombrófilo tropical submontano	0	0	0	0	0	0
Bosque peremnifolio ombrófilo tropical montano	0	0	0	0	0	0
Bosque nuboso	0	0	0	0	0	0
Pastizales y cultivos	540	800	967	1629	1892	2205
Rastrojos	1754	2215	2429	3671	4043	4320
Total	2317	3043	3425	5345	5996	6618

Habitat Sitio 1

HABITAT	Nivel 80	Nivel 90	Nivel 95	Nivel 100	Nivel 105	Nivel 110
Bosque peremnifolio ombrófilo tropical de tierras bajas	23	28	29	46	60	93
Bosque peremnifolio ombrófilo tropical submontano	0	0	0	0	0	0
Bosque peremnifolio ombrófilo tropical montano	0	0	0	0	0	0
Bosque nuboso	0	0	0	0	0	0
Pastizales y cultivos	520	778	944	1605	1847	2159
Rastrojos	1575	2021	2215	3430	3739	4004
Total	2118	2827	3188	5080	5647	6256

Habitat Sitio 2

HABITAT	Nivel 80	Nivel 90	Nivel 95	Nivel 100	Nivel 105	Nivel 110	Nivel 115
Bosque peremnifolio ombrófilo tropical de tierras bajas	23	xxxxxxxxxx	29	46	60	93	129
Bosque peremnifolio ombrófilo tropical submontano	0	xxxxxxxxxx	0	0	0	0	0
Bosque peremnifolio ombrófilo tropical montano	0	xxxxxxxxxx	0	0	0	0	0
Bosque nuboso	0	xxxxxxxxxx	0	0	0	0	0
Pastizales y cultivos	429	xxxxxxxxxx	815	1446	1671	1971	2180
Rastrojos	1242	xxxxxxxxxx	1787	2940	3211	3458	3656
Total	1694		2631	4432	4942	5522	5966

Habitat Sitio 4

HABITAT	Nivel 80	Nivel 90	Nivel 95	Nivel 100	Nivel 105	Nivel 110	Nivel 115
Bosque peremnifolio ombrófilo tropical de tierras bajas	4	xxxxxxxxxx	7	21	32	65	101
Bosque peremnifolio ombrófilo tropical submontano	0	xxxxxxxxxx	0	0	0	0	0
Bosque peremnifolio ombrófilo tropical montano	0	xxxxxxxxxx	0	0	0	0	0
Bosque nuboso	0	xxxxxxxxxx	0	0	0	0	0
Pastizales y cultivos	384	xxxxxxxxxx	755	1385	1610	1911	2119
Rastrojos	1113	xxxxxxxxxx	1632	2769	3027	3266	3455
Total	1500		2393	4175	4669	5241	5675

Habitat Sitio 6

HABITAT	Nivel 80	Nivel 90	Nivel 95	Nivel 100	Nivel 105	Nivel 110	Nivel 115	Nivel 120
Bosque peremnifolio ombrófilo tropical de tierras bajas	0	xxxxxxxxxx	xxxxxxxxxx	4	8	29	59	189
Bosque peremnifolio ombrófilo tropical submontano	0	xxxxxxxxxx	xxxxxxxxxx	0	0	0	0	0
Bosque peremnifolio ombrófilo tropical montano	0	xxxxxxxxxx	xxxxxxxxxx	0	0	0	0	0
Bosque nuboso	0	xxxxxxxxxx	xxxxxxxxxx	0	0	0	0	0
Pastizales y cultivos	291	xxxxxxxxxx	xxxxxxxxxx	1271	1494	1791	2000	2976
Rastrojos	637	xxxxxxxxxx	xxxxxxxxxx	1955	2148	2336	2487	3159
Total	928			3230	3649	4156	4546	6324

Habitat Sitio 7

HABITAT	Nivel 80	Nivel 90	Nivel 95	Nivel 100	Nivel 105	Nivel 110	Nivel 115	Nivel 120
Bosque peremnifolio ombrófilo tropical de tierras bajas	0	xxxxxxxxxx	xxxxxxxxxx	4	8	29	59	189
Bosque peremnifolio ombrófilo tropical submontano	0	xxxxxxxxxx	xxxxxxxxxx	0	0	0	0	0
Bosque peremnifolio ombrófilo tropical montano	0	xxxxxxxxxx	xxxxxxxxxx	0	0	0	0	0
Bosque nuboso	0	xxxxxxxxxx	xxxxxxxxxx	0	0	0	0	0
Pastizales y cultivos	276	xxxxxxxxxx	xxxxxxxxxx	1250	1472	1768	1976	2951
Rastrojos	592	xxxxxxxxxx	xxxxxxxxxx	1824	2013	2198	2346	3015
Total	869			3078	3492	3996	4381	6154

Bosque peremnifolio ombrófilo tropical de tierras bajas	(Elevac< 500 mts)
Bosque peremnifolio ombrófilo tropical submontano	(500<Elevac< 1000 mts)
Bosque peremnifolio ombrófilo tropical montano	(1000<Elevac< 1500 mts)
Bosque nuboso	(Elevac>1500 mts)

Fuente: Estudios Socioambientales - Consultora Louis Berger

Habitat Sitio 10

HABITAT	Nivel 80	Nivel 90	Nivel 95	Nivel 100	Nivel 105	Nivel 110
Bosque peremnifolio ombrófilo tropical de tierras bajas	B/. 233 290	B/. 314 540	B/. 345 935	B/. 528 815	B/. 707 425	B/. 950 730
Bosque peremnifolio ombrófilo tropical submontano	B/. 0	B/. 0	B/. 0	B/. 0	B/. 0	B/. 0
Bosque peremnifolio ombrófilo tropical montano	B/. 0	B/. 0	B/. 0	B/. 0	B/. 0	B/. 0
Bosque nuboso	B/. 0	B/. 0	B/. 0	B/. 0	B/. 0	B/. 0
Pastizales y cultivos	B/. 592 957	B/. 863 028	B/. 1 032 697	B/. 1 701 267	B/. 1 954 800	B/. 2 268 286
Rastrojos	B/. 3 210 821	B/. 4 012 686	B/. 4 363 457	B/. 6 305 642	B/. 6 901 437	B/. 7 340 505
Total	B/. 4 037 068	B/. 5 190 254	B/. 5 742 089	B/. 8 535 724	B/. 9 563 662	B/. 10 559 521

Habitat Sitio 0

HABITAT	Nivel 80	Nivel 90	Nivel 95	Nivel 100	Nivel 105	Nivel 110
Bosque peremnifolio ombrófilo tropical de tierras bajas	B/. 115 575	B/. 139 305	B/. 146 930	B/. 227 665	B/. 302 050	B/. 463 900
Bosque peremnifolio ombrófilo tropical submontano	B/. 0	B/. 0	B/. 0	B/. 0	B/. 0	B/. 0
Bosque peremnifolio ombrófilo tropical montano	B/. 0	B/. 0	B/. 0	B/. 0	B/. 0	B/. 0
Bosque nuboso	B/. 0	B/. 0	B/. 0	B/. 0	B/. 0	B/. 0
Pastizales y cultivos	B/. 539 786	B/. 799 934	B/. 966 721	B/. 1 628 822	B/. 1 891 746	B/. 2 205 168
Rastrojos	B/. 2 630 726	B/. 3 322 806	B/. 3 643 514	B/. 5 505 768	B/. 6 065 222	B/. 6 479 384
Total	B/. 3 286 087	B/. 4 262 045	B/. 4 757 165	B/. 7 362 255	B/. 8 259 018	B/. 9 148 452

Habitat Sitio 1

HABITAT	Nivel 80	Nivel 90	Nivel 95	Nivel 100	Nivel 105	Nivel 110
Bosque peremnifolio ombrófilo tropical de tierras bajas	B/. 115 575	B/. 139 305	B/. 146 930	B/. 227 665	B/. 302 080	B/. 463 900
Bosque peremnifolio ombrófilo tropical submontano	B/. 0	B/. 0	B/. 0	B/. 0	B/. 0	B/. 0
Bosque peremnifolio ombrófilo tropical montano	B/. 0	B/. 0	B/. 0	B/. 0	B/. 0	B/. 0
Bosque nuboso	B/. 0	B/. 0	B/. 0	B/. 0	B/. 0	B/. 0
Pastizales y cultivos	B/. 519 990	B/. 778 282	B/. 944 244	B/. 1 604 679	B/. 1 847 456	B/. 2 159 217
Rastrojos	B/. 2 362 601	B/. 3 031 400	B/. 3 321 768	B/. 5 145 281	B/. 5 608 181	B/. 6 006 317
Total	B/. 2 998 166	B/. 3 948 987	B/. 4 412 942	B/. 6 977 625	B/. 7 757 717	B/. 8 629 434

Habitat Sitio 2

HABITAT	Nivel 80	Nivel 90	Nivel 95	Nivel 100	Nivel 105	Nivel 110	Nivel 115
Bosque peremnifolio ombrófilo tropical de tierras bajas	B/. 115 575	xxxxxxxxxxx	B/. 146 930	B/. 227 665	B/. 302 080	B/. 463 900	B/. 645 260
Bosque peremnifolio ombrófilo tropical submontano	B/. 0	xxxxxxxxxxx	B/. 0	B/. 0	B/. 0	B/. 0	B/. 0
Bosque peremnifolio ombrófilo tropical montano	B/. 0	xxxxxxxxxxx	B/. 0	B/. 0	B/. 0	B/. 0	B/. 0
Bosque nuboso	B/. 0	xxxxxxxxxxx	B/. 0	B/. 0	B/. 0	B/. 0	B/. 0
Pastizales y cultivos	B/. 428 866	xxxxxxxxxxx	B/. 814 748	B/. 1 446 188	B/. 1 670 559	B/. 1 971 032	B/. 2 180 411
Rastrojos	B/. 1 862 363	xxxxxxxxxxx	B/. 2 679 989	B/. 4 409 969	B/. 4 816 200	B/. 5 187 023	B/. 5 484 276
Total	B/. 2 406 804		B/. 3 641 667	B/. 6 083 822	B/. 6 788 839	B/. 7 621 955	B/. 8 309 947

Habitat Sitio 4

HABITAT	Nivel 80	Nivel 90	Nivel 95	Nivel 100	Nivel 105	Nivel 110	Nivel 115
Bosque peremnifolio ombrófilo tropical de tierras bajas	B/. 19 815	xxxxxxxxxxx	B/. 33 120	B/. 105 015	B/. 162 455	B/. 324 380	B/. 505 385
Bosque peremnifolio ombrófilo tropical submontano	B/. 0	xxxxxxxxxxx	B/. 0	B/. 0	B/. 0	B/. 0	B/. 0
Bosque peremnifolio ombrófilo tropical montano	B/. 0	xxxxxxxxxxx	B/. 0	B/. 0	B/. 0	B/. 0	B/. 0
Bosque nuboso	B/. 0	xxxxxxxxxxx	B/. 0	B/. 0	B/. 0	B/. 0	B/. 0
Pastizales y cultivos	B/. 383 644	xxxxxxxxxxx	B/. 755 174	B/. 1 384 973	B/. 1 609 510	B/. 1 910 548	B/. 2 119 252
Rastrojos	B/. 1 668 782	xxxxxxxxxxx	B/. 2 447 402	B/. 4 153 796	B/. 4 540 161	B/. 4 898 753	B/. 5 182 377
Total	B/. 2 072 241		B/. 3 235 696	B/. 5 643 784	B/. 6 312 126	B/. 7 133 681	B/. 7 807 014

Habitat Sitio 6

HABITAT	Nivel 80	Nivel 90	Nivel 95	Nivel 100	Nivel 105	Nivel 110	Nivel 115	Nivel 120
Bosque peremnifolio ombrófilo tropical de tierras bajas	B/. 0	xxxxxxxxxxx	xxxxxxxxxxx	B/. 19 475	B/. 38 200	B/. 146 840	B/. 292 820	B/. 945 455
Bosque peremnifolio ombrófilo tropical submontano	B/. 0	xxxxxxxxxxx	xxxxxxxxxxx	B/. 0	B/. 0	B/. 0	B/. 0	B/. 0
Bosque peremnifolio ombrófilo tropical montano	B/. 0	xxxxxxxxxxx	xxxxxxxxxxx	B/. 0	B/. 0	B/. 0	B/. 0	B/. 0
Bosque nuboso	B/. 0	xxxxxxxxxxx	xxxxxxxxxxx	B/. 0	B/. 0	B/. 0	B/. 0	B/. 0
Pastizales y cultivos	B/. 291 376	xxxxxxxxxxx	xxxxxxxxxxx	B/. 1 270 919	B/. 1 493 809	B/. 1 791 294	B/. 2 000 057	B/. 2 976 032
Rastrojos	B/. 954 849	xxxxxxxxxxx	xxxxxxxxxxx	B/. 2 932 098	B/. 3 221 765	B/. 3 503 442	B/. 3 731 042	B/. 4 738 896
Total	B/. 1 246 225			B/. 4 222 492	B/. 4 753 774	B/. 5 441 576	B/. 6 023 919	B/. 8 660 383

Habitat Sitio 7

HABITAT	Nivel 80	Nivel 90	Nivel 95	Nivel 100	Nivel 105	Nivel 110	Nivel 115	Nivel 120
Bosque peremnifolio ombrófilo tropical de tierras bajas	B/. 0	xxxxxxxxxxx	xxxxxxxxxxx	B/. 19 475	B/. 38 200	B/. 146 840	B/. 292 820	B/. 945 455
Bosque peremnifolio ombrófilo tropical submontano	B/. 0	xxxxxxxxxxx	xxxxxxxxxxx	B/. 0	B/. 0	B/. 0	B/. 0	B/. 0
Bosque peremnifolio ombrófilo tropical montano	B/. 0	xxxxxxxxxxx	xxxxxxxxxxx	B/. 0	B/. 0	B/. 0	B/. 0	B/. 0
Bosque nuboso	B/. 0	xxxxxxxxxxx	xxxxxxxxxxx	B/. 0	B/. 0	B/. 0	B/. 0	B/. 0
Pastizales y cultivos	B/. 276 439	xxxxxxxxxxx	xxxxxxxxxxx	B/. 1 249 747	B/. 1 471 602	B/. 1 768 093	B/. 1 975 618	B/. 2 950 532
Rastrojos	B/. 888 389	xxxxxxxxxxx	xxxxxxxxxxx	B/. 2 736 518	B/. 3 018 875	B/. 3 297 536	B/. 3 519 711	B/. 4 522 304
Total	B/. 1 164 828			B/. 4 005 740	B/. 4 528 677	B/. 5 212 469	B/. 5 788 149	B/. 8 418 291

REFERENCIAS DE PRECIOS PARA HABITAT

Bosque peremnifolio ombrófilo tropical de tierras bajas	5000	$/Hectárea
Bosque peremnifolio ombrófilo tropical submontano	5000	$/Hectárea
Bosque peremnifolio ombrófilo tropical montano	5000	$/Hectárea
Bosque nuboso	5000	$/Hectárea
Pastizales y cultivos	1000	$/Hectárea
Rastrojos	1500	$/Hectárea

Fuente: Estudios Socioeconomicos IRG-Dames -Moore

Uso del Suelo en Hectareas Sitio 10

Uso del suelo	Nivel 80	Nivel 90	Nivel 95	Nivel 100	Nivel 105	Nivel 110
Agua	125	126	126	126	126	126
Area de Ganaderia	881	1 190	1 349	2 073	2 332	2 588
Bosque Denso poco Intervenido de Tierra Bajas	29	38	42	66	83	104
Bosque Intervenido	508	640	688	946	1 062	1 143
Cultivos Anuales	34	48	52	84	91	100
Matorral Rastrojo	869	1 119	1 221	1 878	2 060	2 245
No Data	335	439	533	839	943	1 046
Total	2 780	3 601	4 011	6 011	6 697	7 352

Uso del Suelo en Hectareas Sitio 0

Uso del suelo	Nivel 80	Nivel 90	Nivel 95	Nivel 100	Nivel 105	Nivel 110
Agua	104	105	105	105	105	105
Area de Ganaderia	772	1 060	1 213	1 927	2 184	2 440
Bosque Denso poco Intervenido de Tierra Bajas	14	17	19	33	44	55
Bosque Intervenido	398	497	535	757	846	911
Cultivos Anuales	30	42	46	76	82	91
Matorral Rastrojo	720	948	1 042	1 681	1 850	2 030
No Data	279	373	465	767	884	986
Total	2 317	3 043	3 425	5 345	5 996	6 618

Uso del Suelo en Hectareas Sitio 1

Uso del suelo	Nivel 80	Nivel 90	Nivel 95	Nivel 100	Nivel 105	Nivel 110
Agua	97	98	98	98	98	98
Area de Ganaderia	720	1 000	1 146	1 850	2 083	2 335
Bosque Denso poco Intervenido de Tierra Bajas	12	15	17	30	36	47
Bosque Intervenido	343	442	472	687	760	822
Cultivos Anuales	27	40	43	72	78	86
Matorral Rastrojo	649	867	956	1 586	1 734	1 911
No Data	271	365	456	757	859	958
Total	2 118	2 827	3 188	5 081	5 647	6 256

Uso del Suelo en Hectareas Sitio 2

Uso del suelo	Nivel 80	Nivel 90	Nivel 95	Nivel 100	Nivel 105	Nivel 110	Nivel 115
Agua	87	xxxxxxxxxx	89	89	89	89	89
Area de Ganaderia	578	xxxxxxxxxx	955	1 615	1 819	2 061	2 251
Bosque Denso poco Intervenido de Tierra Bajas	10	xxxxxxxxxx	15	28	34	43	49
Bosque Intervenido	274	xxxxxxxxxx	388	595	664	723	773
Cultivos Anuales	17	xxxxxxxxxx	27	53	58	66	70
Matorral Rastrojo	508	xxxxxxxxxx	784	1 394	1 532	1 700	1 829
No Data	219	xxxxxxxxxx	373	659	746	841	905
Total	1 694		2 631	4 432	4 942	5 522	5 966

Uso del Suelo en Hectareas Sitio 4

Uso del suelo	Nivel 80	Nivel 90	Nivel 95	Nivel 100	Nivel 105	Nivel 110	Nivel 115
Agua	76	xxxxxxxxxx	78	78	78	78	78
Area de Ganaderia	523	xxxxxxxxxx	883	1 540	1 743	1 985	2 173
Bosque Denso poco Intervenido de Tierra Bajas	7	xxxxxxxxxx	11	22	27	37	42
Bosque Intervenido	209	xxxxxxxxxx	312	507	566	620	666
Cultivos Anuales	15	xxxxxxxxxx	24	50	55	63	67
Matorral Rastrojo	474	xxxxxxxxxx	739	1 346	1 480	1 645	1 771
No Data	197	xxxxxxxxxx	347	632	719	813	878
Total	1 500		2 393	4 175	4 669	5 241	5 675

Uso del Suelo en Hectareas Sitio 6

Uso del suelo	Nivel 80	Nivel 90	Nivel 95	Nivel 100	Nivel 105	Nivel 110	Nivel 115	Nivel 120
Agua	63	xxxxxxxxxx	xxxxxxxxxx	64	64	64	64	64
Area de Ganaderia	337	xxxxxxxxxx	xxxxxxxxxx	1 278	1 469	1 697	1 876	2 721
Bosque Denso poco Intervenido de Tierra Bajas	3	xxxxxxxxxx	xxxxxxxxxx	12	13	16	17	34
Bosque Intervenido	92	xxxxxxxxxx	xxxxxxxxxx	280	312	348	379	551
Cultivos Anuales	8	xxxxxxxxxx	xxxxxxxxxx	33	37	41	44	55
Matorral Rastrojo	281	xxxxxxxxxx	xxxxxxxxxx	1 000	1 110	1 256	1 369	1 914
No Data	144	xxxxxxxxxx	xxxxxxxxxx	562	643	734	796	986
Total	928			3 230	3 649	4 156	4 546	6 325

Uso del Suelo en Hectareas Sitio 7

Uso del suelo	Nivel 80	Nivel 90	Nivel 95	Nivel 100	Nivel 105	Nivel 110	Nivel 115	Nivel 120
Agua	59	xxxxxxxxxx	xxxxxxxxxx	60	60	60	60	60
Area de Ganaderia	310	xxxxxxxxxx	xxxxxxxxxx	1 234	1 424	1 651	1 828	2 672
Bosque Denso poco Intervenido de Tierra Bajas	3	xxxxxxxxxx	xxxxxxxxxx	12	13	16	17	33
Bosque Intervenido	87	xxxxxxxxxx	xxxxxxxxxx	262	292	327	357	528
Cultivos Anuales	8	xxxxxxxxxx	xxxxxxxxxx	29	33	37	40	50
Matorral Rastrojo	261	xxxxxxxxxx	xxxxxxxxxx	948	1 057	1 203	1 314	1 857
No Data	140	xxxxxxxxxx	xxxxxxxxxx	533	613	703	764	953
Total	869			3 078	3 492	3 996	4 381	6 155

Fuente: Estudios Socioeconomicos IRG-Dames -Moore

Uso del Suelo en Hectareas Sitio 10

Uso del suelo	Nivel 80	Nivel 90	Nivel 95	Nivel 100	Nivel 105	Nivel 110
Agua	B/. 24 906	B/. 25 114	B/. 25 124	B/. 25 127	B/. 25 123	B/. 25 126
Area de Ganaderia	B/. 3 201 153	B/. 4 324 349	B/. 4 899 903	B/. 7 530 642	B/. 8 471 211	B/. 9 403 672
Bosque Denso poco Intervenido de Tierra Bajas	B/. 17 347	B/. 22 981	B/. 25 206	B/. 39 835	B/. 49 912	B/. 62 507
Bosque Intervenido	B/. 253 767	B/. 320 230	B/. 344 102	B/. 472 994	B/. 531 052	B/. 571 477
Cultivos Anuales	B/. 111 843	B/. 159 962	B/. 174 749	B/. 279 634	B/. 305 018	B/. 334 331
Matorral Rastrojo	B/. 347 761	B/. 447 692	B/. 488 351	B/. 751 124	B/. 824 018	B/. 898 195
No Data	B/. 134 106	B/. 175 768	B/. 213 275	B/. 335 405	B/. 377 351	B/. 418 204
Total	**B/. 4 090 882**	**B/. 5 476 095**	**B/. 6 170 710**	**B/. 9 434 760**	**B/. 10 583 686**	**B/. 11 713 511**

Uso del Suelo en Hectareas Sitio 0

Uso del suelo	Nivel 80	Nivel 90	Nivel 95	Nivel 100	Nivel 105	Nivel 110
Agua	B/. 20 890	B/. 21 099	B/. 21 092	B/. 21 099	B/. 21 099	B/. 21 095
Area de Ganaderia	B/. 2 803 651	B/. 3 851 165	B/. 4 406 306	B/. 6 999 748	B/. 7 934 421	B/. 8 863 027
Bosque Denso poco Intervenido de Tierra Bajas	B/. 8 251	B/. 10 328	B/. 11 324	B/. 19 928	B/. 26 396	B/. 33 146
Bosque Intervenido	B/. 199 150	B/. 248 708	B/. 267 652	B/. 378 416	B/. 423 213	B/. 455 665
Cultivos Anuales	B/. 98 652	B/. 140 858	B/. 153 385	B/. 251 984	B/. 275 099	B/. 302 920
Matorral Rastrojo	B/. 287 987	B/. 379 033	B/. 416 847	B/. 672 276	B/. 739 858	B/. 811 824
No Data	B/. 111 629	B/. 149 263	B/. 185 860	B/. 306 629	B/. 353 544	B/. 394 300
Total	**B/. 3 530 210**	**B/. 4 800 454**	**B/. 5 462 465**	**B/. 8 650 079**	**B/. 9 773 630**	**B/. 10 881 975**

Uso del Suelo en Hectareas Sitio 1

Uso del suelo	Nivel 80	Nivel 90	Nivel 95	Nivel 100	Nivel 105	Nivel 110
Agua	B/. 19 369	B/. 19 656	B/. 19 586	B/. 19 589	B/. 19 588	B/. 19 585
Area de Ganaderia	B/. 2 616 734	B/. 3 633 171	B/. 4 164 061	B/. 6 722 332	B/. 7 565 893	B/. 8 482 761
Bosque Denso poco Intervenido de Tierra Bajas	B/. 7 105	B/. 9 192	B/. 10 177	B/. 18 091	B/. 21 761	B/. 27 951
Bosque Intervenido	B/. 171 258	B/. 220 773	B/. 236 048	B/. 343 743	B/. 380 072	B/. 410 978
Cultivos Anuales	B/. 89 508	B/. 132 319	B/. 143 418	B/. 239 980	B/. 259 065	B/. 286 188
Matorral Rastrojo	B/. 259 661	B/. 346 768	B/. 382 265	B/. 634 223	B/. 693 469	B/. 764 572
No Data	B/. 108 327	B/. 146 170	B/. 182 574	B/. 302 854	B/. 343 457	B/. 383 120
Total	**B/. 3 271 962**	**B/. 4 508 049**	**B/. 5 138 129**	**B/. 8 280 813**	**B/. 9 283 305**	**B/. 10 375 155**

Uso del Suelo en Hectareas Sitio 2

Uso del suelo	Nivel 80	Nivel 90	Nivel 95	Nivel 100	Nivel 105	Nivel 110	Nivel 115
Agua	B/. 17 361	xxxxxxxxxxx	B/. 17 744	B/. 17 744	B/. 17 743	B/. 17 743	B/. 17 744
Area de Ganaderia	B/. 2 101 255	xxxxxxxxxxx	B/. 3 471 157	B/. 5 867 836	B/. 6 609 673	B/. 7 488 321	B/. 8 178 693
Bosque Denso poco Intervenido de Tierra Bajas	B/. 6 212	xxxxxxxxxxx	B/. 9 023	B/. 16 551	B/. 20 111	B/. 25 974	B/. 29 251
Bosque Intervenido	B/. 136 889	xxxxxxxxxxx	B/. 194 152	B/. 297 572	B/. 332 199	B/. 361 331	B/. 386 543
Cultivos Anuales	B/. 57 537	xxxxxxxxxxx	B/. 90 413	B/. 176 033	B/. 193 730	B/. 220 082	B/. 234 598
Matorral Rastrojo	B/. 203 400	xxxxxxxxxxx	B/. 313 449	B/. 557 443	B/. 612 747	B/. 679 856	B/. 731 452
No Data	B/. 87 430	xxxxxxxxxxx	B/. 149 059	B/. 263 546	B/. 298 417	B/. 336 207	B/. 362 050
Total	**B/. 2 610 082**		**B/. 4 244 996**	**B/. 7 196 725**	**B/. 8 084 619**	**B/. 9 129 514**	**B/. 9 940 331**

Uso del Suelo en Hectareas Sitio 4

Uso del suelo	Nivel 80	Nivel 90	Nivel 95	Nivel 100	Nivel 105	Nivel 110	Nivel 115
Agua	B/. 15 295	xxxxxxxxxxx	B/. 15 515	B/. 15 505	B/. 15 516	B/. 15 522	B/. 15 514
Area de Ganaderia	B/. 1 898 410	xxxxxxxxxxx	B/. 3 206 355	B/. 5 595 554	B/. 6 334 059	B/. 7 211 719	B/. 7 895 337
Bosque Denso poco Intervenido de Tierra Bajas	B/. 4 096	xxxxxxxxxxx	B/. 6 618	B/. 13 299	B/. 16 468	B/. 22 259	B/. 25 450
Bosque Intervenido	B/. 104 480	xxxxxxxxxxx	B/. 156 212	B/. 253 736	B/. 283 144	B/. 310 014	B/. 333 089
Cultivos Anuales	B/. 50 669	xxxxxxxxxxx	B/. 80 181	B/. 165 649	B/. 183 135	B/. 209 490	B/. 223 909
Matorral Rastrojo	B/. 189 449	xxxxxxxxxxx	B/. 295 644	B/. 538 420	B/. 592 084	B/. 658 175	B/. 708 533
No Data	B/. 78 630	xxxxxxxxxxx	B/. 138 694	B/. 252 888	B/. 287 615	B/. 325 346	B/. 351 036
Total	**B/. 2 341 027**		**B/. 3 899 218**	**B/. 6 835 050**	**B/. 7 712 021**	**B/. 8 752 526**	**B/. 9 552 869**

Uso del Suelo en Hectareas Sitio 6

Uso del suelo	Nivel 80	Nivel 90	Nivel 95	Nivel 100	Nivel 105	Nivel 110	Nivel 115	Nivel 120
Agua	B/. 12 619	xxxxxxxxxxx	xxxxxxxxxxx	B/. 12 834	B/. 12 834	B/. 12 834	B/. 12 835	B/. 12 834
Area de Ganaderia	B/. 1 224 561	xxxxxxxxxxx	xxxxxxxxxxx	B/. 4 643 610	B/. 5 338 047	B/. 6 165 608	B/. 6 814 796	B/. 9 885 487
Bosque Denso poco Intervenido de Tierra Bajas	B/. 1 610	xxxxxxxxxxx	xxxxxxxxxxx	B/. 7 300	B/. 8 048	B/. 9 664	B/. 10 454	B/. 20 297
Bosque Intervenido	B/. 46 088	xxxxxxxxxxx	xxxxxxxxxxx	B/. 139 868	B/. 155 864	B/. 174 007	B/. 189 471	B/. 275 375
Cultivos Anuales	B/. 27 317	xxxxxxxxxxx	xxxxxxxxxxx	B/. 111 249	B/. 125 054	B/. 137 384	B/. 148 173	B/. 182 087
Matorral Rastrojo	B/. 112 398	xxxxxxxxxxx	xxxxxxxxxxx	B/. 400 161	B/. 443 966	B/. 502 476	B/. 547 752	B/. 765 509
No Data	B/. 57 513	xxxxxxxxxxx	xxxxxxxxxxx	B/. 224 651	B/. 257 349	B/. 293 450	B/. 318 394	B/. 394 565
Total	**B/. 1 482 105**			**B/. 5 539 673**	**B/. 6 341 161**	**B/. 7 295 424**	**B/. 8 041 874**	**B/. 11 536 155**

Uso del Suelo en Hectareas Sitio 7

Uso del suelo	Nivel 80	Nivel 90	Nivel 95	Nivel 100	Nivel 105	Nivel 110	Nivel 115	Nivel 120
Agua	B/. 11 750	xxxxxxxxxxx	xxxxxxxxxxx	B/. 11 968	B/. 11 971	B/. 11 970	B/. 11 967	B/. 11 970
Area de Ganaderia	B/. 1 128 036	xxxxxxxxxxx	xxxxxxxxxxx	B/. 4 484 782	B/. 5 172 502	B/. 5 997 309	B/. 6 642 679	B/. 9 708 012
Bosque Denso poco Intervenido de Tierra Bajas	B/. 1 610	xxxxxxxxxxx	xxxxxxxxxxx	B/. 7 073	B/. 7 822	B/. 9 438	B/. 10 228	B/. 20 071
Bosque Intervenido	B/. 43 644	xxxxxxxxxxx	xxxxxxxxxxx	B/. 130 913	B/. 145 896	B/. 163 600	B/. 178 627	B/. 264 113
Cultivos Anuales	B/. 26 900	xxxxxxxxxxx	xxxxxxxxxxx	B/. 98 275	B/. 111 175	B/. 123 119	B/. 133 714	B/. 167 741
Matorral Rastrojo	B/. 104 569	xxxxxxxxxxx	xxxxxxxxxxx	B/. 379 260	B/. 422 682	B/. 481 066	B/. 525 760	B/. 742 989
No Data	B/. 56 013	xxxxxxxxxxx	xxxxxxxxxxx	B/. 213 017	B/. 245 388	B/. 281 115	B/. 305 497	B/. 381 276
Total	**B/. 1 372 521**			**B/. 5 325 289**	**B/. 6 117 436**	**B/. 7 067 616**	**B/. 7 808 472**	**B/. 11 296 171**

Referencia de precios basados en el Uso del suelo

Agua	B/. 200	$/Hectárea
Area de Ganaderia	B/. 3 633	$/Hectárea
Bosque Denso poco Intervenido de Tierra Bajas	B/. 600	$/Hectárea
Bosque Intervenido	B/. 500	$/Hectárea
Cultivos Anuales	B/. 3 337	$/Hectárea
Matorral Rastrojo	B/. 400	$/Hectárea
No Data	B/. 400	$/Hectárea

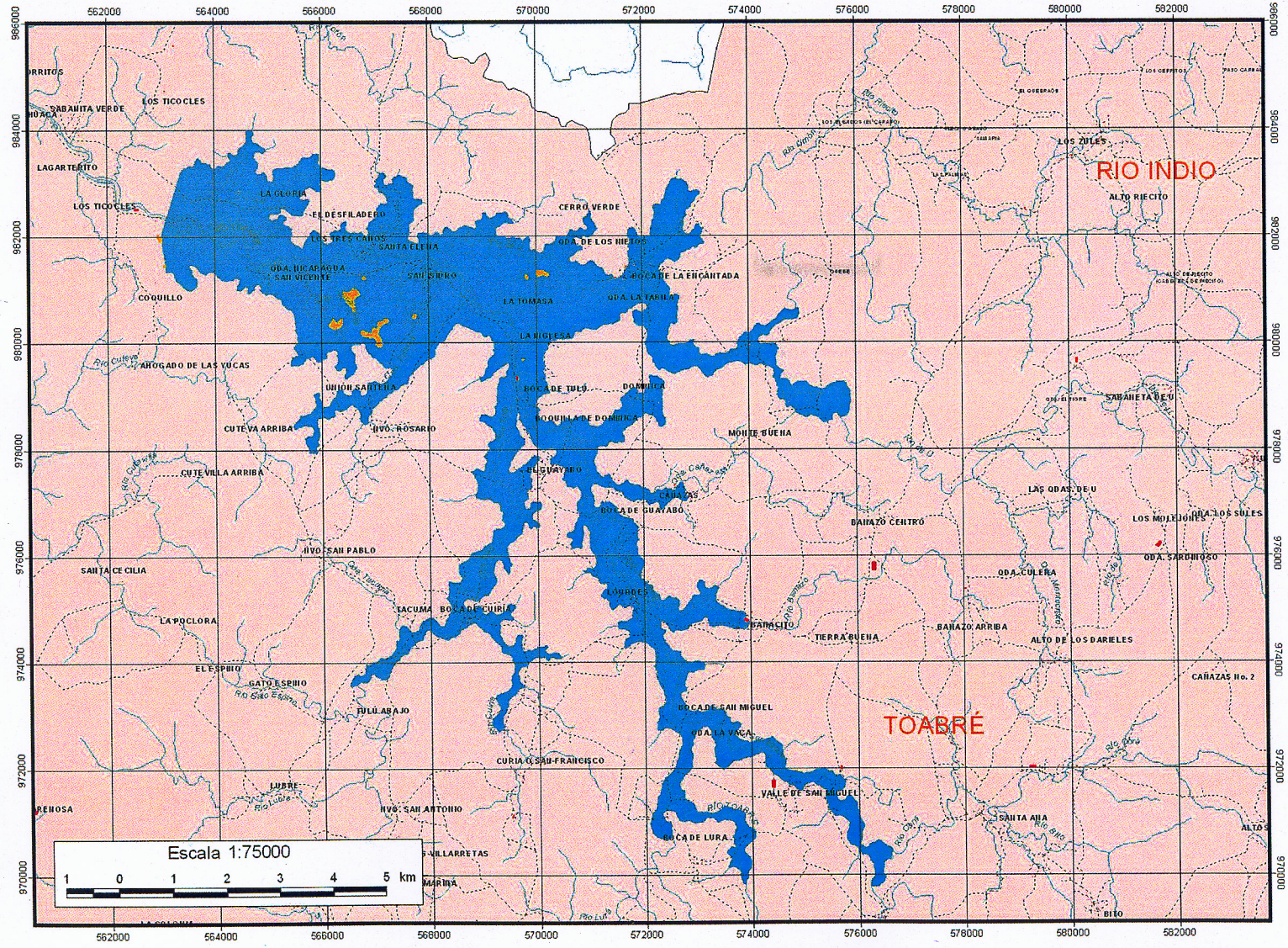
Comentarios

Se utilizó valor catastral
Centro Regional de Estudios en Economía Ecológica
Bosque no maderable con rendimiento de 50.00 $/Ha/año

Centro Regional de Estudios en Economía Ecológica

ticocles_95.jpg (2844x1650x16M jpeg)

Proyecto Río Toabré
Alternativas de Sitio de Presa
Los Ticocles Elevación 95



División de Administración Ambiental

Sección de Manejo de Cuenca

Unidad de Sensores Remotos

ACP

Leyenda

- Poblados

Red Vial

- Carreteras Principales
- Carreteras Secundarias
- Caminos
- Ríos

Superficie del Embalse 4010.84 Ha

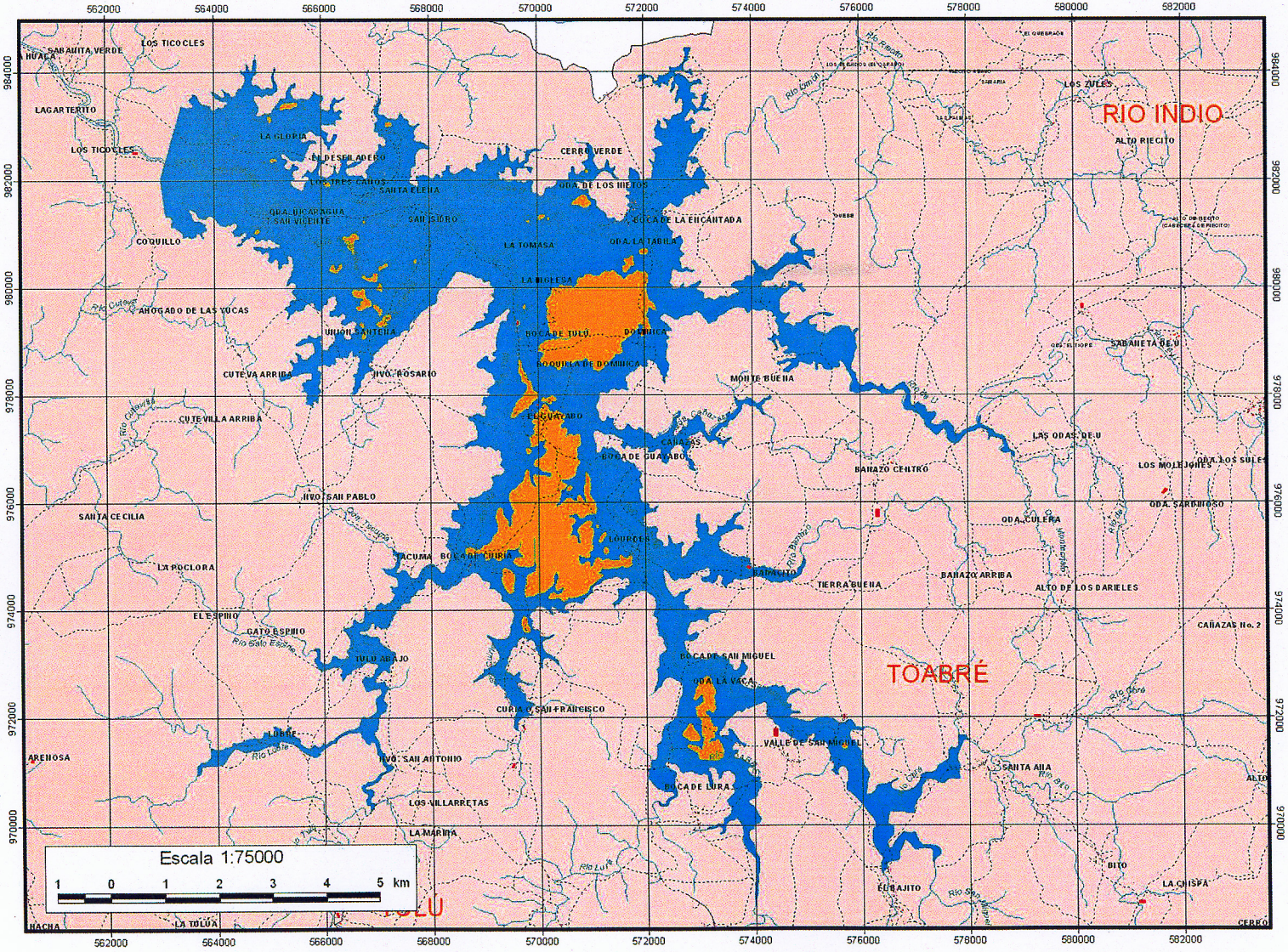
- Lago 3988.24 Ha
- Islas 22.60 Ha

Poblados	Habitantes
LA BOCA DE TULU (P)	105
BOCA DE LA ENCANTADA (P)	193
CAÑAZAS NO. 1	68
BOCA DE SAN MIGUEL	5
DOMINICA	17
EL GUAYABO (...O TOABRE ABAJO)	95
LOURDES	114
BOQUILLA DE DOMINICA	51
BOCA DE GUAYABO	30
QUEBRADA LA TABILA	22
QUEBRADA LA VACA	23
BOCA DE CUIRIA	142
SAN ISIDRO	129
SAN VICENTE	74
UNION SANTEÑA	40
LA BOCA DE TULU (P)	10
SANTA ELENA	66
LA INGLESA	12
QUEBRADA NICARAGUA	9
LA TOMASA	7
LA GLORIA	20
LOS TRES CAÑOS	14
QUEBRADA DE LOS NIETOS	2
TOTALES	1248

ticocles_100.jpg (2848x1650x16M jpeg)

Proyecto Río Toabré
Alternativas de Sitio de Presa
Los Ticocles Elevación 100

División de Administración Ambiental
Sección de Manejo de Cuenca
Unidad de Sensores Remotos



Leyenda

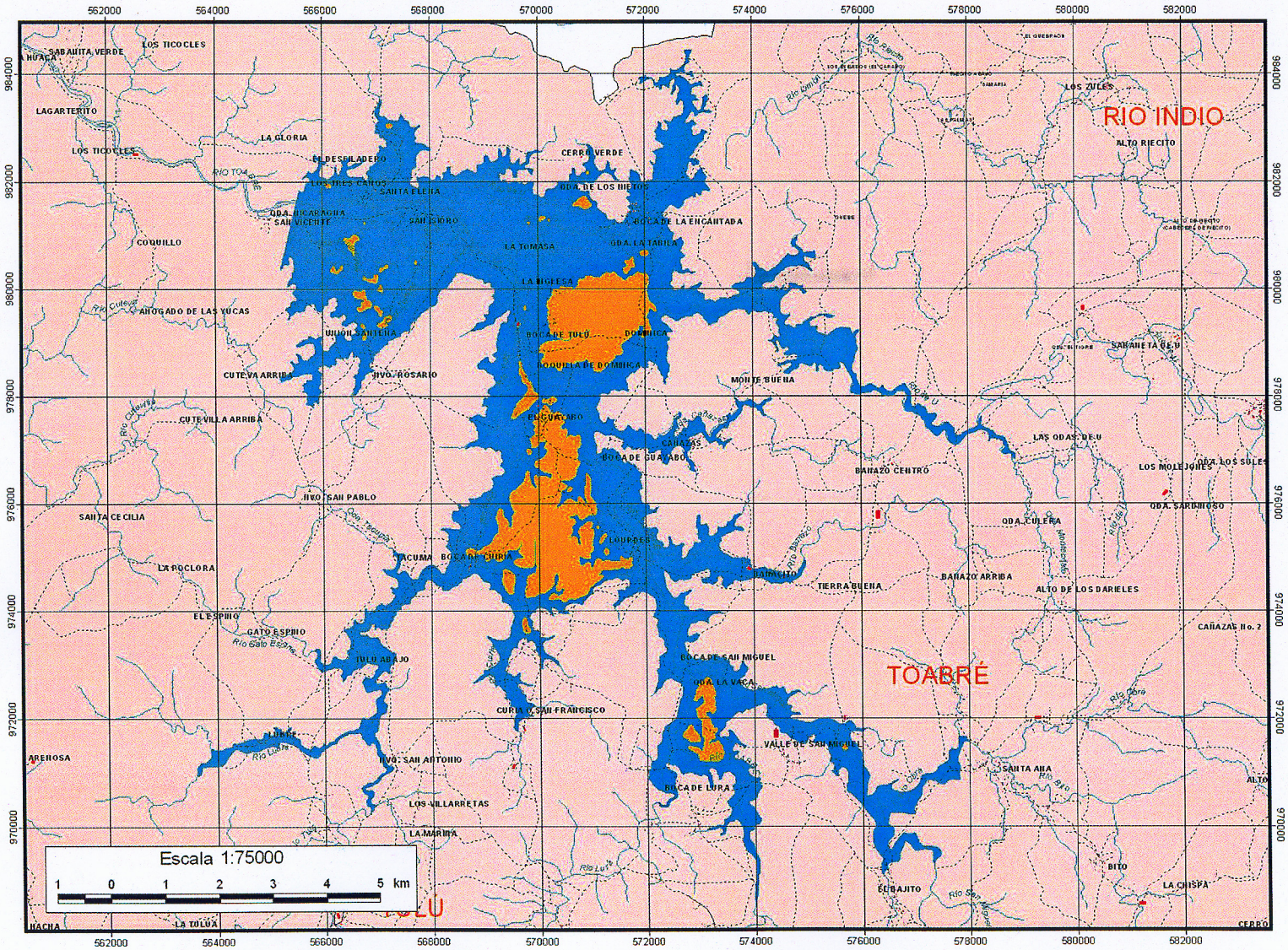
- Poblados
- Red Vial
  - Carreteras Principales
  - Carreteras Secundarias
  - Caminos
  - Ríos
- Superficie del Embalse 6010.8 Ha
  - Lago 5196.87 Ha
  - Islas 813.93 Ha

Poblados	Habitantes
LA BOCA DE TULU (P)	105
BOCA DE LA ENCANTADA (P)	193
CAÑAZAS NO. 1	68
BANACITO (BOCA DE BANAZO O...)	123
BOCA DE SAN MIGUEL	5
DOMINICA	17
EL GUAYABO (...O TOABRE ABAJO)	95
LOURDES	114
BOQUILLA DE DOMINICA	51
BOCA DE GUAYABO	30
QUEBRADA LA TABILA	22
QUEBRADA LA VACA	23
BOCA DE CUIRIA	142
LUBRE	33
TULU ABAJO	37
SAN ISIDRO	129
SAN VICENTE	74
UNION SANTEÑA	40
LA BOCA DE TULU (P)	10
SANTA ELENA	66
LA INGLESA	12
QUEBRADA NICARAGUA	9
LA TOMASA	7
EL DESFILADERO	7
LA GLORIA	30
LOS TRES CAÑOS	14
QUEBRADA DE LOS NIETOS	2
TOTAL	1448

san_vicente_100.jpg (2828x1650x16M jpeg)

Proyecto Río Toabré
Alternativas de Sitio de Presa
San Vicente Elevación 100

División de Administración Ambiental
Sección de Manejo de Cuenca
Unidad de Sensores Remotos



Leyenda

- Poblados

Red Vial

- Carreteras Principales
- Carreteras Secundarias
- Caminos
- Ríos

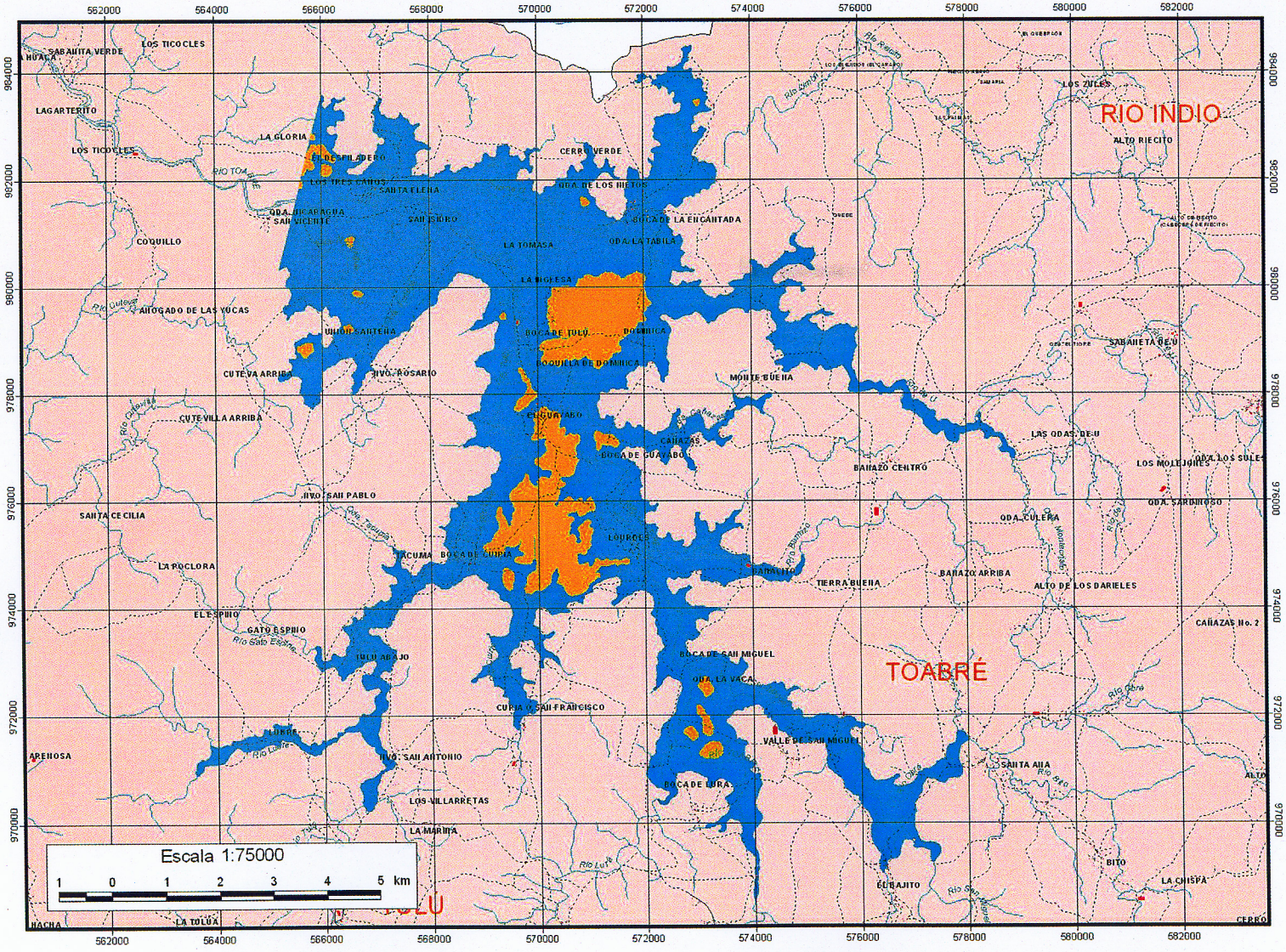
Superficie del Embalse 5344.88 Ha

- Lago 4535.52 Ha
- Islas 809.36 Ha

Poblados	Habitantes
LA BOCA DE TULU (P)	105
BOCA DE LA ENCANTADA (P)	193
CAÑAZAS NO. 1	68
BANACITO (BOCA DE BANAZO O...)	123
BOCA DE SAN MIGUEL	5
DOMINICA	17
EL GUAYABO (...O TOABRE ABAJO)	95
LOURDES	114
BOQUILLA DE DOMINICA	51
BOCA DE GUAYABO	30
QUEBRADA LA TABILA	22
QUEBRADA LA VACA	23
BOCA DE CUIRIA	142
LUBRE	33
TULU ABAJO	37
SAN ISIDRO	129
UNION SANTEWA	40
LA BOCA DE TULU (P)	10
SANTA ELENA	66
LA INGLESA	12
LA TOMASA	7
EL DESFILADERO	7
LOS TRES CAMOS	14
QUEBRADA DE LOS NIETOS	2
TOTAL	1345

san_vicente_105.jpg (2849x1650x16M jpeg)

Proyecto Río Toabré
Alternativas de Sitio de Presa
San Vicente Elevación 105



División de Administración Ambiental

Sección de Manejo de Cuenca

Unidad de Sensores Remotos

ACP

Leyenda

- Poblados

Red Vial

- Carreteras Principales
- Carreteras Secundarias
- Caminos
- Ríos

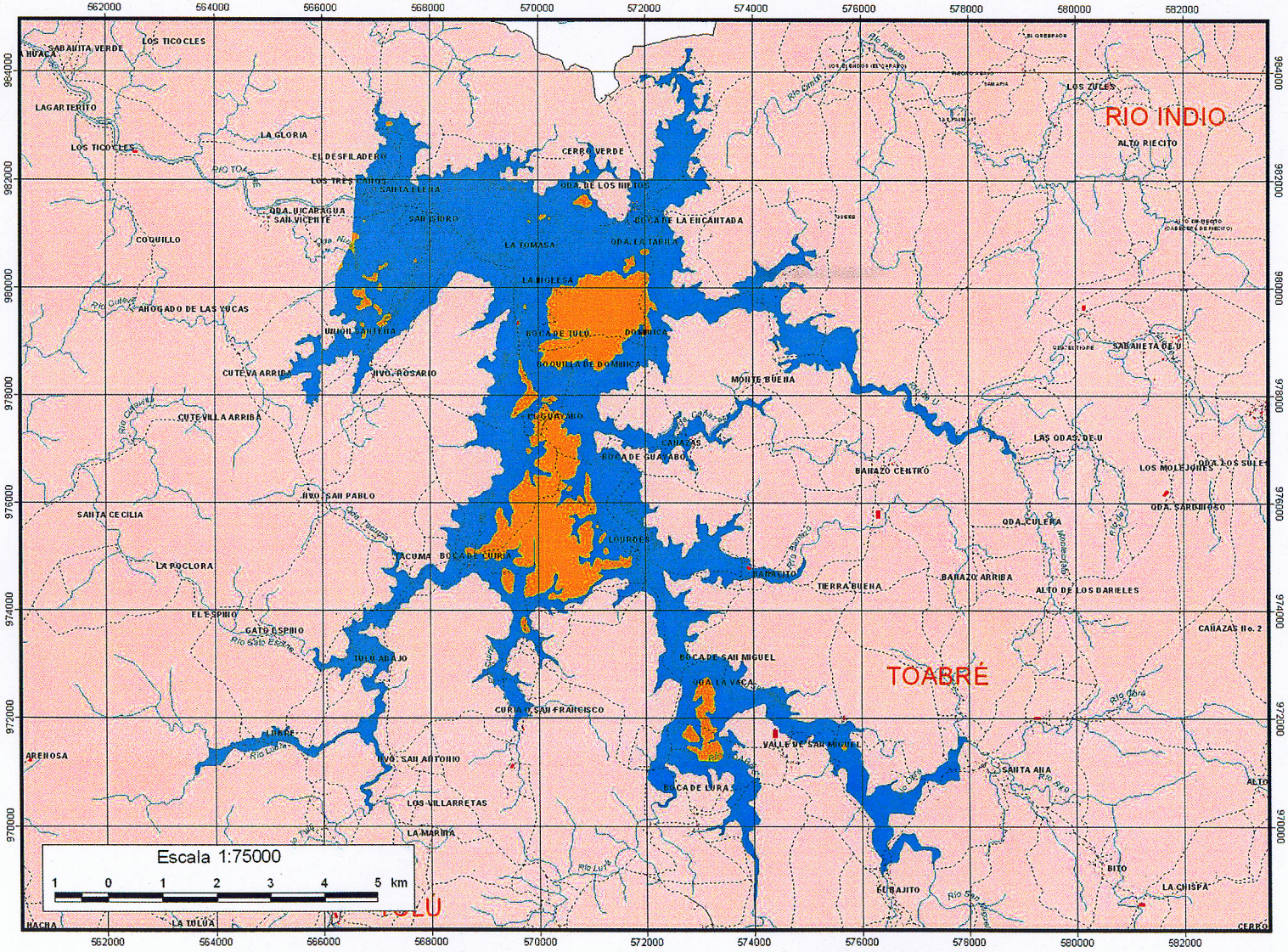
Superficie del Embalse 5995.64 Ha

- Lago 5283.91 Ha
- Islas 711.73 Ha

Poblados	Habitantes
LA BOCA DE TULU (P)	105
BOCA DE LA ENCANTADA (P)	193
CAÑAZAS NO. 1	68
BANACITO (BOCA DE BANAZO O...)	123
BOCA DE SAN MIGUEL	5
DOMINICA	17
EL GUAYABO (...O TOABRE ABAJO)	95
LOURDES	114
VALLE DE SAN MIGUEL	256
BOQUILLA DE DOMINICA	51
BOCA DE GUAYABO	30
QUEBRADA LA TABILA	22
QUEBRADA LA VACA	23
BOCA DE CUIRIA	142
LUBRE	33
TULU ABAJO	37
SAN ISIDRO	129
UNION SANTEÑA	40
LA BOCA DE TULU (P)	10
SANTA ELENA	66
LA INGLESA	12
LA TOMASA	7
EL DESFILADERO	7
LOS TRES CAÑOS	14
QUEBRADA DE LOS NIETOS	2
TOTAL	1601

santa_elena100.jpg (2832x1650x16M jpeg)

Proyecto Río Toabré
Alternativas de Sitio de Presa
Santa Elena Elevación 100



División de Administración Ambiental

Sección de Manejo de Cuenca

Unidad de Sensores Remotos

ACP

Leyenda

- Poblados

Red Vial

- Carreteras Principales
- Carreteras Secundarias
- Caminos

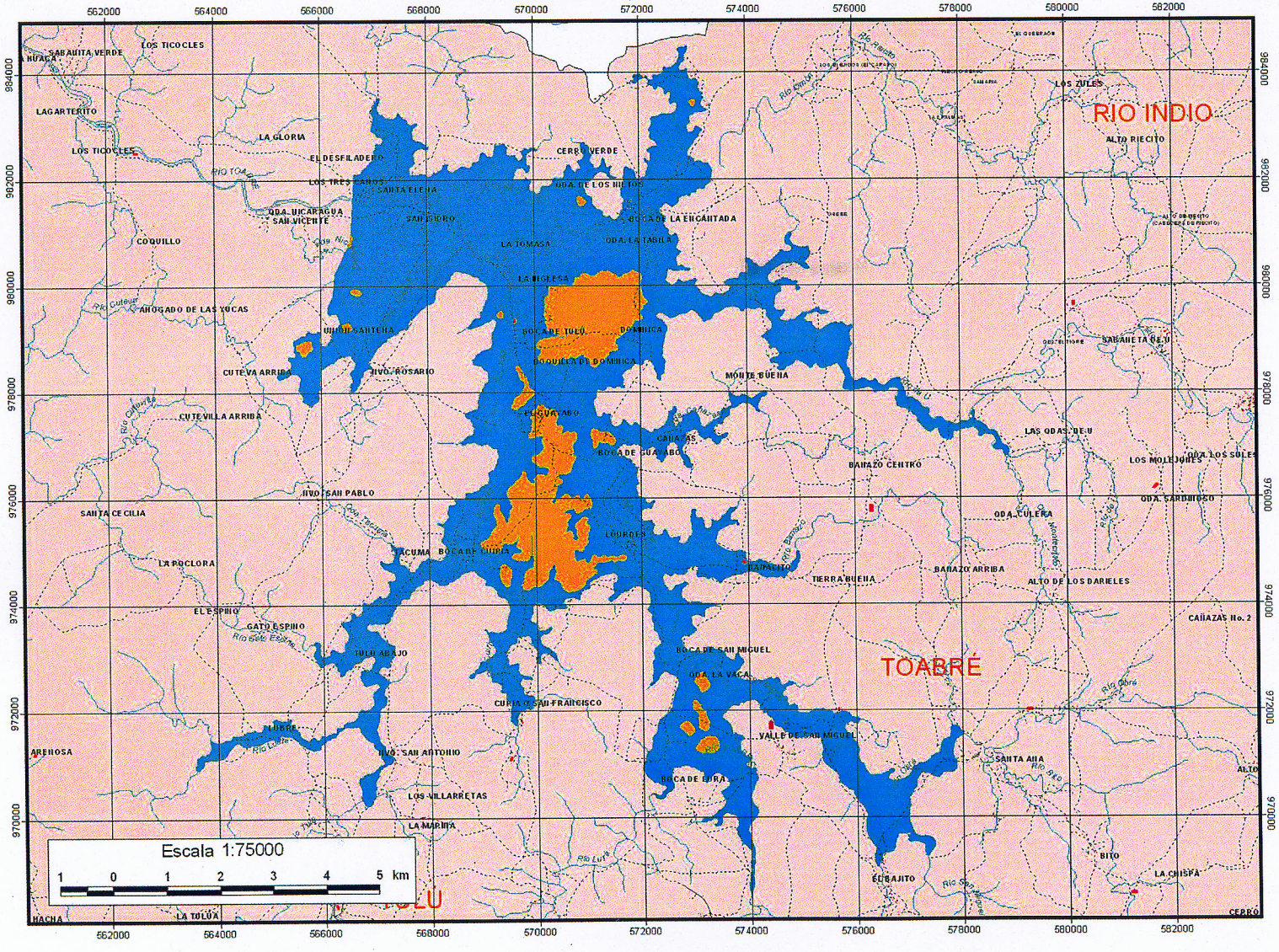
- Ríos

Superficie del Embalse 5080.41 Ha

- Lago 4275.10 Ha
- Islas 805.31 Ha

Poblado	Habitantes
LA BOCA DE TULU (P)	105
BOCA DE LA ENCANTADA (P)	193
CAÑAZAS NO. 1	68
BANACITO (BOCA DE BANAZO O...)	123
BOCA DE SAN MIGUEL	5
DOMINICA	17
EL GUAYABO (...O TOABRE ABAJO)	95
LOURDES	114
BOQUILLA DE DOMINICA	51
BOCA DE GUAYABO	30
QUEBRADA LA TABILA	22
QUEBRADA LA VACA	23
BOCA DE CUIRIA	142
LUBRE	33
TULU ABAJO	37
SAN ISIDRO	129
UNION SANTEÑA	40
LA BOCA DE TULU (P)	10
SANTA ELENA	66
LA INGLESA	12
LA TOMASA	7
QUEBRADA DE LOS NIETOS	2
TOTAL	1324

Proyecto Río Toabré
Alternativas de Sitio de Presa
Santa Elena Elevación 105



División de Administración Ambiental

Sección de Manejo de Cuenca

Unidad de Sensores Remotos

ACP

Leyenda

- Poblados

Red Vial

- Carreteras Principales
- Carreteras Secundarias
- Caminos
- Rios

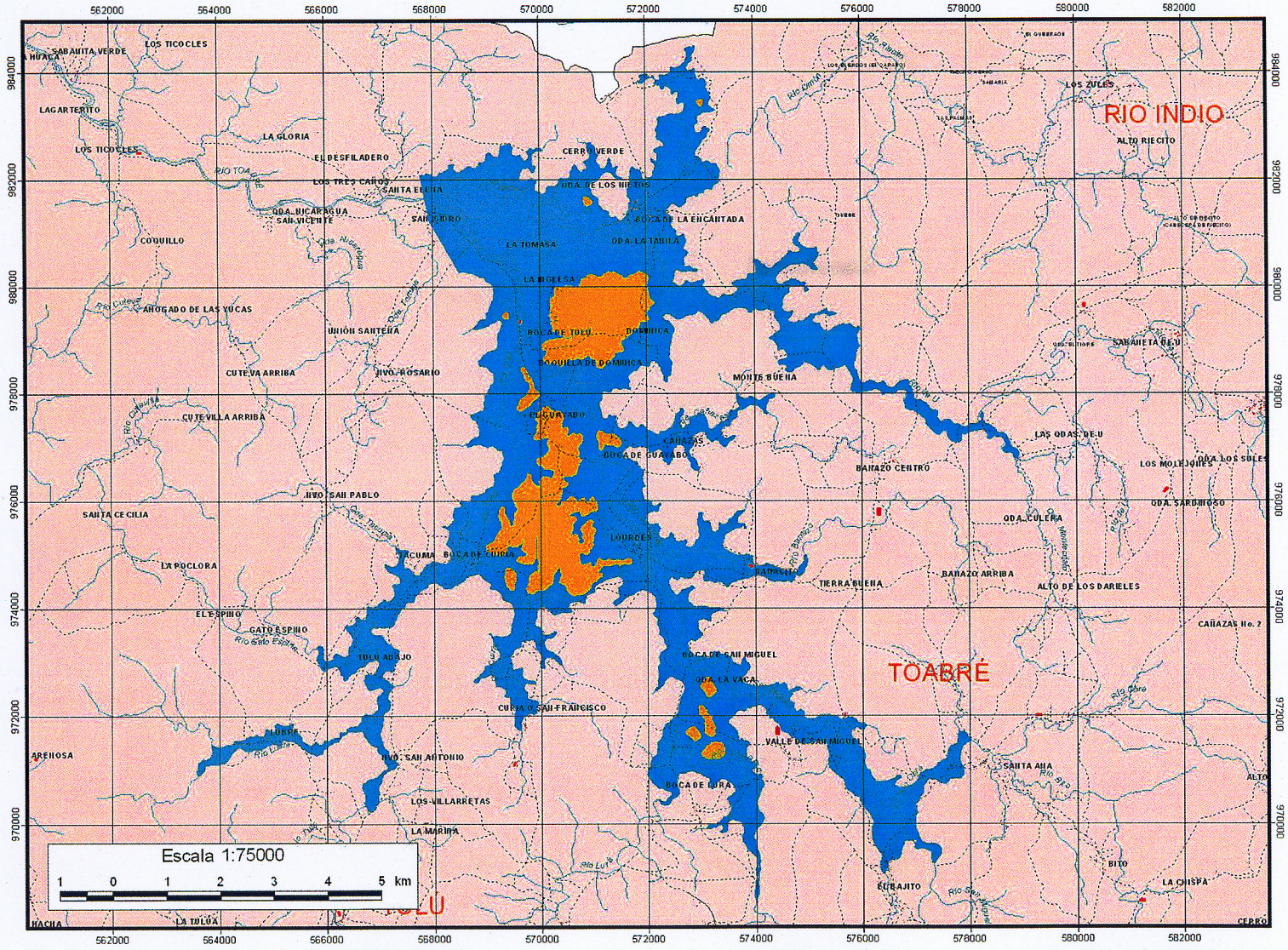
Superficie del Embalse 5646.65 Ha

- Lago 4956.51 Ha
- Islas 690.14 Ha

Poblados	Habitantes
LA BOCA DE TULU (P)	105
BOCA DE LA ENCANTADA (P)	193
CAÑAZAS NO. 1	68
BANACITO (BOCA DE BANAZO O...)	123
BOCA DE SAN MIGUEL	5
DOMINICA	17
EL GUAYABO (...O TOABRE ABAJO)	95
LOURDES	114
VALLE DE SAN MIGUEL	256
BOQUILLA DE DOMINICA	51
BOCA DE GUAYABO	30
QUEBRADA LA TABILA	22
QUEBRADA LA VACA	23
BOCA DE CUIRIA	142
LUBRE	33
TULU ABAJO	37
SAN ISIDRO	129
UNION SANTEÑA	40
LA BOCA DE TULU (P)	10
SANTA ELENA	66
LA INGLESA	12
LA TOMASA	7
QUEBRADA DE LOS NIETOS	2
TOTAL	1580

san_isidro_105.jpg (2841x1650x16M jpeg)

Proyecto Río Toabré
Alternativas de Sitio de Presa
San Isidro Elevación 105



División de Administración Ambiental
Sección de Manejo de Cuenca
Unidad de Sensores Remotos

ACP

Leyenda

- Poblados

Red Vial

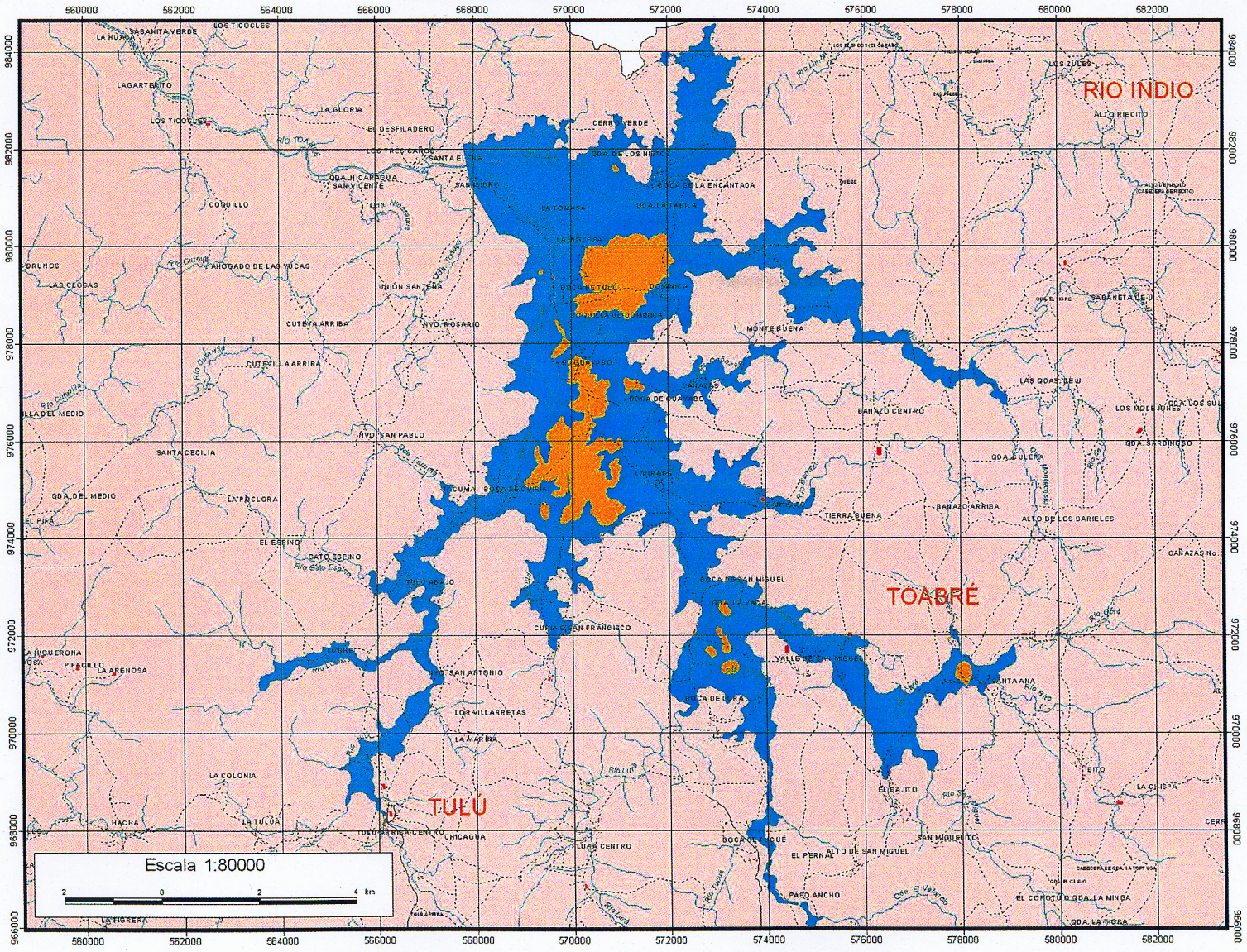
- Carreteras Principales
- Carreteras Secundarias
- Caminos
- Ríos

Superficie del Embalse 4941.77 Ha

- Lago 4269.76 Ha
- Islas 679.01 Ha

Poblados	Habitantes
LA BOCA DE TULU (P)	105
BOCA DE LA ENCANTADA (P)	193
CAÑAZAS NO. 1	68
BANACITO (BOCA DE BANAZO O...)	123
BOCA DE SAN MIGUEL	5
DOMINICA	17
EL GUAYABO (...O TOABRE ABAJO)	95
LOURDES	114
VALLE DE SAN MIGUEL	256
BOQUILLA DE DOMINICA	51
BOCA DE GUAYABO	30
QUEBRADA LA TABILA	22
QUEBRADA LA VACA	23
BOCA DE CUIRIA	142
LUBRE	33
TULU ABAJO	37
SAN ISIDRO	129
LA BOCA DE TULU (P)	10
LA INGLESA	12
LA TOMASA	7
QUEBRADA DE LOS NIETOS	2
TOTAL	1474

Proyecto Río Toabré
Alternativas de Sitio de Presa
San Isidro Elevación 110



División de Administración Ambiental

Sección de Manejo de Cuenca

Unidad de Sensores Remotos

ACP

Leyenda

- Poblados

Red Vial

- Carreteras Principales
- Carreteras Secundarias
- Caminos
- Ríos

Superficie del Embalse 5521.81 Ha

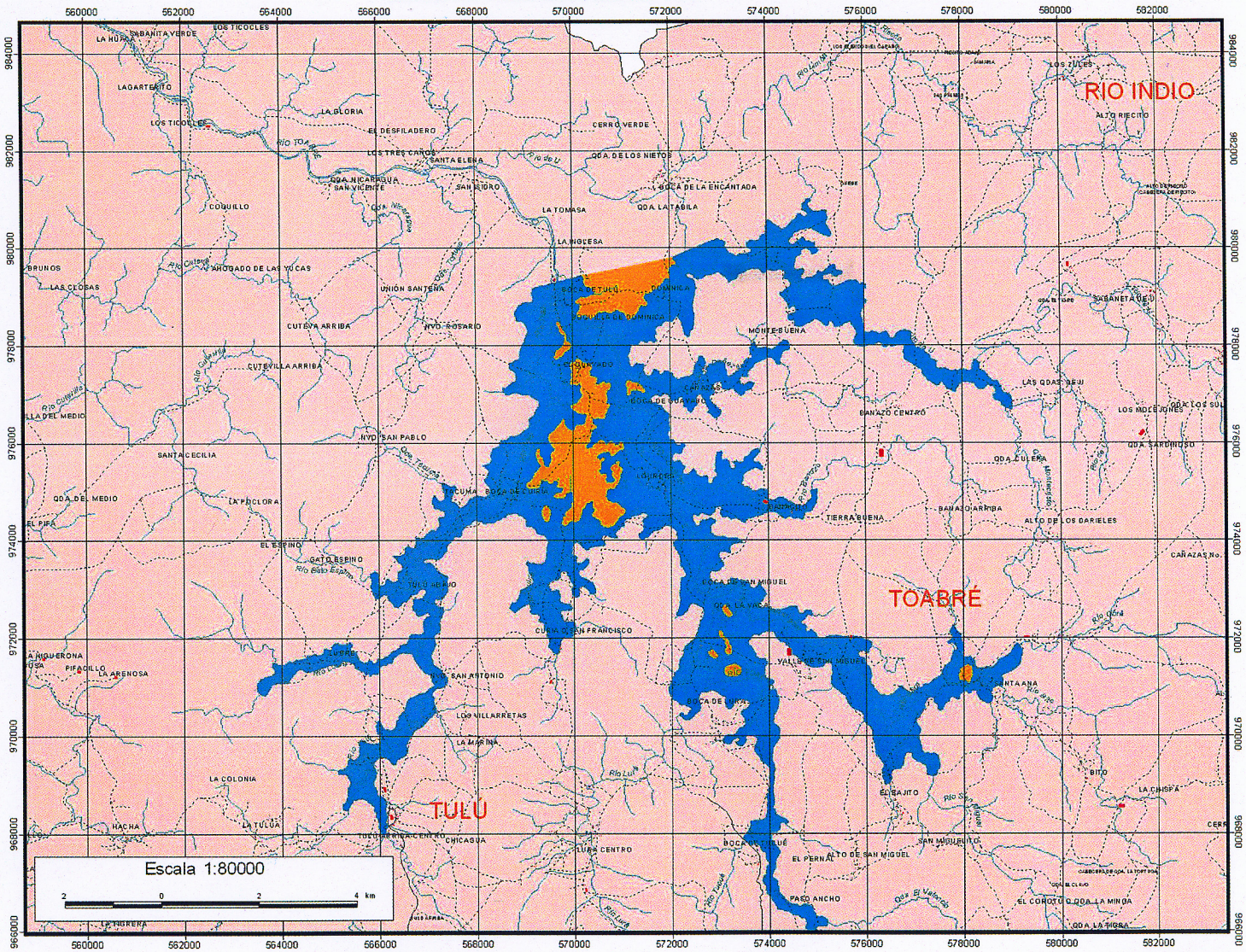
- Lago 4899.92 Ha
- Islas 621.89 Ha

Poblados	Habitantes
LA BOCA DE TULU (P)	105
BOCA DE LA ENCANTADA (P)	193
CAÑAZAS NO. 1	68
BANACITO (BOCA DE BANAZO O...)	123
BOCA DE SAN MIGUEL + Valle	5 + 256
DOMINICA	17
EL GUAYABO (...O TOABRE ABAJO)	95
LOURDES	114
SANTA ANA ABAJO	206
BOQUILLA DE DOMINICA	51
CUIRIA O SAN FRANCISCO	95
BOCA DE GUAYABO	30
QUEBRADA LA TABILA	22
QUEBRADA LA VACA	23
BOCA DE CUIRIA	142
LUBRE	33
TULU ABAJO	37
SAN ISIDRO	129
LA BOCA DE TULU (P)	10
LA INGLESA	12
LA TOMASA	7
QUEBRADA DE LOS NIETOS	2
BOCA DE LA ENCANTADA (P)	16
TOTAL	1731 ~~1596~~

boca_tulu_115.jpg (3850x2200x16M jpeg)

Proyecto Río Toabré
Alternativas de Sitio de Presa
Boca de Tulú Elevación 115

División de Administración Ambiental
Sección de Manejo de Cuenca
Unidad de Sensores Remotos



Leyenda

- Poblados

Red Vial

- Carreteras Principales
- Carreteras Secundarias
- Caminos
- Ríos

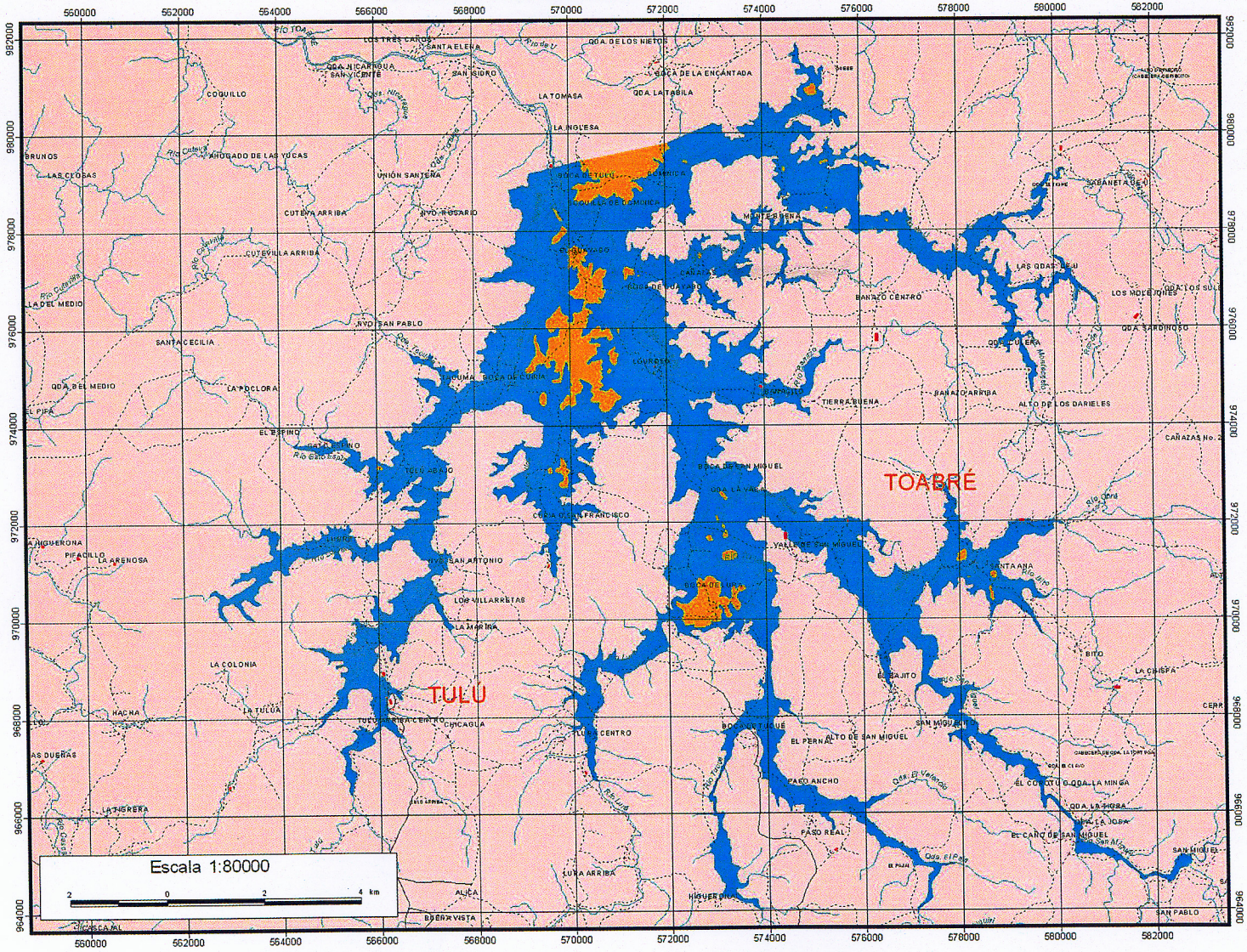
Superficie del Embalse 4545.97 Ha

- Lago 4074.12 Ha
- Islas 471.85 Ha

Población	Habitantes
LA BOCA DE TULU (P)	105
CAÑAZAS NO. 1	68
BANACITO (BOCA DE BANAZO O...)	123
BOCA DE SAN MIGUEL + VALLE	5 +256
BOCA DE TUCUE	208
DOMINICA	17
EL GUAYABO (...O TOABRE ABAJO)	95
LOURDES	114
SANTA ANA ABAJO	206
BOQUILLA DE DOMINICA	51
CUIRIA O SAN FRANCISCO	95
BOCA DE GUAYABO	30
QUEBRADA LA VACA	23
BOCA DE CUIRIA	142
LUBRE	33
TULU ABAJO	37
LA BOCA DE TULU (P)	10
NUEVO SAN ANTONIO	99
TOTAL	1717 ~~1461~~

boca_tulu_120.jpg (3850x2200x16M jpeg)

Proyecto Río Toabré
Alternativas de Sitio de Presa
Boca de Tulú Elevación 120



División de Administración Ambiental

Sección de Manejo de Cuenca

Unidad de Sensores Remotos

ACP

Leyenda

Poblados

Red Vial

Carreteras Principales

Carreteras Secundarias

Caminos

Ríos

Superficie del Embalse 6324.37 Ha

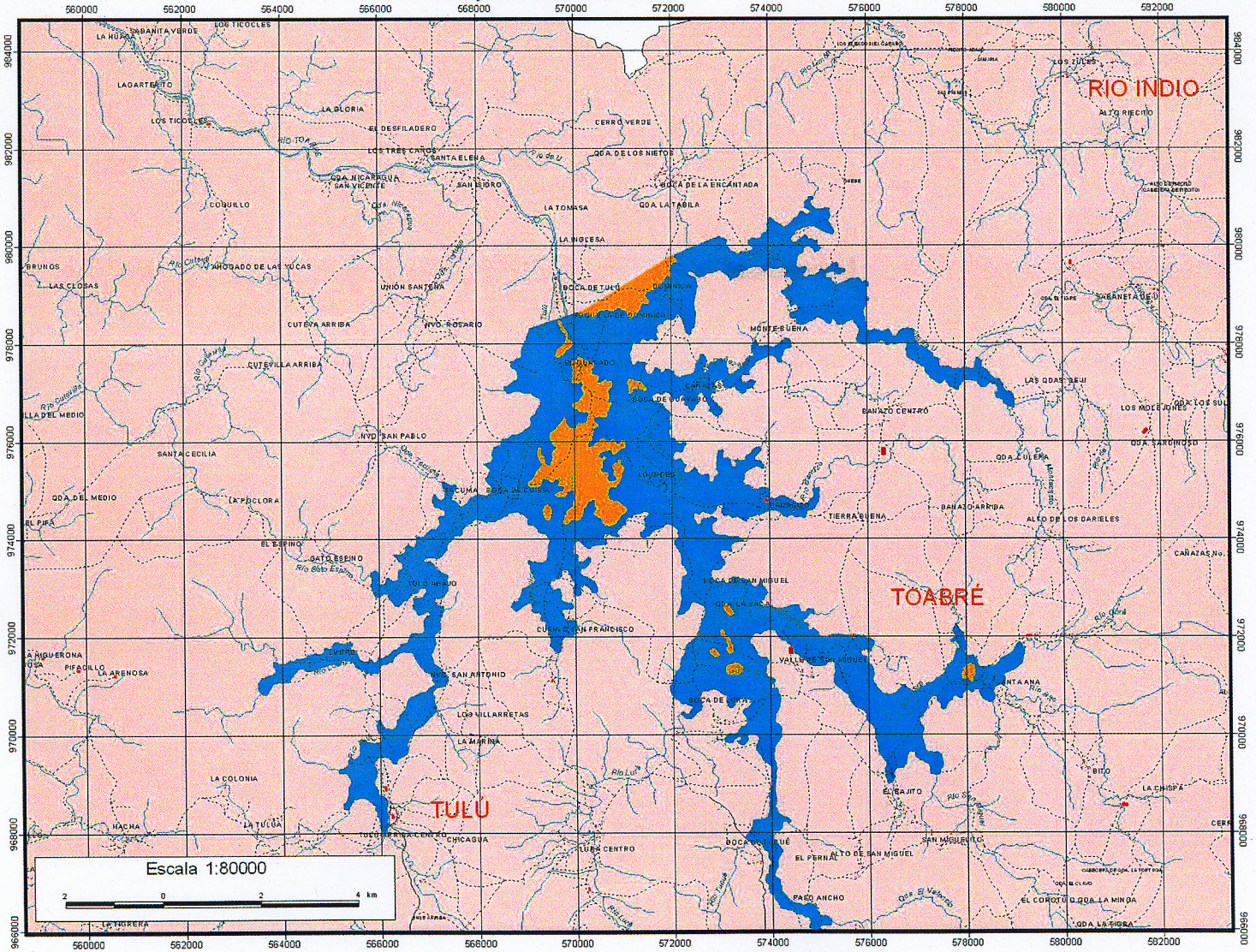
Lago 5837.62 Ha

Islas 486.75 Ha

Poblados	Habitantes
LA BOCA DE TULU (P)	105
CAÑAZAS NO. 1	68
ALTO DE SAN MIGUEL	42
BANACITO (BOCA DE BANAZO O...)	123
BOCA DE LURA	164
BOCA DE SAN MIGUEL	5
BOCA DE TUCUE	208
DOMINICA	17
EL GUAYABO (...O TOABRE ABAJO)	95
LOURDES	114
LAS QUEBRADAS DE U (LAS QUEBRADAS)	64
SANTA ANA ABAJO	206
QUEBRADA CULEBRA	19
VALLE DE SAN MIGUEL	256
BOQUILLA DE DOMINICA	51
CUIRIA O SAN FRANCISCO	95
BOCA DE GUAYABO	30
QUEBRADA LA VACA	23
BOCA DE CUIRIA	142
LUBRE	33
LURA CENTRO	328
TULU ABAJO	37
TULU CENTRO	278
LA BOCA DE TULU (P)	10
NUEVO SAN ANTONIO	99
TOTAL	2612

el_guayabo115.jpg (3850x2200x16M jpeg)

Proyecto Río Toabré
Alternativas de Sitio de Presa
El Guayabo Elevación 115



División de Administración Ambiental
Sección de Manejo de Cuenca
Unidad de Sensores Remotos

ACP

Leyenda

Poblados

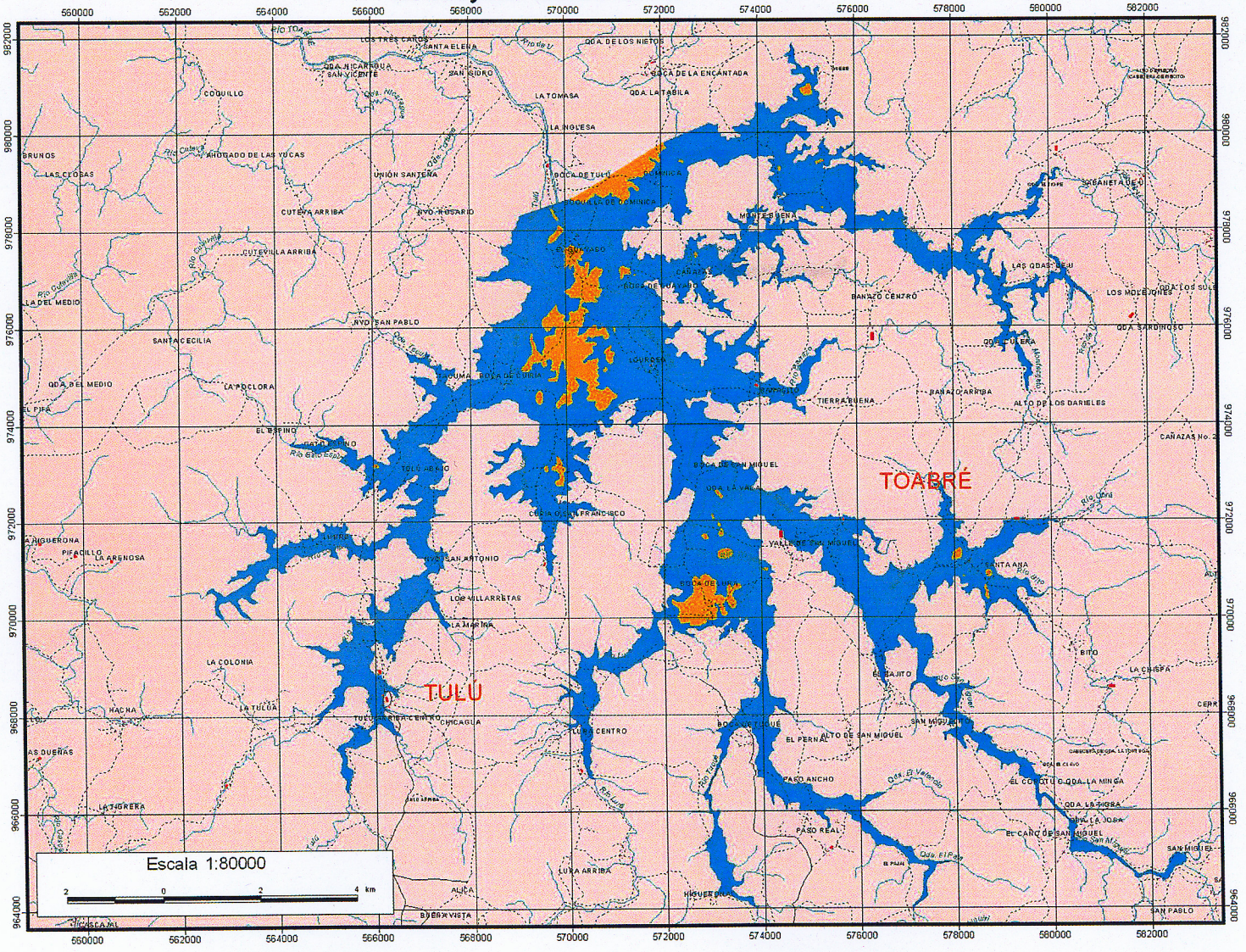
Red Vial
- Carreteras Principales
- Carreteras Secundarias
- Caminos
- Ríos

Superficie del Embalse 4380.65 Ha
- Lago 3972.98 Ha
- Islas 407.67 Ha

Poblados	Habitantes
CAÑAZAS NO. 1	68
BANACITO (BOCA DE BANAZO O...)	123
BOCA DE SAN MIGUEL + VALLE	5 + 256
BOCA DE TUCUE	208
DOMINICA	17
EL GUAYABO (...O TOABRE ABAJO)	95
LOURDES	114
SANTA ANA ABAJO	206
BOQUILLA DE DOMINICA	51
CUIRIA O SAN FRANCISCO	95
BOCA DE GUAYABO	30
QUEBRADA LA VACA	23
BOCA DE CUIRIA	142
LUBRE	33
TULU ABAJO	37
NUEVO SAN ANTONIO	99
TOTAL	1602 ~~3346~~

el_guayabo120.jpg (3850x2200x16M jpeg)

Proyecto Río Toabré
Alternativas de Sitio de Presa
El Guayabo Elevación 120



División de Administración Ambiental
Sección de Manejo de Cuenca
Unidad de Sensores Remotos

ACP

Leyenda

Poblados

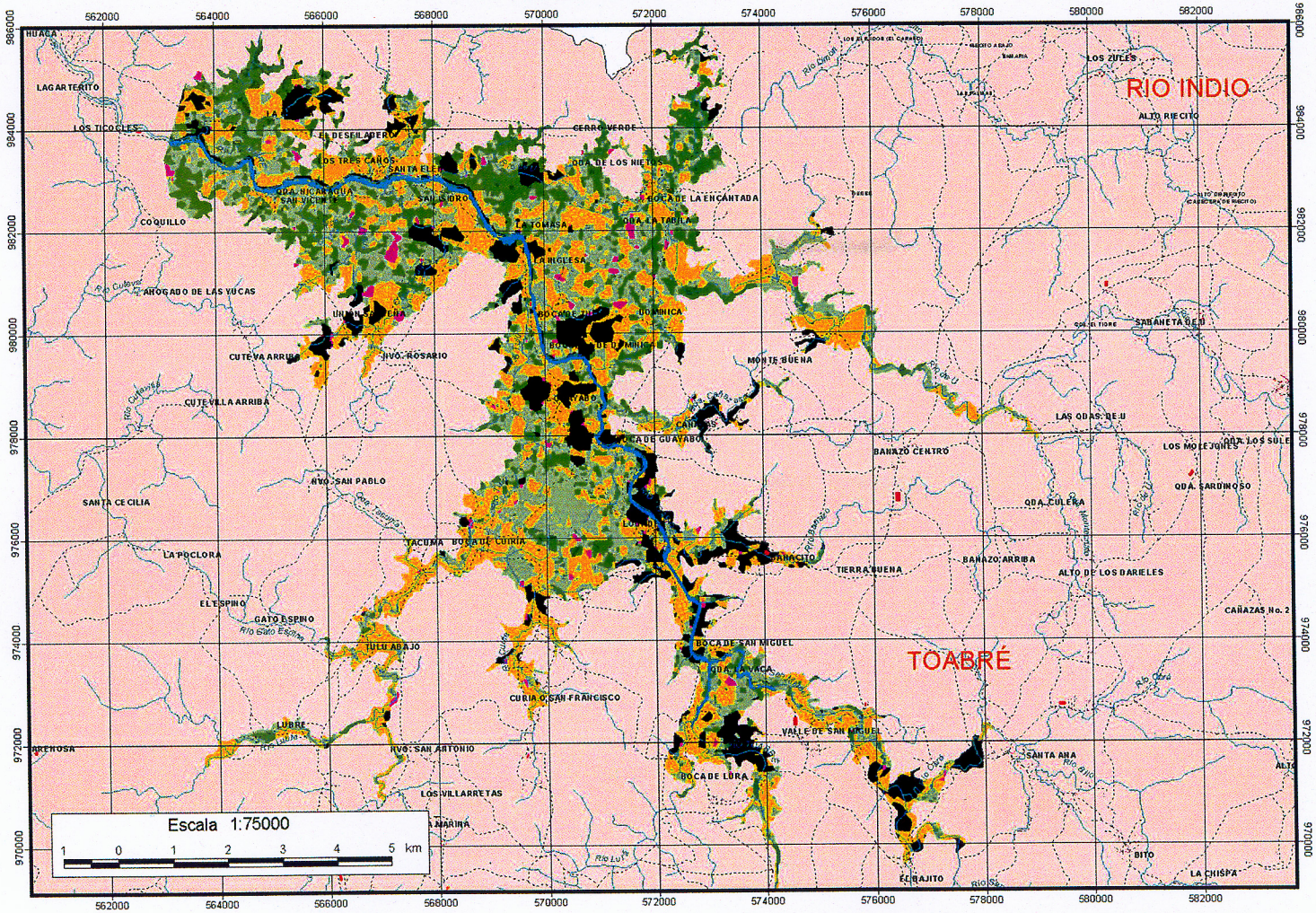
Red Vial
Carreteras Principales
Carreteras Secundarias
Caminos
Ríos

Superficie del Embalse 6154.47 Ha
Lago 5728.03 Ha
Islas 426.44 Ha

Poblados	Habitantes
CAÑAZAS NO. 1	68
ALTO DE SAN MIGUEL	42
BANACITO (BOCA DE BANAZO O...)	123
BOCA DE LURA	164
BOCA DE SAN MIGUEL	5
BOCA DE TUCUE	208
DOMINICA	17
EL GUAYABO (...O TOABRE ABAJO)	95
LOURDES	114
LAS QUEBRADAS DE U (LAS QUEBRADAS)	64
SANTA ANA ABAJO	206
QUEBRADA CULEBRA	19
VALLE DE SAN MIGUEL	256
BOQUILLA DE DOMINICA	51
CUIRIA O SAN FRANCISCO	95
BOCA DE GUAYABO	30
QUEBRADA LA VACA	23
BOCA DE CUIRIA	142
LUBRE	33
LURA CENTRO	328
TULU ABAJO	37
TULU CENTRO	278
NUEVO SAN ANTONIO	99
TOTAL	2497

ticocles_uso100.jpg (3085x1650x16M jpeg)

Proyecto Río Toabré
Uso del Suelo
Los Ticocles Elevación 100



División de Administración Ambiental

Sección de Manejo de Cuenca

Unidad de Sensores Remotos

ACP

Leyenda

Poblados

Red Vial

Carreteras Principales

Carreteras Secundarias

Caminos

Ríos

Agua

Area de Ganaderia

Bosque Denso poco Intervenido de Tierra Bajas

Bosque Intervenido

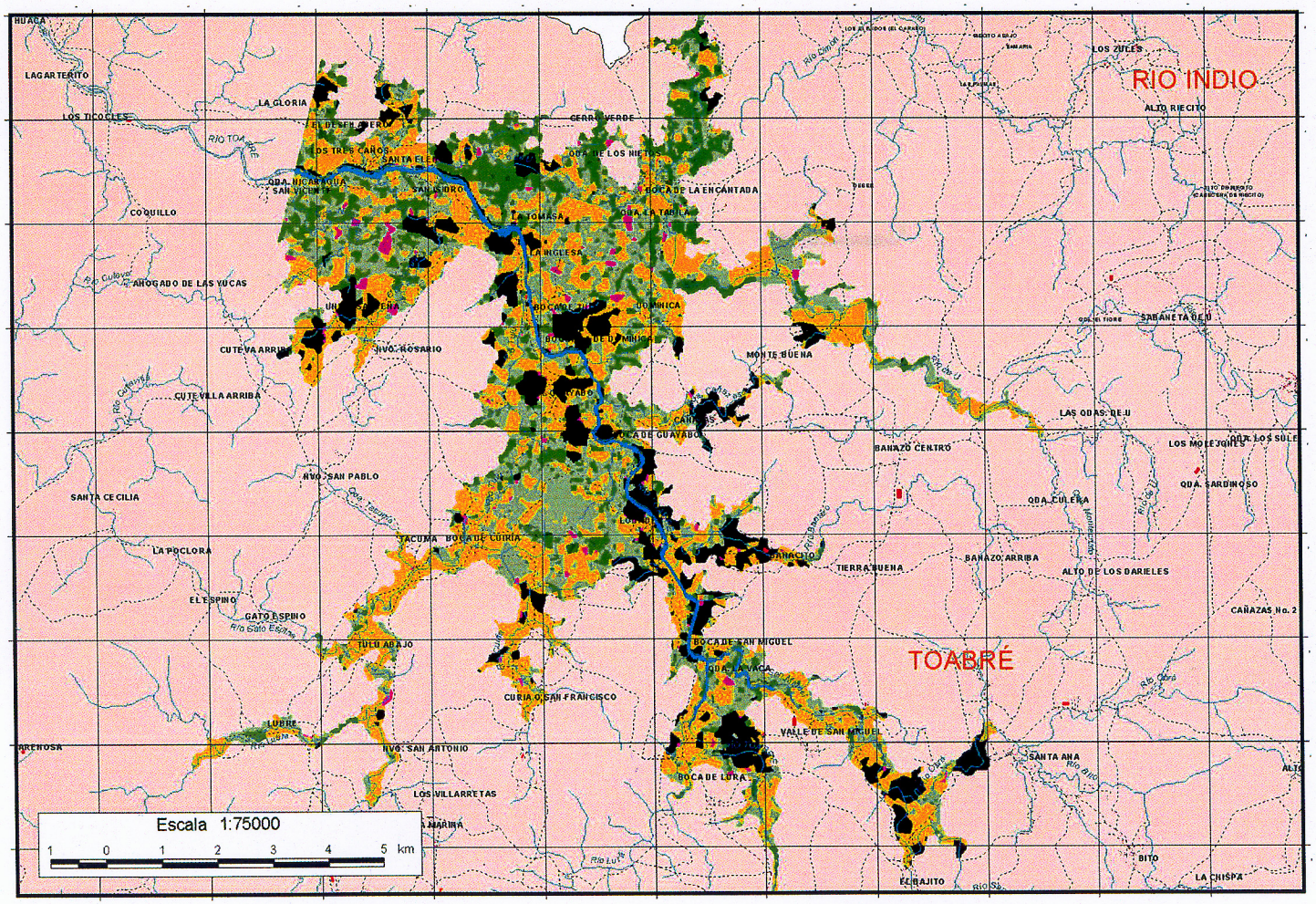
Cultivos Anuales

Matorral Rastrojo

No Data

Descripción	Hectáreas
Agua	125.636
Area de Ganadería	2072.844
Bosque Denso poco Intervenido de Tierra Bajas	66.391
Bosque Intervenido	945.988
Cultivos Anuales	83.798
Matorral Rastrojo	1877.809
No Data	838.512

Proyecto Río Toabré
Uso del Suelo
San Vicente Elevación 105



División de Administración Ambiental
Sección de Manejo de Cuenca
Unidad de Sensores Remotos

ACP

Leyenda

Poblados

Red Vial
- Carreteras Principales
- Carreteras Secundarias
- Caminos

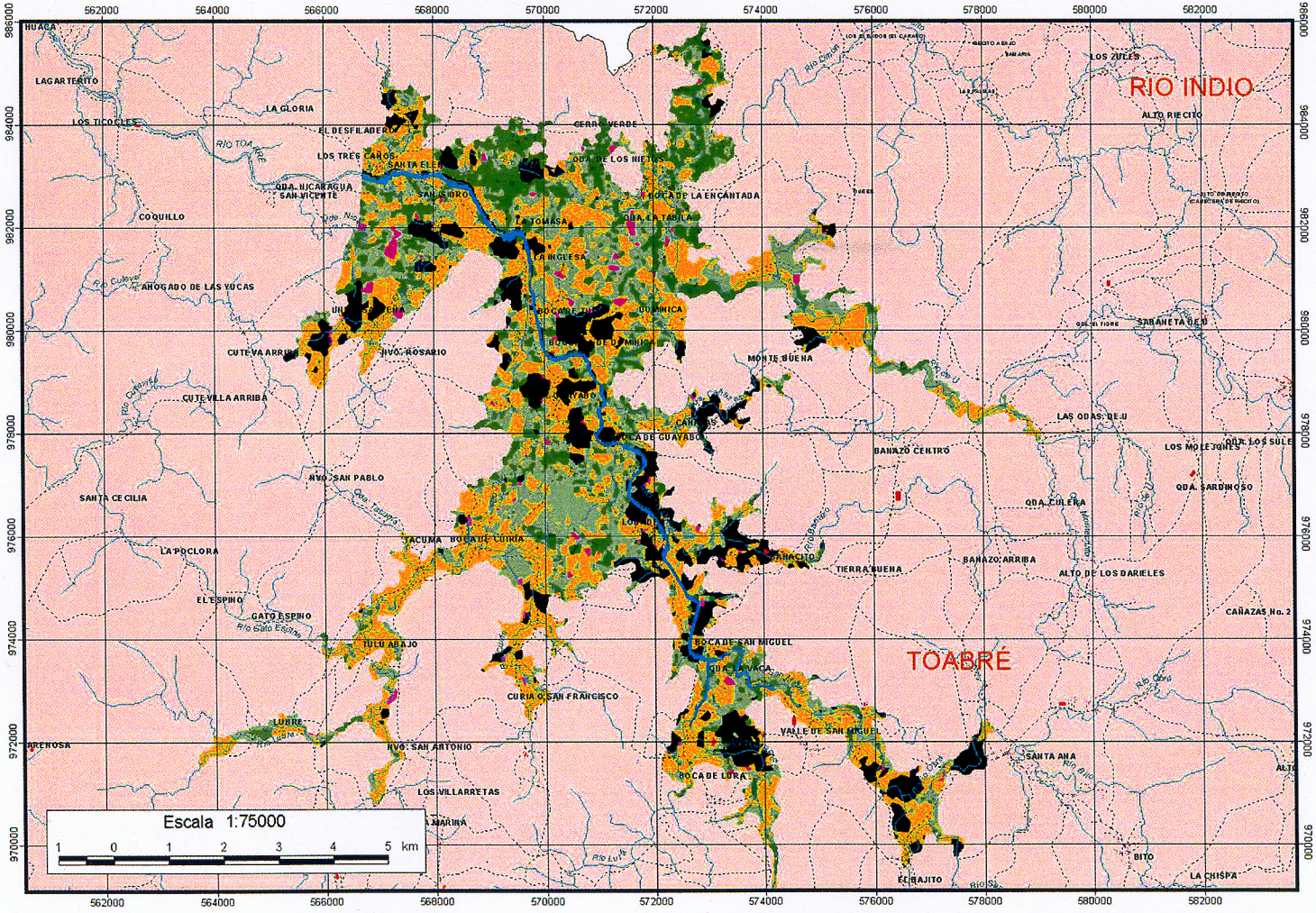
Ríos

- Agua
- Area de Ganaderia
- Bosque Denso poco Intervenido de Tierra Bajas
- Bosque Intervenido
- Cultivos Anuales
- Matorral Rastrojo
- No Data

Descripción	Hectáreas
Agua	105.495
Area de Ganadería	1926.713
Bosque Denso poco Intervenido de Tierra Bajas	33.213
Bosque Intervenido	756.832
Cultivos Anuales	75.512
Matorral Rastrojo	1680.689
No Data	766.573

santa_elena_uso105.jpg (3085x1650x16M jpeg)

Proyecto Río Toabré
Uso del Suelo
Santa Elena Elevación 105



División de Administración Ambiental

Sección de Manejo de Cuenca

Unidad de Sensores Remotos

ACP

Leyenda

Poblados

Red Vial

Carreteras Principales

Carreteras Secundarias

Caminos

Ríos

Agua

Area de Ganaderia

Bosque Denso poco Intervenido de Tierra Bajas

Bosque Intervenido

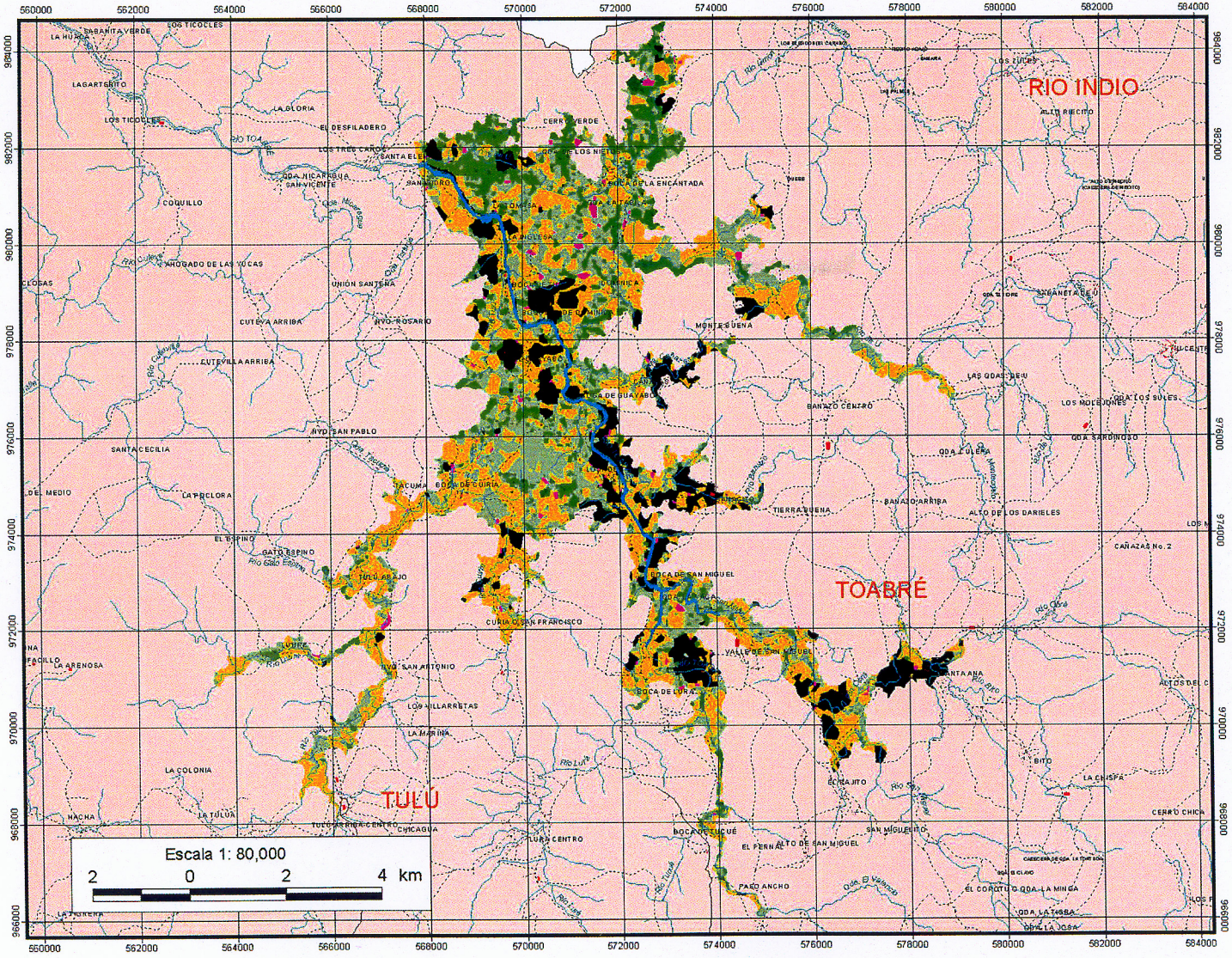
Cultivos Anuales

Matorral Rastrojo

No Data

Descripción	Hectáreas
Agua	97.941
Area de Ganadería	2082.547
Bosque Denso poco Intervenido de Tierra Bajas	36.268
Bosque Intervenido	760.144
Cultivos Anuales	77.634
Matorral Rastrojo	1733.672
No Data	858.643

Proyecto Río Toabré
Uso del Suelo
San Isidro Elevación 110



División de Administración Ambiental
Sección de Manejo de Cuenca
Unidad de Sensores Remotos

ACP

Leyenda

Poblados

Red Vial

Carreteras Principales
Carreteras Secundarias
Caminos

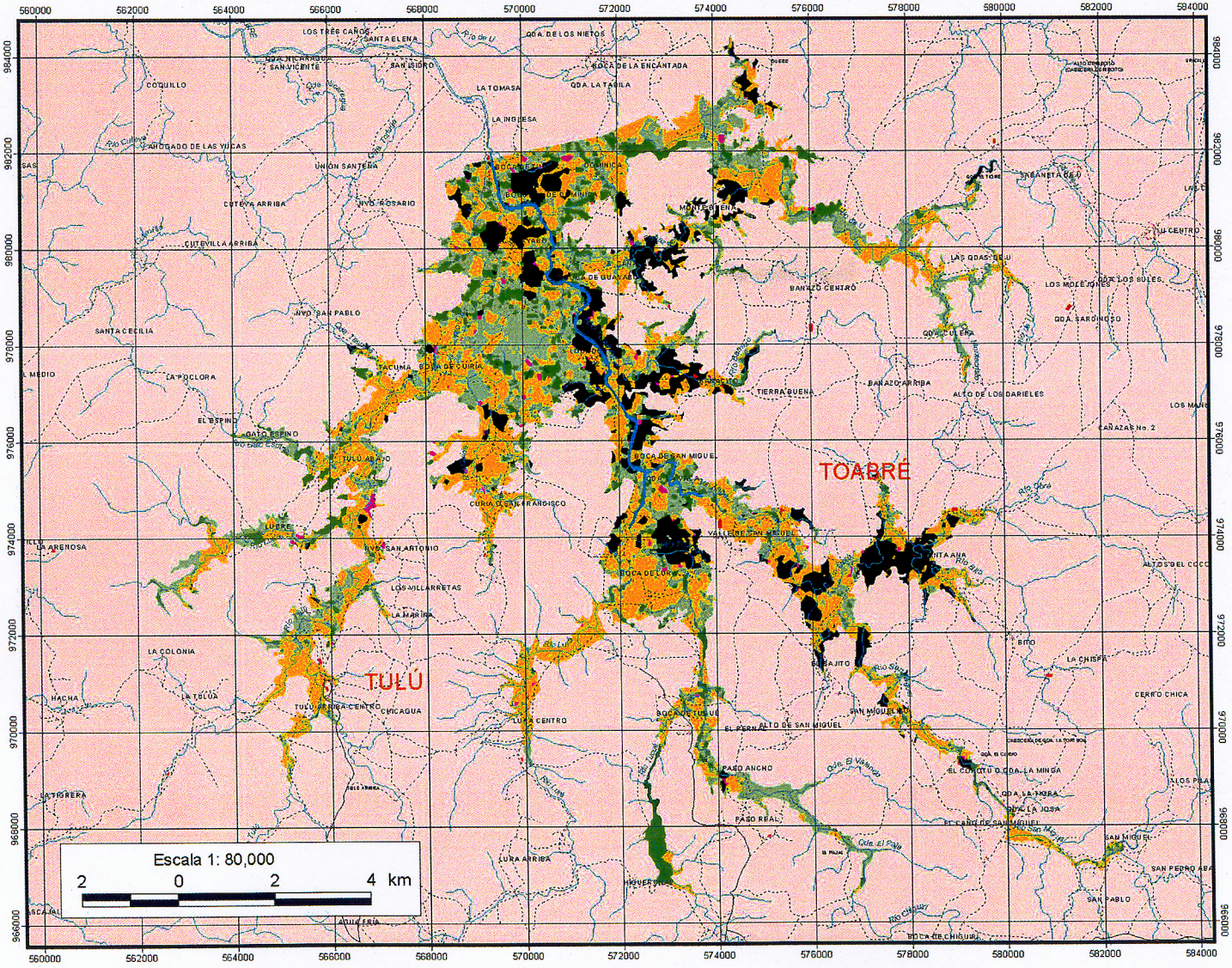
Ríos

Agua
Area de Ganaderia
Bosque Denso poco Intervenido de Tierra Bajas
Bosque Intervenido
Cultivos Anuales
Matorral Rastrojo
No Data

Descripción	Hectáreas
Agua	88.713
Area de Ganadería	2061.195
Bosque Denso poco Intervenido de Tierra Bajas	43.290
Bosque Intervenido	722.662
Cultivos Anuales	65.952
Matorral Rastrojo	1699.640
No Data	840.518

tulu_uso120.jpg (2850x1650x16M jpeg)

Proyecto Río Toabré
Uso del Suelo
Boca de Tulú Elevación 120



División de Administración Ambiental

Sección de Manejo de Cuenca

Unidad de Sensores Remotos

ACP

Leyenda

Poblados

Red Vial

Carreteras Principales

Carreteras Secundarias

Caminos

Ríos

Agua

Area de Ganaderia

Bosque Denso poco Intervenido de Tierra Bajas

Bosque Intervenido

Cultivos Anuales

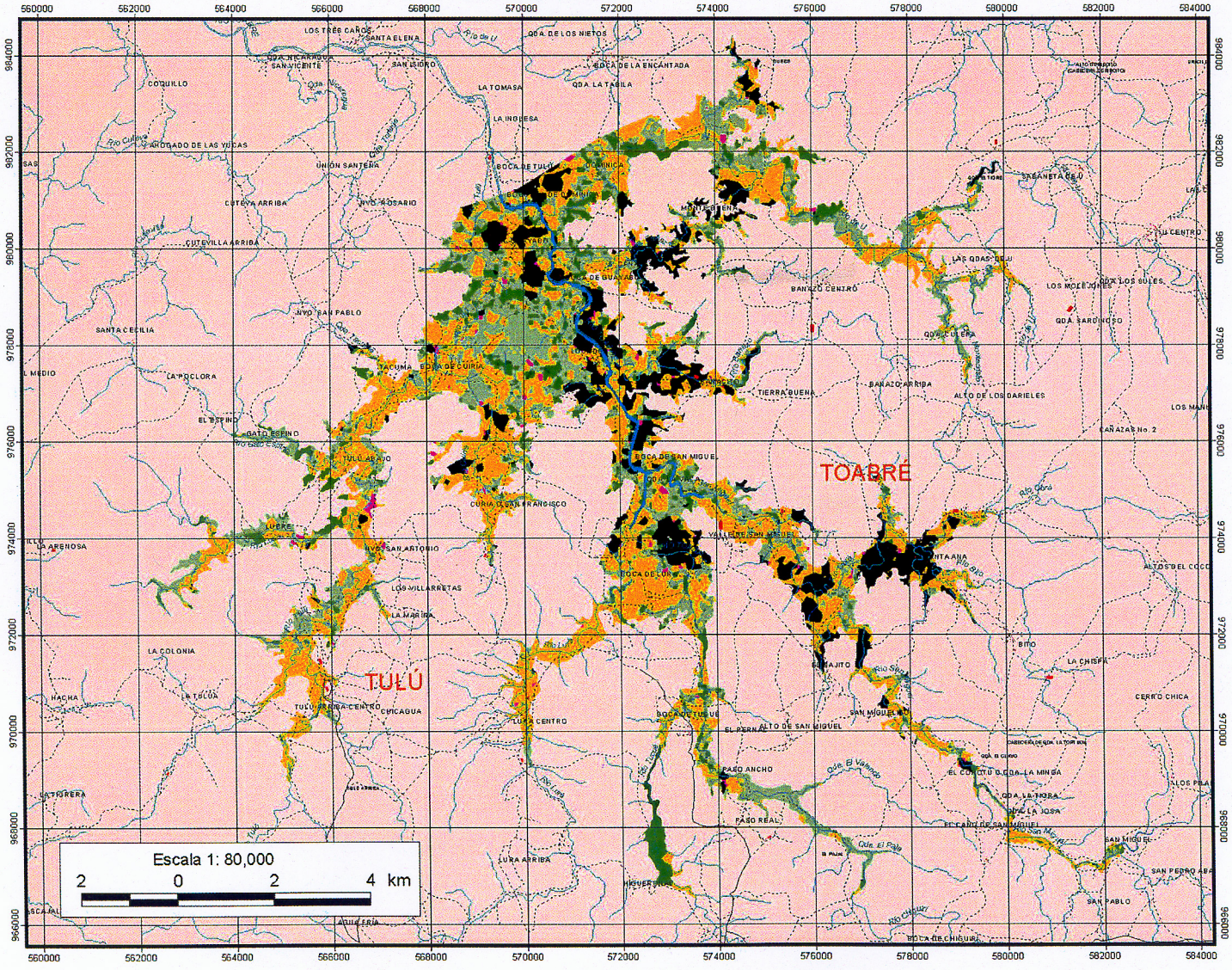
Matorral Rastrojo

No Data

Descripción	Hectáreas
Agua	64.171
Area de Ganadería	2721.026
Bosque Denso poco Intervenido de Tierra Bajas	33.829
Bosque Intervenido	550.749
Cultivos Anuales	54.566
Matorral Rastrojo	1913.773
No Data	986.413

guayabo_uso120.jpg (2850x1650x16M jpeg)

Proyecto Río Toabré
Uso del Suelo
El Guayabo Elevación 120



División de Administración Ambiental
Sección de Manejo de Cuenca
Unidad de Sensores Remotos

ACP

Leyenda

Poblados

Red Vial

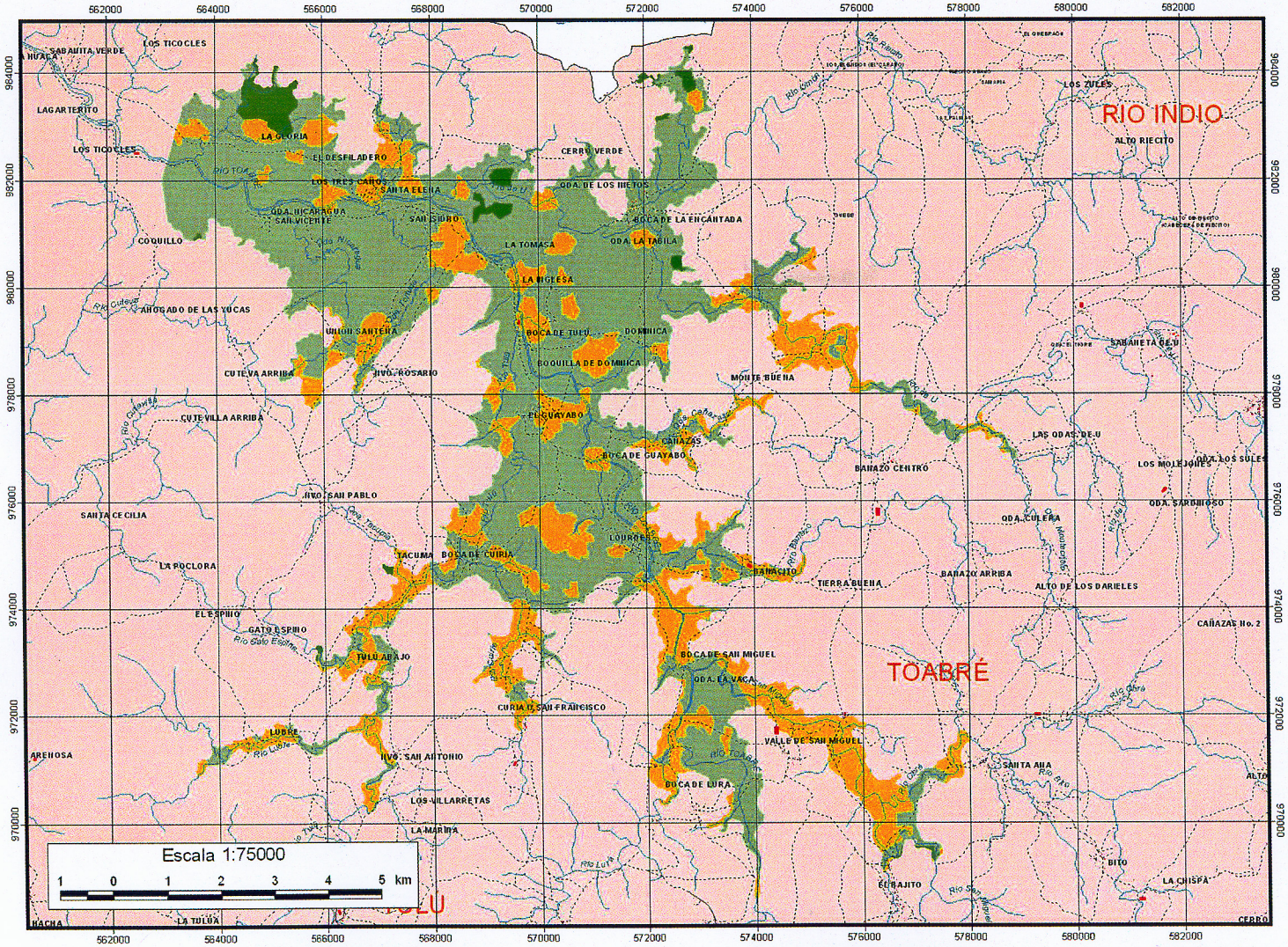
Carreteras Principales
Carreteras Secundarias
Caminos

Ríos

Agua
Area de Ganaderia
Bosque Denso poco Intervenido de Tierra Bajas
Bosque Intervenido
Cultivos Anuales
Matorral Rastrojo
No Data

Descripción	Hectáreas
Agua	59.849
Area de Ganadería	2672.175
Bosque Denso poco Intervenido de Tierra Bajas	33.452
Bosque Intervenido	528.226
Cultivos Anuales	50.267
Matorral Rastrojo	1857.472
No Data	953.189

Proyecto Río Toabré
Habitat
Los Ticocles Elevación 105



División de Administración Ambiental

Sección de Manejo de Cuenca

Unidad de Sensores Remotos

ACP

Leyenda

Poblados

Red Vial

Carreteras Principales

Carreteras Secundarias

Caminos

Ríos

Bosque Nuboso

Bosque perennifolio ombrófilo tropical de tierras bajas

Bosque perennifolio ombrófilo tropical montano

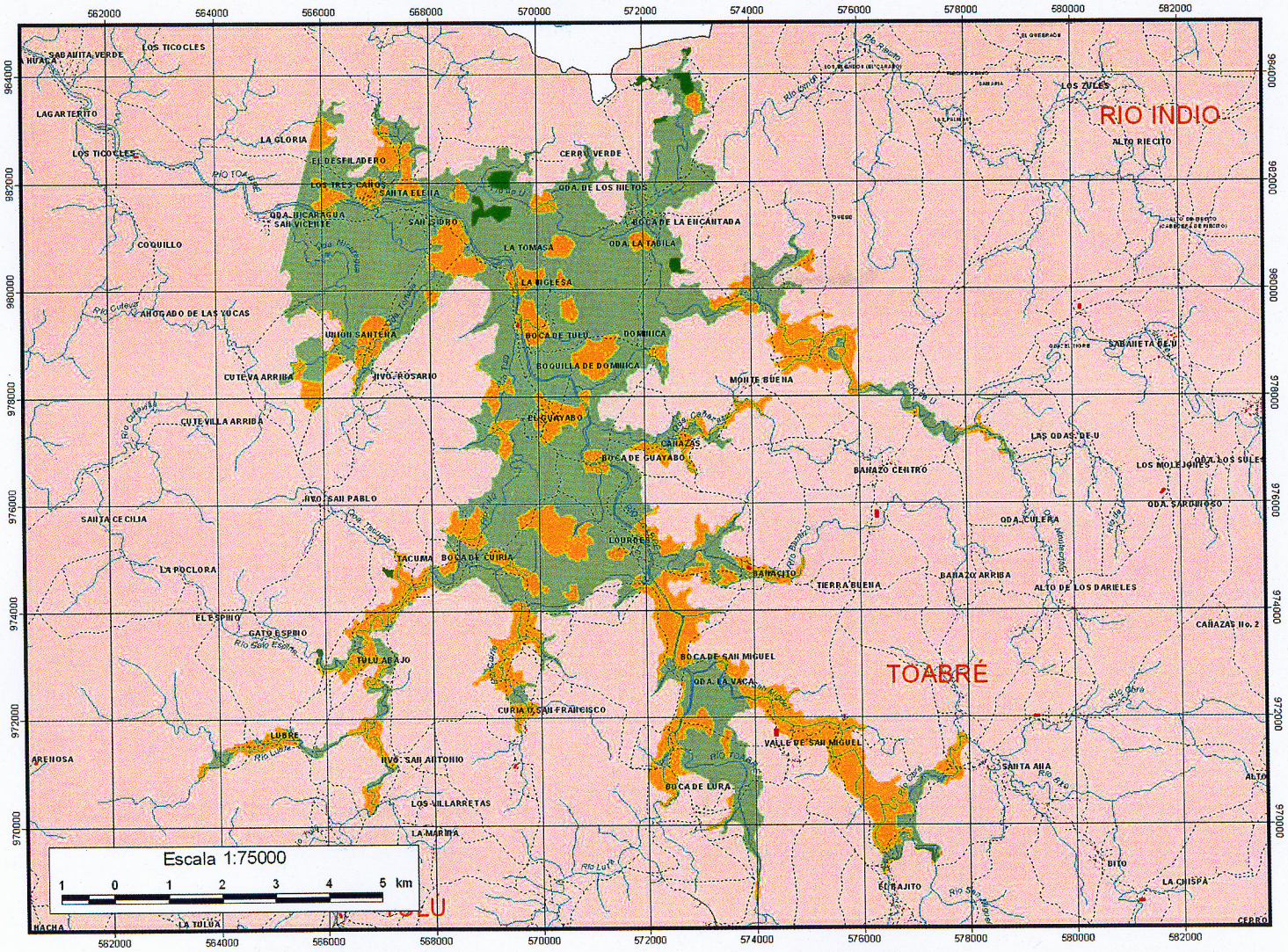
Bosque perennifolio ombrófilo tropical submontano

Pastizal

Rastrojo

Habitat	Hectáreas
Bosque perennifolio ombrófilo tropical de tierras bajas	141.485
Pastizal	1954.800
Rastrojo	4600.958

Proyecto Río Toabré
Habitat
San Vicente Elevación 105



División de Administración Ambiental

Sección de Manejo de Cuenca

Unidad de Sensores Remotos

ACP

Leyenda

Poblados

Red Vial

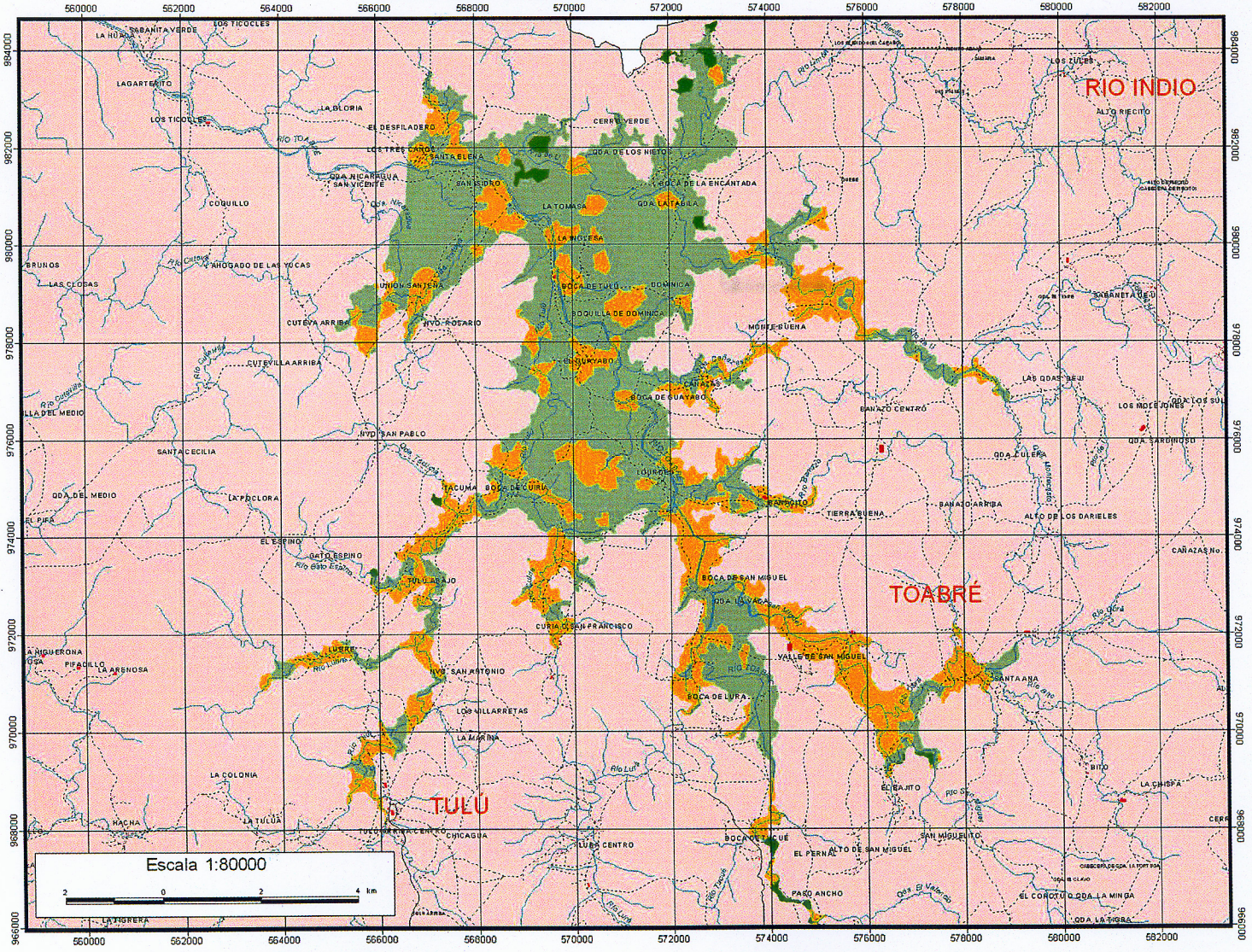
- Carreteras Principales
- Carreteras Secundarias
- Caminos

Ríos

- Bosque Nuboso
- Bosque perennifolio ombrófilo tropical de tierras bajas
- Bosque perennifolio ombrófilo tropical montano
- Bosque perennifolio ombrófilo tropical submontano
- Pastizal
- Rastrojo

Habitat	Hectáreas
Bosque perennifolio ombrófilo tropical de tierras bajas	60.416
Pastizal	1891.746
Rastrojo	4043.481

Proyecto Río Toabré
Habitat
Santa Elena Elevación 110



División de Administración Ambiental

Sección de Manejo de Cuenca

Unidad de Sensores Remotos

ACP

Leyenda

Poblados

Red Vial

Carreteras Principales

Carreteras Secundarias

Caminos

Rios

Bosque Nuboso

Bosque perennifolio ombrófilo tropical de tierras bajas

Bosque perennifolio ombrófilo tropical montano

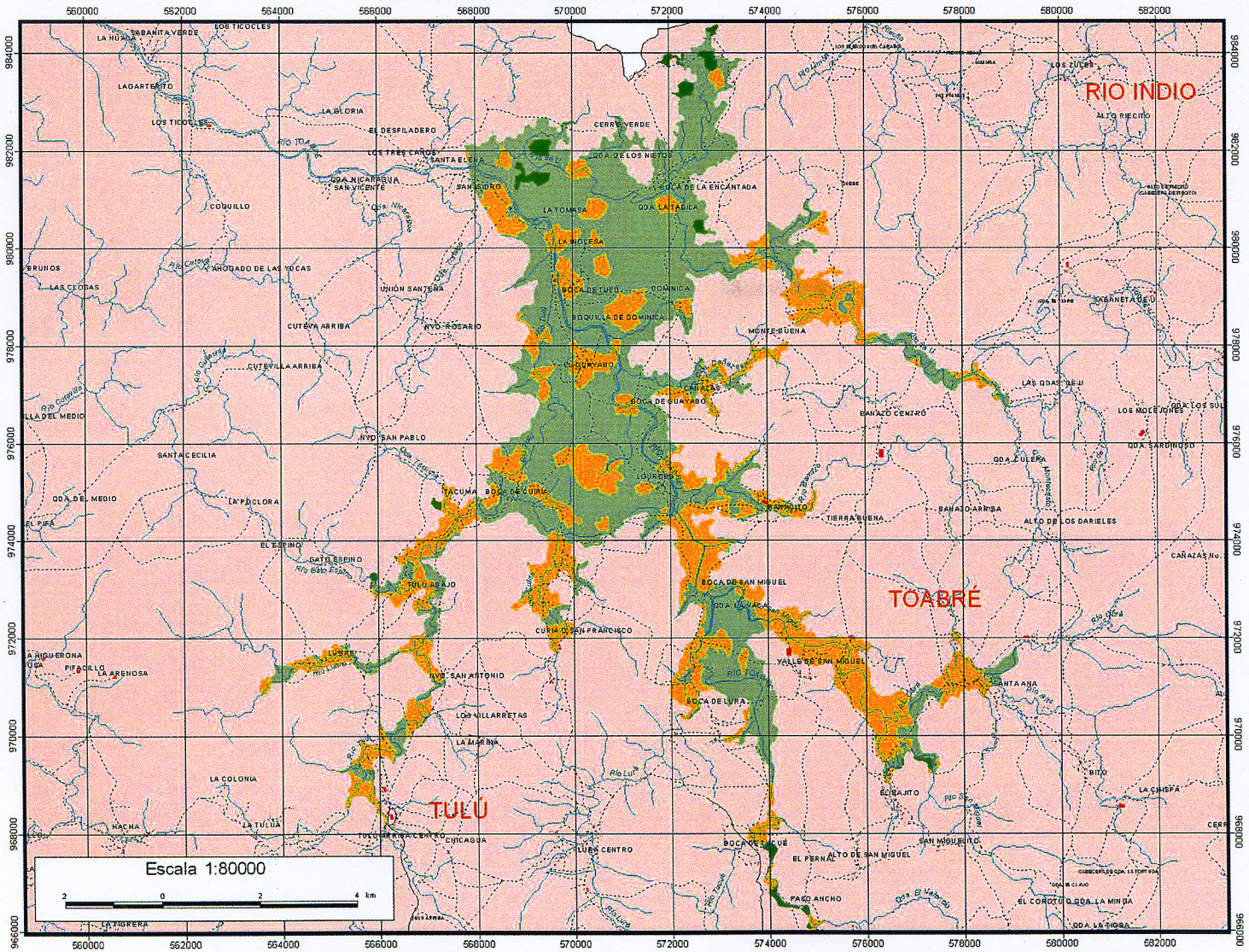
Bosque perennifolio ombrófilo tropical submontano

Pastizal

Rastrojo

Habitat	Hectareas
Bosque perennifolio ombrófilo tropical de tierras bajas	92.780
Pastizal	2159.217
Rastrojo	4004.211

Proyecto Río Toabré
Habitat
San Isidro Elevación 110



División de Administración Ambiental

Sección de Manejo de Cuenca

Unidad de Sensores Remotos

ACP

Leyenda

Poblados

Red Vial

Carreteras Principales

Carreteras Secundarias

Caminos

Ríos

Bosque Nuboso

Bosque perennifolio ombrófilo tropical de tierras bajas

Bosque perennifolio ombrófilo tropical montano

Bosque perennifolio ombrófilo tropical submontano

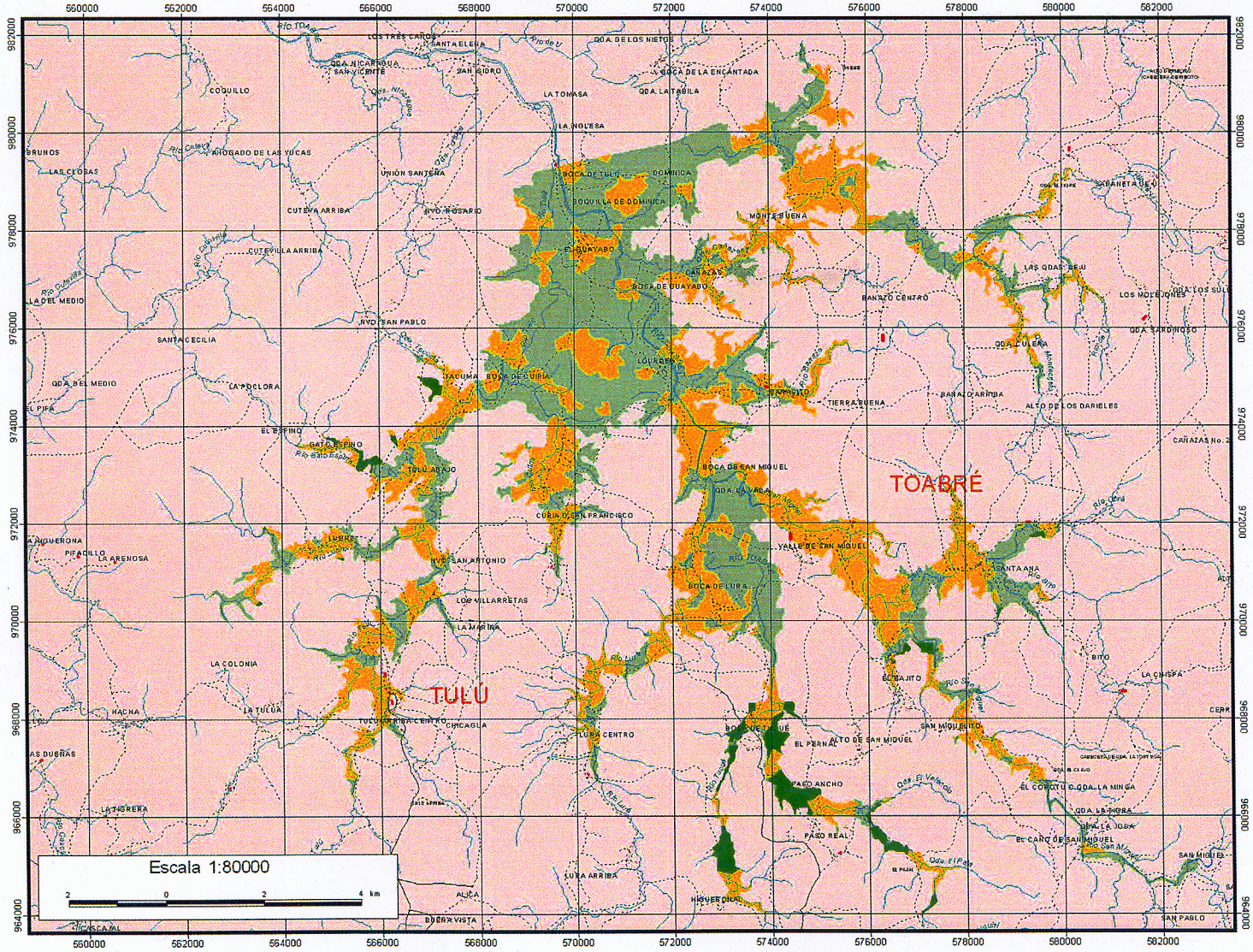
Pastizal

Rastrojo

Habitat	Hectáreas
Bosque perennifolio ombrófilo tropical de tierras	92.780
Pastizal	1971.032
Rastrojo	3458.015

boca_tulu120_habitat.jpg (3850x2200x16M jpeg)

Proyecto Río Toabré
Habitat
Boca de Tulú Elevación 120



División de Administración Ambiental

Sección de Manejo de Cuenca

Unidad de Sensores Remotos

ACP

Leyenda

Poblados

Red Vial

Carreteras Principales

Carreteras Secundarias

Caminos

Ríos

Bosque Nuboso

Bosque perennifolio ombrófilo tropical de tierras bajas

Bosque perennifolio ombrófilo tropical montano

Bosque perennifolio ombrófilo tropical submontano

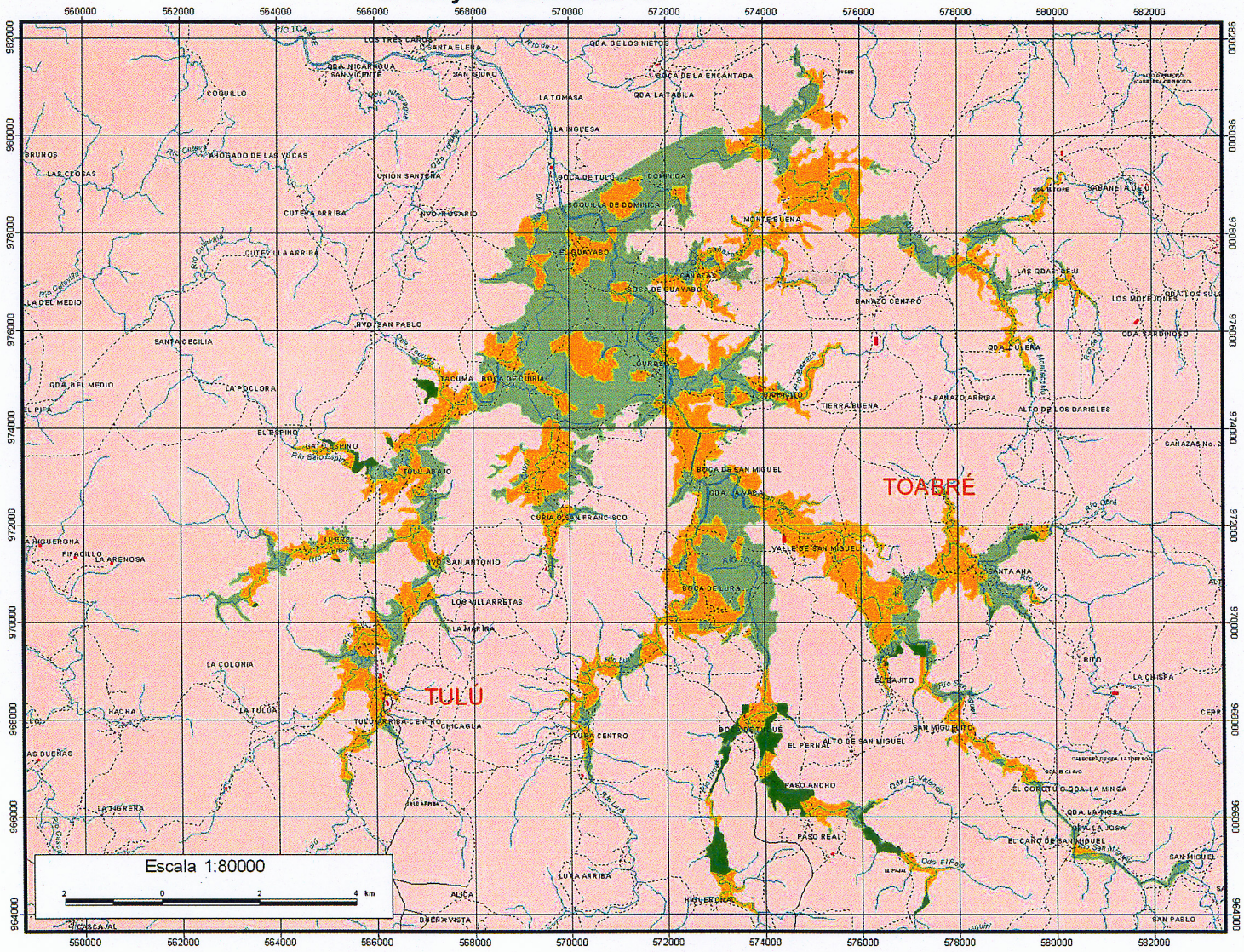
Pastizal

Rastrojo

Habitat	Hectáreas
Bosque perennifolio ombrófilo tropical de tierras bajas	189.091
Pastizal	2976.032
Rastrojo	3159.264

guayabo_120_habitat.jpg (3850x2200x16M jpeg)

Proyecto Río Toabré
Habitat
El Guayabo Elevación 120



División de Administración Ambiental
Sección de Manejo de Cuenca
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Poblados

Red Vial
- Carreteras Principales
- Carreteras Secundarias
- Caminos

Ríos

- Bosque Nuboso
- Bosque perennifolio ombrófilo tropical de tierras bajas
- Bosque perennifolio ombrófilo tropical montano
- Bosque perennifolio ombrófilo tropical submontano
- Pastizal
- Rastrojo

Habitat	Hectáreas
Bosque perennifolio ombrófilo tropical de tierras	189.091
Pastizal	2950.532
Rastrojo	3014.869

ACP
AUTORIDAD DEL CANAL DE PANAMÁ

RIO TOABRE WATER TRANSFER PROJECT

Feasibility Study

FEASIBILITY REPORT

VOLUME IIB - TECHNICAL REPORT
FEASIBILITY STUDY

COYNE ET BELLIER
Bureau d'Ingénieurs Conseils
PARIS - FRANCE

Ref 10932 RP 06 - June 2003

RIO TOABRE WATER TRANSFER PROJECT

Feasibility Study

FEASIBILITY REPORT

VOLUME II B

TECHNICAL REPORT - FEASIBILITY STUDY

Report n° 10932 RP 06

C	June 2003	Final edition	JMV	JCO	JCO
B	May 2003	Pre-final edition	JMV	JCO	JCO
A	March 2003	First emission	JMV	JCO	JCO
Revision	**Date**	**Revision object**	**Redaction**	**Control**	**Approbation**

{INCORPORER Unknown}

COYNE ET BELLIER
Bureau d'Ingénieurs Conseils

PART I – SYNOPSIS OF PROJECT

PART I – SYNOPSIS OF PROJECT

1. SUMMARY

The Feasibility Study of the Rio Toabre Water Transfer Project has been initially launched to determine the technical-economical optimum for the development of the Project as part of a general Panama Canal Infrastructures Development. The present lack of possibilities to estimate 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 text of the present report focus on the basic alternative at NWL 95 masl, but presents also the specific characteristics of each of the two others lower and higher project alternatives.

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 x 10^6 m^3 to 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 Toabre Water Transfer Project are summarised 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/m3)	**0.347**	**0.325**	**0.330**

2. 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	m3/s	41		
Peak flow of 25-y flood (construction)	m3/s	2 000		
Peak flow of 1 000-y flood (design)	m3/s	4 100		
Peak flow of PMF	m3/s	9 500		
• Reservoir				
Catchment area	km²	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	km²	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	m3/s	2 400	2 200	2 000
Maximum discharge for PMF	m3/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	m3/s	2 000		
Upstream cofferdam crest elevation	masl	36		
Downstream cofferdam crest elevation	masl	31		
Cofferdams fill volume	m3	120 000		

Normal Water Level	**masl**	**90**	**95**	**100**
• Minimum Release Facility				
Type		steel pipe located in diversion temporary opening		
Maximum Capacity at NWL	m3/s	7		
Minimum Capacity at MOL	m3/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	m3/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	m3/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)	m3/s	40		
Maximum capacity	m3/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	m	NO	NO	YES 5
Left bank saddle dam		NO	NO	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

3. PROJECT CONSTRUCTION COST (MUSD – 2003)

Normal Water Level	**90**	**95**	**100**
• *Dam & Appurtenant Civil Works*	132	146	162
• *Toabre / Indio Tunnel Civil Works*	103	103	103
• *Access Road / Owner's Camp*	10.3	10.3	10.3
• *Environmental and Social Costs*	19	27	31
Cost of Works (MUSD)	264.3	286.3	306.3
• *Contingencies*	50.4	53.9	57.5
Direct Cost (MUSD)	314.7	340.2	363.8
• *Engineering / Administration*	47.3	51.2	54.7
Construction Cost (MUSD – 2003)	362	391.4	418.5

PART II - STUDIES

PART II - STUDIES

1. GENERAL CONTEXT OF THE STUDY

The Panama Canal Authority (ACP) is undertaking a Canal Capacity Study to evaluate the feasibility of upgrading current Canal infrastructures by means of the following works:

- additional sources of water supply, storage, and hydropower generation,
- incorporating modern lock technology and water-saving methods to existing facilities,
- alternate systems for raising and lowering vessels,
- making channel improvements,
- constructing new locks and providing support facilities with the purpose of designing a long-range master plan to augment Canal capacity and capability.

The studies are geared to meet future traffic demand and customer needs by continuing to provide reliable, efficient, and competitive service for the next fifty years and beyond.

The **Rio Toabre Water Transfer Project** falls within this Canal infrastructures development with the purpose to increase sources of water supply for meeting the Post Panamax locks operation and the growing municipal and industrial water uses of the Metropolitan Area.

2. BACKGROUND TO DEVELOPMENT STUDIES ON THE TOABRE RIVER

The transit of ships through the Panama Canal is dependent upon the availability of the fresh water stored in Madden and Gatun reservoirs. This stored supply comes from the rain that falls in the watershed and is captured by the two reservoirs. Water availability at the Panama Canal is limited and, even at present traffic levels, is not sufficient to meet traffic demand during prolonged dry periods.

As water demand continues to increase for Canal operations and for municipal and industrial use, it becomes more evident that the existing water supplies will be insufficient to offer the level of reliability required to provide efficient and competitive Canal service in the future.

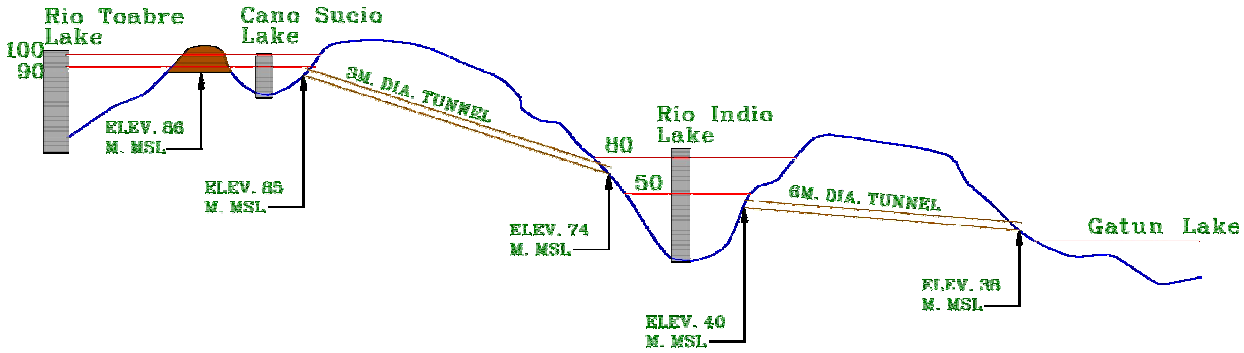
Accordingly, water resources must be managed more efficiently and additional sources of water supply must be developed to meet the growing requirements for municipal and industrial use and for Canal operations. Therefore, new sources of water supply must be

identified, defined, and evaluated to ensure that there will be additional water flowing into the existing watershed system to efficiently meet long-term overall increased demand.

Three projects have been identified in the initial screening phase of the Canal Capacity Studies performed by the Panama Canal Commission as having significant potential to augment the existing water supply to the Panama Canal: **Rio Indio**, **Rio Cocle del Norte** and **Rio Toabre** projects.

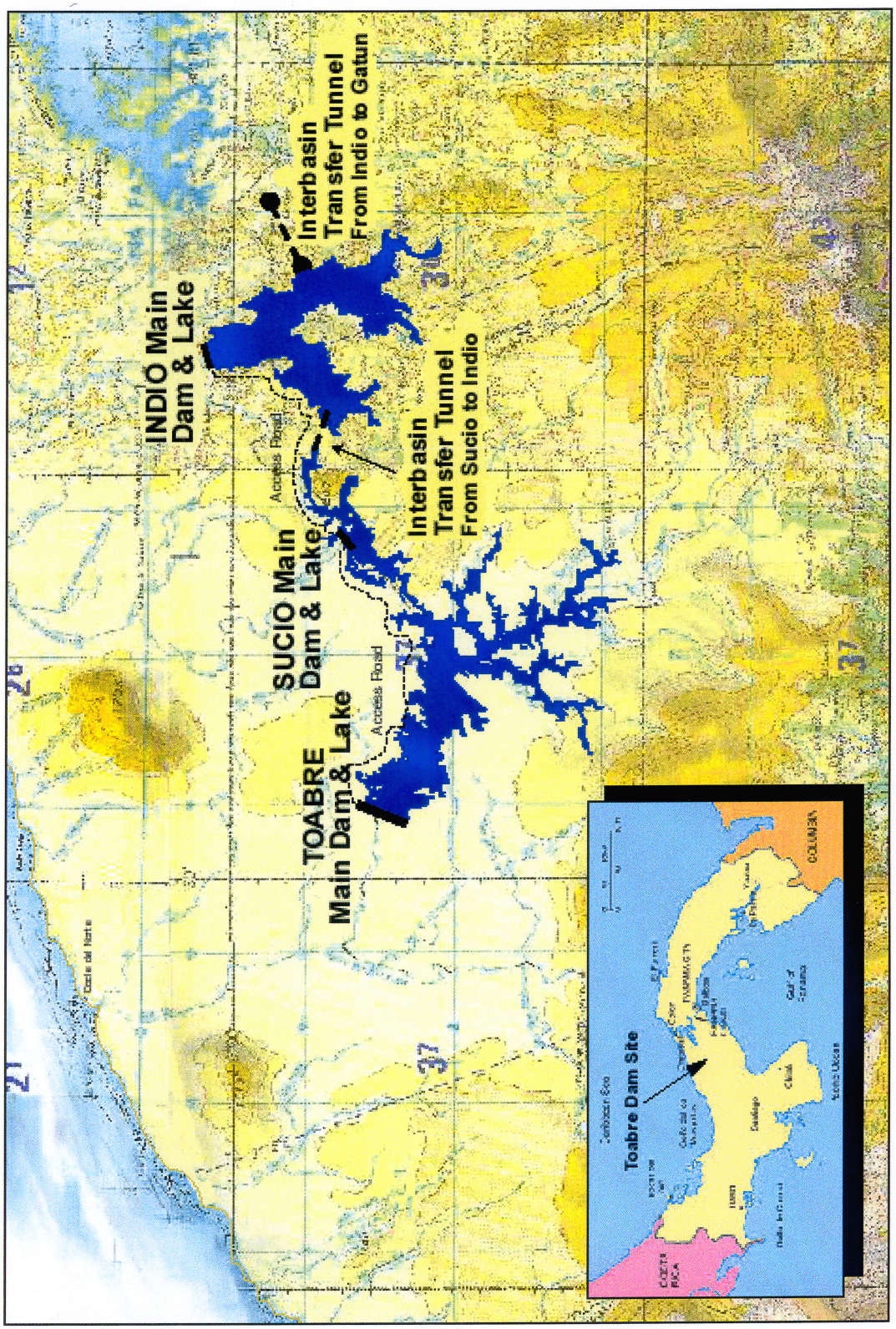
A Reconnaissance Study of these projects was accomplished in 1999 by the US Army Corps of Engineers (1). The Rio Toabre project included a reservoir dam on the Rio Toabre and a reservoir dam on the nearby Rio Cano Sucio, connected by an open channel. With operating levels between El. 100 masl (Normal Water Level) and El. 90 masl, the Toabre / Cano Sucio water was transferred from the Cano Sucio reservoir to the Rio Indio reservoir (operated between El. 80 and El. 50 masl) by means of a tunnel connecting the two reservoirs.

The following sketch and **Figure 1** present the **USACE Design of the Toabre / Cano Sucio Project** operated in conjunction with Indio Lake (1999) :



(1) *Ref : Reconnaissance Study – US Army Corps of Engineers - Dec. 1999*
Section 4: General description of engineering, economic, and environmental investigations methodologies
Section 5 : Rio Indio
Section 9 : Rio Toabre and Rio Cano Sucio.

FIGURE 1 - Rio Toabre / Cano Sucio Project
General Layout – USACE – 1999



With the construction of the proposed Toabre / Cano Sucio and Indio projects the current hydrologic reliability (99.6%) of the Panama Canal could be continued as demand increases up to 60% above current levels.

The structures for the Toabre / Cano Sucio project, with an estimated total cost of 400 millions USD, consisted of:

	Rio Toabre	Rio Cano Sucio
RESERVOIR		
Normal Water Level	100 masl	
Minimum Operating Level	90 masl	
Storage capacity (together)	468 MCM	
DAM		
type	rockfill dam with central clay core	
crest elevation	105 masl	105 masl
maximum height	90 m	20 m
length	1 130 m	185 m
SPILLWAY		
type	ungated concrete spillway	ungated concrete spillway
length	219 m	74 m
maximum discharge	3 400 m^3/s	1 140 m^3/s
TRANSFER TUNNEL		Cano Sucio to Indio
capacity		27.8 m^3/s
diameter		3 m
length		2 km
HYDROPOWER PLANTS		
location	toe of the dam	outlet of transfer tunnel
installed capacity	2 x 11 MW = 22 MW	1 x 6 MW

In addition a transmission line was required to carry the energy from the dam site to the Rio Indio powerhouse and substation and then to a connection on the existing power grid near La Chorrera.

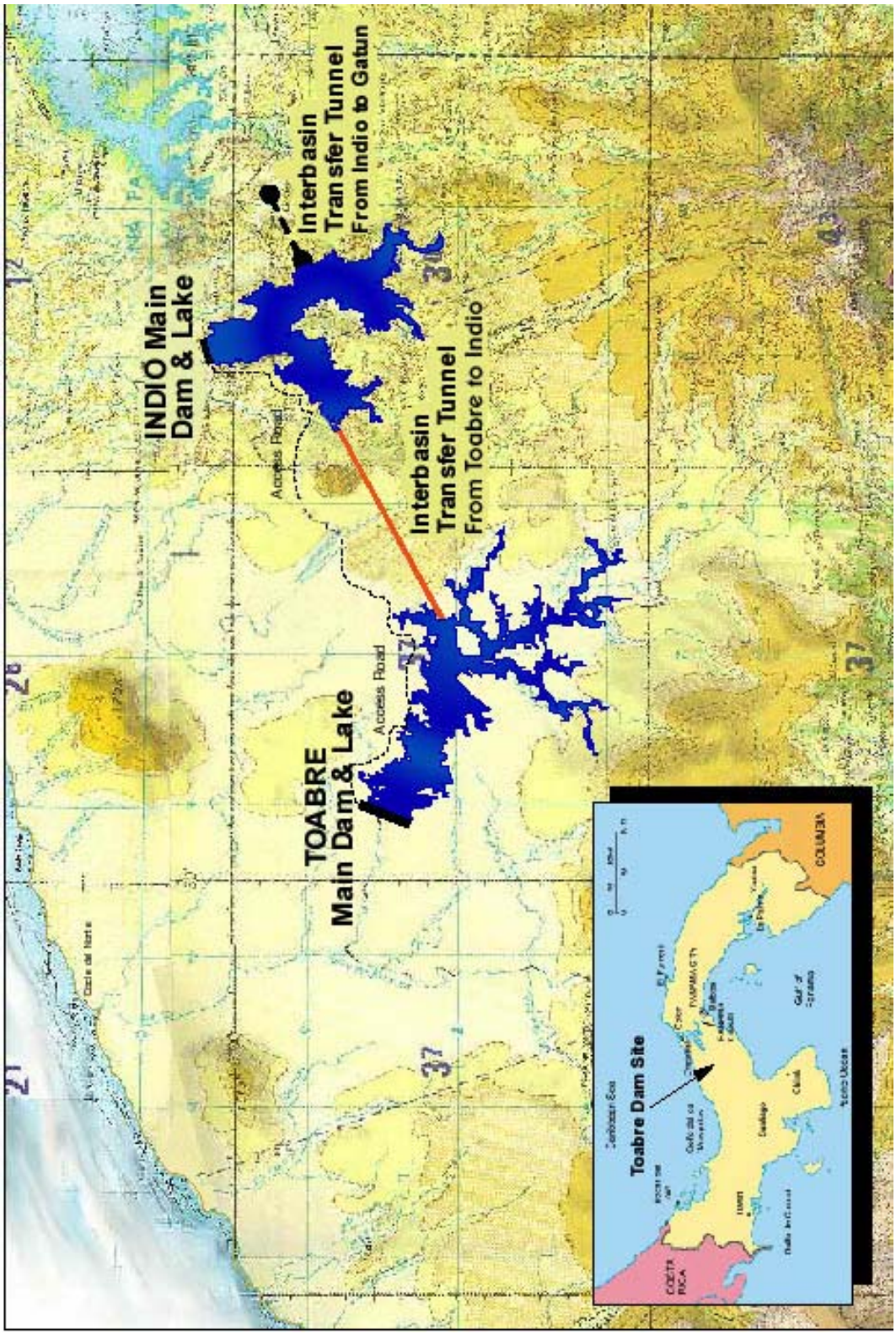
Access to the lake area and the various construction sites required new or upgraded access roads and bridges and/or culverts at streams.

3. THE BACKGROUND AND OBJECTIVES OF CURRENT STUDY

Under a contract signed February 2002, the Canal Authority of Panama (ACP), assigned the firm Coyne et Bellier (COB) to carry out the engineering feasibility studies for the Rio Toabre water project as proposed by the Division of Canal Capacity Projects (IPC), but modified from the plan previously studied under the Reconnaissance Study :

Indeed the current preferred plan, not yet studied in detail, is to transfer directly water from the Toabre Lake to the Indio Lake through an approximately 18 km long inter-basin transfer tunnel connecting the two reservoirs (see **Figure 2**).

FIGURE 2 - Rio Toabre Project
General Layout for Feasibility Study - 2002



The Rio Toabre project would then function in conjunction with the Rio Indio project to transfer water into Gatun Lake. The Rio Indio project is studied in parallel at feasibility stage by the US firm MWH-TAMS and is not part of this contract.

HEC-5 simulations performed in 2001 by ACP [2] show that Toabre reservoir [3], (including the Caño Sucion reservoir) operating between El. 100 and El. 60, in conjunction with Indio reservoir (operating between El. 80 and El. 50) and the Lake Gatun deepening [4] will guarantee the current 99.6% reliability of the Canal System as demand increases up to 104% above current levels.

Engineering studies and analyses will be prepared to the feasibility design level of detail to provide a design which defines the physical size of the project features and elements in sufficient detail to develop an adequate basis for the project construction schedule and a baseline cost estimate and then to assess the viability of the project in terms of technical, economical, scheduling, environmental [5] and financing considerations.

In the event that this project is considered feasible**,** these engineering feasibility design studies shall establish the foundation for future detailed engineering design for construction.

4. SCOPE OF THE FEASIBILITY STUDY

The Scope of the Services of the initial Feasibility Study have been modified during the study. The final Feasibility Study comprises four main tasks:

- **Site Identification and Selection Study**, presented in the Volume II.A,
- **Basic Data Collection** covering the following items:
  - previous studies
  - topography
  - geology / seismic hazard
  - hydrology
  - river hydraulics
- **Water Management & Power Study**, to be performed with the HEC-5 model developed by ACP for the previous studies,

---

(2) simulation models reviewed in June 2001 by R.J. Hayes. Ref: Review and Recommendations of HEC-5 modeling of Water Supply alternatives to the Panama Canal – June 2001

(3) Simulation models with 6 mts diameter transfer tunnel from Toabré to Indio and from Indio to Gatun

(4) deepening of the navigation channel which allows Lake Gatun to provide full navigation service down to a lake elevation of 78.5 ft (in place of the current lower limit of 81.5 ft)

(5) the environmental evaluation is being accomplished by ACP who will furnish all the necessary informations.

- **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,

The previously required **Economical Studies** have been cancelled by ACP during the development of the Feasibility Study, due to the lack of benefits estimation.

5. ANNUAL COST

The annual operating costs include the costs of Operation and Maintenance for the various features, administration by the Owner and insurance.

The Operation and Maintenance for the dam and water transfer tunnel was estimated, according to practice, as 0,4% of the Operation and Maintenance Cost.

Administration and general annual expenses of the Owner were estimated at 25% of Operation and Maintenance annual costs.

The annual cost of insurance was estimated as 0,1% of the construction cost.

The annual Operation and Maintenance Costs are summarized as below:

Item	Annual Cost
Operation and Maintenance	1 560 000
Administration and General Expenses	390 000
Insurance	390 000
Annual Cost (USD)	2 340 000

PART III - TOPOGRAPHY

PART III - TOPOGRAPHY

1. LOCATION AND DESCRIPTION OF THE DAM SITE

The ACP's selected dam site is located 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, in the central part of the country.

The site is located in the vicinity of the village of San Vicente, at approximate geographical co-ordinates 8°53'°N and 80°25'°W (981 500 N – 565 500 W), i.e. about 100 km West, as the crow flies, of Panama City.

At the moment, direct access by vehicles is not yet possible; the site is directly accessed only by helicopter. An alternative terrestrial route consists to reach the village of San Miguel by 4x4 vehicle via Toabre and Tambo villages, some 20 km upstream the dam site, at the upstream extremity of the future reservoir. And then to descend the river by boat or to follow footpaths with horses.

The project location is shown on **Figure 1 and Drawing 10-300**.

At the Toabre site the valley narrows, the river bed being about 50 m wide. In the period of low flow, the river level is close to El. 20 masl.

The valley is particularly asymmetric with a relatively regular steep right bank while the left bank is much flatter. Particularly, the left bank presents a 350 m wide area between El. 25 and El. 40 masl with succession of hills and deep gullies with streams.

The top of both banks presents large plateau at El. 110-120 masl approximately which constitutes the topographical limit of the site, with saddles at El. 105 masl on both banks. The valley is about 600 m wide at El. 50, 1 100 m wide at El. 100 and 1 600 m at El. 120.

2. TOPOGRAPHY

The following topographical maps and drawings are available:

- 1:50 000 scale maps drawn up by Instituto Geografico Nacional from 1965 to 1999 with 20 m contour lines. **Figure 2** presents the key plan of these maps:

  the dam site is on the map n°4142 IV (Cerro Miguel); the tunnel layout is shown on maps n°4142 IV and I (Las Marias); the reservoir area is completely shown on the two map n°4142 IV and III (Tulu). **Figure 3** presents a montage of these two maps showing the whole reservoir area.

  from the digital format of these maps a 1/200 000 drawing (A3 format) of the reservoir and project area is presented on **Drawing 10-101**. **Drawing 10-102** shows a 1/50 000 representation of the project area.

- map of the Toabre dam site ground survey done in 2002 with 1 m contour lines, with some extension by photogrametry on the left bank, shown on **Drawing 10-103**.

- a additional map of the saddle area of the left bank issue from a specific ground survey, also shown on **Drawing 10-103**.

- map of 3 ha of the tunnel inlet area (**Drawing 10-104**).

- 10 topographical cross sections of the Rio Toabre in the vicinity of the dam site, shown on **Drawing 10-105**.

- 1/20 000 aerial photo (2000) covering the Toabre reservoir area. The dam site is on pictures P26-22/23, the tunnel inlet on picture P26-26 and the tunnel outlet on pictures P24-16/17.

- *three maps issued from recent photorestitution works (February 2003) with 1 m contour lines, shown on **Drawings 10-107 to 10-109** : dam site area, tunnel inlet and outlet areas;*

  these maps provided by ACP at the end of the present feasibility study have been only partially considered for this study (see § 4).

Figure 4 presents the comparison between the 1/50 000 map and the recent ground survey of the dam site area. This exercise reveals acceptable differences, some differences being more noticeable locally on the right bank, probably due to the steep slope and the vegetation cover. The accuracy of the 1/50 000 is estimated to 5 m minimum, which is a usual value for this kind of maps.

Drawing 10-106 presents a synthetic 1 / 10 000 map of the project area issued from the topographical survey and the 1 / 50 000 map, and recently locally completed (upstream left bank) at the end of the feasibility study with the photorestitution map (2003) of the dam site area.

3. RESERVOIR AREA

The available documents show the following topographical limits of the Toabre reservoir:

. saddle at El. 100 masl approximately 8 km East from the dam site, in the Quebrada la Encantada valley, with connexion with the Cano Sucio basin (rio Limon),

. saddle at El. 104 masl, 1 km from the top of the Left Bank,

. saddle at El. 108 masl at the top of the Right Bank.

The Height / Surface / Volume (H/S/V) relationship for the Toabre reservoir is based on measurement of surface areas delimited with the contours of the available 1/50 000 topographic maps (1). A polynomial adjustment has been set to establish the relation S = f(Z) and then V = g(Z) by integration of this adjustment.

The H/S/V curves of the Toabre reservoir is presented on the following table and **Figure 5**:

Elevation Z masl	Surface planimetred km²	Surface polynomial adjustment km²	Volume polynomial integration hm3
20	0.3	0.2	1
30		0.9	5
40	2.6	2.7	28
45		4.0	44
50		5.7	68
55		7.8	102
60	10.2	10.7	148
65		13.1	207
70		15.9	280
75		19.2	367
80	22.7	22.4	472
85		26.8	594
90		32.2	741
95		38.8	918
100	45.7	46.4	1 131
105		*55.0*	*1 384*
110		*64.7*	*1 682*
115		*75.5*	*2 032*
120	*87.3 (1)*	*87.3*	*2 439*

(1) the surface area at El. 120 has been determined with theoretical closure at identified saddles.

4. FURTHER INFORMATION

During the development of the present feasibility study, ACP has contracted works to get 1/20 000 maps (by photogrametry) of the project areas. The recommended areas specified by Coyne et Bellier for this restitution were :

- ***Dam site area*** (**Figure 6**): 10 km² around the recent topographic map of the dam area; this will allow a better definition of the limits of the reservoir in both banks (saddles), the condition of restitution of the flows downstream, the location of the camp and the installations, the access…

- ***Tunnel Inlet area*** (**Figure 6**) : 5 km² ; to optimise the location of the tunnel inlet and precise the limits of the Rio Toabre Reservoir close to the Cano Sucio Reservoir (saddles).

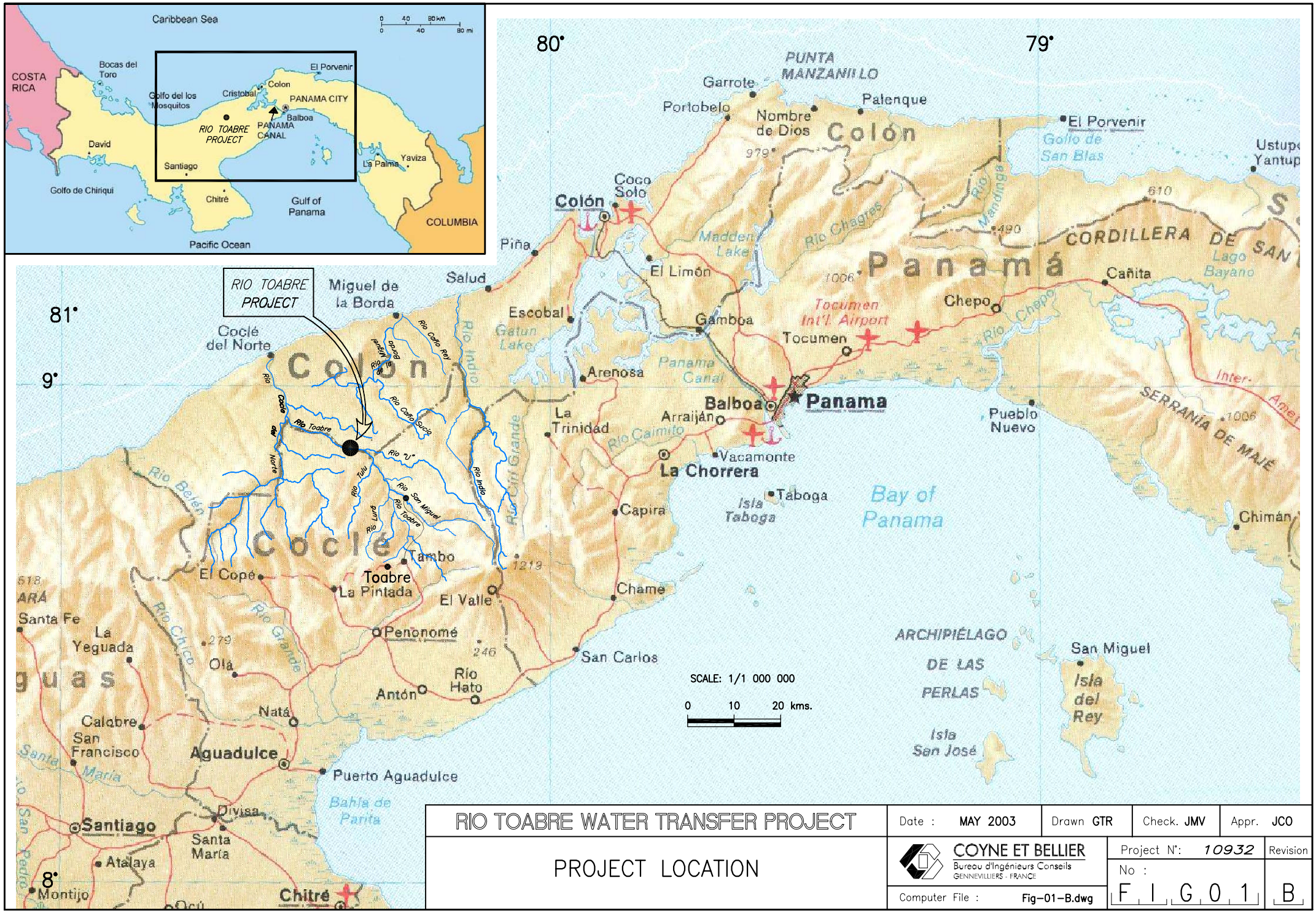
- ***Tunnel Outlet area*** (**Figure 7**) : 2 km² ; to optimise the location of the tunnel outlet.

These maps have been available only at the end of the Feasibility Study, on February 2003, and have been consequently only partially used for the present study (tunnel structures). They should be considered more specifically for the next phase of the study and are only listed and shown in the present report (Drawings 10-107 to 10-109) with the following preliminary comments:

. a simple comparison of these maps with the previous 1/50 000 maps doesn't reveal significant differences which may change any results or design currently based on these less accurate maps;

. a rough comparison of the surface areas delimited with the contours lines El. 80 and El. 100 within the common dam site area shows slightly greater values of the reservoir surface (and then capacity) with the 1/50 000 maps, the difference being considered as representative of the accuracy of such maps:

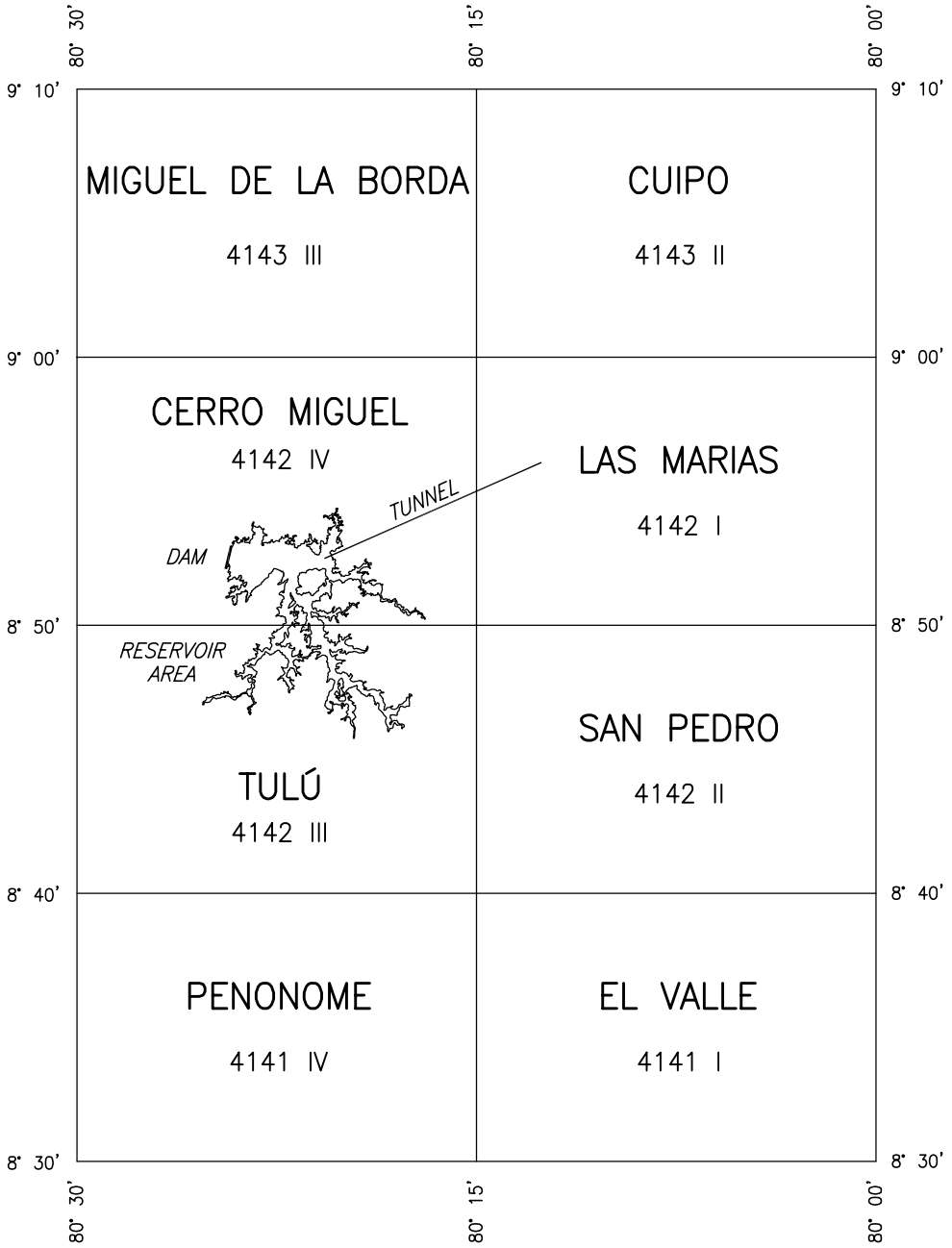
source	photorestitution dam site area	1/50 000 (same area)
Surface at El. 80 (ha)	501.8	540.4 (+ 7.7%)
Surface at El. 100 (ha)	701.1	731.7 (+ 4.3%)
Capacity between El. 80 and 100 (hm3)	120.3	127.2 (+ 5.7%)



RIO TOABRE WATER TRANSFER PROJECT

PROJECT LOCATION

Date : MAY 2003	Drawn GTR	Check. JMV	Appr. JCO
COYNE ET BELLIER Bureau d'Ingénieurs Conseils GENNEVILLIERS - FRANCE	Project N°: 10932	Revision
Computer File : Fig-01-B.dwg	No : F I G 0 1	B



RIO TOABRE WATER TRANSFER PROJECT	Date : MAY 2002	Drawn GTR	Check. JMV	Appr. JCO
1/50 000 MAPS KEY PLAN	COYNE ET BELLIER Bureau d'Ingénieurs Conseils GENNEVILLIERS - FRANCE	Project N°: 10932		Revision
	Computer File : Fig-02-B.dwg	No : F I G 0 2		B

RIO TOABRE WATER TRANSFER PROJECT

1/50 000 MAPS

EXTRACT OF MAPS N° 4142 IV & III

Date : MAY 2003	Drawn GTR	Check. JMV	Appr. JCO

COYNE ET BELLIER
Bureau d'Ingénieurs Conseils
GENNEVILLIERS - FRANCE

Computer File : Fig-03-B.dwg

Project N°: 10932 | Revision

No : FIG03 | B

ACP DAM AXIS

PROVINCIA DE COCLÉ

NOTE

CONTOUR LINE FROM DAM SITE TOPO SURVEY (2002)

CONTOUR LINE FROM 1/50 000 MAP

N

565000

566000

981000

982000

ACP DAM AXIS

RIO TOABRE

0 25.00 100.00 200.00 m

RIO TOABRE WATER TRANSFER PROJECT

TOPOGRAPHIC COMPARISON

1/50 000–MAP/TOPOGRAPHY SURVEY (2002)

Date : MAY 2002 | Des. GTR | Contr. JMV | Appr. JCO

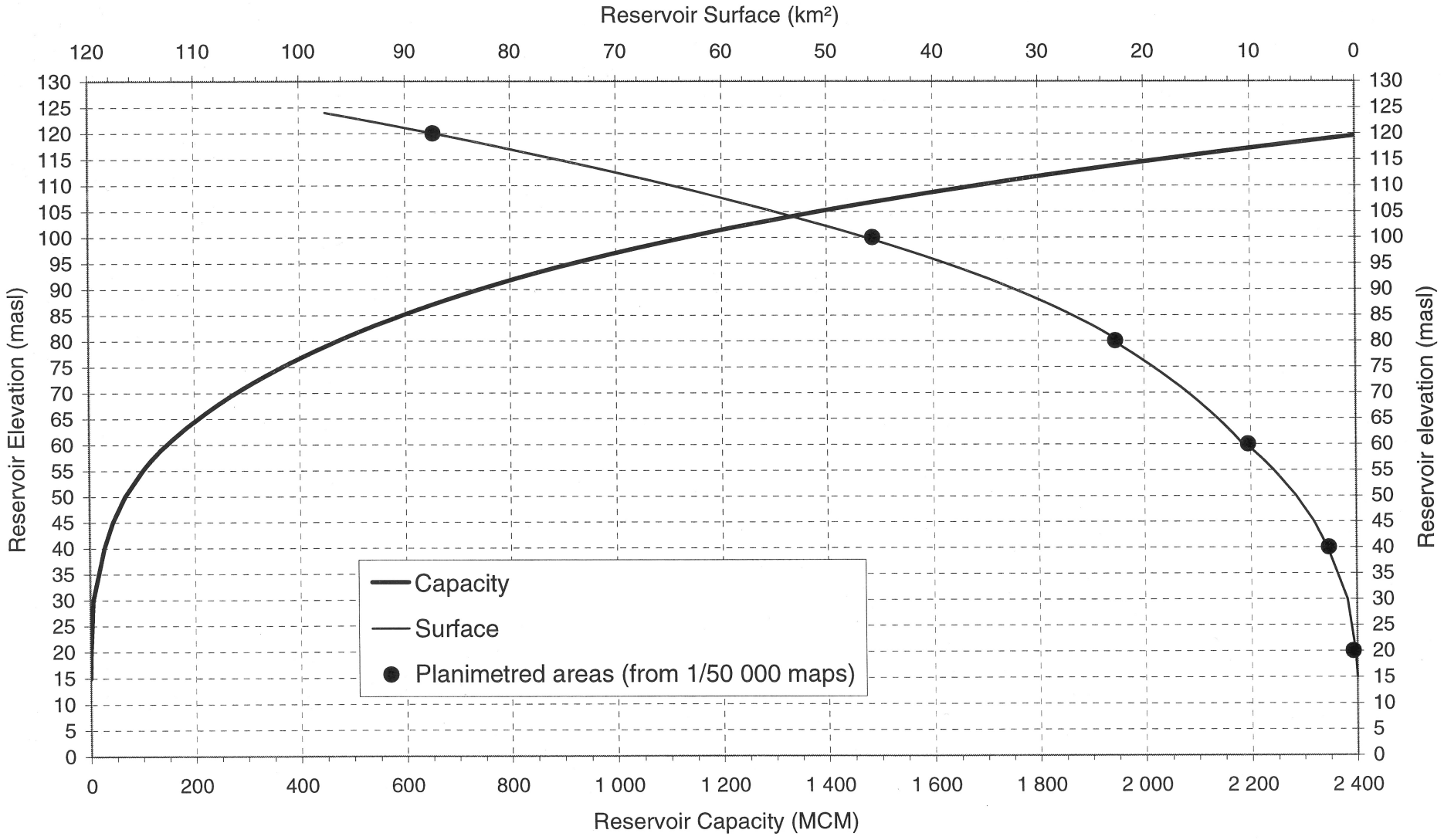
COYNE ET BELLIER
Bureau d'Ingénieurs Conseils
GENNEVILLIERS - FRANCE

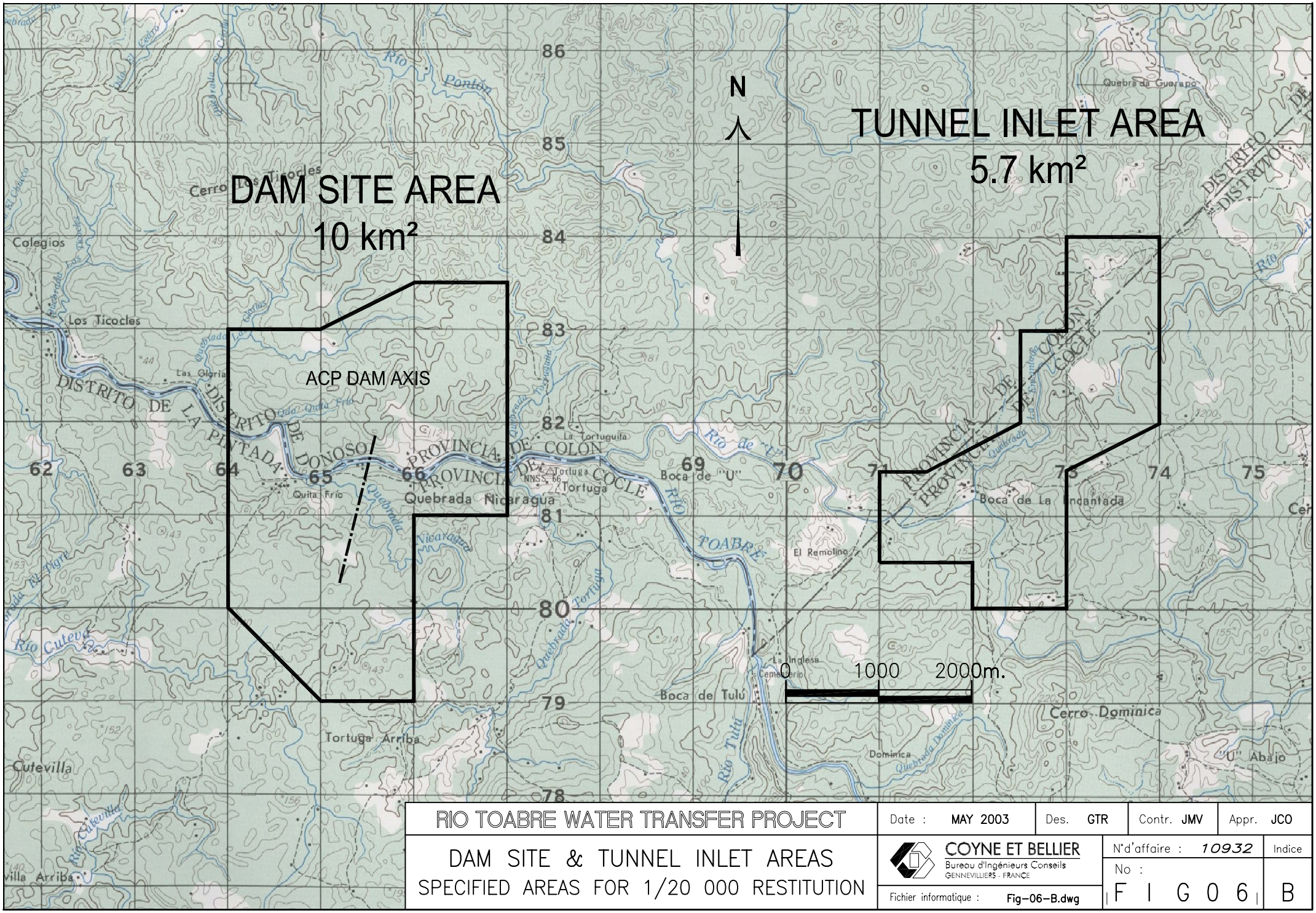
N°d'affaire : 10932 | Indice

No : F I G 0 4 | B

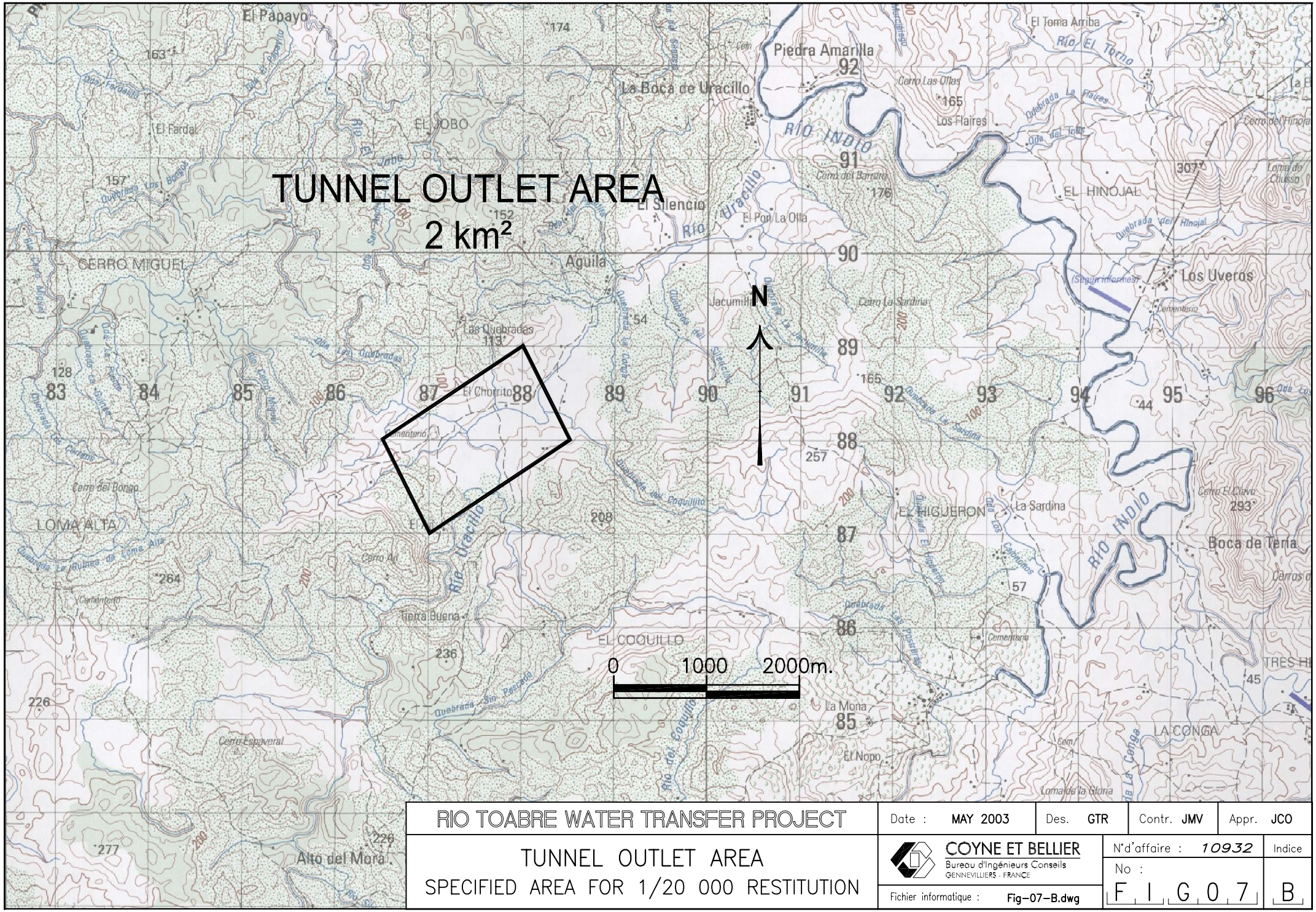
Fichier informatique : Fig-04-B.dwg

FIGURE 5 - RIO TOABRE RESERVOIR ELEVATION / SURFACE / CAPACITY CURVES





RIO TOABRE WATER TRANSFER PROJECT	Date : MAY 2003	Des. GTR	Contr. JMV	Appr. JCO
DAM SITE & TUNNEL INLET AREAS SPECIFIED AREAS FOR 1/20 000 RESTITUTION	COYNE ET BELLIER Bureau d'Ingénieurs Conseils GENNEVILLIERS - FRANCE	N°d'affaire : 10932	Indice	
	Fichier informatique : Fig-06-B.dwg	No : FIG06	B	



RIO TOABRE WATER TRANSFER PROJECT

TUNNEL OUTLET AREA

SPECIFIED AREA FOR 1/20 000 RESTITUTION

Date : MAY 2003	Des. GTR	Contr. JMV	Appr. JCO

COYNE ET BELLIER
Bureau d'Ingénieurs Conseils
GENNEVILLIERS - FRANCE

N°d'affaire : 10932 | Indice

No : F I G 0 7 | B

Fichier informatique : Fig-07-B.dwg

PART IV – GEOLOGY

PART IV – GEOLOGY

1. PREAMBLE

1.1. Existing Study Reports

Previously to the present feasibility study stage of the Toabre Dam project, the regional and local analysis of various projects of Inter-Basins Water Transfer towards the eastern Gatun Lake included several steps of initial pre-feasibility studies from which two major reports were issued:

- Reconnaissance Study – US Army Corps of Engineers - Dec. 1999
  - . Section 5 : Rio Indio. [Ref. 1]
  - . Section 9 : Rio Toabre and Rio Cano Sucio. [Ref. 2]

Regional and local geological features presented in these reports did not result from specific investigations or surveys but were chiefly derived from some field visits and observations and from general records and documentation, such as the existing regional geological maps:

- Mapa geologico Republica de Panama, scale 1/250 000, Ministerio de Comercio e Industrios; hojas 3, 4, 5 y 6. [Ref.3]

The three above mentioned references constitute the main documentation that was used for the preparation of the Part III of the present report which presents the regional geology and some local geological features of the Toabre Dam project. Available aerial photographs at 1:20 000 scale were mainly used to retrieve structural features. In addition to these documents, the seismic hazard analysis carried out by the Consultant and presented in Part V of this report significantly reinforces the data basis for the assessment of the regional geological context.

1.2. Reconnaissance Survey for the Feasibility Study Stage

At the present stage of feasibility study, the reconnaissance survey of the project area would have required a minimum of investigation works at the dam site for the assessment of the natural conditions of foundation. Actually, due to adverse reasons of delay time and site accessibility, the Consultant could only perform so far short field visits to the area of the ACP dam axis. As part of a additional 'site selection study' a field visit took place from December 10 to 12, 2002 for the assessment of eleven alternative sites (see Volume II A). These sites are referred to in the present report as location landmarks.

Helicopter survey focused on the overall estimation of the geomorphological setting, inventory of outcrops and of possible structural features, as well as of potential construction materials sources (chiefly potential quarry sites). The conditions of excavation at the portal of the future inlet of the derivation tunnel towards the Rio Indio storage project were also assessed using helicopter survey.

Ground geological observations, starting from helicopter and boat stops, completed the investigations. The outcrops are generally scarce throughout the study area and most of the geological features were retrieved from the observation of the best rock exposures, located in the following areas:

- Site 0, quebrada Nicaragua in the left bank
- Site 0, right abutment
- Site 6, both abutments
- The confluence between Rio Toabre and Rio Tulù, in the central section of site 7
- Site 10, left abutment

In addition, all major outcrops in the Rio Toabre and Rio Tulù riverbeds between site No. 7, upstream, and site No. 10, downstream, were subject to geological observation.

Subsequently to the field visit of April 2002, the Consultant recommended a minimum programme of preliminary investigations, restricted to field mapping, geophysical survey, auger holes excavation, soil sampling and laboratory tests, as the conflictive local social conditions reported by ACP were not appropriate for the implementation of a full, standard reconnaissance program including boreholes, pits, trenches, field tests and adits.

The Field Mission Report, by Coyne et Bellier, April 2002 [Ref. 4] presented the conclusions of this field visit and the definition of the minimum investigations to perform. The main features of this report are included in **Appendix A**.

This minimum programme was launched by the beginning of July 2002 and was completed during October 2002. The actual reconnaissance program consisted of 2730 m of refraction seismic lines and of laboratory testing of soils and rocks collected in the overburden at the dam site and from potential quarries (investigated sources for aggregate and rockfill).

➢ *Recommended borehole campaign*

The particular local social conditions mentioned above have led Coyne et Bellier to design the reconnaissance surveys up to this stage without drilling. In the absence of outcrops in the site area, **boreholes are the only mean to validate the seismic results** and to supply additional information of the subsurface foundation of the dam. **A borehole program has been proposed by Coyne et Bellier in October 2002**.

2. REGIONAL GEOLOGICAL FEATURES

2.1. The Seismo-Tectonic Pattern of Panama

Within the seismo-tectonic frame of Central America, the Panama Block (**Figure 1**) corresponds to a complex zone of interference between most of the regional plates: South America, Central America, Caribbean, Nazca and Cocos. However, the Panama block is considered as a rigid and rather homogeneous block which is predominantly influenced by the active Caribbean plate subduction which shows up along the Northern Panama Deformed Belt (see details in Part V - Seismic Hazard).

This active NE trending corridor of widespread faulting, which is chiefly developed from the Caribbean coast down across Costa Rica has short extension towards south-east, through the western boundary of the Panama Block. This feature was duly confirmed by analysis of satellite imageries which did not reveal any evidence of active faulting and even faults in the western part of the Panama Block in which the Toabre dam site is located.

The Toabre project area is consequently regarded as a zone that is not under the near-field influence of regional seismo-tectonic activity. At the same time, the extension and degree of activity of other findings is assumed to be low, so that the local seismicity is considered as low to moderate.

2.2. Regional Geological Features

The regional geologic map (**Figure 2**, extract from [Ref.3]), over the proposed project area, is the only document available allowing to anticipate the geological context of the selected Rio Toabre dam Project area. Accordingly, the Tertiary Cañazas Formation (labelled as TM-CA), is inferred to prevail in the reservoir area, consisting of andesitic and basaltic lava flows, volcanic breccia and tuffs. It is expected to show a wide range in rock strength from high quality of the extrusive lava flows to the potentially weathered and lesser quality volcanic tuffs.

The volcanic tuffaceous formation is underlain by the Oligocene sedimentary rocks of the Caimito Formation, a bedded marine sequence composed of tuffaceous sandstone, tuffaceous siltstone and limestone, mainly outcropping towards the East but also in the ACP dam axis area. These rocks are generally hard and less altered than the volcanic tuffs but some siltstone horizons appear to be strongly weakened by weathering.

The site selection investigations [Ref 8] allowed refining the distribution of the different geological units in the reservoir area. Considering the outcrops at the riverbed level, three sections can be distinguished in the study area:

- Basalts / basaltic andesites, upstream from site no.6
- Sediments, downstream from Rio Toabre / Rio de "U" confluence
- An intermediate zone, where volcanic and sedimentary rocks are alternatively exposed in small outcrops

The proposed inter-basin transfer tunnel connecting the future Toabre reservoir to the Indio Lake is anticipated to be excavated in both sedimentary Caimito and overlying volcanic Cañazas Formations. The inlet shall be founded in this last one while moderately hard siltstone, fitting the description of strata of the principal member of the Caimito Formation should be encountered along the major part of the tunnel length as inferred from local exposures. These exposures of sedimentary rocks are reported to be located in several waterfalls [Ref.2] in the vicinity of the saddle dam of the Rio Caño Sucio project.

Further development of this project shall require geological mapping and core drilling to determine the general lithological and structural framework along the tunnel alignment. Reconnaissance survey should supply all the data needed for the establishment of a reliable geological cross-section along the proposed tunnel alignment.

3. LOCAL GEOLOGICAL FEATURES OF THE RIO TOABRE DAM PROJECT

3.1. Introduction

Taking into account the local particular social context reported by ACP, the Consultant designed a restricted reconnaissance program, including geological mapping, refraction seismic survey, auger and pit soil sampling and laboratory testing.

This minimum program was launched by the beginning of July 2002 and was completed during October 2002. The available reconnaissance data consisted of:

. Regional 1:250 000-scale geological maps [see Ref. 3]

. Direct observation of scarce outcrops and geomorphological features during the field visit of April 2002 [see Ref. 4]

. An additional field survey carried out to investigate potential sources for aggregate and rockfill [see Ref. 5]

. Refraction seismic survey in the dam site area, consisting of 21, 130 m – long profiles : 8 along the dam axis proposed by ACP and 13 roughly perpendicular on this axis, totalling 2 730 m. See **Drawing 10-201** for location and **Drawings 10-203 and 10-204** for depth models as presented by the Contractor [see Ref. 6].

. Geotechnical and geomechanical tests on soils sampled in the dam area and on rock samples collected at various locations upstream from the dam site (**Figure 3**). 12 hand-driven auger holes (TO-A1 to TO-A12), down to a maximum depth of 4 m and 15 pits (TO-C1 to TO-C15) were dug mainly along the ACP dam axis (see **Drawing 10-206** for location). Laboratory soil testing comprised 26 index tests on samples from TO-A1 to TO-A12, 12 compaction tests on samples from TO-C1 to TO-C4, TO-C7 and TO-C9 to TO-C15 and 2 direct shear tests on undisturbed samples from TO-C5 and TO-C6. In addition, six rock samples from potential quarries were submitted to the point load test [see Ref. 7].

As already mentioned in § 1.2, a recommended borehole campaign, which would be now feasible, has been recently proposed by Coyne et Bellier. **Drawing 10-202** and **Appendix B** present this program, not yet started at this date.

➢ ***Reliability of the seismic data***

Some incongruences motivated the Consultant to ask Bachy-Fundaciones for a revision of the seismic data. The revised version of the report still contains contradictory results, probably owing to the physical limits of the method in the local complex geological context and biased interpretation of the raw data.

Subsequently, the seismic results and, in particular, the depth to the foundation levels of the various dam alternatives can not be accurately defined at this stage.

Provisions should therefore be considered in the design of the dam at this stage. Actual foundation levels shall be more accurately indicated after the full completion and interpretation of the recommended boreholes campaign.

3.2. Geomorphology

From [Ref.2], the dam axis was selected downstream in the Rio Toabre watershed where the valley is narrow and the surrounding hillsides relatively steep and high. The alignment of the axis has been shifted several times and it is not yet definitive. One reason of this change was individual opposition to the project from local inhabitant.

The main geomorphological features, as observed during the field visits and retrieved from the topographic maps are:

- rugged and quite irregular topographic surface on the both banks of the Toabre valley with succession of hills and deep gullies, scarps and slided soil masses,
- scarce outcrops over the whole area except for discontinuous sections in and close to the river bed,

- soil instability, indicated by several features including recent, large scale or minor landslides along both banks of the valley, which can affect a large thickness of the soil overburden,

- active erosion along numerous streams and gullies which sharply and deeply cut slopes on both sides of the valley.

The geomorphological conditions of the ACP dam axis are rather irregular, with apparently thick soil overburden and very few rock exposures. Site-specific geomorphological conditions show that modifications within the boundaries of the future reservoir are to be expected when impounding. They should consist in local instabilities of the soil overburden as landslides and local erosion.

3.3. Lithology-Structure

As specified before, no boreholes were drilled on this site, owing to particular social conditions. On the other hand, the auger holes and pit excavations did not reach the top of the bedrock and the poor description of the cut material does not allow characterising precisely the foundation rocks.

The description of local lithology at this stage relays on observation of outcrops. Very good exposures were mapped along the quebrada Nicaragua in the left bank, at elevations ranging between 25 and 40 m, and in a small stream running almost parallel to the axis in the right bank, between elevations 25 and 65.

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

Previous investigations had reported the presence of volcanic tuff fragments, particularly in exploration pits excavated in the top layers of the overburden, while a thick sedimentary sequence was explored during the last field visit (December 2002) in the lower part of the banks. It can be inferred that volcanic rocks, not yet exposed in outcrops in this area, might overtop the sediments or that the rock fragments represent transported material.

Assuming a relatively undisturbed, sub-horizontal structure, the knowledge about the sedimentary sequence in the dam foundation could be completed from scarce outcrops mapped up- and downstream from the dam site, as described below.

The outcrop in the right bank at the confluence with Rio de “U”, less than 200 m upstream from site no.2, is mainly composed of calcareous sandstones, including a 10 cm thick bioclastic limestone layer and finely laminated siltstones. They feature NE trending, 15° SE dipping bedding, consistent with measurements at sites no.5 and 6, but downstream from

this point all outcrops show sub-horizontal bedding. Visible fracturing pattern at this location consists of two vertical, closed and non-persistent joint sets, trending N45° and N140°, respectively.

A fresh cut in the right bank at Santa Elena shows horizontal, finely bedded, light brown-yellowish siltstones and fine-grained sandstones. Strong weathering and moisturizing might explain the relatively loosened condition of these rocks.

About 250 m downstream from site no.1, sub-horizontal, decimetric layers of micritic, slightly marly limestones and rare, centimetric marl interlayers, form a 3 m high cliff in the right bank (photo 5). Local joint system includes two vertical, planar, closed joint sets, trending ESE and NE, respectively.

The outcrop in the left bank of Rio Toabre at San Vicente shows coarse sandstone, featuring 1 to 3 mm quartz and feldspars fragments, mainly sub-rounded and subordinately sub-angular, in a fine-grained matrix. Rare and discontinuous sub-horizontal surfaces could be interpreted as bedding, but the overall aspect is rather massive. Vertical joint system comprises N175° and N90° joint sets, with dm to metric spacing, both already mapped upstream, at site 0.

The detailed structural features at the site scale are interpreted from the observation of outcrops and inferred from regional geological maps, aerial photographs and geomorphologic observations. In the absence of boreholes needed to validate the interpretation of the seismic results, these ones can not be currently used to retrieve reliable structural information. NW- and NE trending discontinuities dominate the regional fracturing pattern. Subordinately, N-S and E-W trending fractures are revealed on the regional geological map and by local alignments of river channels. The NW-SE, N-S and E-W trends were confirmed by field observations, as indicated hereafter.

Few discontinuities could be mapped in the left bank, where the main vertical joint set shows a N90° (E-W) to N100° trend. In the right bank, the fracturing pattern is dominated by several discontinuities, N130-140° trending, featuring decimetric to metric zones of intense jointing and local argillic alteration. In addition, a recent, local and shallow landslide exposed an E-W trending, 50-70° S dipping, undulating slide surface, about 100 m upstream from the axis and 30 m N of the riverbed. This discontinuity is part of the joint set of similar trend mapped on the opposite river and coincides with the overall E-W orientation of the riverbed in this section. Locally, a minor joint set, N175° trending was also mapped in the right bank.

One of the best-exposed fault zones was identified in the left bank, about 500 m upstream from the dam axis (see **photos 6 and 7** in Volume II A). The fresh cut, exposing locally microfolded and strongly fractured marls and marly limestone layers, coincides with a recent minor slide, obviously related to the fragility of the materials along the fault. Several vertical planar joints, NNW trending, indicate the orientation of the fault (**photo 8** in Volume II A). The extension of this fault in both directions along the same NNW-SSE trend is suggested by the alignment of topographical features such as creeks and saddles, over several kilometers. It's worth noticing that the prolongation of the fault to the NNW would intersect the extremity of the ACP dam axis' right abutment.

Preliminary interpretation of the aerial photographs confirmed the general trends of the tectonic pattern and suggests that major discontinuities NW- and NE trending have a normal component, generally down-throwing the SW- and NW compartments respectively.

The soil overburden is widely extended over the whole dam site and the project area, with dense vegetation. It is composed of thick silty-clayey latosoil resulting from the alteration of the underlying bedrock. Its thickness increases as bank slopes rise from the riverbed. Depth models derived from seismic data ([Ref. 6] and **Drawings 10-203 and 10-204**) indicate an overall thickness of about 5-10 m with a maximum of 15-20 m at the top of the right bank.

Instability phenomena, mainly shallow, involving residual soil and colluvial deposits, are widespread throughout the whole reservoir area. Slope instability in the right bank at the dam site is attested by the presence of small scale, shallow recent slides, debris flow deposits and deeply incised topography in the downstream half of the right abutment. This local instability can be related to fracturing and steep slopes on prominent topography, which, in turn, would indicate more resistant rocks.

3.4. Engineering Geology

3.4.1. Transfer Tunnel

Among the different alternatives of inter-basin transfer facilities connecting the Toabre Lake and Indio Lake, the direct rectilinear transfer tunnel is presently considered. The inlet, in the Toabre reservoir, and the first part of this transfer tunnel shall be excavated in the Cañazas volcanic tuff as deducted from general documentation and preliminary field observations.

The major length of this transfer tunnel alignment to the Rio Indio reservoir is inferred to be excavated in the sedimentary marine 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 rock foundation of the transfer tunnel.

From preliminary observations, it may be assumed that the local structural features correspond to the regional ones with two major and conjugated trends of tectonic discontinuities: SE-NW and NE-SW. The latter coincides with the 10 km long topographical straight alignment which is formed by successive tributary branches, from the southern “quebrada la Encantada” (at the inlet location), through the “Rio Limon” up to the straight stretch of the northern“Rio Caño Sucio”.

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.

3.4.2. Dam Foundation

Owing to the relatively low amount and quality of the data currently available (cf. reliability of seismic 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.

Basically, the depth models derived from seismic data ([Ref. 6] presented on **Drawings 10-203 and 10-204**) 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 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 characterised by velocities ranging between 1 900 and 3 000 m/s (some values of 1 500 m/s locally).

The Contractor specified [Ref. 6] that velocity within the sound bedrock could not be retrieved from the raw data. As mentioned above (beginning of paragraph 3) offset shots, required by the Consultant but not performed, in the proximity of the river channel or of adjacent streams, where bedrock is outcropping, would have supplied valuable data.

Taking into account possible modifications documented by further reconnaissance surveys, in particular the drilling campaign, the interpretation of the seismic results comprising the foundation level proposed at this stage is given as cross sections along the reference ACP axis and the proposed alternative dam axis in **Drawing 10-205**. This interpretation was based on the original depth models supplied by the Contractor (**Drawings 10-203 and 10-204**) by cross checking longitudinal and transversal depth models and integrating local geological aspects as inferred from surface investigations. The interpretative 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.

Anomalous seismic data at several locations could be related to intensive fracturing or faults. Such zones were identified on LL3, LL5 and at the common end of LR1 and LR2 profiles. In particular, the latter of these potential fault zones correspond with the steep slope and escarpment in 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 unfavorable.

3.4.3. Construction Materials

Impervious materials for the core section of dam embankment alternatives are locally available in sufficient quantity and adequate quality to supply any project needs.

If dam structures others than embankments can be envisaged, adequate construction material should be searched such as rock for rockfill or aggregates and filters production. In this respect, a preliminary field survey was tentatively conducted within the rim of the future reservoir area that must be developed in the further steps of investigation.

- ***Soils***

Index tests comprising sieving and hydrometer analysis, water content, Atterberg limits and specific gravity were performed on both disturbed and undisturbed samples collected in auger holes and in pits at the dam site.

With very few exceptions, the samples are classified as silty sands (SM class) according to the UCS and they feature relatively high water content and low to medium plasticity as indicated by the plasticity chart. Should these materials be further considered as source for an impervious core, they should be submitted to mineralogical analysis and dispersivity tests.

Compaction tests showed that optimum dry density varies between 103,1 and 118,9 lb/ft^3 (1,65 and 1,90 t/m^3) for optimum water content ranging from 27,2 to 41,8 %. Owing to the high natural water content, which should be partially related with sampling during the wet

season, all samples range on the wet side of the Proctor Optimum, the difference reaching up to 35 %.

Two direct shear tests performed on undisturbed silty sand samples yielded the following peak values:

Φ_{CD} = 22° / c_{CD} = 87 kPa and Φ_{CD} = 24° / c_{CD} = 63 kPa.

Tests results of index and compaction tests are synthetically shown in **Figures 4 to 6**.

- ***Rock Material***

During the preliminary field visits, two areas were identified as possible quarries (RQ1 and RQ2), located along the upstream course of the Toabre River (see [Ref. 4]).

As recommended by the Consultant, preliminary reconnaissance survey was carried out on these areas and other potential construction materials (mainly gravel and sand) sources upstream from the dam site (**Figure 3**).

The field visit is fully reported in [Ref. 5]. The main results are summarised herein.

The Toabre river channel for about 8 km upstream from the dam site and its major tributaries were briefly investigated. The outcrops exposed pyroclastic tuffs and agglomerates, andesites and locally limestone. Pyroclastic rocks in outcrop are relatively more altered, while andesites featuring massive texture are more sound and are considered to be an appropriate source of concrete aggregate.

Samples from the main rock types were submitted to the point load test, which allows an estimation of the unconfined compressive strength. The results presented in **Figure 7** outline the low strength of the agglomerate (14 MPa), but also a strong variation of the strength of the andesite (38 to 106 MPa). The degree of alteration in outcrop has a strong influence on these results which will be completed during the next phases of reconnaissance.

Several areas (RQ-1 to RQ-4, see **Figure 3**) with potential rocky construction material were tentatively designated after the completion of this field visit. Preliminary estimations on RQ-2 and RQ-4 areas indicate that large volumes of andesite (5 millions of m^3) would be available. The use of the limestone as possible concrete aggregate source can also be considered but it is subject to further tests.

In addition, two areas located closer to the dam site (RQ-5 and RQ-6), were recommended for further investigation as potential sources of construction material.

It is anticipated that most of the strata of the Cañazas Formation would make satisfactory rock fill for a dam, but a significant amount may not be satisfactory for production of concrete aggregate owing to inappropriate shape. In addition, this Formation may also contain constituents that are reactive with alkalis in cement. If this proposed project is carried forward, it is recommended to perform core drilling in the potential areas of quarry early during the planning studies to determine general depths of weathering and to determine the suitability of the rock for use as concrete aggregate and other construction materials.

Excavated rock material from the transfer tunnel could also be a potential source of construction material. The characteristics of the Caimito formation material are still very poorly known through a few UCS values and at this stage it is difficult to anticipate if these sedimentary rocks can supply adequate material for dam construction. Further development of this project requires field and laboratory analyses to identify the material and to determine its general suitability for use as construction material.

- ***Gravel and Sandy Material***

Some alluvial deposits were observed in the vicinity of the dam site along the riverbed. Evaluation of the available quantities and granulometry of these deposits must be made through a specific geological and geotechnical survey.

Identification of additional alluvial deposits was also attempted during the field visit of July 2002 [Ref. 5]. This survey could only identify limited amounts of sand and gravel material. Main sites were located upstream from the confluence with the Rio Tulu up to the site known as El Salto. Where present, the alluvial deposits, generally related with andesite or basalt bedrock outcropping in the riverbed, consisted mainly of 5 to 40 cm wide, angular to sub-rounded andesitic blocks.

Further surveys should be extended both upstream and downstream of the site.

LIST OF DOCUMENTS

Ref. 1 Reconnaissance Study – US Army Corps of Engineers - Dec. 1999
Section 5 - Rio Indio

Ref. 2 Reconnaissance Study – US Army Corps of Engineers - Dec. 1999
Section 9 – Rio Toabre and Rio Cano Sucio.

Ref. 3 Mapa geologico Republica de Panama scale 1/250000 Ministerio de Comercio e Industrios; hojas 3, 4, 5 y 6.

Ref. 4 Field Mission Report - Coyne et Bellier, April 2002.

Ref. 5 Informe de gira de campo 8 – 12 Julio 2002 - Aug. 2002

Ref. 6 Reporte prospeccion sismica – Bachy-Fundaciones, S.A., Oct. 2002.

Ref. 7 Laboratory testing results from Toabre Project – ACP, Oct. 2002

Ref. 8 Feasibility Report - Volume II A – Coyne et Bellier, 2003

Figure 1 – Seismo-Tectonic Map of PANAMA

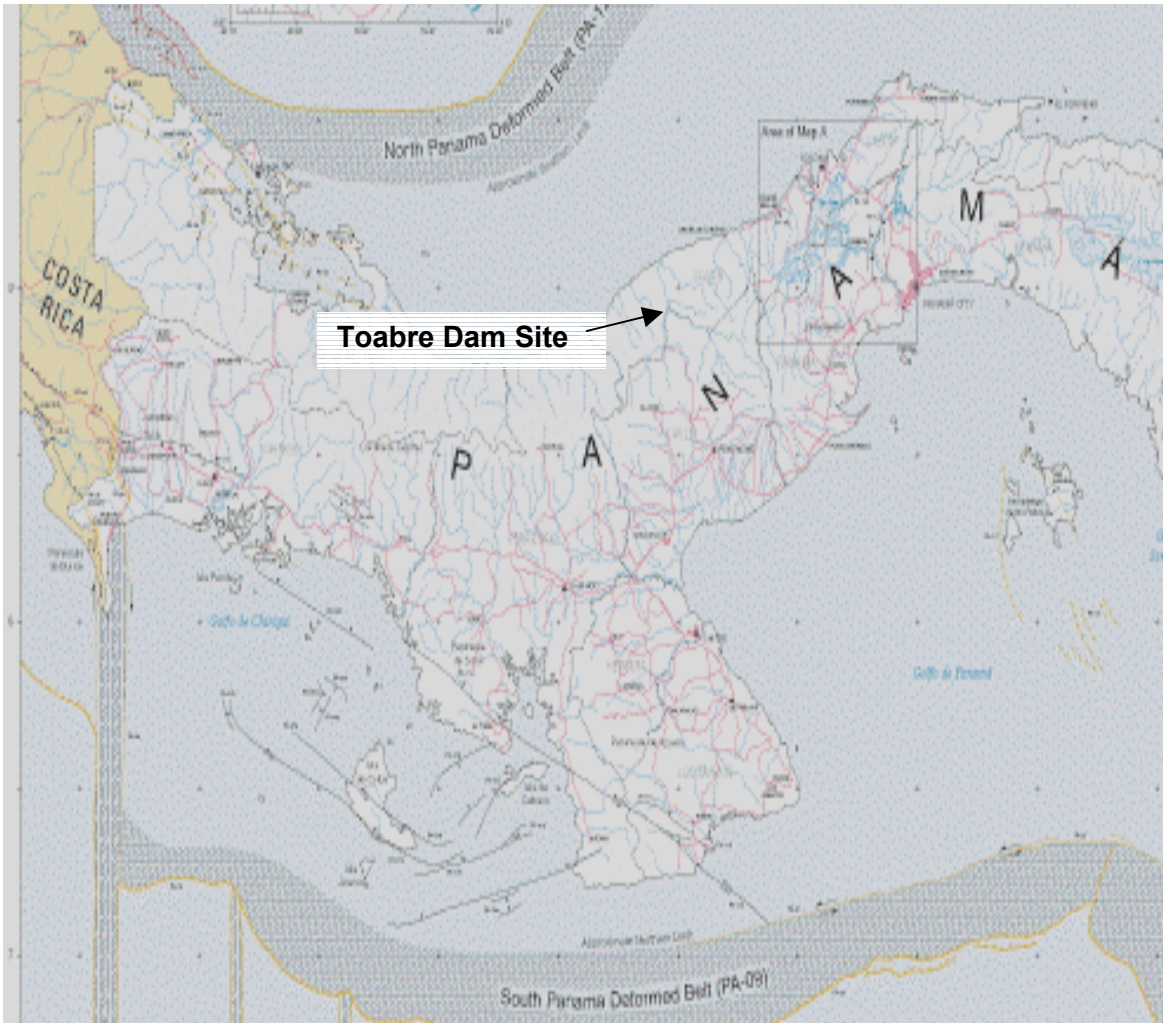
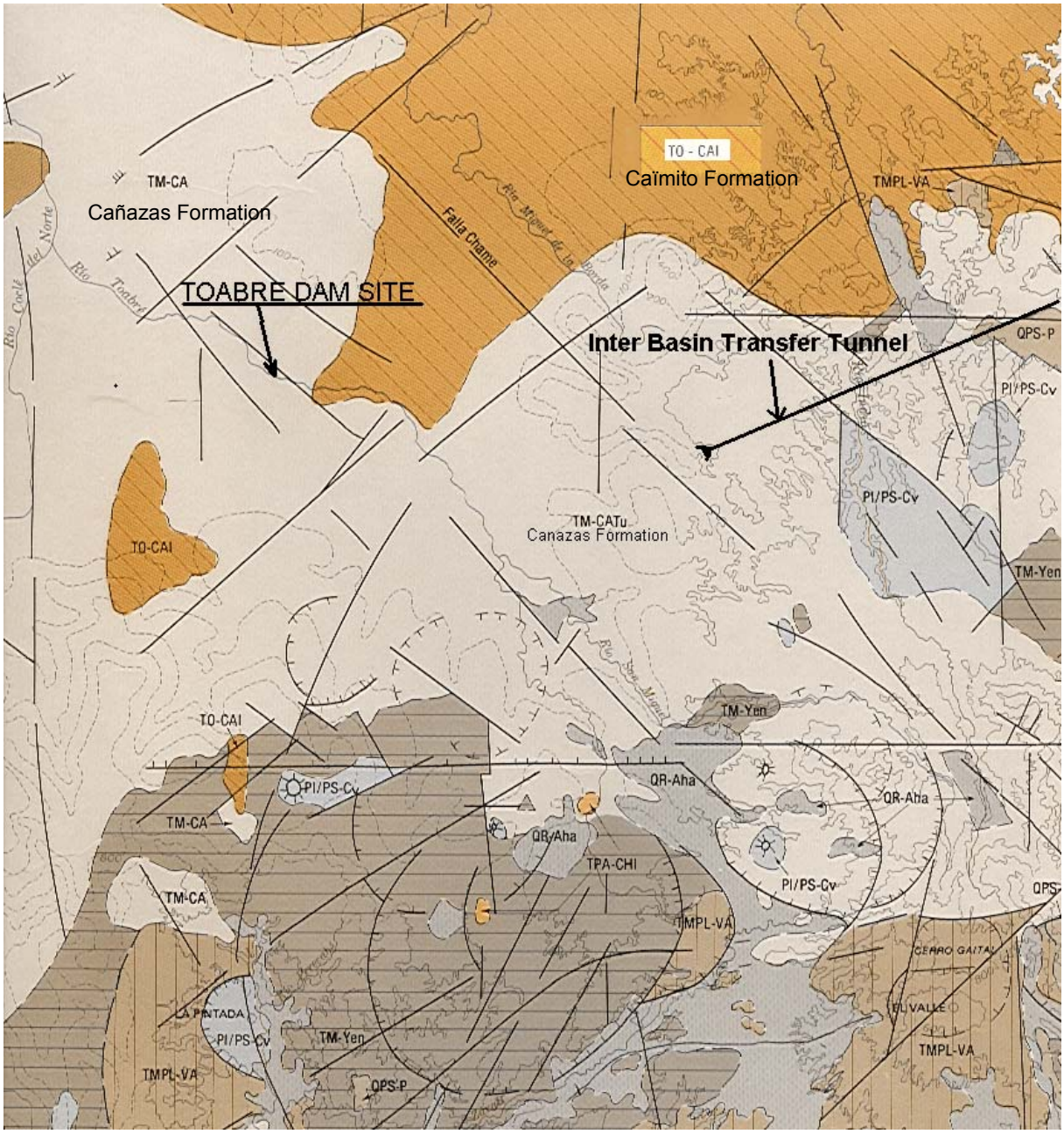


Figure 2 – Regional Geological Map



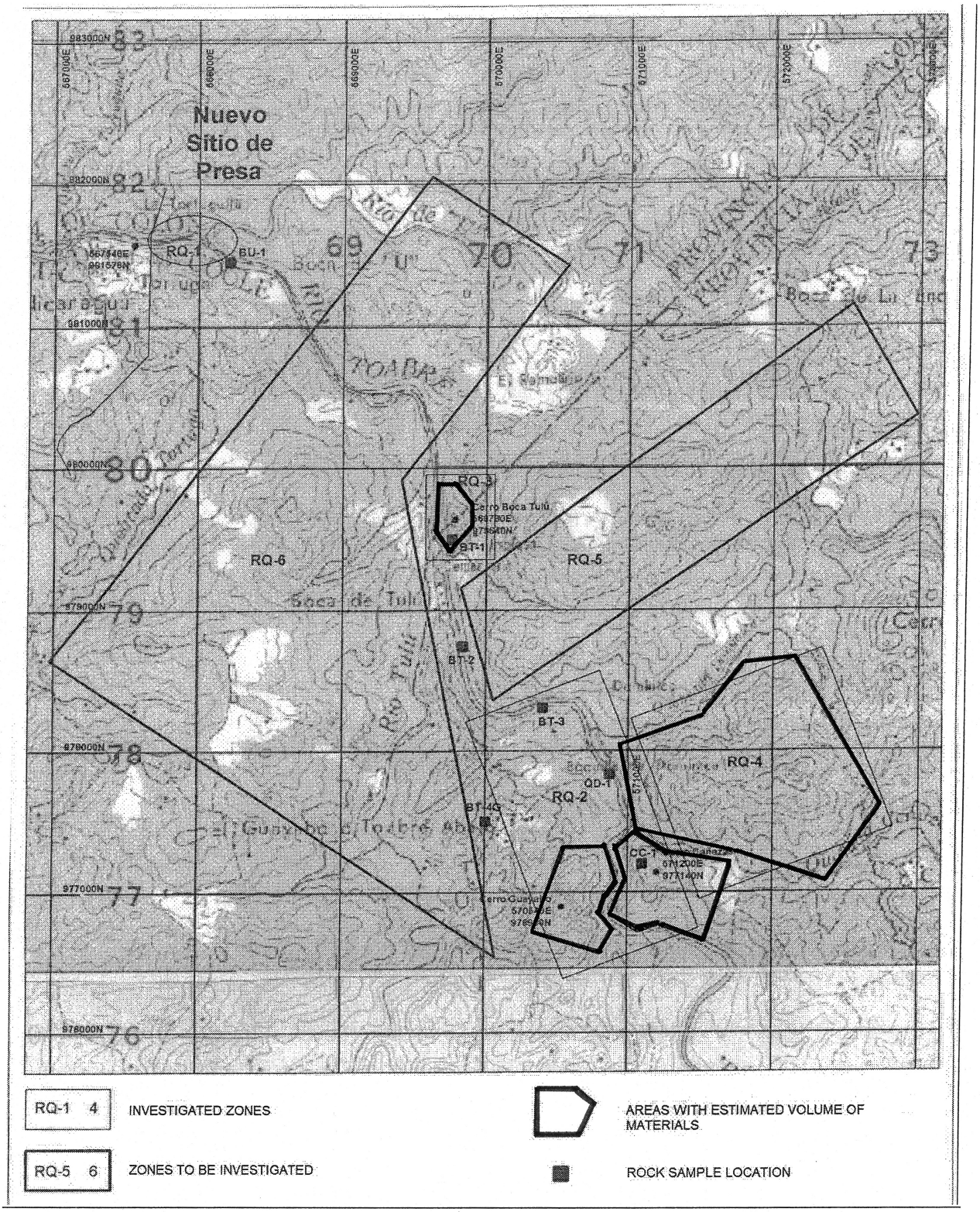


Fig. 3 Location of potential construction material sources and of rock samples

AUTORIDAD DEL CANAL DE PANAMA
DIVISION DE INGENIERIA
SECCION DE GEOTECNIA

SUMMARY RESULTS OF INDEX TESTS

Project: Proyecto de aguas del río Toabré
Location: Río Toabré San Vicente

Auger No.	Sample	Coordenadas	Depth (m)	Moisture Content (%)	Passing No.200 (%)	Liquid Limit LL	Plastic Limit PL	Plastic Index PI	Classific. U.C.S.	Name	Color
TO-A1	1	565325E/980816N	0.00-1.00	91.31	26.81	77	49	28	SM	Silty sand	Yellowish brown
TO-A1	2	565325E/980816N	1.00-1.93	73.99	24.23	72	50	22	SM	Silty sand	Yellowish brown
TO-A2	1	565345E980096N	0.00-1.40	70.40	18.72	70	46	24	SM	Silty sand	Reddish yellow
TO-A2	2	565345E980096N	1.40-1.73	70.40	23.39	62	45	17	SM	Silty sand	Reddish yellow
TO-A3	1	565366E/981015N	0.00-1.00	63.95	21.26	69	46	23	SM	Silty sand	Brownish yellow
TO-A3	2	565366E/981015N	1.00-2.00	63.95	27.05	79	50	29	SM	Silty sand	Reddish yellow
TO-A4	1	565387E/981083N	0.00-1.20	32.78	23.10	51	34	17	SM	Silty sand	Very pale brown
TO-A4	2	565387E/981083N	1.20-2.20	34.97	34.29	43	32	11	SM	Silty sand	Very pale brown
TO-A4	3	565387E/981083N	2.20-4.00	37.30	35.62	43	29	14	SM	Silty sand	Very pale brown
TO-A5	1	565403E/981185N	0.00-1.15	30.49	20.07	37	27	10	SM	Silty sand	Light gray
TO-A5	2	565403E/981185N	1.15-2.40	23.03	23.62	30	22	8	SC	Clayey sand	White
TO-A5	3	565403E/981185N	2.00-3.60	19.82	31.81	22	16	6	SC-SM	Silty, clayey sand	White
TO-A6	1	565412E/981286N	0.00-100	91.11	25.09	88	48	40	SM	Silty sand	Brownish yellow
TO-A6	2	565412E/981286N	1.00-2.20	107.18	59.11	98	42	56	MH	Sandy elastic silt	Brownish yellow
TO-A7	1	565480E/981401N	0.00-1.00	25.16	20.01	34	27	7	SM	Silty sand	Very pale brown
TO-A8	1	565469E/981416N	0.00-1.00	35.13	12.86	40	26	14	SM	Silty sand	Very pale brown
TO-A8	2	565469E/981416N	1.00-2.00	31.74	23.43	39	32	7	SM	Silty sand	Very pale brown
TO-A9	1	565482E981465N	0.00-1.00	36.01	27.04	41	31	10	SM	Silty sand	Very pale brown
TO-A9	2	565462E981465N	1.00-2.00	44.85	33.24	51	34	17	SM	Silty sand	Very pale brown
TO-A10	1	565508E/981568N	0.00-1.00	36.91	24.99	48	30	18	SM	Silty sand	Brown
TO-A10	2	565508E/981568N	1.00-2.00	33.53	25.35	47	30	17	SM	Silty sand	Brown
TO-A11	1		0.00-1.00	47.69	37.77	59	39	20	SM	Silty sand	Very pale brown
TO-A11	2		1.00-2.00	53.71	46.18	54	36	18	SM	Silty sand	Very pale brown
TO-A11	3		2.00-3.00	37.63	46.18	53	35	18	SM	Silty sand	Light yellowish brown
TO-A12	1	565569E/981812N	0.00-1.00	61.46	44.13	75	44	31	SM	Silty sand	Light yellowish brown
TO-A12	2	565569E/981812N	1.00-2.00	59.35	50.47	75	43	32	MH	Sandy elastic silt	Light brown

Tested By: C. Rodriguez, and X. Rios.
Prepared By: Xenia Rios
Checked by: Gustavo Guerra B.
File: ToabreClassification

Fig.4 Summary results of index tests

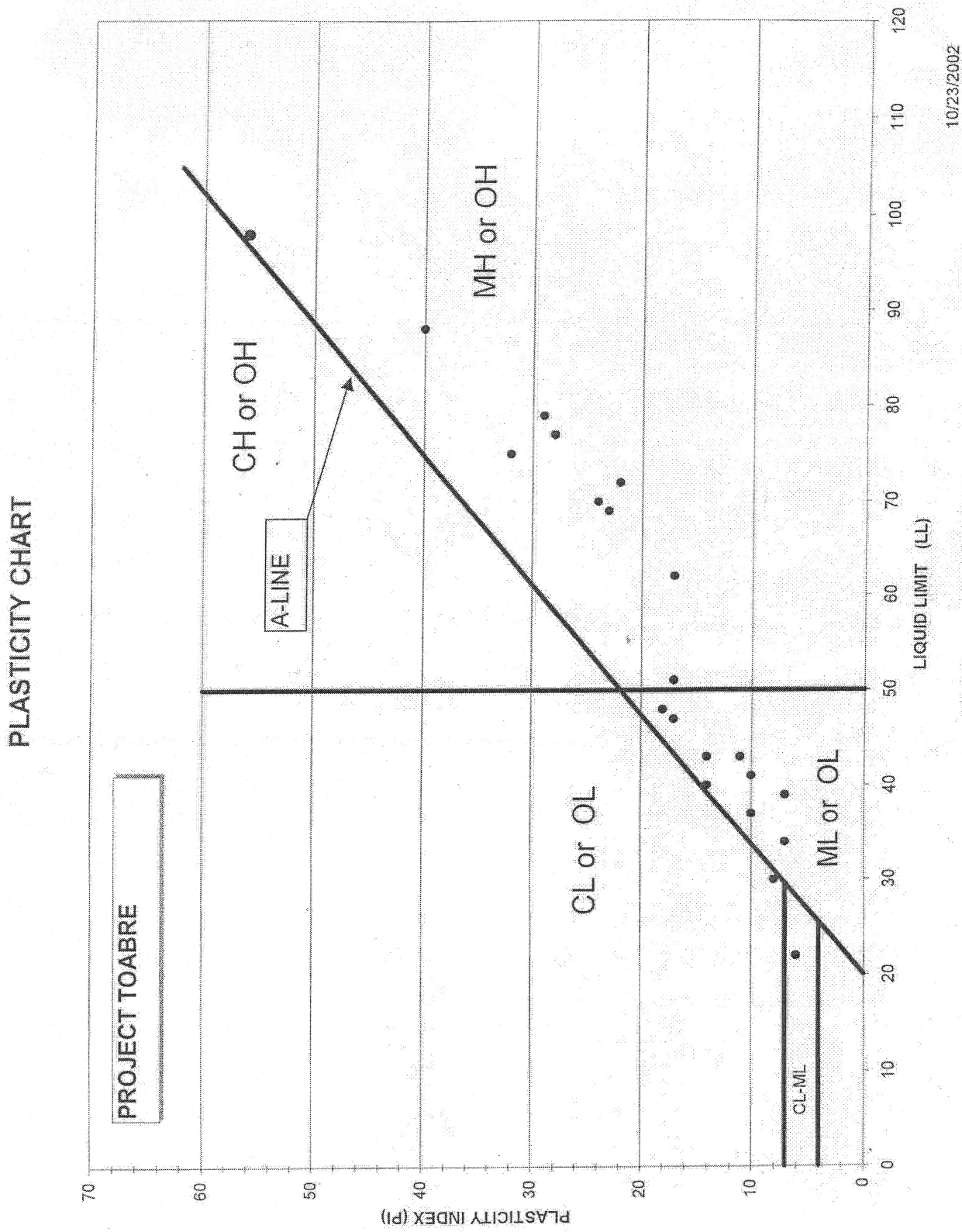


Fig.5 Plasticity chart

PANAMA CANAL AUTHORITY
ENGINEERING DIVISION
GEOTECHNICAL BRANCH

SUMMARY RESULTS OF COMPACTION TESTS

Project: Toabré
Location: San Vicente Toabré
Description of soil: material extracted from pits

Date: 10-14-02
Depth: 1m
Tested By: Xenia Rios, Carlos Rodriguez

No. Test	Boring	Water content %	Proctor laboratory compaction			LL	LP	IP	Specific Gravity Gs	Clay Fraction (0.002mm)%	U.C.S. classification	name
			Wet unit weight (lb/ft3)	Dry unit weight maximum (lb/ft3)	Water content optimum %							
1	TO-C1	67.04	102.5	74.5	37.6				2.62	74.7		
2	TO-C2	73.72	103.1	74.5	38.4				2.63	44.4		
3	TO-C3	68.94	103.7	73.6	40.9				2.62	30.8		
4	TO-C4	66.78	106.2	74.9	41.8				2.56	25.5		
5	TO-C5	65.00				81	53	28	2.31	67.7	SM	Silty sand
6	TO-C6	59.30				86	56	30	2.31	50.7	SM	Silty sand
7	TO-C7	68.75	109	78.9	38.2				2.66	20.5		
8	TO-C8	58.07				74	46	28	2.42	50.3	SM	Silty sand
9	TO-C9	42.14	114.4	88.1	29.9				2.53	32.3		
10	TO-C10	44.57	110.8	82.1	35.0				2.57	48		
11	TO-C11	38.37	116.8	90.7	28.8				2.69	26.4		
12	TO-C12	39.30	118.9	93.5	27.2	42	32	10	2.66	19.3	SM	Silty sand
13	TO-C13	46.53	108.8	82.1	32.6	63	44	19	2.66	27.8	SM	Silty sand
14	TO-C14	51.46	108.9	78.3	39.2				2.59	69.8		
15	TO-C15	44.66	112.4	84.4	33.2				2.73	26.7		

Prepared By: Xenia Rios
Checked By: G. Guerra
File: DensityToabre

Fig.6 Summary results of compaction tests

AUTORIDAD DEL CANAL DE PANAMA
DIVISION DE INGENIERIA
SECCION DE GEOTECNIA

SUMMARY RESULTS OF THE POINT LOAD STRENGTH INDEX OF ROCK
Project: Toabré

Location: Northwest of the Canal

	Boring	Depth (m)	Sample No.	Point Load I. Is_{50} (Mpa)	Estimated Unconf. Comp. σc (Mpa)	Type of rock
1	MBT-4G	site	m-1	6.93	107	vein of quartz
2	MBT-1	site	m-2	2.09	32	limestone
3	MCC1(A)	site	m-3	4.76	84	glassy basalt
4	MBU-1	site	m-4	0.63	14	agglomerate
5	MCC-1	site	m-5	2.14	38	andesite
6	MBT-2	site	m-6	6.04	106	andesite

Remarks: rock color :

vein of quartz	light olive gray
limestone	pale yellowish brown
glassy basalt	dark yellowish brown
agglomerate	ligth olive brown
andesite	dark gray

Tested and prepared By: R. Lam, X. Rios and G. Guerra 10/21/2002

Fig.7 Summary results of the point load tests

PART V – SEISMIC HAZARD

LIST OF FIGURES

Fig. 1 - Seismicity of Central America 1977-1997
Fig. 2 - Seismotectonic map of Panama
Fig. 3 - Macroseismic map of the 1822 earthquake. Star represent the assumed epicenter
Fig. 4 - Macroseismic map or the 1882 earthquake. Star represent the assumed epicenter
Fig. 5 - Macroseismic map of the 1904 earthquake. Star represent the assumed epicenter
Fig. 6 - Macroseismic map of the 1916 earthquake. Star represent the assumed epicenter
Fig. 7 - Curves of magnitude versus return periods for critical seismogenic sources
Fig. 8 - Curves of PGA versus return periods for critical seismogenic sources
Fig. 9 - Curve of PGA derived from the 1985 Valparaiso earthquake. PGA expected for the MCE at Toabre Dam site
Fig. 10 - Curve of PGA derived from the 1985 Valparaiso earthquake. PGA expected for the MCE at Toabre Dam site
Fig. 11 - Response spectra at Toabre Dam site associated to the MCE far- and near-field reference earthquakes
Fig. 12 - Recommended Response spectra at Toabre Dam site
Fig. 13 - Envelop curves used to compute artificial accelerograms
Fig. 14 - Synthetical spectral acceleration response, compared to the evaluated spectrum (5% damping
Fig. 15 - Synthetical accelerograms. From top to bottom: toab1;toab2; toab3; toab4 and toab5

LIST OF TABLES

Table 1 - Return period associated to design earthquakes
Table 2 - Estimate of the reference magnitudes along the identified seismogenic sources.
Table 3 - Estimate of the reference PGA (in g) generated at site (rock).
Table 4 - Recommended PGA (in g) for Toabre dam site
Table 5 - Recommended spectral values for Toabre dam site (5% damping)
Table 6 - Parameters of the exponential envelop curve Table 6 - Parameters of the exponential envelop curve

PART V – SEISMIC HAZARD ANALYSIS

1. INTRODUCTION

The Toabre Dam is located in Panama Block along the Pacific coast in a very complex tectonic zone where South America, Central America, Caribbean, Nazca and Cocos plates interfere giving rise to a significant seismicity.

A regional probabilistic seismic hazard carried out by Camacho *et al.* (1994) results for the Toabre dam site area in Peak Peal Ground Accelerations at bedrock of 0.13 g, 0.18 g and 0.23 g for mean return periods of 250, 500 and 1000 years respectively.

In order to validate/or implement this seismic hazard, an analysis of available scientific literature and technical reports has been conducted taking into account that the reliability of a seismic hazard assessment strongly depends on both a good understanding of the geodynamics of a given region at different scales, from plate tectonics to fault scales and even in favorable cases to seismic scarp scale.

This analysis was addressed throughout both deskwork and a mission in Panama in March 2002. We present hereafter the most relevant data, which have been taken into account for deriving PGA at the Toabre dam site.

2. TECHNICAL DOCUMENTS CONSULTED

The following documents have been provided by ACP for conducting the expertise:

- 1 set of 4 Maps en color: Mapa geologico Republica de Panama scale 1/250,000 Ministerio de comercio e industrios, hojas 3, 4, 5 y 6;
- report: Seismicity Evaluation Tabasara Hydel Project western Panama, ACRES Canada dec. 81;
- report: Excepts from the Star and Herald on the Sept. 1882 Earthquake, from Engineering & Construction Bureau, Luis Carlos Fernandez;
- report: El terremoto de San Blas del 7 de Septiembre 1882; E Camacho y V. Viquez, Universidad de Panama , Junio 1993;
- technical report 2-17: Spectral Strong Motion Attenuation in Central America, NORSAR, August 1994;

- technical report 2-18: Seismic Hazard for Panama, Update, NORSAR, July 1994;

- report: Seismicity of Panama during the interval 1904-83, Seismological Dept. Upsala Sweden, A. Vergara Munoz, 1987;

- report: El terremoto de la Vieja del 2 de Mayo 1621, un sismo intraplaca, V. Viquez y E. Camacho, Universidad de Panama, Mayo 1993;

- report: Historical Seismicity of the North Panama Deformed Belt, E Camacho y V. Viquez, Universidad de Panama;

- report: Sismicidad Historica del Extremo Occidental del Cinturon Deformado del Norte de Panama, E Camacho y V. Viquez, Universidad de Panama , April 1992;

- report HC-ACP-01: Design Earthquakes in the Southeast Area of the Panama Canal Basin, Cowan (2001);

- geotechnical Advisory Board. Meeting n° 8;

- geotechnical Advisory Board. Meeting n° 9;

- design Earthquakes for the Evaluation of Seismic Hazard at the Gatún Dam and Vicinity, Schweig *et al.* (1999);

- report of Seismic Evaluation – Gatún Dam, Panama;

- results of 1997 High-Resolution Seismic Reflection Profiling for Evaluation of the Seismic Hazard at the Gatún Dam, Republic of Panama;

- report final: August 1 (1999) – Results of 1997 High-Resolution Seismic Reflection Profiling in Gaillard cut, Republic of Panama, for Evaluation of the Landslide Hazard in the Panama Canal.

Detailed discussions on seismotectonics and seismology of Panama took place at the Geosciences Institute of Panama with J. Toral (Director), E. Chichaco (Research Coordinator) and A. Tapia (Responsable of the seismological network).

Access to ^{TM}Landsat images and a regional Digital Elevation Model (30 m) was possible thanks to R. Martinez (ACP-Environment division).

3. GEODYNAMIC FRAMEWORK

3.1. Instrumental seismicity and plates boundaries

Regional seismicity in Central America and Caribbean between 1977 and 1997 is reported in Figure 1. Few features may be drawn:

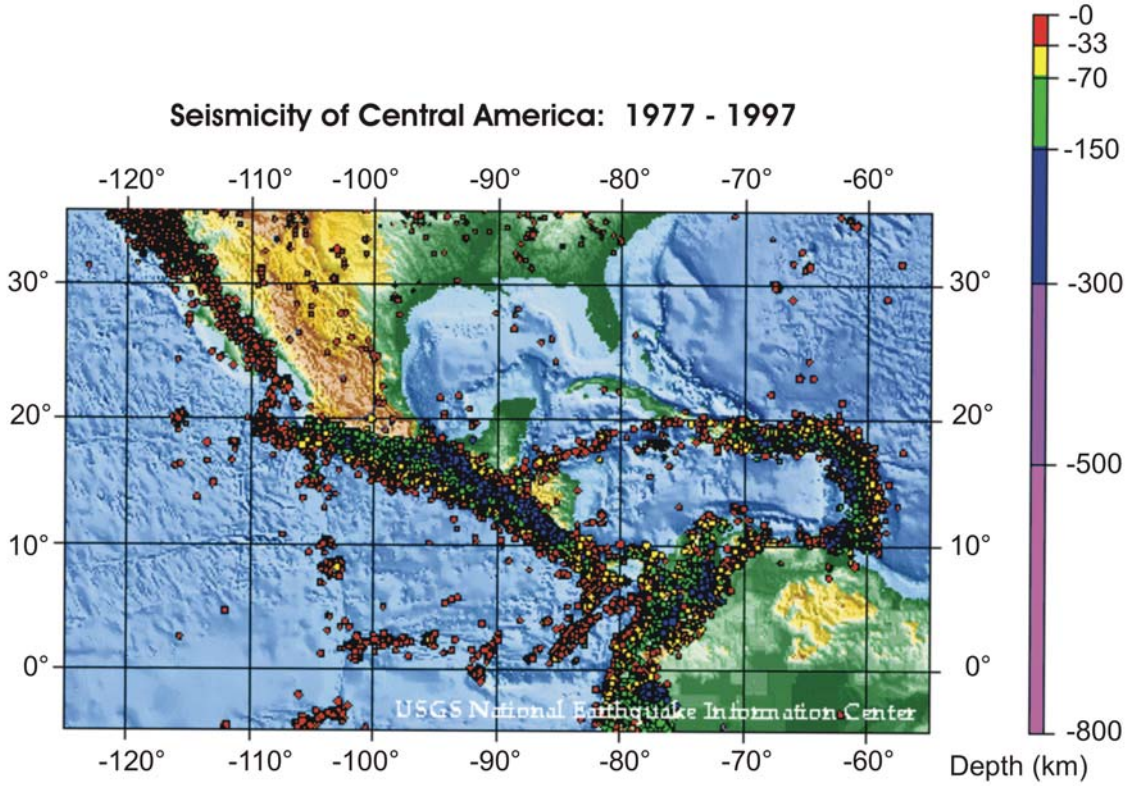


Fig. 1 - Seismicity of Central America 1977-1997.

- the eastward subduction of the pacific plates (Nazca and Cocos) beneath Central and South America characterized by shallow to deep seismicity;
- the westward subduction of the Lesser Antilles bounding to the East the Caribbean plate also characterized by shallow to deep seismicity;
- the northern transcurrent boundary of the Caribbean plate characterized by shallow seismicity extending in Guatemala throughout the Motagua and the Chixoy-Polochic fault systems;
- the relative complexity of the southern boundary of the Caribbean plates characterized by shallow seismicity distributed over Bocono fault system in Venezuela, Subandean thrusts in Colombia and Ecuador, and curved fold and thrust belt north of Colombia and Venezuela;
- the Panama Fracture Zone south of Costa Rica-Panama border between the Cocos and the Nazca oceanic Plate;

- the absence of deep seismicity between the southern end of the Central America subduction and the northern segment of the Colombia Subduction;
- the absence of seismicity within the Panama Gulf;
- shallow and intermediate seismicity bounding to the North the Panama Isthmus.

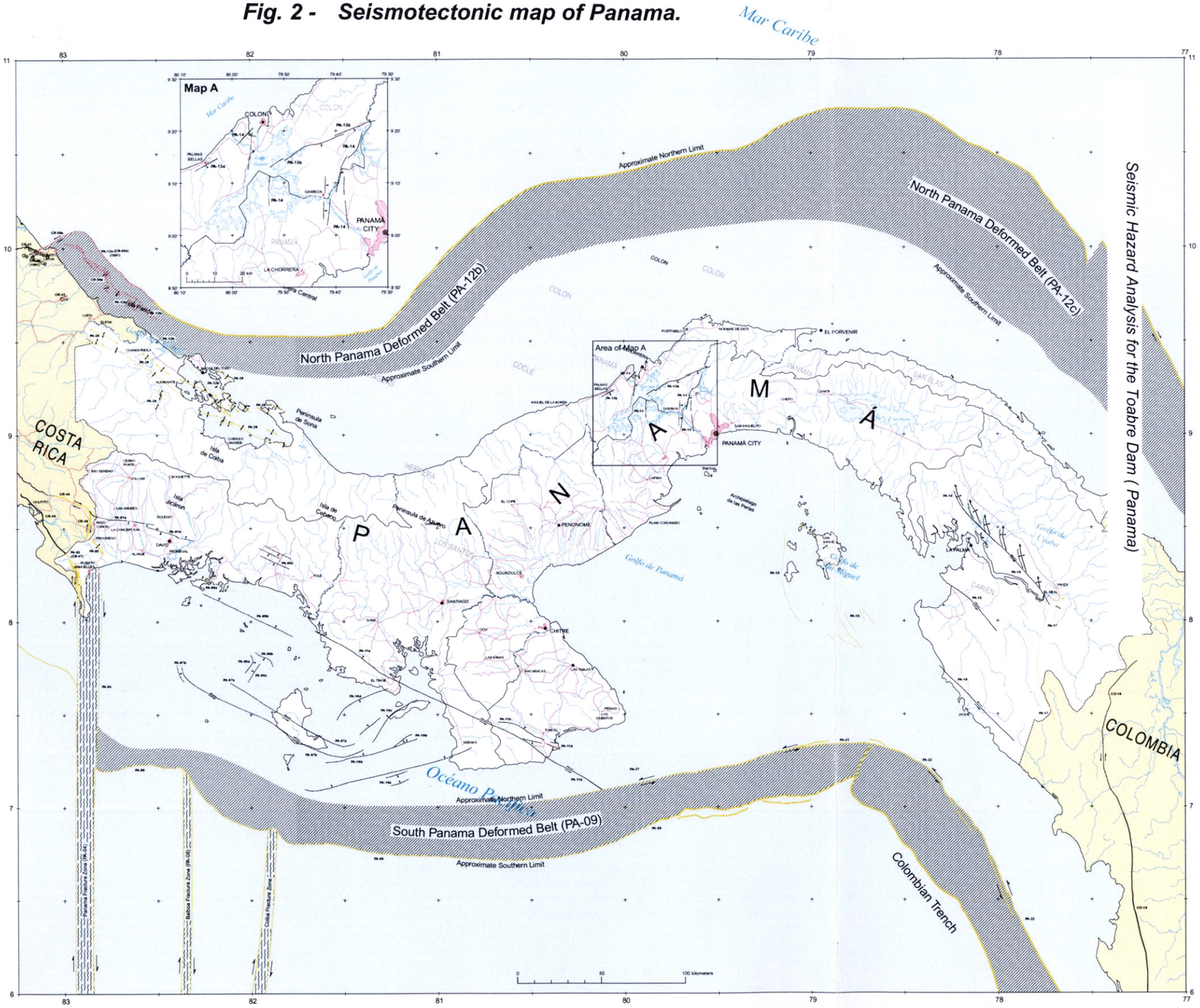
It must be highlighted here that the Isthmus of Panama located in a very complex tectonic area where plate boundaries are not always well defined and where surroundings plates strongly interfere.

3.2. Boundaries of the Panama Block

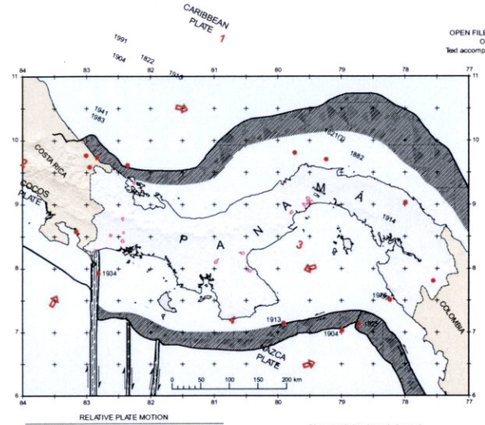
The Toabre dam is located in a tectonic microplate called the Panama Block along the Pacific coast in a very complex tectonic zone where South America, Central America, Caribbean, Nazca and Cocos plates interfere giving rise to a significant regional seismicity (Fig. 2). Surroundings plate boundaries accommodate mostly convergence:

- convergence between Cocos Plate and Central America is currently accommodated within Middle America subduction giving rise to large and damaging earthquakes with magnitude greater than 7.0 (for instance, 1803, 1854, 1882, 1941 and 1983 for Costa Rica where the Cocos Ridge is currently subducting). Present-day convergence rate is about 90 mm/yr in a N30°E direction.
- Cocos and Nazca plate boundary is formed by the right-lateral Panama transform which subducted obliquely at a shallow angle within the South Panama Deformed Belt zone. The Panama Fracture Zone has experience large earthquakes (Ms > 7.0) in 1927, 1934 and 1962. Relative movement between the two oceanic Cocos and Nazca plates is about 50-70 mm/yr. Two sub-parallel fracture zones (Balboa and Coiba) splay off from the Panama Fracture Zone to the NE;
- convergence between Nazca Plate and South America is currently accommodated within Colombia-Ecuador subduction and also generates major earthquakes with magnitude greater than 7.0 (1906, 1942, 1958 and 1979). It is about 50 mm/yr in a N70°E direction. It must be noted that close to Panama Isthmus, the Colombia-Ecuador subduction becomes less active. This feature may be interpreted as a seismic gap with a capability greater than 7.5 (Ms) earthquake;
- the link between the two above-mentioned subduction is formed by the N80°E trending South Panama Deformed Belt where the Nazca plate aseismically subducts in an oblique way (N70°E) consistently with the Nazca-South America convergence movement. It implies a significant left-lateral component along that plate boundary. South of the Azuero Peninsula, where the South Panama Deformed Belt trends progressively WNW-ESE, it seems that part of this lateral component of the movement is actually absorbed along a series of NW-SE trending left-lateral strike-slip faults located south of the Azuero and Sona Peninsulas and in the surroundings of the Coiba Islands. It must be noted that the Azuero area have been already affected by major earthquakes in 1516, 1803, 1845, 1883, 1913, 1943 and 1960;

Fig. 2 - Seismotectonic map of Panama.



Seismic Hazard Analysis for the Toabre Dam (Panama)



OPEN FILE REPORT
OFR 98-779
Text accompanies map

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

Diagram of plate boundaries and major historical earthquakes for Panama

Esquema de límites de placas y terromotos historicos 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)
PA-01	Longitudinal fault zone			
PA-01A	Unnamed section	David (2)	Probably <1.6 m.y.	Probably <1
PA-01B	Unnamed section	David (2)	Probably <1.6 m.y.	Probably <1
PA-02	Madre Vieja Anticline	David (2)	Possibly historic (1934); <15 k.y.	Probably >1 (uplift rate)
PA-03	Medial fault zone	David (2)	Probably <15 k.y.	Probably >10
PA-04	Panama fracture zone	Isla de Coiba (3) and offshore	Historic (1934); <15 k.y for zone	Probably >50
PA-05	Unnamed series of faults			
PA-05A	Unnamed section	David (2)	Probably <15 k.y.	Unknown
PA-05B	Unnamed section	David (2)	Probably <1.6 m.y.	Unknown
PA-05C	Unnamed section	David (2)	Probably <1.6 m.y.	Unknown
PA-06	Unnamed faults			
PA-06A	Unnamed section	Isla de Coiba (3)	<1.6 m.y.	Unknown
PA-06B	Unnamed section	Isla de Coiba (3)	<1.6 m.y.	Unknown
PA-06C	Unnamed section	Isla de Coiba (3)	<1.6 m.y.	Unknown
PA-07	Central and South Coiba fault zones			
PA-07A	Central Coiba fault zone	Isla de Coiba (3)	Probably <1.6 m.y.	Unknown
PA-07B	South Coiba fault zone	Isla de Coiba (3)	Probably <1.6 m.y.	Unknown
PA-08	Balboa fracture zone	Isla de Coiba (3) and offshore	<15 k.y for entire zone	Probably >5
PA-09	South Panama deformed belt	Isla de Coiba (3) and offshore	Probably <15 k.y for entire belt	Probably 1-6
PA-10	Unnamed fault system			
PA-10A	Río Flores fault zone	Chitre (6)	<1.6 m.y.	Unknown
PA-10B	Unnamed fault	Chitre (6)	<1.6 m.y.	Unknown
PA-10C	Unnamed fault	Chitre (6)	<1.6 m.y.	Unknown
PA-10D	Unnamed fault	Chitre (6)	<1.6 m.y.	Unknown
PA-11	Azuero-Soná fault zone			
PA-11A	Azuero-Soná fault	Chitre (6)	Probably <1.6 m.y.	Unknown
PA-11B	Unnamed fault	Chitre (6)	<1.6 m.y.	Unknown
PA-12	North Panama deformed belt			
PA-12A	Limón fault	Bocas del Toro (1)	Historic (1991)	Unknown
PA-12B	Western section	Bocas del Toro (1) Donoso (4) and offshore	<15 k.y	Unknown
PA-12C	Eastern section	Listupo (10) and offshore	Historic (1882); <15 k.y for section	Probably 1-5
PA-13	Unnamed fault system			
PA-13A	Unnamed fault S. of Palmas Bellas	Donoso (4)	<1.6 m.y.	Unknown
PA-13B	Río Gatún fault	Panamá Norte (7)	<1.6 m.y.	Probably <1
PA-14	Unnamed fault system	Panamá Norte (7)	<1.6 m.y.	Unknown
PA-15	Unnamed faults of the East Panama deformed belt	Panamá Sur (8) and offshore	Probably <15 k.y for entire belt	Unknown
PA-16	Samaon Hills fault zone	La Palma (11)	Probably <1.6 m.y.	Unknown
PA-17	Pirre Hills fault zone	Jaqué (12)	Possibly historic (1974); <15 k.y. for zone	Unknown
PA-18	Sambú fault zone	La Palma (11)	Probably <1.6 m.y.	Unknown
PA-19	Jaque River fault zone	Jaqué (12)	Probably <1.6 m.y.	Unknown
PA-20	Unnamed series of folds	Bocas del Toro (1)	Historic (1991); <15 k.y for series	Unknown
PA-21	Southern Panama fault zone	Offshore	Probably historic; <15 k.y for zone	Probably >5
PA-22	Colombian accretionary complex (deformation zone)	Offshore	Probably historic; <15 k.y for zone	>5

† From special series of 12 topographic maps at 1:250,000 scale entitled "Mapa General de la Republica de Panamá" (edition 10) by the Instituto Geografico Nacional "Tommy Guardia" (IGNTG), Ministerio de Obras Publicas, Panamá.

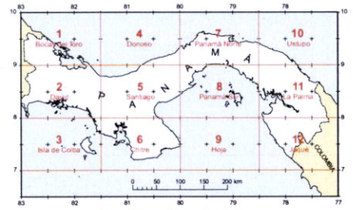


Diagram of topographic map sheets for Panama

Esquema de hojas topográficas para Panamá

MAP EXPLANATION

TIME OF MOST RECENT SURFACE RUPTURE
- Historic
- Holocene (<10,000 yrs) or post glacial (<15,000 yrs)
- Quaternary, undifferentiated (<1,800,000 yrs)

SLIP RATE
- > 5 mm/yr
- 1-5 mm/yr
- < 1mm/yr

QUALITY
- Continuous at map scale
- Poor or discontinuous at map scale
- Inferred or concealed

STRUCTURE TYPE
- Thrust or reverse fault (teeth on upper block)
- Right-lateral (dextral) strike-slip fault
- Left-lateral (sinistral) strike-slip fault
- Normal fault
- Anticline
- Syncline
- Plunge direction

PATTERNS
- Broad deformed belts
- Broad fracture zones

SIMBOLOGIA DEL MAPA

EDAD DE ULTIMA RUPTURA SUPERFICIAL
- Histórica (1991)
- Holoceno (<10,000 años) o post glacial (<15,000 años)
- Cuaternario, undiferenciado (<1,800,000 años)

TASA DE DESPLAZAMIENTO
- > 5 mm/año
- 1-5 mm/año
- < 1mm/año (o desconocida)

CALIDAD
- Continua en la escala del mapa
- Pobre o discontinua en la escala del mapa
- Inferida u oculta

TIPO DE ESTRUCTURA
- Falla inversa o corrimiento (triángulos en bloque superior)
- Falla de rumbo dextral
- Falla de rumbo sinestral
- Falla normal (círculo en bloque nondido)
- Anticlinal
- Sinclinal
- Dirección y buzamiento del eje

ESTAMPADOS
- Zonas ancha deforma
- Zonas ancha de fracturada

Digital data prepared with ARC/INFO version 7.1.2 running under UNIX on a SUN SPARC 5 workstation.

Land elevations from GTOPO30.

Map prepared by K. A. Bacheller using Adobe Illustrator version 6.0.1, and Aldus FreeHand version 4.0.

This report is preliminary and has not been reviewed for conformity with U.S. Geological Survey editorial standards. Any use of trade, product, or firm names is for descriptive purposes only and does not imply endorsement by the U.S. Government.

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 1886 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 1886)

- Caribbean plate currently converges toward both Panama Block and South America plate at about 15 mm/yr in a N105°E direction (although this direction is still under discussion). North of Panama, this relative movement is accommodated along the North Panama Folded Belt. This arcuate wide shallow belt of folds and thrust faults extends offshore parallel to the Caribbean coast of Panama from the Gulf of Uraba to the Limon area in Costa Rica. Schweig *et al.* (1999) described a dipping zone of seismicity extending from depths of 30 to 60 km consistent with the presence of subducted -Caribbean plate beneath Panama Block. This seismogenic structure has generated some of the largest historical earthquakes that affected Panama area: 1822 (Ms ~ 7.5-7.7), 1904 (Ms ~ 7.2), 1916 (Ms ~ 7.2 and Ms~6.9), 1991 (Ms 7.5);
- the western boundary of the Panama Block is still debated although the western end of the North Panama Deformed Zone (near Puerto Limon in Costa Rica) coincides with both a NE trending zone of widespread faulting and a gravity lineament which extend from the Pacific coast (NW of the aseismic Cocos Ridge) across Costa Rica, to the Caribbean coast near Puerto Limon. Distribution and kinematics of the aftershock sequence of the 1991 (Mw 7.7) Limon earthquake apparently support the interpretation of such diffuse left–lateral western boundary of the Panama Block;
- the eastern boundary of the Panama Block is widespread and involves numerous faults of various kinematics both in Panama and in Colombia. For instance, Jaque River, the Sambu and the Sanson Hills left lateral faults seems to partially absorb the tangential component of the displacement of the Nazca plate relative to South America – Panama plates. However, it may also account for accommodating the E-W trending convergence between Panama Block and South America plate when assuming that these strike-slip faults act as a roughly N-S right-lateral bookshelf structure. Moreover thrust and reverse fault such as the N-S trending Pirre Hills, Ungia or Utria fault in Panama seem to accommodate this above-mentioned E-W trending convergence although, to our knowledge, no accurate analysis have never been performed along these faults.

It may be concluded that, even when widespread, each plate boundary above-mentioned is capable for generating major earthquake. The far-field (regional) seismic hazard in a given site will be thus controlled by its closeness to one of these plate boundaries. Within such complex boundary conditions, the Panama Block appears as a rather rigid block. The state of stress prevailing within the Panama Block and its regional variability is nearly unknown, giving rise to somewhat confusing assumptions on both the kinematics and the degrees of activity of intraplate faults within Panama.

4. CRITICAL SEISMOGENIC SOURCES AND SEISMICITY

As far as the above-mentioned plate boundaries are concerned, due to the closeness of the site of interest to the North Panama Deformed Belt (relative to the above-mentioned seismogenic sources) and because of its significant historical seismicity, the North Panama Deformed Belt is controlling the **far-field seismic hazard**. For that reason, although the seismic hazard generated at Toabre dam site by other plate boundaries have been carefully checked, only the seismicity and the seismic hazard associated to the North Panama Deformed Belt seismogenic source are presented hereafter.

However, seismogenic sources may exist within the Panama Block although, to our knowledge, no clear evidence of surface rupture have been never found up to now, instead of detailed field investigations (see for instance Schweig *et al*., 1999, on the Rio Gatun fault or those assumed close to the Gatun dam). In order to estimate **near-field seismic hazard**, uncertainties on widespread seismicity and are discussed in a second chapter.

It must be noted that earthquake catalogue in Panama starts in 16th century although it is rather poor until 1900 because of uneven distribution of population and scarce written chronicles. However, large earthquakes with magnitude greater than 7.0 are recorded from the 18th century, although large uncertainties remain onto their locations (probably > 50 km) specially for the offshore ones.

4.1. The North Panama Deformed Belt

4.1.1. The 1822, May 7 earthquake

This earthquake is now assumed to have occurred near Costa Rica-Panama border. Damages reported at that time are similar to those observed during the 1991 Limon earthquake. Camacho and Viquez (1992) described the effects of this earthquake. Widespread liquefaction is reported along the coastal plain. Based on the regional intensity attenuation (Figs. 2 and 3), Camacho and Viquez (1992) derived a magnitude of about 7.6 (Ms). This earthquake is assumed to have occurred along a thrust of the western North Panama Deformed Belt segment.

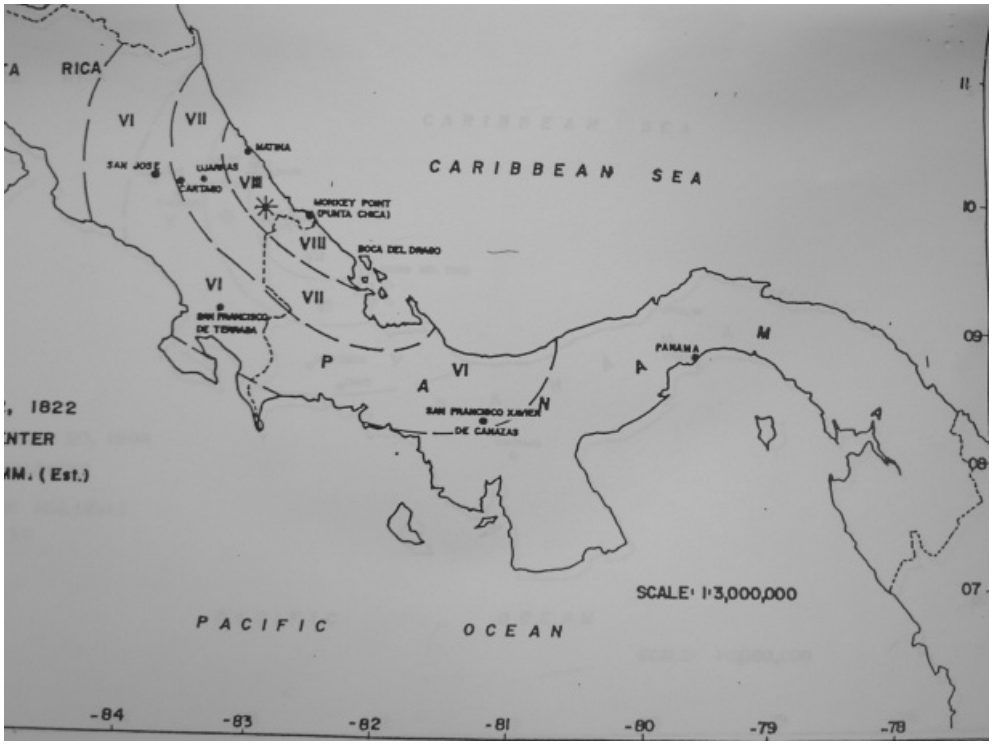


Fig. 3 - Macroseismic map of the 1822 earthquake. Star represent the assumed epicenter.

4.1.2. The 1882, Sept. 7 earthquake

This earthquake is the largest recorded in Panama since the 16th century. Camacho and Viquez (1993) described the effects of this earthquake, also revisited by Schweig et al. (1999). Widespread liquefaction is reported along the coastal plain and river valleys. A tsunami causing 68 victims affected the San Blas islands. Masonry buildings were destroyed or badly damaged in Colon and Panama. A magnitude ranging between 7.5 and 8.0 is generally ascribed to that earthquake. However, based on the regional intensity attenuation (Figs. 2 and 4), Camacho and Viquez (1993) derived a magnitude of 7.7 $\pm$ 0.3 (Ms) which seems to prevail in the former seismic hazard analysis conducted in Panama. This earthquake is assumed to have occurred along a thrust of the North Panama Deformed Belt at a depth of about 30 km. Based on a slip-rate of 15 mm/yr, Camacho and Viquez (1993) derived a deterministic return period of about 300 years.

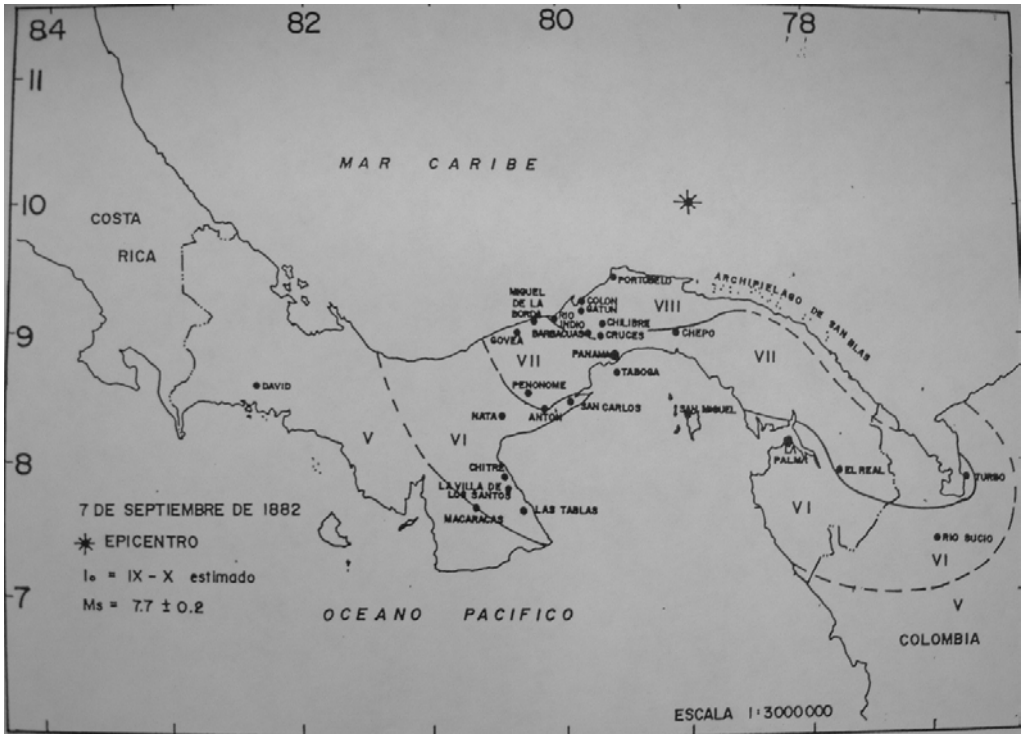


Fig. 4 - Macroseismic map or the 1882 earthquake. Star represent the assumed epicenter.

4.1.3. The 1904, Dec. 20 earthquake

This earthquake affected the same area than in 1822 (Limon-Bocas del Toro) although the far field effects seem to have been more limited (Figs. 2 and 5). Magnitude ascribed to that event varies from 7.0 to 7.5. This earthquake is assumed to have occurred along a thrust of the western North Panama Deformed Belt segment.

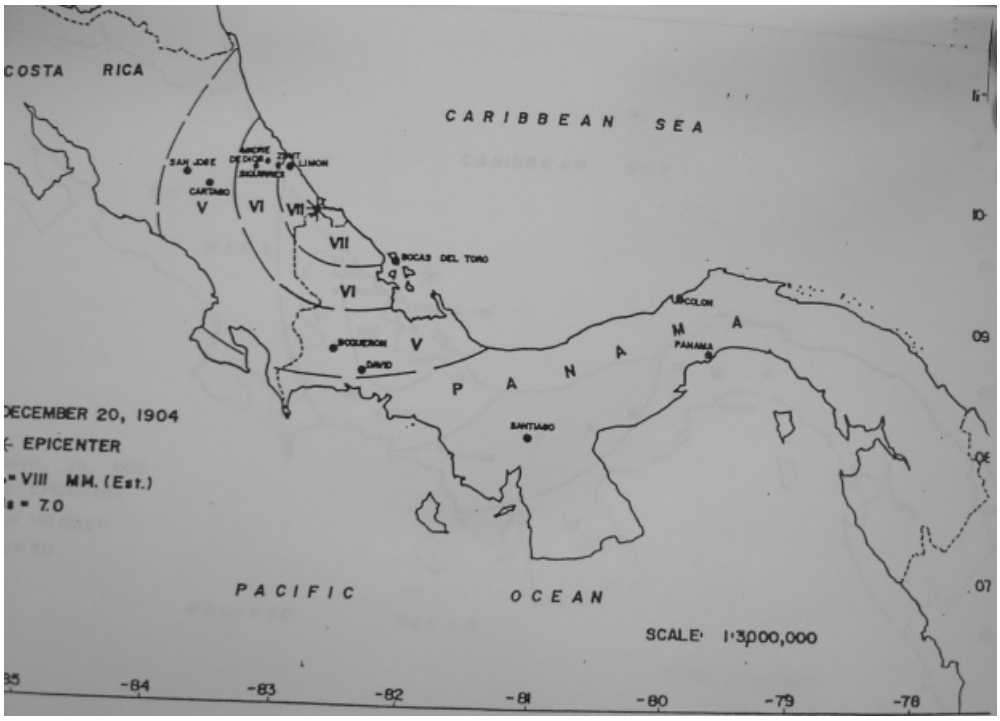


Fig. 5 - Macroseismic map of the 1904 earthquake. Star represent the assumed epicenter.

4.1.4. The 1914, May 27 earthquake

This earthquake occurred along the eastern segment of the North Panama Deformed Belt with an assumed depth of about 70 km beneath the Serrania de San Blas. This event has been strongly felt in Panama and Colon. A magnitude of about 6.5-7.2 is ascribed to that event.

4.1.5. The 1916, April 24 and 25 earthquakes

These earthquakes are assumed to have occurred near Costa Rica-Panama border (Limon-Bocas del Toro) (Fig. 2). Extend of the damages reported are similar to that of the 1904 Earthquake but slightly shifted eastwards (Fig. 6). A tsunami occurred and debris and boats were washed 200 m inland at Bocas town. Magnitudes ascribed to these events vary from 7.0 to 7.3. This earthquake is assumed to have occurred along a thrust of the western North Panama Deformed Belt segment.

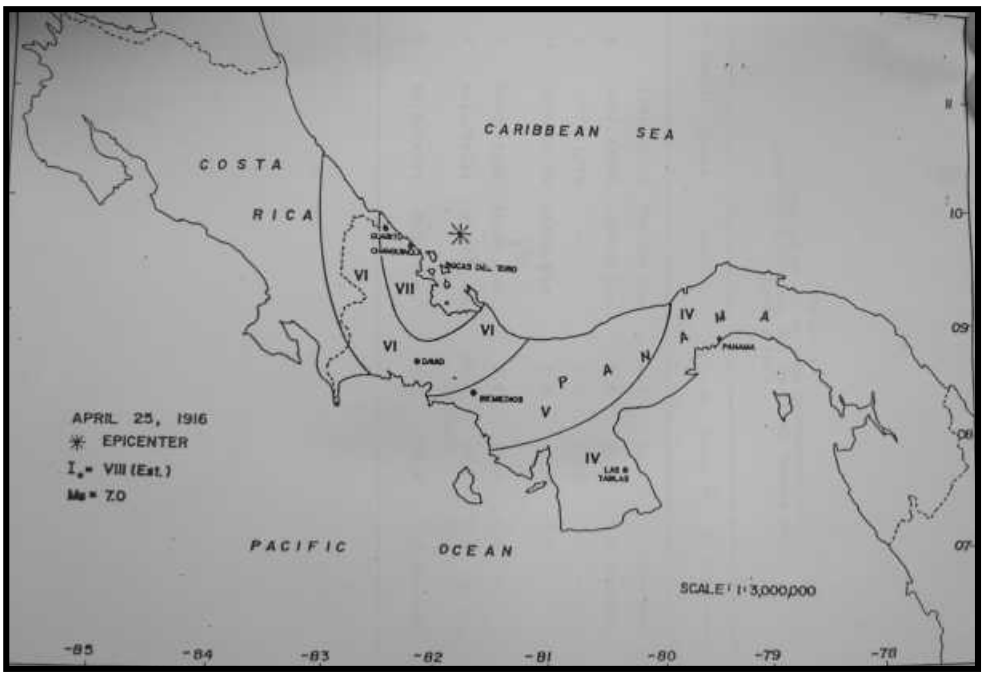


Fig. 6 - Macroseismic map of the 1916 earthquake. Star represent the assumed epicenter.

4.1.6 The 1991, April 22 earthquake

The Limon earthquake badly affected an area of 8 000 km^2 near Costa Rica-Panama border (Fig. 2). It ruptured the North Panama Deformed Belt which dips lanward at an angle of 30°. The rupture mechanism as analyzed by time-histories is quite complex and reveals that several sub-events have likely occurred. Aftershock sequence suggests a 85 x 45 km^2 rupture area. A magnitude 7.5 is given for that recorded event.

4.1.7 The 2000, Feb. 26 Earthquake

An event located 110 km Northeast of Panama City and about 60 km beneath the Serrania de San Blas in the subducted Caribbean plate was felt in Panama City.

4.1.8 North Panama Deformed Belt seismogenic capability

Although very few data are available on the geological structure of the North Panama Deformed Belt, some general features may be drawn from both the above described seismicity and the temporary seismogical records made by Schweig *et al.* (1999):

- The North Panama Deformed Belt corresponds to the Caribbean plate subduction beneath the Panama Block. A dip of the interface seems to range between 30° and 40° whereas deeper earthquakes seem to not exceed 60-70 km. This implies that the plate interface is at a depth of about 35 km beneath the Toabre dam site.
- Four main segments may be inferred from seismicity and strikes: (i) the NW-SW trending western segment (83°W-81.5°W) characterized by sustained significant seismicity with magnitude greater than 7.0, (ii) the NW-SE trending eastern segment (78.5°W-77°W) which also generated major earthquakes at depth of about 50-70 km, (iii) the E-W trending central East segment (80°W-78.5°W) which generated the major 1882 earthquake, and (iv) the NNE-SSW trending central West segment (81.5°W-80°W) characterized by a seismic quiescence associated by some authors to the absence of subduction.
- As far as the Central West segment is concerned when considering a N105°E convergence of Caribbean plate relative to South America plate, it is quite impossible that thrusting does not actually occur along that NNE-SSW trending segment of the North Panama Deformed Belt implying to consider this segment as a seismic gap.
- Thus, North Panama Deformed Belt segments seem to have a rather constant length of about 150 km, a dip of about 30°-40°, and a maximum depth of about 70 km. These features are consistent with 7.5-8.0 (Mw) magnitude earthquakes (see below).

4.2 Active faulting and seismicity within the Panama Block

4.2.1 General pattern of seismicity

Shallow seismicity in Panama Block is not really well-constrained. Since magnitudes are moderate, uncertainties on locations may be significant, and blast events have not been discriminated from the earthquake catalogue. During the USGS temporary (6 months) seismological network, Schweig *et al.* (1999) only recorded 3 earthquakes at shallow crustal

depth, two among them being associated to the Gatun Fault (see below). In the surroundings of Panama City, few features may be drawn (Terral, 2002, pers. comm.) : (i) the Panama Block appears relatively aseismic, (ii) earthquakes recorded are always with magnitude lesser than 5.6 (Ms) and (iii) focal depths are generally about 15 km.

Among these moderate to low magnitude-earthquakes, Viquez and Camacho (1992) discussed the 1621, May 2 earthquake with respect to the 1971 (5.6 Ms), January 20 one. We reported here their main conclusions:

- this earthquake is assumed to have occurred offshore between Panama City and Las Perlas islands. A magnitude between 5.6 and 6.0 is ascribed to that event;
- the damage area is similar that observed in 1971;
- it is assumed that this two earthquakes occurred on the same NW-SE trending fault within the Panama Bay.

This fault would be the southern extension of the so-called “Canal Discontinuity” proposed by Case (1974) based on gravity anomalies in Central Panama. This “Canal discontinuity” was though to crosscut the entire Isthmus following roughly the Panama Canal. However, to our knowledge, neither geological nor geological evidence supports that inference. Cowan (2001) mentioned that marine geophysical and geological studies in the Gulf of Panama evidenced that no deformation took place along the assumed fault trace since at least 3-5 millions years.

Very recently, on 2002, March 17th, a magnitude 5.2 (Ms) earthquake occurred at 40 km East of Panama City. Focal depth is assumed to be about 15 km, although no fault is known in that place.

Finally, Terral (2002, pers. comm.) mentioned a rough NE-SW trending alignment of instrumental seismicity with magnitude lower than 4.8 running from the Gatun Lake towards Toabre dam site.

This brief overview of the seismicity pattern suggests that the Panama block is an area of widespread low to moderate seismicity with probably a conservative upper threshold below about 5.5-6.0 (Mw). As a consequence, as far as seismic hazard analysis is concerned, taking into account the poor knowledge on the seismological characteristics, assuming that such an earthquake may occur everywhere within the Panama Block and in particular beneath the Toabre dam site does not seem too conservative.

4.2.2 Active faulting in the Panama Block

Few intraplate faults are reported in the surroundings of the Panama Canal, but their seismogenic capabilities and their significant distances to the Toabre dam site make them not critical for the present seismic hazard analysis.

They are just mentioned hereafter:

- the ENE trending Rio Gatun fault bounds the Northwest margin of the Madden Basin and the Mountain front of the Sierra Maestra. It separates middle/late Tertiary sediments of Madden basin from older (probably Cretaceous-Paleocene) sedimentary and igneous rocks. It has been mapped from the Gatun Lake to Boqueron River at the north end of the Madden basin. Morphological signature suggest normal faulting although no late Quaternary offsets have been documented on alluvial terraces or fans (Schweig, 1999). Rate < 1 mm/yr is inferred. Seismicity is weakly connected to that structure. Recent seismic hazard analysis assumed a seismognenic capability of 6.8 (Mw) along that the Rio Gatun Fault. Its shortest distance to Toabre damsite is about 90 km;
- the N-S trending, east facing Azote and Limon normal faults are located west and south of the western termination of the Rio Gatun Fault (Geological Map of the Panama Canal, scale 1:100,000, by Steward). To our knowledge, no recent faulting have been never evidenced along that two faults. Taking into their lengths, it seems reasonable to infer that both their seismogenic capability should be lower than 6.0 (Mw) and their degree of activity are comparable to, and even lower than, the Rio Gatun Fault. The shortest distance to the Toabre dam site is about >100 km;
- the faults identified by Schweig *et al*. (1999) in the surroundings of the Gatun dam and within the Limon Bay have a limited extension and are probably inactive or with a very low degrees of activity. Theoretically, they seems capable to generate 5.0-6.0 magnitude earthquakes although their distance to the Toabre dam site remains greater than 50 km;
- careful analysis of both Landsat images and Digital Elevation Model (30 m) does not reveal any evidence of active faulting and even faults in the close surroundings of the Toabre dam. Thus it may be concluded that either capable faults in the near-field do not exist or they should have small extensions and very low degree of activity.

4.2.3 Near-field seismogenic capability

In the present knowledge, in order to take into account uncertainties related to both the widespread seismicity within the Panama Block and the possibility of slow faults of limited extension in the near-field of the dam, it has been conservatively assumed a 5.5-5.9 earthquake located at 15 km beneath the dam site.

5. SEISMIC HAZARD ASSESSMENT

5.1 Introduction

The seismic hazard assessment has been carried out in several steps:

- determination of the period of return of design earthquakes related to the “acceptable” risks considering the service-life;
- determination of the magnitude of the reference earthquakes likely to occur on each identified active faults or/and seismogenic sources during the time-window related to the acceptable risks;
- estimates of the Peak Ground Accelerations (PGA) at site induced by each reference earthquake on each identified active faults;
- estimates of the acceptable ground motions at site.

5.2 Design Earthquakes

We adopt here the recommendations of the “International Commission on Large Dams”[1] suggesting 3 design earthquakes: the Maximum Credible Earthquake (MCE), the Maximum Design Earthquake (MDE), and the Operating Basis Earthquake (OBE). These reference earthquake are expressed in terms of ground motions at the dam site, generally the Peak Ground Acceleration:

- the Maximum Design Earthquake (MDE) will produce the maximum level of ground motion for which the dam should be designed or analyzed. The dam should stay “fail safe”. For dams whose failure would present a great social hazard, the MDE will normally be characterized by a level of motion equal to that induced by the most severe combination of maximum magnitude and minimum distance to the site independent of the return period. Should the failure of the dam present no hazard to life, a lower level of ground motion may be acceptable, based on economic considerations. It is commonly accepted that the probability of occurring of the MDE should be about 10 % during the service life (about 100 years) which corresponds to a 950-years-return period;

- the Operating Basis Earthquake (OBE) represents the level of ground motion at the dam site at which only minor damage is acceptable. The dam, appurtenant structures and equipment should remain functional and damage easily repairable, from the occurrence of earthquake shaking not exceeding the OBE. It is derived taking account both the design period of the structures and the past seismicity identified either in catalogues or dated in the field. Consequently, it is highly dependent on knowledge of the seismogenic behavior of critical active faults in time. Typically, the probability of occurring of the OBE should be

[1] ICOLD, 1989 – Selecting Seismic Parameters for Large Dams – Guidelines.

about 50% during the service life (about 100 years) which corresponds to a 145-years-return period;

- with each of these design earthquakes generating features the notion of Maximum Credible Earthquake (MCE) is linked. This is the largest reasonably conceivable earthquake that appears possible along a recognized fault or within a geographically defined tectonic province, under the presently known or presumed tectonic framework. The MCE is generally defined as an upper bound of expected magnitude.

Table 1 shows the return periods associated to each above-mentioned design earthquakes.

Table 1 - Return period associated to design earthquakes.

Design Earthquakes	Mean return Period (in years)	Codes
MCE	-	ICOLD
MDE	950	ICOLD
OBE	145	ICOLD

5.3 Estimate of the Maximum Credible Earthquake (MCE)

A maximum magnitude (Maximum Credible Earthquake, MCE) has to be assigned to each identified critical seismogenic source, e.g. faults capable of representing a threat to the site of interest. This is the largest reasonable conceivable earthquake that appears possible along a recognized fault, under the presently known or presumed tectonic framework. The capability of these faults should have been ascertained through historical and instrumental seismic data and geological criteria such as the rupture length-magnitude, the rupture area, the slip-vector-magnitude, the slip-rate-magnitude and seismic moment-magnitude relationships.

Recently, the use of seismic moment has provided a physically meaningful measurement of the size of a faulting event. Seismic moment (Mo), in dyne-cm, is expressed by the equation:

$$Mo = \mu \cdot Af \cdot D$$

in which μ is the shear modulus of the material along the fault plane and is typically equal to $3x10^{11}$ dyne/cm^2 for crustal rocks, Af is the area, in square centimeters, of the fault plane undergoing slip, and D, in centimeters, is the average displacement over the slip surface.

Seismic moment provides a basic link between the dimensions of the fault and the seismic waves radiated due to rupturing along the fault. Seismic moment is therefore more reliable than the other methods. Kanamori (1977[2]) and Hanks and Kanamori (1979[3]) introduced a moment-magnitude scale, Mw, in which magnitude is calculated from seismic moment using the following formula:

$$Log\ Mo = c\ Mw + d$$

[2] *Bull. Seism. Soc. Am.,* **69**, 1645-1670.
[3] J.G.R., **84**, 2348-2350.

The moment-magnitude is different from other magnitude scales because it is directly related to average slip and ruptured fault area, while the other magnitude scales reflect the amplitude of a particular type of seismic wave.

The MCE on each identified active fault segment may be derived using a scale transfer from the fault-area (Wells et Coppersmith (1994[4]). These authors compiled worldwide surface breaks related to earthquakes and derived relationships between the seismic moment and the fault-area according to the kinematics of the fault broken.

For reverse faults, the relationship is the following :

$$Mw = 4.33 + 0.9 \times \text{Log}(S)$$

For normal faults, the relationship is the following :

$$Mw = 3.93 + 1.02 \times \text{Log}(S)$$

with S, the fault area in km^2 and a standard deviation of 0.25.

In the present knowledge, the Maximum Credible earthquake to be taken into account in the Toabre dam design is the following:

- for the North Panama Deformed Zone, taking into account both the historical seismicity (in particular the 1822, 1882, 1904, 1914, 1916 and the 1991 earthquakes), the segmentation and the dip of Caribbean-Panama interface above-described, and assuming a seismic rupture of about 130 km long over the half of the seismogenic layer, it seems that the seismogenic capability of this seismogenic source range between 7.7 and 8.0 (Mw) corresponding to a rupture area of 6600 ± 600 km^2 with a co-seismic displacement of about 3.5-5.5 m;
- for the near-field earthquake, in order to take into account uncertainties related to both the widespread seismicity within the Panama Block and the possibility of slow faults of limited extension in the near-field of the dam, it has been conservatively assumed a 5.5-5.9 (Mw) earthquake located at 15 km beneath the dam site onto a fault having a slip rate lower than 0.05 mm/yr. Such an event corresponds to a rupture area of 35 ± 15 km^2.

5.4 Recurrence of Seismicity of critical Seismogenic Source

The seismic parameters that characterize each area are defined by the frequency distribution law or recurrence curve for the different sizes of earthquakes in each area. This distribution was defined by Gutenberg and Richter (1944) and assumes that the number of earthquakes (N) decreases exponentially with its magnitudes (M), according to the following formula:

$$\log_{10} N(M) = a - bM$$

[4] *Bull. Seism. Soc. Am.*, **84**, 974-1002.

where N(M) is the number of earthquakes greater than M, “a” the annual earthquake rate of a magnitude greater than 0 in the region, and “b” is the value which defines the proportion of major earthquakes compared with small earthquakes.

This equation assumes that all earthquakes are independent of space and time, *i.e.* it has the properties of a Poisson model.

According to the detailed analysis of the earthquake catalogue carried out by Camacho *et al.* (1994) for updating the seismic hazard for Panama, the b-value must be taken as equal to 1 for all the Panama territory.

5.5 Estimate of the reference magnitudes

The seismic moment, M_O, is the most physically meaningful parameter to describe the size of an earthquake in terms of static fault parameters

$$Mo = \mu A_r D$$

where μ is the rigidity or shear modules (usually taken to be about 3 x 10^{11} dyne/cm²), A_r is the rupture area on the fault plane undergoing slip during the earthquake, and D is the average displacement over the slip surface. The total seismic moment rate $M_O{}^T$ or the rate of seismic energy release along a fault is estimated by:

$$M_O{}^T = \mu A_f S$$

where S is the average slip rate along the fault, and Af the total fault plane area. The seismic moment rate provides an important link between geologic and seismicity data. Seismic moment is translated to earthquake magnitude according to an expression of the form.

$$\log Mo = c.m + d$$

The moment magnitude, m, is considered to be equivalent to the local magnitude in the magnitude range $3 < M_L < 7$ and to the surface wave magnitude in the magnitude range $5 < M_S < 7½$.

Once the fault slip rate is used to constrain the seismic moment rate on the fault, a model must be assumed for the manner in which the rate of moment release is distributed to earthquakes of various magnitudes. Several authors have developed relationships between earthquake recurrence parameters and fault or crustal deformation rates, assuming an exponential magnitude distribution.

The link between fault slip rate and earthquake rates is made through the use of seismic moment. The total rate of seismic moment can be related to earthquake occurrence rate by the expression

$$M_T^o = \int_{-\infty}^{Mo} n(M).Mo(m).dm \qquad (1)$$

where n(m) is the density function for earthquake occurrence rate and may be expressed according to Youngs and Coppersmith (1985)[5] as:

$$n(m) = \frac{N(m^o)\,\beta \exp(-\beta\left(m - m^o\right)}{1 - \exp\left(-\beta\left(m^u - m^o\right)\right)} \text{ for } m \leq m^u$$

$N(m^o)$ is the normalized number of events per unit time, m^u is the upper bound magnitude ($n(m) = 0$ for $m > m^u$), m^o is some arbitrary reference magnitude, β = b.Ln10 with b from the Gutenberg-Richter exponential frequency magnitude relationship log N(m) = a - b.m, when N(m) is the cumulative number of earthquake of magnitude greater than m, and a and b are constants.

Integrating equation (1), we obtained we obtained the reference magnitude corresponding to a given return period as function of the upper bound magnitude m^u, the associated upper bound seismic moment, the slip-rate assumed along the fault, the chosen period of return, the b-value from the Gutenberg-Richter exponential frequency magnitude relationship, and the total fault plane area.

$$\mu A_f S = bN\left(m^o\right) M_o^u \exp\left(-\beta\left(m^u - m^o\right)\right) / \left(c - b\right)\left(1 - \exp\left(-\beta\left(m^u - m^o\right)\right)\right) \qquad (2)$$

which is equivalent to the relationship developed by Anderson (1979) and the type 2 relationship presented by Anderson and Luco (1983). The term M_o^u is the moment for the upper bound magnitude m^u. Assuming the slip rate, S, on a fault is known, equation (2) provides a constraint on the three parameters of the recurrence relationship $N(m^o)$, b, and m^u.

The constraint imposed by fault slip rate allows the development of fault-specific recurrence relationships in regions where the historical seismicity data are only sufficient to establish the regional recurrence rate for small to moderate size earthquakes. For each fault in the region, estimates of the upper bound magnitude, m^u, can be made using fault characteristics. The historical seismicity data can be used to determine a regional b-value. Assuming the individual faults have all a b-value equal to the regional b-value, the earthquake activity rate for each fault, $N(m^o)$, can be computed from the estimated slip rate for the fault using equation (2).

Hereafter (Table 2), we estimate the reference magnitudes along each identified active faults taking into account the period of return of the reference earthquakes ($N(m_o) = 1/Tm$), the slip-rate along the faults (s) the maximum seismogenic capability of the faults and the b-value.

$$m^o = m^u - \frac{1}{b.\text{In } 10} \text{ In}\left[1 + \frac{N\left(m^o\right) \text{ x } b \text{ x } M_o^u}{\left(1.5 - b\right)\mu \text{ Af S}}\right] \qquad (3)$$

where M_o^u is the seismic moment corresponding to the maximum credible magnitude along a given fault.

[5] *Bull. Seism. Soc. Am.*, **75**, 939-964.

The parameters selected for estimating the magnitude associated to the design return period are :

- North Panama Deformed Belt

m^u = 7.77 ±0.3 (Mw)
b = 1[6]
Af = 6600 ±600 km^2
S = 10-15 mm/yr

- Near-field earthquake

m^u = 5.5 ±0.4 (Mw)
b = 1
Af = 35 ±15 km^2
S = 0. 05-0.01 mm/yr

Curves of magnitude versus mean return periods on each identified fault are reported on Figure 7.

[6] According to the above-mentioned relationships (3), uncertainty lesser than 10 % on the estimate magnitude is obtained when selecting b = 1

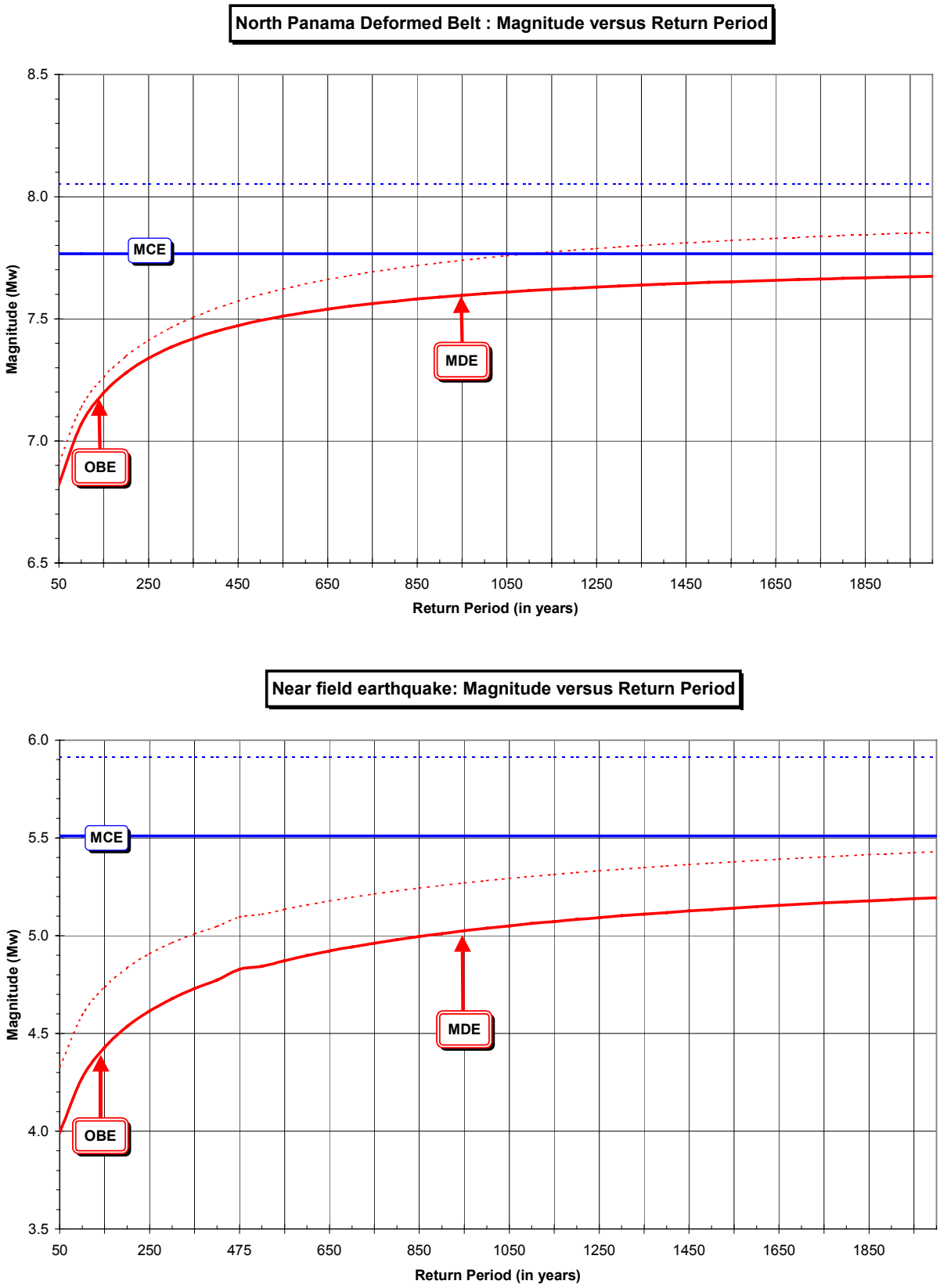


Fig. 7 - Curves of magnitude versus return periods for critical seismogenic sources.

Table 2 - Estimate of the reference magnitudes along the identified seismogenic sources.

Seismogenic Sources	MCE	σ	MDE	σ	OBE	σ
North Panama Deformed Belt	7.77	0.30	7.60	0.14	7.2	0.07
Near field EQ	5.50	0.40	5.02	0.24	4.43	0.31

5.6 Attenuation Laws

The Peak Ground Accelerations (PGA) (peak zero period acceleration) at the bed-rock at sites corresponding to the reference earthquakes (MCE, MDE and OBE, and SMDE and SDE) are inferred from attenuation laws of common practice in Engineering. This solution is statistically more representative than the derivation of a reference ground motion from only one accelerogram.

5.6.1 Campbell, 1997

Campbell (1997) summarizes the results of several years' work developing empirical relations for horizontal and vertical PGA, PGV and SA in active tectonic regions. These latest versions were developed using, a much larger data set than earlier versions. Campbell's suite of attenuation relationships are designed to be used to estimate ground motion from earthquakes of M > 5.0 at sites within 60 km. The 84-percentile PGA value is conservatively adopted in the present analysis.

5.6.2 Sadigh, 1987

The Sadigh relationship (1987) is based on worldwide data instead of exclusive Californian data, specific for shallow depth earthquakes. This predictive equation for randomly oriented horizontal components of peak acceleration has been developed for both rock sites. The equation was derived for strike-slip earthquakes. The 84-percentile PGA value is conservatively adopted in the present analysis.

5.6.3 Dahle, 1995

Dahle (1995) derived new spectral strong motion attenuation models for Central America. Empirical relations for horizontal PGA and SV are developed for rock and soil conditions. The 84-percentile PGA value is conservatively adopted in the present analysis.

5.6.4 Joyner, 1999

Joyner (1999) derived an attenuation law for magnitude-7.7 subduction-earthquakes based on the 1985 Valparaiso Chilean earthquake. For that reason, this law is used for the North Panama Deformed Belt MCE. However, since this law is quite specific and rather conservative with respect those available in the scientific literature, it is recommended to only consider the median value.

5.7 Peak Ground Acceleration at site

Taking into account the North Panama Deformed Belt geometry, the closest distance to the Toabre dam site is about 60 km.

It has been assumed a focal depth of 15 km for the near-field earthquake.

Curves of constant risk on each identified fault are reported in Figures 8 and 9. In Table 3, Peak Ground Acceleration at site associated with the MCE, MDE and OBE design earthquakes are reported.

Recommended PGA for the Toabre dam site are reported in Table 4.

Table 3 - Estimate of the reference PGA (in g) generated at site (rock).

Faults	Laws	MCE	MDE	OBE
North Panama Deformed Belt	Joyner 1999	0.31	-	-
	Sadigh 1987	0.33	0.25	0.20
	Campbell 1997	0.24	0.21	0.17
	Dahle 1995	0.26	0.24	0.21
	Recommended	**0.31**	**0.25**	**0.20**
Pedro Miguel Fault	Sadigh 1987	0.19	0.13	0.09
	Campbell 1997	0.18	0.13	0.08
	Dahle 1995	0.16	0.14	0.12
	Recommended	**0.19**	**0.14**	**0.10**

Table 4 - Recommended PGA (in g) for Toabre dam site.

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

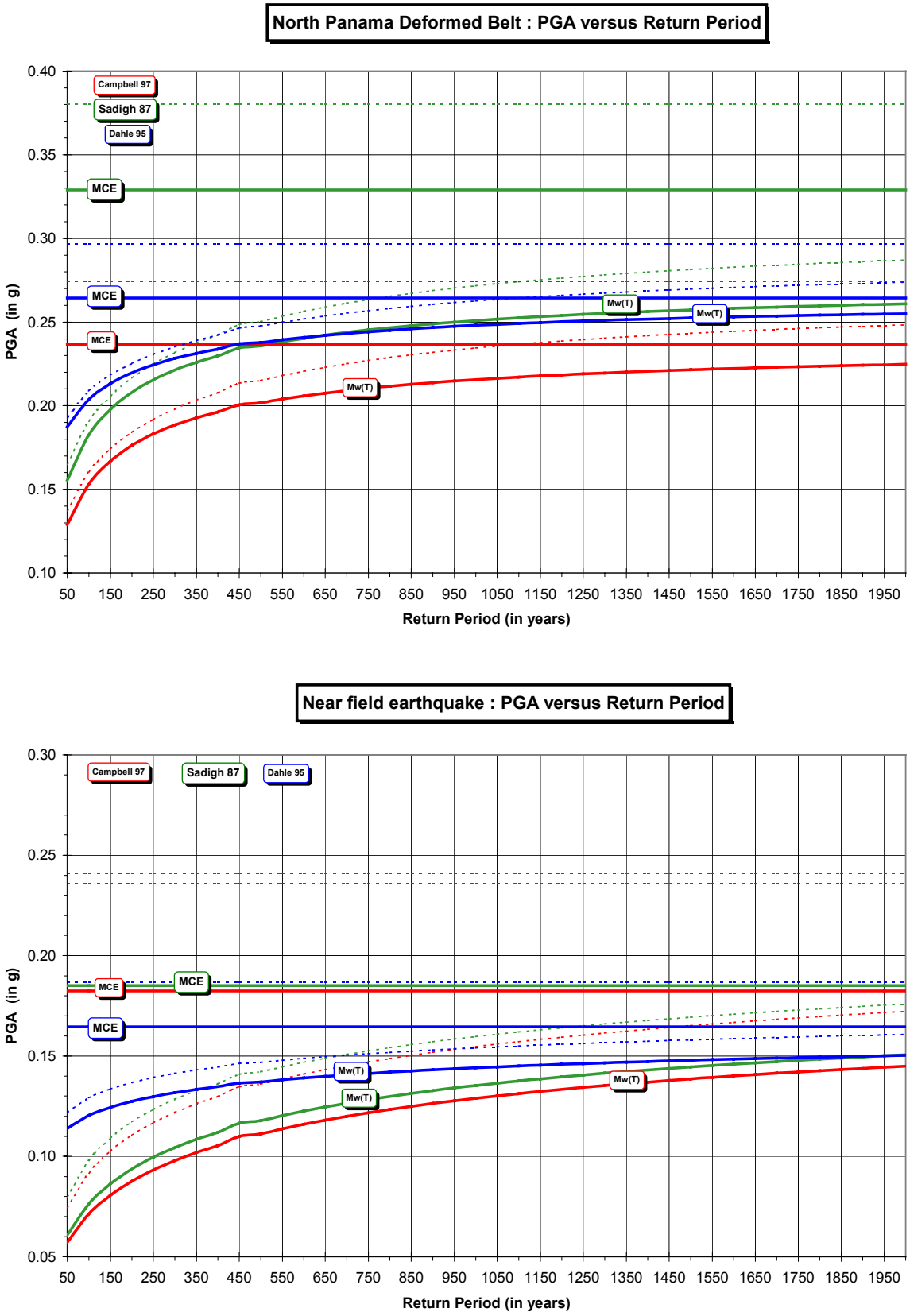


Fig. 8 - Curves of PGA versus return periods for critical seismogenic sources.

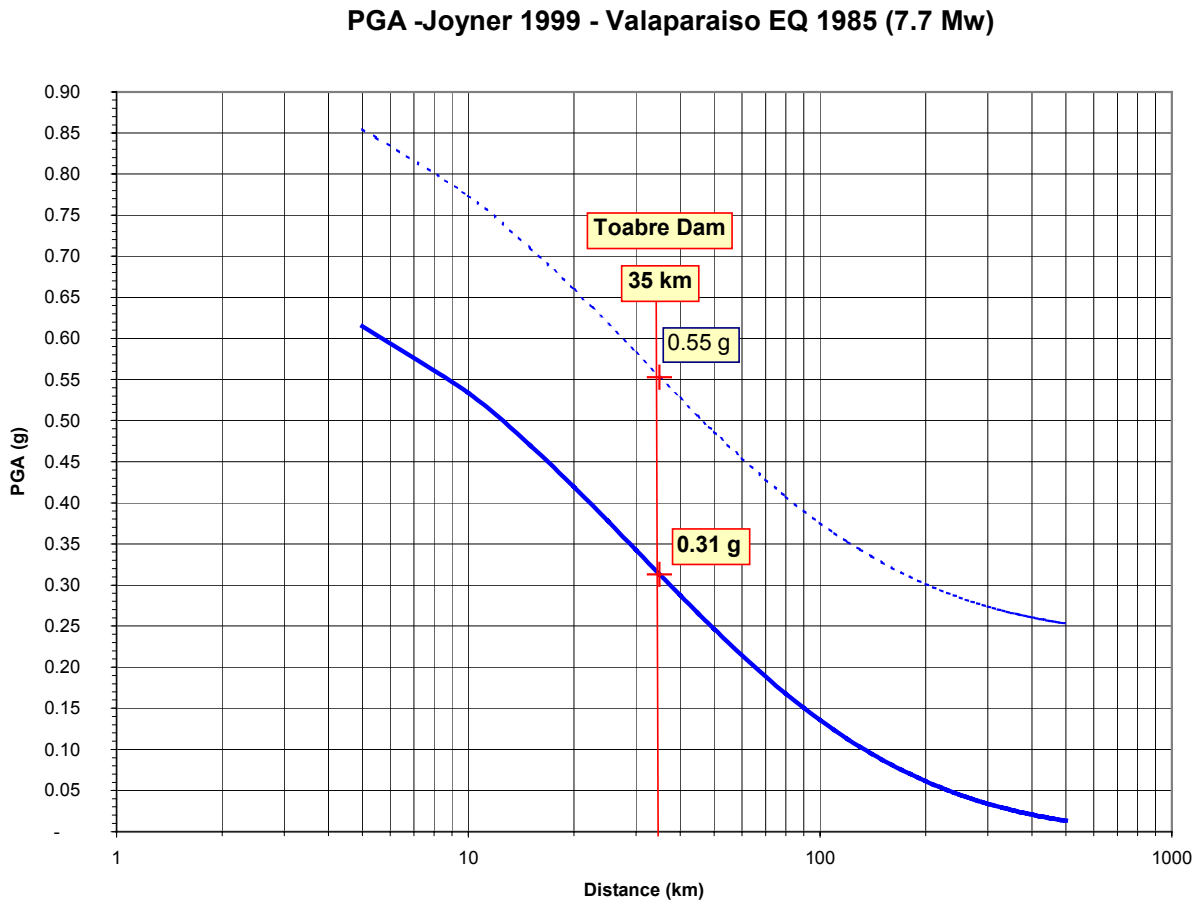


Fig. 9 - Curve of PGA derived from the 1985 Valparaiso earthquake. PGA expected for the MCE at Toabre Dam site.

5.8 Duration of the dynamic solicitation

5.8.1 Introduction

The duration of a seismic signal mainly depends on the two following parameters :

- magnitude of the earthquake,
- distance from the source to the recording station.

The aim of the present work is to estimate the duration of seismic loading to be considered in the design of the Toabre Dam (MCE = 7.7Mw). The duration has been estimated by using accelerometric data, which are available at the BRGM (French Geological Survey).

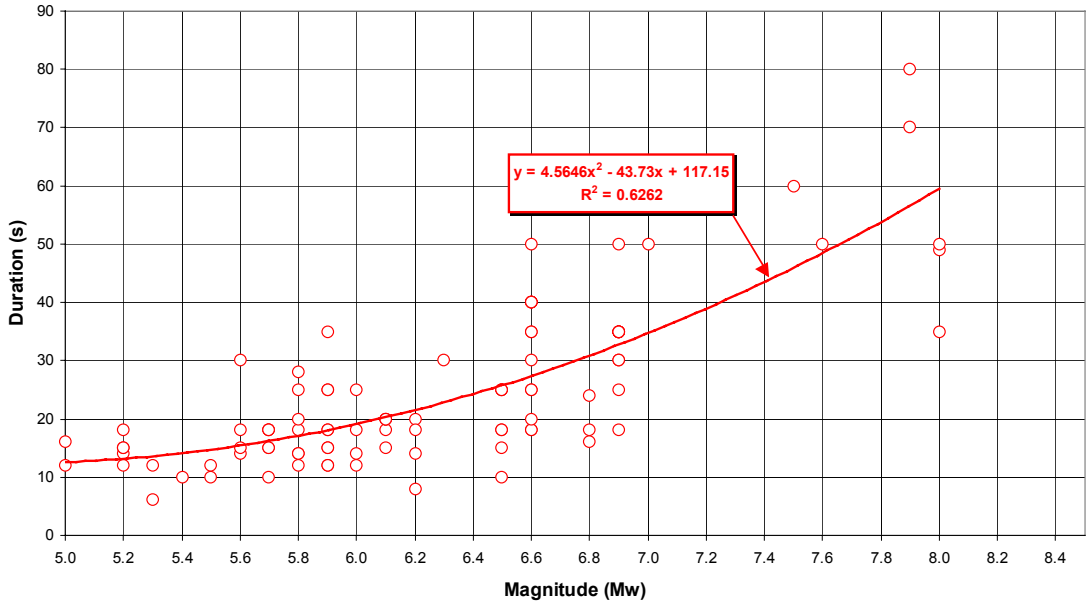
5.8.2 Available data

In 1998, the BRGM has realized, within a research project, an accelerometric data bank. This bank is composed on 108 accelerograms recorded at rock sites, in 14 seismic regions of the world (numerical data of these accelerograms are presently available in the data bank).

For the estimation of duration of signal corresponding to an earthquake of magnitude Mw<8.0, we have selected in the data bank, the 101 records, which respond to the two, following criteria : (i) epicentral distance $\leq$ 100 km, (ii) magnitude Mw $\geq$ 5.

5.8.3 Estimation of the duration of the signal

The duration of the selected records versus magnitude Mw has been reported on a graph (Fig. 10). Then, we have calculated a two-class polynomial regression on those data. The equation of this curve and the uncertainty (R2) are indicated on the figure 10. The tendency curve permit us to estimate the statistical duration of the signal for the Maximum Credible



Earthquake (7.7 Mw) of the order of 50 seconds (R2=0.6262).

Fig. 10 - Curve of PGA derived from the 1985 Valparaiso earthquake. PGA expected for the MCE at Toabre Dam site.

5.9 Response spectra and time histories at site

5.9.1 Response spectra

The horizontal spectral acceleration response is evaluated for rock soil from several laws. Various laws have been considered in that analysis : Sadigh et al. (1987), Sadigh et al. (1997), Campbell (1997), Abrahamson and Silva (1997), RFS98 (1999). We emphasize that these empirical response spectra are statistically more representative than that corresponding to only one given earthquake.

As far as the spectral accelerations are concerned, Campbell (1997) as well as Abrahamson & Silva (1997) give the more constraining law, although Sadigh et al. (1987) displaces the maximum spectral acceleration from 0.15 to 0.2 s.

Response spectra have been estimated for both near- and far-field MCE reference earthquakes (Fig. 11). It must be noted that only the far-field loading is critical for the Toabre Dam.

The spectral acceleration that we take into account is then the one which wrap both the Campbell (1997) and Sadigh's (1987) empirical attenuation laws (Fig. 12). Since these two response spectra have their maximum spectral analysis for different periods, we derived a final response spectra (5% damping) with an horizontal plateau at 0.73 g between periods 0.1 and 0.3 g (see table hereafter). It must be noted that this aspect is quite consistent with response spectra generally recommended in seismic resistant regulation.

Table 5 - Recommended spectral values for Toabre dam site (5% damping).

Period (s)	SA (g)	PSV (CM/S)	Frequency (Hz)
0.01	0.31	0.48	100.00
0.05	0.50	3.90	20.00
0.075	0.58	6.79	13.33
0.1	0.73	11.40	10.00
0.2	0.73	22.79	5.00
0.3	0.73	34.19	3.33
1	0.30	46.84	1.00
2	0.14	43.72	0.50
4	0.05	31.23	0.25

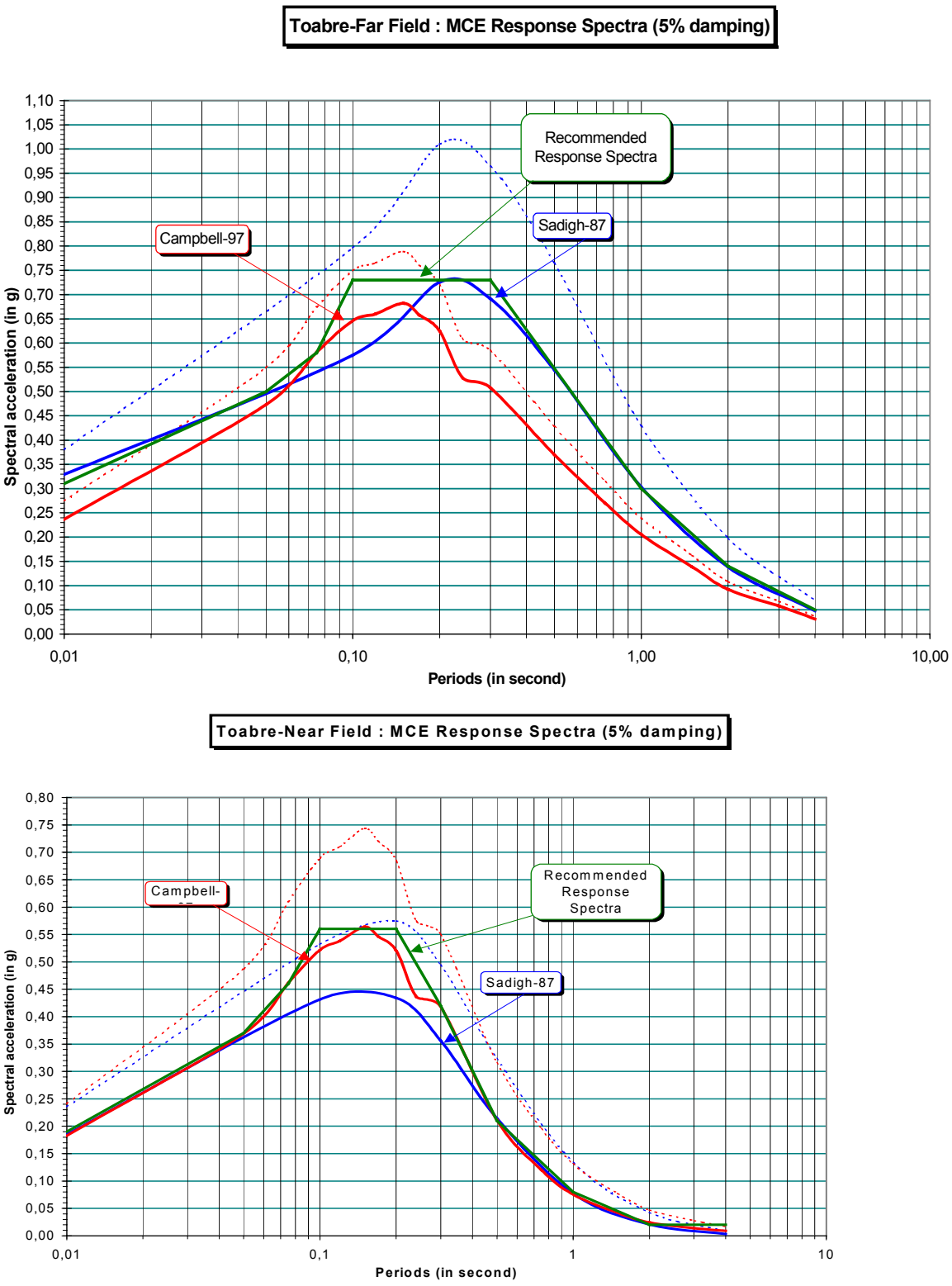


Fig. 11 - Response spectra at Toabre Dam site associated to the MCE far- and near-field reference earthquakes.

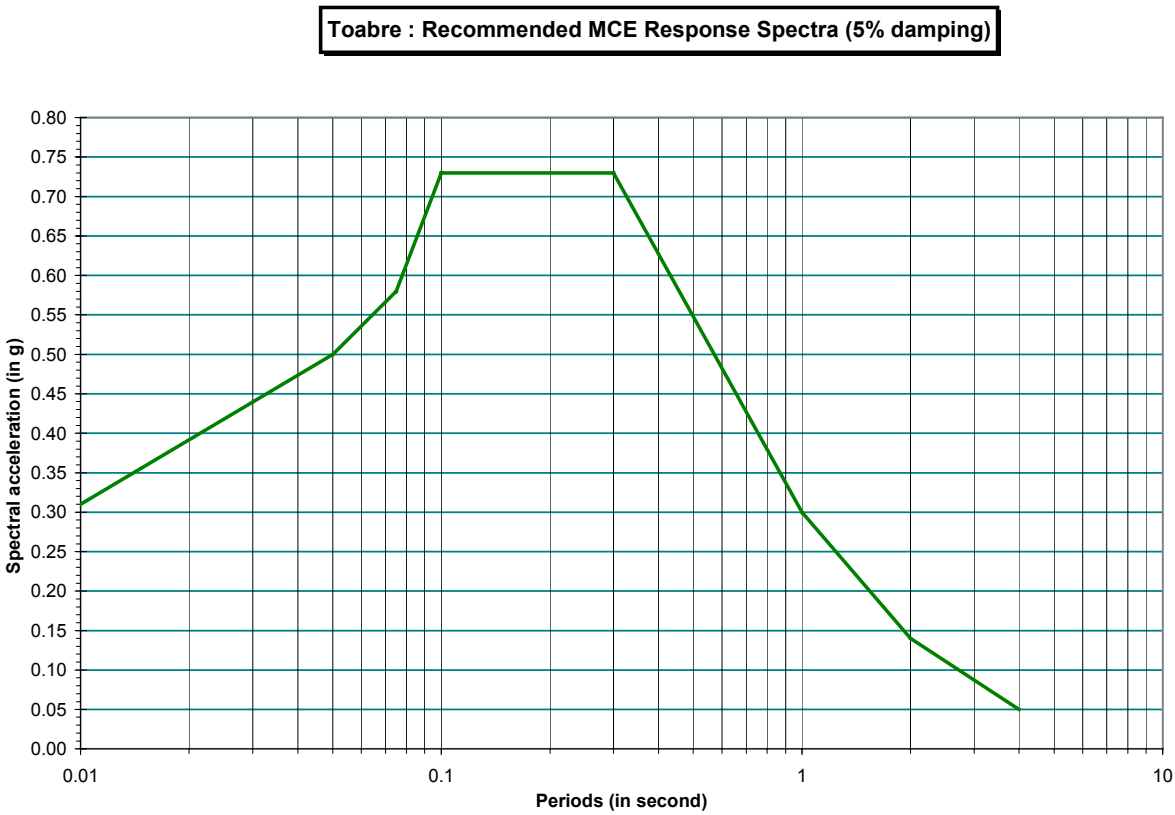


Fig. 12 - Recommended Response spectra at Toabre Dam site.

5.9.2. Synthetics time-histories

SIMQKE (Gasparini & Vanmarcke, 1978) is used to generate statistically independent artificial acceleration time histories. It tries to match a specified response spectrum by iteration. The method used by the code is based on the sum of sinusoidal waves of pseudo-random phase. The artificial times series are the obtained by multiplying the stationary signal with a function chosen by the user which represents the ground motion intensity variation with time. Three kinds of curve can be used: trapezoidal, exponential or compound.

In our simulations, we choose the exponential curve. This curve leads in more realistic time series in which the maximum value of acceleration is reached only a few times. This curve is defined by the relation:

$$F_e(t) = e^{-at} - e^{-bt},$$

where *a* and *b* are two parameters fixing the rising part and the descending part of the curve respectively.

From the spectrum evaluated in the previous chapter, five synthetical accelerograms were computed with SIMQKE using the exponential envelope curve (Fig. 14). Digital data relative to these 5 synthetic time histories are given in the attached floppy disk.

It has been assumed various scenarii with a rapid rising of the solicitation from 5 to 10 s followed by a progressive and smooth decreasing of the signal (Fig. 13). The parameters are given in the table:

Table 6 - Parameters of the exponential envelop curve.

File name	Toab1	Toab2	Toab3	Toab4	Toab5
Sampling (s)	0.01				
Duration (s)	50				
Parameter a	0.30	0.24	0.18	0.13	0.11
Parameter b	0.11	0.10	0.09	0.08	0.08

The number of acceleration maximums is almost equivalent in the five time series (Fig. 15). It is the distribution of these maximums that differs from a synthetics to the other. In toab1 file the maximums are gathered in the first 12 seconds whereas in toab5 they are spread over 20 seconds of signal. This distribution difference allows to test the soil behavior for different kind of plausible seismic solicitations.

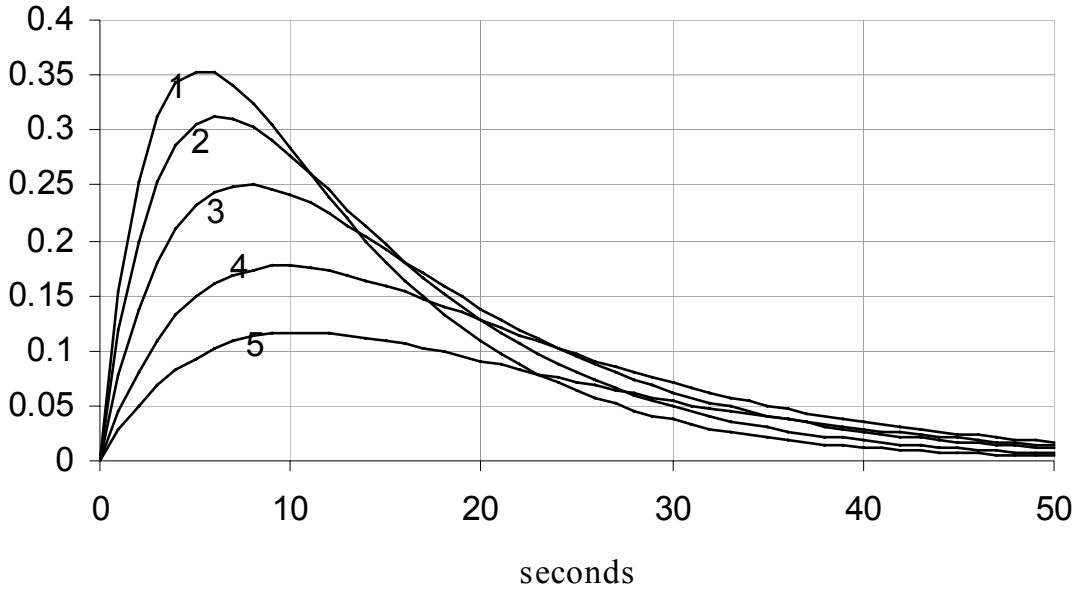


Fig. 13 - Envelop curves used to compute artificial accelerograms.

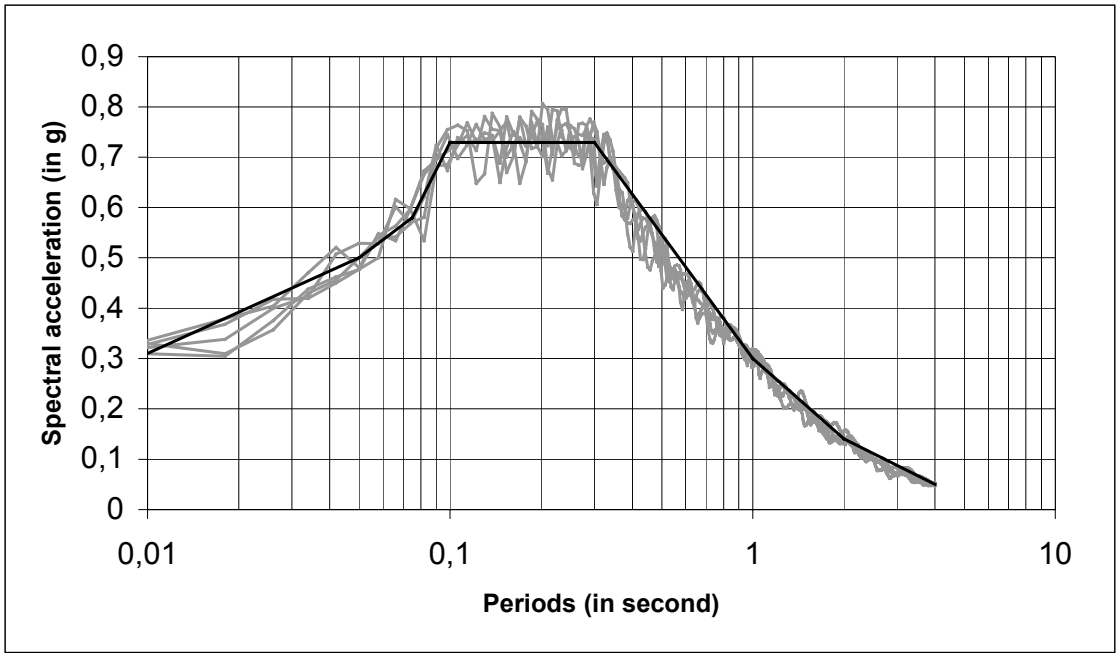


Fig. 14 - Synthetical spectral acceleration response, compared to the evaluated spectrum (5% damping).

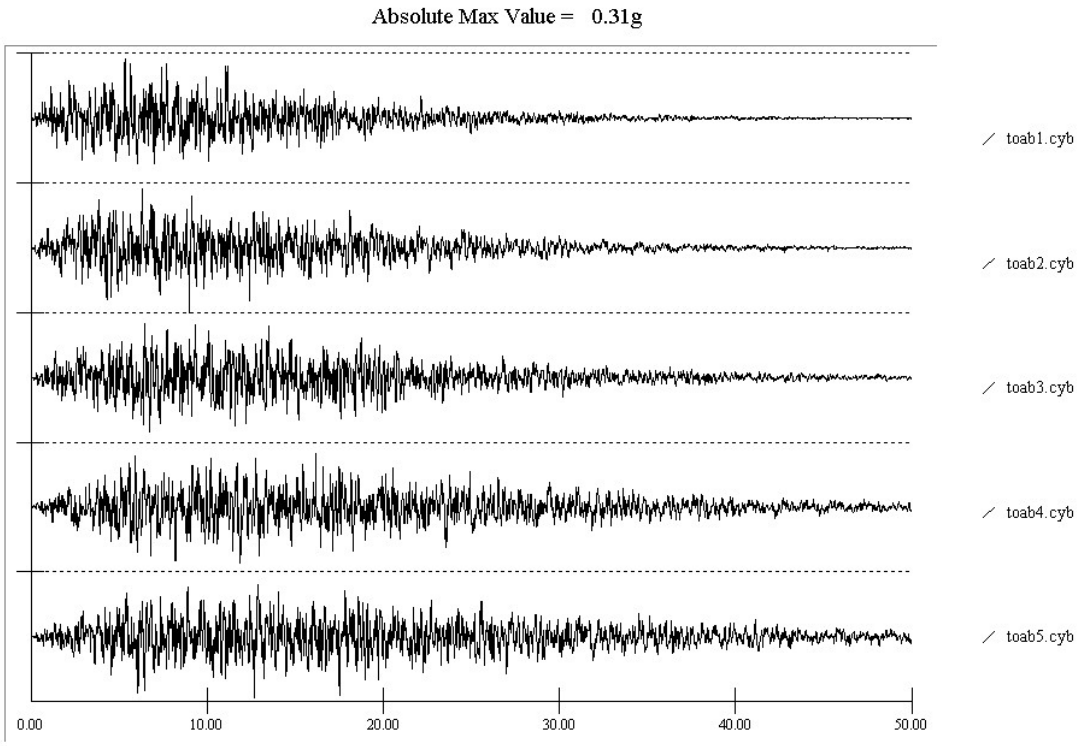


Fig. 15 - Synthetical accelerograms. From top to bottom: toab1;toab2; toab3; toab4 and toab5.

6. CONCLUSIONS

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 interfere giving rise to significant seismicity.

A regional probabilistic seismic hazard carried out by Camacho *et al.* (1994) results for the Toabre dam site area in Peak Peal Ground Accelerations at bedrock of 0.13 g, 0.18 g and 0.23 g for mean return periods of 250, 500 and 1000 years respectively.

In order to validate/or implement this seismic hazard, an analysis of available scientific literature and technical reports has been conducted in March 2002. The main results are the following:

- the North Panama Deformed Belt which corresponds to the Caribbean plate subduction beneath the Panama Block actually controls the **far-field seismic hazard**;
- in the present knowledge, in order to take into account uncertainties related to both the widespread seismicity within the Panama Block and the possibility of slow faults of limited extension in the near-field of the dam, it has been conservatively assumed a 5.5-5.9 earthquake in the **near-field**;
- based on fault segmentation, kinematics, rates, a historical seismicity, the magnitudes associated to design earthquakes recommended by ICOLD have been derived:

Return periods->	MCE -	MDE 950 yrs	OBE 145 years
North Panama Deformed Belt	7.7	7.6	7.2
Near-field EQ	5.5	5.0	4.4
	ICOLD		

- Peak Ground Accelerations at site versus return periods have been derived throughout various attenuation laws. Results for the design earthquakes are reported hereafter:

	MCE	MDE	OBE
North Panama Deformed Belt	0.31	0.25	0.20
Near-field earthquake	0.19	0.14	0.10
Recommended PGA (in g)			
(for rock conditions)	0.31	0.25	0.20
	ICOLD		

- Duration of the seismic solicitations corresponding to the MCE is about 50 seconds.
- Response spectra have been derived for the MCE
- Synthetic time histories have been generated and are provided in digital forms.

PART VI – HYDROLOGY

PART VI – HYDROLOGY

TABLE OF CONTENTS

This Part VI has 69 pages

page

1. SUMMARY 1
1.1. Report Content 1
1.2. Data and Methods 1
1.3. Principal Results 2

2. CLIMATE 6
2.1. Yearly and Monthly Rainfall 6
2.2. Lake Evaporation 13
2.3. Maximum Daily Rainfall 13

3. INFLOWS 29
3.1. Background 29
3.2. Yearly and Monthly Inflows 32

4. FLOODS 40
4.1. General 40
4.2. Daily Peaks at Batatilla 40
4.3. Hydrograph Shapes at Batatilla 48
4.4. Floods at Toabre Damsite 53
4.5. Comments on Obtained Results 58

5. SEDIMENT TRANSPORT 62
5.1. Previous studies 62
5.2. Regional Analysis 63
5.3. Computation of Suspended Load 63
5.4. Discussion of Results 66

List of Tables

Table 1 - Mean Rainfall - Regional Information 7
Table 2 - Monthly Distribution of Rainfall for Toabre River 8
Table 3 - Catchment and Lake Mean Yearly Rainfall 11
Table 4 - Lake and Catchment Mean Monthly Rainfall 12
Table 5 - Toabre Lake Evaporation 13
Table 6 - Maximum Daily Rainfall - Preliminary Analysis 15
Table 7 - Maximum Daily Rainfall - Transposition of the 20 greatest events 24
Table 8 - Toabre Catchment - Maximum Daily Rainfall vs. Return Period 26
Table 9 - Main Features of Batatilla Gauging Station 29
Table 10 - Description of Batailla Gauging Station 30
Table 11 - Rating Curves at Batatilla - Period of Validity 30
Table 12 - Rating Curves at Batatilla - Equations 31
Table 13 - Mean Discharge - Toabre Rivar - Batatilla Station 33
Table 14 - Toabre River at Toabre Damsite - Monthly Discharges 37
Table 15 - Toabre at Damsite - Yearly Discharge vs. Return Period 38
Table 16 - Batatilla (788 km²) - Statistics on Daily Peaks 40
Table 17 - Flood Peaks at Toabre Damsite (730 km²) 54
Table 18 - Toabre Damsite - Flood Hydrographs - Shape A 54
Table 19 - Toabre Damsite - Flood Hydrographs - Shape C 55
Table 20 - Toabre Damsite - Construction Stage Floods 58
Table 21 - Analysis of Flood Volumes at Toabre Damsite 58
Table 22 -River Toabre at Toabre Damsite - Flood Peaks for Usual Floods 60
Table 23 - Rio Toarfe at Toabre Damsite - Flood Peaks for Extreme Floods 60
Table 24 - Sediment Transport (Suspension) in Batatilla - Previous Studies 62
Table 25 - Computation of Suspended Load in Previous Studies 62
Table 26 - Toabre Damsite - Time to fill Dead Storage 66

List of Figures

Figure 1 - Toabre River - Distribution of Monthly Rainfall 8
Figure 2 - Mean Yearly Rainfall over Toabre Catchment 9
Figure 3 - Mean Yearly Rainfall over Toabre Lake 10
Figure 4 - Lake and Catchment Mean Monthly Rainfall 12
Figure 5 - Station Year Approach - Selection of Final Sample 19
Figure 6 - Station-year Approach - Gumbel Fit & Monthly Distribution of Maximum 20
Figure 7 - Extension of Regional Sample Using Gatun Data 22
Figure 8 - Analysis of the Second Step Sample (237 station-years) 23
Figure 9 - Selection of PMP = 650 mm/day 27
Figure 10 - Lombardi's Distribution for Maximum Daily Rainfall 28
Figure 11 - Toabre River at Batatilla - Monthly Regime 35
Figure 12 - Toabre River at Batatilla - Test of the Extension and Completion of Data 36
Figure 13 - Toabre River at Damsite - Monthly and Yearly River Regime 39
Figure 14 - Toabre River - Monthly Flood Regime & Occurrence of Yearly Maximum 41
Figure 15 - Definition of Relationship for Batatilla Flood Data Extension 43
Figure 16 - Extension of Batatilla Daily Peaks Using Gatun DS 44
Figure 17 - Toabre River at Batatilla - Daily Peak vs. Return Period 46
Figure 18 - Batatilla - Selection of Daily PMF = 5 000 m3/s 47
Figure 19 - Toabre River at Batatilla - Daily Peaks vs. Instantaneous Peaks 49
Figure 20 - Toabre River at Batatilla - Typical Floods and Hydrograph Shape A 51
Figure 21 - Toabre River at Batatilla - Hydrograph Shapes B and C 52
Figure 22 - Toabre River at Batatilla - Comparison of Hydrograph Shapes 53
Figure 23 - Toabre Damsite - Flood Hydrographs - Shape A 56
Figure 24 - Toabre Damsite - Flood Hydrographs - Shape C 57
Figure 25 - Regional Information on Suspended Load 64
Figure 26 - Toabre Rivet at Batatilla - Synthesis on Suspended Load 65

List of References

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PART VI – HYDROLOGY

1. SUMMARY

1.1. Report Content

This report deals with hydrological features of the Toabre Dam Project. Besides this summary, it is composed of the following chapters:

Climate

This section presents the climate data of interest for the present stage of project study. Thus it details rainfall and evaporation data.

Inflows

This part is concerned with the derivation of a long record of monthly and yearly inflows at Toabre Damsite. Its content is mostly derived from the analysis of Batatilla gauging station performed by Daly Espinosa A. [1]

Floods

The flood study defines the flood shapes at Toabre damsite for a wide range of return periods. The probable maximum flood (PMP) has been assessed by statistical approaches.

Sediment Transport

The study computed the suspended load from Batatilla and Canoas data. Then, the yearly sediment inflow is compared to the dead storage of Toabre reservoir.

1.2. Data and Methods

Rainfall data from the following stations have been used in the course of the study.

Station	ID Nb	Station	ID Nb
Toabre	105 005	Miguel de la Borda	109 001
Tambo	105 004	Icacal	113 001
Santa Ana	105 010	Boca de Toabre	105 001
Boca de Uracillo	111 001	San Lucas	105 007
Coclesito	105 009	Cocle del Norte	105 003
Sabanita Verde	105 008	Belen	103 001
Chiguiri arriba	105 002		

Discharge data concerned the following stations:

Toabre River at Batatilla (788 km²). In addition, for missing values and for extending the data until obtaining the full record for 1948 / 200, Daly Espinosa [1] made use of the following stations:

Trinidad. (El Chorro River)

El Torno and Canoa. (River Cocle del Norte)

Uracillo and Limón. (Indio River)

Cañones. (Ciri Grande River)

The methods used in this study are classical methods of applied hydrology:

Regional analysis.

Correlation and regression analysis.

Test of data by double mass analysis.

Fit of statistical distributions.

Hydrograph shape analysis.

1.3. Principal Results

1.3.1. Climate

On the basis of existing data about nearby raingauges, the 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 likely wet.

Month	Lake Rainfall (mm)	Catchment Rainfall (mm)	%	Month	Lake Rainfall (mm)	Catchment Rainfall (mm)	%
January	150	121	4.4	August	365	296	10.7
February	99	80	2.9	September	337	273	9.9
March	92	75	2.7	October	409	331	12.0
April	188	152	5.5	November	403	326	11.8
May	374	303	11.0	December	296	240	8.7
June	355	288	10.4				
July	342	277	10.0	Sum	3 411	2 761	100

The Toabre damsite will transform a land and vegetation area into a water body. This will lead to an additional loss of 80 mm/year as shown after.

Month	**Lake Evaporation**	**Lake Rainfall**	**Runoff**	**Ea=Ra-Ru**	**Losses**
	El (mm)	Ra (mm)	Ru (mm)	(mm)	El-Ea(mm)
January	128	150	127	23	105
February	133	99	58	42	91
March	155	92	42	51	105
April	140	188	54	134	6
May	107	374	130	244	-137
June	91	355	183	172	-81
July	90	342	193	149	-59
August	89	365	239	127	-38
September	92	337	261	76	16
October	94	409	320	89	5
November	83	403	327	76	7
December	100	296	258	38	61
Sum	1 300	3 411	2 191	1 220	80

Maximum Daily Rainfall has been computed according to a regional approach. The daily Probable Maximum Precipitation (PMP) is 650 mm/day, which agrees well with the 1978 study about Madden and Gatun PMPs. This estimate of 650 mm/day is about 17% greater than Harza's estimate for Indio River.

Return Period	**Maximum Daily Rainfall**
T	**Pdmx**
(years)	(mm/day)
2	98
5	130
10	151
20	172
50	199
100	218
200	238
500	262
1 000	280
2 000	297
5 000	319
10 000	335
PMP	**650**
PMP / P(10 000)	1.94

1.3.2. Inflows

Daly Espinosa [1], from ACP, reviewed in depth the record of Batatilla gauging station (788 km²). On the basis of her report, a 53-year monthly record has been defined for Toabre damsite (727 km²). The average runoff amounts to 40.8 m3/s. As for the rainfall, the dry season is January to May although heavy runoff could occur in January and May.

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec	Year
M	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
S	21.3	8.5	5.7	11.2	17.7	15.2	15.8	18.3	19.2	18.2	24.6	33.9	9.7
Cv	0.77	0.60	0.63	0.92	0.62	0.37	0.37	0.35	0.32	0.26	0.33	0.60	0.24
Me	22.2	12.1	7.7	8.3	24.1	40.0	40.4	51.4	54.3	69.9	68.2	49.4	39.2
Max	130.3	59.0	30.5	56.9	100.5	83.0	97.2	111.8	118.4	111.7	146.5	150.0	71.4
Min	9.2	5.6	3.1	3.1	7.4	13.6	13.5	16.4	25.2	37.7	36.5	15.2	21.1

Units: m3/s. M= Mean, S= Standard deviation, Cv= S/M, Me= Median, Max= Maximum, Min= Minimum.

The yearly runoff has a range from 23 to 68 m3/s. The median runoff is 39.8 m3/s whereas the discharge exceeded 9 years out of 10 is 29.7 m3/s.

	T (years)	Qyr (m3/s)		T (years)	Qyr (m3/s)
Dry Years	100	23.4	Wet Years	5	48.2
	50	24.9		10	53.3
	20	27.3		20	57.9
	10	29.7		50	63.5
Dry Years	5	32.8	Wet Years	100	67.6
Median Year	2	39.8			

1.3.3. Floods

Frequency analysis for Batatilla gauging station gave the following results about daily peaks:

T (years)	Qdmx (m3/s)	T (years)	Qdmx (m3/s)
2	378	1 000	2 163
5	607	2 000	2 364
10	791	5 000	2 618
20	986	10 000	2 801
50	1 255		
100	1 465	PMF	5 000
200	1 677		
500	1 956		

Using flood statistics at Batatilla and after a synthesis about flood hydrographs, the following flood estimates were found for Toabre Damsite:

Return Period (year)	**Shape**	**V** (10^6 m3)	**Qp** (m3/s)	**Shape**	**V** (10^6 m 3)	**Qp** (m3/s)
20	A	98	1 870	C	131	1 280
50	A	124	2 370	C	167	1 630
100	A	145	2 780	C	194	1 900
1 000	A	214	4 100	C	286	2 800
10 000	A	277	5 310	C	371	3 630
PMF	A	497	9 510	C	664	6 490

Concerning the construction stage floods, following results have been adopted.

T	**Dry Season** (February to April)	**Wet Season** (May to January)	**Wet Season** (May to January)
	Qp-A	**Qp-A**	**Qp-C**
(year)	(m3/s)	(m3/s)	(m3/s)
10	470	1 500	1 030
20	710	1 870	1 280
50	1 140	2 370	1 630
100	1 560	2 780	1 900

1.3.4. Sediment Transport

According to the author the sediment inflow can vary between about 200 000 m3/year and 970 000 m3/year. Even for the worst case, the loss of storage does not appear to be a problem.

Reference	**Suspended Load** (tons/year)	**Total Load** (tons/year)	**Total Volume** (m3/year)	**Specific Volume** (mm/year)	**Time to fill Dead Storage** (years)
[1]	170 758	196 372	188 819	0.24	286
[1]	332 612	382 504	367 792	0.47	147
[2]	873 801	1 004 871	966 222	1.23	56

2. CLIMATE

2.1. Yearly and Monthly Rainfall

ACP has provided the data about yearly and monthly rainfall. A map of rainfall network and a map of mean yearly rainfall (given in inches/year) illustrate the available data. These maps are given in appendices A and B. Appendix C detail the monthly and yearly rainfall for the regional rain gauges.

Table 1 - Mean Rainfall - Regional Information, presents the average rainfall for the 13 stations used in the study. It shows that rainfall may vary between 1 900 and 5 300 mm/year according to the location. The appendix B allows to catch the mean features of rainfall over the Panama Republic. Figure 2 - Mean Yearly Rainfall over Toabre Catchment and Figure 3 - Mean Yearly Rainfall over Toabre Lake display the local features pertinent to the project. It can be seen that the headwaters of Toabre River experiment a smaller rainfall than the area of the Toabre Lake.

Taking into account six stations likely to represent the rainfall features of the catchment, it can be realised that the calendar year is divided into a dry season (from January to April) and a wet season (from May to December).

The dry months represent each between 3 and 6 % of the yearly total.

The wet months amount between 9 and 12% of the yearly total. During the wet season, the repartition is almost constant. (See Figure 1 and Table 2)

Table 3 - Catchment and Lake Mean Yearly Rainfall, details the computation of mean yearly rainfall according to the planimetering of the maps given in Figures 2 and 3.

For the Toabre catchment, the yearly rainfall amounts to about 2 800 mm/year. For the future Toabre Lake, the rainfall is 3 400 mm/year.

Table 4 and Figure 4 present the distribution of mean monthly rainfall (average year) for both the Toabre catchment and the Toabre Lake.

Table 1 - Mean Rainfall - Regional Information

Rainfall in mm

Station	ID Nb	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Toabre	105 005	43	18	25	65	209	214	204	239	267	293	210	100	1 886
Tambo	105 004	36	25	33	63	228	229	222	244	273	303	209	103	1 969
Santa Ana	105 010	90	58	71	110	245	253	219	225	252	332	281	158	2 293
Boca de Uracillo	111 001	114	71	71	171	349	314	274	303	298	405	357	224	2 952
Coclesito	105 009	207	146	120	219	344	283	249	303	278	341	295	327	3 113
Sabanita Verde	105 008	191	132	109	232	352	307	293	321	293	352	380	312	3 274
Chiguiri arriba	105 002	91	62	49	135	379	428	396	434	410	451	402	232	3 470
Miguel de la Borda	109 001	142	99	79	236	362	375	395	432	338	409	492	358	3 718
Icacal	113 001	133	64	81	196	437	380	456	414	336	445	580	366	3 888
Boca de Toabre	105 001	306	194	165	366	471	344	369	418	324	380	509	497	4 344
San Lucas	105 007	292	224	186	317	471	396	487	447	322	440	557	528	4 665
Cocle del Norte	105 003	283	183	174	309	508	475	616	449	342	452	676	528	4 994
Belen	103 001	560	351	253	380	403	392	576	464	285	360	530	736	5 291

Rainfall Distribution in %

Station	ID Nb	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Toabre	105 005	2.3	0.9	1.3	3.5	11.1	11.3	10.8	12.7	14.1	15.5	11.2	5.3	100.0
Tambo	105 004	1.8	1.3	1.7	3.2	11.6	11.6	11.3	12.4	13.9	15.4	10.6	5.3	100.0
Santa Ana	*105 010*	*3.9*	*2.5*	*3.1*	*4.8*	*10.7*	*11.0*	*9.5*	*9.8*	*11.0*	*14.5*	*12.2*	*6.9*	*100.0*
Boca de Uracillo	*111 001*	*3.9*	*2.4*	*2.4*	*5.8*	*11.8*	*10.6*	*9.3*	*10.3*	*10.1*	*13.7*	*12.1*	*7.6*	*100.0*
Coclesito	*105 009*	*6.7*	*4.7*	*3.9*	*7.0*	*11.1*	*9.1*	*8.0*	*9.7*	*8.9*	*10.9*	*9.5*	*10.5*	*100.0*
Sabanita Verde	*105 008*	*5.8*	*4.0*	*3.3*	*7.1*	*10.7*	*9.4*	*9.0*	*9.8*	*8.9*	*10.8*	*11.6*	*9.5*	*100.0*
Chiguiri arriba	*105 002*	*2.6*	*1.8*	*1.4*	*3.9*	*10.9*	*12.3*	*11.4*	*12.5*	*11.8*	*13.0*	*11.6*	*6.7*	*100.0*
Miguel de la Borda	*109 001*	*3.8*	*2.7*	*2.1*	*6.3*	*9.7*	*10.1*	*10.6*	*11.6*	*9.1*	*11.0*	*13.2*	*9.6*	*100.0*
Icacal	*113 001*	*3.4*	*1.6*	*2.1*	*5.0*	*11.2*	*9.8*	*11.7*	*10.6*	*8.7*	*11.5*	*14.9*	*9.4*	*100.0*
Boca de Toabre	105 001	7.0	4.5	3.8	8.4	10.8	7.9	8.5	9.6	7.5	8.8	11.7	11.4	100.0
San Lucas	105 007	6.3	4.8	4.0	6.8	10.1	8.5	10.4	9.6	6.9	9.4	11.9	11.3	100.0
Cocle del Norte	105 003	5.7	3.7	3.5	6.2	10.2	9.5	12.3	9.0	6.8	9.0	13.5	10.6	100.0
Belen	103 001	10.6	6.6	4.8	7.2	7.6	7.4	10.9	8.8	5.4	6.8	10.0	13.9	100.0

Santa Ana: Station used for defining monthly percentage applicable to Toabre catchment and reservoir.

Table 2 - Monthly Distribution of Rainfall for Toabre River

Month	%
January	4.4
February	2.9
March	2.7
April	5.5
May	11.0
June	10.4
July	10.0
August	10.7
September	9.9
October	12.0
November	11.8
December	8.7
Sum	100

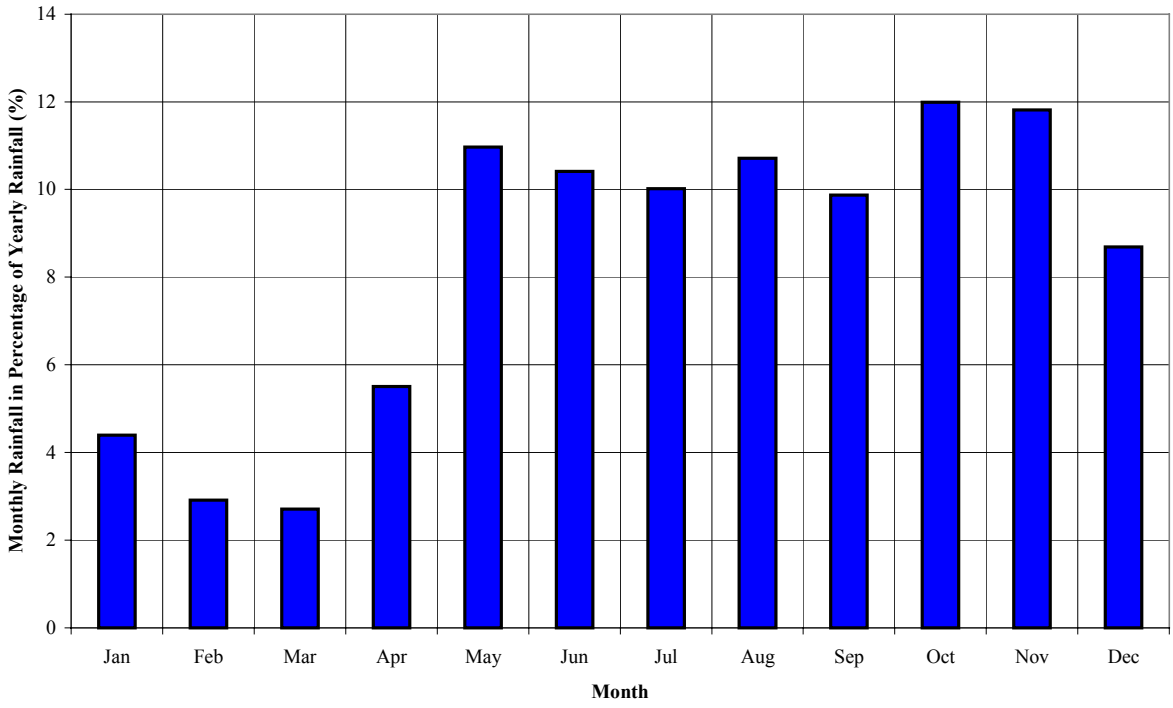


Figure 1 - Toabre River - Distribution of Monthly Rainfall

ISOHYETS (Inches)	SURFACES (m2)
70	756 136 257
75	731 892 190
80	638 160 423
85	595 062 585
90	540 536 640
95	473 131 229
100	408 748 254
110	344 817 741
120	255 768 913
130	177 666 601
140	115 309 992
150	35 804 072
160	16 435 470

San Lucas 007
Río del Norte
Río Cuatro Calles
CUATRO CALLES
Río Caño
Río Miguelito
Río Caño Sucio
Limón
01-02 Boca de Uracillo
Cañones 91.6
El Torno
B. de Toabre 01-01
001
Batatilla 82-01
Canoas 01-02
Río Toabre
Río Cuteva
Río Cocle del Norte
980,000 N
Río "U"
Río Indio
Río Ciri Grande
Río Ciricito
Río Cacaito
Río Cacao
Río Trinidad
Río Chutral
Río Tejo
Los Higuerones 03-01
009
Río Cascajal
Sabanita Verde 008
Sta Ana 010
Río Coclesito
Río Tulú
Río Toabre
Río San Miguel
Río Lurá
960,000 N
Chiguiria 002
Toabre 005
Tambo 004
LLano Grande
El Valle de Antón
EL Harino
El Copé
560,000 E
580,000 E
600,000 E
620,000 E
(2 032mm.)
(2 540mm.)
El Cacao 85
Ciri Grande 95
75.8 Caimito 140-005 (2030)

ISOHYETS
LIMIT OF CATCHMENT AREA
GAUGING STATION
RAIN GAUGE

SCALE ; 1 / 200 000
0 1 5 10 km.

MEAN YEARLY RAINFALL OVER TOABRE CATCHMENT Fig. 2

140

980,000 N

580,000 E

130
(3 302mm.)

120

110

100
(2 540mm.)

95

90

RIO DE "U"

RIO DE "U"

RIO TOABRE

RIO TOABRE

RIO TOABRE

RIO TULU

RIO CUIRIA

RIO SAN MIGUEL

RIO TOABRE

RIO TOABRE

150
(3 810mm.)

SCALE ; 1 / 50 000

0 500 2500 5000m.

ISOHYETS (Inches)	SURFACES (m2)
92	46 481 033
95	45 402 155
100	44 887 568
110	43 502 323
120	38 871 308
130	34 543 969
140	23 230 411

MEAN YEARLY RAINFALL OVER TOABRE LAKE **Fig. 3**

Table 3 - Catchment and Lake Mean Yearly Rainfall

Catchment Yearly Rainfall

P (inches)	A (km²)	DA (km²)	Pm (inches)	Pm x dA (inches x km²)	
70	756				
75	732	24	72.5	1 740	
80	638	94	77.5	7 285	
85	595	43	82.5	3 548	
90	541	54	87.5	4 725	
95	473	68	92.5	6 290	
100	409	64	97.5	6 240	
110	345	64	105	6 720	
120	256	89	115	10 235	
130	178	78	125	9 750	
140	115	63	135	8 505	
150	36	79	145	11 455	
160	16	20	155	3 100	
165	0	16	162.5	2 600	
			Sum	82 193	
			P	109	Inches
			P	**2 761**	**mm**

Lake Yearly Rainfall

P (inches)	A (km²)	DA (km²)	Pm (inches)	Pm x dA (inches x km²)	
92	46.5				
95	45.4	1.1	93.5	103	
100	44.9	0.5	97.5	49	
110	43.5	1.4	105	147	
120	38.9	4.6	115	529	
130	34.5	4.4	125	550	
140	23.2	11.3	135	1 526	
148	0	23.2	144	3 341	
			Sum	6 244	
			P	134	inches
			P	**3 411**	**mm**

Table 4 - Lake and Catchment Mean Monthly Rainfall

Month	Lake Rainfall (mm)	Catchment Rainfall (mm)	%
January	150	121	4.4
February	99	80	2.9
March	92	75	2.7
April	188	152	5.5
May	374	303	11.0
June	355	288	10.4
July	342	277	10.0
August	365	296	10.7
September	337	273	9.9
October	409	331	12.0
November	403	326	11.8
December	296	240	8.7
Sum	3 411	2 761	100

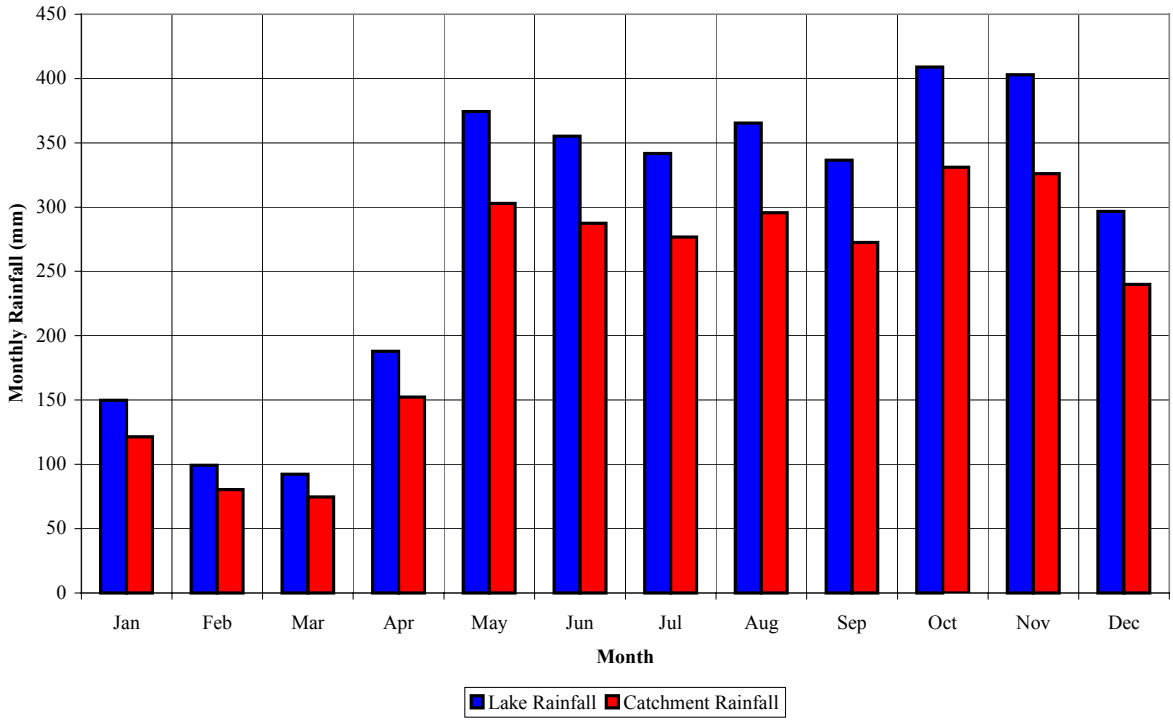


Figure 4 - Lake and Catchment Mean Monthly Rainfall

2.2. Lake Evaporation

Toabre Dam will transform a land and vegetation area into a water body. Thus, for the dam operation studies, it is necessary to compute the losses induced by this change of land use.

This loss is equal to the difference between the future lake evaporation and the actual evapotranspiration from the present soil cover. This computation is detailed below:

Lake evaporation is taken equal to the one of Gatun Lake. The runoff over the area to be impounded is obtained by transposition of Batatilla runoff.

These two quantities (lake rainfall and runoff over impounded area) allow computing the present evapotranspiration. The loss to be taken into account is the difference between E_l and E_a. In fact, the additional loss amounts to 80 mm/year, which is a small value.

Table 5 - Toabre Lake Evaporation

Month	Lake Evaporation	Lake Rainfall	Runoff	Ea=Ra-Ru	Losses
	El (mm)	Ra (mm)	Ru (mm)	(mm)	El-Ea(mm)
January	128	150	127	23	105
February	133	99	58	42	91
March	155	92	42	51	105
April	140	188	54	134	6
May	107	374	130	244	-137
June	91	355	183	172	-81
July	90	342	193	149	-59
August	89	365	239	127	-38
September	92	337	261	76	16
October	94	409	320	89	5
November	83	403	327	76	7
December	100	296	258	38	61
Sum	1 300	3 411	2 191	1 220	80

2.3. Maximum Daily Rainfall

The analysis of hydrograph shapes shows a fast catchment response to rainstorms. This is disclosed by important values of the ratios of instantaneous peaks to daily peaks. (Qp/Qd)

Thus, it is valuable to study the maximum daily rainfall to estimate daily rainfall for a wide range of return periods. Similarly, it is necessary to compute the probable maximum precipitation. (PMP)

The following approach has been taken:

Preliminary analysis of existing data.

In this step, the regional data disclose common trends within the different samples under study. They allow also a first estimation of the daily PMP to be taken into account.

Regional approach by the station year method.

This step leads to define a 189 station-year sample of adimensional daily rainfall. It shows that a part of the sample has a different behaviour than the remaining part. This special part appears as being a bridge between usual rainfall and PMP conditions.

Extension of data using Gatun data.

Using Gatun monthly data it has been possible to extend the 189 station-year sample to a final 237 station-year sample. This sample corresponds to an 89-year period extending from 1911 to 1999. This means that about 2.7 yearly maximums have been retained for analysis.

Fitting a bounded distribution to the regional sample.

Lombardi distribution is a useful tool to describe samples while assuming an upper bound (PMP or PMF) and a lower bound. It provides statistical estimates of PMP that are as meaningful as the Hershfield's estimates. During the mean time, it leads to the computation of rainfall estimates for any desired return period. These estimates are consistent with the derivation of PMP.

In the following text, these four steps of study are discussed.

2.3.1. Preliminary analysis of existing data

Table 6 - Maximum Daily Rainfall - Preliminary Analysis summarises the findings of this step. It consists of three parts.

Part A of this table is concerned by the general sample statistics. In this part, several items are analysed:

Pyr is the yearly rainfall.

Nval is the sample size.

M, Cv, and Me are respectively the mean, coefficient of variation and the median of the sampled data.

Max and Min are the maximum and the minimum observed values.

Cv, M/Pyr and Me/Pyr are adimensional values. They display a relatively low variability. Thus, a regional approach seems a sound tool for data analysis.

Part B presents two computations of PMP by Hershfield's approach. In this approach, PMP is computed according to the formula:

$PMP = M \times (1 + K \times C_v)$, where K is the Herschfield'constant.

The table presents two computations of PMP. The first is performed using the station Cv. The second is obtained using a regional Cv of 0.32. In the first case PMP varies in the range 300 / 800 mm/day. In the second case PMP is in the range 500 / 830 mm/day.

Part C is abstracted from the 1978 PMP study.[1] Schwarz and Riedel conclude to PMPs of 704 mm/day for Madden catchment and of 663 mm/day for Maden catchment. These values are within the range of Hershfield estimates quoted above. In addition the authors of the 1978 study distinguish between two kinds of extreme rainfalls:

Late Fall – Early Winter Maximum.

This event occurs from October trough December. In this season northerly winds bring the moist air across Panama. In the period 1963 to 1976, 15 storms out of 22 occurred during this three-month period.

Hurricane Maximum.

For Schwarz and Riedel, hurricanes are not a threat for Panama. Although Martha (November 1969) affected Panama, its track was abnormal with respect to usual tracks.

Table 6 - Maximum Daily Rainfall - Preliminary Analysis

A. General Information

Station	Pyr (mm)	Nval	M (mm)	Cv	Me (mm)	Max (mm)	Min (mm)	M/Pyr	Me/Pyr
Toabre	1 842	30	83	0.16	84	126	60	0.045	0.046
Santa Ana	2 350	19	86	0.49	74	239	50	0.037	0.031
Boca de Uracillo	2 921	25	108	0.25	107	188	57	0.037	0.037
Chiguiri Arriba	3 099	41	120	0.25	118	185	68	0.039	0.038
Sabanita Verde	3 175	21	104	0.38	90	195	62	0.033	0.028
Coclesito	3 302	19	108	0.18	110	143	75	0.033	0.033
Miguel de la Borda	3 552	24	124	0.25	124	171	73	0.035	0.035
Boca de Toabre	4 369	41	157	0.34	153	306	76	0.036	0.035
San Lucas	4 699	26	163	0.31	159	250	92	0.035	0.034
Cocle del Norte	4 826	31	127	0.36	115	252	54	0.026	0.024

1 *Schwarz F.K, Riedel J.T – Probable Maximum Precipitation Estimates for Drainages Above Gatun and Madden Lakes, Panama Canal Zone – February 1978.*

B. Computation of PMP – Hershfield's Approach

Station	K	Hershfield 1 (mm/day)	Hershfield 2 (mm/day	H1/Me	H2/Me	H1/Max	H2/Max
Toabre	15.5	295	497	3.49	5.89	2.33	3.94
Santa Ana	15.4	735	512	9.94	6.92	3.08	2.14
Boca de Uracillo	14.5	503	611	4.71	5.73	2.67	3.25
Chiguiri Arriba	14.1	542	660	4.60	5.59	2.93	3.57
Sabanita Verde	14.7	685	594	7.59	6.59	3.52	3.05
Coclesito	14.5	395	609	3.59	5.54	2.77	4.27
Miguel de la Borda	14.0	549	679	4.42	5.46	3.21	3.97
Boca de Toabre	12.9	848	808	5.53	5.27	2.78	2.65
San Lucas	12.8	799	830	5.02	5.21	3.20	3.33
Cocle del Norte	13.9	755	693	6.57	6.02	3.00	2.75

C. PMP Estimates for Madden and Gatun Catchments (1978)

10 mi² 24 hr PMP

Catchment	A (mi²)	PMP (inches)	PMP (mm)
Madden	393	27.7	704
Gatun	1 285	26.1	663

10 mi² 3 day storms

Date	P (inches)	P (mm)	704/P	663/P
22/24 October 1923	26.2	665	1.06	1.00
27/29 November 1932	15.9	404	1.74	1.64
7/9 November 1931	23.0	584	1.20	1.13
18/20 December 1943	16.5	419	1.68	1.58
5/7 November 1939	17.0	432	1.63	1.54

2.3.2. Regional approach by the station year method

In this approach, the computations have been the following.

Each yearly maximum (Pdmx) has been transformed into an adimensional rainfall Y by division of Pdmx by the corresponding sample median:

$$Y = \frac{Pdmx}{Me} .$$

Then, all the Ys values are pooled into a common regional sample. This sample has the following statistics:

Sample size	Nval	277
Mean	M	1.04
Standard Deviation	S	0.33
Coefficient of Variation	Cv	0.31
Median	Me	1.00
Maximum	Max	3.23
Minimum	Min	0.47

This sample cannot be yet used for distribution fitting. One needs to exclude non-relevant values of Y. These values correspond to simultaneous events at several stations. A criterion of ± 8 days has been taken to isolate such events. In case of simultaneous events (i.e. within an 8-day period), only the greatest value of Y remains in the regional sample. Doing so, the final sample size is 189 station-years. The statistics of Ys are given below.

Sample size	Nval	189
Mean	M	1.08
Standard Deviation	S	0.35
Coefficient of Variation	Cv	0.32
Median	Me	1.01
Maximum	Max	3.23
Minimum	Min	0.49

Appendix D details the initial samples together with the 189 station-year sample.

Figure 5 - Station Year Approach - Selection of Final Sample presents two graphs. The upper graph shows that the final sample is constituted of independent events. In this graph, no correlation appears between Y(i) and Y(i-1) when the Y values are ordered according to their date of occurrence.

The lower graph shows that the 189 values correspond to a 41-year period. This means that about 4.6 yearly maximums have been selected each year. The graph discloses also that four events correspond to Y-values greater than 2. Only one Y-value exceeds 3.0. These extreme values are:

Station	Date	Pdmx	Y
Sabanita Verde	07/11/88	186	2.07
Sabanita Verde	04/12/81	195	2.16
Cocle del Norte	08/11/85	252	2.19
Santa Ana	05/03/91	239	3.23

Figure 6 - Station-year Approach - Gumbel Fit & Monthly Distribution of Maximum presents two graphs. The upper graph shows that the 189 station-year sample is well described by a Gumbel distribution:

$Y = 0.932 + 0.257 \times u$, where u is the Gumbel variate.

$u = -\ln(-\ln(F))$, where F is the probability of non-exceedance.

It can be seen that the twelve greatest Y-values are located above the Gumbel fit. The Santa Ana data point is obviously an outliner.

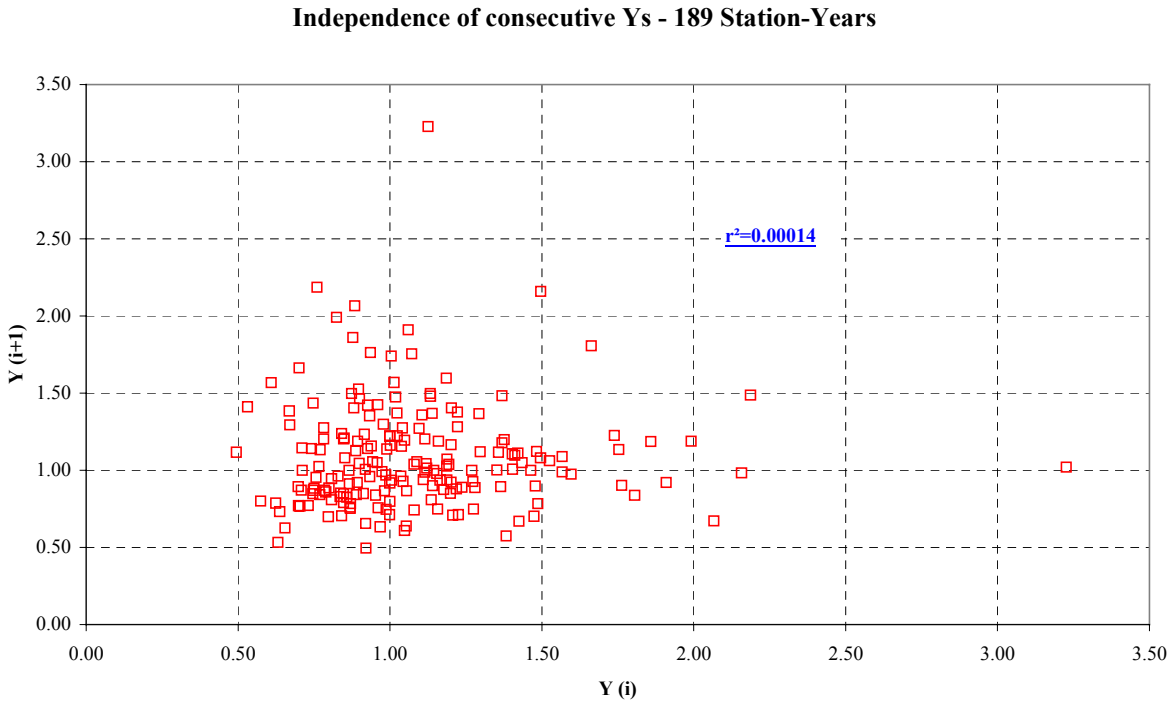
The lower graph compares the occurrence of maximum daily rainfall to the occurrence of maximum monthly rainfall at Gatun. Its discloses the same seasonal pattern:

January to April is rather dry.

May to August is wet.

October to December is also wet.

These overall results can be considered as a sound basis for design. But the hydrology and climatology of the Canal Zone is known since the beginning of the 1900s. Thus, advantage can bed taken from Gatun and Madden data. This is done below.



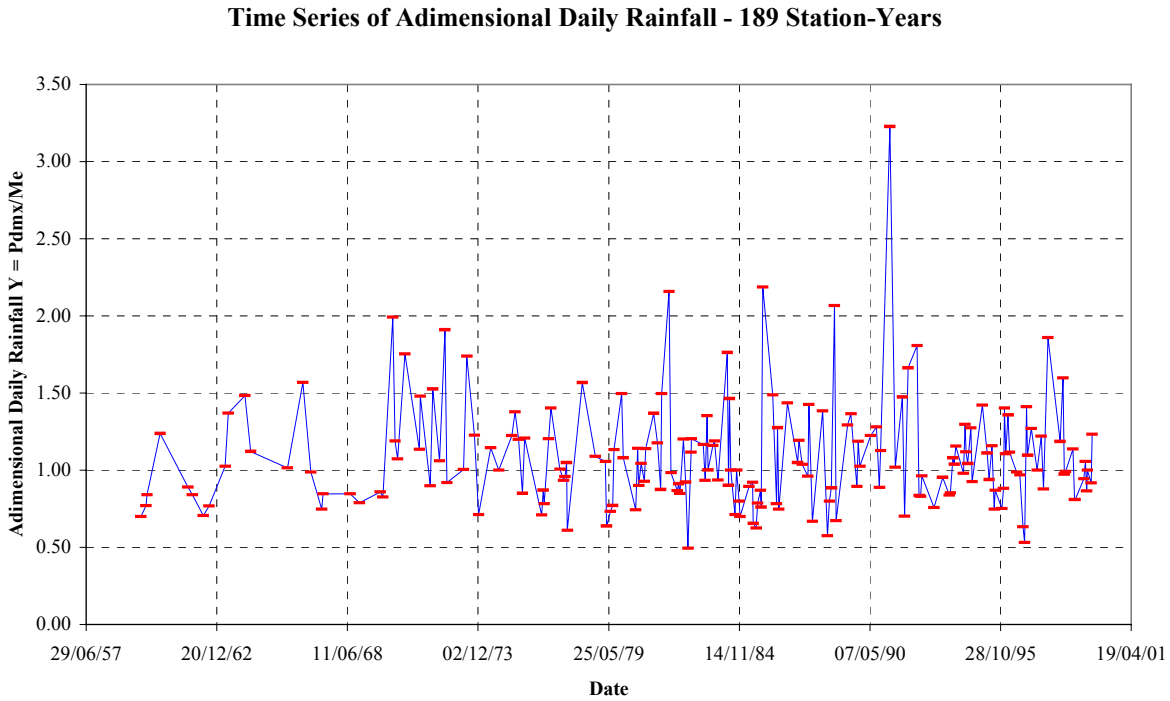
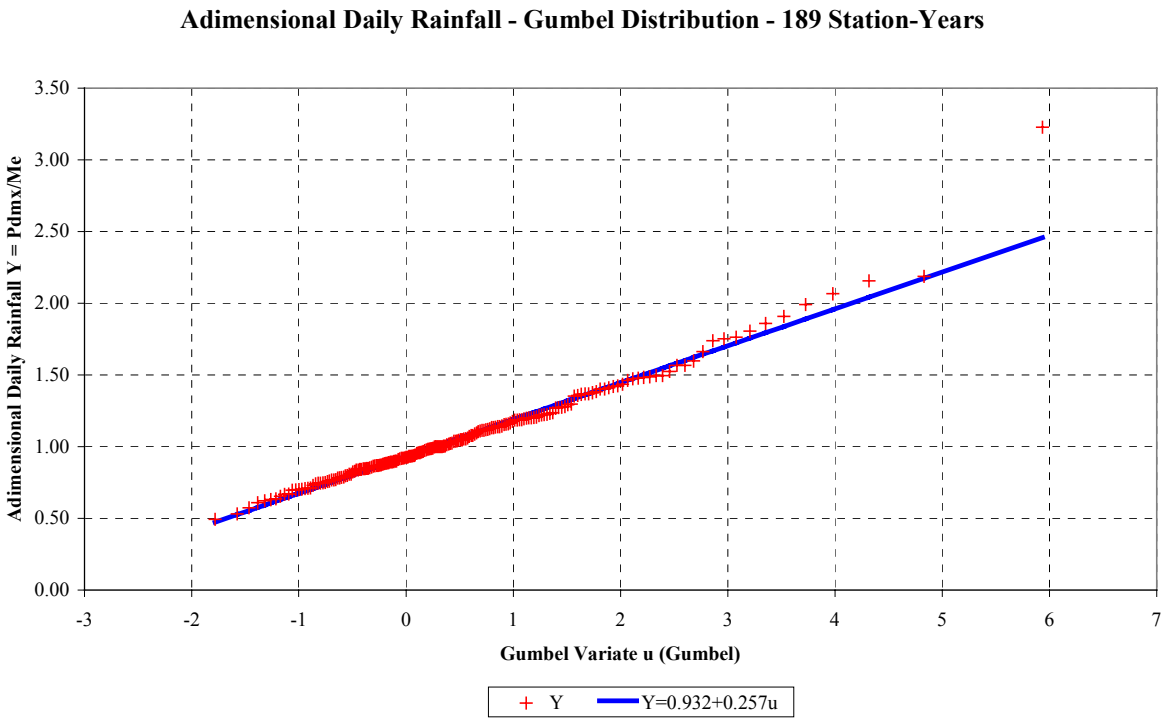


Figure 5 - Station Year Approach - Selection of Final Sample



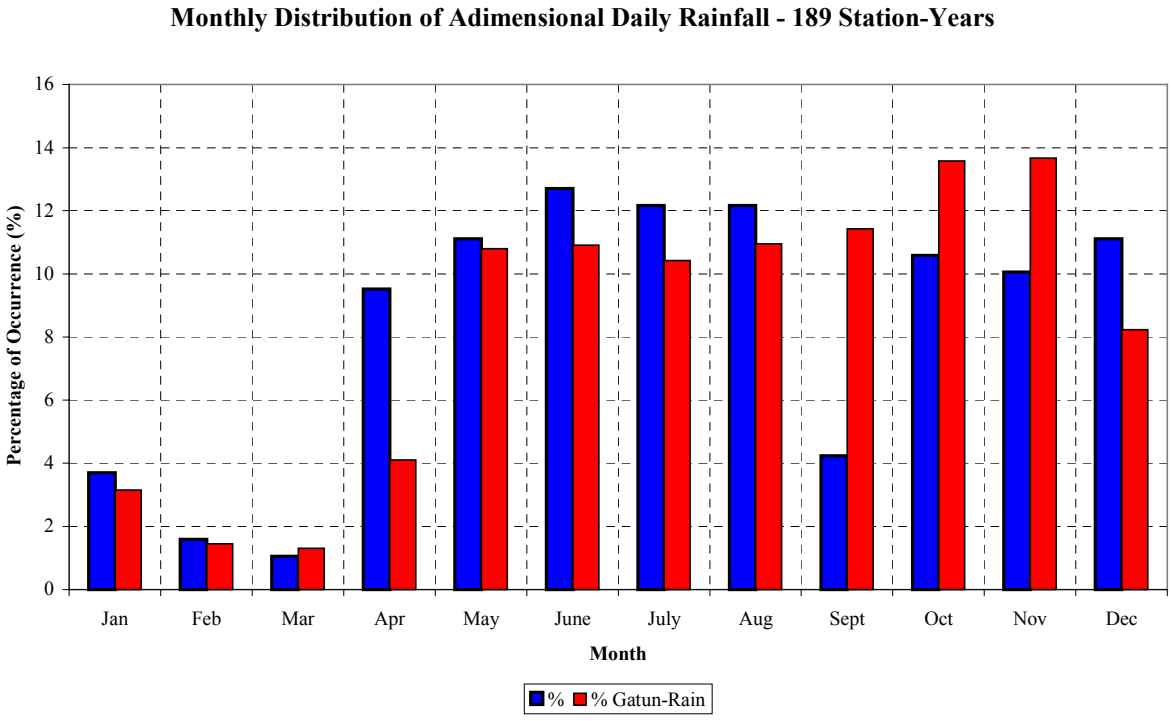


Figure 6 - Station-year Approach - Gumbel Fit & Monthly Distribution of Maximum

2.3.3. Extension of data using Gatun data

It has been seen that the pattern of maximum monthly rainfall for Gatun is very similar to the pattern of maximum daily rainfall in the study area.

The regional sample concerns the period 1959 / 1999 whereas Gatun data are available for the period 1911 / 1999.

Therefore, using Gatun data allows for extending the Toabre rainfall data for the period 1911 to 1958.

Figure 7 - Extension of Regional Sample Using Gatun Data illustrates the data extension.

On the upper graph, the Gatun sample is given. It appears on a Gumbel paper together with its Gumbel fit. On the same graph, the regional Gumbel fit for the 189-year regional sample is presented.

Thus, reading for a given Gumbel variate the Y-values for Toabre area and Gatun, one obtains data points (Y_{Gatun}, $Y_{Regional}$). These data points lead to the computation of a conversion curve, which translate Gatun information into regional information for Toabre area.

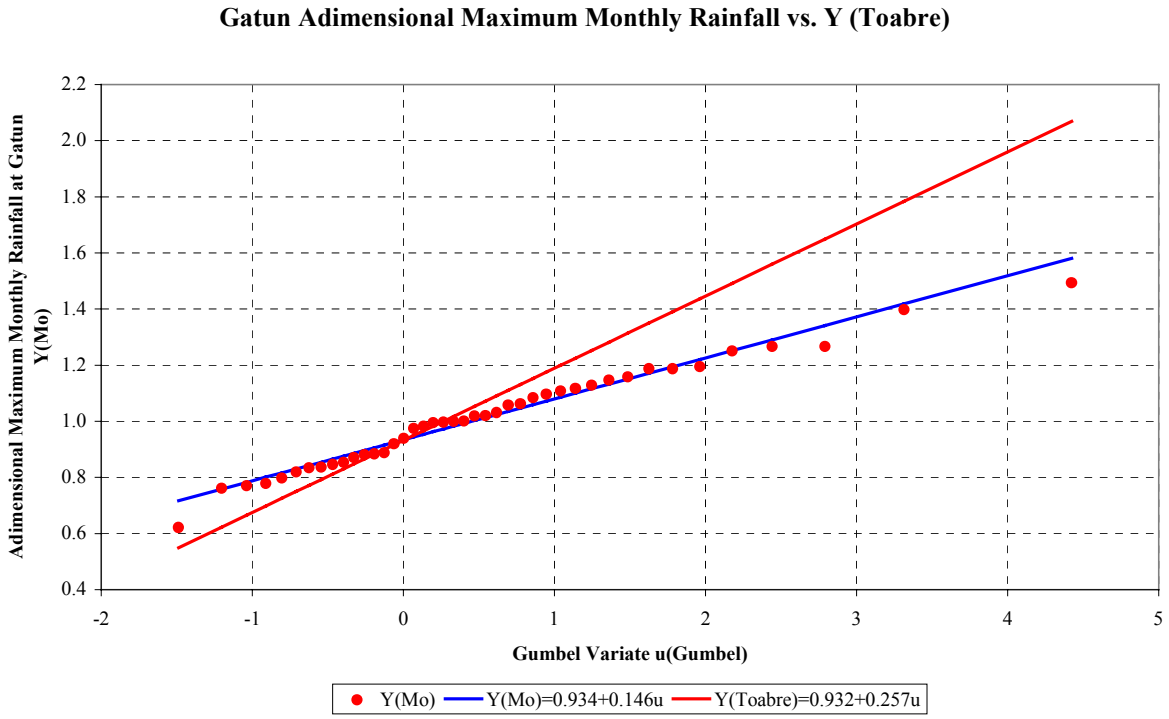
The lower graph details the result of such an approach. The final regional sample has a size of 237-station years. It offers the advantage of incorporating major rainfall events observed from 1911 to 1999.

Figure 8 - Analysis of the Second Step Sample (237 station-years) compares the 189-year and the 237-yar samples.

On the upper graph are given the samples for the period 1911 / 1958 and 1959 / 1999. It can be seen that the sample generated by Gatun data displays higher values than the 189-year sample. This is consistent with the general knowledge of the climate in the Panama Canal Zone.

The lower graph shows that a double-Gumbel distribution is needed to obtain a good fit with the 237-station year data. This sample has the following statistics:

Sample size	Nval	237
Mean	M	1.12
Standard Deviation	S	0.39
Coefficient of Variation	Cv	0.35
Median	Me	1.05
Maximum	Max	3.31
Minimum	Min	0.49



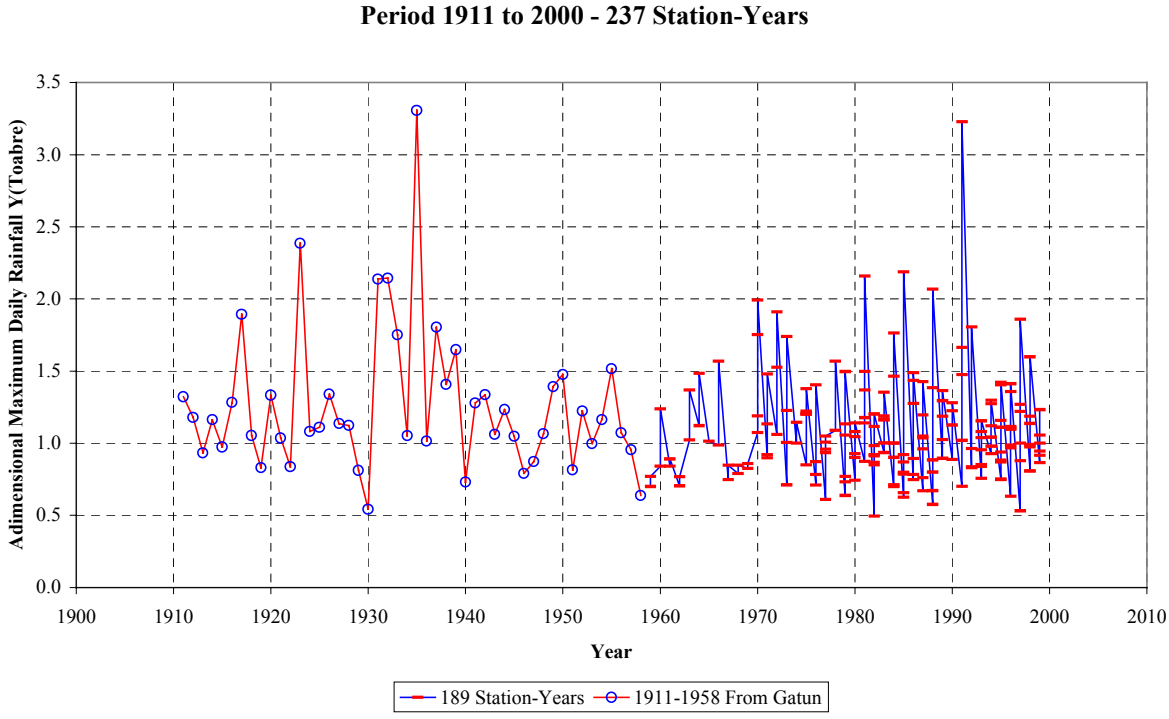
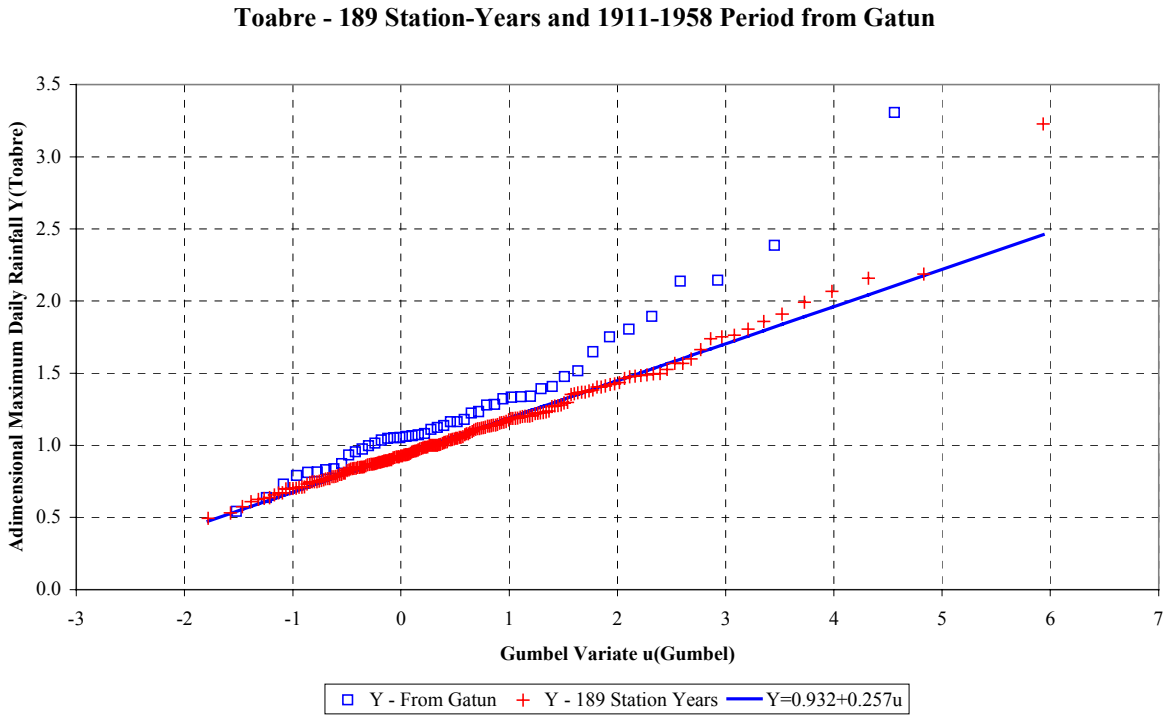


Figure 7 - Extension of Regional Sample Using Gatun Data



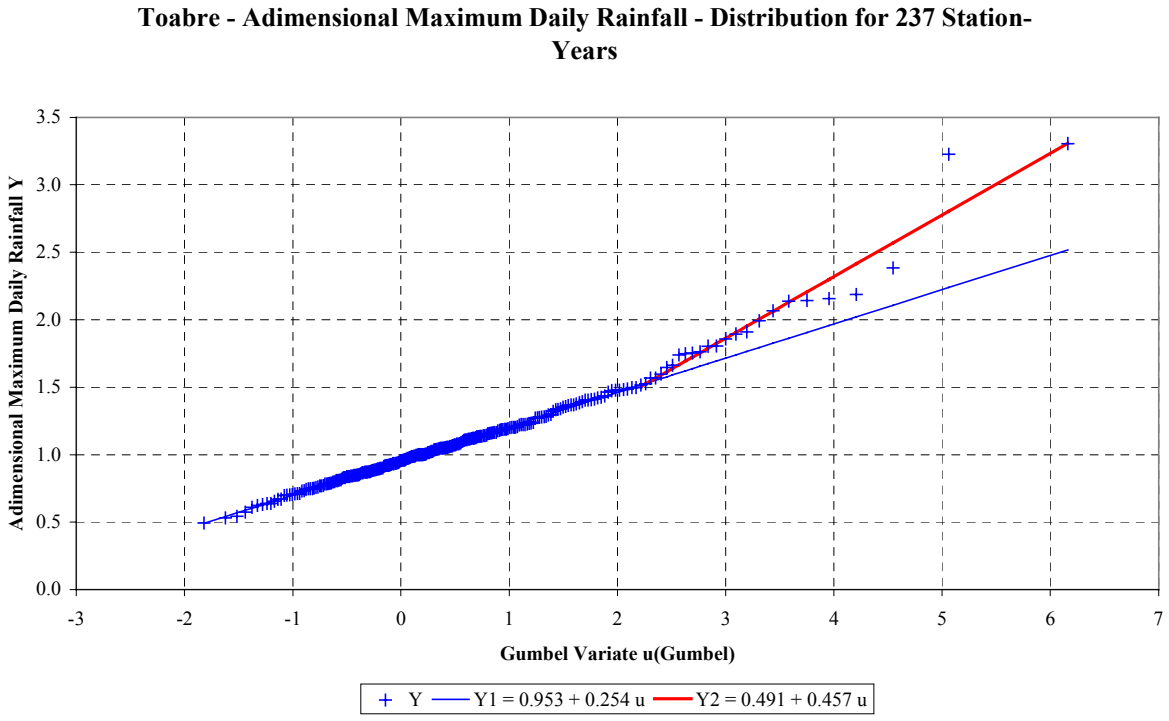


Figure 8 - Analysis of the Second Step Sample (237 station-years)

2.3.4. Fitting a bounded distribution to the regional sample

The preliminary analysis of data seen above allows computing the median daily rainfall as 94 mm/day for Toabre catchment and 116 mm/day for Toabre Lake:

Item	Pyr (mm/year)	Me (Pdmx) (mm/day)
Toabre Lake	3 411	116
Toabre Catchment	2 761	94

Notes: Me = 0.034 Pyr – Period 1959 / 1999

AppendixE details the Gatun data and the transposition to Toabre case.

Table 7 - Maximum Daily Rainfall - Transposition of the 20 greatest events presents a part of the data quoted in Appendix E. It emphasises the fact that pooling the station data into a composite regional sample is a powerful tool. The significant rainstorms are taken into account as can be seen below. For instance, the storms of 1935, 1923, 1931, 1932 and more recent ones appear in the synthetic regional sample.

The table gives also the ratio 650 / Pdmx, which is equivalent to a maximisation ratio (since 650 mm/day is the PMP found by Lombardi's approach, see below). This ratio is fully comparable to the maximisation ratio found during the meteorological approach (using dew point and wind velocity).

Table 7 - Maximum Daily Rainfall - Transposition of the 20 greatest events

Station	Year	Date	Rank	Y	Pdmx	650/Pdmx
Gatun-Extension	1939		218	1.65	155	4.18
Sabanita Verde	1991	09/12/91	219	1.66	157	4.14
Cocle del Norte	1973	12/06/73	220	1.74	164	3.96
Gatun-Extension	1933		221	1.75	165	3.94
Cocle del Norte	1970	06/11/70	222	1.75	165	3.93
Boca de Uracillo	1984	12/05/84	223	1.76	166	3.91
Gatun-Extension	1937		224	1.80	170	3.82
Boca de Toabre	1992	26/04/92	225	1.81	170	3.82
Sabanita Verde	1997	20/10/97	226	1.86	175	3.71
Gatun-Extension	1917		227	1.89	179	3.64
Cocle del Norte	1972	11/07/72	228	1.91	180	3.61
Boca de Toabre	1970	05/05/70	229	1.99	188	3.46
Sabanita Verde	1988	07/11/88	230	2.07	195	3.34
Gatun-Extension	1931		231	2.14	202	3.23
Gatun-Extension	1932		232	2.14	202	3.22
Sabanita Verde	1981	04/12/81	233	2.16	203	3.19
Cocle del Norte	1985	08/11/85	234	2.19	206	3.15
Gatun-Extension	1923		235	2.39	225	2.89
Santa Ana	1991	05/03/91	236	3.23	304	2.14
Gatun-Extension	1935		237	3.31	312	2.08

Note: Y = Pdmx/Me – Pdmx in mm/day

Lombardi (ICOLD, San Francisco 1988) recommends to fit a bounded distribution to a given sample by applying the procedures outlined hereafter.

(i) Determine a first guess of possible (Min, Max) for the observed sample. Then, define the following set of constants:

c = (Max+Min)/2;

A = (Max-Min)/2.

(ii) Compute transforms of Pdmx values by :

x = (Pdmx-c)/A;

and, compute the variable y = ln[(1+x)/(1-x)].

(iii) Compute the observed frequency F and the associated Gauss variate u(F). Then, fit by least-square techniques a relation such as:

y (F) = a + b u(F).

(iv) The fit equation is therefore given by:

y (F') = a + b u(F'), where F' is the frequency for which is sought the Pdmx estimate.

(v) The estimate of Pdmx(F') can be found by:

Pdmx (F') = c + A [(e^y-1)/(e^y+1)].

Table 8 - Toabre Catchment - Maximum Daily Rainfall vs. Return Period gives the results obtained by fitting a Lombardi's distribution to the 237 station-year sample. These results are point rainfall valid for a 10-mi² area. The daily PMP amounts to 650 mm/day.

In terms of PMP, one obtains the following comparison with the Harza estimates for Rio Indio (2000):

Duration (hours)	48	Harza (2000)
PMP (mm)	711	Harza (2000)
Ratio P(24)/P(48)	0.78	Harza (2000)
PMP (24h) (mm)	555	Harza (2000)
PMP (one day) (mm)	**650**	**Present study (2002)**
PMP (24 h) Gatun (mm)	663	Riedel et al., 1978
PMP (24 h) Madden (mm)	704	Riedel et al., 1978
Ratio 650 / 555	1.17	

These sets of results are not conflicting.

Figure 9 - Selection of PMP = 650 mm/day shows the computation of PMP = 650 mm/day.

On the upper graph, the 237-year sample is plotted on a Gumbel paper. A double Gumbel distribution describes the overall sample. Two data points appear to be outliners. The upper Gumbel distribution is used to re-compute their real probability of non-exceedance. Then the Lombardi's Distribution is applied.

On the lower graph, the variation of the coefficient of determination r^2 between observed Pdmx and computed Pdmx (according to Lombardi's distribution) is given. Several computations have been made with increasing Max values from 350 mm/day to 1 600 m/day. On the same graph appear values of observed daily rainfalls for outstanding storms taken from the literature. According to this graph, selecting 650 mm/day as PMP is a sound solution.

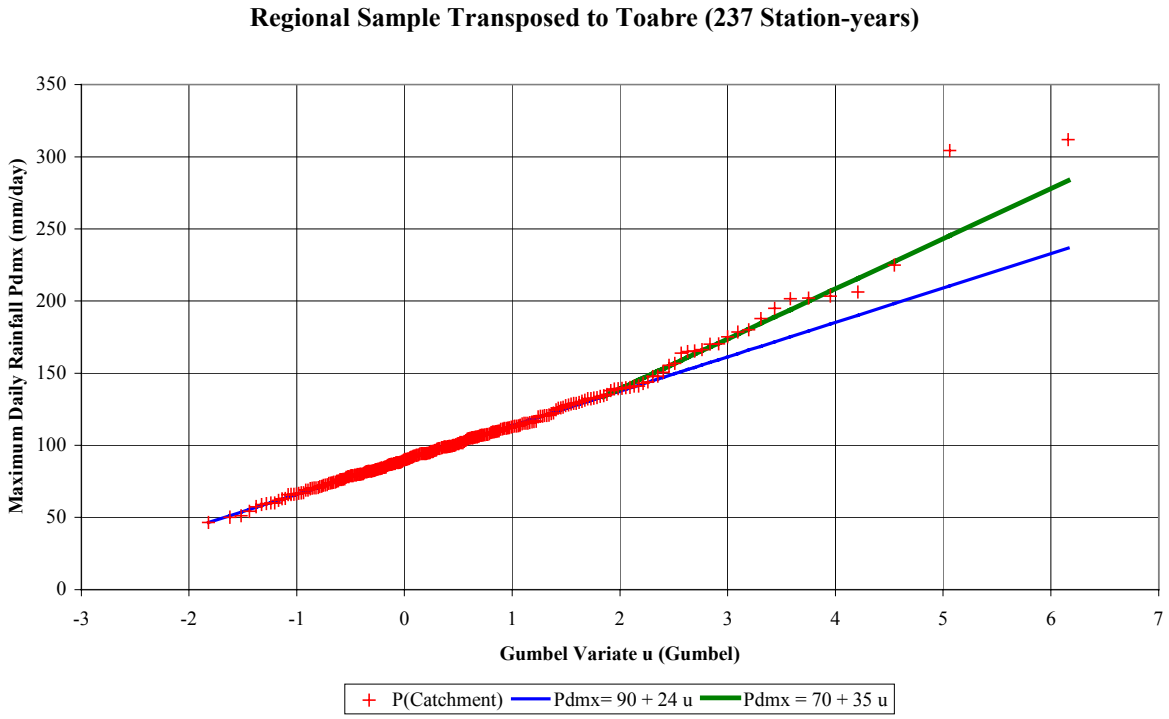
Table 8 - Toabre Catchment - Maximum Daily Rainfall vs. Return Period

Return Period **T** (years)	**Maximum Daily Rainfall** **Pdmx** (mm/day)
2	98
5	130
10	151
20	172
50	199
100	218
200	238
500	262
1 000	280
2 000	297
5 000	319
10 000	335
PMP	**650**
PMP / P(10 000)	1.94

Figure 10 - Lombardi's Distribution for Maximum Daily Rainfall summarises the preceding findings:

On the upper graph, it can be seen that the selected Lombardi's distribution (Min = 40 mm/day, Max = PMP = 650 mm/day) describe closely the regional data transposed to Toabre case.

On the lower graph, the daily rainfalls are plotted against the return period. The whole 237-year sample is well described by the Lombardi's Distribution.



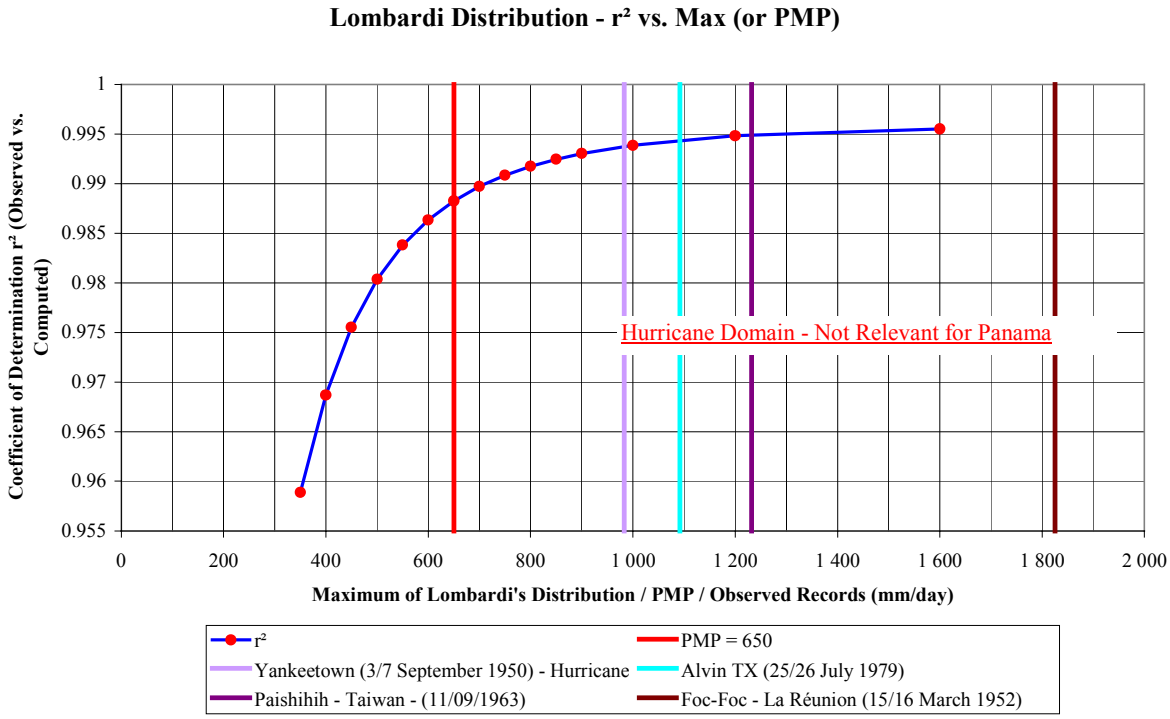
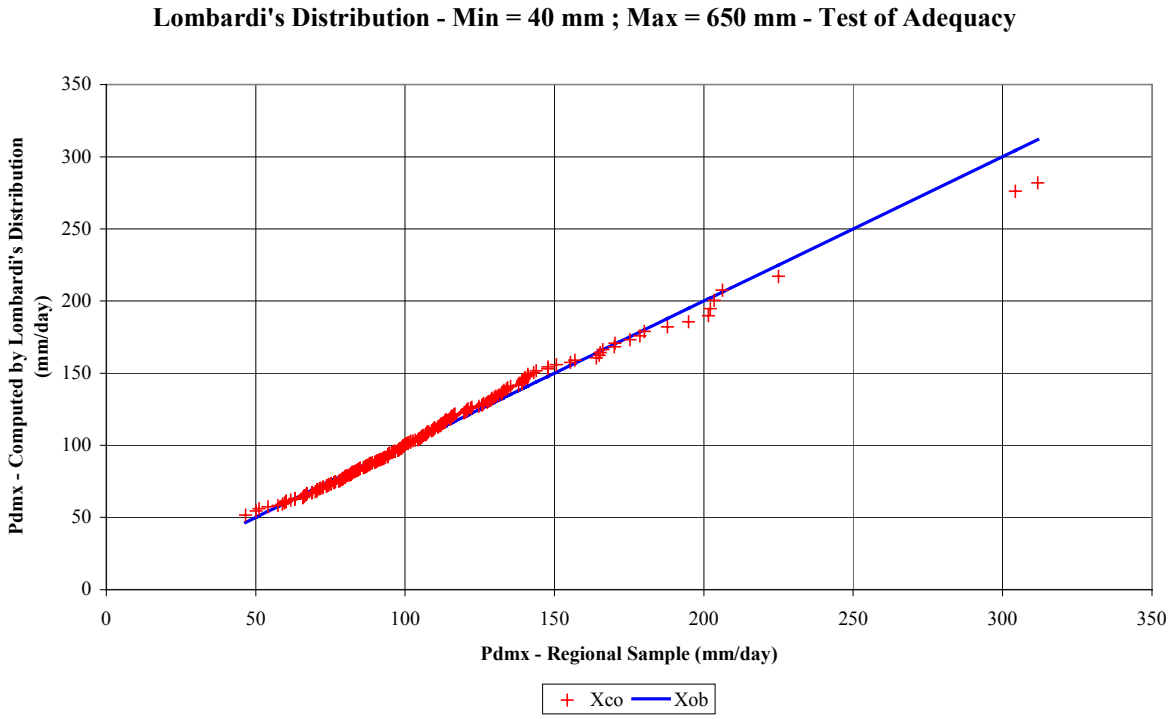


Figure 9 - Selection of PMP = 650 mm/day



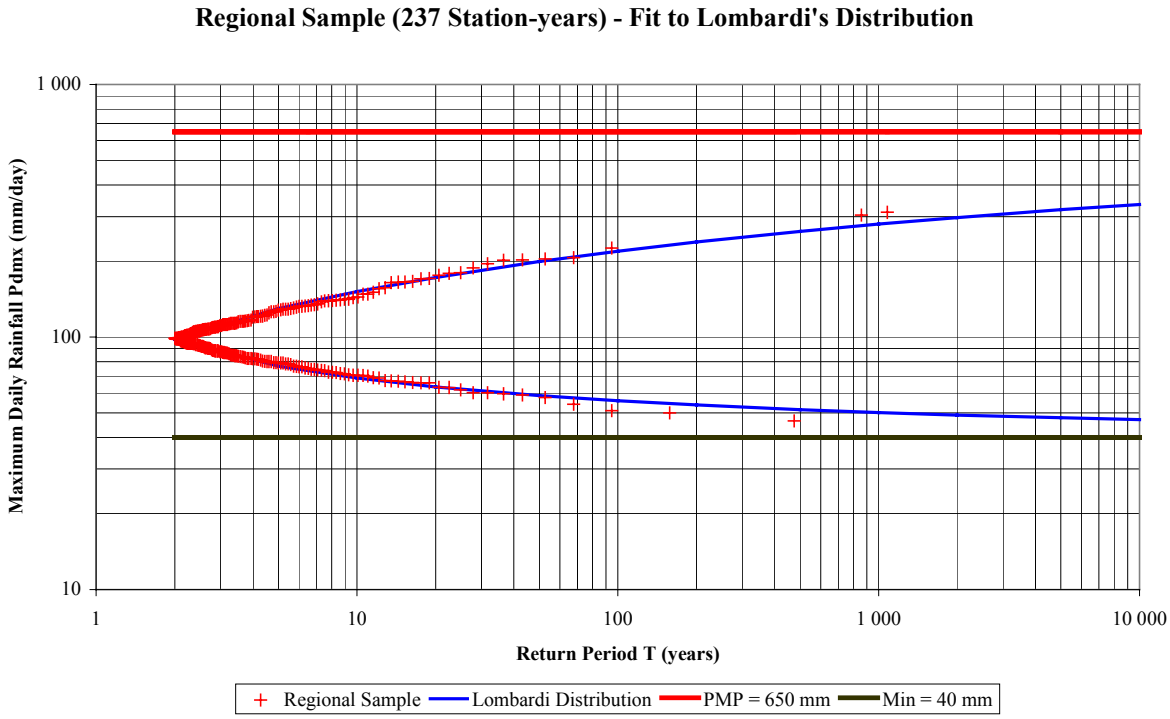


Figure 10 - Lombardi's Distribution for Maximum Daily Rainfall

3. INFLOWS

3.1. Background

This section is mainly based on the report issued by ACP in May 2002:

[] Espinosa D – "Informe de la revisión y recálculo de la estadística de caudal en la estación Batatilla" – ACP

This study of Batatilla gauging station is divided in four parts:

Review of rating curves and gauging data.

Re-computation of discharges and preparation of yearly summaries.

Extension and fill-in of daily discharges to obtain a complete record for the period 1948 / 2000.

Analysis of sediments in suspension.

3.1.1. Main Features of Batatilla Gauging Station

According to this reference, the main features of Batatilla gauging station are the following:

Table 9 - Main Features of Batatilla Gauging Station

Item	Date / Period	Unit	Value
Maximum water level	10/01/70	m	12.97
Maximum peak discharge	10/01/70	m3/s	2 219
Maximum daily discharge	14/01/96	m3/s	1 711
Maximum gauged discharge	25/11/69	m3/s	132
Mean discharge	1958-2000	m3/s	43.8
Mean discharge	1948-2000	m3/s	44.2
Minimum gauged discharge	22/04/98	m3/s	2.70
Minimum daily discharge	April 1983	m3/s	1.96
Dryest year	1976	m3/s	29.8
Average year	1991	m3/s	44.7
Wettest year	1970	m3/s	77.4

3.1.2. Description of the Batatilla gauging station

Daly Espinosa describes the station in the following manner:

Table 10 - Description of Batailla Gauging Station

Period	Equipment	Observations
July 1958 / May 1965	Staff gauges	Two readings per day (7 am and 5 pm) by a local observer
April 1969 / To date	1 stiiling well (9-m high)	Continuous monitoring
	1 cableway (80-m wide)	Topographic section of 13/09/76
	3 staff gauges	
	BMs	
	1 AWLR Stevens A-35	
Total number of gaugings	**356**	

3.1.3. Rating Curves at Batatilla

In her review of Batatilla record, Daly Espinosa found that 8 rating curves could be applied to the period 1958 / 2001. The two following tables detail this information.

Table 11 - Rating Curves at Batatilla - Period of Validity

Curve Nb	From	To	Gaugings	Remarks
1	June 1958	21/06/62	1 to 11	Except n°10
2	22/06/62	29/10/64	12 to 15	Except n°13 and 14
3	11/05/69	08/01/71	9 to 27	
4	09/01/71	05/02/75	28 to 66	
3	06/02/75	29/04/76	67 to 83	
5	30/04/76	06/03/78	84 to 104	
3	07/03/78	11/12/78	105 to 114	
5	12/12/78	02/01/80	115 to 122	
3	03/01/80	18/05/81	123 to 132	
5	19/05/81	11/08/81	133 to 138	
3	12/08/81	13/05/83	139 to 158	
6	14/05/83	02/01/84	159 to 164	
3	03/01/84	13/05/84	165 to 167	
6	14/05/84	13/11/88	168 to 208	Except n°205 and 206
7	14/11/88	09/01/93	209 to 235	
6	10/01/93	23/04/93	236 to 239	
7	24/04/93	16/12/99	240 to 318	
8	17/12/99	31/12/00	319 to 334	
7	01/01/00	10/06/01	335 to 338	
8	11/06/01 …		339 …	

Table 12 - Rating Curves at Batatilla - Equations

Curve Nb	Segment	K	H0	n	Range (m)
1	1-1	79.5	0.11	1.48	0.2 to 0.915
	1-2	70.7	0.06	1.37	0.915 to 1.46
	1-3	66.4	0.007	1.40	1.46 to 5
2	2-1	79.2	0.22	1.38	0.2 to 1.875
	2-2	66.4	0.007	1.40	1.875 to 5
3	3-1	1.61	-0.43	6.98	0.6 to 0.84
	3-2	53.4	0.39	2.21	0.84 to 1.12
	3-3	70.9	0.68	1.21	1.12 to 2.71
	3-4	63.5	0.73	1.42	2.714 to 13
4	4-1	20.1	0.04	5.19	0.6 to 0.814
	4-2	70.5	0.58	1.77	0.814 to 1.045
	4-3	78.6	0.76	1.17	1.045 to 1.625
	4-4	70.9	0.68	1.21	1.625 to 2.714
	4-5	63.5	0.73	1.42	2.714 to 13
5	5-1	1.03	-0.56	6.58	0.4 to 0.713
	5-2	44.0	0.28	2.61	0.713 to 1.10
	5-3	74.8	0.71	1.11	1.10 to 2.04
	5-4	70.9	0.68	1.21	2.04 to 2.714
	5-5	63.5	0.73	1.42	2.714 to 13
6	6-1	4.03	-0.40	5.08	0.6 to 0.977
	6-2	71.6	0.66	1.10	0.977 to 1.975
	6-3	70.9	0.68	1.21	1.975 to 2.714
	6-4	63.5	0.73	1.42	2.714 to 13
7	7-1	42.4	0.23	1.99	0.4 to 0.963
	7-2	52.1	0.39	1.48	0.963 to 1.415
	7-3	67.4	0.59	1.14	1.415 to 2.024
	7-4	70.9	0.68	1.21	2.024 to 2.714
	7-5	63.5	0.73	1.42	2.714 to 13
8	8-1	48.4	0.34	1.47	0.5 to 1.53
	8-2	67.4	0.59	1.14	1.53 to 2.024
	8-3	70.9	0.68	1.21	2.024 to 2.714
	8-4	63.5	0.73	1.42	2.714 to 13

Note: $Q=K(H-H_0)^n$.

3.1.4. Data Fill-in and Data Extension

For missing values and for extending the data until obtaining the full record for 1948 / 200, Daly Espinosa made use of the following stations:

Trinidad. (El Chorro River)

El Torno and Canoa. (River Cocle del Norte)

Uracillo and Limón. (Indio River)

Cañones. (Ciri Grande River)

3.2. Yearly and Monthly Inflows

3.2.1. Rio Toabre at Batatilla (788 km²)

Table 13 - Mean Discharge - Toabre River - Batatilla Station details the monthly discharge record at Batatilla.

Figure 11 - Toabre River at Batatilla - Monthly Regime illustrates the monthly discharge pattern for three typical years. The upper part compares the monthly discharges in m3/s. The lower graph compares the ratios of monthly discharge to corresponding yearly discharge.

Figure 12 - Toabre River at Batatilla - Test of the Extension and Completion of Data concludes the data processing for Batatilla. The upper graph compares the times series of rainfall (Gatun Downstream) and runoff (Batatilla). The lower graph presents a double mass analysis. These two graphs show a good agreement between Gatun and Batatilla data. Daly Espinosa has shown this agreement together with a good agreement between Elchorro at Trinidad and Batatilla.

3.2.2. Rio Toabre at Toabre Damsite (727 km²)

Monthly record data at Toabre dam site have been deduced from Batatilla data by applying the drainage area ratio (DAR):

DAR = 727 / 788 = 0.923.

Table 14 - Toabre River at Toabre Damsite - Monthly Discharges details the monthly discharge record obtained at Toabre Damsite.

Table 15 - Toabre at Damsite - Yearly Discharge vs. Return Period presents the fit of the yearly sample to a gausso-log distribution.

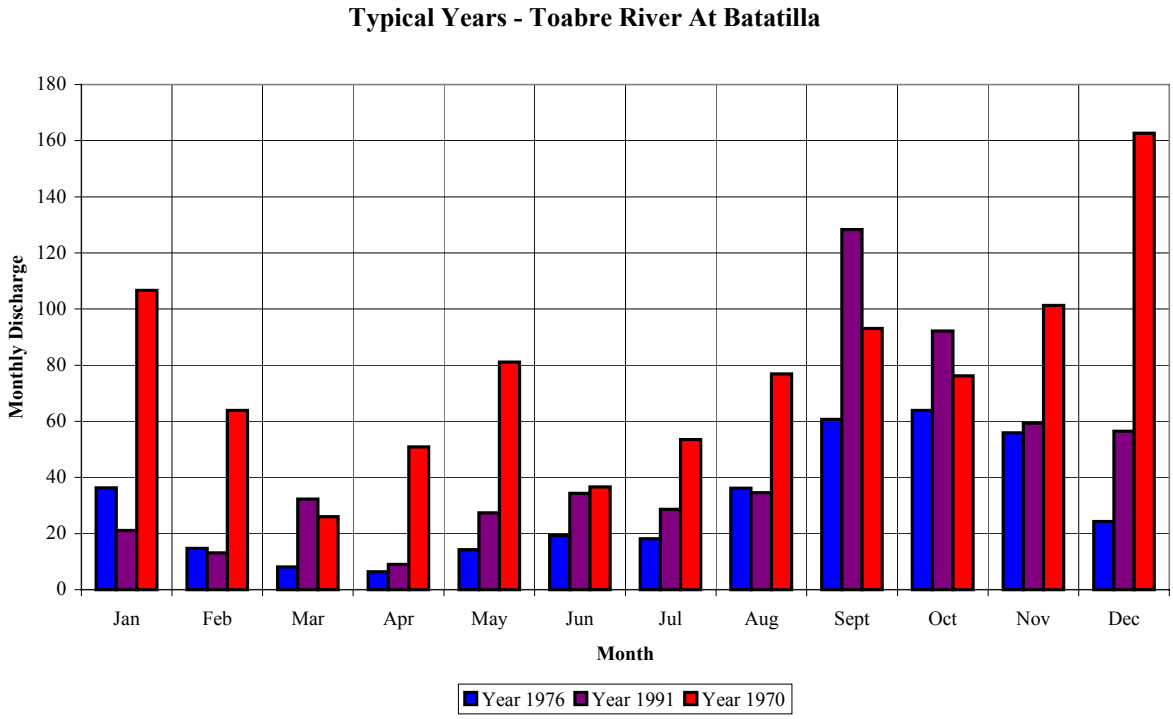
Figure 13 - Toabre River at Damsite - Monthly and Yearly River Regime illustrates the previous results.

Table 13 - Mean Discharge - Toabre River - Batatilla Station

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec	Year
1948	**25.1**	**13.6**	**7.45**	**4.22**	**11.2**	**14.7**	**45.6**	**55.2**	**48.7**	**52.6**	**120**	**41.3**	**36.6**
1949	**13.6**	**6.36**	**3.40**	**3.31**	**11.1**	**62.1**	**58.2**	**63.1**	**95.8**	**78.2**	**138**	**103**	**53.0**
1950	**26.8**	**15.8**	**8.54**	**4.15**	**37.9**	**59.2**	**60.7**	**81.3**	**51.9**	**80.4**	**116**	**95.4**	**53.2**
1951	**33.8**	**22.7**	**11.4**	**8.29**	**34.7**	**48.3**	**48.0**	**59.1**	**47.9**	**65.2**	**81.1**	**52.4**	**42.7**
1952	**21.0**	**12.9**	**6.66**	**5.24**	**13.1**	**36.1**	**32.6**	**38.2**	**65.7**	**93.0**	**64.5**	**124.5**	**42.8**
1953	**50.8**	**23.3**	**11.3**	**7.94**	**46.2**	**42.2**	**38.6**	**28.2**	**39.7**	**78.1**	**81.0**	**43.2**	**40.9**
1954	**17.8**	**10.2**	**6.01**	**5.32**	**48.5**	**43.7**	**105**	**84.3**	**84.3**	**82.0**	**127**	**57.6**	**56.0**
1955	**61.1**	**19.4**	**9.55**	**6.77**	**12.9**	**49.7**	**41.9**	**66.1**	**79.3**	**91.7**	**132**	**65.4**	**53.0**
1956	**57.1**	**19.6**	**12.3**	**9.54**	**31.1**	**51.9**	**63.8**	**39.6**	**73.0**	**112**	**72.2**	**36.8**	**48.3**
1957	**20.4**	**11.2**	**6.90**	**3.82**	**17.3**	**19.1**	**20.5**	**41.0**	**40.2**	**105.9**	**76.7**	**41.4**	**33.7**
1958	**22.7**	**18.2**	**11.0**	**9.38**	**30.5**	**31.7**	34.6	65.0	69.1	70.9	61.5	39.9	38.7
1959	20.8	9.16	4.55	5.40	15.9	**35.8**	**32.2**	53.3	56.4	80.0	72.9	99.9	40.5
1960	40.2	15.1	10.2	20.9	33.7	48.8	47.0	***49.8***	***45.8***	***57.8***	**87.5**	**159**	51.3
1961	**24.8**	**12.3**	**7.53**	13.7	18.5	37.5	49.1	82.7	**59.2**	**74.4**	**73.2**	**55.3**	42.4
1962	25.5	13.07	8.29	7.34	23.4	42.9	31.1	58.7	51.6	72.3	90.0	49.2	39.5
1963	22.5	13.8	5.79	38.2	46.3	53.9	54.8	59.4	47.2	58.2	78.7	35.1	42.8
1964	**14.1**	**7.35**	**4.68**	**5.57**	**21.0**	**71.1**	**70.0**	**71.4**	**86.5**	**93.4**	**110**	**32.7**	**49.0**
1965	**32.8**	**15.8**	**8.79**	**5.04**	**7.98**	**16.4**	**14.6**	**34.4**	**27.3**	**57.7**	**72.2**	**76.8**	**30.8**
1966	**19.1**	**9.1**	**6.06**	**6.50**	**39.9**	**55.6**	**44.4**	**43.9**	**40.3**	**85.3**	**115**	**87.6**	**46.1**
1967	**27.6**	**13.2**	**6.73**	**10.7**	**33.9**	**82.3**	**61.4**	**67.5**	**91.1**	**105.7**	**69.6**	**31.8**	**50.1**
1968	**15.8**	**11.3**	**7.09**	**6.36**	**18.1**	**52.8**	**39.3**	**56.1**	**58.9**	**101.0**	**97.4**	**46.0**	**42.5**
1969	**15.5**	**18.1**	**8.47**	**11.8**	**17.0**	32.2	27.0	44.9	56.3	62.3	70.3	58.5	35.2
1970	**107**	**63.9**	**26.0**	**50.8**	81.1	**36.6**	53.4	76.8	93.0	**76.1**	101.3	163	77.4
1971	44.9	**18.1**	**20.8**	9.56	31.7	62.0	60.7	66.9	74.0	78.9	51.5	22.6	45.2
1972	39.6	15.5	10.4	27.0	**32.0**	34.8	27.7	24.8	52.1	48.5	47.9	22.8	31.9
1973	14.2	8.81	5.13	5.15	22.0	53.9	60.1	62.4	86.5	**87.8**	**103**	77.1	48.8
1974	27.3	14.5	9.10	**17.2**	**58.8**	**42.7**	48.0	45.0	43.5	96.2	62.2	43.1	42.3
1975	16.6	**10.6**	**7.07**	3.82	17.6	**29.3**	**53.1**	**81.3**	**96.3**	121	159	117	59.4
1976	36.3	14.7	8.11	6.43	14.2	19.3	18.1	36.1	60.6	63.9	55.9	24.2	29.8
1977	12.1	7.74	5.01	4.64	12.6	34.5	37.4	76.1	56.3	83.0	54.2	29.9	34.5
1978	14.4	9.84	8.58	61.7	109	42.5	34.2	39.9	63.6	69.8	84.0	32.4	47.5
1979	13.2	8.09	4.87	18.2	20.6	53.8	50.4	84.5	57.1	49.0	45.6	59.8	38.8
1980	48.4	15.3	8.26	9.62	22.6	35.5	37.7	71.8	50.8	76.3	68.7	**54.4**	41.6
1981	**35.7**	**21.6**	**16.3**	**45.0**	68.6	62.3	77.8	81.9	49.8	66.3	103	143	64.3
1982	32.1	15.0	9.30	8.94	17.4	38.2	42.8	37.8	46.0	71.9	53.0	19.0	32.6
1983	11.4	6.07	3.65	3.81	40.9	37.1	23.2	29.2	72.1	56.6	47.6	55.3	32.2
1984	24.1	21.3	16.6	6.18	21.2	48.0	68.3	78.9	78.6	83.1	73.9	27.4	45.6
1985	19.8	10.9	7.92	4.91	9.29	61.8	41.0	55.3	54.1	59.8	78.6	56.4	38.3
1986	21.1	11.6	7.60	27.3	34.4	50.8	56.1	50.4	55.4	118	114	29.3	48.0
1987	13.9	8.97	5.26	18.7	22.4	21.2	30.8	38.5	45.3	110	60.2	35.9	34.3
1988	15.3	13.0	5.00	3.89	33.2	32.6	51.8	**60.3**	**57.7**	**78.0**	78.7	37.4	38.9

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec	Year
1989	24.0	13.8	10.1	6.93	31.4	42.9	59.0	63.8	58.1	**54.5**	73.9	49.2	40.7
1990	26.2	14.5	10.3	8.01	23.8	25.1	**43.0**	**44.8**	**62.6**	**109**	**82.5**	97.1	45.6
1991	21.0	13.1	32.3	**9.02**	**27.4**	**34.3**	**28.6**	**34.5**	**128**	92.2	59.3	56.5	44.7
1992	18.0	10.6	6.16	25.0	49.4	52.2	41.0	50.6	78.8	57.6	46.1	30.8	38.9
1993	28.6	11.2	13.0	13.7	20.8	44.6	39.4	29.9	81.8	60.1	104	69.3	43.0
1994	21.1	12.7	10.2	14.9	36.0	61.7	35.0	52.3	62.5	62.7	59.5	26.0	37.9
1995	16.4	10.3	6.63	11.8	44.3	41.6	49.8	57.1	70.2	40.9	54.2	74.5	39.8
1996	141	44.7	33.1	20.7	67.0	65.2	75.6	87.3	95.0	75.7	**72.2**	**71.3**	70.7
1997	26.8	18.5	9.62	6.87	24.9	17.2	20.6	17.8	28.1	47.9	39.6	16.4	22.9
1998	9.93	6.64	3.95	21.2	22.0	49.7	43.1	48.7	48.6	73.1	58.0	82.6	39.0
1999	**35.2**	19.0	18.2	17.2	46.6	90.0	70.6	121.2	117	73.7	**101**	149	71.6
2000	**76.4**	25.5	14.0	13.0	**31.7**	**80.1**	**54.9**	**74.9**	61.2	44.3	63.0	53.5	49.4
2001	30.6	11.5	8.48	12.4	11.3	44.9	28.3	45.3					
Mean.	**30.2**	**15.2**	**9.89**	**13.2**	**31.0**	**45.1**	**46.0**	**56.8**	**64.2**	**76.3**	**80.4**	**61.5**	**44.2**
Max.	141	63.9	33.1	61.7	109	90.0	105	121	128	121	159	163	163
Min.	9.93	6.07	3.40	3.31	7.98	14.7	14.6	17.8	27.3	40.9	39.6	16.4	3.31

Units: m3/s.



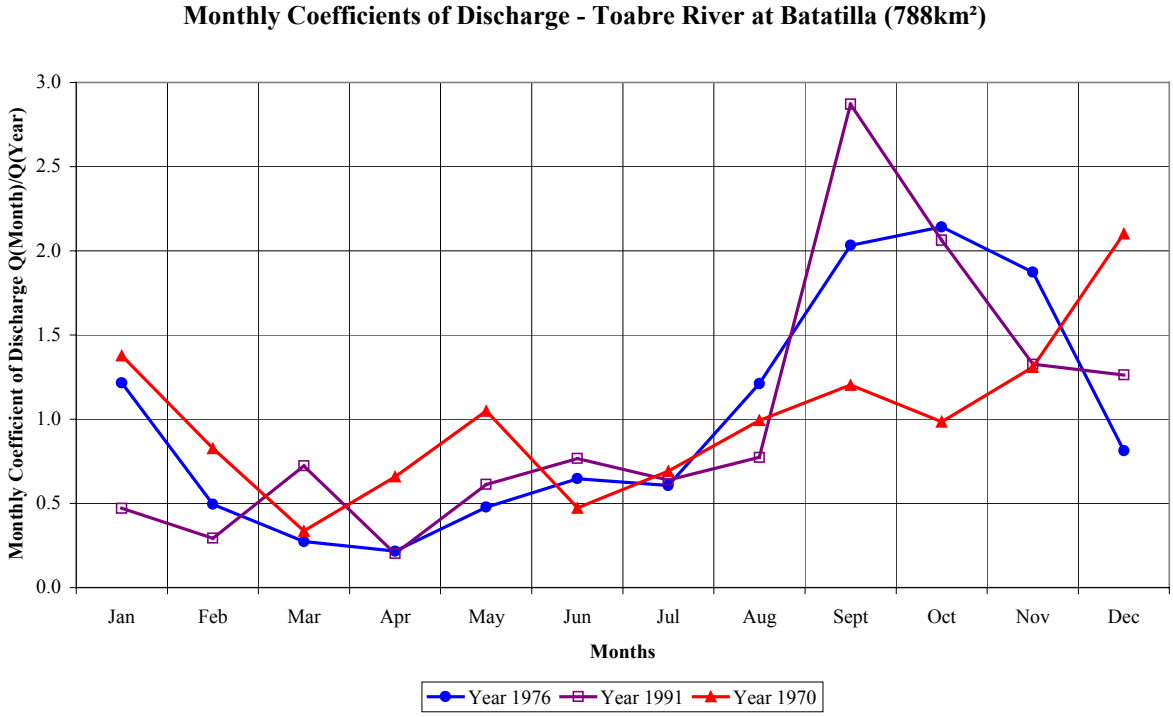
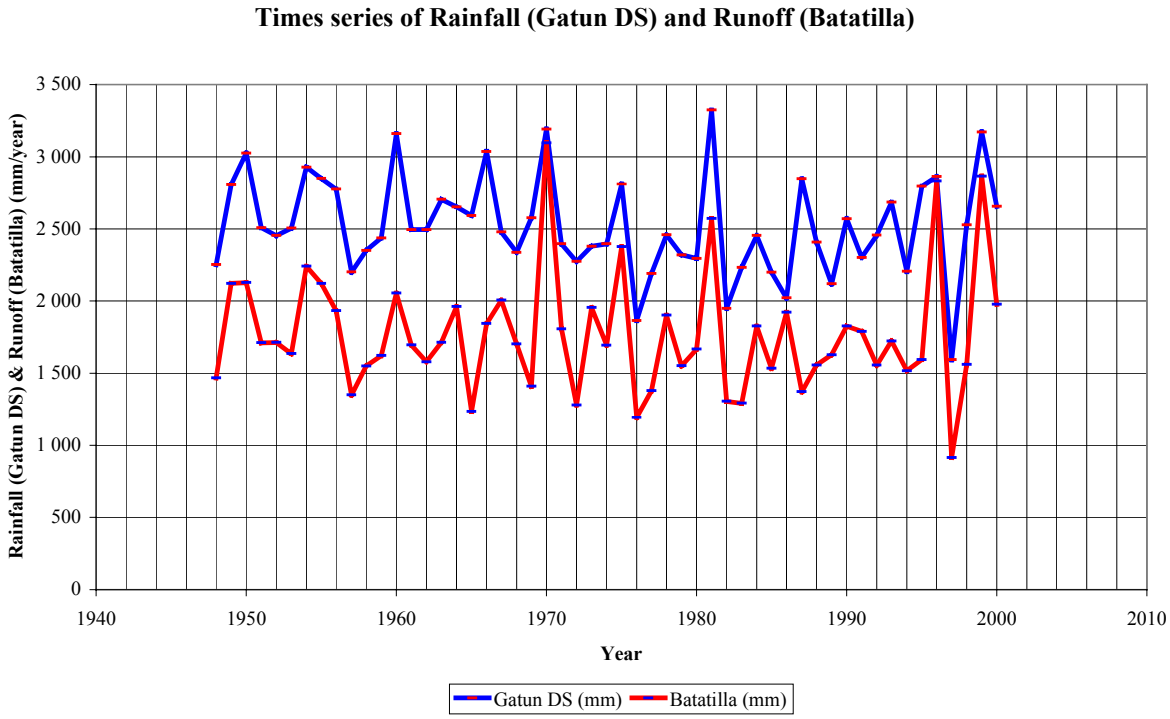


Figure 11 - Toabre River at Batatilla - Monthly Regime



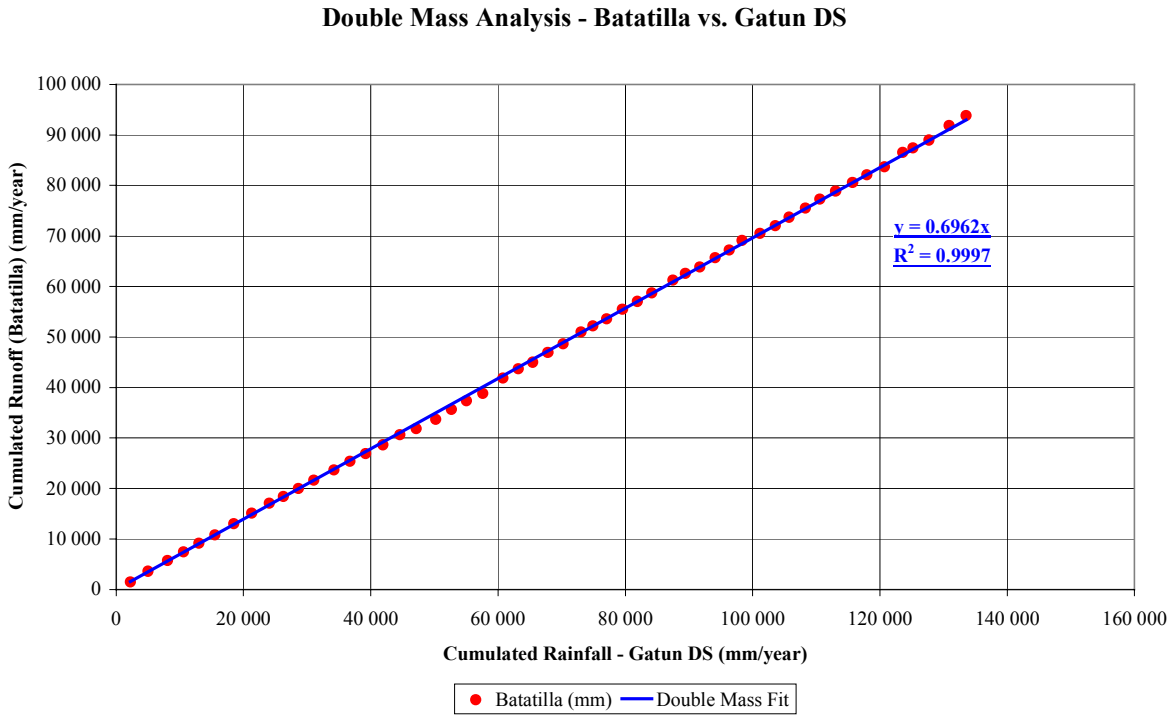


Figure 12 - Toabre River at Batatilla - Test of the Extension and Completion of Data

Table 14 - Toabre River at Toabre Damsite - Monthly Discharges

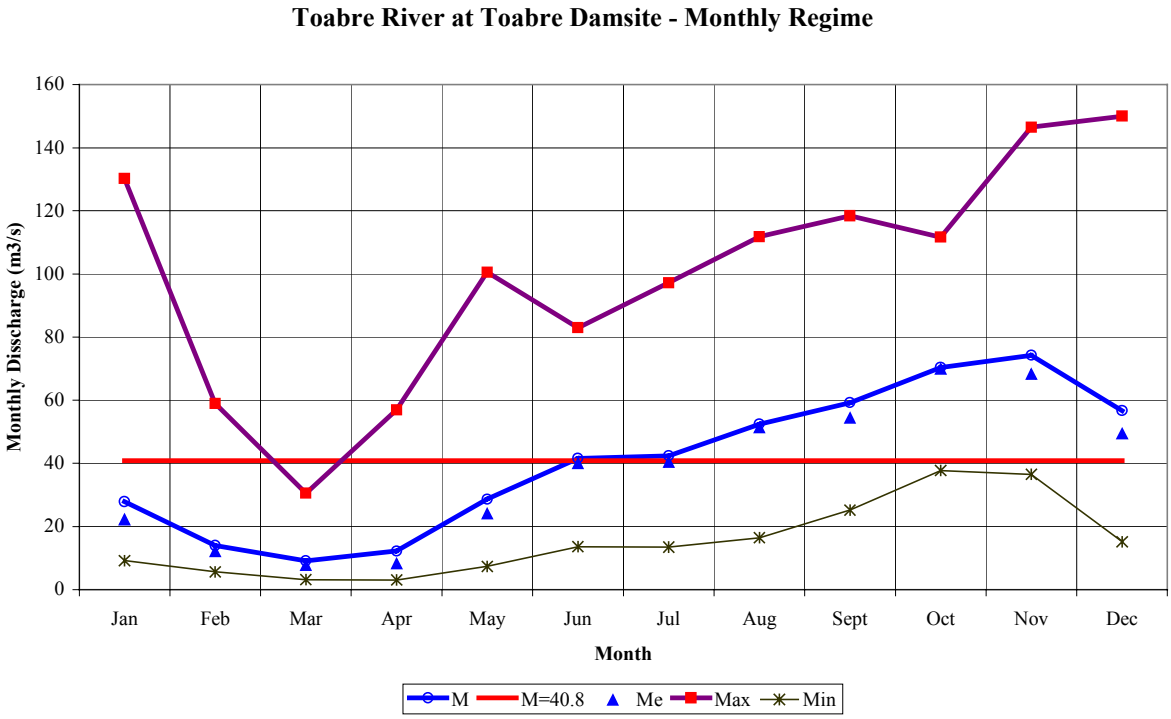
Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec	Year
1948	23.2	12.5	6.9	3.9	10.3	13.6	42.0	50.9	44.9	48.5	110.7	38.1	33.8
1949	12.6	5.9	3.1	3.1	10.2	57.3	53.7	58.2	88.4	72.1	127.6	94.8	48.9
1950	24.7	14.6	7.9	3.8	35.0	54.6	56.0	75.0	47.9	74.2	106.7	88.0	49.0
1951	31.1	20.9	10.6	7.6	32.0	44.6	44.3	54.5	44.2	60.1	74.8	48.3	39.4
1952	19.4	11.9	6.1	4.8	12.1	33.3	30.1	35.3	60.6	85.8	59.5	114.8	39.5
1953	46.9	21.5	10.4	7.3	42.6	38.9	35.6	26.0	36.6	72.1	74.7	39.8	37.7
1954	16.4	9.4	5.5	4.9	44.7	40.3	97.2	77.7	77.8	75.7	117.0	53.2	51.7
1955	56.3	17.9	8.8	6.2	11.9	45.9	38.7	61.0	73.2	84.6	121.9	60.4	48.9
1956	52.7	18.1	11.3	8.8	28.7	47.9	58.8	36.6	67.4	103.7	66.6	34.0	44.5
1957	18.8	10.4	6.4	3.5	16.0	17.7	18.9	37.8	37.1	97.7	70.8	38.2	31.1
1958	20.9	16.7	10.2	8.7	28.1	29.2	32.0	60.0	63.7	65.4	56.7	36.8	35.7
1959	19.2	8.5	4.2	5.0	14.7	33.0	29.7	49.2	52.0	73.8	67.3	92.1	37.4
1960	37.1	13.9	9.4	19.3	31.1	45.1	43.4	46.0	42.3	53.3	80.8	146.5	47.3
1961	22.9	11.3	6.9	12.7	17.1	34.6	45.3	76.3	54.6	68.6	67.5	51.0	39.1
1962	23.5	12.1	7.6	6.8	21.6	39.6	28.7	54.2	47.6	66.7	83.1	45.4	36.4
1963	20.7	12.8	5.3	35.2	42.8	49.7	50.5	54.8	43.5	53.7	72.6	32.4	39.5
1964	13.0	6.8	4.3	5.1	19.4	65.6	64.6	65.9	79.8	86.2	101.8	30.1	45.2
1965	30.3	14.6	8.1	4.6	7.4	15.2	13.5	31.8	25.2	53.2	66.6	70.9	28.4
1966	17.7	8.4	5.6	6.0	36.8	51.3	41.0	40.5	37.2	78.7	106.4	80.8	42.5
1967	25.4	12.2	6.2	9.9	31.3	75.9	56.6	62.3	84.0	97.6	64.2	29.3	46.2
1968	14.6	10.4	6.5	5.9	16.7	48.7	36.3	51.7	54.3	93.2	89.9	42.4	39.2
1969	14.3	16.7	7.8	10.9	15.7	29.7	24.9	41.4	52.0	57.5	64.9	54.0	32.5
1970	98.4	59.0	24.0	46.9	74.8	33.8	49.3	70.9	85.8	70.3	93.5	150.0	71.4
1971	41.4	16.7	19.2	8.8	29.3	57.2	56.0	61.7	68.3	72.8	47.5	20.9	41.7
1972	36.5	14.3	9.6	24.9	29.6	32.1	25.6	22.9	48.1	44.7	44.2	21.1	29.5
1973	13.1	8.1	4.7	4.8	20.3	49.7	55.5	57.6	79.8	81.0	95.0	71.2	45.1
1974	25.2	13.4	8.4	15.9	54.2	39.4	44.3	41.5	40.2	88.8	57.3	39.8	39.0
1975	15.3	9.8	6.5	3.5	16.2	27.1	48.9	75.0	88.8	111.7	146.5	108.1	54.8
1976	33.4	13.6	7.5	5.9	13.1	17.8	16.7	33.3	55.9	58.9	51.5	22.4	27.5
1977	11.1	7.1	4.6	4.3	11.6	31.9	34.5	70.2	51.9	76.6	50.0	27.6	31.8
1978	13.3	9.1	7.9	56.9	100.5	39.2	31.5	36.8	58.7	64.4	77.5	29.9	43.8
1979	12.1	7.5	4.5	16.8	19.0	49.6	46.5	78.0	52.6	45.2	42.1	55.2	35.8
1980	44.7	14.1	7.6	8.9	20.8	32.7	34.8	66.2	46.9	70.4	63.3	50.2	38.4
1981	32.9	20.0	15.0	41.5	63.3	57.5	71.8	75.6	45.9	61.2	94.9	131.7	59.3
1982	29.6	13.9	8.6	8.2	16.0	35.2	39.5	34.9	42.5	66.3	48.9	17.5	30.1
1983	10.6	5.6	3.4	3.5	37.7	34.2	21.4	27.0	66.6	52.3	43.9	51.0	29.8
1984	22.2	19.7	15.3	5.7	19.5	44.3	63.0	72.8	72.5	76.7	68.2	25.3	42.1
1985	18.2	10.0	7.3	4.5	8.6	57.0	37.8	51.0	49.9	55.1	72.5	52.0	35.3
1986	19.5	10.7	7.0	25.2	31.7	46.8	51.8	46.5	51.1	108.7	105.4	27.0	44.3
1987	12.8	8.3	4.8	17.2	20.7	19.5	28.4	35.5	41.8	101.6	55.5	33.1	31.6
1988	14.1	12.0	4.6	3.6	30.7	30.1	47.8	55.6	53.2	71.9	72.6	34.5	35.9
1989	22.1	12.8	9.3	6.4	29.0	39.6	54.4	58.9	53.6	50.3	68.2	45.4	37.5
1990	24.2	13.4	9.5	7.4	22.0	23.1	39.7	41.4	57.7	101.0	76.1	89.6	42.1
1991	19.4	12.0	29.8	8.3	25.3	31.6	26.4	31.9	118.4	85.1	54.7	52.1	41.2
1992	16.6	9.8	5.7	23.1	45.6	48.1	37.8	46.7	72.7	53.1	42.6	28.4	35.8
1993	26.4	10.3	12.0	12.6	19.2	41.1	36.3	27.6	75.4	55.4	96.4	63.9	39.7
1994	19.4	11.7	9.4	13.8	33.2	56.9	32.3	48.3	57.6	57.8	54.9	24.0	34.9
1995	15.1	9.5	6.1	10.9	40.8	38.3	46.0	52.7	64.8	37.7	50.0	68.7	36.7
1996	130.3	41.2	30.5	19.1	61.8	60.1	69.8	80.6	87.6	69.9	66.6	65.8	65.3

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec	Year
1997	24.8	17.1	8.9	6.3	22.9	15.9	19.0	16.4	26.0	44.2	36.5	15.2	21.1
1998	9.2	6.1	3.6	19.5	20.3	45.8	39.8	44.9	44.8	67.5	53.5	76.2	35.9
1999	32.5	17.6	16.8	15.9	43.0	83.0	65.1	111.8	108.3	68.0	93.4	137.1	66.0
2000	70.5	23.5	13.0	12.0	29.3	73.9	50.7	69.1	56.5	40.9	58.1	49.4	45.6
2001	28.2	10.6	7.8	11.4	10.4	41.4	26.1	41.8					
M	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
S	21.3	8.5	5.7	11.2	17.7	15.2	15.8	18.3	19.2	18.2	24.6	33.9	9.7
Cv	0.77	0.60	0.63	0.92	0.62	0.37	0.37	0.35	0.32	0.26	0.33	0.60	0.24
Me	22.2	12.1	7.7	8.3	24.1	40.0	40.4	51.4	54.3	69.9	68.2	49.4	39.2
Max	130.3	59.0	30.5	56.9	100.5	83.0	97.2	111.8	118.4	111.7	146.5	150.0	71.4
Min	9.2	5.6	3.1	3.1	7.4	13.6	13.5	16.4	25.2	37.7	36.5	15.2	21.1

Units: m3/s.

Table 15 - Toabre at Damsite - Yearly Discharge vs. Return Period

	T (years)	Qyr (m3/s)
Dry Years	100	23.4
	50	24.9
	20	27.3
	10	29.7
Dry Years	5	32.8
Median Year	2	39.8
Wet Years	5	48.2
	10	53.3
	20	57.9
	50	63.5
Wet Years	100	67.6



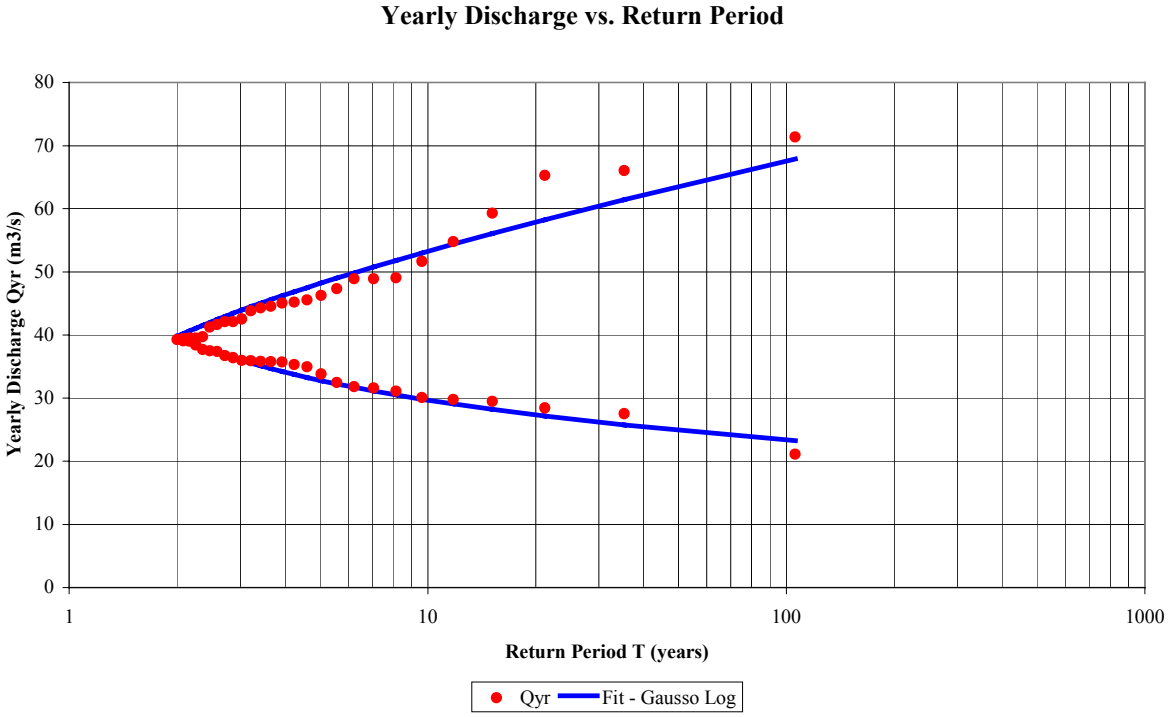


Figure 13 - Toabre River at Damsite - Monthly and Yearly River Regime

4. FLOODS

4.1. General

Flood study aims at defining the Inflow Design Flood (IDF) for the spillway design and the Construction Stage Flood 5CSF) for the safety of structures and works during the dam construction. In order to achieve these purposes the study deals with the following topics:

Daily Peaks at Batatilla.

Hydrograph Shapes at Batatilla.

Floods at Toabre Damsite.

Appendix G Flood Data details relevant information.

4.2. Daily Peaks at Batatilla

4.2.1. Preliminary Analysis of Toabre Data

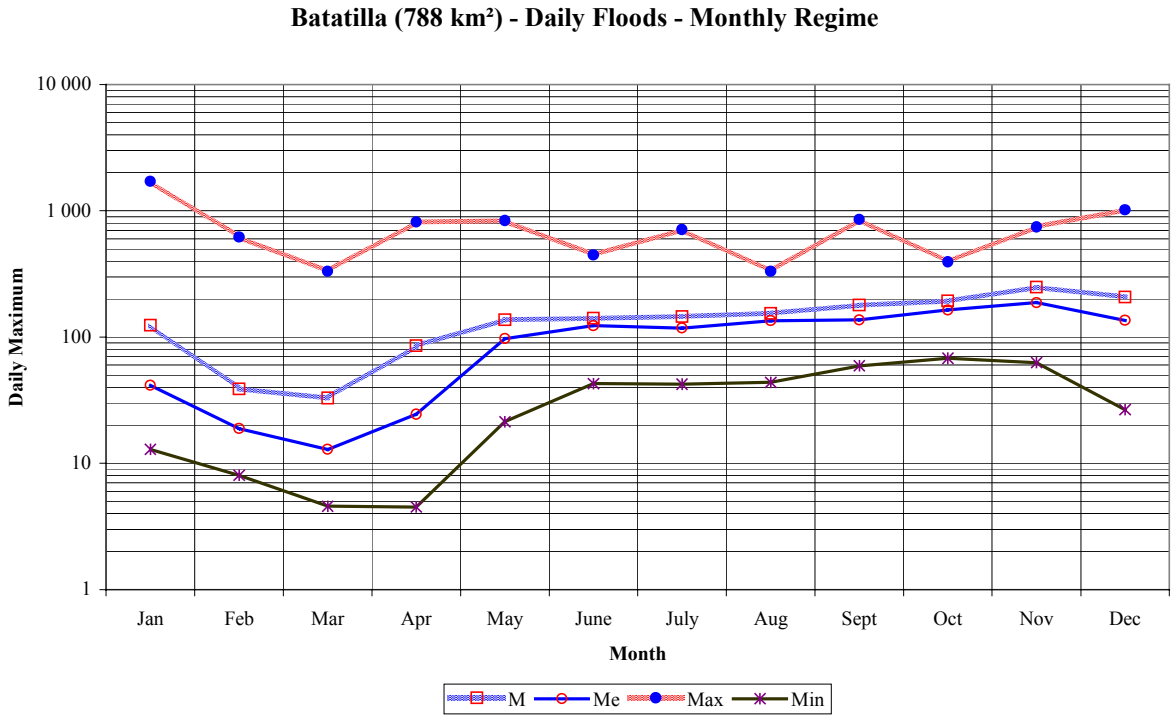
presents the sample statistics on a monthly and yearly level. The maximum daily peak of 1 711 m3/s affects the coefficient of variation for January and to a lesser amount the Cv for the yearly peak. The dry season appears clearly for the sample median. For the sample maximum, the seasonal pattern is not clear-cut.

Figure 14 - Toabre River - Monthly Flood Regime & Occurrence of Yearly Maximum details the overall daily flood pattern. The upper part describes the monthly regime of floods. It shows that February and March are really dry months. January, April and May are rather dry. But they can experience heavy floods also. The lower graph shows the monthly distribution of the 53 maximum daily peaks. October to January and May are the flood prone months.

Table 16 - Batatilla (788 km²) - Statistics on Daily Peaks

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Max
Nval	54	54	54	54	54	54	54	54	53	53	53	53	53
M	124	39	33	85	137	141	145	154	179	193	248	207	435
S	264	85	58	150	132	80	109	70	120	84	163	193	266
Cv	2.13	2.19	1.77	1.76	0.96	0.57	0.75	0.45	0.67	0.43	0.66	0.93	0.61
Me	42	19	13	25	97	123	118	135	137	164	188	136	352
Max	1 711	618	332	816	835	445	711	331	853	393	744	1 018	1 711
Min	13	8	5	5	21	43	42	44	59	68	63	27	137

Units: m3/s



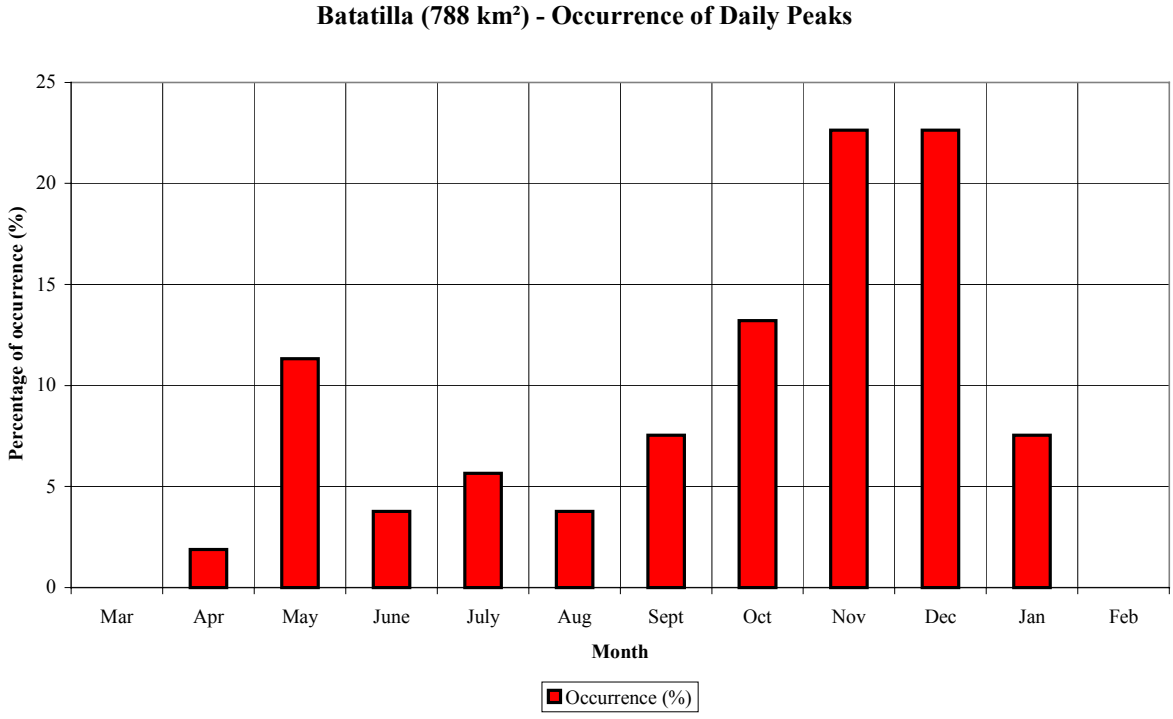


Figure 14 - Toabre River - Monthly Flood Regime & Occurrence of Yearly Maximum

4.2.2. Extension of Batatilla Record Using Gatun DS

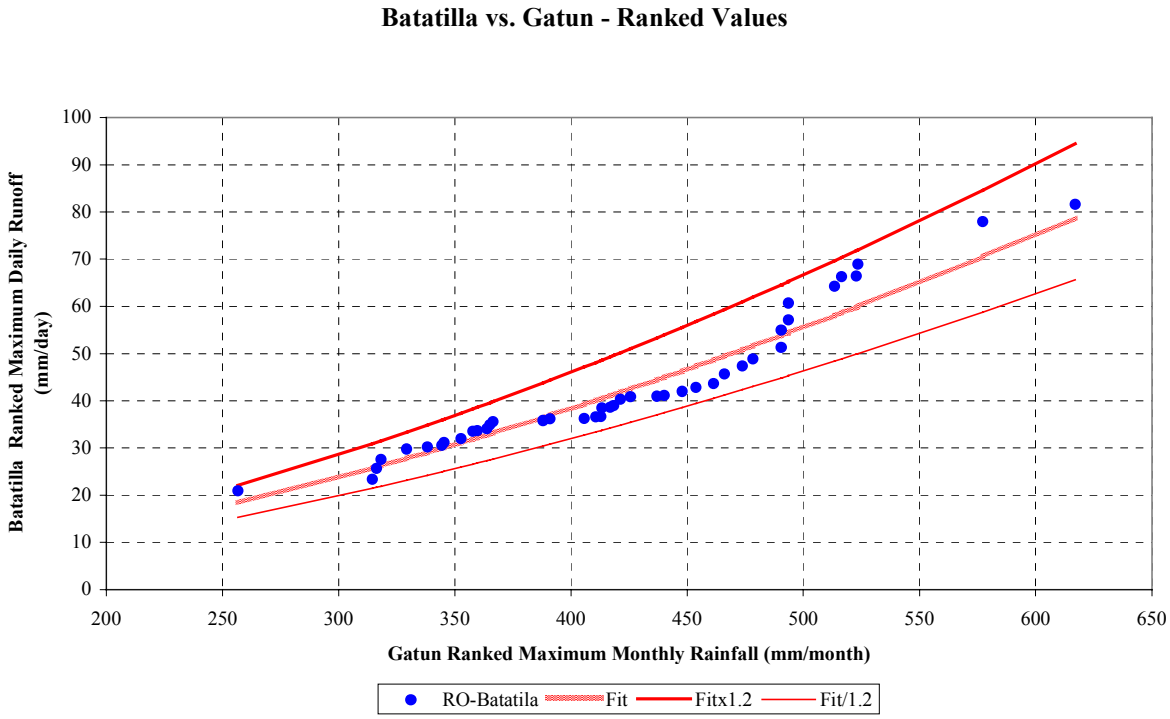
Figure 15 - Definition of Relationship for Batatilla Flood Data Extension details the approach. On the upper graph, the relationship between Batatilla and Gatun DS is based on the ranked values. A power fit describes well the data scatter. On the lower graph, the Gatun DS and Batatilla values are given together with the adopted relationship and its random noise.

Figure 16 - Extension of Batatilla Daily Peaks Using Gatun DS details the extension both as a time series and as a double mass check. The following summary allows for comparison between the 53-year and 90-year samples.

Item	Batailla – Initial	Batatilla – Extended
Nval	53	90
M	435	452
S	266	256
Cv	0.61	0.57
Me	352	382
Max	1 711	1 711
Min	137	137

Units: m3/s

Appendix G3 details the sample after data extension.



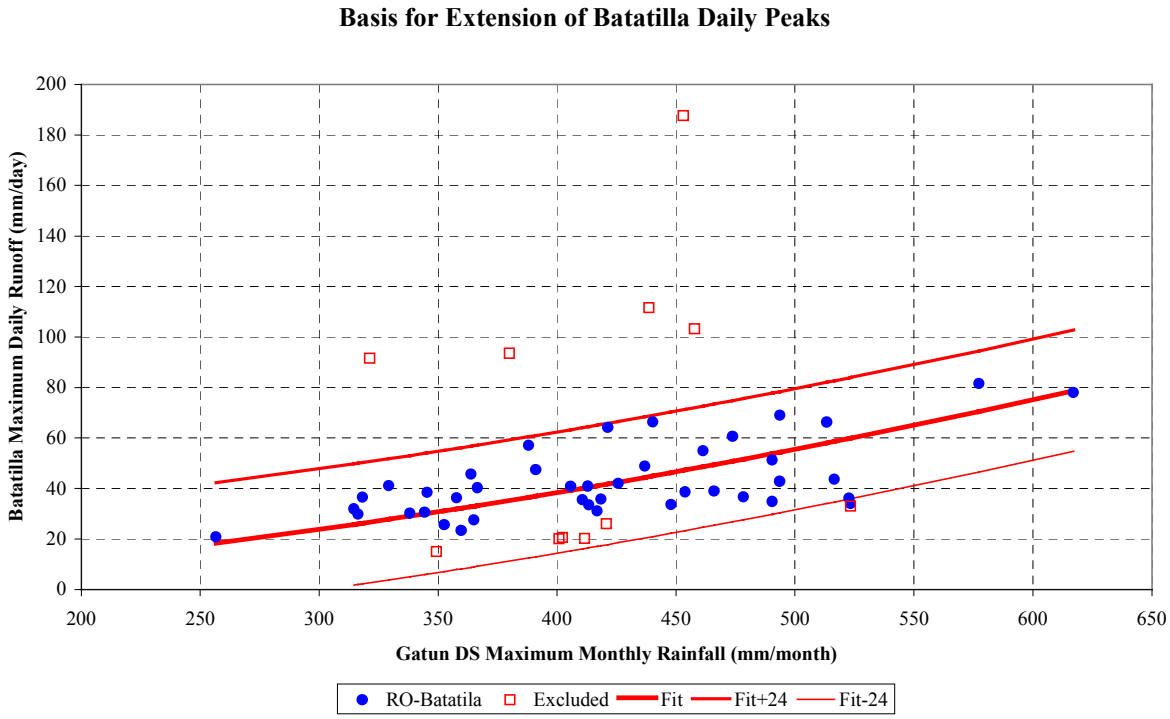
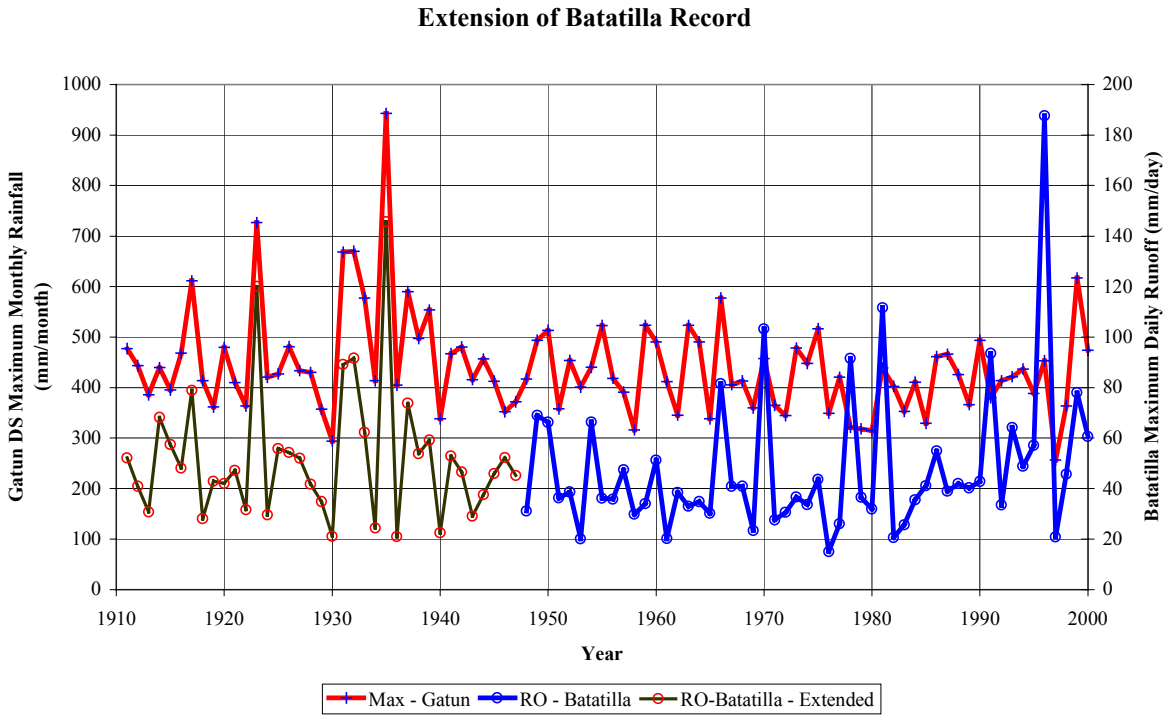


Figure 15 - Definition of Relationship for Batatilla Flood Data Extension



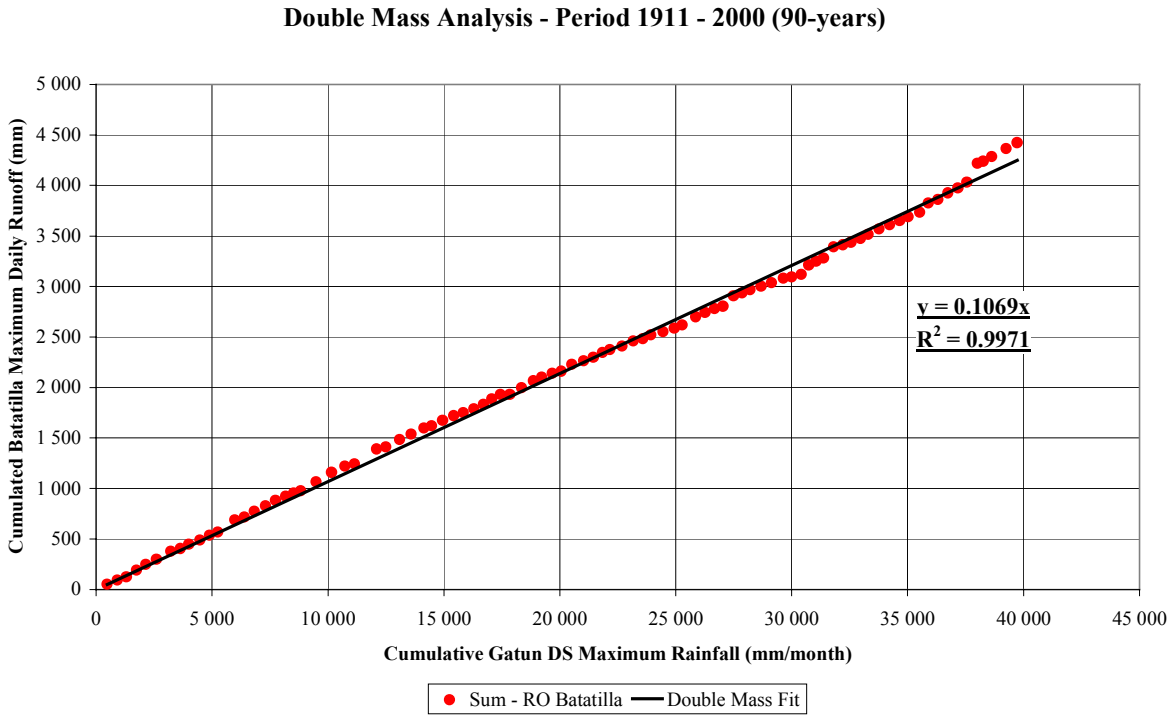


Figure 16 - Extension of Batatilla Daily Peaks Using Gatun DS

4.2.3. Frequency Distribution of Daily Peaks

A Lombardi's Distribution has been fit to the 90-year sample of daily peaks.

Figure 17 - Toabre River at Batatilla - Daily Peak vs. Return Period presents the daily peaks estimates Qdmx (T). It gives also the curve of daily peak against return period. The daily PMF amounts to 5 000 m3/s whereas the 10 000-year daily flood is 2 801 m3/s. The maximum observed daily discharge is 1 711 m3/s on 14/01/96. The Lombardi's distribution assigns a return period of 200-year to a daily discharge of about 1 680 m3/s.

Figure 18 - Batatilla - Selection of Daily PMF = 5 000 m3/s details the process of adopting a daily PMF of 5 000 m3/s. On the upper graph, it appears that the choice of Lombardi's parameters (Min = 130 and Max = 5 000) yields a good fit between observed and commuted daily peaks. The lower graph discloses that, with PMF = 5 000 m3/s, the coefficient of variation r^2 exceeds 0.99. Other values might be adopted, but they are not physically acceptable since they would correspond to the hurricane flood domain.

T (years)	Qdmx (m3/s)	T (years)	Qdmx (m3/s)
2	378	1 000	2 163
5	607	2 000	2 364
10	791	5 000	2 618
20	986	10 000	2 801
50	1 255		
100	1 465	PMF	5 000
200	1 677		
500	1 956		

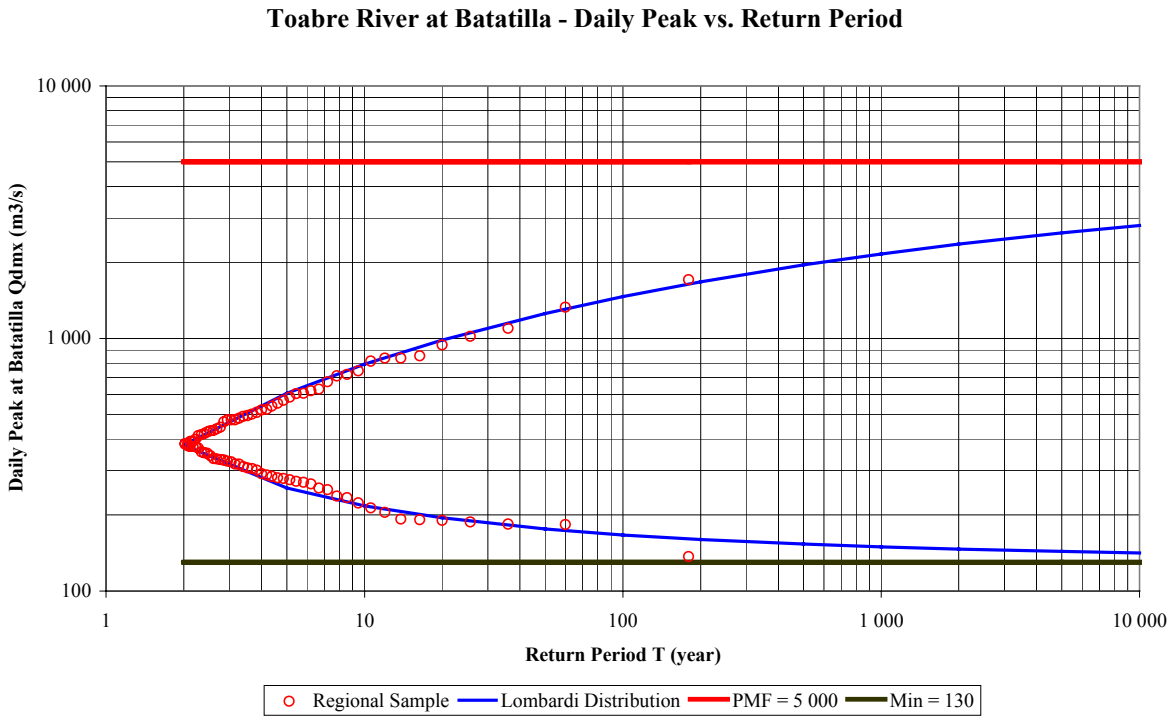
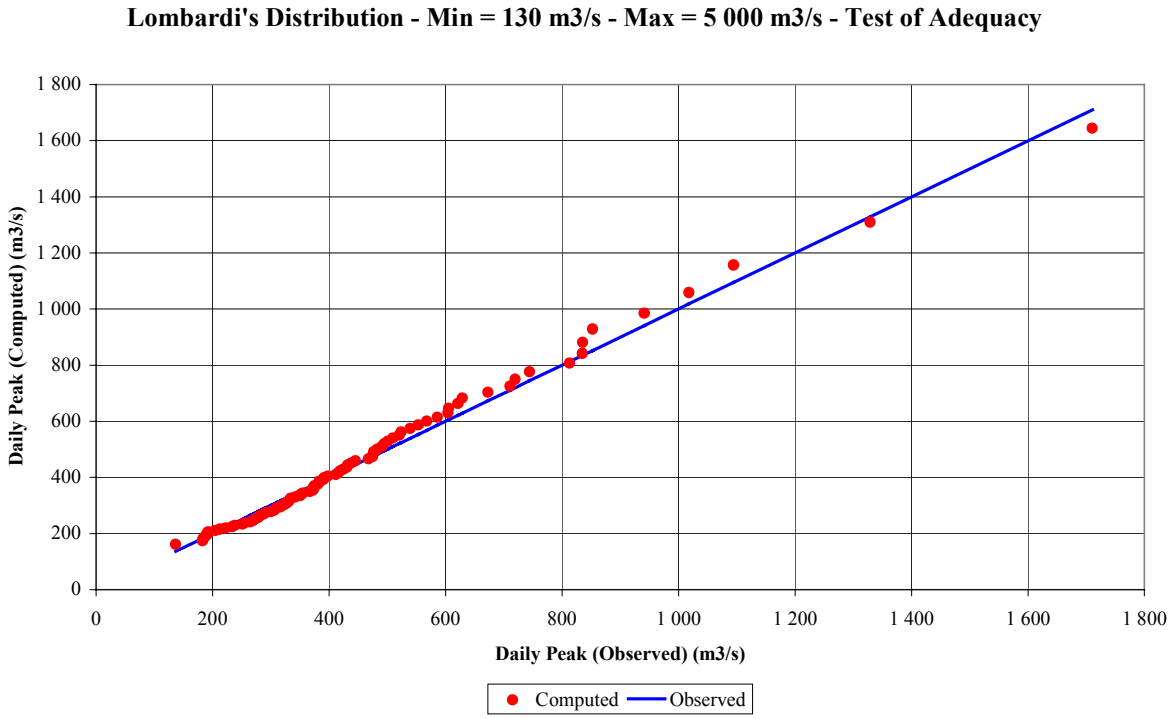


Figure 17 - Toabre River at Batatilla - Daily Peak vs. Return Period



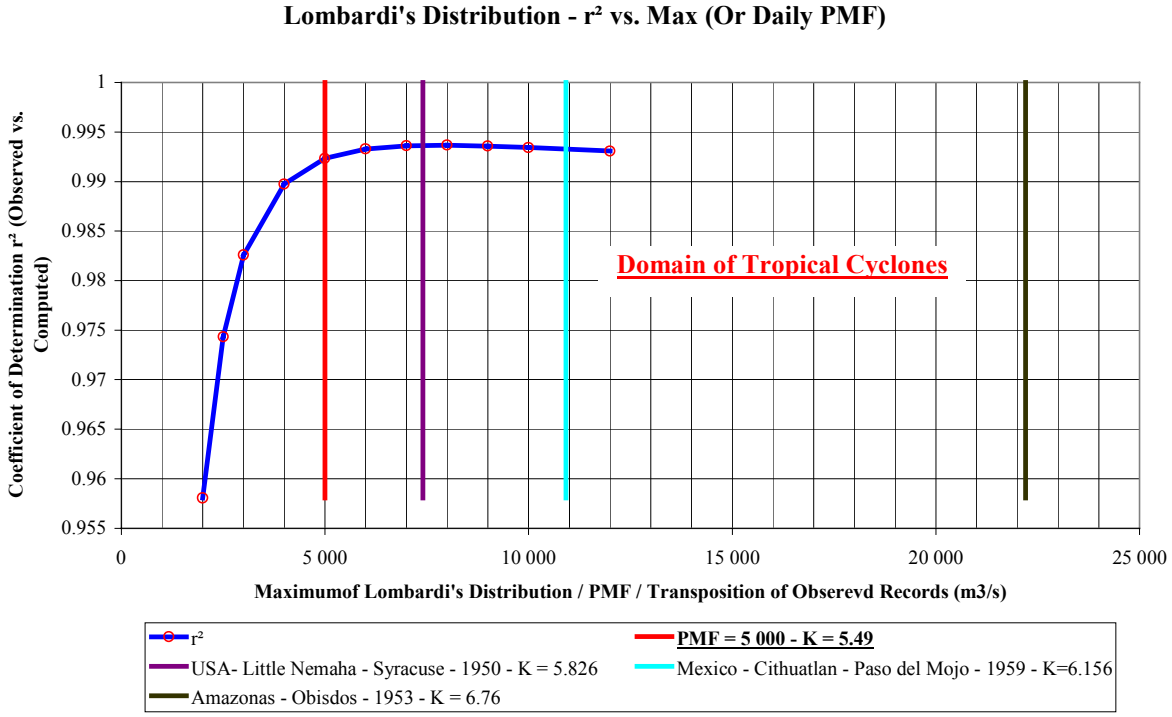


Figure 18 - Batatilla - Selection of Daily PMF = 5 000 m3/s

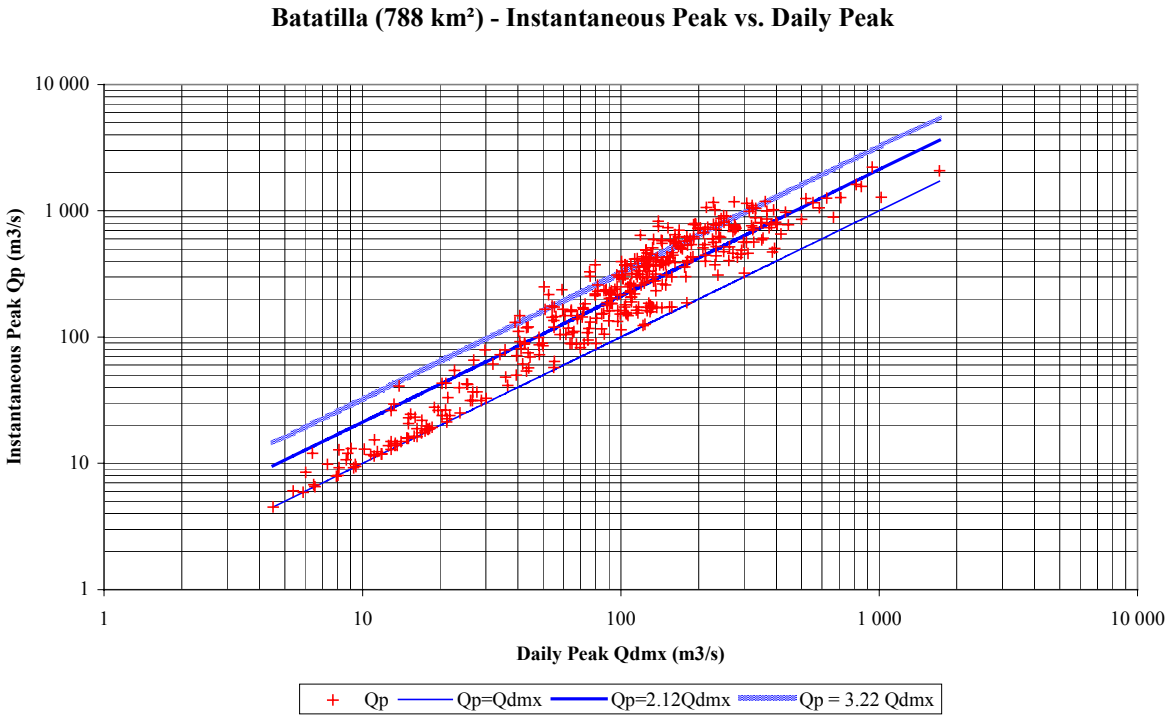
4.3. Hydrograph Shapes at Batatilla

4.3.1. Preliminary analysis of Ratios Qp / Qd

Appendix G1 and Appendix G2 provide a large sample of Instantaneous Peaks and corresponding daily peaks.

Figure 19 - Toabre River at Batatilla - Daily Peaks vs. Instantaneous Peaks illustrates the available data. The upper graph shows a relatively important scatter of data. The points near from the Qp = Qd line are obviously dry season discharge. Data points above Qp = 3.22 Qd are likely to correspond to floods resulting from very sudden rainstorms.

The lower graph is a partition of data points according to the hydrograph shape performed below. It can be seen that Shape B does not apply to important daily discharges.



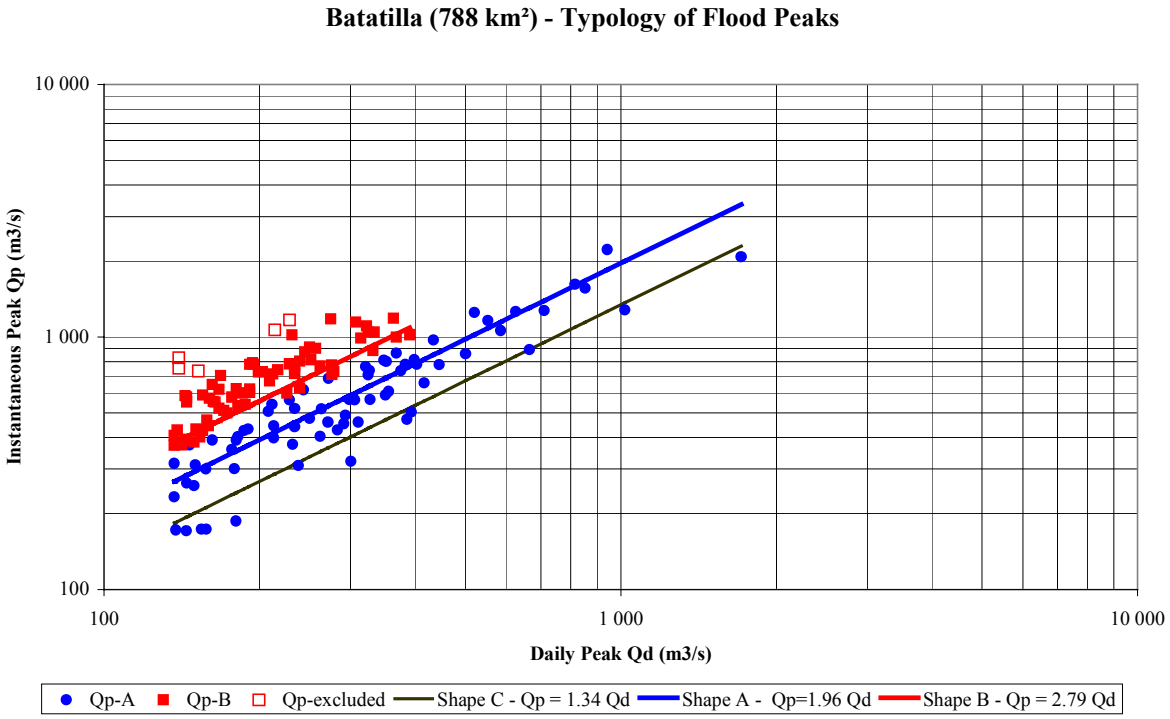


Figure 19 - Toabre River at Batatilla - Daily Peaks vs. Instantaneous Peaks

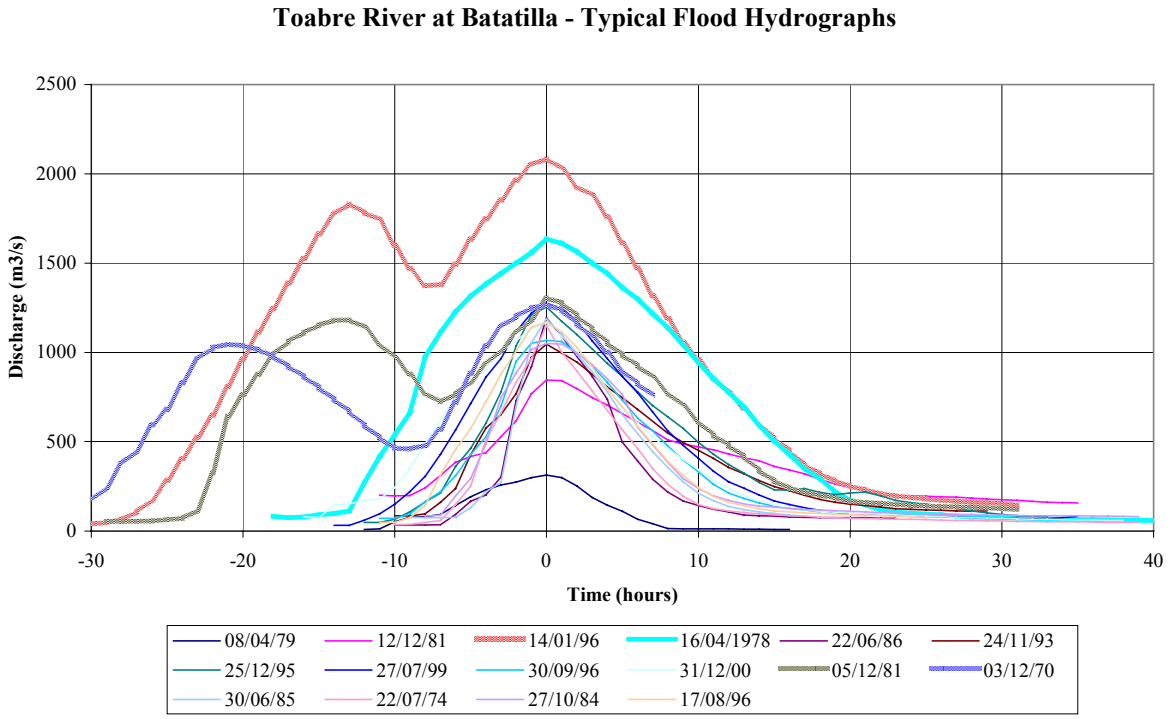
4.3.2. Hydrograph Shape Analysis

Sixteen (16) flood hydrographs have been provided by ACP. (See G.4 and G.5) These hydrographs allow for determining three hydrograph shapes as described below.

Figure 20 - Toabre River at Batatilla - Typical Floods and Hydrograph Shape A describes the initial data sample (upper graph). This graph shows a contrast between long duration floods and short duration floods. The lower part shows the determination of flood shape A.

Figure 21 - Toabre River at Batatilla - Hydrograph Shapes B and C details the computation of flood shapes B and C.

Figure 22 - Toabre River at Batatilla - Comparison of Hydrograph Shapes allows for the comparison between the three types of flood. For a same peak, it is obvious that shape C has the greatest flood volume.



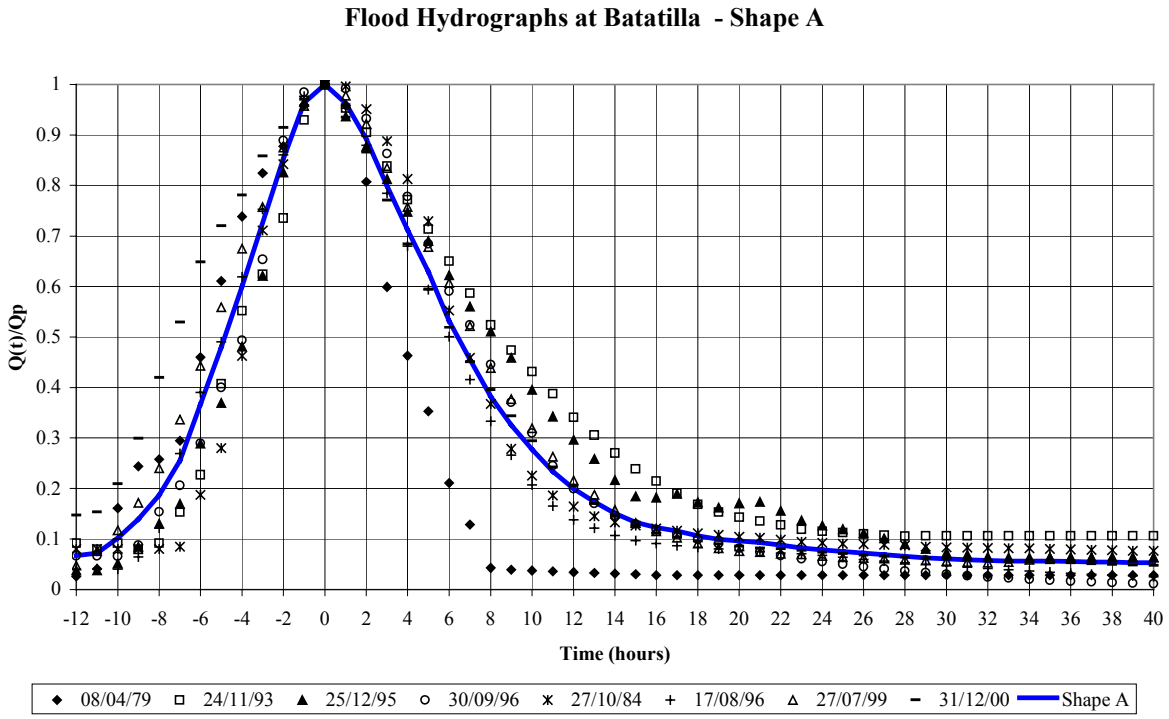
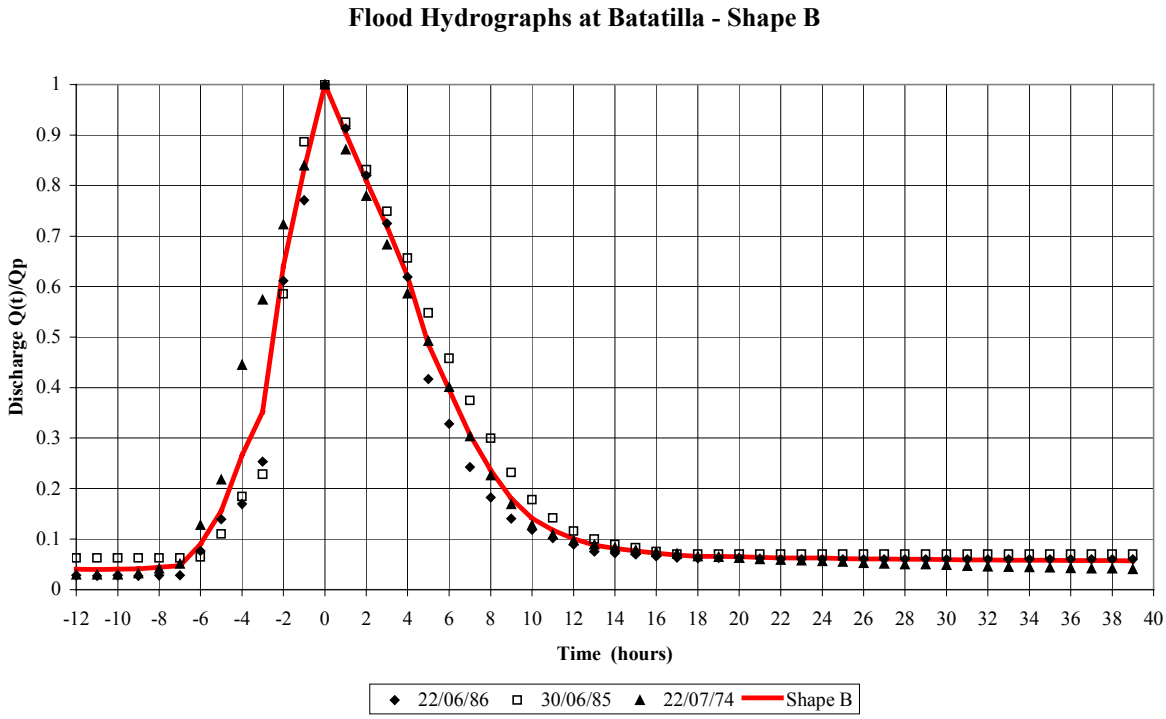


Figure 20 - Toabre River at Batatilla - Typical Floods and Hydrograph Shape A



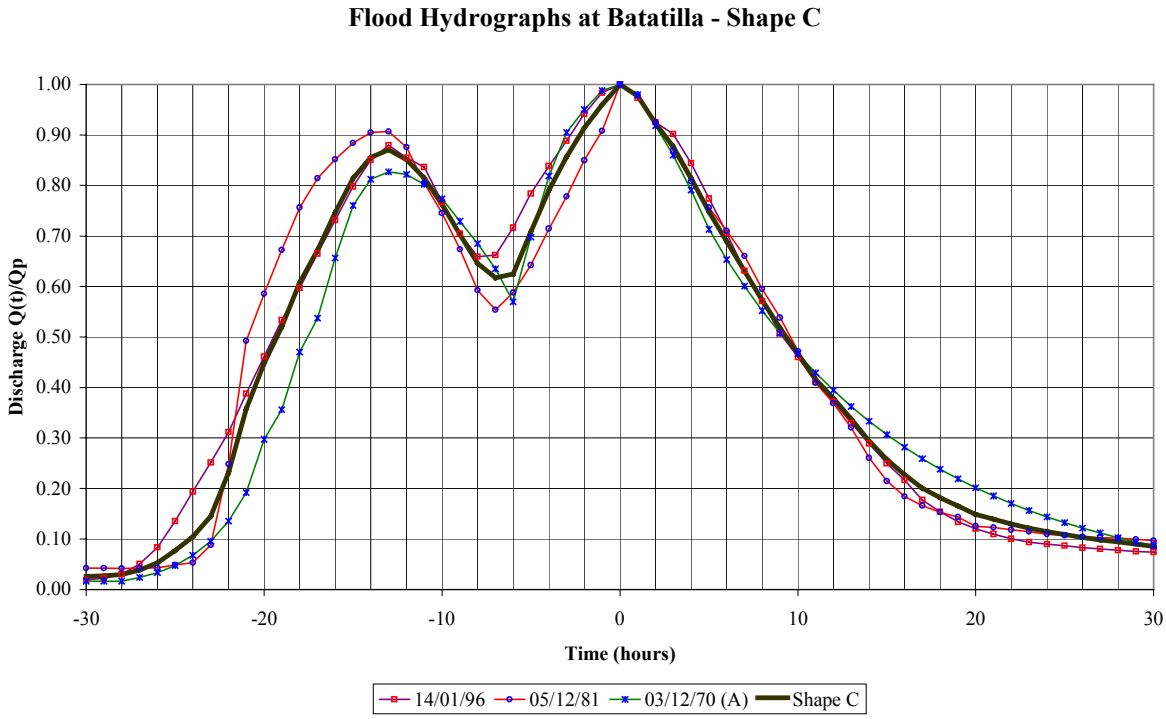


Figure 21 - Toabre River at Batatilla - Hydrograph Shapes B and C

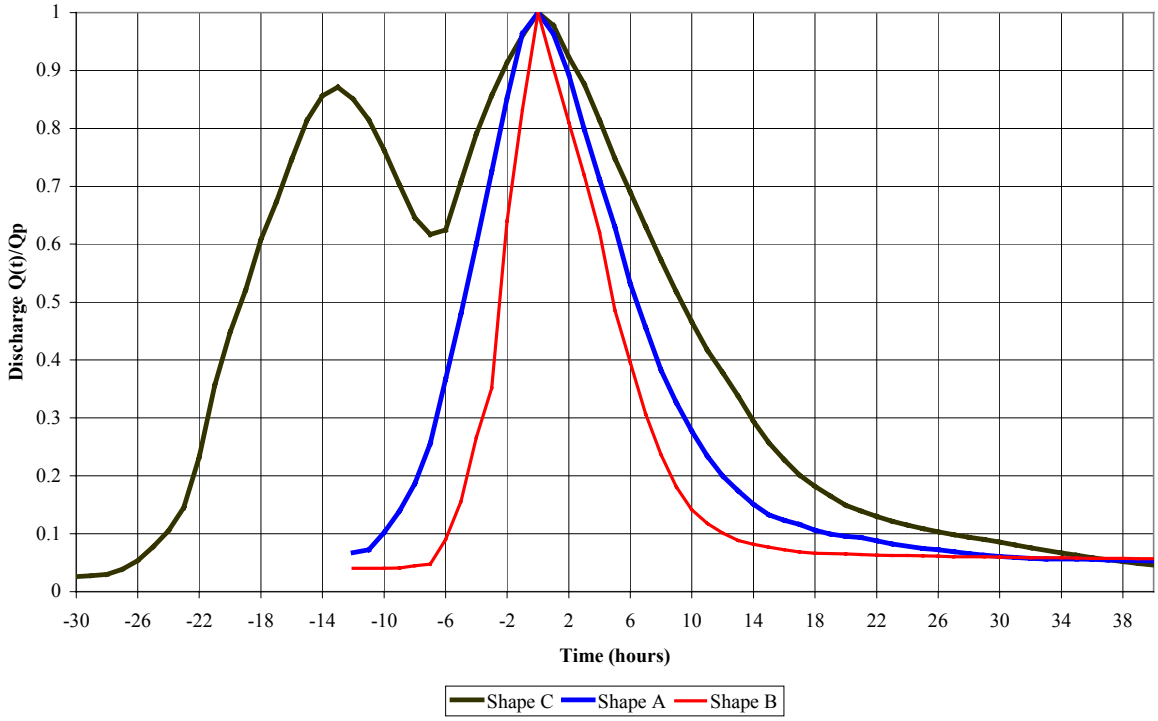


Figure 22 - Toabre River at Batatilla - Comparison of Hydrograph Shapes

4.4. Floods at Toabre Damsite

4.4.1. Yearly and Wet Season Floods

Floods at Toabre Damsite have been deduced from those at Batatilla. For this purpose, the coefficient of Francou-Rodier K (Qp) has been computed for each Batatilla flood estimate and transposed to Toabre Damsite (A = 730 km²). Shapes A and C have been considered as relevant for yearly maximums.

Table 17 - Flood Peaks at Toabre Damsite (730 km²)

T (year)	Qp-A (m3/s)	Qp-C (m3/s)	T (year)	Qp-A (m3/s)	Qp-C (m3/s)
2	720	490	1 000	4 100	2 800
5	1 150	790	2 000	4 490	3 060
10	1 500	1 030	5 000	4 970	3 390
20	1 870	1 280	10 000	5 310	3 630
50	2 370	1 630			
100	2 780	1 900	PMF	9 510	6 490
200	3 170	2 170			
500	3 710	2 540			

Table 18 - Toabre Damsite - Flood Hydrographs - Shape A

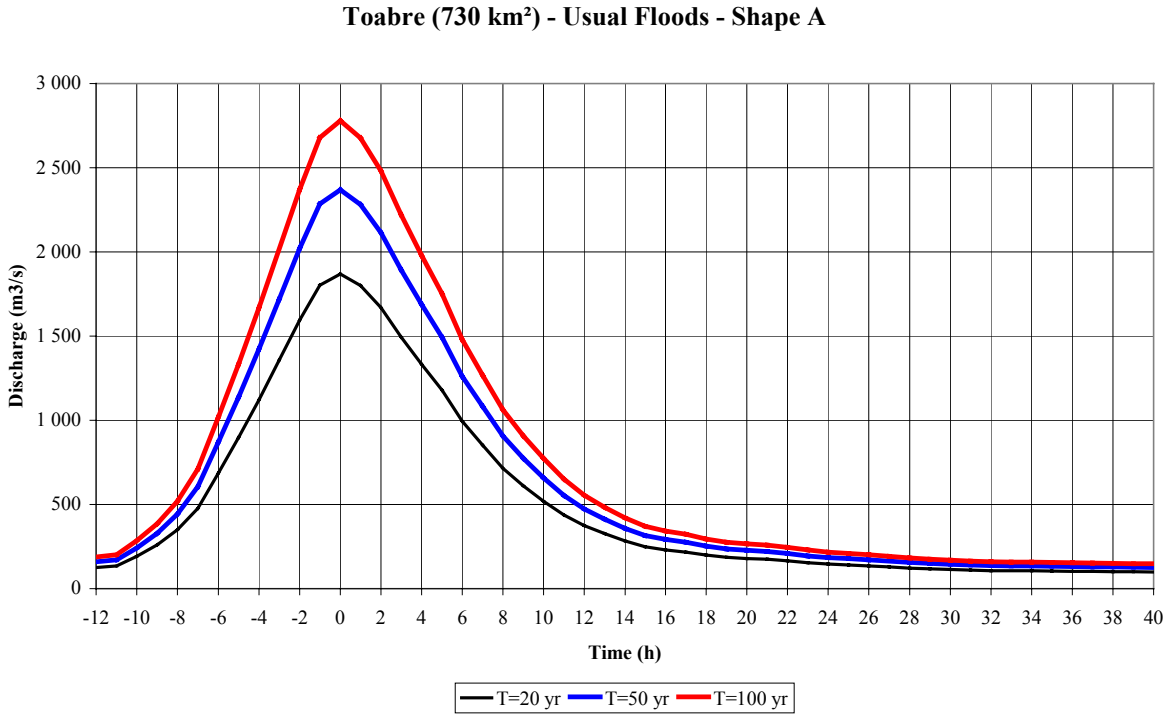
t (h)	T=20 yr	T=50 yr	T=100 yr	T=1 000 yr	T=10 000 yr	PMF
-12	126	159	187	275	357	639
-11	134	170	200	295	382	683
-10	191	242	284	419	542	971
-9	260	329	386	570	738	1 322
-8	349	443	520	766	992	1 777
-7	478	605	710	1 047	1 356	2 429
-6	686	869	1 020	1 504	1 947	3 488
-5	897	1 137	1 333	1 967	2 547	4 562
-4	1 123	1 423	1 669	2 461	3 188	5 709
-3	1 356	1 719	2 016	2 974	3 852	6 898
-2	1 594	2 021	2 370	3 496	4 527	8 108
-1	1 802	2 284	2 679	3 952	5 118	9 166
0	**1 870**	**2 370**	**2 780**	**4 100**	**5 310**	**9 510**
1	1 800	2 282	2 676	3 947	5 112	9 155
2	1 669	2 115	2 481	3 659	4 739	8 488
3	1 494	1 893	2 221	3 275	4 242	7 597
4	1 331	1 687	1 979	2 919	3 780	6 770
5	1 177	1 492	1 750	2 581	3 343	5 987
6	994	1 260	1 478	2 180	2 824	5 057
7	852	1 080	1 267	1 869	2 420	4 334
8	715	906	1 063	1 567	2 030	3 635
9	610	773	906	1 337	1 731	3 100
10	519	658	772	1 139	1 475	2 641
11	437	553	649	957	1 240	2 221
12	373	473	554	818	1 059	1 897
14	282	357	419	618	801	1 434
16	230	291	342	504	652	1 168
18	199	252	295	436	564	1 011
20	179	227	267	393	509	912
25	140	178	208	307	398	712
30	114	144	169	249	323	578
35	105	133	156	230	297	533
40	99	125	147	217	280	502
V (m3)	97 690 959	123 811 536	145 230 410	214 188 734	277 400 531	496 813 380

Units: m3/s

Table 19 - Toabre Damsite - Flood Hydrographs - Shape C

T (h)	T=20 yr	T=50 yr	T=100 yr	T=1 000 yr	T=10 000 yr	PMF
-30	33	42	49	73	94	169
-25	99	126	147	216	280	501
-20	573	730	851	1 254	1 626	2 907
-15	1 042	1 327	1 547	2 280	2 955	5 284
-10	975	1 242	1 448	2 134	2 766	4 946
-9	899	1 145	1 335	1 967	2 550	4 559
-8	826	1 052	1 227	1 808	2 344	4 190
-7	790	1 006	1 172	1 728	2 240	4 004
-6	800	1 018	1 187	1 749	2 268	4 054
-5	906	1 154	1 345	1 982	2 570	4 595
-4	1 012	1 289	1 502	2 214	2 870	5 131
-3	1 097	1 397	1 629	2 400	3 112	5 563
-2	1 170	1 490	1 736	2 559	3 318	5 931
-1	1 229	1 565	1 824	2 688	3 485	6 231
0	**1 280**	**1 630**	**1 900**	**2 800**	**3 630**	**6 490**
1	1 251	1 593	1 857	2 737	3 548	6 344
2	1 181	1 504	1 753	2 584	3 350	5 989
3	1 122	1 429	1 666	2 455	3 183	5 690
4	1 043	1 328	1 548	2 281	2 957	5 286
5	957	1 219	1 421	2 094	2 715	4 854
6	883	1 124	1 311	1 931	2 504	4 477
7	807	1 028	1 198	1 766	2 289	4 092
8	733	934	1 088	1 604	2 079	3 717
9	662	843	983	1 449	1 878	3 358
10	597	760	886	1 305	1 692	3 026
15	329	419	488	719	933	1 667
20	191	243	283	417	541	967
25	139	177	206	304	394	705
30	110	140	163	240	311	557
35	80	102	119	175	227	406
40	58	74	87	128	166	296
V (m3)	130 863 016	166 645 872	194 249 790	286 262 848	371 119 335	663 516 386

Units: m3/s



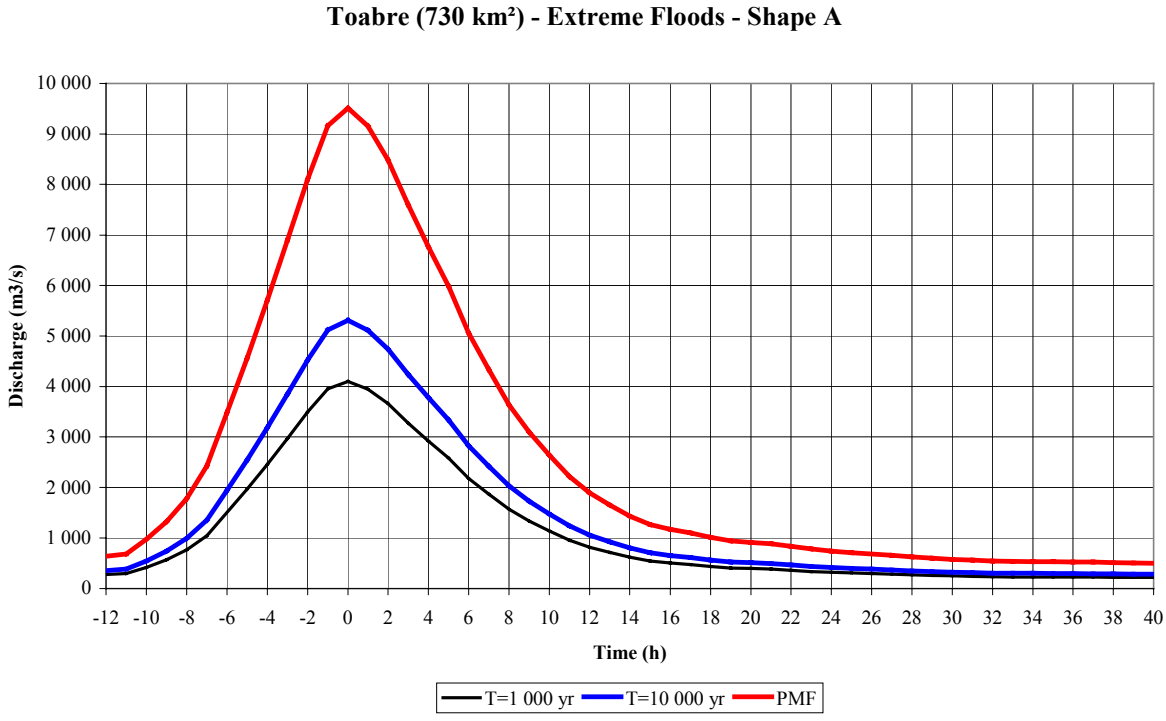
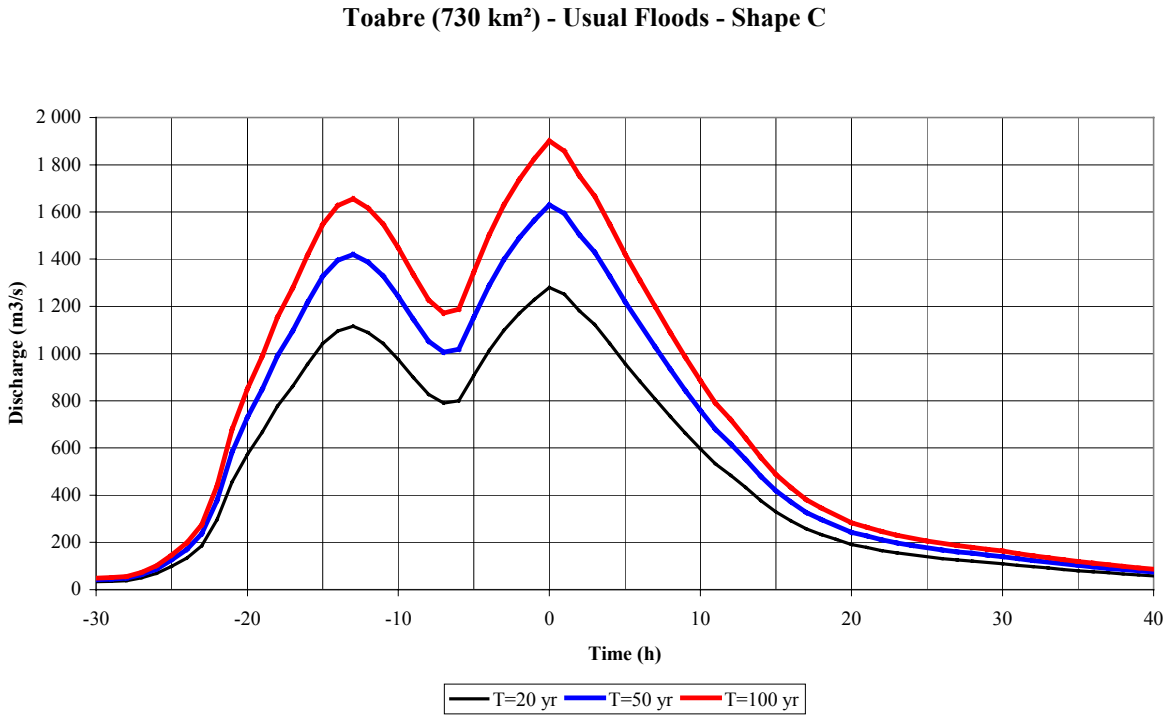


Figure 23 - Toabre Damsite - Flood Hydrographs - Shape A



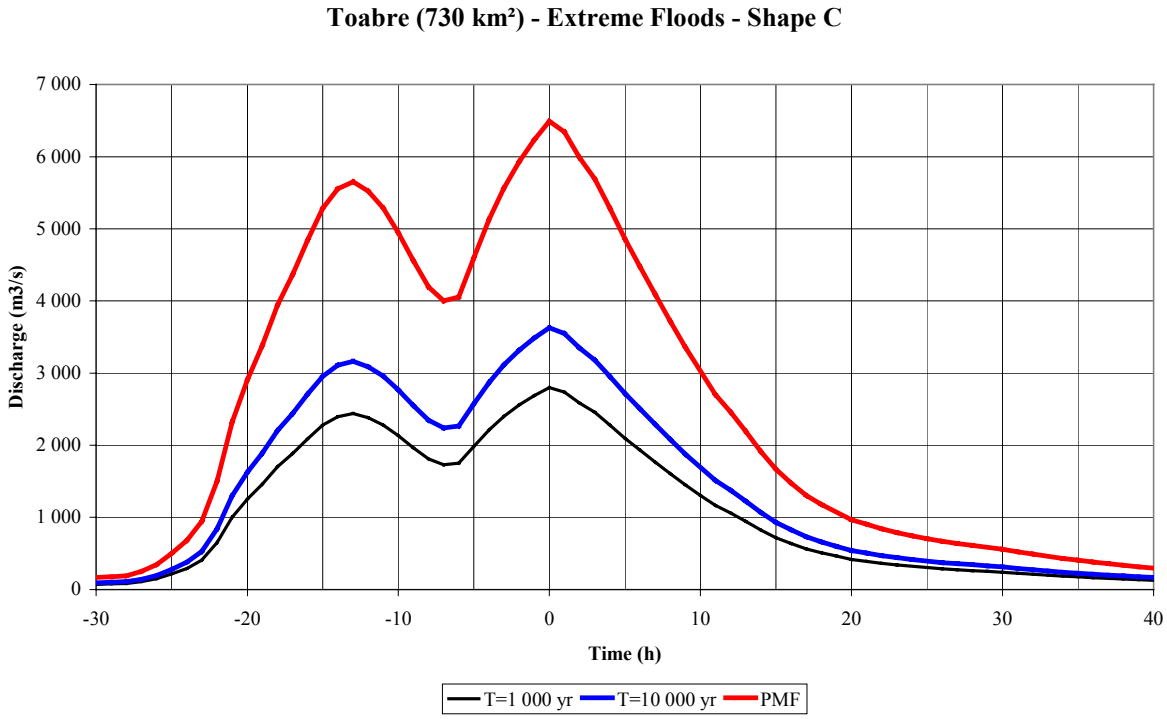


Figure 24 - Toabre Damsite - Flood Hydrographs - Shape C

4.4.2. Construction Stage Floods

It has been considered that the dry season was restricted to the period February to April. Frequency analysis of the maximum daily peaks of this period lead to the following results.

Table 20 - Toabre Damsite - Construction Stage Floods

T	Dry Season (February to April) Qp-A	Wet Season (May to January) Qp-A	Wet Season (May to January) Qp-C
(year)	(m3/s)	(m3/s)	(m3/s)
10	470	1 500	1 030
20	710	1 870	1 280
50	1 140	2 370	1 630
100	1 560	2 780	1 900

4.5. Comments on Obtained Results

4.5.1. Flood Volumes

Table 21 - Analysis of Flood Volumes at Toabre Damsite presents the flood volumes for flood shapes A and C. The table gives also the results found by Harza for Rio Indio.

As shown below, the Harza PMF is comparable to shape A PMF: They display the same Qp/V ratio and they have similar coefficients of runoff (0.82 for shape A against 0.89 for Harza PMF). The runoff (RO) is also similar (respectively 681 mm for Shape A and 635 mm for Rio Indio).

Concerning shape C, the obtained runoff can be explained by assuming a 3-day rainfall at the origin of the flood. Doing so, the coefficients of runoff for Shape C are consistent with those obtained for Shape A.

Table 21 - Analysis of Flood Volumes at Toabre Damsite

Return Period (year)	Shape	V (10^6 m3)	Qp (m3/s)	Qp/V	RO (mm)	Pdmx (mm)	P48 (mm)	RO/P48
20	A	98	1 870	19.1	134	172	221	0.61
50	A	124	2 370	19.1	170	199	255	0.67
100	A	145	2 780	19.2	199	218	279	0.71
1 000	A	214	4 100	19.2	293	280	359	0.82
10 000	A	277	5 310	19.2	379	335	429	0.88
PMF	A	497	9 510	19.1	681	650	833	0.82
PMF	Rio Indio	242	4 345	18.0	635	555	711	0.89

Return Period	Shape	V	Qp	Qp/V	RO	Pdmx	P72	RO/P72
(year)		(10^6 m3)	(m3/s)		(mm)	(mm)	(mm)	
20	C	131	1 280	9.8	179	172	268	0.67
50	C	167	1 630	9.8	229	199	310	0.74
100	C	194	1 900	9.8	266	218	340	0.78
1 000	C	286	2 800	9.8	392	280	437	0.90
10 000	C	371	3 630	9.8	508	335	523	0.97
PMF	C	664	6 490	9.8	910	650	1 014	0.90

4.5.2. Flood Peaks

lists the results found for Toabre and compare them to other data from Panama and Costa Rica.

In order to be able to compare floods for different catchment areas, us is made of Francou-Rodier's Flood index. The Francou-Rodier formula is:

$\frac{Q}{10^6} = \left[\frac{A}{10^8}\right]^{1-0.1K}$; where Q is in m3/s and A is in km².

This formula leads to define the flood index as being:

$K = 10 \times \left[1 - \frac{\ln(Q/10^6)}{\ln(A/10^8)}\right]$.

The K-values in the table show that the results found for Toabre damsite are in good agreement with the background information for usual floods.

Table 22 -River Toabre at Toabre Damsite - Flood Peaks for Usual Floods

Site	River	T or Date	A(km²)	Qp (m3/s)	K(Qp)	Source
Boca de Uracillo	Indio	10	365	713	4.21	Harza [2]
Boca de Uracillo	Indio	20	365	762	4.27	Harza [2]
Boca de Uracillo	Indio	Dec. 91	365	772	4.28	Harza [2]
Angostora	Reventazon	14/10/55	1 337	1 670	4.30	Costa Rica [5]
Boca de Uracillo	Indio	50	365	820	4.32	Harza [2]
Boca de Uracillo	Indio	100	365	859	4.36	Harza [2]
Toabre Damsite	*Toabre*	*20-C*	*730*	*1 280*	*4.37*	*Present Study*
Toabre Damsite	*Toabre*	*50-C*	*730*	*1 630*	*4.57*	*Present Study*
Tempisque	Guardia	27/10/60	955	2 060	4.65	Costa Rica [5]
Grande de Terralba	Palmar	19/09/71	4 765	4 960	4.67	Costa Rica [5]
Toabre Damsite	*Toabre*	*20-A*	*730*	*1 870*	*4.69*	*Present Study*
Toabre Damsite	*Toabre*	*100-C*	*730*	*1 900*	*4.70*	*Present Study*
Batatilla	Toabre	10/01/70	788	2 219	4.80	Present Study and [1]
Toabre Damsite	*Toabre*	*50-A*	*730*	*2 370*	*4.89*	*Present Study*
Toabre Damsite	*Toabre*	*100-A*	*730*	*2 780*	*5.02*	*Present Study*
Angostora	Reventazon	09/04/70	1 337	3 800	5.03	Costa Rica [5]
Grande de Taracoles	Alumbre	25/11/69	1 745	4 400	5.05	Costa Rica [5]
Grande de Terralba	Palmar	29/08/73	4 765	7 300	5.06	Costa Rica [5]

The K-values in the table show that the results found for Toabre damsite are in good agreement with the background information for extreme floods.

Table 23 - Rio Toabre at Toabre Damsite - Flood Peaks for Extreme Floods lists the results found for Toabre and compare them to other data from Panama and Colombia.

The K-values in the table show that the results found for Toabre damsite are in good agreement with the background information for extreme floods.

Table 23 - Rio Toabre at Toabre Damsite - Flood Peaks for Extreme Floods

Site	River	T or Date	A(km²)	Qp (m3/s)	K(Qp)	Source
Betania		1 000	13 572	3 263	3.57	Project in Colombia
Porce 2		1 000	3 020	1 700	3.87	Project in Colombia
Rio Guavio		1 000	700	1 230	4.35	Project in Colombia
Indio Damsite	Indio	1 000	381	920	4.40	Section 5
Rio Negro		1 000	81	402	4.43	Project in Colombia
Guarinó Bajo		1 000	760	2 354	4.87	Project in Colombia
Toabre Damsite	*Toabre*	*1 000-C*	*730*	*2 800*	*5.03*	*Present Study*
Cano Sucio Damsite	Cano Sucio	1 000	111	1 141	5.06	Section 9
Andaquí		1 000	4 497	7 921	5.17	Project in Colombia
Toabre Damsite	Toabre	1 000	730	3 391	5.19	Section 9
Miel 1		1 000	770	3 644	5.23	Project in Colombia
Toabre Damsite	*Toabre*	*10 000-C*	*730*	*3 630*	*5.25*	*Present Study*
Toabre Damsite	*Toabre*	*1 000-A*	*730*	*4 100*	*5.35*	*Present Study*

Rio Negro		PMF	81	1 520	5.37	Project in Colombia
Guarinó Bajo		PMF	760	5 263	5.55	Project in Colombia
Toabre Damsite	*Toabre*	*10 000-A*	*730*	*5 310*	*5.57*	*Present Study*
Indio Damsite	Indio	PMF	381	4 345	5.64	Harza [2]
Toabre Damsite	*Toabre*	*PMF-C*	*730*	*6 490*	*5.74*	*Present Study*
Porce 2		PMF	3 020	11 920	5.74	Project in Colombia
Rio Guavio		PMF	700	6 900	5.81	Project in Colombia
San Carlos		PMF	584	7 500	5.94	Project in Colombia
Toabre Damsite	*Toabre*	*PMF-A*	*730*	*9 510*	*6.06*	*Present Study*
Andaquí		PMF	4 497	19 720	6.08	Project in Colombia
Betania		PMF	13 572	31 130	6.10	Project in Colombia
Miel 1		PMF	770	12 780	6.30	Project in Colombia

5. SEDIMENT TRANSPORT

5.1. Previous studies

Daly Espinosa [1] and Harza [2] have used the same data base to assess sediment transport. The following table quotes the formulas used either by ETESA or by Harza.

Table 24 - Sediment Transport (Suspension) in Batatilla - Previous Studies

Author	N°	Equation	Range
ETESA	1	$Qs = 0.346\ Q^{1.38}$	Q<39 m3/s
	2	$Qs = 0.000045\ Q^{3.83}$	39<Q<107 m3/s
	3	Qs = 24.4 Q	Q>107 m3/s
Harza	1	$Qs = 0.346\ Q^{1.38}$	Q<39 m3/s
	2	$Qs = 0.000045\ Q^{3.83}$	39<Q<107 m3/s
	3	$Qs = 0.077\ Q^{2.23}$	107<Q<300 m3/s
	4	$Qs = 0.287\ Q^{2.00}$	300<Q<3 000 m3/s
	5	Qs = 864 Q	Q>3 000 m3/s

Using these equations the following estimates have been found:

Table 25 - Computation of Suspended Load in Previous Studies

Equation	Reference	Period	Yearly Sediment Transport in Suspension (tons/year)	Specific Load (t/yr/km²)
ETESA	[1]	1948/2000	170 758	217
Harza	[1]	1948/2000	332 612	422
Harza	[2]	1958/1998	873 801	1 109

There is a discrepancy between Harza estimates and results from reference [1].

The difference may arise partly from the plotting position adopted by Harza for discharge greater than 1 000 m3/s.

For instance, the maximum observed daily discharge is 1 711 m3/s. It corresponds to a probability of 0.005 %, which is the plotting position taken by Harza for 2 400 m3/s.

The second source of difference is the maximum concentration taken by the different authors.

5.2. Regional Analysis

Figure 25 - Regional Information on Suspended Load details the available data at Batatilla and Canoas. The upper graph shows that Canoas has smaller suspended load than Batatilla. The lower graph discloses that Canoas data can be transferred to Batatilla conditions. For the low discharges, a same regional fit can be used.

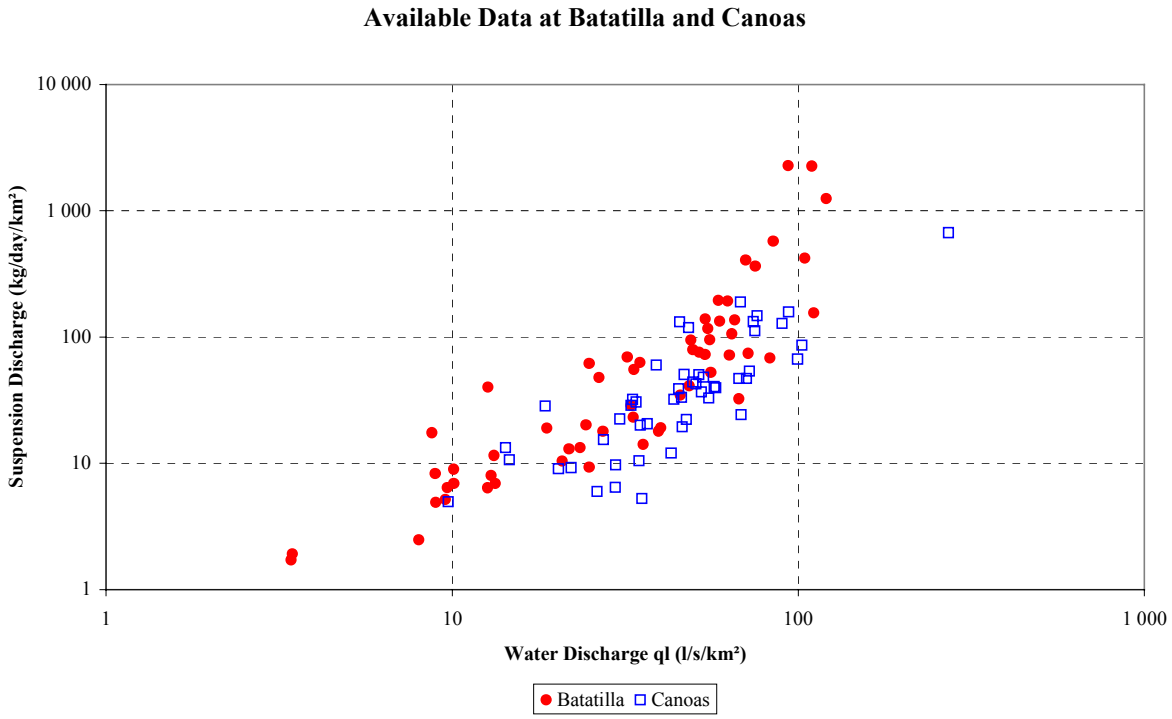
Figure 26 - Toabre Rivet at Batatilla - Synthesis on Suspended Load details the analysis performed in the present study.

On the upper graph, the several sediment-rating curves are presented. The regional fit used herein is substituted to Equation 1 of ETESA – Harza. Equation 2 of ETESA – Harza is conserved. Then a maximum concentration of 800 mg/l is adopted instead of 282 mg/l (ETESA) or 10 000 mg/l (Harza).

The lower graph displays the duration curve of monthly discharge (period 1948 / 2000 on a monthly basis) to which are applied the sediment rating curves found above. This lead to an average load of 453 tons/day.

5.3. Computation of Suspended Load

Using the monthly approach, it has been found that the suspended load is about 165 413 tons/year, which corresponds to a specific yield of 210 t/yr/km². These values are in good agreement with the results found in reference [1]. Due to the monthly approach, they are a lower bound.



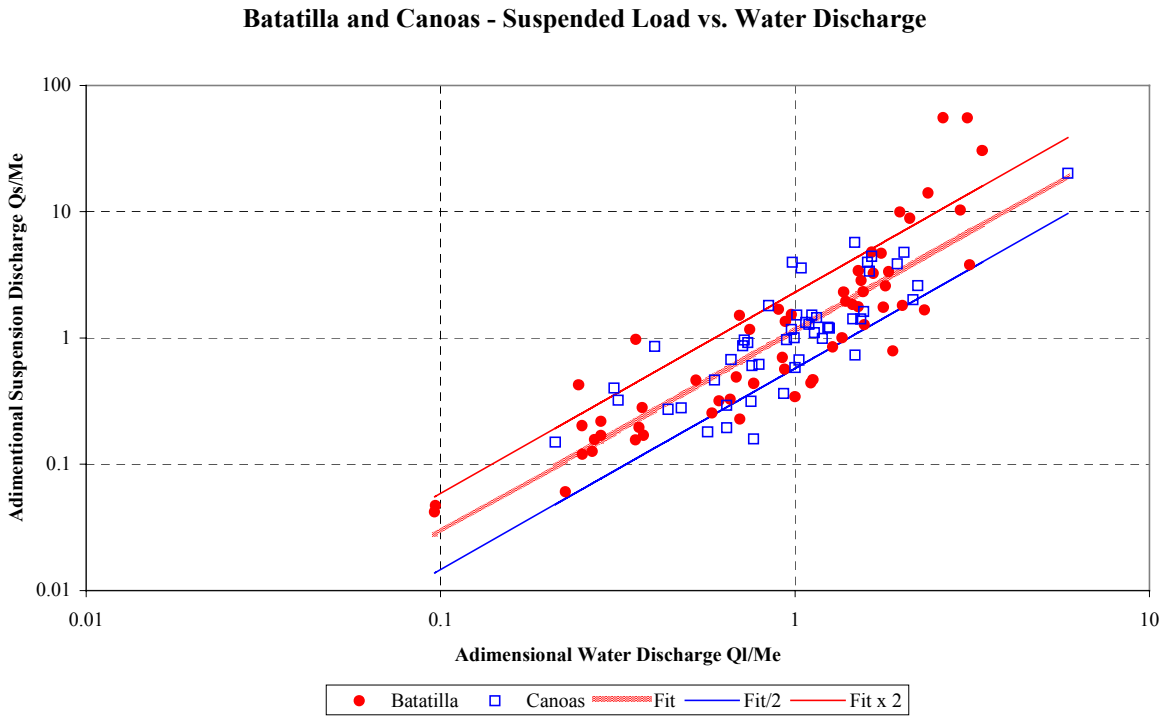
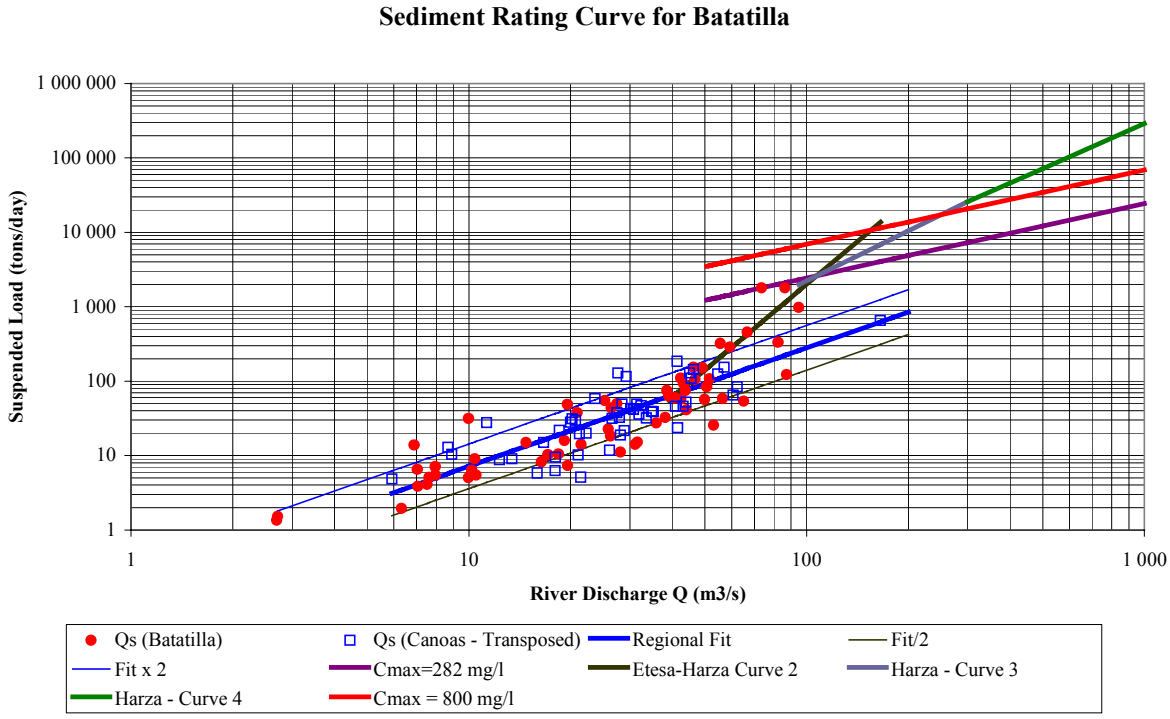


Figure 25 - Regional Information on Suspended Load



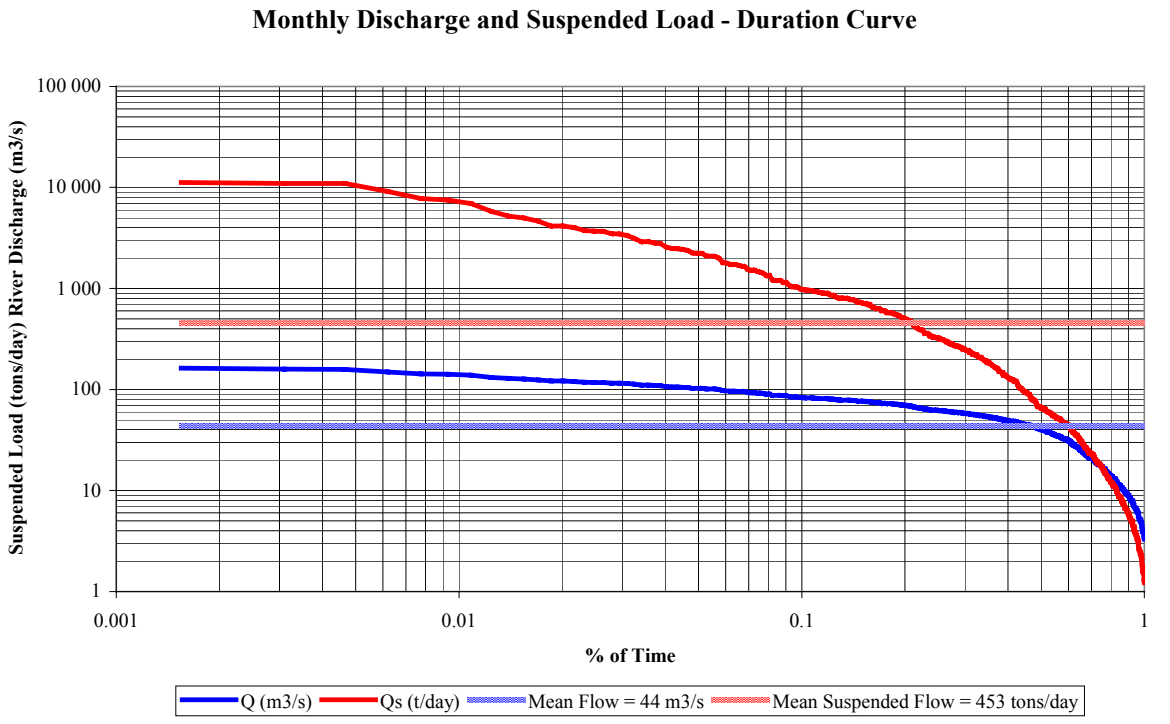


Figure 26 - Toabre Rivet at Batatilla - Synthesis on Suspended Load

5.4. Discussion of Results

A bed load of 15% and a specific weight of 1.04 has been quoted in reference [2]. Applied to the highest estimate, these features lead ton a sediment inflow of 966 200 m3/year.

Even with these values, the dead storage being 54 000 000 m3, the loss of storage is not a problem.

Table 26 - Toabre Damsite - Time to fill Dead Storage

Reference	Suspended Load	Total Load	Total Volume	Specific Volume	Time to fill Dead Storage
	(tons/year)	(tons/year)	(m3/year)	(mm/year)	(years)
[1]	170 758	196 372	188 819	0.24	286
[1]	332 612	382 504	367 792	0.47	147
[2]	873 801	1 004 871	966 222	1.23	56

PART VII – RIVER HYDRAULICS

PART VII – RIVER HYDRAULICS

1. BASIC DATA

1.1. Gauging stations

The nearest operational gauging station on the Rio Toabre is located at Batatilla, 14 km downstreamwards of the dam site. The description and the main features of Batatilla gauging station are detailed in the Part VI – Hydrology.

Figure 1 presents the cross section and the rating curve of this station transmitted by ACP. This adjusted rating curve is given until the maximum peak discharge (2 200 m^3/s) observed in 1970 with a river level at El. 14.362 masl. Above this elevation, no information (topography or rating curve) is available.

The recently installed station at the dam site, located 1300 m downstream of the dam axis, is not yet operational. None value of requested simultaneous records of river elevation in Batatilla and Toabre stations has yet been transmitted by ACP for the needs of this study.

1.2. Cross sections of the Rio Toabre

Drawing 10-105 (see Volume III) shows the eight useful cross-sections (1) and their location on the Rio Toabre levelled in the vicinity of the dam site.

Profile n°3 is located on the ACP dam axis. Profile 1 is 850 m upstream while profile 8 is 1 500 m downstream.

Profile 6 is located at the recently installed Rio Toabre gauging station.

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(1) profiles n°1 to n°8. Profile n°9 and n°10 are incomplete on the banks.

2. RATING CURVE AT THE DAM SITE

2.1. Waterlines

On the base of the above data, waterline calculations have been performed with the HEC-RAS software. Batatilla station has been considered as the section of control for subcritical flow. Without any contradictory information for the river elevation at the dam site, calibration of the model was not possible. A global coefficient of friction Ks = 25 has been taken as reference for the streambed and sensitivity analysis have been made on this coefficient.

Figure 2 presents the different waterlines obtained on the longitudinal profile of the river in the dam site area in this reference case.

2.2. Rating curve of Toabre river at the dam site

Figure 3 shows the rating curves get from this waterlines calculations on the differents cross sections of the river, until 2 200 m^3/s.

Figure 4 presents the sensitivity analysis with the friction coefficient Ks on the rating curve of the Toabre river at the ACP Dam axis. This figure shows also the tentative extension for larger flows proposed for the current feasibility study with a friction coefficient Ks = 20 for flood plain above El. 30 masl. The real rating curve should be comprised between the maximum and minimum limits of this figure.

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

Important note :

during the performance of the current Feasibility Study an important flood occurred on the Rio Cocle Del Norte and Toabre: on November 23, 2002 the Rio Toabre reaches a maximum level at El. 15 masl (measured after the flood with observed floods marks) at the Batatilla gauging station, i.e. 65 cm above the previous observed maximum flow of 1970.

with an extrapolation of the current adjusted rating curve the peak flood can be estimated around 2 400 m^3/s. But it is worthwhile to notice that, according to ACP, the simultaneous flood of Rio Cocle Del Norte created a direct downstream effect on Rio Toabre, impact judged perceptible until the village of Sabanita Verde, 8 km upstream of Batatilla (affected) and 5.5 km downstream of San Vicente (non affected). The real peak flood could be consequently lower than this estimation.

the estimated maximum level of the Rio Toabre at the San Vicente gauging station (measured after the flood, according to local people indications) is El. 26.5 masl, to be compared with the El. 28 masl (+1.5 m) estimated for a 2 400 m^3/s flow with the waterlines calculations performed with Ks = 25 (see Figure 3 - profile 6). This same figure indicates a flow of 1 800 m^3/s for this elevation El. 26.5 masl.

taken into account the (non-assessed) downstream effect from Cocle Del Norte flood at Batatilla, it can be considered that the present informations about this recent flood confirm (or at least doesn't invalidate) the rating curve established at the dam site for the needs of this study.

FIGURE 1 - BATATILLA GAUGING STATION
CROSS SECTION & RATING CURVE

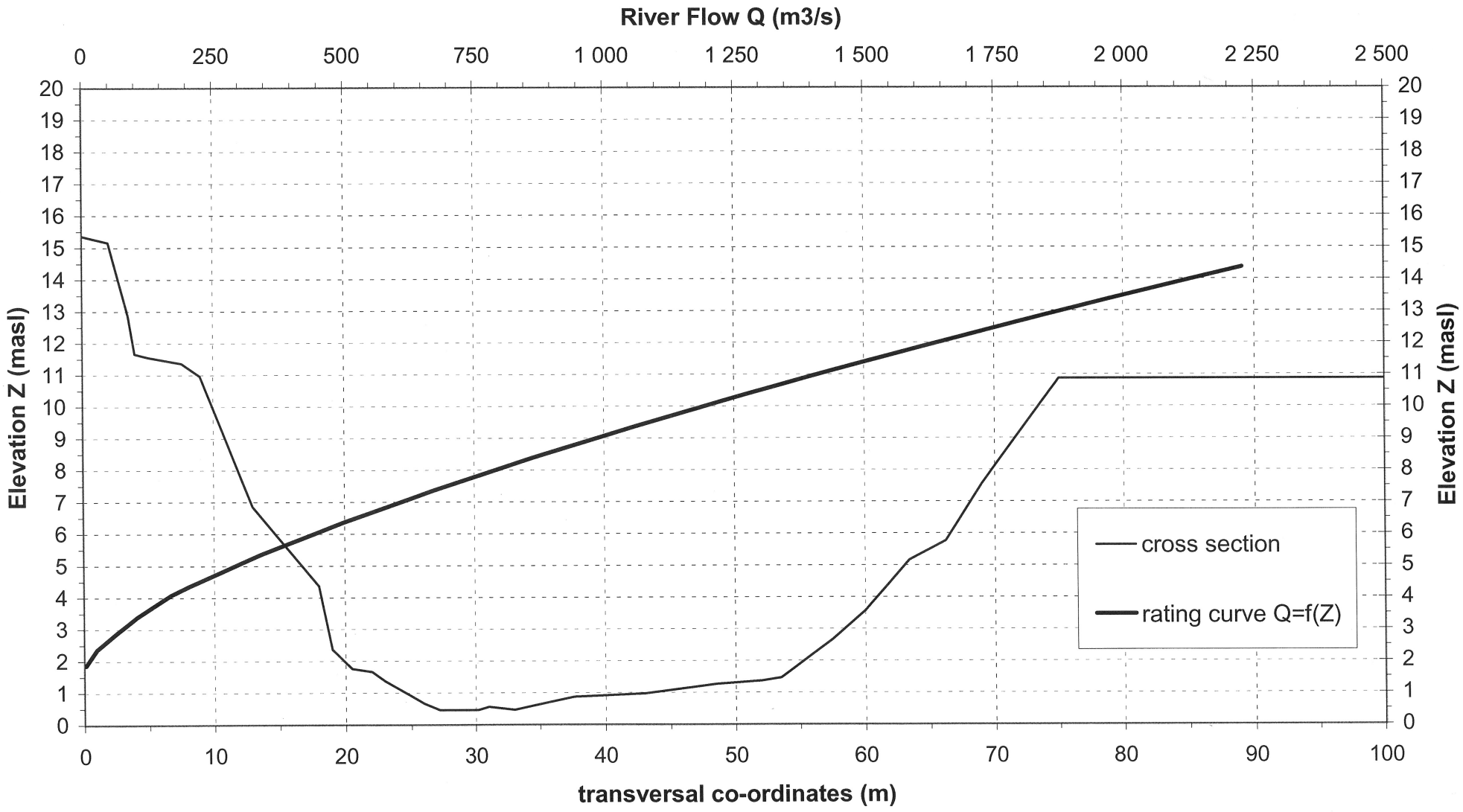


FIGURE 2 - WATERLINES OF THE TOABRE RIVER IN THE DAM SITE AREA
(calcul with Ks = 25)

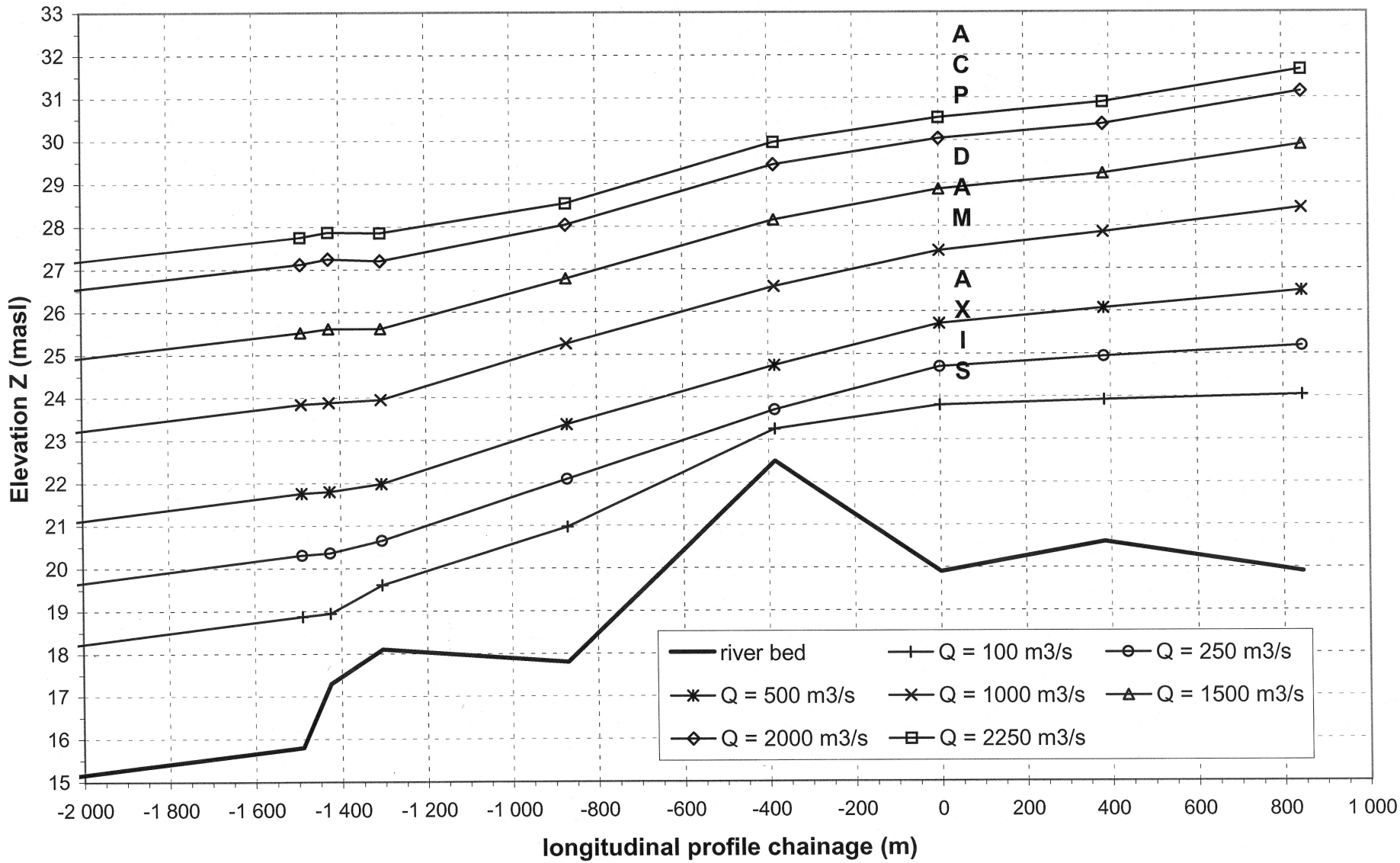


FIGURE 3 - RATING CURVES OF TOABRE RIVER CROSS SECTIONS IN THE DAM SITE AREA (calcul with Ks = 25)

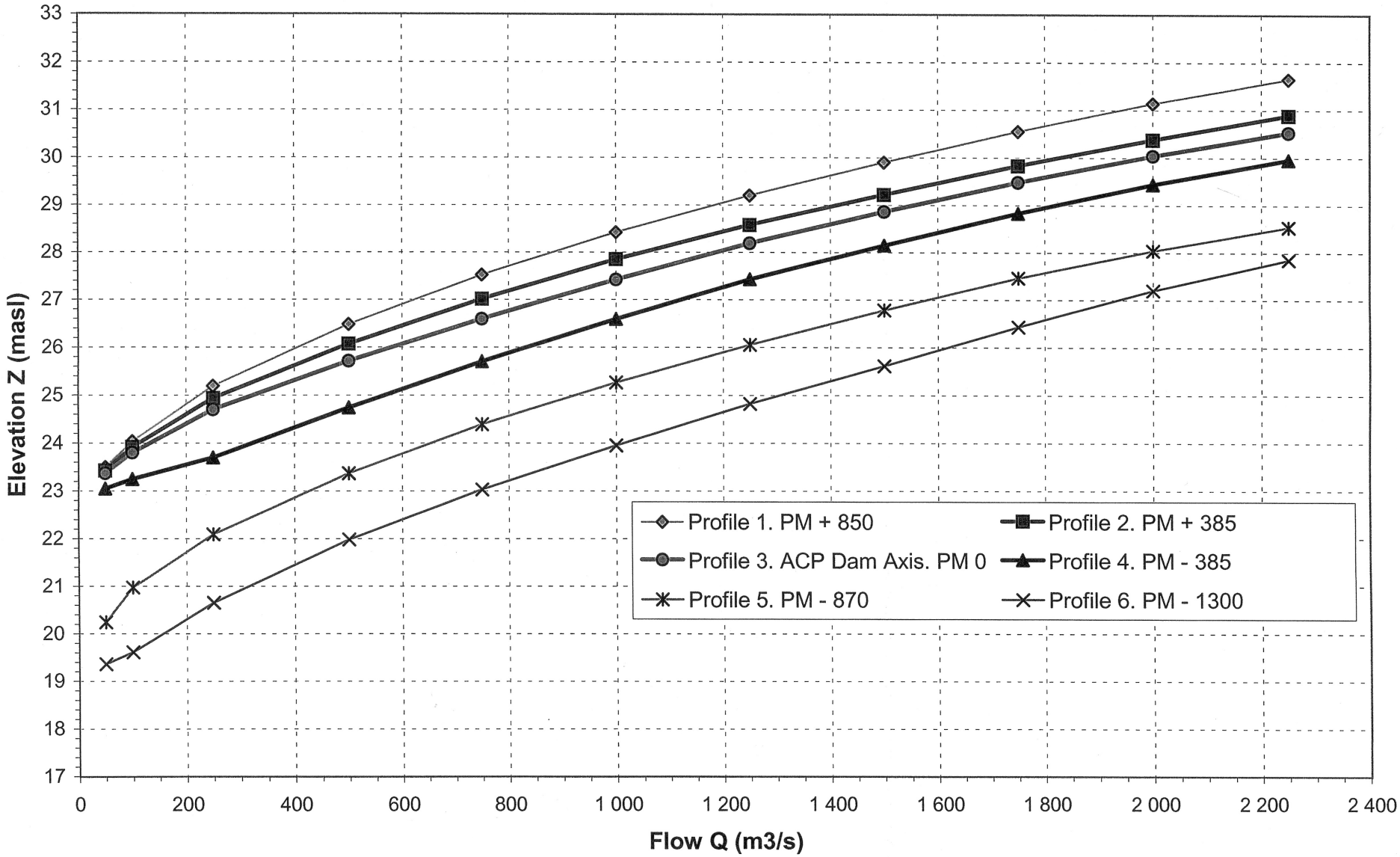
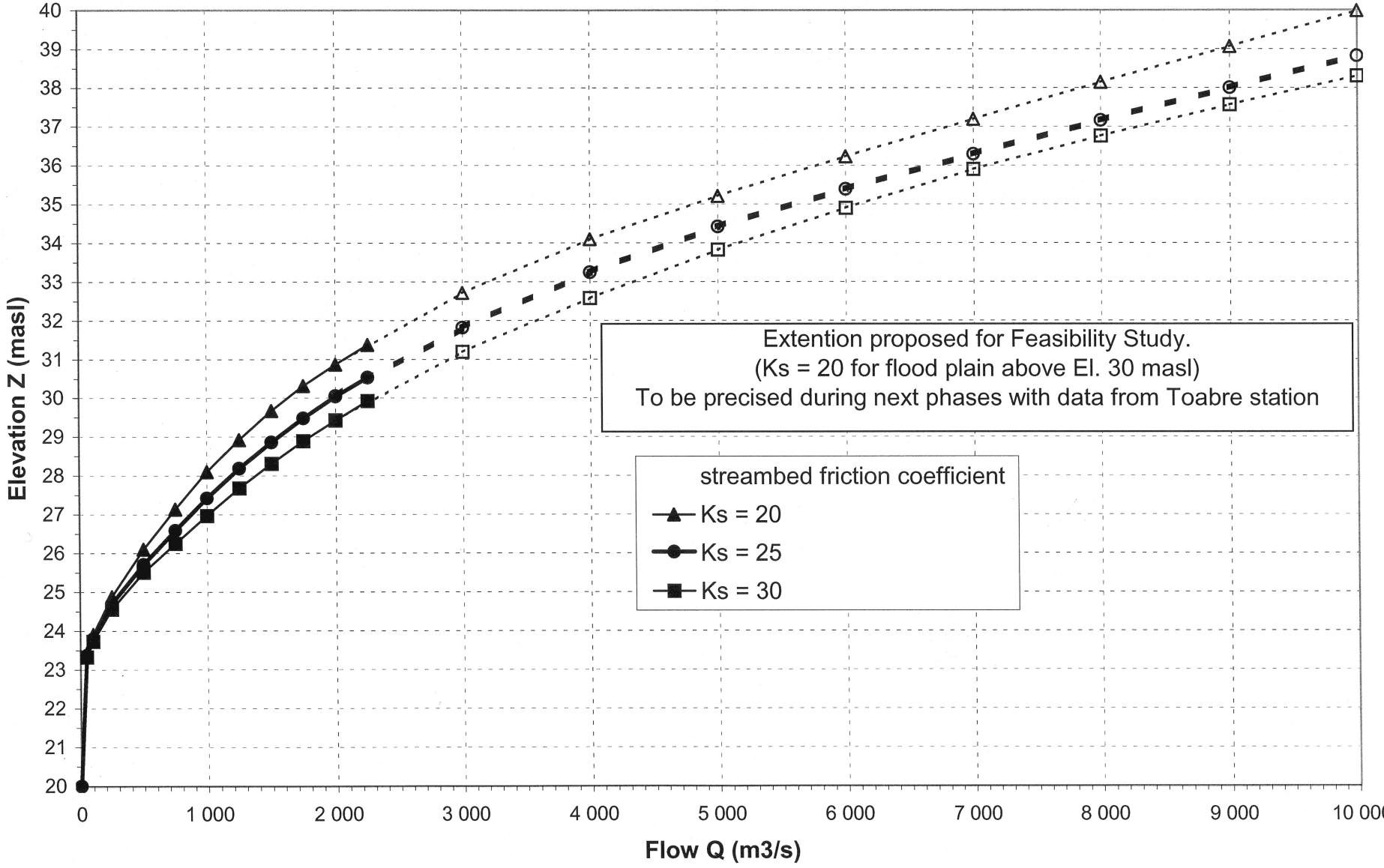


FIGURE 4 - RATING CURVE AT ACP DAM AXIS
SENSITIVITY STUDY WITH Ks & TENTATIVE EXTENTION



PART VIII – WATER MANAGEMENT & POWER STUDY

PART VIII – WATER MANAGEMENT & POWER STUDY

1. INTRODUCTION

At the start of the present Feasibility Study the result of the Rio Indio Feasibility Study were not yet available, especially considerations about Indio reservoir sizing and simulations details. To not delay the study of Rio Toabre, it has been decide (1) 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 preliminary phase have been performed with the SIM software from Coyne et Bellier, while the second phase simulations have been run with the HEC-5 program used by ACP for the previous studies.

2. PRELIMINARY SIMULATIONS WITH TOABRE RESERVOIR ALONE

2.1. BASIC DATA

Period of simulation	1948-1999
Calculation step	Monthly
Inflow	1948-1999 Series *(cf. Part VI - Hydrology)* Annual mean Inflow = 1 289 hm^3 (or 41 m^3/s). (see **Figure 1)**
Evaporation	Monthly Average Rate *(cf. Part VI - Hydrology)*
Height/Surface/Volume curve	*cf. Part III - Topography* (see **Figure 2**)
Ecological flow	10% of annual mean inflow = 4 m^3/s constant

(1) cf. 'Memorandum of ACP's mission in France 27 May – 06 June 2002'

2.2. YIELD OF TOABRE RESERVOIR ALONE

2.2.1. Objective

The main purpose of the Rio Toabre Reservoir will be to transfer water to the Panama Canal System to support the Navigation and M&I demand. This transfer of water will be operated via the Rio Indio Reservoir by a transfer tunnel connecting the two reservoirs and then to Gatun Lake by the tunnel between Indio and Gatun.

The aim of the first phase of the simulations study is to quantify the order of magnitude of the volume of water that can be regulated by the Toabre reservoir to be transferred to Indio Reservoir, but without taking into account the real demand for the Panama Canal System at Gatun lake. For this calculation, the modelisation of the single reservoir of Toabre is sufficient, with a demand expressed at Indio as the main parameter.

For the probable optimal operation of the future reservoir of Toabre in the Canal System, two different scenario of Regulation Demand have been envisaged:

Scenario	Demand
D1	Annual = Qr constant (m^3/s) all the year
D2	Seasonal = Qr constant (m^3/s) from January to June (6 months)

The objective of this phase is to draw the curve of Yield (Qr) vs. Reservoir Capacity (or Reservoir Normal Water Level) of Rio Toabre Reservoir with reliability of 99% and 95%. The reliability (in volume) is defined as the ratio of the mean annual volume of water effectively transferred by the reservoir, on the simulation period, with the annual demand of yield Qr.

2.2.2. Water Levels

The Normal Water Level (NWL) of the Rio Toabre Reservoir has been first studied in the range El. 80 (= NWL at Indio) – El. 105 (topographical limit of the reservoir); but in order to better show the evolution of the reservoir performance with lower and higher capacity, additional NWL at El. 75 and El. 115 (2) have been computed.

The Minimum Operating Level (MOL) has been chosen at El. 50 as reference, i.e. 10 m above the MOL of the Rio Indio Reservoir. Sensibility analysis has been performed on this MOL.

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(2) this reservoir elevation necessitates not negligible saddle dams (Left Bank and Cano Sucio area)

2.2.3. Yield results

The following table summarises the results obtained for the Annual Yield Qr:

NWL / MOL	Total Capacity CT	Active Storage CU	Scenario D1 (cst all year)		Scenario D2 (6 months)	
masl	hm^3	hm^3	Qr 99% (hm^3)	Qr 95% (hm^3)	Qr 99% (hm^3)	Qr 95% (hm^3)
75 / 50	367	299	825			
80 / 50	472	404	915	1 080	555	635
90 / 50	**741**	**673**	**1 060**	**1 160**	**775**	**905**
95 / 50	**918**	**850**	**1 105**	**1 185**	**880**	**1 035**
100 / 50	**1 131**	**1 063**	**1 125**	**1 200**	**990**	**1 115**
105 / 50	1 384	1 316	1 140	1 205	1 075	1 155
110 / 50	1 682	1 614			1 110	1 190
115 / 50	2 032	1 964			1 125	

Sensibility analysis on MOL :

90 / 60	741	593	1 025	1 145	725	835
100 / 60	1 131	983	1 120	1 195	950	1 095
90 / 70	741	461	950	1 105	610	700
100 / 70	1 131	851	1 105	1 185	880	1 035

These results are also presented on **Figures 3-4** (Qr expressed in hm^3/y) and **Figures 5-6** (Qr expressed in m^3/s on the regulation period).

These figures show that:

- with a constant regulation all along the year (scenario D1), the regulation potential tends to reach a limit for reservoirs with a NWL above El. 95 approximately.

  with a limited 6 months regulation (scenario D2) this fact occurs for reservoirs with a NWL above El. 105 approximately.

- in terms of navigation benefits, the Rio Toabre Reservoir, with a range of NWL comprised between El 90 and El. 100, could guarantee the equivalent of 14 to 15 additional lockages (3) per day to the Canal System (via the Indio reservoir) all along the year with a 99% reliability - Qr around 1 100 hm^3/y or 35 m^3/s.

  for this same range of NWL, this potential raises to 21 to 26 additional lockages per day if the water transfer from Rio Toabre Reservoir to the Canal is concentrated only during the 6 months from January to June - Qr around 800-1000 hm^3/y or 50-65 m^3/s.

The **Figure 7** gives the resulting adimensional yield curves of the Rio Toabre Reservoir, valid for any combination of NWL / MOL.

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(3) assuming 1 lockage = 55 Million Gallon

2.2.4. Typical cases simulations

Detailed results of the alternative case Qr 99% - NWL 95 / MOL 50 are presented on **Figures 8 to 13** for the two scenarios D1 and D2 : evolution of the reservoir level, supply of the yield showing the deficit, spillage etc…

For this same NWL at El. 95, the reservoir behaves slightly differently with scenarios D1 or D2 : interseasonal behaviour with D1, showing periods of several years with partial filling related to sequences of repeated dry years, and then rare spillage; with the scenario D2 the reservoir has a more seasonal behaviour with a quite annual full filling and then more frequent spillage.

The listings of the output from the SIM software are presented in Appendix for these two cases NWL 95 / MOL 50 – Qr 99% - Scenario D1 & D2.

2.3. ENERGY POTENTIAL OF TOABRE RESERVOIR ALONE

2.3.1. General

As an additional purpose to the main water transfer for the Canal System (Navigation), the Toabre Reservoir could generate hydroelectricity: at least by turbining the constant ecological flow (4 m^3/s) and a part of the spillage; but eventually also a variable part of the water devoted, at term, to the Navigation until the Navigation Demand reaches the maximum regulation potential of the reservoir : then, the part of the available water of the reservoir that could be turbined should decrease with the increase of the Navigation demand which requires the increase of the water transfer.

2.3.2. Objective

It was then interesting during this first phase to quantify the performance of the Toabre Reservoir in terms of maximum energy potential, with the theoretical assumption that no water is transferred for the navigation (no demand for navigation).

The objective is then to draw the curve of Energy Production (firm) (Ef) vs. Reservoir Capacity (or Reservoir Normal Water Level) of Toabre Reservoir with reliability of 99%, 95% and 90% (in time).

2.3.3. Energy results

The **firm energy** of the Rio Toabre scheme is the energy production—assumed constant over the whole year—that the reservoir can provide for a given shortfall rate. The **shortfall rate** here is defined as the ratio of the number of months when the required energy cannot be satisfied to the total number of months in the simulation period. The basic value for the whole study is **5%** (i.e. a 31-month shortfall for a 52-year simulation). A number of shortfall sensitivity studies were also carried out (1% and 10%). The energy effectively generated (firm energy less shortfalls) is called the "**energy produced**".

The energy is calculated by : **{**INCORPORER Equation.2**}**, with :

- E = Energy in GWh/month,
- Q = Flow turbined in hm^3/month,
- H_n = Head in m, assuming a downstream restitution level at El. 16 masl (4),
- α = Coefficient of 8.5, assuming a global and constant efficiency of equipment

Secondary energy is the energy produced by generating with excess flows up to the total turbine discharge under maximum head (5). The **total energy** is therefore defined as the sum of the energy produced and the secondary energy.

The Minimum Operating Level (MOL) has been chosen with the usual ratio of Hmin / Hmax = 75% for Turbines Francis. Sensibility tests with ratio of 60% have been computed.

The following table summarises the results obtained in terms of maximum energy generation:

NWL	MOL (75%)	Total Capacity	Active Storage	Firm Energy Ef GWh/y			Total Energy Et GWh/y			Peq (6) (If 0.6)
masl	masl	hm^3	hm^3	99%	95%	90%	99%	95%	90%	MW
75	60.25	367	217		99					19
80	64	472	278		121			144		23
90	71.5	741	437	147	162	172		178	181	31
95	75.25	918	546		182			195		35
100	79	1 131	681	193	196	205	210	208	205	37
105	82.75	1 384	848	211	214	219	228	223	221	41
110	86.5	1 682	1 047		232			239		44
120	94	2 439	1 559		268			271		51

(4) value issued from 1/50 000 map; recent topographical levelling indicates a water level around El. 21 masl. Present Energy calculations are then overestimated from 5 to 10%.

(5) as a first step this discharge under maximum head is based on an installed capacity which allows generating the firm energy with a mean load factor of 0.6.

(6) Peq = Equivalent Installed Capacity calculated with an average load factor of 0.6
*Peq (MW) = Ef 95% (MWh) / (0.6 * 8760)*

Sensitivity tests with MOL:

NWL	MOL (60%)	Total Capacity	Active Storage	Ef 95%	Et 95%
masl	masl	hm^3	hm^3	GWh/y	GWh/y
100	66.4	1131	905	194	202
110	72.4	1682	1362	230	

Results are also presented on **Figures 14 & 15**.

2.3.4. Typical case simulations

Figures 16 to 20 present some detailed results of the alternative case NWL 95 / MOL 75.25 – Ef 95% : evolution of the reservoir level, energy production, spillage etc.

2.4. CONCLUSIONS

This preliminary phase of the Water Management & Power Study was voluntarily simplified, with the modelisation of the Rio Toabre Reservoir alone. The introduction of the Toabre Reservoir in the whole Panama Canal System with Gatun + Madden + Indio reservoirs, based on the HEC-5 model previously developed by ACP, is the purpose of a second phase of the study.

Nevertheless this phase allowed determining the order of magnitude of the expected potential of the Toabre Reservoir for a selected range of Normal Water Level (NWL), primary in terms of water transfer regulation, and secondary in terms of energy production.

Figure 21 synthesises this potential of the Rio Toabre Reservoir vs. Capacity (or NWL), between the identified limits of the possible NWL : lower limit at El. 80 due to Rio Indio NLW and upper limit at El. 105 based on topographical/economical conditions/considerations.

It is worthwhile to notice that this fixed upper limit at El. 105 coincides anyway with the drastic limitation of the increase of the potential for higher NWL.

It is then recommended, in the second phase of the Water Management & Power Study, to perform HEC-5 simulations focused on the three following alternatives for the Normal Water Level of the Rio Toabre Reservoir: El. 90, El. 95 and El. 100.

The currently 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	hm^3/y	m^3/s	lockage/d	hm^3/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

3. SIMULATIONS WITH HEC-5 CANAL SYSTEM MODELING

3.1. INTRODUCTION

ACP was in charge of this part of the Water Management & Power Study, with the utilisation 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 HEC-5 reservoir system model was developed by the U.S. Army Corps of Engineers' Hydrologic Engineering Center in Davis, California. The existing system model (base model) was developed in order 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). The flood control zone is used to store excess inflow and for power generation, the conservation zone is used to store water to meet future demands, and the inactive zone, (dead storage) is where no releases can be made.

Water demands include minimum flow goals, diversions, and hydroelectric power generation. Reservoirs are linked to other reservoirs and control points (non-reservoir locations) using routing reaches. A combination of reservoirs, control points and connecting routing reaches then defines a reservoir model system.

3.2. BASE MODEL DATA

The base model represents the existing ACP water supply system. Madden and Gatun reservoirs are the primary elements of the system. HEC-5 can only process one diversion from each reservoir. The municipal water supply and the lockages for Gatun and Pedro Miguel were combined into one diversion from Gatun.

All data are in foot-acres units. The basic simulation time-interval is one month. However, this model could operate at time steps as small as one-hour. Given the monthly time-step, the seasonally varying data are all defined over the 12 months. There is no river-reach routing data required for the monthly time step.

The average-monthly flow data are input to Madden and Gatun. The inflow is assigned as incremental-local flow, which means that the inflow to Gatun only represents the catchment not controlled by Madden.

- ***Madden Reservoir***

The model begins with a Madden Reservoir (location 50) which receives basin inflow, provides M&I water supply, and release flow to Gatun. Reservoir releases are assumed to pass through the hydroelectric facility and energy generation is computed up to the limits of power capacity. The outflow from Madden Powerhouse is "routed" to Gatun reservoir. The penstock capacity was set to 102 m^3/s (3,600cfs) based on operation manual information; however, that value should not be a controlling factor in the monthly simulation.

Elevation-Storage: HEC-5 defines the reservoir with a set of storage-based relationships. Reservoir outflow capacity, elevation, and area are defined as a function of storage. The data between elevations 57.9 masl and 82.3 masl (190 and 270 feet) were input on a 0.60 m (two-foot interval), except for the 60.9 masl to 67.1 masl (200 to 220 feet) range where data input is on 0.30 m (one-foot) interval. Data below elevation 57.9 masl (190 feet) and above 80.5 masl (264 feet) were estimated by extrapolation. There are two reasons for this: one is that the reservoir operating range is between elev. 57.9 masl and 76.8 masl (190 and 252 ft), so that information within this range should be more accurate. The other reason is that the program interpolates on a straight line between points, and in order to be more precise in the part of the curve where the slope changes more rapidly, closer points will be needed.

Outflow Capacity: The outflow capacity is a constraint on releases in HEC-5. The program does not simulate gate openings, it only ensures that the release does not exceed the maximum outflow capacity of the reservoir. The spillway capacity was set to 2,120 m^3/s (75,000 cfs) based on flood operation manual information;

Reservoir guide-curve: The guide curve for the top-of-conservation is defined by the target storage at the end of each month. The reservoir guide curve has changed over the years. Since this analysis is for the existing system, the current guide-curve was used in the model. The guide curve is data input supplied by ACP, more information will be given on its development in following sections.

Reservoir evaporation: The evaporation for Madden is the computed reservoir evaporation, in inches, provided by ACP.

Hydropower data: The total installed capacity is 36 MW, 3 x 12 MW units; no overload is assumed. The tailwater was set at 27.1m (89 feet). The efficiency was set at 83%, based on turbine testing data and an assumed generator efficiency of 96%. No hydropower requirements were specified. A leakage value of 0.6 m^3/s (20 cfs) was used, as determined by the Meteorological & Hydrographic Branch (Met & Hyd) of ACP. The program will pass that value as a minimum and that flow will not be used for energy computation.

M&I Diversions: The municipal and industrial water supply is diverted from Madden to nowhere, i.e. the diverted flow leaves the system. Average monthly values for the 5-year period 1993-1997 were used. These were the last 5 complete years of information available when the base model was set in late 1998.

- ***Gatun Reservoir***

Gatun (location 40) is the next location below Madden. The input flow data to Gatun is the uncontrolled flow downstream from Madden. The total inflow is the sum of Madden releases and input flow data. The release from Gatun routes to the Caribbean Sea. As with Madden, the reservoir releases will be used to generate electrical energy. Flow diversion from Gatun includes municipal water supply and the combined lockages for Gatun and Pedro Miguel Locks.

Elevation-Storage: HEC-5 defines the reservoir same as with Madden. The data between elevations 23.5 masl and 27.4 masl (77 and 90 feet) were input on 0.30 m (one-foot) interval. The data were not defined below elevation 23.5 masl and above elevation 27.4 masl, so that data was estimated by extrapolating the given curves. Reasoning for this same as that for the Madden reservoir storage data.

Outflow capacity: Criteria is the same as that for Madden. The outflow capacity was taken from information by ACP for all 14 gates open from an elevation of 23.8 masl to 28.0 masl (78 to 92 feet). Outflow capacity for elevations 21.3 masl and 23.5 masl (70 and 77 feet) were estimated using the weir equation and a coefficient of 3.

Reservoir Guide-Curves and Reservoir evaporation: Same considerations as those for Madden.

Hydropower data: The total installed capacity is 24 MW, 3 x 3 MW units and 3 x 5 MW units. No overload is assumed. The tailwater elevation was set at 2.7 masl (9 feet), based on tailwater data from unit testing. The efficiency was set at 85%, based on turbine testing data and an assumed generator efficiency of 96%. No hydropower requirements were specified. A leakage value of 0.8 m^3/s (27 cfs) is used, information provided by ACP`s Met & Hyd Branch.

Gatun and Pedro Miguel Locks: The diversions from Gatun include the combined flow for lockages.

M&I Diversions: The diversion from Gatun for municipal and industrial water supplies is included with the flow for locks as the diversion from Gatun. Average monthly values for the 5-year period 1993 to 1997 were used. These were the last 5 years of complete information available since the base model was set in late 1998.

Flow data: It is a requirement of the model to define the starting storage values and the corresponding date for each reservoir.

3.3. BASE MODEL VALIDATION

To validate the model configuration and data, a simulation run of the operation of Lake Madden and Lake Gatun was made for the period of January 1970 to December 1997. Then the simulation should yield the same results as historically recorded. For both reservoirs, the validation model elevations are essentially the same as the observed elevations, therefore, the model configuration is consistently accounting for the water in the system.

The resultant **Hydrologic Volumetric Reliability**, represented by a ratio of the volume of water provided to the volume of water demanded for canal operations during the designated period with no draft restrictions at Gatún Lake, was calculated as **99.6 %** for 50.5 years, 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 hm3/year or equivalent 38.7 lockages/day, assuming 55 millions gallons (= 208 000 m3) per lockage.

3.4. RESERVOIR RULE CURVES

ACP has developed rule curves for the tandem operation of Gatun and Madden Lakes. The purpose of the curves is to comply with a minimum draft for ships as well as obtain a maximum level of reliability with minimum shortages. Several curves have been in use throughout the more than 85 years of operation of the Canal, the existing conservation rule curve was implemented in the beginning of 1980's, meanwhile the spilling curve has been adjusted to the late pratice by raising it to the actual upper bound of 26.75 mts at the end of the rainy season.

The development of the curves has been based on the experience with the hydrology in the Panama Canal Watershed, with a dry season extending from January through April and the

rainy season from May through December. In general the intent of the curves is to use in the dry season the water stored during the rainy season and to fill both lakes by the end of the year.

Though the current set of curves was mostly developed on an empirical base, a study was conducted on April 1999 by Manuel B. Vilar from the Met & Hyd Branch of ACP to validate them. The study consisted on two distinctive approaches in simulating lake operations with the daily data from 1965 to 1994, based on an historical analysis and a stochastic analysis.

3.5. HYDROLOGIC RELIABILITY WITH TOABRE RESERVOIR

3.5.1. Principle - Methodology

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 hm3/year, equivalent to 60.5 lockages/day, i.e. 1.56 time the current average Demand.**

In order to determine the effect of the proposed Toabré Reservoir on the hydrologic reliability of the Panama Canal, the existing HEC-5 model was modified to include the Toabré Lake in conjunction to Indio Lake operation. The existing Gatun and Madden Lake parameters (surface areas, storages, and local inflows) are kept as before, while the Indio Lake parameters were partially modified to contemplate the increased flow transfer provided by the Toabré Lake: indeed it is required that Rio Indio Lake be connected to the Panama Canal watershed at Gatun Lake via a tunnel with increased capacity (bigger diameter or double tunnel). Water impounded in these lakes would be transferred to the Panama Canal watershed as needed to support M&I and navigation demands.

Following is a description of the parameters involved in the modeling of the new Canal System with the introduction of Toabre reservoir. But it is important to notice first that the present HEC-5 study has been continually delay due to for long unsolved HEC-5 calculation problems with the introduction of Toabre in the Canal System. **During the study ACP contracts HEC-5 expert R. Hayes to solve these problems and provide required results; but this expertise has not been yet performed and the present results should be reviewed and validated.**

Among the encountered problems emerges the fact to get deficit on Demand even with no-empty upstream reservoirs, due to the particular inaptitude for HEC-5 to balance transfer of water from tandem or parallel reservoir during the same step of calculation. By the same the intended operation of reservoirs on the principle of 'equivalent reservoir filling' has been only

approached. These problems have been nevertheless reduced by the latter introduction of weekly step calculations.

As a result the time was too short to have a critical view of the present results and perform optimisation; the present results are taken as provided by ACP, with the **recommendation to review the methodology of calculation with R. Hayes to both validate these results and optimise some important parameters as transfer tunnels diameter.**

- ***Toabré Reservoir***

Lake Operation: The water surface of the lake will fluctuate from the normal operating lake (study of three alternatives : NWL 90, 95 and 100 masl) down to the minimum operating lake level at elevation 50 masl with 675 to 1065 million cubic meters of usable storage. The maximum flood lake level would be about 5 m above. The volume between the maximum flood lake level and the normal operating lake level would store floodwater.

Inflows: According to Part V - Hydrology, the Toabré Lake (location 400) would receive a monthly average runoff of 40.9 m^3/s (1 289 hm3/y) from approximately 727 km^2 of the upper portion of the watershed.

Releases flow to Indio will go through a 16 km long horseshoe tunnel (study in the range of 3 m to 6.0 m of diameter) connected to the Indio watershed. Toabré reservoir will release to Indio as required by the system and governed by the differential elevation between Toabré and Indio reservoirs. The outflow from Toabré tunnel is routed to Indio reservoir, while the spillage and the ecological flow is routed out of the system to the Atlantic Ocean.

Elevation-Storage: HEC-5 defines the reservoir with a set of storage-based relationships. Reservoir outflow capacity, elevation, and area are defined as a function of storage.

Outflow Capacity: The outflow capacity is a constraint on releases in HEC-5. The program does not simulate gate openings, it only ensures that the release does not exceed the maximum outflow capacity of the reservoir.

Reservoir evaporation: A set of net evaporation rates to account the transformation from land and vegetative cover into a water body were calculated for Toabré Lake. A detailed explanation of this is submitted in Part V – Hydrology.

Hydropower data: HEC5 runs were executed considering only a small hydropower plant at the dam equipped for the ecological flow (4 m3/s) with a load factor of 0.50. The tailwater elevation was based on the elevation at the toe of the dam.

- ***Indio Reservoir***

Lake Operation: The water surface of the lake will fluctuate from the normal operating lake level 80 masl down to the minimum operating lake level at elevation 40 m with 1,294 million cubic meters of usable storage. The maximum flood lake level would be at elevation 82.5 m. The volume between the maximum flood lake level and the normal operating lake level would store floodwater.

Inflows: The Indio Lake (location 200) would receive a monthly average runoff of 25.8 m^3/s from approximately 380 km^2 of the upper portion of the watershed in addition to the water transfer from Toabré watershed. The calculated discharge at the Rio Indio dam site is obtained from streamflow data of the Boca de Uracillo Hydrologic station.

Releases flow to Gatun will go through **the 8.4 km long horseshoe tunnel of 4.5 m of diameter (not optimized at this stage)**, designed for the feasibility study of Rio Indio, connected to the Panama Canal watershed. Indio reservoir will release to Gatun reservoir during the whole year as much as required and limited by the constraint of the tunnels to support M&I demands and navigation. Reservoir releases are assumed to pass through the hydroelectric facility located at the end of the tunnel and energy generation is computed up to the limits of power capacity. The outflow from Indio is routed to Gatun reservoir.

Elevation-Storage: HEC-5 defines the reservoir with a set of storage-based relationships. Reservoir outflow capacity, elevation, and area are defined as a function of storage.

Outflow Capacity: The outflow capacity is a constraint on releases in HEC-5. The program does not simulate gate openings, it only ensures that the release does not exceed the maximum outflow capacity of the reservoir.

Reservoir guide-curve: The guide curve for the top-of-conservation is defined by the target storage at the end of each month. The guide curve is a data input supplied by ACP, and obtained using the 25% of active storage.

Reservoir evaporation: Because of the proximity of Rio Indio to Gatun Lake, and because of the absence of site specific information, the monthly evaporation rates established for Gatun Lake were considered appropriate for the evaporation rates of Indio lake.

Hydropower data: HEC5 runs were executed considering a 5 MW hydropower plant at the dam and a 25 MW hydropower plant at the inter basin transfer tunnel outlet. No overload was assumed. The only limitation of power output was the powerplant rated capacity. The efficiency was set at 86%. The tailwater elevation was based on the elevation at Gatun.

3.5.2. Results

The yield with 99.6% reliability has been evaluated as follows for each of the studied cases:

	lockages/day	hm3/y
System yield with Gatun, Madden and Indio 80/40/4.5	60.45	4 593
System yield with Toabre NWL / MOL / Diam. tunnel	X (HEC-5)	X (HEC-5)
Yield attributed to Toabre NWL / MOL / Diam. tunnel	Y = 60.45- X	Y = 4 593-X

Table 1 presents the synthetic results of the studied cases, while the complete results and details of HEC-5 simulations are presented in Appendix.

A preliminary analysis, detailled in Appendix, on the base of Cost / Yield Index for each of the studied cases allowed to retain a common 5 m diameter tunnel for the three alternatives of the Toabre Project, associated with a common additional 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 hm3 / 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 hm3 / year	1 043	1204	1269
expressed in equivalent additional lockages / day	13.73	15.86	16.71

4. POWER AND ENERGY

4.1 Rio Indio Project – 2015/2028

With reference to Feasibility Design for Rio Indio Water Supply Project – Appendix E – Power and Energy Studies by MWH-TAMS-(2003), maximization of output at Isla Pablon Power Plant, located at the downstream end of the Rio Indio / Gatun Lake transfer tunnel, is technically feasible.

Accordingly, the recommended scheme, expressed in the next flow chart, is the following:

- Generate from 65 GWh/y down to 33 GWh/y at Isla Pablon 14 MW Power Plant, with maximum transfer flow,
- generate 9,7 GWh/y energy at Indio 2,5 MW Mini Power Plant, with ecological flow (e_{min} = 2,3 m^3/s).

During the intermediate period, between year 1, when navigation benefits from Rio Indio Water Supply Project will start being mobilized, and, year 14, when navigation benefits will be fully mobilized, Isla Pablon Power Plant will produce as shown in following charts schedule, according to rated discharges (curve A) from Rio Indio reservoir towards Gatun Lake.

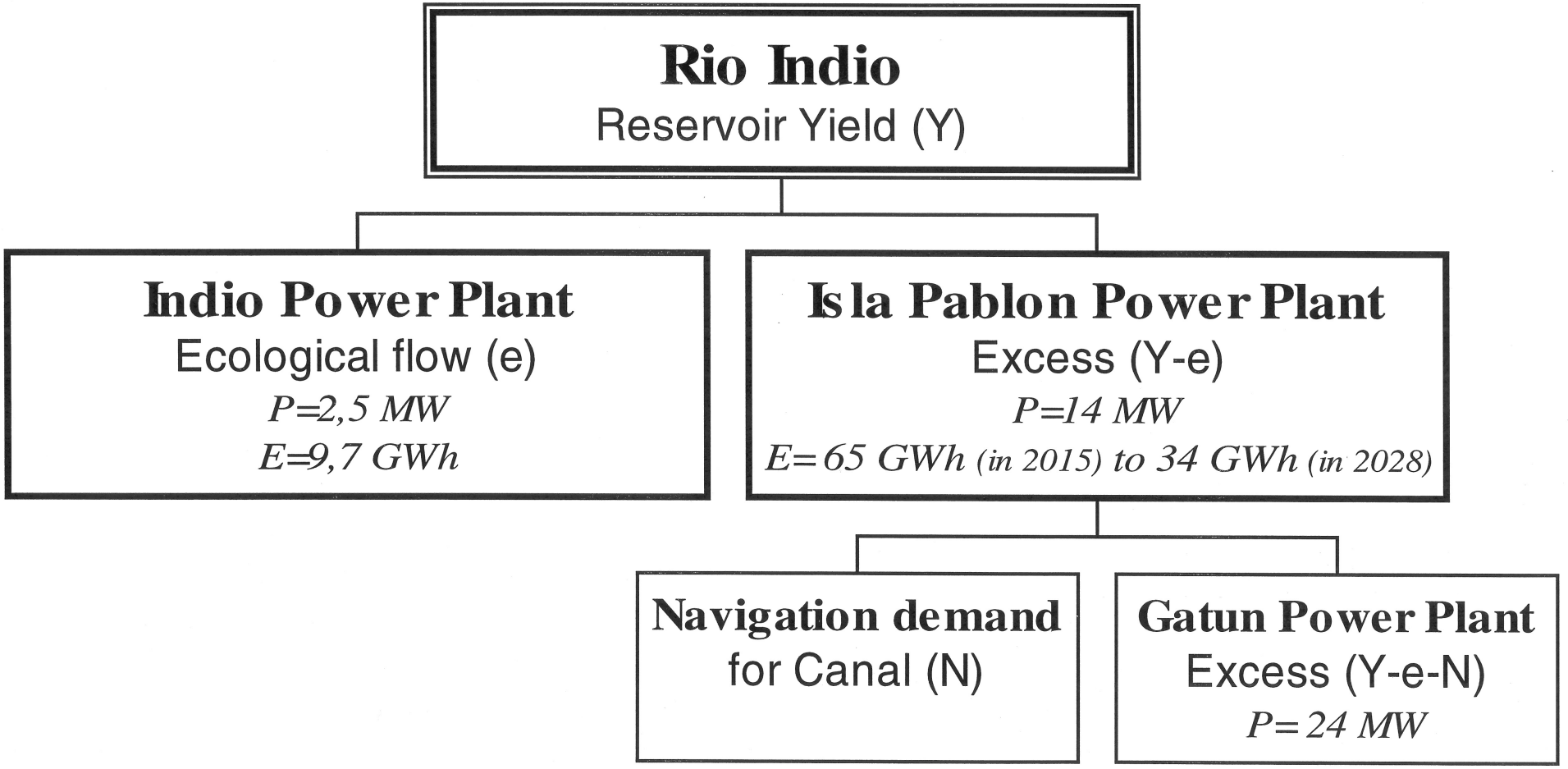
With:

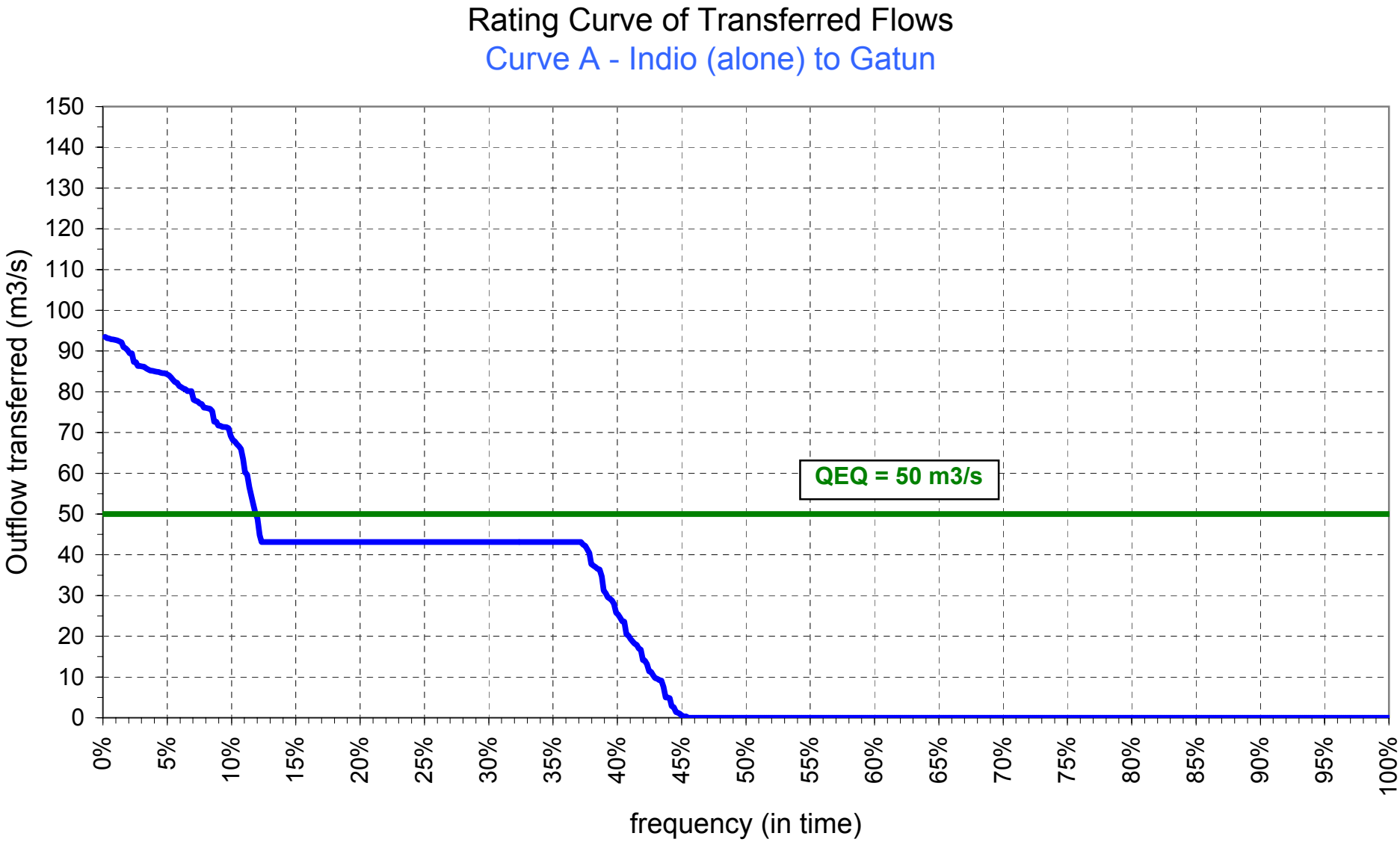
- a 28 MUSD investment cost mobilized from year (-4) to year (0),
- a 245 000 USD/year Operation and Maintenance annual cost,
- revenues valued with 45 USD per MWh of energy and 60 USD per kw of firm capacity, Isla Pablon powerstation economic analysis shows a return likely to be insufficient for development.

During the intermediate period [starting year (1)], as long as the yield from Indio will exceed canal navigation demand, additional energy can be generated at Gatun Power Plant. This additional energy will decrease progressively while navigation demand will increase.

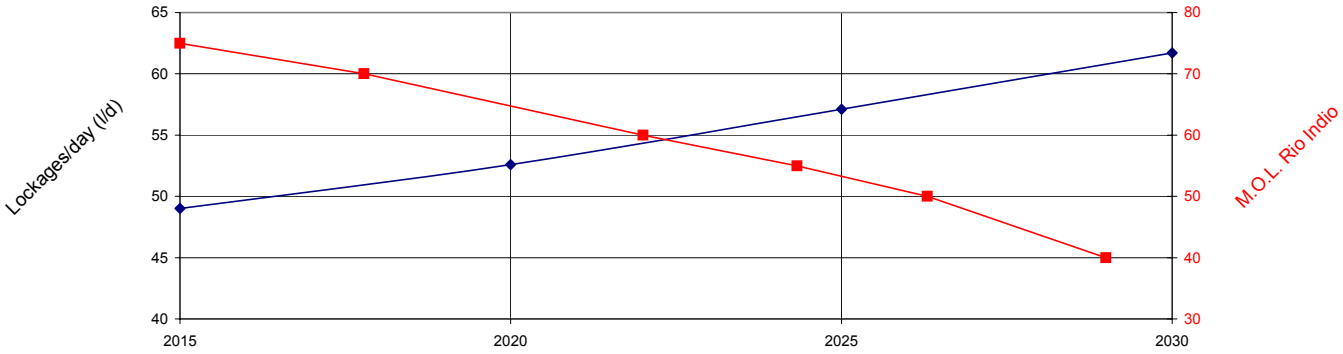
Rio Indio Power and Energy

Ref. MWH-TAMS- APPENDIX E (2003)

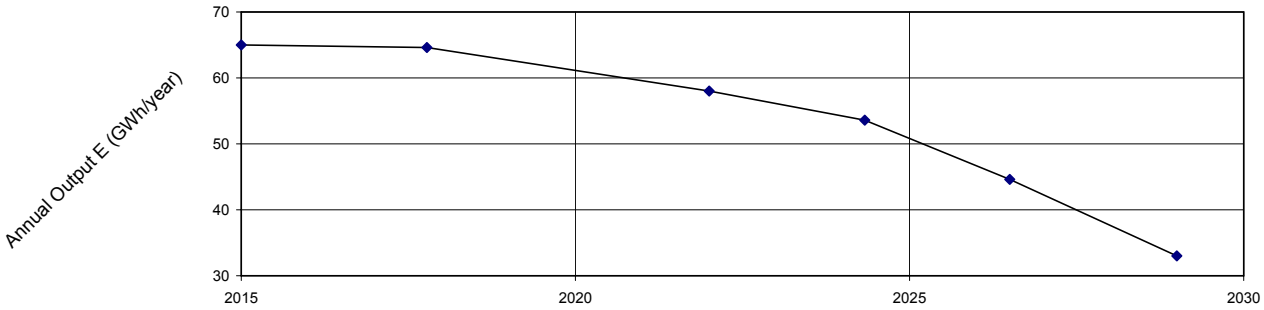


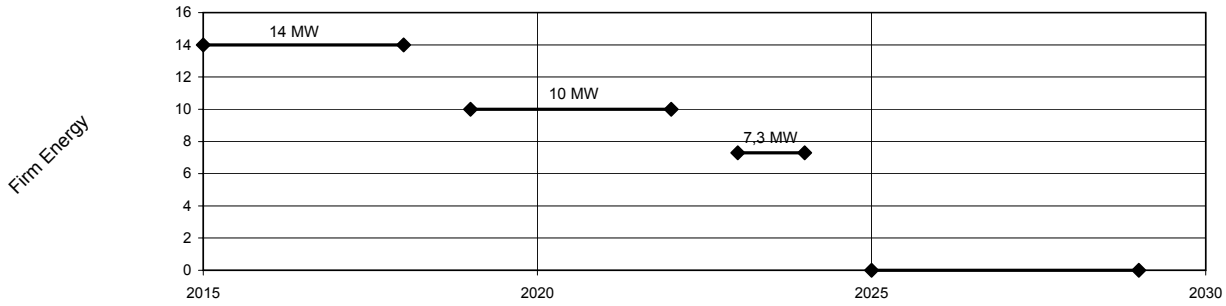

Rating Curve of Transferred Flows
Curve A - Indio (alone) to Gatun
Outflow transferred (m3/s)
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
QEQ = 50 m3/s
0%
5%
10%
15%
20%
25%
30%
35%
40%
45%
50%
55%
60%
65%
70%
75%
80%
85%
90%
95%
100%
frequency (in time)

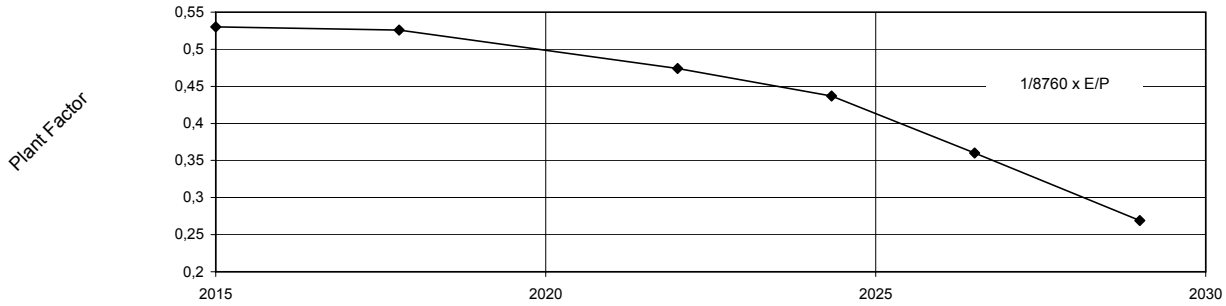
RIO INDIO RESERVOIR - NAVIGATION AND M.O.L. DEMAND



ISLA PABLON POWER PLANT - 14 MW







ISLA PABLON - POWER AND ENERGY

Ref: MWH-TAMS - APPENDIX E (2003)

4.2 Rio Toabre from 2029

Generation of energy at the end of Rio Toabre / Rio Indio transfer tunnel is not justified, because the available gross head is largely balanced by headlosses in the transfer tunnel.

While the navigation demand will grow progressively, beyond year 2028, the Rio Toabre yield can be used to generate energy:

- either primarily at the dam toe, maximizing output at Rio Toabre Power Plant,
- or primarily at the end of the Rio Indio / Gatun Lake transfer tunnel, maximizing output at Isla Pablon Power Plant (defined in Rio Indio Feasibility Study).

Rio Toabre Power Plant being situated far from national distribution network, it is justified to extrapolate Rio Indio conclusions to Rio Toabre Power and Energy recommendations that this power plant will be more likely marginal.

Accordingly, the recommended scheme will be:

- a Rio Toabre 4 MW mini hydropower plant, generating 18 GWh/year at toe of the dam, with ecological flow,
- an Isla Pablon 9 MW supplementary unit at the end of Rio Indio / Gatun Lake transfer tunnel, as justified here below.

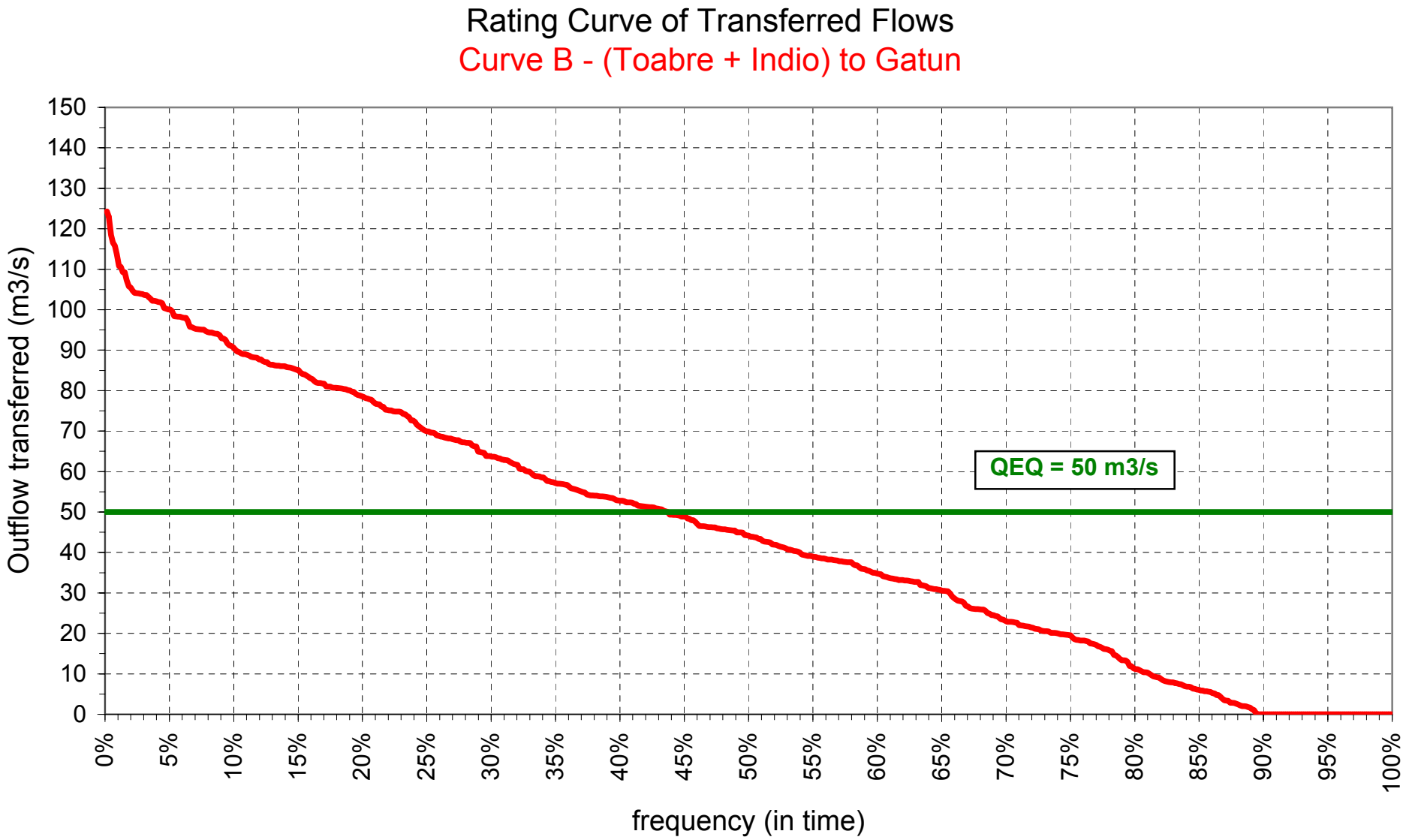
Assuming that the Isla Pablon Power Plant can accommodate 50 m^3/s under 43 meters mean head, with the water transfer rated discharges (curve B), when Rio Toabre and Rio Indio reservoirs storages will be mobilized for ultimate navigation uses, an extra 40 GWh/year energy can be generated (from an approximate 390 MCM/year additional volume of water available) beyond year (15).

With:

- a 15 MUSD supplementary investment cost mobilized from year (12) to year (14), for the implementation of the additional 9 MW unit along with the corresponding Civil Works,
- a 130 000 USD/year supplementary Operation and Maintenance annual cost from year (15),

The Isla Pablon powerstation economic analysis shows a (+2.2%) increase on the internal rate of return raising its value from 9.1 % to 11.3% likely to be sufficient for development. A further (+1%) increase is gained when power and energy revenues are increased by 10%.

During the intermediate period [starting year (15)], as long as the yield from Toabre will exceed canal navigation demand, additional energy can be generated at Gatun Power Plant. This additional energy will decrease progressively while navigation demand will increase.


Rating Curve of Transferred Flows
Curve B - (Toabre + Indio) to Gatun
Outflow transferred (m3/s)
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
0%
5%
10%
15%
20%
25%
30%
35%
40%
45%
50%
55%
60%
65%
70%
75%
80%
85%
90%
95%
100%
frequency (in time)
QEQ = 50 m3/s

4.3 Conclusions

Rio Taobre water transfer for Isla Pablon hydropower plant allow an uprating by 9 MW supplementary capacity, as compared with initial 14 MW rating, whith Rio Indio water transfer alone. As such, a maximum 40 GWh/year supplementary energy can be generated.

With combined scenario defined by following scenario B figure, Rio Toabre brings a global (+2.2%) increase in the economical rates of return of the Isla Pablon Power Plant, raising the same to 11.3 %, all other assumptions made in the Feasibility Design of Rio Indio Power and Energy studies being kept identical.

RIO TOABRE WATER TRANSFER
POWER AND ENERGY

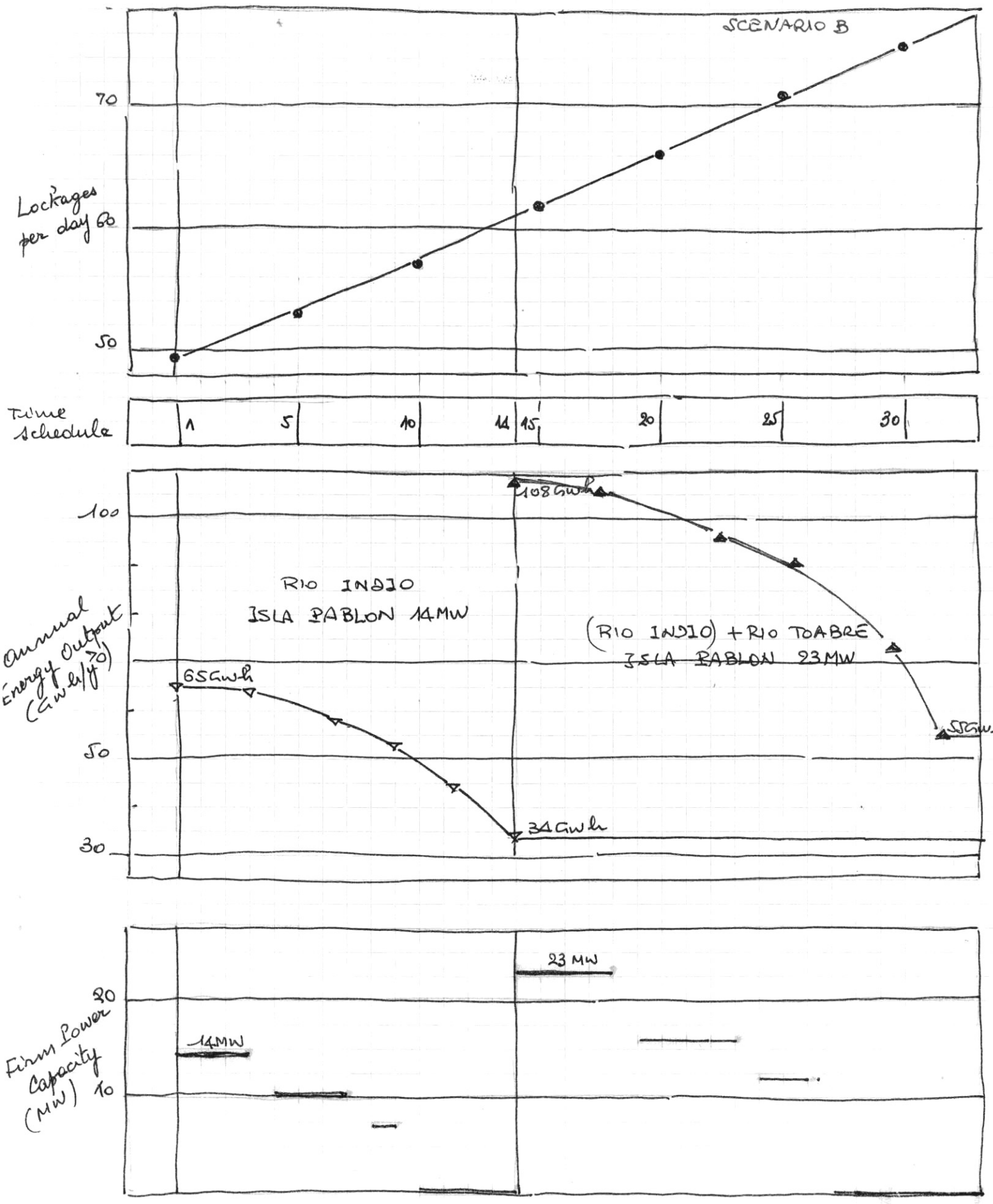


TABLE 1 - HEC-5 Synthetic Results

Yield of Global Canal System : Gatun deepened, Madden, Indio and Toabre Reservoirs
Increase rate from Current Yield

Toabre NWL/MOL	Toabre – Indio Tunnel Diameter (m)					
	3	4	4.5	5	5.5	6
90 - 50	1.740	1.900	1.925	1.935	1.935	1.935
95 - 50	1.760	1.935	1.975	1.980	1.980	1.980
95 - 55	1.760	1.938	1.970	1.970	1.974	1.977
100 - 50	1.780	1.975	2.025	2.032	2.036	2.036
100 - 55	1.780	1.975	2.020	2.025	2.030	2.025
100 - 60	1.780	1.975	2.015	2.015	2.015	2.015

Yield of Global Canal System : Gatun deepened, Madden, Indio and Toabre Reservoirs
expressed in equivalent lockages / day

Toabre NWL/MOL	Toabre – Indio Tunnel Diameter (m)					
	3	4	4.5	5	5.5	6
90 - 50	67.30	73.49	74.46	74.85	74.85	74.85
95 - 50	68.08	74.85	76.39	76.59	76.59	76.59
95 - 55	68.08	74.96	76.20	76.20	76.35	76.47
100 - 50	68.85	76.39	78.33	78.60	78.75	78.75
100 - 55	68.85	76.39	78.13	78.33	78.52	78.33
100 - 60	68.85	76.39	77.94	77.94	77.94	77.94

Yield attributed to Toabre Project (in conjunction with other elements of the system)
expressed hm3 / day

Toabre NWL/MOL	Toabre – Indio Tunnel Diameter (m)					
	3	4	4.5	5	5.5	6
90 – 50	521	991	1065	1094	1094	1094
95 – 50	580	1094	1211	1226	1226	1226
95 - 55	580	1103	1197	1197	1208	1217
100 - 50	638	1211	1359	1379	1391	1391
100 - 55	638	1211	1344	1359	1373	1359
100 - 60	638	1211	1329	1329	1329	1329

PART VIII – FIGURES

(this part has 22 pages)

PRELIMINARY PHASE : SIMULATIONS WITH TOABRE RESERVOIR ALONE

BASIC DATA

FIGURE 1 Rio Toabre Inflows
FIGURE 2 Rio Toabre Reservoir – Elevation / Surface / Capacity Curves

YIELD POTENTIAL

FIGURE 3 Annual Yield (hm^3) vs. Reservoir NWL
FIGURE 4 Annual Yield (hm^3) vs. Reservoir Capacity
FIGURE 5 Yield (m^3/s) vs. Reservoir NWL
FIGURE 6 Yield (m^3/s) vs. Reservoir Capacity
FIGURE 7 Adimensional Yield Curves

Alternative NWL 95 / MOL 50 – Scenario D1 – Qr 99%
FIGURE 8 Reservoir Level
FIGURE 9 Global Flow Release
FIGURE 10 Rating Curves of Flows

Alternative NWL 95 / MOL 50 – Scenario D2 – Qr 99%
FIGURE 11 Reservoir Level
FIGURE 12 Global Flow Release
FIGURE 13 Rating Curves of Flows

ENERGY POTENTIAL

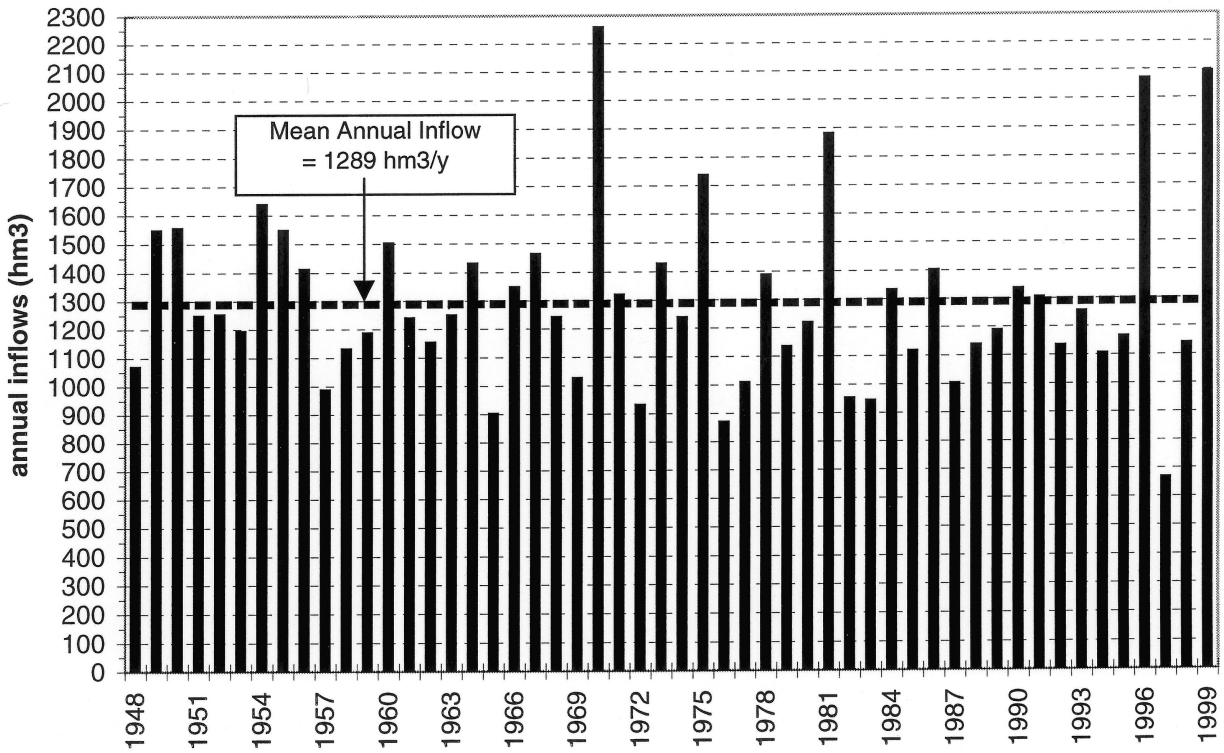
FIGURE 14 Energy Production vs. Reservoir NWL
FIGURE 15 Energy Production vs. Reservoir Capacity

Alternative NWL 95 / MOL 75.25 – Ef 95%
FIGURE 16 Reservoir Level
FIGURE 17 Monthly Energy
FIGURE 18 Annual Total Energy
FIGURE 19 Global Flow Release
FIGURE 20 Rating Curves of Flows

CONCLUSION

FIGURE 21 Synthetic Potential of Rio Toabre Reservoir

FIGURE 1 - RIO TOABRE INFLOWS
ANNUAL INFLOWS



MONTHLY INFLOWS (m3/s)

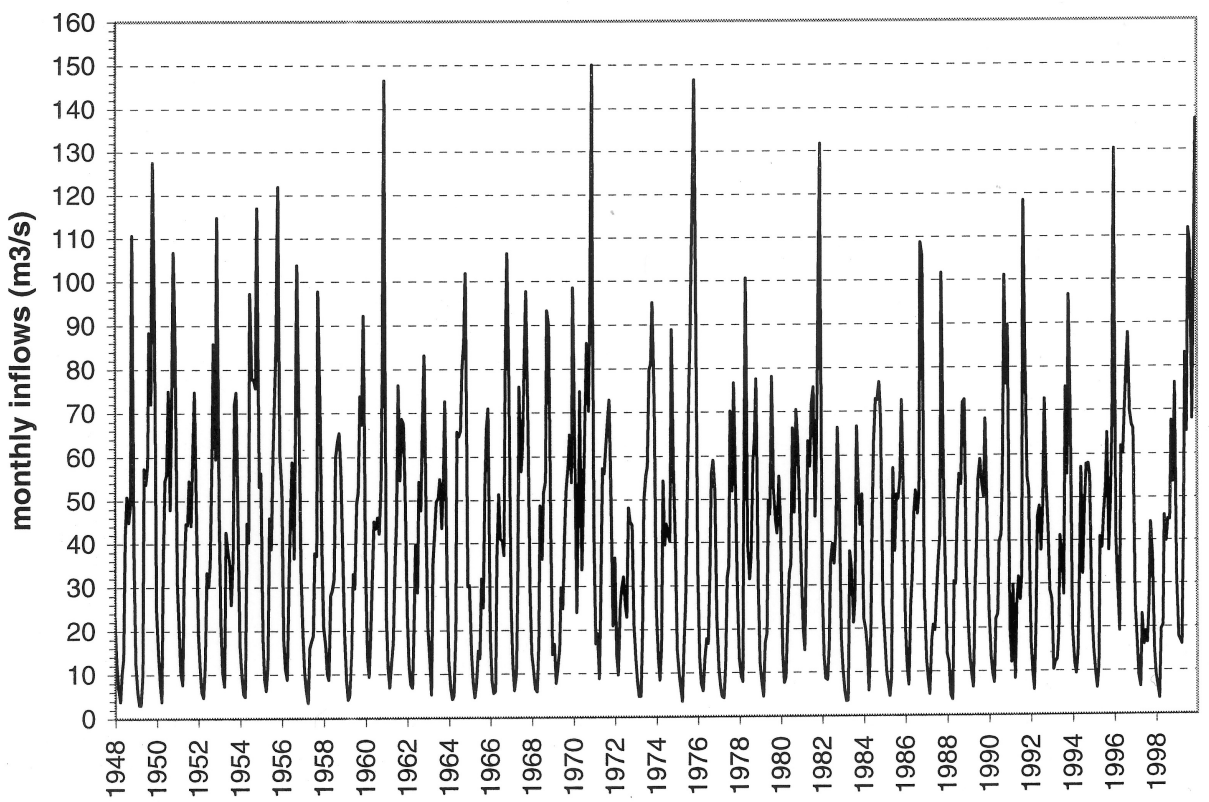


FIGURE 2 - RIO TOABRE RESERVOIR
ELEVATION / SURFACE / CAPACITY CURVES

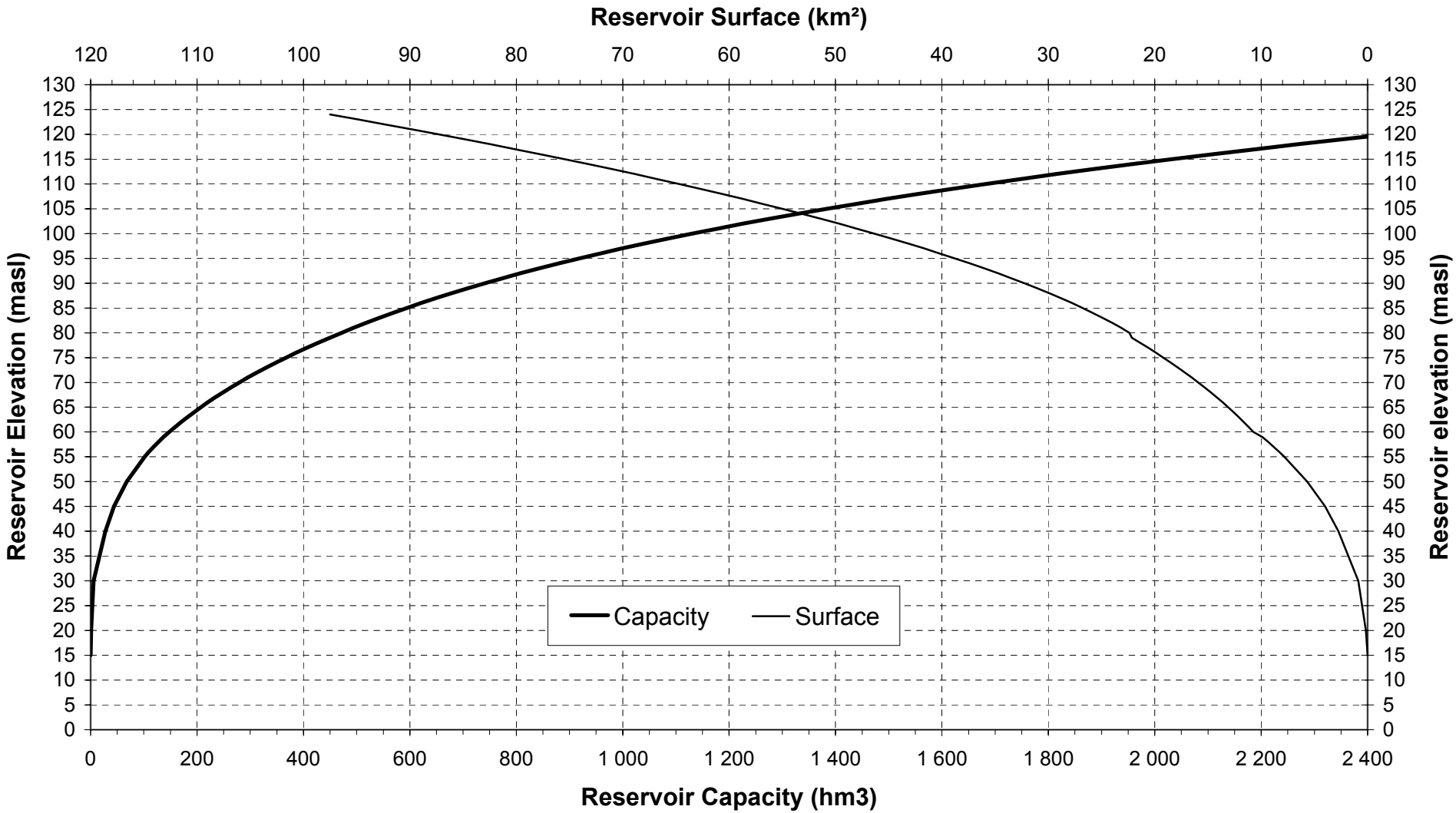


FIGURE 3 - ANNUAL YIELD vs. RESERVOIR NWL
(MOL = El. 50)

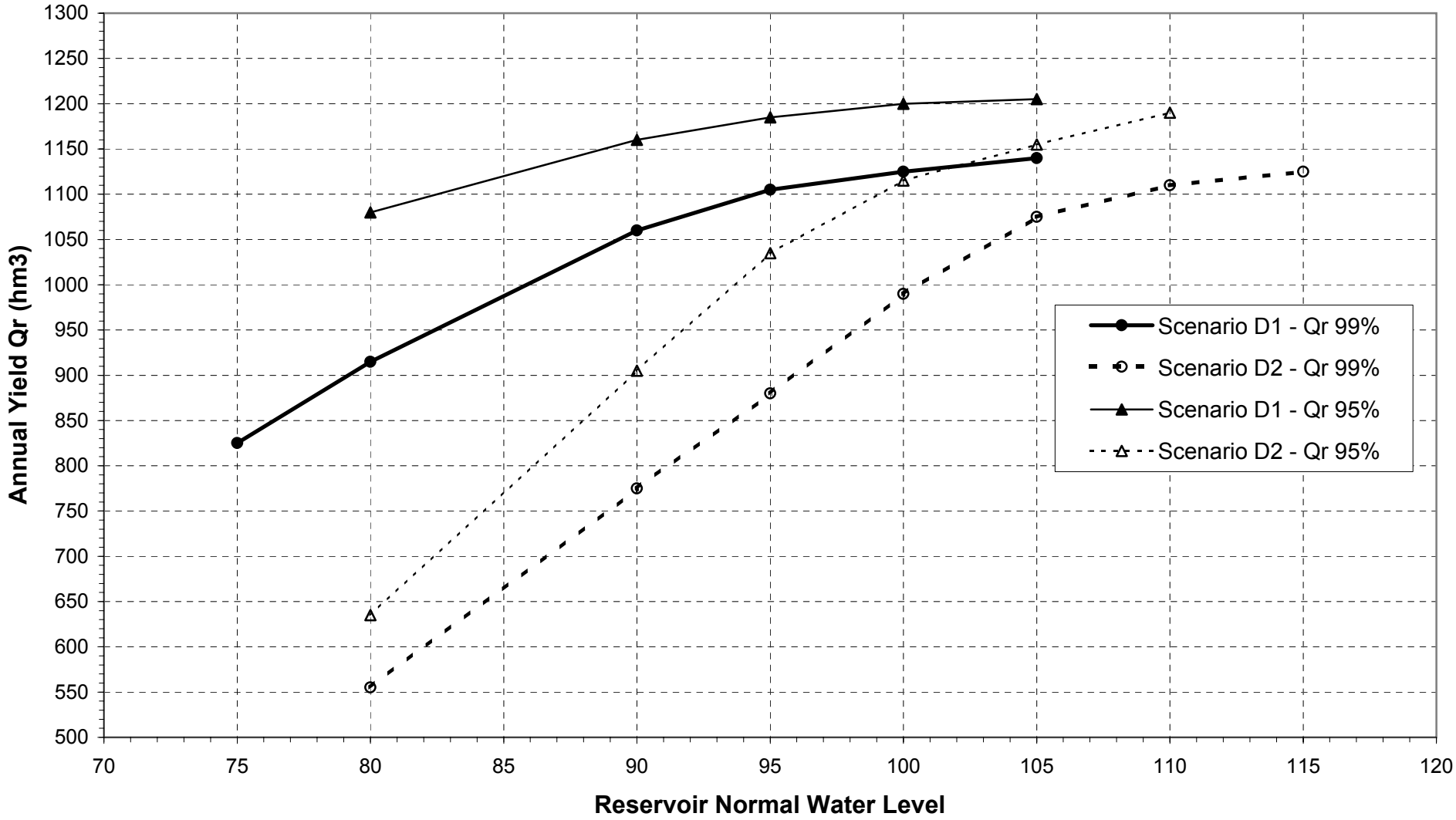


FIGURE 4 - ANNUAL YIELD vs. RESERVOIR CAPACITY
(MOL = El. 50)

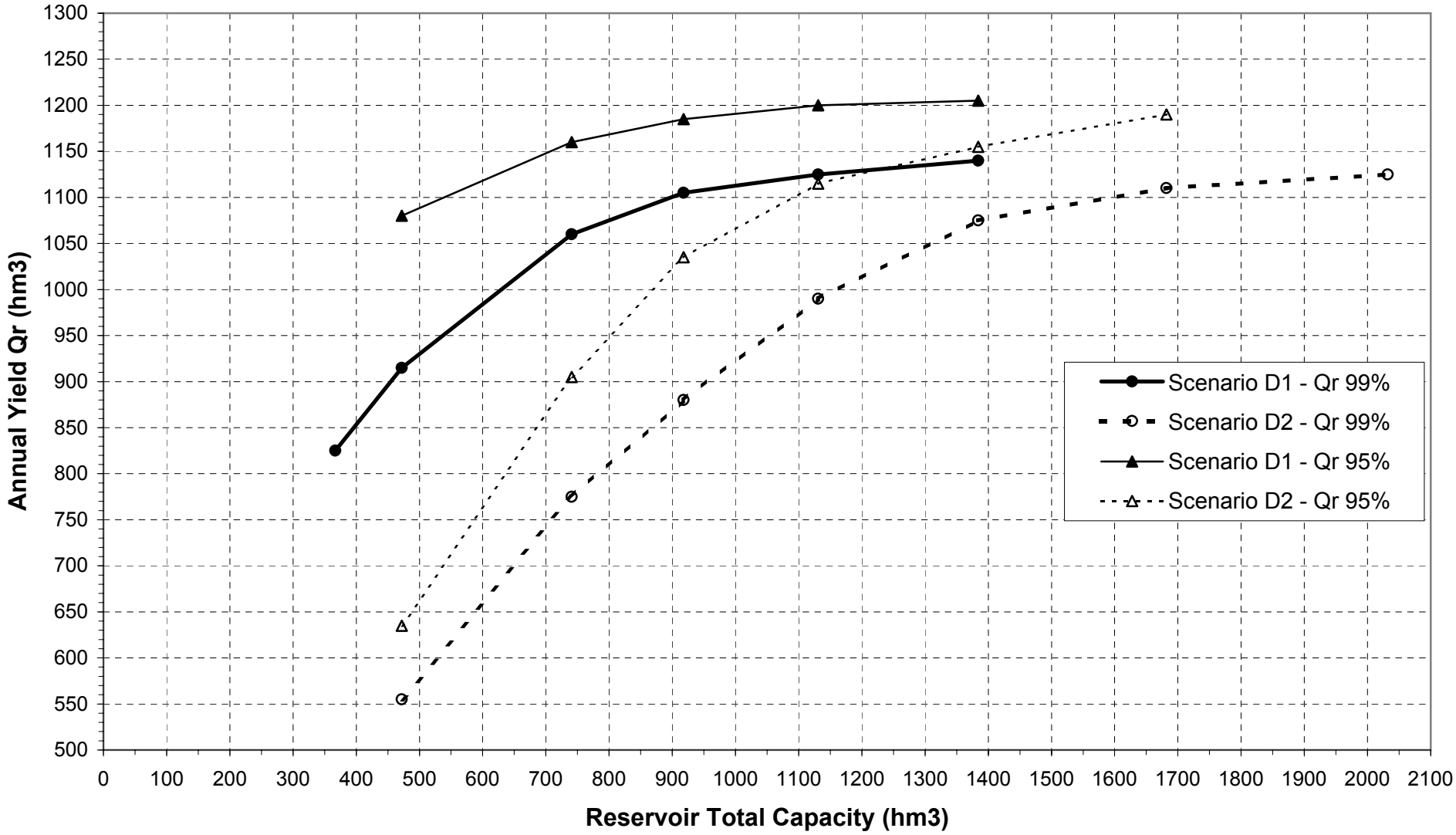


FIGURE 5 - YIELD (m3/s) vs. RESERVOIR NWL
(MOL = El. 50)

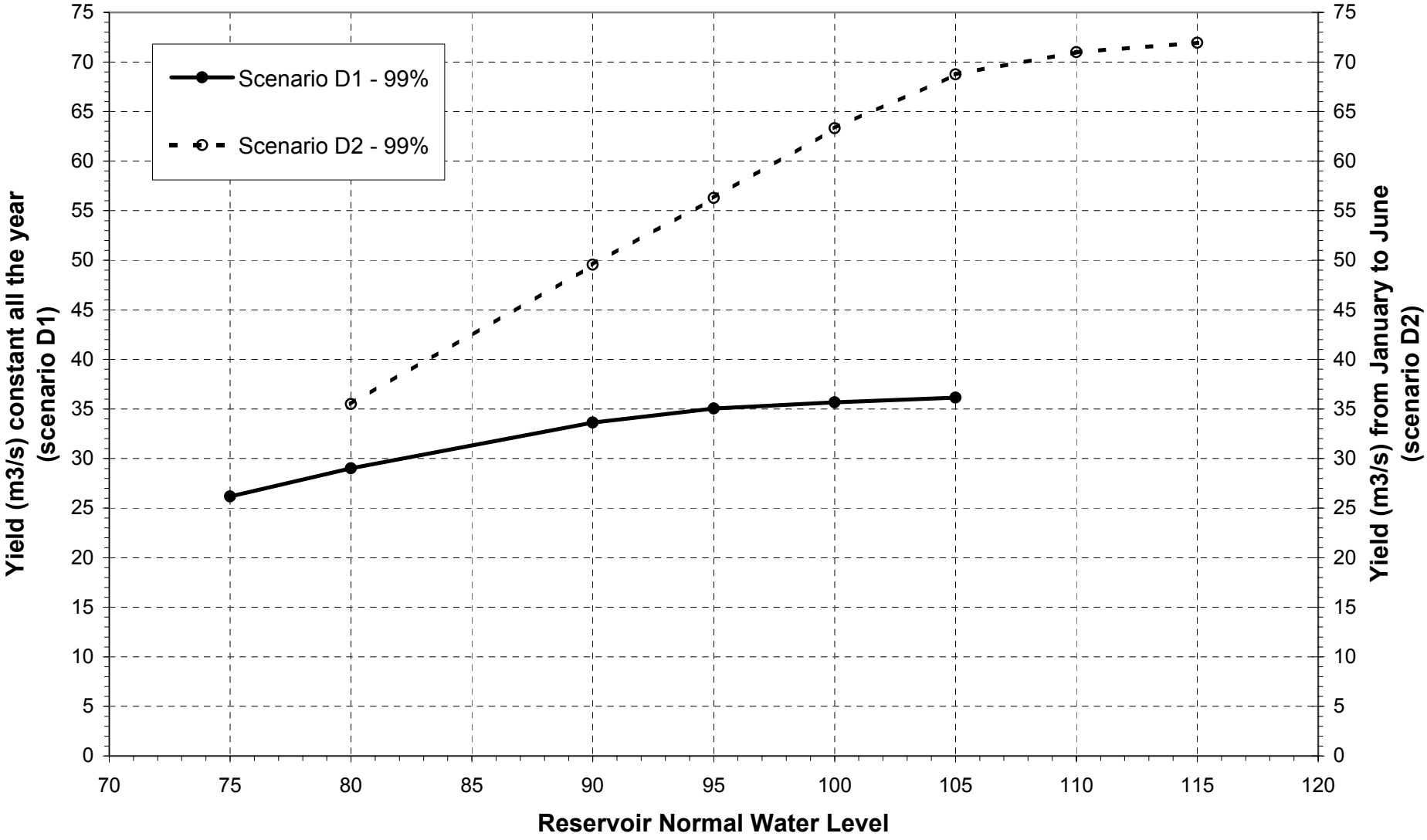


FIGURE 6 - YIELD (m3/s) vs. RESERVOIR CAPACITY
(MOL = El. 50)

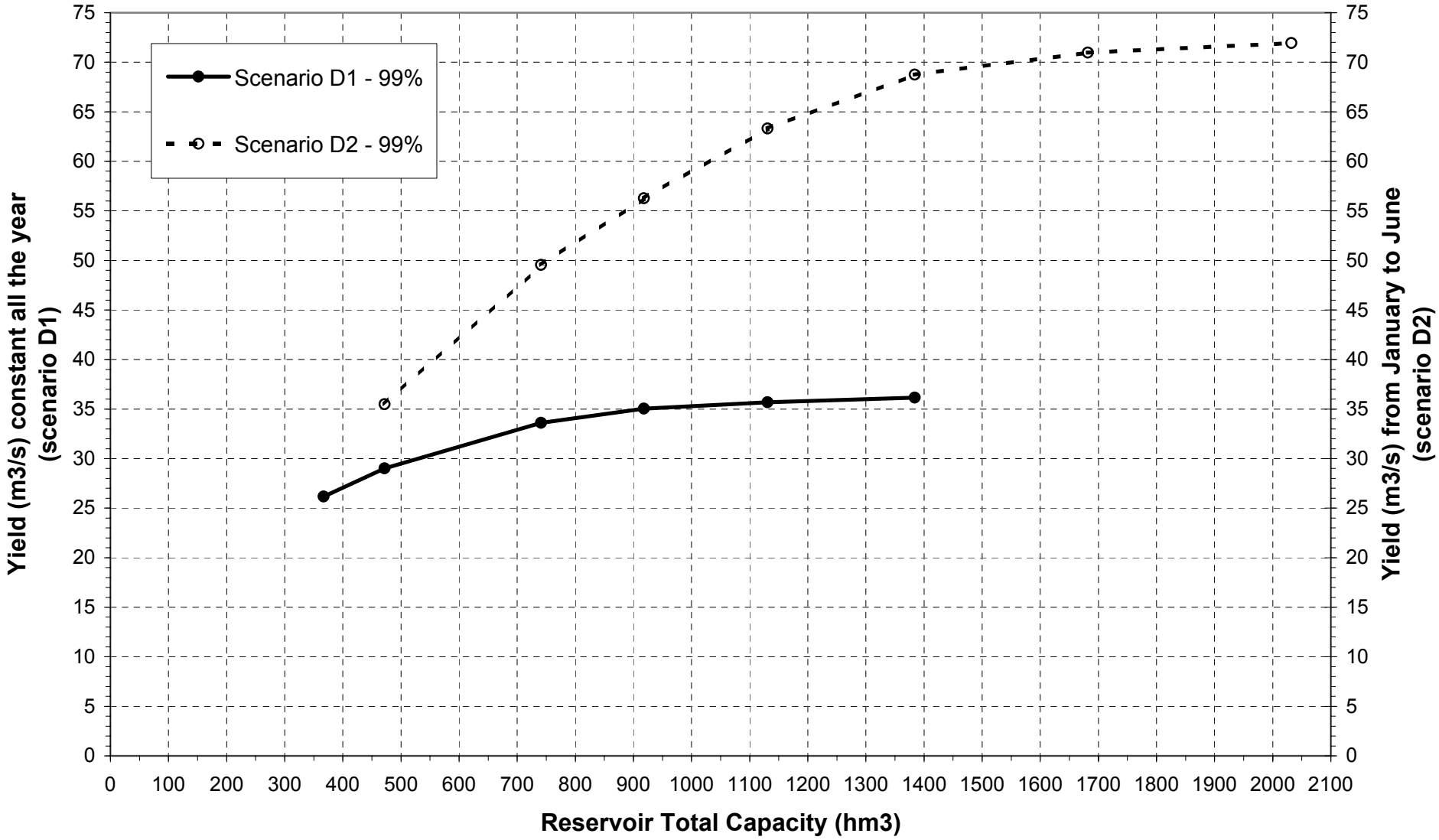


FIGURE 7 - ADIMENSIONAL YIELD CURVES
(all combinaisons NWL / MOL)

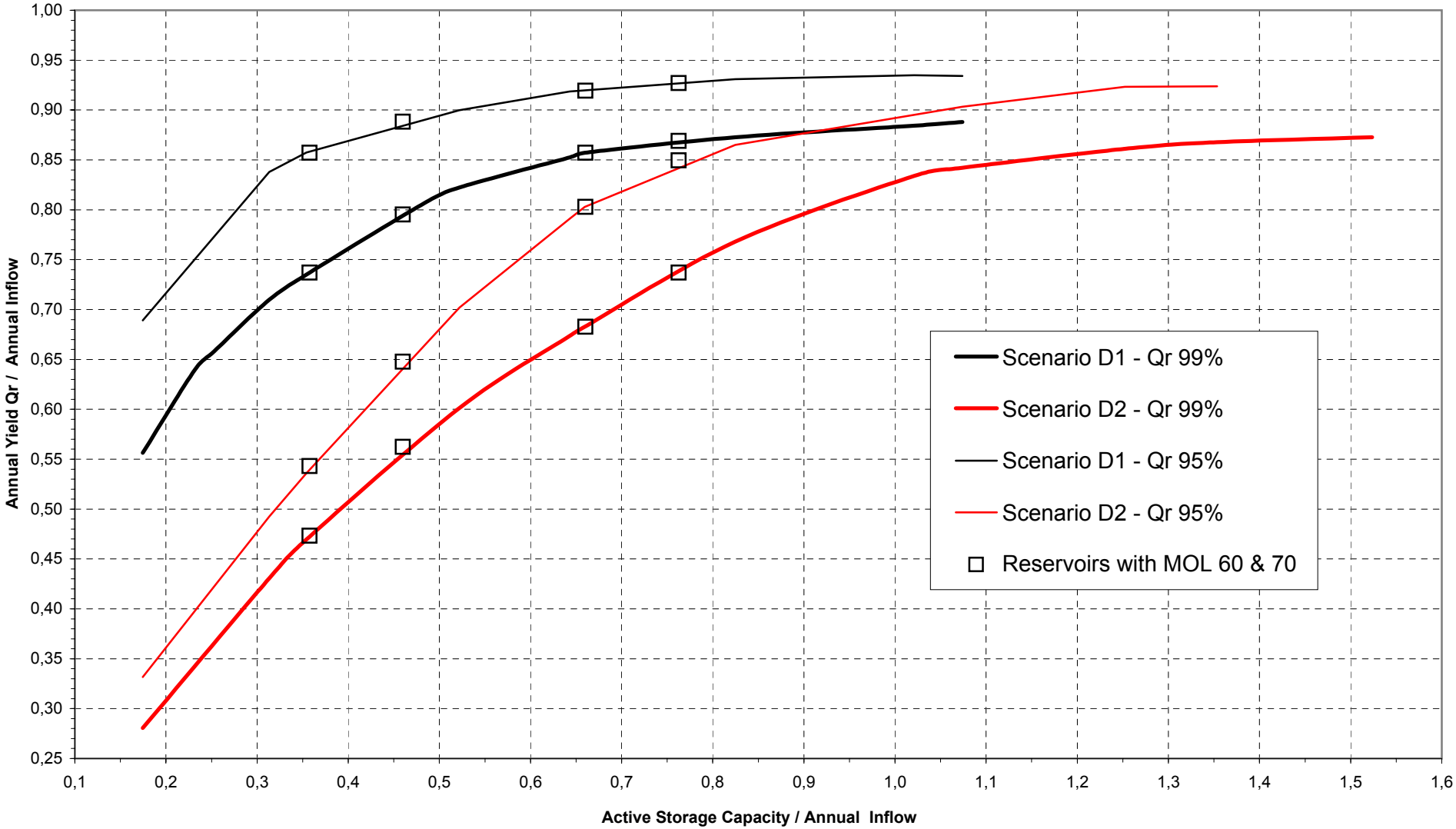
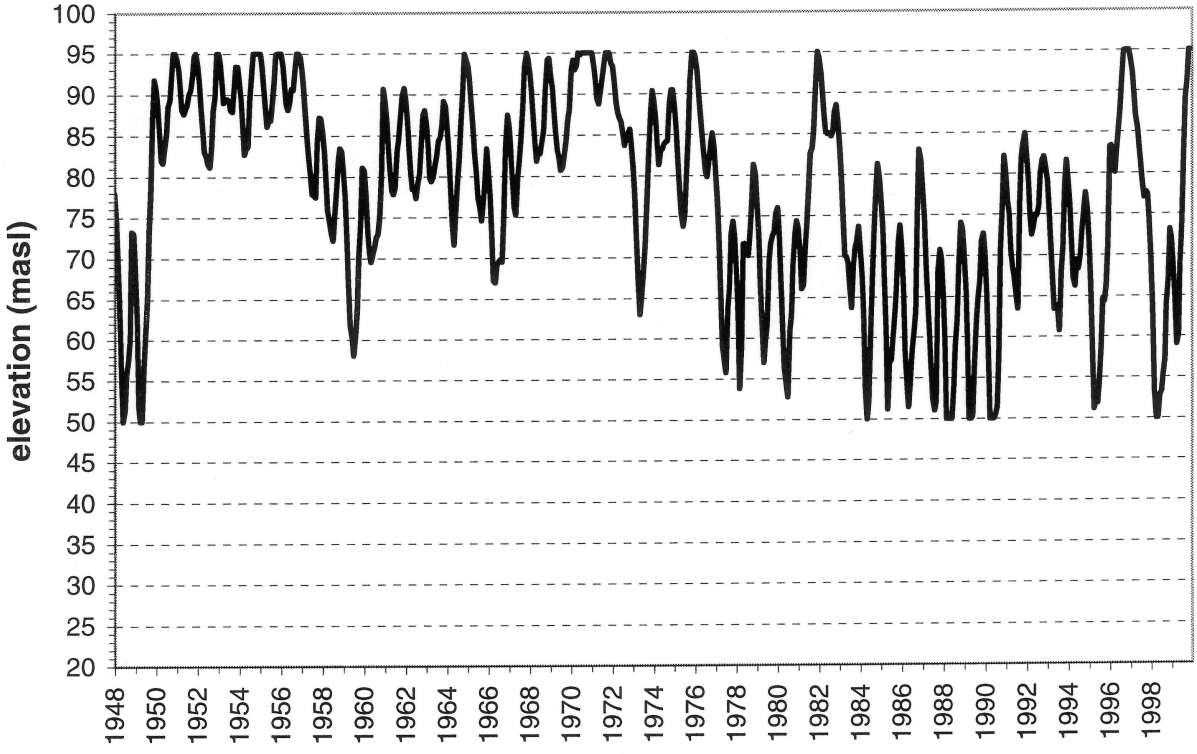


FIGURE 8 - ALTERNATIVE NWL 95 / MOL 50
SCENARIO D1 - Qr 99% - RESERVOIR LEVEL



RATING CURVE OF RESERVOIR LEVEL

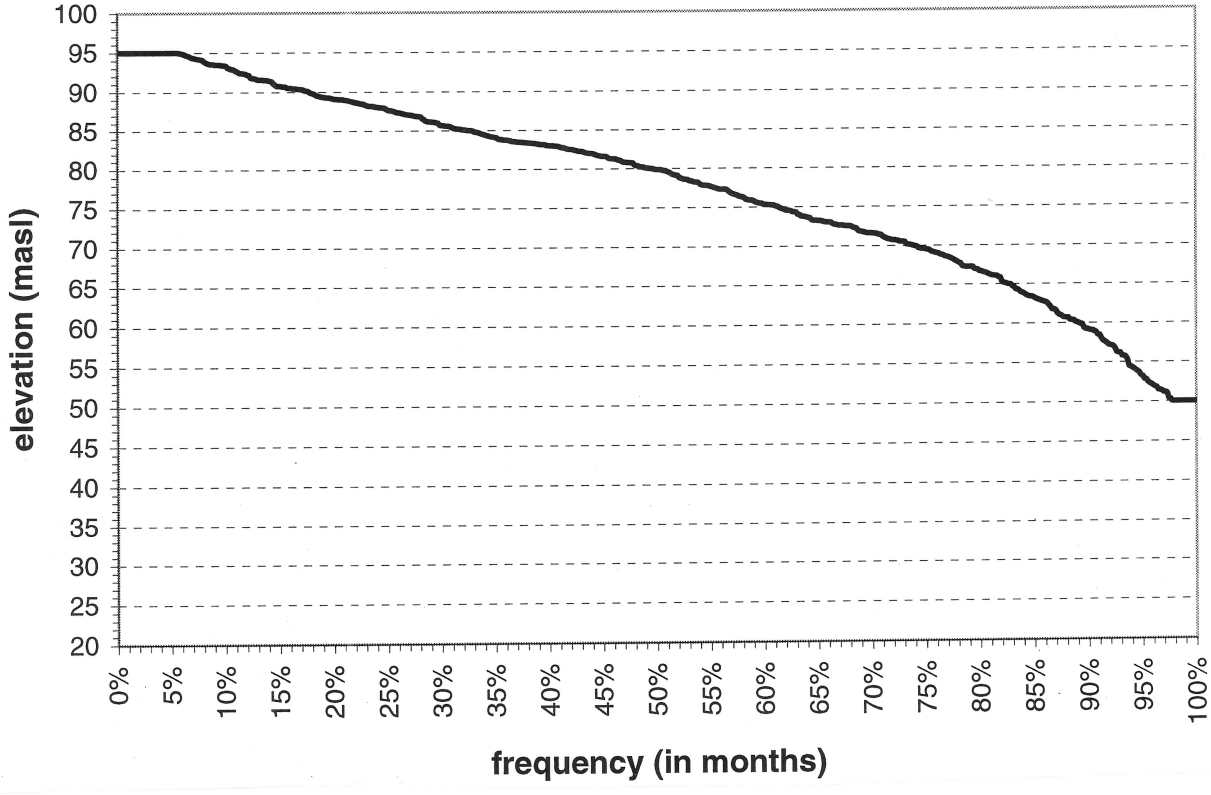


FIGURE 9 - ALTERNATIVE NWL 95 / MOL 50
SCENARIO D1 - Qr 99% - GLOBAL FLOW RELEASE

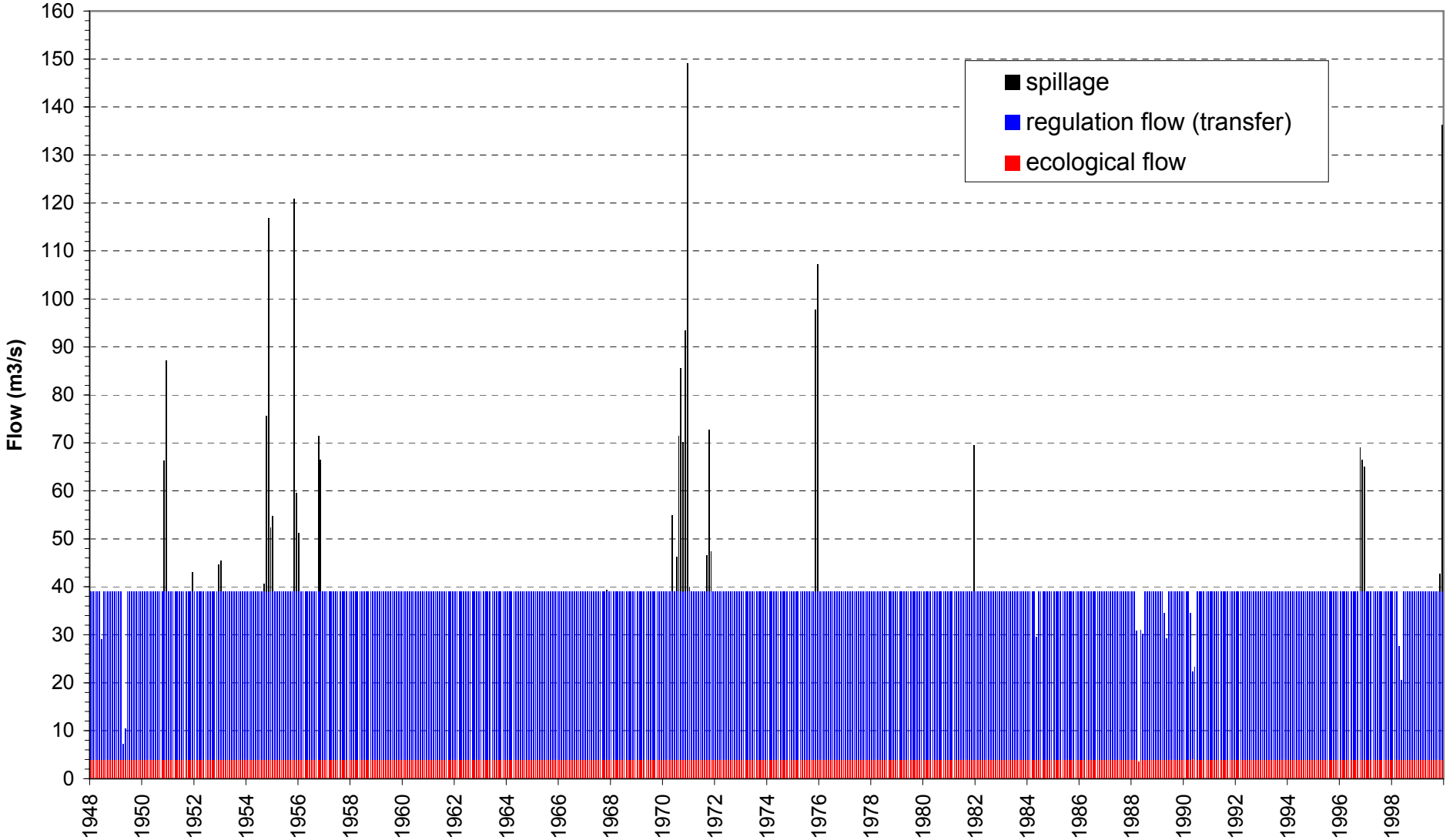


FIGURE 10 - ALTERNATIVE NWL 95 / MOL 50
SCENARIO D1 - Qr 99% - RATING CURVES OF FLOWS

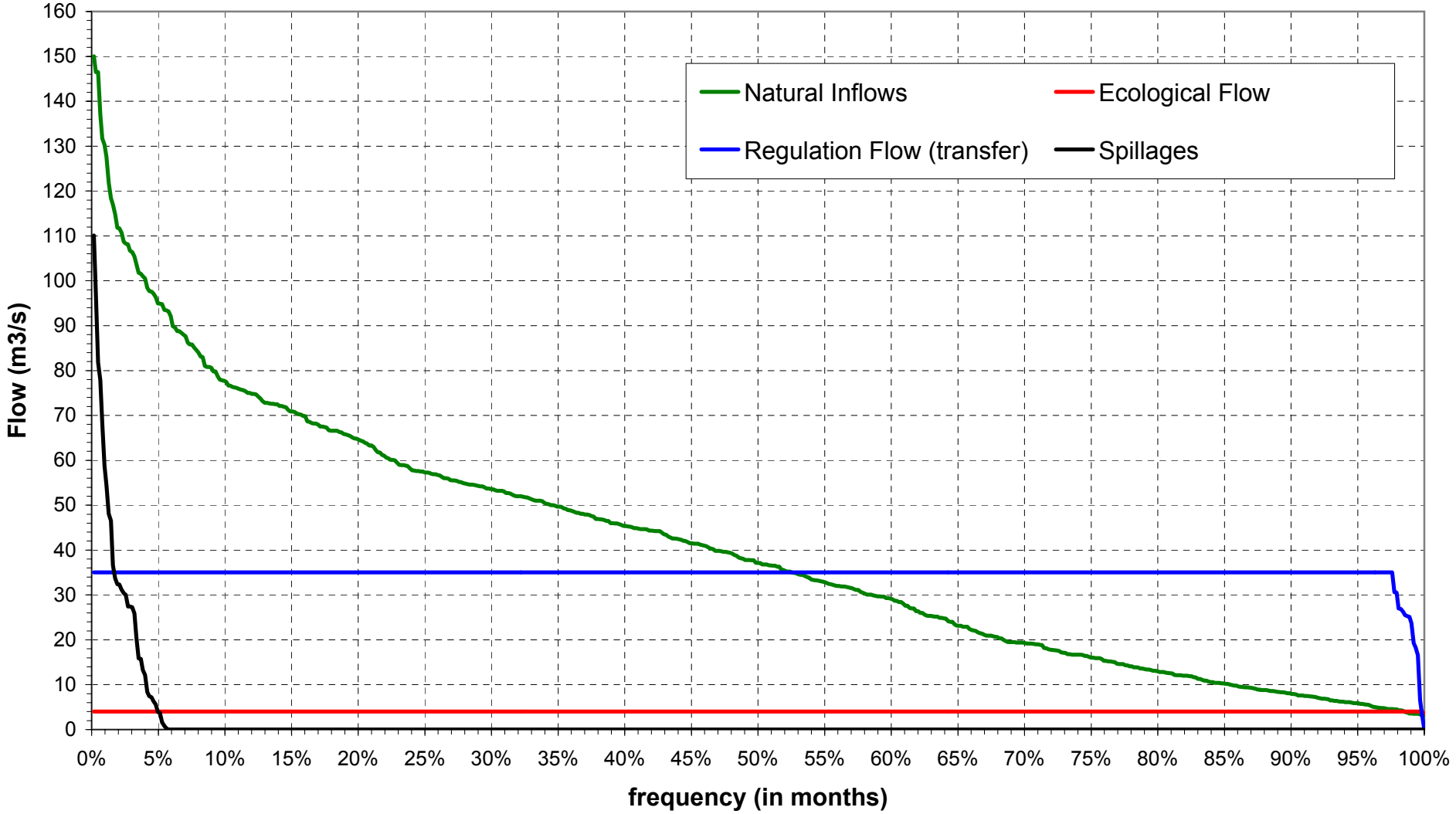
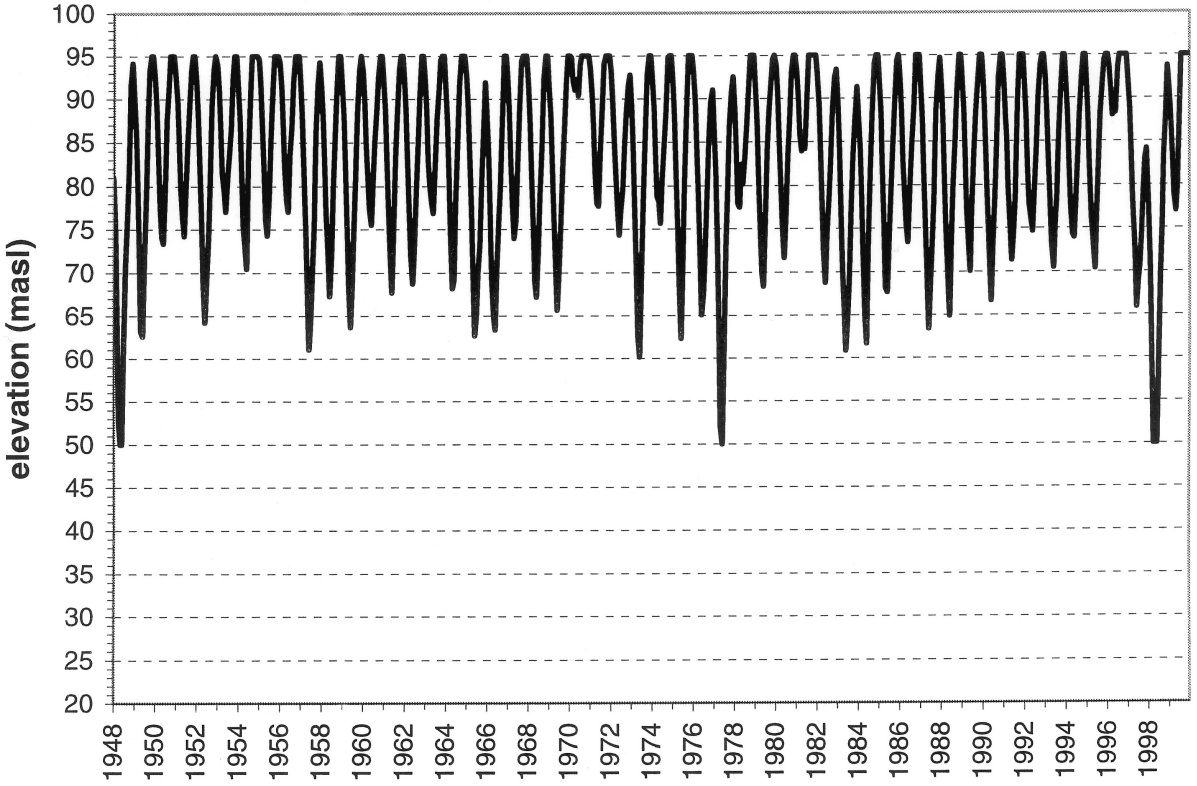


FIGURE 11 - ALTERNATIVE NWL 95 / MOL 50
SCENARIO D2 - Qr 99% - RESERVOIR LEVEL



RATING CURVE OF RESERVOIR LEVEL

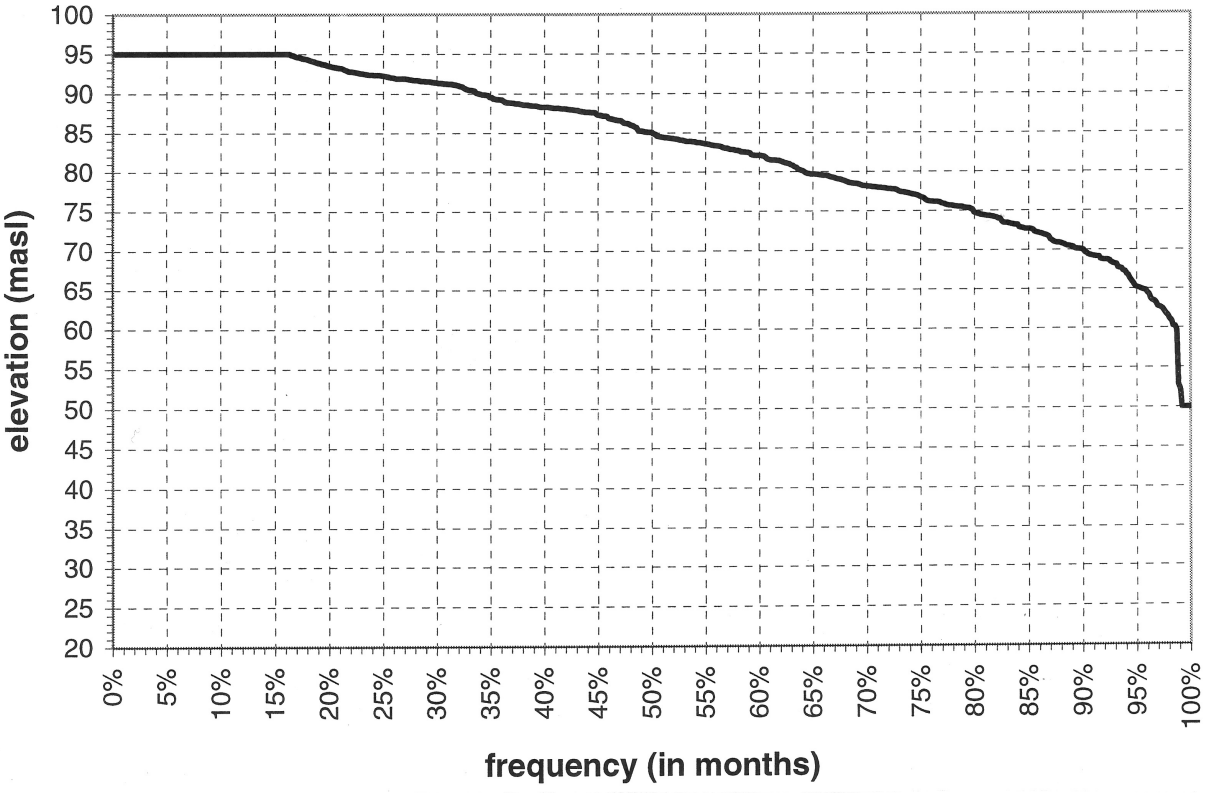


FIGURE 12 - ALTERNATIVE NWL 95 / MOL 50
SCENARIO D2 - Qr 99% - GLOBAL FLOW RELEASE

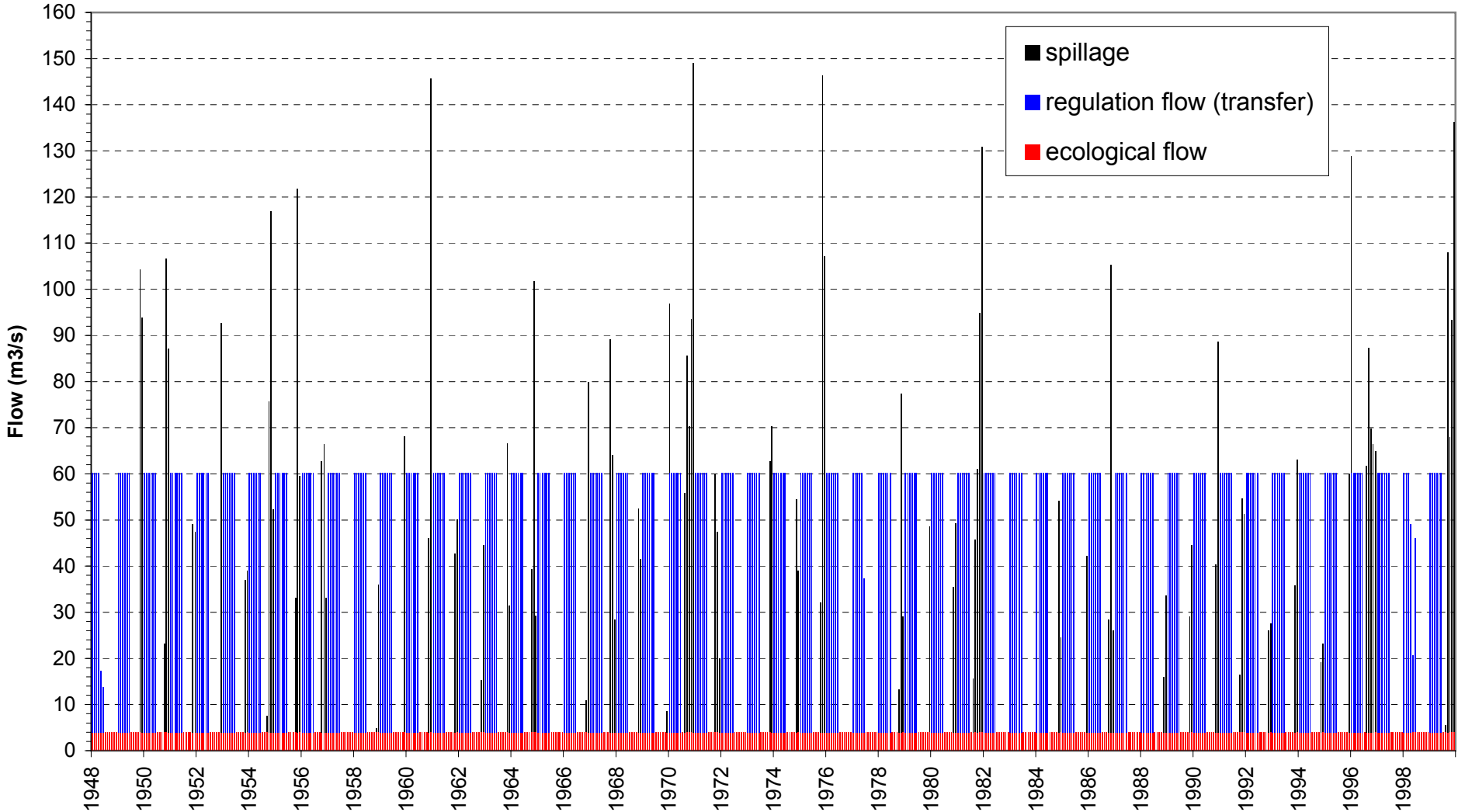


FIGURE 13 - ALTERNATIVE NWL 95 / MOL 50
SCENARIO D2 - Qr 99% - RATING CURVES OF FLOWS

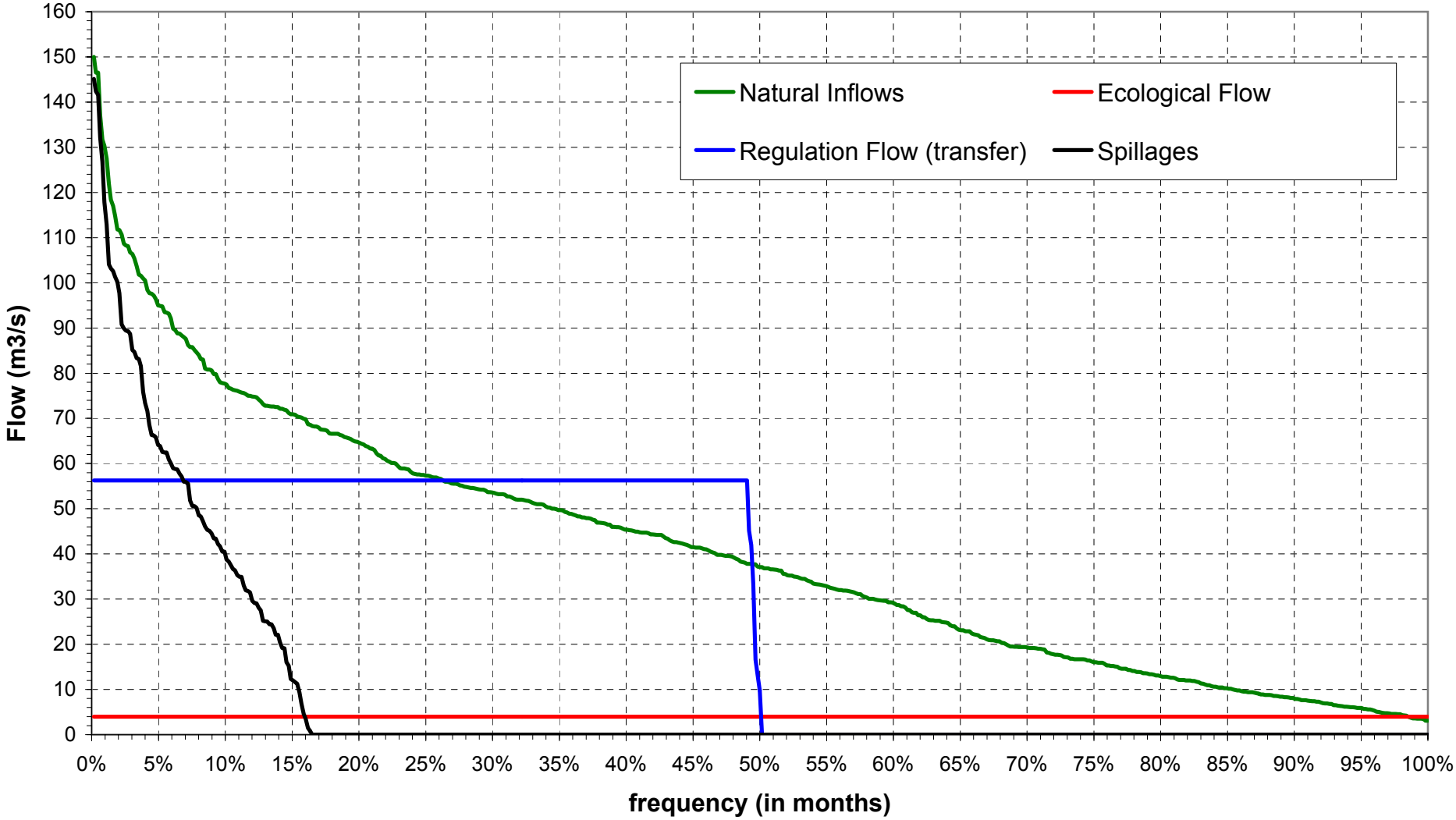


FIGURE 14 - ENERGY PRODUCTION vs. RESERVOIR NWL

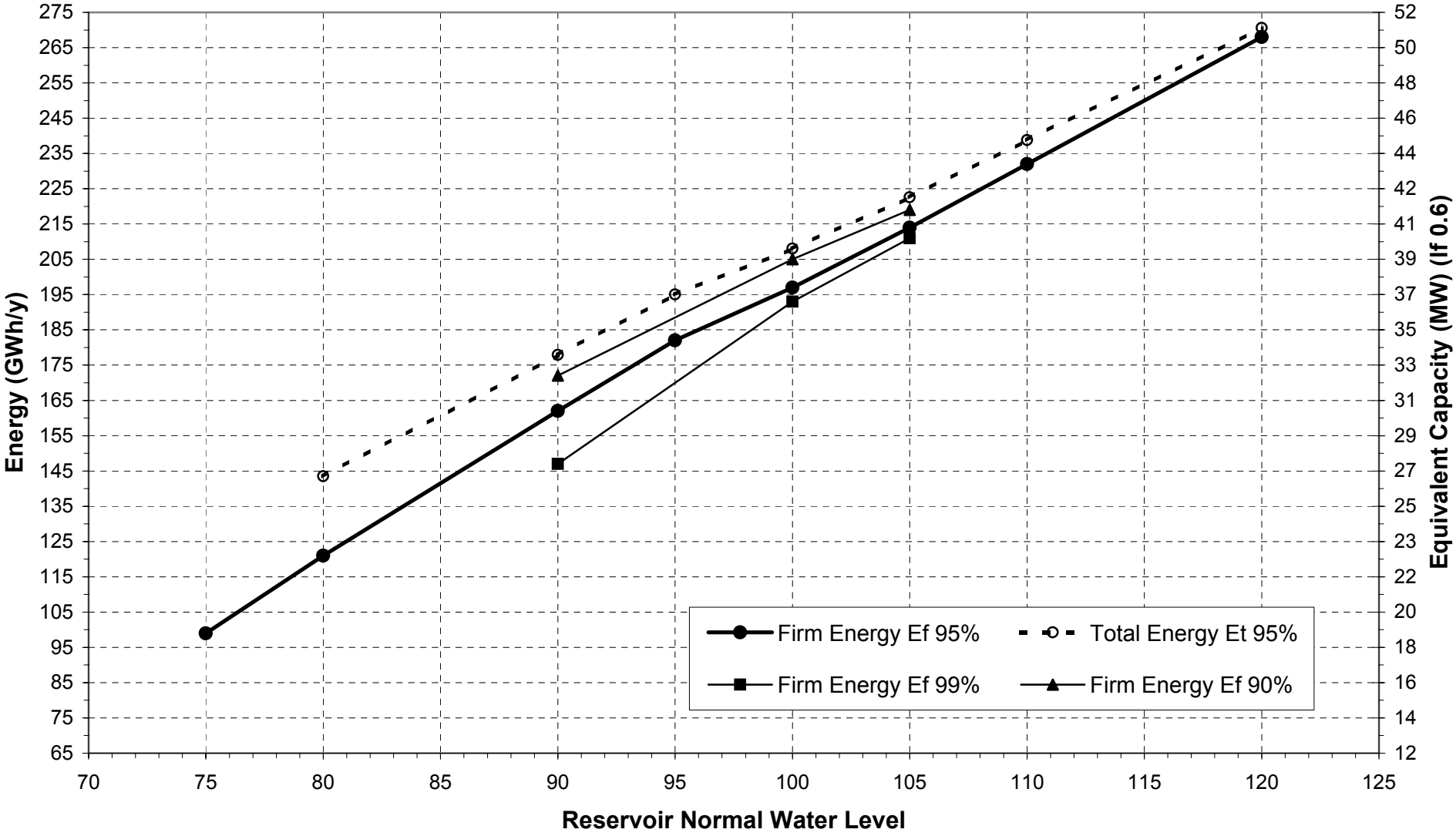


FIGURE 15 - ENERGY PRODUCTION vs. RESERVOIR CAPACITY

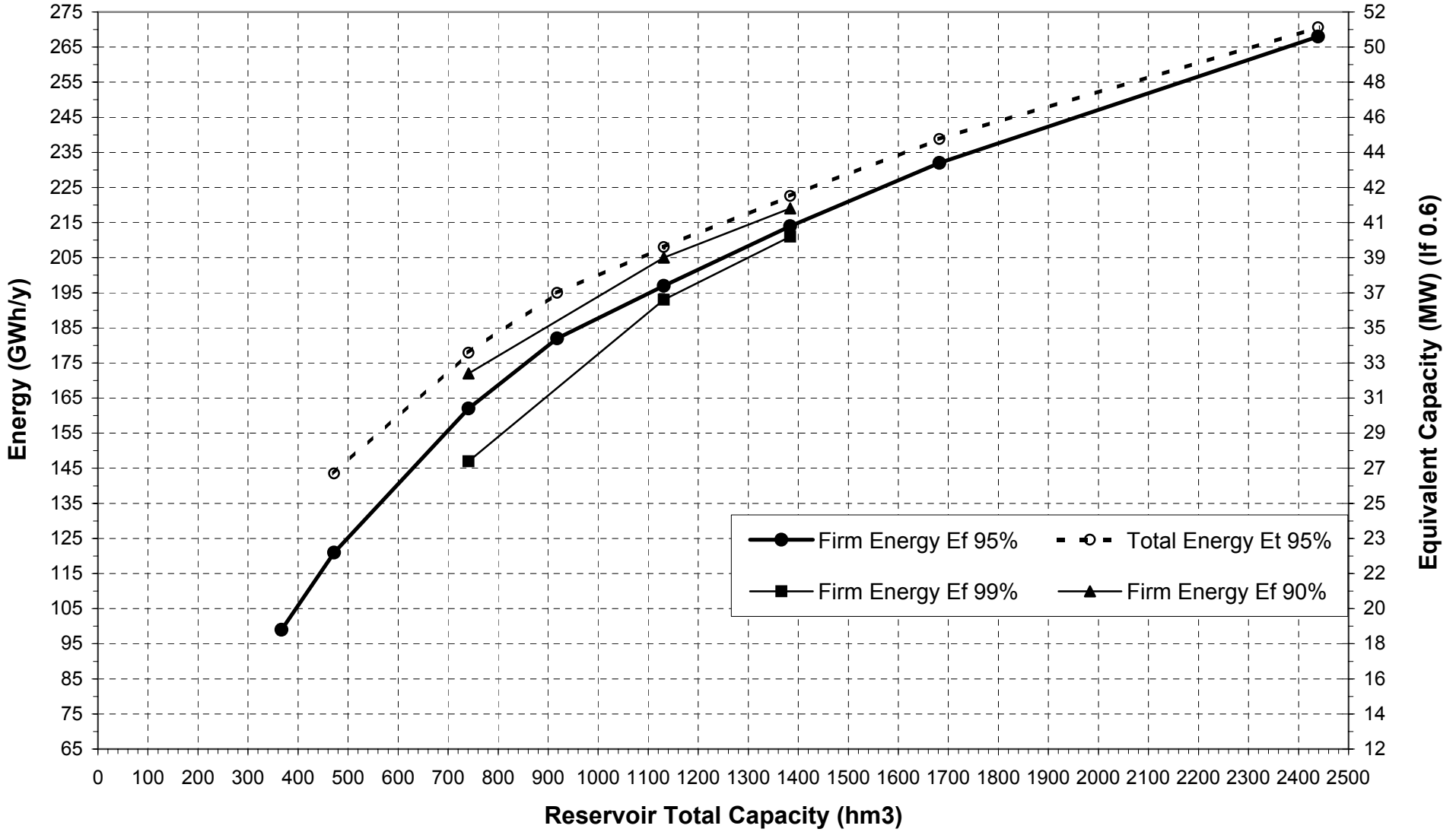
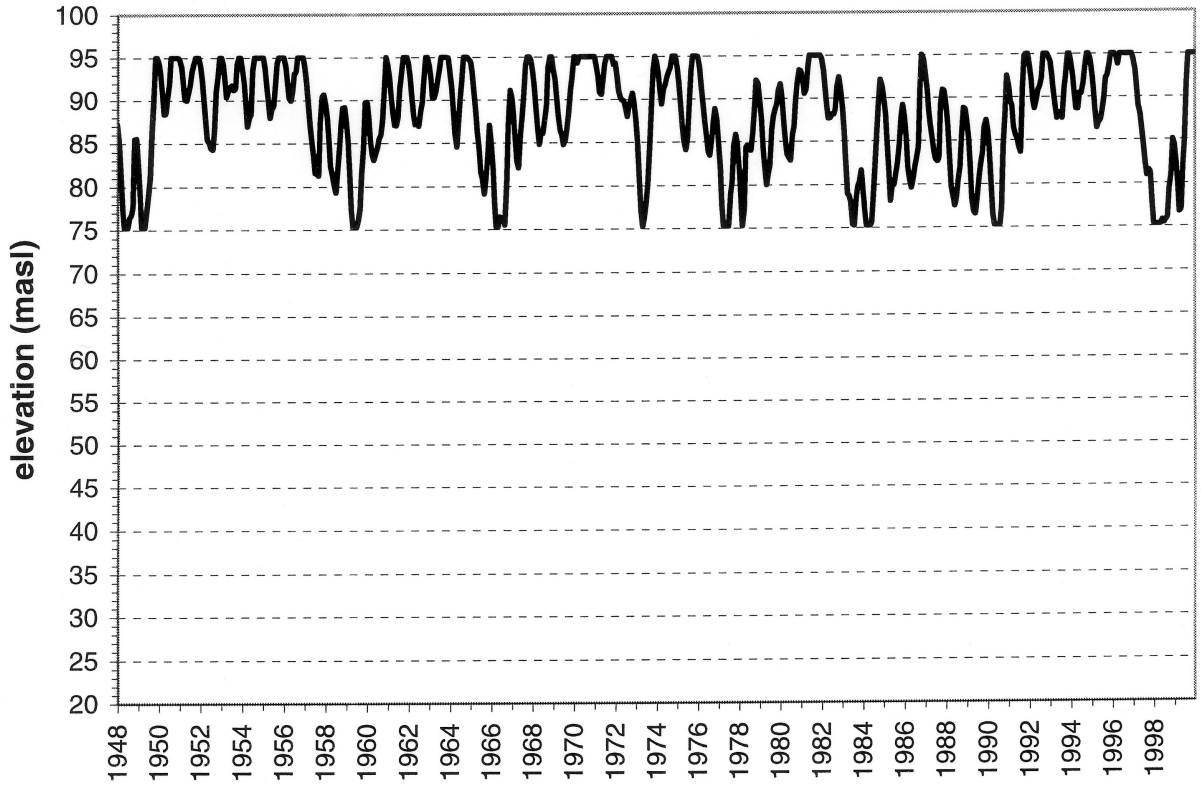


FIGURE 16 - ALTERNATIVE NWL 95 / MOL 75.25
Ef 95% - RESERVOIR LEVEL



RATING CURVE OF RESERVOIR LEVEL

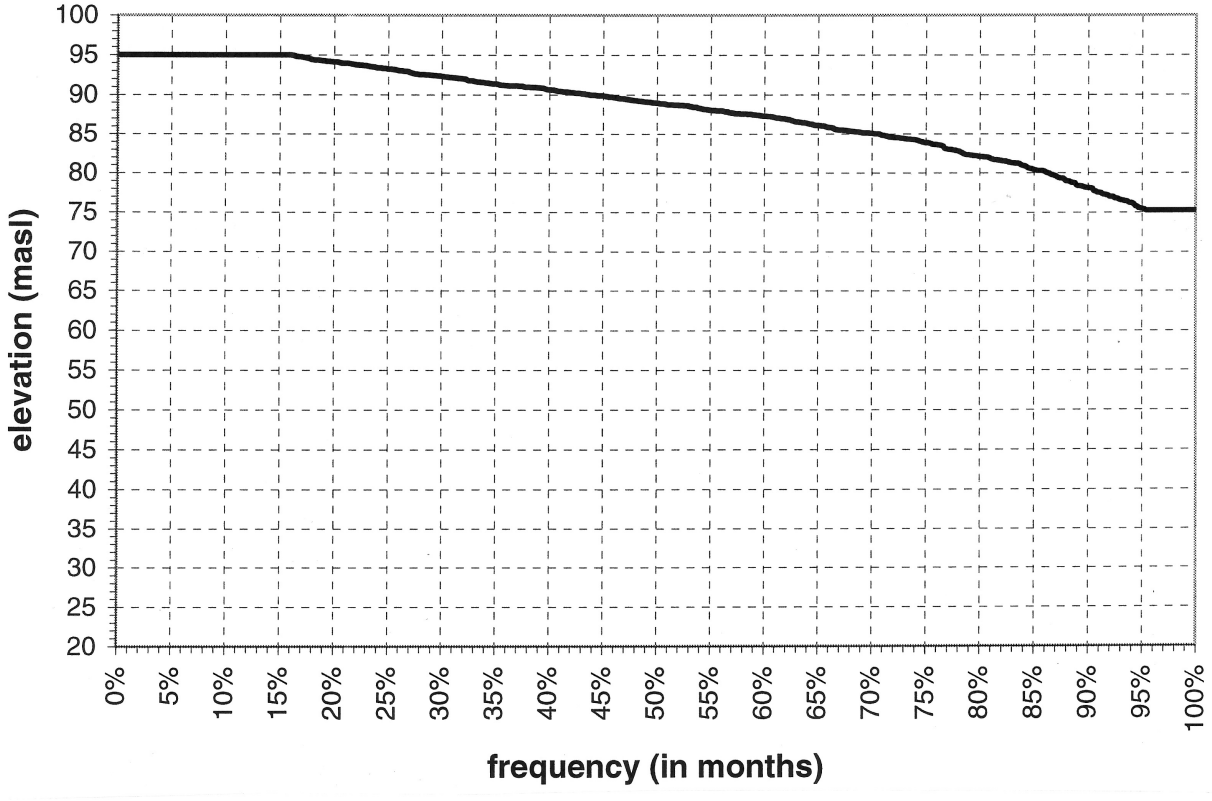


FIGURE 17 - ALTERNATIVE NWL 95 / MOL 75.25
Ef 95% - MONTHLY ENERGY

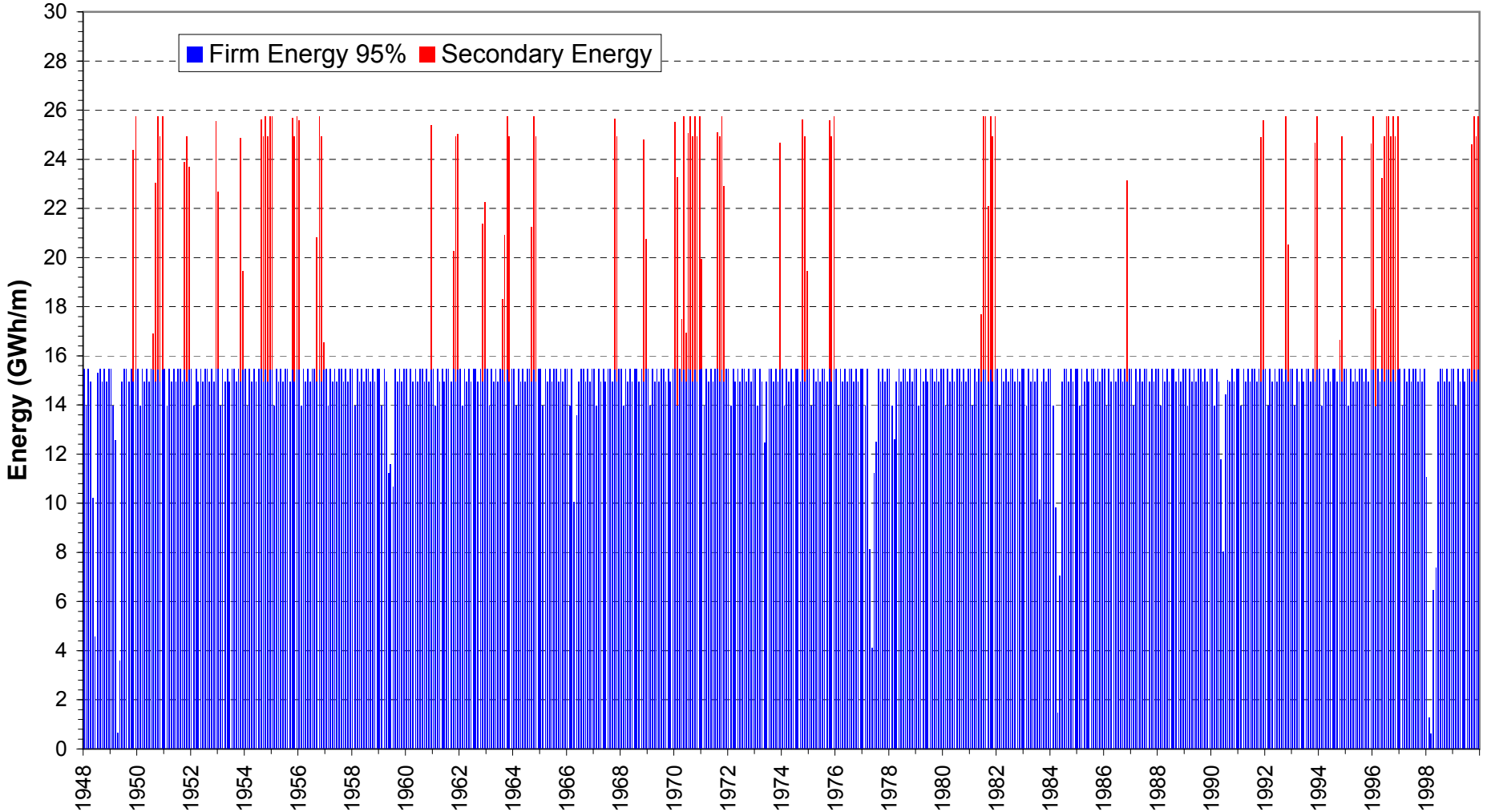


FIGURE 18 - ALTERNATIVE NWL 95 / MOL 75.25
Ef 95% - ANNUAL TOTAL ENERGY

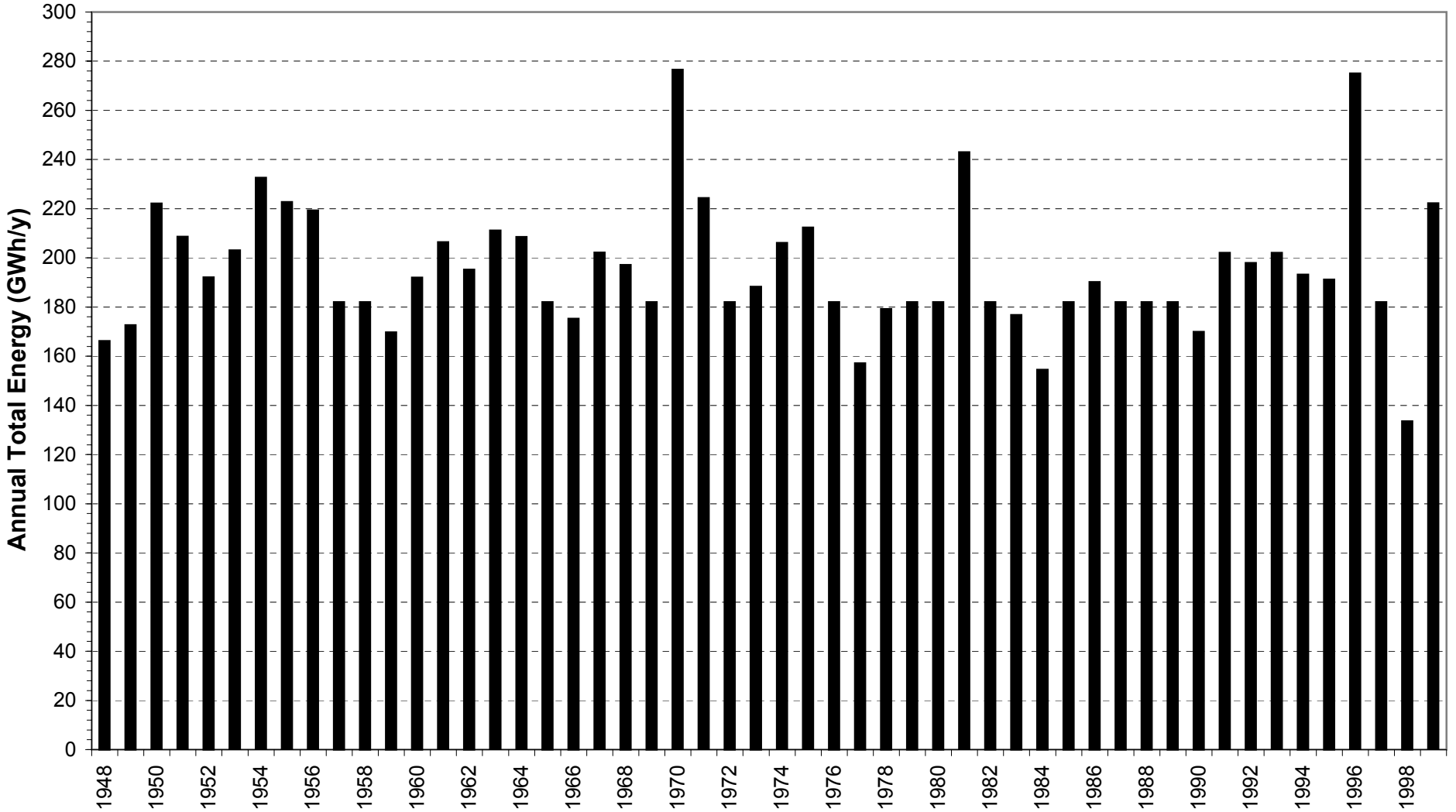


FIGURE 19 - ALTERNATIVE NWL 95 / MOL 75.25
Ef 95% - GLOBAL FLOW RELEASE

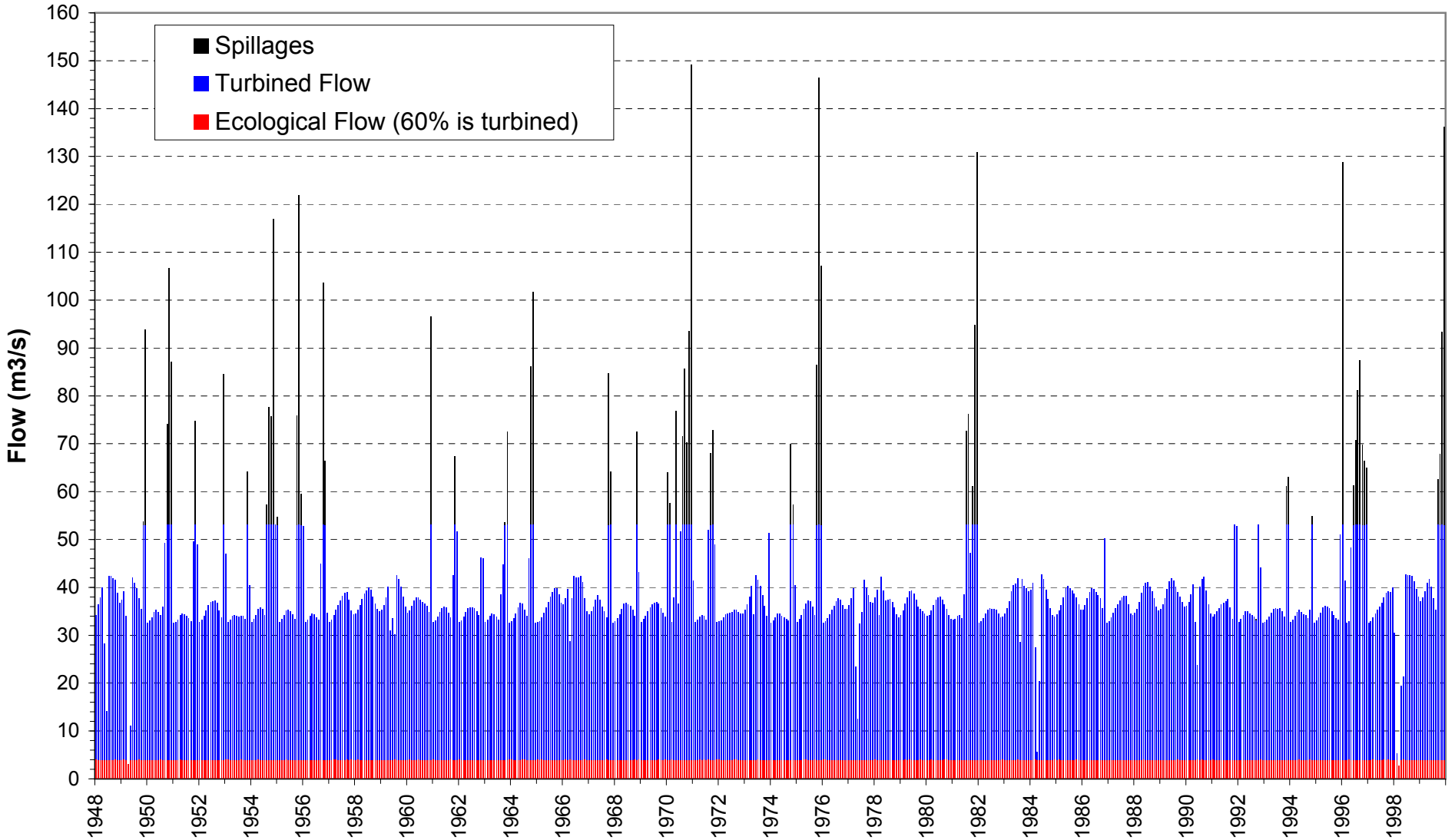


FIGURE 20 - ALTERNATIVE NWL95 / MOL 75.25
Ef 95% - RATING CURVES OF FLOWS

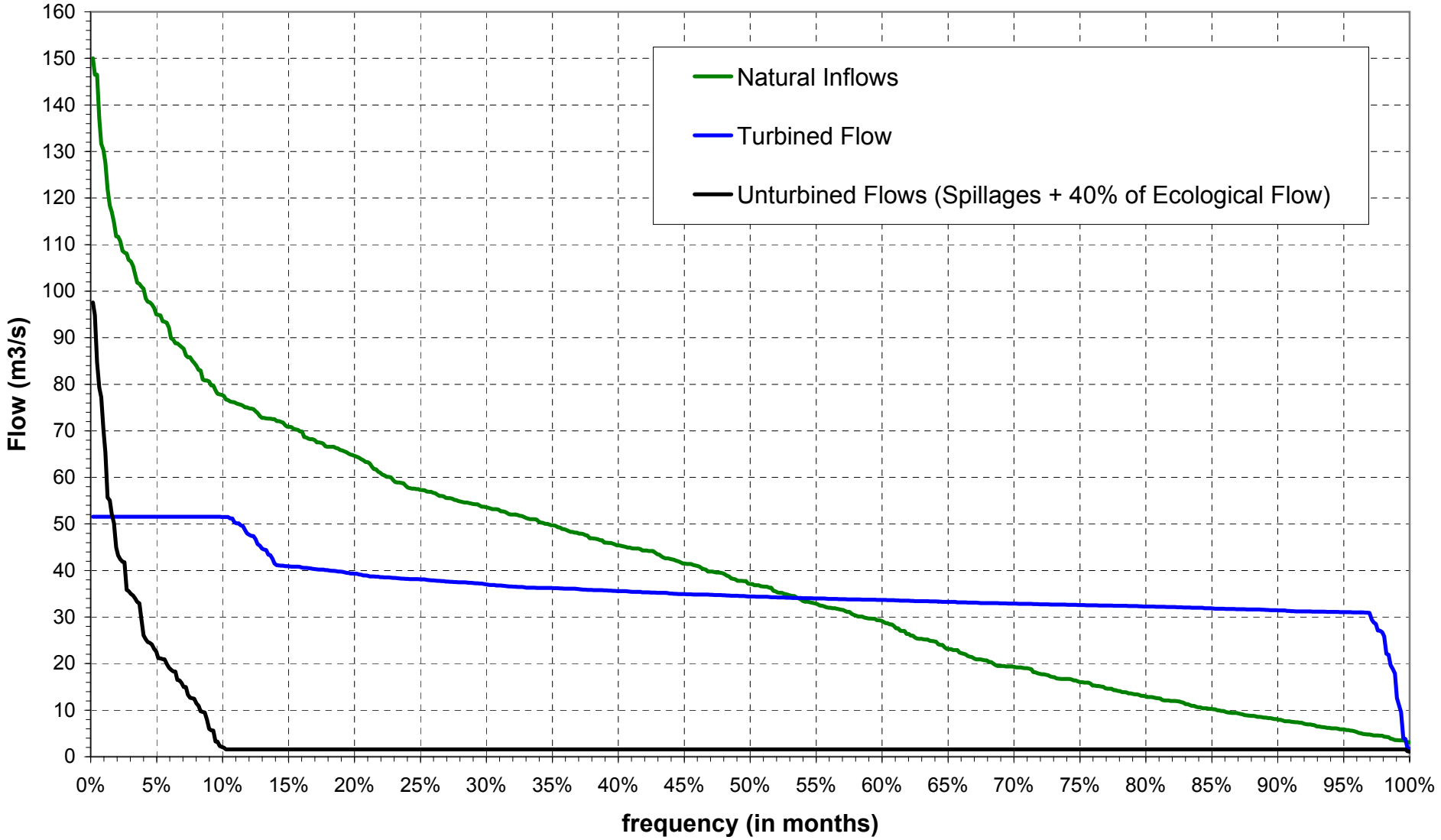
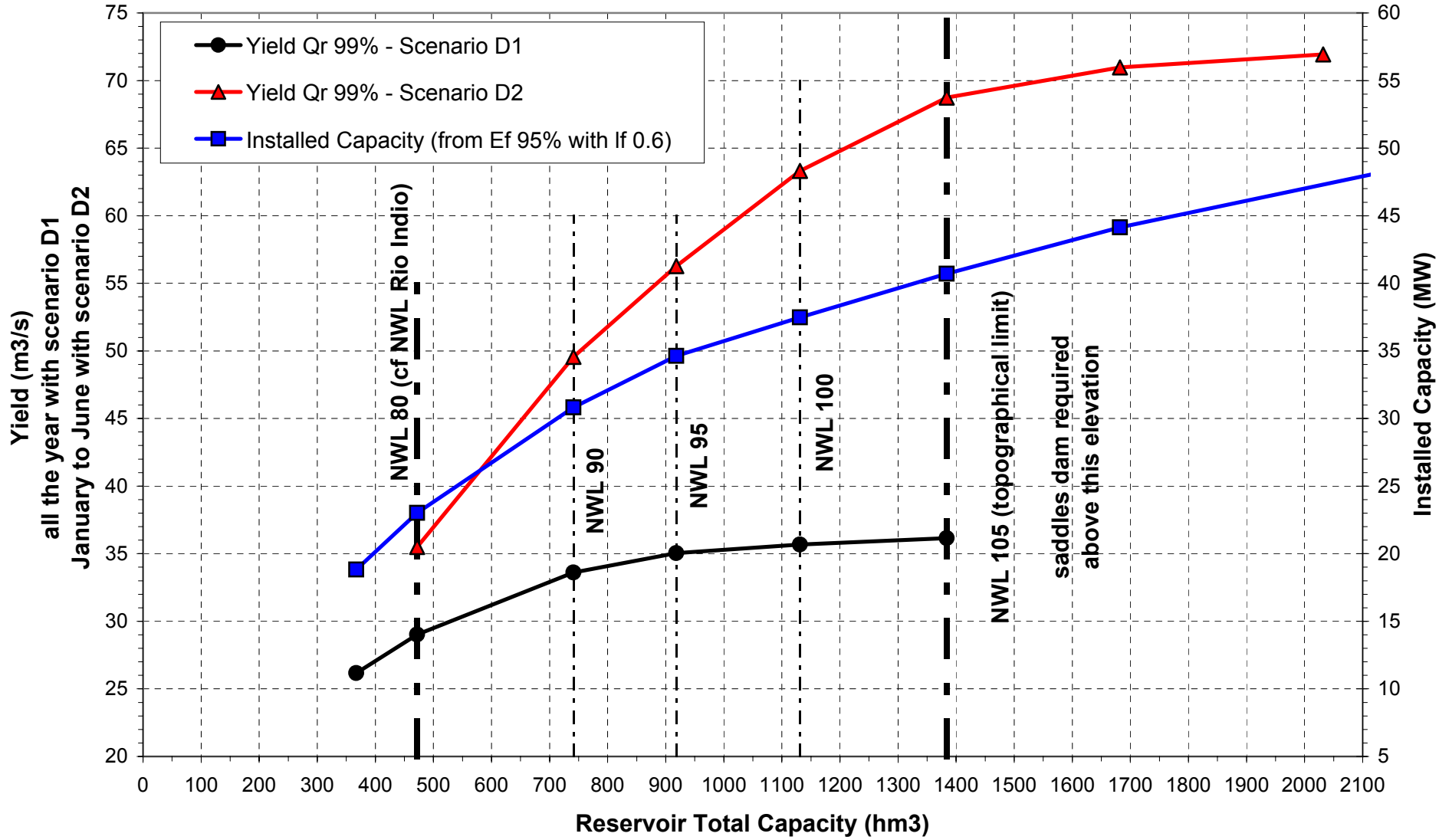


FIGURE 21 - SYNTHETIC POTENTIAL OF RIO TOABRE RESERVOIR



PART IX – DAM TYPE SELECTION

PART IX – DAM TYPE SELECTION

1. INTRODUCTION

The dam type selected in the 1999 Reconnaissance Study (cf. Part I) was a rockfill dam with central clay core with a crest at El. 105 masl, creating a reservoir with a Normal Water Level at El. 100 masl.

The project also included:

. an ungated spillway, 219 m wide, located on the right abutment with a capacity of 3 400 m3/s under a Maximum Water Level of El. 104 masl, continued by a stepped natural rock cut tailrace channel of about 1 000 m length.

. two 8 m diameter tunnel, 1 100 m long, for diversion works through the right abutment, converted at the final stage in bottom outlet and hydropower facility,

. an inter-basin transfer tunnel with associated power facility, a transmission line and access roads.

The present Feasibility Study includes the reviewing of this design. The purpose of the present Part VIII is to examine and compare, at a preliminary stage, several dam type alternatives, in order to select the most appropriate of these for the Toabre project. Then a more detailed design will be performed, at a feasibility stage, on the selected alternative.

2. PRELIMINARY DESIGN

2.1. Dam Types Alternatives

➢ ***Alternatives Considered***

In light of the topographical, hydrological and geological characteristics of the Toabre site conditions, such as the assumed presence of an economically reachable bedrock substratum, two types of dam could be considered and compared. These are:

- a gravity dam built in Rolled Compacted Concrete (**RCC**),

- a Concrete Face Rockfill Dam (**CFRD**).

Another possible alternative could be a rockfill dam with central impervious core. But due to the extended rain period of the Toabre Site, the constraints for placing this impervious material, highly dependant of such rainy conditions, will result in a longer construction period or extra cost impacts. Considering also the more restrictive flood protection requirement than for a CFRD, this alternative has consequently been discarded and was not considered further.

At this stage of the studies, the cost comparison for these two alternatives has been based on drawings of the engineering structures for calculation of the main quantities involved, namely:

. excavations : overburden, rock (surface and underground)

. fills : cofferdam, rockfill, filter

. concrete works : RCC, CVC for facing, plinth, structures etc.

. grouting (when notably different) : consolidation grouting

➢ ***Design Criteria***

The general criteria for the dam type selection are as follows:

. dam located at the Toabre site identified in the reconnaissance study with possible adjustment of the ACP's axis (coordinates: 981 769 N / 565 612 E ; 980 907 N / 565 169 E) to better adjust the dam layout to the accurate topographical data.

. design based on the available basic data at date, as reported in the corresponding parts of the present report (Topography, Geology, Seismic Hazard, Hydrology etc).

. according to the recommendation of the 'Water Management & Power Study Report' (ref. 10932 RP 03 - October 2002) the selected reservoir Normal Water Level for this dam type selection has been chosen at El. 95 masl; the Minimum Operating Level is at El. 50 masl.

. flood protection with equivalent security and efficiency (as much as possible); as a result the flood cases will be as follows, according to international recommendations :

	Construction Flood	Design Flood	PMF
RCC	25 years	1 000 years	YES
CFRD	50 years	10 000 years	YES

in addition, preference is given to ungated spillway solution in this remote region. Indeed, compared to gated spillway with possible human or mechanical deficiency, this solution presents a better security, associated with lower operation and maintenance costs.

. for the purpose of comparing different types of dam, design details and cost estimates were concentrated on those elements which differ for the different alternatives. Then common features to all dam types such as the transfer tunnel to Indio reservoir, the Toabre hydroelectric powerplant and the bottom outlet main components were not considered and included in the comparison process.

2.2. RCC Dam Alternative

➢ *General layout*

The general layout is presented on sketch SKE-01 which demonstrates how this RCC dam alternative allows an easy and economical integration of all appurtenant structures.

The design of the different structures is detailed hereafter.

➢ *RCC dam*

A typical cross-section of the dam is shown on sketch SKE-02. The dam is designed on the following conventional principles which guarantee its satisfying behaviour for stability and watertighness:

. 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 (defined in Geology part). This requires excavations of the complete overburden (5 to 15 m) and the upper, most weathered, part of the rock substratum (assumed 5 m thick). Excavation depth is then 10-15 m average and reaches 20 m maximum in places (top of Right Bank).

consolidation grouting of upper part of the foundation is foreseen.

. the crest is 8 m wide at El. 99.5 masl. Due to the seismic level at Toabre site a preliminary conservative design has been adopted : upstream face sloped at 1 V : 0.2 H and downstream face sloped at 1 V : 0.7 H.

. the dam body has a volume of 2 x10^6 m^3 and is made of RCC, the economics and speed of construction of which are now well established. At Toabre, this technique will be applied as follows:

  . the RCC aggregates will be produced by crushing the rock available in the identified quarries. In the light of previous experience, the cement content could be around 100 kg/m^3, value that gives at the RCC satisfying mechanical properties.

  . the dam body will use the conventional RCC placement technique of 30 cm thick lifts compacted by heavy vibrating rollers.

  . the upstream face has an impervious slab of conventional concrete, 0.5 to 0.75 min (average) thick, and built in successive layers at the same time as RCC. The downstream face is protected from weather effects by steps of conventional concrete (0.3 m minimum thickness),

. a drainage curtain in the upstream part of the dam will check the circulation of any water and will control uplift pressures. It will consist of boreholes intersecting the horizontal galleries in the dam which will serve all necessary access, inspection, monitoring, and maintenance functions.

a grout curtain and a drainage curtain are foreseen in the foundation at the upstream toe of the dam.

➢ *Spillway*

A typical cross-section of the spillway is shown on sketch SKE-02.

The spillway chute is advantageously located on the downstream face of the RCC dam in the centre of the valley. Its ungated concrete sill is at the NWL El. 95 masl and is 300 m long.

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 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 (0.6 m height) cast and anchored onto the sloped downstream RCC face. With a specific flow of 8 $m^3/s/m$ for the design flood (and still acceptable 20 $m^3/s/m$ for PMF) this design 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.

➢ *Diversion works and Outlet*

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. This concrete structure will be easily built in this naturally protected area during the first rainy season, while the Toabre river flow in its natural bed. (see sketches SKE-01 and SKE-02).

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 [(1)].

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 other two will be easily converted into bottom outlet (not detailed at this stage of the study).

---

(1) the flood routing capacity of the lower part of the reservoir, with no significant reduction for the cost of this RCC alternative, has not been considered at this stage of the study.

➢ ***Power generation works***

A surface powerplant can be easily located at the toe of the dam, on the right of the spillway in the river bed. The intake structure will consist of adequate openings within the RCC dam continued with penstocks routed down the downstream face of the dam until the powerplant.

The design of these structures is not detailed for this dam type selection phase.

➢ ***Quantities***

The main quantities are as follows :

Designation	Quantity
Overburden	1 500 000 m3
Rock Excavation	800 000 m3
RCC	2 000 000 m3
Concrete	175 000 m3

2.3. CFRD Alternative

➢ ***General layout***

The general layout is presented on sketch SKE-03. The two abutments are used to locate the different appurtenant works which can not be, classically, integrated in the CFRD dam.

The design of the different structures is detailed hereafter.

➢ ***CFRD dam***

A typical cross-section of the dam is shown on sketch SKE-04, based on the following general principles :

- the downstream shell is founded on moderately weathered rock while the upstream shell supporting the concrete slab is founded on slightly weathered or sound rock for settlement risk reason (cf. concrete plinth). As for the RCC dam alternative this requires excavations of the complete overburden (5 to 15 m) and the upper, most weathered, part of the rock under the upstream shell.

. the crest is 8 m wide at El. 100 masl. Due to the seismic level at Toabre site a preliminary conservative design (as for the RCC alternative) has been adopted : upstream face sloped at 1 V : 1.6 H and downstream face sloped at 1 V : 1.7 H.

- the dam body is in rockfill, largely self-draining, thus avoiding the generation of uplift pressure in the foundations which, in the event of failure or circumvention of the

watertight injection screen, would be immediately released and controlled when coming into contact with the rockfill. Rockfill material will be provided from appurtenant works excavations and identified quarries.

the dam body is zoned according the standard zones 1, 2 and 3 for CFRD with following characteristics:

. Zone 1 : impervious materials for the lower upstream part of the dam,

. Zone 2 : layer of processed (or alluvial) 0-100 mm transition under the concrete slab to have a uniform and firm support to the slab, and a self-healing zone in case of leakage through the slab,

. Zone 3A : selected rockfill screened at 300 mm for transition between 2 and 3B (compressibility and permeability),

. Zone 3B and 3C : random rockfill, with bigger (3C: 1.2 m) downstream.

- watertighness is ensured by an upstream reinforced concrete slab, the thickness of which varies from 0.3 m at the top to 0.6 m at its base. The slab has vertical joints incorporating all customary sealing devices. On the 5 upper meters below the crest this concrete slab extents, classically, as a vertical concrete retaining wall which allow to save the corresponding quantity of rockfill in the upstream shell.

- a grout curtain ensuring the watertighness of the dam foundation is executed from the plinth.

➢ *Spillway*

The design of the spillway is shown on sketches SKE-03 and SKE-05.

The spillway is located on the top of the left bank. It comprises a large excavated approach channel for a 300 m long ungated duckbill concrete weir at the NWL El. 95 masl, continued by a sloped concrete channel (400 m long, 100 m wide) founded and anchored on rock and terminated on a flip bucket at El. 40 which projects the flow in a pre-formed scour before the restitution to the Toabre river bed.

The construction of this spillway requires significant excavations, in both overburden and rock, with possible use of large quantities as rockfill in the dam body.

Taking account of the flood routing capacity of the reservoir, the 5 300 m^3/s of the design flood (T = 10 000 years) are handled with spillway discharge of practically 2 900 m^3/s under a Maximum Water Level at El. 97.9 masl, leaving a freeboard of about 2.1 m (cf. RCC dam) 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 El. 99.5 masl, i.e. 50 cm below the dam crest elevation.

➢ *Diversion works and Outlet*

During dam construction the Toabre river will be routed into two 9.5 m diameter concrete lined tunnels, 650 m long, excavated through the right bank (see sketches SKE-03 and SKE-06).

Due to their impact on the total cost of the CFRD alternative, the sizing of the diversion structures has been optimised to minimize their cost. The flood routing capacity of the lower part of the reservoir has been considered to minimize the size of the tunnels and cofferdams, and the optimisation made with the following constraints :

. diversion with two tunnels minimum because one will be converted into bottom outlet;

. upstream cofferdam limited to El. 42 masl (if possible) to avoid an additional cofferdam on the saddle (at this elevation) between Toabre and Resumidero riverbeds (Left Bank).

The water will be controlled by upstream (crest at El. 42 masl) and downstream (crest at El. 30 masl) cofferdams. The two tunnels have a total section of 150 m^2, or enough to control the routed construction flood (peak of 2 350 m^3/s routed to 1 600 m3/s) under El. 41.5 masl.

Inlet and outlet open channel will be excavated to connect the Toabre river to the tunnels. The location of the tunnels takes advantage of the downstream gully to minimise the depth of the excavations of the outlet channel.

In the final phase of construction, one of the tunnels will be plugged, and the other will be converted into bottom outlet. This will require an access shaft to an underground control room, not detailed at this stage; but it can be anticipated that these dispositions will be more expensive than the ones necessary to convert the diversion structure layout of the RCC alternative.

➢ *Power generation works*

A surface powerplant can be installed at the outlet of the diversion tunnels. The waterway will use one of the tunnel with an adequate intake structure at the inlet.

The design of these structures is not detailed for this dam type selection phase. But it can be anticipated that the cost of these waterways (intake, steel lining etc.) will be higher than the cost of the simple layout possible with the RCC dam alternative.

➢ *Quantities*

The main quantities are as follows :

- the reinforced concrete plinth (4 m and 6 m wide) at the toe of the face deserves particular attention. The plinth is founded and anchored in sound rock consolidated by injection. A system combining joint flexibility and seal-tightness is incorporated at the point of connection between the plinth and the dam face.

Designation	Quantity
Overburden	3 400 000 m3
Rock Excavation & Tunnel	2 000 000m3
Rockfill	7 000 000 m3
Filter	300 000 m3
Concrete	165 000 m3

3. COMPARISON OF THE DAM TYPE ALTERNATIVES

3.1. Methodology

The choice of the best alternative to be selected for the feasibility stage of the study should be based on the evaluation and comparison of the following factors:

. construction cost

. technical, environmental and operation considerations

3.2. Construction Cost Estimate

3.2.1. Unit Prices

For this preliminary dam type selection phase, a total unit prices database has been established for cost comparison between the two options.

Such total unit prices are developed according to the 'aggregation method' based on the analysis of the prices/costs of similar works (type/volumes) obtained from past and present international construction contracts. Aggregated unit prices are then derived from the unit prices indicated in the Bill of Quantities of such awarded construction contracts containing several hundreds of unit prices, which are consolidated to sort out the total cost of the works and adjusted to current prices representative of the Toabre Project works.

These aggregated prices include all direct and indirect construction costs relating to: labour, materials, equipment, installations, overheads etc. This aggregation method is of common use in Europe to estimate the cost of projects at a conceptual design stage and even in more detailed study stages.

Application of these prices to a limited number of representative items provides a sound estimate of the project construction cost, excluding, at this preliminary stage, the cost of all common elements for both alternatives as : transfer tunnel, powerplant, grout curtain, monitoring, access roads, etc.

A series of such total unit prices representing local conditions for the project, has been prepared on the basis of recent construction market prices for engineering structures of a type and size similar to those involved for Toabre dam.

The following aggregate prices were finally used for comparison of the alternatives at this preliminary stage :

Item	Unit	Unit Price (USD)
Clearing	m^2	1
Overburden Excavation	m^3	3
Rock Excavation	m^3	10
Tunnel Excavation (including supports)	m^3	75
Rockfill (from excavations with rehandling)	m^3	5
Rockfill (from quarry)	m^3	10
Filter-Transition	m^3	15
Cofferdam fill	m^3	5
Rolled Compacted Concrete (RCC)	m^3	40
Conventional Vibrated Concrete (CVC)		
CVC for RCC Dam Faces	m^3	200
CVC for CFRD Dam Face and Plinth (including joint treatment)	m^3	250
CVC for Spillway	m^3	200
Levelling CVC	m^3	150
Mass CVC	m^3	100
CVC for Structures	m^3	200 to 300
Underground Mass CVC	m^3	150
Underground CVC	m^3	300
Consolidation Grouting	ml	100

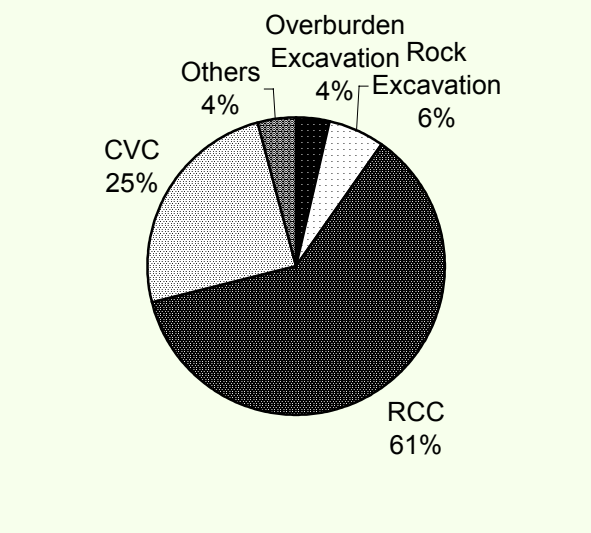
It can be noticed that this list, at this preliminary stage, has been voluntarily shorted. For example the different global unit prices 'CVC' includes the concrete itself (with adequate cement content, constraints for placing etc) but also the formwork, the steel reinforcement and the joint treatment. The differences in these CVC unit prices reflect then also the different proportions of these components (for one m^3 of concrete) according to the concrete use.

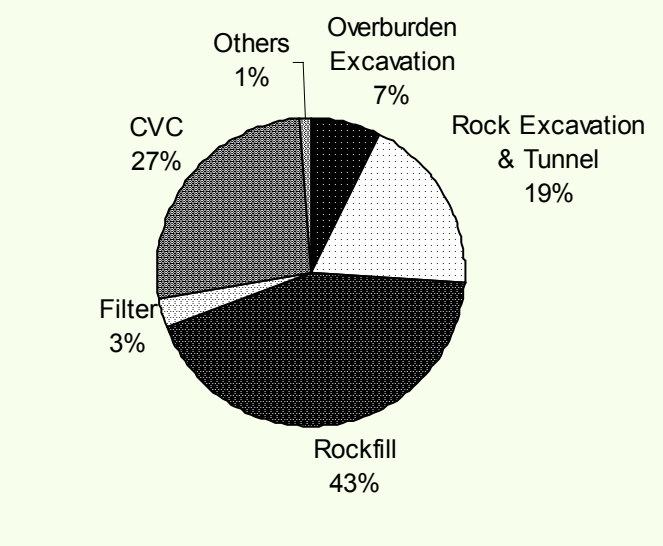
A more detailed aggregate prices list will be used to estimate the selected alternative at the feasibility stage.

3.2.2. Cost Estimate

Application of the unit prices listed above to the various quantities estimated from the preliminary engineering drawings (with a NWL at El. 95 masl) gives the project construction costs detailed in Tables 1 and 2 and summarises as follows :

Structures	**RCC Alternative Cost (MUSD)**	**CFRD Alternative Cost (MUSD)**
Dam	110	96
Spillway	8	29
Diversion Works	12	20
Bottom Outlet & Power Plant	negligible (-)	negligible (+)
Grouting and Drainage	common	common
Transfer Tunnel	common	common
Infrastructures	common	common
Environmental Impacts	common	common
Engineering	common	common
Total (comparative)	**130**	**145 (+ 12%)**





Breakdown of Project Cost by Main Items

RCC Alternative **CFRD Alternative**

Recall : the above costs are only comparative costs, not total. They don't include all common structures and cost. By the same they don't include contingencies on either quantities or unit costs. Final costs for the selected solution are detailed in Part XIII.

3.2.3. Sensitivity analysis

The above cost comparison shows that the CFRD alternative is approximately 12% more expensive than the RCC alternative. Given the uncertainties underlying cost estimates at this preliminary stage of the studies, both in terms of unit prices and quantities, this difference could be insufficient, on its own, to justify directly the choice of the RCC alternative.

Sensitivity analysis has been performed to evaluate the effects on the project cost of changes in the most significant features of the dam design and cost.

➢ ***Sensitivity on unit prices***

The RCC body classically represents more than 60% of the construction cost of the RCC alternative (80% with the concrete facing). This cost is then primarily dependent on the unit cost of RCC. Sensitivity analysis on both RCC and Rockfill unit prices is shown on Figure 1, within a range of realistic unit cost variation.

Construction costs of both alternatives are equal in the following cases:

RCC unit cost (USD/m3)	Rockfill (quarry) unit cost (USD/m3)
40 (reference cost)	7.5 (- 25%)
45 (+ 12.5%)	9 (- 10%)
48 (+ 20%)	10 (reference cost)

➢ ***Sensitivity on quantities***

The possible modification of the assumed foundation level (see § 3.3) has a direct impact on the quantities of the dam body and then on the construction cost. This was evaluated as follows:

. in the extreme theoretical case, assuming the same present level of foundation for the CFRD rockfill shells (and for the spillway on the left bank, see after), it has been calculated that the foundation level of the whole RCC structures should be deepened of 4 additional meters for the construction cost of RCC alternative to be equal to the present cost of the CFRD alternative.

. in another side, a general raising of the foundation level for RCC and concrete plinth/rockfill upstream shell of CFRD by 3 m (assuming then the removal of 2 m of weathered rock instead of 5 m) will increase the difference cost between RCC and CFRD alternatives (+ 15% for CFRD instead of + 13%).

The impact of a lower rock substratum could also be important for the design, and then the cost, of the spillway of the CFRD alternative (where no geological survey has been performed on this spillway zone), which could result in larger quantities of both overburden and rock excavation to reach an acceptable foundation for the concrete weir and channel.

➢ ***Sensitivity on general layout***

A rough estimate of a gated spillway for the CFRD alternative (4 gates 8.5 m wide x 10 m high with a concrete weir at El. 85 masl) followed by a 50 m wide concrete channel show that this solution should allow a 5 MUSD reduction for this alternative (i.e. still + 8 % than the RCC Alternative), but with the associated negative impacts on operation safety and O&M costs described above.

By the same a shorter layout, but with poorer hydraulic conditions, for the diversion tunnels with a restitution closer to the downstream toe of the dam (length reduction of 200 m, i.e. 30%) should allow an additional 6 MUSD reduction for the CFRD alternative. But on the other side it is recalled that the conversion of these tunnels into bottom outlet and power waterways should be more expensive than for the RCC alternative (not detailed at this stage).

➢ ***Conclusion***

The CFRD alternative construction cost could be reasonably considered some 5% to 15% more expensive than the RCC alternative construction cost, this difference being within the accuracy of this comparative cost estimate.

3.3. Technical, Environmental and Operation considerations

The main uncertainty of the Toabre site remains, without any boreholes, the sufficient knowledge of the rock substratum in both terms of quality and depth. If the soil/rock contact can be roughly estimated from the geophysical results, the quality and then the depth of the competent rock can only be assumed for the foundation of the RCC structures and the concrete plinth of the CFRD (with the associated rockfill upstream shell).

The need of good quality rock foundation is stricter for RCC than for rockfill materials. As a consequence the impact of adverse geological conditions will be higher for the RCC dam than for the CFRD. By the same such adverse geological conditions can have an important impact on the CFRD spillway and more on any underground works, as the big diversion tunnels for the CFRD alternative.

The following table lists the advantages (+) and drawbacks (-) of both alternatives:

	RCC Alternative	CFRD Alternative
Sensitivity to change of foundation level	(-) higher for RCC structures (but margin of 4 m)	(+) lower for rockfill shells (-) high for concrete plinth
Geological risk	(+) no underground works	(-) high for diversion tunnels
Flood control	(+) lower risk	(-) more sensitive to overflows (-) large tunnels (9.5 m)
Appurtenant works	(+) easy integration or conversion from diversion structures	(-) dependant of foundation conditions (-) more delicate conversion of tunnels into final structures
Construction difficulties	(-) RCC placing under heavy rain	(-) realisation of concrete plinth (+) rockfill placing
Materials	(-) importation of cement	(+) local resources
Environmental impacts	(-) road traffic from Panama to the site (cement)	(-) important quarry for rockfill (5 MCM)
Construction time	(+) shorter period	(-?) longer period
Operation & Maintenance	(+) toe gallery for additional grouting or drainage	(-) underground bottom outlet

4. RECOMMENDATION

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%).

Given the number of advantages presented by the RCC alternative, especially the fewer imponderables associated chiefly with underground works and the easy integration of simple appurtenant works structures, **it is recommended to proceed to the feasibility design of this RCC alternative**.

But it is worthwhile to notice than the conclusion of the present Dam Type Selection Phase could be eventually reviewed in the light of the results of the recommended boreholes campaign.

TABLE 1 RCC ALTERNATIVE - CONSTRUCTION COST

Designation	unit	Quantity	Unit price USD/unit	Cost USD
Dam & Spillway				
Clearing	m2	200 000	1	200 000
Overburden Excavations	m3	1 000 000	3	3 000 000
Rock Excavations	m3	500 000	10	5 000 000
RCC	m3	2 000 000	40	80 000 000
CVC U/S facing	m3	50 000	200	10 000 000
CVC D/S facing	m3	20 000	200	4 000 000
CVC Spillway	m3	40 000	200	8 000 000
Levelling CVC	m3	20 000	150	3 000 000
Consolidation grouting	ml	50 000	100	5 000 000
sub total Dam				*118 200 000*
Diversion works				
Overburden Excavations	m3	500 000	3	1 500 000
Rock Excavations	m3	300 000	10	3 000 000
Cofferdam fill	m3	120 000	5	600 000
Mass CVC	m3	20 000	100	2 000 000
CVC structures	m3	25 000	200	5 000 000
sub total Diversion Works				*12 100 000*
TOTAL			**USD**	**130 300 000**

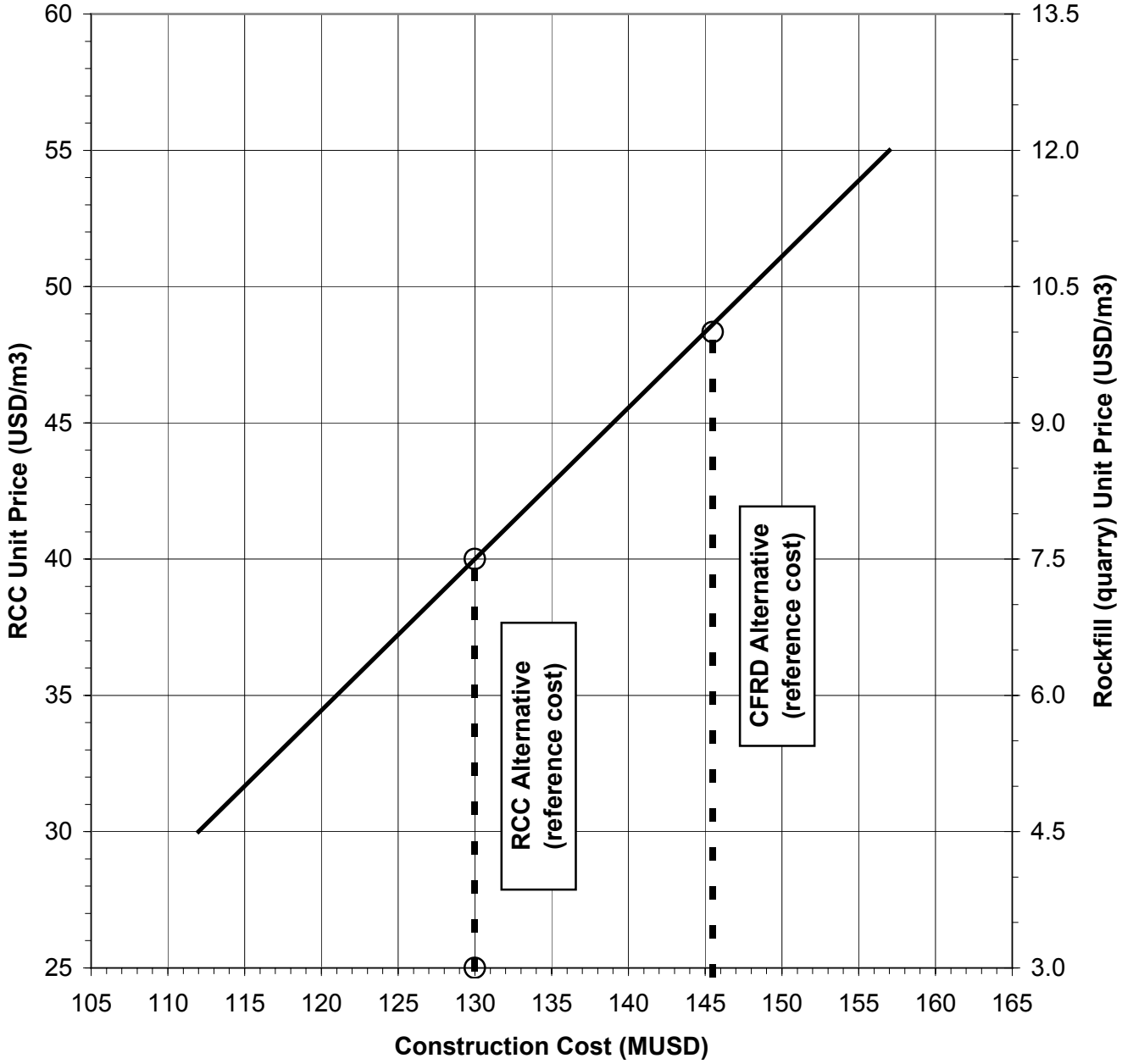
Note: these costs are only comparative costs, not total. They don't include all common structures (transfer tunnel, access roads etc.) and common cost (environmental impacts, engineering etc.). By the same reason they don't include contingencies on either quantities or unit costs.

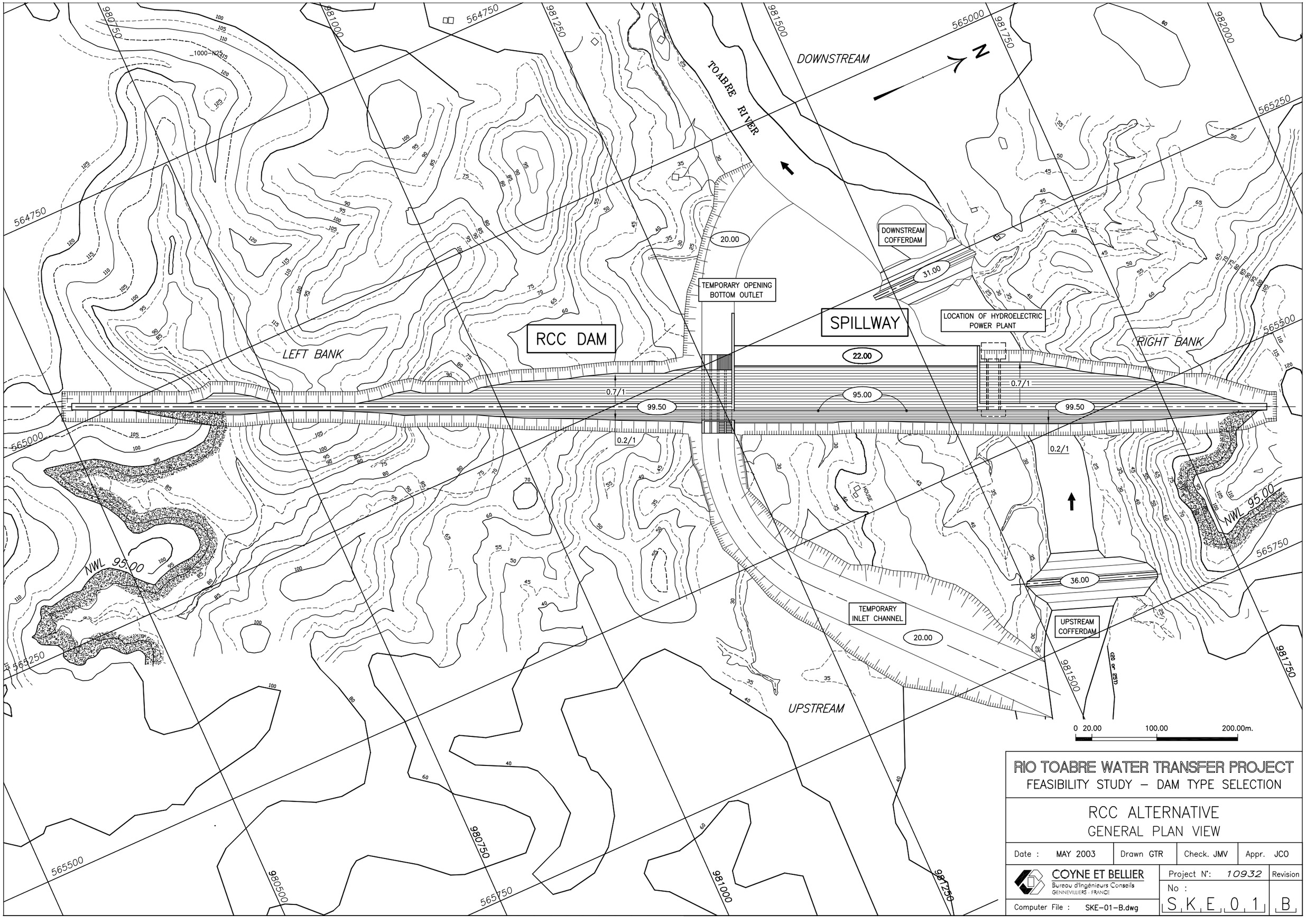
TABLE 2 CFRD ALTERNATIVE - CONSTRUCTION COST

Designation	unit	Quantity	Unit price USD/unit	Cost USD
Dam				
Clearing	m2	450 000	1	450 000
Overburden Excavations	m3	1 800 000	3	5 400 000
Rock Excavations	m3	600 000	10	6 000 000
Rockfill from excavations (rehandling)	m3	1 500 000	5	7 500 000
Rockfill from quarry	m3	5 500 000	10	55 000 000
Filter- Transition	m3	300 000	15	4 500 000
CVC (face+plinth)	m3	55 000	250	13 750 000
CVC (wall crest)	m3	10 000	300	3 000 000
Consolidation grouting	ml	5 000	100	500 000
sub total Dam				*96 100 000*
Spillway				
Overburden Excavations	m3	1 300 000	3	3 900 000
Rock Excavations	m3	1 100 000	10	11 000 000
CVC Spillway	m3	70 000	200	14 000 000
sub total Spillway				*28 900 000*
Diversion works				
Overburden Excavations	m3	300 000	3	900 000
Rock Excavations	m3	150 000	10	1 500 000
Tunnel Excavations	m3	120 000	75	9 000 000
Cofferdam fill	m3	190 000	5	950 000
CVC structures	m3	8 000	200	1 600 000
Underground mass CVC	m3	3 500	150	525 000
Underground CVC	m3	20 000	300	6 000 000
sub total Diversion Works				*20 475 000*
TOTAL			**USD**	**145 475 000**
			ratio CFRD/RCC	1.12

Note: these costs are only comparative costs, not total. They don't include all common structures (transfer tunnel, access roads etc.) and common cost (environmental impacts, engineering etc.). By the same reason they don't include contingencies on either quantities or unit costs.

FIGURE 1 - RCC and CFRD Alternatives
Construction Costs - Sensitivity Analysis on Main Unit Prices





RIO TOABRE WATER TRANSFER PROJECT

FEASIBILITY STUDY – DAM TYPE SELECTION

RCC ALTERNATIVE

GENERAL PLAN VIEW

Date : MAY 2003	Drawn GTR	Check. JMV	Appr. JCO

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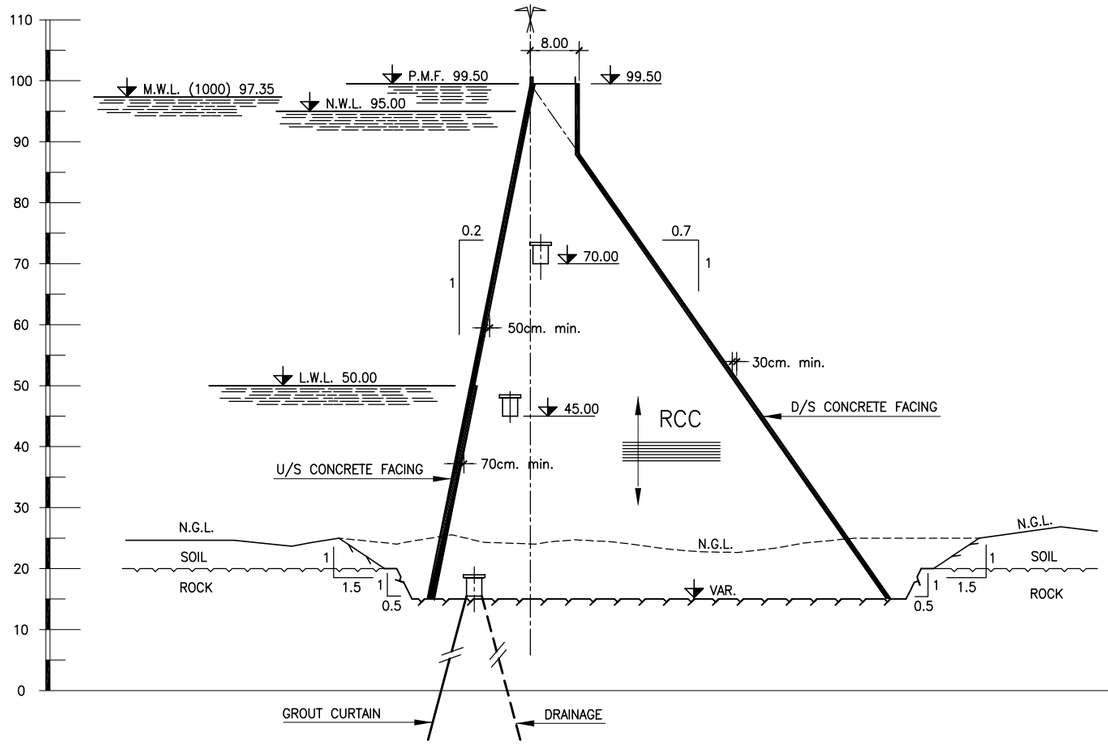
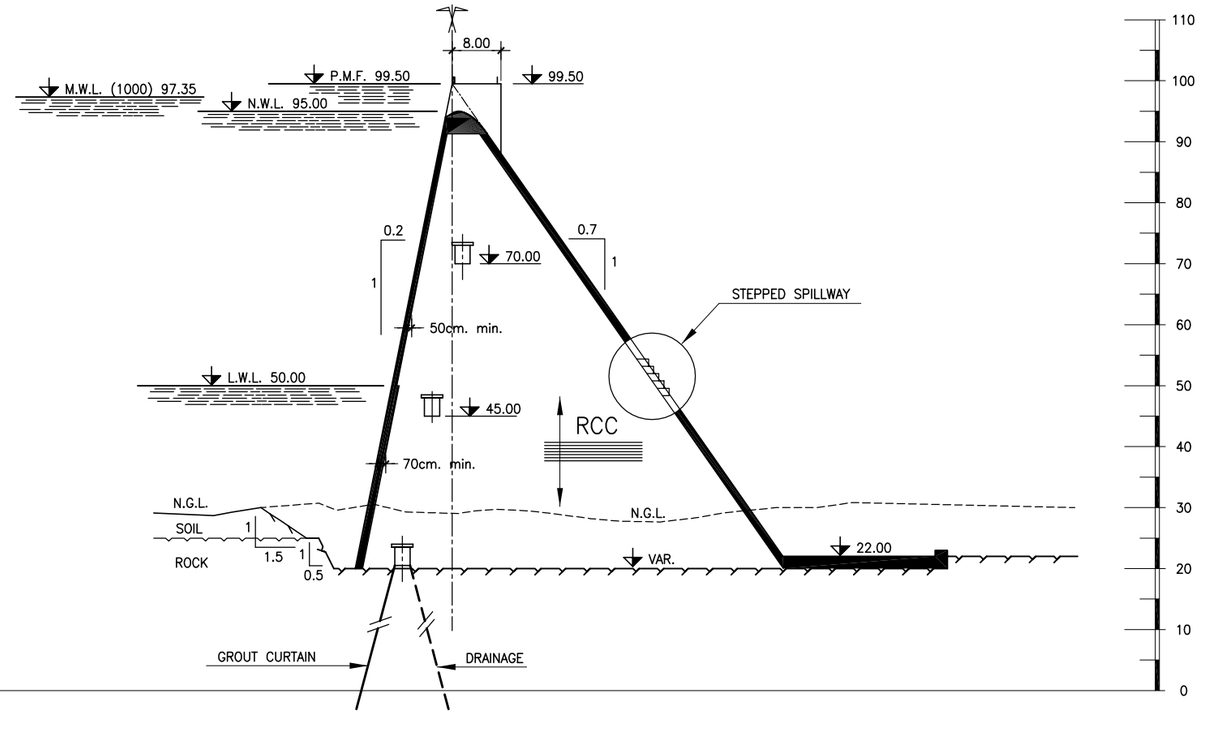
RCC DAM SECTION

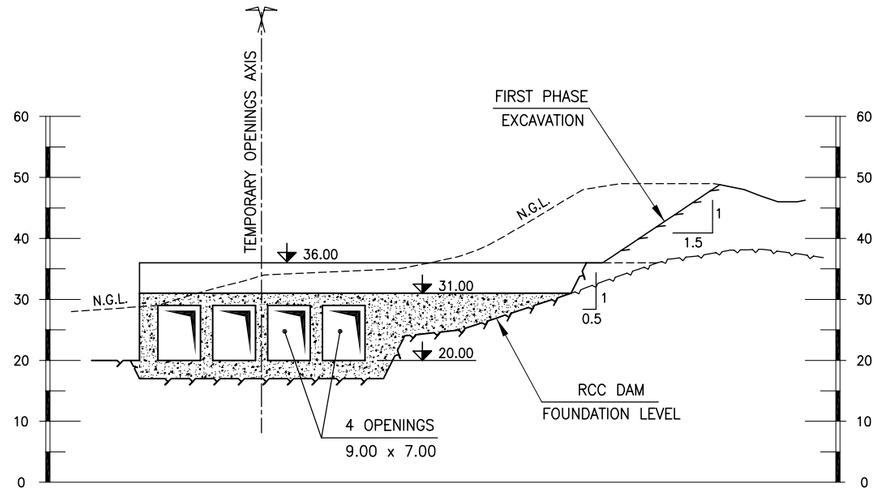


RCC SPILLWAY SECTION

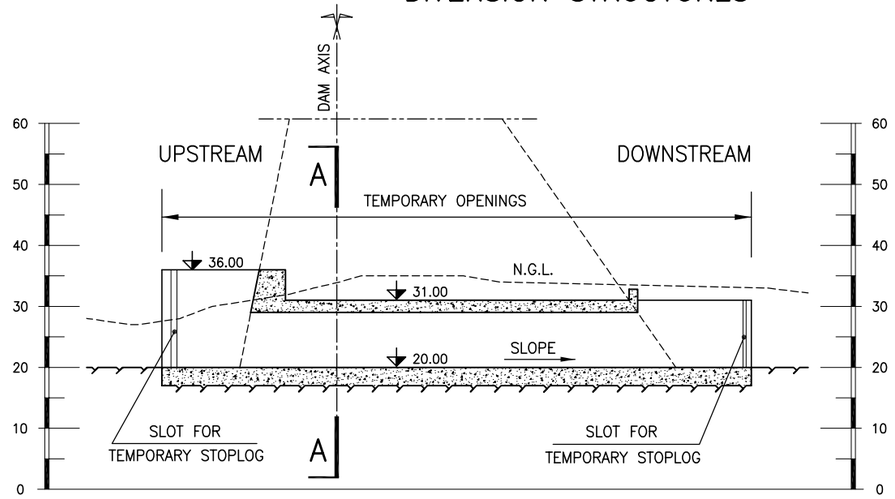
(LENGHT = 300m.)



SECTION A–A



DIVERSION STRUCTURES



RIO TOABRE WATER TRANSFER PROJECT

FEASIBILITY STUDY – DAM TYPE SELECTION

RCC ALTERNATIVE

DAM – TYPICAL CROSS SECTIONS

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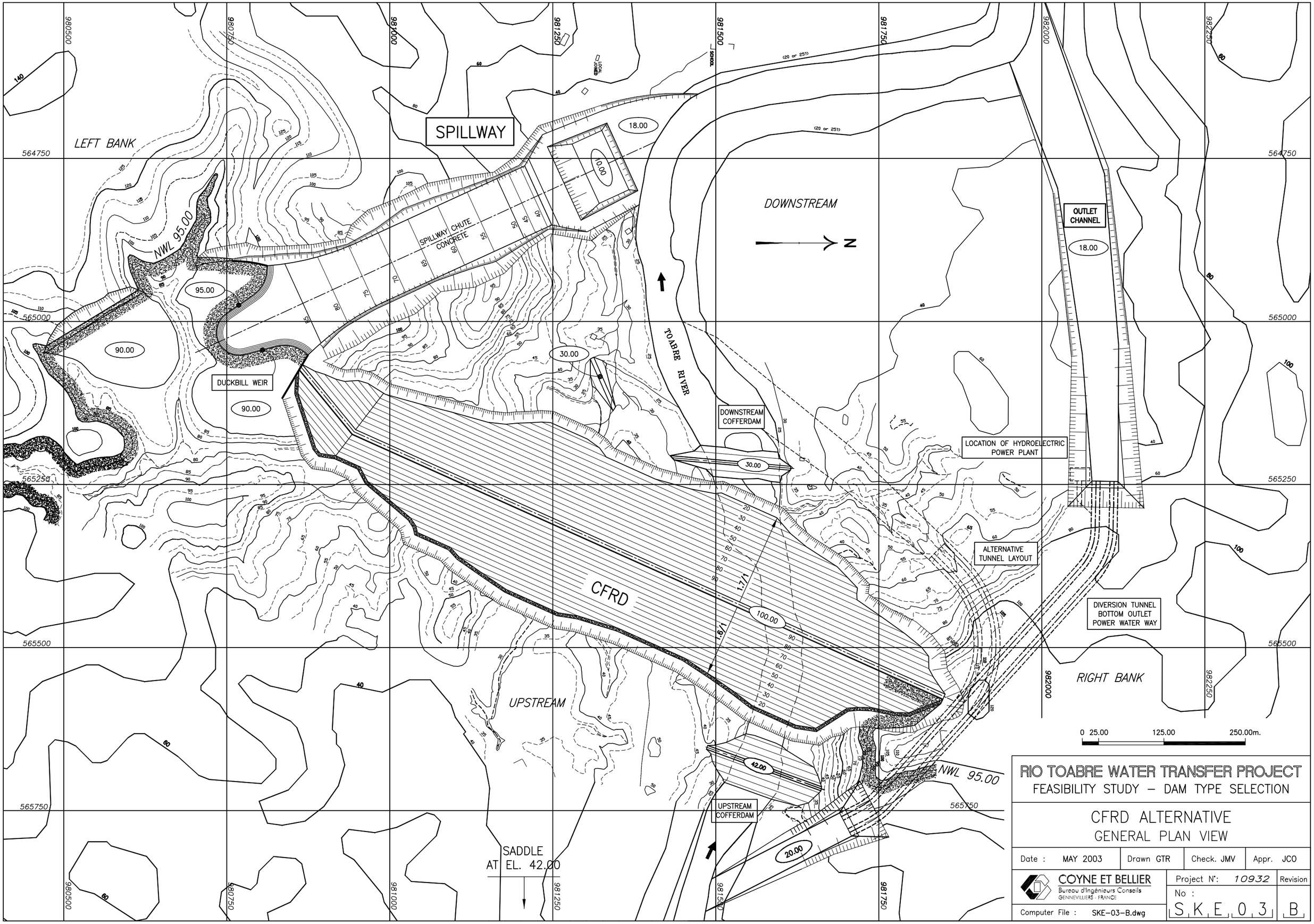

RIO TOABRE WATER TRANSFER PROJECT

FEASIBILITY STUDY – DAM TYPE SELECTION

CFRD ALTERNATIVE

GENERAL PLAN VIEW

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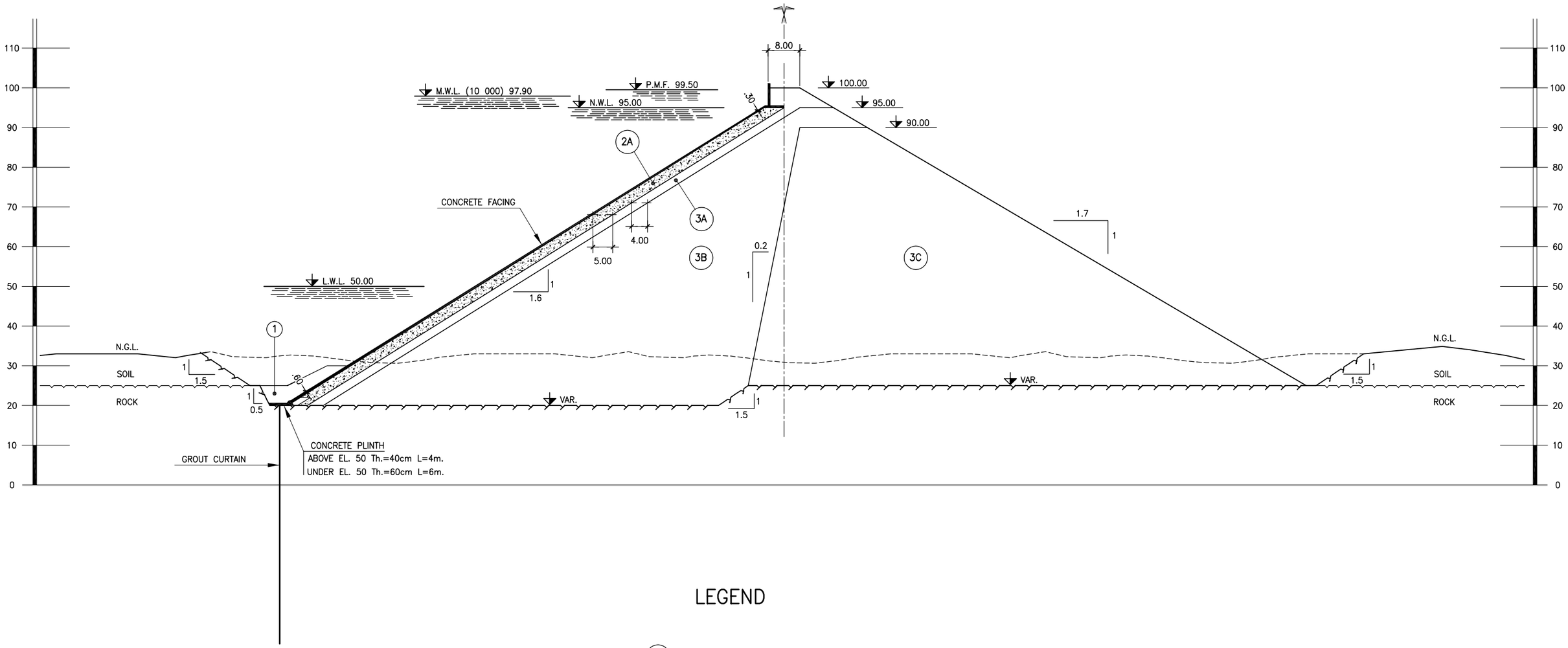
TYPICAL CROSS SECTION



LEGEND

(1) IMPERVIOUS MATERIAL

(2A) TRANSITION 0–100mm

(3A) SELECTED ROCKFILL Dmax 300mm

(3B) RANDOM ROCKFILL Dmax 800mm

(3C) RANDOM ROCKFILL Dmax 1200mm

0 5.00 25.00 50.00m.

RIO TOABRE WATER TRANSFER PROJECT
FEASIBILITY STUDY – DAM TYPE SELECTION

CFRD ALTERNATIVE
DAM – TYPICAL CROSS SECTION

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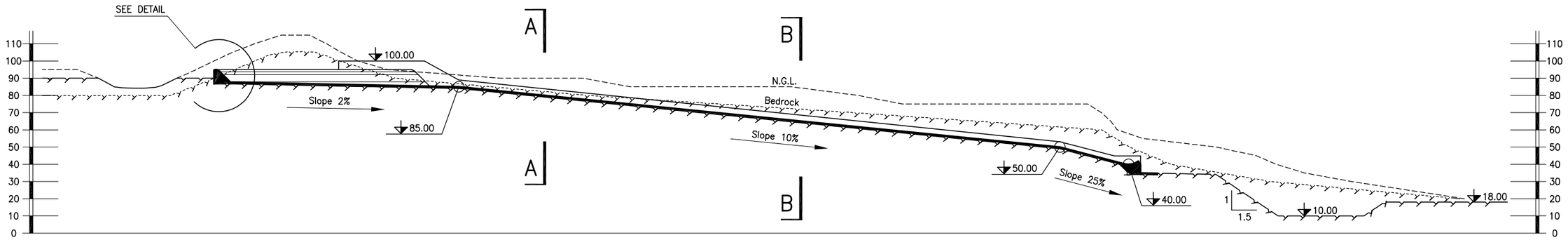
SECTION ALONG SPILLWAY AXIS

0 12.50 50 100 m

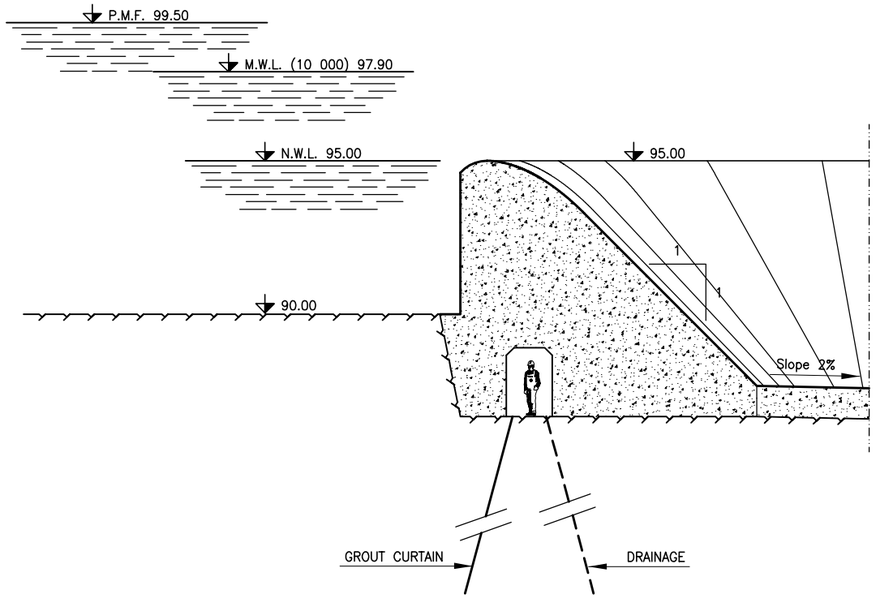
DUCKBILL CONCRETE WEIR
(DEVELOPED LENGTH = 300m.)

SPILLWAY CONCRETE CHUTE (LENGHT = 400m.)



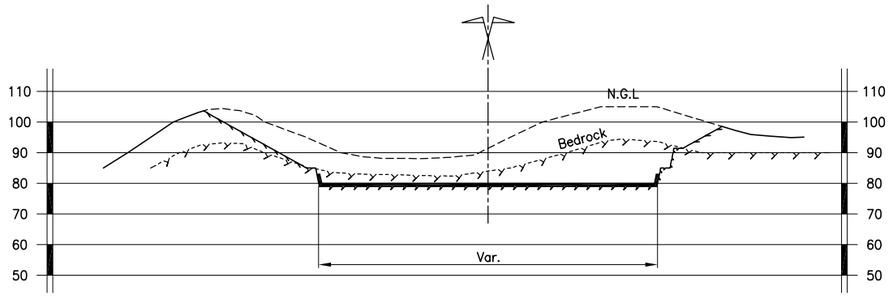
DUCKBILL CONCRETE WEIR

0 1.00 5.00 10.00 m

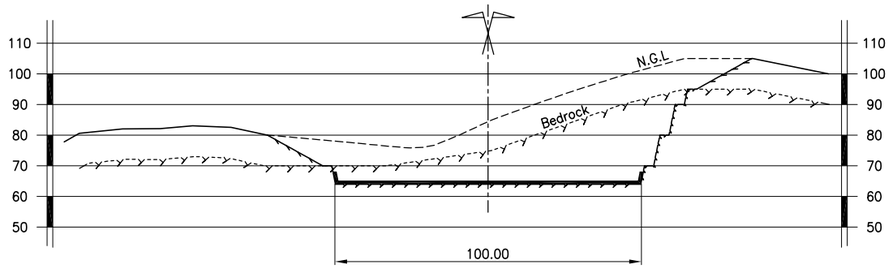


SECTION A–A

0 10.00 50.00 100.00 m



SECTION B–B



RIO TOABRE WATER TRANSFER PROJECT

FEASIBILITY STUDY – DAM TYPE SELECTION

CFRD ALTERNATIVE

SPILLWAY – CONCRETE CHUTE

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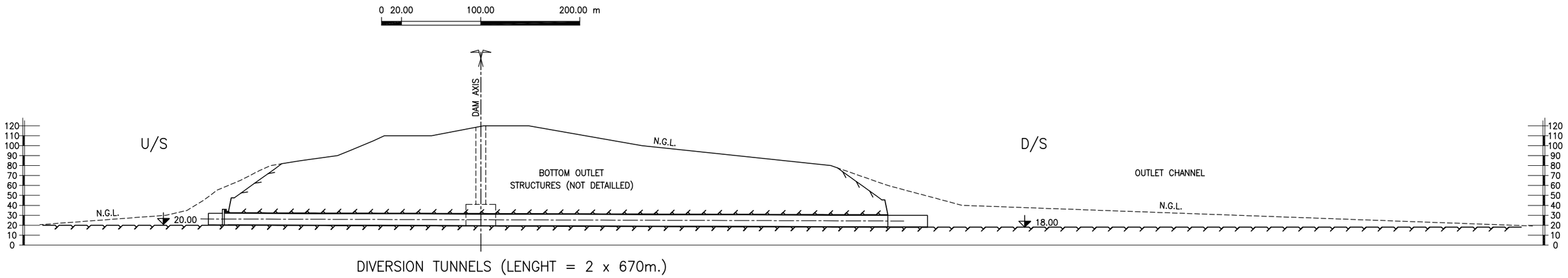
PROFILE ALONG TEMPORARY DIVERSION



DIVERSION TUNNELS
TYPICAL SECTION

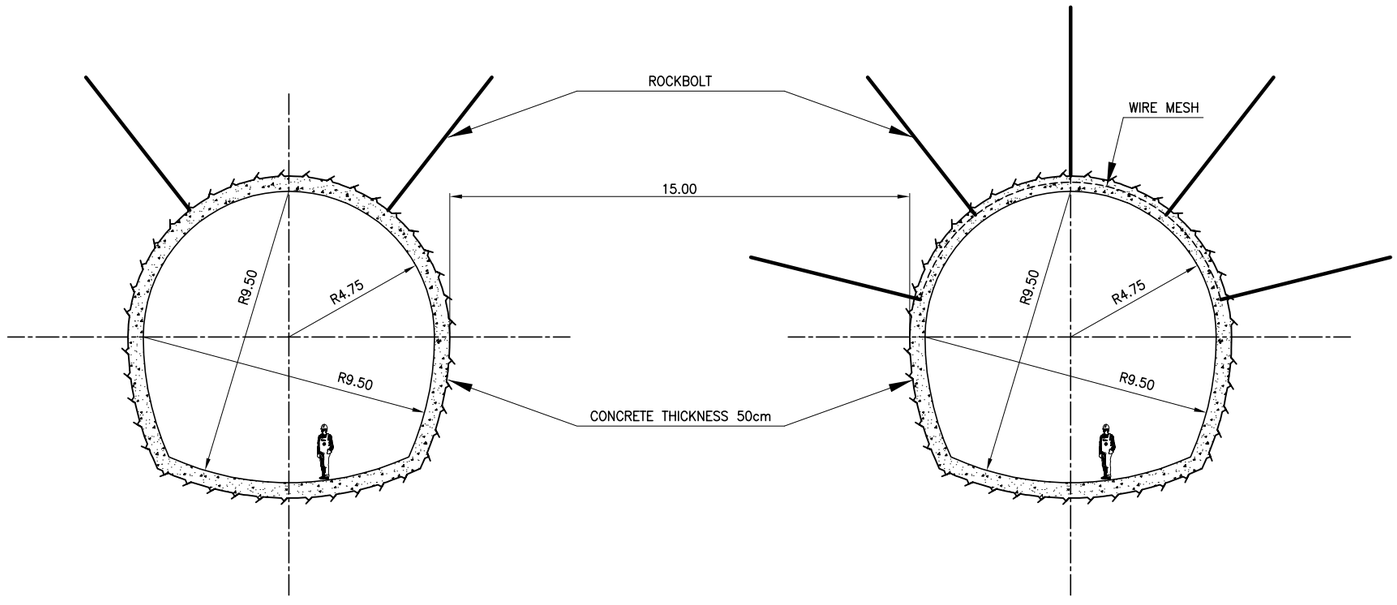
0 1.00 5.00 10.00 m

TYPE I

RANDOM ROCKBOLT

TYPE II

SYSTEMATIC PATTERN ROCKBOLT
WITH MESH OVER CROWN



RIO TOABRE WATER TRANSFER PROJECT
FEASIBILITY STUDY – DAM TYPE SELECTION

CFRD ALTERNATIVE
DIVERSION WORKS – PROFILE AND SECTION

Date : MAY 2003	Drawn GTR	Check. JMV	Appr. JCO

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Project N°: 10932 | Revision

No : SKE06 | B

Computer File : SKE-06-B.dwg

PART X – PROJECT DESCRIPTION

PART X – PROJECT DESCRIPTION

1. INTRODUCTION

Following the results of the studies of alternatives presented in the previous parts, the technical feasibility studies consider :

- a RCC dam designed for a Normal Water Level at El. 95 masl (reference), with the associated corresponding transfer tunnel to Indio reservoir.

- 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 is 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 following text, as the corresponding drawings of the Volume III of the present Feasibility Report, are related to the reference scheme designed with NWL 95 masl. In the principle, the alternatives with lower or higher NWL (respectively El. 90 and El. 100) are very similar and don't justify, at this stage of the studies, to modify or adapt the main text or the drawings accordingly.

Nevertheless, for these two alternatives NWL 90 and NWL 100, the main characteristic changes are listed in the adequate paragraphs and reported in the synthetic data sheet presented in the Part I.

All the works of the Toabre scheme are shown on **Drawing 10-301**. A description of the fundamental layout of the project, at a feasibility stage, follows.

2. DAM AND APPURTENANTS STRUCTURES

2.1. General layout

On the base of the layout already developed during the preliminary study of the RCC dam alternative (see Part IX), the structures have been optimised to better integrate the general layout of the scheme.

The present layout, presented on **Drawing 10-302**, includes:

. a 1 200 m long RCC dam with a crest at El. 99.5 masl, implemented along a slightly adjusted linear axis (coordinates: 980 800 N / 565 110 E ; 981 900 N / 565 600 E),

. 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 opening mentioned hereabove.

The design of these different structures is detailed hereafter.

2.2. RCC dam

The typical cross-section of the RCC dam is shown on **Drawing 10-303**.

The design of this 85 m maximum high and 1 150 m long dam is based on the following conventional principles :

- ***Foundation***

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. This requires excavations of the complete overburden (5 to 15 m) and the upper, most weathered, part of the rock substratum (assumed 5 m thick). Excavation depth is then 10-15 m average and reaches 20 m maximum in places (top of Right Bank).

Levelling concrete will be placed on the bottom of the foundation area. By the same the RCC / rock foundation contact on the banks will be made by placing concrete (or bedding mortar) just before placing each lift of RCC to guarantee a good contact of the dam body with the foundation;

In addition, consolidation grouting of upper part of the foundation is also foreseen.

- ***Design and stability***

The preliminary design established during the dam type selection phase is kept : the crest, 8 m wide, is fixed at El. 99.5 masl, i.e. 4.5 m above the NWL at El. 95 masl; the upstream face is sloped at 1 V / 0.2 H and the downstream face at 1 V / 0.7 H,

This design guarantees the stability of the dam in all conditions, especially under seismic load, as shown in the stability analysis presented in Appendix – Project Description – Appendix A – Stability Analysis of the RCC Dam Section.

- ***Construction of the RCC dam body***

The 2 MCM of the dam body are made of Rolled Compacted Concrete (RCC), the economics and speed of construction of which are now well established. At Toabre, this technique will be applied as follows:

. the RCC aggregates will be produce by crushing the rock available in the identified quarries. This will probably give a lack of fines in the obtained sand. An addition of flyash (or pozzolan or slag) will improve both the workability and the strength of the RCC. In the light of previous experience, the cement and flyash (or equivalent fine material) contents could be respectively around 80-100 kg/m^3 and 50-70 kg/m^3, value that gives at the RCC satisfying mechanical properties.

. the dam body will use the conventional RCC placement technique of 30 cm thick lifts compacted by heavy vibrating rollers.

. vertical joint will be formed every 30-40 m maximum by the insertion of joint sheets into each layers of RCC. These joints will be appropriate to control the thermal shrinkage. If necessary, additional joints will be placed in sections which present topographical or geotechnical discontinuities.

- ***Faces***

The upstream face has an impervious slab of Conventional Vibrated Concrete (CVC) built in successive layers at the same time as RCC with the "Christmas tree" method. At this feasibility stage it is forecasted to place a steel reinforcement in the CVC upstream face.

The downstream face is protected from weather effects by steps of CVC (0.3 m minimum thickness),

Both upstream and downstream concrete faces should be cast again cantilever formworks or slipformed. This last solution involves forming a strip of facing for every two lifts of RCC, using a slipform machine of the kind used for roadworks. The surface of the faces of the dam makes this solution technically feasible and economically interesting. An economical comparison during the next phase of the study should show which alternative is the most economic.

- ***Watertightness and drainage***

The RCC material is generally always enough impermeable in its mass; the watertightness of the dam is then governed by its discontinuities : horizontal lifts surfaces between each RCC layers and vertical construction joints.

. horizontal lift joints will be made thoroughly impermeable by placing a bedding mortar over a sufficient distance from the upstream face just before placing each lift of RCC. This mortar is also suitable to increase the cohesion between RCC layers, favourable under seismic load.

. vertical joints will be equipped with waterstops embedded in the upstream slab of CVC. Behind the waterstop, a hole is provided to allow for drainage by using in each layer a circular form during the casting of the CVC, removed after setting.

One perimetral gallery along the upstream toe of the dam and two horizontal galleries (at El. 45 and El. 70) will be arranged in the RCC body near the upstream face. These galleries, easily made with the RCC technique, will serve all necessary access, inspection, monitoring, and maintenance functions.

A drainage curtain in the upstream part of the dam, consisting of boreholes intersecting these galleries, will check the circulation of any water 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 (see § 2.6 after).

2.3. Spillway

A typical cross-section of the spillway is shown on **Drawing 10-304**.

The spillway chute 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.

- ***Capacity of the spillway***

The ungated sill is at the NWL El. 95 masl. It is divided by the 21 piers of the bridge into 22 passes of 14.2 m 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.

- ***Design of the spillway***

The sill is made in conventional concrete according to a standard Creager profile which joint the spillway chute sloped at 1 V : 0.7 H.

This chute is designed as steps of reinforced vibrated concrete (0.6 m height) cast and anchored onto the sloped downstream RCC face. The transverse joints in the RCC dam body will continue through the spillway, where they will be fitted with waterstops. Drainage pipes placed at the RCC / CVC step contact will also improve the safety of the spillway chute.

With a specific flow of 8 $m^3/s/m$ for the design flood (and still acceptable 20 $m^3/s/m$ for the PMF) this design 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.

2.4 Diversion Works and Outlets

- ***Diversion works***

The general principle of water control during the construction works is shown on **Drawing 10-306** : the diversion works is based on the construction of four openings in a concrete structure built within the dam footprint, in the Resumidero (1) stream bed on the left bank, shown on **Drawing 10-307**.

The topography of this area of the left bank allows to consider the diversion of the Toabre river into two main phases:

. in a first phase, with the Toabre river still flowing in its natural bed, the concrete structure and the main part of the excavation of the inlet and outlet channels will be completed in this naturally protected area.

. during a second phase, the Toabre river will be routed through these temporary openings, allowing to works in the central part of the valley and the riverbed. The river will be diverted to the openings with the construction, at the beginning of the dry season, of upstream and downstream cofferdams to close and protect the working area of this second phase.

The 4 openings have a total section of 250 m^2, or enough to control the construction flood (T = 25 years, Qp = 2 000 m^3/s) under El. 35.5 masl (pressure flow). The closing of the area at El. 36 masl is ensured by a continuous concrete wall 5 m high built above the openings and the lateral concrete filling which will form the upstream face of the dam in this area.

The topography of the area allows to limit the length of the cofferdams, allocated on twoplaces: one set on the riverbed to route the flow towards the excavated channels and the second set to provide the connection to the openings using lateral concrete retaining walls. The upstream cofferdams have the crest at El. 36 masl and the downstream ones at El. 31 masl, leaving a freeboard of 50 cm.

It can be highlighted that 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 the 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 (see after).

---

(1) also named Quebrada Nicaragua.

- ***Minimum Release Facility and Bottom Outlet***

➢ Minimum release facility of an ecological flow of 4 m^3/s (10% of the mean flow) is required to maintain flow in the river downstream of the dam.

Drawing 10-305 presents this minimum release facility structure.

One of the openings in the diversion structure described above will be equipped as follows: a 700 mm steel pipe will be installed with the standard control structures from upstream to downstream: trashrack 3.0 x 3.0, stoplog 1.4 x 1.4 (which can be raised to the top of the dam along slots casted on the upstream face of the dam), and a 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.

In order to get better water quality for this minimum release facility, the concrete intake structure is raised above the upstream wall of the diversion structure at El. 36 masl [(2)].

➢ In addition a bottom outlet is required to control the reservoir (during the initial filling for example) and to provide drawdown of the reservoir if necessary. It would be also advantageously used during floods to partially flush the sediment trapped in the reservoir.

This bottom outlet is designed to discharge a maximum of 150 m^3/s under NWL 95 masl; i.e. 3.5 times the mean inflow.

Drawing 10-305 presents this bottom outlet structure installed in another opening of the diversion structure which includes :

. a 17 m long steel lined opening of 2.7 x 2.0 at El. 22 masl conventionally controlled by:

  - an upstream fixed-wheel guard gate (3.0 x 2.0), operated by servomotor from the top of the dam along slot (including air vent) casted on the upstream face of the dam,

  - a downstream radial control gate (2.7 x 2.0) operated from a control room installed just behind the upstream wall of the diversion structure at El. 31 masl. The perimetral gallery allows access to the room and necessary aeration of the flow just downstream of the gate;

. an upstream concrete trashrack of 100 m²;

. a flip bucket at the downstream end of the opening for a good dissipation of the energy and restitution of the flow to the river.

The initial sizes of the temporary opening allow sufficient air volume to guarantee a free-surface flow regime downstream of the radial gate. Steel plates at the invert (5 m wide) and on the lateral walls (5 m high) will be casted in this 'free-surface flow' opening section to limit problem of cavitation du to high velocity.

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(2) A multi level in the structure could be provided using this arrangement depending on the predictions of a model for water quality downstream the dam.

2.5. Hydropower Facilities

- ***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.

The first phase of the water management study performed by Coyne et Bellier (see Part VIII) gives some indications of the energy potential of the Toabre Project : with the theoretical assumption that the Project is devoted only to hydropower generation, without any release for the Canal operation, it can generate a maximum of 180 GWh/y of firm energy (with a reliability of 95% in time) with a 35 MW installed capacity powerplant located at the toe of the dam (load factor of 0.6).

ACP indicated that a recent power market concluded that there is a substantial market for additional power in the near future and that all the Toabre hydropower could be easily absorbed into the Panama Integrated System (PNIS).

But the feasibility study for the Rio Indio Water Supply Project, available during the development of the present study, reveals that the cost of the optional hydropower facilities associated to the Project (especially the transmission line to connect the envisaged powerplants to the national grid) make such development non economic and didn't recommend any hydroelectric development at this time; it is obvious that such impact of cost will be worst for the more remote Toabre project.

Based of this conclusion, ACP decided to retain only the following hydropower alternative for the Rio Toabre Transfer Project : **mini hydropower plant located at the toe of the dam and designed with the ecological flow for local distribution**.

Any development of higher capacity at the dam site would require a non-economic connection to the national grid and has not been envisaged further. By the same a hydropower plant located in the (very long) transfer tunnel between Toabre and Indio reservoirs cannot be economically justified due to the too low available net head.

- ***Mini Hydropower plant at the dam site***

The design of such mini powerplant is based on the following criteria: 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.

Due to the small sizes of such mini hydropower plant (for both civil works and equipment) it can be economically located in one of the temporary diversion opening.

The general layout shown on **Drawing 10-309** is proposed as optional and then independently of the adjacent river and bottom outlets. This should be optimized with these structures (location and arrangement) at the next phase of the study if this optional mini powerplant is definitively retained.

The power generation works includes:

. an intake similar to the one designed for the river outlet, located on the upstream face of the dam, above the upstream wall of the diversion structure at El. 36 masl. It consists of one concrete opening equipped with trashrack 3.4 x 3.5 and controlled by a wheel gate 2.0 x 1.8 operated from the top of the dam along slot (with air vent) casted on the upstream face of the dam;

. a 70 m long ϕ 1 600 mm penstock installed in the diversion opening;

. a surface powerhouse which consists of a rectangular reinforced concrete structure built at the downstream end of the diversion opening and which houses the following generating set :

Turbine type		Horizontal-shaft Francis
Speed	rpm	600
Unit output	MW	4
Net head	m	rated: 60; range: 70 to 40
Mean discharge	m^3/s	8
Generator capacity	MVA	5.5
Generator power factor		0.8
Generator output voltage	kV	13.8

horizontal-shaft Francis is for such size of turbines (ϕ 1 m) a common disposition, which shows the following advantages:

. excellent accessibility to all the components (turbine, wheel, alternator, …)

. shallow foundation of each turbine group, simply fixed on a regular thick slab

. easy introduction of an inertia wheel between the turbine and the generator, that will reduce over-speed and overpressure effects during emergency power shutdown

. use of standard alternator (reduce the cost)

. simplified setting

the turbine will be equipped with a ϕ 1 600 mm butterfly valve. The opening of the butterfly valve is ensured by an oil pressure mechanism and the closing by gravity.

the powerhouse is served by an overhead travelling crane. The crane will be used for the turbine/generator equipment and the erection/maintenance floor. Electrical and control equipment will be gathered in special separated rooms, preferentially air-conditioned.

the transformer, to be designed according to the local network specifications, will be located on a platform at El. 31 masl, downstream of the powerhouse. It will be connected to a local grid (60 Hz) to be developed in the area of the project, not designed at this stage of the studies.

. a concrete weir at El. 24 masl located in the tailrace channel to control the downstream water level for optimal operation.

2.6. Grouting and drainage

Drawing 10-308 shows the preliminary principles adopted for the grouting and drainage layout in the dam and foundation. Extent and disposition should be confirmed on the next stage of study when more detailed geological conditions become available.

- ***Grouting***

The upper fringe of the whole bedrock foundation area will be consolidated by grouting : grid 3 m x 3 m; depths: 9 m below El. 50 and 6 m above.

A general grout curtain will be set in the foundation at a maximum depth of 60 m in the central part, extended laterally into both banks. The spacing of the grout holes will depends on the permeability of the foundation; the grouting will generally include primary and secondary holes and even tertiary holes in any areas where cracking is more intense.

The grout curtain will be easily built in advance from the foundation level or during the RCC works from the perimetral gallery along the upstream toe of the dam.

- ***Drainage***

Uplift pressure in the foundation will be controlled by a drainage network extending beyond the drainage network in the dam (see § 2.2). It will consist of boreholes drilled obliquely downstream of the grouting curtain from the perimetral gallery.

The abutments will be drained as necessary at depth by vertical drains bored from two subhorizontal galleries excavated at El. 50 in the right bank and El. 70 in the left abutment.

2.7. Monitoring

The RCC dam will be equipped with conventional monitoring equipment adopted for gravity dams: direct and inverted pendulums (at 3 sections), thermocouples (at three elevations of the RCC body), pressure cells and piezometers at the contact and into the foundation, jointmeter, seepage flow control, etc.

3. TRANSFER TUNNEL

3.1. General criteria

- ***Diameter***

The tunnel allows the transfer of water from Toabre reservoir to Indio reservoir, from where this flow can be transferred to Gatun lake for Canal operations by the transfer tunnel from Indio reservoir to Gatun lake. Note that the impact of the Toabre Project on the design of this last transfer tunnel is discussed on § 6.

The feasibility study of the Rio Indio Water Supply Project recommends the development of a reservoir with a Normal Water Level (NWL) at El. 80 masl and a Minimum Operating Level (MOL) at El. 40 masl.

The Toabre and Indio reservoirs will be operated in parallel, very likely on the base of equivalent reservoir filling (same percentage of the active storage capacity). With this assumption, the head difference is 10 m minimum, corresponding to the difference between the MOL of each reservoirs, respectively El. 50 masl at Toabre and El. 40 masl at Indio, while the available rough head at NWL reaches respectively 10 m, 15 m and 20 m, difference between respective NWL 90, NWL 95 and NWL 100 at Toabre and NWL 80 masl at Indio.

In can be noticed that, for these three alternatives operated with the 'equivalent reservoir filling' rule, this head between the NWL of Toabre reservoirs and Indio NWL 80 reservoir is more or less constant over the major range of reservoir variation (decrease approximately under percentage of filling of 20%).

The first phase of the water management study performed by Coyne et Bellier (see Part VIII) gives some preliminary indications of the yield of the Toabre Project : with the simple consideration of the reservoir alone, it appears that Toabre NWL 95 can guarantee, with a reliability of 99% in volume, a constant flow of 35 m3/s all the year or 56 m3/s during 6 months (January to June) for the Canal operations (via Indio Reservoir). With a design head of 10 m minimum, the corresponding diameter of tunnel are 4.7 m and 5.6 m; with a design head of 15 m (major part of operation) the required diameter reduces to 4.35 m and 5.2 m.

This preliminary estimation didn't consider the Toabre reservoir as a part of the complex Canal System including Gatun lake (deepened) and Madden and Indio reservoirs to satisfy a specific demand for navigation and M&I water.

As part of the Canal Capacity Study developed in parallel, ACP used the HEC-5 reservoir system model to evaluate the effectiveness of proposed alternatives to improve the Canal system capability and reliability.

Operation simulations with HEC-5 are presented in Part VIII, with some recommendation about future possible optimisation of reservoirs operation, not yet performed du to specific difficulties in HEC-5 use with four tandem and parallel reservoirs. On the base of these calculations a 4.5 to 5 m diameter should be recommended for the tunnel associated with the alternative reservoir NWL 95 / MOL 50.

Taken into account possible future optimisation of HEC-5 calculation, **the value of 5 m has been retained as the reference diameter of the transfer tunnel**. For further economical consideration and optimisation, **the cost of a 4 m diameter alternative is also estimated**.

- ***Alignment***

The absence of drilled holes along possible alignments alternatives for the transfer tunnel between Toabre and Indio reservoirs makes any geological optimisation of this alignment not realistic and conducts to select a linear alignment as the base of the implementation.

The location of the inlet and outlet of the tunnel have been nevertheless optimised in order to minimise the length of the tunnel, while guarantees an adequate topographical cover along its whole length and minimise the approach and outlet open channels. This topographical optimisation was based on the recently available photorestitution maps of these areas.

The proposed tunnel axis coordinates are : 981 000 N / 572 390 E ; 987 700 N / 587 000 E.

3.2. Design

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. **Drawings n°10-310 to 10-313** present the location and the design of these different structures.

The approach channel will lead to the intake portal at El. 33 masl. It consists of large excavations in both soil and rock along the Rio de U streambed.

The intake structure which forms the tunnel portal is a reinforced concrete structure with a concrete trashrack. The invert of the inlet structure is horizontal at El. 35 masl (and the top at El. 40, the MOL of Indio reservoir) to allow proper hydraulic conditions at MOL 50 and guarantee to the entire length of the tunnel to be underwater in any case.

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) and the capacity is 42 m3/s with a gross head of 10 m minimum between Toabre and Indio reservoirs (velocity around 2 m/s). With a (normally not foreseen with

normal operation) maximum head of 55 m between the two reservoir (Toabre at NWL 95 and Indio at MOL 40) the maximum discharge reaches 100 m3/s, with a velocity of 4.7 m/s.

Along the straight-line layout of the tunnel the natural ground level varies between El. 100 masl and El. 200 masl (El. 260 masl maximum), with neither low cover problem nor specific stress related problem because of great cover.

With the present lack of knowledge of the geological conditions it is assumed that the tunnel construction would utilise drill and blast technique from multiple headings. A minimum of two sloped (10%) construction adits is planned along the tunnel alignment. In case of relatively uniform and good (to fair) rock formation, the alternative method with one (or two) Tunnel Boring Machine (TBM) could be economically appropriate. Further geological investigations are required to finalise the selection of the tunnelling method.

The tunnel is designed as fully lined throughout mostly for hydraulic reasons, but also to control water loss in areas of severely fractured rock and to prevent erosion and deterioration of the rock in areas on soft or highly fractured rock. The lining will be cast-in-place concrete with a minimum thickness of 40 cm. Reinforcement, thicker concrete and steel lining will be included as required, depending on the rock quality, as proposed on **Drawing 10-311**.

An upstream shaft, shown on **Drawing 10-312**, is designed for operation control. This vertical shaft is located 135 m downstream of the tunnel inlet (with the bedrock above El. 100 masl). It includes a gate room with two bonneted gates 4.0 m x 3.0 m for flow control.

A downstream shaft, located 280 m upstream of the tunnel outlet (with the bedrock above El. 85 masl), allows tunnel dewatering by pumping and additional flow control with one 4.0 m x 3.0 m bonneted gate. This shaft presented on **Drawing 10-313** allows also the introduction of small vehicles for easier inspection of this long tunnel.

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. The downstream and upstream part of the tunnel can be inspected as necessary with the exceptional drawdown of the corresponding reservoir under the inlet of the tunnel.

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.

4. SADDLES DAMS AND BACKFILL

A selected part of the rock and earth materials removed from the required excavation for structures should be advantageously used to backfill the gully which gash the top of the left bank; this arrangement should avoid the reservoir to extent along this gully, far downstream of the dam axis (even if it will be topographically closed). Adequate disposals will be managed to assure stable and safe backfill of this area above the dam crest elevation.

The rest of excavated material that is unsuitable, in excess or impractical for use in the temporary or finished work shall be stockpiled in designated areas and sloped to drain in order to provide a stable mass.

The saddle between Toabre reservoir and Cano Sucio basin at El. 100 masl will be closed as necessary (normally only for the alternative NWL 100 masl) by a low earthfill saddle dam, not significant for the Project evaluation.

5. ACCESS ROAD AND CAMP

5.1. Access road

Two options can be envisaged for the main access to the Rio Toabre Project :

. new access to be developed from the nearest existing access from Panama City on the Pacific side;

. new road extending from the future access associated to the Rio Indio Project. This project will be accessible from the two main population centres on both Atlantic and Pacific coasts, respectively Colon and Panama City. This alternative assumes that the Rio Indio Project would be completed prior to construction of the Toabre Project, which should be the case.

According to discussions with ACP the first option has been retained. This alternative is independent of the future Rio Indio and/or Cano Sucio projects and should be eventually optimised in conjunction with the development of these projects in a further stage of the studies.

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, at the upstream end of the reservoir along the Toabre riverbed.

This access shown on **Drawing 10-301** includes :

. the improvement of 12 km of the existing dry-weather road from Tambo to the vicinity of San Miguel, at the upstream end of the reservoir along the Rio San Miguel valley;

. the construction of 29 km of new road through mountainous terrain, following the right bank of the reservoir via the saddle between Toabre and Cano Sucio basins.

The project for this 41 km long access road would require 10 stream crossings (4 of which existing on the Tambo-San Miguel road, to be improved), by culverts or bridges.

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

By the same, temporary access required for construction of the project will be developed from this main access road:

. access to tunnel portals;

. access to adits along the tunnel alignment;

. access to quarries;

. temporary bridge over the Toabre river at the dam site.

The eventual necessary improvement of the actual all-weather road from Penonome to Tambo and its infrastructures is not considered as part of the Toabre Project.

5.2. Owner's camp

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

This area, located about 5 km from the dam site and 8 km from the tunnel inlet is convenient for supervision during construction and residential and/or administration use after completion of the works.

For the supervision of the construction of the additional tunnel Indio to Gatun, the camp already built with the Indio project will be used.

6. 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 carry the yields from Toabre besides Fhose from Indio.

7. ALTERNATIVE PROJECTS AT NWL 90 AND NWL 100

The design of these two alternative projects is made on the same principles as the one made for the reference Project with NWL 95 masl.

The application of the same design criteria for these two different dams and reservoirs involves adaptations of some characteristics as :

. reservoir levels (NWL, MWL, PMF) with adequate dam crest elevation associated to adjusted spillway capacity and performance,

. equipment of the bottom outlet,

. diameter of the transfer tunnel,

. saddles dam etc.

These specific adaptations are presented in Appendix – Project Description – Appendix B – Adaptation for NWL 90 masl and NWL 100 masl.

The data sheet presented in the Part I of this Volume II.B summarised the main characteristics of these two alternatives, in parallel with the reference one.

In addition all the Drawings of the Volume III established for the reference Project NWL 95 masl are also representative of these two alternatives Projects.

PART XI – ENVIRONMENTAL IMPACTS

PART XI – ENVIRONMENTAL IMPACTS

The present chapter about the Environmental Impacts has been established by ACP. Some particular aspects about these Environmental Impacts, especially cost estimate, have been preliminary developed for the Site Identification and Selection Study. For details, reference is made to the Part III – Appendices of the Volume II. A. of the present Feasibility Report.

1. DESCRIPTION OF BIOLOGICAL, PHYSICAL AND CHEMICAL CONDITIONS

The Toabre river basin is part of the Cocle del Norte river watershed and it originates in the "*corregimiento*" of Toabré. This river basin passes through the "*corregimientos*" Llano Grande, Tulu and Cocle del Norte.

The data for climatologic, physical, biological and cultural elements is based on general information on conditions of the Cocle del Norte watershed, obtained through contracted baseline studies of the Occidental Region of the Panama Canal Watershed.

1.1. Climatologic elements

The climate and orography of the region determine an abundant rainy season with a strong gradient from north to south. The average precipitation is 3,187 mm per year with an average run-off of 2,441 mm, and a total run-off coefficient of 0.77.

The temperature monthly average is of 25.6°C, the potential evaporation-transpiration is 1,503 but the current one is 1,344. The altitude of the area oscillates between 150 - 200 masl.

1.2. Physical elements

Since the producers of this area are fundamentally small scale farmers, their activities are developed through "*tala*", clearing and burning, which produces air contamination due to the increase in solid particles in the air as a result of the erosion produced by the wind. Nevertheless, air quality is considered good, since there is no industrial contamination or vehicular traffic.

The water is turbid and samples taken during the studies contained bacteriological fecal coliform (E. coli). There is no evidence of contamination of the ground by organic chlorinated pesticides or PCBs. Nevertheless, ground contamination occurs from handling of domiciliary solid wastes and residual and sanitary waters.

Table 1 indicates only 21.73 % of the land of the Toabre river watershed is still forest, and 78.27 %, has been affected by human activities through a deforestation process that transform the land cover to shrubs, pastures and annual crops areas.

Table 1
VEGETATIVE COVER TOABRE RIVER WATERSHED IN HECTARES AND PERCENTAGE

HABITAT	hectares	Percentage
Bosque perennifolio ombrófilo tropical de tierras bajas	15768	21,73 (FOREST)
Bosque perennifolio ombrófilo tropical submontano	1519	
Pastizal (pastures)	20182	78,27 (PASTURE, CROPS AND SHRUBS)
Rastrojo (shrubs)	42084	
TOTAL	**79553**	**100**

1.3. Biological elements

Major Findings for the Cocle del Norte Watershed :

Flora

. According to Table 1, Toabré River Watershed has 79,553 hectares of vegetative cover where 21,73 % is forest and 78,27 % has been affected by human activities.

. In the Toabré river watershed tropical forests (bosque perennifolio ombrófilo tropical de tierras bajas) are located under 500 masl, trees can reach up to 30 meters in height.

. Site 'San Vicente' at level 90 has a vegetative cover of 3 425 hectares (see table 2), which represents 4,31 % of the total vegetative cover of Toabre river (see table 3). At level 95 the cover is 5 346 hectares or 6,72 % of the vegetation cover and at level 100 the cover is 5 995 hectares representing 7,54 % of forest cover of Toabre river watershed.

There is slight increase in vegetation cover between levels 95 and 100, compared to a higher increase of affected areas between levels 90 and 95 (see table 2).

Fauna

. 117 amphibian and reptile species have been reported, which represent 29% of the country herpetofauna. Of these species, 52 are considered of special interest.

. 317 bird species, representing 46 families and 15 orders. Also 75 species of mammals have been reported, a quantity that represent 38% of all mammals in the Western Watershed Region, 32 of these are considered of special interest.

. Aquatic flora composition changes as the river descends from the mountains to the low lands and the sea. Prevailing conditions on the rainy season favour molluscs. Biomass amount is abundant, also crustaceans and fish, both used for human consumption.

. Insect families of special interest with major numeric presence are *Chironomidae and Simuliidae.*

. All species of amphibians, reptiles, birds, and mammals of Coclé del Norte Watershed have also been registered at Site "0" San Vicente.

1.4. Description of direct impact area

The direct impact area for each of the alternatives contemplates a 5 meters buffer zone to accommodate the Probable Maximum Flood above the Normal Water Level (NWL). This Maximum Walter Level (MWL) affectation is included in each impacted area for every alternative.

The direct impact area for a reservoir at level 90 (NWL 90 masl, MWL 95 masl) would be approximately 3 425 hectares, at level 95 (NWL 95 masl, MWL 100 masl) 5 346 hectares, and at level 100 (NWL 100 masl, MWL 105 masl) 5 995 hectares. For all the considered elevations, less than one percent of the direct impact area is forest, the remaining areas are bush, pastures, annual crops and livestock areas, indicating that the area has been severely intervened.

1.5. Major environmental impacts

There would be impacts on the fauna, as it is expected that some specimens may migrate, others will adapt and others will die. The impacts will not cause the disappearance of any known or reported species. The impacts on water quality cannot be established at this point.

A major environmental impact would be the loss of approximately 29 hectares of forest (low land) at levels 90 (NWL=90, MWL=95), 46 hectares at level 95 (NWL=95, MWL=100), and 60 hectares at level 100 (NWL=100, MWL=105). In all cases the impact would be irreversible and permanent. This area of affected forest represents only 0.19% to 0.38% of the total forest cover of the Toabre river watershed. (see table 2).

Table 2 ***HABITAT PERCENTAGE AT DIFFERENT SITES IN RELATION TO TOTAL WATERSHED***		
LEVEL 90 (N.W.L.=90 mts ; M.W.L.=95)		
HABITAT	**hectares**	**% of total watershed**
Bosque perennifolio ombrófilo tropical de tierras bajas (forest).	29	0,19
Pastizal (pastures)	967	4,79
Rastrojo (shrubs)	2429	5,77
TOTAL	**3425**	
LEVEL 95 (N.W.L.=95 mts ; M.W.L.=100)		
HABITAT	**hectares**	**% of total watershed**
Bosque perennifolio ombrófilo tropical de tierras bajas (forest).	46	0,29
Pastizal (pastures)	1629	8,07
Rastrojo (shrubs)	3671	8,72
TOTAL	**5346**	
LEVEL 100 (N.W.L.=100 mts ; M.W.L.=105)		
HABITAT	**hectares**	**% of total watershed**
Bosque perennifolio ombrófilo tropical de tierras bajas (forest).	60	0,38
Pastizal (pastures)	1892	9,37
Rastrojo (shrubs)	4043	9,61
TOTAL	**5995**	

Reference price for Habitat, mitigation and compensation cost: Forest US 5 000 per hectare, pastures and annual crops US 1 000 and shrubs US1 500.

Table 3 ***HABITAT PERCENTAGE IN DIFFERENT SITES IN RELATION TO WATERSHED***		
SITE	**hectares**	**Percentage**
TOABRÈ RIVERS	79553	100
SITE LEVEL 90 (NWL=90, MWL=95)	3425	4,31
SITE LEVEL 95 (NWL=95, MWL=100)	5346	6,72
SITE LEVEL 100 (NWL=100,MWL=105)	5995	7,54

1.6. Cultural elements

The Cocle del Norte river has reported 227 archaeological sites, 45 inside Toabre river and 4 in the direct impact area (see table 4):

Table 4 - ARCHEOLOGICAL SITE "0", SAN VICENTE.		
Number	**Community**	**Type of site**
Do – 66.	Boca Tulú	Indigenous village and lithic work shop
Do – 69.	La Encantada	Rock shelter with remainings of indigenous culture.
Pn – 23.	San Isidro	Indigenous village.
Pn – 67.	Boca de San Miguel	Indigenous village.

2. DESCRIPTION OF SOCIO – ECONOMIC CONDITIONS

2.1. Social and economic aspects. Description of Coclé del Norte watershed.

The Toabré river is a tributary of the Coclé del Norte river and it is considered part of its watershed. The whole population of the Coclé del Norte watershed was estimated in 2000 in 26,348 persons, most of them (94%) belong to the Coclé Province; population density is 16 persons per square kilometer. 73 % of the inhabitants live in towns with populations larger than 100 people. The rate of growth has varied in the last 30 years; from 1960 to 1970 it reached 3.7% per year while in the last decade (1990 to 2000) it slowed to 1.2% per year. This change is due largely to migration patterns.

No indigenous populations are reported in this area. Infant mortality is considered high compared to national standards (32 per 1000) although it has diminished in the last ten years. Illiteracy rate is 9% and is higher than the national average. Regarding the housing characteristics, 31 % of houses have access to potable water, 90% don't have electricity and 90% use wood for cooking.

Agriculture and cattle ranching are the main economic activities; per capita income falls below the extreme poverty level (less than 519 USD per year).

Pastures occupy more than 22% of the surface and the number of cows according to the census was 18,343, basically 2 hectares per cow, an indication of low productivity and mismanagement of resources. Basic crops are rice, corn and beans. Productivity of all of these staples is considered low when compared with national averages.

The regional gross product of the Cocle del Norte watershed was estimated in 4.3 millions USD for 2000. There is a lack of infrastructure in the area; the main roads are the ones connecting the Coclesito town with the Cocle Province. Medical services are distant (more than one hour of travel time for 80 % of the population) and only 50% of towns have some type of infrastructure.

2.2. Description of the direct impact area

The possible project area that could be affected (see table 5) has a population that varies from 1 601 persons for (NWL=100, MWL=105) to 1 145 persons for (NWL=90, MWL=95). This represents less than 6,1% of the population of the whole Cocle del Norte Watershed. The number of towns in the area is 21 at level 100, 20 at level 95, and 15 at level 90 and the number of houses amounts to: 349 at level 100, 316 at level 95 and 235 at level 90.

Table 5 - Social data for direct impact area

NWL masl	MWL masl	**Population**	Number towns	**Infrastructure**
90	95	1 145	15	295
95	100	1 345	20	402
100	105	1 601	21	447

It is important to notice that the highest alternative (**NWL 100**) will require 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 village of Banacito (123 people, i.e. 60%), and in the two villages of Lubre and Tulu Abajo, in the SW part of the reservoir.

The land is used predominately for cattle and annual agricultural crops. There are metallic mining concession requests in the area according to the Ministry of Industry and Commerce.

2.3. Major social impacts

The most important social impact would be the displacement of 1.145 persons at elevation 90 (NWL 90, MWL 95), 1.345 persons at elevation 95 (NWL 95, MWL 100) and 1.601 persons at elevation 100 (NWL 100, MWL 105), this last alternative including the 256 people of the village of Valle de San Miguel.

The consequences of involuntary resettlement in this area are associated with the fact that it is a rural population and land plays an important role as means of subsistence and the main asset of peasants. The movement from the affected land would disrupt the main activities of the population even under an appropriate resettlement program.

In the first year agricultural production could fall, and re-establishing production of some fruit trees and coffee may take longer (3 years). Livestock would also be affected unless land is provided in acceptable conditions for that type of activities.

Affected structures have been estimated at 447 for NWL 100, 402 for NWL 95 and 295 for NWL 90. Of these structures 349 are houses for NWL 100, 316 for NWL 95 and 235 for NWL 90. Of the remaining structures schools, churches, cemeteries could be considered the ones with higher values. For NWL 100 there are 34 of these structures while for NWL 95 and 90, 27 and 18 are accounted respectively.

Considering the conditions and construction materials of the area, the infrastructure is replaceable and the property loss can be mitigated.

Family and community ties will be under pressure particularly if following the project implementation, the affected people decide to migrate far form their original area. Psychological conditions are also altered since people have to begin a new adaptation process elsewhere.

During construction, the increase in workers from other locations brings different attitudes and behaviors that may affect not only people in the impact area but also in its surroundings. Also, the relocation itself may have effects in the new areas of resettlement.

Positive impacts for the population would be associated with the construction of roads that would break the isolation conditions of the region and could help in the development of a more productive agriculture. If a resettlement program is implemented with sufficient resources, social and economic conditions of the population could improve substantially.

3. SOCIO–ECONOMIC AND ENVIRONMENTAL MITIGATION AND COMPENSATION COST

Mitigation measures could be implemented once agreements with the affected communities have been reached. These could include payments for affected structure (individual and communal), assistance in relocation, indemnification payments per family (in the order of USD 25,000), and help in the acquisition of other lands. Mitigation for habitat loss has also been estimated and included.

A cost per alternative of the different elevations has been estimated. They are detailled in the Volume II A and reported in Table 6 :

Table 6 - Mitigation and Compensation Cost

NWL	MWL	Cost
90	95	USD 19 millions
95	100	USD 27 millions
100	105	USD 31 millions

PART XII – IMPLEMENTATION AND CONSTRUCTION SCHEDULES

PART XII – IMPLEMENTATION AND CONSTRUCTION SCHEDULES

1. IMPLEMENTATION SCHEDULE

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 others 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 (cf. Feasibility Report by MWH - 2003).

. moreover, ACP anticipates that the Toabre additional yield will be required to meet Navigation and M&I Demand maybe only 10 to 20 years after the implementation of Rio Indio Project.

In this context, none of the required steps for implementation should be on a critical path and will be launched as necessary. The next step should be the consideration / integration of the Toabre Project as part of the global Panama Canal Master Plan which should decide of its optimal date of completion.

This date will fix the date to launch the following major successive steps of the implementation schedule to guarantee the completion of the Project at the desired date, as presented on **Figure 1** with an estimated minimum period of 8 years:

- Final Design including necessary field investigations for confirmation and optimisation of the current Feasibility Design
- Environmental Studies, including Resettlement Plan (until completion of Project)
- Funding
- Tender Document for advertising and award phase
- Award of construction contracts
- Construction, scheduled in two separate Contracts :

  . Access Roads and Owner's Camp, which will start first and can be let to a local contractor

  . Dam and Transfer Tunnels awarded to a international contractor.

  implementation requires land acquisition. Lands for camp and facilities project features, which include the access roads, would be acquired initially. Lands for the dam site, tunnel and lake would then be acquired.

Construction schedule of the main component of the Project is presented hereafter.

2. CONSTRUCTION SCHEDULE

The schedule for construction of the Toabre Project is shown in **Figure 2**. It has been established from a starting year 1, not yet scheduled in the future.

The construction works including the construction of the Access Road, the Dam with its appurtenant works and the Transfer Tunnels are anticipated to take about 7 years.

2.1. Preparatory Works (Access Roads and Owner's Camp)

The mobilization of a local Contractor for these preparatory works should be rapid.

The improvement of the 12 km of existing road followed by the construction of 29 km of new road to the dam site, and the 16 km service road along the tunnel alignment is anticipated to require a minimum of 2 years of construction.

The construction of the camp will start so that its completion (less than one year) coincides with the completion of the main access road for an efficient start of the Main Contract.

2.2. Dam and Transfer Tunnels

This Contract should be awarded to coincide with the completion of the main access road and camp to allow an efficient start after the Notice to Proceed.

The completion of the works with an anticipated filling of the reservoir is planned 5 years after the award notification to the selected Contractor.

The major activities of this schedule are commented hereafter:

i.) Preliminary works

The preliminary works will start after the Notice to Proceed and will last 15 months. They include:

- mobilization of staff and equipment,
- construction of Contractor's camp and temporary access listed in Part X.
- rock quarries selection and preparation,

- installations including power supply, crushing plant, RCC and concrete plants etc…

  due to the lack of energy source in the vicinity of the site the Contractor will generate the required power by diesel generator,

  the crushing plant with an aggregate stockpile area will be established near the selected quarry,

  the RCC batching plant will be installed near the dam site area, probably on the flat downstream area of the right bank.

ii.) Dam

Works will start with the construction, on the naturally protected area on the Resumidero streambed, of the excavations to build the concrete diversion structure, to be achieved at the end of the second year. The cofferdams will then been installed at the beginning of the dry season of year 3, allowing the diversion of the Toabre River in the temporary openings for all the construction period.

The dam excavations, started at the end of year 2 will be finished at mid-year 4; consolidation grouting is made as the excavations progress. The foundation of the section in the riverbed will be excavated and prepared just after the diversion of the river.

The placement of the 2 millions m3 of the RCC dam body will start at the beginning of year 3 and is planned for two years with a reasonable average placement rate, considering the climatic conditions at the site : around 120 000 m^3/month during the four 'dry' months (January to April with work 20 h / d), reduced to 70 000 m3/month during the eight others wet months (placement during 12 h / d). That production requires a batching plant and delivery system with a capacity of around 800 ton/h (peak).

The construction of the spillway chute will follow the RCC progress; the construction of the concrete sill and the bridge will occur during the year 5.

The grout and drainage curtain can be executed from the perimetral gallery simultaneously with the RCC dam construction and are not on the critical path.

During the low flow season of year 5 the conversion works of two temporary opening of the diversion structure into the minimum release facility and the bottom outlet (and optional powerplant if retained) will be built, protected by upstream cofferdam placed in convenient location while the river continues to be diverted to the other openings.

iii.) Transfer tunnel Toabre to Indio

As already mentionned on Part X, it is assumed that the tunnel construction would utilise drill and blast technique from multiple headings. A minimum of two sloped construction adits are planned along the tunnel alignment, representing a total of 6 different excavation fronts which should be worked simultaneously (including inlet and outlet portals).

The advance rate of excavation greatly depends on the rock quality: it can vary from approximately 50 m per month in very poor ground (Type IV-V) to 200 m per month in the best ground (Type I). With the present assumed rock quality along the tunnel alignement an average rate of 100 m per month is assumed. As a result the excavation of the whole tunnel length (including adits) is planned for 3 years from the designed multiples headings.

In case of relatively uniform and good (to fair) rock formation, the alternative method with one (or two) Tunnel Boring Machine (TBM) could be economically adequate with a advance rate of 500 m/month. Further geological investigations are required to finalise the selection of the tunnelling method and the time required for construction.

Tunnel lining will be excecuted following the tunneling progress with a slight delay, section by section with an assumed advance rate of 300 m per month. A concrete batching plant will be installed close to the tunnel working areas.

The construction of the other structures, such as the two shafts and the installation of the corresponding hydromechanical equipment are not on the critical path of the tunnel construction works.

The total period of construction for the tunnel is anticipated to be about 4 years.

iv.) Reservoir filling

The reservoir filling can start at the beginning of the wet season of year 5 after the completion of the outlet structures, even before the completion of the transfer tunnel, provided that the inlet structures are completed and operational.

Due to the size of the reservoir (920 hm3) compared to the mean annual inflow (1 290 hm3/y) the filling of the reservoir should be completed (or nearly) at the end of this first wet season, with the completion of all the works.

FIGURE 1 - IMPLEMENTATION SCHEDULE

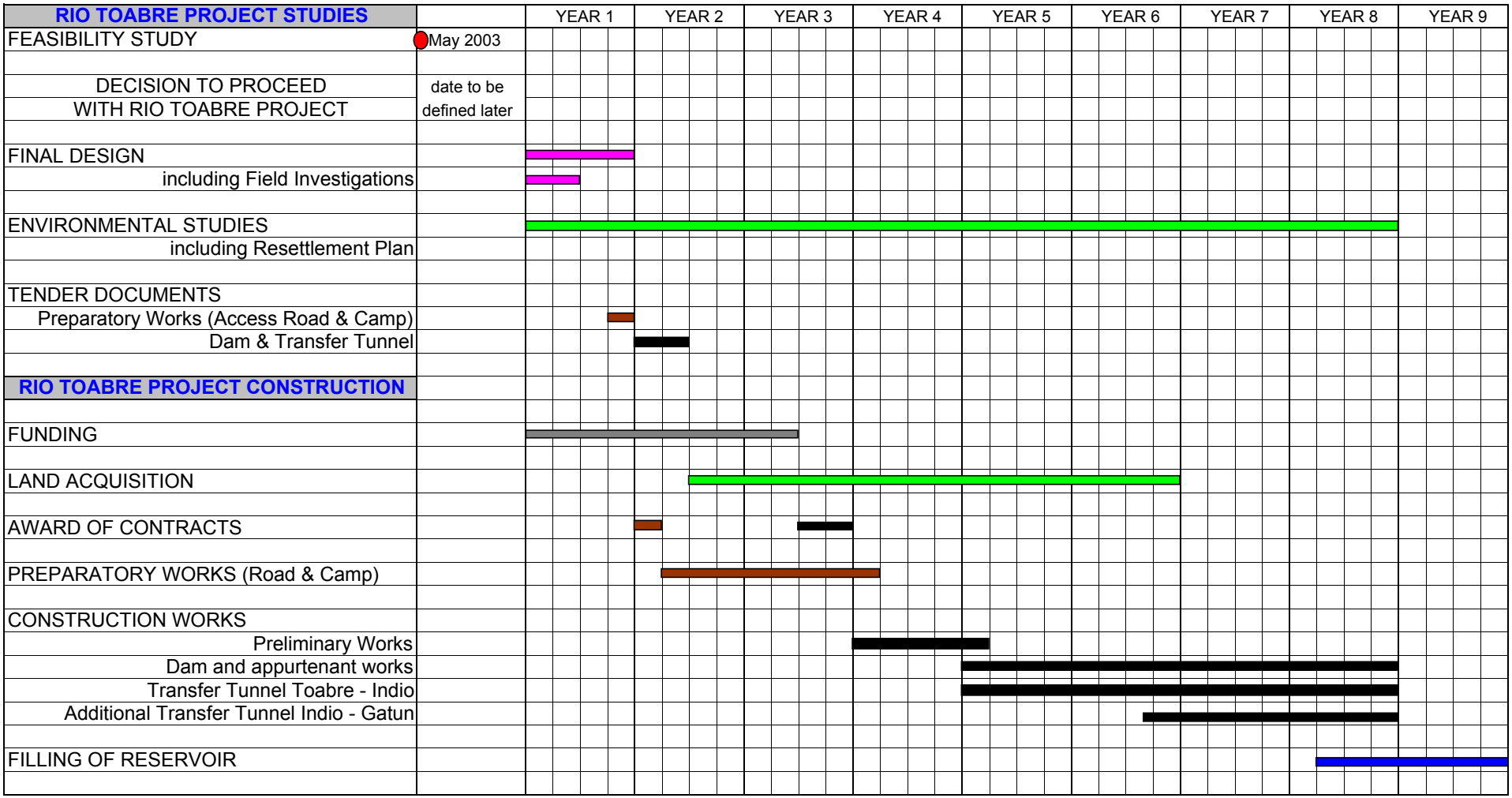
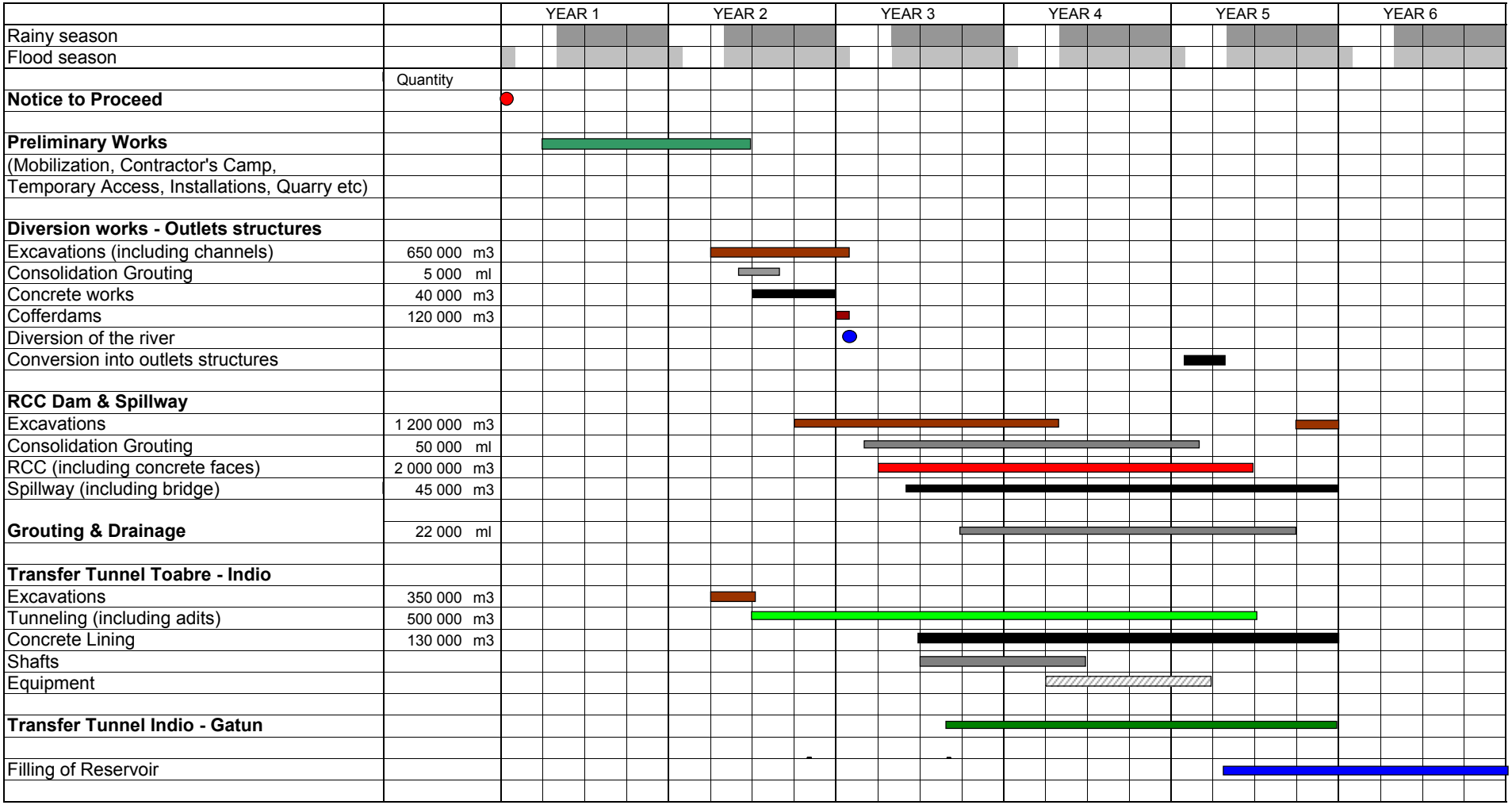


FIGURE 2 - CONSTRUCTION SCHEDULE



PART XIII – COST ESTIMATE

PART XIII – COST ESTIMATE

1. BASIS FOR ESTIMATES

The Project construction cost should include all items as civil works, equipment, access, camp, environmental costs (as resettlement and mitigation costs), contingencies, engineering and administration costs.

The costs of these different items have been estimated on the basis of the following principles, at a feasibility level.

1.1. Civil works

The cost of the civil works has been estimated on the basis of a series of unit prices for major construction elements adapted to the conditions of this study.

Such total unit prices are developed according to the 'aggregation method' based on the analyse of prices/costs of similar works (type/volumes) obtained from past and present international construction contracts. Aggregated unit prices are then derived from the unit prices indicated in the Bill of Quantities of such awarded construction contracts containing several hundreds of unit prices, which are consolidated to sort out the total cost of the works and adjusted to current prices representative of the Toabre Project works.

These aggregated prices include all direct and indirect construction costs relating to: labour, materials, equipment, installations, overheads etc. Application of these prices to a limited number of representative items provides a correct estimate of the project construction cost This aggregation method is of common use in Europe to estimate the cost of projects at a conceptual design stage and even in more detailed study stages.

A series of such total unit prices representing local conditions for the project has been prepared on the basis of several recent construction market prices for engineering structures and recent studies of a type and size similar to those involved for Toabre dam. Among the main data used to establish such unit price list it can be pointed out :

. the detailed 'aggregated' unit price study recently performed by Coyne et Bellier as part of the 'Diseño Conceptual de las Esclusas Post Panamax' study for ACP (ref. R4-M-601 Rev B - Task 4), on the base of several recent construction awarded contracts, and including a RCC unit price analysis. Major features of this study are presented in Appendix – Cost Estimate – Appendix A.

. the cost estimate of a 4 MCM RCC Dam in Guinea with a RCC analytical price study in collaboration with an international Contractor in similar conditions (labour, material, importation of cement and flyash etc…).

. two recent contracts awarded in Guatemala.

. in addition the unit prices developed in the Feasibility study of Rio Indio Project performed by MWH has been looked to check the consistency of such list.

In particular the RCC price take into account the facts that the aggregates (as for conventional concrete) will be manufactured on site by crushing rock material obtained from excavation (selection) and authorized quarries (main source of andesite), while the cement could be available within the Republic of Panama and the concrete additives and cement replacement (fly ash, etc.) would be imported.

The following aggregate prices were finally used for cost estimate at this feasibility stage :

Item	Unit	Unit Price (USD)
Clearing	m^2	1
Overburden Excavation	m^3	3
Rock Excavation	m^3	10
Transfer Tunnel Excavation (including supports)	m^3	100
Adit (all included)	m^3	150
Shaft Excavation (including supports)	m^3	200
Cofferdam fill	m^3	7
Rolled Compacted Concrete (RCC)	m^3	40
Conventional Vibrated Concrete (CVC)		
CVC for RCC Dam Faces	m^3	150
CVC for Spillway	m^3	160
Levelling CVC	m^3	150
Mass CVC	m^3	100
CVC for Structures	m^3	170
Underground CVC	m^3	200 to 235
Formwork	m²	25 to 30
Tunneling Forwork	m²	25
Underground Formwork	m²	50
Reinforcement bars	kg	1.2
Consolidation Grouting	ml	120
Grout Curtain	ml	135
Drainage curtain	ml	100
Crest road	m²	10

1.2. Equipment

Major metal items and supplies (hydraulic gates, embedded metal etc.) would be fabricated outside the Republic of Panama and imported for final assembly and installation on sites.

The cost of equipment has been estimated item by item from a preliminary estimation of weight and type of gate / weight relationship. For practical reason the cost of these equipement (low compared to the total) have been integrated in the cost of the civil works of the corresponding structures.

1.3. Access road and Owner's camp

Estimates for the access road are based on the prices provided and used by ACP for corresponding works in the Environmental Impacts Study : 125 000 USD / km for permanent asphaltic road and 75 000 USD / km for permanent gravel road.

Estimates for the camp are based on the prices of contracts for the corresponding work in similar projects.

1.4. Environment & Resettlement

A special study of environmental costs was carried out by ACP, as presented in Part XI.

1.5. Contingencies

Provision is made for contingencies with a certain percentage of the cost of the items considered; these percentages vary from 10% to 20%, depending on the type of works. As a regular practice, 20% was used on civil wprks, 15% on access roads and Owner's camp and 10% on environmental and social costs.

1.6. Engineering and administration

The cost of engineering services and administration is calculated as a percentage (15%) of the total for each item, including contingencies.

2. COST ESTIMATE

2.1. Toabre Project - Civil works & Equipment

Application of the unit prices listed above to the various quantities estimated [1] from the feasibility engineering drawings (with a NWL at El. 95 masl) gives the project construction costs detailed in Tables 1 to 3 for the Dam and Appurtenants Works (at respective NWL) and in Table 4 for the 5 m diameter common Transfer Tunnel.

These costs are summarised as follows (in MUSD):

Structures	NWL 90	NWL 95	NWL 100
RCC Dam	89.60	101.35	115.00
Spillway	9.60	10.00	10.45
Diversion Works	13.70	13.70	13.70
Outlet Structures	1.95	1.95	1.95
Hydropower Plant	2.75	2.75	2.75
Grouting and Drainage	8.45	9.20	10.30
Miscellaneous	6.30	6.95	7.70
Sub Total Dam & Appurtenant Works (MUSD)	**132.35**	**145.90**	**161.85**
Toabre – Indio Transfer Tunnel	id	98.30	id
Miscellaneous	id	4.90	id
Sub Total Transfer Tunnel (MUSD)	**id**	**103.20**	**id**
TOTAL CIVIL WORKS & EQUIPMENT (MUSD)	**235**	**249**	**265**

Figure 1 presents the evolution of the sub-total and total costs of the civil works & equipment with the reservoir NWL.

Note : the variation of the cost of the transfer tunnel in function of the finished diameter has been established (see Appendix – Cost Estimate – Appendix B) for eventual further optimisation of combination 'Reservoir NWL / Tunnel Diameter. It is summarized as follows:

Tunnel diameter (finished)	4.0	4.5	5.0	5.5
Cost (MUSD)	80	92	103	115

(1) with the expressed reserves on foundation level or rock quality due to the lack of sufficient geological knowledge (delay of the recommended boreholes campaign).

2.2. Access Road & Owner's Camp

The cost estimate of the access road and the Owner's camp is as follows:

Item	Unit	Quantity	Unit Price (USD/unit)	Total Cost (MUSD)
Construction of asphaltic road from improvement of existing track	km	12	125 000	1.5
Construction of new asphaltic road	km	29	125 000	3.6
Construction of new service gravel road	km	16	75 000	1.2
Total for Access Road		**57**		**6.3**
Owner's Camp				**4.0**

2.3. Total Cost

The following tables sum up all the investment costs for the Rio Toabre Water Transfer Project as determined in accordance with the above outline, for the three envisaged reservoir alternatives NWL 90, NWL 95 and NWL 100 masl :

Designation	Cost	Contingencies	Eng. & Admin. (15%)	TOTAL (MUSD)
Dam & Appurtenant works	132.0	26.5 (20%)	23.8	182.3
Transfer Tunnel Toabre – Indio	103.0	20.5 (20%)	18.6	142.1
Access Road & Owner's Camp	10.3	1.5 (15%)	1.8	13.6
Environmental Costs	19.0	1.9 (10%)	3.1	24.0
TOTAL COST	**264**	**50.4**	**47.3**	**362**

Total cost of the operation – TOABRE NWL 90 masl

Designation	Cost	Contingencies	Eng. & Admin. (15%)	TOTAL (MUSD)
Dam & Appurtenant works	146.0	29.2 (20%)	26.3	201.5
Transfer Tunnel Toabre – Indio	103.0	20.5 (20%)	18.6	142.1
Access Road & Owner's Camp	10.3	1.5 (15%)	1.8	13.6
Environmental Costs	27.0	2.7 (10%)	4.5	34.2
TOTAL COST	**286.3**	**53.9**	**51.2**	**391.4**

Total cost of the operation – TOABRE NWL 95 masl

Designation	Cost	Contingencies	Eng. & Admin. (15%)	TOTAL (MUSD)
Dam & Appurtenant works	162.0	32.4 (20%)	29.2	223.6
Transfer Tunnel Toabre – Indio	103.0	20.5 (20%)	18.6	142.1
Access Road & Owner's Camp	10.3	1.5 (15%)	1.8	13.6
Environmental Costs	31.0	3.1 (10%)	5.1	39.2
TOTAL COST	**306.3**	**57.5**	**54.7**	**418.5**

Total cost of the operation – TOABRE NWL 100 masl

3. PROJECT CONSTRUCTION COST (MUSD – 2003)

Normal Water Level	**90**	**95**	**100**
• *Dam & Appurtenant Civil Works*	132	146	162
• *Toabre / Indio Tunnel Civil Works*	103	103	103
• *Access Road / Owner's Camp*	10.3	10.3	10.3
• *Environmental and Social Costs*	19	27	31
Cost of Works (MUSD)	264.3	286.3	306.3
• *Contingencies*	50.4	53.9	57.5
Direct Cost (MUSD)	314.7	340.2	363.8
• *Engineering / Administration*	47.3	51.2	54.7
Construction Cost (MUSD – 2003)	362	391.4	418.5

4. ANNUAL COST

The annual operating costs include the costs of Operation and Maintenance for the various features, administration by the Owner and insurance.

The Operation and Maintenance for the dam and water transfer tunnel was estimated, according to practice, as 0,4% of the Construction Cost.

Administration and general annual expenses of the Owner was estimated as 25% of Operation and Maintenance annual cost.

The annual cost of insurance was estimated as 0,1% of the Construction Cost.

The annual Operation and Maintenance costs are summarized as below:

ITEM	ANNUAL COST
Operation and Maintenance	1 560 000
Administration and General Expenses	390 000
Insurance	390 000
Annual Cost (USD)	2 340 000

PART XIII – TABLES & FIGURES

(this part has 6 pages)

TABLES

Civil Works & Equipment

TABLE 1 Construction Cost Toabre NWL 90 – Dam & Appurtenant Works
TABLE 2 Construction Cost Toabre NWL 95 – Dam & Appurtenant Works
TABLE 3 Construction Cost Toabre NWL 100 – Dam & Appurtenant Works
TABLE 4 Construction Cost Toabre NWL 90-95-100 – Transfer Tunnel

FIGURES

FIGURE 1 Evolution of Civil works & Equipment Costs vs. NWL

TABLE 1 - TOABRE PROJECT NWL 90 - CONSTRUCTION COST
Dam & Appurtenant Works Civil Works & Equipment

Designation	unit	Quantity	Unit price USD/unit	Cost USD
RCC Dam				
Clearing	m2	100 000	1	100 000
Overburden Excavations	m3	550 000	3	1 650 000
Rock Excavations	m3	320 000	10	3 200 000
RCC	m3	1 750 000	40	70 000 000
Levelling CVC	m3	11 000	150	1 650 000
CVC U/S facing	m3	46 000	150	6 900 000
CVC D/S facing	m3	17 000	150	2 550 000
Formwork	m²	96 000	25	2 400 000
Steel Reinforcement	t	900	1 200	1 080 000
Crest road	m²	6 500	10	65 000
sub total RCC Dam			*USD*	*89 595 000*
Spillway (excluding RCC)				
Clearing	m2	20 000	1	20 000
Overburden Excavations	m3	170 000	3	510 000
Rock Excavations	m3	100 000	10	1 000 000
CVC	m3	36 000	160	5 760 000
Formwork	m²	26 000	25	650 000
Steel Reinforcement	t	710	1 200	852 000
Bridge	ls	1	800 000	800 000
sub total Spillway			*USD*	*9 592 000*
Diversion works				
Clearing	m2	60 000	1	60 000
Overburden Excavations	m3	350 000	3	1 050 000
Rock Excavations	m3	250 000	10	2 500 000
Cofferdam fill	m3	120 000	7	840 000
Mass CVC	m3	13 000	100	1 300 000
CVC structures	m3	34 000	170	5 780 000
Formwork	m²	16 000	30	480 000
Steel Reinforcement	t	1 400	1 200	1 680 000
sub total Diversion Works			*USD*	*13 690 000*
Outlets structures (2d phase)				
CVC plug	m3	3 000	150	450 000
CVC structures	m3	2 500	170	425 000
Formwork	m²	2 000	30	60 000
Steel Reinforcement	t	100	1 200	120 000
Equipment				
Trashrack 3 x 3	ls	1	10 000	10 000
Stoplog 1.4 x 1.4	ls	1	10 000	10 000
Butterfly valve ϕ 700	ls	1	50 000	50 000
Hollow jet ϕ 600	ls	1	100 000	100 000
Steel pipe ϕ 700	ls	1	100 000	100 000
Wheel gate 2.7 x 1.9	ls	1	150 000	150 000
Radial gate 2.4 x 1.9	ls	1	170 000	170 000
Steel lining	ls	1	300 000	300 000
sub total Outlet Structures			*USD*	*1 945 000*
Hydropower Plant (2d phase)				
CVC structures	m3	1 000	170	170 000
Formwork	m²	1 200	30	36 000
Steel Reinforcement	t	50	1 200	60 000
Building	ls	1	200 000	200 000
Equipment				
Wheel gate 2 x 1.8	ls	1	100 000	100 000
Penstock ϕ 1600	ls	1	200 000	200 000
Generating set	ls	1	2 000 000	2 000 000
sub total Powerplant			*USD*	*2 766 000*
Grouting & Drainage				
Consolidation grouting	ml	50 000	120	6 000 000
Grout curtain	ml	11 000	135	1 485 000
Drainage curtain	ml	9 500	100	950 000
sub total Grouting & Drainage			*USD*	*8 435 000*
Sub Total Dam & Appurt. Works			***USD***	***126 023 000***
Miscellaneous works	5%		***USD***	***6 301 150***
Total Dam & Appurt. Works			**USD**	***132 324 150***

TABLE 2 - TOABRE PROJECT NWL 95 - CONSTRUCTION COST
Dam & Appurtenant Works Civil Works & Equipment

Designation	unit	Quantity	Unit price USD/unit	Cost USD
RCC Dam				
Clearing	m2	120 000	1	120 000
Overburden Excavations	m3	600 000	3	1 800 000
Rock Excavations	m3	350 000	10	3 500 000
RCC	m3	2 000 000	40	80 000 000
Levelling CVC	m3	12 000	150	1 800 000
CVC U/S facing	m3	50 000	150	7 500 000
CVC D/S facing	m3	18 500	150	2 775 000
Formwork	m²	105 000	25	2 625 000
Steel Reinforcement	t	975	1 200	1 170 000
Crest road	m²	6 500	10	65 000
sub total RCC Dam			*USD*	*101 355 000*
Spillway (excluding RCC)				
Clearing	m2	20 000	1	20 000
Overburden Excavations	m3	170 000	3	510 000
Rock Excavations	m3	100 000	10	1 000 000
CVC	m3	38 000	160	6 080 000
Formwork	m²	28 000	25	700 000
Steel Reinforcement	t	750	1 200	900 000
Bridge	ls	1	800 000	800 000
sub total Spillway			*USD*	*10 010 000*
Diversion works				
Clearing	m2	60 000	1	60 000
Overburden Excavations	m3	350 000	3	1 050 000
Rock Excavations	m3	250 000	10	2 500 000
Cofferdam fill	m3	120 000	7	840 000
Mass CVC	m3	13 000	100	1 300 000
CVC structures	m3	34 000	170	5 780 000
Formwork	m²	16 000	30	480 000
Steel Reinforcement	t	1 400	1 200	1 680 000
sub total Diversion Works			*USD*	*13 690 000*
Outlets structures (2d phase)				
CVC plug	m3	3 000	150	450 000
CVC structures	m3	2 500	170	425 000
Formwork	m²	2 000	30	60 000
Steel Reinforcement	t	100	1 200	120 000
Equipment				
Trashrack 3 x 3	ls	1	10 000	10 000
Stoplog 1.4 x 1.4	ls	1	10 000	10 000
Butterfly valve ϕ 700	ls	1	50 000	50 000
Hollow jet ϕ 600	ls	1	100 000	100 000
Steel pipe ϕ 700	ls	1	100 000	100 000
Wheel gate 3 x 2	ls	1	150 000	150 000
Radial gate 2.7 x 2	ls	1	170 000	170 000
Steel lining	ls	1	300 000	300 000
sub total Outlet Structures			*USD*	*1 945 000*
Hydropower Plant (2d phase)				
CVC structures	m3	1 000	170	170 000
Formwork	m²	1 200	30	36 000
Steel Reinforcement	t	50	1 200	60 000
Building	ls	1	200 000	200 000
Equipment				
Wheel gate 2 x 1.8	ls	1	100 000	100 000
Penstock ϕ 1600	ls	1	200 000	200 000
Generating set	ls	1	2 000 000	2 000 000
sub total Powerplant			*USD*	*2 766 000*
Grouting & Drainage				
Consolidation grouting	ml	55 000	120	6 600 000
Grout curtain	ml	12 000	135	1 620 000
Drainage curtain	ml	10 000	100	1 000 000
sub total Grouting & Drainage			*USD*	*9 220 000*
Sub Total Dam & Appurt. Works			***USD***	***138 986 000***
Miscellaneous works	5%		***USD***	***6 949 300***
Total Dam & Appurt. Works			**USD**	***145 935 300***

TABLE 3 - TOABRE PROJECT NWL 100 - CONSTRUCTION COST
Dam & Appurtenant Works Civil Works & Equipment

Designation	unit	Quantity	Unit price USD/unit	Cost USD
RCC Dam				
Clearing	m2	130	1	130
Overburden Excavations	m3	650 000	3	1 950 000
Rock Excavations	m3	380 000	10	3 800 000
RCC	m3	2 300 000	40	92 000 000
Levelling CVC	m3	13 000	150	1 950 000
CVC U/S facing	m3	54 000	150	8 100 000
CVC D/S facing	m3	20 000	150	3 000 000
Formwork	m²	115 000	25	2 875 000
Steel Reinforcement	t	1 075	1 200	1 290 000
Crest road	m²	7 350	10	73 500
sub total RCC Dam			*USD*	*115 038 630*
Spillway (excluding RCC)				
Clearing	m2	20 000	1	20 000
Overburden Excavations	m3	170 000	3	510 000
Rock Excavations	m3	100 000	10	1 000 000
CVC	m3	40 000	160	6 400 000
Formwork	m²	30 000	25	750 000
Steel Reinforcement	t	800	1 200	960 000
Bridge	ls	1	800 000	800 000
sub total Spillway			*USD*	*10 440 000*
Diversion works				
Clearing	m2	60 000	1	60 000
Overburden Excavations	m3	350 000	3	1 050 000
Rock Excavations	m3	250 000	10	2 500 000
Cofferdam fill	m3	120 000	7	840 000
Mass CVC	m3	13 000	100	1 300 000
CVC structures	m3	34 000	170	5 780 000
Formwork	m²	16 000	30	480 000
Steel Reinforcement	t	1 400	1 200	1 680 000
sub total Diversion Works			*USD*	*13 690 000*
Outlets structures (2d phase)				
CVC plug	m3	3 000	150	450 000
CVC structures	m3	2 500	170	425 000
Formwork	m²	2 000	30	60 000
Steel Reinforcement	t	100	1 200	120 000
Equipment				
Trashrack 3 x 3	ls	1	10 000	10 000
Stoplog 1.4 x 1.4	ls	1	10 000	10 000
Butterfly valve ϕ 700	ls	1	50 000	50 000
Hollow jet ϕ 600	ls	1	100 000	100 000
Steel pipe ϕ 700	ls	1	100 000	100 000
Wheel gate 3.2 x 2.2	ls	1	150 000	150 000
Radial gate 2.9 x 2.2	ls	1	170 000	170 000
Steel lining	ls	1	300 000	300 000
sub total Outlet Structures			*USD*	*1 945 000*
Hydropower Plant (2d phase)				
CVC structures	m3	1 000	170	170 000
Formwork	m²	1 200	30	36 000
Steel Reinforcement	t	50	1 200	60 000
Building	ls	1	200 000	200 000
Equipment				
Wheel gate 2 x 1.8	ls	1	100 000	100 000
Penstock ϕ 1600	ls	1	200 000	200 000
Generating set	ls	1	2 000 000	2 000 000
sub total Powerplant			*USD*	*2 766 000*
Grouting & Drainage				
Consolidation grouting	ml	60 000	120	7 200 000
Grout curtain	ml	14 000	135	1 890 000
Drainage curtain	ml	12 000	100	1 200 000
sub total Grouting & Drainage			*USD*	*10 290 000*
Sub Total Dam & Appurt. Works			***USD***	***154 169 630***
Miscellaneous works	5%		***USD***	***7 708 482***
Total Dam & Appurt. Works			**USD**	***161 878 112***

TABLE 4 - TOABRE PROJECT NWL 90-95-100 - CONSTRUCTION COST

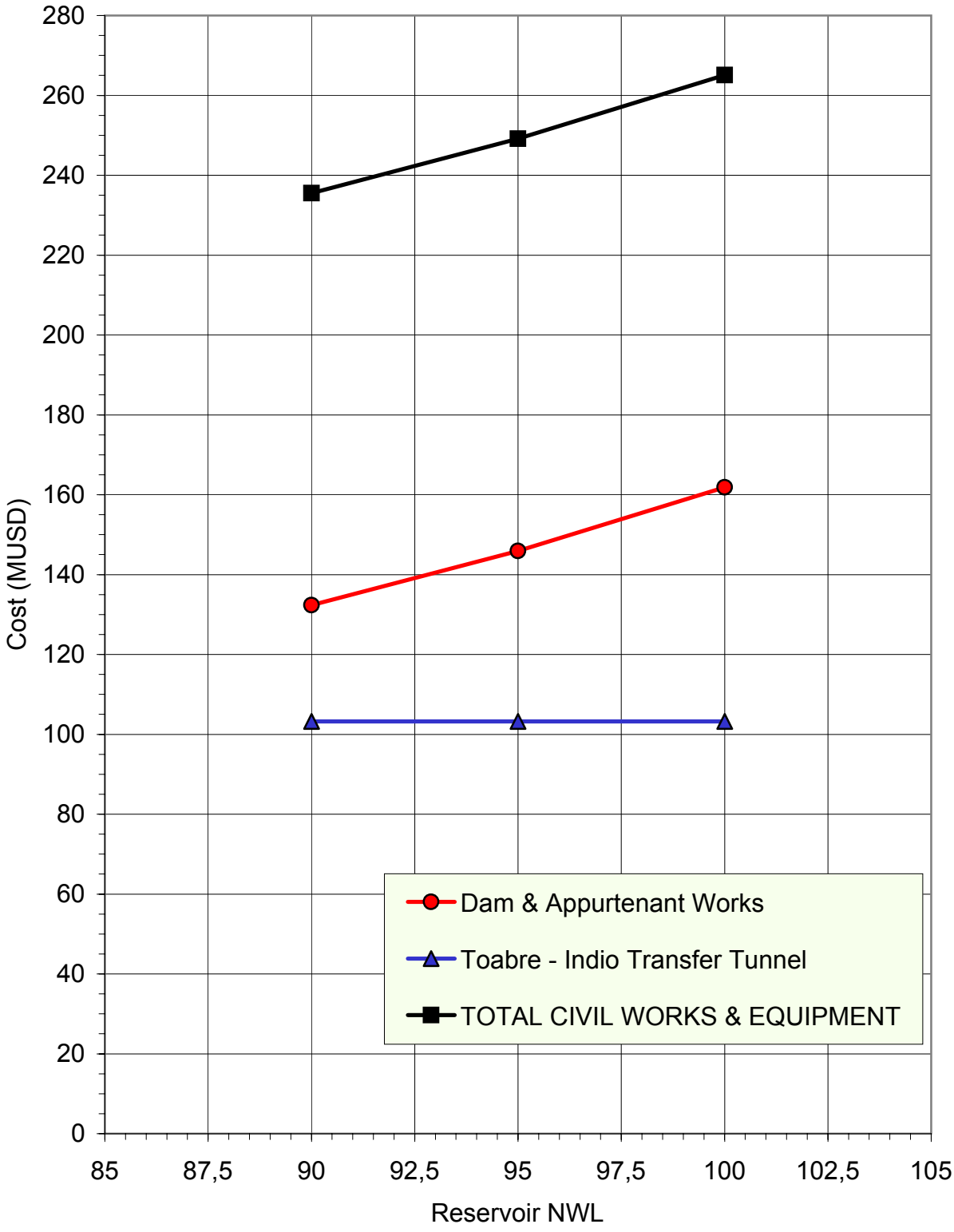
Transfer Tunnel Toabre - Indio Civil Works & Equipment

Designation	unit	Quantity	Unit price USD/unit	Cost USD
Transfer Tunnel				
Inlet Structures				
Clearing	m2	15 000	1	15 000
Overburden Excavations	m3	120 000	3	360 000
Rock Excavations	m3	60 000	10	600 000
Shaft excavation	m3	3 500	200	700 000
CVC	m3	1 500	235	352 500
Formwork	m^2	1 800	50	90 000
Steel Reinforcement	t	75	1 200	90 000
Bonneted gate 4 x 3	ls	2	300 000	600 000
Transfer Tunnel				
Adits	m3	30 000	150	4 500 000
Tunnel Excavations	m3	500 000	100	50 000 000
Concrete lining	m3	130 000	200	26 000 000
Formwork	m^2	200 000	25	5 000 000
Steel Reinforcement	t	6 500	1 200	7 800 000
Outlet Structures				
Clearing	m2	15 000	1	15 000
Overburden Excavations	m3	120 000	3	360 000
Rock Excavations	m3	60 000	10	600 000
Shaft excavation	m3	3 000	200	600 000
CVC	m3	800	235	188 000
Formwork	m^2	1 400	50	70 000
Steel Reinforcement	t	40	1 200	48 000
Bonneted gate 4 x 3	ls	1	300 000	300 000
Sub Total Transfer Tunnel			***USD***	***98 288 500***
Miscellaneous works	5%		***USD***	***4 914 425***
Total Transfer Tunnel			**USD**	***103 202 925***

FIGURE 1 - RIO TOABRE PROJECT

CONSTRUCTION COSTS - CIVIL WORKS & EQUIPMENT

(excluding Contingencies, Engineering & Administration)



ACP
AUTORIDAD DEL CANAL DE PANAMÁ

RIO TOABRE WATER TRANSFER PROJECT

Feasibility Study

FEASIBILITY REPORT

VOLUME III - DRAWINGS

COYNE ET BELLIER
Bureau d'Ingénieurs Conseils
PARIS - FRANCE

Ref 10932 RP 06 - June 2003

RIO TOABRE WATER TRANSFER PROJECT

Feasibility Study

FEASIBILITY REPORT

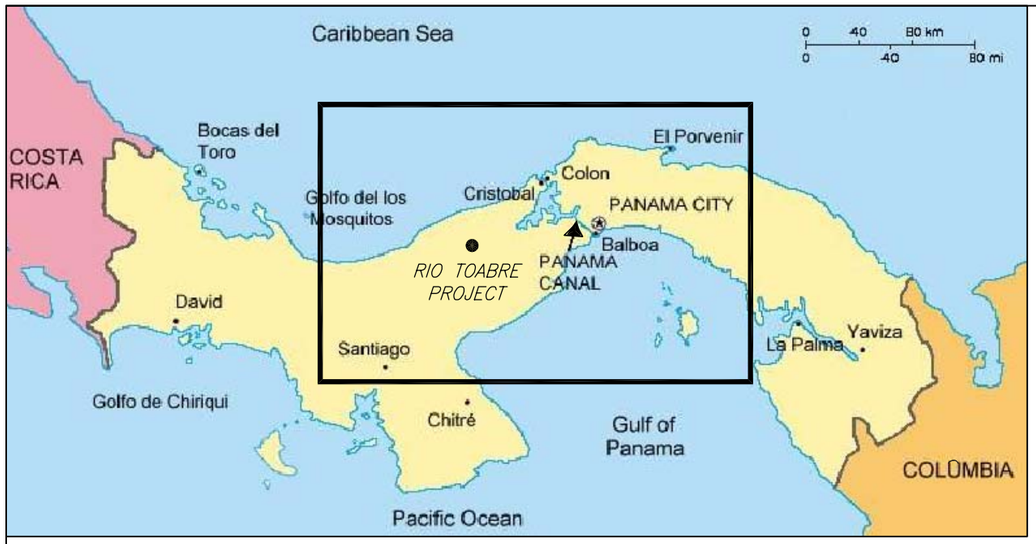
VOLUME III – DRAWINGS

Report n° 10932 RP 06

COYNE ET BELLIER
Bureau d'Ingénieurs Conseils

PROJECT

10-300	Project Location
10-301	General Plan of Development
10-302	Dam – Plan View and Downstream Elevation
10-303	RCC Dam – Typical Cross Section and Details
10-304	Spillway - Typical Cross Section and Details
10-305	Bottom Outlet and River Outlet – Sections and Details
10-306	Diversion Works – General Principles
10-307	Diversion Structures – Plan View ans Sections
10-308	Grouting and Drainage – Elevation and Sections
10-309	Optional Hydropowerplant – Section and Details
10-310	Transfer Tunnel – General Layout and Longitudinal Section
10-311	Transfer Tunnel – Typical Sections
10-312	Transfer Tunnel – Intake Structures – Sections and Details
10-313	Transfer Tunnel – Outlet Structures – Sections and Details



B	MAY 2003	GTR	JMV	JCO	FINAL EMISSION	
A	MAR. 2003	MHL	JMV	JMV	First Emission	
Revis.	DATE	DRAWN BY	CHECKED BY	APPROVED BY	NATURE OF REVISION	STATUS

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

ACP AUTORIDAD DEL CANAL DE PANAMÁ

RIO TOABRE WATER TRANSFER PROJECT
FEASIBILITY STUDY

PROJECT LOCATION

Scale : 1/500 000	Format : A3	Plate : 1/1	Project N° : 10932	Revision
COYNE ET BELLIER Bureau d'Ingénieurs Conseils	Computer File : 10-300B.dwg		No : 1,0,3,0,0	B

INDIO DAM

RIO INDIO
RESERVOIR
N.W.L. 80.00

POSSIBLE LIAISON
TO INDIO DAM

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.

C	JUNE 2003	CTR	JMV	JCO	MODIFIED SERVICE ROAD	
B	MAY 2003	CTR	JMV	JCO	FINAL EMISSION	
A	MAR 2003	CTR	JMV	JMV	First Emission	
Revis.	DATE	DRAWN BY	CHECKED BY	APPROVED BY	NATURE OF REVISION	STATUS

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

ACP AUTORIDAD DEL CANAL DE PANAMA

RIO TOABRE WATER TRANSFER PROJECT
FEASIBILITY STUDY

GENERAL PLAN OF DEVELOPMENT

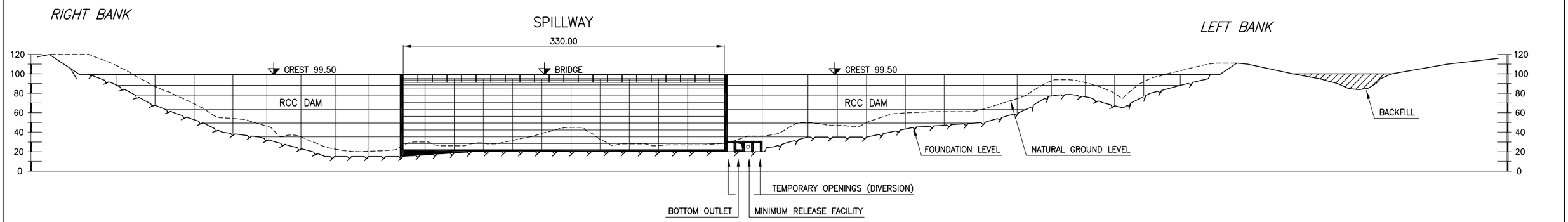
COYNE ET BELLIER
Bureau d'Ingénieurs Conseils
Ingenieurs - Raadgevers

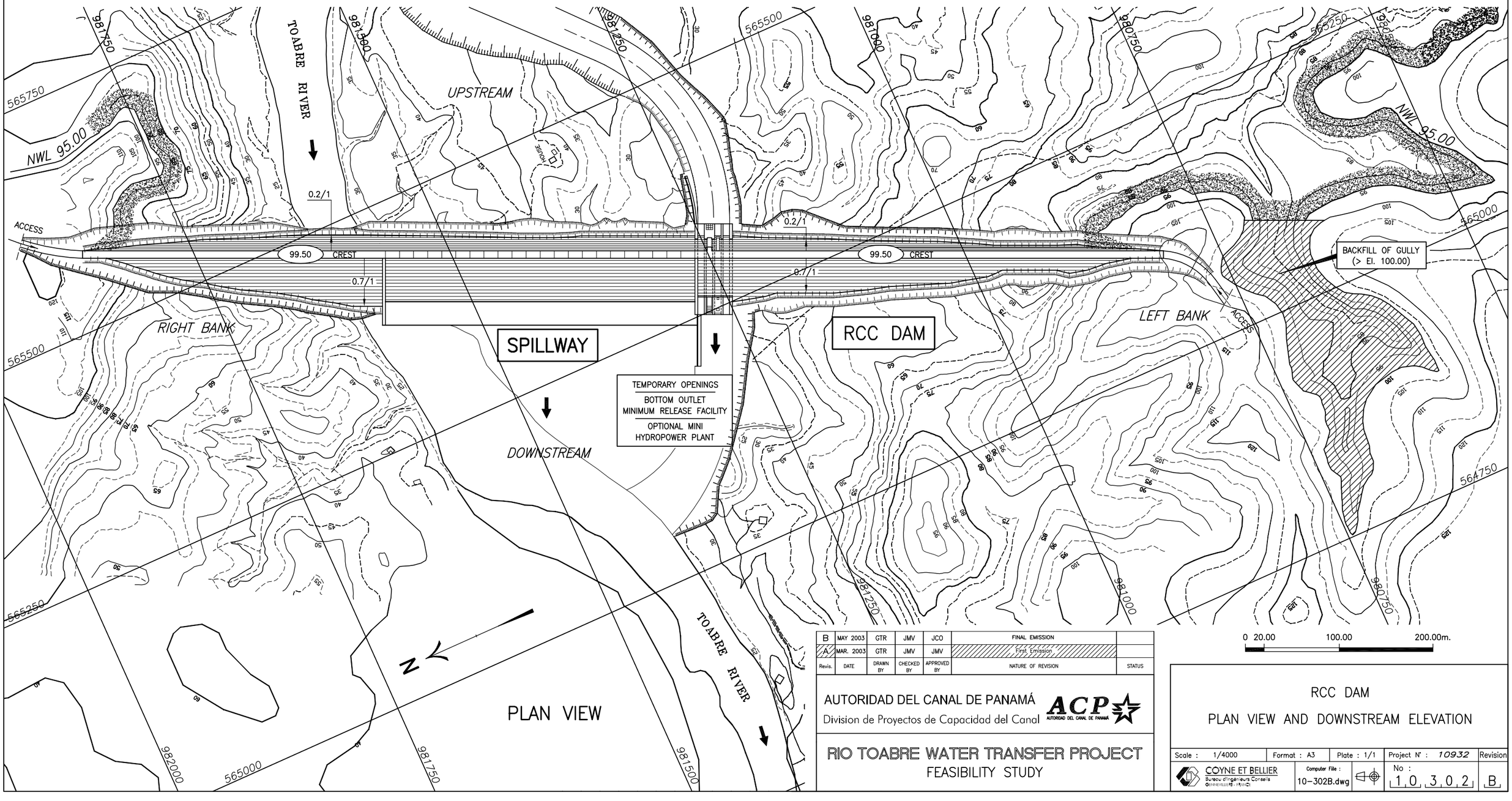
Scale :	Format :	Plate :	Project N° :	Revision
1/100 000	A3	1/1	10932	

Computer File: 10-3010.dwg

No : 1.0.3.0.1. C.

DOWNSTREAM ELEVATION





PLAN VIEW

Revis.	DATE	DRAWN BY	CHECKED BY	APPROVED BY	NATURE OF REVISION	STATUS
B	MAY 2003	GTR	JMV	JCO	FINAL EMISSION	
A	MAR. 2003	GTR	JMV	JMV	First Emission	

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

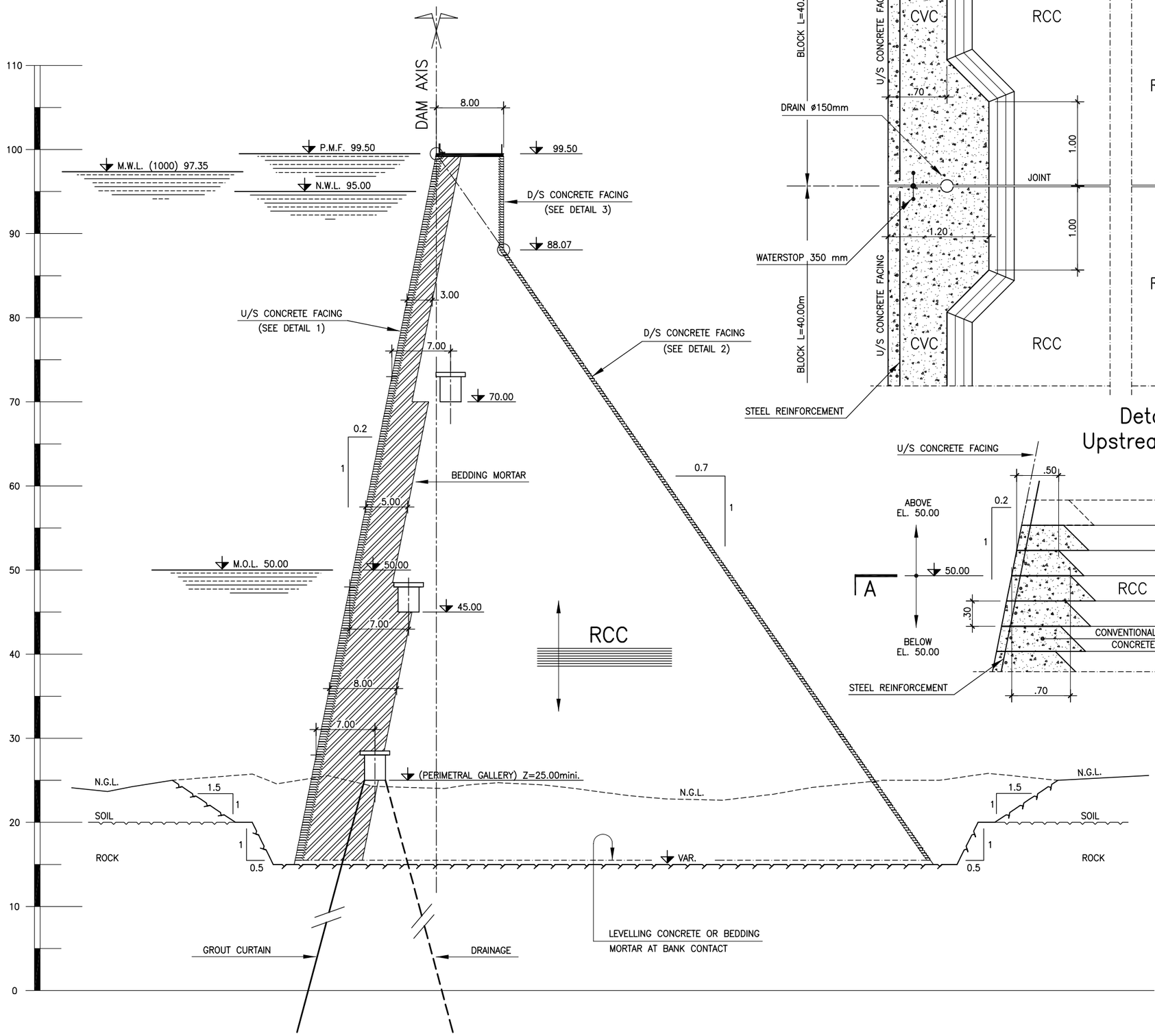
ACP AUTORIDAD DEL CANAL DE PANAMÁ

RIO TOABRE WATER TRANSFER PROJECT
FEASIBILITY STUDY

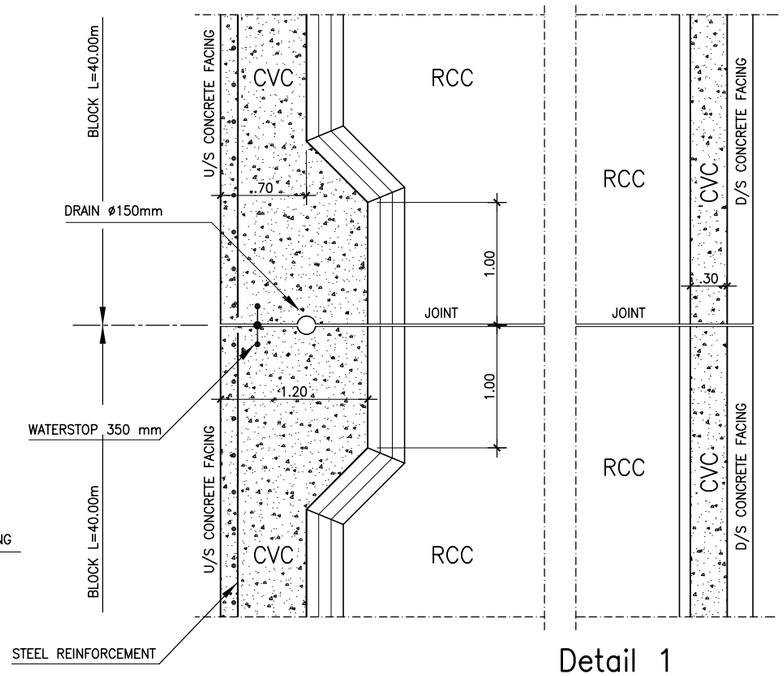
RCC DAM
PLAN VIEW AND DOWNSTREAM ELEVATION

Scale : 1/4000	Format : A3	Plate : 1/1	Project N° : 10932	Revision
COYNE ET BELLIER Bureau d'Ingénieurs Conseils GENNEVILLIERS - FRANCE	Computer File : 10-302B.dwg		No : 10302	B

RCC DAM SECTION

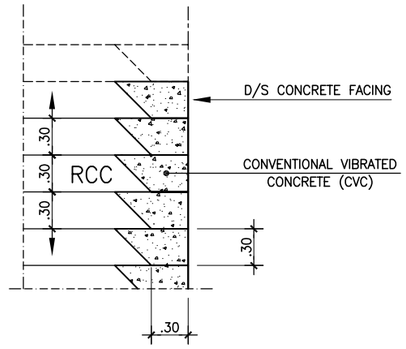


SECTION A–A Facing on Joints

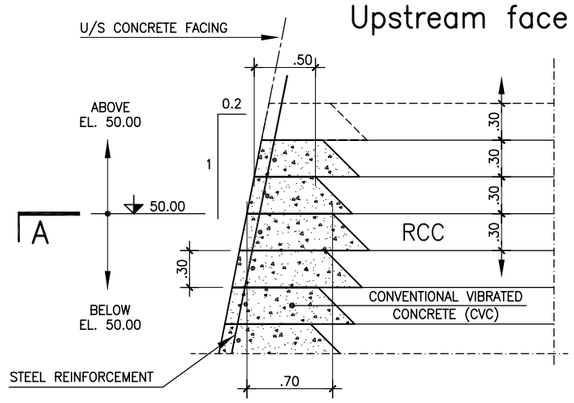


0 25 1.00 2.00 m

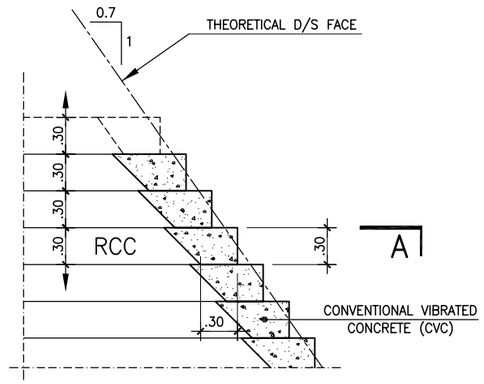
Detail 3
Downstream face



Detail 1
Upstream face



Detail 2
Downstream face



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A	MAR. 2003	GTR	JMV	JMV	First Emission	

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

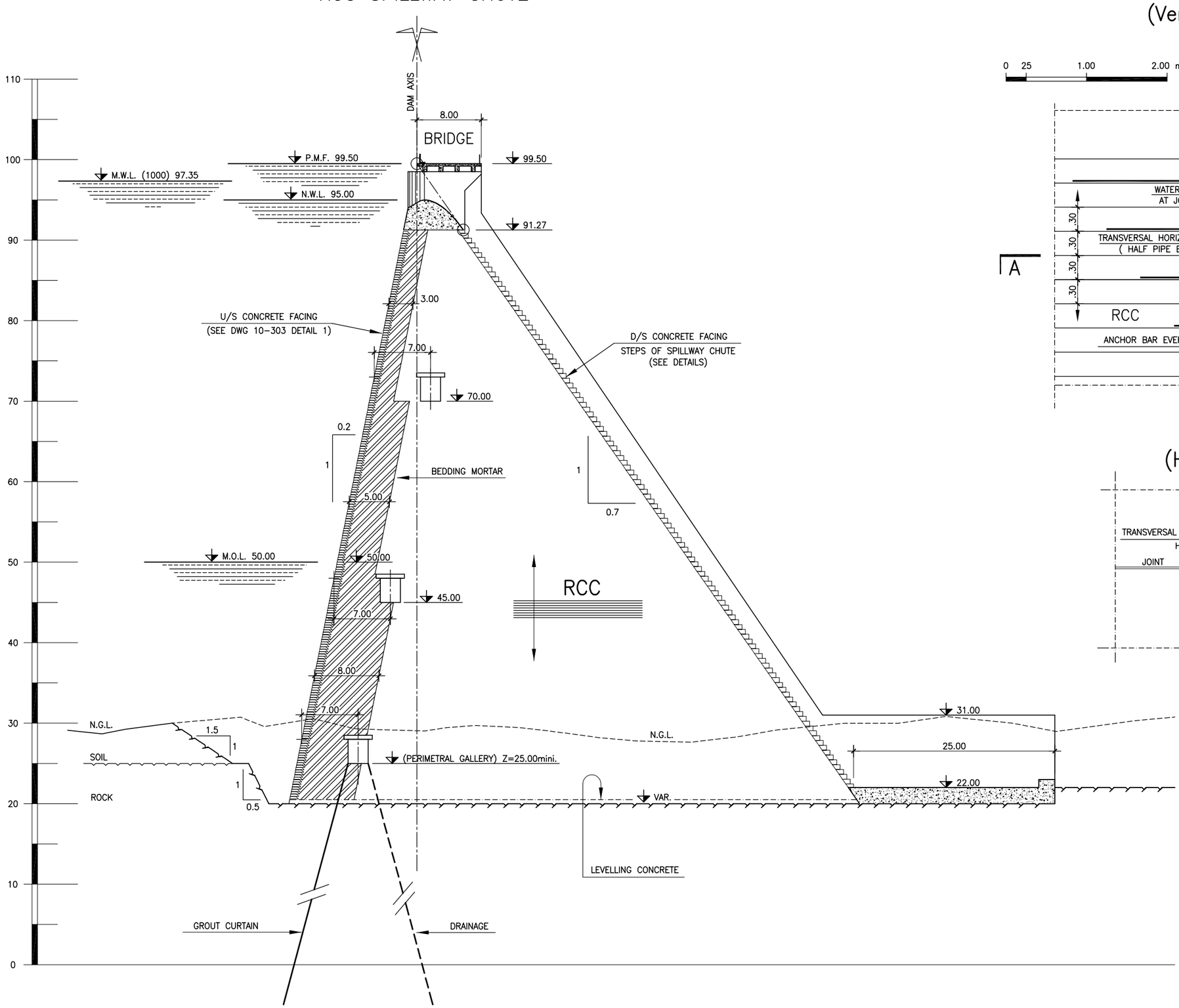
RIO TOABRE WATER TRANSFER PROJECT
FEASIBILITY STUDY

RCC DAM

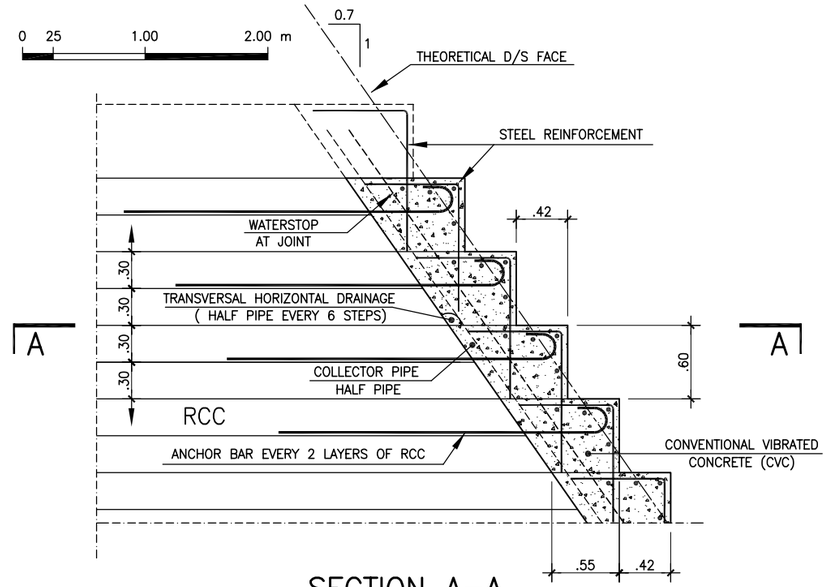
TYPICAL CROSS SECTION AND DETAILS

Scale : 1/500 – 1/50	Format : A3	Plate : 1/1	Project N° : 10932	Revision
COYNE ET BELLIER Bureau d'ingénieurs Conseils GENNEVILLIERS - FRANCE	Computer File : 10-303B.dwg		No : 1,0,3,0,3,	B

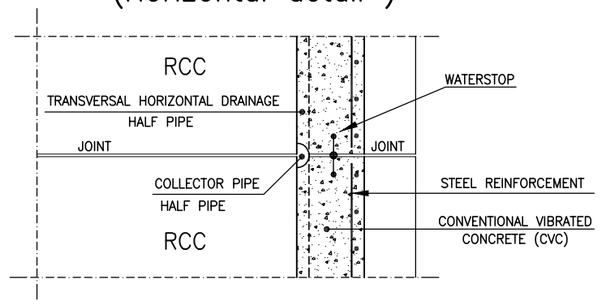
RCC SPILLWAY CHUTE



STEPS OF SPILLWAY CHUTE
(Vertical detail)



SECTION A–A
(Horizontal detail)



Revis.	DATE	DRAWN BY	CHECKED BY	APPROVED BY	NATURE OF REVISION	STATUS
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A	MAR. 2003	GTR	JMV	JMV	First Emission	

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

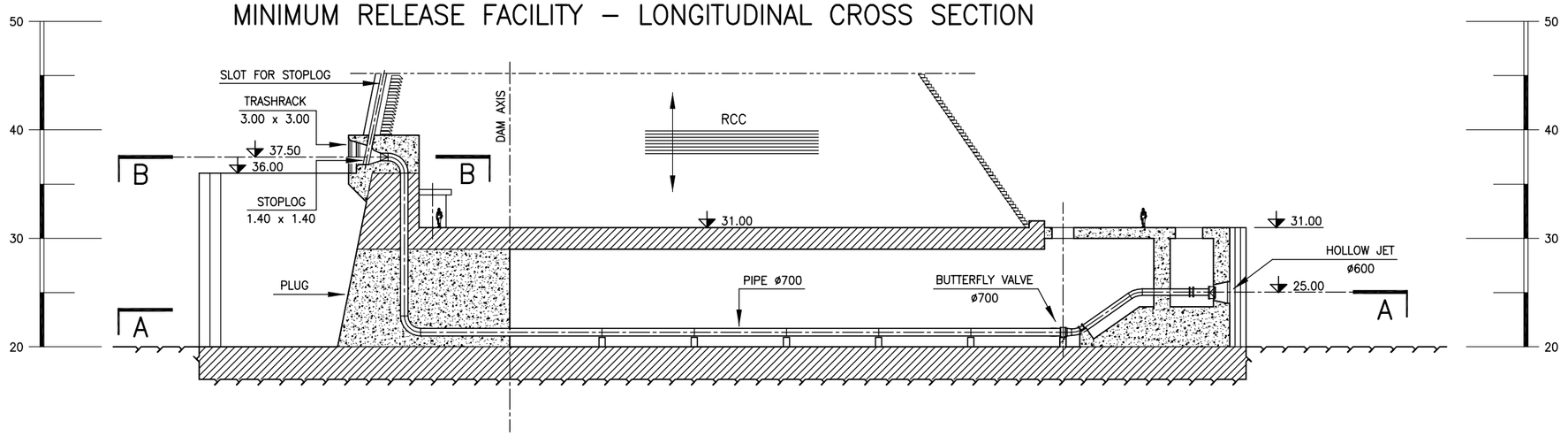
RIO TOABRE WATER TRANSFER PROJECT
FEASIBILITY STUDY

SPILLWAY

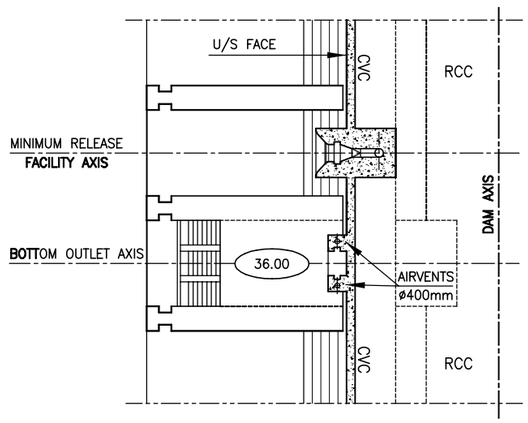
TYPICAL CROSS SECTION AND DETAILS

Scale : 1/500 – 1/50	Format : A3	Plate : 1/1	Project N° : 10932	Revision
COYNE ET BELLIER Bureau d'ingénieurs Conseils GENNEVILLIERS - FRANCE	Computer File : 10-304B.dwg		No : 10304	B

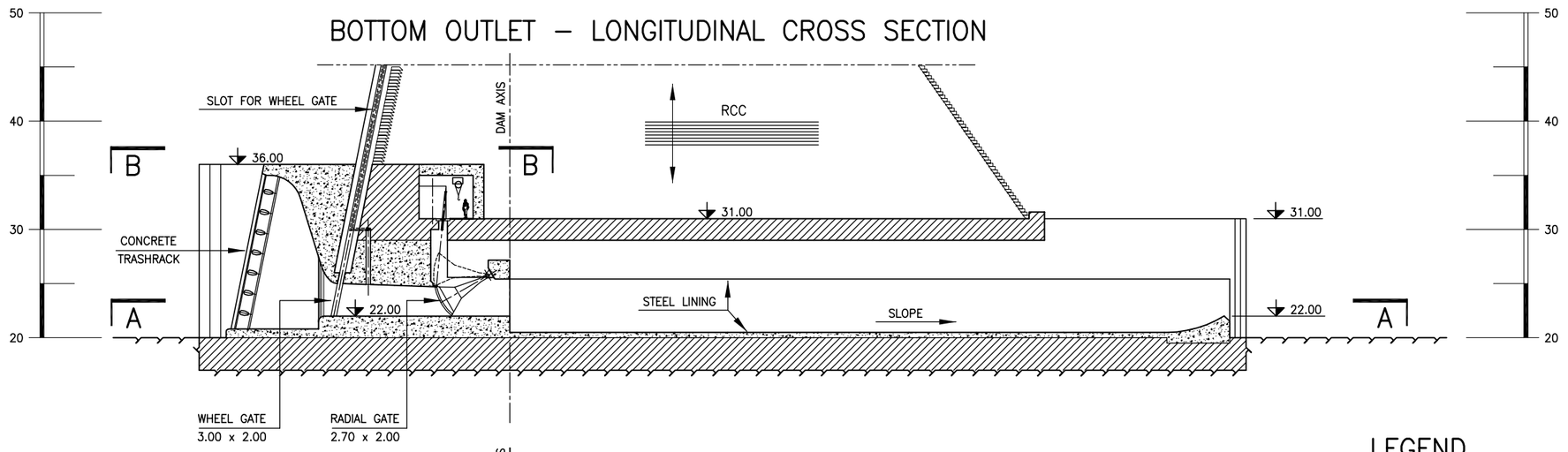
MINIMUM RELEASE FACILITY – LONGITUDINAL CROSS SECTION



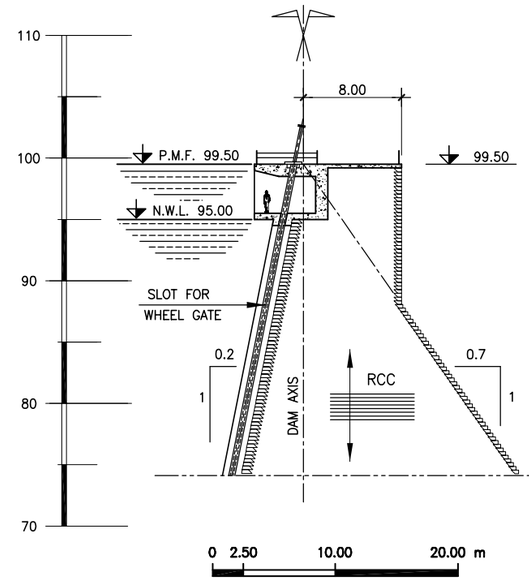
SECTION B–B



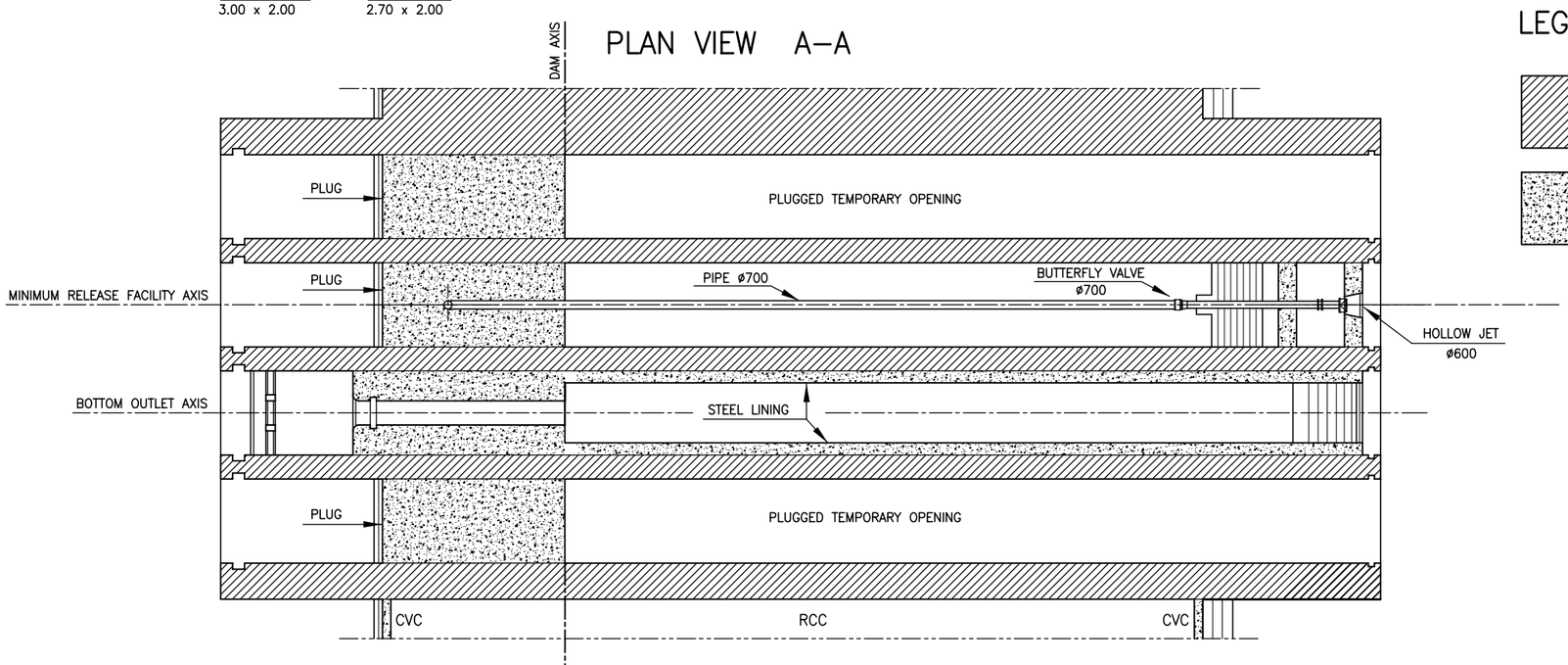
BOTTOM OUTLET – LONGITUDINAL CROSS SECTION



BOTTOM OUTLET – CREST DETAIL



PLAN VIEW A–A



LEGEND

FIRST STAGE CONCRETE

SECOND STAGE CONCRETE

Revis.	DATE	DRAWN BY	CHECKED BY	APPROVED BY	NATURE OF REVISION	STATUS
B	MAY 2003	GTR	JMV	JCO	FINAL EMISSION	
A	MAR. 2003	GTR	JMV	JMV	First Emission	

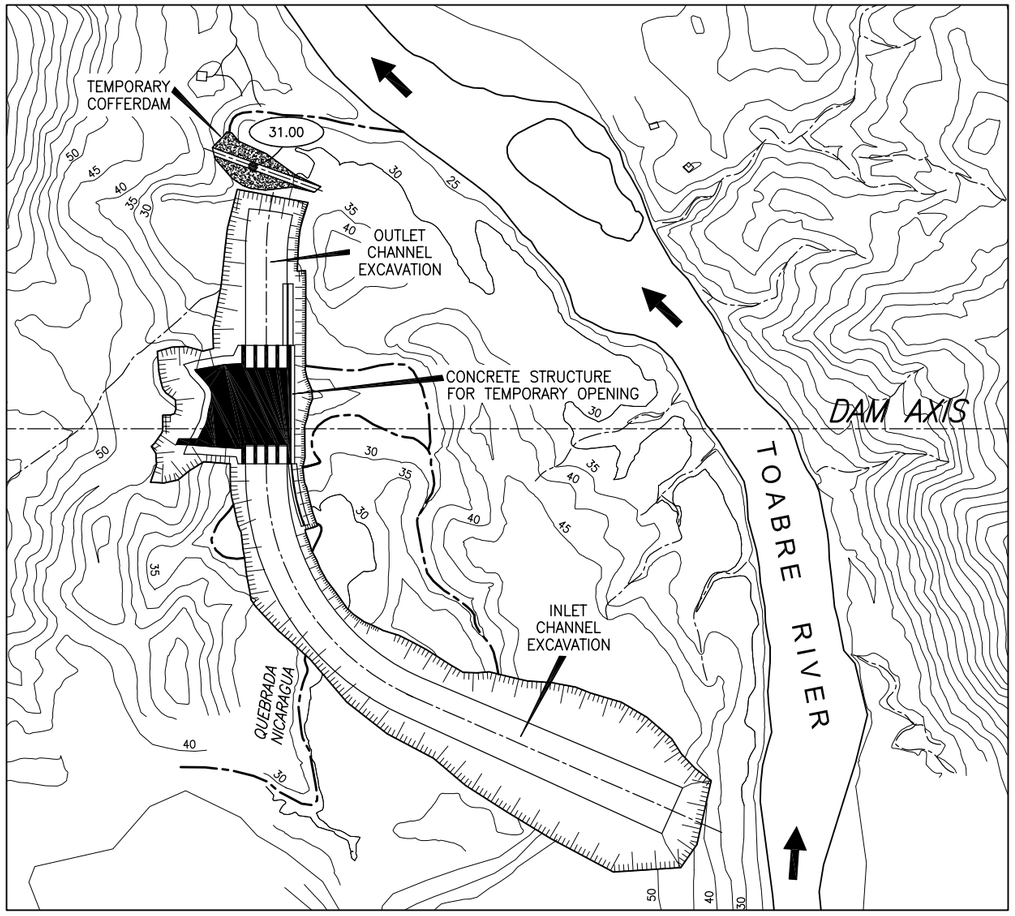
AUTORIDAD DEL CANAL DE PANAMÁ
Division de Proyectos de Capacidad del Canal

RIO TOABRE WATER TRANSFER PROJECT
FEASIBILITY STUDY

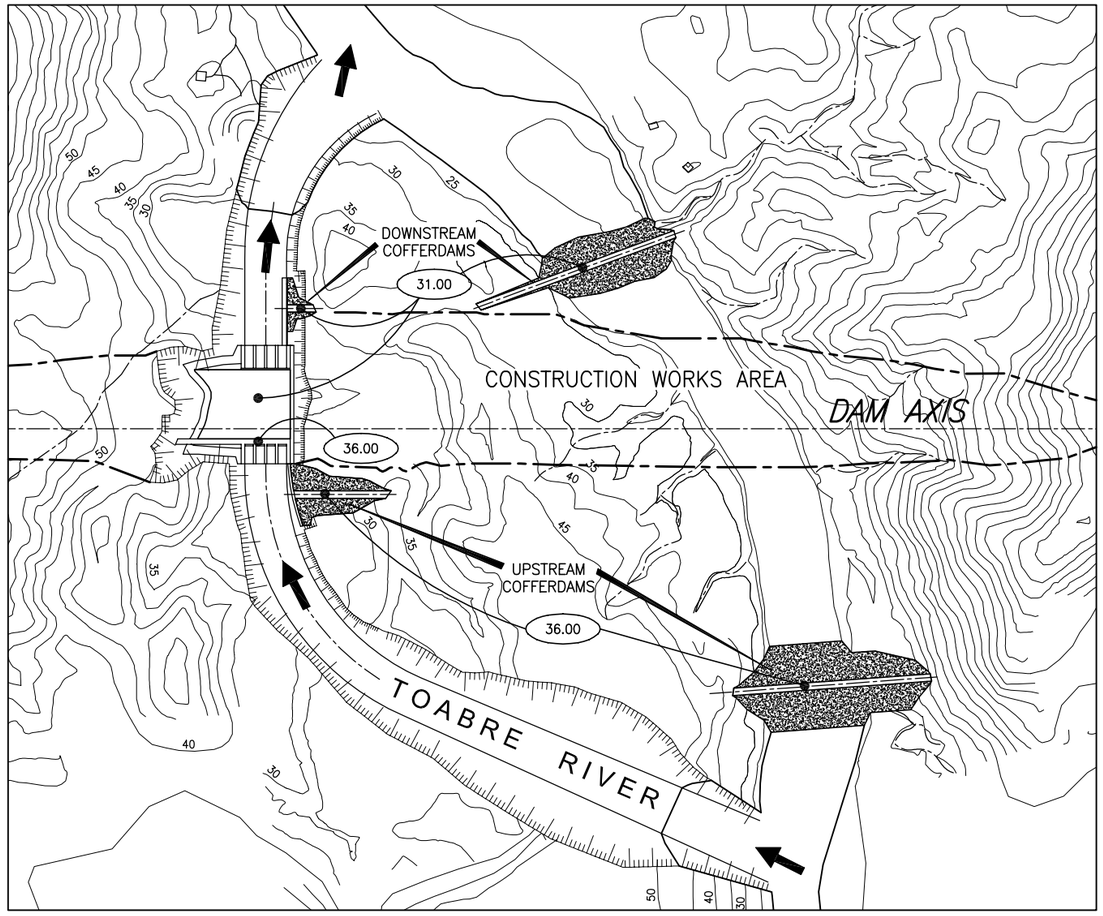
BOTTOM OUTLET AND MINIMUM RELEASE FACILITY SECTIONS AND DETAILS

Scale : 1/500	Format : A3	Plate : 1/1	Project N° : 10932	Revision
COYNE ET BELLIER Bureau d'Ingénieurs Conseils	Computer File : 10-305B.dwg		No : 10305	B

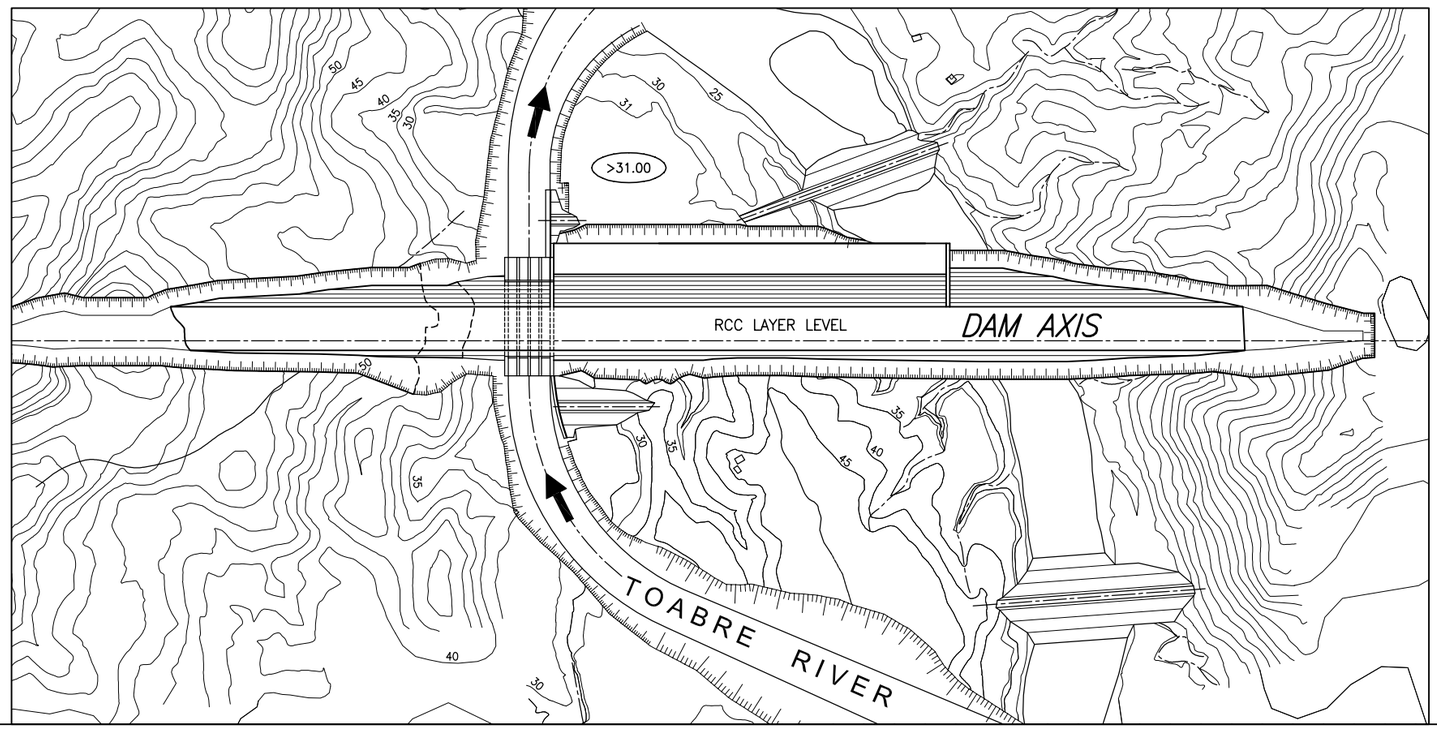
PRELIMINARY PHASE : CONSTRUCTION OF DIVERSION STRUCTURES



DIVERSION PHASE OF TOABRE RIVER



RCC DAM CONSTRUCTION PHASE



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Revis.	DATE	DRAWN BY	CHECKED BY	APPROVED BY	NATURE OF REVISION	STATUS
B	MAY 2003	GTR	JMV	JCO	FINAL EMISSION	
A	MAR. 2003	GTR	JMV	JMV	First Emission	

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

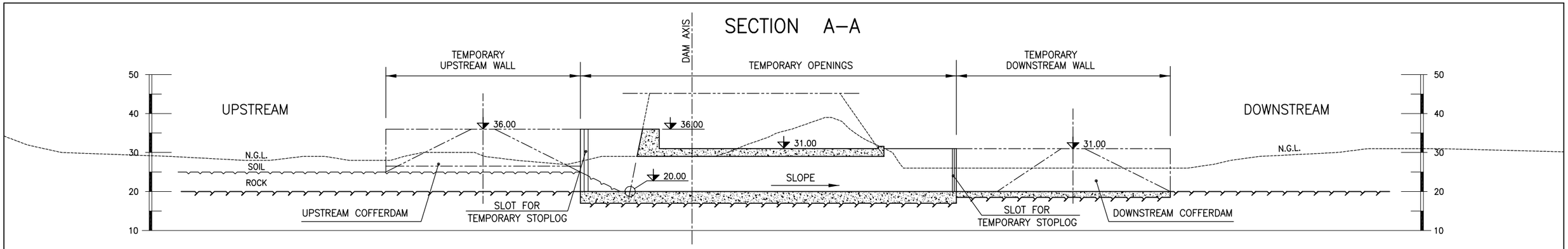
ACP AUTORIDAD DEL CANAL DE PANAMÁ

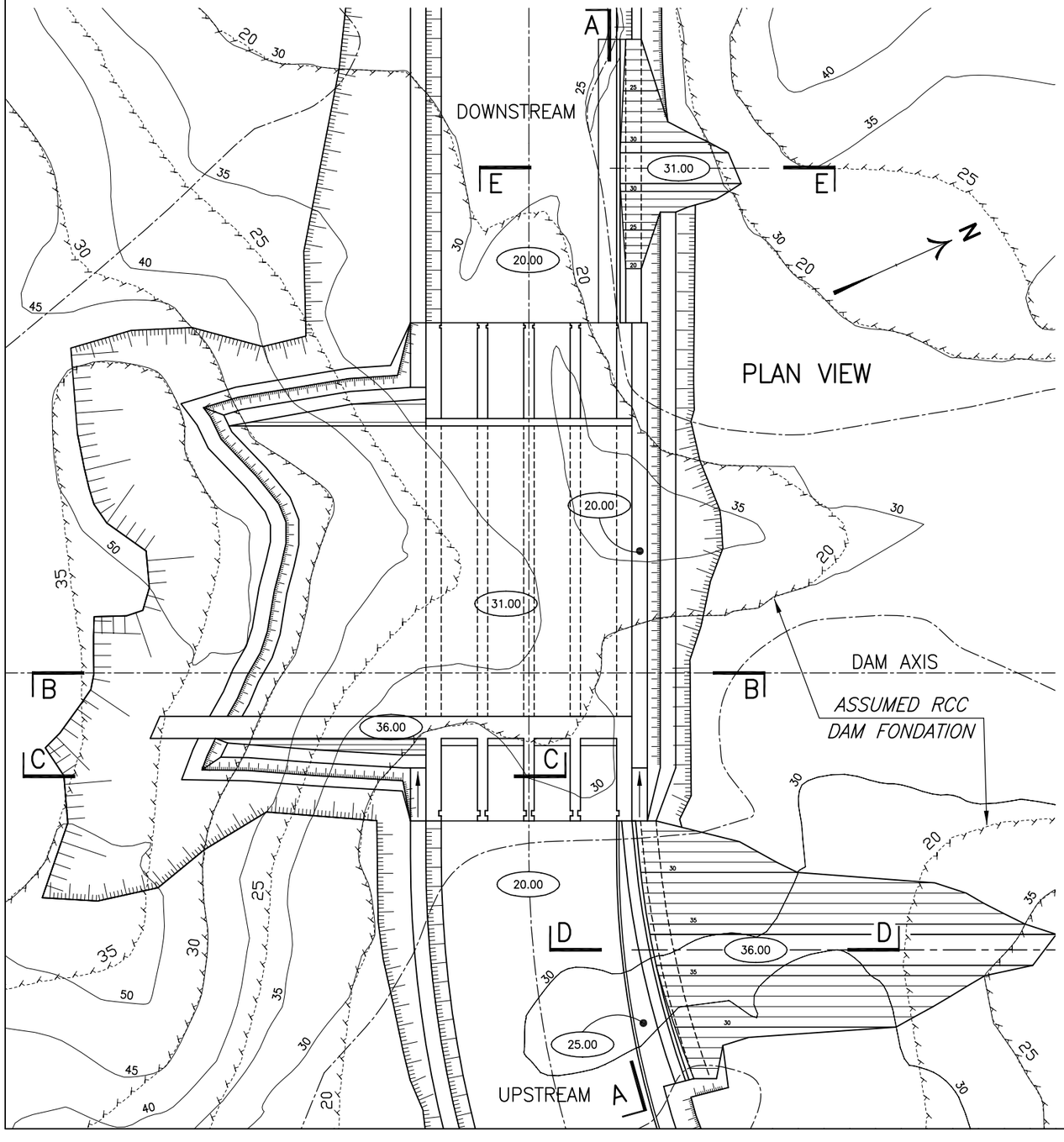
RIO TOABRE WATER TRANSFER PROJECT
FEASIBILITY STUDY

DIVERSION WORKS
GENERAL PRINCIPLES

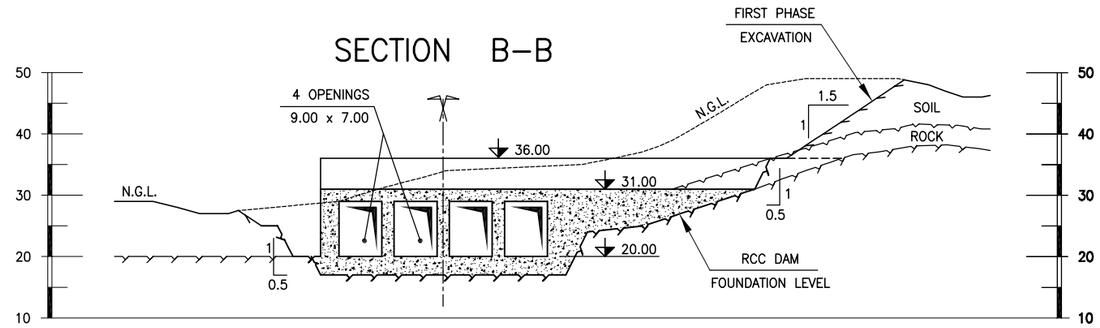
Scale : 1/5000	Format : A3	Plate : 1/1	Project N° : 10932	Revision
COYNE ET BELLIER Bureau d'ingénieurs Conseils GENNEVILLIERS - FRANCE	Computer File : 10-306B.dwg		No : 10306	B

SECTION A–A

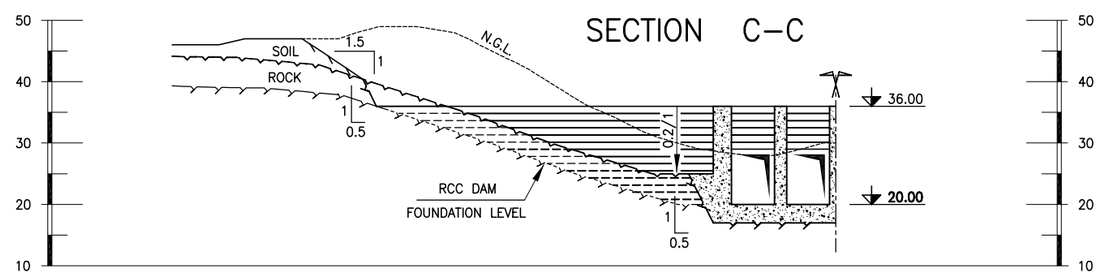




SECTION B–B



SECTION C–C



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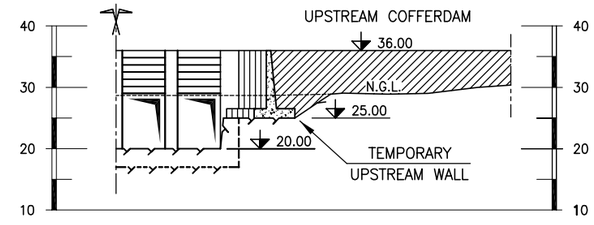

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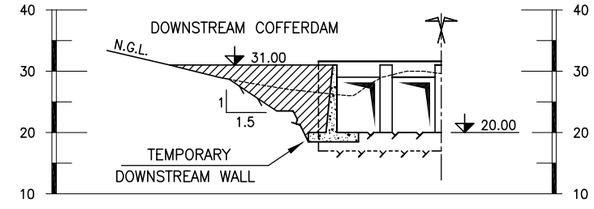

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Revis.	DATE	DRAWN BY	CHECKED BY	APPROVED BY	NATURE OF REVISION	STATUS
B	MAY 2003	GTR	JMV	JCO	FINAL EMISSION	
A	MAR. 2003	GTR	JMV	JMV	First Emission	

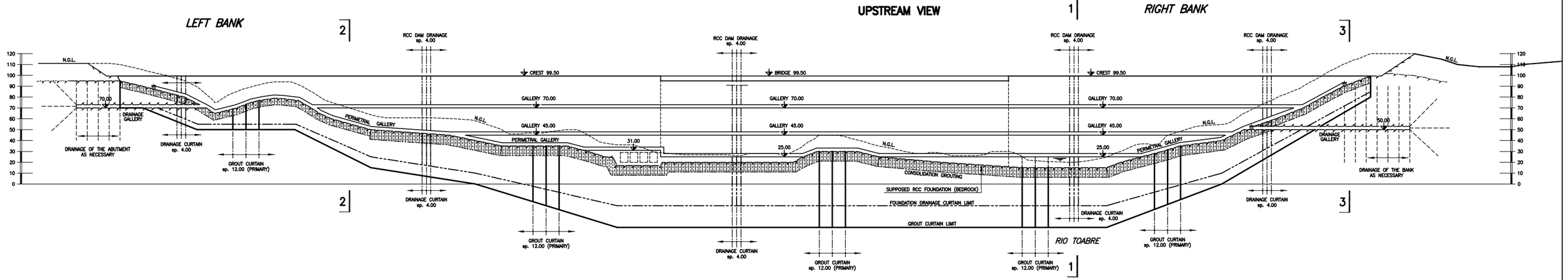
AUTORIDAD DEL CANAL DE PANAMÁ
Division de Proyectos de Capacidad del Canal

RIO TOABRE WATER TRANSFER PROJECT
FEASIBILITY STUDY

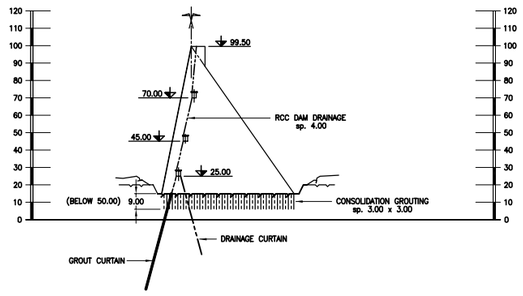
DIVERSION STRUCTURES
PLAN VIEW AND SECTIONS

Scale : 1/1000	Format : A3	Plate : 1/1	Project N° : 10932	Revision
COYNE ET BELLIER Bureau d'ingénieurs Conseils	Computer File : 10-307B.dwg		No : 10307	B

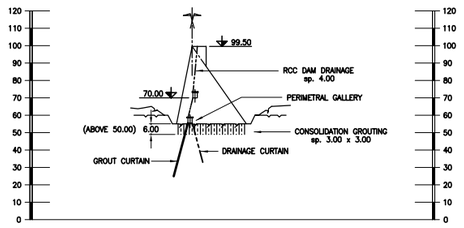
UPSTREAM VIEW



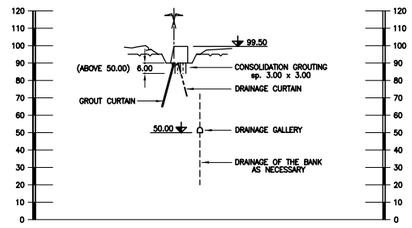
SECTION 1–1



SECTION 2–2



SECTION 3–3



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Revis.	DATE	DRAWN BY	CHECKED BY	APPROVED BY	NATURE OF REVISION	STATUS
B	MAY 2003	GTR	JMV	JCO	FINAL EMISSION	
A	MAR. 2003	GTR	JMV	JMV	For Comment	

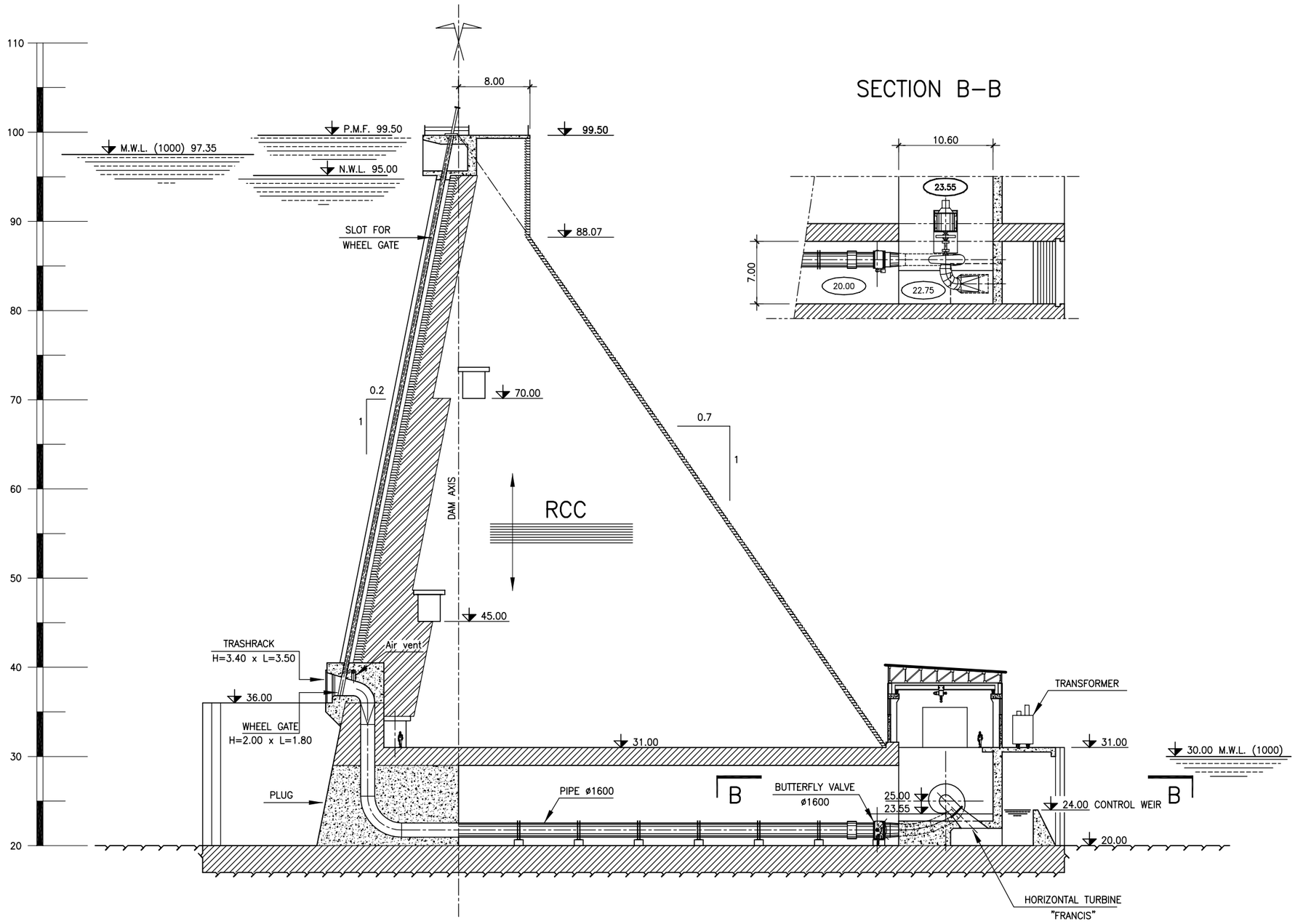
AUTORIDAD DEL CANAL DE PANAMÁ
Division de Proyectos de Capacidad del Canal

RIO TOABRE WATER TRANSFER PROJECT
FEASIBILITY STUDY

GROUTING AND DRAINAGE
ELEVATION AND DETAILS

Scale : 1/2000	Format : A3 +	Plate : 1/1	Project N° : 10932	Revision
COYNE ET BELLIER	Computer File : 10-308B.dwg		No : 1.0.3.0.8.	B.

CROSS SECTION



SECTION B–B

NOTE

Location of the optional hydropower plant in one of the temporary diversion opening. General arrangement to be optimised with River Outlet and Bottom Outlet location and arrangement.

LEGEND

FIRST STAGE CONCRETE

SECOND STAGE CONCRETE

0 2.50 10.00 20.00 m

Revis.	DATE	DRAWN BY	CHECKED BY	APPROVED BY	NATURE OF REVISION	STATUS
B	MAY 2003	GTR	JMV	JCO	FINAL EMISSION	
A	MAR. 2003	BPL	JMV	JMV	First Emission	

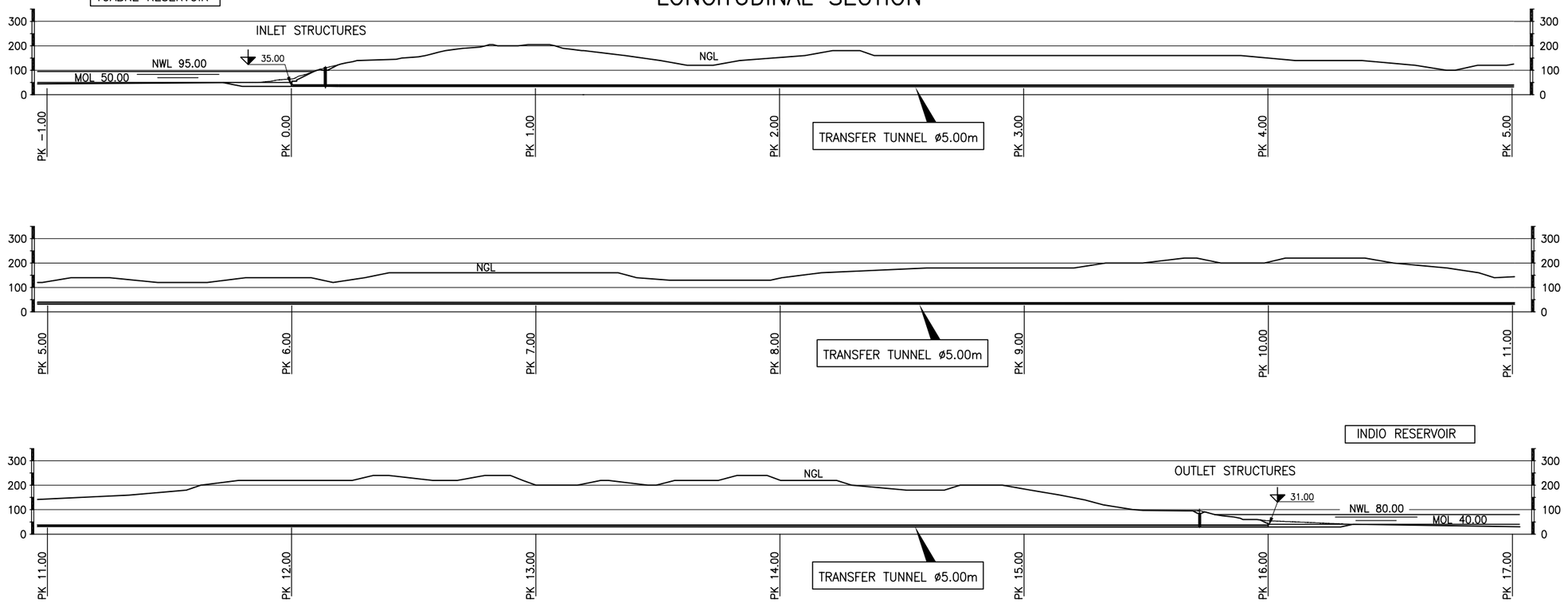
AUTORIDAD DEL CANAL DE PANAMÁ
Division de Proyectos de Capacidad del Canal

RIO TOABRE WATER TRANSFER PROJECT
FEASIBILITY STUDY

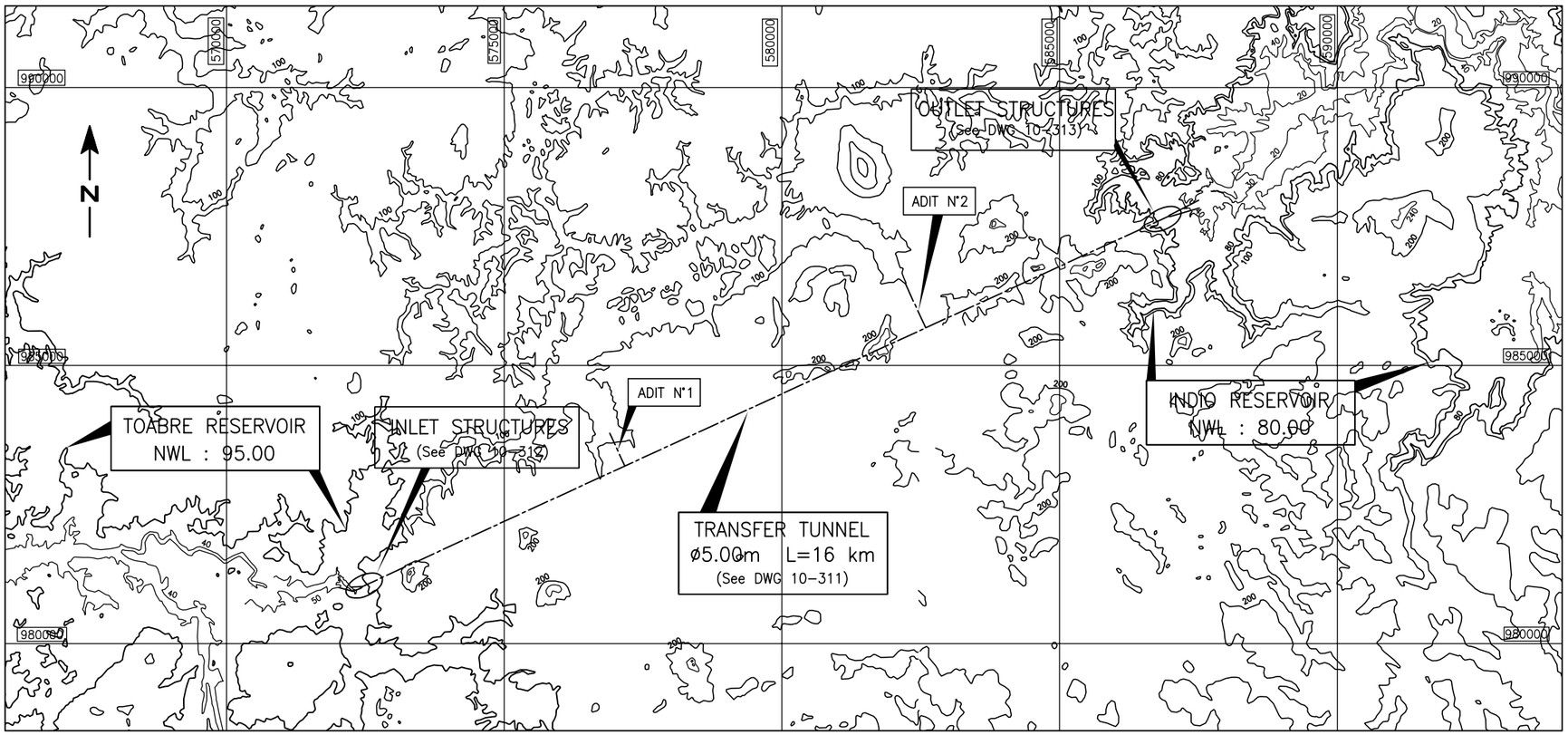
OPTIONAL HYDROPOWER PLANT 4MW
SECTIONS AND DETAILS

Scale : 1/500	Format : A3	Plate : 1/1	Project N° : 10932	Revision
COYNE ET BELLIER Bureau d'Ingénieurs Conseils	Computer File : 10-309B.dwg		No : 1,0,3,0,9	B

LONGITUDINAL SECTION



GENERAL LAYOUT



0 100 500 1000m.

0 500 2500 5000m.

Revis.	DATE	DRAWN BY	CHECKED BY	APPROVED BY	NATURE OF REVISION	STATUS
B	MAY 2003	GTR	JMV	JCO	FINAL EMISSION	
A	MAR. 2003	JMT	JMV	JMV	First Emission	

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

ACP AUTORIDAD DEL CANAL DE PANAMÁ

RIO TOABRE WATER TRANSFER PROJECT
FEASIBILITY STUDY

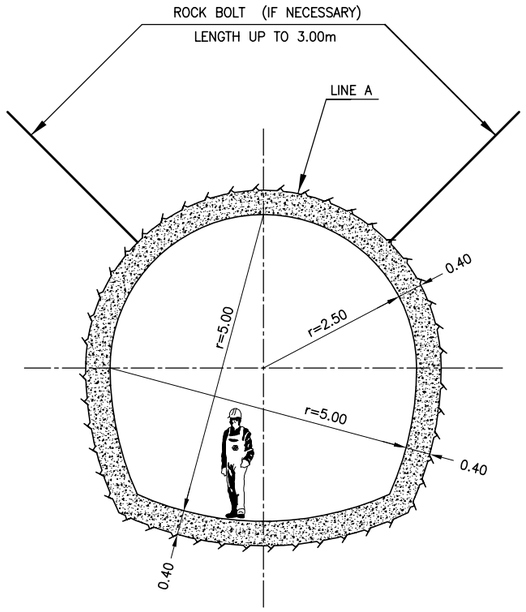
TRANSFER TUNNEL

GENERAL LAYOUT AND LONGITUDINAL SECTION

Scale :	Format : A3	Plate : 1/1	Project N° : 10932	Revision
COYNE ET BELLIER Bureau d'Ingénieurs Conseils GRENOBLE (FRANCE)	Computer File : 10-310B.dwg		No : 1,0,3,1,0	B

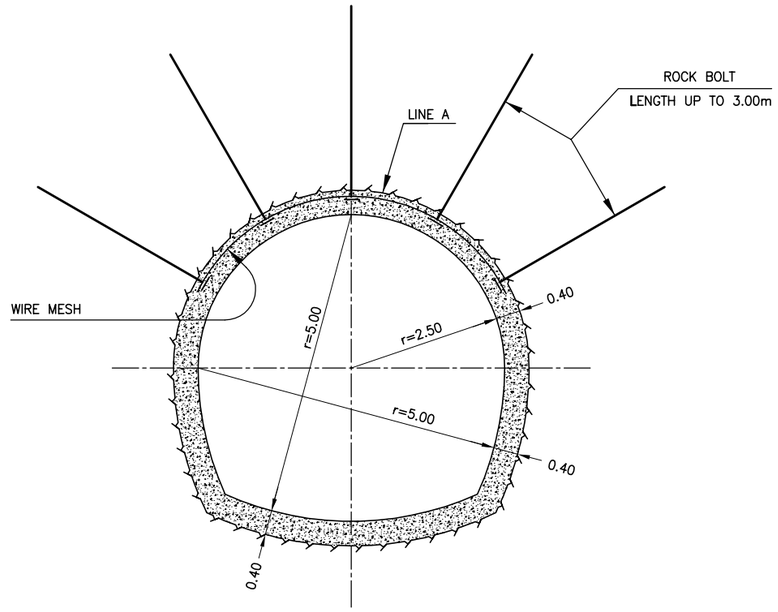
PROFILE Ⅰ

RANDOM ROCK BOLT



PROFILE Ⅱ

SYSTEMATIC PATTERN ROCK BOLTS
WITH MESH OVER CROWN

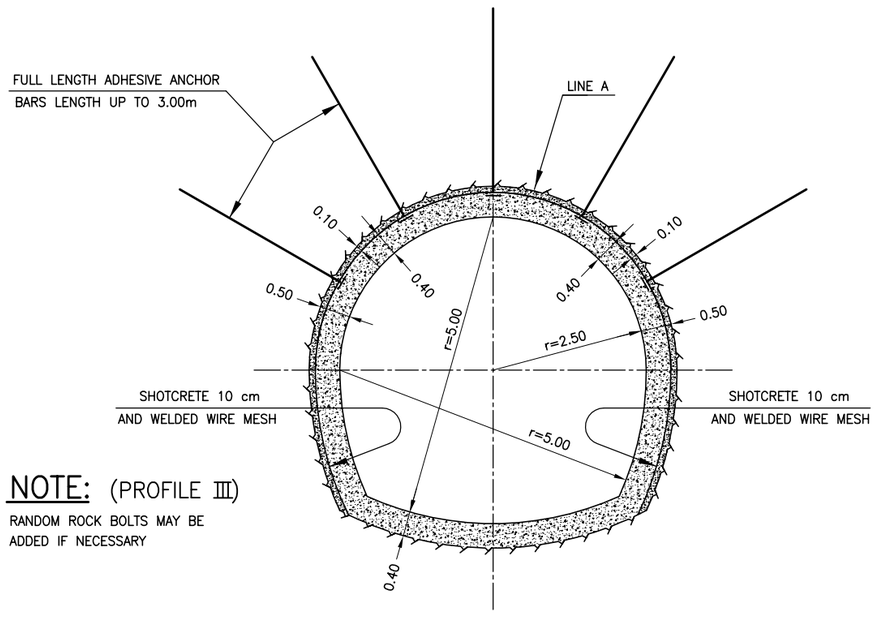


ROCK SUPPORT CLASS

VERY GOOD	Ⅰ
GOOD TO FAIR	Ⅱ
FAIR TO POOR	Ⅲ
POOR	Ⅳ
VERY POOR	Ⅴ

PROFILE Ⅲ

SYSTEMATIC PATTERN FULL LENGTH ADHESIVE
ANCHORS WITH REINFORCED SHOTCRETE

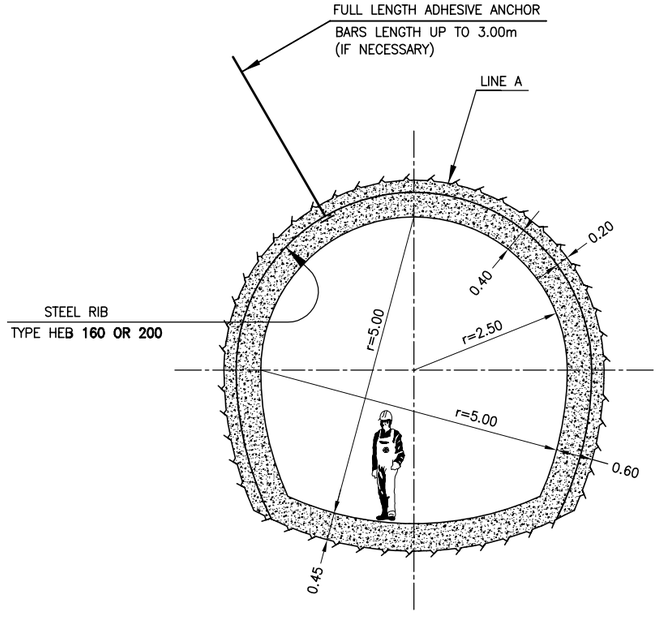


NOTE: (PROFILE Ⅲ)

RANDOM ROCK BOLTS MAY BE
ADDED IF NECESSARY

PROFILE Ⅳ AND Ⅴ

STEEL RIBS



0 50 2.50 5.00 m

Revis.	DATE	DRAWN BY	CHECKED BY	APPROVED BY	NATURE OF REVISION	STATUS
B	MAY 2003	GTR	JMV	JCO	FINAL EMISSION	
A	MAR. 2003	GTR	JMV	JMV	First Emission	

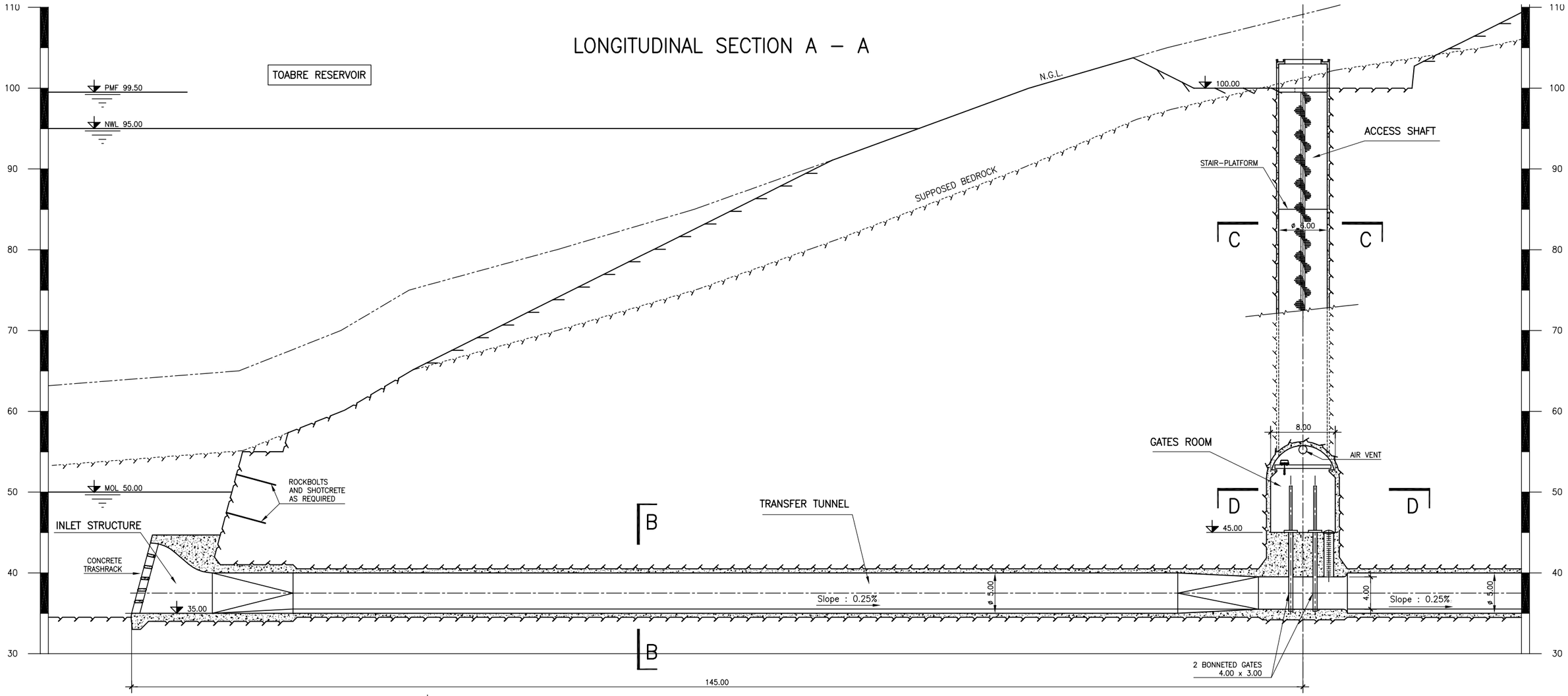
AUTORIDAD DEL CANAL DE PANAMÁ
Division de Proyectos de Capacidad del Canal

RIO TOABRE WATER TRANSFER PROJECT
FEASIBILITY STUDY

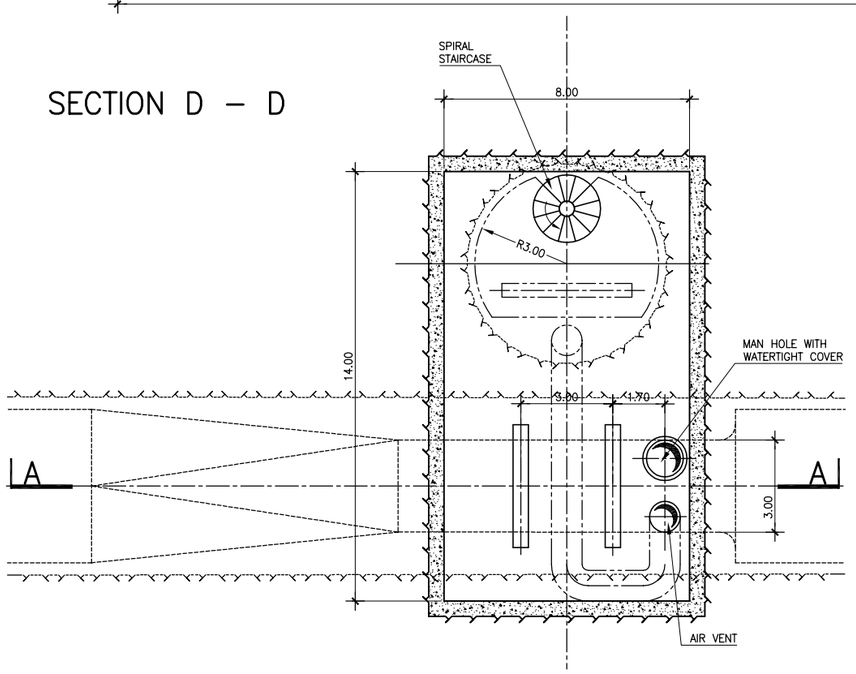
TRANSFER TUNNEL
TYPICAL CROSS SECTIONS

Scale : 1/100	Format : A3	Plate : 1/1	Project N° : 10932	Revision
COYNE ET BELLIER Bureau d'Ingénieurs Conseils GENNEVILLIERS - FRANCE	Computer File : 10-311B.dwg		No : 1,0,3,1,1,	B

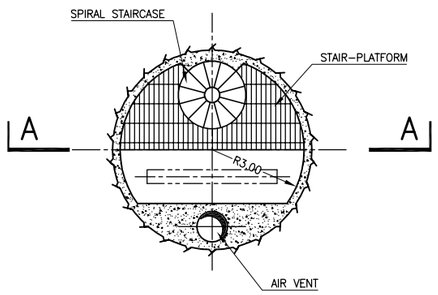
LONGITUDINAL SECTION A – A



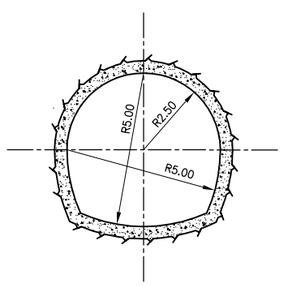
SECTION D – D



SECTION C – C



SECTION B – B



0 2.50 12.50 25.00 m

0 1.00 5.00 10.00 m

Revis.	DATE	DRAWN BY	CHECKED BY	APPROVED BY	NATURE OF REVISION	STATUS
B	MAY 2003	GTR	JMV	JCO	FINAL EMISSION	
A	MAR. 2003	JMT	JMV	JMV	First Emission	

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

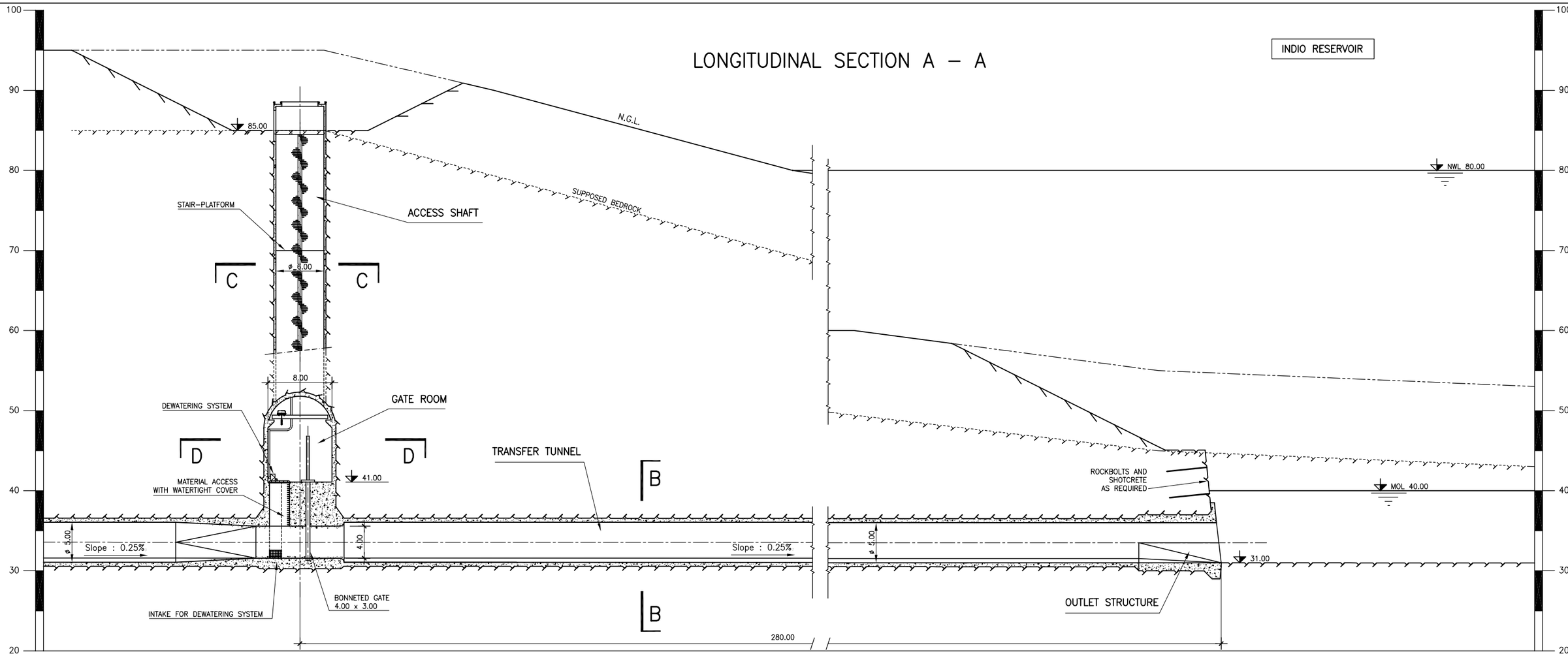
RIO TOABRE WATER TRANSFER PROJECT
FEASIBILITY STUDY

TRANSFER TUNNEL
INLET STRUCTURE AND ACCESS SHAFT

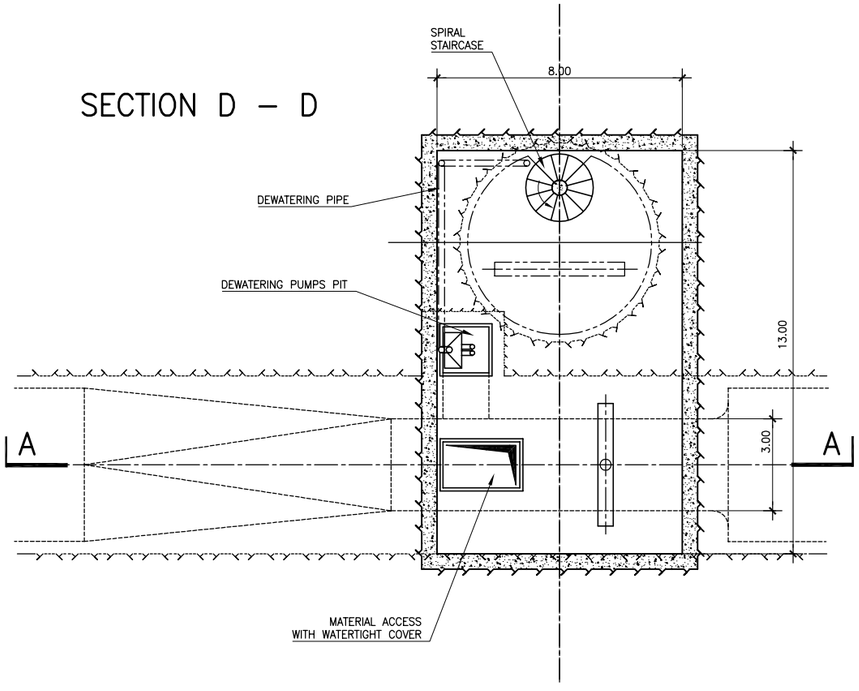
Scale : 1/500	Format : A3	Plate : 1/1	Project N° : 10932	Revision
COYNE ET BELLIER Bureau d'ingénieurs Conseils GONNEVILLIERS - FRANCE	Computer File : 10–312B.dwg		No : 1,0,3,1,2	B

LONGITUDINAL SECTION A – A

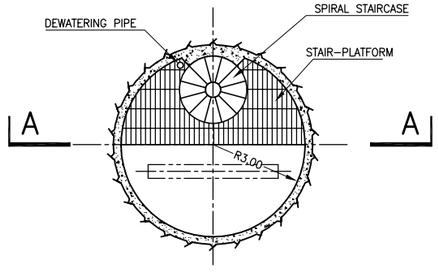
INDIO RESERVOIR



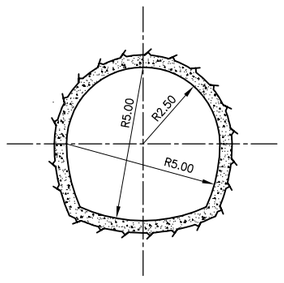
SECTION D – D



SECTION C – C



SECTION B – B



0 2.50 12.50 25.00 m

0 1.00 5.00 10.00 m

Revis.	DATE	DRAWN BY	CHECKED BY	APPROVED BY	NATURE OF REVISION	STATUS
B	MAY 2003	GTR	JMV	JCO	FINAL EMISSION	
A	MAR. 2003	JMT	JMV	JMV	First Emission	

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

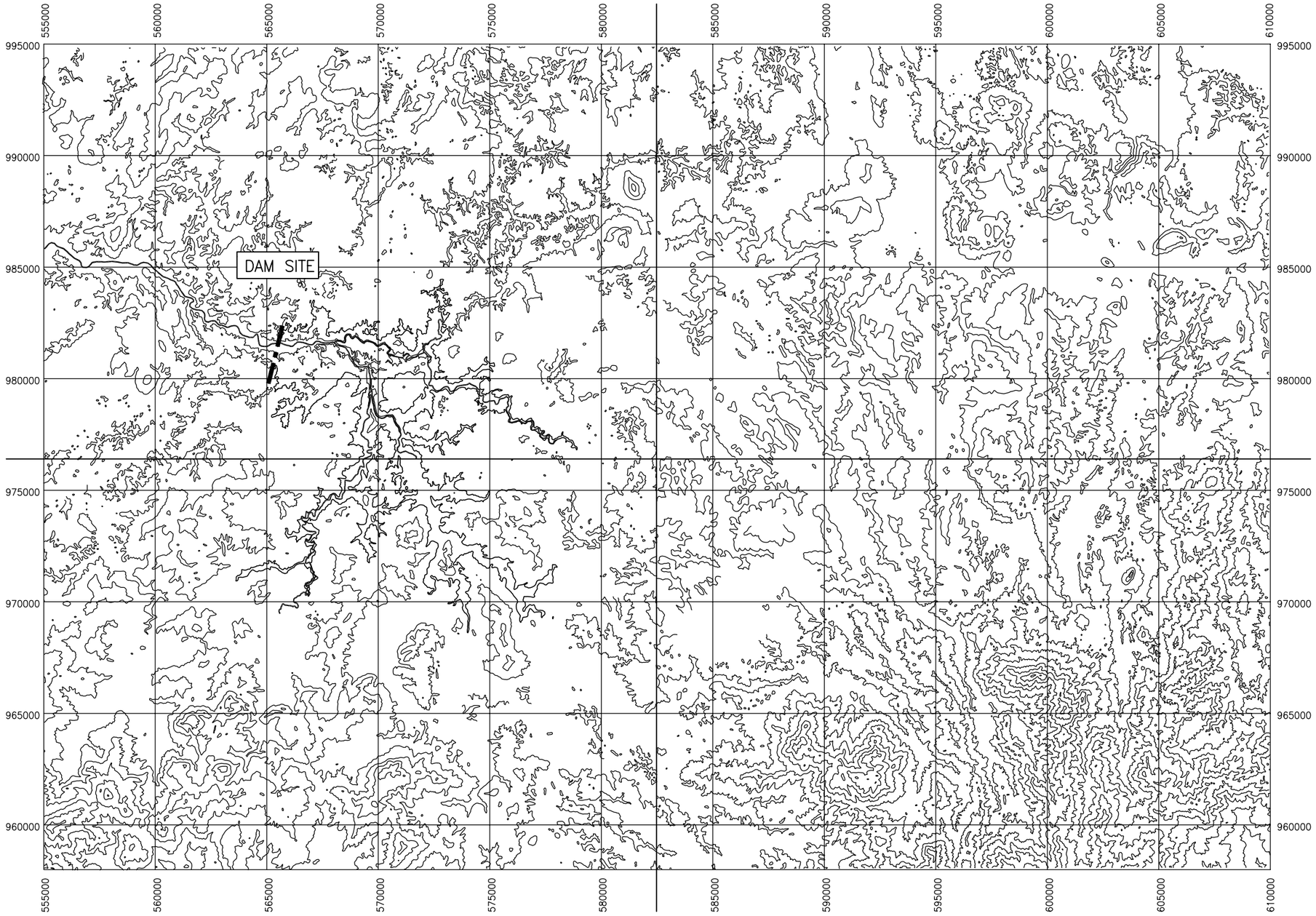
RIO TOABRE WATER TRANSFER PROJECT
FEASIBILITY STUDY

TRANSFER TUNNEL
OUTLET STRUCTURE AND ACCESS SHAFT

Scale : 1/500	Format : A3	Plate : 1/1	Project N° : 10932	Revision
COYNE ET BELLIER Bureau d'Ingénieurs Conseils	Computer File : 10–313B.dwg		No : 1,0,3,1,3	B

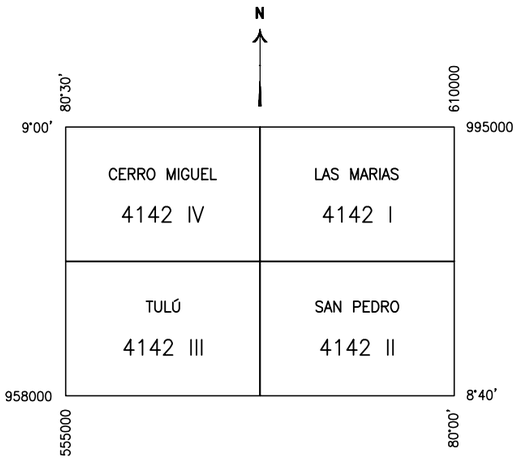
TOPOGRAPHY

10-101	1 / 200 000 map of the project Area
10-102	1 / 50 000 map of the project Area
10-103	Dam site – Topographical ground survey (2002)
10-104	Tunnel Inlet – Topographical ground survey (2002)
10-105	Cross sections of the Rio Toabre – Topographical ground survey (2002)
10-106	1 / 10 000 map of the project area
10-107	1 / 20 000 map of the dam site area (photorestitution 2003)
10-108	1 / 10 000 map of the tunnel inlet area (photorestitution 2003)
10-109	1 / 10 000 map of the tunnel outlet area (photorestitution 2003)



KEY PLAN

NOTE
DIGITILIZED FROM 1/50 000 MAPS IGN–JICA



0 1 5 10km.

Revis.	DATE	DRAWN BY	CHECKED BY	APPROVED BY	NATURE OF REVISION	STATUS
B	MAY 2003	GTR	JMV	JCO	FINAL EMISSION	
A	NOV. 2002	GTR	JMV	JMV	First Emission	

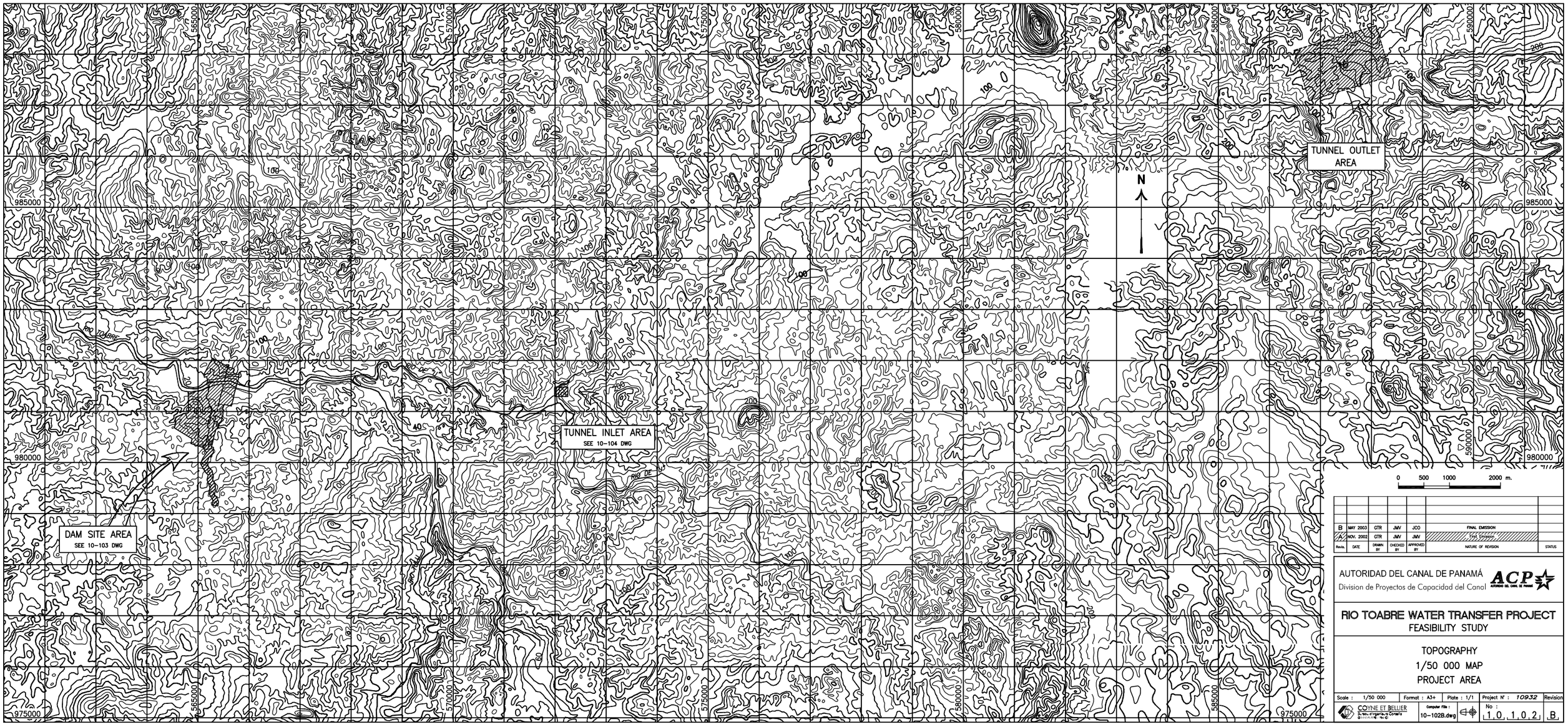
AUTORIDAD DEL CANAL DE PANAMÁ
Division de Proyectos de Capacidad del Canal

ACP AUTORIDAD DEL CANAL DE PANAMÁ

RIO TOABRE WATER TRANSFER PROJECT
FEASIBILITY STUDY

TOPOGRAPHY
1/200 000 MAPS
OF THE PROJECT AREA

Scale : 1/200 000	Format : A3	Plate : 1/1	Project N° : 10932	Revision
COYNE ET BELLIER Bureau d'Ingénieurs Conseils GENNEVILLIERS - FRANCE	Computer File : 10–101B.dwg		No : 1,0,1,0,1	B



Revis.	DATE	DRAWN BY	CHECKED BY	APPROVED BY	NATURE OF REVISION	STATUS
B	MAY 2003	GTR	JMV	JCO	FINAL EMISSION	
A	NOV. 2002	GTR	JMV	JMV	For Review	

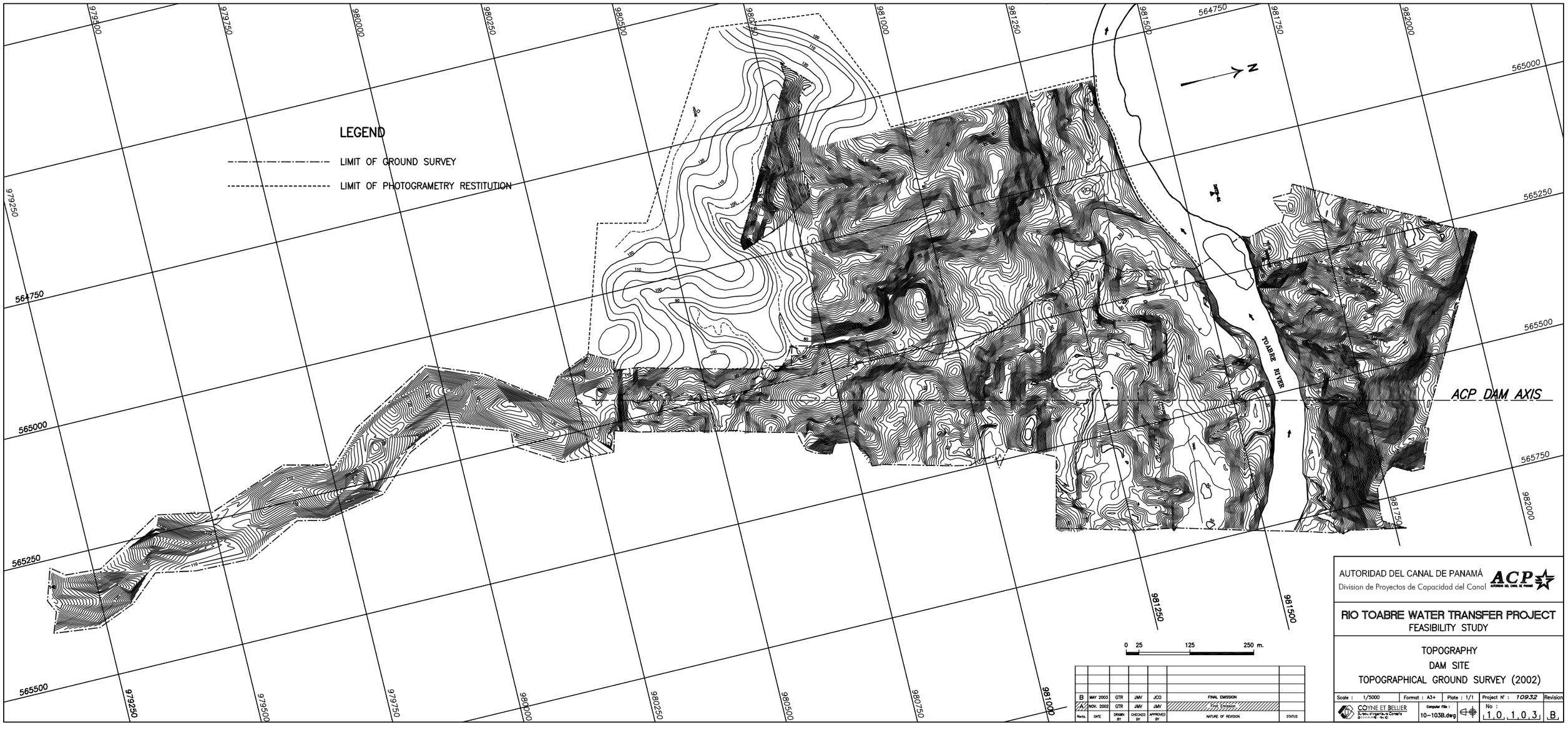
AUTORIDAD DEL CANAL DE PANAMÁ
Division de Proyectos de Capacidad del Canal

ACP AUTORIDAD DEL CANAL DE PANAMÁ

RIO TOABRE WATER TRANSFER PROJECT
FEASIBILITY STUDY

TOPOGRAPHY
1/50 000 MAP
PROJECT AREA

Scale : 1/50 000	Format : A3+	Plate : 1/1	Project N° : 10932	Revision
COYNE ET BELLIER Ingénierie Conseil	Computer File : 10-102B.dwg		No : 10,102,	B



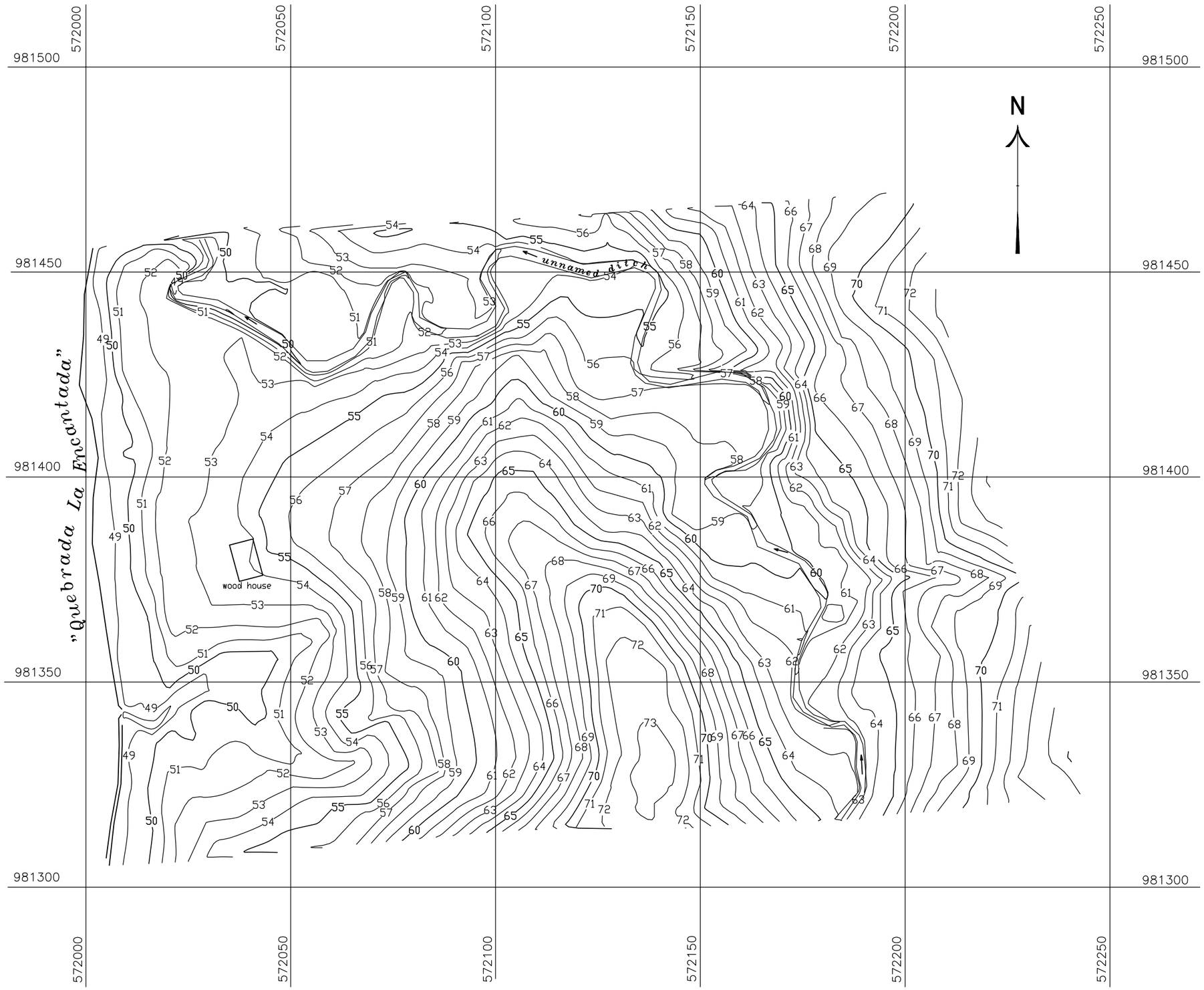
Revis.	DATE	DRAWN BY	CHECKED BY	APPROVED BY	NATURE OF REVISION	STATUS
B	MAY 2003	GTR	JMV	JCO	FINAL EMISSION	
A	NOV. 2002	GTR	JMV	JMV	For Review	

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

RIO TOABRE WATER TRANSFER PROJECT
FEASIBILITY STUDY

TOPOGRAPHY
DAM SITE
TOPOGRAPHICAL GROUND SURVEY (2002)

Scale : 1/5000	Format : A3+	Plate : 1/1	Project N° : 10932	Revision
COYNE ET BELLIER	Computer File : 10-103B.dwg		No : 10,103,	B



0 5.00 25.00 50.00 m

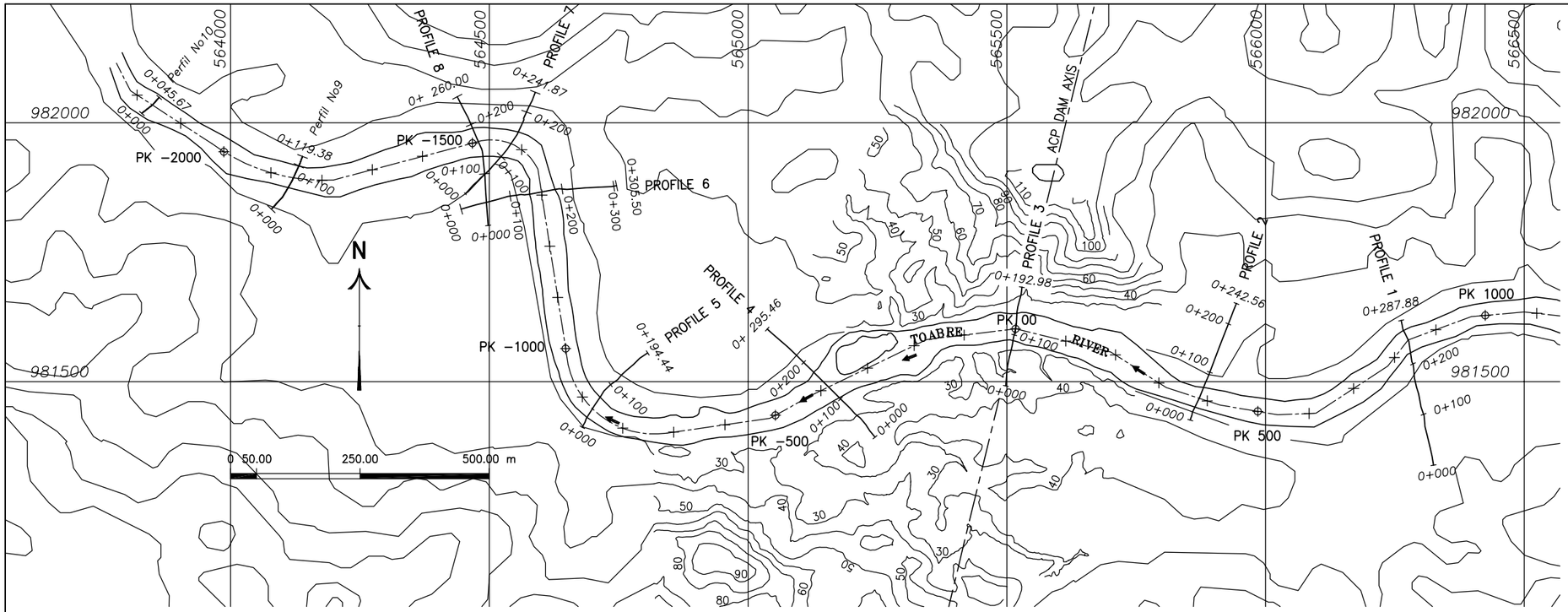
Revis.	DATE	DRAWN BY	CHECKED BY	APPROVED BY	NATURE OF REVISION	STATUS
B	MAY 2003	GTR	JMV	JCO	FINAL EMISSION	
A	NOV. 2002	GTR	JMV	JMV	First Emission	

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

RIO TOABRE WATER TRANSFER PROJECT
FEASIBILITY STUDY

TOPOGRAPHY
TUNNEL INLET
TOPOGRAPHICAL GROUND SURVEY (2002)

Scale : 1/1000	Format : A3	Plate : 1/1	Project N° : 10932	Revision
COYNE ET BELLIER Bureau d'Ingénieurs Conseils GENNEVILLIERS - FRANCE	Computer File : 10-104B.dwg		No : 1,0,1,0,4,	B



PROFILE 1 PK 843		PROFILE 2 PK 384		PROFILE 3 PK 00		PROFILE 4 PK −384	
X	Z	X	Z	X	Z	X	Z
0	38.7	0	35.7	0	34.4	0	36.0
18	35.2	11	29.0	30	30.5	16	37.3
33	33.7	17	24.0	40	32.6	30	32.4
59	32.8	19	22.7	56	32.6	60	29.7
76	34.0	32	21.1	70	30.0	74	29.4
115	28.5	42	20.6	80	29.1	80	26.5
141	29.7	62	22.4	91	23.15	94	23.7
156	31.3	72	23.1	94	22.4	95	22.9
171	30.1	77	26.1	104	21.8	104	22.9
192	28.0	87	30.4	125	19.9	114	22.8
198	26.0	97	30.6	135	21.3	124	22.5
204	23.7	128	30.1	144	23.15	144	22.7
207	22.4	157	29.4	147	26.0	154	22.8
230	21.0	214	33.0	150	26.9	164	22.7
240	19.9	225	37.0	154	26.7	174	22.5
260	21.9	243	42.2	166	24.2	181	27.3
263	23.7			180	31.0	194	26.3
269	29.7			193	37.5	224	30.4
280	37.0					262	29.0
288	40.7					284	33.4
						294	35.3

PROFILE 5 PK −870		PROFILE 6 PK −1306		PROFILE 7 PK −1424		PROFILE 8 PK −1488	
X	Z	X	Z	X	Z	X	Z
0	36.9	0	31.2	0	28.1	0	30.9
11	27.8	73	30.6	25	29.1	16	30.6
20	23.1	93	30.2	33	29.9	45	30.8
21	20.7	102	29.8	43	29.9	96	29.7
27	20.4	111	29.2	53	29.4	99	30.1
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82	27.9	165	18.5	106	24.8	144	23.7
99	27.7	175	18.1	117	23.8	148	22.0
116	29.1	185	21.0	123	21.4	149	20.8
129	30.7	194	24.6	123	20.9	159	18.3
141	30.6	209	26.1	134	20.5	169	17.5
159	31.0	243	26.4	144	17.6	179	16.0
176	31.8	268	27.2	154	17.3	189	15.8
194	32.0	294	29.9	164	17.3	199	18.6
		305	33.1	174	17.9	214	21.1
				184	19.8	226	26.0
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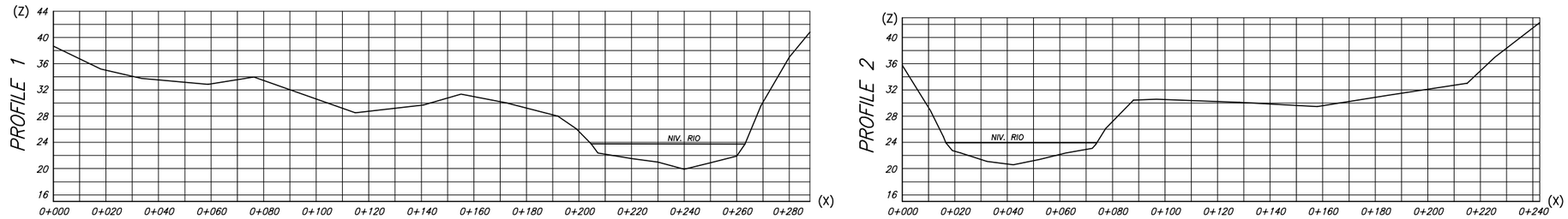
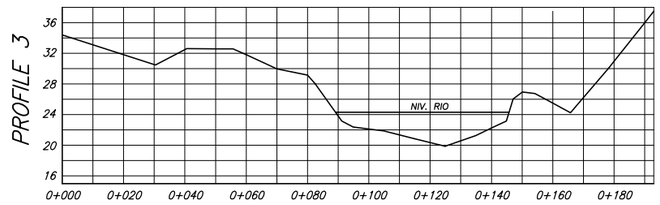
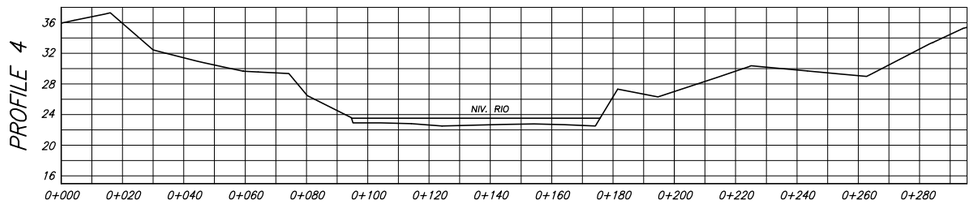
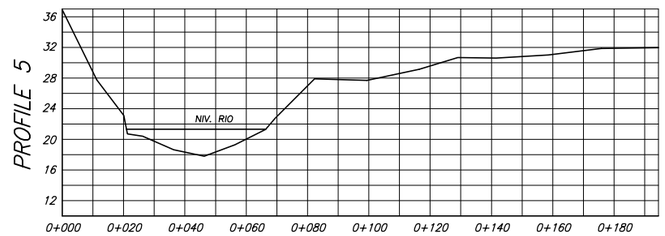
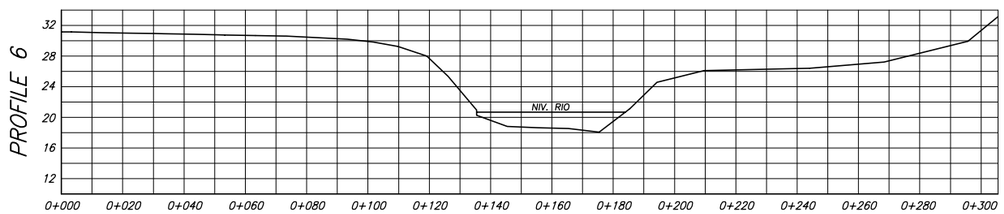
				210	24.9	260	33.4
				224	31.0		
				243	39.6		

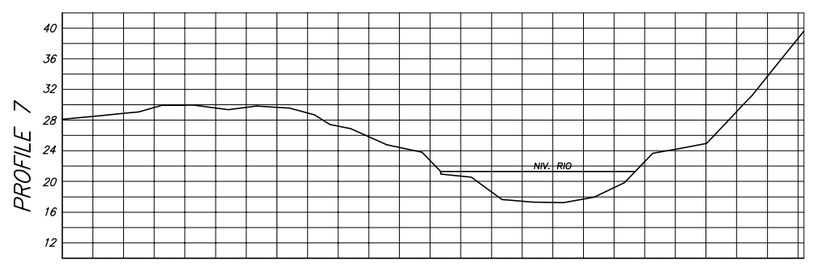


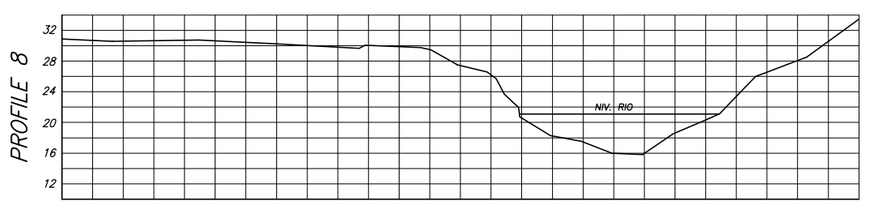












Revis.	DATE	DRAWN BY	CHECKED BY	APPROVED BY	NATURE OF REVISION	STATUS
B	MAY 2003	GTR	JMV	JCO	FINAL EMISSION	
A	NOV. 2002	GTR	JMV	JMV	First Emission	

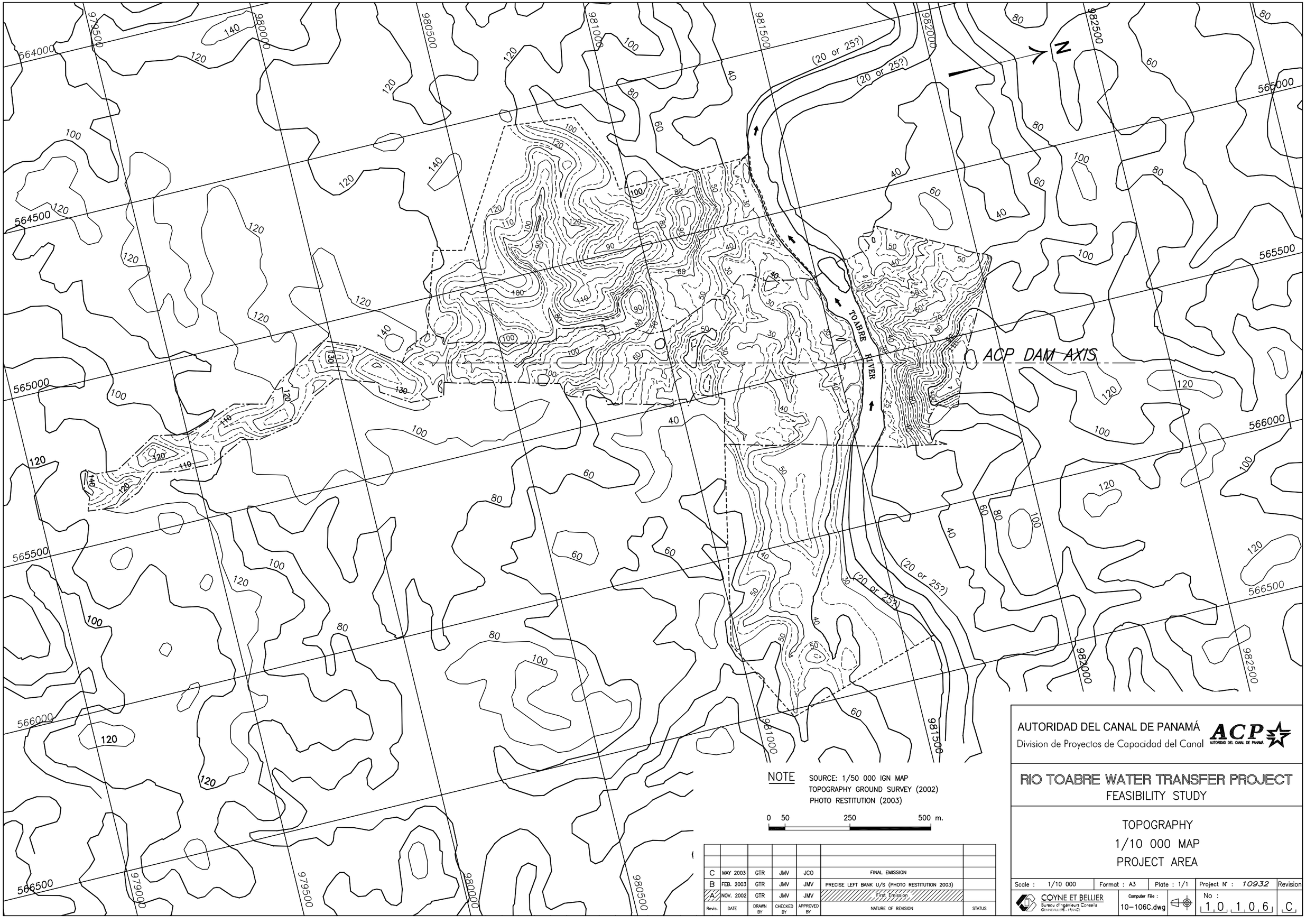
AUTORIDAD DEL CANAL DE PANAMÁ
Division de Proyectos de Capacidad del Canal

RIO TOABRE WATER TRANSFER PROJECT
FEASIBILITY STUDY

TOPOGRAPHY

CROSS SECTIONS OF THE RIO TOABRE
TOPOGRAPHICAL GROUND SURVEY (2002)

Scale : 1/10 000	Format : A3	Plate : 1/1	Project N° : 10000	Revision
COYNE ET BELLIER Bureau d'ingénieurs Conseils GENNEVILLIERS - FRANCE	Computer File : 10−105B.dwg		No : 1,0,1,0,5	B



NOTE

SOURCE: 1/50 000 IGN MAP
TOPOGRAPHY GROUND SURVEY (2002)
PHOTO RESTITUTION (2003)

0 50 250 500 m.

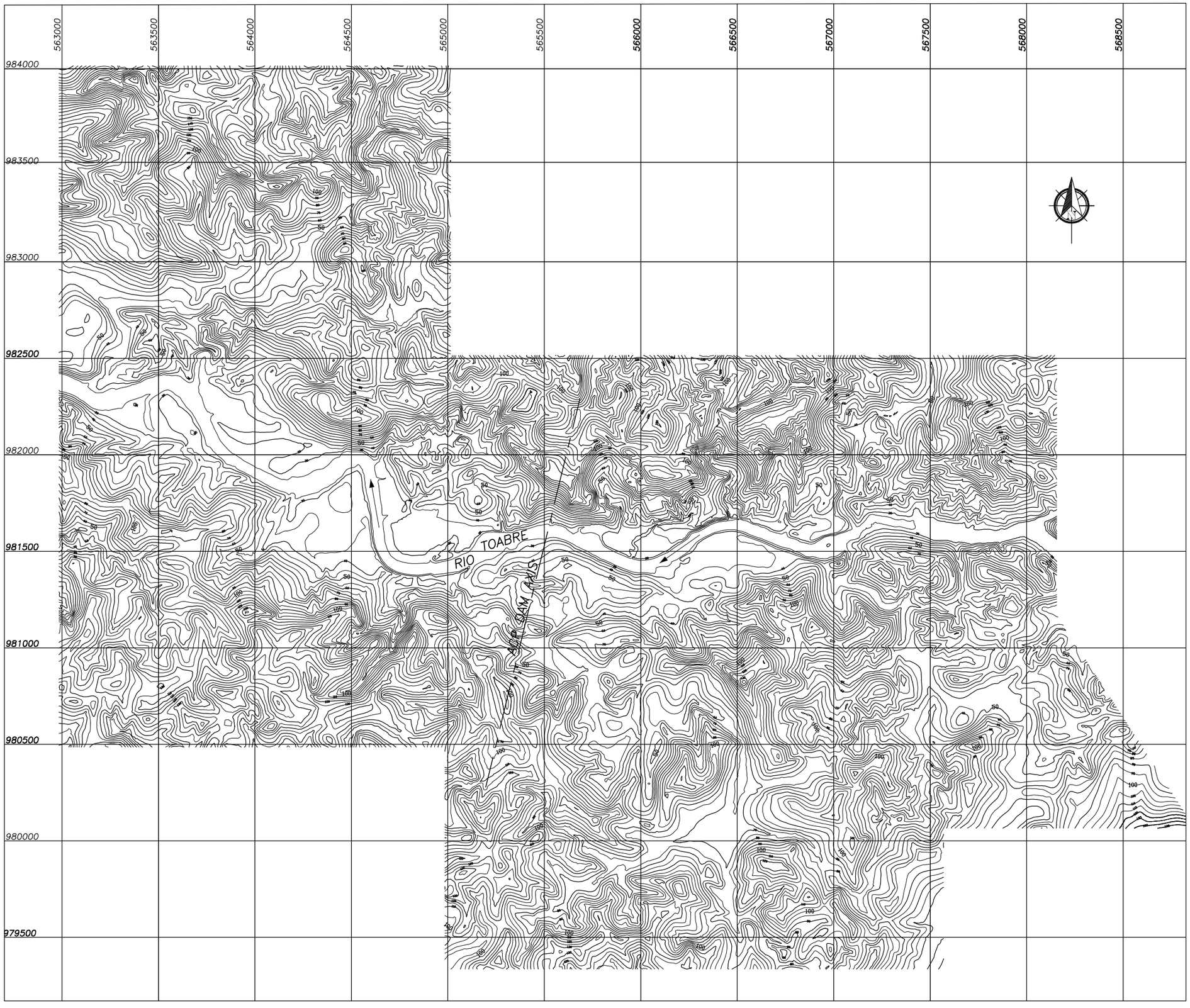
Revis.	DATE	DRAWN BY	CHECKED BY	APPROVED BY	NATURE OF REVISION	STATUS
C	MAY 2003	GTR	JMV	JCO	FINAL EMISSION	
B	FEB. 2003	GTR	JMV	JMV	PRECISE LEFT BANK U/S (PHOTO RESTITUTION 2003)	
A	NOV. 2002	GTR	JMV	JMV	First Emission	

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

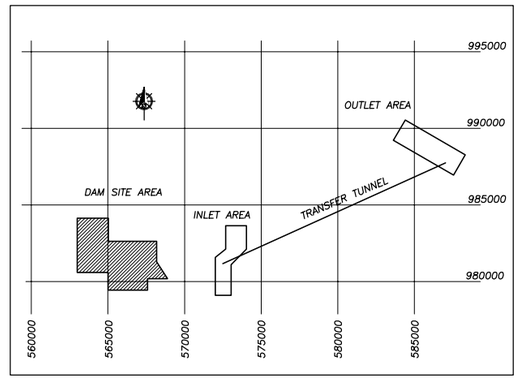
RIO TOABRE WATER TRANSFER PROJECT
FEASIBILITY STUDY

TOPOGRAPHY
1/10 000 MAP
PROJECT AREA

Scale : 1/10 000	Format : A3	Plate : 1/1	Project N° : 10932	Revision
COYNE ET BELLIER Bureau d'Ingénieurs Conseils	Computer File : 10-106C.dwg		No : 10106	C



KEY PLAN



0 100.00 500.00 1000.00 m

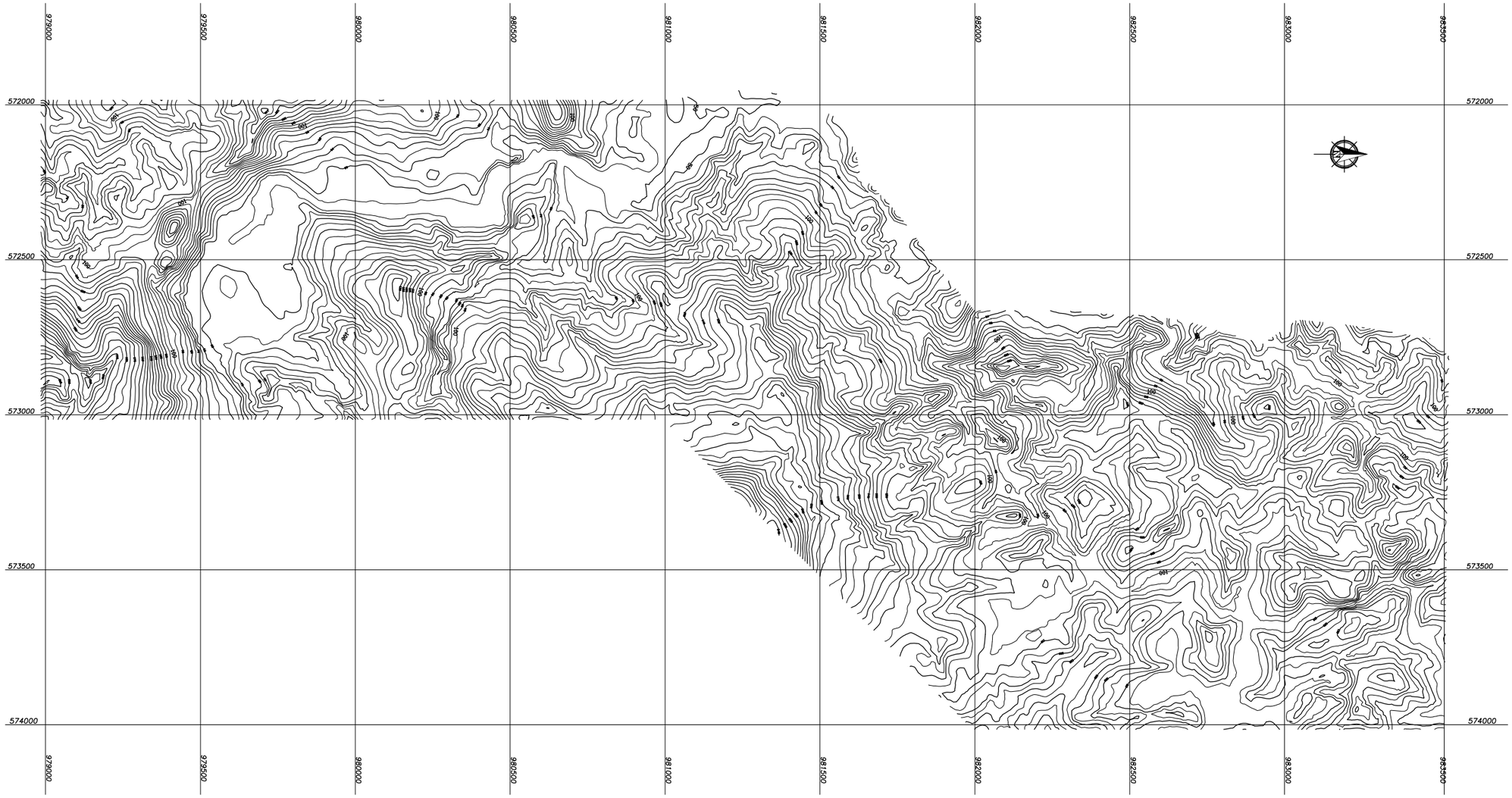
Revis.	DATE	DRAWN BY	CHECKED BY	APPROVED BY	NATURE OF REVISION	STATUS
B	MAY 2003	GTR	JMV	JCO	FINAL EMISSION	
A	19/02/03	MHL	JMV	JMV	First Emission	

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

RIO TOABRE WATER TRANSFER PROJECT
FEASIBILITY STUDY

TOPOGRAPHY
PHOTO RESTITUTION (2003)
SHEET 1/3 – DAM SITE AREA

Scale : 1/20 000	Format : A3	Plate :	Project N° : 10932	Revision
COYNE ET BELLIER Bureau d'Ingénieurs Conseils GENNEVILLIERS - FRANCE	Computer File : 10-107B.dwg		No : 1,0,1,0,7	B



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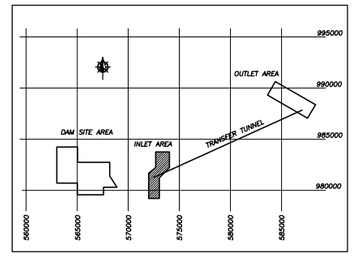


0 50.00 250.00 500.00 m

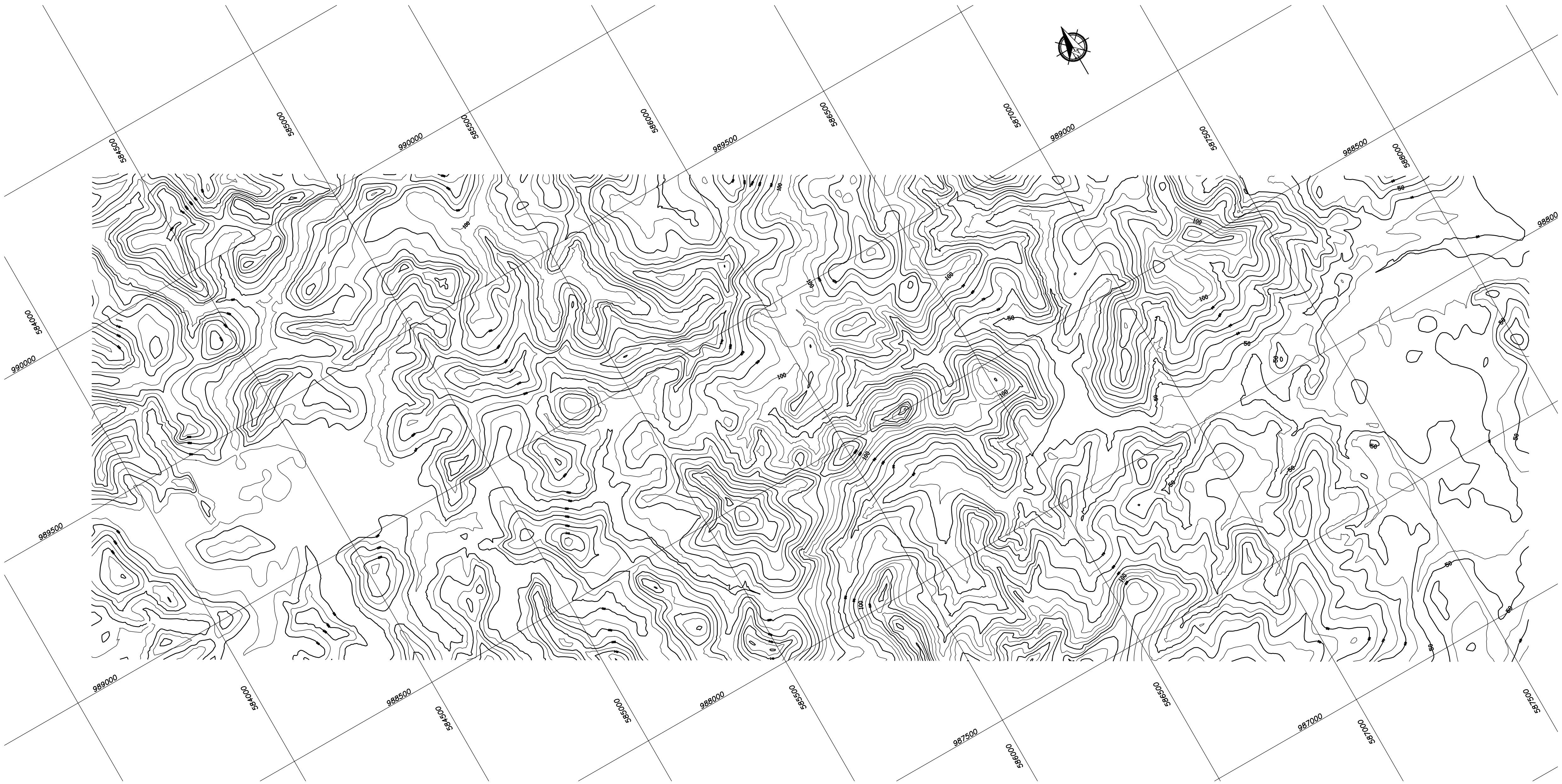
Revis.	DATE	DRAWN BY	CHECKED BY	APPROVED BY	NATURE OF REVISION	STATUS
B	MAY 2003	GTR	JMV	JCO	FINAL EMISSION	
A2	20/02/03	MHL	JMV	JMV	Final Emission Type Emission	

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

RIO TOABRE WATER TRANSFER PROJECT
FEASIBILITY STUDY

TOPOGRAPHY
PHOTO RESTITUTION (2003)
SHEET 2/3 – TUNNEL INLET AREA

Scale : 1/10 000	Format : A3+	Plate :	Project N° : 10932	Revision
COYNE ET BELLIER	Computer File : 10-108B.dwg		No : 1,0,1,0,8,	B



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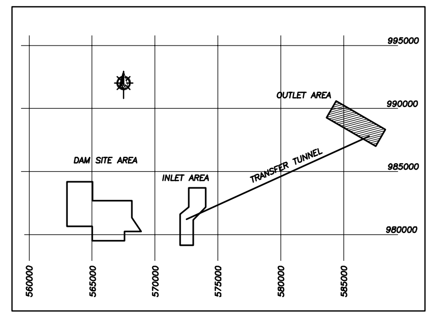

0 50.00 250.00 500.00 m

Revis.	DATE	DRAWN BY	CHECKED BY	APPROVED BY	NATURE OF REVISION	STATUS
B	MAY 2003	GTR	JMV	JCO	FINAL EMISSION	
A	20/02/03	MHL	JMV	JMV	First Emission	

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

RIO TOABRE WATER TRANSFER PROJECT
FEASIBILITY STUDY

TOPOGRAPHY
PHOTO RESTITUTION (2003)
SHEET 3/3 – TUNNEL OUTLET AREA

Scale : 1/10 000	Format : A3+	Plate :	Project N° : 10932	Revision
COYNE ET BELLIER Bureau d'Ingénieurs Conseils GENNEVILLIERS - FRANCE	Computer File : 10–109B.dwg		No : 10 109	B

GEOLOGY

10-201	Geophysical Survey – Location
10-202	Recommended Boreholes Campaign – Location
10-203	Geophysical Results – Right Bank
10-204	Geophysical Results – Left Bank
10-205	Geological Interpretation along ACP and Alternative Dam Axis
10-206	Soil Investigations – Location

NOTE

130m — SEISMIC REFRACTION SPREAD

T : TRANSVERSAL

L : LONGITUDINAL

N

ALTERNATIVE DAM AXIS

ACP DAM AXIS

TOABRE RIVER

TL1 TL2 TL3 TL4 TL5 TL6 TL7 TL8

LL1 LL2 LL3 LL4 LL5 LL6

LR1 LR2 LR3 LR4 LR5

0K+480

1K+380

0 20 100 200 m.

Revis.	DATE	DRAWN BY	CHECKED BY	APPROVED BY	NATURE OF REVISION	STATUS
B	MAY 2003	GTR	JMV	JCO	FINAL EMISSION	
A	Nov.2002	GTR	JMV	JMV	First Emission	

AUTORIDAD DEL CANAL DE PANAMÁ

Division de Proyectos de Capacidad del Canal

ACP AUTORIDAD DEL CANAL DE PANAMÁ

RIO TOABRE WATER TRANSFER PROJECT

FEASIBILITY STUDY

GEOPHYSICAL SURVEY

LOCATION

Scale : 1/4 000	Format : A3	Plate : 1/1	Project N° : 10932	Revision
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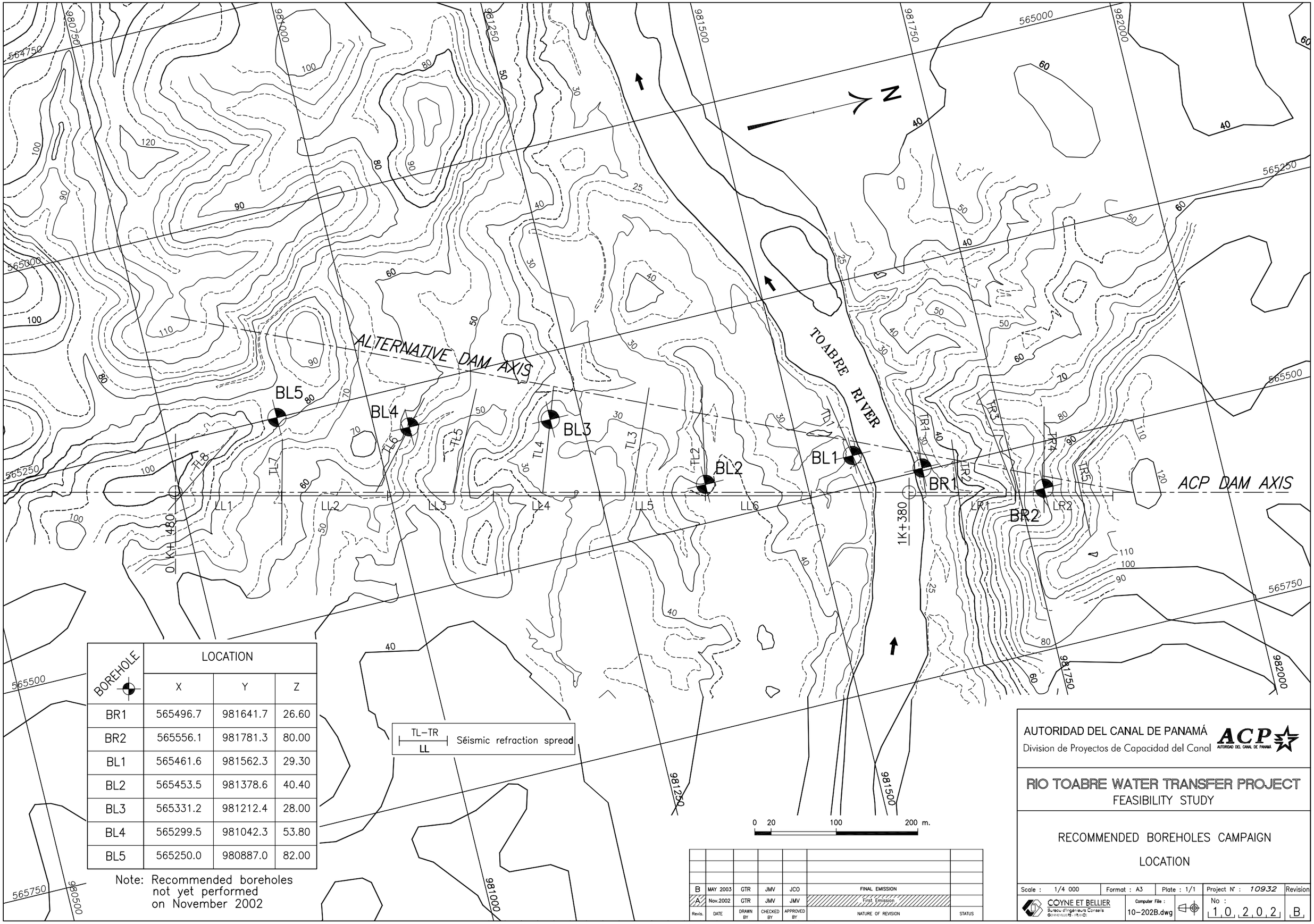

BOREHOLE	LOCATION		
	X	Y	Z
BR1	565496.7	981641.7	26.60
BR2	565556.1	981781.3	80.00
BL1	565461.6	981562.3	29.30
BL2	565453.5	981378.6	40.40
BL3	565331.2	981212.4	28.00
BL4	565299.5	981042.3	53.80
BL5	565250.0	980887.0	82.00

Note: Recommended boreholes not yet performed on November 2002

TL–TR / LL — Séismic refraction spread

Revis.	DATE	DRAWN BY	CHECKED BY	APPROVED BY	NATURE OF REVISION	STATUS
B	MAY 2003	GTR	JMV	JCO	FINAL EMISSION	
A	Nov.2002	GTR	JMV	JMV	First Emission	

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

RIO TOABRE WATER TRANSFER PROJECT
FEASIBILITY STUDY

RECOMMENDED BOREHOLES CAMPAIGN

LOCATION

Scale : 1/4 000	Format : A3	Plate : 1/1	Project N° : 10932	Revision
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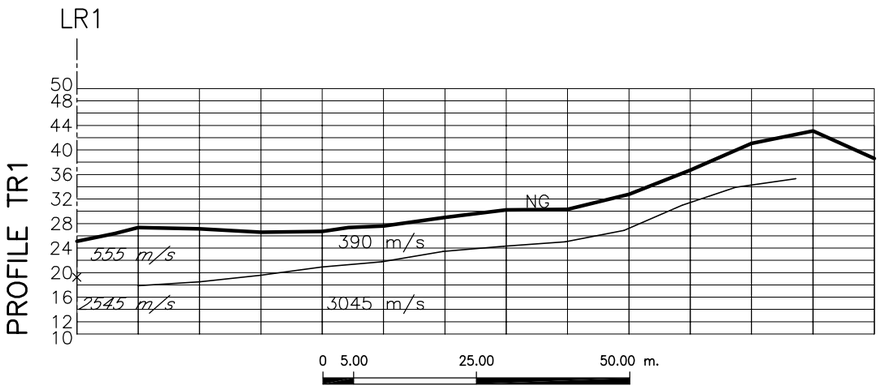
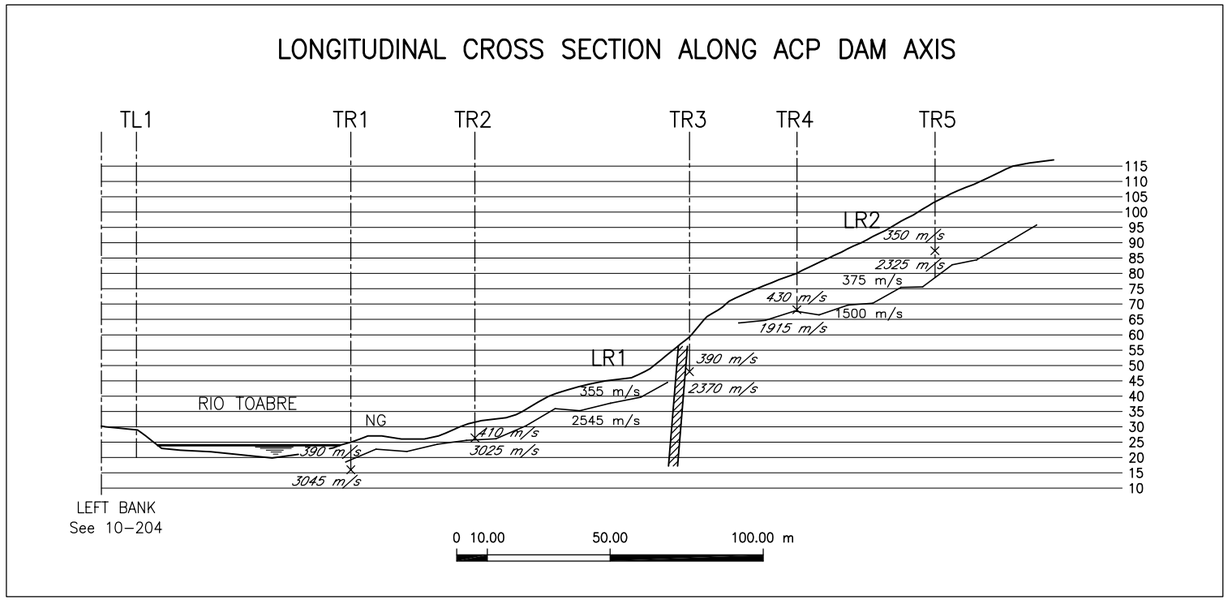
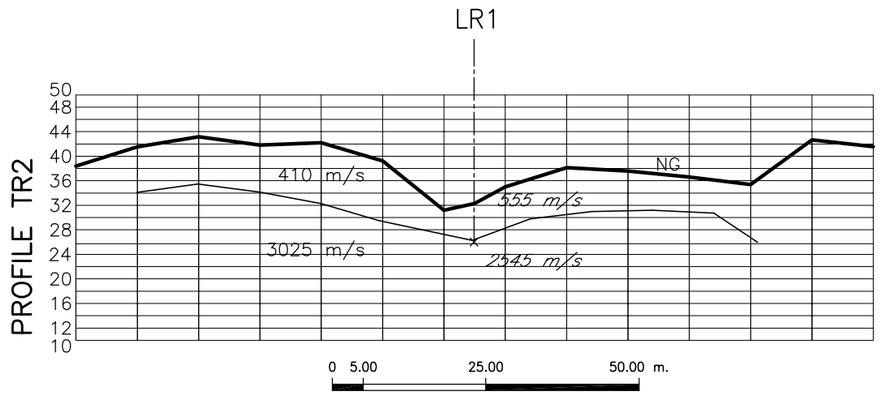
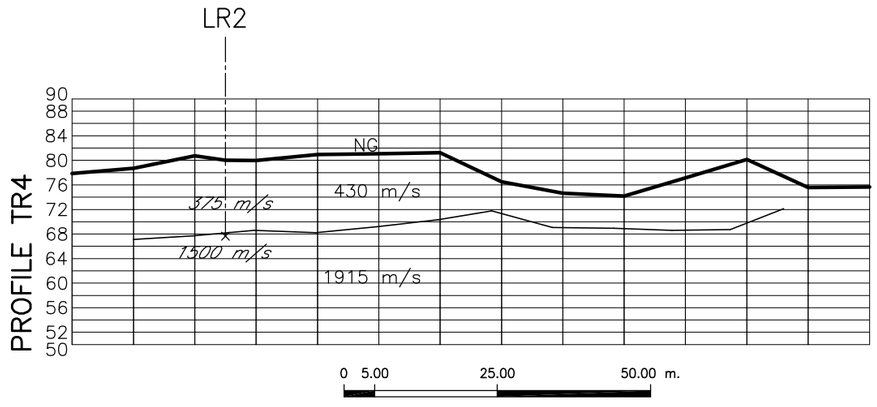








LEGEND

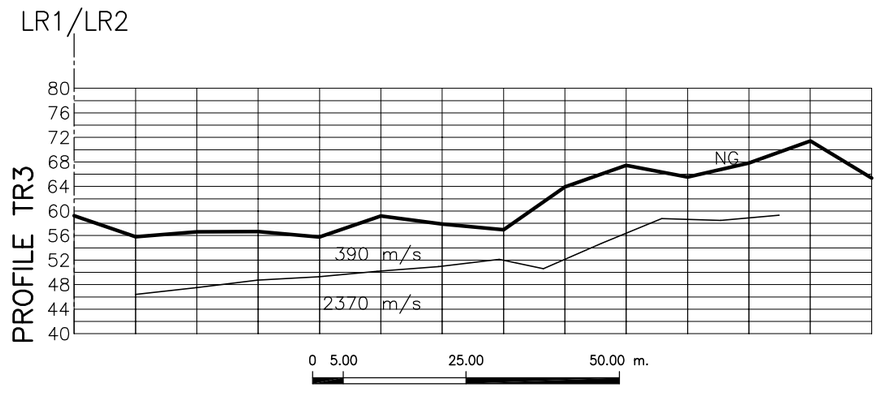
NG — Natural ground

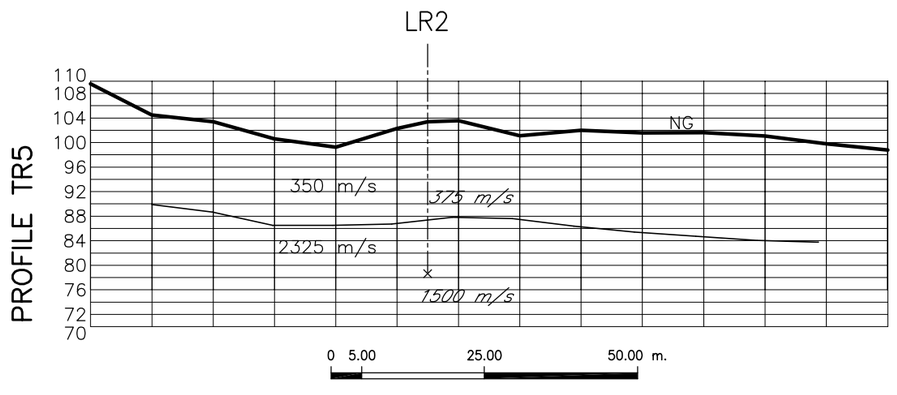
355 m/s / 2545 m/s — Séismic limit with velocity

TR5 — 350 m/s — 2325 m/s — Séismic limit with velocity at intersection

Séismic anomaly

Note: depth model as presented by Contractor





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B	MAY 2003	GTR	JMV	JCO	FINAL EMISSION	
A	Nov.2002	MBA	JMV	JMV	First Emission	

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

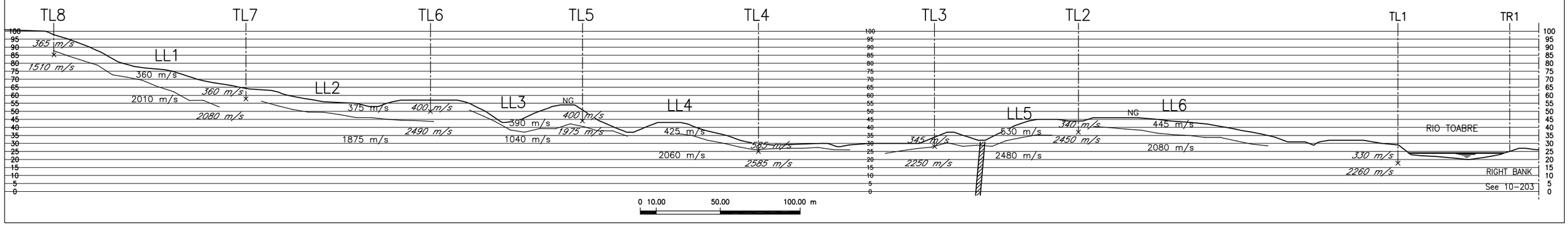
RIO TOABRE WATER TRANSFER PROJECT
FEASIBILITY STUDY

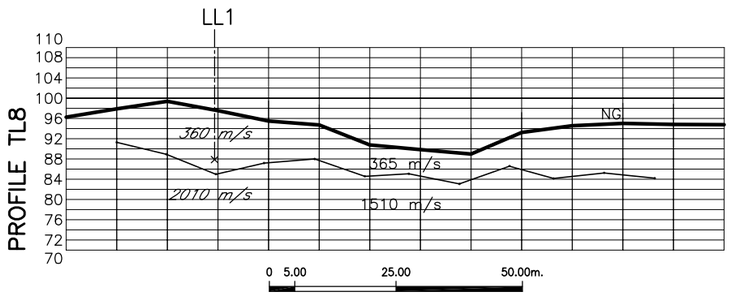
GEOPHYSICAL SURVEY

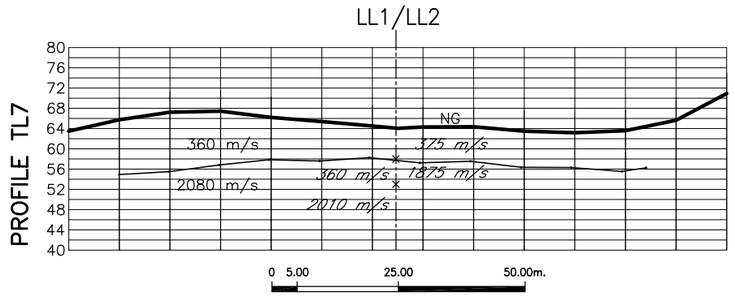
RESULTS – RIGHT BANK

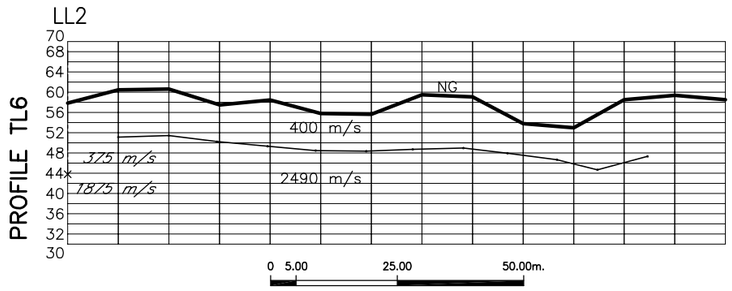
Scale :	Format : A3	Plate : 1/1	Project N° : 10932	Revision
COYNE ET BELLIER Bureau d'Ingénieurs Conseils	Computer File : 10-203B.dwg		No : 10203	B

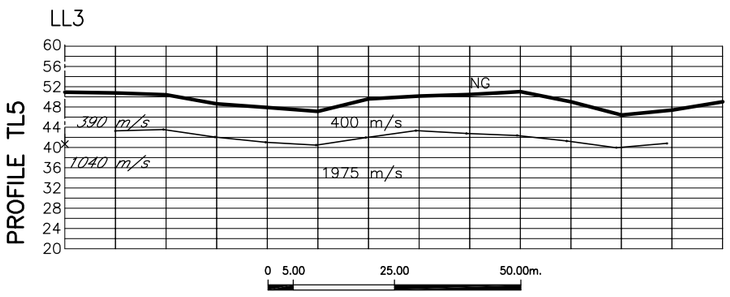
LONGITUDINAL CROSS SECTION ALONG ACP DAM AXIS

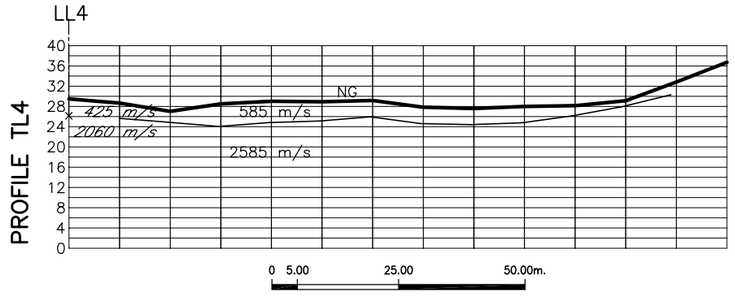


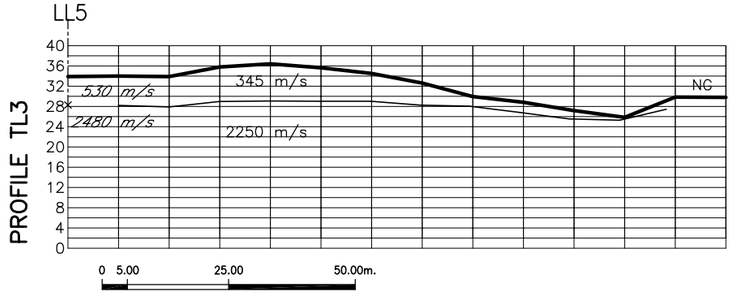


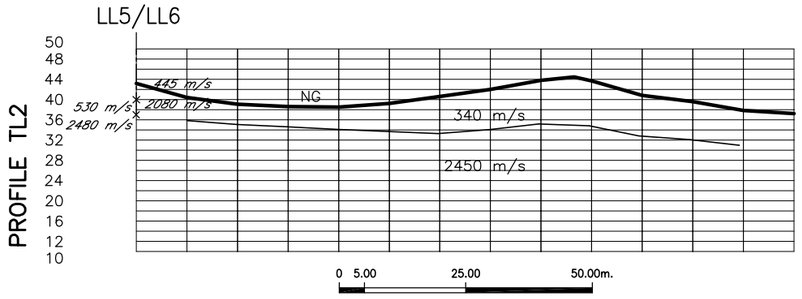


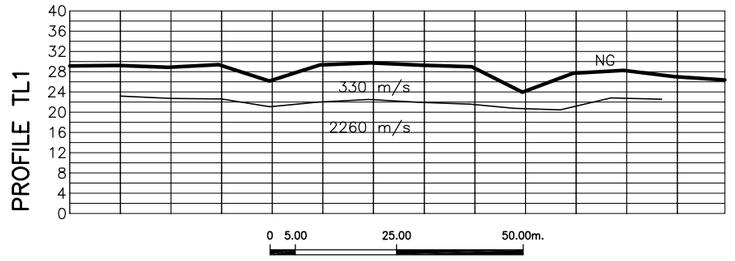












LEGEND

NG — Natural ground

355 m/s / 2545 m/s — Séismic limit with velocity

TL4 / 585 m/s / 2585 m/s — Séismic limit with velocity at intersection

Séismic anomaly

Note: depth model as presented by Contractor

Revis.	DATE	DRAWN BY	CHECKED BY	APPROVED BY	NATURE OF REVISION	STATUS
B	MAY 2003	GTR	JMV	JCO	FINAL EMISSION	
A	Nov.2002	MBA	JMV	JMV	First Emission	

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

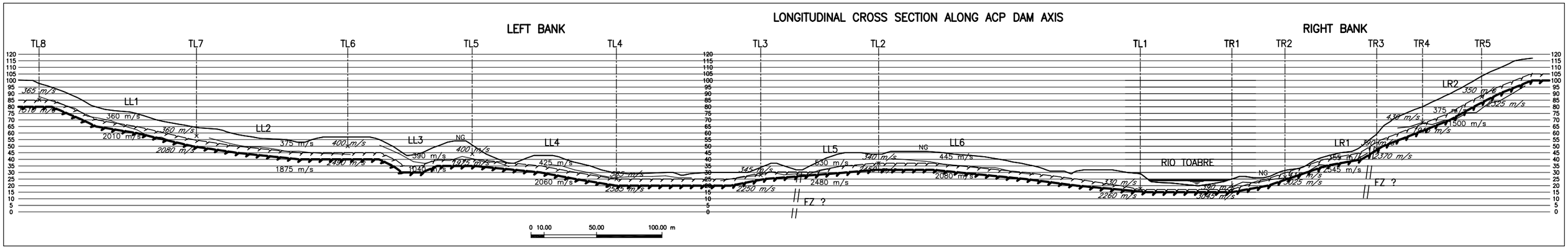
RIO TOABRE WATER TRANSFER PROJECT
FEASIBILITY STUDY

GEOPHYSICAL SURVEY

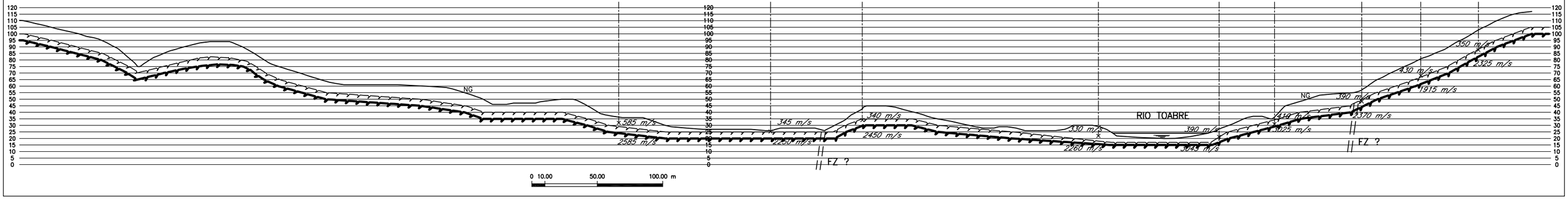
RESULTS – LEFT BANK

Scale :	Format : A3+	Plate : 1/1	Project N° : 10932	Revision
COYNE ET BELLIER Bureau d'Ingénieurs Conseils	Computer File : 10-204B.dwg		No : 10,204	B

LONGITUDINAL CROSS SECTION ALONG ACP DAM AXIS



LONGITUDINAL CROSS SECTION ALONG ALTERNATIVE DAM AXIS



Legend

- NG — Natural ground
- Foundation level:
- Rockfill
- Concrete (CFRD plinth) or RCC structures
- // FZ ? — Possible fault zone inferred from seismic anomalies

Note: Preliminary geological interpretation based on geophysical survey results.

It should be validated after full completion and interpretation of the recommended boreholes campaign.

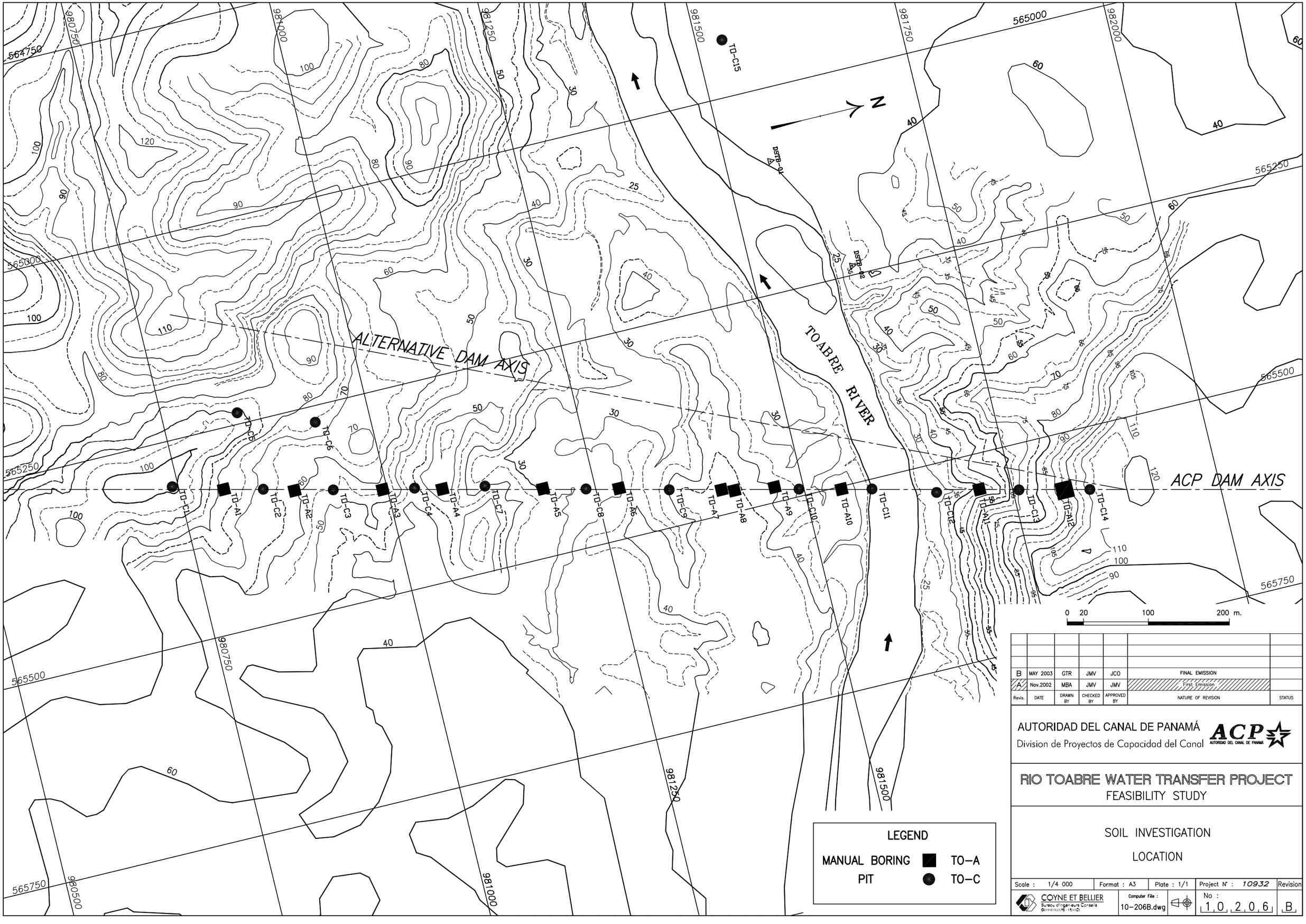
Revis.	DATE	DRAWN BY	CHECKED BY	APPROVED BY	NATURE OF REVISION	STATUS
B	MAY. 2003	CTR	JMV	JCO	FINAL EMISSION	
A	MAR. 2003	MBA	JMV	JMV	PRELIMINARY	

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

RIO TOABRE WATER TRANSFER PROJECT
FEASIBILITY STUDY

GEOLOGICAL INTERPRETATION
ACP AND ALTERNATIVE DAM AXIS

Scale : 1/2000	Format : A3+	Plate : 1/1	Project N° : 10932	Revision
COYNE ET BELLIER	Computer File : 10-205B.dwg		No : 1.0.2.0.5	B



LEGEND

MANUAL BORING ■ TO–A

PIT ● TO–C

Revis.	DATE	DRAWN BY	CHECKED BY	APPROVED BY	NATURE OF REVISION	STATUS
B	MAY 2003	GTR	JMV	JCO	FINAL EMISSION	
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AUTORIDAD DEL CANAL DE PANAMÁ

Division de Proyectos de Capacidad del Canal

RIO TOABRE WATER TRANSFER PROJECT

FEASIBILITY STUDY

SOIL INVESTIGATION

LOCATION

Scale : 1/4 000	Format : A3	Plate : 1/1	Project N° : 10932	Revision
COYNE ET BELLIER Bureau d'ingénieurs Conseils GIENNEVILLIERS - FRANCE	Computer File : 10–206B.dwg		No : 1,0,2,0,6	B

ACP
AUTORIDAD DEL CANAL DE PANAMÁ

RIO TOABRE WATER TRANSFER PROJECT

Feasibility Study

FEASIBILITY REPORT

VOLUME IV - APPENDICES

COYNE ET BELLIER
Bureau d'Ingénieurs Conseils
PARIS - FRANCE

Ref 10932 RP 06 - june 2003

RIO TOABRE WATER TRANSFER PROJECT

Feasibility Study

FEASIBILITY REPORT

VOLUME IV

APPENDICES

Report n° 10932 RP 06

C	June 2003	Final edition	JMV	JCO	JCO
B	May 2003	Pre-final edition	JMV	JCO	JCO
A	March 2003	First emission	JMV	JCO	JCO
Revision	**Date**	**Revision object**	**Redaction**	**Control**	**Approbation**

{INCORPORER Unknown}

COYNE ET BELLIER
Bureau d'Ingénieurs Conseils

APPENDIX - GEOLOGY

(this part has 8 pages)

APPENDIX A Field Mission Report – Coyne et Bellier – April 2002 – Extracts

APPENDIX B Boreholes Campaign – Specifications

APPENDIX A – FIELD MISSION REPORT COYNE ET BELLIER – APRIL 2002 Extracts

FIELD MISSION REPORT

by J.Hugonin and J.M.Vuillot

1. INTRODUCTION

The Consultant's engineers visited the site area on April 18-19, 2002, accompanied by ACP's engineers. The field visit was performed by walking along both banks of the dam site for assessing the natural conditions of dam foundations. In addition, the visit was completed by a helicopter survey around the project area for checking the potentialities in construction materials (chiefly potential quarry sites) and the conditions at the tunnel inlet.

[…]

According to the first major conclusions of the visit, a programme of preliminary investigations is recommended by the Consultant in order to get indispensable geological data basis for preparing the feasibility dam design. Such programme which would usually consist with boreholes, pits, trenches, field tests, adits, geophysical survey, and so on, was actually restricted due to local context and then limited to geophysical survey, auger holes excavation, soil sampling and laboratory tests.

2. ATTENDANTS TO THE FIELD VISIT:

ACP

Roderik Lee (only April 19)	Project Manager
Derek Irving	Geologist
Emilio Messina	Sociologist

Consultant

J. Hugonin	Geologist
J.M. Vuillot	Design Engineer
A. Ramirez	Geologist

[…]

4. RECOMMENDED PROGRAMME OF INVESTIGATIONS AT THE DAM SITE

4.1. Seismic Refraction Survey

Refraction seismic profiling is programmed at the early stage of investigations of the dam site for a preliminary assessment of the natural conditions of foundation. It shall provide the basic information on the geological context such as :

- thickness and nature of the soil overburden,
- thickness of the decompressed rock zone (weathered or fissured) and the depth of the underlying hard rock. Offset shots are duly recommended for that purpose as the bedrock surface is inferred to be more or less deep and irregular.
- the presence of fault zones and highly fractured areas.

The distribution of the seismic profiles to be carried out along (//) or perpendicularly (⊥) to the topo alignment A1 is given in Table 1 and shown on Figures 3 & 4:

Spread	Location	Direction / A1	Priority
S1	Toe of RB	//	1
S2+S3+S4+S5+S6	Low part of LB from river	//	1
R1	Toe of RB	⊥ D/S	1
L1	Toe of LB	⊥ D/S	1
L2	LB peg n°2007	⊥ D/S	1
L3	LB Qbd Resumidero	⊥ D/S	1
R2	RB El. 40	⊥ Mid	2
R3	RB El. 60	⊥ Mid	2
R4	RB El. 80	⊥ Mid	2
R5	RB El. 100	⊥ Mid	2
L4	LB El. 40	⊥ D/S	3
L5	LB El. 60	⊥ D/S	3
L6	LB El. 80	⊥ D/S	3
L7	LB El. 100	⊥ D/S	3
R6	Top RB	North-South	4
R7	Top RB	⊥ R6 Mid	4
TOTAL = 20 spreads			

Table 1 – Distribution of Seismis Profiles

Note :

Spreads L and R are transversal (perpendicular or oblique) to the topo alignment A1. It is recommended to locate their alignment along a contour line to avoid too sharp topographic irregularities. D/S means that the transversal spread starts from the A1 alignment toward downstream; Mid means that the spread is centred on the A1 alignment.

4.2. Augering

Vertical holes shall be excavated by hand-driven or mechanical auger every 50 m along the topo alignment (A1). The excavation shall be managed in such a way that each identified soil layer, removed from the excavation, shall be taken as representative disturbed soil sample to be sent to laboratory for geotechnical identification: natural water content, sieve analysis, Atterberg limits, specific gravity.

Holes shall be tentatively dug down to the bedrock surface through the soil layers, which shall be described in detail.

4.3. Soil Sampling and Laboratory Tests

Five (5) undisturbed (U) and ten (10) disturbed (D) soil samples shall be taken from shallow pits (≤1 m deep) to be dug at various locations along or downstream of the topo alignment (A1), as shown on Figure 4.

The list of tests to be performed is given hereafter:

Test	Sample from pit n°
Identification : natural water content, sieve analysis and sedimentometry, Atterberg limits, specific gravity	All samples from Pit 1 to Pit 15.
Proctor then **shear test** on remoulded sample	6 samples : Pits 5, 6, 7, 8, 9, 15.
Shear test on undisturbed sample	5 samples : Pits 1, 2, 4, 10, 12.

5. RECOMMENDED PROGRAMME OF INVESTIGATIONS FOR CONSTRUCTION MATERIALS

From the site survey it is obvious that large quantities of clayey material are available over the whole extent of the project area. Identification and characteristics of this material will be properly withdrawn from the results of the tests programmed for the dam site (see § 4).

On the opposite, rock material for aggregates and/or rockfill as well as gravel and sand are poorly exposed in the project area and along the river course only. In this respect, investigations of potential quarry site are still to be undertaken, according to the following programme.

5.1. Rock Material

During the field visit two areas were identified as possible quarries (RQ1 and RQ2), located along the upstream course of the Toabre river (see Figure 5). Complementary detailed geological survey of these two areas shall be performed in order to estimate the quality and available quantity of borrowable rock (not only in the riverbed but more specifically in both banks).

Searching of others potential sites is recommended over the project area (approximately 20 km long radius from the dam site) by direct inquiries to the local population.

5.2. Gravel and Sandy Material

Some alluvial deposits were observed in the vicinity of the dam site along the riverbed. Evaluation of the available quantities and granulometry of these deposits must be done by a specific geological survey.

Searching of such deposits must be extended even far upstream and downstream of the site.

6. TECHNICAL SPECIFICATIONS FOR INVESTIGATIONS

6.1. Refraction Seismic Survey

Special requirements for the seismic refraction profiling are:

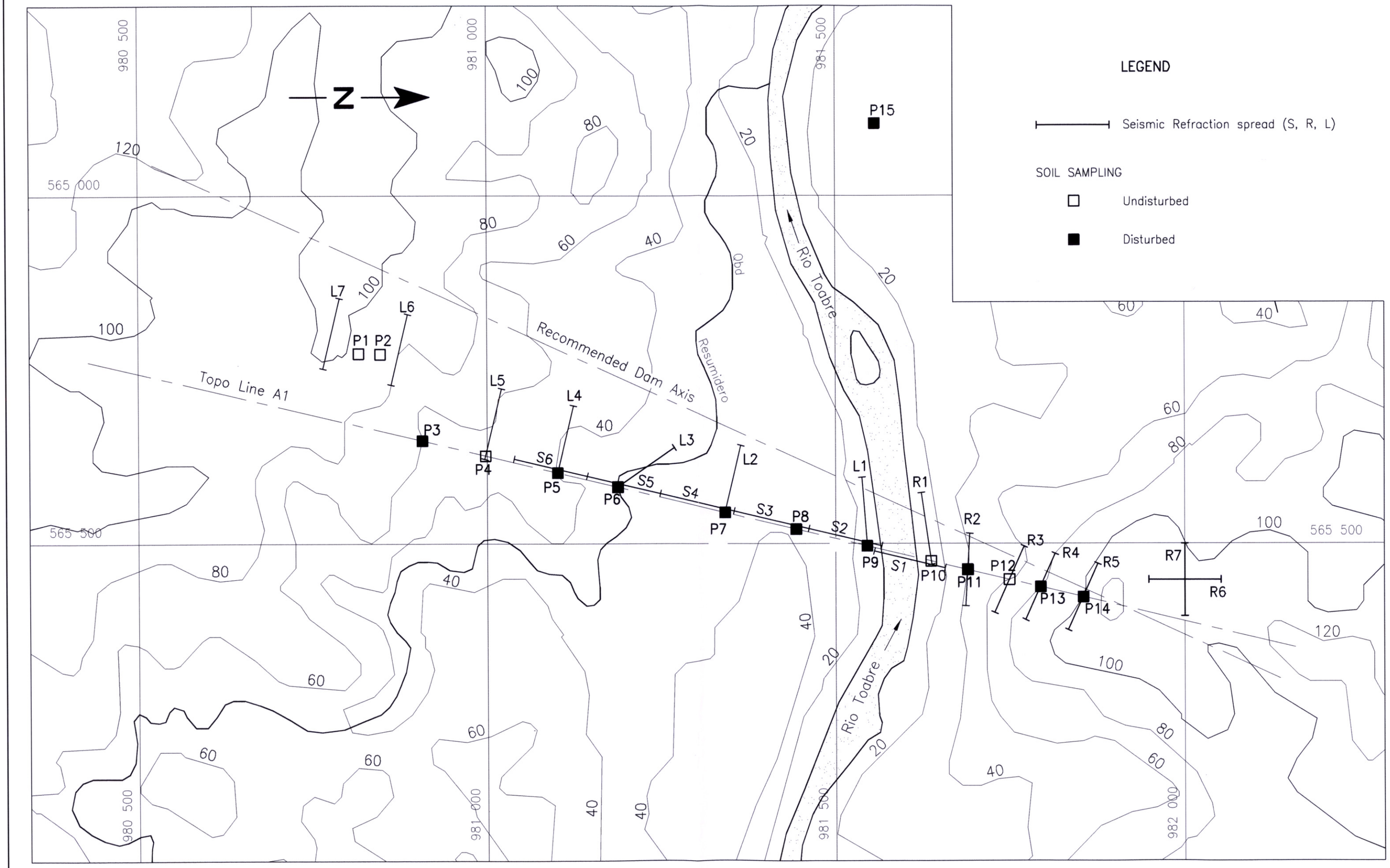
- individual spread of 12 geophones with a 10 m long spacing between geophones,
- minimum of five shocks by spread, i.e. one in the middle, one forward, one reverse and two offsets (at a linear distance of 2 to 5 times the spread length),
- shocks by using a Betsy gun,
- hydrophones if possible for the seismic spread in the river course,
- detailed topographical survey (in elevation) of each geophone,
- interpretation with plus-minus method,
- report with vertical sections at 1/1000 scale.

6.2. Soil Sampling and Laboratory Tests

Undisturbed block samples shall be taken in pit floor. Block samples shall be excavated in a proper way for avoiding wetting, drying out or mechanical disturbance. They shall be sealed using paraffin wax, securely packed in a stout wooden box and labelled with complete indications.

Proctor tests shall be performed following the method by five compaction stages (preparation and sieving of the sampled material for each of five stage of compaction) that requires about 50 kg of material. Energy of compaction shall be the Standard Proctor one.

Speed of shearing (shear tests) shall be low, within the range of 2-micron/per minute.



RIO TOABRE WATER TRANSFER PROJECT

INVESTIGATIONS

PLAN VIEW

Date : 26/04/02	Des. BPL	Contr. JMV	Appr. JMV
COYNE ET BELLIER Bureau d'Ingénieurs Conseils GENNEVILLIERS - FRANCE	N°d'affaire : 10932		Indice
	No : FIG 4		A

Fichier informatique : Fig3-4-invest-A.dwg

APPENDIX B
RECOMMENDED BOREHOLES CAMPAIGN SPECIFICATIONS

The aim of this boreholes campaign is to calibrate and validate the interpretation of the seismic refraction results recently obtained at the Rio Toabre Dam Site. The final goal is to define the foundation level for the dam and its appurtenant works.

The program has been defined taking into account ACP's recommendation to perform this campaign as quick as possible in order to minimise possible problems with the field owners.

The proposed tentative program comprises 7 boreholes with 2 main degrees of priority : priority 1 for 4 indispensable boreholes and priority 2 for 3 additional boreholes. For both main priority a second-degree priority has been also defined (A-B-C-D) in order to get essential information if any problem stops the campaign before completion.

Drawing 10-202 gives the location and the priority of the 7 boreholes; for practical reason each location is chosen on the topographical transversal profiles levelled prior to the seismic survey.

The boreholes will be drilled according to the following specifications:

- direction: vertical.
- diameter: NQ minimum.
- depth: reach and identify the soil/rock contact and then proceed down into the rock sequence (with a minimum of 5 m) until penetrate 2 m into the sound rock layer.
- coring: full core recovery from soil/rock contact ; destructive drilling in soil sequence is acceptable if significant time is saved, except for BL4, BL5 and BR2 where coring of soil sequence is also required. Storage in boxes.
- logging on site by geologist. Photos of cores.

A permanent supervision of the works by an experienced geologist is required, especially to define / adapt the depth of the boreholes with the results during progress to meet the specifications (sound rock level).

Logs will be sent to Coyne et Bellier as the works progress. A field data report with all useful information (logs, photos, observations, water level in boreholes, etc.) will be issued (in English) by the geologist.

APPENDIX - HYDROLOGY

(this part has 41 pages)

APPENDIX A – HYDROMETEOROLOGICAL STATIONS NETWORK

APPENDIX B – YEARLY ISOHYETS MAP IN INCHES – PERIOD 1974-1998

APPENDIX C – MONTHLY AND YEARLY RAINFALL DATA

APPENDIX D – MAXIMUM DAILY RAINFALL DATA

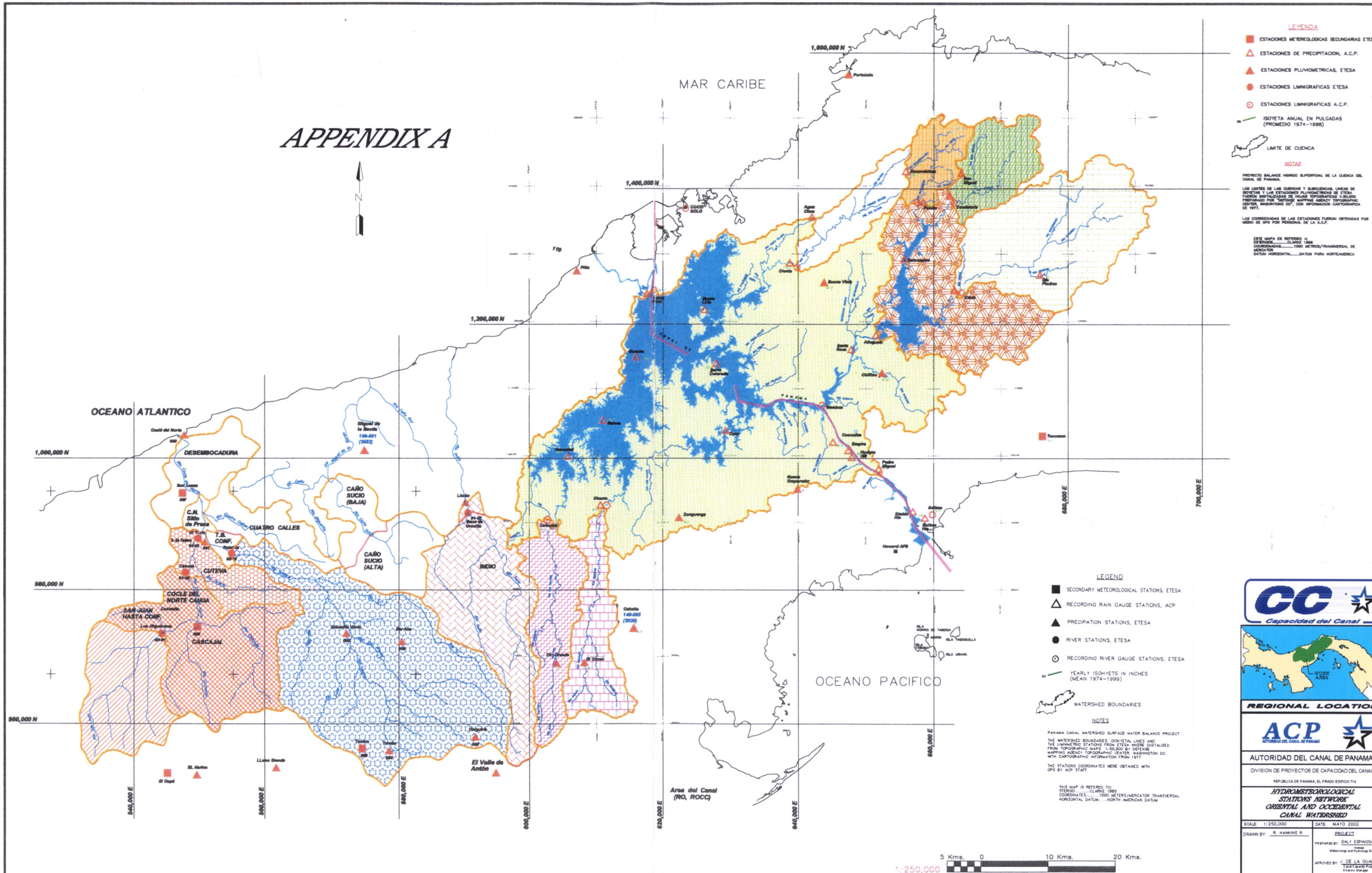
APPENDIX E – EXTENSION OF MAXIMUM DAILY RAINFALL USING GATUN DATA

APPENDIX F – YEARLY RAINFALL AT GATUN DS VS. RUNOFF AT BATATILLA

APPENDIX G – FLOOD DATA

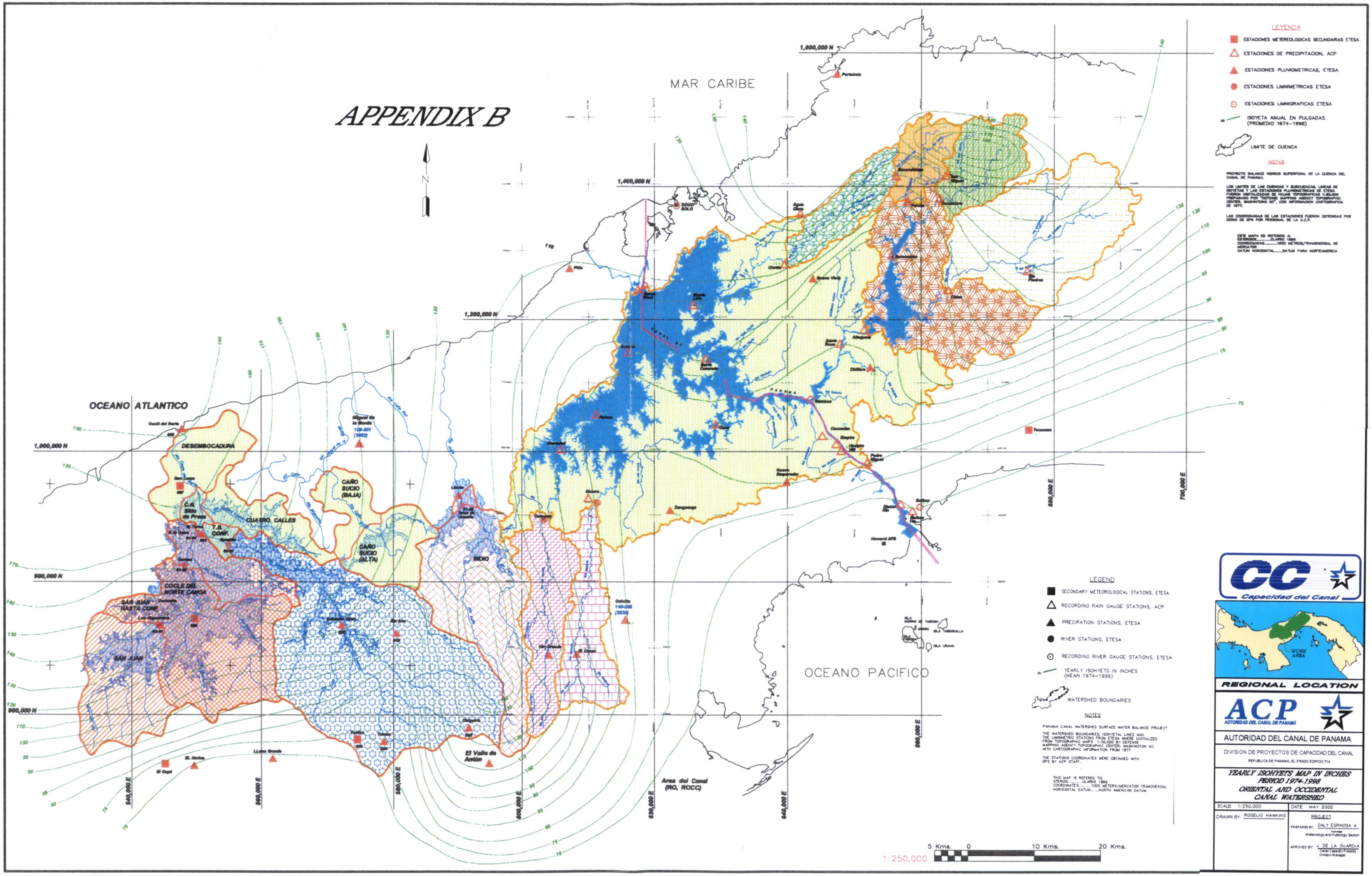
APPENDIX H – SEDIMENT TRANSPORT

APPENDIX A



MAR CARIBE
OCEANO ATLANTICO
OCEANO PACIFICO
DESEMBOCADURA
CUATRO CALLES
CAÑO SUCIO (BAJA)
CAÑO SUCIO (ALTA)
INDIO
CUTEVA
COCLE DEL NORTE CAÑA
SAN JUAN HASTA CONF.
CASCAJAL
El Valle de Antón
Area del Canal (RO, ROCC)
1,600,000 N
1,400,000 N
1,200,000 N
1,000,000 N
980,000 N
960,000 N
540,000 E
560,000 E
580,000 E
600,000 E
620,000 E
640,000 E
660,000 E
680,000 E
700,000 E
5 Kms. 0 10 Kms. 20 Kms.
1: 250,000
LEYENDA
ESTACIONES METEREOLOGICAS SECUNDARIAS ETESA
ESTACIONES DE PRECIPITACION, A.C.P.
ESTACIONES PLUVIOMETRICAS, ETESA
ESTACIONES LIMNIGRAFICAS ETESA
ESTACIONES LIMNIGRAFICAS A.C.P.
ISOYETA ANUAL EN PULGADAS (PROMEDIO 1974–1998)
LIMITE DE CUENCA
NOTAS
PROYECTO BALANCE HIDRICO SUPERFICIAL DE LA CUENCA DEL CANAL DE PANAMA.
LOS LIMITES DE LAS CUENCAS Y SUBCUENCAS, LINEAS DE ISOYETAS Y LAS ESTACIONES PLUVIOMETRICAS DE ETESA FUERON DIGITALIZADAS DE HOJAS TOPOGRAFICAS 1:50,000 PREPARADO POR "DEFENSE MAPPING AGENCY TOPOGRAPHIC CENTER, WASHINTONG DC", CON INFORMACION CARTOGRAFICA DE 1977.
LAS COORDENADAS DE LAS ESTACIONES FUERON OBTENIDAS POR MEDIO DE GPS POR PERSONAL DE LA A.C.P.
ESTE MAPA ES REFERIDO A:
ESTEROIDE..........CLARKE 1866
COORDENADAS..........1000 METROS/TRANSVERSAL DE MERCATOR
DATUM HORIZONTAL......DATUM PARA NORTEAMERICA
LEGEND
SECONDARY METEOROLOGICAL STATIONS, ETESA
RECORDING RAIN GAUGE STATIONS, ACP
PRECIPATION STATIONS, ETESA
RIVER STATIONS, ETESA
RECORDING RIVER GAUGE STATIONS, ETESA
YEARLY ISOHYETS IN INCHES (MEAN 1974–1999)
WATERSHED BOUNDARIES
NOTES
PANAMA CANAL WATERSHED SURFACE WATER BALANCE PROJECT
THE WATERSHED BOUNDARIES, ISOHYETAL LINES AND THE LIMNIMETRIC STATIONS FROM ETESA WHERE DIGITALIZED FROM TOPOGRAPHIC MAPS 1:50,000 BY DEFENSE MAPPING AGENCY TOPOGRAPHIC CENTER, WASHINGTON DC. WITH CARTOGRAPHIC INFORMATION FROM 1977
THE STATIONS COORDINATES WERE OBTAINED WITH GPS BY ACP STAFF.
THIS MAP IS REFERED TO:
STEROID..........CLARKE 1866
COORDINATES..........1000 METERS/MERCATOR TRANSVERSAL
HORIZONTAL DATUM......NORTH AMERICAN DATUM
Capacidad del Canal
WORK AREA
REGIONAL LOCATION
ACP
AUTORIDAD DEL CANAL DE PANAMA
AUTORIDAD DEL CANAL DE PANAMA
DIVISION DE PROYECTOS DE CAPACIDAD DEL CANAL
REPUBLICA DE PANAMA, EL PRADO EDIFICIO 714
HYDROMETEOROLOGICAL STATIONS NETWORK ORIENTAL AND OCCIDENTAL CANAL WATERSHED
SCALE: 1:250,000
DATE: MAYO 2002
DRAWN BY: R. HAWKINS R.
PROJECT
PREPARED BY: DALY ESPINOSA A.
Meteorology and Hydrology Sections
APROVED BY: J. DE LA GUARDIA
Canal Capacity Projects Division Manager

APPENDIX B



MAR CARIBE
OCEANO ATLANTICO
OCEANO PACIFICO
LEYENDA
ESTACIONES METEREOLOGICAS SECUNDARIAS ETESA
ESTACIONES DE PRECIPITACION, ACP
ESTACIONES PLUVIOMETRICAS, ETESA
ESTACIONES LIMNIMETRICAS ETESA
ESTACIONES LIMNIGRAFICAS ETESA
ISOYETA ANUAL EN PULGADAS (PROMEDIO 1974-1998)
LIMITE DE CUENCA
NOTAS
LEGEND
SECONDARY METEOROLOGICAL STATIONS, ETESA
RECORDING RAIN GAUGE STATIONS, ACP
PRECIPITATION STATIONS, ETESA
RIVER STATIONS, ETESA
RECORDING RIVER GAUGE STATIONS, ETESA
YEARLY ISOHYETS IN INCHES (MEAN 1974-1999)
WATERSHED BOUNDARIES
NOTES
PANAMA CANAL WATERSHED SURFACE WATER BALANCE PROJECT
THE STATIONS COORDINATES WERE OBTAINED WITH GPS BY ACP STAFF.
DESEMBOCADURA
CUATRO CALLES
CAÑO SUCIO (BAJA)
CAÑO SUCIO (ALTA)
INDIO
COCLE DEL NORTE CANOA
SAN JUAN HASTA CONF.
SAN JUAN
El Valle de Antón
Area del Canal (RIO, ROCC)
1,600,000 N
1,400,000 N
1,200,000 N
1,000,000 N
980,000 N
960,000 N
540,000 E
560,000 E
580,000 E
600,000 E
620,000 E
640,000 E
660,000 E
680,000 E
700,000 E
5 Kms. 0 10 Kms. 20 Kms.
1: 250,000
CC Capacidad del Canal
REGIONAL LOCATION
WORK AREA
ACP AUTORIDAD DEL CANAL DE PANAMA
AUTORIDAD DEL CANAL DE PANAMA
DIVISION DE PROYECTOS DE CAPACIDAD DEL CANAL
YEARLY ISOHYETS MAP IN INCHES PERIOD 1974-1998 ORIENTAL AND OCCIDENTAL CANAL WATERSHED
SCALE 1:250,000
DATE MAY 2002
DRAWN BY: ROGELIO HAWKINS
PROJECT
PREPARED BY: DALY ESPINOSA A.
APROVED BY: J. DE LA GUARDIA

APPENDIX C – MONTHLY AND YEARLY RAINFALL DATA

C.1 – Toabre (105 005)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1970						215	224	179	395	439	213	289	
1971	166	11	56	14	188	245	187	252	325	290	288	36	2 060
1972	105	27	63	176	113	76	133	195	203	135	107	74	1 408
1973	6	33	1	46	181	266	370	299	399	501	338	100	2 540
1974	22	28	14	36	100	269	231	190	356	266	170	30	1 711
1975	10	6	7	10	203	186	178	413	246	454	551	164	2 426
1976	42	15	12	73	86	94	139	222	266	246	46	34	1 273
1977	17	13	3	11	331	219	174	371	146	256	194	106	1 839
1978	30	15	100	171	243	190	181	247	296	408	339	72	2 292
1979	10	17	4	247	303	253	361	338	186	257	137	168	2 281
1980	59	29	3	24	264	306	158	302	214	416	307	119	2 201
1981	76	26	44	173	391	213	271	419	252	335	310	234	2 744
1982	78	6	14	125	307	164	215	173	148	330	38	10	1 607
1983	19	0	8	41	146	132	153	91	267	267	140	174	1 439
1984	22	48	42	34	210	315	436	398	316	304			
1985	70	10	18	12	170	376	145	373	282	250	233	81	2 021
1986	52	6	28	103	130	335	210	210	291	381	305	12	2 062
1987	19	11	2	91	54	129	260	124	224	364	110	47	1 435
1988	11	20	4	52	285	235	294	438	368	384	303	96	2 490
1989	28	29	9	8	259	243	226	156	143	160	309	150	1 719
1990	32	11	44	17	213	133	179	228	361	276	197	149	1 840
1991	7	12	81	2	216	165	173	134	338	140	73	64	1 407
1992	10	3	0	72	153	346	126	218	187	230	92	61	1 497
1993	133	14	65	31	160	263	63	155	295	289	240	90	1 799
1994	11	10	37	63	358	185	116	134	141	251	111	15	1 431
1995	7	5	6	76	186	161	136	126	347	153	133	128	1 118
1996	115	55	14	72	359	154	208	287	352	124	198	177	2 041
1997	24	13	0	17	65	74	95	34	89	295	201	28	936
1998	13	18	21	40	174	253	276	228	382				
M	43	18	25	65	209	214	204	239	267	293	210	100	1 886

Units: mm

C.2 – Tambo (105 004)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1970		197	258	380	765	478	230	141	244	545	261	224	
1971	90	26	34	13	65	218	224	228	299	192	217	79	1 682
1972	58	25	32	98	81	78	141	201	227	164	77	45	1 227
1973	8	11	2	29	191	272	329	261	351	403	292	85	2 233
1974	15	32	21	31	125	211	254	222	299	359	164	22	1 755
1975	8	5	1	3	221	160	244	373	382	445	513	267	2 621
1976	24	9	0	66	95	145	152	230	261	266	24	29	1 302
1977	3	6	0	8	185	209	168	354	181	161	160	49	1 484
1978	27	10	102	122	313	238	292	265	396	303	300	124	2 493
1979	22	15	6	142	211	261	186	333	280	287	190	84	2 017
1980	42	18	4	17	323	279	116	229	169	384	358	124	2 063
1981	78	34	51	125	252	116	224	287	169	222	254	189	1 999
1982	69	4	13	100	252	208	361	207	204	376	40	19	1 850
1983	11	1	14	66	299	172	145	102	248	283	124	151	1 616
1984	24	66	30	33	242	356	387	454	201	322	210	51	2 376
1985	64	12	24	4	161	445	194	365	252	249	326	118	2 213
1986	49	5	16	128	86	316	279	191	234	332	309	24	1 969
1987	16	14	2	62	104	173	212	184	285	386	146	46	1 628
1988	5	18	0	71	322	280	255	350	449	406	304	110	2 571
1989	43	32	23	11	266	272	238	172	117	166	263	138	1 740
1990	53	0	41	18	159	98	212	353	366	317	158	160	1 935
1991	7	20	87	0	206	173	199	148	363	214	95	138	1 649
1992	5	16	1	53	229	334	233	130	208	350	84	35	1 677
1993	82	4	64	38	117	254	81	169	232	232	321	101	1 695
1994	0	0	72		357	160	230	227		396	117	24	1 582
1995	16	6	10	86	269	180	180	343	426	205	157	151	2 028
1996	149	114	43	27	386	237	288	263	314	202	293	294	2 610
1997	31	11	2	6	93	98	165	78	184	282	113	14	1 076
1998	9	21	0	32	241	227	229	218	310	329			
M	36	25	33	63	228	229	222	244	273	303	209	103	1 969

Units: mm

C.3 – Santa Ana (105 010)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1980											381	377	
1981	188	115	95	261	457	245	402	412	119	414	438	404	3 549
1982	174	35	38	153	161	258	249	203	208	424	107	95	2 103
1983	60	12	28	87	381	178	104	255	311	316	250	251	2 233
1984	70	149	47	21	305	345	359	349	358	339	238	77	2 655
1985	142	32	72	41	215	308	192	348	199	228	287	98	2 162
1986	103	15	70	301	132	415	277	273	207	489	403	50	2 733
1987	49	37	12	187	189	147	249	137	233	418	184	120	1 961
1988	46	62	12	89	319	180	292	303	188	356	309	109	2 265
1989	67	51	79	51	248	350	296	248	220	280	349	139	2 376
1990	67	23	84	71	207	192	133	158	387	442	408	225	2 397
1991	56	47	332	62	309	227	234	209	369	424	266	133	2 668
1992	43	51	16	123	308	238	157	200	313	225	229	117	2 021
1993	162	36	88	91	80	151	108	163	200	321	274	168	1 843
1994	62	29	133	133	266	205	210	236	345	291	185	71	2 165
1995	71	23	95	111	256	275	243	214	258	264	224	136	2 170
1996	163	191	30	69	194	226	221	138	225	216	374	216	2 262
1997	81	116	27	57	233	105	125	58	136	205	151	65	1 358
1998	20	25	20	64	153	501	90	142					
M	90	58	71	110	245	253	219	225	252	332	281	158	2 293

Units: mm

C.4 – Boca de Uracillo (111 001)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1974									196	354	536	120	
1975	65	35	60	27	418	247	241	451	364	567	610	616	3 700
1976	101	74	32	126	310	243	142	198	431	365	303	166	2 490
1977	59	64	25	77	318	309	229	337	166	477	337	222	2 618
1978	196	110	185	388	404	222	374	287	306	380	363	97	3 309
1979	36	134	31	216	416	433	471	533	327	323	258	219	3 396
1980	195	125	19	68	438	371	391	246	170	291	329	310	2 954
1981	222	122	169	396	352	386	407	378	190	330	520	466	3 939
1982	163	41	56	139	183	216	347	366	244	514	197	74	2 540
1983	58	23	10	105	413	313	251	248	395	411	314	320	2 860
1984	144	126	73	63	608	358	263	431	323	406	358	111	3 263
1985	201	44	79	37	306	435	315	311	286	411	349	248	3 021
1986	105	21	54	517	257	297	196	249	288	462	405	77	2 928
1987	74	61	14	234	319	253	353	287	338	473	307	187	2 900
1988	38	87	20	126	325	250	313	495	390	472	446	154	3 114
1989	55	103	40	77	232	258	236	438	193	475	391	168	2 665
1990	160	22	115	116	561	235	235	305	566	586	282	408	3 590
1991	60	60	140	106	295	225	180	131	440	355	288	268	2 547
1992	70	56	22	200	396	328	301	303	254	315	327	164	2 734
1993	109	59	122	323	212	332	181	173	343	432	397	282	2 964
1994	78	39	161	148	526	389	212	186	394	366	368	128	2 995
1995	151	28	79	257	319	509	345	257	320	312	344	260	3 181
1996	305	217	141	118	373	355	235	186	225	427	366	280	3 229
1997	67	37	10	54	168	232	134	137	193	206	178	36	
1998	36	22	56	195	224	333	239	344	100				
M	114	71	71	171	349	314	274	303	298	405	357	224	2 952

Units: mm

C.5 – Coclesito (105 009)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1980	197	188	44	131	259	166	205	292	325	404	387	406	3 002
1981	346	253	143	653	378	296	233	308	194	332	456	503	4 095
1982	193	147	106	261	266	334	439	240	167	293	224	194	2 862
1983	176	36	61	166	527	163	152	371	177	353	224	344	2 747
1984	301	395	87	78	396	280	190	437	296	303	370	202	3 336
1985	262	98	111	62	265	411	205	198	250	286	239	232	2 619
1986	262	98	111	64	265	411	205	198	250	286	239	232	2 621
1987	122	47	35	573	223	201	311	166	391	625	247	238	3 179
1988	105	160	50	74	323	262	207	454	347	379	235	275	2 871
1989	208	69	120	137	400	396	425	370	243	153	325	262	3 108
1990	254	101	248	150	354	185	302	446	227	436	326	371	3 399
1991	93	134	252	144	380	295	246	327	380	341	310	495	3 396
1992	143	127	37	399	374	263	211	272	269	217	238	275	2 823
1993	253	123	188	163	308	244	192	221	437	354	360	559	3 402
1994	122	71	178	388	381	392	191	307	197	529	291	245	3 292
1995	131	102	152	216	209	217	221	320	240	207	256	332	2 604
1996	469	339	211	199	483	323	211	416	364	341	388	658	4 401
1997	226	219	30	94	404	250	339	119	248	295	202	66	2 491
1998	73	72											
M	207	146	120	219	344	283	249	303	278	341	295	327	3 113

Units: mm

C.6 – Sabanita Verde (105 008)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1979	44	127	111	303	337	558	263	442	174	377	330	448	3 512
1980	211	120	12	143	397	447	342	293	294	429	351	548	3 586
1981	336	183	148	650	364	296	387	452	152	361	458	620	4 406
1982	262	97	87	245	359	245	504	329	278	392	289	176	3 264
1983	209	36	22	184	597	240	275	320	319	211	394	398	3 204
1984	229	339	101	49	370	268	228	471	274	291	402	171	3 192
1985	219	70	135	52	222	413	293	160	271	479	374	220	2 909
1986	248	48	144	452	335	318	251	421	267	361	489	145	3 479
1987	105	198	65	399		194	250	292	260	175			
1988	88	108	45	97	430	302	328	286	318	482	567	250	3 301
1989	165	138	134	94	366	294	308	372	258	293	373	291	3 084
1990	175	83	153	182	347	209	294	314	208	526	353	286	3 129
1991	110	93	75	154	294	253	237	282	406	310	352	581	3 146
1992	107	182	69	263	325	244	261	300	331	233	335	227	2 876
1993	305	78	134	225	263	330	274	275	499	349	440	274	3 446
1994	139	93	229	292	367	419	256	274	286			171	2 526
1995	143	109	163	256	240	244	246	290	331	319	411	336	3 088
1996	407	211	257	127	363	301	267	396	289	348	353	410	3 729
1997	177	307	35	110	342	147	177	205	349	400	198	70	2 518
1998	136	31	63	368	364	416	427	241					
M	191	132	109	232	352	307	293	321	293	352	380	312	3 274

Units: mm

C.7 – Chiguiri arriba (105 002)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1958							458	450	460	485		165	
1959	51	15	20	112	220	463	367	403	347	542	224	369	3 131
1960	150	50	68	189	414	424	511	513	341	371	619	434	4 083
1961	79	28	6	60	179	421	366	449	307	445	364	364	3 065
1962	86	27	39	204	353	412	239	673	289	425	492	216	3 453
1963	81	99	21	262	308	405	484	371	261	381	353	162	3 186
1964	46	191	61	293	364	398	527	493	392	608	319	93	3 783
1965	140	42	15	3	188	288	374	448	239	297	404	310	2 746
1966	123	34	32	196	489	507	614	412	519	430	545	516	4 414
1967	96	48	25	193	298	623	417	430	536	554	475	308	4 001
1968	13	105	102	85	350	489	454	255	399	540	418	241	3 448
1969	85	41	23	84	310	370	351	364	503	290	506	196	3 120
1970	215	85	137	198	551	271	619	353	493	475	343	577	4 315
1971	145	160	264	72	492	520	600	668	412	485	453	94	4 363
1972	193	49	34	348	287	377	290	261	370	370	185	87	2 847
1973	30	38	14	79	390	635	380	469	400	526	689	176	3 824
1974	116	32	30	48	264	285	342	334	432	613	365	54	2 912
1975	40	20	22	25	336	436	290	591	343	491	807	384	3 782
1976	82	35	12	81	318	247	172	382	348	426	189	66	2 355
1977	28	29	19	78	408	394	356	409	344	504	211	102	2 878
1978	68	61	215	203	486	349	317	422	293	458	624	68	3 562
1979	16	32	15	289	311	303	324	442	390	338	263	405	3 125
1980	119	51	12	52	415	362	373	482	315	517	319	171	3 186
1981	131	99	82	303	557	328	462	510	459	407	536	462	4 335
1982	113	18	25	270	372	363	321	361	207	426	306	69	2 848
1983	41	10	15	148	744	566	278	509	670	402	242	350	3 975
1984	78	229	32	2	302	382	405	424	497	487	238	66	3 142
1985	69	22	18	14	142	487	194	412	353	488	353	203	2 754
1986	30	4	15	158	124	525	345	386	318	427	393	59	2 784
1987	56	48	6	159	168	237	215	241	556	479	145	96	2 407
1988	31	64	13	113	409	421	434	396	430	485	354	226	3 376
1989	72	57	40	24	424	328	428	574	314	374	447	176	3 259
1990	120	93	55	37	398	261	354	395	468	467	308	241	3 196
1991	31	35	125	58	382	311	326	464	412	442	208	144	2 938
1992	35	33	11	191	379	423	293	324	482	349	306	153	2 978
1993	125	31	126	101	164	517	350	359	413	435	716	244	3 580
1994	32	23	26	182	636	520	612	433	605	685	378	172	4 122
1995	60	15	87	218	750	700	488	724	368	606	693	414	4 516
1996	544	244	83	97	784	817	616	485	609	327	518	579	5 703
1997	87	176	5	45	255	319	317	292	508	434	375	67	2 880
1998	9	17	35	187	465	637	557			375			
M	91	62	49	135	379	428	396	434	410	451	402	232	3 470

Units: mm

C.8 – Miguel de la Borda (109 001)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1975		151	148	28	398	576	402	481	194	316	461	643	
1976	126	91	11	299	351	128	325	542	743	561	555	491	4 223
1977	52	95	47	44	484	490	356	562	357	737	733	442	4 400
1978	118	39	218	415	200	393	698	532	395	472	473	125	4 077
1979	47	162	45	174	478	467	235	314	286	309	492	462	3 471
1980	188	143	19	37	335	388	336	423	430	425	290	524	3 536
1981	261	244	118	750	415	237	377	397	272	456	746	747	5 019
1982	171	100	114	184	168	432	496	537	423	536	421	201	3 782
1983	93	24	17	215	433	311	477	350	588	341	362	711	3 921
1984	314	219	79	79	444	459	366	380	255	310	432	176	3 513
1985	145	67	96	39	420	279	402	309	537	491	556	408	3 749
1986	102	29	81	491	337	317	487	401	229	327	321	80	3 202
1987	44	31	27	226	279	242	298	261	256	501	407	334	2 906
1988	46	25	19	116	236	304	360			244	478	381	
1989	54	60	82	115	340	463	373	504	246	658	439	184	3 519
1990	126	55	48	185	430	255	327	500	297	422	338	462	3 444
1991	158	52	183	99	474	511	456	341	559	391	867	196	4 285
1992	134	112	20	460	324	119	572	436	283	310	504	168	3 442
1993	104	68	138	475	122	405	260	516	259	334	536	438	3 653
1994	165	65	113	203	496	418	358	647	145	269	421	142	3 441
1995	129	6	111	308	330	328	322	264	328	265	523	588	3 503
1996	422	192	74	229	408	528	421	384	258	493	688	297	4 394
1997	169	299	4	87	324	318	248	309	309	449	268	26	2 810
1998	104	53	90	405	454	640	525	556	133	210			
M	142	99	79	236	362	375	395	432	338	409	492	358	3 718

Units: mm

C.9 – Icacal (113 001)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1959	50	11	10	82	484	424	427	308	586	243	685	463	3 772
1960	134	65	395	531	489	359	495	271	296	627	597	1 016	5 274
1961	68	67		52	303	543	339	950	317	575	691	388	
1962	155	73	48	142	625	345	791	367	159	211	736	365	4 016
1963	185	176	39	139	715	220	476	361	362	450	526	176	3 824
1964	193	36	48	115	538	492	453	378	294	518	564	196	3 823
1965	222	35	8	136	451	457	370	538	291	689	1 166	415	4 778
1966	75	7	70	225	665	286	461	652	290	615	1 081	468	4 896
1967	167	35	71	160	338	527	497	671	257	272	620	304	3 919
1968	10	205	115	48	409	266	580	510	308	668	515	83	3 717
1969	133	107	36	156	516	222	493	327	313	421	384	612	3 720
1970	284	51	134	509	572	278	380	252	311	423	1 005	757	4 956
1971	156	112	146	9	457	602	587	367	227	315	398	167	3 543
1972	408	73	112	627	454	196	341	393	325	673	273	236	4 112
1973	46	29	20	104	424	412	376	466	292	343	516	417	3 445
1974	63	67	72	40	461	348	699	484	117	284	955	130	3 719
1975	43	37	137	34	418	770	669	342	353	438	451	668	4 359
1976	64	60	9	155	355	290	343	393	502	502	329	207	3 210
1977	23	31	8	40	339	426	313	568	416	728	601	480	3 972
1978	102	72	147	369	250	556	464	375	269	401	473	109	3 586
1979	22	137	7	214	565	512	364	358	354	359	550	399	3 839
1980	206	79	18	14	431	144	374	323	457	548	283	449	3 324
1981	158	96	81	677	553	334	534	389	352	416	926	656	5 171
1982	271	52	220	114	106	291	565	373	418	490		167	
1983	63	30	74	240	551	299	410	473	346	199	237	547	3 468
1984		125	78	71	423	386	405	339	229	346	547	142	
1985	183	56	52	25	439	393	444	171	367	407			
1986		40	89	413	403	478	783	546	455	575	505	185	4 472
1987	73	47	33	522	608	324	510	373	572	840	366	423	4 689
1988	48	67	32	77	411	295	446	356	218	373	590	314	3 227
1989	28	55	70	18	207	425	288	740	481	677	484	220	3 693
1990	79	10	59	170	412	246	432	425	496	587	433	467	3 816
1991	119	60	126	190	816	442	395	309	435	552	755	196	4 394
1992	49	0			249			472	366	343	524	278	
1993	94	32	203	278	290	30	86	226	236	354	582	373	2 785
1994	72	46	62	78	322	565	439	364	405	288	597	149	3 386
1995	178	34	93	193	498	528	490	137	152	227	707	645	3 881
1996	568	168	121	159	345	437	476	369	257	223	542	361	4 024
1997	178	59	5	67	215	223	339	354	411	316	333	23	2 522
1998	70	26	34	454	379	462	439	471	172	301	514	609	3 932
M	133	64	81	196	437	380	456	414	336	445	580	366	3 888

Units: mm

C.10- Boca de Toabre (105 001)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1958					337	172	322	386					
1959	219	79	74	368	487	299	555	434	315	278	377	794	4 276
1960	410	215	177	396	259	341	220	302	230	375	506	796	4 224
1961	241	49	57	337	465	473	325	567	209	425	405	731	4 281
1962	295	122	94	190	473	281	265	300	301	336	534	386	3 575
1963	265	259	225	661	355	339	417	402	172	348	490	300	4 231
1964	228	79	118	670	462	578	255	304	407	350	381	242	4 071
1965	515	122	43	103	659	375	413	273	376	419	463	515	4 273
1966	293	66	147	286	383	465	435	253	236	403	950	723	4 635
1967	326	136	163	454	722	425	315	510	221	450	363	513	4 594
1968	147	206	483	147	383	381	408	396	329	259	348	434	3 919
1969	185	191	98	265	268	176	237	457	365	296	424	609	3 567
1970	491	245	166	668	970	407	400	496	297	371	914	817	6 239
1971	433	270	430	115	595	530	360	499	260	316	299	236	4 341
1972	680	264	197	600	419	294	503	231	480	364	359	367	4 756
1973	273	131	61	185	538	257	299	366	234	382	920	504	4 148
1974	431	242	212	215	417	296	414	451	343	515	639	321	4 493
1975	338	109	109	73	777	260	362	419	387	468	622	598	4 518
1976	285	227	55	284	206	269	280	454	328	320	345	211	3 260
1977	113	117	130	317	245	233	437	651	322	447	340	251	3 600
1978	190	123	264	650	568	323	280	295	364	249	532	231	4 067
1979	77	202	102	518	429	495	382	431	327	417	433	548	4 360
1980	369	245	78	303	274	366	429	365	307	354	450	628	4 166
1981	379	372	174	889	526	338	526	484	211	394	862	955	6 108
1982	355	213	158	303	252	238	536	526	362	325	368	257	3 891
1983	221	59	89	236	720	254	330	444	395	219	485	574	4 026
1984	393	649	128	90	526	428	292	403	315	345	373	303	4 244
1985	350	118	193	109	319	383	357	281	180	412	348	476	3 525
1986	517	150	274	707	485	397	451	636	389	467	713	237	5 420
1987	184	130	73	868	295	241	364	345	298	361			
1988	193	233	105	150	602	345	282	452	409	348	453	428	3 998
1989	246	225	217	171	516	344	473	606	327	395	588	361	4 467
1990	403	137	250	357	506	242	306	553	397	636	486	567	4 840
1991	189	206	316	242	550	433	434	360	701	400	584	661	5 075
1992	154	215	66	633	657	283	439	574	400	417	375	305	4 517
1993	314	129	200	411	281	271	327	267	462	353	816	710	4 540
1994	199	168	201	382	526	475	383	451	244	396	511	373	4 307
1995	213	102	186	297	304	353	371	308	264	309	422	872	3 697
1996	678	472	379	333	556	331	300	465	230	414	734	938	5 831
1997	260	399	50	153	527	275	395	375	266	508	155	103	3 464
1998	193	97	79	500	324	435	263	367					
M	306	194	165	366	471	344	369	418	324	380	509	497	4 344

Units: mm

C.11 – San Lucas (105 007)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1974		59	239	250	439	425	549	576	265	401	845	408	
1975	510	172	139	65	854	466	450	448	208	453	590	758	5 111
1976	311	217	45	376	398	255	429	564	347	354	476	413	4 184
1977	122	161	96	387	295	467	610	615	392	585	501	274	4 504
1978	139	179	286	756	610	372	350	367	387	235	632	299	4 610
1979	143	206	199	380	397	505	346	556	192	439	517	724	4 605
1980	394	264	78	213	292	487	449	396	211	365	529	853	4 532
1981	340	383	201	1 117	415	327	537	427	131	516	841	824	6 058
1982	437	211	237	262	356	322	717	406	321	323	349	347	4 288
1983	209	72	119	104	599	220	427	477	433	264	382	774	4 080
1984	400	678	135	126	549	490	291	429	335	395	402	270	4 500
1985	283	106	196	84	466	449	273	272	309	323	352	324	3 434
1986	394	202	211	284	175	373	683	495	287	554	912	257	4 826
1987	232	117	48	313	205	225	575	209	257	1 013	505	578	4 278
1988	174	262	124	250	284	280	263	281	247	373	387	496	3 420
1989	273	158	271	175	873	608	511	621	283	501	597	294	5 165
1990	385	117	214	378	593	373	392	579	393	543	451	622	5 040
1991	241	213	341	268	613	509	605	508	624	434	601	588	5 544
1992	194	117	81	472	546	256	691	326	372	441	480	434	4 408
1993	229	165	223	381	277	349	493	420	416	278	691	544	4 466
1994	80	137	329	416	518	647	973	629	341	223	625	501	5 418
1995	297	127	174	334	420	413	298	246	268	309	567	877	4 329
1996	833	529	524	364	572	451	346	418	369	493	778	1 030	6 708
1997	233	607	38	68	548	239	441	455	348	735	360	172	4 242
1998	146	138	97	100									
M	292	224	186	317	471	396	487	447	322	440	557	528	4 665

Units: mm

C.12 – Cocle del Norte (105 003)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1969					437	721	746	549	330	637	675	669	
1970	340	426	935	895	1 098	642	791	536	463	511	1 288	911	8 836
1971	472	253	467	134	558	745	632	518	175	252	299	241	4 746
1972	496	133	100	286	357	351	453	398	718	462	520	396	4 670
1973	814	139	38	104	754	468	668	303	217	362	1 065	777	5 709
1974	423	131	144	171	583	674	937	404	17	370	563	273	4 688
1975	320	146	190	78	762	620	656	353	109	410	440	811	4 894
1976	283	160	39	226	512	325	535	421	578	485	598	456	4 617
1977	86	114	65	232	328	450	804	501	193	563	558	318	4 211
1978	114	103	393	808	576	304	567	372	276	182	603	213	4 510
1979	90	204	77	252	198	267	420	400	217	274	290	475	3 164
1980	200	226	60	104	223	391	390	287	305	380	556	625	3 745
1981	226	234	135	775	372	395	519	322	173	473	973	880	5 476
1982	526	171	191	298	334	465	836	615	286	486	488	260	4 955
1983	176	49	50	245			744	464	736	616	506	1 004	
1984	361	624	72	113	609	576	371	476	323	495	654	262	4 935
1985	173		95	18	561	551	660	520	434	465	772	396	4 646
1986	390	245	130	518	308	554	511	458	408	625	1 101	227	5 473
1987	127		52	422	438	331	771	517	370	820	517	336	4 701
1988	91	88	59	162	427	248	306	324	244	413	560	544	3 465
1989	150	142	291	214	589	558	518	503	219	596	519	256	4 553
1990	307	28	66	146	552	380	567	528	393	504	535	491	4 496
1991	157	90	68	226	731	460	672	340	528	484	717	402	4 875
1992	184	239	60	335	646	284	862	499	436	602	539	316	5 001
1993	153	44	259	391	331	549	638	434	425	398	1 313	887	5 822
1994	167	95	290	433	567	709	897	796	413	240	799	538	5 944
1995	312	91	218	434	492	507	647	302	305	211	638	891	5 049
1996	815	411	419	519	477	475	400		278	330	927	1 350	
1997	184	321	49	30	562	145	402	444	347	644	596	103	3 183
1998	70	32	39	396	348	626	569	439					
M	283	183	174	309	508	475	616	449	342	452	676	528	4 994

Units: mm

C.13 – Belen (103 001)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1979					452	621	356	482	172	217	671	905	
1980	678	565	174	718	457	607	595	322	383	647	687	1 332	7 164
1981	590	580	550	951	299	384	536	438	217	189	943	800	6 475
1982	645	633	217	542	205	347	804	852	253	419	638	681	6 235
1983	312	187	223	461	535	261	547	500	548	456	360	801	5 189
1984	707	769	145	223	395	723	484	747	133	571	649	614	6 159
1985	621	299	306	164	419	631	475	525	225	362	495	752	5 273
1986	958	328	385	576	400	807	734	506	425	293	215	426	6 054
1987	397	218	230										
1988				64	205	32		193	232	479	161	821	
1989	840	281	120	276	614	373	508	220	113	436	447		
1990	667	196	154	399	159	57	182	424	448	134	304	635	3 759
1991	306	170	205	314	453	256	611	332	203	59	606	409	3 925
1992	309	207	108						190	272	470	741	
1993	506	83	529	153	113	357	744	487	355	386	578	730	5 020
1994	465	190	293	199	355		855	642	329	289		792	
1995	518	332	205	348	334	278	463	174	204	251	721	813	4 640
1996	785	610	324	533	695	226	411	329	301	376	452	793	5 834
1997	351	526	146	104	729	356	905	720	399	654	605	470	5 965
1998	422	151	249	437	435	357							
M	560	351	253	380	403	392	576	464	285	360	530	736	5 291

Units: mm

APPENDIX D – MAXIMUM DAILY RAINFALL DATA

D.1 – Chuiguiri Arriba & Boca de Toabre

Station	Year	Date	Pdmx	Y	Station	Year	Date	Pdmx	Y
Chiguiri Arriba	1959	15/10/59	83	0.70	Boca de Toabre	1959	31/12/59	118	0.77
Chiguiri Arriba	1960	06/08/60	146	1.24	Boca de Toabre	1960	17/01/60	129	0.84
Chiguiri Arriba	1961	03/10/61	105	0.89	Boca de Toabre	1961	10/12/61	129	0.84
Chiguiri Arriba	1962	22/08/62	91	0.77	Boca de Toabre	1962	27/05/62	108	0.70
Chiguiri Arriba	1963	11/06/63	162	1.37	Boca de Toabre	1963	27/04/63	157	1.02
Chiguiri Arriba	1964	24/02/64	175	1.48	Boca de Toabre	1964	23/05/64	172	1.12
Chiguiri Arriba	1965	09/12/65	68	0.57	Boca de Toabre	1965	03/12/65	156	1.01
Chiguiri Arriba	1966	27/07/66	185	1.57	Boca de Toabre	1966	25/11/66	152	0.99
Chiguiri Arriba	1967	04/06/67	100	0.85	Boca de Toabre	1967	12/05/67	115	0.75
Chiguiri Arriba	1968	22/07/68	100	0.85	Boca de Toabre	1968	10/12/68	121	0.79
Chiguiri Arriba	1969	27/11/69	91	0.77	Boca de Toabre	1969	04/12/69	127	0.82
Chiguiri Arriba	1970	16/07/70	127	1.07	Boca de Toabre	1970	05/05/70	306	1.99
Chiguiri Arriba	1971	30/06/71	175	1.48	Boca de Toabre	1971	11/08/72	141	0.92
Chiguiri Arriba	1972	11/04/72	100	0.85	Boca de Toabre	1972	07/01/72	234	1.53
Chiguiri Arriba	1973	22/04/73	119	1.00	Boca de Toabre	1973	10/12/73	109	0.71
Chiguiri Arriba	1974	13/10/74	118	1.00	Boca de Toabre	1974	24/05/74	86	0.56
Chiguiri Arriba	1975	12/08/75	142	1.20	Boca de Toabre	1975	15/11/76	185	1.20
Chiguiri Arriba	1976	27/08/76	68	0.58	Boca de Toabre	1976	25/08/76	113	0.74
Chiguiri Arriba	1977	25/07/77	113	0.96	Boca de Toabre	1977	29/08/77	94	0.61
Chiguiri Arriba	1978	01/11/78	129	1.09	Boca de Toabre	1978	16/04/78	169	1.10
Chiguiri Arriba	1979	08/12/79	177	1.50	Boca de Toabre	1979	21/04/79	98	0.64
Chiguiri Arriba	1980	12/08/80	95	0.80	Boca de Toabre	1980	01/01/80	145	0.94
Chiguiri Arriba	1981	04/12/81	161	1.37	Boca de Toabre	1981	04/12/81	272	1.77
Chiguiri Arriba	1982	03/11/82	132	1.12	Boca de Toabre	1982	21/09/82	76	0.49
Chiguiri Arriba	1983	12/05/83	138	1.17	Boca de Toabre	1983	12/05/83	115	0.75
Chiguiri Arriba	1984	28/05/84	90	0.76	Boca de Toabre	1984	24/11/84	107	0.70
Chiguiri Arriba	1985	03/10/85	92	0.78	Boca de Toabre	1985	31/07/85	96	0.62
Chiguiri Arriba	1986	21/06/86	151	1.28	Boca de Toabre	1986	17/11/86	180	1.17
Chiguiri Arriba	1987	29/09/87	113	0.96	Boca de Toabre	1987	14/10/87	178	1.16
Chiguiri Arriba	1988	11/05/88	120	1.01	Boca de Toabre	1988	11/05/88	212	1.38
Chiguiri Arriba	1989	20/07/89	89	0.75	Boca de Toabre	1989	27/05/89	129	0.84
Chiguiri Arriba	1990	17/05/89	98	0.83	Boca de Toabre	1990	10/08/90	196	1.28
Chiguiri Arriba	1991	29/08/91	95	0.80	Boca de Toabre	1991	14/09/91	226	1.47
Chiguiri Arriba	1992	30/05/92	98	0.83	Boca de Toabre	1992	26/04/92	277	1.81
Chiguiri Arriba	1993	15/11/93	123	1.04	Boca de Toabre	1993	23/11/93	156	1.02
Chiguiri Arriba	1994	11/06/94	123	1.04	Boca de Toabre	1994	14/06/94	157	1.02
Chiguiri Arriba	1995	08/08/95	103	0.87	Boca de Toabre	1995	24/12/95	184	1.20
Chiguiri Arriba	1996	13/01/96	130	1.11	Boca de Toabre	1996	17/02/96	208	1.36
Chiguiri Arriba	1997	08/07/97	144	1.22	Boca de Toabre	1997	20/10/97	153	1.00
Chiguiri Arriba	1998	06/11/98	134	1.14	Boca de Toabre	1998	25/04/98	175	1.14
Chiguiri Arriba	1999	11/08/99	108	0.92	Boca de Toabre	1999	26/08/99	189	1.23

Pdmx in mm. Y = Pdmx/Me

D.2 – Toabre & Cocle del Norte

Station	Year	Date	Pdmx	Y	Station	Year	Date	Pdmx	Y
Toabre	1970	09/06/70	100	1.19	Cocle del Norte	1969	26/10/69	99	0.86
Toabre	1971	30/11/71	76	0.90	Cocle del Norte	1970	06/11/70	202	1.75
Toabre	1972	20/04/72	90	1.06	Cocle del Norte	1971	18/06/71	130	1.13
Toabre	1973	06/10/73	104	1.23	Cocle del Norte	1972	11/07/72	220	1.91
Toabre	1974	11/06/74	97	1.14	Cocle del Norte	1973	12/06/73	200	1.74
Toabre	1975	20/11/75	66	0.78	Cocle del Norte	1974	15/06/74	95	0.83
Toabre	1976	02/08/76	60	0.71	Cocle del Norte	1975	02/05/75	141	1.22
Toabre	1977	17/08/77	89	1.05	Cocle del Norte	1976	20/12/76	161	1.40
Toabre	1978	24/10/78	77	0.91	Cocle del Norte	1977	03/07/77	107	0.93
Toabre	1979	05/04/79	89	1.05	Cocle del Norte	1978	14/04/78	172	1.50
Toabre	1980	02/10/80	88	1.04	Cocle del Norte	1979	24/07/79	89	0.77
Toabre	1981	11/08/81	126	1.50	Cocle del Norte	1980	01/01/80	54	0.47
Toabre	1982	18/05/82	72	0.85	Cocle del Norte	1981	11/12/81	139	1.20
Toabre	1983	22/07/83	85	1.00	Cocle del Norte	1982	04/01/82	113	0.98
Toabre	1984	03/07/84	84	1.00	Cocle del Norte	1983	03/10/83	133	1.16
Toabre	1985	19/08/85	66	0.79	Cocle del Norte	1984	02/10/84	115	1.00
Toabre	1986	11/07/86	63	0.75	Cocle del Norte	1985	08/11/85	252	2.19
Toabre	1987	05/07/87	88	1.04	Cocle del Norte	1986	13/11/86	148	1.29
Toabre	1988	23/09/88	75	0.88	Cocle del Norte	1987	14/10/85	87	0.76
Toabre	1989	03/12/89	87	1.02	Cocle del Norte	1988	01/12/88	77	0.67
Toabre	1990	27/09/90	75	0.89	Cocle del Norte	1989	17/10/89	103	0.89
Toabre	1991	14/09/91	94	1.11	Cocle del Norte	1990	15/05/90	122	1.06
Toabre	1992	19/06/92	70	0.83	Cocle del Norte	1991	17/10/91	81	0.70
Toabre	1993	19/09/93	72	0.85	Cocle del Norte	1992	06/07/92	111	0.96
Toabre	1994	24/05/94	87	1.03	Cocle del Norte	1993	11/12/93	133	1.15
Toabre	1995	03/05/95	79	0.94	Cocle del Norte	1994	18/08/94	107	0.93
Toabre	1996	17/08/96	82	0.97	Cocle del Norte	1995	22/01/95	163	1.42
Toabre	1997	15/10/97	93	1.10	Cocle del Norte	1996	12/12/96	126	1.10
Toabre	1998	27/06/98	82	0.97	Cocle del Norte	1997	13/08/97	101	0.88
Toabre	1999	17/05/99	89	1.06	Cocle del Norte	1998	01/12/98	93	0.81
					Cocle del Norte	1999	11/08/99	78	0.68

Pdmx in mm. Y = Pdmx/Me

D.3 – Sabanita Verde & Cocle del Norte

Station	Year	Date	Pdmx	Y	Station	Year	Date	Pdmx	Y
Sabanita Verde	1979	21/06/79	66	0.73	San Lucas	1974	01/06/74	116	0.73
Sabanita Verde	1980	12/12/80	103	1.14	San Lucas	1975	15/11/75	192	1.21
Sabanita Verde	1981	04/12/81	195	2.16	San Lucas	1976	25/08/76	139	0.87
Sabanita Verde	1982	11/07/82	108	1.20	San Lucas	1977	17/07/77	109	0.68
Sabanita Verde	1983	22/07/83	81	0.90	San Lucas	1978	14/04/78	250	1.57
Sabanita Verde	1984	08/09/84	64	0.71	San Lucas	1979	07/08/79	161	1.01
Sabanita Verde	1985	02/10/85	78	0.87	San Lucas	1980	20/11/80	148	0.93
Sabanita Verde	1986	10/04/86	134	1.49	San Lucas	1981	12/04/81	218	1.37
Sabanita Verde	1987	29/04/87	62	0.68	San Lucas	1982	08/05/82	114	0.71
Sabanita Verde	1988	07/11/88	186	2.07	San Lucas	1983	20/12/83	149	0.94
Sabanita Verde	1989	22/05/89	93	1.03	San Lucas	1984	30/06/84	106	0.66
Sabanita Verde	1990	21/10/90	90	1.00	San Lucas	1985	14/06/85	104	0.65
Sabanita Verde	1991	09/12/91	150	1.66	San Lucas	1986	17/11/86	229	1.44
Sabanita Verde	1992	26/04/92	79	0.88	San Lucas	1987	15/10/87	227	1.42
Sabanita Verde	1993	23/05/93	86	0.95	San Lucas	1988	24/07/88	92	0.57
Sabanita Verde	1994	04/04/94	88	0.98	San Lucas	1989	28/05/89	206	1.29
Sabanita Verde	1995	16/11/95	68	0.75	San Lucas	1990	09/08/90	176	1.11
Sabanita Verde	1996	10/03/96	101	1.12	San Lucas	1991	28/05/91	162	1.02
Sabanita Verde	1997	20/10/97	168	1.86	San Lucas	1992	27/04/92	203	1.28
Sabanita Verde	1998	25/04/98	107	1.19	San Lucas	1993	13/11/93	99	0.62
Sabanita Verde	1999	23/04/99	85	0.94	San Lucas	1994	26/07/94	203	1.27
					San Lucas	1995	24/12/95	224	1.40
					San Lucas	1996	24/11/96	225	1.41
					San Lucas	1997	15/02/97	99	0.62
					San Lucas	1998	17/07/98	158	0.99
					San Lucas	1999	24/04/99	137	0.86

Pdmx in mm. Y = Pdmx/Me

D.4 – Coclesito & Miguel de la Borda

Station	Year	Date	Pdmx	Y	Station	Year	Date	Pdmx	Y
Coclesito	1980	10/07/80	82	0.74	Miguel de la Borda	1975	20/06/75	171	1.38
Coclesito	1981	15/04/81	75	0.68	Miguel de la Borda	1976	21/12/76	131	1.05
Coclesito	1982	08/04/82	95	0.87	Miguel de la Borda	1977	08/05/77	125	1.01
Coclesito	1983	12/05/83	116	1.05	Miguel de la Borda	1978	14/04/78	161	1.29
Coclesito	1984	31/05/84	99	0.90	Miguel de la Borda	1979	14/12/79	108	0.87
Coclesito	1985	05/06/85	86	0.78	Miguel de la Borda	1980	26/08/80	112	0.90
Coclesito	1986	05/06/86	86	0.78	Miguel de la Borda	1981	11/08/80	142	1.14
Coclesito	1987	25/04/87	115	1.05	Miguel de la Borda	1982	11/11/82	149	1.20
Coclesito	1988	11/05/88	110	1.00	Miguel de la Borda	1983	08/07/83	168	1.35
Coclesito	1989	13/05/89	111	1.01	Miguel de la Borda	1984	15/11/84	94	0.76
Coclesito	1990	09/08/90	139	1.26	Miguel de la Borda	1985	08/11/85	124	0.99
Coclesito	1991	04/03/91	136	1.23	Miguel de la Borda	1986	10/04/85	111	0.89
Coclesito	1992	26/04/92	121	1.10	Miguel de la Borda	1987	14/05/87	73	0.58
Coclesito	1993	17/09/93	90	0.82	Miguel de la Borda	1988	08/11/88	79	0.63
Coclesito	1994	29/04/94	143	1.30	Miguel de la Borda	1989	03/06/89	83	0.67
Coclesito	1995	10/12/95	97	0.88	Miguel de la Borda	1990	17/08/90	103	0.82
Coclesito	1996	29/06/96	109	0.99	Miguel de la Borda	1991	06/09/91	112	0.90
Coclesito	1997	08/07/97	128	1.16	Miguel de la Borda	1992	28/04/92	126	1.02
Coclesito	1998	26/04/98	110	1.00	Miguel de la Borda	1993	31/08/93	104	0.84
					Miguel de la Borda	1994	17/05/94	86	0.69
					Miguel de la Borda	1995	03/04/95	138	1.11
					Miguel de la Borda	1996	28/11/96	165	1.33
					Miguel de la Borda	1997	05/02/97	158	1.27
					Miguel de la Borda	1998	10/06/98	161	1.30

Pdmx in mm. Y = Pdmx/Me

D.5 – Boca de Uracillo & Santa Ana

Station	Year	Date	Pdmx	Y	Station	Year	Date	Pdmx	Y
Boca de Uracillo	1975	14/10/75	91	0.85	Santa Ana	1981	08/06/81	87	1.18
Boca de Uracillo	1976	08/09/76	84	0.78	Santa Ana	1982	30/04/82	68	0.91
Boca de Uracillo	1977	17/08/77	80	0.75	Santa Ana	1983	30/10/83	88	1.19
Boca de Uracillo	1978	16/04/78	119	1.11	Santa Ana	1984	16/06/84	108	1.46
Boca de Uracillo	1979	14/08/79	121	1.13	Santa Ana	1985	09/11/84	59	0.80
Boca de Uracillo	1980	01/01/80	115	1.08	Santa Ana	1986	17/04/86	106	1.43
Boca de Uracillo	1981	28/07/81	93	0.87	Santa Ana	1987	09/12/87	50	0.67
Boca de Uracillo	1982	13/08/82	98	0.92	Santa Ana	1988	11/05/88	97	1.31
Boca de Uracillo	1983	08/06/83	100	0.93	Santa Ana	1989	20/07/89	101	1.36
Boca de Uracillo	1984	12/05/84	188	1.76	Santa Ana	1990	16/10/90	83	1.13
Boca de Uracillo	1985	04/06/85	98	0.92	Santa Ana	1991	05/03/91	239	3.23
Boca de Uracillo	1986	16/04/86	100	0.94	Santa Ana	1992	28/05/92	62	0.84
Boca de Uracillo	1987	13/05/87	127	1.19	Santa Ana	1993	08/01/93	56	0.76
Boca de Uracillo	1988	24/08/88	85	0.80	Santa Ana	1994	30/04/94	64	0.86
Boca de Uracillo	1989	06/11/89	127	1.19	Santa Ana	1995	23/07/95	55	0.75
Boca de Uracillo	1990	17/05/90	131	1.22	Santa Ana	1996	26/11/96	64	0.86
Boca de Uracillo	1991	04/12/91	145	1.35	Santa Ana	1997	09/05/97	74	1.00
Boca de Uracillo	1992	28/04/92	129	1.21	Santa Ana	1998	08/06/98	118	1.60
Boca de Uracillo	1993	26/10/93	115	1.08	Santa Ana	1999	04/06/99	64	0.86
Boca de Uracillo	1994	16/05/94	119	1.12					
Boca de Uracillo	1995	15/06/95	124	1.16					
Boca de Uracillo	1996	05/10/96	67	0.63					
Boca de Uracillo	1997	28/10/96	57	0.53					
Boca de Uracillo	1998	13/12/98	86	0.81					
Boca de Uracillo	1999	18/06/99	107	1.00					

Pdmx in mm. Y = Pdmx/Me

D.6 – Final Regional Sample (189 Station-years)

Station	Date	Pdmx	Y	Station	Date	Pdmx	Y
Boca de Toabre	21/09/82	76	0.49	Miguel de la Borda	08/05/77	125	1.01
Boca de Uracillo	28/10/96	57	0.53	Boca de Toabre	03/12/65	156	1.01
San Lucas	24/07/88	92	0.57	San Lucas	28/05/91	162	1.02
Boca de Toabre	29/08/77	94	0.61	Boca de Toabre	27/04/63	157	1.02
Boca de Toabre	31/07/85	96	0.62	Toabre	03/12/89	87	1.02
Boca de Uracillo	05/10/96	67	0.63	Toabre	05/07/87	88	1.04
Boca de Toabre	21/04/79	98	0.64	Chiguiri Arriba	15/11/93	123	1.04
San Lucas	14/06/85	104	0.65	Chiguiri Arriba	11/06/94	123	1.04
Santa Ana	09/12/87	50	0.67	Toabre	02/10/80	88	1.04
Cocle del Norte	01/12/88	77	0.67	Coclesito	25/04/87	115	1.05
Boca de Toabre	24/11/84	107	0.70	Toabre	17/08/77	89	1.05
Chiguiri Arriba	15/10/59	83	0.70	Toabre	05/04/79	89	1.05
Cocle del Norte	17/10/91	81	0.70	Toabre	17/05/99	89	1.06
Boca de Toabre	27/05/62	108	0.70	Toabre	20/04/72	90	1.06
Toabre	02/08/76	60	0.71	Chiguiri Arriba	16/07/70	127	1.07
Boca de Toabre	10/12/73	109	0.71	Boca de Uracillo	01/01/80	115	1.08
Sabanita Verde	08/09/84	64	0.71	Boca de Uracillo	26/10/93	115	1.08
Sabanita Verde	21/06/79	66	0.73	Chiguiri Arriba	01/11/78	129	1.09
Coclesito	10/07/80	82	0.74	Cocle del Norte	12/12/96	126	1.10
Boca de Toabre	12/05/67	115	0.75	Chiguiri Arriba	13/01/96	130	1.11
Santa Ana	23/07/95	55	0.75	Miguel de la Borda	03/04/95	138	1.11
Toabre	11/07/86	63	0.75	Chiguiri Arriba	03/11/82	132	1.12
Sabanita Verde	16/11/95	68	0.75	Sabanita Verde	10/03/96	101	1.12
Santa Ana	08/01/93	56	0.76	Boca de Uracillo	16/05/94	119	1.12
Cocle del Norte	14/10/85	87	0.76	Boca de Toabre	23/05/64	172	1.12
Chiguiri Arriba	22/08/62	91	0.77	Santa Ana	16/10/90	83	1.13
Boca de Toabre	31/12/59	118	0.77	Boca de Uracillo	14/08/79	121	1.13
Cocle del Norte	24/07/79	89	0.77	Cocle del Norte	18/06/71	130	1.13
Coclesito	05/06/86	86	0.78	Chiguiri Arriba	06/11/98	134	1.14
Boca de Uracillo	08/09/76	84	0.78	Sabanita Verde	12/12/80	103	1.14
Toabre	19/08/85	66	0.79	Miguel de la Borda	11/08/80	142	1.14
Boca de Toabre	10/12/68	121	0.79	Toabre	11/06/74	97	1.14
Santa Ana	09/11/84	59	0.80	Cocle del Norte	11/12/93	133	1.15
Boca de Uracillo	24/08/88	85	0.80	Boca de Uracillo	15/06/95	124	1.16
Cocle del Norte	01/12/98	93	0.81	Cocle del Norte	03/10/83	133	1.16
Boca de Uracillo	13/12/98	86	0.81	Chiguiri Arriba	12/05/83	138	1.17
Boca de Toabre	04/12/69	127	0.82	Santa Ana	08/06/81	87	1.18
Toabre	19/06/92	70	0.83	Sabanita Verde	25/04/98	107	1.19
Santa Ana	28/05/92	62	0.84	Boca de Uracillo	06/11/89	127	1.19
Miguel de la Borda	31/08/93	104	0.84	Santa Ana	30/10/83	88	1.19
Boca de Toabre	17/01/60	129	0.84	Toabre	09/06/70	100	1.19
Boca de Toabre	10/12/61	129	0.84	Boca de Uracillo	13/05/87	127	1.19
Chiguiri Arriba	04/06/67	100	0.85	Chiguiri Arriba	12/08/75	142	1.20
Chiguiri Arriba	22/07/68	100	0.85	Sabanita Verde	11/07/82	108	1.20
Toabre	18/05/82	72	0.85	Miguel de la Borda	11/11/82	149	1.20
Boca de Uracillo	14/10/75	91	0.85	Boca de Toabre	15/11/76	185	1.20
Toabre	19/09/93	72	0.85	San Lucas	15/11/75	192	1.21

Cocle del Norte	26/10/69	99	0.86	Chiguiri Arriba	08/07/97	144	1.22
Santa Ana	04/06/99	64	0.86	Cocle del Norte	02/05/75	141	1.22
Coclesito	08/04/82	95	0.87	Boca de Uracillo	17/05/90	131	1.22
Sabanita Verde	02/10/85	78	0.87	Toabre	06/10/73	104	1.23
Chiguiri Arriba	08/08/95	103	0.87	Boca de Toabre	26/08/99	189	1.23
San Lucas	25/08/76	139	0.87	Chiguiri Arriba	06/08/60	146	1.24
Boca de Uracillo	28/07/81	93	0.87	Miguel de la Borda	05/02/97	158	1.27
Cocle del Norte	13/08/97	101	0.88	San Lucas	26/07/94	203	1.27
Coclesito	10/12/95	97	0.88	Chiguiri Arriba	21/06/86	151	1.28
Toabre	23/09/88	75	0.88	Boca de Toabre	10/08/90	196	1.28
Toabre	27/09/90	75	0.89	San Lucas	28/05/89	206	1.29
Chiguiri Arriba	03/10/61	105	0.89	Coclesito	29/04/94	143	1.30
Miguel de la Borda	10/04/85	111	0.89	Miguel de la Borda	08/07/83	168	1.35
Cocle del Norte	17/10/89	103	0.89	Boca de Toabre	17/02/96	208	1.36
Toabre	30/11/71	76	0.90	Santa Ana	20/07/89	101	1.36
Miguel de la Borda	26/08/80	112	0.90	San Lucas	12/04/81	218	1.37
Coclesito	31/05/84	99	0.90	Chiguiri Arriba	11/06/63	162	1.37
Santa Ana	30/04/82	68	0.91	Miguel de la Borda	20/06/75	171	1.38
Chiguiri Arriba	11/08/99	108	0.92	Boca de Toabre	11/05/88	212	1.38
Boca de Toabre	11/08/72	141	0.92	San Lucas	24/12/95	224	1.40
Boca de Uracillo	04/06/85	98	0.92	Cocle del Norte	20/12/76	161	1.40
Boca de Uracillo	13/08/82	98	0.92	San Lucas	24/11/96	225	1.41
Cocle del Norte	18/08/94	107	0.93	Cocle del Norte	22/01/95	163	1.42
San Lucas	20/11/80	148	0.93	San Lucas	15/10/87	227	1.42
Boca de Uracillo	08/06/83	100	0.93	San Lucas	17/11/86	229	1.44
Cocle del Norte	03/07/77	107	0.93	Santa Ana	16/06/84	108	1.46
San Lucas	20/12/83	149	0.94	Boca de Toabre	14/09/91	226	1.47
Toabre	03/05/95	79	0.94	Chiguiri Arriba	30/06/71	175	1.48
Sabanita Verde	23/04/99	85	0.94	Chiguiri Arriba	24/02/64	175	1.48
Sabanita Verde	23/05/93	86	0.95	Sabanita Verde	10/04/86	134	1.49
Chiguiri Arriba	25/07/77	113	0.96	Chiguiri Arriba	08/12/79	177	1.50
Chiguiri Arriba	29/09/87	113	0.96	Toabre	11/08/81	126	1.50
Cocle del Norte	06/07/92	111	0.96	Boca de Toabre	07/01/72	234	1.53
Toabre	17/08/96	82	0.97	San Lucas	14/04/78	250	1.57
Toabre	27/06/98	82	0.97	Chiguiri Arriba	27/07/66	185	1.57
Sabanita Verde	04/04/94	88	0.98	Santa Ana	08/06/98	118	1.60
Cocle del Norte	04/01/82	113	0.98	Sabanita Verde	09/12/91	150	1.66
Coclesito	29/06/96	109	0.99	Cocle del Norte	12/06/73	200	1.74
Boca de Toabre	25/11/66	152	0.99	Cocle del Norte	06/11/70	202	1.75
San Lucas	17/07/98	158	0.99	Boca de Uracillo	12/05/84	188	1.76
Toabre	03/07/84	84	1.00	Boca de Toabre	26/04/92	277	1.81
Chiguiri Arriba	13/10/74	118	1.00	Sabanita Verde	20/10/97	168	1.86
Cocle del Norte	02/10/84	115	1.00	Cocle del Norte	11/07/72	220	1.91
Santa Ana	09/05/97	74	1.00	Boca de Toabre	05/05/70	306	1.99
Boca de Uracillo	18/06/99	107	1.00	Sabanita Verde	07/11/88	186	2.07
Toabre	22/07/83	85	1.00	Sabanita Verde	04/12/81	195	2.16
Chiguiri Arriba	22/04/73	119	1.00	Cocle del Norte	08/11/85	252	2.19
				Santa Ana	05/03/91	239	3.23

Pdmx in mm. Y = Pdmx/Me

APPENDIX E – EXTENSION OF MAXIMUM DAILY RAINFALL USING GATUN DATA

E.1 – Maximum Monthly Rainfall - Gatun

Year	Max	Year	Max	Year	Max
1911	477	1941	467	1971	365
1912	444	1942	480	1972	344
1913	386	1943	416	1973	478
1914	440	1944	456	1974	448
1915	395	1945	413	1975	517
1916	468	1946	352	1976	349
1917	611	1947	371	1977	421
1918	414	1948	417	1978	321
1919	362	1949	494	1979	318
1920	480	1950	513	1980	315
1921	410	1951	358	1981	439
1922	363	1952	454	1982	402
1923	727	1953	401	1983	353
1924	421	1954	440	1984	411
1925	427	1955	523	1985	329
1926	481	1956	418	1986	461
1927	434	1957	391	1987	466
1928	430	1958	316	1988	426
1929	357	1959	523	1989	367
1930	294	1960	491	1990	494
1931	668	1961	412	1991	380
1932	670	1962	345	1992	413
1933	578	1963	523	1993	421
1934	414	1964	491	1994	437
1935	943	1965	338	1995	388
1936	405	1966	577	1996	453
1937	590	1967	406	1997	257
1938	497	1968	413	1998	364
1939	554	1969	360	1999	617
1940	338	1970	458	2000	474

Units : mm/month

E.2 – Final 237-Station Year Sample Transposed to Toabre Catchment

Station	Year	Date	Rank	Y	Pdmx
Boca de Toabre	1982	21/09/82	1	0.49	47
Boca de Uracillo	1997	28/10/96	2	0.53	50
Gatun-Extension	**1930**		3	**0.54**	**51**
San Lucas	1988	24/07/88	4	0.57	54
Boca de Toabre	1977	29/08/77	5	0.61	57
Boca de Toabre	1985	31/07/85	6	0.62	59
Boca de Uracillo	1996	05/10/96	7	0.63	60
Gatun-Extension	**1958**		8	**0.64**	**60**
Boca de Toabre	1979	21/04/79	9	0.64	60
San Lucas	1985	14/06/85	10	0.65	62
Santa Ana	1987	09/12/87	11	0.67	63
Cocle del Norte	1988	01/12/88	12	0.67	63
Boca de Toabre	1984	24/11/84	13	0.70	66
Chiguiri Arriba	1959	15/10/59	14	0.70	66
Cocle del Norte	1991	17/10/91	15	0.70	66
Boca de Toabre	1962	27/05/62	16	0.70	66
Toabre	1976	02/08/76	17	0.71	67
Boca de Toabre	1973	10/12/73	18	0.71	67
Sabanita Verde	1984	08/09/84	19	0.71	67
Gatun-Extension	**1940**		20	**0.73**	**69**
Sabanita Verde	1979	21/06/79	21	0.73	69
Coclesito	1980	10/07/80	22	0.74	70
Boca de Toabre	1967	12/05/67	23	0.75	70
Santa Ana	1995	23/07/95	24	0.75	70
Toabre	1986	11/07/86	25	0.75	71
Sabanita Verde	1995	16/11/95	26	0.75	71
Santa Ana	1993	08/01/93	27	0.76	71
Cocle del Norte	1987	14/10/85	28	0.76	72
Chiguiri Arriba	1962	22/08/62	29	0.77	72
Boca de Toabre	1959	31/12/59	30	0.77	73
Cocle del Norte	1979	24/07/79	31	0.77	73
Coclesito	1986	05/06/86	32	0.78	74
Boca de Uracillo	1976	08/09/76	33	0.78	74
Toabre	1985	19/08/85	34	0.79	74
Boca de Toabre	1968	10/12/68	35	0.79	74
Gatun-Extension	**1946**		36	**0.79**	**75**
Santa Ana	1985	09/11/84	37	0.80	75
Boca de Uracillo	1988	24/08/88	38	0.80	75
Cocle del Norte	1998	01/12/98	39	0.81	76
Boca de Uracillo	1998	13/12/98	40	0.81	76
Gatun-Extension	**1929**		41	**0.81**	**76**
Gatun-Extension	**1951**		42	**0.81**	**77**
Boca de Toabre	1969	04/12/69	43	0.82	78
Toabre	1992	19/06/92	44	0.83	78
Gatun-Extension	**1919**		45	**0.83**	**78**
Santa Ana	1992	28/05/92	46	0.84	79
Gatun-Extension	**1922**		47	**0.84**	**79**

Station	Year	Date	Rank	Y	Pdmx
Miguel de la Borda	1993	31/08/93	48	0.84	79
Boca de Toabre	1960	17/01/60	49	0.84	79
Boca de Toabre	1961	10/12/61	50	0.84	79
Chiguiri Arriba	1967	04/06/67	51	0.85	80
Chiguiri Arriba	1968	22/07/68	52	0.85	80
Toabre	1982	18/05/82	53	0.85	80
Boca de Uracillo	1975	14/10/75	54	0.85	80
Toabre	1993	19/09/93	55	0.85	80
Cocle del Norte	1969	26/10/69	56	0.86	81
Santa Ana	1999	04/06/99	57	0.86	82
Coclesito	1982	08/04/82	58	0.87	82
Sabanita Verde	1985	02/10/85	59	0.87	82
Chiguiri Arriba	1995	08/08/95	60	0.87	82
San Lucas	1976	25/08/76	61	0.87	82
Gatun-Extension	**1947**		62	**0.87**	**82**
Boca de Uracillo	1981	28/07/81	63	0.87	82
Cocle del Norte	1997	13/08/97	64	0.88	83
Coclesito	1995	10/12/95	65	0.88	83
Toabre	1988	23/09/88	66	0.88	83
Toabre	1990	27/09/90	67	0.89	84
Chiguiri Arriba	1961	03/10/61	68	0.89	84
Miguel de la Borda	1986	10/04/85	69	0.89	84
Cocle del Norte	1989	17/10/89	70	0.89	84
Toabre	1971	30/11/71	71	0.90	85
Miguel de la Borda	1980	26/08/80	72	0.90	85
Coclesito	1984	31/05/84	73	0.90	85
Santa Ana	1982	30/04/82	74	0.91	86
Chiguiri Arriba	1999	11/08/99	75	0.92	86
Boca de Toabre	1971	11/08/72	76	0.92	87
Boca de Uracillo	1985	04/06/85	77	0.92	87
Boca de Uracillo	1982	13/08/82	78	0.92	87
Cocle del Norte	1994	18/08/94	79	0.93	87
San Lucas	1980	20/11/80	80	0.93	87
Boca de Uracillo	1983	08/06/83	81	0.93	88
Gatun-Extension	**1913**		82	**0.93**	**88**
Cocle del Norte	1977	03/07/77	83	0.93	88
San Lucas	1983	20/12/83	84	0.94	88
Toabre	1995	03/05/95	85	0.94	88
Sabanita Verde	1999	23/04/99	86	0.94	89
Sabanita Verde	1993	23/05/93	87	0.95	90
Gatun-Extension	**1957**		88	**0.96**	**90**
Chiguiri Arriba	1977	25/07/77	89	0.96	90
Chiguiri Arriba	1987	29/09/87	90	0.96	91
Cocle del Norte	1992	06/07/92	91	0.96	91
Toabre	1996	17/08/96	92	0.97	91
Gatun-Extension	**1915**		93	**0.97**	**92**
Toabre	1998	27/06/98	94	0.97	92
Sabanita Verde	1994	04/04/94	95	0.98	92
Cocle del Norte	1982	04/01/82	96	0.98	93
Coclesito	1996	29/06/96	97	0.99	93

Station	Year	Date	Rank	Y	Pdmx
Boca de Toabre	1966	25/11/66	98	0.99	93
San Lucas	1998	17/07/98	99	0.99	93
Gatun-Extension	**1953**		100	**1.00**	**94**
Toabre	1984	03/07/84	101	1.00	94
Chiguiri Arriba	1974	13/10/74	102	1.00	94
Cocle del Norte	1984	02/10/84	103	1.00	94
Santa Ana	1997	09/05/97	104	1.00	94
Boca de Uracillo	1999	18/06/99	105	1.00	94
Toabre	1983	22/07/83	106	1.00	94
Chiguiri Arriba	1973	22/04/73	107	1.00	95
Miguel de la Borda	1977	08/05/77	108	1.01	95
Boca de Toabre	1965	03/12/65	109	1.01	96
Gatun-Extension	**1936**		110	**1.01**	**96**
San Lucas	1991	28/05/91	111	1.02	96
Boca de Toabre	1963	27/04/63	112	1.02	97
Toabre	1989	03/12/89	113	1.02	97
Gatun-Extension	**1921**		114	**1.04**	**98**
Toabre	1987	05/07/87	115	1.04	98
Chiguiri Arriba	1993	15/11/93	116	1.04	98
Chiguiri Arriba	1994	11/06/94	117	1.04	98
Toabre	1980	02/10/80	118	1.04	98
Gatun-Extension	**1945**		119	**1.05**	**99**
Coclesito	1987	25/04/87	120	1.05	99
Toabre	1977	17/08/77	121	1.05	99
Gatun-Extension	**1934**		122	**1.05**	**99**
Gatun-Extension	**1918**		123	**1.05**	**99**
Toabre	1979	05/04/79	124	1.05	99
Toabre	1999	17/05/99	125	1.06	100
Toabre	1972	20/04/72	126	1.06	100
Gatun-Extension	**1943**		127	**1.06**	**100**
Gatun-Extension	**1948**		128	**1.07**	**100**
Gatun-Extension	**1956**		129	**1.07**	**101**
Chiguiri Arriba	1970	16/07/70	130	1.07	101
Boca de Uracillo	1980	01/01/80	131	1.08	102
Boca de Uracillo	1993	26/10/93	132	1.08	102
Gatun-Extension	**1924**		133	**1.08**	**102**
Chiguiri Arriba	1978	01/11/78	134	1.09	103
Cocle del Norte	1996	12/12/96	135	1.10	103
Chiguiri Arriba	1996	13/01/96	136	1.11	104
Miguel de la Borda	1995	03/04/95	137	1.11	105
Gatun-Extension	**1925**		138	**1.11**	**105**
Chiguiri Arriba	1982	03/11/82	139	1.12	105
Sabanita Verde	1996	10/03/96	140	1.12	105
Boca de Uracillo	1994	16/05/94	141	1.12	106
Boca de Toabre	1964	23/05/64	142	1.12	106
Gatun-Extension	**1928**		143	**1.12**	**106**
Santa Ana	1990	16/10/90	144	1.13	106
Boca de Uracillo	1979	14/08/79	145	1.13	107
Cocle del Norte	1971	18/06/71	146	1.13	107
Chiguiri Arriba	1998	06/11/98	147	1.14	107

Station	Year	Date	Rank	Y	Pdmx
Gatun-Extension	**1927**		148	**1.14**	**107**
Sabanita Verde	1980	12/12/80	149	1.14	107
Miguel de la Borda	1981	11/08/80	150	1.14	108
Toabre	1974	11/06/74	151	1.14	108
Cocle del Norte	1993	11/12/93	152	1.15	109
Boca de Uracillo	1995	15/06/95	153	1.16	109
Cocle del Norte	1983	03/10/83	154	1.16	109
Gatun-Extension	**1914**		155	**1.16**	**110**
Gatun-Extension	**1954**		156	**1.16**	**110**
Chiguiri Arriba	1983	12/05/83	157	1.17	110
Santa Ana	1981	08/06/81	158	1.18	111
Gatun-Extension	**1912**		159	**1.18**	**111**
Sabanita Verde	1998	25/04/98	160	1.19	112
Boca de Uracillo	1989	06/11/89	161	1.19	112
Santa Ana	1983	30/10/83	162	1.19	112
Toabre	1970	09/06/70	163	1.19	112
Boca de Uracillo	1987	13/05/87	164	1.19	113
Chiguiri Arriba	1975	12/08/75	165	1.20	113
Sabanita Verde	1982	11/07/82	166	1.20	113
Miguel de la Borda	1982	11/11/82	167	1.20	113
Boca de Toabre	1975	15/11/76	168	1.20	113
San Lucas	1975	15/11/75	169	1.21	114
Chiguiri Arriba	1997	08/07/97	170	1.22	115
Cocle del Norte	1975	02/05/75	171	1.22	115
Gatun-Extension	**1952**		172	**1.22**	**115**
Boca de Uracillo	1990	17/05/90	173	1.22	115
Toabre	1973	06/10/73	174	1.23	116
Boca de Toabre	1999	26/08/99	175	1.23	116
Gatun-Extension	**1944**		176	**1.23**	**116**
Chiguiri Arriba	1960	06/08/60	177	1.24	117
Miguel de la Borda	1997	05/02/97	178	1.27	120
San Lucas	1994	26/07/94	179	1.27	120
Chiguiri Arriba	1986	21/06/86	180	1.28	120
Gatun-Extension	**1941**		181	**1.28**	**121**
Boca de Toabre	1990	10/08/90	182	1.28	121
Gatun-Extension	**1916**		183	**1.28**	**121**
San Lucas	1989	28/05/89	184	1.29	122
Coclesito	1994	29/04/94	185	1.30	122
Gatun-Extension	**1911**		186	**1.32**	**125**
Gatun-Extension	**1920**		187	**1.33**	**126**
Gatun-Extension	**1942**		188	**1.34**	**126**
Gatun-Extension	**1926**		189	**1.34**	**126**
Miguel de la Borda	1983	08/07/83	190	1.35	128
Boca de Toabre	1996	17/02/96	191	1.36	128
Santa Ana	1989	20/07/89	192	1.36	129
San Lucas	1981	12/04/81	193	1.37	129
Chiguiri Arriba	1963	11/06/63	194	1.37	129
Miguel de la Borda	1975	20/06/75	195	1.38	130
Boca de Toabre	1988	11/05/88	196	1.38	130
Gatun-Extension	**1949**		197	**1.39**	**131**

Station	Year	Date	Rank	Y	Pdmx
San Lucas	1995	24/12/95	198	1.40	132
Cocle del Norte	1976	20/12/76	199	1.40	132
Gatun-Extension	**1938**		200	**1.41**	**133**
San Lucas	1996	24/11/96	201	1.41	133
Cocle del Norte	1995	22/01/95	202	1.42	134
San Lucas	1987	15/10/87	203	1.42	134
San Lucas	1986	17/11/86	204	1.44	135
Santa Ana	1984	16/06/84	205	1.46	138
Boca de Toabre	1991	14/09/91	206	1.47	139
Gatun-Extension	**1950**		207	**1.48**	**139**
Chiguiri Arriba	1971	30/06/71	208	1.48	139
Chiguiri Arriba	1964	24/02/64	209	1.48	140
Sabanita Verde	1986	10/04/86	210	1.49	140
Chiguiri Arriba	1979	08/12/79	211	1.50	141
Toabre	1981	11/08/81	212	1.50	141
Gatun-Extension	**1955**		213	**1.52**	**143**
Boca de Toabre	1972	07/01/72	214	1.53	144
San Lucas	1978	14/04/78	215	1.57	148
Chiguiri Arriba	1966	27/07/66	216	1.57	148
Santa Ana	1998	08/06/98	217	1.60	151
Gatun-Extension	**1939**		218	**1.65**	**155**
Sabanita Verde	1991	09/12/91	219	1.66	157
Cocle del Norte	1973	12/06/73	220	1.74	164
Gatun-Extension	**1933**		221	**1.75**	**165**
Cocle del Norte	1970	06/11/70	222	1.75	165
Boca de Uracillo	1984	12/05/84	223	1.76	166
Gatun-Extension	**1937**		224	**1.80**	**170**
Boca de Toabre	1992	26/04/92	225	1.81	170
Sabanita Verde	1997	20/10/97	226	1.86	175
Gatun-Extension	**1917**		227	**1.89**	**179**
Cocle del Norte	1972	11/07/72	228	1.91	180
Boca de Toabre	1970	05/05/70	229	1.99	188
Sabanita Verde	1988	07/11/88	230	2.07	195
Gatun-Extension	**1931**		231	**2.14**	**202**
Gatun-Extension	**1932**		232	**2.14**	**202**
Sabanita Verde	1981	04/12/81	233	2.16	203
Cocle del Norte	1985	08/11/85	234	2.19	206
Gatun-Extension	**1923**		235	**2.39**	**225**
Santa Ana	1991	05/03/91	236	3.23	304
Gatun-Extension	**1935**		237	**3.31**	**312**

APPENDIX F – YEARLY RAINFALL AT GATUN DS VS. RUNOFF AT BATATILLA

Year	Gatun DS (mm)	Batatilla (m3/s)	Batatilla (mm)
1948	2 252	36.6	1 466
1949	2 806	53.0	2 122
1950	3 025	53.2	2 127
1951	2 507	42.7	1 710
1952	2 453	42.8	1 713
1953	2 505	40.9	1 636
1954	2 928	56.0	2 241
1955	2 849	53.0	2 121
1956	2 776	48.3	1 932
1957	2 200	33.7	1 349
1958	2 350	38.7	1 549
1959	2 437	40.5	1 622
1960	3 158	51.3	2 053
1961	2 495	42.4	1 695
1962	2 495	39.5	1 579
1963	2 704	42.8	1 714
1964	2 652	49.0	1 961
1965	2 592	30.8	1 234
1966	3 035	46.1	1 845
1967	2 479	50.1	2 006
1968	2 338	42.5	1 702
1969	2 577	35.2	1 409
1970	3 192	77.4	3 096
1971	2 395	45.2	1 807
1972	2 274	31.9	1 278
1973	2 379	48.8	1 955
1974	2 395	42.3	1 693
1975	2 810	59.4	2 377
1976	1 865	29.8	1 193
1977	2 189	34.5	1 379
1978	2 458	47.5	1 901
1979	2 319	38.8	1 551
1980	2 295	41.6	1 665
1981	3 323	64.3	2 571
1982	1 949	32.6	1 305
1983	2 233	32.2	1 291
1984	2 453	45.6	1 826
1985	2 199	38.3	1 533
1986	2 021	48.0	1 921
1987	2 846	34.3	1 371
1988	2 407	38.9	1 557
1989	2 119	40.7	1 627
1990	2 570	45.6	1 826
1991	2 302	44.7	1 789
1992	2 456	38.9	1 555
1993	2 685	43.0	1 723
1994	2 205	37.9	1 516

Year	Gatun DS (mm)	Batatilla (m3/s)	Batatilla (mm)
1995	2 795	39.8	1 593
1996	2 862	70.7	2 831
1997	1 592	22.9	915
1998	2 528	39.0	1 559
1999	3 171	71.6	2 865
2000	2 655	49.4	1 976
Nval	53	53	53
M	2 520	44.2	1 770
S	348	10.6	423
Cv	0.14	0.24	0.24
Me	2 479	42.5	1 702
Max	3 323	77.4	3 096
Min	1 592	22.9	915

APPENDIX G. FLOOD DATA

G.1 - Daily Peaks at Batatilla (788 km²)

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Max
1948	**32**	**18**	**10**	**7**	**33**	**43**	**140**	**284**	**195**	**133**	**227**	**72**	284
1949	**24**	**8**	**5**	**14**	**49**	**147**	**128**	**172**	**224**	**208**	**629**	**468**	629
1950	**37**	**20**	**15**	**10**	**121**	**204**	**338**	**158**	**120**	**165**	**604**	**187**	604
1951	**51**	**39**	**18**	**13**	**146**	**153**	**141**	**331**	**282**	**99**	**145**	**108**	331
1952	**39**	**35**	**10**	**9**	**56**	**78**	**127**	**83**	**321**	**252**	**140**	**352**	352
1953	**156**	**45**	**15**	**18**	**183**	**143**	**97**	**101**	**106**	**167**	**155**	**85**	183
1954	**24**	**14**	**9**	**13**	**223**	**107**	**287**	**293**	**170**	**177**	**605**	**114**	605
1955	**320**	**29**	**13**	**14**	**47**	**145**	**148**	**212**	**291**	**330**	**310**	**136**	330
1956	**264**	**28**	**16**	**27**	**72**	**107**	**302**	**102**	**283**	**326**	**149**	**66**	326
1957	**32**	**14**	**9**	**5**	**207**	**92**	**62**	**140**	**67**	**269**	**432**	**140**	432
1958	39	97	19	16	98	71	66	130	271	144	127	90	271
1959	37	13	7	16	97	105	90	126	133	154	128	311	311
1960	124	26	25	103	84	105	100	119	88	94	261	468	468
1961	38	16	10	97	65	72	86	138	105	156	184	140	184
1962	80	19	15	36	107	351	64	122	131	158	232	99	351
1963	55	42	10	300	180	115	117	130	131	117	179	70	300
1964	**20**	**10**	**9**	**18**	**112**	**247**	**127**	**144**	**180**	**261**	**318**	**54**	318
1965	**118**	**21**	**12**	**7**	**21**	**45**	**87**	**116**	**60**	**157**	**153**	**275**	275
1966	**31**	**12**	**10**	**27**	**134**	**162**	**168**	**88**	**100**	**249**	**744**	**208**	744
1967	**41**	**20**	**9**	**78**	**324**	**248**	**188**	**150**	**204**	**373**	**167**	**59**	373
1968	**21**	**41**	**13**	**23**	**55**	**166**	**114**	**133**	**140**	**373**	**288**	**100**	373
1969	**43**	**138**	**54**	**40**	**53**	**126**	51	90	203	140	199	213	213
1970	941	618	123	665	403	81	116	180	229	150	434	626	941
1971	209	21	112	15	128	144	149	173	251	158	109	61	251
1972	279	44	38	130	81	73	110	55	137	95	101	39	279
1973	41	13	6	9	80	146	155	124	217	182	334	283	334
1974	48	24	15	123	146	136	307	104	88	243	180	137	307
1975	21	12	9	5	44	79	130	208	326	393	398	314	398
1976	66	20	12	20	36	48	50	136	137	108	109	41	137
1977	16	9	6	8	64	116	110	213	118	238	93	65	238
1978	21	16	34	816	835	86	107	109	127	234	386	87	835
1979	18	11	7	150	92	133	102	195	89	93	74	333	333
1980	291	22	12	97	76	91	76	250	129	182	171	122	291
1981	72	45	34	250	167	167	234	262	113	121	276	1 018	1 018
1982	55	20	13	21	54	133	98	125	129	186	188	28	188
1983	19	8	5	26	234	108	42	61	191	164	92	86	234
1984	50	55	75	9	81	194	145	208	177	324	162	39	324
1985	92	15	11	6	30	363	127	239	97	153	348	375	375
1986	42	18	13	113	185	275	144	226	125	257	501	48	501
1987	21	11	6	149	80	90	80	122	155	355	88	71	355
1988	21	19	9	8	383	89	119	126	84	120	177	55	383
1989	43	17	13	8	327	120	367	137	104	116	192	142	367

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Max
1990	45	18	15	11	76	72	105	88	95	230	200	390	390
1991	30	16	332	11	74	84	45	61	853	234	100	262	853
1992	24	15	9	264	306	134	129	109	239	126	104	67	306
1993	84	17	134	106	43	144	131	60	324	117	586	272	586
1994	29	17	23	64	115	445	58	143	162	139	191	40	445
1995	20	13	14	51	97	92	212	134	122	68	123	521	521
1996	1 711	160	229	68	140	168	277	229	214	231	152	368	1 711
1997	41	32	14	9	190	54	56	44	59	125	63	27	190
1998	13	10	5	293	143	163	129	159	125	326	276	417	417
1999	75	27	104	71	100	191	711	277	321	151	211	298	711
2000	382	37	18	27	82	232	98	322	157	121	352	553	553
2001	245	14	13	110	40	119	102	88					
N	54	54	54	54	54	54	54	54	53	53	53	53	53
M	124	39	33	85	137	141	145	154	179	193	248	207	435
S	264	85	58	150	132	80	109	70	120	84	163	193	266
Cv	2.13	2.19	1.77	1.76	0.96	0.57	0.75	0.45	0.67	0.43	0.66	0.93	0.61
Me	42	19	13	25	97	123	118	135	137	164	188	136	352
Max	1 711	618	332	816	835	445	711	331	853	393	744	1 018	1 711
Min	13	8	5	5	21	43	42	44	59	68	63	27	137

Units: m3/s.

G.2 - Instantaneous Peaks at Batatilla (788 km²)

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Max
1958							**111**	**159**	**460**	**171**	**162**	**134**	**460**
1959	**41.5**	**14.4**	**6.54**	**23.2**	**133**	**156**	**161**	**172**	**173**	**173**	**186**	**460**	**460**
1960	**126**	**31.5**	**42.5**	**173**	**116**	**153**	**114**						
1961				**162**	**88.7**	**88.7**	**106**	**172**					
1962	**88.7**	**19.3**	**15.7**	**48.4**	**148**	**588**	**89.0**	**123**	**173**	**173**	**375**	**153**	**588**
1963	**64.2**	**61.1**	**12.9**	**321**	**187**	**163**	**155**	**179**	**168**	**173**	**301**	**82.4**	**321**
1964													
1969					217	465	166	226	729	752	726	445	752
1970	2219			890	780	231	418	624	782		973	1261	2219
1971	671		254	22.9	372	553	383	499	812	468	266	105	812
1972	729	57.0			141	183	208	173	372	239	333	131	729
1973	148	13.8	12.0	12.0	214	374	589	358	742	534		428	742
1974	86.7	39.8	20.6				1147	375	234	617	390	316	1147
1975	33.2			4.51	75.3					504	812	990	990
1976	35.2	24.0	11.9	42.9	79.2	99.5	89.3	279	407	259	233	80.9	407
1977	16.3	9.82	5.90	12.8	164	300	319	398	335	310	184	108	398
1978	26.4	18.9	72.5	1616	707	154	250	207	300	521	471	84.0	1616
1979	18.9	11.7	9.82	311	233	297	290	780			108	1045	1045
1980	453	24.0	11.9	311	132	223	303	911	418	403	511		911
1981				476	621	523	716	769	417	401	774	1278	1278
1982	57.5	26.3	12.9	42.9	177	511	300	300	332	426	541	36.7	541
1983	27.8	8.04	6.06	42.2	441	226	87.7	148	603	551	203	234	603
1984	85.3	136	117	9.42	258	791	393	507	577	1047	390	50.0	1047

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Max
1985	185	15.7	11.4	8.48	78.9	1185	377	801	250	401	810	735	1185
1986	90.1	19.8	26.2	219	600	1177	264	600	418	902	858	72.5	1177
1987	22.6	12.4	6.78	258	219	203	374	367	426	608	238	144	608
1988	21.2	18.3	9.25	9.25	778	188	314				358	120	778
1989	53.6	18.0	13.9	7.91	565	258	998	233	310			374	998
1990	69.6	18.6	15.9	15.4	330	166						1020	1020
1991	32.7	16.4	882						1558	769	218	404	1558
1992	25.1	24.5	10.7	519	563	364	397	380	628	374	372	88.3	628
1993	152	21.9	277	367	119	579	453	166	707	358	1059	685	1059
1994	31.4	17.5	54.4	160	314	776	105	586	649	428	778	71.1	778
1995	18.0	9.44	41.0	250	216	218	715	594	433	140	268	1250	1250
1996	2079	572	563	148	828	704	744	1166	1065	1018	733	862	2079
1997	92.3	61.2	13.9	13.1	433	143	145	121	238	489	118	31.4	489
1998	14.8			489	389	555	426	445	488	737	711	656	737
1999	94.7	36.8	180	171	397	623	1272	754	763	433	541	565	1272
2000			18.7	65.7				1105	300	297	799	1162	1162
2001	872	14.8	29.5	190	111	642	291	178					872
Nval	34	30	31	34	35	34	35	34	32	31	33	35	37
M	258	46	89	218	321	408	379	437	508	473	479	448	938
S	525	102	187	317	228	286	298	289	292	243	275	418	435
Cv	2.03	2.24	2.10	1.45	0.71	0.70	0.79	0.66	0.57	0.51	0.57	0.94	0.46
Me	67	19	16	154	219	298	303	371	422	428	390	316	872
Max	2 219	572	882	1 616	828	1 185	1 272	1 166	1 558	1 047	1 059	1 278	2 219
Min	15	8	6	5	75	89	88	121	168	140	108	31	321

Units: m3/s.

G.3 - Daily Peaks at Batatilla – 90-year Sample

Year	Qdmx	Year	Qdmx	Year	Qdmx
1976	**137**	1984	**324**	1960	**468**
1953	**183**	1956	**326**	1927	475
1961	**184**	1955	**330**	1911	476
1982	**188**	1951	**331**	1946	476
1997	**190**	1979	**333**	1941	483
1936	191	1973	**334**	1938	491
1930	192	1944	342	1926	495
1940	205	1962	**351**	1986	**501**
1969	**213**	1952	**352**	1925	509
1934	223	1987	**355**	1995	**521**
1983	**234**	1989	**367**	1915	524
1977	**238**	1967	**373**	1939	539
1971	**251**	1912	373	2000	**553**
1918	255	1968	**373**	1933	568
1943	265	1985	**375**	1993	**586**
1924	269	1928	381	1950	**604**
1958	**271**	1988	**383**	1954	**605**
1965	**275**	1920	383	1914	621
1972	**279**	1990	**390**	1949	**629**
1913	280	1919	391	1937	673
1948	**284**	1975	**398**	1999	**711**
1922	288	1947	412	1917	720
1980	**291**	1998	**417**	1966	**744**
1963	**300**	1945	420	1931	813
1992	**306**	1942	425	1978	**835**
1974	**307**	1921	431	1932	836
1959	**311**	1957	**432**	1991	**853**
1929	317	1916	438	1970	**941**
1964	**318**	1994	**445**	1981	**1 018**
				1923	1 095
				1935	1 329
				1996	**1 711**

G.4 – Flood Hydrographs (A)

t	08/04/79	12/12/81	14/01/96	16/04/1978	22/06/86	24/11/93	25/12/95	27/07/99
-30			40					
-29			47					
-28			63					
-27			105					
-26			174					
-25			282					
-24			404					
-23			525					
-22			650					
-21			809					
-20			962					
-19			1 113					
-18			1 245	81				
-17			1 387	74				
-16			1 525	78				
-15			1 664	90				
-14			1 773	97				31
-13			***1 834***	113				31
-12	8		1 783	270			48	61
-11	13	200	1 744	418			48	96
-10	50	196	1 600	536	33	85	64	149
-9	76	198	1 469	662	33	83	107	219
-8	80	241	1 374	974	33	96	163	306
-7	92	311	1 381	1 112	34	160	212	429
-6	144	384	1 493	1 227	92	237	362	565
-5	191	418	1 635	1 315	166	426	463	713
-4	231	439	1 748	1 384	202	577	603	861
-3	257	527	1 853	1 443	302	653	778	966
-2	274	617	1 963	1 500	729	769	1 035	1 116
-1	299	769	2 051	1 560	920	972	1 210	1 221
0	**312**	**845**	**2 085**	**1 635**	**1 193**	**1 046**	**1 254**	**1 275**
1	299	841	2 029	1 611	1 089	996	1 174	1 247
2	252	797	1 930	1 565	978	946	1 100	1 176
3	187	746	1 880	1 500	865	876	1 019	1 064
4	144	705	1 760	1 443	739	807	938	966
5	110	658	1 614	1 364	497	746	865	865
6	66	608	1 472	1 300	391	680	780	774
7	40	561	1 315	1 217	289	614	702	665
8	13	511	1 190	1 140	218	548	640	560
9	12	487	1 056	1 043	168	496	575	481
10	12	471	959	942	142	451	496	407
11	11	455	856	853	122	405	429	336
12	11	431	775	776	107	356	372	275
13	10	409	687	694	90	320	324	239
14	10	393	602	593	86	282	271	201
15	9	361	521	504	83	249	231	168
16	9	342	451	429	79	224	228	147

t	08/04/79	12/12/81	14/01/96	16/04/1978	22/06/86	24/11/93	25/12/95	27/07/99
17		321	369	349	76	200	237	131
18		289	321	292	74	176	216	116
19		263	279	220	75	160	203	104
20		244	250	171	75	149	214	97
21		224	229	146	73	142	218	94
22		210	209	119	72	134	196	91
23		197	195	107	72	124	171	89
24		197	187	99		121	158	85
25		195	180	95		118	149	81
26		191	172	90		115	140	80
27		190	167	82		112	127	78
28		183	162	79		110	113	75
29		178	158	77		111	101	74
30		175	154	74			92	72
31		171	144	73			86	70
32		166		69			81	68
33		161		68			79	69
34		158		66				75
35		157		64				81
36				63				
37				62				
38				61				
39				60				
40				58				

G.5 – Flood Hydrographs (B)

t	30/09/96	31/12/00	05/12/81	03/12/70	30/06/85	22/07/74	27/10/84	17/08/96
-30				171				
-29			55	243				
-28			54	376				
-27			55	450				
-26			56	594				
-25			63	680				
-24			69	830				
-23			115	962				
-22			324	1 027				
-21			642	***1 046***				
-20			763	1 039				
-19			876	1 015				
-18			986	978				
-17			1 062	922				
-16		80	1 110	867				
-15		74	1 152	803				
-14		145	1 180	737				
-13		152	***1 182***	669				
-12		171	1 142	593				
-11	71	178	1 050	522				48
-10	70	244	972	463		34		47
-9	94	349	878	460	76	37		75
-8	164	489	773	481	75	48	84	142
-7	220	617	722	568	75	59	89	315
-6	309	756	767	720	77	147	196	456
-5	427	839	837	882	131	251	294	573
-4	527	910	932	1 035	219	512	486	724
-3	698	1 000	1 015	1 144	271	660	746	880
-2	950	1 066	1 108	1 202	696	832	884	1 006
-1	1 052	1 131	1 184	1 249	1 054	966	1 016	1 142
0	**1 068**	**1 165**	**1 304**	**1 264**	**1 189**	**1 150**	**1 050**	**1 169**
1	1 060	1 089	1 278	1 238	1 100	1 002	1 045	1 114
2	996	1 009	1 206	1 161	988	896	998	1 029
3	922	898	1 133	1 087	890	786	932	918
4	832	797	1 054	1 000	780	674	853	795
5	731	693	986	902	651	567	765	694
6	631	605	926	826	544	461	580	586
7	560	526	861	759	445	349	482	486
8	476	461	776		356	260	385	390
9	396	401	702		275	195	292	311
10	331	343	615		211	147	237	243
11	262	282	534		169	125	195	193
12	214	240	481		138	112	172	161
13	182	198	418		119	103	152	142
14	156	169	340		106	96	140	125
15	139	146	280		98	90	133	113
16	127	130	240		89	86	127	107

t	30/09/96	31/12/00	05/12/81	03/12/70	30/06/85	22/07/74	27/10/84	17/08/96
17	118	120	216		83	82	122	101
18	107	111	200			76	117	97
19		105	187			74	113	94
20		100	164			72	110	90
21		96	160			69	107	88
22		94	154			67	104	85
23		90	149			66	99	83
24		86	143			65	97	79
25		83	140			63	95	74
26		79	137			61	94	
27		77	134			59	93	
28		74	133			58	92	
29		73	130			57	89	
30		70	126			56	88	
31		68	120			54	87	
32		66				53	86	
33		64				52	86	
34		64				51	85	
35		62				50	84	
36		62				49	83	
37		59				48	82	
38		58				47	82	
39						47	81	
40								

APPENDIX H – SEDIMENT TRANSPORT

H.1 – Toabre River at Batatilla – (788 km²)

N°	Date	Ql	C	Qs	N°	Date	Ql	C	Qs
		m3/s	mg/l	tons/day			m3/s	mg/l	tons/day
1	22/04/98	2.7	5.8	1.3	31	01/07/89	31.1	5.3	14.2
2	06/04/83	2.7	6.4	1.5	32	15/12/92	31.6	5.5	15.1
3	23/02/88	6.3	3.6	1.9	33	01/12/94	35.9	8.8	27.4
4	19/03/94	6.9	23.1	13.8	34	14/11/97	38.1	9.8	32.3
5	24/02/87	7.0	10.7	6.5	35	24/08/83	38.5	22.4	74.6
6	13/03/86	7.1	6.3	3.9	36	11/08/87	39.1	18.6	62.8
7	28/04/82	7.5	6.3	4.1	37	01/09/92	40.8	16.9	59.6
8	19/02/95	7.6	7.7	5.1	38	08/09/82	42.4	15.6	57.1
9	16/01/83	8.0	10.3	7.1	39	09/09/94	42.4	30.0	109.9
10	17/03/89	8.0	7.9	5.4	40	21/09/85	43.2	24.7	92.2
11	03/06/66	10.0	5.8	5.0	41	23/11/83	43.8	19.8	75.0
12	15/03/97	10.0	36.5	31.5	42	17/11/96	44.0	10.8	41.2
13	18/05/84	10.2	7.2	6.3	43	29/07/82	46.3	38.5	154.0
14	05/03/85	10.4	10.1	9.1	44	11/12/85	46.7	26.0	104.9
15	10/03/82	10.5	6.0	5.5	45	28/09/95	49.2	35.6	151.4
16	30/03/84	14.8	11.7	15.0	46	29/11/84	49.9	13.1	56.5
17	09/05/95	16.4	5.8	8.2	47	30/08/84	50.6	19.1	83.5
18	26/01/84	17.2	6.9	10.2	48	21/10/99	51.6	24.2	107.8
19	03/02/82	18.4	6.6	10.5	49	24/11/89	53.1	5.6	25.5
20	19/05/87	19.2	9.6	15.8	50	27/10/88	55.6	66.9	320.9
21	10/06/94	19.6	28.7	48.6	51	18/11/90	56.4	12.0	58.5
22	01/02/99	19.6	4.3	7.3	52	04/12/95	59.2	56.0	286.5
23	31/07/97	20.9	20.8	37.6	53	26/11/86	65.2	9.5	53.7
24	17/08/93	21.5	7.6	14.1	54	19/10/84	66.7	78.8	454.1
25	23/06/85	25.3	25.0	54.6	55	06/10/87	73.6	282.1	1 793.9
26	05/09/91	25.9	10.1	22.6	56	27/10/82	82.3	46.8	332.8
27	26/05/83	26.3	8.0	18.3	57	08/10/86	86.2	239.3	1 782.2
28	24/11/82	26.4	19.1	43.6	58	04/12/99	87.3	16.2	122.4
29	12/08/98	27.5	20.8	49.4	59	06/07/84	94.9	120.1	984.3
30	10/07/96	28.1	4.6	11.1					

H.2 – Cocle del Norte at Canos – (571 km²)

N°	Date	Ql	C	Qs	N°	Date	Ql	C	Qs
		m3/s	mg/l	tons/day			m3/s	mg/l	tons/day
1	21/04/98	5.6	5.9	2.8	24	07/08/00	26.3	8.4	19.0
2	17/03/94	8.1	10.8	7.6	25	13/05/00	26.4	4.9	11.1
3	25/02/87	8.4	8.4	6.1	26	21/06/85	26.7	12.5	28.8
4	17/02/96	10.6	17.7	16.2	27	28/01/84	27.1	5.4	12.6
5	01/04/84	11.6	5.2	5.2	28	20/05/84	27.5	28.6	67.8
6	14/03/86	12.6	4.9	5.3	29	07/10/87	28.3	10.3	25.2
7	16/03/89	15.0	2.6	3.4	30	24/02/88	28.9	9.7	24.3
8	21/11/90	15.6	6.5	8.8	31	08/06/04	29.5	11.3	28.7
9	11/08/98	16.9	2.5	3.7	32	26/10/88	29.9	8.1	20.9
10	14/03/97	17.0	3.8	5.6	33	30/07/97	30.4	10.5	27.5
11	10/05/95	17.4	8.5	12.8	34	30/11/94	31.5	6.9	18.8
12	08/07/95	18.8	10.1	16.4	35	13/11/97	32.7	8.2	23.0
13	23/11/83	19.0	11.1	18.3	36	21/10/84	33.0	7.9	22.6
14	01/03/85	19.4	10.4	17.5	37	09/07/84	38.5	8.1	26.8
15	30/06/89	19.8	3.5	6.0	38	29/09/95	38.9	32.2	108.1
16	08/09/94	20.0	6.6	11.5	39	27/11/86	39.0	4.1	13.9
17	02/09/92	20.2	1.7	3.0	40	15/11/90	40.5	7.7	26.8
18	20/09/85	20.9	6.5	11.7	41	28/11/84	41.3	8.6	30.6
19	01/12/95	22.2	17.8	34.1	42	19/08/93	42.3	20.7	75.5
20	17/12/92	24.5	3.3	6.9	43	29/08/84	42.8	17.3	63.9
21	12/08/87	25.0	8.5	18.4	44	09/10/86	43.5	22.4	84.1
22	20/05/87	25.8	10.0	22.2	45	22/08/96	51.3	16.5	73.1
23	04/09/91	25.9	33.6	75.2	46	23/11/89	53.5	19.5	90.2
47	12/12/85	56.9	7.8	38.2					
48	16/11/96	58.5	9.7	49.2					
49	03/12/99	155.2	28.6	383.0					

APPENDIX – WATER MANAGEMENT & POWER STUDY

(this part has 10 pages + 31 pages of software output)

APPENDIX A Output Listings from the SIM software for the two cases NWL 95 / MOL 50 – Qr 99% - Scenario D1 & D2.

APPENDIX B HEC-5 Simulations Results and Analysis

APPENDIX A1 - Output Listings from the SIM software

Case NWL 95 / MOL 50 – Qr 99% - Scenario D1

(17 pages)

COYNE ET BELLIER - BUREAU D INGENIEURS CONSEILS - PARIS - FRANCE

CALCUL EFFECTUE PAR LE PROGRAMME S I M - REV 2.10 2002/10/15 10H16M55

Simulation TOABRE

-----> APPORT TOABRE INFLOWS (HM3)

ANNEE	J	F	M	A	M	J	J	A	S	O	N	D	MOY	CUM
1948	62.10	30.20	18.50	10.10	27.60	35.30	112.50	136.30	116.40	129.90	286.90	102.00	88.98	1067.8
1949	33.70	14.30	8.30	8.00	27.30	148.50	143.80	155.90	229.10	193.10	330.70	253.90	128.88	1546.6
1950	66.20	35.30	21.20	9.80	93.70	141.50	150.00	200.90	124.20	198.70	276.60	235.70	129.48	1553.8
1951	83.30	50.60	28.40	19.70	85.70	115.60	118.70	146.00	114.60	161.00	193.90	129.40	103.91	1246.9
1952	52.00	28.80	16.30	12.40	32.40	86.30	80.60	94.50	157.10	229.80	154.20	307.50	104.32	1251.9
1953	125.60	52.00	27.90	18.90	114.10	100.80	95.40	69.60	94.90	193.10	193.60	106.60	99.38	1192.5
1954	43.90	22.70	14.70	12.70	119.70	104.50	260.30	208.10	201.70	202.80	303.30	142.50	136.41	1636.9
1955	150.80	43.30	23.60	16.10	31.90	119.00	103.70	163.40	189.70	226.60	316.00	161.80	128.82	1545.9
1956	141.20	43.80	30.30	22.80	76.90	124.20	157.50	98.00	174.70	277.80	172.60	91.10	117.57	1410.9
1957	50.40	25.20	17.10	9.10	42.90	45.90	50.60	101.20	96.20	261.70	183.50	102.30	82.18	986.1
1958	56.00	40.40	27.30	22.60	75.30	75.70	85.70	160.70	165.10	175.20	147.00	98.60	94.13	1129.6
1959	51.40	20.60	11.20	13.00	39.40	85.50	79.50	131.80	134.80	197.70	174.40	246.70	98.83	1186.0
1960	99.40	33.60	25.20	50.00	83.30	116.90	116.20	123.20	109.60	142.80	209.40	392.40	125.17	1502.0
1961	61.30	27.30	18.50	32.90	45.80	89.70	121.30	204.40	141.50	183.70	175.00	136.60	103.17	1238.0
1962	62.90	29.30	20.40	17.60	57.90	102.60	76.90	145.20	123.40	178.60	215.40	121.60	95.98	1151.8
1963	55.40	31.00	14.20	91.20	114.60	128.80	135.30	146.80	112.80	143.80	188.20	86.80	104.08	1248.9
1964	34.80	16.50	11.50	13.20	52.00	170.00	173.00	176.50	206.80	230.90	263.90	80.60	119.14	1429.7
1965	81.20	35.30	21.70	11.90	19.80	39.40	36.20	85.20	65.30	142.50	172.60	189.90	75.08	901.0
1966	47.40	20.30	15.00	15.60	98.60	133.00	109.80	108.50	96.40	210.80	275.80	216.40	112.30	1347.6
1967	68.00	29.50	16.60	25.70	83.80	196.70	151.60	166.90	217.70	261.40	166.40	78.50	121.90	1462.8
1968	39.10	25.20	17.40	15.30	44.70	126.20	97.20	138.50	140.70	249.60	233.00	113.60	103.38	1240.5
1969	38.30	40.40	20.90	28.30	42.10	77.00	66.70	110.90	134.80	154.00	168.20	144.60	85.52	1026.2
1970	263.60	142.70	64.30	121.60	200.30	87.60	132.00	189.90	222.40	188.30	242.40	401.80	188.07	2256.9
1971	110.90	40.40	51.40	22.80	78.50	148.30	150.00	165.30	177.00	195.00	123.10	56.00	109.89	1318.7
1972	97.80	34.60	25.70	64.50	79.30	83.20	68.60	61.30	124.70	119.70	114.60	56.50	77.54	930.5
1973	35.10	19.60	12.60	12.40	54.40	128.80	148.70	154.30	206.80	217.00	246.20	190.70	118.88	1426.6
1974	67.50	32.40	22.50	41.20	145.20	102.10	118.70	111.20	104.20	237.80	148.50	106.60	103.16	1237.9
1975	41.00	23.70	17.40	9.10	43.40	70.20	131.00	200.90	230.20	299.20	379.70	289.50	144.61	1735.3
1976	89.50	32.90	20.10	15.30	35.10	46.10	44.70	89.20	144.90	157.80	133.50	60.00	72.43	869.1
1977	29.70	17.20	12.30	11.10	31.10	82.70	92.40	188.00	134.50	205.20	129.60	73.90	83.97	1007.7
1978	35.60	22.00	21.20	147.50	269.20	101.60	84.40	98.60	152.20	172.50	200.90	80.10	115.48	1385.8
1979	32.40	18.10	12.10	43.50	50.90	128.60	124.50	208.90	136.30	121.10	109.10	147.80	94.44	1133.3
1980	119.70	34.10	20.40	23.10	55.70	84.80	93.20	177.30	121.60	188.60	164.10	134.50	101.43	1217.1
1981	88.10	48.40	40.20	107.60	169.50	149.00	192.30	202.50	119.00	163.90	246.00	352.70	156.60	1879.2
1982	79.30	33.60	23.00	21.30	42.90	91.20	105.80	93.50	110.20	177.60	126.70	46.90	79.33	952.0
1983	28.40	13.50	9.10	9.10	101.00	88.60	57.30	72.30	172.60	140.10	113.80	136.60	78.53	942.4
1984	59.50	47.70	41.00	14.80	52.20	114.80	168.70	195.00	187.90	205.40	176.80	67.80	110.97	1331.6
1985	48.70	24.20	19.60	11.70	23.00	147.70	101.20	136.60	129.30	147.60	187.90	139.30	93.07	1116.8
1986	52.20	25.90	18.70	65.30	84.90	121.30	138.70	124.50	132.50	291.10	273.20	72.30	116.72	1400.6
1987	34.30	20.10	12.90	44.60	55.40	50.50	76.10	95.10	108.30	272.10	143.90	88.70	83.50	1002.0
1988	37.80	29.00	12.30	9.30	82.20	78.00	128.00	148.90	137.90	192.60	188.20	92.40	94.72	1136.6
1989	59.20	31.00	24.90	16.60	77.70	102.60	145.70	157.80	138.90	134.70	176.80	121.60	98.96	1187.5
1990	64.80	32.40	25.40	19.20	58.90	59.90	106.30	110.90	149.60	270.50	197.30	240.00	111.27	1335.2
1991	52.00	29.00	79.80	21.50	67.80	81.90	70.70	85.40	306.90	227.90	141.80	139.50	108.68	1304.2
1992	44.50	23.70	15.30	59.90	122.10	124.70	101.20	125.10	188.40	142.20	110.40	76.10	94.47	1133.6
1993	70.70	24.90	32.10	32.70	51.40	106.50	97.20	73.90	195.40	148.40	249.90	171.10	104.52	1254.2
1994	52.00	28.30	25.20	35.80	88.90	147.50	86.50	129.40	149.30	154.80	142.30	64.30	92.03	1104.3
1995	40.40	23.00	16.30	28.30	109.30	99.30	123.20	141.20	168.00	101.00	129.60	184.00	96.97	1163.6
1996	349.00	99.70	81.70	49.50	165.50	155.80	187.00	215.90	227.10	187.20	172.60	176.20	172.27	2067.2
1997	66.40	41.40	23.80	16.30	61.30	41.20	50.90	43.90	67.40	118.40	94.60	40.70	55.53	666.3
1998	24.60	14.80	9.60	50.50	54.40	118.70	106.60	120.30	116.10	180.80	138.70	204.10	94.93	1139.2
1999	87.00	42.60	45.00	41.20	115.20	215.10	174.40	299.40	280.70	182.10	242.10	367.20	174.33	2092.0
MOY.	72.43	33.59	24.27	31.62	77.62	106.18	114.01	140.17	153.61	190.12	193.17	152.27	107.42	1289.1
EC-T	55.99	20.57	15.63	29.67	47.83	38.38	42.56	49.28	50.14	48.02	64.04	91.53	25.92	311.0
C.VR	.77	.61	.64	.94	.62	.36	.37	.35	.33	.25	.33	.60	.24	.2

COYNE ET BELLIER - BUREAU D INGENIEURS CONSEILS - PARIS - FRANCE

CALCUL EFFECTUE PAR LE PROGRAMME S I M - REV 2.10 2002/10/15 10H16M55

Simulation TOABRE

-----> &AP_S INFLOWS (M3/S)

ANNEE	J	F	M	A	M	J	J	A	S	O	N	D	MOY	CUM
1948	23.19	12.48	6.91	3.90	10.30	13.62	42.00	50.89	44.91	48.50	110.69	38.08	33.79	405.4
1949	12.58	5.91	3.10	3.09	10.19	57.29	53.69	58.21	88.39	72.10	127.58	94.80	48.91	586.9
1950	24.72	14.59	7.92	3.78	34.98	54.59	56.00	75.01	47.92	74.19	106.71	88.00	49.03	588.4
1951	31.10	20.92	10.60	7.60	32.00	44.60	44.32	54.51	44.21	60.11	74.81	48.31	39.42	473.0
1952	19.41	11.90	6.09	4.78	12.10	33.29	30.09	35.28	60.61	85.80	59.49	114.81	39.47	473.6
1953	46.89	21.49	10.42	7.29	42.60	38.89	35.62	25.99	36.61	72.10	74.69	39.80	37.70	452.3
1954	16.39	9.38	5.49	4.90	44.69	40.32	97.18	77.70	77.82	75.72	117.01	53.20	51.65	619.8
1955	56.30	17.90	8.81	6.21	11.91	45.91	38.72	61.01	73.19	84.60	121.91	60.41	48.91	586.8
1956	52.72	18.11	11.31	8.80	28.71	47.92	58.80	36.59	67.40	103.72	66.59	34.01	44.56	534.6
1957	18.82	10.42	6.38	3.51	16.02	17.71	18.89	37.78	37.11	97.71	70.79	38.19	31.11	373.3
1958	20.91	16.70	10.19	8.72	28.11	29.21	32.00	60.00	63.70	65.41	56.71	36.81	35.71	428.4
1959	19.19	8.52	4.18	5.02	14.71	32.99	29.68	49.21	52.01	73.81	67.28	92.11	37.39	448.7
1960	37.11	13.89	9.41	19.29	31.10	45.10	43.38	46.00	42.28	53.32	80.79	146.51	47.35	568.1
1961	22.89	11.28	6.91	12.69	17.10	34.61	45.29	76.31	54.59	68.59	67.52	51.00	39.06	468.7
1962	23.48	12.11	7.62	6.79	21.62	39.58	28.71	54.21	47.61	66.68	83.10	45.40	36.41	436.9
1963	20.68	12.81	5.30	35.19	42.79	49.69	50.52	54.81	43.52	53.69	72.61	32.41	39.50	474.0
1964	12.99	6.82	4.29	5.09	19.41	65.59	64.59	65.90	79.78	86.21	101.81	30.09	45.22	542.5
1965	30.32	14.59	8.10	4.59	7.39	15.20	13.52	31.81	25.19	53.20	66.59	70.90	28.45	341.4
1966	17.70	8.39	5.60	6.02	36.81	51.31	40.99	40.51	37.19	78.70	106.40	80.79	42.54	510.4
1967	25.39	12.19	6.20	9.92	31.29	75.89	56.60	62.31	83.99	97.60	64.20	29.31	46.24	554.8
1968	14.60	10.42	6.50	5.90	16.69	48.69	36.29	51.71	54.28	93.19	89.89	42.41	39.21	470.5
1969	14.30	16.70	7.80	10.92	15.72	29.71	24.90	41.41	52.01	57.50	64.89	53.99	32.49	389.8
1970	98.42	58.99	24.01	46.91	74.78	33.80	49.28	70.90	85.80	70.30	93.52	150.01	71.39	856.7
1971	41.41	16.70	19.19	8.80	29.31	57.21	56.00	61.72	68.29	72.80	47.49	20.91	41.65	499.8
1972	36.51	14.30	9.60	24.88	29.61	32.10	25.61	22.89	48.11	44.69	44.21	21.09	29.47	353.6
1973	13.10	8.10	4.70	4.78	20.31	49.69	55.52	57.61	79.78	81.02	94.98	71.20	45.07	540.8
1974	25.20	13.39	8.40	15.90	54.21	39.39	44.32	41.52	40.20	88.78	57.29	39.80	39.03	468.4
1975	15.31	9.80	6.50	3.51	16.20	27.08	48.91	75.01	88.81	111.71	146.49	108.09	54.78	657.4
1976	33.42	13.60	7.50	5.90	13.10	17.79	16.69	33.30	55.90	58.92	51.50	22.40	27.50	330.0
1977	11.09	7.11	4.59	4.28	11.61	31.91	34.50	70.19	51.89	76.61	50.00	27.59	31.78	381.3
1978	13.29	9.09	7.92	56.91	100.51	39.20	31.51	36.81	58.72	64.40	77.51	29.91	43.81	525.7
1979	12.10	7.48	4.52	16.78	19.00	49.61	46.48	77.99	52.58	45.21	42.09	55.18	35.75	429.0
1980	44.69	14.10	7.62	8.91	20.80	32.72	34.80	66.20	46.91	70.42	63.31	50.22	38.39	460.6
1981	32.89	20.01	15.01	41.51	63.28	57.48	71.80	75.60	45.91	61.19	94.91	131.68	59.27	711.2
1982	29.61	13.89	8.59	8.22	16.02	35.19	39.50	34.91	42.52	66.31	48.88	17.51	30.09	361.1
1983	10.60	5.58	3.40	3.51	37.71	34.18	21.39	26.99	66.59	52.31	43.90	51.00	29.76	357.1
1984	22.21	19.72	15.31	5.71	19.49	44.29	62.99	72.80	72.49	76.69	68.21	25.31	42.10	505.2
1985	18.18	10.00	7.32	4.51	8.59	56.98	37.78	51.00	49.88	55.11	72.49	52.01	35.32	423.8
1986	19.49	10.71	6.98	25.19	31.70	46.80	51.78	46.48	51.12	108.68	105.40	26.99	44.28	531.3
1987	12.81	8.31	4.82	17.21	20.68	19.48	28.41	35.51	41.78	101.59	55.52	33.12	31.60	379.2
1988	14.11	11.99	4.59	3.59	30.69	30.09	47.79	55.59	53.20	71.91	72.61	34.50	35.89	430.6
1989	22.10	12.81	9.30	6.40	29.01	39.58	54.40	58.92	53.59	50.29	68.21	45.40	37.50	450.0
1990	24.19	13.39	9.48	7.41	21.99	23.11	39.69	41.41	57.72	100.99	76.12	89.61	42.09	505.1
1991	19.41	11.99	29.79	8.29	25.31	31.60	26.40	31.88	118.40	85.09	54.71	52.08	41.25	494.9
1992	16.61	9.80	5.71	23.11	45.59	48.11	37.78	46.71	72.69	53.09	42.59	28.41	35.85	430.2
1993	26.40	10.29	11.98	12.62	19.19	41.09	36.29	27.59	75.39	55.41	96.41	63.88	39.71	476.5
1994	19.41	11.70	9.41	13.81	33.19	56.91	32.30	48.31	57.60	57.80	54.90	24.01	34.95	419.3
1995	15.08	9.51	6.09	10.92	40.81	38.31	46.00	52.72	64.81	37.71	50.00	68.70	36.72	440.6
1996	130.30	41.21	30.50	19.10	61.79	60.11	69.82	80.61	87.62	69.89	66.59	65.79	65.28	783.3
1997	24.79	17.11	8.89	6.29	22.89	15.90	19.00	16.39	26.00	44.21	36.50	15.20	21.10	253.1
1998	9.18	6.12	3.58	19.48	20.31	45.79	39.80	44.91	44.79	67.50	53.51	76.20	35.93	431.2
1999	32.48	17.61	16.80	15.90	43.01	82.99	65.11	111.78	108.29	67.99	93.40	137.10	66.04	792.4
MOY.	27.04	13.88	9.06	12.20	28.98	40.96	42.57	52.33	59.26	70.98	74.53	56.85	40.72	488.7
EC-T	20.90	8.50	5.84	11.45	17.86	14.81	15.89	18.40	19.35	17.93	24.71	34.17	9.82	117.8
C.VR	.77	.61	.64	.94	.62	.36	.37	.35	.33	.25	.33	.60	.24	.2

COYNE ET BELLIER - BUREAU D INGENIEURS CONSEILS - PARIS - FRANCE

CALCUL EFFECTUE PAR LE PROGRAMME S I M - REV 2.10 2002/10/15 10H16M55

Simulation TOABRE

-----> HAUTEUR TOABRE RESERVOIR LEVEL (MASL)

ANNEE	J	F	M	A	M	J	J	A	S	O	N	D	MOY	CUM
1948	78.01	74.74	69.62	63.06	55.68	50.00	51.38	55.78	57.59	60.06	73.24	73.03	63.52	
1949	68.59	62.53	51.81	50.00	50.00	56.72	60.68	65.02	73.28	77.78	87.10	91.78	66.27	
1950	90.53	88.57	85.58	82.00	81.69	83.41	85.21	88.60	89.33	92.16	95.00	95.00	88.09	
1951	94.33	93.06	90.74	88.16	87.65	88.23	88.76	90.10	90.49	92.16	94.68	95.00	91.11	
1952	93.50	91.54	88.72	85.65	83.04	82.51	81.57	81.19	83.47	88.01	89.72	95.00	86.99	
1953	95.00	93.78	91.51	89.00	89.43	89.50	89.27	88.16	87.93	90.74	93.40	93.39	90.93	
1954	91.56	89.28	86.14	82.76	83.49	83.70	89.26	92.40	95.00	95.00	95.00	95.00	89.88	
1955	95.00	93.55	91.13	88.47	86.13	86.82	86.85	88.88	91.58	94.93	95.00	95.00	91.11	
1956	95.00	93.56	91.34	88.94	88.16	89.00	90.69	90.53	92.67	95.00	95.00	94.58	92.04	
1957	93.03	90.92	88.05	84.78	82.51	80.22	77.82	77.70	77.45	84.21	87.19	87.05	84.24	
1958	85.22	83.05	79.61	75.89	74.54	73.24	72.21	75.31	78.40	81.56	83.43	83.14	78.80	
1959	80.81	77.32	72.31	66.69	61.70	60.36	58.06	60.65	63.55	70.10	74.36	81.07	68.92	
1960	80.73	77.87	73.76	70.77	69.58	70.64	71.40	72.54	73.01	75.07	80.20	90.67	75.52	
1961	89.23	86.87	83.58	80.76	78.23	77.78	78.61	83.00	84.54	87.38	89.80	90.72	84.21	
1962	89.33	87.05	83.86	80.39	78.41	78.55	77.32	79.24	80.23	83.35	87.52	88.04	82.77	
1963	86.24	83.77	79.86	79.40	79.99	81.30	82.64	84.33	84.76	86.20	89.15	88.50	83.85	
1964	86.00	82.94	78.77	74.46	71.63	75.50	78.84	82.06	86.12	90.30	94.88	94.18	82.97	
1965	93.45	91.68	89.05	86.01	82.93	80.38	77.31	76.39	74.56	76.48	79.81	83.37	82.62	
1966	80.91	77.41	72.64	67.28	67.01	69.20	69.58	69.87	69.55	75.60	83.44	87.47	74.16	
1967	86.11	83.56	79.73	76.17	75.27	79.88	81.99	84.50	88.60	93.29	95.00	94.25	84.86	
1968	92.35	90.20	87.25	84.12	81.86	82.99	82.74	84.10	85.58	90.41	94.16	94.34	87.51	
1969	92.42	90.74	87.98	85.42	83.17	82.27	80.73	81.05	82.43	84.37	86.81	88.13	85.46	
1970	92.88	94.10	92.90	93.45	95.00	94.73	95.00	95.00	95.00	95.00	95.00	95.00	94.42	
1971	95.00	93.47	91.86	89.49	88.80	90.35	91.77	93.52	95.00	95.00	95.00	93.65	92.74	
1972	93.36	91.57	89.06	87.82	87.09	86.55	85.33	83.71	84.60	85.17	85.66	83.78	86.98	
1973	80.82	77.29	72.35	66.69	62.98	65.24	68.42	71.56	77.19	82.22	87.62	90.35	75.23	
1974	89.09	86.90	83.77	81.33	83.14	83.26	83.86	84.15	84.25	88.95	90.41	90.42	85.79	
1975	88.29	85.75	82.26	78.18	75.33	73.79	75.24	79.86	85.13	91.53	95.00	95.00	83.78	
1976	94.50	92.74	90.14	87.33	85.00	82.97	80.49	79.83	81.73	83.87	85.11	83.33	85.59	
1977	80.05	76.34	71.21	65.16	59.06	57.22	55.79	63.84	66.32	72.75	74.32	72.54	67.88	
1978	68.16	62.64	53.86	59.21	71.55	71.65	70.50	70.16	73.19	76.71	81.28	80.13	69.92	
1979	76.67	72.54	66.52	62.00	57.00	59.83	61.70	69.47	71.61	72.57	73.03	75.28	68.18	
1980	75.94	72.63	67.24	61.04	56.27	54.30	52.79	60.95	62.73	68.91	72.74	74.34	64.99	
1981	73.33	70.52	66.09	66.58	70.96	73.81	78.24	82.59	83.29	85.55	90.37	95.00	78.03	
1982	94.23	92.47	89.94	87.31	85.27	84.98	85.09	84.71	85.03	87.61	88.47	86.43	87.63	
1983	83.48	79.96	75.32	70.08	69.99	69.28	66.09	63.70	68.84	71.07	71.80	73.59	71.93	
1984	70.85	67.76	62.86	53.97	50.00	52.30	59.87	67.23	72.64	77.84	81.26	79.54	66.34	
1985	76.84	73.09	67.72	60.66	51.19	57.46	57.15	60.34	62.81	66.13	71.78	73.72	64.91	
1986	70.54	65.83	58.44	54.18	51.46	54.42	58.50	60.39	63.12	75.14	82.99	81.58	64.72	
1987	78.33	74.57	69.08	65.11	61.20	56.18	52.50	51.05	52.19	67.99	70.71	69.66	64.05	
1988	64.93	59.23	50.00	50.00	50.00	50.00	53.68	58.94	62.25	68.79	73.99	73.25	59.59	
1989	70.46	66.10	59.39	50.00	50.00	50.31	56.17	61.54	64.65	66.89	71.71	72.65	61.65	
1990	70.15	65.85	59.12	50.00	50.00	50.00	50.35	51.44	57.77	70.68	75.99	82.13	61.12	
1991	79.73	76.57	75.23	70.74	68.55	67.35	64.94	63.46	76.30	81.93	83.57	84.85	74.43	
1992	82.38	79.19	74.77	72.49	73.62	74.96	74.84	75.91	80.01	81.65	82.03	80.76	77.72	
1993	79.11	75.70	71.61	67.25	63.38	63.91	63.36	60.74	68.07	70.87	78.66	81.57	70.35	
1994	79.12	75.87	71.41	67.24	66.22	69.45	68.34	69.97	72.85	75.53	77.55	75.50	72.42	
1995	71.87	67.25	60.00	51.17	52.08	51.87	54.53	58.82	64.60	64.32	66.43	71.54	61.21	
1996	83.22	83.34	82.30	80.06	82.81	85.00	87.97	91.49	94.94	95.00	95.00	95.00	88.01	
1997	93.89	92.32	89.81	86.99	85.61	83.41	81.27	78.58	76.98	77.64	77.32	74.03	83.15	
1998	69.16	63.29	53.32	50.00	50.00	52.85	53.20	55.30	57.13	64.11	66.91	73.08	59.03	
1999	71.94	68.64	64.27	59.04	60.13	69.01	73.28	82.52	89.02	91.38	95.00	95.00	76.60	
MOY.	83.38	80.53	76.25	72.59	71.27	71.90	72.56	74.66	77.30	81.10	84.24	85.22	77.58	
EC-T	9.11	10.33	12.28	13.16	13.60	13.23	12.90	12.15	11.41	9.92	8.85	8.47	10.46	
C.VR	.11	.13	.16	.18	.19	.18	.18	.16	.15	.12	.11	.10	.13	

COYNE ET BELLIER - BUREAU D INGENIEURS CONSEILS - PARIS - FRANCE

CALCUL EFFECTUE PAR LE PROGRAMME S I M - REV 2.10 2002/10/15 10H16M55

Simulation TOABRE

-----> SURFACE TOABRE RESERVOIR SURFACE (KM²)

ANNEE	J	F	M	A	M	J	J	A	S	O	N	D	MOY	CUM
1948	21.41	19.01	15.67	12.13	8.14	5.70	6.25	8.19	9.10	10.73	17.97	17.82	12.68	
1949	15.05	11.86	6.42	5.70	5.70	8.66	11.04	13.11	17.99	21.23	28.91	34.43	15.01	
1950	32.89	30.59	27.38	24.00	23.75	25.27	27.01	30.62	31.46	34.91	38.80	38.80	30.46	
1951	37.87	36.09	33.16	30.09	29.52	30.17	30.81	32.33	32.84	34.90	38.36	38.80	33.74	
1952	36.69	34.15	30.76	27.45	24.94	24.46	23.66	23.35	25.32	29.91	31.89	38.80	29.28	
1953	38.80	37.10	34.12	31.10	31.57	31.65	31.40	30.09	29.83	33.16	36.55	36.55	33.49	
1954	34.17	31.41	27.94	24.69	25.34	25.53	31.39	35.23	38.80	38.80	38.80	38.80	32.57	
1955	38.80	36.77	33.66	30.47	27.93	28.62	28.65	30.96	34.19	38.70	38.80	38.80	33.86	
1956	38.80	36.79	33.91	31.02	30.09	31.10	33.10	32.89	35.58	38.80	38.80	38.22	34.93	
1957	36.04	33.40	29.96	26.58	24.46	22.58	21.26	21.16	20.96	26.01	29.01	28.86	26.69	
1958	27.02	24.95	22.28	19.82	18.88	17.97	17.32	19.42	21.68	23.65	25.28	25.02	21.94	
1959	23.05	20.86	17.39	14.01	11.48	10.88	9.33	11.02	12.37	15.96	18.75	23.26	15.70	
1960	22.99	21.29	18.33	16.36	15.65	16.28	16.78	17.52	17.81	19.25	22.56	33.07	19.82	
1961	31.35	28.67	25.42	23.01	21.56	21.22	21.82	24.90	26.34	29.21	31.98	33.13	26.55	
1962	31.46	28.86	25.67	22.71	21.69	21.79	20.86	22.17	22.58	25.21	29.37	29.95	25.19	
1963	28.04	25.59	22.36	22.22	22.40	23.44	24.58	26.13	26.56	28.00	31.26	30.50	25.92	
1964	27.80	24.85	21.94	18.82	16.94	19.55	21.99	24.05	27.92	32.58	38.63	37.66	26.06	
1965	36.63	34.32	31.16	27.81	24.83	22.71	20.85	20.18	18.89	20.23	22.34	25.24	25.43	
1966	23.12	20.93	17.59	14.34	14.21	15.42	15.65	15.82	15.63	19.62	25.30	29.32	18.91	
1967	27.91	25.41	22.32	20.02	19.39	22.36	23.99	26.30	30.62	36.41	38.80	37.75	27.61	
1968	35.15	32.46	29.07	25.92	23.89	24.89	24.67	25.90	27.38	32.74	37.63	37.88	29.80	
1969	35.25	33.16	29.88	27.22	25.06	24.24	22.98	23.24	24.39	26.17	28.61	30.05	27.52	
1970	35.84	37.54	35.87	36.63	38.80	38.42	38.80	38.80	38.80	38.80	38.80	38.80	37.99	
1971	38.80	36.66	34.54	31.64	30.86	32.66	34.42	36.72	38.80	38.80	38.80	36.91	35.80	
1972	36.51	34.18	31.16	29.71	28.90	28.35	27.13	25.54	26.40	26.97	27.46	25.60	28.99	
1973	23.06	20.83	17.41	14.02	12.09	13.22	14.95	16.89	20.75	24.20	29.49	32.65	19.96	
1974	31.20	28.70	25.59	23.46	25.03	25.13	25.67	25.95	26.05	31.04	32.74	32.74	27.77	
1975	30.25	27.55	24.23	21.52	19.43	18.36	19.37	22.36	26.93	34.14	38.80	38.80	26.81	
1976	38.10	35.66	32.38	29.16	26.80	24.87	22.79	22.35	23.79	25.69	26.91	25.20	27.81	
1977	22.44	20.14	16.64	13.18	9.95	8.91	8.20	12.52	13.79	17.65	18.72	17.53	14.97	
1978	14.80	11.92	7.33	10.07	16.88	16.96	16.20	16.00	17.93	20.40	23.43	22.50	16.20	
1979	20.37	17.52	13.91	11.60	8.80	10.56	11.48	15.58	16.92	17.54	17.82	19.40	15.13	
1980	19.86	17.58	14.32	11.22	8.43	7.52	6.81	11.18	11.96	15.25	17.64	18.74	13.38	
1981	18.03	16.21	13.65	13.95	16.48	18.36	21.57	24.53	25.16	27.35	32.69	38.80	22.23	
1982	37.72	35.31	32.13	29.14	27.07	26.78	26.89	26.51	26.83	29.48	30.47	28.23	29.71	
1983	25.33	22.39	19.42	15.95	15.89	15.47	13.65	12.45	15.21	16.55	17.06	18.21	17.30	
1984	16.41	14.58	12.03	7.39	5.70	6.62	10.60	14.31	17.59	21.27	23.40	22.26	14.35	
1985	20.49	17.86	14.56	11.03	6.18	9.03	8.87	10.87	12.00	13.68	17.05	18.30	13.33	
1986	16.23	13.52	9.56	7.47	6.28	7.57	9.60	10.89	12.16	19.30	24.89	23.67	13.43	
1987	21.63	18.90	15.35	13.16	11.28	8.39	6.70	6.12	6.57	14.69	16.33	15.70	12.90	
1988	13.07	10.08	5.70	5.70	5.70	5.70	7.24	9.86	11.72	15.18	18.49	17.98	10.54	
1989	16.17	13.66	10.21	5.70	5.70	5.82	8.38	11.42	12.92	14.13	17.00	17.59	11.56	
1990	15.99	13.53	10.00	5.70	5.70	5.70	5.84	6.28	9.19	16.31	19.89	24.11	11.52	
1991	22.32	20.30	19.36	16.34	15.03	14.37	13.07	12.33	20.11	23.94	25.41	26.65	19.10	
1992	24.35	22.16	19.04	17.49	18.24	19.17	19.09	19.84	22.40	23.72	24.03	23.01	21.04	
1993	22.13	19.69	16.93	14.33	12.29	12.55	12.28	11.07	14.74	16.42	21.86	23.66	16.50	
1994	22.14	19.81	16.79	14.32	13.73	15.57	14.90	15.88	17.71	19.57	21.04	19.55	17.58	
1995	17.11	14.32	10.70	6.17	6.53	6.45	7.61	9.79	12.90	12.76	13.86	16.88	11.26	
1996	25.10	25.20	24.27	22.45	24.73	26.80	29.86	34.08	38.72	38.80	38.80	38.80	30.64	
1997	37.24	35.12	31.99	28.79	27.41	25.27	23.42	21.81	20.59	21.11	20.85	18.52	26.01	
1998	15.40	12.25	7.06	5.70	5.70	6.84	7.00	7.95	8.87	12.65	14.15	17.86	10.12	
1999	17.16	15.09	12.73	9.93	10.76	15.31	17.99	24.47	31.12	33.96	38.80	38.80	22.18	
MOY.	26.84	24.55	21.37	18.82	17.96	18.29	18.76	20.17	22.06	24.95	27.60	28.46	22.49	
EC-T	8.25	8.47	8.78	8.67	8.74	8.60	8.67	8.57	8.68	8.42	8.24	8.11	7.84	
C.VR	.31	.34	.41	.46	.49	.47	.46	.42	.39	.34	.30	.29	.35	

COYNE ET BELLIER - BUREAU D INGENIEURS CONSEILS - PARIS - FRANCE

CALCUL EFFECTUE PAR LE PROGRAMME S I M - REV 2.10 2002/10/15 10H16M55

Simulation TOABRE

-----> VOLUME TOABRE RESERVOIR VOLUME (HM3)

ANNEE	J	F	M	A	M	J	J	A	S	O	N	D	MOY	CUM
1948	428.18	361.97	273.91	182.73	107.43	68.00	76.28	108.25	123.33	148.63	334.26	330.61	211.97	
1949	257.87	176.34	78.83	68.00	68.00	115.77	155.52	207.28	334.98	423.43	652.80	800.37	278.27	
1950	758.40	696.24	609.67	518.11	510.54	552.78	599.71	697.07	719.59	813.58	918.00	918.00	692.64	
1951	892.66	845.36	765.40	683.72	668.98	685.78	701.70	744.31	757.20	813.48	905.95	918.00	781.88	
1952	861.36	792.36	700.52	611.54	543.14	530.27	507.76	498.59	554.13	679.24	732.05	918.00	660.75	
1953	918.00	872.01	791.45	708.96	722.76	724.93	717.63	683.86	677.09	765.48	857.66	857.47	774.77	
1954	792.97	718.10	624.94	536.29	554.81	560.17	717.42	822.15	918.00	918.00	918.00	918.00	749.90	
1955	918.00	863.31	778.48	693.19	624.71	644.78	645.61	705.54	793.55	915.42	918.00	918.00	784.88	
1956	918.00	863.81	785.68	707.09	683.68	709.13	763.90	758.60	831.58	918.00	918.00	902.17	813.30	
1957	844.00	771.46	680.49	588.22	530.20	476.89	424.26	421.71	416.38	573.42	655.55	651.52	586.17	
1958	599.92	543.40	463.52	384.80	358.25	334.30	316.49	373.29	436.89	507.42	553.07	545.57	451.41	
1959	489.78	413.82	318.27	229.97	166.73	151.97	127.55	155.15	188.58	281.66	354.76	495.76	281.17	
1960	488.15	425.20	343.60	292.30	273.28	290.26	302.86	322.14	330.27	368.42	476.50	762.96	389.66	
1961	716.23	646.21	557.14	488.70	433.09	423.35	441.34	542.01	581.92	660.93	734.53	764.62	582.50	
1962	719.48	651.46	564.26	480.52	436.97	440.14	413.77	455.20	477.05	550.98	665.02	680.26	544.59	
1963	627.96	561.94	468.89	458.77	471.85	501.28	533.40	576.57	587.77	626.87	713.69	694.02	568.59	
1964	621.06	540.57	444.90	356.78	306.79	376.98	446.57	519.34	624.57	750.77	913.25	886.94	565.71	
1965	859.62	797.13	710.66	621.19	540.23	480.46	413.44	394.87	358.66	396.50	467.77	551.75	549.36	
1966	491.94	415.67	323.91	238.22	234.22	267.18	273.33	277.86	272.82	378.98	553.46	663.75	365.94	
1967	624.11	556.61	465.98	390.36	372.34	469.42	517.78	581.03	697.12	853.81	918.00	889.57	611.35	
1968	820.15	747.68	657.11	571.05	514.74	541.69	535.80	570.67	609.77	754.67	886.25	893.00	675.22	
1969	822.76	765.49	678.34	605.28	546.54	524.39	487.96	495.17	528.41	577.72	644.55	682.85	613.29	
1970	838.73	883.70	839.50	859.70	918.00	907.55	918.00	918.00	918.00	918.00	918.00	918.00	896.27	
1971	918.00	860.41	803.40	724.80	703.07	752.69	800.05	862.10	918.00	918.00	918.00	867.07	837.13	
1972	856.43	793.25	710.80	673.92	652.73	637.09	602.80	560.57	583.67	598.68	611.90	562.16	653.67	
1973	490.02	413.05	318.91	230.01	181.77	210.36	255.28	305.59	410.93	523.27	668.11	752.45	396.65	
1974	711.96	647.06	561.98	501.84	545.69	548.63	564.25	571.87	574.46	707.57	754.67	754.71	620.39	
1975	687.71	614.19	524.14	431.91	373.69	344.28	371.80	468.88	597.53	792.04	918.00	918.00	586.85	
1976	898.86	833.83	745.63	659.55	594.08	541.16	482.77	468.27	511.63	564.75	596.88	550.68	620.68	
1977	473.17	393.87	299.49	209.30	137.65	119.96	108.33	192.08	225.19	325.76	354.05	322.25	263.42	
1978	251.44	177.63	93.02	139.29	305.31	307.09	287.93	282.58	333.34	401.19	500.75	474.86	296.20	
1979	400.34	322.12	227.82	170.05	117.98	146.10	166.67	271.44	306.30	322.76	330.55	372.70	262.90	
1980	385.80	323.63	237.62	159.45	112.12	96.42	85.50	158.50	178.73	262.71	325.52	354.38	223.37	
1981	335.95	288.25	222.18	228.51	295.36	344.51	433.33	532.09	549.51	608.72	753.34	918.00	459.15	
1982	888.66	824.37	739.10	659.02	601.35	593.56	596.37	586.34	594.92	667.83	693.13	633.61	673.19	
1983	554.49	471.22	373.41	281.20	279.83	268.53	222.18	190.43	261.65	297.11	309.61	340.60	320.85	
1984	293.63	245.37	180.28	93.82	68.00	82.07	146.60	237.44	323.93	424.68	500.14	461.95	254.83	
1985	403.75	331.63	244.79	155.21	75.16	122.18	119.35	151.72	179.66	222.64	309.26	342.96	221.53	
1986	288.67	218.63	131.35	95.41	76.77	97.39	131.98	152.28	183.42	369.89	541.77	507.99	232.96	
1987	435.25	358.91	265.27	208.59	161.23	111.45	83.49	74.28	81.30	248.80	291.41	274.55	216.21	
1988	206.14	139.49	68.00	68.00	68.00	68.00	91.78	136.39	172.94	260.92	347.83	334.54	163.50	
1989	287.29	222.36	141.26	68.00	68.00	69.87	111.36	164.91	202.44	232.52	308.03	324.03	183.34	
1990	282.42	218.91	138.32	68.00	68.00	68.00	70.08	76.64	124.95	290.84	386.84	521.06	192.84	
1991	465.97	398.48	371.58	291.78	257.26	239.19	206.17	187.51	393.02	516.26	556.71	590.09	372.83	
1992	527.23	454.26	362.67	321.27	341.20	366.19	363.96	385.22	472.12	509.64	518.69	488.76	425.93	
1993	452.49	380.91	306.38	237.79	186.59	192.90	186.28	156.09	250.12	293.89	442.48	507.69	299.47	
1994	452.64	384.46	303.02	237.53	223.83	271.26	254.12	279.52	327.38	377.53	418.50	376.96	325.56	
1995	310.75	237.73	147.96	75.01	80.59	79.23	98.25	135.18	201.84	198.21	226.53	305.13	174.70	
1996	547.79	550.75	525.24	473.40	537.42	594.03	678.05	790.53	915.89	918.00	918.00	918.00	697.26	
1997	875.76	819.31	734.86	649.78	610.47	552.70	500.53	440.76	406.62	420.36	413.62	348.49	564.44	
1998	266.58	185.52	89.27	68.00	68.00	85.97	88.42	104.42	119.21	195.40	232.82	331.50	152.93	
1999	312.06	258.64	197.49	137.43	149.43	264.21	334.95	530.48	709.60	786.98	918.00	918.00	459.77	
MOY.	587.90	524.58	442.13	376.80	356.31	364.47	374.63	409.28	458.62	535.62	609.12	633.35	472.73	
EC-T	230.39	236.36	237.51	228.70	227.20	224.31	228.91	232.34	238.10	235.37	230.16	226.46	212.98	
C.VR	.39	.45	.54	.61	.64	.62	.61	.57	.52	.44	.38	.36	.45	

COYNE ET BELLIER - BUREAU D INGENIEURS CONSEILS - PARIS - FRANCE

CALCUL EFFECTUE PAR LE PROGRAMME S I M - REV 2.10 2002/10/15 10H16M55

Simulation TOABRE

-----> EVAPOR. TOABRE EVAPORATION (HM3)

ANNEE	J	F	M	A	M	J	J	A	S	O	N	D	MOY	CUM
1948	2.36	1.95	2.00	.09	-1.66	-.66	-.34	-.24	.13	.05	.08	1.10	.40	4.8
1949	1.87	1.37	1.25	.04	-.78	-.46	-.51	-.42	.21	.09	.15	1.76	.38	4.5
1950	3.62	2.99	3.21	.16	-3.29	-1.92	-1.49	-1.03	.49	.16	.24	2.37	.46	5.5
1951	4.07	3.45	3.79	.20	-4.12	-2.39	-1.78	-1.17	.52	.16	.24	2.34	.44	5.3
1952	4.07	3.34	3.59	.18	-3.76	-2.02	-1.44	-.90	.37	.13	.21	1.95	.48	5.7
1953	4.07	3.53	3.90	.20	-4.26	-2.56	-1.87	-1.19	.48	.15	.23	2.23	.41	4.9
1954	3.84	3.11	3.30	.17	-3.38	-2.05	-1.51	-1.19	.56	.19	.27	2.37	.47	5.6
1955	4.07	3.53	3.86	.20	-4.17	-2.26	-1.69	-1.09	.50	.17	.27	2.37	.48	5.7
1956	4.07	3.53	3.86	.20	-4.25	-2.44	-1.84	-1.26	.53	.18	.27	2.37	.44	5.2
1957	4.01	3.28	3.51	.18	-3.64	-1.98	-1.33	-.81	.34	.10	.18	1.77	.47	5.6
1958	3.03	2.46	2.62	.13	-2.72	-1.53	-1.06	-.66	.31	.11	.17	1.54	.37	4.4
1959	2.63	2.10	2.19	.10	-1.92	-.93	-.64	-.35	.18	.06	.11	1.14	.39	4.6
1960	2.44	2.09	2.24	.11	-2.24	-1.27	-.96	-.64	.28	.09	.13	1.38	.30	3.6
1961	3.47	2.85	3.01	.15	-3.15	-1.75	-1.25	-.83	.40	.13	.20	1.95	.43	5.1
1962	3.48	2.86	3.03	.15	-3.11	-1.76	-1.29	-.79	.35	.11	.18	1.79	.42	5.0
1963	3.14	2.55	2.69	.13	-3.04	-1.81	-1.38	-.93	.42	.13	.20	1.91	.33	4.0
1964	3.20	2.53	2.61	.13	-2.58	-1.37	-1.15	-.84	.38	.14	.23	2.36	.47	5.6
1965	3.95	3.33	3.60	.19	-3.81	-2.01	-1.34	-.79	.32	.09	.14	1.36	.42	5.0
1966	2.65	2.10	2.20	.11	-1.96	-1.15	-.91	-.59	.25	.08	.14	1.54	.37	4.4
1967	3.08	2.54	2.67	.13	-2.74	-1.57	-1.32	-.91	.42	.15	.25	2.37	.42	5.0
1968	3.96	3.20	3.41	.17	-3.55	-1.94	-1.47	-.94	.41	.14	.23	2.30	.49	5.9
1969	3.98	3.21	3.48	.18	-3.73	-2.03	-1.43	-.87	.37	.12	.18	1.75	.43	5.2
1970	3.16	3.26	3.94	.22	-5.02	-3.14	-2.27	-1.47	.62	.19	.27	2.37	.18	2.1
1971	4.07	3.53	3.85	.21	-4.34	-2.50	-1.93	-1.31	.59	.19	.27	2.37	.42	5.0
1972	3.88	3.32	3.59	.19	-4.07	-2.34	-1.67	-1.03	.41	.13	.19	1.68	.36	4.2
1973	2.69	2.10	2.19	.10	-1.92	-.98	-.78	-.57	.27	.10	.17	1.80	.43	5.1
1974	3.43	2.84	3.01	.15	-3.21	-2.03	-1.48	-.98	.42	.13	.22	2.00	.37	4.4
1975	3.44	2.75	2.89	.15	-2.95	-1.57	-1.08	-.74	.36	.13	.24	2.37	.50	5.9
1976	4.07	3.47	3.74	.19	-4.00	-2.17	-1.47	-.87	.36	.12	.18	1.64	.44	5.2
1977	2.65	2.04	2.11	.10	-1.81	-.81	-.53	-.31	.20	.07	.12	1.14	.42	4.9
1978	1.84	1.35	1.25	.04	-1.38	-1.37	-1.00	-.62	.26	.09	.14	1.43	.17	2.0
1979	2.36	1.85	1.84	.08	-1.59	-.71	-.62	-.44	.25	.08	.12	1.09	.36	4.3
1980	2.04	1.81	1.85	.09	-1.54	-.68	-.44	-.26	.18	.06	.11	1.08	.36	4.2
1981	1.97	1.64	1.70	.08	-1.91	-1.33	-1.08	-.82	.39	.13	.19	1.99	.25	2.9
1982	4.07	3.43	3.71	.19	-3.99	-2.19	-1.58	-1.02	.42	.13	.21	1.86	.44	5.2
1983	2.96	2.31	2.35	.12	-2.18	-1.29	-.91	-.52	.20	.08	.12	1.04	.36	4.2
1984	1.91	1.49	1.53	.07	-1.01	-.46	-.39	-.40	.23	.09	.15	1.43	.39	4.6
1985	2.34	1.86	1.88	.09	-1.51	-.50	-.53	-.34	.17	.06	.10	1.04	.39	4.6
1986	1.92	1.48	1.42	.06	-1.02	-.51	-.45	-.36	.17	.06	.14	1.52	.37	4.4
1987	2.48	1.97	1.98	.09	-1.80	-.91	-.50	-.25	.10	.03	.10	1.00	.36	4.2
1988	1.65	1.19	1.06	.03	-.78	-.46	-.34	-.28	.16	.06	.11	1.13	.29	3.5
1989	1.89	1.47	1.43	.06	-.78	-.46	-.34	-.32	.18	.06	.10	1.04	.36	4.3
1990	1.85	1.46	1.42	.06	-.78	-.46	-.34	-.22	.10	.05	.11	1.21	.37	4.4
1991	2.53	2.03	2.13	.12	-2.24	-1.22	-.85	-.50	.20	.10	.17	1.55	.34	4.0
1992	2.80	2.22	2.33	.11	-2.40	-1.48	-1.13	-.73	.32	.11	.17	1.47	.32	3.7
1993	2.42	2.01	2.07	.10	-1.96	-1.00	-.74	-.47	.18	.07	.11	1.33	.34	4.1
1994	2.48	2.01	2.08	.10	-1.96	-1.11	-.92	-.57	.25	.09	.14	1.28	.32	3.8
1995	2.05	1.56	1.50	.06	-.84	-.53	-.38	-.29	.16	.06	.09	.85	.36	4.2
1996	1.77	2.28	2.65	.15	-3.08	-2.00	-1.58	-1.13	.55	.19	.27	2.37	.20	2.4
1997	4.07	3.39	3.69	.19	-3.94	-2.22	-1.49	-.89	.35	.10	.15	1.27	.39	4.6
1998	1.94	1.40	1.29	.04	-.78	-.46	-.40	-.27	.13	.04	.09	.86	.32	3.8
1999	1.88	1.56	1.58	.08	-1.36	-.87	-.90	-.68	.39	.16	.24	2.37	.37	4.4
MOY.	2.96	2.44	2.58	.13	-2.58	-1.45	-1.08	-.71	.32	.11	.17	1.68	.38	4.6
EC-T	.84	.75	.89	.05	1.19	.71	.51	.33	.14	.04	.06	.50	.07	.9
C.VR	.29	.31	.34	.41	.00	.00	.00	.00	.42	.39	.34	.30	.19	.2

COYNE ET BELLIER - BUREAU D INGENIEURS CONSEILS - PARIS - FRANCE

CALCUL EFFECTUE PAR LE PROGRAMME S I M - REV 2.10 2002/10/15 10H16M55

Simulation TOABRE

-----> DEVERSE TOABRE SPILLAGE (HM3)

ANNEE	J	F	M	A	M	J	J	A	S	O	N	D	MOY	CUM
1948	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1949	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1950	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	70.74	128.77	16.63	199.5
1951	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	10.45	.87	10.4
1952	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	15.04	1.25	15.0
1953	16.96	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	1.41	16.9
1954	.00	.00	.00	.00	.00	.00	.00	.00	4.10	98.04	201.84	35.57	28.30	339.5
1955	42.16	.00	.00	.00	.00	.00	.00	.00	.00	.00	211.96	54.87	25.75	309.0
1956	32.56	.00	.00	.00	.00	.00	.00	.00	.00	86.65	71.14	.00	15.86	190.3
1957	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1958	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1959	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1960	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1961	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1962	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1963	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1964	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1965	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1966	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1967	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.77	.00	.06	.7
1968	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1969	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1970	.00	.00	.00	.00	42.46	.00	19.26	86.81	120.59	83.54	140.94	294.87	65.71	788.4
1971	2.26	.00	.00	.00	.00	.00	.00	.00	19.32	90.24	21.64	.00	11.12	133.4
1972	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1973	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1974	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1975	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	152.31	182.57	27.91	334.8
1976	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1977	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1978	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1979	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1980	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1981	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	81.49	6.79	81.4
1982	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1983	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1984	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1985	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1986	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1987	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1988	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1989	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1990	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1991	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1992	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1993	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1994	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1995	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1996	.00	.00	.00	.00	.00	.00	.00	.00	.00	80.34	71.14	69.27	18.40	220.7
1997	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1998	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1999	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	9.65	260.27	22.49	269.9
MOY.	1.81	.00	.00	.00	.82	.00	.37	1.67	2.77	8.44	18.31	21.79	4.66	56.0
EC-T	7.62	.00	.00	.00	5.89	.00	2.67	12.04	16.88	26.20	49.90	61.99	11.69	140.3
C.VR	4.22	.00	.00	.00	7.21	.00	7.21	7.21	6.10	3.10	2.73	2.84	2.51	2.5

COYNE ET BELLIER - BUREAU D INGENIEURS CONSEILS - PARIS - FRANCE

CALCUL EFFECTUE PAR LE PROGRAMME S I M - REV 2.10 2002/10/15 10H16M55

Simulation TOABRE

-----> &DEV_S SPILLAGE (M3/S)

ANNEE	J	F	M	A	M	J	J	A	S	O	N	D	MOY	CUM
1948	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1949	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1950	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	27.29	48.08	6.28	75.3
1951	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	3.90	.33	3.9
1952	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	5.62	.47	5.6
1953	6.33	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.53	6.3
1954	.00	.00	.00	.00	.00	.00	.00	.00	1.58	36.61	77.87	13.28	10.78	129.3
1955	15.74	.00	.00	.00	.00	.00	.00	.00	.00	.00	81.78	20.49	9.83	118.0
1956	12.16	.00	.00	.00	.00	.00	.00	.00	.00	32.35	27.45	.00	6.00	71.9
1957	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1958	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1959	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1960	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1961	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1962	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1963	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1964	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1965	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1966	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1967	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.30	.00	.02	.3
1968	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1969	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1970	.00	.00	.00	.00	15.85	.00	7.19	32.41	46.52	31.19	54.38	110.09	24.80	297.6
1971	.85	.00	.00	.00	.00	.00	.00	.00	7.45	33.69	8.35	.00	4.20	50.3
1972	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1973	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1974	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1975	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	58.76	68.16	10.58	126.9
1976	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1977	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1978	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1979	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1980	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1981	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	30.42	2.54	30.4
1982	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1983	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1984	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1985	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1986	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1987	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1988	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1989	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1990	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1991	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1992	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1993	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1994	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1995	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1996	.00	.00	.00	.00	.00	.00	.00	.00	.00	30.00	27.45	25.86	6.94	83.3
1997	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1998	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1999	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	3.72	97.17	8.41	100.9
MOY.	.67	.00	.00	.00	.30	.00	.14	.62	1.07	3.15	7.06	8.14	1.76	21.2
EC-T	2.85	.00	.00	.00	2.20	.00	1.00	4.49	6.51	9.78	19.25	23.14	4.42	53.1
C.VR	4.22	.00	.00	.00	7.21	.00	7.21	7.21	6.10	3.10	2.73	2.84	2.51	2.5

COYNE ET BELLIER - BUREAU D INGENIEURS CONSEILS - PARIS - FRANCE

CALCUL EFFECTUE PAR LE PROGRAMME S I M - REV 2.10 2002/10/15 10H16M55

Simulation TOABRE

-----> FOURNIT DEM3 FURNITURE ECOLOGICAL FLOW (HM3)

ANNEE	J	F	M	A	M	J	J	A	S	O	N	D	MOY	CUM
1948	10.71	9.68	10.71	10.37	10.71	10.37	10.71	10.71	10.37	10.71	10.37	10.71	10.51	126.1
1949	10.71	9.68	10.71	10.37	10.71	10.37	10.71	10.71	10.37	10.71	10.37	10.71	10.51	126.1
1950	10.71	9.68	10.71	10.37	10.71	10.37	10.71	10.71	10.37	10.71	10.37	10.71	10.51	126.1
1951	10.71	9.68	10.71	10.37	10.71	10.37	10.71	10.71	10.37	10.71	10.37	10.71	10.51	126.1
1952	10.71	9.68	10.71	10.37	10.71	10.37	10.71	10.71	10.37	10.71	10.37	10.71	10.51	126.1
1953	10.71	9.68	10.71	10.37	10.71	10.37	10.71	10.71	10.37	10.71	10.37	10.71	10.51	126.1
1954	10.71	9.68	10.71	10.37	10.71	10.37	10.71	10.71	10.37	10.71	10.37	10.71	10.51	126.1
1955	10.71	9.68	10.71	10.37	10.71	10.37	10.71	10.71	10.37	10.71	10.37	10.71	10.51	126.1
1956	10.71	9.68	10.71	10.37	10.71	10.37	10.71	10.71	10.37	10.71	10.37	10.71	10.51	126.1
1957	10.71	9.68	10.71	10.37	10.71	10.37	10.71	10.71	10.37	10.71	10.37	10.71	10.51	126.1
1958	10.71	9.68	10.71	10.37	10.71	10.37	10.71	10.71	10.37	10.71	10.37	10.71	10.51	126.1
1959	10.71	9.68	10.71	10.37	10.71	10.37	10.71	10.71	10.37	10.71	10.37	10.71	10.51	126.1
1960	10.71	9.68	10.71	10.37	10.71	10.37	10.71	10.71	10.37	10.71	10.37	10.71	10.51	126.1
1961	10.71	9.68	10.71	10.37	10.71	10.37	10.71	10.71	10.37	10.71	10.37	10.71	10.51	126.1
1962	10.71	9.68	10.71	10.37	10.71	10.37	10.71	10.71	10.37	10.71	10.37	10.71	10.51	126.1
1963	10.71	9.68	10.71	10.37	10.71	10.37	10.71	10.71	10.37	10.71	10.37	10.71	10.51	126.1
1964	10.71	9.68	10.71	10.37	10.71	10.37	10.71	10.71	10.37	10.71	10.37	10.71	10.51	126.1
1965	10.71	9.68	10.71	10.37	10.71	10.37	10.71	10.71	10.37	10.71	10.37	10.71	10.51	126.1
1966	10.71	9.68	10.71	10.37	10.71	10.37	10.71	10.71	10.37	10.71	10.37	10.71	10.51	126.1
1967	10.71	9.68	10.71	10.37	10.71	10.37	10.71	10.71	10.37	10.71	10.37	10.71	10.51	126.1
1968	10.71	9.68	10.71	10.37	10.71	10.37	10.71	10.71	10.37	10.71	10.37	10.71	10.51	126.1
1969	10.71	9.68	10.71	10.37	10.71	10.37	10.71	10.71	10.37	10.71	10.37	10.71	10.51	126.1
1970	10.71	9.68	10.71	10.37	10.71	10.37	10.71	10.71	10.37	10.71	10.37	10.71	10.51	126.1
1971	10.71	9.68	10.71	10.37	10.71	10.37	10.71	10.71	10.37	10.71	10.37	10.71	10.51	126.1
1972	10.71	9.68	10.71	10.37	10.71	10.37	10.71	10.71	10.37	10.71	10.37	10.71	10.51	126.1
1973	10.71	9.68	10.71	10.37	10.71	10.37	10.71	10.71	10.37	10.71	10.37	10.71	10.51	126.1
1974	10.71	9.68	10.71	10.37	10.71	10.37	10.71	10.71	10.37	10.71	10.37	10.71	10.51	126.1
1975	10.71	9.68	10.71	10.37	10.71	10.37	10.71	10.71	10.37	10.71	10.37	10.71	10.51	126.1
1976	10.71	9.68	10.71	10.37	10.71	10.37	10.71	10.71	10.37	10.71	10.37	10.71	10.51	126.1
1977	10.71	9.68	10.71	10.37	10.71	10.37	10.71	10.71	10.37	10.71	10.37	10.71	10.51	126.1
1978	10.71	9.68	10.71	10.37	10.71	10.37	10.71	10.71	10.37	10.71	10.37	10.71	10.51	126.1
1979	10.71	9.68	10.71	10.37	10.71	10.37	10.71	10.71	10.37	10.71	10.37	10.71	10.51	126.1
1980	10.71	9.68	10.71	10.37	10.71	10.37	10.71	10.71	10.37	10.71	10.37	10.71	10.51	126.1
1981	10.71	9.68	10.71	10.37	10.71	10.37	10.71	10.71	10.37	10.71	10.37	10.71	10.51	126.1
1982	10.71	9.68	10.71	10.37	10.71	10.37	10.71	10.71	10.37	10.71	10.37	10.71	10.51	126.1
1983	10.71	9.68	10.71	10.37	10.71	10.37	10.71	10.71	10.37	10.71	10.37	10.71	10.51	126.1
1984	10.71	9.68	10.71	10.37	10.71	10.37	10.71	10.71	10.37	10.71	10.37	10.71	10.51	126.1
1985	10.71	9.68	10.71	10.37	10.71	10.37	10.71	10.71	10.37	10.71	10.37	10.71	10.51	126.1
1986	10.71	9.68	10.71	10.37	10.71	10.37	10.71	10.71	10.37	10.71	10.37	10.71	10.51	126.1
1987	10.71	9.68	10.71	10.37	10.71	10.37	10.71	10.71	10.37	10.71	10.37	10.71	10.51	126.1
1988	10.71	9.68	10.71	9.27	10.71	10.37	10.71	10.71	10.37	10.71	10.37	10.71	10.42	125.0
1989	10.71	9.68	10.71	10.37	10.71	10.37	10.71	10.71	10.37	10.71	10.37	10.71	10.51	126.1
1990	10.71	9.68	10.71	10.37	10.71	10.37	10.71	10.71	10.37	10.71	10.37	10.71	10.51	126.1
1991	10.71	9.68	10.71	10.37	10.71	10.37	10.71	10.71	10.37	10.71	10.37	10.71	10.51	126.1
1992	10.71	9.68	10.71	10.37	10.71	10.37	10.71	10.71	10.37	10.71	10.37	10.71	10.51	126.1
1993	10.71	9.68	10.71	10.37	10.71	10.37	10.71	10.71	10.37	10.71	10.37	10.71	10.51	126.1
1994	10.71	9.68	10.71	10.37	10.71	10.37	10.71	10.71	10.37	10.71	10.37	10.71	10.51	126.1
1995	10.71	9.68	10.71	10.37	10.71	10.37	10.71	10.71	10.37	10.71	10.37	10.71	10.51	126.1
1996	10.71	9.68	10.71	10.37	10.71	10.37	10.71	10.71	10.37	10.71	10.37	10.71	10.51	126.1
1997	10.71	9.68	10.71	10.37	10.71	10.37	10.71	10.71	10.37	10.71	10.37	10.71	10.51	126.1
1998	10.71	9.68	10.71	10.37	10.71	10.37	10.71	10.71	10.37	10.71	10.37	10.71	10.51	126.1
1999	10.71	9.68	10.71	10.37	10.71	10.37	10.71	10.71	10.37	10.71	10.37	10.71	10.51	126.1
MOY.	10.71	9.68	10.71	10.35	10.71	10.37	10.71	10.71	10.37	10.71	10.37	10.71	10.51	126.1
EC-T	.00	.00	.00	.15	.00	.00	.00	.00	.00	.00	.00	.00	.01	.2
C.VR	.00	.00	.00	.01	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0

COYNE ET BELLIER - BUREAU D INGENIEURS CONSEILS - PARIS - FRANCE

CALCUL EFFECTUE PAR LE PROGRAMME S I M - REV 2.10 2002/10/15 10H16M55

Simulation TOABRE

-----> &VR3_S FURNITURE ECOLOGICAL FLOW (M3/S)

ANNEE	J	F	M	A	M	J	J	A	S	O	N	D	MOY	CUM
1948	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	48.0
1949	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	48.0
1950	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	48.0
1951	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	48.0
1952	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	48.0
1953	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	48.0
1954	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	48.0
1955	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	48.0
1956	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	48.0
1957	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	48.0
1958	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	48.0
1959	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	48.0
1960	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	48.0
1961	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	48.0
1962	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	48.0
1963	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	48.0
1964	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	48.0
1965	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	48.0
1966	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	48.0
1967	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	48.0
1968	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	48.0
1969	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	48.0
1970	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	48.0
1971	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	48.0
1972	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	48.0
1973	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	48.0
1974	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	48.0
1975	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	48.0
1976	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	48.0
1977	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	48.0
1978	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	48.0
1979	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	48.0
1980	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	48.0
1981	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	48.0
1982	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	48.0
1983	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	48.0
1984	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	48.0
1985	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	48.0
1986	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	48.0
1987	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	48.0
1988	4.00	4.00	4.00	3.57	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	3.96	47.5
1989	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	48.0
1990	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	48.0
1991	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	48.0
1992	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	48.0
1993	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	48.0
1994	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	48.0
1995	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	48.0
1996	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	48.0
1997	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	48.0
1998	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	48.0
1999	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	48.0
MOY.	4.00	4.00	4.00	3.99	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	48.0
EC-T	.00	.00	.00	.06	.00	.00	.00	.00	.00	.00	.00	.00	.00	.1
C.VR	.00	.00	.00	.01	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0

COYNE ET BELLIER - BUREAU D INGENIEURS CONSEILS - PARIS - FRANCE

CALCUL EFFECTUE PAR LE PROGRAMME S I M - REV 2.10 2002/10/15 10H16M55

Simulation TOABRE

-----> DEFICIT DEM3 DEFICIT ECOLOGICAL FLOW (HM3)

ANNEE	J	F	M	A	M	J	J	A	S	O	N	D	MOY	CUM
1948	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1949	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1950	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1951	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1952	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1953	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1954	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1955	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1956	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1957	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1958	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1959	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1960	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1961	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1962	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1963	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1964	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1965	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1966	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1967	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1968	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1969	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1970	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1971	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1972	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1973	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1974	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1975	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1976	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1977	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1978	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1979	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1980	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1981	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1982	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1983	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1984	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1985	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1986	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1987	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1988	.00	.00	.00	1.10	.00	.00	.00	.00	.00	.00	.00	.00	.09	1.1
1989	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1990	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1991	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1992	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1993	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1994	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1995	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1996	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1997	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1998	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1999	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
MOY.	.00	.00	.00	.02	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
EC-T	.00	.00	.00	.15	.00	.00	.00	.00	.00	.00	.00	.00	.01	.2
C.VR	.00	.00	.00	7.21	.00	.00	.00	.00	.00	.00	.00	.00	7.21	7.2

COYNE ET BELLIER - BUREAU D INGENIEURS CONSEILS - PARIS - FRANCE

CALCUL EFFECTUE PAR LE PROGRAMME S I M - REV 2.10 2002/10/15 10H16M55

Simulation TOABRE

-----> DEMANDE DEM4 DEMAND REGULATED FLOW (HM3)

ANNEE	J	F	M	A	M	J	J	A	S	O	N	D	MOY	CUM
1948	93.85	84.79	93.85	90.82	93.85	90.82	93.85	93.85	90.82	93.85	90.82	93.85	92.08	1105.0
1949	93.85	84.79	93.85	90.82	93.85	90.82	93.85	93.85	90.82	93.85	90.82	93.85	92.08	1105.0
1950	93.85	84.79	93.85	90.82	93.85	90.82	93.85	93.85	90.82	93.85	90.82	93.85	92.08	1105.0
1951	93.85	84.79	93.85	90.82	93.85	90.82	93.85	93.85	90.82	93.85	90.82	93.85	92.08	1105.0
1952	93.85	84.79	93.85	90.82	93.85	90.82	93.85	93.85	90.82	93.85	90.82	93.85	92.08	1105.0
1953	93.85	84.79	93.85	90.82	93.85	90.82	93.85	93.85	90.82	93.85	90.82	93.85	92.08	1105.0
1954	93.85	84.79	93.85	90.82	93.85	90.82	93.85	93.85	90.82	93.85	90.82	93.85	92.08	1105.0
1955	93.85	84.79	93.85	90.82	93.85	90.82	93.85	93.85	90.82	93.85	90.82	93.85	92.08	1105.0
1956	93.85	84.79	93.85	90.82	93.85	90.82	93.85	93.85	90.82	93.85	90.82	93.85	92.08	1105.0
1957	93.85	84.79	93.85	90.82	93.85	90.82	93.85	93.85	90.82	93.85	90.82	93.85	92.08	1105.0
1958	93.85	84.79	93.85	90.82	93.85	90.82	93.85	93.85	90.82	93.85	90.82	93.85	92.08	1105.0
1959	93.85	84.79	93.85	90.82	93.85	90.82	93.85	93.85	90.82	93.85	90.82	93.85	92.08	1105.0
1960	93.85	84.79	93.85	90.82	93.85	90.82	93.85	93.85	90.82	93.85	90.82	93.85	92.08	1105.0
1961	93.85	84.79	93.85	90.82	93.85	90.82	93.85	93.85	90.82	93.85	90.82	93.85	92.08	1105.0
1962	93.85	84.79	93.85	90.82	93.85	90.82	93.85	93.85	90.82	93.85	90.82	93.85	92.08	1105.0
1963	93.85	84.79	93.85	90.82	93.85	90.82	93.85	93.85	90.82	93.85	90.82	93.85	92.08	1105.0
1964	93.85	84.79	93.85	90.82	93.85	90.82	93.85	93.85	90.82	93.85	90.82	93.85	92.08	1105.0
1965	93.85	84.79	93.85	90.82	93.85	90.82	93.85	93.85	90.82	93.85	90.82	93.85	92.08	1105.0
1966	93.85	84.79	93.85	90.82	93.85	90.82	93.85	93.85	90.82	93.85	90.82	93.85	92.08	1105.0
1967	93.85	84.79	93.85	90.82	93.85	90.82	93.85	93.85	90.82	93.85	90.82	93.85	92.08	1105.0
1968	93.85	84.79	93.85	90.82	93.85	90.82	93.85	93.85	90.82	93.85	90.82	93.85	92.08	1105.0
1969	93.85	84.79	93.85	90.82	93.85	90.82	93.85	93.85	90.82	93.85	90.82	93.85	92.08	1105.0
1970	93.85	84.79	93.85	90.82	93.85	90.82	93.85	93.85	90.82	93.85	90.82	93.85	92.08	1105.0
1971	93.85	84.79	93.85	90.82	93.85	90.82	93.85	93.85	90.82	93.85	90.82	93.85	92.08	1105.0
1972	93.85	84.79	93.85	90.82	93.85	90.82	93.85	93.85	90.82	93.85	90.82	93.85	92.08	1105.0
1973	93.85	84.79	93.85	90.82	93.85	90.82	93.85	93.85	90.82	93.85	90.82	93.85	92.08	1105.0
1974	93.85	84.79	93.85	90.82	93.85	90.82	93.85	93.85	90.82	93.85	90.82	93.85	92.08	1105.0
1975	93.85	84.79	93.85	90.82	93.85	90.82	93.85	93.85	90.82	93.85	90.82	93.85	92.08	1105.0
1976	93.85	84.79	93.85	90.82	93.85	90.82	93.85	93.85	90.82	93.85	90.82	93.85	92.08	1105.0
1977	93.85	84.79	93.85	90.82	93.85	90.82	93.85	93.85	90.82	93.85	90.82	93.85	92.08	1105.0
1978	93.85	84.79	93.85	90.82	93.85	90.82	93.85	93.85	90.82	93.85	90.82	93.85	92.08	1105.0
1979	93.85	84.79	93.85	90.82	93.85	90.82	93.85	93.85	90.82	93.85	90.82	93.85	92.08	1105.0
1980	93.85	84.79	93.85	90.82	93.85	90.82	93.85	93.85	90.82	93.85	90.82	93.85	92.08	1105.0
1981	93.85	84.79	93.85	90.82	93.85	90.82	93.85	93.85	90.82	93.85	90.82	93.85	92.08	1105.0
1982	93.85	84.79	93.85	90.82	93.85	90.82	93.85	93.85	90.82	93.85	90.82	93.85	92.08	1105.0
1983	93.85	84.79	93.85	90.82	93.85	90.82	93.85	93.85	90.82	93.85	90.82	93.85	92.08	1105.0
1984	93.85	84.79	93.85	90.82	93.85	90.82	93.85	93.85	90.82	93.85	90.82	93.85	92.08	1105.0
1985	93.85	84.79	93.85	90.82	93.85	90.82	93.85	93.85	90.82	93.85	90.82	93.85	92.08	1105.0
1986	93.85	84.79	93.85	90.82	93.85	90.82	93.85	93.85	90.82	93.85	90.82	93.85	92.08	1105.0
1987	93.85	84.79	93.85	90.82	93.85	90.82	93.85	93.85	90.82	93.85	90.82	93.85	92.08	1105.0
1988	93.85	84.79	93.85	90.82	93.85	90.82	93.85	93.85	90.82	93.85	90.82	93.85	92.08	1105.0
1989	93.85	84.79	93.85	90.82	93.85	90.82	93.85	93.85	90.82	93.85	90.82	93.85	92.08	1105.0
1990	93.85	84.79	93.85	90.82	93.85	90.82	93.85	93.85	90.82	93.85	90.82	93.85	92.08	1105.0
1991	93.85	84.79	93.85	90.82	93.85	90.82	93.85	93.85	90.82	93.85	90.82	93.85	92.08	1105.0
1992	93.85	84.79	93.85	90.82	93.85	90.82	93.85	93.85	90.82	93.85	90.82	93.85	92.08	1105.0
1993	93.85	84.79	93.85	90.82	93.85	90.82	93.85	93.85	90.82	93.85	90.82	93.85	92.08	1105.0
1994	93.85	84.79	93.85	90.82	93.85	90.82	93.85	93.85	90.82	93.85	90.82	93.85	92.08	1105.0
1995	93.85	84.79	93.85	90.82	93.85	90.82	93.85	93.85	90.82	93.85	90.82	93.85	92.08	1105.0
1996	93.85	84.79	93.85	90.82	93.85	90.82	93.85	93.85	90.82	93.85	90.82	93.85	92.08	1105.0
1997	93.85	84.79	93.85	90.82	93.85	90.82	93.85	93.85	90.82	93.85	90.82	93.85	92.08	1105.0
1998	93.85	84.79	93.85	90.82	93.85	90.82	93.85	93.85	90.82	93.85	90.82	93.85	92.08	1105.0
1999	93.85	84.79	93.85	90.82	93.85	90.82	93.85	93.85	90.82	93.85	90.82	93.85	92.08	1105.0
MOY.	93.85	84.79	93.85	90.82	93.85	90.82	93.85	93.85	90.82	93.85	90.82	93.85	92.08	1105.0
EC-T	.02	.00	.02	.01	.02	.01	.02	.02	.01	.02	.01	.02	.00	.0
C.VR	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0

COYNE ET BELLIER - BUREAU D INGENIEURS CONSEILS - PARIS - FRANCE

CALCUL EFFECTUE PAR LE PROGRAMME S I M - REV 2.10 2002/10/15 10H16M55

Simulation TOABRE

-----> FOURNIT DEM4 FURNITURE REGULATED FLOW (HM3)

ANNEE	J	F	M	A	M	J	J	A	S	O	N	D	MOY	CUM
1948	93.85	84.79	93.85	90.82	93.85	65.02	93.85	93.85	90.82	93.85	90.82	93.85	89.93	1079.2
1949	93.85	84.79	93.85	8.43	17.37	90.82	93.85	93.85	90.82	93.85	90.82	93.85	78.84	946.1
1950	93.85	84.79	93.85	90.82	93.85	90.82	93.85	93.85	90.82	93.85	90.82	93.85	92.08	1105.0
1951	93.85	84.79	93.85	90.82	93.85	90.82	93.85	93.85	90.82	93.85	90.82	93.85	92.08	1105.0
1952	93.85	84.79	93.85	90.82	93.85	90.82	93.85	93.85	90.82	93.85	90.82	93.85	92.08	1105.0
1953	93.85	84.79	93.85	90.82	93.85	90.82	93.85	93.85	90.82	93.85	90.82	93.85	92.08	1105.0
1954	93.85	84.79	93.85	90.82	93.85	90.82	93.85	93.85	90.82	93.85	90.82	93.85	92.08	1105.0
1955	93.85	84.79	93.85	90.82	93.85	90.82	93.85	93.85	90.82	93.85	90.82	93.85	92.08	1105.0
1956	93.85	84.79	93.85	90.82	93.85	90.82	93.85	93.85	90.82	93.85	90.82	93.85	92.08	1105.0
1957	93.85	84.79	93.85	90.82	93.85	90.82	93.85	93.85	90.82	93.85	90.82	93.85	92.08	1105.0
1958	93.85	84.79	93.85	90.82	93.85	90.82	93.85	93.85	90.82	93.85	90.82	93.85	92.08	1105.0
1959	93.85	84.79	93.85	90.82	93.85	90.82	93.85	93.85	90.82	93.85	90.82	93.85	92.08	1105.0
1960	93.85	84.79	93.85	90.82	93.85	90.82	93.85	93.85	90.82	93.85	90.82	93.85	92.08	1105.0
1961	93.85	84.79	93.85	90.82	93.85	90.82	93.85	93.85	90.82	93.85	90.82	93.85	92.08	1105.0
1962	93.85	84.79	93.85	90.82	93.85	90.82	93.85	93.85	90.82	93.85	90.82	93.85	92.08	1105.0
1963	93.85	84.79	93.85	90.82	93.85	90.82	93.85	93.85	90.82	93.85	90.82	93.85	92.08	1105.0
1964	93.85	84.79	93.85	90.82	93.85	90.82	93.85	93.85	90.82	93.85	90.82	93.85	92.08	1105.0
1965	93.85	84.79	93.85	90.82	93.85	90.82	93.85	93.85	90.82	93.85	90.82	93.85	92.08	1105.0
1966	93.85	84.79	93.85	90.82	93.85	90.82	93.85	93.85	90.82	93.85	90.82	93.85	92.08	1105.0
1967	93.85	84.79	93.85	90.82	93.85	90.82	93.85	93.85	90.82	93.85	90.82	93.85	92.08	1105.0
1968	93.85	84.79	93.85	90.82	93.85	90.82	93.85	93.85	90.82	93.85	90.82	93.85	92.08	1105.0
1969	93.85	84.79	93.85	90.82	93.85	90.82	93.85	93.85	90.82	93.85	90.82	93.85	92.08	1105.0
1970	93.85	84.79	93.85	90.82	93.85	90.82	93.85	93.85	90.82	93.85	90.82	93.85	92.08	1105.0
1971	93.85	84.79	93.85	90.82	93.85	90.82	93.85	93.85	90.82	93.85	90.82	93.85	92.08	1105.0
1972	93.85	84.79	93.85	90.82	93.85	90.82	93.85	93.85	90.82	93.85	90.82	93.85	92.08	1105.0
1973	93.85	84.79	93.85	90.82	93.85	90.82	93.85	93.85	90.82	93.85	90.82	93.85	92.08	1105.0
1974	93.85	84.79	93.85	90.82	93.85	90.82	93.85	93.85	90.82	93.85	90.82	93.85	92.08	1105.0
1975	93.85	84.79	93.85	90.82	93.85	90.82	93.85	93.85	90.82	93.85	90.82	93.85	92.08	1105.0
1976	93.85	84.79	93.85	90.82	93.85	90.82	93.85	93.85	90.82	93.85	90.82	93.85	92.08	1105.0
1977	93.85	84.79	93.85	90.82	93.85	90.82	93.85	93.85	90.82	93.85	90.82	93.85	92.08	1105.0
1978	93.85	84.79	93.85	90.82	93.85	90.82	93.85	93.85	90.82	93.85	90.82	93.85	92.08	1105.0
1979	93.85	84.79	93.85	90.82	93.85	90.82	93.85	93.85	90.82	93.85	90.82	93.85	92.08	1105.0
1980	93.85	84.79	93.85	90.82	93.85	90.82	93.85	93.85	90.82	93.85	90.82	93.85	92.08	1105.0
1981	93.85	84.79	93.85	90.82	93.85	90.82	93.85	93.85	90.82	93.85	90.82	93.85	92.08	1105.0
1982	93.85	84.79	93.85	90.82	93.85	90.82	93.85	93.85	90.82	93.85	90.82	93.85	92.08	1105.0
1983	93.85	84.79	93.85	90.82	93.85	90.82	93.85	93.85	90.82	93.85	90.82	93.85	92.08	1105.0
1984	93.85	84.79	93.85	90.82	68.32	90.82	93.85	93.85	90.82	93.85	90.82	93.85	89.96	1079.4
1985	93.85	84.79	93.85	90.82	93.85	90.82	93.85	93.85	90.82	93.85	90.82	93.85	92.08	1105.0
1986	93.85	84.79	93.85	90.82	93.85	90.82	93.85	93.85	90.82	93.85	90.82	93.85	92.08	1105.0
1987	93.85	84.79	93.85	90.82	93.85	90.82	93.85	93.85	90.82	93.85	90.82	93.85	92.08	1105.0
1988	93.85	84.79	72.02	.00	72.27	68.09	93.85	93.85	90.82	93.85	90.82	93.85	79.00	948.0
1989	93.85	84.79	93.85	79.43	67.77	90.82	93.85	93.85	90.82	93.85	90.82	93.85	88.96	1067.5
1990	93.85	84.79	93.85	79.10	48.97	49.99	93.85	93.85	90.82	93.85	90.82	93.85	83.96	1007.5
1991	93.85	84.79	93.85	90.82	93.85	90.82	93.85	93.85	90.82	93.85	90.82	93.85	92.08	1105.0
1992	93.85	84.79	93.85	90.82	93.85	90.82	93.85	93.85	90.82	93.85	90.82	93.85	92.08	1105.0
1993	93.85	84.79	93.85	90.82	93.85	90.82	93.85	93.85	90.82	93.85	90.82	93.85	92.08	1105.0
1994	93.85	84.79	93.85	90.82	93.85	90.82	93.85	93.85	90.82	93.85	90.82	93.85	92.08	1105.0
1995	93.85	84.79	93.85	90.82	93.85	90.82	93.85	93.85	90.82	93.85	90.82	93.85	92.08	1105.0
1996	93.85	84.79	93.85	90.82	93.85	90.82	93.85	93.85	90.82	93.85	90.82	93.85	92.08	1105.0
1997	93.85	84.79	93.85	90.82	93.85	90.82	93.85	93.85	90.82	93.85	90.82	93.85	92.08	1105.0
1998	93.85	84.79	93.85	61.36	44.47	90.82	93.85	93.85	90.82	93.85	90.82	93.85	85.51	1026.1
1999	93.85	84.79	93.85	90.82	93.85	90.82	93.85	93.85	90.82	93.85	90.82	93.85	92.08	1105.0
MOY.	93.85	84.79	93.43	86.48	89.16	89.10	93.85	93.85	90.82	93.85	90.82	93.85	91.15	1093.8
EC-T	.02	.00	3.03	17.26	14.66	7.27	.02	.02	.01	.02	.01	.02	2.90	34.8
C.VR	.00	.00	.03	.20	.16	.08	.00	.00	.00	.00	.00	.00	.03	.0

COYNE ET BELLIER - BUREAU D INGENIEURS CONSEILS - PARIS - FRANCE

CALCUL EFFECTUE PAR LE PROGRAMME S I M - REV 2.10 2002/10/15 10H16M55

Simulation TOABRE

-----> &VR_S FURNITURE REGULATED FLOW (M3/S)

ANNEE	J	F	M	A	M	J	J	A	S	O	N	D	MOY	CUM
1948	35.04	35.05	35.04	35.04	35.04	25.09	35.04	35.04	35.04	35.04	35.04	35.04	34.21	410.5
1949	35.04	35.05	35.04	3.25	6.48	35.04	35.04	35.04	35.04	35.04	35.04	35.04	30.01	360.1
1950	35.04	35.05	35.04	35.04	35.04	35.04	35.04	35.04	35.04	35.04	35.04	35.04	35.04	420.4
1951	35.04	35.05	35.04	35.04	35.04	35.04	35.04	35.04	35.04	35.04	35.04	35.04	35.04	420.4
1952	35.04	35.05	35.04	35.04	35.04	35.04	35.04	35.04	35.04	35.04	35.04	35.04	35.04	420.4
1953	35.04	35.05	35.04	35.04	35.04	35.04	35.04	35.04	35.04	35.04	35.04	35.04	35.04	420.4
1954	35.04	35.05	35.04	35.04	35.04	35.04	35.04	35.04	35.04	35.04	35.04	35.04	35.04	420.4
1955	35.04	35.05	35.04	35.04	35.04	35.04	35.04	35.04	35.04	35.04	35.04	35.04	35.04	420.4
1956	35.04	35.05	35.04	35.04	35.04	35.04	35.04	35.04	35.04	35.04	35.04	35.04	35.04	420.4
1957	35.04	35.05	35.04	35.04	35.04	35.04	35.04	35.04	35.04	35.04	35.04	35.04	35.04	420.4
1958	35.04	35.05	35.04	35.04	35.04	35.04	35.04	35.04	35.04	35.04	35.04	35.04	35.04	420.4
1959	35.04	35.05	35.04	35.04	35.04	35.04	35.04	35.04	35.04	35.04	35.04	35.04	35.04	420.4
1960	35.04	35.05	35.04	35.04	35.04	35.04	35.04	35.04	35.04	35.04	35.04	35.04	35.04	420.4
1961	35.04	35.05	35.04	35.04	35.04	35.04	35.04	35.04	35.04	35.04	35.04	35.04	35.04	420.4
1962	35.04	35.05	35.04	35.04	35.04	35.04	35.04	35.04	35.04	35.04	35.04	35.04	35.04	420.4
1963	35.04	35.05	35.04	35.04	35.04	35.04	35.04	35.04	35.04	35.04	35.04	35.04	35.04	420.4
1964	35.04	35.05	35.04	35.04	35.04	35.04	35.04	35.04	35.04	35.04	35.04	35.04	35.04	420.4
1965	35.04	35.05	35.04	35.04	35.04	35.04	35.04	35.04	35.04	35.04	35.04	35.04	35.04	420.4
1966	35.04	35.05	35.04	35.04	35.04	35.04	35.04	35.04	35.04	35.04	35.04	35.04	35.04	420.4
1967	35.04	35.05	35.04	35.04	35.04	35.04	35.04	35.04	35.04	35.04	35.04	35.04	35.04	420.4
1968	35.04	35.05	35.04	35.04	35.04	35.04	35.04	35.04	35.04	35.04	35.04	35.04	35.04	420.4
1969	35.04	35.05	35.04	35.04	35.04	35.04	35.04	35.04	35.04	35.04	35.04	35.04	35.04	420.4
1970	35.04	35.05	35.04	35.04	35.04	35.04	35.04	35.04	35.04	35.04	35.04	35.04	35.04	420.4
1971	35.04	35.05	35.04	35.04	35.04	35.04	35.04	35.04	35.04	35.04	35.04	35.04	35.04	420.4
1972	35.04	35.05	35.04	35.04	35.04	35.04	35.04	35.04	35.04	35.04	35.04	35.04	35.04	420.4
1973	35.04	35.05	35.04	35.04	35.04	35.04	35.04	35.04	35.04	35.04	35.04	35.04	35.04	420.4
1974	35.04	35.05	35.04	35.04	35.04	35.04	35.04	35.04	35.04	35.04	35.04	35.04	35.04	420.4
1975	35.04	35.05	35.04	35.04	35.04	35.04	35.04	35.04	35.04	35.04	35.04	35.04	35.04	420.4
1976	35.04	35.05	35.04	35.04	35.04	35.04	35.04	35.04	35.04	35.04	35.04	35.04	35.04	420.4
1977	35.04	35.05	35.04	35.04	35.04	35.04	35.04	35.04	35.04	35.04	35.04	35.04	35.04	420.4
1978	35.04	35.05	35.04	35.04	35.04	35.04	35.04	35.04	35.04	35.04	35.04	35.04	35.04	420.4
1979	35.04	35.05	35.04	35.04	35.04	35.04	35.04	35.04	35.04	35.04	35.04	35.04	35.04	420.4
1980	35.04	35.05	35.04	35.04	35.04	35.04	35.04	35.04	35.04	35.04	35.04	35.04	35.04	420.4
1981	35.04	35.05	35.04	35.04	35.04	35.04	35.04	35.04	35.04	35.04	35.04	35.04	35.04	420.4
1982	35.04	35.05	35.04	35.04	35.04	35.04	35.04	35.04	35.04	35.04	35.04	35.04	35.04	420.4
1983	35.04	35.05	35.04	35.04	35.04	35.04	35.04	35.04	35.04	35.04	35.04	35.04	35.04	420.4
1984	35.04	35.05	35.04	35.04	25.51	35.04	35.04	35.04	35.04	35.04	35.04	35.04	34.25	410.9
1985	35.04	35.05	35.04	35.04	35.04	35.04	35.04	35.04	35.04	35.04	35.04	35.04	35.04	420.4
1986	35.04	35.05	35.04	35.04	35.04	35.04	35.04	35.04	35.04	35.04	35.04	35.04	35.04	420.4
1987	35.04	35.05	35.04	35.04	35.04	35.04	35.04	35.04	35.04	35.04	35.04	35.04	35.04	420.4
1988	35.04	35.05	26.89	.00	26.98	26.27	35.04	35.04	35.04	35.04	35.04	35.04	30.04	360.4
1989	35.04	35.05	35.04	30.64	25.30	35.04	35.04	35.04	35.04	35.04	35.04	35.04	33.86	406.3
1990	35.04	35.05	35.04	30.52	18.28	19.29	35.04	35.04	35.04	35.04	35.04	35.04	31.95	383.4
1991	35.04	35.05	35.04	35.04	35.04	35.04	35.04	35.04	35.04	35.04	35.04	35.04	35.04	420.4
1992	35.04	35.05	35.04	35.04	35.04	35.04	35.04	35.04	35.04	35.04	35.04	35.04	35.04	420.4
1993	35.04	35.05	35.04	35.04	35.04	35.04	35.04	35.04	35.04	35.04	35.04	35.04	35.04	420.4
1994	35.04	35.05	35.04	35.04	35.04	35.04	35.04	35.04	35.04	35.04	35.04	35.04	35.04	420.4
1995	35.04	35.05	35.04	35.04	35.04	35.04	35.04	35.04	35.04	35.04	35.04	35.04	35.04	420.4
1996	35.04	35.05	35.04	35.04	35.04	35.04	35.04	35.04	35.04	35.04	35.04	35.04	35.04	420.4
1997	35.04	35.05	35.04	35.04	35.04	35.04	35.04	35.04	35.04	35.04	35.04	35.04	35.04	420.4
1998	35.04	35.05	35.04	23.67	16.60	35.04	35.04	35.04	35.04	35.04	35.04	35.04	32.56	390.6
1999	35.04	35.05	35.04	35.04	35.04	35.04	35.04	35.04	35.04	35.04	35.04	35.04	35.04	420.4
MOY.	35.04	35.05	34.88	33.36	33.29	34.38	35.04	35.04	35.04	35.04	35.04	35.04	34.69	416.2
EC-T	.00	.01	1.13	6.66	5.47	2.80	.00	.00	.00	.00	.00	.00	1.10	13.3
C.VR	.00	.00	.03	.20	.16	.08	.00	.00	.00	.00	.00	.00	.03	.0

COYNE ET BELLIER - BUREAU D INGENIEURS CONSEILS - PARIS - FRANCE

CALCUL EFFECTUE PAR LE PROGRAMME S I M - REV 2.10 2002/10/15 10H16M55

Simulation TOABRE

-----> DEFICIT DEM4 DEFICIT REGULATED FLOW (HM3)

ANNEE	J	F	M	A	M	J	J	A	S	O	N	D	MOY	CUM
1948	.00	.00	.00	.00	.00	25.80	.00	.00	.00	.00	.00	.00	2.15	25.8
1949	.00	.00	.00	82.39	76.48	.00	.00	.00	.00	.00	.00	.00	13.24	158.8
1950	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1951	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1952	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1953	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1954	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1955	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1956	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1957	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1958	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1959	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1960	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1961	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1962	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1963	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1964	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1965	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1966	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1967	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1968	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1969	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1970	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1971	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1972	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1973	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1974	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1975	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1976	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1977	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1978	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1979	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1980	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1981	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1982	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1983	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1984	.00	.00	.00	.00	25.53	.00	.00	.00	.00	.00	.00	.00	2.13	25.5
1985	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1986	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1987	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1988	.00	.00	21.83	90.82	21.58	22.73	.00	.00	.00	.00	.00	.00	13.08	156.9
1989	.00	.00	.00	11.39	26.08	.00	.00	.00	.00	.00	.00	.00	3.12	37.4
1990	.00	.00	.00	11.72	44.88	40.83	.00	.00	.00	.00	.00	.00	8.12	97.4
1991	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1992	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1993	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1994	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1995	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1996	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1997	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1998	.00	.00	.00	29.46	49.38	.00	.00	.00	.00	.00	.00	.00	6.57	78.8
1999	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
MOY.	.00	.00	.42	4.34	4.69	1.72	.00	.00	.00	.00	.00	.00	.93	11.2
EC-T	.00	.00	3.03	17.26	14.66	7.27	.00	.00	.00	.00	.00	.00	2.90	34.8
C.VR	.00	.00	7.21	3.97	3.12	4.23	.00	.00	.00	.00	.00	.00	3.12	3.1

COYNE ET BELLIER - BUREAU D INGENIEURS CONSEILS - PARIS - FRANCE

CALCUL EFFECTUE PAR LE PROGRAMME S I M - REV 2.10 2002/10/15 10H16M55

Simulation TOABRE

-----> &DEF_S DEFICIT REGULATED FLOW (M3/S)

ANNEE	J	F	M	A	M	J	J	A	S	O	N	D	MOY	CUM
1948	.00	.00	.00	.00	.00	9.95	.00	.00	.00	.00	.00	.00	.83	9.9
1949	.00	.00	.00	31.79	28.55	.00	.00	.00	.00	.00	.00	.00	5.03	60.3
1950	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1951	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1952	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1953	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1954	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1955	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1956	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1957	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1958	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1959	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1960	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1961	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1962	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1963	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1964	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1965	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1966	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1967	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1968	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1969	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1970	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1971	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1972	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1973	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1974	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1975	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1976	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1977	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1978	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1979	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1980	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1981	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1982	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1983	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.79	9.5
1984	.00	.00	.00	.00	9.53	.00	.00	.00	.00	.00	.00	.00	.00	.0
1985	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1986	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1987	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	5.00	60.0
1988	.00	.00	8.15	35.04	8.06	8.77	.00	.00	.00	.00	.00	.00	1.18	14.1
1989	.00	.00	.00	4.39	9.74	.00	.00	.00	.00	.00	.00	.00	3.09	37.0
1990	.00	.00	.00	4.52	16.76	15.75	.00	.00	.00	.00	.00	.00	.00	.0
1991	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1992	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1993	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1994	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1995	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1996	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1997	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	2.48	29.8
1998	.00	.00	.00	11.37	18.44	.00	.00	.00	.00	.00	.00	.00	.00	.0
1999	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	
MOY.	.00	.00	.16	1.68	1.75	.66	.00	.00	.00	.00	.00	.00	.35	4.2
EC-T	.00	.00	1.13	6.66	5.47	2.80	.00	.00	.00	.00	.00	.00	1.10	13.3
C.VR	.00	.00	7.21	3.97	3.12	4.23	.00	.00	.00	.00	.00	.00	3.12	3.1

COYNE ET BELLIER - BUREAU D INGENIEURS CONSEILS - PARIS - FRANCE

CALCUL EFFECTUE PAR LE PROGRAMME S I M - REV 2.10 2002/10/15 10H16M55

Simulation TOABRE

-----> &DEF DEFICIT REGULATED FLOW %

ANNEE	J	F	M	A	M	J	J	A	S	O	N	D	MOY	CUM
1948	.00	.00	.00	.00	.00	28.40	.00	.00	.00	.00	.00	.00	2.37	28.4
1949	.00	.00	.00	90.72	81.49	.00	.00	.00	.00	.00	.00	.00	14.35	172.2
1950	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1951	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1952	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1953	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1954	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1955	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1956	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1957	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1958	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1959	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1960	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1961	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1962	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1963	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1964	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1965	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1966	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1967	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1968	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1969	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1970	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1971	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1972	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1973	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1974	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1975	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1976	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1977	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1978	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1979	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1980	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1981	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1982	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1983	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1984	.00	.00	.00	.00	27.20	.00	.00	.00	.00	.00	.00	.00	2.27	27.2
1985	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1986	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1987	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1988	.00	.00	23.26	100.00	23.00	25.02	.00	.00	.00	.00	.00	.00	14.27	171.2
1989	.00	.00	.00	12.54	27.79	.00	.00	.00	.00	.00	.00	.00	3.36	40.3
1990	.00	.00	.00	12.91	47.82	44.95	.00	.00	.00	.00	.00	.00	8.81	105.6
1991	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1992	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1993	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1994	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1995	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1996	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1997	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1998	.00	.00	.00	32.44	52.62	.00	.00	.00	.00	.00	.00	.00	7.09	85.0
1999	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
MOY.	.00	.00	.45	4.78	5.00	1.89	.00	.00	.00	.00	.00	.00	1.01	12.1
EC-T	.00	.00	3.23	19.00	15.62	8.00	.00	.00	.00	.00	.00	.00	3.15	37.8
C.VR	.00	.00	7.21	3.97	3.12	4.23	.00	.00	.00	.00	.00	.00	3.12	3.1

COYNE ET BELLIER - BUREAU D INGENIEURS CONSEILS - PARIS - FRANCE

CALCUL EFFECTUE PAR LE PROGRAMME S I M - REV 2.10 2002/10/16 16H24M13

Simulation TOABRE

-----> HAUTEUR TOABRE RESERVOIR LEVEL (MASL)

ANNEE	J	F	M	A	M	J	J	A	S	O	N	D	MOY	CUM
1948	81.04	75.51	66.86	52.85	50.00	50.00	62.01	71.01	76.74	82.12	91.69	94.17	71.17	
1949	90.42	85.98	79.65	72.17	63.18	62.62	71.89	79.32	87.88	93.40	95.00	95.00	81.37	
1950	92.31	88.87	83.75	77.38	74.11	73.38	80.24	87.63	91.22	95.00	95.00	95.00	86.16	
1951	92.79	89.89	85.26	79.65	76.23	74.24	79.53	85.14	88.75	93.23	95.00	95.00	86.23	
1952	91.90	88.18	82.75	76.25	69.11	64.24	69.23	74.22	81.19	89.27	93.49	95.00	81.24	
1953	93.95	91.20	86.79	81.51	79.56	77.08	81.02	83.47	86.60	92.36	95.00	95.00	86.96	
1954	91.66	87.70	82.10	75.48	73.42	70.46	82.83	89.85	95.00	95.00	95.00	95.00	86.12	
1955	94.61	91.69	87.20	81.90	76.12	74.30	78.90	85.27	91.18	95.00	95.00	95.00	87.18	
1956	94.36	91.42	87.12	82.08	78.49	77.07	83.55	86.82	92.02	95.00	95.00	95.00	88.16	
1957	91.85	88.00	82.57	75.87	69.29	61.05	64.46	70.69	75.48	86.22	91.78	94.26	79.29	
1958	91.19	87.76	82.70	76.70	72.27	67.30	72.08	79.68	85.94	91.28	95.00	95.00	83.07	
1959	91.88	87.88	82.17	75.59	68.70	63.66	68.70	75.71	81.47	88.44	93.35	95.00	81.05	
1960	93.24	89.86	85.10	80.84	77.40	75.54	80.56	85.14	88.59	92.59	95.00	95.00	86.57	
1961	92.17	88.44	83.15	77.74	71.81	67.71	74.42	83.33	88.07	93.30	95.00	95.00	84.18	
1962	92.21	88.56	83.36	77.27	71.94	68.72	72.81	79.54	84.26	90.04	95.00	95.00	83.23	
1963	92.00	88.36	82.90	80.11	78.12	76.89	82.53	87.61	90.87	94.59	95.00	95.00	87.00	
1964	91.39	87.17	81.33	74.57	68.19	69.18	78.09	85.10	91.55	95.00	95.00	95.00	84.30	
1965	92.73	89.34	84.34	78.20	70.86	62.69	64.80	69.96	73.23	79.72	86.24	91.92	78.67	
1966	88.29	83.67	77.15	69.34	65.13	63.39	70.40	75.89	79.93	87.71	95.00	95.00	79.24	
1967	92.36	88.73	83.42	77.73	73.97	76.12	82.56	88.32	94.41	95.00	95.00	95.00	86.89	
1968	91.52	87.62	82.11	75.63	69.10	67.19	72.66	79.12	84.56	92.38	95.00	95.00	82.66	
1969	91.49	88.11	82.86	77.17	70.88	65.65	69.56	75.33	81.16	86.69	91.72	95.00	81.30	
1970	95.00	94.83	92.06	91.04	92.31	90.36	93.90	95.00	95.00	95.00	95.00	95.00	93.71	
1971	93.55	90.41	86.70	81.57	77.99	77.70	83.78	89.27	94.10	95.00	95.00	95.00	88.34	
1972	93.20	89.84	85.10	81.45	77.90	74.35	77.31	79.68	84.42	88.29	91.52	92.78	84.65	
1973	88.88	84.32	77.85	70.05	62.50	60.14	70.51	78.20	86.25	92.76	95.00	95.00	80.12	
1974	92.34	88.81	83.74	78.82	78.22	75.67	80.80	84.88	88.18	94.82	95.00	95.00	86.36	
1975	91.57	87.63	82.13	75.34	68.63	62.31	70.92	80.61	88.86	95.00	95.00	95.00	82.75	
1976	92.97	89.53	84.51	78.55	72.22	65.07	67.58	72.52	79.27	85.33	89.53	90.98	80.67	
1977	86.59	81.53	74.38	65.21	52.21	50.00	60.18	72.86	79.07	86.86	90.73	92.52	74.34	
1978	88.58	84.07	77.95	77.53	82.45	80.19	83.35	86.65	91.22	95.00	95.00	95.00	86.42	
1979	91.32	87.14	81.32	76.09	70.07	68.38	75.12	84.01	88.49	91.88	94.59	95.00	83.62	
1980	93.79	90.49	85.69	80.33	75.49	71.64	76.17	83.60	87.64	93.09	95.00	95.00	85.66	
1981	92.93	89.97	85.79	83.94	84.39	84.19	90.46	95.00	95.00	95.00	95.00	95.00	90.56	
1982	92.68	89.23	84.25	78.52	72.65	68.76	74.44	78.54	82.89	88.90	92.41	93.36	83.05	
1983	89.32	84.62	78.05	70.11	66.20	60.82	64.79	69.15	78.02	83.60	87.37	91.32	76.95	
1984	88.02	84.41	79.25	72.05	65.00	61.69	72.72	81.68	88.28	94.05	95.00	95.00	81.43	
1985	91.80	87.91	82.56	75.99	68.14	67.65	73.28	79.53	84.47	89.25	94.38	95.00	82.50	
1986	91.90	88.09	82.74	78.76	75.21	73.43	79.77	84.52	88.81	95.00	95.00	95.00	85.68	
1987	91.38	87.28	81.52	76.38	70.71	63.41	68.27	73.44	78.35	88.60	92.63	94.69	80.55	
1988	91.13	87.29	81.51	74.59	70.16	64.90	72.63	79.57	84.84	90.92	95.00	95.00	82.30	
1989	92.11	88.49	83.46	77.34	73.18	70.07	77.48	83.88	88.47	92.25	95.00	95.00	84.73	
1990	92.27	88.72	83.75	77.82	72.68	66.67	72.77	77.95	83.92	92.50	95.00	95.00	83.25	
1991	91.90	88.18	85.21	79.68	75.36	71.32	74.76	78.45	89.78	95.00	95.00	95.00	84.97	
1992	91.68	87.75	82.19	77.91	76.13	74.62	79.06	83.94	90.10	93.88	95.00	95.00	85.60	
1993	92.43	88.67	83.94	78.67	73.32	70.47	75.40	78.49	86.09	90.61	95.00	95.00	84.01	
1994	91.90	88.16	83.09	77.80	74.33	73.95	77.80	83.05	88.10	92.51	95.00	95.00	85.06	
1995	91.56	87.59	82.03	76.18	73.63	70.36	76.61	82.52	88.29	91.11	94.44	95.00	84.11	
1996	95.00	93.69	91.32	87.96	88.23	88.30	93.62	95.00	95.00	95.00	95.00	95.00	92.76	
1997	92.31	89.07	84.09	78.10	73.17	65.90	68.77	70.89	74.16	79.39	83.03	84.12	78.58	
1998	78.16	71.15	59.73	50.00	50.00	50.00	61.47	69.64	75.63	83.30	87.96	93.71	69.23	
1999	91.50	88.19	83.89	79.00	76.99	79.79	86.39	95.00	95.00	95.00	95.00	95.00	88.40	
MOY.	91.41	87.71	82.39	76.59	72.26	69.43	75.44	81.26	86.30	91.20	93.69	94.40	83.51	
EC-T	2.92	3.73	4.98	6.60	7.78	8.34	7.58	6.81	5.88	4.22	2.62	1.75	4.54	
C.VR	.03	.04	.06	.09	.11	.12	.10	.08	.07	.05	.03	.02	.05	

COYNE ET BELLIER - BUREAU D INGENIEURS CONSEILS - PARIS - FRANCE

CALCUL EFFECTUE PAR LE PROGRAMME S I M - REV 2.10 2002/10/16 16H24M13

Simulation TOABRE

-----> SURFACE TOABRE RESERVOIR SURFACE (KM²)

ANNEE	J	F	M	A	M	J	J	A	S	O	N	D	MOY	CUM
1948	23.23	19.55	14.11	6.84	5.70	5.70	11.60	16.51	20.42	24.11	34.32	37.64	18.31	
1949	32.74	27.78	22.29	17.30	12.19	11.91	17.13	22.20	29.76	36.55	38.80	38.80	25.62	
1950	35.10	30.94	25.58	20.90	18.58	18.07	22.59	29.49	33.77	38.80	38.80	38.80	29.28	
1951	35.73	32.07	27.06	22.29	20.06	18.67	22.26	26.94	30.80	36.33	38.80	38.80	29.15	
1952	34.58	30.11	24.68	20.08	15.37	12.72	15.44	18.65	23.35	31.39	36.68	38.80	25.15	
1953	37.33	33.74	28.59	23.61	22.27	20.66	23.22	25.32	28.40	35.17	38.80	38.80	29.66	
1954	34.29	29.56	24.09	19.54	18.10	16.18	24.75	32.03	38.80	38.80	38.80	38.80	29.48	
1955	38.26	34.32	29.02	23.92	19.98	18.71	22.03	27.07	33.72	38.80	38.80	38.80	30.29	
1956	37.90	34.00	28.93	24.07	21.74	20.65	25.40	28.62	34.72	38.80	38.80	38.80	31.04	
1957	34.52	29.91	24.51	19.81	15.47	11.22	12.83	16.31	19.53	28.02	34.43	37.76	23.69	
1958	33.73	29.63	24.63	20.39	17.36	14.35	17.25	22.30	27.74	33.84	38.80	38.80	26.57	
1959	34.56	29.77	24.16	19.61	15.12	12.43	15.12	19.69	23.57	30.42	36.49	38.80	24.98	
1960	36.34	32.04	26.90	23.07	20.92	19.58	22.85	26.94	30.60	35.46	38.80	38.80	29.36	
1961	34.92	30.42	25.04	21.19	17.07	14.55	18.80	25.19	29.99	36.42	38.80	38.80	27.60	
1962	34.97	30.57	25.23	20.82	17.16	15.13	17.69	22.26	26.06	32.26	38.80	38.80	26.64	
1963	34.70	30.34	24.81	22.48	21.48	20.53	24.48	29.47	33.33	38.23	38.80	38.80	29.79	
1964	33.97	28.99	23.46	18.90	14.82	15.41	21.47	26.90	34.16	38.80	38.80	38.80	27.87	
1965	35.65	31.48	26.14	21.54	16.42	11.94	13.00	15.88	17.96	22.31	28.04	34.60	22.91	
1966	30.24	25.50	20.72	15.51	13.16	12.29	16.14	19.82	22.38	29.58	38.80	38.80	23.58	
1967	35.16	30.78	25.28	21.18	18.48	19.99	24.51	30.29	37.97	38.80	38.80	38.80	30.00	
1968	34.12	29.48	24.10	19.64	15.36	14.30	17.59	22.14	26.36	35.20	38.80	38.80	26.32	
1969	34.09	30.03	24.77	20.73	16.43	13.43	15.63	19.43	23.33	28.49	34.37	38.80	24.96	
1970	38.80	38.56	34.78	33.55	35.10	32.67	37.26	38.80	38.80	38.80	38.80	38.80	37.06	
1971	36.77	32.74	28.50	23.65	21.40	21.16	25.60	31.40	37.54	38.80	38.80	38.80	31.26	
1972	36.28	32.02	26.90	23.56	21.32	18.74	20.85	22.30	26.22	30.25	34.13	35.72	27.36	
1973	30.96	26.12	21.28	15.93	11.85	10.77	16.20	21.54	28.05	35.69	38.80	38.80	24.67	
1974	35.15	30.88	25.56	21.97	21.55	19.67	23.04	26.68	30.11	38.55	38.80	38.80	29.23	
1975	34.19	29.49	24.12	19.44	15.08	11.75	16.45	22.89	30.94	38.80	38.80	38.80	26.73	
1976	35.96	31.68	26.31	21.78	17.33	13.14	14.49	17.51	22.18	27.13	31.68	33.47	24.39	
1977	28.39	23.63	18.77	13.21	6.58	5.70	10.79	17.72	22.12	28.66	33.14	35.37	20.34	
1978	30.60	25.87	21.36	21.02	24.40	22.55	25.22	28.45	33.76	38.80	38.80	38.80	29.14	
1979	33.88	28.96	23.46	19.97	15.94	14.93	19.28	25.81	30.49	34.56	38.23	38.80	27.03	
1980	37.10	32.83	27.49	22.67	19.54	16.95	20.02	25.44	29.50	36.12	38.80	38.80	28.77	
1981	35.91	32.16	27.59	25.75	26.19	25.99	32.80	38.80	38.80	38.80	38.80	38.80	33.37	
1982	35.58	31.35	26.05	21.77	17.59	15.16	18.81	21.78	24.80	30.98	35.23	36.50	26.30	
1983	31.46	26.42	21.43	15.97	13.72	11.11	13.00	15.39	21.41	25.44	29.21	33.89	21.54	
1984	29.92	26.21	22.17	17.23	13.10	11.48	17.63	23.74	30.24	37.47	38.80	38.80	25.57	
1985	34.46	29.80	24.51	19.89	14.78	14.53	18.00	22.26	26.27	31.37	37.93	38.80	26.05	
1986	34.58	30.01	24.67	21.93	19.35	18.10	22.33	26.32	30.87	38.80	38.80	38.80	28.71	
1987	33.95	29.10	23.61	20.17	16.33	12.31	14.86	18.11	21.64	30.62	35.53	38.36	24.55	
1988	33.65	29.12	23.61	18.91	16.00	13.05	17.58	22.27	26.64	33.40	38.80	38.80	25.99	
1989	34.84	30.49	25.31	20.87	17.93	15.94	20.98	25.69	30.46	35.03	38.80	38.80	27.93	
1990	35.05	30.77	25.57	21.26	17.61	14.00	17.66	21.36	25.73	35.35	38.80	38.80	26.83	
1991	34.58	30.12	27.01	22.30	19.45	16.73	19.03	21.71	31.96	38.80	38.80	38.80	28.28	
1992	34.31	29.63	24.17	21.33	19.99	18.93	22.12	25.75	32.32	37.23	38.80	38.80	28.61	
1993	35.26	30.70	25.75	21.87	18.03	16.18	19.48	21.75	27.89	32.99	38.80	38.80	27.29	
1994	34.58	30.09	24.98	21.24	18.73	18.46	21.24	24.95	30.02	35.36	38.80	38.80	28.11	
1995	34.17	29.44	24.03	20.03	18.24	16.12	20.33	24.47	30.25	33.64	38.02	38.80	27.29	
1996	38.80	36.96	33.88	29.85	30.18	30.26	36.87	38.80	38.80	38.80	38.80	38.80	35.90	
1997	35.10	31.18	25.89	21.47	17.92	13.55	15.16	16.43	18.61	22.22	24.92	25.92	22.37	
1998	21.51	16.61	10.48	5.70	5.70	5.70	11.39	15.68	19.64	25.17	29.86	37.00	17.04	
1999	34.10	30.13	25.70	22.10	20.59	22.34	28.19	38.80	38.80	38.80	38.80	38.80	31.43	
MOY.	34.15	29.89	24.79	20.57	17.78	16.08	19.97	24.35	28.88	34.10	37.12	38.02	27.14	
EC-T	3.16	3.52	3.76	4.28	5.06	5.25	5.67	5.99	5.80	4.84	3.23	2.15	3.71	
C.VR	.09	.12	.15	.21	.28	.33	.28	.25	.20	.14	.09	.06	.14	

COYNE ET BELLIER - BUREAU D INGENIEURS CONSEILS - PARIS - FRANCE

CALCUL EFFECTUE PAR LE PROGRAMME S I M - REV 2.10 2002/10/16 16H24M13

Simulation TOABRE

-----> VOLUME TOABRE RESERVOIR VOLUME (HM3)

ANNEE	J	F	M	A	M	J	J	A	S	O	N	D	MOY	CUM
1948	494.84	377.12	232.13	85.92	68.00	68.00	170.11	296.13	401.89	520.97	797.32	886.51	366.58	
1949	754.82	620.33	464.28	315.92	184.16	177.42	311.20	457.03	675.40	857.62	918.00	918.00	554.51	
1950	818.69	704.99	561.51	414.93	350.06	336.84	477.18	668.22	781.57	918.00	918.00	918.00	655.66	
1951	835.79	737.33	600.93	464.24	391.56	352.56	461.64	597.76	701.56	851.68	918.00	918.00	652.59	
1952	804.49	684.34	536.04	392.07	265.79	197.10	267.73	352.09	498.52	717.48	861.08	918.00	541.23	
1953	878.09	780.89	643.81	506.31	462.21	408.59	494.49	554.25	638.36	820.60	918.00	918.00	668.63	
1954	796.39	670.16	520.33	376.65	337.60	287.34	537.87	736.19	918.00	918.00	918.00	918.00	661.21	
1955	903.29	797.30	655.87	515.56	389.31	353.70	447.78	601.30	780.19	918.00	918.00	918.00	683.19	
1956	893.69	788.23	653.53	519.93	438.70	408.43	556.43	644.67	808.53	918.00	918.00	918.00	705.51	
1957	802.89	679.14	531.67	384.39	268.58	159.50	200.04	291.01	376.57	627.45	800.38	889.85	500.96	
1958	780.46	671.98	534.73	400.96	317.62	238.50	314.32	464.95	619.32	783.66	918.00	918.00	580.21	
1959	803.89	675.54	522.18	378.81	259.46	189.96	259.47	381.12	505.23	692.09	855.90	918.00	536.81	
1960	851.89	736.38	596.78	490.39	415.42	377.79	484.42	597.76	696.56	828.48	918.00	918.00	659.32	
1961	813.79	692.10	545.98	422.50	309.77	244.63	356.06	550.46	681.18	854.00	918.00	918.00	608.87	
1962	815.39	695.70	551.46	412.68	312.00	259.76	326.83	461.98	574.65	742.40	918.00	918.00	582.40	
1963	807.89	689.92	539.51	474.33	430.58	404.89	530.68	667.69	769.64	902.55	918.00	918.00	671.14	
1964	787.29	654.89	501.92	358.75	251.90	266.88	430.06	596.66	792.65	918.00	918.00	918.00	616.25	
1965	833.69	719.94	576.90	432.42	293.74	178.24	204.42	279.39	334.06	465.75	627.82	805.28	479.30	
1966	687.62	559.35	410.24	269.49	208.79	186.62	286.43	384.82	470.52	670.49	918.00	918.00	497.53	
1967	820.49	700.98	552.92	422.24	347.51	389.48	531.54	688.64	895.48	918.00	918.00	918.00	675.27	
1968	791.59	667.88	520.75	379.68	265.64	236.85	324.18	452.62	582.59	821.34	918.00	918.00	573.26	
1969	790.79	682.28	538.60	410.52	294.03	216.13	272.90	373.67	497.78	640.95	798.57	918.00	536.18	
1970	918.00	911.36	810.18	775.34	818.81	753.02	876.23	918.00	918.00	918.00	918.00	918.00	871.08	
1971	863.39	754.64	641.17	507.57	427.88	421.68	562.21	717.76	883.88	918.00	918.00	918.00	711.18	
1972	850.29	735.78	596.69	504.80	425.89	354.59	413.58	464.95	578.91	687.76	791.77	835.47	603.37	
1973	705.39	576.36	424.78	280.83	175.98	149.51	288.12	432.32	628.39	834.53	918.00	918.00	527.68	
1974	819.99	703.38	561.21	446.03	432.81	380.43	489.56	590.92	684.31	911.24	918.00	918.00	654.66	
1975	793.49	668.27	521.14	373.87	258.50	173.70	294.67	485.47	704.93	918.00	918.00	918.00	585.67	
1976	841.99	725.81	581.15	440.07	316.72	208.00	242.75	321.78	456.02	602.99	725.92	773.26	519.70	
1977	638.02	506.82	355.21	209.97	81.45	68.00	150.01	327.70	451.54	645.91	764.93	826.09	418.80	
1978	696.54	569.94	427.00	418.14	528.79	476.14	551.15	639.98	781.35	918.00	918.00	918.00	653.59	
1979	784.89	654.10	501.73	388.86	281.06	254.73	369.38	568.29	693.80	804.03	902.51	918.00	593.45	
1980	872.19	757.11	612.63	479.33	376.71	306.86	390.34	557.68	668.49	846.22	918.00	918.00	641.96	
1981	840.59	739.91	615.31	566.51	578.11	573.00	756.11	918.00	918.00	918.00	918.00	918.00	771.63	
1982	831.79	716.34	574.62	439.54	323.99	260.38	356.36	439.85	539.32	706.08	822.18	856.21	572.22	
1983	719.35	584.17	429.07	281.81	223.57	157.05	204.28	266.35	428.33	557.60	660.85	784.94	441.45	
1984	679.45	578.62	455.44	313.87	207.00	166.64	325.29	510.24	687.38	881.91	918.00	918.00	553.49	
1985	801.19	676.45	531.49	386.81	251.10	243.77	335.11	461.67	580.24	716.98	894.29	918.00	566.43	
1986	804.69	681.63	535.75	444.68	371.15	337.79	466.84	581.46	703.16	918.00	918.00	918.00	640.10	
1987	786.79	657.99	506.41	394.64	291.37	186.96	253.07	338.01	435.64	696.91	830.22	906.03	523.67	
1988	778.37	658.50	506.31	359.24	282.60	205.66	323.71	462.56	589.72	771.47	918.00	918.00	564.51	
1989	811.69	693.71	553.98	414.20	333.33	281.15	417.07	564.95	693.06	816.88	918.00	918.00	618.00	
1990	817.29	700.69	561.43	424.25	324.63	229.73	326.13	426.98	565.86	825.51	918.00	918.00	586.54	
1991	804.49	684.54	599.74	464.85	374.28	301.52	362.49	437.89	734.06	918.00	918.00	918.00	626.49	
1992	796.99	671.76	522.52	426.04	389.64	359.73	451.32	566.54	744.15	875.47	918.00	918.00	636.68	
1993	823.19	699.07	566.52	442.84	335.80	287.53	374.97	438.88	623.56	761.10	918.00	918.00	599.12	
1994	804.49	683.84	544.44	423.87	354.25	347.03	423.90	543.39	681.91	825.84	918.00	918.00	622.41	
1995	792.89	666.97	518.75	390.68	341.29	285.84	399.27	530.52	687.75	777.88	896.86	918.00	600.56	
1996	918.00	868.36	784.74	677.81	685.97	687.99	866.05	918.00	918.00	918.00	918.00	918.00	839.91	
1997	818.89	711.29	570.38	430.30	333.11	219.53	260.51	294.26	351.02	458.61	542.68	571.13	463.48	
1998	431.58	298.61	145.04	68.00	68.00	68.00	164.21	274.22	379.70	549.68	677.82	869.38	332.85	
1999	791.06	684.75	565.15	449.97	406.77	467.31	632.30	918.00	918.00	918.00	918.00	918.00	715.61	
MOY.	792.40	677.07	536.77	412.57	335.83	291.39	395.63	519.52	646.71	790.81	872.71	896.96	597.36	
EC-T	87.11	97.88	106.03	113.40	132.45	137.61	159.25	169.22	161.94	131.44	87.04	58.08	101.03	
C.VR	.11	.14	.20	.27	.39	.47	.40	.33	.25	.17	.10	.06	.17	

COYNE ET BELLIER - BUREAU D INGENIEURS CONSEILS - PARIS - FRANCE

CALCUL EFFECTUE PAR LE PROGRAMME S I M - REV 2.10 2002/10/16 16H24M13

Simulation TOABRE

-----> EVAPOR. TOABRE EVAPORATION (HM3)

ANNEE	J	F	M	A	M	J	J	A	S	O	N	D	MOY	CUM
1948	2.83	2.11	2.05	.08	-.94	-.46	-.34	-.44	.26	.10	.17	2.09	.63	7.5
1949	3.95	2.98	2.92	.13	-2.37	-.99	-.70	-.65	.36	.15	.26	2.37	.70	8.4
1950	4.07	3.19	3.25	.15	-2.86	-1.50	-1.07	-.86	.47	.17	.27	2.37	.64	7.6
1951	4.07	3.25	3.37	.16	-3.05	-1.62	-1.10	-.85	.43	.15	.25	2.37	.62	7.4
1952	4.07	3.15	3.16	.15	-2.75	-1.24	-.75	-.59	.30	.12	.22	2.24	.67	8.0
1953	4.07	3.40	3.54	.17	-3.23	-1.80	-1.22	-.88	.41	.14	.25	2.37	.60	7.2
1954	4.07	3.12	3.10	.14	-2.68	-1.47	-.95	-.94	.51	.19	.27	2.37	.65	7.7
1955	4.07	3.48	3.60	.17	-3.28	-1.62	-1.10	-.84	.43	.17	.27	2.37	.64	7.7
1956	4.07	3.45	3.57	.17	-3.30	-1.76	-1.22	-.97	.46	.17	.27	2.37	.61	7.2
1957	4.07	3.14	3.14	.15	-2.71	-1.25	-.66	-.49	.26	.10	.20	2.10	.67	8.0
1958	3.97	3.07	3.11	.15	-2.79	-1.41	-.85	-.66	.36	.14	.24	2.37	.64	7.6
1959	4.07	3.14	3.13	.14	-2.69	-1.22	-.73	-.57	.32	.12	.21	2.23	.68	8.1
1960	4.07	3.31	3.36	.16	-3.16	-1.69	-1.16	-.87	.43	.15	.25	2.37	.60	7.2
1961	4.07	3.18	3.19	.15	-2.90	-1.38	-.86	-.71	.40	.15	.25	2.37	.66	7.9
1962	4.07	3.18	3.21	.15	-2.85	-1.39	-.89	-.67	.36	.13	.23	2.37	.66	7.8
1963	4.07	3.16	3.19	.15	-3.08	-1.74	-1.21	-.93	.47	.17	.27	2.37	.57	6.8
1964	4.07	3.09	3.04	.14	-2.59	-1.20	-.91	-.82	.43	.17	.27	2.37	.67	8.0
1965	4.07	3.24	3.30	.16	-2.95	-1.33	-.70	-.49	.25	.09	.16	1.71	.63	7.5
1966	3.63	2.75	2.68	.12	-2.12	-1.07	-.73	-.61	.32	.11	.21	2.37	.64	7.6
1967	4.07	3.20	3.23	.15	-2.90	-1.50	-1.18	-.93	.48	.19	.27	2.37	.62	7.4
1968	4.07	3.11	3.10	.14	-2.69	-1.24	-.84	-.67	.35	.13	.25	2.37	.67	8.0
1969	4.07	3.10	3.15	.15	-2.84	-1.33	-.79	-.59	.31	.12	.20	2.10	.64	7.6
1970	4.07	3.53	4.05	.21	-4.60	-2.84	-1.93	-1.42	.62	.19	.27	2.37	.38	4.5
1971	4.07	3.35	3.44	.17	-3.24	-1.73	-1.25	-.97	.50	.19	.27	2.37	.60	7.1
1972	4.07	3.30	3.36	.16	-3.23	-1.73	-1.11	-.79	.36	.13	.21	2.08	.57	6.8
1973	3.75	2.82	2.74	.13	-2.18	-.96	-.64	-.62	.34	.14	.25	2.37	.68	8.1
1974	4.07	3.20	3.24	.15	-3.01	-1.75	-1.16	-.88	.43	.15	.27	2.37	.59	7.0
1975	4.07	3.11	3.10	.14	-2.66	-1.22	-.69	-.63	.37	.15	.27	2.37	.70	8.3
1976	4.07	3.27	3.33	.16	-2.98	-1.40	-.77	-.55	.28	.11	.19	1.93	.64	7.6
1977	3.51	2.58	2.48	.11	-1.81	-.53	-.34	-.41	.28	.11	.20	2.02	.68	8.2
1978	3.71	2.78	2.72	.13	-2.88	-1.98	-1.33	-.96	.46	.17	.27	2.37	.46	5.4
1979	4.07	3.08	3.04	.14	-2.74	-1.29	-.88	-.73	.41	.15	.24	2.33	.65	7.8
1980	4.07	3.38	3.45	.16	-3.11	-1.58	-1.00	-.76	.41	.15	.25	2.37	.65	7.7
1981	4.07	3.27	3.38	.17	-3.53	-2.12	-1.53	-1.25	.62	.19	.27	2.37	.49	5.9
1982	4.07	3.24	3.29	.16	-2.98	-1.42	-.89	-.71	.35	.12	.22	2.15	.63	7.5
1983	3.83	2.86	2.77	.13	-2.19	-1.11	-.66	-.49	.25	.11	.18	1.78	.62	7.4
1984	3.56	2.72	2.75	.13	-2.36	-1.06	-.68	-.67	.38	.15	.26	2.37	.63	7.5
1985	4.07	3.14	3.13	.15	-2.73	-1.20	-.86	-.68	.36	.13	.22	2.31	.67	8.0
1986	4.07	3.15	3.15	.15	-3.00	-1.57	-1.07	-.85	.42	.15	.27	2.37	.60	7.2
1987	4.07	3.09	3.06	.14	-2.76	-1.32	-.73	-.56	.29	.11	.21	2.17	.65	7.7
1988	4.03	3.06	3.06	.14	-2.59	-1.30	-.77	-.67	.36	.13	.23	2.37	.67	8.0
1989	4.07	3.17	3.20	.15	-2.86	-1.45	-.94	-.80	.41	.15	.25	2.37	.64	7.7
1990	4.07	3.19	3.23	.15	-2.91	-1.43	-.83	-.67	.34	.13	.25	2.37	.66	7.9
1991	4.07	3.15	3.16	.16	-3.06	-1.58	-.99	-.72	.35	.16	.27	2.37	.61	7.3
1992	4.07	3.12	3.11	.15	-2.92	-1.62	-1.12	-.84	.41	.16	.26	2.37	.60	7.1
1993	4.07	3.21	3.22	.15	-3.00	-1.46	-.95	-.74	.35	.14	.23	2.37	.63	7.5
1994	4.07	3.15	3.16	.15	-2.91	-1.52	-1.09	-.81	.40	.15	.25	2.37	.61	7.3
1995	4.07	3.11	3.09	.14	-2.74	-1.48	-.95	-.77	.39	.15	.24	2.32	.63	7.5
1996	4.07	3.53	3.88	.20	-4.09	-2.44	-1.79	-1.40	.62	.19	.27	2.37	.45	5.4
1997	4.07	3.19	3.27	.16	-2.94	-1.45	-.80	-.58	.26	.09	.16	1.52	.58	6.9
1998	2.72	1.96	1.74	.06	-.78	-.46	-.34	-.43	.25	.10	.18	1.82	.57	6.8
1999	3.88	3.10	3.16	.15	-3.03	-1.67	-1.32	-1.07	.62	.19	.27	2.37	.56	6.6
MOY.	3.97	3.11	3.14	.15	-2.82	-1.44	-.95	-.76	.39	.14	.24	2.26	.62	7.4
EC-T	.28	.29	.37	.02	.59	.41	.31	.22	.10	.03	.03	.20	.06	.7
C.VR	.07	.09	.12	.15	.00	.00	.00	.00	.25	.20	.14	.09	.10	.1

COYNE ET BELLIER - BUREAU D INGENIEURS CONSEILS - PARIS - FRANCE

CALCUL EFFECTUÉ PAR LE PROGRAMME S I M - REV 2.10 2002/10/16 16H24M13

Simulation TOABRE

-----> DEVERSE TOABRE . SPILLAGE (HM3)

ANNEE	J	F	M	A	M	J	J	A	S	O	N	D	MOY	CUM
1948	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1949	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	259.69	240.81	41.71	500.5
1950	.00	.00	.00	.00	.00	.00	.00	.00	.00	51.38	265.95	222.61	44.99	539.9
1951	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	116.95	116.31	19.44	233.2
1952	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	237.62	19.80	237.6
1953	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	85.58	93.51	14.92	179.0
1954	.00	.00	.00	.00	.00	.00	.00	.00	9.00	191.88	292.65	129.41	51.91	622.9
1955	.00	.00	.00	.00	.00	.00	.00	.00	.00	77.89	305.35	148.71	44.33	531.9
1956	.00	.00	.00	.00	.00	.00	.00	.00	.00	157.44	161.95	78.01	33.12	397.4
1957	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1958	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	2.05	85.51	7.30	87.5
1959	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	171.65	14.30	171.6
1960	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	109.26	379.31	40.71	488.5
1961	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	100.37	123.51	18.66	223.8
1962	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	29.19	108.51	11.48	137.7
1963	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	162.11	73.71	19.65	235.8
1964	.00	.00	.00	.00	.00	.00	.00	.00	.00	94.66	253.25	67.51	34.62	415.4
1965	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1966	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	17.71	203.31	18.42	221.0
1967	.00	.00	.00	.00	.00	.00	.00	.00	.00	227.97	155.75	65.41	37.43	449.1
1968	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	125.71	100.51	18.85	226.2
1969	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	12.35	1.03	12.3
1970	98.09	.00	.00	.00	.00	.00	.00	138.82	211.40	177.38	231.75	388.71	103.85	1246.1
1971	.00	.00	.00	.00	.00	.00	.00	.00	.00	149.97	112.45	42.91	25.44	305.3
1972	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1973	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	152.10	177.61	27.48	329.7
1974	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	131.09	93.51	18.72	224.6
1975	.00	.00	.00	.00	.00	.00	.00	.00	.00	75.25	369.05	276.41	60.06	720.7
1976	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1977	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1978	.00	.00	.00	.00	.00	.00	.00	.00	.00	24.96	190.25	67.01	23.52	282.2
1979	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	119.26	9.94	119.2
1980	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	81.69	121.41	16.93	203.1
1981	.00	.00	.00	.00	.00	.00	.00	31.14	108.00	152.98	235.35	339.61	72.26	867.0
1982	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1983	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1984	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	130.07	54.71	15.40	184.7
1985	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	102.55	8.55	102.5
1986	.00	.00	.00	.00	.00	.00	.00	.00	.00	65.39	262.55	59.21	32.26	387.1
1987	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1988	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	31.06	79.31	9.20	110.3
1989	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	65.06	108.51	14.46	173.5
1990	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	94.19	226.91	26.76	321.1
1991	.00	.00	.00	.00	.00	.00	.00	.00	.00	33.08	131.15	126.41	24.22	290.6
1992	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	57.23	63.01	10.02	120.2
1993	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	82.39	158.01	20.03	240.4
1994	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	39.51	51.21	7.56	90.7
1995	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	149.82	12.49	149.8
1996	183.49	.00	.00	.00	.00	.00	.00	154.63	216.10	176.28	161.95	163.11	87.96	1055.5
1997	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1998	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1999	.00	.00	.00	.00	.00	.00	.00	4.05	269.70	171.18	231.45	354.11	85.87	1030.5
MOY.	5.42	.00	.00	.00	.00	.00	.00	6.32	15.66	35.15	100.65	115.03	23.19	278.2
EC-T	28.62	.00	.00	.00	.00	.00	.00	28.73	56.56	65.14	102.98	103.25	24.14	289.7
C.VR	5.28	.00	.00	.00	.00	.00	.00	4.55	3.61	1.85	1.02	.90	1.04	1.0

COYNE ET BELLIER - BUREAU D INGENIEURS CONSEILS - PARIS - FRANCE

CALCUL EFFECTUE PAR LE PROGRAMME S I M - REV 2.10 2002/10/16 16H24M13

Simulation TOABRE

-----> &DEV_S SPILLAGE (M3/S)

ANNEE	J	F	M	A	M	J	J	A	S	O	N	D	MOY	CUM
1948	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1949	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	100.19	89.91	15.84	190.1
1950	.00	.00	.00	.00	.00	.00	.00	.00	.00	19.18	102.60	83.11	17.07	204.9
1951	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	45.12	43.43	7.38	88.5
1952	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	88.72	7.39	88.7
1953	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	33.02	34.91	5.66	67.9
1954	.00	.00	.00	.00	.00	.00	.00	.00	3.47	71.64	112.91	48.32	19.69	236.3
1955	.00	.00	.00	.00	.00	.00	.00	.00	.00	29.08	117.81	55.52	16.87	202.4
1956	.00	.00	.00	.00	.00	.00	.00	.00	.00	58.78	62.48	29.13	12.53	150.3
1957	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1958	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.79	31.93	2.73	32.7
1959	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	64.09	5.34	64.0
1960	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	42.15	141.62	15.31	183.7
1961	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	38.72	46.11	7.07	84.8
1962	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	11.26	40.51	4.31	51.7
1963	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	62.54	27.52	7.51	90.0
1964	.00	.00	.00	.00	.00	.00	.00	.00	.00	35.34	97.71	25.21	13.19	158.2
1965	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1966	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	6.83	75.91	6.89	82.7
1967	.00	.00	.00	.00	.00	.00	.00	.00	.00	85.11	60.09	24.42	14.14	169.6
1968	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	48.50	37.53	7.17	86.0
1969	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	4.61	.38	4.6
1970	36.62	.00	.00	.00	.00	.00	.00	51.83	81.56	66.23	89.41	145.13	39.23	470.7
1971	.00	.00	.00	.00	.00	.00	.00	.00	.00	55.99	43.38	16.02	9.62	115.4
1972	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1973	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	58.68	66.31	10.42	124.9
1974	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	50.58	34.91	7.12	85.4
1975	.00	.00	.00	.00	.00	.00	.00	.00	.00	28.10	142.38	103.20	22.81	273.6
1976	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1977	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1978	.00	.00	.00	.00	.00	.00	.00	.00	.00	9.32	73.40	25.02	8.98	107.7
1979	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	44.53	3.71	44.5
1980	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	31.52	45.33	6.40	76.8
1981	.00	.00	.00	.00	.00	.00	.00	11.63	41.67	57.12	90.80	126.80	27.33	328.0
1982	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1983	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1984	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	50.18	20.43	5.88	70.6
1985	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	38.29	3.19	38.2
1986	.00	.00	.00	.00	.00	.00	.00	.00	.00	24.41	101.29	22.11	12.32	147.8
1987	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1988	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	11.98	29.61	3.47	41.5
1989	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	25.10	40.51	5.47	65.6
1990	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	36.34	84.72	10.09	121.0
1991	.00	.00	.00	.00	.00	.00	.00	.00	.00	12.35	50.60	47.20	9.18	110.1
1992	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	22.08	23.53	3.80	45.6
1993	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	31.79	58.99	7.57	90.7
1994	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	15.24	19.12	2.86	34.3
1995	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	55.94	4.66	55.9
1996	68.51	.00	.00	.00	.00	.00	.00	57.73	83.37	65.82	62.48	60.90	33.23	398.8
1997	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1998	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1999	.00	.00	.00	.00	.00	.00	.00	1.51	104.05	63.91	89.29	132.21	32.58	390.9
MOY.	2.02	.00	.00	.00	.00	.00	.00	2.36	6.04	13.12	38.83	42.95	8.78	105.3
EC-T	10.68	.00	.00	.00	.00	.00	.00	10.73	21.82	24.32	39.73	38.55	9.14	109.7
C.VR	5.28	.00	.00	.00	.00	.00	.00	4.55	3.61	1.85	1.02	.90	1.04	1.0

COYNE ET BELLIER - BUREAU D INGENIEURS CONSEILS - PARIS - FRANCE

CALCUL EFFECTUE PAR LE PROGRAMME S I M - REV 2.10 2002/10/16 16H24M13

Simulation TOABRE

-----> &VR3_S FURNITURE ECOLOGICAL FLOW (M3/S)

ANNEE	J	F	M	A	M	J	J	A	S	O	N	D	MOY	CUM
1948	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	48.0
1949	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	48.0
1950	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	48.0
1951	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	48.0
1952	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	48.0
1953	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	48.0
1954	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	48.0
1955	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	48.0
1956	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	48.0
1957	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	48.0
1958	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	48.0
1959	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	48.0
1960	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	48.0
1961	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	48.0
1962	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	48.0
1963	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	48.0
1964	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	48.0
1965	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	48.0
1966	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	48.0
1967	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	48.0
1968	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	48.0
1969	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	48.0
1970	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	48.0
1971	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	48.0
1972	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	48.0
1973	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	48.0
1974	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	48.0
1975	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	48.0
1976	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	48.0
1977	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	48.0
1978	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	48.0
1979	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	48.0
1980	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	48.0
1981	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	48.0
1982	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	48.0
1983	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	48.0
1984	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	48.0
1985	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	48.0
1986	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	48.0
1987	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	48.0
1988	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	48.0
1989	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	48.0
1990	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	48.0
1991	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	48.0
1992	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	48.0
1993	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	48.0
1994	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	48.0
1995	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	48.0
1996	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	48.0
1997	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	48.0
1998	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	48.0
1999	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	48.0
MOY.	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	48.0
EC-T	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
C.VR	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0

COYNE ET BELLIER - BUREAU D INGENIEURS CONSEILS - PARIS - FRANCE

CALCUL EFFECTUE PAR LE PROGRAMME S I M - REV 2.10 2002/10/16 16H24M13

Simulation TOABRE

-----> FOURNIT DEM3 FURNITURE ECOLOGICAL FLOW (HM3)

ANNEE	J	F	M	A	M	J	J	A	S	O	N	D	MOY	CUM
1948	10.71	9.68	10.71	10.37	10.71	10.37	10.71	10.71	10.37	10.71	10.37	10.71	10.51	126.1
1949	10.71	9.68	10.71	10.37	10.71	10.37	10.71	10.71	10.37	10.71	10.37	10.71	10.51	126.1
1950	10.71	9.68	10.71	10.37	10.71	10.37	10.71	10.71	10.37	10.71	10.37	10.71	10.51	126.1
1951	10.71	9.68	10.71	10.37	10.71	10.37	10.71	10.71	10.37	10.71	10.37	10.71	10.51	126.1
1952	10.71	9.68	10.71	10.37	10.71	10.37	10.71	10.71	10.37	10.71	10.37	10.71	10.51	126.1
1953	10.71	9.68	10.71	10.37	10.71	10.37	10.71	10.71	10.37	10.71	10.37	10.71	10.51	126.1
1954	10.71	9.68	10.71	10.37	10.71	10.37	10.71	10.71	10.37	10.71	10.37	10.71	10.51	126.1
1955	10.71	9.68	10.71	10.37	10.71	10.37	10.71	10.71	10.37	10.71	10.37	10.71	10.51	126.1
1956	10.71	9.68	10.71	10.37	10.71	10.37	10.71	10.71	10.37	10.71	10.37	10.71	10.51	126.1
1957	10.71	9.68	10.71	10.37	10.71	10.37	10.71	10.71	10.37	10.71	10.37	10.71	10.51	126.1
1958	10.71	9.68	10.71	10.37	10.71	10.37	10.71	10.71	10.37	10.71	10.37	10.71	10.51	126.1
1959	10.71	9.68	10.71	10.37	10.71	10.37	10.71	10.71	10.37	10.71	10.37	10.71	10.51	126.1
1960	10.71	9.68	10.71	10.37	10.71	10.37	10.71	10.71	10.37	10.71	10.37	10.71	10.51	126.1
1961	10.71	9.68	10.71	10.37	10.71	10.37	10.71	10.71	10.37	10.71	10.37	10.71	10.51	126.1
1962	10.71	9.68	10.71	10.37	10.71	10.37	10.71	10.71	10.37	10.71	10.37	10.71	10.51	126.1
1963	10.71	9.68	10.71	10.37	10.71	10.37	10.71	10.71	10.37	10.71	10.37	10.71	10.51	126.1
1964	10.71	9.68	10.71	10.37	10.71	10.37	10.71	10.71	10.37	10.71	10.37	10.71	10.51	126.1
1965	10.71	9.68	10.71	10.37	10.71	10.37	10.71	10.71	10.37	10.71	10.37	10.71	10.51	126.1
1966	10.71	9.68	10.71	10.37	10.71	10.37	10.71	10.71	10.37	10.71	10.37	10.71	10.51	126.1
1967	10.71	9.68	10.71	10.37	10.71	10.37	10.71	10.71	10.37	10.71	10.37	10.71	10.51	126.1
1968	10.71	9.68	10.71	10.37	10.71	10.37	10.71	10.71	10.37	10.71	10.37	10.71	10.51	126.1
1969	10.71	9.68	10.71	10.37	10.71	10.37	10.71	10.71	10.37	10.71	10.37	10.71	10.51	126.1
1970	10.71	9.68	10.71	10.37	10.71	10.37	10.71	10.71	10.37	10.71	10.37	10.71	10.51	126.1
1971	10.71	9.68	10.71	10.37	10.71	10.37	10.71	10.71	10.37	10.71	10.37	10.71	10.51	126.1
1972	10.71	9.68	10.71	10.37	10.71	10.37	10.71	10.71	10.37	10.71	10.37	10.71	10.51	126.1
1973	10.71	9.68	10.71	10.37	10.71	10.37	10.71	10.71	10.37	10.71	10.37	10.71	10.51	126.1
1974	10.71	9.68	10.71	10.37	10.71	10.37	10.71	10.71	10.37	10.71	10.37	10.71	10.51	126.1
1975	10.71	9.68	10.71	10.37	10.71	10.37	10.71	10.71	10.37	10.71	10.37	10.71	10.51	126.1
1976	10.71	9.68	10.71	10.37	10.71	10.37	10.71	10.71	10.37	10.71	10.37	10.71	10.51	126.1
1977	10.71	9.68	10.71	10.37	10.71	10.37	10.71	10.71	10.37	10.71	10.37	10.71	10.51	126.1
1978	10.71	9.68	10.71	10.37	10.71	10.37	10.71	10.71	10.37	10.71	10.37	10.71	10.51	126.1
1979	10.71	9.68	10.71	10.37	10.71	10.37	10.71	10.71	10.37	10.71	10.37	10.71	10.51	126.1
1980	10.71	9.68	10.71	10.37	10.71	10.37	10.71	10.71	10.37	10.71	10.37	10.71	10.51	126.1
1981	10.71	9.68	10.71	10.37	10.71	10.37	10.71	10.71	10.37	10.71	10.37	10.71	10.51	126.1
1982	10.71	9.68	10.71	10.37	10.71	10.37	10.71	10.71	10.37	10.71	10.37	10.71	10.51	126.1
1983	10.71	9.68	10.71	10.37	10.71	10.37	10.71	10.71	10.37	10.71	10.37	10.71	10.51	126.1
1984	10.71	9.68	10.71	10.37	10.71	10.37	10.71	10.71	10.37	10.71	10.37	10.71	10.51	126.1
1985	10.71	9.68	10.71	10.37	10.71	10.37	10.71	10.71	10.37	10.71	10.37	10.71	10.51	126.1
1986	10.71	9.68	10.71	10.37	10.71	10.37	10.71	10.71	10.37	10.71	10.37	10.71	10.51	126.1
1987	10.71	9.68	10.71	10.37	10.71	10.37	10.71	10.71	10.37	10.71	10.37	10.71	10.51	126.1
1988	10.71	9.68	10.71	10.37	10.71	10.37	10.71	10.71	10.37	10.71	10.37	10.71	10.51	126.1
1989	10.71	9.68	10.71	10.37	10.71	10.37	10.71	10.71	10.37	10.71	10.37	10.71	10.51	126.1
1990	10.71	9.68	10.71	10.37	10.71	10.37	10.71	10.71	10.37	10.71	10.37	10.71	10.51	126.1
1991	10.71	9.68	10.71	10.37	10.71	10.37	10.71	10.71	10.37	10.71	10.37	10.71	10.51	126.1
1992	10.71	9.68	10.71	10.37	10.71	10.37	10.71	10.71	10.37	10.71	10.37	10.71	10.51	126.1
1993	10.71	9.68	10.71	10.37	10.71	10.37	10.71	10.71	10.37	10.71	10.37	10.71	10.51	126.1
1994	10.71	9.68	10.71	10.37	10.71	10.37	10.71	10.71	10.37	10.71	10.37	10.71	10.51	126.1
1995	10.71	9.68	10.71	10.37	10.71	10.37	10.71	10.71	10.37	10.71	10.37	10.71	10.51	126.1
1996	10.71	9.68	10.71	10.37	10.71	10.37	10.71	10.71	10.37	10.71	10.37	10.71	10.51	126.1
1997	10.71	9.68	10.71	10.37	10.71	10.37	10.71	10.71	10.37	10.71	10.37	10.71	10.51	126.1
1998	10.71	9.68	10.71	10.37	10.71	10.37	10.71	10.71	10.37	10.71	10.37	10.71	10.51	126.1
1999	10.71	9.68	10.71	10.37	10.71	10.37	10.71	10.71	10.37	10.71	10.37	10.71	10.51	126.1
MOY.	10.71	9.68	10.71	10.37	10.71	10.37	10.71	10.71	10.37	10.71	10.37	10.71	10.51	126.1
EC-T	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
C.VR	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0

COYNE ET BELLIER - BUREAU D INGENIEURS CONSEILS - PARIS - FRANCE

CALCUL EFFECTUE PAR LE PROGRAMME S I M - REV 2.10 2002/10/16 16H24M13

Simulation TOABRE

-----> DEFICIT DEM3 DEFICIT ECOLOGICAL FLOW (HM3)

ANNEE	J	F	M	A	M	J	J	A	S	O	N	D	MOY	CUM
1948	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1949	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1950	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1951	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1952	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1953	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1954	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1955	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1956	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1957	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1958	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1959	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1960	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1961	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1962	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1963	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1964	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1965	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1966	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1967	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1968	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1969	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1970	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1971	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1972	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1973	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1974	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1975	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1976	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1977	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1978	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1979	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1980	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1981	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1982	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1983	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1984	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1985	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1986	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1987	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1988	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1989	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1990	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1991	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1992	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1993	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1994	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1995	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1996	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1997	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1998	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1999	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
MOY.	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
EC-T	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
C.VR	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0

COYNE ET BELLIER - BUREAU D INGENIEURS CONSEILS - PARIS - FRANCE

CALCUL EFFECTUE PAR LE PROGRAMME S I M - REV 2.10 2002/10/16 16H24M13

Simulation TOABRE

-----> DEMANDE DEM4 DEMAND REGULATED FLOW (HM3)

ANNEE	J	F	M	A	M	J	J	A	S	O	N	D	MOY	CUM
1948	150.72	136.14	150.72	145.86	150.72	145.86	.01	.01	.01	.01	.01	.01	73.34	880.0
1949	150.72	136.14	150.72	145.86	150.72	145.86	.01	.01	.01	.01	.01	.01	73.34	880.0
1950	150.72	136.14	150.72	145.86	150.72	145.86	.01	.01	.01	.01	.01	.01	73.34	880.0
1951	150.72	136.14	150.72	145.86	150.72	145.86	.01	.01	.01	.01	.01	.01	73.34	880.0
1952	150.72	136.14	150.72	145.86	150.72	145.86	.01	.01	.01	.01	.01	.01	73.34	880.0
1953	150.72	136.14	150.72	145.86	150.72	145.86	.01	.01	.01	.01	.01	.01	73.34	880.0
1954	150.72	136.14	150.72	145.86	150.72	145.86	.01	.01	.01	.01	.01	.01	73.34	880.0
1955	150.72	136.14	150.72	145.86	150.72	145.86	.01	.01	.01	.01	.01	.01	73.34	880.0
1956	150.72	136.14	150.72	145.86	150.72	145.86	.01	.01	.01	.01	.01	.01	73.34	880.0
1957	150.72	136.14	150.72	145.86	150.72	145.86	.01	.01	.01	.01	.01	.01	73.34	880.0
1958	150.72	136.14	150.72	145.86	150.72	145.86	.01	.01	.01	.01	.01	.01	73.34	880.0
1959	150.72	136.14	150.72	145.86	150.72	145.86	.01	.01	.01	.01	.01	.01	73.34	880.0
1960	150.72	136.14	150.72	145.86	150.72	145.86	.01	.01	.01	.01	.01	.01	73.34	880.0
1961	150.72	136.14	150.72	145.86	150.72	145.86	.01	.01	.01	.01	.01	.01	73.34	880.0
1962	150.72	136.14	150.72	145.86	150.72	145.86	.01	.01	.01	.01	.01	.01	73.34	880.0
1963	150.72	136.14	150.72	145.86	150.72	145.86	.01	.01	.01	.01	.01	.01	73.34	880.0
1964	150.72	136.14	150.72	145.86	150.72	145.86	.01	.01	.01	.01	.01	.01	73.34	880.0
1965	150.72	136.14	150.72	145.86	150.72	145.86	.01	.01	.01	.01	.01	.01	73.34	880.0
1966	150.72	136.14	150.72	145.86	150.72	145.86	.01	.01	.01	.01	.01	.01	73.34	880.0
1967	150.72	136.14	150.72	145.86	150.72	145.86	.01	.01	.01	.01	.01	.01	73.34	880.0
1968	150.72	136.14	150.72	145.86	150.72	145.86	.01	.01	.01	.01	.01	.01	73.34	880.0
1969	150.72	136.14	150.72	145.86	150.72	145.86	.01	.01	.01	.01	.01	.01	73.34	880.0
1970	150.72	136.14	150.72	145.86	150.72	145.86	.01	.01	.01	.01	.01	.01	73.34	880.0
1971	150.72	136.14	150.72	145.86	150.72	145.86	.01	.01	.01	.01	.01	.01	73.34	880.0
1972	150.72	136.14	150.72	145.86	150.72	145.86	.01	.01	.01	.01	.01	.01	73.34	880.0
1973	150.72	136.14	150.72	145.86	150.72	145.86	.01	.01	.01	.01	.01	.01	73.34	880.0
1974	150.72	136.14	150.72	145.86	150.72	145.86	.01	.01	.01	.01	.01	.01	73.34	880.0
1975	150.72	136.14	150.72	145.86	150.72	145.86	.01	.01	.01	.01	.01	.01	73.34	880.0
1976	150.72	136.14	150.72	145.86	150.72	145.86	.01	.01	.01	.01	.01	.01	73.34	880.0
1977	150.72	136.14	150.72	145.86	150.72	145.86	.01	.01	.01	.01	.01	.01	73.34	880.0
1978	150.72	136.14	150.72	145.86	150.72	145.86	.01	.01	.01	.01	.01	.01	73.34	880.0
1979	150.72	136.14	150.72	145.86	150.72	145.86	.01	.01	.01	.01	.01	.01	73.34	880.0
1980	150.72	136.14	150.72	145.86	150.72	145.86	.01	.01	.01	.01	.01	.01	73.34	880.0
1981	150.72	136.14	150.72	145.86	150.72	145.86	.01	.01	.01	.01	.01	.01	73.34	880.0
1982	150.72	136.14	150.72	145.86	150.72	145.86	.01	.01	.01	.01	.01	.01	73.34	880.0
1983	150.72	136.14	150.72	145.86	150.72	145.86	.01	.01	.01	.01	.01	.01	73.34	880.0
1984	150.72	136.14	150.72	145.86	150.72	145.86	.01	.01	.01	.01	.01	.01	73.34	880.0
1985	150.72	136.14	150.72	145.86	150.72	145.86	.01	.01	.01	.01	.01	.01	73.34	880.0
1986	150.72	136.14	150.72	145.86	150.72	145.86	.01	.01	.01	.01	.01	.01	73.34	880.0
1987	150.72	136.14	150.72	145.86	150.72	145.86	.01	.01	.01	.01	.01	.01	73.34	880.0
1988	150.72	136.14	150.72	145.86	150.72	145.86	.01	.01	.01	.01	.01	.01	73.34	880.0
1989	150.72	136.14	150.72	145.86	150.72	145.86	.01	.01	.01	.01	.01	.01	73.34	880.0
1990	150.72	136.14	150.72	145.86	150.72	145.86	.01	.01	.01	.01	.01	.01	73.34	880.0
1991	150.72	136.14	150.72	145.86	150.72	145.86	.01	.01	.01	.01	.01	.01	73.34	880.0
1992	150.72	136.14	150.72	145.86	150.72	145.86	.01	.01	.01	.01	.01	.01	73.34	880.0
1993	150.72	136.14	150.72	145.86	150.72	145.86	.01	.01	.01	.01	.01	.01	73.34	880.0
1994	150.72	136.14	150.72	145.86	150.72	145.86	.01	.01	.01	.01	.01	.01	73.34	880.0
1995	150.72	136.14	150.72	145.86	150.72	145.86	.01	.01	.01	.01	.01	.01	73.34	880.0
1996	150.72	136.14	150.72	145.86	150.72	145.86	.01	.01	.01	.01	.01	.01	73.34	880.0
1997	150.72	136.14	150.72	145.86	150.72	145.86	.01	.01	.01	.01	.01	.01	73.34	880.0
1998	150.72	136.14	150.72	145.86	150.72	145.86	.01	.01	.01	.01	.01	.01	73.34	880.0
1999	150.72	136.14	150.72	145.86	150.72	145.86	.01	.01	.01	.01	.01	.01	73.34	880.0
MOY.	150.72	136.14	150.72	145.86	150.72	145.86	.01	.01	.01	.01	.01	.01	73.34	880.1
EC-T	.02	.03	.02	.03	.02	.03	.00	.00	.00	.00	.00	.00	.00	.0
C.VR	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0

COYNE ET BELLIER - BUREAU D INGENIEURS CONSEILS - PARIS - FRANCE

CALCUL EFFECTUE PAR LE PROGRAMME S I M - REV 2.10 2002/10/16 16H24M13

Simulation TOABRE

-----> FOURNIT DEM4 FURNITURE REGULATED FLOW (HM3)

ANNEE	J	F	M	A	M	J	J	A	S	O	N	D	MOY	CUM
1948	150.72	136.14	150.72	145.86	35.74	25.39	.01	.01	.01	.01	.01	.01	53.72	644.6
1949	150.72	136.14	150.72	145.86	150.72	145.86	.01	.01	.01	.01	.01	.01	73.34	880.0
1950	150.72	136.14	150.72	145.86	150.72	145.86	.01	.01	.01	.01	.01	.01	73.34	880.0
1951	150.72	136.14	150.72	145.86	150.72	145.86	.01	.01	.01	.01	.01	.01	73.34	880.0
1952	150.72	136.14	150.72	145.86	150.72	145.86	.01	.01	.01	.01	.01	.01	73.34	880.0
1953	150.72	136.14	150.72	145.86	150.72	145.86	.01	.01	.01	.01	.01	.01	73.34	880.0
1954	150.72	136.14	150.72	145.86	150.72	145.86	.01	.01	.01	.01	.01	.01	73.34	880.0
1955	150.72	136.14	150.72	145.86	150.72	145.86	.01	.01	.01	.01	.01	.01	73.34	880.0
1956	150.72	136.14	150.72	145.86	150.72	145.86	.01	.01	.01	.01	.01	.01	73.34	880.0
1957	150.72	136.14	150.72	145.86	150.72	145.86	.01	.01	.01	.01	.01	.01	73.34	880.0
1958	150.72	136.14	150.72	145.86	150.72	145.86	.01	.01	.01	.01	.01	.01	73.34	880.0
1959	150.72	136.14	150.72	145.86	150.72	145.86	.01	.01	.01	.01	.01	.01	73.34	880.0
1960	150.72	136.14	150.72	145.86	150.72	145.86	.01	.01	.01	.01	.01	.01	73.34	880.0
1961	150.72	136.14	150.72	145.86	150.72	145.86	.01	.01	.01	.01	.01	.01	73.34	880.0
1962	150.72	136.14	150.72	145.86	150.72	145.86	.01	.01	.01	.01	.01	.01	73.34	880.0
1963	150.72	136.14	150.72	145.86	150.72	145.86	.01	.01	.01	.01	.01	.01	73.34	880.0
1964	150.72	136.14	150.72	145.86	150.72	145.86	.01	.01	.01	.01	.01	.01	73.34	880.0
1965	150.72	136.14	150.72	145.86	150.72	145.86	.01	.01	.01	.01	.01	.01	73.34	880.0
1966	150.72	136.14	150.72	145.86	150.72	145.86	.01	.01	.01	.01	.01	.01	73.34	880.0
1967	150.72	136.14	150.72	145.86	150.72	145.86	.01	.01	.01	.01	.01	.01	73.34	880.0
1968	150.72	136.14	150.72	145.86	150.72	145.86	.01	.01	.01	.01	.01	.01	73.34	880.0
1969	150.72	136.14	150.72	145.86	150.72	145.86	.01	.01	.01	.01	.01	.01	73.34	880.0
1970	150.72	136.14	150.72	145.86	150.72	145.86	.01	.01	.01	.01	.01	.01	73.34	880.0
1971	150.72	136.14	150.72	145.86	150.72	145.86	.01	.01	.01	.01	.01	.01	73.34	880.0
1972	150.72	136.14	150.72	145.86	150.72	145.86	.01	.01	.01	.01	.01	.01	73.34	880.0
1973	150.72	136.14	150.72	145.86	150.72	145.86	.01	.01	.01	.01	.01	.01	73.34	880.0
1974	150.72	136.14	150.72	145.86	150.72	145.86	.01	.01	.01	.01	.01	.01	73.34	880.0
1975	150.72	136.14	150.72	145.86	150.72	145.86	.01	.01	.01	.01	.01	.01	73.34	880.0
1976	150.72	136.14	150.72	145.86	150.72	145.86	.01	.01	.01	.01	.01	.01	73.34	880.0
1977	150.72	136.14	150.72	145.86	150.72	86.31	.01	.01	.01	.01	.01	.01	68.38	820.5
1978	150.72	136.14	150.72	145.86	150.72	145.86	.01	.01	.01	.01	.01	.01	73.34	880.0
1979	150.72	136.14	150.72	145.86	150.72	145.86	.01	.01	.01	.01	.01	.01	73.34	880.0
1980	150.72	136.14	150.72	145.86	150.72	145.86	.01	.01	.01	.01	.01	.01	73.34	880.0
1981	150.72	136.14	150.72	145.86	150.72	145.86	.01	.01	.01	.01	.01	.01	73.34	880.0
1982	150.72	136.14	150.72	145.86	150.72	145.86	.01	.01	.01	.01	.01	.01	73.34	880.0
1983	150.72	136.14	150.72	145.86	150.72	145.86	.01	.01	.01	.01	.01	.01	73.34	880.0
1984	150.72	136.14	150.72	145.86	150.72	145.86	.01	.01	.01	.01	.01	.01	73.34	880.0
1985	150.72	136.14	150.72	145.86	150.72	145.86	.01	.01	.01	.01	.01	.01	73.34	880.0
1986	150.72	136.14	150.72	145.86	150.72	145.86	.01	.01	.01	.01	.01	.01	73.34	880.0
1987	150.72	136.14	150.72	145.86	150.72	145.86	.01	.01	.01	.01	.01	.01	73.34	880.0
1988	150.72	136.14	150.72	145.86	150.72	145.86	.01	.01	.01	.01	.01	.01	73.34	880.0
1989	150.72	136.14	150.72	145.86	150.72	145.86	.01	.01	.01	.01	.01	.01	73.34	880.0
1990	150.72	136.14	150.72	145.86	150.72	145.86	.01	.01	.01	.01	.01	.01	73.34	880.0
1991	150.72	136.14	150.72	145.86	150.72	145.86	.01	.01	.01	.01	.01	.01	73.34	880.0
1992	150.72	136.14	150.72	145.86	150.72	145.86	.01	.01	.01	.01	.01	.01	73.34	880.0
1993	150.72	136.14	150.72	145.86	150.72	145.86	.01	.01	.01	.01	.01	.01	73.34	880.0
1994	150.72	136.14	150.72	145.86	150.72	145.86	.01	.01	.01	.01	.01	.01	73.34	880.0
1995	150.72	136.14	150.72	145.86	150.72	145.86	.01	.01	.01	.01	.01	.01	73.34	880.0
1996	150.72	136.14	150.72	145.86	150.72	145.86	.01	.01	.01	.01	.01	.01	73.34	880.0
1997	150.72	136.14	150.72	145.86	150.72	145.86	.01	.01	.01	.01	.01	.01	73.34	880.0
1998	150.72	136.14	150.72	117.10	44.47	108.79	.01	.01	.01	.01	.01	.01	59.00	707.9
1999	150.72	136.14	150.72	145.86	150.72	145.86	.01	.01	.01	.01	.01	.01	73.34	880.0
MOY.	150.72	136.14	150.72	145.31	146.46	141.69	.01	.01	.01	.01	.01	.01	72.59	871.1
EC-T	.02	.03	.02	3.99	21.50	19.06	.00	.00	.00	.00	.00	.00	3.39	40.7
C.VR	.00	.00	.00	.03	.15	.13	.00	.00	.00	.00	.00	.00	.05	.0

COYNE ET BELLIER - BUREAU D INGENIEURS CONSEILS - PARIS - FRANCE

CALCUL EFFECTUE PAR LE PROGRAMME S I M - REV 2.10 2002/10/16 16H24M13

Simulation TOABRE

-----> &VR_S FURNITURE REGULATED FLOW (M3/S)

ANNEE	J	F	M	A	M	J	J	A	S	O	N	D	MOY	CUM
1948	56.27	56.27	56.27	56.27	13.34	9.80	.00	.00	.00	.00	.00	.00	20.69	248.2
1949	56.27	56.27	56.27	56.27	56.27	56.27	.00	.00	.00	.00	.00	.00	28.14	337.6
1950	56.27	56.27	56.27	56.27	56.27	56.27	.00	.00	.00	.00	.00	.00	28.14	337.6
1951	56.27	56.27	56.27	56.27	56.27	56.27	.00	.00	.00	.00	.00	.00	28.14	337.6
1952	56.27	56.27	56.27	56.27	56.27	56.27	.00	.00	.00	.00	.00	.00	28.14	337.6
1953	56.27	56.27	56.27	56.27	56.27	56.27	.00	.00	.00	.00	.00	.00	28.14	337.6
1954	56.27	56.27	56.27	56.27	56.27	56.27	.00	.00	.00	.00	.00	.00	28.14	337.6
1955	56.27	56.27	56.27	56.27	56.27	56.27	.00	.00	.00	.00	.00	.00	28.14	337.6
1956	56.27	56.27	56.27	56.27	56.27	56.27	.00	.00	.00	.00	.00	.00	28.14	337.6
1957	56.27	56.27	56.27	56.27	56.27	56.27	.00	.00	.00	.00	.00	.00	28.14	337.6
1958	56.27	56.27	56.27	56.27	56.27	56.27	.00	.00	.00	.00	.00	.00	28.14	337.6
1959	56.27	56.27	56.27	56.27	56.27	56.27	.00	.00	.00	.00	.00	.00	28.14	337.6
1960	56.27	56.27	56.27	56.27	56.27	56.27	.00	.00	.00	.00	.00	.00	28.14	337.6
1961	56.27	56.27	56.27	56.27	56.27	56.27	.00	.00	.00	.00	.00	.00	28.14	337.6
1962	56.27	56.27	56.27	56.27	56.27	56.27	.00	.00	.00	.00	.00	.00	28.14	337.6
1963	56.27	56.27	56.27	56.27	56.27	56.27	.00	.00	.00	.00	.00	.00	28.14	337.6
1964	56.27	56.27	56.27	56.27	56.27	56.27	.00	.00	.00	.00	.00	.00	28.14	337.6
1965	56.27	56.27	56.27	56.27	56.27	56.27	.00	.00	.00	.00	.00	.00	28.14	337.6
1966	56.27	56.27	56.27	56.27	56.27	56.27	.00	.00	.00	.00	.00	.00	28.14	337.6
1967	56.27	56.27	56.27	56.27	56.27	56.27	.00	.00	.00	.00	.00	.00	28.14	337.6
1968	56.27	56.27	56.27	56.27	56.27	56.27	.00	.00	.00	.00	.00	.00	28.14	337.6
1969	56.27	56.27	56.27	56.27	56.27	56.27	.00	.00	.00	.00	.00	.00	28.14	337.6
1970	56.27	56.27	56.27	56.27	56.27	56.27	.00	.00	.00	.00	.00	.00	28.14	337.6
1971	56.27	56.27	56.27	56.27	56.27	56.27	.00	.00	.00	.00	.00	.00	28.14	337.6
1972	56.27	56.27	56.27	56.27	56.27	56.27	.00	.00	.00	.00	.00	.00	28.14	337.6
1973	56.27	56.27	56.27	56.27	56.27	56.27	.00	.00	.00	.00	.00	.00	28.14	337.6
1974	56.27	56.27	56.27	56.27	56.27	56.27	.00	.00	.00	.00	.00	.00	28.14	337.6
1975	56.27	56.27	56.27	56.27	56.27	56.27	.00	.00	.00	.00	.00	.00	28.14	337.6
1976	56.27	56.27	56.27	56.27	56.27	56.27	.00	.00	.00	.00	.00	.00	28.14	337.6
1977	56.27	56.27	56.27	56.27	56.27	33.30	.00	.00	.00	.00	.00	.00	26.22	314.6
1978	56.27	56.27	56.27	56.27	56.27	56.27	.00	.00	.00	.00	.00	.00	28.14	337.6
1979	56.27	56.27	56.27	56.27	56.27	56.27	.00	.00	.00	.00	.00	.00	28.14	337.6
1980	56.27	56.27	56.27	56.27	56.27	56.27	.00	.00	.00	.00	.00	.00	28.14	337.6
1981	56.27	56.27	56.27	56.27	56.27	56.27	.00	.00	.00	.00	.00	.00	28.14	337.6
1982	56.27	56.27	56.27	56.27	56.27	56.27	.00	.00	.00	.00	.00	.00	28.14	337.6
1983	56.27	56.27	56.27	56.27	56.27	56.27	.00	.00	.00	.00	.00	.00	28.14	337.6
1984	56.27	56.27	56.27	56.27	56.27	56.27	.00	.00	.00	.00	.00	.00	28.14	337.6
1985	56.27	56.27	56.27	56.27	56.27	56.27	.00	.00	.00	.00	.00	.00	28.14	337.6
1986	56.27	56.27	56.27	56.27	56.27	56.27	.00	.00	.00	.00	.00	.00	28.14	337.6
1987	56.27	56.27	56.27	56.27	56.27	56.27	.00	.00	.00	.00	.00	.00	28.14	337.6
1988	56.27	56.27	56.27	56.27	56.27	56.27	.00	.00	.00	.00	.00	.00	28.14	337.6
1989	56.27	56.27	56.27	56.27	56.27	56.27	.00	.00	.00	.00	.00	.00	28.14	337.6
1990	56.27	56.27	56.27	56.27	56.27	56.27	.00	.00	.00	.00	.00	.00	28.14	337.6
1991	56.27	56.27	56.27	56.27	56.27	56.27	.00	.00	.00	.00	.00	.00	28.14	337.6
1992	56.27	56.27	56.27	56.27	56.27	56.27	.00	.00	.00	.00	.00	.00	28.14	337.6
1993	56.27	56.27	56.27	56.27	56.27	56.27	.00	.00	.00	.00	.00	.00	28.14	337.6
1994	56.27	56.27	56.27	56.27	56.27	56.27	.00	.00	.00	.00	.00	.00	28.14	337.6
1995	56.27	56.27	56.27	56.27	56.27	56.27	.00	.00	.00	.00	.00	.00	28.14	337.6
1996	56.27	56.27	56.27	56.27	56.27	56.27	.00	.00	.00	.00	.00	.00	28.14	337.6
1997	56.27	56.27	56.27	56.27	56.27	56.27	.00	.00	.00	.00	.00	.00	28.14	337.6
1998	56.27	56.27	56.27	45.18	16.60	41.97	.00	.00	.00	.00	.00	.00	22.72	272.5
1999	56.27	56.27	56.27	56.27	56.27	56.27	.00	.00	.00	.00	.00	.00	28.14	337.6
MOY.	56.27	56.27	56.27	56.06	54.68	54.66	.00	.00	.00	.00	.00	.00	27.85	334.2
EC-T	.00	.00	.00	1.54	8.03	7.35	.00	.00	.00	.00	.00	.00	1.29	15.4
C.VR	.00	.00	.00	.03	.15	.13	.00	.00	.00	.00	.00	.00	.05	.0

COYNE ET BELLIER - BUREAU D INGENIEURS CONSEILS - PARIS - FRANCE

CALCUL EFFECTUE PAR LE PROGRAMME S I M - REV 2.10 2002/10/16 16H24M13

Simulation TOABRE

-----> DEFICIT DEM4 DEFICIT REGULATED FLOW (HM3)

ANNEE	J	F	M	A	M	J	J	A	S	O	N	D	MOY	CUM
1948	.00	.00	.00	.00	114.97	120.47	.00	.00	.00	.00	.00	.00	19.62	235.4
1949	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1950	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1951	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1952	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1953	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1954	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1955	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1956	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1957	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1958	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1959	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1960	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1961	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1962	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1963	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1964	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1965	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1966	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1967	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1968	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1969	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1970	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1971	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1972	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1973	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1974	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1975	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1976	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1977	.00	.00	.00	.00	.00	59.55	.00	.00	.00	.00	.00	.00	4.96	59.5
1978	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1979	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1980	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1981	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1982	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1983	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1984	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1985	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1986	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1987	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1988	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1989	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1990	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1991	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1992	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1993	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1994	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1995	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1996	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1997	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1998	.00	.00	.00	28.76	106.25	37.07	.00	.00	.00	.00	.00	.00	14.34	172.0
1999	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
MOY.	.00	.00	.00	.55	4.25	4.17	.00	.00	.00	.00	.00	.00	.75	9.0
EC-T	.00	.00	.00	3.99	21.50	19.06	.00	.00	.00	.00	.00	.00	3.39	40.7
C.VR	.00	.00	.00	7.21	5.05	4.57	.00	.00	.00	.00	.00	.00	4.53	4.5

COYNE ET BELLIER - BUREAU D INGENIEURS CONSEILS - PARIS - FRANCE

CALCUL EFFECTUE PAR LE PROGRAMME S I M - REV 2.10 2002/10/16 16H24M13

Simulation TOABRE

-----> &DEF_S DEFICIT REGULATED FLOW (M3/S)

ANNEE	J	F	M	A	M	J	J	A	S	O	N	D	MOY	CUM
1948	.00	.00	.00	.00	42.93	46.48	.00	.00	.00	.00	.00	.00	7.45	89.4
1949	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1950	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1951	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1952	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1953	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1954	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1955	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1956	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1957	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1958	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1959	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1960	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1961	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1962	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1963	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1964	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1965	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1966	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1967	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1968	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1969	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1970	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1971	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1972	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1973	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1974	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1975	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1976	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1977	.00	.00	.00	.00	.00	22.97	.00	.00	.00	.00	.00	.00	1.91	22.9
1978	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1979	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1980	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1981	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1982	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1983	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1984	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1985	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1986	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1987	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1988	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1989	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1990	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1991	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1992	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1993	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1994	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1995	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1996	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1997	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
1998	.00	.00	.00	11.09	39.67	14.30	.00	.00	.00	.00	.00	.00	5.42	65.0
1999	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
MOY.	.00	.00	.00	.21	1.59	1.61	.00	.00	.00	.00	.00	.00	.28	3.4
EC-T	.00	.00	.00	1.54	8.03	7.35	.00	.00	.00	.00	.00	.00	1.29	15.4
C.VR	.00	.00	.00	7.21	5.05	4.57	.00	.00	.00	.00	.00	.00	4.52	4.5

APPENDIX A2 - Output Listings from the SIM software

Case NWL 95 / MOL 50 – Qr 99% - Scenario D2

(14 pages)

APPENDIX B - HEC-5 Simulations Results and Analysis

1. Results

The rough results given by the HEC-5 simulations for a 99.6% volumetric reliability are:

Yield of Global Canal System : Gatun deepened, Madden, Indio and Toabre Reservoirs
Increase rate from Current Yield (Rate 1.0 = 2 939 MCM/y or 38.68 lockages/day, average Demand of years 1993-1997 with a 99.6% reliability)

Toabre	Toabre – Indio Tunnel Diameter (m)					
NWL/MOL	3	4	4.5	5	5.5	6
90 – 50	1.740	1.900	1.925	1.935	1.935	1.935
95 – 50	1.760	1.935	1.975	1.980	1.980	1.980
95 – 55	1.760	1.938	1.970	1.970	1.974	1.977
100 – 50	1.780	1.975	2.025	2.032	2.036	2.036
100 – 55	1.780	1.975	2.020	2.025	2.030	2.025
100 – 60	1.780	1.975	2.015	2.015	2.015	2.015

Yield of Global Canal System : Gatun deepened, Madden, Indio and Toabre Reservoirs
expressed in MCM/y

Toabre	Toabre – Indio Tunnel Diameter (m)					
NWL/MOL	3	4	4.5	5	5.5	6
90 – 50	5 114	5 584	5 658	5 687	5 687	5 687
95 – 50	5 173	5 687	5 804	5 819	5 819	5 819
95 – 55	5 173	5 696	5 790	5 790	5 801	5 810
100 – 50	5 231	5 804	5 952	5 972	5 984	5 984
100 – 55	5 231	5 804	5 937	5 952	5 966	5 952
100 – 60	5 231	5 804	5 922	5 922	5 922	5 922

Yield of Global Canal System : Gatun deepened, Madden, Indio and Toabre Reservoirs
expressed in equivalent lockages / day

Toabre	Toabre – Indio Tunnel Diameter (m)					
NWL/MOL	3	4	4.5	5	5.5	6
90 – 50	67.30	73.49	74.46	74.85	74.85	74.85
95 – 50	68.08	74.85	76.39	76.59	76.59	76.59
95 – 55	68.08	74.96	76.20	76.20	76.35	76.47
100 – 50	68.85	76.39	78.33	78.60	78.75	78.75
100 – 55	68.85	76.39	78.13	78.33	78.52	78.33
100 – 60	68.85	76.39	77.94	77.94	77.94	77.94

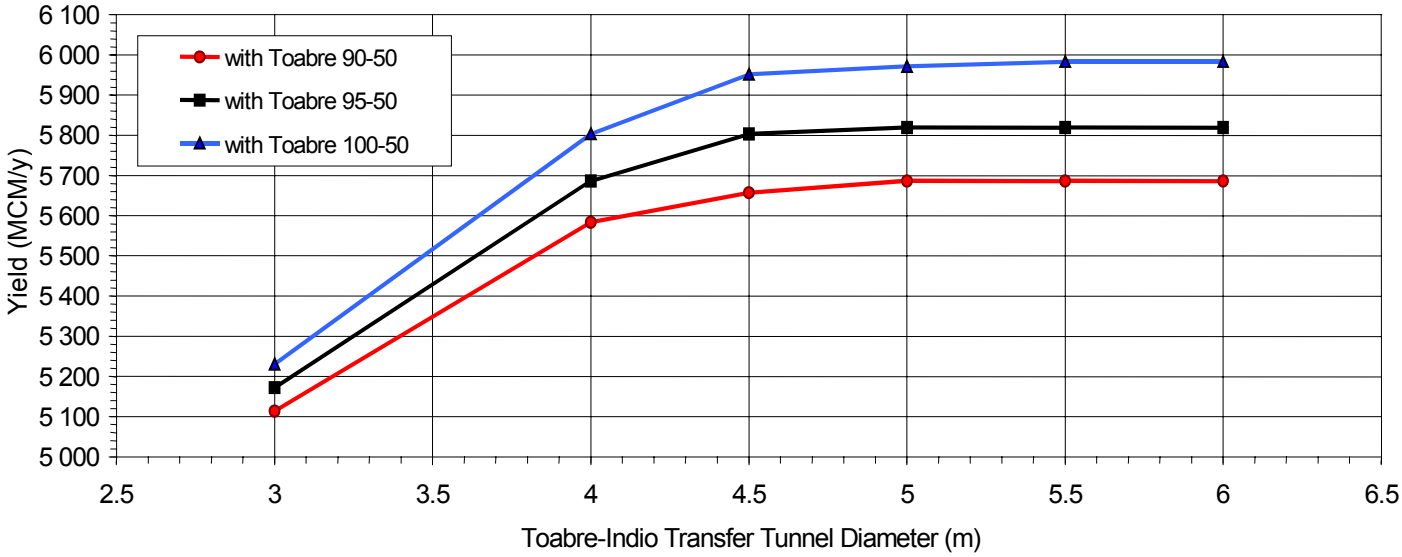
Yield attributed to Toabre Project
expressed in MCM / year

Toabre	Toabre – Indio Tunnel Diameter (m)					
NWL/MOL	3	4	4.5	5	5.5	6
90 – 50	521	991	1 065	1 094	1 094	1 094
95 – 50	580	1 094	1 211	1 226	1 226	1 226
95 – 55	580	1 103	1 197	1 197	1 208	1 217
100 – 50	638	1 211	1 359	1 379	1 391	1 391
100 – 55	638	1 211	1 344	1 359	1 373	1 359
100 – 60	638	1 211	1 329	1 329	1 329	1 329

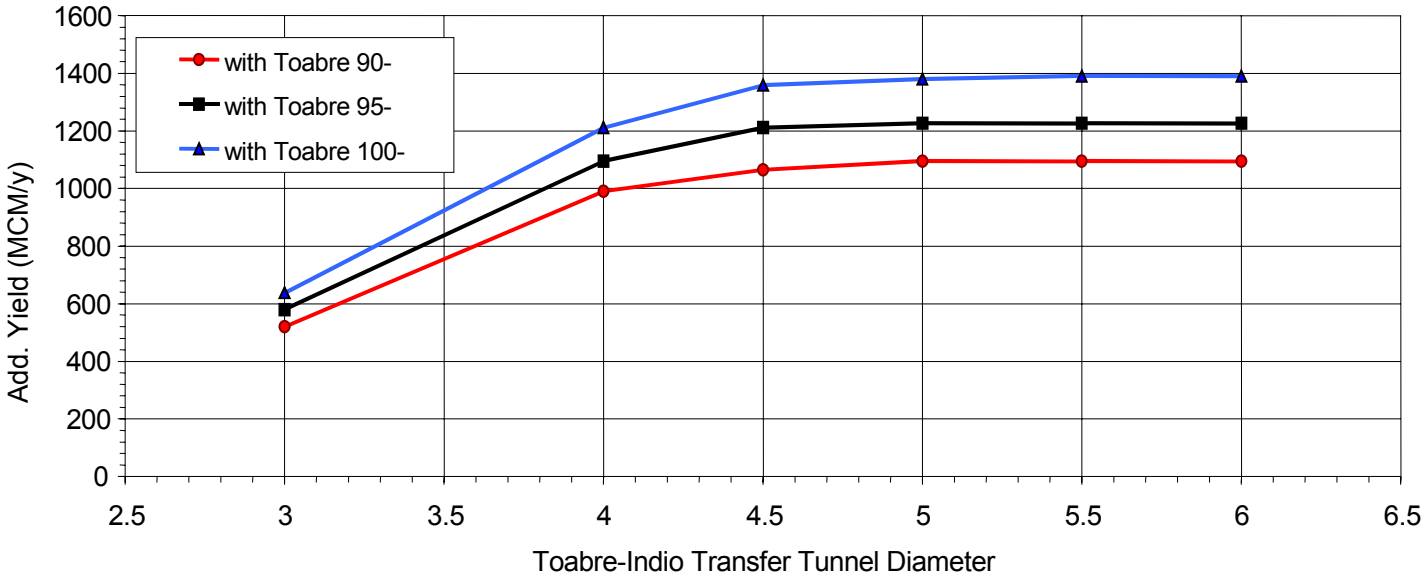
Yield attributed to Toabre Project
expressed in equivalent lockages / day

Toabre	Toabre – Indio Tunnel Diameter (m)					
NWL/MOL	3	4	4.5	5	5.5	6
90 – 50	6.9	13.0	14.0	14.4	14.4	14.4
95 – 50	7.6	14.4	15.9	16.1	16.1	16.1
95 – 55	7.6	14.5	15.8	15.8	15.9	16.0
100 – 50	8.4	15.9	17.9	18.2	18.3	18.3
100 – 55	8.4	15.9	17.7	17.9	18.1	17.9
100 – 60	8.4	15.9	17.5	17.5	17.5	17.5

Yield (with 99.6% reliability) of Panama Canal System



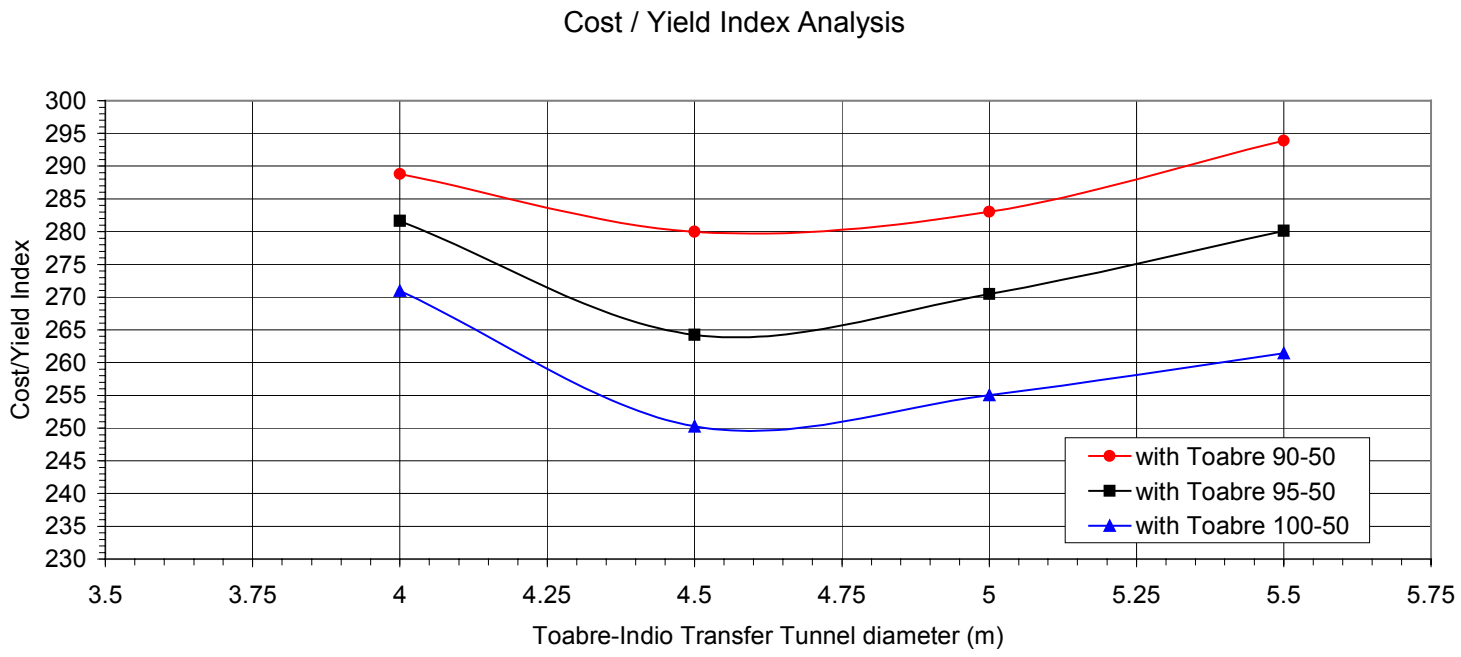
Yield attributed to Toabre Project



2. Preliminary Analysis on Cost/Yield Index

The Total Cost (excluding Contingencies and Engineering & Administration Costs) of each alternative is established in the corresponding chapter of the volume IIB:

tunnel diameter (m)	4	4.5	5	5.5
Toabre 90-50				
Yield (MCM/y)	991	1 065	1 094	1 094
Total Cost (MUSD)	286	298	310	322
Cost/Yield Index	0.289	0.280	0.283	0.294
Toabre 95-50				
Yield (MCM/y)	1 094	1 211	1 226	1 226
Total Cost (MUSD)	308	320	332	344
Cost/Yield Index	0.282	0.264	0.270	0.280
Toabre 100-50				
Yield (MCM/y)	1 211	1 359	1 379	1 391
Total Cost (MUSD)	328	340	352	364
Cost/Yield Index	0.271	0.250	0.255	0.261

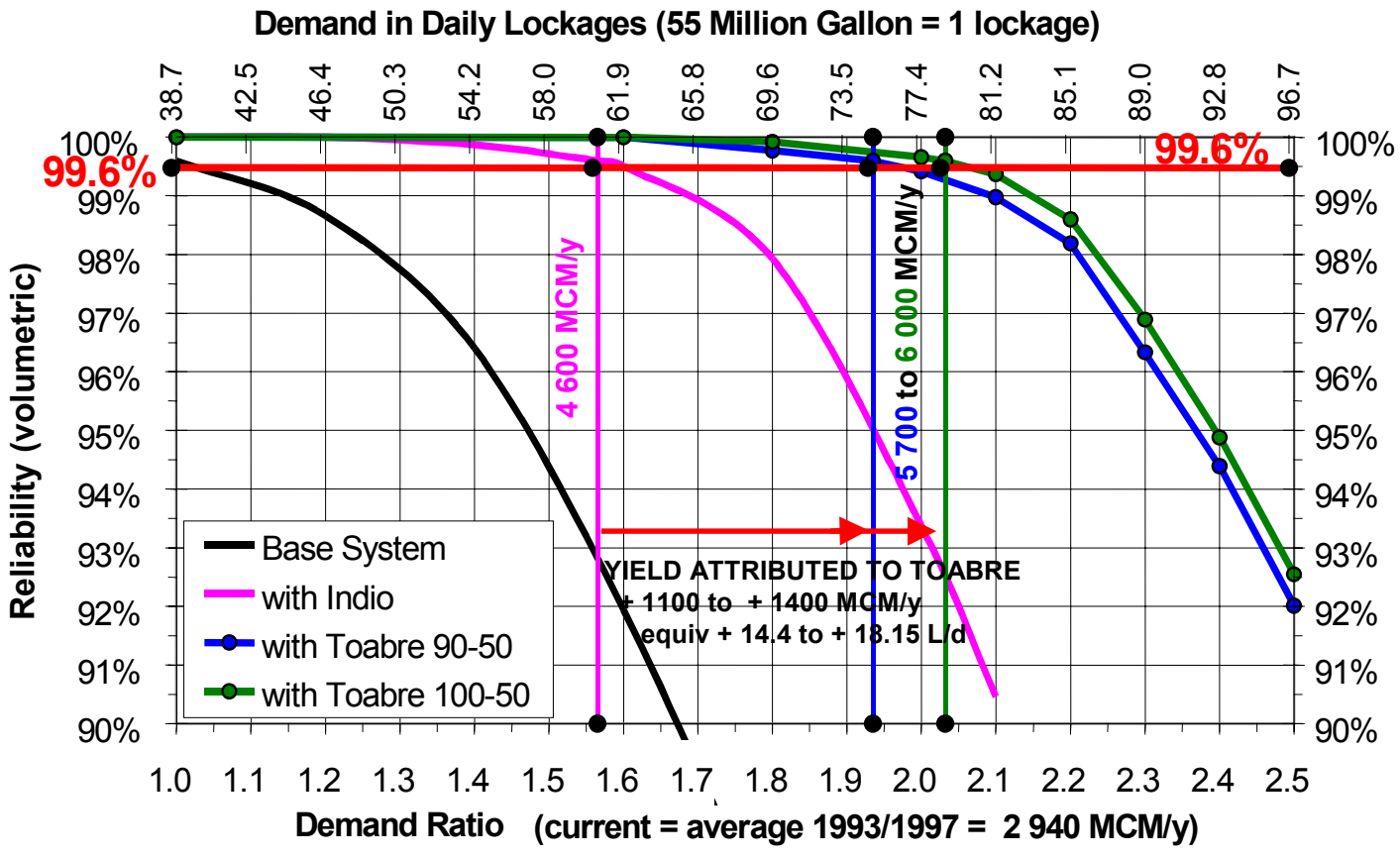


The "optimum" of the Cost / Yield Index is between 4.5 m and 5 m for the three alternatives reservoirs of Toabre. To anticipate a possible slight increase of the yield with an improved operation of the Toabre reservoir (not yet performed) the 5 m diameter option (with only a slightly higher cost / yield index) has been selected for the next step of the studies for the three alternatives reservoirs.

3. Variation of Volumetric Reliability for Panama Canal with Toabre Project

Results with Transfer Tunnel Toabre-Indio 5m and Transfer Tunnels Indio-Gatun 4.5m

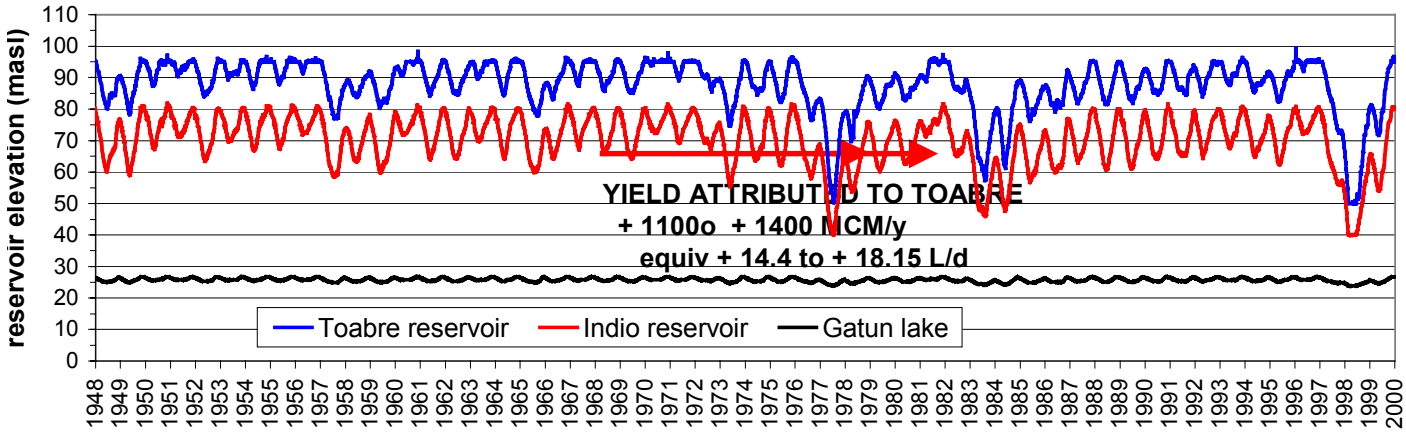
Demand Ratio	Base System	Gatun deepened + Madden + Indio 80-40 (2)	(2) + Toabre 90-50	(2) + Toabre 95-50	(2) + Toabre 100-50
1	**99.6%**	100.0%	100.0%	100.0%	100.0%
1.2	98.7%	100.0%			
1.4	96.4%	99.9%			
1.565	92.8%	**99.6%**			
1.6	91.9%	99.5%	100.0%	100.0%	100.0%
1.8	86.4%	97.9%	99.8%	99.8%	99.9%
1.935			**99.6%**		
1.98				**99.6%**	
2		93.4%	99.4%	99.5%	99.7%
2.03					**99.6%**
2.1		90.5%	99.0%	99.2%	99.4%
2.2			98.2%	98.4%	98.6%
2.3			96.3%	96.6%	96.9%
2.4			94.4%	94.7%	94.9%
2.5			92.0%	92.3%	92.6%



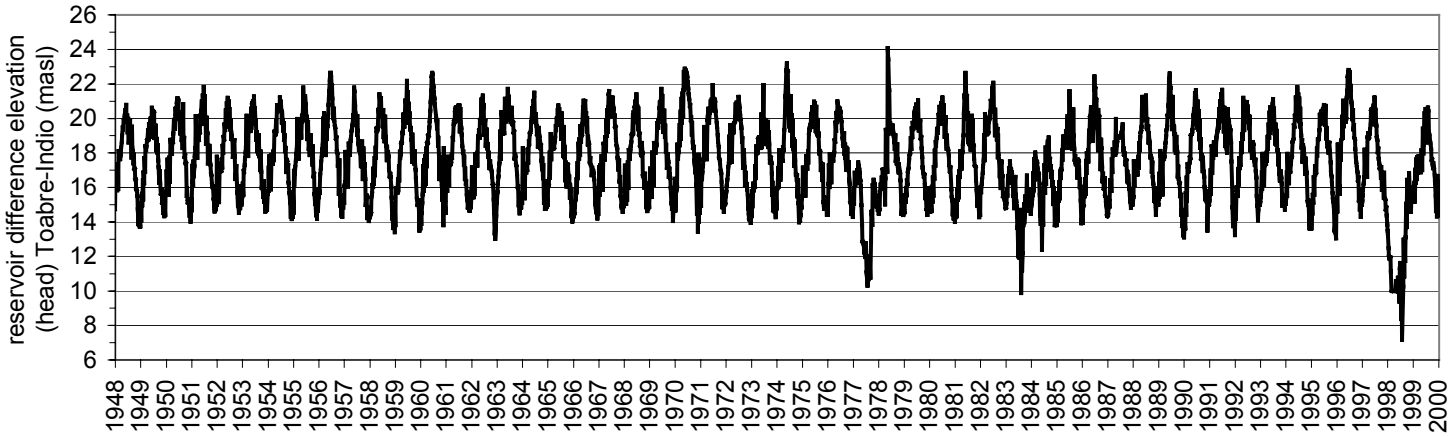
4. HEC-5 parameters variation or analysis – Alternative Toabre 95-50

Results corresponding to a Panama Canal Yield of 5 820 MCM/y (equivalent 76.6 l/d) with a 99.6% reliability, including Toabre Reservoir 95-50, a Transfer Tunnel Toabre-Indio 5 m and one Transfer Tunnels Indio-Gatun 4.5 m.

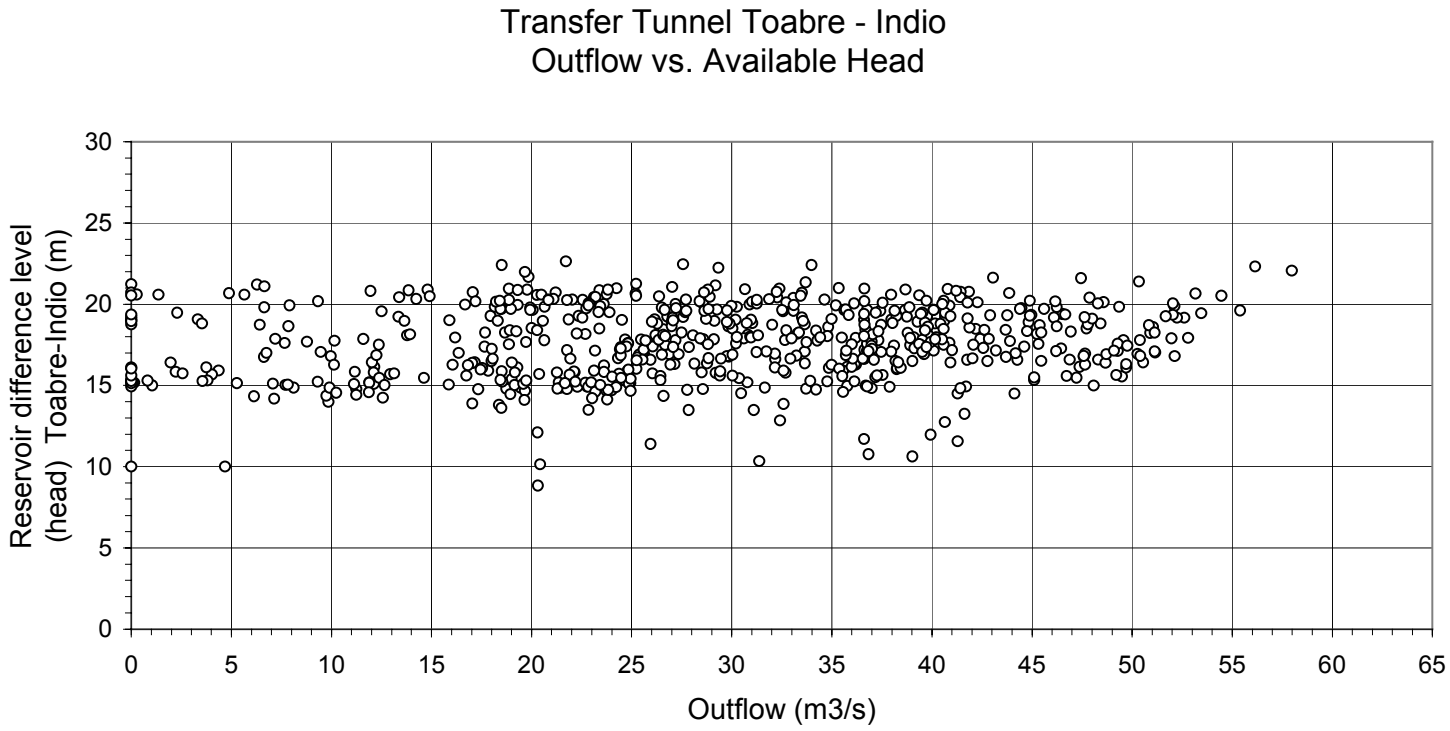
➢ ***Reservoirs elevations***

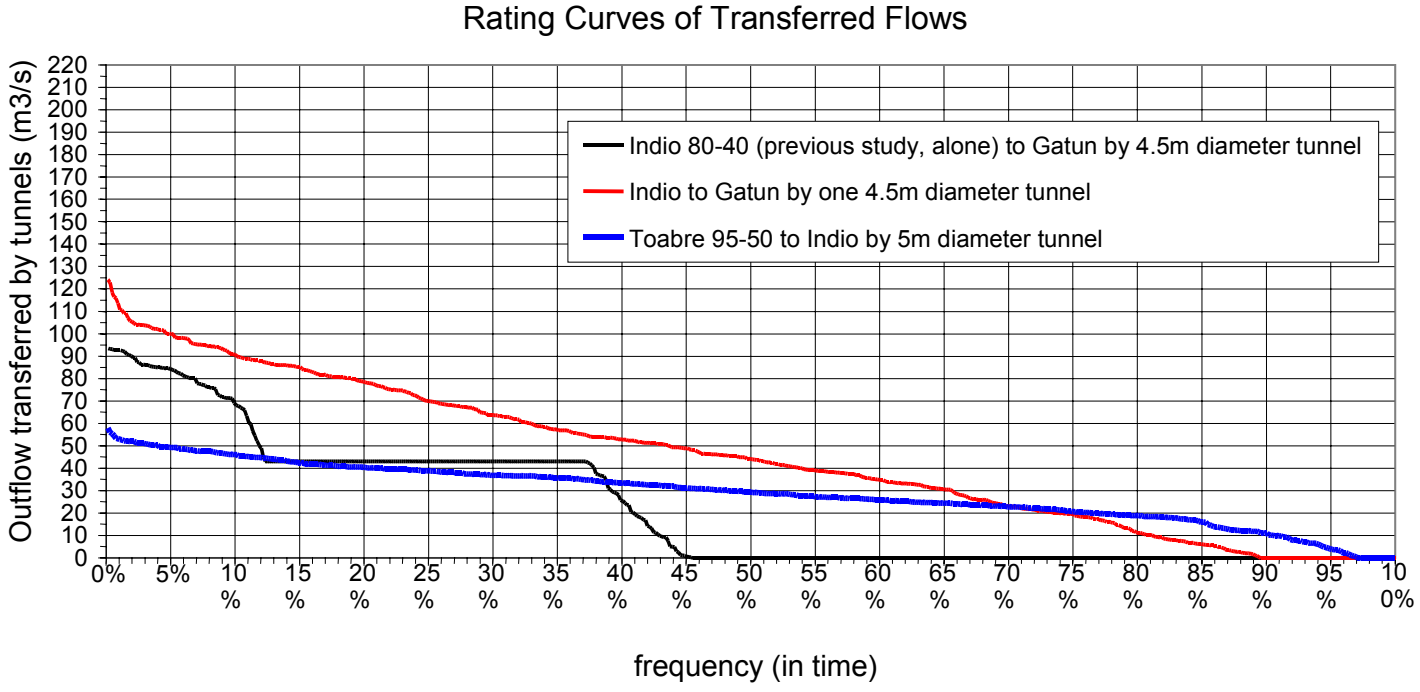


➢ ***Reservoir difference level (Head) between Toabre and Indio reservoirs***



➢ ***Outflows (monthly=average of 4 weeks) from reservoirs transferred by tunnel***





5. RIO INDIO / GATUN LAKE TUNNEL(S)

The HEC-5 simulations were done using two tunnels of 4,50 m diameter between Rio Indio reservoir and Gatun Lake. All the previous tables reflect this assumption.

However, we have continued the optimization process of the HEC-5 runs, using only one tunnel from Indio to Gatun. It appears that the same yield will be obtained using one tunnel.

Further optimization (by changing seasonal operation) will end, at least, with the same yields presented in the previous tables of this Appendix.

APPENDIX – PROJECT DESCRIPTION

(this part has 10 pages of text + 42 pages of software output)

APPENDIX A Stability Analysis of the RCC dam section

APPENDIX B Adaptation for NWL 90 masl and NWL 100 masl

APPENDIX A - Stability Analysis of the RCC dam section

1. Introduction – Studied cases

The stability analysis has been performed by a two-dimensional method on the highest section of the dam. The principal characteristics are :

Upstream slope : 0,2
Downstream slope : 0,7
Crest level : 99,5
Crest width : 8
Foundation level : 15
Reservoir bottom level : 25

It consists of evaluating the resistance of the structure against sliding and overturning and to check that the stresses remain in an allowable range. The load combinations used in the calculations are:

Case	Reservoir water level	Downstream water level	Drainage	Seismic forces
Normal	NWL 95	20	Yes	No
Unusual	MWL 97.35	30	Yes	No
	NWL 95	20	No	No
	NWL 95	20	Yes	OBE : 0.2 g
Extreme	PMF 99.5	35	Yes	No
	NWL 95	20	Yes	MDE : 0.25 g

Note: the stability with the MCE 0.31g where sliding with irreversible displacement is accepted is not considered in the present stability analysis. This case should be considered during the next phase of the study by a dynamic analysis (Newmark Method) by computing the displacement of the dam.

2. Stability criteria and methodology

The criteria for safety is as follows:

➢ *Stability criteria*

Criteria	Normal loading	Unusual loading	Extreme loading
Sliding coefficient tan ϕ	$\leq$ 0,75	< O,9	< 1
Shear friction factor (SFF)	$\geq$ 2	$\geq$ 1,7	$\geq$ 1,3
Maximal stress of compression (with fc = 15 Mpa)	fc / 3	fc / 2	fc
Vertical stress of traction	No stress	Tensile stress limited to the upstream third	

For normal loading conditions, the resultant of all forces must pass through the middle third of the base of the structure.

➢ *General assumptions for calculations*

Physical parameters

- Water density 1.00 t/m3
- RCC density 2.40 t/m3
- friction angle of RCC and foundation 45°
- cohesion into RCC body 1 Mpa
- cohesion in foundation 0,25 Mpa

Calculations are made for a dam block of 1 m wide.

➢ ***Method of calculations***

The calculations have been carried out by using the software STABCON developed by Coyne et Bellier. During the computed process, the section of the dam is divided into slices. For each level, the software computes the stability of the block made of the slices located above that level. It gives the distribution of stresses at the level, the value and location of the resultant of all forces acting on the dam above that level. Sliding coefficient, shear friction factor and vertical stresses are calculated as follows:

Tan ϕ = **{** INCORPORER Equation.3 **}** sliding coefficient

SFF = **{** INCORPORER Equation.3 **}** Shear Friction Factor

$\sigma_{upstream}$ = **{** INCORPORER Equation.3 **}** upstream stress

$\sigma_{downstream}$ = **{** INCORPORER Equation.3 **}** downstream stress

with H = horizontal forces (positive to downstream)

V = vertical forces (positive upwards)

M = Moment of the resultant of horizontal and vertical forces against the gravity centre

S = area of considered base

I = moment of inertia of the section against its gravity centre

$\nu_{upstream}$ = distance between gravity centre and upstream face

$\nu_{downstream}$ = distance between gravity centre and downstream face

C = cohesion

ϕ_e = friction angle

Calculations are done with both linear distribution of total stresses and linear distribution of effective stresses. Results are considered in ‘’total stresses’’ for the dam body and in ‘’effective stresses’’ at the RCC / foundation contact.

When a linear distribution of effective stresses is considered, the structure is studied by a 'no-tension' analysis, and when a crack develops (tensile stress), iterations are made to extend the crack till stabilisation of stresses (no more tension). In total stresses, it is supposed not to have cracks but an allowable tensile zone.

3. Results

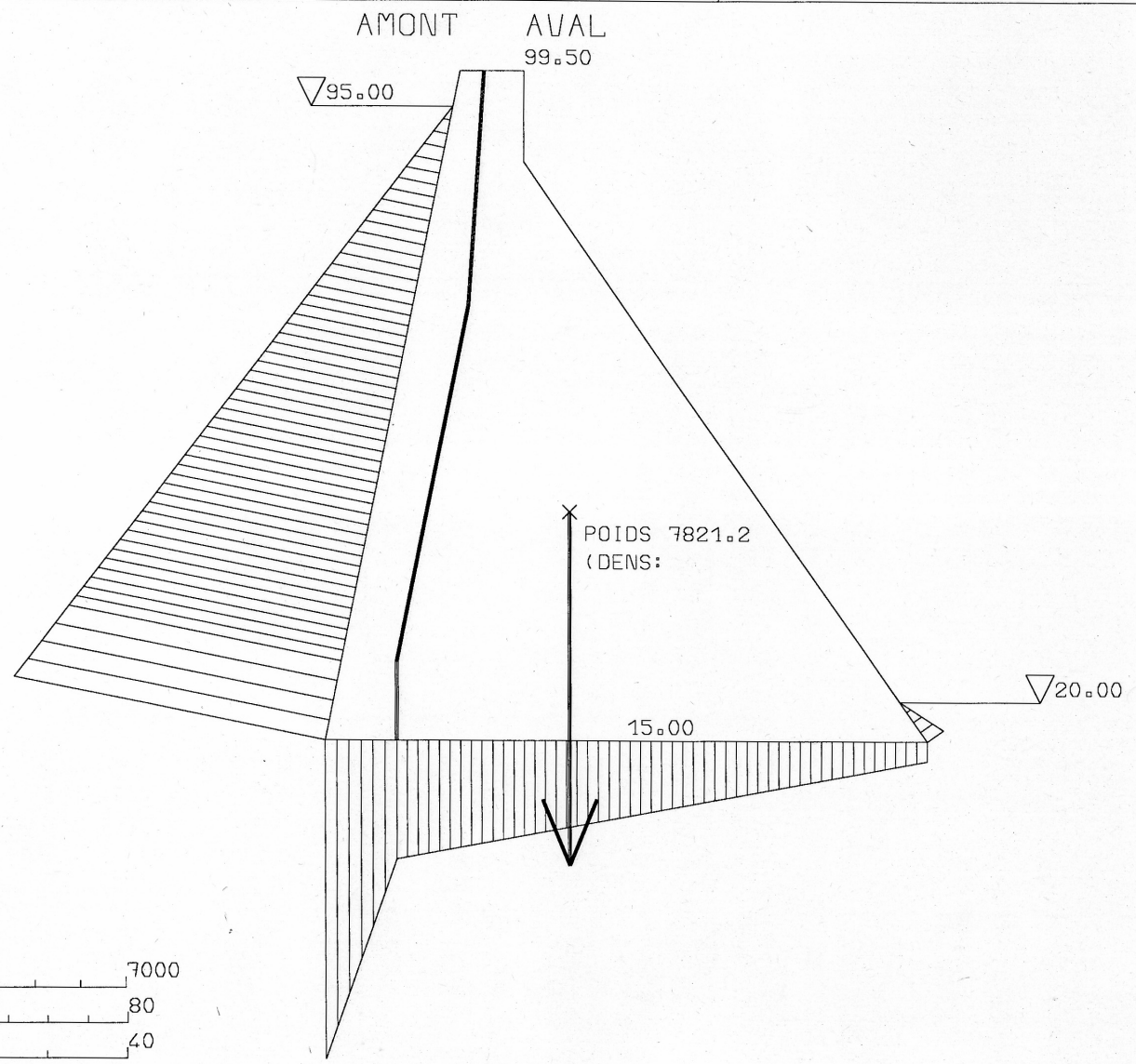
- the results at the RCC / foundation contact are summarised in the following table:

Loading	**Normal**	**Unusual**			**Extreme**	
	NWL 95	MWL 97.35	NWL 95 + no drainage	OBE	PMF	MDE
Computed SFF	2.73	2.49	2.24	1.75	2.36	1.52
Allowable SFF	2	1.7	1.7	1.7	1.3	1.3
tan ϕ	0.47	0.52	0.61	0.73	0.56	0.82
Allowable tan ϕ	0.75	0.9	0.9	0.9	1	1
σ_{us} (Mpa)	0.6	0.45	0.20	0.05	0.35	0
σ_{ds} (Mpa)	1.2	1.2	1.15	1.8	1.25	2
Cracking (m)	no	no	no	no	no	9
Criteria	Resultant in the middle third. No tensile stress	Resultant in the middle of the base.			Resultant in the base.	

- The results at different elevation into the RCC dam body shows that the stability is ensured for all cases, with minimum acceptable tensile stress limited to 0.3 Mpa and 0.45 Mpa respectively to OBE and MDE cases, with maximum limited tensile zone of 4.5 m to 6 m, still upstream of the internal drainage curtain.

For each case of loading is annexed a view of the section with the location of the resultant and the representation of the expected cracked zones, the graphics of the Shear Friction Factor and the graphics of the upstream and downstream stresses. That is given for both ''total'' and ''effective stresses'' computations **(42 pages follows) :**

COYNE ET BELLIER	STABCON	
FEASIBILITY STUDY MARCH 2003	RCC DAM STABILITY	



TOABRE RCC DAM

NORMAL CASE : NWL 95

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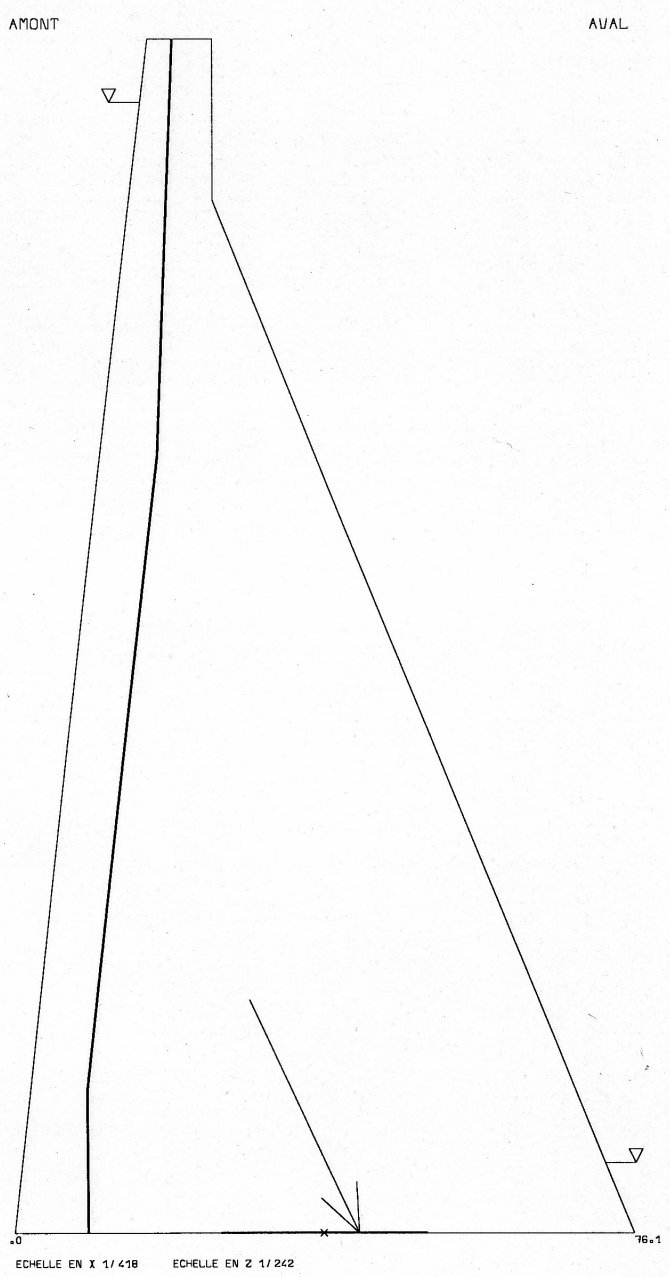

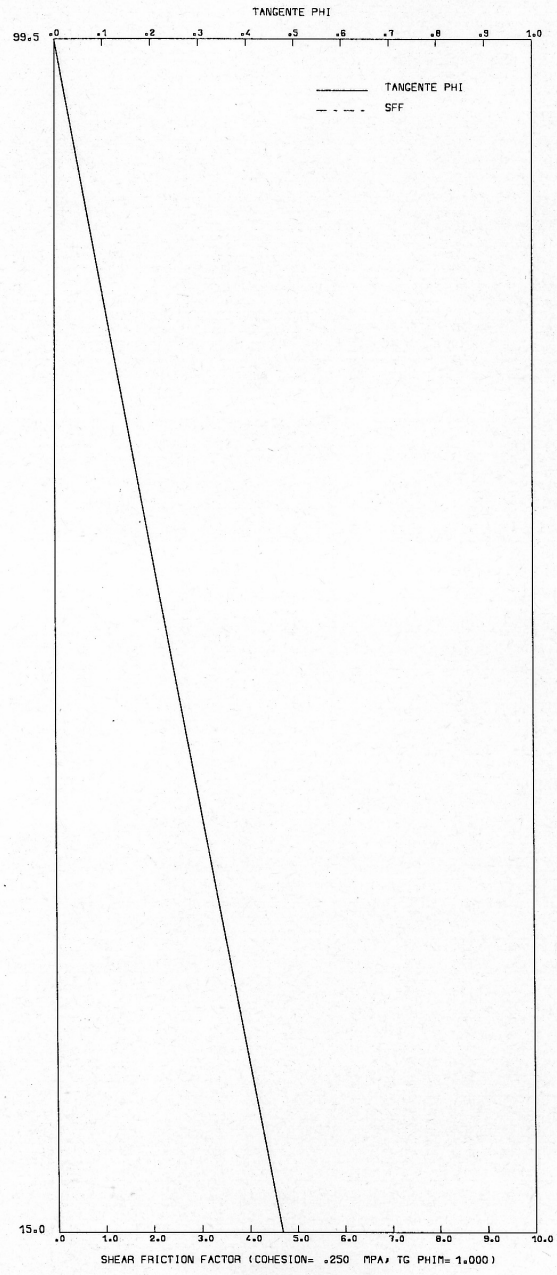

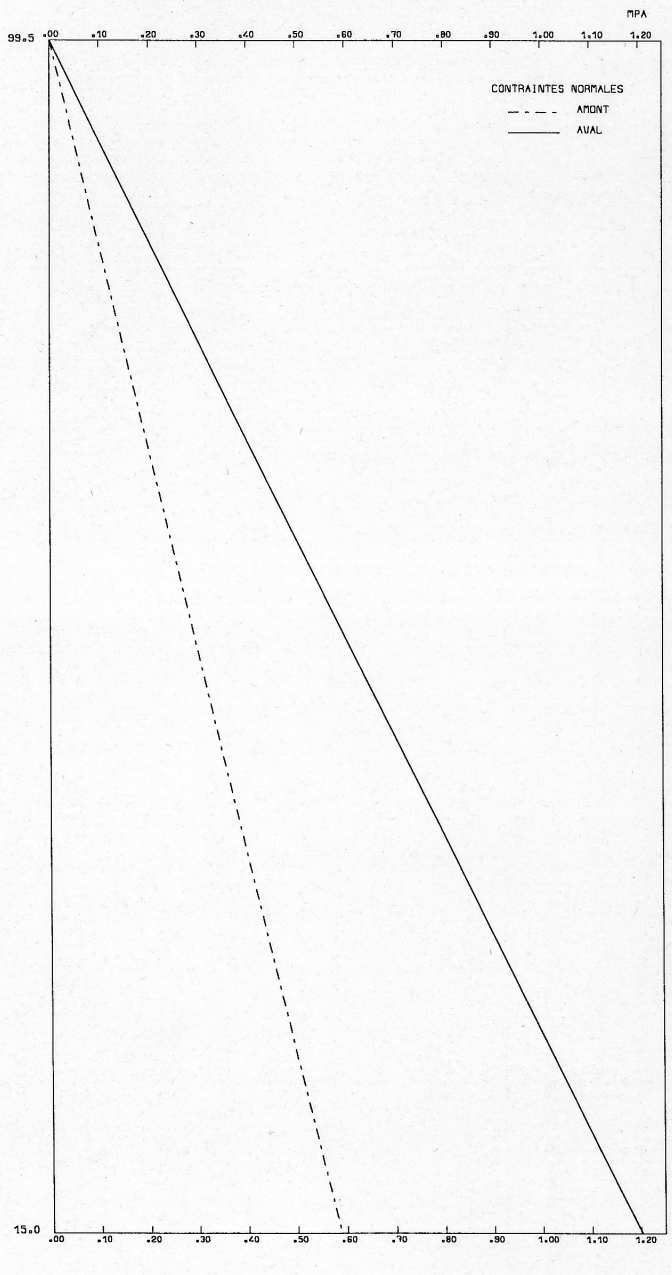

TOABRE RCC DAM

NORMAL CASE : NWL 95

CNTES EFFECTIVES LINEAIRES - FISSURATION AUTO - EPS = .0100 %

ENGLISH / FRENCH DICTIONARY

STABCON - FICHIER DES SORTIES CONDENSEES

Toabre RCC Dam
Normal case : NWL 95
Cntes totales lineaires

Elev. | Faces Abscisse u/s u/s d/s d/s | Area | Inertia | Force Horiz. Vert. Absc.

NIVEAU (m)	ABSCISSES DES PAREMENTS NOYAU amont (m)	amont (m)	aval (m)	aval (m)	SURFACE (m2)	INERTIE (m4)	RESULTANTE DES EFFORTS horiz. (kT)	vert. (kT)	absc. (m)
88.07	14.61	14.61	24.90	24.90	10.29	90.69	.024	-.228	20.76
80.00	13.00	13.00	30.55	30.55	17.55	450.41	.112	-.457	22.01
70.00	11.00	11.00	37.55	37.55	26.55	1559.60	.313	-.915	24.85
60.00	9.00	9.00	44.55	44.55	35.55	3744.01	.613	-1.589	27.93
50.00	7.00	7.00	51.55	51.55	44.55	7368.21	1.013	-2.470	31.06
40.00	5.00	5.00	58.55	58.55	53.55	12796.68	1.513	-3.557	34.20
30.00	3.00	3.00	65.55	65.55	62.55	20393.92	2.112	-4.851	37.34
20.00	1.00	1.00	72.55	72.55	71.55	30524.44	2.813	-6.313	40.63
15.00	.00	.00	76.05	76.05	76.05	36653.59	3.188	-6.811	42.37

Elev. Tanp. Centre gravity

NIVEAU (m)	TG	SFF (*)	CENTRE GRAVITE (m)	CONTRAINTES AMONT u/s stress absc. (m)	contr. (MPA)	long. tendue (m)	CONTRAINTES AVAL d/s stress absc. (m)	contr. (MPA)	long. tendue (m)
					stress			stress	
88.07	.105	52.335	19.76	14.61	.0826	.00	24.90	.3451	.00
80.00	.246	19.663	21.77	13.00	.2040	.00	30.55	.2646	.00
70.00	.342	11.424	24.27	11.00	.2247	.00	37.55	.3630	.00
60.00	.385	8.399	26.78	9.00	.2269	.00	44.55	.5018	.00
50.00	.410	6.840	29.28	7.00	.2263	.00	51.55	.6519	.00
40.00	.425	5.892	31.78	5.00	.2256	.00	58.55	.8063	.00
30.00	.436	5.257	34.28	3.00	.2253	.00	65.55	.9628	.00
20.00	.446	4.788	36.78	1.00	.2255	.00	72.55	1.1204	.00
15.00	.468	4.523	38.03	.00	.2237	.00	76.05	1.1538	.00

(*) SFF = Shear Friction Factor

Total and effective stresses data

STABCON - FICHIER DES CONTRAINTES TOTALES ET EFFECTIVES

Toabre RCC Dam
Normal case : NWL 95
Cntes totales lineaires

Elevation | Absaisse | Total Stress | Pressure | Effective stress

Cote (m)	Abscisse (m)	Cnte TOTALE (MPa)	Pression (MPa)	Cnte EFFECTIVE (MPA)
88.07	Longueur tendue : .00 m - fissuration .00 %			
	14.61	.1519	.0693	.0826
	19.16	.2374	.0229	.2145
	24.90	.3451	.0000	.3451
80.00	Longueur tendue : .00 m - fissuration .00 %			
	13.00	.3540	.1500	.2040
	18.64	.3253	.0495	.2758
	30.55	.2646	.0000	.2646

Tension Length .00m. Cracking .00%

STABCON - FICHIER DES SORTIES CONDENSEES

Toabre RCC Dam
Normal case : NWL 95
Cntes effectives lineaires - Fissuration auto - eps = .0100 %

NIVEAU (m)	ABSCISSES DES PAREMENTS				SURFACE (m2)	INERTIE (m4)	RESULTANTE DES EFFORTS		
	NOYAU								
	amont (m)	amont (m)	aval (m)	aval (m)			horiz. (kT)	vert. (kT)	absc. (m)
15.00	.00	.00	76.05	76.05	76.05	36653.59	3.188	-6.811	42.37

NIVEAU (m)	TG	SFF	CENTRE GRAVITE (m)	CONTRAINTES AMONT			CONTRAINTES AVAL		
				absc. (m)	contr. (MPA)	long. tendue (m)	absc. (m)	contr. (MPA)	long. tendue (m)
15.00	.468	2.733	38.03	.00	.5885	.00	76.05	1.2027	.00

STABCON - FICHIER DES CONTRAINTES TOTALES ET EFFECTIVES

Toabre RCC Dam
Normal case : NWL 95
Cntes effectives lineaires - Fissuration auto - eps = .0100 %

Cote (m)	Abscisse (m)	Cnte TOTALE (MPa)	Pression (MPa)	Cnte EFFECTIVE (MPA)
15.00	Longueur tendue : .00 m - fissuration .00 %			
	.00	1.3885	.8000	.5885
	9.00	.9587	.2975	.6612
	76.05	1.2527	.0500	1.2027

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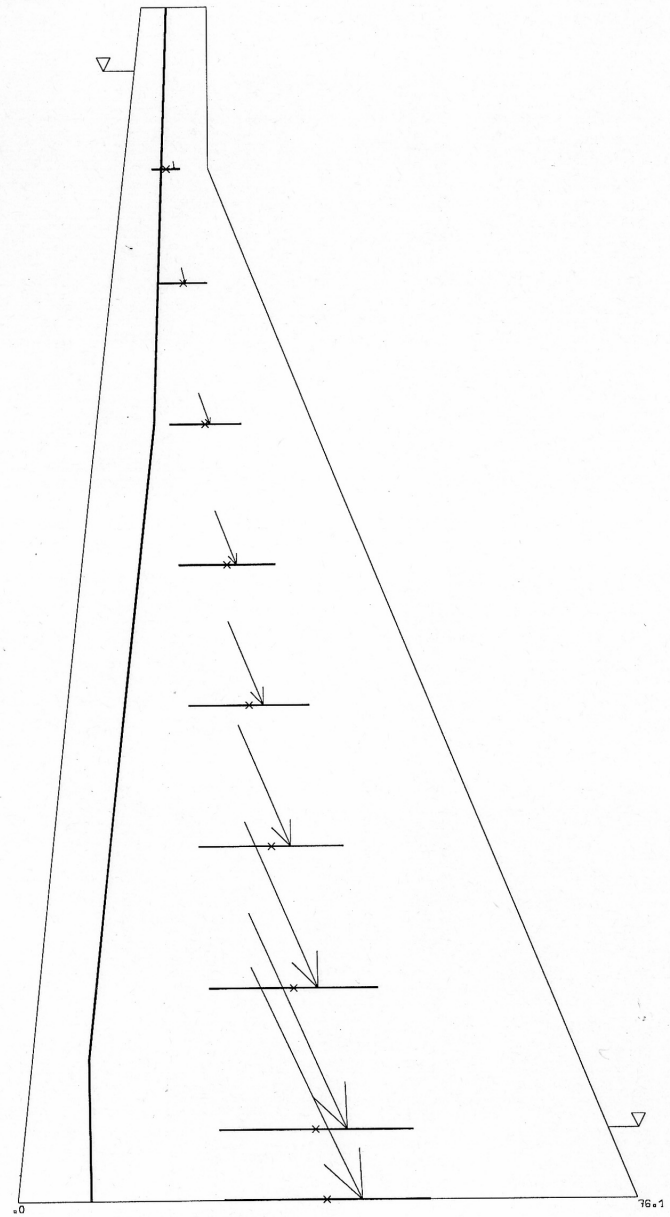

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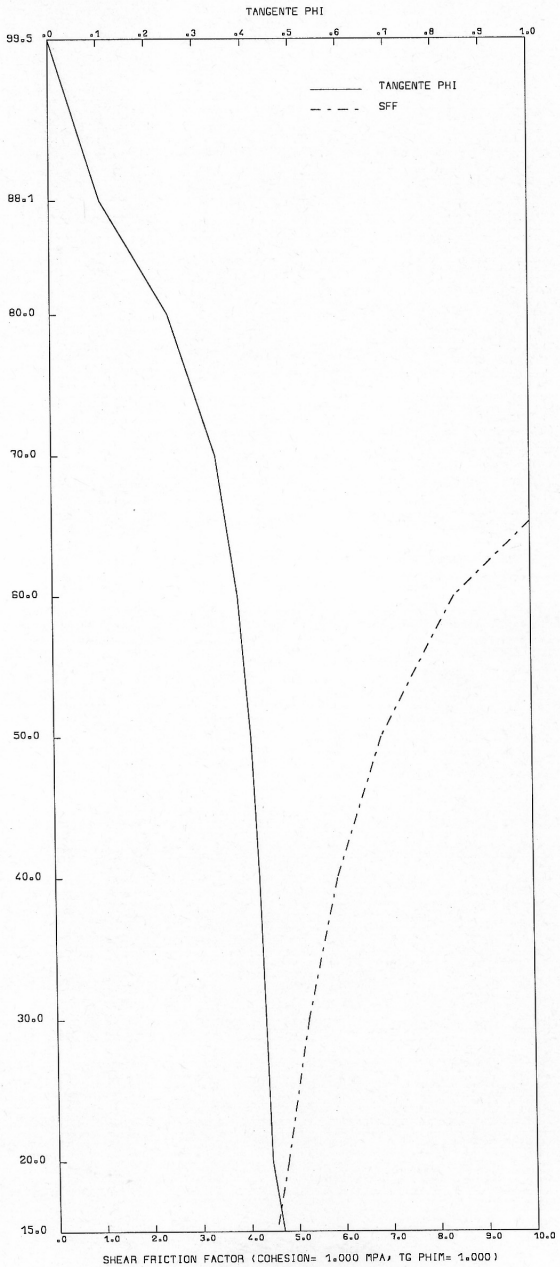
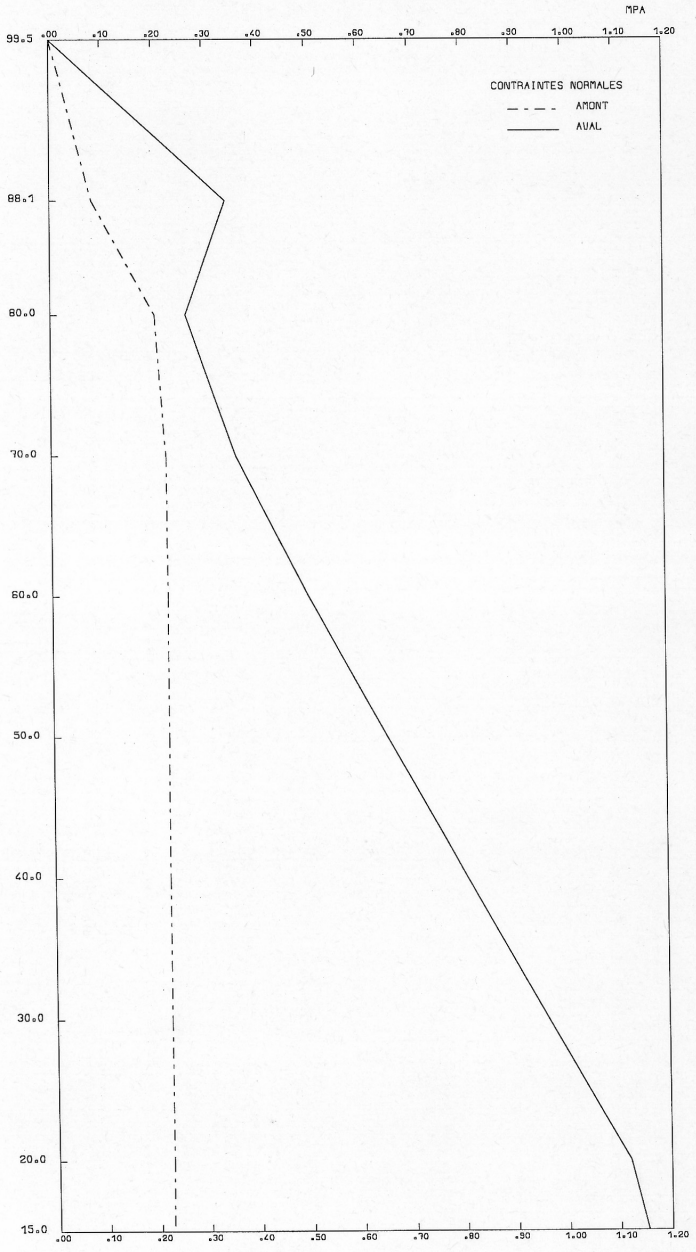


SHEAR FRICTION FACTOR (COHESION= 1.000 MPA, TG PHIM= 1.000)



TOABRE RCC DAM

NORMAL CASE : NWL 95

CNTES TOTALES LINEAIRES

STABCON - FICHIER DES SORTIES CONDENSEES

Toabre RCC Dam
Normal case : NWL 95
Cntes totales lineaires

NIVEAU (m)	ABSCISSES DES PAREMENTS NOYAU amont (m)	amont (m)	aval (m)	aval (m)	SURFACE (m2)	INERTIE (m4)	RESULTANTE DES EFFORTS horiz. (kT)	vert. (kT)	absc. (m)
88.07	14.61	14.61	24.90	24.90	10.29	90.69	.024	-.228	20.76
80.00	13.00	13.00	30.55	30.55	17.55	450.41	.112	-.457	22.01
70.00	11.00	11.00	37.55	37.55	26.55	1559.60	.313	-.915	24.85
60.00	9.00	9.00	44.55	44.55	35.55	3744.01	.613	-1.589	27.93
50.00	7.00	7.00	51.55	51.55	44.55	7368.21	1.013	-2.470	31.06
40.00	5.00	5.00	58.55	58.55	53.55	12796.68	1.513	-3.557	34.20
30.00	3.00	3.00	65.55	65.55	62.55	20393.92	2.112	-4.851	37.34
20.00	1.00	1.00	72.55	72.55	71.55	30524.44	2.813	-6.313	40.63
15.00	.00	.00	76.05	76.05	76.05	36653.59	3.188	-6.811	42.37

NIVEAU (m)	TG	SFF	CENTRE GRAVITE (m)	CONTRAINTES AMONT absc. (m)	contr. (MPA)	long. tendue (m)	CONTRAINTES AVAL absc. (m)	contr. (MPA)	long. tendue (m)
88.07	.105	52.335	19.76	14.61	.0826	.00	24.90	.3451	.00
80.00	.246	19.663	21.77	13.00	.2040	.00	30.55	.2646	.00
70.00	.342	11.424	24.27	11.00	.2247	.00	37.55	.3630	.00
60.00	.385	8.399	26.78	9.00	.2269	.00	44.55	.5018	.00
50.00	.410	6.840	29.28	7.00	.2263	.00	51.55	.6519	.00
40.00	.425	5.892	31.78	5.00	.2256	.00	58.55	.8063	.00
30.00	.436	5.257	34.28	3.00	.2253	.00	65.55	.9628	.00
20.00	.446	4.788	36.78	1.00	.2255	.00	72.55	1.1204	.00
15.00	.468	4.523	38.03	.00	.2237	.00	76.05	1.1538	.00

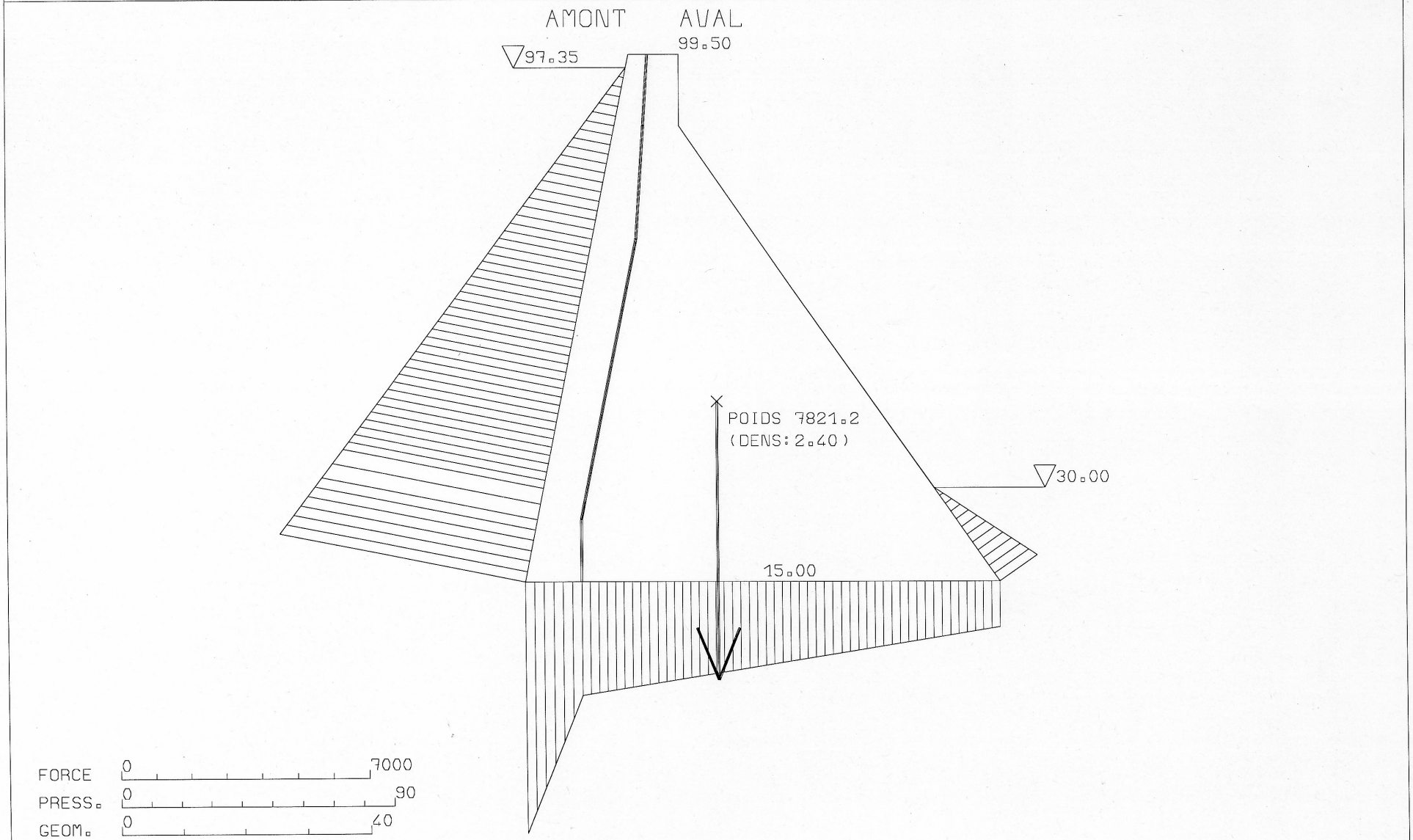
STABCON - FICHIER DES CONTRAINTES TOTALES ET EFFECTIVES

Toabre RCC Dam
Normal case : NWL 95
Cntes totales lineaires

Cote (m)	Abscisse (m)	Cnte TOTALE (MPa)	Pression (MPa)	Cnte EFFECTIVE (MPA)
88.07	Longueur tendue : .00 m - fissuration .00 %			
	14.61	.1519	.0693	.0826
	19.16	.2374	.0229	.2145
	24.90	.3451	.0000	.3451
80.00	Longueur tendue : .00 m - fissuration .00 %			
	13.00	.3540	.1500	.2040
	18.64	.3253	.0495	.2758
	30.55	.2646	.0000	.2646
70.00	Longueur tendue : .00 m - fissuration .00 %			
	11.00	.4747	.2500	.2247
	18.00	.4452	.0825	.3627
	37.55	.3630	.0000	.3630
60.00	Longueur tendue : .00 m - fissuration .00 %			
	9.00	.5769	.3500	.2269
	16.00	.5621	.1155	.4466
	44.55	.5018	.0000	.5018
50.00	Longueur tendue : .00 m - fissuration .00 %			
	7.00	.6763	.4500	.2263
	14.00	.6725	.1485	.5240
	51.55	.6519	.0000	.6519
40.00	Longueur tendue : .00 m - fissuration .00 %			
	5.00	.7756	.5500	.2256
	12.00	.7796	.1815	.5981
	58.55	.8063	.0000	.8063
30.00	Longueur tendue : .00 m - fissuration .00 %			
	3.00	.8753	.6500	.2253
	10.00	.8851	.2145	.6706
	65.55	.9628	.0000	.9628
20.00	Longueur tendue : .00 m - fissuration .00 %			
	1.00	.9755	.7500	.2255
	9.00	.9917	.2475	.7442
	72.55	1.1204	.0000	1.1204
15.00	Longueur tendue : .00 m - fissuration .00 %			
	.00	1.0237	.8000	.2237
	9.00	1.0450	.2975	.7475
	76.05	1.2038	.0500	1.1538

FIN DU TRAITEMENT

	COYNE ET BELLIER	STABCON	
FEASIBILITY STUDY MARCH 2003		RCC DAM STABILITY	



TOABRE RCC DAM

UNUSUAL CASE : MWL 97.35 (1000)

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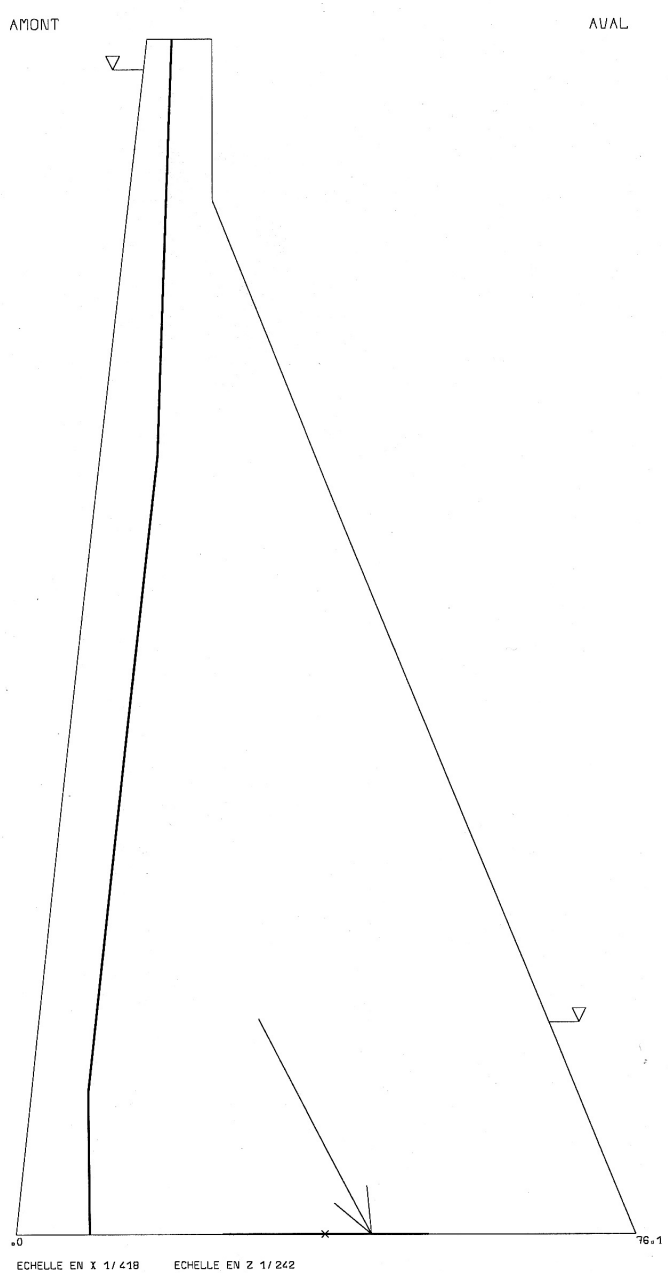
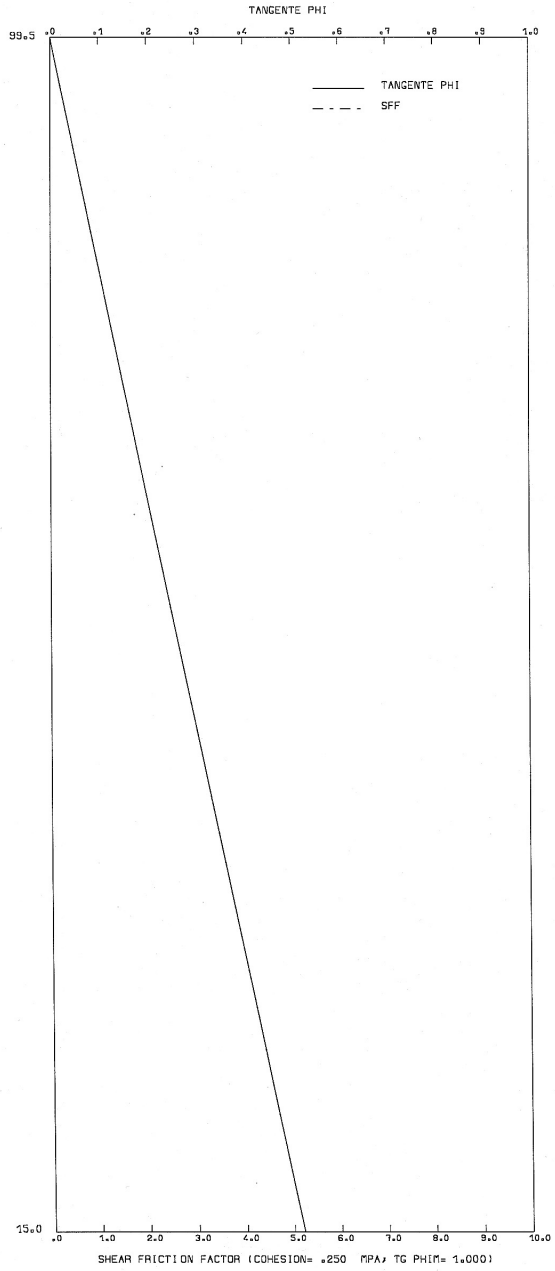
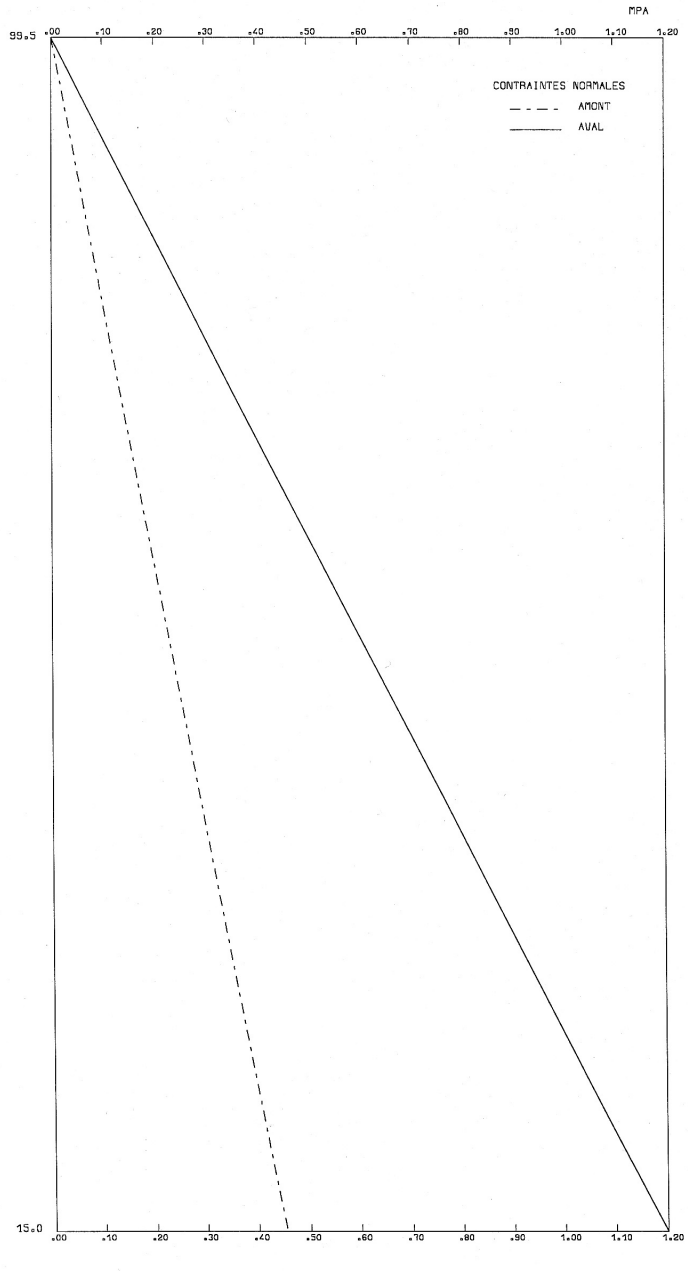


ECHELLE EN X 1/418 ECHELLE EN Z 1/242



SHEAR FRICTION FACTOR (COHESION= .250 MPA, TG PHIM= 1.000)



TOABRE RCC DAM

UNUSUAL CASE : MWL 97.35 (1000)

CNTES EFFECTIVES LINEAIRES - FISSURATION AUTO - EPS = .0100 x

STABCON - FICHIER DES SORTIES CONDENSEES

Toabre RCC Dam
UNUSUAL CASE : MWL 97.35 (1000)
Cntes effectives lineaires - Fissuration auto - eps = .0100 %

NIVEAU (m)	ABSCISSES DES PAREMENTS				SURFACE (m2)	INERTIE (m4)	RESULTANTE DES EFFORTS		
	NOYAU								
	amont (m)	amont (m)	aval (m)	aval (m)			horiz. (kT)	vert. (kT)	absc. (m)
15.00	.00	.00	76.05	76.05	76.05	36653.59	3.278	-6.289	43.74

NIVEAU (m)	TG	SFF	CENTRE GRAVITE (m)	CONTRAINTES AMONT			CONTRAINTES AVAL		
				absc. (m)	contr. (MPA)	long. tendue (m)	absc. (m)	contr. (MPA)	long. tendue (m)
15.00	.521	2.498	38.03	.00	.4543	.00	76.05	1.1997	.00

STABCON - FICHIER DES CONTRAINTES TOTALES ET EFFECTIVES

Toabre RCC Dam
UNUSUAL CASE : MWL 97.35 (1000)
Cntes effectives lineaires - Fissuration auto - eps = .0100 %

Cote (m)	Abscisse (m)	Cnte TOTALE (MPa)	Pression (MPa)	Cnte EFFECTIVE (MPA)
15.00	Longueur tendue : .00 m - fissuration .00 %			
	.00	1.2778	.8235	.4543
	9.00	.9147	.3723	.5425
	76.05	1.3497	.1500	1.1997

FIN DU TRAITEMENT

COYNE ET BELLIER

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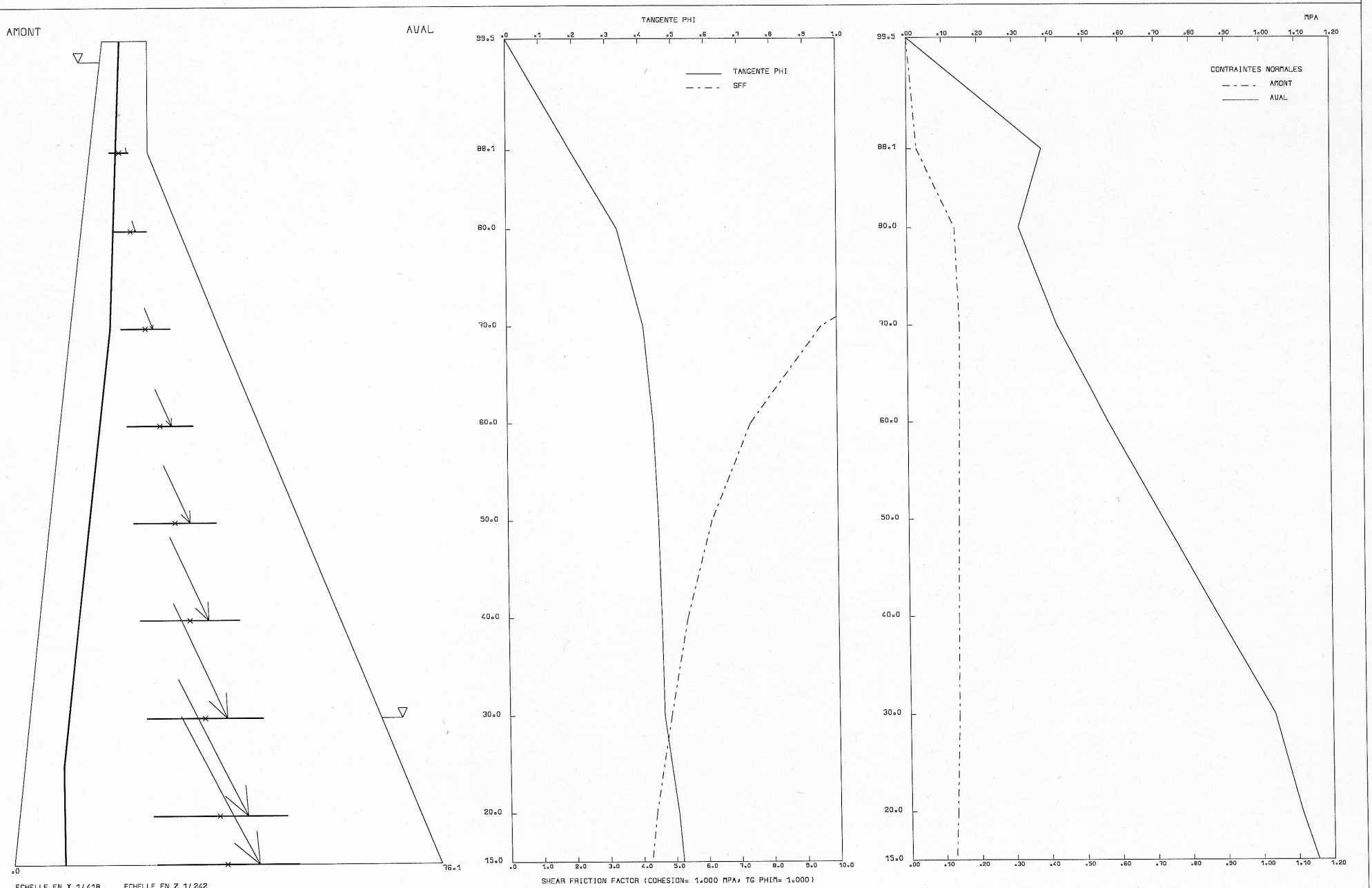


ECHELLE EN X 1/418 ECHELLE EN Z 1/242

TOABRE RCC DAM

UNUSUAL CASE : MWL 97.35 (1000)

CNTES TOTALES LINEAIRES

STABCON - FICHIER DES SORTIES CONDENSEES

Toabre RCC Dam
UNUSUAL CASE : MWL 97.35 (1000)
Cntes totales lineaires

NIVEAU (m)	ABSCISSES DES PAREMENTS NOYAU amont (m)	amont (m)	aval (m)	aval (m)	SURFACE (m2)	INERTIE (m4)	RESULTANTE DES EFFORTS horiz. (kT)	vert. (kT)	absc. (m)
88.07	14.61	14.61	24.90	24.90	10.29	90.69	.043	-.223	21.16
80.00	13.00	13.00	30.55	30.55	17.55	450.41	.151	-.451	22.69
70.00	11.00	11.00	37.55	37.55	26.55	1559.60	.374	-.909	25.72
60.00	9.00	9.00	44.55	44.55	35.55	3744.01	.698	-1.584	28.87
50.00	7.00	7.00	51.55	51.55	44.55	7368.21	1.121	-2.466	32.03
40.00	5.00	5.00	58.55	58.55	53.55	12796.68	1.645	-3.555	35.19
30.00	3.00	3.00	65.55	65.55	62.55	20393.92	2.268	-4.849	38.33
20.00	1.00	1.00	72.55	72.55	71.55	30524.44	2.942	-5.789	41.83
15.00	.00	.00	76.05	76.05	76.05	36653.59	3.278	-6.289	43.74

NIVEAU (m)	TG	SFF	CENTRE GRAVITE (m)	CONTRAINTES AMONT absc. (m)	contr. (MPA)	long. tendue (m)	CONTRAINTES AVAL absc. (m)	contr. (MPA)	long. tendue (m)
88.07	.193	29.057	19.76	14.61	.0281	.00	24.90	.3835	.00
80.00	.334	14.658	21.77	13.00	.1355	.00	30.55	.3184	.00
70.00	.412	9.529	24.27	11.00	.1484	.00	37.55	.4251	.00
60.00	.440	7.368	26.78	9.00	.1465	.00	44.55	.5682	.00
50.00	.455	6.174	29.28	7.00	.1435	.00	51.55	.7209	.00
40.00	.463	5.418	31.78	5.00	.1411	.00	58.55	.8772	.00
30.00	.468	4.896	34.28	3.00	.1396	.00	65.55	1.0350	.00
20.00	.508	4.400	36.78	1.00	.1320	.00	72.55	1.1102	.00
15.00	.521	4.238	38.03	.00	.1267	.00	76.05	1.1557	.00

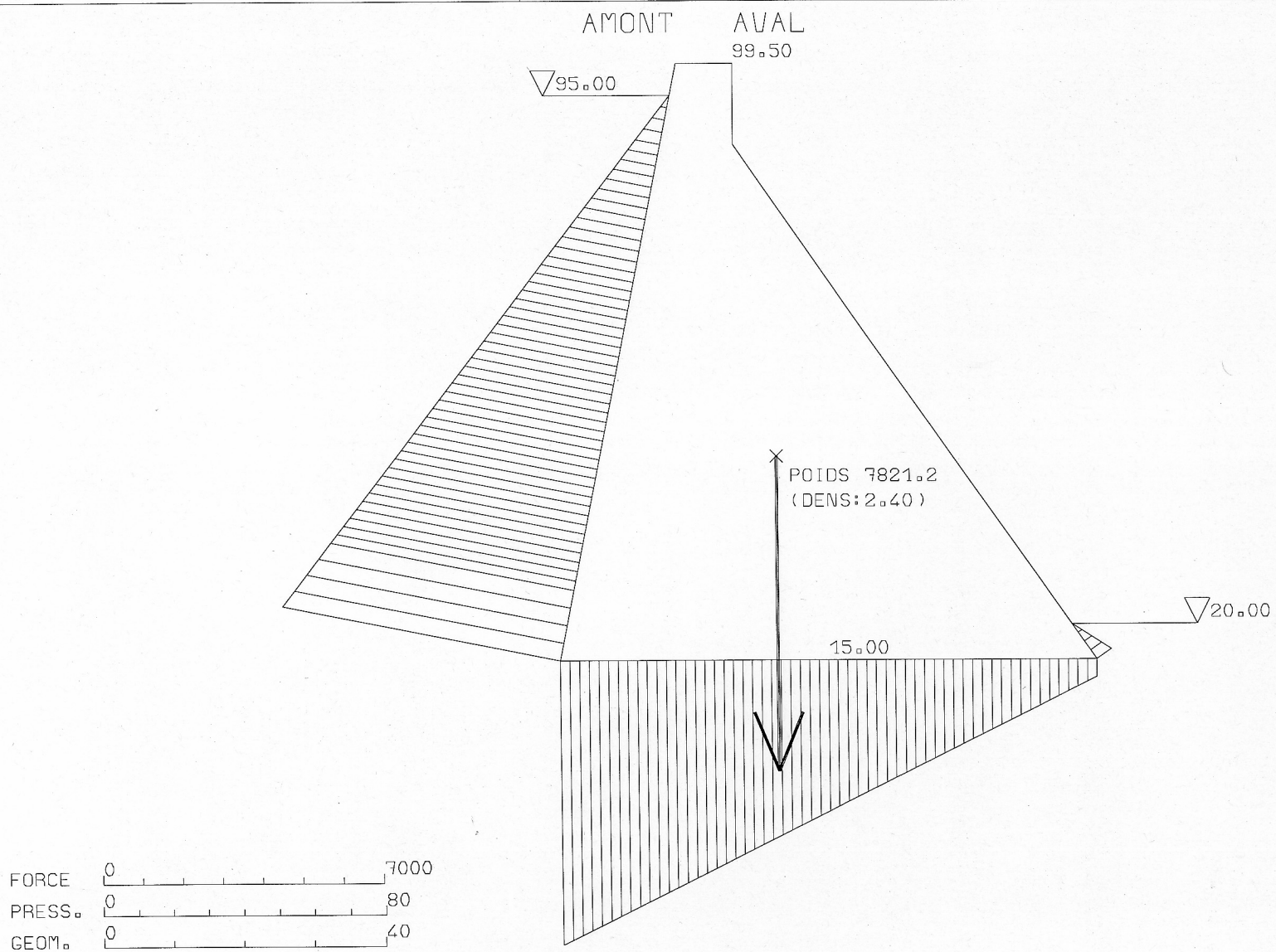
STABCON - FICHIER DES CONTRAINTES TOTALES ET EFFECTIVES

Toabre RCC Dam
UNUSUAL CASE : MWL 97.35 (1000)
Cntes totales lineaires

Cote (m)	Abscisse (m)	Cnte TOTALE (MPa)	Pression (MPa)	Cnte EFFECTIVE (MPA)
88.07	Longueur tendue : .00 m - fissuration .00 %			
	14.61	.1209	.0928	.0281
	19.16	.2371	.0306	.2064
	24.90	.3835	.0000	.3835
80.00	Longueur tendue : .00 m - fissuration .00 %			
	13.00	.3090	.1735	.1355
	18.64	.3120	.0573	.2547
	30.55	.3184	.0000	.3184
70.00	Longueur tendue : .00 m - fissuration .00 %			
	11.00	.4219	.2735	.1484
	18.00	.4227	.0903	.3325
	37.55	.4251	.0000	.4251
60.00	Longueur tendue : .00 m - fissuration .00 %			
	9.00	.5200	.3735	.1465
	16.00	.5295	.1233	.4063
	44.55	.5682	.0000	.5682
50.00	Longueur tendue : .00 m - fissuration .00 %			
	7.00	.6170	.4735	.1435
	14.00	.6333	.1563	.4771
	51.55	.7209	.0000	.7209
40.00	Longueur tendue : .00 m - fissuration .00 %			
	5.00	.7146	.5735	.1411
	12.00	.7359	.1893	.5466
	58.55	.8772	.0000	.8772
30.00	Longueur tendue : .00 m - fissuration .00 %			
	3.00	.8131	.6735	.1396
	10.00	.8380	.2223	.6157
	65.55	1.0350	.0000	1.0350
20.00	Longueur tendue : .00 m - fissuration .00 %			
	1.00	.9055	.7735	.1320
	9.00	.9396	.3223	.6173
	72.55	1.2102	.1000	1.1102
15.00	Longueur tendue : .00 m - fissuration .00 %			
	.00	.9502	.8235	.1267
	9.00	.9923	.3723	.6200
	76.05	1.3057	.1500	1.1557

FIN DU TRAITEMENT

COYNE ET BELLIER	STABCON
FEASIBILITY STUDY MARCH 2003	RCC DAM STABILITY



TOABRE RCC DAM

UNUSUAL CASE : NWL 95 + NO DRAINAGE

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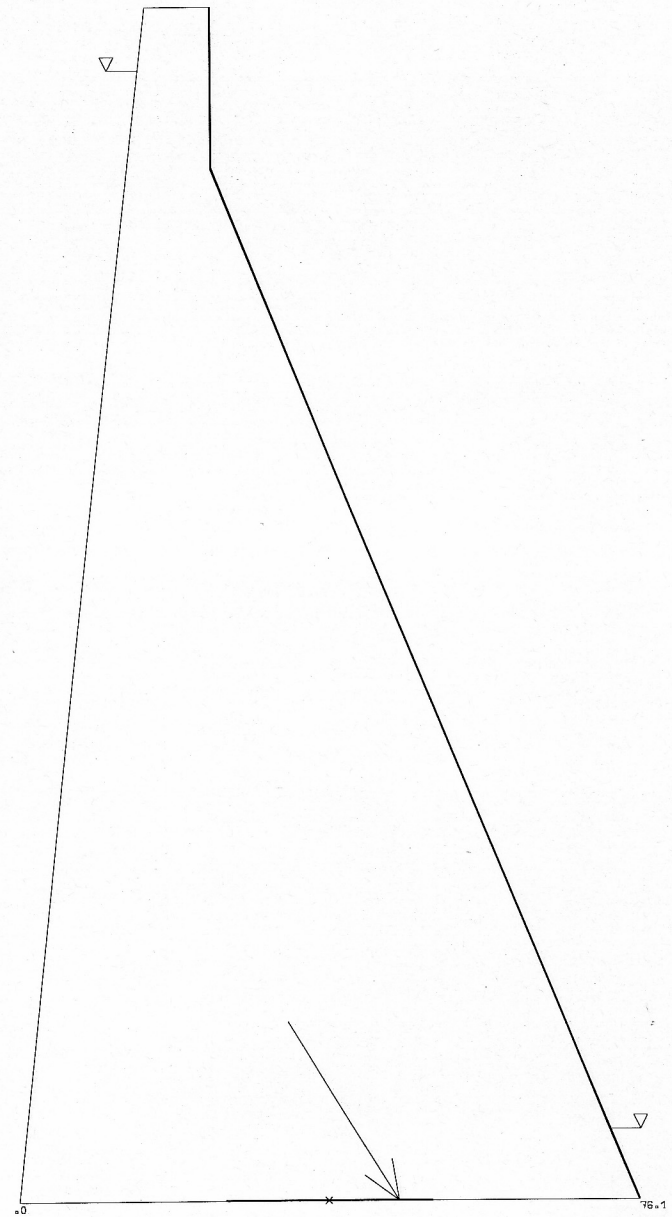
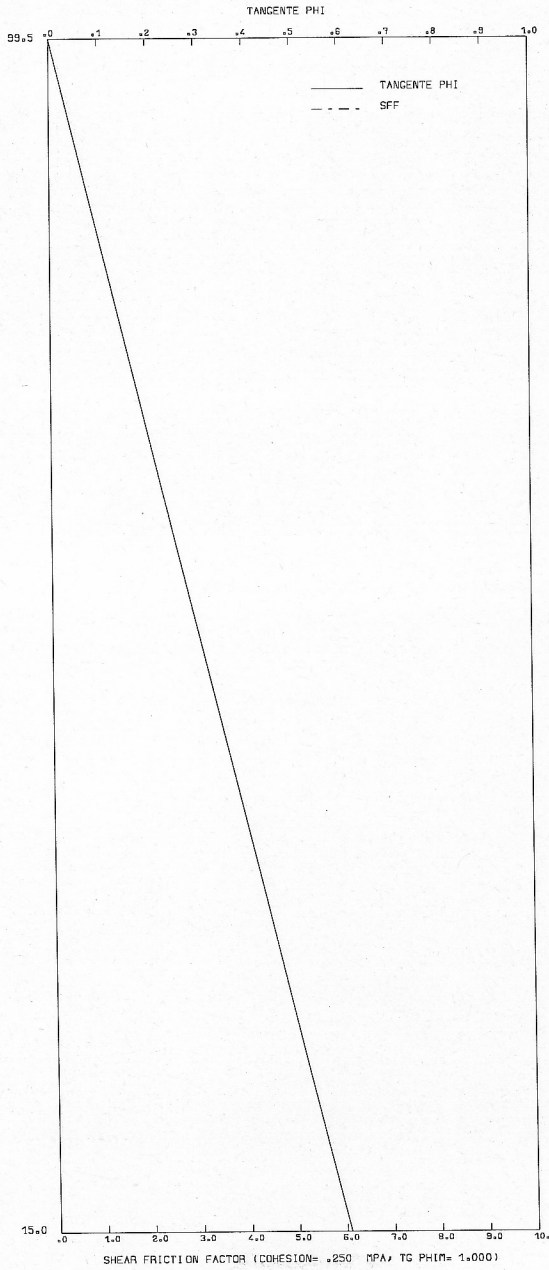
COYNE ET BELLIER

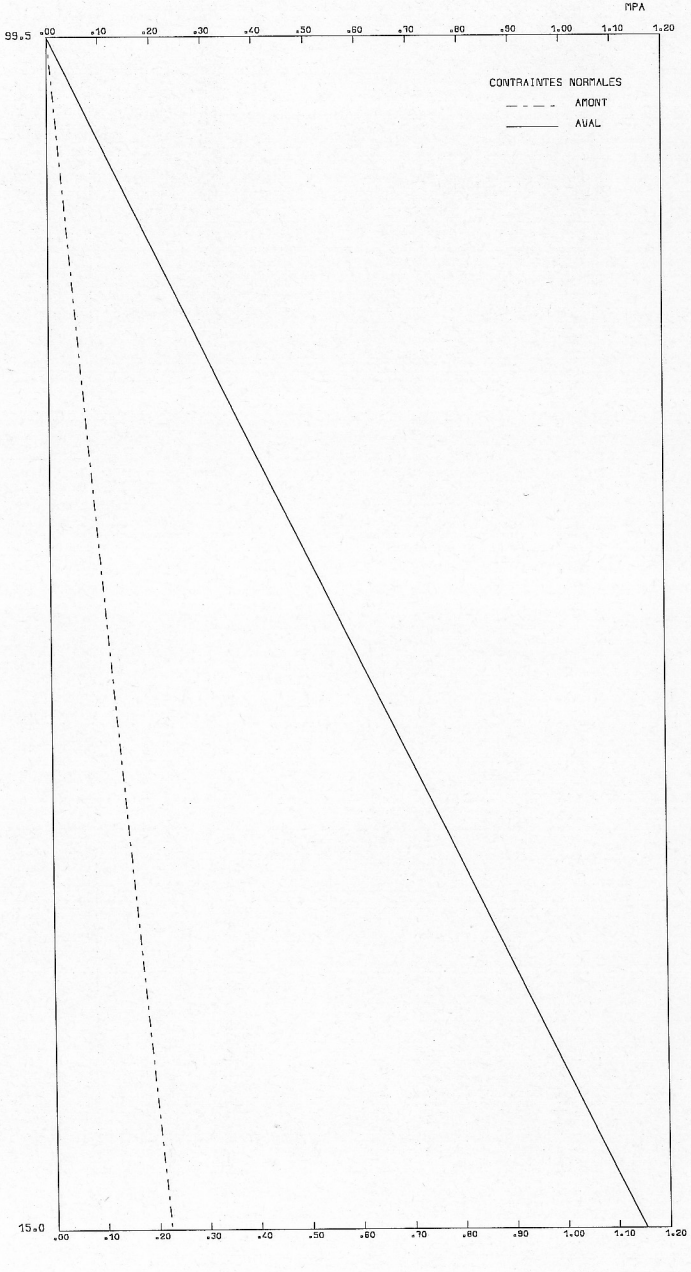
STABCON

STABCON (C) - COPYRIGHT COYNE ET BELLIER



ECHELLE EN X 1/418 ECHELLE EN Z 1/242





TOABRE RCC DAM

UNUSUAL CASE : NWL 95 + NO DRAINAGE

CNTES EFFECTIVES LINEAIRES - FISSURATION AUTO - EPS = 0.0100 %

STABCON - FICHIER DES SORTIES CONDENSEES

Toabre RCC Dam
UNUSUAL CASE : NWL 95 + no drainage
Cntes effectives lineaires - Fissuration auto - eps = .0100 %

NIVEAU (m)	ABSCISSES DES PAREMENTS NOYAU amont (m)	NOYAU amont (m)	NOYAU aval (m)	NOYAU aval (m)	SURFACE (m2)	INERTIE (m4)	RESULTANTE DES EFFORTS horiz. (kT)	RESULTANTE DES EFFORTS vert. (kT)	RESULTANTE DES EFFORTS absc. (m)
15.00	.00	.00	76.05	76.05	76.05	36653.59	3.188	-5.238	46.58

NIVEAU (m)	TG	SFF	CENTRE GRAVITE (m)	CONTRAINTES AMONT absc. (m)	CONTRAINTES AMONT contr. (MPA)	CONTRAINTES AMONT long. tendue (m)	CONTRAINTES AVAL absc. (m)	CONTRAINTES AVAL contr. (MPA)	CONTRAINTES AVAL long. tendue (m)
15.00	.609	2.240	38.03	.00	.2237	.00	76.05	1.1538	.00

STABCON - FICHIER DES CONTRAINTES TOTALES ET EFFECTIVES

Toabre RCC Dam
UNUSUAL CASE : NWL 95 + no drainage
Cntes effectives lineaires - Fissuration auto - eps = .0100 %

Cote (m)	Abscisse (m)	Cnte TOTALE (MPa)	Pression (MPa)	Cnte EFFECTIVE (MPA)
15.00	Longueur tendue : .00 m - fissuration .00 %			
	.00	1.0237	.8000	.2237
	76.05	1.2038	.0500	1.1538

FIN DU TRAITEMENT

COYNE ET BELLIER

STABCON

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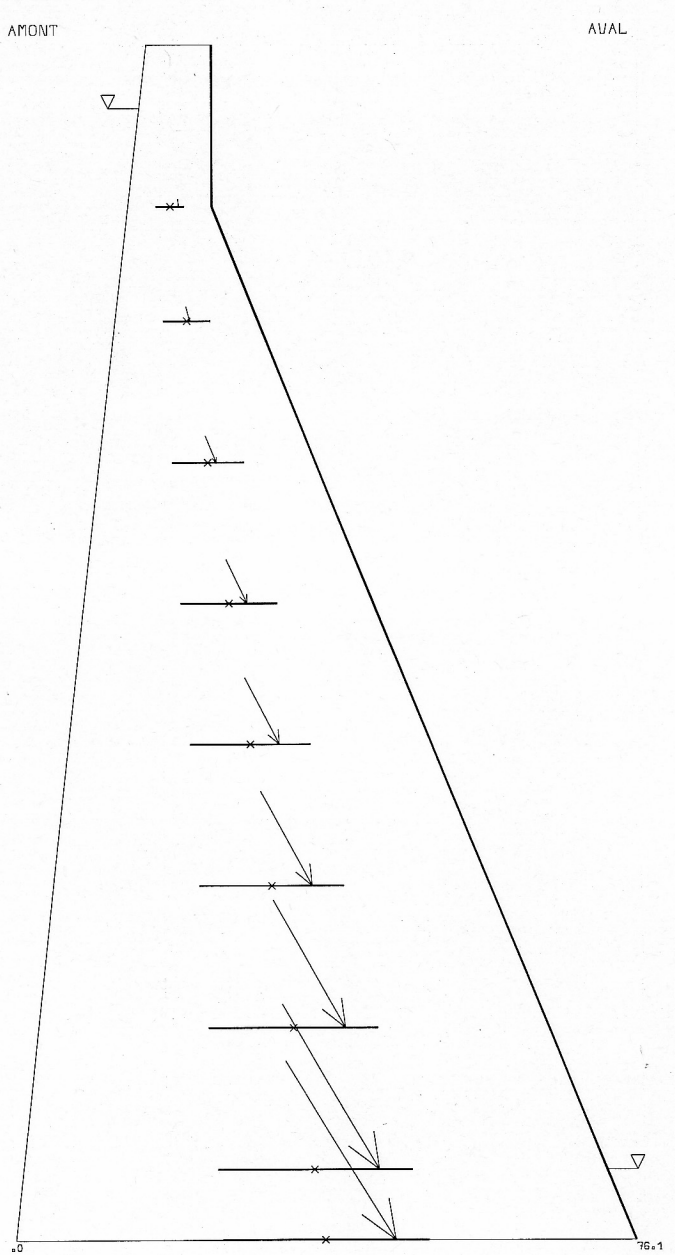
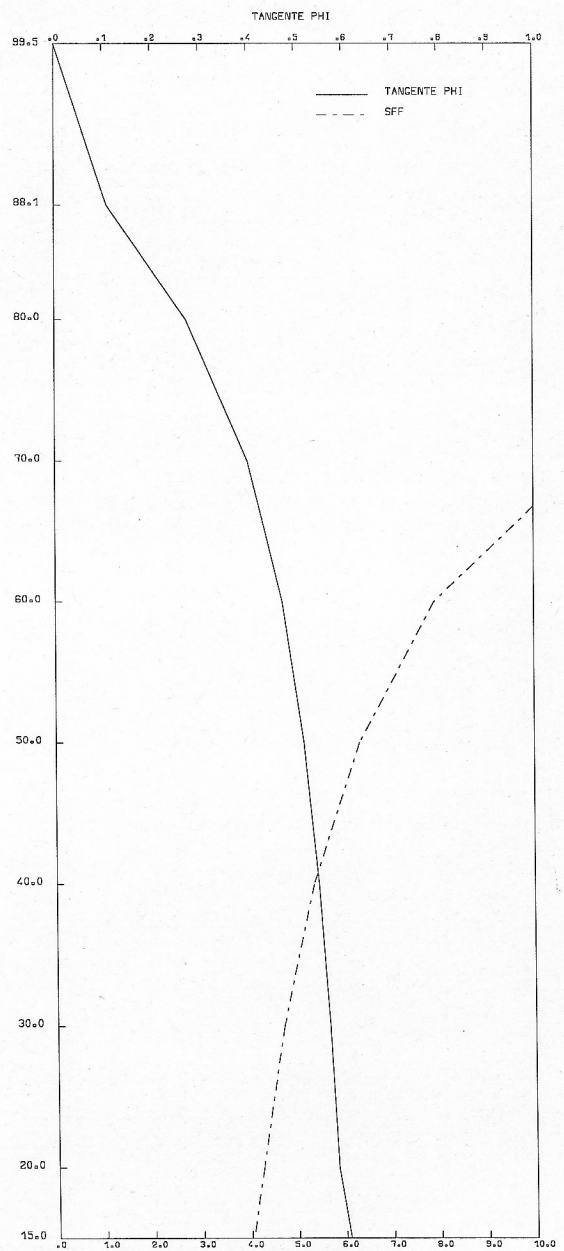
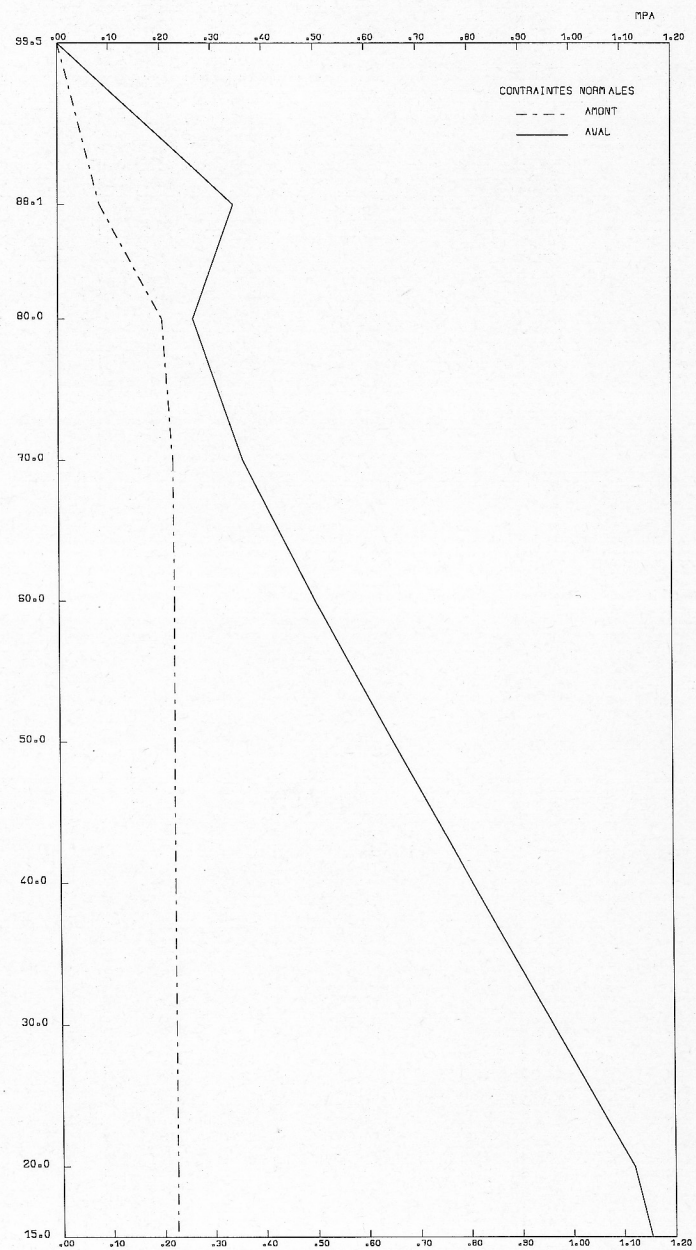


ECHELLE EN X 1/418 ECHELLE EN Z 1/242



SHEAR FRICTION FACTOR (COHESION= 1.000 MPA, TG PHIM= 1.000)



TOABRE RCC DAM

UNUSUAL CASE : NWL 95 + NO DRAINAGE

CNTES TOTALES LINEAIRES

STABCON - FICHIER DES SORTIES CONDENSEES

Toabre RCC Dam
UNUSUAL CASE : NWL 95 + no drainage
Cntes totales lineaires

NIVEAU (m)	ABSCISSES DES PAREMENTS NOYAU amont (m)	amont (m)	aval (m)	aval (m)	SURFACE (m2)	INERTIE (m4)	RESULTANTE DES EFFORTS horiz. (kT)	vert. (kT)	absc. (m)
88.07	14.61	14.61	24.90	24.90	10.29	90.69	.024	-.220	20.81
80.00	13.00	13.00	30.55	30.55	17.55	450.41	.112	-.411	22.15
70.00	11.00	11.00	37.55	37.55	26.55	1559.60	.313	-.780	25.32
60.00	9.00	9.00	44.55	44.55	35.55	3744.01	.613	-1.295	29.01
50.00	7.00	7.00	51.55	51.55	44.55	7368.21	1.013	-1.956	32.87
40.00	5.00	5.00	58.55	58.55	53.55	12796.68	1.513	-2.763	36.80
30.00	3.00	3.00	65.55	65.55	62.55	20393.92	2.112	-3.716	40.75
20.00	1.00	1.00	72.55	72.55	71.55	30524.44	2.813	-4.815	44.70
15.00	.00	.00	76.05	76.05	76.05	36653.59	3.188	-5.238	46.58

NIVEAU (m)	TG	SFF	CENTRE GRAVITE (m)	CONTRAINTES AMONT absc. (m)	contr. (MPA)	long. tendue (m)	CONTRAINTES AVAL absc. (m)	contr. (MPA)	long. tendue (m)
88.07	.109	51.997	19.76	14.61	.0826	.00	24.90	.3451	.00
80.00	.274	19.255	21.77	13.00	.2040	.00	30.55	.2646	.00
70.00	.401	10.993	24.27	11.00	.2247	.00	37.55	.3630	.00
60.00	.473	7.919	26.78	9.00	.2269	.00	44.55	.5018	.00
50.00	.518	6.332	29.28	7.00	.2263	.00	51.55	.6519	.00
40.00	.547	5.367	31.78	5.00	.2256	.00	58.55	.8063	.00
30.00	.568	4.720	34.28	3.00	.2253	.00	65.55	.9628	.00
20.00	.584	4.256	36.78	1.00	.2255	.00	72.55	1.1204	.00
15.00	.609	4.029	38.03	.00	.2237	.00	76.05	1.1538	.00

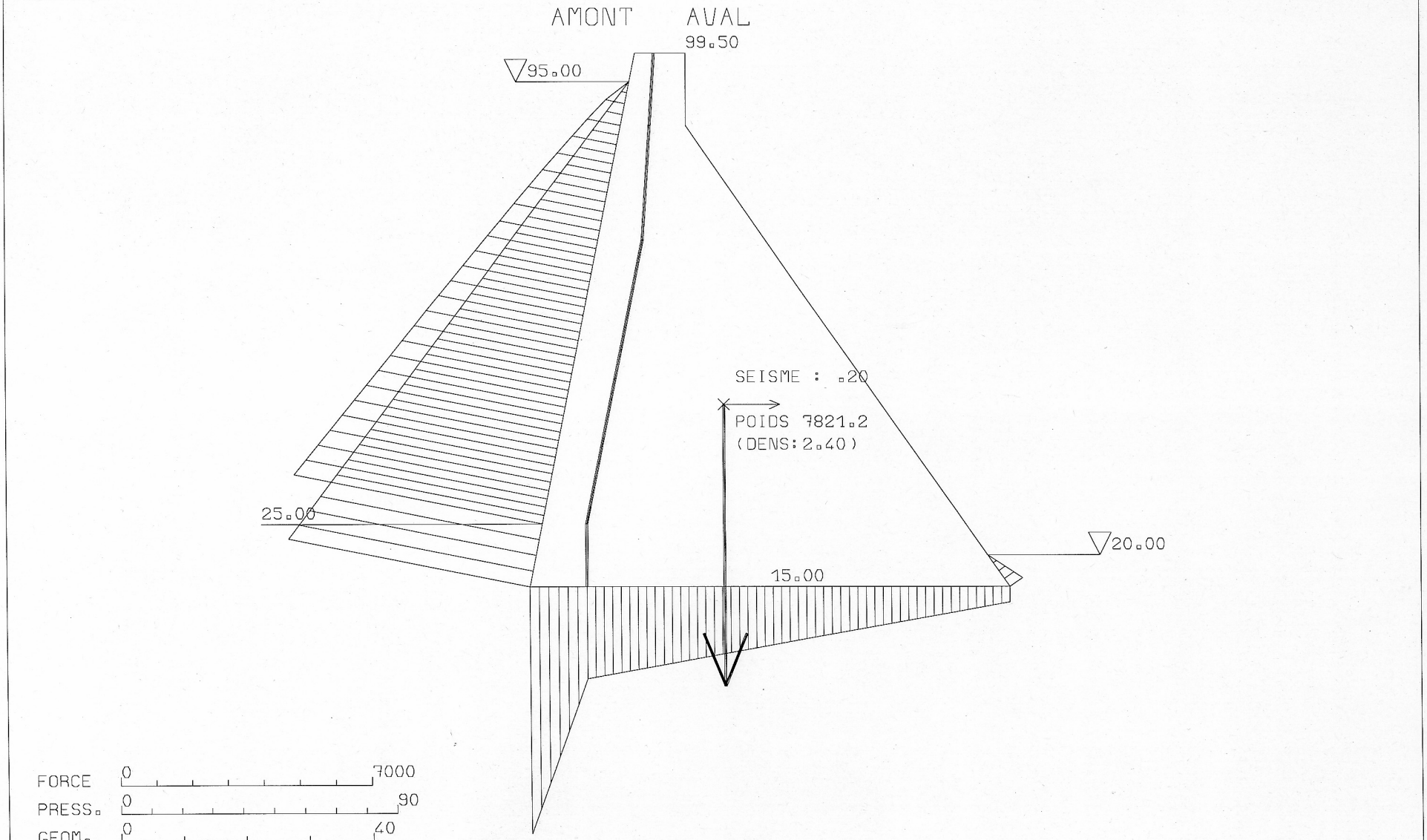
STABCON - FICHIER DES CONTRAINTES TOTALES ET EFFECTIVES

Toabre RCC Dam
UNUSUAL CASE : NWL 95 + no drainage
Cntes totales lineaires

Cote (m)	Abscisse (m)	Cnte TOTALE (MPa)	Pression (MPa)	Cnte EFFECTIVE (MPA)
88.07	Longueur tendue : .00 m - fissuration .00 %			
	14.61	.1519	.0693	.0826
	24.90	.3451	.0000	.3451
80.00	Longueur tendue : .00 m - fissuration .00 %			
	13.00	.3540	.1500	.2040
	30.55	.2646	.0000	.2646
70.00	Longueur tendue : .00 m - fissuration .00 %			
	11.00	.4747	.2500	.2247
	37.55	.3630	.0000	.3630
60.00	Longueur tendue : .00 m - fissuration .00 %			
	9.00	.5769	.3500	.2269
	44.55	.5018	.0000	.5018
50.00	Longueur tendue : .00 m - fissuration .00 %			
	7.00	.6763	.4500	.2263
	51.55	.6519	.0000	.6519
40.00	Longueur tendue : .00 m - fissuration .00 %			
	5.00	.7756	.5500	.2256
	58.55	.8063	.0000	.8063
30.00	Longueur tendue : .00 m - fissuration .00 %			
	3.00	.8753	.6500	.2253
	65.55	.9628	.0000	.9628
20.00	Longueur tendue : .00 m - fissuration .00 %			
	1.00	.9755	.7500	.2255
	72.55	1.1204	.0000	1.1204
15.00	Longueur tendue : .00 m - fissuration .00 %			
	.00	1.0237	.8000	.2237
	76.05	1.2038	.0500	1.1538

FIN DU TRAITEMENT

	COYNE ET BELLIER	STABCON	
FEASIBILITY STUDY MARCH 2003		RCC DAM STABILITY	



TOABRE RCC DAM

UNUSUAL CASE : OBE 0.20 G + NWL 95

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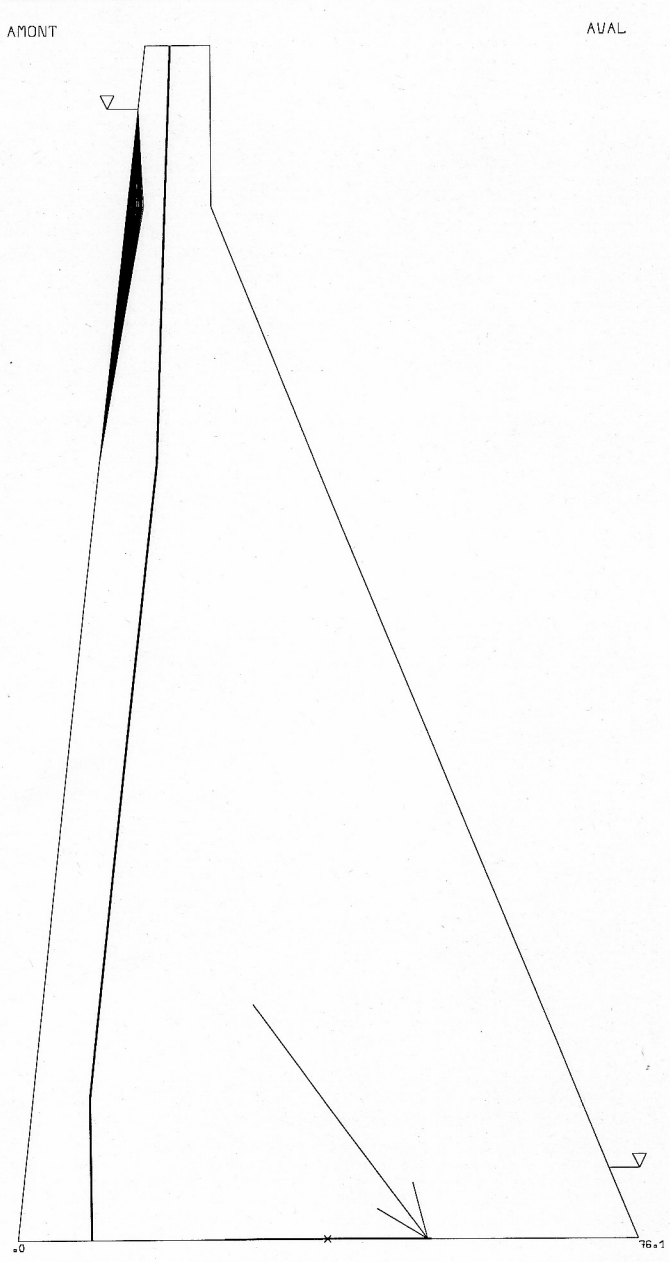

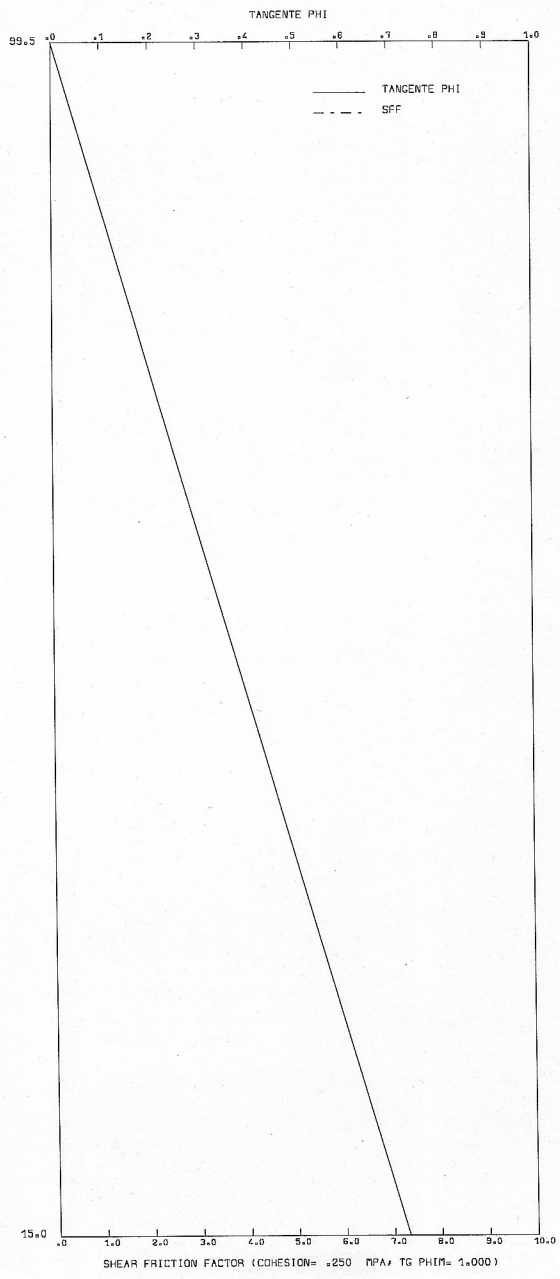

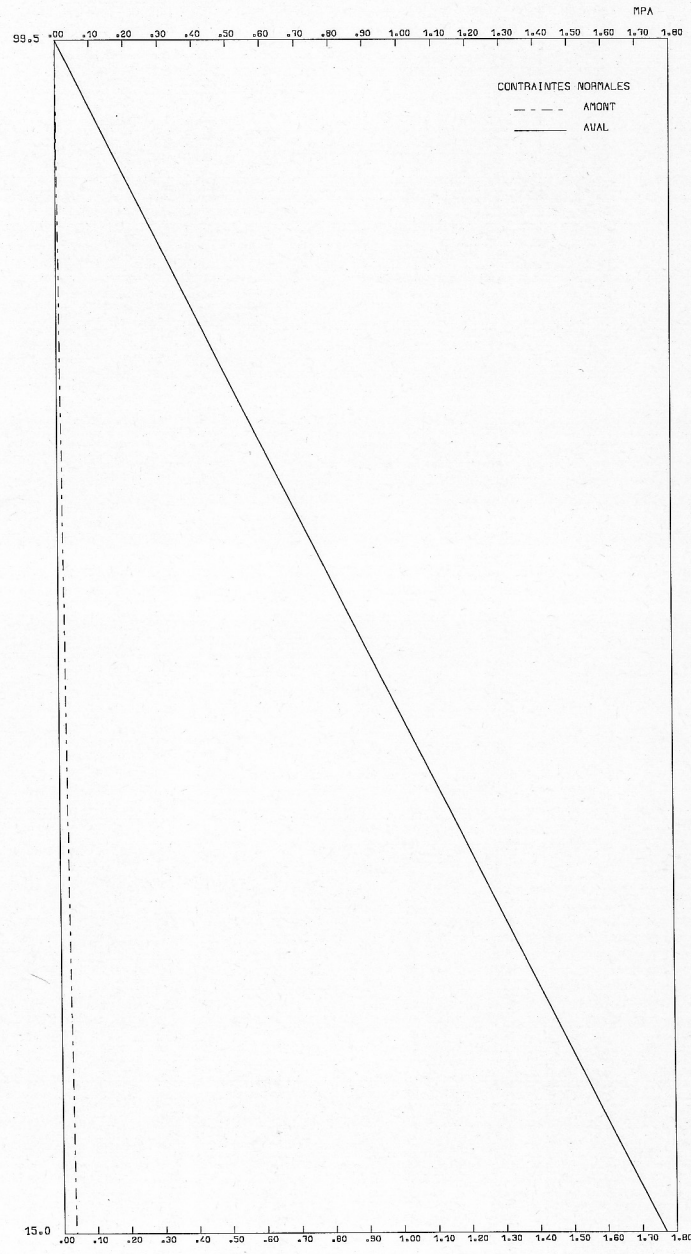

TOABRE RCC DAM

UNUSUAL CASE : OBE 0.20 G + NWL 95

CNTES EFFECTIVES LINEAIRES - FISSURATION AUTO - EPS = .0100 %

STABCON WALA - FICHIER DES SORTIES CONDENSEES

Toabre RCC Dam
UNUSUAL CASE : OBE 0.20 g + NWL 95
Cntes effectives lineaires - Fissuration auto - eps = .0100 %

NIVEAU (m)	ABSCISSES DES PAREMENTS NOYAU amont (m)	amont (m)	aval (m)	aval (m)	SURFACE (m2)	INERTIE (m4)	RESULTANTE DES EFFORTS horiz. (kT)	vert. (kT)	absc. (m)
15.00	.00	.00	76.05	76.05	76.05	36653.59	5.026	-6.866	50.20

NIVEAU (m)	TG	SFF	CENTRE GRAVITE (m)	CONTRAINTES AMONT absc. (m)	contr. (MPA)	long. tendue (m)	CONTRAINTES AVAL absc. (m)	contr. (MPA)	long. tendue (m)
15.00	.732	1.744	38.03	.00	.0358	.00	76.05	1.7698	.00

STABCON WALA - FICHIER DES CONTRAINTES TOTALES ET EFFECTIVES

Toabre RCC Dam
UNUSUAL CASE : OBE 0.20 g + NWL 95
Cntes effectives lineaires - Fissuration auto - eps = .0100 %

Cote (m)	Abscisse (m)	Cnte TOTALE (MPa)	Pression (MPa)	Cnte EFFECTIVE (MPA)
15.00	Longueur tendue : .00 m - fissuration .00 %			
	.00	.8358	.8000	.0358
	9.00	.5385	.2975	.2410
	76.05	1.8198	.0500	1.7698

FIN DU TRAITEMENT

COYNE ET BELLIER

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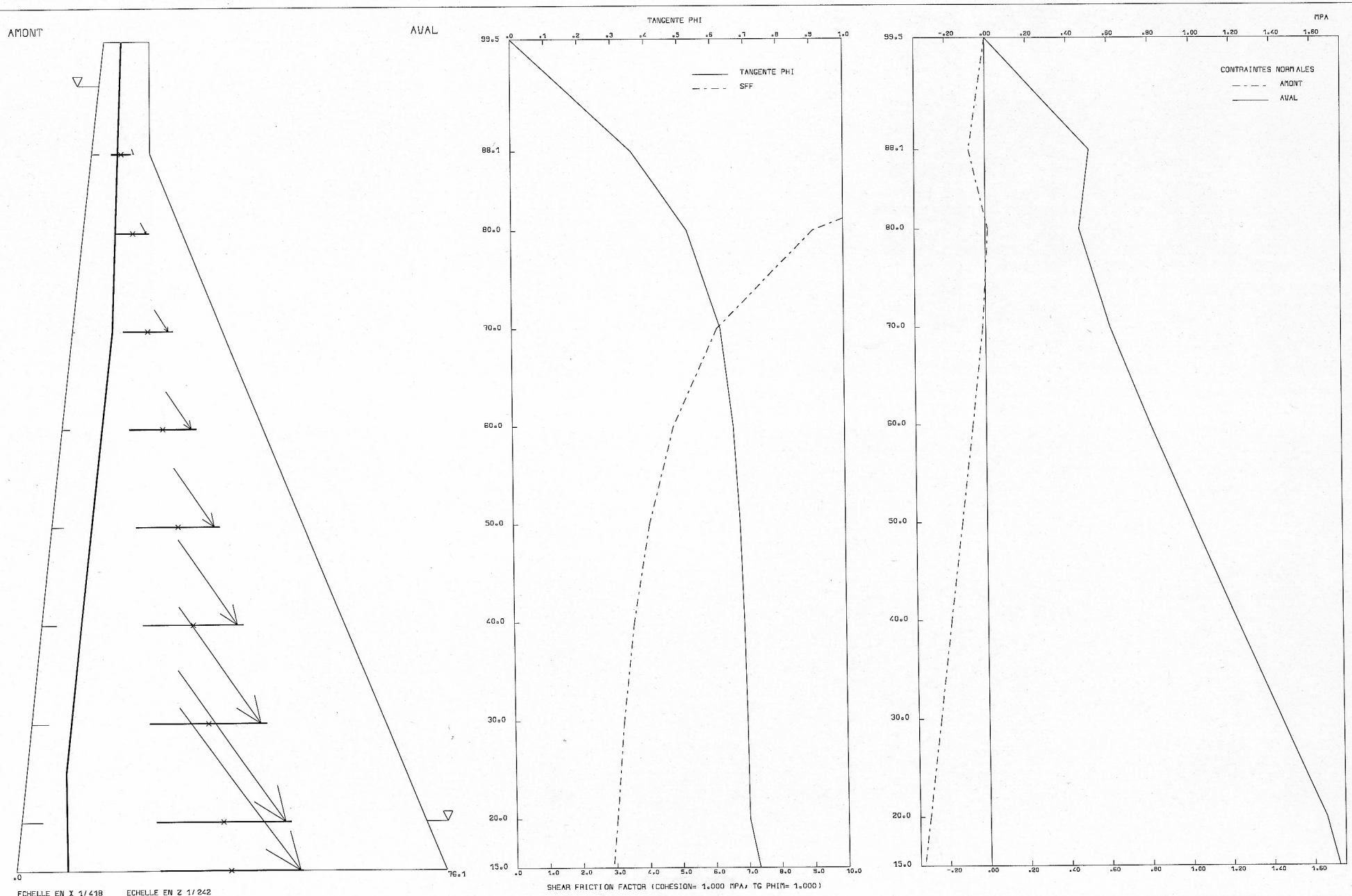


TOABRE RCC DAM

UNUSUAL CASE : OBE 0.20 G + NWL 95

CNTES TOTALES LINEAIRES

STABCON WALA - FICHIER DES SORTIES CONDENSEES

Toabre RCC Dam
UNUSUAL CASE : OBE 0.20 g + NWL 95
Cntes totales lineaires

NIVEAU (m)	ABSCISSES DES PAREMENTS NOYAU amont (m)	amont (m)	aval (m)	aval (m)	SURFACE (m2)	INERTIE (m4)	RESULTANTE DES EFFORTS horiz. (kT)	vert. (kT)	absc. (m)
88.07	14.61	14.61	24.90	24.90	10.29	90.69	.083	-.230	22.02
80.00	13.00	13.00	30.55	30.55	17.55	450.41	.244	-.463	24.17
70.00	11.00	11.00	37.55	37.55	26.55	1559.60	.581	-.927	27.94
60.00	9.00	9.00	44.55	44.55	35.55	3744.01	1.068	-1.609	31.83
50.00	7.00	7.00	51.55	51.55	44.55	7368.21	1.705	-2.498	35.75
40.00	5.00	5.00	58.55	58.55	53.55	12796.68	2.490	-3.595	39.67
30.00	3.00	3.00	65.55	65.55	62.55	20393.92	3.423	-4.900	43.58
20.00	1.00	1.00	72.55	72.55	71.55	30524.44	4.474	-6.368	47.71
15.00	.00	.00	76.05	76.05	76.05	36653.59	5.026	-6.866	50.20

NIVEAU (m)	TG	SFF	CENTRE GRAVITE (m)	CONTRAINTES AMONT absc. (m)	contr. (MPA)	long. tendue (m)	CONTRAINTES AVAL absc. (m)	contr. (MPA)	long. tendue (m)
88.07	.360	15.212	19.76	14.61	-.0805	1.32	24.90	.5116	.00
80.00	.527	9.096	21.77	13.00	.0123	.00	30.55	.4626	.00
70.00	.627	6.165	24.27	11.00	-.0148	.39	37.55	.6114	.00
60.00	.664	4.833	26.78	9.00	-.0662	1.37	44.55	.8058	.00
50.00	.682	4.078	29.28	7.00	-.1227	2.10	51.55	1.0135	.00
40.00	.693	3.594	31.78	5.00	-.1802	2.63	58.55	1.2264	.00
30.00	.699	3.258	34.28	3.00	-.2379	3.02	65.55	1.4417	.00
20.00	.703	3.022	36.78	1.00	-.2977	3.74	72.55	1.6589	.00
15.00	.732	2.879	38.03	.00	-.3290	4.51	76.05	1.7209	.00

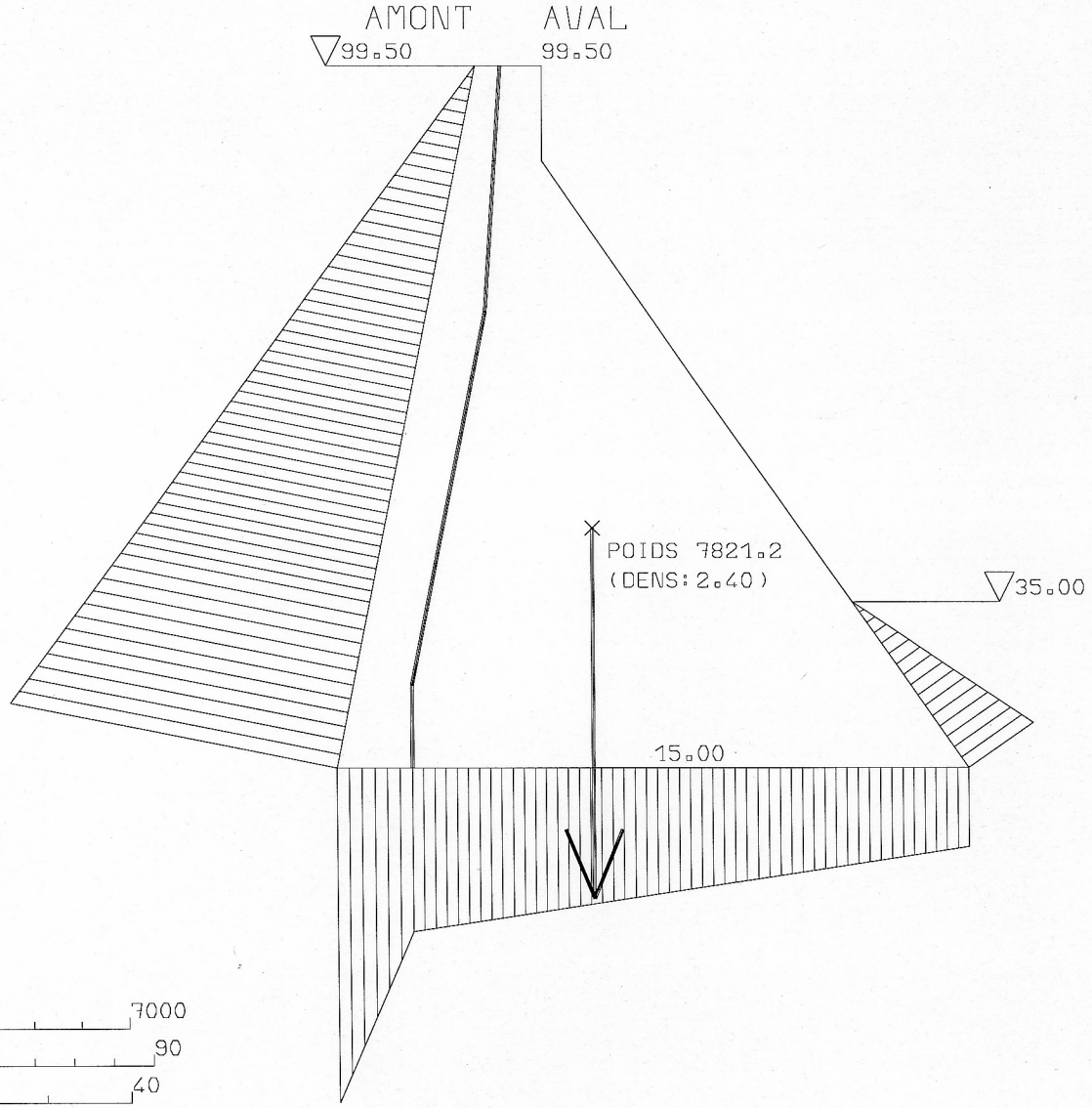
STABCON WALA - FICHIER DES CONTRAINTES TOTALES ET EFFECTIVES

Toabre RCC Dam
UNUSUAL CASE : OBE 0.20 g + NWL 95
Cntes totales lineaires

Cote (m)	Abscisse (m)	Cnte TOTALE (MPa)	Pression (MPa)	Cnte EFFECTIVE (MPA)
88.07	Longueur tendue : 1.32 m - fissuration .00 %			
	14.61	-.0112	.0693	-.0805
	19.16	.2200	.0229	.1972
	24.90	.5116	.0000	.5116
80.00	Longueur tendue : .00 m - fissuration .00 %			
	13.00	.1623	.1500	.0123
	18.64	.2589	.0495	.2094
	30.55	.4626	.0000	.4626
70.00	Longueur tendue : .39 m - fissuration .00 %			
	11.00	.2352	.2500	-.0148
	18.00	.3344	.0825	.2519
	37.55	.6114	.0000	.6114
60.00	Longueur tendue : 1.37 m - fissuration .00 %			
	9.00	.2838	.3500	-.0662
	16.00	.3866	.1155	.2711
	44.55	.8058	.0000	.8058
50.00	Longueur tendue : 2.10 m - fissuration .00 %			
	7.00	.3273	.4500	-.1227
	14.00	.4352	.1485	.2867
	51.55	1.0135	.0000	1.0135
40.00	Longueur tendue : 2.63 m - fissuration .00 %			
	5.00	.3698	.5500	-.1802
	12.00	.4818	.1815	.3003
	58.55	1.2264	.0000	1.2264
30.00	Longueur tendue : 3.02 m - fissuration .00 %			
	3.00	.4121	.6500	-.2379
	10.00	.5274	.2145	.3129
	65.55	1.4417	.0000	1.4417
20.00	Longueur tendue : 3.74 m - fissuration .00 %			
	1.00	.4523	.7500	-.2977
	9.00	.5872	.2475	.3397
	72.55	1.6589	.0000	1.6589
15.00	Longueur tendue : 4.51 m - fissuration .00 %			
	.00	.4710	.8000	-.3290
	9.00	.6249	.2975	.3274
	76.05	1.7709	.0500	1.7209

FIN DU TRAITEMENT

	COYNE ET BELLIER	STABCON	
FEASIBILITY STUDY MARCH 2003		RCC DAM STABILITY	



TOABRE RCC DAM

EXTREME CASE : PMF 99.50

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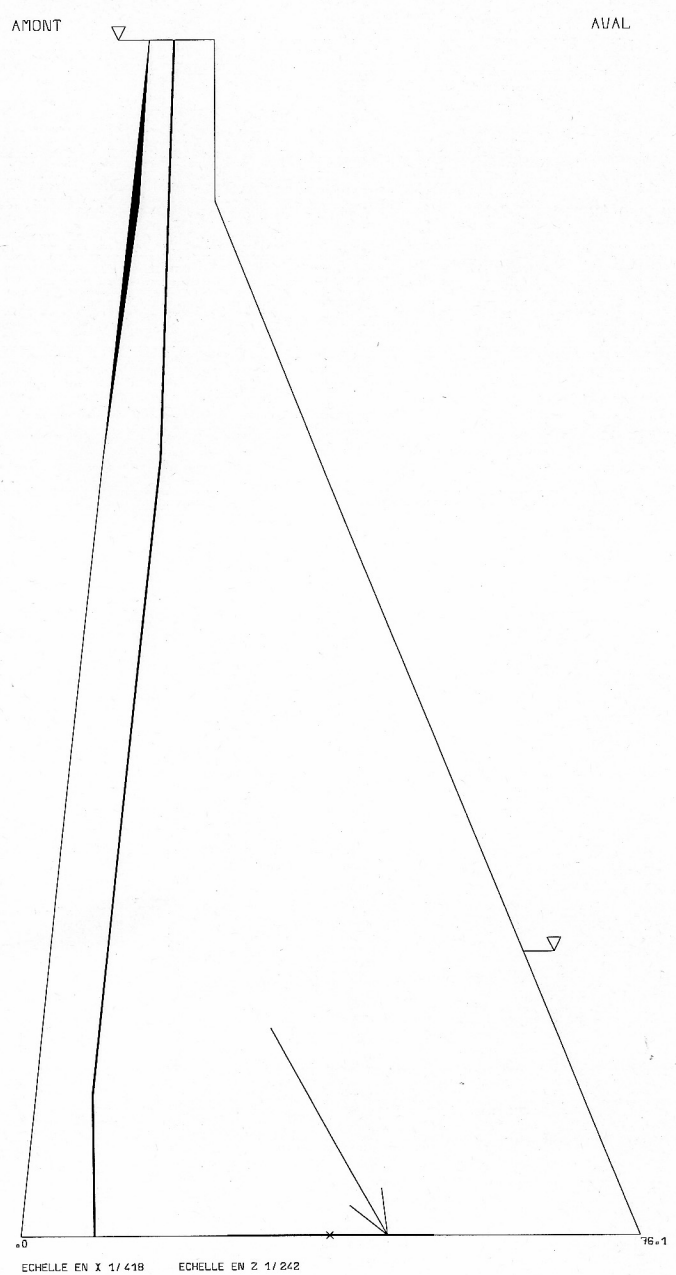

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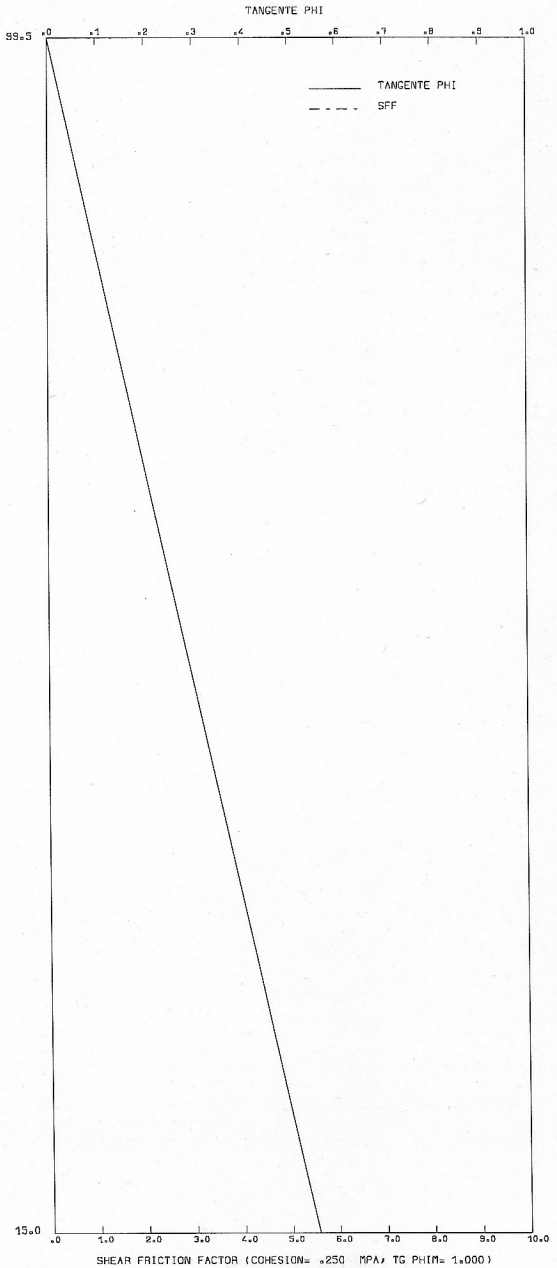
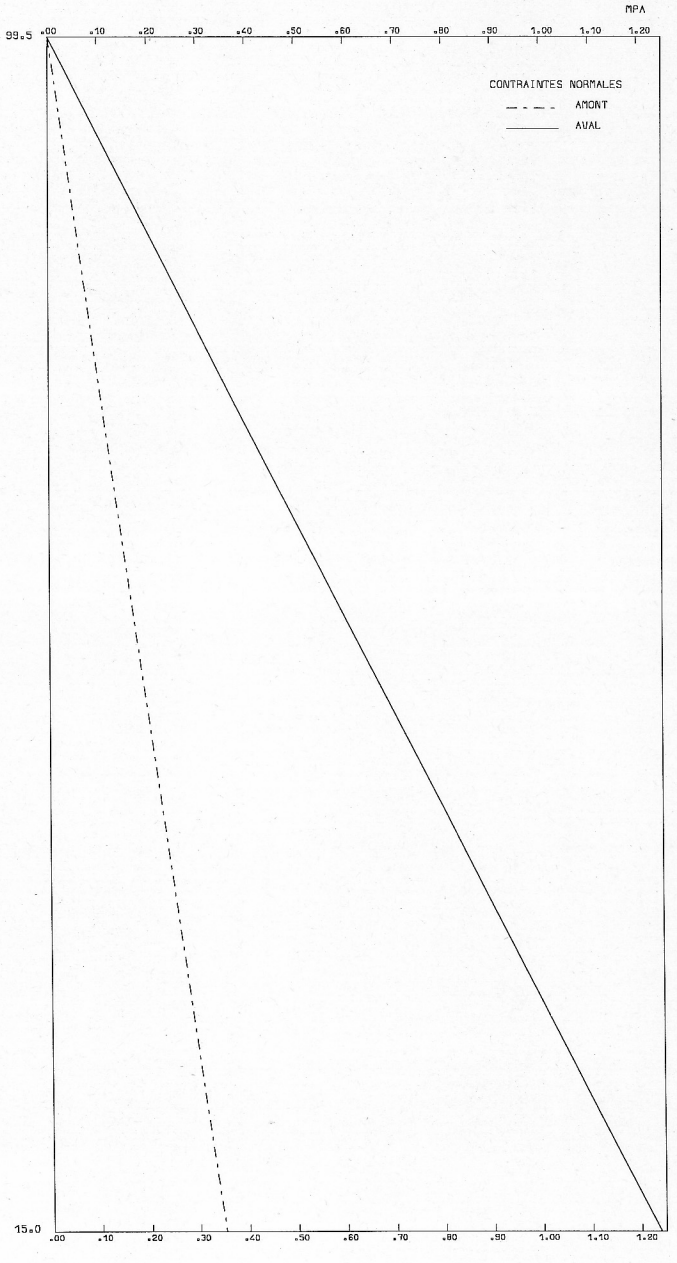


SHEAR FRICTION FACTOR (COHESION= .250 MPA, TG PHIM= 1.000)



TOABRE RCC DAM

EXTREME CASE : PMF 99.50

CNTES EFFECTIVES LINEAIRES - FISSURATION AUTO - EPS = .0100 %

STABCON - FICHIER DES SORTIES CONDENSEES

Toabre RCC Dam
EXTREME CASE : PMF 99.50
Cntes effectives lineaires - Fissuration auto - eps = .0100 %

NIVEAU (m)	ABSCISSES DES PAREMENTS				SURFACE (m2)	INERTIE (m4)	RESULTANTE DES EFFORTS		
	NOYAU								
	amont (m)	amont (m)	aval (m)	aval (m)			horiz. (kT)	vert. (kT)	absc. (m)
15.00	.00	.00	76.05	76.05	76.05	36653.59	3.370	-6.055	45.08

NIVEAU (m)	TG	SFF	CENTRE GRAVITE (m)	CONTRAINTES AMONT			CONTRAINTES AVAL		
				absc. (m)	contr. (MPA)	long. tendue (m)	absc. (m)	contr. (MPA)	long. tendue (m)
15.00	.557	2.361	38.03	.00	.3528	.00	76.05	1.2394	.00

STABCON - FICHIER DES CONTRAINTES TOTALES ET EFFECTIVES

Toabre RCC Dam
EXTREME CASE : PMF 99.50
Cntes effectives lineaires - Fissuration auto - eps = .0100 %

Cote (m)	Abscisse (m)	Cnte TOTALE (MPa)	Pression (MPa)	Cnte EFFECTIVE (MPA)
15.00	Longueur tendue : .00 m	-	fissuration	.00 %
	.00	1.1978	.8450	.3528
	9.00	.8706	.4129	.4578
	76.05	1.4394	.2000	1.2394

FIN DU TRAITEMENT

COYNE ET BELLIER

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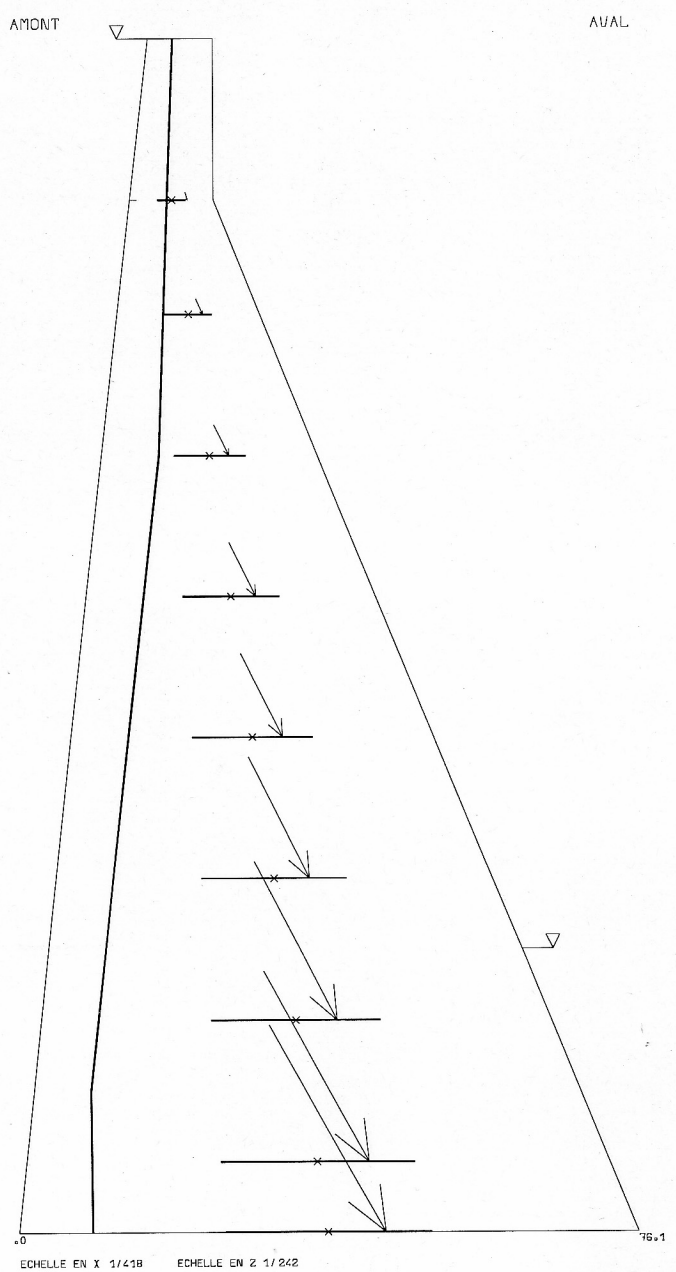

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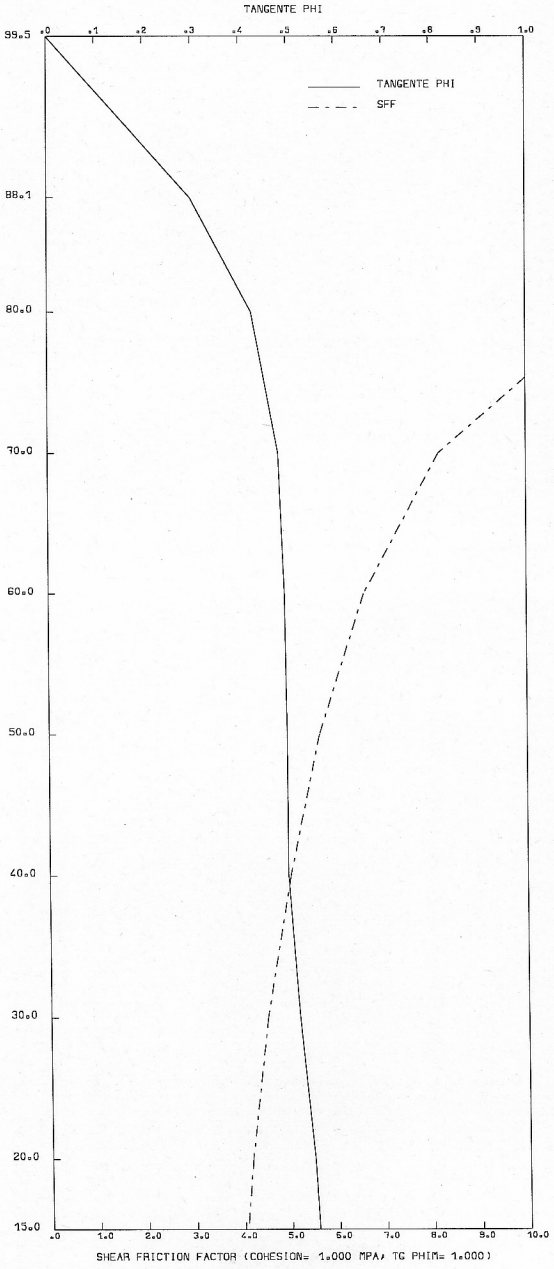
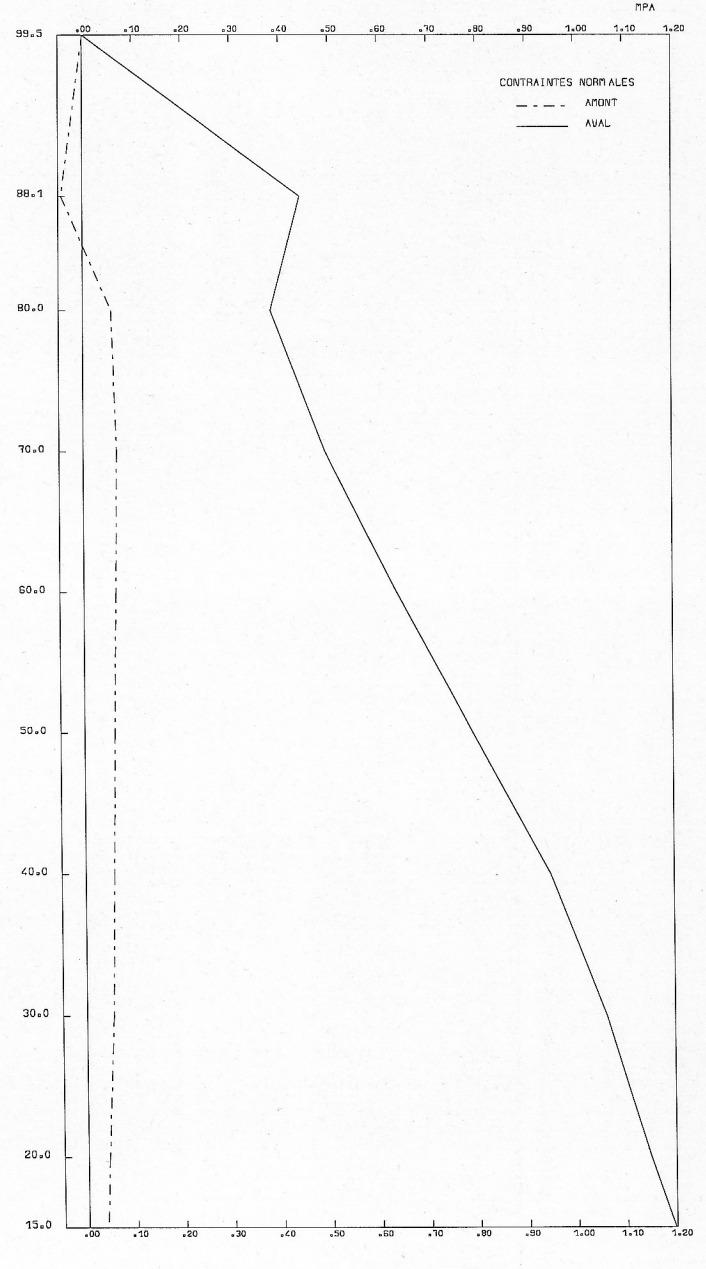




TOABRE RCC DAM

EXTREME CASE : PMF 99.50

CNTES TOTALES LINEAIRES

STABCON - FICHIER DES SORTIES CONDENSEES

Toabre RCC Dam
EXTREME CASE : PMF 99.50
Cntes totales lineaires

NIVEAU (m)	ABSCISSES DES PAREMENTS NOYAU amont (m)	amont (m)	aval (m)	aval (m)	SURFACE (m2)	INERTIE (m4)	RESULTANTE DES EFFORTS horiz. (kT)	vert. (kT)	absc. (m)
88.07	14.61	14.61	24.90	24.90	10.29	90.69	.065	-.218	21.71
80.00	13.00	13.00	30.55	30.55	17.55	450.41	.190	-.447	23.50
70.00	11.00	11.00	37.55	37.55	26.55	1559.60	.435	-.904	26.66
60.00	9.00	9.00	44.55	44.55	35.55	3744.01	.780	-1.581	29.83
50.00	7.00	7.00	51.55	51.55	44.55	7368.21	1.225	-2.464	33.00
40.00	5.00	5.00	58.55	58.55	53.55	12796.68	1.770	-3.553	36.16
30.00	3.00	3.00	65.55	65.55	62.55	20393.92	2.403	-4.614	39.41
20.00	1.00	1.00	72.55	72.55	71.55	30524.44	3.048	-5.554	43.12
15.00	.00	.00	76.05	76.05	76.05	36653.59	3.370	-6.055	45.08

NIVEAU (m)	TG	SFF	CENTRE GRAVITE (m)	CONTRAINTES AMONT absc. (m)	contr. (MPA)	long. tendue (m)	CONTRAINTES AVAL absc. (m)	contr. (MPA)	long. tendue (m)
88.07	.299	19.091	19.76	14.61	-.0443	.83	24.90	.4431	.00
80.00	.425	11.581	21.77	13.00	.0580	.00	30.55	.3834	.00
70.00	.481	8.180	24.27	11.00	.0684	.00	37.55	.4928	.00
60.00	.493	6.583	26.78	9.00	.0652	.00	44.55	.6372	.00
50.00	.497	5.647	29.28	7.00	.0614	.00	51.55	.7908	.00
40.00	.498	5.033	31.78	5.00	.0585	.00	58.55	.9476	.00
30.00	.521	4.524	34.28	3.00	.0544	.00	65.55	1.0610	.00
20.00	.549	4.170	36.78	1.00	.0434	.00	72.55	1.1489	.00
15.00	.557	4.053	38.03	.00	.0391	.00	76.05	1.1973	.00

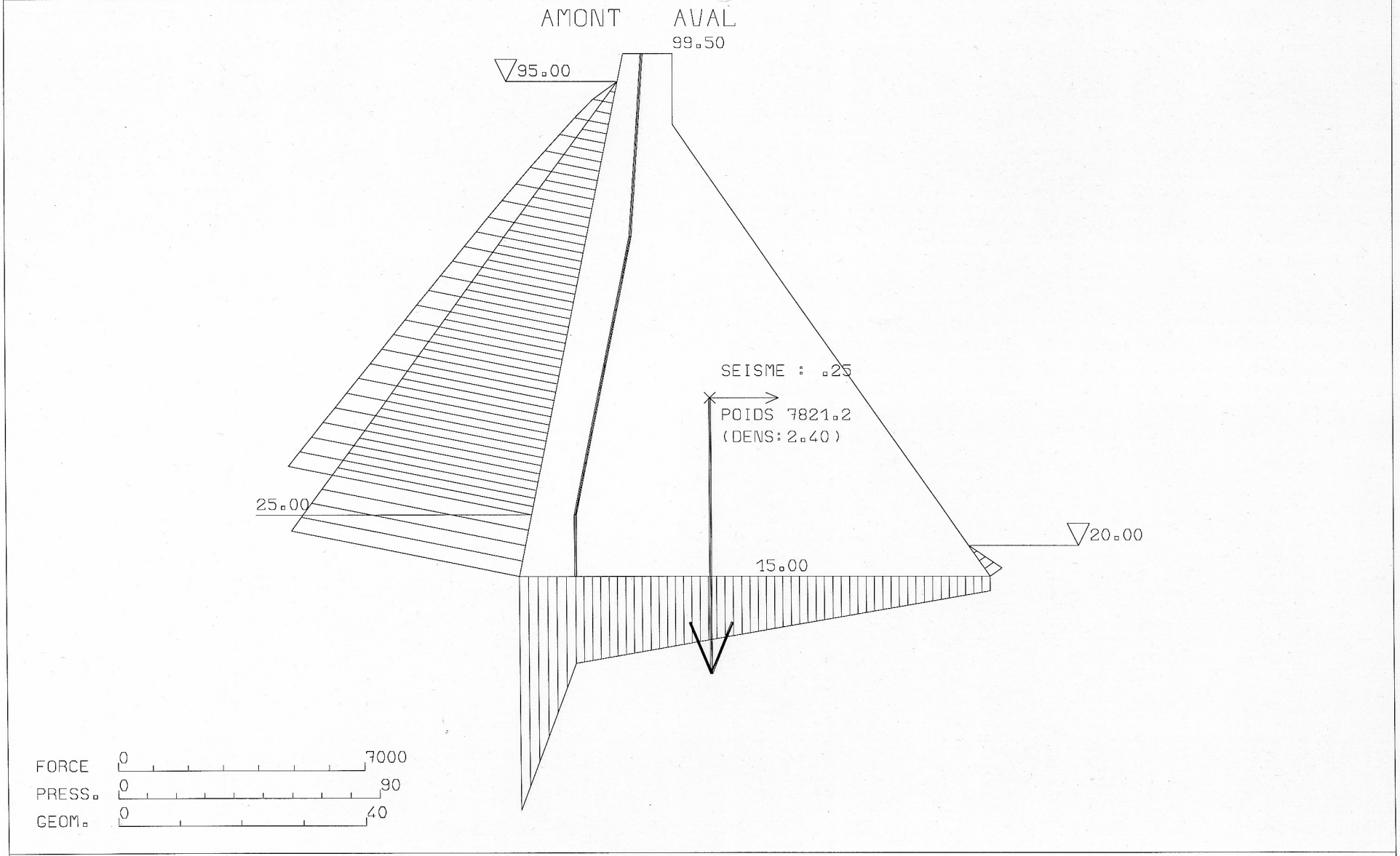
STABCON - FICHIER DES CONTRAINTES TOTALES ET EFFECTIVES

Toabre RCC Dam
EXTREME CASE : PMF 99.50
Cntes totales lineaires

Cote (m)	Abscisse (m)	Cnte TOTALE (MPa)	Pression (MPa)	Cnte EFFECTIVE (MPA)
88.07	Longueur tendue : .83 m - fissuration .00 %			
	14.61	.0700	.1143	-.0443
	19.16	.2350	.0377	.1973
	24.90	.4431	.0000	.4431
80.00	Longueur tendue : .00 m - fissuration .00 %			
	13.00	.2530	.1950	.0580
	18.64	.2949	.0644	.2306
	30.55	.3834	.0000	.3834
70.00	Longueur tendue : .00 m - fissuration .00 %			
	11.00	.3634	.2950	.0684
	18.00	.3975	.0974	.3002
	37.55	.4928	.0000	.4928
60.00	Longueur tendue : .00 m - fissuration .00 %			
	9.00	.4602	.3950	.0652
	16.00	.4951	.1304	.3647
	44.55	.6372	.0000	.6372
50.00	Longueur tendue : .00 m - fissuration .00 %			
	7.00	.5564	.4950	.0614
	14.00	.5933	.1634	.4299
	51.55	.7908	.0000	.7908
40.00	Longueur tendue : .00 m - fissuration .00 %			
	5.00	.6535	.5950	.0585
	12.00	.6920	.1964	.4956
	58.55	.9476	.0000	.9476
30.00	Longueur tendue : .00 m - fissuration .00 %			
	3.00	.7494	.6950	.0544
	10.00	.7898	.2629	.5270
	65.55	1.1110	.0500	1.0610
20.00	Longueur tendue : .00 m - fissuration .00 %			
	1.00	.8384	.7950	.0434
	9.00	.8899	.3629	.5271
	72.55	1.2989	.1500	1.1489
15.00	Longueur tendue : .00 m - fissuration .00 %			
	.00	.8841	.8450	.0391
	9.00	.9449	.4129	.5320
	76.05	1.3973	.2000	1.1973

FIN DU TRAITEMENT

	COYNE ET BELLIER	STABCON	
FEASIBILITY STUDY MARCH 2003		RCC DAM STABILITY	



TOABRE RCC DAM

EXTREME CASE : MDE 0.25 G + NWL 95

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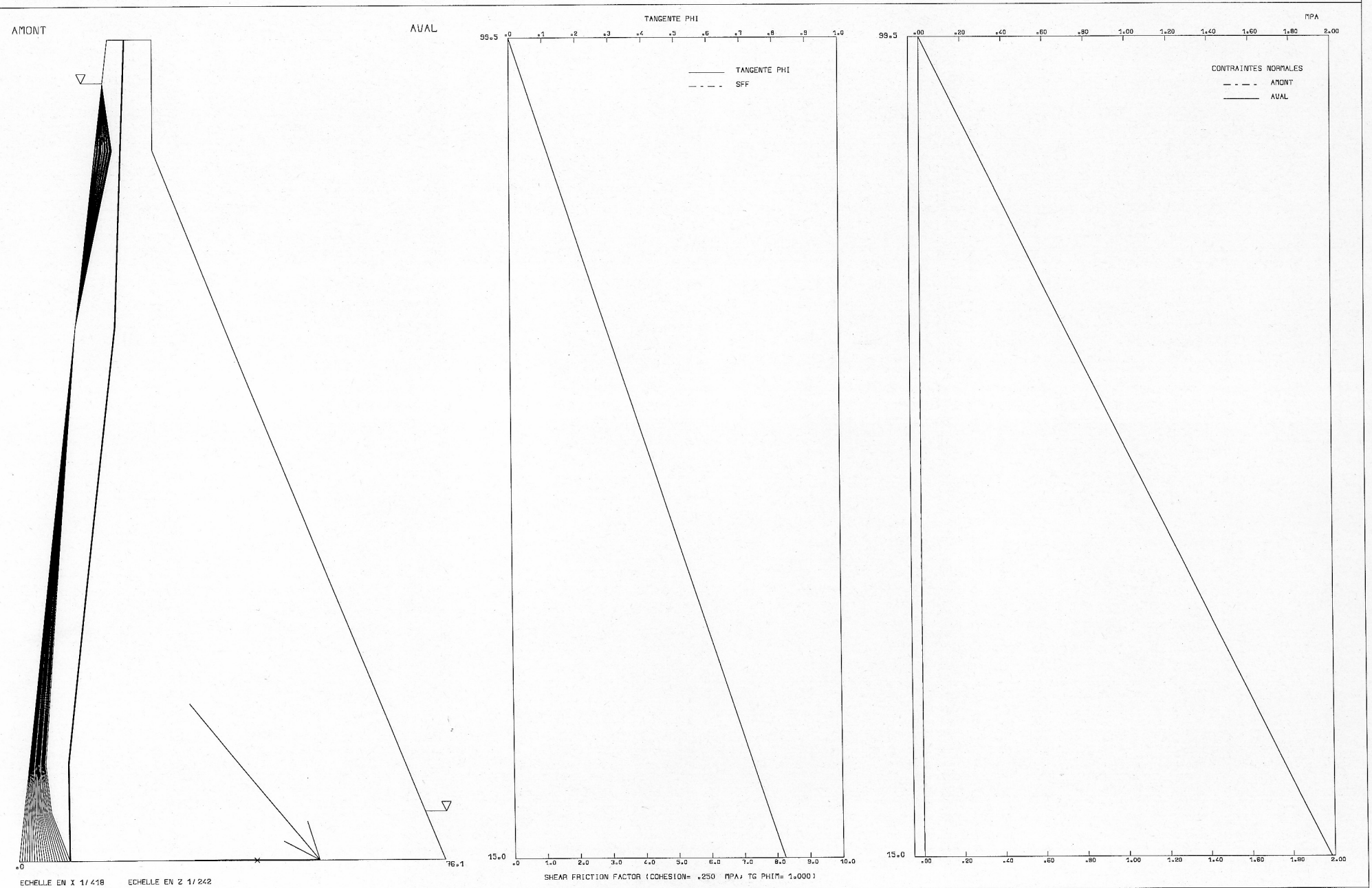

TOABRE RCC DAM

EXTREME CASE : MDE 0.25 G + NWL 95

CNTES EFFECTIVES LINEAIRES - FISSURATION AUTO - EPS = .0100 %

STABCON WALA - FICHIER DES SORTIES CONDENSEES

Toabre RCC Dam
EXTREME CASE : MDE 0.25 g + NWL 95
Cntes effectives lineaires - Fissuration auto - eps = .0100 %

NIVEAU (m)	ABSCISSES DES PAREMENTS NOYAU amont (m)	amont (m)	aval (m)	aval (m)	SURFACE (m2)	INERTIE (m4)	RESULTANTE DES EFFORTS horiz. (kT)	vert. (kT)	absc. (m)
15.00	.00	8.98	76.05	76.05	67.07	25138.11	5.486	-6.654	53.70

NIVEAU (m)	TG	SFF	CENTRE GRAVITE (m)	CONTRAINTES AMONT absc. (m)	contr. (MPA)	long. tendue (m)	CONTRAINTES AVAL absc. (m)	contr. (MPA)	long. tendue (m)
15.00	.824	1.519	42.52	8.98	-.0004	.01	76.05	1.9847	.00

STABCON WALA - FICHIER DES CONTRAINTES TOTALES ET EFFECTIVES

Toabre RCC Dam
EXTREME CASE : MDE 0.25 g + NWL 95
Cntes effectives lineaires - Fissuration auto - eps = .0100 %

Cote (m)	Abscisse (m)	Cnte TOTALE (MPa)	Pression (MPa)	Cnte EFFECTIVE (MPA)
15.00	Longueur tendue : .01 m - fissuration 11.81 %			
	.00	.8000	.8000	.0000
	8.98	.7996	.8000	-.0004
	9.00	.2976	.2975	.0001
	76.05	2.0347	.0500	1.9847

FIN DU TRAITEMENT

COYNE ET BELLIER

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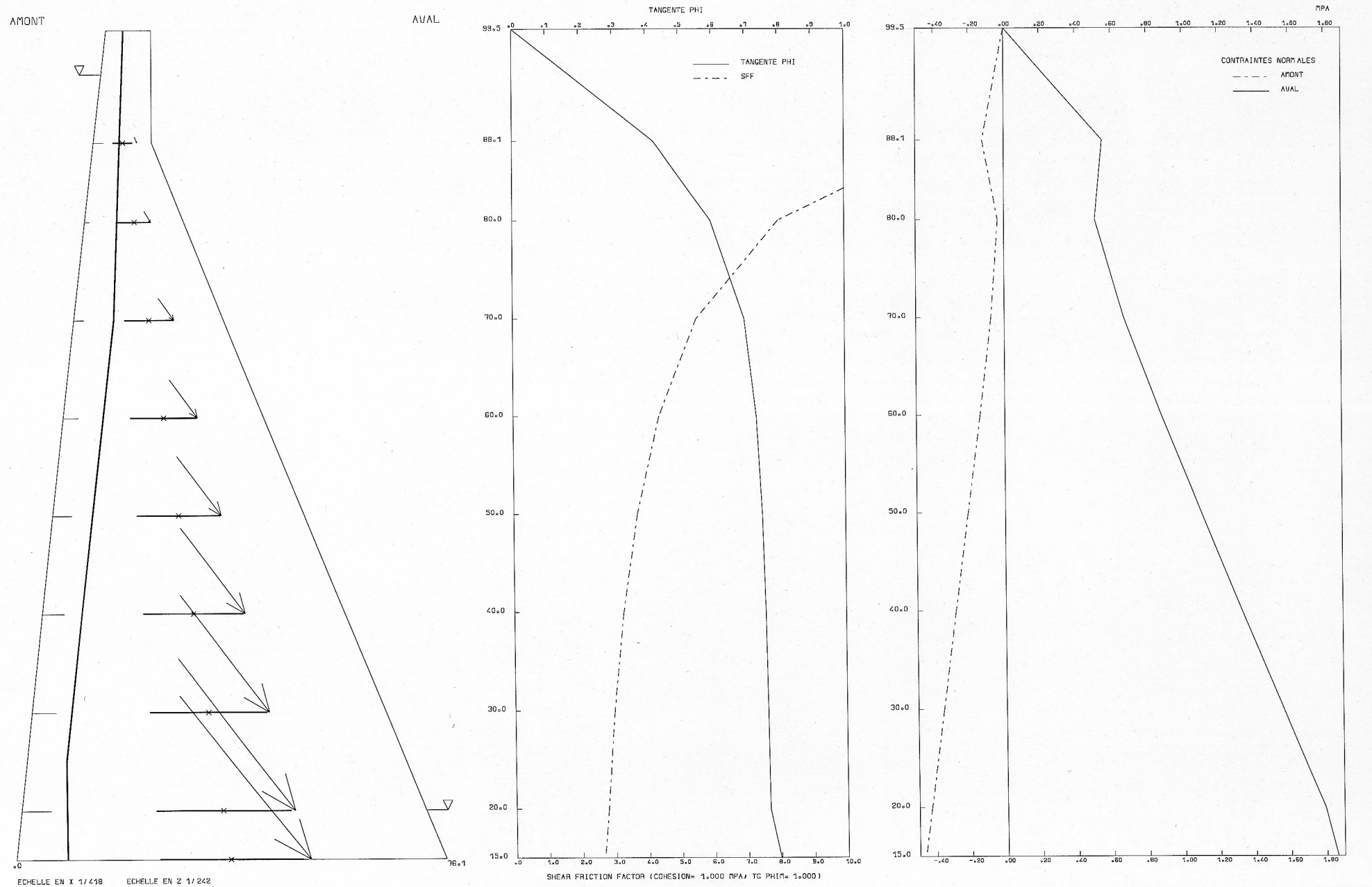

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TOABRE RCC DAM

EXTREME CASE : MDE 0.25 G + NWL 95

CNTES TOTALES LINEAIRES

STABCON WALA - FICHIER DES SORTIES CONDENSEES

Toabre RCC Dam
EXTREME CASE : MDE 0.25 g + NWL 95
Cntes totales lineaires

NIVEAU (m)	ABSCISSES DES PAREMENTS (NOYAU) amont (m)	amont (m)	aval (m)	aval (m)	SURFACE (m2)	INERTIE (m4)	RESULTANTE DES EFFORTS horiz. (kT)	vert. (kT)	absc. (m)
88.07	14.61	14.61	24.90	24.90	10.29	90.69	.097	-.230	22.33
80.00	13.00	13.00	30.55	30.55	17.55	450.41	.277	-.464	24.70
70.00	11.00	11.00	37.55	37.55	26.55	1559.60	.648	-.930	28.70
60.00	9.00	9.00	44.55	44.55	35.55	3744.01	1.182	-1.614	32.78
50.00	7.00	7.00	51.55	51.55	44.55	7368.21	1.878	-2.506	36.90
40.00	5.00	5.00	58.55	58.55	53.55	12796.68	2.735	-3.605	41.02
30.00	3.00	3.00	65.55	65.55	62.55	20393.92	3.751	-4.912	45.12
20.00	1.00	1.00	72.55	72.55	71.55	30524.44	4.889	-6.381	49.46
15.00	.00	.00	76.05	76.05	76.05	36653.59	5.486	-6.880	52.13

NIVEAU (m)	TG	SFF	CENTRE GRAVITE (m)	CONTRAINTES AMONT absc. (m)	contr. (MPA)	long. tendue (m)	CONTRAINTES AVAL absc. (m)	contr. (MPA)	long. tendue (m)
88.07	.423	12.924	19.76	14.61	-.1213	1.76	24.90	.5532	.00
80.00	.596	8.021	21.77	13.00	-.0357	.88	30.55	.5121	.00
70.00	.697	5.531	24.27	11.00	-.0747	1.75	37.55	.6734	.00
60.00	.733	4.371	26.78	9.00	-.1395	2.66	44.55	.8818	.00
50.00	.750	3.706	29.28	7.00	-.2099	3.36	51.55	1.1039	.00
40.00	.759	3.276	31.78	5.00	-.2817	3.89	58.55	1.3315	.00
30.00	.764	2.977	34.28	3.00	-.3537	4.29	65.55	1.5614	.00
20.00	.766	2.768	36.78	1.00	-.4285	5.14	72.55	1.7936	.00
15.00	.797	2.640	38.03	.00	-.4671	6.10	76.05	1.8626	.00

STABCON WALA - FICHIER DES CONTRAINTES TOTALES ET EFFECTIVES

Toabre RCC Dam
EXTREME CASE : MDE 0.25 g + NWL 95
Cntes totales lineaires

Cote (m)	Abscisse (m)	Cnte TOTALE (MPa)	Pression (MPa)	Cnte EFFECTIVE (MPA)
88.07	Longueur tendue : 1.76 m - fissuration .00 %			
	14.61	-.0520	.0693	-.1213
	19.16	.2157	.0229	.1928
	24.90	.5532	.0000	.5532
80.00	Longueur tendue : .88 m - fissuration .00 %			
	13.00	.1143	.1500	-.0357
	18.64	.2423	.0495	.1928
	30.55	.5121	.0000	.5121
70.00	Longueur tendue : 1.75 m - fissuration .00 %			
	11.00	.1753	.2500	-.0747
	18.00	.3066	.0825	.2241
	37.55	.6734	.0000	.6734
60.00	Longueur tendue : 2.66 m - fissuration .00 %			
	9.00	.2105	.3500	-.1395
	16.00	.3427	.1155	.2272
	44.55	.8818	.0000	.8818
50.00	Longueur tendue : 3.36 m - fissuration .00 %			
	7.00	.2401	.4500	-.2099
	14.00	.3758	.1485	.2273
	51.55	1.1039	.0000	1.1039
40.00	Longueur tendue : 3.89 m - fissuration .00 %			
	5.00	.2683	.5500	-.2817
	12.00	.4073	.1815	.2258
	58.55	1.3315	.0000	1.3315
30.00	Longueur tendue : 4.29 m - fissuration .00 %			
	3.00	.2963	.6500	-.3537
	10.00	.4379	.2145	.2234
	65.55	1.5614	.0000	1.5614
20.00	Longueur tendue : 5.14 m - fissuration .00 %			
	1.00	.3215	.7500	-.4285
	9.00	.4861	.2475	.2386
	72.55	1.7936	.0000	1.7936
15.00	Longueur tendue : 6.10 m - fissuration .00 %			
	.00	.3329	.8000	-.4671
	9.00	.5198	.2975	.2223
	76.05	1.9126	.0500	1.8626

FIN DU TRAITEMENT

APPENDIX B – Adaptation for NWL 90 masl & NWL 100 masl

The design of these two alternative projects is made on the same principles as the one made for the reference Project with NWL 95 masl.

The application of the same design criteria for these two different dams and reservoirs involves adaptations of some characteristics as :

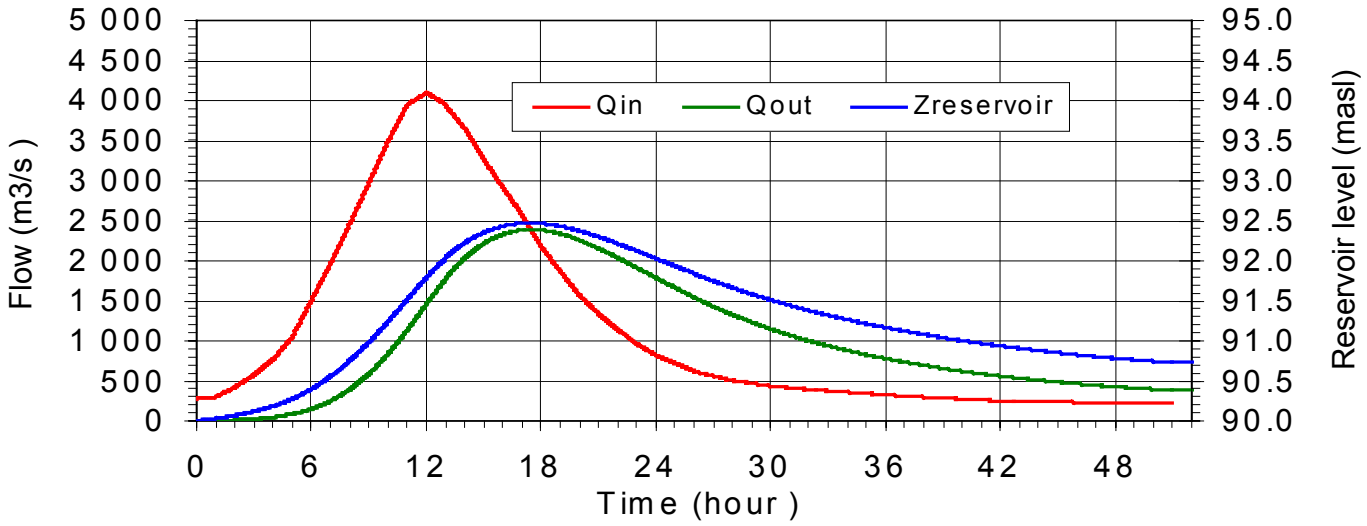
- reservoir levels (NWL, MWL, PMF) with adequate dam crest elevation associated to adjusted spillway capacity and performance,

The following table summarised these respective levels obtained from reservoir flood routing calculations with the same 330 m long spillway (including bridge piers), as presented on Figures 1 to 3:

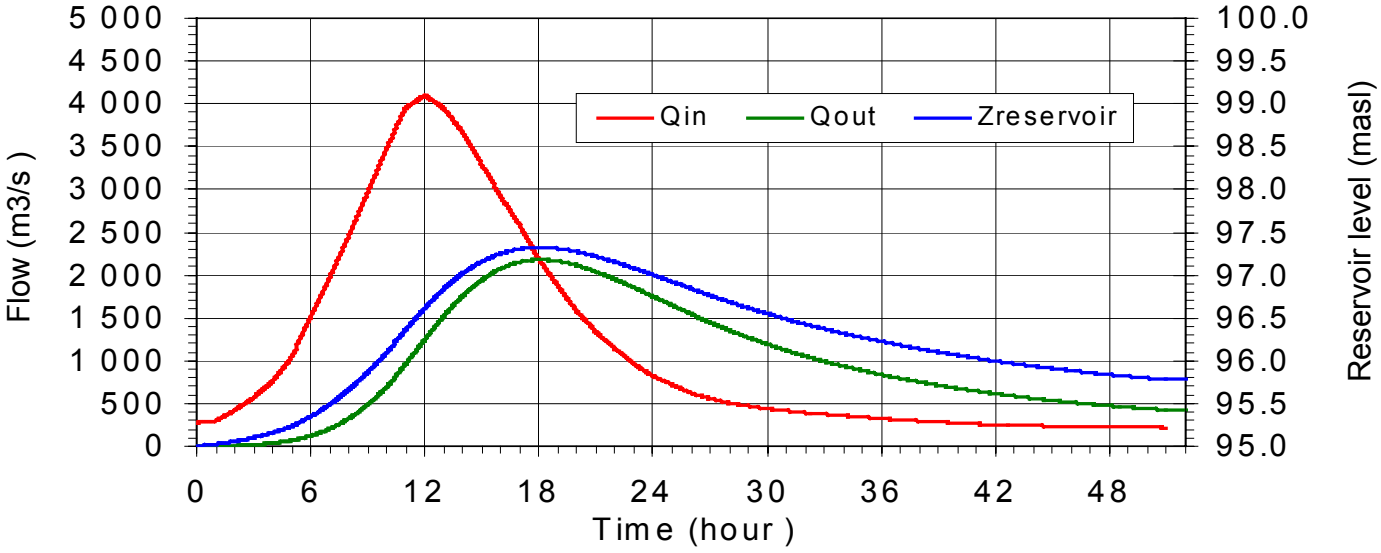
Alternative		**NWL 90**	**NWL 95**	**NWL 100**
spillway sill elevation	masl	90	95	100
spillway total length	m	330	330	330
spillway effective length	m	308	308	308
Design Flood (T = 1 000y)				
MWL	masl	92.50	97.35	102.20
freeboard (to dam crest)	m	2.25	2.15	2.10
released flow	m^3/s	2 395	2 180	1 980
specific released flow	$m^3/s/m$	7.25	6.6	6.0
Extreme Flood (T= 10 000 y)				
MMWL level	masl	93.0	97.85	102.7
released flow	m^3/s	3 240	2 970	2 740
specific released flow	$m^3/s/m$	9.8	9.0	8.3
PMF				
PMF level (= dam crest)	masl	94.75	99.50	104.30
released flow	m^3/s	6 330	5 875	5 430
specific released flow	$m^3/s/m$	19.20	17.80	16.45

FIGURE 1 – DESIGN FLOOD RESERVOIR ROUTING

NWL 90 - DESIGN FLOOD A - T=1/1000



NWL 95 - DESIGN FLOOD A - T=1/1000



NWL 100 - DESIGN FLOOD A - T=1/1000

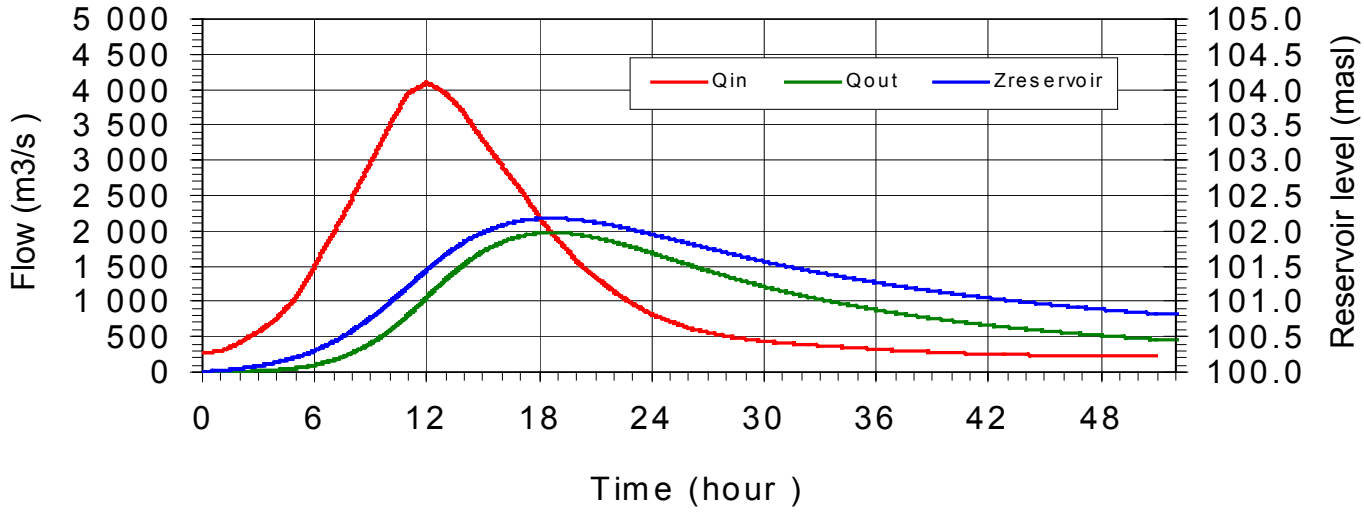


FIGURE 2 – PMF A RESERVOIR ROUTING

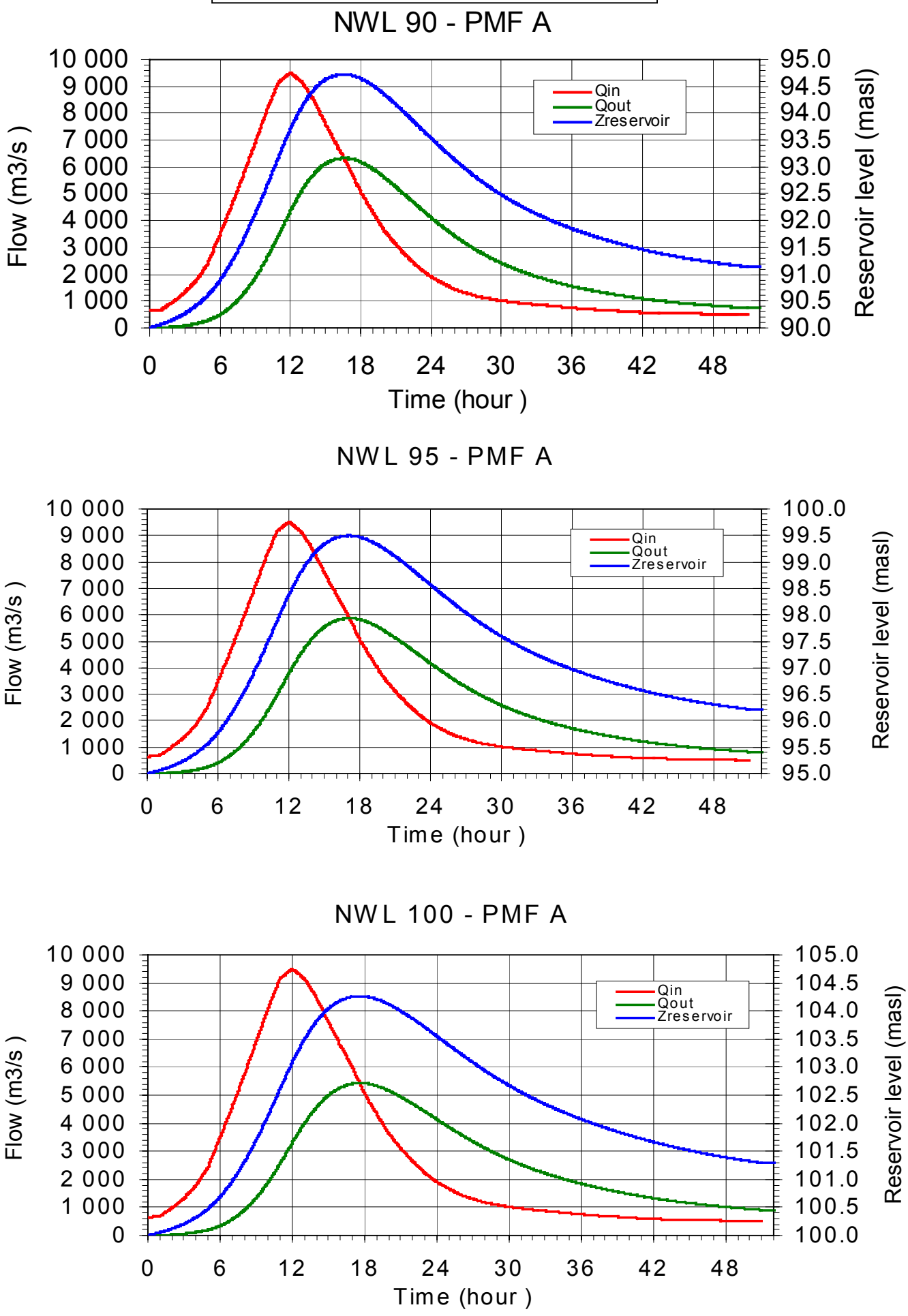
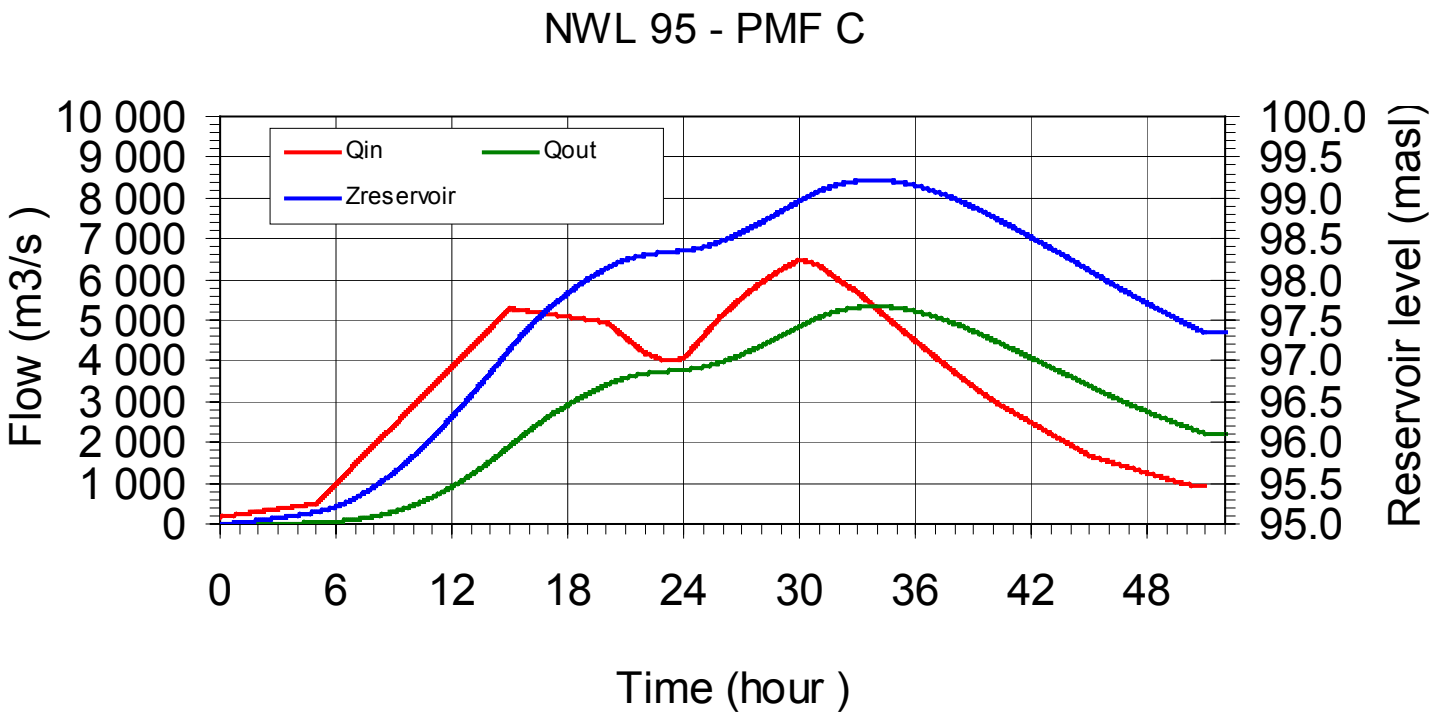


FIGURE 3 – PMF C RESERVOIR ROUTING



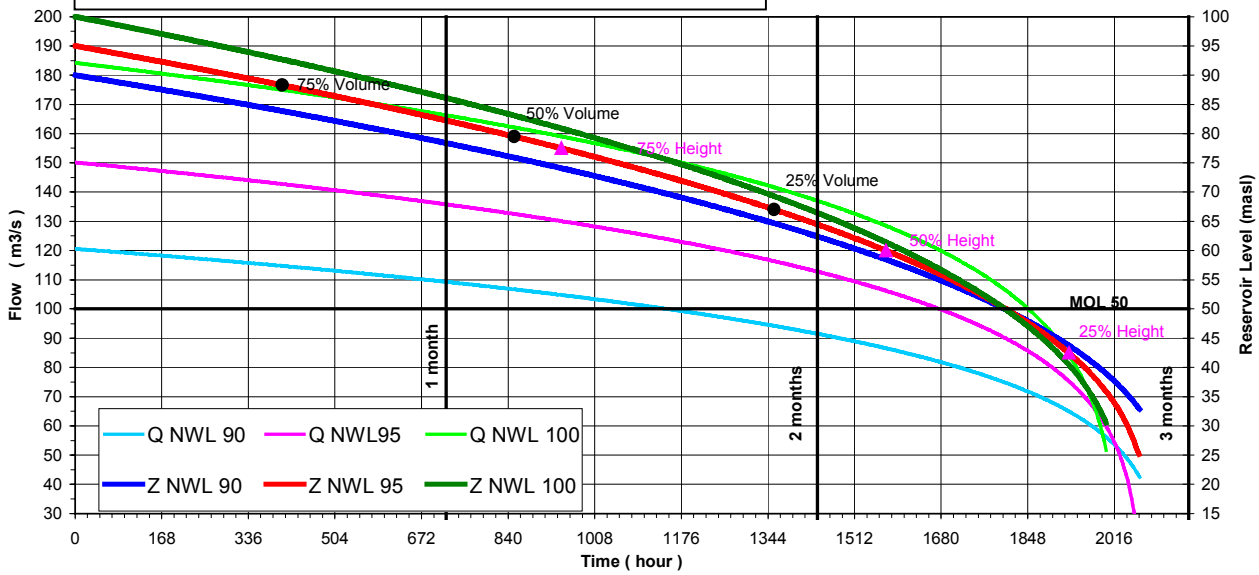
- equipment in the bottom outlet, in order to ensure the drawdown of the reservoir in the same conditions for the three alternatives:

drawdown reservoir volume	time (maximum)
75%	30-40 days
50%	50-60 days
25%	80-100 days

Reservoir drawdown calculations have been made to size the required bottom outlet structures to satisfy the above criteria, with the following additional assumptions : design with one opening, no inflow and no consideration of the transfer tunnel capacity to pass flow to Indio reservoir until it reaches its maximum reservoir level (80 masl maximum).

Sizing for alternative NWL 95 masl has been made first according to all the criteria, as shown on Figure 4; the sizing for the two other alternatives has been made in order to allow the same time to drawdown the reservoir until MOL 50 in 75 days (see Figure 4).

FIGURE 4 – RESERVOIR DRAWDOWN



The size of the bottom outlet structures to comply with the above criteria is as follows:

Normal Water Level	**masl**	**90**	**95**	**100**
Type		conversion of diversion	temporary opening	
Number of outlets		1	1	1
Capacity at NWL	m3/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

APPENDIX A – Civil Works Unit Price – Data Source and Details

The cost of the civil works has been estimated on the basis of a series of unit prices for major construction elements adapted to the conditions of this study.

Such total unit prices are developed according to the 'aggregation method' based on the analysis of the prices/costs of similar works (type/volumes) obtained from past and present international construction contracts. Aggregated unit prices are then derived from the unit prices indicated in the Bill of Quantities of such awarded construction contracts containing several hundreds of unit prices, which are consolidated to sort out the total cost of the works and adjusted to current prices representative of the Toabre Project works.

These aggregated prices include all direct and indirect construction costs relating to: labour, materials, equipment, installations, overheads etc. Application of these prices to a limited number of representative items provides an accurate estimate of the project construction cost This aggregation method is a common use in Europe to estimate the cost of projects at a conceptual design stage and even in more detailed study stages.

A series of such total unit prices representing local conditions for the project have been prepared on the basis of recent construction market prices for engineering structures and recent studies of a type and size similar to those involved for Toabre dam. Among the main data used to establish such unit price list it can be pointed out :

- the detailed 'aggregated' unit price study recently performed by Coyne et Bellier as part of the 'Diseño Conceptual de las Esclusas Post Panamax' study for ACP (ref. R4-M-601 Rev B - Task 4), on the basis of several recent construction awarded contracts, and, in addition, RCC unit price analysis with reference to international publications. Major features of this unit price study are presented in Figures 1 to 6, as presented in this detailed study, with the addition of the developed unit prices for the Toabre Project for the following major items :

  overburden excavations
  rock excavations
  rockfill (for CFRD alternative)
  Rolled Compacted Concrete (see also after)
  Conventional Vibrated Concrete
  reinforcement steel.

- in addition the RCC unit price has been particularly analysed, on the base of a recent cost estimate of a 4 MCM RCC Dam in Guinea with a RCC analytical price study performed in collaboration with an international Contractor in similar conditions (labour, material, importation of cement and flyash etc…).

  in particular the RCC unit price take into account the facts that the aggregates (as for conventional concrete) will be manufactured on site by crushing rock material obtained

from excavation (selection) and authorised quarries (main source of andesite), while the cement would be available within the Republic of Panama (or imported if necessary) and the concrete additives and cement replacement (fly ash, pozzolan etc.) would be imported. The transport distance to the site is also considered.

the breakdown of the RCC unit price of 40 USD/m^3 is as follows:

item	unit price of item	cost in $/m3 of RCC
cement - 90 kg/m^3	120 $/ton	10.8
flyash (or equiv.) – 60 kg/m^3	90 $/ton	5.4
crushed aggregates – 2 150 kg/m^3	5 $/ton	10.75
placing (including installations)		13.0
TOTAL RCC		**40 $/$m^3$**

- for the tunnel excavation the same kind of analysis in aggregate unit price has been performed with two parallel approach:

  . analysis of aggregate unit prices from similar recent contracts awarded as presented in figure 7,

  . assumption of the following geological rock quality distribution along the tunnel layout with representative weighting of support cost:

Type	Type I	Type II	Type III	Type IV	Type V
Quality	excellent	good to fair	fair to poor	poor	very poor
conservative	10%	20%	40%	29%	1%
medium	20%	30%	30%	19%	1%
Cost factor	1	1.1	1.2	2	2.5

  the average resulting global weighting coefficient is respectively 1.3 and 1.4 for the medium and the conservative assumption of rock distribution. Application of this coefficient to a unit price of 70 $/$m^3$ for non supported excavation (good rock) (cf. figure 7, lower curve) gives a global unit price of 90 to 100 $/$m^3$ for supported excavations for medium to conservative assumption of rock quality distribution.

  With the present insufficient geological knowledge the conservative assumption has been retained with an average unit price of 100 $/$m^3$ for supported tunnel excavations, corresponding to the upper curve of the figure 7.

- in addition the unit prices developed by MWH in the Feasibility study of Rio Indio Project performed has been looked for consistency of such list. In particular the tunnel excavation unit price for the 8.5 km long 4.5 m diameter (modified horseshoe shape), including the supports according to the rock quality distribution MWH assumed, is 105 USD/m^3 (75 USD/m^3 without supports).

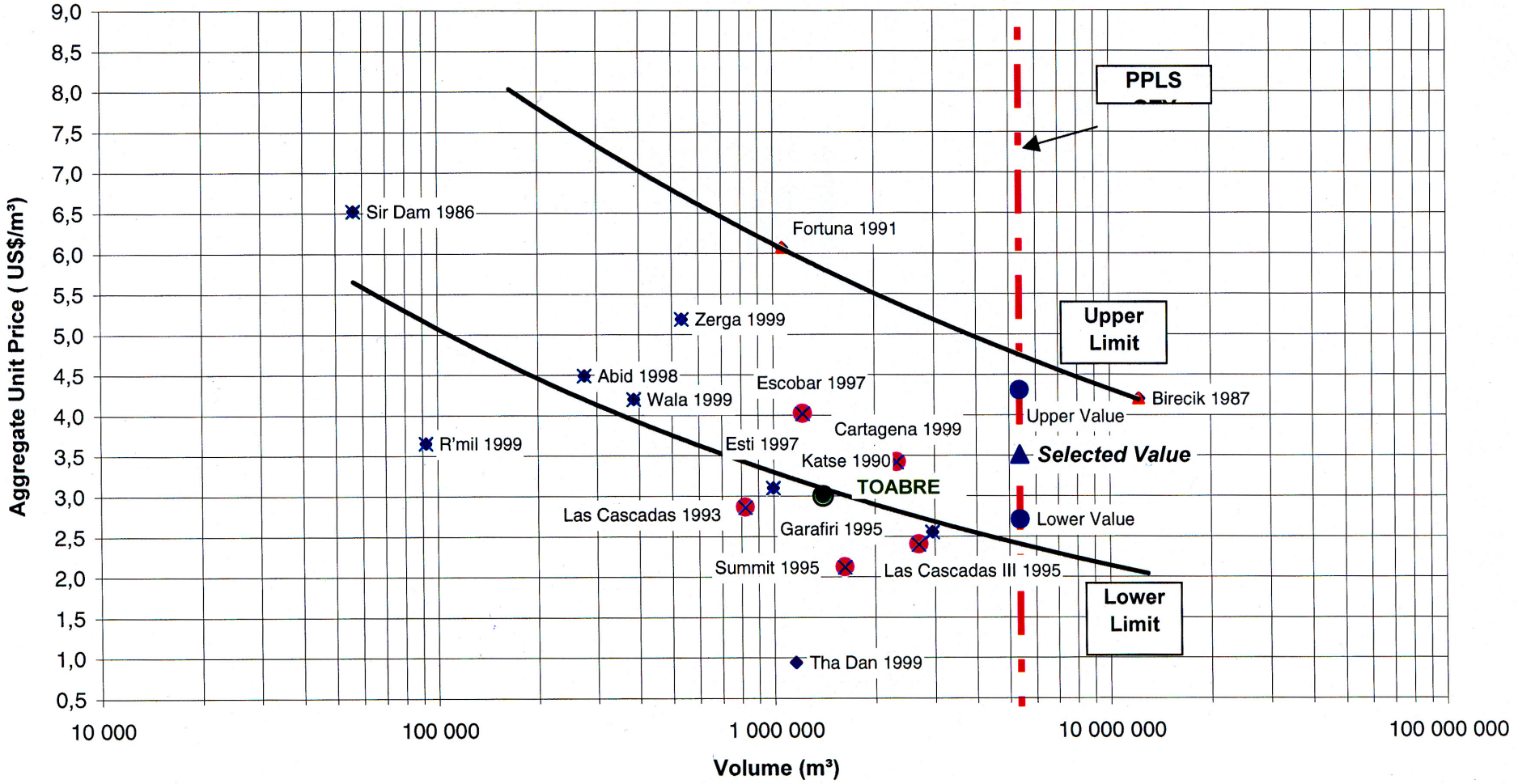
The following aggregate prices has been established from the Data source, mentioned previously for cost estimate at this feasibility stage :

Item	Unit	Unit Price (USD)
Clearing	m^2	1
Overburden Excavation	m^3	3
Rock Excavation	m^3	10
Transfer Tunnel Excavation (including supports)	m^3	100
Adit (all included)	m^3	150
Shaft Excavation (including supports)	m^3	200
Cofferdam fill	m^3	7
Rolled Compacted Concrete (RCC)	m^3	40
Conventional Vibrated Concrete (CVC)		
CVC for RCC Dam Faces	m^3	150
CVC for Spillway	m^3	160
Levelling CVC	m^3	150
Mass CVC	m^3	100
CVC for Structures	m^3	170
Underground CVC	m^3	200 to 235
Formwork	m²	25 to 30
Tunneling Forwork	m²	25
Underground Formwork	m²	50
Reinforcement bars	kg	1.2
Consolidation Grouting	ml	120
Grout Curtain	ml	135
Drainage curtain	ml	100
Crest road	m²	10

FIGURE 1

Graph B.1 Conceptual Design Post-Panamax Lock Structures (Pacific)

Overburden Excavation Aggregate Unit Prices

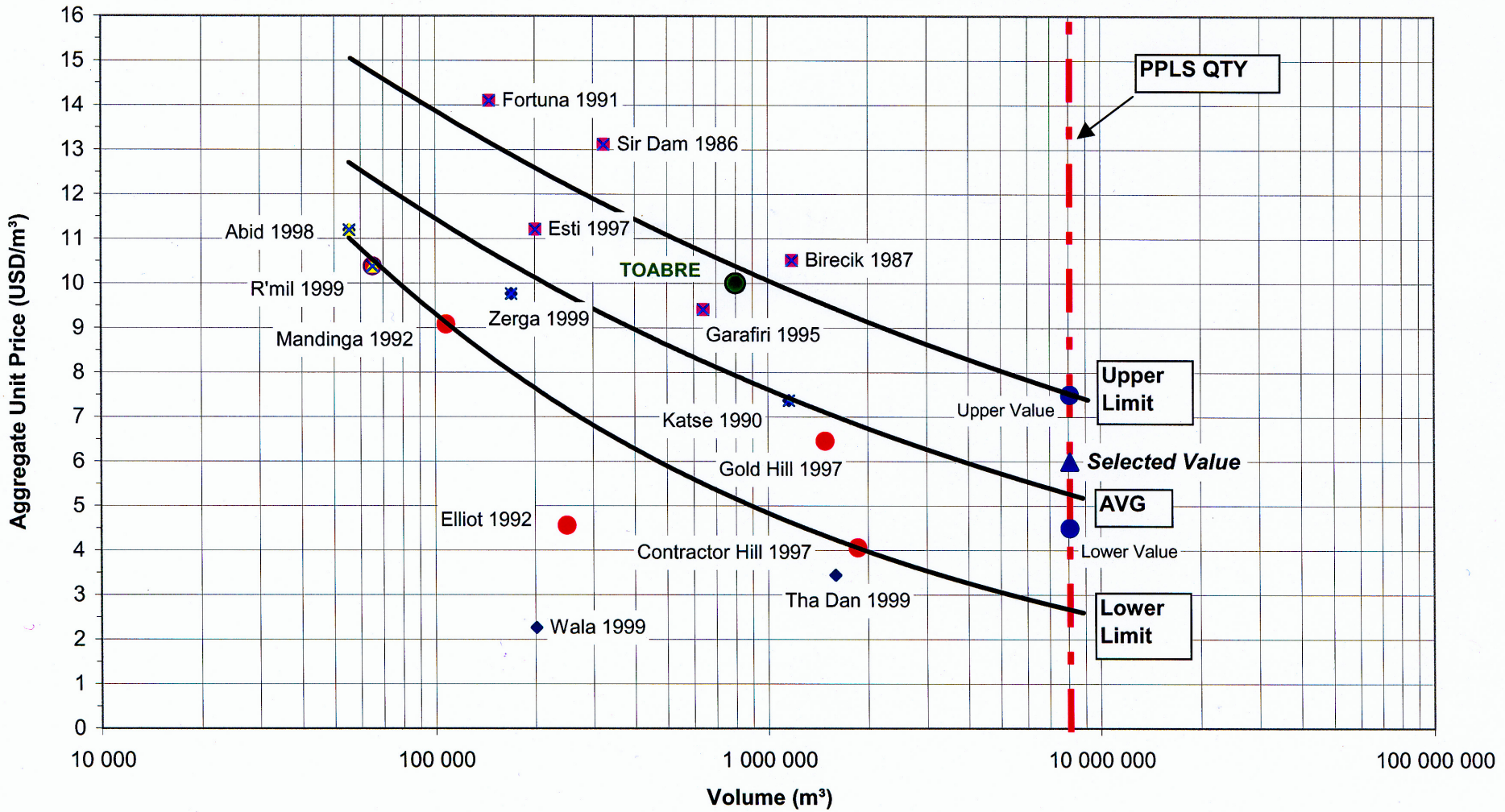


Consorcio Post Panamax / CAI
vol_IV_cost.xls / FIG1

FIGURE 2

Graph B.2 Conceptual Design Post-Panamax Lock Structures (Pacific)

Rock Excavation Aggregate Unit Prices



Consorcio Post Panamax / CAI
vol_IV_cost.xls / FIG2

FIGURE 3

Graph B.4 Conceptual Design Post-Panamax Lock Structures (Pacific)

Rockfill Aggregate Unit Price

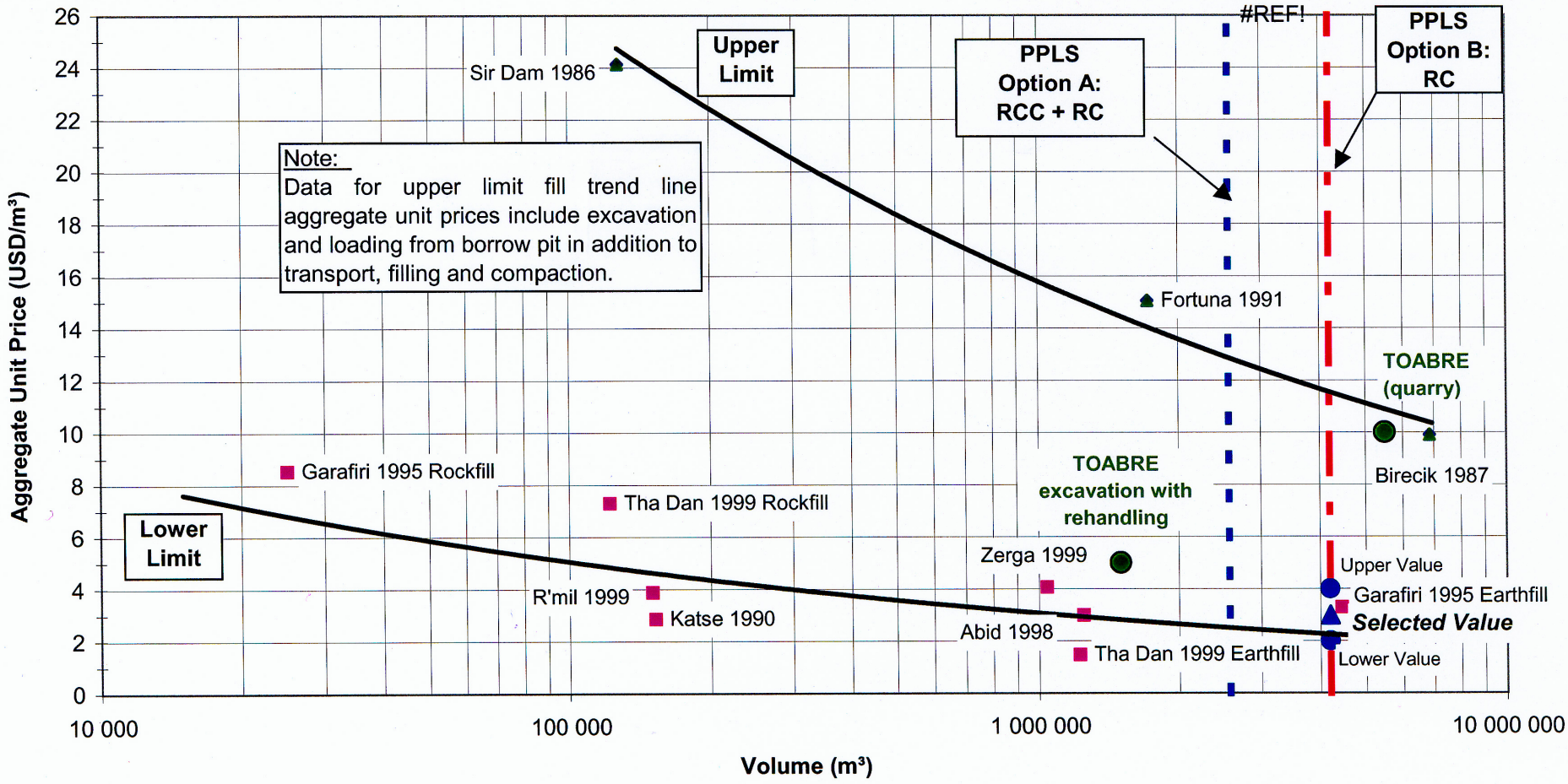


FIGURE 4

Graph B.7 Conceptual Design Post-Panamax Lock Structure (Pacific)

RCC World Price

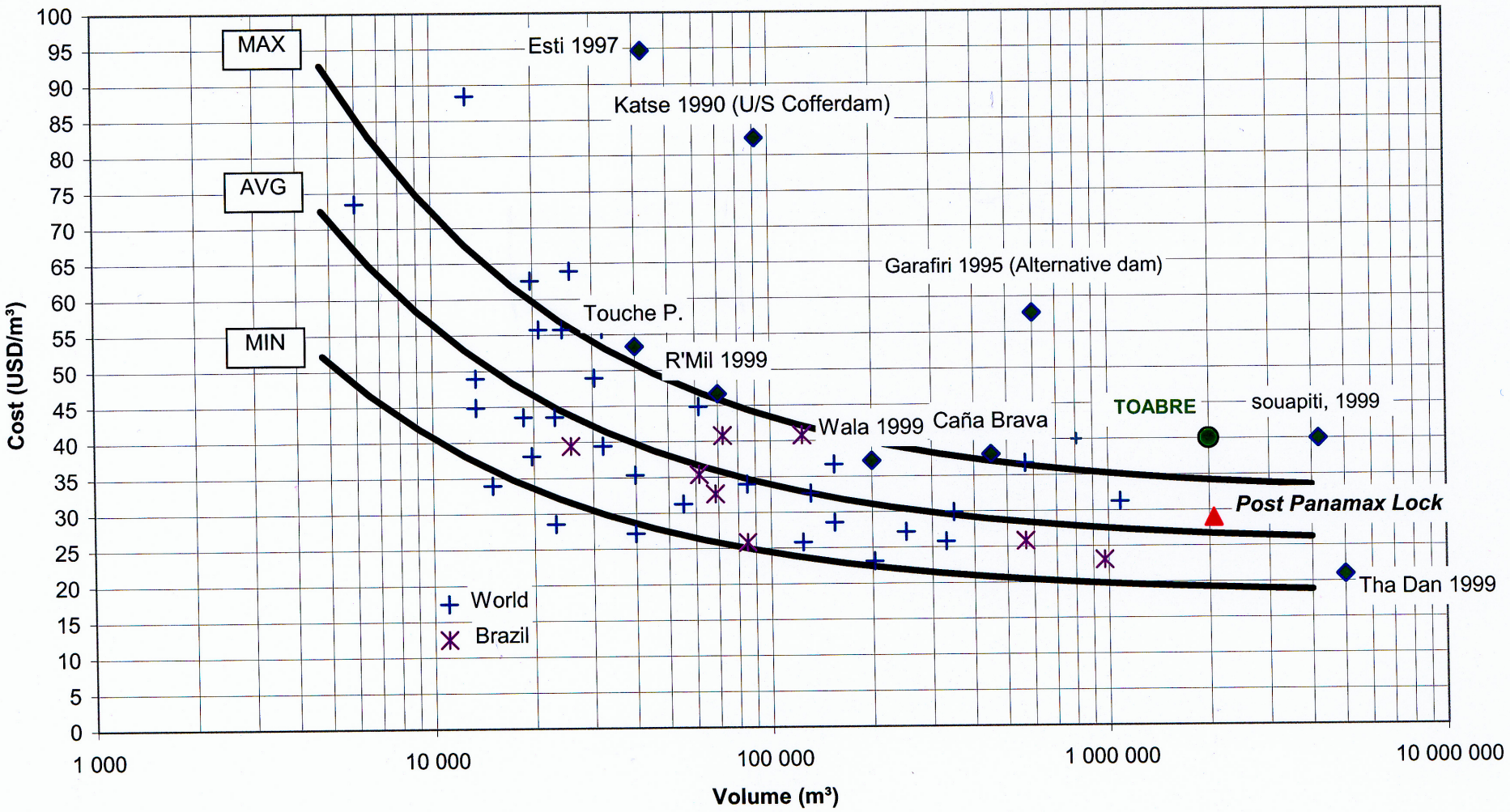


FIGURE 5

Graph B.5 Conceptual Design Post-Panamax Lock Structures (Pacific)

Concrete Aggregate Unit Prices

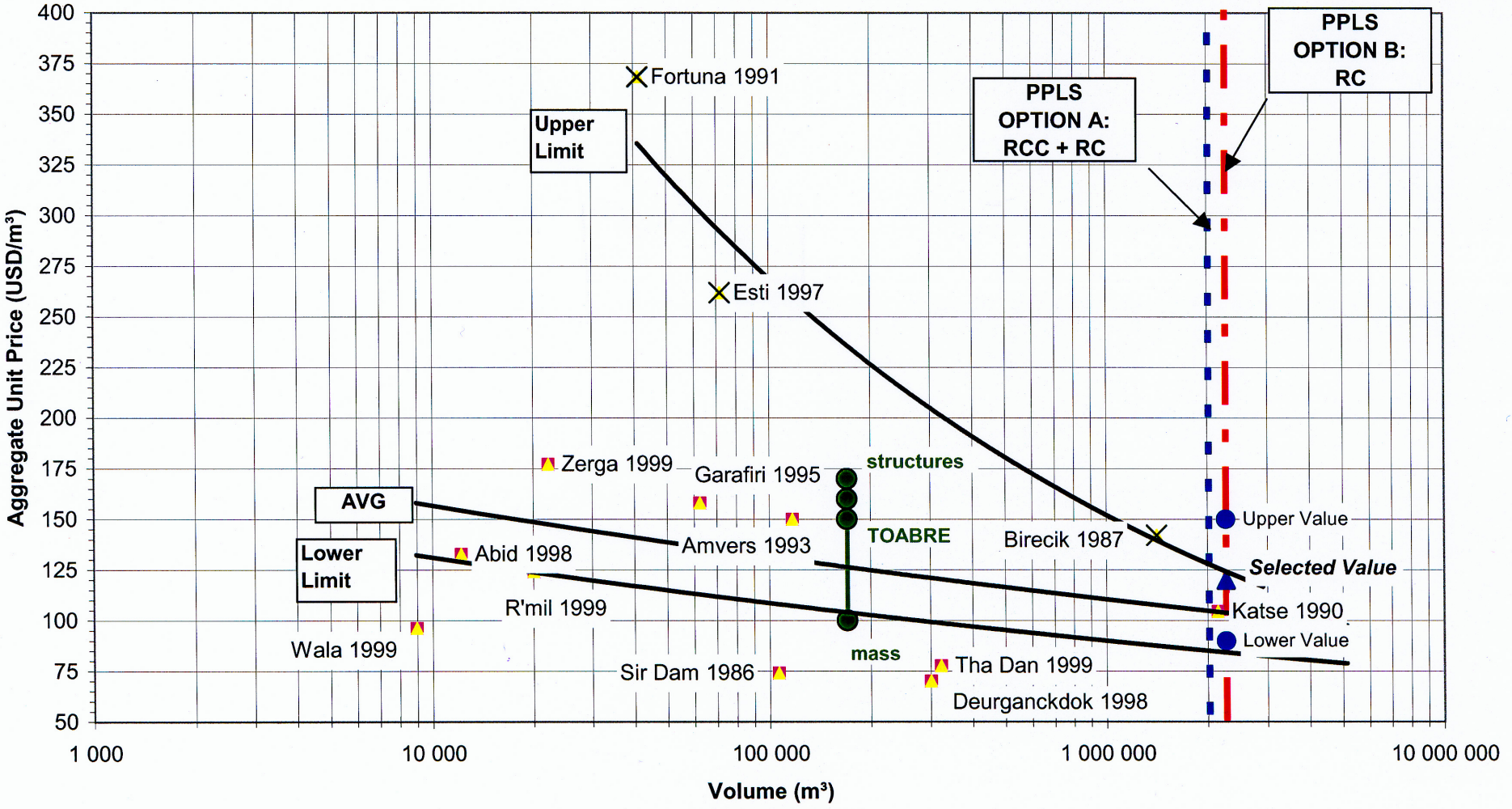


FIGURE 6

Graph B.8 Conceptual Design Post-Panamax Lock Structures (Pacific)

Reinforcement Steel Aggregate Prices

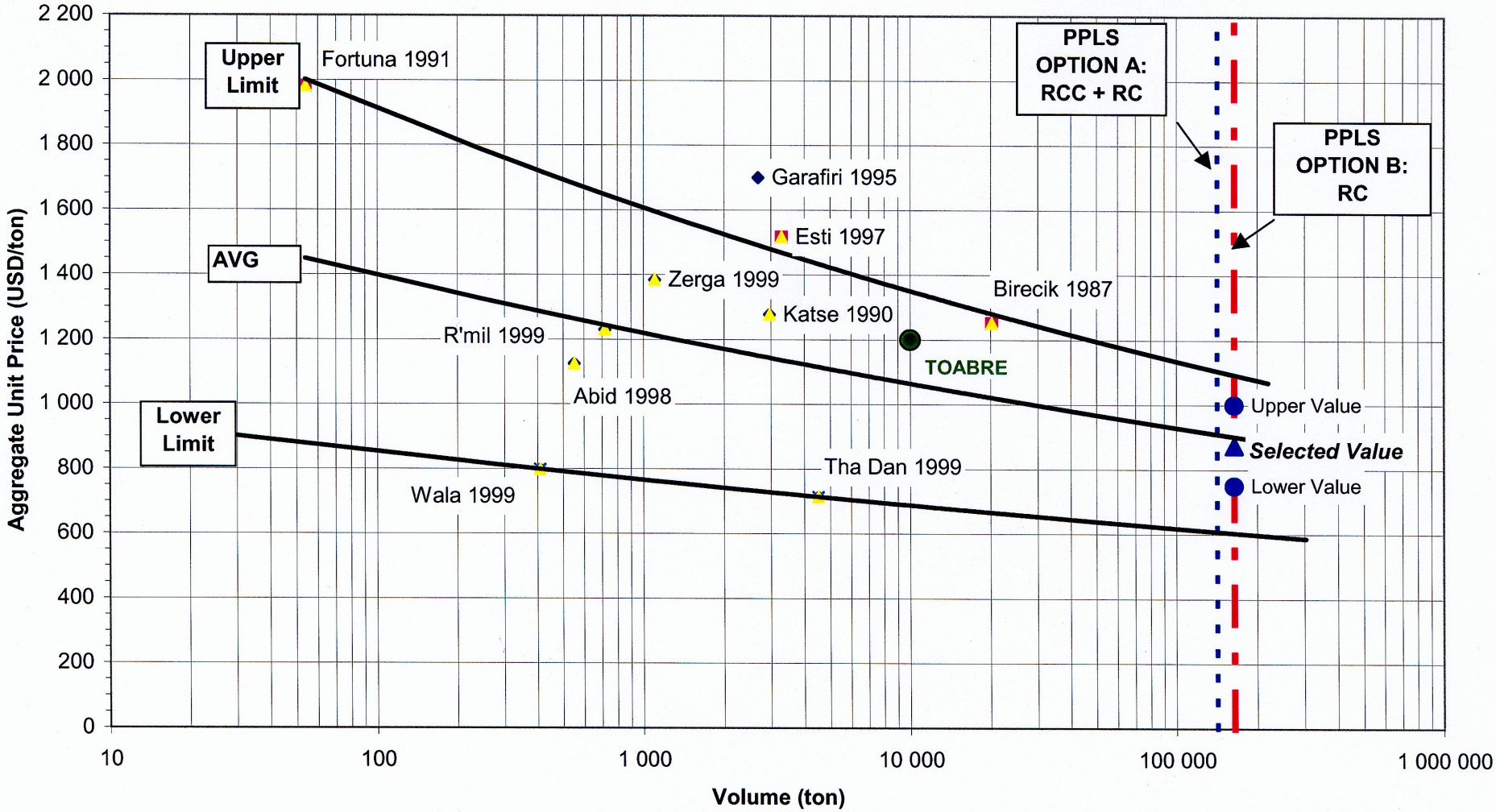
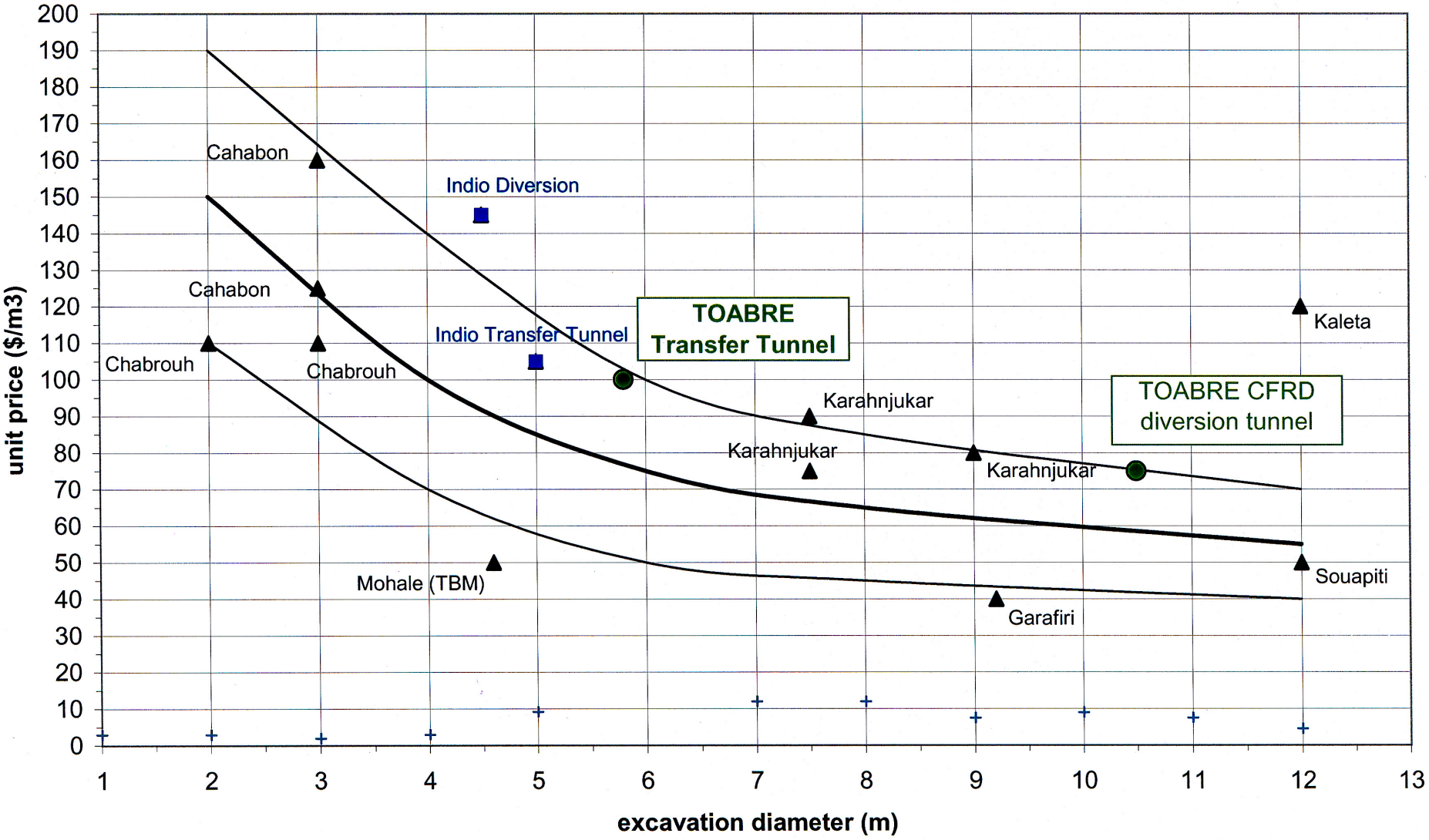


FIGURE 7 - UNIT PRICE OF TUNNEL EXCAVATIONS



APPENDIX B – Cost estimate of transfer tunnel for different diameters

The variation of the cost (Civil Works & Equipment) of the transfer tunnel has been established for diameters in the range of 4 m to 5.5 m.

It is detailed in the following tables:

➢ *Transfer Tunnel Toabre - Indio - Diameter 4 m*

Designation	unit	Quantity	Unit price USD/unit	Cost USD
Transfer Tunnel				
Inlet Structures				
Clearing	m^2	15 000	1	15 000
Overburden Excavations	m^3	120 000	3	360 000
Rock Excavations	m^3	60 000	10	600 000
Shaft excavation	m^3	3 500	200	700 000
CVC	m^3	1 500	235	352 500
Formwork	m^2	1 800	50	90 000
Steel Reinforcement	t	75	1 200	90 000
Bonneted gate 4 x 3	ls	2	300 000	600 000
Transfer Tunnel				
Adits	m^3	30 000	150	4 500 000
Tunnel Excavations	m^3	345 000	100	34 500 000
Concrete lining	m^3	108 000	200	21 600 000
Formwork	m^2	160 000	25	4 000 000
Steel Reinforcement	t	5 350	1 200	6 420 000
Outlet Structures				
Clearing	m^2	15 000	1	15 000
Overburden Excavations	m^3	120 000	3	360 000
Rock Excavations	m^3	60 000	10	600 000
Shaft excavation	m^3	3 000	200	600 000
CVC	m^3	800	235	188 000
Formwork	m^2	1 400	50	70 000
Steel Reinforcement	t	40	1 200	48 000
Bonneted gate 4 x 3	ls	1	300 000	300 000
Sub Total Transfer Tunnel 4 m			***USD***	***76 008 500***
Miscellaneous works	5%		***USD***	***3 800 425***
Total Transfer Tunnel 4 m			**USD**	***79 808 925***

➢ *Transfer Tunnel Toabre - Indio - Diameter 4.5 m*

Designation	unit	Quantity	Unit price USD/unit	Cost USD
Transfer Tunnel				
Inlet Structures				
Clearing	m^2	15 000	1	15 000
Overburden Excavations	m^3	120 000	3	360 000
Rock Excavations	m^3	60 000	10	600 000
Shaft excavation	m^3	3 500	200	700 000
CVC	m^3	1 500	235	352 500
Formwork	m^2	1 800	50	90 000
Steel Reinforcement	t	75	1 200	90 000
Bonneted gate 4 x 3	ls	2	300 000	600 000
Transfer Tunnel				
Adits	m^3	30 000	150	4 500 000
Tunnel Excavations	m^3	420 000	100	42 000 000
Concrete lining	m^3	120 000	200	24 000 000
Formwork	m^2	180 000	25	4 500 000
Steel Reinforcement	t	6 000	1 200	7 200 000
Outlet Structures				
Clearing	m^2	15 000	1	15 000
Overburden Excavations	m^3	120 000	3	360 000
Rock Excavations	m^3	60 000	10	600 000
Shaft excavation	m^3	3 000	200	600 000
CVC	m^3	800	235	188 000
Formwork	m^2	1 400	50	70 000
Steel Reinforcement	t	40	1 200	48 000
Bonneted gate 4 x 3	ls	1	300 000	300 000
Sub Total Transfer Tunnel 4.5 m			***USD***	***87 188 500***
Miscellaneous works	5%		***USD***	***4 359 425***
Total Transfer Tunnel 4.5m			**USD**	***91 547 925***

➢ *Transfer Tunnel Toabre - Indio - Diameter 5 m*

Designation	unit	Quantity	Unit price USD/unit	Cost USD
Transfer Tunnel				
Inlet Structures				
Clearing	m^2	15 000	1	15 000
Overburden Excavations	m^3	120 000	3	360 000
Rock Excavations	m^3	60 000	10	600 000
Shaft excavation	m^3	3 500	200	700 000
CVC	m^3	1 500	235	352 500
Formwork	m²	1 800	50	90 000
Steel Reinforcement	t	75	1 200	90 000
Bonneted gate 4 x 3	ls	2	300 000	600 000
Transfer Tunnel				
Adits	m^3	30 000	150	4 500 000
Tunnel Excavations	m^3	500 000	100	50 000 000
Concrete lining	m^3	130 000	200	26 000 000
Formwork	m²	200 000	25	5 000 000
Steel Reinforcement	t	6 500	1 200	7 800 000
Outlet Structures				
Clearing	m^2	15 000	1	15 000
Overburden Excavations	m^3	120 000	3	360 000
Rock Excavations	m^3	60 000	10	600 000
Shaft excavation	m^3	3 000	200	600 000
CVC	m^3	800	235	188 000
Formwork	m²	1 400	50	70 000
Steel Reinforcement	t	40	1 200	48 000
Bonneted gate 4 x 3	ls	1	300 000	300 000
Sub Total Transfer Tunnel 5m			***USD***	***98 288 500***
Miscellaneous works	5%		***USD***	***4 914 425***
Total Transfer Tunnel 5m			**USD**	***103 202 925***

➢ *Transfer Tunnel Toabre - Indio - Diameter 5.5 m*

Designation	unit	Quantity	Unit price USD/unit	Cost USD
Transfer Tunnel				
Inlet Structures				
Clearing	m^2	15 000	1	15 000
Overburden Excavations	m^3	120 000	3	360 000
Rock Excavations	m^3	60 000	10	600 000
Shaft excavation	m^3	3 500	200	700 000
CVC	m^3	1 500	235	352 500
Formwork	m^2	1 800	50	90 000
Steel Reinforcement	t	75	1 200	90 000
Bonneted gate 4 x 3	ls	2	300 000	600 000
Transfer Tunnel				
Adits	m^3	30 000	150	4 500 000
Tunnel Excavations	m^3	580 000	100	58 000 000
Concrete lining	m^3	140 000	200	28 000 000
Formwork	m^2	220 000	25	5 500 000
Steel Reinforcement	t	7 200	1 200	8 640 000
Outlet Structures				
Clearing	m^2	15 000	1	15 000
Overburden Excavations	m^3	120 000	3	360 000
Rock Excavations	m^3	60 000	10	600 000
Shaft excavation	m^3	3 000	200	600 000
CVC	m^3	800	235	188 000
Formwork	m^2	1 400	50	70 000
Steel Reinforcement	t	40	1 200	48 000
Bonneted gate 4 x 3	ls	1	300 000	300 000
Sub Total Transfer Tunnel 5.5 m			***USD***	***109 628 500***
Miscellaneous works	5%		***USD***	***5 481 425***
Total Transfer Tunnel 5.5m			**USD**	***115 109 925***

APPENDIX C – Project Construction Cost (MUSD – 2003)

Normal Water Level	**90**	**95**	**100**
• *Dam & Appurtenant Civil Works*	132	146	162
• *Toabre / Indio Tunnel Civil Works*	103	103	103
• *Access Roads / Owner's Camp*	10.3	10.3	10.3
• *Environmental and Social Costs*	19	27	31
Cost of Works (MUSD)	264.3	286.3	306.3
• *Contingencies*	50.4	53.9	57.5
Direct Cost (MUSD)	314.7	340.2	363.8
• *Engineering / Administration*	47.3	51.2	54.7
Construction Cost (MUSD – 2003)	362	391.4	418.5