DONA FRANCISCA HYDROELECTRIC DEVELOPMENT ON THE JACUÍ RIVER

Author: Sérgio de Pauli Basso

DONA FRANCISCA HYDROELECTRIC DEVELOPMENT ON THE JACUÍ RIVER

1. INTRODUCTION

Owned by the consortium formed by the Dona Francisca Energética S.A. and the CEEE, the Dona Francisca Hydroelectric Power Plant, with a gross head of 38.15 m and 125 MW of installed power, is located in the Jacuí River, between the municipalities of Agudo and of Palma, State of Rio Grande do Sul. The geographical coordinates are 29 27' South and 53 16' West.

The Dona Francisca HPP is the last development along the course of the river, and is located downstream of the power plants of Itaúba, Gov. Leonel Brizola, Passo Real, Cotovelo do Jacuí and Ernestina.

The concession of the rights for developing the project was originally granted to the CEEE - Companhia Estadual de Energia Elétrica do Estado do Rio Grande do Sul, a public state utility, in 1979. In 1997, a consortium was formed between the CEEE and the companies GERDAU, COPEL, INEPAR, CELESC and DESENVIX, which in August of 1998 created the company Dona Francisca Energética S.A. (DFESA).

Its construction was begun in August of 1998 and, 30 months later, in February of 2001, it entered commercial operation.

DFESA contracted the Consórcio CONFRAN in the form of an EPC composed by the following firms:

- Ivaí Engenharia de Obras, civil works;
- Torno do Brasil Ltda., civil works;
- Inepar Indústria e Construções S.A., supplier of electromechanical equipment;
- Engevix Engenharia S/C Ltda., responsible for the development of the projects.

The area of the catchment basin of the Jacuí river is 76,000 km^2 and at the project site is 13,975 km^2. The long term mean flow is 281 m^3/s. The reservoir covers 22.30 km^2 and stores 335 hm^3.

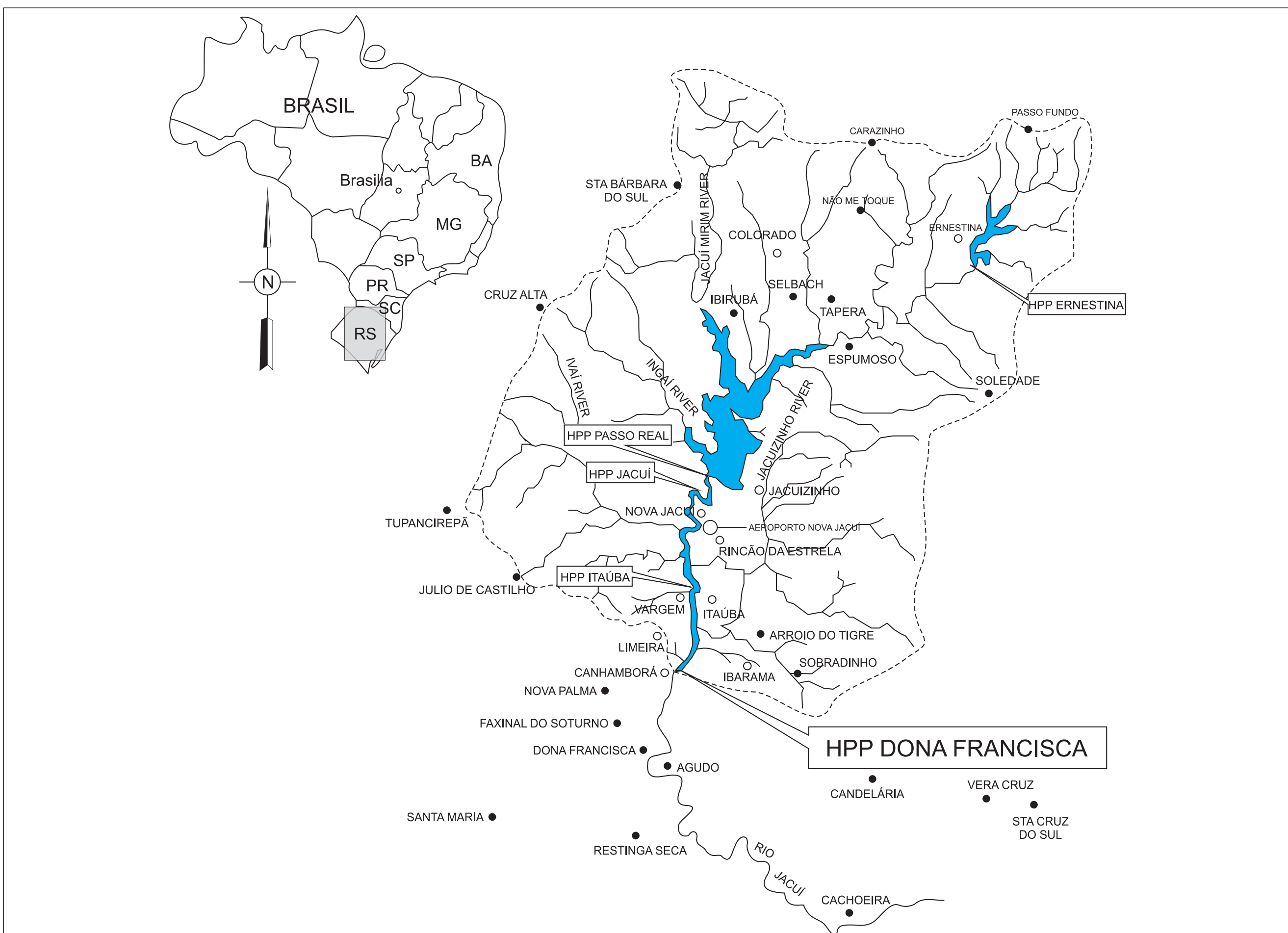


Figure 1 - Location of the Dona Francisca HPP and its Reservoir

2. DESCRIPTION OF THE DEVELOPMENT

The preliminary layout of Dona Francisca was developed by the CEEE, the concessionaire for generation, transmission and distribution of electrical energy in the state of Rio Grande do Sul, at the beginning of the 1980 decade. At this time, the project presented little attraction due to the high costs of implementation (principally caused by the large diversion and gated spillway structures with rockfill and clay core dam) and the long term required for the implantation of the power plant.

In 1996/97 the layout was totally modified in relation to the preliminary project.

The proposed modifications permitted a group of private investors, the DFESA, to form a partnership with the CEEE to develop the new project, resulting in an enterprise with a competitive cost of energy production.

The layout revised by ENGEVIX presented the following characteristics (see Figure 1):

- Dam/spillway in Roller Compacted Concrete RCC, associated with the water intake and the concrete diversion structures, with a total length of 610 m and with the crest at El. 102.00 m in the abutments, and a maximum height of 50.50 m.
- The second stage of the diversion through four sluiceways with 5.50 m x 11.00 m, complemented by three passages in the right side of the dam/spillway for periods of floods, with the following dimensions: 9.60 x 5.50 m;
- Overflow spillway at the crest of the dam, at El. 94.50 m, with a total length of 335 m, energy dissipation in steps and a stilling basin.
- Water intake of the hollow gravity type, excavated in the rock, constituted by a single block, with two penstocks 6.30 m in diameter and with a length of approximately 80 m;
- Indoor type powerhouse with two Francis type generators of 62.50 MW each.

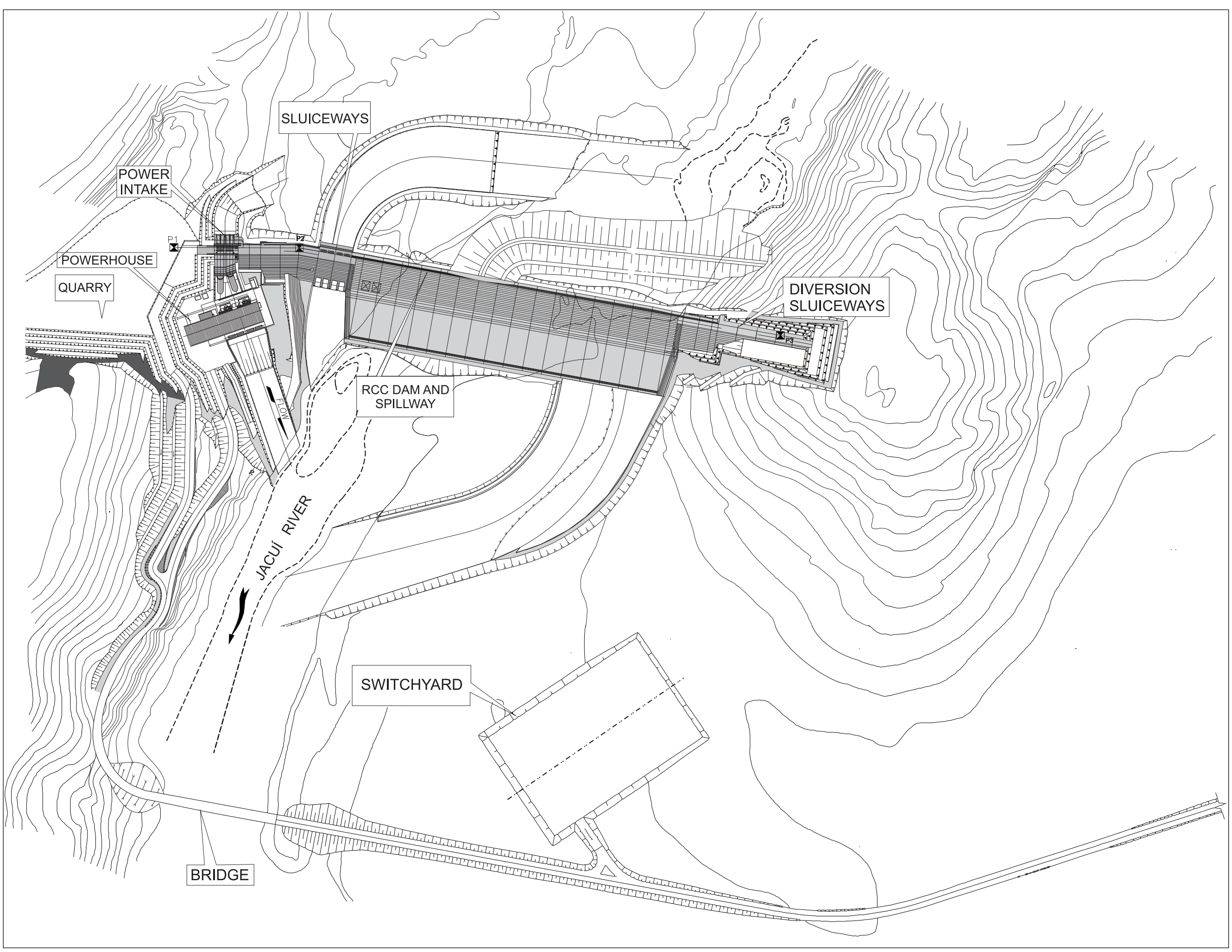


Figure 2 - Dona Francisca HPP - General Layout

Photo 1 - Dona Francisca HPP - General View

3. GEOLOGY, GEOTECHNOLOGY AND FOUNDATIONS

3.1. Local Geology

The Dona Francisca Hydroelectric Power Plant is situated on the southern border of the basaltic rock package that fills the Paraná sedimentary basin. This is an intracratonic basin containing sediments from the Palaeozoic and Mesozoic ages covered by a sequence of basaltic flows formed during the volcanic phase of the Cretaceous Era. The local geology, with special aspects regarding lithology, structure and stratigraphy, exerted a strong conditioning effect upon the characteristics of the project, representing a decisive factor in the definition of the layout and of the foundations of the structures. The geotechnical site embraces the following different geological formations: quaternary alluvia; basalts of the Serra Geral formation (Jurassic/Cretaceous); sandstones from the Botucatu formation (Jurassic) and sandstones and clayey siltstones from the Caturrita Formation (Rosário do Sul Group - Triassic).

At the dam site the thickness of the basaltic flow package is considerably reduced by the erosion and in the bottom of the valley of the Jacuí River the basalt no longer exists. In the abutments, at the contact of the basalt flows with the underlying sedimentary rocks, there is a layer of plastic clay with a thickness of 10 to 40 cm and white nodules of degraded deuterate minerals, with pronounced declivities, reaching 50% of the right abutment and 67% of the left abutment. In the Paraná basin the basalts of the Serra Geral formation normally rest upon the aeolian Botucatu sandstones. In the Dona Francisca area the Botucatu sandstone was partially removed by erosion prior to the basaltic flows.

Four different types of basaltic rock were characterised, designated as GM, BM, B2 and B1, based on their geomechanical characteristics, from the most fractured type, GM, as crowning, with cubic fragments smaller than 5 cm, until the type B1, at greater depths, with fractures spaced more that 20 cm, sealed and without traces of water percolation.

The sedimentary package was classified, in accordance with its geotechnical features, in: siltstones and/or claystones (only occurring as slender intercalations within the sandstone mass). Interbedded siltstones, claystones and sandstones (packages with successive intercalations between fine sandstone, siltstone and/or claystone). Type AV sandstone (layers or lenses that have suffered little or no lithification). Type AIII sandstone (fine sandstone with granulometric variations from medium to rarely coarse, roseate and reddish colour, good cementation). Type AI (similar to the AIII, but with intense cementation based on silica, high hardness and roseate colour, represented in some outcrops situated in the left bank of the river, a few metres upstream of the axis).

The studies carried out in the wider area, with utilization of photographs and satellite images, indicated the possibility of vertical faults with diagonal slips following N 0º-10ºE and N 70º-90ºE, as well as a sub-orthogonal fracture system following N 20º-40ºE and N 20º-50ºW. The field surveys of the fracture orientations of the Botucatu sandstone, with more than 300 measurements taken on both banks of the dam site, outlined the direction N 66ºE / 88ºSE as the principal plane of shearing.

3.2. Foundation of the Dam

The foundation of the dam/spillway, between the blocks 10 and 27, is constituted by fine to medium arkosean sandstones, of reddish to greyish colouring, massive or with cross-channelled stratification of the Caturrita Formation. Intercalated with the sandstones there is occurrence of sub-horizontal levels and layers of siltstones, claystones and breccias and/or intraformation conglomerates with thicknesses varying from centimetres to metres. They are soft, reddish coloured rocks, with fine stratification in the horizontal plane, and their contact relationships with the sandstones can be gradual or brusque, with sealed contacts. The attitude of the strata is seldom flat, frequently showing undulations and wedged and truncated shapes, conditioned by the cross-channelled stratification and successive cycles of erosion/deposition. Intermixed with these horizons there are strata of material with soil characteristics, in a sub-horizontal attitude and variable thicknesses from millimetres to centimetres, and lateral continuity of up to some tens of metres. Their origin is probably associated with the disaggregation process of the siltstones or claystones.

In the blocks 22 and 23, longitudinal trenches about 1 m deep were opened, starting approximately from El. 43.50, and which indicated adequate conditions for foundation without the presence of a continuous layer of clay, which appeared instead in an interjoined form. The remaining blocks were excavated close to 0.50 m to 1.00 m below the elevations previously foreseen in the original stability calculations. Figure 3 depicts the cross section of the foundation of block 25 which is a typical foundation of the dam.

4. HYDROLOGY, HYDRAULICS AND ENERGY STUDIES

The average long-term flow at the site of the hydroelectric development is 281 m^3/s. The maximum average daily flow observed during the historical period (1940-1970) presented the value of 4,447 m^3/s and the minimum of 18.2 m^3/s.

Taking into account the previously mentioned geological conditioning factors, with the presence of thick layers of alluvium in the river bed, the conditions of discharge into the river of the diverted and spilled flows assume great importance. Therefore, the spillway was designed with as an overflow sill, without control by gates, with a capacity to discharge the ten thousand year flood with a 5.60 m high nappe.

This solution permitted lowering the specific flow of the flood, to about 32 $m^3/s/m$, since the chute of the spillway is much wider than that of the river itself. The energy dissipation, in the steps for smaller flows, and in the hydraulic jump basin for greater flows, was intended to limit to acceptable values the velocities over the alluvium.

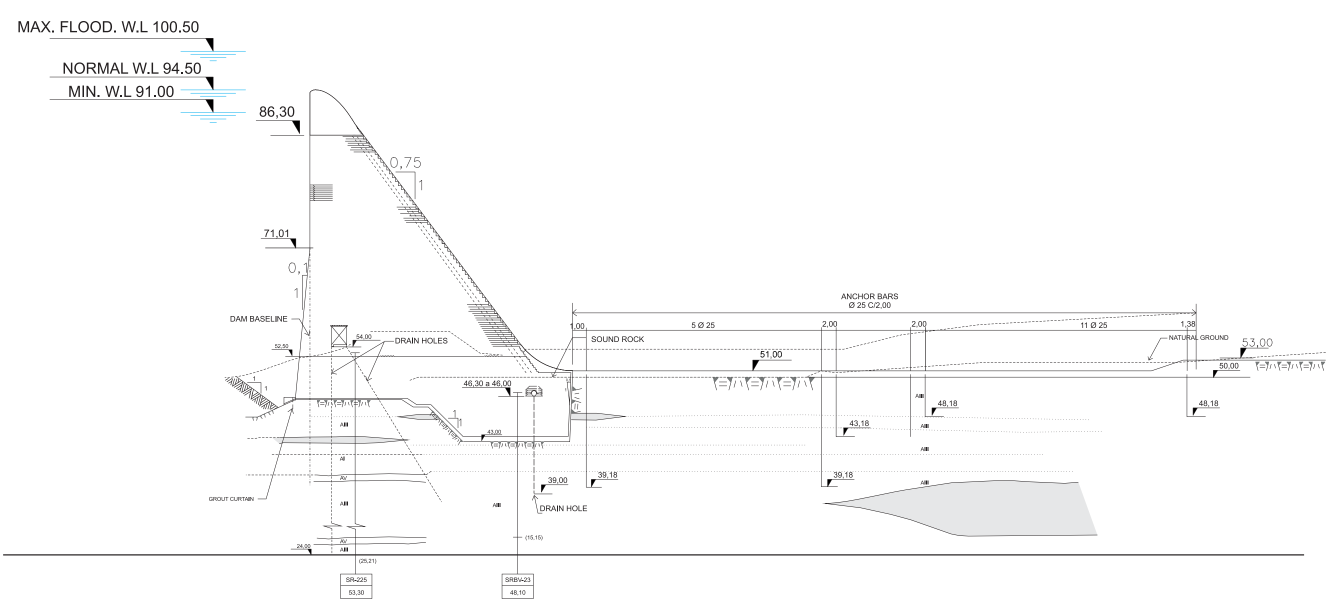


Figure 3 - Foundation of Block 25 - Typical of the Dam

With the solution adopted for the spillway, the flow with greatest erosive potential became that resulting from the operation of the diversion sluiceways (close to 75 $m^3/s/m$). Therefore, the structure of the diversion sluiceways was positioned in a manner to direct the outflow to the riverbed, in the region where the major part of the flow is naturally concentrated, and in the place where the foundation rock presented the best characteristics.

The diversion sluiceways, with structure for closure by gates, were designed for floods with a recurrence period of 10 years during the dry period. During the wet period, the discharge capacity for 10 year floods is complemented by three bays located in the RCC body of the spillway, whose dissipation occurs within the basin of the structure.

With respect to the flood regime, the floods can occur at any season of the year, but are more frequent and of greater magnitude in the period from May to October.

The flows adopted for the river diversion were:

- 1st phase of diversion - 4,460 m^3/s (25 year period of recurrence);
- 2nd phase of diversion - 3,520 m^3/s (10 year period of recurrence).

Due to the existence of hydroelectric developments upstream of the power plant, the ten thousand year design flood of the spillway project was calculated based on the outgoing flood discharged from the Itaúba HPP, which is approximately 8,130 m^3/s, increased by the natural flood coming from the incremental basin between the two developments. The ten thousand year flood obtained in this manner was of 10,600 m^3/s.

The principal structures of the development and the stages of the diversion were tested on the small scale hydraulic model in the CEHPAR laboratory.

The tests executed on the model were:

- Studies of the 1st phase of diversion;
- Studies of the 2nd phase of diversion ;
- Closure studies of the pre-cofferdams;
- Spillway studies on the two and three-dimensional model;
- Studies of the hydraulic generation circuit.

The 1st phase diversion channel showed itself adequate for the design flows (25 year recurrence period), and the maximum velocities obtained were around 5 m/s.

For the 2nd phase of the diversion, the lower sluiceways associated with the upper bays provided in the body of the dam, guaranteed protection against floods with a ten year recurrence, and the levels obtained concurred with the mathematical model.

The spillway was originally tested on the two-dimensional model to verify the energy dissipation in the steps and the basin. After the adjustments to the spilling profile and to the extension of the basin, the tests were executed on the three-dimensional model.

The model tests permitted reducing the length of the overflow sill from the initially forecast length of 356 m, to 335 m without increasing the water level of the reservoir. The length of the dissipation basin was reduced from 50 m to 43 m. For heads of up to 3 m, a good part of the energy is dissipated through the steps; for greater flows, the dissipation is attained through the hydraulic jump of the basin.

The tests with a movable bed (loose material) permitted the qualitative evaluation of the erosions downstream, which were within expectations, not indicating problems such as the formation of bars in the region of the tailrace channel.

5. PRINCIPAL STRUCTURES

- River diversion

2nd Phase of the diversion ran through four sluiceways with dimensions of 5.5 x 11.0 m (see Figure 4), complemented by three bays in the body of the spillway with dimensions of 9.6 x 5.50 m.

The river diversion was executed in two phases, in which the first phase occurred through a channel excavated in the left bank. The works of the first stage were protected against floods with a period of recurrence of 25 years by a cofferdam parallel to the flow, allowing the partial execution of about 60% of the damming works.

During the second phase of the diversion, the river discharged through four sluiceways constructed in the right bank, complemented, subsequently, by three bays left in the body of the spillway.

The diversion through the sluiceways permitted dewatering the stretch of the channel of the first phase and left bank, permitting the construction of the rest of the dam/spillway.

In this phase, the works of the dam were protected by two cofferdams against floods with a period of recurrence of 10 years. After the RCC structure had reached El. 72.00 m, the dam protected itself.

- Dam / Spillway

Overflow spillway, situated on the crest of the dam at El. 94.50 m, with a total length of 335 m and energy dissipation through steps and a hydraulic jump basin (see Figures 5 and 6);

The principal characteristics of the overflow dam in RCC are:

- Waterproofing concrete in the upstream face of the "Christmas tree" type, with a thickness of 0.50 m;
- Contraction joints in the entire section, every 20 m;
- Layers of RCC 0.30 m thick;
- Bonding mortar along the entire extension of the section;
- A drainage gallery;
- Grout curtain through the upstream slab.

The typical details of the RCC dam are shown in Figure 7.

Photo 2 shows the spillway in operation.

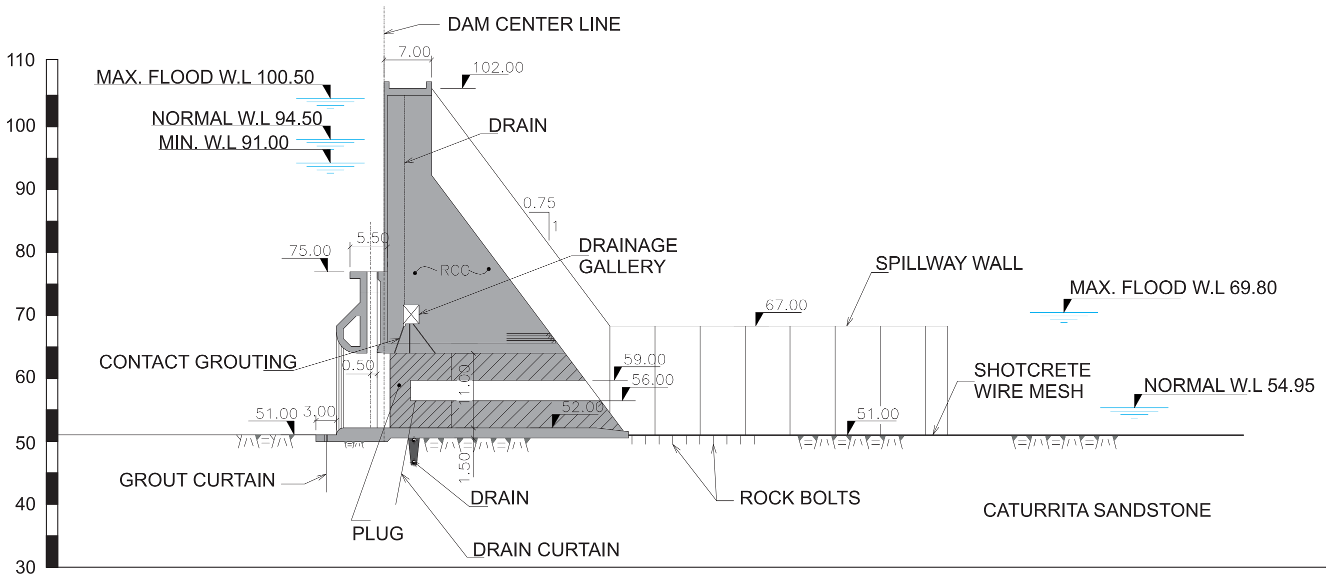


Figure 4 - Diversion Sluiceways in the Right Bank Dam

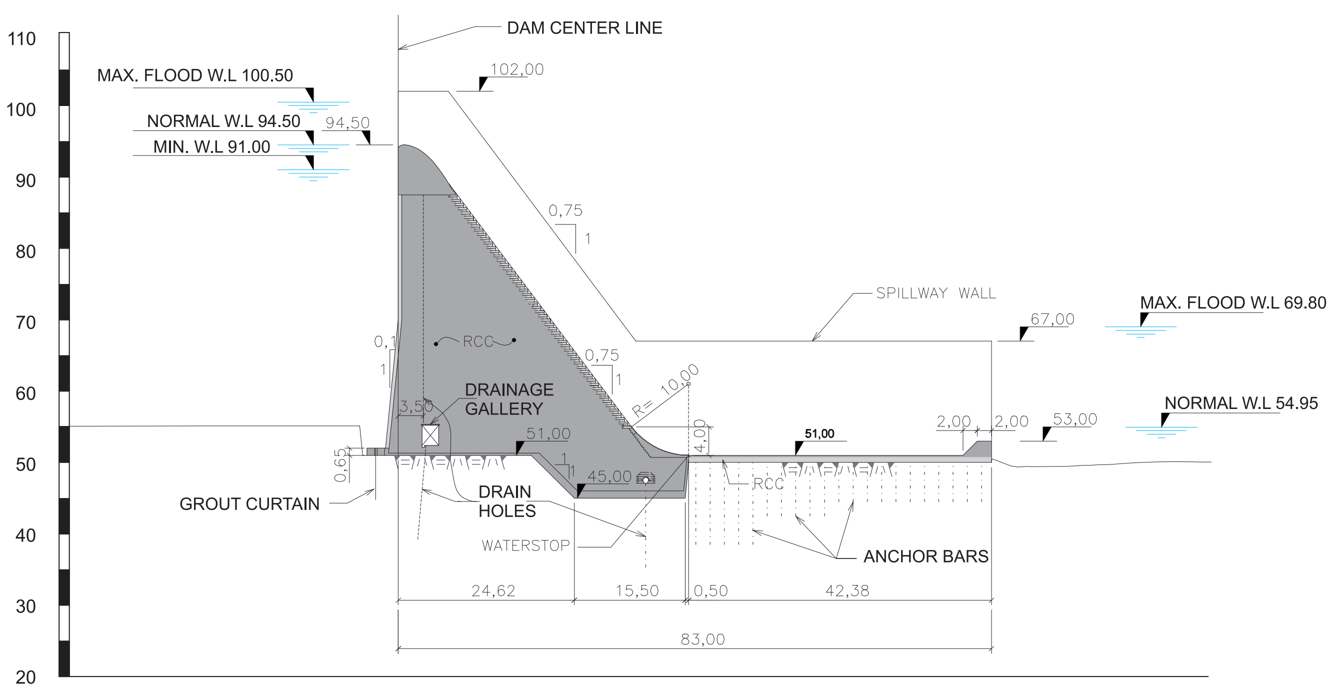


Figure 5 - Typical Section of the Spillway

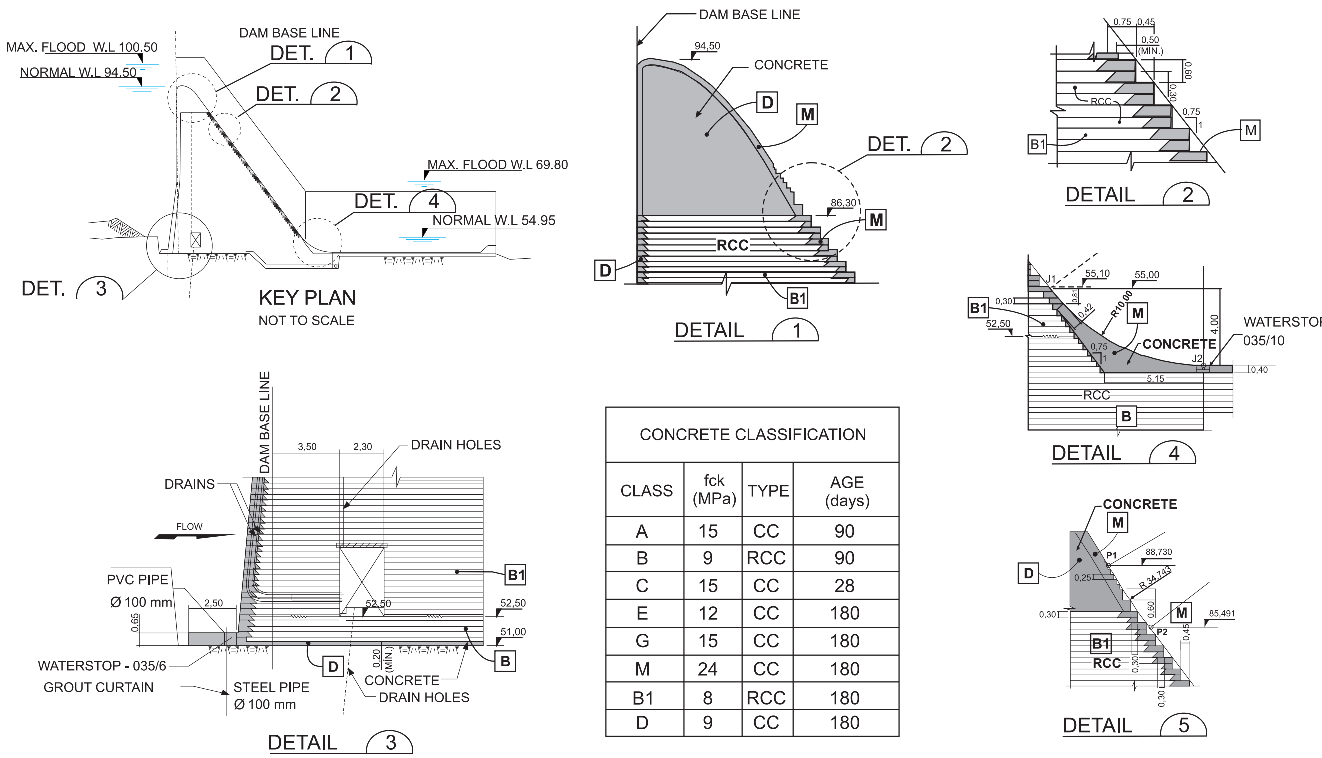
- Water intake and penstocks

Hollow gravity-type water intake, encased in rock, in a single block and two penstocks of 6.30 m in diameter, with an average length of around 80 m. The water intake is controlled by two fixed wheel gates and a set of stoplogs. The hydraulic oil pumping centre, including its electrical control boards, are situated downstream, incorporated into the water intake. The structure contains a drainage gallery and, further below, a drainage tunnel in the right bank, which intercepts the seepage flow of the rock foundation upstream of the powerhouse structures, relieving the uplift pressures. This tunnel is 140 m in length, has a diameter of 3.30 m and a section of 5.87 m^2.

- Powerhouse

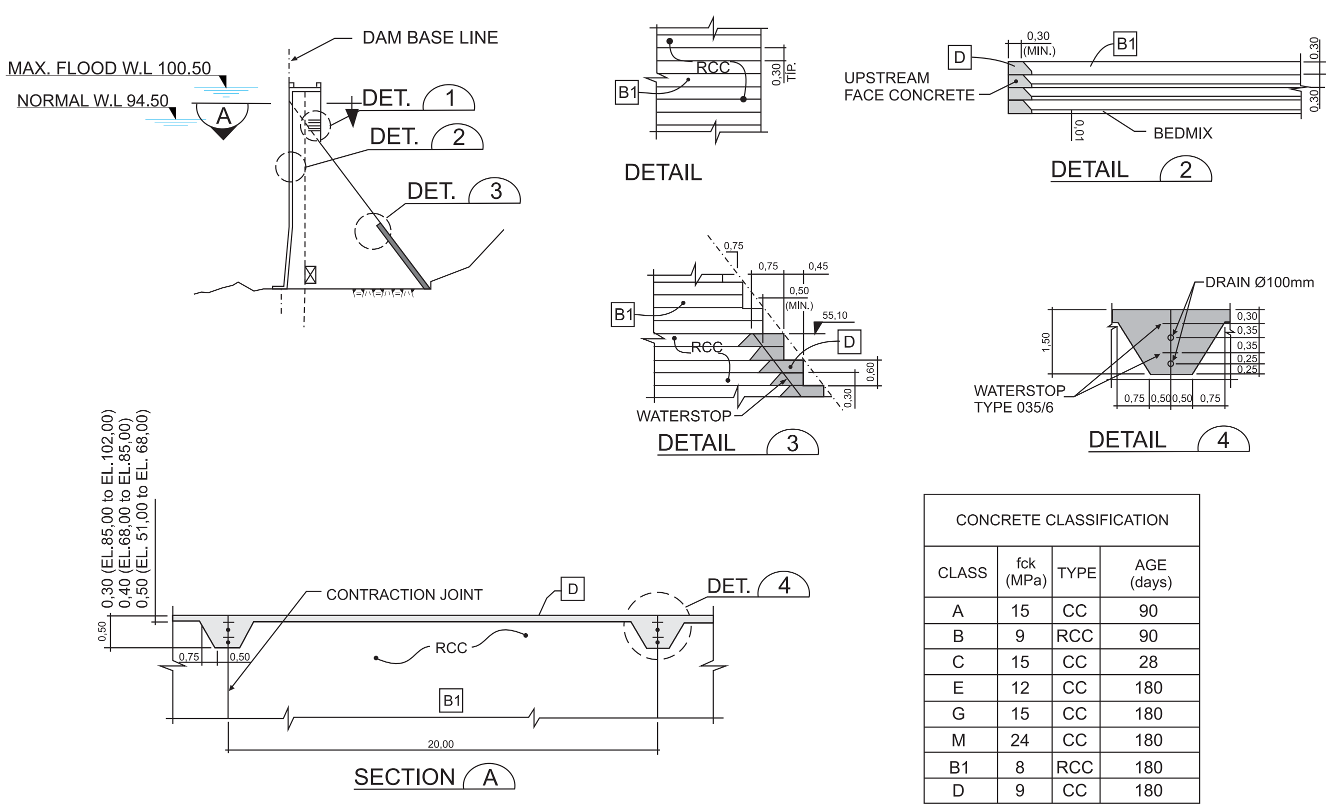
Powerhouse is of the indoor type, with a length of 79.25 m, and housing two Francis type generator units, of which the turbines each have a rated capacity of 64.2 MW and a rated head of 38.15 m. The rated input flow is 182 m^3/s and the generators are of the synchronous type. The erection area, workshops, rooms for batteries and ventilation, pits for drainage and sumps are situated to the hydraulic right of the generator units. The electrical and mechanical galleries are situated upstream.

Figure 8 depicts the intake/powerhouse hydraulic circuit.



CONCRETE CLASSIFICATION			
CLASS	fck (MPa)	TYPE	AGE (days)
A	15	CC	90
B	9	RCC	90
C	15	CC	28
E	12	CC	180
G	15	CC	180
M	24	CC	180
B1	8	RCC	180
D	9	CC	180

Figure 6 - Typical Details of the Spillway



CONCRETE CLASSIFICATION			
CLASS	fck (MPa)	TYPE	AGE (days)
A	15	CC	90
B	9	RCC	90
C	15	CC	28
E	12	CC	180
G	15	CC	180
M	24	CC	180
B1	8	RCC	180
D	9	CC	180

Figure 7 - Typical Details of the RCC Dam

Photo 2 - Dona Francisca Spillway in Operation

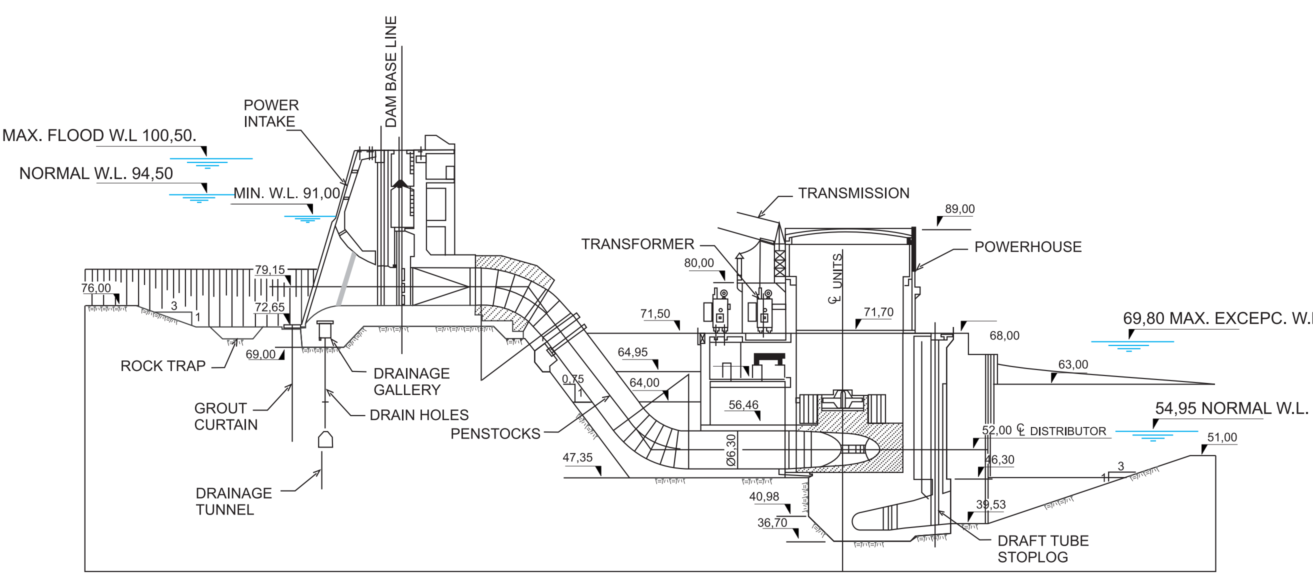


Figure 8 - Hydraulic Circuit

6. CONSTRUCTION

The river diversion was executed in two phases, of which the first phase took place through a channel excavated in the left bank, allowing the partial execution of close to 60% of the works of the dam (El. 72.00).

The excavations and concrete pours of the diversion sluiceways and of the hydraulic generation circuit were independent of the river diversion and of the execution of the dam.

During the first phase of the diversion, the jobs of foundation excavation and treatment in the left abutment were begun.

The sequence of execution of the dam/spillway is as follows:

• execution of the excavations, treatments and roller compacted concrete of the stretch of the riverbed dewatered during the first phase of the diversion, until reaching El. 60.80 (floor of the upper bays);
• after the conclusion of the concrete pour of the diversion sluiceways, the execution of excavations, treatments and roller compacted concrete in the stretch of the right abutment up to El. 64.00;
• execution of the treatments and concrete pours of the spillway dissipation basin in the stretch that was dewatered in the first phase;
• increasing the height of the dam/spillway up to El. 72.00, in the stretch dewatered during the first phase of the diversion;
• after the diversion through the sluiceways, removal of the first phase cofferdams and dewatering, execution of the roller compacted concrete in the stretch dewatered during the second phase of the diversion until reaching El. 72.00;
• increasing the height of the entire dam/spillway in RCC until reaching El. 87.50;
• execution of the rest of the spillway dissipation basin;
• execution of the conventional concrete of the crest and the downstream facing of the spillway;
• complementation of the dam in the abutments until reaching El. 102.00;
• plugging with concrete the upper bays of the second phase diversion.

7. ENVIRONMENTAL, SOCIAL AND ECONOMIC ASPECTS

The environmental programmes were developed following all the environmental regulations in force as well as all the recommendations of the FEPAM (Fundação Estadual de Proteção Ambiental- State Foundation for the Environmental Protection - Henrique Luis Roessler), with a view to minimizing the environmental impacts and enhancing the benefits of the development.

The measures prescribed in the Basic Environmental Plan (BEP) were based on diagnoses and prognoses obtained from data surveys in the physical, biotic, social-economical, and cultural media that evolved with the passage of time.

The BEP of the Dona Francisca HPP was prepared in 1991, based on the data of the EIS (Environmental Impact Study), carried out in 1989, and thus somewhat out of date. Due to this, for the implantation of the environmental plans and programmes suggested therein, the BEP was revised in order to update the data surveyed.

Within a vision of sustainable development, the DFESA launched the possibility of forming technical partnerships with the scientific and student community for the implantation of environmental programmes, notably those affecting the physical and biotic media, acknowledging that this sphere of society should make possible the establishment of the base for development and conservation expected for the region of the enterprise.

Following this line of reasoning, associations and partnership covenants were entered into with universities, centres of research, organisms of the state and federal governments and non-governmental organizations.

The programmes relating to the expropriation and resettlement of the population directly impacted by the enterprise, are undoubtedly the most important and for this reason, the most onerous, being fundamentally based on two types of data which change with time: the number of families affected and the prices of the lands and the improvements.

Faced by this panorama, the DFESA chose to carry out, on an emergency basis, the essential services for the development of the works, which are: the updating of the social-economic registers and research to update the prices of lands and improvements, contracting for the execution of these services the firm ICODES Sociedade Civil Ltda. of Santa Maria.

Various working meetings between the representatives of DFESA and the technicians of the ICODES led to the establishment of all the directives for the realization of these services, in order to determine with the greatest possible precision the budget involved in the programmes of expropriation and resettlement.

After carrying out the tasks of updating the data of the social-economic records, in a meeting with the Commission of the Affected, the municipal commissions (Agudo, Ibarama, Estrela Velha, Nova Palma, Arroio do Tigre and Pinhal Grande) were provided with a preliminary list of the families, in order for the people affected to check out the updated information themselves.

Based on this information, including the results of the research on prices, the DFESA representatives prepared the document with the title "DRAFT WITH SPECIFIC CRITERIA FOR PROVIDING UNIFORM TREATMENT WITH A VIEW TO THE FULFILMENT OF THE TERMS OF AGREEMENT", discussed in detail with the Commission of The Affected only after defining the public targeted by the expropriation and resettlement programmes.

8. PERFORMANCE OF THE UNDERTAKING

The dam and the water intake received the installation of multiple extensometers, piezometers, triorthogonal metres, flow-metres and direct pendulums.

For the calculation of the pumped flows, a finite element model was prepared with the Seep/W programme. The finite element model was based on the geological model with the characteristics of permeability of each foundation layer and of the depth of the drains. The calculated flows were confirmed by the measurements of the flow-metres.

The deformations and movements of the dam were estimated on finite element models prepared by the SAP 90 programme. Geological models were prepared with two conditions for the foundation: one more rigid and one more deformable, above and below the values actually expected. These models calculated minimum and maximum values of deformation for the multiple extensometers, with rods inclined upstream, vertical and inclined downstream rods. Values were also calculated for the direct pendulum. The values observed in the field remained within the calculated limits.

For the calculating of the values predicted for the piezometric data, models were prepared with the Percol programme, considering the geological characteristics of each block. The calculated values were increased for the dam stability calculations, although the measured values were very close to the calculated ones.

In general terms, the structural behaviour and the deformations of the dam remained within the calculated values.

9. TECHNICAL CHARACTERISTICS

General

Location	State of Rio Grande do Sul, Municipality of Agudo, Jacuí River, downstream of the Itaúba power plant.
Year commenced	1998
Year concluded	2001
Owner	Dona Francisca Energética S.A and CEEE
Designer	Engevix Engenharia S/A.
Contractors, manufacturers and erectors	Ivaí Engenharia de Obras, Torno do Brasil Ltda., Inepar Indústria e Construções S/A.

Basic data

Area of the hydrographical basin at the dam site	13,975 km^2
Incremental area: Itaúba - Dona Francisca	3,375 km^2
Mean annual precipitation	1,676 mm
Mean annual temperature	18.9º C

Reservoir

Area at the maximum normal level	22.30 km^2
Flooded area	19.20 km^2
Total stored volume	335 x 10^6 m^3
Active stored volume	62.80 x 10^6 m^3
Maximum normal water level	94.50 m
Maximum flood water level	100.50 m
Minimum water level	91.00 m

Tailrace channel

Maximum normal water level	54.95 m
Maximum flood water level	69.80 m
Minimum water level	54.35 m

Flows

Average incoming flow	281 m^3/s
Minimum daily recorded flow	18.2 m^3/s
Maximum incoming flow recorded	4,447 m^3/s
Design diversion flood and time of recurrence	4,458 m^3/s - 25 years
Ten thousand year flow	10,600 m^3/s

Dam

Type	Gravity RCC, overflow dam
Length	610 m
Height	50.50 m
Crest elevation of the overflow spillway	94.5 m
Elevation of the dam crest	102.0 m
Width of the crest	7 m

Spillway

Type	Overflow, incorporated into the dam
Width	335 m
Capacity	10,600 m^3/s
Maximum specific discharge	32 m^3/s

Water Intake

Type	Hollow
Length	20.90 m
Maximum height	33.00 m

Intake gates

Type	1 stoplog and two fixed wheel gates
Width	6.30 m
Height	6.54 m
Manufacturer	IMPSA

Diversion

Type	Sluiceways incorporated into the dam
Height	11 m

Penstock

Type	Tubing in carbon steel
Number	2 units
Internal diameter	6.30 m
Length	85.24/80.26 m
Manufacturer	INEPAR

Powerhouse

Type	Indoor
Height	52.3 m
Length	79.25 m
Installed capacity	125 MW

Turbine

Type	Francis
Number of units	2
Rated power	64.2 MWA
Rated head	38.15 m
Maximum discharge per unit	182 m^3/s
Rated speed	120 rpm
Manufacturer	GE Hydro

Generator

Type	Synchronous
Rated power	70 MWA
Voltage	13.8 kV
Frequency	60 Hz
Rotation	120 rpm
Manufacturer	GE Hydro INEPAR

Step-up transformers

Number	2 units
Type	Three-phase, immersed in insulating oil
Rated power	70 MWA
Voltage	13.8/230 kW
Manufacturer	Toshiba

Quantities

Excavations	2,172,000 m^3
Earth and rockfill	705,000 m^3
Concrete (RCC, conventional)	650,000 m^3

10. BIBLIOGRAPHY

[1] Tajima, Roberto; Pereira, Rafael Fernandes (2001). "Mapeamento, Injeção e Drenagem da Fundação da Barragem", Engevix Engenharia Ltda. Florianópolis/ Brasil.

[2] "UHE Dona Francisca - Technical Report for the Board of Consultants". Board Meetings nos 7, 8, 9 (2000/ 2001)Curitiba/Brasil,.

[3] Franco, Dr. Sérgio de Golveia; Margarido, Dr. Aloísio Fontana; Scandiuzzi, Dr. Luércio (1994). "Distância entre Juntas". São Paulo/Brasil,

[4] Andriolo, Francisco Rodrigues (1998). "The Use of Roller Compacted Concrete". São Paulo/Brasil.

[5] Sobrinho, J. Antunes; Fernandes, A. M.; Foes, P. A. "Dona Francisca Hydropower Plant". Engevix Engenharia Ltda., Florianópolis/Brasil.

[6] Repoarta on the Basic Project, Octoiber 1997.

[7] ENGEVIX ENGENHARIA S/C LTDA. (1997) "UHE DONA FRANCISCA" - Adaptação e Otimização do Projeto Básico - Volume I - Memorial Descritivo";

[8] CEHPAR - Centro de Hidráulica e Hidrologia - Prof. Parigot de Souza (1997) "Projeto HL-98 - Estudos Hidráulicos em Modelo Reduzido do Aproveitamento Hidrelétrico de Dona Francisca - Estudo do Vertedouro em Degraus.

[9] The advantages of use RCC for Dona Francisca Project (2003) - Mussi, Jorge Murad Possebon (DFESA Energética, Curitiba, Brasil), Moser, Douglas Emerson & Steffen, Ruy Dikram (Institute of Technology for Development - LACTEC, Curitiba, Brasil)