1.8 Implementation of Priority Projects

1.8.1 Water Resources Development Plan

Of the water resources development projects proposed in the Master Plan, the priority projects as shown in Table-1.19 are selected according to the following criteria.

1) Projects: requiring urgent implementation due to great water shortage
2) Projects: developing large amount of water and serving higher populations
3) Projects: requiring longer periods for study and desing

Table-1.19 Priority Projects

Classification	Project
< Integrated Water Supply Projects >	- Project Expansion of Sao Francisco Pipeline System (on-going) - Aracaju Well Development Project (on-going) - Project Expansion of Agreste Pipeline System (PROAGUA) - Project Expansion of Piauitinga Pipeline System (PROAGUA) - Xingo Dam Pipeline Project (multi-purpose project) - Vaza Barris Dam Project (multi-purpose project) - Project Expansion of Itabaianinha Pipeline System
< Independent Water Supply Projects >	- Neopolis Water Supply Project (Direct Intake from Sao Francisco River) - Riachuelo Water Supply Project (Weir and Deep Wells) - Rosario Do Catete Water Supply Project (Weir and Deep Wells) - Estancia Water Supply Project (Weirs and Deep Wells) - Itaporanga d'Ajuda Water Supply Project (Weirs)
< Small Rural Water Supply Project >	- Small Rural Water Supply Project in Semi-arid and Agreste Region (PROAGUA)
< Irrigation Water Supply Projects >	- Jacare-Curituba Irrigation Project (on-going) - Jacarecica II irrigation Project (on-going) - Sao Francisco Irrigation Project (multi-purpose project) - Vaza Barris Irrigation Project (multi-purpose project)

Except on-going and existing planned projects, Xingo Dam Pipeline Project and Vaza Barris Dam Project, proposed as a multi-purpose project, should have high priority. Feasibility study of these projects should be commence at an early stage.

1.8.2 Water Resources Management Plans

(1) Institutional Plans

Fundamental programs are establishing granting system of water rights and realizing public participation. Then, highest priority should be placed on organization set-up of phase 1, which includes strengthening SRH for the preparation of water right granting and introduction of public participation in water resources management. To establish the basic rules for charging on use of water resources and cost allocation of multi-purpose would have the next priority.

(2) Water Resources Management Programs

Enhancement of hydrological assessment and classification of waters are fundamental programs. On the base of these two programs, effective programs and projects for water resources development, management and conservation can be implemented. These two programs should have the highest priority.

(3) Operation and Maintenance Plan

Customers of municipal water services are paying to inefficient management. It is urgent to improve the efficiency of municipal water supply. To establish basic rules for the management of rural water services should also have high priority.

1.9 Recommendations

(1) Implementation of the Water Resources Development Plan

The Master Plan proposes water resources development projects mainly for domestic/industrial and agricultural water supply, to meet the future water demand estimated on the basis of long-term socio-economic framework. As a regional development framework, "strategic scenario", of which the policy is decentralization of GRDP and population from Aracaju to exterior cities, was adopted, instead of "trend scenario" following the present trend of socio-economic development. The following projects were proposed in the Master Plan for the target year of 2020:

- Ten (10) Projects of Integrated Water Supply for Urban and Large Rural Areas
- Thirty-five (35) Projects of Independent Water Supply for Urban and Large Rural Areas
- Deep Wells Development Project for Small Rural Areas of 75 municipalities
- Eight (8) Projects for Irrigation Water Development

Since the fundamental frame on water resources development, namely "Water Resources Master Plan in the State of Sergipe" has been formulated, the next step should be the implementation of these projects according to their priority, in order to attain better living standards for the State peoples and the stable state economic development. Except on-going projects, Xingo Dam Multi-purpose Pipeline Projects and Vaza Barris Multi-purpose Dam Project should be commenced as soon as possible. Besides, although small rural projects present low economic feasibility, positive implementation is recommended for the minority suffering from severe drought.

(2) Review of Water Resources Master Plan

Proposed water resources development plan is formulated based on the projected population and GRDP increases, for 20 years towards 2020. Socio-economic development plans are normally formulated every five years with projections of population and target economic growth. Water resources development plan should also be reviewed every five years, if necessary, based on these revised projections.

Water supply to Aracaju City, which is the political, economic and cultural center of the State, is estimated to require a large volume of water to be conveyed over a long distance, 130 km from Sao Francisco River. The project for Aracaju is estimated to cost R$ 285 million or 29% of the whole cost of water development project in the State. As the Master Plan assumes "strategic scenario", the strong state direction is inevitable to realize the decentralization. In the viewpoint of the above, future GRDP and population might be varied and the review of the Master Plan is essential for sustainable water resources development and management.

When revising the Master Plan, security level of existing water supply is necessary to be evaluated, using the hydrological data that will be continuously observed, archived and processed.

(3) Financing of the Project Cost

In the Master Plan, total initial investment for all 54 projects amounts to R$ 1,370 million (equivalent to US$ 1,160 million at the exchange rate of August 1998).

The initial investment cost for 46 projects of Domestic and Industrial Water Supply System amounts to R$ 950 million, of which R$ 660 million or 70 % of initial investment cost concentrates in the first decade. The state budget is considered as the principal source of funds for the initial investment, which would be R$ 390 million in the first decade and R$ 510 million in the second decade. In case that the economic growth as set in the plan would be attained, this required investment will possibly be arranged by the state. Public entities are assumed to share the financial burden of 10 % of the initial investment. Consequently, an amount of R$ 210 million should be raised from a soft loan in the first decade. However, initial investment in the second decade could be covered entirely by the state budget.

As for the eight (8) irrigation water supply projects in the Master Plan, total initial investment cost amounts to R$ 430 million. These funds should be covered by the government, considering the size of investment costs and financial conditions of agricultural producers.

(4) Continuous Effort to Collecting Hydrometric Data

For the further study of the plan on water resources development, hydrometric data such as rainfall, river discharge and water quality must be observed at the present water resources development points and future promising sites. Observed data should be continuously measured, archived and processed.

CHAPTER 2 THE PROJECT OF WATER RESOURCES DEVELOPMENT AND SUPPLY IN VAZA BARRIS RIVER – SERGIPE (PROVABASE)

2.1 Summary of the Project

2.1.1 Necessity of the Project

(1) Necessity of New Water Resources Development in Vaza Barris River

Itabaiana and Lagarto Water Supply areas (Agreste and Piauitinga Integrated Pipeline Systems) are located in Agreste/Semi-arid areas and are the second and third largest populated areas in Sergipe State. These areas are of poor ground/surface water resources potential and have been suffering from water shortage. In order to cope with present water shortage and increasing water demand, groundwater is not enough in both quantity and quality and it costs too much if surface water is conveyed from other river basins affluent in water resources, Sao Francisco River for example. Vaza Barris River has large water resources potential and is located between the large water-consumed cities of Itabaiana and Lagarto. Therefore, it has been expected to develop the river water not only by benefiting municipalities but also by the state of Sergipe.

(2) Refreshing High-chloric River Water by a Proposed Dam System

River water of the main stream has large potential of water resources but has not been able to be utilized as potable and irrigation water due to high chloric concentration of flow from upstream. After elaborate investigation of river water quality, however, it was found that river flow has high chloric concentration only during low flow condition from upstream and has less chloric concentration during flood time and in the downstream. Considering such condition of the water quality in Vaza Barris River, the following reservoir operation plan is being established: 1) Low flow from the upstream with high chloric concentration is bypassed around the dam to the downstream; 2) River water with less chloric concentration during flood and in the downstream is stored in the dam reservoir. Introducing such reservoir operation plan with a new system for river water quality, river water that could not be utilized before becomes clean and comes to be utilized as potable and irrigation water.

(3) Insufficient Water Supply

In the State of Sergipe in 2020, necessary supply water amount is estimated to be totally 830,000 m^3/day including 547,000 m^3/day of supply water shortage. Of this water shortage, Itabaiana and Lagarto Water Supply areas (Agreste and Piauitinga Integrated Pipeline System) are short of 129,000 m^3/day (equivalent to 24%) of water. The population of these areas is 259,000 inhabitants in 1996 and is estimated to be 540,000 in 2020. The lack of adequate water supply is a serious obstacle to the development of the so mentioned regions and creates a migratory pressure towards the State capital, worsening even more problems in Aracaju.

Therefore, it's mandatory to try to stabilize the water supply for high-concentrated population, indispensable to boost its social-economical development and to improve the quality of life. The positive consequences will spread all over the State, contributing to reduce the regional differences and alleviating the population and social-economic pressures towards the area of Aracaju.

(4) Irrigation Development

Fertile land suitable for irrigation extends around the right side of the planned dam site. This area is located between the three largest cities in the State of Sergipe, such as Aracaju, Itabaiana and Lagarto. It means the area has an advantage being near to large consumer cities. This area, which is presently utilized as orchards and pastures, could be irrigated to increase productivity and the agricultural production is to be supplied to the city areas. This irrigation project promotes improvement of agricultural productivity and activation of regional economy.

2.1.2 Objectives and Components of the Project

"The Project of Water Resources Development and Supply in Vaza Barris River –Sergipe (PROVABASE)" is proposed for securing stable life of the state people through sustainable water resources development. The objectives of the project are set as follows:

- To improve river water quality and to develop potable water resources.
- To supply clean and enough water for the people through public water supply.
- To supply irrigation water to agriculturally potential land for the achievement of high productivity.
- To develop maintenance water of the river for riparian environment.

The project components of the facilities are summarized in Table-2.1. The target facilities of the project components in this feasibility study are:

- Facilities of Vaza Barris Multipurpose Dam
- Water conveyance pipelines of domestic/industrial water supply facilities

Table-2.1 Project Component and Facilities

Project Components	Facilities	
(1) Vaza Barris Multipurpose Dam		
Dam Facilities	- Main Dam	- Spillway
	- Check Dam (Bypass Intake)	- Low Flow Bypass
(2) Domestic/Industrial Water Supply Facilities: <Itabaiana Water Supply Area>		
Water Conveyance Pipeline	- Intake and raw water pump station	- Pipeline
Treatment and Distribution Facilities	*- Water treatment station*	*- Distribution pipeline network*
(3) Domestic/Industrial Water Supply Facilities: <Lagarto Water Supply Area>		
Water Conveyance Pipeline	- Intake and raw water pump station	- Pipeline
Treatment and Distribution Facilities	*- Water treatment station*	*- Distribution pipeline network*
(4) Irrigation Water Supply Facilities		
Water Conveyance Pipeline	*- Intake and raw water pump station*	*- Pipeline*
Irrigation Facilities	*- Farmland development*	*- Irrigation channel*

Note: Italic parts show the facilities not including in this feasibility study.

2.2 Condition of the Project Area

2.2.1 Project Area

Vaza Barris Dam and its main appurtenances are located in main river course of the Vaza Barris River. Dam itself is planed to be set near the border between Lagarto and Campo do Brito municipality. Reservoir formed by the Vaza Barris Dam will extend toward north- west up to the center of Sao Domingos municipality. The area to be supplied with water by the pipeline system extended form the Vaza Barris Dam is nine (9) municipalities, these are; Areia Branca, Campo do Brito, Itabaiana, Macambira, Sao Domingos, Poco Verde, Simao Dias, Lagarto and Riachao do Dantas.

2.2.2 Socio-Economy

(1) Whole Area of Vaza Barris River Basin

Vaza Barris River hydrological basin is located in both states, Bahia State (rise) and Sergipe (mouth) State, and has a total area of 16,229 km^2, of which the Bahia State owns an area of 13,670 km^2 or 84% of total area. The total population in the Vaza Barris river basin area both in the Bahia State and the Sergipe State ran up to 382,000 in the 1991 census. The population of the Bahia State was estimated at 240,000. However, the population density (persons/km^2) was 17.6 that was lower compared with 55.5 of the Sergipe State because of the typical semi-arid climate in the region. On the other hand, the population density of the Sergipe State is higher than of the Bahia State due to the 2nd and 3rd largest cities of the state such as Lagarto and Itabaiana locating in the area.

(2) Project Area

The project area contains nine (9) municipalities. The population and GRDP are summarized in Table-2.2, 2.3 and 2.4.

The population of the project area was 0.26 million in the 1996 census or 16% of the state population. The population of the project area in 2020 was projected at 0.54 million. In consequence, the annual growth rate of the area between 1996 and 2020 results in 3.1% that is larger than the state annual growth rate of 2.3% during the same period.

GRDP of the project area was R$0.43 billion in 1995 or 9.7% of the State and is estimated to increase at an amount of R$1.85 billion in 2020 or 12.3%. The growth rate of the project area during the period between 1995 and 2020 is 6.0% that is larger than 5.0% of the state during the same period. GRDP per capita of the project area was R$1,820 in 1998 or 59% of the state's level and is estimated to increase at R$3,430 in 2020 or 64% of the state's level. Thus, the regional disparity could mitigate and the people lives would get closer to the national level for this period.

Table-2.2 Population

Unit: 1000 persons

Region	Census	Projection				Growth %
	1996	1998	2000	2010	2020	1996/2020
Brazil	157,080	161,070	165,715	184,157	200,306	1.0
Sergipe	1,624	1,684	1,750	2,163	2,778	2.3
Project Area	259	268	278	394	539	3.1
By River Basin						
Sergipe	71	76	81	149	231	5.1
Vaza Barris	57	59	61	74	91	2.0
Piaui	110	112	115	149	192	2.3
Real	21	21	21	22	25	0.7

Table-2.3 GRDP at 1998 Constant Prices

Unit: R$ billion

Region	Actual	Projection				Growth %
	1995	1998	2000	2010	2020	1995/2020
Brazil	799.39	912.21	1,005.71	1,453.30	1,860.35	3.4
Sergipe	4.43	5.13	5.66	9.22	15.02	5.0
Project Area	0.43	0.49	0.53	0.96	1.85	6.0

Table-2.4 Per Capita GRDP at 1998 Constant Price

Unit: R$

Region	Actual	Projection				Growth %
	1995	1998	2000	2010	2020	1995/2020
Brazil	5,160	5,660	6,070	7,890	9,290	2.4
Sergipe	2,770	3,050	3,230	4,260	5,400	2.7
Project Area	—	1,820	1,910	2,420	3,430	2.9
By River Basin						
Sergipe	—	940	950	1,110	1,750	2.8
Vaza Barris	—	1,560	1,630	2,150	3,170	3.3
Piaui	—	2,790	3,000	4,170	5,970	3.5
Real	—	450	460	460	450	0.0

Note: Growth rate of project area and river basin is 1998/2020.

2.2.3 Natural Condition

(1) Climate and Hydrological Characteristics

<u>Climate and Rainfall</u>

The Vaza Barris river basin (16,229 km^2) lies in both of Bahia and Sergipe state, 84% of the total area lies in the state of Bahia occupying interior part, on the other hand 16% of the total area lies in the state of Sergipe occupying the coastal part. The climate varies widely across the river basin from the tropical humid Leste region at the coast, through the drier intermediate Agreste region of state of Sergipe, to the semi-arid interior and finally to the arid regions of state of Bahia. Average temperatures vary from 25 °C in the most downstream around the coast, to 23 °C in the most upstream interior. Evaporation is also varying from 1,200mm at the coast to 500mm in the arid interior.

Vaza Barris basin clearly can be divided into two regions. Namely, the humid /semi – humid region with rainfall between 1800mm and 800mm per year, and the semi-arid / arid interior with rainfall of between 800mm and 500mm per year. The majority of the Vaza Barris River basin within Sergipe State belong to the humid /semi –humid region. Within the Vaza Barris River basin in Sergipe State, there are five rainfall gauges. In can be seen that highest average annual rainfall is over 1500 mm/year for the stations at Fazenda Belem located at the most downstream of the five gauges, on the other hand, the lowest is less than 800 mm/year for Carira in the semi-arid interior near to the border with Bahia State. It can be seen that the year is clearly divided into a rainy winter season (April to July) and a dry summer season (October to January) in Sergipe. Probable annual rainfall at Fazenda Belem nearest to the dam site of these five gauges is as follows;

10-year return period	:	1,072mm(min.),	2,007mm(max.)
50-year return period	:	790mm(min.),	2,289mm(max.)
100-year return period	:	690mm(min.),	2,389mm(max.)

Hydrology

Vaza Barris River originates in the municipality of Uaua in the State of Bahia. It has a total length of around 410km, of which only 125km lies in the State of Sergipe. Vaza Barris River has the total basin area of 16,229km^2, of which only 2,559km^2 or 16% lies in the State of Sergipe making up 11.6% of the state area(22,050km^2). Though the majority of Vaza Barris River lies in Bahia state, the discharge in Bahia is intermittent and it is only within Sergipe State that Vaza Barris River becomes a perennial river. There are four (4) flowing-gauging stations within the whole Vaza Barris River basin, two stations(from upstream; Agua Branca and Jeremoabo) at upstream in Bahia and two stations(from upstream; Ponte SE-302 and Fazenda Belem)at downstream in Sergipe. The average flow of these four stations are 0.95m^3/s(Agua Branca), 2.91 m^3/s (Jeremoabo), 4.19 m^3/s (Ponte SE-302) and 11.86 m^3/s (Fazenda Belem) respectively. Provable flood discharge at Fazenda Belem near the Vaza Barris Dam site, was studied presenting 536m^3/s (10-year), 976m^3/s (50-year), 1,211m^3/s (100-year), 2,198m^3/s (1000-year) and 3,588m^3/s (10,000-year).

(2) Topography and Geology

Vaza Barris River basin lies in tablelands of peneplain in Sergipe State and Bahia State. Within Sergipe State, the elevation of the basin is no more than 100m in the middle-stream and 200m in upper stream with higher remained hills of not more than 400m in height. Vaza Barris river and its tributaries cut down the tablelands forming steep valleys. Vaza Barris river flows from the north-west to south-west, which corresponds with the direction of large scale geological structural line, which affected the direction of Vaza Barris river course. The river course of Vaza Barris has remarkable bends in many places along the river course, of which direction are dominated by the direction of faults of geological age.

Within the Sergipe State, the geology of Vaza Barris basin consists of 1)Pre-Cambrian rock forming the geological basement of the region, 2)Tertiary covering the basement, 3)Alluvial sediments distributed along the rivers. The Pre-Cambrian rock consists of many type of rocks such as phyllite, sandstone, limestone, schist, gneiss, quartzite. These rocks are slightly weathered on the superficial part of the ground. Pre-Cambrian rocks outcrop on the surface of the ground in the middle-stream and up-stream of the basin but are overlaid by the Tertiary in the down-stream. The Tertiary consists of unconsolidated/consolidated silt, sand and gravel. Alluvial sediment is deposited forming terraces at both of the river bank of less than 10m in height from the river floor, which consists of soft silt and loose sand. The width of the terraces is closely related to the width of the valleys.

(3) Water Quality

In the parameters that were observed in Vaza Barris River, Chlorine (Cl) concentration is high and critical for potable water, as well as Electric Conductivity (EC), Sodium (Na), Magnesium (Mg), Calcium (Ca), Carbonic Acid (HCO_3) and pH Value (pH) are important for irrigation planning. The relationship between river flow and the said water quality parameters, as well as the correlation between EC and Na/Mg/Ca/Cl were established at Ponte SE-302 and Fazenda Belem. These results characterize water quality in Vaza Barris River as follows:

1) The parameters of Cl, EC, Na, Mg and Ca have relationship with river flow, presenting less concentration while the larger river flow.

2) It is found that HCO_3 and pH have no relationship with river flow.
3) In the viewpoint of long watercourse of Vaza Barris River as well as setting the bypass system, the agrotoxics effects on the future reservoir would be practically null.
4) The trophic level predicted for Vaza Barris Dam reservoir would correspond to the range of oligotrophic stage. This simulated trophic category would not constitute any problems to multiple use of future Vaza Barris Dam reservoir.

2.2.4 Current Water Use

Current water use points in Vaza Barris River concerning with water intake on industry/municipal/irrigation water are located in the tributaries of Vaza Barris River, not in the main stream.

2.3 Water Demand and Water Supply Plan

2.3.1 Domestic and Industrial Water Supply Plan

This project, Water Resources Development and Supply in Vaza Barris River – Sergipe, is planned to supply water to Itabaiana and Lagarto Water Supply areas. Water demand and shortage conditions in these areas in the year of 2020 are described in Table-2.5.

Table-2.5 Water Demand and Shortage in 2020

Items	Itabaiana Water Supply Area	Lagarto Water Supply Area	Total
Water Demand (m^3/day)			
Private-tap System	67,545	88,411	155,956
- Industrial Water	22,296	57,518	79,814
- Domestic Water: Urban Area	40,467	24,427	64,894
- Domestic Water: Large Rural Area	4,782	6,466	11,248
Public-tap System (Small Rural Area)	1,196	1,617	2,813
Total	68,741	90,028	158,769
Necessary Supply Water (m^3/day)			
Private Industrial Water	11,148	27,739	38,887
Private-tap System	74,286	79,664	153,950
- Industrial Water	14,864	39,704	54,568
- Domestic Water: Urban Area	53,957	32,570	86,527
- Domestic Water: Large Rural Area	5,465	7,390	12,855
Public-tap System (Small Rural Area)	1,107	1,497	2,604
Total (Except self-supplied ind.)	75,393	81,161	156,554
Current Water Supply Capacity (m^3/day)			
Private-tap System (Urban & Large Rural Area)	12,810	12,130	24,940
Public-tap System (Small Rural Area)	150	225	375
Total	12,960	12,355	25,315
Supply Water Shortage (m^3/day)			
Private-tap System (Urban &Large Rural Area)	61,476	67,534	129,010
Public-tap System (Small Rural Area)	957	1,272	2,229
Total	62,433	68,806	131,239

To settle the water supply shortage described table above, two projects namely 1) Project of Water Resources Development and Supply in Vaza Barris River- Sergipe, 2) Expansion project proposed to PROAGUA are being proposed. The water supply plan for urban and large rural area of the project area is shown in Table-2.6.

Table-2.6 Domestic and Industrial Water Supply in Agreste and Piauitinga Areas

Area Covered	Agreste Integrated Pipeline System		Piauitinga Integrated Pipeline System		Total Supply	
	(m^3/day)	(m^3/s)	(m^3/day)	(m^3/s)	(m^3/day)	(m^3/s)
Water amount necessary to be supplied in 2020	74,286	0.860	79,664	0.922	153,950	1.782
Present Capacity	12,810	0.148	12,130	0.141	24,940	0.289
Expansion project to be proposed to PROAGUA	22,200	0.257	30,200	0.349	52,400	0.606
Required development water amount in this project	39,276	0.455	37,334	0.432	76,610	0.887

Other than urban and large rural area, public water supply system by deep wells is proposed and for small rural area. Besides, private industrial water, which is supplied not through public water supply system, is assumed that individual factories will develop water through groundwater development.

2.3.2 Irrigation Water Supply Plan

Concerning irrigation plan related to the Vaza Barris Dam project, it is not included in the JICA Study (Study on Vaza Barris Dam Project), then SEPLANTEC conducted pre-feasibility study for it. Proposed site for the Vaza Barris Irrigation Project is located on the right bank of Vaza Barris River in Lagarto municipality. The site expands to Sape town in the east, Jenipapo town in the north and Brasilia town in the west with the total irrigation area of 4,519 ha. Soil in the site is categorized mainly Yellow Podzolic Soil which has the potential for irrigation with high soil fertility. Considering current land-use (agricultural land in full) and scale of farmers, the project consists of 6 types in terms of area as shown in Table-2.7. Recommended crops were determined through the agricultural market analysis in order to select the most profitable crops for the internal market. As a result, vegetable and fruit cultures are recommended. Area of each type, recommended crops and irrigation methods depending on crops are summarized in Table-2.7.

Table-2.7 Irrigation Models

Model	Culture	Lot Area (ha)	Lot Number	Total Area (ha)	Irrigation Method
A	Vegetables	3	268	804	Conventional Sprinkling
B1	Vegetables, Papaya, Lemon	5	113	565	Conventional Sprinkling for Vegetables and Micro-sprinkling for Fruit
B2	Acerola, Papaya, Lemon	5	98	490	Micro-sprinkling
C	Orange, Lemon, Pineapple, Passion Fruit	10	148	1,480	Micro-sprinkling, except Pineapple (Conventional Sprinkling)
D	Orange, Tangerine, Pineapple, Acerola, Passion Fruit	20	24	480	Micro-sprinkling, except Pineapple (Conventional Sprinkling)
E	Orange, Tangerine, Pineapple, Acerola, Passion Fruit	50	14	700	Micro-sprinkling, except Pineapple (Conventional Sprinkling)
Total Irrigation Area of Project (ha)			665	4,519	

Source: SEPLANTEC, "Pre-Feasibility Study of Vaza Barris Irrigation Project/Sergipe, Volume I - III", 1999

Source Water Requirement for reference crop above was calculated by month and shown in Table-2.8. In the calculation, application efficiencies of conventional sprinkling and micro-sprinkling were assumed to be 70 % and 85 %, respectively, while distribution and conveyance efficiencies were assumed to be 90 %. As shown in Table-2.8, the maximum project water requirement is 2.912 m^3/s in January. All the water required for this irrigation project is planned to be taken from the Vaza Barris dam

Table-2.8 Source Water Requirement of Vaza Barris Irrigation Project

Unit: m^3/s

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Water Requirement at Intake	2.912	2.469	2.022	0.717	0.273	0.000	0.033	0.542	1.344	2.484	2.463	2.820

Source: SEPLANTEC, "Pre-Feasibility Study of Vaza Barris Irrigation Project/Sergipe, Volume I - III", 1999

2.4 Water Resources Development Plan

2.4.1 Criteria of Plan and Design

< Newly Developed Water Amount >

Water Amount newly developed by Vaza Barris Dam is as follows :

- Domestic and Industrial Water : 0.887 m^3/s
- Irrigation Water : 2.912 m^3/s (1.507m^3/s on Average)
- Total : 3.799m^3/s (2.394m^3/s on Average)

< Compensation Discharge >

The "compensation discharge" Q_{CM} could be defined as the discharge necessary to maintain the normal function of a river, and consists of maintenance discharge and water-use discharge. Maintenance discharge has been stipulated to maintain river function even at the times of low flow, and water-use discharge is the flow necessary for the exclusive use of the river water at all points downstream. As no water use in the downstream of the dam site, compensation discharge was set as the 100% of the 10-year return period 7-day flow (Q7, 10), namely 0.44 m^3/s at the dam site.

< Reservoir Reliability (Security Level of Water Supply) >

Low flow security in the plan has been set to ensure the intake of newly developed discharge even in the worst drought in ten years for domestic/industrial and irrigation water supply.

< Design Discharges >

According to the "Criteria of Civil Design of Hydro-electric Plant, 1994 May, Preliminary Edition, CEMIG (Energy Company of Minas Gerais)", design flood discharge of a dam is set as the probable maximum discharge. As the other design discharges are not defined in the criteria mentioned above, the Japanese standard for dam design are referred.

2.4.2 Reservoir Operation Plan

(1) Concept of Reservoir Operation Plan of Vaza Barris Dam

The proposed dam, Vaza Barris Dam has the functions of not only "Storing Water" but also "Improvement of Reservoir Water". To improve reservoir water quality, a new system of a low flow bypass was introduced into reservoir operation plan of Vaza Barris Dam, considering water quality behavior that river flow has high chloric concentration only during low flow condition but not during flood (Refer to Figure-2.1). On dam reservoir operation, then, high saline concentration water is bypassed around the dam reservoir and clean or low chloric concentration water is stored in the dam reservoir as shown in Figure-2.2.

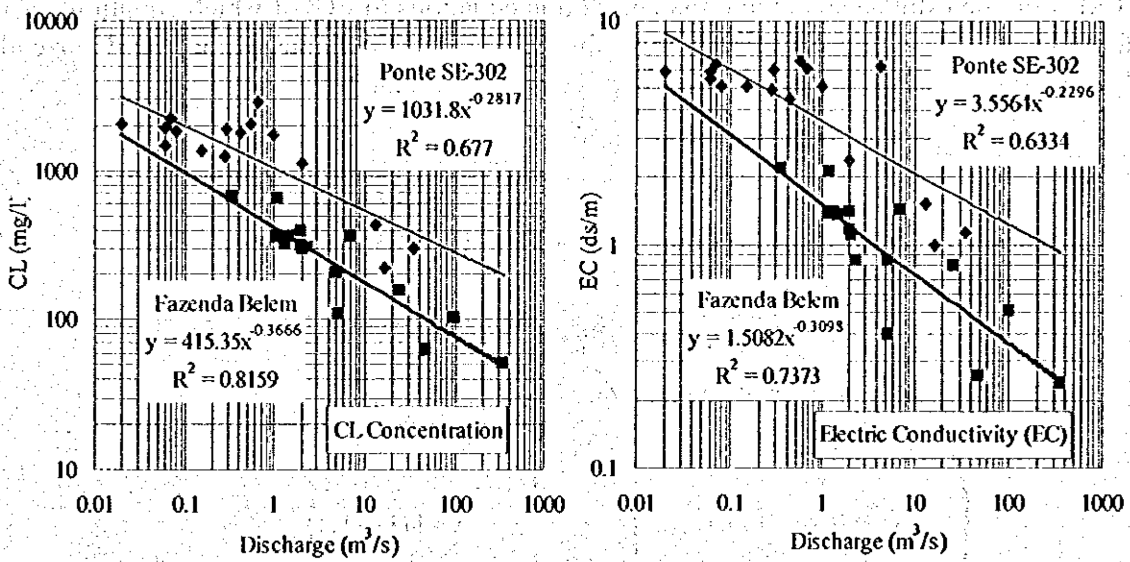


Figure-2.1 Relationship between Cl/EC and River Flow

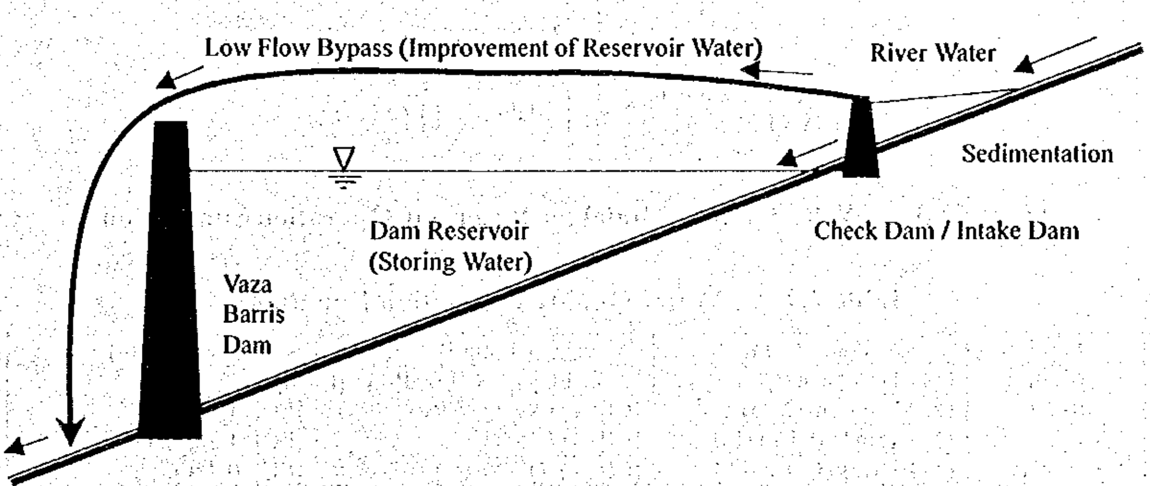


Figure-2.2 Main Function of Vaza Barris Dam

(2) Reservoir Operation Model

Hydrological reference points were set at the check dam and the main dam. These daily discharge is calculated by following equations, based on the discharge at Ponte SE-302 (Q_{PSE}) and Fazenda Belem (Q_{FB}), introducing "Runoff Contribution Factors" set considering the basin areas, the basin mean rainfalls and the runoff rates of the basins between Ponte SE-302 and Fazenda Belem.

$$Q_{CheckDam} = Q_{PSE} + 0.24 \cdot (Q_{FB} - Q_{PSE}) \qquad Q_{MainDam} = Q_{CheckDam} + 0.54 \cdot (Q_{FB} - Q_{PSE})$$

Water Quality Model of reservoir operation simulation is formulated as shown in Figure-2.3 and Table-2.9. River water quality of Sodium (Na), Magnesium (Mg) and Calcium (Ca) could be estimated applying the correlation equations to EC, of which equations were formulated based on the water quality observation data at Ponte SE-302 and Fazenda Belem.

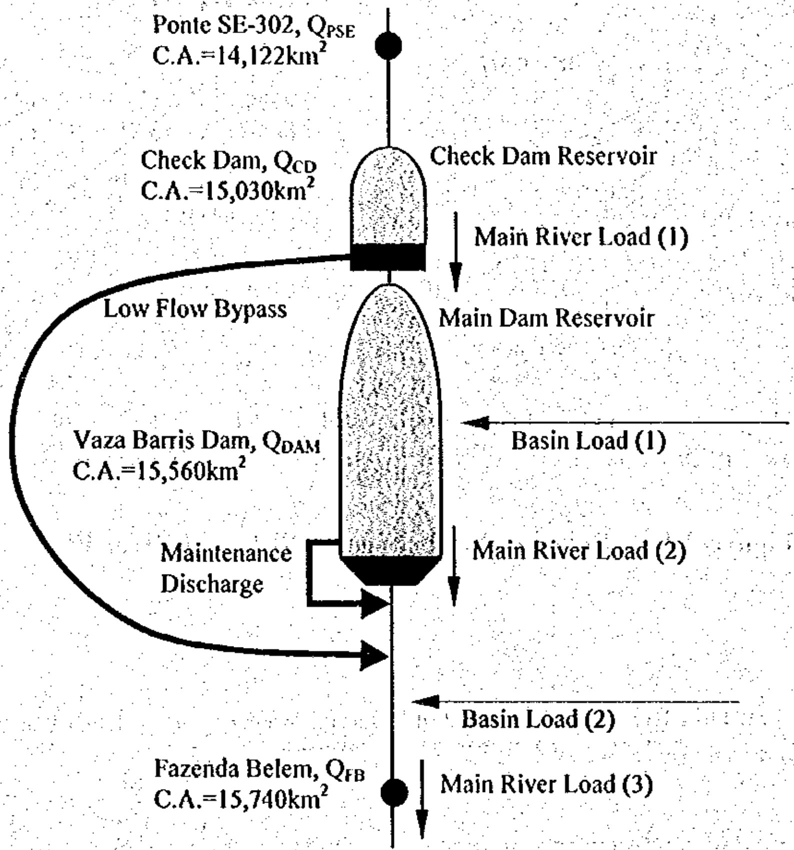


Figure-2.3 Water Quality Model for Reservoir Operation Simulation

Table-2.9 Water Quality Estimation Equation

Load	Point/Basin	Cl (mg/l)	EC (ds/m)
Main River Load	(1) Check Dam (CD)	$[Cl \text{ or } EC]_{CD} = ([Load]_{MD} - [Load]_{CD\text{-}MD}) / Q_{CD}$	
	(2) Main Dam (MD)	$[Cl]=427.99*Q^{-0.3597}$	$[EC]=1.5483*Q^{-0.3036}$
	(3) Fazenda Belem (FB)	$[Cl]=415.35*Q^{-0.3666}$	$[EC]=1.5082*Q^{-0.3098}$
Tributary Basin Load	(1) Between CD and MD	$[Cl]=80*Q^{-0.37}$	$[EC]=0.4*Q^{-0.31}$
	(2) Between MD and FB	$[Cl]=80*Q^{-0.37}$	$[EC]=0.4*Q^{-0.31}$
Water Quality Items		Correlation equation with EC (ds/m)	
Na (mg/l)		[Na] = 104.53*[EC]	
Mg (mg/l)		[Mg] = 35.514*[EC]	
Ca (mg/l)		[Ca] = 56.833*[EC]	

(3) Simulation Result of Reservoir Operation

Based on trial simulation of the cases of "without water quality capacity for dilution" and "with that", the following sets of bypass discharge and total reservoir volume are examined as alternatives of reservoir operation of Vaza Barris Dam.

Bypass Discharge: Q_{BP} = 0.7-1.3 m^3/s
Total Reservoir Volume: V_{RES} = 85-96 million m^3

Consequently, the most economical alternative was adopted and the design discharge of the low flow bypass and the total reservoir volume are set as follows:

Design Discharge for Low Flow Bypass: 0.75 m^3/s
Total Reservoir Volume (N.W.L): 93000,000 m^3 (EL. 47.50 m)

(4) Reservoir Operation Plan

The simulation result of the reservoir operation for Vaza Barris Dam is shown in Figure-2.4 and Figure-2.5. These figures show variation of reservoir water volume, inflow, chlorine concentration (Cl) and electric conductivity (EC). To identify the effect of low flow bypass, the simulation result in the case of no bypass is also presented in the same figures. Table-2.10 shows the maximum and the average of reservoir water quality during the calculation period of 1986 to 1995.

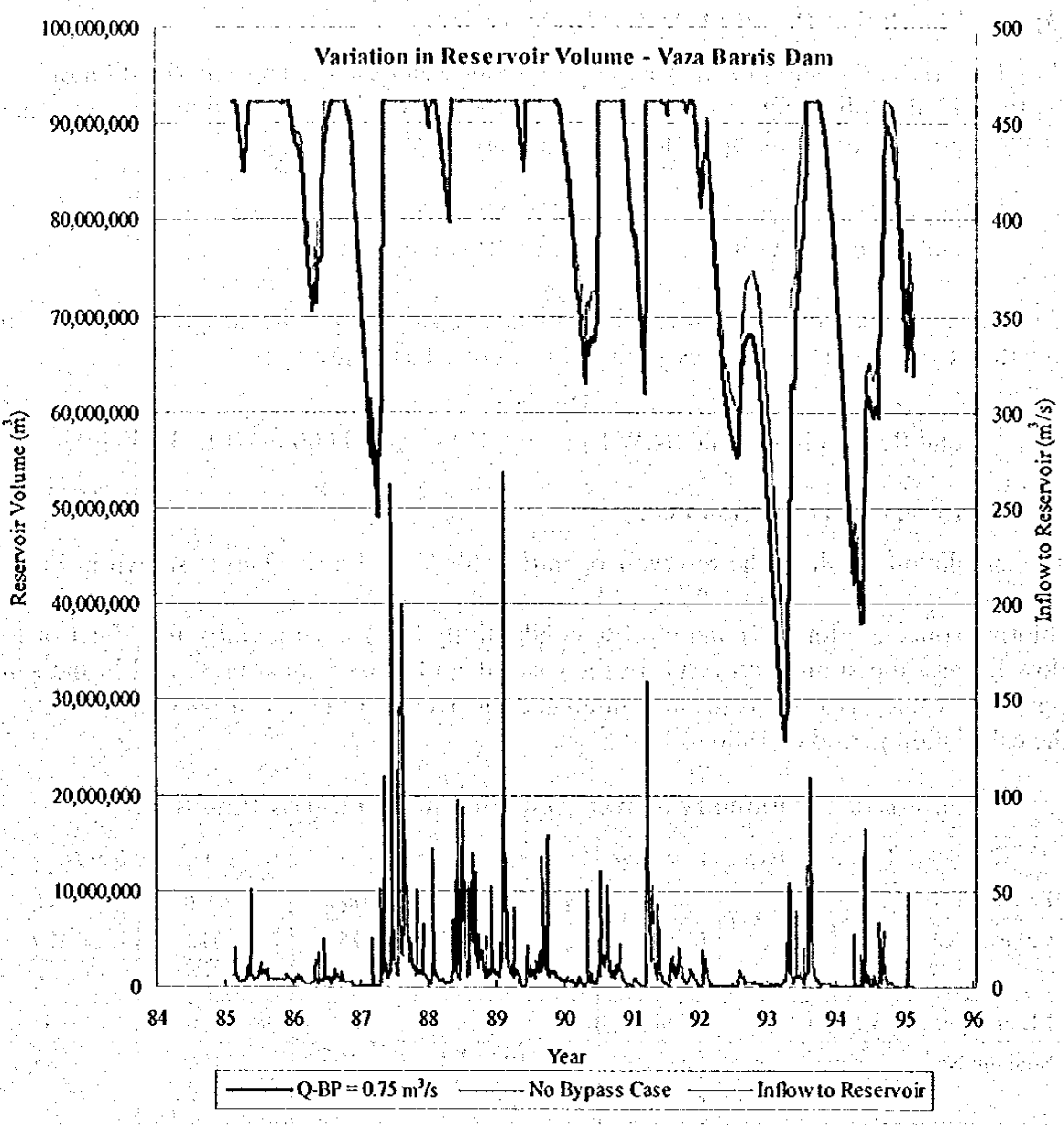
Table-2.10 Summary of Water Quality in Vaza Barris Dam Reservoir

Low Flow Bypass Discharge / Parameter		Q_{BP} = 0.75 m^3/s		Q_{BP} = 0.0 m^3/s	
		Maximum	Average	Maximum	Average
Chloride: Cl	(mg/l)	250	175	312	199
	(me/l)	7.1	4.9	8.8	5.6
Electric Conductivity: EC	(dS/m)	1.00	0.73	1.20	0.82
Sodium: Na	(mg/l)	104	77	126	85
	(me/l)	4.5	3.3	5.5	3.7
Calcium: Ca	(mg/l)	57	42	68	46
	(me/l)	2.8	2.1	3.4	2.3
Magnesium: Mg	(mg/l)	35	26	43	29
	(me/l)	2.9	2.1	3.5	2.4
Sodium Absorption Rate: SAR		2.7	2.3	2.9	2.4
Carbonic Acid: HCO_3 *	(mg/l)	50 – 180			
	(me/l)	0.8 - 3.0			
pH *		6.9 - 8.3			

* HCO_3 and pH are not dependent on discharge.

(5) Specifications of the Plan of Vaza Barris Dam

Based on reservoir operation simulation, reservoir capacity distribution was set as shown in Figure-2.6. Planned specification of Vaza Barris Dam on development discharge, dam reservoir allocation, Dam/Spillway, check dam, low flow bypass is summarized in Table-2.11.



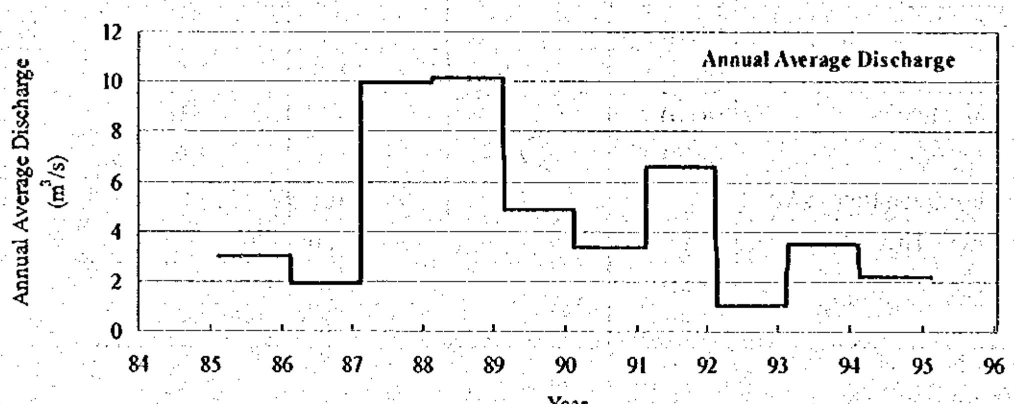
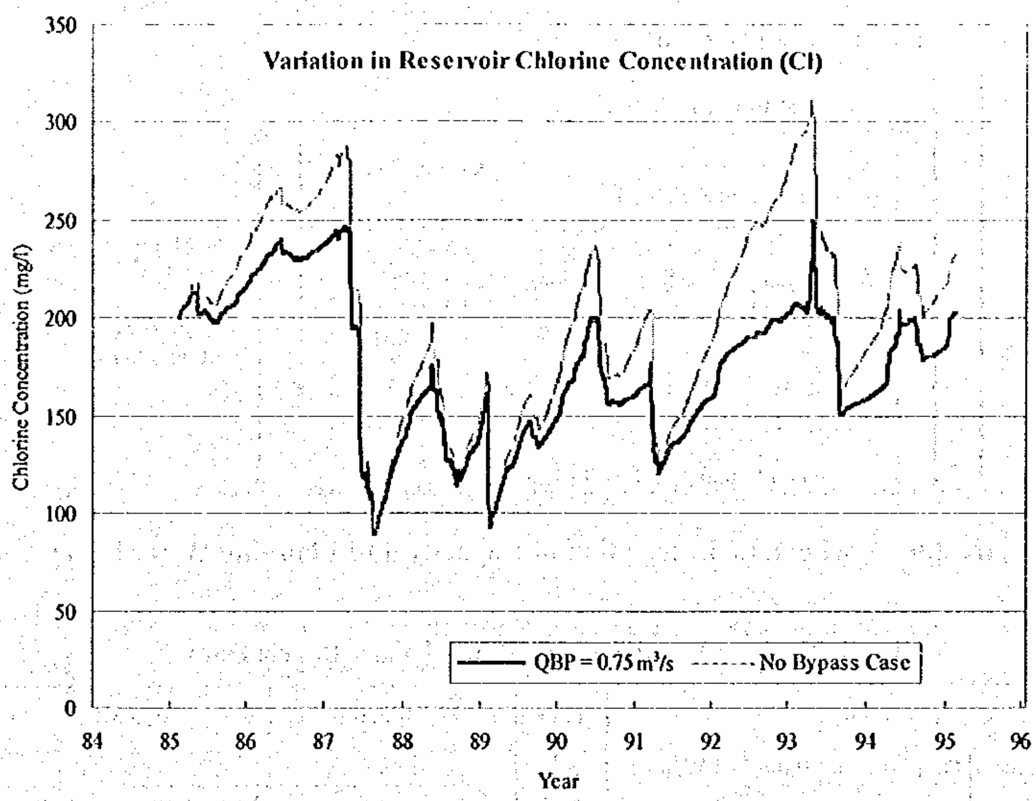


Figure-2.4 Variation of Reservoir Volume and Inflow



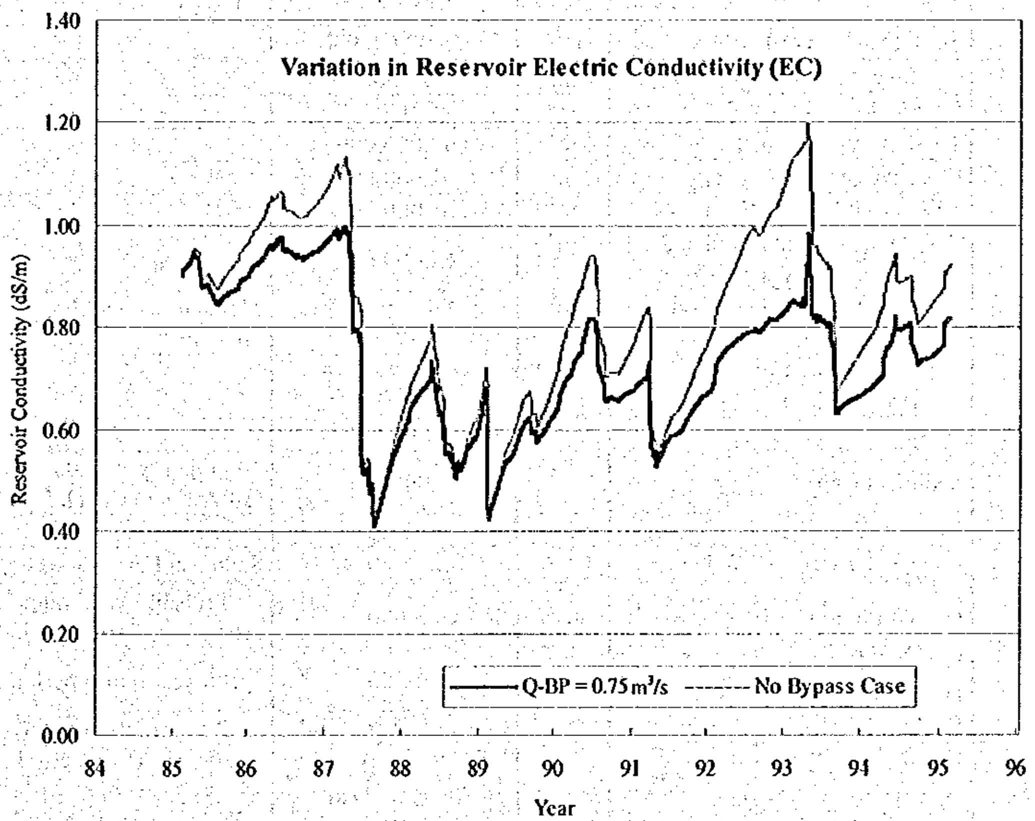


Figure-2.5 Variation of Chloric Concentration and Electric Conductivity in the Vaza Barris Dam Reservoir

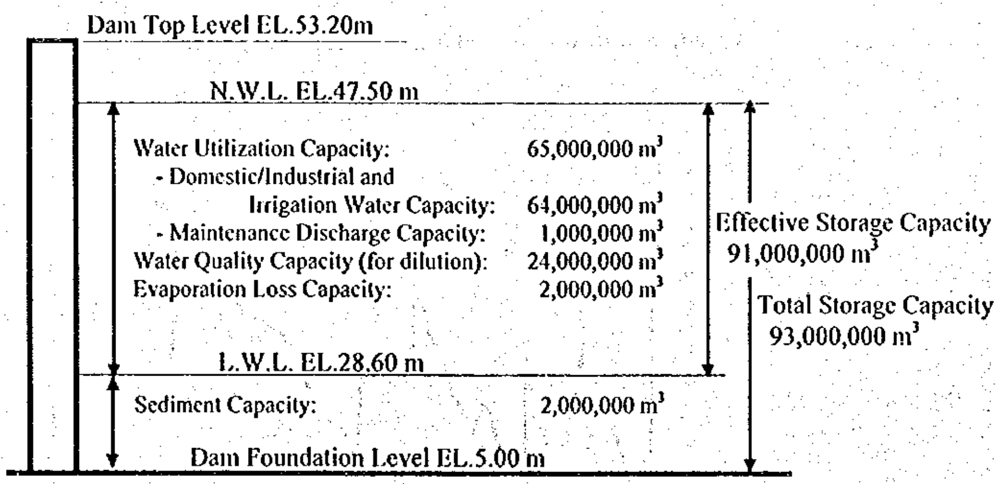


Figure-2.6 Schematic Description of Capacity and Planning Water Level

Table-2.11 Planed Specification of Vaza Barris Dam

Items		Unit	Specification	Remarks
Development Discharge	Domestic and Industrial Water	m^3/s	0.887	
	Irrigation Water (Max. /Ave.)	m^3/s	2.912 / 1.507	Vaza Barris Irrigation Project
	Total (Max. /Ave.)	m^3/s	3.799 / 2.394	
Dam Reservoir	Catchment Area	km^2	15,560	
	Reservoir Area (N.W.L.)	Ha	950	
	Total Storage Capacity	m^3	93,000,000	
	Effective Storage Capacity	m^3	91,000,000	
	Water Utilization Capacity	m^3	65,000,000	
	- Domestic/Industrial and Irrigation Water Capacity	m^3	64,000,000	
	- Maintenance Discharge Capacity	m^3	1,000,000	Maintenance Discharge: 0.44 m^3/s
	Water Quality Capacity (for dilution)	m^3	24,000,000	
	Evaporation Loss Capacity	m^3	2,000,000	
	Sediment Capacity	m^3	2,000,000	10 m^3/km^2/year, 100 years (10Mm³ into Check Dam)
	Normal Water Level (N.W.L.)	EL.m	47.50	
	Low Water Level (L.W.L.)	EL.m	28.60	Sediment Level
Dam and Spillway	Design Flood Discharge	m^3/s	3,600	Probable Maximum (10,000-yr. Return Period)
	Design Discharge of Energy Dissipater	m^3/s	1,200	100-year return period
	Design Discharge of Diversion Channel during Construction	m^3/s	Concrete Dam: 200 Fill Dam: 720	2-year return period 20-year return period
Check Dam	Dam Type	-	Concrete Dam	
	Dam Top Level	EL.m	63.00	
	Design Discharge of Spillway	m^3/s	1,400	1.2 times of 100-year return period
	Sediment Capacity	m^3	10,000,000	Level at EL.63.0m
Low Flow Bypass	Design Discharge	m^3/s	0.75	

2.4.3 Design of Vaza Barris Dam

(1) Selection of Dam Site

Dam site was selected taking account of river discharge, reservoir volume, valley shape, geological condition and water quality. The area available for dam construction was specified based on the river discharge and the topographical condition that Vaza Barris river suddenly becomes wider in the down-stream. Then four (4) sites were selected for candidates of dam site with preferable topographical conditions for dam construction. Finally one site was selected for a dam site with the best geological condition of the four candidates.

(2) Topography and Geology of Dam Site

Topographical units constituting the Vaza Barris dam site and spillway site are; 1) tablelands forming peneplains, 2)valleies dissected down by Vaza Barris river, 3)river floors and Alluvial traces in the both side of the river floors. Geology of the Vaza Barris river consists of superficial sediments and basement rock. Superficial sediments consists of river deposit (Rd) in the river floor and terraces of the riversides, and colluvial deposit (Co) on the slopes behind the river terraces. The basement rock consists of phyllite distributed in whole the dam site. In rock mass classification, the phyllite is classified into C_M or C_H classes under the river bed, and is classified into D, C_L ,C_M classes in the slopes of the river sides . The rock mass classification is shown in Figure-2.11. The rock of the site is more or less permeable at the depth of less than 10m. On the other hand, the rock is almost impermeable at the depth of more than 10m. Especially, the rock is extremely impermeable under the river floor. Around the dam site, it is seems to be difficult to find earth materials and rock materials suitable for dam construction in quality and quantity. On the other hand, the rock materials suitable for the dam construction was found in Itabaiana Dome area, thus it is most desirable to obtain rock materials from Itabaiana Dome area.

(3) Selection of Dam Type

Four (4) dam types: gravity concrete dam, rock-fill dam with zone type, rock-fill dam with concrete facing type and earth-fill dam are compared. Type of Vaza Barris Dam: ***Gravity Concrete Dam Type*** is decided due to low cost and workability of construction under the following considerations:

1) Rock material and concrete aggregate are procured at the existing quarry site located near the Cajaiba Dam and 15 km far from the dam site. Concrete type dam, necessary material volume is minimum, is advantageous.
2) Due to big design flood discharge for spillway, a large scale of spillway facility is necessary. Fill type dam requires large volume of concrete for spillway facility. Spillway for concrete type dam is installed easily on the dam body. Concrete type dam is advantageous from viewpoints of construction cost and construction workability.
3) Fill type dam can be constructed on the rather less hard rock on the ground surface. That is an advantage of fill type dam. At the dam site, the layer of this "rather less hard rock", namely D-class rock or C_L-class rock, is very thin or nothing. Concrete type dam is constructed on the hard rock foundation: C_M-class rock or more. At the dam site, the difference between fill type dam foundation and

concrete type dam foundation is very small. Therefore, fill type dam has no advantage at the dam site.

4) Near the dam site, layers of soil and weathered rock are very thin. Therefore, a large area is necessary to collect core material and earth material. Considering the current land use (pastureland) near the dam site, it is impossible to collect soil material in the wide areas.

5) Water depth in flood time is very high due to low slope of river channel gradient. This high water depth is disadvantage for diversion tunnel during construction period. Therefor, partial bulkhead for diversion is recommendable. Partial bulkhead method is applicable for concrete type dam because the design diversion discharge is small and concrete dam is resistant against dam-top overflow. For fill type dam, diversion during construction period is very difficult at the Vaza Barris dam site.

(4) Specification of the Dam

As a result of dam design according to the dam operation plan, the specification of Vaza Barris Dam is summarized as follows:

< Dam Body >

- Dam Type : Gravity Concrete Dam
- Elevation of Dam Top : EL. 53.2 m
- Elevation of Dam Foundation : EL. 5.0 m (C_M Class Rock)
- Dam Height : 48.2 m
- Dam Top Length : 280 m
- Dam Top Width : 5.0 m
- Volume of Dam Body : 216,100 m^3 (include energy dissipater)
- Slope of Upstream : Vertical
- Slope of Downstream : 1:0.88
- Backfilling Volume of Concrete : 43,600 m^3

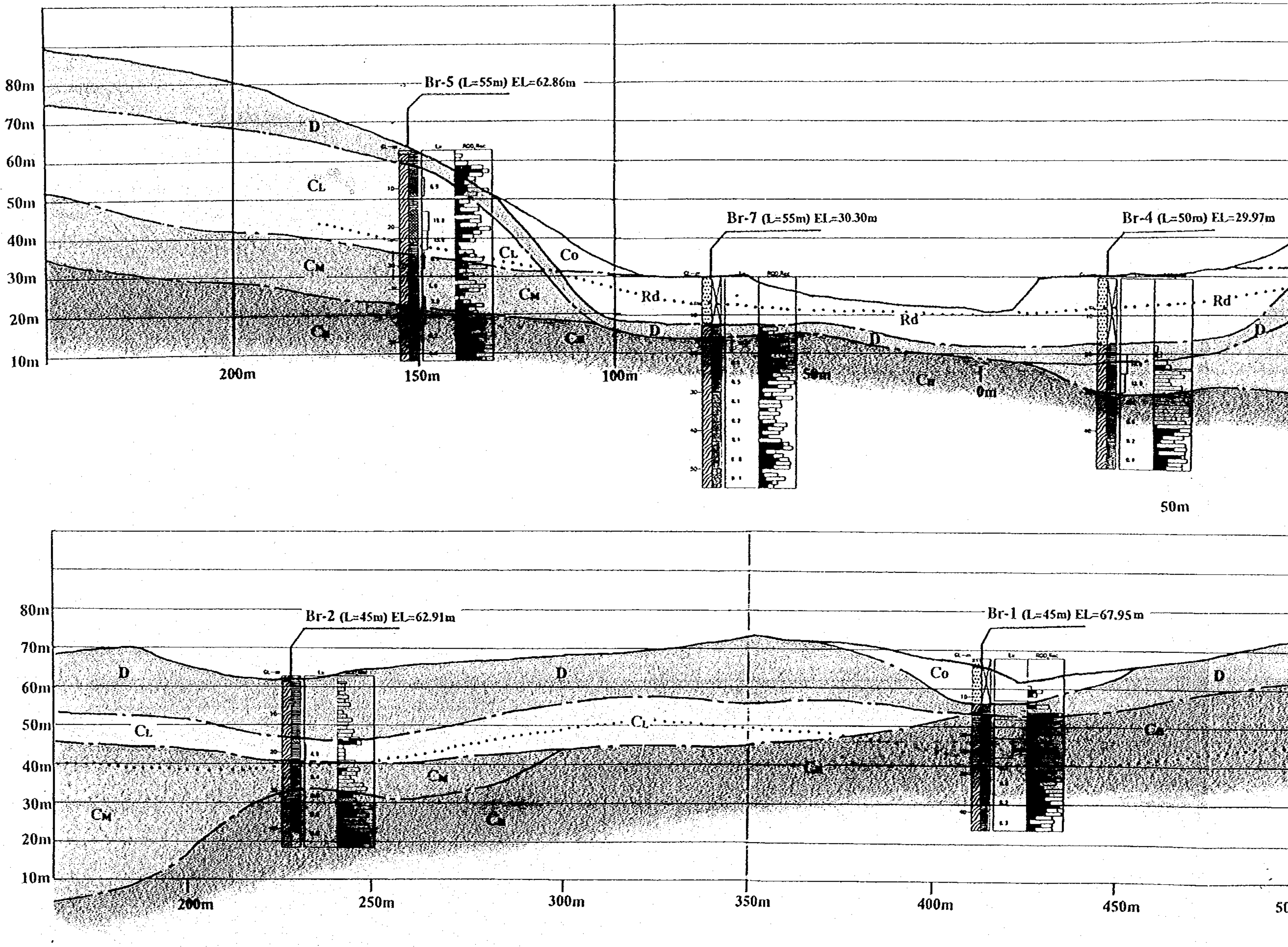
< Spillway >

- Design Discharge for Spillway : 3,600 m^3/s
- Design Discharge for Energy Dissipater : 1,200 m^3/s
- Type of Spillway : Free Overflow Type
- Size of Spillway : Overflow Depth 5.2 m
Overflow width 150 m
(include the width of the bridge pier 2 m x 5 piers = 10 m)
- Type of Energy Dissipater : Forced Hydraulic Jump with Chute Block and End Sill
- Size of Energy Dissipater : Basin Width 150 m
Basin Length 26 m
Basin Wall Height 12 m

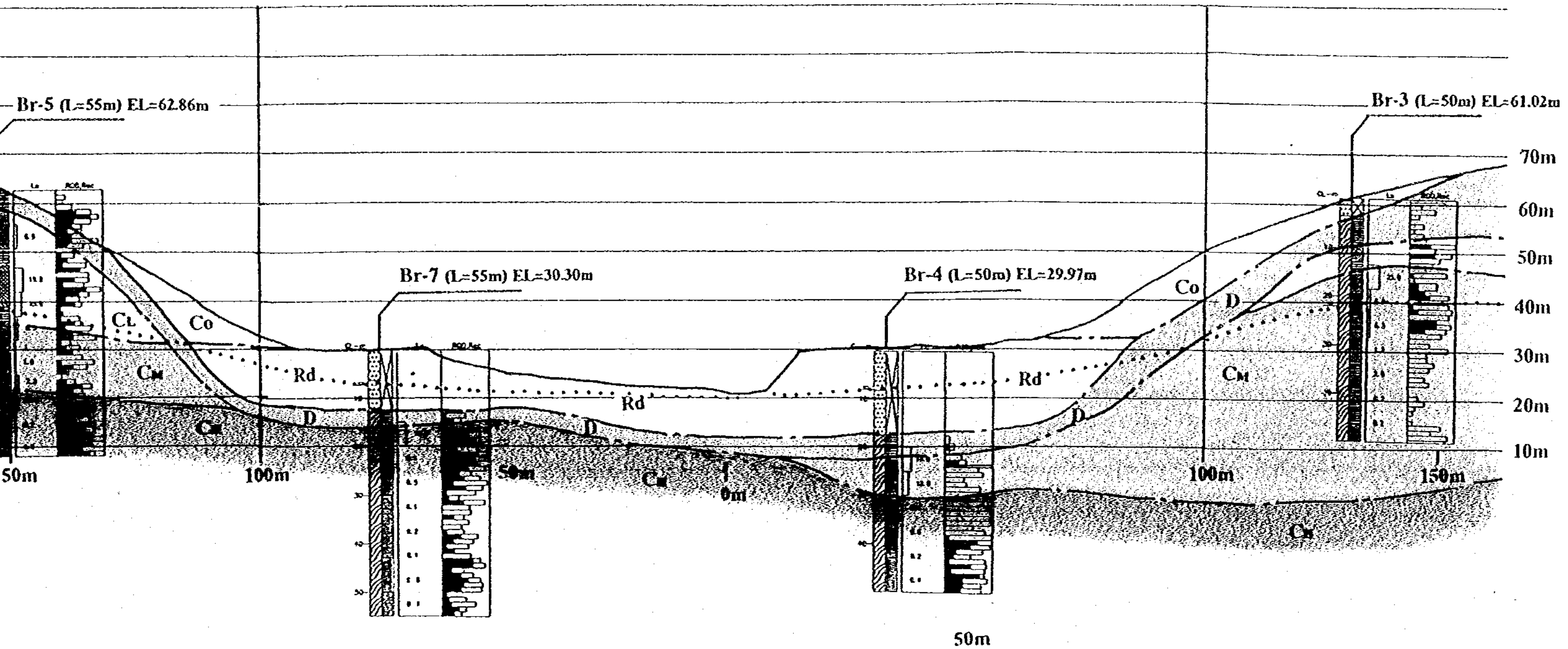
<Low Flow Outlet>

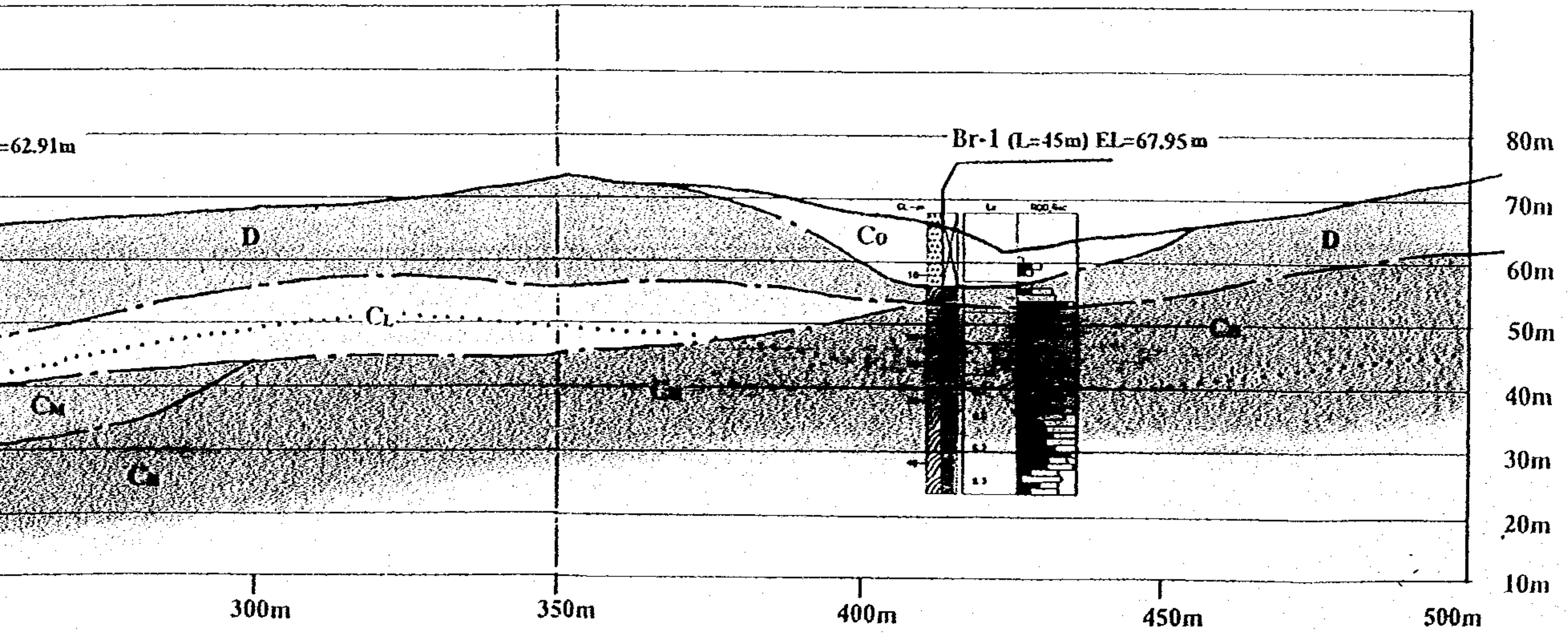
- - Design Outflow : 0.44 m^3/s
- - Diameter of Outlet Pipe : ϕ 800 mm
- - Diameter of Gate : ϕ 250 mm

Geological Cross Section



Geological Cross Section





Legend

- Rd ; River deposit
- Co ; Colluvial deposit
- C_H, C_M, C_L, D ; Rock mass class
- Lu ; Lugeon value
- RQD ; Rock quality designation
- Rec ; Core recovery rate

- -·-·-· Rock mass class boundary
- ········ Groundwater level

Column
- River deposit and Colluvial deposit
- Meta-phyllite
- Calcarious shist

Figure-2.7 Geological Cross Section of Vaza Barris Dam Site

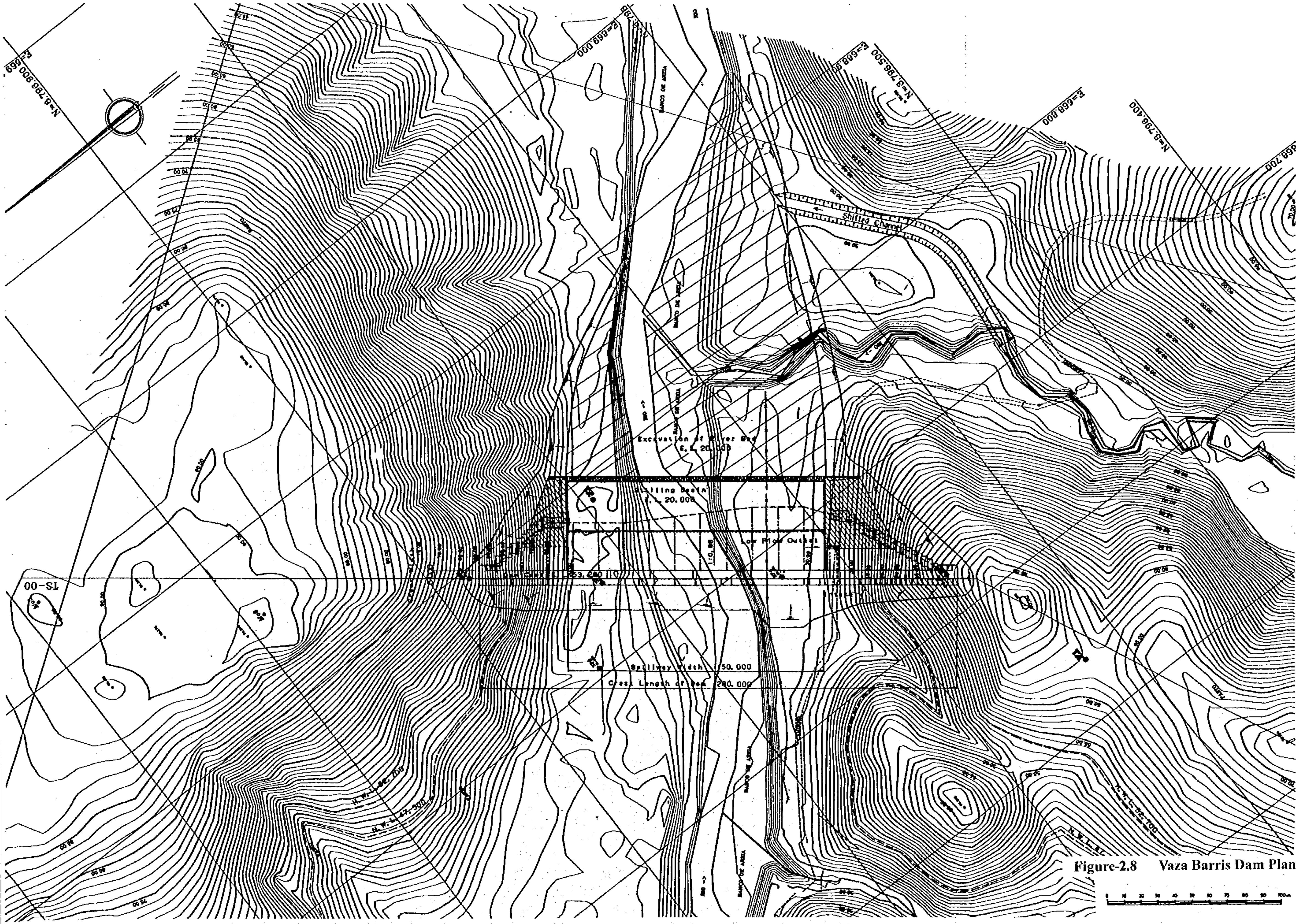


Figure-2.8 Vaza Barris Dam Plan

LONGITUDINAL SECTION OF VAZA BARRIS DAM AXISL S=1:500

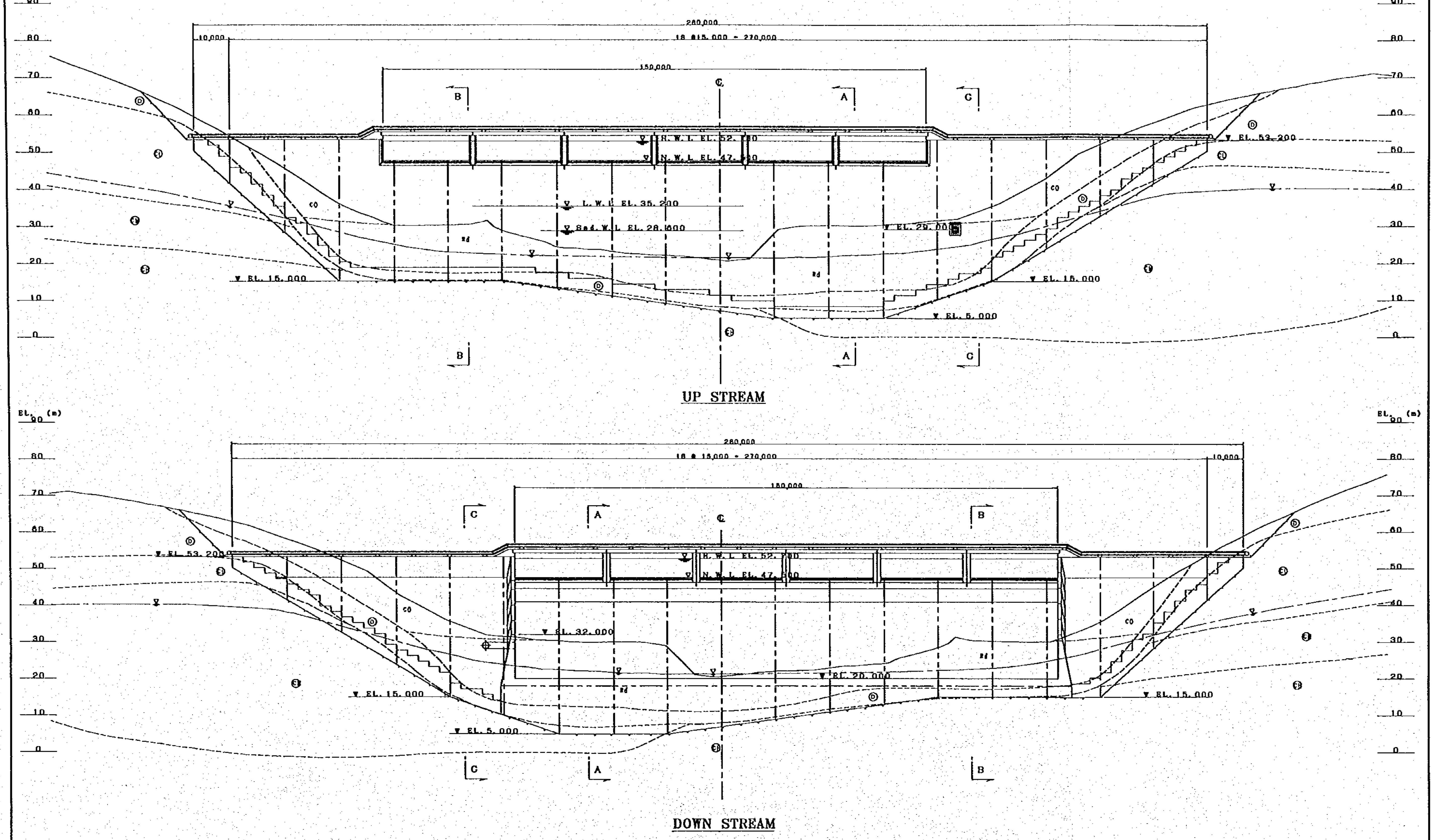


Figure-2.9 Longitudinal Section of Vaza Barris Dam Axis

(5) Plan of Temporary Diversion Works

Since it is judged based on flow regime and topographic feature that a temporary diversion tunnel is very difficult to be constructed, "diversion flowing half of river section" was adopted in this plan. The size of temporary diversion is set as follows, while design discharge is 200 m^3/s (2-year return period).

< Excavated Open Channel >

Trapezium water channel: Base width 15 m, Slope gradient 1:1.0, Water depth 4 m

< Rectangular Channel Inside of the Dam >

Width 3-4 m x Height 3-4 m

2.4.4 Design of Check Dam

(1) Selection of Check Dam Site

Site for the check dam was selected taking into account of valley shape, geology and functions necessary for check dam. The finally selected site is located almost at the top end of the reservoir which is formed by the planed Vaza Barris dam. This site has narrow valley which can make the volume of dam body small, moreover this site has the small Alluvial terrace along the riverside where the facilities can be set for water intake. Furthermore, there are some rocks found in the river floor and the slopes, thus this site also has advantage in geological aspect. No other sites can satisfy the above conditions around this site.

(2) Topography and Geology of Check Dam Site.

In the dam sate, valley is narrow and its slope is considerably steep. Alluvial terraces extend along the river but not wide. The rock is covered by thin superficial sediments, and is outcropping in some places in the river floor and both of the hill slopes. Geology of the site consists of river sediments (Alluvial terrace) and basement rock. River sediments is sandy soil with thickness of 2 – 9m. The basement rock consists of phyllite classified into C_L class of 3m thickness in the superficial part of the rock mass and C_M class under it.

(3) Specification of Check Dam

According to the reservoir operation plan, design reservoir sedimentation volume was set as 12,000,000 m^3. Out of this volume, 10,000,000 m^3 of sediment volume is to be stored in the check dam reservoir, in order to decrease sedimentation in the main dam reservoir. As the result of the design, the specification of the check dam is summarized as follows:

- Dam Type : Gravity Concrete Dam
- Elevation of the Top of Waterway : EL. 63.0 m
- Size of Waterway : Width 70 m x Water Depth 4.95 m
- Dam height : 20 m
- Concrete Volume : 28,400 m^3 (include sub-dam works)

2.4.5 Design of Low Flow Bypass

To convey low flow water not entering reservoir and to decrease salinity of reservoir water, the following two types of the low flow bypass are planned as alternatives:

- Open Type: Open type channel is installed along the periphery of reservoir. A channel crosses a valley or steep slope as a bridge.
- Closed Type: Closed type of pipeline or box culvert is installed in the bottom of the reservoir.

Table-2.12 shows the comparative evaluation on the alternative designs of low flow bypass. In this Feasibility Study, the box culvert bypass of the closed type was adopted as a low flow bypass, which is superior on economy, workability and environment, although it has difficulty on maintenance.

Table-2.12 Comparison of Low Flow Bypass

Items	Open Type: Open Channel	Closed Type: Box Culvert	Closed Type: Pipeline
Location	Reservoir edge with higher elevation of the dam top	Crossing through the dam body by pile with flow control valve	Crossing through the dam body by pile with flow control valve
Section	Concrete rectangular channel: W1.5m x H1.5m	Concrete box culvert: W1.05m x H1.05m	Steel pipe: ϕ 1,000 mm
Length	30.0 km	27.7 km	27.7 km
Head	8.0 m	38.0 m	38.0 m
Flow Type	Open type	Pressure type	Pressure type
Flow Velocity	0.6 m/s	0.7 m/s.	1.0 m/s.
Construction Workability	Bad in some	Good	Good
Construction Cost	R$ 47.1 million	R$ 32.8 million	R$ 44.5 million
Maintenance	Easy.	Difficult	Difficult
Impact to Environment	Large impacts (Excavation of slope)	Almost no impacts (Submersible box culvert)	Almost no impacts (Submersible box culvert)

2.4.6 Plan and Design of Water Conveyance

(1) Planning Conditions

Water supply regions will be Lagarto and Itabaiana regions.
Planning conditions are as follows:

Target year : 2020
Water Supply Rate : 100%
Water Supply Population : Lagarto region 229,700, Itabaiana region 309,800
Effective Water Supply Rate : 75%
Water Supply Load Factor : 83.3%
Average Design Daily Water Supply Volume per capita
Urban area : 160 liter/capita/day
Large rural area : 120 liter/capita/day
Average Design Daily Water Supply Volume
Piauitinga region : 37,334m^3/day
Agreste region : 39,276m^3/day

(2) Pump Facility Plan

Pump facility will be divided into two pumping systems, namely water intake pump and water lift pump, so as to prevent the technical difficulty caused by the long distance water conveyance, the high suction head of 30m and high fluctuation of seasonal change of water intake level in the reservoir and to assure easy operation and maintenance of whole pumping system. Number of pumps will be taken as 3 or 4 pumps with 1 stand-by pump included considering the risk dissipation, flow volume control and the construction works in two phases. Electric power will be supplied from the existing Cajaiba substation via new 69kV transmission line.

< Water Intake Pump Station, WIPS >

Water Intake Pump House, WIPH, with water intake tower will be constructed in the Vaza Barris reservoir at the right bank of the river near to the Vaza Barris Dam. WIPH and the right bank will be connected by a bridge and water intake pipes will run along the both sides of the bridge toward the connecting reservoirs. WIPS will supply water for Piauitinga and Agreste water supply systems. Number of pumps will be 4 with 1 stand-by pump included. Pump specification will be vertical flow type, total head of 40m, discharge volume of 10.7m^3/min per pump, rotation of motor of 1,775rpm, power of 110kW and required electric power of 440V/60Hz/3 phase. Surface water intake will be effected by stop log operation.

< Connecting Reservoirs >

Reinforced concrete connecting reservoirs will be constructed on the right bank of the river approximately 80m apart from WIPS. The connecting reservoirs will be constructed in order to secure smooth water flow to water lift pumps even when emergencies such as operational troubles in the water intake pumps or power outage will occur. The capacity of the reservoir will be 3,000m^3 for each region determined considering the frequency of occurrence and duration of power outage. The reservoir will be divided into two basins with 1,500m^3 of storage capacity for the easy maintenance of the reservoir.

< Water Lift Pump Stations, WLPS >

WLPS will be constructed next to the connecting reservoirs, one for Piauitinga water supply system and the other for Agreste water supply system. Number of pumps will be 3 with 1 stand-by pump included. Pump specification will be horizontal type, total head of 161m, discharge volume of 7.8m^3/min per pump, rotation of motor of 1,780rpm, power of 294kW and required electric power of 440V/60Hz/3 phase.

< Water Conveyance Pipeline >

In principle, all pipe materials will be ductile cast iron. Class of push-on Joint Type pipe will be K7 in accordance with the water pressure in the pipeline.
Pipeline from Vaza Barris Dam to Piauitinga region will be installed along the existing roads passing through Jenipapo, Brasilia, Acuvelho and Urubutinga villages. Pipeline with total length of 25.4km is divided into three portions, namely 1-ϕ700mm pressure pipe with 10.4km long up to Brasilia, 2-ϕ600mm gravity pipe with 7.8km long and 2-ϕ500mm gravity pipe with 7.2km long up to Lagarto. One pipeline of combination of ϕ600mm and ϕ500mm will be constructed in each construction phase. Countermeasures for water hammer in the pressure pipeline will be one way surge tank and flywheel. Two

surge tanks will be provided between WLPS and Brasilia and flywheel will be provided to the water lift pumps. Connecting reservoir will be constructed at the connection point of ϕ700 pipe and ϕ600 pipe with the same structural details of the connecting reservoir at WLPS.

Pipeline from Vaza Barris Dam to Agreste region will be laid along the existing pipelines of DESO passing Ribeira, Cajaiba and Carrilho villages. Pipeline with total length of 24.0km is divided into three portions, 1-ϕ700mm pressure pipe with 8.8km long up to Ribeira, 2-ϕ500mm gravity pipe with 7.7km long and 2-ϕ600mm gravity pipe with 7.5km long up to Itabaiana. One pipeline of combination of ϕ500mm and ϕ600mm will be constructed in each construction phase. Countermeasures for water hammer in the pressure pipeline will be one way surge tank. One surge tank will be provided between WLPS and Ribeira. Connecting reservoir will be constructed at the connection point of ϕ700 pipe and ϕ500 pipe with the same structural details of the connecting reservoir at WLPS.

There will be no large river crossings along both routes of pipelines and column type reinforced concrete structures can be applied for such river crossings.

(3) Water Treatment Stations and Water Distribution Facilities

Plan and Design of Water Treatment Stations and Water Distribution Facilities in Piauitinga and Agreste regions will be executed at the implementation stage of this Project. The construction cost for these works will be obtained by adjusting the construction costs for these works estimated in Master Plan multiplied by price escalation rate.

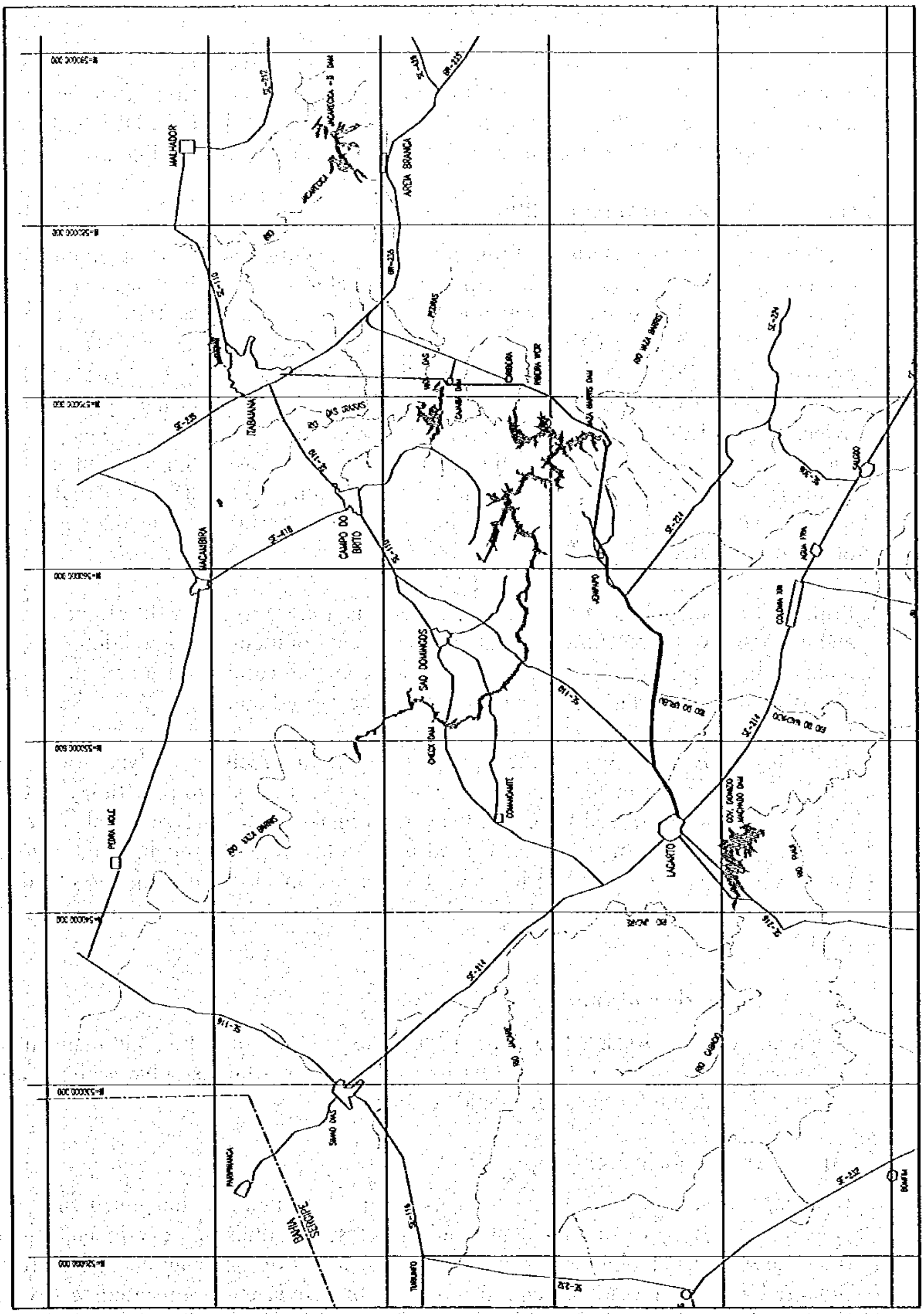


Figure-2.10 Pipeline Routes