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THE REPUBLIC OF KENYA
AND
THE UNITED REPUBLIC OF TANZANIA
FEASIBILITY STUDY ON THE TAVETA-VOI WATER SUPPLY PROJECT

FINAL REPORT
VOLUME IX
IMPLEMENTATION PROGRAM

MARCH 1988

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JAPAN INTERNATIONAL COOPERATION AGENCY

CENTRO DE REHABILITACION DE MANABI (CRM)
THE REPUBLIC OF ECUADOR

THE DETAILED DESIGN STUDY ON THE WATER TRANSBASIN SCHEMES FOR CHONE - PORTOVIEJO RIVER BASINS

FINAL REPORT
VOLUME X
IMPLEMENTATION PROGRAM

MARCH 1995

NIPPON KOEI CO., LTD.
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FINAL REPORT

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THE WATER TRANSBASIN SCHEMES FOR CHONE-PORTOVIEJO RIVER BASINS

IMPLEMENTATION PROGRAM

SUMMARY

1. The Province of Manabi has long been suffering a habitual water shortage problem. The Chone and Portoviejo river basins are located in the central part of Manabi Province and have a great potential for socio-economic development if only a sufficient quality and quantity of water supply is assured. The Centro de Rehabilitación de Manabí (CRM) has been making greatest efforts to solve this severe water shortage problem since its establishment in 1962, and has implemented and has been implementing several water resources development projects in the Project area, which, however, cannot meet ever growing water demands without the implementation of the Water Transbasin Schemes for the Chone-Portoviejo river basins (the Project) diverting water of the existing Daule-Peripa reservoir to the Project area.

2. CRM started a comprehensive master plan study on the integrated water resources development of Manabi Province (PHIMA) in 1986 in cooperation with other relevant Governmental institutions. The Organization of American States (OAS) joined the PHIMA study in late 1987 and the Government of Japan also joined the PHIMA study in early 1989 through the Japan International Cooperation Agency (JICA). The PHIMA final report issued in January 1990 by JICA recommended to conduct a feasibility study on the water transbasin schemes from the Daule-Peripa reservoir to the Chone-Portoviejo river basins.

   A feasibility study on the Project was conducted by JICA in collaboration with CRM and other relevant institutions of the Government of Ecuador from March 1991 to December 1992. The feasibility study justified the Project to be socio-economically feasible and environmentally sound.

   At the request of the Government of Ecuador, the Government of Japan agreed to proceed with the Project into the Detailed Design Stage. JICA, in collaboration with CRM, executed the detailed design study on the Project from October 1993 to March 1995.

3. The objective of the Project is to contribute the socio-economic development of the Project area by stable water supply to meet the following water demands:

(1) Water supply for domestic, tourism and industrial use to cover the population of 650,000 in the Portoviejo river basin including the Manta and Jipijapa area (70% of the total population) and the population of 40,000 in the Chone river basin (12% of the total population) in the year 2020.

(2) Water supply for irrigation in a net area of 12,150 ha in the Portoviejo river basin and 1,000 ha in the Chone river basin.

(3) Fresh water supply to shrimp farms in a gross area of 5,500 ha in the estuaries of the Chone and Portoviejo rivers.

(4) Increase of river maintenance flow to improve water quality and to conserve eco-systems of the Chone and Portoviejo rivers including their estuaries.

4. Manabi Province has an area of about 19,000 km^2, while the Project area, the Chone-Portoviejo river basins has an area of 4,871 km^2. Topographically, the Project area forms higher elevations towards the east from the flat coastal area in the west. Major geological layers in the Project area are Borbón, Onzole and Tosagua formations in Tertiary. The Onzole formation consisting of soft sandstone and mudstone is profoundly related to engineering works of the Project.

The Project area is dominated by a complicated tropical climate affected by the Humboldt cold current and El Niño phenomenon. Mean annual rainfall in the Project area varies from 400 mm in the south-western part to 1,800 mm in the eastern part, with about 90% of the annual rainfall concentrated in the rainy season from December to May. The seasonal fluctuation of mean monthly temperature, on the other hand, is small, the lowest of 23.8°C in August and the highest of 26.0°C in March in Portoviejo City.

The Project area is basically formed by two river systems, the Chone river system with a catchment area of 2,267 km^2 and the Portoviejo river system with a catchment area of 2,060 km^2. The Carrizal river is a major tributary of the Chone river with a catchment area of 1,166 km^2, and the Chico river is a major tributary of the Portoviejo river with a catchment area of 585 km^2.

5. Population of Ecuador is 9.7 million in 1990. Population of Manabi Province was 1,032,000 in 1990, while the population of the Project area was 480,300 in the same year. The population of the Project beneficiary area including Manta and Jipijapa area was 685,600 in 1990, and is forecasted to increase to 1,240,300 in 2020. Gross Domestic Product (GDP) of Ecuador was S/.8,130 billion in 1990, with GDP per capita

of S/.840,000 equivalent to US$ 1,030. Gross Regional Product (GRP) of Manabi Province was S/.599 billion in 1990, with GRP per capita of S/.580,000 equivalent to US$ 710.

6. In the Project area, a number of water resources development projects have been planned, studied and implemented. The following projects and studies are, among others, closely related to the Project.

(1) Poza Honda Multipurpose Project in the Portoviejo river basin

(2) Daule-Peripa Dam Project on the Daule river, located immediate east of the Project area.

(3) La Esperanza Dam Project on the Carrizal river, a major tributary of the Chone river.

(4) Water Transbasin Project from the Daule-Peripa to the Poza Honda and the La Esperanza reservoirs.

(5) Carrizal-Chone Multipurpose Project in the Chone river basin.

The Poza Honda project was implemented by CRM in the following stages:

- Construction of the Poza Honda dam in 1971
- Construction of Guarumo water treatment plant with a capacity of 43,000 m^3/day with water transmission system to Portoviejo and Manta in 1976
- Construction of Santa Ana intake weir and an irrigation system for 3,300 ha in 1984
- Construction of Caza Lagartos treatment plant with a capacity of 20,000 m^3/day with a pertinent water transmission system to Manta in 1987
- Cuatro Esquinas treatment plant at Portoviejo with a capacity of 90,000 m^3/day with the water transmission pipeline system to Portoviejo to be completed in late 1995
- El Ceibal treatment plant at Rocafuerte with a capacity of 90,000 m^3/day with the water transmission pipeline system to Manta and Rocafuerte, to be completed in late 1995.

The PHIMA Study evaluated a water supply capacity of the Poza Honda dam at Santa Ana intake weir site with a catchment area of 481 km^2 including the Poza Honda catchment of 175 km^2, to be 107 MCM/year. On the other hand, water demand in 1990 was estimated by PHIMA to be 25 MCM/year for water supply and 75 MCM/year for irrigation, totaling 100 MCM/year. Although it is technically possible for the Poza Honda dam to meet the 1990 water demand, CRM actually limited the irrigation supply to assure domestic water supply even during consecutive dry years. The Poza Honda dam cannot afford to feed the new treatment plants with additional 66 MCM/year of water demand without suspending the irrigation water supply. This is one of the major reasons for urgent necessity of water to be diverted from the Daule-Peripa to the Portoviejo river basin. The Poza Honda reservoir will function as a water receiving pond to be diverted from the La Esperanza reservoir to supply the Portoviejo river basin under the Project.

The Daule-Peripa dam was constructed by CEDEGE in 1987, with the main objectives of (i) flood control, (ii) domestic water supply, (iii) irrigation water supply and (iv) hydroelectric power generation. It is noted that a reservoir capacity of 500 MCM is allocated for use in Manabi province. According to the inter-institutional agreement signed in late 1986 between CEDEGE and CRM, CRM is entitled to divert up to 500 MCM/year with the maximum diversion of 18 m^3/s.

The construction of the La Esperanza dam was commenced in 1992 by CRM in the upper reach of the Carrizal river and is scheduled to be completed in 1996. The objectives of La Esperanza are (i) flood control and (ii) irrigation water supply to the Carrizal-Chone area. Once La Esperanza is constructed, the inundation problem in the rainy season and the water shortage problem in the dry season will mostly be solved in the Chone river basin. The Portoviejo river basin will, however, still remain without water until the Project is realized. La Esperanza will function as an intermediate pond to divert water from Daule-Peripa to Poza Honda.

The water transbasin project was formulated in 1987 in the following plan by CRM.

(1) Water of the Daule-Peripa reservoir will be diverted to La Esperanza with a transbasin capacity of 12 m^3/s.

(2) Water released by Daule-Peripa will be pumped up at the Daule river at about 30 km downstream of Daule-Peripa, by about 150 m to be diverted into Poza Honda with a final capacity of 12 m^3/s.

The PHIMA study in 1989 recommended to give a capacity of 18 m^3/s instead of 12 m^3/s to the Daule-Peripa-La Esperanza transbasin. CRM requested CEDEGE to construct the tunnel entrance with a capacity of 18 m^3/s, and CEDEGE constructed it in 1990 accordingly. CRM also revised the tunnel design from Daule-Peripa to La Esperanza to have a capacity of 18 m^3/s in 1989. The water transbasin scheme from Daule-Peripa to La Esperanza is one of the important components of the Project.

CRM conducted a feasibility study on the Carrizal-Chone irrigation project, to which water is supplied by the La Esperanza dam. Since the La Esperanza dam is scheduled to be completed in 1996, CRM has a strong desire to proceed with the project. In late 1994,CAF, Corporación Andina de Fomento, accepted to finance US$ 4.0 million for the detailed design of the project.

7. Three regional water supply systems currently serve the expanded Project area including Manta and Jipijapa area. They are Poza Honda System, La Estancilla System and Chone System, all of which are operated and maintained by CRM, except Caza Lagartos treatment plant which is managed by the Manta Municipal Water Supply Company.

Water demands in the service area are projected as follows:

Regional Water Supply System	Average Water Demand (m^3/day)			
	1990	2000	2010	2020
Poza Honda	89,950	155,470	252,730	395,800
Chone	8,780	17,260	27,510	39,570
La Estancilla	12,500	30,760	52,180	76,940
Total	111,230	203,480	332,420	512,290
in MCM/year	41	74	121	187
Unit demand (l/p/d)	207	285	355	428

8. There are three irrigation systems in the Project area. They are (i) Poza Honda, (ii) Chico and (iii) La Estancilla. The service areas and actually irrigated areas in 1988 are as follows:

Irrigation System	Commanding area (ha)	Irrigated area in 1988 (ha)
Poza Honda	8,750	4,850
Chico	2,050	1,380
La Estancilla	2,730	1,520
Total	13,530	7,750

Although the Project area is provided with irrigation facilities covering an area of 13,530 ha, an area of 7,750 ha was insufficiently irrigated in 1988 due to shortage of water resources.

The following eight irrigation schemes with a total net area of 29,250 ha are formulated in the Project area and the irrigation water requirements were calculated for a once in 5 year dry year.

Scheme	River Basin	Net Irrigation Area (ha)	Water Requirement (MCM/year)
Carrizal-Chone	Carrizal and Chone	15,000	253
Amarillos	Carrizal	1,000	19
Guarango	Portoviejo	1,500	36
Río Chico	Chico	1,700	31
Pechiche-Pasaje	Chico and Portoviejo	850	20
Santa Ana	Portoviejo	3,300	74
Mejía	Portoviejo	1,250	28
Ceibal-Guayaba	Portoviejo	4,650	111
Total		29,250	572

9. Shrimp farming is practiced in the estuary of the Chone river where 4,967 ha was operated in 1990 and 5,417 ha will be operated in 2000. Salinities are influenced by seasonal fluctuation of rainfall and runoff. Water around shrimp ponds have salinities as low as 0 parts per thousand (ppt) in the rainy season due to heavy rainfall and abundant runoff of the river, while it rises more than 40 ppt equal to or even higher than that of seawater in the dry season. The optimum range of salinity for good growth of shrimp is from 15 to 25 ppt. If proper fresh water supply controls the salinity of water in the shrimp ponds within the optimum range, shrimp production will be notably increased.

Annual fresh water requirement in 2000 onward is estimated to be 100 MCM in the Chone estuary and 3 MCM in the Portoviejo estuary as explained below.

	Gross Area (ha)	Net Area (ha)	Area receiving fresh water (ha)	Unit water requirement (m^3/ha)	Total water requirement (MCM/year)
Chone river					
Zone A (Sea side)	990	594	475	49,500	23.5
Zone B (River Side)	4,427	2,656	2,125	35,700	76.0
Portoviejo river	130	78	63	44,300	2.8
Total	5,547	3,328	2,663	-	102.3

(Note) Net area is assumed to be 60% of the gross area. Also, the area actually receiving fresh water from the Project is assumed to be 80% of the net area.

10. An integrated reservoir operation and water balance study is conducted under the following conditions:

(1) The interbasin flows, the natural flows from the catchment area downstream of a dam, can be used to meet water demands especially during the rainy season. Use of up to 60% of the interbasin flow is assumed to be allowed.

(2) A dam should release a constant flow as a river maintenance flow. The river maintenance flows are 8 MCM/year from Poza Honda and 16 MCM/year from La Esperanza.

(3) Dilution water equivalent to 20% of the irrigation water requirement is applied to dilute irrigation return flows.

The study confirmed that all the water demands can be met with a guarantee level of more than 80% (water shortage is allowed in only one year out of five years) under the following conditions.

(1) Full capacity pumping up from La Esperanza is only possible for reservoir water levels higher than EL. 47 m.

(2) Water diversion from Poza Honda to Mancha Grande is only possible for reservoir water levels higher than EL. 94 m.

(3) Target water levels are EL. 63.5 m for La Esperanza and EL. 102.5 m for Poza Honda. This means that water transbasin from Daule-Peripa to La Esperanza is suspended when La Esperanza water levels are higher than EL. 63.5 m and that water transbasin from La Esperanza to Poza Honda is suspended when Poza Honda levels are higher than EL. 102.5 m.

(4) Water transbasin capacities are as follows.

Daule-Peripa ~ La Esperanza	:	18 m^3/s
La Esperanza ~ Poza Honda	:	16 m^3/s
Poza Honda ~ Mancha Grande	:	4 m^3/s

11. The Project comprises three water transbasin schemes as shown below:

(1) Daule-Peripa ~ La Esperanza Transbasin Scheme

Diversion tunnel	
Capacity	18 m^3/s, Free flow
Length	8.3 km
Section	3.7 m in diameter
	Standard horseshoe section
Gradient	1/1,500
Access roads	
Conguillo access road	22.6 km
Membrillo access road	0.4 km
El Guasmo access road	1.6 km

(2) La Esperanza ~ Poza Honda Transbasin Scheme

Severino pumping station	
Pumping capacity	16 m^3/s
Maximum head	70.0 m
Design head	60.0 m
Nos.of pump unit	6 units (one for reserve)
Discharge of one unit	192 m^3/min. (3.2 m^3/s)
Type	Vertical shaft, single suction volute type
Penstock	
Length	173 m (No.1 penstock)
	170 m (No.2 penstock)
Nos. of lanes	2 lanes
Diameter	1,000 - 2,400 mm
Head tank	
Width	16.8 m - 8.8 m
Length	56.7 m
Open channel	
Capacity	16 m^3/s
Length	5.5 km
Gradient	1/3,000
Section	Trapezoidal

Syphons

Syphon No.	Length	Max.head
1	72 m	8.7 m
2	233 m	36.6 m
3	326 m	47.6 m
4	76 m	5.5 m
5	174 m	17.5 m

Diversion tunnel

Capacity	16 m^3/s, Free flow
Length	11.4 km
Section	3.5 m in diameter
	Standard horseshoe section
Gradient	1/1,500

Severino substation

Capacity	2 x 12.5 MVA
Voltage ratio	138/13.8 kV

Daule-Peripa ~ Severino Transmission Line

Length	32.6 km
Voltage	138 kV

Access roads

Severino access road	9.3 km
Caña Dulce inlet access road	2.7 km
Los Cuyuyes access road	14.8 km
La Seca access road	3.8 km

(3) Poza Honda-Mancha Grande Transbasin Schemes

Diversion tunnel

Capacity	4 m^3/s, Free flow
Length	4.1 km
Section	2.5 m in diameter
	Standard horseshoe section
Gradient	1/3,900

Access road

Poza Honda Inlet access road	0.7 km

12. The Project is proposed to be implemented by the following three contract packages:

Package 1: Civilworks for Daule-Peripa~La Esperanza Transbasin Scheme

Package 2: Civilworks for La Esperanza~Poza Honda and Poza Honda~Mancha Grande Transbasin Schemes

Package 3: Electrical and Mechanical Works including Power Transmission Line

The following basic schedule for Project implementation is established.

(1) Financial arrangement for construction : 10 months from April 1995 to January 1996

(2) Selection of a consultant : 3 months from February 1996 to April 1996

(3) Tendering and contracts including prequalification for Packages 1 and 2

Package 1	:	13 months from May 1996 to May 1997
Package 2	:	13 months from May 1996 to May 1997
Package 3	:	11 months from July 1997 to May 1998

(4) Construction works

Package 1	:	54 months from June 1997 to November 2001
Package 2	:	54 months from June 1997 to November 2001
Package 3	:	42 months from June 1998 to November 2001

(5) Commissioning of the Project : December 2001

13. Environment Impact Assessment (EIA) is conducted for the Project for the following four issues based on the Project features and the results of the Initial Environmental Examination (IEE).

(1) Impacts on water quality of La Esperanza and Poza Honda reservoirs

(2) Impacts on river flow regime

(3) Impacts on water quality in rivers and estuaries

(4) Impacts on eco-system and fishery

Although several environmental impacts having certain effects on the environment are pointed out through EIA, these are not considered substantial for the Project because most of them could be mitigated by proper countermeasures. Therefore, the Project is judged acceptable from the environmental viewpoint.

Even if the results of EIA conclude that the Project is acceptable from the environmental viewpoint, it is not possible to eliminate all uncertainties related to environmental impacts caused by the Project. Unexpected environmental problems might arise after implementation of the Project. It is important to monitor the effectiveness and efficiency of the proposed mitigation measures, and, therefore, CRM will conduct an Environmental Management and Monitoring Plan (EMMP) as an associated project to the Transbasin Project.

14. The executing agency of the Project is the Manabi Rehabilitation Center (CRM), who is reponsible for development of water resources including potable water supply and irrigation in the province of Manabi as well as urban and regional development of Manabi Province. Major projects handled and managed by CRM are the Poza Honda Multipurpose Project, small irrigation schemes such as the La Estancilla irrigation system, the Chico river irrigation system, etc., the Chone and La Estancilla water supply systems, and the Carrizal-Chone Multipurpose Project including the La Esperanza dam.

15. A transbasin project office will be organized towards the construction of the Project. The main project office will be located at the Severino pumping station site and branch offices are located at the Conguillo tunnel inlet site and at the Poza Honda tunnel inlet site. An international consultant as well as an Ecuadorian consultant will be employed by CRM to assist CRM in construction supervision of the Project.

Upon completion of the Project construction, CRM will hand over the transmission line between Daule-Peripa and Severino to INECEL for operation and maintenance. Also, the access roads will be handed over to the Ministry of Public Works (MOP) for maintenance. CRM will be responsible for operation and maintenance of the remaining Project facilities. The Severino project office will become a Severino operation and maintenance center (O&M Center) responsible for operation and maintenance of Project facilities except the Conguillo tunnel inlet and the Poza Honda tunnel inlet which will be

operated and maintained by the Conguillo O&M branch office and the Poza Honda O&M branch office, respectively.

16. CRM intends to employ an international consulting firm for engineering services during the implementation of the Project, in accordance with regulations of the Government of Ecuador and with guidelines of the financing institutions. The scope of works for the international consulting firm will be (i) pre-construction services during prequalification, tender, tender evaluation and contract award and (ii) construction supervision.

The construction works will be executed in three contract packages as described in 12 hereinbefore. The Project administration for the implementation of the Project will be done by a force-account of CRM through the Transbasin Project Office at the Severino site. Land acquisition and compensation will be done by CRM based on the recommendations of the National Directorate of Valuation and Cadastre.

17. Project costs are estimated at the price level of August 1994 as follows.

(US$ million)

	Foreign Currency	Local Currency	Total
Package 1	29.04	14.20	43.24
Package 2	52.30	27.47	79.77
Package 3	25.05	2.64	27.69
Sub-total	106.39	44.31	150.70
Administration	-	0.25	0.25
Land Acquisition	-	3.01	3.01
Engineering Service	10.01	1.53	11.54
Physical Contingency	9.38	4.50	13.88
Price Contingency	17.76	7.67	25.43
Total Cost	143.54	61.27	204.81

The annual disbursement is estimated according to the construction schedule and summarized as follows,

(US$ million)

Year	Foreign Currency	Local Currency	Total
1996	-	0.14	0.14
1997	27.43	14.48	41.91
1998	35.59	15.30	50.89
1999	30.27	14.13	44.40
2000	39.66	12.47	52.13
2001	10.59	4.75	15.34
Total	143.54	61.27	204.81

18. The Government of Ecuador has decided to implement the Daule Peripa ~ La Esperanza Transbasin scheme separately from the ther transbasin schemes under its own financial arrangement. CRM now intnds to apply for a soft loan to the Japanese government for the construction of the remaining two transbasins. The requested amount of the soft loan is tentatively estimated to be US$ 117.02 million as explained below.

	(US$ million)
Project cost for the remaining two tansbasins	145.16
Foreign currency portion	103.52
Local currency portion	41.64
Interest during construction (IDC) (Annual interest rate of 3% is assumed)	10.87
Project cost including IDC	156.03
Amount of soft loan 156.03 x 75%	117.02
Amount to be arranged by CRM or the Government of Ecuador	39.01

19. The economic internal rates of return (EIRR) are calculated for various unit water values for potable water supply as shown below.

Assumed Unit Water Value (US$/m^3)	EIRR (%)
0.3	11.9
0.4	13.4
0.5	14.8

The financial internal rates of return (FIRR) are also calculated as follows for various unit water prices for potable water supply.

Assumed Unit Water Price (US$/m^3)	FIRR (%)
0.15	8.6
0.20	10.0
0.25	11.2

Besides the tangible benefits as analyzed above, the Project will surely bring about enormous socio-economic impacts in the Project area. They are, among others, as follows.

- Socio-economic impact during construction of the Project
- Impact on local commercial activities
- Impact on industrial development
- Improvement of sanitary condition
- Impact on rural area development including eco-tourism development

IMPLEMENTATION PROGRAM

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ABBREVIATION

Ecuadorian Institutions

CEDEGE	:	Committee for Guayas River Basin Development
CETUR	:	Ecuadorian Corporation for Tourism
CLIRSEN	:	Integrated Center for Remote Sensing Survey
CONADE	:	National Development Council
CPC	:	Chamber of Shrimp Producer
CRM	:	Manabi Rehabilitation Center
DIGMER	:	Directorate General of Merchant Marine
DINAC	:	National Directorate of Valuation and Cadastre
DINAF	:	National Directorate of Forestry
DITURIS	:	Directorate of Tourism
EMAPAM	:	Municipal Enterprise of Potable Water and Sewerage of Manta
ESPOL	:	Polytechnic Littoral College
GOE	:	Government of Ecuador
IEOS	:	Ecuadorian Institute of Sanitary Works
IERAC	:	Ecuadorian Institute for Agrarian Reform
IGM	:	Geographic Military Institute
INAMHI	:	National Institute of Meteorology and Hydrology
INEC	:	National Institute of Statistics and Census
INECEL	:	Ecuadorian Institute for Electrification
INEFAN	:	Ecuadorian Institute of Forestry and Natural Areas
INEN	:	Ecuadorian Institute of Standards
INERHI	:	Ecuadorian Institute of Water Resources
INIAP	:	Institute of Agricultural Investigations
INOCAR	:	Military Oceanographic Institute
JRH	:	Jipijapa and Pajan Board of Water Resources
MAG	:	Ministry of Agriculture and Livestock
MICIP	:	Ministry of Industry, Commerce, Integration and Fishery
MOP	:	Ministry of Public Works and Communications
PFI	:	Institutional Reinforcement Planning Unit of CRM

PHIMA	:	Integrated Water Resources Development Plan of Manabi
PMRC	:	Management Program of Coastal Resources

International or Foreign Institutions

ACI	:	American Concrete Institute
ASCE	:	American Society of Civil Engineers
ASTM	:	American Society for Testing and Materials
CAF	:	Corporación Andina de Fomento
CEPIS	:	Panamerican Center for Sanitary Engineering and the Environment
CIDIAT	:	Interamerican Center for Integrated Development of Water and Land
FAO	:	Food and Agriculture Organization of the United Nations
IDB/BID	:	Interamerican Development Bank
IEC	:	International Electrotechnical Commission
JEC	:	Japanese Electrotechnical Committee
JICA	:	Japan International Cooperation Agency
JIS	:	Japanese Industrial Standards
OAS/OEA	:	Organization of American States
OECF	:	Overseas Economic Cooperation Fund of Japan
SCS	:	Soil Conservation Service of USDA
UNDP	:	United Nations Development Program
USA	:	United States of America
USAID	:	United States Agency for International Development
USDA	:	United States Department of Agriculture
WHO	:	World Health Organization of the United Nations

Technical Terms

A.C.	:	Alternating Current
ACSR	:	Aluminum Cable Steel Reinforced
BOD	:	Biochemical Oxygen Demand
COD	:	Chemical Oxygen Demand

D.C.	:	Direct Current
DO	:	Dissolved Oxygen
EC/CE	:	Electrical Conductivity
EIA	:	Environmental Impact Assessment
EMMP	:	Environmental Management and Monitoring Plan
FEM	:	Finite Element Method
F.M.	:	Finess Modulus
F/S	:	Feasibility Study
FWL	:	Flood Water Level
GPS	:	Global Positioning System
H	:	Horizontal
HWL	:	High Water Level
IEE	:	Initial Environmental Examination
IPM	:	Integrated Pest Management
LACAT	:	Program for Warm Tropical Lakes
LWL	:	Low Water Level
MOL	:	Minimum Operating Level
NATM	:	New Austrian Tunneling Method
PLC	:	Power Line Carrier
RWL	:	Reservoir Water Level
SPT	:	Standard Penetration Test
ST	:	Station
T-N	:	Total Nitrogen
T-P	:	Total Phosphorus
TRMS	:	Transbasin and Reservoir Management System
TSS	:	Total Suspended Solid
V	:	Vertical
ZEM	:	Special Zone for Management

Economic Terms and Others

CIF	:	Cost Insurance and Freight

EIRR	:	Economic Internal Rate of Return
FC	:	Foreign Currency
FIRR	:	Financial Internal Rate of Return
FOB	:	Free on Board
GDP	:	Gross Domestic Product
GRP	:	Gross Regional Product
IVA	:	Sales Tax or Value Added Tax
LC	:	Local Currency
NGO/ONG	:	Non Governmental Organization

ABBREVIATION OF MEASURES

Length

mm	=	millimetre
cm	=	centimetre
m	=	metre
km	=	kilometre
masl	=	metre above sea level
EL.	=	elevation

Area

ha	=	hectare
m^2	=	square metre
km^2	=	square kilometre

Volume

l, lit	=	litre
Kl, Klit	=	kilolitre
l/s	=	litre per second
m^3	=	cubic metre
m^3/s, cms	=	cubic metre per second
m^3/min	=	cubic metre per minute
m^3/hr	=	cubic metre per hour
MCM, mcm	=	million cubic metre
m^3/d, cmd	=	cubic metre per day

Weight

mg	=	milligram
mg/l	=	milligram per litre
meq/l	=	milli-equivalent per litre
g	=	gram
kg	=	kilogram
t, ton	=	ton
t/y	=	ton per year
MT	=	metric ton

Time

sec	=	second
min	=	minute
hr, HR	=	hour
d	=	day
yr	=	year

Money

S/.	=	Ecuadorian Sucres
¥	=	Japanese Yen
US$	=	U. S. Dollars

Energy

Kcal	=	Kilocalorie
KW, Kw	=	kilowatt
MW, Mw	=	megawatt
KWh, Kwh	=	kilowatt-hour
GWh, Gwh	=	gigawatt-hour
V	=	volt
KV	=	kilovolt
KVA	=	kilovolt ampere
MVA	=	megavolt ampere
Hz	=	Hertz

Others

%	=	percent
°	=	degree
'	=	minute
"	=	second
°C	=	degree Celsius
MD, md	=	man-day
mil.	=	million
NO. Nos	=	number
pers.	=	person
Umho	=	micromho
ppt	=	parts per thousand
ppm	=	parts per million
ppb	=	parts per billion
l/h/d	=	litre per person per day
g/c/d	=	gram per capita per day
LS	=	lump sum
MPN	=	most probable numbers
O&M	=	Operation and Maintenance
p.a.	=	per annum
rpm	=	revolutions per minutes

1. INTRODUCTION

1.1 General

This Implementation Program (I/P) on the Water Transbasin Schemes for Chone-Portoviejo River Basins (the Project) has been prepared by the Centro de Rehabilitación de Manabí (CRM) to apply to bilateral or multi-lateral financing institutions for a soft loan for the implementation of the Project.

The Province of Manabí has long been suffering from a habitual water shortage problem. The Chone-Portoviejo river basins are located in the central part of Manabí Province and have a great potential for socio-economic development if only a sufficient quality and quantity of water is supplied. CRM has been making greatest efforts to solve this severe water shortage problem since its establishment in 1962, and has implemented or has been implementing several water resources development projects such as the Poza Honda Multipurpose Project in the Portoviejo river basin, the Carrizal-Chone Multipurpose Project in the Chone river basin, etc. These water resources development projects, however, cannot meet ever growing water demands in the Project area without the implementation of the Project which diverts water from the Daule river basin to the Project area.

1.2 History of the Project

Well recognizing an urgent necessity of solving a habital water shortage problem in the Province of Manabí, the Manabí Rehabilitation Center (CRM) started a comprehensive master plan study on the integrated water resources development of Manabí province (PHIMA) in late 1986, in cooperation with the National Development Council (CONADE) and the Ecuadorian Institute of Water Resources (INERHI). The Organization of American States (OAS) joined the PHIMA study in late 1987 and the Government of Japan also joined the PHIMA Study in early 1989 through the Japan International Cooperation Agency (JICA), at the request of the Government of Ecuador.

The final report on the PHIMA study was prepared in January 1990 by JICA in collaboration with OAS and the Government of Ecuador (CONADE, INERHI and CRM), which recommended to conduct a feasibility study on the water resources development in the Chone and Portoviejo river basins, more specifically on the water transbasin schemes from the existing Daule Peripa dam to the Chone-Portoviejo river basins. The PHIMA study identified six alternative plans for water transbasin from the Daule Peripa to the Chone-Portoviejo river basins.

The feasibility study on the proposed water transbasin schemes was conducted by JICA in collaboration with CRM and other relevant institutions of the Government of Ecuador in two phases: Phase I from March 1991 to March 1992 for examination of the six alternative transbasin schemes and selection of the best alternative, and Phase II from May 1992 to December 1992 for elaboration of a feasibility study on the selected transbasin plan. In Phase I study, Alternative-5 was selected as the best plan of the studied six alternatives, and in Phase II study, the selected alternative plan was optimized and Alternative-5A, which is the proposed transbasin plan under the Project, was finally selected and studied at a feasibility level. The proposed water transbasin plan was judged to be socio-economically feasible and environmentally sound.

At the request of the Government of Ecuador, the Government of Japan agreed to proceed with the Project in the Detailed Design Stage. The detailed design study on the Project was planned to be executed by JICA in two phases: Phase I from October 1993 to March 1994 for preparation of basic designs of the Project including some additional topographic surveys and geotechnical investigations, and Phase II from May 1994 to March 1995 for preparation of detailed designs of the Project including tender documents for several contract packages to be used for international competitive bidding.

1.3 Objectives of the Project

The objectives of the Project are to develop water resources by means of water transbasin facilities from the existing Daule-Peripa dam to the Chone-Portoviejo river basins, and to contribute the socio-economic development of the Project area by stable water supply to meet the following water demands:

(i) Water supply for domestic, tourism and industrial use to cover the population of 150,000 in the Portoviejo river basin including the Manta and Jipijapa area (24% of the total population) in year 2000 and to cover the population of 650,000 in the Portoviejo river basin including the Manta and Jipijapa area (70% of the total population) and the population of 40,000 in the Chone river basin (12% of the total population) in the year 2020.

(ii) Water supply for irrigation in a net area of 12,150 ha in the Portoviejo river basin and 1,000 ha in the Chone river basin.

(iii) Fresh water supply to shrimp farms practiced in a gross area of 5,100 ha in 1990 in the estuaries of the Chone and Portoviejo rivers, which will expand to 5,500 ha in 2000.

(iv) Increase of river maintenance flow to improve water quality and to conserve eco-systems of the Chone and Portoviejo rivers including their estuaries.

2. THE PROJECT AREA

2.1 Location of the Project Area

Ecuador is located on the west coast of South America, between 1°30' north latitude and 5°05' south latitude and between 81° and 75°10' west longitude. It borders Colombia in the north, Perú in the east and south, and the Pacific Ocean in the west. The Galapagos Islands, 1,000 km off the coast, are part of the Ecuadorian territory. The Andean range crossing the country from north to south divides the territory into three regions, i.e. the Highlands (La Sierra), the Coast (La Costa) and the Amazonic region (La Amazonía/El Oriente).

The Project area is the Chone-Portoviejo river basins located in the central part of Manabí province, one of the provinces in the Costa region facing to the Pacific Ocean as shown in Fig. 2.1. Manabí province has an area of about 19,000 km^2, while the Project area, the Chone-Portoviejo river basins, has an area of 4,871 km^2, consisting of the Bahía area of 544 km^2, the Chone river basin of 2,267 km^2 and the Portoviejo river basin of 2,060 km^2, as shown in Fig. 2.2

2.2 Topography and Geology

Topographically, the Project area forms higher elevation towards the East from the flat area in the West. Hilly area with the elevations ranging from 400 m to 600 m runs in a north-south direction in the central part of the Manabí province as shown in Fig.2.3.

Geologically, basement of this area is Piñón formation, Cretaceous in geological age and basalt in rock type. This layer outcrops at Picoazá town in the western vicinity of Portoviejo city. Major geological layers in the Project area are Borbón, Onzole and Tosagua formations in Tertiary.

The Borbon formation is distributed around the Daule-Peripa dam. The Onzole formation consisting of soft sandstone and mudstone is profoundly related to engineering works of the Project, extending over almost all the Project area except for a local area of Guarango. The Tosagua formation spreads over the Guarango-Rocafuerte area and is composed of homogeneous calcareous mudstone. Gypsum, anhydrite or other swelling minerals are involved in this formation.

The anticline axis NE to SW in direction is presumed to extend from Portoviejo city toward Daule-Peripa dam. However, since the gradient of anticline is very gentle the dip of bedding actually appears horizontally in outcrops. Small scale faults, one to two km in

length, are supposed to exist in some places. Regarding the fault system, two directions, NE and SE, are dominant.

As a geomorphological feature, appearance of cliffs are noted in places higher than 200 m in elevation. These cliffs consist of mudstone and are presumably formed by the difference of erosion between the mudstone and the underlied coarser sandstone.

2.3 Climate and Hydrology

The Project area is dominated by a complicated tropical climate affected by the Humboldt cold current and El Niño phenomenon. When El Niño takes place, the Project area is usually subjected to much more rainfall than normal like in the year 1982/83.

Areal and seasonal fluctuations of rainfall are notable. The isohyetal map shown in Fig. 2.4 indicates that the mean annual rainfall in the Project area varies from 400 mm in the south-western part to 1,800 mm in the eastern part, with about 90% of the annual rainfall concentrated in the rainy season from December to May.

On the other hand, the seasonal fluctuation of mean monthly temperature is only about 2°C in Portoviejo, 23.8°C in August to 26.0°C in March/April as shown in Fig. 2.5. Average annual relative humidity in Portoviejo is 77% with a little fluctuation from 74% in December to 81% in March. The average daily evaporation is 4.5 mm in Portoviejo.

The Project area is basically formed by two river systems, the Chone river system with a catchment area of 2,267 km^2 and the Portoviejo river system with a catchment area of 2,060 km^2.

The Chone river system consists of the Chone river and the Carrizal river, as detailed below.

River	Station	Catchment Area (km^2)
Carrizal	La Esperanza damsite	445
Carrizal	Calceta	523
Carrizal	La Estancilla	770
Carrizal	Confluence with Chone	1,166
Chone	Mosquito	187
Chone	Confluence with Carrizal	755
Chone	Estuary	2,267

The natural runoffs of the Chone river system are estimated as follows.

(MCM)

Station	Annual Mean Runoff	Rainy Season Runoff	Dry Season Runoff
La Esperanza Damsite	391 (352)	349 (327)	42 (25)
Calceta	460 (413)	411 (384)	49 (29)
La Estancilla	662 (604)	532 (502)	130 (102)
Confluence with Chone	849 (750)	753 (692)	96 (58)
Mosquito	109 (92)	100 (88)	9 (4)
Confluence with Carrizal	385 (324)	355 (311)	30 (13)
Chone Estuary	1,378 (1,206)	1,140 (1,031)	238 (175)

Figures in parenthesis are values when an extraordinarily wet year of 1982/83 is excluded.

The Portoviejo river system consists of the Portoviejo river and the Chico river, as detailed below.

River	Station	Catchment Area (km^2)
Chico	Alajuela	183
Chico	La Ciénaga	347
Chico	Confluence with Portoviejo	585
Portoviejo	Poza Honda Damsite	170
Portoviejo	Santa Ana	482
Portoviejo	Confluence with Chico	1,190
Portoviejo	El Ceibal	1,794
Portoviejo	Estuary	2,060

The natural runoffs of the Portoviejo river system are estimated as follows.

(MCM)

Station	Annual Mean Runoff	Rainy Season Runoff	Dry Season Runoff
Alajuela	110 (99)	86 (79)	24 (20)
La Ciénaga	199 (181)	140 (130)	59 (51)
Confluence with Portoviejo	202 (177)	151 (135)	51 (42)
Poza Honda Damsite	102 (92)	79 (73)	23 (19)
Santa Ana	233 (208)	177 (161)	56 (47)
Confluence with Chico	431 (380)	320 (286)	111 (94)
El Ceibal	681 (609)	432 (396)	249 (213)
Portoviejo Estuary	699 (622)	444 (405)	255 (217)

Figures in parenthesis are values when an extra-ordinarily wet year of 1982/83 is excluded.

2.4 Socio-economic Activities

2.4.1 Population

According to the National Institute of Statistics and Census (INEC), population in Ecuador is 9.9 million in 1992. Population growth was 2.9% p.a. in 1950's, 3.0% p.a. in 1970's and 1.7% p.a. in 1980's, while it is projected to be 1.3% p.a. in 1990's. The urban population is increasing more than the rural population. It was 40% in 1970 and increased to 55% in 1990.

Population of Manabí province was 1,032,000 in 1990, of which the shares of urban and rural population were 41% and 59%, respectively. Population density of Manabí was 54.7 persons/km2. Total number of households was 187,120, resulting in an average family member of 5.5. An average annual population growth rate was 1.36% during the period from 1974 to 1990, 3.61% for urban population and 0.21% for rural population.

The population of the Project area was 480,300 in 1990, accounting for 46.5% of the total population of Manabí. The population density of the Project area was 98.6 person/ km2, which is almost twice of that of the whole Manabí province. The population of the Project area is forecasted to increase to 842,000 in 2020 by INEC.

The population of the Project beneficiary area including Manta and Jipijapa area was 685,600 in 1990, accounting for 66.4% of the total population of Manabí. The population of the Project beneficiary area is forecasted to increase to 1,240,300 in 2020 by INEC, with an averaged annual growth rate of 2.0%.

2.4.2 GDP and GRP

Gross Domestic Product (GDP) of Ecuador was S/.5,140 billion in 1989 and S/.8,130 billion in 1990 at current prices. The real growth rate of GDP was 1.85% p.a. during the period from 1981 to 1990. Among the industrial origins of GDP, the sectors of agriculture (17.4%), petroleum and mines (12.4%), manufacturing (16.3%) and commerce (14.8%) are dominant in 1990, contributing 60.9% of the total GDP.

GDP per capita of Ecuador was S/.840,000, equivalent to US$1,030 in 1990. The real growth rate of GDP per capita was 0.24% during the same period from 1981 to 1990.

Gross Regional Product (GRP) of Manabí province was S/.598,900 million in 1990 at current prices, or 7.4% of the total GDP of Ecuador. Among the industrial origins, the agriculture and livestock sector is dominant, accounting for 38.4% of the GRP of Manabí in 1990.

During the last 10 years, about 40% or more of economically active population of the Manabí province was engaged in the agriculture and livestock sector.

Major agricultural products in Manabí province in 1990 were coffee (47,900 tons), cocoa (15,800 tons), maize (89,900 tons), cotton (18,300 tons), banana/platano (305,500 tons) and citrus (36,100 tons). Livestock farming is also an important industry of Manabí, especially cattle (726,000 heads) and hog (398,000 heads) farming. The aquaculture of shrimp has been developed in estuary areas of Manabí, including lower reaches of the Chone and the Portoviejo rivers. The shrimp production in Manabí, which was only 427 tons in 1981, increased to 5,026 tons in 1986 and to 9,054 tons in 1990.

Main export products in 1990 from Manabí province were coffee (US$ 46 million), shrimp (US$ 32 million), fishes (US$ 28 million), cocoa (US$ 10 million), etc.

2.4.3 Financial status of the Government of Ecuador

Export and import of Ecuador in recent years are summarized below.

(US$ million)

	1981	1984	1987	1990	1993
Export					
Crude Oil	1,175	1,678	646	1,258	1,149
Banana	218	135	267	468	503
Coffee	102	175	192	104	74
Shrimp	93	160	383	340	451
Cocoa	40	96	83	75	43
Others	540	376	450	469	684
Total	2,168	2,620	2,021	2,714	2,904
Import					
Construction materials	66	36	73	86	75
Industrial materials	452	622	792	811	783
Oil and lubricant	220	179	204	92	88
Industrial goods	461	260	501	376	607
Durable goods	73	48	84	79	339
Non-durable goods	99	112	125	99	246
Transport equipment	252	117	202	204	321
Others	298	242	177	115	103
Total	1,921	1,616	2,158	1,862	2,562

As shown in the above table, major export commodities were crude oil (39.6%), banana (17.3%), shrimp (15.5%) and coffee (2.5%) in 1993, while major import commodities were industrial materials (30.6%), industrial goods (23.7%), durable goods (13.2%), transportation equipment (12.5%) and non-durable goods (9.6%) in the same year.

In 1992, the government total receipt was S/.3,294 billion consisting of net current revenue of S/.3,009 billion, capital income of S/.139 billion and the initial balance of S/.146 billion. The total receipt corresponds to 18.2% of GDP. The government expenditure in the same year was S/.3,103 billion consisting of ordinary expenditure of S/.1,986 billion, expenditure for development of S/.89 billion and amortization of loan of S/.1,028 billion. The amortization of loan was composed of interest payment of S/.100 billion for internal loans and S/.373 billion for external loans, and amortization of S/.64 billion for internal loans and S/.491 billion for external loans.

2.4.4 Infrastructures in the province of Manabí

In the Province of Manabí, there are an international sea port in Manta, and two domestic airports in Portoviejo and Manta. Roads are divided into two categories, i.e. (i) trunk roads and (ii) secondary roads. The total length of the trunk road is 1,170 km, of which 73% is asphalt-paved, while that of the secondary roads is 4,920 km, of which only 2% is asphalt-paved.

Number of customers of telephone was 17,750 in 1990, with an annual growth rate of 6.3% during the period from 1981 to 1990. The electric energy consumption in the same year was 275 GWh with the number of customers at 86,700. An annual growth rate of energy consumption was 7.8% during the period from 1981 to 1990.

There are four regional water supply systems in Manabí which served 55% of the entire population and 64% of the urban population in 1986. Sewage is treated by central sewerage systems or individual septic tanks, etc. In 1988, about 350,000 people enjoyed the sewerage service, equivalent to 32% of the population. The central sewerage systems consist of sewage collection network and sewage treatment generally by stabilization lagoons.

3. PROJECTS AND STUDIES RELATED TO THE PROJECT

3.1 General

In the Project area, a central zone of Manabí province mainly consisting of the Chone-Portoviejo river basins, a number of water resources development projects have been studied and some of them were constructed, some are under construction and the others are waiting for further studies for implementation. The following projects and studies are, among others, closely related to the Project.

(1) Poza Honda Multipurpose Project in the Portoviejo river basin.

(2) Daule-Peripa Dam Project on the Daule river, located immediate east of the Project area.

(3) La Esperanza Dam Project on the Carrizal river, a major tributary of the Chone river.

(4) Water Transbasin Project from the Daule-Peripa to the Poza Honda and La Esperanza reservoirs.

(5) Carrizal-Chone Multipurpose Project in the Chone river basin.

3.2 Poza Honda Multipurpose Project

The United Nations Development Program (UNDP) conducted a feasibility study on the water resources development project of the Portoviejo river basin in 1963 and CRM prepared a definite design of the Poza Honda dam in October 1965.

With an agreement on technical and financial cooperation between the Government of Ecuador and the Government of Germany, CRM started a revision of the definite design, employing a consortium of German consultants in January 1967. A revised definite design of the dam was prepared by the consortium in August 1968. The Poza Honda Multipurpose Project was proposed to be implemented in the following three stages.

Stage 1: Construction of the Poza Honda dam

Stage 2: Construction of water treatment plant of Guarumo and water transmission lines with pumping

Stage 3: Construction of an intake weir at Santa Ana and irrigation system commanding 3,300 ha in between Santa Ana and Portoviejo.

As the Stage I development of the project, the Poza Honda dam was constructed in 1971 in the upper reach of the Portoviejo river. Technical features of the dam are as follows.

Hydrology		
	Catchment area	175 km^2
	Annual mean basin rainfall	1,300 mm
	Annual mean inflow	95 MCM
	Runoff coefficient	42%
	Probable max. flood	1,120 m^3/s
Reservoir		
	Gross storage capacity	98 MCM
	Dead storage	13 MCM
	Emergency storage	10 MCM
	Effective storage	75 MCM
	Flood water level	EL. 112.3 m
	Normal high water level	EL. 108.5 m
	Emergency water level	EL. 93.5 m
	Low water level	EL. 90.3 m
	Riverbed level	EL. 75 m
	Reservoir area at HWL	4.9 km^2
Dam		
	Type	Homogeneous earthfill with asphalt facing.
	Height	40 m
	Crest elevation	EL. 114.3 m
	Crest length	531 m
Spillway		
	Type, Control structure	Non-gated overflow weir
	Water conveyance	Open chute
	Energy dissipator	Stilling basin
	Length of overflow weir	70 m
	Overflow weir level	EL.108.5 m
	Outflow peak discharge	875 m^3/s
Intake and Outlet		
	Intake level	EL. 89 m
	Outlet capacity	30 m^3/s

(Note) A bench mark survey performed in the basic design stage of the Project revealed that the elevations of the Poza Honda dam should be about 2 meters lower than those shown above in connection with La Esperanza elevations.

The Stage 2 development including the construction of the Guarumo treatment plant at just downstream of the dam and a pertinent water transmission system to Portoviejo and Manta was completed in 1976. The Guarumo treatment plant has a capacity of 43,000 m3/day, and the Poza Honda water supply system was greatly improved with an assured water source of the Poza Honda reservoir.

The Santa Ana irrigation project was constructed in 1984, consisting of Santa Ana intake weir and an irrigation canal network covering an area of 3,300 ha along the Portoviejo river between Santa Ana and Portoviejo, as the Stage 3 development of the project.

The Poza Honda Multipurpose Project was implemented by a technical and financial cooperation of the German government. In order to meet an increasing demand for domestic water mainly in Portoviejo and Manta, the Poza Honda water supply system was expanded in 1987 by a construction of the Caza Lagartos treatment plant with a capacity of 20,000 m3/day at Santa Ana and a pertinent water transmission system to Manta.

The PHIMA study evaluated a water supply capacity of the Poza Honda dam at Santa Ana to be 107 MCM/year at 80% guarantee (no water shortage in four years out of 5 years). The catchment area at Santa Ana is 481 km^2, including the Poza Honda catchment of 175 km^2. On the other hand, water demand in 1990 was estimated also by PHIMA to be 25 MCM/year for water supply and 75 MCM/year for irrigation, totaling 100 MCM/year. Although it is technically possible for the Poza Honda dam to meet all the 1990 water demand, CRM actually limits the irrigation supply to assure domestic water supply at practically 100% guarantee even during consecutive dry years.

CRM, to meet an ever growing domestic water demand mainly in Portoviejo and Manta, started to construct two new water treatment plants with a total capacity of 180,000 m^3/day as explained below.

Cuatro Esquinas treatment plant at Portoviejo
- 45,000 m^3/day (Operation Stage I)
- 45,000 m^3/day (Operation Stage II)

El Ceibal treatment plant at Rocafuerte
- 45,000 m^3/day (Operation Stage I)
- 45,000 m^3/day (Operation Stage II)

Water transmission pipeline system
- 30 km from El Ceibal to Manta
- 5 km from El Ceibal to Rocafuerte
- 5 km from Cuatro Esquinas to Portoviejo

The total construction cost is estimated to be US$ 37 million, a major part of which was agreed to be financed by the French government. The construction was commenced in August 1991 with a scheduled full completion in late 1995 for both Cuatro Esquinas and El Ceibal. Raw water supply to these new plants in the dry season when the natural flow of the Portoviejo river is almost depleted should depend on the Poza Honda reservoir. The Poza Honda reservoir, however, cannot afford to feed the new plants with additional 66 MCM/year of water without suspending the irrigation water supply to the Poza Honda irrigation system. This is one of the major reasons for urgent necessity of water to be diverted from the Daule-Peripa to the Portoviejo river basin.

The Poza Honda reservoir will function as a water receiving pond to be diverted from the La Esperanza reservoir to supply the Portoviejo river basin under the Project.

3.3 Daule-Peripa Dam Project

The first comprehensive study on the water resources development of the Guayas river basin was conducted by OAS in 1964 at a master plan level, in which the construction of the Daule-Peripa dam was proposed as a master reservoir for basin development. UNDP made a preliminary study on the Daule-Peripa Dam Project in 1972. With a finance of the Interamerican Development Bank (IDB), a feasibility study on the Daule-Peripa Project was conducted in 1978. The Committee for Guayas River Basin Development (CEDEGE) started the construction of the Daule-Peripa dam in September 1982 and completed it in December 1987 with the IDB financing. The total construction cost was around US$ 140 million. The main objectives of the Daule-Peripa dam are (i) flood control, (ii) domestic water supply, (iii) irrigation water supply and (iv) hydroelectric power generation. Technical features of the dam are as follows.

Hydrology	
Catchment area	4,200 km^2
Annual mean basin rainfall	2,700 mm
Annual mean inflow	5,000 MCM
Runoff coefficient	44%
Probable max. flood	14,350 m^3/s
Reservoir	
Gross storage capacity	5,300 MCM
Dead storage	1,300 MCM
Effective storage	4,000 MCM
Flood water level	EL. 88.0 m
Normal high water level	EL. 85.0 m

Low water level	EL. 60.0 m
Riverbed level	EL. 12 m
Reservoir area at FWL	290 km^2
Reservoir area at HWL	270 km^2
Allocation of Reservoir Capacity	
Flood space	700 MCM
Power generation	3,500 MCM
Irrigation	1,800 MCM
Water supply	500 MCM
Use in Manabí province	500 MCM
Main Dam	
Type	Zoned earthfill
Height from foundation	90 m
Crest elevation	EL. 90.0 m
Crest length	250 m
Dam volume	3,000,000 m^3
Sub-dam	
Type	Homogeneous earthfill
Length	18 km
Average height	10 m (max. 27 m)
Embankment volume	5,900,000 m^3
Spillway	
Type, Control structure	Gated overflow weir
Water conveyance	Open chute
Energy dissipator	Stilling basin
Width of overflow weir	59 m
Overflow weir level	EL. 77.0 m
Design peak discharge	3,480 m^3/s
Spillway gates	
No of gates	3 nos
Type	Tainter gate
Dimensions	H = 8.0 m, W = 17.0 m
Power facilities (Not yet installed as of Mar. 1995)	
Installed capacity	65 MW x 2 units = 130 MW
Annual energy output	510 Gwh (firm)
Design head	58.2 m

Design discharge	132.3 m^3/s per unit
Outlet facilities	
Tunnel diameter and length	9.0 m, 530 m
Outlet capacity	400 m^3/s

It is to be noted that a reservoir capacity of 500 MCM is allocated for use in the central zone of Manabí province. According to the inter-institutional agreement between CEDEGE and CRM, which was signed in December 1986 and fully endorsed by the Minister of Agriculture and Livestock, CRM is entitled to divert up to 500 MCM/year with the maximum diversion of 18 m^3/s.

3.4 La Esperanza Dam Project

A feasibility study on the La Esperanza Dam Project was started in 1970 and completed in 1975. A definite design was prepared in 1976 and the construction was commenced in 1978. CRM was the executing agency of the project and the cost was financed by the Ecuadorian government.

During the initial stage of construction, however, the construction work was suspended due to a geotechnical problem of the dam foundation, and the contract for construction was terminated in 1980. A complete revision of the design including some more geotechnical investigation was started in September 1982 and completed in June 1984. The dam construction, however, had been suspended up to 1990 due to a financial problem.

The financial problem was solved in 1991. Out of the total construction cost of US$ 80 million, US$ 30 million was to be financed by the Spanish government, US$ 30 million to be financed by Spanish banks and the remaining US$ 20 million to be financed by the Ecuadorian government. CRM commenced the construction work from early 1992, which will be completed in mid 1996.

The technical features of the La Esperanza dam are as follows.

Hydrology	
Catchment area	445 km^2
Annual mean basin rainfall	1,520 mm
Annual mean inflow	376 MCM
Runoff coefficient	56%
Probable max. flood	3,040 m^3/s

Reservoir	
Gross storage capacity	455 MCM
Dead storage	64 MCM
Effective storage	391 MCM
Flood water level	EL. 67.7 m
Normal high water level	EL. 66.0 m
Low water level	EL. 37.0 m
Riverbed level	EL. 22 m
Reservoir area at FWL	24.0 km^2
Reservoir area at HWL	22.7 km^2
Dam	
Type	Zoned earthfill
Height from foundation	57.0 m
Crest elevation	69.0 m
Crest length	696.0 m
Dam volume	3,700,000 m^3
Spillway	
Type, Control structure	Gated overflow weir
Water conveyance	Open chute
Energy dissipator	Stilling basin
Width of overflow weir	39.0 m
Overflow weir level	62.0 m
Design peak discharge	900.0 m^3/s
Spillway gates	
No of gates	4 nos
Type	Tainter gate
Dimensions	H = 4.0 m, W = 7.5 m
Outlet facilities	
Irrigation outlet	Capacity 25 - 38 m^3/s
Low level outlet	Capacity 110 m^3/s
Outlet for river maintenance	Capacity 5 m^3/s

The objectives of the La Esperanza dam are (i) flood control in the Carrizal river, and (ii) irrigation water supply to the Carrizal-Chone irrigation area of about 15,000 ha and Los Amarillos-Guarango irrigation area of about 2,500 ha. Once the La Esperanza dam is constructed in the upper reach of the Carrizal river, the habitual inundation problem in the rainy season and the severe water shortage problem in the dry season will mostly be solved in the Chone river basin. The water shortage problem of the Portoviejo river basin will still

remain until the Project is realized to divert water from Daule-Peripa to the Portoviejo river basin through La Esperanza.

Under the Project, the La Esperanza Reservoir will receive Daule-Peripa water and will also function as an intermediate pond to divert water from Daule-Peripa to the Portoviejo river basin.

3.5 Water Transbasin Project from Daule-Peripa to Manabí

CRM started a study on water transbasin project from Daule-Peripa to the central part of Manabí in 1984, when the Daule-Peripa dam was under construction. A definite design for the water transbasin scheme was prepared in 1987 in the following plan.

(i) Water in the Daule-Peripa reservoir will be diverted to the La Esperanza reservoir through a 8.3 km tunnel by gravity with a transbasin capacity of 12 m^3/s.

(ii) Water in the Daule river at about 30 km downstream of the Daule-Peripa dam will be pumped up by about 150 m to be diverted into the Poza Honda reservoir through a steel pipeline of 13.3 km in length and a diversion tunnel of 11.2 km in length with an initial capacity of 8 m^3/s and a final capacity of 12 m^3/s.

The construction cost was estimated at a price level of October 1986 to be US$ 26.4 million for transbasin from Daule-Peripa to La Esperanza and US$ 80.3 million for transbasin from Daule river to Poza Honda, totaling US$ 106.7 million.

The PHIMA study in 1989 did not recommend the proposed plan mainly because of high pumping requirement and resultant high operation cost. CRM, in line with the PHIMA recommendation, requested CEDEGE for construction of the tunnel entrance at the Daule-Peripa reservoir with a capacity of 18 m^3/s, instead of 12 m^3/s, and CEDEGE constructed the tunnel entrance in 1990 accordingly. CRM also revised the tunnel design from Daule-Peripa to La Esperanza to have a capacity of 18 m^3/s in 1989.

According to the revised design prepared in 1989 by a Brazilian-Ecuadorian Consortium who designed the Water Transbasin Project in 1987, the diversion tunnel has a length of 8.3 km and a semi-circular section of 4.6 m in diameter, with an inlet sill elevation at EL. 66 m and an outlet sill elevation at EL. 58.5 m. The construction cost of the diversion tunnel was also revised to be US$ 37.9 million at a price level of October 1989, which is about 70% higher than the original estimate because of capacity increase from 12 m^3/s to 18 m^3/s and the time difference of 3 years from 1986 to 1989. The water transbasin scheme

from Daule-Peripa to La Esperanza is one of the important components of the Project. The Brazilian design was reviewed and a revised design is proposed by JICA.

3.6 Carrizal-Chone Multipurpose Project

During the years from 1986 to 1989, in parallel with the financial arrangement for construction of the La Esperanza dam, CRM conducted a feasibility study on the Carrizal-Chone Multipurpose Project including river training and irrigation and drainage system over a net irrigation area of 16,720 ha in the Carrizal-Chone plain and the Guarango-Amarillos plain. The Guarango plain is located in the lower basin of the Portoviejo river and, therefore, the proposed irrigation system involves the water transbasin of 5.0 m^3/s from Chone to Portoviejo through a diversion tunnel of 5.1 km in length and with a diameter of 3.0 m at a level of EL. 72 m, including pumping of about 53 m. The total construction cost was estimated to be US$ 65.4 million at a price level of September 1989.

A head reach canal with a capacity of 23 m^3/s starts from the La Esperanza dam at EL. 32 m for a distance of 10 km and the left main canal is branched off from the head reach canal. At a point 18.1 km from the beginning point of the left main canal, a canal with a capacity of 5 m^3/s is further branched off at EL. 21.4 m for irrigation of the Guarango-Amarillos plain. A level of the diversion tunnel was optimized to be at EL. 72 m with regard to a tunnel length and a pumping head, though the Guarango-Amarillos irrigation area is lower than EL. 60 m.

This idea of water transbasin from Chone to Portoviejo was adopted by the PHIMA Study and included in various alternative transbasin schemes, because it is difficult to justify a diversion tunnel only to irrigate the Guarango area of about 1,500 ha. The diverted water would most probably be used for uncontaminated water supply to El Ceibal treatment plant at Rocafuerte.

The Carrizal-Chone Irrigation Project is directly connected with the La Esperanza Dam Project because water is planned to be supplied from La Esperanza. Since the construction of the La Esperanza dam was under way with a financial cooperation of Spain, CRM had a strong desire to proceed with the project. In late 1994, CAF (Corporación Andina de Fomento) accepted to finance US$ 4 million for the detailed design work of the project.

4. WATER DEMANDS

4.1 Water Supply Sector

4.1.1 Present water supply systems

Three regional water supply systems currently serve in the expanded Project area including Manta and Jipijapa area. They are Poza Honda System, La Estancilla System and Chone System, all of which are operated and maintained by CRM, except Caza Lagartos Treatment Plant which is operated by EMAPAM.

In the Poza Honda System, potable water is produced by two major water treatment plants. One is Guarumo Treatment Plant with a capacity of 43,200 m^3/day (Raw water from the Poza Honda reservoir) located just downstream of the dam, and the other is Caza Lagartos Treatment Plant of 20,000 m^3/day (Raw water from the Portoviejo river) located near Santa Ana. Also, Las Pulgas Treatment Plant of 3,000 m^3/day (Raw water from the Portoviejo river) located in Portoviejo city and Los Bajos Treatment Plant of 600 m^3/day (Taking groundwater) located at Montecristi supplement the system. A schematic layout of the system is shown in Fig. 4.1. The Poza Honda System supplies the municipalities in the Portoviejo river basins and the Manta and Jipijapa area as shown in Fig. 4.1.

As described in 3.2 herein, the Poza Honda System will be expanded with the completion of two new treatment plants, Cuatro Esquinas Treatment Plant at Portoviejo with a capacity of 90,000 m^3/day and El Ceibal Treatment Plant at Rocafuerte with a capacity of 90,000 m^3/day, and water transmission pipeline system from El Ceibal to Manta (30 km), from El Ceibal to Rocafuerte (5 km) and from Cuatro Esquinas to Portoviejo (5 km). This new water supply system including two new treatment plants is scheduled to be put into service in late 1995.

In the La Estancilla System, La Estancilla Treatment Plant with a capacity of 9,000 m^3/day (Raw water from the Carrizal river) located at La Estancilla supplies major municipalities in the Carrizal river basin and in Bahía area. A new treatment plant with an additional capacity of 18,000 m^3/day has recently been constructed. The present water source of the system is the natural flow of the Carrizal river which is marginally sufficient to supply raw water to the existing plant of 9,000 m^3/day. The future water source will be the La Esperanza Dam under construction at the upper reach of the Carrizal river. A schematic layout of the system is given in Fig. 4.2, together with the Chone System.

The Chone System supplies Chone and San Antonio in the Chone river basin by a treatment plant with a capacity of 5,300 m^3/day located at Chone city. CRM is presently

constructing a new plant with an additional capacity of 5,300 m^3/day to meet an increasing water demand.

4.1.2 Demand for potable water supply

Water demand includes that for industrial use and for tourism, in addition to that for domestic use. Future water demand in the service area was projected by the following procedure:

i) Projection of water served population
ii) Projection of tourists
iii) Projection of unit water demand
iv) Water demand forecast

The water served population in the service area was projected as follows:

Year	Water Served Population (1,000 persons) Poza Honda	Estancilla	Chone	Total
1990	462 (80)	86 (70)	50 (70)	538 (77.2)
2000	529 (85)	120 (80)	66 (80)	715 (83.6)
2010	687 (90)	164 (90)	86 (90)	937 (90.0)
2020	881 (95)	212 (95)	103 (95)	1,196 (95.0)

Figures in parenthesis are coverage rate in percent.

Tourism population in several resort areas was estimated as follows:

Year	Tourism Population (Persons/day) Crucita	Charapotó	Manta	Bahía	Total
1990	500	1,430	2,670	8,830	13,430
2000	1,190	3,510	6,890	46,010	57,600
2010	1,900	5,690	9,250	57,440	74,280
2020	2,820	8,450	9,250	58,360	78,880

Unit domestic water demand recommended by IEOS in 1991 and the unit industrial water demand which was estimated to be 20% of the unit domestic demand for cities with the population more than 100,000 and to be 10% for cities with the population from 5,000 to 100,000 are given in Table 4.1. These figures were taken as a target to estimate future unit

water demand in the service area. The actual level of unit water supply is about 50%-60% of the recommended unit demands of IEOS. This level was estimated to increase in future in the following pace:

Year	1990	2000	2010	2020
Level (%)	55	70	85	100

Projected unit water demands in the service area are also given in Table 4.1. Unit water demand for tourism population was estimated based on the domestic unit water demand for cities with population more than 100,000. By means of the above-mentioned procedures, the water demands in the service area were projected as follows:

Regional Water Supply System	Average Water Demand (m^3/day) 1990	2000	2010	2020
Poza Honda System	89,950	155,470	252,730	395,800
Chone System	8,780	17,260	27,510	39,570
La Estancilla System	12,500	30,760	52,180	76,940
Total	111,230	203,480	332,420	512,290
(in m^3/s)	(1.29)	(2.36)	(3.85)	(5.93)
Unit demand* (l/p/d)	207	285	355	428

* Including industrial water (10-15%), tourism water (2-8%) and unaccounted-for water (around 45%).

4.1.3 System expansion plan

The Poza Honda System will be expanded in the following schedule to meet the future water demand discussed in 4.1.2 herein.

Plant	Production Capacity (Daily Maximum) m^3/day			
	1990	2000	2010	2020
Guarumo	43,200	43,200	43,200	56,000*
Caza Lagartos	20,000	20,000	20,000	20,000
Las Pulgas	3,000	3,000	-	-
Los Bajos	600	-	-	-
Cuatro Esquinas	-	90,000	163,700*	272,300*
El Ceibal	-	90,000	152,400*	245,400*
Total	66,800	246,200	379,100	593,700
Water Demand (Daily Maximum)	134,900	233,200	379,100	593,700

(Note) Plant capacity = 1.05 x Production capacity

Production capacity ≥ Daily maximum demand to fully meet the water demand

Daily maximum demand = 1.5 x Average daily demand.

* Further system expansion is required.

A schematic layout of the Poza Honda System in the years of 2000 and 2020 is shown in Fig. 4.3 and Fig. 4.4, respectively.

The Chone System will have no additional water source in future, while the La Estancilla System will have an abundant water source by the construction of the La Esperanza dam. To meet an increasing water demand in the Chone area, the Chone System is proposed to be integrated in the La Estancilla System. The integrated Chone-La Estancilla System will be expanded in the following schedule.

Plant	Production Capacity (Daily Maximum) m^3/day			
	1990	2000	2010	2020
La Estancilla	9,000	61,400*4/	108,900*	164,200*
Chone	5,300	10,600*5/	10,600	10,600
Total		72,000	119,500	174,800
Water Demand (Daily Maximum)	18,750 1/ 13,170 2/	72,000 3/	119,500 3/	174,800 3/

(Note) 1/: Demand for La Estancilla System
2/: Demand for Chone System
3/: Demand for Integrated Chone-La Estancilla System
4/: La Estancilla capacity will be increased to 27,000 m^3/d in 1995.
5/: Chone capacity will be increased to 10,600 m^3/day in 1995.
* Further system expansion is required.

A schematic layout of the Integrated Chone-La Estancilla System in the years 2000 and 2020 is shown in Fig. 4.5 and Fig. 4.6, respectively.

4.2 Irrigation Sector

4.2.1 Existing irrigation systems

There are three irrigation systems in the Project area, i.e. (i) Poza Honda, (ii) Chico, and (iii) La Estancilla.

The Poza Honda irrigation system extends along the Portoviejo river, consisting of 7 sub-systems. The service areas and actually irrigated areas in 1988 are as follows:

Name of Sub-system	Commanding area (ha)	Irrigated area in 1988 (ha)
Santa Ana	2,750	1,170
Lote 5A	200	190
Mejía	830	580
Ceibal	2,700	1,790
La Jagua	1,570	660
El Cerrito	400	350
La Guayaba	300	110
Total	8,750	4,850

Only a part of the Santa Ana sub-system is supplied by the Poza Honda dam throughout the year, but the rest of the Poza Honda system depends on the natural flow of the Portoviejo river. Because of water shortage and poor maintenance of the irrigation system, only an area of 4,850 ha was insufficiently irrigated in 1988 out of the total commanding area of 8,750 ha.

The Chico irrigation system includes 4 sub-systems i.e. Alajuela, La Ciénaga, Pechiche and Pasaje, as shown below:

Name of Sub-system	Commanding area (ha)	Irrigated area in 1988 (ha)
Alajuela	600	-
Ciénaga	300	290
Pechiche	650	610
Pasaje	500	480
Total	2,050	1,380

The Chico irrigation system fully depends on the natural flow of the Chico river, which is the major tributary of the Portoviejo river. Irrigation in the dry season is only possible in its early stage (June and July) because the Chico river is almost depleted in the later part of the dry season.

The La Estancilla and the Canuto irrigation systems cover 2,730 ha, of which 1,520 ha was insufficiently irrigated in 1988 due to shortage of the natural flow of the Carrizal river, which is the major tributary of the Chone river.

In summary, the project area is provided with irrigation facilities covering an area of 13,530 ha, but the actual irrigated area is limited to about 7,750 ha due to shortage of water resources. The existing irrigation areas are shown in Fig. 4.7.

4.2.2 Irrigation development

The present land use of the project area is summarized as follows.

(Unit: km^2)

Land Category	Chone including Bahía	Portoviejo	Total
(1) Agricultural lands			
- Crop and horticulture	561.9	604.0	1,165.9
Annual crops	107.3	204.2	311.5
Perennial crops	454.6	399.8	854.4
- Pasture	902.6	450.7	1,353.3
- Complex of crops and pasture	778.5	481.4	1,259.9
Sub-total	2,243.0	1,536.1	3,779.1
(2) Non-agricultural lands	568.0	523.9	1,091.9
	2,811.0	2,060.0	4,871.0

From the viewpoint of land classification, the land suitable for agriculture amounts to 123,000 ha consisting of Categories A and B, as shown below.

(km^2)

Basin	A	B	C	X	Total
Bahía	58	60	46	380	544
Chone	318	342	611	996	2,267
Portoviejo	339	113	368	1,240	2,060
Total	715	515	1,025	2,616	4,871

(Note) Category A: Potentially irrigable lands without any limitation or with slight limitation.

Category B: Potentially irrigable lands with moderate limitation.

Category C: Potentially irrigable lands with severe limitation.

Category X: Non-irrigable lands.

The lands of Categories A and B are presently fully utilized for cultivation. There is no room for further expansion of the agricultural lands. The agriculture development should, therefore, be directed to intensified farming by means of irrigation. Irrigation development area was delineated in the following manner:

a) Delineation was made on topographic maps of 1:50,000 in scale.

b) Irrigation development area is located downstream of existing and proposed dams.

c) The area is irrigable by a gravity system from dams or diversion dams.

d) The existing irrigation areas are included.

e) The gross area is converted into a net area with a conversion factor of 80% for the category "A", 70% for "B" and 30% for "C" in the land classification.

The following 8 schemes with the total net area of 29,250 ha were thus formulated in the Project area.

Scheme	River Basin	Net Irrigation Area (ha)
Carrizal-Chone	Carrizal and Chone	15,000
Amarillos	Carrizal	1,000
Guarango	Portoviejo	1,500
Río Chico	Chico	1,700
Pechiche-Pasaje	Chico and Portoviejo	850
Santa Ana	Portoviejo	3,300
Mejía	Portoviejo	1,250
Ceibal-Guayaba	Portoviejo	4,650
Total		29,250

The proposed irrigation schemes are shown in Fig. 4.8 and Fig. 4.9.

4.2.3 Irrigation water requirement

The irrigation water requirement was calculated by the following formula:

$$ET\ crop = Et_p * Kc$$
$$IR = ET\ crop + PD - ER$$
$$DWR = IR/Ef$$

where, ET crop : Crop evapotranspiration (mm/month) (Crop consumptive use)
ET_p : Potential evapotranspiration (mm/month)
Kc : Crop coefficient
IR : Net irrigation requirement (mm/month)
PD : Water requirement for land preparation of paddy field (mm/month)
ER : Effective rainfall (mm/month)
DWR : Diversion water requirement (mm/month)
E_f : Irrigation efficiency

Et_p was estimated by the modified Penman method based on the meteorological data at Portoviejo, Rocafuerte, Santa Ana, La Estancilla and Calceta. Kc values of annual crops were calculated by Grassi-Christiansen formula and those of citrus, banana and rice were quoted from the feasibility report on the Carrizal-Chone Multipurpose Project. Water requirement of 120 mm was added for paddy field as PD. ER is related to actual rainfall and

ET crop. The SCS method established by USDA was applied to estimate ER, taking rainfall data corresponding to 5-year return period of drought. E_f was taken at 0.53 for paddy and 0.46 for upland crops.

Irrigation water requirements were calculated on monthly basis in accordance with the proposed cropping pattern as shown in Fig. 4.10. The water requirement of the total irrigation development area of 29,250 ha was calculated to be 571 MCM/year with 80% guarantee and peak requirement occurs in September as shown in Table 4.3

4.3 Shrimp Farming Sector

4.3.1 Existing shrimp farming and its future expansion

The shrimp farming in Manabí province was practiced in 12,074 ha in 1990, accounting for about 8% of the country's total. The shrimp farms are concentrated in the estuary of the Chone river where 4,967 ha were operated in 1990. In 1989, Manabí produced 7,458 tons of shrimps, corresponding to about 9% of the country's total. The shrimp production in the Project area is 4,061 tons in 1989 accounting for 54% of the total shrimp production in Manabí province.

Salinities are influenced by seasonal fluctuation of rainfall and runoff. Surface waters in the upstream side of the shrimp ponds have salinities as low as 0 parts per thousand (ppt) in the rainy season due to heavy rainfall and abundant runoff of the river, while it rises more than 40 ppt equal to or higher than that of seawater in the dry season.

Shrimp farming is practiced throughout the year because of the perennial supply or availability of postlarvae from the wild and hatcheries. The average growing period is three to four months, and it is not difficult to harvest two crops a year. The present productivity ranges from 425 to 900 kg/ha/crop, with the average at 660 kg/ha/crop. Since the number of crops a year is 2.0, the average productivity a year is 1,320 kg/ha.

The optimum range of salinity for good growth of shrimps is from 15 to 25 ppt. If proper fresh water supply controls the salinity of water in the shrimp ponds within the optimum range, shrimps will grow faster and the number of crops a year may increase from the present 2.0 to 3.5, while the future productivity is assumed to improve from the present 660 kg/ha/crop to 830 kg/ha/crop. The annual shrimp production is thus estimated to be 2,905 kg with fresh water supply and 1,660 kg without fresh water supply. Fresh water is required only during the dry season when the salinity increases more than 25 ppt. The

shrimp ponds extended in the estuaries of the Chone river and the Portoviejo river are as follows as well as their future probable area expansions.

(ha)

	1984	1987	1990	1995	2000
Chone Estuary					
Zone A (Sea side)	-	-	990	990	990
Zone B (River side)	4,120	4,827	3,977	4,157	4,427
Portoviejo Estuary	103	130	130	130	130
Total	4,223	4,957	5,097	5,277	5,547

4.3.2 Water requirement for shrimp farming

Based on the current salinity data at the estuaries, annual fresh water requirement in 2000 onward was estimated as follows:

	Gross area (ha)	Net area (ha)	Area receiving fresh water (ha)	Unit water requirement (m^3/ha)	Total water requirement (MCM/year)
Chone river					
Zone A	990	594	475	49,500	23.5
Zone B	4,427	2,656	2,125	35,700	76.0
Portoviejo river	130	78	63	44,300	2.8
Total	5,547	3,328	2,663	-	102.3

(Note) Net area is assumed to be 60% of the gross area. Also, the area actually receiving fresh water from the Project is assumed to be 80% of the net area.

Seasonal fluctuation of the fresh water requirement was estimated as follows:

(MCM)

Month	Chone (Zone A)	Chone (Zone B)	Portoviejo	Total
July	3.9	-	0.4	4.3
August	3.9	-	0.4	4.3
September	4.0	-	0.5	4.5
October	3.9	25.4	0.5	29.8
November	3.9	25.5	0.5	29.9
December	3.9	25.1	0.5	29.5
Total	23.5	76.0	2.8	102.3

4.4 Other Water Demands

Dams in Ecuador are obliged to release a certain volume of water as a river maintenance flow.

In the Project area, the Poza Honda dam must release a constant flow of 0.25 m^3/s throughout the year in addition to the various water requirements. The La Esperanza dam under construction is also needed to release a constant flow of 0.50 m^3/s. This river maintenance flow will amount 23.7 MCM per year.

5. RESERVOIR OPERATION STUDY

5.1 Diversion from Daule to Manabí

The Daule-Peripa reservoir is planned to be operated to meet the demands for power (minimum water level for power generation, EL.65 m), domestic water, irrigation including dilution water of irrigation return flow, transbasin to La Esperanza (minimum level for transbasin, EL.66.6 m) and transbasin to the Santa Elena Peninsula and Macul. The design water levels of the Daule-Peripa reservoir are as follows.

Normal High Water Level	EL.85 m
Low Water Level	EL. 60 m
Flood Water Level	EL. 88 m

At the request of CRM, CEDEGE conducted a reservoir operation study, generating synthetic flows as inflows to the reservoir, for 30 series of 30 years each.

According to the proposed tunnel design from the Daule-Peripa reservoir to the La Esperanza reservoir, divertable discharge is dependent on the Daule-Peripa reservoir water level. The transbasin discharge is 0 m^3/s for a reservoir level lower than EL.66.6 m and more than 18 m^3/s for a reservoir level higher than EL.76.6 m. The interinstitutional agreement between CEDEGE and CRM limits the water transbasin up to 18 m^3/s and 500 MCM/year.

The reservoir operation study by CEDEGE indicated that the transbasin to La Esperanza in a volume of 500 MCM/year is secured at about 90% guarantee as shown below.

Level of guarantee (%)	Divertable water volume (MCM/year) Qmax = 18 m^3/s
Maximum volume	568
50	568
80	537
89	495
Minimum volume	136

It is understood that water of 537 MCM/year can be diverted to La Esperanza at 80% guarantee (4 years assured out of 5 years). Technically divertable water (Qmax =

18 m^3/s) and adjusted diversion to limit an annual volume to 500 MCM for each month are proposed as follows.

Water Diversion from Daule-Peripa to La Esperanza.

Month	Volume to be diverted technically (MCM)	Adjusted volume (MCM)	Adjusted discharge (m^3/s)
January	41.9	29.4	11.0
February	37.9	25.5	10.5
March	39.2	26.7	10.0
April	38.9	38.9	15.0
May	48.2	48.2	18.0
June	46.6	46.6	18.0
July	48.2	48.2	18.0
August	48.2	48.2	18.0
September	46.6	46.6	18.0
October	48.2	48.2	18.0
November	46.6	46.6	18.0
December	46.9	46.9	17.5
Total/Average	537.4	500.0	15.8

The adjustment is made by reducing the diversion water volume to La Esperanza in three months from January to March when rainfalls are maximum and water demands are minimum. The adjusted volumes for each month are applied to the reservoir operation study as the maximum divertable water from Daule-Peripa to La Esperanza.

5.2 Integrated Reservoir Operation of La Esperanza and Poza Honda

5.2.1 General concepts of reservoir operation

La Esperanza receives natural flows from its own basin and diverted flows from Daule-Peripa. La Esperanza together with the available interbasin flows of the Chone river system should meet water demands for shrimp farming in the Chone estuary (99 MCM/ year), river maintenance (16 MCM/year), water supply to the Chone-La Estancilla water supply system (45 MCM/year), Carrizal-Chone irrigation of 15,000 ha (253 MCM/year), Los Amarillos irrigation of 1,000 ha (19 MCM/year) and Dilution Water equivalent to 20% of the irrigation water requirement.

La Esperanza should also divert water to Poza Honda. Poza Honda receives natural flows from its own basin and diverted flow from La Esperanza. Poza Honda together with the available interbasin flows of the Portoviejo river should meet water demands for water supply to the Poza Honda water supply system except the El Ceibal treatment plant (89 MCM/year), irrigation for Santa Ana system of 3,300 ha (74 MCM/ year), for Pechiche-Pasaje system of 850 ha (20 MCM/year), for Mejía system of 1,250 ha (28 MCM/year), for Ceibal-Guayaba system of 4,650 ha (111 MCM/year) and for Guarango system of 1,500 ha (36 MCM/year), shrimp farming in the Portoviejo estuary (3 MCM/year), river maintenance (8 MCM/year) and Dilution Water equivalent to 20% of the irrigation water requirement.

Poza Honda should also divert water to Mancha Grande of the Chico river basin. The diverted flows together with the available natural flow of the Chico river should meet water supply to El Ceibal treatment plant (63 MCM/year), irrigation for Chico system of 1,700 ha (31 MCM/year) and Dilution Water equivalent to 20% of the irrigation water requirement.

5.2.2 Basic conditions for integrated reservoir operation study

(1) Reservoir Storage Curves

Reservoir storage curves after 50 years sedimentation are used to make the study conservative.

(2) Irrigation Water Requirement

Irrigation water requirement is affected by the effective rainfall. For the study, irrigation water requirement calculated for a drought year with a return period of 5 years is used.

(3) Dilution Water

Dilution water equivalent to 20% of the irrigation water requirement is applied to the study to dilute irrigation return flows.

(4) Use of Interbasin Flows

The interbasin flows, the natural flows from the catchment area downstream of the dam, can be used to meet water demands especially during the rainy season. Use of up to 60% of the interbasin flow is assumed to be allowed.

(5) Water Demand Level

Water demands in the target year of 2020 are used for the study.

(6) Target Reservoir Water Levels

The transbasin from Daule-Peripa to La Esperanza is planned to be made by gravity. Water transbasin is recommended to be continued as far as possible. The design condition to maintain an open free flow in the diversion tunnel will, however, limit a range of the target water level of La Esperanza not more than EL. 63.5 m. Therefore, it is planned to suspend water transbasin from Daule-Peripa when La Esperanza water level is higher than EL. 63.5 m. In other words, a target water level of La Esperanza is fixed at EL. 63.5 m.

The transbasin from La Esperanza to Poza Honda is planned to be made by pumping. Lower target water level of Poza Honda is desirable to save pumping energy cost and to aim at maximum utilization of the own basin flow limiting a spillout volume from Poza Honda to the minimum. However, if the target water level is too low, more frequent water shortage will take place during operation because the reservoir storage capacity cannot be used effectively. A number of trial calculations concluded that the Poza Honda target water level should be EL.102.5 m, 4.0 m below the high water level of Poza Honda.

(7) Intake Level of Severino Pumping Station at La Esperanza

An intake water level of the Severino pumping station for water transbasin from La Esperanza to Poza Honda should be low enough to continue water pumping in low level period of La Esperanza. However, the following two design conditions require to fix the intake level at EL. 47 m, higher than the low water level of La Esperanza by 10 m.

- Anticipated reservoir sedimentation level of EL.45 m at the Severino pumping station site.

- Allowable drawdown of La Esperanza water level during construction of the Severino pumping station, fulfilling the required minimum functions of La Esperanza.

(8) Intake Level of Poza Honda-Mancha Grande Diversion Tunnel

The transbasin from Poza Honda to Mancha Grande is planned to be made by gravity. The topographic conditions at the tunnel outlet limit the lowest intake water level of Poza Honda at EL.94 m.