7.4.2 New Power Intake and Low Level Outlet

This alternative countermeasure would consist of constructing a new power intake about 35 m upstream from the existing intake near the left gravity wall and converting the existing power intake into a low level outlet for sediment sluicing. The general plan of this alternative is shown in Figure 7.22.

(1) Site Geology:

All the proposed new structures will be located on the left bank of the damsite and downstream. The site is situated in a deep narrow gorge of the Plio-Pleistocene ignimbrite. Pre-Tertiary basement rocks, exposed in ridges in the surroundings, are covered by thick acidic tuffs including the ignimbrite in the zone around the Apulco River.

The ignimbrite, forming almost vertical cliffs of outcrops in the lower part of the gorge, is hard rock which has been supporting the Soledad arch dam of 90 metres in height. In the upper part of the gorge, however, the younger ignimbrites or tuffs are softer for cementing of lower grade. The boundary is not very clear, but can be around EL. 750 m. Above this boundary, the rock is soft, but compact and massive. The dykes of concrete gravity dam type stretching on the sides of the arch dam are founded in this bed of tuff, which is generally medium to coarse grained or sandy and homogeneous with sparse inclusion of pumice fragments.

There appears to be another boundary at a level between EL. 780 m and 790 m, which is represented by change of topography from the steep slopes in the lower level to the gentle slopes in the upper level. While this topographic difference seems to reflect a stratigraphic difference, the tuffs above and below this boundary do not show sharp difference in the grade of cementing. It seems that it rather represents the unconformity plane at the base of the youngest unit of the acidic tuff, which is scarcely cemented and remains at places at varied levels undergoing severe erosion.

The branch tunnel for the sediment diversion will be laid out at around EL. 750 m, through the intermediate soft, compact tuff. The existing headrace tunnel was also driven in the same geological zone. Rock bolting may not be effective in some part of this soft tuff. Supporting with steel ribs installed at close intervals, e.g. one metre, could be necessary.

The rock condition for the new intake at EL. 785 m may be less favourable for tunnelling for larger proportion of the soft rock. The section of the intake tunnel at this level being short, it should be passed through even with heavier supporting. Possible loosening of the tunnel periphery by seepage water during the construction work is to be taken into consideration. Measures for groundwater drainage may be necessitated.

(2) New Power Intake:

The plan and sections of the new power intake are shown on Figures 7.23 and 7.24 and the pertinent data is given in Table 7.5. The features of the new power intake include a vertical intake structure, a gate control house located on top of the intake, retaining walls and a new tunnel segment to connect the intake to the existing power tunnel. The new intake and tunnel segment are designed for a flow of 55.2 m^3/s, the same design flow used for the existing facilities.

The new power intake would be a reinforced concrete structure approximately 12 m wide by 16 m long by 22 m high. The deck of the intake will be at El. 806.5 m, the same as the existing dam crest elevation. The invert of the intake was set at El. 785 m based on estimated future sediment levels determined from the sedimentation analysis and expected operating levels of the reservoir for power generation. The intake will be provided with a service gate, bulkhead and trashrack. The trashrack area was sized based on a maximum water velocity through the gross area of 1.0 m/sec. A control house will contain all the mechanical and electrical equipment for control of the service gate. A hoist will be mounted on the outside of the gate house for raising and lowering the bulkhead.

The intake will be connected to the existing power tunnel by a new 114 m long tunnel segment. The tunnel will be concrete lined and have an inside diameter of 4 m to match the size of the existing tunnel. At the design discharge, the maximum water velocity in the tunnel is 4.4 m/sec. A typical section of the tunnel is shown on Figure 7.25. Once construction of the new intake and tunnel is complete, the existing power tunnel will be permanently plugged just upstream of the connection.

As shown on Figure 7.23, the area around the new intake will be filled to El. 806.5 m. Concrete retaining walls will be provided on both sides of the intake to keep the fill in place. Access to the new intake will be from the crest of the existing dam.

A minimum water submergence above the tunnel crown of 5 m is recommended to avoid the possible formation of vortices which could cause air entrainment and reduced turbine efficiency. Therefore, the minimum reservoir level for power operation would be at El. 794.0 m.

In the detail design stage, it is recommended to review on necessity of trashboom for preventing floating materials from entering the intake and water pressure meter which will detect clogging of the trashrack, though trash-related problems do not appear so serious at present. Further, an alternative plan to construct an intake tower on the tunnel instead of the proposed intake structure is subject to further comparative study.

(3) New Low Level Outlet:

The new low level outlet for sediment sluicing near the intake area will utilize the existing power intake, and will include the construction of a new pressure tunnel segment and outlet works located approximately 200 m downstream of the arch dam. The profile and section of the new low level outlet works are shown on Figure 7.26, and the pertinent data is given in Table 7.6.

Minor modifications will be made to the existing power intake for use as a low level outlet and sediment sluice. These modifications will include rehabilitation of the existing control gate and replacement of the existing trashrack. The new trashrack will be provided with larger openings to facilitate sediment sluicing.

A new 290 m long tunnel segment will be constructed from the existing power tunnel to the Apulco River channel downstream of the arch dam as shown on Figure 7.22. The tunnel will be concrete line and have a 4.0 m inside diameter. To meet minimum rock cover criteria for pressure tunnels, a 48 - m length of steel liner will be provided in the tunnel at the downstream end to provide adequate confinement to withstand internal water pressures. From the geologic investigations, it was concluded that a relatively soft rock exists above El. 760 m. Therefore, the major portion of the tunnel was located below El. 760 m to avoid the soft rock unit, and reduce the amount of support requirements that would be needed during tunnel construction.

The tunnel diameter was established based on velocity considerations. The velocity in the existing power tunnel (4 m) at maximum discharge is 4.4 m/sec. There has been no apparent damage to the existing tunnel lining, however, operation of the new tunnel with heavy sediment loads, larger sediment particle sizes and high velocities may cause scour damage. Therefore, it is recommended to limit maximum velocities to 5 to 6 m/sec to reduce the possible of damaging the tunnel lining. The maximum flushing flows for sediment sluicing were estimated to be in the range of 50 to 70 m^3/s. The velocity in the 4 m diameter tunnel at 70 m^3/s would be 5.6 m/sec, a relatively high velocity.

Discharges at the tunnel outlet will be controlled by a 2.4 m fixed cone valve. The centerline of the valve will be at El. 748 m. Discharges from the valve will be directed into the Apulco River channel approximately 38 m below. A butterfly valve will be provided immediately upstream of the fixed cone valve for maintenance or emergency use. A valve house will be constructed on a platform above the valves to contain the electrical and pneumatic control equipment for operation of the valves.

The Apulco River channel from the outlet works to the downstream end of the chute spillway is about 300 m long. This reach of the channel will need to be cleared of vegetation. Large boulders in the river channel below the spillway flip bucket will also need to be removed to facilitate flushing of sediment downstream.

7.4.3 Check Dam

(1) Site Geology

The proposed check damsite is located approximately 1.8 kilometres upstream of the bridge over the Apulco River on the highway through Zacapoaxtla to Cuetzalan. The right abutment of the proposed damsite will be on a thin ridge of 300 metres in width, developing upstream of a right bank tributary, Papuloateno River. The left abutment will be on a slope descending from Mt. Ixtaczayo or the Zacapoaxtla - Cuetzalan highway. The geological map and section at the proposed damsite are shown in Figures 7.27 and 7.28.

Topography of the dam site is characterized by steep slopes on both sides of the valley, gentler slopes of talus deposits at their feet and several hundred metres wide valley floor. While the bedrock of the steep slopes is hard ignimbrite, the deep narrow gorge characteristic to that rock is not formed yet around the damsite but starts only in the vicinity of the bridge downstream. The proposed damsite is at a location of the narrowest valley floor of about 150 metres in width.

The bedrock is generally the hard ignimbrite, which is stratigraphically situated at the bottom of the Quaternary acidic tuffs. The ignimbrite includes a several metres thick layer with pores of a few centimetres in size around the level of the dam crest and an intercalation of a highly rhyolitic layer near the level of the river bed. The ignimbrites are generally hard, with shear strength conservatively assumed of 20 kg/cm^2 in cohesion and 40 degrees in internal angle of friction.

Thickness of the talus deposits at the foot of the steep slope of the ignimbrite is unknown and to be examined with core drilling in future. Probably it is 10 metres or slightly less in thickness. The riverbed is covered by sand and gravel bed of unknown thickness. In the wide valley floor immediately upstream, it seems that a poorly cemented Quaternary (presumably Pleistocene) mudstone and sandstone bed horizontally covers the hard bedrock and is covered by the flood plain deposit.
It is recommended for the future investigation to carry out core drilling at least at five locations on the dam axis; one in the riverbed, two on the talus deposits and two at both ends of the dam crest. Seismic refraction prospecting will help. The most essential is to confirm the levels of the hard bedrock for the concrete gravity dam foundation. Considering that the bedrock could be hard enough, empirically assumed values for the strength criteria will be sufficiently reliable and usable for the preliminary design.

(2) Large Check Dam

As established in the previous studies, the location of the check dam is on the Apulco River near the town of Huahuaxtla. The required reservoir storage capacity is based on an annual sediment deposition rate of 1.17 mcm/year. The deposition rate is based on an estimated annual sediment load of 1.8 mcm/year and a trap efficiency of 65%. The trap efficiency was established based on trapping particles with a size greater than or equal to 0.0625 mm.

A roller - compacted concrete (RCC) type of dam was selected as the most practical based on layout and cost considerations at the site, and the ability of constructing the project in stages. A fill dam at this site would likely have a high construction cost due to large excavations in one of the dam abutments for spillway construction and the need to provide a tunnel to divert the river during construction of the dam.. A masonry type of dam is possible, however, the height of dam would be limited to about 25 m above bedrock which is not sufficient to provide adequate storage capacity for long term sediment control.

Based on a preliminary analysis of project size for different periods of useful project life and considering project costs, it is considered prudent to build the project in stages with the first stage sized for a useful life of 15 years. Once constructed and operating, the project effectiveness can be evaluated and the need for future raising of the dam can be more accurately determined.

The general project and sections are shown on Figures 7.29 and 7.30 and pertinent data for the project is given in Table 7.7. The project is sized to provide a reservoir storage capacity of 17.6 mcm which, based on average conditions, will trap sediments for 15 years before completely filling. The project consists of an RCC gravity dam, central spillway and stilling basin, and a river diversion/reservoir outlet structure.

The crest of the dam is at El. 1494 m (based on the 1:10,000 scale maps but subject to correction when a new map is prepared.) with a total length of 294 m. The maximum height of the dam above the riverbed is 34 m. The dam would be founded on solid bedrock which is estimated to be 10 m below the ground surface from the riverbed level up to about El. 1490 m. Above El. 1490 m, the rock surface is estimated to be 3 m below ground level on the left abutment and near the surface on the right abutment.

The spillway is an uncontrolled free overflow type designed for a flood discharge of 1,206 m^3/s m which is equivalent to the 1,000 year recurrence interval. The spillway crest is at El. 1489 m and has a width of 100 m. A stilling basin is provided for energy dissipation of spillway discharges to prevent excessive scouring around the dam foundation and the downstream river section. The stilling basin is 100 m wide and approximately 35 m long.

An intake tower with a bottom intake at the base of the dam is provided for diverting the river during initial dam construction as discussed in more detail in Chapter 8. The river diversion outlet through the dam is 5.5 m wide by 5.5 m high with a length of about 30 m. The outlet is sized to pass the estimated 5 - year flood peak of 340 m^3/s. The river diversion intake structure will be sealed with a bulkhead and permanently plugged with concrete after construction of the dam is complete and the reservoir is filled.

(3) Further Investigation for Large Check Dam

The optimum arrangement for the check dam needs to be established in further stage. This should include the following items:

- An evaluation to determine the optimum dam height and life of the project.
- An evaluation to determine whether a single stage dam or a multiple stage dam is more beneficial.
- If staging is selected, an evaluation should be performed to determine the most appropriate provisions that should be incorporated in the initial stage design to faciliitate subsequent raising of the dam.

In this study, the diversion of the Apulco River has been planned in two stages with the construction of the dam in three stages. This is a technically viable means of construction and may well be the most economical. However, before final design is initiated other alternatives should be evaluated.

In principal, the most efficient method of construction for RCC dams is for placement of the RCC in continuous lifts along the entire length of the dam. This generally results in the shortest construction time and thus savings in cost. In addition, it is best to minimize the use of formed structures within the main body of the dam as this interrupts the placement of the RCC lifts which prolongs construction time.

An alternative river diversion plan which allows the construction of the dam in one stage should be evaluated in future studies. This should include the use of a single upstream and downstream cofferdam. With a single upstream cofferdam the Apulco River can be diverted through: (1) a tunnel located in the hill at the right abutment of the dam, or; (2) a long concrete conduit which would most likely be located through the left side of the dam near the spillway. Both alternatives would require a much higher upstream cofferdam and construction of additional structures which would substantially increase the cost for river diversion during construction.

The higher river diversion costs would most likely be offset by a savings in cost for dam construction. The actual cost differences will need to be evaluated with an in-depth investigation which should consider final dam design and construction techniques, involving discussions with experienced contractors in RCC dam construction.

In general, use of the diversion tunnel is expected to be the least favorable of the alternatives for the following reasons:

- The cost of tunnels is much higher than for concrete conduits.
- The right side of the river is the best for construction operations - the tunnel will cross this area.
- As presently conceived, the RCC dam will be designed for subsequent future raising necessitating the construction of a tower intake for future river diversion during construction. The tower (or inclined) intake for the tunnel will be much more difficult to construct and access, leading to much higher construction costs.

Use of the long concrete diversion conduit has the following disadvantages:

- The most beneficial use of this arrangement is when the conduit can be conveniently located below the foundation of the dam so as not to interfere with dam construction. Due to the deep foundation level this is not practical. Moving the conduit further into the left abutment to realize this benefit would require a substantial increase in cofferdam height and in excavation for the conduit and the approach and exit channel.

- Construction of the diversion intake within the upstream cofferdam would be much more elaborate and costly as it would be a free standing structure, unlike the alternative presented in this study which benefits from being attached to the dam.

On the other hand, a question may arise on an adequacy that the reservoir water surface would remain at a high water level coinciding with the spillway overflow crest even after the flood season finishes. Though the reservoir is eventually filled with sediment, more in-depth review will be required in the design stage for providing an appropriate outlet to lower the water level to the sedimentation level before the reservoir is filled up with sediment.

(4) Low Check Dam and Dam Heightening

For the large check dam, an alternative plan is contemplated which considers the construction of several low check dams in stage on the main Apulco River or the heightening of the dam on the same site. A comparison between the large dam and low dam at site B was made as follows.

Items	Large Dam	Low Dam (I)	Low Dam (II)
(1) Dam height above riverbed (m)	34	24	15
(2) Height of overflow section (m)	29	19	10
(3) Storage volume (x 10^6 m^3)	17	5	2
(4) Annual inflow (x 10^6 m^3)	233	233	233
(5) Storage/Inflow ratio	0.073	0.021	0.0086
(6) Trap efficiency (%)	65	57	45
(7) Dam volume (m^3)	171,000 (RCC)	90,000	33,000

Notes : The inflow into Site B is prorated by the catchment area ratio for the runoff at Buenos Aires.

$$8.85\ m^3/s \times \frac{1{,}173km^2}{1{,}405km^2} \times 31.5 \times 10^6\ s = 233 \times 10^6 m^3$$

The number of low check dams required to have the same storage function of the large dam is estimated as follows in consideration of the trap efficiency.

- Low Dam (I)

$$\frac{17 \times 10^6 \times 0.65}{5 \times 10^6 \times 0.57} = 3.8$$

- Low Dam (II)

$$\frac{17 \times 10^6 \times 0.65}{2 \times 10^6 \times 0.45} = 12.2$$

For the storage function for sediment load, the dam needs more than a given level of height and a number of low dams are necessary. The required total volume of the low dam would be 340,000 m^3 for the dam (I) and 400,000 m^3 for the dam (II). Considering the effect of the low check dams built on the tributaries whose maximum storage is 416,000 m^3 or 350,000 m^3 (most of them have less than tens of thousand cubie meters, 1.34 x $10^6 m^3$ in total for 25 dams), the construction of low dams does not appear very effective for sediment trapping. Further, it would be difficult to find other suitable storage sites on the Apulco river except for Site B. Therefore, the low dam scheme on the main river is not recommendable.

It is worth while to seek for a stage-wise construction of the dam at Site B. However, due care should be taken for the river diversion system during the heightening works since the runoff in the main river is 2 m3/s to 3m3/s even during the dry months.

7.4.4 Dredging

Removal of reservoir deposits by dredging is commonly practiced in many reservoirs. However, depending on the physical properties and volume of materials to be dredged, dredging needs well-planned preparation and operation. It is still considered necessary to continue dredging in the reservoir by improving the present system for the following reasons.

- to remove the increasing sediment deposits before and during the construction of check dam and low level outlet.
- to remove the deposits in the vicinity of the arch dam which could not be sluiced through the low level outlet and spillway.
- to remove the deposits near the power intake in couple with the operation of the low level outlet.

In this study, review was made on the dredging system which CFE introduced previously. In this system a 650 m long discharge pipe of 200 mm in diameter is arranged from the dredger to the end of spillway terminal structure through the dam crest. However, the specified pump capacity appears too small due to its friction loss in the long pipe. The friction loss is given by the following equation.

$$h_f = f' \cdot \frac{L}{R} \cdot \frac{V^2}{2g}$$

where, h_f = friction loss (m)

L = length of pipe (m)

R = hydraulic radius (m)

V = velocity (m/s)

f' = friction coefficient

$$f'/R = \frac{124.5 \times n^2}{D^{4/3}} \quad \text{(circular section)}$$

The required pump capacity is given by the following equation.

$$S = \frac{0.163 \times Q \times Ht \times \rho}{\eta \times 60}$$

where, S = pump capacity (kW)

Q = discharge (m^3/hr)

Ht = total head (m)

ρ = specific weight of flow (= 1.02)

η = pump efficiency (= 0.6)

The discharge capacity of the present system was checked using the above equations and the results are as follows.

Items		Discharge	
		15.1 m^3/min (1	7.55 m^3/min (2
Q	(m^3/s)	0.252	0.126
"	(m^3/hr)	906	453
n		0.016	0.016
D	(m)	0.20	0.20
A	(m^2)	0.0314	0.0314
V	(m/s)	8.02	4.01
f'/R		0.272	0.272
$V^2/2g$	(m)	3.28	0.820
L	(m)	650	650
hf	(m)	580	145
Ht = hf x 1.2	(m)	696	174
S	(kW)	2,912	364

Notes : (1 : Nominal capacity of pump : 4,000 gallons/min

(2 : A half of the nominal capacity is examined.

The above calculation indicates that the system can only convey about 7.55 m^3/min of mixture, because the maximum pump capacity would be limited to about 344 kW, judging from the nominal electric motor capacity of 413 kW (553 Hp). Under the present system, if operated properly, the materials to be dredged would be only 180,000 m^3 per year as computed below for the sediment concentration rate of 10 %.

$$Vs = 7.55\ m^3/min \times 60\ min \times 15\ hrs \times 22\ days \times 12\ months \times 0.1$$
$$= 179{,}388\ m^3$$

For resuming the dredging operation, CFE is recommended to confirm the above. The pump capacity should be checked first. Investigation is necessary for provision of water jets or bottom cutter blades for effective operation. Further in order to reduce the friction loss of the discharge pipe, it is conceivable to replace it by pipe of larger diameter such as 250 mm or 300 mm. Another method may be to discharge the sediment to the midway of the spillway chute by cutting the delivery pipe length with the aid of flushing water from the spillway.

Here, reference is made to the dredging scheme which was recently implemented for a hydropower project in Ecuador as an example of large-scale and deep-water dredging schemes. The principal features of the project are as follows.

- Name of project	:	Paute Hydroelectric Project
- Executing agency	:	Ecuadorian Electrification Institute (INECEL)
- Installed capacity	:	550 MW (1983) plus 575 MW (1992)
- Dam	:	Gravity arch dam of 170m in height and 400 m in crest length
- Reservoir active storage	:	$100 \times 10^6\ m^3$
- Annual sediment inflow	:	$3 \times 10^6\ m^3$ to $3.5 \times 10^6\ m^3$

In this project, the Phase I dredging scheme was commenced in 1989, aiming at removing about 500,000 m^3 of clay, silt, and fine sand annually in the area within a distance of 500 m from the dam. A water jet vertical flexible hose suction pump dredger was used with a discharge pipe of 300 mm in diameter (700 m long off-shore) and 350 mm in diameter (200 m long on-shore). The required electric capacity was 1,100 kVA. The pump consists of the following units.

- Submergible dredging pump (750 m^3/hr, 36 m head, 190 kW)
- Discharge pump (750 m^3/hr, 71.5 m head, 450 kW)
- Jet water pump (180 m^3/hr, 150 m head, 132 kW)

One of the specific features for this project is a deep dredging depth, being 110 m at maximum. The sediment dredging capacity was specified at 150 m^3/hr to 210 m^3/hr, depending on the reservoir water level. The actual performance was reportedly nearly double (*650,000 m^3 for 4.5 months*) the value initially planned. Following the above Phase 1 scheme, INECEL continued the Phase 2 scheme by adding new dredgers.

CHAPTER 8

COST ESTIMATE AND IMPLEMENTATION PROGRAM

CHAPTER 8 COST ESTIMATE AND IMPLEMENTATION PROGRAM

8.1 Cost Estimate

8.1.1 Construction Cost

Cost estimates were developed for the proposed countermeasures based on the preliminary designs. Plans and sections of the major project components were prepared and used as the basis for estimating civil works quantities and the size of major equipment required.

The direct construction cost estimates were based on the quantity estimates and unit prices. All unit prices for the civil works, except for roller - compacted concrete, were supplied by CFE in December 1992. For some items not suitable for detailed estimating, lump sum costs developed from recent similar projects were used. Equipment costs were developed from manufacturers estimates and cost curves developed from experiences with similar equipment.

The total construction cost includes the direct cost and indirect cost. The indirect cost include an allowance for contingencies and engineering and administration costs. A contingency allowance of 20 to 25 percent on all items was included to cover additional costs which may be incurred because of unforeseen site conditions, possible omissions, approximations, and the chance for future design changes. An allowance of 15 percent was included to cover the costs for Engineering Services prior to and during construction and Administration Costs of the owner chargeable to the Project. In developing the cost estimates an exchange rate of $US 1.00 to N. Peso 3.00 was used.

The detailed construction cost estimates for the proposed structures are given in Tables 8.1 and 8.2, and a summary of the total construction costs are given below:

Proposed Structures for Rehabilitation Plan	Total Costs ($\times 10^6$) N. Peso	$US equivalent
(1) New Power Intake and Low Level Outlet	35.2	11.7
(2) Check Dam	47.0	15.7

Installation of the Digipit governors to 4 units will cost about US$ 0.4 million.

It is difficult for the Study Team to estimate the repair cost to resume operation of the present dredging system. If a new system aiming at removing the deposits at a rate of 500 m^3/hr in terms of mixture of sediment and water is employed instead of the present system, the initial investment cost would be around US$ 10 million including the cost for dredger pump, discharge pump, jet water pump, discharge pipe, spare parts, etc. Under this new system, the unit rate of dredging operation is roughly estimated at US$ 6/m^3 to US$ 9/m^3 for the annual total dredging volume of 500,000 m^3, depending on more detailed analysis.

The initial investment cost for the rehabilitation plan is summarized as follows.

- New power intake and low level outlet and check dam	:	US$ 27.4 million
- Digipid governor	:	US$ 0.4 million
- New dredger (subject to repair of existing dredger)	:	US 10.0 million
Total with new dredger		US$ 37.8 million
Total without new dredger		US$ 27.8 million

8.1.2 Field Investigation Cost and Engineering Cost

Prior to the construction work of the proposed rehabilitation plan, engineering design of the proposed structures should be carried out to optimize and consolidate their structural details and to make cost estimate, incorporating more detailed information and data on topography, geology, construction materials, etc. to be obtained by the field investigation. Independently of this field investigation, re-analysis should be made on the existing arch dam whose stability might be jeopardized by the increasing earth pressure as described in Chapter 9. It is recommended to proceed to make the re-analysis at the earliest opportunity regardless of the implementation schedule and modification of the proposed rehabilitation plan.

The field investigation cost and the engineering service cost required for the above re-analysis are estimated as follows.

- Re-analysis of arch dam	US$ 200,000
- Field investigation	US$ 265,000
Topo-survey	(130,000)
Geological survey	(125,000)
Concrete material survey	(10,000)

The engineering service cost for detail design of the new structures and construction supervision is estimated at US$ 2.9 million by assuming 12% of the direct construction cost. This cost is included in the total construction cost presented in the preceding section.

8.2 Implementation Program

8.2.1 Overall Implementation Schedule

The overall implementation schedule for the rehabilitation plan is presented in Figure 8.1. Immediately after the financial arrangement is decided, the re-analysis of the arch dam should be made by a qualified professional consultant. The re-analysis will include assessment of deformation and stress in the arch dam and foundation in due consideration of seismic load and thermal load at present and in future against the predicted sedimentation level. Concurrently with this re-analysis, the field investigation program including topography, geology and construction materials should be executed by the CFE's own force or by contract.

After the design (or tender design) is refined and consolidated based on the information and data thus obtained, the construction work will start, selecting a qualified constructor(s) by competitive bidding.

8.2.2 Field Investigation Schedule

The following field investigation will need to be performed in order to obtain basic data:

(1) New Intake and Low Level Outlet

- Topographic mapping of the new intake area, the area along the new sluice tunnel alignment and at the outlet works, and the area of the Apulco River bed from the proposed outlet structure to the end of the spillway.

- A drilling and testing program is required at the new intake area and along the new tunnel alignment to establish foundation conditions for the new intake, and to establish rock quality for tunnel construction including probable tunnel support requirements.

(2) Check Dam

- Topographic mapping of the reservoir area and dam site. Reservoir mapping is required to get an accurate Elevation-Area-Volume Curve, for establishing reservoir elevations and dam height, and the area to be inundated by the reservoir.

- A drilling and testing program is required at the dam site to provide data on the dam foundation which affects dam design and layout.

- Sources of construction materials need to be established, in particular the location of appropriate aggregate sources. This is important to establish and accurate dam design, RCC mix, and cost of dam construction.

The implementation schedule and major items of these investigations are shown in Figure 8.2. The locations of the proposed geological investigations such as core drilling and seismic refraction prospecting are also shown on the attached figures for the structural layouts and profiles.

8.2.3 Construction Plan and Schedule

(1) New Power Intake and Low Level Outlet

The construction of the new power intake and low level outlet will be performed concurrently to curtail the construction time, while they can be also built in stage. As shown in Figure 8.1 and Figure 8.3, the overall construction period is expected to last for 2 years.

In order to construct the new power intake, a cofferdam will be required as shown on Figure 7.23 to allow unwavering of the area during construction. Once the cofferdam is in place and the area is dewatered, fill will be placed along the dam to provide access from the top of the dam to the construction site. Construction of the cofferdam and access to the site is expected to take about 5 months.

The tunnel will be excavated starting from the upstream end. The tunnel will first be excavated to a point near the existing power tunnel at which time tunneling will temporarily stop to allow the construction of the intake and other facilities. Lining of the tunnel with concrete will proceed while the intake is being constructed. Construction of the retaining walls and placement of backfill will begin after the tunnel concrete is completed and the intake partially constructed. Construction of the intake, retaining walls and backfill will take about 8 months. Near the end of this period the new intake gate and bulkhead will be installed.

Once the intake gate is installed, the removal of the cofferdam will begin and the area will be flooded. During removal of the cofferdam an access shaft will be constructed over the existing power tunnel, located as shown on Figure 7.23. This will allow construction access for completing tunnel construction and making the connection between the new and existing tunnels, and for plugging the existing tunnel. A two month period is planned for the plugging of the existing tunnel, at which time the existing intake gate will need to be closed and sealed and power generation at the Mazatepec power plant will be halted. Once plugging of the tunnel is complete, the new intake and power tunnel can be used to resume power generation at the Mazatepec power plant. The existing intake gate will remain closed during the construction of the new low level outlet facilities.

Construction of the new low level outlet tunnel will proceed starting from the upstream end using a second construction access shaft. Tunnel excavation and lining are estimated to take about 10 months to complete. Construction of the outlet works structure will begin near the end of tunnel construction of coinciding with the closure of the existing intake. Other activities such as replacement of the existing trashrack and clearing of the downstream Apulco riverbed to the spillway area can be scheduled any time during the period. Rehabilitation of the existing intake gate can be performed any time after the new construction is complete.

(2) Check Dam

The construction of the dam and spillway will be performed in three stages and is expected to take approximately 18 months to complete. The plan for diverting the Apulco River during construction of the dam and spillway is shown graphically on Figure 7.29, and the schedule for construction is given in Figure 8.3. The construction schedule of the check dam is worked out so that the reservoir filling would coincide with the 2 month shutdown of the power plant when the existing power tunnel will be plugged.

In the first stage, a small fill cofferdam will be constructed beginning in the dry season to enclose the right bank area as shown on Figure 7.29. The Apulco River will then be diverted along the left bank of the river through the channel formed by the cofferdam and river bank. The following construction activities will be performed in the first stage:

- Foundation excavation and treatment
- Construction of the river diversion intake and bottom outlet through the dam partial construction of the intake tower
- Construction of the right side of the stilling basin and training wall
- Placement of the RCC fill to El. 1468 m

The first stage of construction is expected to be completed within 8 months, including the initial two months which is allocated for the mobilization of the equipment and work force, and two months for Stage I cofferdam.

In the second stage, the second stage cofferdam will be constructed and the first stage cofferdam removed. The Apulco River will then be diverted through the bottom outlet. The construction activities in the second stage are similar to those in the first stage as given below:

- Foundation excavation and treatment
- Construction of the left side of the stilling basin and training wall
- Placement of the RCC fill to El. 1468 m

The second stage construction will take approximately 4 months to complete. At the end of the second stage the completed right and left portions of the dam will be at the same level, El. 1468 m.

In the third and final stage of construction the second stage cofferdam will be removed and the dam will be constructed to its final crest elevation. During the final stage, placement of the RCC will be done in lifts along the entire length of the dam. After construction is complete, stoplogs will be lowered into position to close off the river diversion intake, and permit the initial filling of the reservoir. A mobile crane will be used for stoplog placement. Once the reservoir is filled and it has been determined that there is no need to empty the reservoir the stoplogs will be grouted in place and a concrete plug will be installed to permanently close the river diversion intake. Reservoir release can be subsequently made through the high level opening provided at the top of the intake tower.

(3) Dredging

CFE is recommended to make efforts to repair the present dredging system. If a new system is procured, manufacturing of equipment will take about 12 months and it will take about nearly two years in total including manufacturing, shipping and inland transportation, field assembling and installation, and test and experimental operation prior to production operation after the contract is concluded.

CHAPTER 9

JUSTIFICATION OF REHABILITATION PLAN

CHAPTER 9 JUSTIFICATION OF REHABILITATION PLAN

9.1 Storage Volume to be Required and Sedimentation Level

For establishing a rehabilitation plan for the reservoir sedimentation, a primary concern is how much the storage volume be conserved or maintained to continue power generation in future. From the results of the detailed simulation study on the required storage capacity, however, no significant recovery of energy output could be expected even if the reservoir were rehabilitated to have a capacity as originally designed as given below.

	Effective storage ($\times 10^6 m^3$)	(%)	Annual energy (GWh)	(%)
Original:	30.2	(100)	615.9	(100.0)
	17.9	(59)	610.6	(99.1)
	12.2	(40)	608.8	(98.8)
Present:	9.2	(30)	604.3	(98.1)

It is apparently not feasible technically and economically to try to recover 2% of energy loss by removing $21 \times 10^6 m^3$ of the reservoir deposits plus the continued sediment inflow. Therefore, the recovery of storage capacity should be a minimum from the operational and economical viewpoints. The required storage capacity should be a one which is sufficient for regulating the flow on a daily or weekly basis. If this power station is planned as a run - of - river plant of conventional type, the required flow regulating capacity would be:

$$Vr = (Qmax - Qm) \times Tp \times 3{,}600 \times \alpha$$

where, Vr = Volume to be required (m^3)

Qmax = Max plant discharge (m^3/s)

Qm = Mean discharge (m^3/s)

Tp = Full peaking time (hr)

α = Allowance

Assuming that the daily peak duration time be about 5 hours, the minimum required storage capacity would be:

$$55.2\ m^3/s \times 5\ hr \times 3{,}600\ sec = 993{,}600\ m^3 = \text{approx. } 1 \text{ million } m^3$$

If a 10-hour peaking time is allowed for, the required storage is 2 million m^3. The current effective storage capacity is 18.4×10^6 m^3 between El. 804.5 m and El. 775.0 m and 10.2×10^6 m^3 between El. 804.5 m and El. 797.5 m. As far as the current capacity is maintained, it is possible to continue to fully operate the power station as a peaking hydropower plant, and also to have a capacity for 5 to 6 day regulation in a week.

On the other hand, earth pressure acting on the existing arch dam has gradually increased due to the rise of sedimentation level in the vicinity of the dam. It is supposed that the earth pressure was duly considered in the original design through no detailed data on the design criteria was available. The current earth pressure has increased about three times from the original design value if the design silt level was assumed to be at El. 750 m. The earth pressure is given by the equation below.

$$Pe = 1/2 \cdot C \cdot W' \cdot H^2$$

where,

Pe	:	Earth pressure (t/m)
C	:	Coefficient of static earth pressure (approx. 0.5)
W'	:	Unit weight of sediment load in water (t/m^3) = Ws - (1 - λ) Wo
Ws	:	Unit weight of sediment in air (t/m^3)
λ	:	Porosity
Wo	:	Unit weight of water (t/m^3)
H	:	Depth of sediment (m)

Original H : 750 - 715 = 35 m

Current H : 775 - 715 = 60 m

It is important to know a contribution of earth pressure in the total load acting on the dam. The present load by earth pressure is about 28 % of water pressure as given below.

Water pressure:

$$Pw = 1/2 \cdot Wo \cdot H^2 = 0.5 \times 1.0 \times (804.5 - 715)^2 = 4{,}005 \text{ t/m}$$

Earth pressure:

$$Pe = 1/2 \cdot C \cdot W' \cdot H^2 = 0.5 \times 0.5 \times 1.25 \times (775 - 715)^2 = 1{,}125 \text{ t/m}$$

Further, a contribution of the above earth pressure under a seismic condition (seismic coefficient K = 0.25) to the total load is about 17% as estimated below.

- Static water pressure:

Pw			=	4,005 t/m

- Dynamic water pressure:

Pwd	=	$7/12 \cdot Wo \cdot K \cdot H^2$	=	1,168 t/m

- Inertia force:

Pi	=	$Wc \cdot B \cdot L \cdot K$		
	=	2.3 x 7.5 x 91.5 x 0.25	=	395 t/m

- Earth pressure

Pe			=	1,125 t/m
Total load				6,693 t/m

However, it should be noted that the above evaluation does not discuss any change of stress distribution in the dam and foundation in accordance with the change of external load, and is deemed indicative for further consideration.

CFE is recommended to make clarification on the allowable earth pressure acting on the dam in the original design, with consultation to the engineering consultant who was responsible for the original design. Further, it is recommended to preceed to make reanalysis of the stability of the arch dam at the earliest time. Anyway, it is quite essential to limit any further rise of the sedimentation level or to lower it for the stability of the arch dam.

9.2 Selected Rehabilitation Plan

An appropriate countermeasure for the rehabilitation plan is selected as a package of alternatives of different functions. The sediment balance under the rehabilitation plan is illustrated as shown in Figure 9.1.

The check dam is planned to trap 1.17 x 10^6 m^3 of sediment load annually out of the total sediment inflow of 1.8 x 10^6 m^3, which is about 90% of the total sediment inflow into Soledad Reservoir. The total sediment inflow into Soledad Reservoir would reduce to 0.83 x 10^6 m^3 after the check dam is built, consisting of 0.63 x 10^6 m^3 of the outflow from the check dam and 0.20 x 10^6 m^3 of the sediment load from the area between the check dam and Soledad Dam.

As experienced in Soledad Reservoir, about 0.29 x 10^6 m^3 of the sediment load would pass through the turbines without significant damage to the turbines and 0.54 x 10^6 m^3 would be trapped by the reservoir if a trap efficiency of 65 % is assumed. Then, it is assumed that 0.54 x

10^6 m^3 of sediment load be sluiced through the low level outlet which is to be provided by conversion of the existing power intake. A part of this sediment load will be removed by dredging if the present system is repaired. Sediment concentration rate for the sluicing will be a few percent judging from the estimated sediment rating curve. Taking a 3 % concentration rate, water required for the sluicing is about 18 x 10^6 m^3/yr, which is 3.1 % of the annual mean inflow of water into the reservoir.

The flushing operation will be more effectively made for a limited time during a high flow period when the sediment concentration is quite high. It is also effective to lower the reservoir level as low as possible. Some sample operation modes are as follows.

Max Discharge (m^3/s)	Duration time for sluicing (days, 12 hrs/day)	Total volume of water (x 10^6 m^3)
41.6	10	18
21.8	20	18
13.8	30	18
10.4	40	18

9.3 Economic Evaluation

For a package of countermeasures, an economic justification was made under a "with and without project concept".

If any countermeasure is provided, the reservoir sedimentation would continue to occur and the foreset of the sediment deposits will encroach on the power intake and eventually power production would be obliged to stop due to clogging of the power intake. Further rising of the sediment level also would affect much to the stability of the dam.

With reference to the simulation result on the future reservoir sedimentation progress it is assumed that the Mazatepec power station would stop to operate in the year 2000 if no provision is made but it could continue to generate energy if the proposed countermeasures are immediately provided, though some decrease of energy output is inevitable due to loss of water for periodical sluicing of sediment load through the low level outlet.

It is assumed that the benefit accruing from the rehabilitation works be power and energy outputs which would be otherwise lost under without rehabilitation work.

Here a coal - fired power plant is considered as a proxy of the Mazatepec plant for the conservative sake of economic evaluation. Table 9.1 shows the basic cost data as of 1991 for power generation by different power plants estimated by CFE. To apply these data to the 1993 price level, the values are adjusted with 15% increase referring to the recent economic indexes. For a simplicity of calculation, investment cost and fuel cost of coal - fired plant is deemed as a benefit. A cash flow of the cost for the packaged rehabilitation plan and the alternative cost as a benefit is presented in Tables 9.2 and 9.3 and the basic values used are as follows.

(1) Cost:

- Total investment for rehabilitation : US\$ 28.25 x 10^6 (excld. dredging)
- Annual O & M cost (Existing US\$ 2.0 x 10^6 plus Additional US\$ 0.55 x 10^6) : US\$ 2.55 x 10^6
- Loss of energy during construction : US\$ 2.40 x 10^6

(2) Benefit:

- Capital cost of thermal plant : US\$ 222.97 x 10^6
  US\$ 1,339/kW x 1.15 x 144,800 kW
- O & M cost of thermal plant : US\$ 1.13 x 10^6
  US\$ 0.00176 x 1.15 x 621 x 10^6 kWh x 0.9
- Fuel cost of thermal plant : US\$ 12.98 x 10^6
  US\$ 0.0202 x 1.15 x 621 x 10^6 kWh x 0.9

Notes : (1) Total investment cost is US\$ 28.252 x 10^6, consisting of:
- Field investigation US\$ 0.265 x 10^6
- Re-analysis of arch dam US\$ 0.200 x 10^6
- Construction (excld. dredging) US\$ 27.787 x 10^6

(2) O&M cost (existing) does no include tax, and additional O&M cost is 2 % of the investment cost.

(3) Loss of energy will occur for 2 months in the 2nd year of construction for plug concrete in the power tunnel:
621 x 10^6 kWh x 2/12 x US\$ 0.0202 kWh x 1.15= US\$ 2.40 x 10^6

(4) 144,800 kW is an estimated dependable peak capacity of the Mazatepec power plant based on a 5-hour peak operation with the 90% dependable flow of 7.57 m^3/s.

(5) Energy output of the Mazatepec power plant is 621 GWh on average in the past, of which 10% is assumed to be lost due to use of water for sediment *sluicing*.

In the cash flow, it is assumed that the construction work starts in 1995 and ends in 1997, while the corresponding benefit would accrue in and after the year 2000. The evaluation period is 15 years in consideration of the useful life of the check dam.

Table 9.2 shows a cash flow where the rehabilitation work only contributes to fuel saving in a coal-fired plant for the conservative sake. The economic internal rate of return (EIRR) is derived at 18.3%. Table 9.3 shows a cash flow where the rehabilitation work is deemed to build and operate a new thermal plant. In this case the EIRR is 177%.

The above evaluation does not include the cost for dredging. If a new dredger is introduced instead of the existing one, the EIRR is 10.9% in terms of fuel saving and 137% in terms of replacement cost. If the existing dredger can be successfully repaired for normal operation with a quarter (25%) of the cost required for procuring a new dredger, the EIRR is 16.2% and 165% respectively. These economic indicators proves that the proposed rehabilitation plan is fully viable economically. The result of the economic evaluation are summarized below.

Items	Without dredging	With repair of existing dredger *1	With procurement of new dredger
1. Additional investment	-	US$ 2.5 x 10^6	US$ 10.0 x 10^6
2. Additional annual O & M cost	-	US$ 0.5 x 10^6	US$ 2.0 x 10^6
3. Total initial investment cost	US$28.25 x 10^6	US$ 30.75 x 10^6	US$ 38.25 x 10^6
4. EIRR by fuel saving	18.3%	16.2%	10.9%
5. EIRR by replacement cost	177%	165%	137%

Note: *1 Assuming 25% of the purchase cost of a new dredger for the cost required for repairing the existing dredger.

9.4 Financial Evaluation

The financial feasibility of the rehabilitation plan was evaluated for its financial internal rate of return (FIRR) and repayability of loan, though no condition and term have been decided on the financing and executing system of construction.

Here, it is assumed that the rehabilitation plan includes the dredging operation by repairing the existing dredger. The revenue was estimated by multiplying the current power tariff to the salable energy which is derived by deducting the energies for station use and sediment sluicing and loss in the transmission/distribution system from generated energy. Thus, the annual revenue from the Mazatepec Power Station is computed at US$ 25.15 x 10^6 as follows.

$$621 \times 10^6 \text{ kWh} \times (1 - 0.1) \times (1 - 0.1) \times \text{US\$ } 0.050/\text{kWh} = \text{US\$ } 25.15 \times 10^6$$

where,

Average annual energy production	:	621 x 10^6 kWh
Average tariff	:	N.P 0.150/kWh (US$ 0.050/kWh)
Energy for station use and other lossess	:	10%
Energy loss by sediment sluicing	:	10%

The above total revenue should be duly allocated to recover the cost accuring not only from generating side but also from transmission/distribution side. However, it is difficult to know a proper share of the generating side. Then, it is assumed that a half of the revenue be allocated to the generating side. Under this assumption, the FIRR is computed at 14.05% as shown in Table 9.4, which is deemed fully acceptable.

The financial aspect was also examined in terms of repayment capability of loan for the initial investment cost. The loan conditions are provisionally assumed as follows.

- Interest rate : 5% per anum
- Repayment period : 15 years including 5-year grace period

It is also assumed that the principal be repaid uniformly over the 10 years after the grace period and the interest be paid after the loan is disbursed. As shown in a cash flow in Table 9.5, the rehabilitation plan is financially sound since the accumlated balance would become positive 7 years after the loan is disbursed.

CHAPTER 10

ENVIRONMENTAL ASPECTS OF REHABILITATION PLAN

CHAPTER 10 ENVIRONMENTAL ASPECTS OF REHABILITATION PLAN

10.1 Comments on the Watershed Management Plan in the Upper Catchment

10.1.1 Previous Soil Conservation Measures Implemented by CFE

Various soil conservation measures have been implemented in the basin to date, with varying degrees of success. Contour farming is practiced in some areas, and in some locations this is accompanied by the establishment of rows of maguey or other drought resistant vegetation at intervals of 10 to 20 meters to retard runoff down the slope.

Between the years 1976 to 1988, CFE also conducted a program of watershed management in the central portion of the basin. This multifaceted effort included the reforestation of eroded slopes, the development of terraces and ditches to intercept and retard the flow of water, the development of rock walls (muros secos) to intercept runoff and silt in drainageways (barrancas), and the construction of 25 check dams to act as silt retention basins on tributaries of the Rio Apulco.

Generally, these watershed management activities were concentrated in the area between Ocotzingo and a little west of Tlajamulco, with very little activity in the basin upstream of Tlajamulco.

10.1.2 Comments to Soil Conservation Programs

It is possible to develop extensive watershed management and soil conservation programs in the Rio Apulco basin. Such programs could improve local conditions within the basin, but major questions exist concerning the effectiveness of such programs in helping CFE to reduce significantly the amount of sediment entering Soledad Reservoir. The total cost for the watershed management efforts, excluding the check dams (Presas de Mamposteria), was approximately US$515,000. Watershed management efforts undertaken by CFE from 1980 to 1987 were discontinued as being too expensive for the limited results obtained in the relatively small areas that could be improved in any one year.

Observations in the Rio Apulco Basin indicate that much of the erosion is taking place in the middle and upper reaches of the Basin, where Feozem and Regosoles are predominant. In this upstream area the watershed management programs were previously implemented by CFE. This is an area of very dry, erodible soils, with little or no vegetative cover, much of which is subject to cultivation or grazing. These characteristics greatly affect the feasibility of many of the potential soil conservation measures for reducing the inflow of silt and sediment to the reservoir.

(1) Revegetation

Some eroded areas, particularly in the vicinity of Zautla, have previously been revegetated by CFE. It would appear that the results of these efforts have been mixed. Some slopes have been stabilized, but problems were encountered with goats, ants, and drought conditions. Also, much of the ground surface between the individual trees has remained unprotected by vegetation, and thus continues to be subject to erosion. Ultimately, the reforestation nursery that had been established for this purpose was dismantled as not being cost effective. For these reasons, it is believed that extensive reforestation programs over hundreds of hectares, particularly in the extremely dry upstream areas where they are needed most, would result in few benefits to the project, even in the moderately long term.

Observation of the area indicates that it would be a very difficult area to revegetate and return to productive use at reasonable expense. Revegetation on a more limited, selected scale could likely benefit the basin in general, but would not be expected to significantly reduce the sediment input to the reservoir.

(2) Contour planting of effective vegetation

Cooperative efforts with the farmers in the basin to encourage them to utilize contour farming to the extent practical, and to plant maguey or other vegetation on the contour may be one method of generally improving conditions in the basin and reducing the introduction of sediment into the river. Such activities would only be useful where cultivation is restricted to moderate slopes, and sufficient moisture is available to support the maguey or other species planted to bind the soil and retard runoff. In order to be effective, the farmers would have to understand the benefits that they could personally derive from such a program and would have to be willing participants in maintaining the contour strips once they were established. The vegetation strips should be planted at intervals of 10 to 20 meters, depending on the slope. Wherever possible, the vegetation planted should also provide economic benefit. Maguey is apparently cultivated and utilized extensively in the basin, and presently is used for contour plantings.

(3) Alternative Economies

It appears that subsistence agriculture, particularly on steep slopes, seasonal burning of old vegetation to stimulate sprouting of tender new growth or to clear areas for planting, and overgrazing by livestock may be three of the problems that are causing erosion in the basin. These problems are common to many areas of the world. They are directly related to the population and the socio-economy of the area, and will not lend themselves to a simple or quick solutions. It is believed that solutions to these problems are beyond the scope of the present studies because they would require some basic changes in the policies and attitudes that presently control land ownership and land use in the area.

(4) Soil Stabilization Measures

Like reforestation, efforts at slope protection have been conducted in the past. Under the proper conditions, they have stabilized slopes and permitted the reestablishment of herbaceous and other vegetation. However, for the reasons stated in relation to revegetation, it is not believed that extensive efforts to construct slope stabilization works would be effective in the severely eroded upstream portion of the basin where sheet erosion is a basic problem. The one exception to this is that new construction activities such as the improved road into the basin at Zautla should implement soil stabilization activities as work progresses to minimize potential erosion problems.

From observations in the basin, it does not appear that river bank protection works are needed. Generally, the river is deeply incised in hard rock, and bank cutting is not a significant problem. However, throughout the length of the river there presently is a large accumulation of sediment that will continue to wash downstream and into the reservoir. This sediment has entered the river in the past from earlier upland erosion.

(5) Check Dams

Twenty five (25) relatively small sediment check dams were constructed to date in the tributaries of the basin. Several of those located downstream of Zautla are still serving their intended function by trapping any sediment that enters their impoundment. Upstream of Zautla, most of the storage capacity of the dams has been filled with sediment, some in as little as five years or less. The establishment of additional small (5 - 10 meters high) sediment retention dams may be a short term solution for specific problem areas, but would require detailed knowledge of the principal sources of sediment, and how much might be expected to accumulate at any given location if a sediment dam were constructed. Once the storage area is filled, however, the dam serves no further benefit, and may create additional problems downstream if it were to fail and release its stored sediment.

(6) Construction of a Major Storage Facility

Soledad Dam has effectively stopped the movement of sediment in the river for 30 years. Construction of a new facility with significant storage capacity upstream of the present reservoir could, likewise, stop further sediment accumulation into Soledad Reservoir. The costs and benefits to be derived from such a project should be studied in detail, but it would seem that for the short to intermediate term (i.e., 30-50 years), such a facility may offer a cost effective way of retaining the viability of the Mazatepec Project.

10.1.3 Recommendation to Watershed Management

If future watershed management activities are contemplated in the Apulco basin upstream of Soledad Reservoir, such activities should be implemented cooperatively with the appropriate agencies of the State of Puebla for maintenance and improvements in the environmental conditions in the basin. For example, there should be a coordinated effort for soil stabilization in relation to the ongoing road construction near Zautla.

Likewise, such activities should include a strong program of community and individual involvement by the inhabitants of the basin. This should be included in order to identify and implement cost effective means of watershed management that would benefit both the local inhabitants and the project. Local involvement would be critical for the long term viability of any watershed management programs that might be implemented.

Typical soil conservation measures practiced in many places are illustrated as shown in Figures 10.1 and 10.2.

Areas significantly contributing to the sediment loading of the river should be identified and quantified to the extent possible. Such knowledge would facilitate the planning for cost effective control measures aimed at the specific, significant source locations. Two potential methods for acquiring and evaluating such information have been suggested during these investigations.

First, an expanded sediment sampling program could be implemented so that the relative contribution of sediment from various locations can be quantified. In this manner, those areas with the greatest soil loss to the river could be identified so that specific corrective measures could be implemented.

Second, a series of satellite images, starting in 1972, could be obtained and analyzed to identify areas without significant vegetation, and the changes in the size and location of such areas over time.

10.2 Preliminary Environmental Evaluation of Alternative Countermeasures

10.2.1 Alternative Measures for Environmental Evaluation

The alternative measures were evaluated in the preceding sections from the engineering viewpoint. This section considers the environmental aspects of those countermeasures.

Here, the following alternative countermeasures are retained for further evaluation in the formulation of a complete project rehabilitation plan, through some eliminated alternatives are included to confirm their adverse environmental implications.

- Alternative C plus F – Conversion of power intake into a low level outlet, plus a new power intake located u/s of the existing intake structure
- Alternative G – Settling basin with a new sluice shaft/tunnel
- Alternative I – New check dam at Site B (near Huahuaxtla)
- Alternative J – Sediment diversion tunnel with a diversion weir
- Alternative K – Dredging

(1) Alternative C plus F – Conversion of power intake into a low level outlet plus a new power intake located u/s of the existing intake structure

These two alternatives need to be considered together because of their related functions.

The environmental aspects of this alternative combination would include disturbance of a small area adjacent to the existing intake facility and another area downstream of the dam, and the periodic discharge of sediment, mostly silt, sand, and gravel with particle sizes up to approximately 32 mm, into the old river channel downstream from the dam. The sediment would be flushed with sufficient water so that it would be moved downstream rather than accumulating in the immediate vicinity of the dam.

As discussed in chapter 4, no resource utilization of the river channel was noted in the reach from the dam to the power station and on downstream to the confluence with the Rio Necaxa, so it is not anticipated that the discharge of sediment into this reach will have significant adverse environmental effects. If a situation occurs that sediment laden-water should not be discharged, construction of a series of low check dams is conceivable between the dam and power station.

This existing, almost sediment-free discharge is actually an artificial phenomenon created by the original construction of Soledad Dam and the consequential retention of sediment behind the dam. Prior to the initial construction some 35 years ago, all of the sediment carried by the Rio Apulco passed continuously the project site.

During the study, the turbidity of water in the reservoir and river was measured using a turbidity meter Model FN-5TD, Toho Dentan Co., Ltd. Japan provided by JICA. The results of measurement of turbidity are given in Table 10.1 and 10.2 and the measuring points are shown in Figure 10.3. However, it is noted that the values of turbidity expressed in ppm should be considered as a reference due to its indirect measuring method of the sediment concentration rate by use of electricity.

In October 6, 1992 (in wet season), the turbidity of the reservoir water at a relatively shallow depth was 50 to 60 ppm and that of turbine discharge water (tail water) was around 60 ppm when the 4 units were fully operated. In September 23, 1993, the turbidity of reservoir water at its shallow depth was around 70 ppm and that of tailwater was 80 ppm.

On the other hand, on September 24, 1993, the turbidity of the river water downstream of the power station was 170 ppm at the location 40 km downstream of the Mazatepec power station and 220 to 360 ppm in the downstream section of the Tecolutla River. These measurement results indicate that the discharge from the reservoir would not give a significant influence to the turbidity of river water in the downstream reaches.

(2) Alternative G – Settling basin with a new sluice shaft/tunnel

This alternative considers the construction of a new settling basin to exclude sand particles (approximately 0.5 mm or greater, subject to further study) from entering the power tunnel. The retained sediment would be sluiced periodically through a shaft and tunnel to the river channel downstream from the arch dam. Larger particle sizes may be retained in the settling basin and will have to be removed by other mechanical methods.

The environmental aspects of this alternative would be similar to those of the C-F alternative, minimal disturbance for new construction, and the discharge of sediment into the old river channel downstream from the dam. Environmentally, the only difference is the manner in which the sediment particles larger than the designated size is excluded from the power intake and flushed downstream.

(3) Alternative I – New check dam at Site B (near Huahuaxtla)

This alternative involves the construction of a major new check dam upstream of Soledad Reservoir to retain the sediment that would otherwise continue to enter the existing reservoir.

Out of alternative sites preliminary identified, the proposed check damsite (B) near Huahuaxtla was clearly preferable from an engineering and cost standpoint. Environmentally, the site B has an advantage for accessibility and would not require disturbance of the forested area.

The proposed new sediment check dam at site (B) would be located near the town of Huahuaxtla, approximately 1.5 km upstream of the Zacapoaxtla – Cuetzalan highway bridge. Land use in the reservoir area includes second growth forest and some subsistence agriculture for corn and beans. A trout hatchery run by the State of Puebla is located downstream of the dam alignment, but it receives its water supply from a tributary stream and would thus be unaffected by project construction or operation. A park and waterfall along the tributary stream would likewise not be affected by project activities.

However, the gravel road past the hatchery and park, and along the Apulco River through the dam alignment and reservoir area is the only access to and from the town of Atzalan (population under 2,500). Thus, new access to this community would have to be provided as part of the project. Also, the proposed reservoir would be located at the base of the hill upon which the town of Huahuaxtla is located, and would be readily visible from the town. The elevation of the town ranges from El. 1500 m up to more than 1600 m.

The proposed crest elevation of the dam would be 1,494 m at maximum, and thus it is not anticipated that the reservoir would inundate any area or structures related to the village and town. No extensive relocation of inhabitants is required. However, this will need to be verified if planning for this facility continues. At the present stage of project planning, no other potentially significant environmental effects related to the proposed sediment storage facility have been identified. However, the precise topography of the area, and final project definition and operation will need to be evaluated in terms of potential impacts on the town and surrounding area. As planned, the new check dam would act as a sediment trap in much the same manner as the existing Soledad reservoir has retained sediment for the past thirty (30) years.

(3) Alternative J – Sediment diversion tunnel with diversion weir

This alternative would involve a diversion weir and tunnel designed to flush the sediment load of the Rio Apulco into the next river basin to the north. Further refinements to this concept would be required to identify appropriate locations for the diversion dam, the tunnel intake, and the discharge path into the adjacent waterway.

The specific environmental consequences of this alternative can not be identified until more information is developed, but the two major, generic consequences would be a) the loss of flow from the Rio Apulco basin with resulting loss of power generation at the Mazatepec powerplant, and b) the environmental consequences of the discharge of sediment laden water into the other basin. These aspects will have to be carefully considered if this alternative is to be considered in detail.

(4) Removal of sediment from the reservoir by dredging

CFE has attempted to remove some of the sediment accumulation from the reservoir area by dredging and discharging the sediment downstream of the spillway. Results of this effort have not been very successful for a variety of mechanical problems

If sediment is to pass downstream, questions as to where it will be deposited and its effects on downstream water use and aquatic conditions will need to be carefully considered. A preliminary overflight of the downstream reach of the river using a helicopter did not identify any potential significant problems, but additional information on water use and aquatic resources would need to be obtained.

10.2.2 Recommended Future Environmental Studies

The preliminary environmental evaluation reviewed the potential environmental consequences of the proposed counter measures on the basis of available information. On the basis of the aerial and ground level observations of the lower basin, it is concluded that proposed project activities would not significantly affect conditions or resource utilization of the river course downstream of the Mazatepec Project, particularly downstream of the confluence with the Rio Necaxa. The other tributaries to the river system, like the Apulco, contribute heavy sediment loads to the system. In addition, the sand and gravel extraction operations also add silt to the river. Project related activities will not measurably affect either flows or water quality in the lower, 20-km, estuarine reach of the river that is important to the fishery resource. Other identified water uses likewise will not be affected by the proposed project rehabilitation activities. No significant water resource utilization was observed in the reach of the Rio Apulco between the Mazatepec hydroelectric station and the confluence with the Rio Necaxa. However, the precise impacts of each alternative can only be fully identified and evaluated after the project plans are completely formulated.

Information on the precise topography of the Huahuaxtla and new sediment storage facility (Alternative I, site B) area, and the final project definition in terms of alignment, maximum reservoir elevation, and project operation will need to be evaluated in terms of potential impacts on the town, the surrounding area, and the operation of the Mazatepec Project

The specific consequences of Alternative J (diverting sediment out of the basin), though discarded, can not be evaluated until information is available concerning the more definitive locations of the diversion weir, tunnel intake, and the discharge path into the adjacent waterway.

When information is available on the amount and timing of any sediment discharge downstream of Soledad Dam, studies should be made of where this material may accumulate and any potential effects related thereto.

CHAPTER 11

CONCLUSIONS AND RECOMMENDATIONS

CHAPTER 11 CONCLUSIONS AND RECOMMENDATIONS

11.1 Conclusions

The Mazatepec Hydroelectric Power Station should continue power and energy production as having done for the past 30 years since it was commissioned in 1962. However, it is feared that the station could not operate properly due to the increasing reservoir sedimentation. The total annual sediment inflow is approximately 2.0 x 10^6 m^3, of which about 1.3 x 10^6 m^3 has been deposited and the rest has been transported mainly through the turbines. Sand abrasion effect to the hydro-mechanical equipment will become more serious than in the past because of encroachment of coarser particles of the sediment load to the intake. A simulation analysis indicates that the reservoir would be filled up to a level of El. 792 m by sediment in and around the year 2000.

For the above situation, alternative studies were made including field investigations for seeking for an appropriate countermeasure against the reservoir sedimentation. Out of the alternatives identified, the following package of countermeasures are selected from technical and economical viewpoints for limiting further rise of the sedimentation level.

- Construction of new power intake and conversion of existing intake into low level outlet
- Construction of large check dam on the main Apulco River
- Repair of the present dredging system (or introduction of a new dredger)
- Introduction of erosion-reducing method for turbines

The proposed structural measures are justified technically and economically.

From the environmental viewpoint, the discharge of sediment from the reservoir through the low level outlet or by dredging would not have significant adverse effect to the riparian conditions in the downstream reaches. Regarding the sediment storage facility proposed on the main stem of the Rio Apulco in the vicinity of Huahuaxtla, land in the proposed reservoir area is used for second growth forest and some subsistence agriculture for corn and beans, but it is not anticipated that the reservoir would inundate any residential area or structures. However, a gravel surface road along the Apulco River through the dam and reservoir area will be submerged, which is the only access to and from the town of Atzalan. Therefore, a new access road to this community would have to be provided as part of the rehabilitation project.

11.2 Recommendations

The following recommendations are made to maintain the present function and role of the Mazatepec Power Station and to prolong the useful life of the Project.

(1) Reservoir sedimentation survey should be continued with care periodically. It is essential to fix the range lines for all surveys to make comparison of the results. It is essential to set the survey posts at each end of the range lines and to measure the distance between the posts in advance.

(2) It is noted that the present method employed for measuring suspended solids at the three gaging stations does not offer a proper value of total sediment yield into the reservoir. Use of a depth-integrated sampler is recommended instead of the present sampling method.

(3) CFE is recommended to make clarification of the design conditions and criteria employed in the original design, especially for the allowable earth pressure acting on arch the dam. If the data is not available, it is advised to consult with the engineering consultant who participated in the original design. Further, reanalysis of stability of the dam should be made by specialist at the earlist time.

(4) CFE is recommended to consult with the manufacturer of the turbines for possible introduction of Digipit governors, which control the number of jet nozzles in partial load operation aiming at erosion-reducing operation.

(5) CFE is recommended to take necessary actions immediately for the implementation of the proposed rehabilitation works, including the repair of the existing dredging system. The financing plan and method and the executing system (conventional design and construction by contracts or turn-key, etc.), should be decided at the earliest time.

(6) Sluicing of the reservoir deposits should be made during the high flow months when the sediment concentration rate is rather high. It is also advised to lower the reservoir level when the sluicing is made, though this operation leads to a loss of energy.

(7) For controling the turbidity of water in sluicing and dredging the sediment load from the reservoir, an appropriate monitoring and communication system should be established between the project and the downstream points in collaboration with the CFE's Hydrology

Division.

(8) Operation and maintenance of the project facilities are well performed in accordance with the existing guide lines and mannual. These efforts should be continued in future. The following are some recommendations for operation and maintenance.

- Provision of safety fence on the outlet canal of Tunnel No. 1.
- Measurement of thickness of steel penstock when water is drained.
- Provision of bund walls at tanks for transformer oil.

TABLES

TABLE 1.1 LIST OF JICA STUDY TEAM MEMBERS AND COUNTERPARTS OF CFE

Name	Position	
1. JICA Study Team		
K. Miyake	Team Leader	(Nippon Koei)
S. Hatao	Hydropower Planner	(Nippon Koei)
K. Kawai	Power System Planner	(Nippon Koei)
George C. Antonopoulos	Civil Engineer (I)	(Harza*)
David Sulkowski	Civil Engineer (II)	(Harza*)
P. Bam	Hydro-Mechanical Engineer	(Harza*)
M. Ogino	Hydrologist	(Nippon Koei)
Khalid Jawed	Sedimentation Analyst	(Harza*)
S. Nishioka	Geologist	(Nippon Koei)
E. Dudlay	Environmentalist	(Harza*)
M. Tanifuji	Socio-Economist	(Nippon Koei)
Note: * Experts furnished by Harza Engineering Company, USA under agreement with Nippon Koei.		
2. CFE's Counterparts		
Ing. Juan Jose Vazquez Garcia	Subgerente de Ingenieria Civil Gerencia de Generacion Y Transmision	
Ing. Mariano Cabrera Villa	Subgerente Regional Gen. Hidro. Papaloapan	
Ing. Ramon M. Castillo Paramo	Jefe del Depto. de Comportamiento de Estructuras	
Ing. Gregorio Aguilar Lagunes	Suptte. Reg. de Ingenieria Civil Hidro. Papaloapan	
Ing. Miguel Flores Ortega	Jefe Depto. Estudios a Mediano Plazo	
Ing. Carlos Bremauntz Monge	Jefe de La Disciplina de Ingenieria Basica	
Ing. Hugo Toro Castro	Depto. Comp. de Estructuras	
Ing. Fernando Hernandez Hernandez	Subg. Ing-Civil	
Ing. Ivan Rodriguez R	Depto. Comp. de Estructuras	
Ing. Lauro Guzman Granados	Suptte. Gral. C. H. Mazatepec	
Ing. Jesus C. Acuna Torres	Suptte Electromecanico C. H. Mazatepec	
Ing. Victor Ortega Mendez	Suptte Aux. Civil, C. H. Mazatepec	
Ing. Ranulto Moreno Gonzalez	Jefe de Division Hidrometrica Golfo	
Ing. Leopoldo Espinosa Graham	Jefe Departmento de Geotecnia	
Ing. Felipe Caneino Lopez	Gerencia de Ing. Exp. Control	
Ing. Jose M. Fernandez Davila	Subgte. Gen. Hidroelectrica	

TABLE 2.1 INSTALLED CAPACITY OF POWER PLANTS BY GENERATING TYPE

(Unit: MW)

YEAR	Hydro	Oil Fired	Combined Cycle	Gas-turbine	Internal Comb.	Geo-thermal	Carbon Fired	Nuclear	Total
1974	3,521	3,378	130	971	259	75	37		8,371
1975	4,044	3,785	610	1,028	251	75	37		9,830
1976	4,541	5,012	610	948	274	75			11,460
1977	4,723	5,061	720	1,266	247	75			12,092
1978	5,225	6,456	720	1,267	249	75			13,992
1979	5,219	6,716	720	1,259	234	150			14,298
1980	5,992	6,616	540	1,190	137	150			14,625
1981	6,550	7,486	1,223	1,539	118	180	300		17,396
1982	6,550	8,325	1,223	1,686	101	205	300		18,390
1983	6,532	8,655	1,223	1,698	91	205	600		19,004
1984	6,532	8,929	1,227	1,760	107	205	600		19,360
1985	6,532	9,599	1,450	1,789	112	425	900		20,807
1986	6,532	9,949	1,450	1,789	111	535	900		21,266
1987	7,546	10,299	1,550	1,789	111	650	1,200		23,145
1988	7,749	10,800	1,624	1,792	89	700	1,200		23,954
1989	7,761	11,301	1,618	1,770	89	700	1,200		24,439
1990 *1	7,805	11,367	1,687	1,770	89	705	1,200	675	25,298

Note : *1 Preliminary numbers
Since 1980 real power is reported. Before that data are correspond to capacity of plant.
Source : INFORME ANUAL 1990, CFE

TABLE 2.2 GROSS ENERGY PRODUCTION BY GENERATING TYPE

(Unit: GWh)

YEAR	Hydro	Oil Fired	Combined Cycle	Gas-turbine	Internal Comb.	Geo-thermal	Carbon	Nuclear	Total *2
1974	16,602	17,915	198	2,068	762	463			38,008
1975	15,016	19,562	1,646	3,403	734	518			40,879
1976	17,087	22,128	1,932	2,366	540	579			44,632
1977	19,035	25,280	2,045	1,537	456	592			48,945
1978	16,066	30,322	2,488	3,027	476	598			52,977
1979	17,839	33,098	2,317	3,343	454	1,019			58,070
1980	16,740	37,012	3,267	3,623	311	915			61,868
1981	24,446	35,527	3,456	3,202	251	964	33		67,879
1982	22,729	40,025	5,272	2,438	187	1,296	1,278		73,225
1983	20,583	44,822	4,281	1,261	107	1,353	2,424		74,831
1984	23,448	46,342	4,122	939	100	1,424	3,132		79,507
1985	26,087	48,322	4,554	853	43	1,641	3,852		85,352
1986	19,876	53,247	5,866	600	63	3,394	6,337		89,383
1987	18,200	58,298	7,440	602	63	4,418	7,289		96,310
1988	20,777	60,838	7,047	474	73	4,661	8,035		101,905
1989	24,199	65,087	7,150	629	98	4,675	7,890	372	110,100
1990 *1	23,333	66,915	7,487	669	77	5,124	7,774	2,938	114,317

Note : *1 Preliminary numbers
*2 Including total generation, import and interchanges
Source : INFORME ANUAL 1990, CFE

TABLE 2.3 CONSUMPTION OF FUELS

Unit: 10^12 kilocalories

YEAR	OIL	DIESEL	MIXED OIL	GAS	CARBON	TOTAL
1974	42.0	6.5	0.10	15.0	0.60	64.2
1975	45.9	11.9	0.20	21.1	0.50	79.5
1976	54.0	10.7	0.30	17.2	0.60	82.8
1977	60.5	8.3	0.30	16.5	0.60	86.2
1978	77.0	16.5	0.30	21.3		115.1
1979	70.8	11.2	0.30	30.6		112.9
1980	86.7	10.9	0.20	30.1		127.9
1981	90.7	10.5	0.20	25.6	0.04	127.1
1982	97.2	8.0	0.05	28.2	3.00	136.5
1983	110.7	3.0		23.3	6.00	142.9
1984	119.9	3.9		18.7	7.40	149.9
1985	123.2	2.6		19.6	8.90	154.3
1986	131.7	2.1		25.5	14.70	174.0
1987	144.4	3.2		27.5	16.80	191.9
1988	150.7	1.9		25.6	18.40	196.5
1989	159.6	2.9		27.0	18.60	208.1
1990 *1	157.5	3.7		34.3	18.20	213.7

Note : *1 Preliminary numbers
Source : INFORME ANUAL 1990, CFE

TABLE 2.4 INSTALLATION OF TRANSMISSION AND DISTRIBUTION LINES

	Voltage (kV)	Length of Transmission and Distribution Line (km) 1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
CFE	400	5,997	6,035	6,080	6,287	7,610	7,827	7,906	8,380	8,810	9,099
	230	9,581	10,801	10,892	11,515	12,237	13,174	13,380	15,283	16,090	16,417
	161	1,035	1,062	1,066	1,166	920	924	947	949	948	764
	150	875	875	875	868	868	791	774	775	775	774
	138	918	1,056	1,056	1,068	1,068	1,203	1,132	1,168	1,160	1,185
	115	22,172	22,937	23,721	25,474	27,757	27,299	27,034	28,089	29,240	29,827
	85	360	328	328	391	392	385	412	271	244	244
	69	5,190	5,384	5,609	5,114	5,002	4,924	4,842	4,606	4,379	4,236
	44	472	242	242	242	242	160	161	11	11	8
	35	20,345	33,459	34,239	35,347	36,417	39,497	43,437	45,361	46,607	47,393
	23	12,387	14,357	14,796	15,253	15,576	13,034	14,368	15,006	15,637	16,264
	13.8	96,254	125,903	130,063	132,613	136,312	145,110	157,596	157,489	164,175	169,534
	6.6	2,114	1,133	1,133	1,135	1,556	1,355	1,783	1,828	1,863	1,563
	SUBTOTAL	177,700	223,572	230,100	236,473	245,957	255,683	273,772	279,216	289,939	297,308
CLFC	400	225	291	291	291	291	291	291	342	379	379
	230	786	786	786	834	842	842	851	851	888	918
	150	8	8	8	8	8	8	8	8	8	9
	115	0	0	0	0	0	72	72	72	109	109
	85	2,069	2,074	2,274	2,275	2,275	2,068	2,088	2,092	1,905	1,718
	23	7,421	7,688	7,938	8,279	8,717	9,199	9,470	9,691	9,865	10,140
	13.8	0	0	0	0	0	854	861	862	904	904
	6.6	5,225	5,101	5,090	4,997	4,972	4,695	4,679	4,650	4,632	4,721
	SUBTOTAL	15,734	15,948	16,387	16,684	17,105	18,029	18,320	18,568	18,690	18,898
	TOTAL	193,434	239,520	246,487	253,157	263,062	273,712	292,092	297,784	308,629	316,206

Source : INFORME ANUAL 1990, CFE

TABLE 2.5 CAPACITY OF SUBSTATION

Type of Substation	Capacity of Substation (MVA) 1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
Step-up	25,212	26,847	28,407	30,312	30,420	30,420	31,343	33,472	34,322	34,650
Step-down	35,273	41,013	44,901	46,188	47,041	47,273	48,065	57,107	60,367	54,274
CLFC	10,890	11,646	12,278	13,657	14,187	14,301	14,991	15,088	15,278	16,273
Total	71,375	79,506	85,586	90,157	91,648	91,994	94,399	105,667	109,967	105,197

Source : INFORME ANUAL 1990, CFE

TABLE 2.6 RURAL ELECTRIFICATION

Year	Habitants	Rural Centers	Total Length of Distribution Lines (km)	Line Postes
1974	495,976	993	3,236	43,496
1975	988,857	1,976	6,068	87,896
1976	868,188	1,781	5,097	74,461
1977	612,816	1,321	3,342	53,106
1978	584,983	1,207	3,161	48,631
1979	1,209,967	2,137	4,925	92,896
1980	1,150,599	2,324	5,465	96,406
1981	945,330	2,268	6,051	103,588
1982	870,073	1,863	5,656	78,311
1983	855,589	1,848	3,613	67,863
1984	1,096,678	2,258	4,021	92,112
1985	1,481,821	2,926	4,699	99,722
1986	939,112	2,144	3,905	65,626
1987	728,566	1,718	2,917	56,518
1988	1,003,065	2,582	4,662	77,104
1989	1,229,220	2,827	4,330	89,131
1990	1,348,246	3,539	3,562	99,953

Note : In the population centers electrified, rural villages, expanded villages and colonies are taken into account.
Source : INFORME ANUAL 1990, CFE

TABLE 2.7 ENERGY SALES

Unit: GWh

Year	Residentical	Commercial	Industrial	Service	Agriculture	Total
1974	5,509	4,073	17,752	2,453	2,069	32,054
1975	6,056	4,224	19,202	2,619	2,257	34,567
1976	6,706	4,429	21,205	2,891	2,437	37,888
1977	7,362	4,657	23,085	3,160	2,652	41,159
1978	8,269	5,022	25,271	3,296	2,935	45,058
1979	9,210	5,404	27,521	3,437	3,328	49,197
1980	10,038	5,821	28,744	3,667	3,746	52,301
1981	11,211	6,665	31,731	3,932	3,842	57,044
1982	12,511	6,657	33,254	4,220	4,801	61,457
1983	12,979	6,526	34,300	3,888	4,440	62,217
1984	13,411	6,718	37,471	3,894	4,646	66,233
1985	14,285	7,004	40,115	4,131	4,962	70,614
1986	15,079	7,057	40,948	4,332	5,413	74,288
1987	15,712	7,155	44,071	4,506	6,006	79,491
1988	16,825	7,303	46,893	4,456	6,409	83,881
1989	18,813	7,798	50,284	4,426	7,216	90,469
1990	20,389	8,265	52,213	4,549	6,707	94,069

Note : "Commercial" includes services for maize mill factories.
"Service" includes temporary services.
"Total" includes sales in tariff 10 and export.
Source : INFORME ANUAL 1990, CFE

TABLE 2.8 NUMBER OF CONSUMERS

Unit : 1,000 Nos.

Year	Residentical	Commercial	Industrial	Service	Agriculture	Total
1974	5,844	945	18	32	18	6,857
1975	6,255	978	20	36	20	7,309
1976	6,618	1,005	22	38	24	7,707
1977	6,978	1,044	24	36	27	8,109
1978	7,168	1,055	24	35	29	8,311
1979	7,626	1,121	27	38	32	8,844
1980	8,143	1,178	30	41	37	9,429
1981	8,730	1,233	33	45	41	10,082
1982	9,331	1,294	36	48	45	10,754
1983	9,923	1,350	39	49	49	11,410
1984	10,434	1,401	41	52	53	11,981
1985	10,959	1,443	43	55	57	12,557
1986	11,568	1,485	45	57	60	13,215
1987	12,134	1,515	47	59	65	13,820
1988	12,707	1,555	50	62	69	14,443
1989	13,313	1,625	53	65	73	15,129
1990	13,952	1,712	56	69	76	15,865

Note : "Commercial" includes services for maize mill factories.
"Service" includes temporary services.
Source : INFORME ANUAL 1990, CFE

TABLE 2.9 UNIT CONSUMPTION OF ENERGY

Unit : kWh/nos.

Year	Residentical	Commercial	Industrial	Service	Agriculture
1974	79	359	81,255	6,352	9,409
1975	81	360	80,451	6,139	8,905
1976	84	367	80,498	6,361	8,337
1977	88	372	82,033	7,312	8,173
1978	96	397	86,724	7,821	8,372
1979	101	402	85,979	7,504	8,558
1980	103	412	80,318	7,432	8,551
1981	107	451	79,675	7,360	7,823
1982	112	429	76,505	7,368	8,836
1983	109	403	73,255	6,608	7,523
1984	107	400	75,721	6,243	7,278
1985	109	404	77,411	6,269	7,302
1986	109	396	75,216	6,327	7,485
1987	108	394	77,433	6,343	7,711
1988	110	391	78,312	5,999	7,707
1989	118	399	79,947	5,684	8,214
1990	122	402	77,981	5,496	7,326

Note : "Commercial" includes services for maize mill factories.
"Service" includes temporary services.
Source : INFORME ANUAL 1990, CFE

TABLE 2.10 ELECTRICITY DEMAND 1970-1990

Year	Required Energy				Sales		GDP		IBF			Population	
	Gross		Net								IBF/GDP		
	(GWh)	(%)	(GWh)	(%)	(GWh)	(%)	($80*10^9)	(%)	($80*10^9)	(%)	(%)	(10^3)	(%)
1970	26,030		25,434		21,758		2,396.1		497.2		20.75	51,176	
1971	28,693	10.2	27,808	9.3	23,705	8.9	2,496.0	4.17	488.7	-1.71	19.58	52,884	3.34
1972	31,805	10.8	30,864	11.0	26,412	11.4	2,707.9	8.49	548.5	12.24	20.25	54,661	3.36
1973	34,781	9.4	33,789	9.5	29,021	9.9	2,934.4	8.37	629.3	14.75	21.45	56,481	3.33
1974	38,407	10.4	37,455	10.8	32,152	10.8	3,115.0	6.15	679.1	7.90	21.80	58,320	3.26
1975	41,228	7.3	40,017	6.8	35,419	10.2	3,289.7	5.61	742.0	9.27	22.55	60,153	3.14
1976	44,927	9.0	43,591	8.9	38,211	7.9	3,429.2	4.24	745.3	0.45	21.73	61,979	3.04
1977	49,010	9.1	47,247	8.4	41,517	8.7	3,547.2	3.44	695.3	-6.71	19.60	63,813	2.96
1978	53,048	8.2	51,067	8.1	45,423	9.4	3,839.9	8.25	800.8	15.17	20.85	65,658	2.89
1979	58,087	9.5	55,608	8.9	49,429	8.8	4,191.4	9.15	962.9	20.25	22.97	67,517	2.83
1980	62,490	7.6	59,937	7.8	52,658	6.5	4,540.3	8.25	1,106.8	14.94	24.38	69,393	2.78
1981	68,213	9.2	65,699	9.6	57,455	9.1	4,901.2	7.95	1,286.4	16.23	26.25	71,284	2.73
1982	73,222	7.3	70,292	7.0	61,479	7.0	4,874.6	-0.54	1,070.4	-16.79	21.96	73,188	2.67
1983	74,843	2.2	71,518	1.7	62,099	1.0	4,617.5	-5.27	767.7	-28.28	16.63	75,107	2.62
1984	79,538	6.3	76,007	6.3	66,333	6.8	4,787.3	3.68	817.0	6.43	17.07	77,043	2.58
1985	85,514	7.5	81,656	7.4	70,652	6.5	4,920.4	2.78	881.2	7.85	17.91	78,996	2.53
1986	89,500	4.7	85,282	4.4	74,331	5.2	4,735.7	-3.75	777.2	-11.80	16.41	80,970	2.50
1987	96,488	7.8	91,846	7.7	79,532	7.0	4,817.7	1.73	775.2	-0.26	16.09	82,966	2.47
1988	102,096	5.8	97,160	5.8	83,925	5.5	4,884.2	1.38	821.6	5.99	16.82	84,976	2.42
1989	110,726	8.5	105,449	8.5	90,665	8.0	5,037.8	3.14	870.4	5.94	17.28	86,993	2.37
1990	115,000	3.9	109,316	3.7	94,285	4.0	5,234.2	3.90	961.8	10.50	18.38	89,012	2.32

Source: DESARROLLO DEL MERCADO ELECTRICO 1986-2000, CFE

TABLE 2.11 ELECTRICITY DEMAND FORECAST 1991-2000

Year	Required Energy				Sales		GDP		IBF			Population	
	Gross			Net			($80*		($80*		IBF/GDP		
	(GWh)	(%)	(GWh)	(%)	(GWh)	(%)	10^9)	(%)	10^9)	(%)	(%)	(10^3)	(%)
						Medium Scenario							
1991	120,679	4.9	114,844	5.1	98,885	4.9	5,433.1	3.80	1,049.9	9.16	19.32	91,036	2.27
1992	129,673	7.5	123,597	7.6	106,539	7.7	5,740.1	5.65	1,163.6	10.83	20.27	93,070	2.23
1993	139,083	7.3	132,386	7.1	114,190	7.2	6,064.4	5.65	1,274.1	9.50	21.01	95,107	2.19
1994	149,656	7.6	142,249	7.4	122,728	7.5	6,407.0	5.65	1,391.5	9.21	21.72	97,141	2.14
1995	160,354	7.1	152,471	7.2	131,559	7.2	6,727.4	5.00	1,487.1	6.87	22.10	99,165	2.08
1996	171,929	7.2	163,595	7.3	141,154	7.3	7,063.7	5.00	1,577.3	6.07	22.33	101,178	2.03
1997	183,669	6.8	174,746	6.8	150,720	6.8	7,416.9	5.00	1,677.0	6.32	22.61	103,191	1.99
1998	195,790	6.6	186,083	6.5	160,286	6.3	7,787.8	5.00	1,787.9	6.61	22.96	105,193	1.94
1999	210,231	7.4	199,961	7.5	172,380	7.5	8,177.2	5.00	1,901.4	6.35	23.25	107,192	1.90
2000	225,883	7.4	215,209	7.8	185,515	7.6	8,586.0	5.00	2,018.2	6.14	23.51	109,180	1.86
Ave.		7.0		7.0		7.0		5.10		7.70			2.10
						High Scenario							
1991	121,038	5.3	115,186	5.4	99,179	5.2	5,469.7	4.50	1,070.8	11.33	19.58	91,036	2.27
1992	130,343	7.7	124,236	7.9	107,909	8.0	5,797.9	6.00	1,200.5	12.12	20.71	93,070	2.23
1993	140,168	7.5	133,419	7.4	115,081	7.5	6,145.8	6.00	1,325.4	10.40	21.57	95,107	2.19
1994	151,282	7.9	143,795	7.8	124,062	7.8	6,514.5	6.00	1,458.3	10.03	22.39	97,141	2.14
1995	162,779	7.6	154,777	7.6	133,549	7.6	6,872.8	5.50	1,575.9	8.06	22.93	99,165	2.08
1996	175,369	7.7	166,868	7.8	143,978	7.8	7,250.9	5.50	1,690.0	7.24	23.31	101,178	2.03
1997	188,378	7.4	179,226	7.4	154,584	7.4	7,649.7	5.50	1,814.7	7.38	23.72	103,191	1.99
1998	202,076	7.3	192,057	7.2	165,432	7.0	8,070.4	5.50	1,952.2	7.58	24.19	105,193	1.94
1999	218,431	8.1	207,761	8.2	179,104	8.3	8,514.3	5.50	2,093.6	7.24	24.59	107,192	1.90
2000	236,389	8.2	225,219	8.4	194,144	8.4	8,982.5	5.50	2,239.3	6.96	24.93	109,180	1.86
Ave.		7.5		7.5		7.5		5.60		8.80			2.10
						Low Scenario							
1991	120,269	4.6	114,454	4.7	98,549	4.5	5,391.2	3.00	1,026.2	6.70	19.04	91,036	2.27
1992	128,945	7.2	122,903	7.4	105,941	7.5	5,677.0	5.30	1,123.8	9.51	19.80	93,070	2.23
1993	137,937	7.0	131,295	6.8	113,249	6.9	5,977.8	5.30	1,220.9	8.64	20.42	95,107	2.19
1994	147,974	7.3	140,650	7.1	121,349	7.2	6,294.7	5.30	1,323.8	8.43	21.03	97,141	2.14
1995	157,900	6.7	150,137	6.7	129,545	6.8	6,577.9	4.50	1,399.6	5.72	21.28	99,165	2.08
1996	168,515	6.7	160,347	6.8	138,351	6.8	6,873.9	4.50	1,468.7	4.94	21.37	101,178	2.03
1997	179,072	6.3	170,372	6.3	146,948	6.2	7,183.3	4.50	1,546.3	5.28	21.53	103,191	1.99
1998	189,749	6.0	180,342	5.9	155,341	5.7	7,506.5	4.50	1,633.6	5.65	21.76	105,193	1.94
1999	202,463	6.7	192,572	6.8	166,010	6.9	7,844.3	4.50	1,723.0	5.47	21.96	107,192	1.90
2000	216,064	6.7	205,854	6.9	177,451	6.9	8,197.3	4.50	1,814.6	5.32	22.14	109,180	1.86
Ave.		6.5		6.5		6.5		4.60		6.60			2.10

Source: DESARROLLO DEL MERCADO ELECTRICO 1986-2000, CFE

TABLE 2.12 POWER BALANCE OF THE NATIONAL INTERCONNECTED SYSTEM (1/6)

JANUARY

TIME ZONE	E5	E4	E3	E2	E1	DAILY	MONTHLY
DURATION	1	3	11	7	2		
NUCLEAR	591.6	591.6	591.6	591.6	591.6	14,198	440,150
GEOTHERMAL	92.8	92.8	92.8	92.8	92.8	2,227	69,043
COAL FIRED THERMAL	1335.9	1335.9	1335.9	1335.9	1335.9	32,062	993,910
COMBINED CYCLE	1080.6	1080.6	1080.6	1080.3	939.8	25,651	795,172
MAJOR THERMAL IV	685.5	685.5	685.5	685.5	685.5	16,452	510,012
MAJOR THERMAL III	940.3	940.3	940.3	940.3	798.4	22,283	690,785
MAJOR THERMAL II	1697.8	1494.7	1190.7	1147.2	1004.4	29,319	908,883
MAJOR THERMAL I	4037.2	3967.5	3981.7	3467.2	3319.3	90,647	2,810,069
MINOR THERMAL	405.9	339.8	347.3	316.8	256	7,975	247,231
GAS TURBINE	593.5	170.8	0	0	0	1,106	34,283
THERMAL POWER TOTAL	11461.1	10699.5	10246.4	9657.6	9023.7	241,921	7,499,539
MAJOR HYDRO	691.9	520.9	475.9	394.6	164.7	10,581	328,014
MINOR HYDRO	1703.7	1668.2	745.5	134.1	68	15,984	495,489
GRIJALVA HYDRO SYS.	2629.8	1936.1	1571.1	584	0	29,808	924,054
HYDRO POWER TOTAL	5025.4	4125.2	2792.5	1112.7	232.7	56,373	1,747,557
GENERAC. TOTAL	16486.5	14824.7	13038.9	10770.3	9256.4	298,293	9,247,095
% DURATION ANNUALLY	94.16%	84.67%	74.47%	61.51%	52.87%		
MONTHLY	100.00%	89.92%	79.09%	65.33%	56.15%	L.F.=	75.39%

FEBRUARY

TIME ZONE	E5	E4	E3	E2	E1	DAILY	MONTHLY
DURATION	1	3	11	7	2		
NUCLEAR	591.6	591.6	591.6	591.6	591.6	14,198	397,555
GEOTHERMAL	90.5	90.5	90.5	90.5	90.5	2,172	60,816
COAL FIRED THERMAL	1136.7	1136.7	1136.7	1136.7	1136.7	27,281	763,862
COMBINED CYCLE	981	981	981	980.5	963.7	23,506	658,165
MAJOR THERMAL IV	640.7	640.7	640.7	640.7	640.7	15,377	430,550
MAJOR THERMAL III	662.3	662.3	662.3	662.3	650.8	15,872	444,422
MAJOR THERMAL II	1763.1	1744.4	1520.4	1287.5	1243	35,219	986,138
MAJOR THERMAL I	4402.5	4296.1	4250.6	3750.6	3628.5	97,559	2,731,641
MINOR THERMAL	448	369.2	384.8	350.8	310.1	8,864	248,198
GAS TURBINE	585.9	146.8	7.2	0	0	1,106	30,954
THERMAL POWER TOTAL	11302.3	10659.3	10265.8	9491.2	9255.6	241,154	6,752,301
MAJOR HYDRO	933.2	767.2	723.2	644.2	471.4	16,642	465,982
MINOR HYDRO	1675.9	1608.5	761.9	163.4	113.6	16,253	455,092
GRIJALVA HYDRO SYS.	2700.3	1873.5	1558.4	675.9	0	30,195	845,446
HYDRO POWER TOTAL	5309.4	4249.2	3043.5	1483.5	585	63,090	1,766,520
GENERAC. TOTAL	16611.7	14908.5	13309.3	10974.7	9840.6	304,244	8,518,821
% DURATION ANNUALLY	94.88%	85.15%	76.01%	62.68%	56.20%		
MONTHLY	100.00%	89.75%	80.12%	66.07%	59.24%	L.F.=	76.31%

TABLE 2.12 POWER BALANCE OF THE NATIONAL INTERCONNECTED SYSTEM (2/6)

MARCH

TIME ZONE	E5	E4	E3	E2	E1	DAILY	MONTHLY
DURATION	1	3	11	7	2		
NUCLEAR	591.6	591.6	591.6	591.6	591.6	14,198	440,150
GEOTHERMAL	91.3	91.3	91.3	91.3	91.3	2,191	67,927
COAL FIRED THERMAL	1362.4	1362.4	1362.4	1362.4	1362.4	32,698	1,013,626
COMBINED CYCLE	1020.6	1020.6	1020.6	1020.1	1020.1	24,490	759,187
MAJOR THERMAL IV	442.8	442.8	442.8	442.8	442.8	10,627	329,443
MAJOR THERMAL III	922.4	922.4	922.4	922.4	922.4	22,138	686,266
MAJOR THERMAL II	1599.2	1590.4	1573.2	1176.8	1166.2	34,246	1,061,614
MAJOR THERMAL I	4516.3	4432	4405.1	3847.7	3704	100,610	3,118,919
MINOR THERMAL	470.7	409.7	424	392.5	356.7	9,825	304,566
GAS TURBINE	602.8	167.7	0	0	0	1,106	34,283
THERMAL POWER TOTAL	11620.1	11030.9	10833.4	9847.6	9657.5	252,128	7,815,980
MAJOR HYDRO	849.6	717.6	682.6	605.3	448.6	15,645	485,004
MINOR HYDRO	1681.4	1605.4	655	168.2	127.7	15,135	469,197
GRIJALVA HYDRO SYS.	2879.3	2025.2	1665.6	959.6	155	34,304	1,063,415
HYDRO POWER TOTAL	5410.3	4348.2	3003.2	1733.1	731.3	65,084	2,017,616
GENERAC. TOTAL	17030.4	15379.1	13836.6	11580.7	10388.8	317,213	9,833,597
% DURATION ANNUALLY	97.27%	87.84%	79.03%	66.14%	59.33%		
MONTHLY	100.00%	90.30%	81.25%	68.00%	61.00%	L.F.=	77.61%

APRIL

TIME ZONE	E5	E4	E3	E2	E1	DAILY	MONTHLY
DURATION	1	3	11	7	2		
NUCLEAR	591.6	591.6	591.6	591.6	591.6	14,198	425,952
GEOTHERMAL	86.9	86.9	86.9	86.9	86.9	2,086	62,568
COAL FIRED THERMAL	1275.4	1275.4	1275.4	1275.4	1275.4	30,610	918,288
COMBINED CYCLE	1235.9	1235.9	1235.9	1235.3	1235.3	29,656	889,686
MAJOR THERMAL IV	587.4	587.4	587.4	587.4	587.4	14,098	422,928
MAJOR THERMAL III	822.2	822.2	822.2	822.2	822.2	19,733	591,984
MAJOR THERMAL II	1737.9	1730.2	1634.2	1229.1	1209.8	35,928	1,077,840
MAJOR THERMAL I	4302.7	4254.6	4159.5	3638.3	3479.7	95,249	2,857,455
MINOR THERMAL	469.2	468.7	418.6	365.2	302.5	9,641	289,239
GAS TURBINE	559.3	182.2	0	0	0	1,106	33,177
THERMAL POWER TOTAL	11668.5	11235.1	10811.7	9831.4	9590.8	252,304	7,569,117
MAJOR HYDRO	853.8	746.8	698.8	566.6	443.1	15,633	469,002
MINOR HYDRO	1651.7	1548.5	730.8	111.1	57	15,228	456,831
GRIJALVA HYDRO SYS.	3240.5	2324.2	1872.4	1152.8	113.4	39,106	1,173,177
HYDRO POWER TOTAL	5746	4619.5	3302	1830.5	613.5	69,967	2,099,010
GENERAC. TOTAL	17414.5	15854.6	14113.7	11661.9	10204.3	322,271	9,668,127
% DURATION ANNUALLY	99.46%	90.55%	80.61%	66.61%	58.28%		
MONTHLY	100.00%	91.04%	81.05%	66.97%	58.60%	L.F.=	77.11%

TABLE 2.12 POWER BALANCE OF THE NATIONAL INTERCONNECTED SYSTEM (3/6)

MAY

TIME ZONE	E5	E4	E3	E2	E1	DAILY	MONTHLY
DURATION	1	3	11	7	2		
NUCLEAR	591.6	591.6	591.6	591.6	591.6	14,198	440,150
GEOTHERMAL	91.4	91.4	91.4	91.4	91.4	2,194	68,002
COAL FIRED THERMAL	1456.2	1456.2	1456.2	1456.2	1456.2	34,949	1,083,413
COMBINED CYCLE	1042.9	1042.4	1056.7	1038.3	1038.3	25,139	779,294
MAJOR THERMAL IV	501.6	501.6	501.6	501.6	501.6	12,038	373,190
MAJOR THERMAL III	787.9	787.9	787.9	787.9	787.9	18,910	586,198
MAJOR THERMAL II	1949.7	1947.4	1929.9	1403	1387.6	41,617	1,290,127
MAJOR THERMAL I	4446.5	4401.8	4348.5	3976.5	3679.3	100,680	3,121,065
MINOR THERMAL	557.5	510.8	482.4	456.1	415	11,419	353,989
GAS TURBINE	518.8	195.7	0	0	0	1,106	34,283
THERMAL POWER TOTAL	11944.1	11526.8	11246.2	10302.6	9948.9	262,249	8,129,710
MAJOR HYDRO	828.5	734.5	699.5	625.5	447.8	16,001	496,019
MINOR HYDRO	1706.3	1617.9	781.1	159.5	104.1	16,477	510,781
GRIJALVA HYDRO SYS.	3030.2	2276.9	1796.9	1151.1	443.8	38,572	1,195,735
HYDRO POWER TOTAL	5565	4629.3	3277.5	1936.1	995.7	71,050	2,202,535
GENERAC. TOTAL	17509.1	16156.1	14523.7	12238.7	10944.6	333,298	10,332,244
% DURATION ANNUALLY	100.00%	92.27%	82.95%	69.90%	62.51%		
MONTHLY	100.00%	92.27%	82.95%	69.90%	62.51%	L.F.=	79.32%

JUNE

TIME ZONE	E5	E4	E3	E2	E1	DAILY	MONTHLY
DURATION	1	3	11	7	2		
	1	2	3	4	5		
NUCLEAR	591.6	591.6	591.6	591.6	591.6	14,198	425,952
GEOTHERMAL	85.5	85.5	85.5	85.5	85.5	2,052	61,560
COAL FIRED THERMAL	1613.2	1613.2	1613.2	1613.2	1613.2	38,717	1,161,504
COMBINED CYCLE	1094	1094	1094	1093.3	1090.5	26,244	787,323
MAJOR THERMAL IV	605.8	605.8	605.8	605.8	605.8	14,539	436,176
MAJOR THERMAL III	940.3	940.3	940.3	940.3	940.3	22,567	677,016
MAJOR THERMAL II	1563.5	1183.1	1183.1	1183.1	1183.1	28,775	863,244
MAJOR THERMAL I	4822.9	4778.5	4746	4148.2	3998.4	108,399	3,251,958
MINOR THERMAL	460.1	459.9	482.8	430.4	361.9	10,887	326,616
GAS TURBINE	489.2	196.9	2.8	0	0	1,111	33,321
THERMAL POWER TOTAL	12266.1	11548.8	11345.1	10691.4	10470.3	267,489	8,024,670
MAJOR HYDRO	1210.6	1109.6	1073.6	1002.1	818.6	25,001	750,027
MINOR HYDRO	1637.5	1581.1	805.1	218.1	105.3	16,974	509,226
GRIJALVA HYDRO SYS.	2315.5	1895.3	1605	742.8	0	30,856	925,680
HYDRO POWER TOTAL	5163.6	4586	3483.7	1963	923.9	72,831	2,184,933
GENERAC. TOTAL	17429.7	16134.8	14828.8	12654.4	11394.2	340,320	10,209,603
% DURATION ANNUALLY	99.55%	92.15%	84.69%	72.27%	65.08%		
MONTHLY	100.00%	92.57%	85.08%	72.60%	65.37%	L.F.=	81.36%

TABLE 2.12 POWER BALANCE OF THE NATIONAL INTERCONNECTED SYSTEM (4/6)

JULY

TIME ZONE	E5	E4	E3	E2	E1	DAILY	MONTHLY
DURATION	1	3	11	7	2		
NUCLEAR	591.6	591.6	591.6	591.6	591.6	14,198	440,150
GEOTHERMAL	92.7	92.7	92.7	92.7	92.7	2,225	68,969
COAL FIRED THERMAL	1659.4	1659.4	1659.4	1659.4	1659.4	39,826	1,234,594
COMBINED CYCLE	1062.3	1062.3	1062.3	1061.7	882.7	25,132	779,086
MAJOR THERMAL IV	564.2	564.2	564.2	564.2	564.2	13,541	419,765
MAJOR THERMAL III	779.7	779.7	779.7	779.7	605.3	18,364	569,284
MAJOR THERMAL II	1458.4	1345.4	1345.4	1345.4	1239.1	32,190	997,890
MAJOR THERMAL I	4718.7	4595.9	4334.6	4058	3939.5	102,472	3,176,632
MINOR THERMAL	432.9	432.1	461.4	419.2	359.7	10,458	324,210
GAS TURBINE	515.7	198.3	0	0	0	1,111	34,429
THERMAL POWER TOTAL	11875.6	11321.6	10891.3	10571.9	9934.2	259,516	8,045,008
MAJOR HYDRO	1269.4	1114.4	1075.4	992.8	868.8	25,129	779,005
MINOR HYDRO	1716.9	1693.1	968.7	297.9	150.4	19,838	614,978
GRIJALVA HYDRO SYS.	2176.9	1611.2	1391.3	260	0	24,135	748,179
HYDRO POWER TOTAL	5163.2	4418.7	3435.4	1550.7	1019.2	69,102	2,142,162
GENERAC. TOTAL	17038.8	15740.3	14326.7	12122.6	10953.4	328,618	10,187,170
% DURATION ANNUALLY	97.31%	89.90%	81.82%	69.24%	62.56%		
MONTHLY	100.00%	92.38%	84.08%	71.15%	64.29%	L.F.=	80.36%

AUGUST

TIME ZONE	E5	E4	E3	E2	E1	DAILY	MONTHLY
DURATION	1	3	11	7	2		
NUCLEAR	267.2	267.2	267.2	267.2	267.2	6,413	198,797
GEOTHERMAL	88.7	88.7	88.7	88.7	88.7	2,129	65,993
COAL FIRED THERMAL	1516.4	1516.4	1516.4	1516.4	1516.4	36,394	1,128,202
COMBINED CYCLE	1229	1229	1244.2	1228.3	1087.9	29,376	910,659
MAJOR THERMAL IV	685.5	685.5	685.5	685.5	685.5	16,452	510,012
MAJOR THERMAL III	683	683	683	683	543.8	16,114	499,522
MAJOR THERMAL II	1648.5	1351.3	1351.3	1351.3	1351.3	32,728	1,014,580
MAJOR THERMAL I	5210.7	5200.8	4871.5	4438.8	4324.5	114,120	3,537,726
MINOR THERMAL	458.9	458.6	468.4	448.4	386.2	10,898	337,847
GAS TURBINE	545.5	188.3	0	0	0	1,110	34,422
THERMAL POWER TOTAL	12333.4	11668.8	11176.2	10707.6	10251.5	265,734	8,237,760
MAJOR HYDRO	1150.5	1013.5	978.5	900.2	759.2	22,774	706,003
MINOR HYDRO	1711.6	1660.6	911.6	234.6	61.2	18,486	573,054
GRIJALVA HYDRO SYS.	2116.1	1635.4	1394.9	433.4	0	25,400	787,400
HYDRO POWER TOTAL	4978.2	4309.5	3285	1568.2	820.4	66,660	2,066,457
GENERAC. TOTAL	17311.6	15978.3	14461.2	12275.8	11071.9	332,394	10,304,217
% DURATION ANNUALLY	98.87%	91.26%	82.59%	70.11%	63.24%		
MONTHLY	100.00%	92.30%	83.53%	70.91%	63.96%	L.F.=	80.00%

TABLE 2.12 POWER BALANCE OF THE NATIONAL INTERCONNECTED SYSTEM (5/6)

SEPTEMBER

TIME ZONE	E5	E4	E3	E2	E1	DAILY	MONTHLY
DURATION	1	3	11	7	2		
NUCLEAR	39.4	39.4	39.4	39.4	39.4	946	28,368
GEOTHERMAL	91.8	91.8	91.8	91.8	91.8	2,203	68,299
COAL FIRED THERMAL	1416	1416	1416	1416	1416	33,984	1,053,504
COMBINED CYCLE	1242.7	1242.7	1242.7	1242	1125	29,585	917,120
MAJOR THERMAL IV	560.1	560.1	560.1	560.1	560.1	13,442	416,714
MAJOR THERMAL III	932.3	932.3	932.3	932.3	768.3	22,047	683,463
MAJOR THERMAL II	1815.3	1363.1	1363.1	1363.1	1363.1	33,167	1,028,165
MAJOR THERMAL I	5168.1	5146.8	4995.8	4410	4277.3	114,987	3,564,594
MINOR THERMAL	471.1	407.7	429.6	393.3	313.4	9,800	303,791
GAS TURBINE	582.8	175.9	0	0	0	1,111	34,426
THERMAL POWER TOTAL	12319.6	11375.8	11070.8	10448	9954.4	261,271	7,838,118
MAJOR HYDRO	992.4	820.4	778.4	702.5	533.4	18,000	540,009
MINOR HYDRO	1725.1	1708.1	1005	261.4	50	19,834	595,026
GRIJALVA HYDRO SYS.	2433	1954	1354.1	593.8	0	27,347	820,401
HYDRO POWER TOTAL	5150.5	4482.5	3137.5	1557.7	583.4	65,181	1,955,436
GENERAC. TOTAL	17470.1	15858.3	14208.3	12005.7	10537.8	326,452	9,793,554
% DURATION ANNUALLY	99.78%	90.57%	81.15%	68.57%	60.19%		
MONTHLY	100.00%	90.77%	81.33%	68.72%	60.32%	L.F.=	77.86%

OCTOBER

TIME ZONE	E5	E4	E3	E2	E1	DAILY	MONTHLY
DURATION	1	3	11	7	2		
NUCLEAR	591.6	591.6	591.6	591.6	591.6	14,198	440,150
GEOTHERMAL	93.1	93.1	93.1	93.1	93.1	2,234	69,266
COAL FIRED THERMAL	1516.4	1516.4	1516.4	1516.4	1516.4	36,394	1,128,202
COMBINED CYCLE	1248	1248	1248	1247.4	1106.9	29,666	919,634
MAJOR THERMAL IV	604.6	604.6	604.6	604.6	604.6	14,510	449,822
MAJOR THERMAL III	926.3	926.3	926.3	926.3	476	21,331	661,249
MAJOR THERMAL II	1769.4	1353.4	1348.2	1277.4	1053.4	31,708	982,960
MAJOR THERMAL I	4875.4	4725.9	4537.6	4208.7	4131.6	106,691	3,307,415
MINOR THERMAL	396.3	395.4	400.6	358.5	321	9,141	283,359
GAS TURBINE	608.7	167.3	0	0	0	1,111	34,429
THERMAL POWER TOTAL	12629.8	11622	11266.4	10824	9894.6	266,983	8,276,485
MAJOR HYDRO	884.5	720.5	609.5	520.4	400.4	14,194	440,017
MINOR HYDRO	1704.5	1681.5	847.1	255.1	119.2	18,091	560,827
GRIJALVA HYDRO SYS.	2119.8	1766.8	1138	0	0	19,938	618,084
HYDRO POWER TOTAL	4708.8	4168.8	2594.6	775.5	519.6	52,224	1,618,929
GENERAC. TOTAL	17338.6	15790.8	13861	11599.5	10414.2	319,207	9,895,414
% DURATION ANNUALLY	99.03%	90.19%	79.17%	66.25%	59.48%		
MONTHLY	100.00%	91.07%	79.94%	66.90%	60.06%	L.F.=	76.71%

TABLE 2.12 POWER BALANCE OF THE NATIONAL INTERCONNECTED SYSTEM (6/6)

NOVEMBER

TIME ZONE	E5	E4	E3	E2	E1	DAILY	MONTHLY
DURATION	1	3	11	7	2		
NUCLEAR	591.6	591.6	591.6	591.6	591.6	14,198	425,952
GEOTHERMAL	89.4	89.4	89.4	89.4	89.4	2,146	64,368
COAL FIRED THERMAL	1416	1416	1416	1416	1416	33,984	1,019,520
COMBINED CYCLE	1183	1183	1183	1182.4	1065.4	28,153	844,578
MAJOR THERMAL IV	685.5	685.5	685.5	685.5	685.5	16,452	493,560
MAJOR THERMAL III	914.4	900.9	900.9	900.9	900.9	21,635	649,053
MAJOR THERMAL II	1464.3	1397.9	1173.6	1025.8	1017.5	27,783	833,496
MAJOR THERMAL I	4445.2	4386.5	4355.5	3837.4	3697.2	99,771	2,993,142
MINOR THERMAL	427.4	381.7	364	319.7	276.6	8,368	251,028
GAS TURBINE	603	169.2	0	0	0	1,111	33,318
THERMAL POWER TOTAL	11819.8	11201.7	10759.5	10048.7	9740.1	253,601	7,608,015
MAJOR HYDRO	848.3	652.3	530.3	447.3	298.3	12,366	370,986
MINOR HYDRO	1670.1	1642.1	739.9	202.5	82.8	16,318	489,552
GRIJALVA HYDRO SYS.	3072.4	2200.3	1628.5	600.6	0	31,791	953,730
HYDRO POWER TOTAL	5590.8	4494.7	2898.7	1250.4	381.1	60,476	1,814,268
GENERAC. TOTAL	17410.6	15696.4	13658.2	11299.1	10121.2	314,076	9,422,283
% DURATION ANNUALLY	99.44%	89.65%	78.01%	64.53%	57.81%		
MONTHLY	100.00%	90.15%	78.45%	64.90%	58.13%	L.F.=	75.16%

DECEMBER

TIME ZONE	E5	E4	E3	E2	E1	DAILY	MONTHLY
DURATION	1	3	11	7	2		
NUCLEAR	591.6	591.6	591.6	591.6	591.6	14,198	440,150
GEOTHERMAL	93.3	93.3	93.3	93.3	93.3	2,239	69,415
COAL FIRED THERMAL	1659.4	1659.4	1659.4	1659.4	1453.5	39,414	1,221,828
COMBINED CYCLE	1151.2	1151.2	1151.2	1052.7	1010.8	26,659	826,414
MAJOR THERMAL IV	685.5	685.5	685.5	685.5	685.5	16,452	510,012
MAJOR THERMAL III	787.9	787.9	787.9	787.9	412.6	18,159	562,929
MAJOR THERMAL II	1826.8	1371.1	1351.5	1082.7	935.6	30,257	937,958
MAJOR THERMAL I	4628.9	4566.8	4309	4164.5	3836.5	102,553	3,179,137
MINOR THERMAL	485.1	424.9	416.9	366.5	325.3	9,562	296,416
GAS TURBINE	598	169.3	0	0	0	1,106	34,283
THERMAL POWER TOTAL	12507.7	11501	11046.3	10484.1	9344.7	260,598	8,078,541
MAJOR HYDRO	644.7	462.7	356.7	287.9	110.9	8,194	254,002
MINOR HYDRO	1677.8	1648.8	659.2	160.3	86.2	15,170	470,267
GRIJALVA HYDRO SYS.	2214.9	1646.7	1024.1	0	0	18,420	571,023
HYDRO POWER TOTAL	4537.4	3758.2	2040	448.2	197.1	41,784	1,295,292
GENERAC. TOTAL	17045.1	15259.2	13086.3	10932.3	9541.8	302,382	9,373,833
% DURATION ANNUALLY	97.35%	87.15%	74.74%	62.44%	54.50%		
MONTHLY	100.00%	89.52%	76.77%	64.14%	55.98%	L.F.=	73.92%

Source : CFE

TABLE 2.13 POWER PLANTS COMPLETED IN 1990

	Project Name	Unit	Capacity (MW)
(A)	Power station entered into operation		
	Boca Pozos Azufres	#9	5
	Laguna Verde	#1	675
	TOTAL		680
(B)	Power Station in Preparation of Tests		
	Guadalupe Victoria	#1	160
	Filipe Carrillo Puerto (Valladolid)	#1	70
	Filipe Carrillo Puerto (Valladolid)	#2	70
	Presidente Juarez (Rasarito 11)	#1	160
	Adolfo Lopez Mateos	#1	350
	Adolfo Lopez Mateos	#2	350
	Boca Pozo Los Humeros	#1	5
	Boca Pozo Los Humeros	#2	5
	Boca Pozo Los Humeros	#3	5
	Boca Pozos Azufres	#8	5
	TOTAL		1,180

Source : INFORME ANUAL 1990, CFE

TABLE 2.14 TRANSMISSION LINES AND SUBSTATIONS COMPLETED IN 1990

Transmission Lines completed in 1990

Voltage	Length(km)
400 kV lines	67
230 kV lines	829
Lines less than 230 kV	828
Total	1,724

Substation completed in 1990

Voltage	Capacity(MVA)
Of 400 kV	815
Of 230 kV	350
Less than 230 kV	484
Total	1,649

Note : Exclude lines/substations in charge of Subdirection of Production and Distribution.
Source : INFORME ANUAL 1990, CFE

TABLE 2.15 POWER PLANTS UNDER CONSTRUCTION

PROJECT	UNIT *1	CAPACITY (MW)	LOCATION	DATE OF COMPLETION *2
Hydroelectric Power				
Agua Prieta	2	240	Zapopan, Jal.	Oct-91
Comedero	2	110	Cosala, Sin.	Jul-91
Aguamilpa	3	960	Tepic, Nay.	Jun-95
Zimapan	2	280	Zimzpan,Hgo.	Feb-95
Sub-total	9	1590		
Geothermal Power				
Boca Pozo Los Humanos	4	20	Chignautla, Pue.	*4
Boca Pozo Los Azufres	2	10	Zinapecuaro,Mich	Aug-90
Sub-total	6	30		
Oil Fired Thermal Power				
Adolfo Lopez Mateos *3	2	700	Tuxpan, Ver.	Feb-91
Guadalupe Victoria (lerdo)	2	320	Lerdo, Dgo.	May-91
Presidente Juarez (Rosarito II)	2	320	Tijuana, B.C.	Jul-91
San Carlos	2	65	Comondu, B.C.S.	Aug-91
Felipe Carrillo Puerto (Valladolid)	2	75	Valladolid, Yuc.	Sep-91
Petacalco *3	2	700	La Union, Gro.	May-93
Sub-total	12	2180		
Combined Cycle Thermal Power				
Felipe Carrillo Puerto (Valladolid)	3	220	Valladolid, Yuc.	Apr-91
Sub-total	3	220		
Coal Fired Thermal Power				
Carbon II *3	2	700	Nava, Coah.	Oct-92
Sub-total	2	700		
Nuclear Power				
Laguna Verde	1	675	Alto Lucero,Ver.	Jun-94
Sub-total	1	675		
TOTAL	32	5395		

Note : *1 Number of units which conform to total project, except Laguna Verde.
*2 Commercial entry of the latest unit of the project.
*3 1st stage
*4 Subject to delivery from turbo-generator on the part of supplier.

Source : INFORME ANUAL 1990, CFE

TABLE 3.1 RECORD OF GROSS ENERGY GENERATION OF MAZATEPEC POWER STATION

(Unit : MWh)

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
1962						740	24,790	11,066	32,614	47,440	27,691	21,260	165,601
1963	24,080	13,062	13,142	11,042	16,351	27,831	84,631	64,280	60,881	57,711	53,030	23,060	449,101
1964	28,371	21,311	15,693	14,989	29,361	61,790	71,652	43,341	36,941	68,813	52,033	61,753	506,048
1965	42,181	34,222	23,742	19,736	29,641	30,579	66,979	108,210	54,960	74,363	60,889	41,597	587,099
1966	26,882	17,667	22,183	22,501	31,132	34,658	101,190	69,252	80,912	107,620	81,364	30,552	625,913
1967	26,874	37,488	25,794	25,016	28,812	35,742	39,772	38,328	74,834	101,970	51,190	37,029	522,849
1968	36,079	17,460	23,663	22,900	37,741	44,755	71,912	75,037	81,070	72,354	52,354	39,204	574,529
1969	39,771	34,846	25,460	23,066	20,149	24,637	62,705	82,001	132,450	114,250	70,328	39,492	669,155
1970	35,993	32,486	38,203	26,883	34,470	44,468	66,952	83,621	79,245	99,942	47,251	29,534	619,048
MEAN	32,529	26,068	23,485	20,767	28,457	33,911	65,620	63,904	70,434	82,718	55,126	35,942	524,371
1971	31,060	24,250	24,890	30,190	29,300	38,400	61,810	65,500	59,200	116,190	106,500	44,500	631,790
1972	44,126	33,440	26,109	24,277	27,354	99,088	78,481	111,340	86,168	85,130	57,500	44,900	717,913
1973	32,600	20,730	22,880	24,640	31,280	42,610	101,290	125,790	113,660	88,880	57,760	46,320	708,440
1974	40,000	23,910	27,710	19,070	24,870	77,470	128,510	69,410	96,810	94,710	67,160	53,010	722,640
1975	40,480	30,400	26,810	22,880	25,890	49,470	63,760	64,600	92,990	115,840	48,220	46,080	627,420
1976	60,160	45,070	28,030	28,920	28,610	53,360	104,080	75,920	75,150	75,110	72,150	46,110	692,670
1977	36,774	24,110	40,872	23,036	29,040	35,064	65,338	49,719	50,420	82,212	63,534	32,228	532,347
1978	32,620	26,200	29,780	28,400	19,820	63,210	67,620	101,220	86,190	133,630	76,260	32,870	697,820
1979	36,974	24,730	34,512	31,920	22,496	50,492	57,346	112,120	144,640	76,586	68,014	48,594	708,424
1980	39,708	25,100	38,294	26,907	36,566	30,806	33,326	70,146	83,838	112,300	61,080	40,160	598,231
MEAN	39,450	27,794	29,989	26,024	27,523	53,997	76,156	84,577	88,907	98,059	67,818	43,477	663,770
1981	35,266	32,174	38,290	31,170	34,616	98,104	141,900	88,082	143,300	139,900	73,114	48,886	904,802
1982	44,038	26,108	42,902	28,630	50,836	31,496	53,332	46,218	75,342	107,900	53,330	36,514	596,646
1983	43,310	23,350	28,480	27,360	19,520	16,050	94,640	66,430	78,390	79,880	84,430	41,550	603,390
1984	42,970	29,090	28,880	14,080	45,020	91,820	126,990	86,280	143,730	103,360	53,370	37,130	802,720
1985	37,670	28,650	36,970	25,620	29,760	48,540	74,180	81,050	94,630	125,870	42,340	41,830	667,110
1986	37,500	29,560	32,790	18,290	34,970	80,820	68,950	35,050	45,630	83,330	84,740	40,430	592,060
1987	29,966	21,832	24,888	18,266	21,262	41,430	81,932	97,828	76,700	69,052	35,234	26,270	544,660
1988	26,070	20,148	22,382	36,830	20,844	65,798	65,414	70,572	100,850	56,766	45,056	33,610	564,340
1989	29,756	28,895	29,118	24,166	21,242	28,042	55,240	61,620	132,160	83,012	68,558	46,730	608,539
1990	34,940	29,800	36,340	32,090	37,690	39,270	88,540	91,710	137,430	115,490	70,620	56,920	770,840
MEAN	36,149	26,961	32,104	25,650	31,576	54,137	85,112	72,484	102,816	96,456	61,079	40,987	665,511
MEAN (1962-1990)	36,294	27,003	28,886	24,388	29,237	47,812	75,975	73,991	87,970	92,745	61,555	40,280	621,108

TABLE 3.2 MONTHLY POWERPLANT DISCHARGES AND RESERVOIR INFLOWS (CMS)

YEAR		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1976	Qp	19.2	15.4	9.0	9.6	9.1	17.7	33.3	24.4	24.8	24.0	23.9	14.8
	Qi	23.4	16.5	12.6	11.0	11.1	28.4	40.6	27.4	38.6	45.0	25.1	16.1
1977	Qp	11.7	8.5	13.0	7.7	9.3	11.7	21.1	16.1	16.9	26.5	21.2	
	Qi	13.0	11.9	9.7	8.4	9.1	10.8	17.7	16.3	15.8	28.5	18.0	13.2
1978	Qp	10.5	9.4	9.7	9.5	6.5	21.5	21.7	32.6	28.5	42.7	25.3	
	Qi	10.0	8.9	8.9	7.1	6.2	23.6	20.5	30.3	35.3	44.6	24.3	14.4
1979	Qp	11.8	8.7	9.1	10.8	7.3	16.6	18.3	36.1	48.1	24.6	22.6	15.6
	Qi	12.4	11.5	9.6	8.6	9.2	19.4	16.9	36.2	70.3	23.6	24.3	16.7
1980	Qp	12.7	8.9	12.3	8.9	11.7	10.3	10.9	22.8	28.0	36.2	20.4	12.9
	Qi	13.7	11.8	10.5	9.6	9.7	9.9	10.4	21.6	44.0	32.3	19.2	12.6
1981	Qp	11.4	11.4	12.3	10.4	11.2	32.4	45.6	28.4	47.5	45.0	24.3	15.7
	Qi	12.6	14.6	11.6	10.4	10.2	42.9	43.5	58.8	62.0	46.1	25.0	19.4
1982	Qp	13.9	9.2	13.6	9.4	16.3	10.4	17.1		24.9	34.6	17.7	12.1
	Qi	12.1	12.2	11.4	11.9	13.9	11.4	15.1	14.9	32.3	39.2	20.5	14.4
1983	Qp	13.8	8.3	9.1	9.1	6.3	5.3	30.4	21.4	26.0	29.3	27.9	13.2
	Qi	12.2	9.8	8.7	7.5	7.1	8.1	24.0	20.1	34.1	25.4	27.8	16.6
1984	Qp	13.6	9.9	9.2	4.7	14.3	31.3	40.6	27.6	47.5	33.0	17.5	11.8
	Qi	12.4	10.7	8.5	7.0	16.5	29.0	41.8	26.9	121.9	31.9	17.4	13.8
1985	Qp	12.0	10.1	11.8	8.4	9.5	16.1	23.7	25.9	31.4	40.2	14.1	13.3
	Qi	12.1	11.0	11.1	9.6	9.1	15.9	22.7	24.5	31.8	45.4	15.5	15.0
1986	Qp	11.9	10.9	10.4	6.0	11.1	26.7	22.0	11.2	15.1	26.7	28.0	12.9
	Qi	13.3	11.1	9.1	7.9	9.9	25.0	22.2	12.4	13.8	27.3	32.6	12.7
1987	Qp	9.5	7.7	8.0	6.1	7.0	13.7	25.9	31.3	25.4	22.1	11.7	8.4
	Qi	10.2	8.7	8.4	7.2	6.7	12.3	29.3	28.9	25.8	20.3	13.3	9.7
1988	Qp	8.4	6.9	7.1	12.2	6.7	21.8	20.9	22.7	33.5	18.1	14.9	10.7
	Qi	8.2	7.7	6.9	12.6	7.1	20.9	20.8	21.5	48.5	19.3	14.8	13.4
1989	Qp	9.5	10.2	9.4	8.1	6.9	9.3	17.7	19.7	43.7	26.6	22.7	15.2
	Qi	10.0	11.2	8.3	8.6	7.2	10.2	18.3	20.6	82.4	26.5	24.1	18.0
1990	Qp	11.2	10.5	11.6	10.6	12.0	13.0	28.3	29.4	45.3	36.9	23.3	18.2
	Qi	12.5	11.3	10.5	11.6	11.4	12.5	26.8	28.8	48.9	34.4	23.8	19.2

Remarks : Qp : Monthly powerplant discharge
Qi : Monthly reservoir inflow

TABLE 3.3 ELEVATION-SURFACE AREA-CAPACITY OF SOLEDAD RESERVOIR

ELE-	1962		1977		1988		1990		1992	
VATION	AREA	VOL.	AREA	VOL.	AREA	VOL.	AREA	VOL.	AREA	VOL.
(m)	(ha)	(mcm)	(ha)	(mcm)	(ha)	(mcm)	(ha)	(mcm)	(ha)	(mcm)
710.0	0.0	0.000								
720.0	2.1	0.274								
730.0	5.8	0.822								
740.0	12.7	2.055								
750.0	22.6	3.973								
760.0	39.5	6.986								
765.0	47.7	9.315								
768.8										
770.0	67.8	12.740	2.4	0.000						
775.0	82.6	17.123	26.6	0.724	3.6	0.000	3.6	0.000		0.000
780.0	99.0	21.233	38.0	2.339	12.2	0.317	10.1	0.342	7.1	0.179
785.0		26.165	55.1	4.667	29.2	1.354	31.2	1.377	16.6	0.771
789.5										
790.0	134.6	31.096	72.0	7.843	66.9	3.759	58.5	3.619	46.5	2.347
795.0		40.000	147.5	13.328	91.7	7.726	78.5	7.044	75.3	5.392
797.5		45.413								8.157
798.4	168.1	47.361								9.152
800.0	173.4	50.000	164.0	21.114	170.4	14.279	167.8	13.212	145.9	10.922
804.5		58.753		28.828		22.305		21.171		18.398
805.0	196.7	59.726	178.8	29.685	186.3	23.197	186.3	22.055	186.4	19.229

Source : Published elevation-area-capacity curves by CFE, above values may differ slightly from actual surveyed data.

TABLE 3.4 LOSS IN RESERVOIR STORAGE CAPACITY

ELEVATION (M)	1962 STORAGE (MCM)	1992 STORAGE (MCM)	LOSS (MCM)
775.0	17.1	0.0	17.1
780.0	21.2	0.2	21.1
785.0	26.2	0.8	25.4
790.0	31.1	2.3	28.7
795.0	40.0	5.4	34.6
797.5	45.4	8.2	37.3
798.4	47.4	9.2	38.2
800.0	50.0	10.9	39.1
804.5	58.8	18.4	40.4
805.0	59.7	19.2	40.5

TABLE 3.5 RESERVOIR LONGITUDINAL PROFILES
(Distances Measured from Non Overflow Section of Dam)

1962		1977		1990		1992	
Dist. (m)	Elev. (m)	Dist. (m)	Elev. (m)	Dist. (m)	Elev. (m)	Dist. (m)	Elev. (m)
0	720.5	130	770.0	0	775.0	0	776.2
220	722.2	180	770.0	244	772.0	130	776.6
270	727.0	475	771.5	369	773.4	226	776.6
400	730.0	730	778.0	471	773.4	426	777.2
500	731.0	815	778.0	569	776.4	546	779.9
700	732.7	865	777.0	673	779.3	652	781.2
770	735.0	945	775.5	851	783.9	818	785.8
1,120	740.0	1,135	773.5	963	782.7	898	784.9
1,750	744.5	1,355	773.0	1,060	782.4	1,028	785.5
		1,550	773.0	1,238	783.7	1,228	786.5
		1,735	772.5	1,346	785.0	1,308	787.1
		1,830	773.8	1,493	786.2	1,398	788.4
		2,000	775.0	1,611	787.4	1,468	789.1
		2,125	780.5	1,741	790.0	1,598	793.5
		2,190	783.0	1,867	790.0	1,758	794.1
		2,275	783.0	1,967	791.0	1,890	797.0
		2,340	789.0	2,027	791.8	1,980	797.2
		2,430	789.0	2,097	796.2	2,100	795.9
		2,485	789.5	2,207	796.0	2,160	796.4
		2,545	790.0	2,283	796.5	2,290	798.0
		2,645	790.7	2,513	795.8	2,330	798.1
		2,715	790.4			2,420	796.7
		2,775	790.0			2,530	798.6
		2,995	790.0			2,800	798.2
		3,090	790.5			3,040	798.2
		3,195	791.0			3,220	798.0
		3,345	791.8			3,350	799.7
		4,890	792.5			3,590	800.0
		5,325	794.0			3,690	799.3
						4,480	800.0

TABLE 3.6 RESERVOIR CROSS SECTIONS AT INTAKE

May-90		Jun-92	
Dist. (m)	Elev. (m)	Dist. (m)	Elev. (m)
0	800.5 RB	0	800.0 RB
5	797.5	11	795.0
10	793.2	14	790.0
16	789.4	15	789.0
21	786.9	17	788.0
26	786.9	19	787.0
31	785.4	22	786.0
52	785.0	30	785.0
58	785.0	36	784.0
63	784.9	62	784.0
79	784.5	89	784.0
89	783.7	91	783.0
105	782.3	121	782.0
126	782.0	130	781.0
131	781.4	135	780.0
136	781.0	144	779.0
147	779.5	159	779.0
173	778.1	185	778.0
210	777.4	205	778.0
230	777.0	225	777.0
291	776.0	291	777.0
346	775.5	354	775.0
352	774.5	358	774.0 LB
356	771.9 LB		

TABLE 3.7 PERFORMANCE OF CHECK DAMS

	Name of Check Dam	Drainage Area (Ha)	Year of Constr.	Total Capacity (m3)	Status Year Filled	Annual Sediment Deposition (m3)						
						1980	1981	1982	1984	1985	1986	1987
1	Sta. Ines Morelos	3,325	1979	37,176				4,043				23,147
2	El Durazno	556	1979	14,805				2,831	5,449			6,512
3	Tenanpulco No. 3	1,169	1977-78	25,093	1987			1,202	23,086			25,093
4	Coacal No. 1	694	1977-78	43,889					901	2,441	6,450	15,805
5	Sta. Cruz	2,925	1976	182,501				44,246				
6	Pantijacan	112	1981	6,602	1987				1,146	1,296		6,602
7	Amaxac No. 10	42	1980	17,494	1985			9,976		17,494		
8	Amaxac No. 7	3,475	1976-77	350,394				162,181			220,925	254,474
9	Xalahuit No. 1	238	1978	12,134				1,435	2,821	6,760		
10	XalahuitNo. 2	11	1982	675							281	
11	Sn. Luis No. 1	144	1983	3,444					580			965
12	Apopoza	9	1981	1,750				139	316			
13	Quiquimititan	28	1982	1,773				20	453	936		
14	Sn. Anores Yahuitlalpan	2,181	1979-80	10,631	1981		10,631					
15	La Paz	192	1980	3,500	1985			3,152	3,332	3,500		
16	Pedacillos	355	1980	8,702				969		1,385		
17	Zocavon	23	1981	1,157	1985			421	510	1,157		
18	Nopala	1,917	1980	19,542	1985			3,600	18,942	19,542		
19	Sta. Maria Soltoltepec	1,569	1979	18,277	1981		18,277					
20	Los Plumajes	2,469	1980	35,466	1980	35,466						
21	El Pipian	119	1981	13,665	1985			2,799	9,850	13,665		
22	Atemoloni	365	1983-84	33,023					5,018			7,886
23	Acatla	3,125	1984	20,824	1985				11,547	20,824		
24	Tatempango	3,135	1986	61,629							22,922	32,342
25	Cuchac No. 1	16,883	1987	416,000								30,000
	Total	45,061		1,340,146								

TABLE 3.8 ESTIMATED EROSION RATES BASED ON SEDIMENT DEPOSITION BEHIND CHECK DAMS

NO.	NAME OF DAM	DRAINAGE AREA (km2)	STORAGE CAPACITY (m3)	SEDIMENT VOLUME (m3)	NO. OF YEARS	CAP-INFL RATIO	TRAP EFFI-CIENCY	EROSION VOLUME (m3)	EROSION RATE (mm/yr.)
1	Sta. Ines Morelos	33.25	37,176	23,147	8	0.010	0.47	49,249	0.185
2	El Durazo	5.56	14,805	5,449	5	0.023	0.62	8,789	0.316
3	Tenanpulco No.3	11.69	25,093	23,086	6	0.020	0.60	38,477	0.549
4	Coacal NO.1	6.94	43,889	15,805	9	0.055	0.67	23,590	0.378
5	Sta. Cruz	29.25	182,501	44,246	6	0.054	0.67	66,039	0.376
6	Pantijacan	1.12	6,602	6,602	6	0.051	0.66	10,003	1.489
7	Amaxac No.10	0.42	17,494	17,494	5	0.362	0.82	21,334	10.159
8	Amaxac No.7	34.75	350,394	254,474	10	0.088	0.72	353,436	1.017
9	Xalahuit No.1	2.38	12,134	6,760	7	0.044	0.65	10,400	0.624
10	Xalahuit No.2	0.11	675	281	4	0.053	0.67	419	0.952
11	Sn. Luis No.1	1.44	3,444	965	4	0.021	0.57	1,693	0.294
12	Apopoza	0.09	1,750	316	3	0.168	0.77	410	1.519
13	Quiquimititan	0.28	1,773	936	3	0.055	0.67	1,397	1.663
14	Sn. AnoresYahuitlalpan	21.81	10,631	10,631	1	0.004	0.35	30,374	1.393
15	La Paz	1.92	3,500	3,152	2	0.015	0.53	5,947	1.549
16	Pedacillos	3.55	8,702	1,385	5	0.020	0.57	2,430	0.137
17	Zocavon	0.23	1,157	1,157	4	0.041	0.65	1,780	1.935
18	Nopala	19.17	19,542	19,542	4	0.008	0.44	44,414	0.579
19	St. Maria Soltoltepec	15.69	18,277	18,277	2	0.007	0.43	42,505	1.355
20	Los Plumajes	24.69	35,466	35,466	1	0.008	0.44	80,605	3.265
21	El Pipian	1.19	13,665	13,665	4	0.067	0.68	20,096	4.222
22	Atemoloni	3.65	33,023	7,886	3	0.079	0.70	11,266	1.029
23	Acatla	31.25	20,824	20,824	1	0.005	0.38	54,800	1.754
24	Tatempango	31.35	61,629	32,342	2	0.016	0.54	59,893	0.955
25	Cuchac NO.1	168.83	416,000	30,000	1	0.014	0.52	57,692	0.342
	Total	450.61	1,340,146	593,888					

TABLE 4.1 LIST OF CLIMATOLOGICAL STATION

	STATION	LOCATION		OBSERVATION	ALTITUDE
		LAT.	LONG.	PERIOD	(EL. m)
1	SAN JUAN ACATENO	19° 52'	97° 22'	1956 - 1991	1,656
2	ATEXCACO	19° 55'	97° 24'	1960 - 1991	1,085
3	LA PAGODA	19° 54'	97° 25'	1960 - 1991	1,560
4	LA SOLEDAD	19° 57'	97° 27'	1954 - 1991	816
5	TEPECAPAN	19° 58'	97° 39'	1979 - 1991	542
6	HUAHUAXTLA	19° 55'	97° 38'	1954 - 1991	1,625
7	TLATLAUQUI	19° 51'	97° 30'	1953 - 1991	2,025
8	GOMEZ PONIENTE	19° 46'	97° 29'	1982 - 1991	2,430
9	ZAUTLA	19° 43'	97° 40'	1954 - 1991	1,940
10	CAPULUAQUE	19° 48'	97° 46'	1954 - 1991	2,200
11	AQUIXTLA	19° 48'	97° 56'	1961 - 1991	2,310
12	IXTACAMAXTITLAN	19° 37'	97° 49'	1954 - 1991	2,175
13	SAN ANTONIO	19° 33'	97° 50'	1954 - 1991	3,140
14	LA GLORIA	19° 37'	97° 59'	1955 - 1991	2,750

TABLE 4.2 MEAN MONTHLY RAINFALL

(Unit:mm)

	STATION	OBSERVATION PERIOD	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
1	SAN JUAN ACATENO	1956 - 1991	58	44	46	62	113	340	348	356	474	259	140	71	2,311
2	ATEXCACO	1960 - 1991	141	111	110	126	174	475	576	543	624	373	231	162	3,647
3	LA PAGODA	1960 - 1991	100	77	77	93	142	380	371	387	531	316	192	115	2,781
4	LA SOLEDAD	1954 - 1991	87	66	91	103	178	452	610	534	575	344	184	102	3,325
5	TEPECAPAN	1979 - 1991	77	51	58	79	152	284	345	274	509	251	135	84	2,300
6	HUAHUAXTLA	1954 - 1991	69	57	65	67	106	246	199	207	485	282	153	77	2,015
7	TLATLAUQUI	1953 - 1991	38	36	35	41	63	183	137	130	274	182	94	47	1,260
8	GOMEZ PONIENTE	1982 - 1991	22	19	23	34	37	122	104	92	208	112	74	31	878
9	ZAUTLA	1954 - 1991	10	10	12	25	44	101	78	73	115	45	19	10	543
10	CAPULUAQUE	1954 - 1991	18	16	16	34	53	161	126	107	213	107	47	21	920
11	AQUIXTLA	1961 - 1991	11	13	15	27	46	124	104	98	134	73	30	13	688
12	IXTACAMAXTITLAN	1954 - 1991	9	10	16	41	71	104	89	83	96	42	14	8	584
13	SAN ANTONIO	1954 - 1991	16	18	21	60	101	174	155	159	164	81	31	18	998
14	LA GLORIA	1955 - 1991	11	12	16	42	70	148	155	149	126	56	18	10	814

TABLE 4.3 LA SOLEDAD RAINFALL STATION HOURLY RAINFALL

Year	Month	Date	Hour	Rain mm
1990	10	5	19	10
			20	24
			21	16
			22	14
1990	10	18	21	1
			22	0
			23	7
			24	5
		19	1	16
			2	13
			3	9
			4	9
			5	4
			6	8
1991	8	11	20	
			21	10
			22	20
			23	19
1991	9	24	18	9
			19	16
			20	6
			21	9
			22	10
			23	12
			24	5
1991	11	8	9	15
			10	33
			11	26
			12	18
			13	9
			14	4
1992	5	16	1	20
			2	16
			3	10
1992	5	28	16	30
			17	24
			18	35
			19	22
			20	23
			21	7
			22	8
			23	24
1992	6	16	19	49
1992	7	23	20	39
1992	8	16	15	2
			16	6
			17	10
			18	12
			19	25
			20	19
			21	26
			22	20
			23	10
			24	10
		17	1	20
			2	13
			3	5
			4	2

NOTE : 10 MM RAIN OCCURRED IN 15 MINUTES AND 35 MM RAIN OCCURRED IN ABOUT 30 MINUTES IN SOME CASES.

TABLE 4.4 MEAN MONTHLY EVAPORATION

(Unit:mm)

	STATION	OBSERVATION PERIOD	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
1	SAN JUAN ACATENO	1960 - 1991	55	62	87	94	101	80	71	73	68	62	58	54	867
2	ATEXCACO	1960 - 1991	41	45	70	79	93	80	68	69	61	51	45	41	745
3	LA PAGODA	1960 - 1991	64	70	97	103	106	87	78	79	73	69	65	64	953
4	LA SOLEDAD	1955 - 1991	45	54	83	101	117	114	105	111	97	78	53	43	999
5	TEPECAPAN	1979 - 1991	45	53	87	104	117	108	96	99	89	78	56	43	976
6	HUAHUAXTLA	1978 - 1991	71	76	114	124	125	88	69	72	67	71	71	66	1013
7	TLATLAUQUI	1953 - 1991	67	79	124	136	133	96	75	80	68	65	63	60	1045
8	GOMEZ PONIENTE	1982 - 1991	83	87	109	105	138	79	66	63	61	56	71	81	1000
9	ZAUTLA	1979 - 1991	81	88	128	133	141	102	91	82	75	79	75	74	1148
10	CAPULUAQUE	1978 - 1991	72	79	121	130	129	96	82	81	68	69	70	65	1062
11	AQUIXTLA	1978 - 1991	115	128	184	186	184	131	115	121	96	105	108	101	1574
12	IXTACAMAXTITLAN	1979 - 1991	101	113	159	153	149	132	130	129	108	108	98	89	1469
13	SAN ANTONIO	1979 - 1991	103	121	152	150	139	110	100	99	86	99	92	95	1346
14	LA GLORIA	1978 - 1991	107	110	156	142	141	108	99	103	87	99	97	94	1343

TABLE 4.5 MEAN MONTHLY TEMPERATURE

(Unit: °C)

	STATION	OBSERVATION PERIOD	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
1	SANJUAN ACATENO	1960 - 1991	11.1	11.9	13.5	15.6	17.3	16.8	16.1	16	15.8	14.3	13.1	12.2	14.5
2	ATEXCACO	1960 - 1991	14	15.1	17.6	20.2	22	21.5	20.5	20.7	20.2	18.3	16.8	15	18.5
3	LA PAGODA	1960 - 1991	11.2	12.4	14.6	16.8	18.4	17.7	17.1	17	16.7	15.1	13.8	12.8	15.3
4	LA SOLEDAD	1955 - 1991	14.9	15.8	18.1	21	22.9	23.2	22.2	22.4	22.1	20.2	17.7	15.8	19.7
5	TEPECAPAN	1979 - 1991	15.9	16.9	19.4	21.9	24.2	24.3	23.2	23.5	22.7	21.2	18.3	16.6	20.7
6	HUAHUAXTLA	1978 - 1991	11.9	12.9	15.4	17.4	18.5	18	17	17.3	17.2	15.5	14.3	12.7	15.7
7	TLATLAUQUI	1953 - 1991	12	12.9	15.4	17.2	18	17.1	15.9	16.2	15.9	14.6	13.6	12.6	15.1
8	GOMEZ PONIENTE	1982 - 1991	10.8	11.6	12.8	14.8	15.3	14.1	13.3	13.6	13.2	12	12.2	11.5	12.9
9	ZAUTLA	1979 - 1991	12.8	13.9	16.4	18.3	19	18.2	16.9	17	16.8	15.6	14.4	13.3	16.1
10	CAPULUAQUE	1978 - 1991	11.2	12.7	14.6	16.8	17.8	16.4	14.9	14.9	14.6	13.4	12.8	11.8	14.3
11	AQUIXTLA	1978 - 1991	13.3	14.1	16.9	18.1	18.7	17.8	16.6	16.7	16.9	15.3	14.7	13.9	16.1
12	IXTACAMAXTITLAN	1979 - 1991	13.2	14.1	16.4	18	18.8	18.5	17.7	18	17.4	16.3	14.7	13.8	16.4
13	SAN ANTON10	1979 - 1991	7.2	8.3	10.3	11.2	11.9	10.6	9.2	9.4	9.1	8.7	8.3	7.3	9.3
14	LA GLORIA	1978 - 1991	11.4	12.6	14.2	15.3	15.6	14.3	13.3	13.4	13	12.6	12.5	12	13.3

TABLE 4.6 MEAN MONTHLY RUNOFF - BUENOS AIRES (CA : 1,405 km2)

(Unit: cms)

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
1963	3.43	3.16	2.38	2.30	2.92	(5.16)	20.34	7.76	11.02	9.58	8.32	4.28	(6.72)
1964	3.33	2.72	2.25	2.12	3.53	7.76	6.62	4.03	4.59	10.45	7.28	7.18	5.15
1965	4.56	2.92	2.37	2.98	3.52	6.37	7.34	16.95	7.99	15.70	7.48	3.02	6.77
1966	2.38	2.63	2.83	2.77	3.66	10.80	15.06	13.29	35.25	19.37	8.68	4.64	10.11
1967	4.16	3.24	2.72	2.90	4.19	4.78	4.06	5.58	26.62	12.33	6.49	4.69	6.81
1968	3.32	3.14	2.30	3.34	4.10	11.78	10.08	7.73	16.17	11.60	4.65	6.42	7.05
1969	4.25	3.02	2.41	2.45	1.95	2.93	7.36	27.91	51.00	15.66	7.39	5.00	10.94
1970	3.61	3.86	2.80	2.48	3.05	7.22	6.45	13.25	16.86	12.65	4.39	2.81	6.62
1971	2.77	2.68	2.93	3.61	2.96	5.47	6.48	8.83	10.67	24.97	23.74	4.98	8.34
1972	3.52	3.06	3.45	2.62	2.93	18.61	12.31	16.01	11.51	9.79	7.02	4.86	7.97
1973	3.25	3.05	2.53	1.48	2.37	6.67	17.32	23.54	18.21	13.94	6.42	6.46	8.77
1974	3.60	2.89	2.40	2.44	2.33	27.06	23.17	7.35	59.59	28.15	11.30	7.35	14.80
1975	5.27	4.45	3.20	2.85	4.48	10.55	12.86	10.68	34.82	36.87	9.02	7.96	11.92
1976	10.03	6.81	4.52	4.17	4.62	13.12	22.59	14.66	21.62	33.14	11.01	6.19	12.71
1977	4.41	3.88	2.93	2.74	3.21	4.55	5.93	5.93	6.30	9.79	6.10	3.91	4.97
1978	2.74	2.37	2.86	1.96	1.76	9.76	6.78	11.59	22.09	24.87	10.65	4.73	8.51
1979	3.93	3.70	2.88	3.62	2.74	8.52	7.03	18.40	51.44	10.67	9.94	5.96	10.74
1980	4.81	3.90	3.33	3.08	3.98	3.62	4.27	11.81	21.41	14.45	7.16	3.53	7.11
1981	3.93	5.56	3.73	3.34	3.91	23.94	22.56	34.48	36.07	25.42	11.20	8.28	15.20
1982	4.68	4.05	3.78	4.01	4.90	3.65	4.26	4.01	15.60	17.66	7.57	4.27	6.54
1983	3.48	2.87	2.57	2.29	2.01	2.46	8.37	7.91	14.46	9.22	12.11	4.71	6.04
1984	3.67	3.03	2.45	2.10	8.34	12.39	23.59	11.20	95.95	15.43	6.39	4.83	15.78
1985	4.09	3.49	3.40	3.25	3.13	6.67	10.16	10.54	14.61	25.84	5.23	5.45	7.99
1986	4.14	3.44	2.82	2.68	3.75	12.54	7.22	3.44	3.95	10.48	14.44	3.59	6.04
1987	3.07	2.76	2.58	2.20	2.12	5.72	14.19	12.07	9.69	8.23	4.45	3.03	5.84
1988	2.89	2.76	2.57	4.46	2.59	8.17	8.20	9.33	30.96	7.67	5.38	4.76	7.48
1989	3.49	3.62	2.88	2.86	2.80	4.85	7.83	10.70	60.27	13.00	9.96	7.67	10.83
1990	4.13	3.74	3.24	3.45	3.60	3.83	11.68	13.96	29.03	14.56	9.18	7.66	9.01
1991	5.58	4.37	3.19	2.46	2.76	8.33	22.22	6.24	12.40	30.42	14.08	6.68	9.89
Ave.	4.02	3.49	2.91	2.86	3.39	8.87	11.60	12.04	25.87	16.96	8.86	5.34	8.85

Note : ( ) including missing daily data

TABLE 4.7 MEAN MONTHLY RUNOFF - SONTALACO
(CA : 25 km2)

(Unit: cms)

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
1963			0.25	0.18	0.21	0.14	1.96	1.57	2.60	1.54	1.41	0.86	(0.89)
1964	0.69	0.43	0.31	0.29	0.25	1.86	2.38	0.95	1.19	2.68	1.41	1.50	1.16
1965	1.19	0.56	0.41	0.59	0.68	1.17	1.82	2.46	1.16	1.96	1.32	0.35	1.14
1966	0.35	0.49	0.49	0.35	0.24	1.95	3.37	1.56	3.37	2.94	1.00	0.53	1.39
1967	0.59	0.59	0.51	0.27	0.43	0.77	0.63	1.05	3.24	2.07	1.32	0.99	1.04
1968	0.60	0.42	0.41	0.45	0.72	1.27	1.68	2.06	2.57	2.08	0.80	1.46	1.21
1969	0.99	0.52	0.40	0.34	0.27	0.26	1.85	4.08	5.96	2.36	1.31	0.76	1.59
1970	0.43	0.65	0.45	0.27	0.54	0.85	2.26	2.55	3.17	2.10	0.86	0.44	1.21
1971	0.37	0.31	0.36	0.82	0.32	0.35	1.46	1.35	1.50	3.81	2.60	0.78	1.17
1972	0.67	0.48	0.68	0.26	0.24	2.39	2.77	2.73	1.83	1.32	1.30	0.88	1.30
1973	0.49	0.43	0.35	0.20	0.72	1.77	2.26	2.66	1.90	2.42	1.07	1.00	1.27
1974	0.44	0.35	0.25	0.21	0.17	3.60	2.03	1.22	4.92	2.72	1.22	0.84	1.50
1975	0.54	0.39	0.20	0.17	0.15	0.29	0.40	1.64	5.35	4.29	0.79	1.07	1.27
1976	1.54	0.59	0.40	0.28	0.24	2.84	2.15	1.20	3.07	3.13	1.42	0.61	1.46
1977	0.42	0.41	0.28	0.18	0.17	0.43	1.57	1.05	0.91	2.88	1.32	0.78	0.87
1978	0.44	0.31	0.36	0.28	0.16	1.80	1.94	3.69	3.08	3.31	1.38	0.53	1.44
1979	0.50	0.49	0.36	0.25	0.46	1.46	0.95	2.82	4.75	1.07	1.54	0.88	1.29
1980	0.58	0.37	0.33	0.26	0.15	0.18	0.20	0.80	5.53	2.48	1.03	0.53	1.04
1981	0.64	0.80	0.53	0.39	0.35	3.92	3.43	5.63	4.35	2.87	(1.45)	1.20	(2.13)
1982	0.50	0.43	0.43	0.41	0.67	0.48	1.22	1.20	3.34	2.97	1.15	0.68	1.12
1983	0.53	0.36	0.25	0.18	0.16	0.20	2.52	1.67	4.92	2.84	2.74	1.75	1.51
1984	0.74	0.59	0.34	0.21	0.88	3.13	4.06	2.49	8.40	1.86	0.57	0.39	1.97
1985	0.28	0.27	0.44	0.29	0.24	0.71	1.38	1.96	2.39	3.78	0.74	0.73	1.10
1986	0.62	0.43	0.24	0.20	0.32	1.80	2.34	0.89	0.99	2.72	2.86	0.45	1.15
1987	0.43	0.33	0.34	0.24	0.20	0.54	2.61	3.04	2.30	1.24	0.69	0.44	1.03
1988	0.21	0.18	0.16	1.06	0.23	2.26	1.92	1.75	3.58	0.93	0.73	0.71	1.14
1989	0.42	0.62	0.29	0.34	0.18	0.25	1.19	1.26	5.77	1.11	1.62	0.79	1.15
1990	0.46	0.45	0.51	0.79	0.78	0.81	2.22	2.28	5.22	2.86	1.65	1.06	1.59
1991	0.81	0.59	0.37	0.22	0.22	0.66	2.71	0.78	1.80	3.43	1.62	0.48	1.14
Ave.	0.59	0.46	0.37	0.34	0.36	1.32	1.98	2.01	3.42	2.47	1.34	0.81	1.29

Note : ( ) including missing daily data

TABLE 4.8 MEAN MONTHLY RUNOFF - CANAL TUNNEL NO. 1

(CA : 370 km2 *)

(Unit: cms)

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
1963	4.05	3.65	2.95	2.85	3.63	3.80	5.71	5.49	5.73	6.25	6.25	5.24	4.63
1964	4.82	4.55	4.06	8.72	9.68	7.83	8.83	6.67	7.21	10.55	8.21	8.19	7.44
1965	7.40	6.26	5.29	5.53	5.55	6.80	7.59	10.59	7.38	7.90	8.72	6.29	7.11
1966	5.72	5.55	5.58	4.97	4.58	7.63	12.89	8.93	12.93	15.25	9.53	7.28	8.40
1967	6.84	6.36	5.69	4.65	5.27	6.00	5.88	6.53	12.42	10.57	8.71	6.98	7.16
1968	6.12	5.77	5.12	4.72	5.47	7.06	8.89	9.08	9.69	9.64	7.33	8.38	7.27
1969	7.35	6.26	5.89	5.32	4.79	4.66	8.16	11.73	18.24	15.30	11.42	8.61	8.98
1970	7.61	7.61	6.78	5.42	6.11	7.70	9.06	11.40	13.86	13.23	8.58	6.93	8.69
1971	6.73	6.16	6.16	6.71	5.37	6.08	8.77	8.90	9.03	13.54	14.19	8.67	8.36
1972	7.79	6.97	6.60	5.52	5.75	11.33	12.99	14.01	12.02	11.04	9.90	8.32	9.35
1973	7.07	6.50	5.85	4.64	5.67	7.09	10.05	13.82	12.40	13.48	9.09	8.89	8.71
1974	7.01	6.42	5.52	5.52	4.81	8.72	13.62	9.72	7.55	0.98	11.01	9.60	7.54
1975	8.31	7.61	6.48	5.85	5.70	6.84	7.18	8.49	11.22	18.44	9.51	8.95	8.71
1976	10.22	8.52	7.30	6.27	6.00	9.58	13.72	10.42	10.87	5.64	11.28	8.72	9.05
1977	7.77	7.28	6.25	5.49	5.57	5.48	8.75	8.31	7.69	13.27	9.25	7.78	7.74
1978	6.36	5.90	5.27	4.54	4.08	10.24	9.82	11.34	7.06	13.05	10.88	8.60	8.09
1979	7.44	6.79	5.95	4.44	5.51	7.93	7.92	12.15	9.37	10.75	11.28	8.97	8.21
1980	7.74	7.11	6.46	5.96	5.59	5.92	5.77	8.21	11.55	12.88	10.01	7.97	7.93
1981	7.36	7.41	6.78	6.26	5.73	11.20	14.10	12.99	17.24	14.98	10.94	8.69	10.31
1982	6.45	7.24	6.78	7.06	7.64	6.75	8.35	8.50	10.05	15.57	10.57	8.71	8.64
1983	7.67	6.23	5.65	4.88	4.74	5.25	10.55	8.86	9.78	10.49	10.19	8.36	7.72
1984	7.25	6.45	5.37	4.45	6.54	10.24	10.12	10.73	9.11	12.79	9.82	8.42	8.44
1985	7.49	6.93	6.81	5.74	5.45	7.80	9.68	10.15	12.36	11.96	8.75	8.08	8.43
1986	7.93	6.87	5.76	4.83	5.51	8.91	10.28	7.16	7.93	11.40	12.48	8.25	8.11
1987	6.29	5.30	5.10	4.48	4.21	5.46	9.83	10.65	11.54	9.60	7.43	5.82	7.14
1988	4.88	4.53	4.01	5.79	4.08	8.19	8.72	8.68	10.25	9.76	7.98	7.24	7.01
1989	5.64	6.35	4.80	5.04	4.03	4.89	7.86	7.42	10.42	11.27	11.06	8.76	7.29
1990	7.36	6.70	6.23	6.55	6.21	7.56	10.72	10.21	12.72	14.92	11.33	9.39	9.16
1991	8.98	7.31	6.26	4.63	4.56	6.45	6.65	6.88	9.58	11.23	12.05	8.63	7.77
Ave.	7.02	6.43	5.75	5.41	5.44	7.36	9.40	9.59	10.59	11.58	9.92	8.09	8.05

Note : * including the Atexcaco diversion area and other small tributaries.

TABLE 4.9 MEAN MONTHLY RUNOFF - RANCHO APULCO (CA : 1,204 km2)

(Unit: cms)

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
1945												3.62	
1946	3.22	3.03	2.71	3.01	3.34	4.93	3.71	3.04	3.94	8.79			
1947											2.80	2.30	
1948	2.29	2.02	1.82	1.91	3.64	5.69	5.39	2.71	7.68	4.02	2.80	1.96	3.49
1949	1.73	1.59	1.58	1.46	2.20	4.67	2.90	3.12	10.20	4.70	2.65	2.25	3.25
1950	2.00	1.91	2.03	2.43	3.01	4.93	3.21	2.89	3.64	3.34	3.28	2.02	2.89
1951	1.54	1.68	1.51	1.23	4.47	6.51	6.27	6.89	6.47	6.78	1.86	1.84	3.92
1952	2.00	1.75	1.41	2.30	3.42	17.12	6.67	6.21	25.15	18.14	8.82	4.14	8.09
1953	3.05	2.43	2.11	2.10	2.11	3.88	4.16	5.45	10.56	10.50	5.30	2.50	4.51
1954*	1.97	1.97	1.64	1.71	2.57	4.95	8.34	4.24	38.72	52.80	8.56	5.14	11.05
1955*	3.90	3.29	2.57	2.21	2.77	3.14	8.07	15.33	52.46	88.18	38.12	4.84	18.74
1956*	4.07	2.91	2.17	1.89	2.40	6.90	8.89	7.42		9.71	5.28	4.04	
1957	3.59	3.79	2.75	3.05	4.92	3.20	3.21	3.30	4.75	3.81	3.07	2.28	3.48
1958	3.10	1.89	1.75	2.00	5.15	4.76	11.58	7.94	20.90	19.27	6.82	3.61	7.40
1959	2.26	1.26	2.08	2.62	2.62	12.36	11.68	10.97	11.70	15.22	5.99	2.81	6.80
1960	2.45	1.90	1.72	1.62	1.90	2.91	3.04	4.06	5.98	2.69	2.32	1.74	2.69
1961	1.56	1.36	1.30	1.14	1.17	4.98	7.10	4.28	5.69	7.18	8.24	2.23	3.85
1962	1.68	1.70	1.58	2.38	1.76	2.73	2.54	2.83	4.29	4.79	1.72	1.46	2.46
1963	1.31	1.22	1.19	1.21	1.82	4.98	14.70	4.46	3.97	4.58	3.79	2.09	3.78
1964	1.77	1.48	1.36	1.35	2.57	4.14	3.23	2.60	2.86	3.31	3.00	2.67	2.53
1965	2.02	1.68	1.50	1.45	2.18	2.89	3.93	11.30	4.44	7.27	3.78	2.03	3.71
1966	1.70	1.52	1.91	2.15	3.14	5.86	6.27	7.87	13.20	8.44	3.94	2.50	4.88
1967	2.51	1.84	1.55	2.17	2.89	2.78	3.01	3.61	12.50	5.83	2.64	2.02	3.61
1968	1.56	1.67	1.28	2.29	2.59	6.13	5.39	4.04	8.08	5.40	2.35	2.53	3.61
1969	2.09	1.71	1.58	1.77	1.35	2.62	4.06	12.60	28.20	6.92	3.66	3.07	5.80
1970	2.75	2.62	2.42	2.27	2.45	5.46	2.96	6.44	8.52	4.54	2.08	1.57	3.67
1971	1.42	1.40	1.40	1.53	2.10	4.31	4.29	6.08	6.72	12.10	7.99	3.60	4.41
1972	2.59	1.99	1.85	2.05	2.40	7.38	4.76	7.31	6.79	5.45	3.66	2.37	4.05
1973	1.73	2.02	1.91	2.05	2.25	5.62	11.00	14.30	12.10	6.49	3.96	3.50	5.58
1974	0.00	2.24	2.45	2.27	1.92	7.86	14.60	5.41	23.80	18.60	6.05	3.94	7.64
1975	3.25	2.77	2.01	1.83	3.45	7.42	9.97	6.24	13.60	11.50	4.13	3.10	5.77
1976	2.70	1.99	1.63	2.51	2.93	5.56	14.40	9.79	12.30	20.30	5.30	4.04	6.95
1977	2.76	2.35	2.04	1.79	2.05	2.63	3.35	3.96	4.30	2.71	2.29	1.69	2.66
1978	1.44	1.35	1.86	1.16	1.10	12.40	13.50	14.80	17.80				
Ave.	2.25	2.01	1.83	1.97	2.65	5.68	6.76	6.61	12.62	12.37	5.36	2.80	4.49**

Note : * Records from 1954 to 1956 are estimated from those at other station.

** Average excluding 1954-1956

TABLE 4.10 MEAN MONTHLY RESERVOIR INFLOW

(Total Contribution Area : 1,830 km2)

(Unit: cms)

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
1963	8.03	6.94	5.58	5.33	6.76	9.10	28.01	14.82	19.35	17.38	15.98	10.38	12.31
1964	8.85	7.70	6.62	11.14	13.46	17.45	17.83	11.65	13.00	23.68	16.90	16.88	13.76
1965	13.15	9.74	8.08	9.10	9.75	14.33	16.75	29.99	16.53	25.56	17.52	9.65	15.01
1966	8.45	8.67	8.90	8.09	8.48	20.39	31.31	23.77	51.55	37.56	19.21	12.45	19.90
1967	11.59	10.20	8.91	7.82	9.89	11.56	10.57	13.17	42.28	24.98	16.51	12.66	15.01
1968	10.04	9.33	7.84	8.51	10.28	20.11	20.66	18.86	28.42	23.32	12.78	16.25	15.53
1969	12.59	9.81	8.70	8.11	7.00	7.85	17.37	43.72	75.19	33.32	20.12	14.37	21.51
1970	11.64	12.12	10.03	8.17	9.69	15.77	17.77	27.20	33.89	27.99	13.83	10.18	16.52
1971	9.87	9.15	9.45	11.14	8.65	11.89	16.71	19.08	21.20	42.31	40.53	14.44	17.87
1972	11.98	10.52	10.73	8.40	8.92	32.33	28.06	32.76	25.36	22.16	18.22	14.06	18.62
1973	10.81	9.98	8.73	6.32	8.76	15.53	29.63	40.01	32.51	29.85	16.58	16.35	18.76
1974	11.05	9.66	8.18	8.17	7.30	39.37	38.82	18.29	72.06	31.85	23.54	17.79	23.84
1975	14.13	12.44	9.88	8.88	10.33	17.67	20.44	20.81	51.38	59.60	19.31	17.98	21.90
1976	21.79	15.93	12.22	10.72	10.85	25.54	38.46	26.27	35.56	41.91	23.71	15.52	23.21
1977	12.60	11.57	9.47	8.41	8.94	10.47	16.26	15.28	14.89	25.94	16.67	12.47	13.58
1978	9.54	8.58	8.49	6.79	6.00	21.80	18.54	26.62	32.23	41.24	22.91	13.86	18.05
1979	11.87	10.98	9.18	8.32	8.71	17.91	15.90	33.38	65.56	22.49	22.75	15.81	20.24
1980	13.13	11.39	10.12	9.29	9.73	9.72	10.24	20.82	38.49	29.81	18.19	12.02	16.08
1981	11.94	13.77	11.03	9.99	9.99	39.05	40.08	53.09	57.65	43.21	23.59	18.17	27.63
1982	11.63	11.72	10.99	11.48	13.20	10.88	13.83	13.70	29.00	36.20	19.29	13.67	16.30
1983	11.69	9.46	8.48	7.35	6.90	7.92	21.45	18.44	29.16	22.56	25.05	14.83	15.27
1984	11.67	10.06	8.15	6.76	15.77	25.77	37.77	24.41	113.45	30.09	16.77	13.65	26.19
1985	11.86	10.68	10.65	9.29	8.82	15.18	21.22	22.65	29.36	41.58	14.72	14.26	17.52
1986	12.69	10.75	8.82	7.70	9.58	23.25	19.83	11.48	12.87	24.60	29.78	12.28	15.30
1987	9.80	8.39	8.03	6.93	6.53	11.72	26.62	25.76	23.52	19.07	12.57	9.28	14.02
1988	7.98	7.47	6.74	11.31	6.90	18.61	18.84	19.76	44.78	18.36	14.09	12.72	15.63
1989	9.55	10.59	7.97	8.24	7.01	9.99	16.88	19.38	76.46	25.39	22.64	17.23	19.28
1990	11.95	10.89	9.97	10.79	10.60	12.20	24.62	26.46	46.97	32.34	22.15	18.12	19.76
1991	15.37	12.26	9.83	7.31	7.55	15.44	31.58	13.90	23.78	45.09	27.75	15.79	18.80
Ave.	11.63	10.37	9.03	8.62	9.18	17.54	22.97	23.64	39.88	31.02	20.13	14.25	18.19

TABLE 4.11 FLOOD / RAINSTORM RECORDS (1/2)

Date	Runoff at Buenos Aires (m3/sec)		Daily Rainfall (mm) Station							
	Daily	Peak	La Soledad	Huahuaxtla	Tlatlauqui	Zautla	Capuluaque	Ixtacamax-titilan	San Antonio	La Gloria
1974										
Sep 19	6.4		4.5	12.0	5.8	18.0	4.0	0.0	0.6	0.0
20	21.4		3.3	4.5	10.5	20.0	2.5	0.0	2.3	0.7
21	418.0	(711.0)	288.7	345.0	255.4	160.0	195.5	104.5	96.0	70.1
22	245.0		37.0	58.0	39.1	39.0	51.0	12.0	20.3	27.1
23	212.0		21.0	20.0	17.2	34.0	26.0	27.0	28.0	28.4
24	143.0		36.4	10.0	13.4	4.0	0.3	1.0	8.5	7.1
25	86.3		2.6	-	0.0	0.0	0.0	1.0	4.9	1.8
1979										
Sep 15	33.2		20.0	20.3	22.5	3.0	7.5	1.0	2.5	0.2
16	58.5		12.5	55.8	38.9	10.0	19.5	1.0	2.6	1.0
17	104.0		11.5	13.8	10.2	10.0	18.8	3.0	2.7	2.1
18	292.0	(413.0)	94.8	141.6	78.2	105.0	143.0	23.0	22.7	19.5
19	216.0		64.5	70.4	37.2	31.5	46.7	4.5	6.5	4.2
20	119.0		13.0	17.2	12.7	4.0	10.0	0.0	3.0	0.5
21	69.1		0.0	-	0.0	0.0	-	1.5	2.3	2.1
1981										
Aug 25	25.2		64.0	40.0	18.3	1.0	12.0	0.0	7.0	2.4
26	106.0		98.0	127.0	72.8	18.0	68.1	5.0	14.0	4.0
27	267.0		153.5	193.0	82.8	29.5	69.0	12.0	15.5	16.0
28	215.0	(451.0)	186.5	96.0	46.1	23.4	53.5	23.5	25.0	33.0
29	116.0		58.7	23.0	23.9	23.5	20.5	24.0	45.5	12.0
30	68.5		-	-	-	0.0	-	0.0	3.0	16.3
31	50.1		0.5	3.0	0.0	-	0.0	4.5	6.2	7.3

TABLE 4.11 FLOOD / RAINSTORM RECORDS (2/2)

Date	Runoff at Buenos Aires (m3/sec)		Daily Rainfall (mm) Station							
	Daily	Peak	La Soledad	Huahuaxtla	Tlatlauqui	Zautia	Capuluaque	Ixtacamax-titilan	San Antonio	La Gloria
1984										
Sep 13	134.0		80.2	120.0	100.0	20.0	54.0	3.9	19.7	12.2
14	119.0		19.7	34.0	9.5	3.0	48.0	14.0	32.4	10.9
15	199.0		28.8	47.0	20.0	9.8	16.0	10.5	22.3	44.6
16	527.0	(655.0)	156.5	220.0	120.0	18.5	81.0	11.5	12.3	12.0
17	497.0		153.0	164.0	80.0	25.0	50.0	3.0	19.0	2.5
18	270.0		103.0	92.0	42.5	13.0	29.0	1.5	14.7	2.3
19	126.0		18.2	36.0	11.0	0.6	11.0	-	3.8	0.3
1988										
Sep 2	32.0		89.0	51.0	20.0	9.4	21.0	4.5	1.7	1.0
3	34.6		40.0	24.0	38.2	10.6	22.5	4.5	16.0	22.0
4	83.1		29.0	58.0	42.3	4.5	20.0	9.0	26.8	3.0
5	373.0	(540.0)	295.0	270.0	123.4	48.0	104.0	56.0	40.3	32.0
6	99.8		12.8	12.0	46.9	8.0	9.0	12.5	5.6	20.0
7	46.1		-	0.0	-	-	0.0	0.0	0.0	0.0
8	29.1		-	0.0	0.0	-	0.0	0.0	0.0	0.0
1989										
Sep 18	96.2		52.0	120.0	27.6	19.8	50.5	14.5	5.3	15.0
19	299.0		67.2	135.0	12.7	37.0	70.0	31.0	20.1	29.8
20	244.0	(404.0)	83.0	170.0	9.5	30.0	13.0	16.5	10.0	23.0
21	115.0		0.6	3.0	7.3	0.3	-	9.5	20.4	29.2
22	110.0		42.5	30.0	-	18.3	40.0	4.5	15.5	10.2
23	264.0		80.0	190.0	-	28.0	63.0	19.0	0.0	10.0
24	119.0		28.0	24.0	0.0	44.0	7.0	0.0	5.0	1.0

TABLE 4.12 ANNUAL MAXIMUM FLOOD PEAKS

(m3/sec)

Year	Buenos Aires	Rancho Apulco	Sontalaco	Canal Tunnel I
1948		107.7		
1949		123.6		
1950		20.7		
1951		135.4		
1952		249.6		
1953		-		
1954		518.9		
1955		1675.0		
1956		89.2		
1957		39.0		
1958		243.0		
1959		164.3		
1960		95.3		
1961		288.0		
1962		142.0		
1963	134.0	189.0	51.2	14.8
1964	192.0	94.1	26.1	41.9
1965	183.0	94.8	37.9	35.6
1966	440.0	124.0	33.9	31.5
1967	181.0	94.8	21.8	30.5
1968	166.0	112.0	15.2	26.1
1969	282.0	220.0	70.0	27.6
1970	87.7	178.0	33.4	26.7
1971	232.0	90.0	45.4	28.2
1972	148.0	55.9	36.4	27.3
1973	256.0	88.6	22.1	31.3
1974	711.0	135.0	86.5	29.9
1975	249.0	111.0	59.1	32.1
1976	225.0	166.0	78.0	31.3
1977	41.2	112.0	18.9	31.3
1978	225.0		43.7	32.1
1979	413.0		46.4	32.1
1980	183.0		282.0	31.7
1981	451.0		166.0	33.8
1982	221.0		34.8	33.1
1983	152.0		280.0	37.2
1984	655.0		60.3	32.6
1985	245.0		32.2	33.5
1986	196.0		29.3	33.5
1987	128.0		26.3	32.1
1988	540.0		46.3	34.3
1989	404.0		29.0	33.5
1990	175.0		39.4	32.4
1991	184.0			

TABLE 4.13 FLOOD PEAK AT BUENOS AIRES AND BASIN AVERAGE RAINFALL

Year	Flood Peak (m3/sec)	Rainfall (mm) 1-day	2-day	3-day
1963	134.0	39.9	45.2	46.9
1964	192.0	12.4	19.4	20.7
1965	183.0	32.4	50.7	63.1
1966	440.0	63.6	101.2	122.9
1967	181.0	50.1	64.3	76.9
1968	166.0	19.6	26.5	28.8
1969	282.0	66.3	89.8	97.2
1970	87.7	9.8	26.2	50.4
1971	232.0	27.0	44.8	46.2
1972	148.0	13.4	19.1	23.3
1973	256.0	19.0	34.9	42.5
1974	711.0	155.7	188.5	193.8
1975	249.0	30.7	36.8	44.3
1976	225.0	54.7	68.6	70.8
1977	41.2	4.0	12.4	21.0
1978	225.0	45.0	47.7	52.8
1979	413.0	69.1	76.8	90.4
1980	183.0	49.3	97.8	127.9
1981	451.0	41.1	94.6	129.6
1982	221.0	48.3	77.7	82.9
1983	152.0	9.6	11.4	14.9
1984	655.0	53.5	92.7	117.4
1985	245.0	39.5	47.8	49.0
1986	196.0	39.6	78.5	86.7
1987	128.0	18.6	30.1	30.8
1988	540.0	85.2	103.3	120.7
1989	404.0	46.9	84.3	116.7
1990	175.0	34.9	68.7	70.3
1991	184.0	26.5	45.0	61.7
Correlation Coefficient		0.790	0.808	0.808

TABLE 4.14 FLOOD PEAK AT RANCHO APULCO AND BASIN AVERAGE RAINFALL

Year	Flood Peak (m3/sec)	Rainfall (mm) 1-day	2-day	3-day
1955	(1675.0)	113.8	208.8	216.1
1956	(89.2)	16.1	18.0	18.6
1957	39.0	26.2	37.4	46.9
1958	243.0	41.1	63.4	66.7
1959	164.3	16.0	29.3	37.6
1960	95.3	12.1	21.0	30.0
1961	288.0	20.0	24.7	39.4
1962	142.0	27.9	62.1	99.1
1963	189.0	14.6	20.6	22.6
1964	94.1	12.4	19.7	21.0
1965	94.8	14.5	28.6	35.8
1966	124.0	46.1	73.0	91.1
1967	94.8	19.7	25.4	25.4
1968	112.0	31.3	59.2	70.4
1969	220.0	46.0	61.7	66.0
1970	178.0	10.3	27.0	50.0
1971	90.0	17.2	25.0	38.4
1972	55.9	15.2	23.3	27.7
1973	88.6	15.4	26.1	32.9
1974	135.0	129.3	159.2	164.0
1975	111.0	45.1	68.0	90.9
1976	166.0	52.3	66.1	67.3
1977	112.0	18.7	24.5	26.1
Correlation Coefficient		0.142	0.138	0.142

Note : Data with ( ) are excluded from calculation of correlation coefficien since data with ( ) are estimated from other gauging station.