1.2 Sewerage System in Future

No data of future sewerage development plan of D.F. Mexico and Mexico State are available. JICA Study Team has assumed the sewerage service population ratio to estimate the wastewater discharge volume. The ratio is mentioned below:

Year	D.F. Mexico	Mexico State
1997	98 %	95 %
2015	100 %	100 %

2. Discharged Wastewater

2.1 Quantity of Discharged Wastewater

Generally, the quantity of wastewater for treatment is determined with due consideration to the groundwater infiltration into the sewerage system. However in the Study Area, the groundwater table is rather low with the depth of 6 m in average. Hence groundwater infiltration is neglected for calculating wastewater quantity.

The quantity of total discharged wastewater is estimated by multiplying wastewater generation with the sewerage service population ratio. The Quantity of discharged wastewater in D.F. and Mexico State is mentioned below.

1) D.F. Mexico

The existing and future wastewater generation in the D.F. Mexico, as described in Appendix B are as follows:

Existing	:	24.71 m^3/sec
Future in 1997 (Urgent Project)	:	26.14 m^3/sec
Future in 2015 (Final Project)	:	34.08 m^3/sec

Existing and future expected population service ratio is as follows:

Existing	:	94 %
Future in 1997	:	98 %
Future in 2015	:	100 %

Hence existing and future wastewater discharge quantity in the Study Area of D.F. Mexico are estimated as follows.

Existing	:	23.23 m^3/sec
Future in 1997 (Urgent Project)	:	25.62 m^3/sec
Future in 2015 (Final Project)	:	34.08 m^3/sec

2) Mexico State

The existing and future wastewater generation in the Mexico State, as described in Appendix B are as follows:

Existing	:	10.79 m^3/sec
Future in 1997 (Urgent Project)	:	11.51 m^3/sec
Future in 2015 (Final Project)	:	13.30 m^3/sec

Existing and future expected population service ratio are as follows:

Existing	:	85 %
Future in 1997	:	95 %
Future in 2015	:	100 %

Hence the existing and future wastewater discharge in the Study Area of Mexico State are estimated as follows.

Existing	:	9.17 m^3/sec
Future in 1997 (Urgent Project)	:	10.93 m^3/sec
Future in 2015 (Final Project)	:	13.30 m^3/sec

From the above discussions the total discharged wastewater quantity in the study area of D.F. and Mexico state are as follows:

		D.F.	Mexico State
Existing	:	23.23 m^3/sec	9.17 m^3/sec
Future in 1997 (Urgent Project)	:	25.62 m^3/sec	10.93 m^3/sec
Future in 2015 (Final Project)	:	34.08 m^3/sec	13.30 m^3/sec

2.2 Quality of Discharged Wastewater

As discussed in Appendix B, the discharged wastewater in the study area is being carried by Gran Canal, hence characteristics of Gran Canal give approximate estimation of the quality of discharged wastewater. The Appendix B further elaborate the unit per capita pollution load, in terms of BOD_5 and SS, being discharged in the study area. In D.F., unit pollution load in terms of BOD_5 and SS is estimated to be 50.8 g/cd and 52.5 g/cd respectively. In Mexico state, unit pollution load in terms of BOD_5 and SS is estimated to 40.3 g/cd and 41.7 g/cd respectively.

The quality of discharged wastewater in the Year 1997 and 2015 is estimated under the following conditions:

- Unit per capita pollution load generation in the future is found to be same as that of existing for both D.F. and Mexico state

- Treated water reused for industrial purpose will return back to sewerage system

- Future discharged sludge volume from wastewater treatment plants will be the same as existing one. It means that new small treatment plants to be constructed for the requirement of reuse water (ref. Appendix D, section 4) will have their own sludge treatment facilities.

From Appendix D, section 2.1 total discharged wastewater quantity in the year 1997 and 2015 is estimated as follows

Study Area	Discharged Wastewater Quantity (m^3/sec)	
	1997	2015
D.F. Mexico	25.62	34.08
Mexico state	10.93	13.30

Hence total discharged wastewater quantity in the study area for the year 1997 and 2015 are 36.55 m^3/sec and 47.38 m^3/sec.

Design influent wastewater quality in terms of BOD_5 for the year 1997 is calculated as follows:

BOD_5 load of D.F.	=	50.8	g/cd x 9277200 x 98 %
	=	461,856	Kg BOD_5 / day
BOD_5 load of Mexico state	=	40.3	g/cd x 5612900 x95 %
	=	214,890	Kg BOD_5 / day

Hence BOD_5 of municipal wastewater in study area = 214 mg/l

Similarly BOD_5 of municipal wastewater in study area in the year 2015 is found to be 233 mg/l. SS of municipal wastewater in the study area for the year 1997 and 2015 are found to be 221 mg/l and 241 mg/l.

3. Sewer Networks

3.1 Sewer Networks in D.F. Mexico

3.1.1 Existing Sewer Networks

The sewer network system in D.F. consists of following six (6) components:

- Secondary Sewer (Red Secundaria)
- Main Sewer (Red Primaria)

- Intermediate Level Sewer
- Deep Level Sewer
- Drainage Pumping Station
- Drainage pumping station at Road Intersection

1) Secondary Sewer

Sewer with a diameter less than 450 mm is identified as Secondary Sewer. Secondary sewers of 11,226.4 km with a pipe diameter ranging from 300 mm to 450 mm exist in the Study Area of D.F. Mexico. Length of secondary sewer in each district is shown in Table D.2 (1). Secondary sewer length per unit administrative area ranges from 1.15 km/km^2 to 49.81 km/km^2 with an average of 8.37 km/km^2. The most densely laid secondary sewer area is found to be in Benito Juarez district having sewer length per unit administrative area ratio of 49.81 km/km^2. And the lowest ratio of 1.15 km/km^2 is observed in Cuajimalpa district.

2) Main Sewer

Main sewer is a pipe having diameter more than 610 mm. In 1991, total length of main sewer was 1,408.4 km. The length of main sewer for each diameter is shown below.

Diameter of Sewer (mm)	Total Length (m)
610	417,432
760	206,093
910	159,877
1,070	146,185
1,220	113,742
1,520	150,691
1,830	88,474
2,130	35,626
2,440	57,450
3,000	25,905
4,000	6,925
Total	1,408,400

Length of main sewer in each district is shown in Table D.2 (1).

3) Intermediate Level Sewer

Intermediate level sewer is laid at the depth of 8-10 meters below ground surface. Intermediate level sewer carries both sewage and storm water collected by secondary and main sewers. Total length of intermediate level sewer is 6.0 km with Iztapalapa intermediate level sewer of 5.29 km and Obrero Mundial intermediate sewer of 0.71 km. The location is shown in Fig. D.3.

4) Deep Level Sewer

Deep level sewer is constructed at a depth greater than 20 meters below ground surface. Deep level sewer has been constructed since 1975 and still now some are under construction. There are six (6) deep level sewer lines with a total length of 121.1 km in D.F. Mexico. Length, diameter and laying depth of these six (6) existing deep level sewers are described in Table D.3 and their locations are shown in Fig. D.3.

5) Drainage Pumping Station

About 70 drainage pumping stations are existing in the Study Area of D.F. Mexico. Capacity and location of each pumping station is shown in Table D.4. Capacity of drainage pumping station ranges from 0.10 m^3/sec (San Luis Tlaxialtemalco) to 49.60 m^3/sec (No.2 pump station in V. Carranza).

6) Drainage Pumping station at Road Intersection

For draining storm water on the roads and the footways, 91 pumping stations exist in the Study Area of D.F. Mexico. The capacity of these pumping stations ranges from 0.01 m^3/sec to 0.84 m^3/sec.

3.1.2 Future Plan

Intermediate level sewer and deep level sewer are being constructed as per schedule, however main and secondary sewers are constructed depending on the availability of budget and the urgency.

Following intermediate level sewers and deep level sewers are now under construction/planning stage.

Name of Sewer	Location	Remarks
Intermediate Level Sewer		
Canal National-	Iztapalapa, Tlahuac	Under Construction
Canal de Chalco	Xochimilco	
Cuautepec	G. A. Madero	Planning
Indios Veldes	G. A. Madero	Planning
Ermiti	Iztapalapa, Tlahuac	Planning
Deep Level Sewer		
Oriente (1 st stage)	G. A. Madero	Under Construction
Oriente (2 nd stage)	G. A. Madero	Planning
Oriente - Oriente	Iztapalapa	Planning
Oriente Sur (2 nd stage)	Iztapalapa	Planning
Central	Benito Juarez	Planning

3.2 Sewer Networks in Mexico State

The sewer network system in Mexico state consists of following three (3) components:

- Secondary Sewer
- Main Sewer
- Drainage Pumping Station

1) Secondary Sewer

Secondary sewer of about 4170 km with a pipe diameter ranging from 300 mm to 450 mm exist in the Study Area of Mexico State. Length of secondary sewer in each municipality is shown in Table D.2 (2). Secondary sewer length per unit administrative area ranges from 0 Km/km^2 to 23.11 Km/km^2, with an average of 2.98 Km/km^2. The most densely laid secondary sewer area is found to be in Ecatepec municipality having sewer length per unit administrative area ratio of 23.11 Km/km^2. And the lowest ratio of 0 Km/km^2 is observed in Jilotzingo municipality.

2) Main Sewer

In 1993, total length of main sewer was 762.3 Km. The length of main sewer in each municipality is shown in Table D.2 (2). Main sewer length per unit administrative area ranges from 0.01 Km/km^2 to 2.15 Km/km^2 with an average of 0.55 Km/km^2. The most densely laid main sewer area is found to be in Nezahualcoyotl municipality having sewer length per unit area ratio of 2.15 Km/km². The lowest of 0.01 Km/km² is observed in Jilotzingo municipality.

3) Drainage Pumping Station

In 1993, total 78 drainage pumping stations were found to exist in the study area. The location and capacity of each pump are being examined.

4. Wastewater Treatment Plant

4.1 Wastewater Treatment Plant in D.F. Mexico

Existing 21 wastewater treatment plants in D.F. were constructed to create the new water resources from treated water. These wastewater treatment plants treat only 11.6% of total average discharged wastewater of 23.23 m^3/sec. in the Study Area of D.F. Mexico. Details of existing 21 wastewater treatment plants are described in Table D.5(1) and the locations are shown in Fig. D.4.

The total design capacity of existing 21 treatment plants is 5.860 m^3/sec, however the average operating capacity in 1992 is found to be 2.697 m^3/sec, which is about 46% of the total design capacity. These treatment plants are very small and design capacity ranges from 0.0075 m^3/sec. to 4.0 m^3/sec. The average operating capacity in 1992 was found to vary between 0.005 m^3/sec. to 1.409 m^3/sec. Largest treatment plant, i.e., Cerro de la Estrella with a design capacity of 4.0 m^3/sec., now treats only 1.409 m^3/sec. which is 35% of the design capacity.

The oldest wastewater treatment plant of Chapultepec with an operation capacity of 0.106 m^3/sec. located in Miguel Midalgo District was constructed in 1956 to create the irrigation water for Chapultepec park.

All existing wastewater treatment plants employ the conventional activated sludge process as a secondary treatment process with a baffle diffuser system and/or surface aeration system. Only three (3) existing treatment plants, i.e., El Rosario in Azcapotzalco district, Iztacalco in Iztacalco district and San Luis Tlaxialtemalco in Xochimilco district are equipped with tertiary treatment process. Sand filtration and /or activated carbon filtration are employed as tertiary treatment process.

The treatment plants constructed before 1981 have no sludge treatment process. The sludge produced from these 17 treatment plants has been discharged to sewer system without any treatment. Remaining four (4) treatment plants are equipped with sludge treatment process of anaerobic digestion with drying bed, anaerobic digestion with mechanical dewatering and aerobic digestion with thickener and drying bed. However, at present the sludge produced from these 4 treatment plants is being discharged to sewer system without any treatment. This is because of operational problems in sludge treatment system and unavailability of equipment for repairing.

4.2 Wastewater Treatment Plant in Mexico State

All existing eight (8) wastewater treatment plants were constructed to reuse the treated water for irrigation and industrial purpose. Details of existing treatment plants are shown in Table D.5 (2) and their locations are shown in Fig D.4.

Total design capacity of existing 8 treatment plants is 0.855 m^3/sec with an existing operation capacity of 0.375 m^3/sec which is about 44% of the design capacity. All existing wastewater treatment plants have small design capacity ranging from 0.005 m^3/sec to 0.40 m^3/sec.

Among 8 existing treatment plants, only one (1) treatment plant of Naucalli treatment plant having capacity of 0.04 m^3/sec is governed by CEAS.

Pintores and Nezahualcoyotl plants are being operated by municipality itself having capacity of 0.005 m^3/sec and 0.20 m^3/sec respectively. And five (5) treatment plants are being operated by private factories.

5. Treated Wastewater Quality and Reuse

The reuse of treated water is mainly being practiced within the D.F. area, though there are some in the state of Mexico area as well. In fact all the existing treatment plants have been constructed with the objective of reusing treated water and are not aimed at environmental improvement.

The treated wastewater is conveyed, mostly through pressure pipe system, for various reuses in D.F. area with the major reuse being irrigation of green areas and parks including ecological replenishment of lakes, ponds and canals (83%), followed by cooling water for industry (10%), agricultural irrigation (5%) and non potable commercial use (2%).

The existing pressure pipe distribution system of reuse water in D.F. area along with the future expansion until the year 2000 is shown in Fig. D.5.

It is noted that within the D.F. area, unlike those states of Mexico and Hidalgo, only treated wastewater at least up to a secondary level, is reused even for agricultural irrigation. Hence, there is no cropping restriction.

Almost the entire treated wastewater for such agricultural irrigation is supplied by the largest wastewater treatment plant in D.F., the Cerro de la Estrella in Iztapalapa, secondary treatment plant with a capacity of 4 m^3/s. This plant is being upgraded to a tertiary treatment level.

The agricultural areas of this treated wastewater irrigation are located in the districts of Milpa Alta, Tlahuac, and Xochimilco, located along the south eastern fringes of the D.F. area.

A variety of agricultural crops including the economically attractive ones of cauliflower, cabbage and artichoke are being cultivated in those areas of treated wastewater irrigation.

The above reuses of treated wastewater, under the existing conditions, covers almost the entire spectrum of alternatives for conventional reuse. In addition, some amount of the tertiary treated wastewater is used for groundwater recharge of aquifer by injection, a non conventional reuse.

There are two (2) of such injection wells of groundwater recharge. One is in Xochimilco, operated on a pilot basis using a portion of the tertiary treated wastewater from the San Luis treatment plant. At present, however, this pilot well is not in operation.

The other well is operated on an experimental basis at Santa Catarina in Tlahuac. The necessary tertiary treatment for the secondary treated wastewater conveyed from the Cerro de la Estrella plant is conducted at the site of the injection well. The tertiary treatment process employed is preaeration followed with dual media (sand and anthracite) filtration, activated carbon adsorption and chlorination for disinfection. The capacity of tertiary treatment plant is 20 l/s (1,700 m^3/d) which is also the quantity of reuse water injected to aquifer.

5.1 Monitoring of Reuse Water Quality

(1) Conventional Reuse

The water quality of the supplied treated wastewater for conventional reuses, the discharge water quality, and also the environmental (stream) water quality of the lakes and canals replenished with the treated wastewater are monitored at 78 monitoring stations located at various types of reuse areas in D.F..

The number and locations of the monitoring stations do not remain the same, though they cover all major locations of various reuse type.

The monitoring is done by the Central Laboratory on a weekly (59 locations) and semimonthly (19 locations) basis.

All of the semimonthly monitoring stations are those of environmental (stream) water quality located in lakes and canals.

Of these 78 monitoring stations, as of 1994, the most (45 locations) are in lakes and canals, followed with green areas and parks of irrigation (16 locations), industrial cooling (9 locations), agricultural irrigation (6 locations) and one (1) each in recreational facility and public washing facility.

Breakdown of these monitoring stations in D.F. area according to the category of reuse and that of characteristics of sampling point, is shown below.

Reuse Type	Number of Monitoring Stations	
	Before reusing at the discharge point	After reusing in the environment
Lakes and canals	2	43
Irrigation-green area	16	0
Irrigation-agriculture	6	0
Industrial cooling	9	0
Recreational facility	1	0
Public washing facility	1	0
Total	35	43

The water quality parameters measured cover the typical physical, chemical and biological ones including those of heavy metals (a total of 41 parameters).

It has been reported that most of the parameters conform to the standard requirement for the concerned reuse as described in Chapter C, section 6. Only Coliforms as MPN/100ml were found to exceed the prescribed maximum limit as also shown in Appendix D, section 5.

All these conventional reuses require secondary treatment, and all existing treatment plants have a minimum of secondary treatment level. Hence conformity to the standards of reuse is in accordance with the expectation.

(2) Non Conventional Reuse

Groundwater recharge by injection, at Santa Catarina (Tlahuac) and San Luis (Xochimilco), is the only non conventional reuse of treated water being practiced at present, as mentioned in previous section.

The water quality of the experimental tertiary treatment plant at Santa Catarina is monitored weekly by the Central Laboratory. Besides influent and effluent, water quality is monitored at the end of each intermediate process.

The water quality analysis results for about the six (6) months period from September 1992 to March 1993 indicated the results for about fifty (50) measured parameters. The measured parameters included major physical, chemical and biological ones including those of heavy metals. Most of the measured parameters, prior to injection, including those of BOD_5, COD, Coliforms and heavy metals were in conformity with their standard limitation specified for the reuse of "recharge to aquifers with direct injection" as mentioned in Appendix C, section 6.

The significant non conformity with the standards was with respect to the parameter "oil and grease". Even though the standards specified zero (0) concentration for this parameter, consistently rather high concentration in the range of 2.5-16 mg/l were noted. This indicate the need for instituting more efficient oil removal process to the tertiary treatment system at Santa Catarina.

On the other hand, since the aquifer recharge well in San Luis is not in operation at present, no recent water quality data is available.

5.2 Future Reuse

The latest available report on treatment and reuse of wastewater was produced by DGCOH in the year 1990 (Plan Maestro de Tratamiento y Reuso del Distrito Federal). This report analyses various alternatives of conventional and non conventional reuses of both the treated wastewater and the storm water until the year 2010.

The report envisages on a short term basis in the near future, expansion of treated wastewater reuse for agricultural irrigation and industry (cooling water), because for these reuses secondary wastewater treatment level would be adequate.

In fact agricultural irrigation with untreated wastewater is widely practiced in the Mexico and Hidalgo States utilizing the wastewater generated in D.F. area and the surrounding urban areas of the state of Mexico (Metropolitan areas the Mexico State).

Since the principal source of this wastewater generation is D.F. area, even though these reuse irrigation areas are located beyond the jurisdiction of D.F. area, provision of necessary treatment prior to irrigation to these existing wastewater irrigation areas shall be of high priority, as per the above near future plan.

On a long term basis, the above mentioned report of 1990 envisages more non conventional reuse of treated wastewater. The two (2) important non conventional reuses considered are:

1. Aquifer recharge
2. Non potable domestic reuse

With the above two (2) non conventional reuses, all possible alternative reuses of treated wastewater, both conventional and non conventional ones, are taken into consideration in future (until 2010).

At present groundwater accounts for almost 75% of the entire potable water demand of D.F. area. Over exploitation of groundwater has become a serious issue as the result of progressing land subsidence in Mexico Valley.

These two (2) non conventional reuses of the treated (rather renovated) wastewater are considered as the most significant and effective means of mitigating over exploitation of groundwater for potable use, and hence the resultant land subsidence.

In order to realize these non conventional reuses a minimum of tertiary wastewater treatment level may be necessary to meet the stringent standards. In fact on pilot scale and experimental basis tertiary treated wastewater are being used in Xochimilco and Tlahuac for aquifer injection, as described in foregone section.

Conformance to even drinking (potable) water quality standards may become a technical prerequisite in future to alleviate the toxicological and epidemiological concerns to the population served with non potable domestic reuse water. Even then, social and economical aspects may still remain potential constraints.

In an attempt to produce treated wastewater conforming to that of drinking water quality, an experimental advanced treatment unit is being run at the Cerro de la Estrella treatment plant.

The capacity of this experimental unit, that produces water conforming to that of potable water quality, is 30 l/min, and uses the secondary treated effluent of the treatment plant as its influent.

The advanced treatment process used in the experimental unit is preaeration, followed with chemical precipitation, desorption, recarbonation, filtration, ozonation, adsorption, reverse osmosis and chlorination.

Though the technical feasibility of this experimental unit to produce "potable water" is confirmed, its technical and economic feasibility in producing such water in large quantity, in a typical advanced treatment plant, remain to be investigated.

It is to be noted that the water quality requirement of non potable domestic reuse is dependent on the intended use. For example, if the use could be limited to flushing of toilets only, then even a secondary treated effluent would be adequate.

5.3 Water Quality Standards of Reuse

The water quality standards on National basis as well as on D.F. basis, regarding the quality of wastewater to be reused, have been established. These regulations are listed below.

1. Regulations for water reuse in Federal District (Reglamento para el Reuso del Agua en el Distrito Federal 1987). This law prescribes limits of various parameters based on the type of reuse.

2. Mexican Official Standard Nom-CCA-032-ECOL/1993. This law dictates the maximum limit of pollutants for irrigation waters.

3. Mexican Official Standard Nom-CCA-033-ECOL/1993. This law dictates the maximum limit of bacteriological parameters for irrigation waters.

The above mentioned water Quality Standards for reuse have been already discussed in detail in Appendix C, section 6.

6. Reuse of Sludge

Compared to reuse of wastewater the reuse of sludge is negligible. Only four (4) existing treatment plants have sludge processing/treatment facility. The plants are of small capacity and the quantity of dried sludge produced is not very significant. The dried sludge produced in this plant is supplied to farmers for reuse as fertilizer. However due to operation problem sludge processing facilities are not in operation and sludge is being discharged to sewerage system.

In future, with the installation of sludge processing/treatment facilities, as per the policy of DGCOH, in those plants with no sludge treatment facilities as well as with new treatment plants which would be constructed with due consideration to sludge treatment, the quantity of sludge production would increase. Accordingly, appropriate reuse alternatives for sludge would become an important consideration.

7. Design Conditions and Criteria of Existing Treatment Plant

Any design criteria for wastewater treatment plant of D.F. Mexico and Mexico state were not established. All existing treatment plants were designed based on the design standards of EPA and/or WEF, and also the reference book published by Metcalf & Eddy.

While designing the blower for aeration tank, the factor that Mexico is located at a high altitude of about 2,240 meters, should be considered. The larger capacity of blower is required to diffuse the sufficient oxygen to dissolve organic matter in the wastewater than that required in the areas of normal altitude.

The design conditions, such as capacity and effluent quality of all the existing treatment plants have been decided based on the requirements of reuse conditions.

Details of design criteria of Cerro de la Estrella with a design capacity of 4.0 m^3/sec. are summarized in Table D.6.

8. Operation and Maintenance

8.1 Operation and Maintenance in D.F. Mexico

Wastewater treatment system in D.F. Mexico is managed by General Direction of Construction and Hydraulic Operation (DGCOH).

All existing 70 wastewater pumping stations and 16 wastewater treatment plants are operated and maintained by the staffs belonging to Operation and Maintenance section of DGCOH. Total number of staffs of the operation and maintenance section are 470. Total number of administrative staffs are 35.

Annual expenditure of N$ 18.482 million for the operation and maintenance of wastewater treatment system in the year 1993 has been reported. The breakdown of the expenditure is as follows:

- Personal expenditure : N$ 10.681 million
- Fuel and power cost : N$ 2.580 million
- Chemical cost : N$ 0.320 million
- Repairing cost : N$ 2.645 million
- Other cost : N$ 2.256 million

8.2 Operation and Maintenance of Cerro de la Estrella Wastewater Treatment Plant

As a reference for the operation and maintenance program of the proposed Texcoco wastewater treatment plant, existing operation and maintenance condition of the biggest existing wastewater treatment plant, i.e., Cerro de la Estrella were studied.

Design capacity and existing operation capacity of Cerro de la Estrella treatment plant has been mentioned in the previous section.

Total number of staffs working in this treatment plant is 120. The number of staff in various sections are mentioned below:

A)	Operation staffs	-	57
B)	Maintenance staffs for machinery and electricity	-	50
C)	Administrative staffs	-	12
D)	Director of treatment plant	-	1

Operation staff is grouped into four (4) teams. Three (3) teams each having 15 members operate treatment plant on weekdays, from Monday to Friday. Another team having 12 members is responsible for operation on Saturday and Sunday only. However in the initial stages of the operation of Cerro de la Estrella plant each team had 11 members and the design capacity of the plant was 2.0 m^3/sec.

Monthly operation and maintenance cost of N$ 1.159 million in the year 1992 has been reported. The breakdown of the expenditure is as follows:

- Personal expenditure	:	N$ 0.173 million	(14.9 %)
- Power cost	:	N$ 0.285 million	(24.6 %)
- Repairing cost	:	N$ 0.632 million	(54.5 %)
- Chemical cost	:	N$ 0.060 million	(5.2 %)
- Other cost	:	N$ 0.009 million	(0.8%)

Equipment installed at the existing treatment plant are mainly imported ones and that could be the reason of higher repairing cost.

The unit operation and maintenance cost is found to be N$ 0.317 /m^3 of average treated wastewater of 1.409 m^3/sec.. The operation and maintenance cost for sludge treatment have not been included in this O/M cost, because no sludge treatment plant is existing at Cerro de la Estrella treatment plant.

9. Organization and Law

9.1 Organization

The organizations directly concerned to sanitation in the Study Area are DGCOH in the Federal District, CEAS in the Mexico State and CNA at the national level.

DGCOH and CEAS are responsible for the planning, construction and operation & management of water supply and sanitation facilities in their respective jurisdictions. CNA is responsible for the establishment of national plan on hydraulics, sanitation and river management.

9.1.1 DGCOH

DGCOH is one of the organizations composing Department of the Federal District (DDF).

DDF is one of the 20 Ministries and Departments under the Office of the President of the United States of Mexico.

This department is composed of:

i. 4 General Secretariats and 6 other similar level organizations and
ii. 29 General Directorates.

The 4 Secretarias General Secretariats are:

i. General Secretariat of the Government,
ii. General Secretariat of Social Development,
iii. General Secretariat of Works and
iv. General Secretariat of Protection and Road Engineering.

DGCOH is one of the 3 General Directorates under General Secretariat of Works, the other 2 General Directorates being:

i. General Directorate of Public Works and
ii. General Directorate of Urban Services.

DGCOH is comprized of 6 Directorates, namely:

i. Technical Directorate,
ii. Directorate of Construction
iii. Directorate of Operation
iv. Directorate of Maintenance
v. Directorate of Hydraulic Services to Users and
vi. Directorate of Hydraulic Operation Support Services.

(For further details refer to Fig.D.6.)

DGCOH 's total work force reached 12,935 in 1993, of which managers, technicians, workers and clerks accounted for 0.5%, 9.4%, 80.7% and 9.4% respectively.

The revenue budget of DDF for 1994 comes to N$ 16,380 million, of which N$ 703 million or 4.3% derives from water supply services. On the other hand, the organization-wise expenditure budget of the Department for the same year sums up to N$ 15,818 million, of which the allocation for DGCOH is N$ 1,222 million or 7.7%. It is to be noted that the revenue attributed to DGCOH meets only 57.5% of the expenditure of the organization.

Each of the 17 Districts in the Federal District is responsible for the operation and maintenance of water supply and sewerage facilities under its jurisdiction.

9.1.2 CEAS

CEAS is one of the organizations composing SDUOP, i.e.Secretariat of Urban Development and Public Works. The latter constitutes one of 12 Secretarias under Governorship of the Mexico State.

SDUOP is composed of 4 organizations, the other three being:

i. Commission for Land Regulation of the Mexico State
ii. Institute of Urban Action and Social Interaction and
ii. Council of Electrification.

Regarding the organization structures of CEAS, it is made up of 6 Directorates, namely:

i. Internal Auditor
ii. Directorate of studies and Projects
iii. Directorate of Construction
iv. Directorate of Treatment Plants
v. Directorate of Operation and
vi. Directorate of Administration and Finance.

(For more details refer to Fig.D.7.)

The total work force of CEAS came to 1,573 in 1993, of which managers, technicians & workers and clerks accounted for 3.0%, 68.3% and 28.7% respectively.

Each of the 121 Municipalities in the Mexico State is responsible for the operation and maintenance of water supply and sewerage facilities under its jurisdiction. The total personnel for that purpose reached 4,880 in 1993.

The expenditure budget of the Government of the Mexico State for the fiscal year 1994 is N$ 3,211 million, of which N$ 288 million or 9.0% is allocated to CEAS.

Operating revenue of CEAS amounted to N$ 224.1 million in 1993, while the total cost and expenses added up to N$ 311.9 million. That is to say, the revenue covered 71.8% of the total expenditure in the same year.

9.1.3 CNA

CNA is a national organization under Ministry of Agriculture and Hydraulic Resources (SARH). It was established in January, 1989 as an organ carrying the mission to resolve or manage the various conflicts arising in connection with the distribution, exploitation and use of water.

CNA is a nation-wide executing agency of hydraulic projects. Based on their experience in hydrological studies, management of dam, waterworks design and construction, CNA will be responsible for bulk water supply.

The main office of CNA is in Mexico City. There are, in addition, six (6) regional offices and permanent staff in each of the state capitals. CNA has jurisdiction over all water in the country. This includes surface and ground water, sewage, and water for irrigation.

This organization is composed of four (4) General Sub-Directorates and one Sub-Directorate, namely:

i. General Sub-Directorate for Planning and Finance
ii General Sub-Directorate of Hydro-Agricultural Infrastructure
iii General Sub-Directorate of Hydraulic, Industrial and Urban Infrastructure
iv General Sub-Directorate for Water Administration
v. Administration Sub-Directorate

(For more details refer to Fig. D.8)

As of November, 1990 the staff of CNA consisted of 2,100 in Mexico City Offices, 4,200 in Regional Offices and 25,000 in State Offices, totaling 31,300. Out of it, administrators, manages, office staff and general payroll staff accounted for 0.03%, 0.2%, 8.4% and 91.4% respectively.

The roles of CNA in the matter of sanitation are clarified in the Law of National Water as mentioned in Appendix D, section 9.2.1.

9.2 Law

9.2.1 Laws and Regulations Concerning Water and Sanitation

DDF enforced the Regulation on Water Supply and Sewerage Services for the Federal District in January, 1990. In Article 4 of the regulation it is provided in connection with sanitation that the Department is concerned with:

i. Protection of ecological balance, water quality and sanitation of natural ponds, springs, riverbeds, dams and reservoirs
ii. Application of Technical Standards of Ecology to regulate the discharges of water to the sewerage system
iii. Establishment and operation of wastewater treatment system in conformity with Technical Standards of Ecology

(For more details and for other aspects refer to Table D.7.)

In December, 1992 Law of National Water was enforced by the United States of Mexico. The main objectives of the law were:

i. Comprehensive management of water, in which users shall be involved to a greater extent.
ii. Establishment of water plan and establishment of a single federal organ in charge of the administration of water in respect of its quantity and quality.
iii. Legal guarantee in the use and exploitation of water so that civilians may properly plan medium- and long-term activities.
iv. Efficient and rational use of water for the modernization of farm land and the country.
v. A greater participation of civilians in the construction and operation of infrastructure and in water services.

Especially, the item ii. is to be stressed in connection with this study. The law was introduced by the law-makers who felt deep concern and uncertainty regarding ever-widening discrepancies between the supply and demand of water as well as ever-worsening pollution problems in public waters, brought on by the rapid growth of population and industries.

In connection the item ii. with special references to its water quality aspects it is provided in Article 86 of the Law that CNA is in charge of:

i. Promoting, as need arises, executing and operating the federal infrastructure and necessary services for the protection, preservation and improvement of water quality in hydraulic basins and aquifers in accordance with the respective Mexican official standards and particular conditions of discharges

ii. Establishing and supervising the fulfillment of particular conditions of discharge which shall be met by wastewater which are generated in the estate and zones of federal jurisdiction

iii. Supervising that the use of wastewater may comply with the quality standards of water emitted for that purpose

States and other administrative organizations are now being forced to redirect their hydraulic and sanitation plan and programs.

(For more details and for other aspects refer to Table D.8.)

9.2.2 Water Tariffs

Different water tariffs are enforced between the Federal District and the Mexico State. The tariffs applied to the Federal District are provided in Finance Law of the Department of the Federal District, while those applied to the Mexico State are provided in Municipal Finance Law of the Mexico State.

The tariffs of DDF are basically composed of the one for the clients with water meters and the one for the clients without water meters. Further, the former is composed of the one for domestic clients and the one for non-domestic clients. The latter is composed in the same way.

The tariffs of the Mexico State are basically composed of the one for domestic clients and the one for non-domestic clients. Further, the former is composed of the one for clients with meters and the one for clients without meters. Also, the latter is composed in the same way.

Regarding DDF tariffs for domestic clients with meters, those who bimonthly consume up to 10 m^3 are exempted from any charges, those who bimonthly consume 10.1 m^3 to 20 m^3 will pay N$ 0.55 per m^3 and those who bimonthly consume 20.1 m^3 to 30 m^3 will pay N$ 0.60 per m^3. The unit charge progressively goes up as consumption gets greater. Non-domestic clients with meters will pay about two times more compared with domestic clients for the same volume of consumption.

Domestic clients without meters in the Federal District will pay fixed bimonthly charges, whose amount varies depending on the assessed type of areas and the assessed value of buildings from zero up to N$ 401.45. Non-domestic clients without meters will pay fixed bimonthly charges of N$ 100.35 to N$ 799,623.90 based on the diameter of the tap.

The 121 Municipalities of the Mexico State are divided into Group A and Group B based on their general economic level. Under the tariffs of the Mexico State domestic clients with meters who bimonthly consume up to 25 m^3 will pay N$ 0.56 per m^3 (Group A) or N$ 0.45 per m^3 (Group B) and those who bimonthly consume 25.01 m^3 to 50 m^3 will pay N$ 0.90 per m^3 (Group A) or N$ 0.73 per m^3 (Group B). Domestic clients without meters will pay fixed bimonthly charges of N$ 38.30 to N$ 860.94 depending on the group they belong, the income class they belong and the diameter of the tap they use.

Non-domestic clients with meters in the Mexico State will pay about two times more compared with domestic clients for the same volume of consumption. Non-domestic clients without meters will pay fixed bimonthly charges of N$ 89.49 to N$ 16,653.17 depending on the group they belong and the diameter of the tap they use (For details refer to Table D.9).

Table D.1 Existing Sewerage Service Area and Population by District / Municipality in Study Area

No.	Name of District / Municipality	Total Area (km^2)	Existing (1993) Population	Service Area Area (km2)	Service Area (%)	Service Population Population	Service Population (%)
District in Federal District			1)		3)		3)
1.	Alvaro Obregon	94.50	690,100	94.50	100%	690,100	100%
2.	Azcapotzalco	33.50	493,000	33.50	100%	493,000	100%
3.	Benito Juarez	26.60	426,100	26.60	100%	426,100	100%
4.	Coyoacan	54.40	666,700	54.40	100%	666,700	100%
5.	Cuajimalpa	80.90	127,300	40.45	50%	89,100	70%
6.	Cuauhtemoc	32.44	625,700	32.44	100%	625,700	100%
7.	G. A. Madero	87.00	1,326,100	82.65	95%	1,326,100	100%
8.	Iztacalco	22.90	467,000	22.90	100%	467,000	100%
9.	Iztapalapa	117.50	1,567,900	99.88	85%	1,364,100	87%
10.	Magdalena Contreras	68.00	204,200	40.80	60%	153,200	75%
11.	Miguel Hidalgo	42.50	430,900	42.50	100%	430,900	100%
12.	Milpa Alta	222.16	67,000	44.43	20%	20,100	30%
13.	Tlahuaqc	93.00	221,300	83.70	90%	199,200	90%
14.	Tlalpan	212.23	515,500	127.34	60%	386,600	75%
15.	Venustiano Carranza	32.42	547,200	32.42	100%	547,200	100%
16.	Xochimilco	122.00	286,600	97.60	80%	243,600	85%
	Total of District	1,342.05	8,662,600	956.11	71%	8,128,700	94%
Municipality in Mexico State			2)		3)		3)
17.	Amecameca	181.20	38,100	27.18	15%	5,700	15%
18.	Atizapan de Zaragoza	48.13	330,700	38.50	80%	281,100	85%
19.	Ayapango de Gabriel R. Millan	42.50	4,400	6.38	15%	700	15%
20.	Cocotitlan	40.00	8,500	6.00	15%	1,300	15%
21.	Chalco	203.75	296,800	30.56	15%	59,400	20%
22.	Ecatepec	69.69	1,022,300	55.75	80%	920,100	90%
23.	Huixquilucan	122.50	138,400	73.50	60%	83,000	60%
24.	Jilotzingo	85.00	5,100	25.50	30%	1,500	30%
25.	Juchitepec	40.94	4,200	6.14	15%	800	20%
26.	Naucalpan	158.13	825,200	142.32	90%	742,700	90%
27.	Nezahualcoyotl	93.13	1,317,800	88.47	95%	1,251,900	95%
28.	Temamatla	56.88	5,600	8.53	15%	800	15%
29.	Tenango del Aire	90.31	6,500	13.55	15%	1,300	20%
30.	Tlalmanalco	119.06	23,200	17.86	15%	3,500	15%
31.	Tlalnepantla	46.34	737,300	44.02	95%	700,400	95%
	Total of Municipality	1,397.56	4,764,100	584.26	42%	4,054,200	85%
	Total of Study Area	2,739.61	13,426,700	1,540.37	56%	12,182,900	91%

Source : 1) DGCOH
2) Comissión Estatal de Agua y Saneamiento (CEAS)
3) JICA

Table D.2 (1) Length of Main and Secondary Sewers of Each District in D.F. Mexico

Name of District	Area (km2)	Sewer Length (km)		Sewer Length per Unit Area (km/km2)	
		Main	Secondary	Main	Secondary
Alvaro Obregon	94.50	58.3	1,508.3	0.62	15.96
Azcapotzalco	33.50	85.3	401.4	2.55	11.98
Benito Juarez	26.60	84.2	1,325.0	3.17	49.81
Coyoacan	54.40	103.0	729.0	1.89	13.40
Cuajimalpa	80.90	2.6	92.8	0.03	1.15
Cuauhtemoc	32.44	87.5	487.8	2.70	15.04
G.A.Madero	87.00	205.0	1,682.0	2.36	19.33
Iztacalco	22.90	39.7	491.0	1.73	21.44
Iztapalapa	117.50	255.0	1,118.0	2.17	9.51
Magdalena Contreras	68.00	19.3	218.0	0.28	3.21
Miguel Hidalgo	42.50	162.0	1,173.0	3.81	27.60
Milpa Alta	222.16	27.9	433.0	0.13	1.95
Tlahuac	93.00	70.0	185.0	0.75	1.99
Tlalpan	212.23	57.2	459.0	0.27	2.16
Venustiano Carranza	32.42	95.0	700.0	2.93	21.59
Xochimilco	122.00	56.4	223.1	0.46	1.83
Total	1,342.05	1,408.4	11,226.4	1.05	8.37

Table D.2 (2) Length of Main and Secondary Sewers of Each Municipality in Mexico State

Name of District	Area (km2)	Sewer Length (km)		Sewer Length per Unit Area (km/km2)	
		Main	Secondary	Main	Secondary
Amecameca	181.20	3.80	42.3	0.02	0.23
Atizapan de Zaragoza	48.13	50.70	396.2	1.05	8.23
Ayapango de Gabriel R. Millan	42.50	2.80	4.4	0.07	0.10
Cocotitlan	40.00	0.90	11.0	0.02	0.28
Chalco	203.75	8.40	66.2	0.04	0.32
Ecatepec	69.69	136.50	1,610.8	1.96	23.11
Huixquilucan	122.50	93.90	149.7	0.77	1.22
Jilotzingo	85.00	0.50	0.0	0.01	0.00
Juchitepec	40.94	2.70	30.8	0.07	0.75
Naucalpan	158.13	183.50	682.7	1.16	4.32
Nezahualcoyotl	93.13	200.60	686.3	2.15	7.37
Temamatla	56.88	6.00	4.0	0.11	0.07
Tenango del Aire	90.31	2.40	17.4	0.03	0.19
Tlalmanalco	119.06	3.30	32.8	0.03	0.28
Tlalnepantla	46.34	66.30	435.0	1.43	9.39
Total	1,397.56	762.3	4,169.6	0.55	2.98

Table D.3 Deep and Intermediate Level Sewer

(1) Intermediate Level Sewer

Sewer	Length (km)	Diameter (m)	Capacity (m^3/s)	Depth (m)	
				Min.	Max.
Collector Iztapalapa Intermediate	5.29	3.1	20	11.5	15.5
Collector Obrero Mundial Intermediate	0.71	3.1	20	10	16
Total	6.00				

Note : 1994

(2) Deep Level Sewer

Sewer	Length (Km)	Diameter (m)	Capacity (m^3/s)	Depth (m)	
				Min.	Max.
Collector del Poniente Deep	16.5	4.0	25	12	18
Collector Centro - Poniente Deep	16.5	4.0	40	22	51
Collector Centro Deep	16.1	5.0	90	22	41
Collector Oriente Deep	18.6	5.0	85	37	55
Emisor Central	49.7	6.5	220	48	217
Collector Centro - Centro Deep	3.7	5.0	90	25	26
Total	121.1				

Note : 1994

Table D.4 (1) Pumping Station Operated by DGCOH

No	Name	Location (District)	Discharge to	Planned Capacity (m^3/s)
1	San Antonio	Alvaro Obregòn	La Piedad	2.40
2	Nueva Santa Marìa	Azcapotzalco	Consulado	3.60
3	Churubusco	Benito Juàrez	La Piedad	10.00
4	Iztaccìhuatl	Benito Juàrez	La Piedad	11.00
5	Tonalà	Benito Juàrez	La Piedad	10.00
6	Nicolàs San Juan	Benito Juàrez	La Piedad	3.25
7	Pedregal de San Francisco	Coyoacàn	La Piedad	0.30
8	Miramontes	Coyoacàn	Canal Nacional	6.00
9	Hueso	Coyoacàn	Canal Nacional	6.00
10	Las Bombas	Coyoacàn	Canal Nacianal	3.00
11	San Cosme	Cuauhtèmoc	Consulado	14.00
12	Pinacoteca Virreynal	Cuauhtèmoc	Consulado	0.11
13	Rodamo	Cuauhtèmoc	Consulado	0.70
14	Templo Mayor	Cuauhtèmoc	Consulado	0.68
15	Sòtano	Cuauhtèmoc	Consulado	0.165
16	Mecànicos	Cuauhtèmoc	Consulado	9.00
17	Chimalpopoca	Cuauhtèmoc	La Piedad	1.00
18	No. 5	Gustavo A. Madero	Gran Canal	8.60
19	No. 6	Gustavo A. Madero	Gran Canal	20.00
20	No. 6 - A	Gustavo A. Madero	Gran Canal	13.00
21	No. 7	Gustavo A. Madero	Gran Canal	20.00
22	No. 8	Gustavo A. Madero	Gran Canal	9.00
23	Pozo Indio	Gustavo A. Madero	Gran Canal	3.00
24	La Raza	Gustavo A. Madero	Consulado	8.00
25	C. T. M.	Gustavo A. Madero	Consulado	8.25
26	Patronato del Maguey	Gustavo A. Madero	Consulado	2.75
27	Acueducto de Guadalupe	Gustavo A. Madero	Consulado	4.40
28	Chiquihuite	Gustavo A. Madero	Consulado	3.20
29	Km 6 1/2	Iztacalco	Churubusco	9.00
30	Ejèrcito de Oriente	Iztacalco	Churubusco	16.00
31	Lomas Estrella	Iztapalapa	Canal Nacional	1.25
32	Aculco	Iztapalapa	Churubusco	40.00
33	Municipio Libre	Iztapalapa	La Piedad	6.00
34	Escuadròn 201	Iztapalapa	La Piedad	4.00
35	Central de Abastos I	Iztapalapa	Churubusco	16.00

Table D.4 (2) Pumping Station Operated by DGCOH

No.	Name	Location (District)	Discharge to	Planned Capacity (m^3/s)
36	Central de Abastos II	Iztapalapa	Churubusco	20.00
37	Laguna Mayor de Regulaciòn	Iztapalapa	Churubusco	2.00
38	Ejèrcito de Oriente	Iztapalapa	Churubusco	2.00
39	Càrcamo "A"	Iztapalapa	Churubusco	2.00
40	Càrcamo "C"	Iztapalapa	Churubusco	2.00
41	Canal Nacional Canal de Chalco	Iztapalapa	Canal Nacional	6.00
42	Canal de Garay	Iztapalapa	Canal Nacional	4.80
43	Marina Nacional	Miguel Hidalgo	Consulado	0.60
44	Tizoc	Miguel Hidalgo	Consulado	5.50
45	Politècnico	Miguel Hidalgo	Consulado	4.00
46	Sindicalismo	Miguel Hidalgo	La Piedad	2.00
47	Distriuidor Chapultepec	Miguel Hidalgo	Consulado	4.50
48	Riachuelo Serpentino	Tlàhuac	Canal Nacional	6.00
49	Villa Coapa	Tlalpan	Canal Nacional	8.30
50	No. 4 - A	V. Carranza	Gran Canal	8.00
51	No.1	V. Carranza	Gran Canal	31.50
52	No. 1 - A	V. Carranza	Gran Canal	29.00
53	No. 2	V. Carranza	Gran Canal	49.60
54	No. 3	V. Carranza	Gran Canal	5.10
55	No. 5 - A	V. Carranza	Gran Canal	22.00
56	Expenitenciaria	V. Carranza	Gran Canal	0.50
57	Lòpez Mateos	V. Carranza	Churubusco	4.00
58	Lago	V. Carranza	Churubusco	30.00
59	Arenal	V. Carranza	Churubusco	3.75
60	Zoquipa	V. Carranza	La Piedad	16.00
61	Nativitas	Xochimilco	Canal Nacional	0.80
62	Santa Cruz Acalpixca	Xochimilco	Canal Nacional	0.20
63	San Gregorio Atlapulco	Xochimilco	Canal Nacional	0.48
64	San Luis Tlaxialtemalco	Xochimilco	Canal Nacional	0.10
65	Barrio San Sebastian	Xochimilco	Canal Nacional	1.75
66	San Buenaventura	Xochimilco	Canal Nacional	20.00
67	Ermita Zaragoza	Estado de MËxico	Churubusco	5.00
68	Oceanìa	G.A.M.	Gran Canal	6.00
69	Renovacòn	Iztapalapa	Churubusco	8.00
70	El Saldo	Iztapalapa	Churubusco	20.00
Total				605.14

Table D.4 (3) Pumping Station Operated by Mexico State

No.	Name	Location (Municipality)	Discharge to	Planned Capacity (m^3 /sec)
1	San Fancisco	Atizapan de Zaragoza	Canal Atizapan	0.320
2	La Piedad	Atizapan de Zaragoza	Canal Atizapan	0.250
3	Palacio Municipal	Atizapan de Zaragoza	Canal Atizapan	0.062
4	Bellavista	Atizapan de Zaragoza	Rio Tlanepantla	0.030
5	Planta de Bombeo No. 1	Chalco	Canal General	4.702
6	Planta de Bombeo No. 2	Chalco	Canal General	6.153
7	Planta de Bombeo No. 3	Chalco	Canal General	6.153
8	Planta de Bombeo No. 4	Chalco	Dren 45	3.356
9	Solidarida 2	Chalco	Canal de la Compañía	4.102
10	Isidro Fabela y Oriente 32	Chalco	Canal Isidro Fabela	0.300
11	Isidro Fabela y Norte 6	Chalco	Canal Isidro Fabela	0.250
12	Isidro Fabela y Norte 17	Chalco	Canal Isidro Fabela	0.250
13	Isidro Fabela y Cuahutemoc	Chalco	Canal Isidro Fabela	0.855
14	Canal General y Agostadero	Chalco	Canal General	0.855
15	Canal General y Tezozomoc	Chalco	Canal General	0.855
16	Anahuac y Oriente 5	Chalco	Canal Anahuac	0.060
17	Moctezuma y Oriente 5	Chalco	Canal Moctezuma	0.020
18	López Mateos e Isidro Fabela	Chalco	Canal Isidro Fabela	0.090
19	Solidaridad 1	Chalco	Rio de la Compañía	0.090
20	San Isidro	Chalco	Rio de la Compañía	0.060
21	Tezozomoc y Poniente 23	Chalco	Canal General	0.060
22	Culturas de México	Chalco	Canal Solidaridad	0.060
23	Avandaro	Chalco	Rio de la Compañía	0.090
24	Dren 46 y Canal General	Chalco	Canal General	0.350
25	La Fragata	Ecatepec	Margen Izq. del Gran Canal	1.000
26	Industriales	Ecatepec	Margen Izq. del Gran Canal	3.800
27	El Chopo	Ecatepec	Margen Izq. del Gran Canal	4.800
28	Los Laureles	Ecatepec	Margen Izq. del Gran Canal	0.660
29	Las Vegas	Ecatepec	Margen Der. del Gran Canal	7.000
30	Granjas del Valle de Guadalupe	Ecatepec	Margen Der. del Gran Canal	6.900
31	Jardines de Casa Nueva	Ecatepec	Margen Der. del Gran Canal	4.600
32	Industrias Ecatepec	Ecatepec	Margen Der. del Gran Canal	6.600
33	R - 1	Ecatepec	Gran Canal	0.200
34	Aragón Norte	Ecatepec	Rio de los Remedios	3.500
35	Aragón Sur	Ecatepec	Rio de los Remedios	0.960
36	Canal de Sales	Ecatepec	Canal de Sales	0.300

Table D.4 (4) Pumping Station Operated by Mexico State

No.	Name	Location (Municipality)	Discharge to	Planned Capacity (m^3 /sec)
37	La Florida	Ecatepec	Canal de Sales	0.200
38	San Agustin	Ecatepec	Canal de Sales	0.500
39	Nueva Aragón	Ecatepec	Canal de Sales	1.200
40	Poligonos 1, 2 y 5	Ecatepec	Canal de Sales	6.600
41	Poligonos 3	Ecatepec	Canal de Sales	2.755
42	Sagitario 8	Ecatepec	Canal de Sales	1.250
43	Jardines de Santa Clara	Ecatepec	Gran Canal	0.100
44	La Florida	Naucalpan	Rio Chico de los Remedios	0.170
45	Bosques de Echegaray	Naucalpan	Rio Chico de los Remedios	0.200
46	Alce Blanco	Naucalpan	Rio Hondo	0.040
47	Parque Naucalli	Naucalpan	Rio Chico de los Remedios	0.060
48	San Agustin	Naucalpan	Rio Chico de los Remedios	1.000
49	Colón Echegaray	Naucalpan	Rio Hondo	0.060
50	Jardin de las Flores	Naucalpan	Rio Chico de los Remedios	0.200
51	Pastores	Naucalpan	Rio Hondo	0.140
52	Hacienda de Echegaray	Naucalpan	Rio Chico de los Remedios	0.165
53	Escultores	Naucalpan	Canal Xocoyahualco	0.400
54	Chimalhuacan	Nezahualcoyotl	Rio Churubusco	5.000
55	Maravillas	Nezahualcoyotl	Dren Xochiaca	12.000
56	Central	Nezahualcoyotl	Dren Xochiaca	4.000
57	Sor Juana	Nezahualcoyotl	Dren Xochiaca	4.000
58	Vicente Villada	Nezahualcoyotl	Dren Xochiaca	4.000
59	Carmelo Perez	Nezahualcoyotl	Rio de la Compañía	4.500
60	Esperanza	Nezahualcoyotl	Rio de la Compañía	3.500
61	Los Reyes	Nezahualcoyotl	Rio de la Compañía	4.500
62	Ahuachuetes	Chihuahua Esq. Merida	Rio San Javier	0.300
63	Ericson	Gustavo Baz Esq. Mario Colin	Rio Tlalmepantla	0.350
64	Francisco Villa	Mario Colin Esq. Fco. Villa	Rio Tlalmepantla	2.230
65	Guerrero	Priv. Guerrero Esq. Mario Colin	Rio Tlalmepantla	1.500
66	Indeco los Reyes	Blvd. Rio Remedios S/N	Rio Remedios	0.420
67	Izcalli del Rio	Rio Tlalnepantla y Rio Tula	Rio San Javier	0.260
68	Izcalli Piramide	Cerrada Turin S/N	Rio San Javier	0.700
69	Jacaramoas	Veracruz y Rio Tlalnepantla	Rio Tlalnepantla	2.120
70	La Romana	Valle de Bravo S/N	Rio San Javier	0.250
71	Mario Colin	Av. Mario Colin y Aut. Qro.	Rio Tlalnepantla	0.100
72	Miraflores	Bugambilia y Azucena	Rio Tlalnepantla	0.520

Table D.4 (5) Pumping Station Operated by Mexico State

No.	Name	Location (Municipality)	Discharge to	Planned Capacity (m^3 /sec)
73	Nueva Ixtacala	Av. Tlalnepantla Esq. Metepec	Rio Remedios	0.620
74	Pirules	Popocatepetl S/N	Emisor Poniente	0.400
75	Prado Vallejo	San Juan de Ulua Esq. I. Sta. Cruz	Rio Remedios	0.660
76	Premsa Nacional	Impar Esq. Heraldo	Rio Remedios	0.570
77	Radial Toltecas	Radial Toltecas S/N	Rio San Javier	0.100
78	Rosario Ceylan	Cicilia y Rio Remedios	Rio Remedios	1.000
79	Rosario II	Cultura Romana S/N	Rio Remedios	6.000
80	San Buenaventura	Cda. San Buenaventura	Rio San Javier	0.200
81	San Javier	Jilotepec y Rio San Javier	Rio San Javier	6.000
82	San Rafael	Ciruelos Esq. Amates	Zanja Madre	0.350
83	Santiaguito	Acueducto Temayuca S/N	Rio Tlalnepantla	2.000
84	Tabla Honda	Cir. Ceremonial S/N	Rio San Javier	2.300
85	Tecnologico	Mario Colin Esq. Toltecas	Rio Tlalnepantla	0.900
86	Tequexquinahuac	Fdo. M. De Oca S/N	Zanja Madre	0.300
87	U.S. Social	Fco. Marques S/N	Zanja Madre	0.300
88	Valle Ceylan	Vialidad Ceylan S/N	Rio San Javier	0.150
89	Valle Ceylan	Guadalajara Esq. Chihuahua	Rio San Javier	1.300
90	Valle Dorado I	Pto. Principe Esq. Ontario	Emisor Poniente	2.600
91	Valle Dorado II	Valparaiso Esq. P. de las Aves	Emisor Poniente	0.900
92	Valle Hermoso I	Cda. de Jazmin S/N	Emisor Poniente	0.350
93	Valle Hermoso II	Cda. de Jazmin S/N	Emisor Poniente	2.800
94	Xocoyahualco	Cerrada Juarez	Rio Remedios	2.000
95	San Joan Ixhoatepec	Cerrada Juarez	Rio Remedios	0.160
96	La Laguna	Cerrada Juarez	Rio Remedios	0.800
97	La Laguna I	Cerrada Juarez	Rio Remedios	0.200
98	Marina Nacional	Cerrada Juarez	Rio Remedios	0.300
99	Campos Hermanoe	Cerrada Juarez	Zanja Madre	0.200
100	Confraco	Cerrada Juarez	Zanja Madre	1.500
Total				169.943

Table D.5 (1) Existing and Planned Wastewater Treatment Plant in D.F. Mexico

(1) Existing Wastewater Treatment Plant

No.	Name	Location (Distict)	Wastewater (m^3 /sec) Planned	Wastewater (m^3 /sec) Operated	Construction Year	Area of Treatment Plant (m^2)	Treatment Process	Water Quality (Upper : Planned / Lower : Operated) SS (mg/l) Influent	SS (mg/l) Effluent	BOD (mg/l) Influent	BOD (mg/l) Effluent	Purpose of Reuse
1	Chapultepec	Miguel Hidalgo	0.160	0.106	1956	22,900	(1) (2)	208.3 242.6	8.0 11.0	203.3 206.2	6.0 4.8	(1) (3)
2	Coyoacàn	Coyoacàn	0.400	0.336	1959	39,600	(1) (2)	91.0 132.0	12.0 28.6	117.7 171.0	6.3 7.4	(1) (3)
3	Ciudad Deportiva	Iztacalco	0.230	0.080	1958	12,000	(1) (2)	126.5 350.6	--- 10.3	290.5 297.4	--- 2.7	(1) (4)
4	San Juan de Aragòn	Gustavo A. Madero	0.500	0.364	1964	30,200	(1) (2)	144.6 219.6	94.0 19.8	215.5 220.0	10.0 7.8	(1) (3)
5	Tlatelolco	Cuauhtemoc	0.020	0.014	1965	2,300	(1) (2)	297.8 388.0	9.5 5.3	138.5 115.8	4.4 5.5	(1)
6	Cerro de la Estrella	Iztapalapa	4.000	1.409	1971	108,200	(1) (2)	73.0 123.2	20.0 23.8	112.5 155.2	3.0 8.2	(2) (4)
7	Bosques de las Lomas	Miguel Hidalgo	0.055	0.027	1973	2,400	(1) (2)	175.3 228.6	26.5 10.6	145.6 174.2	4.3 6.0	(1)
8	Acueducto de Guadalupe	Gustavo A. Madero	0.080	0.057	1975	15,600	(1) (4)	352.5 408.6	10.0 4.0	296.0 324.2	3.5 5.6	(1)
9	El Rosario	Azcapotzalco	0.025	0.022	1981	3,900	(1) (2) (6)	219.0 421.0	23.8 5.6	294.3 294.0	1.8 1.9	(1)
10	Reclusorio Sur	Xochimilco	0.030	0.013	1981	2,300	(1) (2)	69.3 129.0	12.5 6.7	62.3 108.3	4.5 2.7	(1) (3)
11	Colegio Militar	Tlalpan	0.020	0.018	1980	7,600	(1) (3)	320.0 254.5	--- 17.5	537.0 363.0	--- 10.5	(1)
12	Iztacalco	Iztacalco	0.015	0.010	1971	1,800	(1) (2) (7)	292.0 174.4	7.5 8.3	305.0 267.0	1.3 4.4	(1)
13	San Luis Tlaxialtemalco	Xochimilco	0.150	0.110	1989	29,500	(1) (5) (6)	303.0 184.8	5.0 5.6	183.7 183.5	3.7 4.2	(1) (3) (5)
14	San Miguel Xicalco	Tlalpan	0.0075	0.005	1993	2,200	(1) (5)	-	-	-	-	(1)
15	Parres	Tlalpan	0.0075	0.0075	1993	600	(1) (5)	-	-	-	-	(1)
16	Abasolo	Tlalpan	0.0150	0.0150	1993	1,200	(1) (5)	-	-	-	-	(1)
17	La Lupita	Tlalpan	0.0150	0.0150	–	–	–	–	–	–	–	–
18	San Nicolas Tetelco	Tlalpan	0.0150	0.0150	–	–	–	–	–	–	–	–
19	CD. Universitaria	Coyoacan	0.0600	0.0270	–	–	(1) (2)	–	–	–	–	(1)
20	Pemex Picacho	Tlalpan	0.0250	0.0200	1984	–	(1) (2)	–	–	–	–	(1)
21	Campo Militar	Miguel Hidalgo	0.0300	0.0260	1994	–	(1) (2)	–	–	–	–	(1)
	TOTAL		5.860	2.697								

Note: Treatment Process

(1) Conventional Activated Sludge Process

(2) Sludge : Drain

(3) Sludge : Aerobic Digestion and Drying Bed

(4) Sudge : Anaerobic Digestion and Drying Bed or Centrifuge

(5) Sludge : Aerobic Digestion, Concentration and Drying Bed

(6) Tertiary Treatment : Filtration

(7) Tertiary Treatment : Sand Filter Tower and Activate Carbon Filter Tower

Purpose of Reuse

(1) Irrigation of Green Field

(2) Irrigation of Crops

(3) Recriation of Pond or Canal

(4) Industrial Use

(5) Ground Water Recharge

Table D.5 (2) Existing and Planned Wastewater Treeatment Plant in Mexico State

(1) Existing Wastewater Treatment Plant

No.	Name	Location (Municipality)	Wastewater (m^3 /sec)		Responsible	Purpose of Reuse
			Planned	Operated		
17	Papelera San Cristòbal	Ecatepec	0.400	0.250	Private	Industrial Use
18	San Juan Ixhuatepec	Tlalnepantla	0.150	0.030	Private	Industrial Use
19	Pintores	Naucalpan	0.005	0.005	Municipality	Irrigation
20	Naucalli	Naucalpan	0.040	0.030	C.E.A.S.	Irrigation
21	Nezahualcòyotl	Netzahualcòyotl	0.200	——	Municipality	Irrigation
22	Club de Golf Chiluca	Atizapàn	0.020	0.020	Private	Irrigation
23	Rellagigedo Chiluca	Atizapàn	0.020	0.020	Private	Irrigation
24	La Estandia Chiluca	Atizapàn	0.020	0.020	Private	Irrigation
TOTAL			0.855	0.375		

Note : C.E.A.S = Comisiòn Estatal de Aguas y Saneamiento

Table D.6 Design Criteria of Cerro de la Estrella

Facility	Design Criteria
Primary Sedimentation Tank	
Surface Loading	48 $m^3/m^2/day$
Effective Depth	2.6 m
Retention Time	1.3 hrs.
Aeration Tank	
F/M ratio	0.4 kg BOD_5/kg VSS day
MLSS Concentration	1,670 mg/l
Aeration Time	4.8 hrs
Return Sludge Ratio	25 %
Return Sludge Concentration	8,000 mg/l
Effective Depth	5.0 m
Secondary Sedimentation Tank	
Surface loading	36 $m^3/m^2/day$
Effective Depth	3.3 m
Retention Time	2.2 hrs.

Table D.7 (1) Excerpts of "Regulation on Water Supply and Sewerage Services for the Federal District" with Particular References to Sanitation

Part I.

Chapter 1. General Rules

Article 4. The Department is concerned with:

1. Construction, authorization of construction and supervision of works for treatment and distribution of wastewater.
2. Operation and maintenance of the function of the systems for provision and distribution of treated wastewater.
6. Protection of ecological balance, water quality and sanitation of natural ponds, springs, riverbeds, dams and reservoirs.
7. Application of Technical Standards of Ecology to regulate the discharges of water to the sewerage system.
8. Establishment and development of water re-utilization policy in cooperation with CNA.
9. Establishment and operation of wastewater treatment system in conformity with Technical Standards of Ecology.
13. Determining and imposing sanctions to those who abuse treated wastewater and its system.

These attributions and functions are executed by the Department through Administrative Units following Organization Law and Interior Regulation.

Part IV. On the public service of water treatment

Chapter 1. Preliminary Rules

Article 62. Treatment will be done to the wastewater of domestic and industrial origin carrying organic and non-organic suspended materials with the objective of increasing and diversifying its use.

Article 64. The wastewater supplied by the Department for its reuse and treatment arising from public, commercial, industrial and domestic activities will be used according to the following order:

1. Public services for watering of green areas and filling of recreation lakes
2. Water for livestock
3. Culture of fish
4. Commerce
5. Irrigation of pastures
6. Irrigation of land for agricultural products consumed raw without requiring preparation.This water must be free from toxic contaminants and pathological organisms.
7. Recharging aquifers by means of injection wells and infiltration lakes
8. Watering of private lot
9. Industrial
10. Washing vehicles
11. Others

The technology used in the treatment plants and the physical, chemical and biological quality standards of treated wastewater must conform to the Technical Standards of Ecology and Sanitation to avoid danger to health.

Article 74. Wastewater treatment plants must have a laboratory for the control of physical, chemical and biological quality of produced treated water in conformity to the Technical Standards of Ecology and Sanitation.

Chapter 6. On Concessions

Article 80. The Department can concede the operation and maintenance of wastewater treatment plants.

Table D.7 (2) Excerpts of "Regulation on Water Supply and Sewerage Services for the Federal District" with Particular References to Sanitation

Part V.

Chapter 1. Verification of Water Consumption

- Article 84. All users must apply for or permit the installation of meters at a visible place so that the Department can verify the consumption of potable water, treated wastewater or well water in accordance with the Finance Law of the Department.
- Article 85. Users are responsible for the correct use and maintenance of meters installed in their property, houses, establishments, shops or factories and must report all the damage and trouble of them as well as permit inspections by the Department.
- Article 86. When it is found during inspection visits that the defects of meters are intentionally caused or have resulted from users' imprudence, the responsibles will be sanctioned by the Finance Law of the Department.
- Article 87. If it is detected in reading meters that an establishment, shop or factory consumes more than 500 m3 of piped or well water in 2 months, the users will be obliged to present to the Department a quantitative report on the uses of water in its diverse phases within 90 days following the date in which the volume of consumption is known.In case of condominium or tenant buildings, the obligation to present the quantitative report on the uses of water will arise when the bimonthly water consumption exceeds 200 m3 per apartment, household or tenant.
- Article 88. The Department can estimate the consumption of water according to the stipulation of the Finance Law of the Department.

Part VI. Drainage and Sewerage System

Chapter 1. General Rules

- Article 89. The drainage system has two types: combined and separate.
- Article 91. New urban developments must include the construction of the separate system for wastewater and rain water drainage.
- Article 95. Owners and occupants of the property and the house and titular persons of establishments, shops and factories are obliged to apply for discharge installations within 3 months following the date in which the installation of sewerage system is let known to the beneficiaries.
- Article.100. It is prohibited to throw in the sewerage system solid wastes susceptible of settling and obstructing pipes, greases, inflammable liquids or substances, toxics, corrosives and in general any waste, object or substance that can deteriorate pipes, structures or functions of the system, affect the environmental and sanitary conditions, cause damages to the population, etc. Owners and occupants of factories and shops that handle this type of wastes must establish the necessary devices in accordance with the Technical Standards of Ecology.

Chapter 3. Discharges of Industrial Wastewater

- Article 109. The discharge of wastewater resulting from industrial processes that requires connection to the sewerage and drainage system must follow the maximum permissible limits and the procedure for the determination of contaminants in wastewater discharges provided in the Technical Standards of Ecology.
- Article 112. The discharge of wastewater resulting from industrial processes must not exceed the authorized volume or the tolerances established in the Technical Standards of Ecology.
- Article 114. The Department will resolve the acceptance of the wastewater of factories and shops in consideration of the volume and its fluctuation, physical, chemical and biological conditions and the installations of collection, treatment and discharge in conformity with the Technical Standards of Ecology.
- Article 118. The Department can inspect any time the appraisal, sample or physical, chemical and biological analysis of the wastewater generated by the users.

Table D.8 (1) Excerpts of "Law of National Water" with Particular References to Sanitation

Part I. Preliminary Rules

Chapter 1.

Article 1. This law is the regulation of the article 27 of the Constitution of the United States of Mexico in respect of national water. It is to be observed in general in all the national territory. Its rules are for public order and social interest and as the objective have the exploitation and use of water, its distribution and control as well as the preservation of its quantity and quality for the attainment of its comprehensive, sustainable development.

Article 2. The rules of this law are applicable to all the national water whether it be superficial or underground water. These rules are also applicable to the national estate which this law indicates.

Part II. Administration of Water

Chapter 1. General Rules

Article 4. The authority and administration in connection with national water and its inherent pulic estate belong to the Federal Executive whether they are exercised directly or through CNA.

Article 5. For the attainment and application of this law the Federal Executive will promote the coordination of activities with the State governments and Municipalities.

Chapter 2. Federal Executive

Article 7. The following are declared public utility:

IV. Re-establishment of hydraulic equilibrium of national surface and underground water

V. Installation of wastewater treatment plants and execution of measures for the reuse of treated water as well as construction of works for the prevention and control of water pollution

VIII. Installation of necessary devices for measuring the quantity and quality of national water

Chapter 3. CNA

Article 8. The attributions of the Ministry of Agriculture and Hydraulic Resouces are as follows:

I. Proposing the hydraulic policy of the country to the Federal Executive.

II. Functioning as the President of the Technical Council of CNA.

Article 9. The attributions of CNA are as follows:

II. Formulating respective national hydraulic program, updating and supervising its completion

III. Proposing criteria and guidelines which enable to give unity and consistency to the activities of federal government in the matter of national water, and assuring and supervising the coherence between respective programs and the assignment of resources for their execution

VI. Programing, studying, constructing, operating, preserving and maintaining federal hydraulic works directly or through contracts or concessions with third parties, and realizing the activities for the comprehensive exploitation of water and the preservation of its quality

X. Exercising fiscal attributions in matters of administration, determination, liquidation, recovering, collection and audit of taxes and revenues

Table D.8 (2) Excerpts of "Law of National Water" with Particular References to Sanitation

Part VII. Prevention and Control of Water Pollution

Chapter 1.

Article 86. CNA is in charge of:

I. Promoting, as need arises, executing and operating the federal infrastructure and necessary services for the protection, preservation and improvement of water quality in hydraulic basins and aquifers in accordance with the respective Mexican official standards and particular conditions of discharges

III. Establishing and supervising the fulfillment of partiular conditions of discharge which must be met by wastewater which are generated in the estate and zones of federal jurisdiction

V. Supervising that the water for human consumption may comply with the corresponding quality standards and that the use of wastewater may comply with the quality standards of water emitted for that purpose

VI. Promoting or realizing necessary measures to prevent garbage, refuse, toxic materials and substances and the mud producted from wastewater treatment from polluting surface and undergound water

Article 87. CNA will determine the parameters which wastewater must fulfill, the capacity of assimilation and dilution of national water bodies and the pollution charges which they can admit, as well as quality goals and the period of attainment through the issuance of the Declaration on the Classification of National Water Bodies in the Official Diary of the Federation.

Article 88. Physical or juridical persons require the permit of CNA for discharging wastewater in permanent, intermittent or fortuitous form in receptor bodies such as national water or other national estate including sea water, as well as when wastewater is infiltrated into the ground such as national estate or other ground when it can pollute underground or aquifers.

Part VIII. Investment in Hydraulic Infrastructure

Chapter 3. Recovery of Public Investment

Article 108. Public investment in the federal hydraulic infrastructure will be recovered through the establishment of charges to be paid by the beneficiaries who directly use, exploit or explore the infrastructure.

Article 109. Operation, preservation and maintenance of hydraulic infrastructure will be done at beneficiaries' expense. The charges will be fixed based on the the prior estimation of the cost of services taking economic efficiency into consideration.

Chapter 4. Charge Collection for Exploitation and Use of National Water and National Estate

Article 112. Exploitation and use of national water including groundwater as well as the national estate which CNA adiministers will give rise to the payment of charges which the Federal Law of Charges establishes on the part of the user. Exploitation and use of the estate of public domain of the Nation like receptor bodies of the discharges of wastewater will give rise to the payment of charges which the Federal Law of Charges establishes.

Table D.9 (1) Existing Water Tariffs in the Study Area

The major part of the water tariffs now applied to the beneficiaries in the Federal District and the State of Mexico are as follows:

I. Water Tariffs of DDF

1. With the Water Meter

1) The Domestic Client

(Unit: N$/m^3/2 months)

	Consumption of Water			Water Rate
1.	0.1	to	10	Exempted
2.	10.1	to	20	0.55
3.	20.1	to	30	0.60
4.	30.1	to	60	1.40
5.	60.1	to	120	1.70
6.	120.1	to	240	2.30
7.	240.1	to	420	2.60
8.	420.1	to	660	3.00
9.	660.1	to	960	3.35
10.	more than 960			3.80

2) The Non-Domestic Client

(Unit: N$/m^3/2 months)

	Consumption of Water			Water Rate
1.	0.1	to	30	1.40
2.	30.1	to	60	2.40
3.	60.1	to	120	2.75
4.	120.1	to	240	3.60
5.	240.1	to	420	4.20
6.	420.1	to	660	5.00
7.	660.1	to	960	5.85
8.	more than 960			6.70

2. Without the Water Meter

1) The Domestic Client

(Unit: N$/2 months)

	Assessed type of the area where the building in which the water tap is installed is located	Water Rate
1.	0	Exempted
2.	1	7.90
3.	2,3 and 8	15.55
4.	4,5 and 7	66.90
5.	6	156.50
	The buildings located in the types of the area 6 and 7 with the assessed value of N$ 171,035.40 or more	401.45

Table D.9 (2) Existing Water Tariffs in the Study Area

2) The Non-Domestic Client

(Unit: N$/2 months)

	Diameter of the Tap in mm				Water Rate
1.	13				100.35
2.	more than	13	to	15	1,573.60
3.	more than	15	to	19	2,574.85
4.	more than	19	to	26	5,006.35
5.	more than	26	to	32	7,724.60
6.	more than	32	to	39	11,300.75
7.	more than	39	to	51	20,026.60
8.	more than	51	to	64	30,039.35
9.	more than	64	to	76	42,913.65
10.	more than	76	to	102	87,257.40
11.	more than	102	to	150	188,819.40
12.	more than	150	to	200	334,726.45
13.	more than	200	to	250	523,545.90
14.	more than	250	to	300	753,848.70
15.	more than 300				799,623.90

II. Water Tariffs of the State of Mexico

1. The Domestic Client

1) With the Water Meter

(Unit: N$/m³/2 months)

	Consumption of Water			Group A	Group B
1.	0	to	25	0.56	0.45
2.	25.01	to	50	0.90	0.73
3.	50.01	to	85	1.18	0.95
4.	85.01	to	100	1.46	1.18
5.	100.01	to	135	2.02	1.57
6.	135.01	to	165	2.52	2.02
7.	165.01	to	480	2.74	2.18
8.	more than 480			3.08	2.46

Note : Municipalities are classified into Group A and Group B based on their general economic level.

2) Without the Water Meter

(Unit: N$/2 months)

Consumption of the Tap	Group A	Group B
1. 13 mm		
1) Common People	47.82	38.30
2) Medium Class Residence	143.47	114.80
3) High Class Residence	430.42	344.40
2. 19 mm to 26 mm	860.94	688.69

Table D.9 (3) Existing Water Tariffs in the Study Area

2. The Non-Domestic Client

1) With the Water Meter

(Unit: N$/m^3/2 months)

Consumption of Water				Group A	Group B
1.	0	to	25	1.23	1.01
2.	25.0	to	50	1.85	1.46
3.	50.01	to	85	2.46	1.96
4.	85.01	to	100	3.02	2.46
5.	100.01	to	135	4.14	3.30
6.	135.01	to	165	5.15	4.14
7.	165.01	to	480	5.66	4.48
8.	more than 480			6.38	5.15

2) Without the Water Meter

(Unit: N$/2 months)

Diameter of the Entrance Pipe		Group A	Group B
1.	up to 13 mm	111.89	89.49
2.	up to 19 mm	1,474.48	1,179.58
3.	up to 26 mm	2,409.12	1,927.30
4.	up to 32 mm	3,600.46	2,880.42
5.	up to 39 mm	4,502.18	3,601.81
6.	up to 51 mm	7,602.45	6,082.05
7.	up to 64 mm	11,334.62	9,067.74
8.	up to 75 mm	16,653.17	13,322.51

Fig. D.1 Existing Sewerage Service Area and Collection System

THE FEASIBILITY STUDY ON WASTEWATER TREATMENT IN THE FEDERAL DISTRICT OF MEXICO

JICA

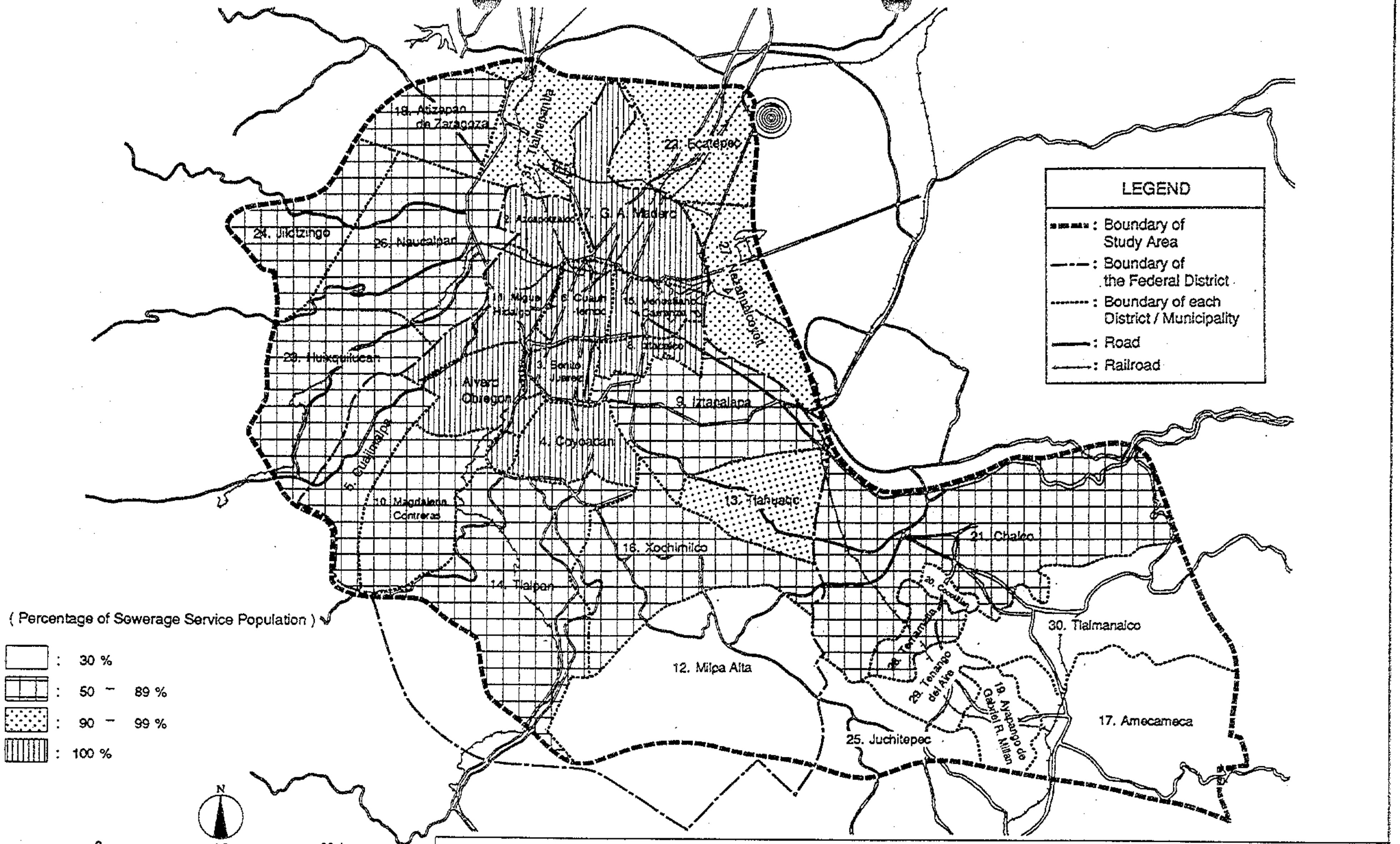

Fig. D.2 Percentage of Existing Sewerage Service Population by District / Municipality (1993)

THE FEASIBILITY STUDY ON WASTEWATER TREATMENT IN THE FEDERAL DISTRICT OF MEXICO

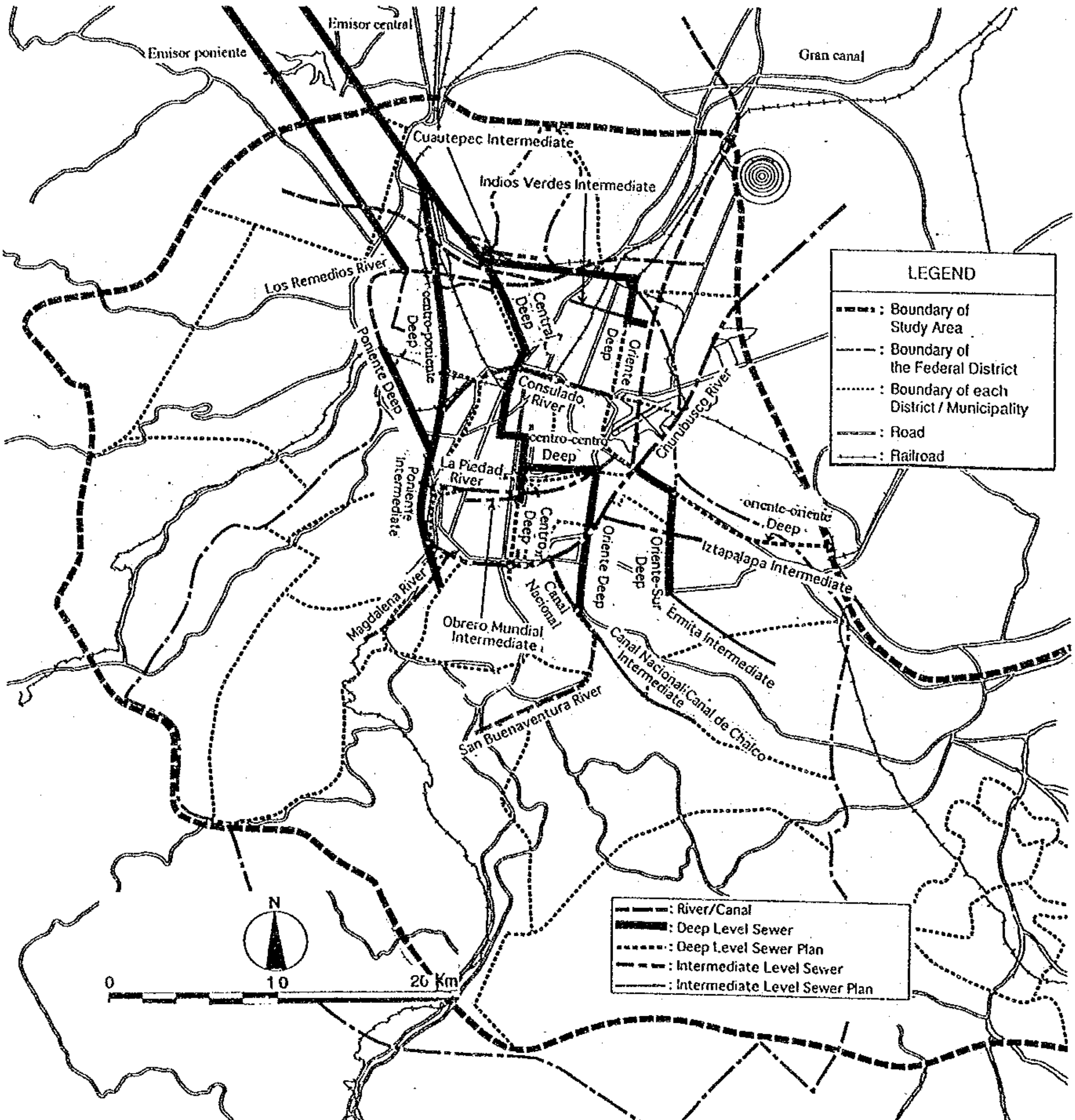

Fig. D.3 Location of Intermediate and Deep Level Sewer in D. F.

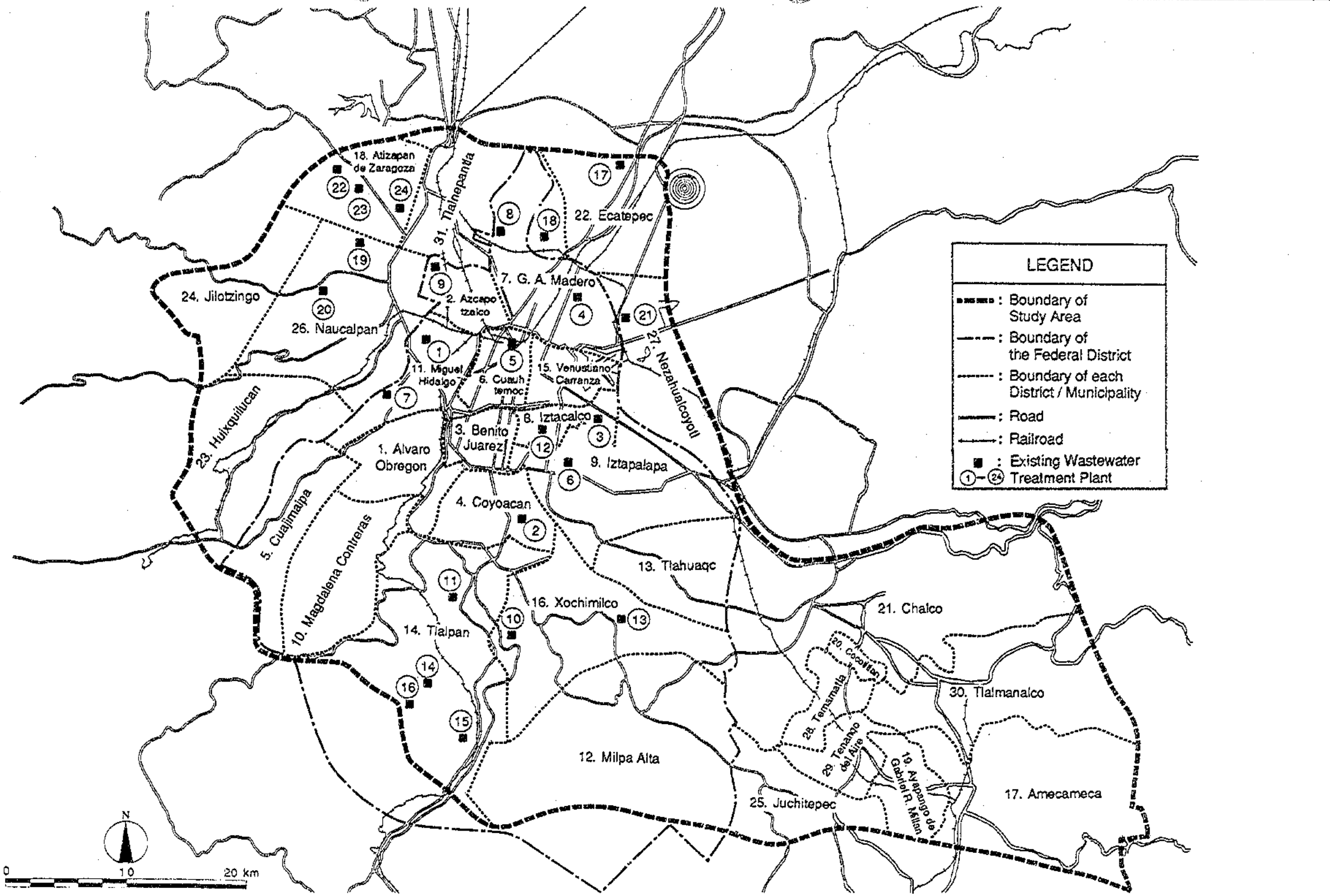

Fig. D.4 Location of Existing Wastewater Treatment Plant

THE FEASIBILITY STUDY ON WASTEWATER TREATMENT IN THE FEDERAL DISTRICT OF MEXICO

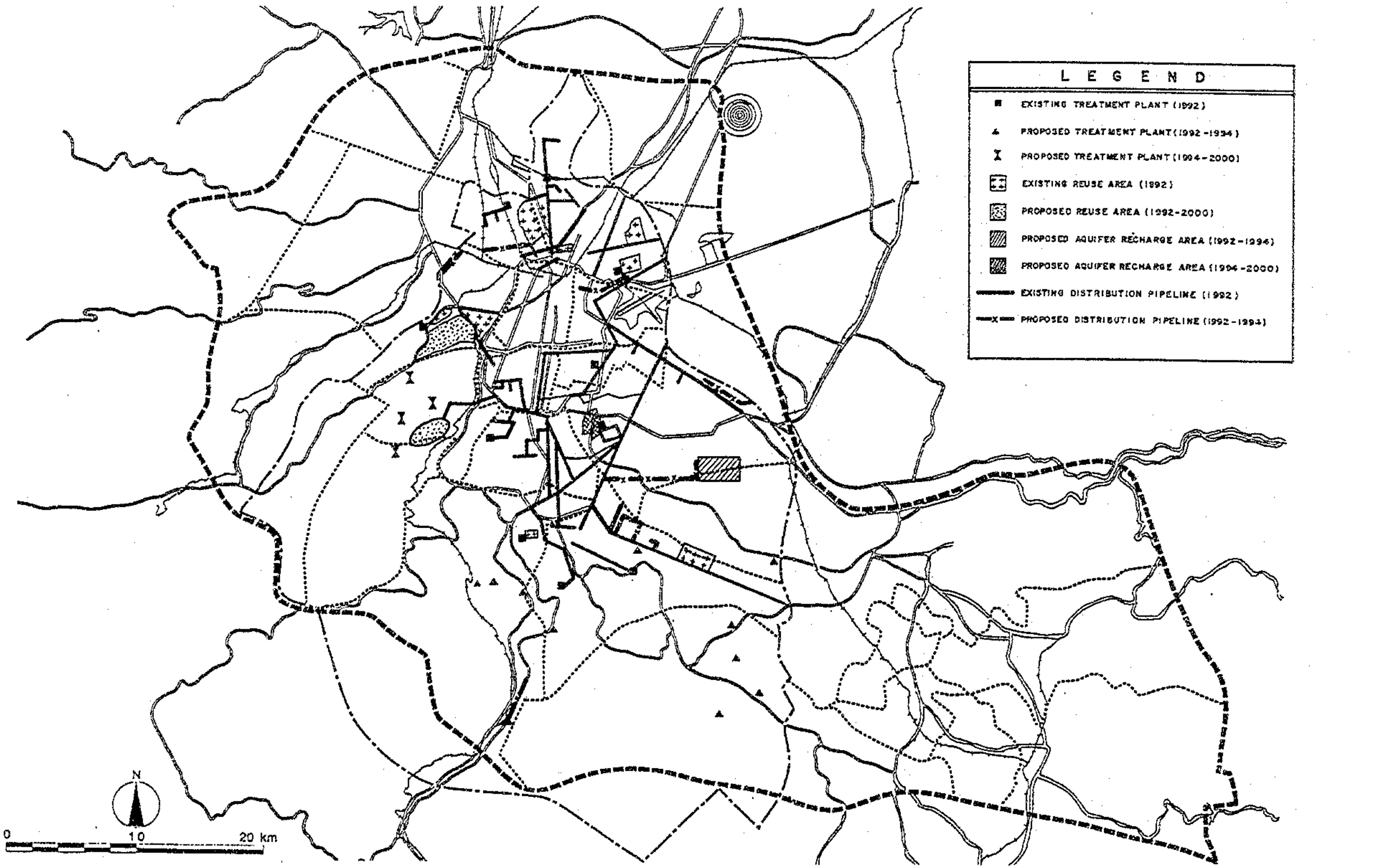

Fig. D.5 Existing and Proposed Pressure Pipe System of Reuse Water in D.F.

THE FEASIBILITY STUDY ON WASTEWATER TREATMENT IN THE FEDERAL DISTRICT OF MEXICO

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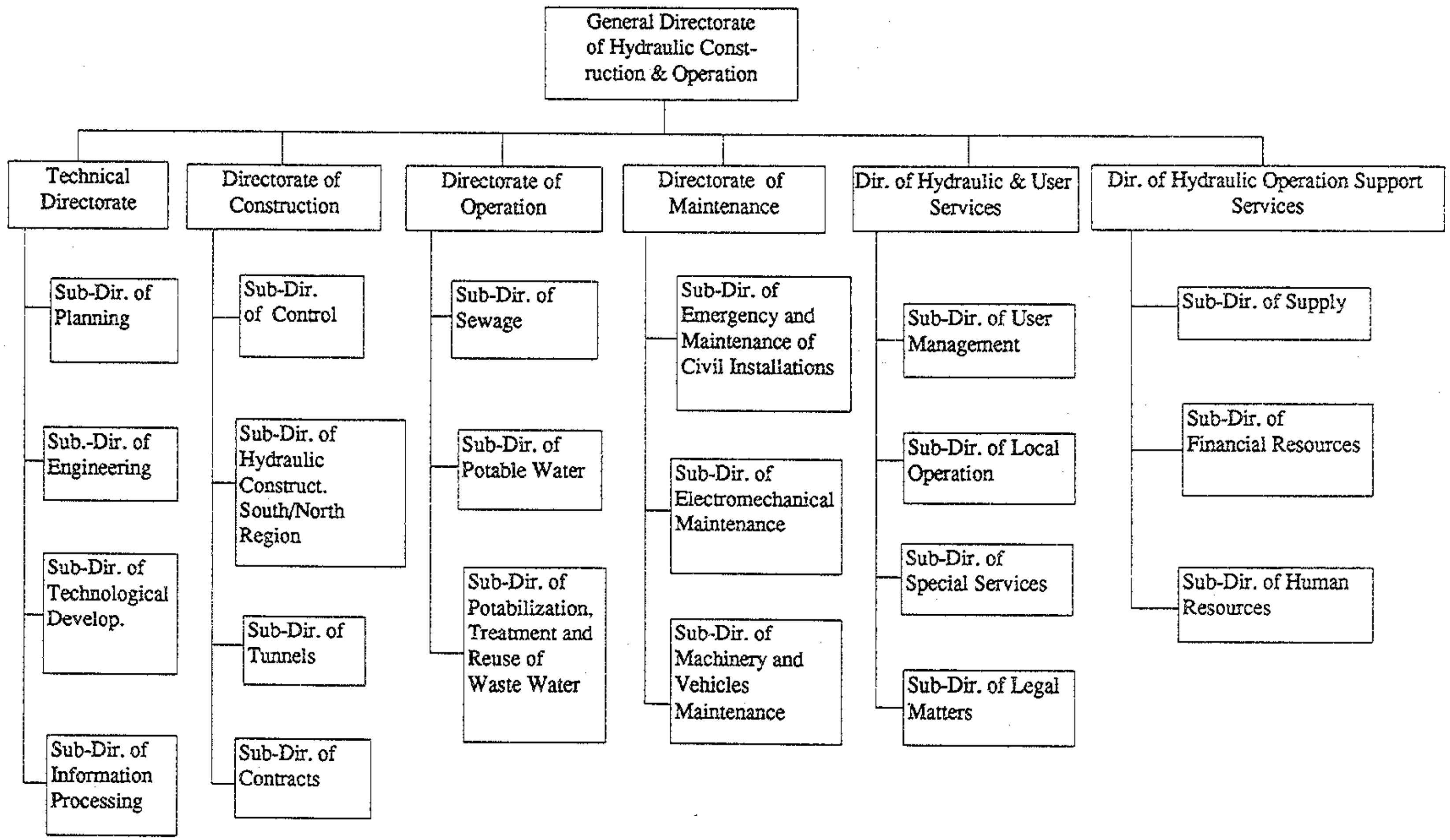

Fig. D.6 Organization Structure of DGCOH

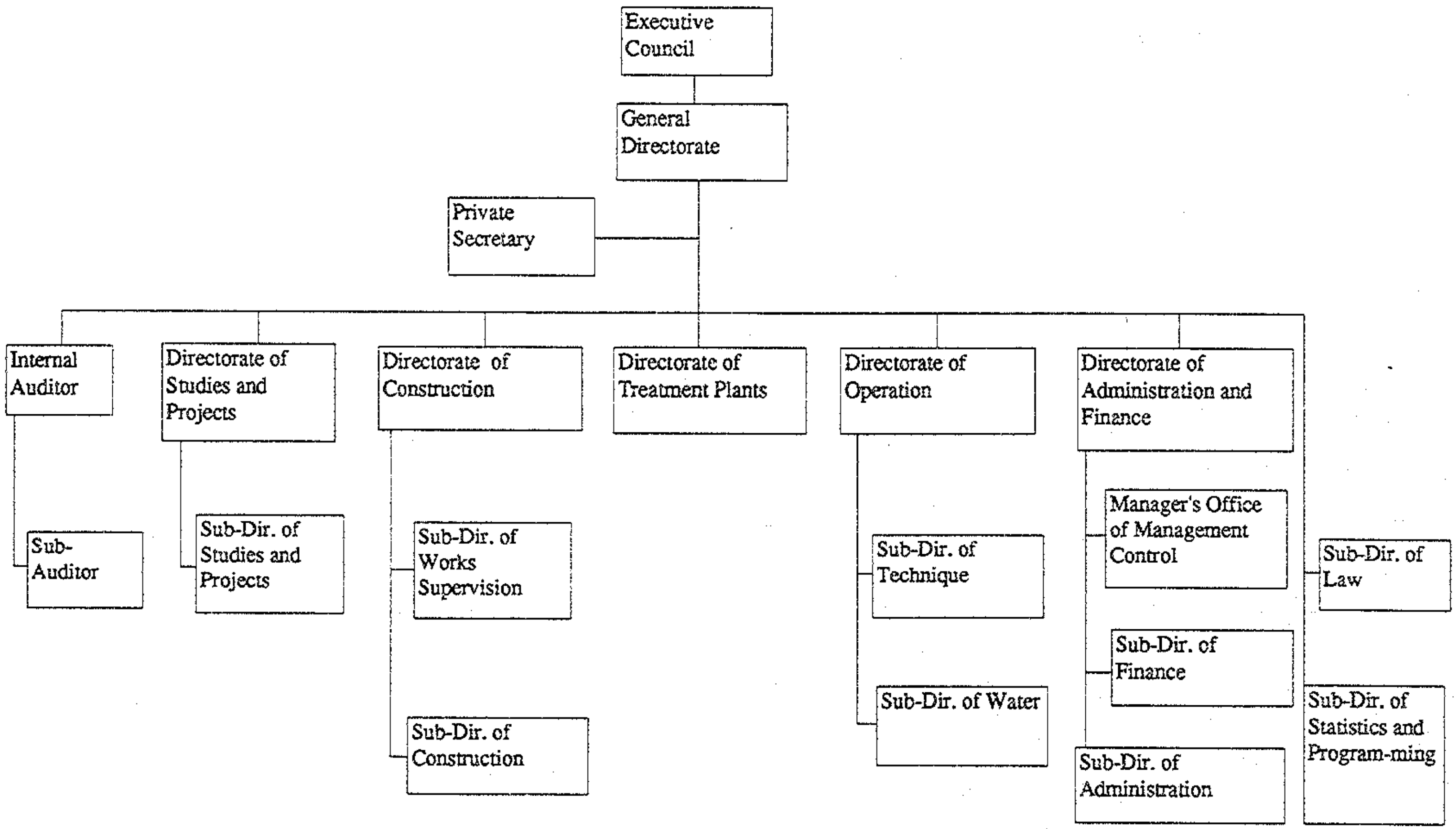

Fig. D.7 Organization Structure of CEAS

THE FEASIBILITY STUDY ON WASTEWATER TREATMENT IN THE FEDERAL DISTRICT OF MEXICO

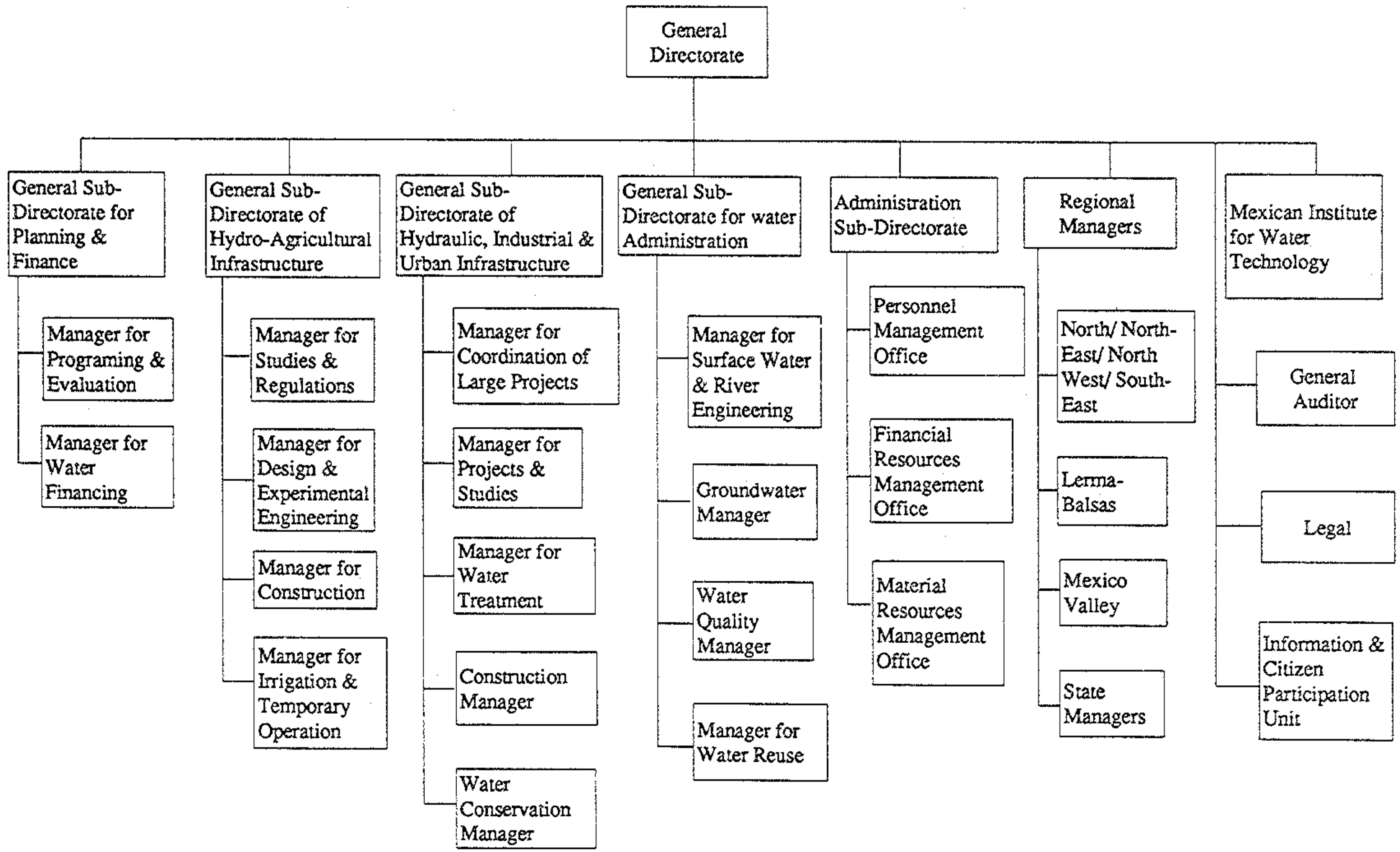

Fig. D.8 Organization Structure of CNA

THE FEASIBILITY STUDY ON WASTEWATER TREATMENT IN THE FEDERAL DISTRICT OF MEXICO

APPENDIX E

APPENDIX E STUDY OF RELEVANT REPORTS

1. Wastewater Disposal for the Valley of Mexico (The Master Plan, 1993)

This Master Plan study was conducted by National Water Commission (CNA) in the year 1993. The report consists of following seven (7) chapters:

(1) Existing Drainage System
(2) Wastewater Quality
(3) Sanitary and Environmental Problems caused by Wastewater
(4) Laws and Regulations related to Wastewater discharge
(5) Solution proposed for Wastewater disposal
(6) Cost Estimates
(7) Financial Evaluation

The contents of these seven (7) chapters are summarized below.

(1) Existing Drainage System

The existing drainage system is a combined system, carrying wastewater as well as storm water generated in the valley of Mexico. About 1.6 billion m^3 per annum of discharge is being generated. Out of which 1.2 billion m^3 corresponds to wastewater and 0.4 billion m^3 to stormwater. The generated wastewater and stormwater are carried to the North by three main conduits; Gran Canal, Emisor Central and Emisor Poniente. The location of these three (3) main conduits is shown in Fig. C.1, Appendix C.

The central part of the urban area has suffered land subsidence problem mainly due to the characteristics of the soil and the pumping for extracting drinking water from the underground. The situation has made it necessary to pump the wastewater and stormwater to the Texcoco lake and Gran Canal. Also due to land sinking problem, the drainage capacity of Gran Canal has reduced from 30 m^3/sec to 15 m^3/sec in the last three (3) years. As a result the discharge volume of Emisor Central, which was initially designed to carry stormwater only, is increased and is drained throughout the year.

Among annual discharge water of 1.6 billion m^3, 0.15 billion m^3 is reused in the urbanized area, 0.1 billion m^3 is used for recreational purpose at Texcoco lake and the remaining 1.35 billion m^3 is carried by the above mentioned three conduits towards Tula area. About 1.3 billion m^3 of discharge is being directly used for irrigation covering about 90,000 ha in Chicomautla, Zumpango, and Tula areas as shown in Fig. D.5, Appendix D. And about 0.05 billion m^3 is stored in Endo dam which is afterwards used for irrigation.

In D.F. Mexico, 32 secondary wastewater treatment plants are being operated with the objective of reusing the treated water for irrigation of parks at Chapultepec, San Juan de Aragon and Xochimilco. The total design capacity of these treatment plants is 8.7 m^3/sec and the operating capacity is 4.8 m^3/sec.

(2) Wastewater Quality of Gran Canal and Emisor Central

The wastewater has typical characteristics of sewage with SS varying from 200-500 mg/l, BOD of 150-300 mg/l and Coliforms about 3.0 E+08 No/100 ml. The important point is that no dilution of pollutants is observed during rainy season. In fact SS were increased in the rainy season. Probably the settled solids get re suspended with the larger flows in rainy season.

(3) Sanitary and Environmental Problems Caused by Wastewater

Irrigation area in Tula region is being used to achieve secondary treatment. The water discharged to the rivers from the irrigation areas has reasonably good quality with BOD less than 10 mg/l and DO of 5 mg/l. However Coliforms are still high of the order of 1.0 E+07 No/100 ml in the irrigation water. Due to poor sanitary conditions chances of getting infected by contaminated irrigation water are very high. It has been observed that the inhabitants of the irrigation area suffer from parasital infections with the indexes between 6 and 22 times greater than in other areas. The high contraction ratio of helminths in this area could also affect the hygiene in the urbanized area of D.F. Mexico. And in 1992, the regulation was stipulated which prohibits to grow crops, to be eaten raw. Furthermore Consumption of untreated irrigated water can affect the animal health also.

Hence, to improve the sanitary conditions of the irrigation area, discharged wastewater of urbanized area should be treated before using it for irrigation. The main purpose of wastewater treatment should be to remove bacteria and helminth eggs. The organic substances and nutrients, which will be used as fertilizer, should be remained in the wastewater.

(4) Laws and Regulations Related to Wastewater Discharge

The following four (4) laws related to wastewater discharge exist in United Mexican states.

- The General Law for Ecological Balance and Environmental Protection
  (La Ley General de Equilibrio Ecologico Y Proteccion del Ambiente)

- The National Water Law
  (La Ley de Aguas Nacionales)

- The Federal Law of Rights of National Waters
  (La Ley Federal de Derechos de Aguas Nacionales)

- The Health Law
  (La Ley de Salud)

The General Law of Ecological Balance empowers SEDESOL (Secretaria de Desarrollo Social) to stipulate the effluent water quality standards. Related to wastewater reuse for irrigation purpose Nom-PA-CCA-032 and Nom-PA-CCA-033 have been established. Nom-PA-CCA-032 states the maximum limits of pollutants in the municipal wastewater which is to be disposed as irrigation waters and Nom-PA-CCA-033 states the maximum permissible limits of bacteriological parameters in the municipal wastewater to be used for the irrigation of vegetables and fruits.

The National Water Law empowers the CNA to establish particular discharge conditions the water must meet, in addition to the already established NOM guidelines, attending the problems of particular discharge cases that need additional guidelines. Thus CNA has been authorized to decide bacteriological parameters for the irrigation waters to protect the inhabitants.

The Federal Law of Rights of National Waters stipulates to remove the pollutants from the wastewater before discharging. According to this Law if untreated discharge is thrown to the water bodies, penalty should be paid.

The Health Law imposes restrictions to substances that can be thrown to the canals or natural water bodies. This Law specially control specific toxic and hazardous materials in the discharges.

(5) Solution Proposed for Wastewater Disposal System

To solve the existing wastewater disposal problems, the development of drainage and wastewater treatment system is urgently needed. The primary treatment with some advanced technologies will remove the pathogens by sedimentation and disinfection by chlorination will remove the bacteria. As secondary treatment will be carried out by irrigation area, hence not necessary. Proposed wastewater treatment system is as follows :

Wastewater Treatment Plants

Two (2) wastewater treatment plants have been proposed in the Texcoco Lake area; One is the existing treatment plant near Nabor Carrillo lake with the capacity of 3.0 m^3/sec and other is the new proposed treatment plant of 35 m^3/sec capacity at the North of Texcoco Lake. The treated wastewater will be discharged to Gran Canal.

Another treatment plant with a capacity of 25 m^3/sec is proposed at the outlet of Emisor Central to treat wastewater discharged in the rainy season.

Several wastewater treatment plants with a total capacity of 20 m^3/sec are additionally proposed to treat wastewater discharged from Emisor Poniente, Cuautitlan, Tepoztlan, the North of Guadalupe and Texcoco area. Location and required capacity of each treatment plant will be studied in the wastewater disposal Master plan for these areas.

In other words 83 m^3/sec of wastewater can be treated by these Treatment plants which is almost double of the wastewater generated and hence storm water can also be treated in the rainy season.

Wastewater Treatment Process

Advanced Primary treatment as shown in Fig. E.1 has been proposed for the Texcoco treatment plant with the capacity of 35 m^3/sec. Lime stabilization process will be adopted for sludge stabilization and stabilized sludge will be dried utilizing the existing drying beds. Thus the offensive odor of sludge and breeding of insects can be controlled. Furthermore pathogens present in the sludge can also be reduced.

All other treatment plants can also have the same treatment process, but due to limited space available belt sludge drying system should be used in place of drying beds.

Sewage Infrastructure

Keeping in view the problem of Land sinking, construction of pumping station with a capacity of 30 m^3/sec is required at the junction of Gran Canal and Los Remedios. The pumping main of about 5 km length along the Remedios river between the Gran Canal and Texcoco should be constructed to carry the discharge. A regulation Lagoon should be built at Texcoco to receive the discharge. Another pumping station and pumping main of about 4 km length, with the capacity of 40 m^3/sec should be constructed to carry discharge to the treatment plant site.

Other Countermeasures

Enhancement of monitoring system of heavy metals in the discharged wastewater is required. And also the proper monitoring of heavy metals in the industrial effluents should be done and proper penalty in case of violation of Law should be imposed.

Wastewater disposal system for Tula area is also necessary.

Environmental Impacts of the Project

The positive impacts of the project are listed below :

- Improved sanitary conditions in the irrigation area
- Prevention of water borne diseases spreading to other areas
- Improved Livestock health
- Improved water quality in Tula river and Endo Lake

The main negative impact of the project is the removal of nutrients from the irrigation water. Investigations are being carried out to find its affect on agricultural productivity and possibility of using chemical fertilizers.

The sludge from the wastewater treatment process should be disposed properly to avoid the negative impacts on the environment. Lime stabilization is proposed for this purpose. Adequate period should be considered to remove eggs of helminth from the sludge.

(6) Cost Estimates

The necessary construction cost for the treatment plant, with the proposed treatment process is estimated to be N$ 10 million for each m^3/sec. Thus total construction cost for Texcoco treatment plant is estimated to be N$ 350 million. And the total construction cost required for the treatment of 83 m^3/sec would be N$ 830 million. Breakdown of construction and O/M costs of the Texcoco treatment plant is summarized in Table E.1. Unit O/M cost of Texcoco treatment plant is estimated to be N$ 0.091/m^3 and investment mortgage is estimated to be N$ 0.042/m^3. Hence total O/M cost is estimated to be N$ 0.13/m^3. The other plants will be treating storm water and hence will have high mortgage cost of the order of N$ 0.07/m^3, making a total of N$ 0.16/m^3.

The total treated volume including storm water is estimated to be 1.5 billion m^3 per annum. While the annual water consumption in the urbanized area of Mexico city is estimated to be about 1.0 billion m^3. O/M cost of wastewater treatment plants of N$ 0.16/m^3 is supposed to be borne by beneficiaries as water supply charge. Thus water supply charge will increase by N$ 0.24/m^3 as shown below.

$$0.16 \text{ N\$/m}^3 \times 1.5 \ / \ 1.0 = 0.24 \text{ N\$ / m}^3$$

Additional 180 million N$ is required for construction of pumping stations and new sewer pipes.

(7) Financial Evaluation

The wastewater treatment cost must be paid by the users of potable water. The average water supply charge in D.F. is N$ 0.82 /m^3. The total invoiced volume is about 69% of the total water supplied and about 60% of the invoiced volume is recovered. Hence Annual revenue of water supply in D.F. is about N$ 440 million, which accounts for 41% of the total water supplied. In 1992, annual revenue of water supply in D.F. was about N$ 457 million whereas annual O/M cost were N$ 1,163 million. It is obvious that even if 100% of supplied water is invoiced, it will be still not enough to bear O/M cost.

Further DDF has planned to invest N$ 280 million for improving the sanitary conditions in D.F. Mexico. The break down of this investment is described below:

Water Supply	:	N$	110 million
Sewage disposal	:	N$	80 million
Storm water drainage	:	N$	90 million

Based on these investment costs and O/M cost, water supply charges will have to be increased. The investment cost for storm water drainage should be included in Property Tax and not in water supply charges because the storm water drainage facilities protect urbanized areas from flooding. Newly proposed water supply charge will be N$ 1.50/m^3.

Sewerage service charges should be collected based on the consumption of water supply. For the industries with their own water resources, sewerage service charges should be collected based on the amount of discharged wastewater. Sewerage service charges of N$ 0.24/m^3 will be added to water supply charges and thus increase it by 17%.

Annual O/M cost for wastewater treatment in the D.F. shall be N$ 151 million.

The average water supply charge in Mexico state is N$ 0.90 /m^3. The total invoiced volume is about 60% of the total water supplied and about 60% of the invoiced volume is recovered. In 1992, annual revenue of water supply in Mexico state was about N$ 339 million whereas annual O/M cost were N$ 282 million. However annual O/M cost will increase in the future when Cutzamala water supply will start functioning in the Mexico state. Similar to D.F. 100% of the supplied water must be recovered in the Mexico state also. Unit water supply charge and annual revenue of each municipality in the Mexico state is shown in Table E.2.

The total investment planned for the coming years in Mexico state is about N$ 550 million. The break down of this investment is described below:

Water Supply	:	N$	150 million
Sewage disposal	:	N$	180 million
Storm water drainage	:	N$	220 million

Hence it is necessary to increase 50% of water supply charges to shoulder the O/M cost in each municipality in the Mexico state.

Annual O/M cost for wastewater treatment in the Mexico State shall be N$ 89 million.

2. Treatment and Reuse Master Plan, 1990 (TRMP)

This report is revision of Treatment and Reuse Master Plan (1982) and explore further possible reuse options. The report contains eleven chapters as described below :

1. Background
2. Introduction
3. Current Situation of the Drinking Water System
4. Current Situation of the Treatment and Reuse System
5. Evaluation of Treatment and Reuse Master Plan (1982) and Current Situation
6. Factors affecting the TRMP development
7. Perspectives
8. Options for the Treatment and Reuse System Development
9. Proposal to Develop the Treatment and Reuse System for the Federal District
10. Objectives, Policies and Goals of TRMP
11. Programs

The contents of TRMP report are summarized below.

(1) Background

The increasing population coupled with scarcity of water resources led to the over exploitation of the aquifers in the Mexico Valley and consequently problems such as pollution of aquifers and sinking of Mexico city were observed.

The perspectives of developing new water sources are less encouraging and hence treated water has been considered as the possible alternative water source. Specially for green areas watering and Lake filling, treated water has been considered as an attractive alternative. The main emphasis has been given to explore those water usage categories which do not require drinking water quality.

Treatment and Reuse Master Plan developed in 1982 states the policies, goals and actions for the development annual programs. However in the recent years, policies in the water management have changed, making the treated water reuse more attractive economically. Hence revision of the TRMP has been carried out.

(2) Introduction

The Department of Federal District faces serious problem of water shortage and treated water reuse is necessary to reduce the import of water from the neighboring states. Besides irrigation, reuse of treated water for industry, lake filling and groundwater recharging should also be explored.

This report contains the proposed strategies and programs for the treatment and reuse of the wastewater in the Federal District. In the report, evaluation of Treatment and Reuse Master Plan (1982) has been carried out. Water balance in terms of supply and demand is conducted for the future. Five possible alternatives are analyzed and strategy is proposed so as to promote wastewater reuse.

(3) Current Situation of the Drinking Water System

Water supply situation in the Mexico valley can be described as follows:

- There exists deficit in the water supply-Demand balance.
- Uneven distribution of the drinking water between the Federal District and the municipalities of the Mexico state is found.
- Water quality is different for Federal District and the surrounding municipalities.
- Over exploitation of aquifers necessitates the substitution of pumping equipments to have deeper wells so as to find new supplying sources.
- Infrastructure of water supply system does not avail the sources efficiently as sources are mainly located at the western part of the Federal District.

(4) Current Situation of the Treatment and Reuse System

The total quantity of wastewater being treated is about 4,320 l/sec in the nine small treatment plants. The amount being treated in the dry season is about 1,876 l/sec i.e., 43% of the total capacity and in rainy season is only 884 l/sec i.e., 20% of the total capacity.

Samples from influent and effluent of treatment plant are collected weekly to monitor physico-chemical and biological quality of the treated water. Sampling is being done also at reuse sites weekly. The total number of sampling stations at reuse sites are 53, involving sites being used for recreational purpose, industrial purpose and commercial purpose.

In the 1982 Master plan the maximum permissible concentration of physico-chemical and biological parameters has been specified. Based on the type of reuse, number of parameters to be considered have been prescribed. Table E.3 shows the number of pollutants to be considered for different type of reuse.

The treated water quality of eight treatment plants is examined to check the suitability for different reuse purposes. Most of the plants do not pass the quality criteria for green area watering, lake filling and steam production, but for cooling only Coyoacan and Tlateloco do not pass the quality criteria. Best quality of treated water is obtained in Cerro de la Estrella. It is found that the parameters that exceeded the maximum permissible limits, for green area watering, are volatile dissolved solids, total suspended solids, volatile suspended solids, phosphorous, phosphates, soluble COD, total COD, and SAAM (MBAS i.e. Methylene blue active substance). In case of recreational lake filling except COD, all parameters exceeded the maximum prescribed limit.

In general terms, treated water does not pass the prescribed quality criteria for green area watering and lake filling. The parameters which exceeded the permissible limit are basically of biological nature.

(5) Evaluation of the Treatment and Reuse Master Plan (1982 version) and Current Situation

Nine (9) treatment plants were existing by the year 1982 namely; Acueducto de Guadalupe, Azcapotzalco, Chapultepec, Cerro de la Estrella, Bosques de las Lomas, Ciudad Deportiva, Coyoacan, San juan de Aragon and Tlatelolco. In all the treatment plants operation efficiency is found to be 10-30% of the design capacity. The main reason of low operation efficiency are as follows:

- variable composition of influent due to industrial flow
- poor operating conditions of electromechanic equipments
- improper control of treatment process
- poor physical condition of equipments and facilities
- lack of laboratory facilities to monitor effluent quality
- low demand of reuse of treated water
- differential sinking in the primary and secondary sedimentation units

The following measures have been proposed to improve the capacity of treatment plants:

- intense maintenance of sedimentation tanks to rectify the differential settlement
- complete substitution of the obsolete electromechanical equipments
- providing adequate mixing in the aeration tanks
- providing adequate disinfection facility
- providing proper laboratory facilities
- providing sludge treatment facilities

(6) Factors Affecting the TRMP Development

The objective of TRMP is to increase the demand of treated water not only in D.F. but also in the surrounding municipalities. Hence it is necessary to identify the obstacles faced in the implementation of the TRMP (1982). The aspects to be considered for the implementation of TRMP are listed below:

a) Legal / Institutional Aspects

The quality of industrial effluent being discharged to sewerage system should be monitored and controlled. Industrial effluents affect the characteristics of raw wastewater, which further affect the performance of the treatment plant. The strategy requires the following institutional aspects for implementation:

- Obligatory: by the SARH, through its National Commission of the Water (CNA); SEDUE; SESA; and DDF
- Coordinated: by the Government of the Mexico state and the Town Council of the conurbed municipalities
- Induced and Concerted: by the industrial sector.

b) Economical Aspects

The main barrier in reusing the treated water is the cost. Sometimes cost of using treated water is higher than other water supply sources.

By making treated water economically attractive the reuse of treated water can be encouraged.

c) Financial Aspects

The water supply system has been financed from the funds available for infrastructure development. This limits the investment to improve the treatment and reuse system and money being spent for maintaining the facilities is very less. As a part of the water supply system, the treatment and reuse program requires the financial support from D.F. government as well as from users.

d) Social Aspects

It is necessary to explain the objectives, benefits and structure of the water reuse program to the public. This activity should be supported by citizen's private organizations and other institutions related to the reuse program such as SEDUE, SESA and SARH.

e) Administrative Aspects

The shortcoming in the implementation of TRMP (1982) reflects the poor organization structure of the drinking water and sewage services, as a result dispersion of duties. The treatment and reuse program could improve the financial and commercial aspects, if the drinking water and sewage services are integrated in a single unit with the technical, administrative and financial components. Another limitation is lack of well trained personnel of different levels which a system require.

f) Technical Aspects

DGCOH carried out basic studies to evaluate water quality, treatment efficiency and environmental impact to encourage the treatment and reuse system. To achieve process control, experimental studies on laboratory scale models are being carried out. Handbooks on the biological treatment process operation are being prepared. Geohydrological studies have been carried out to find appropriate site and structure suitable for artificial recharge of the aquifer.

(7) Perspectives

Due to scarcity of water sources, program on the efficient use of the water (PUEDA) has been established since 1984. The main objectives are listed below:

- Reduction of water consumption in sanitary toilets and hydraulic devices
- Encouraging users to contribute for the efficient use of water
- Rule the drinking water service
- utilize maximum of the available sources.

The above mentioned strategy can reduce the water consumption to a great extent. Further the water spring in Coyoacan district is appropriate for green area watering as well as for cooling water.

Even after implementing PUEDA and making use of water spring in Coyoacan it is necessary to reuse treated wastewater for conventional and non conventional uses which do not require drinking water quality standards.

Potential demand of treated wastewater in the Federal District for conventional uses is estimated to be 5,629 l/s for the conventional uses, as shown below:

	Current Situation	Potential Demand
Green areas	952 l/s	2,426 l/s
Industry	83.2 l/s	495 l/s
Common land irrigation	840 l/s	2,708 l/s
Total	1,875.2 l/s	5,629 l/s

The program has been developed for refilling the aquifer by treated water and total output assumed to be 3,420 l/s. The recharging of aquifer will help in solving the sinking problem of the soil. However the cost required to treat the wastewater for achieving required quality should be carefully calculated. In recharging groundwater, public health and socioeconomic factors are more important. For safety purpose surface spreading can be preferred on injection method. In any case extraction well should be appropriately located in order to assure sufficient long route time to improve the water quality.

Domestic use is the other possible reuse category which requires strict quality control program. Present percapita water consumption of 220 lpcd is expected to be reduced to 140 lpcd even after installing low water consuming toilets. And at present about 45-50% of the domestic use doesn't require drinking water quality. Installing parallel distribution system for treated water for domestic use can be other feasible alternative.

But require strict quality monitoring program. Also economical aspects should also be carefully evaluated.

The user should pay for the drinking water that is substituted by treated water. In other words the fee policies of the treated water should consider following points:

- The price for the final user should be considerably lower than the drinking water.
- The fee should be enough to recover all the costs of the treated water system (Capital, operation, maintenance and administration)
- The price should also include an accumulative excedent to finance the system enlargement

(8) Options for the Treatment and Reuse System Development

Based on current treatment and reuse system five alternatives have been projected. The first two elaborate what will happen if treated water quantity and quality is not improved and remaining three include the proposed improvement in quantity and quality.

a) Alternative 1

Treatment plants are assumed to operate at the present level. Operation and maintenance cost is included, so treatment plants after reaching useful life will deteriorate, resulting in the decrease of the quantity of treated water available for reuse. In other words only drinking water supply will be available and total available water supply will go on reducing.

b) Alternative 2

In this alternative, proper maintenance of treatment plants have been taken into account thus constant water supply will be available with time.

c) Alternative 3

In this case improved quantity and quality of treated water has been taken into account and total water supply has been found to increase with time.

d) Alternative 4

This alternative is projected from Alternative 3 and conventional uses of treated water are taken into account.

e) Alternative 5

This alternative involves non conventional uses such as groundwater recharging.

The above mentioned five (5) alternatives are analyzed using Min-Max programming model. The drinking water demand required with different alternatives are compared in Table E.4.

(9) Proposal to Develop the Treatment and Reuse System for D.F.

This chapter explains the strategy proposed for the development of TRMP. Table E.5 shows the demand of various categories of reuses. The demands for non conventional reuses have been estimated based on the development plans of the Federal District hence will not vary in long term. The demand of non drinking water for domestic purpose may only vary in long term. Non drinking domestic use is assumed to be 20-30% of the current drinking water consumption in housing area and can be substituted by the renewed resource. For green area watering, recreational lake filling and common land irrigation the supply should be provided 12 hours a day. For industrial zones, rescue of lake zone and aquifer refilling the supply should be provided constantly throughout the day.

a) Proposed Alternative

As described earlier five (5) alternatives have been proposed and these alternatives are analyzed using programming model and different development alternatives were studied for each alternative for the short, medium and long term objective. Finally two development plans have been selected and emphasis is given to increase the supply and demand of the treated water in the zones of higher demand. The actions that are included in the alternatives for the development of the treatment and reuse system are shown in Table E.6.

b) Proposed Strategy

The treatment and reuse Master plan has been developed based on the following criteria:

- The treated water supply should be increased to fulfill the demand and quality should be according to the potential use.
- To enlarge the treated water contribution to the conventional uses so as to satisfy 100% demand.
- Pilot test related to aquifer recharging should be carried out.
- Provide treated water for non drinking domestic uses.

c) Development of the System

The system to be developed is shown in Table E.7. The development do not include the treated water supply required to satisfy non drinking domestic purpose, since it requires detailed analysis about the enlargement of the system to the priority zones.

The three treatment plants that should produce treated water to refill aquifer are:

Cerro de la Estrella	216,432 m^3/d
San Juan de Aragon	47,952 m^3/d
San Luis Tlaxialtemalco	31,104 m^3/d

Thus treated water from Cerro de la Estrella should be distributed as follows:

Green areas	19,224 m^3/d
Common Lands	35,208 m^3/d
Industrial zone	7,344 m^3/d
Lake zone	67,392 m^3/d
Batteries 2,3 and 6	177,984 m^3/d
Battery 4	38,448 m^3/d
Total	345,600 m^3/d

The San juan de Aragon will supply 47,952 m^3/d to battery 4 to refill the aquifer and remaining 38,448 m^3/d will be used for conventional uses. The San luis Tlaxialtemalco plant will provide 31,104 m^3/d for groundwater recharging (battery 5) and 1,296 m^3/d will be free for other uses.

With the proposed development about 7,140 l/s of treated water supply will be available which is enough to cover the estimated demands for conventional uses and aquifer recharging. In fact 83,582 m^3/d of supply is in excess and can be used for non drinking domestic uses.

(10) Objectives, Policies and Goals of TRMP

a) Objectives

- To increase the reuse of treated water for irrigation and industrial purpose as these uses do not require quality similar to drinking water
- To improve the quality of treated water so that it can be used for recharging groundwater and for domestic purposes
- Optimize usage of water quantitatively and qualitatively
- To reduce over exploitation of the aquifers
- To substitute the drinking water with treated water as far as possible

b) Policies

- To fully utilize the existing infrastructure available for the production and distribution of the treated water
- To carry out proper maintenance of the existing wastewater treatment plants
- To impulse the capacity of the personnel in charge of the wastewater treatment
- To increase the usage of treated water to conventional uses through efficient supplying patterns
- To develop research program so as to increase the non conventional uses
- To study administrative options which favors the elimination of subsidies and enable the establishment of concession schemes of the wastewater treatment system
- To implement effectively the legislation related to industrial effluent discharge to sewerage system

c) Goals

Short term

- Construction of 67 km of treated water pipeline
- Construction of four pumping stations for treated water each of 150 l/s
- Construction of treatment plants
    * in Milpa Alta directorate
    * in Tlahuac directorate
    * third module of San Juan de Aragon (500 l/s)
    * third and fourth module of San Luis Tlaxialtemalco (75 l/s each)
- Rehabilitation of the treatment facilities and optimization of its quality
    * Addition of foaming, coagulation-flocculation and filtrationprocesses to the Cerro de la Estrella, Azcapotzalco and Coyoacan plants.
    * Installation of foaming, coagulation-flocculation filtration and activated carbon adsorption processes to the San juan de Aragon and Ciudad Deportiva
    * Addition of foaming and filtration processes to the Acueducto de Guadalupe, Tlatelolco and Chapultepec
- Conduct theoretical-practical courses for operators of treatment plants
- Complete the development of operation handbooks
- Study soil behavior during groundwater recharging by injection method
- Provide sufficient laboratory facilities at the treatment plants
- Strengthen the central laboratory to improve the reliability level required for reusing treated water specially for groundwater recharging and domestic purpose
- Utilize water from the Santa Ursula spring in Coyoacan

Medium Term

- Construction of 80 km of treated water lines, including the proposed interconnections

- Construction of six (6) pumping station for treated water each of 150 l/s
- Construction of 4 and 5 module of San Luis Tlaxialtemalco plant
- Rehabilitation of the facilities to operate treatment plants at nominal capacity
- Groundwater recharging with treated water as per DGCOH plan
- Construction of storage tanks close to treatment plants, with the total capacity of 318,000 m^3 to regulate during 12 hrs, the treated water flow and thus optimize its distribution.

Long Term

- Lower down the drinking water consumption by 30%, substituting it by treated water
- Establish administration and operation to commercialize the treated water
- Establish fee system for the drinking water based on the real value of the resource, hence making it attractive due to low cost.

(11) Programs

In order to achieve the proposed goals in the TRMP 1990, it is necessary to structure the following programs.

a) Infrastructure Development

- Rehabilitate the treatment lines to achieve an appropriate hydraulic functioning
- Substitute or repair diffusers and sprays
- Repair for the settlement of sedimentation tanks
- Install the sand removers
- Repair purge control system
- Repair for the settlement of drill systems
- Install disinfection facilities
- Equipping the laboratories at the treatment plants
- Install the equipment to measure flow rate
- Modify treatment processes to obtain desired effluent quality
- Enlarge distribution networks.

The investment costs involved are shown in Table E.8.

b) Operation and Maintenance

The lack of proper maintenance has resulted in the deterioration of the building and equipments of the treatment plants. Hence it is necessary to allot certain part of the expenses for maintenance. Table E.9 shows the operation and maintenance costs.

c) Quality Control

In order to replace drinking water with treated water for conventional and non conventional purposes it is necessary to have a strict control on the effluent quality of the treatment plants. Hence variation in the PhQB quality of the wastewater generated should be determined and treated water should have required PhQB quality.

The proposed actions to carry out the program are as follows:

- Implementation of the regulation related to wastewater discharge to the sewage
- Analytic monitoring of networks for wastewater and treated water should be operated
- Laboratory analysis of the concerned parameters should be carried out
- Computerized analysis of the laboratory information

d) Diversification of the Treated Water Reuse

TRMP, 1990 has many feasible options for the use of treated water in the aquifer refilling and in several non conventional uses. However it may require following actions:

- Studies related to spread of pollutants in soils and sediments
- High quality effluent using advanced treatment processes
- To conduct toxicological risk studies related to aquifer refilling
- To conduct epidemiological studies
- Elimination of toxic organic matter
- to select appropriate location to assure the flow tracks and long route
- To carry out sanitary cleaning of river beds and basins, where the aquifer refilling is possible with pluvial water

- Monitoring of recharged aquifer to find the flow direction, water movement rate and changes in the quality
- Effect on the properties of the aquifer material due to reaction with treated water

Another important non conventional use is for domestic purpose which does not require drinking water quality. However it requires to conduct proper toxicological and epidemiological studies and reliability studies related to the water quality. The main actions to be carried out are as follows:

- Quality should be similar to that for recreational purpose with contact
- Construction of treated water distribution system
- Study of feasibility of the dual system
- Strengthening of laboratory facilities to monitor quality

e) Technologic Development

- To develop appropriate methods to detect virus in the treated water
- Improve the performance of treatment process
- Develop analytical techniques to measure the pollutants
- Study technical, economical and mechanical feasibility for constructing wastewater treatment devices in the Mexico.

f) Support Programs

Lack of economic resources has resulted in improper maintenance of the treatment system and hence making treated water cost higher and not competitive with the drinking water. The financial program which can help in promoting treated water reuse is as follows:

- Develop a financial and simulating program to favor the production and use of treated water in D.F.
- Develop fiscal simulating policies so as to promote manufacturing of wastewater treatment equipments
- Develop program in which private enterprises rehabilitate and construct the needed structure to distribute the treated water or DGCOH construct infrastructure and private enterprises operate and maintain

- Develop social acceptance of the usage of treated water for agricultural, industrial and domestic purpose.

Besides financial program it is necessary to have program for training the personnel. The actions involved are as follows:

- Training courses to analysts and technicians
- Personnel having proper knowledge of laboratory techniques be employed
- Training courses for the operators of treatment plants
- Completion of the handbooks related to the operation of treatment plants.

Table E.1 Breakdown of Construction and O/M Costs for the Texcoco Treatment Plant proposed by CNA

Cost / Item	Construction Cost (million N$)	Investment Mortgage (million N$/year)	Operation and Maintenance Cost (million N$/year)						
			Operation Cost	Maintenance Cost	Energy Cost	Material Cost	Chemical Cost		Total
							(million N$/year)	(ton/year)	
Preliminary Treatment	19,874	2.660	4,006	1.392	0.267	0.497	——	——	6,162
Primary Sedimentation Tank	269,080	36.024	3,244	1.208	0.267	2.690	42,494	27,594.00	49,904
Chemical Dosig Equipment	3,290	0.440	2,364	1.208	0.138	0.065	16,550	551.88	20,325
Disinfection Tank	28,859	3.863	1,484	0.872	0.436	0.402	10,320	11,037.60	13,514
Gravity Thickener	22,172	2.968	1,178	0.563	0.040	0.221	——	——	2,002
Lime Mixing Tank	1,759	0.235	1,178	0.563	0.208	0.035	6,250	33,602.26	8,234
Total	345,034 (N$ 0.042/m3)	46.190	13,454	5.806	1.356	3.910	75,614	72,785.74	100,141 (N$ 0.091/m 3)

Note: Interest Rate : 12%
Depreciation : 20 Years

Table E.2 Unit Water Supply Charge and Annual Revenue in the Mexico State

Municipality	Population (x 1,000)	Unit Water Supply Chrge (N$)	Annual Revenue (x 1,000 N$)
Ecatepec	1,473	0.82	51,010
Netzahualcoyotl	1,301	0.91	25,686
Naucalpan	836	0.89	68,779
Tlalnepantla	740	0.87	55,429
Cuautitl·n Itz.	429	0.84	24,580
Atizapan	397	0.64	18,644
Chalco	377	0.54	6,478
Chilmlhuac·n	359	—	6,873
Tultitl·n	323	0.94	18,103
Nicol·s Romero	222	0.65	7,663
Coacalco	182		11,890
Ixtapaluca	167	0.89	9,690
Huixquilucan	165	—	16,698
Los Reyes - La Paz	158	—	8,754
Tecamac	148	—	4,703
Chicoloapan	76	0.22	380
Cuautitlan de R.	56	—	3,555
Total	7,409	—	338,915

Table E.3 Number of Sanctioned Pollutants for Different Treated Water Use

Propose of Reuse	Number of Pollutants Sanctioned
Drinking Water	152
Swimming	150
Aquaculture and Fishing	149
Drinking Trough	149
Raw Consumption Green Vegetable Irrigation	149
Manufactured Consumption Vegetables, Vegetable Garden and Vineyards	148
Fodder, Textiles and Green areas Watering	148
Recreational Lakes Filling	125
Sport Navigation	114
Non Potable municipal Water	57
Steam Production	56
Cooling	56

Source : Treatment and Reuse Master Plan 1982, DGCOH

Table E.4 Comparison of Drinking Water Demand for Different Alternatives

Year	Demand with 250 l/inhab./d	Alternative 1 (m^3/s)	Alternative 2 (m^3/s)	Alternative 3,4 &5 (m^3/s)
1988	31.13	29.156	29.156	29.156
1990	32.70	30.899	30.726	30.726
1991	33.50	31.989	31.526	30.466
1994	36.11	34.767	34.136	32.426
2000	41.87	41.668	39.896	34.270
2010	53.20	52.998	51.226	42.700

Table E.5 Potential Demand of Treated Water in the Federal District

Users	Demand (m^3/day)
– Green Areas Watering, Equipment and Recreative Lake Filling	104,803
– Industrial Use	42,768
– Lake Zone (Xochimilco-Tlahuac Rescue)	67,392
– Common Land Irrigation	53,967
– Aquifer Refil	264,384
– Non Drinking Domestic Use	405,179
Total	938,493

Table E.6 Actions Included in the Proposed Scenes and Projected for Two Different Development Alternatives of the Master Plan

Development Alternative 1	Development Alternative 2	Actions
1989-1991	1989-1991	Actions included in the Annual Operative Programme of the DGCOH 1990-1991; and on the Programme to Rescue the Lake Zones of Xochimilco, Tlahuac and Mixquic 1989-1991, also by the DGCOH.
1992-1994	1992-1994	Improve the quality of the renewed water, produced in the plants operated by the DGCOH, so the uses can be diversified and interconnected; besides, that it can be fulfilled with the Regulation proposal for the Reuse of the Treated Wastewater, by the DGCOH, in the Federal District.
1992-1992	1992-1996	Reach the 225 l/s foreseen for the San Luis Tlaxialtemalco plant, through the construction of two more modules, 75 l/s each. Enlarge to 400 l/s the Cerro de la Estrella Plant.
1995-1997	1997-2001	Increase the renewed water production through the rehabilitation of the existing plants, in such a way that all of them get to operate at its nominal capacity with an optimus quality.
1998-2000	2002-2006	Carry out the interconnection of the plants, concluded after the analysis were carried out. These interconnections are: - Aqueduct de Guadeloupe - Tlatelolco (POA) - Tlatelolco - Azcapotzalco (therefore, Aqueduct de Guadeloupe with Azcapotzalco - Coyoacan - Cerro de la Estrella).
1998-2000	2002-2006	Regulation at the 100 % of the flow produced by the treatment plants, in order to increase the offer of renewed water to the potential users. So, it's foreseen the construction of regulation tanks near the treatment plants. The storm tanks of the West will be used only to regulate the flow of the Chapultepec Plant, since they are very far from the other plants.
1995-1996	1998-1999	Construction of two more modules of 75 l/s each and respective regulation tank, at the San Luis Tlaxialtemalco Plant.
1990-1992	1990-1992	Pilot tests to refil the aquifer with renewed water coming from the San Luis Tlazialtemalco plant.
1996-2000	2003-2010	Construction works of injection wells and the needed infrastructure to refil the aquifers, according to the DGCOH, where 5 refil batteries with treated rain water and with pluvial water.
2001-2010	2003-2010	Infrastructure needed to supply renewed water for non drinking domestic use, which should include new plants and new distribution lines.

Table E.7 Treatment and Reuse System Development (supply in m/day)

Plant	Alternative	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Acueducto de	1	2,030																	
Guadalupe	2	2,030												3,456					6,912
Azcapotzalco	1	778							1,080			2,160							
	2	778												1,080					2,160
Tlatelolco	1	778							864			1,728							
	2	778												864					1,728
San Juan de	1	6,480		28,080				43,200			86,400								
Aragon	2	6,480		28,080							43,200					86,400			
Chapultepec	1	5,616		6,912								13,824							
	2	5,616		6,912															13,824
Cd. Deportiva	1	6,912							9,936			19,872							
	2	6,912											9,936					19,872	
Coyoacan	1	8,165								54,000			108,000						
	2	8,165										54,000					108,000		
Cerro de la	1	51,279		94,479		137,679		172,800			345,600								
Estrella	2	51,279		94,479		137,679					172,800				345,600				
San Luis	1	1,728	3,240		6,480		9,720	16,200	32,400										
Tlaxialtemalco	2	1,728	3,240		6,480		9,720				16,200	34,400							
TOTAL	1	83,765	85,277	151,373	154,413	193,813	201,053	207,533	278,813	324,648	540,648	562,896	616,896						
	2	83,765	85,277	151,373	154,413	197,813	201,053	201,053	236,174	257,774	319,809	322,833	324,647	497,447	540,647	594,647	604,583	616,896	
Production	1	1,919	1,974	3,504	3,579	4,579	4,654	5,967	6,079	7,140	7,140	7,140	7,140	7,140	7,140				
Total (l/s)	2	1,919	1,974	3,504	3,579	4,579	4,654	4,654	4,654	5,467	5,967	7,028	7,098	7,140	7,140				

Table E.8 Financial Programme of Development
(Millions of 1989 pesos per year)

Concept	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Construction of Treated water Lines		2,952	5,482	1,600		1,600	3,200	3,200		7,700		
Construction of Treated water Pumping Plants	260	210	390		200		200	400	200	200	200	
Construction of Treatment Plants		11,970	25,404	3,174	50,013	3,174	6,348					
Improve Quality in Plants, rehabilitation & Equipment		18,200	33,800	3,528	1,309	5,947	3,199	526	2,630			
Aquifers Refilling	1,000	1,500	1,500	1,000			1,000	27,000	27,000	27,000	27,000	22,000
Regulation Tanks								125		864	216	71
Total	1,260	34,832	66,576	9,302	51,522	10,721	13,947	31,251	29,830	35,764	27,416	22,071

Table E.9 Financial Programme of Development
(1989 pesos)

Year	Costs (Million $)	Offer (m3/day)
Present	10,302	83,765
1994	26,574	201,053
2000	46,565	616,896
2010	77,359	938,493

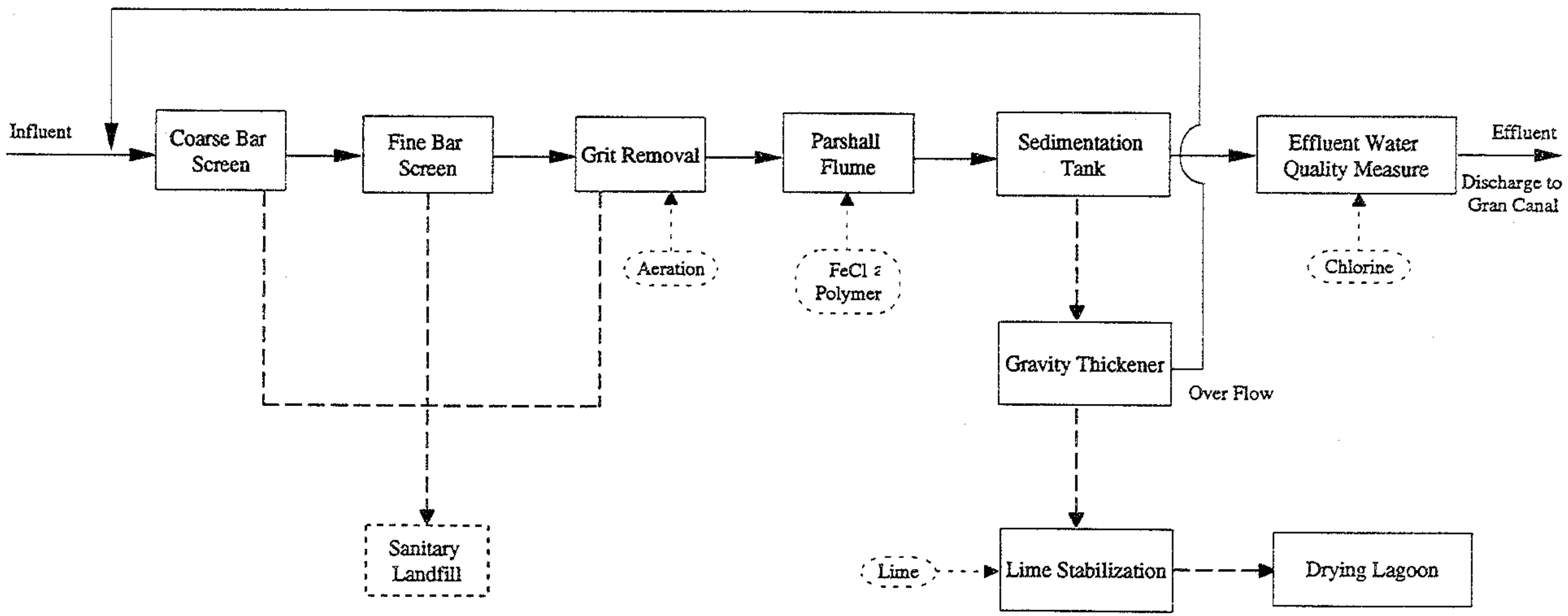

Fig. E.1 Flow Diagram of Advanced Primary Treatment of Master Plan

THE FEASIBILITY STUDY ON WASTEWATER TREATMENT IN THE FEDERAL DISTRICT OF MEXICO

APPENDIX F

APPENDIX F WASTEWATER AND SLUDGE TREATMENT PLANT FOR THE FINAL PROJECT

1. Treatment Plant Site

1.1 Location

The proposed wastewater treatment plant site is located in the Texcoco area, Ecatepec municipality in the state of Mexico (Refer to Fig. F.1). More precisely, the treatment plant site is at a point in the Texcoco area where Gran Canal changes its direction from north east to north west.

1.2 Land Use Plan of the Treatment Plant Site

The proposed treatment plant site is in the north of Texcoco which was known as Texcoco lake in the Pre Hispanic period. Lately, this place was used as soda producing factory. The proposed site was used as drying beds and residue stockyard of this factory. The factory has been closed since end of 1993 and the land is now under the jurisdiction of the National Water Commission (CNA), the government of Mexico.

The land is almost flat except some stock residue of soda producing factory. The total area available is about 8,000 ha. The required area for the treatment plant in the year 2015 is about 192 ha.

1.3 Land Elevation

The existing ground elevation of the former soda producing factory is located at the altitude from 2,234 to 2,236 meter. The land is almost flat except the stock yard of residue of the soda product which is about 10 meter high with an area of 17.9 ha.

The river bed elevation of Gran Canal at the proposed effluent discharging point is about 2,226 meter, which is about 9 meter lower than the existing ground elevation of the proposed treatment plant site.

1.4 Soil Condition

The area is reclaimed area of Texcoco Lake. Hence as could be expected the top surface layer of proposed treatment plant site is rather soft. Based on the soil data of previous survey and the survey conducted by JICA Study Team, the base layer of the soil is found at a depth of more than 55 meters from ground surface. The shallower layers consist of clay and sand layers alternatively. The characteristics of the shallow clay and sand layers are described below.

Layer	Depth (m)	Nature of soil	SPT (N value)
(1)	0.0~GL -9.0 m	Very soft clay	0 ~ 3
(2)	GL-9.0~-12.0 m	Silty sand	10
(3)	GL-12.0~16.0 m	Soft clay	< 5
(4)	GL-16.0~19.0 m	Silty sand	10 ~ 50
(5)	GL-19.0~28.0 m	Clay and sand	0 ~ 20
(6)	GL-28.0~37.0 m	Silty sand	30 ~ 50
(7)	GL-37.0~55.0 m	Soft clay and silty sand	10 ~ 50 *

Note: STP with * is assumed from the data, which was conducted at the end of 1993.

Among these seven (7) layers, consolidation settlements are expected to occur at the clay layers of (1), (3), (5) and (7). Based on the consolidation test conducted by JICA Study Team, if the ground water is continuously withdrawn from the layer deeper than 50 meters from ground surface, ultimate consolidation settlement of each layer has been estimated and is shown below.

Layer	Depth (m)	Nature of soil	Ultimate Consolidation Settlement (m)
(1)	0.0~GL -9.0 m	Very soft clay	1.5
(3)	GL-12.0~16.0 m	Soft clay	1.0
(5)	GL-19.0~28.0 m	Clay and sand	0.2

Based on the soil data of the previous survey, consolidation settlement in the (7) layer will be assumed to be 1.5 cm per annum.

The silty sand layer, found at the depth of 28.0 m to 37.0 m from the ground surface, with the SPT value of 30~50 is proposed to be the foundation layer of the proposed treatment facilities.

2. Formulation of Design Conditions

2.1 Wastewater Discharge to the Treatment Plant

The wastewater to be treated is basically carried by Gran Canal. However due to land subsidence problem, which is the severe most at the intersection point of Los Remedios river and La Compania river along the Gran Canal, the pumping of wastewater is necessary. The drainage pumping station will be constructed at the intersection point and wastewater will be continuously conveyed by pressure pumping main.

2.2 Wastewater Quantity

As described in Appendix D, section 2.1, the total discharged wastewater quantity in the study area of D.F.and Mexico state are as follows:

	DF	Mexico State
Yr 1997 (Urgent Project)	25.62 m^3/sec	10.93 m^3/sec
Yr 2015 (Final Project)	34.08 m^3/sec	13.30 m^3/sec

Based on Agua 2000 (Estrategia para la Ciudad de Mexico), existing and future expected wastewater quantity for reuse of industry and irrigation has been prescribed for D.F.and Mexico state. Further keeping in view the shortage of water supply sources, JICA study team has assumed the quantity of wastewater required to be reused in the Year 2015. These quantities are described below:

1) D.F.Mexico

Year	Industrial Use (m^3/sec)	Irrigation Use (m^3/sec)
1993	0.39	2.20
1997	1.40	2.20
2015	2.30	4.40

Note : Wastewater reuse quantity in 1997 is estimated by JICA on the basis of Agua 2000.

Wastewater reuse quantity in 2015 is estimated by JICA.

2) Mexico State

Year	Industrial Use (m^3/sec)	Irrigation Use (m^3/sec)
1993	0.28	0.10
1997	1.32	1.10
2015	2.30	2.60

Note : Wastewater reuse quantity in 1997 is estimated by JICA on the basis of Agua 2000.

Wastewater reuse quantity in 2015 is estimated by JICA.

The above mentioned quantities, which are required for reuse purpose, will be treated by small treatment plants within D.F.and Mexico state, similar to existing situation (ref Appendix D, section 4.1.1).

The amount of treated water being reused for industrial purpose will be discharged again to the sewerage system, however treated water being reused for irrigation purpose will not return to the sewerage system.

Hence the expected wastewater quantity for the Texcoco treatment plant is calculated by subtracting the quantity to be reused for irrigation purpose from the total discharged wastewater quantity. The expected wastewater quantity, in the year 1997 and 2015, is described below.

	DF (m^3/sec)	Mexico State (m^3/sec)	Total (m^3/sec)
Existing	21.03	9.07	30.10
Future in 1997 (Urgent Project)	23.42	9.83	33.25
Future in 2015 (Final Project)	29.68	10.70	40.38

The design wastewater quantity of the treatment plant in the year 1997 for the Urgent Project and in the year 2015 for the Final Project are determined based on the drainage capacity of Gran Canal and the capacity of the above mentioned drainage pumping station.

Design wastewater quantity of Urgent and Final Project are as follows:

	Urgent Project (1997)	Final Project (2015)
Daily average	35 m^3/sec.	40 m^3/sec.
Peak flow	35 m^3/sec.	40 m^3/sec.

2.3 Wastewater Quality

The discharged wastewater quality has been determined based on the characteristics of wastewater being generated in the study area as discussed in Appendix B, section 2.2 and Appendix D, section 2.2. The discharged wastewater quality in terms of BOD_5 and SS is shown below.

	1997	2015
BOD_5 (mg/l)	214	233
SS (mg/l)	221	241

The influent wastewater quality in terms of BOD_5 and SS for the Texcoco treatment plant is not the same, as sludge from the treatment plants of capacity 2.97 m^3/sec (also mentioned in Appendix B, section 2.2) is discharged back into sewerage system.

Assuming BOD_5 of sludge is 45% of the influent BOD_5, the influent BOD_5 of Texcoco treatment plant is calculated as follows:

$$(33.25 \times 214 + 2.97 \times 214 \times 0.45\ ) / 33.25$$
$$= 222 \text{ mg/l}$$

Similarly influent SS in the year 1997 and 2015 and BOD_5 in the year 2015 has been calculated and results are summarized below:

	1997	2015
BOD_5	222 mg/l	241 mg/l
SS	236 mg/l	256 mg/l

The influent wastewater quality of the treatment plant for the Urgent Project and Final Project are established as follows.

	1997	2015
BOD_5	220 mg/l	245 mg/l
SS	235 mg/l	260 mg/l
Coliforms (MPN/100ml)	10^7	10^7

For designing suitable treatment process, further wastewater characteristics in terms of SS and BOD were examined. One (1) set of data for San Cristobal and Lopez Portillo for the dry and rainy season is illustrated below.

Sampling Station	SS (mg/l)	Dry Season BOD_5 (mg/l)		SS (mg/l)	Rainy Season BOD_5 (mg/l)	
		Soluble	Particulate		Soluble	Particulate
San Cristobal	230	169	66			
Lopez Portillo	235	182	69	266	108	78

The data from the sampling stations San Cristobal and Lopez Portillo (near the proposed treatment plant) shows that in dry season soluble BOD constitutes about

70% and particulate BOD constitutes only 30%. And in Rainy season soluble BOD constitutes about 60%.

Further data from the Termoelectrica Valle de Mexico treatment plant (being operated by CFE), which is treating Gran Canal Wastewater, was examined and it was obseved that 20% BOD removal efficiency and 40% SS removal efficiency was observed in primary sedimentation tank. However after secondary treatment, BOD removal efficiency and SS removal efficiency are found to be 92% and 90% respectively.

2.4 Design Effluent Quality

The treated wastewater is intended to be reused for irrigation purpose in the Tula irrigation area. The quality of treated wastewater to be reused for irrigation purpose is governed by Mexican Official Standards Nom-CCA-032-ECOL/1993 and Nom-CCA-033-ECOL/1993, as discussed in Appendix C, section 6. For the Urgent Project treated water is proposed as Type III water (ref. Appendix C, section 6).

The effluent wastewater quality of the treatment plant for the Urgent Project in the year 1997 are established as follows:

	Effluent
BOD_5	120 mg/l
SS	120 mg/l
Coliforms (MPN/100ml)	< 100,000

The effluent quality standards for the water bodies to be reused for irrigation purpose have been proposed by the study team (ref. Appendix C, section 7). Based on these proposed standards, design effluent quality of the treatment plant for the Final Project has been established which is shown below.

	Effluent
BOD_5	20 mg/l
SS	30 mg/l
Coliforms (MPN/100ml)	< 1,000

2.5 Treated Wastewater Discharge

The treated wastewater will be discharged by channel, crossing the Av Central road, into Gran Canal between the railway crossing and confluence point of Gran

Canal and Canal of Sales. The treated water will be finally carried to the Tula irrigation area.

3. Alternative Study for Wastewater Treatment

3.1 General

The various possible alternatives of wastewater treatment system have been studied with the following basic considerations:

1. Proposed treatment system for the year 2015 should have enough capacity to treat wastewater and treated wastewater quality should meet the proposed design effluent quality.

2. A portion of the proposed optimum wastewater treatment system with or without some modification should be selected as the urgent treatment system.

3. The selected treatment system for the Urgent Project should be in conformity with the treatment system for the year 2015.

A typical wastewater treatment process as shown in Fig. F.2, consists of four (4) steps; preliminary treatment, primary treatment, secondary treatment and effluent disinfection.

Preliminary treatment process prepares wastewater influent for further treatment by reducing or removing problem wastewater characteristics that could otherwise hinder or unduly increase maintenance of downstream processes. Based on the wastewater characteristics, preliminary treatment involves screening and grit removal. Primary treatment is basically to achieve solids separation so that resulted sludge can be conveniently and economically treated. Sedimentation is the most common primary treatment, however sometimes sedimentation with coagulation and preaeration is employed to enhance solid separation. The main objective of secondary treatment process is to achieve organic substance removal. Secondary treatment could be either biological treatment or chemical treatment. Biological treatment is usually employed as secondary treatment process. Sometimes combination of suspended growth and attached growth biological process, i.e., dual process, is employed as secondary treatment process. Natural treatment system which involves physical, chemical and biological processes are also quite often used as secondary treatment process. Finally effluent is disinfected to kill harmful bacteria, virus and other pathogens.

The treatment system will be selected from these treatment systems shown in Fig. F.1.

3.2 Wastewater Treatment System Proposed by the Master Plan for the Year 1997

In the Master Plan conducted by CNA and DGCOH, eight (8) alternatives were compared as the urgent wastewater treatment system (refer to Fig. F.3).

These eight (8) alternatives are capable of achieving the effluent wastewater quality to a level of 120 mg/l of BOD_5 and 120 mg/l of SS. Among these eight (8) alternatives, Alternative C was selected as the optimum urgent wastewater treatment system by the Master Plan from the following considerations:

- Costs of construction, operation and maintenance
- Required land space

3.3 Review of Alternatives Proposed by the Master Plan

JICA Study Team has reviewed eight (8) alternatives proposed by the Master Plan to check their applicability for the Urgent Project (Yr. 1997) and the Final Project (Yr. 2015). In due consideration of the wastewater characteristics of the Gran Canal with probably higher soluble BOD_5 constitution of 60% to the total BOD, Alternative C of primary sedimentation with coagulation is not recommendable for the Urgent Project. hence Alternative C is neglected from the further analysis.

For reviewing remaining seven (7) alternatives, following aspects have been considered:

- Each alternative will be operated in the year 2015 with no modifications
- Effluent wastewater quality should meet the target design effluent quality in the year 2015 as mentioned in Appendix F, section 2.4
- Design wastewater quantity is 40 m^3/sec. in the year of 2015

Among seven (7) alternatives, Alternative E cannot meet the requirement of the design treated wastewater quality of BOD_5 less than 20 mg/l. BF (Biofilter) mentioned in alternative E is assumed to be Trickling Filter. Hence Alternative E is neglected for the Final Project.

The remaining six (6) alternatives are evaluated based on the following criteria:

(1) Required treatment space
(2) Required construction cost
(3) Required operation cost
(4) Required skilled personnel for operation
(5) Quantity of sludge generated

The evaluation of these six (6) alternatives is shown in Table F.1. As evident from the above Table F.1, Alternative A (Stabilization ponds) and Alternative H (Conventional activated sludge process) got rather high points in the evaluation. However the stabilization pond process is not recommendable because of large treatment space requirement which is about 5,600 ha.

3.4 Alternatives of Wastewater Treatment Process for the Final Project (Yr. 2015)

With due consideration to the above discussions JICA Study Team concluded that the following aspects should be considered while analyzing the alternatives of wastewater treatment process.

- Soluble BOD_5 constitutes 60-70% of total BOD_5 and only 20% BOD_5 removal efficiency was achieved by primary sedimentation at Termoelectrica Valle de Mexico treatment plant. Hence biological treatment process is required to achieve design effluent quality in both Final Project (Yr. 2015) and Urgent Project (Yr.1997).
- The treatment process of the Urgent Project should be in conformity with the treatment process for the Final Project of 2015.
- The treatment process with high treatment efficiency per unit treatment space is required because of the large amount of wastewater (3.0 million m^3/day) to be treated.

JICA Study Team proposes three (3) alternatives for wastewater treatment process in the year of 2015 to meet the requirements mentioned above. These alternatives are shown in Fig. F.4.

Alternative I, is the conventional activated sludge process i.e, Alternative H of Master Plan. In Alternative II, primary sedimentation tank with coagulation is proposed to reduce the size of aeration tank and also to reduce energy requirement. Alternative III adopts dual process, i.e., biofilter followed by conventional activated sludge process. This case may lead to less energy consumption and less sludge generation. These three (3) alternatives are compared based on the following criteria to select the optimum system:

- Required technology level of operation and facility management
- Required costs of construction and operation and maintenance
- Required land space

3.5 Design Criteria Considered for the Alternatives

No design criteria of wastewater treatment and sludge treatment are available in Mexico. To establish the design criteria of this project, the design criteria of Cerro de la Estrella, which is the largest existing wastewater treatment plant in D.F. Mexico and design criteria proposed by Design Manuals were studied. The Design Manuals being used as references are as follows:

- Wastewater Engineering (Metcalf / Eddy) (W/E)
- WEF Manual of Practice No.8 & ASCE Manual and Report on Engineering Practice No.76 (WEF)
- Japanese Design Manual on Wastewater Treatment (JDM)

Also actual results obtained in the Termoelectrica Valle de Mexico treatment plant being operated by CFE (CFE) is taken into account.

The results of the comparative study of design criteria are summarized in Table F.2. Based on the comparative study, design criteria used in the evaluation of the alternatives were selected. These design criteria are described below:

(1) Primary Sedimentation Basin

	Design Criteria	References
Over Flow Rate	35 $m^3/m^2 \cdot d$	W/E & JDM
Removal Efficiency	BOD_5 = 20 % SS = 40%	CFE JDM

(2) Primary Sedimentation with Coagulation

	Design Criteria	References
Over Flow Rate	35 $m^3/m^2 \cdot d$	WEF
Removal Efficiency	BOD_5 = 30% SS = 80%	CFE W/E
Chemical Dozing Rate	$Fecl_3$ = 20 mg/l Anionic Polymer = 0.5 mg/l	WEF

(3) Activated sludge process

(Aeration tank)

	Design Criteria	References
F/M Ratio	0.3	W/E & WEF
Activated Sludge Recirculation Ratio	0.35	W/E & WEF
MLSS	1,200 ~ 3,000 mg/l	W/E, WEF & JDM
Hydraulic Retention Time	4 ~ 10 hrs	W/E, WEF & JDM

(Secondary Sedimentation)

	Design Criteria	References
Over Flow Rate	25 $m^3/m^2 \cdot d$	W/E, WEF & JDM

BOD removal efficiency: 85-95 % (W/E, WEF)

(4) Disinfection

	Design Criteria	References
Dozing Rate Final Project	5 mg/l	W/E

Recommended contact time : 15 - 45 min. (W/E)

Chlorine gas is employed for disinfection.

(5) Biofilter

Roughing trickling filter is adopted as the biofilter and design criteria are as follows.

	Design Criteria	References
Hydraulic Loading	100 $m^3/m^2 \cdot d$	W/E
Removal Efficiency	BOD_5 = 40 % SS = 40 %	W/E

4. Alternative Study for Sludge Treatment

As discussed in the previous section, the various alternatives of wastewater treatment plant have been proposed in the Master Plan, however not much detail study about sludge treatment has been carried out.

In this project the evaluation process is not limited to the wastewater treatment unit alone; the interaction of the liquid with the sludge processing alternatives is done as an integral part of the evaluation. Various possible alternatives at each step of sludge treatment as shown in Fig. F.5 are technically evaluated. Then technically possible alternatives are financially evaluated. And the process is selected at each step of sludge treatment system. Hence appropriate sludge treatment is decided.

Finally three (3) alternatives of wastewater treatment combined with appropriate sludge treatment system are financially compared and optimum wastewater and sludge treatment system is selected, which will be discussed in the next section.

4.1 General

Selection of sludge treatment system should go hand in hand with the selection of the liquid treatment system. A typical flow of sludge treatment process is shown in Fig. F.5. Sludge treatment process is usually achieved in four (4) steps as thickening, stabilization, dewatering and disposal. Thickening process reduces the volumetric loading to and increases the efficiency of, subsequent solids processing steps. Stabilization process is usually required to stabilize the organic material in the sludge and to destroy pathogenic bacteria, to make it suitable for final disposal. Stabilization process can be avoided if sanitary landfill is adopted as the final disposal. Dewatering is used to reduce the moisture content of the sludge so that it can be easily handled and disposed off.

4.2 Sludge Thickening

Thickening process is selected depending on the characteristics of the sludge. Generally, two (2) types of sludge are produced at the wastewater treatment plant; primary sludge consists of organic solids, grit, and inorganic fines discharged from primary sedimentation tank and secondary sludge, i.e., biological sludge consisting of the conventional products from soluble wastes in primary effluent and particles escaping primary treatment. The primary sludge is slimy and easy to thicken however biological sludge is generally more difficult to thicken or dewater.

Three (3) systems of sludge thickening are generally adopted for the sludge concentration: