CHAPTER - V SEWERAGE SYSTEM

CHAPTER V

SEWERAGE SYSTEM

1. PRESENT CONDITIONS

1.1 OUTLINE OF SEWERAGE SYSTEM

Sanitary sewer collection and disposal system was originally designed and constructed in 1930's. A stabilization lagoon with 23 ha of treatment area was constructed in 1972 as the first wastewater treatment facility. The collection system is a separate system, which only collect sanitary wastewater. The treated water from the lagoon is discharged to the Puno interior bay of the Titicaca lake.

The major rise in the lake water level up to 3812.51 m.a.s.l. in 1986 flooded the lagoon and caused problems of the main collectors. The stabilization lagoon was not functional until 1992. The major rehabilitation works were performed for the stabilization lagoon and for pump stations in 1995 and 1996. The present sewerage system collects and treats wastewater generated by 46% of population in Puno City.

1.2 EXISTING SEWERAGE SYSTEM

1.2.1 SERVICE AREA

The present service area of the wastewater collection system is shown in *Figure V-1-1*. EMSAPUNO, a public owned company in charge of water supply and sewerage, divides the service area into 8. Besides 2 small areas, Chanu Chanu (VII) and Chejona (VIII), which have own treatment facilities, collected wastewater is led to the Espinar stabilization lagoon either by gravity or through pump stations.

The present service area (900 ha) covers about 70 % of built-up area (1,279 ha) of Puno City and 17 % of the present JICA study area (land area: 5,250 ha).

1.2.2 FACILITIES

(1) Sewer connections

The number of connections to the existing sanitary sewer system is shown in *Table V1.1.*

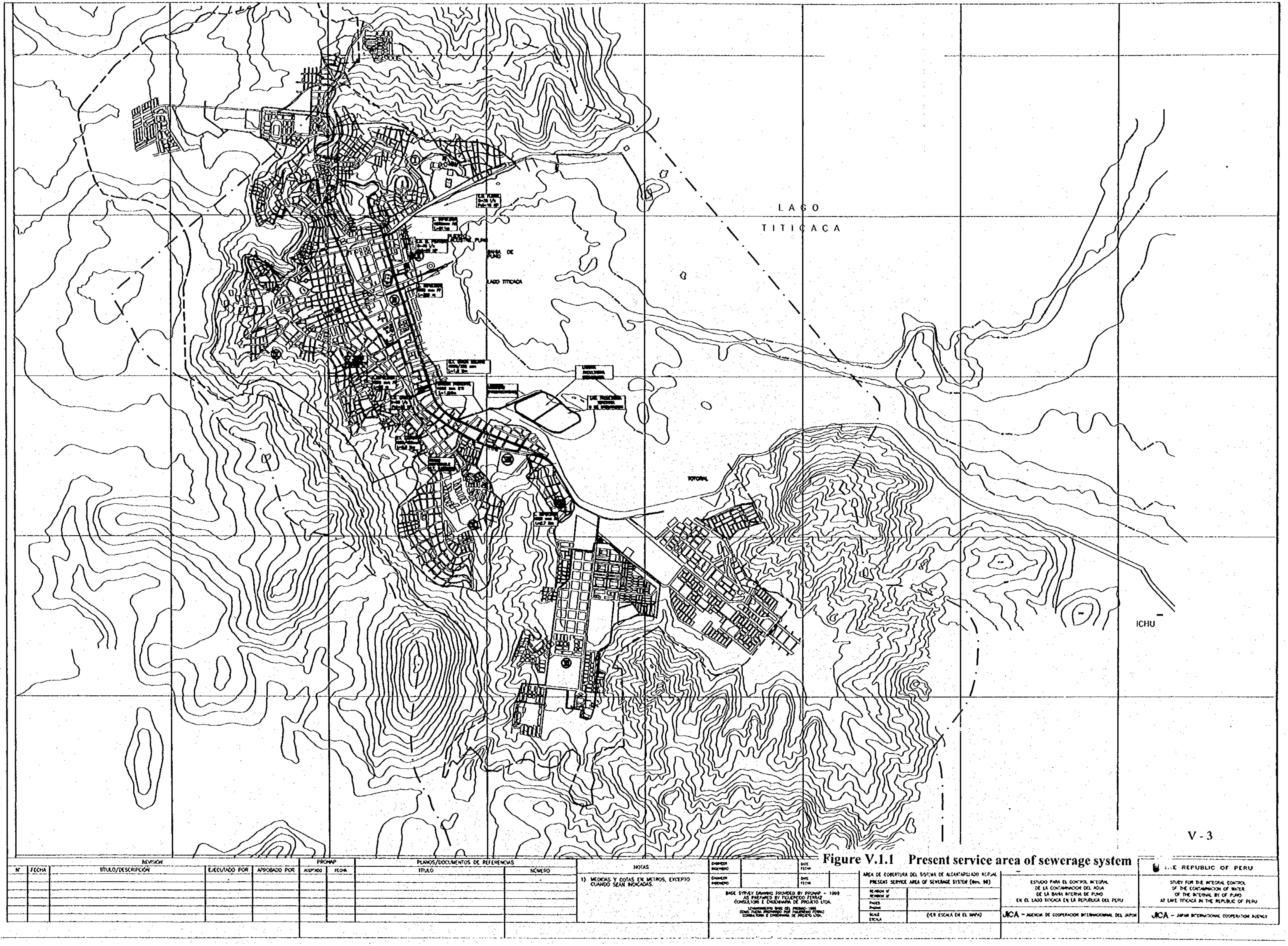


Figure V.1.1 Present service area of sewerage system

Table V.1.1 Sewer connections

Year	Number of connections	Increase rate (%)
1993	8.904	----
1994	9.217	3,5
1995	9.584	4,1
1996	9,972	3.9
1997	11,066	11.0
1998	12,037	8.8

Source: HIDROSERVICE/BWAS (1997) / EMSAPUNO (1999)

The average number of residents per connection is 4.17 for the Puno City (JICA, 1999), therefore the served population is 50,194, which is 46 % of total population (108,457) of the Puno City in 1998.

On the other hand, the Annual Report of EMSAPUNO (1999) estimates that served population of 60,185 (55%) using higher number of residents per connection value.

Table V.1.2 The served population of the sewerage system in 1995

Categories	% population
Connected to sanitary sewer system (Connected to the treatment plants)	59 % (51%)
Not connected to sanitary sewer system (although a sewer line exists in front of the house)	6 %
No connections (excluding the above)	35 %

Source: EMSAPUNO (1995)

The each house connection equips with a wastewater pit which temporally stores wastewater and 6" concrete pipe that connects a wastewater pit to the sewer network.

(2) Sanitary sewer network

The sanitary sewer network consists of branch sewer and sub-mains (pipe diameter 150 mm-200 mm) and main (trunk) sewer (diameter 250 mm-900 mm). Approximate total lengths of the existing sewer pipes are shown below.

Table V.1.3 Length of existing sanitary sewer pipes (1998)

Pipe diameter	Length
150 mm – 200 mm	146 km
250 mm – 900 mm	12.8 km

Source: EMSAPUNO / JICA (1999)

The pipes with diameter less than 200 mm are concrete pipes while those with diameter larger than 250 mm are made of reinforced concrete. The some of the concrete pipes in the city center are more than 30 years old.

The existing sewer network is shown in *Figure V.1.2- a, b.* There are 2 major interceptor sewer lines located along Av. Simon Bolivar and Av. Tacna la Torre. The main collector Tacna la Torre collects wastewater from tributary area of 31 ha (area IV) in the *Figure V.1.1*, and feeds collected wastewater by gravity to the principle interceptor of 900 mm diameter. The principle interceptor starts from the manhole near the Canete pump station in Av. Simon Bolivar to the stabilization lagoon. The interceptor Simon Bolivar collects wastewater from low-lying area of the city (Area I, II, and III in *Figure V.1.1*) to the Cañete pump station, where wastewater is pumped to feed the principle interceptor (dia. 900 mm). The principle interceptor also collects wastewater from the area V and pumped wastewater from the area VI, then discharges all the wastewater to the Espinar stabilization lagoon.

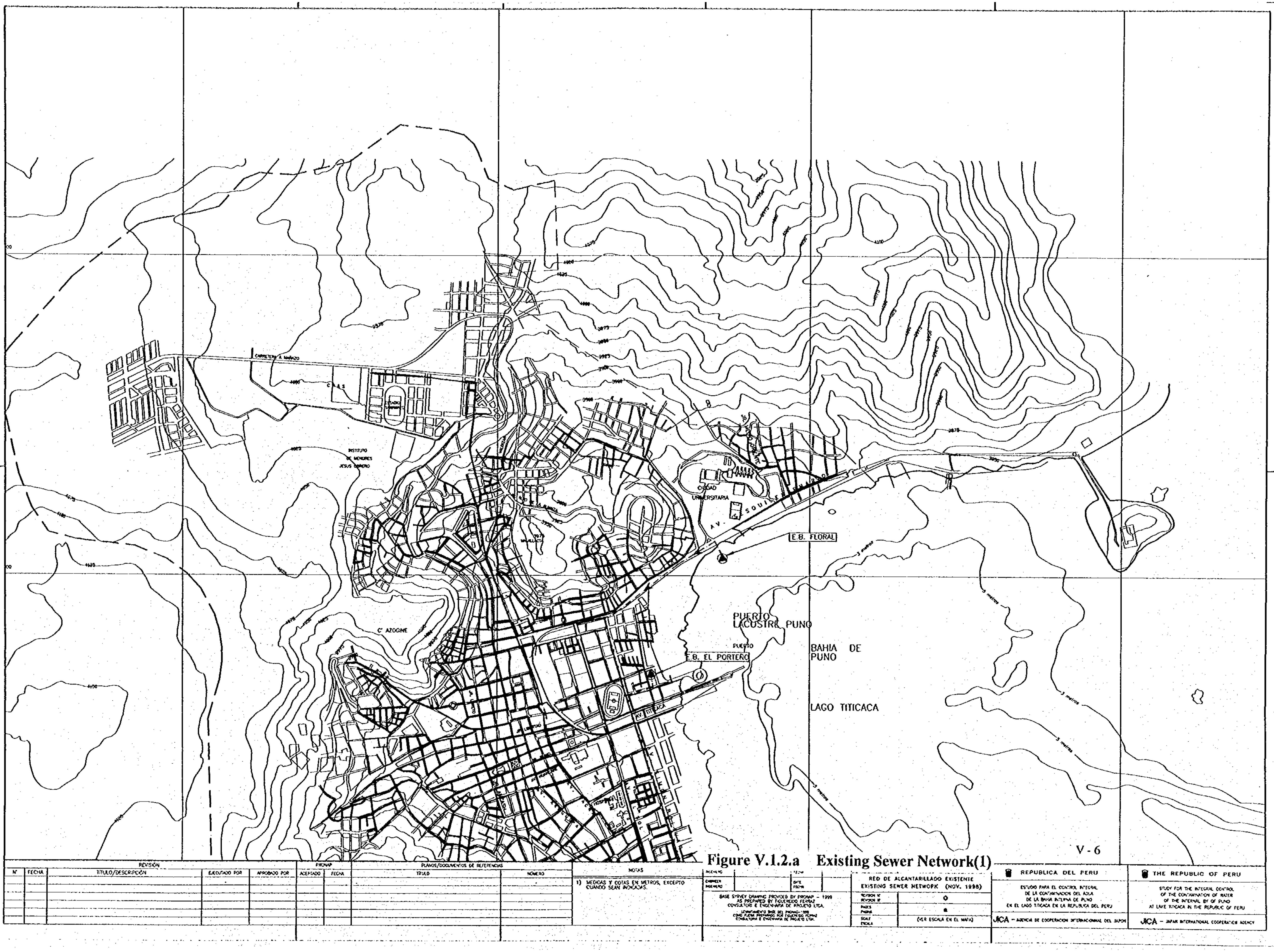


Figure V.1.2.a Existing Sewer Network(1)

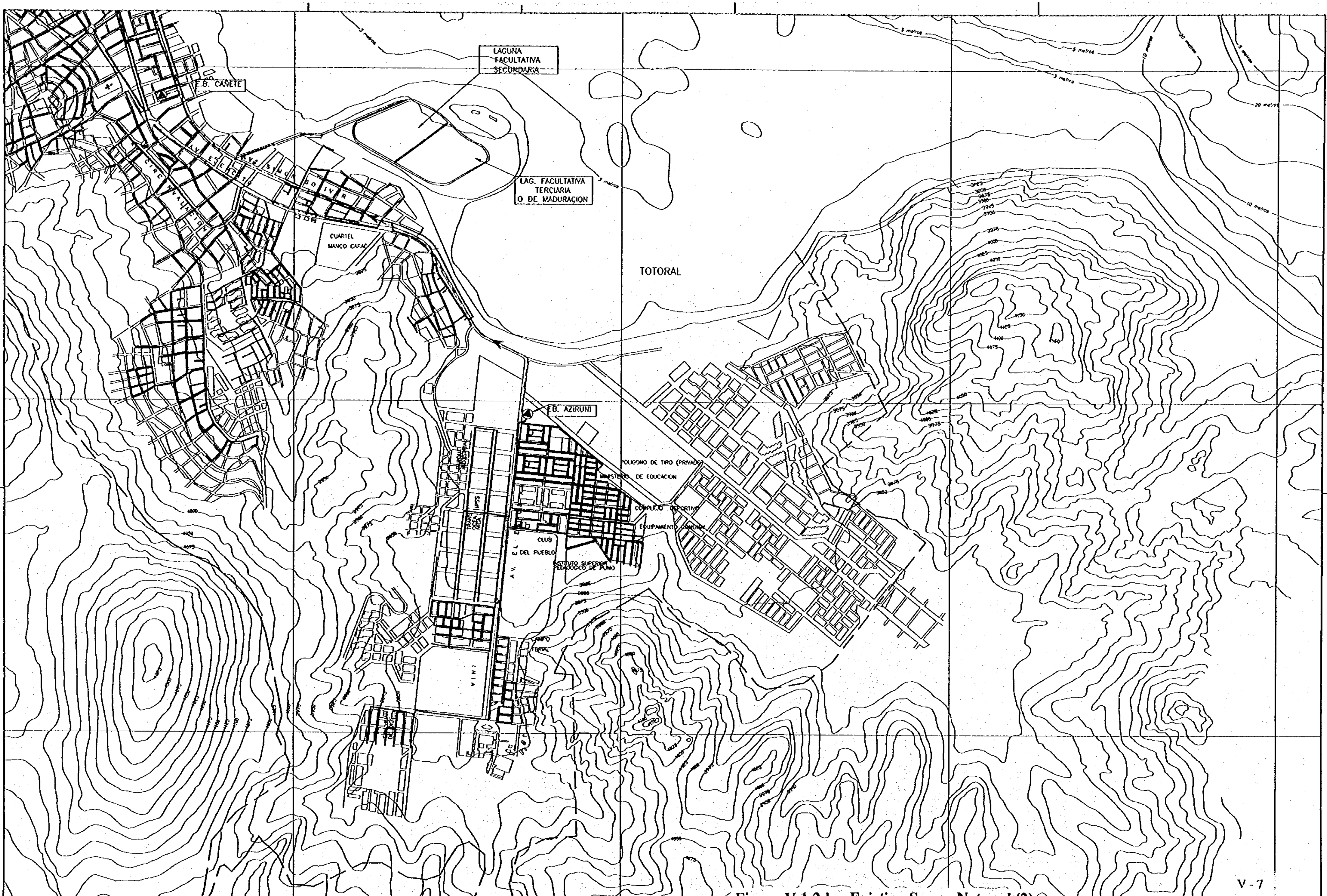


Figure V.1.2.b Existing Sewer Network(2)

REVISION					PRONAP		PLANOS/DOCUMENTOS DE REFERENCIAS	
Nº	FECHA	TITULO/DESCRIPCION	EJECUTADO POR	APROBADO POR	ACEPTADO	FECHA	TITULO	NUMERO

NOTAS

1) MEDIDAS Y COTAS EN METROS, EXCEPTO CUANDO SEAN INDICADAS.

BASE SURVEY DRAWING PROVIDED BY PRONAP - 1999 AS PREPARED BY FIQUEREDO FERRAZ CONSULTORI E ENGENHARIA DE PROJETO LTDA.

LEVANTAMIENTO BASE DEL PRONAP - 1999 COMO FUERA PREPARADO POR FIQUEREDO FERRAZ CONSULTORIA E ENGENHARIA DE PROJETO LTDA.

RED DE ALCANTARILLADO EXISTENTE
EXISTING SEWER NETWORK (NOV, 1998)

REVISION Nº	0
PAGES / PAGINA	b
SCALE / ESCALA	(VER ESCALA EN EL MAPA)

REPUBLICA DEL PERU

ESTUDIO PARA EL CONTROL INTEGRAL DE LA CONTAMINACION DEL AGUA DE LA BAHIA INTERNA DE PUNO EN EL LAGO TITICACA EN LA REPUBLICA DEL PERU

JICA - AGENCIA DE COOPERACION INTERNACIONAL DEL JAPON

THE REPUBLIC OF PERU

STUDY FOR THE INTEGRAL CONTROL OF THE CONTAMINATION OF WATER OF THE INTERNAL BY OF PUNO AT LAKE TITICACA IN THE REPUBLIC OF PERU

JICA - JAPAN INTERNATIONAL COOPERATION AGENCY

(3) Pump stations

4 pump stations operate in the existing sewer network, namely Canete, El Porteno, Floral and Aziruni (Salcedo). At present (February 1999), pump stations only operate from 5 a.m. to 8 p.m. Overflow from the pump wells flows directly to the interior bay of Puno.

1) Canetė pump station (P.S.)

The Canete P.S. is located at the junction of Av. Simon Boliver and Jr. Canete. EMSAPUNO rehabilitated and expanded the capacity of the P.S. in 1995. The P.S. has following characteristics at present.

Bar screen (1" opening):		1 unit
Pump well	low water level:	3803.15 m a.s.l.
	high water level:	3804.40 m a.s.l.
	volume:	32 m^3
Number of pumps:		2 units (one as a stand-by)
New pump installed in 1995:		1 unit
	Capacity:	90 l/s at 20 m head
	Motor:	50 HP (60 Hz, 440 V)
Old pump		1 unit (a stand-by)
	Capacity:	70 l/s at 8 m head
	Motor:	12 HP (60 Hz, 440 V)

The Canete P.S. receives wastewater from the interceptor Simon Bolivar (dia. 525 mm) and pumps it to the manhole located at the junction of Av. Simon Bolivar and Jr. 9 de Octubre through pressure line of 350 mm diameter. This manhole, where the principle interceptor starts, also receives the wastewater from the interceptor Tacna la Torre by gravity.

2) El Porteno pump station

El Porteno P.S. located in Jr. Echave, collects wastewater from the area in-between Av. Simon Bolivar and the shore of the lake Titicaca. It pumps wastewater to the interceptor Simon Bolivar near the stadium through the pressure line with 250 diameter.

Implementation of the rehabilitation program in 1995 replaced one of the 2 pumps. The major components of the P.S. are as follows:

Bar screen (1" opening):		1 unit
Pump well	low water level:	3805.20 m a.s.l.
	high water level:	3806.55 m a.s.l.
	volume:	8 m^3
Number of pumps:		2 units (one as a stand-by)
New pump installed in 1995:		1 unit
	Capacity:	40 l/s at 20 m head
	Motor:	25 HP (60 Hz, 440 V)
Old pump		1 unit (a stand-by)
	Capacity:	25 l/s at 20 m head
	Motor:	12 HP (60 Hz, 440 V)

3) Aziruni P.S.

This P.S. was constructed in 1997. It collects wastewater from Aziruni, Salcedo areas which are shown in *Figure V.1.1* as the area VI. Pumped wastewater goes to the principle interceptor through 250 mm PVC pressure pipes with 2,698 m in length.

Pump well	low water level:	3805.08 m a.s.l.
	high water level:	3806.08 m a.s.l.
	volume:	16 m^3
Number of pumps:		3 units (one as a stand-by)
	Capacity:	30 l/s at 15 m head
	Motor:	10 HP (60 Hz, 440 V)

4) Floral pump station

Floral P.S. receives wastewater from the area I in *Figure V.1.1* and pumps it to the manhole at the junction of Av. Simon Bolivar and Jr. Lampa, where the interceptor Simon Bolivar starts. The P.S. started its operation in 1998 and operated manually at present. The specifications are as follows:

Number of pumps:	1 unit
Capacity:	30 l/s at 15 m head
Motor:	10 HP (60 Hz, 440 V)
Pressure line:	diameter 200 mm x 811m length

EMSAPUNO intends to install another pump of the same capacity as a stand-by.

(4) Wastewater treatment plants

The following 4 wastewater treatment plants presently treat wastewater generated in the Puno City.

1) Espinar stabilization lagoon

2) Chanu Chanu (totora) treatment plant: treatment capacity = 4 l/s

3) Chejona (totora) treatment plant: treatment capacity = 5 l/s

4) UNA (totora) treatment pilot plant: treatment capacity = 8 l/s

1) Espinar stabilization lagoon

The Espinar stabilization lagoon was built in 1972. The rise in the lake water level up to 3812.51.m a.s.l. in 1986 flooded the lagoon and damaged the main collectors. The lagoon became dysfunctional until EMSAPUNO rehabilitated the main collectors in 1992. The further rehabilitation works were performed between 1995 and 1997 as follows:

a. Installation of screen chamber (bar screen: 1" opening)

b. Installation of 7 inlet pipes with diameter of 12" through which incoming wastewater free-falls into the lagoon

c. Construction of central dike to divide the lagoon (23 ha) into 2 lagoons (primary:13.6 ha, secondary: 7.9 ha)

d. Installation of 6 interconnecting pipes (diameter 12"), which prevent floating solids flowing into the secondary lagoon, between 2 lagoons

e. Construction of direct inlet of wastewater from the part of Chanu Chanu area

f. Rehabilitation of the interior of the lagoons to be impermeable

g. Desludging the lagoons to obtain average depth of 1.5 m

h. Rehabilitation of the discharge pipes (diameter 20")

The specifications of the lagoons at present are as follows:

Screen chamber

opening of bars:	1"
dimensions of chamber:	7.4 m length x1.2 m width x1.4 m depth

Primary lagoon

area:	13.6 ha
average depth:	1.5 m
volume:	205,000 m^3

Secondary lagoon

area:	7.9 ha
average depth:	1.5 m
volume:	118,000 m^3

The lagoons have no flow measuring facilities.

2) Chanu Chanu treatment plant

PELT and EMSAPUNO constructed Chanu Chanu treatment plant, together with Chejona treatment plant in 1993 and 1994 as a pilot plant to evaluate the nutrient removal capacity of the constructed wetland that utilizes totora as wetland vegetation. The both treatment plants are free water surface (FWS) wetlands with sedimentation tanks as pre-treatment. In FWS wetlands, the majority of the water flows over the surface of the soil, as a result, wastewater applied to the wetlands only contacts the soil surface.

Design parameters of the plant are shown below.

Design flow:	5 l/s
Inflow BOD:	350 mg/l (54 g /capita/day)
Retention time:	8 days

The specifications of the plant are as follows:

Distribution chamber:	1 unit
Sedimentation tanks:	2 units
dimensions:	5.1 m W. x 8.5 m L. x 1.2 m H.
structure:	reinforced concrete
Wetlands:	3 units in sequence
dimensions:	6 m W. x 40 m L. x 1.2 m H.
structure:	reinforced concrete

3) Chejona treatment plant

Chejona treatment plant, a FWS constructed wetland, has the same components of Chanu Chanu treatment plant.

Design parameters:

Design flow:	10 l/s
Inflow BOD:	350 mg/l (54 g /capita/day)
Retention time:	8 days

The specifications of the plant are as follows:

Distribution chamber:	1 unit
Sedimentation tanks:	2 units
dimensions:	7 m W. x 13 m L. x 1.2 m H.
structure:	reinforced concrete
Wetlands:	3 units in sequence
dimensions:	6 m W. x 160 m L. x 1.2 m H.
structure:	reinforced concrete

4) UNA (Universidad Nacional del Altiplano)

The UNA treatment plant is constructed prior to the Chanu Chanu and Chejona treatment plants as a pilot plant to treat wastewater from UNA. The design capacity of the plant is 8 l/s while 18 kg/day solids are removed through the treatment process.

The plant has following components:

Distribution chamber:		1 unit
	structure:	reinforced concrete
Screen chamber:		2 units
	dimensions:	1.4 m W. x 3 m L. x 0.7 m H.
	structure:	reinforced concrete
Sedimentation tank:		1 unit
	dimensions:	2 m W. x 10 m L. x 0.7 m H.
	structure:	reinforced concrete
Biological reactor:		1 unit (presently not used)
Wetlands:		3 units in sequence
	dimensions:	4 m W. x 20 m L. x 1.2 m H.
	structure:	reinforced concrete

1.2.3 WASTEWATER FLOW AND POLLUTION LOAD GENERATED AND COLLECTED

(1) Wastewater survey

1) Unit pollution load survey

Per capita wastewater flow and pollution load survey was performed from 17 to 19 of February 1999. Three locations in the center of Puno City were selected where water meters are installed for every connection. Wastewater flow was calculated from water meter readings while wastewater samples are taken at the downstream manholes for biological and chemical analysis. The results of the survey were as follows:

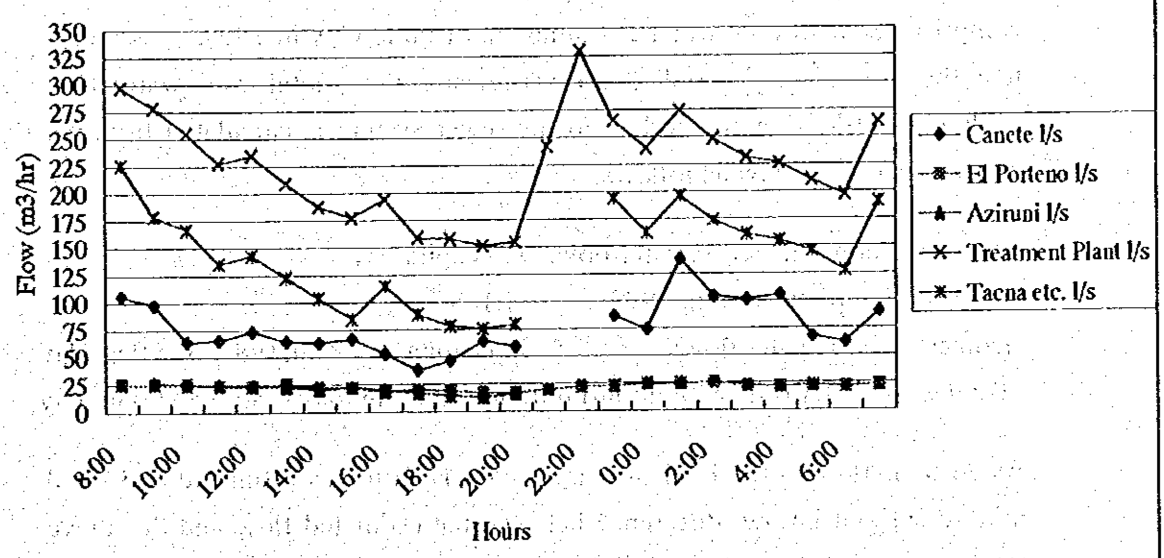
Per capita wastewater flow 92 l/day/capita (domestic water consumption x 0.8)

2) Wastewater flow survey

a) Rainy season

Wastewater flow was measured at three pump stations (Canete, El Porteno and Aziruni) and at the inlet of the Espinar stabilization lagoon. During the measurement, wastewater samples were taken at inlet of the Espinar stabilization lagoon for analysis to estimate incoming pollution loads. The results of flow measurement are shown is *Figure V.1.3*. There ware heavy rains from 20:00 p.m. on 18 February to 8:00 a.m. on 19 February with short interruptions. Total precipitation of this period was 19.2 mm according to the SENAMHI, Puno. Only one hour after the rain started, peak flow was recorded at the Espinar inlet. This indicates a large amount of inflow into sewer system during rainfall. Possible sources are run-off from roofs and pavement, leakage into manholes. Canete pump station receives about one-third of wastewater inflow into the Espinar stabilization lagoon. Besides the peaks recorded at night after the rain started, peak discharge of 304 l/s was recorded at 8 a.m. in the morning at the inlet of the Espinar stabilization lagoon. 24 hour flow to the Espinar was 19,451 m^3/d (= 5.1 million US gallons/day).

Figure V.1.3 Results of Wastewater Flow Survey on 18 February 1999



According to ASCE/WPCF (1982), ratio of hourly maximum wastewater flow to average daily flow is 1.8 as shown in *Fig V.1.4.* Applying this ratio to the measured peak discharge at the Espinar inlet, average daily flow is 165 l/s (= 297 l/s/1.8) while total 24-hour flow is about 14,000 m^3/day. The inflow due to the rainfall is estimated as 5000 m^3.

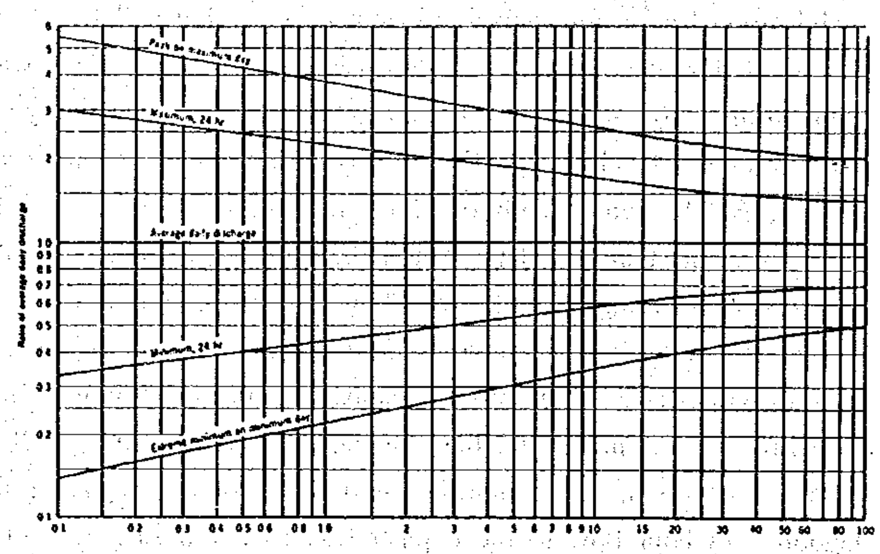


Figure V.1.4 Ratio of extreme flows to average daily flow in New England, USA

(mgd x 3.8 = m^3/day).

Source: ASCE/WPCF (1982)

According to the revised JICA projection, domestic water consumption comprised 86% of total water consumption of Puno City in 1999. Assuming that the same ratio is applied for wastewater flow, total wastewater flow excluding infiltration and inflow to the sewer system is calculated from per capita wastewater flow as follows.

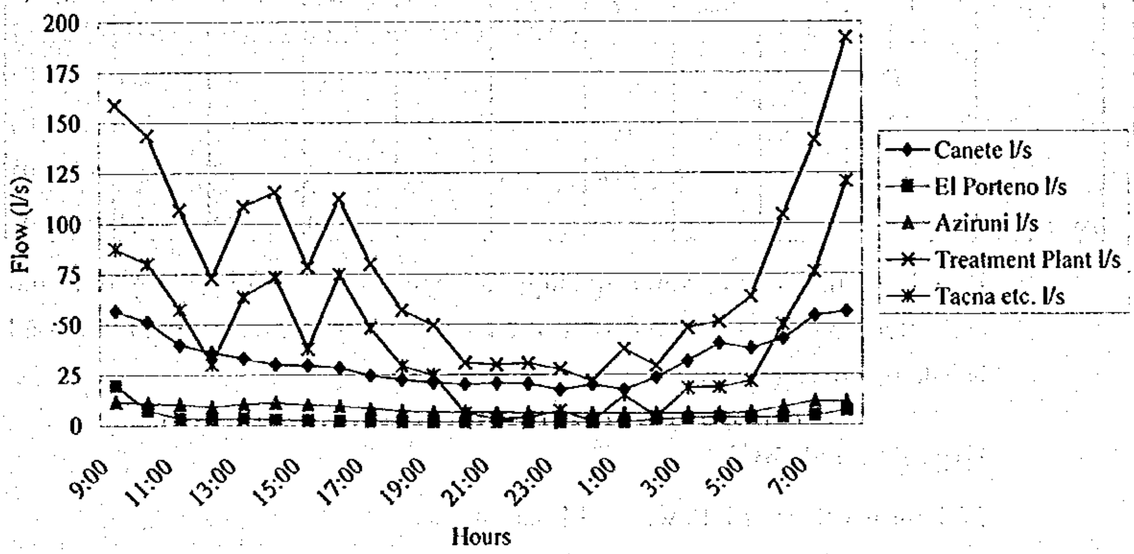
Per capita domestic wastewater flow:	92 l/capita/day
Contributing population in 1999:	54,198
Domestic wastewater flow:	92 l/capita/day × 54,198 = 5,000 m^3/day
Total wastewater flow without infiltration:	5,000 m^3/day/0.86 = 5,800 m^3/day

As 24-hour flow to the Espinar stabilization lagoon was estimated as 14,000 m^3/day without inflow, difference between the estimated flow and the above total wastewater flow, 8,200 m^3/day is considered as ground water infiltration into the sewer system. Infiltration (inflow) rate is calculated as 0.60 l/s/km (= 8,200 m^3/day/159 km (total pipe length)). This value is much higher than the measured infiltration rate in Jaliaca (0.015 l/s/km).

b) Dry season

The identical survey was conducted in the dry season on 22 and 23 July 1999. At the time of the survey, Floral pump station was not operating due to the pump breakdown. This pump station collects wastewater from population of 3,698 with 14 km of sewer pipes. The results are shown in *Figure V.1.5*. No measurable rainfall was recorded during the survey. 24-hour flow to the Espinar stabilization lagoon was 6,815 m^3.

Figure V.1.5 Results of Wastewater Flow Survey on 22 July 1999



Infiltration rate of sewer network is estimated as follows.

Per capita domestic wastewater flow: 92 l/capita/day

Contributing population in 1999: 50,500

Domestic wastewater flow: 92 l/capita/day × 50,500 = 4,600 m^3/day

Total wastewater flow without infiltration: 4,600 m^3/day/0.86 = 5,400 m^3/day

Infiltration flow: 6,815 m^3/day – 5,400 m^3/day = 1,415 m^3/day

Infiltration rate: 1,415 m^3/day/145 km = 0.11 l/s/km

This rate is much lower than the rainy season value of 0.60 l/s/km. The difference implies a large amount of inflow to the sewer system in the rainy season. The existing system requires a thorough inspection of the sewer network for inflow sources as well as appropriate regulations for preventing intentional connection of rainwater drainage, such as roof leaders and land drains, to the network.

C) Estimation of per Capita pollution load

The result of wastewater quality analysis in the rainy season at the inlet of the Espinar stabilization lagoon is shown in *Table V.1.4.*

Table V.1.4 Wastewater quality at inlet of Espinar stabilization lagoon in the rainy season

Date	Sampling time	Flow (l/s)	Temp.	pH	DO (mg/l)	SS (mg/l)	BOD_5 (mg/l)	NH_4-N (mg/l)	T-P (mg/l)	Coliform (n/ml)
18 Feb.'99	8:00	297	14	8.45	0.6	355	145	28	2.4	1.0E+04
	13:00	209	14	7.98	0.3	344	97	19	2.7	1.1E+04
	18:00	157	13.9	8.08	0.1	111	88	19	2.9	5.9E+03
Average						270	110	22	2.7	9.0E+03

Based on the above water quality, 24 hour flow of 14,000 m^3/day and estimated contributing population of 54,198 (1999), per capita pollution load is calculated as follows:

Organic Load (BOD)

24-hour wastewater inflow:	14,000 m^3/day
Average BOD concentration:	110 mg/l
BOD load to Espinar:	14,000 m^3/day × 110 mg/l = 1,540 kg/day
Contributing population:	54,198
BOD load per Capita:	1,540 kg/day/54,198 = 28 g BOD/capita/day

Nitrogen (Ammonia) Load (NH_3-N)

24-hour wastewater inflow:	14,000 m^3/day
Average NH_3-N concentration:	22 mg/l
NH_3-N load to Espinar:	14,000 m^3/day × 22 mg/l = 308 kg/day
Contributing population:	54,198
NH_3-N load per capita:	308 kg/day/54,198 = 5.7 g NH_3-N/capita/day

Phosphorus Load (T-P)

24-hour wastewater inflow:	14,000 m^3/day
Average T-P concentration:	2.7 mg/l
T-P load to Espinar:	14,000 m^3/day × 2.7 mg/l = 37.8 kg/day
Contributing population:	54,198
T-P load per capita:	37.8 kg/day/54,198 = 0.7 g T-P/capita/day

The result of wastewater quality analysis in the rainy season at the inlet of the Espinar stabilization lagoon is shown in *Table V.1.5.*

Table V.1.5 Wastewater quality at inlet of Espinar stabilization lagoon in the dry season

Date	Sampling time	Flow (l/s)	pH	SS (mg/l)	BOD_5 (mg/l)	T.-N (mg/l)	T-P	Coliform (n / ml)
22-Jul-99	8:00	289	8.1	404	390	64	7.6	6.0E+02
	16:00	112	8.1	211	234	50	7.2	5.9E+02
	20:00	31	-	203	201	45	6.6	3.5E+02
	0:00	22	-	177	269	40	5.3	4.6E+02
Average				249	274	50	6.7	5.0E+02

Date	Sampling Time	pH	BOD_5 (mg/l)	Filtrated BOD_5 (mg/l)	NH4-N (mg/l)	Filtrated T-N (mg/l)	PO4-P (mg/l)	T-P (mg/l)	Filtrated T-P (mg/l)
15-Sep-99	9:30	8.3	490	231	76	81	14	12.5	9.0
	13:10	7.9	376	162	77	96	13	7.3	8.4
Average		8.1	433	197	77	88	13	9.9	8.7

The per Capita pollution loads for nutrients are calculated in the same way as for the rainy season data. The results of per capita pollution load survey are summarized in *Table V.1.6.*

Table V.1.6 Results of per capita pollution load survey

(g/capita/day)

Source	BOD	SS	NH_3-N	T – N	T – P
Wastewater flow survey					
Rainy season (18 Feb.'99)	28	70	5.7	–	0.7
Dry season (22 Jul.'99)	37	34	–	6.7	0.9
Dry season (15 Sep.'99)	58	–	10	12	1.3
Dry season (average)	48	34	10	9.4	1.1
Average (rainy – dry season)	38	52	8	9.4	0.9
PRONAP(1997)	40	–	–	–	1.23
PERU Design Standards	50	90	8	12	3

From the average per Capita load of the rainy season and the dry season, organic load (BOD) of 40 g/capita/day is assumed. Other parameters are adjusted using the same ratio (= 40 mg/l / 38 mg/l) as shown in *Table V.1.7.*

Table V.1.7 Present per capita pollution load

(g/capita/day)

	BOD	SS	NH_3-N	T-N	T-P
Per capita pollution load	40	55	8	12	1

Total nitrogen load is assumed as 12 g/capita/day using the ratio between NH_3-N and T-N in Peruvian design standard (S.090).

(2) Pollution load generated and collected

Pollution load generated in the Puno City and pollution load collected by the sanitary sewer system in 1998 were calculated as follows.

a) Organic load (BOD)

Per capita BOD load:	40 g BOD/capita/day
Total population of Puno City:	108,457
Served population of sewer system:	50,194
BOD load generated in Puno City:	40 g BOD/capita/day × 108,456
	= 4,300 kg BOD/day
BOD load collected:	40 g BOD/capita/day × 50,197
	= 2,000 kg BOD / day

b) **Nitrogen load (T-N)**

Per capita T-N load:	12 g T-N/capita/day
Total population of Puno City:	108,457
Served population of sewer system:	50,194
T-N load generated in Puno City:	12 g T-N/capita/day × 108,456 = 1,300 kg T-N/day
T-N load collected:	12 g T-N/capita/day × 50,197 = 600 kg T-N / day

c) **Phosphorus load (T-P)**

Per capita T-P load:	1 g T-P/capita/day
Total population of Puno City:	108,457
Served population of sewer system:	50,194
T-P load generated in Puno City:	1 g T-P/capita/day × 108,456 = 110 kg T-P/day
T-P load collected:	1 g T-P/capita/day × 50,197 = 50 kg T-P / day

(3) Industrial wastewater flow

Industrial water consumption is 240 m^3/month, which consists 0.2 % of total wastewater generated in Puno City. Wastewater contains mostly organic pollutants and its pollution load to the sewerage system is not significant. ISPP hospital discharges treated wastewater from its own activated treatment plant to the sewer network. The estimated flow is less than 3 l/s.

A slaughterhouse located near the UNA discharges wastewater directly to the interior bay of Puno without treatment. Hotel Esteves with approximately 100 rooms discharges wastewater to the totora field next to the hotel.

1.2.4 OPERATION AND MAINTENANCE OF FACILITIES

(1) Sewer connections

Approximately 40 % of sewer pits have broken covers according to the F/S by HIDROSERVICE/BWAS (1997). Some sewerage pits are filled with garbage residents disposed of, which causes clogging and surcharge problems in the sewer network.

(2) Sewer network

The present sewer network receives garbage, stones and sands through wastewater pits and manholes. Those are accumulated in the sewer network and reduce the hydraulic capacity of the sewer network.

In rainy season, rainwater is introduced through manholes where drainage system is inappropriate. Occasionally, manhole covers are removed by the residents in order to prevent the building-up of water levels in the street. As a result, the rainwater introduces silts and garbage into the sanitary sewer system. The lack of street drainage system also causes erosion of the unpaved road surface and makes buried pipes appear on the ground and lose earth support.

EMSAPUNO introduced a high-pressure water pipe cleaning truck through KfW grant aid program in 1997. With the truck, EMSAPUNO have cleaned the main collectors since 1997. The cleaning works of the main collector Tacna la Torre has been done and those of the Simon Bolivar main collector is on-going in November 1998.

(3) Pump stations

After the rehabilitation works in 1996, most of the existing pumps have been operated without major problems. In most cases, failure of the pumps results in direct discharge of wastewater into the lake Titicaca through overflow pipes. Floral pump station requires immediate installation of another pump as it operates without a stand-by pump.

(4) Wastewater treatment plants

1) Espinar stabilization lagoon

The present lagoon does not have fences to prevent access of residents and animals to the facilities. The lagoon does not have flow measuring facilities required for operation and control of the system.

The results of the water quality analysis of influent and effluent of the lagoons performed by PELT (1997), SENCICO (1997) and the present JICA study are shown below.

Table V.1.8 Pollutants removal by stabilization (facultative) lagoons

Source	BOD			T-N			T-P		
	Influent mg/l	Effluent mg/l	Removal %	Influent mg/l	Effluent mg/l	Removal %	Influent mg/l	Effluent mg/l	Removal %
Espinar S.T. PELT (1997)	209	21	90%	56	83	-	6.5	4.2	35%
Espinar S.T. SENCICO (1997)	139	39	72%	55	11	80%	8.7	4.4	49%
JICA study (1998 – 1999)			70%			30%			30%

* Average value

JICA study team estimated as average pollutants removed efficiency of 70% for BOD_5, 30% for nitrogen (T-N), 30% of phosphorus (T-P).

In November 1998 when the JICA mission visited the lagoon, the color of the water in the lagoon was dark red. In February 1999, this color was dark green, due to the micro-algae that grow naturally in it. The average retention time of the each lagoon is 15 days for the primary lagoon and 8 days for the secondary lagoon assuming the inflow of 14,000 m^3/day.

2) Chanu Chanu treatment plant

The plant presently receives 10 l/s wastewater flow that well exceeds the design capacity of 4 l/s. Thus, the plant has been operated under overloaded condition and the effluent quality deteriorates. The effluent is discharged into the ditch made in the totora field to soak into the ground.

3)Chejona treatment plant

The plant was originally built to treat wastewater mainly from ISPP hospital. Since the hospital constructed a new activated sludge treatment plant with the capacity of 3 l/s in September 1998, the Chejona plant only receives wastewater from the Chejona community (barrio). Very little maintenance works have been done on the plant.

4) UNA treatment plant

The plant is maintained by the staff of UNA and obtains clear effluent although biological treatment is not operating. UNA has a plan to expand the plant so as to accommodate the increasing amount of effluent from the university.

1.2.5 FINANCIAL CONDITIONS OF EMSAPUNO

According to the financial report as of December 31, 1997, EMSAPUNO obtained S/. 4,660 net profit for the 1997F/Y. But the revaluation gain of inflation ratio change S/. 485,032 was recorded based upon the inflation accounting principle, so if the revaluation gain was not recorded based upon the GAAP in the world, the total operation loss would be S/. 480,372.

There were not separate accounting records for Agua Potable (Water Supply) department business and Alcantarillado (Sewerage) department business. But the income of sewerage was S/. 1,047,384 and the cost was S/. 48,697. The administration expenses including salary expenses (for approximately 100 staff), maintenance expenses, and so on were not allocated to the two departments business. So it is very difficult to determine if the sewerage business is profitable or not.

The financial interest expense was very a big amount S/. 452,522 (only half of the accrued interest expenses were recorded). If the interest expense did not exist, EMSAPUNO would record only a small operation loss figure. EMSAPUNO borrowed long a term loan S/. 9,398,084 from mainly FONAVI (public fund for Peru citizen to his own house). The loan was not paid back to FONAVI and the current balance as of December 31 ,1998 was S/. 11,826,219 (3 times of sale figure). The detail of the balance is as follows:

The expansion & improvement of water supply in Puno City	S/.	7,418,350
Water treatment plant construction		444,069
The expansion of water supply network		348,832
The expansion of water connection network installation		35,600
The expansions of residential wastewater connection network installation		44,421
The expansions of residential wastewater connection network installation		81,036
The expansion of water supply network		83,850
The expansions & improvement of water supply		1,347,876
The system of water & wastewater supply.		578,210
Adjustment of wastewater new treatment plant function		586,988
Parallel improvement to obtain Water supply plant		858,987
TOTAL		S/. 11,826,219

In 1998 F/Y the interest expenses S/. 1,121,406 and loan principal S/. 981,976 should be paid back to FONAVI according to the payment schedule. But no payment has yet been made. For the purpose of fund management, the debt to FONAVI will not be paid back soon, the accounting manager explained. In January of 1999, legislation to permit 70% of EMSAPUNO's debt about US$ 4 M (S/. 11,826,219) to be capitalized and 30% to be cancelled was approved and becomes effective soon. So sooner or later the debt to FONAVI S/. 11,828,219 will be partially capitalized and cancelled. On the other hand, there are about US$13M debts by Puno citizens to FONAVI for installation charges of water and wastewater equipment. These debts also would be cancelled sooner or later by the above legislation. The reform seems to be related to the possibility of KfW loan arrangement.

In 1997 F/Y report, 14% of produced Water was not billed and the tariff of sewerage was about 45% of Water tariff. If produced Water were billed completely, about s/500,000 additional income would be recorded and a small profit would be recorded even if there were not the revaluation gain S/. 485,032.

Government controls the tariffs of EMSAPUNO. The current tariff was approved in 1997 and is as follows:

Category	Diameter	Tariff average
Domestic	20	S/.18.28
Commercial	30	43.73
Industry	60	131.50
State	50	48.00

Sooner or later the tariff will be revised for EMSAPUNO reconstruction. (The financial report as of December 31, 1998 will be prepared in March of 1999 after confirming physical inventory taking loss and revaluation gain of inflation ratio change. The sales figure for 1998 fiscal year was confirmed already as follows:

Sale of potable water	S/. 3,223,183
Sale of sewerage	S/. 1,450,432

Sale amount increased by 38% respectively. But for the increase of interest expense the net loss S/. 1,916,907 was recorded in 1998.)

PROFIT & LOSS STATEMENT as of December 31, 1997

(unit: S/.)

SALE	(1) Agua Potable	S/2,327,521	
	(2) Alcantarillado	1,047,384	
	(3) Other	541,250	
			3,916,155
COST	(1) Agua Potable	1,125,772	
	(2) Alcantarillado	48,697	
	(3) Other	1,149,799	
			2,324,268
	Gross Margin		1,591,887
EXPENSES		1,982,907	
	Operation loss		391,020
OTHER INCOME	(1) Other income	484,480	
& EXPENSE	(2) Financial expense	452,522	
	(3) Other expense	121,310	
			89,352
	Loss before the inflation revaluation gain		480,372
	Inflation revaluation gain		485,032
	Net Profit		s/4,660

FUND STATEMENTS as of December 31, 1996 and 1997

(unit: S/.)

Nature	1996	1997
Source of fund :		
Depreciation	504,800	539,103
Capital increase	333,072	463,336
Financial income	2,846	333
Other asset decrease	0	480,746
Increase of long term debt	176,676	0
Other	1,554,368	978,718
Total of source	2,571,762	2,462,236
Use of fund :		
Operation expense	677,336	391,020
Fixed asset increase	672,397	1,066,242
Financial expense	757,269	452,522
Decrease of long term debt	0	474,057
Other asset increase	684,439	0
Other	377,028	282185
WORKING FUND DECREASE	(596,707)	(203,790)
Total of use	2,571,762	2,462,236

1.2.6 FUTURE DEVELOPMENT PLAN

The existing development plans for the sewerage system of Puno City are as follows:

	Study name	Completion	Funding Source	Peruvian Authority
1	"Estudios de Factibilidad de los Planos de Expansion de Minimo Costo de los Sistemas de Agua Potable y Alcantarillado" (F/S)	Jan. 1997	IDB*1	PRONAP
2	"Estudios Definitivos de la Primera Etapa de Inversion del Plan de Expansion de Minimo Costo de los Sistemas de Agua Potable y Alcantarillado" (D/D)	July. 1999	IDB*1	PRONAP
3	Conduccion Tratamiento y Manejo Integral de las Agua Servidas – Ciudad de Puno (Sistema Salcedo – Cancharani) (F/S)	Oct. 1997	INADE – PELT	INADE – PELT
4	Conduccion Tratamiento y Manejo Integral de las Agua Servidas – Ciudad de Puno (Sistema Salcedo – Cancharani) (D/D)	Mid. 1999 (Nov.1998 -)	INADE – PELT	INADE – PELT

The PRONAP F/S contains a development plan for water supply and sewerage system up to year 2025. The PELT F/S proposed final disposal options to stop treated water discharge into the interior bay of Puno. Detailed design studies are being carried out separately on the above 2 development plans by consultants. The results of the detailed design studies will be available in the middle of 1999.

(1) PRONAP F/S, D/D

Inter-American Development Bank (IDB) signed an agreement with the Peruvian government to finance "Programa de Apoyo al Sector de Saneamiento Basico" (N° 847/OC-PE). The program was executed under the supervision of PRONAP. Through the program of "Empresas Prestadora de Servicios de Saneamiento", and its sub-project of "Mejoramiento Institucional y Operacional de las Empresas Prestadores de Servicios de Saneamiento", the necessity for the present sub-program "Estudios de Factibilidad de los Planes y Alcantallado", which covers 66 cities in Peru including Puno and Juliaca. The feasibility study for Puno City was initiated in 1994 and finalized in January 1997

The objectives of the study are as follows:

- To develop the feasibility study of the expansion plan of drinking water and sewerage services with the minimum cost, which ought to be economical and socially acceptable for Puno City.
- To identify the first stage of the minimum cost expansion plan, which will be studied through a detailed design study.

Three alternatives of the development plan up to year 2025 were proposed for the sewerage system of Puno City. Based on the proposed alternatives of the above F/S, detailed design study for the first phase of the development plan was initiated in January 1998 and will complete in July 1999. The target of the detailed design is shown in *Table V.1.9.*

Table V.1.9 Target of the PRONAP detailed design

Parameters			PHASE I	
Target year		1995	2005	2008
Population		100,802	130,951	139,628
Water supply	Population served	49 %	80 %	
	Total water supply	13,046 m^3/day	17,971 m^3/day	
	Ineffective water (%)	49 %	30 %	
Sewerage	Population served	39 %		70.2 %
	Collected wastewater (including infiltration)	4,833 m^3/day		11,110 m^3/day

(2) INADE / PELT F/S, D/D

The feasibility study financed by INADE / PELT aims to protect Puno bay ecosystem and to prevent its contamination. The results of the study suggest not only the implementation of programs that manage and control the contamination, but also promotion of employment and social wealth of the population through works for the economical, ecological and tourist development in areas surrounding the interior bay.

Objectives of the study

- To improve the water quality in the bay by preventing physical, chemical and biological contamination, such as inflow of silt and discharge of wastewater to the interior bay.
- To conduct, treat and manage integrally the wastewater from Puno City, avoiding contamination and eutrophication of the Puno bay, allowing other economical uses to the area surrounding the shore of the lake.
- To promote the construction of basic infrastructure that would allow development of the flood areas at the interior bay in order to improve the economical, ecological and tourism potential of Puno City.
- To strengthen the positive impacts and control or mitigate the negative impacts and the vulnerability of different works foreseen in the project in order to preserve the environment for the present and future generations.

The following components or priority sub-projects have been identified.

- Project for the conduction, treatment and integral management of the wastewater in Puno City.
- Project for the environment management in the small rivers.
- Project for the control and discharge of rainfall water
- Project for the eco-tourism development of the interior bay of Puno.

The detailed design study for the project for the conduction, treatment and integral management of the wastewater in Puno City has been started since November 1998 and will complete in the middle of 1999. According to the terms of reference for the study, the following works will be defined.

Wastewater collected by the wastewater collection network will be pumped up to the south of Cancharani mountain where the treated wastewater is used for forestation of 300 ha. The forestation area is the tributary of Llave river. This enables the area where Espinar stabilization lagoon presently occupies to be utilized for tourism and other type development.

Facilities to be designed are as follows:

Main pump station

1.Second and third pump stations

2.Pressure line (HDPE pipes)

3.Wastewater storage tank

4.Conduction line (PVC pipes)

5.Wastewater treatment plant (facultative lagoons)

6.Irrigation canals

1.3 ON-SITE SYSTEM

1.3.1 GENERAL

The present practice of disposing excreta in the area not served by the existing sanitary sewer system is either the use of on-site sanitation systems, such as sanitary toilets and septic tanks, or direct disposal to drainageways and small rivers (microcuencas). The houses on the steep slope above the Av. Circumvallation, not served by the sewerage system do not always have on-site sanitation facilities.

The most of the households not connected to the sewer system dispose sullage (all household wastewater except wastewater from toilets) directory onto the ground, the streets, drainageways and small rivers.

1.3.2 TYPE OF ON-SITE SYSTEMS

Two types of on-site systems exist in the area.

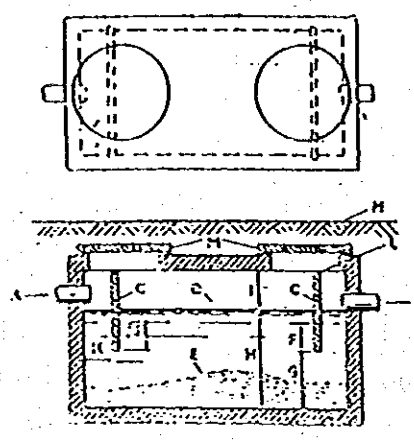
1. Pit latrines
2. Septic tanks

Pit latrines are simple dug holes with various diameters and depths. When it is properly designed, urine infiltrates into the surrounding soil and the fecal solids are digested anaerobically. There is a slow accumulation of solids in the pit, which require emptying. Direccion General de Salud Ambiental (DIGESA), Ministry of Health proposed the standard design for sanitary toilets (pit latrines), which is shown in *Figure V.1.7.* Sanitary toilets can be used as a communal facility for several households.

The standard designs of septic tanks are defined by Organo Informativo del Capitulo de Ingenieros Sanitarios, Peru as "Regulament para el diseno de tanques septicos – normas de desino y principios basicos". The standard drawings for household septic tanks are shown in *Figure V.1.6.* Septic tanks retain household wastewater (toilet wastewater and sullage) for 1-3 days. During this time the solids settle to the bottom of the tank, where they are digested anaerobically. As some sludge accumulates, the tank must be desludged at regular intervals, normally once every one to five years. Installation cost of septic tanks is generally larger than that of sanitary toilets, although septic tanks are normally less expensive than conventional sewerage. They can be used as a communal facility for populations up to 300.

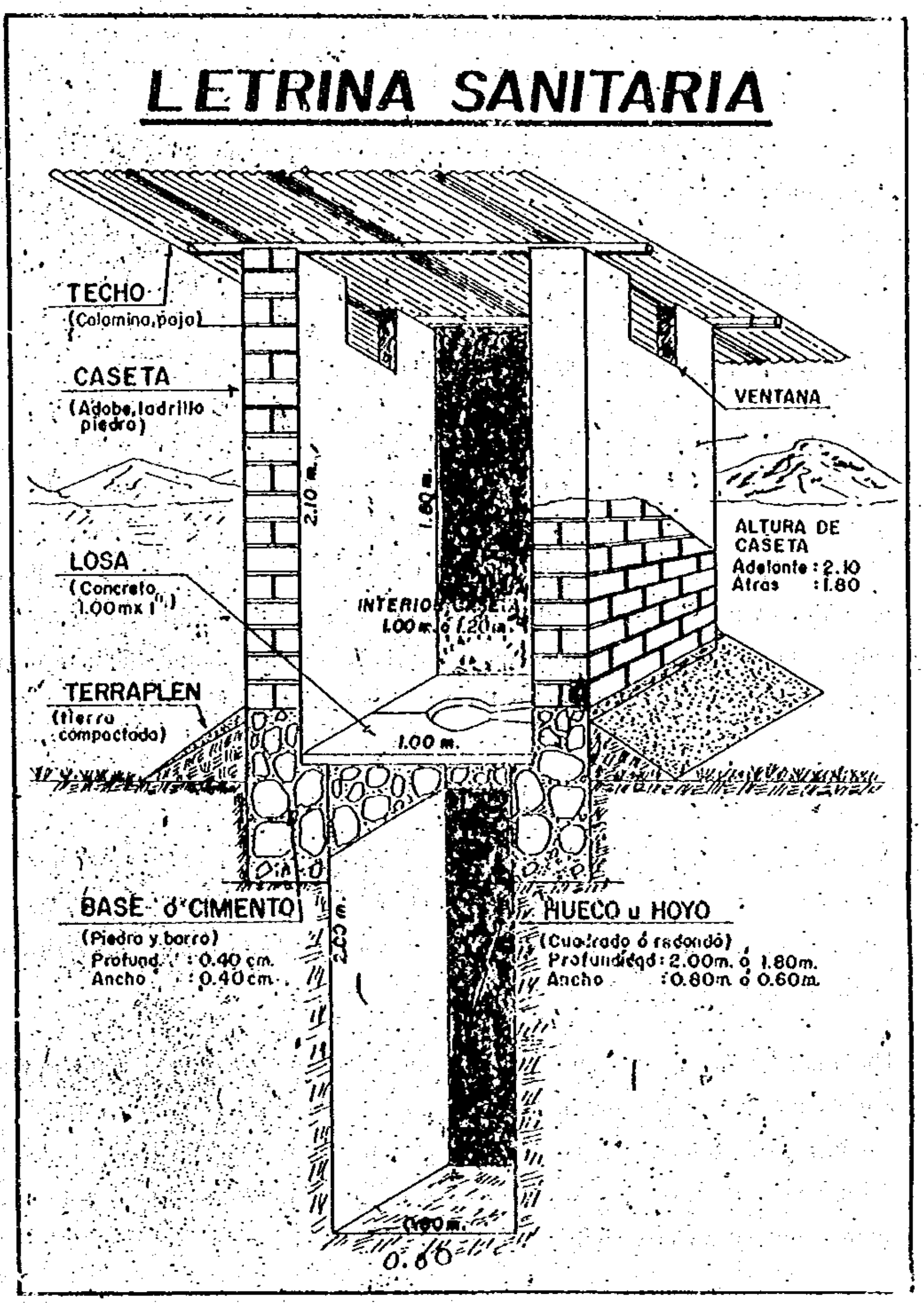
According to the DIGESA Puno office, sanitary toilet is recommended as an on-site sanitation system in Altiplano (high land) region of Peru since ground water table is generally low (more than 2 meters deep) and permeability of the soil is good. The exceptions exist in Cusco, where water table is less than 1 meter deep, require installation of septic tanks.

Figure V.1.6 Standard septic tank design for household



A: Inlet
B: Outlet
C: Baffle
D: Scum
E: Sludge
F: Clear space (baffle)
G: Clear space (sludge)
H: Water height in the ditch
I: Free space
J: Depth of wall penetration
K: Distance from baffle to wall (20 to 30 cm)
L: Upper extreme of baffle in 2,5 cm below the cover to allow the ventilation process
M: Cover, round if possible
N: Ground level

Figure V.1.7 Standard design for sanitary toilet (DIGESA, 1999)



1.3.3 EXISTING SYSTEMS IN STUDY AREA

At present, no statistics are available for the distribution of on-site sanitation systems in Puno City. Puno City intends to survey the existing on-site systems as a part of hygiene education program in the near future.

According to the Puno municipality, installation of a sanitary toilet has become a requirement for the permission of building construction outside the sewerage service area since 1995. Buildings constructed before 1995 do not always have proper sanitation facilities.

1.3.4 OPERATION AND MAINTENANCE OF FACILITIES

For sanitary toilets, soil and lime cover on the accumulated sludge for every 50-cm in depth is recommended as maintenance by DIGESA Puno office, although it is not always practiced by the residents. Pit emptying equipment, such as vacuum trucks is not available in Puno City. At present, sanitary toilets are abandoned when the sludge fills up the pits. Another pit will be dug for a new toilet. This practice is not practical especially for the low-income area near the city center where available land is limited for sanitary toilets.

1.4 EVALUATION OF PRESENT CONDITIONS

According to the annual report of EMSAPUNO, number of household connections has been increased in 1993 to 1998. (*Table V.1.1*). Number of connections increased in the last few years due to the construction of Aziruni and Floral pump stations.

The maintenance works such as cleaning of main collectors by high-pressure water have been performed in the last few years to improve the performance and reliability of collection systems. Despite the above efforts by EMSAPUNO, around 54 % (1998) of the wastewater generated in the Puno City is not collected by the sanitary sewer system.

The Espinar treatment plant, which treats more than 80 % of the sewerage collected by the sewer network removes 70% of Organic matter (BOT), 30% of nitrogen (T-N) and 30% of phosphorus (T-P). It discharges its effluent to the interior bay of Puno. In order to prevent eutrophication of interior Bay, further removal of nutrients is required, especially phosphorus that is regarded as a limiting nutrient for the biological growth in the bay.

On-site systems are not common among the houses without sewer connections. The sullage and leachate from on-site systems pollute ground water, drainage canals and small rivers with organic contaminants such as nitrogen, phosphorus and carbohydrates. The part of those contaminants reaches the lake as a pollution load.

1.5 IDENTIFICATION OF PROBLEMS

Through the evaluation of the existing systems, the following problems are identified.

(1) Low collection rate of wastewater

54 % of the households are not connected to the sewer system. 6% of the households are not connected to the collection system, even though the sewer lines are located on front of their houses.

Increase of the connection rate is essential to reduce organic pollution loads to the interior bay of Puno.

(2) Broken covers of sewer pits

Around 40% of the existing sewer pits have either no covers or broken ones, which allow residents to use sewer pits as rubbish bins. They also let rainwater go into the sewer collection system. Introduced solid wastes and rainwater cause clogging and surcharge in the sewer lines, which damage the sewer collection system.

The repair works of the covers and public awareness of the proper use of the sewer connection facilities are urgently required.

(3) Removal rate of nutrients at the Espinar stabilization lagoon

Although the rehabilitation works were performed on the Espinar stabilization lagoon in the last few years, 600 kg of organic matter (BOD_5) (= 2000 $kgBOD_5/d$ x (100%-70%)/100), 420 kg of nitrogen and 35 kg of phosphorus are discharged daily into the interior bay of Puno from the lagoon. Improvement of the nutrient removal rates is required to reduce the organic load to the interior bay in order to improve eutrophic condition of the bay.

(4) Overload of Chanu Chanu treatment plant

The Chanu Chanu treatment plant receives wastewater 2 times as much as the design flow. As a result, the effluent quality deteriorated and the plant became a pollution source to the interior bay of Puno. The part or all of the sewerage presently flows into the plant should be re-directed to the Espinar stabilization lagoon.

(5) Inflow of rainwater to the collection network

Rainwater introduced to the sanitary sewer system through manholes and sewer connection facilities to drain rainwater in the street and houses, causes hydraulic overloading of both the collection system and the treatment plants. The proper street drainage systems are required as well as formulation of enforceable regulations or ordinances to prevent deliberately planned or devised connection of rainwater sources to the sewer system.

(6) Lack of on-site systems

Very few proper on-site systems are installed to the houses without sanitary sewer connections. In order to reduce organic loads from those houses flowing to the interior bay of Puno, proper on-site systems, such as sanitary toilets and septic tanks shall be installed to every household without sewer connection. Formulation and enforcement of regulations or ordinances to enforce houses and buildings to equip on-site treatment system is urgently required.

2. MASTER PLAN

2.1 TARGET AND STRATEGY

The main objectives of sewerage system development in Puno City are as follows:

1. Improvement of public health through collection of wastewater
2. Improvement of water quality of public waters, especially Puno interior bay of Titicaca lake.

The former is achieved through collecting and conveying wastewater to point of treatment while the latter is achieved by treatment of collected wastewater.

(1) Targets of Master Plan

a) Target year

Target year of Master Plan is set as 2025 with the period of 25 years. The target year is same as that of the feasibility study by PRONAP.

b) Target wastewater

Wastewater of the following origins will be collected and treated.

- Domestic wastewater
- Commercial wastewater
- Industrial wastewater

c) Target area

The projected boundary of Puno City in year 2025, shown in *Figure V.2.1*, is set as the target area of the Master Plan. This area shall be served either by sanitary sewer system or by proper on-site sanitation facilities. The division of the area by the two systems is discussed in section 2.2.1.

d) Target coverage of sanitary sewer system

85% of the total population of Puno City shall be served by sanitary sewer system in year 2025. This coverage is decided in connection with that of water supply (90%), which is proposed by the PRONAP water supply feasibility study (1997). Among the served population of water supply, 95% will have flush toilets that require removal of wastewater by sanitary sewer system. Therefore, the target coverage is set as 85% (= 90 % × 95 %).

Figure V.2.1 Target Area of Sewerage Master Plan (Area 1 – 16)

(2) Strategy of Master Plan

a) Sewer system selection

The existing sewerage system is a separate system, which only collect wastewater. Separate collection of wastewater and storm (rain) water is highly desirable for:

- protection of public waters from pollution
- minimizing construction and operation cost of the wastewater treatment plant by the exclusion of storm water from the treatment system.

From the above reasons, the sewerage system shall remain as a separate system and the storm water drainage will be studied separately in the next chapter.

b) Staged implementation

The Master Plan is formulated over a relatively long period of 25 years, which will be divided into 3 stages. Staged implementation is desirable because of difficulties in projecting the future planning frames precisely, such as social and economic conditions. Through the implementation of the Master Plan, the further stages shall be reviewed based on the previous achievement. The following 3 stages are proposed.

First stage	1998 – 2008	(Phase 1)
Second stage	2009 – 2015	(Phase 2)
Third stage	2016 – 2025	(Phase 3)

2.2 PLANNING CONDITIONS

2.2.1 PLANNING AREA

The target area, Puno City in 2025, is shown in *Figure V.2.1.* The area is divided into 16 zones (1-16) according to population density and land use (see chapter II -3). This area does not coincide with the study area of this Master Plan, which is also shown in *Figure V.2.1.* The part of the study area (I - IV) not included in Puno City is also studied for sanitation improvement, but not regarded as a sanitary sewer development area. The above areas are summarized in *Table V.2.1.*

Table V.2.1 Target area of the Master Plan

Year		1998		2025	
Zone No.	Area (ha)	Population	Density	Population	Density
1	179.5	17,580	97.9	14,160	78.9
2	57.1	11,035	193.3	11,550	202.3
3	86.6	17,624	203.5	17,925	207.0
4	180.3	18,309	101.5	19,560	108.5
5	255.7	6,886	26.9	14,985	58.6
6	254.3	10,550	41.5	21,063	82.8
7	90.1	7,937	88.1	9,354	103.8
8	57.0	3,507	61.5	5,007	87.8
9	194.8	2,843	14.6	7,320	37.6
10	588.6	7,343	12.5	25,974	44.1
11	727.4	4,531	6.2	30,732	42.2
12	100.0	0	0.0	990	9.9
13	131.8	0	0.0	1,404	10.7
14	59.2	312	5.3	1,176	19.9
15	91.6	0	0.0	856	9.3
16	316.0	0	0.0	2,948	9.3
Sub-total	3,370	108,457	32.2	185,004	54.9
I	1,226	1,051	0.9	–	
II	477	200	0.4	–	
III	422	300	0.7	–	
IV	204	13	0.1	–	
Sub-total	2,329	1,564	0.7	–	
Total	5,699	110,021	19.3		

Cf. Study area: 5250 ha (land area)

By year 2025, zones 1 – 14 will be developed as urban areas. (Chapter II - 4) The target area is served either by a sanitary sewer system connected to wastewater treatment facilities or by on-site sanitation facilities. Since a sanitary sewer system requires a large capital investment, served area shall be carefully chosen. As population density decreases towards peripheral areas, extension at sanitary sewer system requires longer pipe length per served population, thus construction costs become too costly to be recovered by tariffs and other available funds. In Japan, densely inhabited districts (DID) with over 40 inhabitants / ha are normally included in a service area of sewer system. Applying those criteria, zones 1 – 11 shall be identified as served area of the sanitary sewer system. Zones 12, 13, 14 include possible urban areas in year 2025. Besides Zone 13, rocky area that is difficult for sewer development, those zones are included in the sanitary sewer area. The target area is divided as follows:

- Area served by sanitary sewer (zones 1 – 12, 14): 2831 ha
- Area served by on-site sanitation facilities (zones13, 15, 16): 539 ha

As target coverage of the sanitary sewer system is 85% of Puno City population, a part of the sanitary sewer area will be served by on-site facilities in year 2025.

2.2.2 POPULATION

The Master Plan sets service coverage of the sanitary sewer system at the end of each phase as follows.

Table V.2.2 Target service coverage of sanitary sewer

	Present 1998	Phase 1 2008	Phase 2 2015	Phase 3 2025
Sanitary sewer	46 %	70 %	78 %	85 %

The projected served population of the target area is set out in *Table V.2.3*.

Table V.2.3 Served population by sanitary sewer system

Year	1998	2008	2015	2025
Sanitary sewer	50,107	97,631	125,731	157,253
On-site facilities	58,350	41,445	34,777	27,751
Total	108,457	139,076	160,508	185,004

2.2.3 WATER SUPPLY

As future wastewater generation is estimated based on water consumption, water consumption is predicted up to year 2025. Water supply demand projection by PRONAP (1997) is reviewed based on the latest operation data of EMSAPUNO and the population projection elaborated by JICA study team.

Water consumption is divided into four categories:

1. Domestic
2. Commercial
3. Industrial
4. State

Number of active connections for the above categories according to EMSAPUNO and the PRONAP projection is shown as *Table V.2.4*.

Table V.2.4 Number of active connections for water supply

Year	Domestic		Commercial		Industrial		State	
	EMSA-PUNO	PRONAP Projection*1	EMSA-PUNO	PRONAP Projection*1	EMSA-PUNO	PRONAP Projection*1	EMSA-PUNO	PRONAP Projection*1
1995		11,573		604		11		61
1996		11,972		619		-		63
1997	12,084	12,991	718	634	9	-	92	64
1998	12,947	14,041	671	650	7	-	121	67

*1: PRONAP projections are annual average while EMSAPUNO data are at the end of each year.

Significant difference between the PRONAP projection and actual data from EMSAPUNO is the number of connections for state use. Average number of state connections in 1998 will be adjusted to 107, the average between values in December 1997 and in December 1998. Revised projection of water consumption is shown in *Table V.2.5*.

Table V.2.5 Projection of water consumption, water intake and production

Year	Population		Service ratio	Average water consumption			Water loss	Water intake (l/s)		Water production (l/s)	
	Total	Served	%	m^3/year	l/s	l/capita/day	%	Average	Daily max.	Average	Daily max.
1995	100,802	49,393	49.0	2,433,662	77	135	49.0	158	205	151	197
1996	103,656	53,072	51.2	2,576,914	82	133	47.8	163	212	157	204
1997	106,591	56,920	53.4	2,721,544	86	131	44.6	162	211	156	203
1998	108,457	60,302	55.6	2,907,875	92	132	41.4	164	213	157	205
1999	111,518	64,457	57.8	3,084,593	98	131	38.2	165	214	158	206
2000	114,579	68,747	60.0	3,264,835	104	130	35.0	166	216	159	207
2001	117,641	75,290	64.0	3,516,108	111	128	34.0	176	229	169	220
2002	120,703	82,078	68.0	3,767,326	119	126	33.0	186	241	178	232
2003	123,764	89,110	72.0	4,025,278	128	124	32.0	196	254	188	244
2004	126,826	96,388	76.0	4,290,404	136	122	31.0	205	267	197	256
2005	129,888	103,910	80.0	4,558,369	145	120	30.0	215	280	206	268
2006	132,951	106,892	80.4	4,712,597	149	121	29.0	219	285	210	274
2007	136,013	109,899	80.8	4,869,821	154	121	28.0	223	290	214	279
2008	139,076	112,930	81.2	5,030,078	160	122	27.0	228	296	218	284
2009	142,138	115,985	81.6	5,193,445	165	123	26.0	232	301	223	289
2010	145,201	119,065	82.0	5,359,960	170	123	25.0	236	307	227	295
2011	148,262	122,465	82.6	5,538,721	176	124	24.4	242	315	232	302
2012	151,324	125,901	83.2	5,721,190	181	124	23.8	248	322	238	310
2013	154,385	129,375	83.8	5,907,442	187	125	23.2	254	330	244	317
2014	157,447	132,885	84.4	6,097,524	193	126	22.6	260	338	250	325
2015	160,508	136,432	85.0	6,291,526	200	126	22.0	266	346	256	333
2016	163,264	139,754	85.6	6,479,178	205	127	21.8	274	356	263	342
2017	166,020	143,109	86.2	6,670,727	212	128	21.6	281	365	270	351
2018	168,775	146,497	86.8	6,851,809	217	128	21.4	288	374	276	359
2019	171,531	149,918	87.4	7,065,822	224	129	21.2	296	385	284	370
2020	174,287	153,373	88.0	7,269,516	231	130	21.0	304	395	292	379
2021	176,430	155,964	88.4	7,434,132	236	131	20.8	310	403	298	387
2022	178,574	158,574	88.8	7,601,586	241	131	20.6	316	411	304	395
2023	180,717	161,200	89.2	7,771,930	246	132	20.4	323	419	310	402
2024	182,861	163,843	89.6	7,945,218	252	133	20.2	329	428	316	410
2025	185,004	166,504	90.0	8,121,484	258	134	20.0	335	436	322	418

Note: Ratio daily maximum / average = 1.3
Operation water loss of purification plant = 4%
Elaboration: JICA (1999)

2.2.4 WASTEWATER FLOW AND POLLUTION LOAD

(1) Wastewater Flow Projection

The sanitary sewer and treatment plant capacity shall be determined from future quantity of domestic, commercial, industrial and state wastewater, as well as anticipated ground water infiltration. Future wastewater flow without infiltration is predicted based on the water consumption projection. Per capita wastewater flow is usually less than per capita water consumption because water is lost through leakage, lawn irrigation, evaporation, etc. This reduction factor is normally 0.7 - 0.8 in Japan. For this study, the reduction factor of 0.8 specified in "Regulamento National de Constructions" (RNC) is used.

Infiltration rate adopted by F/S and D/D by PRONAP is 0.1 l/s/km. Although this value is lower than estimated value of 0.11 l/s/km from the present wastewater flow survey in the dry season, 0.1 l/s/km is to be used for the projection to avoid over-sizing sewer system and treatment plant.

Table V.2.6 shows wastewater flow projection up to year 2025. Maximum daily wastewater flow is calculated by multiplying daily average wastewater flow and coefficient of 1.3, which is the ratio of maximum daily water demand to average daily water demand specified in Regulamento National de construction (S100). Maximum hourly wastewater flow is calculated using coefficient of 1.8 from daily average wastewater flow. These coefficients adopted from RNC (S100) are applicable to the cities with population over 10,000.

Table V.2.6 Wastewater flow projection

Year	Total population	Service ratio (%)	Served population	Per capita consumption (l/capita/day)	Wastewater flow (l/s)	Infiltration flow (l/s)	Average daily flow (l/s)	Maximum daily flow (l/s)	Hourly maximum flow (l/s)
1995	100,802	39.0	39,313	135	49.1	15.1	64.3	79.0	103.6
1996	103,656	41.4	42,914	133	52.9	15.4	68.2	84.1	110.5
1997	106,591	43.8	46,687	131	56.6	15.6	72.3	89.2	117.6
1998	108,457	46.2	50,107	132	61.3	15.9	77.2	95.6	126.2
1999	111,518	48.6	54,198	131	65.8	15.9	81.7	101.4	134.3
2000	114,579	51.0	58,435	130	70.4	15.9	86.3	107.4	142.6
2001	117,641	53.4	62,820	128	74.4	17.1	91.5	113.8	151.0
2002	120,703	55.8	67,352	126	78.4	18.2	96.7	120.2	159.4
2003	123,764	58.2	72,031	124	82.5	18.2	100.8	125.5	166.8
2004	126,826	60.6	76,857	122	86.8	18.2	105.0	131.1	174.5
2005	129,888	63.0	81,829	120	91.1	18.2	109.3	136.6	182.2
2006	132,951	65.4	86,950	121	97.2	18.2	115.5	144.7	193.3
2007	136,013	67.8	92,217	121	103.7	18.2	121.9	153.0	204.8
2008	139,076	70.2	97,631	122	110.3	18.2	128.6	161.7	216.8
2009	142,138	72.6	103,192	123	117.2	18.9	136.1	171.3	229.9
2010	145,201	75.0	108,901	123	124.4	19.6	143.9	181.2	243.4
2011	148,262	75.7	112,185	124	128.7	20.2	149.0	187.6	251.9
2012	151,324	76.3	115,511	124	133.2	20.9	154.1	194.0	260.6
2013	154,385	77.0	118,877	125	137.7	21.6	159.3	200.6	269.4
2014	157,447	77.7	122,284	126	142.3	22.3	164.6	207.3	278.5
2015	160,508	78.3	125,731	126	147.1	22.9	170.0	214.1	287.7
2016	163,264	79.0	128,978	127	151.7	23.6	175.3	220.8	296.6
2017	166,020	79.7	132,262	128	156.4	24.2	180.6	227.6	305.8
2018	168,775	80.3	135,583	128	160.9	24.9	185.8	234.0	314.5
2019	171,531	81.0	138,940	129	166.1	25.6	191.7	241.5	324.6
2020	174,287	81.7	142,334	130	171.1	26.2	197.4	248.7	334.3
2021	176,430	82.3	145,261	131	175.6	26.9	202.5	255.2	343.0
2022	178,574	83.0	148,216	131	180.2	27.5	207.8	261.9	352.0
2023	180,717	83.7	151,200	132	184.9	28.2	213.1	268.6	361.1
2024	182,861	84.3	154,212	133	189.7	28.9	218.6	275.5	370.3
2025	185,004	85.0	157,253	134	194.6	29.5	224.1	282.5	379.8

(2) Pollution load projection

Present per capita pollution loads estimate by JICA study team (see Chapter V Section 1.2.3) are shown in *Table V.2.7* together with various standards for wastewater treatment plant design.

Table V.2.7 Comparison of per capita pollution load (g/capita/day)

	BOD	SS	T-N	T-P
PUNO (JICA)	40	55	12	1
PERU *1	50 (1.0) *4	90 (1.8) *4	12 (0.24) *4	3 (0.06) *4
JAPAN *2	57	43	12	1.2
US *3	77	90	18	3
PRONAP F/S, D/D	45			1.25

*1 Regulamento National de Construccions, Norma de Saneamiento S.090
*2 Japan Sewerage Design Standards
*3 Recommended standards for wastewater facilities (Great Lakes, 1997)
*4 Ratio as BOD = 1.0

Per capita pollution loads may increase as living standard of the inhabitants improves. For this Master Plan study, per capita BOD load of 45 g/capita/day is adopted. Per capita pollution loads for SS and T-N are set using ratios to BOD load proposed by RNC(S.090). Per capita T-P load of 1.0 g/capita/day by JICA study survey was relatively low, but similar to that of PRONAP F/S design value. Thus 1.25 g/capita/day is adopted as per capita T-P load. Design per capita pollution loads are shown in *Table V.2.8*.

Table V.2.8 Design per capita pollution load (g/capita/day)

	BOD	SS	T-N	T-P
Per capita load (Ratio)	45 (1.0)	81 (1.8)	11 (0.24)	1.25 (0.03)

Pollutant load contributions from commercial sources are generally considered within the allowance for domestic sources. As contribution from industrial and state sources are relatively small compared to domestic sources in Puno City, contributions from those sources are ignored in this study.

Projected pollution loads generated in Puno City and collected by sanitary sewer system up to year 2025 are shown in *Table V.2.9*.