CHAPTER - V WASTEWATER CONTROL SYSTEM

CHAPTER - V

WASTEWATER CONTROL SYSTEM

1. PRESENT CONDITIONS

1.1 OUTLINE OF SYSTEMS

(1) Sewer connections

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

(2) Sanitary sewer network

Table V.1.2 Length of existing sanitary sewer pipes (1998)

Pipe diameter	Length
Branch sewer (150 mm – 200 mm)	146 km
Trunk sewer (250 mm – 900 mm)	12.8 km

(3) Pump stations

4 pump stations operate in the existing sewer network, namely Canete, El Porteno, Floral and Aziruni (Salcedo).

(4) Wastewater treatment plants

a) Espinar stabilization lagoon

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

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

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

(5) On-site system

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

1. Pit latrines
2. Septic tanks

1.2 EVALUATION OF PRESENT CONDITIONS

Around 46 % of the raw wastewater generated in Puno City is 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 (BOD_5), 30 % of nitrogen (T-N) and 30 % of phosphorus (T-P). It discharges its effluent to the interior bay of Puno.

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.

1.3 IDENTIFICATION OF PROBLEMS

(1) Low collection rate of wastewater

(2) Broken covers of sewer pits

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

(4) Overload of Chanu Chanu treatment plant

(5) Inflow of rainwater to the collection network

(6) Lack of on-site systems

2. MASTER PLAN

2.1 TARGET AND STRATEGY

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

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

(1) Targets of Master Plan

a) Target year: 2025

b) Target wastewater:

- Domestic wastewater
- Commercial wastewater
- Industrial wastewater

c) Target coverage of sanitary sewer system: 85 % in year 2025

(2) Strategy of Master Plan

a) Sewer system selection: separate system

b) Staged implementation:

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

- Area served by sanitary sewer (zones 1 – 12, 14): 2831 ha

- Area served by on-site sanitation facilities (zones13, 15, 16): 539 ha

2.2.2 POPULATION

Table V.2.1 Target service coverage of sanitary sewer

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

Table V.2.2 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

Table V.2.3 Revised water consumption projection

Year	Population			Water consumption	
	Total	Served	% served	l/s	l/capita/day
1998	108,457	60,302	56	92	132
2008	139,076	112,930	81	160	122
2015	160,508	136,432	85	200	126
2025	185,004	166,504	90	258	134

2.2.4 WASTEWATER FLOW AND POLLUTION LOAD

(1) Wastewater flow projection

Table V.2.4 Revised wastewater flow projection

Year	Population			Wastewater flow (l/s)	Infiltration (l/s)	Daily average (l/s)	Daily maximum (l/s)	Hourly maximum (l/s)
	Total	% served	Served					
1998	108457	46	50107	61.30	14.60	75.90	94.28	124.93
2008	139076	70	97631	110.32	16.90	127.22	160.31	215.47
2015	160508	78	125731	147.08	21.70	168.78	212.91	286.45
2025	185004	85	157253	194.58	28.30	222.88	281.25	378.54

(2) Pollution load projection

Table V.2.5 Design per capita pollution load (g/capita/day)

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

2.3 ALTERNATIVE PLANS FOR STRUCTURAL MEASURES

2.3.1 ON-SITE SYSTEM

On-site facilities:

- Pit latrine
- Pour flush toilet

Pit emptying: small (vacuum) pit emptying machines + sludge trucks
Sludge disposal: land (forest) disposal

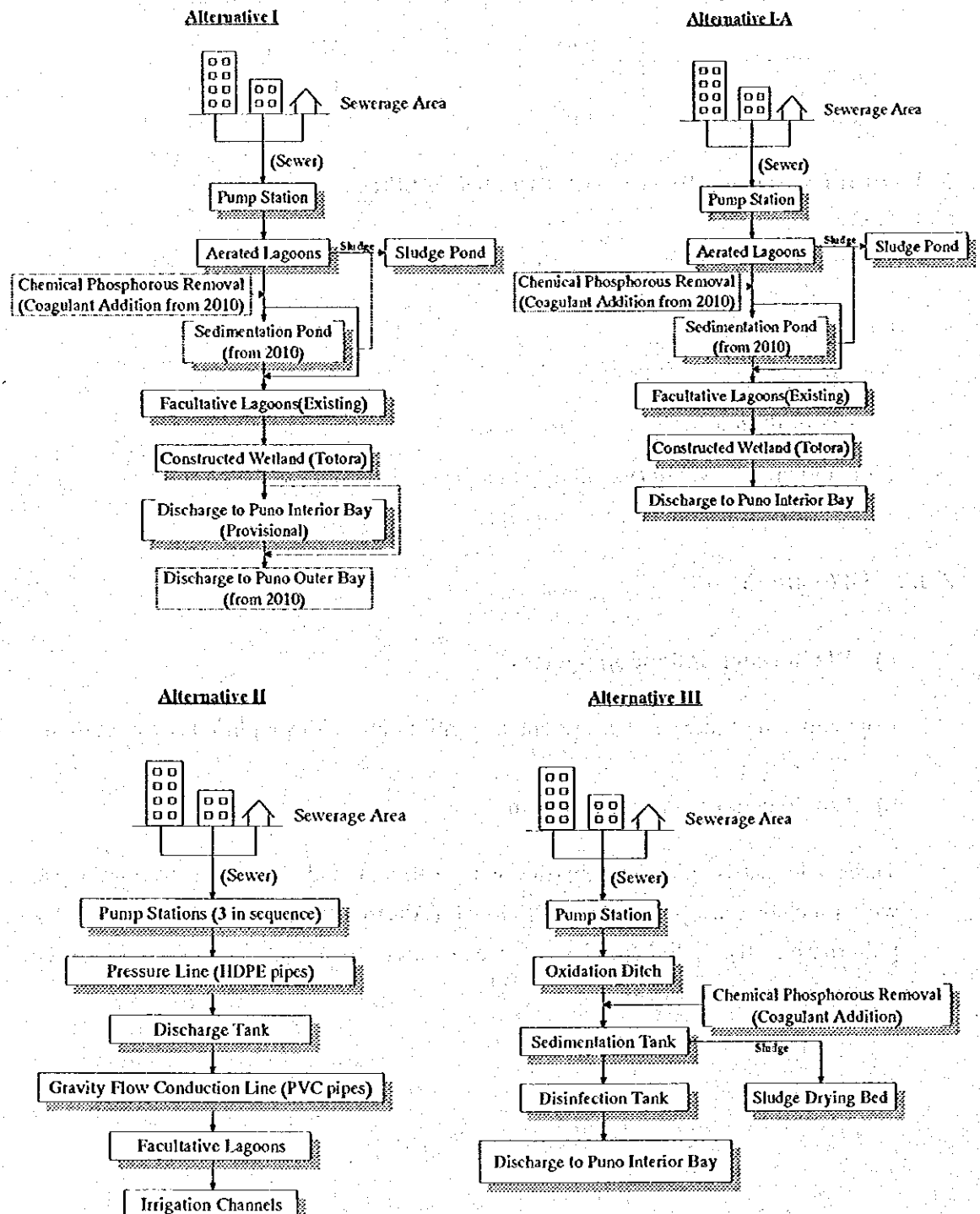
2.3.2 OFF-SITE SYSTEM

a) Wastewater collection system

Conventional sanitary sewer system in combination with simplified sewer system

b) Waste water treatment system

Three Alternative plans for wastewater treatment and disposal processes exist, which include ones proposed by PRONAP (Alternative I, I-A) and INADE-PELT (Alternative II). Schematics of wastewater treatment processes for each alternative are shown below.


Alternative I
Sewerage Area
(Sewer)
Pump Station
Aerated Lagoons
Sludge
Sludge Pond
Chemical Phosphorous Removal
(Coagulant Addition from 2010)
Sedimentation Pond
(from 2010)
Facultative Lagoons(Existing)
Constructed Wetland (Totora)
Discharge to Puno Interior Bay
(Provisional)
Discharge to Puno Outer Bay
(from 2010)
Alternative I-A
Sewerage Area
(Sewer)
Pump Station
Aerated Lagoons
Sludge
Sludge Pond
Chemical Phosphorous Removal
(Coagulant Addition from 2010)
Sedimentation Pond
(from 2010)
Facultative Lagoons(Existing)
Constructed Wetland (Totora)
Discharge to Puno Interior Bay
Alternative II
Sewerage Area
(Sewer)
Pump Stations (3 in sequence)
Pressure Line (HDPE pipes)
Discharge Tank
Gravity Flow Conduction Line (PVC pipes)
Facultative Lagoons
Irrigation Channels
Forest Irrigation
Alternative III
Sewerage Area
(Sewer)
Pump Station
Oxidation Ditch
Chemical Phosphorous Removal
(Coagulant Addition)
Sedimentation Tank
Sludge
Disinfection Tank
Sludge Drying Bed
Discharge to Puno Interior Bay

2.3.3 PRELIMINARY DESIGNS FOR ALTERNATIVE PLANS

The preliminary design for the wastewater treatment plant was prepared with the following capacity.

Name	Capacity at Year 2025
Alternative I	20,400 m^3/day (Average Daily Wastewater Flow)
Alternative I-A	20,400 m^3/day (Average Daily Wastewater Flow)
Alternative II	36,600 m^3/day (Hourly Maximum Wastewater Flow)
Alternative III	24,400 m^3/day (Maximum Daily Wastewater Flow)

(1) Layout

Tentative layouts for the above alternatives are shown in *Figures V.2.1, V.2.2* and *V.2.3*.

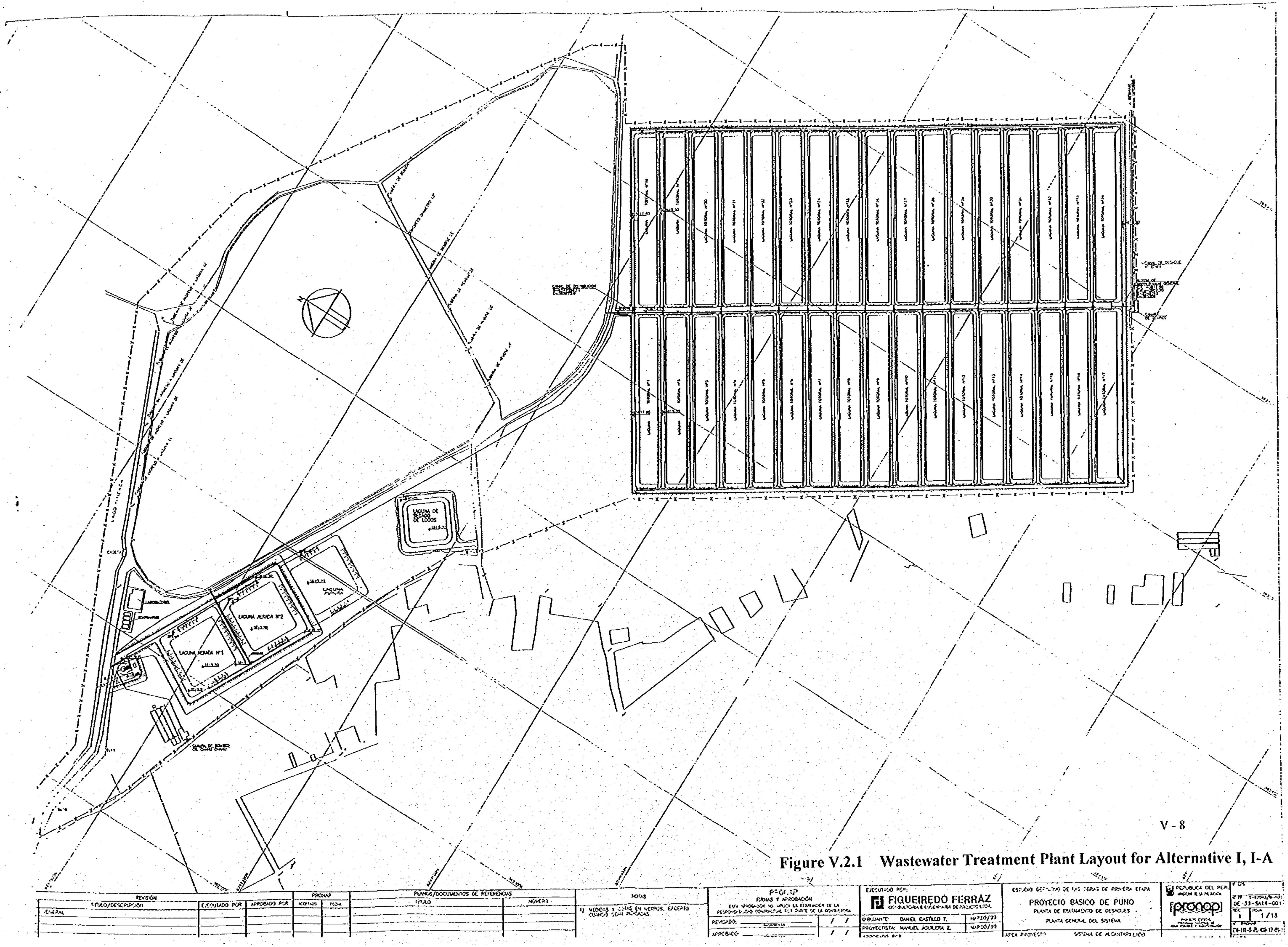
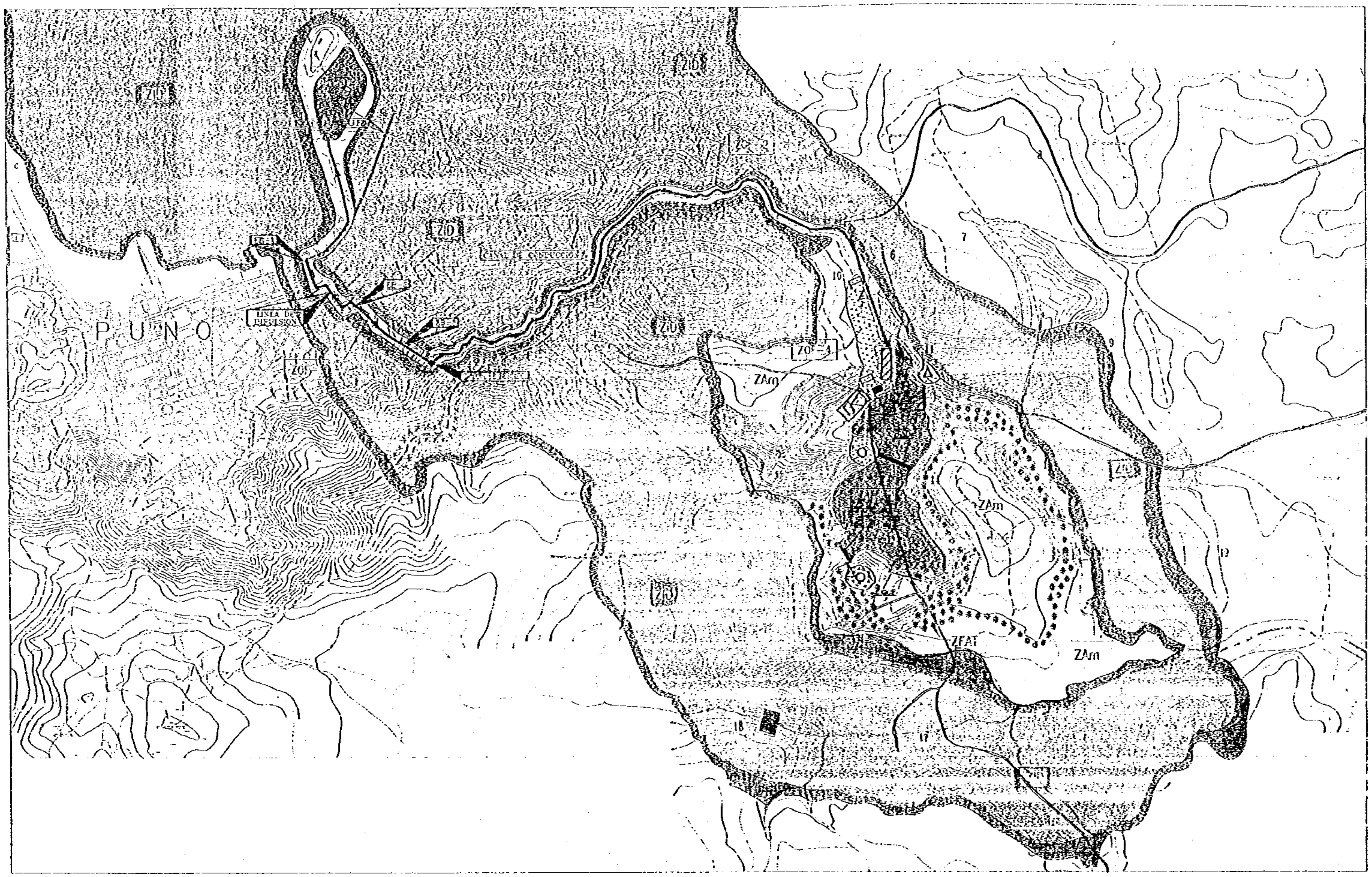


Figure V.2.1 Wastewater Treatment Plant Layout for Alternative I, I-A



LEYENDA

- COLECTOR SUR
- ESTACION DE BOMBEO
- LINEA DE IMPULSION
- CAMARA DE DESCARGA
- CANAL DE CONDUCCION
- LAGUNA DE ESTABILIZACION
- DIQUE
- LIMITE AREA DE IRRIGACION
- LIMITE DE ESTUDIO
- LIMITE DE COMUNIDAD CAMPESINA
- CARRETERA ASFALTADA
- TROCHA CARROZABLE
- CENTRO POBLADO

OBRAS DEL PROYECTO

COLECTOR SUR
ESTACION DE BOMBEO Nº 1 (EB-1)
ESTACION DE BOMBEO Nº 2 (EB-2)
ESTACION DE BOMBEO Nº 3 (EB-3)
CAMARA DE DESCARGA
LINEA DE IMPULSION
CANAL DE CONDUCCION
LAGUNA DE ESTABILIZACION Nº 1
LAGUNA DE ESTABILIZACION Nº 2
DIQUE Nº 1
DIQUE Nº 2
DIQUE Nº 3
DIQUE Nº 4
AREA DE IRRIGACION

UNIDADES DE MANEJO AMBIENTAL	
ZONA DE OCUPACION FISICA DEL PROYECTO	ZOF
Sub-Zona 1 de Bombeo e Impulsión	ZOF-1
Sub-Zona 2 de Conducción	ZOF-2
Sub-Zona 3 de Tratamiento	
Sub-Zona 4 de Servicios	ZOF-4
ZONA DE FORESTACION CON AGUAS TRATADAS	ZFAT
ZONA DE AMORTIGUACION	ZAm
ZONA DE SEGURIDAD	
ZONA DE INFLUENCIA DIRECTA	

COMPONENTES AMBIENTALES ACTUALES Y PROYECTADOS	
RELLENO SANITARIO (Municipalidad Provincial de Puno)	
ZONA ARQUEOLOGICA (San Luis de Alba-INC)	
OFICINA ADMINISTRATIVA DE PLANTA DE TRATAMIENTO	
ESTACION METEOROLOGICA	
PANEL INFORMATIVO	
PUESTO DE CONTROL Y VIGILANCIA	
MIRADOR PARA VISITANTES	
CAMINO DE ACCESO	
ZONA DE FORESTACION PROYECTADA (Plan Director Ciudad de Puno PDCP)	
NUEVA VIA DE CIRCUNVALACION (PDCP)	
CARRETERA TRANSOCEANICA (Trazo Propuesto)	
VIA COLECTORA (Trazo Propuesto)	
LIMITE DE COMUNIDADES CAMPESINAS	

RELACION DE F.O.S.P. (L. de Conduccion)
(1) Barrio Alto Mondo (Sur y Norte)
(2) Barrio Nueva Esperanza
(3) C.C. Los Andes Conchorani
(4) [illegible]
(5) C.C. Conchorani
(6) C.C. Mi Perú
(7) Instituto Tecnologico de Puno (IEA)
(8) C.C. Chimo
(9) Grupo Campesino Collohui Chimo
(10) Ex Fundo... de la CAP-Puno
(11) C.C. Chimo
(12) C.C. Camala
(13) C.C. Siloma... Alojo
(14) P.P.J. Dr. Luis Espezua
(15) U.N.A. (Fac. de Ingeniería-Ex Minas de Laykakota)
(16) C.C. Capullani
(17) C.C. Rapullani
(18) Instituto Nacional de Cultura (INC)
(19) C.C. Jichuyo Pomaya

* F.O.S.P.: Formas de Organización Social de la Producción

Alternative II

PRESIDENCIA DE LA REPUBLICA
MINISTERIO DE LA PRESIDENCIA

INSTITUTO NACIONAL DE DESARROLLO

PROYECTO ESPECIAL BINACIONAL LAGO TITICACA
P. E. L. T.

ESTUDIO DEFINITIVO PARA LA CONDUCCION, TRATAMIENTO Y MANEJO INTEGRAL DE LAS AGUAS SERVIDAS DE LA CIUDAD DE PUNO

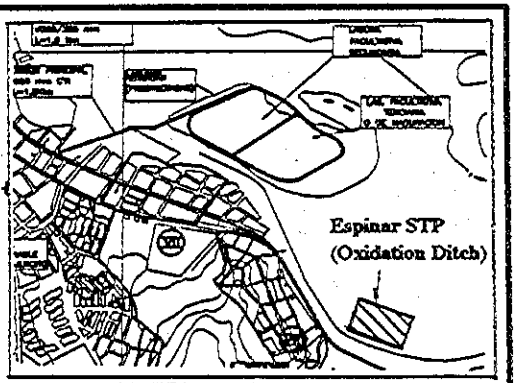
PLANO: ESTUDIO DE IMPACTO AMBIENTAL

MAPA DE MANEJO AMBIENTAL DEL PROYECTO

TOPOGRAFIA:	GEOLOGIA:	DISEÑO:	FECHA: FEBRERO '99	PLANO Nº
DIBUJO: A. Odus C.	ESCALA: 1 / 20 000	V - 9	APROBACION:	E8-IMA-02

ASESORES TECNICOS ASOCIADOS S.A.

Figure V.2.2 Wastewater Treatment Plant Layout for Alternative II



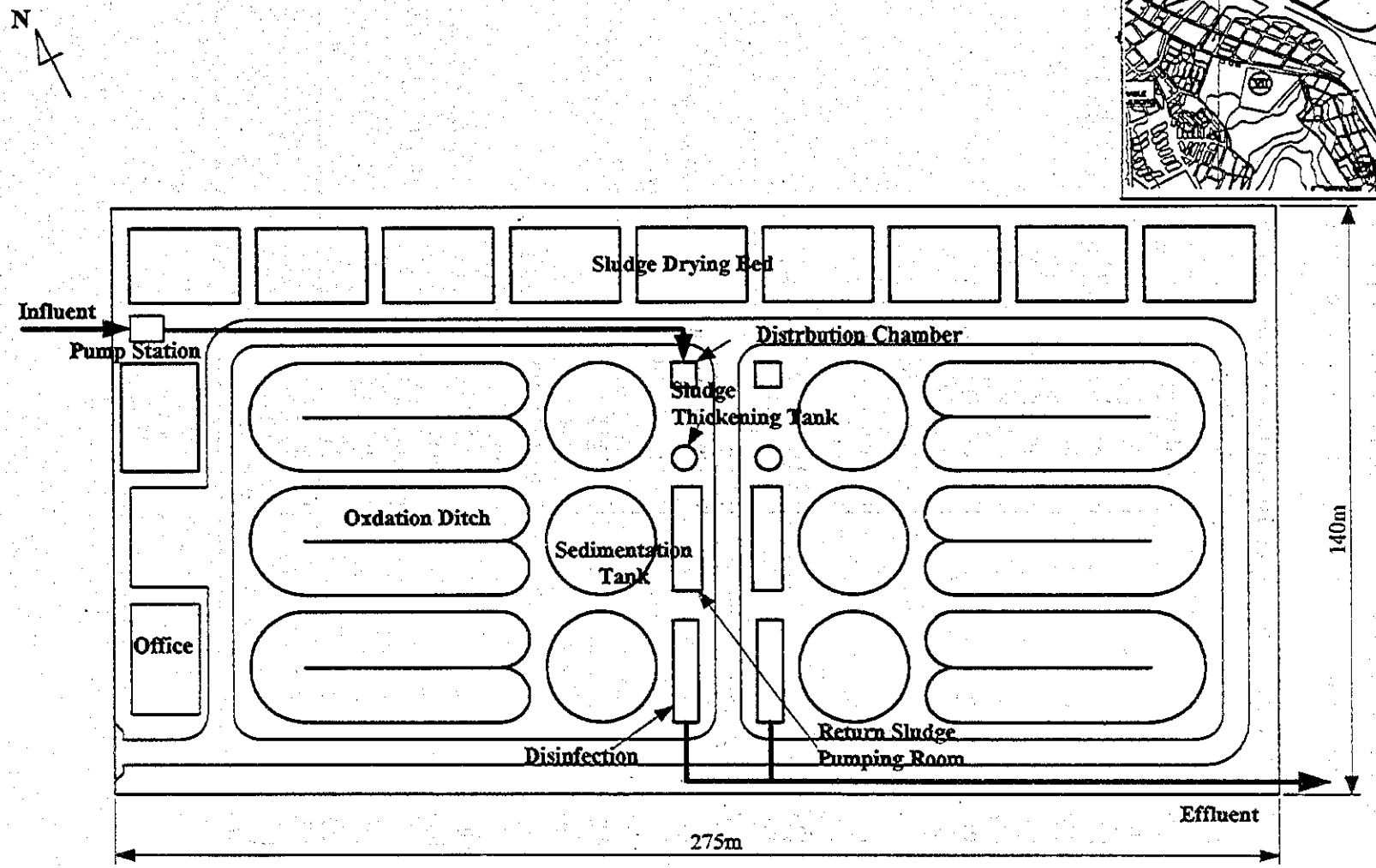


Figure V.2.3 Wastewater Treatment Plant Layout for Alternative III (Oxidation Ditch)

(2) Specifications of facilities

Specifications for each facility of the wastewater treatment plant together with numbers, dimensions and design parameters are shown in the following tables.

Table V.2.6 – a Specifications of Wastewater Treatment Plant (Alternative I, I-A)

Facilities	Specifications
1.Pump Station	
EB Puno	Submersible Pump, 200 l/s, 8.6 m, 30 kW, 2 sets(+1)
2. Aerated Lagoon	3 basins
Type	Rectangular Type
Dimension	64.0 m W x 80.0 m L x 4.0 m D
Aeration Power Level	22.35 kW (4 per Basin)
Retention Time	2.43 days
3. Existing Primary Lagoon	1 basin
Type	Facultative lagoon
Area	13.4 ha
Depth Average	1.5 m
Volume	204,600 m3
4. Existing Secondary Lagoon	1 basin
Type	Facultative lagoon
Area	7.9 ha
Depth Average	1.5 m
Volume	118,350 m3
5. Constructed Wetland	34 basins
Type	Sub-surface flow
Dimension	23.0 m W x 203.0 m L
Depth Average	0.3 - 0.5 m
6. Sludge Pond	2 basins
Type	Rectangular Type
Dimension	46.0 m W x 54.0 m L
Retention Time	3.07 days
7. Sedimentation Basin	1 basin
Type	Circular Type
Dimension	30.0 m Dia. x 3.0 m D

Table V.2.6 – b Specifications of Wastewater Treatment Plant (Alternative I, I-A)

Facilities	Specifications
8.Pump Station (for I)	
E.B. PRINCIPAL	Submersible Pump, 95 l/s, 41 m, 80 kW, 2 sets(+1)
9.Pressure line (for I)	
Diameter	ϕ 400 mm
Pipe Material	Ductile iron pipes
Length	6,839 m
10.Underwater line (for I)	
Diameter	ϕ 500 mm
Pipe Material	Ductile iron pipes
Length	7,455 m

Table V.2.7 Specifications of Wastewater Treatment Plant (Alternative II)

Facilities	Specifications
1.Pump Station (EB-1)	
EB-1	Vertical Type Pump(Single Suction), 141 l/s, 82 m, 187.5 kW, 3 sets
2.Pump Station (EB-2)	
EB-2	Vertical Type Pump(Single Suction), 141 l/s, 82 m, 187.5 kW, 3 sets
3.Pump Station (EB-3)	
EB-3	Vertical Type Pump(Single Suction), 141 l/s, 82 m, 187.5 kW, 3 sets
4.Pressure Line	
Diameter	ϕ 550 mm
Pipe Material	Polyethylene (HDPE)
Length	1,553 m
5.Conduction line	
Diameter	ϕ 750 mm
Pipe Material	PVC
Length	5,874 m
6.Facultative lagoon	2 basins
Area	55 ha (35 ha + 20 ha)
Depth Average	3.0 m
Volume	1,617,500 m^3
Retention time	75 days

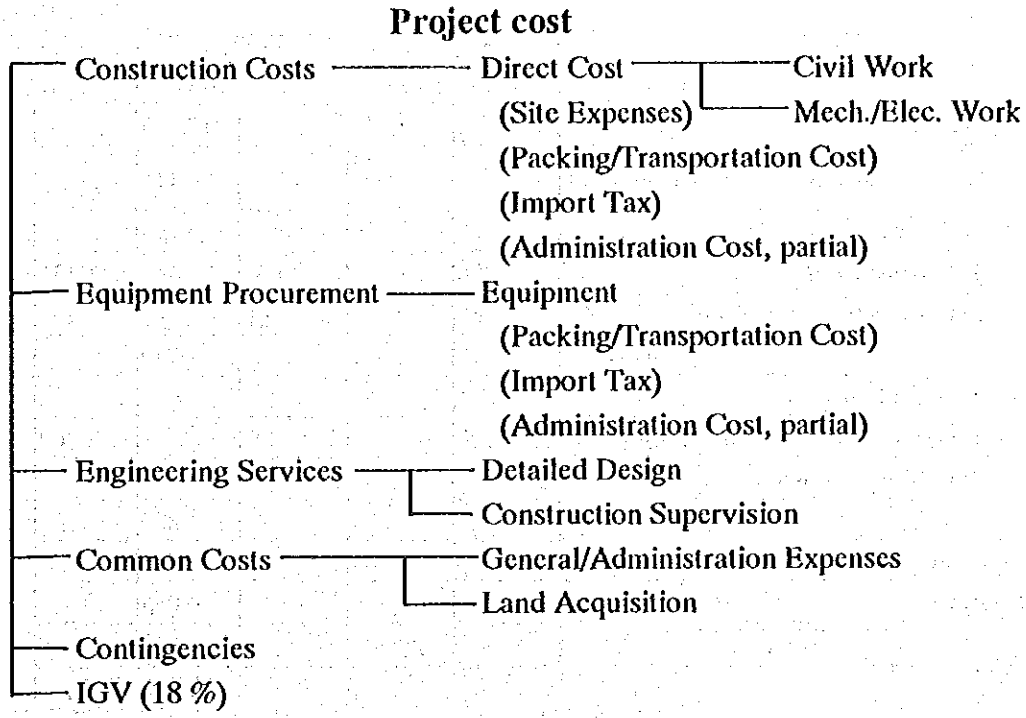
Table V.2.8 Specifications of Wastewater Treatment Plant (Alternative III)

Facilities	Specifications
1. Grit Chamber and Screen	3 basins (including 1 stand-by)
Type	Grit Pit Type
Dimension	0.7 m W ×8.0 m L × 0.5 m D
Average Velocity	0.32 m/sec
2.Pump Station	
EB Puno	Submersible Pump, 200 l/s,10.0 m, 13.85 kW, 2 sets(+1)
3. Oxidation Ditch	6 basins
Type	Horse shoe-shape Type
Dimension	6.0 m W × 225 m L × 3.0 m D
Aeration Power Level	270 kW
Retention Time	24.0 hours
4. Sedimentation Basin	6 basins
Type	Circular Type
Dimension	25.5 m Dia. × 3.0 m D
Water Surface Load	7.9 m3/m2/day
Retention Time	3.4 hours
5. Disinfection Tank	2 basins
Type	Rectangular Type
Dimension	2.0 m W × 21.5 m L × 1.5 m D
Required Chlorine	2.02 kg/hour
Retention Time	15.3 min.
6. Sludge Thickening Tank	2 basins
Type	Circular Type
Dimension	6.0 m Dia.× 4.0 m D
Solid Load	64.2 kg/m2/day
7. Sludge Drying Bed	10 basins
Type	Rectangular Type
Dimension	15.0 m W × 27.0 m L × 0.3 m D
Retention Time	10.0 days

(3) Cost estimation

a) Basic conditions

Components of project cost are shown below:



The project cost is estimated based on the preliminary design for the Master Plan facilities. Unit prices and lump sum prices were determined considering local conditions, sub-contractors, equipment, available construction equipment and materials as well as suitability of the proposed construction method.

Assumptions and conditions used for the cost estimate are as follows:

Price level: as of December 1998

Foreign exchange rate: Peruvian S/. 1.00 = Japanese ¥ 37.00

b) Unit cost

Typical unit costs are as follows:

Concrete:	270 S/./m3
Form Work:	25 S/./m2
Reinforcement:	1.5 S/./kg
Pipe (ϕ200PVC):	66.43 S/./m
Pipe (ϕ200RC):	20.52 S/./m
Electricity:	0.20 S/./kWh

(4) Project cost

Total investment cost of the proposed project is estimated in Peruvian Soles as follows (not including renewal costs of equipment):

Alternative I

Unit: Thousand S/.

	Phase 1 (1998-2008)		Phase 2 (2009-2015)		Phase 3 (2016-2025)	
(1) Construction Cost		23,440		17,703		18,844
(2) Procurement of Maintenance Equipment		234		114		188
(3) Engineering Cost						
1) Detailed Design	1,406		1,062		1,131	
2) Construction Supervision	938		708		754	
Sub-Total		2,344		1,770		1,884
(4) Common Expenses						
1) General/Administration Expenses	200		200		200	
2) Land Acquisition						
Sub-Total		200		200		200
(5) Contingency		3,903		2,938		3,138
(6) IGV 18%		5,386		4,055		4,330
Total		35,506		26,780		28,584
				Grand Total		**90,870**

Alternative I-A

Unit: Thousand S/.

	Phase 1 (1998-2008)		Phase 2 (2009-2015)		Phase 3 (2016-2025)	
(1) Construction Cost		23,440		11,438		18,844
(2) Procurement of Maintenance Equipment		234		114		188
(3) Engineering Cost						
1) Detailed Design	1,406		686		1,131	
2) Construction Supervision	938		458		754	
Sub-Total		2,344		1,144		1,884
(4) Common Expenses						
1) General/Administration Expenses	200		200		200	
2) Land Acquisition	0		0		0	
Sub-Total		200		200		200
(5) Contingency		3,903		1,904		3,138
(6) IGV 18%		5,386		2,628		4,330
Total		35,506		17,428		28,584
				Grand Total		**81,519**

Alternative II

Unit: Thousand S/.

	Phase 1 (1998-2008)		Phase 2 (2009-2015)		Phase 3 (2016-2025)	
(1) Construction Cost		25,339		10,127		21,076
(2) Procurement of Maintenance Equipment		253		101		211
(3) Engineering Cost						
1) Detailed Design	1,520		608		1,265	
2) Construction Supervision	1,014		405		843	
Sub-Total		2,534		1,013		2,108
(4) Common Expenses						
1) General/Administration Expenses	200		100		100	
2) Land Acquisition	100				67	
Sub-Total		300		100		167
(5) Contingency		4,219		1,686		3,509
(6) IGV 18%		5,822		2,327		4,843
Total		38,467		15,354		31,913
				Grand Total		**85,734**

Alternative III

Unit: Thousand S/.

	Phase 1 (1998-2008)		Phase 2 (2009-2015)		Phase 3 (2016-2025)	
(1) Construction Cost		42,452		17,690		23,286
(2) Procurement of Maintenance Equipment		425		177		233
(3) Engineering Cost						
1) Detailed Design	2,547		1,061		1,397	
2) Construction Supervision	1,698		708		931	
Sub-Total		4,245		1,769		2,329
(4) Common Expenses						
1) General/Administration Expenses	200		200		200	
2) Land Acquisition	0		0		0	
Sub-Total		200		200		200
(5) Contingency		7,068		2,945		3,877
(6) IGV 18%		9,754		4,065		5,350
Total		64,145		26,847		35,275
				Grand Total		**126,266**

(5) Implementation plans for alternative plans

Table V.2.9 Implementation and Disbursement Schedule (Alternative I)

Item \ Phase / Year		Phase 1											Phase 2							Phase 3									
		1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Implementation Schedule																													
1. Preparation of Project																													
2. Pre-Construction Stage																													
2.1 Detailed Design																													
2.2 Bidding																													
3. Construction																													
3.1 Collection System																													
3.2 Sewage Treatment Plant																													
- Civil Work																													
- Mechanical/Electrical Work																													
4. Procurement of Maintenance Equipment																													
5. Test Operation																													
Disbursement Schedule	**Total Cost** (Thousand S/.)	Fase 1 35,506											Fase 2 26,780							Fase 3 28,584									
1. Land Acquisition	0																												
2. Administration	600			22	22	22	22	22	22	22	22	22	29	29	29	29	29	29	29	20	20	20	20	20	20	20	20	20	20
3. Construction Work	59,987																												
(1) Sewer - civil works	31,639			2,586	2,586	2,586							1,447	1,447	1,447	1,447	1,447	1,447	1,447	1,375	1,375	1,375	1,375	1,375	1,375	1,375	1,375	1,375	
- mechanical/electorical	0																												
(2) Pump Station - civil works	5,099				34								5,065																
- mechanical/electorical	1,562				181								1,199								181								
(2) Sewage Treatment Plant -civil works	7,819				6,978								494								347								
- mechanical/electorical	13,868				8,489								817								4,562								
4. Maintenance Equipment	536					234							114									188							
5. Engineering Service	5,999		1,406		938								1,062		708					1,131		754							
6. Contingency	9,978		211	388	2,881	423	0	0	0	0	0	0	1,530	217	323	217	217	217	217	376	970	348	206	206	206	206	206	206	206
7. IGV (18 %) (for 3, 4, 5, 6)	13,770		291	535	3,976	584	0	0	0	0	0	0	2,111	299	446	299	299	299	299	519	1,338	480	285	285	285	285	285	285	285
Total Project Cost	90,870		1,908	3,531	26,085	3,849	22	22	22	22	22	22	13,868	1,992	2,953	1,992	1,992	1,992	1,992	3,421	8,794	3,164	1,886	1,886	1,886	1,886	1,886	1,886	1,886
8. Equip. Renewal (with IGV & contng.)	28,566			20			235	512						20		11,765	235	512					2,736	20		11,765	235	512	
9. Maintenance (with IGV)	27,640					550	574	599	623	659	696	735	778	1,096	1,135	1,174	1,215	1,255	1,297	1,338	1,379	1,418	1,464	1,507	1,547	1,588	1,629	1,670	1,713
Total Disbursement	147,077		1,908	3,552	26,085	4,399	831	1,133	646	681	718	757	14,646	3,108	4,088	14,931	3,441	3,759	3,289	4,758	10,172	4,583	6,086	3,414	3,434	15,239	3,750	4,068	3,599

Table V.2.10 Implementation and Disbursement Schedule (Alternative I -A)

Item \ Phase / Year		Phase 1											Phase 2							Phase 3									
		1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Implementation Schedule																													
1. Preparation of Project																													
2. Pre-Construction Stage																													
2.1 Detailed Design																													
2.2 Bidding																													
3. Construction																													
3.1 Collection System																													
3.2 Sewage Treatment Plant																													
- Civil Work																													
- Mechanical/Electrical Work																													
4. Procurement of Maintenance Equipment																													
5. Test Operation																													
Disbursement Schedule	**Total Cost (Thousand S/.)**	Phase 1 35,506											Phase 2 17,428							Phase 3 28,584									
1. Land Acquisition	0																												
2. Administration	600			22	22	22	22	22	22	22	22	22	29	29	29	29	29	29	29	20	20	20	20	20	20	20	20	20	20
3. Construction Work	53,722																												
(1) Sewer - civil works	31,639			2,586	2,586	2,586							1,447	1,447	1,447	1,447	1,447	1,447	1,447	1,375	1,375	1,375	1,375	1,375	1,375	1,375	1,375	1,375	1,375
- mechanical/electorical	0																												
(2) Pump Station - civil works	34				34																								
- mechanical/electorical	363				181																181								
(2) Sewage Treatment Plant -civil	7,819				6,978								494								347								
- mechanical/electorical	13,868				8,489								817								4,562								
4. Maintenance Equipment	536					234							114									188							
5. Engineering Service	5,372		1,406		938								686		458					1,131		754							
6. Contingency	8,945		211	388	2,881	423	0	0	0	0	0	0	534	217	286	217	217	217	217	376	970	348	206	206	206	206	206	206	206
7. IGV (18 %) (for 3, 4, 5, 6)	12,344		291	535	3,976	584	0	0	0	0	0	0	736	299	394	299	299	299	299	519	1,338	480	285	285	285	285	285	285	285
Total Project Cost	81,519		1,908	3,531	26,085	3,849	22	22	22	22	22	22	4,856	1,992	2,613	1,992	1,992	1,992	1,992	3,421	8,794	3,164	1,886	1,886	1,886	1,886	1,886	1,886	1,886
8. Equip. Renewal (with IGV & conting.)	26,939			20			235	512						20		11,765	235	512					1,109	20		11,765	235	512	
9. Maintenance (with IGV)	23,896					550	574	599	623	659	696	735	778	913	945	978	1,012	1,046	1,081	1,114	1,149	1,181	1,219	1,256	1,289	1,322	1,357	1,391	1,427
Total Disbursement	132,354		1,908	3,552	26,085	4,399	831	1,133	646	681	718	757	5,635	2,925	3,558	14,735	3,238	3,549	3,072	4,535	9,942	4,346	4,214	3,163	3,175	14,974	3,478	3,790	3,313

Table V.2.11 Implementation and Disbursement Schedule (Alternative II)

Item \ Phase / Year	Phase 1											Phase 2							Phase 3									
	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Implementation Schedule																												
1. Preparation of Project																												
2. Pre-Construction Stage																												
2.1 Detailed Design																												
2.2 Bidding																												
3. Construction																												
3.1 Collection System																												
3.2 Sewage Treatment Plant																												
- Civil Work																												
- Mechanical/Electrical Work																												
4. Procurement of Maintenance Equipment																												
5. Test Operation																												
Disbursement Schedule	Total Cost (Thousand S/.)	Phase 1 38,467											Phase 2 15,354							Phase 3 31,913									
1. Land Acquisition	167			100															67									
2. Administration	400			22	22	22	22	22	22	22	22	22	14	14	14	14	14	14	14	10	10	10	10	10	10	10	10	10	10
3. Construction Work	56,542																											
(1) Sewer - civil works	31,639			2,586	2,586	2,586							1,447	1,447	1,447	1,447	1,447	1,447	1,447	1,375	1,375	1,375	1,375	1,375	1,375	1,375	1,375	1,375
- mechanical/electorical	0																											
(2) Pump Station - civil works	1,805				1,805																							
- mechanical/electorical	4,618				3,931														687									
(2) Treatment Plant + Pipe lines -civi	18,480				11,846														6,635									
- mechanical/electorical	0																											
4. Maintenance Equipment	565				253							101							211									
5. Engineering Service	5,655		1,520		1,014							608		405					1,265		843							
6. Contingency	9,414		228	388	3,215	388	0	0	0	0	0	0	323	217	278	217	217	217	217	1,526	206	333	206	206	206	206	206	206	206
7. IGV (18 %) (for 3, 4, 5, 6)	12,992		315	535	4,437	535	0	0	0	0	0	0	446	299	383	299	299	299	299	2,106	285	459	285	285	285	285	285	285	285
Total Project Cost	85,734		2,063	3,631	29,108	3,531	22	22	22	22	22	22	2,939	1,978	2,527	1,978	1,978	1,978	1,978	13,881	1,876	3,020	1,876	1,876	1,876	1,876	1,876	1,876
8. Equip. Renewal (with IGV & conting.)	12,969			20			235	512						20		5,334	235	512						20		5,334	235	512	
9. Maintenance (with IGV)	40,597					1,013	1,057	1,102	1,147	1,213	1,281	1,352	1,432	1,515	1,569	1,623	1,679	1,736	1,793	1,849	1,906	1,961	2,024	2,084	2,139	2,195	2,251	2,309	2,368
Total Disbursement	139,300		2,063	3,651	29,108	4,544	1,314	1,635	1,169	1,235	1,303	1,374	4,371	3,513	4,096	8,935	3,891	4,225	3,771	15,730	3,783	4,981	3,900	3,981	4,015	9,405	4,363	4,697	4,244

Table V.2.12 Implementation and Disbursement Schedule (AlternativeⅢ)

Item \ Phase / Year		Phase 1											Phase 2							Phase 3									
		1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Implementation Schedule																													
1. Preparation of Project																													
2. Pre-Construction Stage																													
2.1 Detailed Design																													
2.2 Bidding																													
3. Construction																													
3.1 Collection System																													
3.2 Sewage Treatment Plant																													
- Civil Work																													
- Mechanical/Electrical Work																													
4. Procurement of Maintenance Equipment																													
5. Test Operation																													
Disbursement Schedule	Total Cost (Thousand S/.)	Phase 1 64,145											Phase 2 26,847							Phase 3 35,275									
1. Land Acquisition	0																												
2. Administration	600			22	22	22	22	22	22	22	22	22	29	29	29	29	29	29	29	20	20	20	20	20	20	20	20	20	20
3. Construction Work	83,428																												
(1) Sewer - civil works	31,639			2,586	2,586	2,586							1,447	1,447	1,447	1,447	1,447	1,447	1,447	1,375	1,375	1,375	1,375	1,375	1,375	1,375	1,375	1,375	1,375
- mechanical/electorical	0																												
(2) Pump Station - civil works	2,041				34										2,008														
- mechanical/electorical	5,918				181										5,555						181								
(3) Sewage Treatment Plant -civil works	12,639				10,893																1,747								
- mechanical/electorical	31,190				23,587																	7,603							
4. Maintenance Equipment	835					425										177						233							
5. Engineering Service	8,343		2,547		1,698								1,061		708					1,397		931							
6. Contingency	13,891		382	388	5,847	452	0	0	0	0	0	0	376	217	1,458	244	217	217	217	416	496	1,521	206	206	206	206	206	206	206
7. IGV (18 %) (for 3, 4, 5, 6)	19,169		527	535	8,069	623	0	0	0	0	0	0	519	299	2,012	336	299	299	299	574	684	2,100	285	285	285	285	285	285	285
Total Project Cost	126,266		3,456	3,531	52,916	4,108	22	22	22	22	22	22	3,432	1,992	13,215	2,232	1,992	1,992	1,992	3,782	4,503	13,784	1,886	1,886	1,886	1,886	1,886	1,886	1,886
8. Equip. Renewal (with IGV & conting.)	72,044															32,253									7,538	32,253			
9. Maintenance (with IGV)	31,323					781	815	850	885	936	988	1,043	1,105	1,169	1,211	1,253	1,295	1,339	1,384	1,427	1,471	1,513	1,561	1,608	1,650	1,695	1,737	1,782	1,827
Total Disbursement	229,633		3,456	3,531	52,916	4,889	837	872	907	958	1,011	1,065	4,537	3,161	14,426	35,738	3,287	3,331	3,375	5,209	5,974	15,297	3,448	3,494	11,075	35,833	3,624	3,668	3,714

2.3.4 EVALUATION OF ALTERNATIVE PLANS

(1) Environmental evaluation

Table V.2.13 Treated wastewater quality discharged to the inner bay

	Year	BOD_5 mg/l	Nitrogen (T-N) mg/l	Phosphorus (T-P) mg/l
Alternative I*1	2008	12.7	8.5	2.9
	2015	no discharge	no discharge	no discharge
	2025	no discharge	no discharge	no discharge
Alternative I-A*1	2008	12.7	8.5	2.9
	2015	18.7	8.7	2.9
	2025	26.1	9.1	2.9
Alternative II		no discharge		
Alternative III*2	All period	20	10	1

*1 According to PRONAP calculation

*2 Design values

Table V.2.14 Pollution load reduction by proposed measures in year 2025

	BOD_5		T-N		T-P	
	With Project	Reduction (%)	With Project	Reduction (%)	With Project	Reduction (%)
Without Project	2,541.2	0 %	1,292.0	0 %	155.1	0%
Alternative I	331.5	87 %	31.7	98 %	11.9	92 %
Alternative I-A	814.9	68 %	206.9	84 %	67.7	56 %
Alternative II	331.5	87 %	31.7	98 %	11.9	92 %
Alternative III	716.6	72 %	224.3	83 %	31.2	80 %

Table V.2.15 Initial Environmental Evaluation (IEE)

Environmental concern	Alternative I	Alternative I-A	Alternative II	Alternative III
Lake water pollution				
Inner bay	B	B	D	B
Outer bay*1	B	D	D	D
Sludge disposal	C	C	C	C
Ground water pollution	C	C	B	D
Offensive odor generation	B	B	B	C
Change of landscape	B	B	B	C

A: serious impact is expected
B: minor impact is expected
C: extent of impact is unknown
D: no impact
* Possible drinking water source contamination

(2) Technical aspect

Table V.2.16 Technical evaluation of alternative plans

	Alternative			
	I	I-A	II	III
Previous operation experiences in Peru	○	○	△*1	×*2
Appropriateness of technology used	○	◎	○	○
Ease of O&M	○	◎	△	△
Effective implementation schedule for maximum results	○	○	○	○
Ability to respond to new technology	○	○	○	◎

*1 large scale wastewater pumping

*2 oxidation ditch

◎ : excellent ○ : good △ : inferior × : no good

All of the alternative plans are technically feasible for implementation in Puno City.

(3) Financial aspect

Table V.2.17 Financial Internal Return Rate (FIRR) and Net Present Value (NPV)

	FIRR (%)	NPV (5%) (1,000 soles)
Alternative I	3.5	-4,018
Alternative I-A	5.9	2,094
Alternative II	4.4	-1,683
Alternative III	-3.5	-44,703

Only alternative I-A is regarded as financially feasible unless additional financial resources are available for the project.

(4) Overall evaluation

Environmental evaluation indicates that although Alternative I and II have maximized pollution reduction for the Puno inner bay, those may raise concern over the environment to which treated water is finally discharged. Especially, Alternative I discharges treated water to the Puno outer bay. Its discharge point is not so far from the drinking water intake. This drinking water source is most important for the residents of Puno City and should be protected at all cost. Failure for this may result in increased treatment cost for water supply.

Technical evaluation shows all four alternative plans are feasible for Puno city although staff training is required for the all the alternatives, especially for Alternative III.

Financial evaluation shows that only alternative I-A, which costs minimum among the alternatives, is financially feasible. Other alternatives required substantial rise in sewerage rates or subsidies from the municipality or the government.

From the above evaluation, the study team concludes that Alternative I-A is feasible for the Puno city, especially from the financial point of view. Alternative I-A is further analyzed for optimum performance. An appropriate plan is proposed in section 2.4.

2.4 PROPOSED PLANS

2.4.1 STRUCTURAL MEASURES

(1) On-site system

a) Proposed on-site wastewater treatment/disposal system

Pit Latrine

- Pit Capacity : 0.7 W × 0.7 L × 1.5 H = 0.74 m3
- Sludge Collection : Every 3 years
- Installation: Each house

Small Pit Emptying Machines

- Capacity : 500 L/unit
- Performance : 4.2 pits/day × 250days/year = 1,050 pits/year
- Economic Life : 4 years

Trucks for Sludge Transfer

- Loading Capacity : 2 ton
- Economic Life : 8 years

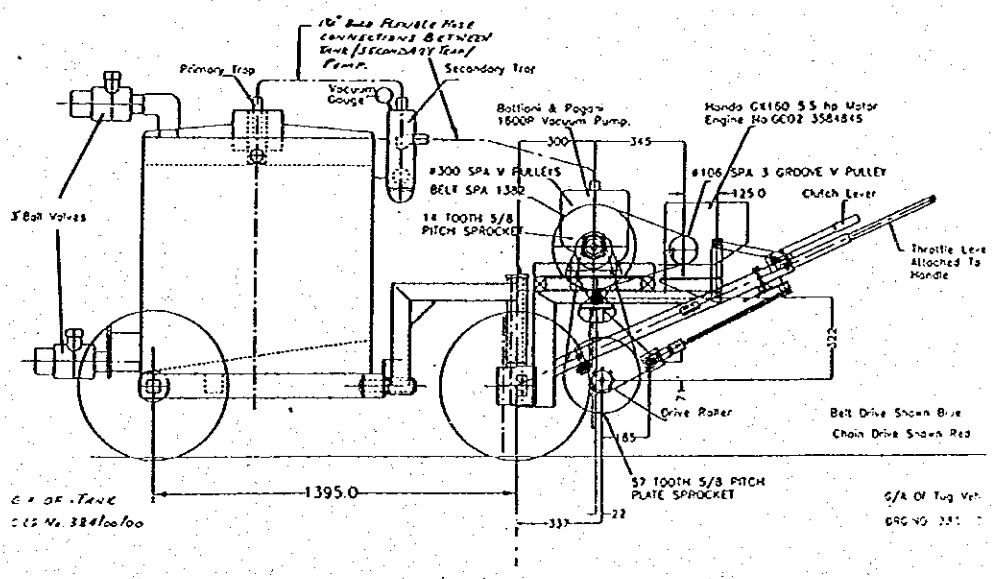


Figure V.2.4 Small (vacuum) pit emptying machine

Source: IRC (1999)

b) Sludge collection cost for on-site system

Total operation cost for sludge collection is calculated as shown in *Table V.2.18*. Average cost per collection is 78 soles. Since the above cost calculation does not include administration cost and interests on capital cost, actual tariff may be set slightly higher.

TableV.2.18 Pit emptying operation cost calculation

Small Pit Emptying Machine			Sludge Transfer (truck)		
Capacity	1,050	houses/year	Capacity	2	ton
Economic Life	4	years	Economic Life	8	years
Price	22,000	soles	Price	60,000	soles
Fuel (petrol)	858	l/year	Fuel (diesel)	3587	l/year
Fuel cost	1,587	soles/year	Fuel cost	4,735	soles/year
Maintenance	2,200	soles/year	Maintenance	3,000	soles/year
Labor cost (2 person/machine)	36,000	soles/year	Labor cost (1 person/truck)	18,000	soles/year

Year	Small Pit Emptying Machine								Truck								Tariff Calculation		
	Required Number	Purchase			Operation and Maintenance				Required Number	Purchase			Operation and Maintenance				Total cost	Family served per year	Cost per collection
		Yearly	Cost	Depreciation	Fuel	Labour	Maintenance	Sub-total		Yearly	Cost	Depreciation	Fuel	Labour	Maintenance	Sub-total			
	(unit)	(unit)	(1,000 soles)	(1,000 soles)	(1,000 soles)	(1,000 soles)	(1,000 soles)	(1,000 soles)	(unit)	(unit)	(1,000 soles)	(1,000 soles)	(1,000 soles)	(1,000 soles)	(1,000 soles)	(1,000 soles)	(1,000 soles)		(soles)
1998	0	0	0		0	0	0	0	0	0	0		0	0	0	0	0	4687	0
1999	0	0	0		0	0	0	0	0	0	0		0	0	0	0	0	4632	0
2000	0	0	0		0	0	0	0	0	0	0		0	0	0	0	0	4565	0
2001	5	5	110	27.5	6.8	180	11	198	4	4	240	30	17.8	72	12	102	357	4483	80
2002	5	0	0	27.5	6.6	180	11	198	4	0	0	30	17.3	72	12	101	356	4389	81
2003	5	0	0	27.5	6.5	180	11	197	4	0	0	30	16.8	72	12	101	356	4281	83
2004	4	0	0	27.5	6.3	144	8.8	159	4	0	0	30	16.2	72	12	100	317	4160	76
2005	4	4	88	22	6.1	144	8.8	159	4	0	0	30	15.6	72	12	100	310	4025	77
2006	4	0	0	22	5.9	144	8.8	159	4	0	0	30	14.9	72	12	99	310	3876	80
2007	4	0	0	22	5.6	144	8.8	158	3	0	0	30	14.2	54	9	77	288	3713	77
2008	4	0	0	22	5.3	144	8.8	158	3	0	0	30	13.4	54	9	76	287	3535	81
2009	4	3	66	16.5	5.1	144	8.8	158	3	3	180	22.5	12.6	54	9	76	272	3342	82
2010	3	0	0	16.5	4.7	108	6.6	119	3	0	0	22.5	11.8	54	9	75	233	3135	74
2011	3	0	0	16.5	4.7	108	6.6	119	3	0	0	22.5	11.7	54	9	75	233	3133	74
2012	3	0	0	16.5	4.7	108	6.6	119	3	0	0	22.5	11.6	54	9	75	233	3128	74
2013	3	3	66	16.5	4.7	108	6.6	119	3	0	0	22.5	11.5	54	9	75	233	3120	75
2014	3	0	0	16.5	4.7	108	6.6	119	3	0	0	22.5	11.4	54	9	74	233	3107	75
2015	3	0	0	16.5	4.7	108	6.6	119	3	0	0	22.5	11.3	54	9	74	233	3091	75
2016	3	0	0	16.5	4.6	108	6.6	119	3	0	0	22.5	11.1	54	9	74	232	3066	76
2017	3	3	66	16.5	4.6	108	6.6	119	3	3	180	22.5	10.9	54	9	74	232	3036	76
2018	3	0	0	16.5	4.5	108	6.6	119	3	0	0	22.5	10.8	54	9	74	232	3003	77
2019	3	0	0	16.5	4.5	108	6.6	119	3	0	0	22.5	10.6	54	9	74	232	2967	78
2020	3	0	0	16.5	4.4	108	6.6	119	3	0	0	22.5	10.4	54	9	73	231	2926	79
2021	3	3	66	16.5	4.3	108	6.6	119	3	0	0	22.5	10.1	54	9	73	231	2872	80
2022	3	0	0	16.5	4.3	108	6.6	119	3	0	0	22.5	9.8	54	9	73	231	2814	82
2023	3	0	0	16.5	4.2	108	6.6	119	3	0	0	22.5	9.6	54	9	73	230	2753	84
2024	3	0	0	16.5	4.1	108	6.6	119	2	0	0	22.5	9.3	36	6	51	209	2688	78
2025	3	3	66	16.5	4.0	108	6.6	119	2	2	120	15	9.0	36	6	51	201	2620	77
Total		24	528	478.5	125.8	3132	191.4	3449		12	720		309.7	1422	237	1969		Average	78

(2) Off-site system

1) Wastewater collection system

The summary of sewer and a pump station conducted in future plan are shown in the following tables.

a) Sewer

Table V.2.19 Summary of Sewer Plan

Phase	Length (m)	Percent of sewered area (%)
Phase 1 (1998-2008)	23,396	36
Phase 2 (2009-2015)	46,832	57
Phase 3 (2016-2025)	66,007	72
Total	136,234	-

b) Pump Station

Table V.2.20 Summary of Pump Station Plan

Name	Specification
E.B. EL PUERTO	Submersible pump, 5.25 l/s, 8.6 m, 1.2 kW, 1 set (+1)

2) Wastewater treatment plant

a) Possible improvement for Alternative I-A

Sedimentation lagoons

As required removal of accumulated solids from the facultative lagoons is quite difficult while continuous operation is required, installation of sedimentation lagoons is proposed. Two lagoons are to be constructed at Phase 2, which operate alternatively as a sedimentation lagoon and a sludge pond. Another lagoon is constructed at the start of Phase 3. Accumulated sludge in the aerated lagoons will be pumped to the sedimentation pond while it is used as a sludge pond.

Inlets for facultative lagoons

Inlets for the facultative lagoons are modified as shown in *Figure V.2.6* to maximize the average retention time of the lagoons.

Outlet facility for the second facultative lagoons

At present, a large amount algae is observed in the effluent of facultative lagoons. In order to minimize the release of algae into the effluent, outlet structure such as *Figure V.2.5* is to be installed.

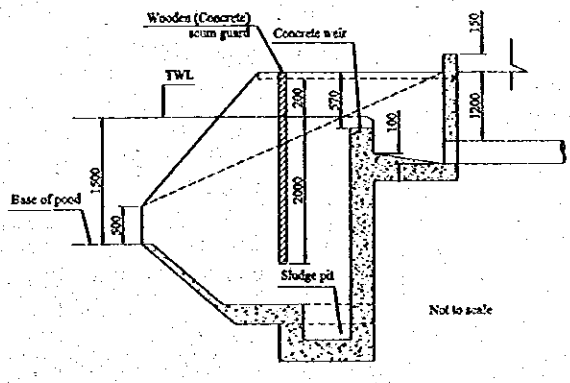
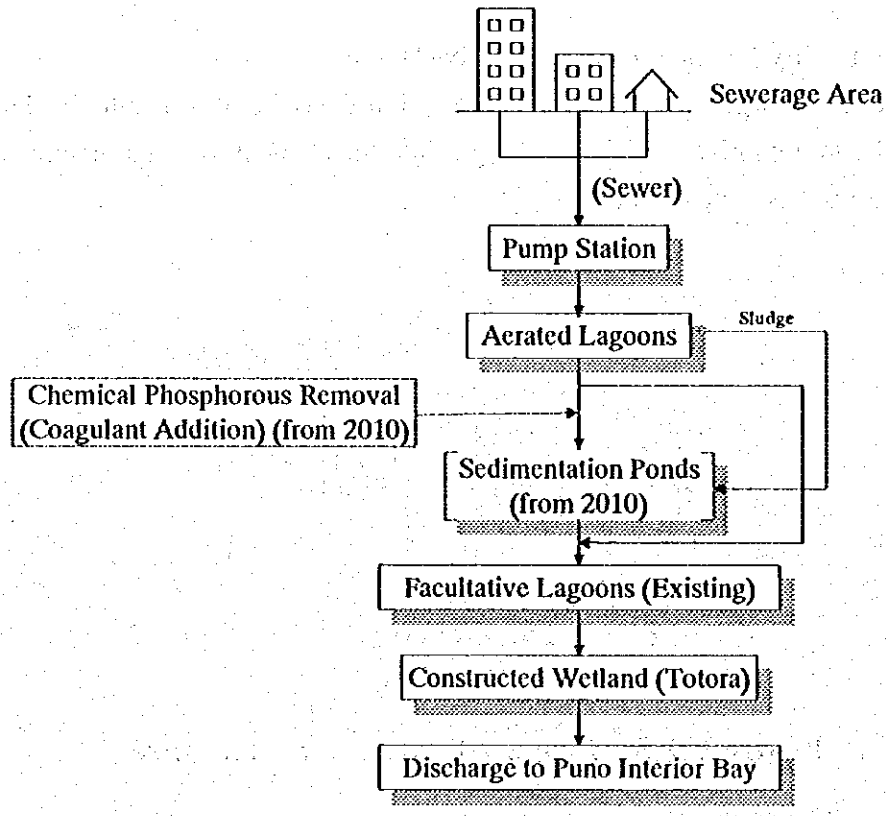


Figure V.2.5 Proposed outlet weir structure

* Source: Mara and Pearson, 1998

b) Proposed wastewater treatment plant

Schematic of the proposed wastewater treatment plant is shown below.



Layout for the proposed wastewater treatment plant is shown in *Figure V.2.6.*

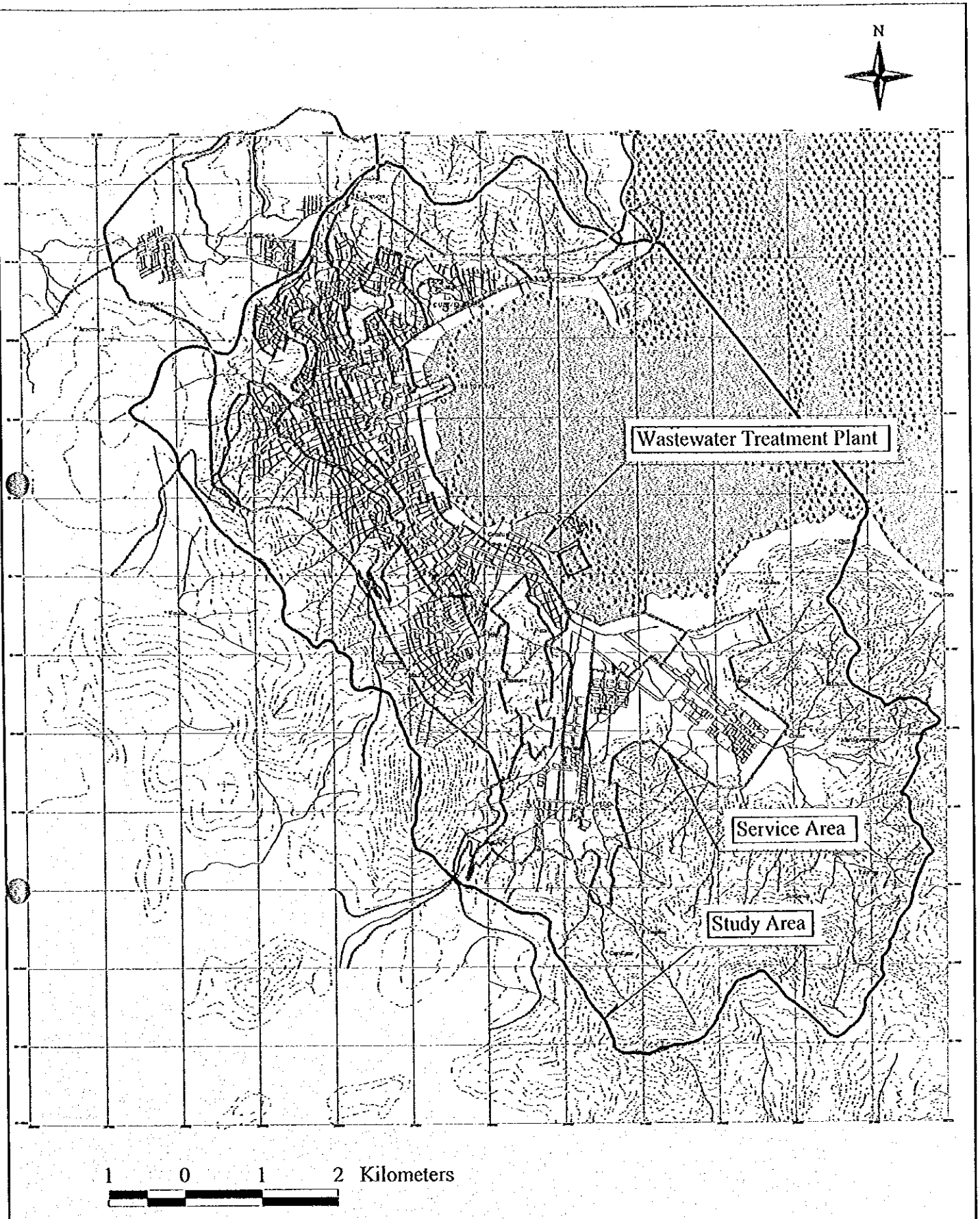
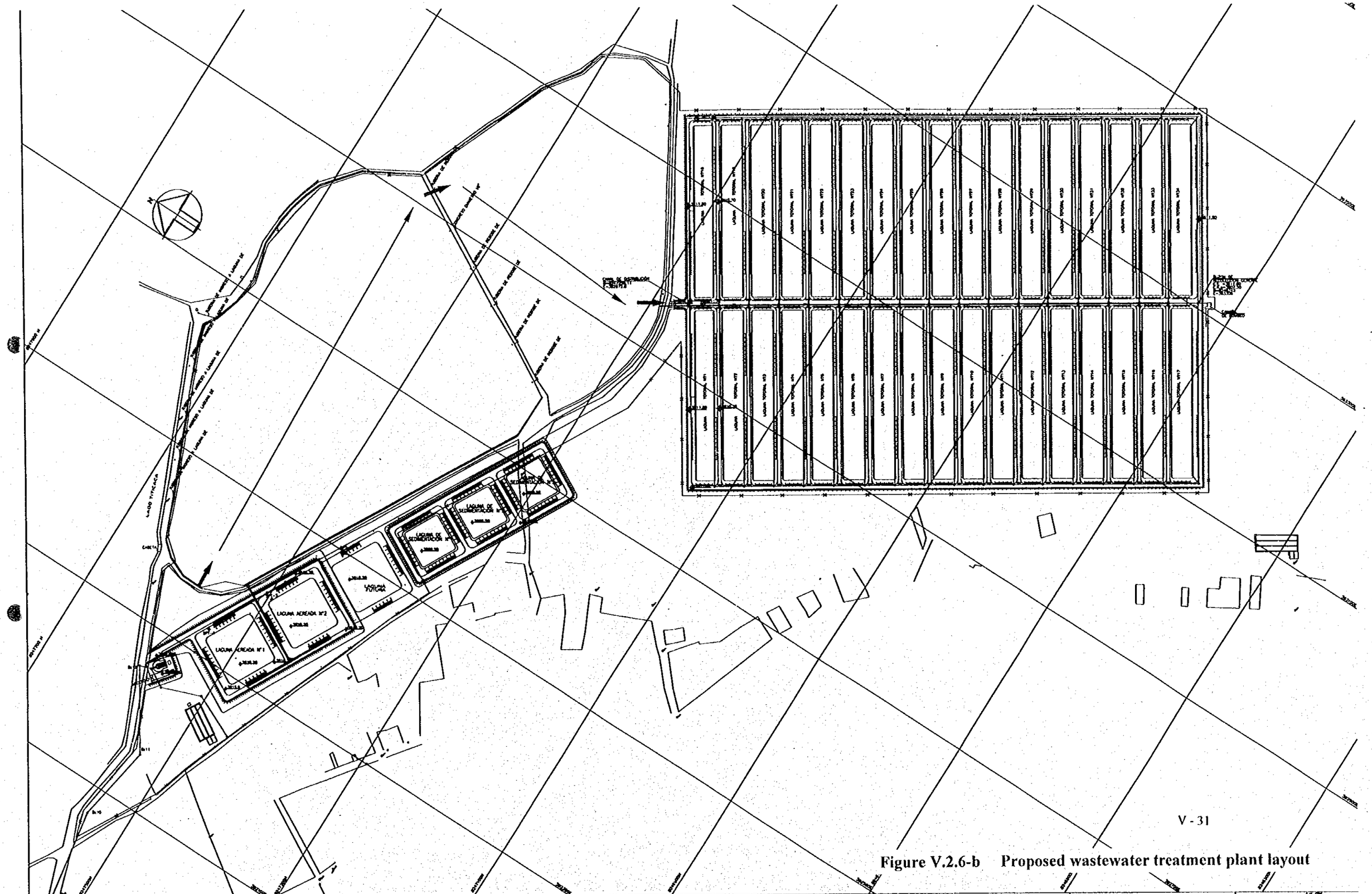


Figure V.2.6-a Proposed wastewater treatment plant layout



REVISTN					PRONAP		PLANOS/DOCUMENTOS DE REFERENCIAS		NOTAS	PRONAP	EJECUTADO POR:	ESTUDIO DEFINITIVO DE LAS OBRAS DE PRIMERA ETAPA		
N°	FECHA	TITULO/DESCRIPCTN	EJECUTADO POR	APROBADO POR	ACEPTADO	FECHA	TITULO	NUMERO	1) MEDIDAS Y COTAS EN METROS, EXCEPTO CUANDO SEAN INDICADAS.	FIRMAS Y APROBACION ESTA APROBACION NO IMPLICA LA ELIMINACION DE LA RESPONSABILIDAD CONTRACTUAL POR PARTE DE LA CONSULTORA	FIGUEIREDO FERRAZ CONSULTORIA E ENGENHARIA DE PROJETO LTDA.	PROYECTO BASICO DE PUNO PLANTA GENERAL DEL SISTEMA	REPUBLICA DEL PERU	N° CPS
0	-	-	-	-						REVISADO: / /	DIBUJANTE: DANIEL CASTILLO T. MAR/99			N° TT 1-97613/98-331
										APROBADO: / /	PROYECTISTA: MANUEL AGUILERA Z. MAR/99			DE-33-5412-001
										VISTO PRONAP: / /	APROBADO POR:	AREA PROYECTO : SISTEMA DE ALCANTARILLADO	E.P.S. EMSAPUNO S.A.	REV. 0 HOJA 1/19
											Firma REG. C.I.P.	SUB-AREA PROYECTO : TRATAMIENTO/HIDRAULICA		N° PRONAP 216-181-5-PL-ABA-17-01-0
														ESCALA 1:2000

Figure V.2.6-b Proposed wastewater treatment plant layout

Specifications for major wastewater treatment facilities are as follows:

TableV.2.21 Specifications of proposed wastewater treatment plant

Facilities	Specifications
1.Pump Station	
EB Puno	Submersible Pump, 200 l/s, 8.6 m, 30 kW, 2 sets(+1)
2. Aerated Lagoon	3 basins
Type	Rectangular Type
Dimension	64.0 m W x 80.0 m L x 4.0 m D
Aeration Power Level	22.35 kW (4 per Basin)
Retention Time	2.43 days
3. Existing Primary Lagoon	1 basin
Type	Facultative lagoon
Area	13.4 ha
Depth Average	1.5 m
Volume	204,600 m3
4. Existing Secondary Lagoon	1 basin
Type	Facultative lagoon
Area	7.9 ha
Depth Average	1.5 m
Volume	118,350 m3
5. Constructed Wetland	34 basins
Type	Sub-surface flow
Dimension	23.0 m W x 203.0 m L
Depth Average	0.3 - 0.5 m
6. Sedimentation ponds	3 basins
Type	Rectangular Type
Dimension	63.0 m W x 63.0 m L x 4.0 m D
Retention Time	2 days in year 2025

2.4.2 NON-STRUCTURAL MEASURES

(1) Institutional and operative capacity strengthening of EMSAPUNO

The on-going "Program MIO" of EMSAPUNO, scheduled to be completed in 2001, shall be further extended to effectively implement the proposed Master Plan. In addition to the above program, staff training program shall be established to provide the existing and future staff to upgrade their knowledge and skills for organization management, operation & maintenance of the facilities.

Training program may include:

- on the job training at various facilities by experienced personnel of EMSAPUNO or other organizations
- training at other water companies, such as SEDAPAL for familiarizing with new management practices and technologies.

Requirement of operation and maintenance staff will be discussed in Section 2.7.

(2) Sanitation promotion

In order to achieve improvement of public health, sanitation promotion among the residents of Puno City is essential. Possible strategies of sanitation promotion are as follows:

- Community management: Community members play a key role in managing the project.
- Involvement of women: Ensure the active participation of women in each stage of the project was ensured.
- Latrine construction: Household latrines to be constructed by family or community personnel.
- Community contribution towards investment costs: This facilitates local ownership of the program although the program may need state subsidies.
- Hygiene and sanitation education and training: This key activity will ensure the effective and sustained use of services. Training materials, such as *Figure V.2.7*, shall be developed for teachers and health workers.

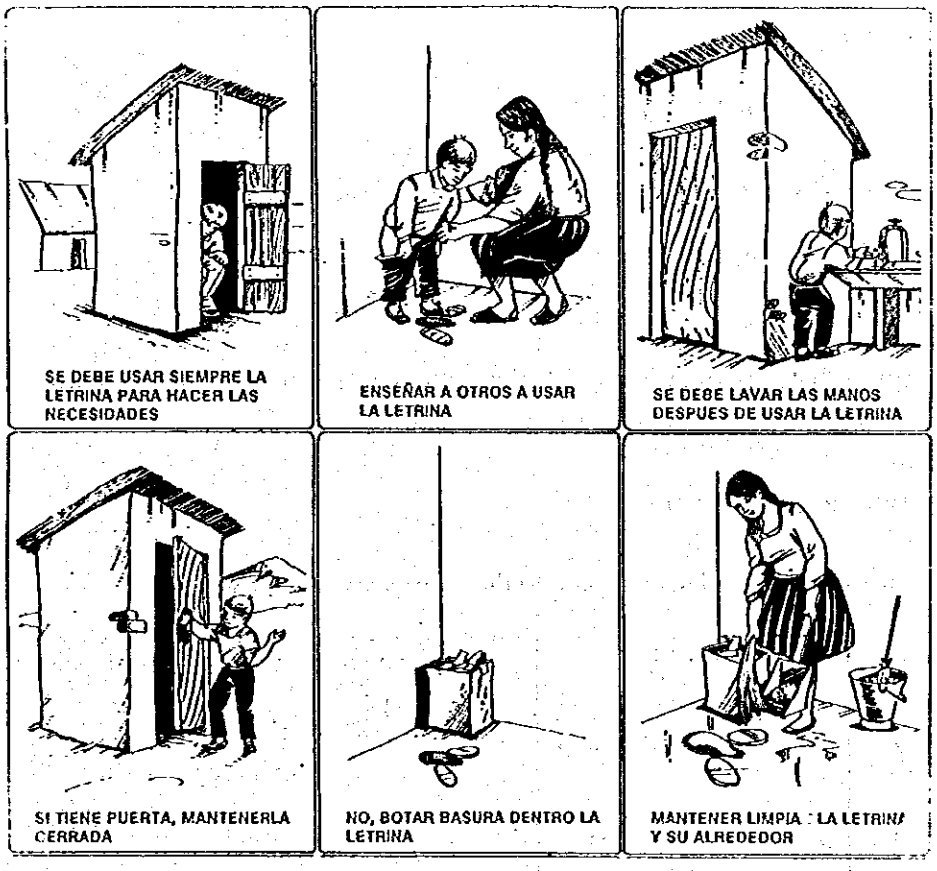


Figure V.2.7 Rules for correctly using a latrine – Reglas para buen uso de letrinas

Source: WHO (1998)

(3) Control of sewerage system use

Sewerage systems are often damaged through public misuse. This results from a public misconception that a sewerage system can be used to carry away any unwanted object. Adequate regulations setting forth proper uses of the system and public cooperation are required to properly maintain and control the sewerage system.

Regulations shall prohibit:

- discharge of explosive or flammable substances into the sanitary sewer
- discharge of corrosive or abrasive wastes
- roof drain connections to the sanitary sewer

Appropriate regulations shall be adopted and enforced by Puno Provincial Municipality, EMSAPUNO and communities.

2.5 IMPLEMENTATION PLAN

Construction works according to the phases are as follows:

Facilities	Sewer Pipe	Pump Station	Wastewater Treatment Plant
Year	2000-2002	2000-2002	2000-2002
Phase 1	ϕ 150-900, L =25,223m	EB EL PUERTO	EB Puno Aerated Lagoon × 2 Constructed Wetland × 34
Phase 2	ϕ 150-300, L = 46,832m	-	<2009> Sedimentation Ponds × 2
Phase 3	ϕ 150-300, L = 66,007m	<2017> EB EL PUERTO (Pump equipment renewal)	<2016-2017> EB Puno (Pump equipment renewal) Aerated Lagoon × 1 Sedimentation Pond × 1

2.6 COST ESTIMATE

Investment cost for the proposed project is estimated following the same procedure explained in section 2.3.3.

Table V.2.22 Investment Cost for Proposed Project

Unit: Thousand S/.

	Phase 1 (1998-2008)		Phase 2 (2009-2015)		Phase 3 (2016-2025)	
(1) Construction Cost		23,431		11,172		18,950
(2) Procurement of Maintenance Equipment		234		112		189
(3) Engineering Cost						
1) Detailed Design	1,406		670		1,137	
2) Construction Supervision	937		447		758	
Sub-Total		2,343		1,117		1,895
(4) Common Expenses						
1) General/Administration Expenses	200		200		200	
2) Land Acquisition	0		0		0	
Sub-Total		200		200		200
(5) Contingency		3,901		1,860		3,155
(6) IGV 18%		5,384		2,567		4,354
Total		35,494		17,028		28,743
				Grand Total		81,265

2.7 ORGANIZATION FOR OPERATION AND MAINTENANCE

2.7.1 WORK PROGRAM FOR OPERATION AND MAINTENANCE

Table V.2.23 Work items by type for sewer O & M

O & M Type	Working Items
Daily inspection	- Operation of pumping facilities - Operation of electrical facilities
Site investigation	- Identification of damage and blockage location - Identification of the percolation point of groundwater - Investigation of the overflow point at manhole - Measurement of the volume of settled soil at the sewer bottom
Pipe cleaning	- Removal of settled soil, silt and foreign matter
Rehabilitation	- Replacement/repair of damaged sewer

Table V.2.24 Work items by type for wastewater treatment plant O & M

O & M Work	Working Items
Daily work	- Measurement of wastewater flow - Removal of screenings at screen - Inspection of operation of aerators - Inspection of operation of electrical facilities - Inspection of operation of on-site sludge collection - Removal of grit and sediments at grit chamber (monthly)
Periodical work	- Inspection/repair of mechanical/electrical facilities (annually) - Overhaul of mechanical/electrical facilities (every 5 to 10 years) - Removal of dried sludge from sedimentation ponds (every 6 month)

Some major water quality parameters for wastewater, such as temperature, pH, BOD, COD, SS, number of coliform bacteria group, total colonies, etc., and temperature, pH and moisture content of sludge should be measured at the treatment plant.

2.7.2 ORGANIZATION FOR OPERATION AND MAINTENANCE

Table V.2.25 Required number of staff for O&M of the proposed sewerage system

(Unit: person)

Field & Position		Phase 1	Phase 2	Phase 3	Duty
Manager		1	1	1	Responsible for wastewater system
Sewer and Pumping Station					
Sewer	Engineer	-	-	-	Responsible for cleaning of sewers
	Foreman	-	-	-	Responsible for site works
	Worker	2	4	6	2 workers/team
	Driver	1	1	1	2 workers/team
					*Vehicle maintenance shall be done by EMSAPUNO
Wastewater Treatment Plant					
Operation	Engineer	1	1	1	Responsible for technical matters
	Foreman	1	1	1	Responsible for operation of each shift
	Operator	1	1	2	1 (2) operator/shift
Maintenance	Technician	1	1	1	Responsible for site works
	Worker	-	-	-	Cleaning
W. Quality Analysis	Chemist	1	1	1	Water quality control
Total		7	9	14	

Administration staffs for EMSAPUNO are not included in the table. Temporary workers are hired for the operation, such as totora cutting and sludge removal.

2.7.3 OPERATION AND MAINTENANCE COST

The operation and maintenance program, as stipulated in the preceding sections, requires the following items and annual funds for proper operation of the wastewater collection system and the wastewater treatment plant.

Table V.2.26 Operation and maintenance cost

(Unit: S/. /year)

Year	2008	2015	2025
- Personnel Expenses	167,802	222,641	294,000
- Electricity Cost	475,114	630,388	832,434
- Chlorine Cost	-	-	-
- Coagulant Cost	-	105,894	139,834
- Totora Cutting	3,853	5,112	6,750
- Repair Cost	87,818	116,518	153,863
Total	734,587	1,080,553	1,426,881

* Figures include IGV.

From the above study, overall implementation and disbursement schedule for the proposed plan is prepared, which is shown in *Table V.2.27.*

Table V.2.27 Implementation and Disbursement Schedule for the Proposed Plan

Item \ Phase / Year		Phase 1											Phase 2							Phase 3									
		1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Implementation Schedule																													
1. Preparation of Project																													
2. Pre-Construction Stage																													
2.1 Detailed Design																													
2.2 Bidding																													
3. Construction																													
3.1 Collection System																													
3.2 Sewage Treatment Plant																													
- Civil Work																													
- Mechanical/Electrical Work																													
4. Procurement of Maintenance Equipment																													
5. Test Operation																													
Disbursement Schedule	**Total Cost (Thousand S/.)**	Phase 1 35,494											Phase 2 17,028							Phase 3 28,743									
1. Land Acquisition	0																												
2. Administration	600			22	22	22	22	22	22	22	22	22	29	29	29	29	29	29	29	20	20	20	20	20	20	20	20	20	20
3. Construction Work	53,553																												
(1) Sewer - civil works	31,639			2,586	2,586	2,586							1,447	1,447	1,447	1,447	1,447	1,447	1,447	1,375	1,375	1,375	1,375	1,375	1,375	1,375	1,375	1,375	1,375
- mechanical/electorical	0																												
(2) Pump Station - civil works	34				34																								
- mechanical/electorical	363				181																181								
(2) Sewage Treatment Plant -civil	7,649				6,969								228								452								
- mechanical/electorical	13,868				8,489								817								4,562								
4. Maintenance Equipment	536					234							112									189							
5. Engineering Service	5,355		1,406		937								670		447					1,137		758							
6. Contingency	8,917		211	388	2,879	423	0	0	0	0	0	0	491	217	284	217	217	217	217	377	986	348	206	206	206	206	206	206	206
7. IGV (18 %) (for 3, 4, 5, 6)	12,305		291	535	3,974	584	0	0	0	0	0	0	678	299	392	299	299	299	299	520	1,360	481	285	285	285	285	285	285	285
Total Project Cost	81,265		1,908	3,531	26,072	3,849	22	22	22	22	22	22	4,471	1,992	2,598	1,992	1,992	1,992	1,992	3,429	8,936	3,172	1,886	1,886	1,886	1,886	1,886	1,886	1,886
8. Equip. Renewal (with IGV & conting.)	26,939			20			235	512						20		11,765	235	512					1,109	20		11,765	235	512	
9. Maintenance (with IGV)	23,896					550	574	599	623	659	696	735	778	913	945	978	1,012	1,046	1,081	1,114	1,149	1,181	1,219	1,256	1,289	1,322	1,357	1,391	1,427
Total Disbursement	132,100		1,908	3,552	26,072	4,400	831	1,133	646	681	718	757	5,249	2,925	3,544	14,735	3,238	3,549	3,072	4,544	10,085	4,354	4,214	3,163	3,175	14,974	3,478	3,790	3,313

2.8 PROJECT EVALUATION

2.8.1 ENVIRONMENTAL ASPECT

(1) Contribution for environmental improvement

Table V.2.28 Treated wastewater quality discharged to the inner bay

	Year	BOD_5 mg/l	Nitrogen (T-N) mg/l	Phosphorus* (T-P) mg/l
Phase1	2008	10	27	4.0
Phase2	2015	12	31	2.9
Phase3	2025	11	33	2.9

* Values for years 2015 and 2025 are with coagulant addition

Total pollution load reduction to the inner bay is shown in *Table V.2.29.*

Table V.2.29 Pollution load reduction by proposed measures in year 2025

	BOD_5		T-N		T-P	
	Discharge (kg/day)	Reduction (%)	Discharge (kg/day)	Reduction (%)	Discharge (kg/day)	Reduction (%)
Without project	2,541	0 %	1,292	0 %	155	0 %
With project	526	79 %	667	48 %	68	56 %

(2) Initial environmental evaluation (IEE)

Table V.2.30 Initial Environmental Evaluation (IEE)

Environmental concern	Evaluation	Remarks
Lake water pollution	B	Treated water reuse can be considered.
Sludge disposal	C	Sludge shall be disposed in a fenced area to prohibit public access outside the catchment area of the Puno inner bay.
Offensive odor and noise generation	B	Offensive odor and noise might be generated at aerated lagoons
Change of landscape	B	Large totora field will change the landscape

A: serious impact is expected
B: minor impact is expected
C: extent of impact is unknown
D: no impact

Only minor environmental impacts are expected from the implementation of the proposed plan.

2.8.2 TECHNICAL ASPECT

The evaluation of technical aspect is summarized in *Table V.2.31*.

Table V.2.31 Technical evaluation of the proposed plan

Criteria	Proposed plan
Previous operation experiences in Peru	O
Appropriateness of technology used	◎
Ease of O&M	◎
Effective implementation schedule for maximum results	O
Ability to respond to new technology	O

The proposed plan is considered technically feasible for implementation in Puno City.

2.8.3 SOCIAL ASPECT

Expectation of improvement of sanitation and lake environment improvement by sewerage system development is very high in Puno City according to the public awareness survey carried out by JICA study team. Implementation of the Master Plan will have the following social effects:

- Improvement of sanitary conditions
- Improvement of tourism development potential by improving the inner lake water quality

The proposed Master Plan is considered socially feasible for Puno City. Social acceptance and effectiveness of the Master Plan will be enhanced through public awareness program.

2.8.4 FINANCIAL ASPECT

(1) Conditions for Finance Analysis

In order to analyze the financial aspect of the proposed plan, there are some conditions as follows,

(a) Inflation rate is omitted.

(b) Profit tax of sewerage project is not counted.

(c) Income of sewerage project will be raised by (1) the increase of Puno population, (2) the increase of wastewater volume, (3) the increase of sewerage treatment service charge (5% up for every 3 year), and (4) the increase of the charge collection rate.

(d) KfW donates 12 million Deutsche Mark (S/. 21,180,000).

(e) The part of construction costs that are not able to be covered by KfW donation will be financed by local loan with 5% interest rate. The local loan will cover contingency of construction work, but will not cover IGV (Impuesto General a las Ventas is equal to General Sales Tax) of construction work.

(f) Maintenance equipment cost, maintenance cost, engineering cost will be financed by local fund without interest.

(g) Civil work for sewerage treatment is depreciated with 40 years.

(h) Maintenance equipment is depreciated with 10 years. After 10 years, the equipment will be purchased again at same price.

(i) Contingency (15%) is considered on the cost of construction work, maintenance equipment and engineering service.

(j) IGV (18 %) is considered on the cost of construction work, maintenance equipment, engineering service, contingency and maintenance.

(k) All facilities and equipment will be sold out by EMSAPUNO at the remaining value in 2025F/Y.

(j) Renewal costs of existing and proposed equipment are included in order to evaluate financial viability of the entire EMSAPUNO's sewage service.

(2) Financial Viability of Proposed Project

NPV (Net Present Value) and FIRR (Financial Internal Rate of Return) are used as indicators in order to estimate financial viability of proposed plan. To calculate NPV of proposed plan, discount rate is supposed as 5%, because internal trade rate between banks in Peru was 5% in August 1999 (Banco Central De Reserva Del Peru, August 1999).

Table V.2.32 FIRR and NPV for the proposed plan

(Unit: 1,000 S/.)

	FIRR	NPV
Proposed Plan	6.0%	S/. 2,277

Notice: Discount rate of NPV is 5%

FIRR and NPV are calculated by using the data of project cost, revenue, and donation. The details of these data are shown in *Table V.2.33*.

FIRR (6.0%) is larger than discount rate (5%) and NPV (S/. 2,277) turns out positive, hence the proposed plan is estimated as feasible. However, the feasibility is based on the conditions mentioned in the previous section, so finding sources of local loan with 5% interest and local fund without interest is crucial.

The change of cash balance is shown in *Figure V.2.8*. The "cash flow out" will expand in 2001 and 2017, because the cost for construction work will swell in these years, and "cash flow out" will increase in 2012 and 2022, because the cost for procurement of equipment will expand in 2012 and 2022. While the "cash flow in" will increase in 2001, because of the donation of KfW. Moreover, "cash flow in" will swell in 2025, because it is supposed that all facilities and equipment will be sold out by EMSAPUNO at the remaining value .

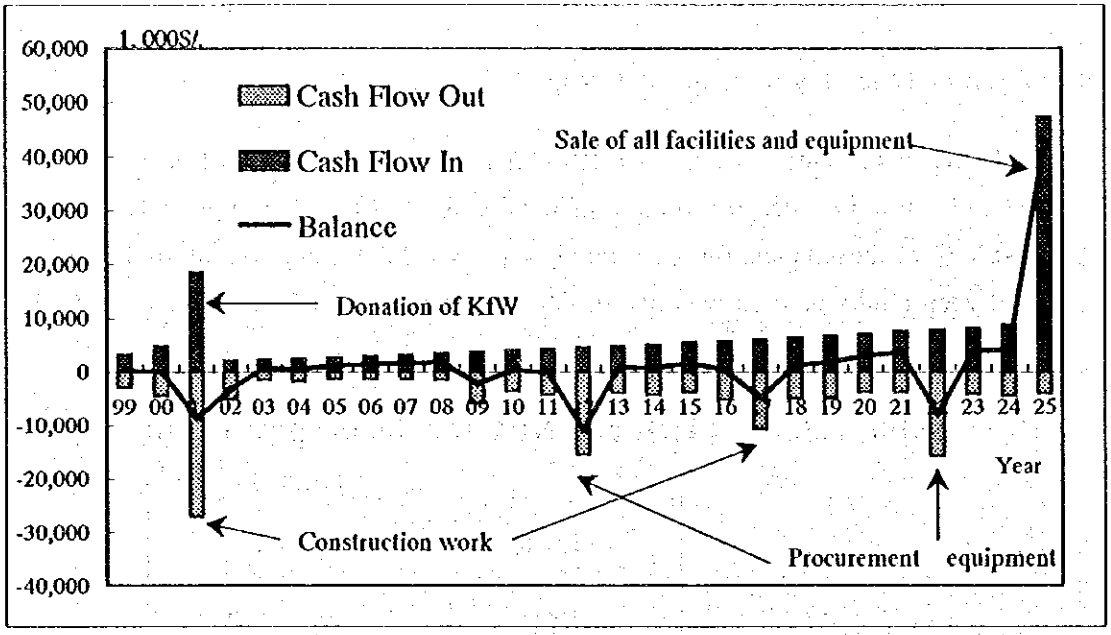


Figure V.2.8 Change of cash balance

(3) Financial Plan

In order that the proposed plan reaches the financially viable level over 5% of FIRR, one of the most effective method is receipt of subsidy or grant. Moreover, not only the financial aspect of the proposed plan but also economic aspect should be considered, because the implementation of the proposed plan for improving water quality of Lake Titicaca will also influence tourism and fish industry in Puno.

To make the proposed plan feasible, the following measures must be taken into account.

(a) Finding a finance source of low interest lower than 5%.

(b) Finding a finance source of no interest.

(c) Increasing a charge collection rate. Present collection rate is approximately 76%.

(d) Increasing a sewerage service charge (5% increase every 3 years). The present sewerage service charge in Puno is approximately 97soles/family/year (EPS EMSAPUNO S.A. MEMORIA ANNUAL 1998). The raise must be regulated and informed well to Puno citizens from the preparation stage of the project.

(e) In order to mitigate the impact of the above raise in the sewerage charge on the lower-income households, a certain type of tariff structure could be considered. For example, progressive tariff system by metering block (usage) with a low basic charge will help lower-income households with small water usage.

2.9 RECOMMENDATIONS

(1) Immediate implementation of sewerage development plan

As eutrophic level of the interior bay of Puno has reached hyper-eutrophic levels, immediate actions to reduce pollution load inflow to the bay are required. Implementation of sewerage development plan will greatly reduce the contaminants input to the lake as discussed in Section 2.8.

(2) Careful Maintenance of Constructed Wetland

The wastewater treatment system contains the process of a subsurface-flow type artificial wetland respecting the design which the Peruvian authority ambitious to construct. In general, the rate of pollution loads reduction by this facility is varied by several local conditions or a quality of maintenance. This type of wetland would not realize the expected performance unless a careful maintenance keeps the facility from being clogged. Therefore an experimental study is necessary to examine the efficiency and the proper maintenance of the facility. The study should also be carried out for alternatives such as a surface-flow type wetland or a treatment system using *Lemna,* and the most suitable type should be decided by the results.

(3) Sanitation promotion

In Puno health sub-region, infant mortality rate is 99 per 1,000 line births, which is much higher than 47, the national average of Peru in 1995. Sanitation promotion

through the proposed measures (Section 2.4.2) is urgently required to improve the present sanitary conditions of Puno City.

(4) Inflow control for sanitary sewer system

Large amount of inflow to the sanitary sewer system was observed during rainfall, which causes extreme wet weather flow. This may overload pump stations and treatment plants, resulting in the direct discharge of untreated wastewater to the interior bay of Puno. Enforceable regulations shall be established to prevent devised connections of rainwater sources to the sanitary system.

(5) Enhancement of environmental awareness

The result of the survey shows that people's awareness on deterioration of environmental sanitation is still not very high. This lack of environmental awareness causes misuse of sanitary sewer system and use of drainage ways as toilet. Enhancement of environmental awareness is strongly recommended as a key factor for the environmental improvement.

Table V.2.33 FIRR and NPV for the Proposed Plan

(Unit : S/.000)

Project expenditure estimation

Fiscal Year	Total(99-25)	1999FY	2000FY	2001FY	2002FY	2003FY	2004FY	2005FY	2006FY	2007FY	2008FY	2009FY	2010FY	2011FY	2012FY	2013FY	2014FY	2015FY	2016FY	2017FY	2018FY	2019FY	2020FY	2021FY	2022FY	2023FY	2024FY	2025FY
Land Acquisition	0																											
Proposed project administration expense	601		22	22	22	22	22	22	22	22	22	29	29	29	29	29	29	29	20	20	20	20	20	20	20	20	20	20
Construction work (a)	53,550		2,586	18,259	2,586							2,492	1,447	1,447	1,447	1,447	1,447	1,447	1,375	6,570	1,375	1,375	1,375	1,375	1,375	1,375	1,375	1,375
Contingency (15%) (b)=(a) x 0.15	8,033		388	2,739	388							374	217	217	217	217	217	217	206	986	206	206	206	206	206	206	206	206
IGV (18%) (c)=(a+b) x 0.18	11,085		535	3,780	535							516	300	300	300	300	300	300	285	1,360	285	285	285	285	285	285	285	285
Maintenance Equipment (d)	20,388		15		234	173	377					112	15		8,670	173	377				189	817	15		8,670	173	377	
Contingency (15%) (e)=(d) x 0.15	3,058		2		35	26	57					17	2		1,301	26	57				28	123	2		1,301	26	57	
IGV (18%) (f) =(d+e) x 0.18	4,220		3		48	36	78					23	3		1,795	36	78				39	169	3		1,795	36	78	
Engineering Service (g)	5,355	1,406		937								670		447					1,137		758							
Contingency (15%) (h)=(g) x 0.15	803	211		141								101		67					171		114							
IGV (18%) (i) =(g+h) x 0.18	1,108	291		194								139		93					235		157							
Maintenance (with IGV)	24,901	317	335	354	550	574	599	623	659	696	735	778	913	945	978	1,012	1,046	1,081	1,114	1,149	1,181	1,219	1,256	1,289	1,322	1,357	1,391	1,427
Total	133,103	2,225	3,887	26,425	4,399	831	1,133	645	681	718	757	5,250	2,925	3,544	14,736	3,240	3,551	3,074	4,543	10,084	4,352	4,214	3,162	3,175	14,973	3,478	3,789	3,313

Donation, Loan & Local Fund

Donation up to S/.21,180 (DM12MIL)	21,180	1,617	2,974	16,589	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Loan available for construction work	42,030	0	0	4,419	2,974	0	0	0	0	0	0	2,866	1,664	1,664	1,664	1,664	1,664	1,664	1,581	7,556	1,581	1,581	1,581	1,581	1,581	1,581	1,581	1,581
Local Fund of non-construction expense	69,893	608	913	5,417	1,425	831	1,133	645	681	718	757	2,384	1,261	1,880	13,072	1,576	1,887	1,410	2,962	2,529	2,771	2,632	1,580	1,594	13,392	1,897	2,208	1,732
Total	133,103	2,225	3,887	26,425	4,399	831	1,133	645	681	718	757	5,250	2,925	3,544	14,736	3,240	3,551	3,074	4,543	10,084	4,352	4,214	3,162	3,175	14,973	3,478	3,789	3,313

Revenue Estimation

wastewater flow estimation (61.3 l/s in 98FY)	3,522	65.8	70.4	74.4	78.4	82.5	86.8	91.1	97.2	103.7	110.3	117.2	124.4	128.7	133.2	137.7	142.3	147.1	151.7	156.4	160.9	166.1	171.1	175.6	180.2	184.9	189.7	194.6
increase rate of wastewater (each year / 98FY)A	57	1.0734	1.1485	1.2137	1.2790	1.3458	1.4160	1.4861	1.5856	1.6917	1.7993	1.9119	2.0294	2.0995	2.1729	2.2463	2.3214	2.3997	2.4747	2.5514	2.6248	2.7096	2.7912	2.8646	2.9396	3.0163	3.0946	3.1746
increase rate of sewerage fee (each year / 98FY)B	34	1.00	1.05	1.05	1.05	1.10	1.10	1.10	1.16	1.16	1.16	1.22	1.22	1.22	1.28	1.28	1.28	1.34	1.34	1.34	1.41	1.41	1.41	1.48	1.48	1.48	1.55	1.55
increase of collection rate (annually 1 %) C	31	1.01	1.02	1.03	1.04	1.05	1.06	1.07	1.08	1.09	1.10	1.11	1.12	1.13	1.14	1.15	1.16	1.17	1.18	1.19	1.20	1.21	1.22	1.23	1.24	1.25	1.26	1.27
estimated revenue (S/. 1450 in 1998 x A x B x C)	128,420	1,572	1,783	1,903	2,025	2,259	2,399	2,542	2,875	3,095	3,322	3,740	4,006	4,181	4,584	4,781	4,983	5,456	5,674	5,900	6,426	6,689	6,948	7,548	7,809	8,077	8,771	9,069

Administration detail(without contingency and IGV)

EMSAPUNO existing administration expense	21,249	787	787	787	787	787	787	787	787	787	787	787	787	787	787	787	787	787	787	787	787	787	787	787	787	787	787	787
Proposed project administration expense	601	0	22	22	22	22	22	22	22	22	22	29	29	29	29	29	29	29	20	20	20	20	20	20	20	20	20	20
Proposed project maintenance equipment	726	0	0	0	318	0	0	0	0	0	0	152	0	0	0	0	0	0	0	0	256	0	0	0	0	0	0	0
total	22,576	787	809	809	1,127	809	809	809	809	809	809	968	816	816	816	816	816	816	807	807	1,063	807	807	807	807	807	807	807

FIRR (Financial Internal Rate of Return)

Cash Flow In (Donation + Revenue + F/A sold)	187,851	3,189	4,757	18,492	2,025	2,259	2,399	2,542	2,875	3,095	3,322	3,740	4,006	4,181	4,584	4,781	4,983	5,456	5,674	5,900	6,426	6,689	6,948	7,548	7,809	8,077	8,771	47,320
Cash Flow Out (Project cost + EMSAPUNO)	154,352	3,012	4,674	27,212	5,186	1,618	1,920	1,432	1,468	1,505	1,544	6,037	3,712	4,331	15,523	4,027	4,338	3,861	5,330	10,871	5,139	5,001	3,949	3,962	15,760	4,265	4,576	4,100
Balance	33,499	177	84	-8,720	-3,161	641	479	1,110	1,407	1,590	1,778	-2,296	294	-150	-10,939	754	646	1,595	344	-4,972	1,287	1,689	2,999	3,586	-7,951	3,812	4,195	43,220

FIRR	5.967
NPR	2,277