CHAPTER – II STUDY AREA

CHAPTER – II

STUDY AREA

1. NATURAL CONDITIONS

1.1 LOCATION

The specific study area (53 km^2 ; as defined in *Figure I.1*) is located in the city of Puno (population 96,717 in 1995), its surrounding mountains and the Puno Interior Bay of Lake Titicaca. Puno city is mainly built around the western shores of Puno Interior Bay (17 km^2), which is itself a part of Puno Bay (550 km^2), a large bay at the north western corner of Lake Titicaca (8,167 km^2).

Lake Titicaca is at an altitude of 3,810 m and the town extends up the surrounding mountain slopes to about 4,200 m (on average). The study area therefore forms a self-contained watershed unit or basin within the general watershed area of Lake Titicaca.

1.2 TOPOGRAPHY, GEOLOGY AND GEOMORPHOLOGY

(1) Topography

The study area basin consists mainly of steep hills with slopes from 20° - 45°. They are highest (to 4500 m) and steepest at the western part behind Puno town where they consist mainly of extinct volcanic cones. At the eastern side of the study area, Puno Interior Bay is bounded by two peninsulas (Chullune to the north and Chimu to the south) that partially isolate it from the main (outer) part of Puno Bay. The distance between the points of these two peninsulas is about 2 km and is occupied by a vegetated mud bank that is continuous apart from two narrow navigation channels that connect Interior and Exterior Puno Bays.

There are only two valley systems of significant size in the Puno basin. Both are located in the south west, the largest being the Jayllihuaya valley (17.5 km^2) and the other the Salcedo valley. In total, the Puno basin contains 123 river and stream beds and rainwater gullies or drains that collect and discharge water to the

Puno Interior Bay. Flows vary from zero in the dry season to a maximum of a few m^3/sec in the wet season.

(2) Geology

The mountains of the Puno basin are mainly of igneous origin, but there are also considerable areas of sedimentary and metamorphic. The lower areas are occupied by alluvial and lacustrine (lake) sediments.

1.3 CLIMATE

The Peruvian altiplano does not have a typical tropical climate due to its altitude. The Puno climate is classified as cold and semi-wet with relatively low average temperatures and pronounced wet and dry seasons. At Puno, the annual average temperature (1930-1998) is 8.7°C, with monthly averages ranging from a maximum of 10.4°C (December) to a minimum of 6.0°C (July). This is the mildest climate of the Peruvian altiplano and is due to its relatively low altitude and proximity to Lake Titicaca, whose temperature never falls below about 10°C.

Rainfall in Puno is determined mainly by latitude and altitude and to a smaller extent by topographic conditions created by the surrounding mountains and distance from the lake. The annual average rainfall at Puno (1964-1998) is 711.3 mm. These range from 391.4 mm (1966) to 1290.6 mm (1984). There is a pronounced wet season from November to March when 79% of the annual rainfall occurs, with transitional periods in April and September/October. In the dry winter period (May –August) only 3.8% of the annual rainfall occurs, with zero rainfall recorded commonly in these months.

Pan evaporation rates are high and exceed annual rainfall. The maximum rates occur between September and December and average 200.2 mm/month. Minimum rates occur during the colder months of May to August with an average of 145.6 mm/month. Over the year as a whole the pan evaporation totals about 2000 mm, about three times the annual rainfall.

The atmospheric pressure at Puno is 61.2% of that at sea level. There is little seasonal variation, with average values ranging from 645.2 mb (November and December) to 646.7 mb (May). Slight pressure differences between the Puno

Basin and Lake Titicaca are responsible for the observed dominant wind directions - onshore during the day and offshore at night.

Detailed wind statistics are only available for the period June 1995 to May 1996, and consist of recordings of wind speed and direction taken daily at 07.00, 13.00 and 19.00 hours. At 07.00 conditions in Puno are generally calm. On these mornings with wind, the dominant directions are from E to SE (onshore, 19.1% of occasions) and NW (9.0% of occasions). At 13.00 hours, the strongly dominant direction was from E (73.7% of occasions). At 19.00, the dominant directions were from S, W-SW and E. Average wind speeds were low, ranging from 1.0 m/s to 6.5 m/s.

Puno has a generally sunny climate, with an annual average of 8.2 hours/day. The sunniest months occur in the dry winter and transitional months, with July having the highest average (9.6 hours/day). The lowest sunshine occurs during the wet summer season, the lowest average being in January (6.2 hours/day).

1.4 HYDROLOGY

The zero datum of the Lake Titicaca is at 3,809.93 m above sea level.Lake Titicaca undergoes changes in level of a time-scale of several years. Since the 1910s, the inter-annual range of variation has been 6.37 m at Puno. The absolute highest level is 3,812.58 m (in April 1986) and the absolute lowest is 3,806.21 m (in December 1943). The annual range of level has varied between 1.80 m (in 1986) and 0.04 m (in 1983). (Roche, M.A., Bourgas, J., Cortes, J. and Mattos, R. 1992. Climatology and Hydrology of the Lake Titicaca Basin. In: C. Dejoux and A. Iltis (Editors). Lake Titicaca: a Synthesis of Limnological Knowledge. ISBN 0-7923-1663-0. Kluwer, The Netherlands. pp63-88).

Lake Titicaca is fed by inflows from the surrounding rivers and by rain falling directly onto the lake. Losses are due to evaporation and surface drainage leaving via the Desaguadero river. From a water balance for the whole catchment area and for the lake, an evaporation is estimated to be 1628～1720 mm/yr.

Catchment area of Puno Interior Bay is about 35 km^2, and much smaller than that of Puno Exterior Bay (4,650km^2) or the whole Lake Titicaca (49,010 km^2). The water level of Puno Interior Bay shows annual fluctuations similar to that of precipitation, though evaporation does not show significant fluctuation. Therefore, the water level of the Interior Bay strongly depends on the outflows of major rivers.

2. SOCIAL AND ECONOMIC CONDITIONS

2.1 ECONOMY

(1) The Peru Economy

The Peruvian economy has grown fast since 1993, but growth has been unbalanced. The industrial sector remains underdeveloped, and there is still a high dependence on mineral exports. Agriculture contributes 13% of total GDP, and is still very important as a provider of employment. In contrast, mining , which accounts for 40% of total exports, only employs 1 % of the working population. So despite impressive aggregate figures for economic growth, economic expansion has not taken place across the board.

(2) The Puno Department's Economy

Puno department's total production (S/.2,442 million in goods and services) was 1.9% of the Gross Domestic Product (GDP) in 1996. The principal activity was agriculture, hunting and forestry which contributed 20.9% of Puno's GDP, followed by commerce, restaurants and hotels with 15.7% and other services with 18.4%.

The contribution of the Region of Moquegua-Tacna-Puno, to Puno's GDP was 47.7% in 1970, and 35.8% in 1995. Puno's GDP has recorded an annual average growth of 1.6% in the 1970~95 period.

In the 1990~95 period, production recovery was recorded which reflected in the regional and Puno departmental economy, both with 6.4%. (In 1997 Puno's economic growth was 7.0%)

2.2 POPULATION

Table II.2.1 shows past and expected future (to 2025) populations, numbers of families, and households in Puno City from 1972 to 2025.

Table II.2.1 Population, Families and Households of Puno

	Year	Numbers of			Average Sizes			
		Population (1)	Families (2)	Households (3)	Family (1)/(2)	Household (1)/(3)	Annual Increase Ratio Family	Annual Increase Ratio Household
Actual	1972	40,453	8,370	8,274	4.83	4.89		
	1981	67,628	13,790	12,796	4.90	5.29	-0.90%	-0.61%
	1993	91,877	22,969	21,372	4.00	4.30		
	1995	96,717	24,179	23,115	4.00	4.18		
Projections	1998	108,457	28,363	26,014	3.82	4.17		
	2000	114,579	30,509	27,821	3.76	4.12		
	2005	129,888	36,179	32,519	3.59	3.99	-0.90%	-0.61%
	2010	145,201	42,307	37,483	3.43	3.87		
	2015	160,508	48,922	42,724	3.28	3.76		
	2020	174,287	55,569	47,834	3.14	3.64		
	2025	185,004	61,704	52,355	3.00	3.53		

Source; INEI Census data for the year 1972, 1981 and 1993, and INADUR's estimation for 1995.
Note; Projections for the year 1998 to 2025 were made by the JICA Study Team.

2.3 LAND USE

(1) Existing Land Use of Puno City

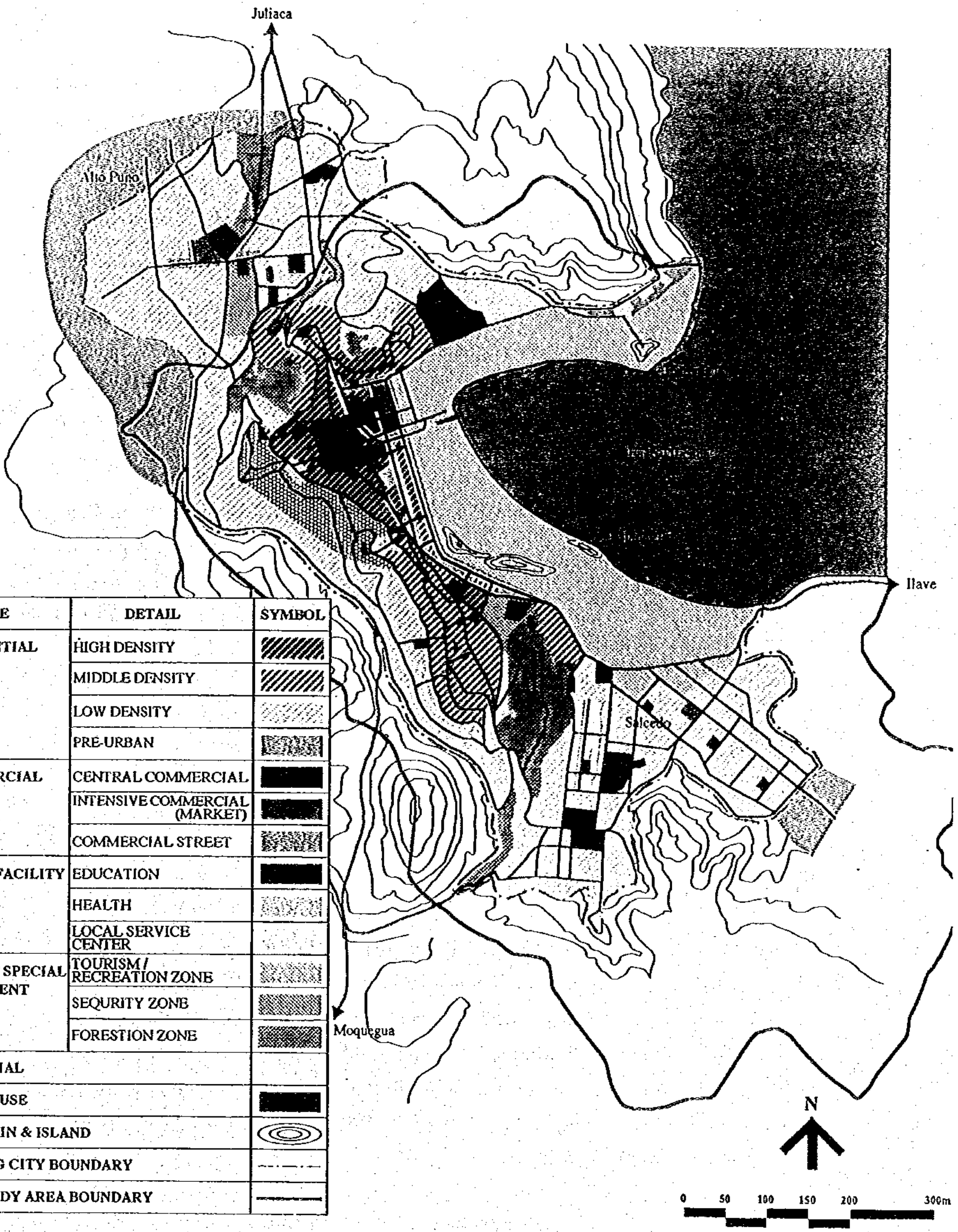
Puno City has 108,457 inhabitants[*1], with an area of 2,179.1 ha[*2], equivalent to a gross population density of 52 inh/ha. The built-up area covers 74% (1,613.4 ha) of the total city area, and the population density in the built-up area is 67 inh/ha. The rest of the area is composed of approved housing project areas, pre-urban areas in the urban periphery, hills and islands. ([*1] According to the updated INEI data of year 1998, *2) Based on the measurement on the existing land use map of INADUR)

Residential use is a predominant land use pattern, with 86% (including the approved housing project areas) of the whole city area.

(2) Future Land Use Plan

In the General Zoning proposal made by the INADUR, residential use was predominant, with 66% of the total area in the year 2010, which contained the areas of special treatment (25%) and the commercial area (3%). Secondly included the tourist-recreational area and areas of afforestation, which reflected the special focus of the plan towards the decontamination of the Lake Titicaca, as well as the reinforcement of the tourist activity. The total city area will be expanded to 3,553.3 ha, of which 2,941.6 ha (83%) is allocated for the future built-up area.

Figure II.2.1 shows the future land use zoning plan for the year 2025 reviewed in this Study.



USE	DETAIL	SYMBOL
RESIDENTIAL	HIGH DENSITY	
	MIDDLE DENSITY	
	LOW DENSITY	
	PRE-URBAN	
COMMERCIAL	CENTRAL COMMERCIAL	
	INTENSIVE COMMERCIAL (MARKET)	
	COMMERCIAL STREET	
PUBLIC FACILITY	EDUCATION	
	HEALTH	
	LOCAL SERVICE CENTER	
ZONE OF SPECIAL TREATMENT	TOURISM / RECREATION ZONE	
	SEQURITY ZONE	
	FORESTION ZONE	
INDUSTRIAL		
SPECIAL USE		
MOUNTAIN & ISLAND		
EXISTING CITY BOUNDARY		
JICA STUDY AREA BOUNDARY		

Figure II.2.1 Reviewed Future Land Use

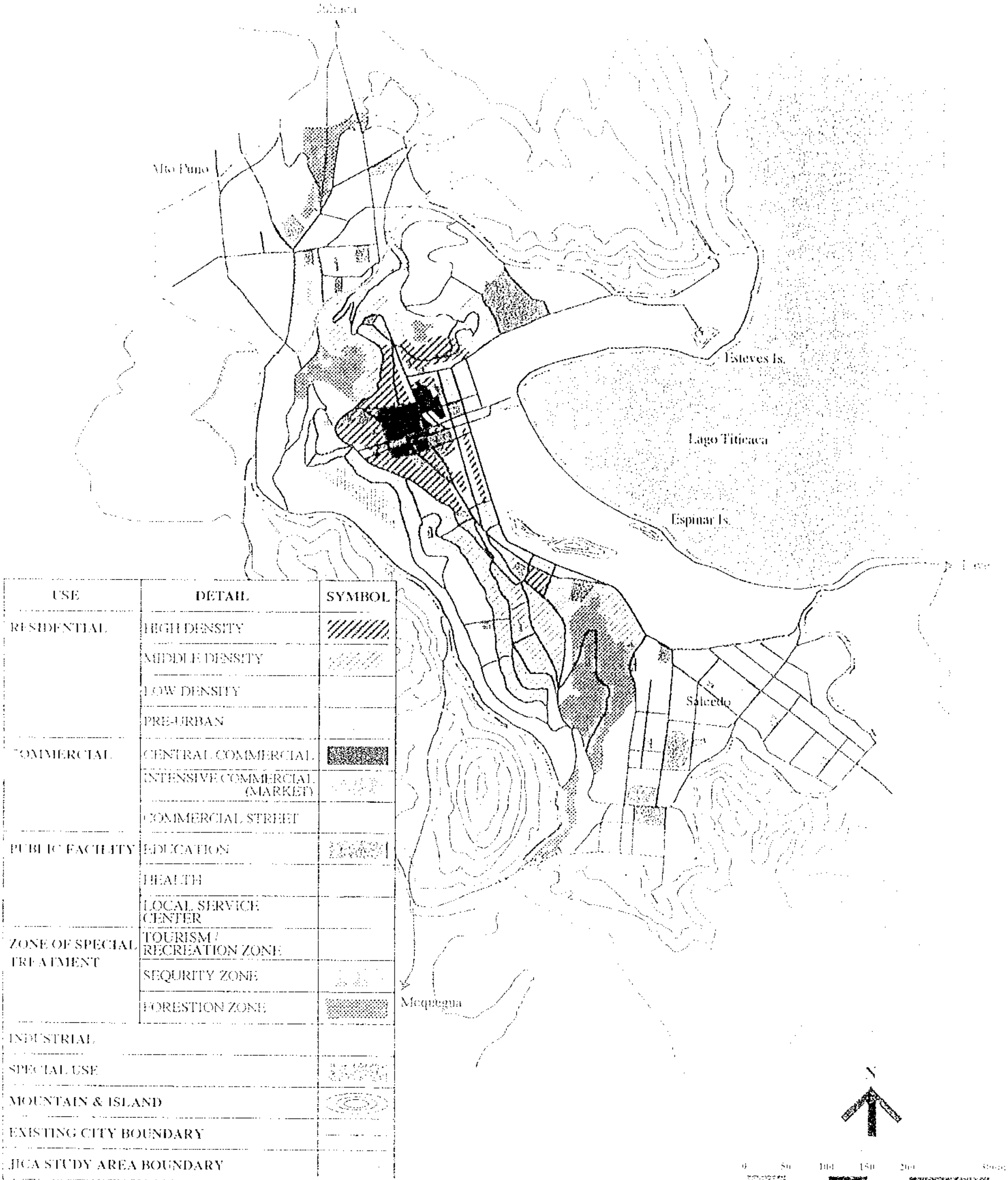


Figure II.2.1 Reviewed Future Land Use

2.4 LAKE WATER USE

(1) Drinking Water

Due to shortage or contamination of water sources such as groundwater, main part (400,000 m^3/month) of drinking water is supplied by pumping lake water from Puno Exterior Bay near Chimu. However, the intake of lake water could be jeopardized by the spread of the pollution problems of Puno Interior Bay.

(2) Fisheries

At present Puno Interior Bay has a small fishery based on two species of native fish, carachi amarillo (*Orestias luteus*) and carachi gris (*O. agassii*) and one introduced (in 1954) species of fish, pejerrey (*Basilichthys bonariensis*) (Ocola and Torres, 1997). Most fishing takes place in the eastern and southern parts of the Interior Bay.

Following a cholera outbreak in Puno in 1993/94, all fishing activity in Puno Interior Bay was prohibited. Fish were believed to have been at least partially responsible for spreading the disease, picking up the cholera pathogen from untreated sewage wastes released to the Inner Bay. The ban has not been lifted and all fishing activities in the Inner Bay are illegal. The fisheries authorities have insufficient resources to enforce it.

2.5 TRANSPORTATION

(1) Existing Conditions

1) Road Transportation

The form of the city, along the lakeshore, creates a linear system of road in the longitudinal axes of north-south, between Alto Puno (exit to Juliaca) and Salcedo (exit to Ilave or Desaguadero), with an exit toward the University (to the east) and another toward the road to Moquegua (to the south-west). The flows of vehicles of Puno City are essentially toward the north (69%) through Juliaca City, toward the south side (18%) going to the frontier with Bolivia, and toward the south-west (13%) going to Moquegua and Tacna.

The vertical axes of east-west(from the lakeshore to the hill area) are not much used, because of poor condition of the roads with narrow, steep, non-paved and bad drainage conditions. This situation causes problems of congestion especially in the central market areas, rain water drainage and city cleaning.

2) Rail Transportation

Puno City has a railroad station, a property of Ferrocarriles Corp.'s National Company (ENAFER), that is located in the center, on the Av. La Torre. A cargo line goes to Puno Port. The Puno railway is a branch of the main line of Arequipa-Juliaca-Cusco.

At present, there are three passenger train services a week between Puno and Arequipa/Cusco. The numbers of passengers of Puno-Cusco and Puno-Arequipa are 36,410 and 7,454 (in 1998) respectively. The train service between Cusco and Puno is important for tourism. As for the cargo transport, the most significant goods are fuel and beer.

3) Lake Transportation

ENAFER also operates a cargo ship between Puno and Bolivia crossing Lake Titicaca. They have 2 ships, one of 2,000 tonnes and the other of 1,800 tonnes, with loading capacities of 750 tonnes and 1,050 tonnes respectively. The major goods are wheat for import and soy beans for export. Annual voyages are between 116 to 168 (1 ship per 2 to 3 days), with loads varying from10 to 100 tonnes;

There are also tourist boat services to the Uros and other tourist islands. The number of tourists has been rapidly increasing and reached 39,000 persons in 1995, almost 3 times as many as that in 1993.

2.6 TOURISM

(1) Existing Conditions

Puno City is located on Peru's most importat tourism corridor of Lima - Cusco – Bolivia. The number of tourist arrivals to Puno is still low and most of the tourists stay for a short period at present (1.3 days on average, in Puno Province). Puno Province has great potential for development as one of the major tourist destinations in Peru considering its attractive nature and cultural resources.

In 1998, in Puno City, there were 63 accommodations in total: 16 hotels, 21 hostals and 26 non-categorized lodgings; with a total capacity of 1,197 rooms, and 2,373 beds in 1998 according to the Director of Lodging Establishments. There were also 40 travel agencies, 23 tour agents, 45 vehicles for tourists, and 228 restaurants according to the data of the regional office of MITINCI.

The number of tourists in Puno Province rapidly increased from 73,286 tourists in 1993 to 109,376 tourists in 1998 with an average annual increase rate of 9.8% (although the number decreased in 1997). It is remarkable that the number of foreign tourists accounted for more than half of the total tourists visiting Puno Province since 1996, with their number reaching 57,660 in 1998. The recent increase of the number of the tourists was probably due to the ending of terrorism and the effects of sales promotions.

(2) Ecotourism Development Plan by PELT

PELT conducted a study on the projection of tourists to Puno District, as shown in the report of "The Definitive Study for Collection, Treatment and Integrated Management of Sewage in Puno City". The tourist projection by PELT was rather ambitious from the viewpoint of regional development as follows:

- Puno District's share of tourists in the whole Puno Department was projected to be 90%, while the current Puno Province's share of hotel arrivals (in 1997) is estimated to be around 60%.
- PELT's estimated the length of tourist's stay in Puno to increase to 4.0 days in the year 2025, which is equivalent to three times the present length of 1.3 days.

Figure II.2.2 shows the layout of the eco-tourism zone proposed by PELT.

According to the plan, the total development area for the eco-tourism zone is 225ha (net area). The inundation area, which extends from Esteves Island in the north to Espinar Island in the south, was proposed as a debelopment site for tourism and recreational facilities.

(3) Tourism Development Plan by JICA/MITINCI

JICA conducted another study on the national tourism development in cooperation with MITINCI from September 1998 to March 1999 ("Master Plan Study on National Tourism Development (Phase-1)"). The projections by JICA/MITINCI seem to be a little conservative.

Puno District's share of tourists in the whole Puno Department was projected to be 70%. The length of tourist's stay in Puno was projected to be 2.6 days in the year 2025, which is equivalent to twice the present length of 1.3 days.

(4) Tourism Development Scenario for the Study

The differences between PELT's Ecotourism Development Plan and the JICA/MITINCI's National Tourism Development Master Plan must be derived from the different planning approaches. PELT's plan is based on a micro-view, but the JICA/MITINCI's plan on a macro-view. In other words, the PELT's plan is focused on a desirable regional development for Puno City, but the JICA/MITINCI's plan is derived from the national tourism development plan.

In this Study, the layout of tourism development plan is based on PELT's plan. The planning frame such as the number of tourists or hotel rooms is based on the JICA/MITINCI plan, because conservative projections can be rather favorable for planning facilities to avoid the risk of excessive investment.

Based on the above-mentioned consideration and data, the tourism development scenario for Puno City is assumed as follows:

① Required hotel rooms in the year 2025 will be 6,528 (of all hotel classess) in total.

② Of which, 1,337 rooms (3 to 5 star classes) will be located along the shore of Puno Interior Bay (inundation area).

③ Most hotels would be located in the zone from Esteves Island to Puno Port, because of the following reasons;

- A hotel construction plan has been committed and the site has been already acquired within the zone near the existing hotel (Esteves Hotel).
- A lake shore road (Boulevard) runs in the zone.
- Lake water quality in front of the zone is relatively clean and favorable for a resort.
- Less influence by/on the traffic congestion problem of the city center.
- Accessibility to Puno Port which is the gateway to the Lake Titicaca boat tour

④ After the year 2015, the other zones between Puno Port and Espinar Island, and further southern zone will be developed for the expansion of tourist and recreation area towards 2025 for both domestic and international tourists, as proposed in the PELT proposal.

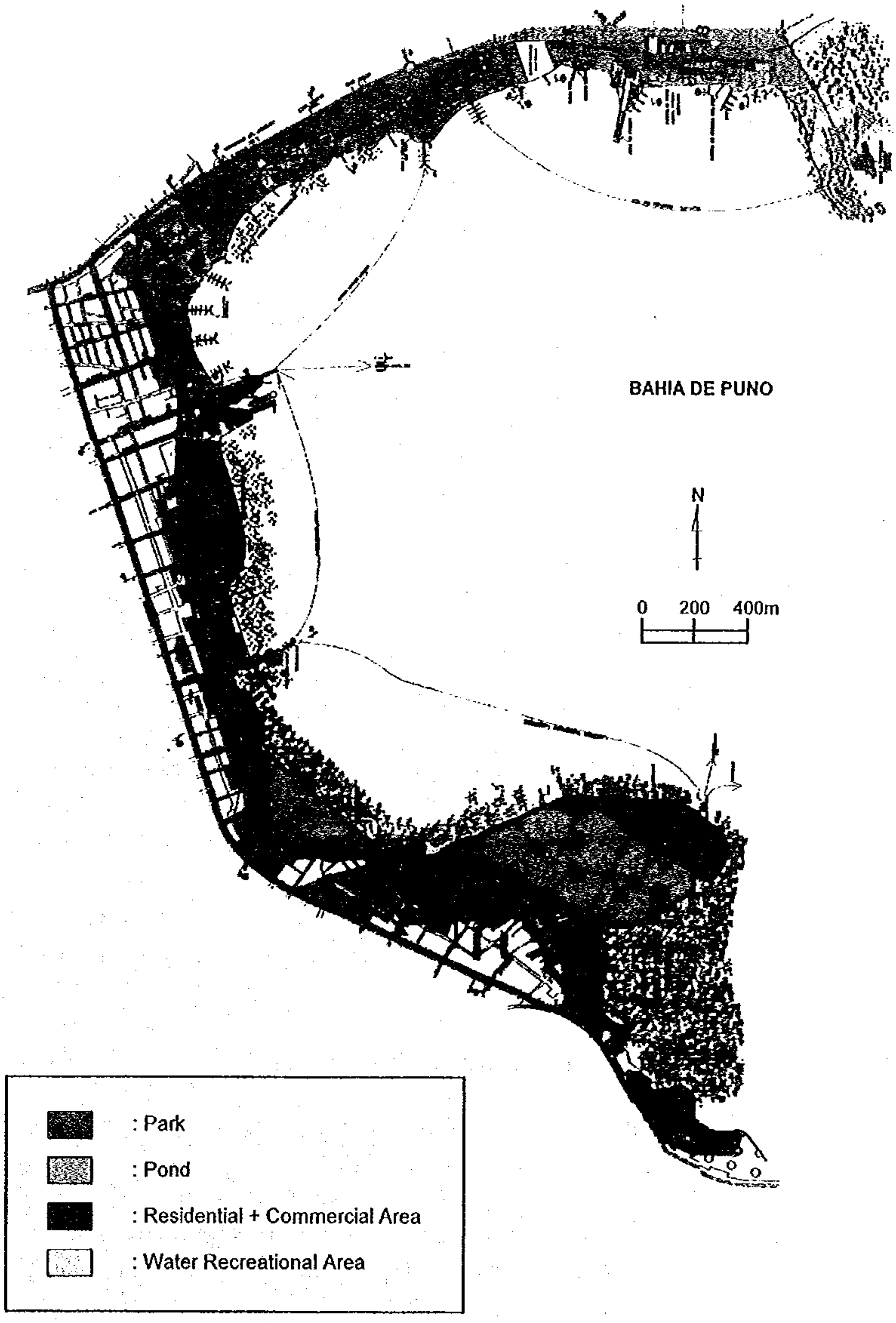


Figure II.2.2 Layout of the Ecotourism Development Plan (PELT)

3. ORGANIZATIONS AND INSTITUTIONS

3.1 GENERAL STRUCTURE OF ADMINISTRATIVE BODIES

Peru is divided into regions, departments, provinces and districts. In 1998, beside Lima Metropolitan which is considered as a specified department, there were 22 departments including the Puno Department.

The Puno Department has 13 provinces, with the total surface area of 71,999 km^2 and the total population of 1,079,849. Puno Province has 6,493 km^2 of surface area and its total population was 201,215 persons in 1998.

Puno Province has 15 districts, including the Puno District, which covers 461 km^2. In 1998, its total population was 100,168 persons, of which 91,877 were in urban areas and 8,291 in rural areas.

The Puno City (La Ciudad de Puno) is the capital of the Puno Department, Puno Province, and Puno District.

(1) Municipality Administrative Institution

The municipalities in Peru are considered to be the eligible administrative organizations composing the local government. There are municipalities in the capital of Peru (Lima), and capitals of departments, provinces and districts. Besides, there are communal municipalities delegated in inhabited centers, rural communities and housing under agreement with the respective Provincial Municipal Council. The Municipality is composed by the Mayor and the Councilmen.

(2) Organization Structure of Puno Provincial Municipality

The organization of the Puno Province Municipality can be classified into two different levels: government level and administrative management level.

In the government level, the Municipality Mayor and Councilmen are responsible for making policies aimed at the development of the Municipality, and managing the Municipal administrative organs in line of these policies. The Municipal Council is the promoter organ of local development.

3.2 ENVIRONMENTAL MANAGEMENT

(1) Related Laws and Regulations

After the Stockholm Conference on human-life environment (Sweden, 1972), and especially after the United Nations' Conference on Environment and Development (Brazil, 1992), Peru has made many efforts to improve its legal system on environment. In consequence of these efforts, a relatively orderly legal system was developed which is seen to be conformable to the modern international principles on environment.

Nevertheless the legal system on environment in Peru is really abundant and it dates back several decades. Among the laws and regulations on protection of natural resources and conservation of the environment, the ones that have most effect to all areas of the national activities are the followings:

- Law No. 26410 (22-12-94), approving the Law on the National Council of the Environment - CONAM.
- Law No. 26834, Law of Protected Natural Areas, pub. 04-07-97.
- Law No. 613, Law on Environment and Natural Resources, pub. 20-01-1998.

(2) Relevant Organizations

At the regional level, **the Binational Special Project of Lake Titicaca** (PELT, Proyecto Especial Binacional Lago Titicaca) is the agency in charge of representing the Peruvian government in cooperation with the Bolivian government for the sustainable development of the Lake of Titicaca.

The PELT is a decentralized organ of the National Institute of Development (INADE). It has technical, economic and administrative autonomy.

Beside the PELT, there is **the Multisectorial Committee of Ecology and Environment** (Multisectorial de Ecología y Medio Ambiente, hereinafter refer to as the Multisectorial Committee), which also takes an important role in the conservation of natural environment of the Puno Bay.

3.3 MANAGEMENT OF SEWERAGE SYSTEM AND DRAINAGE SYSTEM

(1) Relevant Laws and Regulations

The most important laws or regulations relevant to the establishment and management of the sewerage systems and drainage systems in Peru are:

- Law 17752 (24-07-69), General Law on Waters; additionally modified by 014-92-EM (03-06-92).
- Supreme Resolution 006-90-VC-1200 (08-02-90), regulation on the Services of Drinkable Water and Sewer System.
- Law No. 26338, Law on General Services of Sanitation, published on 24 July 1994.
- Ministerial Resolution No. 397-96-PR, approves the new organization and the new regulation on the Organization and Functions of the Project Special National Program of Drinkable Water and Sewer System (PRONAP), pub. 22-09-96.
- Law No. 26737, disposes that the Authority of Waters are in charge of managing the exploitation of materials that are carried and deposited on the waters of their rivers or canals, pub. 05-01-97.

In particular, the Law on General Services of Sanitation is an important law, which inscribes that the Municipalities should provide the services of: (1) potable water, (2) sanitary sewerage, (3) drainage, (4) sanitary excreta disposal, as four basic sanitation services to the Peruvian people living in the urban areas.

(2) Relevant Organizations

At the regional level, the Municipalities are responsible for contributing the sanitation services to their residents. The Municipalities can grant the right of contributing service to the EPS (Service Providing Enterprise), approve the tariffs proposed by the EPS in conformity to the relevant norms issued by the SUNASS.

In Puno Province, the right of supplying piped water and treating wastewater is transferred to **the Municipal Enterprise for Potable Water and Sewerage of Puno (EMSAPUNO).**

The EMSAPUNO is an enterprise established by mean of transferring the right of contributing service from the municipality to the EPS. Its main function is offering services of drinkable water and sewer system to the residents in the urban areas of Puno Province as the basic needs for the preservation of the public health.

3.4 MANAGEMENT OF SOLID WASTE

(1) Relevant Laws and Regulations

Among the laws and regulations related to the management of solid waste in Peru, the Law No. 26338: "Law on General Services of Sanitation", promulgated on July 24, 1994 is the most important one.

(2) Relevant Organizations

At the regional level, according to the Law of Municipality Organization No.23853, the municipality is the sole agency being responsible for public cleaning which includes: the collection, transportation, and disposal of solid wastes, sweeping of streets and avenues. The Municipality can grant the right of contributing these services to the EPS, approve the tariffs proposed by the EPS in accordance to the relevant norms issued by the SUNASS.

In the Municipality of Puno, **the Division of Public Cleaning**, a sub-organ of the of the Directorate of Public Service, is in charge of performing the public cleaning service.

The Division of Public Cleaning (DPC) is responsible for technical and administrative issues relating to the management of solid wastes. Its operational finance is derived from the municipal revenues.

CHAPTER – III PUNO INTERIOR BAY

CHAPTER – III

PUNO INTERIOR BAY

1. GENERAL

Figure III.1.1 summarizes of the last several decade's records of environmental events, meteorological and hydrological observation, and development of sewerage systems. The figure also shows the transition of environmental conditions of Puno Interior Bay.

Water quality of Puno Interior Bay has been deteriorating since the 1970's or earlier. In particular, the western shoreline is affected mainly by domestic and commercial wastewater which is discharged from the urbanized area of Puno City.

Based on the results of surveys and data, the main features of Puno Interior Bay are summarized below.

2. PHYSICAL CONDITIONS

2.1 THE SHAPE OF THE PUNO INTERIOR BAY

The Puno Interior Bay is characterized by shape as described below.

- The Puno Interior Bay is elliptic form and measures 2.4 km from Esteves I. to Espinar I. by 3.5 km from port to the mouth of channel.
- Two channels link the Puno Interior Bay and the Puno External Bay.
- The surface area of the lake is approximately 17.3 km^2.
- The average depth of water in the Puno Interior Bay is approximately 2.4 m, and the maximum depth is from 5 m to 6 m. The surface area of less than 2 meters depth accounts for 50 % of the interior bay.

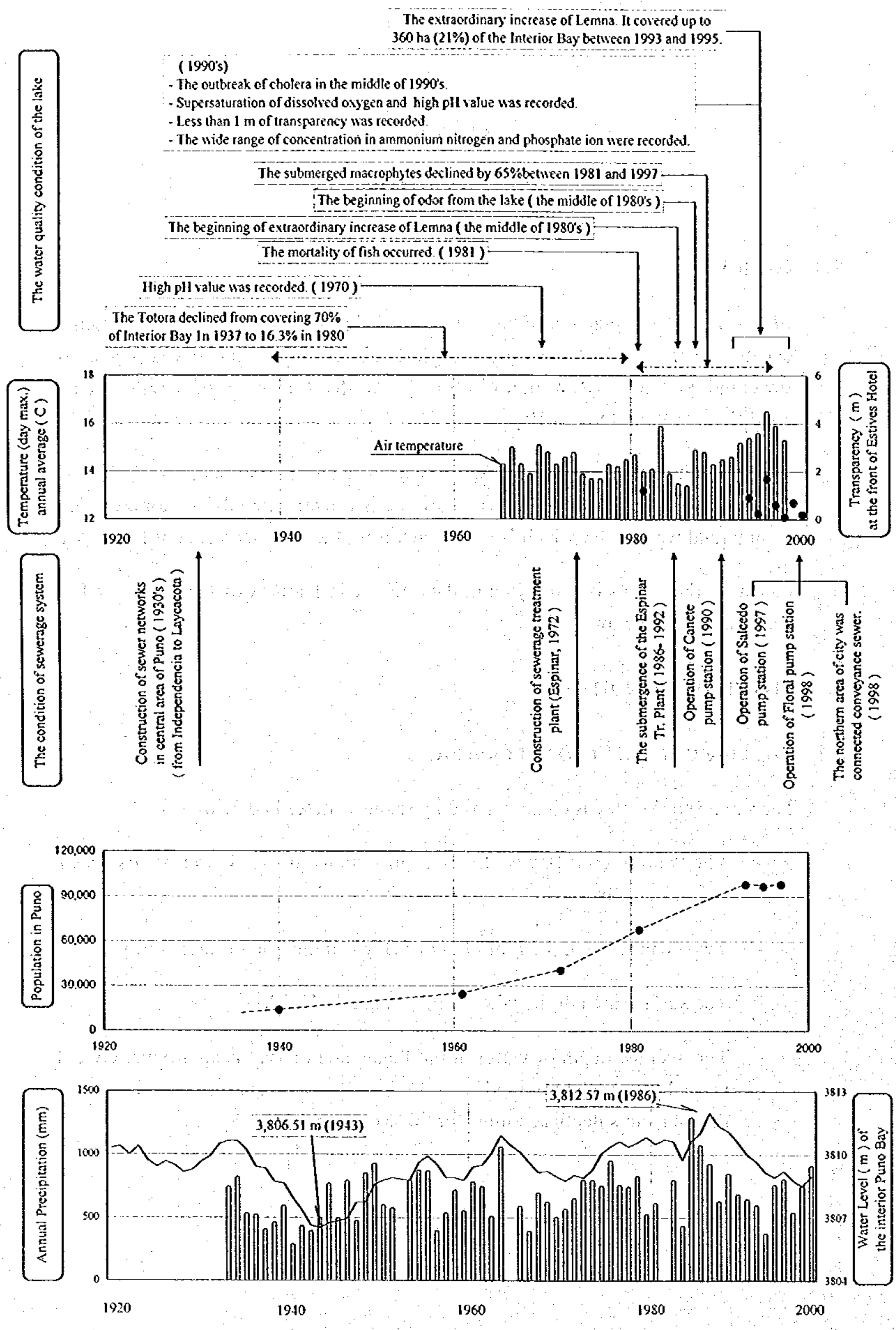


Figure III.1.1 The Transition of Puno Interior Bay and Its Background

2.2 THE CHARACTERISTIC OF CATCHMENT AREA IN THE PUNO INTERIOR BAY

The catchment area of the Puno Interior Bay is $35.5km^2$. The distance from the port to the boundary of the basin is approximately 4 km, and the altitude of the boundary point is nearly 4,200 m on average. The average slope from the top to the lake is 9.5 %, and the slope in the urbanized area is reduced with the decreasing distance to the lake.

2.3 WATER MOVEMENT IN THE LAKE

The formation of water movement in the lake is caused by inflow, variation of water level, wind and water specific gravity that is caused by variation of water temperature. In case of the Puno Interior Bay, it is expected that the water movement is caused by the wind during the daytime.

JICA Study Team and PELT carried out the water movement survey in July 1999, which was measured by tracing a buoy. According to the results of the survey, the water movement in the Puno Interior Bay was too slow to be identified clearly.

However, there seems to be slow water movement from the east to the west in the lake judging from the following circumstantial evidence.

- The dominant east wind in the afternoon all the year round.
- The movement of the *Lemna*.
- Distribution of water quality in the lake.
- A clear movement was observed at the surface of the channel between the Interior Bay and the Exterior Bay. The westward flow of 10 cm/sec was observed at the depth of 1.5 m under the easterly wind condition.

2.4 SEDIMENTATION

Based on the existing study report, the sedimentation dynamics are still poorly known, but the sedimentation rates vary according to the faces and between Lago Grande and Lago Huiñaimarca, according to the existing study report. For example, in the case of carbonate deposits, the velocity of sedimentation rate is 0.5 mm/yr for Lago Grande, whereas in Lago Huiñaimarca this rate is 10 times higher.

3. Chemical Conditions

3.1 Available Data of the Lake (The Transition of the Water Quality in the Lake)

Figure III. 1.1 suggests that the deterioration of water quality in the Puno Interior Bay became conspicuous in 1980's. It can be said the deterioration of the lake was caused by the following factors;

- Rapid increase of population in Puno city
- Insufficiency of sewerage system

Additionally, the wastewater treatment plant was submerged from 1986 to 1992, and all of the wastewater in Puno City was discharged into the lake without treatment. Consequently, it assumed that moreover, the Puno Interior Bay was contaminated.

3.2 Existing Water Quality in the Lake (Results of Water Quality Survey)

The JICA Study Team and PELT conducted several times of lake water quality surveys at 12 points from January to September 1999. Based on the results of the surveys, the water bodies in the Puno Interior Bay were classified as described below. (refer to *Figure III.3.1*)

Water body-A : Heavily polluted water body, which is affected mainly by directly discharged wastewater from the urbanized area of Puno.

Water body-B : Significantly polluted water body, which is caused by the effluent of the Espinar wastewater treatment plant.

Water body-C : Slightly polluted water body, which has undergone a kind of purification and dilution.

Water body-D : Clean water body, which has no external pollution source.

Water body-E : Clean water body, which has the same water quality level as the Puno External Bay.

The reasons of the above mentioned water quality condition are assumed as below.

- The location of the discharged pollution load into the lake is concentrated in the western shore from the University of Altiplano (UNA) to the Espinar wastewater treatment plant.
- It seems that the diffusion of discharged wastewater in the western water bodies of the interior bay is disturbed by the easterly wind during the daytime.

The characteristic water quality in the Puno Interior Bay is mentioned as below.

- **Temperature :** Temperature ranged from 10°C to 16°C in January to September. The vertical variation, which measured at 20 % depth and 80 % depth, was less than 3°C.
- **pH :** pH ranged from 7.8 to 9.5 with an average of 8.9.
- **DO :** The lowest DO was observed near the Espinar Wastewater Treatment Plant with 1.0 mg/l. The second lowest was found at the central point (No.13) of the western water body with 1.3 mg/l.
- **Transparency :** Transparency ranged from 0.2m to 2.7m with an average of 1.3m.
- **SS :** The highest was 110 mg/l at times of stormwater discharge. The average was 27mg/l.
- **BOD :** The averages ranged from 7 mg/l at No. 5, No. 21 and No. 23 in the eastern water bodies to 27 mg/l at the point near the Espinar Wastewater Treatment Plant.
- **Total nitrogen (T-N) / Total phosphorus (T-P) :** The T-N averages ranged from 2 mg/l to 6 mg/l. The T-P averages were from 0.2 mg/l to 1.6 mg/l. The higher concentrations of both parameters were observed in the western water bodies and near the Espinar Wastewater Treatment Plant.

3.3 LAKE SEDIMENT QUALITY

The JICA Study Team and PELT conducted a lake sediment quality survey at 12 points where the water quality survey was carried out. Features of sediment quality are shown in *Figure III.3.2* .

The polluted sediment, namely, high organic content was observed in water bodies-A and B.

The average contents of the sediment in the Puno Interior bay were 16.1 mg/g-dry solid as total nitrogen and 1.4 mg/g-dry solid as total phosphorus.

The total contents of the sediment were estimated as 13,389 tons of nitrogen and 1,164 tons of phosphorus, given the assumptions below. These amounts of nutrients are equal to the discharged pollution load from Puno City for 20 to 40 years.

Assumption:

The average contents of sediment	Total nitrogen = 16.1 mg/g-dry solid Total phosphorus = 1.4 mg/g-dry solid
Moisture content	76 %
Specific gravity	2.2
Subject area	525 ha (the western part of Puno Interior Bay: inside the line which links Hotel Esteves with Espinar Wastewater Treatment Plant)
Sediment thickness	0.3 m thickness
Discharged Pollution Load	Total N = 865 kg/day Total P = 142 kg/day (refer to chapter III, section 4)

Estimation :

Total volume of sediment	831,600 tons = 5,250,000 m2 x 0.3 m x (1.0-0.76) x 2.2
Total content	N: 13,389 tons = 831,600 ton x 16.1 mg/g-DS P: 1,164 tons = 831,600 tons x 1.4 mg/g-DS
Equivalent Discharged P. L.	42 years = 13,389 tons / (865 kg/d. x 365 d.) 22 years = 1,164 tons / (142 kg/d. x 365 d.)

3.4 DISCHARGE OF POLLUTION LOAD TO THE LAKE

The JICA Study Team and PELT conducted a discharged pollution survey at five (5) drainage channels and Espinar wastewater treatment plant. Based on the results of this survey, the share of discharged pollution load from the treatment plant was calculated as below.

Table Ⅲ.3.1 Discharge of Pollution unit : kg/day

		Treatment Plant	Drainage Channels	Total
Rainy Season	BOD_5	3,924 (94 %)	246 (6 %)	4,170
	Inorg.-N	1,016 (90 %)	110 (10 %)	1,126
	T-P	98.3 (91 %)	10.2 (9 %)	108.5
Dry Season	BOD_5	1,514 (83 %)	317(17 %)	1,831
	T-N	303 (73 %)	110(27 %)	413
	T-P	29.0 (62 %)	18.0 (38 %)	47.0

As evident from the above, the following facts are obtained:

- The treatment plant is a major external pollution source in the Puno Interior Bay.
- Discharged pollution load in the rainy season is larger than twice the pollution load in the dry season..
- The share of discharged pollution load from the treatment plant in the rainy season is bigger than in the dry season.

3.5 EVALUATION OF PRESENT CONDITIONS

(1) Regional Distribution of Existing Water Quality in the Puno Interior Bay

The regional distribution of water quality in the Puno Interior Bay is characterized as follows.

- The outlet of the wastewater, namely, drainage channels from Puno City and Espinar treatment plant, is concentrated in the western shore of the lake.
- The diffusion of the wastewater is prevented by the east wind during the daytime.

Consequently, the water body in the western part of the lake is significantly deteriorated.

(2) Eutrophic Level

Based on the results of water quality survey, it was found that the nutrient concentration was high. Judging from the concentration of nutrients, the eutrophic level of the Puno Interior Bay reached hyper-eutrophic (>0.1 mg/l as total Phosphorus).

Table III.3.2 Eutrophic Level unit : mg/l

		Median	Maximum	Minimum
Rainy Season	T-N	1.2	7.35	0.16
	T-P	0.3	1.12	0.14
Dry Season	T-N	3.07	8.93	1.25
	T-P	0.39	4.76	0.06

In general, nitrogen or phosphorus are limiting nutrients in lakes. Based on the balance of the existing whole pollution load in the lake, ratio of nitrogen/phosphorus is approximately 5. Consequently, Nitrogen is assumed as the limiting nutrients in the Puno Interior Bay. The other side, it is assumed that nitrogen and phosphorus participate with limiting nutrient in view the relationship with total nitrogen and total phosphorus of water quality in the lake.

(3) External Pollution Sources

As mentioned above, the deterioration of the Puno Interior Bay is caused by discharged wastewater through drainage channels and the treated wastewater from Espinar wastewater treatment plant. Based on the results of survey, the shares of discharged pollution loads from the treatment plant and from five (5) drainage channels are calculated as below.

Table III.3.3 External Pollution Sources unit : %

		BOD_5	T-N	T-P
Rainy Season	Espinar WWTP	94	90	91
	Drainage Channels	6	10	9
Dry Season	Espinar WWTP	83	73	62
	Drainage Channels	17	27	38

As evident from the above, it is assumed the treatment plant is the major pollution source in the water environment of Puno Interior Bay.

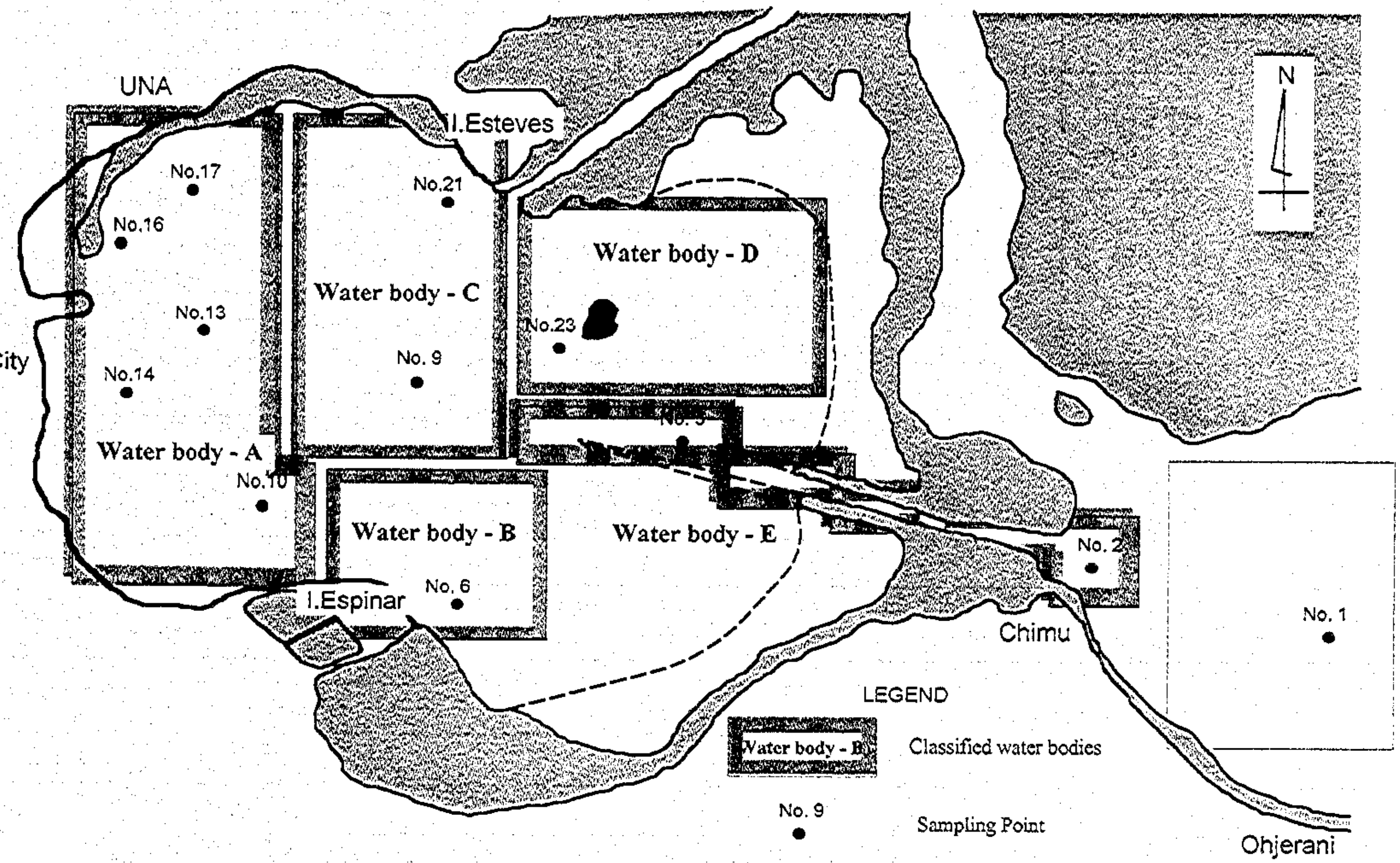
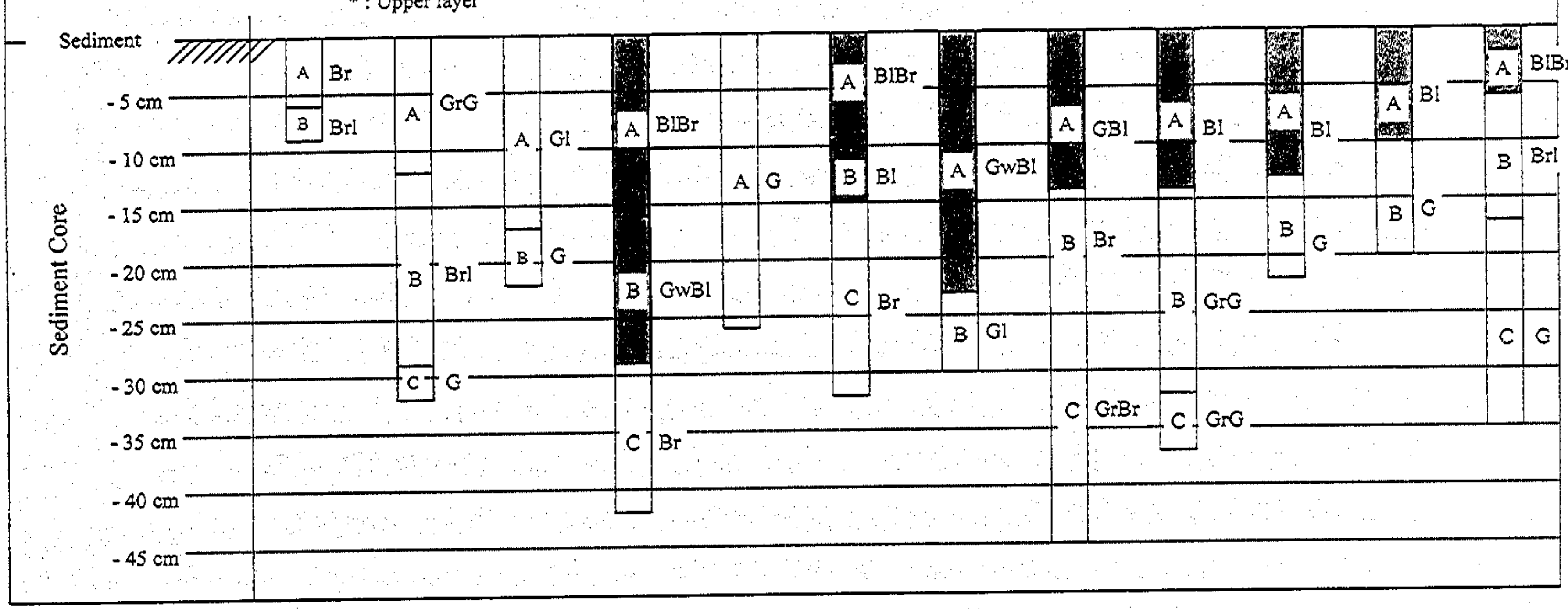


Figure Ⅲ.3.1 Sampling Points of Field Survey and The Classified Water Bodies in Puno Interior Bay

Figure III.3.2-a The Results of Sediment Quality Survey (Date : 6 Feb. 1999)

Items \ Point No.		1	2	5	6	9	10	13	14	16	17	21	23
Sediment Temperature* (C.)		18	18	16	16	15	16	17	17	16	16	16	15
Oxidation reduction potential * (mV)		-75	-307	-16	-378	-325	-346	-389	-288	-321	-363	-32	-308
Moisture Content (%)	A	79	75	62	93	82	90	72	90	88	90	78	87
	B	74	74	38	76	-	66	43	83	89	89	74	78
	C	-	-	-	78	-	93	-	69	-	-	-	65
Ignition Loss (%)	A	13	13	10	48	22	66	66	77	24	27	43	26
	B	12	16	6	31	-	25	19	89	29	29	33	12
	C	-	-	-	23	-	-	-	27	-	-	-	18

* : Upper layer

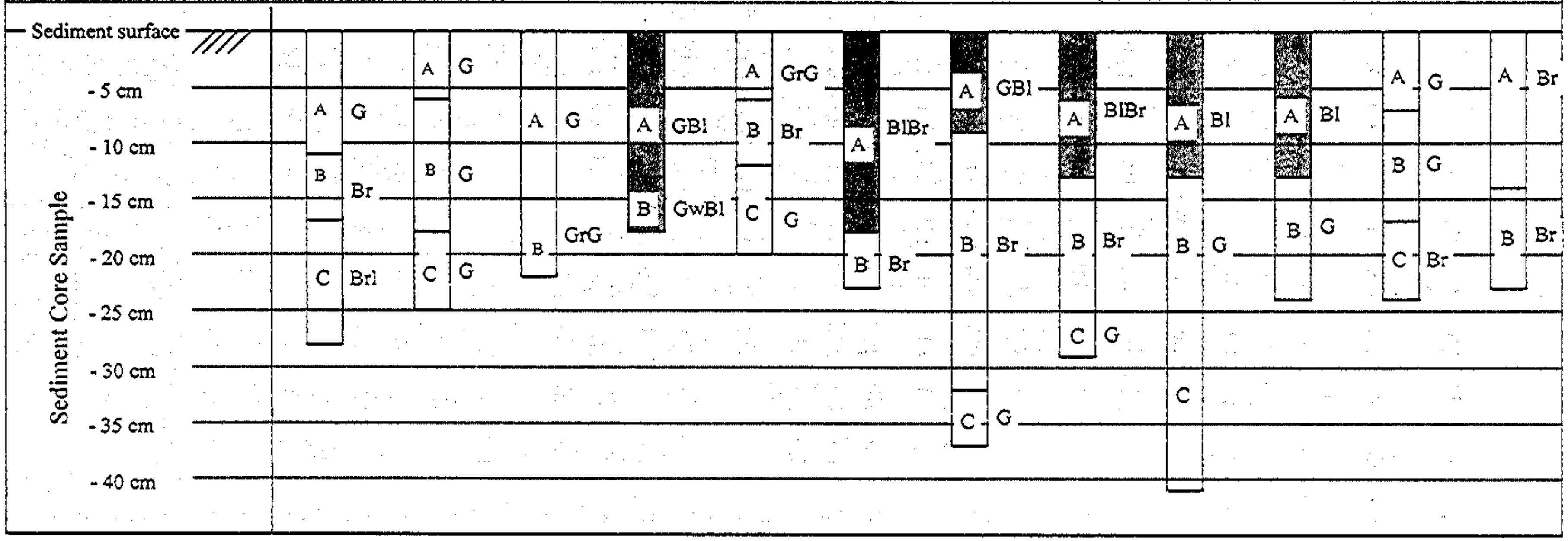


Color of sediment

Bl	: Black	BlBr	: Blackly Brown	Gl	: Gray light	GrBr	: Grayish Brown	[shaded]	: Black / Blackly color
Br	: Brown	G	: Gray	GBl	: Blackly Gray				
Brl	: Brown light	GrG	: Greenish Gray	GwBl	: Gray with Black				

Figure III.3.2-b The Results of Sediment Quality Survey (Date : 5 Jul. 1999)

Items	Point No	1	2	5	6	9	10	13	14	16	17	21	23
Sediment Temperature (C.)	A	13.7	13.3	13.5	13.9	13.9	14.4	13.8	14.3	14.2	15.0	14.7	14.1
	B	13.7	13.9	14.0	14.0	14.3	14.3	14.4	13.8	14.6	14.6	14.9	13.4
	C	14.2	13.9	-	-	14.8	-	14.9	15.9	14.7	-	14.9	-
Oxidation reduction potential (mV)	A	-209	-235	-191	-368	-271	-356	-355	-378	-333	-324	-310	-380
	B	-271	-86	-246	-354	-293	-340	-384	-370	-259	-247	-341	-323
	C	-37	-149	-	-	-343	-	-283	-357	-160	-	-194	-
Moisture Content (%)	A	64	74	63	87	84	87	88	84	76	92	85	88
	B	71	66	36	81	86	83	74	76	82	87	79	71
	C	58	30	-	-	80	-	49	75	76	-	68	-
Ignition Loss (%)	A	8	8	7	29	32	33	30	23	13	28	48	22
	B	12	9	4	21	25	26	20	19	19	27	33	22
	C	7	2	-	-	21	-	12	20	28	-	32	-
Total - N (mg/g-dry)	A	4.00	9.02	8.77	16.66	8.01	13.96	6.08	12.29	14.37	34.22	52.90	23.43
	B	4.04	1.76	3.34	26.89	20.73	23.04	14.68	6.75	22.40	21.97	33.44	9.28
	C	2.74	1.11	-	-	4.02	-	2.74	3.77	9.27	-	35.05	-
Total - P (mg/g-dry)	A	0.70	0.89	0.77	2.46	1.39	1.75	0.49	0.45	2.19	0.29	-	1.38
	B	1.01	0.32	0.95	0.75	1.07	0.85	1.03	1.19	1.13	5.10	1.65	1.25
	C	0.05	0.46	-	-	1.14	-	1.20	1.07	1.56	-	2.33	-



Color of sediment

Bl	: Black	BlBr	: Blackly Brown	Gl	: Gray light	GrBr	: Grayish Brown
Br	: Brown	G	: Gray	GBl	: Blackly Gray		
Brl	: Brown light	GrG	: Greenish Gray	GwBl	: Gray with Black		

(shaded) : Black / Blackly color

4. POLLUTION LOADS

- ESTIMATION OF EXTERNAL POLLUTION LOADS BY THE EXISTING DATA -

Pollution loads which are generated in the catchment area and discharged into Puno Interior Bay have been roughly estimated. Pollution sources were classified as follows:

- Domestic wastewater
- Effluent of sewage treatment plant
- Commercial / Institutional wastewater
- Agricultural wastewater
- Livestock wastewater
- Leachate from illegally dumped solid waste

Basically, pollution loads have been estimated from the existing data on unit pollution loads and socio-economical conditions. Results of the estimation are shown as below:

< Total Pollution Loads discharged into Puno Interior Bay >

Parameter	BOD	T-N	T-P
Pollution Load (kg/day)	2,498	865.3	142.0

Figure III.4.1 shows the shares of the above-mentioned pollution loads by pollution source.

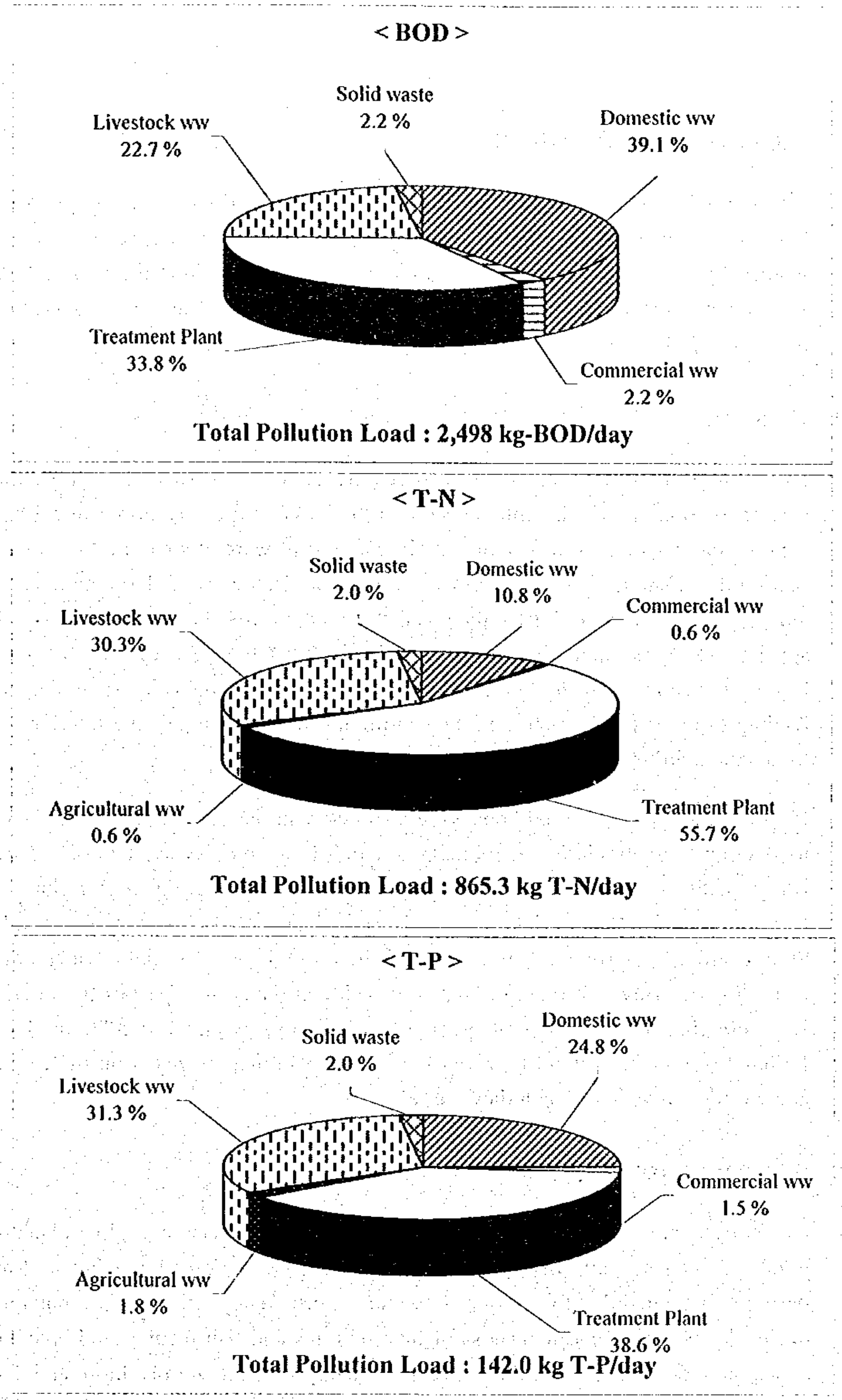


Figure III.4.1 Estimation of Discharged Pollution Load into Puno Interior Bay

5. BIOLOGICAL CONDITIONS

The biological studies carried out in Puno Bay include those on zooplankton, benthos, fauna of the macrophytes and aquatic birds. Other relevant topics studied by consultation, literature search and field trips include the fish of Puno Bay, trophic (nutrient) levels, the adjacent Lake Titicaca National Reserve and macrophyte distribution.

5.1 GENERAL

Biologically, Puno Interior Bay can be readily divided into two parts - a smaller eastern section in which biological conditions were relatively good, and larger central and western sections in which conditions were poor. In the eastern section the submerged macrophytes were in good condition with large numbers of amphipods and snails living on them and the benthos was abundant and diverse in species. Fish populations appeared to be high as this was one of the most heavily fished areas of the Interior Bay. These reed beds provided spawning and feeding grounds for the fish. In the central and western parts of the Interior Bay the fauna and flora were severely depleted.

Physical and chemical conditions were also better in the eastern part of the lake - for example water clarity, aerobic mud conditions and oxygen levels. Better water quality here is believed to be due to clean water entering the Interior Bay from the Exterior Bay via the main navigation channel. This water, blown in by the prevailing easterly winds is colder and therefore denser than the warmer water of the Interior Bay. It therefore tends to reside in the eastern part of the Interior Bay, creating the better biological, chemical and physical conditions here. Polluted waters from Puno City and Espinar WWTP tend to reside in the central and western areas into which they are released.

5.2 PHYTOPLANKTON

One consequence of the highly eutrophic waters was the very high phytoplankton numbers. These have disrupted the Interior Bay's ecology by being at least partially responsible for reduced water transparency, loss of submerged macrophytes with consequent loss of invertebrates and fish feeding and breeding areas, and occasional fish kills. Other changes affect zooplankton and fish ecology and species composition.

5.3 MACROPHYTE

There is no doubt that the macrophytes of Puno Interior Bay have declined over at least the last 20 years, both in terms of species and area covered. Thus Puno Interior Bay was in a bad condition so far as they are concerned. With a maximum depth of about 7m, all of the Interior Bay is shallow enough to support macrophytes given the right conditions. The main factors responsible for this decrease were probably low light conditions and low oxygen levels in most of the deeper parts of the Interior Bay.

5.4 ZOOPLANKTON

The zooplankton (copepods and cladocera) of the Interior Bay occurred in high numbers compared to those of the Exterior Bay and Lake Titicaca in general. Additionally, cladocera greatly outnumbered copepods. Both of these findings indicated that the Interior Bay had a high nutrient status. This provides the basis for high growths of phytoplankton, which provides the main food for zooplankton.

5.5 BENTHOS

On the other hand, the benthos of much of the Interior Bay was severely depleted, particularly in the central, southern, northern and western areas. This was caused by low levels or absence of oxygen in the deeper waters and/or mud bottoms that made it impossible for any or many species to live there. The benthos of the eastern part of the Interior Bay however was very rich, as it was on the submerged macrophyte beds that grow there. The densities in these eastern muds are amongst the highest recorded anywhere from Lake Titicaca, and much greater than those of the Exterior Bay. This indicates a high nutrient status of the water but not to a point where biological activity and organic matter reduction causes oxygen levels to drop too low.

5.6 FISH

The fish of Puno Interior Bay have declined in abundance and species over at least the last 20 years. This is as a result of the declines in benthos and submerged macrophytes, the latter providing spawning areas and nursery grounds for young fish. Overfishing may also be partially responsible. Compared to the rest of Lake Titicaca the fish fauna is poor in species, abundance and growth of at least one species.

5.7 BIRDS

Puno Interior Bay is an important area for aquatic birds. Some species appear to have declined or disappeared in recent years, whilst others have increased. Overall though, the Interior Bay's conditions do not appear to have adversely affected the bird fauna. The sheltered waters of the eastern part provide good roosting places for birds and many thousands can be seen there at times during the migration season.

5.8 NATURE RESERVE

Adjacent to Puno Interior Bay is the Lake Titicaca National Reserve. This is an area of world significance, particularly for its birds. Conditions in Puno Interior Bay are not seriously affecting the Reserve, and the Government of Peru is under an international obligation to ensure that they don't.

6. PUBLIC HEALTH CONDITIONS

6.1 GENERAL

The waters of Puno Interior Bay are a major health hazard to anyone coming into contact with them. They contain large numbers of Total and Fecal coliform as well as the eggs and other developmental stages of intestinal helminth parasites.

6.2 COLIFORM BACTERIA

Fecal and coliform bacteria were found in large numbers by Rivera *et al* (1989) in the waters of Puno Interior Bay in the early 1980s. Fecal coliforms occurred in numbers of up to 10^5/100 ml, with numbers being highest at the western end of the Interior Bay along the Puno waterfront close to major sewage and run-off discharges. Numbers decreased to zero by the center of the bay, some 2000 m from the shore. Ocola and Torres (1997) found similar numbers (1.4 x 10^4 - 22.5 10^4) of both total and fecal coliforms along the western seafront and at Espinar Island close to the discharge point from the treatment lagoon.

6.3 PARASITE

Sanchez *et al* (1989) found the eggs of a variety of intestinal parasites in the waters of the Interior Bay, particularly close to the western shores. These included the helminth parasites *Trichuris* sp, *Ascaris* sp, *Hymenolepis nana,* *Taenia* sp and *Ligula intestinalis*. A survey amongst people living close to the shore in Puno Bay showed that 14% were infected by one or more helminth, with rates up to 40% for young people. Helminths are spread by ingesting their eggs or other developmental stages from contaminated water and food as well as from hands of infected people soiled by fecal matter.

6.4 CHOLERA

In the middle 1990s there was a cholera outbreak in Puno. Its spread was believed due at least in part to eating cholera-contaminated fish from the Interior Bay, the pathogen arriving in the first place from improperly treated sewage or from the inundation zone.

7. IDENTIFICATION OF PROBLEMS

The existing water environment problems in Puno Interior Bay, which are identified by the field survey and interview, are described as below.

(1) Enclosed Water Body

Puno Interior Bay is a virtually enclosed nature system (turnover periods estimated at 18-64 years), with minimal water exchange with the Exterior Bay via the two navigation channels. All materials and substances entering the Interior Bay tend to stay there and accumulate. On the positive side this barrier (of alluvial sediments) prevents contamination from entering the Exterior Bay where the lake water is used for water supply or fishery.

(2) Water Use Problems caused by Significant Eutrophication

Under the significant eutrophication, over-production of phytoplankton causes loss of water clarity and excessive oxygen consumption on their death and decay. The water quality deterioration depreciates the value of water use such as water supply, fishery, or tourism.

The floating plant *Lemna* (duckweed) has spreads over Puno Interior Bay due to significant eutrophication. When the wind blows westward, *Lemna* comes near the western lakeshore and its density reaches 10 to 15 cm thickness. Consequently, a dense carpet of *Lemna* not only obstructs boat navigation but also affects the scenic view, which depreciates the value of tourist attractions.

The harvest of *Lemna* as a measure to limit these problems was conducted by the Multi Sectorial Committee for the Environmental Improvement of Puno Interior Bay in 1998. The harvest of *Lemna* is efficacious against obstruction of ship activity and also assists with improvement as below. Accordingly, it is necessary that removal of *Lemna* be continued.

- Removal of nutrient from the lake
- Protection of sediment formation by *Lemna*
- Improvement of the view which is depreciated by *Lemna*.

(3) Depreciation of tourism resources

A healthy ecosystem in Lake Titicaca is important for the tourism industry in this area. However, the existing ecosystem in Puno Interior Bay is depreciated by the water pollution as listed below:

- Occurrence of odor from the lake
- Polluted water, liable to cause illness
- Large amounts of floating *Lemna*
- Eutrophication (water color becomes green due to phytoplankton)
- Depreciation of ecosystem in the lake (loss of Totora as the characteristic view of Lake Titicaca)

(4) Problems of Ecosystem

Water quality deterioration of Puno Interior Bay causes the following adverse effects:

- the loss of species and decline in abundance of submerged macrophytes (and their attached fauna), due principally to low light levels and low oxygen content of deeper water and muds:
- the loss of benthos over much of the lake, caused by low oxygen conditions in the deeper waters and bottom sediments;
- the loss of fish spawning and nursery areas, due to loss of macrophytes;

- the loss of fish species and abundance

- a general malfunctioning of the Interior Bay aquatic ecosystem due to the above disruptions.

There is no reason to believe that Puno Interior Bay is now at some stage of biological equilibrium with its environment. The expectation is that if the causes of the biological problems are not effectively dealt with, the Interior Bay ecosystem will continue to decline as it has done for so many years.

(5) Offensive Odor

An offensive odor from the lake has caused problems for residents and tourists. Anaerobic lake sediments give off an offensive odor. According to the survey on bottom sediment, the sediment at the west part of the Interior Bay showed high values of ignition loss and black color, which indicates anaerobic condition.

(6) Public Health Problems

The waters of Puno Interior Bay are a major health problem. Pathogenic organisms are particularly abundant around the shore, especially close to the waterfront. The problems are caused by discharges of untreated and partially treated domestic waste waters and rainfall run-off, as well as the use of the inundation zone as a public latrine by many people in Puno.

CHAPTER – IV

FRAMEWORK OF THE INTEGRATED WATER POLLUTION CONTROL PLAN FOR PUNO INTERIOR BAY

CHAPTER – IV

FRAMEWORK OF THE INTEGRATED WATER POLLUTION CONTROL PLAN FOR PUNO INTERIOR BAY

1. CONCEPT OF THE INTEGRATED WATER POLLUTION CONTROL PLAN

1.1 GOAL

(WHAT IS THE GOAL OF THE PLAN ?)

The Integrated Water Pollution Control Plan aims primarily to improve the water quality of Puno Interior Bay polluted by urbanization of Puno City, and consequently to contribute to the conservation of its unique natural environment and to the development of the regional economy and living conditions.

1.2 SUBJECTS

(WHAT ENVIRONMENTAL FACTORS SHOULD BE CONSERVED ?)

- Water Quality of Puno Interior Bay
- Scenery of Puno Interior Bay
- Flora and Fauna of Puno Interior Bay
- Public Health Conditions of Puno Interior Bay and Puno City

1.3 PURPOSE

(WHY THE WATER POLLUTION OF PUNO INTERIOR BAY SHOULD BE CONTROLLED)

(1) Solution of the Water Quality Problems of Puno Interior Bay

- Reduction of nitrogen and phosphorus levels
- Recovery of the lake water transparency
- Control of the bacterial contamination
- Control of *Lemna* outbreak

(2) Protection of Puno Exterior Bay from Expansion of Water Quality Problems in the Interior Bay

- Control of the intake water quality for water supply
- Control of the water quality for fishery

(3) Conservation of the Natural Environment as a Tourist Attraction

- Improvement of the Scenery
- Conservation of the lake water ecosystem (Totora, wild birds, etc.)

2. STRATEGY OF THE PLAN

2.1 TARGETS

(WHAT LEVEL SHOULD BE REACHED ?)

(1) Lake Water Quality

Recovery of the acceptable water quality as it used to be in the 1970's

(2) Scenery

- Reduction of *Lemna* distribution
- Reduction of littered solid wastes to an insignificant level

(3) Ecosystem

- Rehabilitation of reed (Totora) belt
- Conservation of habitats for wild birds
- Recovery of fish and benthos
- Recovery of submerged macrophytes

(4) Public Health Conditions

- Reduction of littered wastes in the watershed and the lake
- No bacterial or parasite contamination in the watershed and the lake

2.2 TARGET YEAR

(BY WHEN WILL THE PLAN MATERIALIZE ?)

Short-term target year : the year 2008

Mid-term target year : the year 2015

Long-term target year : the year 2025

2.3 TARGET AREAS

(WHERE WILL THE PLAN TARGET ?)

(1) Measures against the Water Quality Problems

1) Watershed / Catchment Area

The whole catchment area of Puno Interior Bay

2) In-Lake

Puno Interior Bay

(2) Measures against the Deterioration of Scenery

The whole of Puno Interior Bay and its Hinterland

(3) Measures against the Ecological Problems

Northern, western and southern shores of Puno Interior Bay

(4) Measures against the Public Health Problems

The whole catchment area and the littoral area of Puno Interior Bay

2.4 METHODOLOGY

(HOW TO CONTROL THE PROBLEMS ?)

In general, possible efforts to improve lake environment are classified into the following three categories:

- Structural Measures
- Non-structural Measures
- Environmental Monitoring

Structural measures are defined as the measures taken by administrative bodies to physically improve the environment of Lake Titicaca. Non-structural measures are defined as the measures which aim to motivate the state/local governments, private sectors or citizens to take some actions for environmental improvement. Environmental monitoring is defined as an environmental administration tool which detects/identifies environmental problems, assesses the effects/impacts caused by the implementation of structural measures, and rouses people's awareness. Although the structural measures must be the main category, the integrated plan will not fulfill its function unless all measures are systematically combined. The conceptual figure of "The Integrated Water Pollution Control Plan for Puno Interior Bay" is shown in *Figure IV.2.1*.

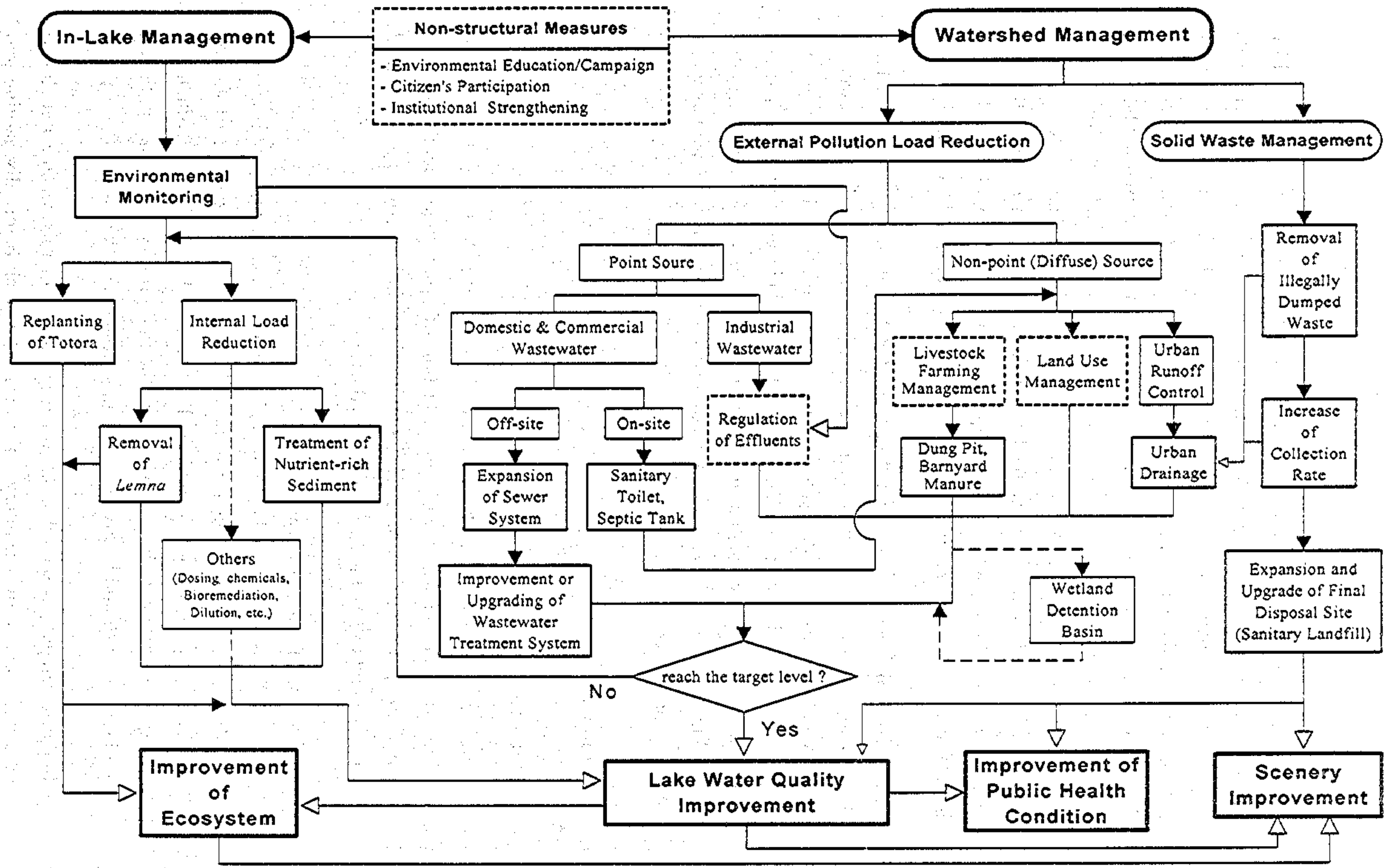


Figure IV.2.1 Conceptual Figure of The Integrated Water Pollution Control Plan for Puno Interior Bay

Water quality problems of Puno Interior Bay have been undoubtedly caused by pollution loads discharged from Puno City and the watershed. Pollution loads have been accumulated in both the lake water column and the bottom sediment for a long time. Lake water pollution has deteriorated ecosystem and scenery in Puno Interior Bay. Poor wastewater management has also caused public health problems such as waterborne diseases. Therefore the first priority of the integrated plan should be given to the improvement of lake water quality. Pollution load reduction in the watershed and in the lake will improve the lake water quality. Consequently, water quality improvement will contribute to improvement of the ecosystem, the public health conditions, and the scenery.

Insufficient solid waste management causes illegal dumping or littered waste in the drainage and on the streets, which affect public health conditions or sewerage systems and clog up urban drainage. Storm water flushes the littered waste into the lake or inundation area, which deteriorate the scenic view of Lake Titicaca that is an important component of tourist attractions. Therefore, in the integrated plan, a high priority should be given to solid waste management as well as water quality improvement.

(1) Structural Measures

1) Water Quality Improvement

Measures should be begun with external pollution load reduction. The external load reduction should begin with the reduction of point source loads, and the reduction of non-point source loads should follow it. Internal pollution load reduction should follow the external load reduction.

a. External Pollution Load Reduction

In Puno City, domestic and commercial wastewater are major point sources of pollution loads. Most of them can be collected by sewer system, treated by wastewater treatment system, and finally discharged to the lake as effluents of wastewater treatment plants. Therefore the first priority of external pollution load reduction should be given to sewerage system development.

In the sewerage non-served area, domestic and commercial wastewater should be treated on site by a sanitary toilet or a septic tank before discharging into streams, drains, --groundwater, or directly into the lake. There are few major industrial pollution sources in Puno City, however major pollution sources such as slaughterhouses should be enforced to install a wastewater treatment facility at their own expense by the effluents control regulation.

Nonpoint (diffuse) pollutant loading to streams or directly to the lake is loading which does not enter from sources such as pipes but instead from overland flow or groundwater seepage. Agricultural and urban areas are important nonpoint sources and are difficult and expensive to control intensively or effectively by structural measures.

b. Internal Pollution Load Reduction

A significant reduction in external pollution load is an essential, but not necessarily sufficient step towards the lake water quality improvement for long term control of eutrophication. External nutrients reduction may not have all of the expected effects of increasing macrophytes or lowering algal biomass until these internal sources are managed.

Possible measures should be divided into two categories, one is to directly decrease pollutants' concentrations in the water column and the other is to reduce pollutants' loading from the bottom sediment

2) Scenery Improvement

In the watershed, littered wastes in the streams, along the shoreline, on the streets or around the final disposal site deteriorate the scenic view of Lake Titicaca. Therefore solid waste management is an urgent measure for scenery improvement in the watershed.

In the lake, nuisance spread of *Lemna* deteriorates the scenic view. Therefore the removal of *Lemna* must be urgent, but the monitoring is indispensable to check unexpected negative impacts such as outbreak of algae which may take *Lemna*'s place. Totora (reed) is the main component of the scenery of Lake Titicaca, and so replanting of Totora would recover the lost natural view.

3) Ecosystem Improvement

Water pollution has caused damage to aquatic ecosystems in Puno Interior Bay. Therefore the aquatic ecosystem will not be improved until the lake water quality is improved.

Totora bush/belt seems to provide an excellent water environment for plankton, benthos and fish. Furthermore it provides a habitat or nesting place for wild birds. Abundance of wild birds is also an excellent component of tourist attractions. Therefore the replanting of Totora will help to recover or enhance the ecological potential in Puno Interior Bay.

4) Public Health Condition Improvement

Removal of illegally dumped and littered wastes is a direct measure against public health problems caused by littered wastes, but not an essential way. The most essential and urgent measure should be an increase of waste collection rate. Furthermore a final disposal site should be expanded in parallel with an increase of collection rate. Sanitary landfill system should be applied to a new final disposal site according to the guidelines proposed by the Ministry of Health.

It is often seen in Puno City that some citizens use the lakeshore as an open-air latrine and sewage overflows after a heavy rainfall. These must cause bacterial contamination in the littoral area of Puno Interior Bay. To solve this public health problem, the sewerage system should be improved or expanded at the highest priority, and the spread of sanitary toilet or septic tank should be encouraged.

(2) Non-structural Measures

Non-structural measures should support or supplement structural measures. A large scale investment will be necessary for some structural measures such as expansion of sewerage systems. To raise the project funds, it will be necessary to raise the water charge rate. In such cases, citizen's understanding and consensus for the projects should be formulated through environmental education or campaign. To reduce the project cost or to make the project run smoothly, it will be necessary to request citizen's voluntary participation. To execute or manage the project effectively, relevant organizations or systems should be effectively strengthened or consolidated.

Industrial wastewater should be controlled by effluent regulation. It is difficult to effectively control non-point sources with a reasonable cost by structural measures, and an appropriate land use should be encouraged to minimize non-point source pollution loads. Because livestock farming seems to generate a great deal of non-point source pollution loads, it should be regulated in the area close to the lake

(3) Environmental Monitoring

Periodical and continuous environmental monitoring should be urgently practiced as a decision-making tool, in order to identify the environmental problems and the measures against the problems, and to monitor the expected effects or the unexpected impacts by the structural measures. Especially, eutrophication is caused by sensitive aquatic ecosystem. Change of nutrient balance may cause new eutrophic problems other than the outbreak of *Lemna*. Monitoring of pollution sources will bring rational bases to regulate the effluents.

2.5 MANAGEMENT AND EXECUTION OF THE PLAN

(WHO WILL BE RESPONSIBLE FOR IMPLEMENTATION OF THE PLAN ?)

(1) Overall Management

A leading state level authority who is competent to coordinate several sectorial organizations, to decide on a policy, to raise funds, to control budget and to supervise the whole project

(2) Execution of component projects

Sectorial organizations who have experiences in each field and capacities to execute component projects

(3) Citizen's Participation

Puno Provincial Municipality or multi-sectorial organization(s) who are composed of representatives of the interested parties, can organize residents campaigns for environmental improvement and can encourage public/private sectors to assist the campaigns voluntarily.