CHAPTER 5
CURRENT STATUS OF WASTEWATER TREATMENT AND DISPOSAL SYSTEM

CHAPTER 5 CURRENT STATUS OF WASTEWATER TREATMENT AND DISPOSAL SYSTEM

5.1 Existing Condition of Wastewater Treatment and Disposal System

5.1.1 Outline

The major wastewater collection system for Astana was started in 1959 and has been extended on a continuous and adhoc basis as the new districts are developed. All discharges were made to the Ishim River until completion of the wastewater treatment plant (WWTP) in 1970. A separate surface water drainage system is also provided for collection of storm water from roads and pavements in some areas. The drainage system is managed by Gorkomkhoz, a communal enterprise under the responsibility of Akimat.

5.1.2 Main Features

The wastewater collection, treatment and disposal system covers about 3,500 ha (5%). The city's 15 wastewater collectors and 32 pump stations (P/S) convey the wastewater collected for about 61,000 customers to the WWTP located about 8km to the south west of the city center. The design capacity for the WWTP is 135,900 m^3/day.

Cesspits and septic tanks are used in areas not provided with a wastewater collection system.

5.2 Wastewater Collection System

5.2.1 Wastewater Quantities and Pollution Loads

The estimated average and peak day flows expected at the wastewater treatment plant are presented in Table 5.2.1. These estimates are in agreement with recent flow measurements at the WWTP.

The calculated per capita discharge of some pollutant is presented on Table 5.2.2 and is comparable with the recommended values proposed in SNiP 2.04.02 – 85.

The measured characteristics of the untreated sewage typically shows a medium strength municipal sewage which should be easily degradable. The pollution loads calculated above include those from industries. Pollution loads from industries is regulated by a statute issued in Tselinograd in 1989 for the Regulations of Industrial Wastewater Discharge to the Sewerage System of the Tselinograd (now Astana).

Table 5.2.1 Estimate of Present Flow Expected at the WWTP

Unit: m^3/day

Wastewater Discharge	1999 Average	1999 Peak Day
Domestic	55,675	66,810
Institutional	4,333	5,199
Commercial/Industry excluding Thermal plant	10,353	12,424
Thermal plant	6,678	8,014
Technical Water excluding Thermal plant	2,000	2,000
Total	**79,039**	**94,446**
Infiltration*	7,904	9,445
Total Discharge	**86,942**	**103,891**

Note: * Infiltration is based on about one third of leakage reaching the sewer system approximately equivalent to 10% of water consumption.

Source: JICA Study Team

Table 5.2.2 Estimate of Per Capita Pollution Loads

Pollutant	Measured Concentration mg/l	Calculated Pollutant mg/day	Calculated PC Loading g/pc	Recommendation SNiP 2.04.02 – 85 g/pc
BOD_5	165	15,640	52.0	50
SS	186	17,637	58.6	65
COD	366	34,782	115.6	

Source: JICA Study Team

ASA monitors the pollutants discharged by 16 industries against the regulations about every 2 months. Prior to perestroika a larger number of industries were monitored but many industries have now closed.

5.2.2 Pipeline Facilities

The topography of the city is flat with elevation of about 345m along the banks of the Ishim River gently rising to about 370m about 10 km to the north east and to 350m to the south. The situation has necessitated many P/Ss and pumping mains in combination with gravity pipelines to convey the wastewater to the WWTP.

The material, diameter and length of pipes on the network are presented on Table 5.2.3. The diameters range between 100mm and 1,500mm. The most commonly used material is cast iron, which was extensively used for the earlier sewer pipelines.

Table 5.2.3 Length of Sewer Pipelines for Different Diameters and Materials

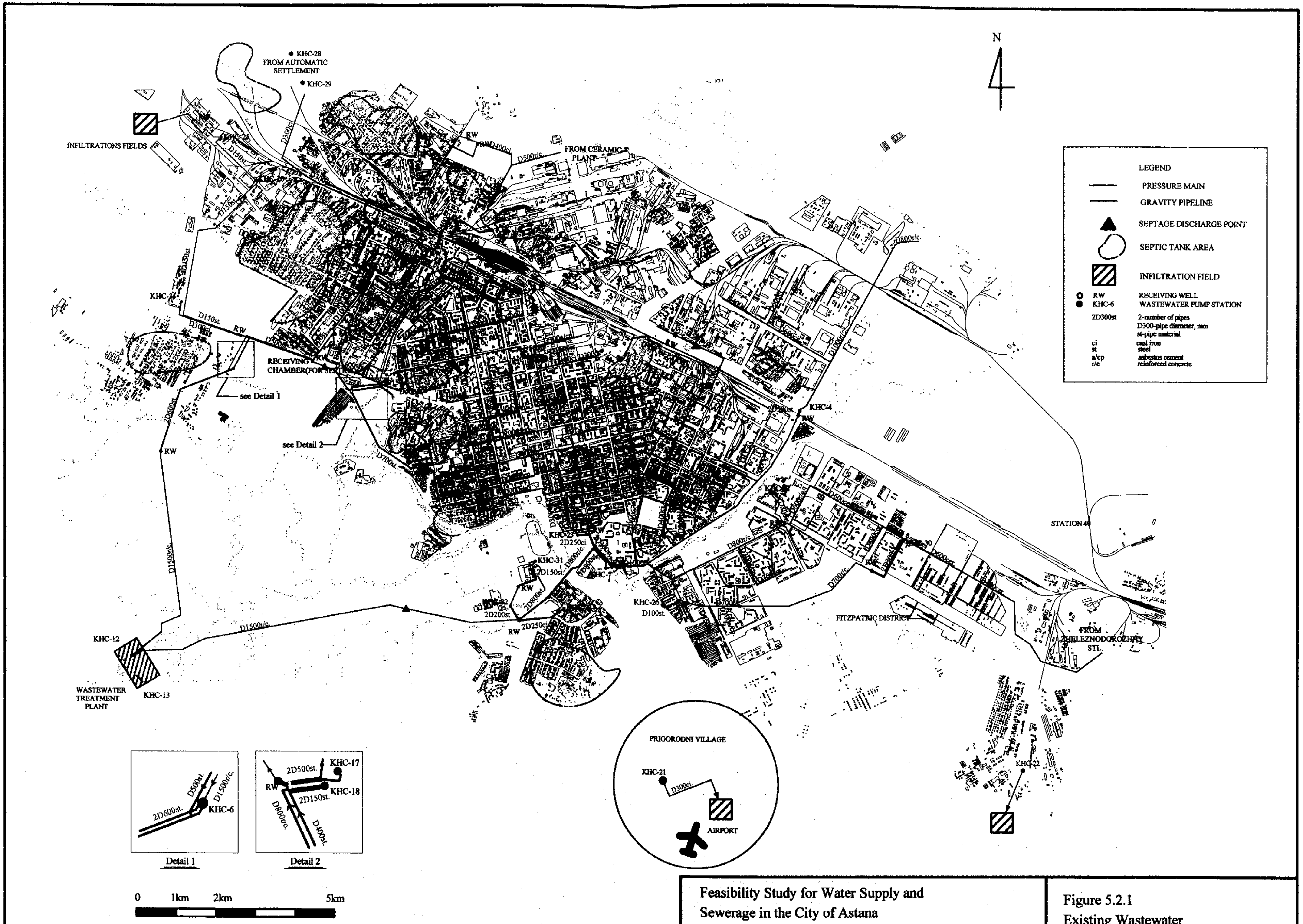
Unit: metre

Pipe Size	Material						
D (mm)	Clay	Asbestos Cement	Reinforced Concrete	Steel	Cast Iron	Polyethylene	Total
100	95	317		2,387	2,958	827	**6,584**
125	133						**133**
150	15,707	14,977		1,103	29,134	1,413	**62,334**
200	8,158	18,876	62	1,892	22,456		**51,444**
250	2,458	2,089			3,359		**7,906**
300	1,554	6,193	234	500	11,758		**21,239**
325				1,380			**1,380**
350				1,100	1,087		**2,187**
400	1,520	159		13,781	9,789		**25,249**
500			366	1,470	760		**2,596**
600	2,077	3,073	1,474	6,700	3,681		**17,005**
700			2,995	1,562			**4,557**
800		52	7,737				**7,789**
900				390			**390**
1000			6,541				**6,541**
1500			8,521				**8,521**
Total	**32,702**	**45,736**	**27,930**	**32,265**	**84,982**	**2,240**	**225,855**
Local System							Approx. 80,000
Grand Total							**305,855**

Source: ASA, October 2000

More recent extensions of the system were constructed of asbestos cement pipes. Steel pipelines are used for pumping mains.

There are approximately 5,300 manholes provided at junctions and changes in direction. Figure 5.2.1 presents the location of the main collectors and P/S in the urban area.



Feasibility Study for Water Supply and Sewerage in the City of Astana

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Figure 5.2.1 Existing Wastewater Collection System

(1) Gravity Pipelines

Gravity pipelines on the wastewater collection system consist of pipes manufactured mainly from cast iron, reinforced concrete, asbestos cement and clay. Between 20 and 50 blockages (depending on season) are reported to ASA daily. This is equivalent to about 1,500 blockages per 100 km/year which is high compared to a maximum of 50 blockages/100 km/year based on international experience.

Verification of the design capacity of the existing pipelines shows that they are generally sufficient. A manhole survey showed that many are buried under asphalt or earth and a significant number has deposits of sediments.

(2) Pumping Mains

Most of the 42 km of pumping mains (100 mm to 800 mm) have been constructed with unprotected steel pipes that have resulted in many corrosion problems such as leaks and collapse (25 - 50 /100km/year). Defects index for steel pipeline is normally in the range 10 - 20 /100km/year. The pipeline with corrosion problems should be replaced.

(3) Cesspits and Septic Tanks

It is estimated that about 30 % of the population of Astana do not have direct access to the sewerage system and rely on cesspits and septic tanks for disposal of human waste. Septage is collected by commercial enterprises and disposed into the sewerage system at 3 locations designated by ASA.

5.2.3 Pump Stations (P/Ss)

There are 34 wastewater P/Ss (including the two main P/Ss at the WWTP on the wastewater system. A visual survey of the condition of each pump showed that many P/Ss, although in working condition, should be rehabilitated. The equipment provided even in some of the new P/Ss has very poor energy efficiency (30% - 50%, compared to expected 70%). The poor efficiency of the pumps is the result of standardized manufacture of an ancient design that has not been improved. Lack of funds prevents the purchase of efficient but more expensive pumps. It has been estimated that a total of about 150 repairs are carried out per year on the system (100 existing pumps) giving a defect index of about 1.5 per pump per year. This is high and international experience indicates that a defect index of between 0.3 and 0.5 per pump per year is considered more usual. Many of the pumps are older than 20 years but require frequent repairs. The details for the larger P/Ss are provided in

Table 5.2.4, which shows the relatively low efficiency of the installed pumps and the age of some of the pumps.

Table 5.2.4 Characteristic of the Large Wastewater Pump Stations

Pump Station Ref.	No of Pumps	Year Manufacture	Installed Pump Rating			Rated Efficiency
			Q(m³/h)	H(m)	P(kw)	e(%)
KHC-1A	3	1998	800	22.5	160	31%
	1	ND	450	22.5	ND	-
KHC-2	2	ND	450	22.0	55	49%
	1	ND	368	16.0	55	29%
KHC-3	4	1970	650	22.5	125	32%
	1	ND	450	22.5	110	25%
KHC-4	1	1972	800	22.0	75	64%
	4	1972	450	22.0	37	73%
KHC-5	1	ND	450	22.0	ND	-
	2	ND	250	22.0	ND	-
KHC-6	3	ND	1600	22.5	250	39%
	1	ND	800	22.5	ND	-
KHC-7	2	1966	3500	19.5	370	50%
	2	1985	1600	25.0	250	43%
	1	1975	800	22.0	132	36%
KHC-10	1	1972	800	22.0	125	38%
	4	1976	450	22.0	75	36%
KHC-12	5	1994	2700	26.5	400	49%
KHC-13	5	1994	2700	26.5	400	49%
KHC-19	1	ND	250	22.0	ND	-
	2	1973	125	22.0	45	17%
KHC-22	2	ND	144	22.0	11	78%
KHC-27	2	ND	114	22.0	22	31%

ND: No Data

5.3 Wastewater Treatment Plant (WWTP)

5.3.1 Outline Description

The WWTP site covers 43 hectares on the shore of Taldy Kol Reservoir. The plant facilities with a design capacity of 135,900 m^3/day presently occupy about 20 ha with an additional 10 ha of sludge drying beds.

Two main collectors (2 x ϕ 1,500) deliver wastewater to the plant from the city. An average flow rate of 95,000 m^3/day (1,100 l/s) is presently arriving at the plant, which is based on the activated sludge process, widely used for large WWTP in this environment. Disposal of effluent is to Taldy Kol Reservoir with emergency discharge to marshland to the west of Taldy Kol Reservoir. Figure 5.3.1 shows the schematic layout of the WWTP and the process units available are presented on Figure 5.3.2.

5.3.2 Diagnostic

The working condition of the plant is satisfactory but some sections require replacement particularly the electromechanical plant which are old and in some cases not working. The civil works are generally in reasonable condition but some structures has steel reinforcement exposed and require major reconstruction.

A diagnostic of the WWTP for a flow of 95,000 m^3/day and load of 14,000 kg BOD_5/day was carried out and the results presented below.

1) Screens

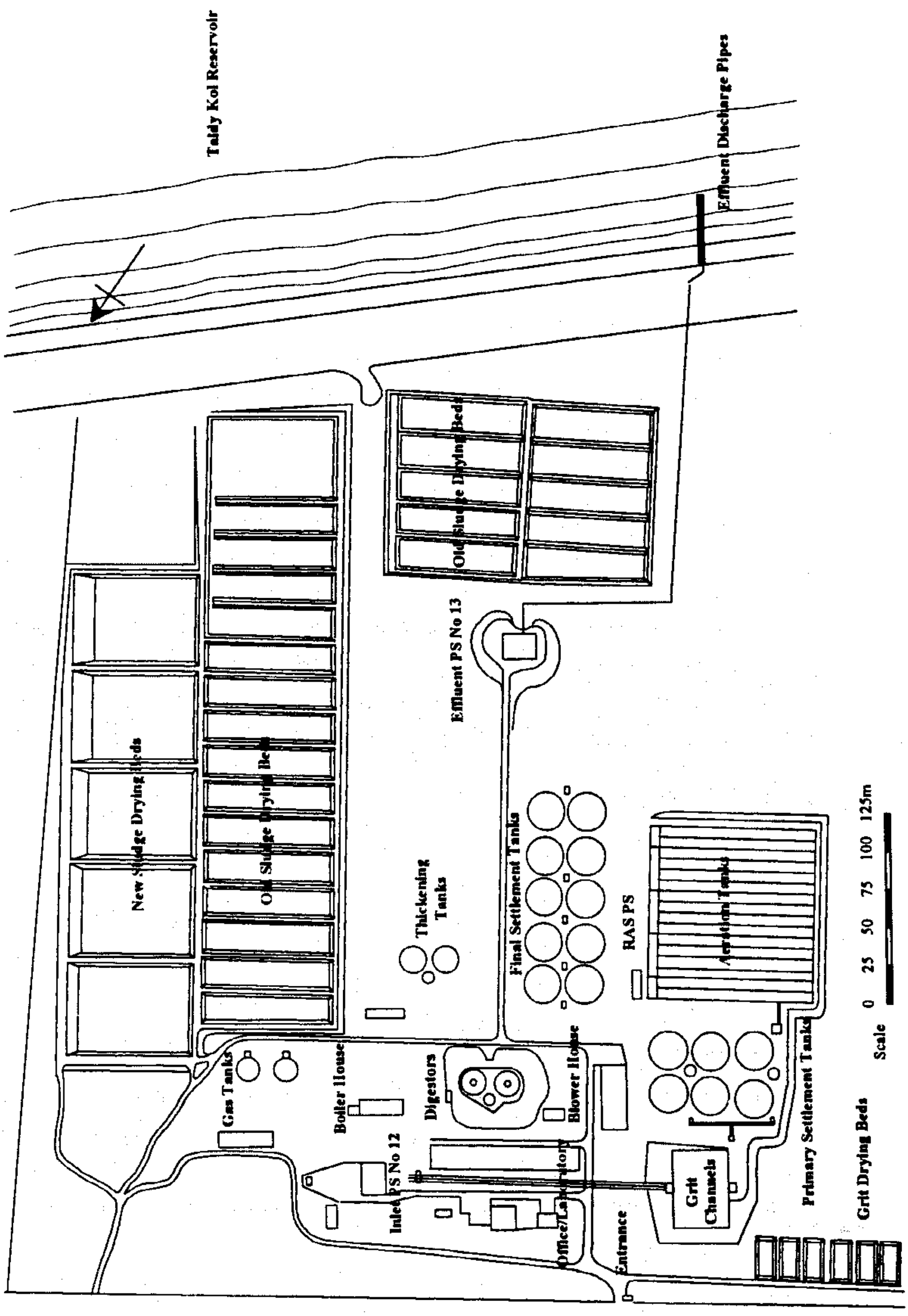
Two of the three screens are defective and should be replaced with 6mm openings mechanical screens. A bypass should be provided to enable isolation of the screens. The screens have not been repaired or replaced because of lack of funds and spare parts. Repairs tend to be of a temporary nature using locally made parts.

2) Inlet Pump Station

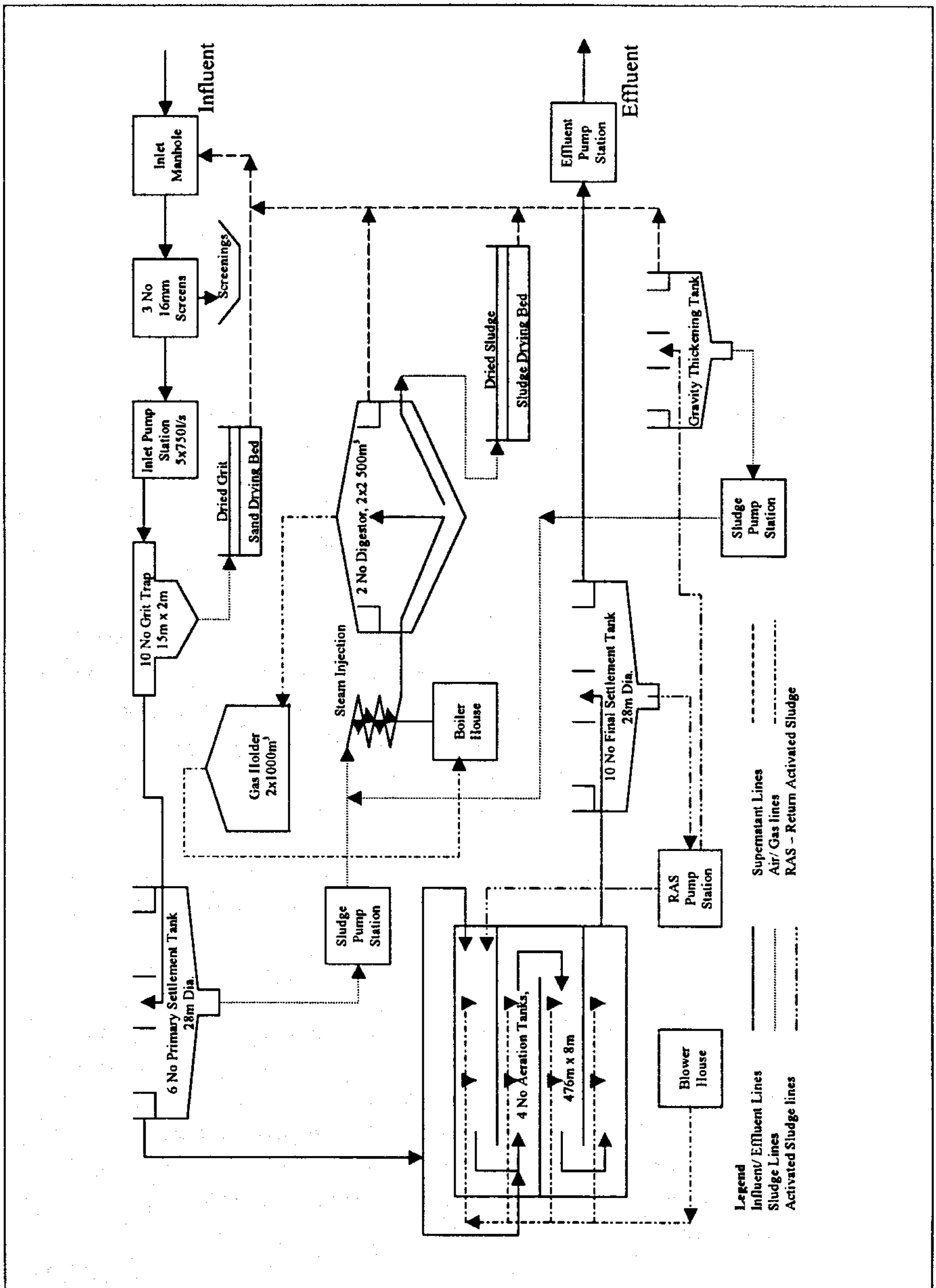
All the pumps are similar with a large capacity, (750 l/s) making operation difficult over the range of flows (900 l/s - 1,200 l/s) presently arriving at the plant. A combination of smaller and larger capacity pumps is more appropriate to cope with the variation in flow. The electromechanical plant although working often breaks down and should be replaced.

3) Grit Trap

The civil works and the electromechanical plant at the grit traps are in poor condition and do not function as required. Grit gets through the trap and deposits in the subsequent process units including the digesters. The concrete is spalled in many places. The grit removal equipment does not work efficiently and manual grit removal is necessary.



Feasibility Study for Water Supply and Sewerage in the City of Astana	Figure 5.3.1
JAPAN INTERNATIONAL COOPERATION AGENCY	Schematic Layout of the Wastewater Treatment Plant



Feasibility Study for Water Supply and Sewerage in the City of Astana	**Figure 5.3.2**
JAPAN INTERNATIONAL COOPERATION AGENCY	**Process Schematic of the Wastewater Treatment Plant**

4) Grit Drying Beds

Grit drying beds are not recommended because the untreated organic waste attached to the drying grit will become septic and cause odours. It is proposed that this facility be abandoned and grit washing be provided with the new degritting facility.

5) Primary Settlement Tanks

The hydraulic loading of the tanks at average flow is about 1.6 $m^3/m^2/hr$ when 4 of the 6 primary settlement tanks are in use. This value complies with SNiP (2.04.03-85) but this facility should be designed for maximum daily flow when the hydraulic loading is increased by 50%. It is recommended that all 6 primary settlement tanks be kept in operation to cover such eventuality. With all of the primary tanks in operation the loading at average flow will be 1.1 $m^3/m^2/hr$.

6) Aeration Tanks

Only 2 of the 4 available aeration tanks are presently in use. A form of contact stabilization and step feed activated sludge process is used for treatment. The biological treatment tank has a total retention time of about 6 hours at present flow of which 2 hours is for stabilization of the sludge. The stabilization time is normal for such system. The contact time is unusually large in comparison with the stabilization time. The efficiency of the aeration system is low when compared to typical values encountered on activated sludge plants. The air blowers are more than 30 years old and only three of the seven blowers are operating but requires constant repairs. The return activated sludge pumps are frequently breaking down because of old age and should be replaced.

7) Final Settlement Tanks

Only 6 of the 10 final settlement tanks are in use and a hydraulic loading of 1.1 $m^3/m^2/hr$ results at average flow. This is considered too high for the sludge produced by such lightly loaded system. A hydraulic loading of about 0.6 $m^3/m^2/hr$ is more appropriate. It is recommended that all 10 final tanks be put into operation. It has also been noted that flow to all the tanks is not equal. This unequal distribution can create a high-suspended solid concentration in the final effluent and should be corrected.

8) Telemetry and Automation

The original construction included a fully automated operation and control system with a dispatching center located at the blower house. This system became completely inoperational after about 10 years due to the lack of funding for its maintenance and replacement.

9) Other Facilities

The laboratory within the complex is used for tracking daily water quality data. It is equipped with water monitoring apparatus which are of basic standard. The workshop, although small in scale, is in working condition and is capable of dealing with day-to-day maintenance. .

5.3.3 Process Control

An operating manual for the process control of the existing WWTP was prepared in 1990 by Kazvodokanal Institute and is used for controlling the process. A treated effluent quality with a BOD_{total} concentration of 15 mg/l has been adopted in the operating manual. This is equivalent to 10 mg BOD_5/l

Process control is carried out by measuring of the sludge volume and maintaining its value to 200ml/l. An average mixed liquor suspended solids of about 2,500 mg/l is maintained in the stabilization tank, which is equivalent to a sludge loading (F/M ratio) at about 0.13 which is normal for the process. Waste activated sludge is very small, equivalent to about 0.2% of the flow and results in a high sludge retention time of about 25 days. This sludge age is more consistent with an extended aeration process than with the process used.

Detailed study of the laboratory results shows that the results are variable emphasizing the lack of monitoring equipment such as flowmeters. The measured mixed liquor suspended solids varies between 1,600 and 4,000. This lack of control can lead to variable quality effluent. Generally the treated effluent quality varying between 5 and 15 mg BOD_5/l meets the designed requirements of 10 mg BOD_5/l. The average BOD_5 for the effluent over the last 14 months is 8.7 mg/l with a standard deviation of 4.8. This standard deviation is high and is equivalent to a 40% probability of effluent quality exceeding the desired value of 10 mg BOD_5/l.

Nitrification of effluent (90%) is effected but the rate is much lower (50%) in winter because of the low temperatures.

5.3.4 Sludge Treatment and Disposal

(1) Treatment Method and Process

Primary sludge is transferred directly into the digesters, whereas waste activated sludge is thickened in gravity thickening tanks before digestion. After digestion the digested sludge is dewatered in drying beds. A total of 400 m^3 (200 m^3 primary sludge and 200 m^3 surplus activated sludge) is produced daily.

(2) Sludge Thickeners

The capacity of the sludge thickeners is about 2,000m^3 and thus equivalent to a retention period of about 10 days of surplus activated sludge. This is too high and will cause the sludge in the thickener to become septic and to produce odors.

(3) Sludge Digestion

Single stage thermophilic digestion is practiced with sludge temperature of about 55 ° C. There are two 2,500 m^3 digestors (retention equivalent to 12 days) but only one tank (retention equivalent to 6 days) is operational. This retention time is low, even with both tanks but it can be improved by appropriate thickening of both primary and surplus activated sludges. This process will reduce the volume to digest and increase the retention time. Solids loading for both tanks are estimated to be 2.7 $kg/m^3/day$, which is normal for a high rate digester.

(4) Boiler House

Three boilers, each producing 4.5 tones of steam/hour, are available at the boiler house. Most of the mechanical equipment is in very poor condition although one of the three boilers has been replaced in the last 2 years because it failed its safety inspection. It is also likely that because of their conditions the other two boilers may not pass this certification process either.

(5) Sludge Disposal

Before final disposal the digested sludge are dewatered on sludge drying beds. It is estimated that at present about 300 m^3 of digested sludge is sent to the drying beds daily. 11 old beds each measuring about 100m x 27m are still in operation together with two new asphalt lined drying beds measuring 100m x 70m each completed in July 1999. Three additional similar beds were completed in October 2000.

Sludge is presently stored on open ground within the confines of the WWTP. This is an unsatisfactory long-term solution.

Table 5.3.1 Average Monthly Characteristics for Influent and Effluent at the Wastewater Treatment Plant between July 1999 and August 2000

	Location	Influent			Effluent			Lake (about 50m from shore)		
Parameter	Units	Maximum	Average	Minimum	Maximum	Average	Minimum	Maximum	Average	Minimum
BOD_5	mg/l	213	156	120	14.5	8.3	4.5	9.5	6.0	4.0
COD (dichromate)	mg/l	548	362	251	89	77	58	82	62	41
Suspended solids	mg/l	343	185	124	17	10	6	15	7	3
Oil and fats	mg/l	31.8	6.8	3.2	0.3	0.2	0.0	0.2	0.0	0.0
Total Alkalinity	meq/l	6.7	5.8	5.0	5.0	4.2	3.6	5.8	5.0	3.8
Detergents	mg/l	4.5	2.5	1.6	1.4	1.1	0.5	0.8	0.3	0.0
Ammonium, NH_4	mg/l	30.0	26.6	21.0	10.3	6.9	1.8	8.8	4.3	0.3
Nitrates, NO_3	mg/l	1.4	0.8	0.2	70.0	44.8	6.7	36.0	17.4	4.0
Phosphates	mg/l	7.6	5.7	4.3	7.2	5.5	4.5	5.8	4.2	3.6
Chlorides	mg/l	324	284	242	313	269	235	292	253	219
Sulphates, SO_4	mg/l	320	241	214	270	219	195	270	208	184
Iron	mg/l	7.2	3.3	1.4	1.2	0.7	0.3	1.3	0.5	0.1
Zinc	mg/l	0.9	0.5	0.2	0.3	0.1	0.0	0.2	0.1	0.0
Fecal Coliforms	No/100ml	3.88E+05	2.82E+05	1.74E+05	17,750	8,361	6,000	1,050	342	51
Total Coliforms	No/100ml	2.50E+10	4.62E+09	1.10E+08	6.75E+06	3.99E+06	2.20E+06	6.00E+05	1.69E+05	7.00E+03

Source: ASA Wastewater Treatment Plant Laboratory

5.3.5 Treated Effluent and Sludge Reuse

After completion of biological treatment the treated effluent is discharged to Taldy Kol reservoir. The reservoir functions as an evaporator, a storage facility and as a facultative pond for additional purification. It can be observed from Table 5.3.1 that improvements in many parameters (BOD, COD, SS, Oils/fats, detergents, ammonium, nitrate, iron, fecal and total coliforms) occur after retention within the reservoir. However the improvements are still insufficient for discharge to rivers used for water supply. It was intended that the treated water be used for agricultural purposes but the project has been suspended. To overcome the rise in water level in Taldy Kol reservoir an emergency siphon is used to discharge water to marsh land to the west of the reservoir during the spring thaw. Permission to discharge surplus water is sought each year from the State Sanitary and Epidemiological Department. Permission is normally given after water quality tests are carried out. Some of the discharged water eventually reaches the Ishim River through infiltration and surface flow. The nearest village is Talapker, which is about 20 kms downstream on the Ishim River. The source of water for the village is hand operated wells.

Digested sludge used to be collected by the farms for use on fields but with perestroika many farms have reduced their production and none of the farms collect sludge from the WWTP anymore.

5.4 Operation and Maintenance

Provision of wastewater collection and treatment services to the area under the administration of Astana Akimat is one of the responsibilities of ASA, a municipal enterprise of Astana Akimat.

Direct operation and maintenance of the wastewater system is mainly carried out by 2 departments, the sewerage department and the WWTP. The sewerage department employs about 125 personnel. About 115 persons are employed at the WWTP, which is continuously manned.

Reports of defects by the public or by employees are normally logged by the dispatching department, who arranges attendance. However not all repairs are logged. Minor repairs to the wastewater collection system is repaired by the sewerage department team whereas more important repairs are carried out by the major repair department which is also responsible for major repairs on the water supply system. The WWTP has its own electromechanical personnel whereas the sewerage department shares the electrical and mechanical departments with the water supply departments. The mechanical department is responsible for the provision and repair of major construction plants such as lorries, excavators and cranes.

The staffing of the two departments is high by western standards where operation of wastewater systems is highly automated and the quality of the collection system and electromechanical equipment is much higher. There is very little simple control system like timers and level control. Some forms of automatic control were installed at many of the facilities during the initial construction but there has been no maintenance or replacement of the failed equipment due to lack of funds. Periodic maintenance is never carried out for the same reason and permanent repair activities.

The high level of staffing for direct operation of the wastewater collection and WWTP is considered necessary by the management because of the degree of maintenance as evidenced by the high number of blockages on the sewerage system and the high number of defects on steel pipelines and on the P/Ss. The staffing level is reported to be in accordance with the Staffing Norms for Water and Wastewater Systems.

The lack of proper record keeping is hindering the operation of the wastewater system for the following reasons. Up to date drawings of the pipe network or of the WWTP are not available. Details of pump stations and of pumps are not recorded. Very little use is made of computers for recording information and there is a high reliance on staff's memory for information.

5.5 Summary of Existing Conditions

Although generally in working condition the wastewater collection system requires a lot of attention to maintain in operation. Adhoc extension has resulted in a large number of pump stations. Most of the pump stations require intensive manual operation because of lack of simple devices such as level control and timers. A high degree of maintenance is necessary because many of the pumps are old. The maintenance personnel are entirely occupied with carrying out urgent repairs thus hindering the application of preventive maintenance. Long sections of pipelines are in poor condition as a result of corrosion and require replacements. Most manholes require attention especially because of poor quality and ill fitting covers.

A similar situation exists at the WWTP where although good quality effluent can be achieved by the plant on occasion, consistent quality cannot be maintained because breakdown of equipment disrupts the treatment process. The sludge treatment process is not operating satisfactorily because of the low retention time of the digester and insufficient number of drying beds. Operation and maintenance staffing is high by modern standards and there is little use of information technology. Storage and retrieval of all kind of information is vital for the efficient operation of any wastewater system.

The rehabilitation works can be prioritized in the order as follows:

- Replacement of corroded steel pumping mains
- Replacement of manhole covers
- Improvements to the sludge treatment process
- Replacement of grit channels
- Replacement of return activated sludge pump station
- Replacement of air blowers at WWTP
- Replacement of screens at WWTP
- Replacement of pumps at existing pump stations
- Replacement of WWTP pipe work
- New final settlement tanks
- New primary settlement tanks

CHAPTER 6
PLAN OF WASTEWATER TREATMENT AND DISPOSAL SYSTEM

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6.1 Policy and Strategy

The following objectives have been adopted in developing the rehabilitation and extension of the wastewater collection, treatment and disposal for Astana City.

- Reuse and rehabilitation of existing structures
- Improve efficiency of operation of mechanical and electrical equipment
- Adopt 2010 as a horizon year for preliminary design
- Use of local norms and regulations where it exists
- Introduction of international standards where necessary

The approach adopted will be as follows:

- Determine reasonable requirements and design criteria to maximize use of existing facilities
- Diagnostic of existing infrastructure and facilities in order to reuse as far as possible.
- Incorporate projects already with approved funding to avoid waste of committed funds.
- Make outline design for 2030 and use as basis for design of required facilities in 2010. This approach will facilitate extension of the system post in 2010.

6.2 Previous Studies

The following previous studies have been carried out for the wastewater collection and disposal system for Astana:

- Original Design for Tselinograd (Former name for Astana/Akmola) Update of Sewerage design by Kazvodocanalproject, 1965
- Tselinograd treated wastewater diversion to Nura River, Kazvodocanalproject, 1985
- Feasibility Study for Reconstruction and Extension of Astana wastewater treatment plant by Kazvodocanalproject, 1999
- Master Plan for Astana by Saudi Bin Ladin Group, February 2000

The original design updated in 1965 included the collection system as well as the wastewater treatment plant. The entire infrastructure proposed were completed in the mid 70's but the reuse component was not constructed.

The treated wastewater diversion study was carried out to determine the requirements for transferring treated wastewater for reuse on farmland to the south of Astana. As a result of the study a pump station and a 1,000mm pipeline was started to the Nura River but never commissioned.

The 1999 feasibility study was commissioned from Kazvodocanal Institute by the Ministry of Construction to study the options available for the reconstruction and extension of the WWTP in Astana. The design was based on a flow treatment of 267,000 m^3/d and consisted of rehabilitation of the existing plant as well as an extension to deal with the increased design flow. Treated wastewater disposal was to be used for irrigation with excess discharged to the Nura River.

All the studies concluded that the original plan to reuse the treated effluent in agriculture is still valid and made proposals for implementation of the plan but only some of the proposals were implemented. Pilot projects for the irrigation schemes were successfully implemented in the late 80's but abandoned as a result of perestroika.

6.3 Wastewater Design Parameters

6.3.1 Wastewater quantities and pollution loads

(1) Discharge Coefficient

The proportion of water consumption discharged to sewers for different consumers are proposed in Table 6.3.1.

SNiP 2.04.03-85 proposes factors varying between 91% and 92% depending on the intended target year.

(2) Projected Wastewater Peak Day Flow Rate

The projected peak day flows expected in the wastewater collection system based on the above proportions and water demand as defined in Chapter 3 have been calculated as presented in Table 6.3.2. It can be noted that in future households will contribute about 70% of the expected flows.

Table 6.3.1 Contribution to Wastewater Flow

Consumer Group	Discharge Coefficient
Public Standpipe	0
House connection without sewerage	0
House/ apartment with sewerage	0.9*
House/ apartment with sewerage and water heater	0.9*
House/ apartment with sewerage, water heater and hot water	0.9*
Dormitory	0.9*
Institutional	0.9*
Commercial/ industry	0.7
Thermal Plant – Potable water	0.3
Thermal Plant – Technical water	0
Industry – Technical Water	0.9

Note: * Based on SNiP 2.04.03-85

Source: SNiP, JICA Study Team

Table 6.3.2 Projected Peak Day Wastewater Flows

Unit: m^3/day

Flows	1999		2010		2020		2030	
	Water Demand	Discharge	Water Demand	Discharge	Water Demand	Discharge	Water Demand	Discharge
Domestic	74,233	66,810	76,688	69,020	124,418	111,977	163,880	147,492
Institutional	5,777	5,199	6,620	5,958	9,612	8,651	11,114	10,003
Commercial	17,748	12,424	5,239	10,744	6,442	15,654	6,674	18,781
Industrial excl. Thermal plants	0	-	15,349	3,667	22,363	4,509	26,830	4,672
Technical excl. Thermal plants	22,200	2,220	23,400	2,340	27,300	2,730	31,200	3,120
Thermal Plants	26,712	8,014	34,308	10,292	40,608	12,182	43,536	13,061
Total	**146,670**	**94,666**	**161,605**	**102,022**	**230,743**	**155,703**	**283,235**	**197,129**
Infiltration, 10%*		9,467		10,202		15,570		19,713
Total arriving at WWTP		**104,133**		**112,224**		**171,273**		**216,842**

Note: * Infiltration is based on about one third of leakage reaching the sewer system approximately equivalent to 10% of water consumption.

Source: JICA Study Team

(3) Per Capita Pollution Load

The projected domestic pollution loads expected at the wastewater treatment plant have been based on the recommendation of SNiP 2.04.02-85 and are as shown on Table 6.3.3. The values proposed be similar to values typically used in other countries like France, UK, Japan.

Table 6.3.3 Per Capita Domestic Pollution Loads

Characteristic	Concentration to be used (g/person/day)
Suspended solids	65
BOD_{total} of raw effluent	75 (50 for BOD_5)
BOD_{total} of settled effluent	40
Ammoniacal nitrogen	8
Phosphorus, PO_4	3.3
Phosphate in Detergents	1.6
Chloride, Cl	9
Detergents	2.5

Source: SNiP 2.04.02-85

Pollution loads from industries will be based on actual measurements on effluent produced by some industries as explained in Chapter 4. Internationally accepted norms will be used where actual measurements are not available.

(4) Projected BOD_5 loading

The connected population and projected BOD_5 loadings for the horizon years are presented in Table 6.3.4. It can be seen that BOD_5 contribution from households with sewerage is about 90%.

Table 6.3.4 Projected Wastewater BOD_5 Loads

Units: kg BOD_5/day

Category	1999	2010	2020	2030
Connected Population	220,100	415,200	634,800	764,500
Domestic	11,005	20,760	31,740	38,225
Commercial (Value for 1999 inc. in industries)	-	537	900	1,240
Industrial	1,575	1,922	2,380	2,640
Total	**12,580**	**23,219**	**35,021**	**42,104**

Source: JICA Study Team

(5) Projected Suspended Solids Loads

A suspended solid loads are based on values recommended in SNiP 2.04.02-85 and are as shown in Table 6.3.5.Domestic load is again the most important.

Table 6.3.5 Projected Suspended Solids Loads

Unit: kg SS/day

Category	1999	2010	2020	2030
Connected Population	220,100	415,200	634,800	764,500
Domestic	14,307	26,988	41,262	49,693
Commercial		591	990	1,364
Industrial	1,043	1,179	1,460	1,619
Total	**15,350**	**28,758**	**43,712**	**52,675**

Source: JICA Study Team

6.3.2 Design Parameters for Wastewater Collection System

Pipe materials shall be selected from the following Table 6.3.6. Pipe materials1, 2 and 3 are generally used in gravity system whereas 4 and 5 are used for pressure system. It is recommended that reinforced concrete pipe, PVC are used for gravity sewers and ductile cast iron pipe be used for pressure pipelines. These pipe materials have been selected because of the lower cost and ease of construction. Reinforced concrete pipes are manufactured locally whereas the other types of pipes are imported.

Table 6.3.6 Comparison of Pipe Materials

Pipe Materials		Remarks	Type of Foundation	Ease of Laying
1	Reinforced Concrete (RC)	- Resistance to loads is large - Worldwide and common use	- Concrete - Gravel - Sand	B
2	Vitrified Clay	- Inexpensive and easy to handle - Fragile compared to others	- Gravel - Sand	B
3	Polyvinyl Chloride (PVC)	- Light in weight and easy to handle - Usually used for smaller diameter pipe - Easy operation in installation	- Sand	A
4	Steel with corrosion protection	- Same as above remarks for RC - Usually used for pressure pipe - Easy process in lining - Cost is higher than the others	- Sand	A
5	Ductile Cast Iron (DIP)	- Same as above remarks for RC - Usually used for pressure pipe - High cost	- Sand	B

Note: Pipe cost means material cost and installation cost for diameter 300 mm. A:very easy, B:easy

Source: JICA Study Team

The design parameters, presented in Table 6.3.7, are proposed for preliminary design and have been selected in conformity with SNiP (2.04.03-85) taking into account local conditions.

Table 6.3.7 Wastewater Collection Design Parameters

Item	Pipe Material, Type and Conditions	Values
1 Roughness Coefficient of Pipes	Concrete	0.014 *
	Polyvinyl Pipe	0.010
	Steel Pipe, Ductile Cast Iron Pipe	0.013 *
2 Minimum Pipe Diameter (mm)	Road	200 *
	Micro District	150 *
	Pressure Pipe	150 *
3 Minimum Earth Covering (m)	Road	1.5 *
4 Maximum Design Velocity (m/s)	Non-metal Pipe	4.0 *
	Metal Pipe	8.0 *
5 Minimum Design Velocity (m/s)		0.6
6 Minimum Gradient	D150	8/1000 *
	D200	7/1000 *

Source: * - In accordance with SNiP 2.04.03-85, JICA Study Team

6.3.3 Wastewater Treatment Plant Design Parameters

The design parameters proposed for basic design of the wastewater treatment plant are presented in Table 6.3.8

Table 6.3.8 Proposed Design Parameters for Wastewater Treatment

Process Unit	Characteristic
Screens bar spacing	6 mm*
Grit removal diameter	Greater than 0.2 mm*
Primary settlement tanks surface loading	Less than 1.1 m^3/m^2/hour*
Aeration tank sludge load	0.2 mg BOD_5/day
Aeration tank MLSS	2,500 mg/l
Final settlement tank surface loading	Less than 0.6 m^3/m^2/hour*

Note: * in accordance with SNiP 2.04.03-85

6.4 Proposed Development Plan

The development plan has been based on the diagnostic of the existing facilities, the population and future discharges expected, the proposed extension of the urban areas.

Many of the existing facilities are still in serviceable condition and will thus be retained. The facilities, which are to be replaced, are identified and the replacement works are described below. New facilities to improve the quality of the service and for extension of the system have been identified.

6.4.1 Rehabilitation of the Existing Wastewater Collection System

Most of the existing wastewater collection systems are to be retained with rehabilitation proposed for the facilities identified below.

(1) Pipelines

It is proposed that about 20km of existing pipelines, as detailed in Table 6.4.1, be replaced mainly because of corrosion. Topographical and geotechnical investigations will be required prior to detailed design.

Table 6.4.1 Length and Diameters of Pipelines to be Replaced

Diameter	Length
100 - 400	14,300
500 - 800	6,600
Total	**20,900**

Source: ASA

(2) Manholes

Improvements in the condition of the 5,300 existing manholes are proposed to prevent blockages from debris falling into the manholes. Improvements will include replacement of covers and repairs to defects in the manhole construction such as broken steps, loose bricks etc.

(3) Pump Stations (P/Ss)

A survey of the pump stations has been carried out. The Table 6.4.2 shows a list of the pump stations (17) considered for rehabilitation. The works proposed at these pump stations are as follows:

- Replacement of inefficient pumps and other electromechanical plant
- Rehabilitation of civil and building works including health and safety works such as handrails, steps, air extractors etc.

Table 6.4.2 Pump Stations in the Worst Condition

Station Reference	Construction Year	Size	Electromechanical Condition	Building Condition
All pump stations considered to be in very poor condition				
KHC-2	1956	Medium	Very poor	Very poor
KHC-4		Medium	Very poor	Very poor
KHC-9	1970	Small	Very poor	Very poor
KHC-11	1964	Small	Very poor	Very poor
KHC-14	1965	Small	Very poor	Very poor
KHC-15	1968	Small	Very poor	Poor
KHC-16	1984	Small	Very poor	Poor
KHC-17	1961	Small	Very poor	Very poor
KHC-21	1965	Small	Very poor	Very poor
KHC-24	1970	Small	Very poor	Very poor
KHC-28		Small	Very poor	Very poor
KHC-33		Small	Very poor	Very poor
KHC-34		Small	Very poor	Very poor
Large pump stations in poor condition				
KHC-1A		Large	Poor	Poor
KHC-6	1970	Large	Poor	Poor
KHC-7	1970	Large	Poor	Good
KHC-10	1966	Large	Poor	Poor

Source: JICA Study Team

6.4.2 Extension of Wastewater Collection System

(1) Development Areas

For the horizon 2010 the Master Plan proposes about 1,300 ha of new development, mostly on the left bank of the Ishim River. Most of the extension of the wastewater collection infrastructure will thus be located in this area. Small isolated areas of development should have independent systems, which will be connected to the main system as the latter extends towards the isolated systems. The design of the wastewater collection system is based on the discharge expected from the population at horizon year 2030 in the development area.

(2) Pipelines

The arrangement for extension of the networks to new areas will be based around a network of large diameter collectors. The priority roads have been identified and design of the main collectors has been arranged along these roads. The flat topography of Astana dictates that a mixture of gravity and pressure pipelines is necessary to collect the wastewater and the design has been carried out so as to minimize the number of pump stations. The arrangement for the year 2030 is presented in Figure 6.4.1. Where the pipe proposed for 2030 is too large a small pipe sufficient for 2010 flows or shortly after is proposed. A second pipe will be necessary for the year 2030 and beyond.

The main collectors identified and proposed for construction to enable development to 2010 are shown in Figure 6.4.2 and the lengths of the different diameters are presented in Table 6.4.3. The hydraulic calculations for the main collectors for Year 2010 are presented in the supporting report.

Table 6.4.3 Length and Diameters of Main Collectors for 2010

Unit: metres

Diameter	Length
350	2,820
400	2,450
500	12,430
600	5,880
800	3,340
900	2,610
1,000	3,120
1,200	2,200
1,500	1,200
Total	**36,050**

Source: JICA Study Team

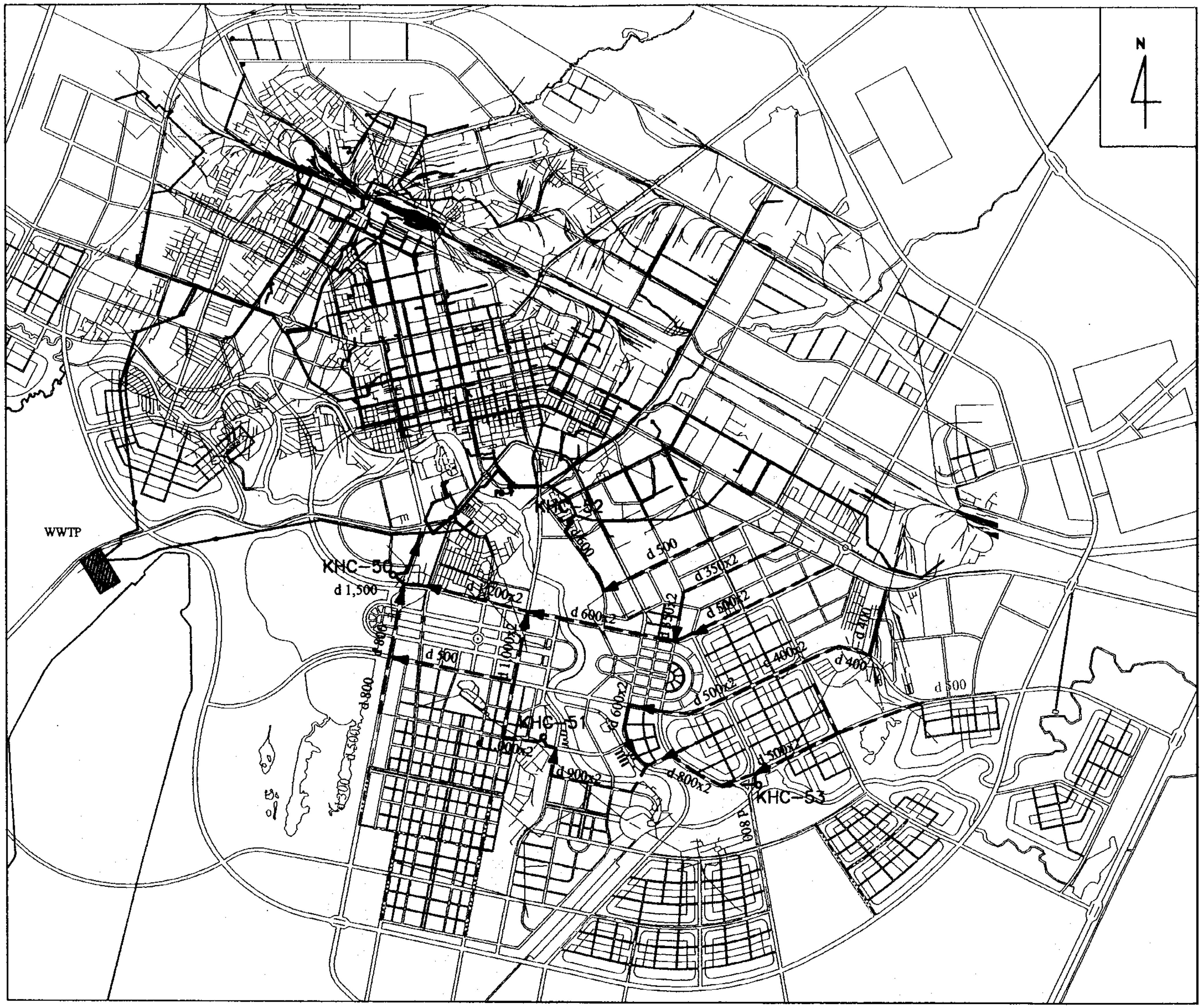
(3) Pump Stations

Three main pump stations are proposed along the main collectors. The locations of the pumping stations are shown in Figure 6.4.2. The installed capacities sufficient for each proposed pump station for the year 2010 are presented in Table 6.4.4.

Table 6.4.4 Capacity of Proposed Pumping Stations

Reference No	Duty Capacity m^3/min	Installed Capacity m^3/min	Head m	Installed kW
KHC 50	49.0	73.5	14	283
KHC 51	25.0	37.5	13	145
KHC 52	10.0	15.0	18	80

Source: JICA Study Team

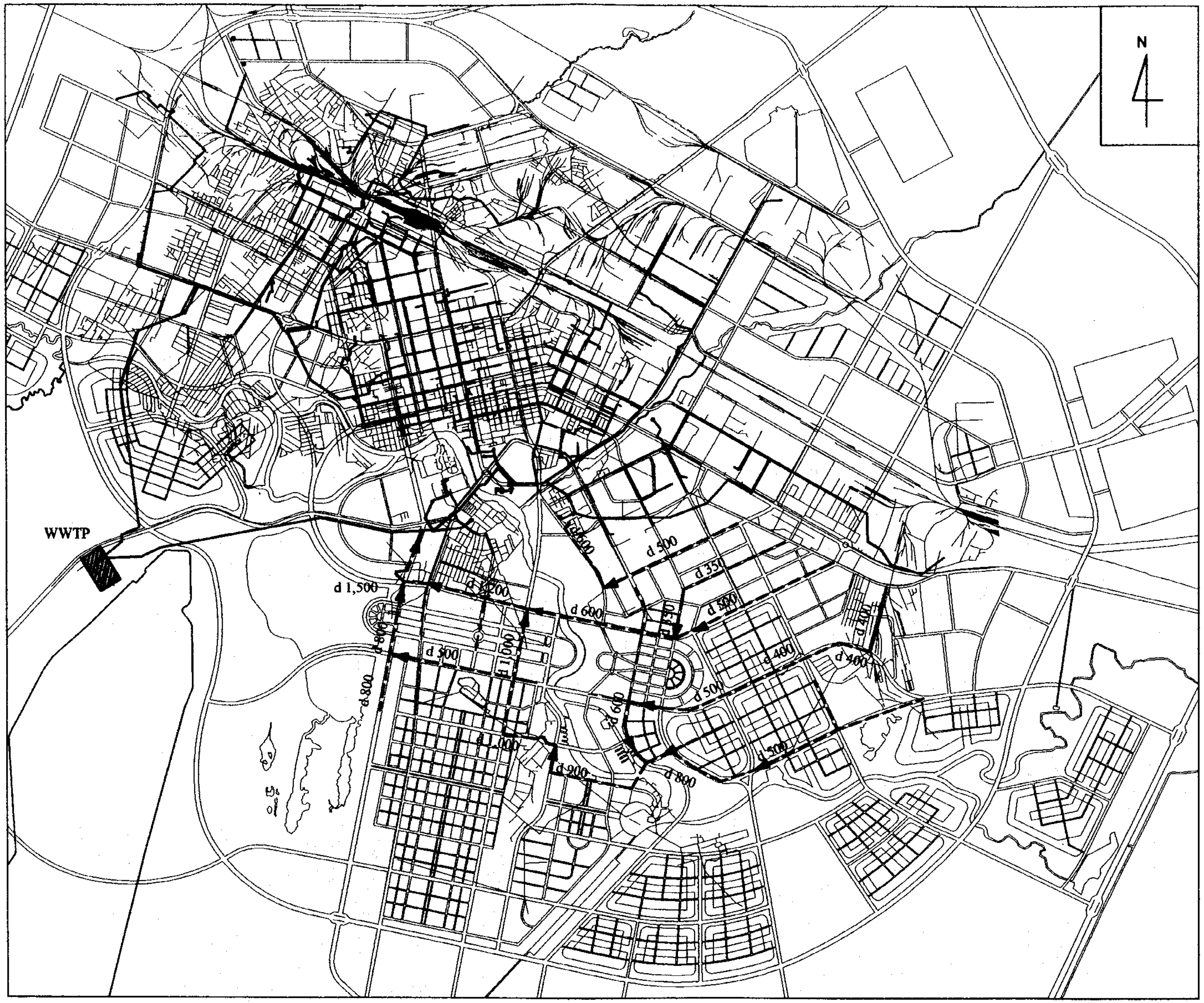


Legend

Existing collector
Proposed collector in 2010
Proposed collector in 2020
Proposed collector in 2030

0 1km 2km 5km

The Feasibility Study on Water Supply and Sewerage in the City of Astana	Figure 6.4.1 Wastewater Collection System in 2030
JAPAN INTERNATIONAL COOPERATION AGENCY	



Legend
- • Existing pump station
- ○ Proposed pump station
- —— Existing collector
- – – – Proposed wastewater collection system for 2010

0 1km 2km 5km

The Feasibility Study on Water Supply and Sewerage in the City of Astana	Figure 6.4.2
JAPAN INTERNATIONAL COOPERATION AGENCY	Proposed Wastewater Collection System in 2010

6.4.3 Wastewater Treatment Plant (WWTP)

Improvements of the existing WWTP to satisfy discharge for the year 2010 are proposed. Preliminary design has been carried out based on the diagnostic of the existing plant. It is assumed that the effluent quality requirements are maintained and advanced treatment if required will be carried out at a separate plant. The necessity for advanced treatment is considered later in this Chapter. The design calculations are presented in the supporting report. Rehabilitation and improvement works required to extend the life of the plant to at least horizon year 2010 are described below. Extension of the plant to satisfy requirements beyond 2010 will require major additional facilities.

(a) Screens and Inlet P/S No 12

- 3 new 6mm mechanically raked screens including new isolating penstocks. Fine screens are recommended to remove the maximum of solids, which can hinder the following treatment processes.
- Screening handling equipment including screw compactors, conveyors and receiving bins. Automatic operation is recommended for hygienic reason and reduces the number of operators.
- 2 pipelines to bypass the screens to enable reconstruction
- Rehabilitate building
- 2 new 450 l/s and 2 new 900 l/s pumps to replace the existing pumps including motor control centres

(b) Grit Removal and Disposal

- 2 new horizontal flow grit traps, 10m diameter
- Bypass to grit traps
- Grit removal pump including classifier, receiving bins and organics return PS

(c) Primary Settling Tanks

- Rehabilitate 2 primary settling tanks distribution chamber
- 2 new 28m diameter primary settling tanks
- Rehabilitation of 2 of 6 existing primary settling tanks
- Rehabilitation of 2 primary sludge P/S (2 x 80 m^3/hr each)

(d) Aeration Tanks

- Rehabilitation of 4 aeration tanks
- Rehabilitation of the blower house
- Replacement of air blowers (6 x 20,100 Nm^3/hr)

- New return activated sludge P/S (150 m^2)
- Replacement of RAS pumps (5 x 950 m^3/hr each)

(e) Final Settling Tanks

- Rehabilitation of 3 distribution chambers
- 2 new 28m diameter final settling tanks
- Rehabilitation of 2 of 10 existing final settling tanks

(f) Pipelines

- Grit trap to new primary settling tanks
- Primary settling tanks to aeration tanks
- Aeration tanks to final settling tanks
- Rehabilitate wastewater system
- Rehabilitate existing pipelines

(g) Telemetry and Automation

- Semi automatic system with local control and remote status display. A central monitoring room will be established where the status of all the equipment can be observed will be constructed. Control of the equipment will only be from the local panel.

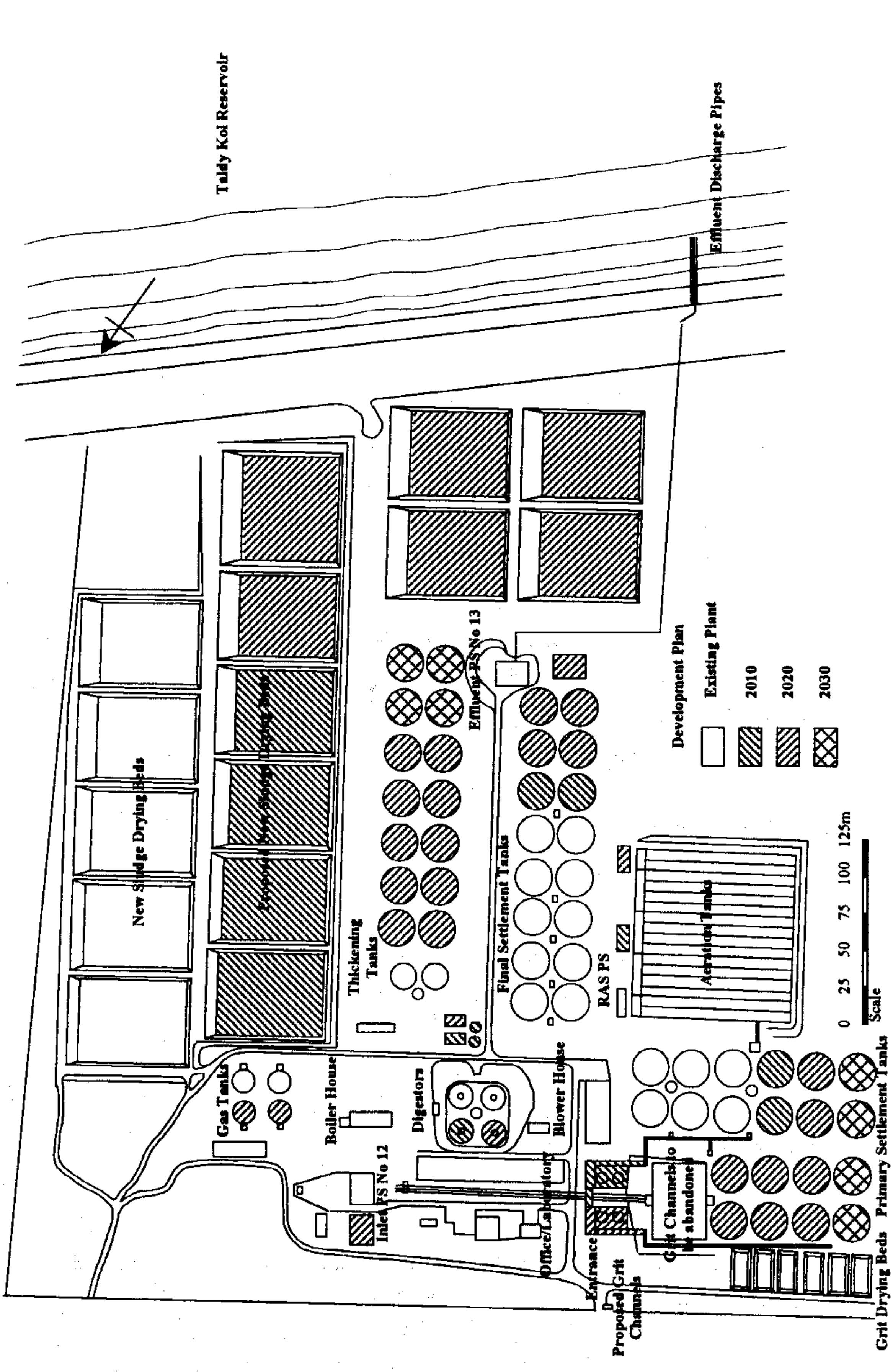
(h) Miscellaneous Buildings, Workshops, Roads and Footpaths

- Rehabilitate all existing buildings (repairs to doors, windows, paintwork), workshops and laboratory including all building services
- Provide workshop and laboratory equipment
- New roads and footpaths

Figure 6.4.3 presents the proposed WWTP development plan for the Year 2030. Independent treatment facilities, such as packaged WWTP will be required for isolated development such as the airport and should be provided by the developer.

6.4.4 Sludge Treatment

The existing sludge treatment facilities require upgrading because it is not operating as designed. The water content of sludge from existing sludge thickening facilities is too high for efficient digestion and mechanical thickening is proposed. The technology used for digesters is difficult to control, it is recommended that a secondary digester be provided. The boiler house requires rehabilitation and two of the three boilers are at the end of their design life. The sludge drying beds area is too small.



Feasibility Study for Water Supply and Sewerage in the City of Astana	**Figure 6.4.3**
JAPAN INTERNATIONAL COOPERATION AGENCY	**Development Plan for the Wastewater Treatment Plant**

Assuming that dried sludge is either to be used for agriculture or disposed in landfill, the following works are proposed for sludge treatment:

(1) Sludge Treatment

- Rehabilitation of 2 existing gravity thickening tanks and provision of covers
- Rehabilitate thickened sludge pump station (2 x 80 m^3/hr)
- Activated sludge belt thickener facility including feed pumps, drainage system, transfer pumps (3 x 80 m^3/hr). Belt thickener is proposed instead of centrifuge because of better reliability and lower energy costs.
- Polyelectrolyte preparation including mixing tanks and dosing pumps
- New belt thickener building and chemical storage (240 m^2)
- Covered blended sludge storage tanks with mixers (2 x 500m^3)
- Thickened blended sludge transfer pump stations

(2) Anaerobic Digestion

- Rehabilitate 2 existing digesters including provision of mixers
- Conversion of existing digesters to a 2 stage thermophilic system including heat exchangers, mixers, recirculation pumps, sampling pipework etc.
- New 2nd stage digestion tank (2,500 m^3)
- Rehabilitate existing boiler house
- Replace 2 boilers (2 x 4.5 tone steam/hour)
- Rehabilitate 2 gas holders

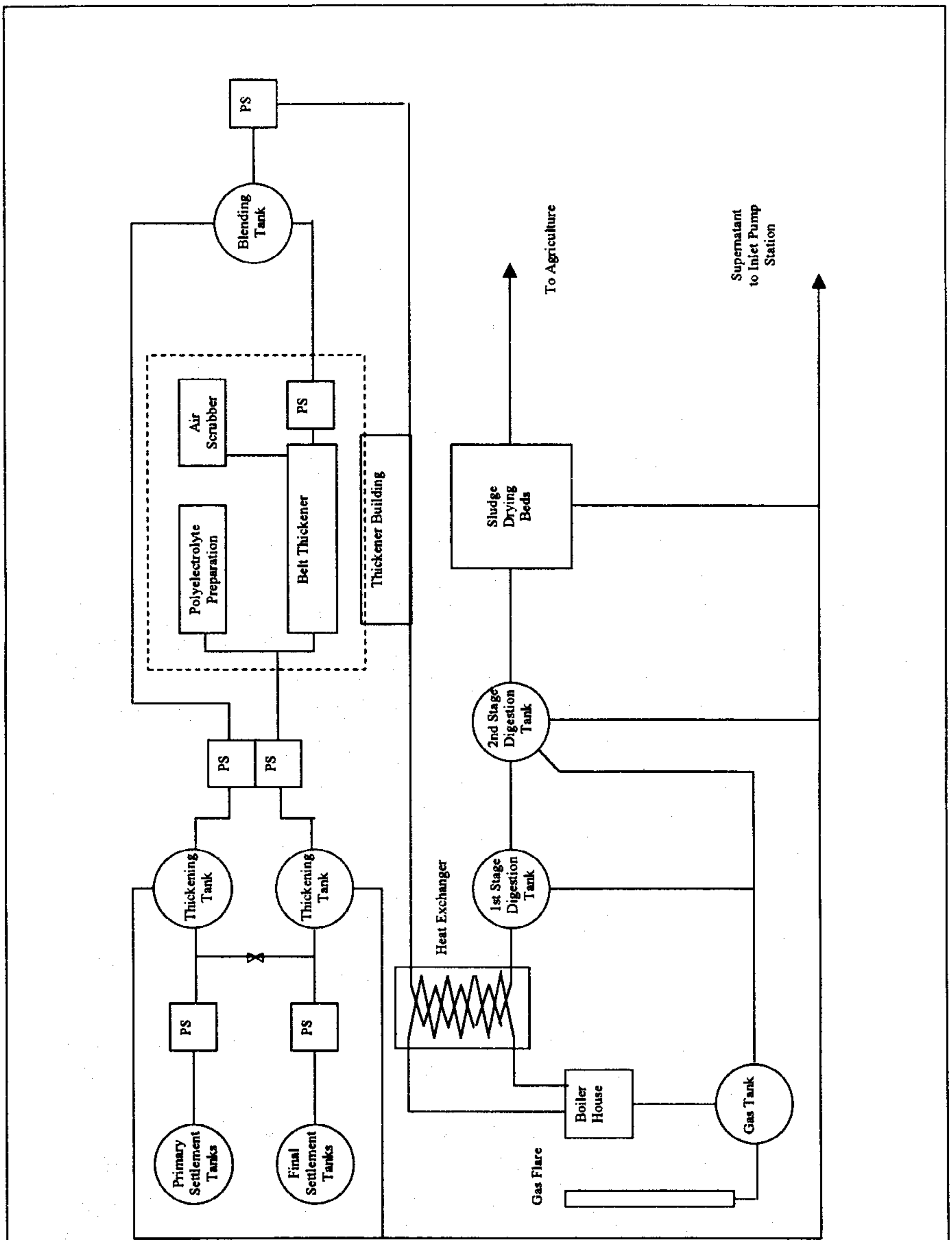
(3) Sludge Pipelines

- Primary tanks to thickening tank and blended sludge storage tank
- Surplus activated sludge P/S to sludge thickening facility and blended sludge storage tank
- Blended sludge storage tanks to digestors
- Digestors to sludge drying beds

(4) Sludge Drying Beds

- 5 new 100 x 70m asphalt lined sludge drying beds
- Drainage system for drying beds

Figure 6.4.4 presents a schematic of the proposed sludge treatment process. Options and recommendation for disposal of sludge are considered later in this chapter.



Feasibility Study for Water Supply and Sewerage in the City of Astana	**Figure 6.4.4**
JAPAN INTERNATIONAL COOPERATION AGENCY	**Process Schematic for Proposed Sludge Treatment**

6.4.5 Operation and Maintenance

The operation and maintenance of the wastewater system has to be highly integrated with the overall organization of ASA, which is considered in a later chapter. This section deals only with the direct operation and maintenance of the wastewater system.

The two direct operation and maintenance departments are responsible for the operation, periodic maintenance and small repairs. Important repairs are carried out by the specialist departments such as mechanical, electrical and major civil work. It is not proposed that this system be changed. Outsourcing can potentially change the organization of operation and maintenance activities but it is not expected that this approach will be adopted in the near future.

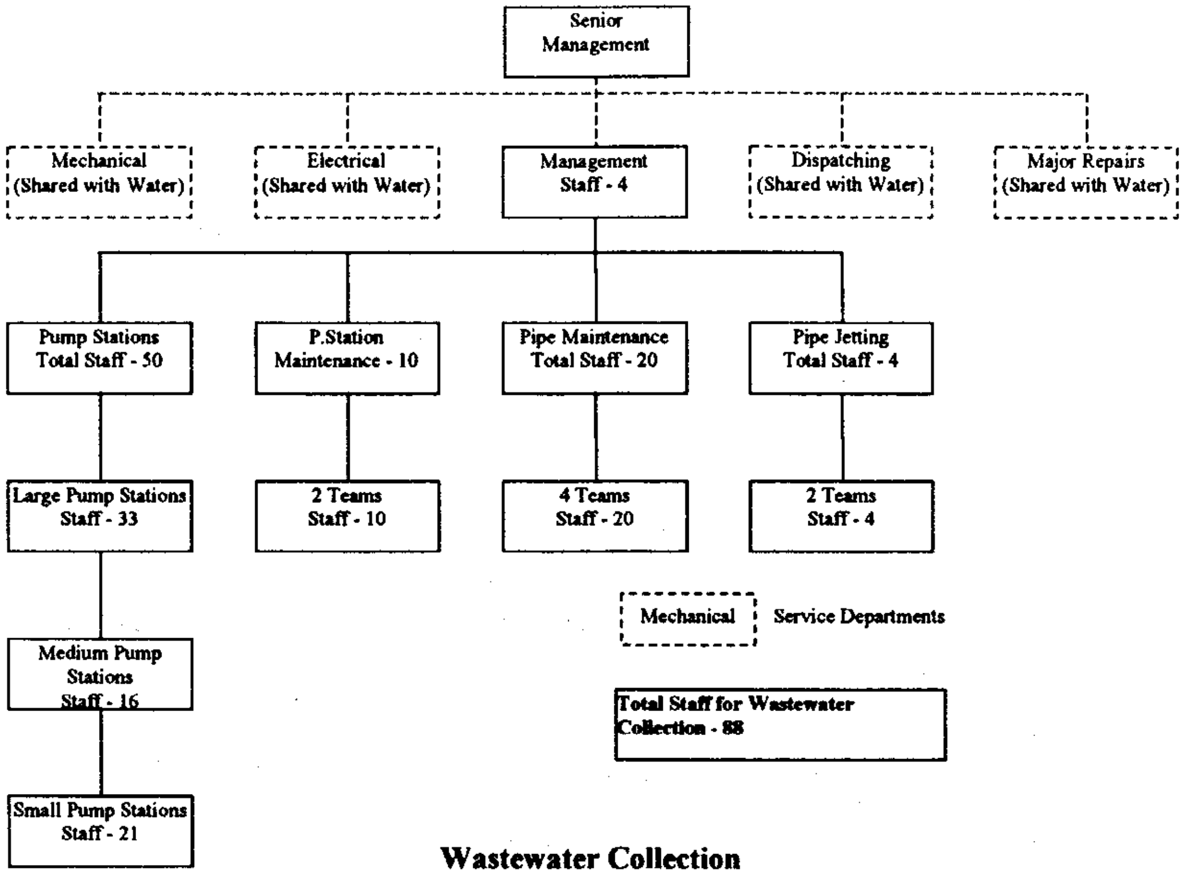
The staffing for the operation and maintenance of wastewater collection system is high by western European and Japanese standards because most of the equipment is based around manual operation. Reduction in staffing can be achieved through installation of simple controls such as timers, level control and flow meters. However installation of a fully automatic control system is not recommended because of the risk that proper maintenance cannot be carried out through lack of expertise and spare parts.

The maintenance requirement of the wastewater system is high because of the disproportionate attention required by the manholes. This requirement will disappear with improvements proposed for the manhole covers and can result in the lowering of the present manning level. On the basis of the above improvements it is expected that the staffing level can be reduced as follows:

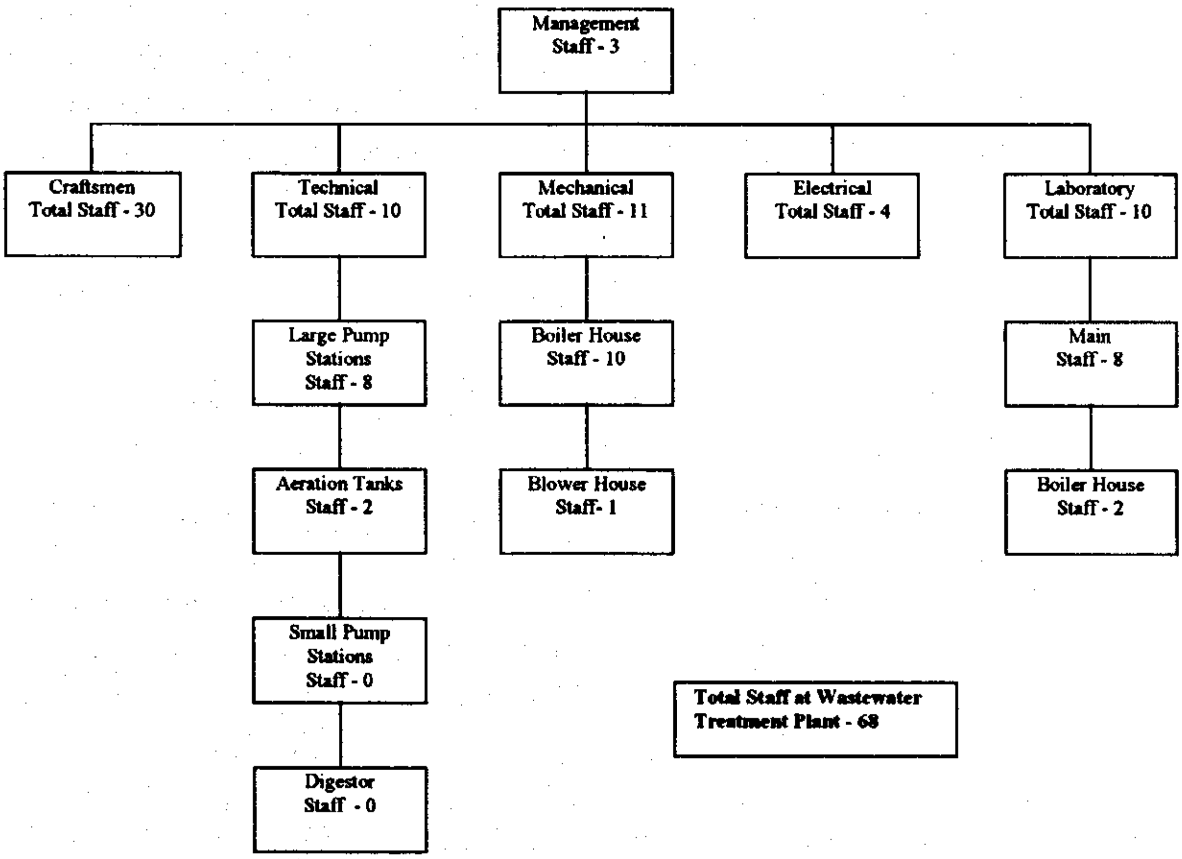
Department	**Present**	**Proposed**
Wastewater Collection	125	88
Wastewater Treatment	115	68
Total	**240**	**156**

The future staffing level assuming that the organization structure stays the same are presented in Figure 6.4.5. Further reduction in staffing is possible if service contracts and outsourcing are introduced for services such as meter readings, preventive maintenance and repairs.

There is at present no management information system to help in the operation and maintenance of the wastewater system. Collection and dissemination of information about the system is important and necessary for an efficient operation.



Wastewater Collection



Wastewater Treatment Plant

Feasibility Study for Water Supply and Sewerage in the City of Astana	**Figure 6.4.5**
JAPAN INTERNATIONAL COOPERATION AGENCY	**Proposed Staffing for Wastewater System**

As part of the introduction of a management information system basic information about the wastewater system has to be gathered and stored such that it is accessible by all authorized personnel. To this end the following tasks are necessary:

- Preparation of an updated map of the wastewater collection network
- Preparation of a sewer network database for all manholes
- Preparation of a pump database
- Preparation of an inventory of all assets
- Provision of a management information system (hardware and software)
- Inspection of Taldy Kol reservoir embankment
- Detailed characterization of treated effluent, surplus activated sludge and digested sludge.

6.5 Treated Wastewater Reuse Potential

(1) Agricultural use

There is a history of treated effluent reuse for irrigation in the area to the south of Astana. Treated wastewater stored in Taldy Kol reservoir was used for irrigation of 1,706 ha of agricultural land, mostly of the Yenbek-Koshi ASU 154/3 agricultural enterprise using 1.3 million m^3 per year until 1995, when the agricultural sector was reorganized and the agricultural enterprises in the area were privatized. The following examines the future potential of reviving this practice. More detailed evaluation of the use of treated effluent from Taldy Kol reservoir is presented in the supporting report.

a) Availability of Treated Wastewater and Water Balance for Taldy Kol Reservoir.

The availability of treated wastewater at the horizon years is given in Table 6.5.1. A volume of 12.4 Mm^3/year has been allowed for evaporation as recommended in the Technical and Economic Assessment for the irrigation system using treated wastewater from Tselinograd City prepared in 1989. The storage volume required assuming a 3 months irrigation program is also shown in Table 6.5.1.

Table 6.5.1 Availability of Treated Wastewater for Irrigation Use

million m^3

Year	1999	2010	2020	2030
Total Annual Average	31.7	34.1	52.1	66.0
Total Available	19.3	21.7	39.7	53.6
Min. Storage Requirements	14.5	16.3	29.8	40.2

Source: JICA Study Team

Recent bathymetric survey of Taldy Kol Reservoir indicated that the reservoir capacity at maximum design level is about 36 Mm^3, less than the original design capacity of 45 Mm^3. It can be seen that this volume is more than sufficient to cover the requirements as shown in Table 6.5.1. However it should be noted that additional storage will be necessary near to the proposed irrigated areas in addition to the volume available in Taldy Kol Reservoir to regulate the irrigation requirements and for emergency purposes. Further studies are necessary to finalise the irrigation storage requirements. The present capacity of Taldy Kol reservoir is approximately equivalent to about 2 years storage of surplus treated waste water. Laboratory tests shows that the deposited sludge do not have excessive concentrations of metals There is therefore no urgency in taking measures to increase its capacity or to remove the deposited sludge.

b) Treated Wastewater and Soil Characteristics

The treated wastewater is considered suitable with a small hazard of soil salinization in accordance with Sanitary Norms 33-2.202-86.

The nature of the soil makes it essential to adopt crop rotation in order to maintain soil fertility. The soil characteristics dictate the use of overhead irrigation. An average of about 3,290m^3/ha is necessary for the proposed crop rotation system to be proposed.

c) Agricultural Enterprises

Astana is within the Tselinogradski agricultural region, with 22 agricultural enterprises registered on 1st January 1998. Nine of these enterprises have used irrigation in the past but only two still carry on with this practice. Only two of the nine enterprises had experience of using treated wastewater. A total of 9,445 ha of irrigable land were developed but only 601 ha are still irrigated using water from the Ishim river.

d) Availability of Land

Two large agricultural enterprises, Ermagambetov & Co and Yenbek-Koshi RSE 121 to the south of Astana, have been identified as holding large areas (about 39,000 ha) of moderately arid steppe agricultural land which can be improved if irrigation is provided. These enterprises were identified in the agricultural development plan of 1991 prepared by Kazgiprovodhoz for the Ministry of Water Economy as being suitable for development using treated wastewater from Astana. The two agricultural enterprises, amongst many others covering a total area of

562,000 ha were identified for the first five years of a ten year program (1991-2000) for land reclamation and development. This program was abandoned when it was realized that there is insufficient water for many of the schemes and the cost of implementation was beyond affordability.

Given that availability of water is the limitation on the irrigation potential, maximum use of the available treated wastewater must be considered. Based on the available volume of treated wastewater the area of land which can be developed for irrigation at the horizon years are presented in Table 6.5.2 and are from the land holdings of the above mentioned farms. An area of 5,000 ha has already been identified by the Technical and Economic Assessment for the irrigation system using treated wastewater from Tselinograd City prepared in 1989.

Table 6.5.2 surface Areas to be developed for Irrigation

Unit: hectares

Year	1999	2010	2020	2030
Area of Irrigation	5,900	6,600	12,100	16,300

Source: JICA Study Team

e) Potential Crops

Crops produced in the past on land irrigated using treated effluent from Taldy Kol reservoir were all for animal feed and include potatoes, corn and other fodder crops

The Alva crop rotation system making use of eight fields growing fodder crops such as corn, barley, oats, peas and alfalfa is proposed.

It is to be noted that the requirements of SanPiN 4630-88 and Sanitary Norms and Regulations for Organization and Utilization of Agricultural Irrigation Fields are applicable. The latter stipulates that only technical, grain and other crops for fodder purposes can be grown on Agricultural Irrigation Field. Cultivation of vegetable is prohibited.

f) Past Studies

Recent studies carried out between 1994 and 1995 in Kazakhstan for the World Bank show that agricultural enterprises provided with irrigation for their land could be economically viable. As a result of these studies, the World Bank and the Asian Development Bank have provided loans to the Government of Kazakhstan for the restructuring of the agricultural sector.

These studies show that there is a large potential for improvement in the agricultural sector.

g) Description of Proposed Project

A preliminary list of facilities required is presented below:

- 1,300 l/s transfer pump station
- 30 million m^3 storage reservoir
- 35 km of 1,000mm diameter transfer pipeline
- 80 km of distribution canals
- 209 centre pivot irrigation system with pump station
- Drainage system
- Environmental Management Plan

Retention of Taldy Kol reservoir is necessary to regulate the flow of treated wastewater and store it during the winter months. Another important feature of Taldy Kol reservoir is its function as a facultative pond, which further improves the quality of the treated wastewater especially improved helminth removal. Maintenance of the reservoir is therefore important for the success of the irrigation project. Integrity of the embankment is therefore important and detailed regular inspection by a dam specialist is recommended. A full feasibility study is necessary in order to verify the economic and financial implications before implementation of the treated wastewater reuse project.

(2) Forestry Watering

Large areas of forest (5,337 ha over the last 4 years) have been planted around the city and mostly (3,861 ha) around Taldy Kol reservoir. The original design was based on species which are resistant to the climatological conditions in Astana and do not require watering. Surveys carried out on these plantings in 1998 indicated that about 50% of the saplings do not survive. The Ministry of Agriculture has decided in July 2000 to amend its policy and watering of these new plantations is now promoted. The watering requirement was specified as 120 litres per sapling in the first year reducing to 30 litres in later years. This is equivalent to an average of about 100 m^3/ha/year. It is recommended that water from Taldy Kol reservoir be used for such purpose. The area of forest close to Taldy Kol reservoir is approximately 4,000 ha which will require about 400,000 m^3/year. This is only a small proportion of the available treated wastewater.

(3) Aquaculture

A fish farming enterprise was in existence about 20 years ago using water from the Nura River. Although the major civil infrastructure is still in existence the enterprise does not exist anymore. It is not known why this industry was abandoned but it is very likely that it was stopped as a result of increased pollution of the water in the Nura river.

It is likely that very strict water quality criteria will be required by the Ministry of Health if treated effluent is used for aquaculture. The World Health Organization has recommended that the fecal coliform index of water used for aquaculture be a maximum of 1,000 per 100ml. The average fecal coliform index for water in Taldy Kol reservoir is 350 per 100ml. Even though it is prohibited some illegal fishing is practiced in Taldy Kol reservoir. No evidence of toxicity to fish life has been noted in the reservoir. It is recommended that the Ministry of Health review its regulation based on SanPiN 4630-88.

(4) Industrial Use

The potential for use of treated effluent as technical water is limited because most of the technical water is used for cooling purposes. Special treatment is necessary to reduce the mineral contents of the water to prevent deposition of scale and to limit corrosion.

(5) Recreational Use

Taldy Kol reservoir is not used for recreation. The sanitary authorities have prohibited the use of the reservoir for any human activities. The average fecal coliform index is about 350, which is acceptable when compared with the following bathing water regulations and standards:

United Nations Environmental Programme	1,000 MPN /100 ml
European Union	2,000 MPN /100 ml

6.6 Advanced Treatment Options

Advanced treatment is required when conventional biological treatment cannot achieve an effluent of sufficiently high quality for direct discharge into either the Ishim, Nura or Selety rivers because there is insufficient flows for dilution of the treated effluent. A minimum flow of about $10m^3/s$ is necessary for such dilution compared to minimum flow of $0.1m^3/s$ in the Ishim River. Emergency discharge from Taldy Kol to marshland and eventually the Ishim River is presently only allowed during the spring thaw and after testing. The three main objectives are as follows:

- Nutrient removal for receiving waters susceptible to eutrophication
- BOD/COD reduction for water supply use
- Improved pathogenic quality for water supply use

The surface quality norms defined in SanPiN 4630 is targeted for water to be used either for water supply or for recreational purposes with no norm for limiting nutrients in effluent. It is therefore assumed that nutrient removal, i.e. removal of nitrogen and phosphorus is not a requirement.

Assuming that Taldy Kol reservoir is retained, BOD and COD reduction to the levels required by SanPiN 4630 can be achieved by coagulation and rapid gravity filtration to remove suspended matter prior to adsorption in granulated activated carbon filters. Rapid gravity filtration will remove coagulated suspended solids and precipitated chemicals. Granular activated carbon is essential for the removal of many liquid organic pollutants and consequently the reduction of chemical oxygen demand.

Improved pathogenic quality is achieved by ultraviolet disinfection which will neutralize practically all bacteria, viruses as well as helminths. This process is more advantageous than chlorine disinfection because of the risk of formation of disinfection byproducts like chloroform etc. High doses of chlorine are normally required to achieve the requirements with the result that de-chlorination will also be necessary.

The process schematic for advanced treatment is presented in Figure 6.6.1. The expected improvement in treated wastewater quality as a result of advanced treatment but no nutrient removal is presented in Table 6.6.1.

Table 6.6.1 Expected Improvements after Advanced Treatment excluding Nutrient Removal

	Units	Average Taldy Kol reservoir	After Rapid Gravity Filtration	After GAC filtration	After UV disinfection	SanPiN 4630-88
Suspended solids	mg/l	7	<4	<2.5	<2.5	
Equivalent NTU	Unit	3	<2	<1	<1	
BOD_5	mg/l	6	4	<3	<3	3
COD	mg/l	62	50	<10	<10	15
Nitrate	mg/l	17	17	17	17	45
Faecal Coliforms	MPN/100ml	342	200	200	<100	100
Total Coliforms	MPN/100ml	1.69E+05	1.7 E+04	1.0 E+04	1.0 E+03	1.0E+05

Source: JICA Study Team

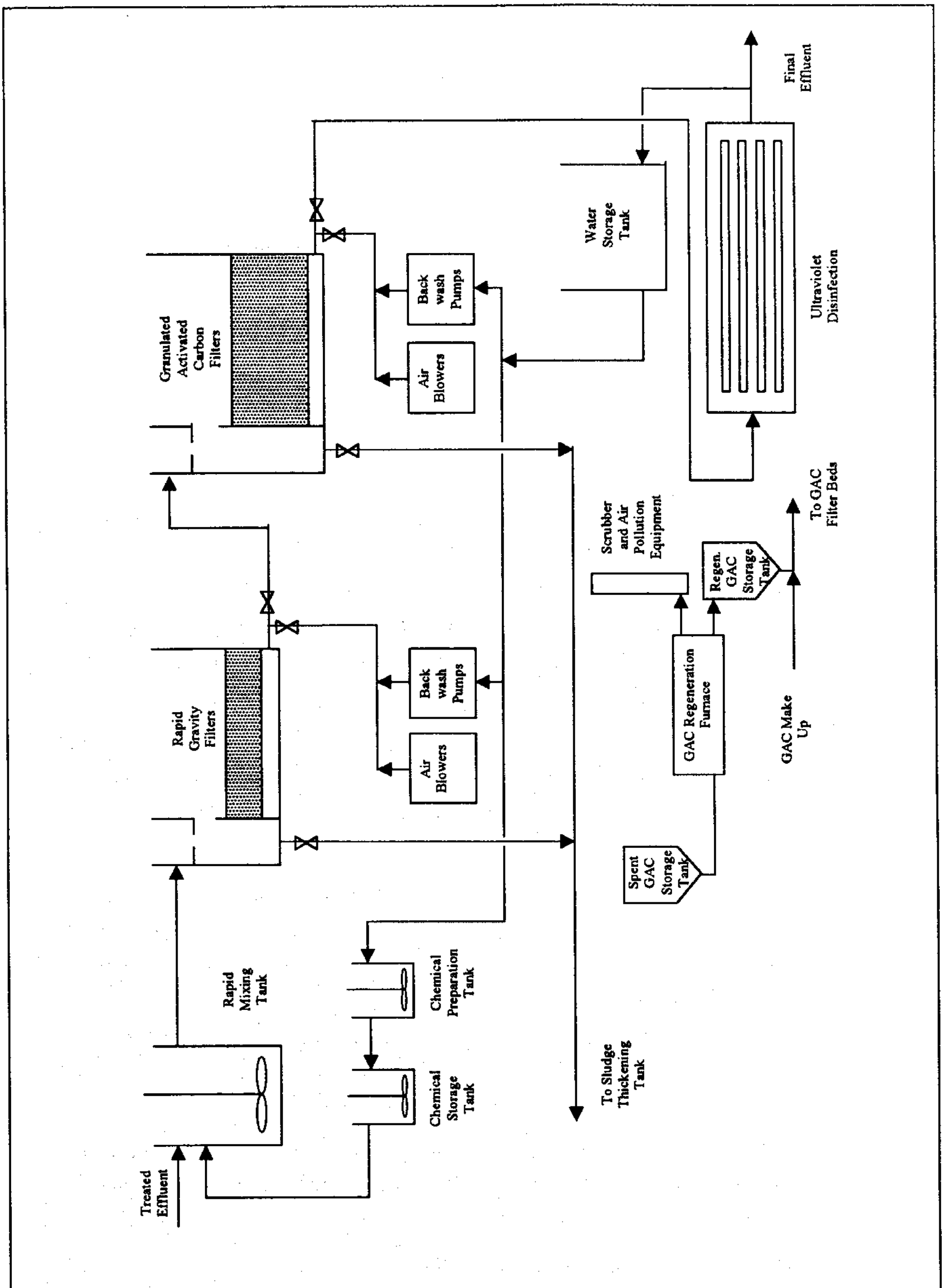
The cost estimates (capital and O & M) for advanced treatment is presented in Table 6.6.2

Table 6.6.2 Cost Estimates for Advanced Treatment

Units: 1,000 USD

Process	Capital Costs		Operating Costs	
	With Nutrient removal	Without Nutrient removal	With Nutrient removal	Without Nutrient removal
Nutrient Removal	7,300		443	
Rapid Gravity Filtration	8,000	8,000	440	440
Granular Activated Carbon Filtration	20,200	20,200	1,022	1,022
UV Disinfection	4,400	4,400	284	284
Total	**39,900**	**32,600**	**2,179**	**1,746**

Source: JICA Study Team



Feasibility Study for Water Supply and Sewerage in the City of Astana	**Figure 6.6.1**
JAPAN INTERNATIONAL COOPERATION AGENCY	**Process Schematic for AdvancedTreatment**

6.7 Alternative Study of Options for Future Wastewater Treatment and Disposal

6.7.1 Selection of Scenarios

The following scenarios have been developed on the basis of reuse of treated effluent, treated effluent quality, discharge location and relocation of the wastewater treatment plant.

1. Retain Taldy Kol reservoir and reuse of the treated effluent for irrigation and agricultural use in the area to the south of Astana
2. Introduction of advanced treatment to achieve desired surfacewater quality for disposal to Ishim River
3. Introduction of advanced treatment to achieve desired surface water quality for disposal to Nura River
4. Introduction of advanced treatment to achieve desired surface water quality for disposal to Selety River
5. Relocation of the existing wastewater treatment plant

Disposal of treated wastewater by infiltration to ground water is not possible in the area surrounding the wastewater treatment plant because of high groundwater which is at ground level close to the plant.

6.7.2 Comparison of Alternatives

All the scenarios are based on either reuse of the treated water for irrigation or advanced treatment to achieve the desired surface water quality.

(1) Scenario 1

Scenario 1 assumes that treated wastewater will be used for irrigation with surplus discharged to marshes near to the Ishim River during the spring thaw. This scenario is part of the original project, which has been suspended as a result of perestroika. Most of the agencies support this scenario.

Reuse of effluent for irrigation and agricultural use will require a storage reservoir to regulate the supply and demand of treated water. Discharge of surplus treated water can be effected during the spring thaw as is presently practiced.

Preliminary study shows that there are potential for reuse of treated water particularly in agriculture. Further studies are required to determine the economic and financial benefits of such reuse.

The advantages of this scenario are as follows:

- Reuse of water that is generally a scarce commodity in this part of Kazakhstan

- Benefits for agriculture
- Least cost for discharge

The disadvantages are:

- Uncertain future for agriculture
- Additional funds required developing irrigation system

The works required for this scenario is the rehabilitation of the existing wastewater treatment plant and the implementation of an irrigation program to be determined through additional studies. Figure 6.7.1 shows the required arrangement for this scenario.

(2) Scenarios 2 to 4

Scenarios 2 to 4 assume all year round discharge to one of the rivers around Astana. The following considerations have to be taken when discharging to the rivers:

- All the rivers in the vicinity of Astana are used for water supply
- All the rivers have low flows in summer and autumn thus limiting discharge during these periods
- All the rivers are frozen in winter
- Large flows are necessary to provide the dilution necessary to maintain river water quality to the regulatory standard and they only occur in spring
- The distance of the wastewater treatment from the point of discharge
- All year discharge to the rivers will require advanced treatment to meet the strict surface water quality requirement

The desired water quality in all the rivers around Astana cannot be achieved by dilution of the treated water with natural flow in the river because the low river flows in summer. Advanced treatment of wastewater can be used to achieve the desired river water quality but it is very costly.

The Ishim River being the closest to the city is the obvious choice because it is already the eventual recipient of treated effluent from Taldy Kol reservoir in the spring when the existing siphon is put into operation. The siphon is also used for emergency purposes when the water level in the reservoir exceeds the design level. Figure 6.6.1 shows the required arrangement for discharge to the Ishim River. The other two rivers, the Nura and Selety are respectively about 20km to the south and 40km to the north of the wastewater treatment plant and will thus require a long transfer pipeline. The pumping head will also be higher thus operating costs will be higher. The comparison of these two scenarios as well as the required works and cost estimates are presented in Figure 6.7.2.

The discharge to the Ishim River after advanced treatment is not supported by many agencies because of the cultural taboos linked to wastewater, even treated. ASA supports this possible scenario.

Disposal to the Nura is preferred to discharge to the Ishim because there are much fewer settlements downstream of the Nura River. This scenario is supported by the State Sanitary Epidemiological Department.

Discharge to the Selety River is supported by the Ecological and Environmental Protection Committee and is promoted to increase irrigation potential to the North of Astana.

The advantages of discharging directly to the rivers are as follows:

- All year round discharge is possible
- No reliance on agricultural use or for forest irrigation
- Maintenance of river water quality
- Improved river flow

The disadvantages are:

- High cost of advanced treatment

(3) Scenario 5

The advantages of relocating the wastewater treatment plant instead of rehabilitating the plant are presented below.

- Release of land for urban development
- No discharge to Ishim River
- Resolution of reported but unconfirmed odour nuisance

The disadvantages of relocation are:

- Extension to infrastructure such as collectors, access and power supply are required
- Very costly new plant
- Relocation of Taldy Kol reservoir necessary if treated effluent is reused

More than 50 hectares of land could be released for development if the plant is relocated but the development plan has earmarked the area for forestry and parks. It is also very unlikely that relocation will prove to be economical because of the high cost of relocation. In addition to the cost of the plant itself the cost of all infrastructure such as access, power supply, collectors etc. will also have to be included. The disposal of Taldy Kol reservoir will release even larger area of land, which can be used for urban development or forest belt. This scenario is supported by Astana Municipality who is concerned about the smell coming from the WWTP. Figure 6.7.3 shows the required arrangement for this scenario.

6.7.3 Selection of the Optimum Scenario

The capital costs and operating costs for each scenario are summarized in Table 6.7.1.

Table 6.7.1 Evaluation of Scenarios

Units: Million USD

Option	Capital Costs	Marginal Operating Costs
Scenario 1	28.4	0.75
Scenario 2	54.4	2.05
Scenario 3	61.0	2.50
Scenario 4	63.1	2.63
Scenario 5	142.0	0.75

It can be seen that Scenario 1 is the least cost scenario and is therefore recommended. This option relies on the reuse of the treated effluent which was the original concept adopted for the wastewater treatment plant and Taldy Kol reservoir in 1975. Further studies are necessary for identifying the best options for reuse and an additional feasibility study for irrigation is required given the economic upheaval resulting from perestroika. The temporary measures presently adopted for disposal of the surplus treated wastewater from Taldy Kol reservoir to marshland should therefore be maintained until the implementation of the project for reuse in agriculture.

The relocation of the wastewater treatment plant and Taldy Kol reservoir described in Scenario 5 will require the additional funding indicated above.

The second priority scenario is the adoption of expensive advanced treatment, which should only be considered if the reuse of treated effluent is impossible.

6.7.4 Sludge Disposal

Digested sludge is fairly inoffensive product but there can still be a high degree of pathogenic bacteria depending on the digestion process. Thermophilic digestion will leave the least level of pathogenic hazards but it is very difficult to control as discussed previously. Careful handling is therefore still required to avoid unnecessary exposure to such hazards. The concentrations of heavy metals in the sludge will dictate the final disposal method. In Astana since most of the wastewater is of domestic origin it is expected that heavy metals contents will be low.

The following final disposal options are available:

- Direct agricultural use
- Forestry use
- Composting
- Fertilizer production
- Pelletisation
- Incineration
- Landfill

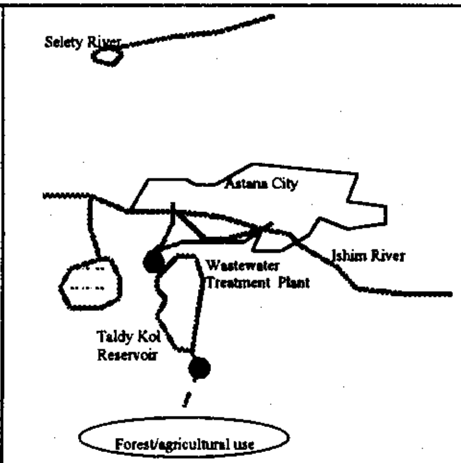
The priority disposal of sludge should be direct to agriculture and forestry. This option is dependent on good control on the application rate to avoid excessive heavy metal application to the land. Careful application is necessary to avoid human contact. The type of treatment also limits the scope for reuse. The reuse of stabilized sludge in agriculture is regulated by the Ministry of Health who has published "The Sanitary Norms and Regulations for the Organization and Utilization of Treated Wastewater in Agricultural Irrigation Fields" issued in Almaty in 1997. This disposal route is promoted by most countries as being the most effective. Farmers used to collect the sludge from the WWTP but it is reported that because of the high cost of transport and the reduction in agricultural production no sludge is collected anymore. There may be a case for ASA to provide the transport of the dried sludge to the farmers to encourage its use.

Composting with other organic matter such as domestic solid waste can be used to further improve the quality of the final product. The domestic waste will have to be sorted for this purpose. One of the improvements resulting from composting is the disinfection of pathogenic bacteria. This is a potential disposal route and should be considered together with the proposals for disposal of solid waste. Marketing of the product is a complication, which will have to be addressed. There are more than 55 such facilities in the USA. This method is also used in the Netherlands. The order of capital costs expected for such facility is expected to be in the range 10 – 90USD per inhabitant.

Scenario 1

Required Works

- Rehabilitate existing wastewater treatment plant
- Irrigation system is required for irrigation and agricultural use in the area south of Astana



Advantages

- Least cost solution for wastewater discharge
- Reuse of treated effluent in the Tselinogradskogo region for irrigation an agriculture

Disadvantages

- Uncertain irrigation and agriculture usage
- Crop irrigation depend on treated effluent quality

Cost Estimate (Excluding cost of irrigation system)

WWTP Rehabilitation	20.4
Advanced Treatment	-
Pipeline	7.1
Pump Station	0.9
Total Capital Costs	**28.4 M USD**

Annual Operating Cost - 0.75 M USD

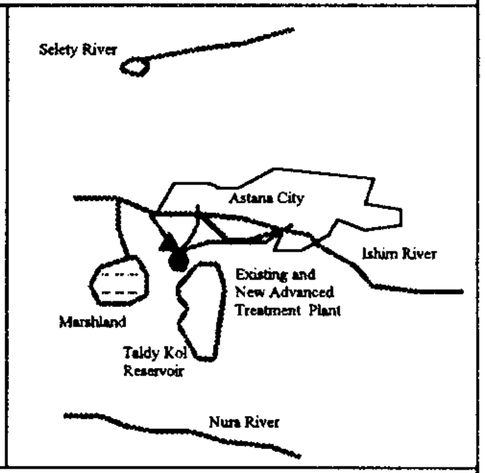
Evaluation

Scenario totally dependent on irrigation and agricultural use. Further studies are necessary

Scenario 2

Required Works

- Rehabilitate existing WWTP
- Advanced Treatment Plant including rapid gravity filters, granular activated carbon filters and ultraviolet disinfection
- Discharge pipeline



Advantages

- Water quality maintained in Ishim river
- Improved low flows in the Ishim River
- Better quality water for irrigation downstream of the Ishim River

Disadvantages

- High cost of tertiary treatment
- Higher tariffs for water

Cost Estimate

WWTP Rehabilitation	20.4
Advanced Treatment	32.7
Pipeline	1.1
Pump Station	0.2
Total Capital Costs	**54.4 M USD**

Annual Operating Cost - 2.05 M USD

Evaluation

High capital and operating cost.

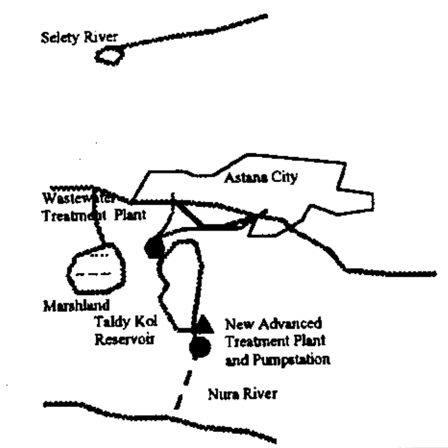
Figure 6.7.1

Wastewater Treatment and Disposal Scenarios 1 and 2

Scenario 3

Required Works

- New treated effluent pumping station
- Advanced wastewater treatment
- New 35 km pipeline



Advantages

- Water quality maintained in the Nura River
- Improved flow in the Nura River
- Potential for reuse downstream of the Nura River

Disadvantages

- Costly advanced treatment
- High capital and operating costs
- Uncertain condition of existing pipeline

Cost Estimate

WWTP Rehabilitation	20.4
Advanced Treatment	32.7
Pipeline	7.1
Pump Station	0.8
Total Capital Costs	**61.0 M USD**

Annual Operating Cost - 2.50 M USD

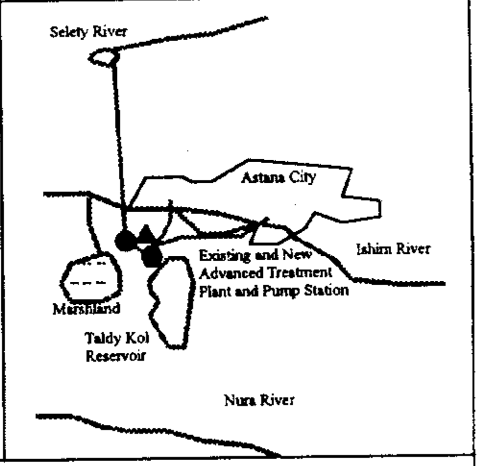
Evaluation

More costly than Scenario 2, but improved condition in Nura River

Scenario 4

Required Works

- New treated wastewater pumpstation
- Advanced wastewater treatment
- New 50km effluent pipeline



Advantages

- Water quality maintained in the Selety River
- Potential reuse in the northern part of the city

Disadvantages

- Costly advanced treatment
- Very long effluent pipeline
- High capital and operating costs

Cost Estimate

WWTP Rehabilitation	20.4
Advanced Treatment	32.7
Pipeline	9.0
Pump Station	1.0
Total Capital Costs	**63.1 M USD**

Annual Operating Cost - 2.63 M USD

Evaluation

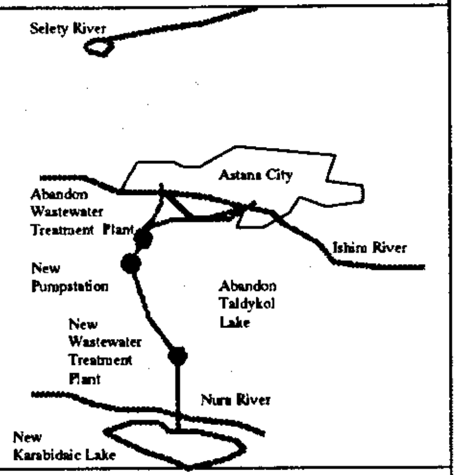
. Very distant discharge and costly scenario

Figure 6.7.2

Wastewater Treatment and Disposal Scenarios 3 and4

Scenario 5

Required Works
- New pumpstation
- New transfer pipeline (35 km, 1m dia.)
- New wastewater treatment plant
- New reservoir (50 million m^3)



Advantages
- Development land released
- Resolution of reported but unconfirmed odour nuisance
- Reuse of treated effluent for irrigation and agricultural use

Disadvantages
- Extension to infrastructure such as collectors and power supply are required
- Very costly new plant
- Relocation of Taldykol reservoir necessary if treated effluent is reused
- Additional cost necessary for advanced treatment if discharge to rivers

Cost Estimate

New WWTP	87.0
Advanced Treatment	-
Pipeline	35.0
Pump Station	10.0
Reservoir	10.0
Total Capital Costs	**142 M USD**

Annual Operating Cost - 0.75 M USD

Evaluation

Most costly scenario, additional cost for advanced treatment is necessary for discharge to rivers

Feasibility Study for Water Supply and Sewerage in the City of Astana

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Figure 6.7.3

Wastewater Treatment and Disposal Scenario 5

Pelletisation and production of fertilizer from sludge through thermal drying is becoming a more common method of final disposal. This method requires the addition of other material, which has to be locally available for this process to be economic. The facility requires a high capital investment, a high production as well as a ready market to be economic. The expected range of capital costs for thermal drying is between 30 – 90 USD per inhabitant. All these conditions are not met in Astana.

Incineration of sludge is a common method of disposal especially for sludge with high level of heavy metals. This method also requires a high capital investment and can be environmentally sensitive. Any future consideration for incineration of solid waste should examine the potential for incineration of sludge. The ash is usually disposed in landfill. At the moment this route is not considered appropriate. The estimated cost for such a facility is expected to be between 20 – 50 USD per inhabitant.

Disposal to landfill is the least desirable because of possible contamination of groundwater or surface water. The high volume of sludge and the strict design requirement for such disposal as well as the application of a landfill tax makes this practice expensive in many countries. This practice is now banned in the European Union. Capital cost for disposal to landfill is the least expensive and is expected to be between 10 – 30 USD per inhabitant.

It is therefore recommended that sludge be disposed to agriculture. In the long run it is less expensive for ASA to provide the transport to the farms than to dispose of sludge in landfill.

6.8 Summary of Proposed Development Plan

The proposed development plan includes the rehabilitation of existing facilities, pipelines, and manholes, pump stations and WWTP in order to improve reliability and to reduce the effort required for operation and maintenance. Extension of the wastewater collection to meet the requirements of the Year 2010 is proposed in new development area on the left bank of the Ishim River. No extension of the WWTP is proposed but improvements to settling and sludge treatment facilities are proposed. Reuse in agriculture is the recommended disposal route for treated effluent and dried digested sludge. Improvements in operation and maintenance can be achieved through staff development and provision of appropriate management tools such an information system.

Although it is recommended that treated wastewater be reused in agriculture the components of such reuse project have been excluded from the package of works identified by this study to be financed by external funds. It is risky to prejudge the result of the reuse feasibility study by proposing a treated wastewater transfer system for a project, which may not become functional for a few years and for which the capacity has yet to be determined. At the moment the optimum transfer capacity is not known and it will not be known until completion of the reuse feasibility study. Any proposal at this moment is likely to be unsuitable for the final irrigation configuration and therefore results in unnecessary expenditure.

Although all the works proposed in this chapter are necessary some of the proposals are more urgent than others. The list of principal works listed in order of priority is as follows :

- Replacement of corroded steel pumping mains
- Replacement of manhole covers
- Construction of wastewater collection system for the Government City
- Improvements to the sludge treatment process
- Replacement of grit channels
- Replacement of return activated sludge pump station
- Replacement of air blowers at WWTP
- Replacement of screens at WWTP
- Replacement of pumps at existing pump stations
- Provision of management information system and other equipment
- Replacement of WWTP pipe work
- New final settlement tanks
- New primary settlement tanks
- Construction of wastewater collection system for the rest of the 2010 development area