TABLE

Table K.1.1 Generated quantity data of Industrial Waste (T/Year)

		1998						1999					
		Hazardous waste classification						Hazardous waste classification					
		V	IV	III	II	I	Total	V	IV	III	II	I	Total
1	TETS-1		78,097.925				78,097.925		52,469.098				52,469.098
2	TETS-2		396,548.746				396,548.746		247,919.442				247,919.442
3	JSC "Astanaenergoservice"						0.000	156.840	231,281.187				231,437.827
4	OJSC "Zhambyldorstroi"						0.000						0.000
5	JSC "Astana-Technopark" (Akmolaselmash)	80.600	38.400				119.000	654.000					654.000
6	LLC "Nysana" (heat networks)						0.000						0.000
7	LLC "Sagzhan"	671.800					871.800	663.100	20.000				683.100
8	SE "Turnys"						0.000	625.000					625.000
9	OJSC "Tselindorstroi"						0.000						0.000
10	LLC Concern "Akmola-Astyk" (bakery)	433.340					433.340	137.000					137.000
11	Locomotive depot (TH-11)	20.000	1.280	15.000			36.280	30.725	0.928	13.140			44.793
12	LLC "Zhanar"						0.000						0.000
13	LVHD-9 (passenger depot)	421.300	1,530.410	3.250			1,954.960	421.300	1,200.410	3.250			1,624.960
14	JSC "Akmola-Zholdary"						0.000						0.000
15	OJSC "Tselindorstroi"						0.000						0.000
16	OJSC "Akmolastroi"		90.000				90.000	2.000	90.000				92.000
17	IC "Agrodor"						0.000						0.000
18	Akmola wagon depot (VHD-8)						0.000	31.050					31.050
19	LLC "Zhana-Zhol"						0.000						0.000
20	Akmola branch RSE						0.000						0.000
21	OJSC JV Kazakh-Turkish Enterprise "Hotel-Astana"						0.000	621.825					621.825
22	LLC "Sagalar"						0.000	13.000					13.000
23	AOC "Zarechny"						0.000						0.000
24	Akmola Car-Repair Plant						0.000	9.140	0.100	1.650		0.025	10.915
25	TE "Artyom"						0.000						0.000
26	JSC "Akmola Munai Onimderi"						0.000						0.000
27	Power Supply Division ED-8	46.530					46.530	47.000					47.000
28	LLC Concern "Naiza"	23.615					23.615	56.870	87.536	1.000		0.007	145.413
29	CJSC "Tselienergoremont" (repair enterprise)	5.000	5.000			8.000	18.000	5.000	5.000				10.000
30	LLc "Rotor"						0.000						0.000
31	Water Heating Division STU (VODH-6)	202.500					202.500	4.090					4.090
32	RSE "International Airport"	0.900	0.750		0.900		2.550	376.025	0.632		0.600		377.257
33	LLC "Zhelezobeton"						0.000	1,644.478					1,644.478
34	Akmola Branch JSC "Kazvtorchermet"						0.000						0.000
35	JSC "Akmolanan"	40.500					40.500	108.850				0.007	108.857
36	RSE HOZU of Ministry of Finance of RK						0.000						0.000
37	LLC "Tsentrax" firm						0.000	10.000		0.010			10.010
38	JSC "Myasomolrybpromtorg"	6.660					6.660	10.830	18.190				29.020
39	Permanent Way Division PH-22						0.000						0.000
40	Akmola Autopark-1						0.000						0.000
41	Track repair workshops						0.000						0.000
42	LLC"Trading equipment plant"	29.400	28.500				57.900						0.000
43	LLC "Asem-A"						0.000						0.000
44	Mostopoezd-65						0.000						0.000
45	Boiler of the dwelling complex of the Traffic Police Dep. of RK						0.000						0.000
46	OJSC "Astana-Motors-Lada"	131.280					131.280	98.460					98.460
47	JSC "Kazelevatormelmontazh"						0.000						0.000
48	Public Bath #8 "Informservice"						0.000						0.000
49	RSE "Management of the administrative buildings' maintenance"						0.000						0.000
50	LLC "Akbulut"						0.000						0.000
51	JSC "AHSEL"						0.000						0.000
52	LLC "Akmola-Dirmen	15.000					15.000	18.400					18.400
53	IC "Tselinhydromash"	83.000	24.000				107.000	24.000	6.000				30.000
	Each Class Total	2,211.425	476,365.011	18.250	0.900	8.000	478,603.586	5,768.783	533,098.523	19.050	0.600	0.039	538,886.994
	Total except ash from TETs	2,211.425	1,718.340	18.250	0.900	8.000	3,956.915	5,612.143	1,428.795	19.050	0.600	0.039	7 060.627

Table K.1.2 Present Hospital list in Astana

#	Name of the facility	Address	Chief medical officer	Number of doctors	Nurses	Junior medical staff	Beds
1	Ambulance hospital	Bogenbaya, 15	Plotnikov V.A.				
2	City polyclinic #1	Seyfullina, 42	Anosova K.N.	53	60	20	
3	City polyclinic #2	Pushkina, 164	Storoshuk V.B.	56	97	26	
4	City polyclinic #3	Pushkina, 132,134		45	51	5	
5	Consulting-diagnostic polyclinic #6	Abylay-han, 22/1	Beybitova G.G.	42	61	13	
6	City hospital # 1	Beybitshilik, 47a	Ovchinnikov S.A.	70	139	83	225
7	State Public Utility Enterprise "City hospital #2"	Abylay-han, 13	Ayguzhin B.S.	96	198	158	310
8	City hospital #3	Bokey-han, 40	Nauryzbaeva B.N.	27	51	30	60
9	City Ambulance Station	Druzhba, 18	Suleymenova B.A.	72	87	57	
10	City isolation hospital	Kulturnaya, 51	Shaydarov M.Z.	29	83	70	180
11	City child isolation hospital	Stroitelnaya, 2/1	Gushina A.S.	32	82	54	120
12	City child hospital #2	Manasa, 10	Demochkin S.M.	73	163	106	215
13	City mental dispenser	Uchilishnaya, 7	Chalovsky B.P.	57	139	187	500
14	City tuberculosis dispenser	Stroiteley, 9	Zhusupova R.ZH.	51	141	88	300
15	Venereal dispenser	Pushkina, 164/1	Danbaeva Zh.S.	33	57	29	100
16	Narcological dispenser	Chehova, 14a	Komarova O.N.	20	36	38	155
17	Onco-dispenser	Vishnevskoe Highway, 1	Konurbaev T.R.	28	46	22	100
18	Perinatal center	Manasa, 8	Kushnarenko O.S.	49	98	65	125
19	Maternity hospital #1	9 May, 70	Ionov S.N.	44	109	80	110
20	Blood transfusion center	Moskovskaya, 82	Chemurzieva M.A.	16	36	26	
21	Center "AIDS"	Naberezhnaya, 37	Lebedev A.S.	12	18	4	
22	SVA "Orbita"	M-r 1	Kartaeva B.H.	8	10	2	
23	SVA "Lesozavodskaya"	Lesozavod	Tashimova K.K.	10	12	1	
24	SVA "Shipager"	Komsomolsky village	Omarov G.N.	5	7	2	
25	SVA "Promyshlenny"	30 years Tseliny, 2	Sharipova G.Z.	6	6	0	
26	Dorozhnaya hospital including:			125	319	115	
	Child polyclinic # 1	Byrzhan sala, 10	Sarbasova K.M.	155	274	82	
	Child specialized polyclinic #	Pushkina, 110	Moon T.A.				
	City child hospital	Zheltoksan, 42	Petuhova N.M.				
	Child policlinic # 2	Auezov, 90					
	Child policlinic # 4	9 May, 69					
	Child policlinic # 6	Abylay-han, 1					

Table K.2.1 Case Study of Unit Generation Rate Change

	Case 1			Case 2			Case 3		
	1% growth			2% growth			3% growth		
	m3/year-	l/day-capita	kg/day-capita	m3/year-	l/day-capita	kg/day-capita	m3/year-	l/day-capita	kg/day-capita
2000	1.40	3.84	0.77	1.40	3.84	0.77	1.40	3.84	0.77
2001	1.41	3.86	0.77	1.43	3.92	0.78	1.44	3.95	0.79
2002	1.42	3.89	0.78	1.46	4.00	0.80	1.48	4.05	0.81
2003	1.43	3.92	0.78	1.49	4.08	0.82	1.52	4.16	0.83
2004	1.44	3.95	0.79	1.52	4.16	0.83	1.57	4.30	0.86
2005	1.45	3.97	0.79	1.55	4.25	0.85	1.62	4.44	0.89
2006	1.46	4.00	0.80	1.58	4.33	0.87	1.67	4.58	0.92
2007	1.47	4.03	0.81	1.61	4.41	0.88	1.72	4.71	0.94
2008	1.48	4.05	0.81	1.64	4.49	0.90	1.77	4.85	0.97
2009	1.49	4.08	0.82	1.67	4.58	0.92	1.82	4.99	1.00
2010	1.50	4.11	0.82	1.70	4.66	0.93	1.87	5.12	1.02
2011	1.52	4.16	0.83	1.73	4.74	0.95	1.93	5.29	1.06
2012	1.54	4.22	0.84	1.76	4.82	0.96	1.99	5.45	1.09
2013	1.56	4.27	0.85	1.80	4.93	0.99	2.05	5.62	1.12
2014	1.58	4.33	0.87	1.84	5.04	1.01	2.11	5.78	1.16
2015	1.60	4.38	0.88	1.88	5.15	1.03	2.17	5.95	1.19
2016	1.62	4.44	0.89	1.92	5.26	1.05	2.24	6.14	1.23
2017	1.64	4.49	0.90	1.96	5.37	1.07	2.31	6.33	1.27
2018	1.66	4.55	0.91	2.00	5.48	1.10	2.38	6.52	1.30
2019	1.68	4.60	0.92	2.04	5.59	1.12	2.45	6.71	1.34
2020	1.70	4.66	0.93	2.08	5.70	1.14	2.52	6.90	1.38
2021	1.72	4.71	0.94	2.12	5.81	1.16	2.60	7.12	1.42
2022	1.74	4.77	0.95	2.16	5.92	1.18	2.68	7.34	1.47
2023	1.76	4.82	0.96	2.20	6.03	1.21	2.76	7.56	1.51
2024	1.78	4.88	0.98	2.24	6.14	1.23	2.84	7.78	1.56
2025	1.80	4.93	0.99	2.28	6.25	1.25	2.93	8.03	1.61
2026	1.82	4.99	1.00	2.33	6.38	1.28	3.02	8.27	1.65
2027	1.84	5.04	1.01	2.38	6.52	1.30	3.11	8.52	1.70
2028	1.86	5.10	1.02	2.43	6.66	1.33	3.20	8.77	1.75
2029	1.88	5.15	1.03	2.48	6.79	1.36	3.30	9.04	1.81
2030	1.90	5.21	1.04	2.53	6.93	1.39	3.40	9.32	1.86

** Bulk Densiy of MSW at generation source is stable as 0.2kg/m3*

FIGURE

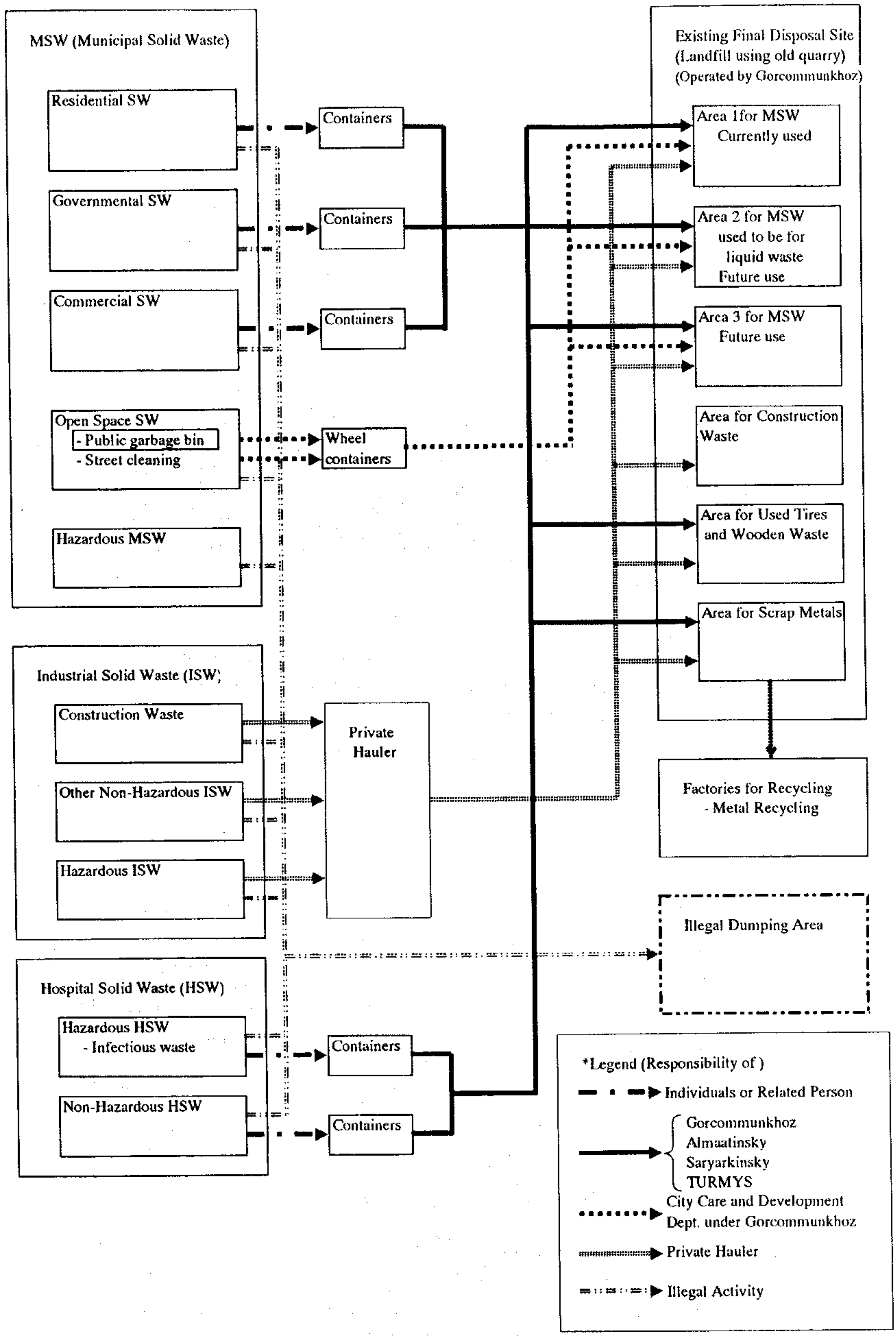
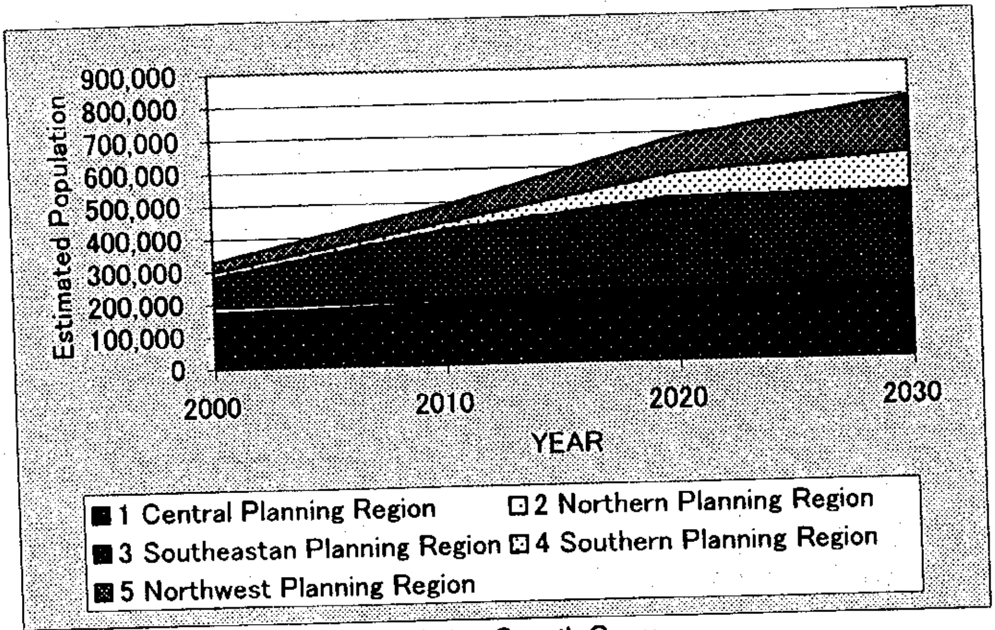


Figure K.1.1 Current Waste Flow in Astana

Future Estimation of Population on each Region

	2000	2010	2020	2030
1 Central Planning Region	175,500	190,800	212,400	218,400
2 Northern Planning Region	16,310	9,034	9,034	9,034
3 Southeastan Planning Region	92,236	217,753	282,403	282,403
4 Southern Planning Region	16,012	21,504	74,001	116,317
5 Northwest Planning Region	30,690	50,945	109,594	169,870
Grand Total	**330,748**	**490,036**	**687,432**	**796,024**



Population Growth Curve

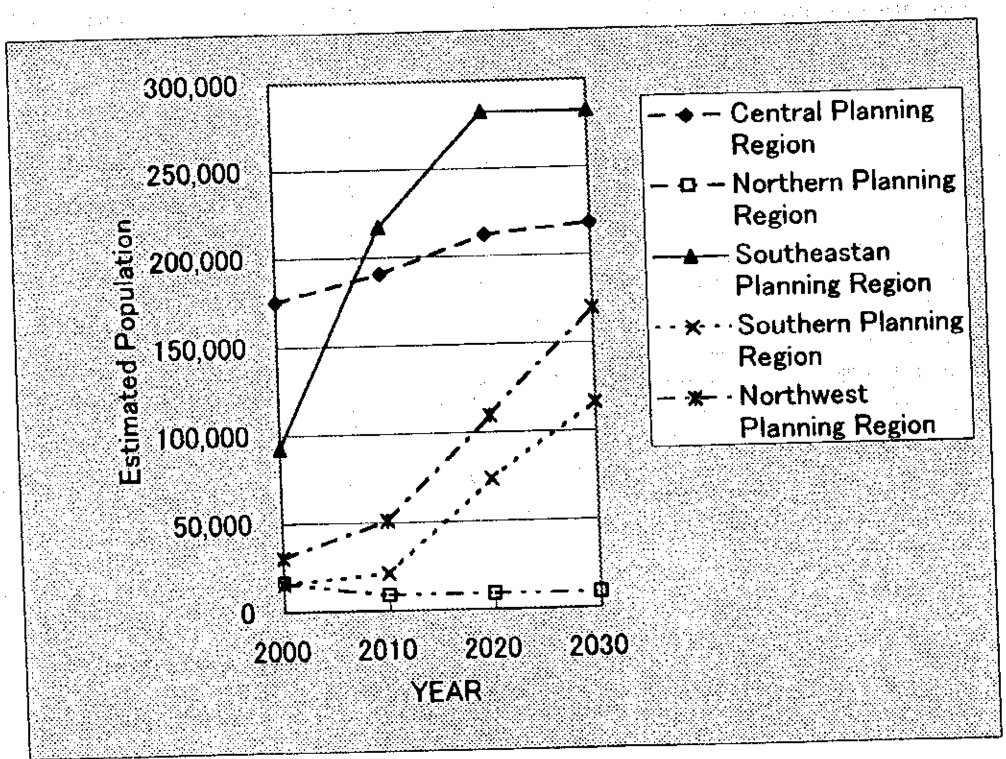


Figure K.2.1 Population Projection

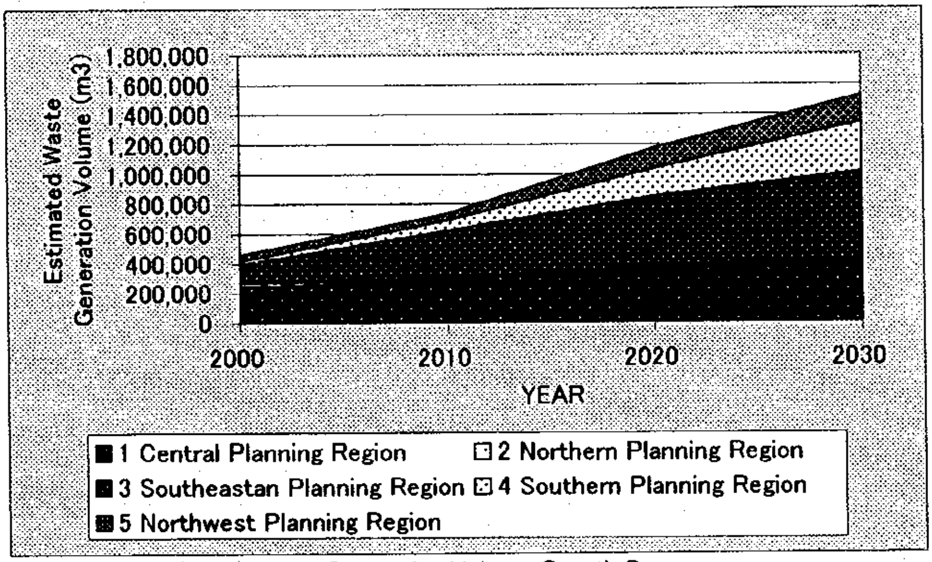
Future Estimation of Unit Generation Rate (1% annual growth base)

	2000	2010	2020	2030
Unit Generatin Rate (Volume Base; m3	1.40	1.50	1.70	1.90
Unit Generatin Rate (Weight Base; t)	0.28	0.30	0.34	0.38

** Bulk Densiy of MSW at generation source is stable as 0.2kg/m3*

Future Estimation of Waste Generation Volume at Source (m3/year)

	2000	2010	2020	2030
1 Central Planning Region	245,700	287,700	362,780	416,860
2 Northern Planning Region	22,834	13,551	15,358	17,165
3 Southeastan Planning Region	129,370	323,135	471,925	580,857
4 Southern Planning Region	22,417	66,972	185,564	330,543
5 Northwest Planning Region	42,966	46,035	139,431	180,914
Grand Total	**463,287**	**737,393**	**1,175,058**	**1,526,339**



Waste Generation Volume Growth Curve

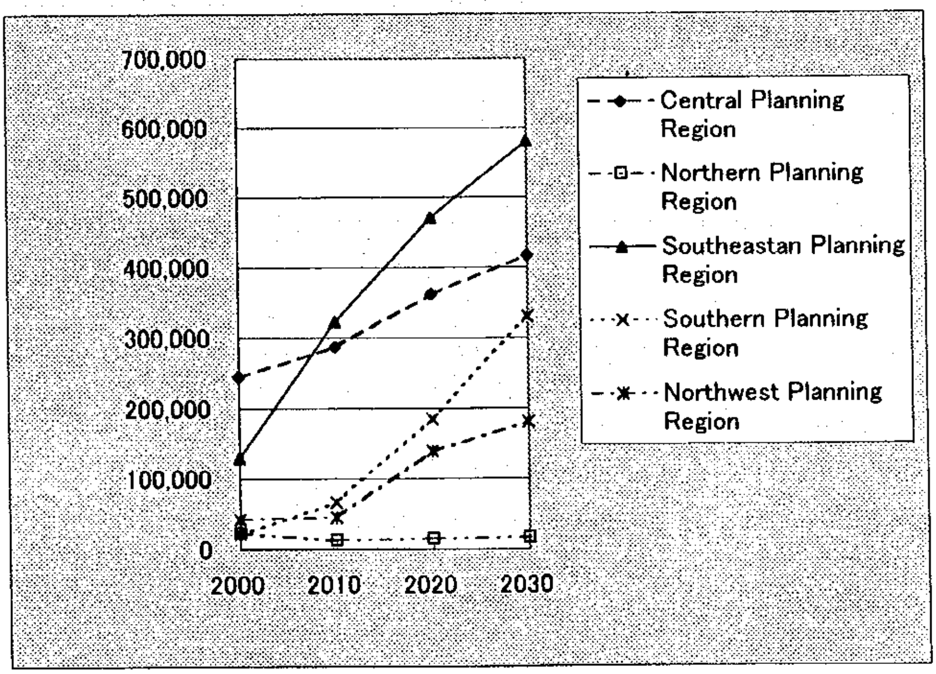
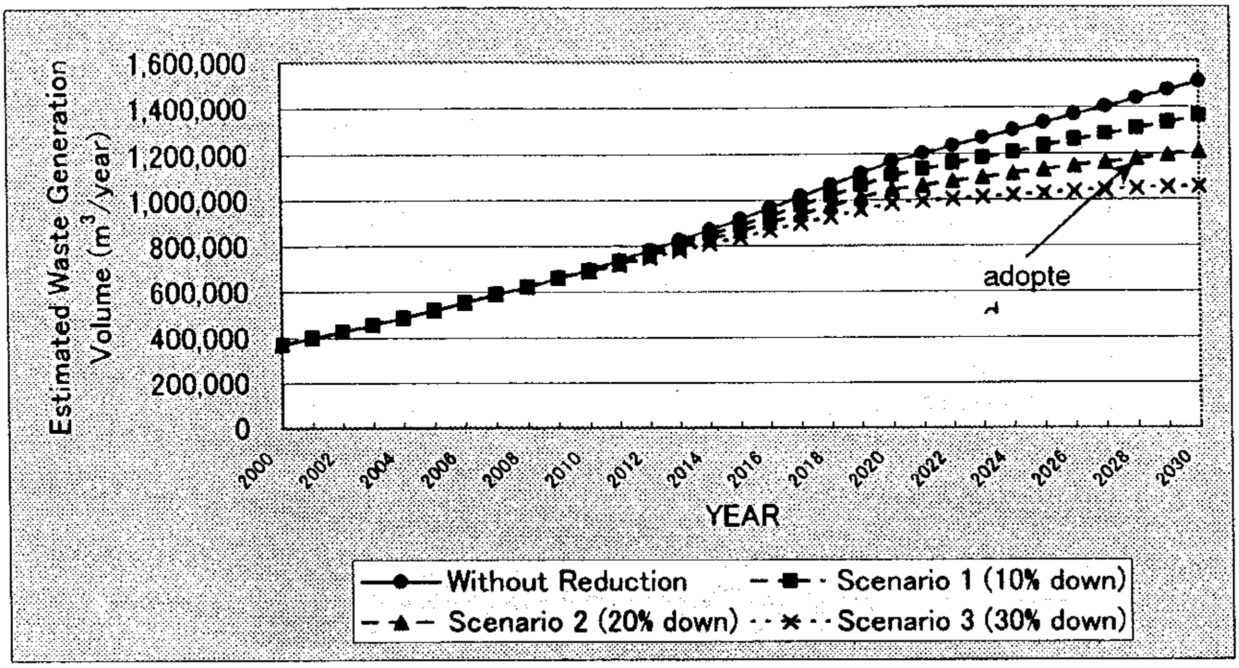


Figure K.2.2 Waste Generation Volume Growth Curve by each Region



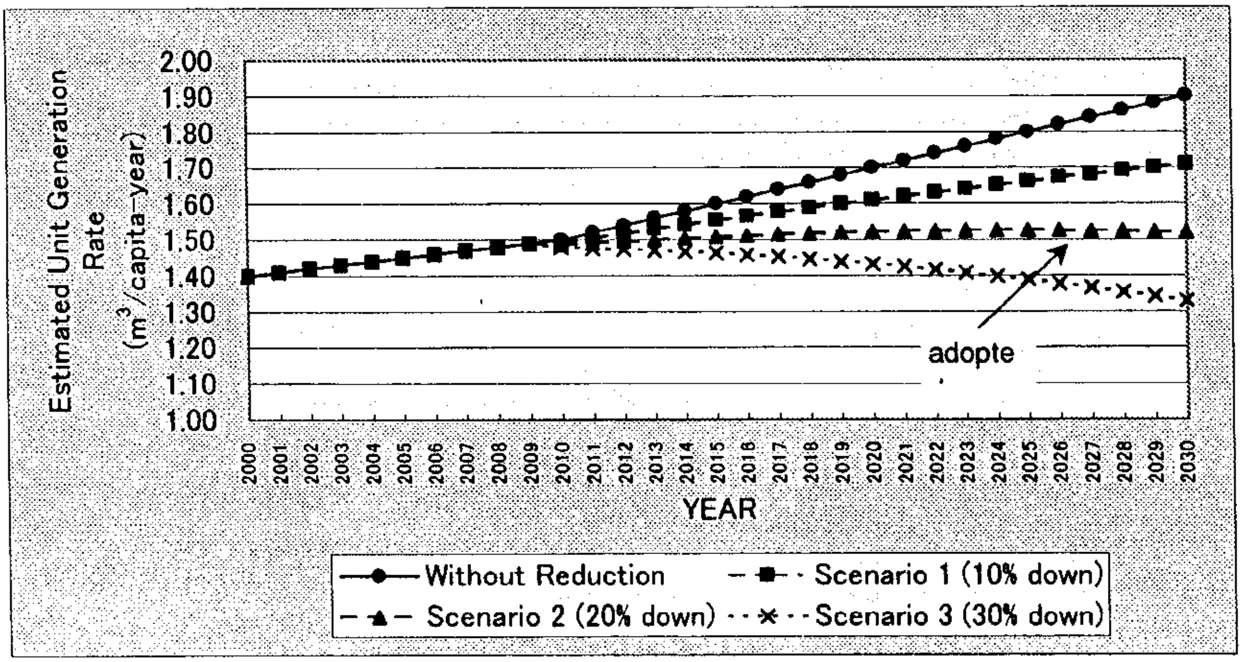


Figure K.4.1 Comparison of Waste Reduction Target Rate

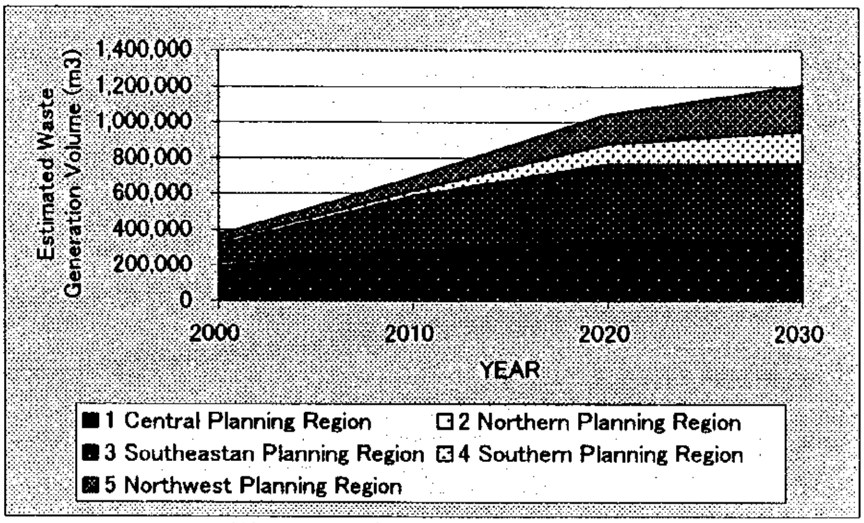
Future Estimation of Unit Generation Rate (1% annual growth base)

	2000	2010	2020	2030
Unit Generatin Rate (Volume Base; m3	1.40	1.50	1.70	1.90
Unit Generatin Rate* (Weight Base; g/	767	822	932	1,041
Collection rate	80%	95%	100%	100%
Waste reduction rate	0.0%	1.0%	10.5%	20.0%
Target Unit Generatin Rate (m3/y)	1.40	1.49	1.52	1.52
Target Unit Generatin Rate* (t/y)	767	814	834	833

** Bulk Densiy of MSW at generation source is stable as 0.2kg/m3*

Future Estimation of Waste Collection Volume at Source (m3/year)

	2000	2010	2020	2030
1 Central Planning Region	196,560	269,301	323,253	331,968
2 Northern Planning Region	18,267	12,751	13,749	13,732
3 Southeastan Planning Region	103,304	307,343	429,790	429,253
4 Southern Planning Region	17,933	30,351	112,622	176,802
5 Northwest Planning Region	34,373	71,905	166,792	258,202
Grand Total	**370,437**	**691,651**	**1,046,206**	**1,209,957**



Waste Collection Volume Growth Curve

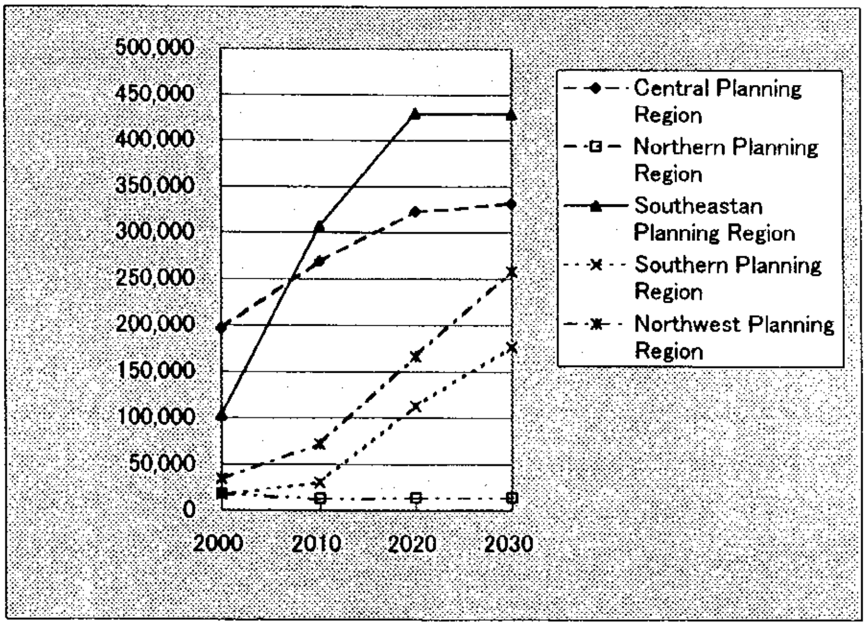


Figure K.4.2 Waste collection Volume Growth Curve by each Region

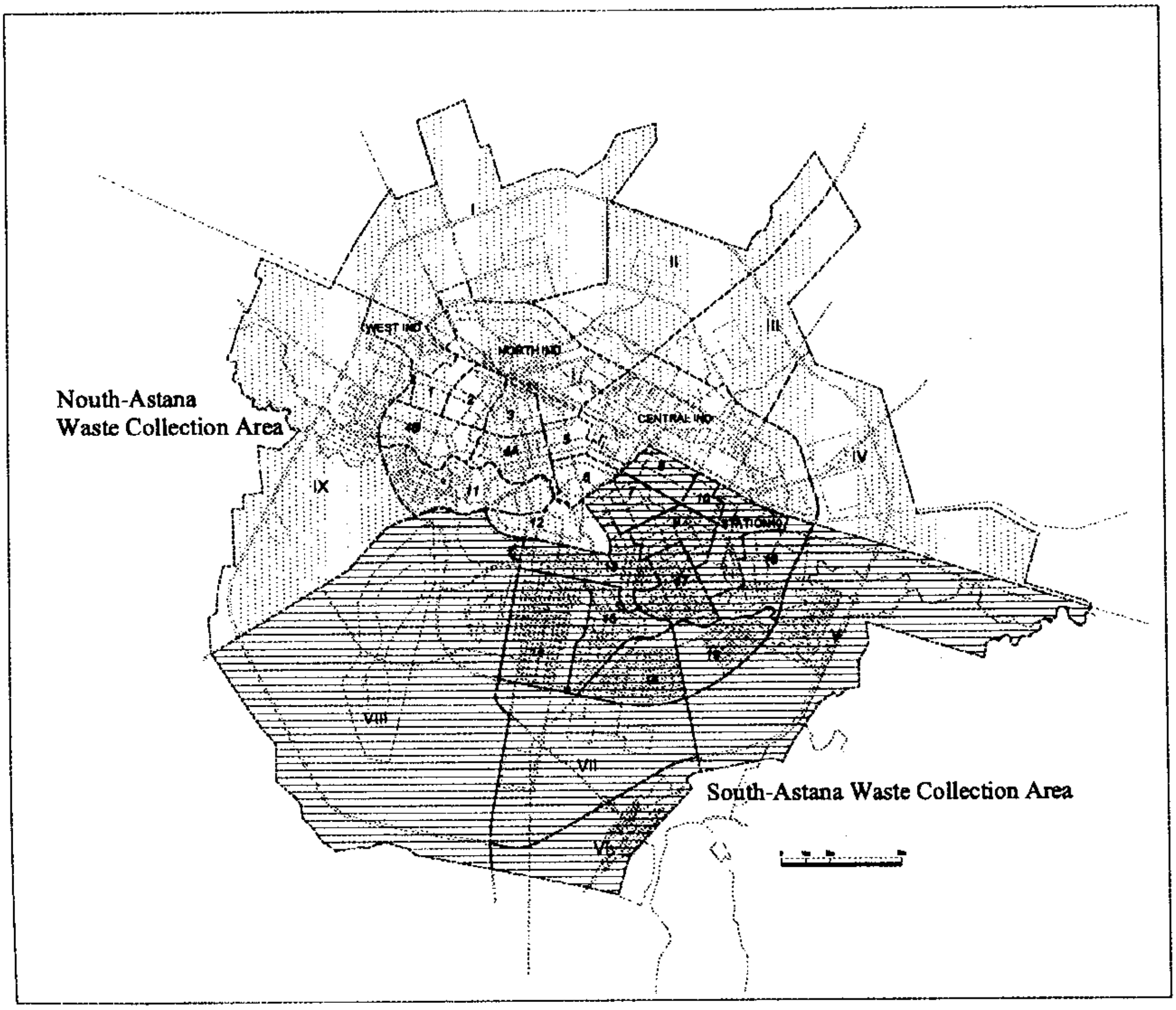
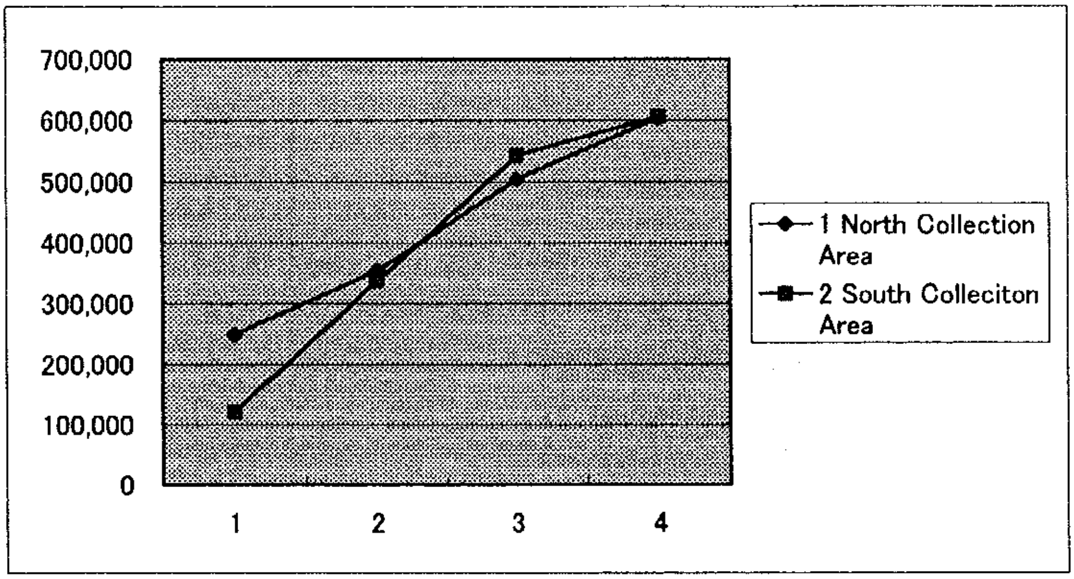


Figure K.4.3 MSW Collection Service Area

	2000	2010	2020	2030
1 North Collection Area	249,200	353,957	503,794	603,902
2 South Colleciton Area	121,237	337,694	542,412	606,055
Grand Total	**370,437**	**691,651**	**1,046,206**	**1,209,957**



	2000	2010	2020	2030
1 Direct Collection volume	370,437	691,651	1,046,206	603,902
2 T/S colleciton volume	0	0	0	606,055
Grand Total	**370,437**	**691,651**	**1,046,206**	**1,209,957**

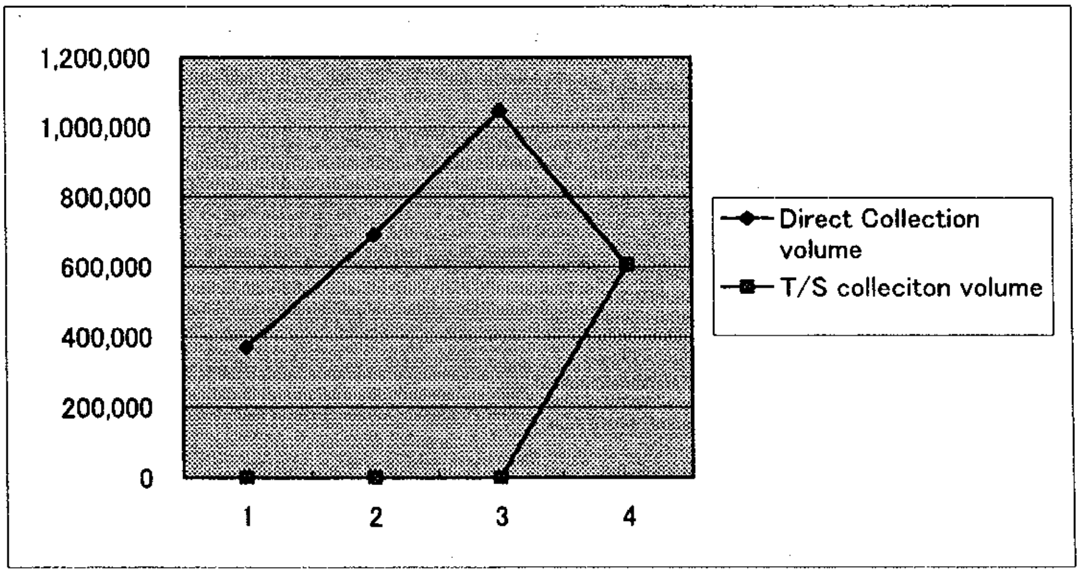


Figure K.4.4 Waste Collection Volume from Two Collection Area

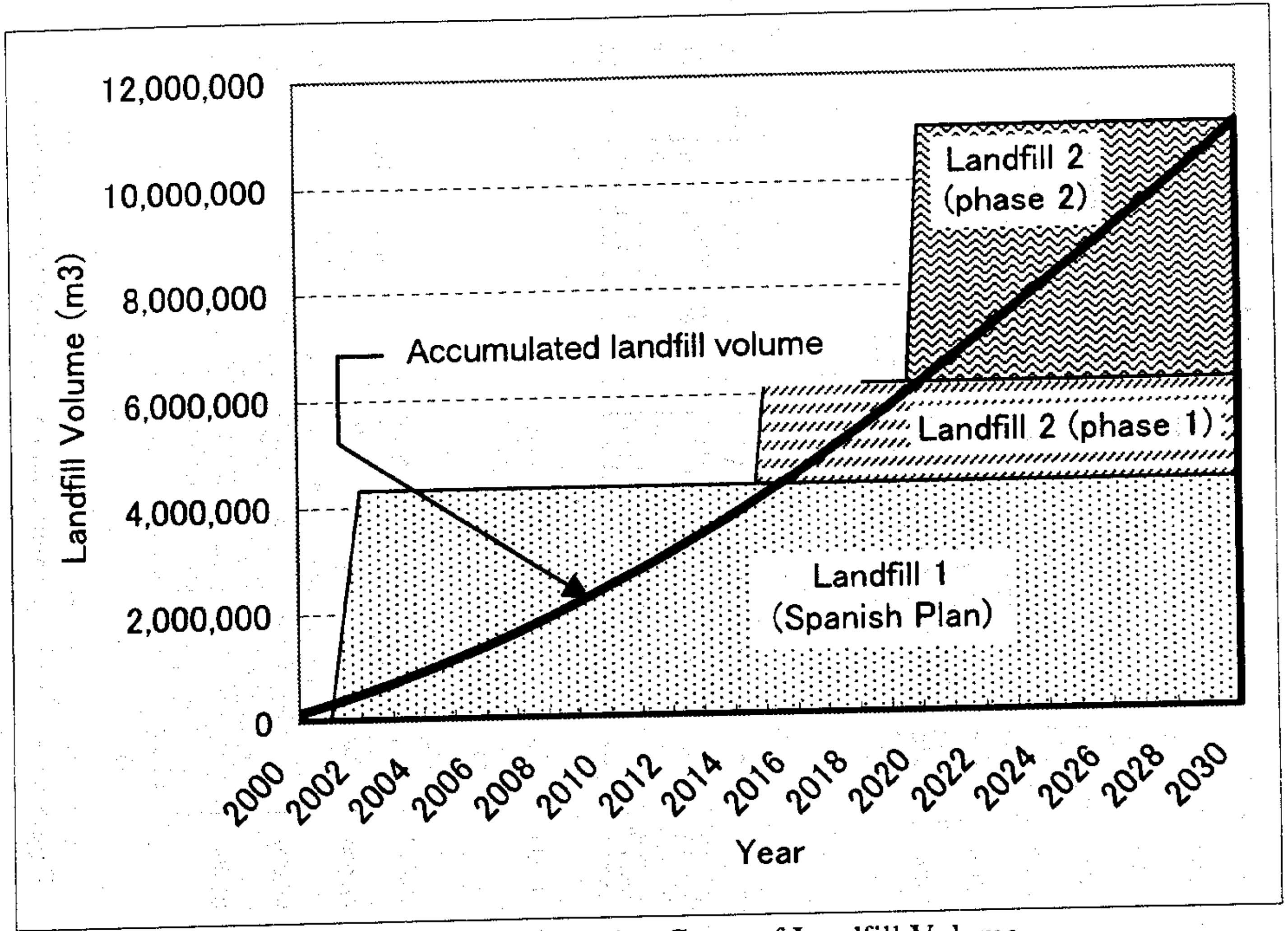
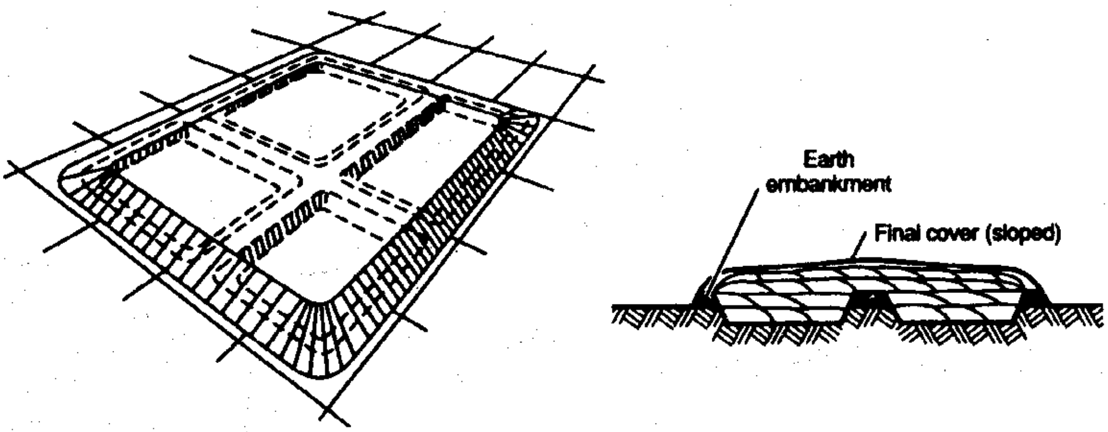
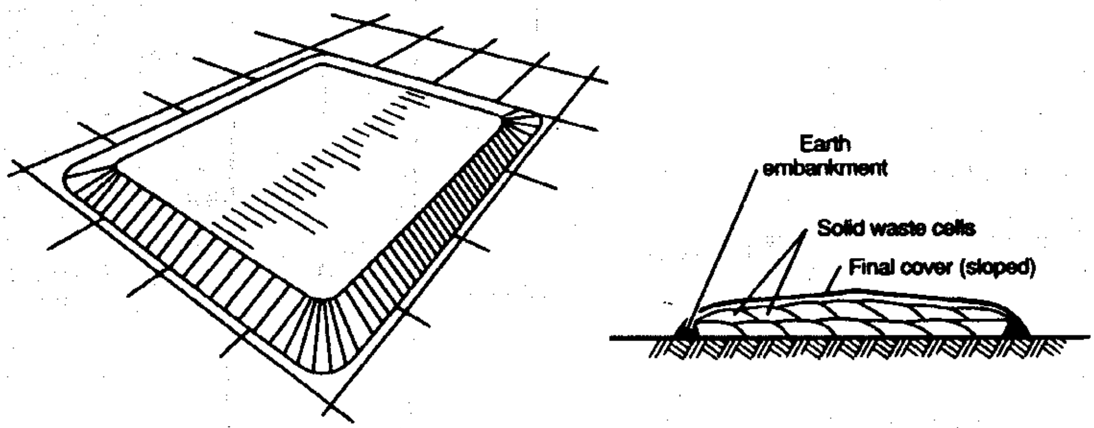


Figure K.4.5 Accumulation Curve of Landfill Volume



(a)



(b)

(a) Excavated cell/trench method (b) Area Method

(Source: Integrated Solid Waste Management, McGraw-Hill, 1993)

Figure K.4.6 Proposed Landfill Type

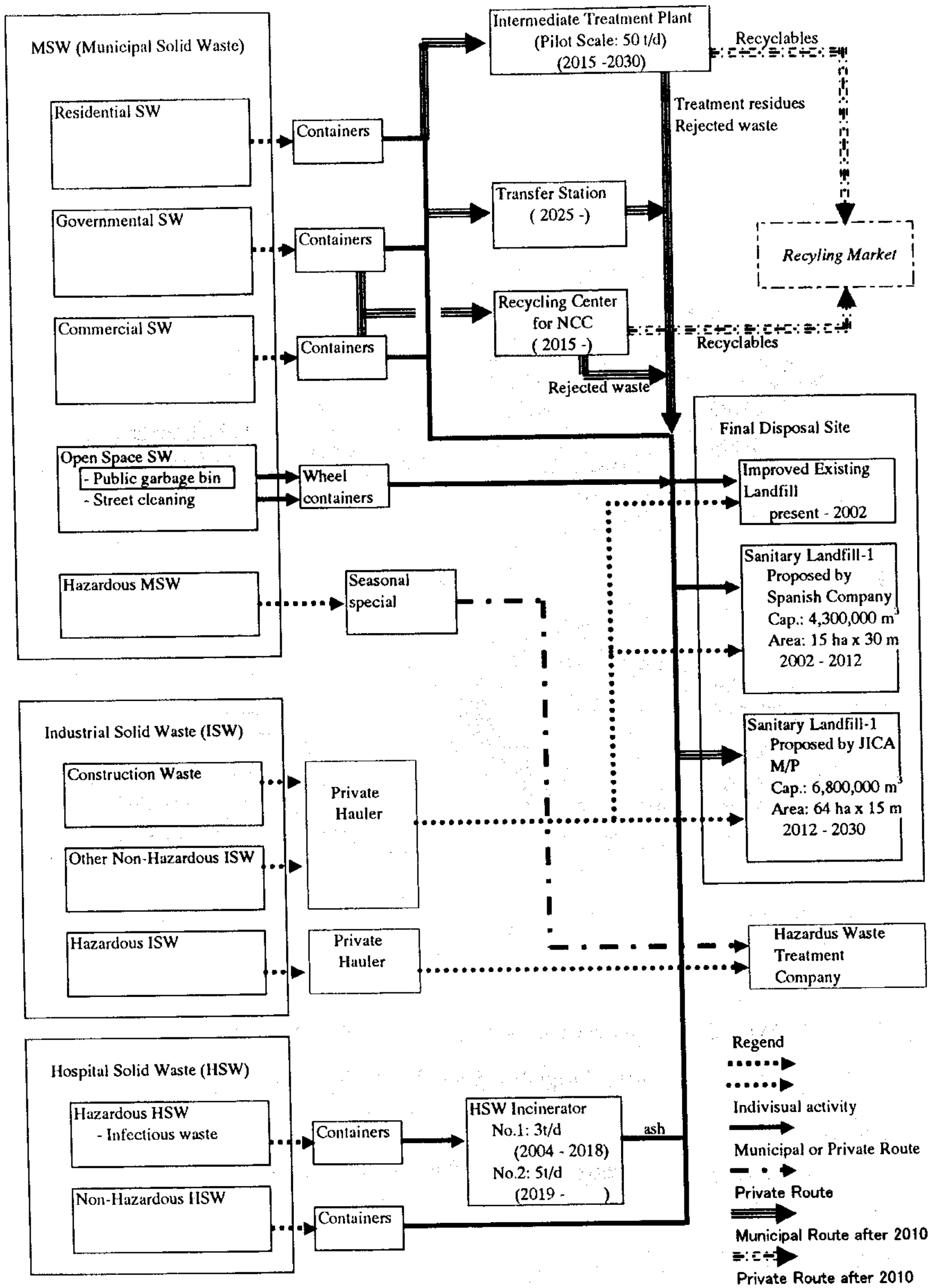
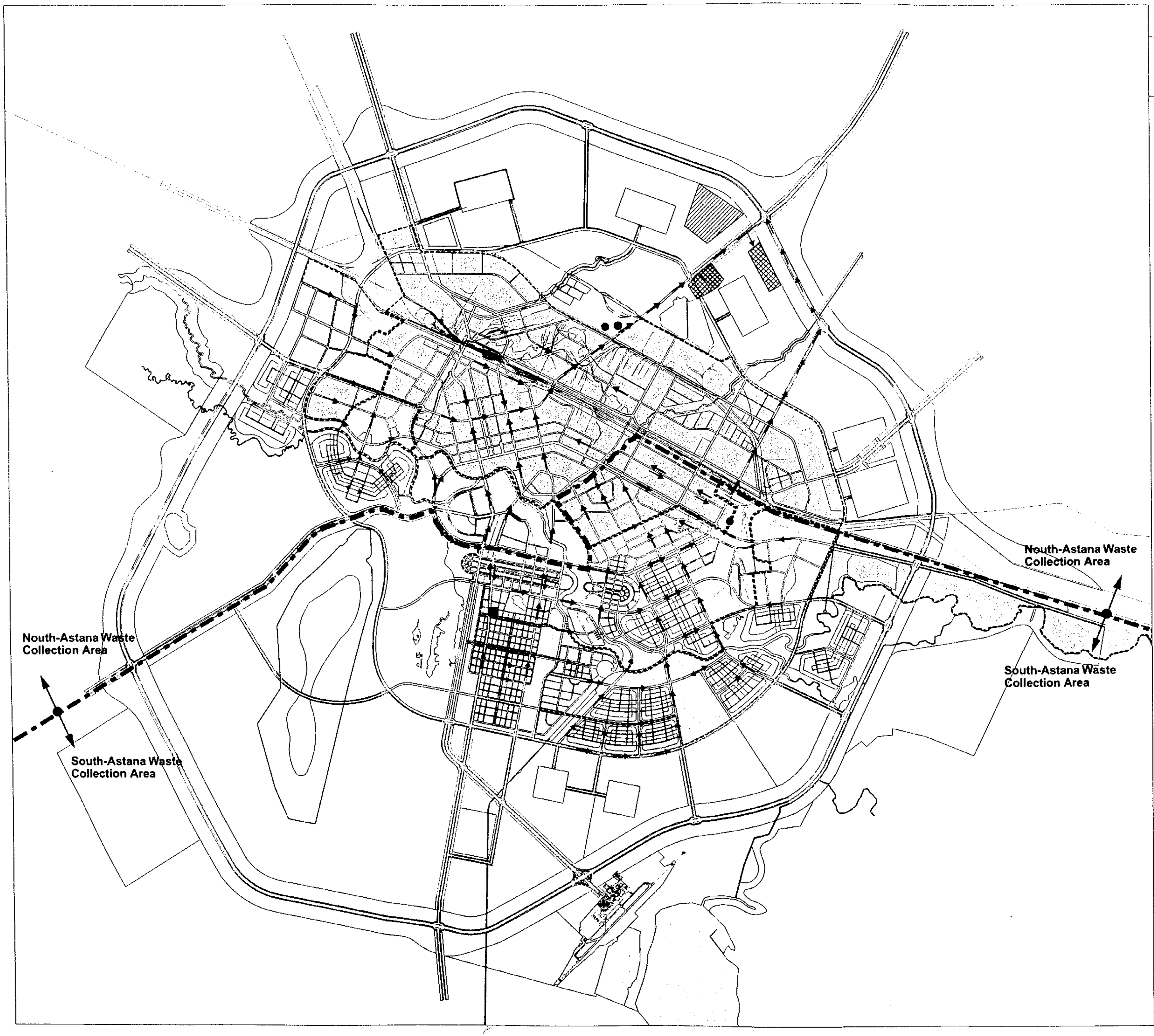


Figure K.7.1 Proposed Future Waste Flow in Astana



ASTANA

THE STUDY ON THE MASTER PLAN
FOR
THE DEVELOPMENT OF THE CITY OF ASTANA
IN
THE REPUBLIC OF KAZAKHSTAN

LEGEND

- LANDFILL (EXISTING) + LANDFILL-1 (2010)
- LANDFILL-2 (2020)
- ALTERNATIVE CANDIDATE AREA FOR LANDFILL-2 (2020)
- HAZARDOUS HOSPITAL WASTE INCINERATOR (2010)
- PILOT SCALE MSW INTERMEDIATE TREATMENT PLANT (2020)

REFUSE DERIVED FUEL (RDF) PLANT
or
ENERGY RECOVERY INCINERATOR

- RECYCLING CENTER FOR NEW CITY CENTER (2020)
- TRANSFER STATION (2030)
- COLLECTION SERVICE AREA (EXISTING)
- COLLECTION SERVICE AREA (2010)
- COLLECTION SERVICE AREA (2020)
- COLLECTION SERVICE AREA (2030)
- TRANSPORT ROUTE DIRECTION (EXISTING)
- TRANSPORT ROUTE DIRECTION (2010)
- TRANSPORT ROUTE DIRECTION (2020)
- TRANSPORT ROUTE DIRECTION (2030)
- WASTE COLLECTION AREA DIVISION

PLAN FOR SOLID WASTE DISPOSAL
2010,2020,2030

JICA MASTER PLAN TEAM

0 1km 2km 5km

FIGURE K.7.2

CHAPTER L
FLOOD PROTECTION AND DRAINAGE

SUPPORTING REPORT L: FLOOD PROTECTION AND DRAINAGE

Contents

List of Tables

List of Figures

L.1 Flood Protection

L.1.1 Present Conditions

(1) Ishim River

The Ishim River has a catchment area of 7,400km^2 at Astana including a sub-catchment of 5,310km^2 at the Vyacheslavsky Reservoir. The rest of a sub-catchment of 2,090km^2 is located between Astana and the reservoir. The river length between Astana and the reservoir is measured as 70km. The Ishim River flows westwards gently down in the relatively flat highland terrain with low hills. The average gradient of the riverbed between Internationalize settlement and Kirovo settlement in Astana is estimated as 0.0005. General location of the study area is shown in the Figure L.1.1.

River discharge is maintained for supply of irrigation water and technical water during whole season by Vyacheslavsky Reservoir. The river course in the urbanized area is smooth due to the river improvement. On the other hand, the river course near the city boundary upstream and downstream of the urbanized area is naturally meandering. The river course is easily affected by spring flood flow because small amount of river flow during dry season disturbs formation of river course.

The present carrying capacity of the Ishim River around the urban area in Astana, where river improvement works have been conducted, is relatively large as at least 750m^3/s. On the other hand, the carrying capacity in upstream and downstream of Astana, where no river improvement works have been conducted, is relatively small as approximately 200m^3/s as shown below. The section is shown in the Figure L.1.2.

Present Carrying Capacity of Ishim River (Full bank)

Section No.	Location	Capacity (m^3/s)
1	Kirovo settlement	200
2	Astana at the existing car bridge	750
3	Internationalize settlement	220

Some tributaries named Karasu River, Akbulak River and Sarybulak River confluence to the Ishim River.

The land on the right bank of the Ishim River has been mainly developed as a residential and an industrial area. The topographic feature around Astana is recognized that the ground elevation of the right bank is higher than that of the left bank. The flood protection dike was provided along the right bank. The flood flow is usually inundated in the natural flood plain on the left bank. Recently, however, the development of the left bank area is under progress. The protection for the left bank area against natural disaster is strongly requested by the Municipality.

(2) River Structures

River structures around Astana are said later.

1) Flood Protection Dike

The Ishim River was only improved along the urbanized area in Astana. The river cross section has been widened around 200m width between the existing pedestrian bridge and the confluence of the Akbulak River was constructed in length of around 2km. The elevation of the crest of the present dike is designed as EL+348.1m. Recently, the flood protection dike on the right bank is under construction in the down stream of the urban area. Construction of flood protection dike on the left bank is now under progress. Location of the dike is shown in the Figure L.1.2.

2) Weir

There are some weirs in the river course in order to keep the sanitation of the river or to keep proper water level for water intake for irrigation or water supply. Two weirs are found near Telman and near Kirovo. The weir of Telman is made of earth material. The main purpose of this weir is maintenance of the proper water level to intake water to the pumping station of technical water supply. The proper water level is requested as EL+348.0m by ASA.

On the other hand, the weir near Kirovo is made of reinforced concrete. The main purpose of this weir is to maintain the proper water level for amenity of the Ishim River along the urban area. The crest elevation of the weir is EL+343.7m to keep the water level of EL+343.88 at the confluence of Akbulak River, which is requested by the Municipality.

The locations of the weirs are shown in the Figure L.1.2.

3) Gate

There is a gate in Aleksandrovka located in 25km west of Astana. The gate is basically opened in ordinary season, and the river flows into the Aleksandrovka settlement through the gate. During spring flood season, the gate is closed to prevent flood flow coming into the settlement. Flood flow is inundated into the existing natural flood plain located on the left bank along the Ishim River between Aleksandrovka and Astana. Inundated flood flow goes down through the natural flood plain and joins into the Ishim River near Telman settlement.

4) Bridges

There are three bridges across the Ishim River around Astana. Two bridges are subject to the car bridge and the other one is subject to the pedestrian bridge. Recently, new car bridge, which is connected to the Sary-Arka street, is under construction.

5) Vyacheslavsky Reservoir

The Vyacheslavsky Reservoir is located in approximately 50km upstream of Astana. The reservoir has been operated from 1970. The major dimensions of the dam and reservoir are shown in the following table. There is no overflow spillway. The location of the reservoir is shown in the Figure L.1.1.

Major Dimensions of Vyacheslavsky Dam and Reservoir

Dam	
Dam Crest Length	1,200m
Dam Height	30m
Crest of the dam EL(m)	406.75
Sill elevation of the gate EL(m)	395.5
Outlet	Pipe in diameter 1,000mm with a valve
Gate Structure	Sluice gate type: 7.5m x 12.0m x 3sets
Reservoir	
High water level EL(m)	404.4
Normal water level EL(m)	403.0
Water surface area (km^2)	60.7 (at Normal pond level)
Storage volume (MCM)	410.9

During spring flood season, the phased operation rule as shown below is adopted to control the gate.

Phased Operation Rule

Operation Phase	Gate Opening (m)			Water Level EL(m)	Discharge (m^3/s)
	Left	Center	Right		
1	closed	0.5	closed	403.0	
2	0.5	0.5	closed	403.0	
3	0.5	0.5	0.5	403.0	
4	0.5	1.0	0.5	403.0	
5	1.0	1.0	0.5	403.0	
6	1.0	1.0	1.0	403.0	
7	1.0	1.5	1.0	403.0	
8	1.5	1.5	1.0	403.0	
9	1.5	1.5	1.5	403.0	400.0
10	1.5	3.0	1.5	403.0	
11	3.0	3.0	1.5	403.0	
12	3.0	3.0	3.0	403.0	
13	3.0	3.5	3.0	403.0	
14	3.5	3.5	3.0	403.0	
15	3.5	3.5	3.5	403.0	
16	3.5	7.5	3.5	403.0	
17	7.5	7.5	3.5	403.0	
18	7.5	7.5	7.5	403.0	1,420.0
19	7.5	7.5	7.5	404.4	1,910.0

The gates are basically controlled to maintain the normal water level of the reservoir as EL+403.0m.

(3) Present Issues of Flood Protection

Present issues of flood protection are summarized as follows;

- Insufficient carrying capacity of the river except in the present urbanized area
- Incomplete flood protection dike or riverbank embankment along the river except for the present urbanized area on the right bank of the Ishim River
- Meandering of the Ishim River in the eastern and western part of Astana

L.1.2 Flood and Flood Damages

(1) Measurement of the Ishim River

The Astana Center of Hydrometorology Monitoring conducts measurement of Ishim River since 1933. There are five observatories around Astana; Telman, Volgodonovka, Vyacheslavsky Reservoir, Nikolaevka and Turgenevka. The locations of these observatories are shown in the Figure L.1.1. The catchment area of each observatory is shown below.

Chatchment Area of Monitoring Station

Station	Astana	Volgodonovka	Vyacheslavsky	Nikoraevka	Turgenevka
Catchment Area (km^2)	7,400	–	5,310	472	3,240
Start Operation	1933	1978	1970	1973	1975

Annual maximum discharge records and daily mean discharge records at each station except Vyacheslavsky Reservoir station are available. The annual maximum discharge records are shown in the Table L.1.1.

(2) Past Flood Damages

Floods usually occur in spring when the accumulated snow melts and rushes downstream in the river channel. The recorded maximum discharge of the Ishim River at Astana was 1,200 m^3/s, which occurred in 1948. The inundated area was combined with the inundated area of the Nura River basin. There were no flood control structures in the river.

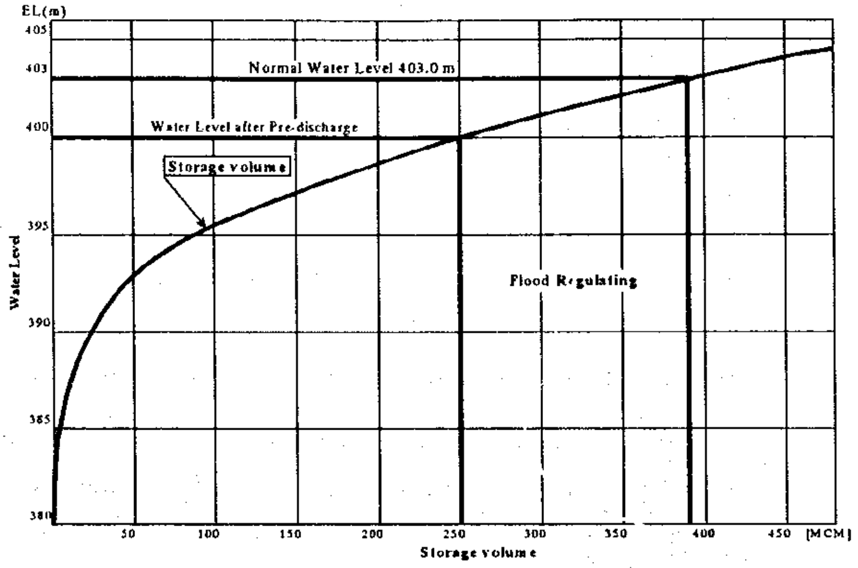
The discharge of the river during spring flood season has been relatively small after the commissioning of the Vyacheslavsky Reservoir in 1970. There has been no inundation in Astana since then except in 1993, when one of the gates at the Vyacheslavsky Reservoir could not be closed due to a mechanical trouble, which was accused as the cause of widespread inundation. The inundated area of the 1993 flood based on the interview survey by the JICA Study Team is shown in the Figure L.1.3.

(3) Present Flood Protection Scheme

The emergency committee is usually organized to establish countermeasures for floods during every spring flood season. Utilization of the Vyacheslavsky Reservoir as a flood regulating reservoir is usually provided by the committee. The committee decides discharging stored water in the reservoir in order to make regulating capacity when a large-scale flood is forecasted. The discharge is carried out in compliance with the water balance between storage volume and forecasted inflow to the reservoir. Pre-discharge has been carried out ten times since 1975 according to the decision of the committee as shown in the Table L.1.2.

Water level is usually made lower up to around EL+400m and storage volume of approximately 140MCM is provided by pre-discharge. The balance between water level and storage volume is shown below.

Balance between water level and storage volume



The local consultant proposed the flood protection scheme in 1998. Ongoing river improvement works is basically designed in compliance of this scheme. According to this scheme, a flood with 1,000-year return period is applied as a design flood. The flood volume is regulated in the Vyacheslavsky reservoir and new flood regulating basin in the upstream of Astana. Flood flow into Astana is decreased until 750m^3/s.

L.1.3 Runoff Analysis

(1) General

For the purpose of flood protection plan, it is necessary to estimate the scale of flood as design value, which is indicated by flood peak discharge and hydrograph. In general, carrying capacity of river channel is designed on the basis of flood peak discharge. Whereas design of flood retention facility for reduction of flood peak discharge requires flood runoff hydrograph in order to examine a retention capacity against runoff volume.

The analysis is therefore carried out for estimation of flood peak discharge as well as flood hydrograph for the Ishim River.

(2) Flood Routing Model

In the flood runoff analysis, flood routing model is constructed in order to evaluate the magnitude of flood by the location. The followings are taking into consideration.

- characteristic of flood runoff (mitigation of the flood peak discharge in the natural flood plain)

- confluence of the Akbulak River and the Sarybulak River
- base point for flood control (locations of existing or planned structures)

The schematic diagram of the flood routing model of the Ishim River is shown in the Figure 5.1.4. Using the flood routing model, flood runoff is computed successively from upstream to down stream.

The computation of runoff by the flood routing model, the runoff retarded by the natural flood plain is evaluated by the Muskingum Method. Natural flood plain formation is found on the left bank of the Ishim River upstream and downstream of Astana. The flood plain upstream of Astana is presently functioning as a flood regulation and retardation basin and thereby mitigating flood flow for Astana. This could be verified by comparison of discharge records of Volgodonovka and Astana as shown in the following table.

Comparison of Discharge Records of Volgodonovka and Astana

Year	1979	1983	1985	1986	1990	1991	1993	1997
Volgodonovka	846	356	239	394	272	269	974	148
	23/4	12/4	15/4	18/4	13/4	19/4	18/4	10/4
486	270	196	294	181	204	750	114	
25/4	13/4	17/4	20/4	15/4	20/4	18/4	13/4	
Peak Reduction	360	86	43	100	91	65	224	34

Note) Upper: Discharge (m^3/s), Lower: Observation Date

The effect of the existing natural flood plain for retardation of flood peak discharge is evaluated on basis of the comparison of flood discharge records of 1993 flood at Vorgodnovka and Astana. The runoff at Astana is successfully calculated by the following formula.

$$O_2 = C'_1*I_2 + C'_2*I_1 + C'_3*O_1$$

Where, O_2: outflow discharge of estimation point

I_1: last calculated inflow discharge of upstream of river section

I_2: inflow discharge of estimation point

O_1: last calculated outflow discharge of estimation point

C'_1, C'_2 and C'_3: coefficient (Coefficients are estimated as $C'_1 = 0.152$, $C'_2 = 0.321$ and $C'_3 = 0.527$.)

(3) Design Flood Duration

A flood discharge of the sub-catchment of the Vyacheslavsky Reservoir during spring flood season was first estimated. The flood discharge records of Nikolaevka and Turgenevka were applied for this estimation. The sub-catchment of Vyacheslavsky reservoir was divided into three sub-catchment areas of the Moildy River, the Ishim River and the reservoir itself as shown in the Figure L.1.1 and the following table.

Sub-catchment of Vyacheslavsky Reservoir

Sub-catchment Name	Moildy	Ishim	Self	Total
Sub-catchment Area (km^2)	797	4,126	387	5,310
Observatory Name	Nikolaevka	Turgenevka	-	-
Observatory Catchment (km^2)	472	3,240	-	-
Rate of Catchmant	1.7	1.3	-	-

The annual maximum discharge of sub-catchment of Moildy and Ishim is estimated by multiplying with the rate of catchment area with the annual maximum discharge of Nikolaevka and Turgenevka. The flood peak discharge of the Vyacheslavsky Reservoir was estimated by multiplying with the combined discharge records of the Moildy and the Ishim and the rate of the catchment between the two sub-catchments of the Moildy and the Ishim, and the Vyacheslavsky Reservoir. The maximum discharge estimation of the above said sub-chatchments is shown in the Table L.1.3 to L.1.5.

The hydrographs of the sub-catchment of the Vyacheslavsky Reservoir from 1975 to 1999 are shown in the Figure L.1.5. Five hydrographs of 1986, 1987, 1990, 1991 and 1993 are selected as samples of larger scale flood. They are shown in the Figure L.1.6.

The relationship between accumulated flood discharge volume and duration is shown in the Figure L.1.7, and the relationship between percentage of accumulated flood discharge volume and duration is shown in the Figure L.1.8. The relationship between accumulated flood discharge volume and duration shows that a great increase of accumulated flood discharge volume appears within 20 days as seen in the Figure L.1.8. Percentage of accumulated flood discharge volume of each selected flood is shown below.

Percentage of Accumulated Flood Discharge Volume

Year	Duration (days)			
	10	20	30	40
1986	51%	93%	97%	99%
1987	33%	83%	94%	99%
1990	43%	83%	91%	96%
1991	0%	63%	93%	98%
1993	30%	80%	92%	98%
Average	31%	81%	93%	98%

From the table above, accumulated flood discharge volume reaches 31% of total flood discharge volume within 10 days, 81% within 20 days, 93% within 30 days and 98% within 40 days. It suggests that the large-scale flood discharge is usually occurred within duration of 20 days. The design flood duration is decided as 20 days.

By the way, according to the Figure L.1.7, the 1993 flood has the largest accumulated flood discharge volume. The type of the design hydrograph is provided on the basis of the hydrograph of the 1993 flood with duration of 20 days as shown in the Figure L.1.9.

(4) Probable Flood Analysis

The annual maximum discharge of the sub-catchment of the Vyacheslavsky Reservoir is shown below according to the Table L.1.5.

Annual Maximum Discharge Estimation of Sub-catchment of Vyacheslavsky

Year	Discharge(m^3/s)	Year	Discharge(m^3/s)	Year	Discharge(m^3/s)
1975	59	1984	280	1993	770
1976	550	1985	500	1994	110
1977	390	1986	820	1995	480
1978	150	1987	740	1996	560
1979	520	1988	490	1997	370
1981	120	1989	170	1998	35
1982	190	1990	670	1999	15
1983	410	1991	690		

A probable flood analysis was carried out by using plotting on the probability paper and the Gumbel Method. The Thomas Plotting Position was applied to plotting position is given below.

$$P(X<x) = i / (N + 1)$$

Where, $P(X<x)$: cumulative probability

i: order of data from smaller

N: number of data

The result of probable flood discharge estimation is shown in the Figure L.1.10. As the result of estimation, the probable flood discharge of the Gumbel Method is bigger than that of Thomas plotting Position. The probable flood discharge of the Gumbel method is applied to the design probable flood discharge of sub-catchment of the Vyacheslavsky Reservoir. The comparison of probable flood discharges with various return periods is given below.

Comparison of Probable Flood Discharge

Return Period (Year)	Probability Paper (m^3/s)	Gumbel Method (m^3/s)
1,000	1,200	1,900
100	960	1,400
10	700	790

The selected hydrograph of 1993 flood with duration of 20 days is expanded according to the rate of flood peak discharge. The hydrographs with various return periods are shown in the Figure L.1.11.

On the other hand, flood discharge at Astana is estimated by using the Muskingum Method. The result of estimation is shown in the Figure L.1.12.

The probable flood peak discharges with various return periods at the Vyacheslavsky Reservoir and Astana are tabulated below.

Probable flood Discharge

Return Period (Year)	Probable Flood Discharge (m^3/s)	
	Vyacheslavsky	Astana
1,000	1,900	1,700
100	1,400	1,200
10	790	700

The probable inundated area in Astana with various return periods are shown in the Figure L.1.13 to L.1.15 and the inundated areas are measured as given below.

Probable Inundated Area

Return Period (Year)	Area (km2)
1,000	220
100	170
10	120

L.1.4 Design Flood Discharge Distribution

(1) Design Flood Discharge

According to SNiP 2.07.01-89, a built-up area requires protection against a flood with 100-year return period. Flood protection for an important area such as the capital, which belongs to the 1st category in SNiP, should be determined based on an engineering study.

The left bank of the Ishim River will accommodate various administrative functions of the Republic, such as Parliament, Presidential Residences, the ministries, central governmental committees and agencies, as well as the republic's. Inundation occurring in such area shall cause enormous harm to the republic's economy. A high level countermeasure against natural disaster is therefore imperative for the capital.

Recently, the flood protection scheme with a 1,000-year return period was proposed by the local consultant and reportedly adopted by Astana Municipality as the flood protection scheme for Astana. The JICA Master Plan Study Team basically adopts the design flood discharge with 1000-year return period for the Master Plan on flood protection.

The design hydrograph with a 1000-year return period adopted by the Municipality is shown in the Figure L.1.16. The flood peak discharge was estimated as 2,100m^3/s. The comparison of the probable flood with various return periods between the JICA Master Plan Study Team and Astana Municipality are shown below.

Comparison of Probable Flood

Return Period (Year)	JICA Study Team (m^3/s)	Astana Municipality (m^3/s)
1,000	1,900	2,100
100	1,400	1,600
10	790	800

(2) Design Discharge Distribution

As shown in the sub-section of L.1.2, flood regulating in the Vyacheslavsky Reservoir is provided during spring flood season. The flood discharge after the Vyacheslavsky Reservoir flood regulating is estimated by using the improved operation rules as shown below.

- Beginning storage volume of the Vyacheslavsky Reservoir in calculation is 250 MCM before flood.
- Maximum allowable water level: EL+404.4m.
- Before flood peak, outflow is equivalent to flood inflow when flood

inflow is less than 1,000m³/s. When flood inflow exceeds 1,000m³/s, outflow depends on reservoir water level and gate opening.

- After flood peak passed, gate operation to be controlled to keep water level in the reservoir as EL+403.0 m

The discharge from the gate of the Vyacheslavsky Reservoir is calculated by using the following formula.

Q = C*B*d*(2gH)1/2

Where, Q: discharge (m^3/s)

B: width of gate (m)

d: gate opening (m)

g: gravity acceration (m/s^2)

H: water depth from gate sill (m)

Calculation of the discharge from the gate is successfully done according to the design hydrographs with 100-year and 1000-year return period. The calculation based on the design hydrograph with 1000-year return period provided by the Astana Municipality is also done as reference. The results of calculation are shown in the Figure L.1.17 to L.1.20 and tabulated below.

Estimation of Flood Regulating at the Vyacheslavsky Reservoir

Inflow (m3/s)	Storage Volume: 250MCM			Storage Volume: 390MCM		
	Max. Discharge	Water Level	Gate Opening	Max. Discharge	Water Level	Gate Opening
1,400	850m³/s	404.0m	3.0m	1300m³/s	404.2m	4.5m
1,900	1,300m³/s	404.4m	4.5m	-	-	-
2,100*	1,300m³/s**	404.3m	4.5m	-	-	-

Note) * : Astana Municipality Estimation

** : Master Plan Study Team Estimation by using Hydrograph of Astana Munisipality

As the result of the estimation, regulated flood peak discharge through the Vyacheslavsky Reservoir is estimated as 1,300m³/s.

Flood discharge before reaching Astana is estimated by the Muskingum Method. The result of estimation is shown in the Figure L.1.21. Flood peak discharge is estimated at 1,270m³/s. Assuming that flood discharge volume retarding in the natural flood plain located along the Ishim River could be derived from the different between two hydrographs in Figure L.1.21, a volume of 220 million m³ would retard in the natural flood plain.

Flood discharge from sub-catchment of the Akbulak River and Sarybulak River are combined at Astana. These two rivers are not observed and there are no discharge records. The hydrograph of each river is assumed based on the hydrograph of the sub-catchment of the Vyacheslavsky Reservoir. It is informed that flood flow of two rivers usually comes earlier than flood flow of the Ishim River since the catchment areas of two rivers are much smaller than that of the Ishim Rivrer. It seems that flood flow of the two rivers do not affect much the flood peak discharge of the Ishim River. The hydrographs of two rivers are shown in the Figure L.1.22.

The design discharge distribution of the Ishim River is shown in the Figure L.1.23.

L.1.5 Flood Protection Alternatives

(1) Basic measures

The basic measures on flood protection are shown below.

Filling

Filling with earth material to elevate the low-lying ground level such as the area on the left bank in the western of Astana is a useful scheme for tentative flood protection in the short term. In such case, excavated material in a suitable condition for filling will be utilized. Excavated material will be generated by construction of the new pond in the west of New City Center. Such material cost is low and construction cost is also low as far as the area is not vast. As a countermeasure for a vast area, however, such filling would be costly and be not advisable.

Embankment

Embankment is constructed around residential area to protect against flooding. This countermeasure is better to be combined with a road plan. When the elevation of the road around the residential area is constructed higher than a housing site, road embankment work also as a flood protection dikes. However, the elevation of the inside area will become lower than the road surface and a storm water drainage method inside of encircled cluster shall need to be well considered duly.

River Improvement

River improvement basically includes increasing the carrying capacity, maintenance of the riverbank and maintenance of river alignment. River improvement work is generally costly and takes long period until completion of work. River improvement is better to combine with other countermeasures as a flood regulating reservoir.

River improvement of the Ishim River along the urbanized area in Astana is now proceeding and the improved section is extended in upstream and downstream. Ongoing river improvement shall be considered to adopt into the Master Plan.

Flood Regulating Reservoir

A regulating reservoir works on peak-cut of floods, proper discharge control and receiving excess flood volume. A large site for construction of regulating reservoir shall be necessary. When a large natural field is located along the river, it is effective to construct a regulating reservoir.

Presently flood flow of the Ishim River is regulated by overflowing into a flood plain along the river in the upstream of Astana. It is recommended to utilize such impounding field as a regulating pond.

Flood Diversion Channel

A diversion channel is applied to distribute an excess flood flow of the projected river. The distributed flow is discharged into the downstream of the projected area, or another river basin. There is large field around Astana to construct such channel. The construction is, however generally costly to acquire the land and construction period is also spent long term.

(2) Proposed Alternative Measures

The alternative measures are basically composed with the combination of some basic measures as shown in the former sub-section. Three alternatives are proposed by the Master Plan Study Team as shown below.

Alternative 1

The river improvement work with 1,000-year return period is proposed as the Alternative 1.

- Carrying capacity of the river to be maintained as 1,300m^3/s
- River section between at least Aleksandorovka located in 25 km upstream of Astana and downstream end to be improved

The proposed typical cross section of improved river is shown in the Figure L.1.24.

Alternative 2

The combination of the river improvement work and the new flood regulating basin is proposed as the Alternative 2.

- Carrying capacity of the river to be maintained as 750m^3/s in compliance with the carrying capacity at the existing car bridge
- New flood regulating basin to be constructed in the upstream of Astana
- Flood control structure to be installed at the exit of the flood regulating basin

The proposed typical cross section of the improved river is shown in the Figure L.1.24.

The river improvement works with carrying capacity of 750m3/s, which is estimated as 15-year return period. Ongoing river improvement work by the Municipality can be preserved as it is.

Alternative 3

The combination of the river improvement work and the flood diversion channel is proposed as the Alternative 3.

- Carrying capacity of the river to be maintained as 750m^3/s
- Flood diversion channel to be constructed on the left bank
- Carrying capacity of the channel to be settled as 550m^3/s
- Diversion structure to be installed at the diversion point located in Aleksandorovka settlement

The proposed typical cross section of the diversion channel is shown in the Figure L.1.24.

The design distribution of the design discharge for each alternative is shown in the Figure L.1.25 to L.1.27.

(3) Conclusion

Alternative 1

- River improvement with the design discharge of 1,300m^3/s widely affects ongoing plan related the Ishim River
- Land acquisition along the river to be necessary larger than another two alternatives
- Construction cost is assumed as at least 190million USD

Alternative 2

- Ongoing river improvement with carrying capacity of 750m^3/s can be preserved

- Utilization of the 3rd ring road as a flood protection dike has little difficulty on technical matter.
- Land inside the flood regulating basin is available as a cultivated lend or a pasture without a residence
- Construction cost is assumed as at least 68million USD.

Alternative 3

- Length of the diversion channel will be very long because its course shall go around the area of Astana.
- Land acquisition will be vast and costly because of its width of 100m and its length of 40km.
- Construction cost is assumed as at least 121million USD.

As a conclusion of alternative study, the Alternative 2 is justified as a proposed alternative countermeasure. The comparison of alternatives is shown in the Figure L1.28.

L.1.6 Flood Protection Master Plan

(1) Structural Measures

The Master Plan on flood protection is established based on a flood with 1,000-year return period. The proposed countermeasures are composed of the Vyacheslavsky Reservoir, the river improvement work and new flood regulating basin. The proposed design parameters of flood control structures are given below.

Vyacheslavsky Reservoir (existing)

- Design Flood Inflow: 1,900m^3/s (1,000-year return period)
- Design Flood Outflow: 1,300m^3/s (peak cut: 600m^3/s)

Flood Regulating Basin (proposed)

- Design Flood from Upstream: 1,270m^3/s
- Design Flood for Downstream: 750m3/s (peak cut: 520m^3/s)
- Area of Regulating Basin: 100km^2
- Volume of Regulating Basin: 229MCM
- Design High Water Level: EL+358.5m
- Design Crest Level: EL+359.5m
- Flood Control Structure
  - Weir crossing the Ishim River with sluice gate (design flood: 750m^3/s)

River Improvement (proposed)

- Design Flood: $750m^3/s$
- Stretch: 30km
- Average Riverbed Gradient 0.0005
- Typical Cross Section
  - Riverbed Width: 150m
  - Riverbank Slope: 1 : 3.0
  - Channel Depth: 4.3m

The high water level is calculated by using non-uniform flow calculation method. The design high water level is decided as envelope of the calculated high water level. The design crest of dike is provided as at least 0.5 m higher than the design high water level in compliance of the SNiP 2.06.15-85. JICA Master Plan Study Team recommends the 1m freeboard on basis of the Japanese Standard. The result of design high water level is estimated as shown in the Figure L.1.29 and the Table L.1.6. Transition between existing improved section and newly improved one shall be considered to make river flow smooth.

Storage volume of the proposed flood regulating basin is estimated in consideration of water balance between inflow and outflow by using the orifice flow. The relationship between water level and storage volume in the flood regulating basin is shown in the Figure L.1.30. The calculation of storage volume of the flood regulating basin is shown in the Table L.1.7. As the result of the calculation, it is necessary for the storage volume as 229MCM to control outflow less than $750m^3/s$. Water level in the flood regulating basin was also estimated as EL+358.5m in that situation. The crest of the dike of the flood regulating basin is decided as EL+359.5m, which is added 1 m as a free board to the calculated high water level. The location of the flood regulating basin is shown in the Figure L.1.31.

(2) Middle Term Countermeasure

The Master Plan for the Development of the City of Astana envisages accomplishing the ultimate target by 2030. The proposed city development plan will be implemented in the manner of phasing implementation towards the ultimate target. The flood control plan is a part of the city development plan and will also be implemented in conformity with the phasing implementation.

The ultimate target of the flood control plan is to achieve the flood protection level of 1,000-year return period for the new capital city by 2030.

Phasing implementation of the flood control plan is proposed in compliance with the implementation plans of relevant infrastructure development schemes in the city development plan and their effects. Completion of each phase should attain a certain increment of flood protection level successively until the ultimate target of flood protection level to be achieved by 2030.

A feasibility study of river improvement work is now underway. According to the plan, the conducted river improvement work comprises widening river cross section to make the carrying capacity to 750m^3/s and construction of the flood protection dike. The carrying capacity of 750m^3/s is estimated as the level of protection with a 15-year return period. If the river improvement work is completed in time for the city development, this could be adopted as the middle-term countermeasure.

As discussed in the sub-section L.1.2, the discharge of 1,400m^3/s for a flood with a 100-year return period can be decreased to 850m^3/s by regulation in Vyacheslavsky Reservoir, which could further be reduced to approximately 750m^3/s in the existing flood plain, preserved as it is.

The river improvement work and Vyacheslavsky Reservoir in combination can thus accommodate a flood with a 100-year return period. This is recommended as the middle-term countermeasure for Astana until 2010.

Taking the proposed city development until 2010 into consideration, the river improvement between the New Capital City Center and the confluence of the Sarybulak River is proposed as 1st phase implementation until 2010.

In this section, there is an improved section of 2km in the existing city area. This section was improved to cope with carrying capacity of the section at the existing carbridge, which is almost equivalent to the design discharge of 750m3/s. This improved section will therefore be maintained as it is and the remaining section of 7km will be improved under the proposed 1st phase implementation.

The Ishim River has a bifurcation upstream of the Kirovo settlement. The northern stream with a larger capacity is recommended for improvement as the main. A new weir is constructed in this section to maintain proper water level of the Ishim River in urbanized area.

The design high water level was estimated by using non-uniform flow calculation method. The cross section

The recommended middle-term countermeasure is shown below.

Recommended Short Term Countermeasure

River Improvement Work	
Length of Improved Section	L = 7km (Except existing improved section)
Typical Cross Section	Riverbed Width: 150m, Riverbank Slope: 1:3
Crest of Flood Protection Dike	EL+343.4m – EL+347.2m(Weir) – EL+348.5m
Crest of Overflow Section of Weir	EL+343.7m

(3) Ultimate Term Countermeasure

The level of flood protection for the ultimate-term countermeasure is recommended as a 1,000-year return period, as discussed earlier.

The river improvement to achieve the carrying capacity of $750m^3/s$ will be further continued according to the implementation of the proposed city development until 2030. It is proposed that the river improvement will be proceeded as follows in conformity with construction of the proposed ring roads.

- 2nd Phase Implementation until 2020: extension of river improvement to 2nd ring road for both upstream and down stream
- 3rd Phase Implementation until 2030: extension of river improvement to 3rd ring road for both upstream and downstream

The downstream end of the river improvement will be at least 1km downstream of the proposed 3rd ring road in consideration of transition from improve and unimproved section.

The river section between the 2nd ring road and the 3rd ring road upstream and downstream of Astana is now naturally meandering. The alignment of the river channel shall be smoothened.

The Ishim River has another bifurcation downstream of the Kirovo settlement. The northern stream is recommended for improvement as the main. The existing weir at Telman settlement is reconstructed in accordance with the improved river cross section.

New flood regulating basin shall be constructed as part of the long-term countermeasures by 2030. The new basin is constructed in the existing flood plain located on the left bank of the Ishim River upstream of Astana. The 3rd ring road is utilized as a part of the dike of the new basin. The flood control gate will be installed at the cross point of the Ishim River and the 3rd ring road.

The recommended ultimate-term countermeasures are shown below.

Recommended Long Term Countermeasure

River Improvement Work	
Length of Improved Section	L = 14km (up to the 2nd ring road until 2020)
	L = 9km (up tp the 3rd ring road until 2030)
Typical Cross Section	Riverbed Width: 150m, Bank Slope: 1:3
Weir at Telman	Crest of Overflow Section: EL+348.0m
Construction of New Flood Regulating Basin	
Area / Storage Volume	120km2 / 360MCM (Full Volume)
Dike	Crest of Dike: EL+359.5m, Length: L=20km
Control Structure	Flood Control Gate: 6.5 x 12.0 x 5sets

Proposed flood protection scheme is shown in the Figure L.1.32.

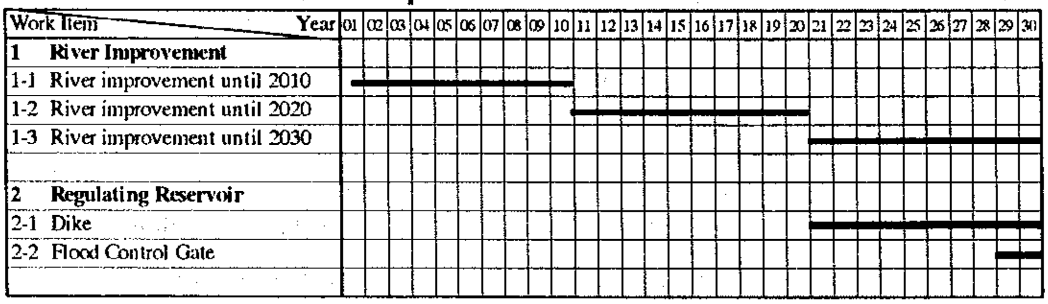
(4) Flood Protection Scheme for New City Center

A feasibility study on flood protection for New City Center has been conducted by Astana Municipality. The Ishim River along New City Center will be improved to the carrying capacity of $750m^3/s$. According to the plan, the flood protection dike along the river will be completed in time of the development of the New City Center until 2010. The flood protection scheme for New City Center prepared by Municipality can be accepted as a part of the Master Plan prepared by JICA Study Team.

(5) Implementation Schedule

Implementation schedule is shown below.

Implementation Schedule



L.2 Storm Water Drainage

L.2.1 Present Conditions

(1) Rainfall in Astana

Rainfall occurs from April and October in Astana. Snowfall takes place in the winter from October to March. The annual precipitation in Astana generally ranges between 300mm and 400mm. Though small in total, rainfall with high intensity sometime occurs in short duration. The monitoring of rainfall has been carried out by the Astana Center of Hydrometeorology Monitoring since 1936. The data of the annual maximum precipitation in the various durations of 10 minutes, 60 minutes and 24 hours are available as shown in the Table L.2.1. According to the past records, the maximum precipitation of the annual maximum precipitation records with respective durations are found as 21.2 mm within 10minutes, 40.0 mm within 60 minutes and 85.8 mm within 24 hours. The actual duration of rainfall, which recorded annual maximum precipitation, is generally recognized less than 2.5 hours. Some records of duration and precipitation are shown below.

Duration and Precipitation

Date	Duration (hour)	Total Precipitation (mm)	Precipitation within 60 min (mm)	Percentage of Precipitation within 60 min (%)
11th Jul, 1974	2.3	44.2	40	90.5
24th Jun, 1981	1.0	25.8	25.4	98.4
20th Jul, 1990	0.6	35.0	35.0	100
25th Jul, 1993	1.3	21.2	20.9	98.9

(2) Present Storm Water Drainage Network and Facilities

Nearly all the present storm water drainage network in Astana had been constructed before 1975. Separate system is adopted as storm water drainage system in Astana. The network was installed on the right bank of the Ishim River, while there is no drainage network on the left bank. The total length of the network is approximately 39 km by gravity drainage system, with pipes ranging in diameter between 200 mm and 1,000 mm.

Present urban area on the right bank of the Ishim River is divided into 11 storm water catchments as shown in the Figure L.2.1 and tabulated below.

Present Storm Water Catchment

No.	Area (ha)	No.	Area (ha)
Ia	452	VI	309
Ib	239	VII	353
II	96	VIII	889
III	142	IX	595
IV	362	X	419
V	337	Total	4,193

Storm water drainage network, however, has been installed in only four sub-catchments in center of urban area. The present network functions poorly, as little maintenance has been carried out since its construction, except in 1988. It is generally informed that many storm water drainage pipes are affected their flow capacity by sediments as sand.

According to the SNiP 2.04.03-85, treatment facilities for collected storm water, as a grit chamber, shall be installed at the end of network before discharging into the river, pond or damp area. Suspended materials and oil shall be removed in the treatment facilities before discharging. Only one treatment station with such treatment facilities is now in operation in the Molodeshny micro-region. Recently, the design of two treatment stations has been completed and construction will be started in 2001.

(3) Present Issues of Storm Water Drainage

As shown above, only one treatment facility is operated now. Two storm water drainage pipelines are connected to this facility. Another storm water pipelines directly discharge collected storm water into the river. It is worried that the water quality of the Ishim River will be contaminated with substances flown into drainage network by rainfall flushing after development of the city. Number of treatment facilities shall be increased according to infrastructure development.

By the way, snow accumulated through the cold winter melts in early spring, when the temperature rises all at once. Water of melting snow usually stays longer in some low areas in spring. Poor drainage tends to cause stagnant water almost everywhere in the city. Stagnant water shall be removed smoothly in order to keep adequate circumstance of residents.

Present issues of storm water drainage are shown below.

- Insufficiency of drainage network existing in the city on the right bank and no drainage network on the left bank
- Insufficiency of treatment facilities for storm water
- No or little operation and maintenance of drainage network

L.2.2 Rainfall Analysis

(1) Rainfall Intensity, Duration and Frequency

The analysis is carried out using the rainfall records at Astana observatory. The annual maximum precipitation with 10 minutes, 60 minutes and 24 hours are shown in the Figure L.2.1. Frequency analysis of storm water precipitation for different duration is made employing the Gumbel's Method as shown in the Figure L.2.2 and tabulated below.

Probable Precipitation Estimation

Return Period (Year)	Cumulative Probability (%)	Probable Precipitation (mm)		
		10 min.	60 min.	24 hrs.
1.01	1.0	-	-	2.284
1.5	33.3	5.706	11.120	19.470
2	50.0	7.922	15.202	24.948
5	80.0	13.375	25.246	38.556
10	90.0	16.985	31.897	47.541
20	95.0	20.449	38.276	56.161
30	96.7	22.441	41.946	61.119
50	98.0	24.931	46.533	67.317
100	99.0	28.291	53.721	75.677

The rainfall intensity, duration and frequency (IDF) are established based on the results of the frequency analysis. The IDF estimation was carried out using the Characteristic Coefficient Method as shown below.

$I_N = B_N * R_N$

$B_N^{10} = I_N^{10} / I_N^{60}$

$I_N = R_N * B_N^{10} = R_N * a' / (t+b)$

$a' = b + 60$

$b = (60 - 10B_N^{10}) / (B_N^{10} - 1)$

Where, I_N: rainfall intensity with n-year return period (mm/hr)

B_N: characteristic coefficient with n-year return period

R_N: precipitation in 60 minutes with n-year return period (mm)

t: duration of rainfall (minutes)

a', b: constants

The estimated parameters for IDF equations are listed below. IDF curves for the respective return period are shown in the Figure L.2.3.

IDF Equation Parameters Estimation

Return Period (Year)	Parameters for Equation					
	IN10	IN60	BN10	a'	b	RN
1.5	34.23	11.12	3.08	73.55	13.55	11.12
2	47.53	15.20	3.13	73.47	13.47	15.20
5	80.25	25.25	3.18	72.94	12.94	25.25
10	101.91	31.90	3.19	72.83	12.83	31.90

(2) Design Storm Rainfall

According to the SNiP 2.04.03-85, it is found that the estimation of storm water run-off from catchment is usually carried out based on a standard value of storm precipitation with duration of 20 minutes in Kazakhstan. The standard value of storm precipitation around Astana is evaluated as 60 liter per second in a hectare. This value is evaluated as equal to 21.6 mm/hr.

The frequency of 0.33-year to 1.5-year return period is generally utilized for the design of the storm water drainage network, which is installed in a flat area.

The design concept as shown above was determined in consideration of environmental and geographical features of objective area. JICA Master Plan Study Team basically adopts this concept for establish of the Storm Water Drainage Master Plan. According to the estimated IDF equation with 1.5-year return period by JICA Master Plan Study Team, the intensity with duration of 20 minutes is computed as 24.2 mm/hr. The IDF equation with 1.5-year return period is adopted for the Storm Water Drainage Master Plan.

(3) Storm Water Run-off Analysis

The estimation of peak value of storm water run-off for the respective catchment is carried out using the Rational Formula as shown below.

$Q = 1/360 * C * I * A$

Where, Q: peak value of storm water run-off (m^3/s)

C: run-off coefficient

I: rainfall intensity (mm/hr)

A: storm water catchment (ha)

The run-off coefficient adopted in Astana on the basis of the SNiP 2.04.03-85 is tabulated below.

Run-off Coefficient of SNiP

Surface Condition	Run-off Coefficient
Roof, Asphalt Concrete Pavement	0.23 – 0.32
Crushed Stone Pavement	0.224
Soil	0.064
Lawn	0.038

As shown above, the coefficient of the SNiP is smaller than the one used in Japan. It is judged to reflect the local environmental condition of rainfall as short duration, small amount of precipitation and thus is adopted as appropriate, however. Basically, JICA Master Plan Study Team adopted it for the storm water run-off analysis. The run-off coefficient for residential area is estimated as the surface condition composed of asphalt and lawn. The 80 % of the residential area are covered with asphalt and the 20 % of the rest area are covered with lawn. The run-off coefficient for respective catchment is estimated as shown in the Table L.2.2.

In this analysis, the storm water catchmant is basically established on the basis of the projected district plan by Master Plan Study Team. Some catchmants are established with some districts combined. Land, which has no development plan until 2030, is excluded from establish of storm water catchment. At last 28 storm water catchmants are established as shown in the Figure L.2.4.

L.2.3 Storm Water Drainage Master Plan

(1) Structural Measures

The drainage network is basically established for respective storm water catchment. The gravity drainage system with closed pipes is adopted for the drainage network. Precast reinforced concrete pipe is available in Astana and construction period using precast pipes is ordinary shorter than that using in-situ concrete culvert.

The storm water pumping station is installed in case of the soil cover on the pipe exceeding 7 m, however. Minimum soil cover of pipeline is usually requested as 1.5 m in Astana. Almost land of present urban area and developed area on the left bank in Astana is formed flat. It seems that the depth of drainage pipes at the downstream of the network is made deep.

The estimation of the drainage pipelines carried out based on the comparison between storm water run-off and discharge capacity of drainage pipelines. Discharge capacity is estimated using the Manning Formula as shown below.

v = 1/n * i1/2 * R2/3

Q = A* v

Where, Q: discharge capacity (m^3/s)

v: velocity (m/s)

n: roughness coefficient (concrete pipe: 0.014)

i: gradient of pipeline

R: hydraulic mean depth (= A / S)

A: wetted area (m^2)

S: wetted perimeter (m)

Allowable velocity is adopted ranging between 0.8 m/s and 3.0 m/s based on Japanese design standard for the storm water drainage pipeline.

The drainage network estimation is tabulated in the Table L.2.3. The main storm water drainage network is shown in the Figure L.2.5.

Collected storm water is basically discharged into the river or pond after removal of suspended materials and oils. Treatment facilities shall be installed at the end of storm water drainage network. As shown in the Figure 5.2.1, storm water pumping stations are basically installed in all catchments. The grit chamber is generally installed at the pumping station in order to remove the suspended materials before pumping. It is recommended that the grit chamber shall be utilized as a treatment facility for storm water. The treatment facilities are designed based on the construction norm as the SNiP. The SN is also utilized as a construction norm in Kazakhstan as well as the SNiP. According to the SN 496-77, general design parameters of a treatment facility for storm water drainage are shown below.

Design Parameters for Treatment Station

Retention Time: T(hr)	More than 2 hours
Velocity in the Chamber: v(m/s)	Less than 0.01m/s
Width of Grit Chamber: B(m)	Less than 40m per unit
Length of Grit Chamber: L(m)	L=1.1 - 1.2*v*T*3600

(2) Infrastructure Master Plan

Storm water drainage network is basically constructed in accordance with the progress of city development. Existing storm water drainage facilities shall be improved to accommodate the design storm water discharge.

There is huge volume of construction work by 2010. Storm water drainage network on the left bank is basically installed in accordance with the development of left bank. On the other hand, Storm water network in the present urban area on the right bank had better be maintained from the important area as a high-density residential area, municipal authorities area and main infrastructure installed area. Recently, damage for the underground pipelines caused by ground water becomes big problem of the city. The construction of storm water drainage network seems to be effective for prevention of surface water permeation into the ground.

The recommended main storm water drainage networks are shown below.

Recommended Main Storm Water Drainage

Main Pipeline until 2010	Dia.: – 1,000mm	L=22km
	Dia.: 1,000mm – 1500mm	L=168km
	Dia.: 1,500mm –	L=14km
	total	L=204km
	Number of Pumping Station with Treatment facilities	19 nos
Main Pipeline until 2020	Dia.: – 1,000mm	L=19km
	Dia.: 1,000mm – 1500mm	L=39km
	total	L=58km
	Number of Pumping Station with Treatment facilities	5 nos
Main Pipeline until 2030	Dia.: – 1,000mm	L=5km
	Dia.: 1,000mm – 1500mm	L=10km
	total	L=15km
	Number of Pumping Station with Treatment facilities	2 nos

(3) Infrastructure Master Plan for New City Center

Design of storm water drainage in New City Center already has been completed by the Municipality. With pipes ranging in diameter between 600 and 800mm, collected water is discharged into the new pond located in the west of the New City Center. The pumping station installed at the end of the network. The design seems to be basically acceptable, though the details need to be further clarified.

(4) Implementation Schedule

Implementation schedule is shown below

Implementation Schedule

Work Item / Year	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
1 **Storm Water Drainage**																														
1-1 Storm water drainage until 2010	━	━	━	━	━	━	━	━	━	━																				
(No.1,2,3,4A,5,6,7,8,9,10,11,12,13,																														
17,Industry(West,North,Central),																														
Station)																														
1-3 Storm water drainage until 2020											━	━	━	━	━	━	━	━	━	━										
(No.4B,14,15,16,17,18,19,																														
Central Ind.,Station)																														
1-4 Storm water drainage until 2030																					━	━	━	━	━	━	━	━	━	━
(No11,14,15,16)																														