Table 3.1 Population Projection by City/Municipality Up to 2025 (1/2)

	Historical Population		Projected Population					Average Annual Growth Rate			% to Region/Province				
	1995 (Sep.) Census	2000 (May) Census	2005	2010	2015	2020	2025	1995-2000	2000-2010	2010-2025	2000	2025	Area (sq. km)	2000 Population Density	2025 Population Density
The Philippines	68,349	76,499	84,241	91,868	99,016	105,507	113,661	2.3%	1.8%	1.4%	-	-	294,454	260	386
Region IV	9,904	11,794	12,860	14,525	16,357	18,225	20,320	3.6%	2.1%	2.3%	-	-	46,844	252	434
NCR (MetroManila)															
Cities															
1) Las Pinas	413	473	609	759	953	1,114	1,290	2.8%	4.8%	3.6%	4.8%	9.8%	41.5	11,398	31,094
2) Manila	1655	1581	1,473	1,345	1,286	1,146	1,011	-0.9%	-1.6%	-1.9%	15.9%	7.7%	38.3	41,279	26,387
3) Makati	484	445	443	432	426	391	356	-1.7%	-0.3%	-1.3%	4.5%	2.7%	29.9	14,883	11,905
4) Mandaluyong	287	278	281	277	280	264	246	-0.6%	-0.1%	-0.8%	2.8%	1.9%	26	10,692	9,473
5) Marikina	357	391	436	472	530	556	576	1.8%	1.9%	1.3%	3.9%	4.4%	38.9	10,051	14,819
6) Muntinlupa	400	379	468	558	639	682	720	-1.1%	3.9%	1.7%	3.8%	5.5%	46.7	8,116	15,416
7) Paranaque	391	450	507	554	637	683	725	2.9%	2.1%	1.8%	4.5%	5.5%	38.3	11,749	18,930
8) Pasig	471	505	555	595	658	679	694	1.4%	1.6%	1.0%	5.1%	5.3%	13	38,846	53,379
9) Valenzuela	437	485	560	624	719	773	823	2.1%	2.5%	1.9%	4.9%	6.3%	47	10,319	17,507
10) Caloocan	1023	1178	1,339	1,471	1,701	1,833	1,956	2.9%	2.2%	1.9%	11.9%	14.9%	55.8	21,111	35,045
11) Pasay	409	355	359	353	344	313	282	-2.8%	-0.1%	-1.5%	3.6%	2.1%	13.9	25,540	20,276
12) Quezon	1989	2174	2,285	2,343	2,533	2,554	2,549	1.8%	0.7%	0.6%	21.9%	19.4%	166.2	13,081	15,338
Sub-Total	8316	8694	9,314	9,783	10,705	10,987	11,228	0.9%	1.2%	0.9%	87.5%	85.5%	555.5	15,651	20,212
Municipalities															
1) Malabon	347	339	369	390	414	411	404	-0.5%	1.4%	0.2%	3.4%	3.1%	23.4	14,487	17,267
2) Navotas	229	230	244	253	267	264	258	0.1%	0.9%	0.1%	2.3%	2.0%	2.6	88,462	99,170
3) Pateros	55	57	57	56	57	55	52	0.7%	-0.2%	-0.4%	0.6%	0.4%	10.4	5,481	5,042
4) San Juan	124	118	109	98	93	82	71	-1.0%	-1.9%	-2.1%	1.2%	0.5%	10.4	11,346	6,866
5) Taguig	381	467	588	711	897	1,055	1,227	4.2%	4.3%	3.7%	4.7%	9.3%	33.7	13,858	36,419
Sub-Total	1136	1211	1,366	1,508	1,729	1,867	2,013	1.3%	2.2%	1.9%	12.2%	14.5%	80.5	15,043	25,007
Metro Manila Total	9452	9933	10,680	11,291	12,434	12,854	13,241	1.0%	1.3%	1.0%	100.0%	100.0%	636	15,574	20,652
Cavite Province															
Cities															
1) Cavite	93	99	97	94	92	89	85	1.3%	-0.6%	-0.6%	4.8%	2.6%	10.9	9,083	7,806
Municipalities															
1) Bacoor	251	306	362	421	492	564	638	4.0%	3.2%	2.8%	14.8%	19.4%	25	12,240	25,504
2) Imus	177	195	240	289	334	379	424	2.0%	4.0%	2.6%	9.5%	12.9%	89	2,191	4,768
3) Kawit	57	63	67	71	75	79	80	2.0%	1.2%	0.8%	3.1%	2.4%	13.4	4,701	6,006
4) Noveleta	27	32	35	37	41	44	47	3.5%	1.5%	1.5%	1.6%	1.4%	5.6	5,714	8,304
5) Rosario	54	74	83	90	104	119	135	6.5%	1.9%	2.7%	3.6%	4.1%	3.6	20,556	37,366
Sub-Total	566	670	792	908	1,046	1,134	1,240	3.4%	3.1%	2.1%	32.5%	40.2%	136.6	4,905	9,077
Total	659	769	879	1,002	1,138	1,251	1,368	3.1%	2.7%	2.1%	37.3%	42.8%	147.5	5,214	9,273
Other Municip.	951	1294	1,478	1,409	1,577	1,736	1,882				62.7%	57.2%			
Cavite Total	1610	2063	2,357	2,411	2,715	2,987	3,250	5.1%	1.6%	2.1%	100.0%	100.0%	1287.6	1,602	2,556

Table 3.1 Population Projection by City/Municipality Up to 2025 (2/2)

	Historical Population		Projected Population					Average Annual Growth Rate			% to Region/Province				
	1995 (Sep.) Census	2000 (May) Census	2005	2010	2015	2020	2025	1995-2000	2000-2010	2010-2025	2000	2025	Area (sq. km)	2000 Population Density	2025 Population Density
Rizal Province															
Cities															
1) Antipolo	346	471	692	984	1,376	1,860	2,453	6.4%	7.6%	6.3%	27.6%	47.8%	306.1	1,539	8,015
Municipalities															
1) Angono	59	75	90	104	124	142	160	4.9%	3.3%	2.9%	4.4%	3.1%	26	2,885	6,149
2) Baras	20	25	28	31	35	39	41	4.6%	2.1%	2.0%	1.5%	0.8%	23.4	1,068	1,773
3) Binangonan	141	188	209	228	264	296	323	5.9%	1.9%	2.4%	11.0%	6.3%	72.7	2,586	4,445
4) Cainta	202	243	338	454	587	733	894	3.8%	6.4%	4.6%	14.2%	17.4%	10.2	23,824	87,634
5) Cardona	36	39	41	42	44	44	43	1.6%	0.7%	0.1%	2.3%	0.8%	31.2	1,250	1,378
6) Jala-Jala	20	23	25	27	30	31	32	2.8%	1.7%	1.2%	1.3%	0.6%	49.3	467	658
7) Rodriguez(Montalb	80	115	130	144	173	201	228	7.5%	2.3%	3.1%	6.7%	4.4%	312.8	368	730
8) Morong	36	42	43	44	47	48	47	3.1%	0.5%	0.5%	2.5%	0.9%	37.6	1,117	1,261
9) Pililla	37	45	48	51	57	60	63	4.0%	1.3%	1.3%	2.6%	1.2%	74	608	847
10) San Mateo	99	136	159	181	218	255	290	6.6%	2.9%	3.2%	8.0%	5.6%	64.9	2,096	4,467
11) Tanay	69	78	89	99	111	119	125	2.5%	2.4%	1.6%	4.6%	2.4%	243.4	320	515
12) Taytay	145	198	226	255	303	349	392	6.4%	2.5%	2.9%	11.6%	7.6%	38.8	5,103	10,101
13) Teresa	24	30	33	36	40	44	46	4.6%	1.7%	1.8%	1.8%	0.9%	18.6	1,613	2,498
Sub-Total	968	1237	1,460	1,697	2,032	2,362	2,686	5.0%	3.2%	3.1%	72.5%	52.3%	1002.9	1,233	2,678
Rizal Total	1314	1707	2,152	2,681	3,409	4,222	5,139	5.4%	4.6%	4.4%	100.0%	100.0%	1309	1,305	3,924
Quezon Province															
Cities															
1) Infanta	40	51	57	62	69	77	85	5.0%	1.9%	2.2%	3.0%	3.8%	134.6	379	631
Municipalities															
1) General Nakar	21	24	28	31	34	38	41	2.7%	2.6%	1.9%	1.4%	1.8%	1343.3	18	31
2) Real (out of Basin)	28	31	37	42	47	52	57	2.1%	3.1%	2.0%	1.8%	2.5%	563.8	55	101
Sub-Total	49	55	65	73	82	90	98	2.3%	2.9%	2.0%	3.3%	4.4%	1907.1	29	52
Total	89	106	121	135	151	149	154	3.6%	2.4%	0.9%	6.3%	8.1%	2041.7	52	75
Other Municip.					1,937	2,011	2,073				93.7%	91.9%			
Quezon Total	1551	1679	1,848	1,974	2,087	2,178	2,255	1.6%	1.6%	0.9%	100.0%	100.0%	8706.6	193	259

Source: (1) "1995 Census-based City/Municipal Population Projections" NSO, December 1999
(2) "1995 Census-based National, Regional and Provincial Population Projections" NSO, June 1999

Note: (1) Population projection by city/municipality up to 2010 was adopted from Source (1) after replacing 2000 figures with Population Census 2000.
For this replacement, average annual growth rates projected by NSO were applied up to 2010.
(2) For Population in 2015 and 2020, the Region/Province population projection of the Source (2) was adopted.
For the projection of City/Municipality level in 2015, 2020 and 2025, the ratios of City/Municipality to each region/province were projected and applied. In this computation, the aggregate of the ratios of City/Municipality was adjusted to be 100% in total.
This was based on the observation that these ratios of City/Municipality to Region/Province are stable in the long term.
(3) Projection of 2025 population :
Philippines: Growth rate of 1.5% per annum shown in LTPDP 2025 was applied to 2020 projected population.
Region: Growth rates of 2015-2020 were applied.
City/Municipality: As stated above (2).

Table 3.2 GDP/GRDP Projections for 2000-2025

	2000	2005	2010	2015	2020	2025	Growth 2000-
The Philippines							
Agriculture, Fishery and Forestry	189,826	209,478	220,164	231,394	243,198	255,603	1.2%
Industrial Sector	332,483	448,251	617,032	849,364	1,169,175	1,609,406	6.5%
Service Sector	439,443	578,664	767,105	1,016,911	1,348,067	1,787,062	5.8%
Total GDP	961,752	1,236,393	1,604,300	2,097,669	2,760,440	3,652,072	5.5%
Average growth (% p.a.)	4.8%	5.2%	5.3%	5.5%	5.6%	5.8%	
NCR (Metro Manila)							
Agriculture, Fishery and Forestry	0	0	0	0	0	0	0
Industrial Sector	111,669	144,337	191,828	254,943	338,825	450,307	5.7%
% share to the nation	33.4%	32.2%	31.1%	30.0%	29.0%	28.0%	
Service Sector	182,193	243,802	328,073	441,472	594,068	799,410	6.1%
% share to the nation	41.5%	42.1%	42.8%	43.4%	44.1%	44.7%	
Total of NCR	293,862	388,140	519,901	696,416	932,894	1,249,716	6.0%
% share to the nation		31.4%	32.4%	33.2%	33.8%	34.2%	
Average growth (% p.a.)	3.9%	5.7%	6.0%	6.0%	6.0%	6.0%	
Region IV (Southern Tagalog)							
Agriculture, Fishery and Forestry	34,404	37,346	38,279	39,236	40,217	41,222	0.7%
% share to the nation	18.3%	17.8%	17.4%	17.0%	16.5%	16.1%	
Industrial Sector	63,960	86,312	118,812	163,548	225,129	309,896	6.5%
% share to the nation	19.3%	19.3%	19.3%	19.3%	19.3%	19.3%	
Service Sector	50,014	67,732	92,055	125,115	170,046	231,114	6.3%
% share to the nation	11.4%	11.7%	12.0%	12.3%	12.6%	12.9%	
Total of Region IV	148,378	191,389	249,146	327,898	435,391	582,232	5.6%
% share to the nation		15.5%	15.5%	15.6%	15.8%	15.9%	
Average growth (% p.a.)	3.4%	5.2%	5.4%	5.6%	5.8%	6.0%	

Table 3.3 Alternative Population Projection of Antipolo

	Area	Census Population (in thousand)					Population density (persons/sq. km)					Population growth rate (% per annum)				
	(sq. km)	1975 (May 1)	1980 (May 1)	1990 (May 1)	1995 (Sep. 1)	2000 (May 1)	1975	1980	1990	1995	2000	1975-1980	1980-1990	1990-1995	1995-2000	1975-2000
MetroManila																
Cities																
Las Pinas	41.5	82	137	297	413	473	1,976	3,301	7,157	9,952	11,398	10.8%	8.0%	6.8%	2.8%	7.3%
Marikina	38.9	168	212	310	357	391	4,319	5,450	7,969	9,177	10,051	4.8%	3.9%	2.9%	1.8%	3.4%
Pasig	13.0	210	269	398	471	505	16,154	20,692	30,615	36,231	38,846	5.1%	4.0%	3.4%	1.4%	3.6%
Municipalities																
Taguig	33.7	74	134	267	381	467	2,196	3,976	7,923	11,306	13,858	12.6%	7.1%	7.4%	4.2%	7.6%
Rizal																
Municipalities																
Angono	26.0	18	27	46	59	75	692	1,038	1,769	2,269	2,885	8.4%	5.5%	5.1%	4.9%	5.9%
Cainta	10.2	37	59	127	202	243	3,627	5,784	12,451	19,804	23,824	9.8%	8.0%	9.7%	3.8%	7.8%
San Mateo	64.9	39	52	82	99	136	601	801	1,263	1,525	2,096	5.9%	4.7%	3.8%	6.6%	5.1%
Taytay	38.8	58	75	112	145	198	1,495	1,933	2,887	3,737	5,103	5.3%	4.1%	5.3%	6.4%	5.0%
Total of eight cities/ municipalities	267	**686**	965	1,639	2,127	**2,488**	2,569	3,614	6,139	7,966	9,318	7.1%	5.4%	5.4%	3.2%	**5.3%**
cf: Antipolo	306.1	41	69	208	346	**471**	134	225	680	1,130	1,539	11.0%	11.7%	10.7%	6.4%	10.3%

Antipolo population in 2025 = 471 x (1+5.3%) ^ 25 **1,713 thousand**

Source: Each Population Census of NSO.

Table 3.4 Assumed Wastewater Volume

Year	Water Supply			Sewerage					
	Water Volume (MLD) 1)			Wastewater (MLD) 2)	Groundwater Infiltration (MLD) 3)	Total Wastewater (MLD)		Treated Volume (MLD) by STP	Sewer coverage 4)
	Area	Billed water	Ave. daily demand	Billed Water x 0.7	27% of Wastewater	This Study	JICA MP 1995		%
2000	Total	1,433	3,663	1,003	271	1,274		125	10%
	East	683	1,519	478	129	607		18	3%
	West	749	2,145	524	142	666		107	16%
2005	Total	1,740	3,783	1,218	329	1,547		284	18%
	East	722	1,569	505	136	641		103	16%
	West	1,019	2,215	713	193	906		181	20%
2010	Total	2,210	4,250	1,547	418	1,965		648	33%
	East	883	1,698	618	167	785		400	51%
	West	1,328	2,553	929	251	1,180		248	21%
2015	Total	2,919	5,033	2,043	552	2,595	2,473	1,037	40%
	East	1,243	2,144	870	235	1,105		575	52%
	West	1,675	2,889	1,173	317	1,489		462	31%
2020	Total	3,754	5,866	2,628	710	3,337		2,034	61%
	East	1,723	2,693	1,206	326	1,532		843	55%
	West	2,031	3,174	1,422	384	1,806		1,192	66%
2025	Total	4,886	6,980	3,420	923	4,344		2,631	61%
	East	2,413	3,447	1,689	456	2,145		1,180	55%
	West	2,473	3,533	1,731	467	2,198		1,451	66%

Note: 1) Water Volume is assumed under this Study.
2) Wastewater Volume and 3) Groundwater infiltration are assumed in the same manner as adopted in JICA Study 1995.
4) Sewer Coverage by concessionare is referred to targets under Concession Agreement.
Expressed as a percentage of the total population in the designated city/municipality connected to the Concessionaire's water system at the time of the target.
Target coverage in 2025 was assumed as the same figure in 2020

Table 3.5 Sewer Coverage Targets under Concession Agreement

City/Municipality		Service Target				
		2001	2006	2011	2016	2021
(West Zone)						
NCR	Pasay	0%	0%	0%	16%	95%
	Callocan	3%	2%	2%	32%	79%
	Las Pinas	0%	0%	0%	0%	50%
	Malabon	2%	2%	2%	38%	94%
	Valenzuela	0%	0%	0%	24%	59%
	Muntinlupa	0%	44%	57%	54%	61%
	Navotas	3%	3%	3%	36%	90%
	Paranaque	0%	0%	0%	0%	52%
Cavite	Cavite City	0%	0%	0%	0%	0%
	Bacoor	0%	0%	0%	0%	0%
	Imus	0%	0%	0%	0%	0%
	Kawit	0%	0%	0%	0%	0%
	Noveleta	0%	0%	0%	0%	0%
	Rosario	0%	0%	0%	0%	0%
(East Zone)						
NCR	Mandaluyong	0%	0%	100%	100%	100%
	Marikina	0%	0%	0%	0%	0%
	Pasig	0%	41%	68%	68%	68%
	Pateros	0%	60%	100%	100%	99%
	San Juan	0%	0%	100%	100%	100%
	Taguig	0%	52%	75%	84%	100%
RIZAL	Antipolo	0%	0%	0%	0%	0%
	Cainta	0%	0%	0%	0%	14%
	Angono	0%	0%	0%	0%	0%
	Baras	0%	0%	0%	0%	0%
	Binangonan	0%	0%	0%	0%	0%
	Cardona	0%	0%	0%	0%	0%
	Jala-Jala	0%	0%	0%	0%	0%
	Morong	0%	0%	0%	0%	0%
	Pililla	0%	0%	0%	0%	0%
	Rodoriguez	0%	0%	0%	0%	0%
	San Mateo	0%	0%	0%	0%	0%
	Tanay	0%	0%	0%	0%	0%
	Taytay	0%	0%	0%	0%	15%
	Teresa	0%	0%	0%	0%	0%
(Common Concession Area)						
NCR	Quezon City					
	East	0%	0%	83%	87%	98%
	West	0%	0%	0%	0%	54%
	Manila					
	East					
	West	55%	71%	77%	83%	91%
	Makati					
	East	22%	52%	100%	100%	100%
	West					
	East	3%	16%	51%	52%	55%
	West	16%	20%	21%	31%	66%

Sewerage service: The Concessionaure shall offer to supply sewerage services to all customers in the Service Area who have sewerage connections for domestic sewerage and industrial effluents compatible with available treatment processes.

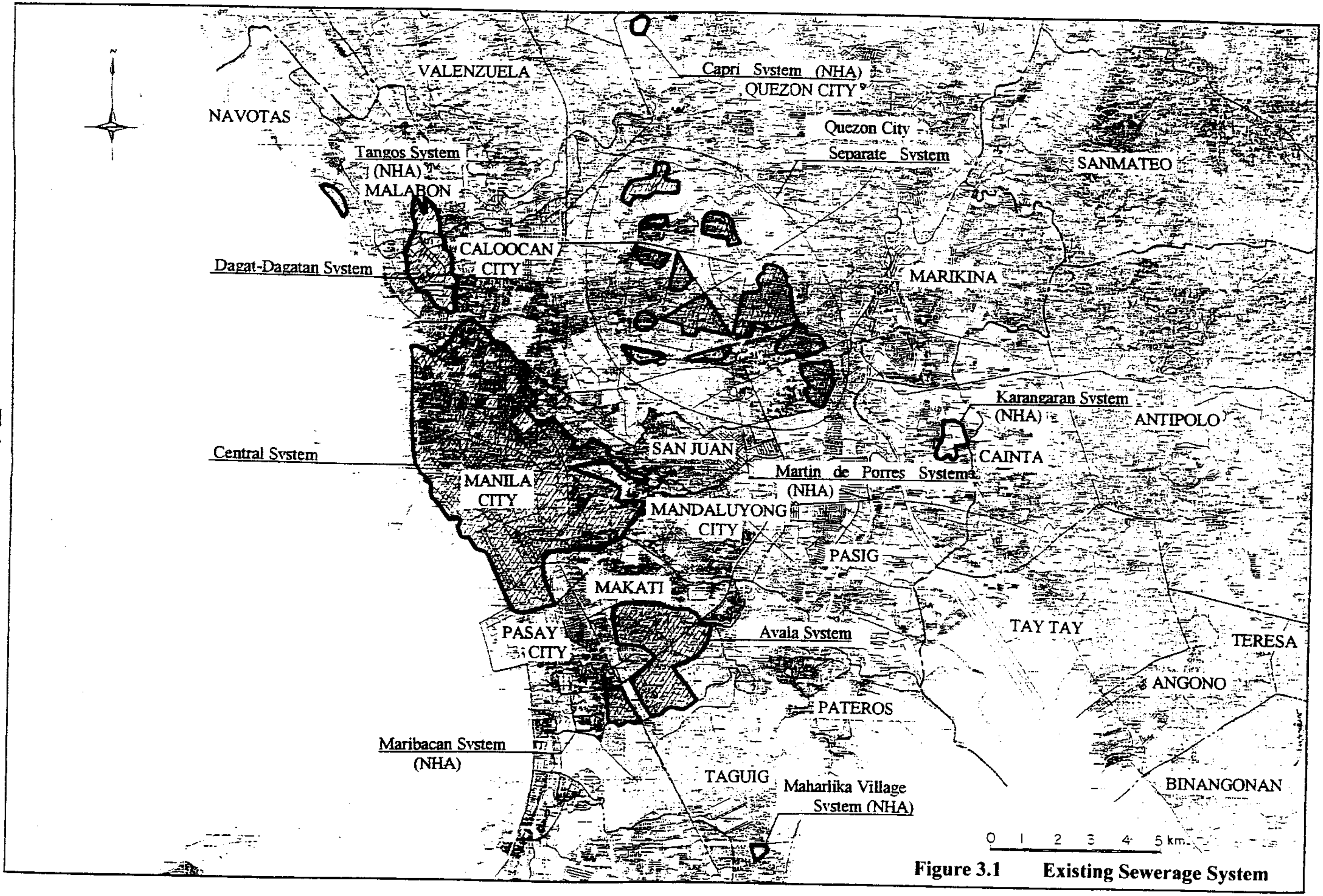


Figure 3.1 Existing Sewerage System

CHAPTER IV SITE CONDITIONS OF PROJECT AREA

4.1 General

The Project Area covers the whole Agos River Basin and the area through which the Kaliwa-Taytay Waterway passes.

This Chapter IV describes the site conditions of the Project Area including the coastal conditions of Infanta Peninsula, which have been clarified through the 2nd Field Investigation conducted in 2002.

4.2 Topographic Condition

The proposed Project contemplates to convey the water resources of the Agos River Basin having a total catchment area of 940 km^2 to Metro Manila. From the scale of the catchment area, it appears that the Agos River Basin can be included in the Major River Basins in the Philippines, since a catchment area of the Amnay-Patric River Basin, the smallest catchment of the 20 Major River Basins, is 993 km^2 that is almost same as that of the Agos River Basin.

The Agos River is the downstream river course from the confluence of its two major tributaries, namely the Kanan and Kaliwa Rivers. The Agos River has a river course length of about 17 km to the river mouth. In the nearby confluence, it dissects the Siera Madre Mountain Range with peak elevations of more than 1,000, and it finally drains into the Pacific Ocean. The alluvial plain spreads along the lowermost reach where there exist the two Municipalities, General Nakar and Infanta. The Agos damsite is selected about 1km downstream of the confluence, where the river bed elevation is about 40 m. One of the focuses of the 2nd Field Investigation is the coastal change that might be cause by the construction of Agos dam as discussed in the succeeding Section 4.7.

The Kaliwa Low Dam site is located on the Kaliwa River, about 10 km upstream of the confluence. The river bed elevation is at El. 95 m. The Kaliwa Low Dam site is topographically characterized by the steep slopes on both abutments thereof. The Kaliwa Low Dam and Kaliwa-Taytay 1st Waterway are planned to be developed in the Stage 1 Development of the Project.

The intake structure of the Kaliwa-Taytay Waterway is situated on the right bank of the Kaliwa Low Dam site. The waterway tunnel (Tunnel No.1) initially takes a southern route to run through the mountainous area on the right bank of the Kaliwa River Basin and then the western direction to pass through the mountainous area of 400 m to 600 m in elevation which is northernmost parts of catchment of the Laguna Lake. After going down along the moderate slope, the waterway reaches the proposed Valve House No.1 site at Barangay Lagundi of Morong, Rizal Province, whose ground elevation is in a range of 110 to 130 m.

The water treatment plan site is selected at the hilly area of 85 m to 105 m in Morong, Rizal Province. After passing through the water treatment plant site in Morong (Morong WTP), the waterway goes down to the low-lying area of 45 m to 50 m in elevation, which is mainly used for residential areas and paddy fields where a pipeline is planned to be installed. The waterway again goes through the mountainous area of 110 m to 230 m in elevation for a section of about 5.3 km till it finally reaches the proposed service reservoir at Taytay (Taytay Service Reservoir) in Rizal Province.

4.3 Hydrology

4.3.1 Rainfall

The rainfall data at 19 stations in and around the Agos River Basin were collected in the Master Plan Study and Feasibility Study stages. The annual basin average monthly rainfall of four (4) catchment areas in the Kaliwa River Basin were estimated by means of the Thiessen Polygons method as summarized in the following table:

Basin Average Monthly Rainfall

(Unit: mm)

Month	Limutan River Basin	Lenatin River Basin	Kaliwa Low Damsite	Kaliwa Confluence
Jan	194.4	143.1	168.7	199.3
Feb	119.8	89.9	105.8	127.2
Mar	100.3	76.5	88.6	103.7
Apr	105.9	84.8	93.1	106.4
May	223.0	190.1	188.5	191.7
Jun	405.3	359.2	337.6	320.2
Jul	509.2	460.8	423.1	396.7
Aug	510.6	456.8	423.6	390.3
Sep	461.0	410.5	387.8	373.2
Oct	496.6	397.6	425.2	458.5
Nov	369.9	278.0	317.2	363.1
Dec	270.8	204.7	244.3	296.8
Total	3,767	3,152	3,204	3,327

As shown in the above table, the annual rainfall in the Kaliwa River Basin range from 3,200 mm to 3,800 mm, while the mean annual rainfall at Infanta situated close to the Agos River mouth is about 4,000 mm for the period from 1930 to 2000 as tabulated in Part-C of Volume III. The isohyetal map prepared in the 1981 JICA study, which is illustrated in Table 2.2, indicates that the high annual rainfall of more than 6,000 mm takes place in the Kanan River Basin

4.3.2 Low Flow

The streamflow data at 8 streamflow gauging stations were collected in the Master Plan Study and Feasibility Study stages. The purpose of low flow analysis is to estimate the long-term discharges at the planned dam and weir sites to be utilized for the water balance and reservoir operation studies at the proposed weir and dam sites in the Agos River Basin.

The Tank model method was used to generate the Kaliwa River low flow series. The runoff analysis was carried out during the Master Plan Study stage as described in detail in Part-C of Volume III and its results are summarized below.

(1) Runoff Analysis

The method of the runoff analysis adopted in the Study is as follows:

a) The tank model parameter of the Kaliwa River Basin was decided for the Limutan and Lenatin streamflow gauging stations where discharge measurement records are available.

b) The long-term discharge at Laiban damsite was estimated by summing up the long-term discharge records at Limutan and Lenatin streamflow gauging stations.

c) The tank model analysis for the Kaliwa Low Damsite and Kaliwa confluence (before joining the Kanan River) used the parameters estimated for the Limutan streamflow gauging station.

d) The runoff at the Agos confluence (just downstream of the Kaliwa-Kanan confluence) and Agos Dam site was derived from the correlation with the long term records at the Banugao streamflow gauging station situated in the lower Agos basin (correlation by catchment area).

e) The runoff of the Kanan River Basin was estimated as the balance between the runoff estimated at Agos confluence and Kaliwa confluence.

As discussed in the succeeding Chapter VI, the two (2) water resource facilities in the Agos River Basin, namely Kaliwa Low Dam on the Kaliwa River and Agos Dam on the Agos mainstream, are planned to be developed under the Project. The estimated annual mean monthly discharges at the Kaliwa Low Dam site and Agos Dam site are shown in the following table:

Mean Monthly Discharges Estimated at Selected Sites

(Unit: m^3/sec)

Location	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Mean
Kaliwa Low Dam site	25.2	18.9	13.5	10.0	10.6	20.3	33.1	38.0	43.2	46.0	41.7	34.3	27.9
Agos Dam site	155.4	104.9	75.5	47.6	42.1	51.3	74.5	88.5	92.2	161.6	221.8	244.4	113.3

(2) Flow Duration Curve

The flow duration curves at the Kaliwa Low Dam site and Agos Dam site are shown in Figure 4.1 and summarized in the following table:

Flow Duration Curve

(Unit : m^3/sec)

Duration	Kaliwa Low Damsite	Agos Damsite
10%	56.63	236.87
20%	44.67	183.56
30%	36.62	140.30
40%	27.39	107.86
50%	22.52	85.27
60%	17.60	70.73
70%	14.23	57.14
80%	10.18	43.45
90%	6.40	30.24
95%	5.22	23.64
100%	3.27	7.58

The minimum flow to be released from each dam site to the downstream is planned herein at 10 % of the 80 % discharge, which is a guideline figure used in several previous studies and is adopted in this Study as a uniform criterion at the phase of the Master Plan Study. Based on this criterion, the minimum flow rate to be assumed at each site is calculated as follows:

- Kaliwa Low Dam site : 10.18 m^3/sec x 10% = 1.02 m^3/sec
- Agos damsite : 43.45 m^3/sec x 10% = 4.35 m^3/sec

4.3.3 Flood

The purpose of flood flow analysis was to estimate probable flood discharges and hydrographs to be utilized in the studies relevant to spillway design and flood control work in the lower Agos. The Study also included the estimate of probable maximum flood (PMF).

(1) Statistical Analysis of Flood Records at Banugao Gauging Station

The maximum discharge records on the Agos River Basin are available at Banugao gauging station for 26 years. For estimating the probable floods, two theoretical probability distributions, Log Pearson Type III and Gumbel methods, were applied to the annual maximum discharges. The results of the frequency analysis are shown in the following table:

Probable Floods at Banugao Streamflow Gauging Station

Return Period	Probable Discharge (m^3/sec)	
	Log Pearson Type III	Gumbel
2-year	1,535	1,690
5-year	2,651	2,979
10-year	3,530	3,832
20-year	4,474	4,650
50-year	5,845	5,709
100-year	6,988	6,503
200-year	8,230	7,294
1,000-year	11,542	9,126
10,000-year	17,472	11,744

As shown in the above table, the Log Pearson Type III method gives higher values than those results by the Gumbel method for a recurrence period of 100-year and larger recurrence periods. Therefore, the Log Pearson Type III method was applied to estimate the probable floods.

(2) Probable Flood at Proposed Damsites

The probable floods at proposed damsite were estimated from the corresponding floods at Banugao gauging station and adjusted by the drainage area ratio using the following Creager's equation:

$$q = 0.503 \times C \times A \times 0.386^{b}$$

$$b = -0.93578 \times A^{-0.048}$$

where, q : Specific flood discharge (m^3/sec/km^2)
A : Drainage area (km^2)
C : Coefficient obtained from the Banugao flood

The estimated probable floods at the respective damsites are shown in Table 4.1.

(3) Probable Maximum Flood (PMF)

The previous study adopted the maximum daily rainfall of 1,168 mm recorded between July 14 and July 17, 1911 at Baguio as the probable maximum precipitation (PMP). The PMP was then transposed to the Agos catchment. Consequently, the PMF at the proposed Agos damsite was estimated at 17,300 m^3/sec applying the PMP to the Nakayasu's synthetic unitgraph.

In this Study, the probable maximum flood (PMF) at the proposed Agos damsite was estimated applying the same methodologies and procedures as those in the previous 1981 JICA study on the Agos hydropower project. As a result, the PMF at the Agos damsite is revised to be about 17,100 m^3/sec because of a small difference of catchment area at the Agos damsite. On the other hand, the 10,000-year probable flood has been so often used as the maximum limit instead of the PMF in designing large dams in the Philippines. As shown in Table 4.1, the 10,000-year probable flood at the Agos Dam site is derived to be about 17,000 m^3/sec that almost coincides with the PMF of 17,100 m^3/sec. In this Study, accordingly, it is determined to adopt the PMF of 17,100 for the design of the Agos Dam and its spillway taking the safer side design thereof. The hydrograph of PMF is given in Figure 4.2.

4.3.4 Sediment Yield

(1) Review of Previous Sediment Study

The sediment analysis for the Agos River Basin is available in the feasibility study on Agos River Hydropower Project (JICA 1981), which was carried out between November 1978 and May 1980. Most of the subsequent studies assessed the sedimentation of the Agos River Basin with reference to the analysis results of the previous JICA study.

In the previous JICA study, 36, 11 and 19 sediment samples were collected at Mahabang Lalim gauging station on the Agos River, Binugawan gauging station on the Kanan River and Nio gauging station on the Kaliwa River, respectively.

Based on those data, the previous study estimated the annual sediment yield, consisting of suspended load and bed load, to be 557 m^3/km^2/year.

As the site reconnaissance conducted by helicopter in July 2000, on the other hand, it was observed that the Kaliwa flow contained much sediment, while the Kanan River water seemed comparatively transparent probably because of the smaller rainfall in that month. Further, the sediment yield of 557 m^3/km^2/year might be slightly small as compared with annual sediment yield rates estimated for the existing and proposed reservoir dam projects in Luzon Island (see Table 4.2). A feasibility study on the Agos Hydropower Project (ELC, 1991) recommended to adopt a sediment yield rate of 1,000 m^3/km^2/year, although it is based on a rule-of-thumb estimate.

(2) Estimate of Sediment Yield

Based on the sediment sampling data collected during the field investigation period (May-August 2001 and January-April 2002), sediment sampling was conducted at the 4 new stream gauging stations shown in Figure 2.2. Then, the sediment yield was estimated at Agos Dam site, Kanan confluence and Kaliwa confluence as summarized below:

Estimated Sediment Yield Rates

Location	Catchment Area	Annual Mean Discharge	Annual Sediment Yield per Year		Sediment Yield/Area/ Discharge
	(km^2)	(m^3/sec)	(10^3m^3)	(m^3/km^2)	($m^3/km^2/m^3$/sec)
Agos Dam site	860	113.3	899.5	1,046	9.23
Kanan Confluence	393	74.5	434.7	1,106	14.85
Kaliwa Confluence	465	37.4	434.4	934	24.98

As far as the results of analysis of discharge and sediment rate relationship indicate, the sediment yield rate per catchment area is almost similar in the Kanan and Kaliwa River Basins, to be around 1,000 m^3/km^2/year or 0.9-1.1 mm/year in denudation rate. Sediment yield at the Agos Dam site was adopted as 1,046 m^3/km^2/year.

Owing to the limited number of sediment sampling data, the above estimate still contains uncertainties. Nevertheless, a certain extent of errors in the estimate can be absorbed by a large volume of dead storage afforded in the Agos Reservoir. Under the condition of the above estimated yield rate (1,046 m^3/km^2 /year), the horizontal sediment level after 100 years is El.86.72 m (90 million m^3). Even if the rate is double, the sediment level is El.102.69 m (180 million m^3), which is still lower than the MOL (El.133.0 m) of the Agos Reservoir.

The catchment area at the Agos River mouth is 940 km^2, including the residual basin of 80 km^2 downstream from the Agos Dam. The sediment yield at the river mouth is estimated at 980,000 m^3/year, applying the same yield rate as estimated for the Agos Damsite, of which the yield from the residual basin is 83,000 m^3.

(3) Trap Efficiency of Reservoir

The sediment deposit volume of the reservoir is determined by sediment yield from upstream basins and trap efficiency of the reservoir. The trap efficiency was estimated by using the Brune's method.

The trap efficiency and sediment trap volume for 100 years, estimated for the Agos reservoir, are as follows:

Trap Efficiency and Trap Volume in Agos Reservoir

Item	Unit	Value
Reservoir Volume/Inflow		0.26
Catchment Area	km^2	860
Trap Efficiency	%	93.0
Sediment Yield	10^3m^3/100-year	90,000.0
Trap Volume	10^3m^3/100-year	83,700.0
Sediment to Agos Downstream	10^3m^3/100-year	6,300.0

After construction of the Agos Dam, sediment release from the Agos Reservoir is some 6,300 m^3/year. Adding the yield from the residual basin of 84,000 m^3/year, the total sediment yield at river mouth is derived to be 90,000 m^3/year.

4.3.5 Examination of Water Loss in Limestone Areas in Kaliwa River Basin

The spot discharge measurement was carried out at several points on the Kaliwa River as discussed in Subsection 2.4.3. Preliminary findings interpreted from the measured data are described below.

<u>Flow Distribution on the Lenatin River (Upstream from Laiban Dam)</u>

a) Loss of flow at the limestone mass between Sta.1 and Sta.2 (Place A in Figure 2.3) seems obvious (See Line 1- 2 of Table 4.3). It is noted that flow at Sta.3 (downstream end of the Lenatin River) is also less than that at Sta.1 (See Line 1-3 of Table 4.3), though the drainage area of Sta.3 is much larger (131 km^2 at Sta.3 and 75 km^2 at Sta.1). This indicates that some extent of leakage loss not returning to Sta.3 seems to be taking place. Sta.3 is just upstream of the Laiban Damsite.

Notes: 1) Specific discharge of the Lenatin River is far less than that of the Limutan River (See Lines 3 and 4 of Table 4.3). This may be partly due to loss of flow in the stretch between Sta.1 and Sta.3.

2) During the field reconnaissance, it was observed there is a possibility of water infiltration at the Batangas Creek (upstream of confluence with San Andres Creek, Laiban Creek, and Unnamed Creek situated between the former two creeks). It could not be confirmed whether water returns back to the Lenatin River.

b) There are two possibilities: (i) water lost in the limestone mass returns back to the Kaliwa River channel in the reach downstream from the Laiban Damsite, and (ii) water is lost southward into the Masungit limestone mass and further to the Laguna de Bay Basin. Discharge measurement conducted this time could not define which is the possible path of the leakage loss.

c) In both the cases of (b) above, leakage water does not return the points upstream of the Laiban damsite. This infers a doubt for water leakage from the Laiban reservoir.

d) However, this issue does not deny the feasibility of the Laiban Dam. It was assessed in the earlier studies that limestone masses distribute at scattered locations and occur at relatively higher elevations. This suggests that provision of grout curtain walls at selected areas may be effective for ensuring the reservoir water-tightness. Further hydrological and geological investigations are required to look into this issue in more detail.

Flow Distribution on the Kaliwa River

a) No limestone mass occurs in the area downstream from Sta.8 (Kaliwa Low Dam No.1 Site, see Figure 2.3). Hence, this point can be regarded as the 'benchmark point' in evaluating the distribution of the Kaliwa River flow.

b) First, discharges between Sta.(3+4) (Lenatin-Limutan Confluence, simple addition of Sta.3 and Sta.4) and Sta.5 (2 km downstream of Lenatin-Limutan Confluence) were compared. It was found that discharge at Sta.5 was larger in most cases[*1] (See Line 5-(3+4) of Table 4.3). Hence, the flow at Sta.5 was regarded as the base flow for comparison with the flow at downstream points. Theoretically, the flow at the downstream points should be larger than the flow at Sta.5, if there is no leakage loss in the stretch between the two places.

Note: [*1] An exception is the case of 18-May, which may be due to error in discharge measurement

c) Loss of flow was evaluated by dividing the river stretches into the following three sections:

- Stretch 5-6: Sta.5-Sta.6 (Just upstream of Sabalanasasin Creek Confluence)
- Stretch 6-7: Sta.6-Sta.7 (Daraitan Gauging Station)
- Stretch 7-8: Sta.7-Sta.8 (Kaliwa Low Dam No.1 Site)

d) The data show that loss of flow in the Stretch 5-6 is apparent (See Line 6-5 of Table 4.3). It is supposed that water infiltrates into the Daraitan limestone mass occurring on the east bank (See Figure 2.3).

e) The data show that loss in the Stretch 6-7 itself is not so obvious (See Line 7-6 of Table 4.3). However, this is partly due to inflow from the Sabalanasasin Creek, which is a major tributary flowing in just downstream of Sta.6. It would be more conservative to assume some extent of leakage taking place also in the Stretch 6-7.

f) In the Stretch 7-8, there is a notable increase of flow, 30.6% in average (See Line 8-7 of Table 4.3). Since drainage areas of Sta.7 and Sta.8 are almost similar, it is inferred that the increase of flow is due to extra inflow of seepage water originated from the upstream reaches (Stretches 5-7). Also, flow at Sta.8 is more than that at Sta.5 (See Line 8-5 of Table 4.3). These indicate that there seems less possibility of water leakage lost outside the Daraitan limestone mass (leakage to the Laguna de Bay Basin).

Note: Table 4.3 also shows the comparison of specific discharges for reference. In general, the implications readable from the data are almost similar to those described above. A matter to be noted is that, although specific discharge is almost comparable between Sta.5 and Sta.8 on the average, the specific discharge at Sta.8 is less than that at Sta.5 on two days (25-May and 3-June) (See Line 8-5 of Table 4.3). This does not directly imply that lower specific discharge at Sta.8 is due to leakage loss outside the basin. Nevertheless, this should be confirmed by collecting more number of discharge measurement data henceforward.

It is supposed that most of water lost in the Stretches 5-7 in the upstream part of Daraitan limestone mass returns back to the Daraitan limestone gorge upstream of Sta.8. As far as the present data indicate, there is no serious concern for the water loss from the Daraitan limestone mass to the outside basin (water loss directing southward). The observation from geological viewpoints also suggests less possibility of water loss through this limestone mass (See Section 4.4 hereinafter).

4.4 Geology

The proposed sites of the Project facilities can be largely divided into three (3) sites, namely (i) Agos Dam on the Agos mainstream, (ii) Kaliwa Low Dam on the Kaliwa River, and (iii) Kaliwa~Taytay Waterway consisting of the Tunnel No.1 between the Kaliwa Intake structure site situated on the left bank of the Kaliwa Low Dam and Valve House No. 1 at Lagundi, and various waterway structures such as Morong WTP, Pipeline No.1 and No.2, Valve House No.2, Antipolo Pump Station, Antipolo Service Reservor and Taytay Service Reservoir in the Morong-Teresa-Antipolo-Taytay area.

This Section describes the geological conditions of the Project facilities stated above that were clarified in the geological investigation performed under the Study.

4.4.1 Regional Geology

The Philippine Islands are situated on the circumpacific seismic belt, which is one of the areas in the world that is most conspicuously subject to earthquake. Geologically, the Project Area is located in the Central Basin, which is characterized by Paleogene and older clastic and volcanic deposits. The Central Basin is bounded by the Philippine Fault system (Philippine Fault Zone: PFZ) on the east and northeast (a branch of which was identified near Infanta) and by the Valley Fault system on the west and southwest. Morphology indicates that the fault near Infanta has been active in the comparatively recent geological times. Further, there are other two faults, starting from the Marikina damsite (previously proposed by MWSP III) in the SSW direction, forming the Marikina graben. Thus, the Project Area can be divided into the following four morphologically and geologically differing zones:

- The rugged mountains of the Sierra Madre between the Philippine Fault (Infanta Fault) and the Faults running from Marikina in the SSW direction
- A triangular hilly zone between the SSW Faults and the Marikina graben
- The Marikina graben

- Gentle hills located west of the Marikina graben, descending to the alluvial plain of Manila Bay

Land of the Project Area, from the lithological viewpoint, consists mainly of eight (8) geological units, namely Quaternary Alluvium, Laguna Guadalupe, Tignoan, Madlum, Angat, Maybangain, Kinabuan, and Barenas-Baito Formations.

4.4.2 Active Fault and Seismic Risk

The previous studies pointed out that the Project Area is situated within a zone of active tectonics represented by the Philippine Fault (Philippine Fault Zone: PFZ) and the Valley Fault system as shown in Figure 4.3. Especially along the Philippine Fault, many large-scale earthquakes were recorded in the past, and the relative movement of 6 cm was observed in the period of 1991 to1993. Therefore, it can be said that the Philippine Fault has a potential to cause the very high seismic activity. According to the PHILVOLCS data, several "active faults" or "assumed active faults" are shown in the Project Area, and some of them pass near the proposed Agos damsite and No.1 Tunnel route.

(a) Agos Damsite

In the case an active fault passes through the nearby location of the proposed Agos damsite, the following two technical problems need to be solved:

i) Seismicity caused by earthquake along active fault, and

ii) Deformation in dam-foundation caused by the movement of active fault

Analysis for i) above can be made through seismic study as described in Clause (c) of this Subsection 4.4.2 hereinafter. With regard to ii) above, no firm analysis method had been suggested in the previous studies. In this Study, therefore, analysis of aerial photographs was carried out to confirm the distribution and certainty of active fault. The photographic analysis was carried out by carefully observing and interpreting the photographs to assess the lineament and topographical features of the Quaternary formations in the area of 10 km in radius around the Agos damsite as shown in Figure 4.4. The certainty of active fault is classified into three categories of Class I, II, III. Class I means the high certainty and Class III indicates the low certainty for active fault in the Japanese standard.

An assumed active fault is drawn 500 m upstream from Agos Dam axis almost along the Kanan River according to the data gathered from PHILVOLCS as indicated as "Ⓐ" in Figure 4.3.

As a result, however, the fault indicated as "Ⓐ" is classified to be the Class III, since no specific factors classifiable as active fault were found in the photo interpretation. Accordingly, it is judged to be an lineament formed by old faults based on the field reconnaissance. Therefore, it can be said that the active fault which will have to be carefully treated does not exist near the Agos Dam site.

Meanwhile, the Agos damsite is located only 7-8 km distant from the active Philippine Fault Zone (Infanta Fault), and large earthquakes attributed to the active fault have been recorded in 17th to 19th century. The photographic analysis classifies the Infanta Fault into Class I, while other two (2) faults near the Infanta Fault into Class II. Therefore, the high seismic risk should be taken into account in the feasibility-grade design as described in the Clause (c) of this Subsection 4.4.2.

(b) Tunnel No.1 Route

The Tunnel No.1 is laid out between Kaliwa Intake Structure at the Kaliwa Low Dam site and Valve House No.1 at Lagundi. The total length is about 27.5 km. The tunnel will encounter a fault designated by PHILVOLCS (2000) as the "assumed active fault" at around 25 km point from the Kaliwa Intake Structure as indicated as "Ⓑ" in Figure 4.3. The fault can be identified clearly through the satellite imagery interpretation. The location of the assumed active fault is indicated in the geological profile along the Tunnel No.1 as shown in Figure 4.9.

(c) Estimate of Earthquake Coefficients

As described above, the Project Area is situated within a zone having a high risk of seismicity. Acceleration value of previous proposed damsites around the Project Area is shown in Table 4.4. According to the previous studies, most of the proposed five damsites: i.e. Laiban, Agos, Kanan B1, Kanan No.1 and Kanan No.2, would be subject to high peak acceleration and exposed to generally high degree of seismicity. The 1981 JICA and 1991 ELC studies suggested to adopt 0.58 g for peak acceleration and 0.15~0.20 g as the design earthquake coefficient for the Agos Dam. In this Study, the seismic conditions were re-analyzed on the basis of the earthquake records for the period of 1907 to 2000. As a result, it can be said that the values derived in the previous studies are appropriate in terms of static seismic design. In the next detailed design stage, however, a dynamic analysis is required to design the Agos Dam to confirm the stability of the dam body in case of occurrence of large-scale earthquake.

4.4.3 Geology of Project Sites

(1) Agos Dam Site

(a) General

The Agos damsite is located just downstream of the confluence of the Kanan and Kaliwa Rivers, about 15 km distant from the river mouth. The comparatively steep geographical features continue from the damsite for a 8 km downstream stretch. The foundation rocks around the damsite consist of the Maybangain Formation and Tignoan Formation of early to middle stage in the Palaeogene Period.

In the Master Plan Study stage, the following four (4) geological issues were pointed out for the Agos damsite selected in the previous studies:

i) Thick river deposit in the riverbed

ii) Thick residual soil or decomposed rock zone on the right abutment

iii) Fault in the riverbed and on the right bank

iv) Assumed active fault along the Kanan River by PHILVOLCS

Taking the above issues into consideration, the alternative damsite was selected in this Study, which is located 700 m downstream from the aforesaid damsite. The geotechnical investigation including core drilling, seismic prospecting, laboratory test and analysis of aerial photographs was carried out for the two (2) alternative damsites, the upstream and downstream damsites, during the 2nd Field Investigation in 2002.

(b) Foundation Rock

The base rock of the both damsites mainly consists of firm and impermeable sandstone and conglomerate. Most parts of the rock are massive, showing little bedding plane except for those observed in intercalation of thin layers of fine sandstone and shale. The fresh part of the foundation rock at the both damsites seems to have the sufficient shear strength to support the proposed fill type dam according to the results of laboratory tests. With regard to the foundation along the plinth of concrete face dam (CFRD) proposed in this Study as discussed in the succeeding Chapter VI, the decomposed rock and/or residual soil zone and cracky weathered rock zone will have to be removed, because they have the medium to high permeability and low shear strength. Moreover, the dam foundation treatment will be performed by curtain grouting from the upper surface of the plinth into the fresh rock zone that indicates more than 5 Lugeon value.

(c) Thick Sand and Gravel Layer of Riverbed

In this Study, additional core drilling and seismic refraction prospecting investigations were carried out to confirm the thickness of riverbed deposit. As a result, river deposit of sand and gravel has a thickness of 30 to 40 m along the both dam axes as shown in Figure 4.6.

From the geographical point of view, the depth of river deposit seems too thick as compared with the river width of some 120 m. The large thickness of the river deposit, however, can be explained by the marine transgression, according to the results of the geomorphological analysis carried out in this Study. About 20,000 years ago, the sea level was assumed to be more than 100 m below the present sea level, and the present V-shaped valley was formed along the Ago River. The thick sand and gravel might be deposited in the valley with the transgression after the glacial period.

(d) Potential Landslide on the Abutments

On the right abutment of the upstream damsite, zone of residual soil and decomposed rock is 20 to 30 m thick in the area below EL.120 m. On the other hand, the zone is observed on the left abutment with 10 to 20 m thickness. These weathered zones including talus and terrace deposits developed at the foot of the slopes should be excavated during construction of the Agos Dam.

It appears that such a thick weathered layer is caused by the landslide. According to the analysis of aerial photographs, several potential landslide blocks are observed around the Agos damsites as shown in Figure 4.5. Especially, the potential landslide blocks distribute on the both banks of upstream Agos damsite. On the other hand, there seems to be no factor to show the slope instability except only one unclear landslide block along the downstream dam axis.

As for the upstream damsite, most of potential landslide areas will be excavated during the construction of the Agos Dam and spillway. The remaining volume of landslides which needs to be treated is estimated at 980,000 m^3 on the minimum. Thus, the excavation works at the Agos Dam site needs to be performed paying enough attention to the stability of the potential landslide areas.

(e) Distribution of Fault

Six (6) low velocity zones are indicated in the base rock by seismic exploration survey along the upstream dam axis. Out of them, the five (5) zones may be faults extended in the E-W direction as shown in Figures 4.5 and 4.6. The faults extending in the E-W direction do not have any serious problems for the stability of proposed Agos Dam, since they cross with dam axis at a right angle. The replacement and grouting works, however, will be required to prevent the water leakage from passing from upstream to downstream of the dam body.

Only the one fault located in the middle part of the right abutment could be investigated in detail by core drilling conducted under the Study. Therefore, other four (4) faults will have to be investigated in more detail in the next detailed design stage.

(f) Comparison of Upstream and Downstream Damsites

The upstream site is recommended in consideration of the following geological conditions:

i) Both damsites are considered to have almost same conditions with respect to the thickness of riverbed deposit, shear strength of base rock and existence of faults.

ii) In case of the downstream damsite, most of potential landslide blocks distributing around the Agos damsite will be submerged by the reservoir water. The treatment cost of the potential landslides for the downstream damsite is estimated to be much higher than that for the upstream dam site.

iii) The left bank of the downstream damsite is formed by a narrow ridge which may cause a large hydraulic gradient.

iv) There is not sufficient space to economically lay out the spillway, diversion tunnel and powerhouse in case of the downstream damsite.

Figure 4.5 presents a distribution map of potential landslides and faults around the Agos damsite. In addition, the profile of upstream damsite is shown in Figure 4.6. The results of the detailed comparison of the two (2) alternative damsites for the Agos Dam are described in the succeeding Chapter VI.

(2) Agos Reservoir Area

(a) General

The Agos damsite is located just downstream of the confluence of the Kanan River and Kaliwa Rivers, about 15 km distant from the river mouth. In case of FSL EL.159 m, the reservoir extends to 12 km upstream along the Kanan River by air distance and 15 km upstream along the Kaliwa reaching around the Barangay Daraitan. Situated in deep narrow gorge, the reservoir area is surrounded by high ridges. Several landslide blocks are observed on the abutments of the reservoir area by aerial photographs. Geologically, most of the reservoir area is composed of the sandstone, conglomerate, shale, pyroclastic rock which belong to the Maybangain and Tignoan Formations in the Cretaceous to Miocene age. The fresh part of the rocks is generally firm and impervious.

(b) Geological Assessment on Possibility of Water Leakage from Daraitan Limestone Area

The most important geological concern of the reservoir area is the Daraitan limestone mass situated at the Kaliwa upstream part in the reservoir area with a width of 1.5-2.0 km, which generally distributes in the N-S direction. As for the Agos Reservoir area and Kaliwa Low Dam site, the previous studies focused on the possibility of water leakage toward south through the soluable cavities in the limestone area. Many cavities, holes, and water-spring points exist in the Daraitan limestone area. This indicates the possibility of existence of many natural water routes inside the deeper part of limestone mass.

In this Study, two (2) core drillings of 350 m and electric prospecting of 5 km in total length were carried out to confirm the continuity of the Daraitan limestone mass toward south. The two-dimensional resistivity profiling method was adopted to conduct the electric exploration.

It is considered that the water leakage problem from the limestone mass is negligible from the results of the geological investigation as well as the discharge measurement results along the Kaliwa River that are described in the foregoing Subsection 4.3.5, as explained below:

i) The loss of water through the fault zone or limestone in the northerly direction is physically impossible.

ii) The permeable limestone mass wedges out towards the south before reaching the Makmira village at the 3 km southern point from Kaliwa River as shown in Figures 4.7 and 4.8. The other impervious beds distribute between the Makmira village and Laguna Bay, which would stop water flow in the direction.

iii) No loss of the river water flow in the sections of limestone area was observed according to the result of discharge measurement (see Subsection 4.3.5).

iv) Groundwater level seems to be shallow around Makmira to Santiago village area because of existence of many surface water streams. This fact indicates the distribution of the impervious bed rocks.

The distribution of limestone mass and water condition around the Daraitan limestone area are presented in Figure 4.7. Figure 4.8 shows a profile of the Daraitan limestone area.

(3) Kaliwa Low Dam Site

The site is located on the Kaliwa River with the river bed elevation of around EL.95 m, approximately 5 km downstream of the Barangay Daraitan located between the Ligundinan and Queboroso creeks, both being the right bank tributaries of the Kaliwa River. The distribution of stiff rock forms comparatively narrow valley around the site.

The Kaliwa Low Dam site consists mainly of firm conglomerate, sandstone, shale that belong to the Maibangain Formation of the early Palaeogene Period. As for the upper layer of conglomerate, the matrix part has a less strength as compared with the hard gravel part. The foundation rock is mostly massive and seems to have enough shear strength and low permeability. Most of foundation rock around the dam axis indicates low Lugeon value of less than 5.

The weathered bedrock is deeper on the right bank and the slope is gentler than that on the left bank. The weathered rock zone of approximately 5 m thickness in the minimum should be excavated in the construction. The thickness of riverbed deposit (sand and gravel) is 1 to 2 meters.

The Kaliwa Intake Structure is proposed to be provided on the right bank of the Kaliwa Low Dam site. The base rock consists mainly of old sandstone and conglomerate that have enough bearing capacity to support the proposed intake structure. The surface weathered zone at the site seems to be comparatively thin at 5 to10 m or less in thickness and needs to be removed in the construction.

(4) Kaliwa-Taytay Waterway

(a) Tunnel No.1

The 27.5 km long Tunnel No.1 is laid out between the Kaliwa Intake Structure and Valve House No.1 at Lagundi. The proposed Tunnel No.1 route is geologically assessed as follows:

i) Owing to alignment along the mountain ridges, there will be no particular problem in view of ground cover and unbalanced ground water pressure.

ii) The Tunnel No.1 will pass through the relatively homogeneous and hard geological layers of the Cretaceous to Old Tertiary Period, not encountering the Quarternary layers. According to the result of laboratory test in this Study, the unconfined compressive strength of foundation rock is estimated at 410-570 kgf/cm^2. It is considered that tunneling by TBM would be effective although the values are derived from the limited number of core pieces sampled on the tunnel route. On the other hand, the previous studies indicated that some parts of foundation rock of the tunnel route have higher unconfined compressive strength values of 500 to 700 kgf/cm^2.

iii) In the fault-fracture zones and limestone sections, there may be difficulties in the tunnel construction due to excessive water seepage and unstable ground.

In the 17.5-22.0 km section from the Kaliwa Intake Structure, the large Masunguit limestone body is chopped up on the surface. The elevation of the bottom of this limestone mass seems to be higher than EL. 200m, which is approximately 100m higher than the elevations of the tunnel route.

In the next detailed design stage, it is required to clarify in more detail the distribution of the limestone area.

iv) The tunnel will encounter a fault defined by PHILVOLCS (2000) as "assumed active fault" at 25 km point from the Kaliwa Intake Structure. Therefore, the tunnel route was aligned to cross the fault at a right angle so as to decrease the tunnel distance which might be affected by the suspected fault. NATM is recommended for the construction of the upstream tunnel section of the fault.

v) In the 0-3.0 km section from the Kaliwa Intake Structure, an attention needs to be paid to the unexpected fault with inflow of confined hot water, since a confined hot spring was observed at a point of about 600 m upstream from the Kaliwa Low Dam site during the field reconnaissance conducted under the Study. The spring seems to have the relation with the lineaments in the 0 to 3.0 km section of the Tunnel No.1 route from the Kaliwa Intake structure.

Figure 4.9 shows the geological profile along the No.1 Tunnel.

(b) Valve House No.1

In the 2nd Home Office Work, the Valve House No.1 is newly proposed to be constructed in the depressed area in Lagundi instead of the Lagundi powerhouse as discussed in succeeding Chapter VI. It is required to carry out the geotechnical investigation at the Valve House No.1 site in the next detailed design stage. From the geomorphological point of view, the surface layer or several meters in thickness seems to consist of overburden material such as plastic clay. Bed rock line will emerge in around 5-10 m depth below the surface, although thick weathered rock distributes above the bed rock line. The said bed rock and weathered zone seem to have enough bearing capacity to support the proposed structure. The ripper or/and blasting will be required for excavation of the bed rock.

(c) Morong Water Treatment Plant

A total of 1500 m x 650 m space in net plant compound area will be acquired to construct the Morong WTP. The site is located in hilly area mostly formed by the Quarternary deposits. These deposits belong to the Guadalupe Formation composed mainly of tuffaceous sediments, tuffaceous sandstone and tuff breccia except for weathered part near the surface zone. The fresh part of said sediments have the sufficient bearing capacity to support the proposed structure. The excavation by blasting will be necessary at the hill side in the southern part because of existence of hard basalt mass, while most of other areas will be able to be excavated by blading and ripping by bulldozer. While, the ground will provide the good basement for embankment except for the soft alluvial deposit poorly distributed in the northern part of the proposed area.

(d) Valve House No.2

The Valve House No.2 is proposed at the low flat area formed by alluvial deposits such as soft clay, silt or sand materials. The surface zone above alluvial deposit seems to be 5-10 m or less in thickness and piling works are recommended to support the proposed structure.

(e) Antipolo Pump Station

The structure is estimated to need a 150 m x 120 m space in the gentle-hilly area. The ground mainly consists of compacted gravelly sand which is mostly of weathered part of volcanic sediment. The upper zone of 4 m in thickness consists of soft plastic clay as overburden. The ground below the 4 m depth from the surface has enough bearing capacity in which the N-value is around 40 to 50. On the other hand, small portion of construction area seems to be located on the low flat area located near a creek. The piling works will be required in case the main structure is founded on the alluvial area.

(f) Antipolo Service Reservoir

The Antipolo Service Reservoir site is situated on the top of hill to have a space of 600 m x 110 m. The basement is composed of extremely weathered pyroclastic sediments. According to the results of core drilling, soft overburden material exists in the depth of 0.80 m from the ground surface. The weathered tuff breccia emerges in the depth of 5 to 20 m from the ground surface, which has the N value of 50. For excavation of the planned reservoir, bulldozer and/or ripping are deemed to be suitable.

(g) Tunnel No.2

The Tunnel No.2 is laid out to pass through under the Antipolo plateau to reach the Taytay Service Reservoir. The total length is about 5.3 km. The proposed Tunnel No.2 route is geologically evaluated as follows:

i) In most of tunnel formation, the foundation seems to be composed of hard and impervious rocks which belong to the Kinabuan Formation of the Cretaceous to Old Tertiary Period. While, the limestone mass distributes in the 0 to 0.7 km section from the upstream tunnel portal.

ii) In the 1.3 to 3.3 km section from the upstream tunnel portal, there is a potentiality that the Guadalupe Formation exists instead of the Kinabuan Formation. The Guadalupe Formation is composed of complex mixture of varied materials including soil, soft rock and hard rock. The lowest layer of the Guadalupe Formation is confined aquifer which supplies water to the wells in the residential area of Antipolo plateau. The groundwater may have a head of around 150 to 170 m according to the previous report (Groundwater Development in Metro Manila, JICA, 1992). The subsurface geological investigation is required to be performed in the next detailed design to clarify the groundwater condition.

iii) Faults distribute at 0.3 km, 0.7 km and 3.6 km points from the upper tunnel portal. In the fault zones, the tunnel excavation may encounter the difficulties due to the excessive water seepage and unstable ground.

(h) Taytay Service Reservoir

The excavation and embankment works will be required to provide the Taytay Service Reservoir with a s total pace of about 780 m x 290 m. The site is located around the boundary between gentle hilly area and a little steep hilly area located near the housing land. The basement of the excavation portion consists mostly of weathered rock belonging to the Kinabuan Formation of the Cretaceous to early Paleocene. Bed rock line emerges in around 10-15 m depth on the average below the ground surface, although thick weathered rock indicating N-value of 50 distributes above the bed rock line. The excavation will be conducted by ripper in the shallow ground zone, while blasting will be necessary in case excavation area reaches the fresh rock zone.

(i) Pipeline (WTP - Antipolo SR)

A total of 9.3 km long Pipeline No.1 is aligned to connect the Morong WTP and Valve House No.2 sites, and Valve House No.2 and Antipolo Service Reservoir sites. While 63% of the pipeline route passes through the gentle-hilly area, the remaining 37% is aligned on the low-flat area. The low-flat area seems to be composed of soft clay, silt or sand. During the construction, the excavation with sheetpiling is recommended for latter part covering 37 % of the total pipeline route.

4.4.4 Construction Materials

(1) Agos Dam

Table 4.5 shows the necessary volume of construction materials and recommended sources for the Agos Dam. The Agos quarry site is selected just upstream of the confluence of the Kaliwa and Kanan Rivers. Besides, rock material can be obtained from the excavation of dam foundation, spillway and diversion tunnel. The fresh rock at these sites consists mainly of sound sandstone and conglomerate with unconfined compressive strength of 500-600 kgf/cm^2, which is hard and stable enough for rockfill material to be used for embankment of the Agos Dam. According to the previous 1981 JICA study report, however, the unconfined compressive strength is derived to be 1160 to 1430 kgf/cm^2 from the laboratory tests on the 3 core pieces sampled from the nearby place of the Agos quarry site.

On the other hand, many calcite veins are observed in the base rock around the southern part of the Agos quarry site. This may become the factor which will cause weathering of rock material. In the detailed design stage, the additional geological investigations including laboratory test will have to be carried out to confirm the distribution of the calcite vein area in the quarry site and its durability against weathering.

Filter and coarse aggregate materials will be acquired from riverbed deposit which can be excavated at the damsite along the Agos River, as well as crashed rock obtained from the Agos quarry site.

As for the impervious material, the highly to completely weathered rock distributing around the Agos dam abutments will be used. The above extremely weathered rock (residual soil) should be blended with gravel collected from river deposit and/or crashed rock fragments.

(2) Kaliwa Low Dam

The construction materials required for the Kaliwa Low Dam include those to be used for random fill, impervious fill, riprap of the dam body as well as concrete aggregates for the Kaliwa Intake Structure.

The random fill and rock materials can be acquired from the excavation of the Kaliwa Intake Structure and Tunnel No.1. The residual soil of extremely weathered zone at the bank slopes will be used as the impervious material. The riverbed deposit material around the damsite is suitable for concrete aggregates. Rocks from the excavation of tunnel and intake are suitable for concrete aggregate after crushing. To obtain the concrete aggregates to be used for construction of the Kaliwa Intake Structure and lining of Tunnel No.1, the rock quarry site was also selected 500 m downstream from the Kaliwa Low Dam site in this Study. The quarry site is composed of firm and stable sedimentary rock such as sandstone, conglomerate and hard shale.

4.5 Water Rights in Agos River Basin

4.5.1 Granted Water Rights

The National Water Resources Board (NWRB) granted six (6) water rights for irrigation, power and water supply purposes in the Kanan, Kaliwa and Agos Rivers. The approved water rights are listed in the table below. No water right has been granted on the use of groundwater in General Nakar and Infanta, Quezon.

List of Approved Water Rights

Permittee	Source	Location	Purpose	Structure/ Facility	Amount of Water Granted (m^3/sec)
National Irrigation Administration	Agos R.	Infanta	Irrigation	Intake	2.250
Farm Systems Development Corp.	Agos R.	Brgys. Anoling & Bangklos in General Nakar	Irrigation	Pump	0.270
National Power Corporation	Kanan R.	Bo. Matatio in General Nakar	Power	Dam (proposed)	93.000
MWSS	Kanan R.	General Nakar	Water Supply	Dam (proposed)	38.000
Municipality of General Nakar & Province of Quezon	Kanan R.	General Nakar	Power	Dam (proposed)	38.000
MWSS	Kaliwa R.	Laiban, Tanay	Water Supply	Dam (proposed)	23.000

Data Source: NWRB

Among the above permittees, only the National Irrigation Administration (NIA) is using the water beneficially for irrigation. No development has been made yet by the other permittees.

With the water right, NIA irrigates the entire service area of Agos River Irrigation System covering 1,400 hectares of farmlands of Infanta and Real, Quezon.

The Farm Systems Development Corporation (FSDC) was already abolished. Their water rights are usually transferred to NIA or Irrigators Associations. In this case, however, there was no transfer of water right according to the records of NWRB.

On the water right of MWSS in the Kanan River, there was a Memorandum of Agreement (MOA) between MWSS and the Municipality of General Nakar in August 1997. MWSS agreed to permit the local government unit (LGU) to use its water right on Kanan River up to the year 2025 for the purpose of power generation and water supply. The MOA however stated that the water shall be made available to MWSS once they decide to develop and tap the Kanan River before 2025.

In view of the above, the Municipality of General Nakar applied for a water right, which was approved and granted 38 m^3/sec for power generation purposes only. In June 1999, the request for amendment of the water permit issued to the Municipality of General Nakar on the Kanan River for power generation purpose to include the Province of Quezon as Co-Permittee was approved by NWRB.

While the National Power Corporation (NPC) has withdrawn the Kanan Project from the list of the projects for their immediate implementation.

4.5.2 Pending Applications of Water Rights

In 1998, there was a request for amendment of water permit issued to the Municipality of General Nakar and Province of Quezon on the Kanan River in the amount of 38 m^3/sec to 93 m^3/sec for power generation purpose. According to the records of NWRB, the request is still pending.

Several water permit applications have been filed and these applications were endorsed to the deputized agencies of NWRB for clearance. The pending water permit applications are listed below:

Pending Water Permit Applications

Water Permit Application No.	Name of Applicant	Location
10700	MWSS	General Nakar
2482	Infanta-General Nakar Water District	Infanta
6547	Municipality of Infanta	Infanta
83771	Aluyon-Burdias Farmers Irrigation Association	Infanta
83772	Sikap at Tiyaga ng mga Magsasaka	General Nakar
3640	Bisig at Pag-asa Farmers Association, Inc.	General Nakar
8007	Jaime V. Portales	General Nakar

Data Source: NWRB

4.6 Water Quality in Agos River Basin

In the previous study of the Manila Water Supply Project III, water quality of the Kaliwa River (samples collected in 1981 to 1983) is summarized as follows:

(a) Color readings ranging from 5 to 1000 color units

(b) Iron content from 0.05 to 3.5 mg/l

(c) Alkalinity ranging from 100 to 200 mg/l as $CaCO_3$

(d) Hardness appears to be moderate with a low of around 70 and a high of about 100 mg/l as $CaCO_3$

(e) pH from 7.8 to 8.4

(f) Turbidity from a low of 0.2 to a maximum in excess of 420 turbidity units, with a mean of 3 NTU

(g) No pesticides and herbicides are at detectable level

(h) Total organic carbon (TOC) varying from 0.6 to 5.9 mg/l

The said report describes that additional sampling during 1985 and 1986 gave similar results for the turbidity, i.e. 3 NTU as the mean turbidity, with the 80th percentile of samples at 10 NTU. The condition of the catchment area can be still described as good and unpolluted.

During the course of this Study, the water quality analysis was carried out for river water of one sample collected from each of the Kaliwa, Kanan and Agos Rivers to examine appropriate water treatment process. The results of water quality analysis conducted in July 2001 and August 2002 are shown in Table 4.6.

Although the number of samples was very limited, water quality of the said rivers shows that concentration of health-related inorganic constituents such as arsenic, cadmium, chromium, cyanide, fluoride, lead, mercury and nitrate are very low and below the detectable limits. BOD_5, COD, $KMnO_4$ consumption and ammonium, which are indicators of contamination, also show low levels.

From the viewpoint of water treatment, color, turbidity, pH, alkalinity, iron, manganese, etc. are the items to be evaluated. Table 4.7 shows raw water and treated water quality of La Mesa No.1 Water Treatment Plant in August 2000 and March 2001. In comparing the water quality of the Agos River Basin with water quality at La Mesa Dam, there is no significant difference. Thus, the conventional water treatment process adopted at La Mesa No1/Balara No.2 WTP can be employed for the treatment of Agos water sources. Even iron with high concentration observed in the samples can be easily removed by employing the conventional unit process (coagulation/flocculation, sedimentation and rapid sand filtration) with pre-chlorination. Intermediate chlorination aiming at manganese removal may not be necessary considering the actual operation status of the existing water treatment plants. In case of adopting intermediate chlorination, further study will be needed regarding the type of manganese (soluble Mn^{2+}) and its concentration.

In addition, the direct filtration may be applicable for low turbidity of water source during the dry season. For safety, feeding apparatus of activated carbon may be equipped to deal with unexpected water contamination in the future.

To verify the adequacy of the selected water treatment process, further monitoring of river water quality through the year is required.

4.7 Coastal Survey for Agos River Mouth

4.7.1 General

The Agos Dam, once built, will reduce sediment release to the downstream reaches. This may cause some changes in the environment of coastlines of the Infanta Peninsula (Infanta-General Nakar Alluvial Plain). In this context, this Section looks into the probable features of future coastal condition.

4.7.2 Available Coastal Data and Field Survey Conducted

For studying this issue, collection of the relevant data was attempted in both the Philippines and Japan. To supplement the scarcity of the availability data, preliminary field survey was also conducted.

(1) Data for Analysis of Present Condition

For analyzing the historical background and present conditions of the coast, collected were satellite imageries, air-photographs, reports/papers and other published data. Interview to the local people was conducted to collect the on-site information.

As a result of visit to the concerned agencies, the Study found that no informative data relevant to the existing condition of the Infanta coast were obtainable from the existing literatures. Hence, the Study had to rely mainly on the limited information.

(2) Data for Coastal Sediment Analysis

To predict the coastal impact in terms of the topographical change of coastal area, the features of sediment transport along the coast needs to be examined. For this purpose, the existing reports/papers and other published data relevant to climate, hydrology and hydraulics were collected. Supplemental field survey was also conducted to obtain necessary field information, such as visual confirmation of in-situ conditions and sampling of coastal sand for grain size analysis.

The sediment transport consists of sediment yielded from the Agos River Basin and littoral drift along the beach.

To examine sediment yield from the basin, it was necessary to collect the data on the river discharges, grain sizes of the riverbed sediments and the representative river cross sections.

Analysis of the sediment transport along the coastline requires the data on wave conditions specific to the area. However, visit to the agencies concerned revealed the unavailability of the data. Hence, the Study was obliged to derive the wave conditions based on wind speed/direction data.

Wind data (speed and direction) were made available from PAGASA records which have been observed for the period of decades at Infanta meteorological observatory. The wind data so collected cover both the daily and monthly data for the period from 1961 to 2000. The method of calculation to derive wave condition from wind speed/direction data is called the “wave forecasting” method.

4.7.3 Historical Change of Infanta Peninsula in Last 50 Years

Figures 4.10 shows the latest condition in 2000 as an example of the study output, where the base map used in the Figure (1/50,000 map) shows the condition in 1951. The results of the analysis are summarized below:

<u>Changes of Sand Bar and Tideland</u>

a) The changes of sand bar at the river mouth indicate active sediment yields from the Agos River. The yielded sediments have filled the portions of coastline including inner low-lying area and moreover developed sand dunes. It also contributed to the formation of sand bar in conjunction with the accumulation of sands transported by near-shore current.

b) Notwithstanding active sediment yields from the Agos River, the protrusion of the river mouth sediments to the seaward direction has been of a limited extent during these 50 years. This is because the sediment deposited at the river mouth is constantly transported southward due to near-shore current. Yet, the sedimentation at the river mouth seems to be active.

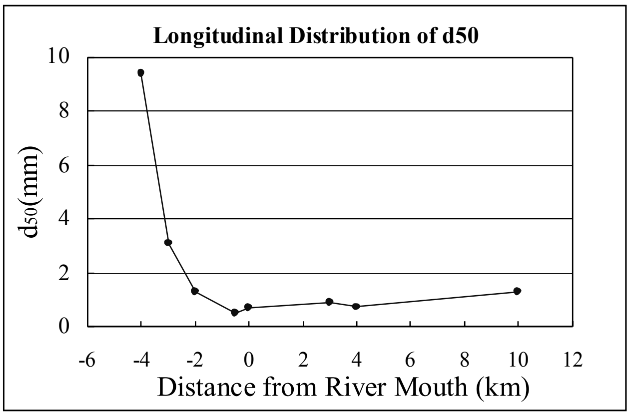
c) The sediment transported southward accumulates along the southern coast extending up to the Dinahican area and partly diffracts into the Lamon Bay forming small sandbars along the south coast of the bay. The rest of sediment is transported to southern sea bottom.

d) In the southern part of the Peninsula plain, small streams originated from the mangrove swamps flow into the Lamon Bay. These streams are virtually the flow of small gradient in the low wet land and do not yield excessive sediments. Nevertheless, the gradual development of low-lying tideland is observed around the river mouth, expanding year by year. This may be the result of sediment yield due to artificial development in the mangrove forests, such as land reclamation, fishpond construction, etc.

4.7.4 Present Condition of Coastal Area

To confirm the present condition of coastal area, field reconnaissance and interview to the local residents along the coast were conducted in February 2002.

(1) Sampling of Coast Sand and Analysis of Grain Size



Sampling of coast sand was conducted at nine (9) points along the coastline of Infanta and General Nakar to obtain the information of grain size distribution of the sand. The distribution of d_{50} along the coast is shown in the right-side figure.

As shown in the figure, the grain size of sand represented by d_{50} is coarser northward and finer southward. This suggests that the sediment transport by littoral drift is evidently southward. Accordingly, it is deemed that sediment discharged from the Agos River mouth is transported to the south direction.

(2) Field Reconnaissance and Interview to Local Residents

The results of interview and field reconnaissance are as follows:

The findings from the field reconnaissance generally coincide with the result of the aerial photograph analysis.

The Agos River has yielded a large amount of sediment from old age and the sediment is transported southward by nearshore current with wave force caused by wind from the north. In the case of attack of typhoon of which north wind is usually dominant, strong wave might have changed the coast especially at the southern coast near the Agos River mouth.

The flow courses of the Agos River have changed heavily in the past due to accumulation of sandbars in the river mouth area. The river course tends to move northward, while sand bars in the southern area seems to be developing. The southern sand bar functions as if it were a jetty creating a sheltered area for waves at southern area of the river mouth. Local scouring at south of the river mouth is caused by the unbalance of sediment transport, which resulted from the existence of sand bar.

In a general term, the whole coast of Infanta Peninsula is under the stable condition, although the occasional local scouring is seen in the area just south from the Agos River mouth.

4.7.5 Prediction of Coastal Change after Completion of Agos Dam

(1) General

For the assessment of future coastal change, various data specific to the objective site, such as sediment yield from the basin, energetic major wave condition throughout the year, sediment size and topography of seabed, are necessary. Due to the lack of these data, however, the coastal study at this stage had to adopt a simplified method.

(2) Sediment Yield

The annual mean bed load yield of the Agos River is estimated at 322.7×10^3 m^3/year. The ratio of sediment yield of bed load to suspended load is about 0.33 according to Annex C of Volume V.

Major sediment yield is distinguished in the period of NE monsoon from October to February and less in summer season from April to June.

(3) Coastal Sediment Transport

The wave condition in deep see is estimated from the wind data measured at Infanta.

The details are described in the Annex E of Volume V.

<u>Wind Wave in Deep Sea</u>

Wave condition in deep sea is calculated from the wind data, such as wind speed, direction, length measured as wind blowing distance (fetch) and duration of wind blowing time. This method is so called SMB method, which is widely used for estimation of the significant wave in deep sea.

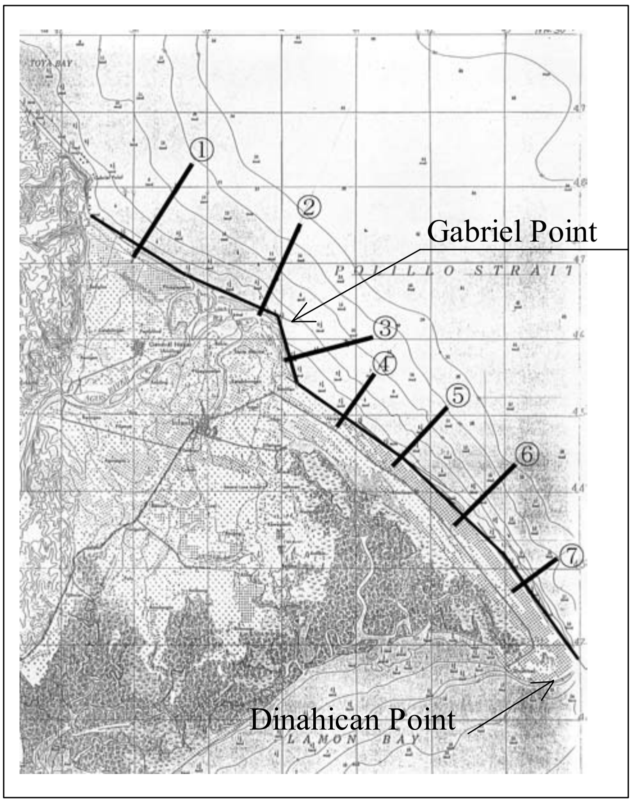
Wave in Shallow Water

Coast from the Gabriel Point to the Dinahican Point was largely divided into seven sections according to its face angle to the sea as shown in the figure below. Wave condition in shallow water was calculated for each of these coastal sections.

As the water depth changes, wave height and wave length also change. The shallow water wave conditions are calculated.

Sediment Transportation

Sediment transportation was calculated by the CERC (Coastal Engineering Research Center, Bagnold/Inman/Komar, 1977) equation, which is most widely used for calculation of the sediment transportation.



From the above results, the annual sediment transport rate is estimated at about $8.3x10^3$ m^3/year to $14.4x10^3$ m^3/year.

Coastal Change

On the basis of the estimated sediment transport rate, the present tendency of coastal change can be assessed. A simplified method was applied to calculate the sediment transport at every coastal point and the coastal change. The method is so called 'One line Model', which is useful for predicting the macroscopic change of coastline.

The tendency of coastal change under the present condition is estimated as follows:

Coastal Point 1 to 2:	stable (+1.0m/year)
Coastal Point 2 to 3:	shoreline retreat (-3.6m/year)
Coastal Point 3 to 5:	weak shoreline retreat (-1.2m/year)
Coastal Point 5 to 7:	stable (+0.2m/year)

The shoreline retreat presumed in the section of Points 2 to 5 is the result of the present formation of sand bar deposited at the river mouth. The tendency of coastal change estimated above is consistent with the information obtained through interviews to the local residents.

(4) Future Coastal Change

Generally, the coast of Infanta Peninsula appears to be in the stable state at present. But if the sediment supply to this area is reduced, the coast may be subject to erosion due to nearshore current starting at northern part.

It is presumed that, after the construction of the Agos Dam, about 90 % of sediment yield from the Agos River Basin will be reduced. It is estimated that the bed load yield of $322.7x10^3$ m^3/year at present will decrease to $32.3x10^3$ m^3/year after completion of the Agos Dam. This will give a certain impact on the coastal area. Hence, it is necessary to monitor the coastal change and carry out adequate countermeasure if any adverse effect arises. The measure should be planned taking into account the total balance of sediment transported to the Infanta Peninsula .

4.7.6 Installation of Monitoring System and Measures for Future Coastal Change

(1) Monitoring System for Coastal Line

Methodology

A possible approach is to estimate the shoreline position and its change by comparing aerial photographs taken in different years.

The ground survey provides the highest quality data in terms of accuracy. The shoreline position at the mean sea level can be obtained by positioning and direct leveling on the beach at the timing coincident with the mean sea level given by the tide table.

An importance is the determination of the exact shoreline position on the site. The shoreline position should be delineated in relation to the mean sea level. For this purpose, tidal stage, wave conditions and beach profile should be known at the time of survey.

Establishment of Base Points

To make the survey easier and to maintain the required survey accuracy, the range lines should be set along the shore at intervals of 0.5 km at the maximum.

The base point should be made with a deep-buried concrete post so as not to be easily removed. Co-relation in elevation between the base point and mean sea level should also be clarified.

Base points should be set before the construction of Agos Dam, and the existing shoreline position should be surveyed to use it as the base line information versus the future change.

Frequency

The measurement of shoreline change should be carried out at least twice a year routinely to clarify the yearly change as well as seasonal change.

Additional measurement should be put into practice in the case a large coastal change has occurred, for example, after a very big storm takes place.

Organization for Monitoring Work

The monitoring of coastal impacts should be conducted by an organization concerned with this kind of monitoring with entrustment from MWSS.

The Department of Environmental Natural Resources (DENR) would be a suitable organization because it has already been managing coastal resources. The discussion among the concerned agencies is necessary to determine a suitable organization that will be responsible for the continuous monitoring.

(2) Measures for Future Coastal Change

a) River Mouth Treatment

To cope with these concerns, construction of a training jetty is proposed as shown in Figure 4.11. The purpose of the training jetty is as follows:

- To make the river mouth more stable and to protect the riverbank
- To discharge the sediment to the coast more smoothly
- To protect the northern and southern coast of the Agos River mouth
- To prevent the sea waves from intruding to the inside of river mouth

At this study stage, it is not possible to delineate the exact location of river mouth in the future. The present natural condition of river mouth is so complicated to predict the future shape of the river courses.

In the future, however, the river course at the river mouth will be more stable. After such a tendency is observed, the riverbank would be protected to fix the river course. The jetty should be constructed as the extension of the riverbank protection.

b) Beach Protection

The beach protection should be done very carefully in utmost consideration of the sediment transport balance. If the sediment along the coastline is unbalanced at one place, the erosion that occurred at the place spreads to the adjacent area (downstream side of littoral drift). Hence, it is important to adopt the most adequate countermeasures that will have the lightest secondary impact to the coast.

One of the methods commonly adopted for preventing the coastal erosion is to construct the jetties. The jetty is expected to cause a relatively less coastal impact, if the appropriate dimension is adopted. Its construction involves less difficulty as compared with other countermeasures such as the detached breakwater, submerged breakwater and headland. The coastal revetment is also one of the selections, but it will deteriorate coastal use for recreational and aesthetic purposes.

As for the sediment transportation, the most active part is breaker zone. If the jetty is constructed in the whole length of breaker zone to stop the sediment transport along the beach, the coast of downstream side of littoral drift will result in heavy erosion. Hence, the length of the jetty protruding to the breaker zone should be as short as possible in order not to stop the whole sediment transport.

Generally, the coastal impact is not easy to predict, so that the construction of coastal structure should be carefully done step-wise by monitoring the result of the previous work. A preliminary plan of typical jetty structure is shown in Figure 4.12.

Interval of jetty installations along the coast should be determined on a trial basis with observation of local erosion and sedimentation appearing actually on the coast. It is supposed to take the period of decades until a stable coastline condition is created.

c) Materials

The materials for construction of jetties on the coast and training jetty at the river mouth are available either from the riverbed of the Agos River (boulders and cobbles) or rock quarries easily found in mountainous area in the west.

(3) Further Studies in Subsequent Stages

A preliminary plan of the proposed countermeasures was discussed in the preceding sections. The plan should be further refined and detailed in the subsequent studies, preferably during the next detailed design stage. The items of further studies are a) directional wave measurement in deep sea, b) bathymetric and geographic survey around the river mouth, c) sand sampling at coast and river for grain analysis, d) cross sectional survey on the beach, e) daily discharge measurement at the downstream point of the Agos River, f) tidal current measurement, g) periodical aerial photography and mapping, and h) detailed numerical model of local coastal area

4.7.7 Cost for Monitoring and Countermeasures

Monitoring Work

The costs for monitoring work consist of costs for the initial establishment of base points and the recurrent measurement of beach cross sections/shoreline points. The establishment of base points should be carried out before the completion of the Agos Dam and the measurement of beach cross sections/shoreline points should be carried out at least twice a year, with additional measurements as required in case the big change of coast occurs. The base point should be installed at every 0.5-km interval along the coast of Infanta Peninsula. The mean sea level of the area should be calculated from the tide table. The cost is estimated as follows:

Cost of Monitoring Work

Item		Unit	Quantity	Unit Price (US$)	Amount	
					US$ equiv.	Peso equiv.
1	Establishment of Base Points (Initial Work)	Place	20	400	8,000	400,000
2	Survey of Beach Cross Sections and Shoreline Positions (twice a year)	Section	20 (Per survey)	40	800	40,000

Note: These costs are included as an item of O&M cost for Agos Dam.

Coastal Protection Work

a) Training Jetty

As described in Subsection 4.7.6 above, the construction of a training jetty is envisaged on the left bank of river mouth. It is supposed that the timing of implementation will be at the period of decades after the construction of the Agos Dam, when the river mouth appears to become in the stable condition.

b) Jetties along the Southern Coast

In case the tendency of retreat of coastal shoreline is observed in the long time span, the coastal protection work will be necessary. One of suitable countermeasures is considered to be the provision of a series of jetties. The timing of implementation is difficult to predict at this study stage, but it would be at the period of decades after the completion of the Agos Dam.

The cost for the protection works is estimated below:

Cost of River Mouth and Coastline Protection Works

Item	Unit	Quantity	Unit Price (US$)	Amount	
				US$ equiv.	Peso equiv.
1. General Installation ((2+3)x30%)	Lump Sum	1	-	1,953,000	97,650,000
2. Jetty	Place	200	30,000	6,000,000	300,000,000
3. Training Jetty	M	300	1,700	510,000	25,500,000
4. Miscellaneous ((1+2+3)x20%)	Lump Sum	1	-	1,692,600	84,630,000
Total				10,155,600	507,780,000

Note: Necessity of these costs is unknown, depending on actual need of the protection works. For a conservative assessment of the Project, however, the costs are included as a part of O&M cost of Agos Dam, incurred over a period of 40 years after the completion.

Table 4.1 Probable Flood at Proposed Damsites

Unit : m^3/sec

Return Period	Banugao Gauging Station	Creager's C	Agos River Basin: Agos Dam	Agos River Basin: Afterbay Weir	Kanan River Basin: Kanan No.2 Dam	Kanan River Basin: Kanan Low Dam	Kaliwa River Basin: Laiban Dam	Kaliwa River Basin: Kaliwa Low Dam
Drainage Area (km^2)	908		860	889	289	356	276	366
2	1,535	23	1,495	1,519	848	951	827	965
5	2,651	39	2,582	2,624	1,465	1,642	1,429	1,667
10	3,530	52	3,438	3,494	1,951	2,186	1,902	2,219
20	4,474	66	4,357	4,428	2,473	2,771	2,411	2,812
50	5,845	86	5,693	5,785	3,231	3,620	3,150	3,674
100	6,988	103	6,806	6,916	3,863	4,328	3,766	4,393
200	8,230	121	8,015	8,146	4,549	5,097	4,435	5,174
500	10,039	148	9,777	9,937	5,549	6,218	5,410	6,311
1,000	11,542	170	11,241	11,424	6,380	7,148	6,220	7,256
2,000	13,169	194	12,825	13,034	7,279	8,156	7,096	8,278
5,000	15,525	229	15,120	15,366	8,582	9,615	8,366	9,759
10,000	17,472	257	17,016	17,294	9,658	10,821	9,415	10,983

Table 4.2 Annual Sediment Yield Estimated in Dam Projects in Luzon Island

Name of Dam	Stream	River System	Drainage Area (km^2)	Annual Sediment Yield ($m^3/km^2/year$)	Data Source
Existing Dam					
Ambuklao	Agno	Agno	617	5,337	*1
Binga	Agno	Agno	860	4,900	*2
Pantabangan	Pampanga	Pampanga	916	1,500	*3
Angat	Pampanga	Pampanga	568	4,500	*3
Magat	Cagayan	Cagayan	4,143	1,600	*3
Caliraya	Caliraya	Caliraya	92	800	*3
Proposed Dam					
Tina	Labugaon	Laoag	99	10	*3
Gosgos	Solsana	Laoag	71	10	*3
Cura	Cura	Laoag	63	10	*3
Paleiguan	Beleiguan	Ilocos	153	1,500	*3
Binongan	Binongan	Abra	377	2,000	*3
Chico IV	Chico	Cagayan	1,410	2,000	*3
Matuno	Matuno	Cagayan	593	600	*3
Casccnan	Casccnan	Cagayan	1,150	1,800	*3
Diduyon	Diduyon	Cagayan	477	1,107	*4
San Roque	Agno	Agno	1,250	6,500	*3
Balog-Balog	Bulao	Bulao	283	2,600	*3
Agos	Agos	Agos	867	557	*5

Note : Data Source

*1 : Ambuklao Rehabilitation, JICA 1988

*2 : Binga Dam Rehabilitation, JICA 1988

*3 : Study on Hydropower Project in Luzon Island, JICA 1987

*4 : Diduyon Hydroelectric Project, JICA 1980

*5 : Agos River Hydropower Project, JICA 1981

Table 4.3 Increase/Loss of Flow in Limestone Area on the Kaliwa River (Discharge Measurement by Current Meter)

Unit : m^3/sec/100km^2

Station	Location	Drainage Area (km^2)	13-May	18-May	25-May	3-Jun	10-Jun
Lenatin River							
1	Upstream of Limestone Area	75	-	0.352	0.724	0.883	0.663
2	Downstream of Limestone Area	75	-	0.348	0.505	0.660	0.611
3	Downstream end of Lenatin River (before confluence)	131	0.098	0.202	0.383	0.438	0.342
Limutan River							
4	Downstream end of Limutan River (before confluence)	145	0.312	0.670	0.896	0.925	0.465
Kaliwa River							
(3+4)	Lenatin-Limutan Confluence (Sta.3+Sta.4)	276	0.211	0.447	0.653	0.694	0.407
5	About 2 km Downstream of Limutan/Lenatin Confluence	278	0.349	0.381	0.735	0.833	0.413
6	Before Junction of Sabalanasasin River, about 1 km Upstream of Daraitan S.G.S.	292	0.266	0.448	0.636	0.672	0.500
7	Daraitan S.G.S.	326	0.278	0.378	0.514	0.713	0.504
8	Kaliwa Low Dam No.1	335	0.498	0.561	0.648	0.742	0.587

Table 4.4 Acceleration Value of Previous Proposed Damsites around the Project Area

Reports	Type	Acceleration of Each Dam Site				
		Laiban	Agos	Kanan		
				-1	-2	B-1
Manila Water Supply III Project (1979, Electrowatt)	Peak Acceleration	0.15g (50years) 0.20g (100years) 0.40g (1000years)	-	-	-	-
Feasibility Report on Agos River Hydropower Project (1981, JICA)	Peak Acceleration	-	0.58g			-
	Design Accelerration	-	0.15~0.20g			-
Manila Water Supply III Project, Engineering Report (1984, Electrowatt & Renardet)	Peak Acceleration	0.50g (MDE) 0.40g (OBE)	-	-	-	-
Feasibility Study - Agos Project (1991, ELC Electroconsult)	Peak Acceleration	-	0.58g	-	-	-
	Design Accelerration	-	0.15~0.20g	-	-	-
Small Hydropower Projects : Kanan B1 Scheme, (1992, Nippon Koei-Lahmeyer)	Peak Acceleration	-	-	-	-	0.46g
	Design Accelerration	-	-	-	-	0.26g
	Design Accelerration	-	-	-	-	0.23g
Manila Water Supply III, Project Review (1997, Electrowatt & Renardet)	Peak Acceleration	0.50g (MDE) 0.30g (OBE)	-	-	-	-

NOTE:
According to the guidelines of the ICOLD (International Committee on Large Dams);
For the MDE (Maximum Design Earthquake) a total failure of the structure has to be avoided, however major damage is accepted. For the OBE (Operating Basis Earthquake)

Table 4.5 Necessary Materials for Agos Dam Construction

<table>
<tr><th colspan="3">Necessary Materials</th><th rowspan="2">Proposed Source</th></tr>
<tr><th>Structure</th><th>Material</th><th>Volume (m3)</th></tr>
<tr><td rowspan="6">Main Dam</td><td rowspan="2">Rock material</td><td rowspan="2">12,000,000</td><td>Agos quarry site
(4,000,000 m3)</td></tr>
<tr><td>Excavation of dam foundation,
spillway and diversion tunnel
(8,000,000 m3)</td></tr>
<tr><td rowspan="2">Filter material</td><td rowspan="2">500,000</td><td>Excavation of riverbed deposit
at the damsite</td></tr>
<tr><td>Riverbed deposit along Agos river</td></tr>
<tr><td>Impermeable material</td><td>200,000</td><td>Residual soil on the abutments
blended with rock fragments</td></tr>
<tr><td>Random material</td><td>760,000</td><td>Excavation of dam foundation,
spillwayb and diversion tunnel</td></tr>
<tr><td rowspan="2">Coffer Dams</td><td>Rock material</td><td>280,000</td><td rowspan="2">Excavation of dam foundation,
spillway, diversion tunnel
and Agos quarry site</td></tr>
<tr><td>Random material</td><td>640,000</td></tr>
<tr><td colspan="2" rowspan="2">Concrete for face slab of main dam,
spillway, diversion tunnel and
hydropower facilities</td><td rowspan="2">290,000</td><td>Riverbed deposit along Agos river</td></tr>
<tr><td>Crashed rock from Agos quarry site</td></tr>
</table>

Table 4.6 Result of River Water Quality Analysis

Category	Laboratory Test Item	Unit	Standard Value/ Maximum Level	July 2001			August 2000		
				Agos River	Kanan River	Kaliwa River	Agos River	Kanan River	Kaliwa River
Inorganic Constituents	Arsenic	mg/L	0.01 mg/L	0.00130	0.00150	0.00053	0.00210	0.00060	0.00150
	Cadmium	mg/L	0.003 mg/L	< 0.001	< 0.001	< 0.001	< 0.002	< 0.002	< 0.002
	Chromium	mg/L	0.05 mg/L	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05
	Cyanide	mg/L	0.07 mg/L	0.002	0.002	0.002	<0.001	<0.001	<0.001
	Flouride	mg/L	1 mg/L	< 0.02	< 0.02	< 0.02	< 0.02	0.062	< 0.28
	Lead	mg/L	0.01 mg/L	< 0.002	< 0.002	< 0.002	<0.005	< 0.005	< 0.005
	Mercury	mg/L	0.001 mg/L	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002
	Nitrate as NO_3-	mg/L	50 mg/L	0.851	1.060	0.287	0.51	0.45	0.49
Physical and Chemical Quality	Color	PCU	5 PCU	40	15	35	10	5	5
	Turbidity	mg/L	5 NTU	43.0	0.6	25.0	11.3	0.3	9.2
	Chloride	mg/L	250 mg/L	2.1	2.1	2.6	7.5	3.7	0.9
	Copper	mg/L	1.0 mg/L	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
	Hardness	mg/L	300 mg/L	142	116	86	89	46	150
	Iron	mg/L	1.0 mg/L	9.40	6.60	0.12	0.78	<0.06	0.58
	Manganese	mg/L	0.5 mg/L	0.18	0.12	< 0.02	0.28	0.22	0.03
	pH *	-	6.5-8.5	7.6	8.0	7.8	6.8	7.1	6.8
	Sodium	mg/L	200 mg/L	6.1	6.3	5.7	6.0	5.7	6.5
	Sulfate	mg/L	250 mg/L	3.9	4.9	2.1	13.2	11.6	2.7
	Zinc	mg/L	5 mg/L	0.038	0.120	0.046	< 0.02	0.020	< 0.02
	Calcium	mg/L	N.S.	47	38	28	31	17	42
Others	Temperature *	^{o}C	N.S.	28.8	28.2	29.0	22.0	21.0	22.0
	Alkalinity	mg/L	N.S.	92.5	60.9	110.0	87.2	55.7	150.8
	Electric Conductivity	$\mu\Omega^{-1}$/cm	N.S.	215	150	252	200	100	200
	Biocarbonate	mg/L	N.S.	123	149	82	106	68	184
	Phosphate	mg/L	N.S.	0.23	< 0.01	0.28	8.07	< 9.81	6.95
	BOD_5	mg/L	N.S.	2.4	1.0	2.5	3.0	5.0	4.0
	COD	mg/L	N.S.	< 5.0	< 5.0	5.0	19.0	30.0	17.0
	$KMnO_4$ Consumption	mg/L	N.S.	1.9	1.1	0.7	0.6	0.6	0.9
	Anminia (NH_3)	mg/L	N.S.	0.75	< 0.01	0.57	0.06	< 0.01	0.05

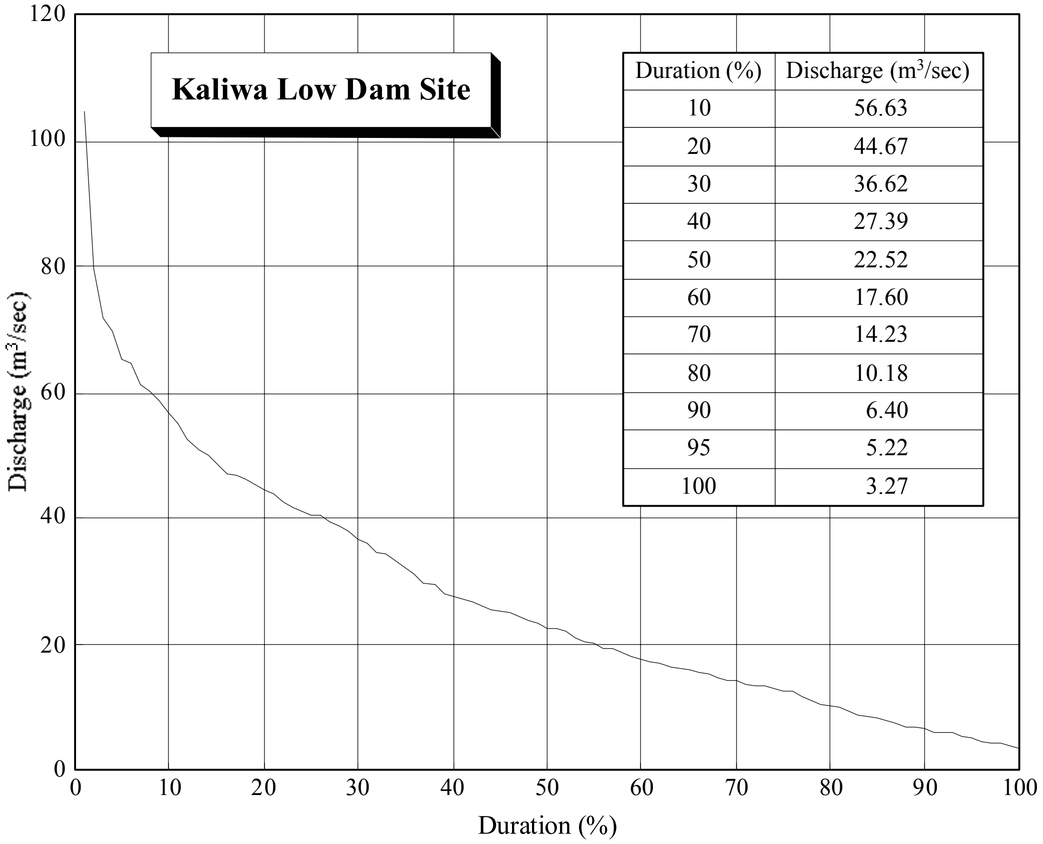
Note : N.S. ; No Standard Provided by the Department of Health (DOH)

* ; Measured on-site

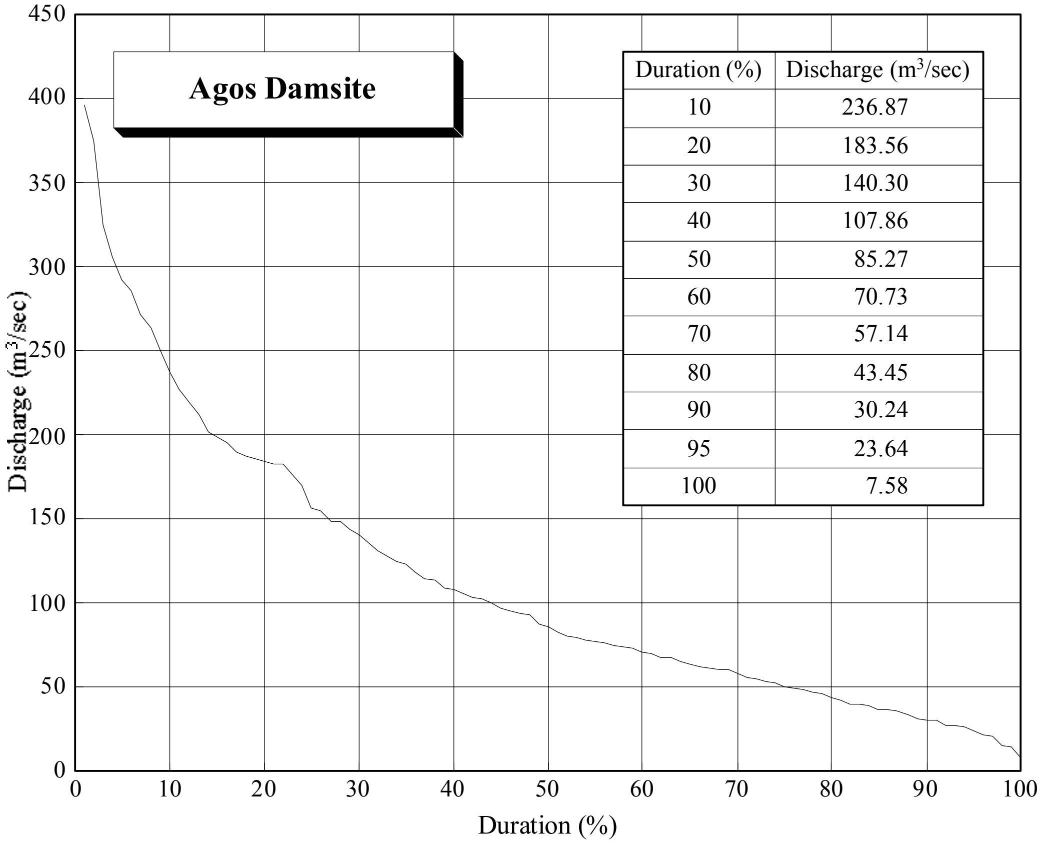
Table 4.7 Water Quality of Raw/Treated Water at La Mesa No.1 Water Treatment Plant

Item		August 2000			March 2001		
		Average	Max.	Min.	Average	Max.	Min.
Tempareture (^{0}C)	Raw water	23.5	25	21.7	24.1	25.9	23.1
	Treated water	24.5	26.7	22.4	25	26.4	23.4
Turbidity (NTU)	Raw water	29.3	101	8.01	8.95	73.7	1.68
	Treated water	1.72	2.26	1.21	0.96	2.19	0.59
pH	Raw water	7.62	7.78	7.47	7.53	7.87	7.37
	Treated water	7.07	7.34	6.9	7.22	7.49	7.02
Color	Raw water	29.2	99.1	10.8	9.97	41.2	5
	Treated water	5	5	5	5	5	5
Physical (mg/l)	Raw water	0.36	1.41	0.06	0.14	1.14	0.02
	Treated water	0.02	0.1	0	0.02	0.04	0.01
Residual Clorine (mg/l)	Raw water	-	-	-	-	-	-
	Treated water	1.28	1.35	1.17	1.19	1.36	0.98
Alkalinity (mg/l)	Raw water	46.7	54	40	43.1	56	24
	Treated water	36.3	48	28	36.5	46	22
Bicarbonate (mg/l)	Raw water	57	65.8	48.8	52.6	68.3	29.2
	Treated water	44.3	58.5	34.1	44.5	56.1	26.8
Acidity (mg/l)	Raw water	6	8	2	7.23	12	4
	Treated water	7.94	18	4	7.1	12	4
Free Carbonic Acid (mg/l)	Raw water	5.28	7.04	1.76	6.36	10.5	3.52
	Treated water	6.98	15.8	3.52	6.25	10.5	3.52
Chloride (Cl^-) (mg/l)	Raw water	4.39	6	3	4.23	8	2
	Treated water	5.77	9	2	4.48	9	2
Total Hardness (mg/l)	Raw water	59.8	74	44	66.4	78	54
	Treated water	60	70	44	63.9	76	46
Calcium Hardness (mg/l)	Raw water	39.4	46	26	43	54	28
	Treated water	38.1	48	25	40.9	52	30
Total Manganese (mg/l)	Raw water	0.26	0.93	0.04	0.1	0.63	0.02
	Treated water	0.02	0.04	0	0.01	0.05	0
Dissolved Manganese (mg/l)	Raw water	0.02	0.05	0	0.01	0.04	0
	Treated water	-	-	-	-	-	-
Calcium (Ca^{2+}) (mg/l)	Raw water	15.7	18.4	10.4	17.2	21.6	11.2
	Treated water	15.2	19.2	10.4	16.3	20.8	12
Magnecium (Mg^{2+}) (mg/l)	Raw water	4.97	8.26	1.94	5.69	7.78	2.92
	Treated water	5.3	8.26	2.43	5.58	7.78	3.4
Electric Conductivity ($\mu\Omega^{-1}$/cm)	Raw water	126	138	100	129	139	102
	Treated water	132	143	110	133	140	102
Total Dissolved Solid (mg/l)	Raw water	59.9	66	48	61.1	65	47
	Treated water	62.5	69	52	62.7	67	49

(Source) La Mesa No.1 Water Treatment Plant, MWSI



Duration (%)	Discharge (m^3/sec)
10	56.63
20	44.67
30	36.62
40	27.39
50	22.52
60	17.60
70	14.23
80	10.18
90	6.40
95	5.22
100	3.27



Duration (%)	Discharge (m^3/sec)
10	236.87
20	183.56
30	140.30
40	107.86
50	85.27
60	70.73
70	57.14
80	43.45
90	30.24
95	23.64
100	7.58

Figure 4.1 Flow Duration Curve at Proposed Damsite

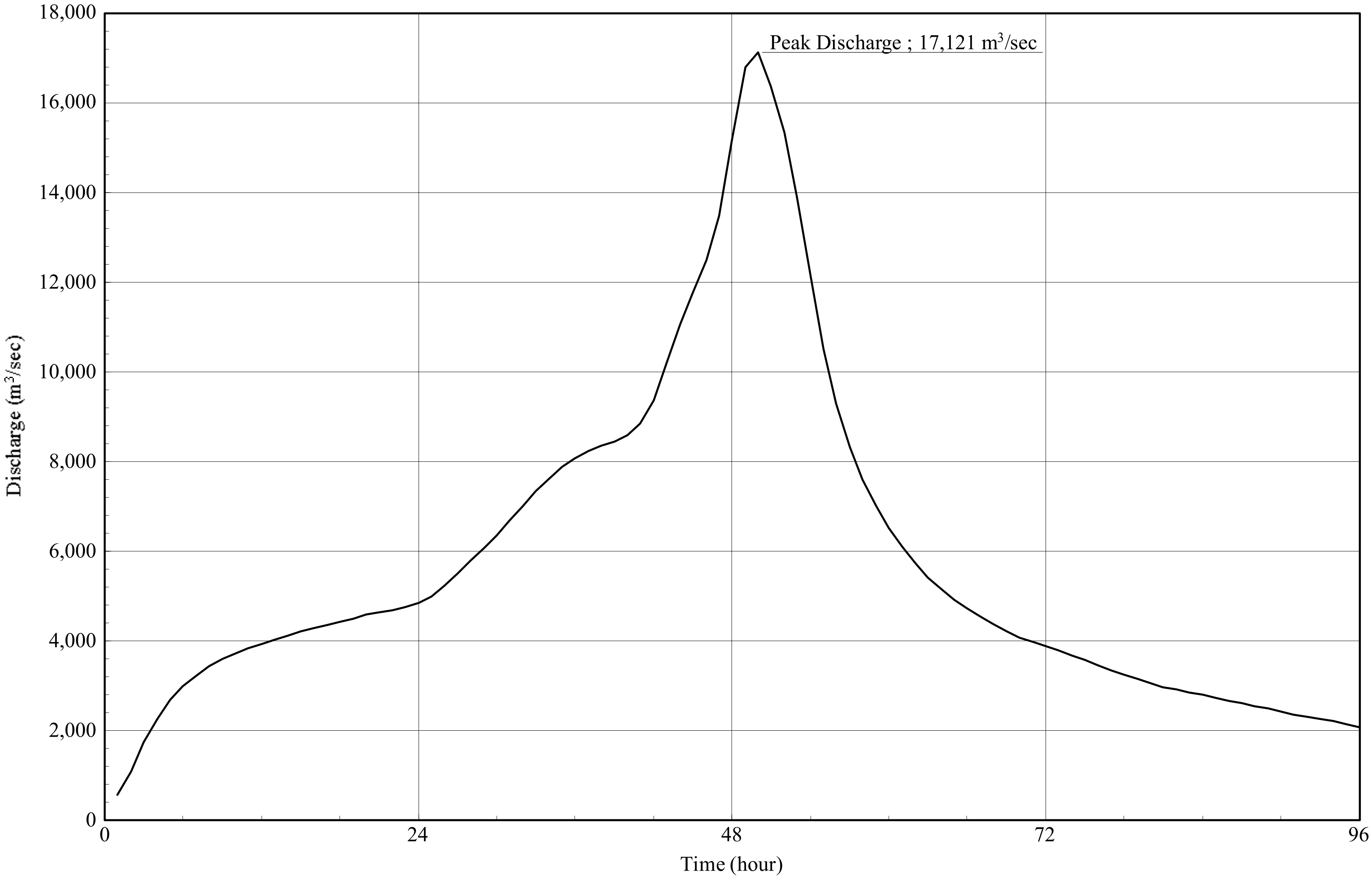
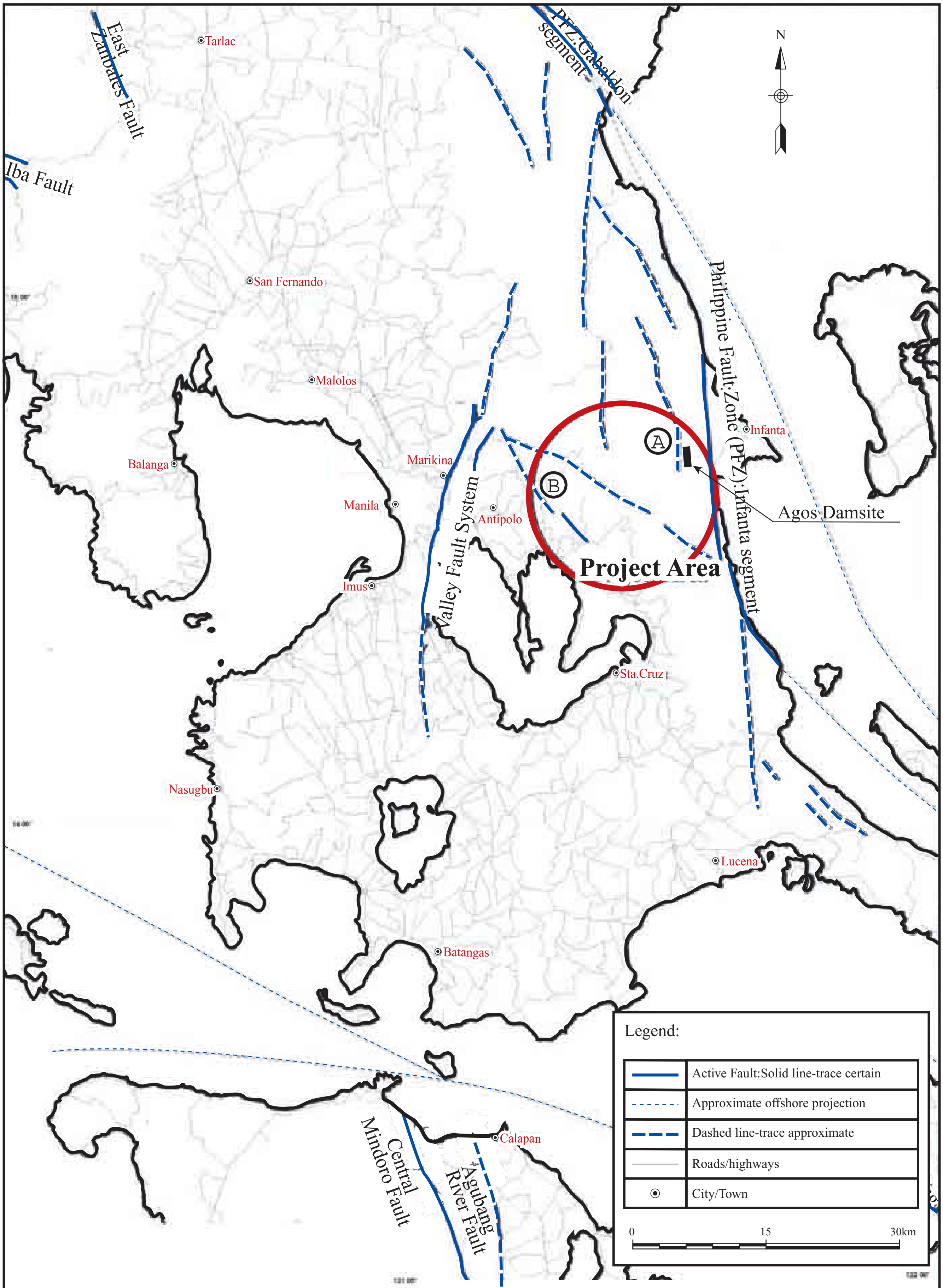


Figure 4.2
Probable Maximum Flood at the Agos Damsite



By PHILVOLCS (2000)

Figure 4.3 Distribution of Active Faults in Southern Luzon

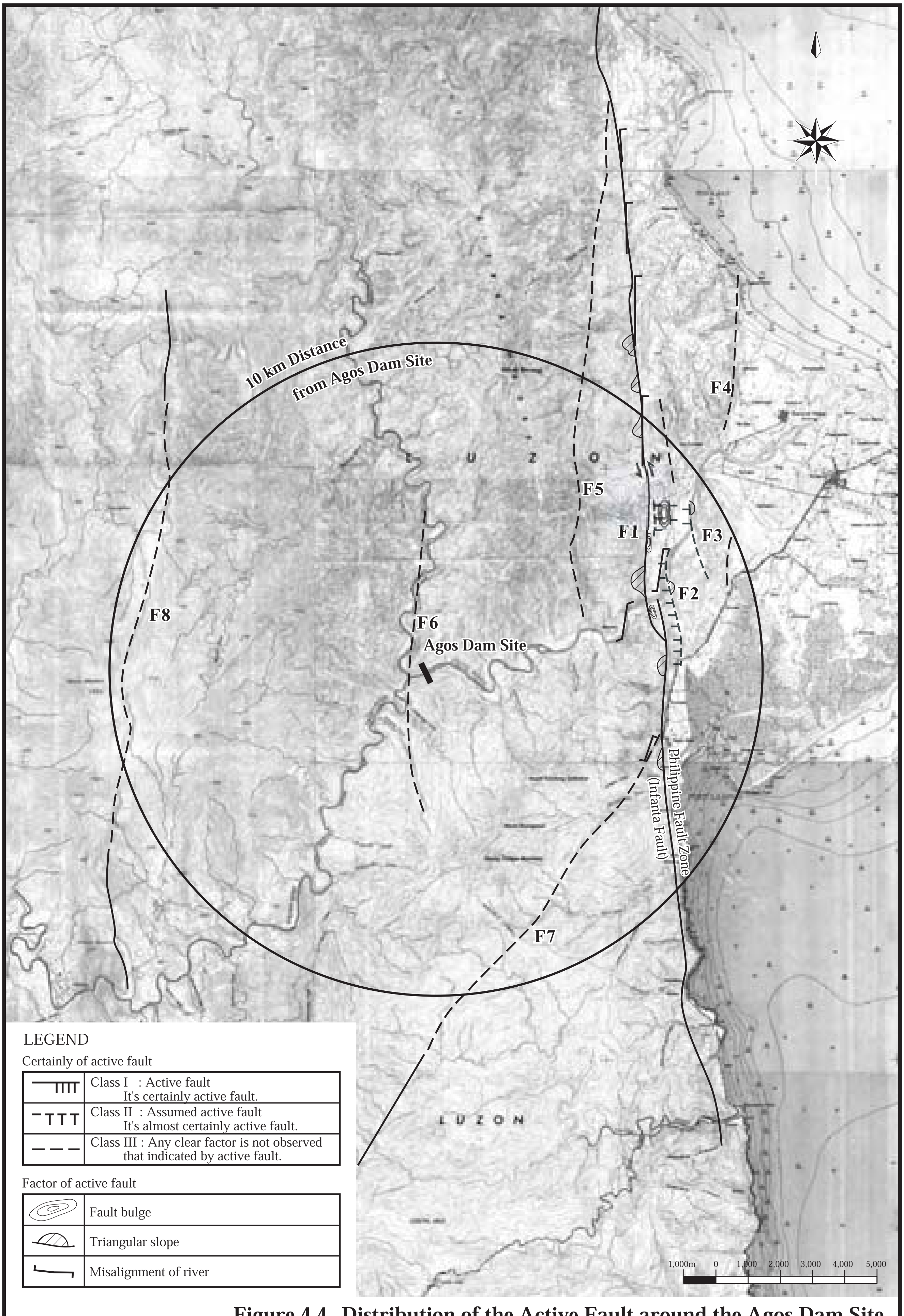


Figure 4.4 Distribution of the Active Fault around the Agos Dam Site
Based on the analysis of aerial photographs