APPENDIX B POPULATION AND LAND USE

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1. The Change of Administrative Formation

Initially administrative boundary of HCMC was divided into inner city and outer city. Inner city having 12 urban districts called as "Quan" and outer city having 6 rural districts called as "Huyen". However urbanization of HCMC has led to establishment of five new urban districts from the rural districts, around the inner city. In the year 1997, on the Northern suburb, district 12 from Hoc Mon district, on the Southern suburb, district 7 from Nha Be district and on the Eastern suburb, Thu Duc district, district 9 and district 2 from Thu Duc district, were established. The urbanization is expanding to these new urban districts. The details of these urban, new urban and rural districts are shown below.

- Inner City
  Urban Districts : District 1, 3, 4, 5, 6, 8, 10, 11, Go Vap, Tan Binh, Binh Than, Phu Nhuan

- Outer City
  New Urban Districts : District 2, 7, 9, 12, Thu Duc
  Rural Districts : Cu Chi, Hoc Mon, Binh Chanh, Nha Be, Can Gio

The urban distiicts and new urban districts are divided into wards called as "Phoung" and rural districts are divided into communes called as "Xa".

The study area includes 12 urban districts from inner city, 5 new urban districts from outer city and some communes of rural districts, Hoc Mon, Binh Chanh and Nha Be. The administrative boundary of study area is shown in Fig. B.1.

2. Population

2.1 Present Population

The population of HCMC in the year 1997 was about 5 million as shown in Table B.1 The population is showing increasing trend. Inner city has about 3.5 million people, which accounts for about 70 % of the population of HCMC. New urban district has population of about 0.6 million. The study area has additionally 0.26 million people from the communes of rural districts included in the study area. Hence total population of study area is about 4.4 million, which is 88 % of the total population of HCMC.

2.2 Trend of Population Increase

The population increasing rate of HCMC has been gradually decreasing in the past few years as shown in Table B.2. Especially in the central districts of inner city having high population density, population increasing rate has hebetated. The population increasing rate of urban districts on the fringes of inner city such as Go Vap, Tan Binh, Binh Thanh and Phu Nhuan and that of districts of outer city is higher than the central districts of inner city.

Natural increase rate though is higher in the suburb/rural districts compared with inner city, the overall trend of Natural increase rate is declining. The social increase rate, which means rate of migration, is calculated by subtracting Natural increase rate from the total population rate. Table B.3 shows comparatively higher migration rate in the fringes of inner city and Thu Duc district.

2.3 Gross Population Density of Wards and Communes

(1) Inner City

Gross population density of each ward in the inner city is shown in Fig. B.2. Several wards in district 10 and 4 have population density higher than 1000 person per ha. In general population density of the wards along the main canals Tau Hu -- Ben Nghe, Doi – Te, Tan Hoa – Ong Buong – Lo Gom and Nhieu Loc – Thi Nghe is relatively higher than the other wards.

(2) Outer City

The population density of outer city is still low mainly due to large area occupied by each ward and commune. Some wards/communes in the outer city have comparatively higher population density of the order of 100 person/ha. Linh Tay and Linh Dong wards in Thu Duc district, Phuoc Binh ward in district 9, An Khanh ward in district 2 and Tan Kieng, Tan Thuan Tay and Tan Qui wards in district 7 have population density varying from 100 – 160 person/ha. The regional distribution of the existing population density by ward is shown in Fig. B.2.

2.4 Future Population of HCMC

According to the Master Plan 2020 of HCMC prepared by UPI, the population is expected to be about 10 million in the year 2020. The main policy of Master Plan is to distribute population between inner city and outer city more evenly. In the year 2020, population in inner city will decrease and population in outer city will increase considerably. The population projected in each district in the year 2020 is shown in Table B.4 and distribution of population density is shown in Fig. B.3.

2.4.1 Policy of Future Population Distribution

At present inner city has very high population density compared with outer city. Government plan to settle the new residents as well as resettle people from the inner city to the suburban residential areas by providing employment opportunities. Several industrial zones are planned in the suburbs as shown in Fig. B.4. Regarding resettling residents from inner city to outer city, first target is the residents living along the canals particularly four main canals.

2.4.2 Calculation of Future Population in Each Ward and Commune

1) Inner City

Data regarding the population living along the canal are obtained from Land and Housing Department. This population will be resettled to outer city in the year 2020. After subtracting the population living along the canal from the present population, the obtained population is compared with the future population as predicted in the Master Plan.

For the district 1, 4, 5, 6, 8, 11, Tan Binh and Binh Than the forecasted population is even less. It means further population will move from these districts to outer city. The future population in the each ward of the above mentioned districts is calculated by first subtracting the population living along the canal in that ward, which is calculated in proportion to the length of canal in that ward. Further reduction of population necessary in the ward is proportionally calculated with more reduction from the wards having comparatively higher population density.

For the district 6, 8, Go Vap Tan Binh, Binh Thanh and Phu Nhanh the forecasted population is more than the present population minus population living along the canal. Future population in ward is proportionally calculated with more increase in the wards having comparatively less population density.

The population in each ward in the year 2020 is shown in Table B.5.

2) Outer City

Future population of new urban districts and rural districts are planned to increase sharply by the year 2020. The population of each ward and commune is calculated following the trend of population increase rate and taking into account future land use plan.

3. Land Use

3.1 Present Land Use

3.1.1 Inner City

Almost all the areas have already been built up as residential areas except some fringes in Go Vap, Binh Thanh, Tan Binh, District 6 and 8. Some agricultural areas can be still found on the border of inner city and outer city. These agricultural lands may also be developed in the near future.

The most peculiar feature of buildings is the narrow frontage on the streets with deep depth. Most of the buildings are one story. There is scarcity of space between the buildings.

There are two major commercial/service areas; District 1 and between District 5 and 6. Ben Nghe ward facing the Saigon River in district 1 is the largest commercial and also tourist zone of HCMC. Binh Tay market in China Town is the other commercial area. However most of the commercial area is also being used for residential purpose.

Ben Nghe ward is not only commercial center but also civic center also having lot of government offices. Historically this area is the origin of HCMC and will remain city center in future also.

Another tendency is to locate industry along the canal. The main reason is that shipping is the main mode of transporting goods. Along Tau Hu – Ben Nghe canal in district 8, 5, 4 and 1 there exists major industrial zone. Another major industrial zone is along Tan Hoa – Lo Gom Canal in district 6 and Tan Binh. The other major industrial areas are located on the canals in Binh Thanh and the area along the Cach Mang Thang Tam street to Au Co street through the north and south in Tan Binh.

Open spaces are not adequate for resident as inner city has very few parks and green areas.

Existing land use pattern of the inner city is shown in Table B.6 and Fig. B.5.

3.1.2 Outer City

Majority of land is being used for agricultural purpose. Residential areas in outer city in comparison to inner city are more scattered except around the district centers. Residential areas are also found with the border of inner city. Some residential areas are also found along the roads and canals.

There are three major industrial areas. One is on provincial road no. 15 connecting to the southern area through district 7 and Nha Be. This is known as Tan Thuan Export Processing zone located on the peninsula of Tan Thuan ward in district 7. The second is along Ha Noi Highway through district 2, 9 and Thu Duc. The third is along the National Road No.1 from Binh Chanh to district 12 and Thu Duc.

Present Land use pattern of the outer city is shown in Table B.7 and Fig. B.6.

3.2 Future Land Use Pattern

3.2.1 Inner City

Some agricultural lands found at present in the fringes of inner city will also be built up in future. The old residential quarters would be redeveloped particularly in the district's center to improve living environment and enhance tourism. The existing major commercial/service areas in Ben Nghe and around Ben Thanh market will be improved and intensified as a city center.

Green belts or parks are planned on the Saigon river side and along some canals. This is the most important policy to develop the open spaces as an urban amenity to improve living environment. Rivers and canals are not only precious open spaces for the residents but also for tourism and transportation purpose. However relocation program will be required for the residents along the canals.

3.2.2 Outer City

In An Khanh, Thu Thiem and An Loi Dong wards of district 2 located on the farther shore of Saigon river from Ben Nghe ward, the new business center is planned to be developed. If the bridges are constructed over the Saigon river, the development potentials of this area will be much higher. The other district centers and commercial/service areas are planned especially on adjoining areas of inner city. In particular Thu Duc is planned to develop over almost the whole area.

New residential areas are mainly planned as follows:

- District 12 : on the west side of Saigon river
- Thu Duc : on the east side of Saigon river
- District 9 : along Ha Noi Highway, in Long Truong ward
- Binh Chanh : Neighbouring area of Vinh Loc industrial zone,
- District center and along Binh Tuan road (Nam Saigon road)
- District 7/Nha Be : evenly cover the wards

Industrial zones are impartially planned for each district though the scales are different. Developed areas are covered around by green areas.

Future land use pattern of the outer city is shown in Fig. B.8.

Table B.1 Population Changes of HCMC

No.	Year / District/ Ward, Commune	Total Area (sq.km)	1979 (Census) Population	1979 (Census) Density (p/ha)	1989 (Census) Population	1989 (Census) Density (p/ha)	1994 Population	1994 Density (p/ha)	1995 Population	1995 Density (p/ha)	1996 Population	1996 Density (p/ha)	1997 Population	1997 Density (p/ha)
Total HCMC		**2,093.7**	**3,293,146**	**16**	**3,924,435**	**19**	**4,649,387**	**22**	**4,764,671**	**23**	**4,880,435**	**23**	**4,989,703**	**24**
Inner City		**140.3**	**2,352,813**	**168**	**2,796,229**	**199**	**3,306,609**	**236**	**3,386,488**	**241**	**3,466,891**	**247**	**3,541,040**	**252**
(1)	Quan 1	7.6	222,760	293	252,263	332	264,859	348	271,292	357	277,115	365	282,063	371
(2)	Quan 3	4.8	213,545	445	238,943	498	244,358	509	249,964	521	255,637	533	260,418	543
(3)	Quan 4	4.0	141,748	354	179,933	450	207,655	519	212,370	531	216,628	542	220,650	552
(4)	Quan 5	4.1	192,081	468	213,720	521	237,084	578	242,274	591	246,965	602	251,387	613
(5)	Quan 6	7.0	175,789	251	213,353	305	264,198	377	269,897	386	275,262	393	280,336	400
(6)	Quan 8	18.8	213,470	114	254,702	135	326,362	174	333,572	177	340,546	181	347,090	185
(7)	Quan10	5.7	207,842	365	229,621	403	256,924	451	262,290	460	267,070	469	271,593	476
(8)	Quan11	5.0	199,302	399	225,264	451	244,358	489	249,958	500	255,220	510	260,159	520
(9)	Go Vap	19.2	127,934	67	162,534	85	217,576	113	223,166	116	229,291	119	234,966	122
(10)	Tan Binh	38.5	264,315	69	333,834	87	466,232	121	480,278	125	496,810	129	512,185	133
(11)	Binh Thanh	20.5	249,640	122	321,246	157	388,196	189	397,872	194	408,173	199	417,739	204
(12)	Phu Nhuan	5.1	144,387	283	170,816	335	188,807	370	193,555	380	198,174	389	202,454	397
Outer City		**1,953.4**	**940,333**	**5**	**1,128,206**	**6**	**1,342,778**	**7**	**1,378,183**	**7**	**1,413,544**	**7**	**1,448,663**	**7**
(13)	Hoc Mon	109.5	208,035	13	243,963	15	289,538	18	297,377	18	305,420	19	185,871	17
(14)	Quan12	52.5	-	-	-	-	-	-	-	-	-	-	127,459	24
(15)	Thu Duc	48.0	239,078	11	297,161	14	354,802	17	364,734	17	375,202	18	171,165	36
(16)	Quan 2	50.2	-	-	-	-	-	-	-	-	-	-	95,219	19
(17)	Quan 9	113.1	-	-	-	-	-	-	-	-	-	-	119,446	11
(18)	Binh Chanh	303.3	164,935	5	201,284	7	244,684	8	251,081	8	257,496	8	263,883	9
(19)	Nha Be	98.4	97,450	7	122,250	9	149,585	11	153,564	11	157,522	12	63,041	6
(20)	Quan 7	35.9	-	-	-	-	-	-	-	-	-	-	98,380	27
(21)	Huyen Cu Chi	428.5	191,614	4	214,266	5	250,727	6	256,631	6	261,881	6	267,026	6
(22)	Can Gio	714.0	39,221	1	49,282	1	53,442	1	54,796	1	56,023	1	57,173	1

Source: Statistical Office of HCM

Table B.2 Recent Population Increase Rate

No.	District/ Ward, Commune	1994-1995	1995-1996	1996-1997	Notes
Total HCMC		**2.48%**	**2.43%**	**2.24%**	
Inner City (Urban Area)		**2.42%**	**2.37%**	**2.14%**	
(1)	Quan 1	2.43%	2.15%	1.79%	
(2)	Quan 3	2.29%	2.27%	1.87%	
(3)	Quan 4	2.27%	2.00%	1.86%	
(4)	Quan 5	2.19%	1.94%	1.79%	
(5)	Quan 6	2.16%	1.99%	1.84%	
(6)	Quan 8	2.21%	2.09%	1.92%	
(7)	Quan10	2.09%	1.82%	1.69%	
(8)	QuanII	2.29%	2.11%	1.94%	
(9)	Go Vap	2.57%	2.74%	2.48%	
(10)	Tan Binh	3.01%	3.44%	3.09%	
(11)	Binh Thanh	2.49%	2.59%	2.34%	
(12)	Phu Nhuan	2.51%	2.39%	2.16%	
Outer City (Rural Area)		**2.64%**	**2.57%**	**2.48%**	
(13)	Hoc Mon	2.71%	2.70%	2.59%	pop. of 1997 contains
(14)	Quan12	-	-	-	Hoc Mon, Quan12
(15)	Thu Duc	2.80%	2.87%	2.83%	pop. of 1997 contains
(16)	Quan 2	-	-	-	Thu Duc, Quan2, Quan9
(17)	Quan 9	-	-	-	
(18)	Binh Chanh	2.61%	2.55%	2.48%	
(19)	Nha Be	2.66%	2.58%	2.48%	pop. of 1997 contains
(20)	Quan 7	-	-	-	Nha Be, Quan7
(21)	Cu Chi	2.35%	2.05%	1.96%	
(22)	Can Gio	2.53%	2.24%	2.05%	

Source: Statistical Office of HCM

Table B.3 Natural/Social Increase Rate

No. District/ Ward, Commune	1994-1995		1995-1996		1996-1997	
	Natural	Social	Natural	Social	Natural	Social
Total HCMC	**1.48%**	**1.00%**	**1.42%**	**1.01%**	**1.40%**	**0.84%**
Inner City (Urban Area)	**1.40%**	**1.01%**	**1.34%**	**1.03%**	**1.32%**	**0.82%**
(1) Quan 1	1.35%	1.08%	1.30%	0.85%	1.28%	0.51%
(2) Quan 3	1.35%	0.94%	1.27%	1.00%	1.26%	0.61%
(3) Quan 4	1.40%	0.87%	1.35%	0.66%	1.34%	0.52%
(4) Quan 5	1.35%	0.84%	1.29%	0.65%	1.27%	0.52%
(5) Quan 6	1.43%	0.72%	1.37%	0.62%	1.35%	0.49%
(6) Quan 8	1.39%	0.82%	1.31%	0.78%	1.29%	0.63%
(7) Quan10	1.35%	0.74%	1.27%	0.55%	1.26%	0.44%
(8) Quan11	1.39%	0.90%	1.31%	0.79%	1.29%	0.64%
(9) Go Vap	1.49%	1.08%	1.44%	1.30%	1.41%	1.06%
(10) Tan Binh	1.49%	1.52%	1.44%	2.00%	1.41%	1.68%
(11) Binh Thanh	1.44%	1.06%	1.39%	1.20%	1.38%	0.97%
(12) Phu Nhuan	1.32%	1.19%	1.25%	1.14%	1.23%	0.93%
Outer City (Rural Area)	**1.68%**	**0.96%**	**1.60%**	**0.97%**	**1.59%**	**0.89%**
(13) Hoc Mon	1.70%	1.00%	1.63%	1.08%	1.62%	0.97%
(14) Quan12	-	-	-	-	1.60%	-
(15) Thu Duc	1.62%	1.18%	1.53%	1.34%	1.51%	1.32%
(16) Quan 2	-	-	-	-	1.52%	-
(17) Quan 9	-	-	-	-	1.55%	-
(18) Binh Chanh	1.69%	0.92%	1.61%	0.94%	1.62%	0.87%
(19) Nha Be	1.71%	0.95%	1.64%	0.94%	1.64%	0.84%
(20) Quan 7	-	-	-	-	1.63%	-
(21) Cu Chi	1.69%	0.66%	1.63%	0.42%	1.62%	0.34%
(22) Can Gio	1.73%	0.80%	1.66%	0.58%	1.66%	0.39%

Source: Statistical Office of HCMC

Table B.4 The Balance Between Existing Population and Frame For Year 2020

Area	Year / District/ Ward, Commune		Total Area (sq km)	1997 Population	1997 Density (p/ha)	1997 Household	2020 Population	2020 Density (p/ha)	Annual Increase Rate
	Total HCMC		**2,093.7**	**4,989,703**	**24**	**988,281**	**10,400,000**	**50**	**3.24%**
S.A.	**Inner City Total**		**140.3**	**3,541,040**	**252**	**707,055**	**4,000,000**	**285**	**0.53%**
	(1)	Quan 1	7.6	282,063	371	62,169	270,000	355	-0.19%
	(2)	Quan 3	4.8	260,418	543	57,536	250,000	521	-0.18%
	(3)	Quan 4	4.0	220,650	552	40,831	210,000	525	-0.21%
	(4)	Quan 5	4.1	251,387	613	51,023	220,000	537	-0.58%
	(5)	Quan 6	7.0	280,336	400	52,689	300,000	429	0.30%
	(6)	Quan 8	18.8	347,090	185	64,463	430,000	229	0.94%
	(7)	Quan10	5.7	271,393	476	56,326	270,000	474	-0.03%
	(8)	QuanII	5.0	260,159	520	50,006	250,000	500	-0.17%
	(9)	Go Vap	19.2	234,966	122	43,640	450,000	234	2.87%
	(10)	Tan Binh	38.5	512,185	133	102,092	600,000	156	0.69%
	(11)	Binh Thanh	20.5	417,739	204	83,958	520,000	254	0.96%
	(12)	Phu Nhuan	5.1	202,454	397	42,322	230,000	451	0.56%
S.A.	**New Urban Area**		**299.7**	**611,669**	**20**	**122,080**	**2,450,000**	**82**	**6.22%**
	(13)	Quan12	52.5	127,459	24	25,933	500,000	95	6.12%
	(14)	Thu Duc	48.0	171,165	36	33,416	550,000	115	5.21%
	(15)	Quan 2	50.2	95,219	19	19,043	650,000	129	8.71%
	(16)	Quan 9	113.1	119,446	11	23,582	400,000	35	5.40%
	(17)	Quan 7	35.9	98,380	27	20,105	350,000	97	5.67%
Partially	**Rural Area**		**511.2**	**512,795**	**10**	**96,495**	**2,350,000**	**46**	**6.84%**
S.A.	(18)	Hoc Mon	109.5	185,871	17	34,397	650,000	59	5.59%
	(19)	Binh Chanh	303.3	263,883	9	50,406	1,300,000	43	7.18%
	(20)	Nha Be	98.4	63,041	6	11,693	400,000	41	8.36%
Out of	**Rural Area**		**1,142.5**	**324,199**	**3**	**62,651**	**1,600,000**	**14**	**7.19%**
S.A.	(21)	Huyen Cu Chi	428.5	267,026	6	53,032	900,000	21	5.42%
	(22)	Can Gio	714.0	57,173	1	9,619	700,000	10	11.51%

Source: Statistical Office of HCMC, Master Plan 2020 of UPI

Note: "S.A." means Study Area

Table B.5 (1) Population Distribution for the Study Area

No.		Year / District / Ward, Commune	1997 Population No.	1997 Density (p/ha)	1997 Household No.	1997 Household Ave.	2010 By same rate of 2020 Population	2010 By same rate of 2020 (p/ha)	2020 District's population from UPI Population	2020 (p/ha)	2020 increase	Total Area (sq km)
Total Ho Chi Minh City			**4,415,147**	**70**	**878,327**	**5.0**	**5,606,407**	**89**	**7,608,615**	**121**	**2.39%**	**627.51**
Inner City (Urban Area)			**3,541,040**	**252**	**707,055**	**5.0**	**3,740,565**	**267**	**4,000,000**	**285**	**0.53%**	**140.30**
(1)	Q.	**Quan 1**	**282,063**	**371**	**62,169**	**4.5**	**275,087**	**362**	**270,000**	**355**	**-0.19%**	**7.60**
1	P.	Tan Dinh	42,469	669	9,325	4.6	42,302	666	42,174	664	-0.03%	0.63
2	P.	Da Kao	29,727	306	6,965	4.3	29,586	304	29,477	303	-0.04%	0.97
3	P.	Ben Nghe	28,114	116	6,709	4.2	28,027	116	27,959	116	-0.02%	2.41
4	P.	Ben Thanh	26,396	283	6,223	4.2	26,244	281	26,127	280	-0.04%	0.93
5	P.	Pham Ngu Lao	28,621	561	6,252	4.6	28,358	556	28,157	552	-0.07%	0.51
6	P.	Nguyen Cu Trinh	29,572	394	6,606	4.5	29,429	392	29,320	391	-0.04%	0.75
7	P.	Nguyen Thai Binh	23,744	484	5,464	4.3	21,742	443	20,318	414	-0.68%	0.49
8	P.	Cau Ong Lanh	20,959	947	3,918	5.3	20,115	909	19,488	881	-0.32%	0.22
9	P.	Co Giang	28,705	829	5,791	5.0	27,291	788	26,251	758	-0.39%	0.35
10	P.	Cau Kho	23,755	726	4,915	4.8	21,994	672	20,729	634	-0.59%	0.33
(2)	Q.	**Quan 3**	**260,418**	**543**	**57,536**	**4.5**	**254,466**	**530**	**250,000**	**521**	**-0.18%**	**4.80**
1	P.	Phuong1	19,760	1,378	4,002	4.9	19,066	1,329	18,548	1,293	-0.27%	0.14
2	P.	Phuong2	14,458	1,260	3,077	4.7	13,831	1,205	13,367	1,165	-0.34%	0.11
3	P.	Phuong3	14,619	956	3,241	4.5	14,125	923	13,757	899	-0.26%	0.15
4	P.	Phuong4	24,846	812	5,655	4.4	24,183	790	23,686	774	-0.21%	0.31
5	P.	Phuong5	20,078	808	4,405	4.6	19,686	792	19,390	780	-0.15%	0.25
6	P.	Phuong6	14,444	166	3,665	3.9	14,319	165	14,223	163	-0.07%	0.87
7	P.	Phuong7	20,602	224	4,795	4.3	20,425	223	20,289	221	-0.07%	0.92
8	P.	Phuong8	22,100	550	5,023	4.4	21,769	542	21,518	536	-0.12%	0.40
9	P.	Phuong9	22,437	546	4,967	4.5	22,075	537	21,800	530	-0.13%	0.41
10	P.	Phuong10	11,669	872	2,438	4.8	11,251	840	10,940	817	-0.28%	0.13
11	P.	Phuong11	27,544	576	5,414	5.1	27,161	568	26,870	562	-0.11%	0.48
12	P.	Phuong12	13,891	807	3,340	4.2	13,406	779	13,044	758	-0.27%	0.17
13	P.	Phuong13	11,041	722	2,518	4.4	10,659	697	10,374	678	-0.27%	0.15
14	P.	Phuong14	22,929	774	4,995	4.6	22,510	759	22,193	749	-0.14%	0.30

Table B.5 (2) Population Distribution for the Study Area

No.		Year / District/ Ward, Commune	1997 Population	1997 Density	1997 Household		2010 By some rate of 2020		2020 District's population from UPI			Total Area
			No.	(p/ha)	No.	Ave.	Population	(p/ha)	Population	(p/ha)	increase	(sq km)
(3)	Q.	**Quan 4**	**220,650**	**552**	**40,831**	**5.398**	**214,304**	**536**	**210,000**	**525**	**-0.21%**	**4.00**
1	P.	Phuong1	10,634	288	1,904	5.6	7,986	217	6,406	174	-2.18%	0.37
2	P.	Phuong2	13,203	776	2,367	5.6	13,018	765	12,877	757	-0.11%	0.17
3	P.	Phuong3	12,717	464	2,325	5.5	12,262	447	11,923	435	-0.28%	0.27
4	P.	Phuong4	17,255	570	3,262	5.3	17,103	565	16,988	561	-0.07%	0.30
5	P.	Phuong5	11,408	754	2,015	5.7	10,973	725	10,649	704	-0.30%	0.15
6	P.	Phuong6	16,860	891	3,041	5.5	16,568	876	16,347	864	-0.13%	0.19
7	P.	Phuong8	19,281	1,359	3,464	5.6	19,425	1,369	19,536	1,377	0.06%	0.14
8	P.	Phuong9	15,119	1,453	2,917	5.2	14,827	1,425	14,606	1,404	-0.15%	0.10
9	P.	Phuong10	14,009	1,235	2,613	5.4	14,167	1,248	14,289	1,259	0.09%	0.11
10	P.	Phuong12	11,829	298	2,367	5.0	11,328	285	10,958	276	-0.33%	0.40
11	P.	Phuong13	13,884	341	2,692	5.2	13,808	340	13,750	338	-0.04%	0.41
12	P.	Phuong14	17,162	1,008	3,188	5.4	17,355	1,020	17,505	1,028	0.09%	0.17
13	P.	Phuong15	14,171	652	2,545	5.6	13,645	627	13,253	609	-0.29%	0.22
14	P.	Phuong16	19,013	628	3,598	5.3	18,786	621	18,613	615	-0.09%	0.30
15	P.	Phuong18	14,106	204	2,535	5.6	13,054	189	12,298	178	-0.59%	0.69
(4)	Q.	**Quan 5**	**251,387**	**613**	**51,023**	**4.9**	**232,954**	**568**	**220,000**	**537**	**-0.58%**	**4.10**
1	P.	Phuong1	26,510	647	5,091	5.2	23,867	582	22,014	537	-0.80%	0.41
2	P.	Phuong2	21,840	764	4,331	5.0	21,068	737	20,494	716	-0.28%	0.29
3	P.	Phuong3	9,164	506	1,829	5.0	8,409	464	7,870	434	-0.66%	0.18
4	P.	Phuong4	15,243	410	2,834	5.4	14,507	390	13,966	376	-0.38%	0.37
5	P.	Phuong5	20,121	1,005	4,126	4.9	18,188	908	16,828	840	-0.77%	0.20
6	P.	Phuong6	13,972	637	3,141	4.4	12,130	553	10,880	496	-1.08%	0.22
7	P.	Phuong7	18,360	770	3,801	4.8	17,551	736	16,952	711	-0.35%	0.24
8	P.	Phuong8	12,719	534	2,718	4.7	12,003	504	11,479	482	-0.44%	0.24
9	P.	Phuong9	17,507	471	3,090	5.7	16,982	457	16,589	446	-0.23%	0.37
10	P.	Phuong10	15,357	700	3,251	4.7	13,535	617	12,282	560	-0.97%	0.22
11	P.	Phuong11	18,047	653	3,991	4.5	17,298	626	16,743	606	-0.33%	0.28
12	P.	Phuong12	7,772	209	1,609	4.8	7,225	194	6,830	184	-0.56%	0.37
13	P.	Phuong13	17,681	742	3,639	4.9	14,652	615	12,680	532	-1.44%	0.24
14	P.	Phuong14	20,402	690	4,381	4.7	19,742	668	19,249	651	-0.25%	0.30
15	P.	Phuong15	16,691	921	3,190	5.2	15,798	872	15,144	836	-0.42%	0.18
(5)	Q.	**Quan 6**	**280,336**	**400**	**52,689**	**5.3**	**290,341**	**415**	**300,000**	**429**	**0.30%**	**7.00**
1	P.	Phuong1	17,633	624	3,251	5.4	17,160	607	16,805	594	-0.21%	0.28
2	P.	Phuong2	15,058	672	2,939	5.1	14,758	658	14,532	648	-0.15%	0.22
3	P.	Phuong3	14,654	654	2,678	5.5	13,891	619	13,330	594	-0.41%	0.22
4	P.	Phuong4	15,377	751	2,789	5.5	15,856	774	16,235	793	0.24%	0.20
5	P.	Phuong5	20,661	963	3,719	5.6	19,538	911	18,716	873	-0.43%	0.21
6	P.	Phuong6	20,907	670	4,035	5.2	22,383	717	23,589	756	0.53%	0.31
7	P.	Phuong7	19,957	445	3,595	5.6	18,951	423	18,212	406	-0.40%	0.45
8	P.	Phuong8	25,741	614	4,857	5.3	26,378	629	26,878	641	0.19%	0.42
9	P.	Phuong9	17,047	624	3,101	5.5	17,846	654	18,487	677	0.35%	0.27
10	P.	Phuong10	16,074	105	3,065	5.2	20,919	137	25,617	167	2.05%	1.53
11	P.	Phuong11	24,438	272	4,726	5.2	26,607	297	28,406	317	0.66%	0.90

Table B.5 (3) Population Distribution for the Study Area

No.		Year / District / Ward, Commune	1997 Population	1997 Density	1997 Household		2010 By same rate of 2020		2020 District's population from UPI			Total Area
			No.	(p/ha)	No.	Ave.	Population	(p/ha)	Population	(p/ha)	increase	(sq km)
12	P.	Phuong12	29,949	415	5,798	5.2	31,584	438	32,902	456	0.41%	0.72
13	P.	Phuong13	21,575	257	4,127	5.2	25,280	302	28,558	341	1.23%	0.84
14	P.	Phuong14	21,265	519	4,008	5.3	19,190	469	17,733	433	-0.79%	0.41
(6)	Q.	**Quan 8**	**347,090**	**185**	**64,463**	**5.4**	**366,024**	**195**	**430,000**	**229**	**0.94%**	**18.80**
1	P.	Phuong1	21,769	436	4,172	5.2	19,687	394	18,222	365	-0.77%	0.50
2	P.	Phuong2	24,979	510	4,508	5.5	26,070	533	26,943	550	0.33%	0.49
3	P.	Phuong3	22,860	432	4,455	5.1	22,697	429	22,574	427	-0.05%	0.53
4	P.	Phuong4	30,569	215	5,781	5.3	32,460	229	33,994	239	0.46%	1.42
5	P.	Phuong5	29,033	188	5,518	5.3	30,666	198	31,985	207	0.42%	1.55
6	P.	Phuong6	25,265	174	4,773	5.3	26,916	186	28,258	195	0.49%	1.45
7	P.	Phuong7	15,499	27	2,862	5.4	33,602	60	60,936	108	6.13%	5.64
8	P.	Phuong8	15,096	467	2,687	5.6	13,847	429	12,956	401	-0.66%	0.32
9	P.	Phuong9	27,203	646	4,867	5.6	26,058	619	25,210	599	-0.33%	0.42
10	P.	Phuong10	24,921	1,018	3,990	6.2	19,834	810	16,640	680	-1.74%	0.24
11	P.	Phuong11	14,852	632	2,878	5.2	8,128	346	5,112	218	-4.53%	0.24
12	P.	Phuong12	24,176	851	4,508	5.4	23,825	839	23,558	830	-0.11%	0.28
13	P.	Phuong13	12,560	558	2,368	5.3	12,342	548	12,177	541	-0.13%	0.23
14	P.	Phuong14	21,369	420	3,853	5.5	19,952	392	18,926	372	-0.53%	0.51
15	P.	Phuong15	29,889	196	5,490	5.4	23,530	154	19,575	128	-1.82%	1.53
16	P.	Phuong16	7,051	20	1,753	4.0	26,410	76	72,934	211	10.69%	3.46
(7)	Q.	**Quan10**	**271,593**	**476**	**56,326**	**4.8**	**270,691**	**475**	**270,000**	**474**	**-0.03%**	**5.70**
1	P.	Phuong1	16,481	723	3,074	5.4	16,432	721	16,395	719	-0.02%	0.23
2	P.	Phuong2	22,089	1,114	4,509	4.9	22,001	1,110	21,933	1,106	-0.03%	0.20
3	P.	Phuong3	11,898	1,200	2,416	4.9	11,810	1,191	11,742	1,185	-0.06%	0.10
4	P.	Phuong4	16,049	1,012	3,218	5.0	15,977	1,007	15,922	1,004	-0.03%	0.16
5	P.	Phuong5	14,726	990	3,093	4.8	14,655	986	14,600	982	-0.04%	0.15
6	P.	Phuong6	10,346	497	2,243	4.6	10,294	493	10,254	493	-0.04%	0.21
7	P.	Phuong7	14,094	1,292	2,696	5.2	14,001	1,284	13,930	1,277	-0.05%	0.11
8	P.	Phuong8	14,611	983	3,123	4.7	14,546	978	14,495	975	-0.03%	0.15
9	P.	Phuong9	23,612	1,134	4,909	4.8	23,533	1,130	23,472	1,128	-0.03%	0.21
10	P.	Phuong10	14,707	824	2,826	5.2	14,633	820	14,577	817	-0.04%	0.18
11	P.	Phuong11	15,771	663	3,210	4.9	15,727	661	15,693	660	-0.02%	0.24
12	P.	Phuong12	22,371	176	4,856	4.6	22,347	176	22,328	176	-0.01%	1.27
13	P.	Phuong13	25,592	527	5,393	4.7	25,548	526	25,514	525	-0.01%	0.49
14	P.	Phuong14	22,267	177	4,848	4.6	22,238	177	22,215	176	-0.01%	1.26
15	P.	Phuong15	26,979	353	5,911	4.6	26,951	353	26,930	353	-0.01%	0.76
(8)	Q.	**Quan11**	**260,159**	**520**	**50,006**	**5.2**	**254,136**	**508**	**250,000**	**500**	**-0.17%**	**5.00**
1	P.	Phuong1	15,976	591	3,071	5.2	12,669	469	10,599	392	-1.77%	0.27
2	P.	Phuong2	14,646	799	2,625	5.6	14,458	788	14,316	781	-0.10%	0.18
3	P.	Phuong3	24,383	324	4,729	5.2	24,242	322	24,134	321	-0.04%	0.75
4	P.	Phuong4	13,069	796	2,672	4.9	12,869	784	12,717	775	-0.12%	0.16
5	P.	Phuong5	24,053	372	4,855	5.0	23,925	370	23,826	368	-0.04%	0.65
6	P.	Phuong6	14,752	899	2,780	5.3	14,534	886	14,369	876	-0.11%	0.16
7	P.	Phuong7	17,190	1,113	3,368	5.1	16,928	1,096	16,730	1,083	-0.12%	0.15

Table B.5 (4) Population Distribution for the Study Area

No.		District/ Ward, Commune	Year	1997				2010		2020			Total
				Population	Density	Household		By same rate of 2020		District's population from UPI			Area
				No.	(p/ha)	No.	Ave.	Population	(p/ha)	Population	(p/ha)	increase	(sq km)
8	P.	Phuong8		15,172	476	2,921	5.2	15,046	472	14,950	469	-0.06%	0.32
9	P.	Phuong9		11,601	751	2,106	5.5	11,388	737	11,227	727	-0.14%	0.15
10	P.	Phuong10		10,962	454	2,075	5.3	10,817	448	10,708	444	-0.10%	0.24
11	P.	Phuong11		16,229	673	3,090	5.3	16,053	665	15,920	660	-0.08%	0.24
12	P.	Phuong12		12,117	966	2,243	5.4	11,889	947	11,717	934	-0.15%	0.13
13	P.	Phuong13		15,208	985	2,956	5.1	14,977	970	14,801	958	-0.12%	0.15
14	P.	Phuong14		19,997	628	3,616	5.5	19,797	621	19,644	617	-0.08%	0.32
15	P.	Phuong15		17,286	213	3,578	4.8	17,184	212	17,106	211	-0.05%	0.81
16	P.	Phuong16		17,518	585	3,320	5.3	17,358	580	17,236	576	-0.07%	0.30
(9)	Q.	**Go Vap**		**234,966**	**122**	**43,640**	**5.4**	**337,485**	**176**	**450,000**	**234**	**2.87%**	**19.20**
1	P.	Phuong1		16,977	293	3,193	5.3	21,136	365	25,016	432	1.70%	0.58
2	P.	Phuong3		27,754	194	5,647	4.9	34,058	239	39,865	279	1.59%	1.43
3	P.	Phuong4		13,593	371	2,335	5.8	16,889	461	19,959	545	1.68%	0.37
4	P.	Phuong5		18,040	117	3,229	5.6	27,203	176	37,310	242	3.21%	1.54
5	P.	Phuong7		16,499	163	3,158	5.2	23,556	233	30,977	306	2.78%	1.01
6	P.	Phuong10		25,304	157	4,993	5.1	32,916	204	40,296	250	2.04%	1.61
7	P.	Phuong11		20,017	97	3,770	5.3	31,325	153	44,207	215	3.50%	2.05
8	P.	Phuong12		25,196	57	4,583	5.5	43,401	97	65,943	148	4.27%	4.46
9	P.	Phuong13		12,411	145	2,018	6.2	19,457	227	27,497	320	3.52%	0.86
10	P.	Phuong15		15,793	115	2,444	6.5	24,583	178	34,549	251	3.46%	1.38
11	P.	Phuong16		21,573	178	3,725	5.8	28,289	233	34,847	287	2.11%	1.22
12	P.	Phuong17		21,807	81	4,546	4.8	34,672	128	49,533	183	3.63%	2.70
(10)	Q.	**Tan Binh**		**512,185**	**133**	**102,092**	**5.0**	**559,051**	**145**	**600,000**	**156**	**0.69%**	**38.50**
1	P.	Phuong1		14,572	397	3,082	4.7	15,711	428	16,648	453	0.58%	0.37
2	P.	Phuong2		23,460	113	5,289	4.4	27,344	131	30,765	148	1.19%	2.08
3	P.	Phuong3		19,280	777	3,463	5.6	19,871	801	20,339	820	0.23%	0.25
4	P.	Phuong4		23,929	97	4,991	4.8	28,393	115	32,387	132	1.32%	2.46
5	P.	Phuong5		21,322	716	4,122	5.2	21,964	738	22,471	755	0.23%	0.30
6	P.	Phuong6		24,537	450	4,492	5.5	25,554	468	26,366	483	0.31%	0.55
7	P.	Phuong7		16,862	340	3,266	5.2	18,191	367	19,285	389	0.59%	0.50
8	P.	Phuong8		20,929	527	4,210	5.0	21,797	549	22,489	567	0.31%	0.40
9	P.	Phuong9		27,530	555	5,086	5.4	28,358	572	29,012	585	0.23%	0.50
10	P.	Phuong10		34,328	412	6,583	5.2	35,414	425	36,273	435	0.24%	0.83
11	P.	Phuong11		24,396	424	4,723	5.2	25,475	443	26,336	458	0.33%	0.58
12	P.	Phuong12		22,756	160	4,631	4.9	25,526	180	27,885	197	0.89%	1.42
13	P.	Phuong13		43,330	217	8,904	4.9	45,428	228	47,110	236	0.36%	1.99
14	P.	Phuong14		17,961	141	3,745	4.8	21,049	166	23,782	187	1.23%	1.27
15	P.	Phuong15		25,502	19	5,436	4.7	33,356	25	41,007	30	2.09%	13.61
16	P.	Phuong16		27,513	71	5,643	4.9	33,488	87	38,954	101	1.52%	3.85
17	P.	Phuong17		21,208	200	4,043	5.2	23,446	221	25,327	239	0.77%	1.06
18	P.	Phuong18		39,850	169	8,278	4.8	42,533	180	44,718	189	0.50%	2.36
19	P.	Phuong19		36,132	195	6,974	5.2	36,487	197	36,762	198	0.08%	1.86
20	P.	Phuong20		26,789	118	5,131	5.2	29,665	131	32,086	141	0.79%	2.27

Table B.5 (5) Population Distribution for the Study Area

No.		Year / District / Ward, Commune	1997 Population	1997 Density	1997 Household		2010 By same rate of 2020		2020 District's population from UPI			Total Area
			No.	(p/ha)	No.	Ave.	Population	(p/ha)	Population	(p/ha)	increase	(sq km)
(11)	Q.	**Binh Thanh**	**417,739**	**204**	**83,958**	**5.0**	**468,520**	**229**	**520,000**	**254**	**0.96%**	**20.50**
1	P.	Phuong1	17,061	648	3,421	5.0	18,676	709	20,022	760	0.70%	0.26
2	P.	Phuong2	18,224	584	3,701	4.9	15,583	499	13,814	442	-1.20%	0.31
3	P.	Phuong3	28,491	679	5,451	5.2	30,056	716	31,314	746	0.41%	0.42
4	P.	Phuong5	16,368	453	3,333	4.9	18,639	516	20,598	571	1.00%	0.36
5	P.	Phuong6	13,288	470	2,740	4.8	15,463	546	17,375	614	1.17%	0.28
6	P.	Phuong7	16,100	402	3,181	5.1	18,641	466	20,866	522	1.13%	0.40
7	P.	Phuong11	27,904	357	5,390	5.2	30,816	395	33,262	426	0.77%	0.78
8	P.	Phuong12	32,798	300	6,862	4.8	35,602	326	37,921	347	0.63%	1.09
9	P.	Phuong13	16,015	63	3,138	5.1	27,210	107	40,908	161	4.16%	2.55
10	P.	Phuong14	13,932	408	2,947	4.7	16,422	481	18,636	546	1.27%	0.34
11	P.	Phuong15	22,035	452	4,358	5.1	20,002	410	18,567	381	-0.74%	0.49
12	P.	Phuong17	24,951	393	4,839	5.2	27,005	426	28,699	452	0.61%	0.63
13	P.	Phuong19	17,474	484	3,500	5.0	18,729	519	19,756	547	0.54%	0.36
14	P.	Phuong21	24,843	637	4,761	5.2	24,367	624	24,008	615	-0.15%	0.39
15	P.	Phuong22	23,086	128	4,706	4.9	26,839	149	30,136	167	1.17%	1.81
16	P.	Phuong24	23,216	410	4,760	4.9	25,106	444	26,663	471	0.60%	0.57
17	P.	Phuong25	26,687	147	5,596	4.8	32,722	180	38,278	211	1.58%	1.81
18	P.	Phuong26	22,314	171	4,451	5.0	26,169	200	29,582	226	1.23%	1.31
19	P.	Phuong27	26,942	317	5,477	4.9	28,968	341	30,631	361	0.56%	0.85
20	P.	Phuong28	6,008	11	1,345	4.5	11,505	21	18,964	35	5.12%	5.48
(12)	Q.	**Phu Nhuan**	**202,454**	**397**	**42,322**	**4.8**	**217,506**	**426**	**230,000**	**451**	**0.56%**	**5.10**
1	P.	Phuong1	13,953	676	3,035	4.6	14,591	707	15,101	731	0.34%	0.21
2	P.	Phuong2	17,143	437	3,505	4.9	18,125	462	18,918	482	0.43%	0.39
3	P.	Phuong3	9,530	486	2,038	4.7	10,403	530	11,129	567	0.68%	0.20
4	P.	Phuong4	13,845	447	2,780	5.0	14,801	478	15,581	503	0.51%	0.31
5	P.	Phuong5	15,582	457	3,266	4.8	16,519	485	17,278	507	0.45%	0.34
6	P.	Phuong7	20,958	472	4,072	5.1	21,871	493	22,600	509	0.33%	0.44
7	P.	Phuong8	10,571	341	2,317	4.6	11,802	381	12,847	415	0.85%	0.31
8	P.	Phuong9	19,825	140	4,394	4.5	22,783	161	25,356	179	1.08%	1.41
9	P.	Phuong10	10,632	322	2,373	4.5	11,936	361	13,046	395	0.89%	0.33
10	P.	Phuong11	11,842	499	2,609	4.5	12,698	535	13,399	564	0.54%	0.24
11	P.	Phuong12	8,075	489	1,739	4.6	8,939	541	9,666	585	0.79%	0.17
12	P.	Phuong13	12,164	620	2,488	4.9	12,857	655	13,416	684	0.43%	0.20
13	P.	Phuong14	10,221	762	2,155	4.7	10,786	804	11,241	838	0.41%	0.13
14	P.	Phuong15	15,893	616	3,262	4.9	16,593	643	17,152	665	0.33%	0.26
15	P.	Phuong17	12,219	740	2,289	5.3	12,802	775	13,269	803	0.36%	0.17

Table B.5 (6) Population Distribution for the Study Area

No.		Year / District / Ward, Commune	1997 Population No.	1997 Density (p/ha)	1997 Household No.	1997 Household Ave.	2010 By same rate of 2020 Population	2010 (p/ha)	2020 District's population from UPI Population	2020 (p/ha)	2020 increase	Total Area (sq km)
New Urban Area			**611,669**	**20**	**122,080**	**5.0**	**1,290,819**	**43**	**2,450,000**	**82**	**6.22%**	**299.70**
(13)	Q.	**Quan12**	**127,459**	**24**	**25,933**	**4.9**	**271,495**	**52**	**500,000**	**95**	**6.12%**	**52.50**
1	P.	Tan Thoi Nhat	16,364	44	3,201	5.1	30,765	82	49,998	133	4.98%	3.75
2	P.	Dong Hung Thuan	31,355	78	6,240	5.0	57,018	141	90,321	223	4.71%	4.04
3	P.	An Phu Dong	9,708	11	2,049	4.7	24,928	28	51,490	57	7.52%	9.02
4	P.	Trung My Tay	11,687	43	2,439	4.8	26,192	97	48,728	181	6.40%	2.70
5	P.	Thanh Chanh Hiep	9,357	22	1,816	5.2	21,520	51	40,839	97	6.62%	4.20
6	P.	Thanh Loc	9,961	17	2,065	4.8	26,576	46	56,534	98	7.84%	5.80
7	P.	Thanh Xuan	10,333	10	2,165	4.8	32,424	33	78,148	79	9.20%	9.90
8	P.	Hiep Thanh	10,800	19	2,136	5.1	16,476	30	22,800	41	3.30%	5.55
9	P.	Thoi An	7,415	15	1,638	4.5	12,425	25	18,481	37	4.05%	5.06
10	P.	Tan Thoi Hiep	10,480	42	2,184	4.8	23,171	93	42,660	172	6.29%	2.48
(14)	Q.	**Thu Duc**	**171,165**	**36**	**33,416**	**5.1**	**329,392**	**69**	**550,000**	**115**	**5.21%**	**48.00**
1	P.	Linh Dong	19,842	144	3,813	5.2	36,035	261	57,023	414	4.70%	1.38
2	P.	Hiep Binh Chanh	17,636	27	3,797	4.6	37,234	56	66,157	100	5.92%	6.60
3	P.	Hiep Binh Phuoc	14,565	20	3,202	4.5	32,596	44	60,573	82	6.39%	7.34
4	P.	Tam Phu	14,237	45	2,606	5.5	29,091	92	50,407	159	5.65%	3.17
5	P.	Linh Xuan	14,546	36	2,989	4.9	19,908	50	25,344	64	2.44%	3.99
6	P.	Linh Chieu	14,272	45	2,326	6.1	25,713	82	40,442	128	4.63%	3.15
7	P.	Truong Tho	16,234	33	3,292	4.9	34,836	70	62,675	127	6.05%	4.95
8	P.	Binh Chieu	13,572	58	2,574	5.3	25,771	110	42,202	181	5.06%	2.33
9	P.	Linh Tay	13,175	101	2,603	5.1	23,670	181	37,149	284	4.61%	1.31
10	P.	Binh Tho	10,865	90	2,013	5.4	20,149	166	32,402	268	4.87%	1.21
11	P.	Tam Binh	8,650	16	1,690	5.1	17,876	34	31,245	59	5.74%	5.27
12	P.	Linh Trung	13,570	19	2,510	5.4	26,513	36	44,381	61	5.29%	7.30
(15)	Q.	**Quan 2**	**95,219**	**19**	**19,043**	**5.0**	**269,369**	**54**	**650,000**	**129**	**8.71%**	**50.20**
1	P.	An Phu	7,465	7	1,438	5.2	30,328	29	89,159	85	11.39%	10.45
2	P.	Thao Dien	6,654	18	1,397	4.8	28,544	79	87,493	241	11.85%	3.63
3	P.	An Khanh	16,136	101	2,983	5.4	31,904	199	53,897	337	5.38%	1.60
4	P.	Binh Khanh	6,950	36	1,388	5.0	17,341	90	35,035	183	7.29%	1.92
5	P.	Binh An	7,855	45	1,848	4.3	25,424	147	62,754	363	9.46%	1.73
6	P.	Thu Thiem	9,732	70	1,716	5.7	23,835	171	47,475	341	7.13%	1.39
7	P.	An Loi Dong	5,881	16	1,350	4.4	25,675	70	79,781	218	12.01%	3.66
8	P.	Binh Trung Tay	10,995	50	2,170	5.1	20,980	95	34,488	156	5.10%	2.22
9	P.	Binh Trung Dong	8,408	25	1,685	5.0	17,045	51	29,355	88	5.59%	3.33
10	P.	Cat Lai	6,405	10	1,329	4.8	10,993	17	16,657	25	4.24%	6.59
11	P.	Thanh My Loi	8,739	6	1,738	5.0	37,301	27	113,906	83	11.81%	13.69
(16)	Q.	**Quan 9**	**119,446**	**11**	**23,582**	**5.1**	**228,755**	**20**	**400,000**	**35**	**5.40%**	**113.10**
1	P.	Phuoc Long A	10,917	43	2,179	5.0	19,302	76	29,921	118	4.48%	2.54
2	P.	Phuoc Long B	8,831	15	2,051	4.3	19,458	33	35,728	61	6.27%	5.87
3	P.	Tang Nhon Phu A	10,725	26	2,403	4.5	15,994	39	21,749	54	3.12%	4.06
4	P.	Tang Nhon Phu B	6,299	12	1,286	4.9	12,830	24	22,177	42	5.62%	5.29
5	P.	Long Truong	5,440	4	987	5.5	22,365	17	66,354	50	11.49%	13.35
6	P.	Thuong Thanh	4,862	5	909	5.3	14,262	15	32,635	35	8.63%	9.34

Table B.5 (7) Population Distribution for the Study Area

No.		Year / District/ Ward, Commune	1997 Population	1997 Density	1997 Household		2010 By same rate of 2020		2020 District's population from UPI			Total Area
			No.	(p/ha)	No.	Ave.	Population	(p/ha)	Population	(p/ha)	increase	(sq km)
7	P.	Phuoc Binh	15,879	166	2,721	5.8	21,733	227	27,667	289	2.44%	0.96
8	P.	Tan Phu	8,461	20	1,720	4.9	14,892	35	23,004	54	4.44%	4.23
9	P.	Hiep Phu	15,306	71	3,126	4.9	27,336	127	42,706	199	4.56%	2.15
10	P.	Long Thanh My	8,821	7	1,763	5.0	14,373	12	20,924	18	3.83%	11.88
11	P.	Long Binh	13,362	8	2,612	5.1	24,764	14	39,804	23	4.86%	17.15
12	P.	Long Phuoc	6,312	3	1,012	6.2	13,981	6	25,775	11	6.31%	24.48
13	P.	Phu Huu	4,229	4	811	5.2	7,464	6	11,555	10	4.47%	11.79
(17)	Q.	**Quan 7**	**98,380**	**27**	**20,105**	**4.9**	**191,808**	**53**	**350,000**	**97**	**5.67%**	**35.90**
1	P.	Phu My	7,352	18	1,343	5.5	21,270	51	48,155	116	8.51%	4.15
2	P.	Phu Thuan	7,427	9	1,473	5.0	16,325	19	29,919	34	6.25%	8.69
3	P.	Tan Phu	7,419	17	1,495	5.0	28,053	63	78,011	176	10.77%	4.43
4	P.	Tan Thuan Dong	13,175	18	2,847	4.6	16,266	22	19,130	26	1.63%	7.43
5	P.	Binh Thuan	6,907	42	1,482	4.7	17,601	107	36,143	221	7.46%	1.64
6	P.	Tan Thuan Tay	15,456	154	3,167	4.9	20,552	205	25,588	256	2.22%	1.00
7	P.	Tan Kieng	13,925	132	2,904	4.8	22,279	212	31,980	304	3.68%	1.05
8	P.	Tan Qui	11,791	142	2,357	5.0	23,488	283	39,908	481	5.44%	0.83
9	P.	Tan Phong	2,231	5	461	4.8	5,990	13	12,804	28	7.89%	4.54
10	P.	Tan Hung	12,697	59	2,578	4.9	19,986	94	28,332	133	3.55%	2.13

Table B.5 (8) Population Distribution for the Study Area

No.		Year / District/ Ward, Commune	1997 Population No.	1997 Density (p/ha)	1997 Household No.	1997 Household Ave.	2010 By same rate of 2020 Population	2010 (p/ha)	2020 District's population from UPI Population	2020 (p/ha)	2020 increase	Total Area (sq km)
Rural Area			**262,438**	**14**	**49,191**	**5.3**	**575,023**	**31**	**1,158,615**	**62**	**6.67%**	**187.51**
(18)	H.	**Hoc Mon**	**32,750**	**40**	**5,342**	**5.0**	**60,405**	**74**	**96,874**	**119**	**4.83%**	**8.14**
7	X.	Xuan Thoi Son*	1,491	9	292	5.1	1,938	11	2,371	14	2.04%	1.71
8	X.	Tan Xuan*	8,092	61	1,532	5.3	16,124	122	27,404	208	5.45%	1.32
10	X.	Ba Dien	24,658	36	3,810	6.5	44,281	65	69,469	102	4.61%	6.82
(19)	H.	**Binh Chanh**	**185,378**	**13**	**35,637**	**5.2**	**451,368**	**32**	**977,241**	**70**	**7.50%**	**139.27**
1	Tt.	An Lac	30,672	50	5,938	5.2	59,901	99	100,240	165	5.28%	6.08
2	X.	Binh Chanh	13,265	16	2,458	5.4	16,848	20	20,250	24	1.86%	8.27
3	X.	Tan Quy Tay*	6,412	11	1,201	5.3	8,143	14	9,788	17	1.86%	5.88
4	X.	Hung Long*	786	3	155	5.1	998	4	1,199	4	1.86%	2.69
7	X.	Phong Phu*	8,645	6	1,606	5.4	35,619	27	105,848	79	11.51%	13.34
8	X.	Binh Hung	13,133	9	2,649	5.0	40,003	28	94,229	67	8.95%	14.13
9	X.	Binh Tri Dong	23,314	20	4,590	5.1	74,096	62	180,337	151	9.30%	11.94
10	X.	Tan Tao*	15,259	12	2,937	5.2	24,801	19	36,036	28	3.81%	12.74
11	X.	Binh Hung Hoa	21,382	14	4,088	5.2	48,746	31	91,886	58	6.54%	15.76
12	X.	Pham Van Hai*	3,434	40	632	5.4	4,362	51	5,243	62	1.86%	0.85
13	X.	Le Minh Xuan*	2,316	12	442	5.2	2,942	15	3,536	18	1.86%	1.99
15	X.	Tan Nhat*	0	0	0	0.0	0	0	0	0	0.00%	1.35
16	X.	Tan Kien*	10,341	10	1,980	5.2	20,210	20	33,839	33	5.29%	10.31
17	X.	Tan Tuc	9,586	11	1,822	5.3	31,527	37	78,782	92	9.59%	8.61
18	X.	An Phu Tay	6,430	11	1,175	5.5	32,829	57	115,056	201	13.36%	5.73
19	X.	Vinh Loc A*	8,009	14	1,580	5.1	20,816	37	43,398	77	7.62%	5.62
20	X.	Vinh Loc B*	12,394	9	2,384	5.2	29,527	21	57,574	41	6.91%	14.00
(20)	H.	**Nha Be**	**44,310**	**11**	**8,212**	**5.4**	**63,250**	**16**	**84,500**	**21**	**2.85%**	**40.09**
1	Tt.	Nha Be	15,539	23	2,665	5.8	20,862	31	26,154	39	2.29%	6.76
2	Tt.	Phu Xuan	14,037	16	2,716	5.2	17,632	20	21,013	24	1.77%	8.82
3	Tt.	Phuoc Kien	7,633	6	1,498	5.1	13,300	10	20,388	15	4.36%	13.29
4	Tt.	Phuoc Loc*	1,212	5	201	6.0	1,942	8	2,789	11	3.69%	2.47
5	Tt.	Nhon Duc*	3,437	5	641	5.4	6,500	9	10,611	15	5.02%	7.20
6	Tt.	Long Thoi*	2,441	16	491	5.0	3,014	19	3,545	23	1.63%	1.55

Note: * means that the wards are partially included in the study area

Q. Quan (District)

P. Phuong (Ward)

H. Huyen (District)

Tt Thi tran (Town)

X. Xa (Commune)

Table B.6 Existing Land Use Pattern of the Inner City

(unit: ha)

No.	Land use / District	Total (ha)	Residential 1)	Commerce./ Services	Industrial Area		Institution Area		Transportation 2)	Park/ Green	Culture/ Sports	Agriculture	River/ Canals	Others	
					Factory	Ware house	Office/ other	Education						Religious	Military
	Total	14,030.0	7,348.0	244.4	465.2	126.4	339.8	171.5	914.3	209.8	116.6	2,830.4	844.4	31.5	387.7
(1)	Quan 1	760.0	362.6	92.9	15.8	14.3	101.7	5.5	0.0	67.1	14.2	0.0	55.0	8.2	22.7
(2)	Quan 3	480.0	322.3	53.1	3.1	0.0	44.3	18.7	17.0	0.0	9.6	0.0	8.3	3.6	0.0
(3)	Quan 4	400.0	214.1	1.6	28.5	19.3	8.7	4.7	27.3	20.5	0.0	0.0	75.2	0.0	0.0
(4)	Quan 5	410.0	268.6	50.9	10.3	1.3	30.4	27.0	0.0	1.8	6.3	0.0	11.1	2.3	0.0
(5)	Quan 6	700.0	397.7	9.4	38.1	3.5	4.9	9.2	0.0	0.0	2.2	177.1	32.8	1.4	23.7
(6)	Quan 8	1,880.0	623.4	4.9	67.9	22.3	15.5	13.3	0.0	0.0	4.2	843.3	277.0	2.0	6.2
(7)	Quan10	570.0	421.0	3.9	7.1	0.8	31.4	27.8	0.0	17.1	7.0	0.0	0.0	2.3	51.6
(8)	Quan11	500.0	381.8	4.3	36.2	6.7	3.7	2.2	0.0	26.0	34.5	2.5	0.4	1.7	0.0
(9)	Go Vap	1,920.0	891.2	7.0	36.8	4.4	46.4	23.3	0.0	40.7	7.8	683.5	49.0	0.0	129.9
(10)	Tan Binh	3,850.0	2,038.2	13.7	160.2	8.6	27.8	27.7	870.0	6.3	13.1	567.2	21.0	6.4	89.8
(11)	Binh Thanh	2,050.0	1,043.4	2.4	43.5	38.8	14.1	1.3	0.0	10.3	13.9	556.8	314.6	2.0	8.9
(12)	Phu Nhuan	510.0	383.6	0.3	17.7	6.4	10.9	10.8	0.0	20.0	3.8	0.0	0.0	1.6	54.9

Note: 1) The figures calculated by subtracting the other areas from total area, and include road area

2) Transportation area means rail station, airport and port. The airport area includes military/defense areas

Source: UPI, JICA Study Team

Table B.7 Existing Land Use Pattern of the Outer City

(unit: ha)

No.	Land use / District	Total (ha)	Residential	Industrial Area		Institution	Agriculture /Others	River/ Canals	Military
				Factory	Warehouse				
	Total	67,841.4	8,593.0	995.5	120.0	390.5	54,315.4	3,240.0	187.0
(13)	Hoc Mon 1)	3,336.0	784.0	5.5	12.0	0.0	2,534.5	0.0	0.0
(14)	Quan12	5,250.0	1,063.0	143.0	0.0	66.0	3,878.0	0.0	99.0
(15)	Thu Duc	4,800.0	717.0	206.0	55.0	72.0	3,514.0	224.0	12.0
(16)	Quan 2	5,020.0	675.0	8.0	10.0	4.0	3,576.0	697.0	50.0
(17)	Quan 9	11,310.0	793.0	127.0	0.0	161.0	8,996.0	1,233.0	0.0
(18)	Binh Chanh 2)	28,462.7	3,460.0	92.0	0.0	45.0	24,865.7	0.0	0.0
(19)	Nha Be 3)	6,072.7	539.0	65.0	19.0	16.0	4,809.7	616.0	8.0
(20)	Quan 7	3,590.0	562.0	348.0	24.0	26.5	2,141.5	470.0	18.0

Note: 1) only Xuan Thoi Son, Tan Xuan and Ba Dien communes

2) except Binh Loi commune

3) except Hiep Phuoc commune

Source: UPI, JICA Study Team

Table B.8 Housing Development Projects of HCMC

Districts	Construction area (ha)	No. of houses to be built				Total investment (billion dong)	Scale of residents (person)	Population density (person/ha)
		Total	Attached & street house	Apartment block	Villas/garden houses			
District 1	33.00	3,100	515	2,585	-	513.8	12,995	394
District 3	3.54	1,136	66	1,046	24	117.8	5,450	1,540
District 4	100.8	6,299	1,995	4,282	22	1,127.2	26,165	260
District 5	3.57	1,784	12	1,772	-	100.2	6,810	1,908
District 6	23.01	7,318	1,631	5,537	150	871.9	29,120	1,266
District 8	472.70	26,415	7,197	11,670	7,548	3,005.5	159,960	338
District 10	8.55	1,094	500	534	60	201.9	4,296	502
District 11	4.74	2,010	-	2,010	-	112.0	8,000	1,688
Go Vap dist.	39.71	2,435	931	840	664	405.0	9,776	246
Phu Nhuan dist.	2.38	756	-	756	-	68.8	3,010	1,265
Tan Binh dist.	26.38	4,551	916	3,503	132	521.3	18,580	704
Binh Thanh dist.	108.2	10,155	2,966	6,403	786	1,828.1	39,574	366
Total of inner city	826.6	67,053	16,729	40,938	9,386	8873.5	323,736	392
Thu Duc dist.	374.0	21,600	5,575	13,445	2,580	2,495.4	81,465	218
Nha Be dist.	277.2	9,306	4,525	1,818	2,963	1,445.0	41,300	149
Hoc Mon dist.	136.5	8,999	5,070	2,583	1,346	1,064.5	52,942	388
Binh Chanh dist.	664.11	35,699	11,573	13,066	11,060	4,971.0	175,730	265
Total of suburbs	1451.80	75,604	26,743	30,912	17,949	9,976	351,437	242
TOTAL	2,278.40	142,657	43,472	71,850	27,335	18,849	675,173	296

Note: the districts concerning with the Study Area, and without unclear information of projects such as no population or too large construction area for the population

Source: Land - Housing Department

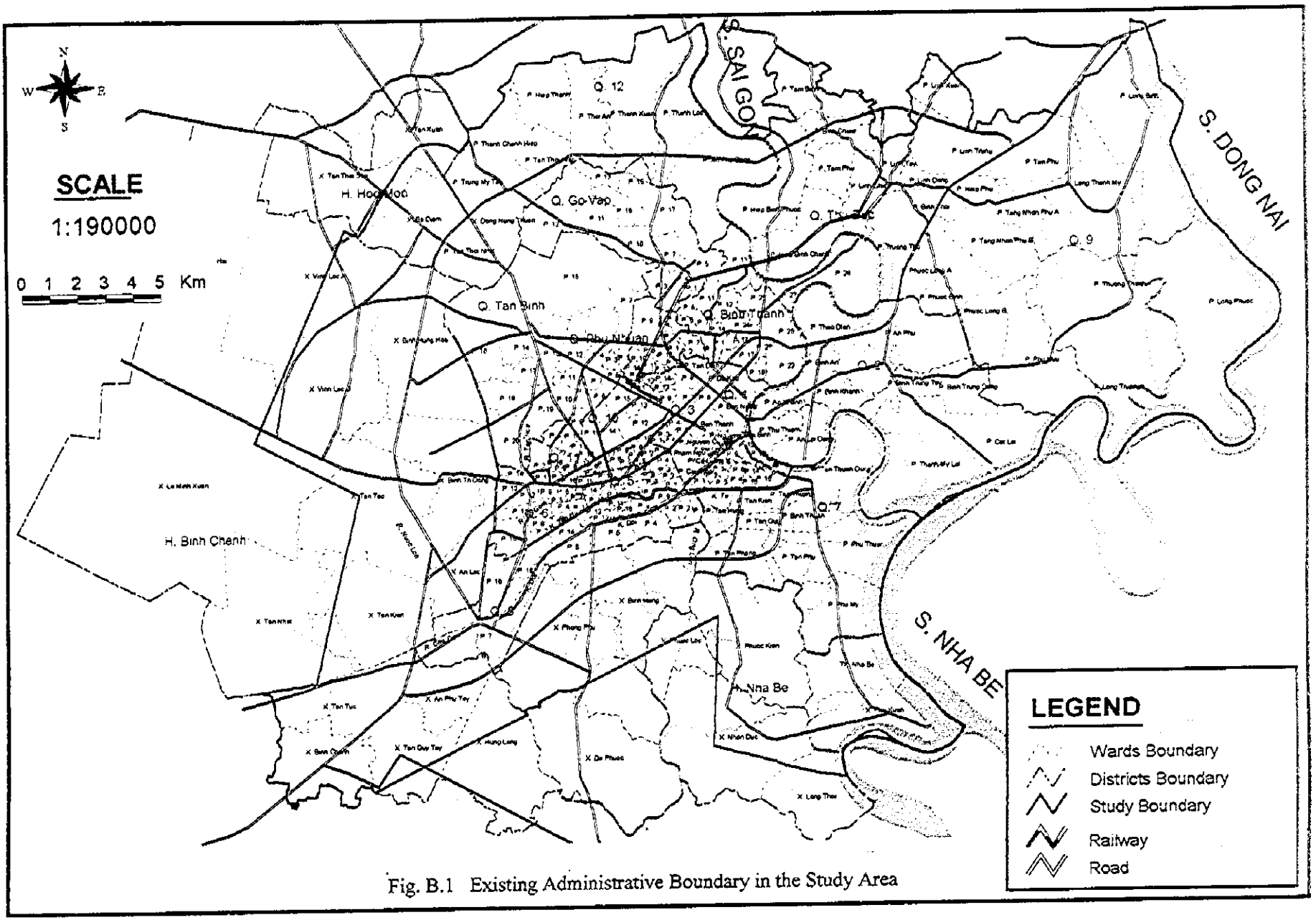


Fig. B.1 Existing Administrative Boundary in the Study Area

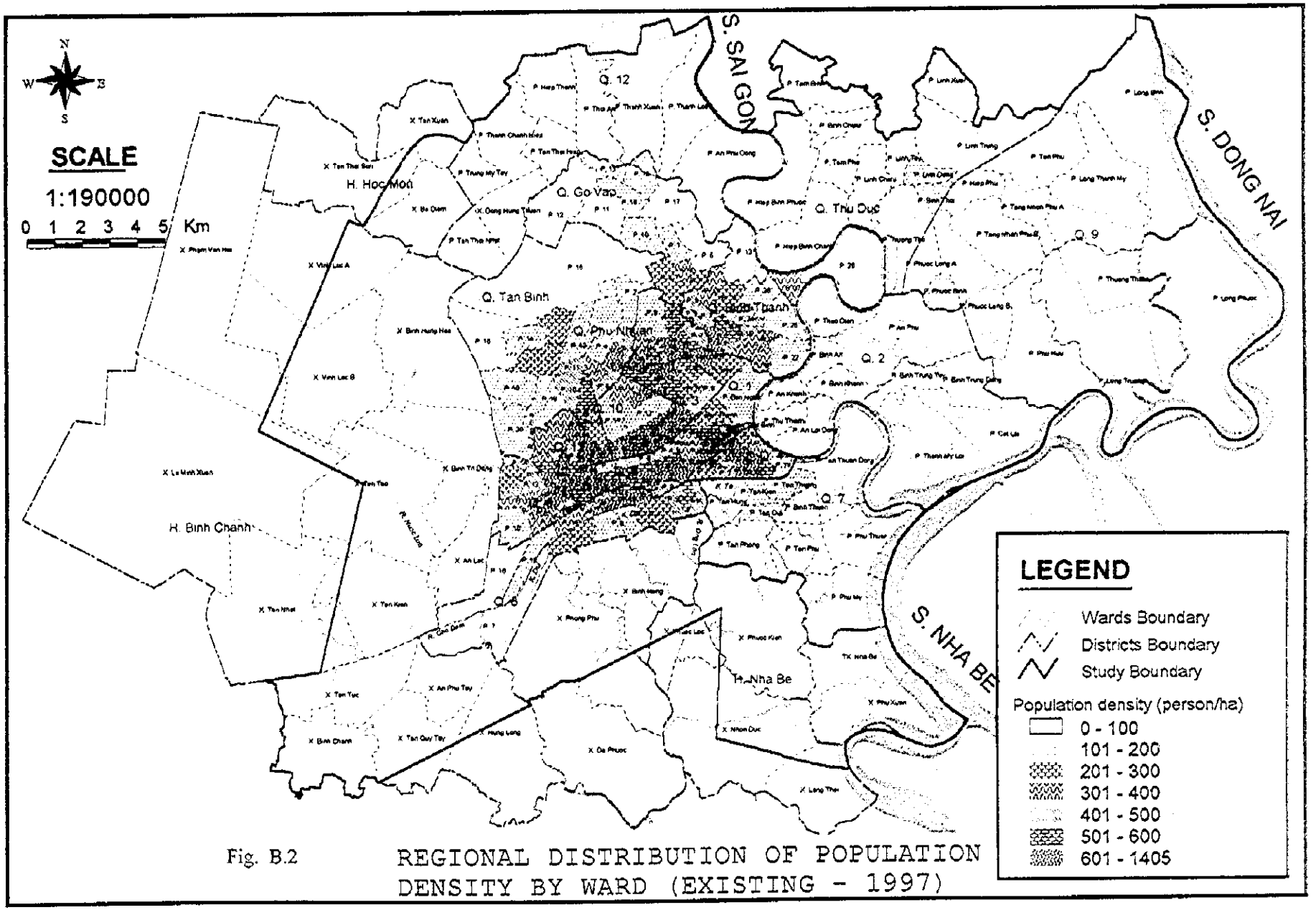


Fig. B.2 REGIONAL DISTRIBUTION OF POPULATION DENSITY BY WARD (EXISTING - 1997)

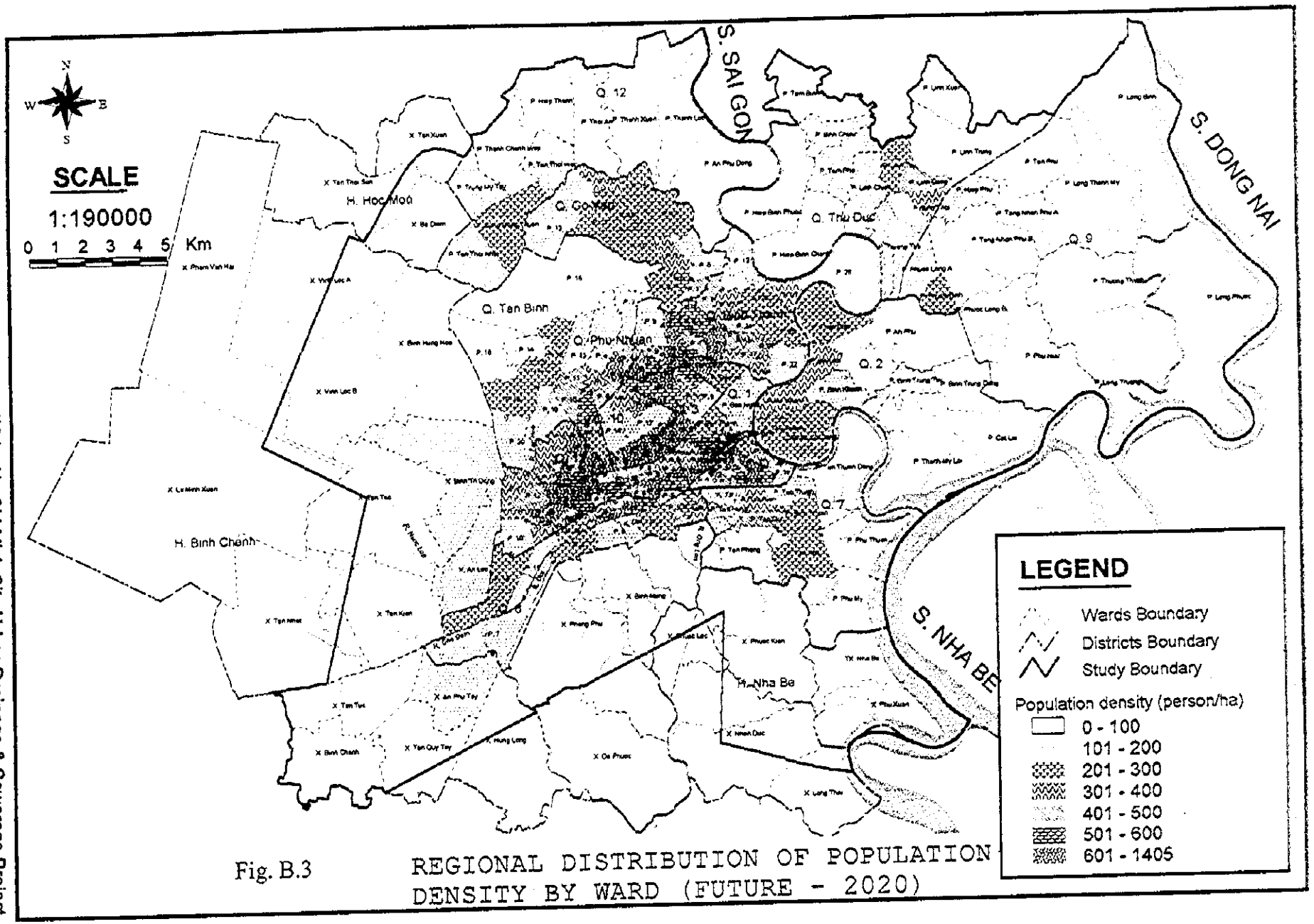


Fig. B.3 REGIONAL DISTRIBUTION OF POPULATION DENSITY BY WARD (FUTURE - 2020)

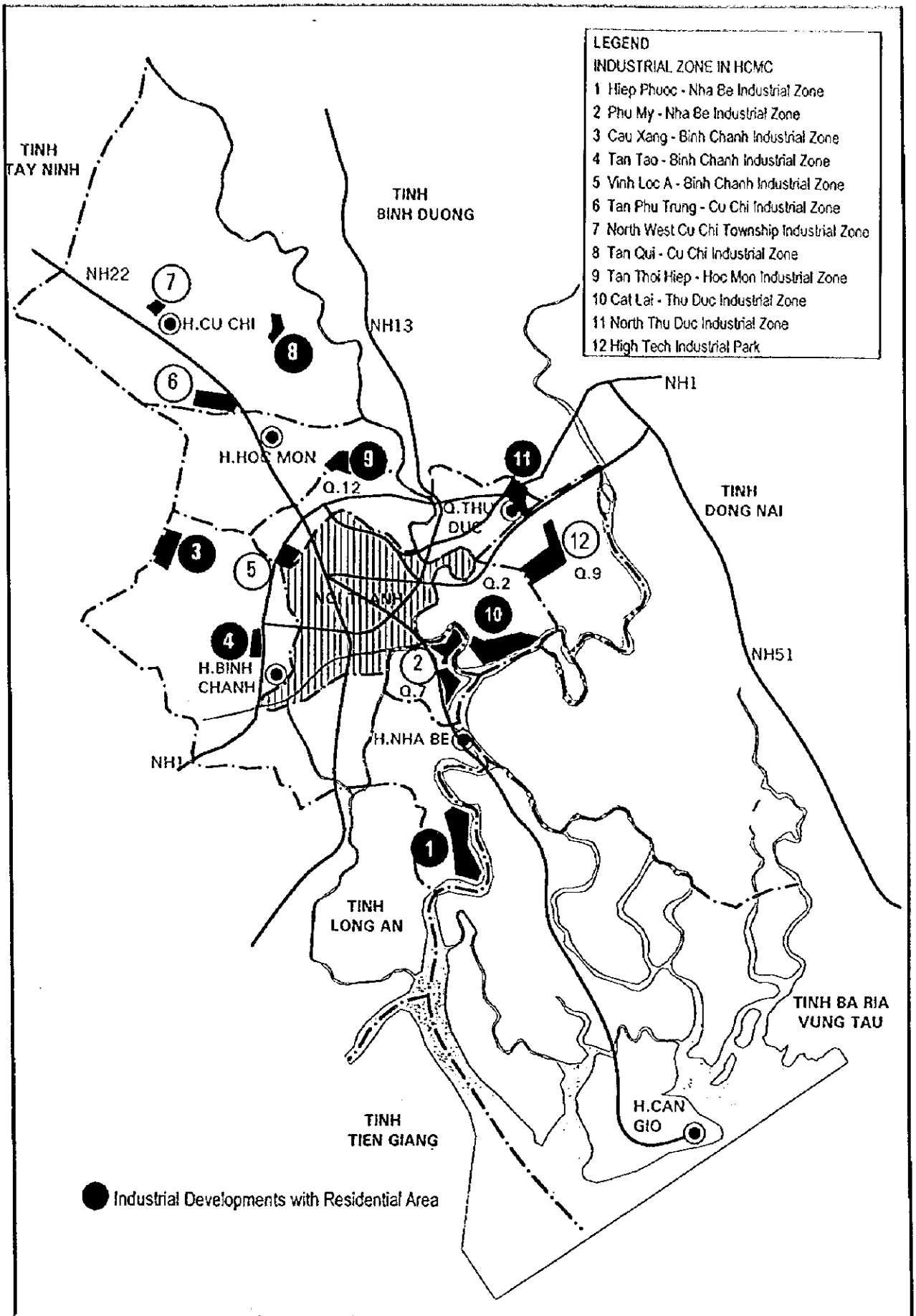


Fig. B.4 Industrial Zone Development Plans In HCMC

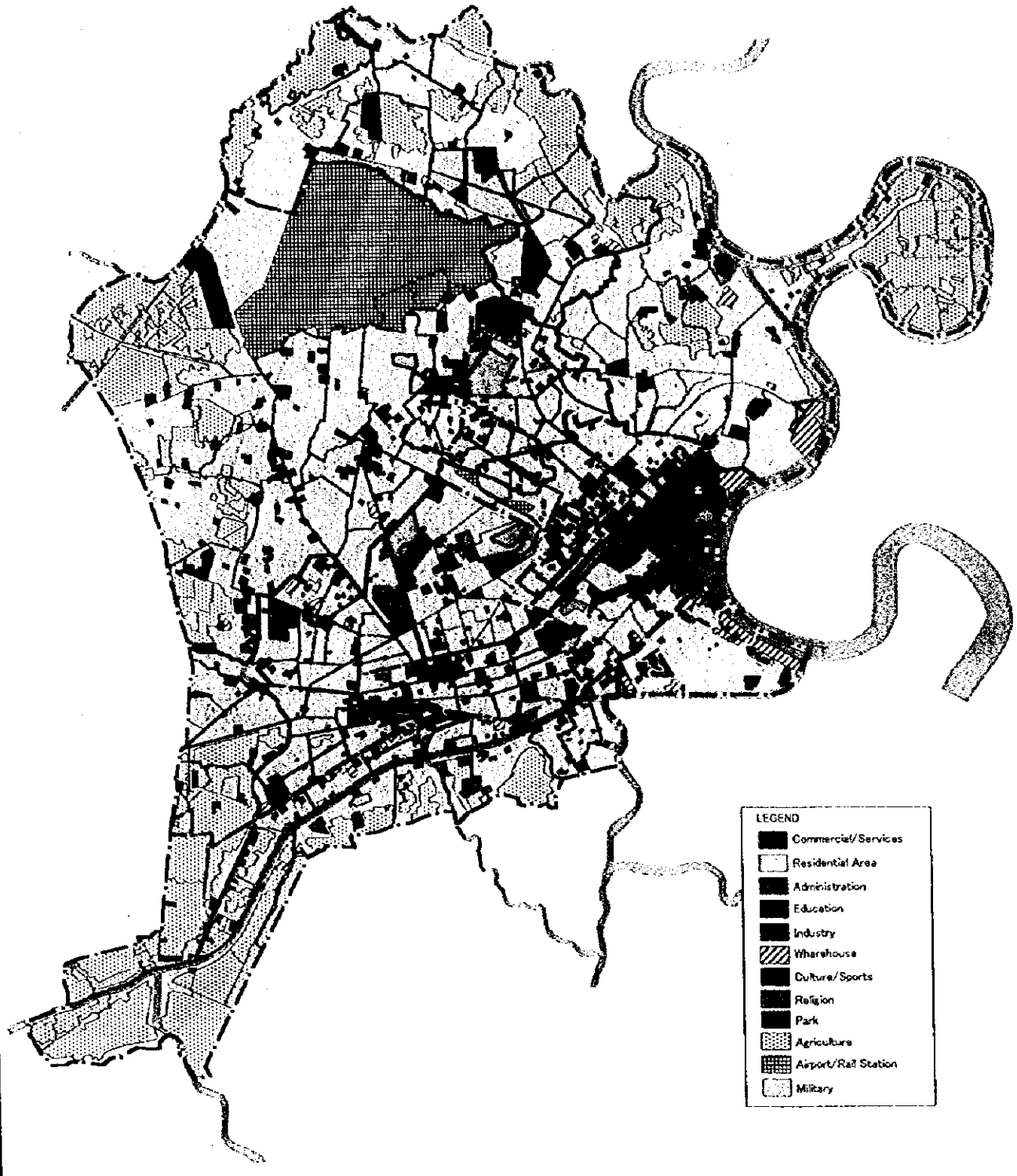


Fig. B.5 **EXISTING LAND USE (INNER CITY)**

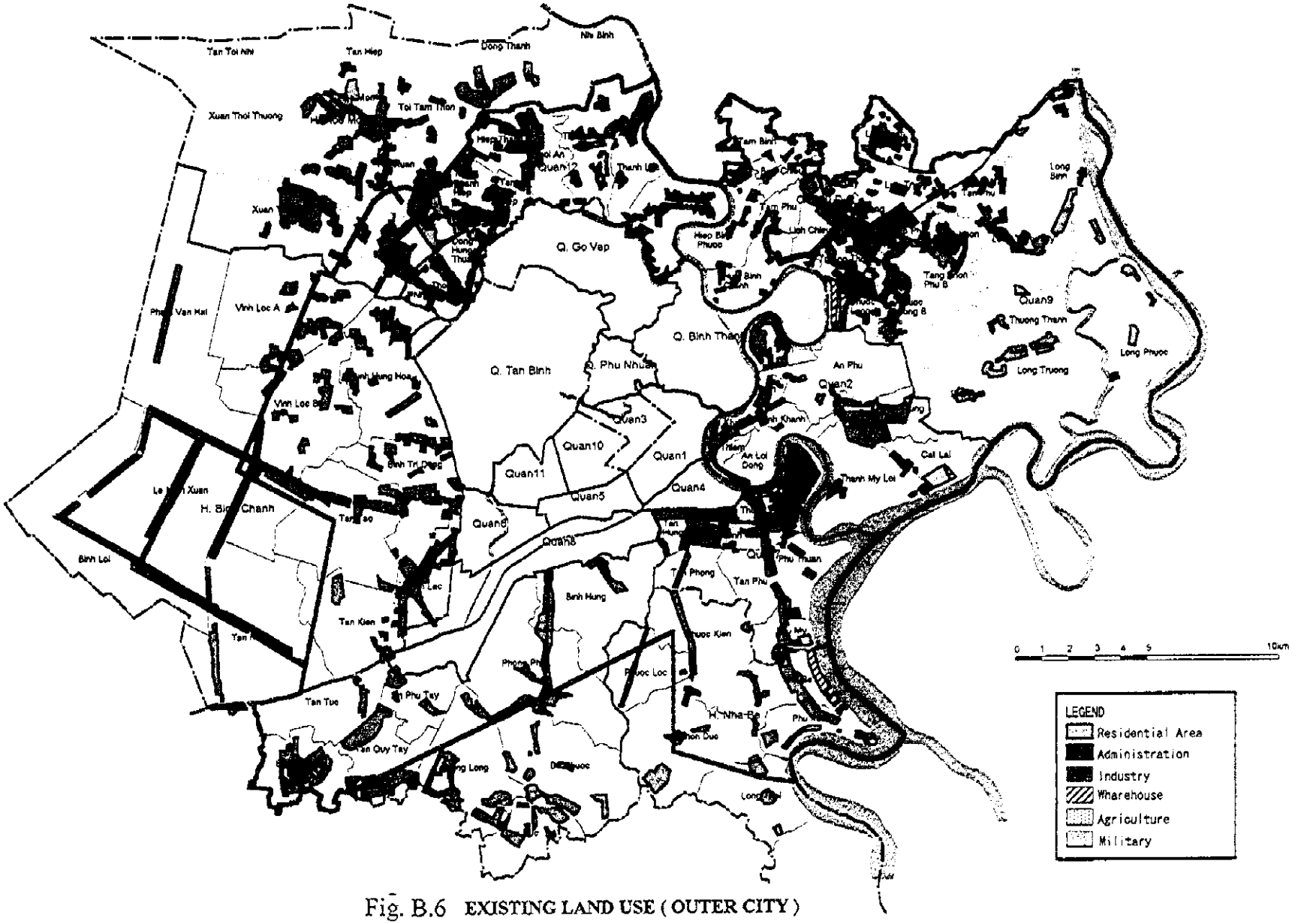
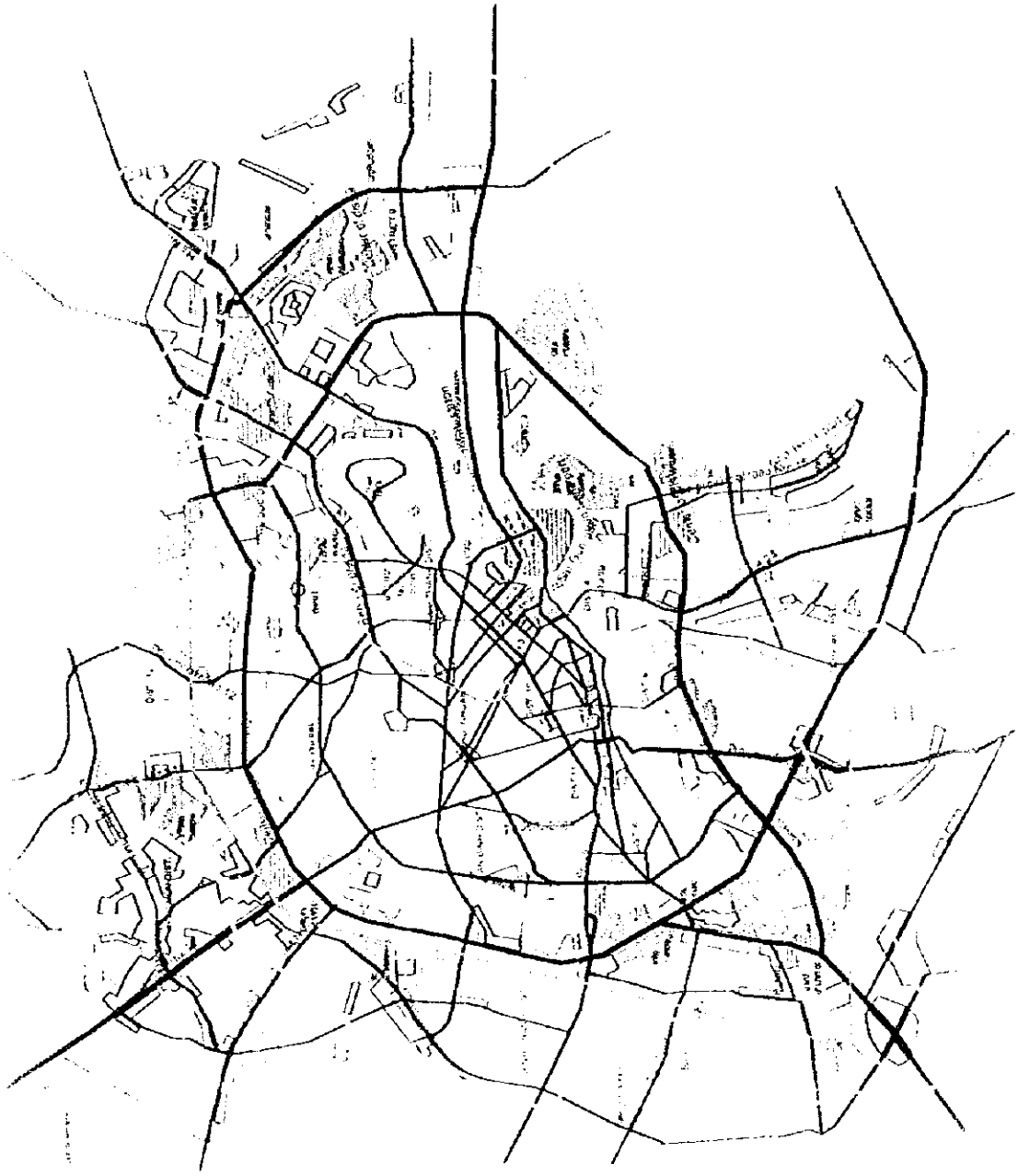


Fig. B.6 EXISTING LAND USE (OUTER CITY)

Fig. B.7 FUTURE LAND USE



APPENDIX C
METEOROLOGY AND HYDROLOGY

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APPENDIX C METEOROLOGY AND HYDROLOGY

This chapter presents the results on meteo-hydrological analysis and hydrodynamic modeling. Previous studies have been reviewed, raw data on meteo-hydrology have been collected and detailed meteo-hydrological and hydraulic analyses have been carried out using the collected raw data, utilizing Geographical Information System (GIS) database developed during the JICA Study and applying one-dimensional unsteady river flow modeling software called "MIKE 11".

1. MONITORING NETWORK ON METEO-HYDROLOGY

Rainfall data have been collected at seven stations located in and around the Study area. The seven stations are at: Tan Son Nhat (TSN), Hoc Mon, Le Minh Xuan, Binh Chanh, Nha Be, Ha Tien cement factory and Long Son. Among them, only Tan Son Nhat station is of automatic type and the rest are of manual type. As such, daily rainfall data have been collected from all the seven stations and short duration rainfall data has been collected from Tan Son Nhat station. Detailed listing of the rainfall stations is presented in Table C.1.1 Locations of the rainfall stations along with areas of Thiessen polygons represented by each station are shown in Fig. C.1.1 It can be seen that distribution of rainfall stations in the study area is too scarce.

Water level data have been collected at five stations located on rivers flowing through and around the Study area. Among them, three stations are of automatic type, which are at: Phu An on Saigon river, Nha Be on Nha Be river and Bien Hoa on Dong Nai river. The rest two stations are of manual type, which are at: Thu Dau Mot on Saigon river and Ben Luc on East Vam Co (Vam Co Dong) river. Only Phu An and Nha Be stations lye within the Study area. There exist no permanent water level station on any canal. Detailed listing of the water level stations is presented in Table C.1.2 and locations of the water level stations are shown in Fig. C.1.1

Bar charts of collected data on rainfall and water level are presented in Table C.1.3 and C.1.4 respectively.

2. GENERAL METEOROLOGICAL CONDITION

General meteorological condition at Tan Son Nhat is shown in Fig. C.2.1 Annual total rainfall is 1,929 mm. There are two distinct seasons : wet season (May to November with rainfall amounting to 1,788 mm or 93% of annual total) and dry season (January to March with rainfall amounting to 18 mm or 1% of annual total) with December and April as the transition months. Maximum rainfall (308 mm) occurs in the month of August and minimum rainfall (2 mm) occurs in the month of February. Annual average temperature and relative humidity are 27.4°C and 77.2% respectively. Annual total sunshine-hour is 2,508, which represents about 29% time of a year.

3. ANALYSES ON RAINFALL

3.1 Probability Analyses on Annual Maximum Daily Rainfalls

Annual maximum daily rainfall amounts with dates are presented in Table C.3.1. At Tan Son Nhat station, data has been collected for the period 1952-1997 and is presented in Table C.3.2. Table C.3.1 shows that amounts as well as dates of annual maximum daily rainfalls at different stations for a particular year are quite different, which implies that spatial as well temporal distribution of annual maximum daily rainfalls over the Study area is likely to be non-uniform.

Probability analysis has been carried out on annual maximum daily rainfalls at the seven stations. Gumbel's distribution method has been applied and the goodness of fit for the probable maximum daily rainfall by Gumbel's distribution has been checked against Thomas (or Weibull's) plotting position formula. The probability plots for six stations are shown in Fig. C.3.1. For Tan Son Nhat station, it is shown in Fig. C.3.4. The results of probability analysis are presented in Fig. C.3.2. It can be seen that Gumbel's distribution gives comparable fits with Thomas plots. Probable maximum daily rainfalls at Tan Son Nhat station for 2, 3, 5 and 10 year return periods are estimated to be about 92, 102, 114 and 128 mm respectively. It can be seen that, compared to probable maximum daily rainfalls at Tan Son Nhat station, that of at Binh Chanh, Ha Tien and Long Son stations vary considerably for higher return periods.

3.2 Correlations on Daily Rainfalls

Correlations on daily rainfalls between Tan Son Nhat station and the six other stations have been investigated using data for two years - 1994 and 1996. The result is shown in Fig. C.3.3. It can be seen that poor correlation exists between Tan Son Nhat and the other stations. Correlation coefficients are quite low for Nha Be (0.32) and Binh Chanh (0.33) stations, less than 0.5 for Le Minh Xuan (0.41), Long Son (0.45) and Hoc Mon (0.48) stations and above 0.5 for Ha Tien (0.64) station.

3.3 Probability Analyses on Annual Maximum Rainfalls at TSN

Annual maximum short and long duration rainfall data at Tan Son Nhat station is presented in Table C.3.2. The values for 15 minutes up to 24-hour represent annual maximum rainfalls from single rainfall events whereas the values for daily rainfalls represent annual maximum rainfalls from compound rainfall (single or multiple) events. It can be seen that most of the annual maximum single rainfall events have durations of 3 to 6 hours and almost no data is available on annual maximum single rainfall events lasting more than 6 hours that can be used for probability analysis. As such, probability analyses for rainfall events of more than 3 hours have been carried out using 6-hour and daily data on annual maximum rainfall.

Probability analyses on annual maximum short duration rainfall (from 15 minutes up to 180 minutes) and for long duration rainfall (from 3 hours up to 24 hours or daily) have been carried out using Gumbel's distribution method, which is widely used all over the world and is also in practice in Ho Chi Minh city (by Hydrological Sub-Institute of HCM city, 1989*). The goodness of fit by Gumbel's distribution has been checked against Thomas (Weibull's) plotting position formula and is shown in Fig. C.3.4. It can be seen that Gumbel's distribution gives comparable fits with Thomas plots. The results of probability analysis are summarized in Table C.3.3. Probable maximum rainfall intensities for 2, 3, 5 and 10 year return periods are estimated to be about 64, 72, 80 and 91 mm/hr respectively.

3.4 Intensity-Duration-Frequency Curves at Tan Son Nhat

At present, there exist two sets of Intensity-Duration-Frequency (IDF) curves at Tan Son Nhat that are in practice in Ho Chi Minh city which are: IDF curves up to 3 hours rainfall duration prepared by Hydrological Sub-Institute, HCMC (KTTV) using 1933-1989 data (Fig. C.3.5) and IDF curves from 3 hours to 24 hours rainfall duration prepared by Ministry of Construction, Hanoi (MOC) using 1953-1983 data (Fig. C.3.6). However, Asian Development Bank (ADB) has also published IDF curves up to 72 hours using 1956-1994 data. None of the above mentioned curves provide any equation and as such, inconvenient for runoff analysis using computer programming.

During this Study, based on the results of probability analysis using collected data ranging from 1952 to 1997, IDF curves have been constructed. To facilitate runoff analysis using computer programming, the best fit equation for the IDF curves has been investigated against three types of equations (Fig. C.3.7). They are the: Kimijima (Wenzel) type, Talbot type and Ministry of Construction, Hanoi (MOC) type equation. It is found that both the Kimijima type and MOC-Hanoi type equations give good fits to calculated values by Gumbel's method whereas Talbot type equation does not fit well. However, a closer look reveals that Kimijima type equation gives the best fit and is also of simpler form compared to MOC-Hanoi type equation. As such, Kimijima type equation is proposed for representing the IDF curves. Since, a single curve does not represent well for rainfall duration up to 24 hours, two sets of curves have been prepared: one set for rainfall duration up to 3 hours and another set for rainfall duration from more than 3 to 24 hours. Based on Kimijima type equation, proposed IDF curves have been compared with the existing IDF curves of KTTV, MOC and ADB (Fig. C.3.8). It can be seen that the proposed IDF curves give comparable and (under most situations) conservative values. The final proposed IDF curves with equations up to 3 hours and from more than 3 to 24 hours are shown in Figs. C.3.9 and C.3.10 respectively.

* Research the drainage capacity and measure to prop up the flood and wastewater pollution for the inner city area of Ho Chi Minh City, Hydrological Sub-Institute, 1989.

3.5 Design Rainfall Hyetographs at Tan Son Nhat

In order to select the duration and rainfall pattern for design rainfall hyetographs, mass curves of ten recent (1983-1998) daily high rainfall events at Tan Son Nhat station (with daily total rainfall amounting 100 mm to more than 100 mm representing return periods lying within 5 to 10 years) have been investigated (Fig. C.3.11 - the top figure). It can be seen that rainfall is intense during the first three hours and it almost ends up within six hours. As such, six hours has been selected as the duration for design rainfall hyetograph To be on conservative side, total amount of rainfall in six hours has been taken to be equal to daily total rainfall. The non-dimensional 6-hour mass curves, expressed as cumulative percent of rainfall in six hours is shown in Fig. C.3.11 (the bottom figure) . From non-dimensional mass curves, two patterns of mass curves have been identified. They are the frontal type and the centered type, as shown in Fig. C.3.11 (the bottom figure) . Compared to centered type rainfall, the frontal type rainfall would have a stronger impact on urban drainage facilities like pumping stations. As such, frontal type rainfall pattern is selected for construction of design rainfall hyetographs. The proposed design rainfall hyetographs for different return periods are shown in Fig. C.3.12.

3.6 Areal Reduction Factor

As discussed in article 3.1, rainfall distribution in the Study area is likely to be non-uniform. Therefore, areal reduction factor for point rainfall has been investigated. Tan Son Nhat is the only rainfall station in and around the Study area where short duration rainfall is available. At other stations, only daily rainfall is available. Also, the rainfall stations are too scarcely distributed in the Study area. Tan Son Nhat station itself represents a Thiessen Polygon area of 161 km^2. As such, it is quite difficult to carry out a detailed analysis on areal reduction factor for point rainfall.

Ministry of Construction (MOC) has specified areal reduction factors for catchment size up to 40 km^2 (Fig. C.3.13 - the top figure). However, the source data or the methodology couldn't be traced out. Based on correlation equations of daily rainfall between Tan Son Nhat and other six stations (Fig. C.3.3) and using Thiessen polygon areas for the seven stations, areal reduction factors for the Study area up to catchment size of about 580 km^2 have estimated (Fig. C.3.13 - the bottom figure). A comparison between the two curves of Fig. C.3.13 implies that the areal reduction factors specified by MOC are over-conservative. Since, the maximum sub-catchment size in the Study area is about 110 km^2 (Rach Tham Luong – Rach Ben Cat), the areal reduction factors specified by MOC have been updated using the same values but extending the catchment size up to 110 km^2 instead of 40 km^2 (using a catchment ratio of 110/40). The updated values have been fitted by a polynomial curve for use in runoff analysis. Even though, areal reduction factor curve is a function of rainfall duration and return period, considering non-availability of adequate data and simplicity in runoff analysis, a

single areal reduction factor curve has been proposed. The proposed areal reduction factor curve with equation is shown in Fig. C.3.14.

4. ANALYSES ON WATER LEVEL

4.1 Monthly Variations in Water Levels

Monthly variation in average maximum, minimum and mean water levels at five stations are shown in Fig. C.4.1. It can be seen that water levels are high during the months of October to January with the highest water levels occurring in the month of October. Water levels are low during the months of February to August with the lowest water levels occurring in the months of June-July. Average of monthly maximum water levels at Phu An and Nha Be stations in the month of October are calculated to be EL. 1.39 and 1.47 m respectively. It can be seen that mean water level at Bien Hoa is comparatively high, probably due to effect of high upstream discharge.

4.2 Correlations on Daily Mean Water Levels

Correlations on daily mean water levels between Phu An station and the four other stations have been investigated using data for different months during the period 1990 to 1997. The results are shown in Fig. C.4.2. It can be seen that excellent correlation exists between Phu An - Nha Be and Phu An - Thu Dau Mot stations (correlation coefficient is 0.99 for both stations). Correlation coefficient for Phu An - Ben Luc stations is also high (0.94) whereas correlation coefficient for Phu An - Bien Hoa stations is quite low (0.81).

4.3 Probability Analyses on Annual Maximum and Minimum Water Levels

Gumbel's distribution method has been applied for probability analysis and the goodness of fit has been checked against Thomas plotting position formula. Probability plots for maximum and minimum water levels at the five stations are shown in Figs. C.4.3 and C.4.4 respectively. Probable maximum and minimum water levels at the five stations are presented in Tables C.4.1 and C.4.2 respectively. Comparison has been made with published values by Hydrological Sub-Institute HCMC, 1990 and Asian Development Bank, 1998. It can be seen that the maximum water levels calculated by the JICA Study Team are relatively higher and are on conservative side. Probable maximum water levels at Phu An for 2, 3, 5 and 10 year return periods are estimated to be EL. 1.42, 1.45, 1.48 and 1.51 m respectively. Probable minimum water levels at Phu An for 2, 3, 5 and 10 year return periods are estimated to be EL. -2.09, -2.15, -2.23 and -2.33 m respectively.

Table C.4.1 shows that increase in probable maximum water levels at Thu Dau Mot, Phu An, Nha Be and Ben Luc stations from 2-year to 10-year return period are only 4, 9,

8 and 14 cm respectively, whereas, that at Bien Hoa station is as high as 27 cm, probably due to high discharge from upstream.

4.4 Design Water Level by Station

High rainfall is observed during the months of June to October with maximum rainfall occurring in the month of August (Fig. C.4.5 - upper left). High water levels are observed during the months of October to January with maximum water level occurring in the month of October (Fig. C.4.5 - lower left). Frequency histograms of annual maximum rainfalls and water levels (Fig. C.4.5 - upper right and lower right respectively) show that historical annual maximum rainfall events occurred in a scattered way during the months of May to October but historical annual maximum water level events occurred mainly during the months of October and November. From the above conditions, Design Flood Level (DFL) is inferred to be the average of monthly maximum water levels during the months of August to November (when both rainfall and water level are high). Table C.4.3 presents reference water levels at the five stations. High Water Level (HWL) represents average of annual maximum water levels. The proposed DFL and HWL correspond to return periods of 1 to 1.5 and almost 2 years respectively. DFLs' at Phu An and Nha Be stations are calculated to be EL. 1.31 and 1.36 m respectively. HWLs' at Phu An and Nha Be stations are calculated to be EL. 1.43 and 1.49 m respectively.

4.5 Design 24-Hour Water Level Profile by Station

Design 24-hour water level profile by station was established through the following two step investigations:

Step 1: Average variation in water level about the daily mean at Phu An station was calculated based on observed maximum water levels in October between 1993 and 1997 (Fig. C.4.6) and a 24-hour DFL profile was established.

Step 2: The 24-hour DFL profile at Phu An station, which was constructed in 1st step investigation, was compared with real time water level profiles with maximum water levels close to DFL occurring in the months of August to October between 1993 and 1997. As shown in Fig. C.4.7, the established 24-hour DFL profile fits quite well against the real time water level profiles.

Design 24-hour water level profiles at other stations were established as shown in Fig. C.4.8 to C.4.11, assuming that water level variations follow same pattern as that of at Phu An station.

4.6 Proposed Water Level by Reach

Water level profiles for the highest water level , high water level and design flood level along Saigon, Nha Be, Dong Nai and Ben Luc rivers have been investigated and is presented in Fig. C.4.12. It can be seen that DFL from Nha Be to Phu An station (27.22 km) along Nha Be – Saigon river varies by only 5 cm whereas DFL from Phu An to Thu Dau Mot station (40.41 km) along Saigon river, from Bien Hoa to Nha Be station (48.44 km) along Dong Nai – Nha Be river and from Phu An to Ben Luc station (42.64 km) along Ben Luc river vary by 9, 14 and 19 cm respectively. Considering direction of flow during high water level and variation in water level along the rivers, four reaches (along with southern boundaries) have been defined to simplify application of water levels for design purposes. The reaches are:

Reach 1: From confluence point of Rach Ba Hong with Saigon river to confluence point of Kinh Te with Saigon river (33.97 km).

Reach 2: From confluence point of Kinh Te with Saigon river to confluence point of Song Muong Chuoi with Nha Be river (27.83 km).

Reach 3: From confluence point of Saigon river with Nha Be river to (northern) confluence point of Song Tac with Dong Nai river (27.83 km).

Reach 4: From confluence point of Kinh Te (as well as Kinh Ben Nhge) with Saigon river to confluence point of Rach Ba Goc with Ben Luc river (15.65 km).

Southern Boundaries : The southern boundaries of Rach Can Giuoc and Rach Ba Lao.

The longitudinal water level profiles along Reach 1, 2 and 3 are steep only for the highest water levels. As for DFL profiles, the maximum differences in water levels along Reaches 1, 2, 3 and 4 are 7, 7, 8 and 7 cm respectively, therefore, representing a balanced water level distribution along the reaches under design condition.

Proposed water level by reach is presented in Tables C.4.4 to C.4.6. Proposed 24-hour design water level profile by reach is shown in Fig. C.4.13.

5. HYDROLOGICAL DATA ON RECENT FLOODS

Historically, big floods occurred in 1952 and 1978. As for recent years, flood occurred in 1994 and 1996. Hourly rainfall and water level data for 1994 flood (28th June) and 1996 flood (October) are presented in Figs. C.5.1 and C.5.2 respectively.

The return period of June 28, 1994 rainfall was 5-year for a 3-hour rainfall depth (93 mm as calculated from 15 minutes resolution data). It can be seen that the main reason of the June 1994 flood was due to coincidence of peak rainfall intensity (54 mm/hr as

calculated from 15 minutes resolution data) having a return period of 1.5-year with peak water levels having return periods of less than 1-year (EL. 1.01 m at Phu An station).

In 1996, flood occurred in the month of October and lasted for one month. Hydrological data for the two most critical conditions (October 13 -- 15 and 26 – 28) are presented in Fig. C.5.2. Even though, peak rainfall intensity was very little on October 14 (having return period of less than 1-year), but the flood stage was quite high during the whole period of October 14 - 15, having return periods lying between 2 to 10 years (EL. 1.43 m with 2-year return period at Phu An station). High water level on October 27 was the most critical, having return period of ≥ 10 years (EL. 1.51 m with 10-year return period at Phu An station) even though the rainfall intensity was quite small.

6. RUNOFF ANALYSES BY RATIONAL METHOD

The dimensions of the drainage canals have been defined following two steps:

Step 1: Design discharges (peak runoffs) and water levels along the canals have been calculated using Rational method and applying Manning's steady uniform flow formula, considering flow through each canal to be independent (discrete flow model). Existing flow capacities of the canals have been evaluated using Manning's formula. Based on design discharges and water levels, canal improvement plan has been proposed.

Step 2: Hydrodynamic simulation using MIKE 11 has been carried out to verify and modify, if necessary, the canal improvement plan proposed in Step 1. Interconnected canal network, runoff hydrograph from individual sub-catchment and water level boundary conditions at the canal outlets form the basis of hydrodynamic model.

6.1 The Rational Method

Peak runoffs from catchments have been estimated. The total drainage area has been divided into 6 zones with 47 catchments and 109 sub-catchments. Basin areas by zones, catchments and sub-catchments are shown in Fig. C.6.1 and listed in Table C.6.1. The total drainage area is 581.51 km^2.

Rational formula has been applied for calculating peak runoffs from the sub-catchments. Runoff equation by Rational formula is expressed by:

$$Q_p = (1/3.6) * C * (f * I) * A$$

where : Q_p => Peak runoff (m^3/s);
C => Runoff coefficient, depends on landuse condition as discussed later;

f => Areal reduction factor, depends on catchment size (refer to article 3.6);
I => Rainfall intensity (mm/hr) and
A => Catchment area (km^2).

Rainfall intensity, as expressed by the equations of the IDF curves is a function of time of concentration, T_c (minutes) which is expressed by:

$$T_c = T_i + T_f$$

where : T_i => Time of inlet (minutes) and
T_f => Time of flow (minutes).

T_i is a function of hydraulic length of overland flow (L_i), catchment slope and landuse condition.

Following the Design Criteria specified by Ministry of Construction, inlet time has been estimated considering three types of areas. They are:

(1) Urbanized area served by sewer :

$$T_i = T_0 + \alpha_1 (L_1 / v_1) + \alpha_2 (L_2 / v_2)$$

where : T_0 => overland flow time, a function of catchment slope and landuse condition (≈ 5 minutes);
α_1 => a coefficient, taking into account time delay due to overland flow storage (= 1.25);
L_1 => flow length over road drains up to manhole (≈ 20 m);
v_1 => velocity of flow through road drains (≈ 1.0 m/s);
α_2 => a coefficient, taking into account time delay due to pressure flow through sewers (= 2.0);
L_2 => length of sewer (m) and
v_2 => velocity of flow through sewers, a function of sewer slope and material (≈ 2.0 m/s).

(2) Urbanized area but not served by sewer :

$$T_i = T_0 + \alpha_1 (L_1 / v_1)$$

where : T_0 => overland flow time (≈ 5 minutes);
α_1 => a coefficient (= 1.25);
L_1 => hydraulic length of overland flow (m) and
v_1 => overland flow velocity, a function of catchment slope and landuse condition (≈ 1.0 m/s).

(3) Non-urbanized area :

$$T_i = T_0 + \alpha_1 (L_1 / v_1)$$

where : T_0 => overland flow time (≈ 10 minutes);
α_1 => a coefficient (= 1.25);
L_1 => hydraulic length of overland flow (m) and
v_1 => overland flow velocity (≈ 0.5 ~ 0.8 m/s).

T_f is given by:

$$T_f = L_f / v_f$$

where : L_f => flow length through the canal (m) and
v_f => flow velocity in the canal (m/s), a function of runoff, hydraulic gradient and canal section; an iterative procedure has been applied to estimate flow velocity through the canals.

6.2 Landuse Analyses and Estimation of Runoff Coefficients

Using Geographical Information System (GIS) database, landuse area by sub-catchment for existing and future (2020) landuse conditions have been estimated and are presented in Tables C.6.2 and C.6.3 respectively. Based on criteria selected for runoff coefficient by landuse category (Table C.6.4), runoff coefficients by zone, catchment and by sub-catchment have been estimated. Estimated runoff coefficients by sub-catchment under existing and future (2020) landuse conditions are presented in Table C.6.2 and C.6.3 respectively. Table C.6.5 presents estimated runoff coefficients by zones and by catchments along with urbanized and non-urbanized areas under existing and future landuse conditions. It can be seen that the existing runoff coefficients of different zones are expected to be increased by 10 to 25% in future except for the Central zone. Table C.6.5 also shows that for the drainage area as a whole, urbanized area is expected to be increased from about 30% at present to about 58% in future.

6.3 Alternative Study on Discharge from Rach Daihan

To evaluate discharge distributions of Rach Tham Luong – Rach Ben Cat and Kinh Chua – Rach Nuoc Len systems, two alternatives for outflow from Rach Daihan have been investigated. In Alternative 1, it is assumed that the outflow from Rach Daihan will be discharged into Rach Tham Luong – Rach Ben Cat system whereas in Alternative 2, it is assumed that the outflow from Rach Daihan will be discharged into Kinh Chua – Rach Nuoc Len system as shown in Fig. C.6.2. Peak runoff calculation by Rational Method for Alternatives 1 and 2 are presented in Tables C.6.6 and C.6.7 respectively. Calculated discharge distributions for the two alternatives are presented in Fig. C.6.3. Even though, the two alternatives give almost same discharge distribution,

Alternative 1 is more simple and close to natural flow. Therefore, Alternative 1 is selected as the optimum alternative.

6.4 Results of Runoff Analyses by Rational Method

Runoff calculation points along the canal systems (having multiple catchments) are shown over map in Fig. C.6.1 and as schematic ones in Fig. C.6.4. Applying Rational method, peak runoffs at the calculation points have been estimated for both existing and future (2020) landuse conditions. The results of runoff calculations are presented in Table C.6.8. Considering inundation along the upper reaches of Rach Ben Da – Rach Ba Hong and along Rach Daihan, reduced velocities due to flood plain storage have been applied for flow through those reaches. Without considering inundation along those reaches, flow velocities as well as discharges through those reaches and downstream would be higher, as shown in Table C.6.9.

6.5 Design Discharge Distributions of the Canals

Based on runoff calculation by Rational method as presented in Table C.6.8, design discharge distributions of the canals have been calculated and are presented in Table C.6.10 and Fig. C.6.5. For canal having drainage area of more than 30 km^2, a 10-year peak runoff and for that of less than 30 km^2, a 5-year peak runoff has been applied as design discharge. Detailed discussion on design scale is presented in Chapter E. Through evaluation on the existing capacities of the canals by Manning's steady flow formula and comparing them with design discharges as calculated by Rational method, canal improvement plan has been proposed (refer to Table E.6.15 of Chapter E).

7. HYDRODYNAMIC (HD) MODELING

As discussed above, the objective of hydrodynamic modeling was to finalize the canal improvement plan proposed in Step 1. As such, simulation has been carried out only for the proposed canal improvement plan. Since, in the Study area, there exists no monitoring network on water level along any of the canal and also, no complete information on flooded area and depth are available during any of the past big flood event, calibration of the developed hydrodynamic model couldn't be carried out. However, for developing the hydrodynamic model, carefully selected hydrologic and hydraulic parameters have been applied through consultation with standard approaches, reviewing previous and on-going studies and verifying specific runoff.

7.1 Methodology and Software

The canal systems in the Study area comprise of a highly complex network. Two integrated hydrodynamic models have been for the interconnected canal networks. Danish Hydraulic Institute's widely used river flow simulation software called "MIKE 11" has been used for hydrodynamic modeling of the canal networks.

MIKE 11 is a modular software for rainfall-runoff, hydrodynamic and water quality simulation where results from rainfall-runoff model can automatically be linked with hydrodynamic model. The hydrodynamic module in MIKE 11 applies an implicit finite difference scheme for simulating fully dynamic wave expressed by Saint-Venant's equation. Dynamic effect of hydraulic structures like pumping stations, gates as well flood plain storages can also be modeled using MIKE 11.

7.2 HD Model Networks

Hydrodynamic simulations have been carried out for two canal systems, namely the Western and the Eastern canal systems as show in Fig. C.7.1 (over map as well as schematic ones). Proposed canal improvement plan, consisting of both existing and proposed sections (refer to Table E.6.15 of Chapter E) has been used to set up the HD models.

Western Canal System : This system comprises interconnected main canals in the Northern, Western, Central and Southern zones. HD model has been set up for a total length of about 130 km consisting of 21 branches and 18 nodes. A flood plain for a length of 3.46 km with a total storage area of about 5 km^2 has been set up along the low-lying area of Kinh Chua. Detailed analysis on flood plain storage along Daihan canal has been carried out separately and is presented in article 8. As such, Daihan canal has not been included as a branch in the HD model network, instead, outflow hydrograph from Daihan canal has been inputted as lateral inflow to the Tham Luong – Ben Cat canal.

Eastern Canal System : This system comprises interconnected main canals in the North-Eastern and South-Eastern zones. HD model has been set up for a total length of about 40 km consisting of 8 branches and 8 nodes.

7.3 Rainfall Hyetographs

To be consistent with rainfall intensities as used in Rational method, 24-hour storm centered rainfall hyetographs, constructed from intensity-duration-frequency (IDF) curves have been used. Simulation has been carried out for 5-year and 10-year return periods. The rainfall hyetographs applied in the hydrodynamic model development are shown in Fig. C.7.2.

7.4 Runoff Hydrographs

Runoff hydrographs from the sub-catchments comprise of two units:

Excess Rainfall Unit : Excess rainfall hyetographs (= design rainfall hyetograph – loss) have been constructed by applying Proportional Loss method, where the loss is expressed by unity minus runoff coefficient, same as in Rational method. Runoff coefficient for individual sub-catchment under future landuse condition (except for catchment NE.5) has been used. For catchment NE.5, onsite storage pond (through landuse regulation) has been proposed to keep runoff same as existing runoff (refer to article 8 for detailed description).

Unit Hydrograph Unit : From the excess rainfall hyetographs, runoff hydrographs have been constructed applying unit hydrograph method. For shape of unit hydrograph, dimensionless unit hydrograph prepared by Soil Conservation Service (SCS) of U.S. Department of Agriculture, which is widely applied all over the world, has been used. Since, sizes of the sub-catchments are quite small, lag time for individual sub-catchment is assumed to be the same as time of concentration, as calculated following the method described in article 6.1.

Runoff hydrographs from a total 54 and 15 sub-catchments with total catchment areas of about 307 and 114 km^2 have been inputted into the HD models for Western and Eastern canal systems respectively. Runoffs from the uppermost sub-catchments and from lateral tributaries to the main canals have been set up as point runoffs whereas runoffs from sub-catchments having no specific discharge point have been set up as distributed runoffs. The basin parameters are listed in Table C.7.1.

7.5 Water Level Boundary Conditions

There are 6 water level boundaries for both Western and Eastern canal systems. HD simulation has been carried out for two scenarios:

Scenario 1: Static (constant) water level boundaries specified by design flood levels as shown in Fig. C.7.2, have been applied. This scenario represents the most critical condition.

Scenario 2: Dynamic water level boundaries (24-hour water level variations as shown in Fig. C.7.2) with maximum water levels same as design flood level have been applied. This scenario represents a situation more close to reality.

7.6 Hydraulic Parameters

Simulation has been carried out for a total duration of 24 hours using a time step of 15 seconds and space steps of 10 to 50 m. Manning's roughness coefficients, as listed in the proposed canal improvement plan (refer to Table E.6.15 of Chapter E) have been applied. For flood plain along Kinh Chua, Manning's roughness coefficient of 0.10 has been applied.

7.7 Results of HD Modeling

Western Canal System

The results are summarized in Table C.7.2. A look into the results on water level under Scenario 1 indicates that except Tham Luong – Ben Cat canal system (Northern zone), a design free board of 40 cm can be maintained along all the canals under the proposed canal improvement plan. The free board along Tham Luong – Ben Cat canal system, as obtained from HD model, varies from 30 to 40 cm. The most critical location is the junction of Tham Luong canal with Ben Cat canal and just downstream of it. Survey data shows that existing canal width, at just downstream of the junction varies from 72 to 76 m which is larger than the proposed canal width of 58.5 m. Existing canal sections at the most downstream portion of Tham Luong – Ben Cat canal is also wider (canal width varies from 67 to 76 m) and deeper, compared to proposed canal sections. Hydrodynamic simulation for Scenario 1 using the wider and deeper existing canal sections shows that free board along Tham Luong – Ben Cat canal can be raised by a maximum of 5 cm from the free board presented in Table C.7.2.

Under Scenario 2, HD simulation results (Table C.7.2) indicate that a design free board of 40 cm can be maintained along all the canals with the proposed canal improvement plan. Simulated maximum water level profiles along Nuoc Len – Kinh Chua – 19 Thang 5 – Tham Luong – Ben Cat canal system and stage hydrographs at runoff point N.2.G on Tham Luong canal (just after junction with Ben Cat canal) for 10-year return period under Scenarios 1 and 2 are shown in Fig. C.7.3 and Fig. C.7.4 respectively.

A high freeboard of 71 cm under Scenario 1 at the downstream runoff point of reach C.3.A (Table C.7.2) implies that the uppermost reach of Tan Hoa – Lo Gom canal can be more economized. Hydrodynamic simulation with reduced section shows that only a marginal (2.5 m) reduction in canal width for that reach can be achieved to have a 40 cm freeboard. As such, the proposed canal improvement plan doesn't need to be modified.

Along the low-lying area of Kinh Chua, under Scenario 1, a maximum inundation depth of 61 cm is obtained. Simulation result under Scenario 2 indicates that the maximum duration of inundation can be up to 12 hrs (4 and 8 hrs during first and second cycles respectively) during a 10-year rainfall event. Stage hydrographs at runoff point W.1.B

on Kinh Chua (along flood plain) for 10-year rainfall event under Scenarios 1 and 2 are shown in Fig. C.7.5.

A look into the results on discharge (Table C.7.2) indicates that under Scenario 1, flow along almost all of the canal reaches in the Northern zone (except reach N.2.D2 on 19 Thang 5 canal), Central zone (except reach C.4.A1 on Tau Hu canal and reach C.4.A2 on Ba Tang canal) and Southern zone (except reach S.1.B3 on Xom Cui canal and reach S.1.C on Ba Lao canal) are uni-directional, whereas flow along all the canal reaches in the Western zone (except reach W.1.A on Tan Phu canal) are bi-directional. For canals with existing cross sections, simulated discharges through those canals represent canal capacities which are different from design discharges, which are peak runoffs from contributing sub-catchments as calculated by Rational method. For canals with proposed cross-sections, it is found that, simulated discharges are lower than design discharges (by Rational method) along the upper reaches whereas simulated discharges are higher than design discharges along the lower reaches (found only for long canals with large time of concentrations). This discrepancy is due to the difference in approaches between the two methods.

Under Scenario 2, flow along all the canal reaches are bi-directional. Discharge hydrographs at runoff points N.2.G and W.1.B for Scenarios 1 and 2 are shown in Fig. C.7.4 and C.7.5 respectively.

Eastern Canal System

The results are summarized in Table C.7.2. Simulation results show that under both Scenarios 1 and 2, a design free board of 40 cm can be maintained along all the canals under the proposed canal improvement plan. Simulated maximum water level profiles along Rach Go Cong – Song Tac system and stage hydrographs at runoff point SE.7.A on Chiec canal (just after junction with Ong Hong and Ong Kieu canals) for 10-year rainfall event under Scenarios 1 and 2 are shown in Fig. C.7.6 and Fig. C.7.7 respectively.

A look into the results on discharge (Table C.7.2) indicates that under Scenario 1, flow along Go Cong canal in the North-Eastern zone (NE.5) is uni-directional whereas canal reaches in the South-Eastern zone have a mixture of uni and bi-directional flow. Regarding discrepancy between simulated (from HD model) and design (by Rational method) discharges, the same discussion as mentioned above for the Western canal system also applies for the Eastern canal system.

Under Scenario 2, flow along all the canal reaches are bi-directional. Discharge hydrographs at runoff point SE.7.A for Scenarios 1 and 2 are shown in Fig. C.7.7.