Secondary & Tertiary	(ø150 - 300 mm)	:	97,220 m
Main Sewer	(ø350 - 800 mm)	:	10,940 m
Force Main	(ø500 mm x 2 units)	:	5,160 m
Total		:	113,320 m

Sewer length by diameter and by earth covering depth is shown in Table A.2.1.

The capacity of the proposed booster pump station is as follows.

- 31.7 m^3/min. x 37 m, one (1) place.

The capacity of the proposed three (3) manhole pumps are as follows.

- 4.08 m^3/min. for Main Sewer A-4
- 3.36 m^3/min. for Main Sewer C-1
- 4.14 m^3/min. for Main Sewer C-4

2.2 Urgent Plan

2.2.1 Selection of Sewerage Service Area

In the sewerage development of Sanur area, priority is given to the improvement of sanitary environments in the tourism area of 143.0 ha located along the beach.

Wastewater of the tourism area is collected by the entire section of main sewer C and part of the main sewer D. However, the above sections of the main sewers C and D cover not only the tourism area of 143.0 ha but also the residential area of 188.8 ha located between Bypass Sanur Rd. and D. Tamblingan Rd.

Hence, the area of 331.8 ha covering the entire C catchment zone and part of D catchment zone (sub-catchment area D-4) is selected as the urgent sewerage service area. Location of the urgent sewerage service area is shown in Fig. A.2.6.

The served population in 2000 is estimated to be 11,513.

2.2.2 Proposed Urgent Sewer Networks

(1) Collection System

Conventional collection system is applied for the whole urgent sewerage service area. Both toilet waste and gray water are collected by a separate collection system.

(2) Design Wastewater Discharge

Design wastewater discharge of the urgent sewerage service area of 331.8 ha is estimated to be 8,564 m^3/day in 2000.

This is estimated by adding up the wastewater generation of each sub-catchment area in 2000. Wastewater generation of each sub-catchment area is estimated by multiplying its own specific wastewater generation by each area. All generated wastewater is assumed to be discharged to the sewer.

The wastewater generation in 2000 by sub-catchment area and by source is shown in Table A.2.5.

(3) Urgent Sewer Networks

The urgent sewer networks has a total length of 42,190 m with the following break-down.

Secondary & Tertiary Sewers	(ø150 - 300 mm)	:	32,720 m
Main Sewer	(ø350 - 800 mm)	:	4,310 m
Force Main	(ø500 mm x 1 unit)	:	5,160 m
Total		:	42,190 m

Alignments of the urgent main sewers are shown in Fig. A.2.7.

For longitudinal profile of the urgent main sewers, refer to Fig. A.2.5.

Earth covering depth of the sewers ranges from 1.0 m to 7.5 m.

Sewer length by diameter and by earth covering depth is shown in Table A.2.6.

Two (2) manhole pumps are installed at the main sewers of C-1 and C-3-1. Their capacity are 2.44 m^3/min. and 2.93 m^3/min. respectively. A booster pump station with a capacity of 17.8 m^3/min. x 40 m is constructed.

Location of the manhole pumps and booster pump station is shown in Fig. A.2.7.

Table A.1.1 Sewerage Service Area & Served Population in Denpasar

Kelurahan & Desa		Administrative Area (ha)	Sewerage Development Area (ha)	Exclusive Area (ha)	Sewerage Service Area (ha)	Population in Kelurahan/Desa		Served Population in Sewerage Service Area			Population Density in Sewerage Service Area (person/ha)		
Code No.	Name					1990	2010	1990	2000	2010	1990	2000	2010
101	Dauh Puri	60	60	0	60	10,751	10,800	10,751	10,800	10,800	179.2	180.0	180.0
102	Dauh Puri Kaja	109	95	4 (*1)	91	10,234	15,200	8,920	11,100	13,200	98.0	122.0	145.1
103	Dauh Puri Kauh	190	125	2 (*2)	123	12,919	25,000	8,499	12,400	16,400	69.1	100.8	133.3
104	Dauh Puri Kangin	59	59	0	59	5,279	7,800	5,279	6,500	7,800	89.5	110.2	132.2
105	Dauh Puri Kelod	188	188	0	188	14,719	27,100	14,719	20,900	27,100	78.3	111.2	144.1
106	Pemecutan	194	194	1 (*3)	193	19,830	29,500	19,830	24,700	29,500	102.7	128.0	152.8
107	Pemecutan Kaja	385	175	1 (*4)	174	21,355	25,900	9,707	10,800	11,800	55.8	62.1	67.8
108	Pemecutan Kelod	450	152	2 (*5)	150	17,721	26,300	5,986	7,400	8,900	39.9	49.3	59.3
115	Ubung	103	14	0	14	6,928	9,100	942	1,100	1,200	67.3	78.6	85.7
117	Tegal Kerta	24	24	0	24	6,472	6,700	6,472	6,600	6,700	269.7	275.0	279.2
118	Tegal Harum	26	26	0	26	5,772	6,200	5,772	6,000	6,200	222.0	230.8	238.5
201	Dangin Puri	65	65	0	65	9,721	11,700	9,721	10,700	11,700	149.6	164.6	180.0
202	Dangin Puri Kauh	72	72	4 (*6)	68	4,503	9,400	4,503	7,000	9,400	66.2	102.9	138.2
203	Dangin Puri Kaja	142	142	0	142	11,125	19,000	11,125	15,100	19,000	78.3	106.3	133.8
204	Dangin Puri Kangin	75	75	6 (*7)	69	10,754	13,500	10,754	12,100	13,500	155.9	175.4	195.7
205	Dangin Puri Kelod	142	142	0	142	12,052	17,900	12,052	15,000	17,900	84.9	105.6	126.1
206	Sumerta	52	52	0	52	7,422	9,300	7,422	8,400	9,300	142.7	161.5	178.8
207	Sumerta Kauh	89	89	0	89	7,090	12,200	7,090	9,600	12,200	79.7	107.9	137.1
208	Sumerta Kaja	73	73	0	73	7,456	11,100	7,456	9,300	11,100	102.1	127.4	152.1
209	Sumerta Kelod	271	271	0	271	9,200	13,700	9,200	11,500	13,700	33.9	42.4	50.6
210	Kesiman	266	62	0	62	6,561	9,700	1,529	1,900	2,300	24.7	30.6	37.1
211	Kesiman Petilan	290	110	0	110	6,282	9,300	2,383	2,900	3,500	21.7	26.4	31.8
213	Tonja	230	86	0	86	9,257	13,800	3,461	4,300	5,200	40.2	50.0	60.5
305	Panjer	359	134	0	134	14,846	22,100	5,541	6,900	8,200	41.4	51.5	61.2
306	Sesetan	739	164	0	164	20,741	30,800	4,603	5,700	6,800	28.1	34.8	41.5
308	Pedungan	749	34	0	34	10,836	16,100	492	600	700	14.5	17.6	20.6
	Total	5,402	2,683	20	2,663	279,826	409,200	194,209	239,300	284,100	72.9	89.9	106.7

Note : Exclusive area :*1 is Niti Praja Park oh 2ha and Badung River of 2ha.
:*2,*3,*4,*5 are area of Badung River.
:*6 is Puputan Park of 4ha.
:*7 is Ngurah Rai Stadium of 6ha.

Table A.1.2 Length of Sewer Pipe by Diameter and by Earth Covering Depth of Denpasar (Alternative A)

Earth Covering Depth / Diameter	0 - 2 m (1.5 m)	2 - 4 m (3.0 m)	4 - 6 m (5.0 m)	6 - 8 m (7.0 m)	8 - 10 m (9.0 m)	10 m (10.0 m)	11 m (11.0 m)	12 m (12.0 m)	Pipe Length (m)
(Secondary & Tertiaty)									
150 mm	258,100								258,100
200 mm	102,100								102,100
250 mm	31,000								31,000
300 mm	27,200								27,200
Sub-total	418,400	---	---	---	---	---	---	---	418,400
(Main Sewer)									
350 mm	6,610	6,070	420						13,100
400 mm	820	2,450	800						4,070
450 mm	2,250	1,100	330						3,680
500 mm	3,570	1,550							5,120
600 mm	770	1,490	760	260	50				3,330
700 mm	2,030	1,170	2,040	300	60				5,600
800 mm		250	2,030	2,950	550				5,780
900 mm	170	30	1,650	320	510				2,680
1,000 mm	1,160			730	1,570				3,460
1,100 mm									---
1,200 mm		570	790	270	70				1,700
1,350 mm									---
1,500 mm						1,250			1,250
(Sub-total)	17,380	14,680	8,820	4,830	2,810	1,250	---	---	49,770
Siphon									
150 mm			50 (x 2 lines)						50
200 mm					50 (x 2 lines)	60 (x 2 lines)			110
250 mm			40 (x 2 lines)	40 (x 2 lines)					80
350 mm									---
400 mm									---
500 mm				40 (x 2 lines)					40
(Sub-total)	---	---	90	80	50	60	---	---	280
Sub-total	17,380	14,680	8,910	4,910	2,860	1,310	---	---	50,050
(Conveyance Sewer)									
1,500 mm						1,250	1,790		3,040
1,800 mm							1,350		1,350
Sub-total	---	---	---	---	---	1,250	3,140	---	4,390
Total (m)	435,780	14,680	8,910	4,910	2,860	2,560	3,140	---	472,840

Table A.1.3 Length of Sewer Pipe by Diameter and by Earth Covering Depth of Denpasar
(Alternative B)

Earth Covering Depth / Diameter	0 - 2 m (1.5 m)	2 - 4 m (3.0 m)	4 - 6 m (5.0 m)	6 - 8 m (7.0 m)	8 - 10 m (9.0 m)	10 m (10.0 m)	11 m (11.0 m)	12 m (12.0 m)	Pipe Length (m)
(Secondary & Tertiaty)									
150 mm	258,100								258,100
200 mm	102,100								102,100
250 mm	31,000								31,000
300 mm	27,200								27,200
Sub-total	418,400	---	---	---	---	---	---	---	418,400
(Main Sewer)									
350 mm	7,990	3,750	290						12,030
400 mm	2,450	2,180	290						4,920
450 mm	1,030	900	110						2,040
500 mm	860	770	470						2,100
600 mm	4,490	1,520	120						6,130
700 mm	3,560	1,720	1,830	320					7,430
800 mm	1,390	1,410			420	1,780			5,000
900 mm	1,480	640	1,660	180	970				4,930
1,000 mm			540	1,300	1,190	330			3,360
1,100 mm	580	500							1,080
1,200 mm									---
1,350 mm									---
1,500 mm					280	990			1,270
(Sub-total)	23,830	13,390	5,310	1,800	2,860	3,100	---	---	50,290
Siphon									
150 mm			60 (x 2 lines)						60
200 mm			40 (x 2 lines)		40 (x 2 lines)				80
250 mm						50 (x 2 lines)			50
350 mm				40 (x 2 lines)					40
400 mm			40 (x 2 lines)						40
500 mm				80 (x 2 lines)					80
(Sub-total)	---	---	140	120	40	50	---	---	350
Sub-total	23,830	13,390	5,450	1,920	2,900	3,150	---	---	50,640
(Conveyance Sewer)									
1,500 mm						1,270	840	930	3,040
1,800 mm								1,350	1,350
Sub-total	---	---	---	---	---	1,270	840	2,280	4,390
Total (m)	442,230	13,390	5,450	1,920	2,900	4,420	840	2,280	473,430

Table A.1.4 Length of Sewer Pipe by Diameter and by Earth Covering Depth of Denpasar (Alternative C)

Earth Covering Depth / Diameter	0 - 2 m (1.5 m)	2 - 4 m (3.0 m)	4 - 6 m (5.0 m)	6 - 8 m (7.0 m)	8 - 10 m (9.0 m)	10 m (10.0 m)	11 m (11.0 m)	12 m (12.0 m)	Pipe Length (m)
(Secondary & Tertiaty)									
150 mm	258,100								258,100
200 mm	102,100								102,100
250 mm	31,000								31,000
300 mm	27,200								27,200
Sub-total	418,400	---	---	---	---	---	---	---	418,400
(Main Sewer)									
350 mm	6,610	6,070	420						13,100
400 mm	820	2,450	800						4,070
450 mm	2,250	1,100	330						3,680
500 mm	3,570	1,550							5,120
600 mm	770	1,490	760	260	50				3,330
700 mm	2,030	1,170	2,040	300	60				5,600
800 mm	2,510	590	960	590					4,650
900 mm	280	230	1,650	320	200				2,680
1,000 mm	2,120	1,340							3,460
1,100 mm									---
1,200 mm		570	790	270	70				1,700
1,350 mm									---
1,500 mm	1,030	220							1,250
(Sub-total)	21,990	16,780	7,750	1,740	380	---	---	---	48,640
Siphon									
150 mm			50 (x 2 lines)						50
200 mm					50 (x 2 lines)	60 (x 2 lines)			110
250 mm			40 (x 2 lines)	40 (x 2 lines)					80
350 mm									---
400 mm									---
500 mm				40 (x 2 lines)					40
(Sub-total)	---	---	90	80	50	60	---	---	280
Sub-total	21,990	16,780	7,840	1,820	430	60	---	---	48,920
(Conveyance Sewer)									
1,500 mm	1,940	1,100							3,040
1,800 mm		1,350							1,350
Sub-total	1,940	2,450	---	---	---	---	---	---	4,390
(Force Main)									
350 mm	1,070 (x 2 lines)								1,070
Total (m)	440,390	16,780	7,840	1,820	430	60	---	---	472,780

Table A.1.5 Length of Sewer Pipe by Diameter and by Earth Covering Depth of Denpasar (Alternative D)

Diameter \ Earth Covering Depth	0 - 2 m (1.5 m)	2 - 4 m (3.0 m)	4 - 6 m (5.0 m)	6 - 8 m (7.0 m)	8 - 10 m (9.0 m)	10 m (10.0 m)	11 m (11.0 m)	12 m (12.0 m)	Pipe Length (m)
(Secondary & Tertiaty)									
150 mm	258,100								258,100
200 mm	102,100								102,100
250 mm	31,000								31,000
300 mm	27,200								27,200
Sub-total	418,400	---	---	---	---	---	---	---	418,400
(Main Sewer)									
350 mm	7,990	3,750	290						12,030
400 mm	2,450	2,180	290						4,920
450 mm	1,030	900	110						2,040
500 mm	860	770	470						2,100
600 mm	4,490	1,520	120						6,130
700 mm	3,560	1,720	1,830	320					7,430
800 mm	1,390	1,410		60					2,860
900 mm	1,480	950	2,440						4,870
1,000 mm		1,880	1,480						3,360
1,100 mm	580	500							1,080
1,200 mm									---
1,350 mm									---
1,500 mm		1,270							1,270
(Sub-total)	23,830	16,850	7,030	380	---	---	---	---	48,090
Siphon									
150 mm			60 (x 2 lines)						60
200 mm			40 (x 2 lines)		40 (x 2 lines)				80
250 mm						50 (x 2 lines)			50
350 mm				40 (x 2 lines)					40
400 mm			40 (x 2 lines)						40
450 mm				80 (x 2 lines)					80
(Sub-total)	---	---	140	120	40	50	---	---	350
Sub-total	23,830	16,850	7,170	500	40	50	---	---	48,440
(Conveyance Sewer)									
1,500 mm		2,720	320						3,040
1,800 mm			1,350						1,350
Sub-total	---	2,720	1,670	---	---	---	---	---	4,390
(Force Main)									
350 mm	1,070 (x 2 lines)								1,070
Total (m)	443,300	19,570	8,840	500	40	50	---	---	472,300

Table A.1.6 Served Population and Population Density of Sub-Catchment Area

Sub-Catchment Area	Service Area (ha)	Served Population			Population Density (person/ha)		
		1990	2000	2010	1990	2000	2010
A-1	27.2	2,279	2,835	3,373	83.8	104.2	124.0
A-2	123.4	9,833	13,099	16,305	79.7	106.2	132.1
A-3	29.2	2,552	3,439	4,302	87.4	117.8	147.3
A-4	12.9	1,320	1,673	2,017	102.3	129.7	156.4
A-5	8.1	1,141	1,280	1,424	140.9	158.0	175.8
A-6	35.1	3,153	4,101	5,086	89.8	116.8	144.9
A-7	37.5	3,702	4,432	5,160	98.7	118.2	137.6
A-8	64.4	9,509	10,249	10,972	147.7	159.1	170.4
A-9	19.9	1,858	2,331	2,806	93.4	117.1	141.0
A-10	51.9	2,450	3,292	4,128	47.2	63.4	79.5
A-11	30.7	861	1,065	1,271	28.0	34.7	41.4
A-12	52.2	1,462	1,813	2,162	28.0	34.7	41.4
Sub-total	492.5	40,120	49,609	59,006	81.5	100.7	119.8
B-1	39.7	2,376	2,696	2,942	59.8	67.9	74.1
B-2	52.3	2,916	3,242	3,550	55.8	62.0	67.9
B-3	39.9	2,227	2,478	2,705	55.8	62.1	67.8
B-4	190.4	17,355	20,989	24,548	91.2	110.2	128.9
B-5	115.1	11,211	13,271	15,310	97.4	115.3	133.0
B-6	143.6	12,624	13,924	15,245	87.9	97.0	106.2
B-7	29.4	2,031	2,964	3,922	69.1	100.8	133.4
B-8	65.6	4,397	6,405	8,463	67.0	97.6	129.0
B-9	59.8	4,764	5,968	7,186	79.7	99.8	120.2
B-10	41.2	892	1,100	1,302	21.7	26.7	31.6
Sub-total	777.0	60,793	73,037	85,173	78.2	94.0	109.6
C-1	31.0	3,038	3,782	4,498	98.0	122.0	145.1
C-2	47.3	3,624	5,121	6,566	76.6	108.3	138.8
C-3	42.5	3,599	4,743	5,875	84.7	111.6	138.2
C-4	51.9	4,670	5,840	7,059	90.0	112.5	136.0
C-5	109.0	11,008	13,790	16,575	101.0	126.5	152.1
C-6	98.3	6,154	8,585	11,021	62.6	87.3	112.1
Sub-total	380.0	32,093	41,861	51,594	84.5	110.2	135.8
D-1	10.7	1,252	1,434	1,622	117.0	134.0	151.6
D-2	53.7	5,894	7,029	8,177	109.8	130.9	152.3
D-3	26.6	3,587	4,160	4,748	134.8	156.4	178.5
Sub-total	91.0	10,733	12,623	14,547	117.9	138.7	159.9
E-1	32.2	1,466	1,819	2,201	45.5	56.5	68.4
E-2	41.1	2,662	3,304	3,963	64.8	80.4	96.4
E-3	40.6	2,662	3,317	3,965	65.6	81.7	97.7
E-4	87.3	8,290	10,528	12,793	95.0	120.6	146.5
E-5	47.0	3,507	4,442	5,355	74.6	94.5	113.9
E-6	15.9	1,350	1,679	2,005	84.9	105.6	126.1
Sub-total	264.1	19,937	25,089	30,282	75.5	95.0	114.7
F-1	35.4	764	931	1,128	21.6	26.3	31.9
F-2	77.4	1,688	2,055	2,476	21.8	26.6	32.0
F-3	44.4	1,345	1,634	1,944	30.3	36.8	43.8
F-4	28.1	3,775	4,314	4,814	134.3	153.5	171.3
F-5	84.0	5,452	6,411	7,310	64.9	76.3	87.0
F-6	88.3	2,999	3,748	4,462	34.0	42.4	50.5
F-7	54.3	1,856	2,320	2,763	34.2	42.7	50.9
F-8	91.8	4,459	5,560	6,636	48.6	60.6	72.3
F-9	15.6	646	803	955	41.4	51.5	61.2
F-10	139.1	7,549	9,305	11,010	54.3	66.9	79.2
Sub-total	658.4	30,533	37,081	43,498	46.4	56.3	66.1
TOTAL	2,663.0	194,209	239,300.0	284,100.0	72.9	89.9	106.7

Table A.1.7 Specific Wastewater Generation of Sub-Catchment Area

Sub-Catchment Area	Area (ha)	Specific Wastewater Generation (m3/ha/day)		
		1990	2000	2010
A-1	27.2	23.5	31.7	39.5
A-2	123.4	17.6	25.1	32.4
A-3	29.2	20.9	30.2	39.0
A-4	12.9	25.3	34.1	42.7
A-5	8.1	35.8	42.8	50.2
A-6	35.1	19.7	27.4	35.4
A-7	37.5	27.0	34.7	42.4
A-8	64.4	40.4	46.8	53.1
A-9	19.9	23.9	32.6	41.1
A-10	51.9	11.1	16.5	21.7
A-11	30.7	5.5	7.5	9.4
A-12	52.2	5.5	7.5	9.4
Sub-total	492.5	20.0	26.5	32.8
B-1	39.7	12.5	16.0	18.7
B-2	52.3	11.3	13.8	16.1
B-3	39.9	11.3	13.8	16.1
B-4	190.4	19.7	25.9	32.1
B-5	115.1	20.1	26.1	32.1
B-6	143.6	16.8	20.4	24.0
B-7	29.4	13.5	21.7	30.0
B-8	65.6	13.1	21.0	29.1
B-9	59.8	19.5	26.1	32.6
B-10	41.2	4.4	5.9	7.5
Sub-total	777.0	16.2	21.4	26.4
C-1	31.0	28.9	39.0	48.6
C-2	47.3	18.8	28.5	37.6
C-3	42.5	22.0	31.2	39.9
C-4	51.9	22.2	30.1	37.9
C-5	109.0	27.8	37.9	47.4
C-6	98.3	16.2	24.8	33.1
Sub-total	380.0	22.4	31.6	40.4
D-1	10.7	30.9	38.6	46.1
D-2	53.7	27.9	35.8	43.6
D-3	26.6	35.6	44.7	53.7
Sub-total	91.0	30.5	38.7	46.8
E-1	32.2	7.8	10.6	13.5
E-2	41.1	11.9	16.1	20.3
E-3	40.6	12.3	16.7	21.1
E-4	87.3	19.5	26.9	34.3
E-5	47.0	20.0	27.0	34.1
E-6	15.9	23.9	31.9	39.8
Sub-total	264.1	16.1	22.0	27.9
F-1	35.4	3.9	6.1	7.7
F-2	77.4	3.9	6.1	7.7
F-3	44.4	5.8	7.8	9.7
F-4	28.1	26.8	33.6	40.0
F-5	84.0	14.8	19.3	23.5
F-6	88.3	9.3	12.8	16.1
F-7	54.3	9.2	12.7	16.0
F-8	91.8	13.3	18.0	22.5
F-9	15.6	7.1	9.7	12.1
F-10	139.1	11.8	15.7	19.5
Sub-total	658.4	10.6	14.3	17.7

Table A.1.8 Service Area and Served Population by Collection System

Sub-Catchment Area	Service Area (ha)		Served Population in 2000	
	Conventional	Interceptor	Conventional	Interceptor
A-1		27.2		2,835
A-2		123.4		13,099
A-3	29.2		3,439	
A-4	12.9		1,673	
A-5	8.1		1,280	
A-6	35.1		4,101	
A-7	37.5		4,432	
A-8	64.4		10,249	
A-9	19.9		2,331	
A-10	51.9		3,292	
Sub-total	259	150.6	30,797	15,934
C-1		31		3,782
C-2		47.3		5,121
C-3	42.5		4,743	
C-4	51.9		5,840	
C-5	109.0		13,790	
C-6	98.3		8,585	
Sub-total	301.7	78.3	32,958	8,903
D-1	10.7		1,434	
D-2	53.7		7,029	
D-3	26.6		4,160	
Sub-total	91	0	12,623	0
E-4		87.3		10,528
E-5	47.0		4,442	
E-6	15.9		1,679	
Sub-total	62.9	87.3	6,121	10,528
TOTAL	714.6	316.2	82,499	35,365

Table A.1.9 Wastewater Discharge of Denpasar Urgent Sewerage Development Area in 2000

Sub-Catchment Area	Service Area (ha)		Wastewater Generation (m3/day)		Toilet Waste Generation in Interceptor Area (m3/day)	Wastewater Discharge (m3/day)
	Conventional Area	Interceptor Area	Conventional Area	Interceptor Area		
A-1		27.2		861	51	810
A-2		123.4		3,106	243	2,863
A-3	29.2		880			880
A-4	12.9		440			440
A-5	8.1		346			346
A-6	35.1		962			962
A-7	37.5		1,299			1,299
A-8	64.4		3,013			3,013
A-9	19.9		647			647
A-10	51.9		857			857
Sub-total	259	150.6	8,444	3,967	294	12,117
C-1		31		1,209	69	1140
C-2		47.3		1,347	96	1251
C-3	42.5		1,325			1,325
C-4	51.9		1,561			1,561
C-5	109.0		4,126			4,126
C-6	98.3		2,437			2,437
Sub-total	301.7	78.3	9,449	2,556	165	11,840
D-1	10.7		413			413
D-2	53.7		1,925			1,925
D-3	26.6		1,190			1,190
Sub-total	91	0	3,528	0	0	3,528
E-4		87.3		2,356	190	2166
E-5	47.0		1,270			1,270
E-6	15.9		507			507
Sub-total	62.9	87.3	1,777	2,356	190	3,943
TOTAL	714.6	316.2	23,198	8,879	649	31,428

Table A.1.10 Length of Sewer Line by Diameter and by Earth Covering Depth in Urgent Works of Denpasar

Diameter \ Earth Covering Depth	0-2m (1.5m)	2-4m (3.0m)	4-6m (5.0m)	6-8m (7.0m)	Total Length (m)
(Secondary & Tertiary)					
150 mm	77,300				77,300
200 mm	30,600				30,600
250 mm	9,300				9,300
300 mm	8,820				8,820
Sub-total	126,020	---	---	---	126,020
(Main Sewer)					
350 mm	750	280			1,030
400 mm					---
450 mm	340				340
500 mm	860		120		980
600 mm	920	750	40		1,710
700 mm	2,280	360			2,640
800 mm	1,390	970			2,360
900 mm	1,480	330	1,300		3,110
1,000 mm		540			540
1,100 mm	580	500			1,080
1,500 mm		1,270			1,270
Sub-total	8,600	5,000	1,460	---	15,060
<u>Siphon</u>					
350 mm				40 (x 2 Lines)	40
400 mm			40 (x 2 Lines)		40
Sub-total	---	---	40	40	80
Sub-total	8,600	5,000	1,500	40	15,140
(Conveyance Sewer)					
1,500 mm		1,980	1,060		3,040
1,800 mm		740	610		1,350
Sub-total	---	2,720	1,670	---	4,390
Total (m)	134,620	7,720	3,170	40	145,550

Note : These length include river crossing at two (2) locations.

Table A.2.1 Length of Sewer Pipe by Diameter and by Earth Covering Depth of Sanur (Alternative A)

Earth Covering Depth / Diameter	0 - 2 m (1.5 m)	2 - 4 m (3.0 m)	4 - 6 m (5.0 m)	6 - 8 m (7.0 m)	8 - 10 m (9.0 m)	Pipe Length (m)
(Secondary & Tertiaty)						
150 mm	56,500					56,500
200 mm	27,920					27,920
250 mm	6,800					6,800
300 mm	6,000					6,000
Sub-total	97,220	---	---	---	---	97,220
(Main Sewer)						
350 mm	1,870	3,350	710	80		6,010
400 mm	350		300			650
450 mm	190	370	240			800
500 mm	350					350
600 mm	580	720		320		1,620
700 mm		250	1,150			1,400
800 mm				110		110
Sub-total	3,340	4,690	2,400	510	---	10,940
(Force Main)						
500 mm	5,160 (x 2 lines)					5,160
Sub-total	5,160	---	---	---	---	5,160
Total (m)	100,560	4,690	2,400	510	---	113,320

Table A.2.2 Length of Sewer Pipe by Diameter and by Earth Covering Depth of Sanur (Alternative B)

Earth Covering Depth / Diameter	0 - 2 m (1.5 m)	2 - 4 m (3.0 m)	4 - 6 m (5.0 m)	6 - 8 m (7.0 m)	8 - 10 m (9.0 m)	Pipe Length (m)
(Secondary & Tertiaty)						
150 mm	56,500					56,500
200 mm	27,920					27,920
250 mm	6,800					6,800
300 mm	6,000					6,000
Sub-total	97,220	---	---	---	---	97,220
(Main Sewer)						
350 mm	3,870	1,780	520			6,170
400 mm	370	460	70			900
450 mm			120			120
500 mm		900				900
600 mm				230		230
700 mm			920	690	330	1,940
800 mm					110	110
Sub-total	4,240	3,140	1,630	920	440	10,370
(Force Main)						
500 mm	5,160 (x 2 lines)					5,160
Sub-total	5,160	---	---	---	---	5,160
Total (m)	101,460	3,140	1,630	920	440	112,750

Table A.2.3 Served Area and Served Population of Sub-Catchment Area in Sanur

Sub-Catchment Area	Area (ha)	Served Population			Served Population Density (person/ha)		
		1990	2000	2010	1990	2000	2010
A-1	17.9	494	614	725	27.6	34.3	40.5
A-2	42.7	1,176	1,486	1,785	27.5	34.8	41.8
A-3	44.0	911	1,079	1,234	20.7	24.5	28.0
A-4	25.7	474	526	562	18.4	20.5	21.9
A-5	25.6	582	729	872	22.7	28.5	34.1
A-6	47.2	1,235	1,652	2,070	26.2	35.0	43.9
A-7	25.4	524	622	712	20.6	24.5	28.0
Sub-total	228.5	5,396	6,708	7,960	23.6	29.4	34.8
B-1	9.7	265	362	459	27.3	37.3	47.3
B-2	77.8	2,124	2,902	3,680	27.3	37.3	47.3
Sub-total	87.5	2,389	3,264	4,139	27.3	37.3	47.3
C-1	34.0	939	1,169	1,387	27.6	34.4	40.8
C-2	8.5	233	304	373	27.4	35.8	43.9
C-3	19.9	543	742	941	27.3	37.3	47.3
C-3-1	33.5	924	1,153	1,368	27.6	34.4	40.8
C-4	65.3	1,783	2,436	3,089	27.3	37.3	47.3
C-5	89.2	2,435	3,327	4,219	27.3	37.3	47.3
C-6	25.7	702	959	1,216	27.3	37.3	47.3
C-7	2.0	55	75	95	27.5	37.5	47.5
Sub-total	278.1	7,614	10,165	12,688	27.4	36.6	45.6
D-1	5.0	86	91	93	17.2	18.2	18.6
D-2	42.5	731	769	790	17.2	18.1	18.6
D-3	30.7	528	555	571	17.2	18.1	18.6
D-4	53.7	1,121	1,348	1,559	20.9	25.1	29.0
Sub-total	131.9	2,466	2,763	3,013	18.7	20.9	22.8
TOTAL	726.0	17,865	22,900	27,800	24.6	31.5	38.3

Table A.2.4 Specific Wastewater Generation by Area and by Source in Sanur

Sub-Catchment Area	Area (ha)	Specific Wastewater Generation (m3/ha/day)						Wastewater Generation (m3/day)		
		Domestic and etc.			Tourism					
		1990	2000	2010	1990	2000	2010	1990	2000	2010
A-1	17.9	6.76	9.19	11.53				121	165	206
A-2	42.7	6.89	9.58	12.2				294	409	521
A-3	44.0	5.02	6.73	8.36				221	296	368
A-4	25.7	4.4	5.29	6.19				113	136	159
A-5	25.6	5.78	8.09	10.39				148	207	266
A-6	47.2	6.91	10.34	13.79				326	488	651
A-7	25.4	5.04	6.69	8.35				128	170	212
Sub-total	228.5							1,351	1,871	2,383
B-1	9.7	7.32	11.03	14.95				71	107	145
B-2	77.8	7.27	11.07	14.9				566	862	1,159
Sub-total	87.5							637	969	1,304
C-1	21.0	6.76	9.19	11.53				142	193	242
C-1-T	13.0				23.1	49	74.9	300	637	974
C-2	8.5	6.94	10.12	13.06				59	86	111
C-3	14.5	7.27	11.07	14.9				105	161	216
C-3-T	5.4				25.4	38.1	50.9	137	206	275
C-3-1	15.5	6.76	9.19	11.53				105	142	179
C-3-1-T	18.0				23.1	49	74.9	416	882	1,348
C-4	39.3	7.27	11.07	14.9				286	435	586
C-4-T	26.0				25.4	38.1	50.9	658	992	1,328
C-5	63.9	7.27	11.07	14.9				464	707	952
C-5-T	25.3				25.4	38.1	50.9	641	964	1,288
C-6	7.5	7.27	11.07	14.9				55	83	112
C-6-T	18.2				25.4	38.1	50.9	462	693	926
C-7	2.0	7.27	11.07	14.9				15	22	30
Sub-total	278.1							3,845	6,203	8,566
D-1	5.0	3.97	4.51	5.02				20	23	25
D-2	27.5	3.97	4.51	5.02				110	124	138
D-2-T	15.0				1.9	13.4	24.8	29	201	372
D-3	30.7	3.97	4.51	5.02				121	138	154
D-4	31.6	5.12	6.79	8.46				163	215	267
D-4-T	22.1				9.4	21.3	33.2	209	472	734
Sub-total	131.9							652	1,173	13,943
Total	726.0							6,485	10,216	26,196

Note : T in the column of Sub-Catchment Area means Tourism area.

Table A.2.5 Wastewater Generation of Sanur Urgent Sewerage Service Area in 2000

Sub-Catchment Area	Service Area (ha)	Wastewater Generation (m3/day)		
		Domestic	Tourism	Total
C-1	34.0	231	777	1,008
C-2	8.5	102	---	102
C-3	19.9	187	251	438
C-3-1	33.5	171	1,076	1,247
C-4	65.3	507	1,206	1,713
C-5	89.2	824	1,174	1,998
C-6	25.7	97	844	941
C-7	2.0	26	---	26
Sub-total	278.1	2,145	5,328	7,473
D-4	53.7	273	818	1,091
Sub-total	53.7	273	818	1,091
Total	331.8	2,418	6,146	8,564

Table A.2.6 Length of Sewer Line by Diameter and by Earth Covering Depth in Urgent Works of Sanur

Diameter \ Earth Covering Depth	0-2m (1.5m)	2-4m (3.0m)	4-6m (5.0m)	6-8m (7.0m)	Total Length (m)
(Main Sewer)					
150 mm	16,700				16,700
200 mm	12,220				12,220
250 mm	2,000				2,000
300 mm	1,800				1,800
Sub-total	32,720	---	---	---	32,720
(Main Sewer)					
350 mm	770	230			1,000
400 mm	150				150
450 mm					---
500 mm	350				350
600 mm	580	720			1,300
700 mm		250	1,150		1,400
800 mm				110	110
Sub-total	1,850	1,200	1,150	110	4,310
(Force Main)					
500 mm	5,160				5,160
Sub-total	5,160	---	---	---	5,160
Total (m)	39,730	1,200	1,150	110	42,190

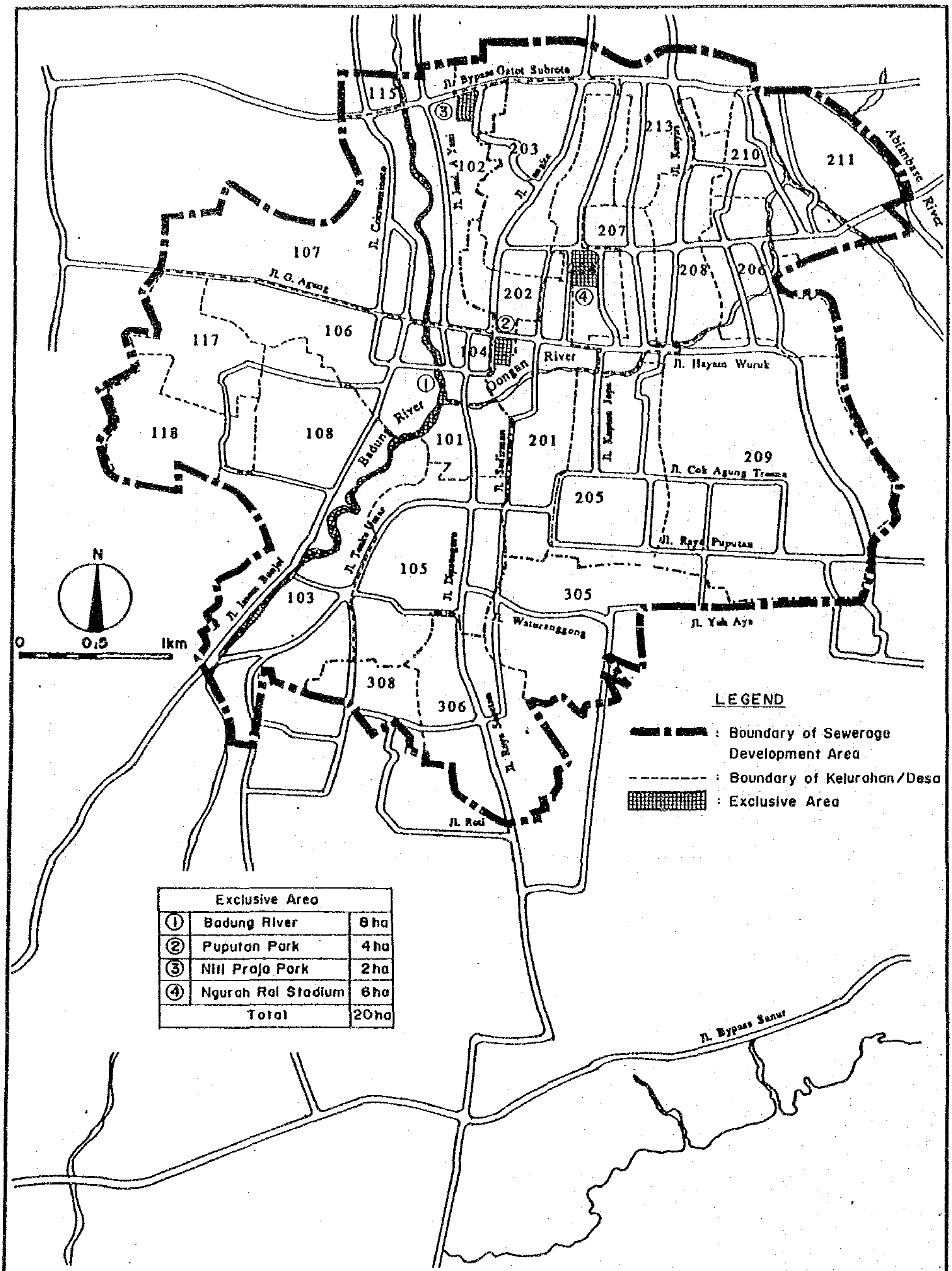


FIG. A.1.1 SEWERAGE DEVELOPMENT AREA OF DENPASAR

THE DEVELOPMENT STUDY ON WASTEWATER DISPOSAL FOR DENPASAR

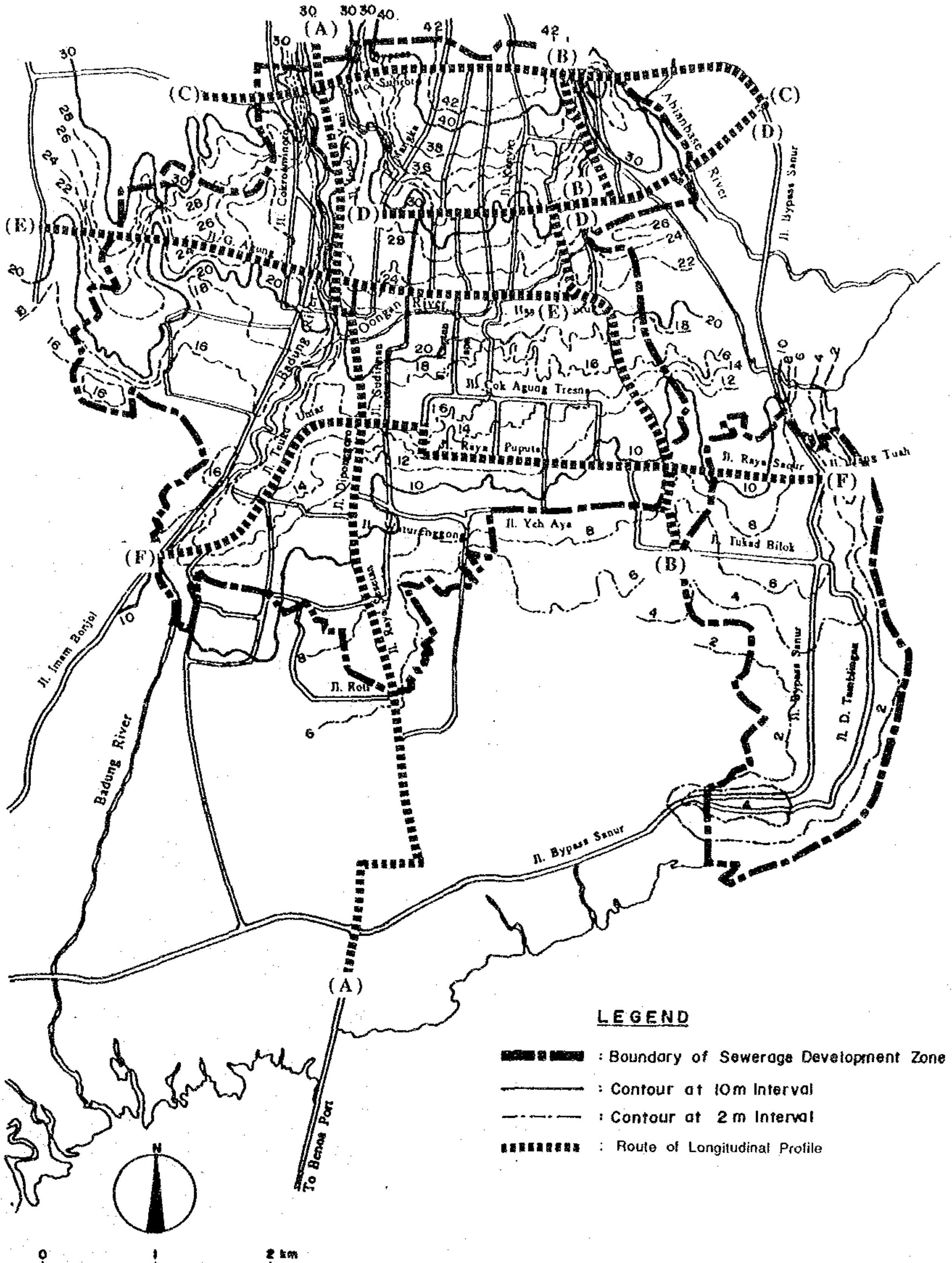
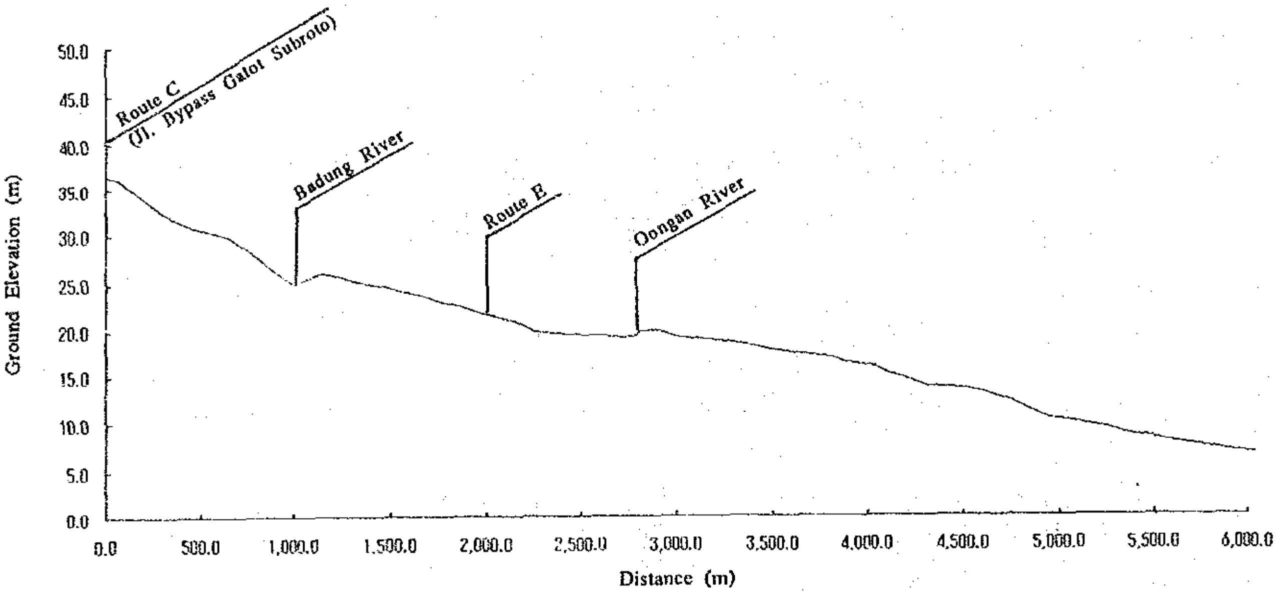


FIG. A.1.2 TOPOGRAPHIC CONDITION

THE DEVELOPMENT STUDY ON WASTEWATER DISPOSAL FOR DENPASAR

JICA A.D 1993

Route - (A-1)



Route - (A-2)

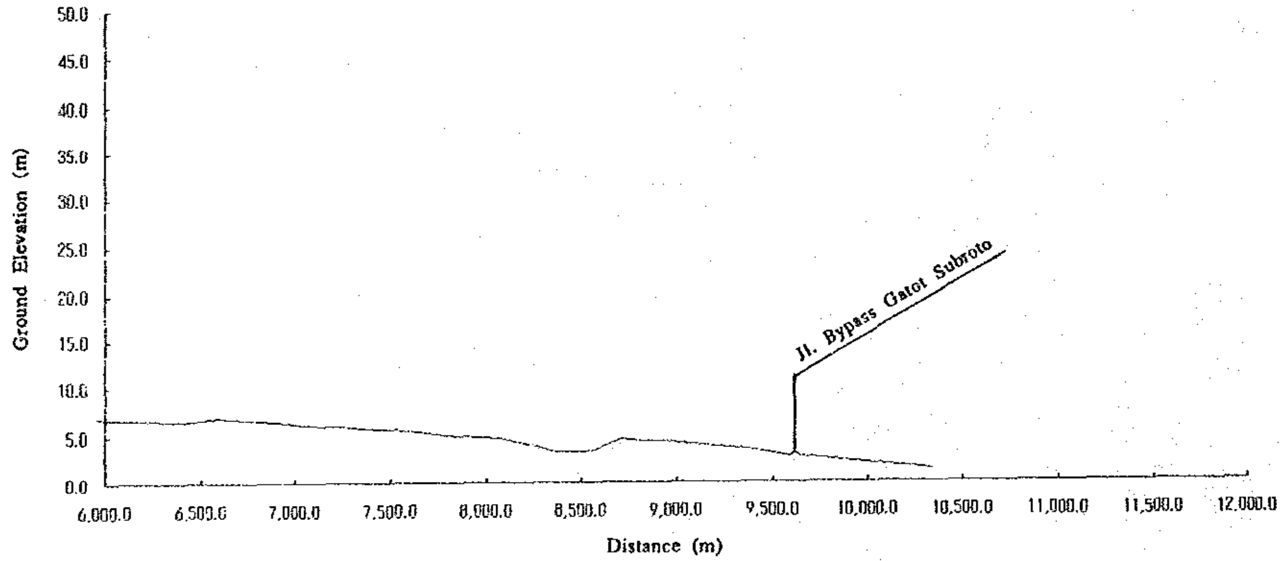
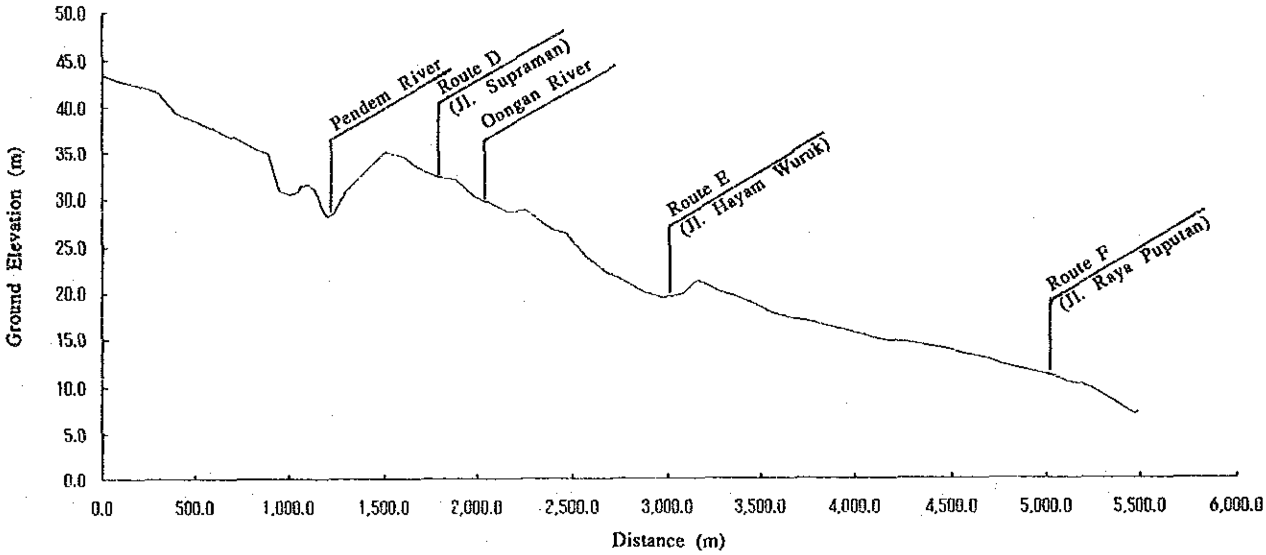


FIG.A.1.3(1) LONGITUDINAL PROFILE (ROUTE-A)

THE DEVELOPMENT STUDY ON WASTEWATER DISPOSAL FOR DENPASAR

Route - B



Route - C

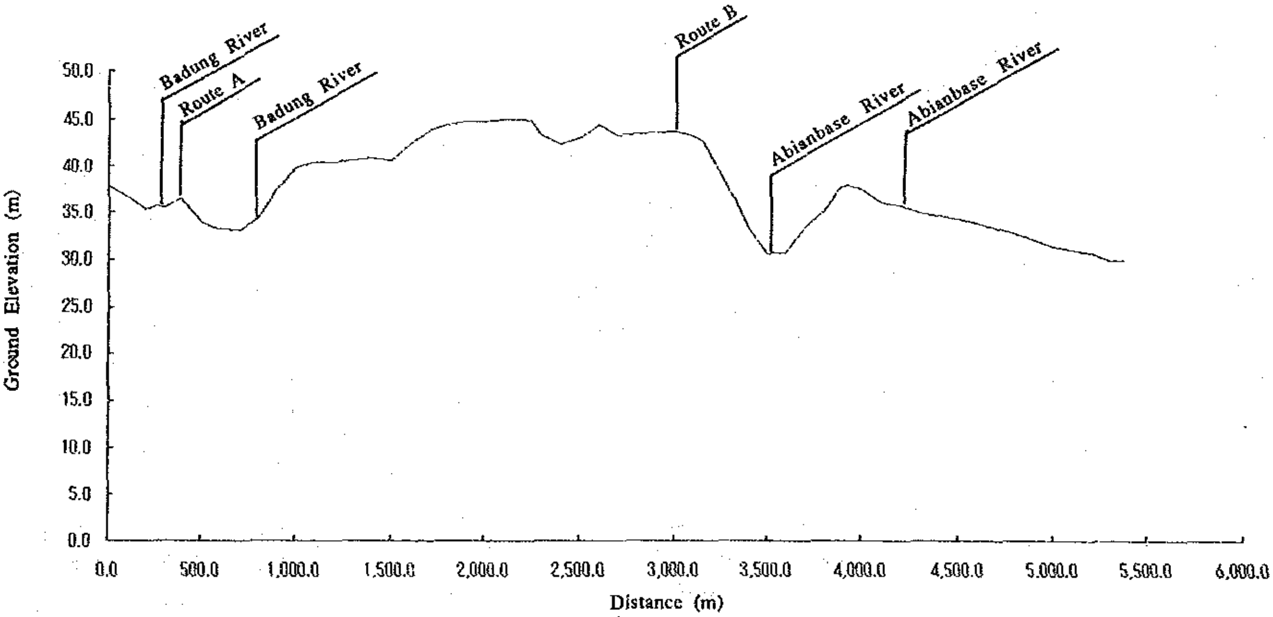
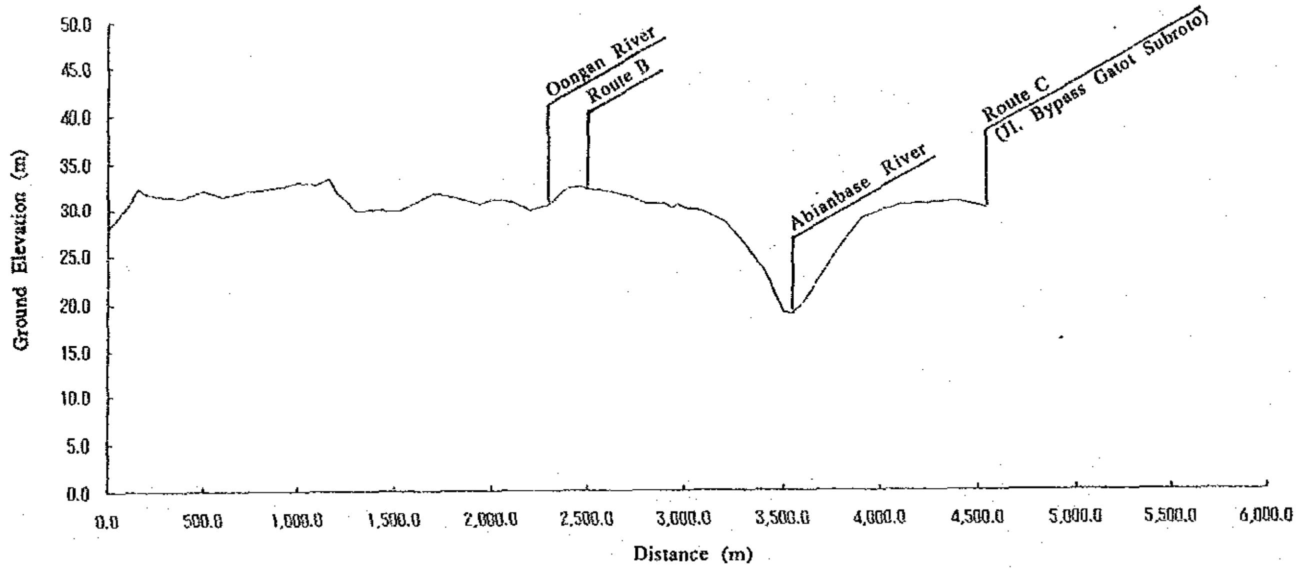


FIG.A.1.3(2)	LONGITUDINAL PROFILE (ROUTE-B & C)

THE DEVELOPMENT STUDY ON WASTEWATER DISPOSAL FOR DENPASAR

Route - D



Route - E

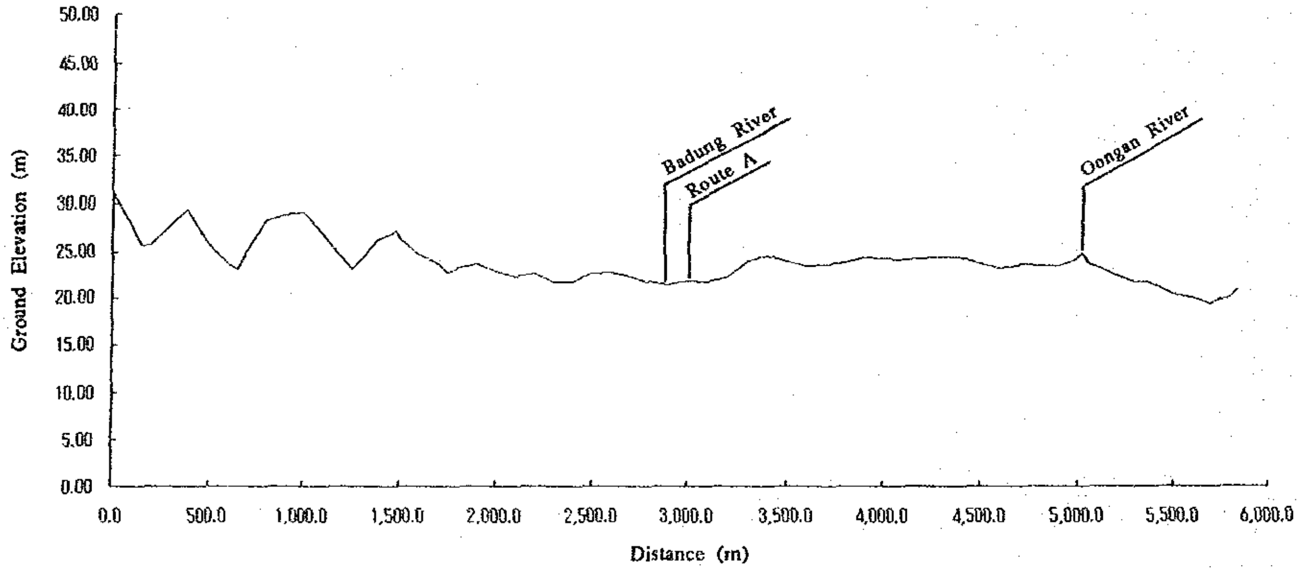
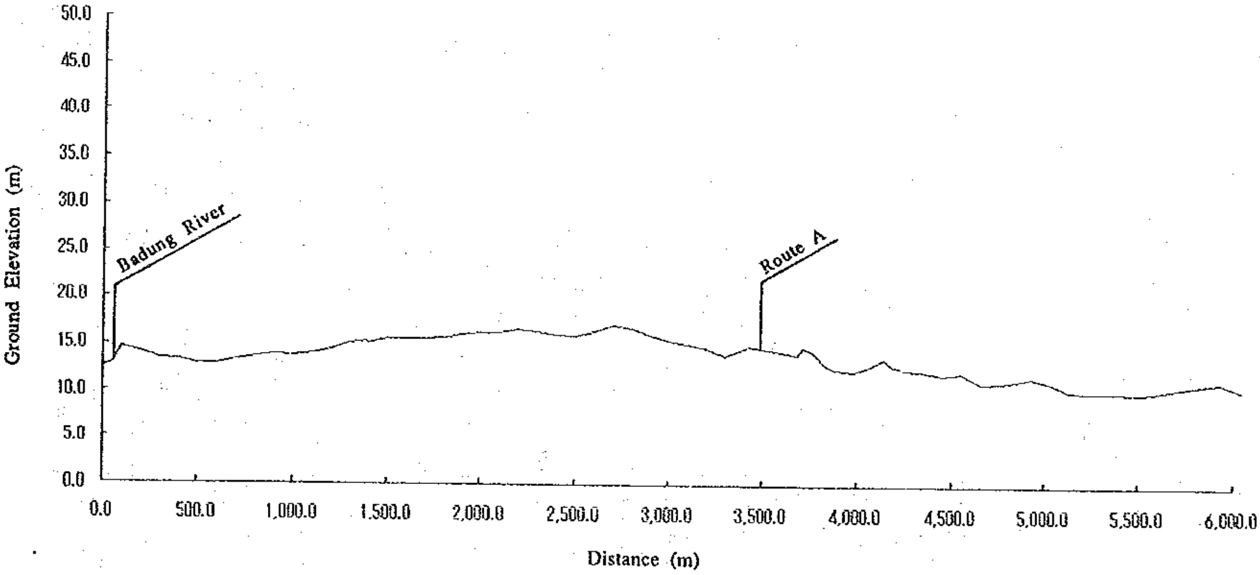


FIG.A.1.3(3)	LONGITUDINAL PROFILE (ROUTE-D & E)

THE DEVELOPMENT STUDY ON WASTEWATER DISPOSAL FOR DENPASAR

Route - (F-1)



Route - (F-2)

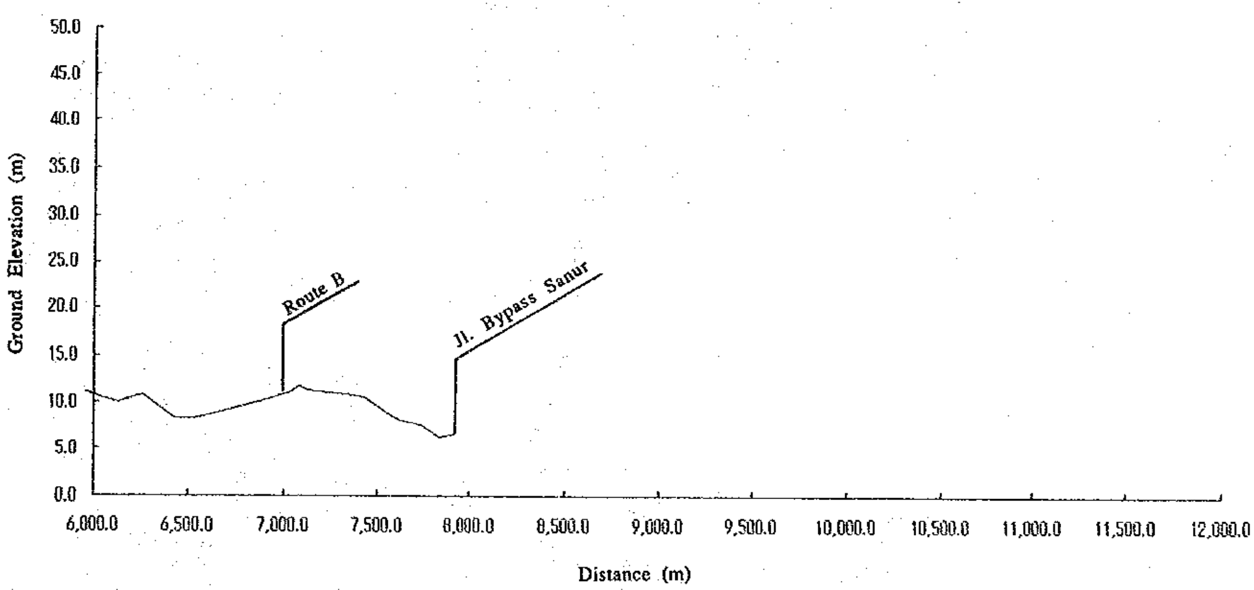
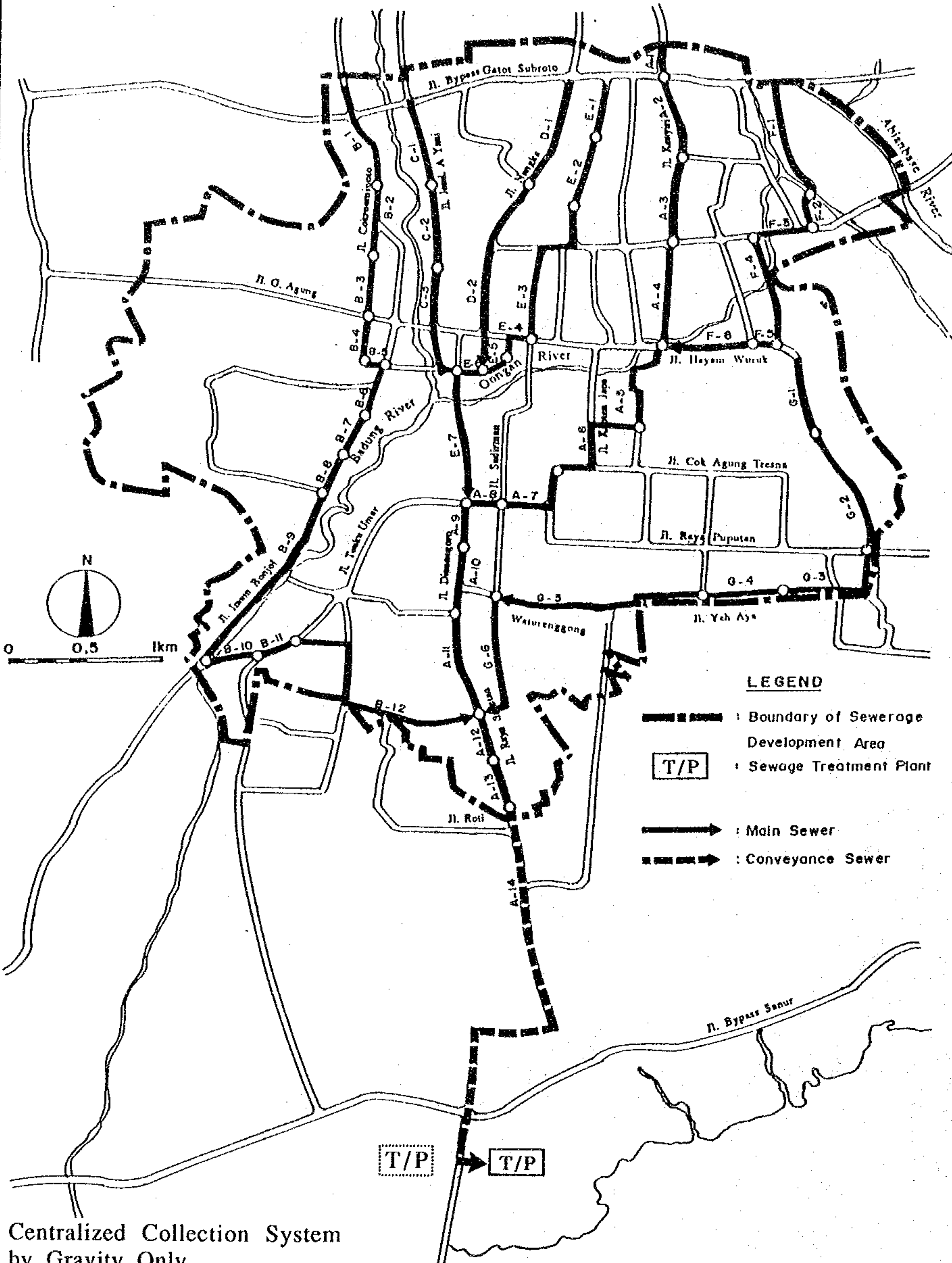


FIG.A.1.3(4) LONGITUDINAL PROFILE (ROUTE-F)

THE DEVELOPMENT STUDY ON WASTEWATER DISPOSAL FOR DENPASAR

JICA A.D 1993



Centralized Collection System by Gravity Only

FIG. A.1.4 ALTERNATIVE A

THE DEVELOPMENT STUDY ON WASTEWATER DISPOSAL FOR DENPASAR

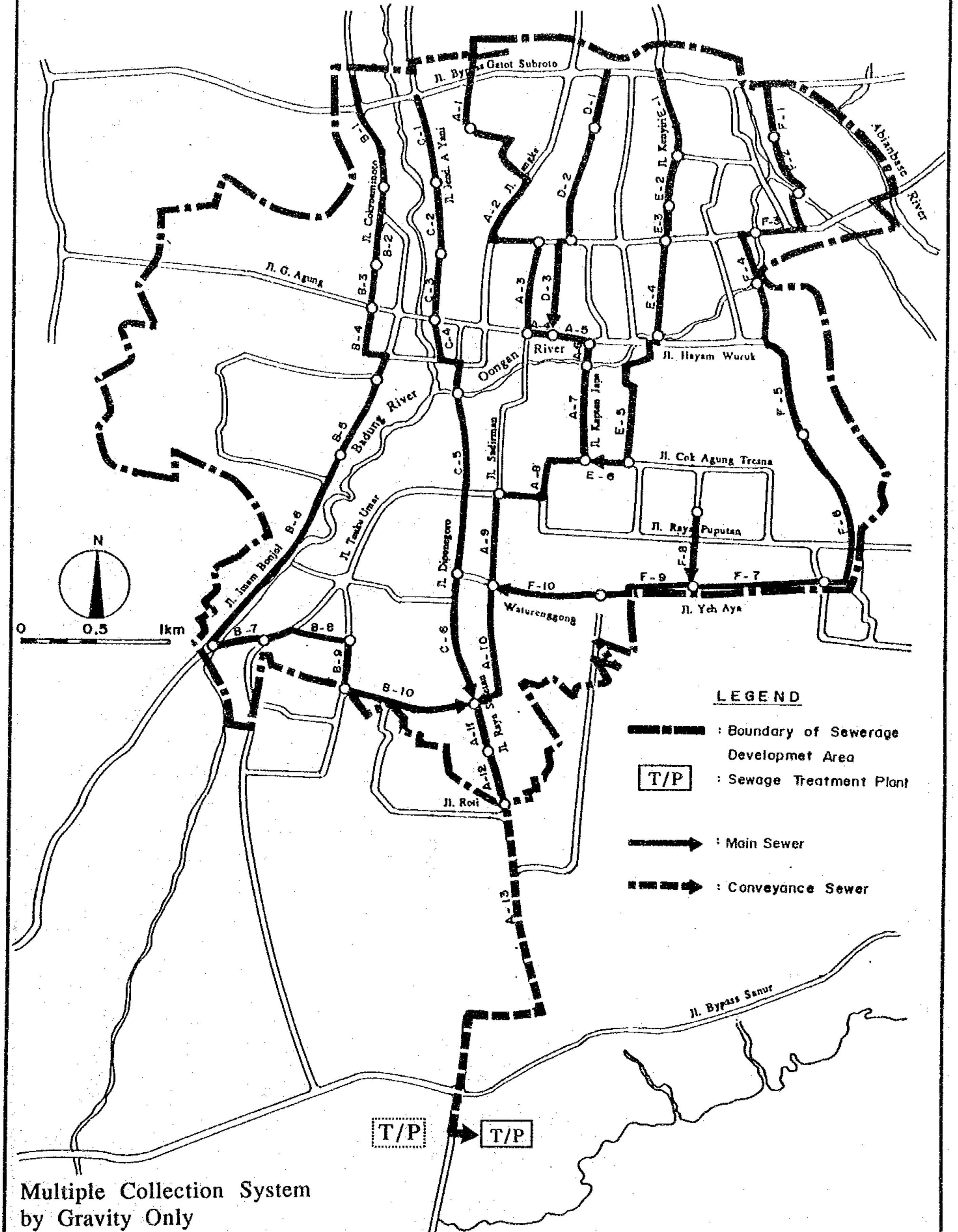
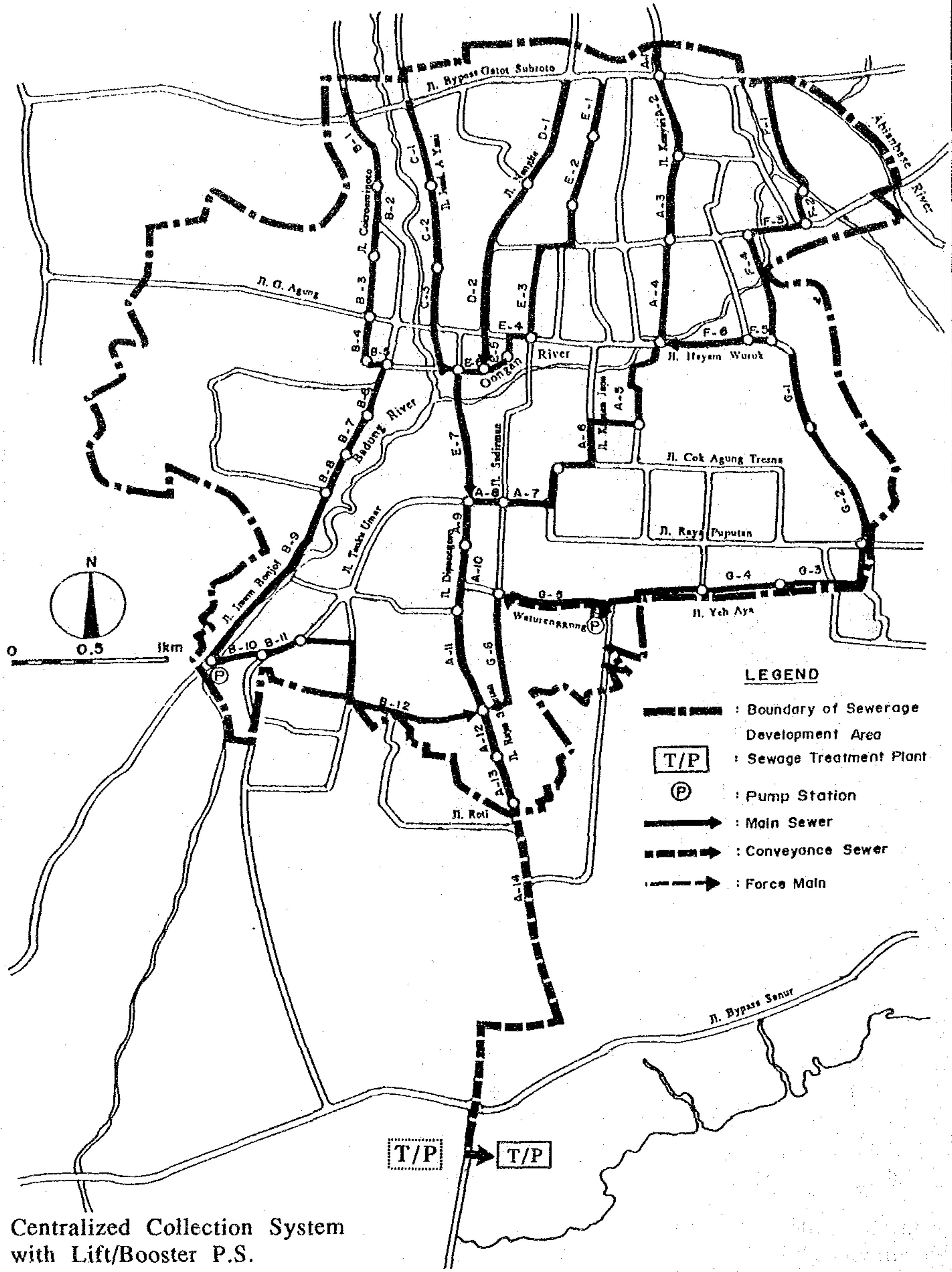


FIG. A.1.5 ALTERNATIVE B

THE DEVELOPMENT STUDY ON WASTEWATER DISPOSAL FOR DENPASAR

JICA A.D 1993



Centralized Collection System
with Lift/Booster P.S.

FIG. A.1.6	ALTERNATIVE C

THE DEVELOPMENT STUDY ON WASTEWATER DISPOSAL FOR DENPASAR

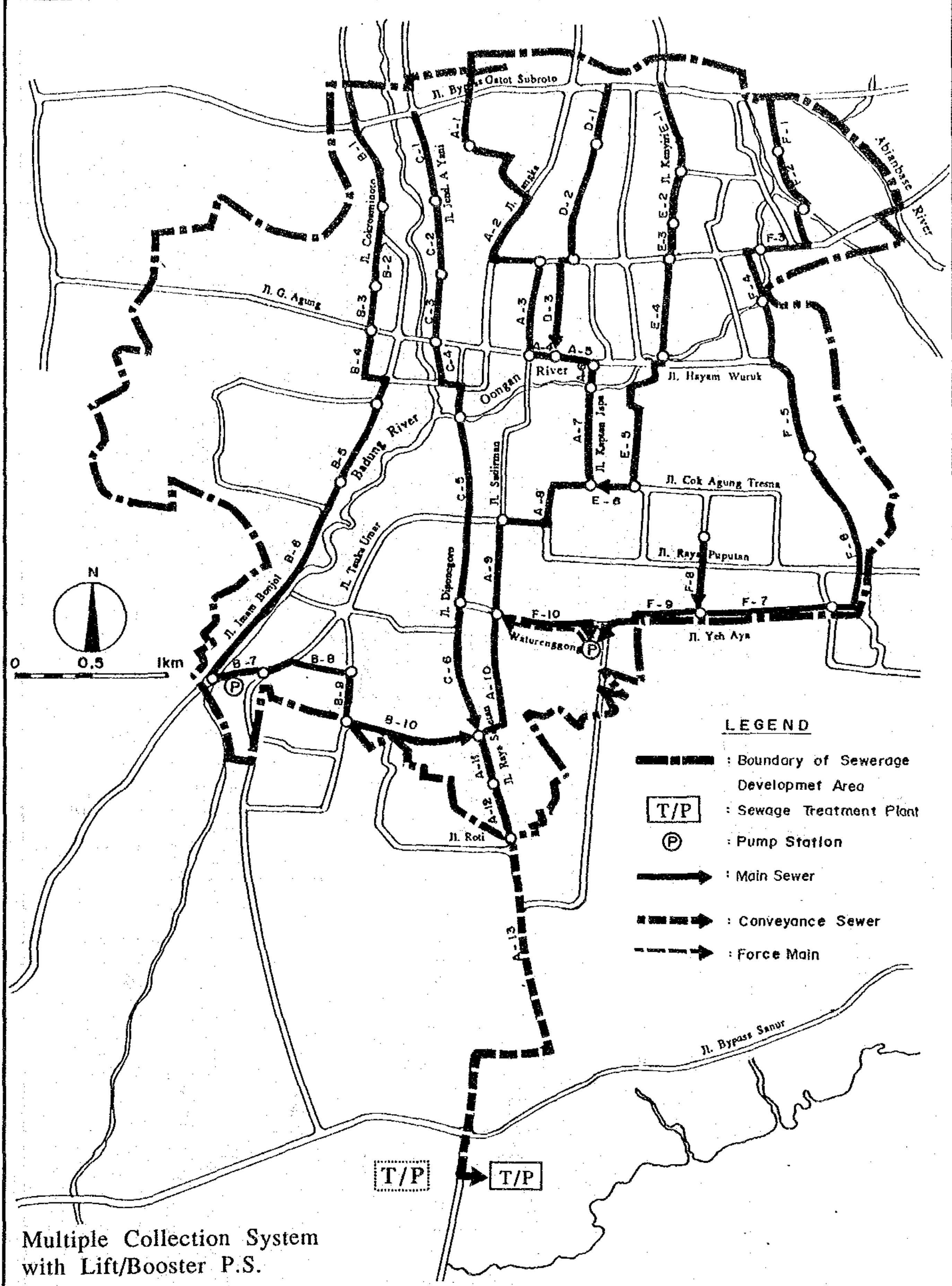


FIG. A.1.7 ALTERNATIVE D

THE DEVELOPMENT STUDY ON WASTEWATER DISPOSAL FOR DENPASAR

JICA A.D 1993

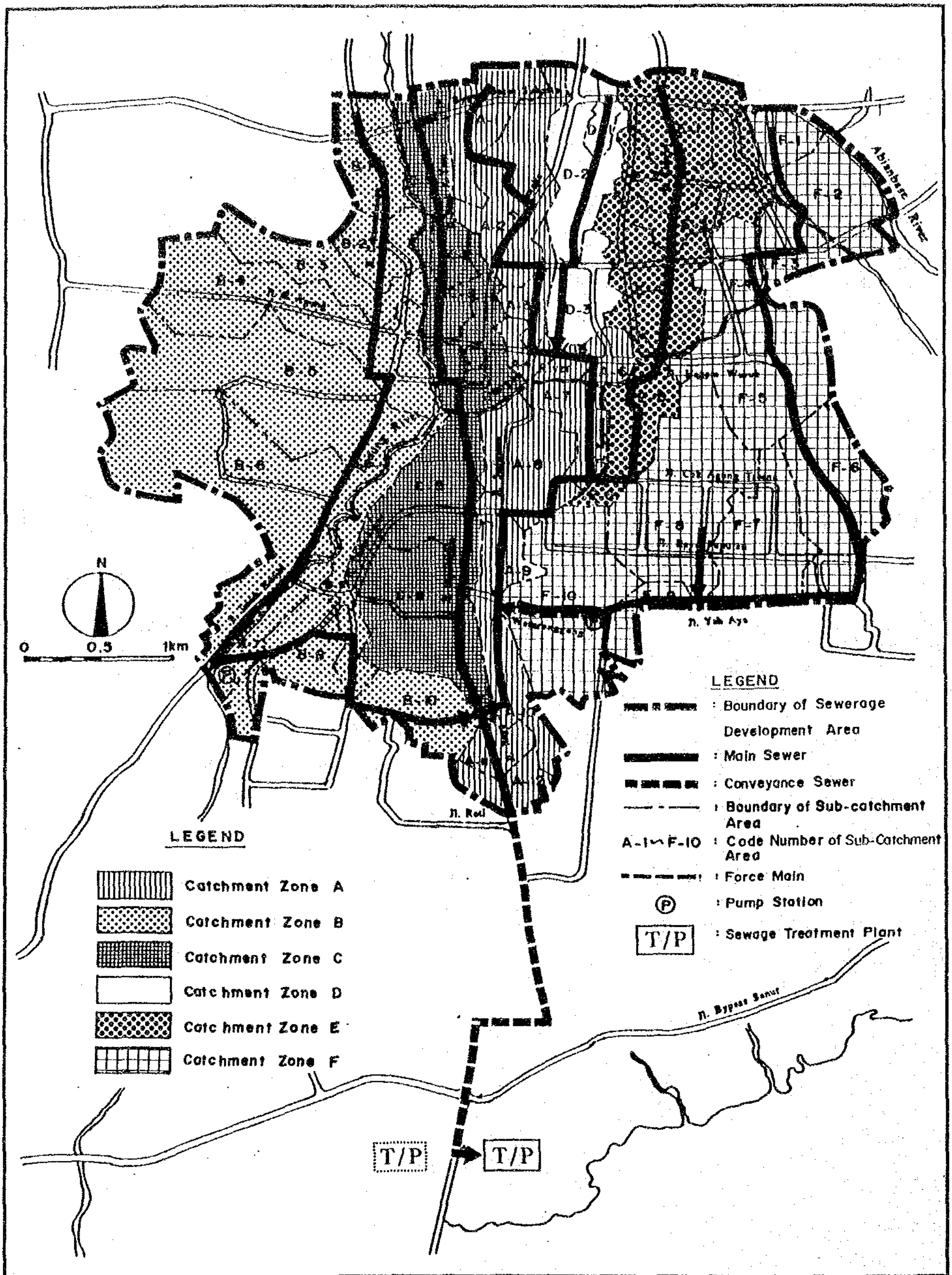


FIG. A.1.8 DIVISION OF SEWERAGE SERVICE AREA

THE DEVELOPMENT STUDY ON WASTEWATER DISPOSAL FOR DENPASAR

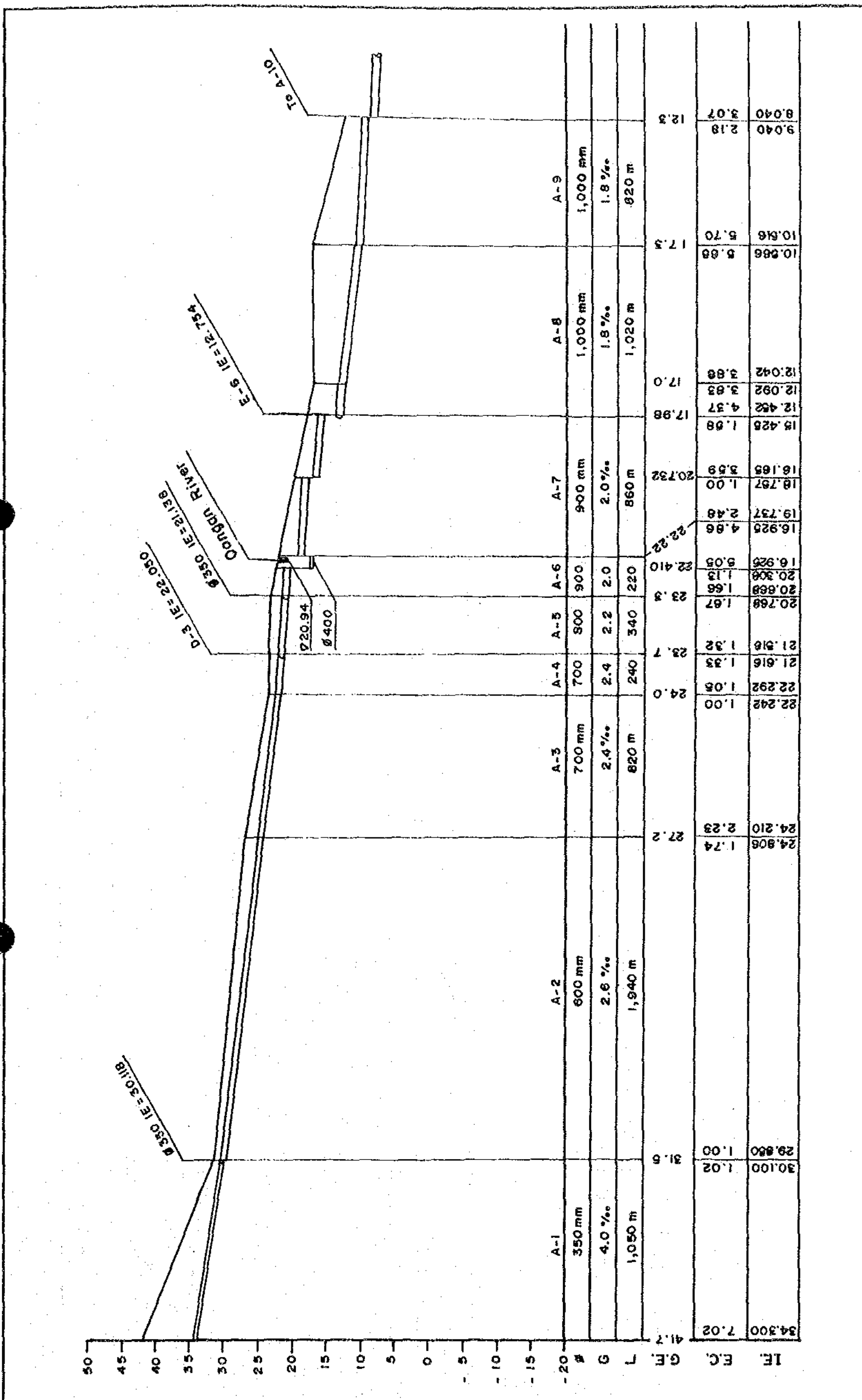


FIG.A.1.9(1) PROPOSED LONGITUDINAL PROFILE

THE DEVELOPMENT STUDY ON WASTEWATER DISPOSAL FOR DENPASAR

JICA A.D 1993

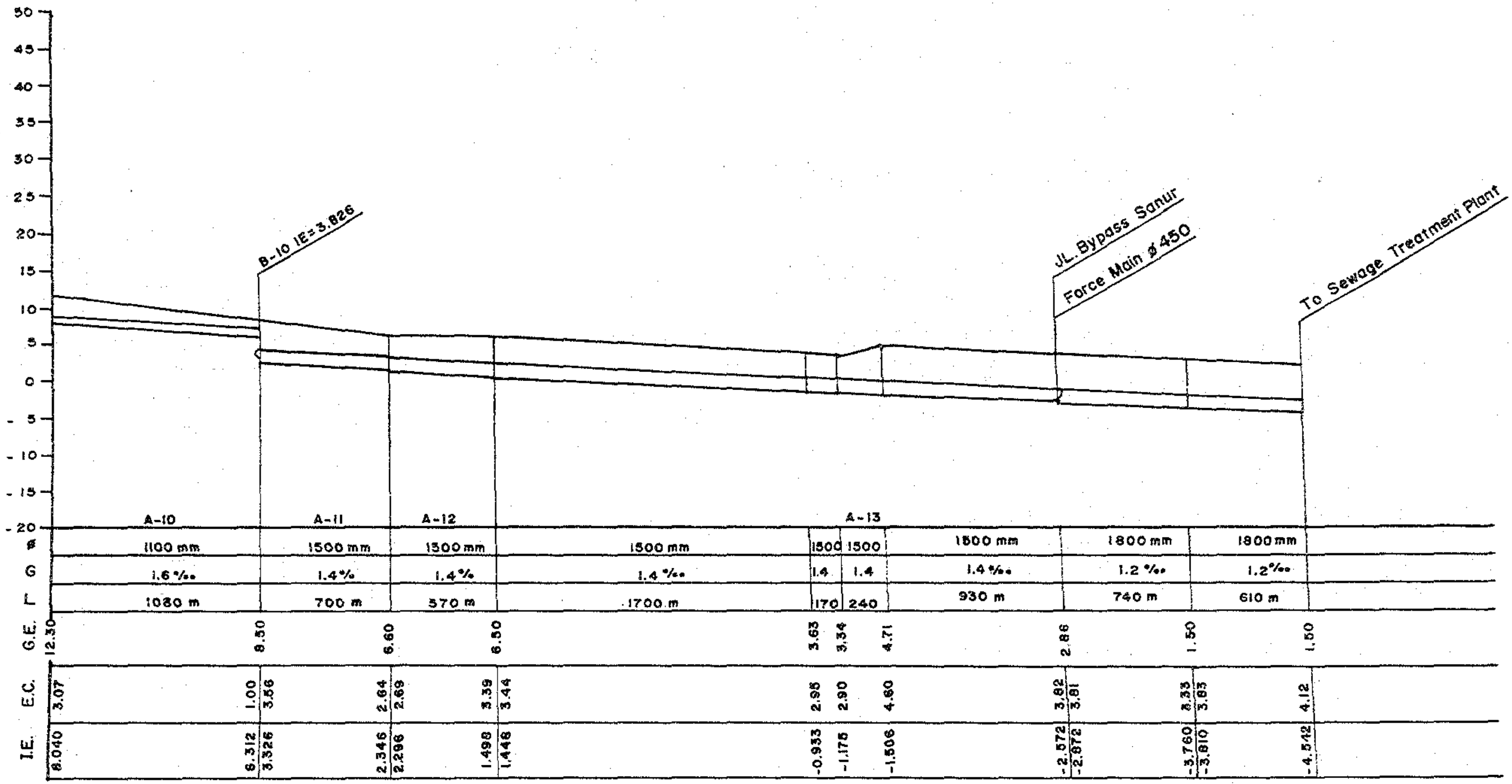


FIG.A.1.9(2) PROPOSED LONGITUDINAL PROFILE

THE DEVELOPMENT STUDY ON WASTEWATER DISPOSAL FOR DENPASAR

JICA A.D 1993

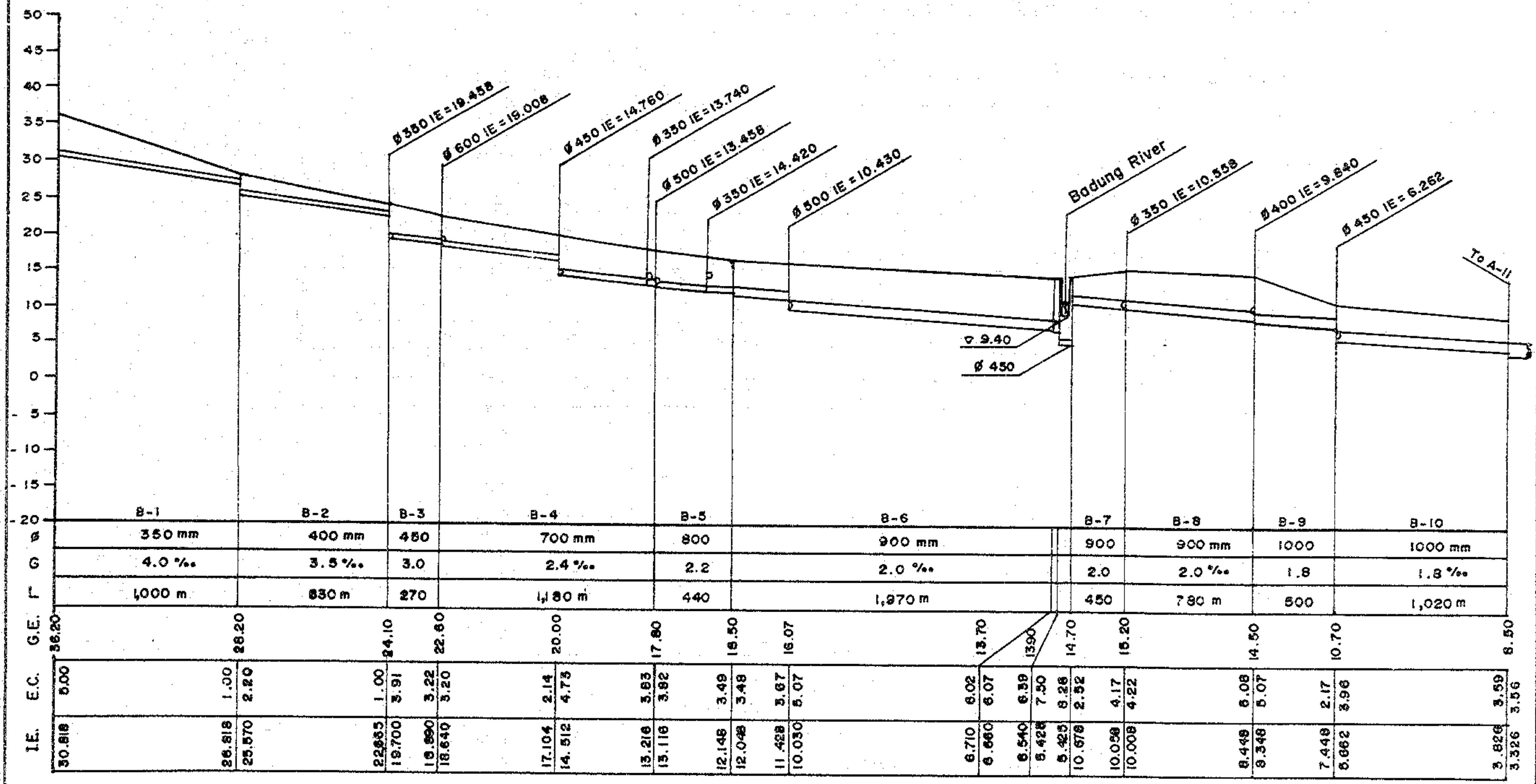


FIG.A.1.9(3) PROPOSED LONGITUDINAL PROFILE

THE DEVELOPMENT STUDY ON WASTEWATER DISPOSAL FOR DENPASAR

JICA A.D 1993

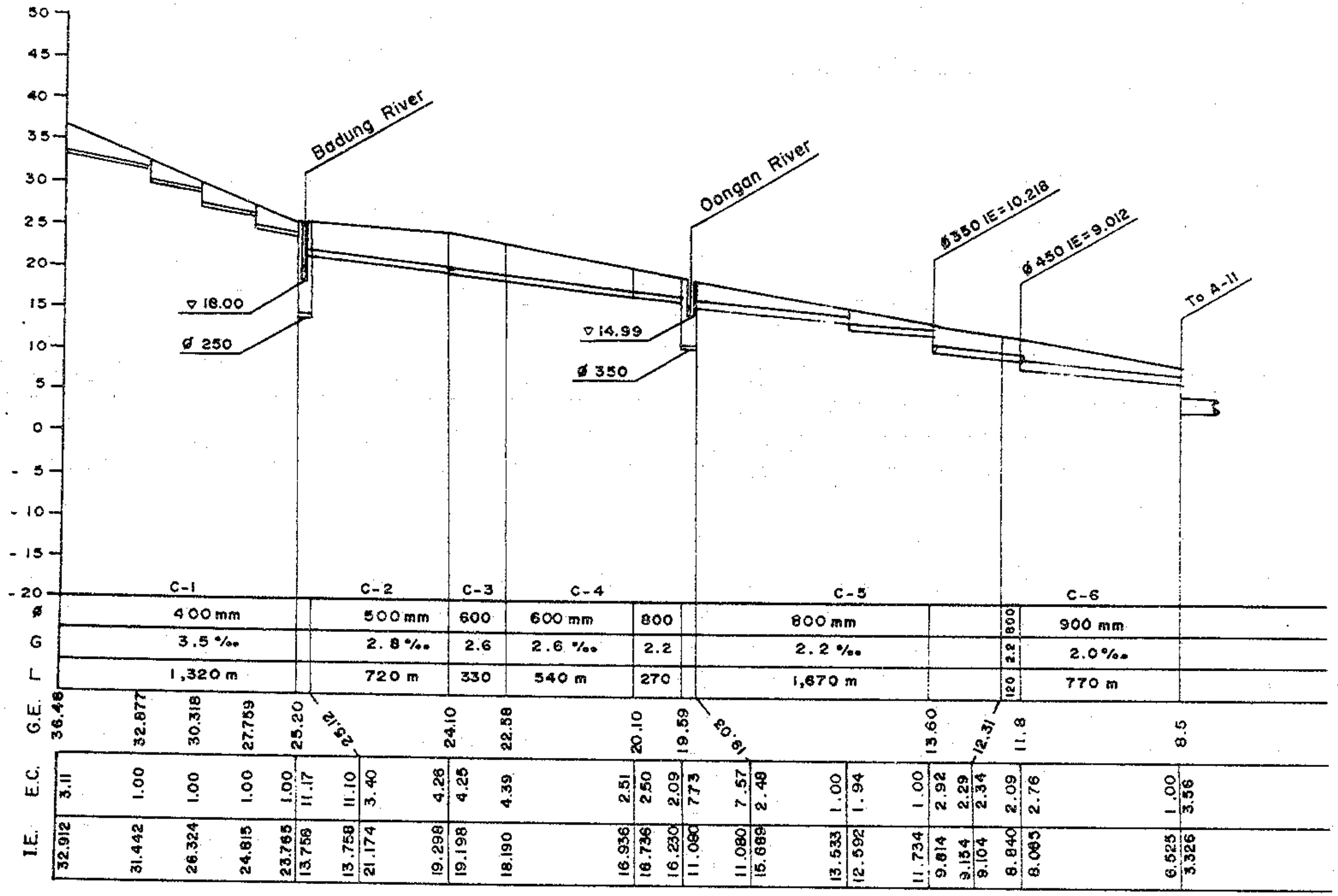


FIG.A.1.9(4)	PROPOSED LONGITUDINAL PROFILE

THE DEVELOPMENT STUDY ON WASTEWATER DISPOSAL FOR DENPASAR

JICA A.D 1993

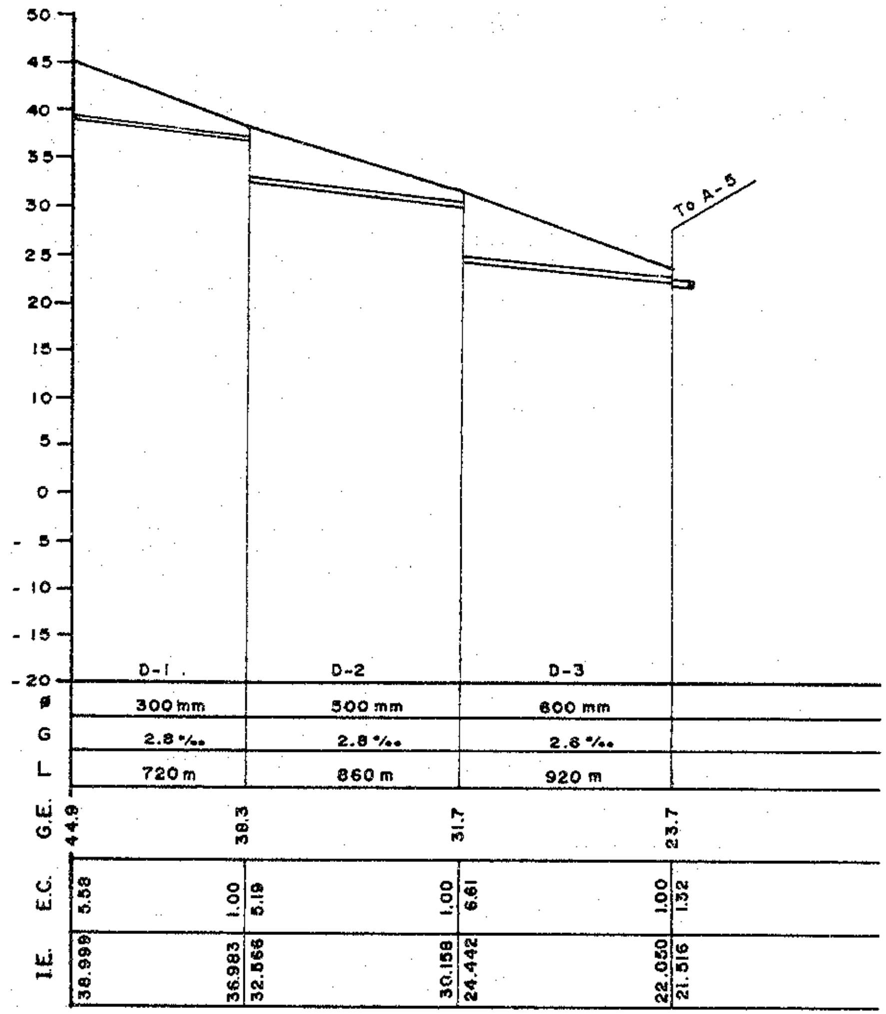


FIG.A.1.9(5) PROPOSED LONGITUDINAL PROFILE

THE DEVELOPMENT STUDY ON WASTEWATER DISPOSAL FOR DENPASAR

JICA A.D 1993

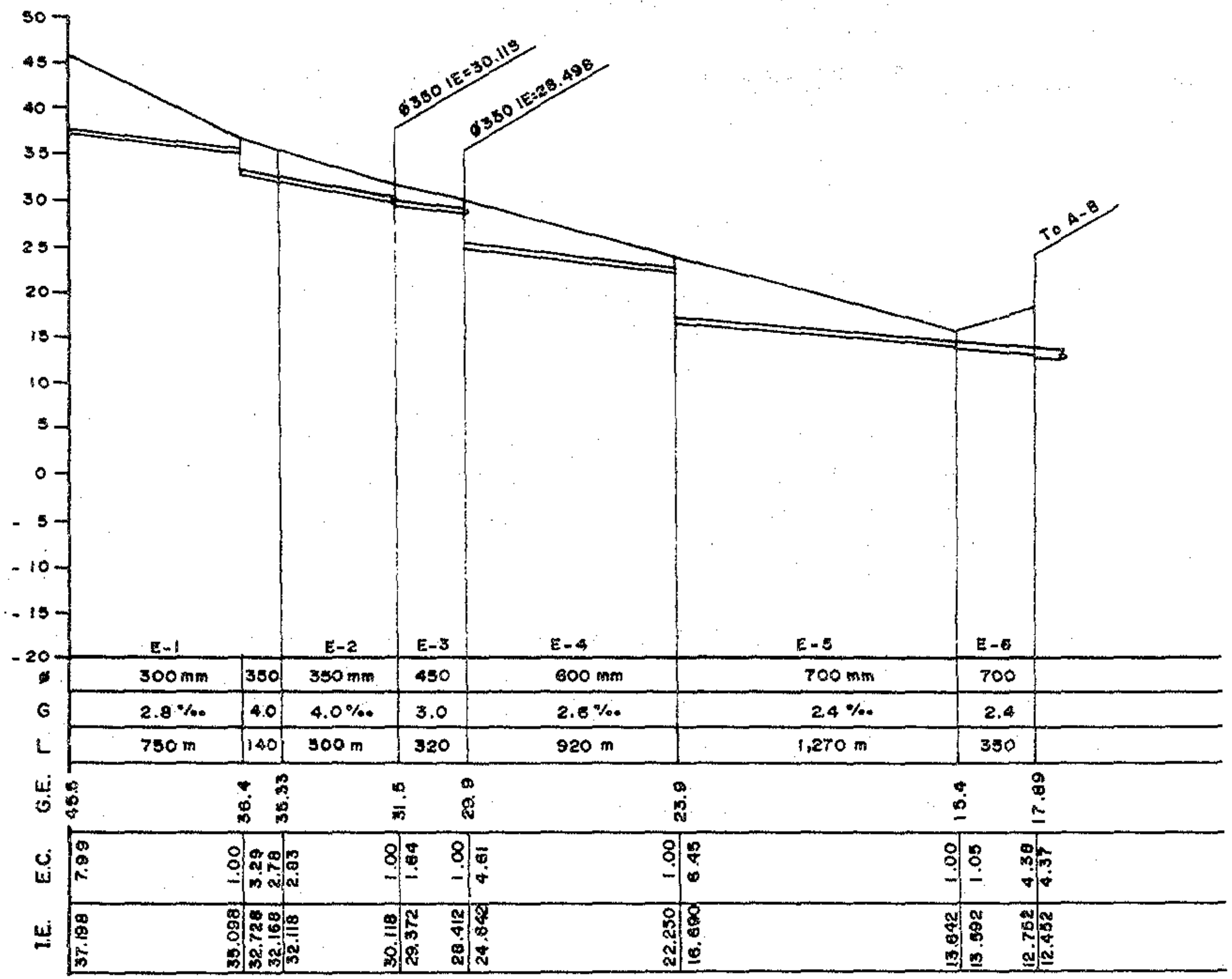


FIG.A.1.9(6) PROPOSED LONGITUDINAL PROFILE

THE DEVELOPMENT STUDY ON WASTEWATER DISPOSAL FOR DENPASAR

JICA A.D 1993

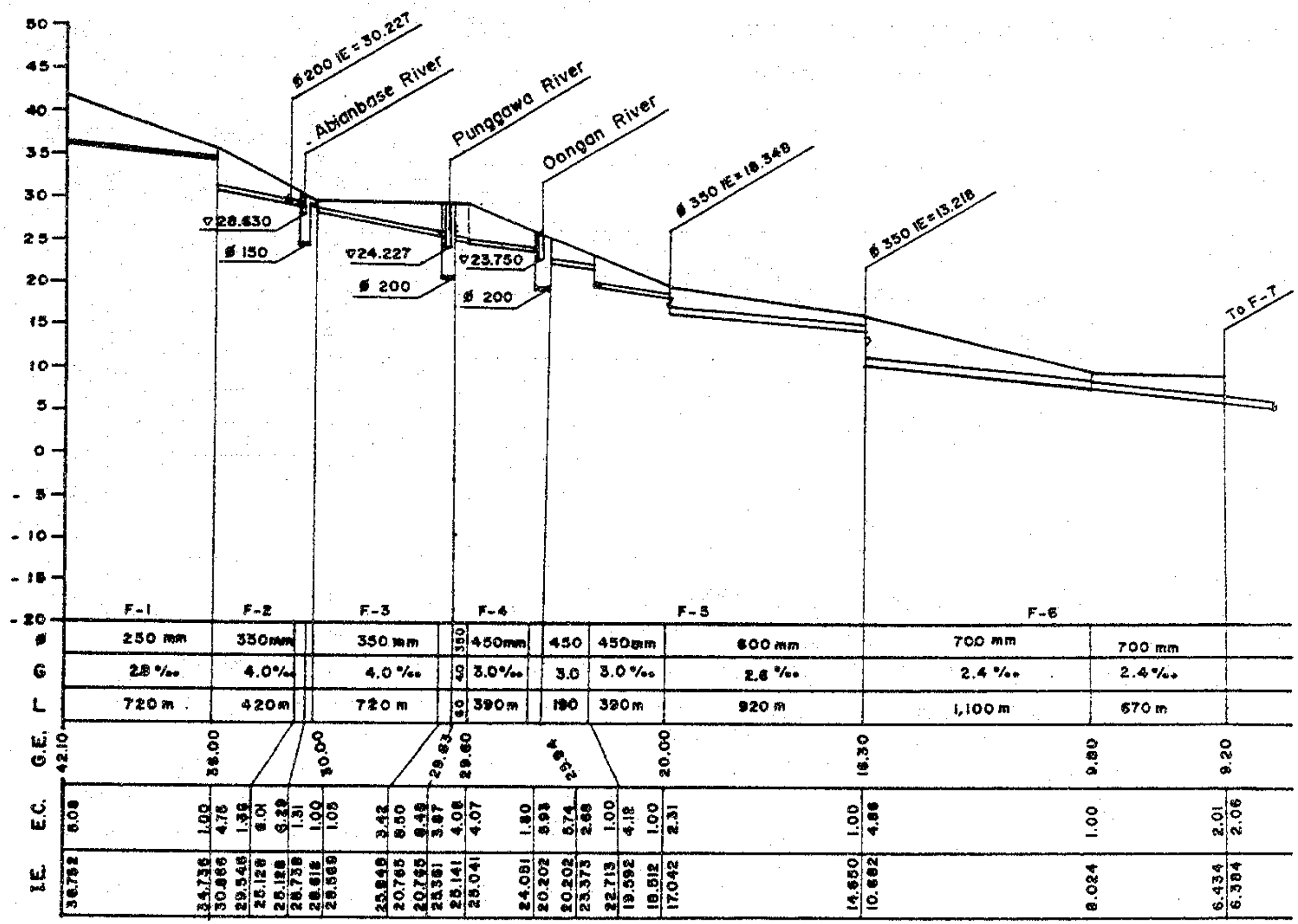


FIG.A.1.9(7) PROPOSED LONGITUDINAL PROFILE

THE DEVELOPMENT STUDY ON WASTEWATER DISPOSAL FOR DENPASAR

JICA A.D 1993

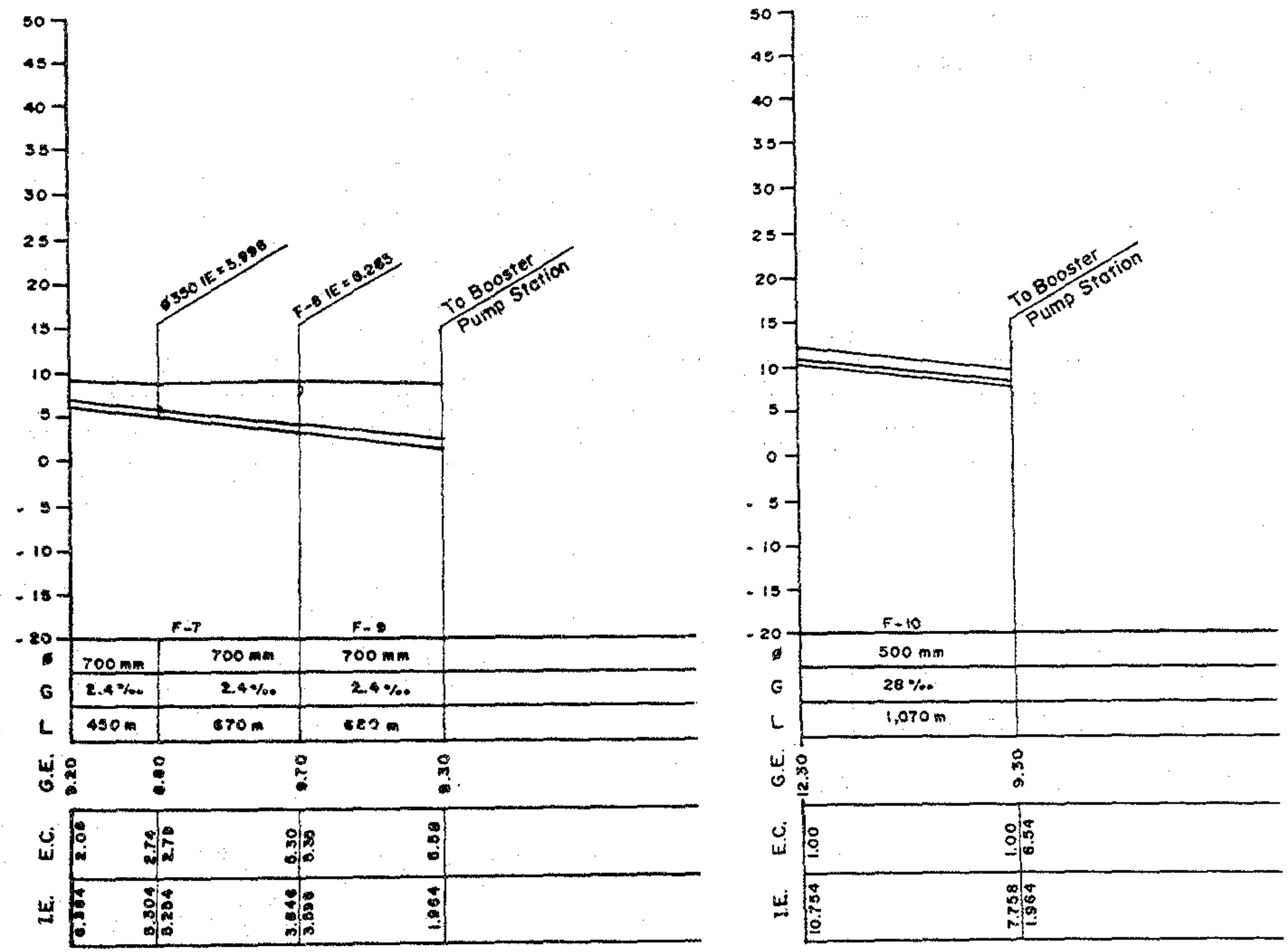


FIG.A.1.9(8)	PROPOSED LONGITUDINAL PROFILE
THE DEVELOPMENT STUDY ON WASTEWATER DISPOSAL FOR DENPASAR	

JICA A.D 1993

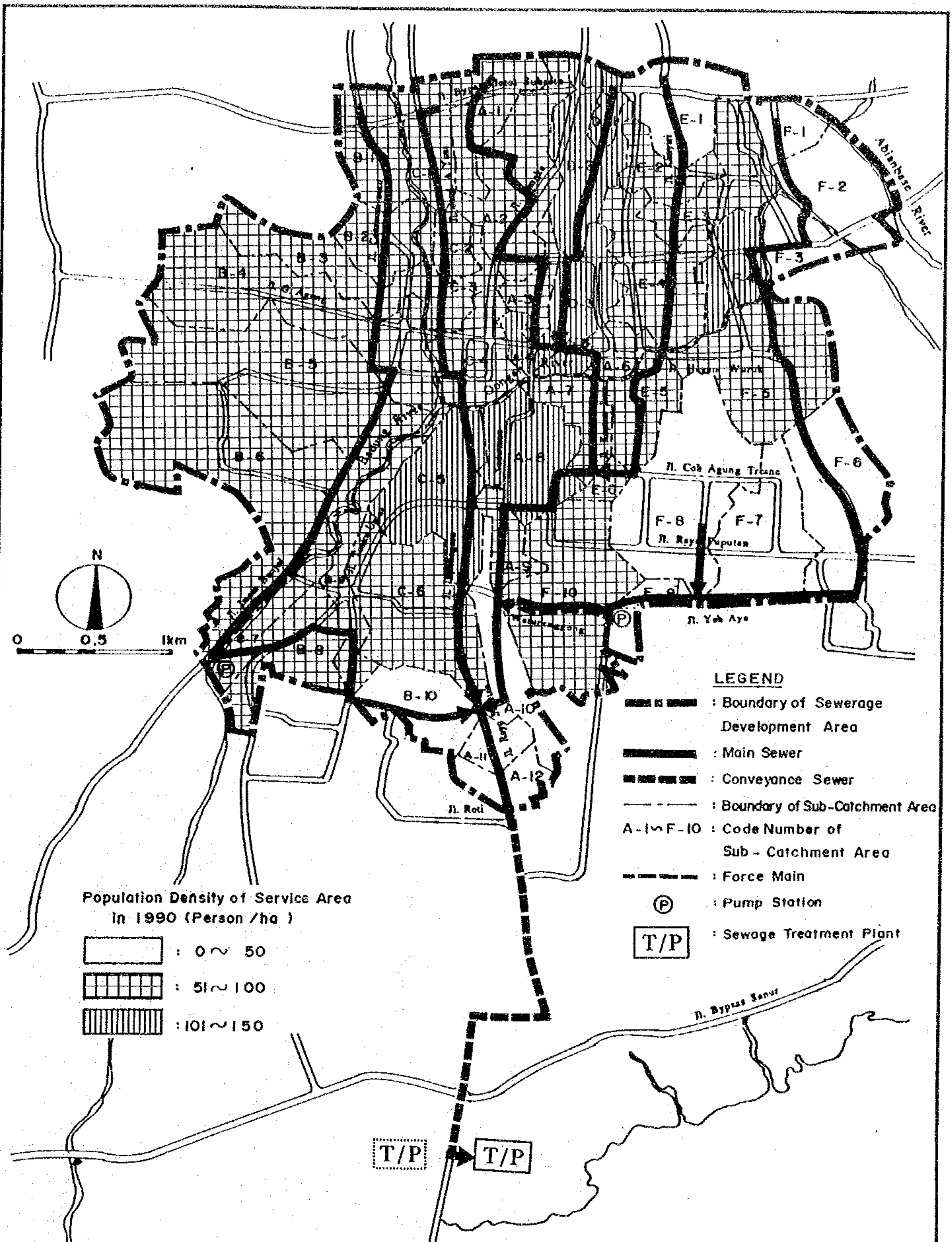


FIG.A.1.10(1) DISTRIBUTION OF EXISTING SERVED POPULATION DENSITY 1990

THE DEVELOPMENT STUDY ON WASTEWATER DISPOSAL FOR DENPASAR

JICA A.D 1993

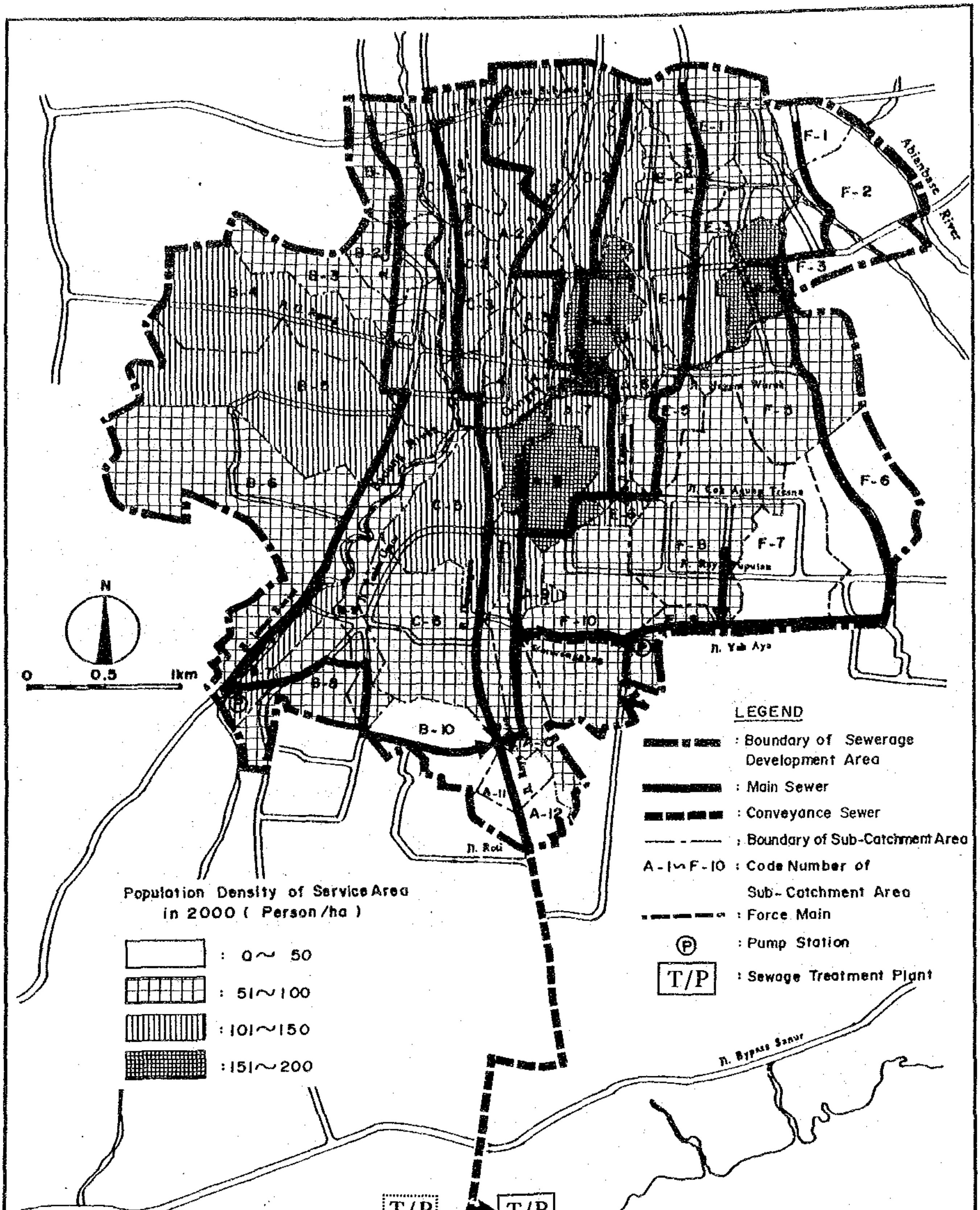


FIG.A.1.10(2)	DISTRIBUTION OF FUTURE SERVED POPULATION DENSITY 2000

THE DEVELOPMENT STUDY ON WASTEWATER DISPOSAL FOR DENPASAR

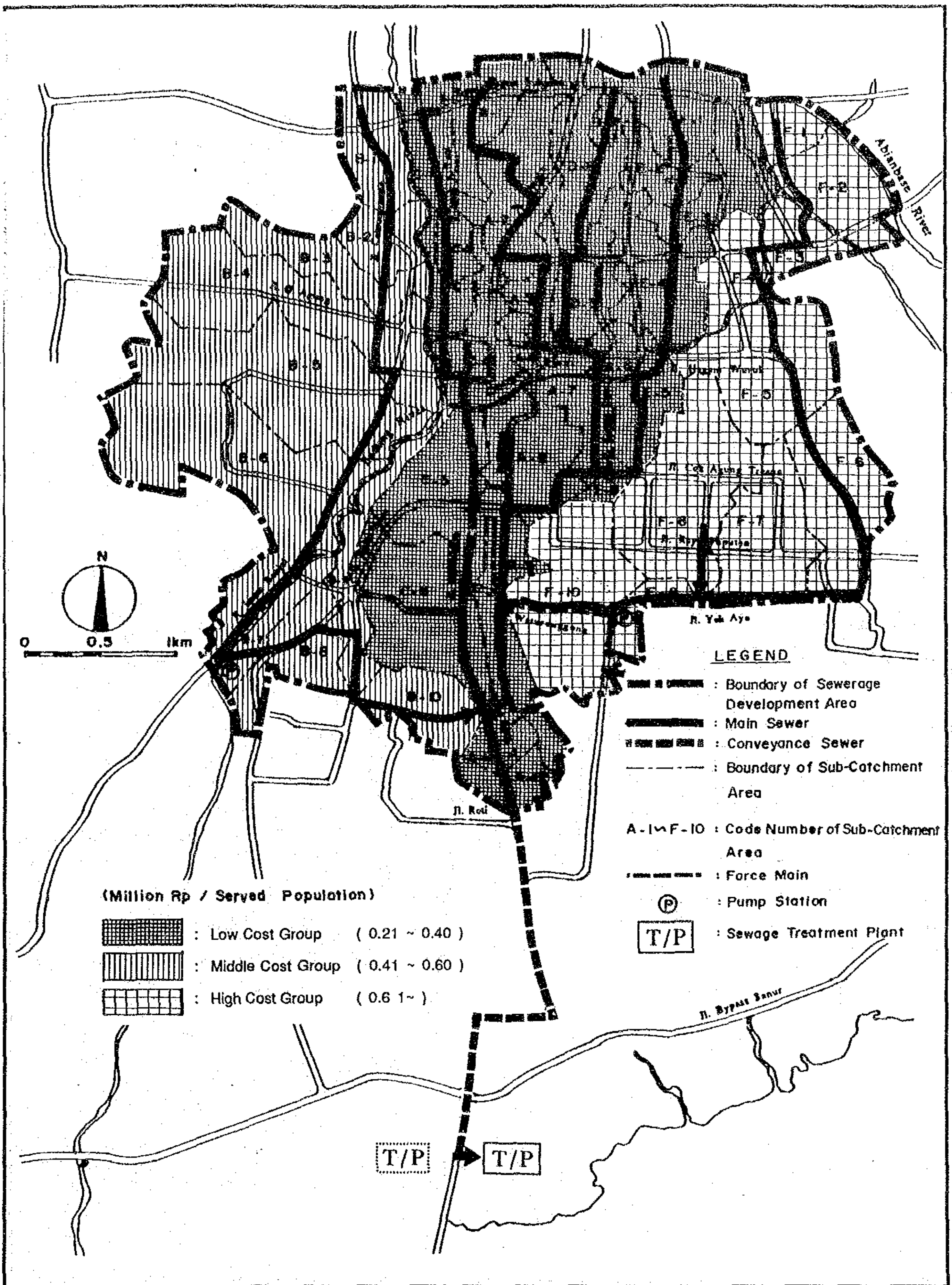


FIG. A 1.11 CLASSIFICATION OF CATCHMENT ZONE BY CONSTRUCTION COST PER SERVED POPULATION

THE DEVELOPMENT STUDY ON WASTEWATER DISPOSAL FOR DENPASAR

JICA A.D 1993

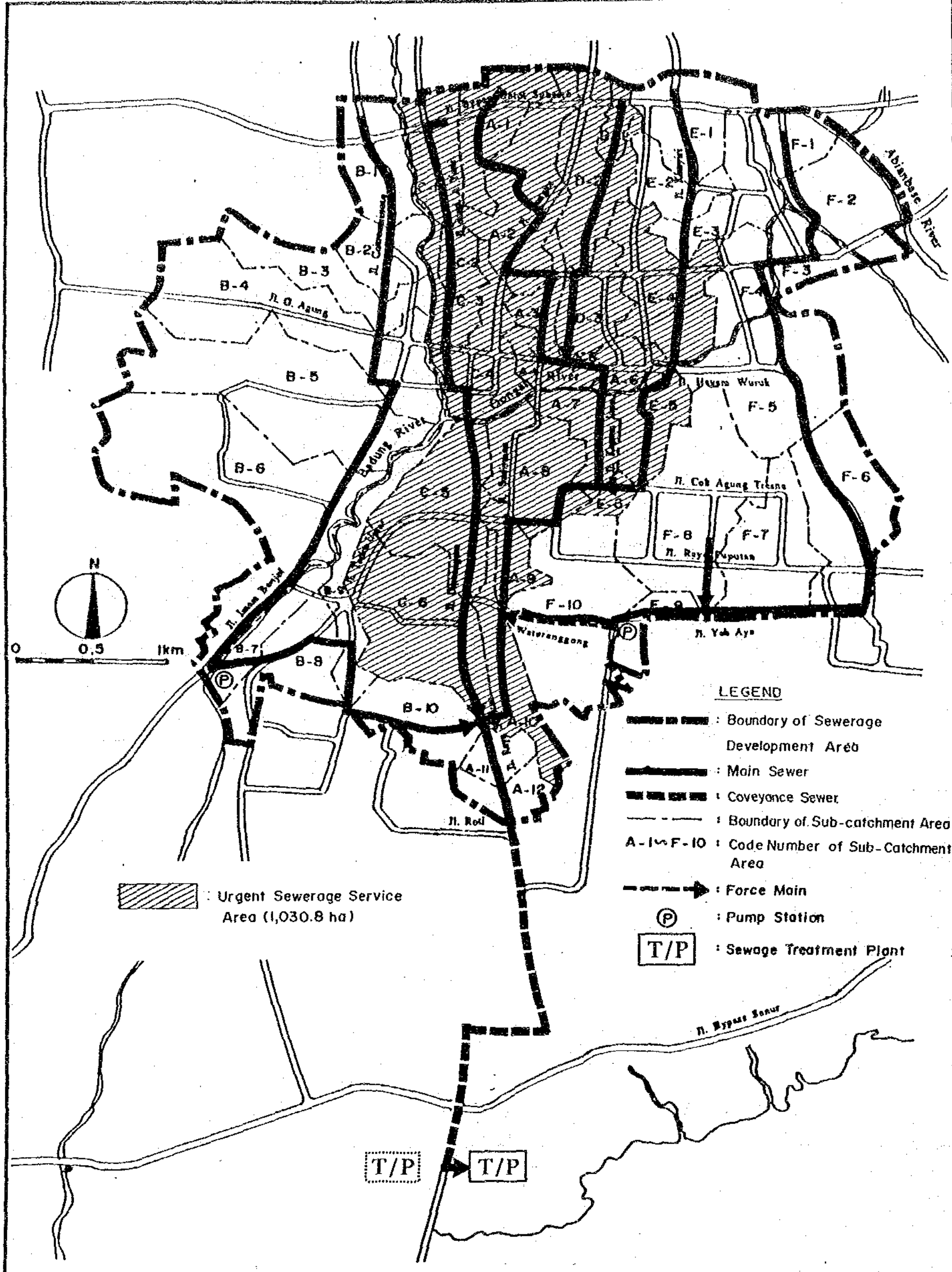


FIG. A.1.12 PROPOSED URGENT SEWERAGE SERVICE AREA

THE DEVELOPMENT STUDY ON WASTEWATER DISPOSAL FOR DENPASAR

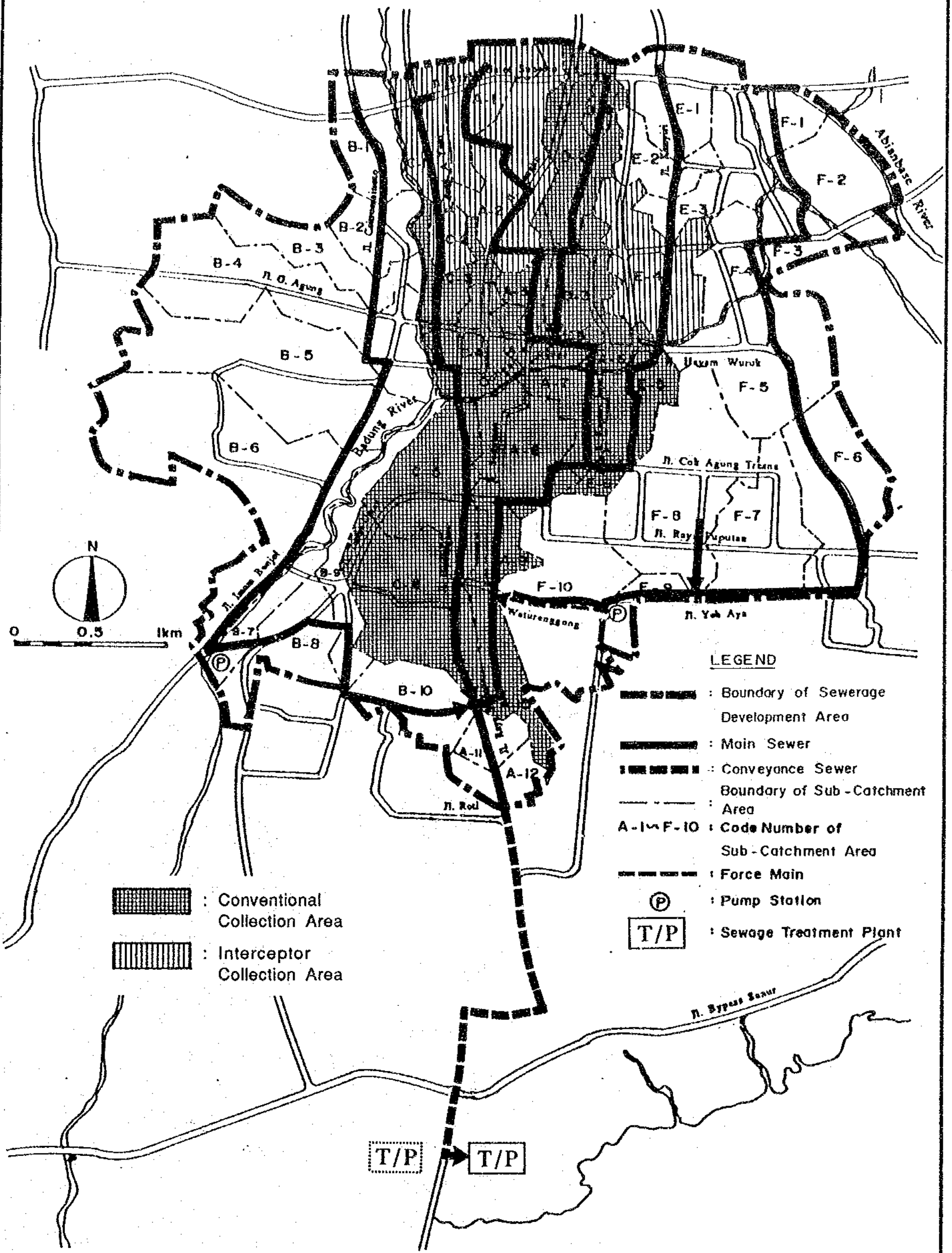


FIG. A.1.13 DELINEATION OF CONVENTIONAL AND INTERCEPTOR COLLECTION SYSTEM

THE DEVELOPMENT STUDY ON WASTEWATER DISPOSAL FOR DENPASAR

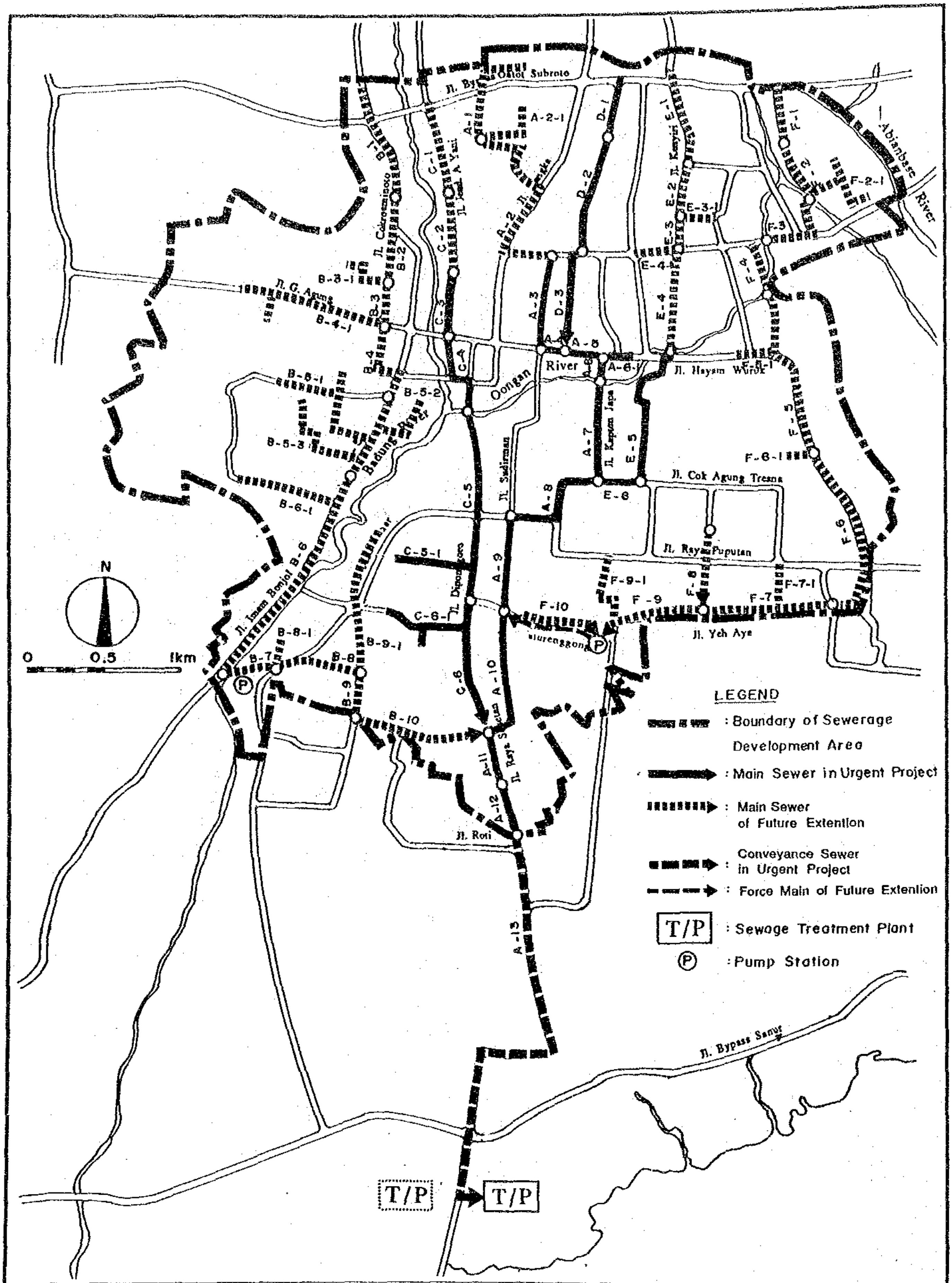


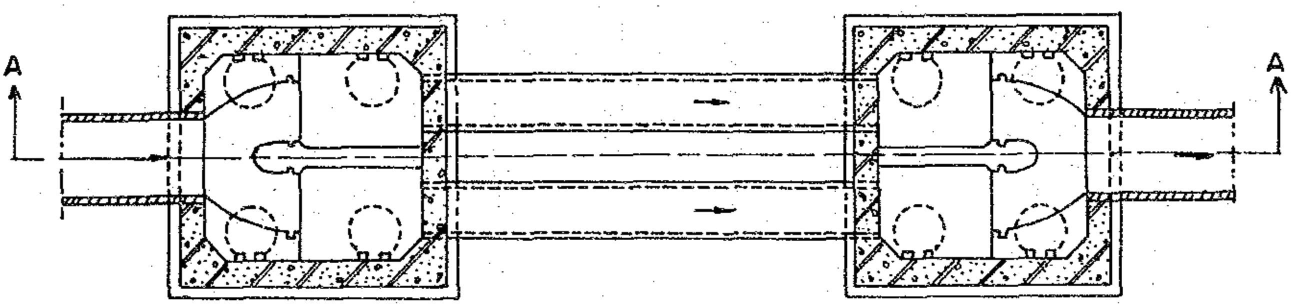
FIG. A.1.14	PROPOSED URGENT MAIN AND CONVEYANCE SEWERS

THE DEVELOPMENT STUDY ON WASTEWATER DISPOSAL FOR DENPASAR

Siphon for River Crossing

Line No.	River Name	Ground Elevation (m)	Upper Pipe D1 (mm)	Upper Pipe IE1 (m)	Lower Pipe D2 (mm)	Lower Pipe IE2 (m)	Siphon D3 (mm)	Siphon IE3 (m)	Siphon EC (m)	Siphon L (m)
A-6	Oongan River	22.22	900	20.31	900	19.74	400	16.93	5.1	40
C-4	Oongan River	19.03	800	16.23	800	15.69	350	11.08	7.7	40

PLAN



SECTION A - A

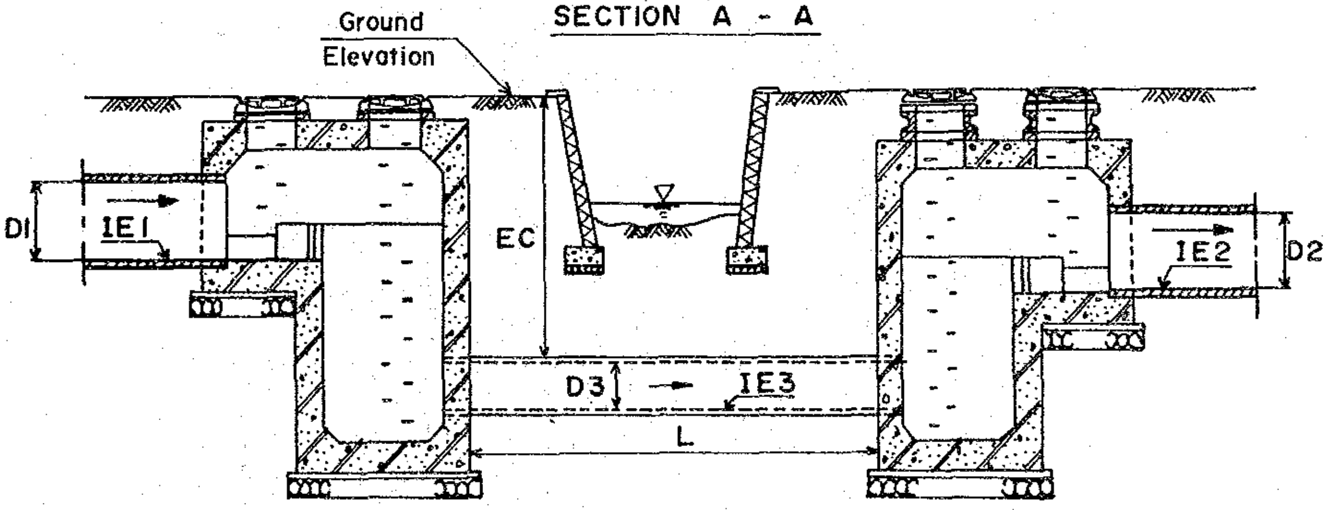


FIG. A.1.15 PROPOSED INVERTED SIPHON

THE DEVELOPMENT STUDY ON WASTEWATER DISPOSAL FOR DENPASAR

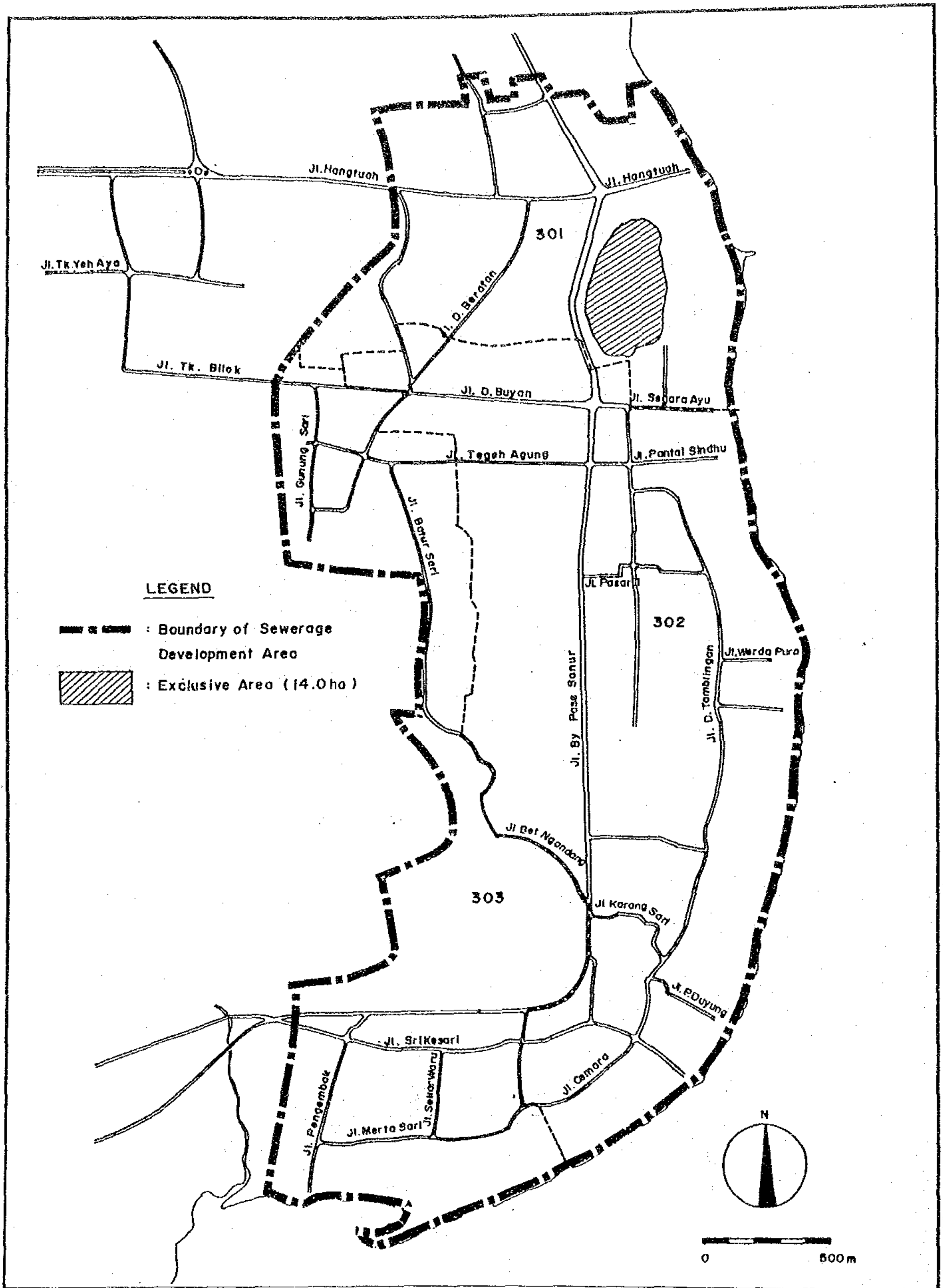


FIG. A.2.1 SEWERAGE DEVELOPMENT AREA OF SANUR

THE DEVELOPMENT STUDY ON WASTEWATER DISPOSAL FOR DENPASAR

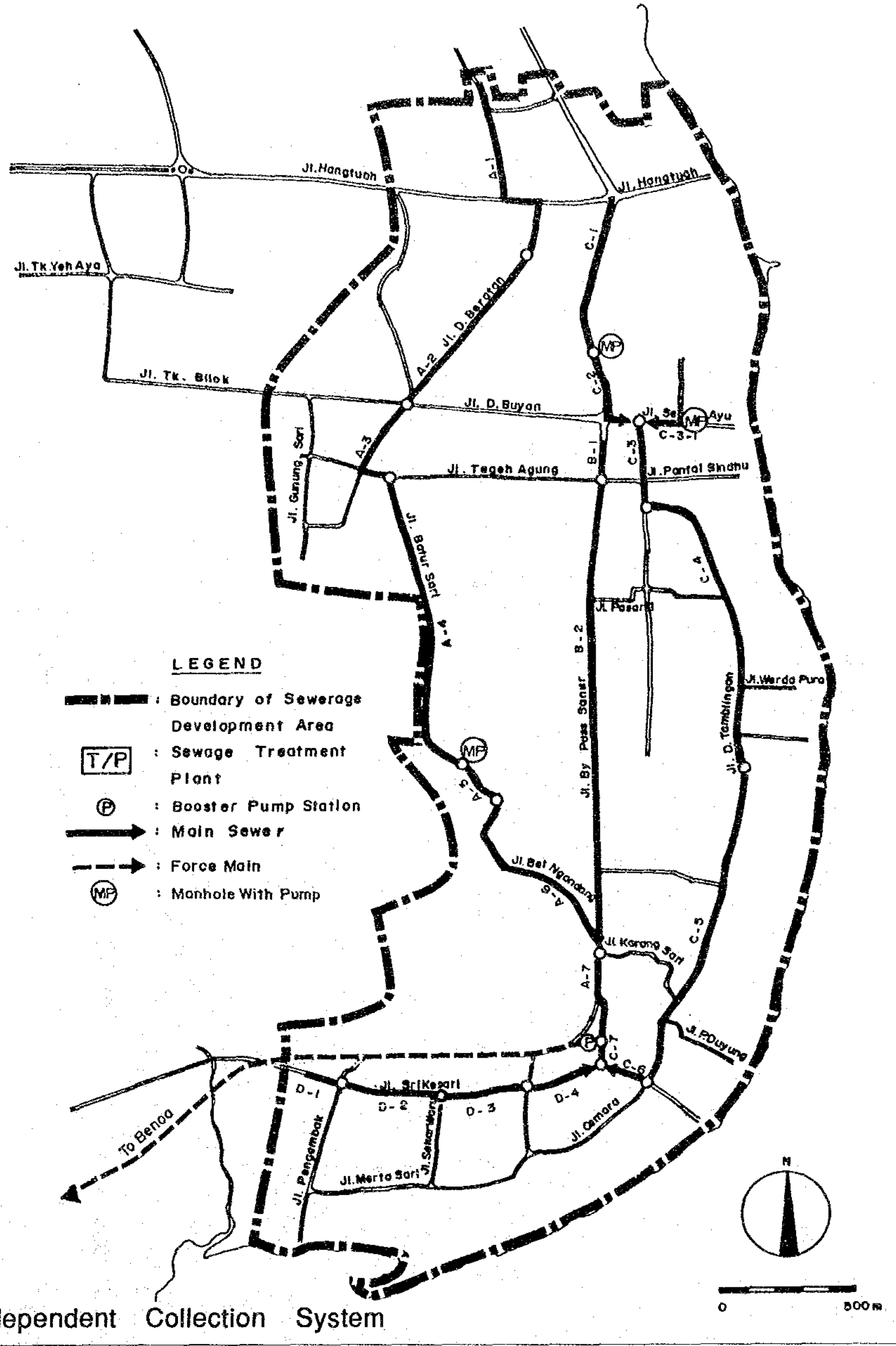
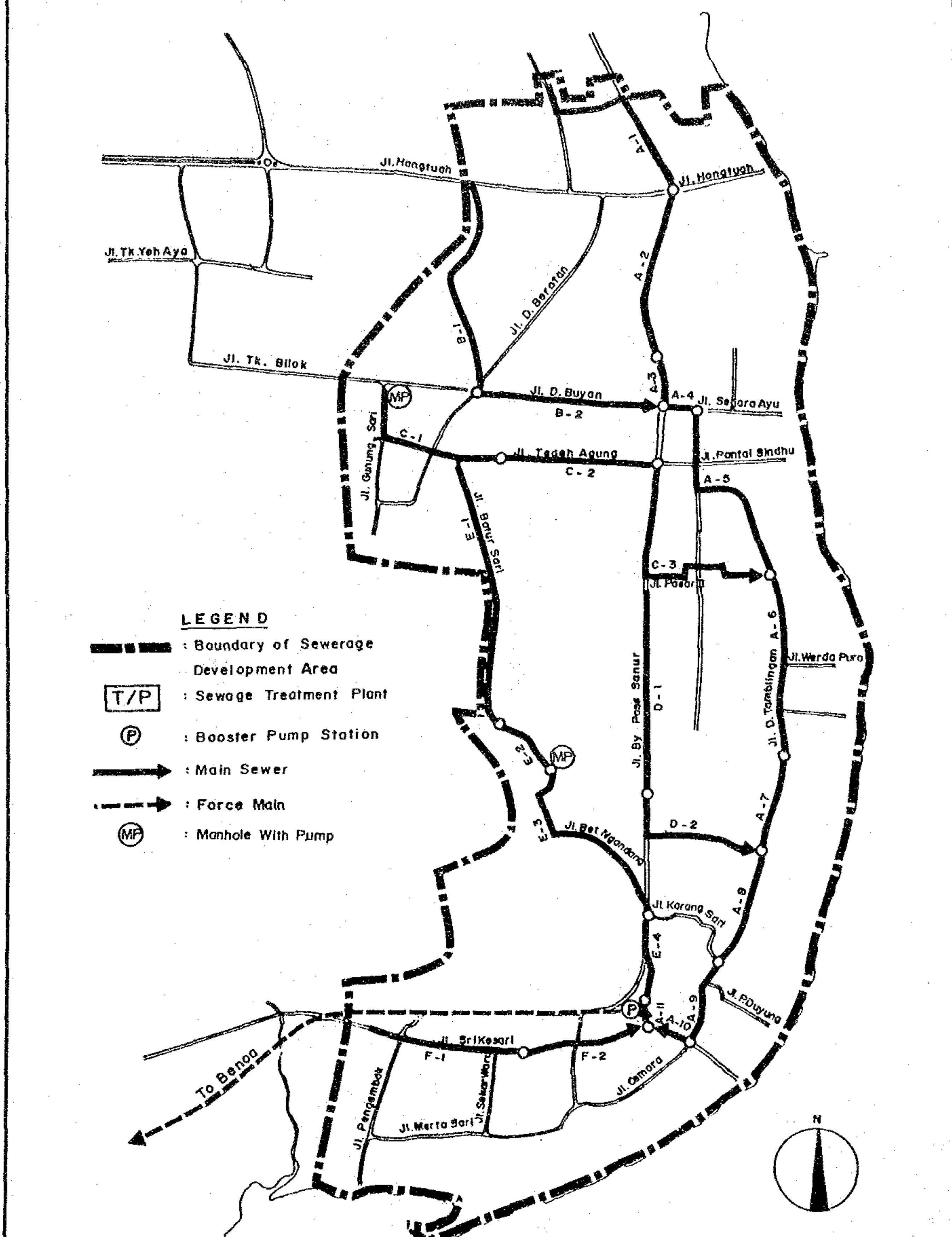


FIG. A.2.2 ALTERNATIVE A

THE DEVELOPMENT STUDY ON WASTEWATER DISPOSAL FOR DENPASAR



Integrated Collection System

FIG. A.2.3	ALTERNATIVE B

THE DEVELOPMENT STUDY ON WASTEWATER DISPOSAL FOR DENPASAR

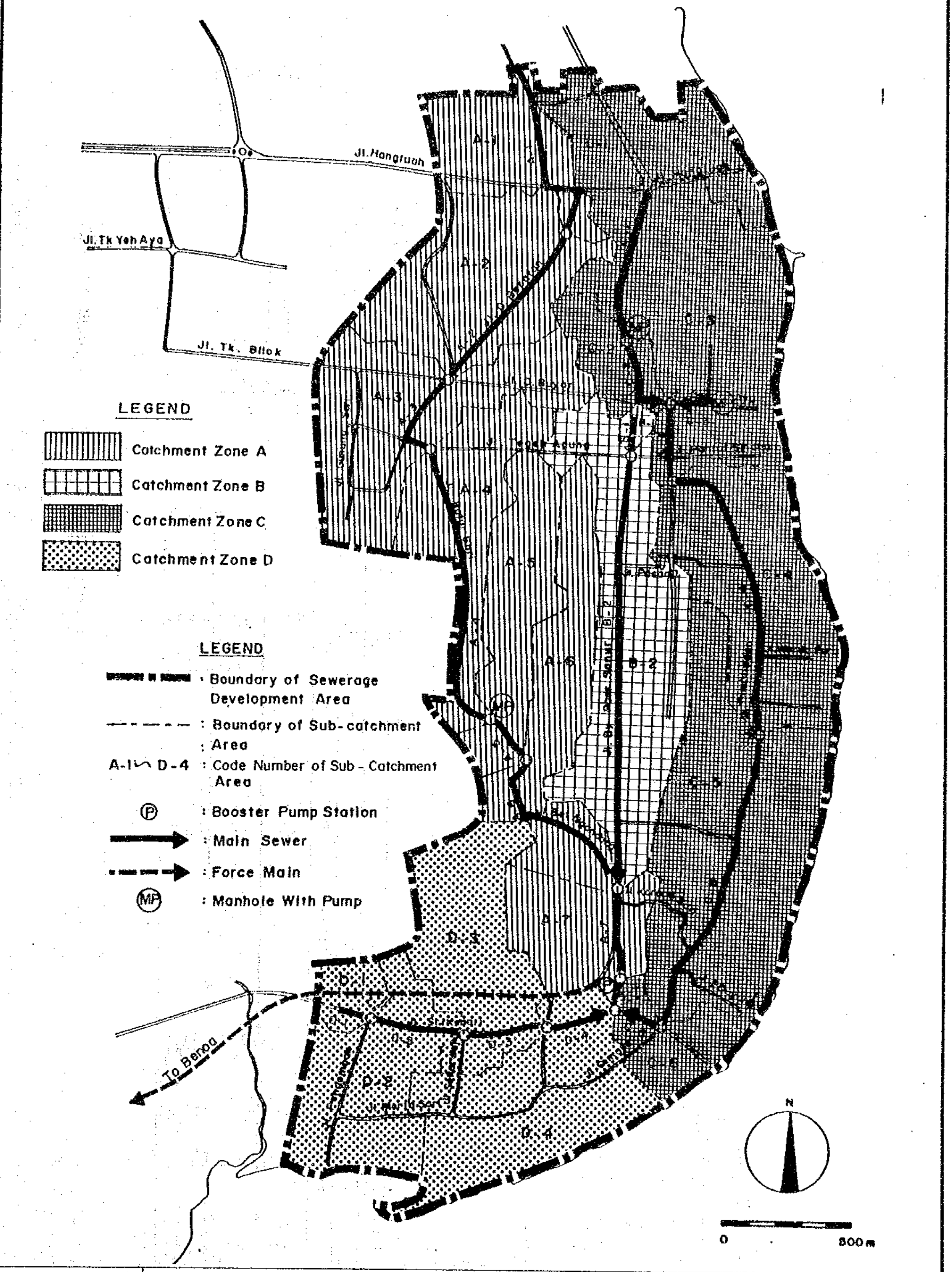


FIG. A.2.4

DIVISION OF SEWERAGE SERVICE AREA

THE DEVELOPMENT STUDY ON WASTEWATER DISPOSAL FOR DENPASAR

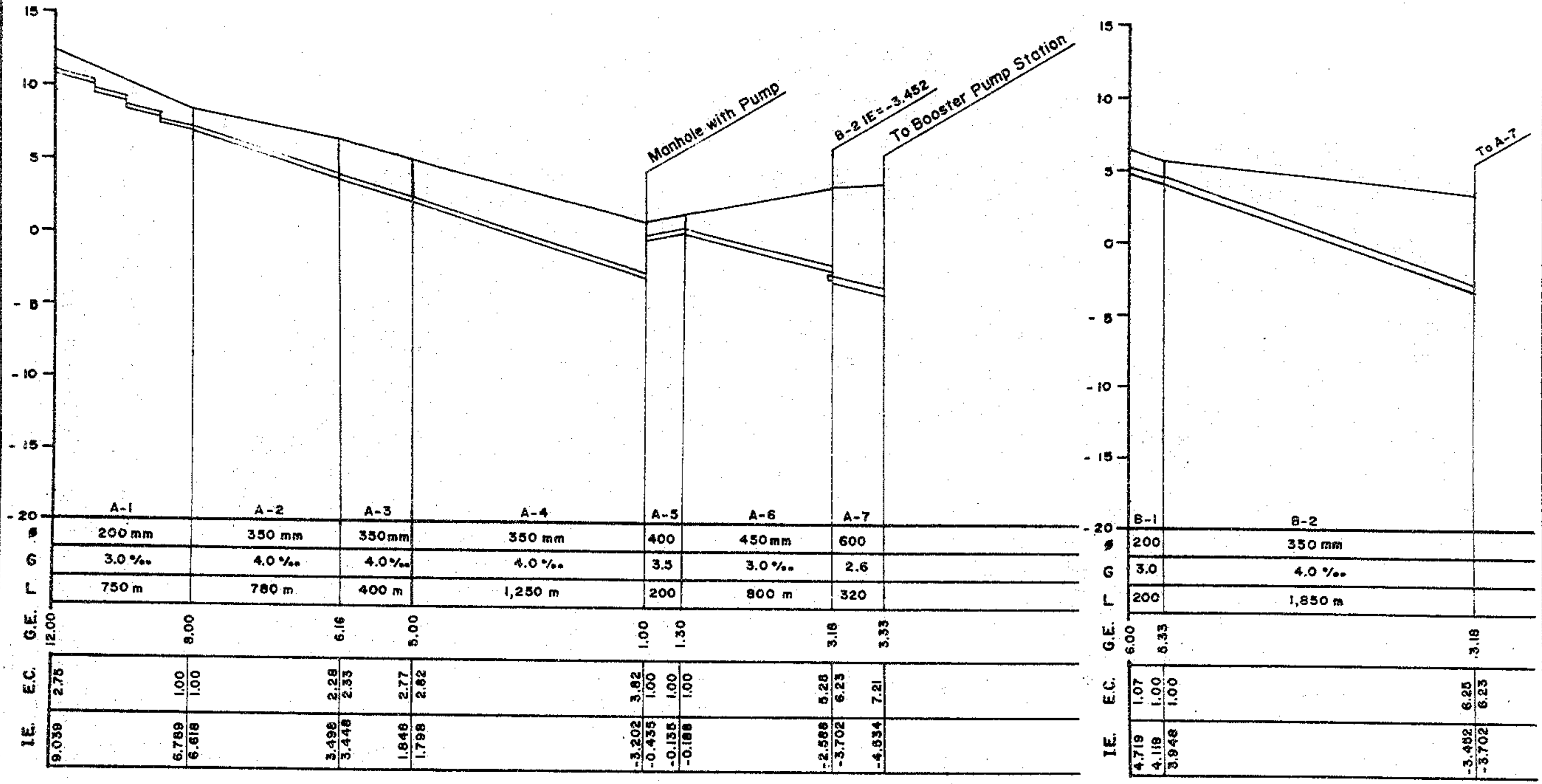


FIG. A.2.5(1)	PROPOSED LONGITUDINAL PROFILE

THE DEVELOPMENT STUDY ON WASTEWATER DISPOSAL FOR DENPASAR

JICA A.D 1993

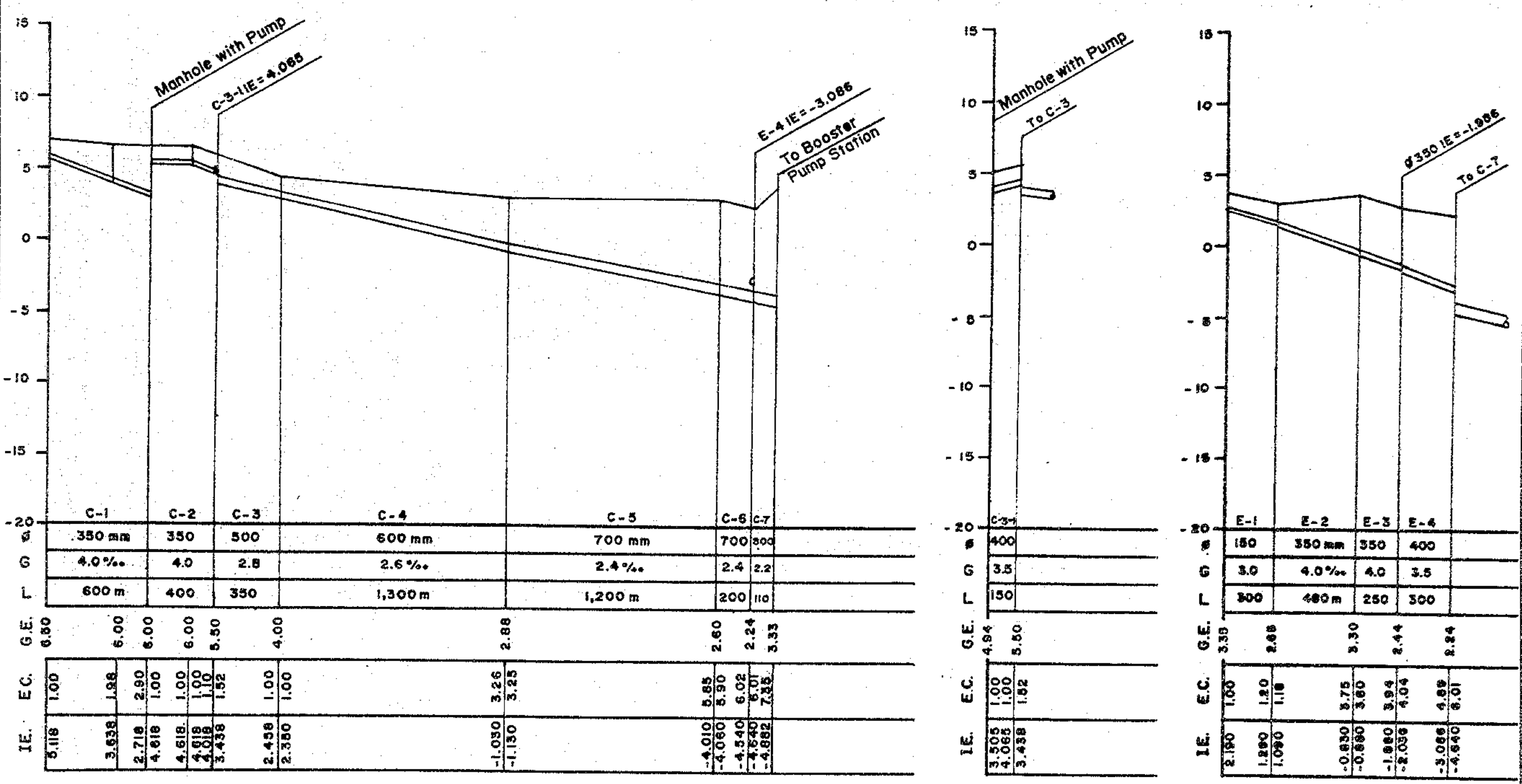


FIG. A.2.5(2) PROPOSED LONGITUDINAL PROFILE

THE DEVELOPMENT STUDY ON WASTEWATER DISPOSAL FOR DENPASAR

JICA A.D 1993

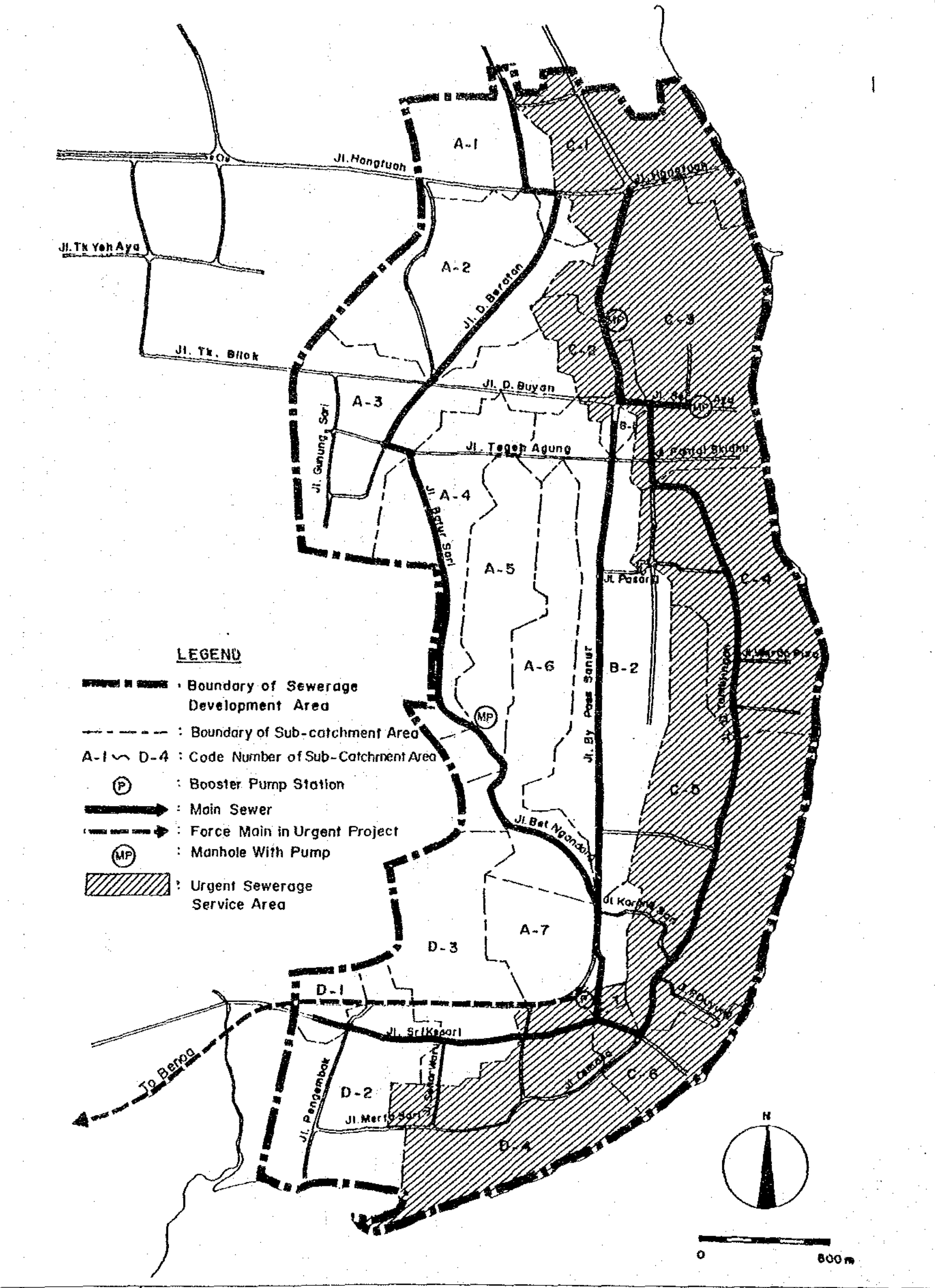


FIG. A.2.6 PROPOSED URGENT SEWERAGE SERVICE AREA OF SANUR

THE DEVELOPMENT STUDY ON WASTEWATER DISPOSAL FOR DENPASAR

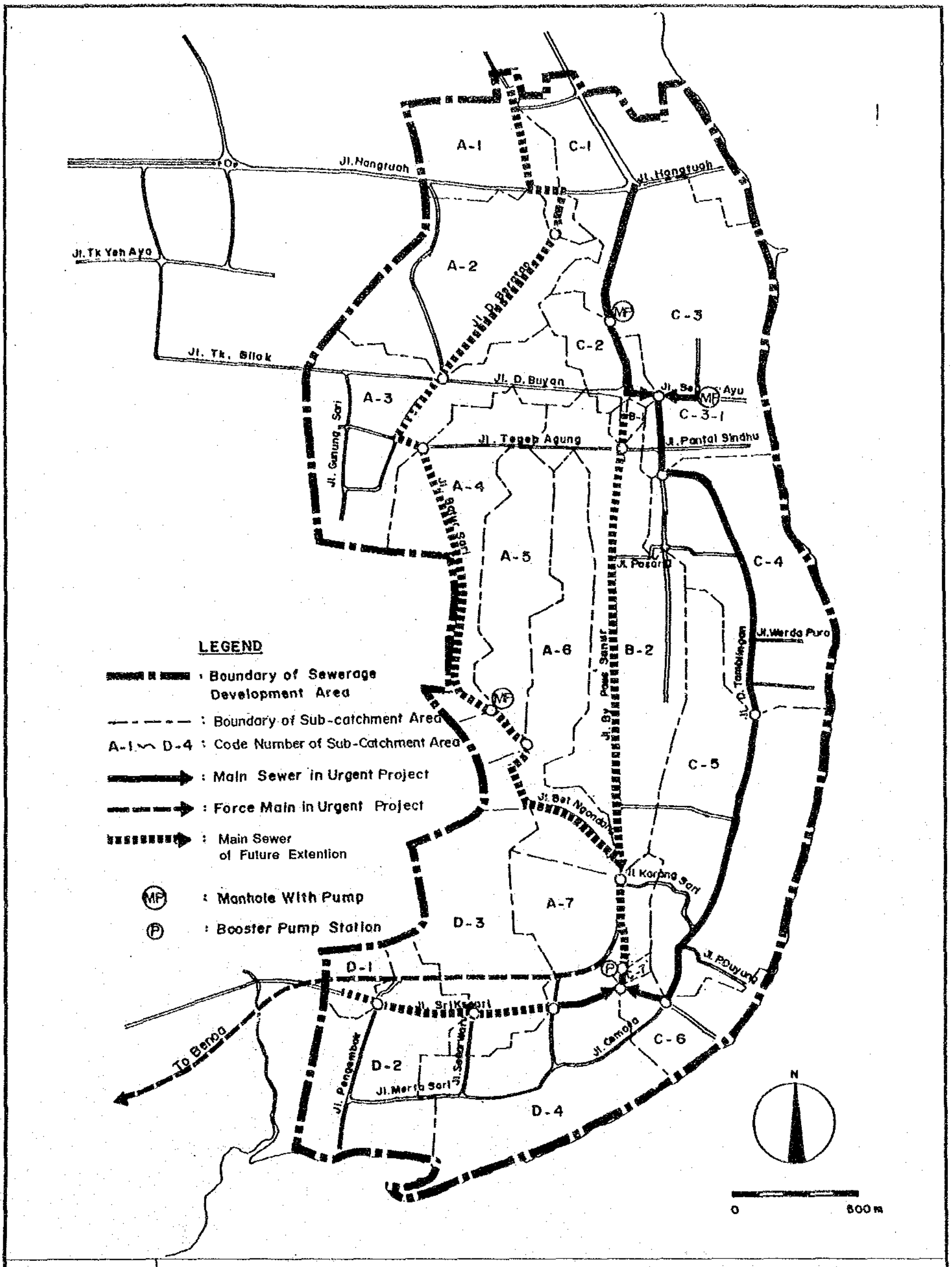


FIG. A.2.7 PROPOSED URGENT SEWERAGE NETWORKS IN SANUR

THE DEVELOPMENT STUDY ON WASTEWATER DISPOSAL FOR DENPASAR

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APPENDIX B

SEWAGE TREATMENT PLAN

APPENDIX B SEWAGE TREATMENT PLAN

1. Treatment Plant Site

1.1 Location

The proposed treatment plant site is swampy area located in Pessanggaran of Kelurahan Pedungan along Jl. Pelabuhan Benoa, the road leading to the Benoa Port. The site is at about 800 m distance along Jl. Pelabuhan Benoa from its intersection (junction) with Jl. Raya Sesetan and Jl. Bypass Ngurah Rai, and is located at left side of the road toward the port (ref. Fig.B.1.1).

The land is under the jurisdiction of the Ministry of Forestry, the Government of Indonesia.

1.2 Condition of Land Use

The existing land use of this swampy area of treatment site is artificial shrimp culture (aquaculture) ponds, that covers an area of more than 394 ha.

Mangrove forestation expands in the swampy area along the southern side of the shrimp pond area toward the Benoa Bay coast.

The required shrimp pond area for the treatment plant, by the urgent project until the year 2000 is about 9.2 ha, while the total requirement of master plan until the year 2010 is about 22 ha. The selected entire treatment plant site is more than 300 m away from the nearest permanent structure, and is essentially remote from residential areas.

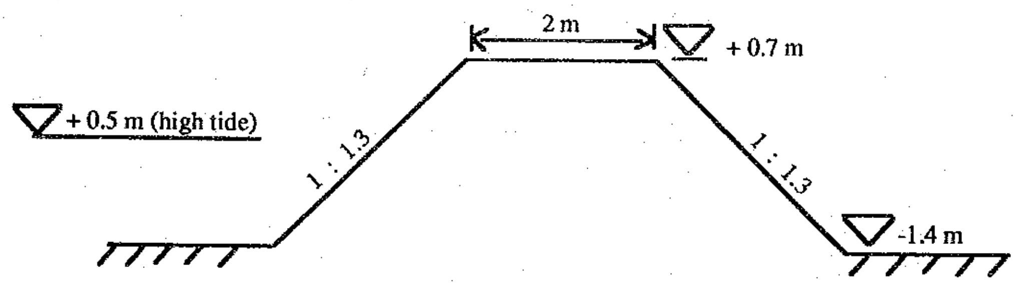
1.3 Land Elevation

The existing average crown elevation of the shrimp pond embankment is : + 0.7 m. The average base elevation of shrimp pond is : - 1.4 m. The high tide of Benoa Bay is : + 0.5 m.

The above elevations are based on the inland survey bench mark used in this project.
The high tide of Benoa Bay based on MSL is + 1.0 m, which is equivalent to 0.5 m level of this project.

The total length of existing shrimp pond embankment within the proposed treatment plant site of 9.2 ha for urgent project is 3,120 m. Its average cross sectional area is 10 m^2. Hence total volume of embankment within the sewage treatment plant area is about 31,200 m^3.

Typical section of shrimp pond embankment is shown below.



1.4 Soil Type

The area is swampy land. Hence, as could be expected the top surface layer of 0 ~ 11 m depth is composed of soft clay with disintegrated coral. While, soft to stiff sandy soil layer with disintegrated coral is encountered at a depth of 12 ~ 23 m, followed with stiff sandy clay layer with disintegrated coral at a depth of 25 ~ 30 m.

Thin coral layers with pores are encountered at depths of 11 m and 23 m.

The N values of this subsoil are as follows :

- Less than 10 at shallow depths less than 17 m
- 15 ~ 20 at depths of 18 ~ 22 m
- Greater than 20 in deep layers deeper than 23 m

The deeper layer at more than 23 m depth is considered to be the bearing stratum.

2. Design Wastewater Quality and Quantity

2.1 General

The design wastewater generation in the year 2000 for the urgent project in both the Denpasar and Sanur service areas are determined in Appendix A.

Moreover the total design wastewater generation in the year 2010, not only from the Denpasar and Sanur service areas, but also from the Kuta service area, other than the portion treated by the Kuta sewerage project under the IUIDP Project, will be treated in the treatment plant of this project by the year 2010.

The design wastewater generation of these areas in the year 2010 is dealt with in details in Appendix E of Supporting Report of Master Plan Study.

2.2 Wastewater Quality

The influent wastewater quality to treatment plant is established as 190 mg/ℓ in BOD_5, while the effluent water quality requirement is 20 mg/ℓ as BOD_5.

The design wastewater temperature is determined as 25°C, which is assumed to remain the same in the treatment system as well (ref. Section 5.6 of Appendix E, Supporting Report of Master Plan Study).

2.3 Wastewater Quantity

The quantity of wastewater for treatment, influent to treatment plant, is determined with due consideration to groundwater infiltration into sewer system. Groundwater infiltration is assumed as 10% of design wastewater discharge into sewer system.

The quantity of wastewater discharge to treatment plant, and hence its required capacity, as per the master plan in the year 2010 and this urgent project in the year 2000 are presented in the subsequent sections.

2.3.1 Treatment Capacity by 2010

The proposed treatment plant will receive wastewater from three (3) service areas of Denpasar, Sanur and Kuta by 2010 (ref. Appendix E of Supporting Report of Master Plan Study).

The design wastewater discharge for treatment, including 10% of groundwater infiltration, as daily average, from each of the above service areas by 2010 are as follows.

Denpasar service area	:	82,834 m^3/d
Sanur service area	:	18,530 m^3/d
Kuta service area	:	20,240 m^3/d
Total in the year 2010	:	121,604 m^3/d

Nevertheless, the ongoing sewerage project in Kuta area by the IUIDP Project, the whole service area of which is encompassed in the above Kuta service area, will have a treatment capacity of about 4,240 m^3/d.

As such, the design wastewater quantity of treatment by this plan in 2010 becomes 117,364 m^3/d.

The design treatment plant capacity of this master plan by 2010, located in Pessanggran, is determined as 117,000 m^3/d.

2.3.2 Treatment Capacity by 2000

The service area will cover only portions of master plan areas in Denpasar and Sanur, as delineated in Appendix A, until the year 2000 as the urgent project.

The quantity of daily average design wastewater discharge to treatment plant, including 10% groundwater infiltration, by 2000 are as follows.

Denpasar service area	:	34,570 m^3/d
Sanur service area	:	9,420 m^3/d
Total in the year 2000	:	43,990 m^3/d

Accordingly, the design capacity of treatment plant for this urgent project is determined as 44,000 m^3/d. This is about 38% of the planned ultimate treatment capacity of 117,000m^3/d, by the year 2010 (ref. Fig. B.1.1).

3. Aerated Lagoon Treatment System

3.1 General

The proposed treatment system, in principle, comprises aerated lagoon system consisting of completely mixed aerobic aerated lagoon followed with partially mixed facultative aerated lagoon and polishing pond in consideration to its simplicity, suitability in hot climatic conditions and also to optimize the extent of land area requirement.

In determining the design parameters of the aerated lagoon system, in addition to the basic theoretical considerations, the following practical aspects are taken into account.

The accumulated Indian experience as reported by Rao and Datta (1987), the experience under hot climatic conditions as of Mara (1976) and the available Malaysian Standards on Sewerage Systems (1991).

The most important design parameter of both the aerated and facultative aerated lagoons (aerated lagoon system) is the detention time (t^*_d), which dictates the area requirement of this treatment system, followed with the design depth, and hence the extent of the overall treatment plant.

It is noted that while established reactor kinetic theory is available for rational design of aerated lagoon, which could be approximated to a completely mixed aerobic reactor, such a rational theoretical aspect is yet to be established for designing the subsequent facultative aerated lagoon.

Nevertheless, as pointed out by Rao and Datta (1987) a series system consisting of aerated lagoon followed with facultative aerated lagoon results in optimum design with superior effluent quality.

Reactor kinetic theory is used to establish the prime design parameter of detention time of aerated lagoon. While practical aspects and overall detention time consideration are used to establish the detention time of subsequent facultative aerated lagoon.

The selected design parameters of aerated lagoon system are illustrated and justified respectively in the subsequent sections.

3.2 Aerated Lagoon

3.2.1 Design Parameter

Design detention time (t^*_d) is 2 day

Design effective depth (De) is 4.0 m

3.2.2 Illustration and Justification

(1) Theoretical Aspect

Aerated lagoon, which is under aerobic condition, is essentially a no recycle actived sludge process. Based on first order kinetics for substrate waste removal, the following mathematical relations for substrate and microorganism concentration in the reactor are established under completely mixed steady state condition with no recycle at constant temperature.

$$\frac{S}{S_o} = \frac{1}{(1 + k X t^*)} \quad \text{..........} \quad (1)$$

$$X = \frac{Y (S_o - S)}{(1 + k_d t^*)} \quad \text{..........} \quad (2)$$

$$t^* = V/Q \quad \text{..........} \quad (3)$$

Where :

S_o = Influent substrate waste to reactor (aerated lagoon) as BOD_5 (mg/ℓ)

S = Effluent BOD_5 , i.e. influent substrate waste that escapes oxidation/microbial synthesis (mg/ℓ)

V = Volume of reactor (m^3)

Q = Flow rate through reactor (m^3/d)

t^* = Detention time in reactor (d)

X = Concentration of microorganism in reactor (mg/ℓ)

k = Specific waste substrate utilization rate by microorganism (ℓ/mg·X/d)

Y = Yield coefficient of microorganism (mg·X/mg·S)

k_d = Death rate coefficient of microorganism (d^{-1})

The total net effluent concentration from the reactor (Et) comprising X (microbial mass) and S (substrate waste) as BOD_5 is given by the following relation :

$$E_t = S + 0.95\,X \qquad \text{..........} \qquad (4)$$

(Note : 0.95 is factor for conversion of X to BOD_5)

Moreover, in Equation-(1) when gross substrate BOD_5 removal rate is represented as K, where,

$$K = k \cdot X \qquad \text{..........} \qquad (5)$$

Equation-(1) is simplified to ;

$$\frac{S}{S_o} = \frac{1}{(1 + K\,t^*)} \qquad \text{..........} \qquad (6)$$

Where K = Gross substrate BOD_5 utilization rate (d^{-1})

In general, above kinetic coefficients and BOD_5 are defined at 20°C, the temperature at which most data are available. The kinetic coefficient at a different temperature could be determined using an appropriate Arrheneous constant (ß). For example, the k at temperature T (k_T) is given by ;

$$k_T = k_{20}\,(\beta)^{T-20} \qquad \text{.............................} \qquad (7)$$

Oxygen requirement for oxidation and microbial synthesis (R_{O2}) is determined based on ultimate BOD (BOD_L) exerted in the reactor (aerated lagoon) as follows :

$$R_{O2} = 1.5\,Q\,(S_O - E_t) \qquad \text{.............................} \qquad (8)$$

This gives R_{O2} in g/d

(Note : 1.5 is factor for conversion of BOD_5 to BOD_L)

By substituting for E_t from Equation-(4), Equation-(8) could also be written as :

$$R_{O2} = 1.5\,Q\,(S_O - S) - 1.42\,Q\,X \qquad \text{.............................} \qquad (8a)$$

(2) Application by Mara

The relations used by Mara (1976) are basically the following :

$$\frac{S}{S_O} = \frac{1}{(1 + K\,t^*)} \qquad \text{.............................} \qquad (6)$$

$$X = \frac{Y\,(S_O - S)}{(1 + k_d\,t^*)} \qquad \text{.............................} \qquad (2)$$

The following kinetic constant values for the above relations are proposed by Mara :

$K = 5.0\ d^{-1}$ (at 20°C)

$Y = 0.6 \sim 0.7\ (0.65)$

$k_d = 0.07\ d^{-1}$ (at 20° C)

Arrheneous constant (ß) = 1.035

In this project area the following basic environmental/process conditions are established.

Influent BOD_5 (S_o) = 190 mg/ℓ
Effluent requirement as $BOD_5 \leq 20$ mg/ℓ
Liquid temperature in lagoon = 25°C
Hence : K_{25} = 5.94
kd_{25} = 0.083

For an effluent S as BOD_5 of 20 mg/ℓ the computed detention time (t^*_d) using Equation-(6) is : 1.43 day.
However, based on practical experience, in order to facilitate the development of flocculant/settleable microbial mass in aerated lagoon, Mara proposes the detention time be not less than 2 day, with a recommended value of 4 day.

Hence a value of 2 day is reasonable for initial aerated lagoon, considering the computed requirement of 1.43 day, with a subsequent 2 day detention time in the facultative aerated lagoon. This would also meet the recommended 4 day detention time by Mara on the basis of overall aerated lagoon treatment system.

It is also noted that Malaysian Standards stipulates a minimum detention time of 1 day for completely mixed aerated lagoon.

Design detention time (t^*_d) of aerated lagoon = 2 d

For this design t^*_d, the actual S, effluent substrate BOD_5 to facultative aerated lagoon, using Equation-(6) is computed as : 14.75 mg/ℓ.

The corresponding concentration of microorganism (X) in reactor (aerated lagoon) using Equation-(2) is computed as : 97.7 mg/ℓ.
Then the total BOD_5 of effluent (E_t) due to both X and S to facultative aerated lagoon using Equation-(4) is computed as : 107.6 mg/ℓ.

Efficiency of the aerated lagoon with respect to substrate waste reduction becomes 92.2% [100 (S_o - S)/ S_o].

The net efficiency of BOD removal within the aerated lagoon becomes 43.4% [100 (S_o - E_t)/ S_o].

The oxygen requirement (R_{o2}) using Equation-(8) for unit (m^3/d) flow (Q) is computed as : 123.6 g/d.

It is pointed out that influent to subsequent facultative aerated lagoon will have a net BOD_5 of 107.6 mg/ℓ of which original influent to the aerated lagoon will contribute only 14.8 mg/ℓ ; the remaining ≈ 93 mg/ℓ is due to settleable microorganism cells synthesized in aerated lagoon.

Settlement of these microorganism cells and their subsequent anaerobic digestion to realize sludge treatment is a major function of facultative aerated lagoon in its anaerobic/facultative zone deep below the surface.

(3) Application in India

Rao and Datta (1987) presented the experience gained in India with aerated lagoon.

The relations used are basically the following :

$$\frac{S}{S_o} = \frac{1}{(1 + k X t^*)} \quad \text{..........................} \quad (1)$$

$$X = \frac{Y (S_o - S)}{(1 + k_d t^*)} \quad \text{..........................} \quad (2)$$

The authors recommend following kinetic constant values for Indian conditions where temperature falls rarely below 15°C.

k = 0.05 ℓ/mg/d (at 20°C)

Y = 0.5

kd = 0.05 d^{-1}

Arrheneous constant (ß) = 1.06

The same environmental/process conditions as the foregone section (i.e. S_o = 190 mg/ℓ, S ≤ 20 mg/ℓ, temperature 25°C) are considered.
Hence : k_{25} = 0.067 ℓ/mg/d

The computed detention time simultaneously solving Equation-(1) and Equation-(2) for t^* for an effluent S of 20 mg/ℓ becomes : 1.61 day.

This is similar to the one computed using Mara case of : 1.43 day.

For a design detention time (t^*_d) of 2 d, as per foregone section, by simultaneously solving for S and X using Equation-(1) and Equation-(2) the following values are obtained.

Effluent S = 16.4 mg/ℓ (Mara : 14.75 mg/ℓ)
Effluent X = 79.0 mg/ℓ (Mara : 97.7 mg/ℓ)

The overall kinetic constant K, as used by Mara, in this case with 2 day (t^*_d), using Equation-(5) is computed as : 5.29 d^{-1}.

This compares with the 25°C K of 5.94 d^{-1} by Mara.

The total BOD_5 of effluent (E_t) due to both X and S using Equation-(4) is computed as : 91.45 mg/ℓ.
(This compares with 107.6 mg/ℓ of Mara)

Aerated lagoon efficiency with respect to substrate waste reduction is : 91.4% (Mara : 92.2%).

The net efficiency within the lagoon becomes : 51.9% (Mara : 43.4%).

The oxygen requirement (R_{O2}) using Equation-(8) for unit volume of flow (Q of 1 m^3/d) is determined as : 147.8 g/d (Mara : 123.6 g/d).

It is noted that the required power rating of aerator in an aerated lagoon is very often governed by the complete mixing requirement rather than oxygen transfer requirement, in practice. The average power requirement for mixing is 5 W/m^3 of reactor volume as per Mara (1976), Rao and Datta (1987) and Malaysian Standards (1991).

Accordingly, mixing power requirement of aerator is selected as 5 W/m^3.

(4) Conclusion

The required theoretical detention time in aerated lagoon to produce an effluent substrate waste of 20 mg/ℓ is about 1.5 day. The design detention time provided is 2.0 day.

3.3 Facultative Aerated Lagoon

3.3.1 Design Parameter

Design detention time (t^*_{df}) is 2 day
Design effective depth (D_{ef}) is 4.5 m

3.3.2 Illustration and Justification

(1) Concept

Conceptually a facultative aerated lagoon has three(3) zones, namely top aerobic zone near the pond surface, that is maintained under aerobic condition by artificial aeration, followed with transitional facultative zone and anaerobic zone that are developed naturally below the surface due to lack of dissolved oxygen (DO) and the resultant anaerobic digestion of settled sludge.

Expansion of this anaerobic digestion induced anaerobic zone to surface, and the resultant degradation in treatment efficiency along with the potential development of odour nuisance is mitigated by maintaining the lagoon surface layer under aerobic conditions by aeration. However, the aeration, on the other hand, should be kept at minimum to facilitate settling of synthesized microbial cells from the aerated lagoon.

(2) Design aspect

A rational theoretical concept for the design of facultative aerated lagoon is very difficult, due to uncertainty in quantifying the settling efficiency of X (microbial cells discharged from aerated lagoon) as well the subsequent effect due on-going anaerobic digestion induced loading to the aerobic layer, in addition to the efficiency of anaerobic digestion itself.

Hence the design consideration is essentially based on practical experience gained with similar systems.

A detention time of more than 3 day is not recommended as it is found to cause nuisance condition due to algae development (Rao and Datta, 1987).

If a detention of 3 day or more is permissible then it is better to design the lagoon as a "natural" facultative pond with shallow depth. Hence it is evident that major advantage of facultative aerated lagoon against facultative pond is the reduced system capacity and area requirement of the lagoon due to its shorter detention time and increased depth.

Based on the above consideration, as well the recommended system detention time of 4 day by Mara (1976), a design detention time of 2 day, same as the initial aerated lagoon, which satisfies both the criteria, is selected.

Moreover, in consideration to typical aerobic zone in a facultative/maturation pond with a depth of about 1 m, it is decided to maintain the top 1 m layer of the lagoon under aerobic condition.

This will be achieved with the provision of sufficient aerator power rating so that complete mixed condition will be attained in this top 1 m layer of the lagoon. The aerator rating be determined conforming the mixing requirement of 5W per m^3 volume of this top 1 m layer.

3.4 Effective Depth of Lagoon

Mara recommend deeper depth in the range of 3~5 m, while Rao and Datta reports a typical range of 2~4 m in India. Malaysian Standards stipulates a maximum depth of 5 m.

In order to optimize the required land area an effective depth of 4 m is selected, which is in accordance with the above reported information. Nevertheless, for facultative aerated lagoon an effective depth of 4.5 m is selected, with an additional 0.5 m depth for storage of digested sludge. Still, the effective depth with respect to liquid reactor content is 4 m.

Reference :

Mara (1976), Sewage Treatment in Hot Climates.

Rao and Datta (1987), Wastewater Treatment.

Malaysian Standard (1991), Code of Practice for Design and Installation of Sewerage Systems.

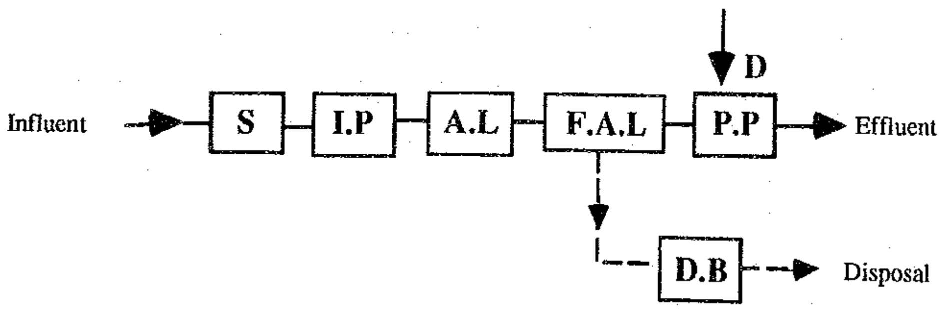
3.5 Polishing Pond

As the major auxiliary unit of the treatment system, polishing pond will be provided as the final treatment stream before discharge of effluent to receiving waters. This is to remove suspended solids that may escape with the effluent of aerated facultative lagoon, due to its conflicting requirement of both settling as well mixing.

The polishing pond be provided with a holding time (detention time) of 0.5 day and of shallow depth, similar to a facultative pond, with an effective depth of 1.5 m and an additional sludge storage of 0.5 m. The pond will be utilized as a disinfection tank as well.

3.6 Treatment Flow Stream

The flow diagram of the sewage treatment stream is shown below.



S : Screen

I.P : Inflow Pump

A.L : Aerated Lagoon

F.A.L : Facultative Aerated Lagoon

P.P : Polishing Pond
D : Disinfection
D.B : Sludge Drying Bed

The layout of the treatment system distinguished between the capacity of urgent project until the year 2000, and that of master plan until the year 2010 is shown in Fig. B.1.1.

The treated effluent will be discharged to the adjacent mangrove swampy area toward the Benoa Coast.

4. Design of Structures

The design of treatment plant structures are categorized into two (2) systems of Inflow Pump Station and Lagoon Treatment System.

4.1 Inflow Pump Station

The inflow pump station of treatment plant consists of initial bar screen followed with the pump facilities.

4.1.1 Basic Consideration

In Chapter 2, the daily average quantity of wastewater discharge for treatment by the urgent project until the year 2000 is determined as 43,990 m^3/d, resulting in a treatment plant capacity of 44,000 m^3/d.

The corresponding hourly maximum wastewater quantity by the year 2000 is 66.0 m^3/min, which is used in determining the design inflow pump capacity.

Moreover the invert level of inflow sewer pipe (ø 1800) of -4.6 m and the design high water level of +1.0 m in the lagoon treatment system are considered in determining the required pump head.