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THE DEVELOPMENT STUDY
ON
WASTEWATER DISPOSAL FOR DENPASAR

SUPPORTING REPORT II
FEASIBILITY STUDY

JANUARY 1993

PACIFIC CONSULTANTS INTERNATIONAL

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SEWER NETWORK PLAN

APPENDIX A SEWER NETWORK PLAN

1. Sewer Networks of Denpasar Area

1.1 Overall Plan

1.1.1 Sewerage Service Area

The Project Area for the overall sewerage development targeting the year 2010 covers an area of 2,683 ha located in central Denpasar as shown in Fig. A.1.1.

The Project Area covers the following 10 Kelurahan and 16 Desa with a total administrative area of 5,402 ha.

- Following are completely covered Kelurahan and Desa.

  Kel. Dauh Puri, Desa Dauh Puri Kangin, Desa Dauh Puri Kelod, Kel. Pemecutan, Desa Tegal Kerta, Desa Tegal Harum, Kel. Dangin Puri, Desa Dangin Puri Kauh, Desa Dangin Puri Kaja, Desa Dangin Puri Kangin, Desa Dangin Puri Kelod, Kel. Sumerta, Desa Sumerta Kauh, Desa Sumerta Kaja and Desa Sumerta Kelod.

- Following are partially covered Kelurahan and Desa.

  Desa Dauh Puri Kaja, Desa Dauh Puri Kauh, Desa Pemecutan Kaja, Desa Pemecutan Kelod, Kel. Ubung, Kel. Kesiman, Desa Kesiman Petilan, Kel. Tonja, Kel. Panjer, Kel. Sesetan and Kel. Pedungan.

However, the following areas are excluded from the sewerage service area.

- Badung River of 8 ha, Puputan Park of 4 ha, Niti Praja Park of 2 ha and Ngurah Rai Stadium of 6 ha

Hence, the sewerage service area covers 2,663 ha with a total population of 194,209 in 1990 and 284,100 in 2010.

The sewerage service area and served population of each Kelurahan and Desa are shown in Table A.1.1.

The existing population density of the sewerage service area in 1990 ranges from 14.5 person/ha of Kel. Pedungan to 269.7 person/ha of Desa Tegal Kerta with an average of 72.9 person/ha. The future population density in 2010 is in the range of 20.6 person/ha in Kel. Pedungan and 279.2 person/ha in Desa Tegal Kerta, averaging 106.7 person/ha.

Population density of the sewerage service area in each Kelurahan and Desa is shown in Table A.1.1.

The land of the sewerage service area descends toward south. The land gradient in north-south direction is steep, ranging from 5‰ to 10‰ in the northern part of Oongan River. However, it is rather gentle, varying from 1‰ to 4‰ in the southern part of Oonga River.

On the other hand, the land gradient in east-west direction is rather gentle but undulated across the sewerage service area.

The topographic map and longitudinal profiles in both north-south and east-west directions across the sewerage service area are shown in Fig. A.1.2 and Fig. A.1.3.

1.1.2 Alternative Study of Sewer Networks

(1) Establishment of Alternative Sewer Networks

Alternative sewer network systems of this Project were established based on the following design policies.

- Main sewers shall be laid in north-south direction as far as possible to minimize the earth covering depth of pipe
- Number of river crossing shall be minimize to avoid difficulties in O&M of the sewerage system
- Number of lift/booster pump station shall be minimized to save O&M cost of the sewerage system

Two (2) sewer network systems are considered as typical alternatives. One is centralized collection system. Another is multiple collection system.

The centralized collection system consists of seven (7) main sewers. They joint at three (3) locations along the central line of the sewerage service area. Wastewater collected by the main sewers is covered by a conveyance sewer from the southern edge of the sewerage service area to the treatment plant located at Suwung Swamp Area (Fig. A.1.4).

The multiple collection system consists of six (6) main sewers laid in north-south direction in parallel. All wastewater is collected at one (1) location in the southern edge of the sewerage service area. It is further transported to the treatment plant by a conveyance sewer (see, Fig. A.1.5).

Furthermore, two (2) collection systems are considered for each of the above alternatives. One is collection system by gravity only. Another is collection system with lift/booster pump station.

Finally, the following four (4) alternative collection systems are compared in this Section.

- Alternative A : centralized collection system by gravity only
- Alternative B : multiple collection system by gravity only
- Alternative C : centralized collection system with lift/booster pump station
- Alternative D : multiple collection system with lift/booster pump station

(2) Alternative A

Seven (7) main sewers are proposed along the following roads (see Fig. A.1.4).

- Main Sewer A : Kenyiri Rd., Kecubung Rd., Jaya Giri Rd., Kapten Japa Rd., Cok Agung Tresna Rd., Raya Puputan Rd. and Diponegoro Rd. to connect the conveyance sewer.
- Main Sewer B : Cokroaminoto Rd., Setiabudi Rd., G. Merapi Rd., Imam Bonjol Rd., Teuku Umar Rd., and Saelus Rd.

- Main Sewer B : Cokroaminoto Rd., Setiabudi Rd., G. Merapi Rd., Imam Bonjol Rd., Teuku Umar Rd., and Saelus Rd. to connect main sewer A at the junction of Raya Sesetan Rd.

- Main Sewer C : Jend. A Yani Rd., Kartini Rd., Sulawesi Rd. and Diponegoro Rd. to connect main sewer A at the junction of Dewi Sartika Rd.

- Main Sewer D : Nangka Rd. and Udayana Rd. to connect main sewer E at the junction of Hasanudin Rd.

- Main Sewer E : Suli Rd., Patimura Rd., Kepundung Rd., Surapati Rd., Hasanudin Rd. and Diponegoro Rd. to connect main sewer A at the junction of Dewi Sartika Rd.

- Main Sewer F : Turi Rd., WR. Supratman Rd., Katrangan Rd. and Hayam Wuruk Rd. to connect main sewer A at the junction of Kecubung Rd.

- Main Sewer G : Hayam Wuruk Rd. Yeh Aya Rd. and Watu Renggong Rd. and Tukad Irawadi Rd. to connect the conveyance sewer at the junction of Raya Sesetan Rd.

The proposed main sewers have a total length of 50,050 m with a diameter ranging from ø350 mm to ø1,500 mm. The earth covering depth varies from 1.0 m to 10.0 m, causing the maximum depth in the lowermost section of the main sewer A.

A conveyance sewer with a total length of 4,390 m is installed between the southern edge of the sewerage service area and the treatment plant to convey the wastewater collected by the main sewers. However, it further receives the wastewater of the Sanur sewerage area at its middle distance, crossing point of Rayan Sesetan Rd. and Bypass Ngurah Rai Rd. The length and diameter of the proposed conveyance sewer are as follows.

Section	Length (m)	Diameter (mm)
Upper Section	3,040	ø1,500
Lower Section	1,350	ø1,800

The earth covering depth of the conveyance sewer is 10.0 m to 11.0 m.

Secondary and tertiary sewers with a total length of 418,400 m are installed to collect the wastewater to the above main sewers. Diameter of the sewers is ø150 mm - ø300 mm.

Sewer length by diameter and by earth covering depth is shown in Table A.1.2.

The total direct construction cost of Alternative A is estimated to be Rp.170.9 billion at 1992 price. The break-down is shown below.

(Unit: billion Rp.)

Works	Construction Cost
Secondary & Tertiary Sewers	56.5
Main Sewer	74.2
Conveyance Sewer	40.2
Total	170.9

In this cost estimation, shield tunneling method was applied for installation of the sewer pipes with a earth covering depth of deeper than 8.0 m, while open trench method is adopted for the sewer sections deeper than 7.0 m. Micro-tunneling method is employed for river crossing.

(3) Alternative B

Six (6) main sewers are proposed along the following roads (see Fig. A.1.5).

- Main Sewer A : Nangka Rd., Patimura Rd., Kepundung Rd., Hayam Wuruk Rd., Kapten Japa Rd., Cok Agung Tresna Rd., Raya Puputan Rd., Tk. Banyusari Rd.

and Diponegoro Rd. to connect the conveyance sewer.

- Main Sewer B : Cokroaminoto Rd., Setiabudi Rd., G. Merapi Rd., Imam Bonjol Rd., Teuku Umar Rd., and Saelus Rd. to connect main sewer A at the junction of Raya Sesetan Rd.

- Main Sewer C : Jend. A Yani Rd., Sulawesi Rd. and Diponegoro Rd. to connect main sewer A at the junction of Tk. Banyusari Rd.

- Main Sewer D : Suli Rd., Patimura Rd. and Melati Rd. to connect main sewer A at the junction of Surapati Rd.

- Main Sewer E : Kenyiri Rd., Kecubung Rd., Jaya Giri Rd. and Cok Agung Tresna Rd. to connect main sewer A at the junction of Kapten Japa Rd.

- Main Sewer F : Turi Rd., WR. Supratman Rd., Katrangan Rd., Hayam Wuruk Rd., Yeh Aya Rd. and Watu Renggong Rd. to connect the main sewer A at the junction of Raya Sesetan Rd.

Total length of the proposed main sewers is 50,640 m and their diameter is ø350 mm - ø1,500 mm. The earth covering depth is in the range of 1.0 m and 10.0 m. The maximum earth covering depth is caused in the lowermost section of the main sewer A.

The alignment, length and diameter of the conveyance sewer of Alternative B is the same as those of Alternative A. Only the earth covering depth is different from Alternative A. It ranges from 10.0 m to 12.0 m.

The secondary and tertiary sewer networks are assumed to be the same as Alternative A.

Sewer length by diameter and by earth covering depth is shown in Table A.1.3.

Construction cost of Alternative B was estimated based on the same construction methods as Alternative A. The estimated total direct construction cost is Rp.164.7 billion at 1992 price. The break-down is shown below.

(Unit: billion Rp.)

Works	Construction Cost
Secondary & Tertiary Sewers	56.5
Main Sewer	67.7
Conveyance Sewer	40.5
Total	164.7

(4) Alternative C

This is a modification of the centralized collection system by gravity only. In Alternative A, sewer pipes must be deeply laid under the roads to collect and convey wastewater by gravity only. Length of the main and conveyance sewers deeper than 8.0 m reaches to 8,560 m.

Hence in Alternative C, lift/booster pump stations are provided to minimize the length of deep sewer.

A lift pump station with a capacity of 31.44 m^3/min. x 9.5 m is installed at the eastern bank of Badung River in the main sewer B-7 (see, Fig. A.1.6).

A booster pump station with a capacity of 19.63 m^3/min. x 23.0 m is constructed at the junction of Watu Reggong Rd. and Pakerisan Rd. in the main sewer G-4. A force main of ø350 mm x 2 units is constructed to transport wastewater from the booster pump station to the main sewer G-6. The length of the force main is 1,070 m (see, Fig. A.1.6).

The alignment, length and diameter of the main and conveyance sewers are the same as Alternative A except the section of the force main.

As a result, the length of the main and conveyance sewers deeper than 8.0 m decreases to 490 m from 8,560 m of Alternative A.

The secondary and tertiary sewer networks are the same as Alternative A.

Sewer length by diameter and by earth covering depth is shown in Table A.1.4.

The total direct construction cost of Alternative C is estimated to be Rp.116.4 billion at 1992 price. The break-down is shown below.

(Unit: billion Rp.)

Works	Construction Cost
Secondary & Tertiary Sewers	56.5
Main Sewer	47.7
Conveyance Sewer	78
Lift & Booster Pumps	4.4
Total	116.4

(5) Alternative D

This a modification of the multiple collection system by gravity only. One (1) lift pump station and one (1) booster pump station are proposed at the same locations as Alternative C (see Fig. A.1.7).

The capacity of the lift and booster pump stations are 31.44 m^3/min. x 9.5 m and 22.56 m^3/min. x 25.0 m respectively. A force main of ø350 mm x 2 units with a length of 1,070 m is constructed to convey wastewater from the booster pump station to the main sewer A-10 (see, Fig. A.1.7).

The alignment, length and diameter of the main and conveyance sewers are the same as Alternative B exception the section of the force main.

The length of the main and conveyance sewers deeper than 8.0 m decreases to 90 m from 9,090 m of Alternative B.

The secondary and tertiary sewer networks are the same as Alternative A.

Sewer length by diameter and by earth covering depth is shown in Table A.1.5.

The total direct construction cost of Alternative D is estimated to be Rp.113.9 billion at 1992 price. The break-down is shown below.

(Unit: billion Rp.)

Works	Construction Cost
Secondary & Tertiary Sewers	56.5
Main Sewer	41.2
Conveyance Sewer	11.6
Lift & Booster Pump Stations	4.6
Total	113.9

(6) Comparative Evaluation

The direct construction costs of Alternative A, B, C and D are compared as follows.

(Unit: billion Rp.)

	Alternatives			
	A	B	C	D
Secondary & Tertiary Sewers	56.5	56.5	56.5	56.5
Main Sewer	74.2	67.7	47.7	41.2
Conveyance Sewer	40.2	40.5	7.8	11.6
Lift & Booster Pump Stations	-	-	4.4	4.6
Total	170.9	164.7	116.4	113.9

It is obvious that Alternative D is the most economical although it requires a certain amount of O&M cost for the lift/booster pump stations every year. Moreover, Alternative D of multiple collection system has much advantage on stagewise construction.

Hence, Alternative D is recommended.

1.1.3 Proposed Sewer Network

(1) Division of Sewerage Service Area

The sewerage service area of 2,663.0 ha is divided into six (6) catchment zones based on the topographic conditions. The proposed six (6) main sewers cover the respective catchment zones as shown in Fig. A.1.8.

Each catchment zone is further divided into several sub-catchment areas based on Kelurahan/Desa boundary. Existing and future served population and population density of each sub-catchment area are shown in Table A.1.6.

(2) Design Wastewater Discharge of Collection and Conveyance Sewers

1) Specific Wastewater Generation

Specific wastewater generation (wastewater generation per hectare per day) including domestic, commercial and institutional, tourism and industrial wastes varies depending on household income level and land use pattern of the objective area.

Wastewater generation of the sewerage service area in 1990 and 2010 by Kelurahan/Desa were estimated in Appendix C, Master Plan Report. Wastewater generation in 2000 by Kelurahan/Desa is obtained by interpolating those in 1990 and 2010.

Then, specific wastewater generation in six (6) catchment zones are obtained by dividing the corresponding wastewater generation of each catchment zone by its sewerage service area. The results are shown below.

Catchment Zone	Specific Wastewater Generation (m^3/ha/day)		
	1990	2000	2010
A	20.0	26.5	32.8
B	16.2	21.4	26.4
C	22.4	31.6	40.4
D	30.5	38.7	46.8
E	16.1	22.0	27.9
F	10.6	14.3	17.7

Specific wastewater generation of each sub-catchment area in 1990, 2000 and 2010 are shown in Table A.1.7.

2) Design wastewater Discharge

Size of collection and conveyance sewers is designed to meet the possible maximum wastewater discharge in the future since flow capacity of collection and conveyance sewers cannot be enlarged in stages. Design wastewater discharge of collection and conveyance sewers, and lift/booster pump station is determined to be hourly maximum wastewater discharge in 2010 plus groundwater infiltration, which is assumed as 10% of daily average wastewater discharge.

Design wastewater discharge of collection and conveyance sewers by catchment zone are shown below.

Catchment Zone	Design Wastewater Discharge (m^3/min.)		
	Wastewater	Groundwater	Total
A	29.36	1.12	30.48
B	36.00	1.43	37.43
C	28.15	1.07	29.22
D	9.52	0.30	9.82
E	15.09	0.51	15.60
F	22.30	0.81	23.11
Total	140.42	5.24	145.66

(3) Longitudinal Profile of Main and Conveyance Sewers

Longitudinal profile of the proposed main and conveyance sewers are shown in Fig. A.1.9.

Earth covering depth of the main sewers in the northern area of Oongan River is shallow in general. Because the land gradient of this area is steep with an average gradient of 5.3‰ from north to south.

While the land gradient becomes gentle in the southern part of Oongan River. The land gradient ranges from 2.1‰ of the main sewer A to 2.7% of the main sewer F.

Hence, earth covering depth of the main sewers A, B and F become deeper in the down stream portion.

(4) Salient Features of Overall Sewer Networks

The proposed overall sewer networks have a total length of 472,610 m with the following break-down.

Secondary & Tertiary	(ø150 - 300 mm)	:	418,400 m
Main		:	48,750 m
Normal Main	(ø350 - 1,500 mm)	:	48,400 m
Siphon	(ø150 - 450 mm)	:	350 m
Conveyance Sewer	(ø1,500 - ø1,800)	:	4,390 m
Force Main	(ø350 mm)	:	1,070 m
Total		:	472,610 m

The earth covering depth of the sewers mostly ranges from 1.0 m to 7 m.

Sewer length by diameter and by earth covering depth is shown in Table A.1.5.

The capacity of the proposed lift/booster pump stations are as follows.

- Lift Pump Station : 31.44 m^3/min. x 9.5 m, one (1) place
- Booster Pump Station : 22.56 m^3/min. x 25.0 m, one (1) place

1.2 Urgent Plan

The urgent plan targets the year of 2000. However, the sewer networks of the urgent plan shall be designed to meet the design wastewater discharge in 2010 because it is difficult to expand the size of sewer pipes in stages.

1.2.1 Selection of Sewerage Service Area

The urgent sewerage service area is selected taking into consideration the existing (1990) and future (2000) population density, and economical efficiency of the project.

(1) Served Population and Population Density

Existing (1990) and future (2000) served population and population density of each sub-catchment area are shown in Table A.1.6. Regional distribution of the existing and future population density are shown in Fig. A.1.10.

Densely populated sub-catchment areas mainly concentrate in catchment zones A, C and E.

Existing and future served population and population density in each catchment zone are summarized as follows.

Catchment Zone	Service Area (ha)	Served Population (Person)		Served Density	Population (Person/ha)
		1990	2000	1990	2000
A	492.5	40,120	49,609	81.5	100.7
B	777.0	60,793	73,037	78.2	94.0
C	380.0	32,093	41,861	84.5	110.2
D	91.0	10,733	12,623	117.9	138.7
E	264.1	19,937	25,089	75.5	95.0
F	658.4	30,533	37,081	46.4	56.3
Total	2,663.0	194,209	239,300	72.9	89.9

(2) Construction Cost of Sewer Network per Served Population

Construction costs of the overall sewer networks of each catchment zone covering main, secondary and tertiary sewers, and lift/booster pump stations are shown below.

Catchment Zone	Construction Cost (Million Rp.)			
	Main Sewer	Secondary & Tertiary	Lift/Booster Pump	Total
A	10,289	10,457	-	20,746
B	16,223	16,498	2,553	35,274
C	4,484	8,069	-	12,553
D	611	1,932	-	2,543
E	1,604	5,608	-	7,212
F	7,965	13,981	2,047	23,993
Total	41,176	56,545	4,600	102,321

Construction cost for the conveyance sewer of Rp.11,558 million is not considered in this comparative evaluation. Because the conveyance sewer is common to all catchment zones.

Construction cost per served population in 2000 for each catchment zone are as follows.

Catchment Zone	Construction Cost per Served Pollution (Rp./Served Population)
A	418,000
B	483,000
C	300,000
D	201,000
E	287,000
F	647,000

Main sewer A collects the wastewater of the catchment zones of D and E as well. Hence, the integrated catchment zones of A, D and E should be considered as one unit in this comparative evaluation. Construction cost of the integrated catchment zones of A, D and E is estimated at Rp.30,501 million then, construction cost per served population becomes Rp.349,000/served population.

Six (6) catchment zones are classified into three (3) groups : low cost, middle cost and high cost groups in terms of construction cost per served population as shown in Fig. A.1.11.

(3) Selected Urgent Sewerage Service Area

The urgent sewerage service area covers the sub-catchment areas meeting the following conditions.

- Population density in 2000 is more than 100 person/ha.
- Located in the catchment zones of A, C, D and E with a high economical efficiency.

The catchment zones of A, C, D and E cover 27 sub-catchment areas in total. among them, eight (8) sub-catchment areas will have a population density of less than 100 person/ha even in 2000 as shown below.

Sub-Catchment Area	Area (ha)	Served Population in 2000	Population Density (Person/ha)
A-6	98.3	8,585	87.3
A-10	51.9	3,292	63.4
A-11	30.7	1,065	34.7
A-12	52.2	1,813	34.7
E-1	32.2	1,819	56.5
E-2	41.1	3,304	80.4
E-3	40.6	3,317	81.7
E-5	49.0	4,442	94.5

However, the sub-catchment areas of A-10, C-6 and E-5 are included in the urgent sewerage service area though their future population density is less than 100 person/ha because the main sewers are planned to run through them.

Finally, the urgent sewerage service area covers an area of 1,030.8 ha with a served population of 117,864 in 2000 (see, Fig. A.1.12).

1.2.2 Conventional and Interceptor Areas

The proposed urgent sewerage service area of 1,030.8 ha is covered by two (2) sewage collection systems: conventional sewage collection system and interceptor sewage collection system.

Conventional collection system collects both toilet waste and gray water separately from storm water through a complete sewer pipe networks consisting of house connection, main, secondary and tertiary sewers with lift/booster pumps, manholes and other appurtenances.

Conventional system is the most applicable sewage collection system to improve community environments and water quality of rivers and sea.

However, for an area where such storm water drainage system of open type as road-side ditches and channels are already developed, interceptor collection system is applied to minimize the construction cost of sewer networks and to facilitate implementation of the project.

Interceptor collection system collects the gray water only through existing road-side ditches and intercepts it to the main sewer in dry weather. However in wet weather, gray water is diluted by storm water in the road-side ditches and directly discharged to the rivers.

Interceptor system is applied for the following areas in the urgent sewerage service area in principle.

(i) Existing road-side ditch has a sufficient slope to avoid sedimentation in the bed in dry weather (more than 5‰).

(ii) Existing road-side ditch is not used as irrigation.

(iii) Bottom of existing road-side ditch is paved by concrete or cement mortar.

(iv) No inundations occur.

(v) Gray water flow is observed in the existing road-side ditch.

(vi) Toilet waste is treated by on-site sanitation system.

Based on the above considerations, interceptor collection system is applied for the sub-catchment areas of A-1, A-2, C-1, C-2 and E-4. Service area and served population by interceptor collection system are as follows.

Service Area and Served Population by Interceptor Collection System

Sub-Catchment Area	Area (ha)	Served Population in 2000
A - 1	27.2	2,835
A - 2	123.4	13,099
C - 1	31.0	3,782
C - 2	47.3	5,121
E - 4	87.3	10,528
Total	316.2	35,365

The proposed conventional collection system covers an area of 714.6 ha or 69% of the total urgent sewerage service area of 1,030.8 ha. The served population in 2000 by this system is estimated to be 82,499.

Service area and served population in 2000 by sub-catchment area and by collection system are shown in Table A.1.8. Both the conventional and interceptor areas are delineated as shown in Fig. A.1.13.

1.2.3 Proposed Urgent Sewer Networks

(1) Design Wastewater Discharge

In the area covered by interceptor collection system, toilet waste is treated by on-site sanitation system and is not discharged to the interceptor sewer. Hence, the toilet waste discharge should be deducted from the design wastewater generation of the interceptor area.

Toilet waste of each sub-catchment area covered by the interceptor system is estimated by multiplying the unit toilet waste discharge by served population. The toilet waste discharge of the interceptor area is estimated at 649 m^3/d in 2000. The break-down of the toilet waste discharge by sub-catchment area is summarized below.

Sub-Catchment Area in Interceptor Area	Wastewater Generation (m^3/d)	Toilet Waste Generation (m^3/d)	Gray Water Discahage to Interceptor (m^3/d)
A - 1	861	51	810
A - 2	3,106	243	2,863
C - 1	1,209	69	1,140
C - 2	1,347	96	1,251
E - 4	2,356	190	2,166
Total	8,879	649	8,230

Gray water discharged from the interceptor area is estimated at 8,230 m^3/day in 2000.

Design wastewater discharge of the urgent sewerage service area of 1,030.8 ha covering both conventional and interceptor areas is

estimated to be 31,428 m^3/day in 2000. The break-down of wastewater discharge by sub-catchment area is shown in Table A.1.9.

(2) Proposed Urgent Sewer Networks

The proposed urgent sewer networks consist of tertiary and secondary sewer, main sewer including siphon, and conveyance sewer. Lift/booster pump station and force main are excluded from the urgent project.

The urgent sewer networks has a total length of 145,550 m with the following break-down.

Secondary & Tertiary	(ø150 - 300 mm)	:	126,020 m
Main		:	15,140 m
Normal Main	(ø350 - 1,500 mm)	:	15,060 m
Siphon	(ø150 - 450 mm)	:	80 m
Conveyance Sewer	(ø1,500 - 1,800 mm)	:	4,390 m
Total		:	145,550 m

Alignments of the urgent main and conveyance sewers are shown in Fig. A.1.14.

For longitudinal profile of the urgent main and conveyance sewers, refer to Fig. A.1.9.

The main sewer crosses the Oongan River at three (3) locations of the main sewer sections of A-6, C-4 and E-4. For river crossing of the main sewer of A-6 and C-4, siphon is constructed. However for the main sewer of E-4, normal sewer pipe is applied. Structures of the siphons are shown in Fig. A.1.15.

Earth covering depth of the sewers ranges from 1.0 m to 7.0 m.

Sewer length by diameter and by earth covering depth is shown in Table A.1.10.

2. Sewer Network of Sanur Area

2.1 Overall Plan

2.1.1 Sewerage Service Area

The Project Area for the overall sewerage development targeting the year 2010 covers Kel. Sanur, Desa Sanur Kaja and Desa Sanur Kauh with a total administrative area of 740 ha.

The proposed sewerage service area also covers the same Kelurahan and Desa areas but excludes Bali Beach Golf Course of 14 ha in Desa Sanur Kaja. Hence, the sewerage service area of Sanur covers 726 ha with a total population of 27,800 in 2010. Break-down by Kelurahan/Desa is shown below.

Kelurahan & Desa	Sewerage Service Area (ha)	Served Population in 2010
Sanur	402	19,000
Sanur Kaja	125	5,100
Sanur Kauh	199	3,700
Total	726	27,800

The sewerage service area of Sanur is shown in Fig. A.2.1.

2.1.2 Alternative Study of Sewer Networks

(1) Establishment of Alternative Sewer Networks

Alternative sewer network systems of this Project were established based on the following design policies and conditions.

- It is difficult to convey the wastewater of this Project Area to the treatment plant by gravity only. A booster pump station with a force main shall be constructed at an appropriate location.
- Earth covering depth of sewer pipe shall be less than 8.0 m to minimize construction cost.

- Number of lift/booster pump station shall be minimized to save O&M cost.

Two (2) sewer network systems are considered as typical alternatives for this Project. One is independent collection system. Another is integrated collection system.

The independent collection system consists of four (4) main sewers laid in parallel with the coast line. Wastewater of this Project area is independently collected to the booster pump station by the four (4) main sewers. The collection wastewater is covered to the treatment plant located at Suwung Swamp Area by the booster pump and force main (see, Fig. A.2.2).

The integrated collection system consists of six (6) main sewers. Among then, four (4) main sewers are integrated into one (1) big main sewer before reaching the booster pump station. This integrated sewer covers a large portion of the Project Area. The remaining two (2) main sewers independently collect wastewater to the booster pump station. The collected wastewater is conveyed to the treatment plant by the booster pump and force main (see, Fig. A.2.3).

The above two (2) alternatives are compared as follows.

(2) Alternative A

This is independent collection system. Tourism wastewater mainly discharged from the hotel areas located along Sanur Beach is collected by the main sewer C and D. Domestic wastewater discharged from the residential areas between Bypass Sanur Rd. and D. Tamblingan Rd. is also collected by the main sewers C and D. The main sewers A and B are installed along Batur Sari Rd. to cover the remaining residential areas.

The proposed main sewer networks has a total length of 10,940 m with a diameter ranging from ø350 mm to ø800 mm. The earth covering depth is in the range of 1.0 m and 7.0 m.

One (1) booster pump station with a capacity of 31.7 m^3/min. x 37 m and a force main of two (2) units with a diameter of ø500 mm each installed to convey the wastewater to the connecting manhole of the conveyance sewer of Denpasar sewerage system. It is located at the junction of Bypass Ngurah Rai Rd. and Raya Sesetan Rd. Length of the force main is 5,160 m.

Secondary and tertiary sewers with a diameter of ø150 mm - ø300 mm has a total length of 97,220 m.

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

(3) Alternative B

This is integrated collection system. The integrated sewer networks consisting of the main sewers: A, B, C and D, covers a large portion of the Project Area including the resort areas along Sanur Beach and residential areas in the west side of Bypass Sanur Rd. All wastewater of this covered area is finally collected by the main sewer A to the booster pump station.

The main sewers of E and F independently collect the wastewater of the respective areas to the booster pump station. The main sewer E covers the residential area in the west side of Bypass Sanur Rd. The main sewer F covers the resort and residential areas along Sanur Beach.

The proposed main networks has a total length of 10,370 m with a diameter of ø350 mm - ø800 mm. The earth covering depth of sewer is 1.5 m - 9.0 m.

The collected wastewater is conveyed to the treatment plant by the booster pump station and force main. The capacity of the booster pump is the same as Alternative A. Length and size of the force main is also the same as Alternative A.

The secondary and tertiary sewers are the same as Alternative A.

Sewer length by diameter and by earth covering depth is shown in Table A.2.2.

(4) Comparative Evaluation

The direct construction costs covering those of main sewer, force main, secondary and tertiary sewers, and booster pump station for Alternative A and Alternative B are compared as follows.

(Unit: billion Rp. 192 price)

	Alternative A	Alternative B
Secondary & Tertiary Sewers	13.2	13.2
Main Sewer	9.4	10.1
Force Main	4.0	4.0
Booster Pump Station	2.3	2.3
Total	28.9	29.6

Alternative A is more economical than Alternative B. Moreover, Alternative A is more advantageous in stage implementation than Alternative B. Hence, Alternative A is recommended.

2.1.3 Proposed Sewer Networks

(1) Division of Sewerage Service Area

The sewerage service area of 726.0 ha is divided into four (4) catchment zones based on the topographic conditions and route of the proposed main sewers as shown in Fig. A.2.4.

Each catchment zone is further divided into sub-catchment areas based on Kelurahan/Desa boundary. Existing and future served population and population density of each sub-catchment area is shown in Table A.2.3.

(2) Design Wastewater Discharge of Collection Sewer

1) Specific Waste Generation

Land use of Sanur sewerage service area is classified into two (2) categories: one is tourism use and another is residential use. The area along sea shore is developed for tourism use and inland area for residential use.

Specific wastewater generation of tourism area is estimated based on the wastewater generated from hotel and restaurant only. On the other hand, specific wastewater generation of residential area is estimated based on the total wastewater generated from domestic, commercial and institutional, and industrial sources.

Specific wastewater generation of tourism area and residential area for the four (4) catchment zones are estimated in the same manner as that of Denpasar Area.

Specific wastewater generation of the four (4) catchment zones by source in 2010 are shown below.

Catchment Zone	Specific Wastewater Generation (m^3/ha/day)	
	Tourism Area	Residential Area
A	-	10.43
B	-	14.90
C	81.20	14.07
D	41.64	6.17

Specific wastewater generation of each sub-catchment area in 1990, 2000 and 2010 by source is shown in Table A.2.4.

Wastewater generation of each sub-catchment area in 1990, 2000 and 2010 is also shown in Table A.2.4.

2) Design Wastewater Discharge

Design wastewater discharge of the sewer network system for Sanur Area is also estimated in the same manner as that of Denpasar Area.

Design wastewater discharge of the sewer network in 2010 by catchment zone are shown below.

Catchment Zone	Design Wastewater Discharge (m^3/min.)			
	Wastewater		Ground-water	Total
	Tourism Area	Residential Area		
A	0	4.31	0.17	4.48
B	0	2.36	0.09	2.45
C	15.54	4.39	0.77	20.70
D	2.79	1.06	0.15	4.00
Total	18.33	12.12	1.18	31.63

3) Longitudinal Profile of Main Sewer

Longitudinal profile of the proposed main sewer is shown in Fig. A.2.5.

The land gradient of the route of four (4) main sewers are gentle with an average slope of 2.4‰.

Hence, three (3) manhole pumps are constructed at the main sewers of A-4, C-1 and C-4 to avoid earth covering depth more than 8.0 m. Location of the manhole pumps are shown in Fig. A.2.4.

Earth covering depth of the main sewers ranges from 1.0 m to 7.0 m.

4) Salient Features of Overall Sewer Networks

The proposed overall sewer networks have a total length of 113,320 m with the following break-down.