2) Trunk Sewer Systems

Two alternative trunk sewer systems were studied. Two alternatives, Alternative A and Alternative B, are shown in *Figures 6.4* and *6.5*, respectively. Major difference in features of two alternatives is as below:

Alternative A: Wastewater from the central part of the area (P/S Unite 22, 17, 13, 15, 9 and New P/S Unite 15) is transmitted to Camberene WWTP through trunk sewer along the Auto Route.
One transmission pump is required.

Alternative B: Wastewater from the central part is transmitted to Camberene WWTP through east trunk sewer by gravity flow.
No pumping station is required.

Construction cost of Alternative B is far less than that of Alternative A because a relatively large pumping station is unnecessary. In addition to the less expensive construction cost, there is obviously an advantage for Alternative B, i.e. less operation and maintenance cost because of elimination of the pumping station. Thus, Alternative B is proposed as the new sewerage system.

6.4 FACILITIES DESIGNING

6.4.1 General

Preliminary design has been carried out for the main sewerage facilities including pumping stations, secondary collectors, wastewater treatment plant, a force main for effluent discharge and an ocean outfall.

Design criteria proposed in the Master Plan were used for the preliminary design of the facilities.

Construction materials and methods which have been readily available in Dakar and adopted for the existing sewerage systems are considered to be applied. There is no facility which requires special construction method except for an ocean outfall. Laying pipes in a ditch on the sea bed for ocean outfall requires some special construction methods. This will be described in the following section.

6.4.2 Pumping Stations

1) New Pumping Stations

As mentioned in Section 6.3.2, three new pumping stations should be constructed. Types, numbers and design capacities of the pumping stations are as follows.

Name of P.S.	Design Capacity (l/s)	Type	Numbers
New P/S Unite 15	145	Dry pit, centrifugal	3 (one stand-by)
New P/S Unite 2	60	Submersible	2 (one stand-by)
New P/S North to Stadium	63	Submersible	2 (one stand-by)

2) Existing Pumping Stations

Pump units of the five existing pumping stations should be replaced by 2000 to meet the following requirements, while the existing civil structures of these pumping stations should be utilized.

Name of P.S.	Design Capacity (l/s)
P/S Unite 15	20
P/S Unite 7	61
P/S Unite 2	16
P/S Unite 23	28
P/S Djily Mbaye	51

3) General

Generator:

One Diesel engine driven generator unit is proposed to be provided to each station for continuous operation when pump unit is replaced.

Monitoring System

In order to catch malfunctioning of pumping stations as soon as possible, introduction of a remote monitoring system is desirable. Several systems are available depending on the requirements of monitoring and controlling.

The simplest system sends signals to the center when malfunctioning of a pumping station occurs. Then, the signals which indicate power failure, stopping of pumps or extraordinary water levels, are displayed in the center. The installation cost of the simplest system in Japan is approximately 2 million FCFA per pumping station and 25 million FCFA per central unit. Thus, if the system is introduced to the proposed sewerage system, the total construction cost is 49 million FCFA.

6.4.3 Secondary Collectors

Secondary collectors are designed based on the Alternative B described in Section 6.3.3. Plans of the collectors are shown in *Figures 6.6.*

Secondary collectors are defined for the preliminary design purpose as those which have contributing service areas of more than 20 ha. The existing branch sewers which have insufficient capacities for the design flow mentioned in Section 6.3.2 have contributing service areas of more than 20 ha. Therefore, some sections of the secondary collectors proposed include replacement of the existing sewers.

6.4.4 Wastewater Treatment Plant

As proposed in the Master Plan, the Camberene WWTP will have design capacity of 100,000 m^3/day in 2010. The facilities are so arranged that staged construction can be carried out to cope with the gradual increase of inflow. There are ten process trains each having 10,000 m^3/day capacity. A general plan is shown in *Figure 6.7.*

As mentioned in Section 6.3.2, two process trains, each of these has the same size as the existing one are to be constructed by two stages. The two trains should be constructed in parallel with the existing one within the boundary of the present site. The main treatment facilities for the second and the third trains to be constructed are as follows.

Main Facilities	Second Train	Third Train
Pump House (civil)	No	Yes
Pump Unit (mech.)	Yes	Yes
Grit Chamber	No	Yes
Primary Sedimentation Tank	Yes	Yes
Aeration Tank	Yes	Yes
Final Sedimentation Tank	Yes	Yes
Chlorination Tank	No	No
Sludge Digester (1st)	Yes	Yes
Sludge Digester (2nd)	No	Yes
Sludge Drying Bed	No	Yes

6.4.5 Force Main, Gravity Sewer and Ocean Outfall for Effluent Discharge

Ductile cast iron pipe (DCIP) is recommended for the force main because of large diameter (900 mm) and water head. Reinforced concrete pipe (RCP) is recommended for the gravity pipe. These pipes should be installed in parallel with the existing ones.

A new junction pit is to be constructed near the existing manhole at the coast of the Camberene village. Provision for connection to the existing manhole and future expansion should be considered.

From the junction pit, a pipe line with diameter 900 mm and length about 200 m is to be laid in a ditch on the sea bed. Steel pipe with external lining against erosion is recommended for pipe material. Plan and section of the pit and outfall pipe are shown in *Figure 6.8*.

6.5 CONSTRUCTION PLAN AND COST ESTIMATION

6.5.1 Construction Plan

The target year of the project is set at the year 2000. However, some of the construction works can not be completed by 2000, e.g. provision of the branch sewers in the already developed but not sewered areas such as Parcelles Assainies. Therefore, the following assumptions are made for cost estimation and implementation schedule.

a. Provision of Branch Sewers

Half of the planned branch sewers in the seven subzones (Nos. 1 to 7) of Pacelles Assainies will be constructed by 2000. The other two subzones of Parcelles Assainies (P.A. P/S Unite 23 and North to Stadium) will be provided with branch sewers so as to raise the connection ratio to about 25 %. The three new development subzones (Nord Foire, Stadium and East to Patte d'Oie) will be fully sewered by 2000.

b. Pumping Stations

All three new pumping stations will be constructed by 2000. For the replacement of pump units, four pumping stations (Unite 9, Unite 7, Unite 23, and Djily Mbaye) should be completed. However, provision of generator should be completed to five pumping stations by 2000.

c. Camberene WWTP

Additional two process trains will be completed by 2000. Although wastewater flow from the study area will not reach design flow, expansion of the Camberene WWTP should be kept pace with the increase of total inflow, because the plant is to receive wastewater from the other areas. However, completion date of the additional trains, the third train in particular, should be reviewed carefully at later stage of the implementation because a sizable amount of investment is necessary for construction.

d. Other Facilities

All other facilities not mentioned above are to be constructed by 2000.

6.5.2 Cost Estimation

1) Basis for Cost Estimation

Components and their estimation are as follows.

Project Cost Components and Their Estimation

1. Direct Construction Cost:	Based on the preliminary design of each facility
2. Land Acquisition Cost:	Land area and unit land price
3. Engineering Cost:	10 % of direct construction cost
4. Government Administration Cost:	1.5 % of direct construction cost
5. Physical Contingency:	10 % of direct construction cost

All costs are indicated at March 1994 price level, i.e. prices after devaluation of FCFA.

2) Direct Construction Cost

Direct construction costs for the above facilities are as follows

Facility	Construction Cost (1,000 FCFA)
1. House Connection	3,328,710
2. Branch sewer	5,212,454
3. Pumping Station	495,500
4. Force Main	802,550
5. Secondary Collectors	1,548,005
6. Camberene WWTP	4,485,157
7. Force Main for Discharge	1,110,600
8. Outfall	308,440
Total of 2 to 8	13,962,706

3) Project Cost

The total project cost is 17,410 million FCFA, and its breakdown is shown in *Table 6.1*. Of the total project cost, 5,669 million FCFA or 33 % is local currency portion, and the remaining 11,740 million FCFA or 67 % is foreign currency portion, as shown below:

Items	Total FCFA (1000 FCFA)	Local Currency Portion (1000FCFA)	Foreign Currency Portion (1000FCFA)
Direct Construction Cost (DCC)	13,962,706	3,644,865	10,317,841
Sewer Cleasing Equipment	445,000	0	445,000
Land Acquisition	350	350	0
Engineering Service	1,396,271	418,882	977,389
Government Administration	209,441	209,441	0
Physical Contingency	1,396,271	1,396,271	0
Total	17,410,039	5,669,809	11,740,230

4) Operation and Maintenance Cost

Increase of the operation and maintenance cost for the sewerage facilities proposed for the study area in 2000 is estimated in the same manner described in Section 5.5.5 of the Master Plan. It is 392 million FCFA annually.

6.6 IMPLEMENTATION PROGRAM

Implementation schedule up to the year 2000 has been developed taking into consideration a period required for the necessary preparatory works, such as survey, design and contract process. The schedule is shown in *Figure 6.9*, and cost breakdown according to the schedule is shown in *Table 6.2*.

6.7 ORGANIZATION AND MANAGEMENT

Institutional matters, including organization and management for the sewerage sector, have been discussed in the Master Plan Study. They are:

- Provision of installment for encouraging the house connection
- Setting up of new sewerage charge system
- Organizational strengthening

Since the priority project is to be implemented as an initial stage of a series of the Master Plan projects, above aspects can be applied to the priority project, too.

However, the priority project is to be implemented in the earliest stage of a series of the Master Plan Projects. The priority project may be realized before whole provision of the above aspects. In particular, organization strengthening, which is expected to be done by re-organization of the present SONEES or creation of a new organization, will take longer time due to manpower requirements. Therefore, following minimum requirements are proposed to realize the priority project.

- Required additional personnel to implement and manage the priority project are as follows:

Camberene WWTP:	24 persons
Pumping stations:	3 persons
Sewer pipe maintenance:	4 persons
Overheads:	3 persons
Total:	34 persons

- As explained in the next sections, sewerage charge should be increased after the year 2001 to ensure necessary operation and maintenance costs and repayment of a loan.

6.8 FINANCIAL ANALYSIS

In the Master Plan study, it was proposed that the government subsidize all the initial investment, although it was known that there was an idea to provide all investment costs by the government loans.

Therefore, the financial source conditions for the feasibility study follow this line (additional five cases shown below were compared for reference).

Case	Financial Conditions (%)		Terms of government loan		
	Loan	Subsidy	Interest rate (%)	Repayment period (years)	Grace period (years)
1	100	0	5	25	5
2	70	30	5	25	5
3	0	100	-	-	-
4	60	40	4	25	5
5	100	0	2	25	5
6	70	30	2	25	5

The required sewerage charge are calculated as below:

up to 2000	2001 to 2010	2011 on
6.1 % of water supply charge	7 % of water supply charge	8 % of water supply charge

6.9 PROJECT EVALUATION

6.9.1 Effect of the Priority Project

The priority project consists of:

i) Improvement of the present sewerage facilities, such as pumping station system, sewer networks and collectors in Parcelles Assainies areas (414 ha).

ii) Installation of sewer networks in the unsewered areas (306 ha).

iii) Expansion of the Camberene WWTP.

iv) Reconstruction of ocean outfall of the treated water from Camberene WWTP.

Improvement of the present sewerage system does not have any significant effect upon increase of the sewered population because it does not expand the sewered area. However, some of present sewerage system does not have enough capacity for the future projected population and increase of the connection ratios. Also the arrangement of the present pumping stations are not simple, causing an operational difficulty and higher operation cost. Therefore, the proposed improvement can resolve the present problems and problems expected in future.

Camberene WWTP is presently operated at the much less wastewater flow rate (3,000 to 4,000 m^3/day) than the designed (10,000 m^3/day). This is considered to be wasting the existing capacity of the facilities constructed, which has been pointed out as a big issue in the appraisal report by the African Development Bank. The priority project increases the wastewater flow to Camberene to 30,000 m^3/day, thus the project can immediately resolve the present problem of the low flow rate.

In the Mater Plan Study, higher priority was put to the expansion of the sewerage service when the Ouakam sewerage system was shifted out from the Master Plan. However, this was not because importance of treatment of the wastewater was neglected. The selection was made under the circumstance where either treatment of wastewater or expansion of sewerage collection service must be selected under financial constraint. Therefore, still increase of the wastewater treatment is important issue in the Sewerage Master Plan. In this regards, priority project can increase treated water amount from the present 3,000 or 4,000 m^3/day to 30,000 m^3/day.

6.9.2 Environmental Effect

Most facilities of the priority project are constructed or installed as expansion or replacement of the existing facilities. Pipes are installed under ground. Most pumping stations are replacement of pumps in the existing pumping stations and new pumping stations are to be constructed to the present pumping stations. Expansion of Camberene WWTP is planned within the present treatment site. Therefore, particular negative environmental impacts by the project during operation are not expected compared to the operation of present facilities.

Reconstruction of the ocean outfall at the Camberene beach could apparently improve sanitary conditions around the beach where presently the treated water are spread around over from a broken manhole. In addition, installation of discharge pipe under the sea bed (200 m offshore) may mitigate the pollution of the coastal water by the treated water.

During construction stage, some extent of negative impacts would be unavoidable. Traffic along roads where pipe installation works taken place would be hindered. But the traffic around the area is not so busy and roads in the area have enough width to provide path beside the excavation works. Noise and vibration due to excavation works also would be unavoidable during construction of pumping stations and pipe installation. However, the impact could be minimized by selecting low-noise type construction equipment as far as practicable.

As such, the environmental impacts by the priority project are expected to be negligible or very minor, if there is.

6.9.3 Financial Evaluation

The project cost for the priority project was estimated at 17,410 million FCFA. Financial projections were carried out for the case where 100 % of initial investment of the project is to be subsidized by the government and the project was judged to be feasible by applying increase of the sewerage charge within the range of willingness to pay of the beneficiaries.

6.9.4 Operation and Maintenance of the Proposed System

The components of the proposed priority project are as same type as those in the existing system. Thus, natures of the required operation and maintenance works for the proposed system would not differ from the present works while quantities of the works would increase according to expansion of the system. Since the existing facilities, such as Camberene WWTP, the pumping stations and sewer collectors, are observed to be well operated, any particular problems are not foreseen in the operation and maintenance of the facilities proposed by the priority project, provided that the number of persons concerned to such operation and maintenance works increases.

6.10 RECOMMENDATION

(1) General

The priority project is a project to be implemented as the first stage of a series of the Master Plan projects Therefore it is considered that all the recommendations related to the sewerage Master Plan should also be applied to the priority project.

However, considering the high priority of the project, special considerations for earlier implementation of the projects should be arranged. As discussed in the previous section, no particular difficulties are foreseen in the implementation of the project. A few matters concerned are a financial aspect and an organizational aspect of the implementation.

(2) Financial Aspect

While the financial analysis conducted in the study indicated that the project would be financially feasible even by the financial source provided by 100 % governmental loan, the organization responsible could bear a heavy financial burden. This may hinder the earliest and smooth implementation of the project by any delay or difficulties in raising the sewerage charge. Therefore, it is recommended that the government should provide special considerations on the financial source conditions applied to the priority project. The special considerations would include providing a governmental subsidy. Such considerations can be justified by a nature of sewerage project where beneficiaries in the sewerage project are not only those who pay sewerage charge but also more public while beneficiaries in water supply projects are limited to those who pay the water supply charge.

(3) Organizational Aspect

The reorganization currently planned by the government will meet the requirement for the organizational strengthening recommended in the Master Plan. The reorganization is expected to proceed along with the progress of the implementation of the priority project. Therefore, it is recommended that reorganization should provide increase of operational persons necessary for the priority project in its earlier stage, as well as keep the present SONEES persons, who have been well experienced in operation of the sewerage system, in the new organization to ensure present operations.

TABLES AND FIGURES

TABLE 6.1 PROJECT COST

(unit: 1,000 FCFA)

Cost Item	L/C	F/C	Total
1. Direct Construction Cost			
1.1 Branch Sewers	1,563,738	3,648,716	5,212,454
1.2 Secondary Collectors	232,200	1,315,805	1,548,005
1.3 Force Mains	120,382	682,168	802,550
1.4 Pumping Stations	123,875	371,625	495,500
1.5 Expansion of Camberene WWTP	1,345,548	3,139,609	4,485,157
1.6 Force Main for Discharge	166,590	944,010	1,110,600
1.7 Outfall	92,532	215,908	308,440
Subtotal	3,644,865	10,317,841	13,962,706
2. Sewer Cleasing Equipment	0	445,000	445,000
3. Land Acquisition	350	0	350
4. Engineering Cost	418,882	977,389	1,396,271
5. Government Administration	209,441	0	209,441
6. Physical Contingency	1,396,271	0	1,396,271
Total Project Cost	5,669,809	11,740,230	17,410,039
	(33%)	(67%)	(100%)

Note : L/C : Local Currency Portion

F/C : Foreign Currency Portion

TABLE 6.2 PROJECT COST UP TO 2000

(unit: 1,000 FCFA)

		1995	1996	1997	1998	1999	2000	Total
I. Direct Construction Cost								
1) Branch Sewers	L/C	77,295	77,295	77,295	77,295	627,279	627,279	1,563,738
	F/C	180,354	180,354	180,354	180,354	1,463,650	1,463,650	3,648,716
	Total	257,649	257,649	257,649	257,649	2,090,929	2,090,929	5,212,454
2) Pumping Station	L/C	0	0	80,550	29,850	0	13,475	123,875
	F/C	0	0	241,650	89,550	0	40,425	371,625
	Total	0	0	322,200	119,400	0	53,900	495,500
3) Force Main	L/C	0	0	60,191	60,191	0	0	120,382
	F/C	0	0	341,084	341,084	0	0	682,168
	Total	0	0	401,275	401,275	0	0	802,550
4) Secondary Collectors	L/C	0	0	77,347	77,347	38,753	38,753	232,200
	F/C	0	0	438,301	438,301	219,602	219,601	1,315,805
	Total	0	0	515,648	515,648	258,355	258,354	1,548,005
5) Camberene WWTP	L/C	0	0	286,840	286,840	385,934	385,934	1,345,548
	F/C	0	0	669,292	669,293	900,512	900,512	3,139,609
	Total	0	0	956,132	956,133	1,286,446	1,286,446	4,485,157
6) Force Main for Discharge	L/C	0	0	0	0	0	166,590	166,590
	F/C	0	0	0	0	0	944,010	944,010
	Total	0	0	0	0	0	1,110,600	1,110,600
7) Outfall	L/C	0	0	0	92,532	0	0	92,532
	F/C	0	0	0	215,908	0	0	215,908
	Total	0	0	0	308,440	0	0	308,440
Total Direct Construction Cost	L/C	77,295	77,295	582,223	624,055	1,051,966	1,232,031	3,644,865
	F/C	180,354	180,354	1,870,681	1,934,490	2,583,764	3,568,198	10,317,841
	Total	257,649	257,649	2,452,904	2,558,545	3,635,730	4,800,229	13,962,706
II. Sewer Cleasing Equipment		0	0	0	0	0	445,000	445,000
III. Land Acquisition		0	250	50	0	50	0	350
IV. Engineering Service	L/C	69,814	69,814	69,814	69,814	69,814	69,812	418,882
	F/C	162,898	162,898	162,898	162,898	162,898	162,899	977,389
	Total	232,712	232,712	232,712	232,712	232,712	232,711	1,396,271
V. Government Administration		3,865	3,865	36,794	38,378	54,536	72,003	209,441
VI. Physical Contingency		25,765	25,765	245,290	255,855	363,573	480,023	1,396,271
VII. Total Project Cost	L/C	176,739	176,989	934,171	988,102	1,539,939	1,853,869	5,669,809
	F/C	343,252	343,252	2,033,579	2,097,388	2,746,662	4,176,097	11,740,230
	Total	519,991	520,241	2,967,750	3,085,490	4,286,601	6,029,966	17,410,039

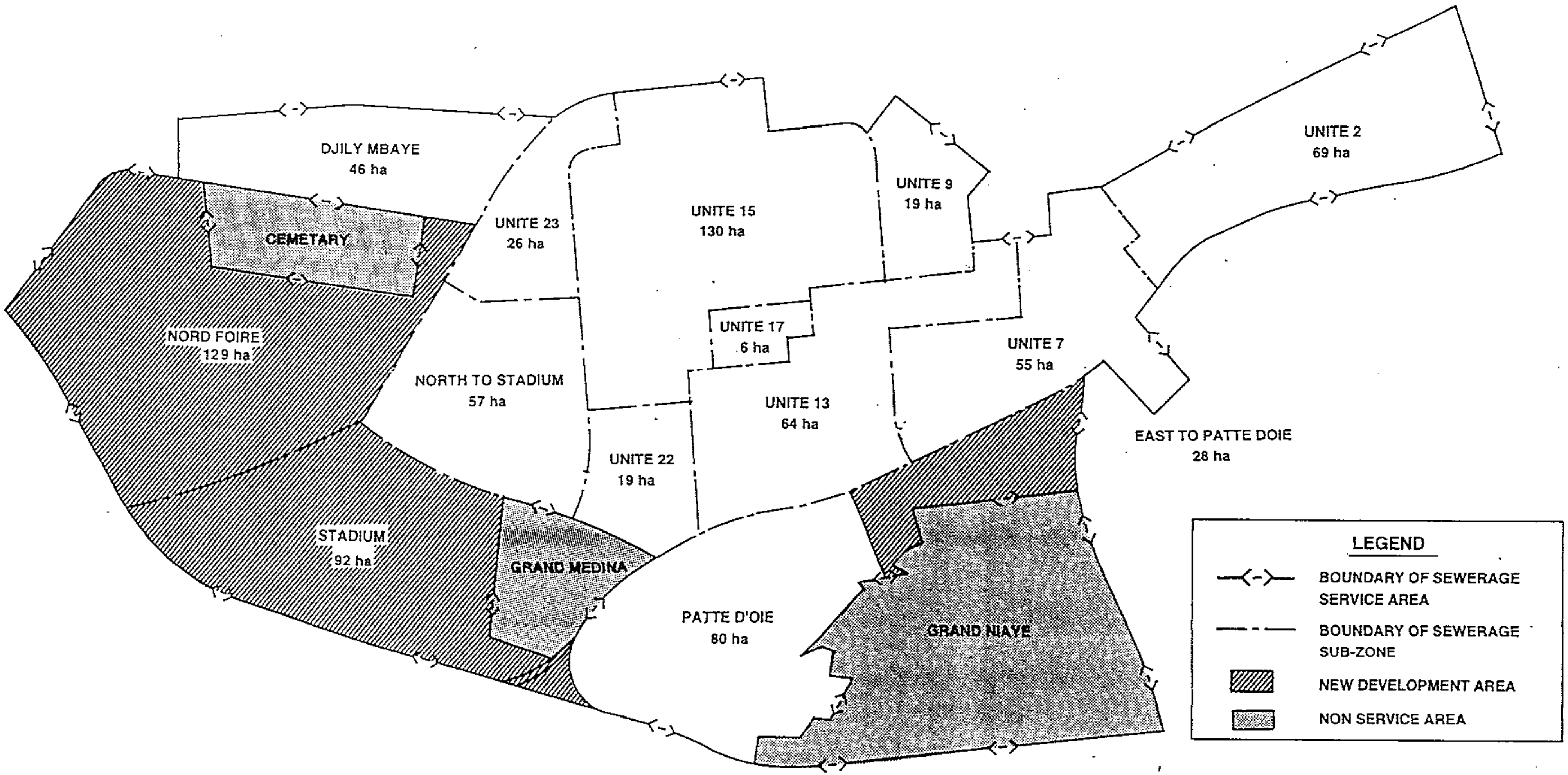


FIGURE 6.1 SEWERAGE PROJECT AREA AND SUBZONES

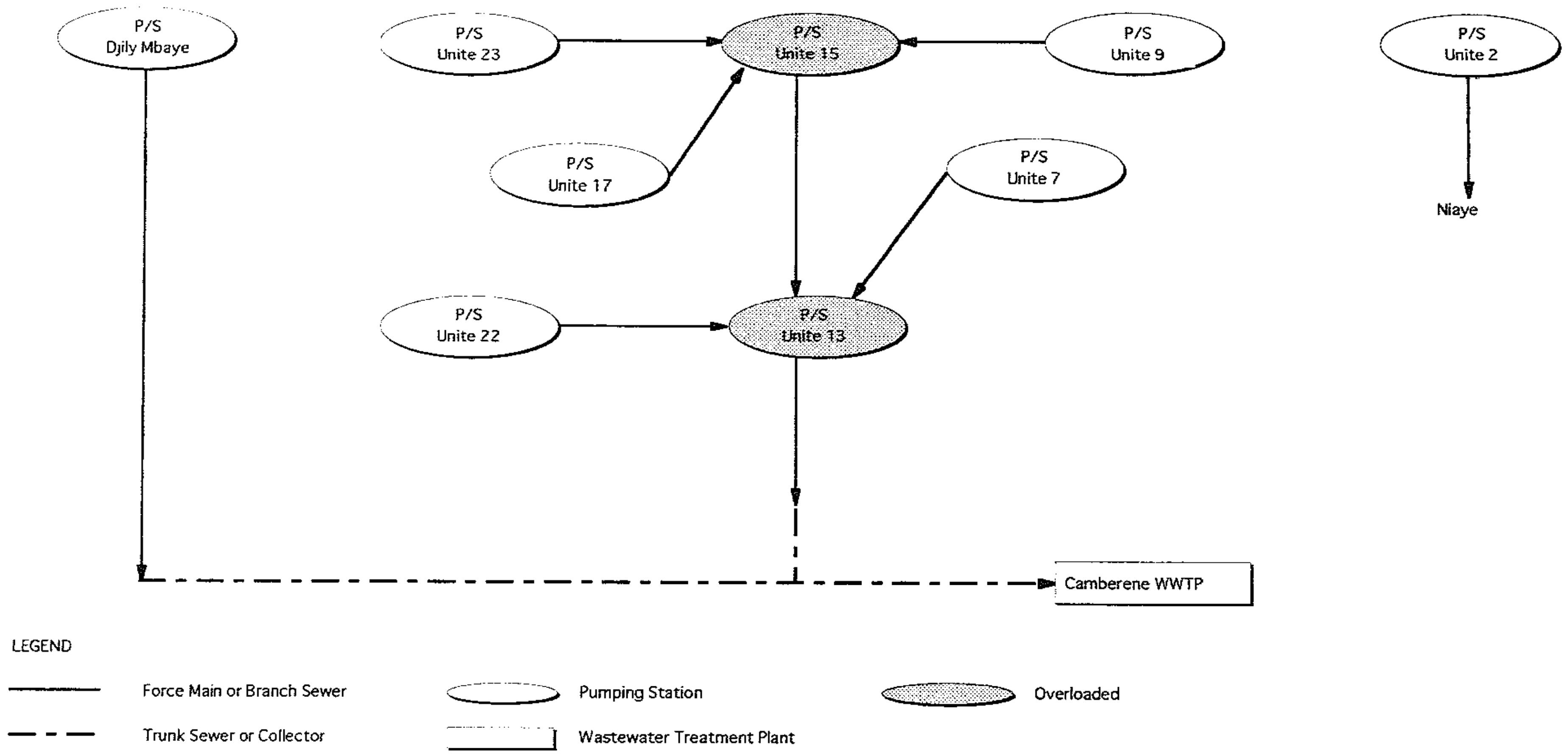


FIGURE 6.2 EXISTING PUMPING STATION SYSTEM

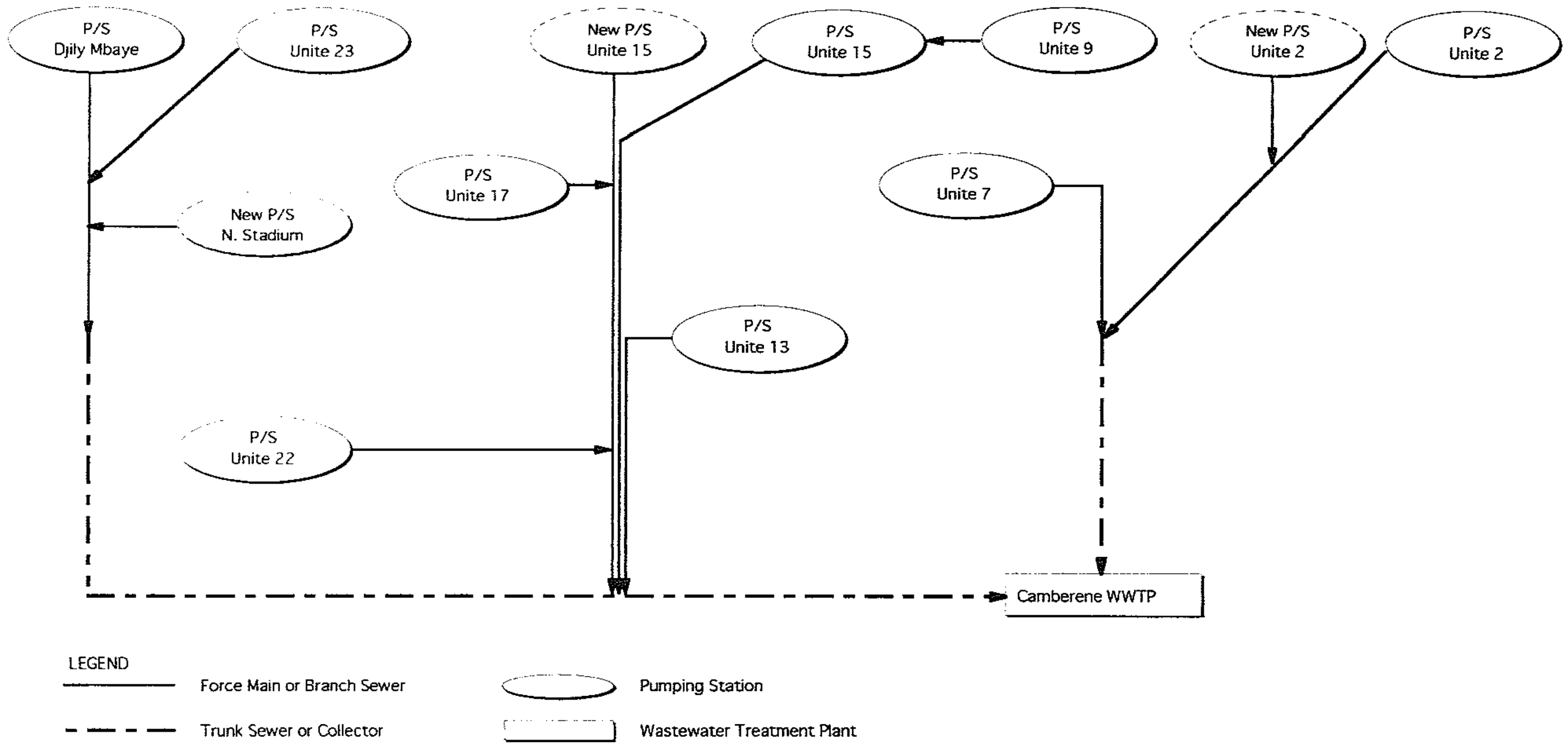


FIGURE 6.3 PROPOSED PUMPING STATION SYSTEM

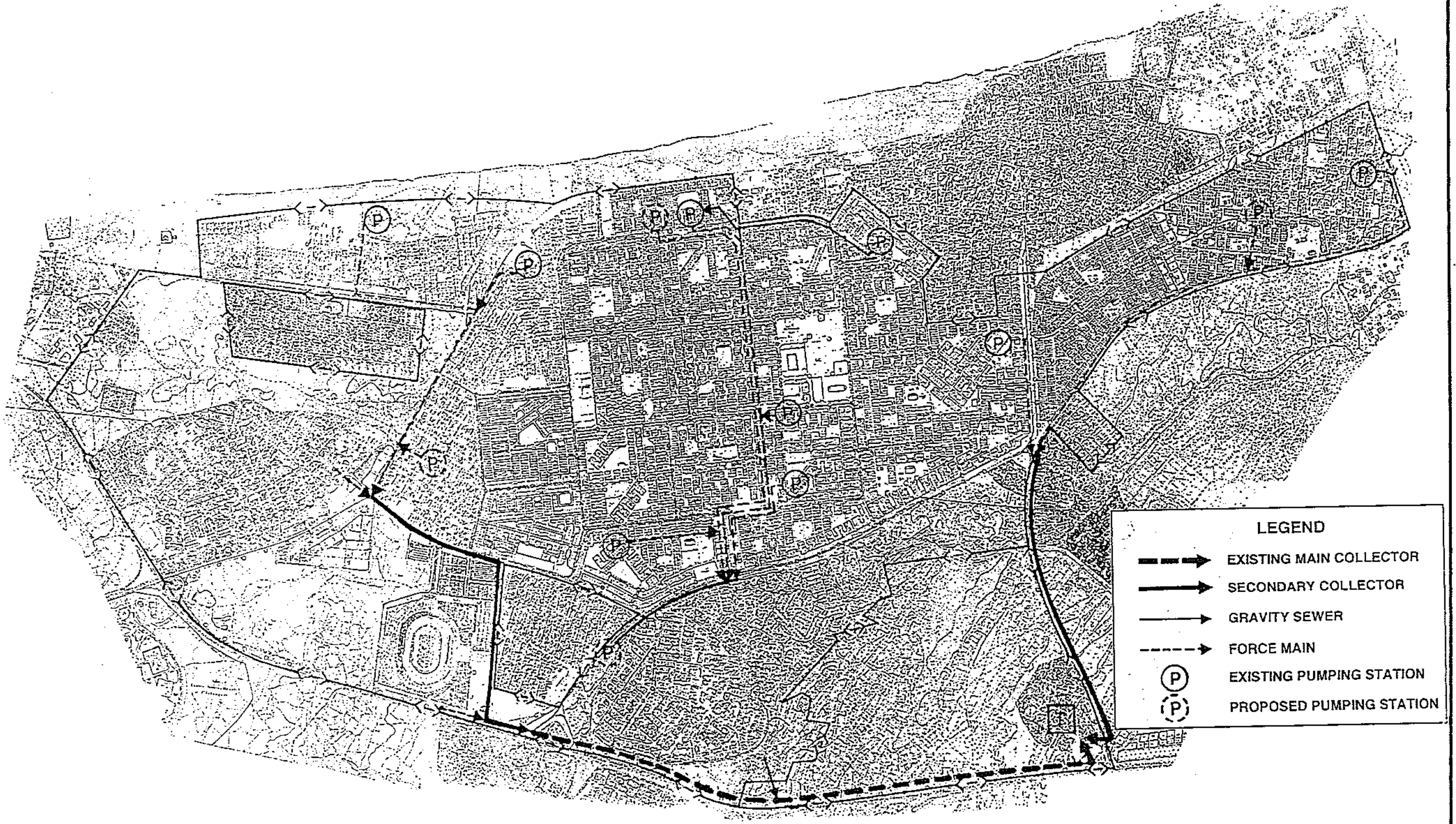


FIGURE 6.4 ALTERNATIVES FOR SECONDARY COLLECTORS : ALTERNATIVE A

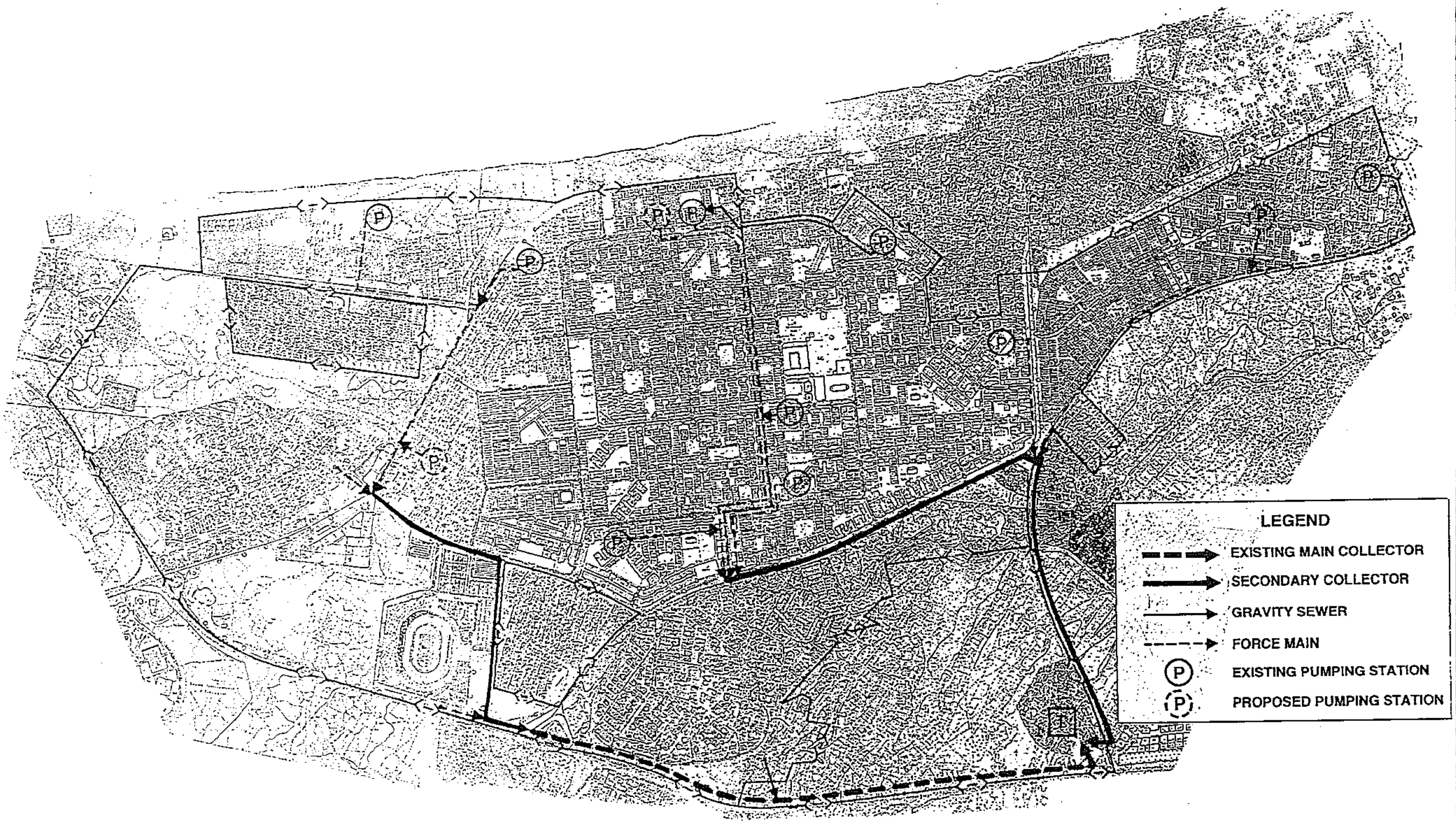


FIGURE 6.5 ALTERNATIVES FOR SECONDARY COLLECTORS : ALTERNATIVE B

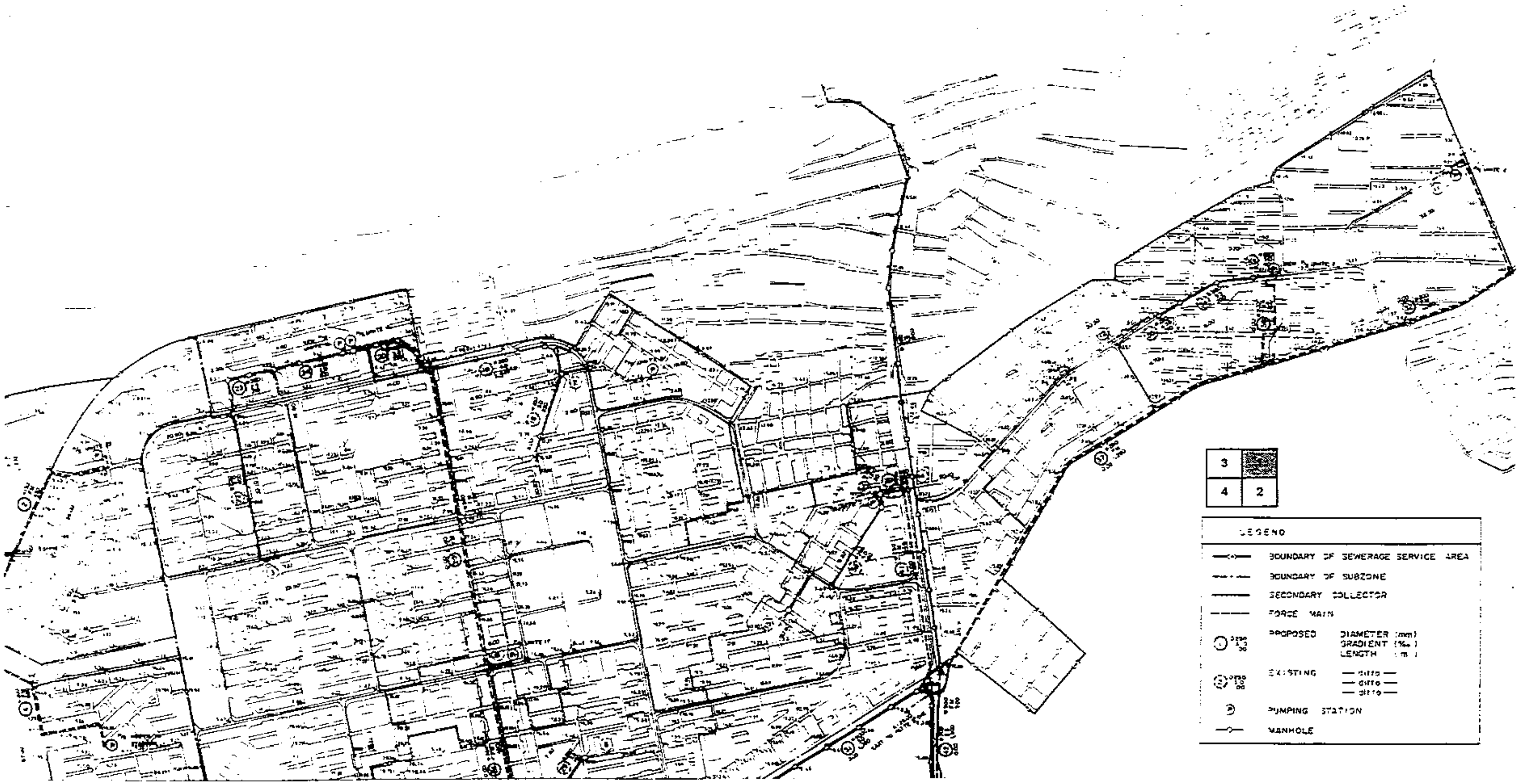


FIGURE 6.6 (1) GENERAL PLAN OF SEWERAGE SYSTEM FOR PARCELLES ASSAINIES AND ITS SURROUNDINGS (1/4)

FIGURE 6.6 (2) GENERAL PLAN OF SEWERAGE SYSTEM FOR PARCELLES ASSAINIES AND ITS SURROUNDINGS (2/4)

FIGURE 6.6 (3) GENERAL PLAN OF SEWERAGE SYSTEM FOR PARCELLES ASSAINIES AND ITS SURROUNDINGS (3/4)

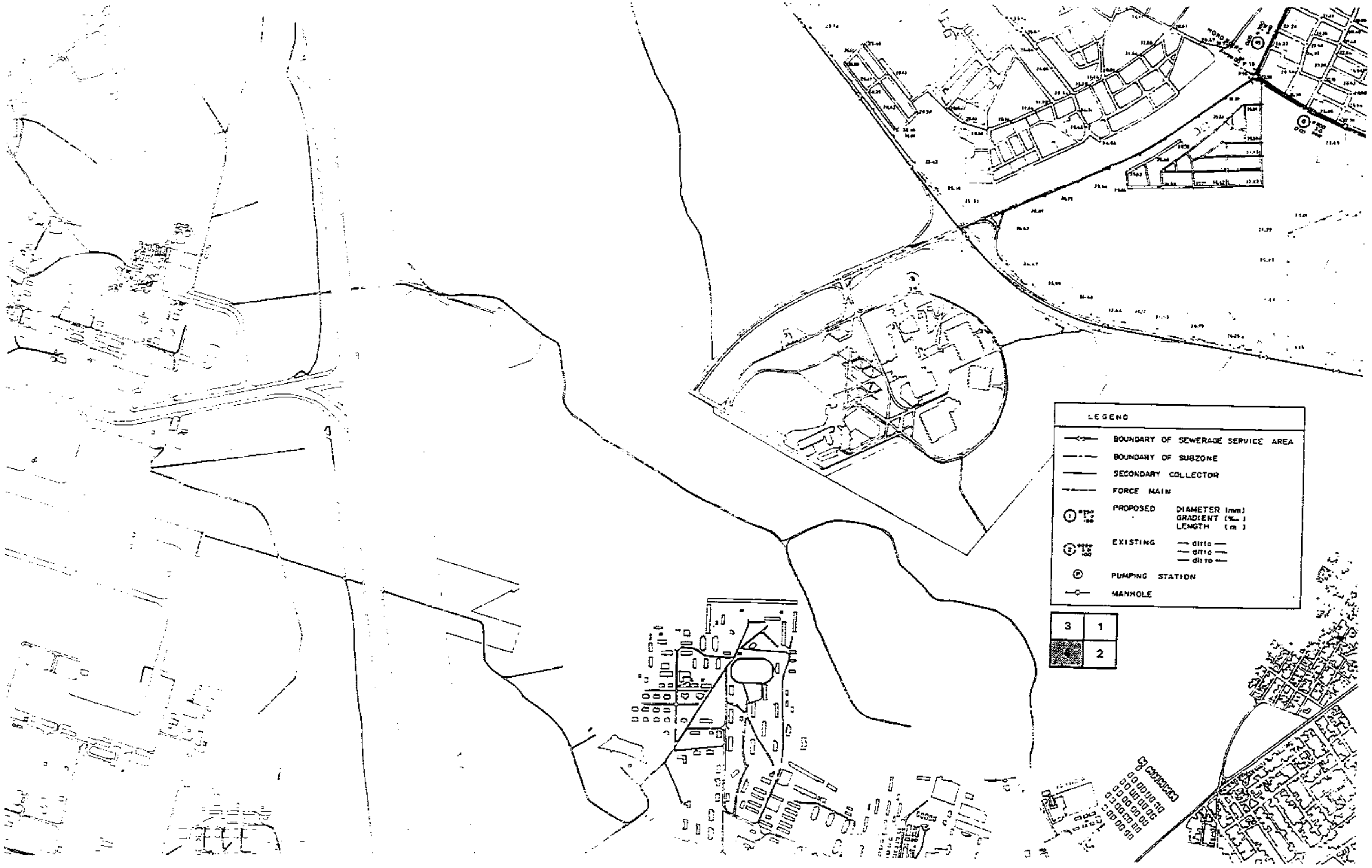


FIGURE 6.6 (4) GENERAL PLAN OF SEWERAGE SYSTEM FOR PARCELLES ASSAINIES AND ITS SURROUNDINGS (4/4)

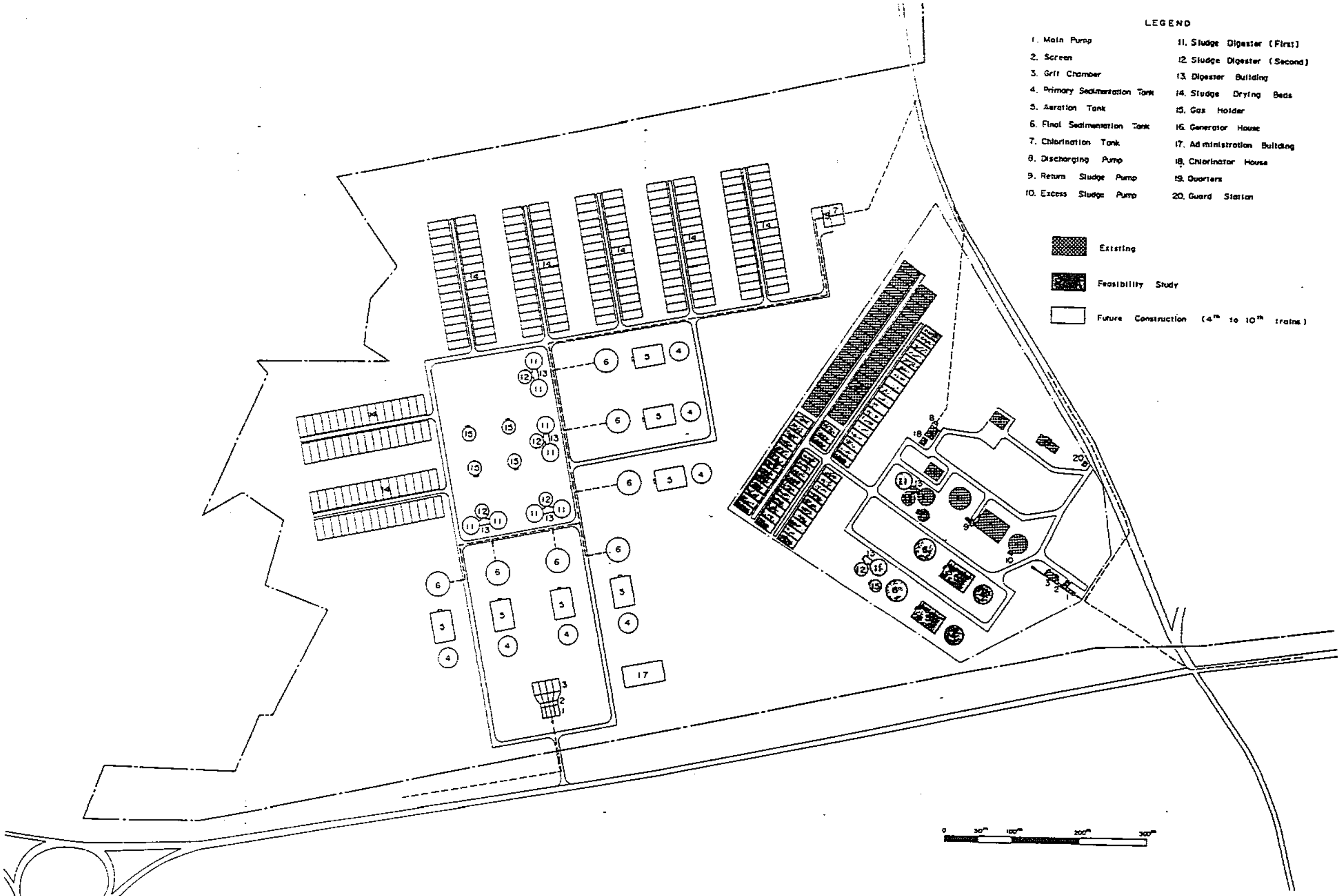


FIGURE 6.7 GENERAL PLAN OF CAMBERENE WWTP

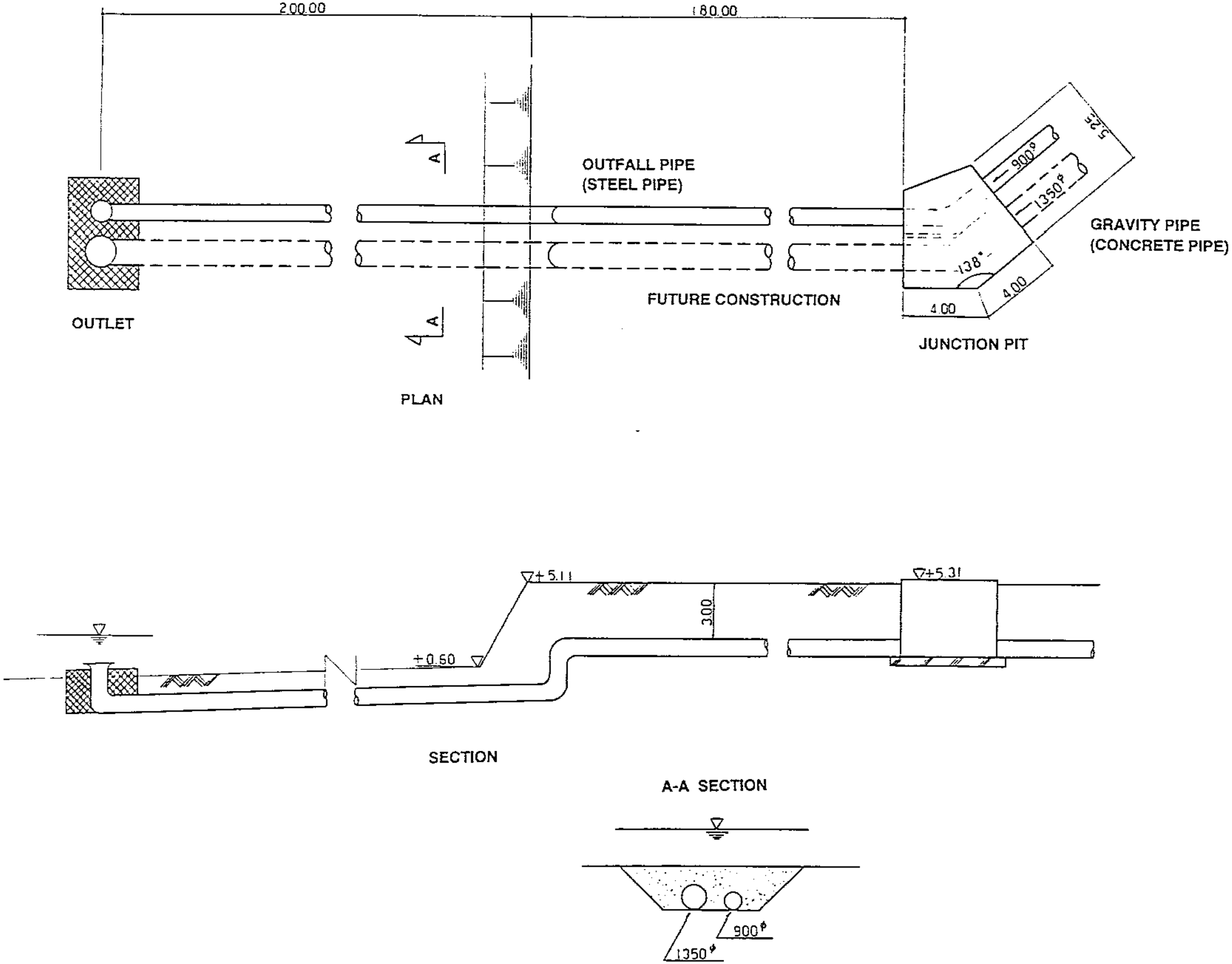
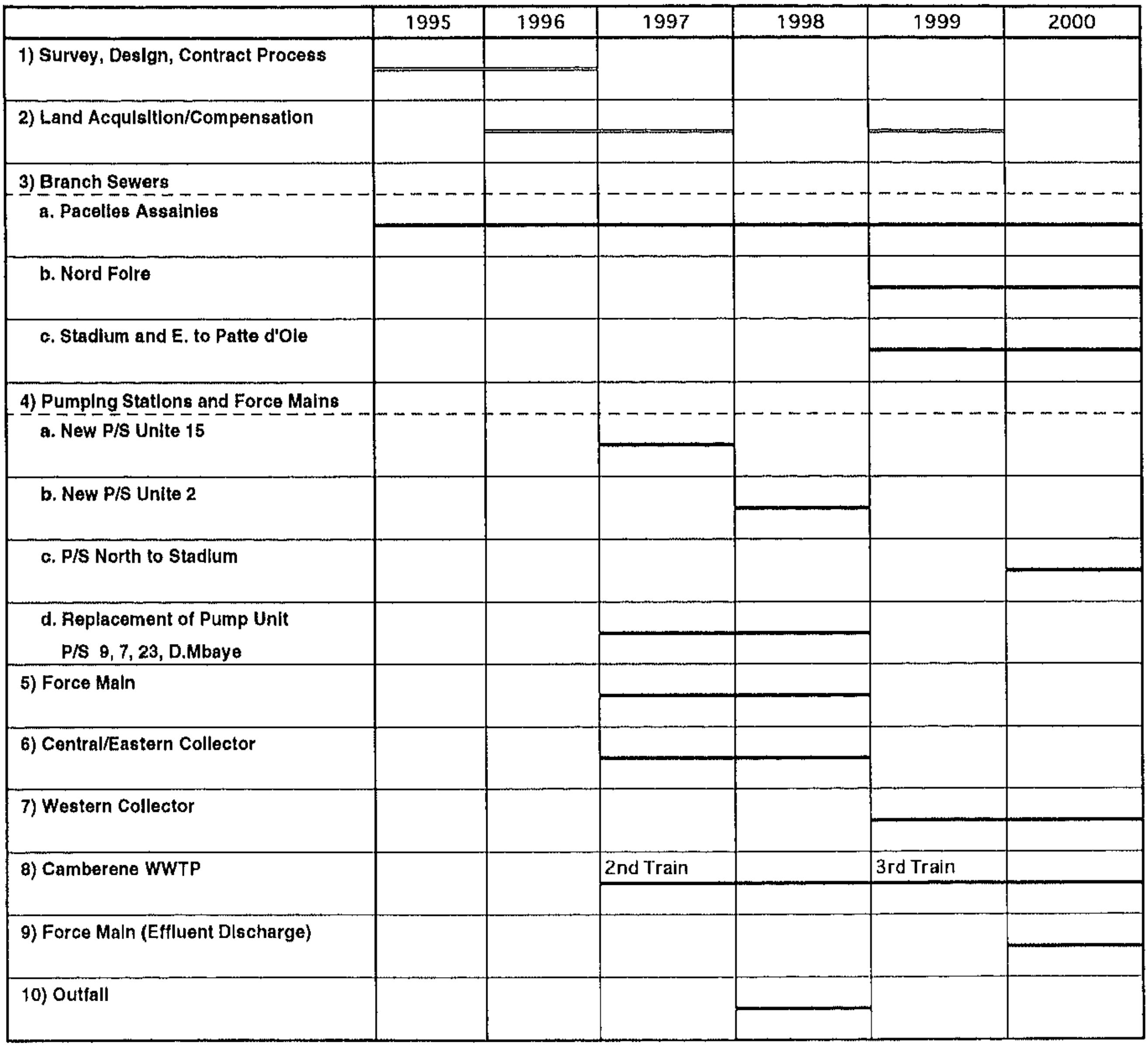


FIGURE 6.8 PLAN AND SECTION OF OCEAN OUTFALL

FIGURE 6.9 IMPLEMENTATION SCHEDULE



PART III

URBAN DRAINAGE SYSTEM

CHAPTER 7

PRESENT DRAINAGE CONDITIONS

CHAPTER 7 PRESENT DRAINAGE CONDITIONS

7.1 GENERAL

7.1.1 Topography and Geology

Dakar, western half of the study area, is generally high and possible to drain by gravity flow. Some low areas are located in Ngor and the coastal areas of Hann Bay. Laterite is widely distributed and permeability is generally low.

Eastern half of the study area is generally covered by sand. This area is characterized by rows of sand dunes and "Niaye", low strips between the sand dunes developed in parallel. Some areas along the coast of Thiaroye Sur Mer are lower than mean sea level.

7.1.2 Rainfall

1) Annual and Monthly Rainfall

Average annual rainfall recorded from 1947 to 1992 at Dakar-Yoff Airport is 458.5 mm and 98% of it occurred in five months from June to October. Usually large storm rainfall occurs in August and September. Monthly rainfall depths are shown in *Table* 7.1.

2) Daily Rainfall

The maximum daily rainfall recorded during past 46 years from 1947 to 1992 are 157.7 mm (August 25, 1964), followed by 153.1 mm (August 26, 1962) and 144 mm (September 17, 1951).

The probability analysis for daily rainfall was conducted. The results are shown in the table below.

Probability Analysis for Daily Rainfall

Return Period	Rainfall (mm)
2 years	66.2
5 years	97.2
10 years	117.7
30 years	148.7
50 years	162.9

Note : Gumbel Method

3) Rainfall Duration and Intensity

The probable rainfall depths for short duration (30 min., 1 hr., 2 hrs., 24 hrs.) are calculated based on analyses of relation between rainfall and its duration as tabulated below:

Probable Rainfall Depth for Short Duration

	Rainfall			
Return Period	0.5 hr	1 hr.	2 hrs.	24 hrs.
2 years	28.2	37.1	45.7	81.0
5 years	41.2	54.4	67.2	119.0
10 years	49.9	65.9	81.3	144.1
30 years	63.0	83.3	102.8	182.0
50 years	69.1	91.2	112.6	199.4

7.1.3 Tide

According to the tide table at the Dakar Port from 1989 to 1993, the tide varies from -0.9 m to +0.95 m. High spring tide occurs in August and September during which heavy rainfall occurs, as shown in *Table* 7.2.

7.1.4 Urbanization

Most of the available land in the study area has been developed except small areas around the Dakar-Yoff Airport, eastern part of the study area, Grand Niaye and some low areas. And some part of these remaining areas are planned to be developed. Comparison of the topographic maps prepared in 1981 and the aerial photographs taken in 1992 indicates the following developments in the last decade:

- Dakar urban area has been extended to the north (Ouakam, Grand Yoff).
- East coast area from Ngor to Guediawaye has been fully urbanized.
- Pikine area has been fully developed except some low areas.
- Grand Niaye, reforestation areas and the lakes have not been developed.
- Area of garbage dumping in Lac Mbeubeusse has been expanded greatly.

7.2 EXISTING DRAINAGE SYSTEM AND PLAN

7.2.1 Group of Drainage Sub-Areas

The study area having a total area of 160.4 sq. km is broadly divided into the following seven (7) group of drainage sub-areas based on natural and drainage conditions.

A-1: Dakar Urban Area (27.9 km^2)

A-2: Grand Yoff and Ouakam Area (6.9 km^2)

A-3: Dakar-Yoff Airport and Its Surrounding Area (17.6 km^2)

A-4: Yoff-Guediawaye Coastal Area (18.5 km^2)

A-5: Grand Niaye Area (15.0 km^2)

A-6: Pikine Area (21.0 km^2)

A-7: Eastern Pikine Area (53.5 km^2)

The drainage sub-areas are shown in *Figure 7.1*.

7.2.2 Existing Drainage Facilities And Plans

Drainage network in the study area is provided for Dakar urban area, Dakar-Yoff Airport area and a small part of Pikine. Most of the stormwater in Dakar is drained by gravity to the sea except the areas where drainage system is not established or areas drained to Grand Niaye.

In Pikine, stormwater drainage system has maintained its natural shape although runoff characteristics have been changed by urbanization. Most of the stormwater is drained to Grand Niaye, other Niayes, Lacs and the sandy ground. Only small areas along the coast are drained to the sea.

Existing drainage network including the boundaries of drainage sub-areas and major drainage channels is shown in *Figure 7.2*.

Existing drainage condition of the sub-drainage areas is described below.

A-1: Dakar Urban Area

The drainage system of Dakar urban area consists of the following drainage basins:

1) Plateau Basin (4.1 km^2)

Stormwater in this area is drained by gravity flow through four pipes to Dakar Port area and four pipes to Madeleines Bay. Stormwater from Cap Manuel with steep topography is drained without any drainage pipe.

2) Gueule Tapee Channel Basin (1.6 km^2)

Stormwater in this area is drained by a two celled box culvert having a drainage capacity of 12.2m^3/s to Soumbedioune Bay. The Gueule Tapee Channel was an open channel before.

3) Channel IV Basin (4.4 km^2)

This area is drained by a concrete lining open channel, Channel IV, to Soumbedioune Bay. Discharge capacity is about 100 m^3/s.

4) Channel IV-3 Basin (3.7 km^2)

This area is drained by an earth open channel to Fann Bay. And its discharge capacity is 10.7 m^3/s.

5) Dakar University Area (1.6 km^2)

The Dakar University Area located between Channel IV and IV-3, is drained by a pipe. Outlet of the pipe is presently clogged with soils and other materials.

6) Channel V & VII Basin (3.5 km^2)

This long area is drained by a large box culvert to the Port area. Discharge capacity of channel V is 5.4 m^3/s.

7) Channel VI & VI-2 Basin (3.8 km^2)

This area is drained to Hann Bay by a concrete lining open channel. Adjacent coastal area is drained by culverts and pipes from factory area. Discharge capacity of channel VI is 25.0 m^3/s.

8) Front de Terre Channel Basin (3.6 km^2)

This area is drained by a wide open channel to a stormwater infiltration area (Centre de Capitage des Eaux), which is covered by sand layer and has a small pond.

A-2: Grand Yoff and Ouakam Area

1) Grand Yoff Basin (4.6 km^2)

There exists no drainage facility in this area. Gravity flow drainage to Hann Bay by a floodway was proposed in the Strategy Plan. Now it has been revised by the Community of Dakar because of high cost due to development of the area along the floodway. The following revised drainage improvement plan is presently being proposed:

- Interceptor to collect the stormwater from higher area around International Trade Center.

- Drainage pumping station for the low area of Grand Yoff town to the interceptor.
- Infiltration of the collected stormwater at the sandy area located north of the Interchange, Patte D'oie.

2) Ouakam Basin (2.3 km^2)

This area is a high basin with minimum elevation of 21 m surrounded by hilly areas. The area is located in the east of Ouakam town and has not been developed yet. The stormwater from this area is found to concentrate to the lowest area and finally infiltrates into the ground since there is no drainage facility.

A-3: Dakar-Yoff Airport and Its Surrounding Area

1) Dakar-Yoff Airport Basin (13.7 km^2)

The airport area is drained by three open channels to the sea at Ngor, Yoff and between these two. The largest earth channel (Airport South Channel) flows through the west side of Ngor village and its drainage capacity is 9.5 m^3/s.

A drainage network of Ouakam town is proposed by the Community of Dakar. The town is located in the uppermost of the Airport South Channel catchment and is drained to the Channel at the east of a culvert under runway.

2) Coastal Area (3.9 km^2)

Narrow coastal areas are drained by natural waterways.

A-4: Yoff-Guediawaye Coastal Area

This area has only one drainage channel along the road located in the eastern Yoff village. There is no drainage facility in the recently developed urban areas. This area is basically drained by infiltration into the ground.

A-5: Grand Niaye Area

There is no artificial drainage facility in this area. Almost all of stormwater from this area concentrates to the Grand Niaye and finally infiltrates into the ground. Stormwater discharged from the southern coast is drained into Hann Bay depending on topography.

A-6: Pikine Area

There is one artificial drainage channel in the low area located in the west of Thiaroye Sur Mer. Drainage of this area is basically by infiltration and storage in many low areas. This area is drained to Grand Niaye, Lacs and other low areas. The area draining to the sea is comparatively small.

A-7: Eastern Pikine Area

There is no artificial drainage facilities in this area. There is a natural stream in Mbaw flowing into Hann Bay (Marigot de Mbaw).

7.3 FLOOD CONDITION

The floods in the study area have been occurring in the rainy season of July, August and September. The recorded largest flood occurred in August 1989. The daily rainfall amount of this storm is recorded to be 113.7 mm and it is estimated to be in a scale of a storm once in 10 years' frequency. The storm coursed flood at many places in Dakar and Pikene. Flood condition survey for the areas shown in the *Figure 7.3* was conducted to know the condition of 1989 flood and annual floods. Through the survey, three (3) flood affected areas were identified (*Figure 7.4*) in Pikine area besides the flood affected areas shown in *Figure* 7.3. Possible causes of these floods have been identified as follows:

- Urbanization took place in low land areas, where stormwater gathered in the rainy season.
- Urbanization increased the storm run-off and decreased the stormwater infiltration capacity of the ground.
- In some areas, drainage systems were not completed.

Major flood affected areas are explained below.

7.3.1 Dakar Urban Area (A-1)

Ground elevation of this area is high except areas around the Dakar Port and the Gueul Tapee. Therefore, stormwater is drained quickly by the existing drainage systems and the roads. 26 areas were flooded by the 1989 flood, but total area affected was small and was for short duration.

7.3.2 Grand Yoff and Ouakam (A-2)

These areas constitute a basin surrounded by hilly areas and all stormwater concentrates to the lowest portion. Therefore, 1989 flood duration was long, 30 days for both of Grand Yoff and Ouakam. The maximum flood depth was 1.4 m for Grand Yoff and 0.5 m for Ouakam.

7.3.3 Ngor (A-3)

A large potential flood area is located in the south of Ngor with ground elevation of 0.5 m to 1.5 m. The reduction of discharge capacity of drainage channel, which carries stormwater from south of the airport, due to sedimentation, clogging and tidal effect has made the above mentioned area flood prone. Inclusion of the large catchment area, located in the south of the airport, into the original natural drainage area may be an another reason of flooding.

1989 flood duration of this area was as long as about six months. The maximum flood depth was about 1.0 m.

1.3.4 Pikine (A-6)

There are narrow and long "Niaye" areas in Pikine. Most of these areas were flooded in 1989 with flood duration of 3 days to 4 months and with flood depth of 0.4 m to 0.7 m.

The low areas along the coast near Thiaroye Sur Mer are habitual flood affected area with long duration. The maximum flood depth was about 1 m. Most of the flood prone area is lower than high tide.

7.4 FINANCIAL CONDITIONS

The urban drainage projects in the study area are planned and executed by the government. The financial resources are shouldered and disbursed by the government.

After drainage facilities are constructed, the operation and maintenance of those facilities are assigned by the government to SONEES and CUD. SONEES takes care of closed channels, while CUD takes charge of open channels.

SONEES annually spends FCFA 121 to 147 million for the operation and maintenance of drainage pipes including the cleaning of drainage pipes, the cleaning and repair of grates and operation of pumping stations. The annual total costs of operation for the whole company come to FCFA 14 to 16 billion. Therefore, the share of drainage pipes in the total O&M costs works out at about 0.9%. CUD spends annually around 40 million FCFA for the operation and maintenance of open channels (including those in Rafisque) at pre-devaluation prices. The expenditure budget of CUD in 1991/1992 was 5,900 million FCFA. Therefore, O & M costs of drainage channels accounted for 0.7% of the total expenditure budget.

TABLES AND FIGURES

TABLE 7.1 MONTHLY AVERAGE RAINFALL (1947-1992) (DAKAR-YOFF AIRPORT)

Unit : mm

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1947	0.0	0.0	0.0	0.0	0.0	1.8	22.8	126.6	220.0	8.9	2.7	0.0	382.8
1948	0.0	1.5	0.0	0.0	0.0	25.3	30.1	350.8	54.5	10.6	0.0	0.0	472.8
1949	0.0	0.0	0.0	0.0	0.0	0.5	110.8	196.1	124.9	22.2	0.0	1.5	456.0
1950	0.0	0.0	0.0	0.0	1.0	5.0	75.0	411.2	259.7	50.3	0.0	0.0	802.2
1951	0.0	0.1	0.0	0.0	15.5	4.9	89.6	217.9	304.4	250.0	18.6	0.0	901.0
1952	0.0	0.0	0.0	1.3	9.4	1.5	67.0	174.7	329.9	29.8	0.0	0.0	613.6
1953	0.0	0.1	0.0	0.0	0.0	11.0	138.5	71.3	157.1	30.7	0.4	0.0	409.1
1954	0.4	20.3	0.0	0.0	0.0	33.4	138.0	382.7	154.1	9.3	22.4	0.0	760.6
1955	0.0	0.0	0.0	0.0	0.6	17.9	272.5	234.6	134.2	13.9	0.0	0.0	673.7
1956	0.3	0.0	0.0	0.0	0.0	2.1	183.6	112.0	97.4	23.7	0.0	58.1	477.2
1957	6.5	0.0	0.0	0.0	0.0	4.6	32.7	141.8	224.6	196.3	0.0	8.8	615.3
1958	0.0	0.0	0.0	0.0	0.0	4.0	75.3	493.1	159.9	86.1	0.0	0.0	818.4
1959	0.0	0.0	0.0	0.0	0.0	5.9	63.3	122.5	77.4	0.0	4.0	0.0	273.1
1960	0.3	0.0	0.0	0.0	0.0	2.4	97.7	298.6	131.3	52.3	0.0	0.0	582.6
1961	0.0	0.0	0.0	0.0	0.0	33.9	223.1	137.5	219.8	0.0	0.0	0.0	614.3
1962	0.0	0.6	0.0	0.0	0.0	13.9	53.3	413.4	55.9	171.8	0.0	0.0	708.9
1963	0.0	0.0	0.0	0.0	0.0	3.5	33.6	200.8	114.1	99.5	0.0	0.0	451.5
1964	3.9	0.0	0.0	0.0	0.0	4.0	142.4	277.0	142.8	0.0	0.0	0.0	570.1
1965	0.0	4.0	0.0	0.0	0.0	5.4	14.8	204.9	170.8	11.8	0.0	0.0	411.7
1966	0.0	0.0	0.0	0.0	0.2	32.4	2.9	139.0	267.3	153.2	0.0	0.0	595.0
1967	0.0	0.0	0.0	0.0	0.0	2.0	86.6	258.1	365.3	183.4	0.0	0.0	895.4
1968	0.0	11.8	0.0	0.0	0.0	2.4	39.2	20.4	129.9	56.0	0.0	0.0	259.7
1969	0.0	0.0	0.0	0.0	0.0	0.0	176.4	279.1	233.1	62.0	0.0	0.7	751.3
1970	0.0	0.0	0.0	0.0	0.0	0.0	6.0	110.1	58.4	2.5	0.0	0.0	177.0
1971	0.0	0.0	0.0	0.0	0.0	12.7	63.7	195.6	68.4	26.3	0.0	0.0	366.7
1972	0.1	0.0	0.0	0.0	0.0	8.7	0.7	31.5	66.0	6.2	0.0	0.0	113.2
1973	0.0	0.7	0.0	0.0	0.0	4.5	59.1	169.7	52.9	0.1	0.0	0.0	287.0
1974	0.0	0.0	0.0	0.0	0.0	0.0	50.7	135.8	148.8	31.0	0.0	0.0	366.3
1975	0.0	0.0	0.0	0.0	0.0	0.0	205.9	179.0	161.2	17.9	0.0	0.0	564.0
1976	0.0	0.5	0.0	0.0	0.0	0.0	17.1	119.1	191.4	43.5	7.6	8.6	387.8
1977	0.0	0.0	0.0	0.0	0.0	1.9	8.4	48.7	112.2	0.0	0.0	0.0	171.2
1978	0.0	0.0	0.0	0.2	0.0	0.0	57.0	149.6	76.1	19.5	19.7	1.3	323.4
1979	50.5	0.0	0.0	0.0	0.0	75.9	81.2	81.7	51.8	0.0	0.0	0.0	341.1
1980	0.0	0.8	0.0	0.0	0.0	0.2	25.7	109.9	226.7	13.8	0.0	0.7	377.8
1981	3.5	0.0	0.0	0.0	0.0	23.5	72.1	175.4	53.1	10.6	0.0	0.0	338.2
1982	0.0	0.0	0.0	0.0	0.3	0.0	104.7	114.5	46.8	43.2	0.0	0.0	309.5
1983	0.0	0.0	0.0	0.0	0.0	10.0	0.4	81.6	62.9	0.0	0.0	0.0	154.9
1984	0.0	0.0	0.0	0.0	0.0	7.7	18.8	69.9	133.5	4.5	0.0	0.0	234.4
1985	0.6	0.0	0.2	0.0	0.0	13.9	72.4	260.1	143.9	15.5	0.0	0.5	507.1
1986	0.0	1.9	0.4	0.0	0.0	0.0	23.5	95.0	260.6	8.4	0.0	0.0	389.8
1987	0.0	0.0	0.0	0.0	0.0	3.7	53.8	247.3	118.8	19.4	0.0	0.0	443.0
1988	0.4	10.5	0.0	0.0	0.0	18.9	9.1	204.9	205.3	22.9	0.0	0.1	472.1
1989	0.0	0.0	0.0	0.0	0.0	27.1	86.2	338.9	92.2	4.4	1.1	0.0	549.9
1990	12.3	0.0	0.0	0.0	0.0	3.4	25.4	99.5	99.7	29.0	0.0	0.0	269.3
1991	0.0	0.0	0.0	0.0	0.0	0.0	26.2	102.2	118.8	23.3	0.0	0.0	270.5
1992	0.0	3.7	0.0	0.0	0.6	0.0	39.2	86.6	48.9	0.8	0.3	1.2	181.3
	1.7	1.2	0.0	0.0	0.6	9.3	71.2	184.1	146.2	40.5	1.7	1.8	458.5

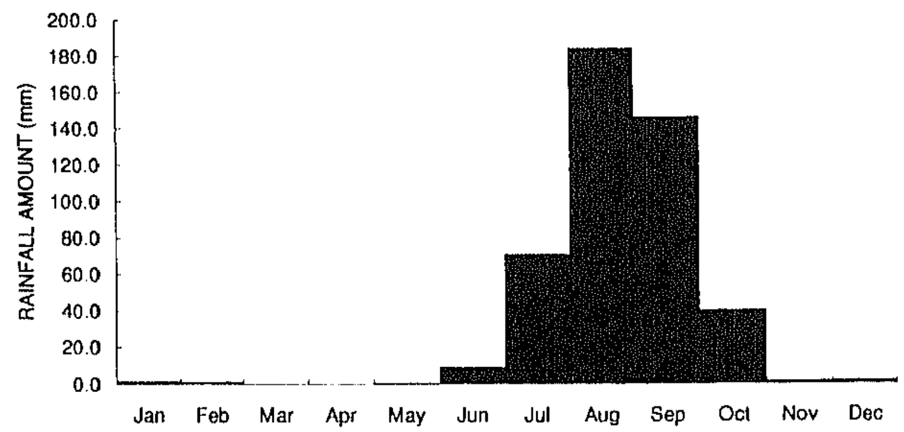


TABLE 7.2 TIDE TABLE OF DAKAR PORT

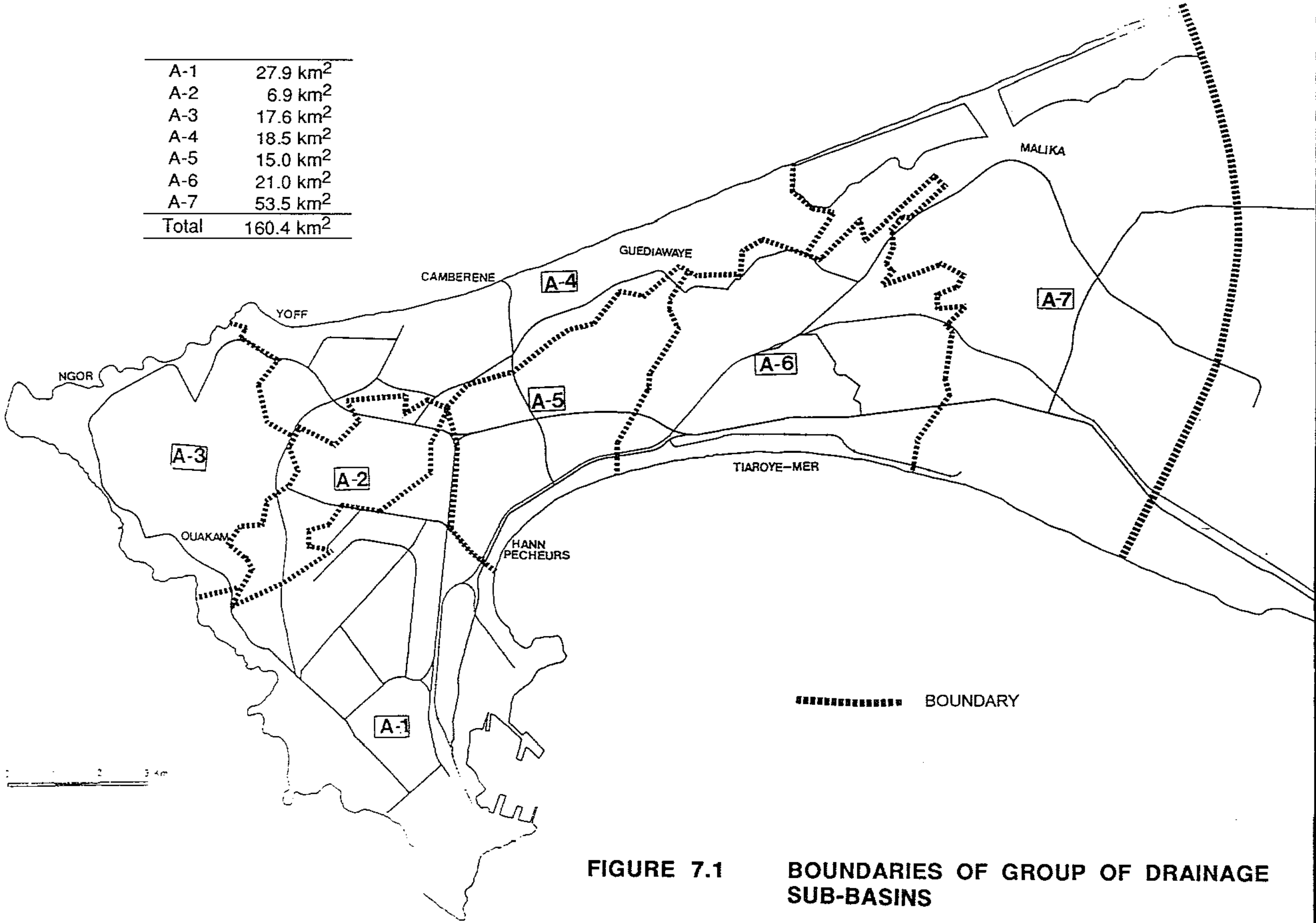
HIGH SPRING TIDE OF DAKAR PORT

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	AVE
1989	1.70	1.75	1.80	1.75	1.70	1.75	1.75	1.80	1.80	1.70	1.65	1.60	
	1.65	1.60	1.55	1.55	1.60	1.70	1.85	1.90	1.90	1.85	1.80	1.75	1.73
1990	1.60	1.70	1.65	1.55	1.55	1.60	1.70	1.80	1.85	1.80	1.80	1.75	
	1.70	1.70	1.70	1.70	1.75	1.80	1.85	1.85	1.80	1.65	1.60	1.60	1.71
1991	1.80	1.75	1.70	1.65	1.75	1.80	1.95	1.95	1.90	1.80	1.70	1.60	
	1.60	1.65	1.65	1.60	1.60	1.65	1.75	1.75	1.75	1.75	1.75	1.75	1.73
1992	1.60	1.60	1.60	1.55	1.65	1.75	1.85	1.95	1.70	1.65	1.65	1.70	
	1.80	1.80	1.75	1.65	1.65	1.70	1.70	1.75	1.90	1.75	1.70	1.65	1.71
1993	1.75	1.80	1.80	1.75	1.75	1.75	1.75	1.80	1.75	1.65	1.65	1.60	
	1.60	1.60	1.55	1.55	1.65	1.75	1.85	1.95	1.90	1.85	1.80	1.75	1.73
AVERAG	1.68	1.70	1.68	1.63	1.67	1.73	1.80	1.85	1.83	1.75	1.71	1.68	1.72

LOW SPRING TIDE OF DAKAR PORT

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	AVE
1989	0.25	0.15	0.10	0.15	0.25	0.40	0.45	0.50	0.45	0.45	0.45	0.45	
	0.35	0.30	0.30	0.35	0.45	0.45	0.40	0.35	0.30	0.25	0.30	0.30	0.34
1990	0.40	0.25	0.25	0.30	0.40	0.50	0.50	0.40	0.35	0.30	0.30	0.30	
	0.30	0.20	0.15	0.20	0.30	0.35	0.40	0.40	0.40	0.45	0.45	0.45	0.35
1991	0.25	0.20	0.20	0.25	0.30	0.35	0.35	0.35	0.35	0.35	0.40	0.45	
	0.35	0.25	0.25	0.35	0.45	0.55	0.50	0.45	0.40	0.35	0.35	0.25	0.35
1992	0.40	0.35	0.30	0.30	0.30	0.35	0.35	0.30	0.45	0.45	0.40	0.35	
	0.20	0.15	0.15	0.25	0.35	0.55	0.50	0.50	0.30	0.30	0.35	0.35	0.34
1993	0.20	0.15	0.10	0.15	0.25	0.40	0.45	0.50	0.45	0.45	0.45	0.40	
	0.35	0.30	0.30	0.35	0.40	0.40	0.35	0.30	0.30	0.25	0.30	0.30	0.33
AVERAG	0.31	0.23	0.21	0.27	0.35	0.43	0.43	0.41	0.38	0.36	0.38	0.36	0.34

Source: Dakar Port Authority
Note: Mean Sea Level (M.S.L.) =1.01m
Unit : meters



A-1	27.9 km^2
A-2	6.9 km^2
A-3	17.6 km^2
A-4	18.5 km^2
A-5	15.0 km^2
A-6	21.0 km^2
A-7	53.5 km^2
Total	160.4 km^2

FIGURE 7.1 BOUNDARIES OF GROUP OF DRAINAGE SUB-BASINS

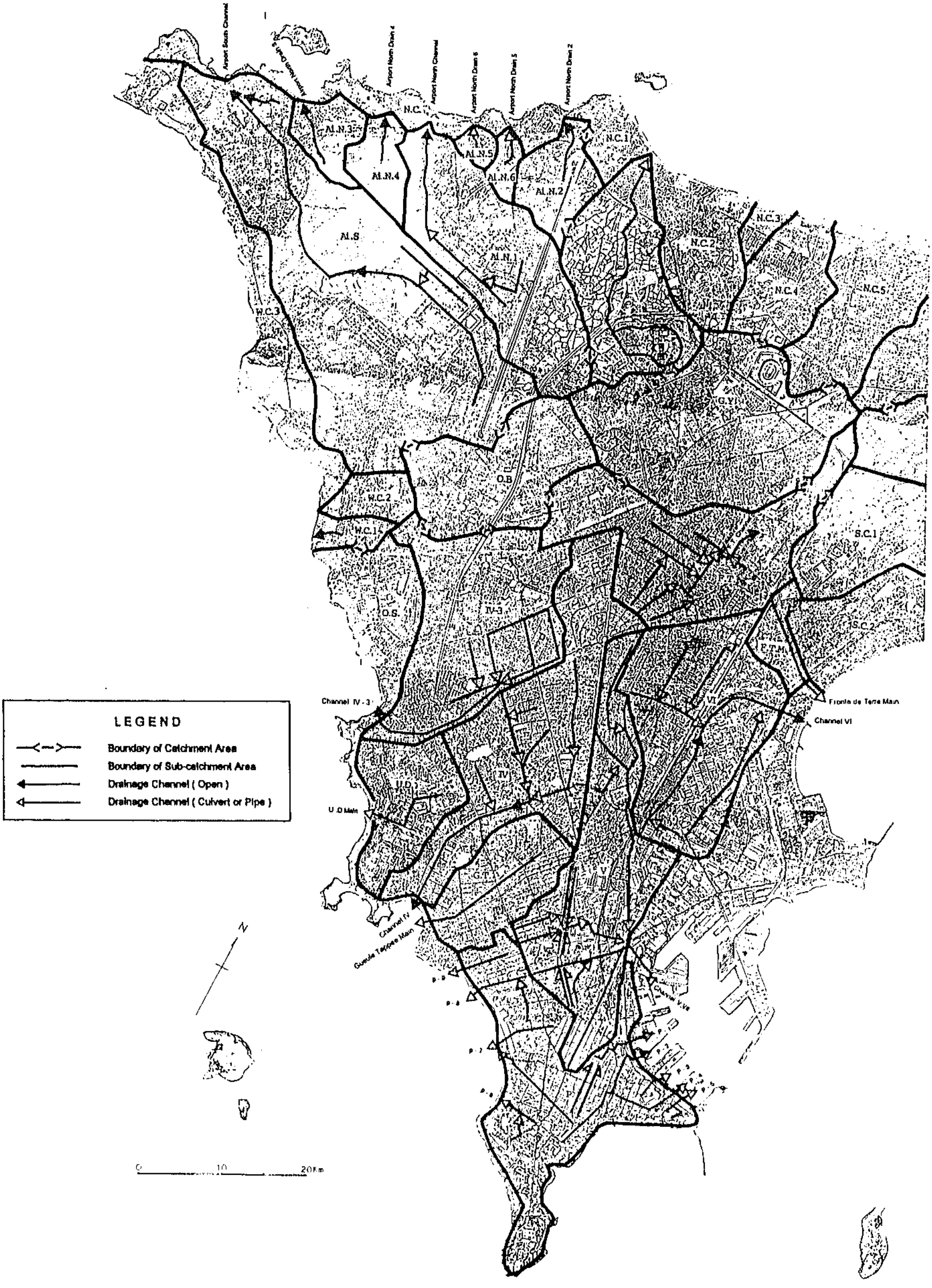


FIGURE 7.2 (1) EXISTING DRAINAGE SYSTEM (DAKAR)

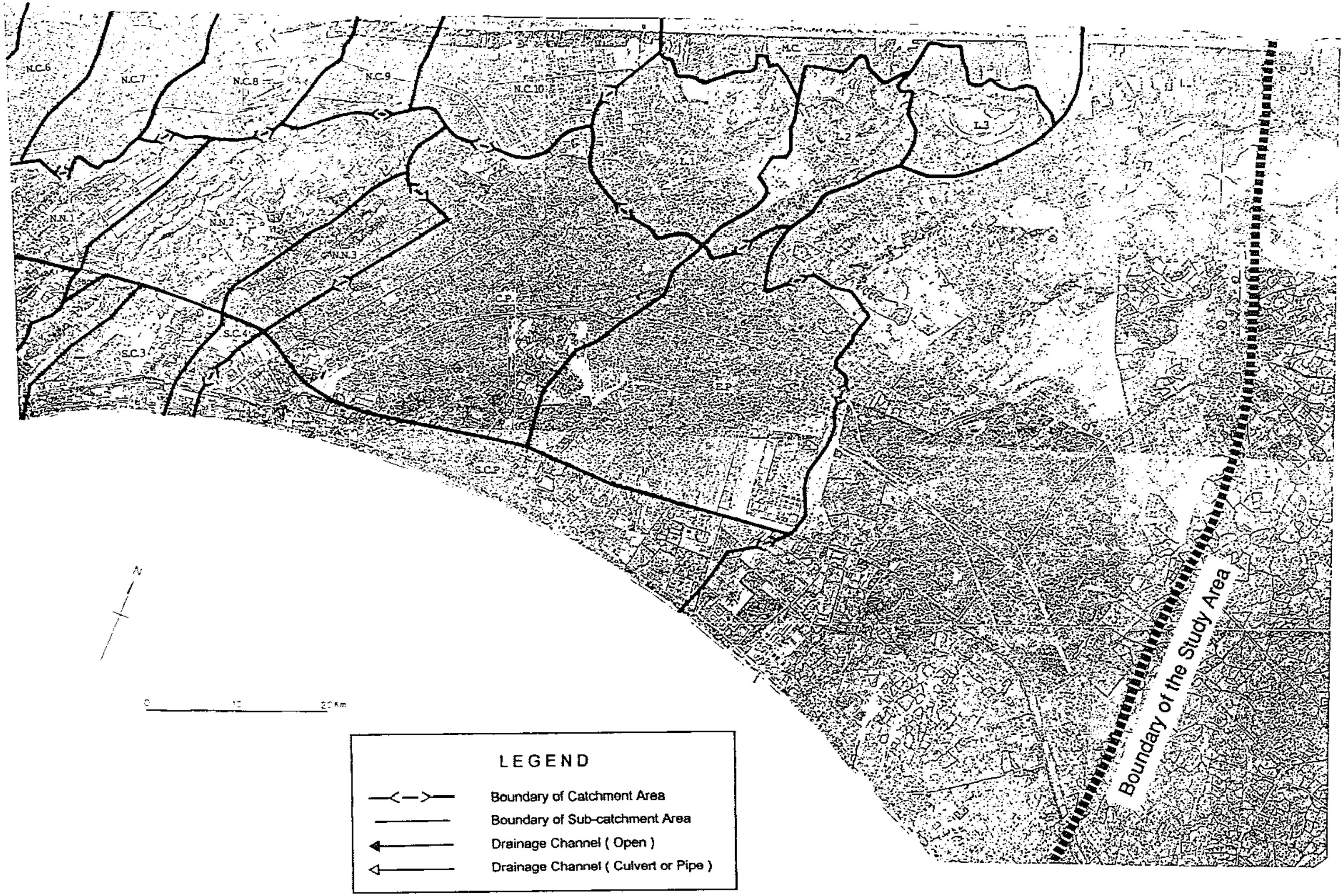


FIGURE 7.2 (2) EXISTING DRAINAGE SYSTEM (PIKINE)

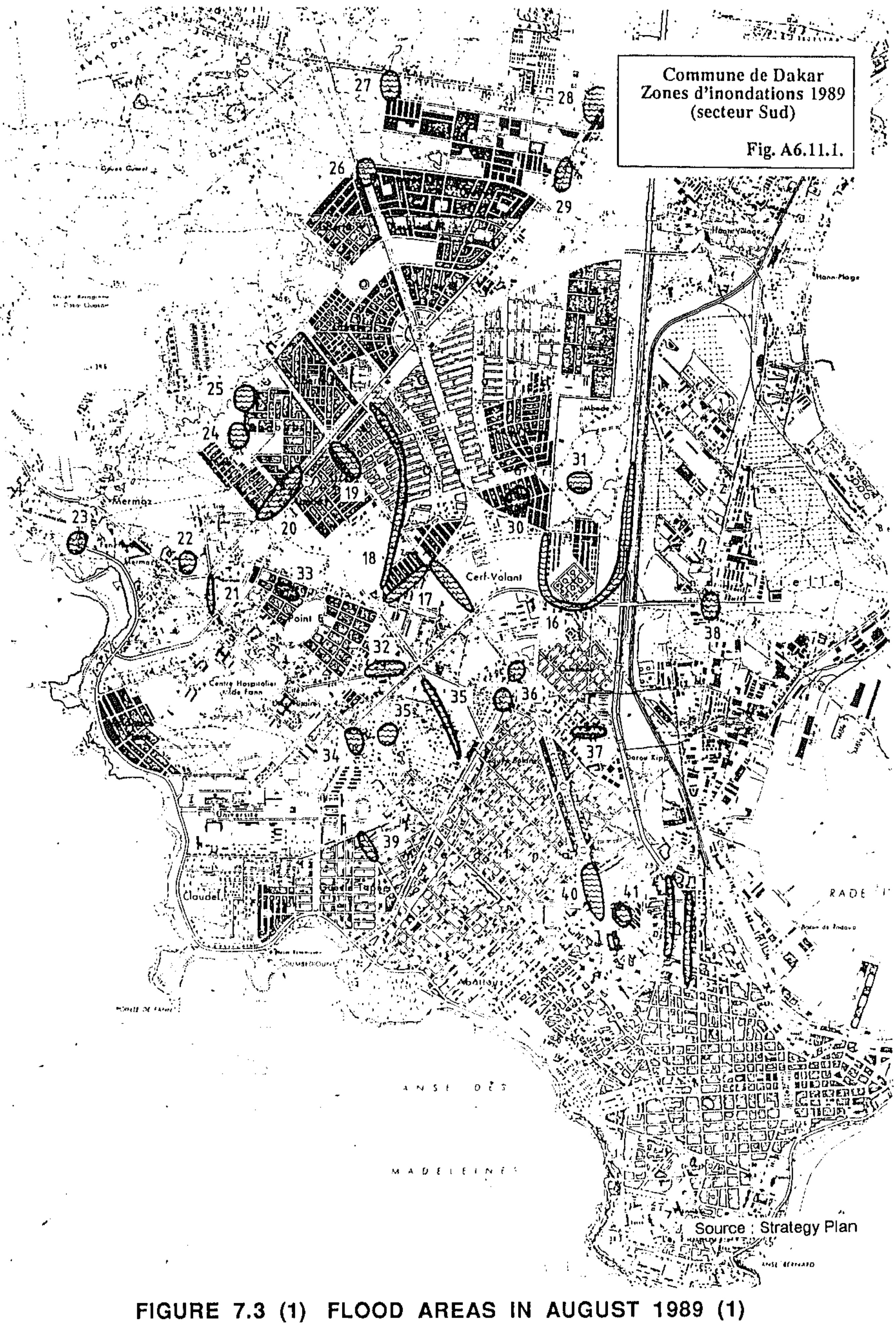


FIGURE 7.3 (1) FLOOD AREAS IN AUGUST 1989 (1)

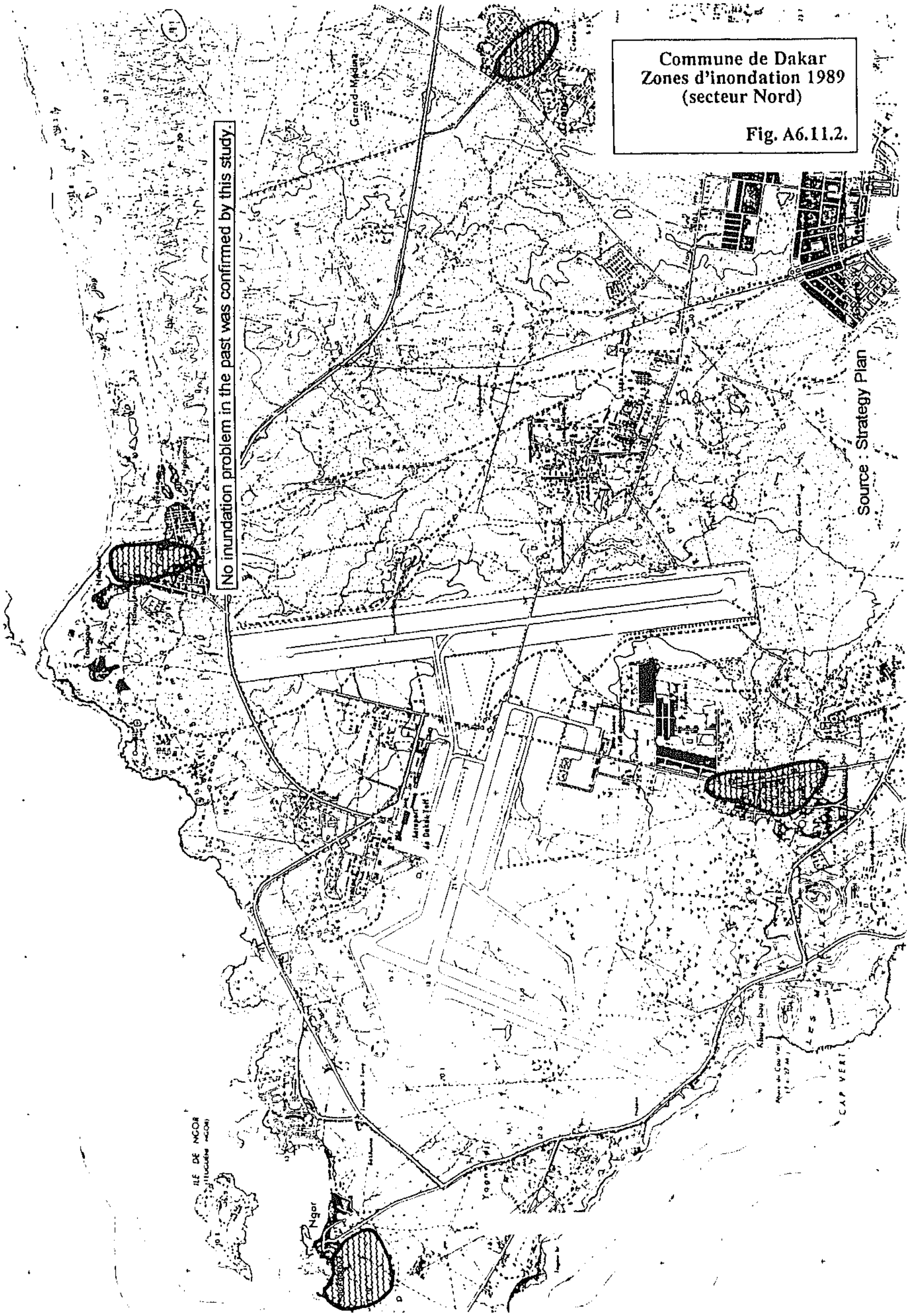


FIGURE 7.3 (2) FLOOD AREAS IN AUGUST 1989 (2)

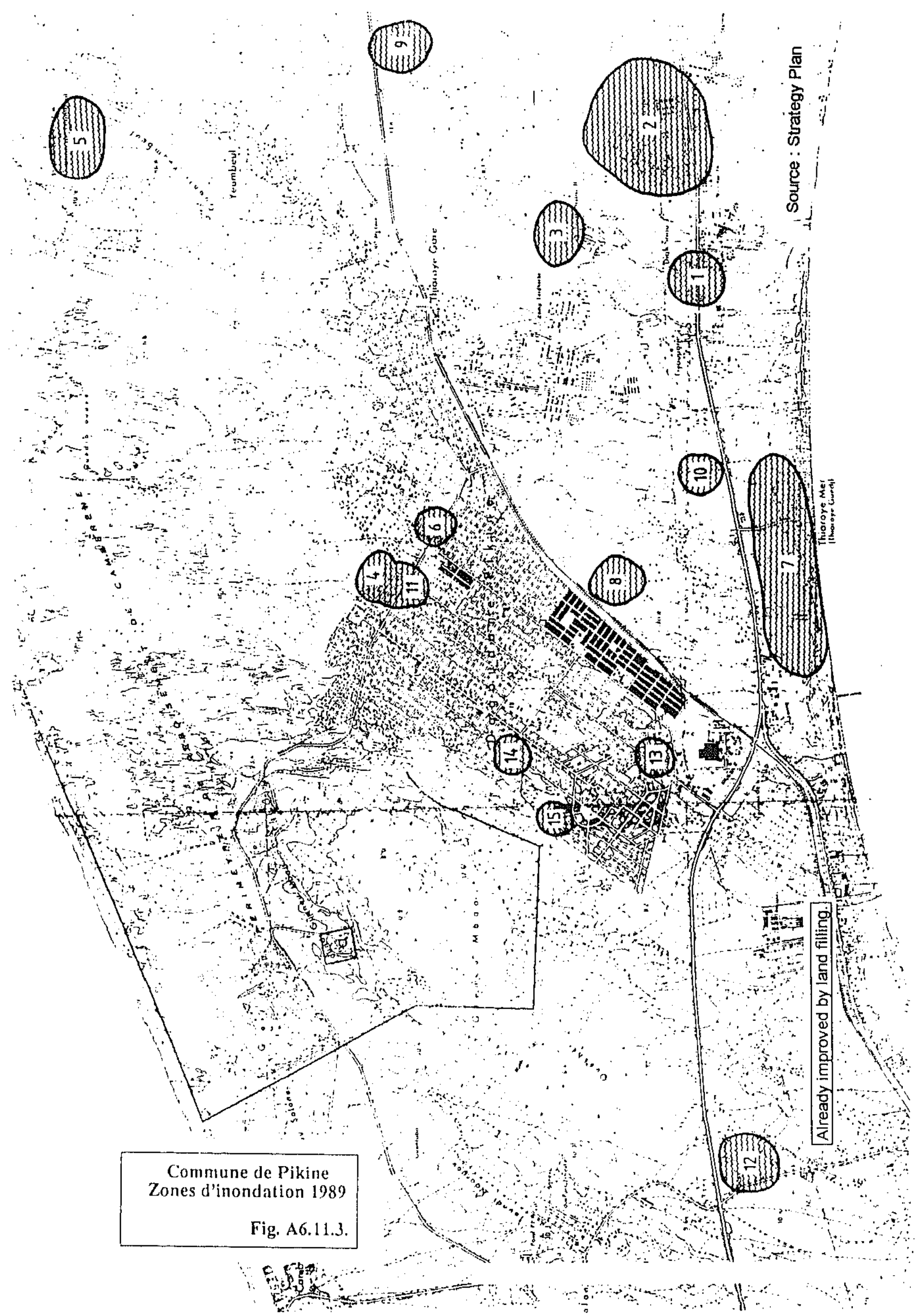


FIGURE 7.3 (3) FLOOD AREAS IN AUGUST 1989 (3)

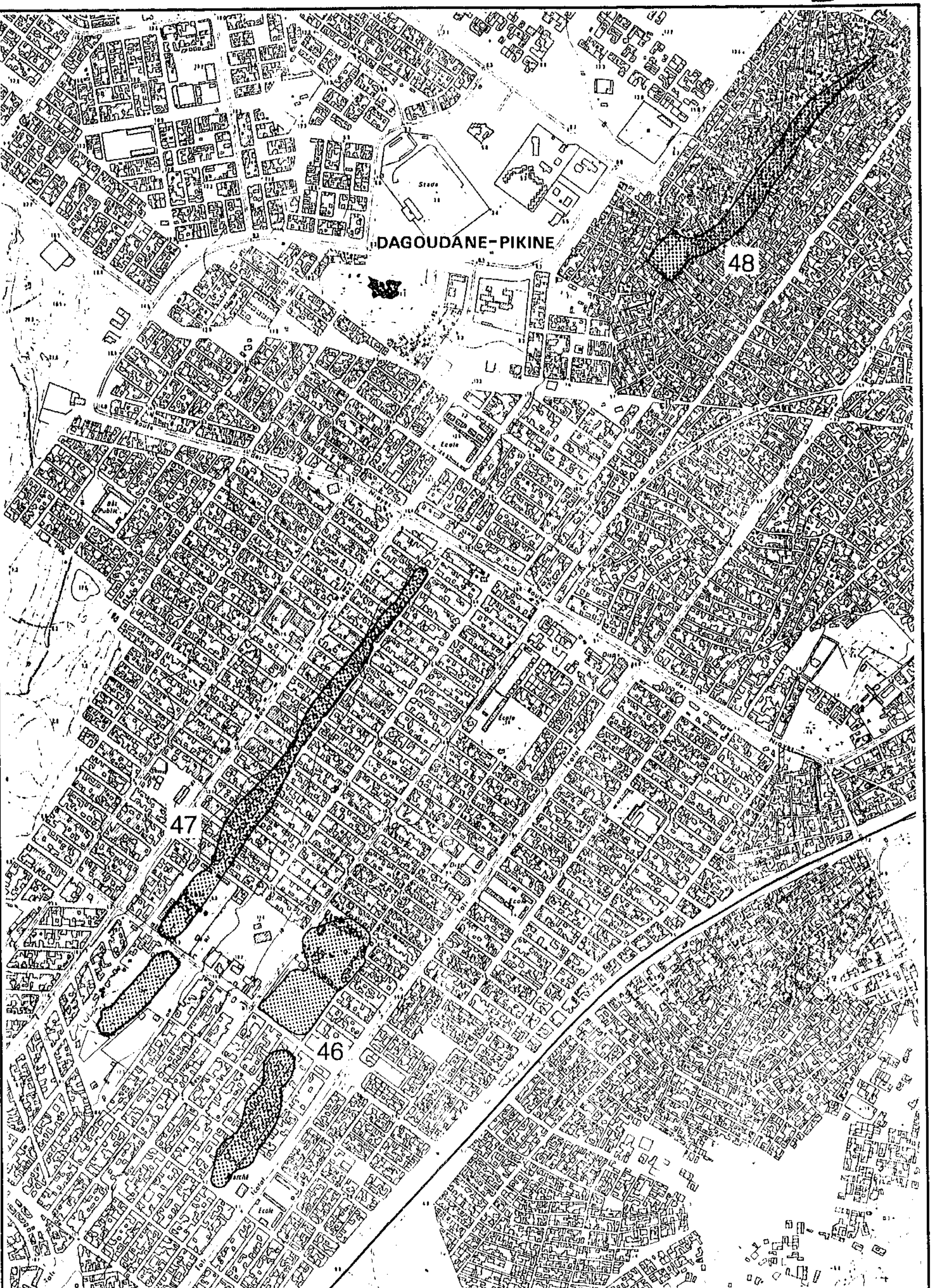


FIGURE 7.4 FLOOD AFFECTED AREA IDENTIFIED BY JICA SURVEY

CHAPTER 8

PLANNING CONDITIONS

CHAPTER 8 PLANNING CONDITIONS

8.1 LAND USE

The land use plan for the year 2010 is applied for the urban drainage planning (refer to *Figure* 8.1).

Planned land use composition of the Study Area is as follows:

Land Use Category	Area (sq. km)
Housing (Village, Spontaneous-irregular)	24.2
Housing (Spontaneous-regular, Planned)	41.3
Housing (Detached house, Flat)	12.1
Equipment (Public Facility)	15.0
Park, Cemetery, Military (Camp)	14.4
Industrial	14.6
Agricultural	24.3
Open Space	3.4
Reforestation	11.1
Total	160.4

Most of the Study Area is expected to be urbanized by 2010 except a part of Grand Niaye, Lacs, reforestation areas, and some part of eastern Pikine.

8.2 DESIGN DISCHARGE

8.2.1 Design Return Period of Rainfall

The design return period of rainfall for the drainage facilities are decided as follows:

- Five years return period for the drainage channels
- Ten years return period of 24 hours rainfall for pumping station and retention/infiltration ponds

8.2.2 Flood Run-off Calculation

1) Run-off Calculation Method

Drainage Channels/Pumping Stations:

The Rational Method is applied in this study for calculation of the design run-off due to following reasons:

- The facilities in the study area have comparatively small basins.

- To design cross section of drainage channel, only peak discharge is needed. To calculate peak discharge, the Rational Method is commonly used .

- Since peak discharge can be calculated by using only three factors such as catchment area, rainfall intensity and run-off coefficient, the Rational Method is useful for planning of these facilities.

- Runoff coefficients can easily be evaluated by land use category.

In the Rational Method, peak discharge is calculated using the following formula.

$$Q = \frac{1}{3.6} F \cdot I \cdot A$$

where, Q : Peak Discharge (m^3/s)
F : Run-off Coefficient
I : Average Rainfall Intensity within the Time of Concentration "T" (mm/hr)
A : Catchment Area (km^2)

The value of I for duration T is calculated by using the following Talbot Formula:

$$I = \frac{b}{T + a}$$

where, I : Rainfall intensity (mm/hr)
T : Duration of rainfall (min.)
a, b : Constants

(1) Run-off Coefficient (F)

The run-off coefficient for each land use category is recommended considering intensity of rainfall, geology and land surface condition and is mentioned below:

Land Use Category	Value of F
Residential Area	
High density	0.40
Medium density	0.30
Low density	0.20
Industrial Area	0.30
Agricultural Area	0.10
Public Facility Area	0.20
Park, Cemetery, etc.	0.20

(2) Time of Concentration (T)

The time of concentration (T) is defined as the time required for the rainfall to reach the exit of the basin since the onset of rainfall. "T" is determined as the sum of time elapsed from the beginning of rainfall until rainwater enters into the relevant channel (time of inlet: T1) and the time elapsed as rainwater flows down to the downstream end through the channel (time of flow T0).

$$T = T1 + T0$$

Infiltration/Retention Ponds:

To design the infiltration/retention ponds, it is necessary to know the stormwater volume discharged from the relevant basin. The discharged stormwater volume is calculated using the following formula.

$$V = F*R*A*1000$$

where, V : Discharged Volume (m^3)
R : Amount of Rainfall (mm)
A : Catchment Area (km^2)
F : Run-off Coefficient

2) Design Rainfall

(1) Drainage Channel

The design rainfall intensity for drainage channels is calculated by using rainfall intensity and duration equation for the 5 years return period of storm.

(2) Pumping Station

The design rainfall pattern for pumping stations is determined by using 24 hours' rainfall amount and intensity-duration equation for the 10 years return period of storm.

The design rainfall pattern for pumping stations is shown in *Figure* 8.2.

(3) Retention/Infiltration Ponds

The design rainfall amount for retention/infiltration ponds is 24 hours' rainfall amount of 10 years return period.

8.3 DESIGN TIDE LEVELS

The design tide levels, as an outlet condition, for the drainage facilities are recommended as follows

- Mean high spring tide in August of 0.85 m above mean sea level for the drainage channels and pumping stations.
- Mean sea level for long term drainage, say more than one day.

TABLES AND FIGURES

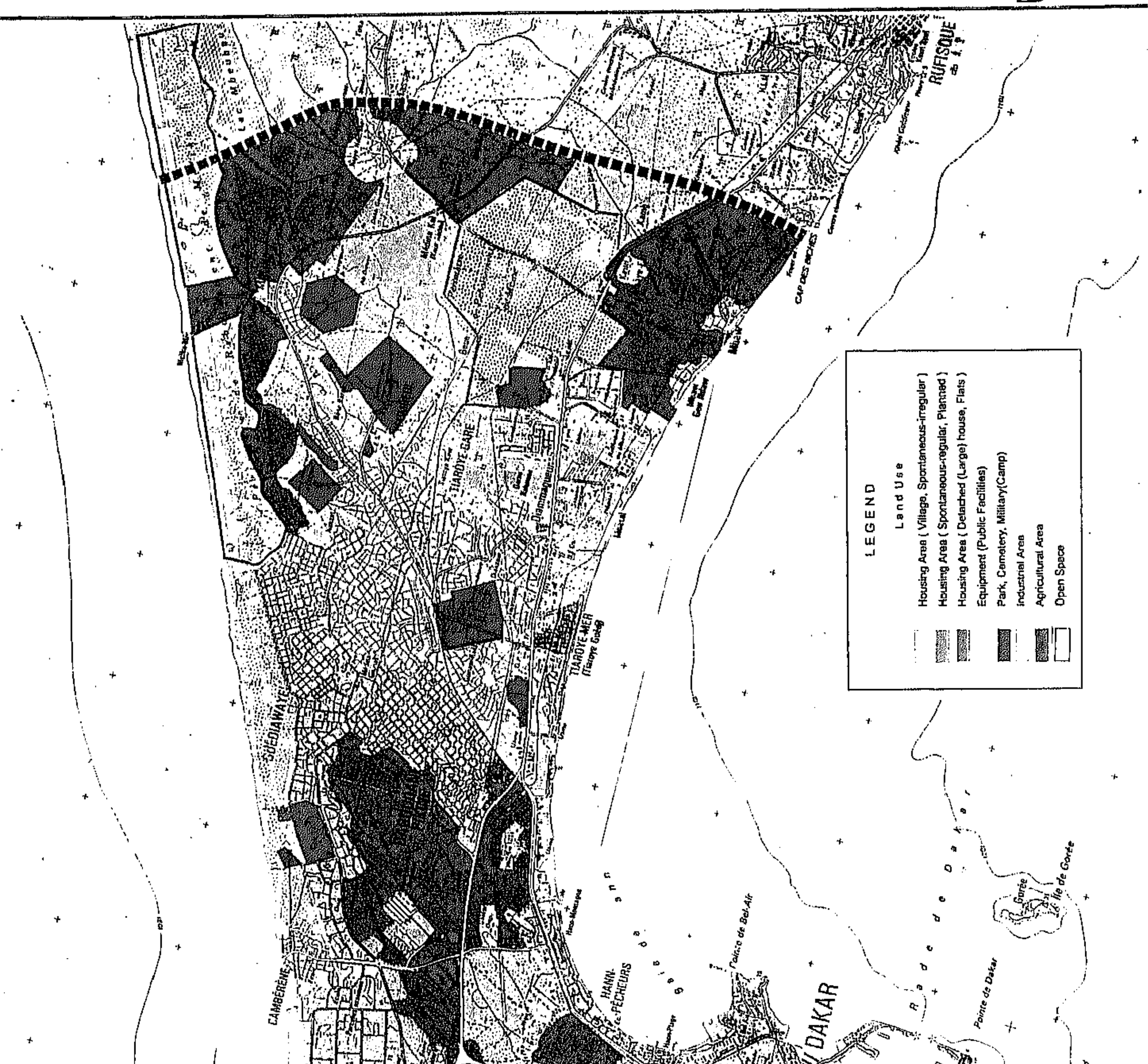
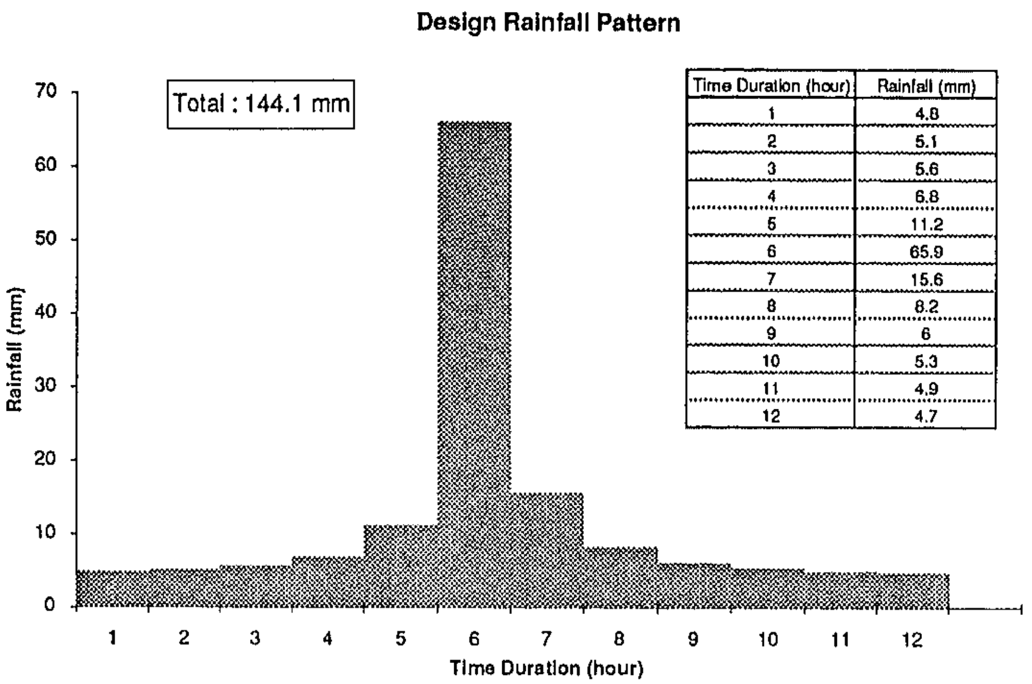


FIGURE 8.1 FUTURE LAND USE PLAN OF THE STUDY AREA



Time Duration (hour)	Rainfall (mm)
1	4.8
2	5.1
3	5.6
4	6.8
5	11.2
6	65.9
7	15.6
8	8.2
9	6
10	5.3
11	4.9
12	4.7

FIGURE 8.2 DESIGN RAINFALL PATTERN

CHAPTER 9

URBAN DRAINAGE MASTER PLAN

CHAPTER 9 URBAN DRAINAGE MASTER PLAN

9.1 GENERAL

The stormwater drainage system of the study area is proposed based on the following concepts:

- Target year of this proposed drainage improvement plan is 2010.
- Drainage sub-areas shall be decided mainly based on natural topography, in order to save the cost of construction and operation/maintenance.
- Stormwater shall be infiltrated as much as possible as a groundwater source.
- Natural gravity flow drainage shall be applied to the maximum extent and pumping drainage shall be minimized.
- Each drainage sub-area shall have an outlet. Existing wet lands such as Niayes, Lacs, inland depressed areas and the Marigot will be used as receiving bodies.
- Drainage channel crossing large roads should be avoided in principle.
- The concrete facility plans are considered as structural measures for the areas which had inundation problem in 1989 flood. For sandy areas with high ground elevation (say more than 5m), non-structural measures such as infiltration, land use regulation of depressed areas, etc. should be applied.

The proposed drainage system of each sub-area is described in the following sections.

9.2 DRAINAGE SYSTEM PLAN

9.2.1 Dakar Urban Area (A-1)

The whole area is covered by the existing drainage system . Since the area can be drained to the sea by gravity flow and flood affectedness is limited in terms of area and duration, no facility construction is required in general. Therefore, enhanced maintenance works of the present facilities are proposed. However, division of the drainage area in Fronte de Terre Drainage Area and construction of an additional drain in Channel IV-3 Drainage Area are required as shown in *Figures* 9.1 and 9.2 respectively.

9.2.2 Grand Yoff and Ouakam Area (A-2)

1) Grand Yoff

The proposed drainage improvement plan by the Community of Dakar, mentioned in 1.2.2, is basically applied for the drainage of Grand Yoff basin. The proposal is modified as shown in *Figure* 9.1.

2) Ouakam Basin

This area is high with the minimum ground elevation of about 20 m surrounded by higher ridges. In order to drain to the sea by gravity flow, a long tunnel of high cost will be required. This area is not urbanized yet, though a housing development is proposed. Therefore, some open spaces for retention/infiltration ponds shall be provided in the development. The ponds are proposed on both sides of the airport property (see *Figure* 9.1).

9.2.3 Dakar-Yoff Airport and Its Surrounding Area (A-3)

The narrow coastal areas, located in the north and west of the airport, can be drained by gravity through the existing natural and artificial waterways.

The drainage improvement plan for the Ouakam town proposed by the Community of Dakar is applied without any modification (see *Figure* 9.3). Downstream reach of the Airport South Channel with a length of about 2.8 km from the estuary to the runway is proposed to be improved by expanding the existing channel. Developments in the low area near Ngor should be done by reclaiming up to at least 2 meters above mean sea level.

The Airport North Channel (2) from the estuary to the runway with a length of 1300 m is proposed to be improved.

9.2.4 Yoff-Guediawaye Coastal Area (A-4)

Generally, infiltration is proposed for drainage in this area. Therefore, the depressed lands in the urbanized area shall be kept as open spaces.

Improvement of the Yoff Channel is proposed between its estuary and International Trade Center. This channel shall include the Airport North Catchment.

9.2.5 Grand Niaye Area (A-5)

Grand Niaye is an important area for drainage and for groundwater recharge. Therefore, the wet land is proposed not to be urbanized in principle.

While the eastern part of Grand Niaye is planned to be reclaimed for the area of industrial complex by the Technopole Project, it was confirmed that the project would not affect Grand Niaye's receiving capacity for Stormwater.

An area around Patte d'Oie is planned to be developed. Main low areas are proposed to reserve for drainage. For other low areas, reclamation should be done at least 2 m higher than mean sea level if those are urbanized.

An open channel is proposed along the south side of national road to collect the stormwater.

9.2.6 Pikine Area (A-6)

1) Central Pikine

In central Pikine, low strips (Niayes) with elevation of 2 m to 4 m are frequently flooded. These areas are proposed to drain into Grand Niaye by pumping with small retention ponds. (see *Figure* 9.4).

2) Thiaroye Sur Mer

The low areas along the national road in Thiaroye Sur Mer are frequently flooded. Some areas are lower than mean sea level and they can be used for retention ponds. This area is proposed to drain into the sea by gravity with small open channel or by a pumping station with retention ponds mentioned above. An open channel along the north side of the national road is proposed to collect the stormwater (see *Figure* 9.4).

9.2.7 Eastern Pikine Area (A-7)

Drainage of this area is proposed to be by infiltration and to be by discharging into the low areas of Lacs, Niayes, Marigot de Mbaw and other depressed areas. Narrow coastal area will be drained to the sea through the creeks around Mbaw. An open channel is proposed along the north side of national road to collect the stormwater.

Flood affected area in Nimzat will be drained to Tiourour by the proposed drains(see *Figure* 9.4). The planned Malika development shall have stormwater retention areas in the existing Niayes. Lac Mbeubeusse shall have some spaces for stormwater retention without reclamation by solid waste.

9.3 FACILITY PLAN

Stormwater drainage facilities to be provided in the master plan stage are drainage channels, pumping stations and infiltration/retention ponds.

Each facility is determined by the following method. The proposed facilities are listed in *Table* 9.1.

- Drainage channel

Size of channel is determined by design peak discharge. Typical cross sections of channels are shown in *Figure* 9.5 to 9.7.

- Pumping Stations

Each pumping station shall have a pond for favorable operation and for saving cost of the pump. The storm run-off of 24 hours with 10 years return period is proposed to drain within 24 hours and within the capacity of pond. Typical plan and section of the proposed pumping stations are shown in *Figure* 9.8.

Transmission pipes associated with the pumping stations are designed to have enough capacity to carry the pumped discharge following the existing land profile.

- Infiltration / Retention Ponds

Capacity of these ponds are calculated to have an effective water volume to store stormwater of 24 hours with 10 years return period. The ponds are proposed to be evacuated by evaporation and by infiltration before next rainy season.

- On-site Infiltration

Infiltration of stormwater is the most effective and desirable non-structural drainage method that supports the structural ones. Infiltration is applicable to drain water from roof, garden, road surface and other surfaces which are not polluted so much. It is applicable to sandy areas having ground elevation of higher than 4 m.

Examples of the infiltration methods are shown in *Figure* 9.9.

9.4 PROJECT COST

9.4.1 Basis of Cost Estimates

The project cost consists of the following components:

- Direct construction cost
- Land acquisition and compensation cost
- Government administration cost
- Engineering service cost
- Physical contingency

The project cost is estimated based on the following assumptions:

The construction cost, land acquisition/compensation costs are estimated based on unit price and cost for each work item prepared by the Ministry of Hydraulics, SONEES and other agencies concerned. The unit price/cost for work items are shown in *Table* 9.2.

The Government administration expenses are estimated at 1.5% of total of construction and land acquisition/compensation costs, to cover the cost of supervision and management of the Project.

The cost of engineering services is estimated at 7% of the construction cost.

The physical contingency is provided to cope with the unforeseen conditions, such as change in site condition, etc. and is assumed to be 10% of total of construction cost, land acquisition cost, compensation cost, engineering service cost and government administration cost.

9.4.2 Local and Foreign Components

The costs are divided into a foreign currency portion and a local currency portion with referring to similar project, as follows:

Item	F.C. (%)	L.C. (%)
Concrete Lining Open Channel	15	85
Earth Channel	15	85
Box Culvert	60	40
Storm Sewer	85	15
Storm Water Pumping Station	75	25
Storm Water Transmission Pipe	85	15
Infiltration/Retention Pond	15	85
Secondary Drain	50	50
Engineering Service	70	30
Others	0	100

Note : F.C. : Foreign Currency
L.C. : Local Currency

9.4.3 Project Cost

The project cost is estimated at FCFA 24,143 million in total at 1994 price. Detailed work volume and breakdown of the cost are given in *Tables* 9.3, 9.4 and 9.5.

9.5 IMPLEMENTATION PROGRAM

9.5.1 Priority of Sub-Projects

1) General

The proposed program of stormwater drainage improvement in the study area consists of sub-projects in the areas of Dakar IV-3, Ouakam Basin, Grand Yoff, Dakar-Yoff Airport, Yoff Channel, Central Pikine and Lac 1 catchment areas.

Priority of sub-projects is proposed taking the following factors into account.

- Present severeness of flooding
- Anticipated flood problems in future due to urbanization
- Required cost of drainage and efficiency of the sub-project
- Difficulty of solution if the sub-project is not conducted
- Progress of the sub-project such as study, design, etc.

2) Project Priority

Judging from the factors mentioned above, priority of sub-projects is proposed as summarized below.

a) 1st Priority

The first priority is given to the densely populated areas with severe flooding.

a. Grand Yoff : already developed, flood depth is large with long duration, drainage is under planning

b. Central Pikine : already developed, flood depth is large with long duration, a drainage channel has been constructed in Thiaroye Sur Mer, drainage by the pumping was proposed in the Strategy Plan.

b) 2nd Priority

The second priority is given to the developing areas where flooding is not so severe.

a. Dakar-Yoff Airport	:	drainage improvement plan of Ouakam town has been completed and will be implemented, flood depth is large with long duration in Ngor and would be affected by the drainage improvement of the upstream area (Ouakam town).
b. Lac 1 (Tiourour)	:	flooding is a constraint for development

c) 3rd Priority

The third priority is given to the areas planned to be developed and anticipated that the flood problem will occur.

a. Ouakam Basin	:	urbanization is planned and there is a flood prone area with long flood duration.
b. IV-3 Channel and Ouakam South	:	planned to be urbanized
c. Yoff Channel	:	northern part of the highway has been developed

9.5.2 Implementation Schedule

Implementation schedule of the sub-projects is proposed for smooth development in the study area depending on urbanization of each sub-area. Therefore, flood prone areas in the existing urban areas require an urgent drainage improvement. Some partial works of a sub-project will be conducted depending on cost and efficiency.

Implementation schedule of the project until the year 2010 is proposed as shown in *Figure* 9.10 and cost disbursement schedule is shown in *Table* 9.6. Implementation schedule is decided based on the following ideas.

- Since construction of pumping stations is the most effective work to solve the problem for the 1st priority areas, it should be implemented urgently.

- Implementation program of the works for the 2nd priority areas is prepared considering existing and future urbanization.

- The works for the 3rd priority areas are proposed to be completed by the year 2010.

9.6 ORGANIZATION AND MANAGEMENT

Presently the Ministry of Hydraulics is responsible for the planning and execution of urban drainage projects and SONEES and CUD are responsible for operation and maintenance of drainage facilities. SONEES is in charge of covered channels and pumping stations of the drainage facilities while CUD is in charge of only open channels.

It would be reasonable that the Ministry takes responsibility for the drainage projects because of more public nature of the system. Also allocation of responsibilities of the operation and maintenance between SONEES and CUD may be justified by their own experiences. Therefore, it is possible to accept the current organization and management scheme as the ones for execution and operation/maintenance of the proposed master plan projects, provided that personnel strengthening of each organization will be done to provide for expansion of the system. SONEES is now under consideration to be privatized. While it is not decided yet that either the department presently responsible for the sewerage system in SONEES will remain in the privatized SONEES or it will be transferred to a organization to be newly established, the operation of drainage system (excluding open channel) should be included in its responsibility.

9.7 PROJECT EVALUATION

9.7.1 General

The proposed urban drainage Master Plan covers the entire study area either by structural measures or by non-structural measures. Under this plan, all the areas flooded by the 1989 August flood, will be protected from inundation against the same level of rainfall.

The plan has identified developing activities that do not concern topographic conditions as a major cause of the inundation problems. Therefore, non-structural measures, such as to reserve low lands for infiltration in development in the future, are strongly recommended while structural measures are proposed for the areas where urbanization has already occurred.

Negative impacts of the project are expected to occur during construction of the proposed facilities. However, these are expected to be small because the facilities are small in scale.

9.7.2 Environmental Evaluation

Possible environmental impacts by the proposed project are evaluated in their construction and operation stages. The environmental impacts by the projects are judged to be minor as shown below.

1) Construction phase

Minor or moderate negative impacts to noise/vibration and traffic conditions would be unavoidable in the vicinity of the construction sites. However, these impacts will be limited within short period and small area. Construction of infiltration/retention ponds and pumping stations may require changes in landuse of those areas. This impact can be minimized by selecting sites at low-lying areas where their land use value is relatively low.

2) Operation phase

There would be negative impacts to noise conditions by operation of pumping station. However, frequency of pump operation is very low because the pumps are to be operated only during rain that exceeds a certain limit.

9.7.3 Economic Evaluation

Economic evaluation is conducted by calculating the economic internal rate of return (EIRR) based on economic costs and economic benefits of the project.

The estimated project costs is 24,143 million FCFA, being composed of foreign component of 10,270 million FCFA and local component of 13,873 million FCFA. Local component is converted to economic cost by multiplying Standard Conversion Factor (SCF: 0.898) while the foreign component is 100 % economic cost. Thus, the economic cost of initial investment is estimated at 22,729 million FCFA. This amount is distributed year-wise according to the implementation schedule. Annual OM costs are also converted to economic cost using the above SCF.

The economic benefits are estimated from direct flood damages and conversion factor (SCF). The flood damage was estimated from results of analysis on the flood survey conducted in this study.

As a result, EIRR of 8.7 % is obtained. While this value is by 1.3 points lower than OCC of 10 %, the project is judged to be economically feasible because of following reasons:

- It is not necessary to stick on the OCC too much, because the drainage project is a public project.

- Only direct flood damage has been counted in this analysis. Therefore, if indirect flood damage is added to the benefits, EIRR would exceed 10 %.

9.8 RECOMMENDATION

- The existing drainage channels in Dakar urban area shall be maintained as proposed in the strategy plan.

- Stormwater should be infiltrated into the ground at each house lot, factory, etc. for groundwater recharge and to reduce the surface run-off.

- The low areas of Grand Niaye should not be urbanized as they serve as receiving bodies of stormwater.

- The depressed areas in Yoff-Guediawaye Coastal Area, Central Pikine and Eastern Pikine should be kept for retention/infiltration of stormwater. The minimum required area is estimated to be 1 ha for drainage area of 1 km^2.

- The low areas in Central Pikine and Eastern Pikine such as Lacs, Niayes, etc. where stormwater is concentrated, should not be urbanized. Some parts of Lac Mbeubeussé should not be reclaimed by garbage for drainage of the adjacent towns.

- The economic internal rate of return (EIRR) of the project turns out to be 8.7%. When other qualitative benefits are taken into account, it is clear that the EIRR will surpass 10%, that is, the estimated opportunity cost of capital. What it all means is that the project is highly beneficial to the economy of Senegal. It is recommended, therefore, the government realize the project as soon as possible.

- The status/power of SONEES vis-a-vis the Government in connection with the urban drainage sector should remain the same as present because of public nature of the urban drainage project.

- The state will continue to plan, finance and execute the urban drainage project. The operation & maintenance (O & M) of the facilities will be done by new organization to be established in near future. However, the O & M cost will be borne by the state.

9.9 SELECTION OF PRIORITY PROJECT FOR FEASIBILITY STUDY

The proposed drainage Master Plan identifies two areas, namely Grand-Yoff and Central Pikine, as the 1st priority areas. Both areas require earlier implementation of the projects because they have been urbanized and flood damage is very severe. There is no decisive factor to select one from the above two areas. However, it was confirmed during the study that the feasibility study conducted by the Government for Grand-Yoff area has shown similar idea and there was an indication of commitment by a foreign agency to finance the project for Grand-Yoff. Therefore, the project for Central Pikine is determined as the priority project for the drainage project. Project components will be as follows:

- Construction of pumping stations with a retention pond at each station
- Construction of C.P.1 drainage channels
- Construction of C.P.2 drainage channels
- Construction of retention ponds