2.11.2 Present Conditions in the Four Districts

(1) Ma'alla District

Ma'alla district spreads east to west along the Inner Habor coast line. An area north of the Ma'alla Main Road facing the harbor is occupied by port facilities. Areas south of the Main Road are residential and commercial areas except for an oil tank area in the west.

There are four pumping stations in operation in the district. Three pumping stations have centrifugal pumps and the other have ejectors. All sewage in the district are collected at the Hedjuff Main Pumping Station and then disposed of to the sea by an ocean outfall. The pump well in the pumping station is an open structure and hence structural damage by hydrogen sulfide gas is not so obvious. However, an inlet pipe (400 mm dia.) was broken and comminuters went out of order by hydrogen sulfide gas attack in the past. Structures of the ejector pumping station are also similarly damaged. Supply of spare parts for mechanical equipment, particularly for the ejector is difficult to obtain because models are obsolete.

Diameters of sewer pipes in the district vary 150 to 600 mm, and they are made of CIP, VCP, CP and ACP. Total length of sewer pipes is approximately 20 km, with approximately 450 rectangular type manholes. Trunk sewers (mostly 380 mm dia.) running under the paved parking areas between the main Road and buildings are deep with covering depth of more than 4 m. Most of the branch and lateral sewers are small in diameters (150 to 225 mm) and shallow (minimum covering depths are 50 to 60 cm).

There are relatively high elevation areas in the western part of the district. A sewer line from Alsaphi and Alzaton areas discharges into the outlet well at the Hedjuff Pumping Station and flows directly to the sea without being pumped.

The ocean outfall from Hedjuff Pumping Station is ACP, and is 460 mm in diameter and 300 m in length. These pipes are supported by concrete beds. At present, sewage leaks half way down of the line because of the clogging in top end. Sea water around the leak is heavily polluted and bubbles of methane gas and smell of gases are obvious.

Hydrogen sulfide gas generation is so serious in some localized areas in the district. Death of two workers who do pipe cleaning and fell down and fainted have been reported. Attempts were made to measure the concentration of hydrogen sulfide gas in these manholes but it resulted in failure as the concentration exceeded the limit of testing device of 200 ppm. High concentration of hydrogen sulfide gas was caused mainly by septicity of sewage produced in upstream septic tanks. Subsidence of a manhole and paved road caused by corrosion of slabs have been reported.

There are three separate sewer lines for stormwater run-off. These pipes cross the Main Road to discharge stormwater run-off collected upstream and downstream of the Main Road. Of the three pipe lines, one line is at present clogged and not in use.

Two sections of the proposed force main route, one between Ma'alla and Tawahi, another near Dakka in the eastern part of the district, skirt along the edges of steep mountain. Excavation of rock might be necessary for installation of force mains.

In the district, around 50 sweepers passages still remain. Total length of these open channels are approximately 2,500 m. Septic tanks are provided at the end of the sweeper passages on the road side. Around 280 households are connected to sweeper passages and served by bucket system for their night soil collection.

In addition to the sweeper passages, there are two unsewered areas in Ma'alla named Alshuly and Alhabil both of which are located on the hillside south of the Aden Ring Road. Approximate number of households and residents in Alshuly area are 100 and 450, and those in Alhabil area are 287 and 1,077 respectively. Sewage in these areas is disposed of by soak pits and buket systems remain for night soil collection.

The existing sewerage system in Ma'alla is illustrated in Figure 2.12.

(2) Tawahi District

Tawahi district is surrounded by steep hills, and flat lands facing the sea are generally narrow. Large areas in the south of the district are occupied by military and ministries, and hence residential areas are limited. The district is divided into small catchment areas which have individual ocean outfalls. Because of the nature of the catchment areas, sewage collected in the district is swiftly disposed of to the sea. Therefore, corrosion of structure and equipment caused by hydrogen sulfide gas is not so serious as in the other districts.

There are seven pumping stations in operation at present. These are small in capacity. Of the seven pumping stations, six are located in the military and ministry areas. Four pumping stations are equipped with centrifugal pumps, while the remaining three are equipped with ejectors. Structures and pump units have deteriorated and a pumping station is operated by a temporary potable pump. Rehabilitation of these pumping stations is urgently needed.

Most of the sewer pipes in the district were installed in 1963. These pipes are 150 to 225 mm in diameter and materials are CIP, VCP and ACP. Total length of the sewers except for those in the military and ministry areas is approximately 7 km. They are generally installed at shallow depth, with covering depths of 50 to 60 cm. About 300 rectangular type manholes are provided in the sewer network.

A sample of an old force main pipe where a section had been reduced to one fourth of the original section was collected from Tawahi. Damaged DCIP and ACP by hydrogen sulfide gas were also replaced in the past.

There are five ocean outfalls discharing sewage to the sea. In addition to these, there is one outfall in the military area which has completely broken. Sewage from the force main streams down the cliffs. About 80 sweeper passages still remain in the district. Septic tanks are provided at the end of passages on road side. Total length of the sweeper passages is approximately 2,400 m. Bucket system for the night soil collection serves about 250 households.

The existing sewerage system in Tawahi is illustrated in Figure 2.13.

(3) Crater District

Crater district has a very favorable topograpic location for a sewerage system. The district is located on an old crater, and most of the areas in the district have gentle slopes which meet at one point. New sewer lines were constructed in 1963 and the old sewer pipes were connected to new lines. These old and new sewer pipes are well maintained and generally in good condition.

There was one ocean outfall in the Front Bay area which discharged sewage to the Front Bay. This ocean outfall is not used at present and sewage is pumped to the Main Pumping Station. All sewage produced in Crater district flow into the Main Pumping Station and then sent through a long ocean outfall for the final disposal to the sea. A long force main pipe made of CIP running along rocky seashore in Holkat Bay discharges sewage off the shore. External surface of the pipes are corroded significantly by winds from the sea.

There are two pumping stations in the district, one in the Front Bay area and the Main Pumping Station. Crater Main Pumping Station is the largest one in Aden. Both pumping stations have deteriorated and need to be rehabilitated. Cracks and peeling-off of the concrete caused by corrosion of steel bars are observed in the pump well of the Main Pumping Station. The structure of the other pumping station is damaged by winds from the sea.

Sewer pipes installed in 1963 are 100 mm to 750 mm in diameter and made of ACP. Total length of sewer pipes is approximately 7 km. A total of 88 rectangular type manholes are provided in the sewer network.

All the sweeper passages in the districts have been improved and there are no open channel collection system.

The existing sewerage system in Crater is illustrated in Figure 2.14.

(4) Khormaksar District

Khormaksar district is the most recently developed among the four districts. A huge area north of the district is occupied by the Aden international airport. There are large military and ministry areas in the district. The district is bounded on the west by Tawahi Bay and on the east by Gulf of Aden. Topography of the district is flat and low-lying.

The district is divided into small sewerage areas each having a small pumping station. Sewage collected by the pumping stations are pumped to the next pumping station and finally transferred to the comminuter station. A total of 20 pumping stations and force mains connecting them form an interlacing network. All of the pumping stations are small in size.

Sewage pumped to the comminuter station flow down to the ocean outfall and are discharged into the sea. This comminuter station was once sealed up to prevent odor nuisance to nearby residents. However, this counter measure worsened corrosion of the structures since hydrogen sulfide gas was confined in the station. Steel bars are exposed and rotting on the ceiling and walls.

Mechanical equipment and structures of the pumping stations have deteriorated badly. Temporary potable pumps have been brought into some pumping stations to replace broken down pumps. Corroded structures have also been replaced by timber.

Sewer pipes are 100 mm to 400 mm in diameter, and made of ACP. Total length excluding those in the military areas is approximately 18 km. A total of 164 rectangular manholes are installed in the network. Because of the flat nature of the district and pump and force main system, and the consequent septicity of the sewage, ACP pipes have been subjected to hydrogen sulfide gas attack for a long time. Subsidence of roads caused by broken pipes are reported at many locations, and repair work has been carried out by the Aden Municipality.

There are no sweeper passages in the district.

The existing sewerage system in Khormaksar is illustrated in Figure 2.15.

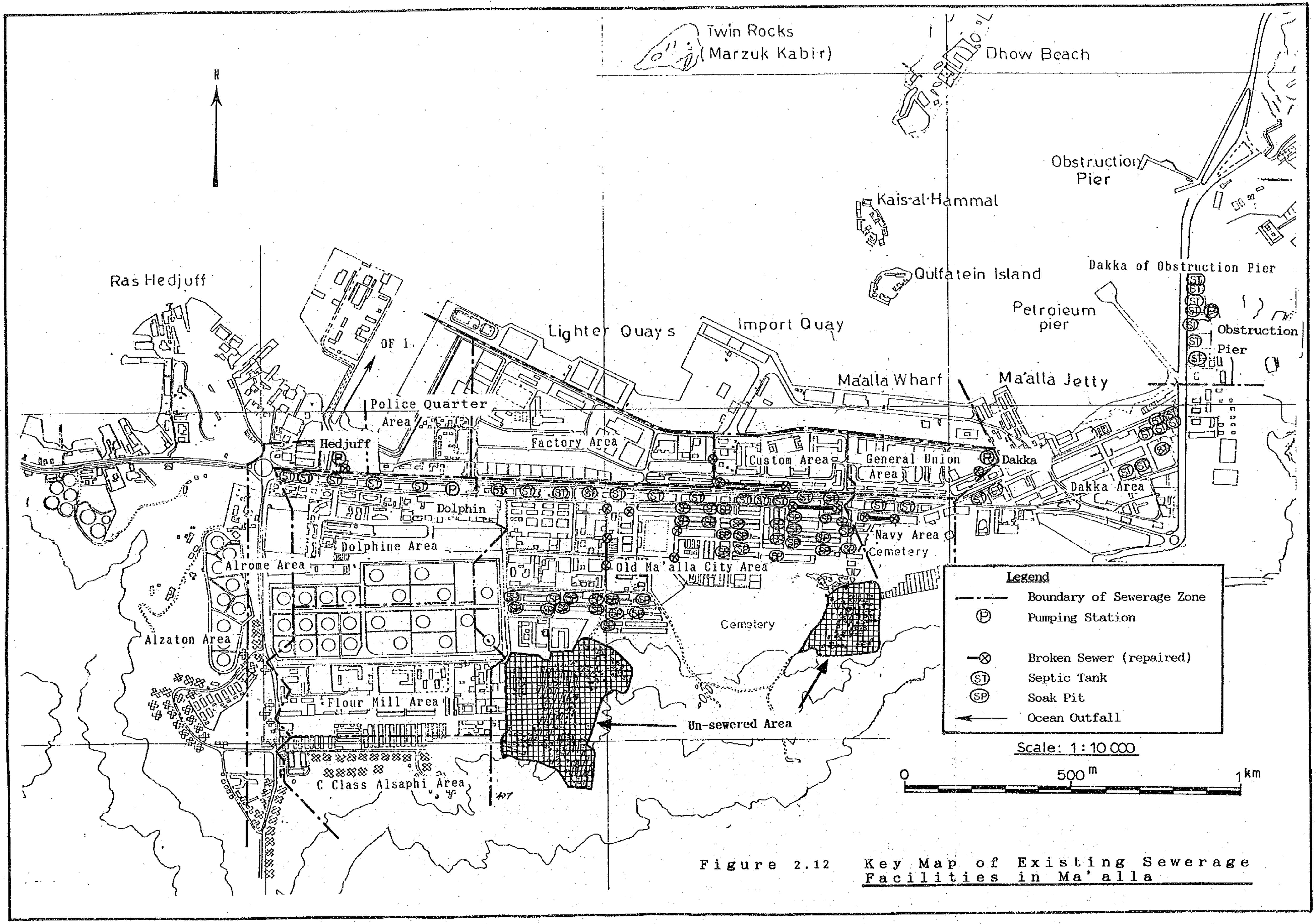


Figure 2.12 Key Map of Existing Sewerage Facilities in Ma'alla

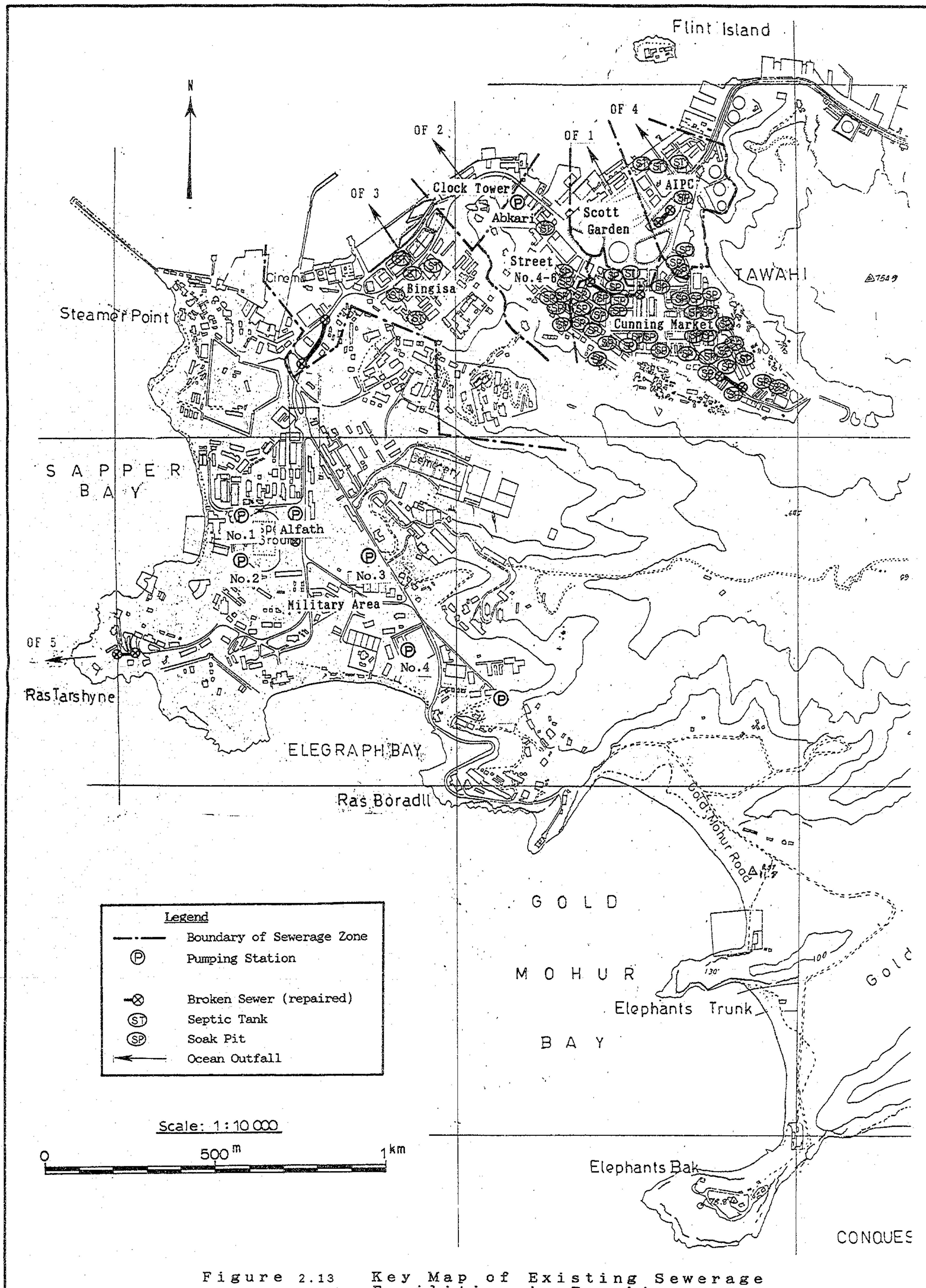


Figure 2.13 Key Map of Existing Sewerage Facilities in Tawahi

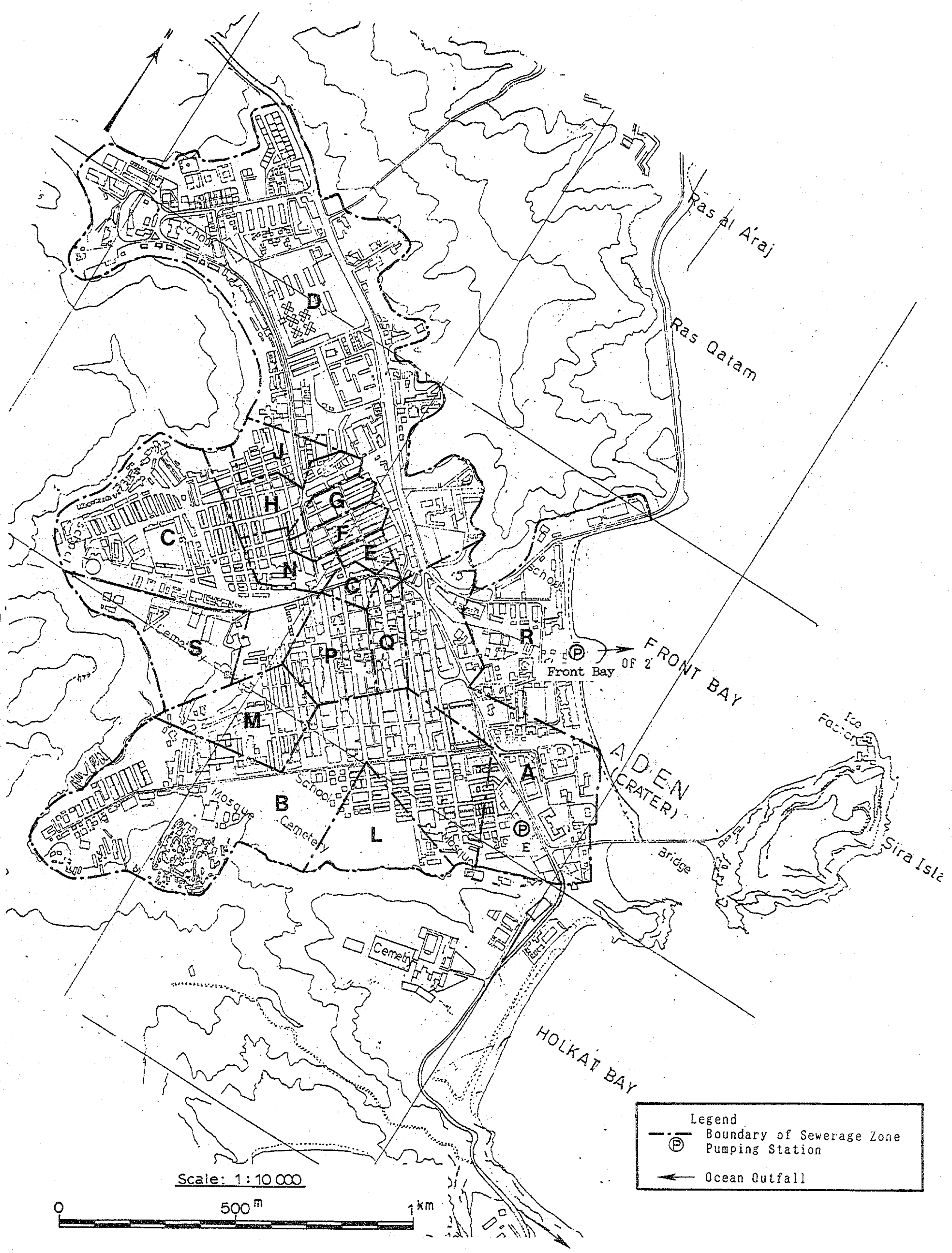


Figure 2.14 Key Map of Existing Sewerage Facilities in Crater

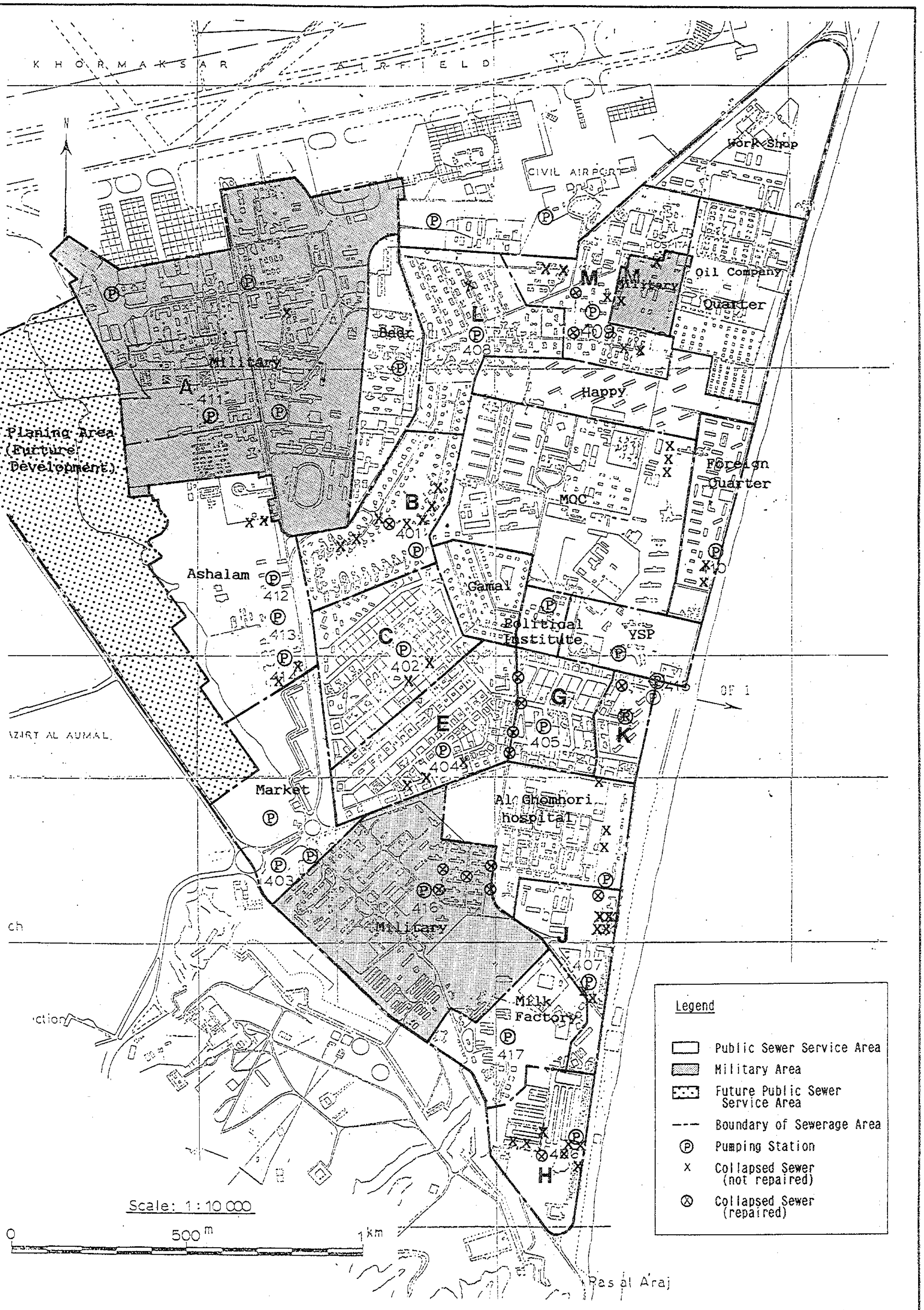


Figure 2.15 Key Map of Existing Sewerage Facilities in Khormaksar

2.12 Environmental Issues

Until quite recently, environmental protection has not been an important issue to the Government of PDRY. The main reasons for this can be attributed to the fact that most of the land had been sparsely populated and industrialization is an infant stage and limited to locality, and therefore, environmental pollution has not been a serious problem in PDRY. However, as population has continued to increase and industrial development has taken place, the government of PDRY and inhabitants in urban area as well, particularly in Aden, have become aware of the adverse effects of development.

Under the circumstances, the first step taken by the Government was the establishment of the National Environmental Council (NEC) in 1976 under the Law No. 13. This Law, however, has never been enforced and replaced by Law No.8 of 1984. Under the new Law No.8, the National Council of Environmental Protection (NCEP) was established. The main functions and competence of NCEP are set out in Articles 6 and 7 of that Law, respectively.

1) Functions (Article 6)

a. to study causes and environmental elements surrounding man and animal which may cause harm to them.

b. to protect land, water and air from any activity which may cause direct or indirect pollution.

c. to ensure observance of laws and regulations concerning environmental protection, etc.

d. to ensure safety in the preparation of poisonous materials, the importation of noxious materials which may cause harm, the sale, transport, use and disposal of them in accordance with laws and regulations relevant to the environmental health and the approval of concerned bodies.

2) Competence (Article 7)

a. to prepare legislation for the protection of the environment in coordination with various concerned bodies.

b. to seek advice from experts and specialists

c. to direct the activities of concerned bodies towards protection of the environment.

d. to issue orders to anybody to suspend, reduce or minimize a specific activity for the benefit of the environment.

The NCEP in principle is only a policy- and decision-maker in the field of the environmental and thereby can not ensure observance of laws and regulations concerning the protection of the environment. In 1984/85, it had been suggested that a new department attached to the Ministry of Public Health be established. However, this suggestion has not been realized until now.

In February 1989, the national seminar on "Environment and Sustainable Development" was jointly convened by the government of PDRY, represented by the Ministry of Public Health, and UNDP in Aden. The seminar was attended by senior members of YSP organs, members of the cabinet, representatives of UNDP, UNEP and other relevant UN organizations. The agenda of the seminar covered various environmental issues comprehensively. The seminar made the declaration and, in its framework, recommendations for institutional arrangement, strategy and policies, legislations, research and studies, short term action plan, environmental awareness, education and training etc.

The seminar was an epoch-making event which, as is stated in the report, "is a true expression of the high concern of the government of PDRY attaches to the environment, and her keen attitude regarding resource development and her spontaneous response to translate that into useful action that serves the issue of environment and sustainable development" (Ref. No.17).

The NCEP has been reactivated. The new environmental law has been drafted and distributed recently to all the ministries concerned for their review. The office of the NCEP secretariat opened in August 1989 with full time staff assigned from the ministries concerned.

There is no law nor regulation which stipulates environmental quality standards in a quantitative manner regarding air, water, soil or any components of the environment at present in PDRY. Water quality standards for specific wastewaters, such as effluent from sewage treatment plant and industrial wastewater, have yet to be regulated.

The laws and regulations in connection with the environmental protection are expected to be legislated or amended in accordance with the recommendations made by the seminar. In this respect, water quality standards both for natural water bodies and for wastewaters are to be regulated. In addition, the role of the sewerage system in connection with environmental protection, reduction of pollutants which will otherwise cause water pollution and production of useful water resource for greenery projects, are to be clearly defined in the amended laws and regulations.

2.13 Green Belt Project

An integrated green belt and agriculture project by utilizing treated sewage from the sewage treatment plant has been planned and implemented in Aden. This project involves the phased development of a combined green belt of a 25 km long, 250-300 m wide and agricultural land for crop cultivation and fodder grazing for up to 60,000 heads of livestock. The green belt will have three parallel lines of trees, 5-10 m in width with agricultural and grazing areas in between.

Objectives and benefits of the project are as follows (Ref.17).

- use of the sewage effluent as a fertilizer which would otherwise be released in Aden harbor, i.e. prevention of further pollution.

- an early and effective contribution to the provision of new agricultural land for crops and grazing

- provision of a windbreak and environmental screening to the recently completed sewage treatment plant

- lessening of air-borne dust pollution around Aden, especially in the period of monsoon winds, i.e. improvement in health

- provision of amenity and recreation areas

- creation of new natural environment for flora and fauna

- supply of wood and animal fodder

- provision for demonstration of integrated development applicable in other areas

- making the sewage treatment plant lie within an environmental control zone

The green belt project is to be implemented in two stages, the first stage from 1988 to 1994 and the second from 1995 onward. The first stage is further phased into three phases. The project areas under each stage and phase are as follows and shown in Figure 2.16.

Stage 1	Phase 1 (1988 - 1989)	West and north to the Al Shaab STP, 180 ha
	Phase 2 (1990 - 1991)	From Little Aden to north to STP, 300 ha
	Phase 3 (1992 - 1994)	From north to STP to Abyan Road, 300ha
Stage 2	(1995 -)	Inside the urban areas, e.g. around industrial areas, power station and houses. Details yet to be decided.

Experimental work to investigate appropriate irrigation methods and kinds of trees have been carried out by Aden Municipality since 1986 when Al Shaab STP started operation. Currently, phase 1 of the project is under way. A total of 12,000 trees have been planted up to now. Because of the proximity of the project site to the treatment plant, effluent is pumped from the discharging channel to the open irrigation channel.

Although the project was already started, there remains many problems for the successful implementation of the project, such as financial and technical problems. The project cost over the next five years has been estimated to be approximately US$ 3 million, but no financial sources are available at present. Accumulation of the data and information bases for planning and design is insufficient.

Considering the benefits that can be derived from the project, these problems should be resolved as soon as possible. Indeed, the Aden Municipality is exerting itself with cooperation from the local and international authorities concerned to continue the project. Further coordination should be sought to integrate the Ma'alla and Tawahi sewerage project to the green belt project.

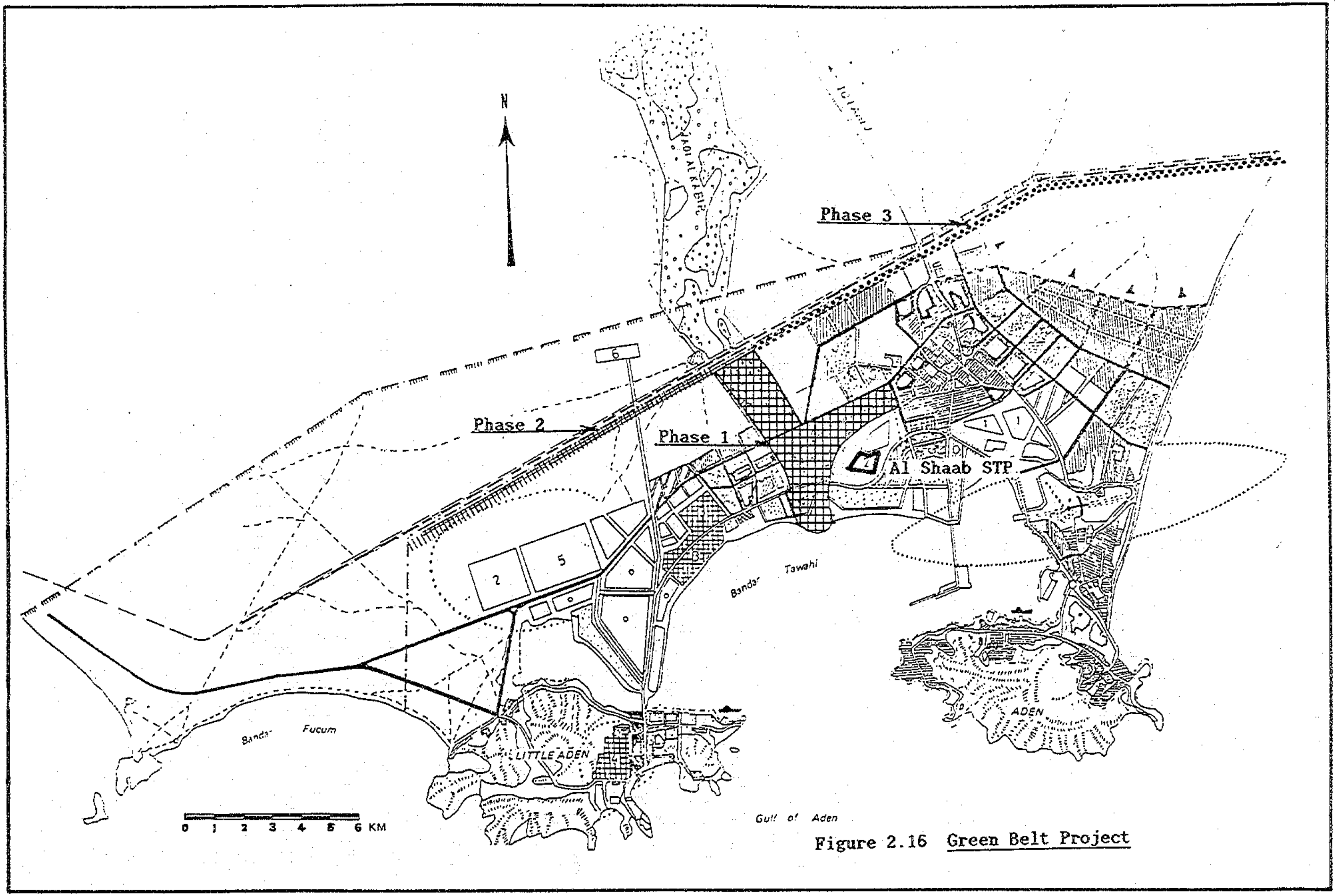


Figure 2.16 Green Belt Project

2.14 Other Public Services

2.14.1 Roads

All the roads in Greater Aden are under the responsibility of Highway Authority, Ministry of Construction. Construction and maintenance of roads is carried out by the Authority. On the other hand, Environmental Health Department of the Aden Municipality is responsible for cleaning of all roads within the Municipality.

Urban centers in Greater Aden which are rather isolated are linked by a road network. Roads may be classified by their importance into two categories, viz. main roads and lateral roads. Main roads are those linking urban centers such as Ma'alla, Tawahi, Crater, and Khormaksar, and further linking Greater Aden with other governorates. Lateral roads are a subsystem of the main roads serving local traffic.

There are several main roads in the study area. From west to east, a main road from Tawahi passes through Ma'alla and reach Ma'alla roundabout at the east end of Ma'alla. From the roundabout, one main road goes to Crater, crossing over a steep pass. Another main road from the roundabout runs along the coast to reach Khormaksar roundabout in front of Aden Hotel. This route further connects to the causeway going northward to Al Mansura.

The Abyan road starts from Crater running northward along the eastern coast of Crater and Khormaksar and further up to the Abyan governorate. There are two short sections of the main roads in Khormaksar which connect to the causeway and the Abyan road. A new main road, called Ring road is expected to open shortly from Ma'alla roundabout to Gold Mohr beach.

Main roads are classified into two types by structure, viz. dual carriageway and single carriageway. Dual carriageway type has center zones which separates the two carriageways. Both types of roads are usually provided with sidewalks on both sides.

Lateral roads are also classified into two types, viz. two-lane and four lane. In addition to major lateral roads, there are a number of small roads, with varying widths, which makes up the road network.

All the main roads and most of the lateral roads in the study area are paved. There are various kinds of pipes and cables under the roads, such as water supply pipes, sewers, oil pipes, electric cables and telephone cables. These are buried mainly under the sidewalks of the roads, but some of are them under the carriageway. Use of the carriageway of the main roads for pipe laying is, in general, prohibited by the Highway Authority.

2.14.2 Electricity Supply

The electricity supply in Greater Aden is the responsibility of Public Corporation of Electric Power (PCEP), under the Ministry of Energy and Minerals. PCEP is also responsible for development and operation of the electric supply projects in Greater Aden as well as in the whole country.

There are three power stations in Greater Aden. Generating capacities of the stations are as follows.

Khormaksar	4 MW X 4 units	Diesel engine
	2 MW X 2 units	Diesel engine
Al Mansura	8 MW X 8 units	Diesel engine
Hiswa	25 MW X 3 units	Steam turbine

At present, expansion of Hiswa Power Station is under way and additional two units of 25 MW generators are to become operational in 1990. The desalination plant is being constructed next to the power station utilizing steam from the station for evaporation of sea water. The first two evaporation batteries have been completed and are now ready for operation. Desalinated water will be blended with groundwater to be used for water supply.

The total capacities of the power stations are sufficient to meet present electric demand in Greater Aden. Extension of the Hiswa Station will meet the increased requirements in the next five years.

PCEP has a high voltage (11 kV) and a medium voltage (415) grid system for electric power supply in Greater Aden. All of the urban areas and their vicinities are supplied with electricity.

Electricity tariff collected from the consumers are classified into five categories. Classification and tariff rate of each category are as follows.

(1) Local Domestic	100 kWh or less	16 Fils/kWh
	more than 100 kWh	27 Fils/kWh
(2) Foreigners		60 Fils/kWh
(3) Commercial		60 Fils/kWh
(4) Agricultural Facilities	8:00 - 14:00	35 Fils/kWh
	14:00 - 17:00	25 Fils/kWh
	17:00 - 23:00	35 Fils/kWh
	23:00 - 8:00	25 Fils/kWh
(5) Temporary Supply		150 Fils/kWh

The electric supply for the sewerage facilities, such as pumping stations and sewage treatment plants, comes under the commercial , while construction work, comes under temporary supply rates.

2.14.3 Solid Wastes Disposal

Collection and disposal of solid wastes is managed by the Cleansing Section, Environmental Department of Aden Municipality. Street cleaning is also managed by the Municipality. However, the Municipality is not responsible for these duties in military and police camps. These are provided with their own facilities for collection and disposal. In addition, disposal of industrial wastes which are deemed to be non-domestic in nature is not the responsibility of the Municipality. Some of the industrial wastes are collected by the Municipality under contracts with factories.

Approximately 200 ton of solid wastes are collected daily at present. However, wastes production in households and other premises is considered more than those collected, since there are some areas where collection service is not available. Moreover, the Municipality suffers continuous shortages in number of laborers and vehicles.

Solid wastes from households and other premises are put into plastic bags and then these bags are put into plastic bins located on the streets. Collection vehicle, mostly compaction vehicles collect wastes from bins to transport them to the disposal sites. Each of the collection gangs is allocated a fixed number of streets or premises to clear.

In low income residential areas on the hillsides, solid wastes collection service is very poor or non-existent. Rubbish is piled up in the vicinity of houses.

There are two solid waste disposal sites in Greater Aden, Dar Saad and Al Mansura. Dar Saad disposal site is designed for sanitary land fill. However, because of shortage of operating machines, this site is not used at present. All the solid wastes collected are dumped and burned at the Al Mansura site causing sometimes nuisance to the nearby inhabitants.

2.15 Need for the Project

At present the four districts in the study area are provided with water borne sewerage systems, most of which were constructed in early 1960s. Sewerage facilities have been well maintained, thanks to the efforts made by the Municipality. However, some of the facilities have deteriorated to a extent which needs urgent rehabilitation and improvement, since no major improvement work have been carried out since then.

Open channel sewage collection systems called "sweeper passage" still remain in various parts of the study area, and this system exposes the inhabitants to public health risk. Night soil collection adopted in a limited number of unsewered areas poses a public health hazard. Sewage and sludge removal from defective sections of network caused by broken pipes or pumps not only compels the residents to suffer inconvenience, but also burdens the Municipality with unnecessary outlay. Improvement of these deficient facilities is of urgent need.

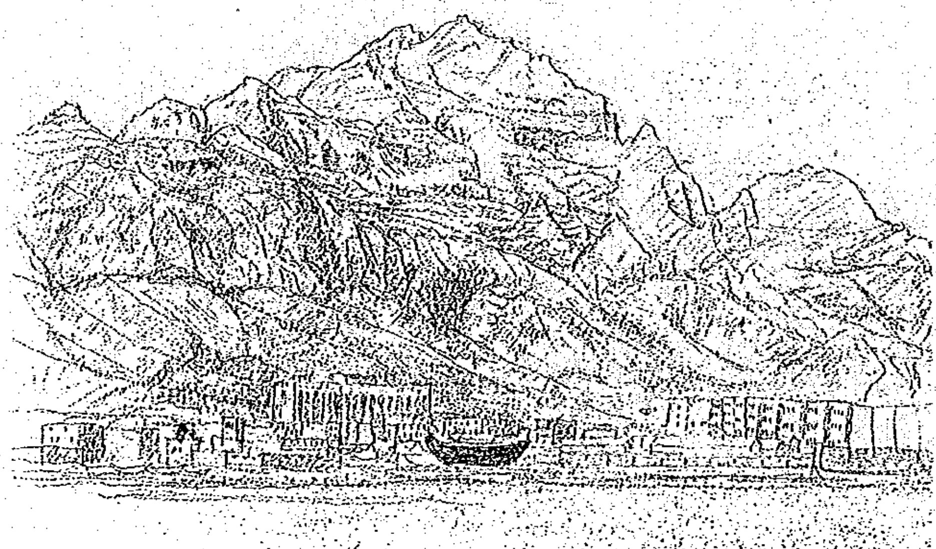
All the sewage collected by sewer networks in the study area are discharged to the sea without any kind of treatment. Disposal of raw sewage into the sea, particularly into the Inner Harbor, causes complaints from many authorities concerned, including YPA and Highway Authority. Although pollution caused by raw sewage disposal is limited to localized areas at present, water pollution will no doubt spread to wider areas with increasing sewage flow in the future. Since the study area is at the center of the national capital, discharge of raw sewage to the water front should cease as soon as possible.

In Aden, development of water resources is in a critical condition because of the scarcity and limitation of available groundwater sources. Use of desalinated sea water is forthcoming, in spite of the very high production cost. If treatment is provided for sewage presently dumped into the sea, treated effluent can be reused for many purposes, e.g. growing greenery in the vicinity of treatment plant. Reuse of treated effluent will greatly contribute to the preservation of limited water resources.

In view of the above, the sewerage system improvement project in the study area is to be initiated immediately. If no action is taken immediately to improve the existing sewerage system, the sanitary condition and the water pollution, which is already quite bad, will become progressively worse.

CHAPTER THREE

PLANNING CONSIDERATIONS



CHAPTER THREE

PLANNING CONSIDERATIONS

3.1 Introduction

This section deals with the planning fundamentals for the sewerage system in the study area. In order to estimate the sewage flow rate and its characteristics, population projection up to the year 2010 was made. Previous population projections made by various studies were reviewed together with the latest census data. Population projection made by DPS 2010 turned out to be the most precise one, as the basis for sewerage planning, since the projection was based on detailed land use. The land use plan developed by DPS 2010 was also utilized for determination of locations of sewerage facilities, particularly selection of the sewage treatment plant site.

To estimate sewage flow rate for the design of the components of the sewerage system, the water supply master plan was reviewed in detail. Future per capita sewage flow was estimated based on the projection of per capita water consumption made by the latest water supply master plan. The water supply master plan projected three different consumptions, viz. high, medium and low consumption, based on various hypotheses regarding population and per capita consumption. For the design of sewerage facilities, high projection was considered to allow for reasonable system allowance.

Population equivalence to be used for the estimation of the sewage flow rate from public organization was calculated from water consumption levels in the water supply master plan for the sake of sewerage planning. Infiltration flow to the sewerage system was estimated for specific areas using the unit flow rate internationally accepted.

Raw sewage characteristics, particularly organic load in term of BOD, were determined taking into account the results of water quality analysis conducted by the study team and recommendations made by WHO.

Alternative plans for possible sanitation systems were evaluated to find out the most appropriate system for the study area. Evaluations cover broad topics, such as on on-site sewage disposal and central sewerage system, and separate system versus combined system.

Finally, in this section, design criteria to be used for the design of the sewerage system is recommended.

3.2 Definition of the Study Area

As defined under the Scope of Work for the study, the study area for the long term program up to 2010 encompasses the four districts in Greater Aden, viz. Ma'alla, Tawahi, Crater and Khormaksar. The study area for the feasibility study was initially limited to Ma'alla and Tawahi districts when the study was commenced, however, Khormaksar district was added later in the course of the study by an amendment to the Scope of Work.

The areas to be served by the sewerage system by 2010 are essentially the same as the urbanized areas envisaged in DPS 2010 prepared by the Town Planning Section of the Ministry of Construction. Land use plan in 2010 is described in the next section. Most of the future urban areas in the study area have already been developed. A sizable area that is presently seashore in Khormaksar, east of the causeway up to the airport is reserved for future residential area and environmental control zone. Future residential area is to be reclaimed and developed at a later stage in the development. This area is included in the planning area. An area within environmental control zone will not be developed by 2010.

In addition to the planning area mentioned above, various outside areas from where sewage flow into the planning area are defined as extra catchment areas. Most of these are military and police camps both inside and outside the planning area. A small village named Al Arish near the airport junction is one of the extra catchment areas. Design of a sewerage system in the extra catchment areas is out of scope of the study. However, sewage flow from these areas are included in the design of sewerage systems in the study area.

The planning area in the four districts totals 1,105 ha, of which 86 ha is undeveloped area in Khormaksar as shown in Table 3.1. Extra catchment areas total 421 ha. The extent of the planning areas in each district, inclusive of extra catchment areas, are shown on Drawing No. 1 in Volume Four.

Table 3.1 Planning Areas for the Study

District	Planning Area (ha) Sewerage System	Future Land Reclamation	Extra Catchment Area: Military or Police Camp	Extra Catchment Area: Others
Ma'alla	279	-	-	-
Tawahi	87	-	119 *1	-
Crater	235	-	-	-
Khormaksar	418	86	181 *2	121 *3
Total	1,019	86	300	121

Note *1: Military camps are located outside the sewerage planning area.
*2: Components of the area are;
Badr Camp 102 ha (inside the sewerage planning area)
Tareq Camp 62 ha (inside the sewerage planning area)
Police Camp 17 ha (outside the sewerage planning area)
*3: Components of the area are;
Isthmus Camp 118 ha (outside the sewerage planning area)
Al Arish Village 3 ha (outside the sewerage planning area)

3.3 Population Projection and Land Use Plan

3.3.1 Nationwide and Greater Aden Population Projection

The latest population census was carried out in 1988 and the population of six governorates were recently published in the Preliminary Report by the Central Statistical Organization. These population figures together with those of the previous census in 1973 are as follows.

Table 3.2 Governorate Population from Census Figures

Governorate	Population 1973		1988		Annual Growth Rate (1973 to 1988, %)
Aden	291,376	(18.3)	418,755	(17.9)	2.4
Lahej	273,611	(17.2)	533,984	(22.8)	4.6
Abyan	311,142	(19.6)	337,706	(14.4)	0.5
Shabwa	161,966	(10.2)	253,836	(10.8)	3.0
Hadramout	491,304	(30.9)	703,151	(29.9)	2.4
Al Mahra	60,876	(3.8)	97,834	(4.2)	3.2
PDRY Total	1,590,275	(100)	2,345,266	(100)	2.6

Note: Figures in parentheses are percentages of population
Source: Preliminary Census Report, CSO

Total population of PDRY in 1988 was 2.35 million. Total population includes those abroad at the time of the investigation. Absent citizens amounted to approximately 0.24 million or 10.2 % of the total population.

During the 15 year period from 1973 to 1988, nationwide population increased by 0.75 million or by an average annual growth rate of 2.6 %. However, population growth in the respective governorates varied significantly. The highest growth rate of 4.6 % was recorded for Lahej governorate, whereas the lowest increase was as low as 0.5 % for Abyan governorate.

In Aden Governorate, the population increase for 15 years was 127,379, or 2.4 % annual growth rate, which is slightly lower than the national average of 2.6 %. Consequently, the percentage of Aden Governorate population to the total population decreased slightly from 18.3 % in 1973 to 17.9 % in 1988. It should be noted that Aden Governorate consists of two different parts, Greater Aden on the main land and Socotora Island. The population in Socotora Island in 1973 was 51,006, but that in 1988 has yet to be published.

The Central Statistical Organization estimated the nationwide and governorate population based on the 1973 census record and a uniform annual growth rate of 2.6 %. This estimation proved to be correct for the total population in PDRY. However, population estimation in the six governorates up to 1987 published in the Statistical Year Book are not found to reflect actual movement of population. Moreover, further breakdown of population estimation by using a flat growth rate into smaller districts might have deviated from real figures.

As projected in the Book, population of PDRY in the year 2000 will be 3.19 million, based on an annual growth rate of 2.6 %. If this growth rate continues for the next 10 years up to 2010, total population will increase to 4.13 million. These are 1.36 and 1.76 times the population in 1988, respectively. Moderately high growth rate of 2.6 % used for the projection can be justified considering the present population composition where the younger age group under 15 years accounts for 43 % of the total population.

Since there is no population projection for Greater Aden based on the 1988 census data at present, projections made for DPS 2010 is referred to and modified. In DPS 2010, future population in Greater Aden up to 2010 was estimated based on the following assumptions.

(1) Population in 1973 by census was 240,370.

(2) Population in 1980, the base year for the scheme was estimated to be 286,123 based on the annual growth rate of 2.6 % from 1973.

(3) From 1980 to 2010, population would increase at a higher growth rate of 3.0 %, since various functions of the national capital would attract migration from other governorates. From this assumption, the population would reach 516,000 and 694,000 in 2000 and 2010 respectively.

(4) After land use plan (Variant IV) had been worked out, population projection was reviewed, and taking into account reasonable population densities in residential areas, modification was made to the population projection. As a result, population in 2010 is finally projected to be 867,000.

The population projections made by DPS 2010 are shown in Table 3.3 and Figure 3.1.

Although the population in Greater Aden in 1988 is yet to be published by CSO, it can be estimated by the two following ways. Firstly, on an assumption that the population in Socotora Island in 1988 accounted for the same percentage to the total population as in 1973, total population in Greater Aden was approximately 346,000. Secondly, on an assumption that population in Greater Aden increased with an annual rate of 2.4 %, which is equal to that for Aden Governorate from 1973 to 1988, the total population is 343,000. From these calculations the population in Greater Aden in 1988 can be estimated to be approximately 345,000.

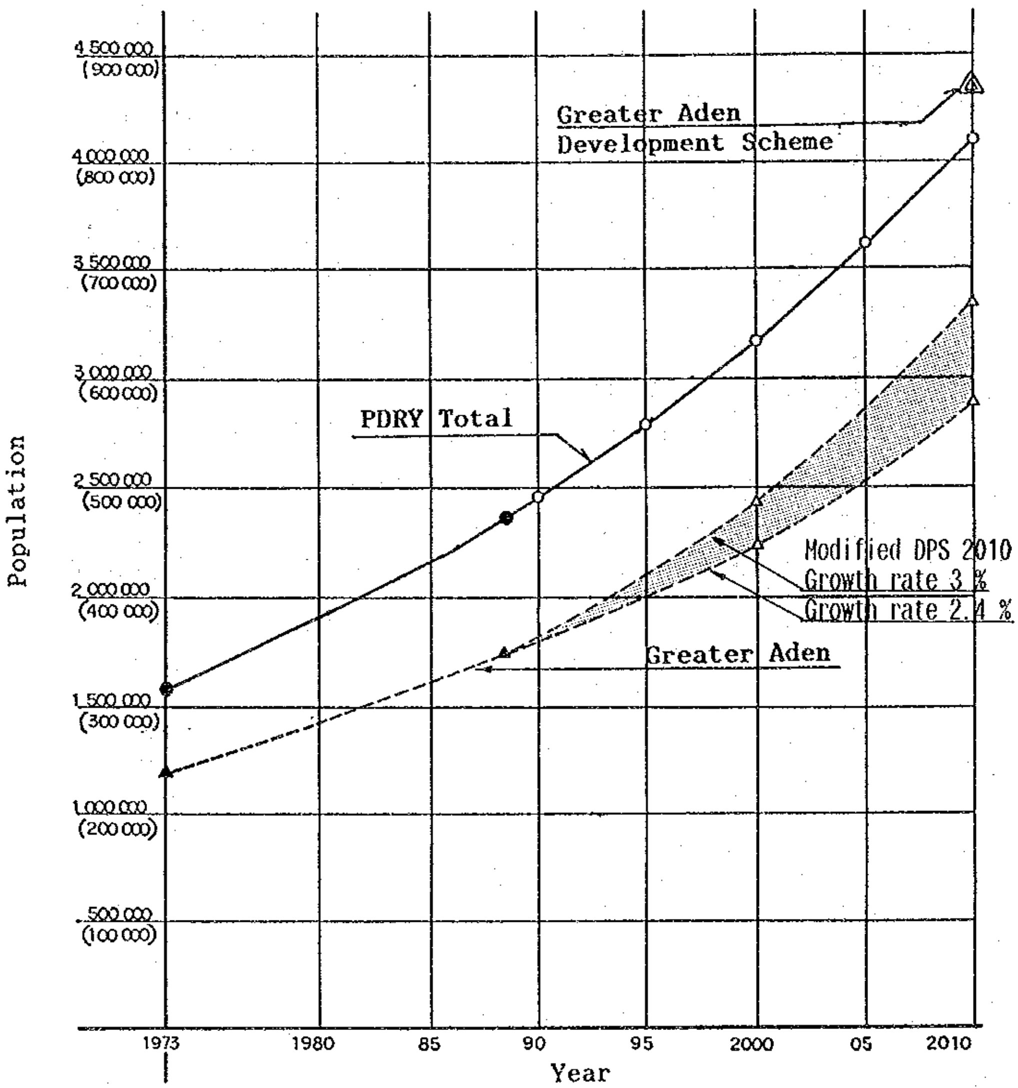
DPS 2010 estimated population in Greater Aden in 1988 to be approximately 362,000, which means that DPS 2010 over-estimated the present population by approximately 17,000. If DPS 2010 population projection was modified according to the present population of 345,000, populations in 2000 and 2010 would be 492,000 and 661,000 respectively with an annual growth rate of 3.0 %. Further, if the annual growth rate is assumed to be at the present level of 2.4 %, it will decrease to 459,000 in 2000 and 581,000 in 2010.

Therefore, the population in Greater Aden is most likely to be around 600,000 in 2010. Thus, the population of 867,000 estimated by DPS 2010 can be considered as the maximum population when the urban areas are fully developed as indicated in DPS 2010, which are shown in Table 3.4 and Figure 3.2 in the next section.

Table 3.3 Population Projection, PDRY and Greater Aden

Year	PDRY	Greater Aden DPS2010	Modified (3.0%)	DPS2010 (2.4%)
1973	1,590,275*1	240,370*1		
1980	1,903,279*2	286,123*2		
1988	2,345,266*1	362,000*3	345,000*4	345,000*4
1990	2,460,000*2	384,000*3	358,000	362,000
1995	2,797,000*2	446,000*3	424,000	407,000
2000	3,180,000*2	516,000*3	492,000	459,000
2005	3,616,000*2	599,000*3	570,000	516,000
2010	4,111,000*2	694,000*3 (867,000)*5	661,000	581,000

Note: *1 Census data
*2 Annual growth rate of 2.6%
*3 Annual growth rate of 3.0%
*4 Estimation by the study team
*5 Final estimation according to Variant IV



Note: Population figures are PDRY total and those in parentheses are for Grater Aden.

Fig. 3. 1 Population Projection up to the Year 2010

3.3.2 Land Use Plan in 2010

The Greater Aden area is divided into four districts for the planning purposes in DPS 2010. The study area comprising the four city districts of Ma'alla, Tawahi, Crater and Khormaksar forms Planning District I. The overall land use plan established as Variant IV by DPS 2010 is shown in Table 3.4 and Figure 3.2.

As shown in Table 3.4 and Figure 3.2, present and future developments are concentrated in Planning District II, which is located in the northeastern and the central parts of Greater Aden, consisting of six new city districts of Sheik Othman, Dar Saad, Al Mansura, Bir Fedel, Al Arish and Caltex.

On the other hand, future expansion of the urban areas is very limited in the study area. This is mainly due to the topographic condition of the study area. Three districts, viz. Ma'alla, Tawahi and Crater, are surrounded by barren and ragged mountains. Steep hillsides around these districts are unlikely to be developed in the foreseeable future for housing, industrial and other usual purposes except for special facilities such as tourism and military.

Khormaksar district lies on flat land, and the airport forms the physical boundary of the district. Although removal of the airport from the present location and construction of new one outside the urbanized area is recommended by DPS 2010, expansion of the Khormaksar district will be physically limited by the airport till the year 2010, most likely many years later than 2010.

Land reclamation has been carried out along the seashore in Ma'alla since the British era in 1950s, and work is still continuing in some parts. Most of the reclaimed land is earmarked as port area to be used for port related activities, such as wharves and warehouses. A sizable area northeast to the causeway in Khormaksar, presently seashore, is reserved for future urban development after land reclamation. Development of the area for housing and a public center is expected by 2010, but at later stage.

The study area has already been urbanized fully until now and future development is limited because of the physical restraints. Therefore, no significant expansion of urban area or change of present land use is envisaged in the study area up to 2010.

Residential and public zones in the study area will increase to 841 ha in 2010 from 755 ha in 1980. Most of the increment is development on presently vacant areas in the urban areas. Land use details in residential and public zones are shown in Table 3.5. A large area of approximately 181 ha is earmarked as city level institutional area in Khormaksar.

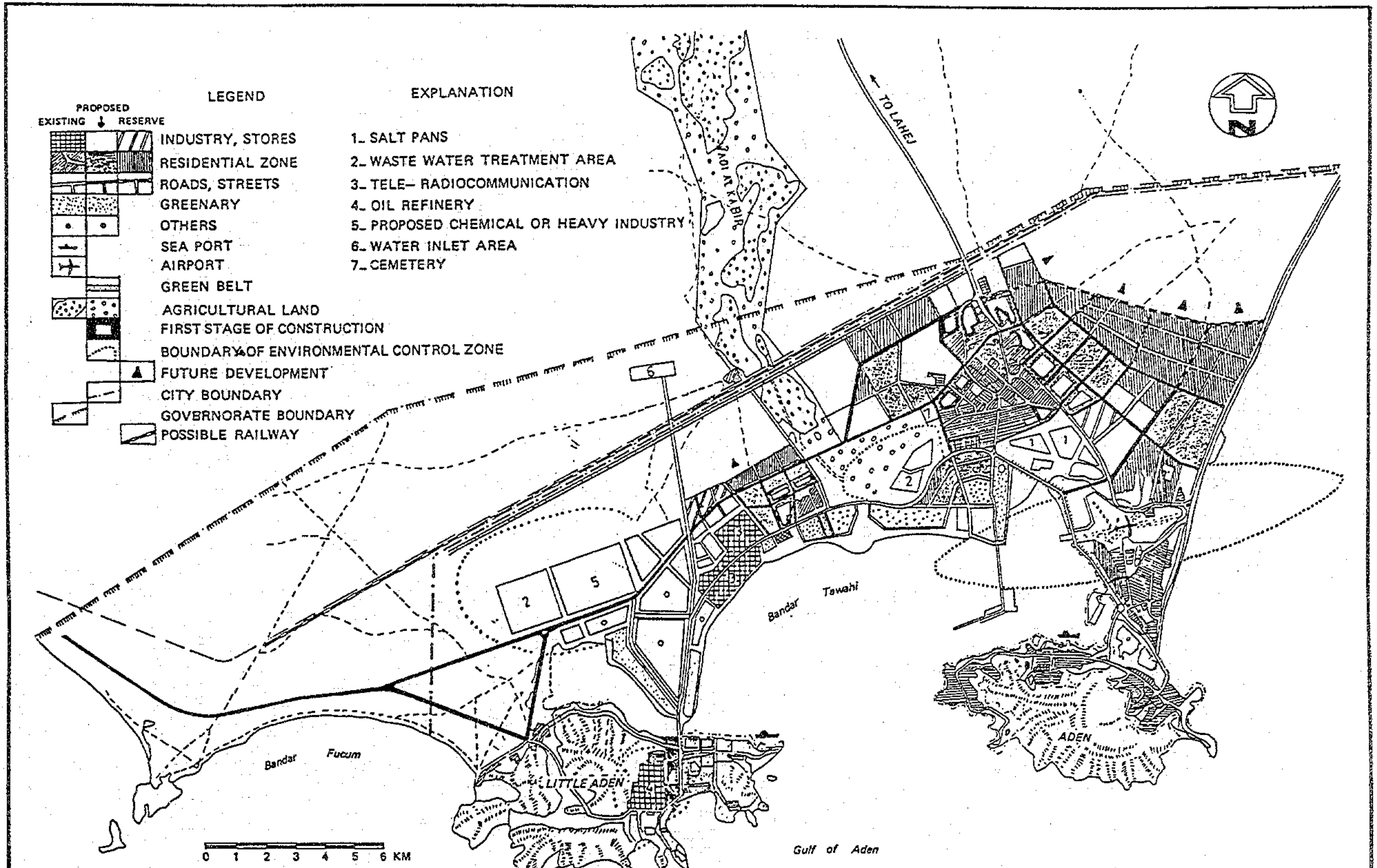
Public institutions at the national and the governorate levels are classified as special zones in DPS 2010. Airport and areas used for port activities are also included in the special zone. Thus, a large area of 656 ha in Khormaksar classified as industrial, stores and special zones category in Table 3.4 is occupied mostly by the airport. The land area in this category in Khormaksar will increase to 1,060 ha in 2010 due mainly to development of a new administrative center at the national or the governorate level.

Table 3.4 Land Use in Greater Aden in 1980, 2010 and Planning Horizon

Unit: ha

City District	Total Area			Residential and Public Zones			Industrial, Stores and Special Zones			Reserve Free Land		
	1980	2010	P.H.	1980	2010	P.H.	1980	2010	P.H.	1980	2010	P.H.
Planning District I												
Ma'alla	341	380	380	169	180	220	89	90	90	83	110	70
Tawahi	255	570	570	110	116	140	90	90	100	55	364	330
Crater	232	516	516	166	225	310	14	10	10	52	281	196
Khormaksar	1,304	1,500	1,500	310	320	380	656	1,060	1,000	338	120	120
Reserve	-	-	1,100	-	-	-	-	-	-	-	-	1,100
Sub-Total	2,132	2,966	4,066	755	841	1,050	849	1,250	1,200	528	875	1,816
Planning District II												
Sheik Othman	448	950	950	243	935	935	26	15	15	179	-	-
Dar Saad	235	800	800	114	350	500	30	300	300	91	150	-
Al-Mansura	467	1,300	1,300	213	450	450	37	300	300	217	550	550
Bir Fadel	-	1,590	1,590	-	350	710	-	420	480	-	820	400
Al-Arish	800	1,800	1,800	-	420	760	400	810	900	400	570	140
Caltex	200	810	810	-	230	270	200	540	540	-	40	-
Reserve	-	-	200	-	-	-	-	-	-	-	-	200
Sub-Total	2,150	7,250	7,450	570	2,735	3,625	693	2,385	2,535	887	2,130	1,290
Planning District III												
Al-Shaab	592	1,570	1,570	47	400	570	480	800	800	65	370	200
Little Aden	782	1,150	1,150	122	175	175	292	300	300	368	675	675
Industry	-	2,220	2,220	-	-	-	-	1,400	1,600	-	820	620
Reserve	-	-	7,350	-	-	-	-	-	-	-	-	7,350
Sub-Total	1,374	4,940	12,290	169	575	745	772	2,500	2,700	433	1,865	8,845
Planning District IV	-	-	4,640	-	-	-	-	-	-	-	-	4,640
Others	-	700	3,500	-	-	-	-	700	3,500	-	-	-
Total Greater Aden	5,656	15,856	31,946	1,494	4,151	5,420	2,314	6,835	9,935	1,848	4,870	16,591

Note: P.H.: Planning Horizon
Others include zones for transport beyond city limits and forest conservation
Source: DPS 2010, Ministry of Construction



Source: DPS 2010, Ministry of Construction

Fig. 3.2 Land Use Plan in 2010

Table 3.5 Land Use Details in Residential and Public Zones in 2010

Unit: ha

Category of Land Use	Planning District I					Other Planning Districts	Total Greater Aden
	Ma'alla	Tawahi	Crater	Khormaksar	Sub-Total		
Residential Zone							
- Schools	12.0	8.0	15.1	8.2	43.3	238.1	281.4
- Creshes and Kindergartens	7.6	5.1	9.6	5.2	27.5	151.6	179.1
- Service Utilities	2.2	1.4	2.7	1.5	7.8	42.9	50.7
- Private Gardens	7.6	5.1	9.6	5.2	27.5	151.6	179.1
- Car Parkings	9.8	6.5	12.3	6.7	35.3	194.8	230.1
- Sport Facilities and Playgrounds	6.5	4.3	8.2	4.5	23.5	129.7	153.2
- Greenary	9.8	6.5	12.3	6.7	35.3	194.8	230.1
- Housing Buildings	38.8	26.3	49.4	27.0	141.5	776.6	918.1
- Paved Passages	14.1	9.4	17.8	9.7	51.0	281.0	332.0
Sub-Toatl	108.4	72.6	137.0	74.7	392.7	2,161.1	2,553.8
Public Zone							
- Service Facilities	14.5	5.0	19.2	5.2	43.9	197.1	241.0
- Greenary	29.0	10.0	38.4	43.4	120.8	401.2	522.0
- Car Parkings	0.6	0.2	0.8	0.24	1.84	10.7	12.54
- Garages	1.2	0.4	1.6	0.46	3.66	27.6	31.26
- Main Streets and Squares	26.3	14.7	28.0	15.1	84.1	428.7	512.8
- Institutions of City Level	-	13.1	-	180.9	194.0	83.6	277.6
Sub-Total	71.6	43.4	88.0	245.3	448.3	1,148.9	1,597.2
Total	180.0	116.0	225.0	320.0	841.0	3,310.0	4,151.0

Source: DPS 2010, Ministry of Construction

3.3.3 Population Projection for the Study Area

In order to project the population to be used for sewerage planning, various previous population projections were reviewed. These are compared in Table 3.6 below.

Table 3.6 Previous Population Projection in 2010 for the Study Area

District	Study or Authority Concerned			
	DPS 2010	Water Supply M/P (2000)	PWC	Sewerage F/S
Ma'alla	58,000	57,700	58,112	50,000
Tawahi	20,000	21,300	21,000	20,000
Crater	77,000	68,230	66,801	-
Khormaksar	21,000	31,130	43,928	-
Total	176,000	178,360	189,841	-

Note: DPS 2010: Development Principal Scheme for 2010, Town Planning Section, 1984

Water Supply M/P: Aden Water Supply Long Term Master Plan, SOGREAH, 1979

PWC: Reply to the study team questionnaire from Public Water Corporation, 1989

Sewerage F/S: First Governorate Report on Sewerage Projects, John Taylor and Sons, 1977

As mentioned in the previous subsection, the four districts in the study area have already been developed and expansion of the urban area is limited. Reflecting this, population projections made by the previous studies do not differ significantly from each other. Although, there is uncertainty in the projection for Greater Aden, the population for the four districts can be projected with good probability. Appropriateness of the projections vis-a-vis sewerage planning is discussed as described below.

Projections made by JTS for the previous sewerage project for Ma'alla and Tawahi can not be used for the study, because it was done 12 years ago and circumstances have changed significantly since then. Projections made by Water Supply M/P is also out of date at present for the same reason. Moreover, this projection was virtually taken over and modified by PWC to reflect present conditions in the study area. The two other projections made by DPS 2010 and PWC are to be referred to. These two projections do not differ significantly for Ma'alla and Tawahi districts. However, populations for other two districts, particularly for Khormaksar, differ.

Consideration has been given to the present conditions and land use plan in the study area. As mentioned in the previous subsection, topography of the study area limits future development. There exist no suitable areas for large scale residential and other development. Small open areas and reclamation of coastal areas are the only possibilities. It was revealed that this situation was duly reflected in land use plan by DPS 2010. Therefore, it is considered appropriate that population projection for sewerage project be based on the projection made by DPS 2010. Population projection by DPS 2010 is shown in Table 3.7 under residential population.

However, from the estimation of land use, it was found that relatively large areas are earmarked for institutional purposes at city, governorate and national levels in the study area, particularly in Khormaksar. In this area, although resident population is very small, a certain amount of sewage flow is envisaged. In the revised Water Supply Master Plan, water consumption by public organization is individually and separately estimated. This public organization category corresponds to institutional area of land use plan. For the convenience of sewerage planning, population equivalence has been considered in estimating the sewage flows in the area. Population equivalence was calculated based on water consumption by public organization and per capita water consumption, both of which had been projected by the revised Water Supply Master Plan. Population equivalence in each district is shown in Table 3.7.

The study team was informed during the period of preparation of Interim Report that new housing development had been approved in April 1989 in Ma'alla. These development areas are located behind the buildings along the Ma'alla Main Road. The height and the number of stories of the flats are similar to those of the existing buildings. A total of 1,000 flats in a total of 3.2 ha area is expected to be constructed.

Also, the study team was informed that a present cemetery area in the middle of residential area in Ma'alla would be reclaimed for housing purposes in the future, although the type of housing and arrangement of buildings are not known.

The population expected from these developments are estimated to be 6,000 and 4,000 respectively. Since these developments were not included in the projection made by DPS 2010, these are added to the previous projections.

Housing development behind Ma'alla Main Road is considered to be completed by 2000, and that in reclaimed cemetery area after 2000. Population in the areas is shown in Table 3.7 under residential population.

Table 3.7 Population Projection for Sewerage Planning

District	Firt Phase Program (2000)			Long Term Program (2010)		
	Residential Population		Population Equivalence for Public Organization	Residential Population		Population Equivalence for Public Organization
	DPS 2010	New Development		DPS 2010	New Development	
Ma'alla	57,300	6,000	6,700	58,000	10,000	6,800
Tawahi	19,700	-	13,200	20,000	-	13,400
Crater	73,100	-	4,200	77,000	-	4,300
Khormaksar	20,000	-	20,600	21,000	-	20,800
Total	170,100	6,000	44,700	176,000	10,000	45,300

3.4 Sewage Quantities and Characteristics

The revised Water Supply Master Plan and information obtained from PWC were carefully examined for the estimation of sewage quantities, since all the water consumed at present and in the future are supplied solely by the PWC water supply system. However, classification of consumers, i.e. producers of sewage, is modified for the convenience of sewage planning taking into account the conditions of the study area.

3.4.1 Domestic Sewage

Domestic sewage is defined for this study as inclusive of domestic, community and a part of commercial and industrial consumption classified in the revised Water Supply Master Plan. Sewage from institutional area which is defined as public organization consumption for water supply planning is separately estimated based on population equivalence.

Community sewage is defined as sewage produced in community facilities such as schools, mosques and small shops. Community water consumption is estimated on a per capita basis of the residential population in the revised Water Supply Master Plan. Characteristics of community sewage is considered to be similar to domestic sewage. Thus, sewage from community facilities are combined with domestic sewage. Domestic sewage in this study includes community sewage.

Water consumption of commercial and industrial sectors accounted for only 3 % of the total water consumption in the study area at present. There are no large scale industrial consumers at present and no industrial estate is envisaged in the future. Therefore, commercial and industry water consumption is not dealt with separately, and sewage from this sector is regarded as a part of domestic sewage.

In order to work out future per capita sewage flow, PWC's projections were examined. PWC considered three hypotheses of per capita domestic (household) consumption rates for the estimation of future water consumption, viz. high, medium and low. For the estimation of community consumption, the same three hypotheses were assumed. The total of the domestic and the community water consumption in 2010 and the per capita consumption rates are shown in Table 3.8 below.

Table 3.8 Domestic and Community Water Consumption in 2010 by Districts

District	Water Consumption (m3/d)			Per Capita Consumption (lcd)		
	High	Medium	Low	High	Medium	Low
Ma'alla	11,148	9,433	7,970	232	170	147
Tawahi	2,696	2,359	2,025	128	114	99
Crater	12,570	10,693	8,912	188	169	145
Khormaksar	7,973	7,030	6,315	182	165	150
Total	34,387	29,515	25,222	(181)	(165)	(141)

Note: Figures in parentheses are weighted average for the four districts.

Thus, domestic and community water consumption in the four districts in 2010 fall in a range of 25,200 to 34,400 m3/d. Corresponding per capita consumption rates are 141 to 181 lcd on an average. For sewerage planning purpose, per capita flow rate based on the high hypothesis is considered, to make adequate allowance in the design of facilities.

The per capita sewage flow is, in general, slightly lower than per capita consumption. Water consumption such as far garden sprinkling do not flow into the sewerage system. It is reported that this type of consumption accounts for about 5 % at present in Aden. This is equal to about 6 lcd in term of per capita consumption.

Taking the above mentioned factors into account, a round figure of 180 lcd is adopted as per capita sewage flow in 2010 for the study. Per capita sewage flow of 150 lcd in 2000 is obtained from interpolation between 118 lcd in 1988 and 180 lcd in 2010.

For the design of such sewerage facilities as gravity sewers, pumps, force mains and any pipes or conduits, peak flow rate is used as a basis, since these facilities should have capacities to deal with peak flow. Peaking factor of 2.0 with respect to the daily average is adopted based on the results of flow measurements in the existing pumping stations (see Appendix D).

Daily maximum water consumption was calculated as 1.1 times daily average consumption in the revised Water Supply Master Plan based on the present record of daily supply. The same factor of 1.1 is used for the calculation of daily maximum sewage flow.

Factors for peak flow and daily maximum flow is uniformly used for the other sewage flow except for infiltration.

Domestic sewage flows in 2000 and 2010 is estimated as shown in Table 3.9.

Table 3.9 Domestic Sewage Flow

(unit: m3/d)

District	First Phase Program (2000)			Long Term Program (2010)		
	Daily Average	Daily Maximum	Peak Flow	Daily Average	Daily Maximum	Peak Flow
Ma'alla	9,495	10,445	18,990	12,240	13,464	24,480
Tawahi	2,955	3,251	5,910	3,600	3,960	7,200
Crater	10,965	12,062	21,930	13,860	15,246	27,720
Khormaksar	3,000	3,300	6,000	3,780	4,158	7,560
Total	26,415	29,058	52,830	33,480	36,828	66,960

3.4.2 Sewage from Public Organization

Sewage flow from public organization at city, governorate and national levels such as Municipality office, ministries and embassies are estimated separately, since most of these buildings are located in the four districts at present and they consume a large quantity of water.

Public organization sewage flow is estimated based on population equivalence. Population equivalence is calculated from water consumption by this category and per capita domestic consumption, both of which are obtained from the revised Water Supply Master Plan.

Estimation of public organization sewage flow is shown in Table 3.10 below.

Table 3.10 Public Organization Sewage Flow

(unit: m3/d)

District	First Phase Program (2000)			Long Term Program (2010)		
	Daily Average	Daily Maximum	Peak Flow	Daily Average	Daily Maximum	Peak Flow
Ma'alla	1,005	1,106	2,010	1,224	1,346	2,448
Tawahi	1,980	2,178	3,960	2,412	2,653	4,824
Crater	630	693	1,260	774	851	1,548
Khormaksar	3,090	3,399	6,180	3,744	4,118	7,488
Total	6,705	7,376	13,410	8,154	8,968	16,308

3.4.3 Other Sewage

Other sewage considered for sewerage planning are flow from various military camps, a police camp and small fringe areas. Present sewage flow from these areas are estimated by pump operation records or by some other way and considered not to change in the future. The names of the facilities and their sewage flow are shown in Table 3.11 below.

Table 3.11 Other Sewage Flow

(unit: m^3/d)

District	Facility	Sewage Flow		
		Daily Average	Daily Max.	Peak Flow
Ma'alla	None	-	-	-
Tawahi	Military Camp	900	990	1,800
Crater	None	-	-	-
Khormaksar	Badr Camp	1,804	1,984	3,608
	Tareq Camp	1,096	1,206	2,192
	Police Camp	70	77	140
	Isthmus Camp	120	132	240
	Khormaksar Total	3,090	3,399	6,180
Total		3,990	4,389	7,980

3.4.4 Infiltration

Design flow rates for sanitary sewers must include an allowance for non-waste components which inevitably become a part of the total flow. Infiltration of groundwater, which is unwanted component, is to be accounted for in the design of sewers because of the topography of the study area. Some parts of the area are occupied by flat and low-lying areas where groundwater level is generally high.

No data is available to estimate infiltration flow quantities into the existing sewerage system. An attempt was therefore made to estimate infiltration based on experimental standards internationally accepted. An allowance of 71 m^3/d per km of sewer pipe length is recommended for small to medium-sized sewers (up to 600 mm) regardless of pipe size in WPCF manual (Ref. No.5).

A small representative area in Khormaksar is selected to estimate infiltration flow on area basis. Sewer length per ha of area is calculated to be 67 m/ha. Then, the infiltration flow rate is calculated as follows.

$$71\ m^3/km/d \times 0.067\ km/ha = 4.8\ m^3/ha/d$$

A round figure of 5 m^3/ha/d is used in the design calculation.

From our observation of existing sewer pipes and information obtained from counterpart personnel, it was realized that groundwater levels in most of Khormaksar district are high enough to reach the depth of sewers. Therefore, In general, areas below the +3.5 m contour lines are considered vulnerable to groundwater infiltration. A total of 629 ha in Khormaksar district is identified for inclusion of infiltration. Total infiltration flow of 3,145 m^3/d is estimated as shown below. Infiltration flow is considered to be constant at any time and therefore no peaking factor is taken into account.

$$629\ ha \times 5\ m^3/ha/d = 3,145\ m^3/d$$

3.4.5 Total Sewage Flow

Total sewage flow in the four districts are summarized in the following Table 3.12.

Table 3.12 Total Sewage Flow

(unit: m3/d)

District	Category	First Phase Program (2000)			Long Term Program (2010)		
		Daily Average	Daily Maximum	Peak Flow	Daily Average	Daily Maximum	Peak Flow
Ma'alla	Domestic	9,495	10,445	18,990	12,240	13,464	24,480
	Public Org.	1,005	1,106	2,010	1,224	1,346	2,448
	Others	-	-	-	-	-	-
	Infiltration	-	-	-	-	-	-
	Total	10,500	11,551	21,000	13,464	14,810	26,928
Tawahi	Domestic	2,955	3,251	5,910	3,600	3,960	7,200
	Public Org.	1,980	2,178	3,960	2,412	2,653	4,824
	Others	900	990	1,800	900	990	1,800
	Infiltration	-	-	-	-	-	-
	Total	5,835	6,419	11,670	6,912	7,603	13,824
Crater	Domestic	10,965	12,062	21,930	13,860	15,246	27,720
	Public Org.	630	693	1,260	774	851	1,548
	Others	-	-	-	-	-	-
	Infiltration	-	-	-	-	-	-
	Total	11,595	12,755	23,190	14,634	16,097	29,268
Khormaksar	Domestic	3,000	3,300	6,000	3,780	4,158	7,560
	Public Org.	3,090	3,399	6,180	3,744	4,118	7,488
	Others	3,090	3,399	6,180	3,090	3,399	6,180
	Infiltration	3,145	3,145	3,145	3,145	3,145	3,145
	Total	12,325	13,243	21,505	13,759	14,820	24,373
Total	Domestic	26,415	29,058	52,830	33,480	36,828	66,960
	Public Org.	6,705	7,376	13,410	8,154	8,968	16,308
	Others	3,990	4,389	7,980	3,990	4,389	7,980
	Infiltration	3,145	3,145	3,145	3,145	3,145	3,145
	Total	40,255	43,968	77,365	48,769	53,330	94,393

3.4.6 Sewage Characteristics

Per capita waste loading in term of BOD5 is calculated to be 38.2 gcd at present as described in Section 2.10. Per capita loading in various parts of the world including industrialized and developing countries vary between 23 to 78 gcd (Ref. No.9). Compared with this, a per capita loading of 38.2 gcd is very normal for urban sewage which is predominantly domestic and contains little industrial wastes.

For planning purposes, increase in per capita loading should be considered since loading rate increases as per capita water consumption increases. If the annual increment in BOD5 per capita loading is assumed to be 0.5 gcd, per capita waste loading will reach 49 gcd in the year 2010.

On the other hand, WHO recommends a per capita waste loading of 45 gcd for all sanitation programs in PDRY. This per capita loading is higher than the present figures by about 7 gcd or 18 %.

The capacity of the treatment plant, particularly stabilization pond, depends on the organic load to be treated. Thus, the higher organic load will result in the higher construction cost. On the other hand, since construction of the sewage treatment plant is to be carried out in stages, adjustment in design can be made at a later stage, based on actual results from operations.

Taking into account the above, a per capita BOD loading of 45 gcd as recommended by WHO, is adopted for design of the treatment plant, subject to possible future adjustment.

The BOD concentration of domestic sewage is calculated based on this per capita waste loading and sewage flow of 180 lcd as follows.

$$45 / 180 \times 10^{-3} = 250 \text{ mg/l}$$

For the design of treatment facilities, BOD5 concentration of 250 mg/l is used.

Concentration of other items are estimated to be proportional to BOD5 with respect to the present data. As a result, sewerage characteristics are estimated as follows.

Table 3.13 Sewage Characteristics

(unit: mg/l)

BOD5	CODcr	CODmn	SS	NH4-N	T-P
250	550	110	200	46	10

3.5 Engineering Considerations for System Planning

3.5.1 Alternative Sewerage Systems

Wastewater collection, treatment and disposal systems are broadly classified into two categories, viz. on-site and central systems. On-site systems serve a household or a building individually. On-site systems usually utilize a soak pit with or without a septic tank. The mixture of sludge and toilet excreta enters, in case of septic tank, into the septic tank where it is stored for a certain period and the supernatant flows into a soak pit to penetrate into the ground. If the subsoil is impermeable, sewage and sludge in septic tank should be removed by vacuum cars or by other means.

On-site systems are, in general, suitable in sparsely populated areas for the following reasons. The system requires space for septic tank or soak pit near the building, which is often very difficult in densely populated areas. In addition, there are indications that in urban areas, septic tanks would, in many cases, cost more on a per capita household basis than the conventional water-borne sewerage system. Capital, operation and maintenance costs for the system have been found to be almost equal, or in particular cases, to exceed the cost of the conventional sewers and sewage treatment.

There are also disadvantages in on-site systems from the technical view point. Overall efficiency in the reduction of the pollutant is far less than that of the central system with treatment. Moreover, the effluent from the septic tank is, from public health viewpoint, as dangerous as raw sewage and so requires further treatment before the final disposal. The septic tank may cause odour, if maintenance is not proper.

In view of the characteristics of the on-site systems mentioned above, this system is not appropriate as a new system or means of improvement of the existing system in the study area.

Theoretically, there are three kinds of water-borne central sewerage systems, viz. i) gravity, ii) vacuum and iii) pressure systems. A brief description of each system is given below together with an evaluation for adoption in the study area.

Vacuum systems comprise a connection pit with vacuum valve, vacuum sewer pipes and a vacuum pump station. Sewage from households flow into the connection pit by gravity. As water level in the pit goes up to reach a certain point, a vacuum valve is opened to suck up sewage into the vacuum sewer pipe. The vacuum valve is closed automatically in a few seconds after the water level goes down. Sewage is mixed with air which is also sucked in from a suction pipe, and the mixture flows in the vacuum sewer pipe at a high velocity to a collection tank. Sewage are then pumped to the treatment facility or to gravity sewer system. Vacuum pumps are installed to keep the sewer pipe system under low enough pressure to suck sewage.

This system was initially developed for small communities of relatively low population density. In these areas, if conventional system is applied, construction cost of the sewer pipes becomes prohivitively high because of a scattering small sewage flow.

Pressurized sewer pipes are used in the pressure sewer system instead of vacuum pipe in the vacuum system. The pressure sewer system comprises the interceptor tank, pump, lateral piping, mainline and their service facilities. Sewage flows into the interceptor tank by gravity, and is then pumped to the mainline through lateral piping.

The interceptor tank has usually more than one day retention time, thus provides initial treatment of the sewage by removing a majority of the solids material. Because of the nature of the supernatant from the interceptor tank, small diameter pipes, as small as 32 mm, can be used. Also, sewer pipes can be installed shallow regardless of the gradient of the ground level thereby resulting in significantly lower construction cost.

The pressure system is a viable alternative to conventional methods of sewage collection under some conditions, such as high groundwater, undulating terrain, unstable soil or rock conditions, and rural community nature.

In view of the present development conditions in the study area, in particular, size of population and high population density, these two systems are not technically suitable for a new sewerage system or as improvement measures. Moreover, if one of the two systems is adopted, replacement of all the existing sewers is required for both systems and additional new facilities are to be constructed, which would require prohibitively large sums of construction cost input than that for improvement of the existing system.

Gravity sewer system is further classified into two systems, viz. conventional and small-bore sewer systems. The small-bore system, which carries settled effluent only, as in case of pressure system, is one possibility for a less expensive sewerage system. The system is designed to receive only the liquid portion of household sewage for off-site treatment and disposal. Grit, grease and other troublesome solids which might cause obstruction in the sewer are separated from the sewage flow in interceptor tanks installed upstream of every connection to the sewers, and the solids which accumulate in the tanks are removed periodically for safe disposal.

Small-bore sewer system has many economical advantages because of i) reduced peak flow, ii) reduced pipe size and iii) reduced excavation for pipe installation. Thus, small-bore sewer system may provide, in general, an economical means of sewage conveyance. However, there is a major constraint in the direct adoption of this system for the region under climatic conditions such as those in Aden. From experience in many locations in the existing conventional sewerage systems, sewers are clogged by sand and other solids which entered the pipes through manholes or inspection chambers, and frequent cleanings are required to properly maintain the function of the facilities. This is particularly true in the areas like Aden where sand and dust tend to enter the sewer system.

The small-bore sewers of 50 to 100 mm diameter will no doubt necessitate much more frequent cleaning of the pipes than the present conventional sewers, thus, will create significant difficulties in proper operation and maintenance, and make O/M costs much higher than other comparable alternative systems. Furthermore, and perhaps most important, the existing sewerage system in the study area has long been planned and constructed as a conventional gravity sewer system, and there is no persuasive reason to change the present system to an altogether different new system without any experience in PDRY.

The conventional gravity sewer system is one of the most reliable sewerage systems, and much experience is available in Aden in planning, design, construction and operation and maintenance, and is most widely applied throughout the world, but in general it is also the most expensive among the possible alternative sanitation systems available for safe disposal of sewage.

The conventional sewer system has many merits. Firstly, it provides the greater user convenience of all waste disposal systems, for they permit the discharge of large amounts of water. Secondly, they do not pose any risks to health when functioning properly. Their maintenance is assumed by the municipality. Thirdly, they generally operate with few service interruptions or emergencies.

Yet, this system also has some disadvantages in addition to its high construction cost. It requires skilled contractors for the construction, a municipal organization for operation and maintenance, and a substantial amount of flushing water, which adds to the operating costs.

Given the high convenience level of the conventional sewerage system and considering the present situation in the study area where this the system has been operated and maintained for a few decades without any serious problems,it is apparent that the existing system can be utilized in the future, provided that some improvements are made. This system is therefore considered the most appropriate one for the study area.

3.5.2 Combined vs. Separate Systems

There are two types of conventional gravity sewer systems, viz. combined and separate systems. Combined sewer system collects both wastewater and stormwater together. In this system, stormwater, up to a design limit, is channeled with sanitary sewage to the treatment plant. When combined flows exceed the design limit, overflows occur and varying amounts of wastewater along with stormwater are discharged to natural water courses.

On the other hand, sanitary sewage and stormwater are collected separately in the separate system. Sanitary sewers collect sanitary sewage only and convey it to the treatment plant. Stormwater is collected by a different sewer system and discharged at convenient locations to natural water courses. Complete separate system has therefore two independent sewer networks. Open channel is often used for drainage of stormwater as a substitute to the stormwater sewer pipes. This system is also a kind of separate system.

There are advantages and disadvantages for both systems from the technical and economical view points. Construction cost of a combined system is in general less expensive than that of a separate system. However, a serious problem of the combined system is discharge of the pollutants without treatment to the natural water courses. When mixed flow exceeds the capacity of the sewer, excess flows are discharged to the natural water courses without treatment. Pollutants contained in the mixed flow cause contamination of the waters.

The existing sewerage system in Aden was designed and constructed as a separate system. Although rainfall is very low and annual average precipitation is only 63 mm, and chances of rainfall is not frequent, rare strong rainfalls cause localized flooding on the streets in several parts of the study area. The covers of the sewerage manholes are often opened to dump such excess stormwater. There are stormwater sewers and culverts in limited areas in Ma'alla to collect and discharge stormwater run-off to the sea.

Intensity-duration rainfall curves for the calculation of stormwater quantities is not calculated because of the lack of data. A German consultant analyzed available data statistically and proposed rainfall intensity to be used for design of drainage facilities for the Aden Ring Road project (Ref. no.18). Rainfall intensities for the return periods of 5 to 200 years are as follows.

Return period	Rainfall intensity (l/s. ha)
5 years	25
10 years	40
25 years	65
50 years	90
100 years	120
200 years	160

Although duration of rainfall intensity is not clear, an attempt was made to calculate stormwater quantities to evaluate the capacities of the existing sewers. As a result, with rainfall intensity of the minimum return period (25 l/s.ha for 5 years), almost all the existing sewers have been revealed to be insufficient to convey sewage and stormwater run-off mixtures. Therefore, existing sewers can not be used as combined system.

Existing sewer networks should, therefore, be utilized as sanitary sewers as they are at present, with necessary improvements, and stormwater run-off should be treated separately considering the capacity of the existing sewerage systems and climatic conditions of the study area.

3.5.3 Need for Treatment

Possible alternatives for final disposal of collected sewage is limited to either i) disposal to the sea without treatment or ii) treatment and reuse for irrigation purpose or disposal to the sea. Other disposal system, such as raw sewage disposal to the desert area, is obviously disadvantageous, because of the geographical conditions of the study area where such desert areas outside of the present and future urban areas are far from the service area.

There are advantages and disadvantages to each of the two methods. The advantage of disposal to the sea without treatment is its low cost. The four districts face the Inner Harbor or Gulf of Aden, and sewage can be discharged at convenient locations in each district. This method is indeed the present practice of disposal in the study area. However, direct discharge of raw sewage from Ma'alla and Tawahi into the Inner Harbor has already caused a pollution problem. In consideration of the increasing sewage flow and importance of Ma'alla and Tawahi districts, the present practice of raw sewage discharge should be ceased as soon as possible to protect the marine environment.

In order to prevent water pollution in the Inner Harbor, extension of the ocean outfalls in Ma'alla and Tawahi, to the points from where no current influence to the Inner Harbor occurs, can be considered. However, in this case an additional pumping station and long outfall pipes become necessary. The construction costs for these facilities are comparable with those required in case of treatment. Therefore, cost savings from raw sewage disposal is not so significant as expected at first glance, in particular, for Ma'alla and Tawahi.

In addition to the disadvantages mentioned above, another disadvantage of the disposal of raw sewage to the sea is impossibility of reuse of the sewage. In Aden, water resources are limited and very scarce. Sewage is a precious water resource. Future water demand in excess of the capacity of the present well fields should be satisfied with desalinated sea water, the cost of which is a few times that of groundwater. If treated sewage can be utilized for any purpose, water demand, which otherwise would consume piped water, can be substituted.

The most probable reuse of treated sewage is irrigation for greenery. The Green Belt project has been started since 1986 with the objectives mentioned in

Section 2.13. It is planned to utilize treated effluent not only from the existing Al Shaab STP but also from the future treatment works for the study area. The Green Belt project will contribute to improvement of the environmental conditions in urban areas in Greater Aden. For reuse of sewage, a certain degree of treatment is necessary.

Opposition to discharge of untreated sewage into the Inner Harbor is expressed strongly by various authorities, including YPA and the Highway Authority. Transportation of raw sewage from Ma'alla and Tawahi to other places for disposal without treatment was rejected at the seminar organized by UNDP and Ministry of Public Health in February 1989.

From the above, sewage treatment should be considered for the sewerage project in the study area, together with consideration of reuse of treated effluent for the Green Belt Project.

3.6 Design Criteria

Following design criteria have been developed for the design or sewerage facilities taking into account the present conditions in Aden and those adopted and accepted in many countries. Design criteria proposed in this section shall, except for special reasons, be the basis for all the facilities.

3.6.1 Sewers

In hydraulic calculation of the pipes, Manning equation is used for gravity sewers with "n" value of 0.013 for VCP and of 0.012 for PVC, and Hazen-Williams equation is used for force mains with "C" value of 110 for DCIP. Peak flow or hourly maximum flow is the basis for calculation of capacities of all pipes and conduits.

A minimum size of 200 mm is adopted for sanitary sewers, but for service connection pipes, a minimum diameter of 150 mm is allowed. All sanitary sewers are designed to maintain a mean flow velocity, when flowing full or half full, of not less than 60 cm/s based on Manning equation. However, to prevent hydrogen sulfide built-up in the sewers, slightly higher velocities are used for the design of sewers.

All sewers are designed not to exceed a flow velocity of 3.0 m/s to protect against sewer erosion. Where ground slope is steep and a velocity of more than 3.0 m/s may result, drop manholes are usually provided to decrease the flow velocity. Special provision is made to protect against displacement by erosion and shock. Standard structure of drop manholes is shown in Drawings 55, 56 and 57 in Volume Three.

All sewers are designed to flow, at all times, with sufficient velocity to prevent the settlement of solid matter and consequent sulfide generation, but no other measures are considered such as air injection to sewer pipe.

Earth covering of sewer pipe should not be less than 1.0 m, and in case of shallower depths, special protection is to be considered.

To protect pipes against live and dead loads, installation and backfilling should be carried out carefully. Methods and materials of bedding are also to be selected carefully. Typical trench sections of the gravity sewers and force mains are shown in Drawings Nos. 55, 56 and 57 in Volume Four. Crushed stone or gravel bedding is proposed for gravity sewers and force mains.

Water tight flexible joints are proposed to avoid as much groundwater intrusion as possible.

3.6.2 Manholes

Manholes shall be provided at each change in direction, in sewer diameter, or wherever there is a considerable change in grade generally with the following maximum spacing.

Maximum Manhole Spacing

Sewer Diameter (mm)	Maximum Manhole Spacing (m)
300 or less	50
600 or less	75
1,000 or less	100
1,500 or less	150
1,650 or more	200

Except for very shallow sewers, all manholes shall have adequate dimensions for entry and operation of cleaning equipment. Two types of manholes, one for sewers with diameters 500 mm or less and another for larger diameter sewers are proposed for the project which are shown in Drawing No. 56 in Volume Four.

3.6.3 Pumping Stations

The design of pumping stations is based on the peak flow rate. All piping and conduits are designed to carry the design peak flow. Capacities and number of pump units are determined in order that at least one standby unit is provided at peak flow, with built-in flexibility to respond to flow fluctuation. Usually, two pump units of the same capacity, one duty and one standby, are considered for smaller pumping stations, and two or more units including one standby unit of the same capacity are considered for larger pumping stations.

Structure of pumping stations is, in general, rectangular in plan following the general practice in Aden. For screw volute pump, separate dry well should be provided to accommodate pumps. Wet wells should be designed to have enough storage capacities to prevent frequent on and off of the pumps. Usually, wet well capacities equal to 6 to 7 minutes of peak flow are provided.

Pumps are proposed to be electric motor driven taking into account electric power supply in the study area. Provision of emergency power supply by diesel engine is considered for certain pumping stations depending on their importance.

3.6.4 Sewage Treatment Plant

The stabilization pond process is recommended for the sewage treatment for the project considering the favorable climatic conditions and minimum requirements for mechanical and electrical equipment and for electric power for operation.

There are several types of stabilization ponds and basically these are classified into the following three categories, i.e. i) facultative pond, ii) anaerobic pond and iii) aerobic pond. Further, various combination of these ponds can be applied for sewage treatment.

In order to select the most appropriate combination of the ponds and design of the individual pond, the following factors should be considered.

(1) Characteristics of sewage, particularly strength of sewage indicated in terms of BOD

(2) Climatic conditions, particularly temperature

(3) Required level of treatment

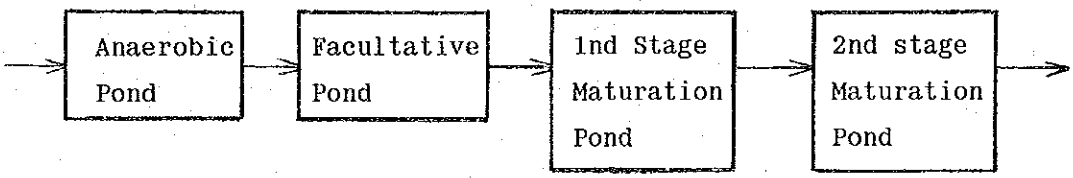
Characteristics of sewage in the study area are considered to be typically domestic, with average BOD concentration of approximately 320 mg/l at present. BOD concentration will change in the future depending on changes of per capita loading and water consumption. For the long term program, BOD concentration is estimated to be around 250 mg/l in 2010.

Climate in Aden is characterized by high temperatures throughout the year. Average daily temperatures in the coldest month of January exceeds 25° C. Because biological reaction in the pond is highly temperature dependent, with higher reduction at the higher temperature, this is most favorable for pond operation.

Effluent quality standards have yet to be provided in PDRY. However, in view of reuse of effluent for irrigation and reasonable standards for stabilization system, 60/60 (BOD/SS) are set as the treatment goal.

There is no data about coliform number in raw sewage. However, the order of coliform number can reasonably be estimated to be 10^7 taking into account the domestic nature of the raw sewage. Effluent standards should be determined depending on the purpose of the reuse or the nature of the receiving water. At present, reuse of the treated effluent for irrigation for greenery is planned, but details of irrigation methods are not apparent. Therefore, strict standards of 100/100 ml for non-restricted irrigation is adopted as the treatment goal.

Based on the discussion mentioned above, and considering the best use of the climatic conditions in the study area, the following combination is proposed as the process train.



Several design procedures can be applied for the design of each pond. These procedures are described in many publications by World Bank, WHO and other international agencies. Some of the design procedures are purely empirical and others are based on kinetic models and less empirical. The following criteria are considered more applicable to the project and therefore used for the design of treatment plant.

(1) Anaerobic Pond

Volumetric organic loading: 0.1 -0.4 kg BOD/m^3/d

Areal organic loading: 4,000 - 16,000 kg BOD /ha/d
(less important than volumetric organic loading)

Depth: 2 - 4 m

BOD reduction: 50 - 60 %

(2) Facultative Pond

Maximum Allowable Areal BOD loading:

i) Simplified linear equation

$$L = 20\ T - 60$$

where

L: areal BOD loading (kg BOD/ha/d)

T: minimum mean monthly ambient temperature (°C)

ii) McGarry and Pescod's equation

$$L = 11.2 \times (1.054)^T$$

where

L: areal BOD loading (kg BOD/ha/d)

T: minimum mean monthly ambient temperature (°F)

Depth: 1 - 1.5 m

BOD reduction: First order kinetics

$$Ce = Ci / (1 + k1\ t)$$

where

Ce: effluent BOD (mg/l)

Ci: influent BOD (mg/l)

k1: first order rate constant

$$k1 = 0.3\ (1.05)^{T-20}$$

T: temperature (°C)

t: retention time (d)

(3) Maturation Pond

Reduction of fecal bacteria

First order kinetics

$$Ne = Ni / (1 + Kb\ t)$$

where

Ne: number of fecal bacteria of effluent (N/100ml)

Ni: number of fecal bacteria of influent (N/100ml)

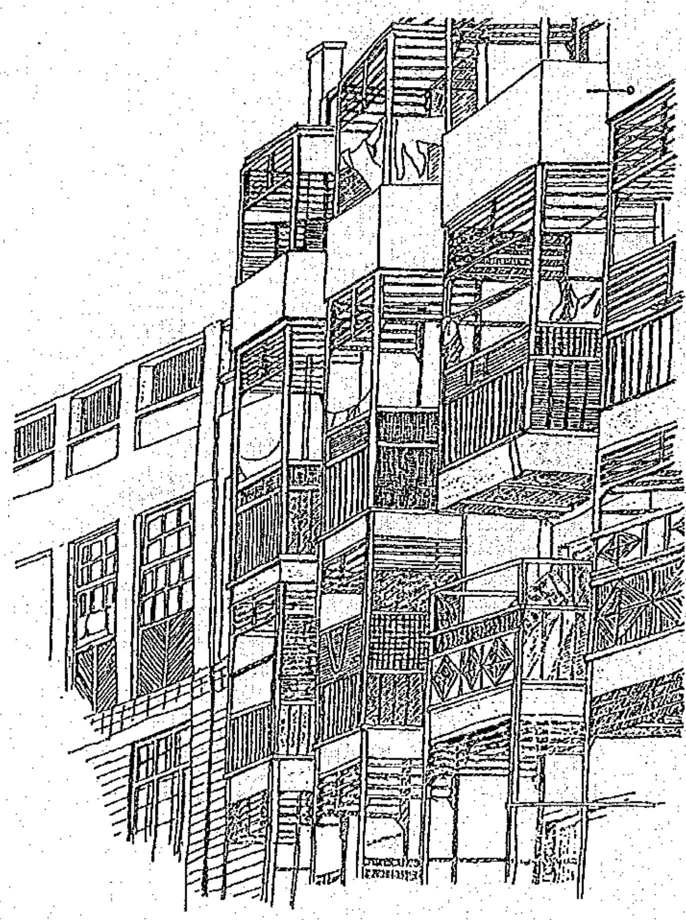
$$Kb = 2.6\ (1.19)^{T-20}$$

T : temperature (°C)

Depth : 1 - 1.5 m

CHAPTER FOUR

LONG TERM PROGRAM



CHAPTER FOUR

LONG TERM PROGRAM

4.1 Proposed Sewerage System

4.1.1 Introduction

The appropriate long term improvement measures to the existing sewerage system in Ma'alla and Tawahi, on which implementation program of the sewerage project will be based, is to be developed. The other two districts, viz. Crater and Khormaksar, should also be considered in developing such a concept together with Ma'alla and Tawahi. Reasons for the inclusion of two additional districts are as follows.

a) There is no suitable site for a sewage treatment plant in Ma'alla and Tawahi except for a small area in Ma'alla. Therefore, sewage from those districts is to be sent either to the existing sewage treatment plant at Al-Shaab or to other places, if stabilization pond is considered.

b) Crater and Khormaksar have been provided with a sewerage system constructed in the same period as Ma'alla and Tawahi system. Sewage in Crater and Khormaksar are disposed of by ocean outfalls without any treatment at present. Combined treatment of this is one of the possible alternatives for long term planning.

c) Development conditions in the four districts are similar to each other. In other words, they have been almost fully developed physically, to date.

d) Considering all this, it is most appropriate to deal with sewage in the four districts together, in developing a long term sewerage development plan.

On the other hand, the other districts in the Greater Aden are at the different development stages from that of the four districts. Moreover, newly developed Sheik Othman and Al Mansura are provided with sewerage system and treatment facilities. New districts proposed by DPS 2010 are now at very early stages of development, and these areas are to be provided with separate sewerage systems because of geographical reasons.

Alternative sewerage systems for the selection of the most appropriate system are, thus, developed considering the four districts mentioned above. Cost of each alternative are estimated for comparison. Elements other than cost are also taken into account. Description of the alternative systems and results of the selection are discussed in this section.

4.1.2 Alternative Sewerage Systems

(1) Location of the Treatment Plant

In developing alternative sewerage systems for the four districts, selection of the treatment plant location is important. The alignment and capacities of the major sewerage facilities, such as pumping stations and force mains, are determined depending on the location of the treatment plant, which in turn affects the cost of the project significantly.

For the selection of the treatment plant site, many factors should be considered from technical, economic and environmental view points. Proximity to the service area is one of the important factors which affects construction cost. However, nuisance to the nearby residents should be avoided at the same time. Proximity to the suitable disposal point is important for environmental protection. Climatic conditions, wind directions in particular, should be considered together with development conditions. As a whole, appropriateness of the treatment site can be judged with land use plan.

Taking into consideration various factors mentioned above, the following three locations are selected as possible sites for the treatment plant.

In Ma'alla and Tawahi, possible sites for the treatment plant are available in Hedjuff area only, in front of the existing pumping station. This area is a shallow cove bounded by port facilities. The available space of the area is limited to approximately 7 ha and no future expansion is possible. Therefore, if the treatment plant is located here, compact facilities should be considered.

The area in the neighborhood of the existing Al Shaab STP is one possible site for the new treatment plant. Although the distance from Ma'alla and Tawahi to the site is considerable, various advantages, such as ease of construction and operation, and effective environmental protection, can be obtained by constructing two treatment plants at one place.

The third alternative location has been sought in the area north of the airport and Khormaksar district, since no vacant land of sizable area suitable for the construction of the treatment plant could be found in Crater and Khormaksar districts. A vast, flat and presently vacant land exists north of the airport. The site has been selected at the location which is the nearest to the service area, but at a sufficient distance from the existing urban area to separate the treatment plant.

(2) Treatment Process

Among the various kinds of secondary treatment processes available at present, the stabilization pond process is recommended for the following reasons.

- minimum requirements of mechanical and electrical equipment
- low construction cost
- ease of operation and maintenance
- availability of favorable climatic conditions
- availability of land space in the vicinity of the service area

In the case of the two sites in the neighborhood of the existing Al Shaab STP and north to Khormaksar, the stabilization pond process is adopted. However, stabilization pond process can not be adopted at the site in Ma'alla because of the limitation of the available space. Therefore, other treatment processes which can be constructed within the demarcated area should be selected.

Among the several compact treatment processes, such as conventional activated sludge and extended aeration processes, oxidation ditch process is adopted for as it has lesser requirement for equipment and for its ease of operation.

(3) Alternative Sewerage Systems

Numerous combinations of the four districts and the three treatment plant sites can be theoretically considered. However, most of them are not viable from the practical point of view. In order to sift out less practical combinations and to select a minimum number of possible alternatives, a preliminary choice was made, based on the following considerations.

Sewage produced in Tawahi district is dealt with that produced in Ma'alla district, because of the closeness of the two districts and nonavailability of space for treatment plant in Tawahi. Sewage produced in Crater district is dealt with that in Khormaksar since Crater district is separated from Ma'alla district by the steep Keyhole pass and no land is available for treatment plant in Crater. Thus, the four districts are classified into two groups, viz. one for Ma'alla and Tawahi, and another for Crater and Khormaksar.

Sewage in Ma'alla and Tawahi districts should be sent for treatment to one of the three sites. On the other hand, it is advantageous to treat the sewage in Crater and Khormaksar districts at the site north to the airport because of proximity of the site to the service area. Therefore, three alternative sewerage systems are developed with respect to the site for treatment plant for Ma'alla and Tawahi districts.

In addition to the three alternatives, a proposal made in the previous study by JTS is selected as one of the alternatives for the comparison. Subsequently, the following four alternatives are developed for the further evaluation.

Alternative 1A: This alternative is the proposal by the previous study. Sewage collected from Ma'alla and Tawahi districts are disposed of by an ocean outfall from Steamer Point without treatment. Enlargement of the existing breakwater and construction of a holding tank to control the discharge to the sea were recommended by the previous study. These facilities have not been found to ensure the prevention of water pollution in the Inner Harbor, and to be expensive to construct. Therefore, instead of these works, a submarine force main of approximately 1 km long extending to the Gulf of Aden is considered as the means of disposal.

Alternative 1B: Sewage collected from Ma'alla and Tawahi districts are treated at the site in front of the Hedjuff pumping station. As mentioned above, more compact oxidation ditch process is adopted as treatment process because of space limitation. Treated effluent is discharged to the Inner Harbor at the same point as the existing outfall. Since the site is a shallow cove at present, land reclamation is necessary for the construction of the treatment plant. Cost for land reclamation is to be estimated, in addition, in the cost comparison.

Alternative 2: Sewage collected from Ma'alla and Tawahi districts are sent to the site adjacent to the existing Al Shaab STP for treatment in this alternative. A long force main from Ma'alla to the site is necessary. The stabilization pond process is adopted as the treatment process. Treated effluent is discharged to the Tawahi Bay at the same point as the existing outfall.

Alternative 3: In this alternative, sewage collected from Ma'alla and Tawahi are sent to the site north to the airport and treated together with those from Crater and Khormaksar. A long force main to the site is also necessary. Stabilization pond is adopted as the treatment process. Treated effluent is discharged to the Gulf of Aden on the beach along the Abyan Road.

The four alternatives are illustrated in Figures 4.1 to 4.4.

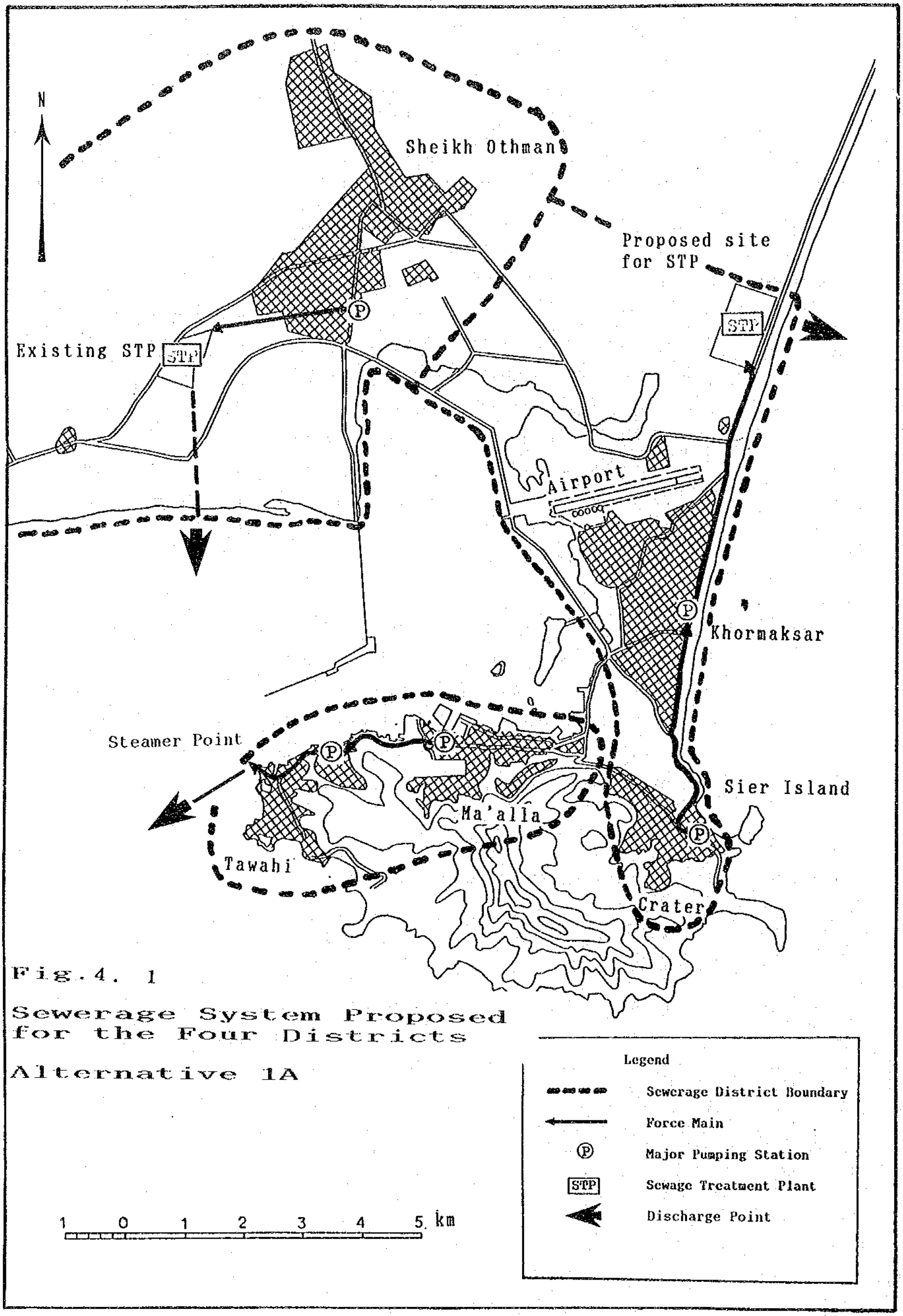


Fig.4. 1

Sewerage System Proposed for the Four Districts

Alternative 1A

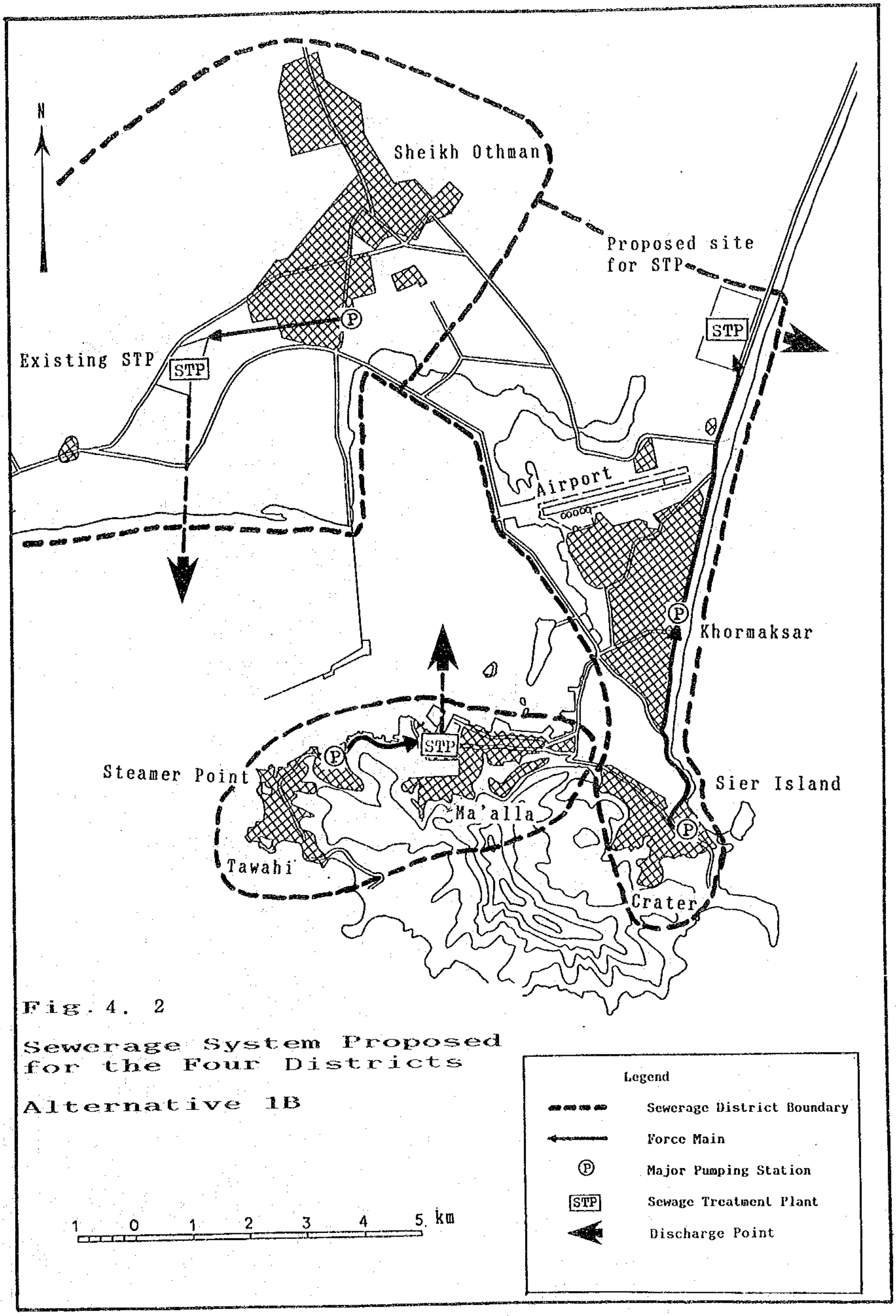


Fig. 4. 2

Sewerage System Proposed for the Four Districts

Alternative 1B

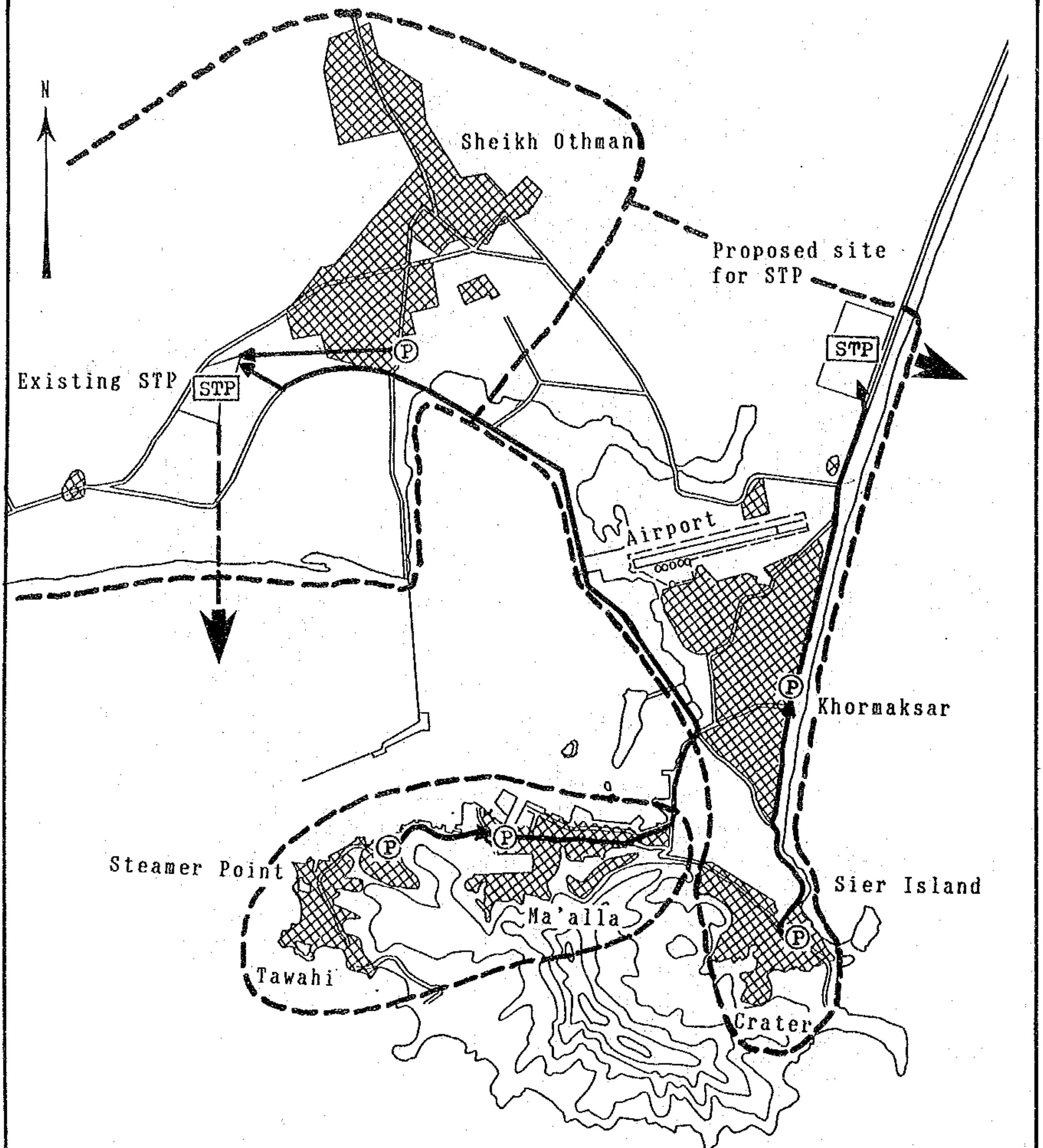


Fig. 4. 3

Sewerage System Proposed for the Four Districts

Alternative 2

1 0 1 2 3 4 5 km

Legend

- Sewerage District Boundary
- Force Main
- Ⓟ Major Pumping Station
- STP Sewage Treatment Plant
- Discharge Point

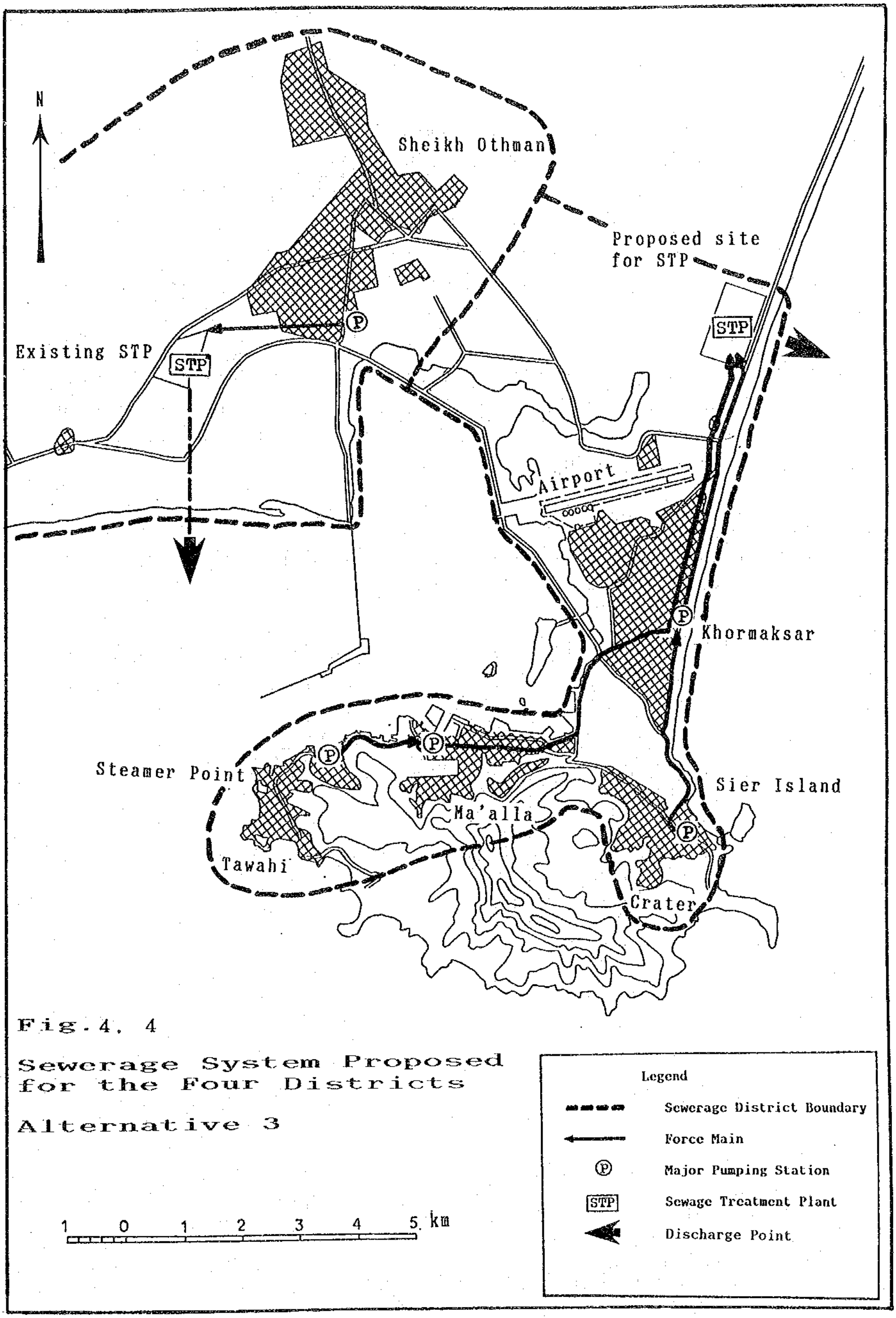


Fig.4. 4

Sewerage System Proposed for the Four Districts

Alternative 3

4.1.3 Evaluation of the Alternatives

Construction cost of each alternative is estimated as the first step of the evaluation. Cost for this scale of construction work varies significantly with the manner of implementation under the present circumstances in Aden. Sources of funding, tendering procedure, nationality of the contractor and construction period are major factors affecting the project cost. Since the purpose of cost estimation in this section is limited to the comparison of each alternative on the same basis, the following assumptions are made for the estimation.

(1) Construction costs for major facilities, such as pumping stations, force mains, and treatment plants are estimated. Costs for the improvement of the existing facilities are excluded from the estimation, since these costs are similar in all alternatives.

(2) All construction costs are on direct cost basis, and do not include the indirect portion of the project cost, because the indirect portion is more or less proportional to the direct portion.

(3) Bidding is on an international basis and a foreign contractor is assumed to be awarded. Source of the imported materials and services is considered to be Japan.

Direct construction costs of the four alternatives are shown in Table 4.1.

Table 4.1 Construction Cost of the Four Alternatives

(Unit: YD 1,000)

District	Facility	Alternative 1A	1B	2	3
Ma'alla Tawahi	Force Main	860	228	4,924	3,274*1
	Pumping Station	963	980	1,017	1,017
	Treatment Plant	-	7,129	1,651	-
	Ocean Outfall	3,947	-	-	-
	Total	5,770	8,337	7,592	4,291
Crater Khormaksar	Force Main	2,014	2,014	2,014	914
	Pumping Station	1,082	1,082	1,082	1,082
	Treatment Plant	2,193	2,193	2,193	3,482*2
	Ocean Outfall	-	-	-	-
	Total	5,289	5,289	5,289	5,478
Total Four Districts		11,059	13,626	12,881	9,769

Note: *1 Section from Khormaksar P/S to STP is included.
*2 One treatment plant for the four districts

As shown in the table, construction cost of Alternative 3 is least expensive, less than that of Alternative 1A. The highest construction cost is in case of Alternative 2, followed by Alternative 1B.

The higher cost of Alternative 1A than that of Alternative 3 is due to the high cost for construction of the ocean outfall. A long submarine force main laid on the bottom of the sea requires high construction cost which is comparable to the construction cost of the stabilization pond process treatment plant. Alternative 1A is disadvantageous from the economic point of view.

The reasons for the cost of Alternative 2 being the highest is the construction cost for the force mains which are necessary to send the sewage from Ma'alla and Tawahi districts to the treatment plant site adjacent to the existing Al Shaab STP. The second highest cost of Alternative 1B is due to the high cost for the construction of the treatment plant which is designed as oxidation ditch process. It should be noted that this process requires not only the higher construction cost but also higher operation and maintenance cost than that of the stabilization pond system. An additional cost for land reclamation is one of the reasons for the high construction cost for the treatment plant. Alternatives 1B and 2 are less attractive than the Alternative 3 from construction cost point of view.

All the alternatives have been evaluated from the environmental protection view point. Three points are considered for the evaluation , viz i) prevention of nuisance to the nearby residents, ii) prevention of water pollution and iii) reuse of effluent for green belt project.

For the prevention of nuisance to the nearby residents, all the alternatives ensure the same minimum level of nuisance or obstruction during construction and operation of the facilities. The treatment site adjacent to the Al Shaab STP is already demarcated as environmental control zone in the land use plan. The treatment plant site north to the airport is presently vacant land and no residential area exists around it. This area can be demarcated as environmental control zone as is the Al Shaab STP, well before the development of the area. The treatment site in Ma'alla is located in the port facility areas, apart from the residential areas.

Construction of the pumping stations, four pumping stations in each alternative may not pose any serious obstruction to the residents and the traffic, since three of them in Ma'alla, Crater and Khormaksar will be constructed adjacent to the existing pumping stations, and another in Tawahi can be constructed within the port facility area. Construction of the force mains in each alternative are planned along the main roads in Greater Aden. Obstruction to traffic can be controlled to the minimum level.

Alternatives 1B, 2 and 3 will greatly contribute to the prevention of the water pollution in the Inner Harbor because of the secondary treatment of raw sewage. Effluent from the treatment plant is free of pathogenic bacteria and organic pollutant in terms of BOD is reduced to less than one-fourth of raw sewage. Untreated raw sewage disposal in case of the Alternative 1A will also contribute to the improvement of the water pollution in the Inner Harbor. However, influence to the broader area in the future is questionable.