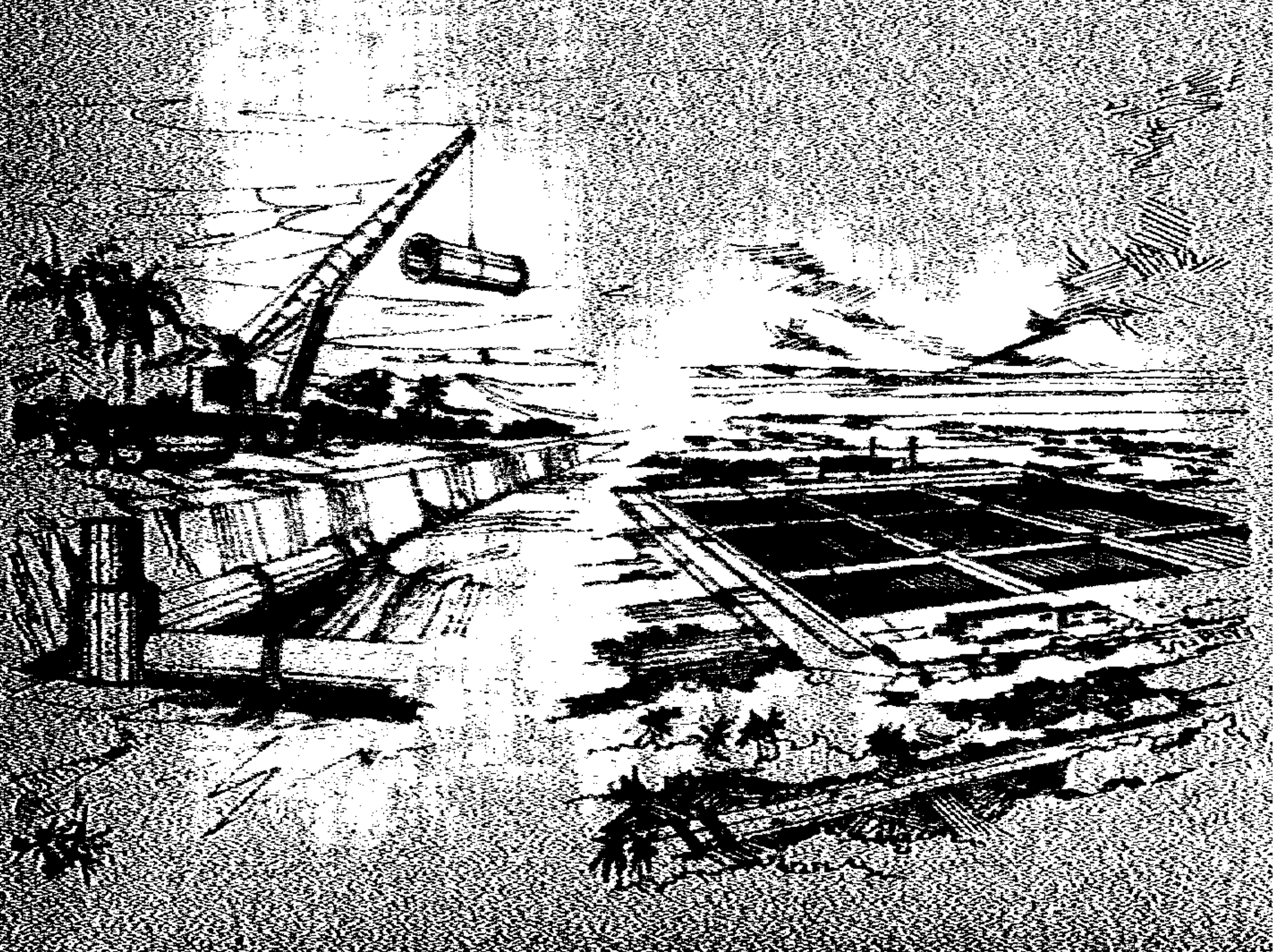
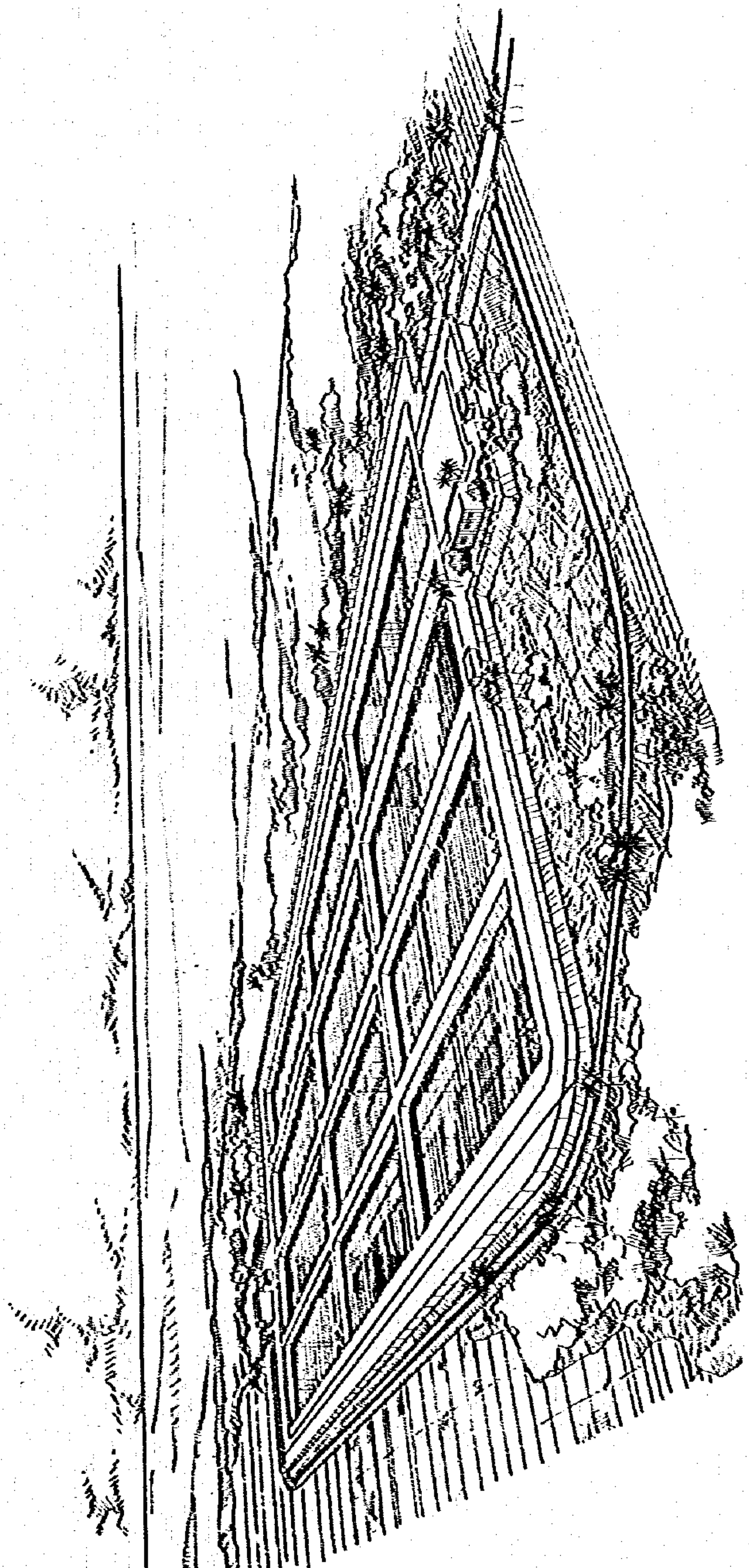
CHAPTER 3

SEWERAGE SYSTEM





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CHAPTER 3. SEWERAGE SYSTEM

3.1 Introduction

3.1.1 General

Sewage generating sources in this planning area can be roughly classified into 3 groups, namely, the tourism industry such as hotels and restaurants, etc., residential, and Tapioca factories. In the internationally famous seaside resort district which corresponds to this planning area, some of the hotels and other facilities which have been completed have absolutely no public facilities for water supply and sewage treatment, and some parts of the seashore are contaminated by non-treated sewage.

Pollution is especially bad in the downtown area located at the southern end of Pattaya Beach and the estuary of the Na Klua River. The former seems to be due to the discharged sewage from restaurants and shops, and the latter seems to be due to sewage from inhabitants and wastewater of Tapioca factories. It is thus very necessary to construct the sewage facilities in order to maintain and develop the said area as a "beach resort."

The planning area in question is about 2,896 ha, and is broken down as follows.

Hotel area	177 ha
Residential area	269 ha
Area to be preserved in present state	2,169 ha
Area for business and other activities	281 ha

3.1.2 Physical Characteristics

(a) Geography - See Fig. 3.1.1

1) At present, there are two town centers in the Pattaya development study area, namely Na Klua, a community center, and South Pattaya (downtown), a tourist center.

2) The area along the shore line has been developed, but the inland area, except a section along Sukhumvit Highway, has remained an agricultural land.

3) The tourism development area is rather concentrated from the central to northern sections of the study area. Commercial, industrial and fishery activities are found at the northern section of the study area.

4) There is an island in the study area, namely Ko Lan. Ko Lan Island has about 80 accommodation units (bungalow type and apartment type) and restaurants.

(b) Physical Features - See Fig. 3.1.2

1) The development study area is generally composed of flat land and a gentle slope begins from the middle part of the study area.

2) Pattaya hill, (100 m above sea level) is located along the seashore at the middle part of the study area; and the hill has high potential to be a landmark of Pattaya beach.

3) As a special feature, the middle section of area between Sukhumvit Highway and Highway 3135 is a swamp area (+4.0 m) where lotus and other vegetation grow.

(c) Geology

1) The downtown area and southern beach are composed of beach sand and the area behind them is characterized by flat alluvial land.

2) There is a granitic hill at the central part of the study area, and this extends to the inland terrace.

3) Rice fields are located in the rich alluvial soil, and tapioca is cultivated in the rather unfertile areas.

(d) Climate - See Fig. 3.1.3

1) The study area is in the tropical rain forest zone, and the climate may be clearly classified into a dry season (November-April) and a wet season (May-October).

2) The average temperature is about 27°C and, the highest and lowest temperatures are recorded respectively in April and in December.

3) The average temperature of Pattaya is 2°C-3°C higher than Hawaii and Miami, but a little lower than Acapulco, Mexico. The temperature does not vary greatly from the average temperature. Humidity is high all year round, and the wet season is long. However, Pattaya Beach is well located in the area where the average temperature is about 1°C lower than Bangkok, and the number of rainy days and the amount of rain are comparatively less than other areas in Thailand, so it is suitable as an ocean resort.

4) The prevailing wind direction is south or south westerly during February-September and northerly during October-January.

(e) Water and Hydrology

1) Storm water flows into the sea from three rivers (Na Klua River, Pattaya River and Na Jom Tiem River), which flow from three different rain catchment areas.

2) These rivers, except the Na Klua, cover a rather limited area and waste watersheds are found within the study area.

(f) Vegetation

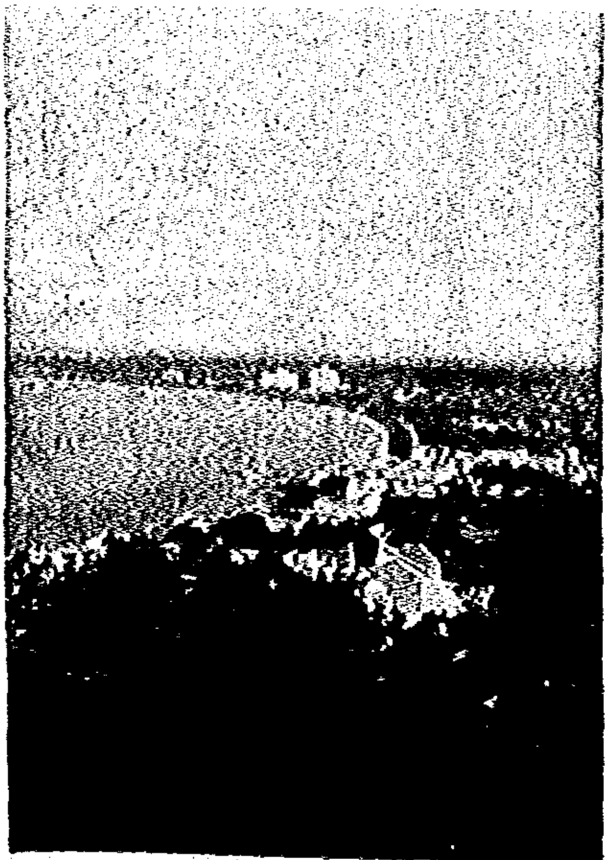
Most of the study area is either agricultural land or forests of coconut trees. Natural vegetation is only found at the seashore sand area and at the hill which is covered by evergreen forests.

Most of the agricultural land is planted with tapioca. There is no existing irrigation or other facilities for rice fields. As an attractive inland feature of the study area, coconut forests which create a natural tropical atmosphere are found in various areas.

(g) Natural Disaster

1) Most tropical typhoons originate in the South China Sea during the months of June to December and pass through the northern vicinity of Thailand during June to September and the Southern vicinity during October to December. No heavy damage has been recorded by tropical typhoons on the eastern side of the Gulf, but on the western side, some damage has occurred.

2) No typhoon damage has been recorded in the study area. Several years ago flooding in the study area occurred, but this was due more from human error than nature. No future natural disaster is anticipated in the study area.



General View of Pattaya from Pattaya Hill

Fig. 3.1.1 Geography

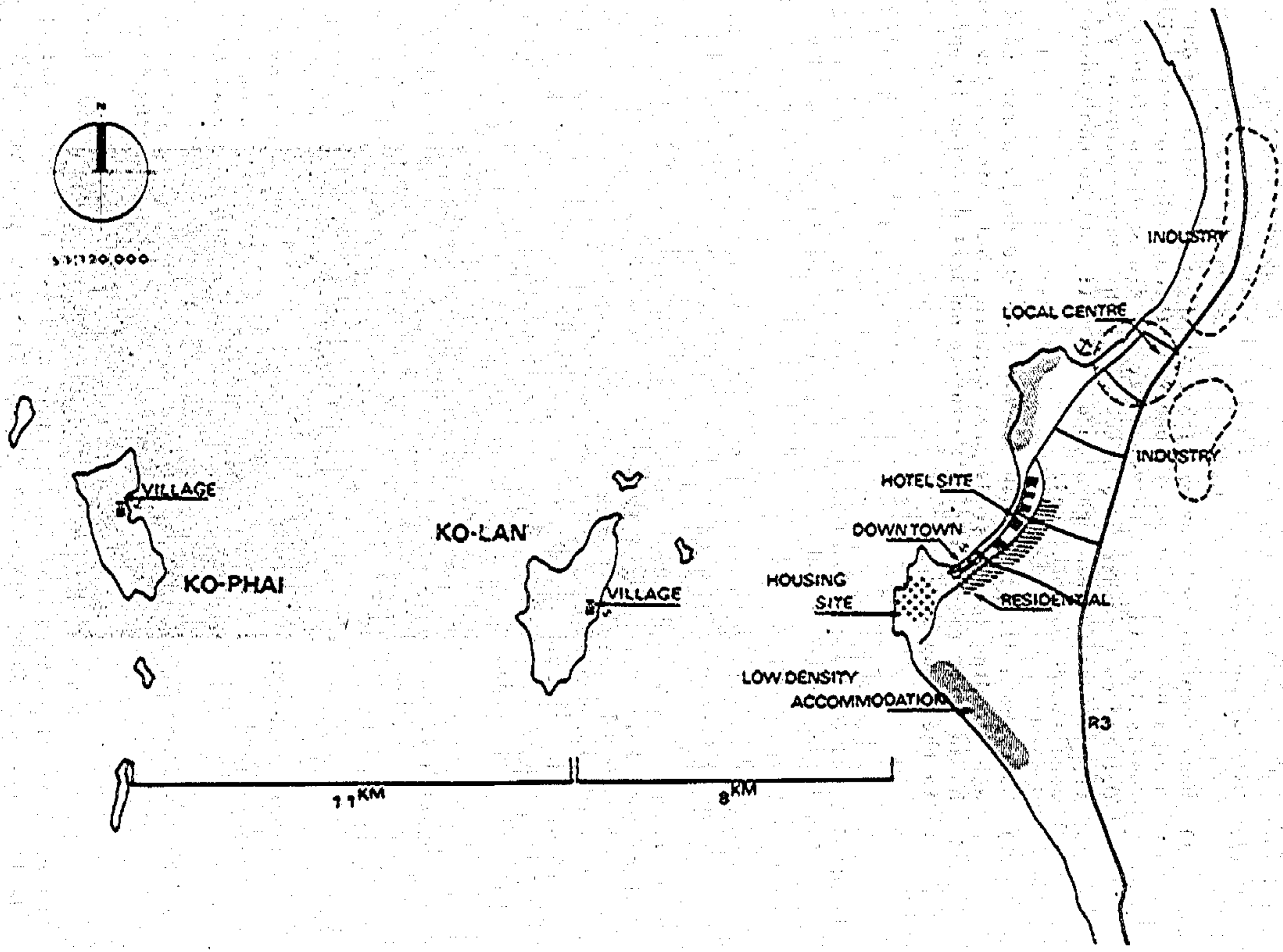


Fig. 3.1.2 Physical Features

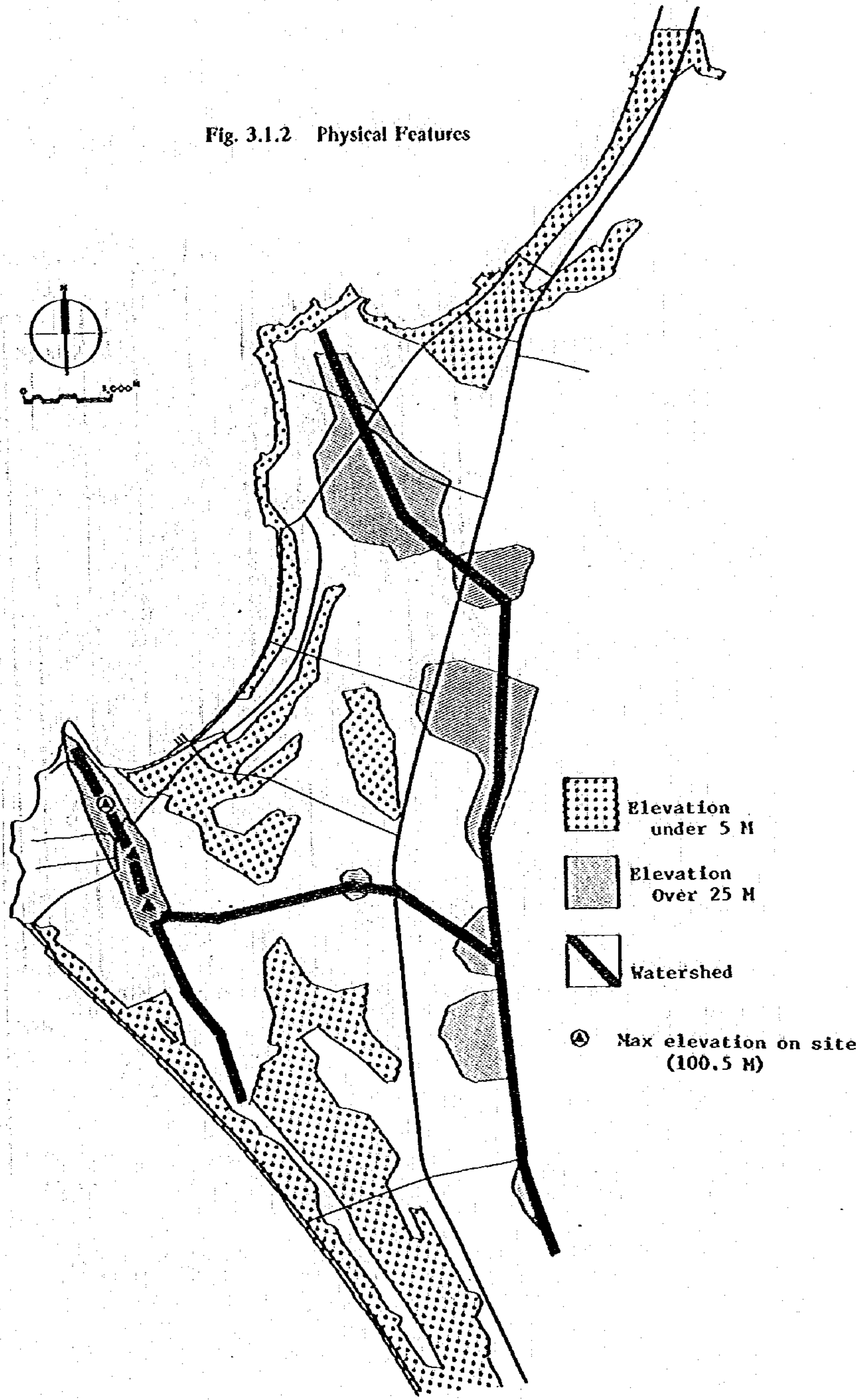


Fig. 3.1.3 Climate

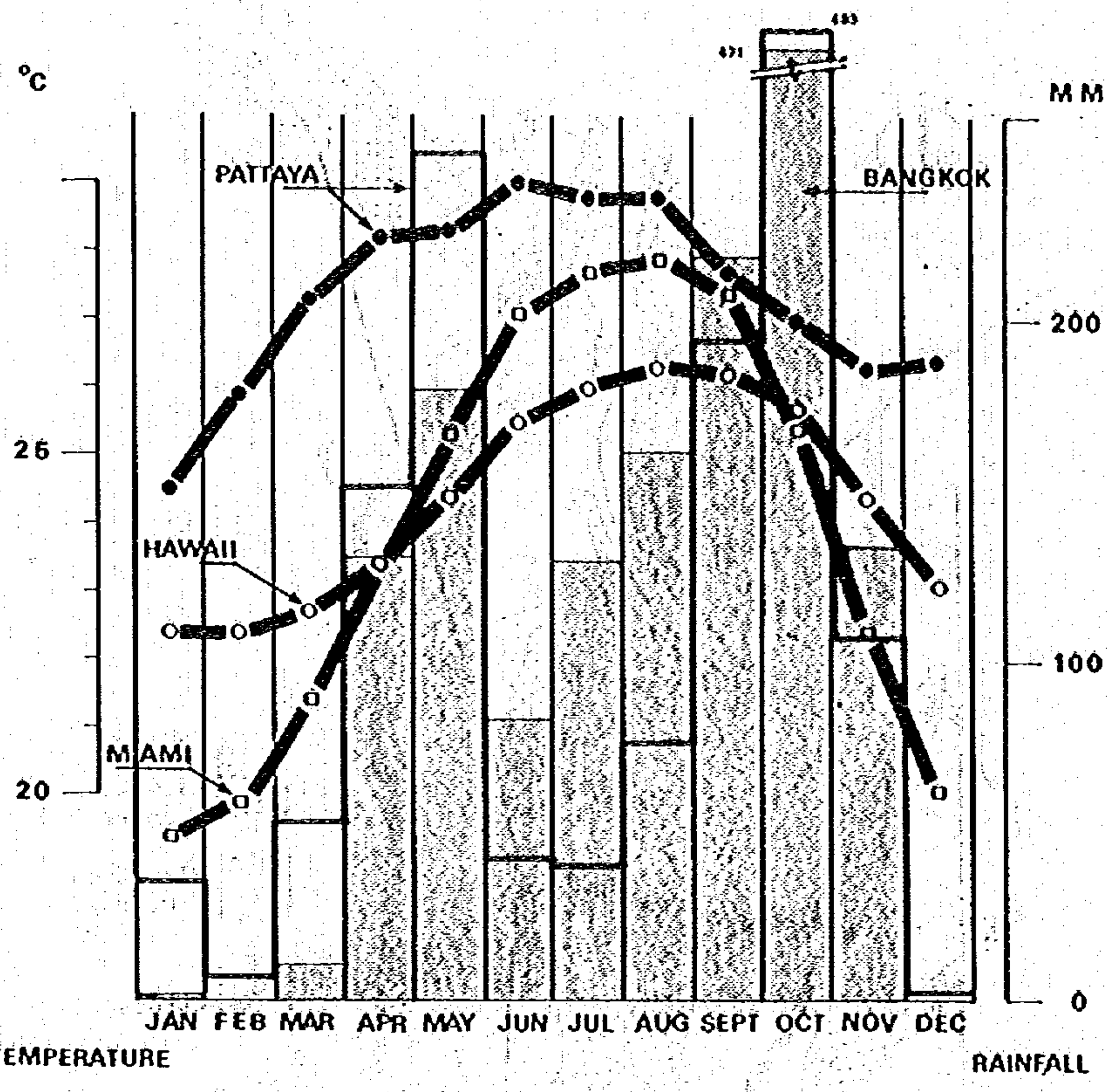
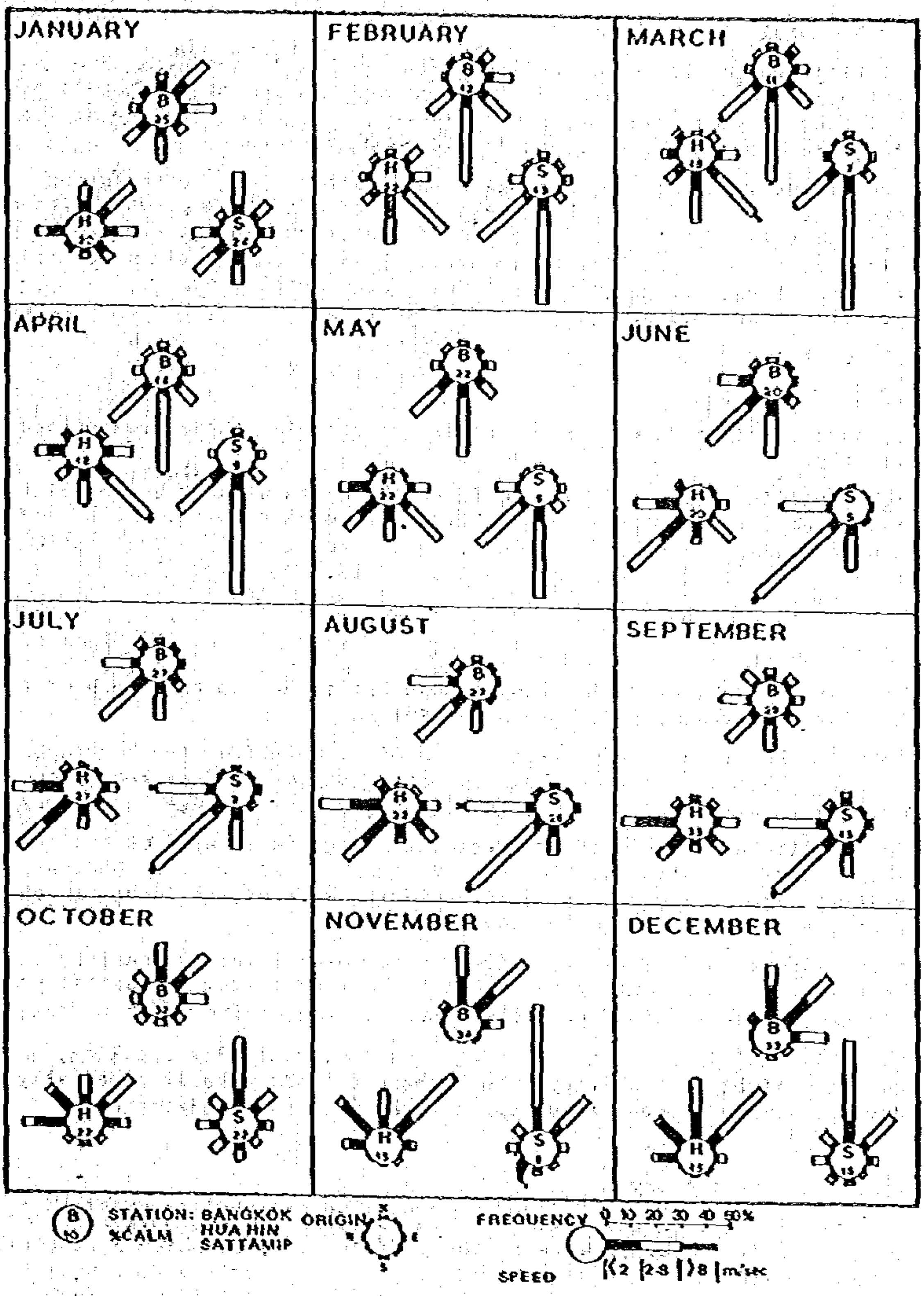


Fig. 3.1.4 Frequencies of Direction and Velocity of Wind in Pattaya



3.2 Present State of Sewage Facilities

The current state of sewage facilities is as follows:

3.2.1 Hotel

Existing sewage treatment facilities in the hotels surveyed were mostly designed to use the activated sludge method. A few of the hotels are treating their sewage very well with new equipment, and some using the activated sludge method are carrying out fairly good maintenance and management.

However, many hotels are, for all practical purposes, not treating their sewage at all. A few of the hotels utilized oxidation ponds and/or septic tanks, but in most cases, it was found that they did not seem to be managing or maintaining these facilities properly. Most of the hotels were utilizing after-treatment sewage on their lawns. Some hotels were spreading untreated sewage on their lawns.

3.2.2 Restaurant

Restaurants along Pattaya Seashore are discharging their sewage into the sea directly.

Night soil is temporarily stored in septic tanks without bottom-plates, discharged into the soil and seawater by natural seepage. Most of such tanks are washed over by the tides. Those restaurants using septic tanks with concrete bottoms use vacuum-cars to clean residual sludge.

3.2.3 Residences

There are 2 types of residences: those built next to the beach or along the side of streams, and those built inland.

Septic tanks are used for treating the night soil from the houses built inland. These septic tanks have no bottom plates, and as residents reported in direct interviews, the tanks are cleaned once in 1-3 years.

Almost all the domestic after-treatment sewage is sprayed on the ground. Septic tanks are also used for the treatment of sewage from houses existing along the beach or on riversides. However, residents in these areas claim that no periodic cleaning is done.

At the estuary of the Na Klua River where water level is sensitive to the tide, and thus tending to push out the sludge from the septic tanks, domestic sewage is discharged directly into the public water bodies.

The soil conditions in the planning area are, generally speaking, sandy and have light permeability. Both these factors make it especially easy for sewage to seep from septic tanks into the environment.

3.2.4 Tapioca factory

In 1976, 176 tapioca factories were in operation in Chonburi Province. Among them, 22 factories were in the project area, of which 9 factories have since stopped.

These tapioca factories are located along the Na Klua River, and the total production of tapioca starch is 172 tons per day by 13 factories.*
In these 13 factories, the amount of sewage generated in the production of 1 ton of starch is estimated to be 30-40m^3.

Regarding the quality of the sewage, the centrifugal system is employed to make the starch separate from raw milk, BOD5 is 3000-7500mg/lit and SS is 1500-2500mg/lit in the case of sewage from First Grade Factories, while these figures are 1200-4200mg/lit, and 1000-2000mg/lit, respectively, in the case of sewage from Second Grade Factories.
For the treatment of wastewater from tapioca factory, stabilization pond system is adopted at present.

According to the reference data*, there are 5 Second Grade Factories and one First Grade Factory which are equipped with the treatment facilities, while the remaining 16 Second Grade Factories have no treatment facilities. The First Grade Factory has a rather high capacity for the treatment of sewage. For details, mention will be made in the survey on water quality discussed in Section 3.5.2 of this report. Fig. 3.6.1 shows the location of tapioca factories.

3.2.5 Other Problems

There are strom water drainage along the streets in a part of the Na Klua area and in downtown Pattaya, and culverts have been constructed at several other places for drainage. Various effluents are discharged from houses to the side ditches for rain-drainage in the Na Klua area and downtown Pattaya, and the residents have been complaining about the objectionable odor caused thereby. The side ditches are from time to time cleaned by a pump-car which can remove sediment by pressured-water.

3.2.6 Effluent standards in Thailand

The following table shows the effluent standards of the Ministry of Industry and the recommended values for effluent standards of Ministry of Public Health.

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* Ministry of Industry by Department of Industry Works Factory Control Division Data on Tapioca Factories in Bang Lamang

* Report on Environmental Survey of Pattaya Environmental Standard Quality Division, The National Environment Board, July 1977

Table 3.2.1 Effluent Standards in Thailand

Characteristics*	Recommended Values of Ministry of Public Health	Ministry of Industry Requirements for Sewage and Industrial Wastewater
BOD	40	20 - 60 depending on dilution
COD	100	-
Suspended Solids	60	30 - 150
Heavy Metals (total)	50	1.0
Arsenic	0.1	-
Zinc	2.0	-
Copper	2.0	-
Iron	5.0	-
Cyanide	1.0	0.2
Ammonia Nitrogen	5.0	-
Sulphide	3.0	1.0
Oil and Grease	15.0	nil
Tar	none visible	nil
Phenols	0.05	1.0
Pesticides	0.01	nil
Detergents	1.5	-
Total Dissolved Solids	2000	2000
pH	5 - 9	5 - 9
Permanganate Values	-	60
Chlorine	5.0	1.0
Temperature	40°C	40°C

* All values are in mg/l, except pH and temperature.

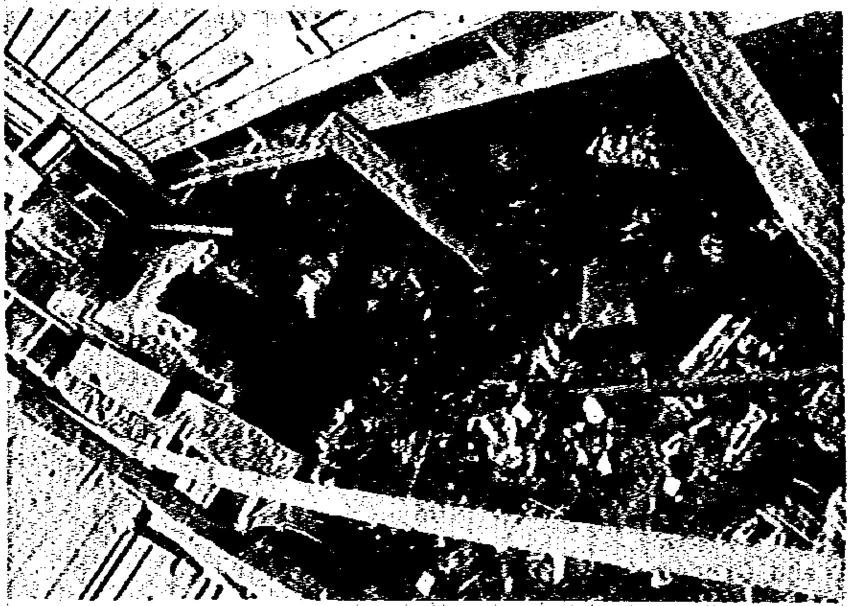
The following are the standard values stipulated by the Industrial Estate Authority of Thailand as effluent standards in the Bang Poo Industrial Estate located in the southwest area of Bangkok.

The quality of wastewater from industries before discharging into the central treatment plant at Bang Poo industrial estate:

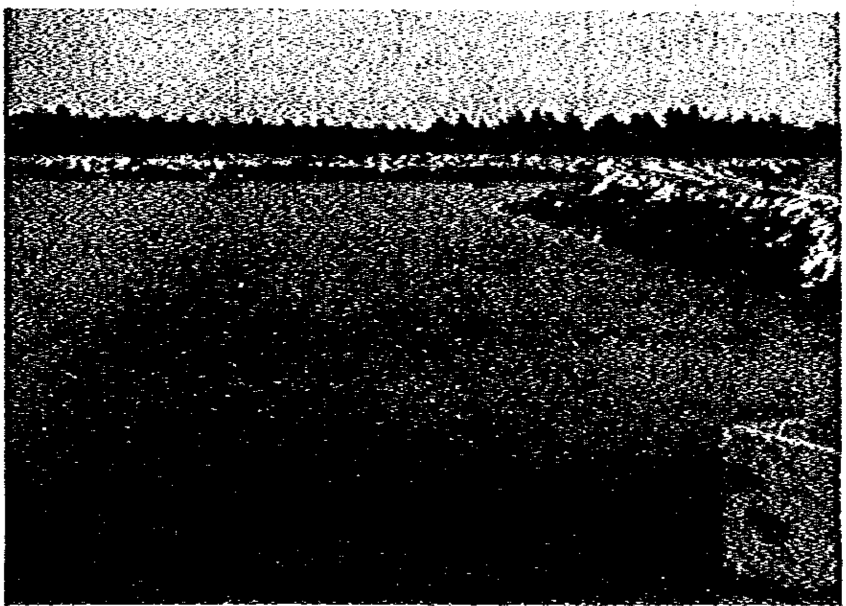
1.	B.O.D. (5 days 20°C)	Not more than	600 mg/l
2.	Suspended Solids	"	200 mg/l
3.	pH value	Between	5 - 10
4.	The temperature	Not more than	45°C
5.	Permanganate value	"	60 mg/l
6.	Sulfide (H_2S)	"	1 mg/l
7.	Cyanide (HCN)	"	0.2 mg/l
8.	Oil and Grease	None	
9.	Tar	None	
10.	Formaldehyde	Not more than	1 mg/l
11.	Phenal and cresols	"	1 mg/l
12.	Free chlorine	"	1 mg/l
13.	Zinc, Chromium, Arsenic, Silver, Selenium, Lead, Nickel	"	1 mg/l
14.	Insecticide, Radioactive Substance	None	

Regulation for the Bang Poo Industrial Estate.
There is a plan for the waste water discharging control at the Bang Poo Industrial Estate which is located south west of Bangkok.

Standard setting by the industrial estate authority of Thailand.

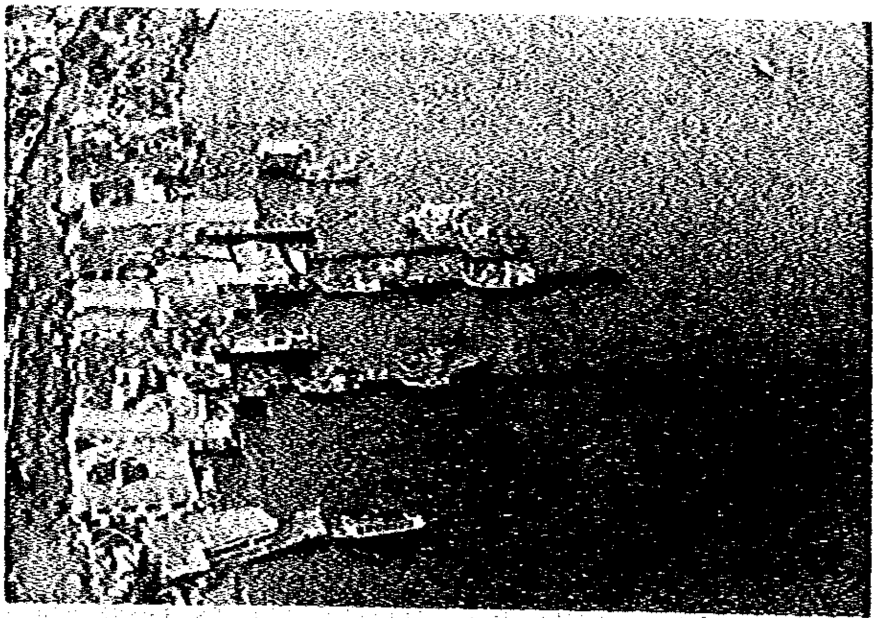


Existing outfall of storm water drainage



Stabilization pond at First Grade Tapioca Factory
(Na Klua)

Residential area along the Na Klua River.



Pattaya down town area.

3.3 Pollution Control by Sewerage System

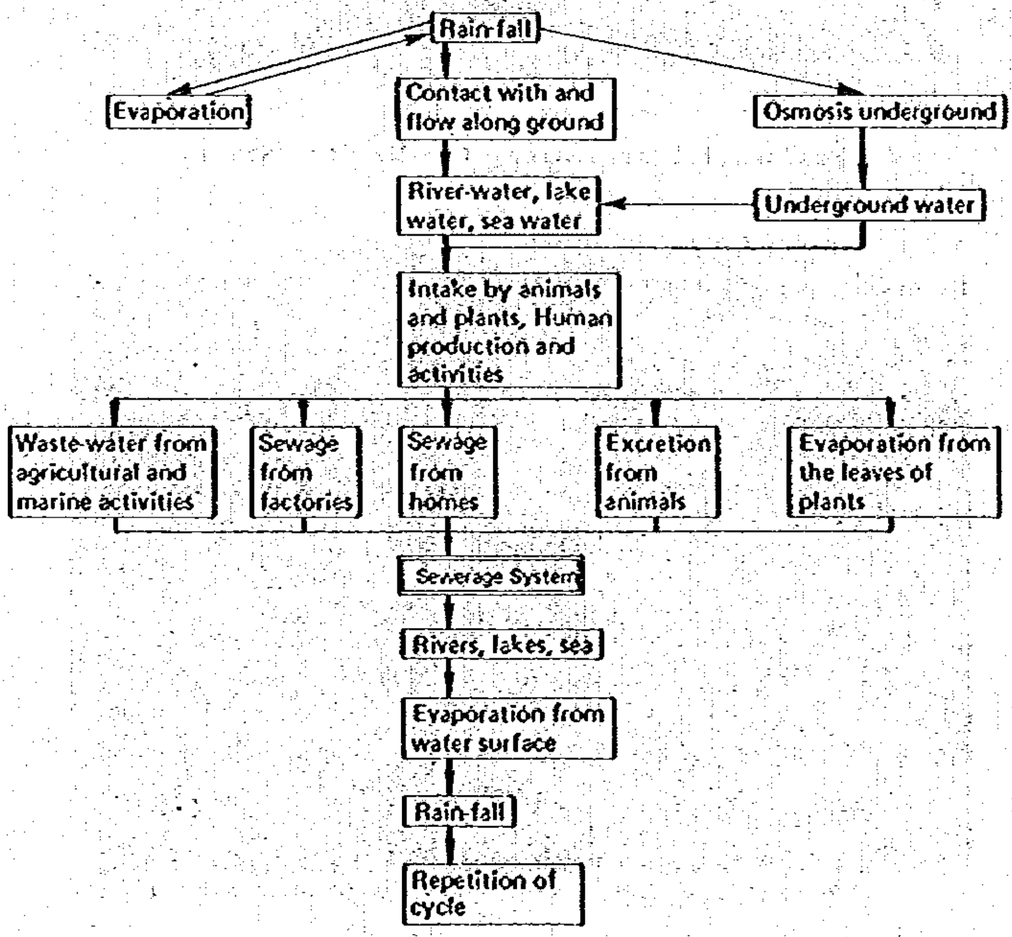
A sewerage system plays a role not only in enhancing the living environment in an urban area, but also plays a role in solving the problems of water pollution in watersheds for public uses.

In general, it is becoming more difficult to develop water as a basic natural resource in the future, and the relations bewteen demand and supply can also be expected to become more strained. This statement is also applicable to the present planning area.

Thus, in order to make effective uses of limited water resources, it may be necessary to try to effect a higher utilization of these resources through a higher degree of sewage treatment, re-use and circulatory uses, as well as through the maintenance of water-quality in public watersheds.

The following diagram shows a water-cycle which demonstrates the close relationship between sewage and water resources.

Fig. 3.3.1 Water Circulation Cycle



A sewerage system in the planning area can play the following roles:

3.3.1 Improvement and Protection of Living Environment of Region

(a) Improvement of regional environment

The sewage from residences and factories is discharged into the covered culverts and removed promptly, thus eliminating open accumulations of sewage where mosquitoes or flies can breed. This is an important way in which the regional environment can be improved.

The pollution at the estuaries of the Pattaya River and the Na Klua River will be eliminated, and residents in those areas can be free from the environmental pollution due to unpleasant odors.

(b) Improvement of living modes

The conventional toilet can be replaced by the more pleasant and hygienic flush toilet. As for the current system of septic tanks, its sewage treating function is low and it is not sufficently maintained. This problem will be solved by the construction of a sewerage system.

(c) Prevention of contagious diseases

Contagious diseases can be prevented by improving the living environment.

(d) Prevention of flood

By improvement of drainage in low-lying marshlands, it will be possible to prevent floods of the rivers in the area.

3.3.2 Water Pollution Control in Public Water Bodies

A sewerage system, by playing an important role in the cleaning of the public watershed, is an essential condition for human health and pleasant living condition which cannot always be measured directly.

For example:

(a) Animals and plants in water channels and by the seaside, can be protected from the natural environment.

(b) Water resource can be protected.

(c) The seaside environment can be maintained for recreational activities.

The Pattaya area is developed as a seaside resort, and maintenance of the water quality of the public water bodies, especially the sea area, is essential.

The following tables indicate sewage volumes and BOD pollution loads under the condition of a future sewerage system and by comparison under the conditions of a continued lack of such a system.

Table 3.3.1 Change in Quality & Quantity of Sewage

(Daily Average)

Non-treated water: Factory 300 mg/l, General 200 mg/l, Underground water 5 mg/l

Treated water: 30 mg/l.

Others: *1 200 mg/l, *2 300 mg/l, *3 30 mg/l, *4 40 mg/l

Area	Item	Non-Sewerage System					Stabilizatoin Pond System							Others		(A)	Ratio of Conversion
		Quantity				Quality	Quantity					Quality		Quantity	Quality		
	Year	Resident & One Day Tripper (m³/d)	Hotel & Villa (m³/d)	Industry (m³/d)	Total (m³/d)	(a) BOD₅ (kg/d)	Resident & One Day Tripper (m³/d)	Hotel & Villa (m³/d)	Industry (m³/d)	Ground Water (m³/d)	Total (m³/d)	(b) BOD₅ (kg/d)	(c) After Treatment (kg/d)	(m³/d)	(d) BOD₅ (kg/d)	(c)+(d) (kg/d)	(1-A/a)x100 (%)
Na Klua	1966	1,650	-	-	1,650	330	-	-	-	-	-	-	-	*1 1,650	330	330	0
	1976	2,750	80	5,000	7,830	2,066	-	-	-	-	-	-	-	*1 2,830 *2 5,000	2,066	2,066	0
	1981	2,910	80	5,000	7,990	2,098	2,090	-	2,600	1,160	5,850	1,204	776	*1 900 *4 2,400	276	452	78
	1986	3,850	80	5,000	8,930	2,286	3,850	-	2,600	1,700	8,150	789	245	*3 80 *4 2,400	98	343	85
	1991	4,760	80	5,000	9,840	2,468	4,760	80	5,000	2,490	12,330	2,480	370	-	-	370	87
	1996	5,550	80	5,000	10,630	2,626	5,550	80	5,000	2,730	13,360	2,640	401	-	-	401	85
Pattaya	1966	2,030	-	-	2,030	406	-	-	-	-	-	-	-	*1 2,030	406	406	0
	1976	2,490	1,920	-	4,410	882	-	-	-	-	-	-	-	*1 4,410	882	882	0
	1981	3,040	1,920	-	4,960	992	960	270	-	430	1,660	248	50	*1 3,730	746	796	20
	1986	3,760	2,280	-	6,040	1,208	3,760	2,110	-	2,040	8,150	1,184	245	*3 170	5	250	79
	1991	4,260	2,280	-	6,540	1,308	4,260	2,280	-	2,260	8,800	1,319	264	-	-	264	80
	1996	4,780	2,270	-	7,050	1,410	4,780	2,270	-	2,380	9,430	1,422	283	-	-	283	80
Total	1966	3,680	-	-	3,680	736	-	-	-	-	-	-	-	*1 3,680	736	736	0
	1976	5,240	2,000	5,000	12,240	2,948	-	-	-	-	-	-	-	*1 7,240 *2 5,000	2,948	2,948	0
	1981	5,950	2,000	5,000	12,950	3,090	3,050	270	2,600	1,590	7,510	1,452	226	*1 4,630 *4 2,400	1,022	1,248	60
	1986	7,610	2,360	5,000	14,970	3,494	7,610	2,110	2,600	3,740	16,300	1,973	490	*3 250 *4 2,400	103	593	83
	1991	9,020	2,360	5,000	16,380	3,776	9,020	2,360	5,000	4,750	21,130	3,799	634	-	-	634	83
	1996	10,330	2,350	5,000	17,680	4,036	10,330	2,350	5,000	5,110	22,790	4,062	684	-	-	684	83

Table 3.3.2 Change in Quality & Quantity of Sewage

(Daily Maximum)

Non-treated water: Factory 300 mg/l, General 200 mg/l, Underground water 5 mg/l

Treated water: 30 mg/l.

Others: *1 200 mg/l, *2 300 mg/l, *3 30 mg/l, *4 40 mg/l

Area	Item	Non-Sewerage System					Stabilization Pond System							Others			Ratio of Conversion
		Quantity				Quality	Quantity					Quality		Quantity	Quality	(A)	
	Year	Resident & One Day Tripper (m^3/d)	Hotel & Villa (m^3/d)	Industry (m^3/d)	Total (m^3/d)	(a) BOD_5 (kg/d)	Resident & One Day Tripper (m^3/d)	Hotel & Villa (m^3/d)	Industry (m^3/d)	Ground Water (m^3/d)	Total (m^3/d)	(b) BOD_5 (kg/d)	(c) After Treatment (kg/d)	(m^3/d)	(d) BOD_5 (kg/d)	(c)+(d) (kg/d)	(1-A/a)x100 (%)
Na Klua	1966	2,480	-	-	2,480	496	-	-	-	-	-	-	-	*1 2,480	496	496	-
	1976	4,130	150	5,000	9,280	2,356	-	-	-	-	-	-	-	*1 4,280 *2 5,000	2,356	2,356	-
	1981	4,460	150	5,000	9,610	2,422	3,190	-	2,600	1,160	6,950	1,424	209	*1 1,420 *4 2,400	380	589	75.7
	1986	5,880	150	5,000	11,030	2,706	5,880	-	2,600	1,700	10,180	1,965	305	*3 150 *4 2,400	101	456	83.1
	1991	7,290	150	5,000	12,440	2,988	7,290	150	5,000	2,490	14,930	3,000	448	-	-	448	85.0
	1996	8,480	150	5,000	13,630	3,226	8,480	150	5,000	2,730	16,360	3,240	491	-	-	491	84.7
Pattaya	1966	3,050	-	-	3,050	610	-	-	-	-	-	-	-	*1 3,050	610	610	-
	1976	3,740	3,810	-	7,550	1,510	-	-	-	-	-	-	-	*1 7,550	1,510	1,510	-
	1981	4,820	3,810	-	8,630	1,726	1,580	560	-	430	2,570	430	77	*1 6,490	1,298	1,375	20.3
	1986	5,960	4,550	-	10,510	2,102	5,960	4,220	-	2,040	12,220	2,046	367	*3 330	10	377	82.1
	1991	6,750	4,550	-	11,300	2,260	6,750	4,550	-	2,260	13,560	2,271	407	-	-	407	82.0
	1996	7,410	4,490	-	11,900	2,380	7,410	4,490	-	2,380	14,280	2,391	428	-	-	428	82.0
Total	1966	5,530	-	-	5,530	1,106	-	-	-	-	-	-	-	5,530	1,106	1,106	-
	1976	7,870	3,960	5,000	16,830	3,866	-	-	-	-	-	-	-	16,830	3,866	3,866	-
	1981	9,280	3,960	5,000	18,240	4,148	4,770	560	2,600	1,590	9,520	1,854	286	10,310	1,678	1,964	52.7
	1986	11,840	4,700	5,000	21,540	4,808	11,840	4,220	2,600	3,740	22,400	4,011	672	2,880	111	833	82.7
	1991	14,040	4,700	5,000	23,740	5,248	14,040	4,700	5,000	4,750	28,490	5,271	855	-	-	855	83.7
	1996	15,890	4,640	5,000	25,530	5,606	15,890	4,640	5,000	5,110	30,640	5,631	919	-	-	919	83.6

Fig. 3.3.2 Total Quantity of Sewage

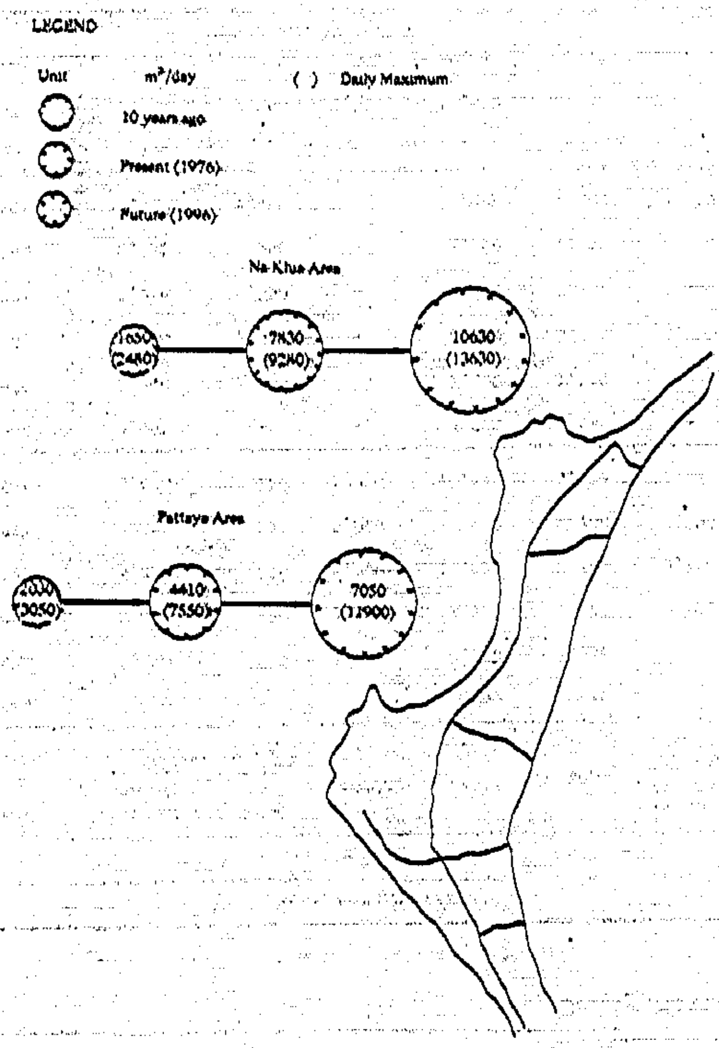
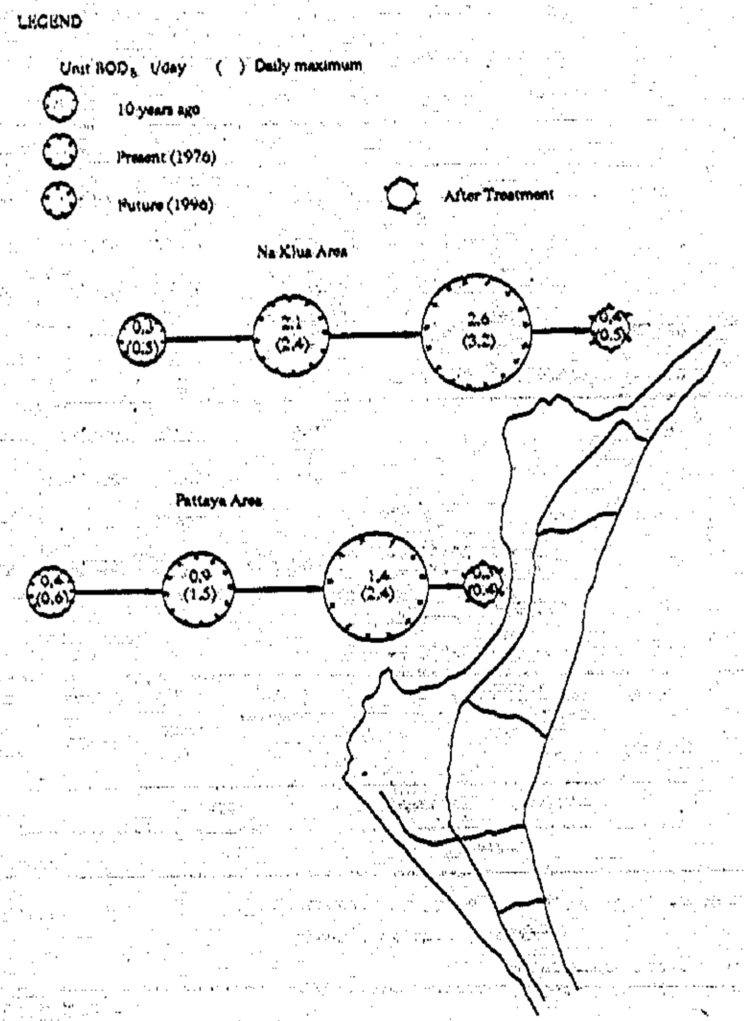


Fig. 3.3.3 Quality of Sewage



3.3.3 Circulatory Uses of Water Resources

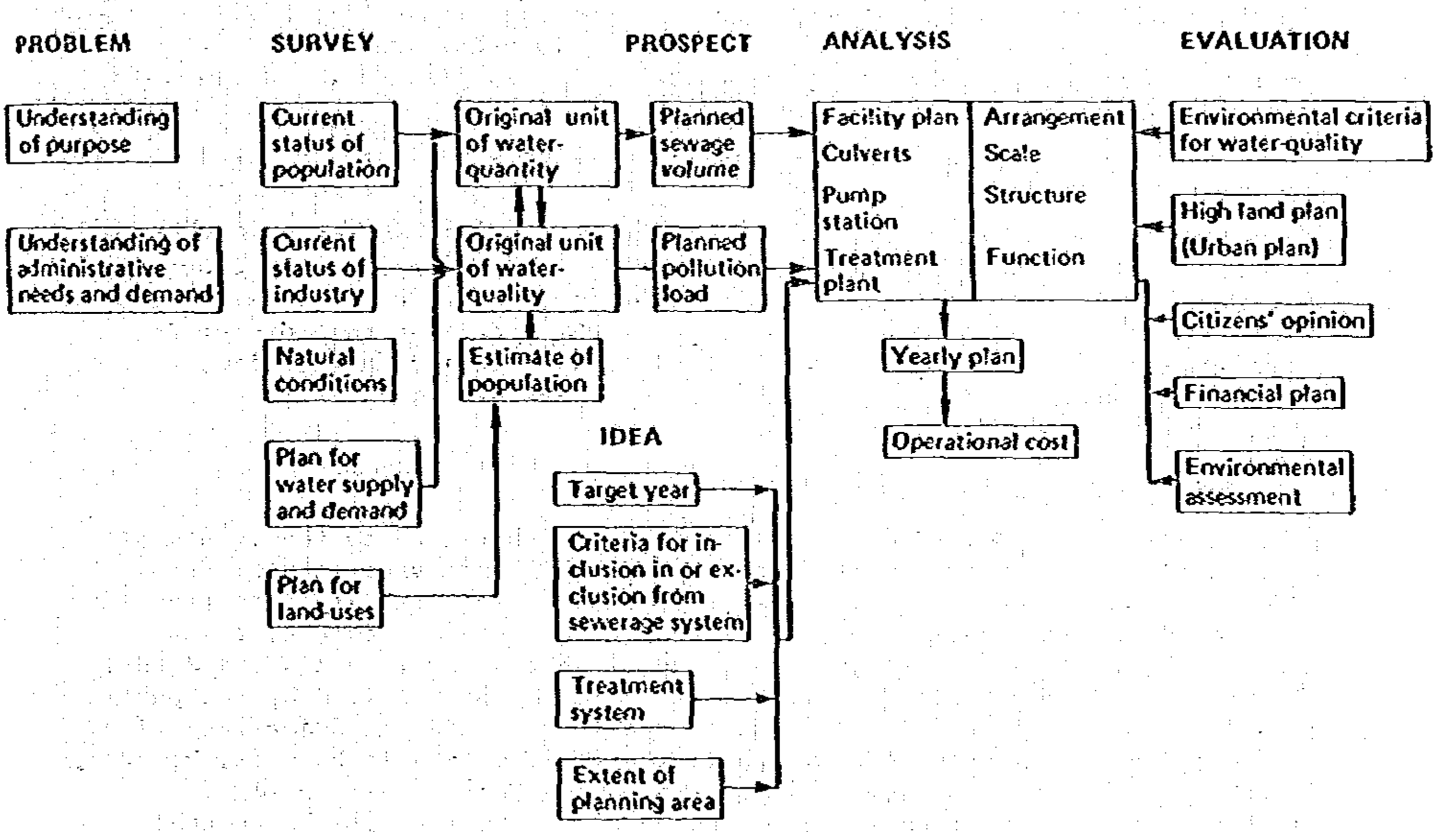
By putting the treated sewage water into the cycle for re-use, effective use can be made of it as a new resource. As mentioned above, a system receives the sewage after clean water taken from public water bodies such as rivers, etc., is used for human lives and activities. It plays an important role in returning resources to the water bodies for public use again, after the sewage has been treated up to the quality of water that was originally used.

In the absence of a treatment system, the advance of pollution in the water bodies for public use would force a lower quality of current water resources. The position of Pattaya as a seaside resort would be lost, and problems of environmental hygiene will be aggravated for the residents.

3.4 Basic Plan

A plan for sewerage system was made in accordance with the following procedure:

Fig. 3.4.1 Flow Chart of the Basic Plan of Sewerage System



The land-use plan and the population estimate were abstracted from the master plan prepared by JICA in 1977.

3.4.1 Basic Policy for the Project

(a) Stepwise transfer from present hotel sewage treatment to public facilities

At present, almost all hotels in Pattaya area have their own sewage treatment facilities. Two or three hotels are obtaining treated water with a good quality. At some hotels in which management and operation are not in good condition, sewage directly seeps into the earth without any treatment.

Therefore, it is recommended that sewage from hotels be treated through a public sewerage system. Transition from private to public sewage treatment will be implemented gradually, starting with those hotels whose current operations are unfavorable.

However, the choice of whether sewage from hotels is to be treated by public sewerage facilities or by the hotel's own facilities is left to the hotels themselves. In case those hotels treat their sewage themselves, water quality standards for treated water must be clearly explained to the hotel managements and these standards must be maintained.

(b) Service ratio for residents

In the master plan, a 100% service ratio was assumed for the sewerage system in the residential area designated in the land use plan, while a 70% service ratio was assumed for the inhabitants in other areas. However, in this feasibility study, a 100% service ratio was planned for a sewerage system extending to all the inhabitants.

However, no planning was made in this feasibility study for the service-piping to the inhabitants in remote areas from the existing main roads.

In order for residents to be able to make use of public sewage facilities, it must be expected that residents will have to bear considerable expenses for the installation of house drain and for improvement of toilets. There is thus some reason to fear that in some cases the diffusion rate of the new sewerage system might fail to reach the levels specified in the plan. A system of monetary loans is suggested as a possible means of overcoming the problems involved.

(c) Policy with respect to tapioca factories

Detailed explanation is made in Section 3.6.1 with regard to the treatment of industrial wastewater. The Government of Thailand issues strict regulations on wastewater from tapioca factories in keeping with its intention of maintaining a clean environment. Thus, in the present project, treatment facilities should meet the requirements of the Government's standards, and the sewage from First Grade Factories need not be received by the public sewerage system. It is planned that sewage from the Second Grade Factories be treated by the public sewerage system. Provision should be made, however, for the possibility that sewage from First Grade Factories in which facilities might fail to meet the Government's criteria, could be treated by the public system. Thus, the plan should take into account the possibility of securing the needed land and extending the necessary pipes to cope with such situations.

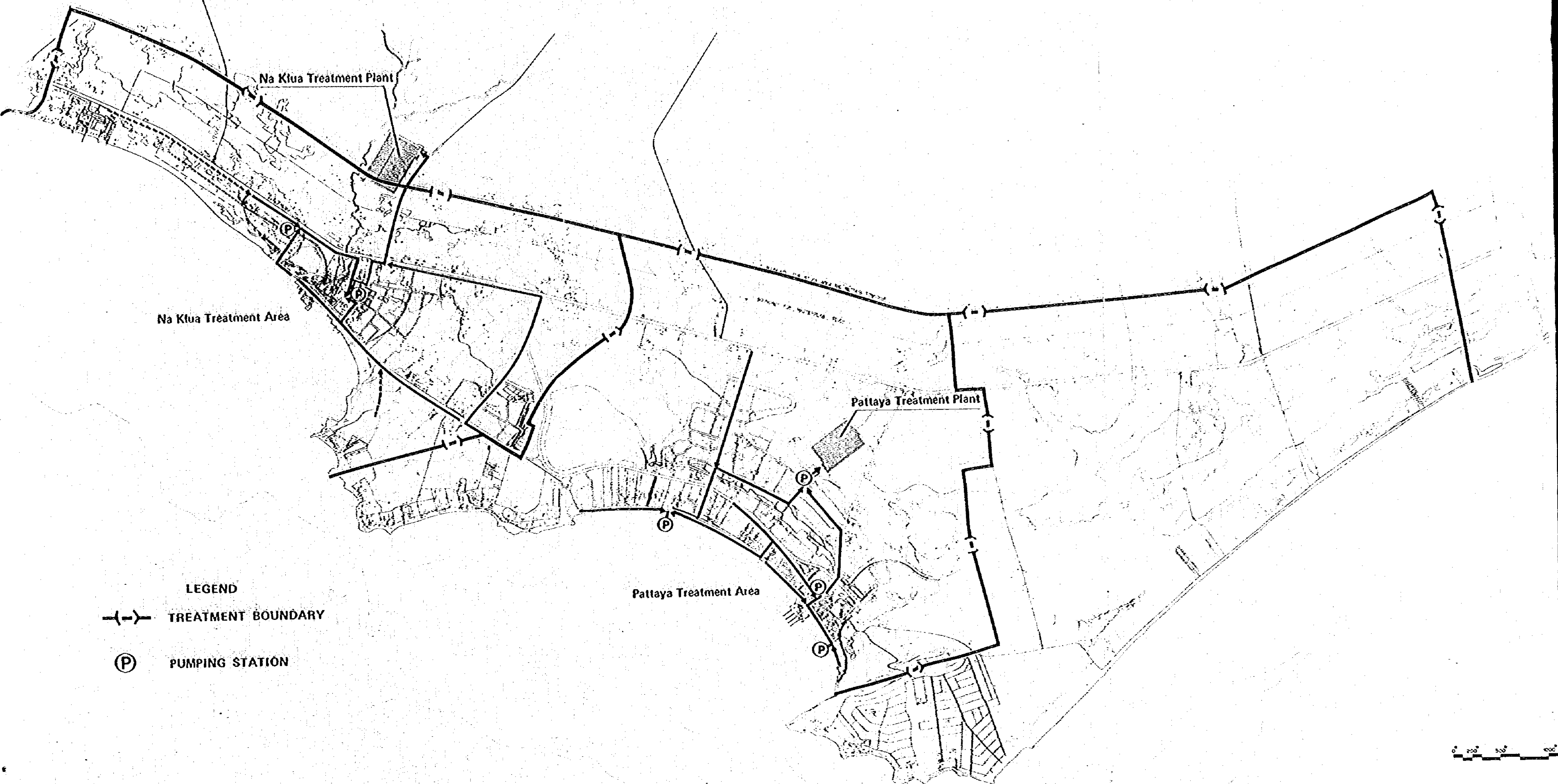


FIG 3.4.2 DRAINAGE AREA FOR SEWERAG

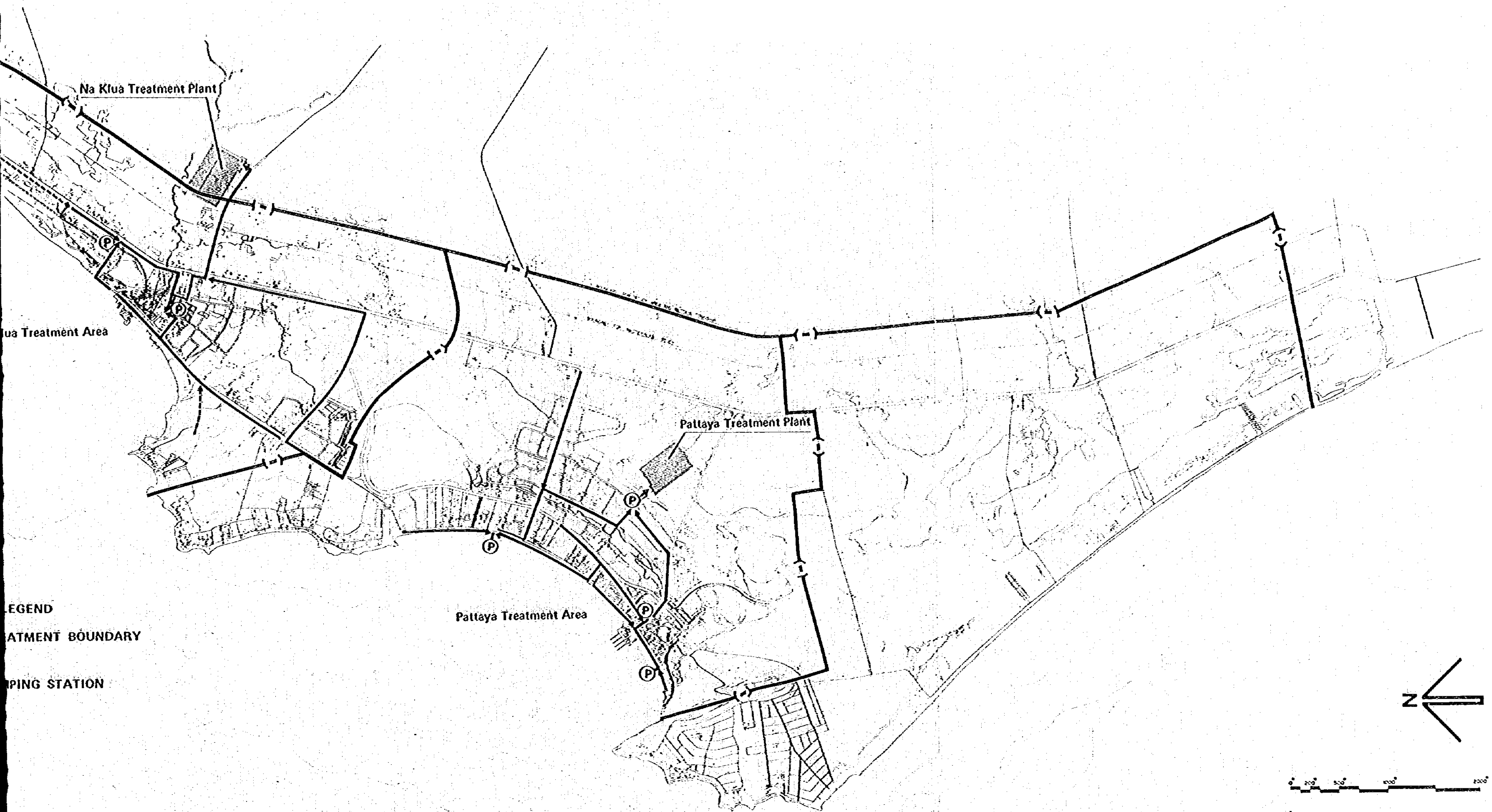
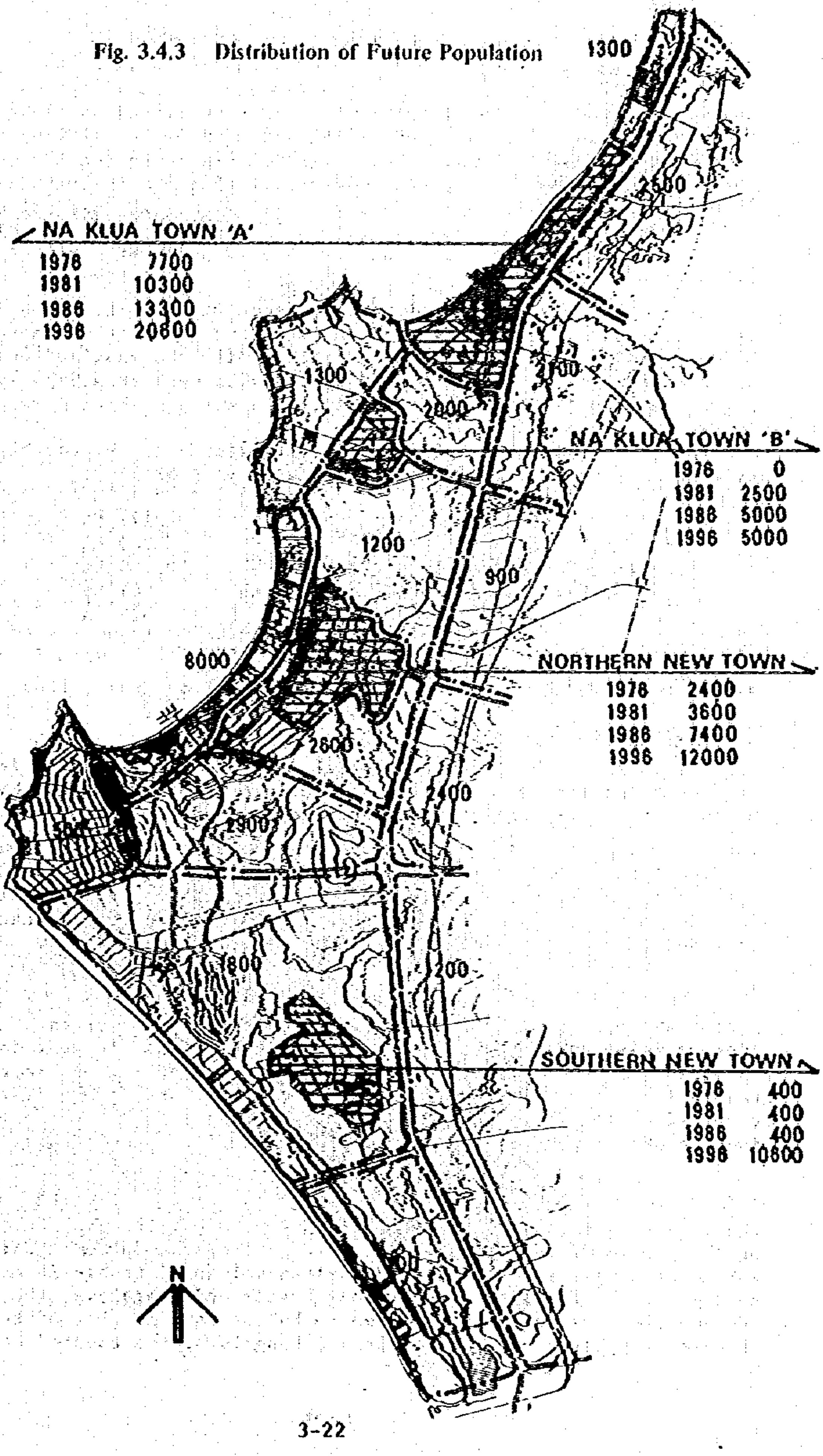


FIG 3.4.2 DRAINAGE AREA FOR SEWERAGE SYSTEM

Fig. 3.4.3 Distribution of Future Population



3.4.2 Planned Target Year

The target year for the planning of a sewerage system shall be 1996, and the planning is made for the facilities needed to meet the expected requirements at that time. However, the estimations for the construction costs and maintenance costs are made for facilities to be constructed by 1986.

3.4.3 Study Area

The study area was designated in accordance with the Land Use Plan of the master plan. The study area shall extend from the southern end of Buddhist College to the auto race track, while the east and west boundaries shall be the east side of the 900m east from Sukhumvit Highway and Ko Lan Island, respectively.

The total area is about 3,400ha. The study area may be roughly divided, by type of land use, into the following 5 types of land:

Hotel & Bungalow area	177 ha
Residential area	269 ha
Area to be preserved in present state	2,169 ha
Area for business and other activities	281 ha
Others	522 ha

3.4.4 Range and Scope

(a) Population forecast

Fig. 3.4.3 shows the population which is expected to benefit from the treatment facilities, as well as the allotment of population by region, based on the estimates of future population made in the master plan.

The study area can be roughly divided into the following 3 areas, namely, Na Klua Area, Pattaya Area and Ko Lan Area. Na Klua Area includes residences, tapioca factories and partial bungalows, while Pattaya Area includes hotels, bungalows, restaurants and residences. Ko Lan Island includes housing sites and resort facilities.

(b) Collection system

A separate system will be adopted for the collection system. The average rainfall in the study area is about 1,500mm per year concentrated in the months from April to October. Periods of uninterrupted rainfall are generally short (usually no more than 1-1.5 hour); thus the combined system would prove to be uneconomical because of the greatness in size of the culvert sections in comparison with the sewage volume.

(c) Amount of sewage

The planned sewage volume was obtained from the forecasts for the volume of the public water supply. Table 3.6.18 shows the planned daily average volume of sewage and the planned maximum volume of sewage in each treatment area. In facilities other than hotels and bungalows, the unit of sewage-volume per person was taken to be the same as that of the volume of water supplied. As for hotels and bungalows, the adopted sewage volume excluded water supply for air conditioning and swimming pools. The volume of underground water was regarded as 20% of the planned maximum volume of sewage. In this calculation, the fact that the level of underground water is very high during the rainy season was taken into consideration, as were also the "Master Plan on Sewerage, Drainage and Flood Protection Systems*" and the "Design Guideline for Sewerage System and its explanation (1972)*" of the Japanese Sewerage Association. As a result of these calculations, the daily maximum planned volume of sewage is 13,240 m^3/d at Na Klua Area, and 12,600 m^3/d at Pattaya Area in 1986.

3.4.5 Relation with Waterworks Plan

There are close relations between the plan for water supply and that for sewerage system, although the former is not included in this feasibility study.

We negotiated during the survey period with N.E.S.D.B. (National Economic and Social Developing Board) in charge of water supply, and thus were able to make an adjustment of the water supply and sewerage systems. Later, responsibility for waterworks was transferred to another institution. Up to the present, no data has been available on current plans for waterworks in the Pattaya Area. In calculating the volume of planned sewage, the standards which we assumed, were derived from the planned volume of water supply as calculated to be in keeping with the information obtained during the survey period.

For more details, see Section 3.6: Estimated Amount of Sewage.

Existing Na Klua Reservoir for Water Supply

3.5 Field Survey

The survey on the existing sewerage system was performed for about 50 days in the period from Dec. 19, 1977 to Feb. 11, 1978. During this period, a survey was made on the topography, subsoil condition and underground water. Also questionnaires were delivered to hotels, houses (homes), factories and restaurants. An outline is given as follows;

3.5.1 Survey of Subsoil Conditions

Fig. 3.5.1 indicates the bore hole points. The survey showed that the seaside areas of Na Klua and Pattaya consist of sand hills of 4-5m depth, underlaid by hard clay and silt. N-values were quite high at all surveyed points, namely, the values were about 15 up to G.L.-2m, 40 up to G.L.-5m, and over 50 in the strata below -5m.

The standard penetration test was used to compute the relative density, the interior frictional angle and the bearing power co-efficient; these are shown graphically in Fig. 3.5.2.

The relative density of the soil at N-values, as given by Terzaghi is as follows:

N-values	Relative density (Terzaghi-Peck)
0 - 4	Very loose
4 - 10	Loose
10 - 30	Medium
30 - 50	Dense
>50	Very dense

Site considerations - when the N-values are below 10, the soil allows easy digging by shovel, at values above 50, digging becomes very difficult. Driving sheet piles also becomes difficult. The allowable bearing power of mat foundation above sand subsurface, according to Terzaghi and Peck, is given below.

Table 3.5.1 Allowable Bearing Power of Mat Foundation above Sand Subsurface

Relative Density	Loose	Medium	Dense	Very Dense
N	<10	10 - 30	30 - 50	>50
$q_a(t/m^2)$	Compress	7 - 25	25 - 45	>45

The clay consistency, the uni-axial compression, and the allowable bearing power at N-values were computed for the viscous soil using the standard penetration test, the results are shown graphically in Fig. 3.5.3.

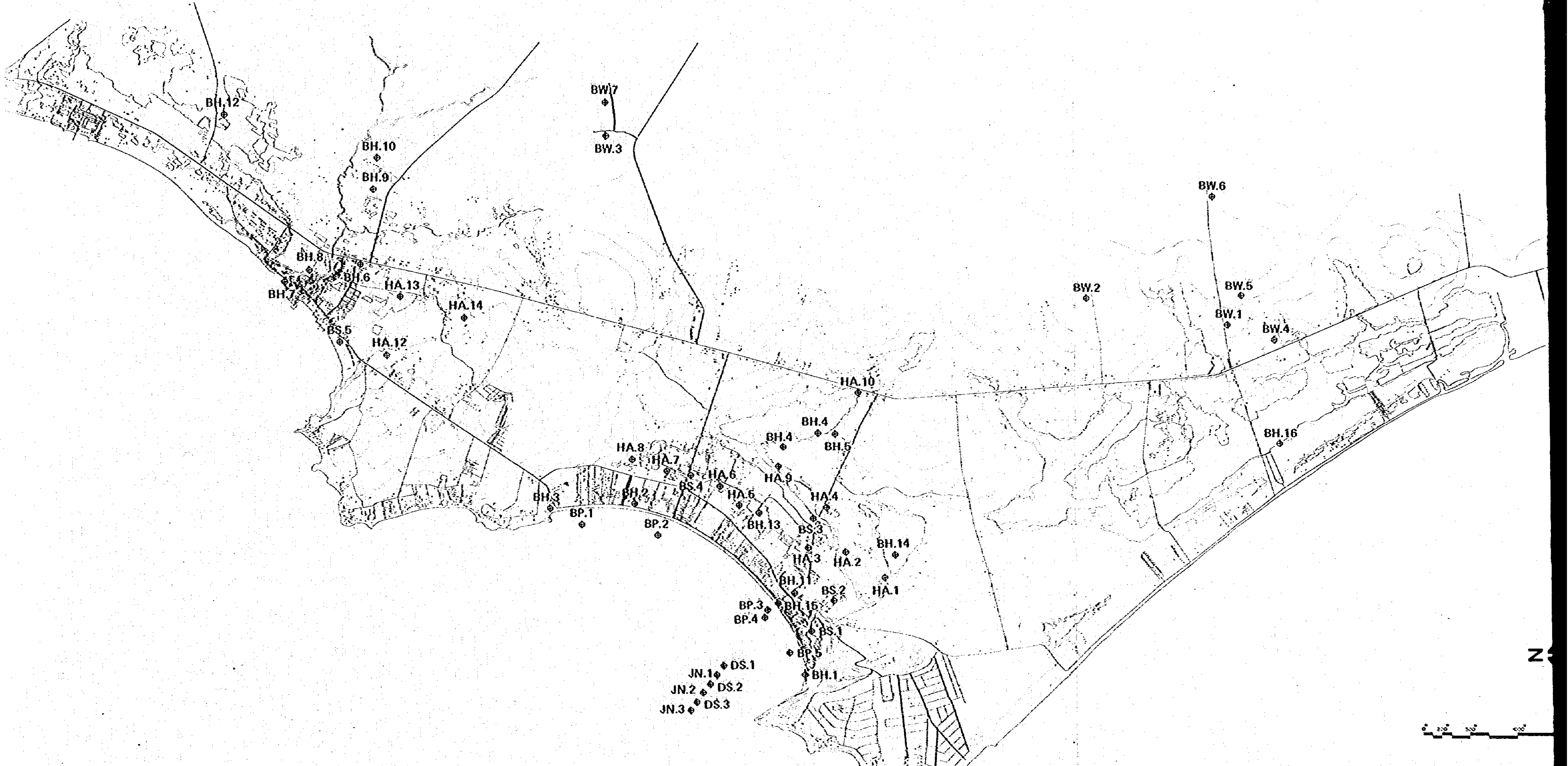


FIG 3.5.1 LOCATION OF FIELD INVESTIG

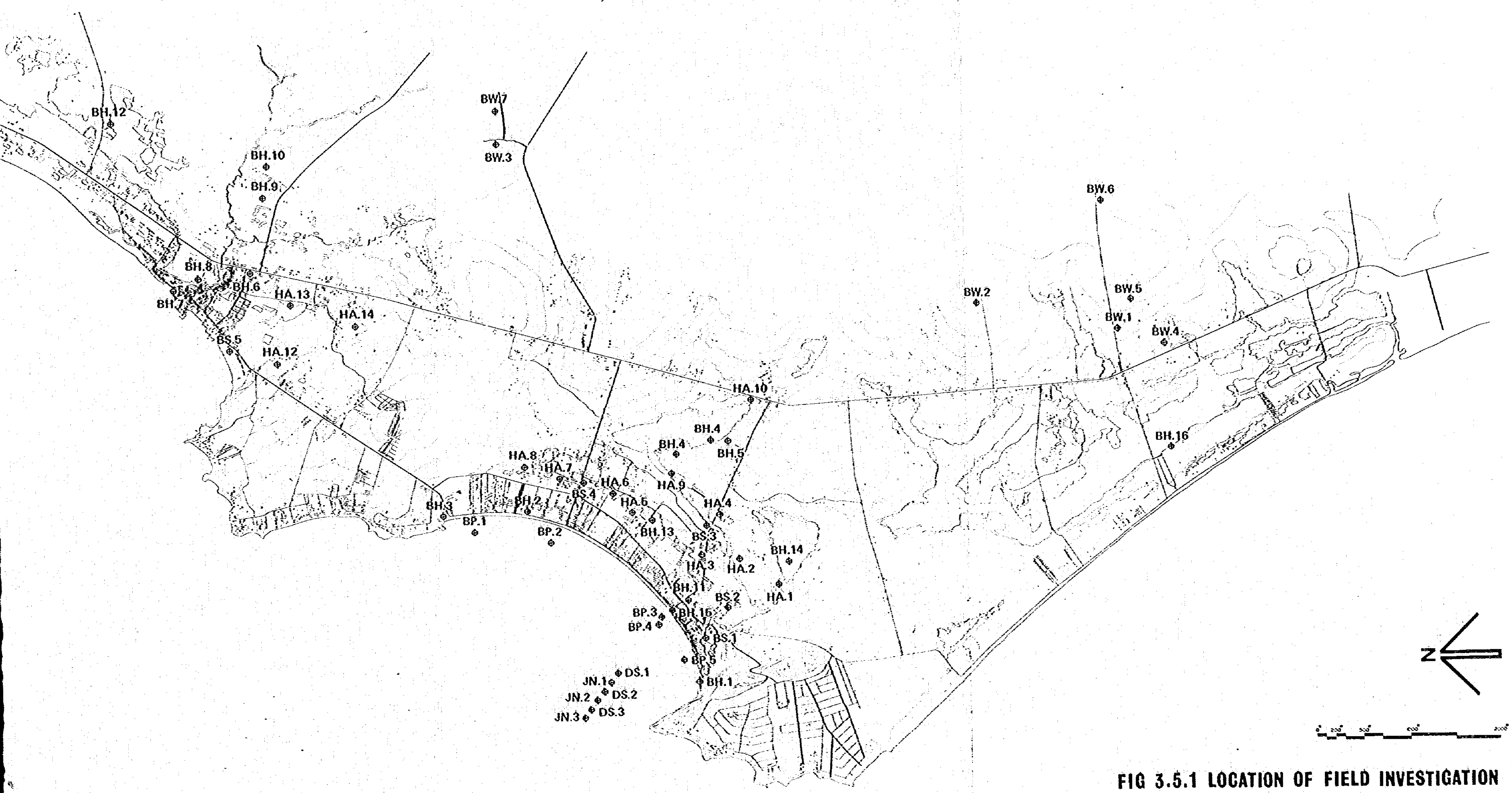


FIG 3.5.1 LOCATION OF FIELD INVESTIGATION

Fig. 3.5.2 Relation between N. Values and Relative Density of Soil. Interior Frictional Angle and Bearing Power Coefficient

(Source: Peck, Hanson, Thornburn)

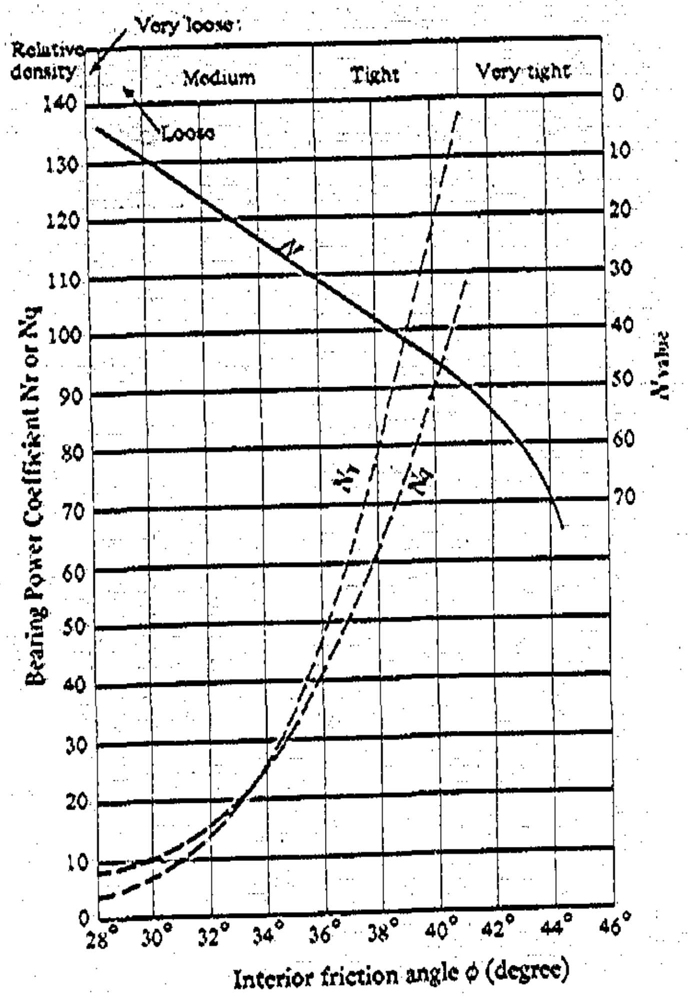
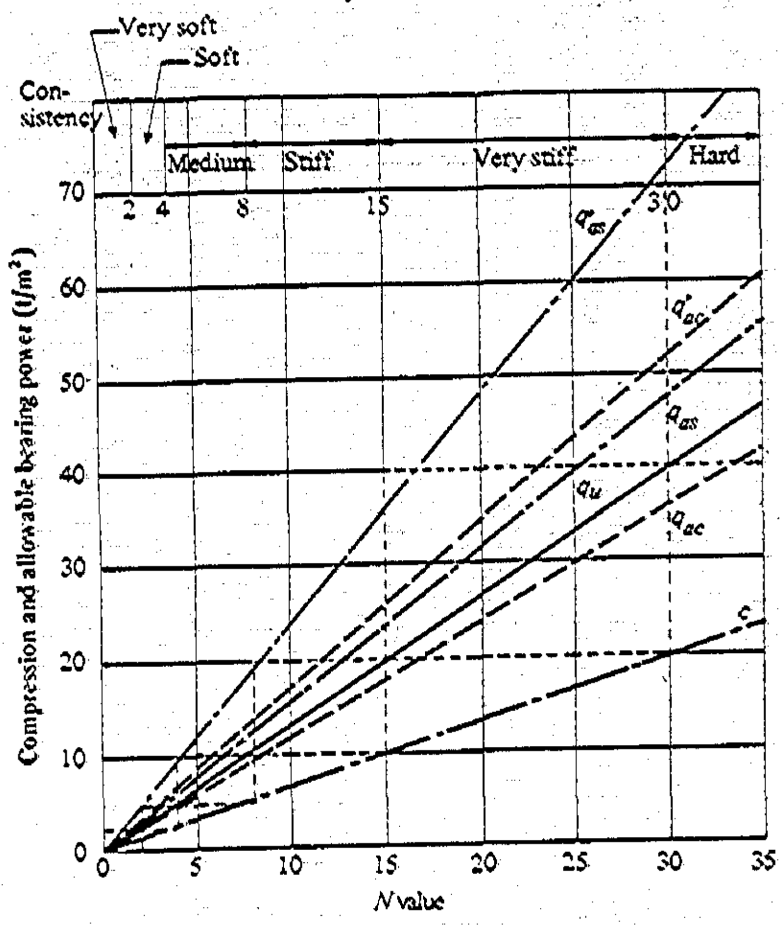


Fig. 3.5.3 Relation between N. Value and Clay Consistency, Uni-axial Compression qu. Viscosity c and Allowable Bearing Power



Allowable bearing power

qac: continuous foundation (safety level 3)
qas: continuous moulding (safety level 3)
q'ac: continuous foundation (safety level 2)
q'as: continuous moulding (safety level 2)

Table 3.5.2 Relation of Consistency, N-Values, and q_u

Clay Consistency	N-Values	On Site Observations	Uni-axial Compression (kg/cm^2)
Very soft	<2	Easily penetrate 10cm with fist	<0.25
Soft	2 - 4	Easily penetrate 10cm with thumb	0.25 - 0.5
Medium	4 - 8	With effort penetrate 10cm with thumb	0.5 - 1.0
Stiff	8 - 15	Can make impression with thumb but not penetrate	1.0 - 2.0
Very stiff	15 - 30	Can make a mark with finger nail	2.0 - 4.0
Hard	>30	Difficult to make a mark with finger nail	>4.0

* Peck-Hanson-Thornborn

The level of groundwater is very high. In the portion of the planning area to the west of Sukhumvit Highway (which registers the lowest levels during the rainy season), the groundwater level is approximately -1.30 during that season. In the dry season, according to the inhabitants, the level of groundwater is reduced by 3m on the eastern mountain side of Sukhumvit Highway. However, according to the soil survey, there is relatively little on the western side of Sukumvit Highway. Namely, groundwater level was about -2.0m during the dry season. As for the permeability index for the surface soil in this area, the survey produced K-values of 10^{-2} - 10^{-5} cm/sec.

The permeability of the soil is given in terms of the coefficient of permeability (k). Permeability is judged according to the value (large or small) of the coefficient.

Terzagh's ranking of permeability is given below.

Very permeable	$k = 1 \times 10^{-1}$ cm/sec or above
Moderately permeable	$k = 1 \times 10^{-1} - 1 \times 10^{-3}$ cm/sec
Slightly permeable	$k = 1 \times 10^{-3} - 1 \times 10^{-5}$ cm/sec
Very slightly permeable	$k = 1 \times 10^{-5} - 1 \times 10^{-7}$ cm/sec
Not permeable	$k = 1 \times 10^{-7}$ cm/sec or below

The American Development Agency gives the following ranking.

Permeable	$k = 1 \times 10^{-4}$ cm/sec or above
Rather permeable	$k = 1 \times 10^{-4} - 1 \times 10^{-6}$ cm/sec
Not permeable	$k = 1 \times 10^{-6}$ cm/sec or below

From the above results, the following policies were established for this feasibility study,

1. Excavation will be done up to the depth of G.L.-2.0m without timbering.
2. The sheet pile technique will be adopted for excavations at depths of over G.L.-2m.
3. Drainage works will be provided for excavations at depths of over G.L.-2.0m,
4. Clay linings will be laid on the bottom of ponds because of the higher ground permeability index.
5. As the level of underground water is rather high, it was planned to avoid as much as possible the deep pipe laying because of the difficulty of the deeper excavations. Thus, as this will lead to difficulties with construction, it is planned to construct 2 lift stations in the Na Klua Treatment Area and 4 stations in the Pattaya Treatment Area.
6. Because of the high N-value, the use of mat foundation piles in construction becomes unnecessary.

However, it will be necessary to conduct more detailed soil quality tests in the Detail Design.

3.5.2 Examination of Water Quality

(a) <u>Location of sampling points</u>

Water quality was examined for sewage sampled from hotels, tapioca factories and restaurants, wells, and water from public water supplies, ponds, rivers and sea.
The examined spots are shown in Table 3.5.3.

(b) <u>Investigated items and results</u>

Items examined are as follows:

1) pH
2) Air Temperature
3) Water Temperature
4) BOD_5 (at 20°C)
5) Suspended Solid
6) COD
7) Total Nitrogen
8) NO_3 - Nitrogen
9) Total Phosphorus
10) Dissolved Oxygen
11) Chlorides
12) Coliform Bacteria
13) Manganese
14) Ferrous
15) Turbidity
16) Alkalinity as $CaCO_3$
17) Hardness as $CaCO_3$

The results are shown in Table 3.5.4.

Examinations of water quality were performed by Dr. N. C. Thanh, Dr. B. N. Lohani, Mrs. S. Muttamara of A.I.T. Environmental Engineering Division and their staffs.

Table 3.5.3 List of Sampling Stations

Sampling Station No.	Location	No. of Sampling	Sampling Station No.	Location	No. of Sampling
1	Orchid Lodge	2	17	Na Klua River (Nearby Tapioca Industry)	1
2	Weekender Hotel	1			
3	Holiday Inn	2	18	2nd Grade Tapioca Factory	2
4	Nang Nual Restaurant	1			
5	Siam Bayshore	1	19	2nd Grade Tapioca Factory	3
6	Pattaya Canal	1			
7	Royal Cliff	2	20	Na Klua River (underneath the bridge on Sukhumvit Highway)	1
8	Asia Pattaya	2			
9	Nachom Tiem River (underneath the bridge on Sukhumvit Highway)	1	21	Na Klua River (River Mouth)	1
10	Nachom Tiem River (River Mouth)	1	22	Water supply well (Na Klua Residential Area)	1
11	1st Grade Tapioca Factory (Cho Chaiwat)	5	23	Public Water supply Tap	1
12	Water supply well	1	24	Swamp	1
13	Water supply well	1	25	Sea (Offshore of Na Klua)	1
14	1st Grade Tapioca Factory (Koh Chang Eah)	8	26	Sea (Offshore of Nang Nual Restaurant)	1
15	Water supply well	1			
16	Water supply well	1	27	Sea (Offshore of South Pattaya)	1

Sampling Station	Location	No. of Samples
R	Hotel Regent Pattaya	9 samples (24 hr sampling, once every 3 hr)

Fig. 3.5.4 Location of Sampling Stations,

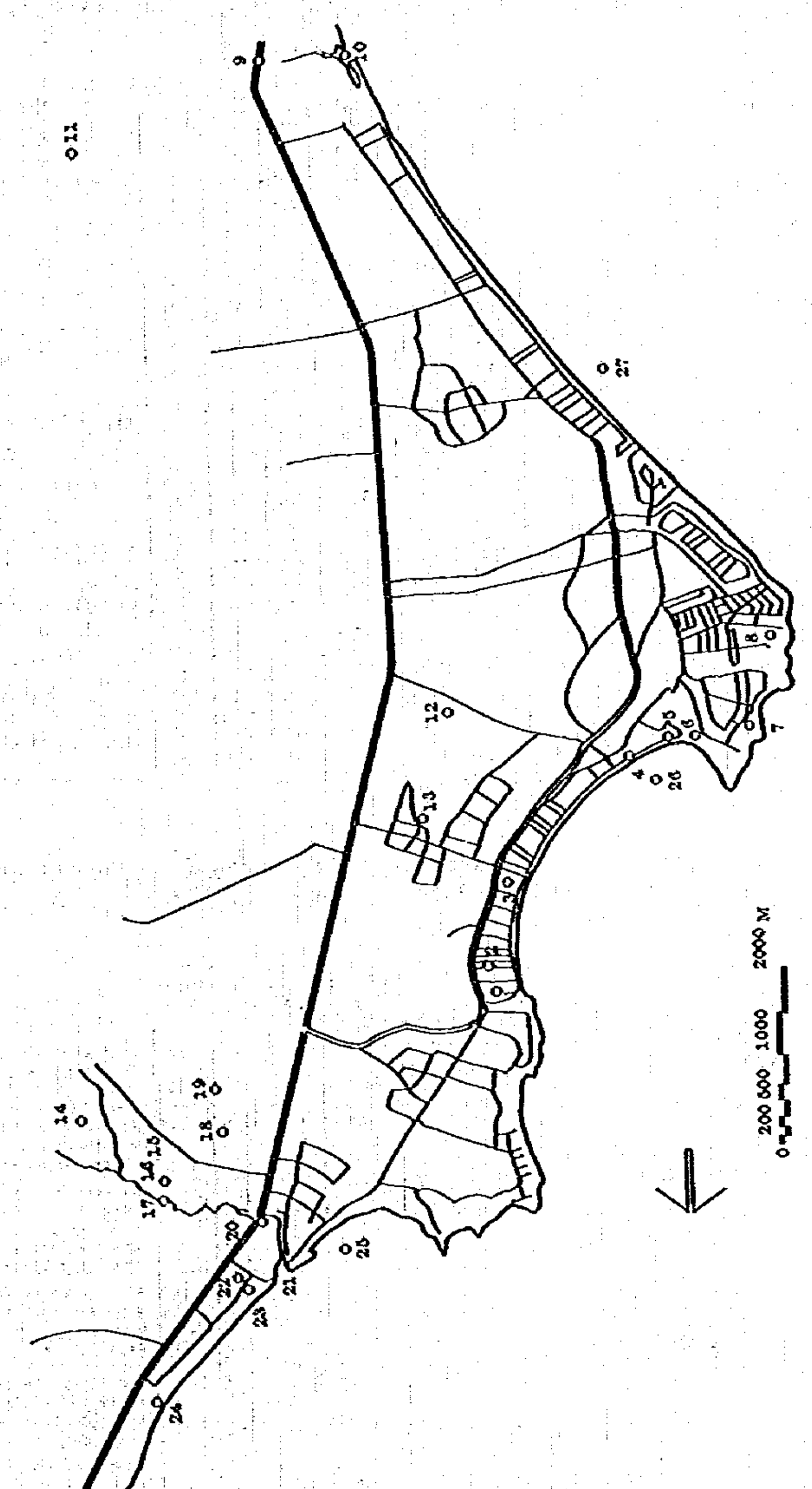


Table 3.5.4 Variation of Influent and Effluent Wastewater Characteristics at Hotel Regent Pattaya (Sampling Date - January 8-9, 1978)

No.	Location	Time	BOD_5	COD	DO	SS	Total N	Total P	pH	Air temp.	Water temp.	Remarks
R-1-1	Influent	1000	120	278	0	83	40.5	9.6	7.5	30	31	flow = 13.75 m^3/hr
R-1-2	Effluent		10	95	0.8	20	nil	4.7	7.4	30	31	
R-1-F	Effluent from Sand Filter		9	88	0.3		2.1	4.7	7.6	30	31	
R-2-1	Influent	1300	135	335	0	113	36.2	8.7	7.8	30	34	flow = 17.49 m^3/hr
R-2-2	Effluent		10	97	0.4	17	3.0	4.7	7.5	30	32	
R-3-1	Influent	1600	130	293	0	133	37.9	10.6	7.6	31	33	flow = 9.68 m^3/hr
R-3-2	Effluent		12	69	0.5	30	3.5	6.0	1.3	31	31	
R-4-1	Influent	1900	110	222	0	70	40.4	7.5	7.8	29	32	flow = 13.45 m^3/hr
R-4-2	Effluent		15	85	0.1	31	5.0	6.5	7.4	29	32	
R-5-1	Influent	2200	125	234	0	74	45.0	8.0	7.7	26	31	no influent
R-5-2	Effluent		30	113	0.4	50	6.9	7.7	7.4	24	31	
R-6-1	Influent	0100	120	230	0	77	43.6	8.0	7.7	24	31	no influent
R-6-2	Effluent		30	120	1.0	52	6.5	6.5	7.4	24	31	
R-7-1	Influent	0400	-	-	-	-	-	-	-	-	-	no influent and
R-7-2	Effluent		-	-	-	-	-	-	-	-	-	no effluent
R-8-1	Influent	0700	155	264	0	94	27.6	8.7	7.2	23	29	flow = 16.98 m^3/hr
R-8-2	Effluent		30	116	1.0	33	15.7	5.2	7.4	23	31	influent pump worked for 2 min. and then stopped
R-9-1	Influent	1000	171	272	0	91	22.6	8.5	7.6	30	32	flow = 13.75 m^3/hr
R-9-2	Effluent		20	95	0.6	22	3.7	4.7	7.4	31	32	

Table 3.5.5 Wastewater Characteristics of Discharges from Hotels and Restaurants (Sampling Date - January 8, 1978)

Station No.	Location	Time	BOD_5 mg/l	COD mg/l	DO mg/l	SS mg/l	Total N mg/l	Total P mg/l	pH	Air Temp.	Water Temp.	Remarks
1-1	Orchid Lodge	10:30	300	384	0.0	139	1.9	3.2	7.7	31	29	Activated sludge performed satisfactorily
1-2			60	96	4.1	49	0	3.0	7.6	31	26	
2-1	Weekender	11:15	120	160	0.4	83	20.2	4.1	7.5	32.5	27.5	Activated sludge was not in operation, or there was no effluent.
2-2			-	-	-	-	-	-	-	-	-	
3-1	Holiday Inn	13:20	180	540	0	315	33.8	5.6	7.2	33	34	No treatment system, just waste holding pond for plant and grass watering. Strong smell and black colour.
3-2			175	352	0	138	27.7	5.4	7.2	33	31	
4	Sang Nual Res	13:55	2070	2280	3.8	1360	62.7	44.0	7.7	29	28	Kitchen waste (dish wash wastewater)
5	Siam Bayshore	11:45	257	316	0	87	3.6	5.0	6.9	26.5	28	Septic tank
6-1	Royal Cliff	14:15	210	364	1.0	159	22.5	7.0	6.5	27	35	Secondary clarifier of Activated sludge was under-designed - Black colour
6-2			100	144	0	87	22.4	5.2	7.0	27	31	
7-1	Asia Pattaya	16:25	250	384	0	139	30.6	6.6	6.6	30	32	$KMnO_4$ was added to aerated lagoon, in order to eliminate smell and odor, destroying microbial flora
7-2			85	236	0.5	128	25.4	5.4	7.2	30	20	

Table 3.5.6 Characteristics of Tapioca Starch Wastewater

Station No.	Location	Time	BOD_5	COD	Chloride	DO	SS	Total N	Total P	pH	Air Temp. °C	Water Temp. °C	Remarks
11-1	CHO CHAIWAT (1st grade)	17:45	1,300	2,580	10.0	0	2,332	23.1	3.3	4.7	26	28	Root wash wastewater
11-2		17:55	2,100	4,193	25.0	0	3,235	0.5	3.4	3.6	26	28	Separator wastewater
11-3		18:30	1,680	3,520	125.0	0	2,760	0.9	2.8	5.5	26	28	Combined wastewater (50:50)
11-4		18:15	3,000	5,584	10.0	0	2,442	3.6	10.4	4.3	24	29	Combined wastewater after discharged into the field
11-5	(Jet extraction wastewater)	18:15	2,000	5,055	10.0	0	3,000	2.5	3.9	5.0	26	27	
14-1	KOH CHANG EAH (1st grade)	10:40	3,500	6,151	-	0	2,462	96.4	13.3	5.5	33	27	Root wash wastewater
14-2		10:30	7,800	12,888	-	0	1,978	138.1	28.6	5.5	33	29	Separator wastewater
14-3		11:00	4,500	8,036	25.0	0	2,138	4.4	10.5	4.3	36	29	Combined wastewater
14-4	Stabilization pond	11:30	2,500	3,793	-	0	648	2.7	18.1	5.1	36	28	4th pond after combined waste holding pond
14-5	Stabilization pond	11:35	2,040	2,923	-	0	274	2.9	11.6	5.3	38	28	5th pond after combined waste holding pond
14-6	Stabilization pond	11:40	1,065	1,822	-	0	134	3.0	9.0	6.4	35	30	8th pond
14-7	Stabilization pond	12:00	420	725	-	0	229	54.6	8.8	7.3	34	30	Influent of last pond
14-7F		-	340	229	-	-	-	-	-	-	-	-	Filtrate BOD_5 and COD
14-8	Stabilization pond	11:50	400	804	-	0	162	53.7	10.9	7.2	35	30	Last pond
14-8F		-	330	502	-	-	-	-	-	-	-	-	Filtrate BOD_5 and COD
18-1	Tapioca Factory CHAROEN ROONG (2nd grade)	14:22	1,500	3,900	10.0	3.5	1,995	0.7	2.4	4.6	29	30	Root wash wastewater
18-2		14:15	8,700	17,257	-	0	7,175	1.8	20.0	5.4	31	27	Supernatant
19-1	Tapioca Factory TONG HENG (2nd grade)	14:57	1,050	1,616	10.0	2.6	988	3.0	0.6	4.3	31	30	Root wash wastewater
19-2		15:02	2,940	4,637	-	0	340	99.0	10.2	4.5	28.5	27	Supernatant
19-3		15:16	3,000	4,778	-	0	313	116.3	8.6	5.2	32	33	Holding pond

Table 3.5.6 Characteristics of Tapioca Starch Wastewater

Stations	Description	Time of sample collection	BOD_5 mg/l	COD mg/l	DO mg/l	SS mg/l	Total N mg/l	NO_3 N mg/l	Total P	M_n mg/l	Fe mg/l	Turbidity FTN	Alkalinity mg/l as $CaCO_3$	Hardness as $CaCO_3$ mg/l	pH	MPL per 100 ML	Air Temp. °C	Water Temp. °C
12	Well (Proposed site for stabilization pond)	13:10	<5	2	4.1	12	0.4	0.7	0	0	2.40	17	72	78	6.6	-	18	27
13	(do)	15:25	<5	4	3.8	11	0.4	0.3	0	0.04	2.30	34	30	50	5.7	-	29	26
15	Village Water Supply Well	14:25	<5	20	1.9	9	0	28.4	0	0.04	0.08	3	40	110	5.7	-	25.5	27
16	Village Water Supply Well	14:35	<5	0	2.9	10	0.1	1.1	0.12	0	0.16	16	20	18	5.6	-	26.5	27
22	Well Offshore of Na Klua	18:10	<5	35	2.0	12	1.1	0.3	0	0	1.60	87	30	32	6.3	1100	30	28
23	Tap Water	18:00	<5	28	5.9	175	0.8	0.2	0.05	0	3.36	161	66	72	8.0	28	29	32
24	Swamp	10:25	<5	20	5.9	10	0.4	-	0.03	-	-	-	-	-	6.6	-	29	25

Table 3.5.8 Water Quality in Rivers (Sampling Date - January 8, 1978)

Station No.	Description of Location	Time of Sampling	BOD_5 mg/l	Chloride mg/l	DO mg/l	SS mg/l	Total N mg/l	Total P mg/l	pH	MPN	Air Temp. °C	Water Temp. °C
6	Pattaya Canal	11:55	45	-	0	47	13.4	2.7	6.9	240 x 10^4	25.5	28.5
9	Na Chom Tien River (underneath the Sukhumvit Bridge)	16:05	<5	-	8.5	61	1.3	0	7.0	930	27.5	28.5
10	Na Chom Tien River (River Mouth)	15:45	<5	17,150	7.2	40	0.3	0	7.1	Greater than 2,400	31	29
17	Na Klua River (Near Tapioca Factory)	14:50	10	-	1.4	25	5.7	0.6	6.7	-	28	31
20	Na Klua River (underneath the Sukhumvit Bridge)	14:10	1620	-	0	171	45.7	5.2	4.3	1,100	34.5	29.5
21	Na Klua River (River Mouth)	13:45	<5	18,500	3.2	106	0.6	0	6.3	1,400	26	28

Table 3.5.9 Quality of Sea Water (Sampling Date - January 9, 1978)

Station No.	Location	Time of Sampling	BOD_5 mg/l	Chloride mg/l	DO mg/l	SS mg/l	Total N mg/l	Total P mg/l	pH	MPN/100ml	Air Temp. °C	Water Temp. °C
25	Sea (offshore of Na Klua Pier) ≒ 200 m	10:15	<5	20,000	1.7	50	0.3	0	7.7	7500	27.5	25
26	Sea (offshore of Pattaya beach, Nang Nual Restaurant) ≒ 200 m	9:55	<5	19,250	5.8	46	0	0	7.6	450	24.5	26
27	Sea (offshore of South Pattaya hill, sea view villa) ≒ 200 m	9:35	<5	19,000	6.1	33	0	0.15	7.1	<3	25	26.5

(c) Evaluation of Examination

1) Hotels and restaurants

The results of examinations of the water quality of sewage from hotels are summarized below.
The summary utilizes data on BOD_5, COD and SS.

Calculation of pollution-load amounts are divided from the water quality surveys.

Average water quality in Hotel Regent Pattaya (Examination was done at three-hour intervals over a 24 hour period.)

Table 3.5.10 Average Water Quality of Sewage from Hotel Regent Pattaya

Time	BOD	COD	SS	Remarks
8th Jan.'78	mg/l	mg/l	mg/l	
10:00	120	278	83	
13:00	135	335	113	
16:00	130	298	133	
19:00	110	222	70	
22:00	125	234	74	no influent
9th Jan.'78				
01:00	120	230	77	no influent
04:00	-	-	-	no influent & no effluent
07:00	155	268	94	
10:00	171	272	91	
Average	133	267	92	

	BOD	COD	SS	Remarks
Minimum	110	222	70	
Maximum	·171	335	133	
Average	141	279	102	

Table 3.5.11 Average Water Quality of Sewage from Hotels except Regent Pattaya

	BOD	COD	SS	Remarks
	mg/l	mg/l	mg/l	Time of sampling
Orchid Lodge	300	384	139	10:30
Weekender	120	160	83	11:15
Holiday Inn	180	540	315	13:20
Siam Bayshore	257	316	87	11:45
Royal Cliff	210	364	159	14:15
Asia Pattaya	250	384	139	16:25
Average	220	358	154	

Table 3.5.12 Water Quality of Sewage from Hotels including Regent Pattaya

	BOD	COD	SS	Remarks
	mg/l	mg/l	mg/l	
Orchid Lodge	300	384	139	
Weekender	120	160	83	
Holiday Inn	180	540	315	
Siam Bayshore	257	316	87	
Royal Cliff	210	364	159	
Asia Pattaya	250	384	139	
Regent Pattaya	141	279	102	
Average	208	347	146	

From the above results, mean values on BOD_5, COD and SS on the water quality of sewage or wastewater from hotels are as follows:

	Regent Pattaya Hotel	All Hotels
BOD_5	141 mg/l	208 mg/l
COD	279 mg/l	347 mg/l
SS	102 mg/l	146 mg/l

Water quality of sewage generated from hotels in this feasibility study for a sewerage system was regarded as BOD_5= 200mg/lit. and SS = 150mg/lit. These figures take into account water quality testing experience in Japan and the survey values obtained at the above hotels.

As for the examination on water quality at restaurants, the biggest restaurant (Nang Nual) in Pattaya Area was tested, and it was found that various effluents were directly discharged from the restaurant into the sea area. Also, water for cooking was brought from the river directly to the cooking room of the restaurant.

Although the volume was not large, the water taken was highly polluted. The value DO = 3.8mg/lit. obtained from the water quality test seems to suggest some natural aeration due to the practice of washing the dishes in the container used for water collection.

2) Tapioca factories

The examination of water quality at tapioca factories was performed at 2 factories of First Grade and 2 factories of Second Grade. The difference between the two grades is in the manufacturing process.

As shown in Fig. 3.5.5, the centrifuge method is used for manufacturing tapioca starch in First Grade factories, while sedimentation-decantation is used in Second Grade factories. A higher amount of sewage is discharged from the more efficient First Grade factories. There are some differences in the sewage quality between 2 types of factories. The manufacturing processes in the 2 types of factories are shown in Fig. 3.5.5.

As shown in the chart, there are 2 types of sewage discharged from the tapioca starch factories, one being wastewater from washing the tapioca and the other being the surplus water left when the tapioca is made into starch.

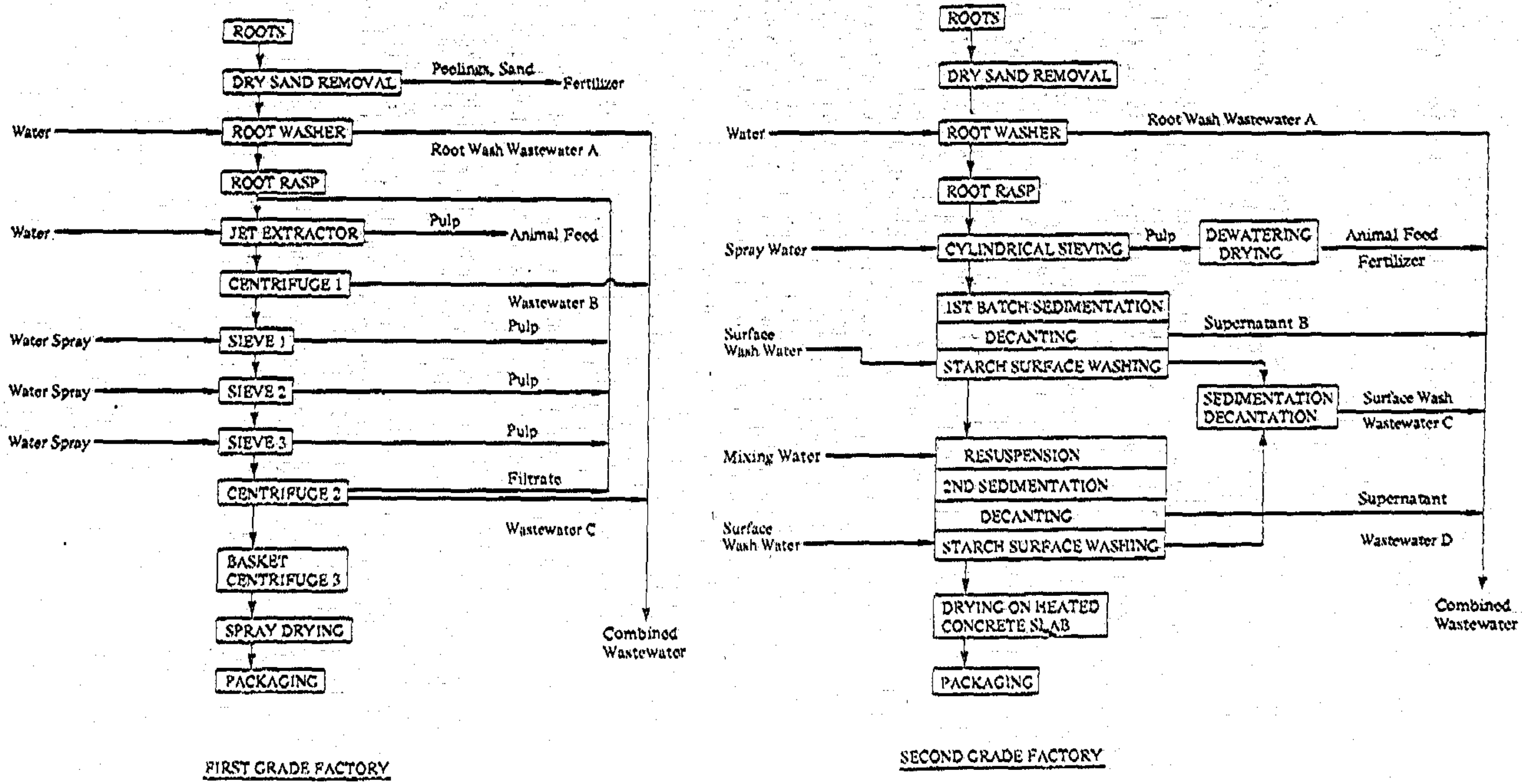
The survey team's results are summarized as follows:

(1) Quality of sewage from tapioca factories

pH of sewage from factory was as low as 3.5-5.5 in the original sewage. BOD_5 was as high as 1300-3500mg/lit. in washing water and 2000-7800 in the surplus water, and quality of mixed sewage was within the following range.

BOD_5	1,680 - 4,500 mg/lit.
SS	2,140 - 2,760 mg/lit.
pH	4.3 - 5.5
COD	3,520 - 8,040 mg/lit.

Fig. 3.5.5 Tapioca Starch Processing in Thailand



Also, the following values are reported on the sewage from the factories surveyed.*

BOD_5	3,000 - 6,000 mg/lit.
SS	1,000 - 3,000 mg/lit.
pH	3.5 - 5

* Data of the Tapioca Factories in Bang Lamung
Ministry of Industry Department of Industry Works Factory Control Division.

Moreover, according to the report* in 1977 by the Envionmental Bureau, $40m^3$ of sewage is generated in manufacturing one ton of tapioca starch in a First Grade factory, and the BOD_5 is reported to be 5000mg/lit.

* Report on Environmental Survey of Pattaya
Environmental Standard Quality Division
The National Environmental Board, July 1977

Also, the above report says that a pollution load of BOD_5 17,230kg is discharged into Na Klua River from the factories. According to the report* on the system of treating sewage from tapioca factories, the operating period is 11 months from June to next April (except in the biggest factories where operations are carried out all year round), and 40-60 m^3 of sewage is discharged per ton of tapioca starch from First Grade factories, or 20-$40m^3$ in the case of Second Grade Factories. Water quality of sewage is different in each factory, but in general BOD_5 is reported to be 3000-5000 mg/lit. and SS 1000-3000mg/lit., and pH is reported to be 3.5-5.

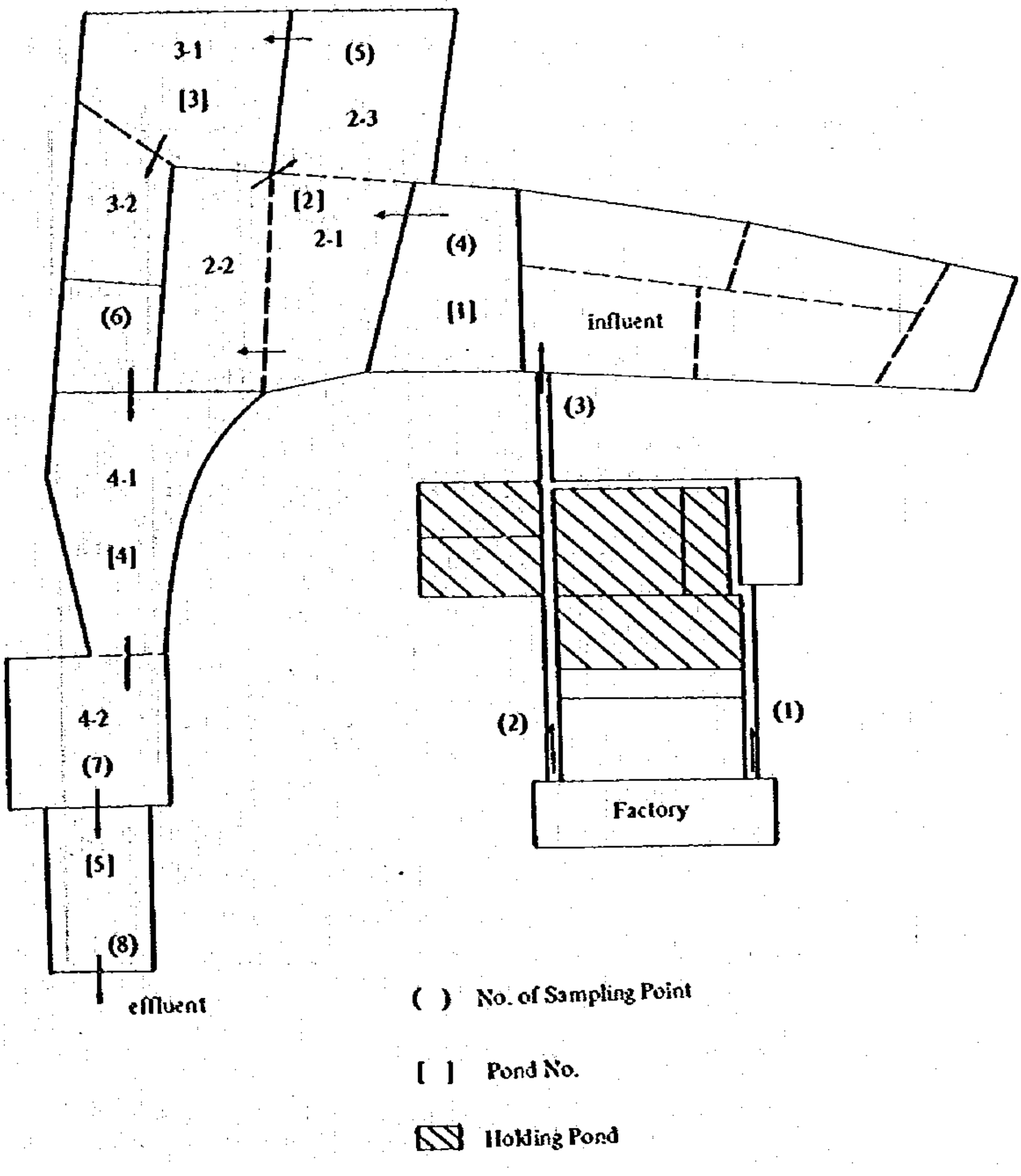
* Design Guidelines for Treatment of Wastewaters from Tapioca Starch Industry
Dr. Pakit Kiravanich, Mr. Yothin Auguravasapoon, Mr. Adisak Thongkaimook.
Environmental Quality Standard Division, Aug. 1976

(2) Removal rate in stabilization ponds at tapioca factories

Treatment conditions at a certain First Grade factory having stabilization ponds in the study area are as follows.
The factory is located on a site along Na Klua River 3.8km to the east of Sukhumvit Road. The output of this factory is 60 tons of starch per day.
Sewage is generated to the amount of $2,400m^3$/day*, and the layout and standards of the stabilization pond in this factory are shown in the following Table and Figure.

* Report on Environmental Survey of Pattaya
(Oct. 1976 - June 1977)
Environmental Standard Quality Division NEB
July 1977

Fig. 3.5.6 Sampling Point of Water Quality in Stabilization Pond of Tapioca Factory (1)



In the diagram, (1) - (8) show water collecting points used in the present water quality survey.

Table 3.5.13 Area and Capacity of Each Stabilization Pond

Pond No.		Area	Capacity	Remarks
1		2,860m^2	5,720m^3	Water depth 2.0m
2	2-1 2-2	3,666	5,499	Water depth 1.5
	2-3	4,320	6,480	Water depth 1.5
	Sub Total	7,986	11,979	
3	3-1	2,580	5,160	Water depth 2.0
	3-2	4,812	7,219	Water depth 1.5
	Sub Total	7,392	12,379	
4	4-1	9,186	2,756	Water depth 0.3
	4-2	2,912	1,456	Water depth 0.5
	Sub Total	12,098	4,212	
5		2,732	1,366	Water depth 0.5
Total		33,068	35,656	

The results of the survey are summarized in the following table.

Table 3.5.14 Quality of Water at Each Station

Station No.	BOD	COD	SS	pH
1	3,500	6,151	2,462	5.5
2	7,800	12,888	1,978	5.5
3	4,500	8,036	2,138	4.3
4	2,500	3,793	648	5.1
5	2,040	2,923	274	5.3
6	1,065	1,822	134	6.4
7	420	725	229	7.3
8	400	804	162	7.2

Unit is mg/lit. except pH.

Table 3.5.15 and Fig. 3.5.7 show the survey results for the loads of BOD_5, COD and SS as well as detention time in each pond.

Table 3.5.15 Results of Water Quality Surveys of Stabilization Pond at Tapioca Starch Factory

Q=2,400 m^3/day

Pond No.	Area		Capacity		Wastewater Quality			Detention Time		BOD_5 Loading		Removal Efficiency		
	Alone m^2	Combined m^2	Alone m^3	Combined m^3	BOD mg/l	COD mg/l	SS mg/l	Alone days	Combined days	Alone kg/h.d	Combined kg/h.d	BOD_5 %	SS %	COD %
Inflow					4,500	8,036	2,138							
1	2,860		5,720		2,500	3,793	648	2.38		37,762		44	70	53
2	7,986	10,846	11,979	17,699	2,040	2,923	274	4.99	7.37	7,513	6,102	55	87	64
3	7,392	18,238	12,379	30,078	1,065	1,822	134	5.16	12.53	3,955	3,591	76	94	77
4	12,098	30,336	4,212	34,290	420	725	229	1.76	14.29	6,068	3,150	91	89	91
5	2,732	33,068	1,366	35,656	400	804	162	0.57	14.86	7,379	3,030	91	92	90

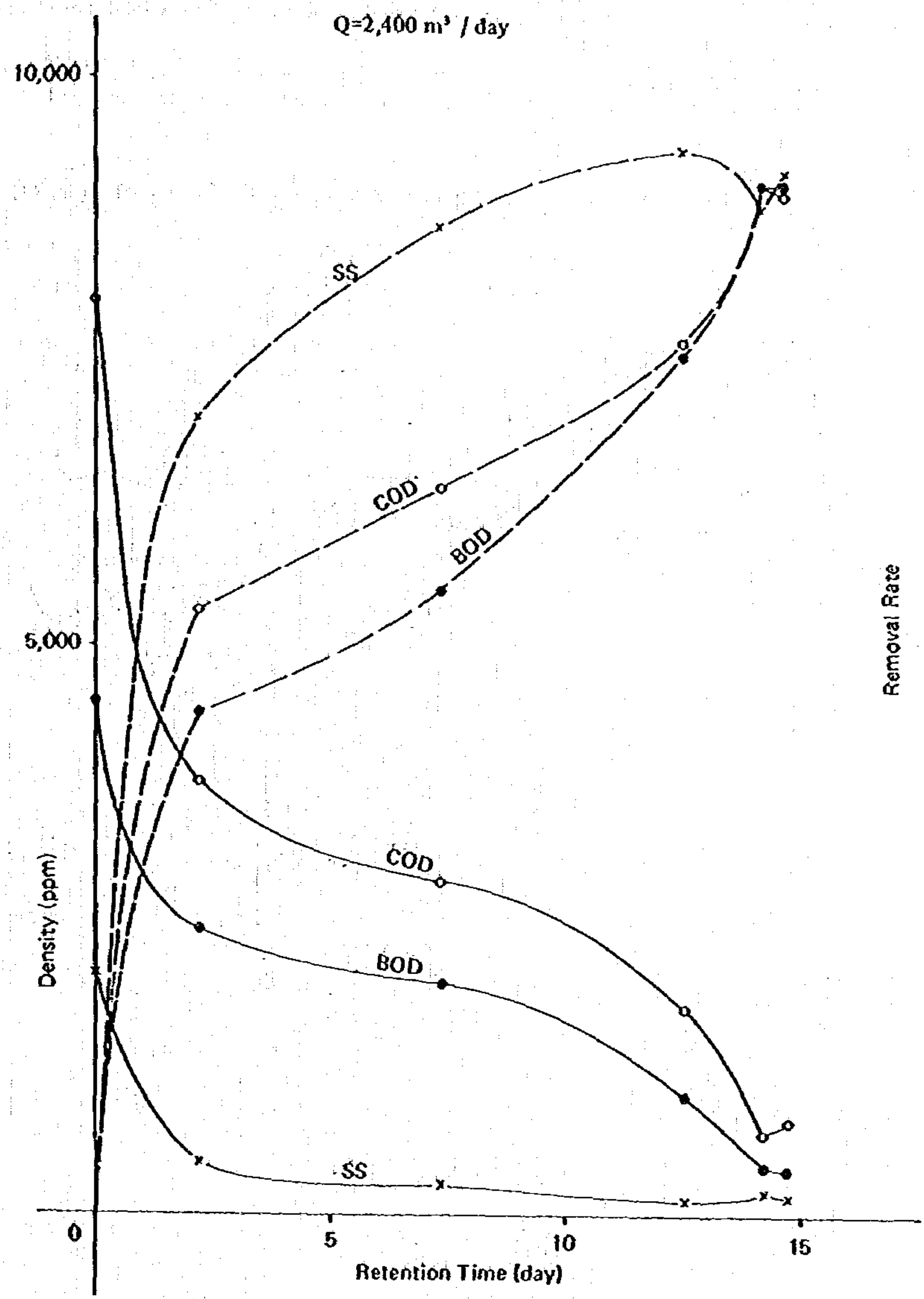
COD Loading

$$\frac{8,036 \times 2,400 \times 10^{-3}}{3.3068} = 5,832 \text{ kg/h.d}$$

COD - Removal Efficiency

$$100 - \frac{804}{8,036} \times 100 = 90\%$$

Fig. 3.5.7 Relation between Retention Time and Removal Rate in Stabilization Pond



Supposing that the discharged volume from a tapioca factory is $2,400m^3$/day, 90% of the BOD_5 load can be removed when the detention period in the stabilization pond is 15 days.

Other survey results on the removal rate at stabilization ponds in the tapioca factories as well as water collecting points are as follows.

Fig. 3.5.8 Sampling Point of Water Quality in Stabilization Pond of Tapioca Factory (2)

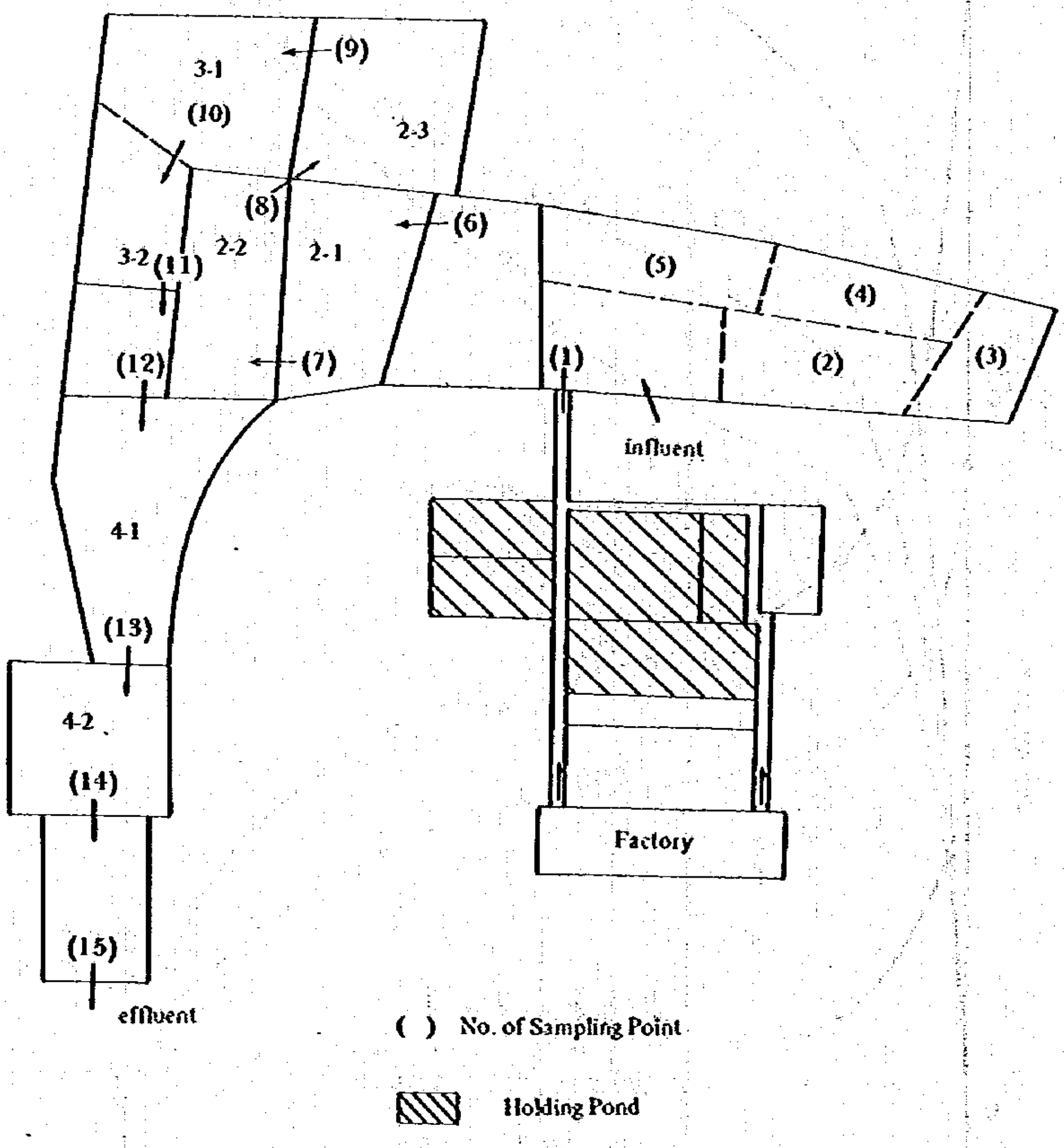


Table 3.5.16 Results of Water Quality Surveys in Stabilization Ponds at Tapioca Factories

Industrial Environmental Control Division
Industrial Control Department
June 27, 1978

	March 2, '78			March 30, '78			April 11, '78			April 26, '78			May 10, '78			Approximate area (m^2)
	BOD	pH	SS	BOD	pH	SS	BOD	pH	SS	BOD	pH	SS	BOD	pH	SS	
Inf_1	5,891.9	4.7	1,300	7,559	4.9	,100	5,616	4.5	,750	4,891	4.6	,060	6,498	4.63	1,528	
E_1	7,342	4.6	1,086	4,915	4.6	2,900	6,218	4.5	1,325	6,238	4.52	1,620	7,785	4.62	1,200	1,247
E_2	2,872	4.7	570	4,756	4.7	2,060	5,958	4.65	666	5,045	4.6	1,140	5,274	4.69	675	1,131
E_3	4,792	4.3	614	3,276	4.9	1,466	5,324	5.0	640	4,032	4.73	616	4,177	4.88	640	3,616
E_4	1,504	5.0	500	2,604	6.1	488	3,697	5.3	350	1,779	5.28	510	2,820	5.2	556	2,750
E_5	2,748	5.3	420	1,721	7.1	440	1,115	6.8	125	825	6.62	245	879	6.7	160	3,213
E_6	766	6.5	433	746	7.25	250	950	7.78	110	556	6.9	200	696	6.97	31	3,225
E_7	1,036	7.1	137	453	7.8	200	798	7.35	80	229	7.18	40	320	7.3	16	4,342
E_8	277	7.3	96	140	8.2	170	272	7.8	210	110	7.38	150	153	7.82	164	3,750
E_9	234	7.5	64	118	8.2	160	159	8.28	200	59	7.8	156	64	8.1	154	7,267
E_{10}	160	7.7	72	97	8.26	120	89.6	8.32	125	64	8.05	108	48	8.12	120	7,150
E_{11}	149	7.9	100	91	8.2	96	82	8.28	60	60	8.09	60	52	8.26	80	3,750
E_{12}	81	7.8	78	93	8.28	98	73	8.21	44	64	8.3	48	42	8.41	53	14,800
E_{13}	46	8.1	70	89	8.68	23	79	8.5	28	59	8.68	30	55	8.7	30	10,600
E_{14}	47	8.2	184	77	8.8	10	72	8.81	24	60	8.9	26	38	9.0	50	5,607
E_{15}	20.3	8.7	64.0	133	9.2	22	71.8	9.1	20	56	9.06	26	31	9.22	30	3,150
																Σ=65,598 = 41 rai