Economic, Institutional and Technical Implications of Alternative Urban Sanitation and Recycling Options

A Case Study of Chonburi, Thailand

AIT Research Report No. 230

Asian Institute of Technology

and

Coopers & Lybrand Associates Co.Ltd.

Bangkok, Thailand
May 1988

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Funded by

Deutsche Gesellschaft
fuer Technische Zusammenarbeit (GTZ) GmbH
Eschborn, Fed. Rep. of Germany

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ACKNOWLEDGEMENTS

This study was financed by the Government of the Federal Republic of Germany through Deutsche Gesellschaft fuer Technische Zusammenarbeit (GTZ) GmbH, Project No.: 83.2085.5. The authors should like to acknowledge the financial and professional support extended by GTZ.

Special thanks are due to the officials of various agencies in Chonburi who readily provided their time for several meetings in order to clarify questions by the AIT team.

The editing assistance of Miss Celine T.M. Vicente and the services of AIT secretarial staff are gratefully acknowledged.

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1. OBJECTIVES AND METHODOLOGY OF THE STUDY

1.1 Introductory Remarks

"Foul water may well rate as the greatest single source of human disease and misery. It is, therefore, encouraging to see it moving towards the head of the world's priority list of basic needs.... However, the emphasis on 'clean water' carries with it a risk. It can allow policymakers to neglect the equally urgent need for sanitation." (Barbara Ward, in RYBCZYNSKI, POLPRASERT and MCGARRY, 1978). Barbara Ward, the late President of the International Institute for Environment and Development, pointed to one of the problems implied in the goals of the International Drinking Water and Sanitation Decade 1980-1990: Providing improved water supply must include the rather more complex requirements of sanitation, i.e. disposal, treatment, and possible reuse of human waste and wastewater.

Sanitation technology for developing countries in the tropics is not limited to either primitive and unhygienic latrines or "Western" waterborne sewerage. Between these extremes, a wide range of alternatives have been advocated that are claimed to be "appropriate", i.e. both effective and affordable. Unfortunately, however, there is a widespread lack of knowledge about acceptable alternatives, apart from the two other primary constraints to sanitation improvements, lack of funds, and lack of trained personnel (KALBERMATTEN et al., 1980).

For more than a decade, the World Bank in particular, as well as other international agencies, have been very active in exploring and publicizing alternative sanitation technologies for developing countries. However, while the available case studies and field manuals provide in-depth coverage of the solutions at the levels of the individual household and the smaller low-income community, there is a lack of applied system comparisons. This would imply a systematic assessment of the technical, economic and institutional problems associated with implementing selected sanitation plans and programmes.

1.2 Objectives and Scope

The broad objective of the study is to show the economic and institional implications of alternative sanitation options, as applied to a typical medium-sized town in Thailand. The term "option" is used to cover specific sets of sanitation systems that consist of alternative solutions to wastewater collection, transportation, treatment and disposal. As the study was not conceptualized as a plan for a particular town, the details of the sanitation options were kept at the level of preliminary engineering design. This permitted to prove the technical feasibility of the options considered as well as to establish a reasonably reliable basis for an economic assessment. For reasons of logical consistency, the four options selected for economic evaluation, were designed to provide identical levels of service, in terms of public health and environmental safety, but not necessarily in terms of user convenience.

The main objectives of the study are:

1. Comparative assessment of the technical feasibility of alternative sanitation systems, as applied to the density and land-use patterns of a typical medium-sized town.

2. Comparative economic evaluation of the sanitation options, with regard to investment costs and annual operation costs, assuming the line of loan financing common in Thailand.

3. Assessment of the possibilities for cost recovery by means of user charges - one-time connection charges and/or annual fees - as well as revenue generation through various forms of recycling, for example biogas production and aquaculture.

4. Assessment of the institutional opportunities and constraints involved in implementing the alternative sanitation systems; in particular, this would refer to the implied funding patterns of the various sanitation systems, which may require very different financial responsibilities to be borne by the public and private sectors.

As the study is not intended to serve as a plan for Chonburi, many data that are used in the calculations are based on secondary sources and reasonably justified estimates, but not on specific surveys. The aim was to make the system comparison reliable in terms of order of magnitude, rather than specific details for the case of Chonburi. This approach is hoped to provide some technical, economic and management answers with regard to the actual "appropriateness" of certain technical solutions that have been advocated in the last few years. At the same time, however, any "appropriate" technology must be within "affordable" limits of the various sectors of the society.

The definition of what may be affordable, to a considerable extent depends on value judgements, apart from hard economic facts and figures. Hence the answer can hardly be a clearcut "yes" or "no". Therefore, the purpose of the study may be seen also in raising some further questions, rather than providing definite answers, in view of the necessary policy discussions among the government bodies concerned.

1.3 Methodology

To a certain extent, the present study aims at demonstrating the principles of sanitation program planning, as applied to the specific conditions of medium-sized towns in Thailand. Much emphasis was put on the discussion of opportunities and constraints for applying the various components of alternative sanitation systems. Therefore, what the study addresses, is the socio-economic and institutional context, and even the political framework, in addition to the technical aspects of sanitation improvements. In other words, the attention paid to the planning and implementation process in the study is as important as its results.

"Sanitation program planning is the process by which the most appropriate sanitation technology for a given community is identified, designed, and implemented. The most appropriate technology is defined as that which provides the most socially and environmentally acceptable level of service at the least economic cost." (KALBERMATTEN et al., 1980: p. 4) Based on this kind of approach, which has been recommended by the World Bank, the first task is to identify the existing sanitation problems specific to the various land use areas and social groups in the sample city. This was done by referring to the urban planning and infrastructure engineering studies that have been undertaken for Chonburi during the last ten years or so.

Apart from describing the problems, the initial review of the existing situation also establishes the scope for what type of sanitation technology would actually constitute an improvement, thus narrowing the scope for the second step of the analysis, i.e., an examination of the principal alternatives that may be available. For example, in Chonburi as well as in the other intermediate cities in Thailand, most households have piped water supply, and virtually all households have individual pour-flush toilets. The problem in many parts of the urban areas is not that of too few or unhygienic toilets, but that of leaking cesspools combined with high ground water tables. Therefore, to continue this example, a whole range of technically sound solutions must be discarded from the outset on the grounds of social acceptability - such as, for example, communal toilet facilities.

The second step of the methodology, a review of possible sanitation improvements, leads on to the formulation of four options, which are technically sound systems to meet the sanitation needs of the city as a whole. The four options considered are:

- Maximum Sewerage Option
- Minimum Sewerage Option
- Small-bore Sewerage Option
- Septic Tank Option

The system options will be presented in Chapter 3, in the context of a broad review of sanitation technologies. This chapter also refers to the physical, socio-economic and administrative conditions of the study area, which is introduced in Chapter 2, entitled "the study scenario".

Both, a more general discussion of technical alternatives as well as the specific calculations related to the four options, are contained in Chapters 4,5, and 6 which deal with

- sewerage systems (Chapter 4),
- on-site wastewater treatment (Chapter 5), and
- central wastewater treatment, including recycling by means of aquaculture (Chapter 6).

The technical systems discussion related to the four options results in a framework of cost estimates for investment as well as operation and maintenance costs. These in turn are used as inputs for an economic evaluation (Chapter 7) and an assessment of the institutional implications (Chapter 8). Chapter 9, finally, presents a set of conclusions - both in terms of definite answers and possible further questions.

REFERENCES

1. KALBERMATTEN, J.M. et al. (1980), Appropriate Technology for Water Supply and Sanitation, A Sanitation Field Manual, The World Bank, Washington, D.C.

2. RYBCZYNSKI, W., C. POLPRASERT, and M. MCGARRY (1978), Low-Cost Technology Options for Sanitation, IDRC, Ottawa, Ont.

2. THE STUDY SCENARIO

2.1 Chonburi as a Representative Example

Chonburi as a study area was selected for two reasons: (i) it is a medium-sized town which in various ways represents the physical, socio-economic, and administrative conditions of many smaller and medium-sized towns in Thailand. Furthermore (ii), there are a number of recent technical studies on urban development as well as infrastructure provision for Chonburi, containing the kind of base line data that were needed for the present study. The emphasis of the study is on a Thailand-specific systematic comparison of sanitation options, but it is not a Chonburi-specific planning project. The available background materials on Chonburi provided sufficient information on most aspects dealt with in the study. Therefore, all socio-economic and land use data were based on secondary sources in order to avoid unnecessary and time-consuming original surveys.

At a population size of just over 100,000, Chonburi, which is the capital of a province of the same name, may be at rank seven or eight among the 124 municipality towns in Thailand. (This number does not include Bangkok which has a different administrative status, equivalent to a province.) It is one of the characteristic features of the urban sector in Thailand that such a statement cannot be made with more certainty: in many cases, the statistical "urban" population number is considerably smaller than the actual urban population, because the administrative area of the municipality is normally much smaller than the actual urban aggregate. However, defining such an area by means of functional geographic criteria would require a special survey, and the resulting figures would be just unofficial estimates. In an attempt at calculating the actual magnitude of urban population in Thailand, KAMMEIER (1986) estimated the urbanization ratio of 1979 at 27% as compared with the "official" figure of under 18%.

In terms of economic growth dynamics, Chonburi may represent a rather smaller number of towns and their corresponding provinces, as Changwat Chonburi has one of the highest provincial per capita incomes (Table 2.1). Nevertheless, in many respects, such as land use and activity patterns as well as local government and its limited financial potential, Chonburi definitely constitutes a typical example of an intermediate city.

2.2 Regional Cities Development in Thailand

Over the last 10 to 15 years, many developing countries have made increasing efforts towards planning and implementing national urbanization strategies. The rationale for such programs is often based on two interrelated themes, i.e., providing complementary urban support functions to rural development, and diverting the migration pressure from the metropolitan regions. In this context, the intermediate cities provide the greatest potential for successful development programs (KAMMEIER and SWAN, 1984).

Table 2.1 Comparative Economic Performance of Changwat Chonburi

Gross Provincial Product (GPP) Per Capita (1984)		
Area	Baht	Index[1]
Whole kingdom (mean)	19,551	100
Chonburi	**47,963**	**245**
Greater Bangkok Area (highest)	56,092	287
Kalasin (lowest)	6,242	32
Central Region[2]		
- Eastern	25,210	129
- Central	16,146	83
- Western	21,228	109

1) Mean value (whole kingdom) = 100
2) Gross Regional Product by statistical subregion (excluding Greater Bangkok Area)

Source: GPP data from **National Economic and Social Development Board**

For many years, the National Development Plans of the Thai Government have emphasized the need to develop the peripheral regions. Although earlier plans had included the importance of decentralized urban development, it has only been since the Fourth Plan (1977-1981) that a specific program for "regional cities" was set up. From the initially nominated nine growth centers, five were selected for the Regional Cities Development Project which was launched in 1980. These cities are: Chiang Mai, Khon Kaen, Nakhon Ratchasima, Hat Yai, and Songkhla. The Regional Cities Development Project aims at strengthening the cities by means of strategic infrastructure projects that are funded by a large World Bank loan. The project is being carried out with technical management by the Office of Urban Development within the Department of Local Administration (DOLA). The work of this office is supported by a UNDP/Australian consulting team, as well as by the respective municipal and provincial offices. On the basis of the appropriate studies at pre-investment and feasibility levels, a number of key infrastructure projects are now under construction. Typically, the proposed infrastructure improvements consist of the following components:

- drainage and flood control
- water supply
- wastewater treatment
- solid waste disposal
- roads
- improvement of mixed-use areas and slums
- specific projects, such as slaughterhouse, bridges, port development, etc.

By the time of completing the feasibility studies, the total cost of these projects in all five cities was estimated at 2,630 million Baht (see SINCLAIR KNIGHT & Partners et al., 1983, Vol. 1 - Main Report).

Chonburi is not included in the Regional Cities Project, but it has received even greater attention as the main center of the Eastern Seaboard Region. The industrial development projects around the new ports at Laem Chabang and Map Ta Phut are in various stages of planning and implementation. Located in between the national capital and the newly developing industrial port centers, Chonburi is expected and proposed to be strengthened as the most important commercial center of the area, with a considerable role in manufacturing as well. Pursuant to the priority proposals for urban development in Chonburi (as described in the Eastern Seaboard Study, Sector Studies, COOPERS & LYBRAND et al., 1982), major efforts are being made for infrastructure improvements in the city. The most important interrelated proposals and projects are on the following subject areas (for detailed references, see Appendix 2.1):

- Urban development, Eastern Seaboard
  (COOPERS & LYBRAND et al., 1982)

- Drainage and flood control
  (ENGINEERING CONSULTANCY Services Centre/TISTR, 1985)

- Sewerage and excreta disposal
  (GTZ/WHO/PWD/SEATEC International, 1983)

- Water supply
  (KOCKS Consult/THAI PROFESSIONAL Engineering Consultants/PWWA, 1984/1985)

All of these studies were used to some extent in order to establish the baseline data for the present study.

Under the Sixth National Development Plan (1987-1991), the current policy for concentrated decentralization of urban development in the regional cities is to be supplemented by a "second generation" of regional cities, as well as a range of lower order centers. Although the present regional cities hardly reach a population size of 200,000, the projected growth rates of 2.5% to 4.3% per annum suggest that, by the end of this century, Thailand may well have a number of cities in the 250 to 350,000 range. Their contribution to national economic and social development will depend on effective planning, which must be concerned with, among other issues, appropriate levels and forms of infrastructure provision. There is no doubt that this requires well-founded early decisions on key systems such as wastewater collection and treatment. In this context, the present study definitely addresses a medium- to long-term perspective, although, for methodical reasons, only current data were used.

2.3 Population and Land Use Characteristics of Small and Medium-Sized Towns

In view of the general applicability of the present study, it will be advantageous to highlight some of the typical features of smaller and medium-sized towns and cities in Thailand. Urban sanitation is one of those fields of infrastructure provision and management where the "human factor" plays a significant role, apart from topographic and climatic data. In other words, any proposed sanitation plan and its eventual implementation and management, will have to respond to certain patterns of the society and the economy, as well as their changing mirror images of land utilization and development.

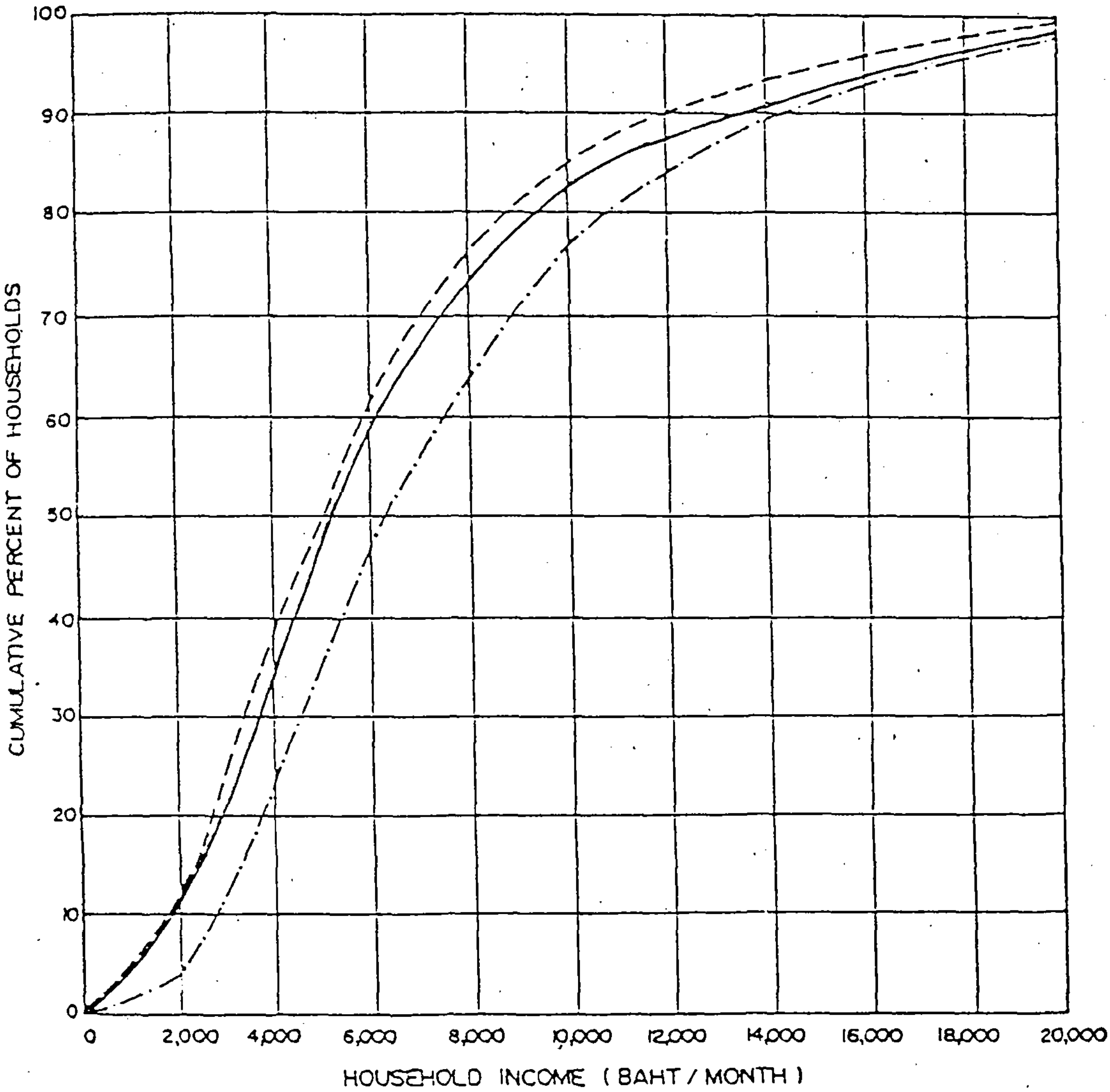
In addressing the complex problem of affordability first, it is extremely difficult to determine the level of costs that a majority of the population is able or rather, willing, to pay for an adequate level of sanitation. Using the data from the Regional Cities Development Project, Figure 2.1 may illustrate representative income distribution patterns. However, it is difficult indeed to relate such statistics to adequate levels of service, or, to a feasible mix of different sanitation systems. This may consist of a simplified "appropriate technology" system of doubtful performance, for poor people's areas, and a more advanced, environmentally safe system for the more affluent sectors of the society. (As a footnote to this complex issue, see Appendix 2.2.) Convincing as a multiple-standard system may sound in theory, it would not be easy to implement it in a city of mixed land uses that lack a clear locational separation of income groups. Another problem in this context is how to determine acceptable, and enforceable, levels of user charges among rather different income groups. It is not clear whether a small but arbitrary percentage can be used on the basis of some international comparison, or, as appears to be the case, that the very low costs of the deficient present sanitation system would have to be used as a yardstick. (In this respect, refer to the discussion of costs and user charges in Chapter 7.)

It may be relevant to use the example of property taxation for comparison. Although the legal basis is already weak, as it grants unusually generous tax exemptions, there appear to be considerable administrative constraints to efficient revenue collection from property taxes (MANNING, 1984). In view of this deficiency, the World Bank loan for regional cities development is combined with a subproject which aims at improving cadastral maps as well as procedures for property tax collection. Among several other cities, Chonburi has already begun to set up detailed new property tax maps (1:1000). However, it is not yet known whether there is any significant effect on raising and collecting more property taxes.

Urban development in Thailand has been dominated by the forces of the market rather than the effects of planning. This refers to urbanization at the national and regional levels, as well as to the local level, where some generalizations can be made with regard to typical development patterns and spatial elements. Normally, a close relationship between urban development and major transport routes can be observed. This applies to locational shifts of the city center away from a river bank or a fishing port, towards a highway connection or intersection that was originally built at the periphery of a town. In most cities in Thailand, road traffic is much more important to the economy than water or rail transport. Apart from the visible influence of accessibility, major public-use locations often attract, like magnets, private commercial land uses.

On the whole, growth and change processes are reflected in some typical urban patterns:

- Most cities and small towns have an older center with one-to two-story wooden shophouses, often along with a busy market that spills over into the adjacent narrow lanes.



Legend:

________	Nakhon Ratchasima
_ _ _ _	All municipalities Excl. Central Region and Bangkok
_._._._	Bangkok

Source: SINCLAIR KNIGHT & Partners et al. (1983)

Figure 2.1 Urban Household Income Distribution, 1981

- Modern centers consist of several large four-story concrete shophouse complexes with considerably wider roads, adjacent to the older center as well as located along the highway; there are many smaller towns where the ribbon development along the highway contains the most important commercial and manufacturing establishments.

- Notably all shophouse areas include high density residential use, comprising a range of incomes and household sizes.

- Residential areas are either of the older traditional type with densely clustered wooden houses or, as yet in a few cities only, of the housing estate type (called muban, i.e., "village") which is often found in Bangkok.

- Buddhist monasteries (wat) traditionally include public facilities such as schools, community halls, and playgrounds; wat areas, often at rather low density with a fair amount of open space, are located adjacent to or within the core areas of cities.

- Slum and squatter areas are not easy to distinguish from "formal" traditional housing areas; in fact, smaller pockets of lower-income, "informal" housing are typically dispersed all over the city.

- With very few exceptions, there are as yet no industrial estates in provincial towns; however, some larger industries are normally located along the highway outside the municipal boundaries; furthermore, many small-scale manufacturing businesses would still be concentrated in the core area.

- Government offices are often clustered in a large area, located away from the old commercial center. Such areas comprise the provincial administration, the high court, the district administration, the police, the municipality, and the offices of major line agencies. Such public-use areas often cover rather large amounts of open space and various types of housing for civil servants.

- Military installations and provincial hospitals typically occupy very large areas at a certain distance from the town center, mostly including housing for the employees.

While such patterns sufficiently describe the physical elements of a typical small- to medium-sized town, the administrative status of contiguous urban areas often differs, between municipality (tesaban) in the core area, and sanitary district (sukapiban) or even village at the periphery. As mentioned before, many towns, including Chonburi, are "underbounded". Apart from the geographical-statistical concern about the actual population or area size of such towns, some serious policy issues are involved. If the local authority is confined to its tightly drawn municipal area only, how can it be expected to take a leading role in planning and managing urban growth - which largely takes place outside its area of jurisdiction? How should urban infrastructure provision be financed if a large part of local tax revenue accrues from industrial establishments just beyond the municipal boundaries? How can the tesaban exert development control if it is easier or not required to obtain building permits for sites outside the municipality area?

Within the land use patterns described, population densities vary considerably, depending on local conditions. In view of the more general orientation of the present study it may be useful to present density ranges as derived from a detailed survey of 25 representative towns (Table 2.2).

Chonburi was one of the 25 towns surveyed, using population data of 1977. Comparing the survey results in Table 2.2 with those that were used for the present study (see Table 2.5), shows that the characteristics of an underbounded town have become even more pronounced: by now slightly more than half of the total population lives outside the municipal boundaries (as compared to about one third then); the rather high actual density within tesaban boundaries continues to be above 180 inhabitants/ha, whereas densities in the non-municipal urban areas are decreasing, thereby lowering the overall density from 123 to 105 inhabitants/ha.

2.4 Basic Population and Land Use Data on Chonburi

The purpose of the study is to compare the economic, institutional, and technical implications of alternative sanitation and recycling options in a typical urban setting in Thailand. The emphasis therefore is on a systems comparison rather than a plan for future development. Given the uncertainty implied in any land use and population projection, the base line data used for the study are those of the present situation, rather than those that may be projected for a future target year (as in a planning study). In this way, the systems comparison was based on the most realistic data with regard to present land use and socio-economic characteristics.

2.4.1 Topography

The settlement area covers a significant portion of the coastal plain of Chonburi, extending from the shore of the Gulf of Thailand to a range of low isolated hills with peaks ranging from 60 m to 120 m height. The coastal plain is about 2 m to 3.75 m above the mean sea level. A considerable part of the area is characterized by mud flats subject to flooding during the rainy season. The attached base maps (Maps 1 and 2) show the main topographic elements relevant to the sanitation study (Appendix 2.3).

2.4.2 Delimitation of the Study Area

In Chonburi, as a typical underbounded town, most of the urban development over the last 20 years has taken place outside the municipality area. Although the local government body concerned (tesaban) has applied for many years to have its boundaries expanded, this is yet to be approved by the Ministry of Interior. Figure 2.2 illustrates the spatial relationship between the urban aggregate and the various administrative boundaries in the vicinity of the municipality. The proposed tesaban boundaries include an area of about 43 km^2, a tenfold increase compared with the existing municipality area.

Table 2.2 Urban Area Characteristics: 25 Small and Medium-sized Towns Compared with Chonburi

Characteristics[1]	Group 1[2]	Group 2[3]	Mean/Chonburi[4]
Total urban population as ratio of tesaban population (%)			
- range	110-198	103-144	
- mean	147	118	140
- **Chonburi**	-	-	**146**
Gross density (inh./ha) (within tesaban boundaries)			
- range	14-184	8-28	
- mean	59	19	38
- **Chonburi**[5]	-	-	**158**
Actual core density (inh./ha) (urbanized area within tesaban)			
- range	64-208	61-115	
- mean	117	82	105
- **Chonburi**	-	-	**187**
Actual total density (inh./ha) (total urbanized area)			
- range	55-172	45-113	
- mean	83	73	80
- **Chonburi**	-	-	**123**

1) Selected results of an air photography survey which was carried out in 1979; population data as of 31 Dec. 1977
2) 17 towns whose boundaries were not expanded after 1968
3) 8 towns whose boundaries were expanded between 1968 and 1978
4) Compare these figures (1977) with the ones used for the present study (1983) - see section 2.4
5) Land area only, not including the 1.5 km^2 of water surface included in the tesaban boundaries

Source: KAMMEIER, 1986, p. 305

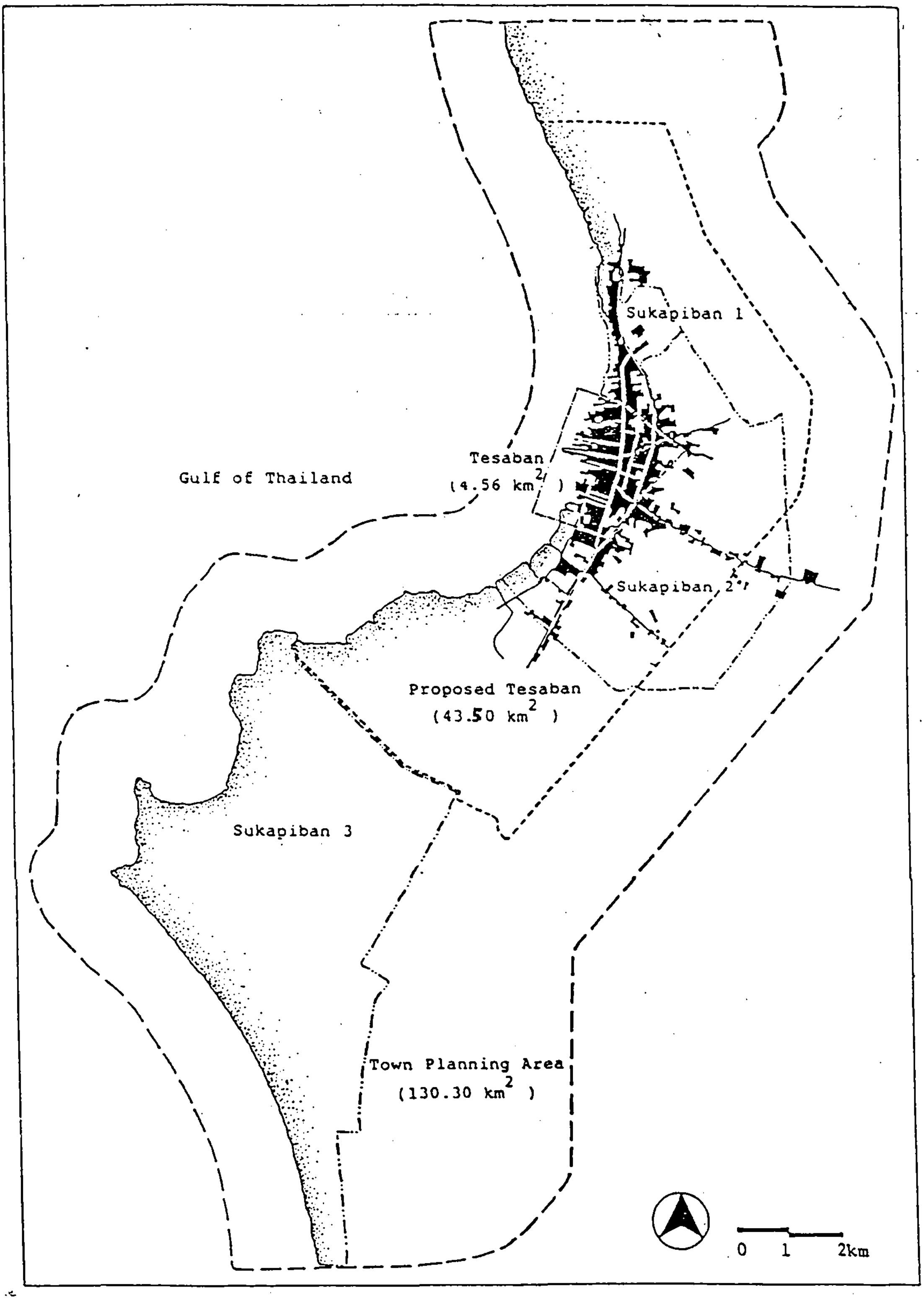


Figure 2.2 Alternative Definitions of Urban Area, Example Chonburi

All of the various infrastructure planning studies that have been undertaken in the last five years, use considerably larger study areas than the municipality. Among them, the land use map of the draft Structure Plan (1983), the Waste Disposal Study (1983), the Water Supply Study (1985), and the Flood Control and Drainage Study (1984/85) are to be mentioned. These studies have been taken into consideration to delimitate the present study area. The study area is delimited in such a way that information from previous studies can be transferred without major difficulties while meeting the requirement of an adequate reference area. Figure 2.3 shows the study area in comparison with those of relevant previous studies. The study area which is in fact equivalent to the proposed tesaban areas, covers approximately 4,353 ha (43.5 km^2) of land, of which the existing municipality occupies only 300 ha. This figure differs from the official municipality area of 457 ha which covers more than 150 ha of water surface in front of the shore line. The same study area was also used in the Drainage and Flood Control Study (1985).

2.4.3 Sources of Base Line Data

The base line data on land use areas and population distribution were mainly derived from the Water Supply Study for its relevance and suitability. Furthermore, to adapt the base line data to the objectives of the present study, the study area was divided into 33 "cells", more or less corresponding to the "zones" of the Water Supply Study, although the latter refers to a considerably larger total area, especially towards the south of Chonburi. The boundaries of cells in the municipality area have also been laid out in such a way that they tally with the municipal boundary as this will facilitate the comparative analysis between areas within and outside the municipality area (refer to Maps 1 and 2).

Table 2.3 shows a comparison between the base line data of the present study and the data from the Water Supply Study. There are eight different land use categories which are based on the Water Supply Study as well as some other considerations. For example, two new land use categories - "Agricultural" and "Residential II" - were introduced, in addition to the single "Residential" category of the Water Supply Study. The land use categories are supposed to describe the general character of the built-up area, and the predominant land utilization in a particular cell. In fact, the residential population is distributed among all categories of land use including "Commercial" in particular, because Chonburi, as all other towns and cities in Thailand, has a thoroughly mixed land use pattern.

2.4.4 Land Use Categories

The land use categories determined for the purpose of the study are:

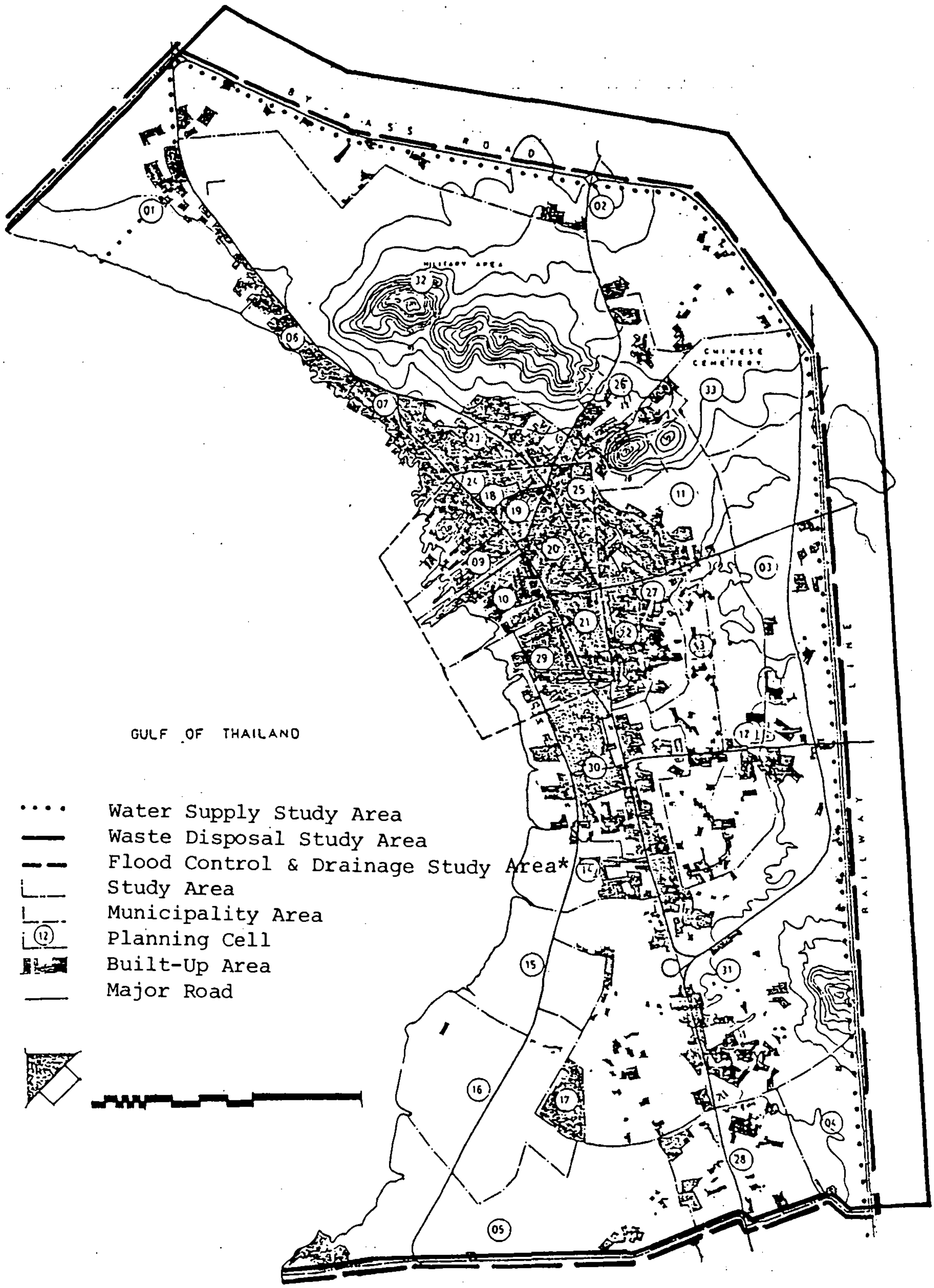
1) Agricultural

2) Residential I

   - Residential areas situated along the coastal plain (high density)

3) Residential II

   - Residential areas other than the coastal plain (lower density, some areas in the process of development)



Source: Based on Land Use Maps by Town and Country Planning Department (1983) and Flood Control and Drainage Study (1984)

Figure 2.3 Delimitation of the Study Area

Table 2.3 Base Line Data in Comparison with Data from the Water Supply Study

BASE LINE DATA FOR THE PRESENT STUDY						WATER SUPPLY STUDY [1]				
Cell No.	Land Use Category	Gross Area (ha)	Built-up Area (ha)	Net Pop. Density (pop./ha)	Population	Zone No.	Land Use Category	Gross Area (ha)	Gross Population Density (pop./ha)	Population (1983)
1	Agricultural	250	22	17	370			250 [2]		
2	Agricultural	350	12	43	520	9	Residential	350 [2]	1.5 [4]	1,200
3	Agricultural	210	31	10	310			210 [2]		
4	Agricultural	60	5	18	90	N.A. [3]	-	60 [2]	1.5 [4]	90 [2]
5	Agricultural	275	10	40	400	(24, 25) [3]	Residential	275 [2]	1.5 [4]	400 [2]
6	Residential I	26	14	250	3,500	1	Residential	26	135	3,500
7	Residential I	22	22	250	5,500					
8	Residential I	33	33	250	8,250	2	Residential	121	248	30,000
9	Residential I	22	22	250	5,500					
10	Residential I	44	44	244	10,750					
11	Residential II	77	32	16	500	7.1	Residential	77	6.5	500
12	Residential II	173	14	82	1,150	7.3	Residential	173	6.6	1,150
13	Residential II	51	14	25	350	7.2	Residential	51	6.9	350
14	Residential II	96	17	35	600	7.4	Residential	96	6.3	600
15	Residential II	101	18	39	700	7.5	Residential	101	6.9	700
16	Residential II	264	50	36	1,800	7.6	Residential	264	6.8	1,800
17	Residential II	28	20	90	1,780	6	Residential	28	64	1,780
18	Commercial	6	6	181	1,100					
19	Commercial	18	18	181	3,300					
20	Commercial	38	38	181	6,900	4	Commercial	117	181	21,200
21	Commercial	30	30	181	5,400					
22	Commercial	25	17	265	4,500					
23	Mixed	84	66	114	7,500					
24	Mixed	20	20	190	3,800					
25	Mixed	38	32	156	5,000	3	Mixed	299	97	29,000
26	Mixed	67	21	186	3,900					
27	Mixed	90	58	152	8,800					
28	Mixed	151	30	53	1,600	(21) [3]	Mixed	151 [2]	10.6	1,600 [2]
29	Institutional	51	39	47	1,850	5	Institutional	212	36	7,700
30	Institutional	161	123	48	5,850					
31	Industrial	670	131	32	4,200	8	Industrial	670	6.3	4,200
	TOTAL	3,531	1,009	105	105,770			3,531	30	105,770 [5]
32	Special	648	N.A.	N.A.	N.A.	N.A. [3]	-	648 [2]	N.A.	N.A.
33	Special	174	N.A.	N.A.	N.A.	N.A. [3]	-	174 [2]	N.A.	N.A.
	GRAND TOTAL (Study Area)	4,353						4,353		

1) Figures from Chonburi Water Supply Project, Vol. II, pp. II-14 to II-18 (Table II. 2-1).

2) Area and population figures marked by this footnote are not explicitly shown in the reference table of the Water Supply Study. However, these figures are reasonably reliable estimates.

3) Cell No. 4, 32 and 33 are not part of the Water Supply Study area, whereas Cell No. 5 and 28 of the present study include small sections of Zones 24 and 25 and a small section of Zone 21, respectively, of the Water Supply Study.

4) Implicit gross density figures.

5) Total population from Water Supply Study (103,680) plus estimated population in Cell No. 4, 5 and 28.

4) Commercial

5) Mixed

- Areas mixed with residential, commercial, and scattered institutional activities

6) Institutional

7) Industrial

8) Special

- Restricted government institutional areas such as military camp, police training centre etc.

The total study area for the purpose of analysis covers 3,531 ha of land and a population of 105,770. Cells 32 and 33 were not included in this total as the population data of these special areas were not available. These areas were assumed to be served by their own wastewater collection and treatment systems. They were therefore excluded from the calculations and considerations under the sanitation options.

The gross density figures used in the Water Supply Study are significant only to a limited extent for the present study. Therefore, a mapping survey had to be carried out with a focus on the **built-up areas**, which provide the more appropriate **net density** figures.

The most densely populated areas (240 to 250 persons/ha in cells 6, 7, 8, 9, 10) are located along the coastal plain with a population of 33,500. These areas fall under the "Residential I" land use category and cover 147 and 135 ha of gross and built-up area respectively. On the other hand, the least densely populated cells 1, 2, 3, 4, 5 (10 to 43 persons/ha) are located all along the Chonburi by-pass and the road to Ang Sila with a population of only 1,690. These areas fall under the "Agricultural" land use category and cover a gross area of about 1,145 ha.

The most densely populated single cell, No. 22 (265 persons/ha) is located just outside the eastern municipal boundary along Sukhumvit Road with a population of 4,500. This area falls under the "Commercial" land use category and covers 17 ha of built-up area. By comparison, the least densely populated single cell, No. 3 (10 persons/ha) is located along the Chonburi by-pass to the east of the study area, with an estimated population of only 310. This area, under the "Agricultural" land use category, covers only 31 ha of built-up areas. A detailed breakdown of all cells is shown in Table 2.3.

2.4.5 Land Use Characteristics

The municipality area and its vicinity are characterized as the core area of Chonburi where most of the residential and commercial dwellings are concentrated (49% of the population on 6.9% of the study area). These areas are situated along and in-between Sukhumvit and Vachiraprakarn Road and extend towards Suk Prayun and Akkaniwat Road. The rest of the area is characterized as agricultural or scattered residential with the exception of cells 30, 31, 32, and 33, where institutional, industrial and special land uses are concentrated (Map 2). The population concentration is the highest in and around the municipality area, ranging from 181 to 265 persons/ha. The structures in and around the municipality area are mostly brick and concrete shophouses used both for commercial and residential purposes except in coastal areas where wooden houses on stilts are found built over tidal mud flats. A descriptive overview of the cells and their land use characteristics is shown in Table 2.4.

2.4.6 Comparison of Land Use Data between the Municipality and the Rest of the Study Area

The total study area covers a total of 4,353 ha of land, of which the municipality area occupies only 300 hectares. However, only 3,531 ha of land were taken into consideration for the purpose of analysis as population data for the remaining 822 ha of special areas were not available. Table 2.5 shows a comparative overview of land use data for the municipality and the rest of the study area.

There are altogether 10 cells which cover the municipality area. These cells lie in between Vachiraprakarn and Sukhumvit Road and extend towards the coastal plain to the west and towards Suk Prayun Road to the east of the study area (Map 2).

The overall net densities of the municipality and the rest of the study area are 184 and 74 persons/ha respectively. The population of the municipality is 51,850, roughly 49% of the total population of 105,770, indicating a high population concentration. The municipality area covers 282 ha of built-up area, which represents 27.96% of the total built-up area of 1,009 ha.

The most densely populated cells (8, 9, 10) in the municipality (248 persons/ha) have altogether 24,500 inhabitants, roughly 23% of the total population, and cover the old coastal settlement areas (Residential I). Although predominantly residential, these areas include a range of activities related to fish and food preservation as well as small workshops.

The most densely populated cells, No. 6, 7 (250 persons/ha) in the rest of the study area have altogether 9,000 inhabitants, 8.51% of the total population. These areas are located north of the municipality boundaries. Their land use character is similar to the old coastal settlement zone within the municipality. The least densely populated cells, No. 24, 25 (169 persons/ha) in the municipality have altogether 8,800 inhabitants, 8.32% of the total population. These cells fall under the "Mixed" land use category.

2.4.7 Distribution of Area and Population by Land Use Category

Among the 8 land use categories, "Residential I" occupies the highest number of inhabitants (33,500), or 31.67% of the total population of 105,770. It has a gross area of 147 and a built-up area of 135 ha, respectively. On the other hand, the least number of inhabitants (1,690) is under the "Agricultural" land use category, roughly 1.60% of the total population. This corresponds to the largest gross area (1,145 ha) but the smallest built-up area (80 ha). A detailed breakdown of area and population figures by land use category is shown in Table 2.6.

Table 2.4 Land Use Characteristics

Cell No.	Land Use Category	Description	Location	Characteristic Figures	
				No. of Stories	Net Pop. Density Range (pop./ha)
1-5	Agricultural	Predominantly used as salt evaporator, rice field, vegetable and upland crop area. Negligible residential structures.	Situated along Chonburi by-pass and west of Sukhumvit Road in the northern part of Chonburi and on both sides of Sukhumvit Road in the southern part of Chonburi	1	10-43
6-10	Residential I	Large portion (75%) of wooden stilt houses built over tidal mud flats except for Cell No. 6 where most of the dwellings are in permanent compounds. Inadequate infrastructure.	To the west of Sukhumvit and Vachiraprakarn Road in the northern part of Chonburi.	1-2	250
11-17	Residential II	At present the dwellings are scattered, with a great variety of types except in Cell No. 17 where most of the houses are bungalow type with all the services available. Such areas are expected to be developed both by the private and public sector with various types of houses and shophouses.	To the north and south of Akkhaniwat Road and west of by-pass. Also to the west of Sukhumvit Road in the southern part of Chonburi.	1-2	16-90
18-22	Commercial	Mostly concrete shophouses used both for commercial and residential purposes; old shophouses 1-2 stories, new shophouses 2-4 stories.	Located mainly between Sukhumvit and Vachiraprakarn Road.	1-2 2-4	181-265
23-28	Mixed	Varies greatly, ranging from market gardening, commercial, residential to institutional use. Most of the dwellings are concrete shophouses especially in the areas facing Sukhumvit, Suk Prayun and Sethakit Road. Wooden structures dominate in other areas.	To the north and east of Chonburi commercial district.	1-2	53-190
29-30	Institutional	Most of the government and other institutions are located in these cells.	To the south of Chonburi commercial district.	-[1)]	48
31	Industrial	At present scattered development. The area is expected to be developed as an industrial estate, as proposed in the Eastern Seaboard Study.	To the southern end of Chonburi by-pass and in the eastern part of Samet.	-[1)]	32
32-33	Special	These cells contain a provincial sports centre, police training centre, Chinese cemetery, military camp and highway department land.	To the east of Sukhumvit Road and to the south of Suk Prayun Road.	-[2)]	-

1) Various types of structures, number of stories not a significant characteristic.

2) Population figures not available; police training centre and military camp not accessible; therefore, no attempt at estimating extent of built-up area.

Table 2.5 Summary of Land Use Data (Municipality vs. Study Area)

Cell No.	Land Use Category	Gross Area Absolute (ha)		Gross Area %		Built-up Area Absolute (ha)		Built-up Area %		Population Absolute (pers.)		Population %		Net Population Density (pop./ha)	
8	Residential I	33	99	0.93	2.80	33	99	3.27	9.81	8,250	24,500	7.80	23.16	250	248
9		22		0.62		22		2.18		5,500		5.20		250	
10		44		1.25		44		4.36		10,750		10.16		244	
18	Commercial	6	92	0.17	2.61	6	92	0.60	9.13	1,100	16,700	1.04	15.79	181	181
19		18		0.51		18		1.79		3,300		3.12		181	
20		38		1.08		38		3.77		6,900		6.52		181	
21		30		0.85		30		2.97		5,400		5.11		181	
24	Mixed	20	58	0.57	1.65	20	52	1.98	5.15	3,800	8,800	3.59	8.32	190	169
25		38		1.08		32		3.17		5,000		4.73		156	
29	Institutional	51		1.44		39		3.87		1,850		1.75		47	
SUB TOTAL I:	Municipality Area	300		8.50 (6.9)		282		27.96		51,850		49.02		184	
1	Agricultural	250	1,145	7.08	32.43	22	80	2.18	7.93	370	1,690	0.35	1.60	17	21
2		350		9.91		12		1.19		520		0.49		43	
3		210		5.95		31		3.07		310		0.29		10	
4		60		1.70		5		0.50		90		0.09		18	
5		275		7.79		10		0.99		400		0.38		40	
6	Residential I	26	48	0.74	1.36	14	36	1.38	3.56	3,500	9,000	3.31	8.51	250	250
7		22		0.62		22		2.18		5,500		5.20		250	
11	Residential II	77	790	2.18	22.36	32	165	3.17	16.34	500	6,880	0.47	6.50	16	42
12		173		4.89		14		1.38		1,150		1.09		82	
13		51		1.44		14		1.38		350		0.33		25	
14		96		2.72		17		1.69		600		0.57		35	
15		101		2.86		18		1.79		700		0.66		39	
16		264		7.48		50		4.95		1,800		1.70		36	
17		28		0.79		20		1.98		1,780		1.68		90	
22	Commercial	25		0.71		17		1.69		4,500		4.25		265	
23	Mixed	84	392	2.38	11.11	66	175	6.54	17.34	7,500	21,800	7.10	20.62	114	125
26		67		1.90		21		2.08		3,900		3.69		186	
27		90		2.55		58		5.75		8,800		8.32		152	
28		151		4.28		30		2.97		1,600		1.51		53	
30	Institutional	161		4.56		123		12.19		5,850		5.53		48	
31	Industrial	670		18.97		131		12.99		4,200		3.97		32	
SUB TOTAL II:	Areas outside Municipal Boundary	3,231		91.50 (74.2)		727		72.04		53,920		50.98		74	
32	Special	648	822	(18.9)		N.A.		-		N.A.		-		N.A.	
33		174				N.A.		-		N.A.		-		N.A.	
	GRAND TOTAL[1] (Study Area)	4,353		(100.0)		1,009		100.00		105,770		100.00		105	

1) Gross Area percentages in parentheses related to total study area; all other totals related to sum of subtotals I and II, i.e., as far as figures (population, built-up area) are available.

Table 2.6 Area and Population Distribution by Land Use Category

Cell No.	Land Use Category	Gross Area Absolute (ha)	Gross Area %	Built-up Area Absolute (ha)	Built-up Area %	Population Absolute (persons)	Population %
1-5	Agricultural	1,145	32.43	80	7.93	1,690	1.60
6-10	Residential I	147	4.16	135	13.37	33,500	31.67
11-17	Residential II	790	22.36	165	16.34	6,880	6.50
18-22	Commercial	117	3.32	109	10.82	21,200	20.04
23-28	Mixed	450	12.76	227	22.49	30,600	28.94
29-30	Institutional	212	6.00	162	16.06	7,700	7.28
31	Industrial	670	18.97	131	12.99	4,200	3.97
TOTAL		3,531	100.00	1,009	100.00	105,770	100.00
32-33	Special	822		Information not available			
GRAND TOTAL (Study Area)		4,353					

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3. APPROPRIATE SANITATION TECHNOLOGY

3.1 Introductory Remarks

Some form of technology and management for water supply and waste disposal has always been used as long as there have been urban settlements. However, it was the unprecedented rapid growth of the industrial city in the 19th century that necessitated major innovations in water and waste management. In fact, the development of the large European cities from about 1850 onwards would have been impossible without the progress in public hygiene and municipal engineering. As is well known, the growing European and American cities in the 19th century adapted and improved their technical infrastructure systems in typical sequences, in order to meet the challenges of hitherto unknown levels of population size and density.

Safe municipal water supply, replacing the earlier individual wells, was the first stage in battling waterborne diseases. However, the availability of piped water greatly increased water consumption figures, including the use of the flush toilet - but then the primitive on-site facilities for waste collection could not cope anymore (although improvements such as bucket latrines and municipal cartage systems had preceeded the introduction of sewerage). It is interesting to note that in many cities the installation of water closets was prohibited at a time when the construction of sewer systems had just commenced (REIDENBACH, 1988: p. 492).

The second stage then was to provide for safe and fast transportation of human waste and wastewater out of the city, by means of a sewer system. The beginnings of modern sewerage are well documented but what appears to be overlooked sometimes in comparisons with the present-day situations in developing countries, are two facts: (i) It took decades to build such systems, in many cases against considerable political objections, because of the costs implied. Figures for a representative set of German cities in 1913 (260,000 to 2 million inhabitants) show that by then between 80 and 99 percent of the urban populations were connected to the sewer systems which had been constructed at a rate of about 6 to 10 km per year (REIDENBACH, 1988: p. 494). (ii) Furthermore, the levels of poverty, the housing situation of the working classes, and the scarcity of public funds may well be compared to those prevailing in today's more advanced developing economies. Thailand is a case in point, especially with regard to the urban areas in the richest provinces (compare Table 2.1 in Chapter 2).

The sequence of sanitation improvements in the growing European and American cities basically proceeded from piped water supply to wastewater and excreta disposal (predominantly in mixed sewerage and drainage systems), and finally, often with considerable delay, sewage treatment plants. It may be worth mentioning in this context that even in countries with the highest connection rates, many of the smaller towns in rural areas constructed their sewer systems and especially their sewage treatment plants only well after the second World War.

3.2 The Search for Affordable Solutions

Comparing "Western" urbanization experiences, especially in the area of sanitation technology, with current urbanization problems in Asian countries, raises some important questions. What are the similarities and differences in terms of economic, socio-cultural, climatic and technical aspects that would speak against adopting or adapting the sanitation technology of industrialized countries? In this respect, it is worth mentioning the considerable differences between the conventional "Western" solution of the sewer network, and the prevailing Japanese system of night-soil collection by vacuum truck. The arguments brought forward against sewerage as the standard solution are (after KALBERMATTEN et al., 1980, as well as RYBCZYNSKI et al., 1978), briefly summarized:

- The magnitude and speed of present urban growth in Asia is so much greater than that in Europe and North America in the past, that the two situations cannot really be compared;

- The financial resources will hardly ever be sufficient to cover sewerage as the standard solution;

- In view of the fecally transmitted diseases due to heat and humidity, the prime purpose of sanitation in a tropical climate must be pathogen destruction, with eventually even higher priority than in temperate regions;

- Periodic or permanent water shortages in many tropical countries are a severe obstacle to waterborne waste-disposal systems; and, finally,

- There are alternative technologies available that provide socially acceptable, technically sound and economically viable sanitation services.

It is further argued that conventional sewerage still provides the best and indeed the only viable solution to the sanitation problem of high-density, modernized ("Westernized") parts of the city. However, a range of less costly, more flexible and thus, more "appropriate", technologies can be applied, although many of them were already available when the now industrialized countries adopted the sewer system.

The documentation and research project which was carried out by the World Bank in 1976-1978 has been widely publicized. Its results indeed provide invaluable guidance to policymakers and sanitary engineers whose education may have left them with an unrealistic bias in favour of conventional sewerage, and, on the other hand, not enough knowledge about possible alternatives. To be mentioned in the context of the World Bank sanitation reports are the IDRC-supported documentation efforts, the comparative economic data, the proposed comprehensive methodology for community-based sanitation planning, and the sanitation field manual (based on the experiences from slum improvement projects in Jakarta).

The World Bank reports clearly show that there is considerable scope for effective as well as affordable improvements, especially at the lower end of the technology range, reviewed with regard to improved on-site facilities. Similarly, at the upper end of the scale, the innovative system of small-diameter sewers has been propagated as a cost-effective alternative to conventional sewerage. One of the most important recommendations arising from the World Bank research results is to plan and implement sanitation systems incrementally. This implies careful analyses of needs and specific objectives, constraints and opportunities, the scope for community participation or self-help, and the potential for waste recycling. Table 3.1 provides a descriptive overview of the three basic classes of sanitation systems that are assessed under various broad criteria of feasibility and appropriateness.

Table 3.1 A Summary of the Significant Characteristics of the Three Classes of Sanitation Systems

	Waterborne	Cartage	On-site
Capital cost	High	High/low	Low
Operating cost	Low	High	Low
Offshore cost component	High	High/low	Nil
Water consumption	High	Low/nil	Low/nil
Optimal density	High density (high rise)	High density (low rise)	High and low density (low rise)
Adaptability to incremental implementation	Nil	High	High
Adaptability to self-help	Nil	Low	High
Reuse potential	High	High	High/low

Source: RYBCZYNSKI, POLPRASERT and MCGARRY (1978)

3.3 Sanitation Program Planning and Technology Selection

Proper sanitation is both an indispensible requirement of public health and an extremely costly element of the technical infrastructure of urban areas. Given the very wide range of local conditions, it is difficult to provide a cost framework for sanitation in comparison with other elements of infrastructure. Based on European data about 1970, the following proportional figures may serve as first approximation for comparative purposes:

(a) Index of basic infrastructure costs per inhabitant (based on BORCHARD, 1974):

- water supply: 100
- sewerage (network + treatment): 450
- access roads: 600

(b) Index of average costs of utility networks (per m) (based on GASSNER, 1982: p. 198):

- electricity: 40
- gas: 70
- water supply: 100
- sewer: 175 (not including sewage treatment)

Even though such figures may be of limited value in the context of a study on urban sanitation in Thailand, the comparison shows that it is obviously necessary to search for every possibility for lowering especially the high costs of the most important infrastructure components, i.e. roads and wastewater disposal. The World Bank research results (KALBERMATTEN et al., 1980) provided the useful measure of TACH (total annual cost per household) as a tool for system comparisons. TACH figures cover all on-site and system investment costs as well as recurrent costs for collection and treatment. In 1978 figures, there were three distinctly different cost groups among the 10 sanitation technologies analyzed:

- low cost: range 18.7 - 64.9 US$
  (a.o., pour-flush toilet, composting toilet, bucket cartage)
- medium cost: range 159.2 - 187.7 US$
  (sewered aquaprivy, aquaprivy, Japanese vacuum truck)
- high cost: range 369.2 - 400.3 US$
  (septic tank, sewerage)

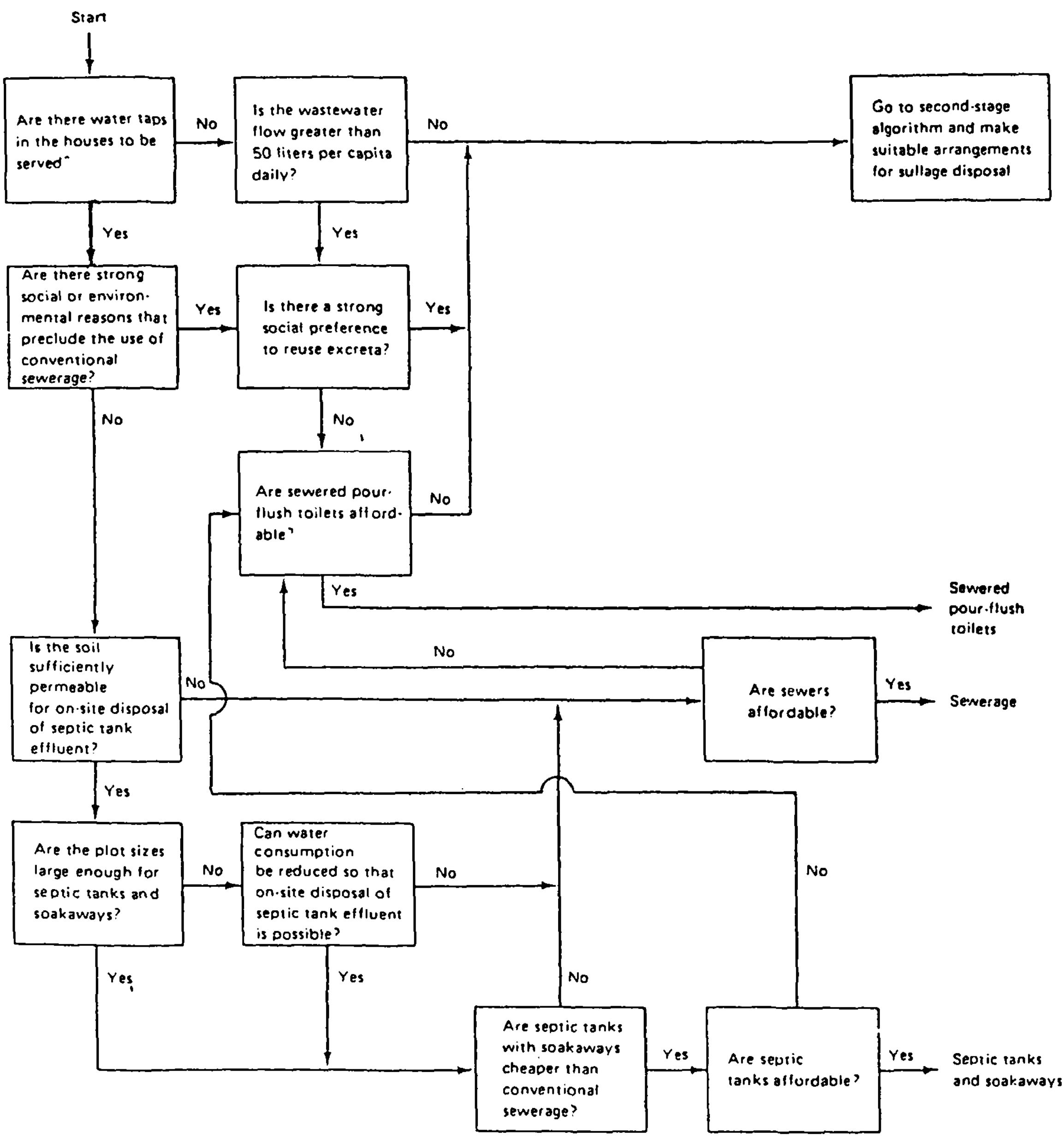
Such cost comparisons must be read cautiously, because the underlying data may have been taken from areas of very different densities, apart from the specific economic conditions of different countries. The extremely high figure for conventional sewerage may have been influenced by case study data from low-density residential areas. Nevertheless, it is very difficult indeed to obtain reasonably reliable comparative cost figures from other sources.

An important result of the World Bank research documentation is the demonstrable effect of "sanitation sequences" on cost reduction. Planned step-by-step implementation of sanitation programs over periods of 20 years would bring the total economic cost per household within an affordable range, while the respective initial stage of basic sanitation provision meets the basic requirements without exceeding the economic capacity of the household or the community.

Apart from its emphasis on sanitation sequences, the World Bank research reports elaborate the need to cover a wide scope of socio-economic and behavioural concerns, apart from the necessary steps of technical feasibility studies. Sanitation program planning as described by KALBERMATTEN et al. (1980) includes a carefully prepared approach to technology selection, as illustrated in Figures 3.1 - 3.3. Using such an approach in addition to the available background data on Chonburi, would provide the logic for a reasonable short list of alternatives to be considered in the framework of the present study.

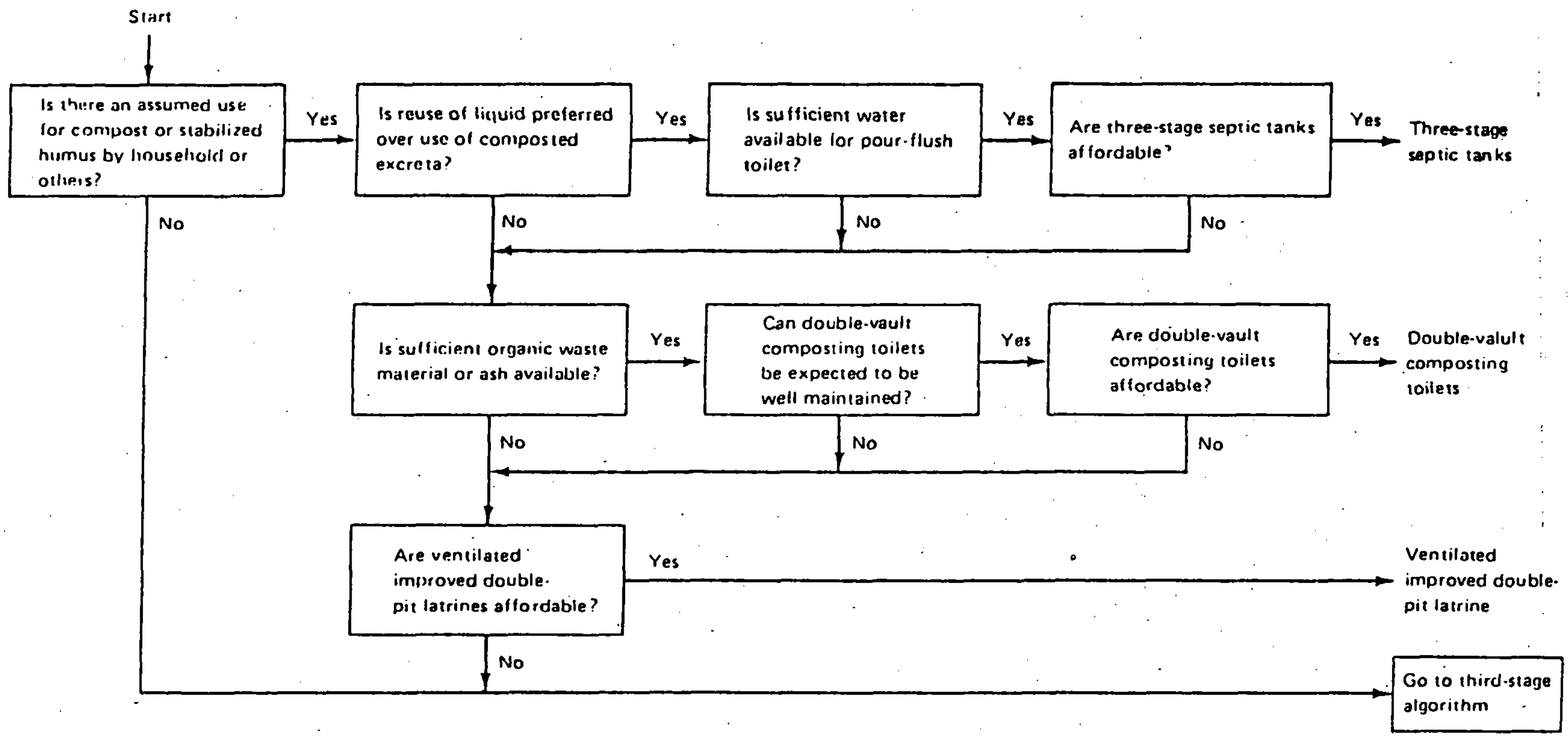
3.4 The Case Study Options

Although a review of the recent literature on appropriate sanitation technology provides an almost bewildering range of technical and operating data, the systems can be classified (i) into household and communal systems, depending on where the treatment of the waste materials (excrements and sullage) takes place; (ii) into dry and wet systems with on-site or off-site collection and treatment. The generic classification in Figure 3.4 shows, in relation to the conditions typical for urban areas in Thailand, that a large number of solutions must be excluded from the outset, on the grounds of social acceptability. In comparison with the many options reviewed in the World Bank research, the present conditions in Chonburi indicate a rather high level of service, i.e. piped water and individual pour flush toilets for most households. Thus the range of alternatives to be considered must constitute genuine improvements for the users while providing higher levels of public health protection. As the greatest problems are associated with high-density areas and adverse ground water conditions, the range of alternatives was reduced essentially to septic tanks and various configurations of conventional or small-bore sewer systems. Applying the sanitation sequence approach to some of the less developedmedium-sized cities in Thailand, may in fact result in a different set of recommendations, because the existing conditions may be poorer.



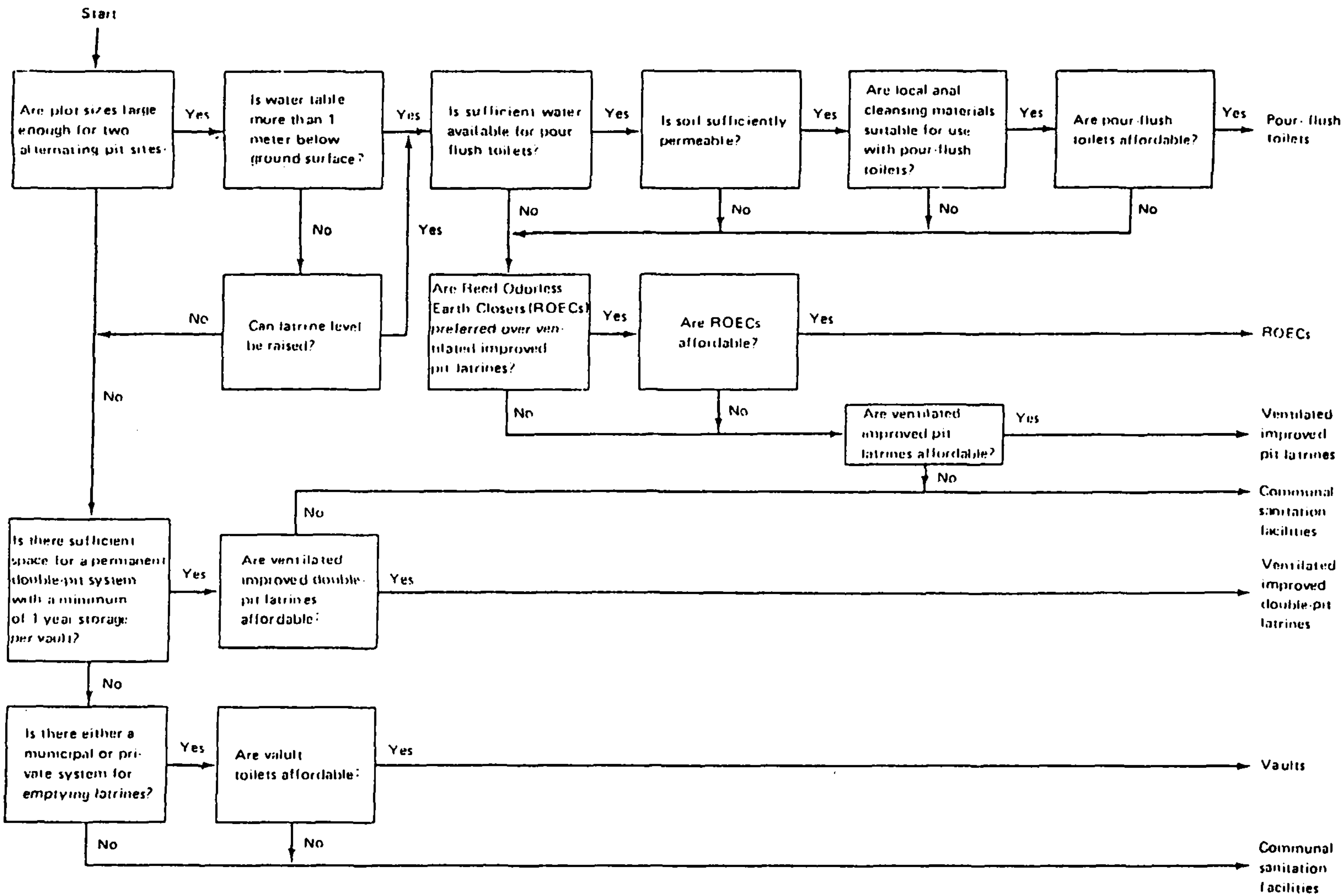
Source: KALBERMATTEN et al. (1980)

Figure 3.1 First-Stage Algorithm for Selection of Sanitation Technology



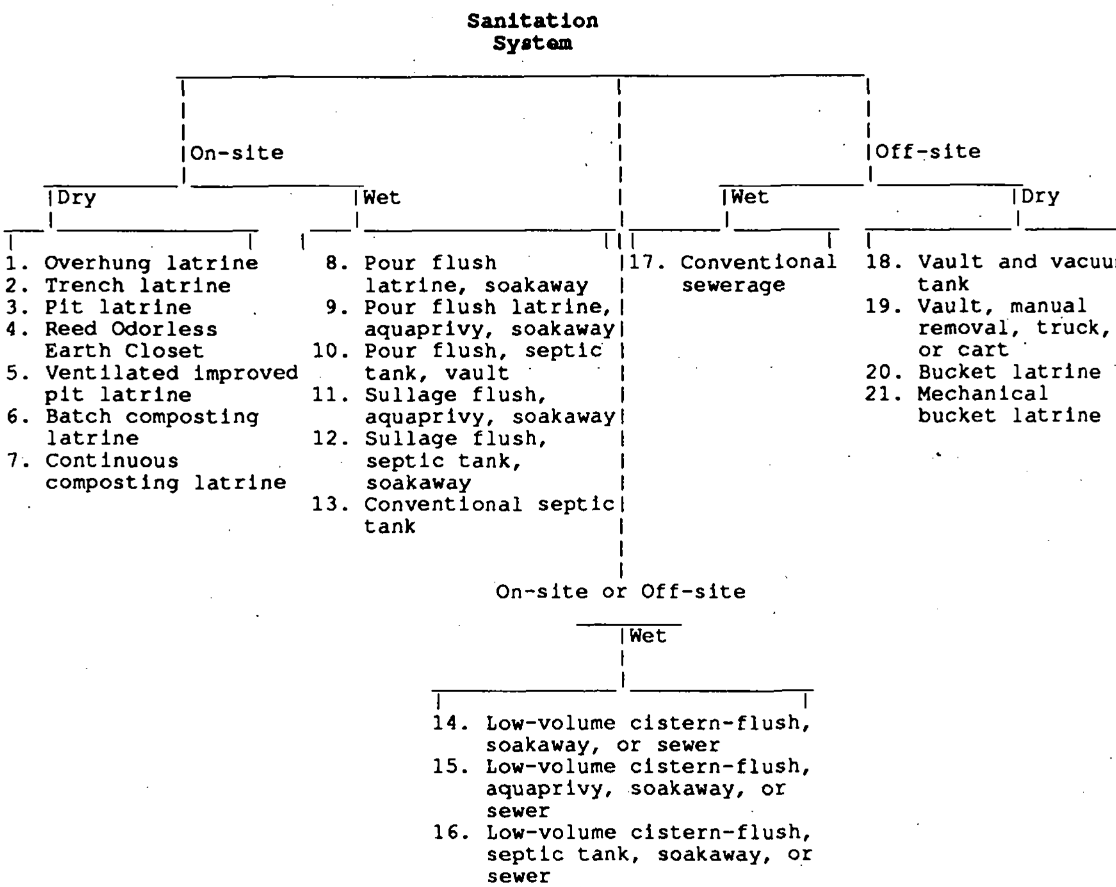
Source: KALBERMATTEN et al. (1980)

Figure 3.2 Second-Stage Algorithm for Selection of Sanitation Technology



Source: KALBERMATTEN et al. (1980)

Figure 3.3 Third-Stage Algorithm for Selection of Sanitation Technology



Source: KALBERMATTEN et al. (1980)

Figure 3.4 Generic Classification of Sanitation Systems

Apart from that, it was considered to be essential to assess the scope for alternative recycling possibilities, especially biogas production and fish cultivation.

The approach was divided into two steps:

(i) discussing and evaluating principal alternatives within the fields of on-site treatment, sewer networks, sewage and septage treatment, and recycling; and

(ii) establishing four exemplary options to be evaluated in greater detail, in terms of their technical, economic and institutional implications.

Table 3.2 shows an overview of the alternatives for preliminary technical and economic assessment; these are discussed within Chapters 4,5 and 6.

As shown in Chapter 2, the very different topographic and land use conditions, especially the densities, require different solutions to be technically and economically sound. Therefore, three of the four options consist of combinations of septic tanks and sewer systems whereas only the fourth option is exclusively based on the assumption of on-site facilities. Table 3.3 provides a synopsis of the four patterns that are referred to as

- Maximum Sewerage Option,
- Minimum Sewerage Option,
- Small-bore Sewerage Option, and
- Septic Tank Option.

For reasons of consistency, all four options were laid out in such a way that the level of service would be identical, thus avoiding the difficulty of comparing and quantifying the different benefits (health and user convenience, for example) within the systems options. Another simplifying assumption was to have the four systems installed as described, without explicitly evaluating intermediate phases of implementation. One may, however, think of the limited sewer network in the Minimum Sewerage Option, as an early stage of a more complete sewer network, such as the one in the Maximum Sewerage Option.

The systematic order of the study was thus hoped to allow sufficiently detailed calculations as to the per-household costs in areas of different densities, as well as the possibilities for partial cost recovery by means of aquaculture.

Table 3.2 Technical Alternatives Selected for Preliminary Assessment

System Component	Alternatives Considered	Remark
In-house facilities	Pour-flush toilet	No alternatives considered, but increasing use of cistern-flush toilet implied in water consumption figure
On-site Treatment	- Two-compartment septic tank (households) - Three-compartment septic tank (institutions)	No alternatives such as lower-cost aquaprivy and vault systems considered
Sewerage	- Various configurations of conventional sewer network - Small-bore sewer network with interceptor tanks, either by using existing on-site facilities, or new tanks	
Sludge Cartage	Standard municipal vacuum trucks	No alternatives considered
Treatment		
(a) Sewage	- Stabilization ponds - Aerated lagoon - Activated sludge	Adopted for further analysis: stabilization ponds
(b) Septage	- Anaerobic digestion (biogas)/facultative pond/sludge drying bed	
	- Stabilization ponds	Adopted for further analysis: stabilization ponds
Recycling	- Biogas production	
	- Aquaculture, using different procedures	Adopted for further analysis

Table 3.3 Synopsis of the Four Options Selected for Economic Evaluation

System Component / Option	I Maximum Sewerage Option		II Minimum Sewerage Option		III Small Bore Sewerage Option		IV Septic Tank Option
	(a) Sewer*)	(b) Septic Tank	(a) Sewer	(b) Septic Tank	(a) Sewer	(b) Septic Tank	
Collection							
Households (%)	84.0	16.0	35.9	64.1	84.0	16.0	100
Institutions (%)	92.5	7.5	2.2	97.8	92.5	7.5	100
Distribution	Larger Convent. Sewer Network v	Sludge Cartage v	Limited Convent. Sewer Network v	Sludge Cartage v	Small-bore Sewer Network (liquids) Sludge Cartage (Interceptor Tanks) →	Sludge Cartage v	Sludge Cartage
Treatment (2-sector plant for sewage and septage/sludge treatment)	Stabilization Ponds: - Anaerobic P. - Facultat. P . - Maturation P.	Stabilization Ponds: - Anaerobic P. - Facultat. P.	Stabiliz. P. (Sewage)	Stabiliz. P. (Septage)	Stabiliz. P. (Sewage)	Stabiliz. P. (Septage)	Stabiliz. Ponds (Septage)
Recycling	Aquaculture (Maturation P.)	(Fertilizer)	Aquaculture	(Fertilizer)	Aquaculture	(Fertilizer)	(Fertilizer)

*) In options I, II, and III different percentages of all households and institutional users are connected to a sewer system, and the balance is served by individual septic tanks

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4. SEWERAGE SYSTEMS

4.1 Design Criteria

The design criteria underlying the design of a sewerage system considerably influence the operational conditions and cost of the system. This becomes apparent, for instance, when comparing the cost of conventional against small bore sewerage. The cost saving and other benefits of small bore sewerage result primarily from its design criteria as differentiated from those for a conventional system. Any comparison between different sewerage systems, or even individual designs for a system of the same type, must therefore take into account the underlying design criteria.

To facilitate the interpretation of the results of this study, respective design criteria are briefly explained. This discussion, is primarily related to parameters for which a wider range of values is in common use and reference is made to literature and locally used values as well.

Sewerage systems in developing countries usually operate under more restrictive conditions compared to those functioning in industrialized countries. For example, financial constraints frequently hinder the acquisition of expensive maintenance equipment. This restrictive situation in developing countries has been taken into account in setting forth the design criteria for this study of alternative sewerage systems. Consequently, rather conservative values have been adopted.

4.1.1 Design Criteria for Conventional Sewers

4.1.1.1 Minimum Slope

METCALF and EDDY (1981) have mentioned that the minimum practicable slope for construction is about 0.8 m/km. However, other sources frequently cite 1 m/km as the minimum value for this parameter. Since the minimum diameter for conventional main sewers adopted in this study is only 300 mm, the minimum slope used here for main sewer design is 1 m/km. METCALF and EDDY (1981) have also suggested that the minimum slopes for gravity flow sanitary sewers of various pipe diameters be based on Manning's equation (n = 0.013), with a minimum velocity of 0.6 m/s. Accordingly, for a 200 mm diameter pipe, the minimum slope suggested is 3.3 m/km, while for a 300 mm diameter pipe, the minimum slope suggested is 1.9 m/km. These values were adopted for checking the depths of some critical lateral sewers, particularly at their point of discharge into the main sewer system. (See also the following paragraph.) House connection pipes are laid at a minimum slope of 20 m/km.

4.1.1.2 Minimum Cover

Whereas it is required that the sewer pipes be protected from damaging activities on the ground, sufficient depth must also be provided for the connection of laterals and for house connections. However, an increase in the minimum depth of ground cover would entail a higher excavation cost. To determine the minimum ground cover for the sewer pipes in this study, the following approach was adopted: Main sewers were designed with a minimum cover depth of 2 m. Then, from the layout plan of the lateral sewer system in representative areas, some critical sewers were selected. Using a minimum cover depth of 1.5 m above the crown of these critical sewers and adopting the slopes mentioned in the previous sub-section, the resulting sewer invert elevation level downstream (critical point) was calculated. This value was compared with the actual main sewer invert elevation at the critical point, as determined by the assumption of a minimum cover depth of 2 m for the main sewers. The minimum cover depth of 2 m for main sewers and 1.5 m for laterals proved sufficient, but less cover depth would make the connection of several laterals and houses in some distance of roads critical. The abovementioned values were, therefore, adopted as the minimum cover depth for conventional sewerage.

4.1.1.3 Maximum Excavation Depth

Previous soil investigations, including shallow and deep borings, for the drainage and flood control project in Chonburi revealed that the ground water table lies near the ground surface (with a difference of less than 2 m) in most places in the study area (TISTR, 1985). Moreover, an earlier study mentioned that shallow wells in the project area usually have water in them at depths of 1 to 1.5 m below ground level, though water levels drop from 2 to 3 m during the dry season (SEATEC International, 1983). These findings imply that the major portion of the proposed sewer network has to be placed below the indicated ground water table. This will require not only higher expenditures for construction and maintenance but also a high standard of construction and workmanship. Considering this, the maximum allowable depth of the sewer invert level below the ground level was limited to 5 m. An exception was made only with regard to the inlet section of the treatment plant in keeping a maximum invert depth of 6.3 m for the Maximum Sewerage Option. In this way, an additional pumping station would be avoided.

4.1.1.4 Hydraulic Design Equation

The Manning equation with the value of 0.013 for the roughness coefficient (n) was used for hydraulic design.

4.1.1.5 Minimum and Maximum Flow Velocity

The main criteria for the minimum velocity of flow in a conduit are the self-cleaning capacity and the prevention of extensive sulphide generation. Most commonly, values between 0.4 to 0.6 m/s for this parameter are suggested. In this study, the minimum flow velocity for conventional sewer pipes was taken as 0.5 m/s, at partial flow conditions. A maximum flow velocity of 3.0 m/s was considered here.

4.1.1.6 Wastewater Peak Factor

Peak factors of 2.5 for the design of main sewers and 3.0 for the design of lateral sewers were considered as the respective average values for residential, commercial, institutional, and industrial wastewater sources.

4.1.1.7 Wastewater Quantities and Infiltration Allowance

The wastewater discharge from domestic areas was taken as 120 l/(c.d). This figure was based on the reports by Kocks Consult-TPEC (1985) and by SEATEC International (1983). The latter report stated that a calculation of the per capita water consumption based on 1981 figures of water supply gives consumption figures of 108 to 150 l/(c.d) in the municipal area of Chonburi. In this study, 80% of 150 l/(c.d) was taken as the wastewater discharge from domestic sources. For other sources such as commercial, institutional, and industrial activities, data were taken from the list of major customers of the

Chonburi water supply system in the same SEATEC Report. An additional 0.1 l/(s.ha) was provided for minor commercial and institutional sources, distributed over the land use categories commercial, institutional, and mixed uses. Table 4.1 presents the total daily average flow rates for the study area.

Table 4.1 Summary of Daily Flow Rates

Cell no.	Land use category	Served Built-up area (ha)	Served Pop. (No.)	Major sources (l/s)	Domestic (l/s)	Comm./ Inst. (l/s)	Max. Sewerage (l/s)	Min. Sewerage (l/s)
(1)	(2)	(3)	(4)	(5)	(6)	(7)= 0.1x(3)	(8)=(5)+ (6)+(7)	(9)=(5)+ (6)+(7)
6	Res.I	14	3500	-	4.9	-	4.9	4.9
7	Res.I	22	5500	-	7.6	-	7.6	7.6
8	Res.I	33	8250	-	11.5	-	11.5	11.5
9	Res.I	22	5500	-	7.6	-	7.6	7.6
10	Res.I	44	10750	-	14.9	-	14.9	14.9
11	Res.II	25.6	400	-	0.6	-	0.6	
18	Comm.	6	1100	-	1.5	0.6	2.1	
19	Comm.	18	3300	-	4.6	1.8	6.4	
20	Comm.	38	6900	1.3	9.6	3.8	14.7	
21	Comm.	30	5400	1.3	7.5	3.0	11.8	
22	Comm.	17	4500	-	6.3	1.7	8.0	8.0
23	Mixed	66	7500	-	10.4	6.6	17.0	
24	Mixed	20	3800	-	5.3	2.0	7.3	
25	Mixed	32	5000	0.8	6.9	3.2	10.9	
26	Mixed	21	3900	-	5.4	2.1	7.5	
27	Mixed	46.4	7040	-	9.8	4.6	14.4	
29	Inst.	39	1850	7.6	2.6	3.9	14.1	
30	Inst.	98.4	4680	14.0	6.5	9.9	30.4	
Special-Military			N.A	7.6	-	-	7.6	
Total		592.4	88870	32.6	123.5	43.2	199.3	54.5

Infiltration/inflow into sewers is dependent on the quality of sewers and building connections, maintenance, and the ground water level with reference to the level of sewers. In the case of the latter factor, the presence of a high ground water table causes considerable leakage into the sewers. Other factors influencing the rate and quantity of infiltration/inflow are the length of the sewers, the area sewered, soil and topographical conditions, and, to some extent, the population density which affects the number and total length of house connections. Design recommendations for the peak inlow/infiltration rate in sewers differ widely. For the design of wastewater pipes of a separate system, literature recommends values ranging from 0.05 to 1.5 l/(s.ha) for inflow/infiltration rates. Other sources recommend a percentage addition to the basic flow rates. Considering the high ground water table as well as the soil and topographical conditions in the study area, a peak infiltration/inflow allowance of 100% of the basic wastewater flow rate from all sources was used here for conventional sewerage. This value is equivalent to about 0.3 l/(s.ha).

4.1.1.8 Manhole Spacing

METCALF and EDDY (1981) have recommended that manholes for smaller sewers of 600 mm diameter and less should be placed at intervals not greater than 100 m. For sewers 700 mm to 1200 mm in diameter, the maximum manhole spacing should be 120 m. But the length between two manholes should not exceed the length of sewers that can be cleaned with the equipment expected to be used. Based on present experience and the fact that cleaning of sewers is mainly undertaken manually, manhole spacing was taken as 25 m for pipes having diameters 500 mm or less and 30 m for pipes of larger diameters.

4.1.2 Design Criteria for Small Bore Sewers

4.1.2.1 Minimum Slope

According to OTIS and MARA (1985), since small bore sewers are designed to collect only the liquid portion of wastewater, the maintenance of strict sewer gradients to ensure minimum self-cleaning velocities is not necessary. Nevertheless, the design of small bore sewers must ensure that sufficient headloss - an overall net fall from the inlet to the outlet - is provided across the system and also that the hydraulic grade line during estimated peak flows does not rise above the outlet of any intercepter tank. "High points where the flow changes from pressure flow to open channel flow and points at the end of long flat sections are critical locations, where the maximum elevation must be established above which the sewer pipe cannot rise."

Considering high flow rates, which require diameters for sewer pipes of up to 1 m, and the eventual effects of backwater or operational disturbances in the main sewers, a more restrictive requirement was set for the minimum slope of main sewers than that for laterals. No inflections were allowed for main sewers, meaning a positive slope is maintained at all sections. This did not influence the hydraulic design since the minimum velocity turned out to be the more restrictive parameter.

4.1.2.2 Minimum Cover

OTIS and MARA (1985) have cited locations in Australia where the minimum cover provided is 1 m. For small bore sewerage in this study, a minimum ground cover of 1.5 m, 1 m, and 0.5 m for main sewers, laterals, and house connections respectively were used.

4.1.2.3 Maximum Depth

As with conventional sewerage, a maximum excavation depth of 5 m was adopted for small bore sewerage.

4.1.2.4 Hydraulic Design Equation

The Manning equation with n = 0.013 was used for small bore sewerage, as for the conventional system.

4.1.2.5 Minimum and Maximum Flow Velocity

Since the small bore sewers are to carry solely interceptor tank effluents and no coarse solids, the minimum velocity required can be lower than that for conventional sewers. A value of 0.3 m/s for the minimum flow velocity, which OTIS and MARA (1985) cited as the value adopted in practice in the USA, was taken. For the maximum flow velocity, a value of 3 m/s, as for conventional sewerage, was taken.

4.1.2.6 Wastewater Peak Factor

OTIS and MARA (1985) have noted that there are very few field data on the magnitude of peak flows in small bore sewers. A peak factor of 1.2 to 1.3 in a system in Westboro, Wisconsin, USA and a design peak factor of 3 in South Australian small bore sewer schemes have been cited. For the small bore sewer system in this study, a design peak factor of 2 for the main sewers was taken, as suggested by OTIS and MARA (1985) in the absence of sufficient field data. A factor of 3 for laterals was adopted.

4.1.2.7 Wastewater Quantities and Infiltration Allowance

The average wastewater discharge quantities from residential, commercial, and institutional sources are presented in Table 4.1. The infiltration allowance in the case of small bore sewers can be less than in the case of conventional sewers as the pipe material for a large part of the small bore sewer network is PVC since smaller diameters are used. Accordingly, a peak infiltration/inflow allowance of 50% of the basic wastewater flow rates from all sources was considered.

4.1.2.8 Cleanouts and Manholes

Cleanouts and manholes are points of access through which sewers are cleaned and maintained. OTIS and MARA (1985) have recommended that cleanouts be used in place of manholes except at major junctions. A manhole spacing of 245 m on straight flat sections is adopted in South Astralian small bore sewer schemes. For the main sewer of the small bore sewer system in this study, the manhole spacing used were 40 m for pipe diameters 300 mm or less and 50 m for pipe diameters greater than 300 mm. For the lateral sewer system, the manhole spacing considered was 150 m. Simple cleanouts in the lateral sewer system, installed after every 25 m of sewer length, enable the necessary flushing of the sewers with water. Cleanouts as replacement for manholes were not adopted in the main sewer system for greater reliability. This seems appropriate since current experience with small bore sewerage is based on a rather small system only, whereas the failure of main sewers of a larger system would affect larger parts of the town.

Design criteria for both conventional and small bore sewer systems are summarized in Table 4.2.

Table 4.2 Summary of Design Criteria for Sewers

Design parameter	Conventional sewer	Small bore sewer
Minimum slope		
main sewers:	1.0 m/km	>0 m/km
lateral sewers:		
300 mm dia.	1.9 m/km	-
200 mm dia.	3.3 m/km	-
Minimum cover		
main sewers:	2.0 m	1.5 m
lateral sewers:	1.5 m	1.0 m
house connections:	1.0 m	0.5 m
Maximum excavation depth	5.0 m	5.0 m
Manning's coefficient	0.013	0.013
Minimum velocity	0.5 m/s	0.3 m/s
Maximum velocity	3.0 m/s	3.0 m/s
W/W peak factor		
main sewers	2.5	2.0
lateral sewers	3.0	3.0
Infiltration allowance	100 %	50%
Minimum diameter		
main sewers	300 mm	200 mm
lateral sewers	200 mm	150 mm
house connections	100 mm	75 mm
Manhole spacing		
dia. $\leq$ 500 mm	25 m	-
dia. $\geq$ 500 mm	30 m	-
dia. $\leq$ 300 mm	-	40 m
dia. $\geq$ 300 mm	-	50 m
lateral sewers	-	150 m
Cleanouts spacing		
laterals	-	25 m
Life time	30 years	30 years

4.1.3 Design Criteria for Pumping Stations

Pumping stations were placed where all alternative sewer layouts caused the sewer invert level to fall more than 5 m below the ground level.

The volume of the pump sump necessary at a pumping station was determined using equation (4.1).

$$V = 0.9 \times Q/z \tag{4.1}$$

where V is the volume of the sump in m^3

Q = peak flow rate in l/s

z = number of pumping cycles per hour (assumed as 10)

The installed power of the pump in the pumping stations was calculated using equation (4.2) with a safety factor of 1.25.

$$N = 1.25\ (9.81 \times 10^{-3} \times Q \times H)/\mu \qquad (4.2)$$

where N = installed power of the pump in kW

Q = peak flow rate in l/s

H = head provided in m

μ = pump efficiency (assumed as 0.7)

The power consumption by the pumps was calculated by equation (4.3).

$$P = (9.81 \times 10^{-3} \times Q \times H \times 24 \times 365)/\mu \qquad (4.3)$$

where P = power consumed in kWh/a

Q = daily average flow rate in l/s

H = head provided in m

μ = pump efficiency (assumed as 0.7)

The lifetime of pumps and electro-mechanical equipment is assumed to be 10 years.

4.2 Unit Costs and Cost Evaluation Procedures

4.2.1 General Procedures for Cost Estimates

Establishing the cost functions needed to compare the various alternatives for sewerage systems was marked by some difficulties, as in obtaining complete and reliable cost data for the various options in consideration. It was not possible to obtain a complete set of unit costs from any single source. Hence, some unit costs were obtained from local sources, e.g. the municipality or local contractors. Also, other unit costs were taken from related studies and from other locations. As far as possible, the unit costs obtained from various sources were compared and checked against standard designs. In obtaining unit costs from local sources, another problem, which may be frequent in countries with limited experience in the construction of sewer systems, became apparent. In some cases, the unit costs obtained from local sources were surprisingly low and considerably lower than costs obtained from other sources. Field surveys of sewers under construction in local areas revealed that poor or substandard workmanship and materials were positively related to extraordinarily low unit costs. Considering this, unit costs obtained from local sources were adjusted, when deemed necessary, to reflect levels at par with appropriate standards of workmanship and construction.

Unit costs of pipe materials and pipe laying were worked out for a range of diameters of pipes laid at various depths. Cost functions for sewers, depending on diameter and depth, were then established through regression analysis. Manholes of specified standard dimensions were considered for use depending on the pipe diameter and depth. Manhole costs obtained from various sources were compared with those estimated from standard designs as well as related material and construction cost.

The cost of pumping stations was derived from the construction cost of the pumping station and the cost of the pump and its accessories, including installation. The costs of pumping stations of varying capacities were estimated from unit material and construction costs. Using these costs, a function relating the pumping station costs to the pump sump volume was determined. The unit costs of pumps and accessories including installation were obtained from various manufacturers or their representatives in Bangkok.

As customary in Thailand, the basic unit cost does not include costs of contingencies, operation, profit, and taxes. The final total cost is derived by multiplying the basic cost by a proportion of the cost according to the scale of the project. A rate of 40% was assumed in this study. This rate allows the subdivision of the project into a number of independent lots.

The annual operational and maintenance cost of sewers was taken as a percentage of the total construction cost. The annual operation and maintenance cost for pumping consists of the annual energy and maintenance cost of pumps. The energy cost was derived by using the prevailing rate per kWh while the maintenance cost of pumps was taken as a percentage of the energy cost.

4.2.2 Construction of Sewers

PVC pipes were selected for use for all required sewer pipes of diameters 200 mm or lower. Inspite of higher unit material costs compared to other pipes, PVC pipes offer a number of advantages. The advantages of using PVC pipes with respect to operation and maintenance include corrosion resistance, high impact strength, less infiltration, and less sedimentation. Since sewer cleaning is done manually and the majority of sewer pipes in the lateral system have a diameter of 200 mm, the increased operational reliability arising from the use of PVC pipes justifies the slightly higher final construction cost. The lateral small bore sewers shall be PVC pipes only. For all pipe diameters greater than 200 mm reinforced concrete pipes shall be used.

Table 4.3 presents the unit costs of pipe materials, pipe laying, and civil works for pipe installation, as derived from TISTR (1986), and information from consultants, the Bangkok municipality, and local sources. All cost figures are given at the 1986 price levels. These unit costs were compared and assessed in order to establish the values adopted for the present study. The unit costs of pipe material and installation - but excluding those of excavation, backfilling, and manholes - for various pipe diameters are illustrated in Figure 4.1. A linear regression analysis of these cost values, including the unit costs of trenching and backfilling, was used in developing cost functions depending on the pipe diameter and invert depth. With a trench width of 1 m for D 400 mm and D + 0.7 m for D > 400 mm, the following cost functions were developed.

Table 4.3 Unit Costs of Pipe Materials andInstallation from Different Sources in Baht

No.	Description	Unit	Various sources (1986 price level)	Present study	
				-	Nos. 2+3+4
1	Excavation and backfill	m^3	47-138	55	
2	Bedding	m^2	80	80	
3	Surface repair	m^2	105	105	
4.1	75 mm dia.	m		113	298
	materials	m	63		
	pipe laying	m	-		
4.2	100 mm dia.			130	315
	materials	m	80		
	pipe laying	m	-		
4.3	150 mm dia.	m		305	490
	materials	m	140-235		
	pipe laying	m	115		
4.4	200 mm dia.	m		460	645
	materials	m	90-500		
	pipe laying	m	130		
4.5	300 mm dia.	m		310	495
	materials	m	160-315		
	pipe laying	m	68		
4.6	400 mm dia.	m		415	600
	materials	m	180-380		
	pipe laying	m	74		
4.7	500 mm dia.	m		490	712
	materials	m	250-470		
	pipe laying	m	80		
4.8	600 mm dia.	m		650	891
	materials	m	275-680		
	pipe laying	m	80		
4.9	700 mm dia.	m		740	999
	material	m	645		
	pipe laying	m	-		
4.10	800 mm dia.	m		840	1118
	material	m	400-980		
	pipe laying	m	84		

For D = 75 mm
$$C = 298 + 55 \times d \tag{4.4}$$

For 100 mm $\leq$ D $\leq$ 200 mm
$$C = -12 + 3300 \times D + 55 \times d \tag{4.5}$$

For D = 300 mm
$$C = 495 + 55 \times d \tag{4.6}$$

For D = 400 mm
$$C = 600 + 55 \times d \tag{4.7}$$

For D > 400 mm
$$C = 68 + 1330 \times D + (D + 0.7) \times d \times 55 \tag{4.8}$$

where C is the cost of sewer material including installation in Baht/m, D is the diameter in m, and d is the sewer invert depth in m.

4.2.3 Cost of Manholes and Cleanouts

Standard manhole designs were considered for both conventional and small bore sewerage. The cost of manholes was obtained from the Sewerage Department of the Bangkok Municipality (BMA) or was estimated from unit material and construction costs as given in Table 4.4. Table 4.5 summarizes the unit costs of manholes according to pipe diameters and depths.

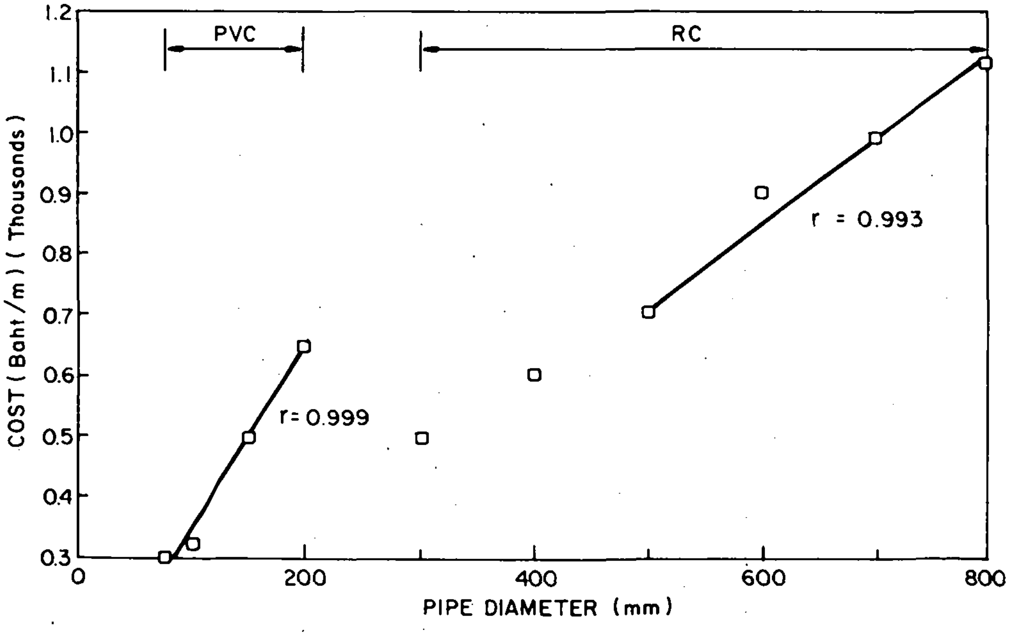

Figure 4.1 Cost of Pipe Materials, Laying and Surface Repair as a Function of the Pipe Diameter (without excavation and backfilling)

Table 4.4 Unit Costs of Civil Works

No.	Description	Unit Cost
1.	Excavation by Machines	25 Baht/m^3
2.	Selected backfill compacted	32 Baht/m^3
3.	Concrete piling dia. (150 mmx12 m)	1500 Baht/unit
4.	Reinforced concrete works	3100 Baht/m^3
5.	Lean concrete works	900 Baht/m^3
6.	Formwork of wood	240 Baht/m^2

Table 4.5 Unit Costs of Manholes

Dia. (mm)	Depth (m)	Manhole Size dia. x depth	Unit cost (Baht)
< 400	< 3	1.0 m x 3 m	10,000
< 400	3 - 5	1.2 m x 5 m	12,500
400 - 1000	< 5	1.2 m x 5 m	12,500

The unit cost of cleanouts for small bore sewers was determined from unit cost values of material and civil works and was estimated to be 2500 Baht each cleanout.

4.2.4 Cost of Pumping Stations

The cost of pumping stations was divided into cost of civil engineering works and cost of pumps, including the required electro-mechanical installations. From standard design and unit costs, a cost function was developed based on the type, capacities, and depths of pumping stations in consideration. This cost function gives the construction cost of civil engineering work depending on the volume of the pump sump. The function is as follows:

$$C = 23,500 \quad V^{0.667} \tag{4.9}$$

where C = construction cost in Baht,

V = sump volume in m^3

The cost of submersible pumps was derived from various manufacturers or their representatives in Bangkok. The unit costs used are presented in Table 4.6.

Table 4.6 Unit Costs of Mechanical and Electrical Equipment

Description	Specifications	Unit costs (Baht)
1. Submersible sewage pump with electric motor & accessories	3 kW , 8 m	90,000
2. - do -	9 kW , 10 m	180,000
3. - do -	12 kW , 10 m	200,000
4. - do -	20 kW , 10 m	350,000
5. - do -	32 kW , 10 m	500,000
6. - do -	38 kW , 10 m	800,000

4.2.5 Operation and Maintenance Cost

The annual operation and maintenance cost for sewers was taken as 1% of the total construction cost. The annual operation and maintenance cost for pumping comprises of annual energy and maintenance costs, the latter taken as 10% of the energy cost. The electricity charge was taken as 1.55 Baht/kWh, the prevailing rate in the study area.

4.3 Design and Evaluation of Basic Costs

4.3.1 Service Areas for Alternative Sewerage Options

As stated in Chapter 3, two service areas differing in size were defined for the provision of sewerage systems, one service area for the Maximum Sewerage Option and another service area for the Minimum Sewerage Option. The main criterion for the identification of the two areas is the population density. The Maximum Sewerage Option would service most parts of the planning area. Only areas with a very low population density were excluded from service through the Maximum Sewerage Option, since on-site sanitation is obviously more economical and does not impose technical difficulties in areas having very low population density. For the Minimum Sewerage Option, only areas with a very high population density were considered. Difficulties in providing sufficient infiltration areas exclude on-site options in these densely populated areas. (However, in this study, the Septic Tank Option also provides on-site sanitation to densely populated areas, as defined for the Minimum Sewerage Option, for the purpose of comparison.)

Table 4.7 and Map 2 show the population densities and the land use characteristics on which the definition of the two different sewerage areas was based. The net population density range of planning cells 1 to 5 of land use category "Agricultural" is between 10 and 43 persons per ha. Cells 12 to 17 of land use category "Residential II" have a net population density between 25 and 90 persons per ha. In both cases (cells 1 to 5 and 12 to 17) the dwellings are very scattered and well distributed over the whole gross area. Planning cell 31 of land use category "Industrial" having a population density of 32 persons per ha is at present also under scattered development over the whole gross area. Population data of planning cells 32 and 33, of land use category "Special", were either unavailable or irrelevant. Planing cells 1 to 5, 12 to 17, and 31 to 33, were assumed to have on-site treatment systems in the form of septic tanks and soakage pits or, for cells 32 and 33, their own wastewater collection and treatment system.

Table 4.7 Gross Area, Built-Up Area, Population Density, and Population in Service Areas Considered for Sewerage

Planning cell no.	Land use category	Gross area (ha)	Built-up area (ha)	Pop. den. (persons /ha)	Pop. (persons)
11	Residential II	77	32.0	16	400
29	Institutional	51	39.0	47	1850
30	Institutional	161	123.0	48	4680
23	Mixed	84	66.0	114	7500
27	Mixed	90	58.0	152	7040
25	Mixed	38	32.0	156	5000
18	Commercial	6	6.0	181	1100
19	Commerical	18	18.0	181	3300
20	Commercial	38	38.0	181	6900
21	Commercial	30	30.0	181	5400
26	Mixed	67	21.0	186	3900
24	Mixed	20	20.0	190	3800
10	Residential I	44	44.0	244	10750
6	Residential I	26	14.0	250	3500
7	Residential I	22	22.0	250	5500
8	Residential I	33	33.0	250	8250
9	Residential I	22	22.0	250	5500
22	Commercial	25	17.0	265	4500
Total		852	635.0		88870

For planning cells 27, 30 and 11, only parts of the planning cell were considered for the provision of sewerage. 20% of the built up area in planning cells 27 and 30, which is a scattered area, and 20% of the built-up area in planning cell 11 were excluded from the provision of sewerage. The latter area is adjacent to cells 25 and 27 which have also been considered for the provision of sewerage.

The areas thus defined for the provision of a sewerage system constitute the service area for the maximum sewerage option. Table 4.7 presents the gross area, built-up area, population, and population densities of the different planning cells to be serviced. 84% of the total population of 105,770 or 88,870 persons are shown to be serviced through the Maximum Sewerage Option. The remaining 16% of the total population (16,900 persons) are to be serviced by on-site treatment in the form of septic tanks and soakage pits. The total area to be served is shown in Figure 4.2 of the following section which presents the main sewer alignment.

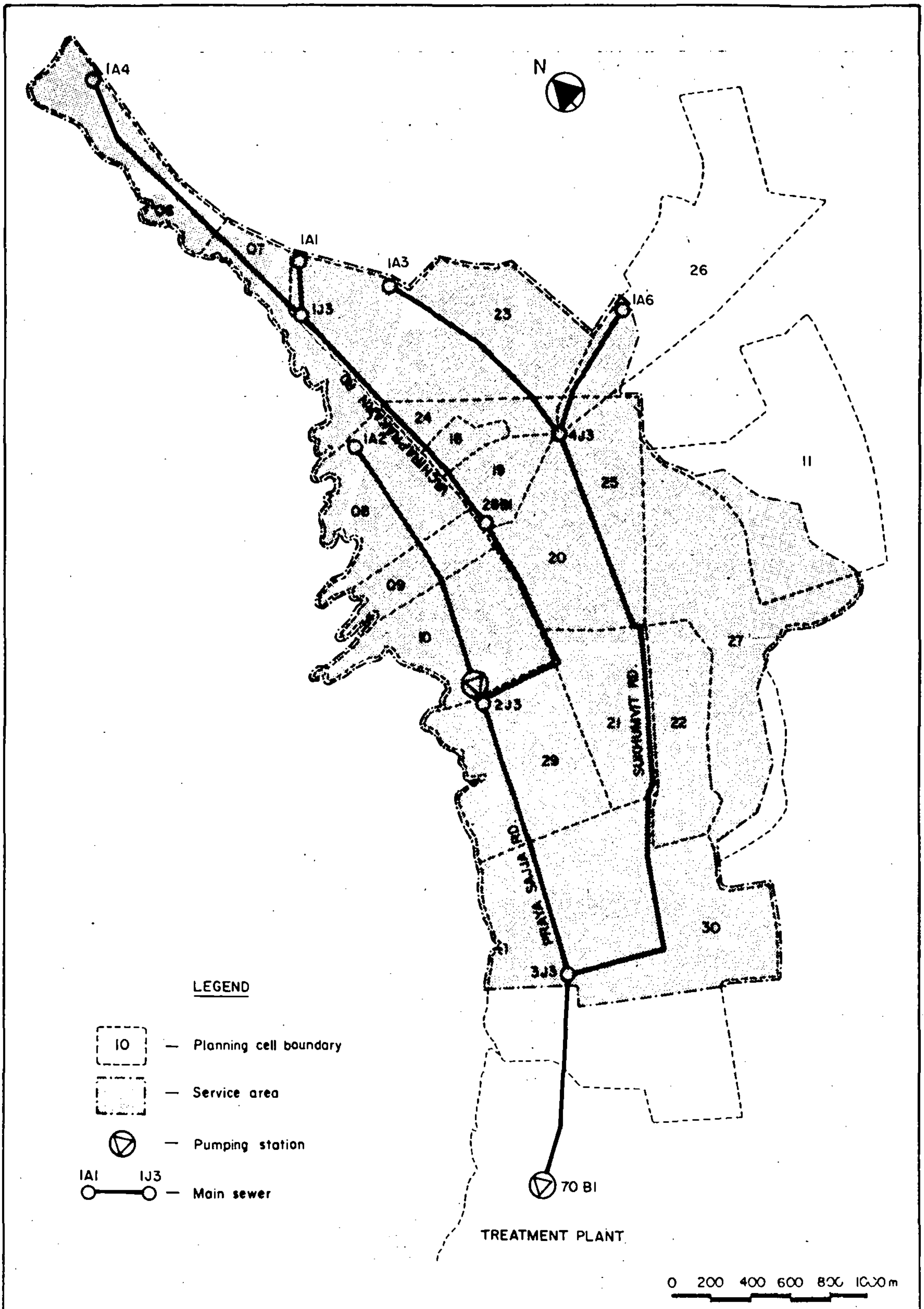

Figure 4.2 Main Sewer Layout for Maximum Sewerage Option I

In the Minimum Sewerage Option only planning cells having a population density greater than 240 were assumed to be provided with conventional sewerage. These areas include planning cells 6, 7, 8, 9, and 10, which fall under "Residential I" land use category and have a population density ranging from 244 to 250 persons per ha, and planning cell 22, which is the most densely populated single cell (265 persons per ha) and is located just outside the eastern municipal boundary. Field observations of land uses in these high population density areas indicated that septic tank and soakage pits would be infeasible in these areas due to the high density of houses, narrow streets, and an extremely high ground water table. The Minimum Sewerage Option services a population of 38,000 (36% of the total population). The remaining part of the study area was assumed to have on-site septic tanks and soakage pits. The area to be served by on-site facilities constitutes a service population of 67,770 (64% of the total population).

The same service area as for the Maximum Sewerage Option was defined for the small bore sewer system in comparing this with conventional sewerage.

4.3.2 Main Sewer Alignment

The natural terrain in the study area (Map 2) generally slopes down from east to west and from north to south. A small chain of hills at the northeast and the east forms a natural border for the inner part of the town. A military camp is on the northeast hillock. A large area is occupied by the Chinese cemetery on the eastern hills.

In accordance with the terrain, the population distribution, and the existing road layout, the main sewers are preferably laid along Sukhumvit road and Vachiraprakarn road. Coming from the north, Sukhumvit road shows a high point with a ground level of 13.4 m at the northern part of planning cell no. 23. Afterwards, Sukhumvit road falls down towards the flat areas at a ground level of about 2 m in the south of the municipality. The eastern main sewer for the Maximum Sewerage Option begins at the high point of Sukhumvit road and follows Sukhumvit road until turning to the west to join the western main sewer at Praya Sajja road.

The Vachiraprakarn main sewer begins at the northern end of the service area (planning cell no.6) on Sukhumvit road and at a ground level of 8.4 m. The sewer diverts from Sukhumvit road before the road ascends to its high point and thereafter follows the lower Vachiraprakarn road. At the southern end of planning cell no. 10, the Vachiraprakarn main sewer turns west and continues along Praya Sajja road in the flat area along the shore-line until the sewer is joined by the Sukhumvit main sewer. From this point, the main sewer continues, still within the flat areas, toward the treatment plant in the south of the planning area. Since the drainage area slopes down from the east to the west, the Vachiraprakarn main sewer accordingly is laid at a lower level than the Sukhumvit main sewer. The area east of the Vachiraprakarn main sewer does not impose major difficulties for the layout of the sewer system. However, the area west of Vachiraprakarn road, in planning cell nos. 8 to 10, is flat and without any significant slope towards Vachiraprakarn road. The situation offers the possibility of exploring alternative concepts for the sewer layout in this flat coastal area. The first alternative is based on the assumption that a main sewer can be built through the center of the critical area. The need for pumping stations is thus reduced by the construction of an additional main sewer. Only one pumping station is required at the end of the additional main sewer to lift the wastewater into the higher Vachiraprakarn main sewer. No additional main sewer is used for the second alternative. However, more pumping stations are required. These two alternatives are denoted as Maximum Sewerage Option I and II. After comparing the cost of the main sewer system for each of these two alternatives, only the more economical one was subjected to further evaluation.

The main sewer system for the Minimum Sewerage Option is in principle based on the same alignment as for the Maximum Sewerage Option. The system for the Minimum Sewerage Option is only reduced in scale in accordance with its smaller service area. The main sewer aligment for the Small Bore Sewerage Option is the same as that for the Maximum Sewerage Option, differing only with respect to the number of pumping stations as required by the hydraulic design. The main sewer alignment for the various options and for alternatives I and II of the Maximum Sewerage Option are shown in Figures 4.2 to 4.5.

According to hydraulic design calculations, the main sewer system for the various options reaches the treatment plant site at different levels. The wastewater shall be lifted up by the inlet pumping station of the treatment plant to a common level of 1.2 m above the ground level in all options. In order to make the sewer system in all options comparable, this inlet pumping station was considered part of the sewer system.

4.3.3 Design and Basic Cost of Main Sewers

For the design of main sewers, a design program developed at the Asian Institute of Technology was used. The program calculates the required sewer diameters and levels, based on given ground levels and design criteria, the latter defined in Chapter 4.1. The program selects from among the various technically feasible solutions the most economical one through dynamic programming and branch-and-bound techniques.

The main advantage in applying this program to the present study is that it allowed the creation of alternative systems by simply changing the data input for the related design criteria. In designing the small bore sewer system, for example, the data set for the Maximum Sewerage Option was used after changing only the values of the minimum slope, the minimum velocity, and the minimum diameter. The cost of manholes was calculated separately and thereafter added to the cost of pipes.

Calculations for the various options and alternatives I and II of the Maximum Sewerage Option are given in the Appendix. The resulting basic costs are summarized in Tables 4.8 to 4.11.

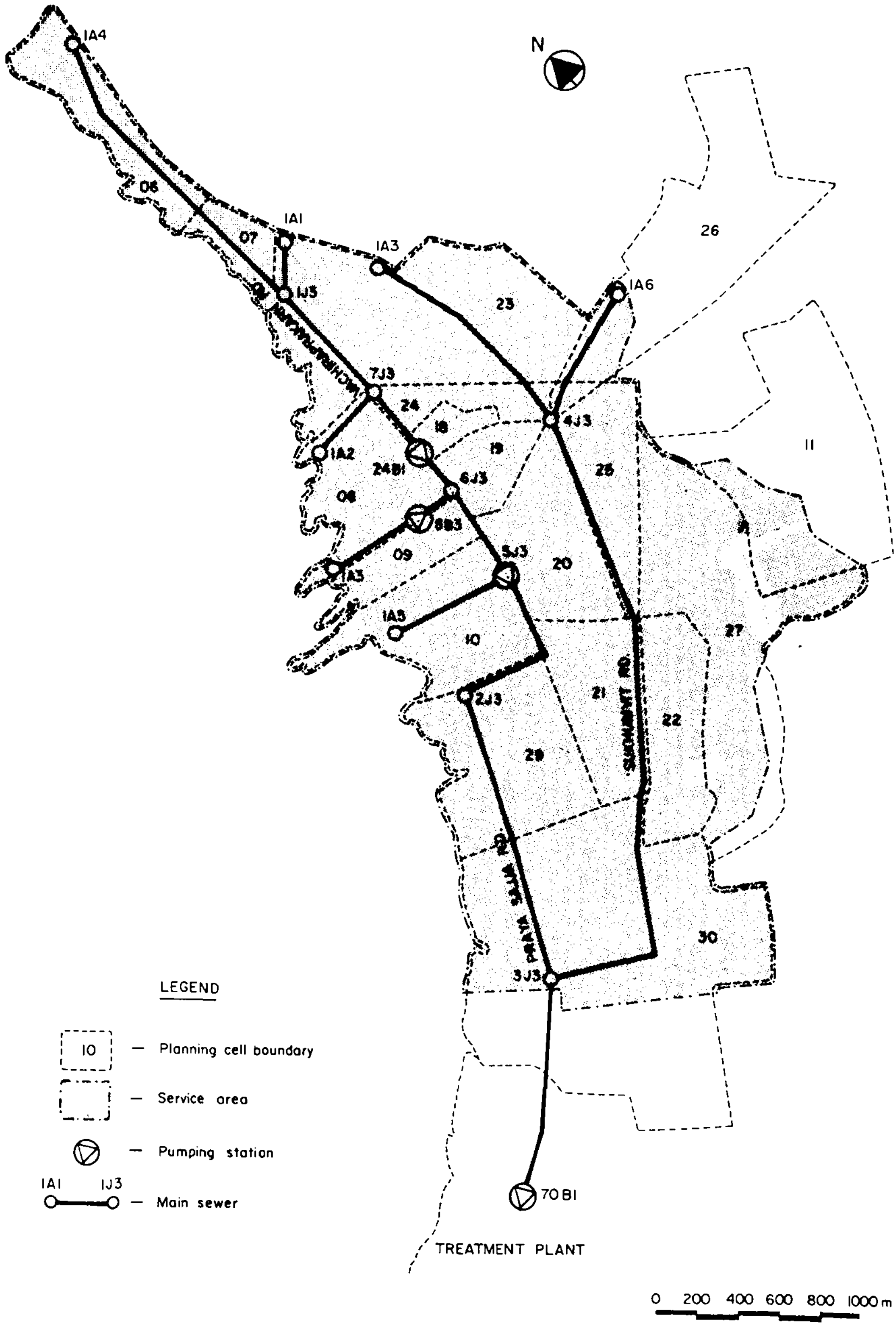

Figure 4.3 Main Sewer Layout for Maximum Sewerage Option II

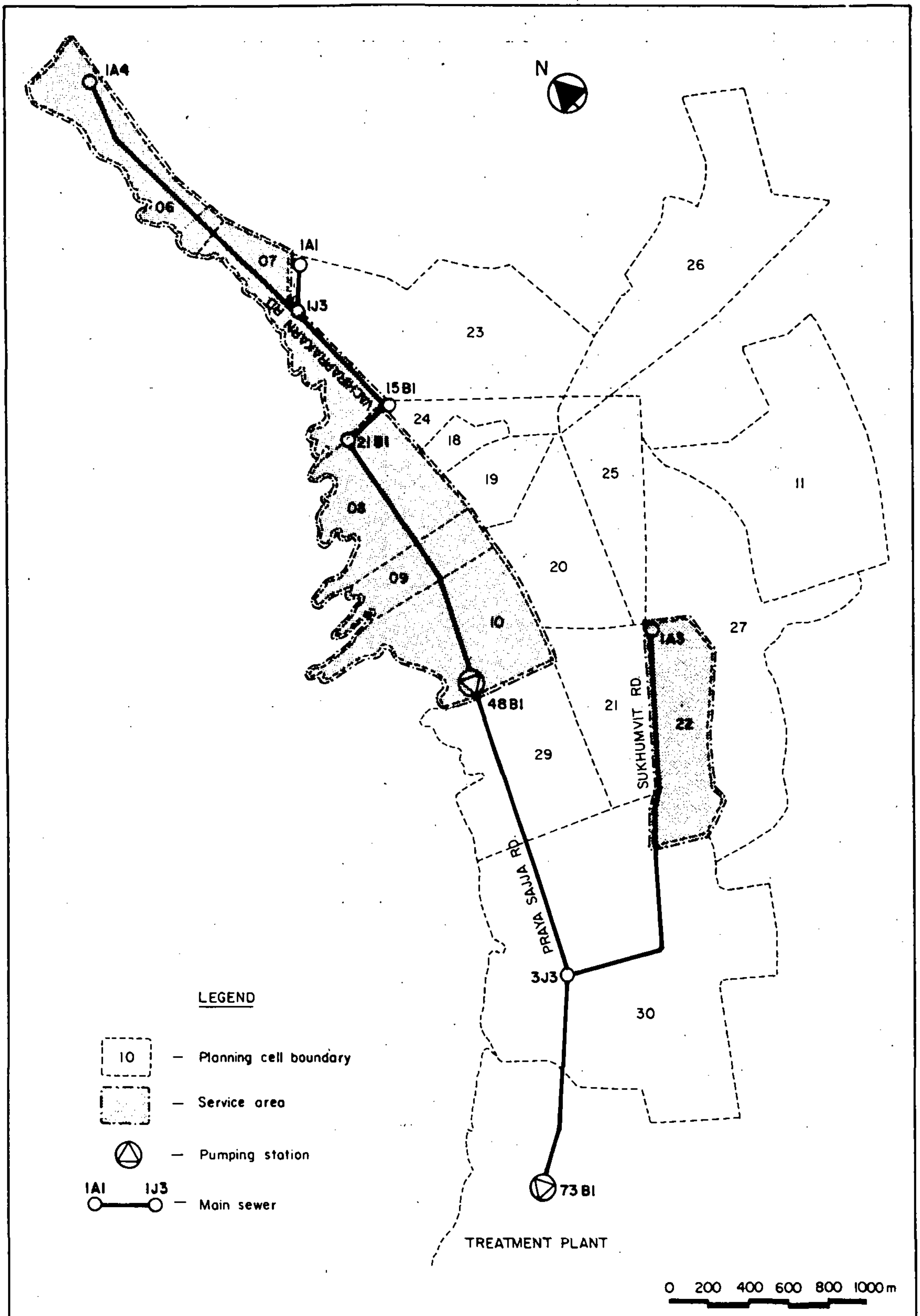

Figure 4.4 Main Sewer Layout for Minimum Sewerage Option

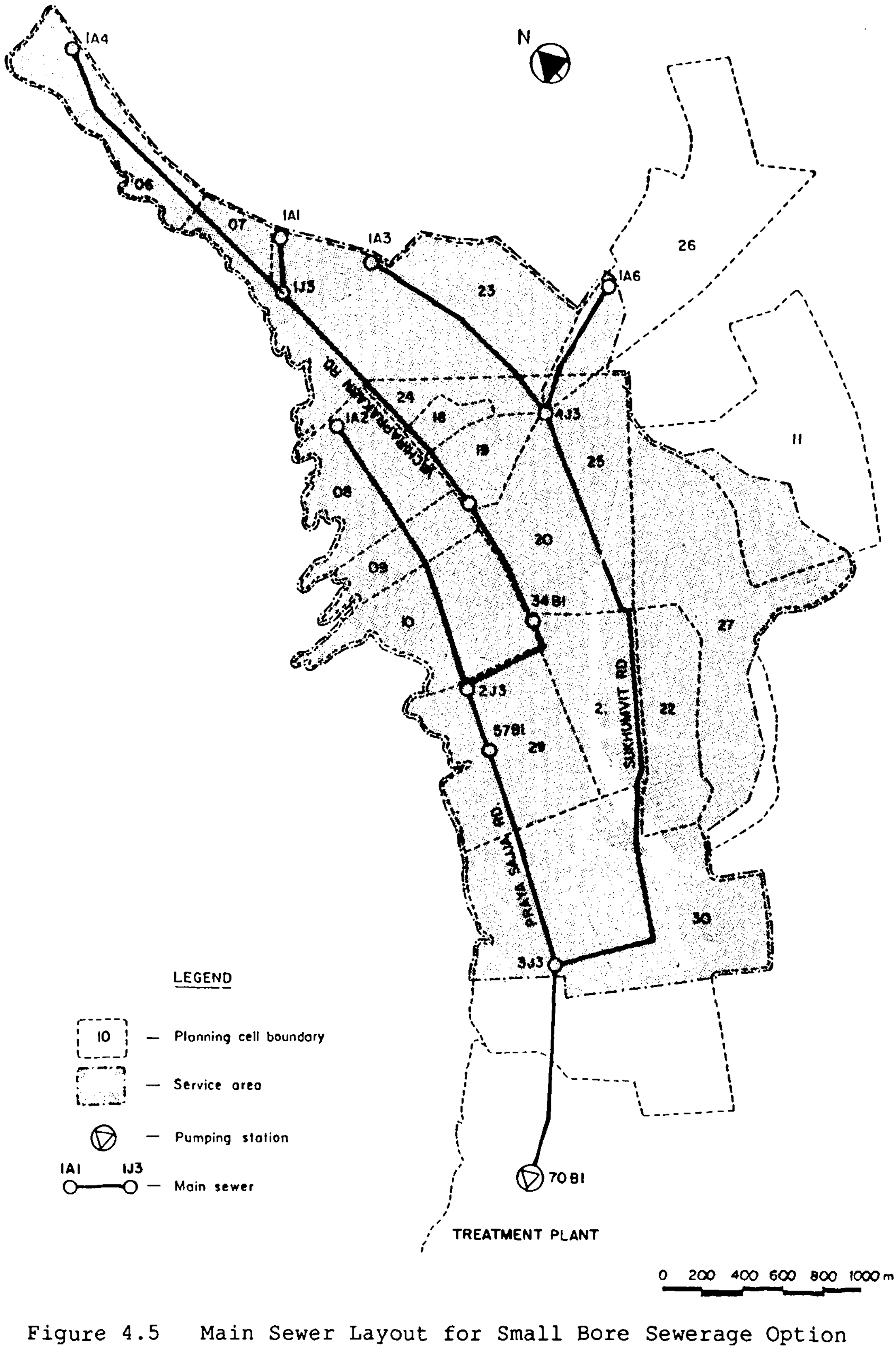

Figure 4.5 Main Sewer Layout for Small Bore Sewerage Option

Table 4.8 Basic Main Sewer Costs: Maximum Sewerage Option, Alternative I

From	To	Length of sewers (m)	Cost of sewers (Baht)	Cost of manholes (Baht)	
1A1 1A4	28B1	3,605	2,531,268	1,577,500	
28B1	2J3	1,248	1,205,850	600,000	
1A2	2J3	1,684	1,244,949	777,500	
1A3 1A6	3J3	5,346	4,620,529	2,270,000	
2J3	70B1	2,697	4,461,844	1,125,000	
Total		14,580	14,064,440	6,350,000	20,414,440

Table 4.9 Basic Main Sewer Cost : Maximum Sewerage Option, Alternative II

From	To	Length of sewers (m)	Cost of sewers (Baht)	Cost of manholes (Baht)	
1A1 1A2 1A4	24B1	3,701	2,549,339	1,532,500	
1A3	8B3	525	361,246	210,000	
8B3 24B1	5J3	946	820,224	452,500	
1A5	5J3	544	383,914	220,000	
5J3	2J3	872	1,013,990	362,500	
1A6 1A3	3J3	5,346	4,620,529	2,270,000	
2J3	70B1	2,697	4,357,776	1,125,000	
Total		14,631	14,107,018	6,172,500	20,279,518

Table 4.10 Basic Main Sewer Costs : Minimum Sewerage Option

From	To	Length of sewers (m)	Cost of sewers (Baht)	Cost of manholes (Baht)	
1A1 1A4	48B1	4,841	3,726,064	2,157,500	
48B1	73B1	2,697	3,177,792	1,125,000	
1A3	3J3	2,038	1,336,030	820,000	
Total		9,576	8,239,886	4,102,500	12,342,386

Table 4.11 Basic Main Sewer Costs : Small Bore Sewerage Option

From	To	Length of sewers (m)	Cost of sewers (Baht)	Cost of manholes (Baht)	
1A1 1A4	34B1	4,053	3,098,575	1,010,000	
1A2	2J3	1,684	1,296,533	417,500	
34B1	57B1	1,511	1,590,885	375,000	
1A3 1A6	3J3	5,346	4,189,924	1,340,000	
57B1	70B1	1,986	3,513,432	500,000	
Total		14,580	13,689,349	3,642,500	17,331,849

4.3.4 Layout and Cost Estimation Procedure for Lateral Sewers

In estimating the cost of the lateral sewer system, unit costs per hectare were derived for the various land use categories in selected representative areas. The unit costs were then multiplied by the area of each land use category in the three sewerage options. The development of unit costs is described in the following paragraphs.

Reference or base maps of the scale 1:2500 were used for the design of the lateral sewer network. Representative areas were chosen for each land use category. The selection of representative areas was restricted to those within the municipality and its vicinity where most of the residential and commercial dwellings are concentrated (49% of the population). Figure 4.6 shows the location of these representative areas. Maps 3, 4, and 5 display the representative areas of landuse categories Residential I, Commercial, Mixed and Institutional. In case of the representative area of landuse category Residential II (Planning cell 11) which falls outside the municipal boundary, the map of the study area (Map 2) was used as the base map, since no more detailed map of this area was available. The lateral sewer network was laid out on the map of representative areas considering the topography and existing network of roads. As far as possible, lateral sewers were laid out to run along existing streets. The representative areas cover about 39% of the total service area.

The area served in hectares and the total length of sewers, as determined from the layout in Maps 3 to 5 for each of the representative areas, are presented in Table 4.12. The area serviced and length of sewers in the case of Residential II land use category (representative area no. 3) were determined from Map 2. Representative area no. 6 is very much different, in terms of length of sewers per hectare, from the other two representative areas (area nos. 4 and 5) of the same land use category (Commercial). Area no. 6 is adjacent to the high population density category Residential I. The differences in sewer length result in considerable differences in the cost per hectare of the lateral system. Thus, in costing the secondary sewers, the total built-up area under the land use category Commercial was divided into the categories Commercial I and Commercial II.

The total number of houses or institutions under each land use category for each of the representative areas was determined from the 1:1000 scale Tax Maps. Similarly, the length of house connection pipes in each of the representative areas was determined, depending on the relative location of the houses with respect to the sewer servicing it. The specific data thus developed for the representative areas are shown in Table 4.12.

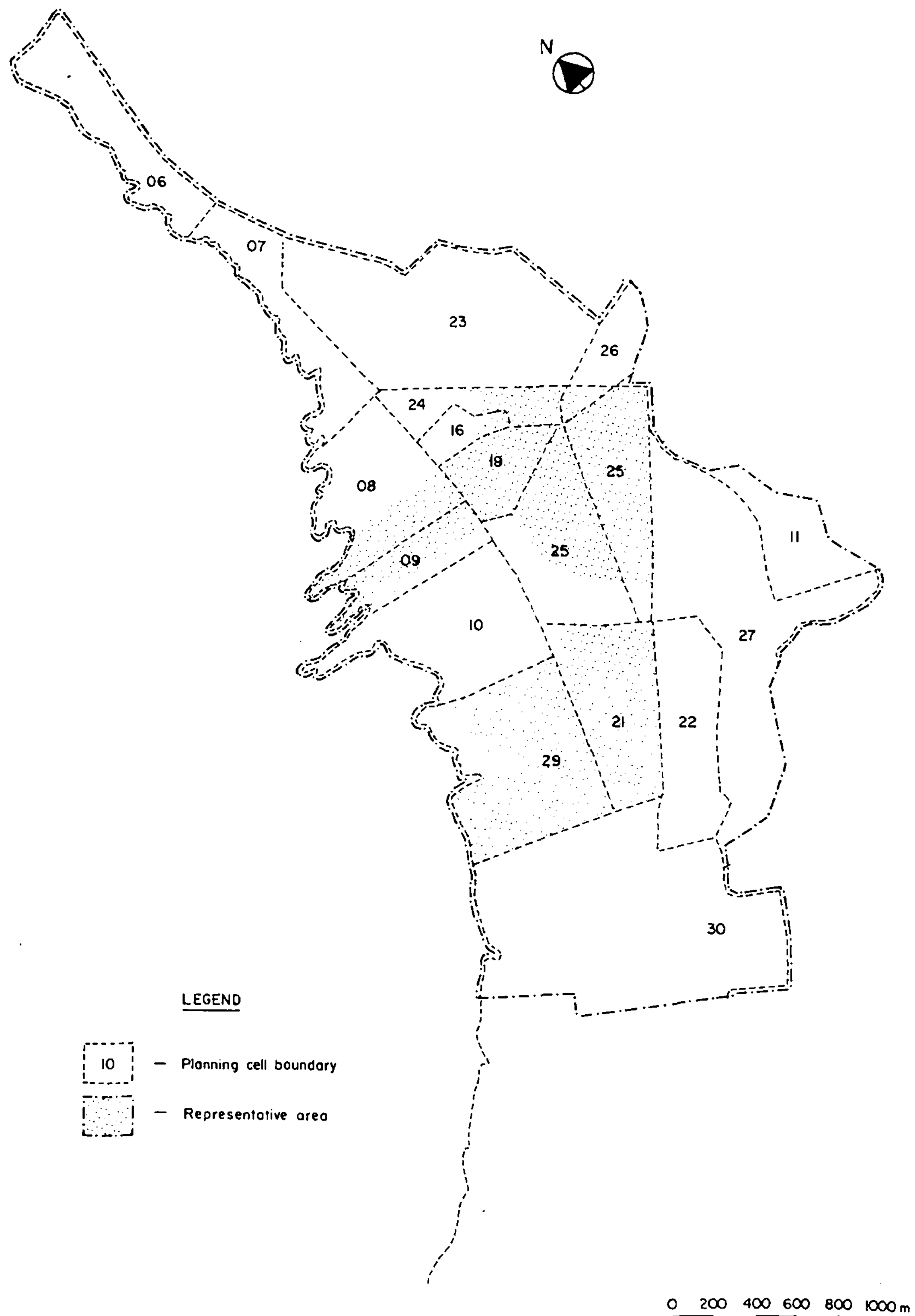

Figure 4.6 Representative Areas for the Lateral Sewer System in Various Landuse Categories

Table 4.12 Length of Lateral Sewers and House Connections, and Number of Houses/Institutions in the Representative Service Areas

Area no.	Land use category	Population density	Built-up area	% of total sewered	Length of sewers		Number of houses/institutions		Length of house connections	
		(no./ha)	(ha)	(%)	(m)	(m/ha)	(no.)	(no./ha)	(m)	(m/ha)
(1)	(2)	(3)	(4)	(5)	(6)	(7) =(6)/(4)	(8)	(9) =(8)/(4)	(10)	(11) =(10)/(4)
1	Residential I	250	27.12	4.6	5620	207.2	920	33.9	5860	216.1
2	Residential I	250	14.70	2.5	3000	204.1	524	35.6	3100	210.9
3	Residential II	16	25.60	4.3	4500	175.8	80	3.1	1200	46.9
4	Commercial I	181	36.08	6.1	5640	156.3	990	27.4	5200	144.1
5	Commercial I	181	30.00	5.1	5375	179.2	620	20.7	3410	113.7
6	Commercial II	181	10.33	1.7	2300	222.7	397	38.4	2350	227.5
7	Institutional	47	21.50	3.6	2800	130.2	352	16.4	3520	163.7
8	Institutional	47	17.50	3.0	2955	168.9	190	10.9	1900	108.6
9	Mixed	169	27.34	4.6	3710	135.7	778	28.5	4280	156.5
10	Mixed	169	17.70	3.6	2963	165.9	493	27.9	2640	149.2

In order to check the outlet levels of the lateral sewer system with respect to the levels of main sewers, 15 critical laterals were selected. These are marked in the maps of representative areas as A1 to A5, B1 to B6, and C1 to C4. These critical sewers start at the most remote parts of the service areas. The outlet levels for the critical laterals were then calculated according to the minimum slope and minimum cover depth, as stated in Chapter 4.1, and compared to the main sewer levels. The result of this analysis was satisfactory except for the case of laterals A3 to A5. These laterals are located in planning cell no. 9 where the built-up area has been extended towards the sea through land reclamation. Nevertheless, it was assumed for the purpose of this study, that the critical situation in the case of laterals A3 to A5 can be corrected in the final design by either modifying the lateral sewer layout and design criteria in this service area, or by lifting the wastewater of this area before its discharge into the main sewer using a small submersible pump. The pumping station would influence the cost of the entire system only insignificantly.

The levels of the critical lateral sewers were then used to evaluate an average pipe invert depth for the lateral sewer system. The average depth of the pipe invert was determind to be 2.5 m.

4.3.5 Basic Cost of the Lateral Sewer System

The cost estimate of lateral sewers for conventional sewerage was based on 90% of the pipes being 200 mm in diameter and the remaining 10% of the pipes being 300 mm in diameter. Using cost equations (4.5) and (4.6), with the pipe invert at an average depth of 2.5 m, as determined above, the resulting cost of sewer pipe materials and installation was calculated to be 770.2 Baht/m. Knowing the length of sewers from Table 4.12 in the representative areas and the criteria for manhole spacing, as cited in Chapter 4.1, the number of manholes along the sewer lines in the representative areas was determined.

Using cost equation (4.5) with a pipe diameter of 100 mm for the house connection pipes laid at an average depth of 1.2 m, the resulting cost of house connection pipes is 384 Baht/m. House connection pipes must be supported properly to avoid their damage by subsequent settling. Also, special joints and fittings may be necessary in connecting each house connection to the street sewer. With these requirements in view, the cost of house connections as calculated above, was increased by 20%. Thus, the final cost of house connections for conventional sewerage is 460.8 Baht/m.

Using the unit costs of sewers, manholes, and house connections, as determined above, the cost of the lateral sewer system per hectare for each of the representative areas was calculated. Results of calculations are presented in Table 4.13. The average cost per hectare, as calculated for each land use category, was used thereafter in calculating the total cost of the lateral sewer system according to the whole service area occupied by the different types of land uses. The resulting basic costs for the lateral sewer system of the Maximum and the Minimum Sewerage Options are presented in Tables 4.14 and 4.15 respectively.

Table 4.13 Basic Cost per Hectare of the Lateral Sewer System for Conventional Sewerage

Area no.	Land use category	Built-up area	Length of sewers		Number of manholes		Length of house connections	Total Cost	Cost of house connections
		(ha)	(m)	(m/ha)	(no.)	(no./ha)	(m/ha)	(Baht/ha)	(Baht/ha)
(1)	(2)	(3)	(4)	(5) = (4)/(3)	(6)	(7) = (6)/(3)	(8)	(9)	(10) = (8)x460.8
1	Residential I	27.12	5620	207.2	225	8.3	216.1	342,164	99,579
2	Residential I	14.70	3000	204.1	120	8.2	210.9	336,381	97,183
	Average							339,272	98,381
3	Residential II	25.60	4500	175.8	180	7.0	46.9	227,013	21,612
4	Commercial I	36.08	5640	156.3	226	6.3	144.1	249,784	66,401
5	Commercial I	30.00	5375	179.2	215	7.2	113.7	262,413	52,393
	Average							256,098	59,397
6	Commercial II	10.33	2300	222.7	92	8.9	227.5	365,356	104,832
7	Institutional	21.50	2800	130.2	112	5.2	163.7	227,713	75,433
8	Institutional	17.5	2955	168.9	119	6.8	108.6	248,130	50,043
	Average							237,921	62,738
9	Mixed	27.34	3710	135.7	149	5.4	156.5	230,631	72,115
10	Mixed	17.70	2963	165.9	119	6.7	149.2	263,528	68,751
	Average							247,079	70,433

Note : (9) = 770.2 x (5) + 10,000 x (7) + 460.8 x (8)
where cost of sewers = 770.2 Baht/m, cost of manholes = 10,000 Baht each and cost of house connections is 460.8 Baht/m

Table 4.14 Basic Cost of the Lateral Sewer System for the Maximum Sewerage Option

Planning cell (1)	Land use category (2)	Built-up area of planning cell from base data (ha) (3)	% of built-up area considered for sewerage (%) (4)	Built-up area considered for sewerage (ha) (5)=(3)x(4)	Average cost per ha: house conn. (Baht/ha) (6)	Average cost per ha: sewer system (Baht/ha) (7)	Cost of house conn. (Baht) (8)=(6)x(5)	Total cost of sewer system (Baht) (9)=(7)x(5)
6	Residential I	14.0	100	14.0				
7	Residential I	22.0	100	22.0				
8	Residential I	33.0	100	33.0				
9	Residential I	22.0	100	22.0				
10	Residential I	44.0	100	44.0				
	Sub-total			135.0	98,381	339,272	13,281,435	45,801,720
11	Residential II	32.0	80	25.6	21,612	227,013	553,267	5,811,533
18	Commerical I	6.0	100	6.0				
19	Commercial I	7.7	100	7.7				
20	Commercial I	28.4	100	28.4				
21	Commercial I	30.0	100	30.0				
	Sub-total			72.1	59,397	256,098	4,282,524	18,464,666
19	Commercial II	10.3	100	10.3				
20	Commercial II	9.6	100	9.6				
22	Commercial II	17.0	100	17.0				
	Sub-total			36.9	104,832	365,356	3,868,301	13,481,636
23	Mixed	66.0	100	66.0				
24	Mixed	20.0	100	20.0				
25	Mixed	32.0	100	32.0				
26	Mixed	21.0	100	21.0				
27	Mixed	58.0	80	46.4				
	Sub-total			185.4	70,433	247,079	13,058,278	45,808,447
29	Institutional	39.0	100	39.0				
30	Institutional	123.0	80	98.4				
	Sub-total			137.4	62,738	237,921	8,620,201	32,690,345
	Total	635.0		592.4			43,664,006	162,058,347

Table 4.15 Basic Cost of the Lateral Sewer System for the Minimum Sewerage Option

Planning cell	Land use category	Area (ha)	Cost of house connections (Baht)	Total cost of sewer system (Baht)
6 to 10	Residential I	135.0	13,281,435	45,801,720
22	Commercial II	17.0	1,782,144	6,211,052
Total			15,063,579	52,012,772

In costing the lateral sewers for the small bore system, it was assumed that 60% of the sewers are 150 mm in diameter while the remaining 40% of the sewers are 200 mm in diameter. The average sewer invert depth was assumed to be 2 m as a result of the lower minimum cover considered for small bore sewerage and the inflective gradient which the sewer may have.

From equation (4.5) and the above assumptions, the cost of pipe materials and installation for the lateral sewers of the small bore sewerage system was calculated. This value was found to be 659 Baht/m. The average cost of a manhole and a cleanout was taken as 10,000 Baht and 2,500 Baht per unit respectively. The cost of house connections was taken as 1.2 times the value obtained as per equation (4.4), using a pipe diameter of 75 mm laid at an average depth of 0.8 m. The cost of house connections was thus determined to be 410.4 Baht/m. Using the above mentioned values, the basic cost per hectare and the total basic cost of the lateral sewers of the Small Bore Sewerage Option were calculated in the same way as for conventional sewerage. The results are presented in Tables 4.16 and 4.17.

4.3.6 Basic Cost of Pumping Stations

The locations of pumping stations required for the main sewer system of the different sewerage options are shown, together with the main sewer alignment, in Figures 4.2 to 4.5. The locations, flow rate, and pumping heads follow the main sewer design. With these information, the basic cost of pumping stations was estimated from the design criteria and unit costs stated in Chapters 4.1 and 4.2. Calculations are shown in Tables 4.18 and 4.19.

Table 4.16 Basic Cost per Hectare of the Lateral Sewer System for the Small Bore Sewerage Option

Area no.	Land use category	Built-up area	Length of sewers		No. of manholes		No. of cleanouts		Length of house connection	Total cost	Cost of house connections
		(ha)	(m)	(m/ha)	(no.)	(no./ha)	(no.)	(no./ha)	(m/ha)	(Baht/ha)	(Baht/ha)
(1)	(2)	(3)	(4)	(5)=(4)/(3)	(6)	(7)=(6)/(3)	(8)	(9)=(8)/(3)	(10)	(11)	(12) =410.4x(10)
1	Residential I	27.12	5620	207.2	38	1.4	187	6.9	216.1	256,482	88,687
2	Residential I	14.70	3000	204.1	20	1.4	100	6.8	210.9	252,055	86,553
	Average									254,269	87,620
3	Residential II	25.60	4500	175.8	30	1.2	150	5.9	46.9	161,850	19,248
4	Commercial I	36.08	5640	156.3	38	1.1	188	5.2	144.1	186,140	59,139
5	Commercial I	30.00	5375	179.2	36	1.2	179	6.0	113.7	191,755	46,662
	Average									188,948	52,901
6	Commerical II	10.33	2300	222.7	16	1.6	77	7.4	227.5	274,625	93,366
7	Institutional	21.50	2800	130.2	19	0.9	93	4.3	163.7	172,734	67,182
8	Institutional	17.50	2955	168.9	20	1.1	99	5.7	108.6	181,125	44,569
	Average									176,929	55,876
9	Mixed	27.34	3710	135.7	25	0.9	124	4.5	156.5	173,904	64,228
10	Mixed	17.70	2963	165.9	20	1.1	99	5.6	149.2	195,560	61,232
	Average									184,732	62,730

Note : (11) = 659 x (5) + 10,000 x (7) + 2500 x (9) + 410.4 x (10)
where cost of sewers = 659 Baht/m, cost of manholes = 10,000 Baht each, cost of cleanouts = 2500 Baht each and cost of house connections is 410.4 Baht/m

Table 4.17 Basic Cost of the Lateral Sewer System for the Small Bore Sewerage Option

Planning cell (1)	Land use category (2)	Built-up area of planning cell from base data (ha) (3)	% of built-up area considered for sewerage (%) (4)	Built-up area considered for sewerage (ha) (5)=(3)x(4)	Average cost per ha: house conn. (Baht/ha) (6)	Average cost per ha: sewer system (Baht/ha) (7)	Cost of house conn. (Baht) (8)=(6)x(5)	Total cost of sewer system (Baht) (9)=(7)x(5)
6	Residential I	14.0	100	14.0				
7	Residential I	22.0	100	22.0				
8	Residential I	33.0	100	33.0				
9	Residential I	22.0	100	22.0				
10	Residential I	44.0	100	44.0				
	Sub-total			135.0	87,620	254,269	11,828,700	34,326,315
11	Residential II	32.0	80	25.6	19,248	161,850	492,749	4,143,360
18	Commerical I	6.0	100	6.0				
19	Commercial I	7.7	100	7.7				
20	Commercial I	28.4	100	28.4				
21	Commercial I	30.0	100	30.0				
	Sub-total			72.1	52,901	188,948	3,814,162	13,623,151
19	Commercial II	10.3	100	10.3				
20	Commercial II	9.6	100	9.6				
22	Commercial II	17.0	100	17.0				
	Sub-total			36.9	93,366	274,625	3,445,205	10,133,663
23	Mixed	66.0	100	66.0				
24	Mixed	20.0	100	20.0				
25	Mixed	32.0	100	32.0				
26	Mixed	21.0	100	21.0				
27	Mixed	58.0	80	46.4				
	Sub-total			185.4	62,730	184,732	11,630,142	34,249,313
29	Institutional	39.0	100	39.0				
30	Institutional	123.0	80	98.4				
	Sub-total			137.4	55,876	176,929	7,677,362	24,310,045
	Total			592.4			38,888,321	120,785,846

Table 4.18 Basic Construction Cost of Pumping Stations

Pumping station location	Peak flow rate (l/s)	Pump sump volume required (m^3)	Cost (Baht)
1. Maximum Sewerage Option I			
2J3	123.9	11	116,326
70B1	697.5	63	372,587
		Total	488,913
2. Maximum Sewerage Option II			
24B1	130.0	12	123,277
8B3	32.6	3	48,900
5J3	220.0	20	173,322
70B1	697.5	63	372,587
		Total	718,086
3. Minimum Sewerage Option			
48B1	164.4	15	143,060
73B1	190.8	17	155,517
		Total	298,577
4. Small Bore Sewerage Option			
70B1	498.3	45	297,688
		Total	297,688

Table 4.19 Annual Energy Consumption and Basic Cost of Pumps

Pumping station location	Flowrate		Pump capacity		Cost of pumps	Energy consumption
	avg. (l/s)	peak (l/s)	required (kW)	provided *) No. x kW	(Baht)	(kWh/a)
1. Maximum Sewerage Option I						
2J3	70.5	123.9	8.7	2 x 9	360,000	34,767
70B1	398.6	697.5	103.7	4 x 3	83,200,000	415,451
				Total	3,560,000	450,218
2. Maximum Sewerage Option II						
24B1	74.3	130.0	11.8	2 x 12	400,000	47,422
8B3	18.6	32.6	3.0	2 x 31	80,000	11,892
5J3	152.9	220.0	20.0	2 x 20	700,000	97,608
70B1	398.6	697.5	103.7	4 x 38	3,200,000	415,451
				Total	4,480,000	572,374
3. Minimum Sewerage Option						
48B1	93.0	164.4	11.5	2 x 12	400,000	46,111
73B1	109.0	190.8	26.2	3 x 12	600,000	105,044
				Total	1,000,000	151,155
4. Small Bore Sewerage Option						
70B1	299.0	498.3	71.6	4 x 32	2,000,000	300,996
				Total	2,000,000	300,996

*) Including stand-by pumps

4.4 Compilation and Comparison of Costs of Sewerage Options

4.4.1 Overview of Costs of the Various Sewerage Options

Two alternative layouts for the main sewer system were compared for the Maximum Sewerage Option. Alternative I contained an additional main sewer branch, thus avoiding the installation of two additional pumping stations as in alternative II. The cost of sewers for the two main sewerage alternatives are 20.4 and 20.3 million Baht respectively. However, adding to these values the cost of pumping stations, alternative I exhibits a cost of 24.5 million Baht which is less than the total cost of alternative II, the latter amounting to 25.5 million Baht. Moreover, alternative II would require higher operation expenses to oparate its pumping stations. Alternative II is therefore excluded from further consideration and the term Maximum Sewerage Option from hereon refers to alternative I only.

The following compilation of total construction cost was derived from the basic construction costs presented in Chapter 4.3 by adding an allowance of 40%, as stated in Section 4.2.1. The total construction cost and the annual operation and maintenance cost for the Maximum Sewerage Option were calculated as follows:

Total construction cost in Baht :

Main sewers	=	28,580,000
Lateral sewers + house con.	=	226,881,000
Pumping stations	=	5,668,500
Total	=	261,129,500

O & M Cost per annum in Baht :

Sewers and pumping stations (1% of capital cost)	=	2,611,300
Energy cost @ 1.55 Baht/kWh	=	697,800
Maintenance and repairof pumps (10% of energy cost)	=	69,800
Total	=	3,378,900

The per capita cost of the construction of conventional sewerage for the service area of 592.4 ha, having a population of 88,870, was then determined to be 2,938 Baht per person. The operation and maintenance cost is 38 Baht per person per annum.

The construction cost of the lateral sewer network constitutes 87% of the total construction cost while the installation of main sewers constitutes about 11% of the total construction cost. The remaining 2% of the construction cost is allotted for the construction of pumping stations and the purchase of submersible pumps.

In the Minimum Sewerage Option, only areas having a population density of more than 240 persons per ha were connected to the sewer system. The total construction cost and the annual operation and maintenance cost for this option were computed as follows:

Total construction cost in Baht :

Main sewers	=	17,279,000
Lateral sewers+ house con.	=	72,818,000
Pumping stations	=	1,818,000
Total	=	91,915,000

O & M Cost per annum in Baht :

Sewers and pumping stations (1% of capital cost)	=	919,000
Energy cost @ 1.55 Baht/kWh	=	234,300
Maintainance and repairof pumps (10% of energy cost)	=	23,400
Total	=	1,176,700

The per capita cost of providing conventional sewerage for the service area of 152 ha, having a population of 38,000, was then determined to be 2,418 Baht per person. The operation and maintenance cost is 31 Baht per person per annum.

The construction cost of the lateral sewer network constitutes 79.1% of the total construction cost while the installation of main sewers constitutes about 19% of the total construction cost. The remaining 2% of the total construction cost is allotted for the construction of the pumping stations and the purchase of submersible pumps.

Comparing the Minimum Sewerage Option with the Maximum Sewerage Option reveals that the extension of the sewerage system to less densely populated areas increases the per capita cost for construction as well as for operation and maintenance by 22% and 23% respectively. This increase in cost is mainly caused by higher per capita costs of the lateral sewers of the Maximum and Minimum Sewerage Options in areas of low population density. The per capita cost of the lateral sewer system including house connections is for the Maximum and the Minimum Sewerage option 2,553 Baht per person and 1,916 Baht per person respectively. This reflects an increase of 33% in the per capita construction cost of lateral sewers of the Maximum Sewerage Option by the extension of sewers to areas of low population density. This effect becomes even more obvious when considering the cost for individual areas instead of the average cost for an entire sewerage option. For instance, the per capita construction cost for lateral sewers in the land use category Residential I with a population density of 250 persons per ha is 1,900 Baht per person. The corresponding value for land use category Residential II with a population density of 16 persons per ha is 19,864 Baht per person.

The total construction cost and the annual operation and maintenance cost for the Small Bore Sewerage Option were calculated as follows:

Total construction cost in Baht :

Main sewers	=	24,265,000
Lateral sewers+ house con.	=	169,100,000
Pumping stations	=	3,216,800
Total	=	196,581,800
Interceptor tanks	=	24,133,000
Total (including int. tanks)	=	220,714,800

O & M Cost per annum in Baht :

Sewers and pumping stations (1% of capital cost)	=	1,965,800
Energy cost @ 1.55 Baht/kWh	=	466,500
Maintenance and repair of pumps (10% of energy cost)	=	46,600
Total	=	2,478,900

The per capita cost of providing small bore sewerage for the service area of 592.4 ha having a population of 88,870 was determined to be 2,212 Baht per person. The operation and maintenance cost is 25 Baht per person per annum. These rates exclude the cost of providing interceptor tanks at individual houses and reflect the situation wherein previously built on-site facilities can be used as interceptor tanks. Including interceptor tanks, the construction as well as operation and maintenance costs are 2,484 Baht per person and 28 Baht per person respectively. Accordingly, if previously built on-site facilities can be used, the saving in cost would constitute about 11% of the per capita construction cost of the small bore sewer system.

The construction cost of the lateral sewer network, including interceptor tanks, constitutes 88% of the total construction cost whereas the installation of main sewers constitutes about 11% of the total construction cost. The remaining 1% of the total construction cost is allotted for the construction of the pumping stations and the purchase of submersible pumps.

4.4.2 Construction Cost of Conventional Sewerage and Small Bore Sewers

The comparison of the economic cost of a conventional sewerage system and a small bore sewerage is presented in Chapter 7. Nevertheless, an analysis of construction costs more clearly shows from which part of the sewerage system cost differences between options originate. Table 4.20 shows the construction costs of the two sewerage systems and the percentage of savings incurred through the installation of small bore sewerage. The construction cost of the lateral and main sewers are about 15% lower for small bore sewerage as compared to that for conventional sewerage. Under the assumption that existing on-site facilities can be used as interceptor tanks for small bore sewerage, the cost saving for the lateral sewers increases to about 25%. Since the construction of lateral sewers constitutes the major part of the total cost, this also contributes to the total saving. The percentage of savings for the lateral sewers and for the total sewerage are almost equal. This applies to the cases where there is and there is no cost for interceptor tanks as well.

The highest saving was incurred with respect to the construction cost of pumping stations, this being 43% less for small bore sewerage. The reason is simply that less pumping stations are required for small bore sewerage because of less stringent slope and flow velocity requirements. The reduced number of pumping stations required for small bore sewerage servicing flat areas obviously offers further advantages besides lower system cost. These benefits include less operational requirements and greater reliability.

It was initially expected that cost saving from the use of small bore sewers would be higher in areas with low population density. Table 4.21 confirms this expectation. The proportion of savings almost continuously increases with decreasing population density. However, the amount of this increase is rather small. The amount of saving increases from about 25% of total cost for serviced areas having densities between 169 and 250 persons per ha to about 29% of total cost for serviced areas having a density of 16 persons per ha.

Table 4.20 Construction Cost of Conventional Sewerage Versus Small Bore Sewerage

Type of system element	Construction cost (million Baht)		Savings in % by small bore sewerage
	Conventional	Small bore	
Main Sewers	28.58	24.27	15.1
Lateral Sewers	226.88	169.10	25.5 [14.8]*
Pumping Stations	5.67	3.22	43.2
Total 1	261.13	196.58	24.7
Interceptor tanks	0.0	24.13	-
Total 2	261.13	220.71	15.5

*) including interceptor tanks

Table 4.21 Basic Areal Costs of Conventional Sewerage versus Small Bore Sewerage for Different Population Densities (without interceptor tanks)

Land use category	Density (persons/ha)	Construction cost (10^3 Baht/ha)		Savings in % by small bore sewerage
		Conventional	Small bore	
Residential I	250	339	254	25.1
Commercial	181	311	232	25.4
Mixed	169	247	185	25.1
Institutional	47	238	177	25.6
Residential II	16	227	162	28.6

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5. ON-SITE WASTEWATER TREATMENT

5.1 Septic Tanks

5.1.1 Introduction

A septic tank is a watertight rectangular or cylindrical chamber, usually located just below ground level, which receives both excreta and flush water from toilets as well as other household wastewaters (or sullage such as water from kitchens, bathrooms, and laundry, etc.). As shown in Figure 5.1, settleable solids settle to the tank bottom, accumulate, and then are anaerobically digested. A scum of lightweight materials (including grease and fats) remain on or rise to the surface of the liquid in the tank. The clarified liquid flows through an outlet structure and is normally treated through a subsurface soil absorption system such as leaching fields or soakage pits. Because the liquid in septic tanks has a retention time of one to three days, the effluent from septic tanks is obnoxious, and contains high concentrations of organic matter, nutrients, and enteric microorganisms. Hence, effluent should not be discharged to nearby storm drains, rivers, or lakes without prior treatment. In developing countries and Southeast Asia, soakage pits are most commonly employed in treating septic tank effluent.

Sludge accumulated in septic tanks, called septage, still contains a high concentration of organic matter, nutrients, and enteric microorganisms. The periodic removal of septage, at intervals of one to five years, is necessary to avoid excessive septage accumulation which can interfere with septic tank efficiency. Septage is usually treated by anaerobic digestion or lagooning. The treated residue can then be reused as a soil conditioner.

A cesspool is a primitive form of septic tank which is made of concrete rings as shown in Figure 5.2. In general, two cesspools arranged in series are constructed for a household. Only excreta and flush water flow into the cesspool. The settleable solids settle at the tank bottom and the liquid seeps out of the concrete rings to the surrounding soil through small holes (2 cm in diameter). Because the surrounding soil is easily clogged, many cesspools have effluent pipes connected to nearby storm drains or canals. Because cesspool effluent possesses characteristics similar to those of septic tank effluent, this practice of cesspool effluent treatment and discharge is technically unsatisfactory. The cesspool effluent pollutes the nearby soil and water courses and, as such, poses as a possible health hazard to the population. Cesspool sludge or septage needs to be periodically removed from cesspool units, as with sludge or septage in septic tanks.

Cities in Thailand are not equipped with sewerage or wastewater collection systems. Cesspool units are commonly used to treat toilet wastewaters while sullage waters (also polluted) are discharged directly into storm drains or nearby canals. Because subsoil in most areas of the country is of impermeable clay and can become clogged sooner or later, overflow from cesspools together with sullage waters usually find their way, either directly or indirectly, into the drainage system, thereby causing pollution and other unsightly conditions, as cited earlier.

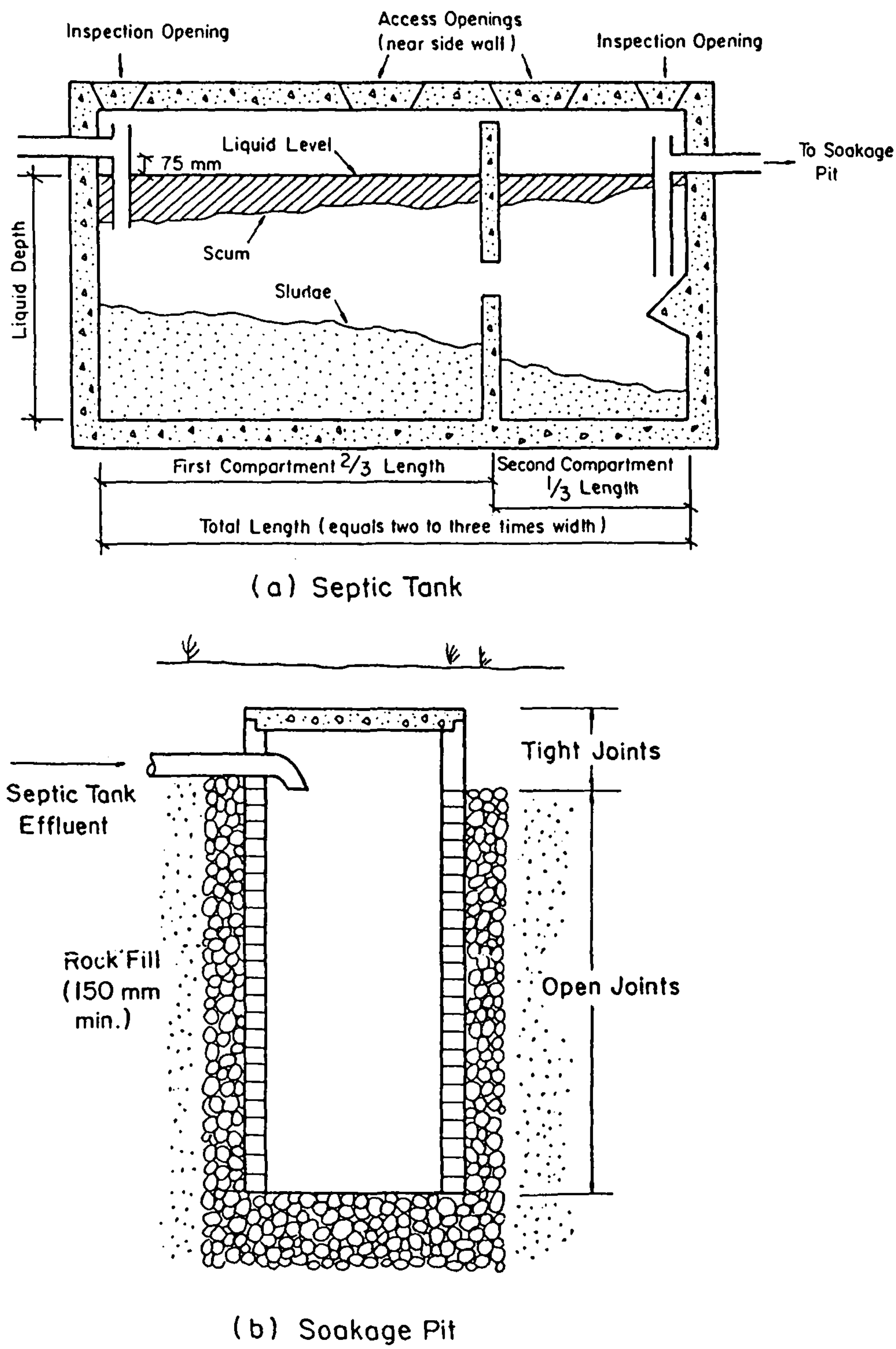


Figure 5.1 Schematic Diagram of Septic Tank and Soakage Pit

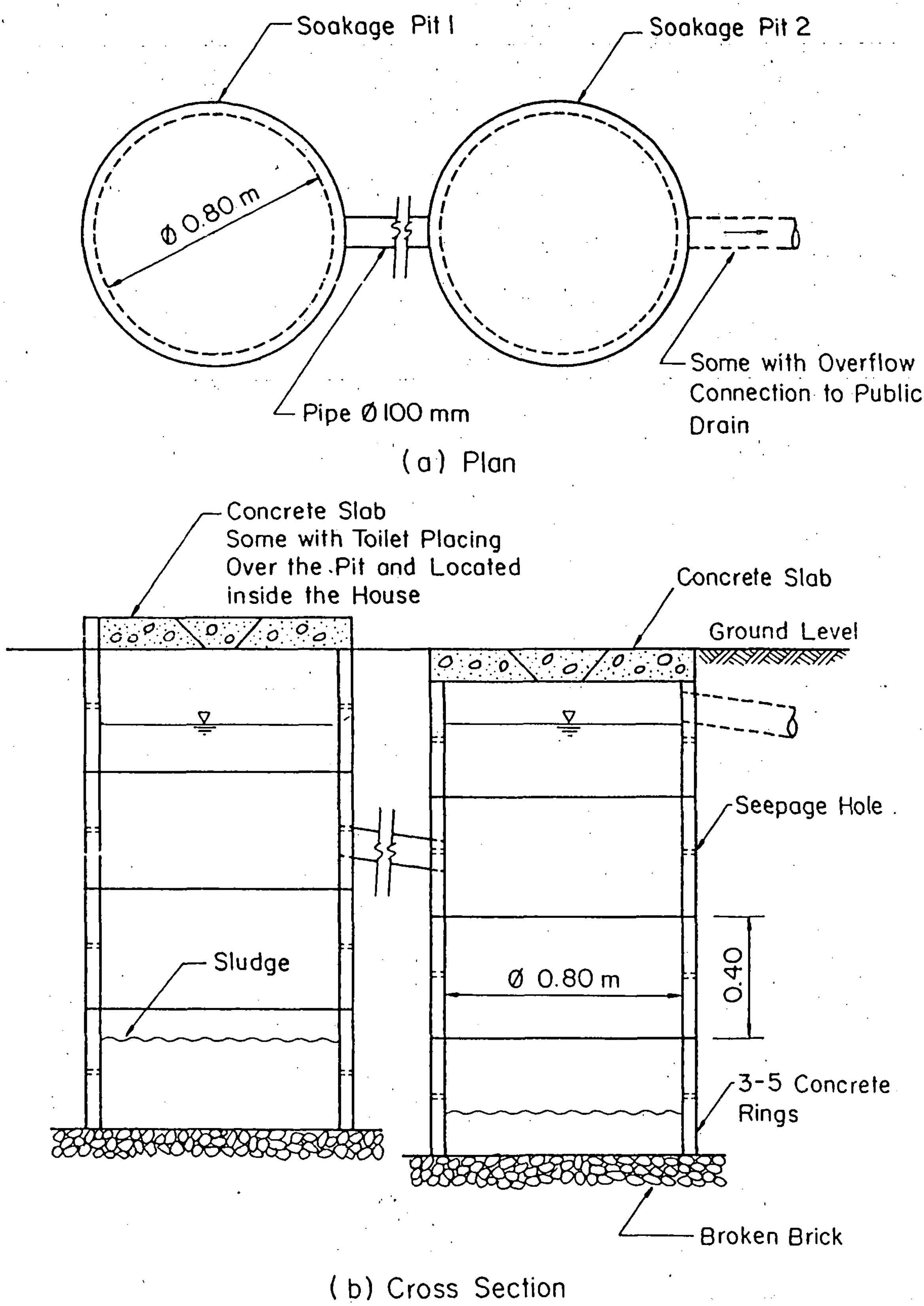


Figure 5.2 Typical Cesspool Unit in Thailand

5.1.2 Excreta and Wastewater Disposal in Chonburi

The Chonburi municipal area was divided into a number of planning cells as shown in Map 1. A survey conducted by SEATEC (1983) found that most of the urban dwellers use pour-flush toilets with toilet wastewaters being treated by cesspool systems (Figure 5.2). Pour-flush toilets are connected to cesspools located either beneath or beside the house.

A typical cesspool pit is constructed of three to five concrete rings whose diameter varies from 0.8 to 1.0 m. The pit depth is 1.2 to 2.0 m. Most of the houses and row shophouses are equipped with two cesspool pits which are constructed in series. Cesspool effluent is usually piped into the nearby storm drains or canals (Figure 5.3).

The infiltration capacitites of soils in the Chonburi municipal area are not known. A serious pollution problem is apparent in the old commercial district (cell number 19 and 20) where shallow wells and cesspools are located near each other. About 10% of the population obtain their waters from shallow wells for domestic uses such as dishwashing, bathing, and other cleansing activities. These well waters are most of the time slightly saline. The total coliforms content was found to be as high as 1800 MPN/100ml (SEATEC, 1983). This is indicative of the possible contamination of the wells by wastewater.

Commercial buildings, government offices, schools, and other institutional establishments normally have septic tanks for toilet wastewater treatment. According to SEATEC (1983) and the survey conducted for this study, soakage pits for the treatment of septic tank effluent are not properly constructed or non-existent. It is probable that some septic tank effluents are discharged directly into storm drains.

It should be noted that in the Chonburi municipality, similar to other provinces in Thailand, all sullage wastewaters are discharged without treatment directly into storm drains or nearby water courses. Since sullage wastewater contains high concentrations of organic matter and fecal microorganisms (FEACHEM et al., 1983), this practice of sullage disposal is also unsatisfactory and is a threat to public health.

The frequency of septage removal or desludging in the Chonburi municipality is given in Table 5.1. According to the survey done by SEATEC (1983), the long periods between emptying the pits had caused the sludge to pile up so that surplus liquid and feces bypassed the tanks and overflowed either into the surrounding subsoil or into adjacent water courses. This condition is evident in the areas of Chonburi which are inaccessible to desludging services such as vacuum trucks. In particular, inaccessibility to desludging services is common in low-income and urban fringe areas where these services are expensive.

The cesspool system relies to a great extent on the capacity of the subsoil to accept the infiltration of liquid from the cesspool pits. Where the ground water table is high and the soil is saturated or impermeable, percolation of effluent is limited so that this liquid flows directly into water courses. Improper design and location of cesspools and septic tanks, especially in high density areas, aggravate the aforementioned pollution problems.

Table 5.1 Excreta Disposal Systems-Chonburi Survey Results (Summarized from Table 5 (SEATEC, 1983)).

Cell number	Land use category	Type of toilet	Type of disposal system	Desludging frequency
6	Res. 1	Pour-flush	Cesspool	> 2 years-50%
7	Res. 1	(100%)	(100%)	1-2 years-45% 0.5-1 year-5%
8	Res. 1	Pour-flush	Cesspool (93%)	1-2 years-80%
9	"	(100%)	direct to	(estimate)
10	"		ground (7%)	
12	Res. II	Pour-flush	Cesspool (87%)	>2 years-10%
13	"	(97%)	Pit latrine (3%)	1-2 years-80%
22	Commercial	Pit latrine (3%)	Cesspool connected to sewers (10%)	0.5-1 year-10%
26	Mixed			
27	"			
30	Institutional			
19	Commerical	Pour-flush (100%)	Cesspool (70-90%)	>2 years-40%
20	"		Cesspool connected to sewers (10-30%)	1-2 years-50% 0.5-1 year-4% <0.5 year-1%
2	Agricul-	Pour-flush	Cesspool (85%)	>2 years-15%
3	tural	(100%)	Cesspool connected to storm sewer (15%)	1-2 years-85%
21	Commercial	Pour-flush	Cesspool (100%)	>2 years-50%
24	Mixed	(100%)		1-2 years-50%
25	"			

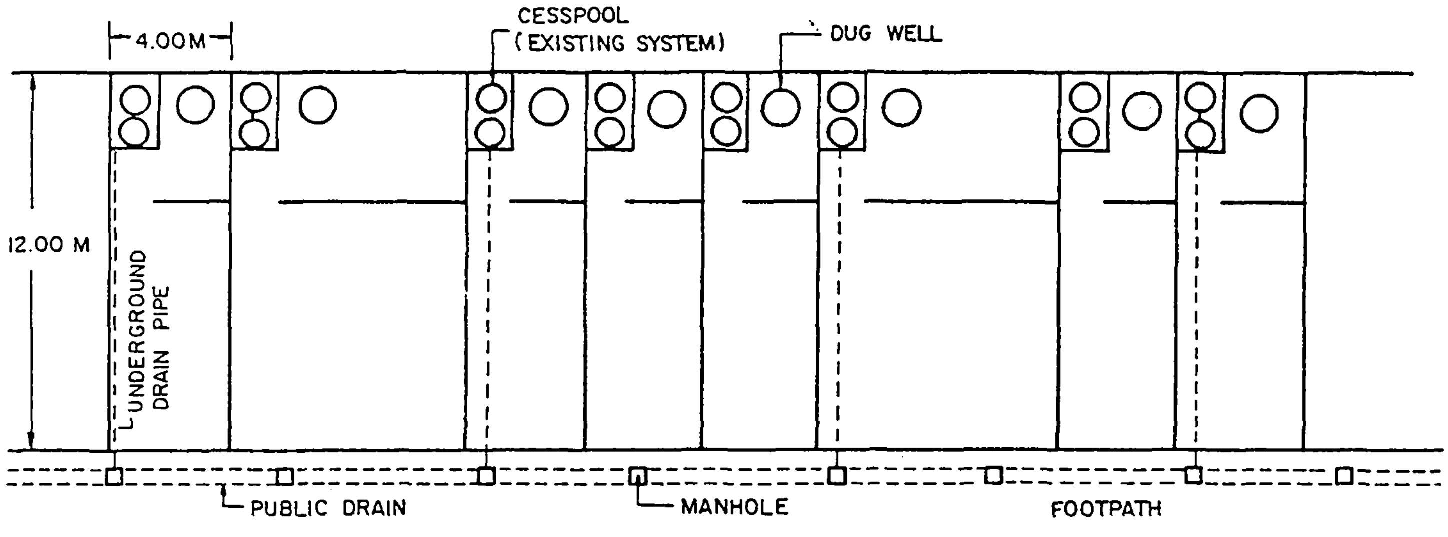


Figure 5.3 Typical Layout of Rowhouse with Drainage of Cesspool System Overflow to Public Drain

It appears from the aforementioned information that the current method of excreta and sullage treatment/disposal in the Chonburi municipality is not technically and hygienically effective, thereby resulting in pollution problems to the surrounding soils, groundwater, and storm drains. In this case study, the septic tank/soakage pit system (Figure 5.1) will be considered as the suitable and effective on-site treatment system. All the toilet and sullage wastewaters shall first be treated in the septic tank and, thereafter, the septic tank effluent shall be treated in the soakage pit. The bacteria adhering to the rock media surrounding the soakage pit shall be responsible for wastewater treatment and also pathogen retention/inactivation. The treated effluent shall seep into the surrounding soil leading to the ground water or nearby surface waters.

Other on-site treatment methods such as composting toilets and pit latrines are not socially accepted by the Thai people and can not treat sullage wastewaters. A watertight vault may be installed in a house to receive all types of wastewater; but septage/wastewater removal in this case must be more frequent, thereby causing additional expenses for households.

5.1.3 Design Criteria of Septic Tank System for Chonburi Municipality

There are several methods available for the design of septic tanks (POLPRASERT and RAJPUT, 1982); but the method proposed by PICKFORD (1980) seemed to be appropriate in the design of household septic tanks for Chonburi. The design equations thus employed followed the detailed stages of calculations as outlined:

$$C = A + B \qquad (5.1)$$

where

C = total capacity of septic tank, l

A = required sludge storage capacity, l

B = required liquid retention capacity, l

A and B were calculated separately from the following equations:

$$A = Pnfs \qquad (5.2)$$

where

P = number of people expected to contribute to the tank inputs

n = number of years between desludging

f = factor which is related to the ambient temperature

s = rate of sludge and scum accumulation, l/(c.a)

According to SEATEC (1983), the number of persons per household (P) should be taken as seven.

The desludging frequency (n) was taken as one per annum to avoid excessive sludge accumulation in the septic tank.

According to PICKFORD (1980), the value of 'f' should be taken as 1.3 for the desludging period of one year.

Also, PICKFORD (1980) suggested that the value of s should be taken as 40 l/(c.a).

The value of B was calculated using equation (5.3).

$$B = Pqt \tag{5.3}$$

where

q = wastewater flow rate which for Chonburi was taken as 120 l/(c.d)

t = hydraulic retention time which is usually taken as one day to allow for sedimentation of settleable solids

Values for B and P are those defined previously.

The number of people to be served by septic tanks in the Maximum Sewerage Option, the Minimum Sewerage Option, and the Small Bore Sewerage Option and the Septic Tank Option are 16900, 67770, 16900, and 105770, respectively.

The value of C for institutional, commercial, and other kinds of establishments can be determined from guidelines prepared by the U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE (1959) as shown in Figure 5.4. The design equation to determine the size of a septic tank is given in equation (5.4).

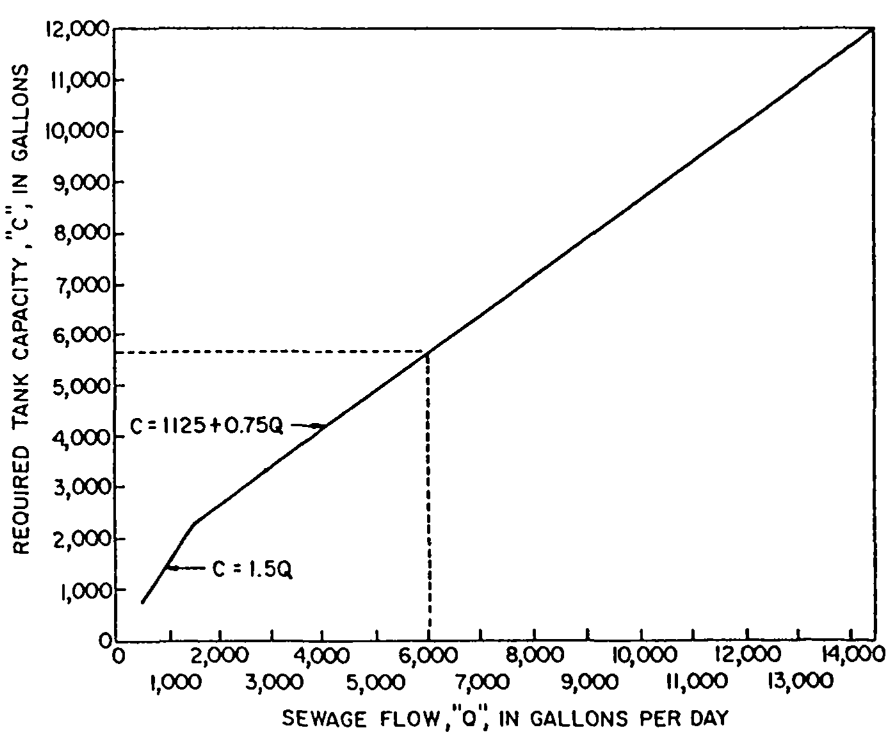


Figure 5.4 Septic Tank Capacities for Sewage Flows up to 14,500 gal/d (54.88 m^3/d)

$$C = 1125 + 0.75\ Q \qquad (5.4)$$

where

C = net volume of the tank, gal

Q = sewage flow rates, gal/d

The wastewater flow rates from institutional sources for the four wastewater treatment options are given in Table 5.2.

Table 5.2 Wastewater Flow Rates from Institutional Sources

Option	Flow rates, l/s
Maximum Sewerage Option	5.7
Minimum Sewerage Option	74.1
Small Bore Sewerage Option	5.7
Septic Tank Option	75.8

Other Design Considerations

A two-compartment rectangular septic tank, as shown in Figure 5.1 is proposed for household wastewater treatment while a three-compartment rectangular septic tank is suggested for the treatment of wastewater from institutional and commercial areas. These multi-compartment septic tanks can reduce flow short-circuiting and produce effluents which contain a low concentration of suspended solids. By installing multi-compartment septic tanks, the surrounding soil would not be easily clogged and the soakage pits would function effectively. For the Chonburi municipality, multi-compartment septic tanks are preferred to single or circular-compartment septic tanks.

To enhance the efficient sedimentation of solid matter, the size of the first compartment of a two-compartment septic tank is usually made to be twice the size of its second compartment. For a three-compartment septic tank, the size of the second and third compartments are both made equal to half of the size of the first compartment.

Because septic tanks must be watertight, structurally durable, and stable, a suitable construction material for these tanks is reinforced concrete. According to MARSHALL (1979), the life span of reinforced concrete septic tanks is 20 years.

Guidelines for the location of septic tank systems, as suggested by KALBERMATTEN et al., (1980), are tabulated in Table 5.3. These guidelines should be considered in siting septic tanks as much as possible.

Table 5.3 Minimum Distance Requirements for Septic Tanks and Soakage Pits in Common Well-Developed Soils

Item	Septic tank (m)	Soakage pit (m)
Buildings	1.5	3.0
Property boundaries	1.5	1.5
Wells	10.0	10.0
Streams	7.5	30.0
Cuts or embankments	7.5	30.0
Water pipes	3.0	3.0
Paths	1.5	1.5
Large trees	3.0	3.0

The selection of soakage pits for use in the disposal of septic tank effluent was based on the economy of its cost and space requirements. The types of soil in Chonburi are mainly sandy loam, loamy sand, and sandy. The average infiltration rate of 0.1 $m^3/(m^2.\ d)$ was adopted with a reasonable safety factor as the design criteria of soakage pits. A circular tank built from open-joint bricks shall be used to allow for the maximum seepage of septic tank effluent into the surrounding rocks and soil.

5.1.4 Design of Septic Tank System

(a) Household Septic Tank System (Equations 5.1, 5.2, and 5.3)

$$A = Pnfs = 7 \times 1 \times 1.3 \times 40 = 364\ l$$

where,

A = required sludge storage capacity, l
P = 7 person/household
f = 1.3
s = 40 l/(c.a)
n = 1 year

$$B = Pqt = 120 \times 7 \times 1 = 840\ l$$

where,

B = required liquid retention capacity in l
q = 120 l/(c.d)
t = 1 d

$$C = A + B = 364 + 840 = 1204\ l$$

where,

C = required volume of septic tank, l

Septic tank effluent to soakage pit = 120 x 7
= 840 l/d

Infiltration rate = 0.1 $m^3/(m^2.d)$

Required area for soakage pit = 0.84/0.1
= 8.4 m^2

- Use 1 septic tank: 0.65 x 2.00 x 1.30 m
  (width x length x depth)
  capacity = 1230 l (Figure 5.5)

- Use 1 soakage pit: 1.50 x 1.80 m
  (diameter x depth)
  surface area of pit
  (side wall and bottom) = 10.3 m^2 (Figure 5.5)

The cost estimates for the household septic tank and soakage pit are given in Tables 5.4 and 5.5, respectively. The total cost includes material and labour cost with about 10% allowance for cost fluctuation. Cost estimation was based mostly on CONTRACTORS ASSOCIATION OF THAILAND, (1987).

Total unit cost of a household septic tank/soakage pit (from Tabs. 5.4 and 5.5) therefore:

6,200 + 5,600 = 11,800 Baht

(b) Institutional Septic Tank System

A standard septic tank unit was designed to treat wastewater from commercial and institutional establishments. The treatment capacity of this standard unit is 0.1 l/s (8.64 m^3/d).

From (Equation 5.4)

$$\begin{aligned} C &= 1,125 + 0.75\ Q \\ &= 1,125 + 0.75 \times 2283 \\ &= 2,837 \text{ gal } (10.74\ m^3) \end{aligned}$$

where,
C = net volume of septic tank, gal
Q = 2283 gal/d (8.64 m^3/d)

The required area of soakage pit = 8.64/0.1 = 86.4 m^2

- Use 1 septic tank : 1.4 x 5.7 x 1.7 m
  (width x length x depth)
  capacity = 10.78 m^3 (Figure 5.6 a,c,d)

- Use 4 soakage pits, each with the dimension of 3.0 x 2.0 m
  (diameter x depth)
  surface area of 4 soakage pits
  (side wall and bottom) = 90.6 m^2 (Figure 5.6 b)

Table 5.4 Cost Estimation of the Household Septic Tank

Item	Quantity	Material cost (Baht)	Labor cost (Baht)
Excavation	6.5 m^3	-	330
Compacted sand	0.6 m^3	60	60
Reinforced concrete work	1.4 m^3	3000	1400
Plastering	10.2 m^2	60	250
Piping work	1 set	290	200

Total = 5650 Baht
Allowance = 10 %
Unit cost = 6,200 Baht/tank

Table 5.5 Cost Estimation of the Household Soakage Pit

Item	Quantity	Material cost (Baht)	Labor cost (Baht)
Excavation	13.0 m^3	-	650
Brick work	8.5 m^2	960	430
Compacted sand, rock fill, cover soil	7.9 m^3	1000	240
Reinforced concrete work	0.5 m^3	1050	500
Piping work	1 set	120	100

Total = 5,050 Baht
Allowance = 10 %
Unit cost = 5,600 Baht/pit

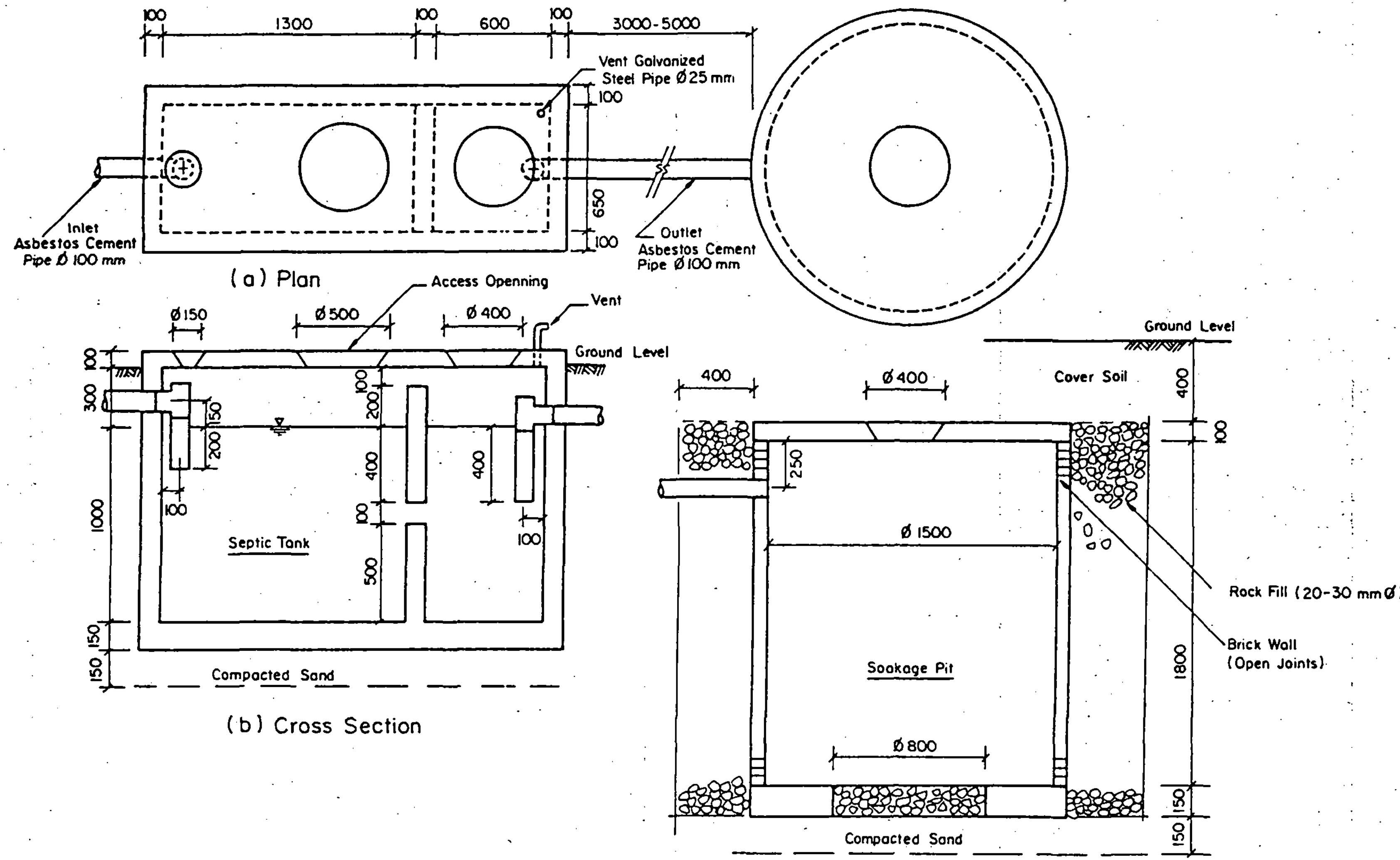
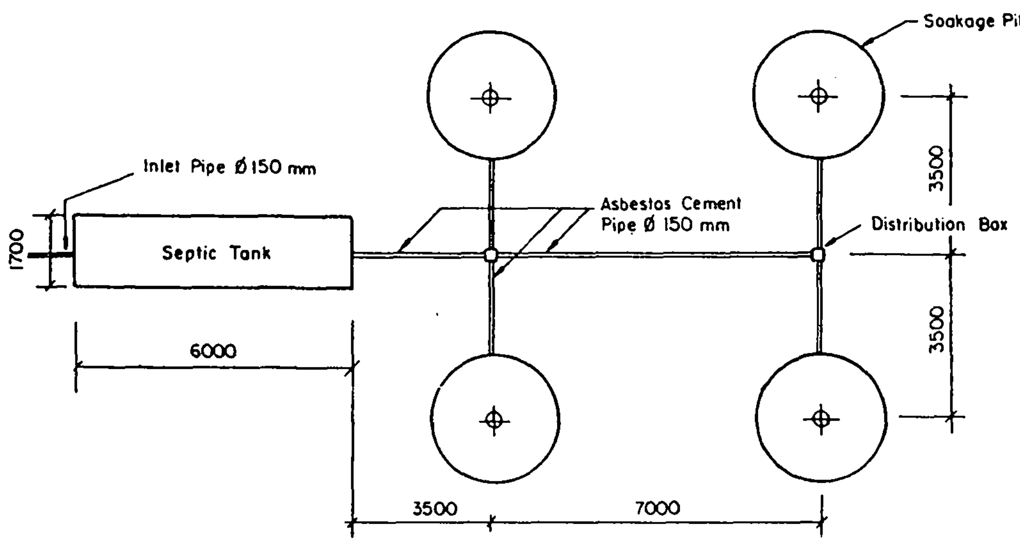
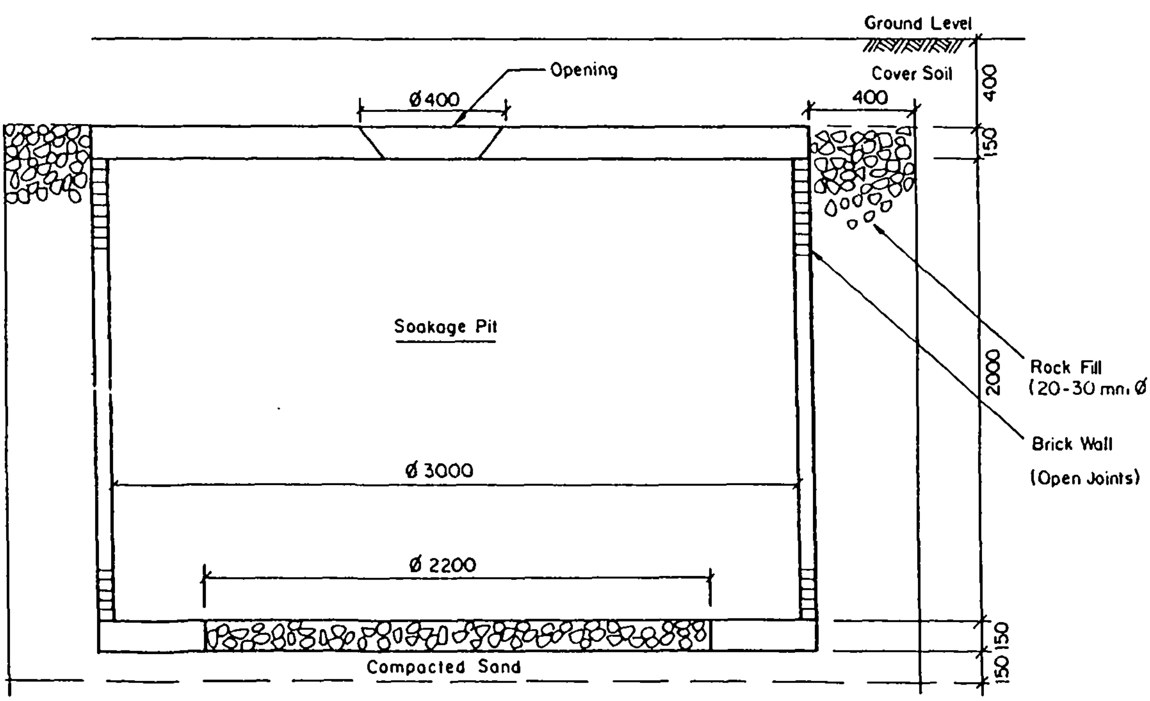


Figure 5.5 Household Septic Tank - Soakage Pit (All units in mm)

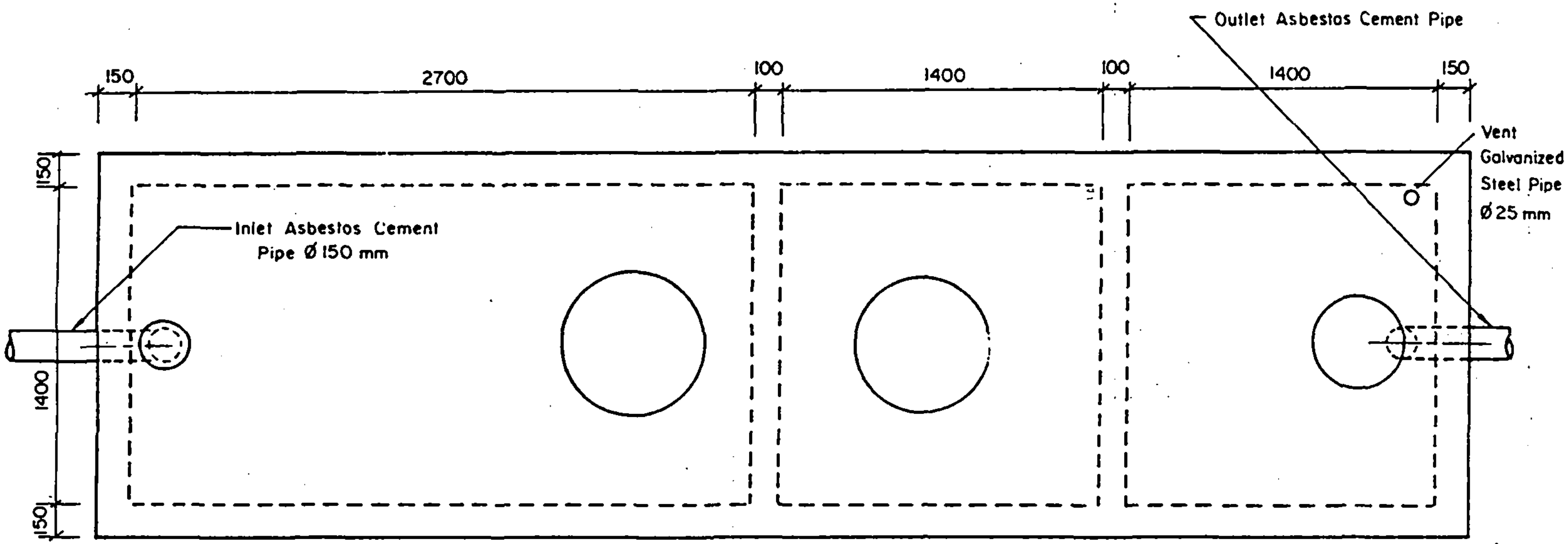


(a) Plan of System

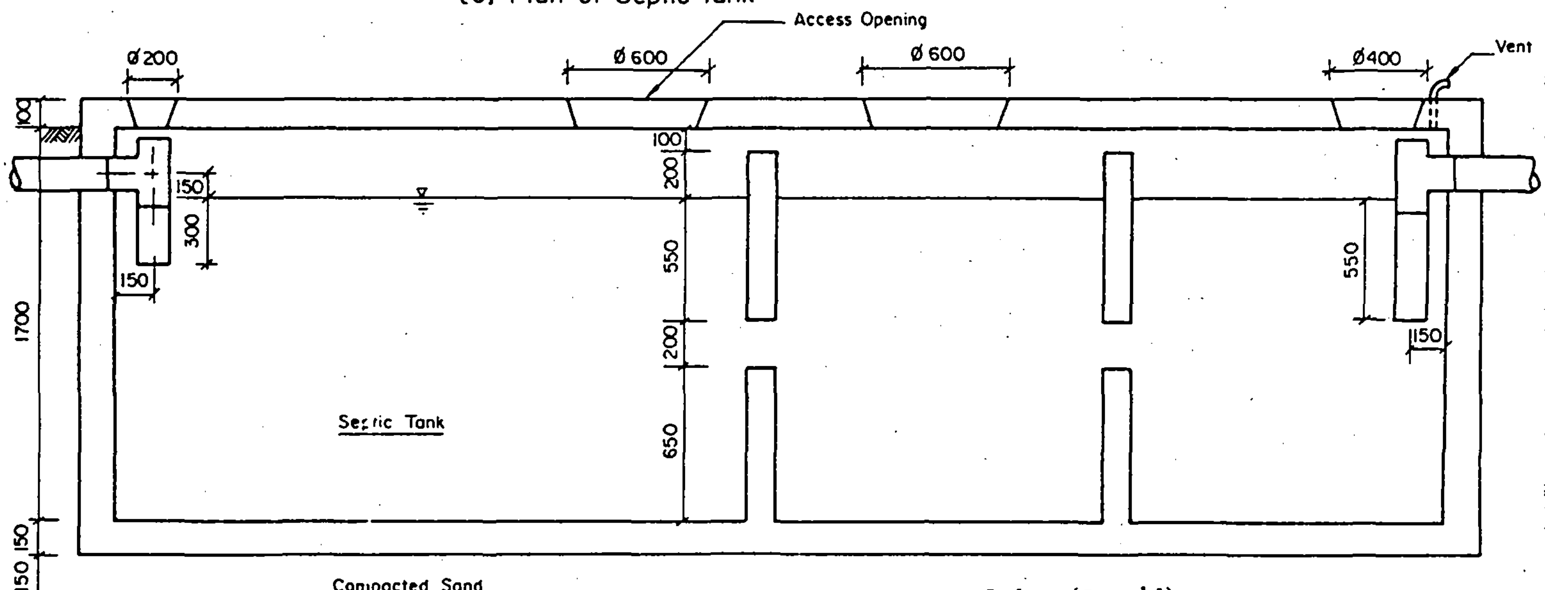


(b) Cross Section of Soakage Pit

Figure 5.6 Institutional Septic Tank with Four Soakage Pits (All units in mm)



(c) Plan of Septic Tank



(d) Cross Section

Figure 5.6 (Cont'd)

The cost estimates for the institutional septic tank and soakage pit are given in Tables 5.6 and 5.7, respectively. The total cost includes material and labor costs, with about 10% allowance for cost fluctuation. Cost estimation was based mostly on CONTRACTORS ASSOCIATION OF THAILAND, (1987).

Table 5.6 Cost Estimation of Institutional Septic Tank

Item	Quantity	Material cost (Baht)	Labor cost (Baht)
Excavation	35.7 m^3	-	1,790
Compacted sand	1.5 m^3	140	80
Reinforced concrete work	4.0 m^3	8,400	4,000
Plastering	23.6 m^2	130	590
Piping work	1 set	340	200

Total = 15,670 Baht
Allowance = 10%
Unit cost = 17,200 Baht/tank

Table 5.7 Cost Estimation of Institutional Soakage Pit

Item	Quantity	Material cost (Baht)	Labor cost (Baht)
Excavation	36.4 m^3	-	1,820
Brick wall	18.9 m^2	2,090	940
Compacted sand, rock fill,cover soil	13.5 m^3	1,440	410
Reinforced concrete work	1.8 m^3	3,780	1,800
Piping work	1 set	120	100

Total = 12,500 Baht/pit
For 4 soakage pits = 12,500 x 4 = 50,000 Baht
Connecting pipe, distribution box = 1,000 Baht
Total cost = 51,000 Baht
Allowance = 10%
Unit cost = 56,100 Baht/4 pits
Total unit cost of institutional septic tank/4 soakage pits (from Tabs. 5.6 and 5.7)
therefore: 17,200 + 56,100 = 73,300 Baht

Existing Cesspool System in Chonburi

The typical existing cesspool system in Chonburi consists of two soakage pits as shown in Figure 5.2. A detailed cost estimate is given in Table 5.8. The total cost includes material and labor costs, with about 10% allowance for cost fluctuation.

Table 5.8 Cost Estimation of Cesspool System

Item	Quantity	Material cost (Baht)	Labor cost (Baht)
Excavation	3.0 m^3	-	150
Broken brick	0.15 m^3	50	50
Concrete ring 0.8x0.4 m (diameter x depth)	8 rings	480	150
Reinforced concrete work	0.13 m^3	280	130
Piping work	1 set	120	100

Total = 1510 Baht
(excluding toilet and super structure)
Allowance = 10%
Unit cost of cesspool = 1,700 Baht

5.1.5 Construction Costs of Septic Tank System

In this case study, it was assumed that all the existing cesspool units would be improved and converted to septic tank units. It is assured that the 25% increase in basic unit cost is added for construction works, i.e. tax, profit, construction supervision, and other related expenses. Since the septic tank construction will be separately distributed to many small local contractors and the work period is relatively short, this allowance is quite reasonable. The construction unit cost of the household septic tank system and the institutional septic tank system are therefore 14,750 and 91,625 Baht, respectively. The construction cost of septic tanks/soakage pits for the four wastewater treatment options considered are given in Table 5.9.

Table 5.9 Construction Costs of Septic Tanks/Soakage Pits

	Domestic sources			Institutional sources		
Option	Population	No. of household septic tanks	Total cost (Baht)	Wastewater flow(other than domestic sources) (l/s)	No. of institutional septic tanks	Total cost (Baht)
Maximum Sewerage Option	16,900	16,900/7 =2,414	35,606,000	5.7	57	5,223,000
Minimum Sewerage Option	67,770	67,770/7 =9,681	142,795,000	74.1	741	67,894,000
Small Bore Sewerage Option	16,900	2,414	35,606,000	5.7	57	5,223,000
Septic Tank Option	105,770	105,770/7 =15,110	222,872,000	75.8	758	69,452,000

5.2 Septage Collection

5.2.1 Septage Quantity and Collection Fee

The frequency of desludging for all septic tanks shall be once a year. The septage accumulation rate from domestic sources was taken as 40 l/(c.a). The quantity of septage from institutional sources was taken in proportion to the flow rate. For an institutional septic tank receiving a flow rate of 8.64 m^3/d, the septage produced is therefore equal to (8,640/120) x 40 = 2,880 l/a. The septage quantities for the four wastewater treatment options are summarized in Table 5.10.

The septage collection rates adopted throughout Thailand, according to the PUBLIC HEALTH ACT (1985), are as follows:

Normal rate	- 250 Baht/m^3
Less than 0.5 m^3	- 150 Baht
More than 0.5 m^3 but less than 1.0 m^3	- 250 Baht

According to the above rates, the septage collection fee for each household septic tank (0.28 m^3, collected once per year) is 150 Baht while the septage collection fee for each institutional septic tank (2.88 m^3, collected once per year) is 750 Baht.

The fee for Small Bore Sewerage Option is assumed to be equal to that for Septic Tank Option. The total collection fees of septage for the four options are summarized in Table 5.11.

Table 5.10 Septage Quantity

Option	From household septic tank (m^3/a)		From institutional septic tank (m^3/a)		Total m^3/a (m^3/d)
Maximum Sewerage Option	16,900 x 40 / 1,000	= 676	57 x 2.88 = 164		840 (2.3)
Minimum Sewerage Option	67,770 x 40 / 1,000	= 2,711	741 x 2.88 = 2,134		4,845 (13.3)
Small Bore Sewerage Option	676)) *3,555)	= 4,231	164)) *2,019)	= 2,183	840))=6,414(17.6) *5,574)
Septic Tank Option	105,770 x 40 / 1,000	= 4,231	758 x 2.88 = 2,183		6,414(17.6)

Remark
* For the small bore sewer system, wastewater will be discharged into interceptor tanks prior to flowing into the sewer. The septage will accumulate in these tanks which would need periodic emptying. The sludge characteristic as well as the accumulation rate are similar to those of septic tanks. The septage collected from household interceptor tanks (population served 88,870) is (88,870 x 40/1,000 = 3,555 m^3/a.

Table 5.11 Collection Fee of Septage

Option	Household Septic Tank		Institutional Septic Tank	
	No. of Tanks	Fee (Baht/a)	No. of Tanks	Fee (Baht/a)
Maximum Sewerage Option	2,414	362,000	57	43,000
Minimum Sewerage Option	9,681	1,452,000	741	556,000
Small Bore Sewerage Option	2,414+ Interceptor tanks	2,266,000	57+ Interceptor tanks	568,000
Septic Tank Option	15,110	2,266,000	758	568,000

5.2.2 Operating Cost of Septage Collection

The desludging facilities proposed in this project are vacuum trucks. The 3 m^3 capacity truck equipped with a 100-Hp diesel engine was selected, since it can easily travel through the narrow roads of Chonburi. The collection team shall include one driver who shall also be responsible for issuing the fee document after completing the septage collection task. There are two laborers who shall perform desludging tasks such as connecting and disconnecting the suction hose and cleaning. The average collection time taken is 40 minutes per household including travel to the next house. On a one-shift working period (8 h/d), about ten household septic tanks can be emptied in a day, with one trip to the septage treatment plant. For institutional septic tanks, more than one trip to the septage treatment plant is possible since the collection time is greatly reduced. The fuel consumption during an average trip includes a 2-hour driving mode (consumption 10 l/h) and a 5-hour idling mode (consumption 3 l/h). The diesel price considered is 6.8 Baht/l and the diesel consumption for an average trip of a vacuum truck is taken to be about 240 baht. The fuel costs of septage collection for the four wastewater treatment options considered are summarized in Table 5.12.

Table 5.12 Fuel Costs of Septage Collection

Option	Septage from household septic tank (m^3/a)	No. of trip per year	Septage from institutional septic tank (m^3/a)	No. of trip per year	Total No. of trip per year	Fuel cost (Baht/a)	No. of truck
Maximum Sewerage Option	676	242	164	57	299	72,000	1
Minimum Sewerage Option	2,711	969	2,134	741	1,710	410,000	5
Small Bore Sewerage Option	4,231**	1,511	2,183**	758	2,269	545,000	7
Septic Tank Option	4,231	1,511	2,183	758	2,269	545,000	7

Remark * Estimated quantity of septage from ten household septic tanks and one institutional septic tank are 2.8 and 2.88 m^3/a, respectively.

** Including septage from interceptor tanks

The cost of a fully-equipped vacuum truck is 420,000 Baht, while the yearly maintenance shall be 5% of the initial cost or 21,000 Baht. The salaries for the driver and laborer shall be 3,000 and 2,000 Baht/month, respectively.

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6. CENTRAL WASTEWATER TREATMENT

6.1 Septage Treatment

6.1.1 Introduction

Septage is generally defined as the liquid and solid materials which are pumped from septic tanks or cesspools. It contains high organic matters, solids as well as pathogens. In areas served by septic tank systems, septage treatment facilities must be provided. There are various septage treatment processes. Anaerobic digestion and pond systems offer two of the most promising technologies for septage treatment. During anaerobic digestion, the degradation of organic materials in the absence of oxygen produces combustible methane gas or "biogas". Two alternatives are suggested for the anaerobic digestion of septage in Chonburi, i.e. through anaerobic digesters and anaerobic ponds. The anaerobic digester maintains biochemical reactions in an enclosed concrete tank having provision for gas storage at the upper part of the digester. Biogas can either be utilized in the treatment plant or nearby community. The anaerobic ponds provide sufficient retention time for anaerobic digestion to occur while the gas produced is directly released into the atmosphere. The effluent from both digestion processes (via anaerobic digesters and anaerobic ponds) is further treated in facultative ponds prior to discharging. The dry sludge cake produced from the digestion process is rich in nutrients and is suitable for use as a soil conditioner. This soil conditioner shall be freely distributed to the nearby farmers. The flow diagram of septage treatment plants applying the two mentioned alternatives is shown in Figure 6.1.

Septage characteristics in this case study are assumed to be similar to those of Bangkok septage as given in Table 6.1 (LIU, 1986):

6.1.2 Septage Treatment - Alternative 1 (Anaerobic digester, facultative pond, sludge drying bed)

Septage shall be unloaded from vacuum trucks, passed through a coarse screen, and stored in the sump. It shall then be pumped to anaerobic digesters where organic matters shall be oxidized into methane and other end products. The anaerobic process shall be enhanced by slurry mixing with a circulation pump. The supernatant from the digester, withdrawn during the no-mixing interval, would still contain high organic content and shall be treated further in a facultative pond before its disposal into a receiving water body. The digested sludge shall be discharged into sludge drying beds. Seven drying beds shall be provided, with one bed being used per day. The dry sludge cake shall be removed daily.

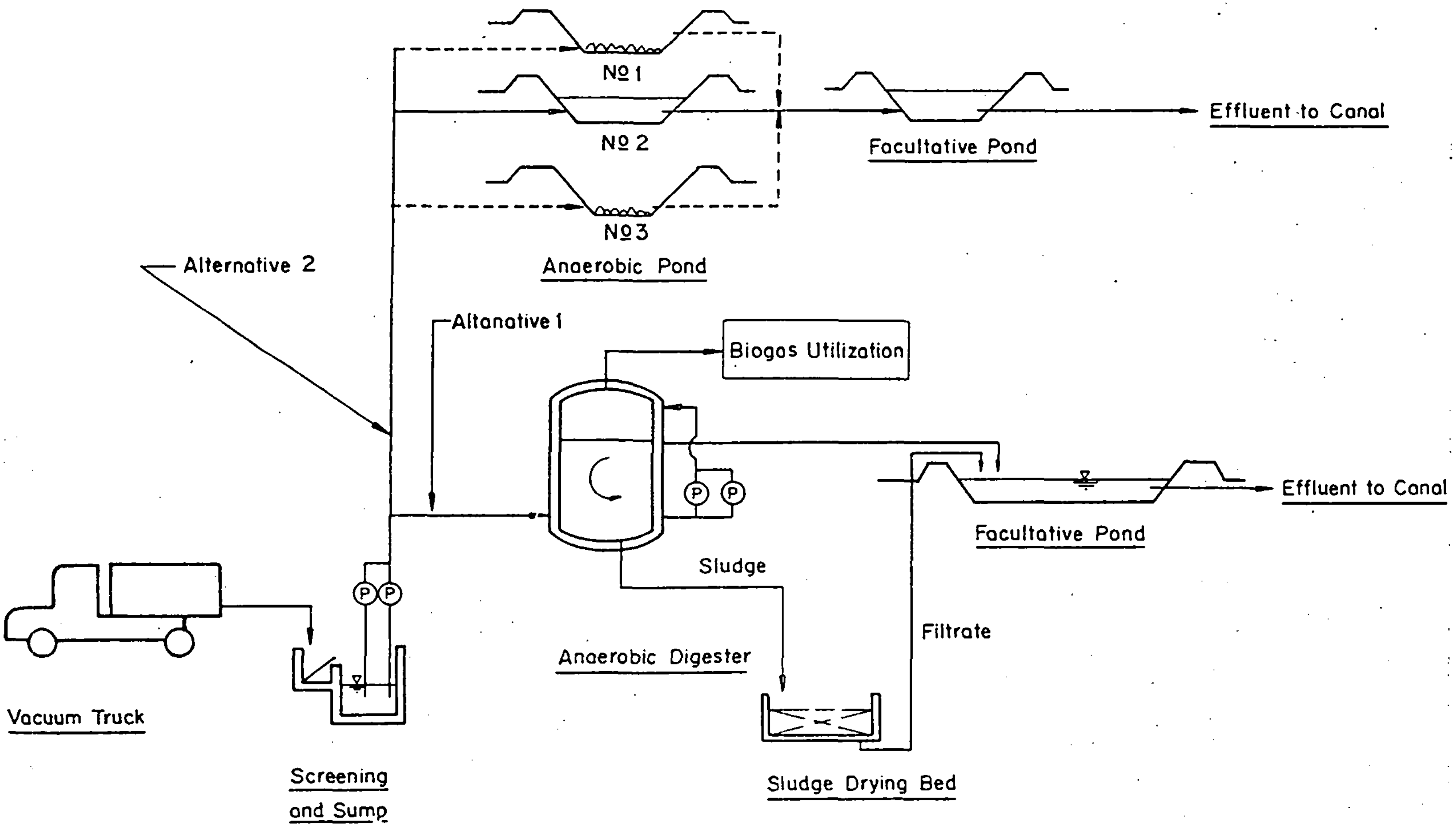

Figure 6.1 Schematic Diagram of a Septic Treatment Plant

Table 6.1 Septage Characteristics

Parameter	Unit	Range	Design value
pH		6.9-8.2	-
BOD_5	mg/l	802-4,040	1,700
COD	mg/l	4,981-32,149	15,200
Suspended solids (SS)	mg/l	3,720-24,132	12,500
Volatile suspended solids (VSS)	mg/l	3,040-18,020	8,700
Total solids (TS)	mg/l	5,122-25,400	13,800
Total volatile solids (TVS)	mg/l	3,296-19,300	9,500
Total coliforms	MPN/100 ml	7.9×10^6 - 1.7×10^8	-
Fecal coliforms	MPN/100 ml	2.0×10^5 - 4.9×10^7	-

Design Criteria

The following design criteria, based mostly on BROWN and PRAKASAM (1985), were adopted :

Anaerobic digester liquid retention time	=	40 d
Gas storage at the upper part of digester (fixed cover)	=	30 % of daily yield
Gas generation rate	=	0.2 m^3/(kg TVS.d)
Maximum quantity of sludge discharging to drying bed	=	40 % of septage quantity
Maximum quantity of dry sludge cake (25% solids)	=	5 % of septage quantity
BOD_5 removal in digester	=	90 %
Inflow to facultative pond	=	70% of septage quantity
Surface organic loading rate to facultative pond	=	70 kg BOD_5/(ha.d)

Construction Material

Reinforced concrete shall be used for the construction of sump and anaerobic digesters. Brick walls shall be used for sludge drying beds. Facultative pond shall be earthen without bottom and wall lining.

Sizing of Septage Treatment Plant

The size of septage treatment units (Alternative 1) and their associated costs are summarized in Table 6.2. The total estimated cost includes material and labor cost, with about 10% allowance for cost fluctuation.

Table 6.2 Sizing of Septage Treatment Units and their Associated Costs (Alternative 1)

Item	Unit	Maximum Sewerage Option	Minimum Sewerage Option	Small Bore Sewerage Option/ Septic Tank Option
Septage quantity	m^3/a m^3/d	840 2.3	4,845 13.3	6,414 17.6
Size of sump	m^3	3	6	9
Receiving capacity of sump, number of truck(s)		1	2	3
Sump unit cost*	Baht/m^3	2,000	2,000	2,000
Sump cost (including screening)	Baht	6,000	12,000	18,000
Total volatile solids (TVS) load	kg/d	21.8	126.4	167.2
Estimated biogas yield	m^3/d	4.4	25.3	33.4
Biogas unit cost**	Baht/m^3	1.4	1.4	1.4
Revenue from biogas	Baht/a	2,000	13,000	17,000
Digester				
- Liquid volume	m^3	92	532	704
- Gas storage volume	m^3	1.3	7.6	10.0
- Total volume required	m^3	93.3	539.6	714
Number of digester(s)		1 (1-phase construction)	2 (2-phase construction)	3 (3-phase construction)

Table 6.2 (Cont'd)

Item	Unit	Maximum Sewerage Option	Minimum Sewerage Option	Small Bore Sewerage Option/ Septic Tank Option
Size of digester	m^3/tank	100	270	240
Digester unit cost*	Baht/m^3	650	650	650
Digester cost	Baht	65,000 Baht/tank x 1 tank	175,500 Baht/tank x 2 tanks	156,000 Baht/tank x 3 tanks
Maximum sludge volume	m^3/d	0.9	5.3	7.0
Drying bed area required (0.2 m sludge depth)	m^2/d	4.5	26.5	35
Use 7 beds with total area	m^2	35 m^2/set x 1 set (1-phase construction)	100 m^2/set x 2 sets (2-phase construction)	90 m^2/set x 3 sets (3-phase construction)
Drying bed unit cost*	Baht/m^2	550	550	550
Drying bed cost	Baht	19,250 Baht/set x 1 set	55,000 Baht/set x 2 sets	49,500 Baht/set x 3 sets
Estimated dry sludge cake (25% solids)	m^3/d	0.1	0.7	0.9
Inflow to facultative pond	m^3/d	1.6	9.3	12.3
BOD_5 load (influent BOD_5 = 170 mg/l)	kg/d	0.27	1.58	2.09
Required pond area	m^2	39	226	299
Use - pond volume (1.5m depth)	m^3	60m^3/pond x 1 pond (1-phase construction	180 m^3/pond x 2 ponds (2-phase construction	160 m^3/pond x 3 ponds (3-phase construction
Pond unit cost	Baht/m^3	50	50	50

Table 6.2 (Cont'd)

Item	Unit	Maximum Sewerage Option	Minimum Sewerage Option	Small Bore Sewerage Option/ Septic Tank Option
Pond cost	Baht	3,000/pond x 1 pond	9,000/pond x 2 ponds	8,000/pond x 3 ponds
Estimated cost of piping work	Baht x 1 phase	1,000/phase x 2 phases	2,000/phase x 3 phases	2,000/phase
Estimated cost of pump				
- Inlet	Baht	5,000/set x 2 sets	5,000/set x 2 sets	5,000/set x 2 sets
- Mixing	Baht	5,000/set x 2 sets /digester x 1 digester	5,000/set x 2 sets /digester x 2 digesters	5,000/set x 2 sets /digester x 3 digesters
Total Construction cost (including 10% allowance)	Baht Phase I Phase II Phase III	-126,000 - -	301,000 277,000 -	279,000 248,000 248,000
Land requirement	ha	0.02	0.08	0.14
Land unit cost	Baht/ha	937,500	937,500	937,500
Land cost	Baht	19,000	75,000	131,000
Total Cost of Septage Treatment Plant***	Baht Phase I Phase II Phase III	-176,000 - -	451,000 346,000 -	480,000 310,000 310,000

Remark * Unit cost excerpted from ENGINEERING CONSULTANCY SERVICES CENTER (1986).

** Biogas contains about 60 % methane and has density of 1.22 kg/m^3. Energy value ratio of methane and butane (representing LPG) is approximately 0.31. Unit cost of LPG is 6 Baht/kg. The unit cost of biogas is about 1.4 Baht/m^3.

*** The 25% increase in total construction cost is added for construction works, i.e. tax, profit, construction supervision and other related expenses

Operating Cost

The operating cost of the septage treatment plant (Alternative 1) is given in Table 6.3.

Table 6.3 Operating Cost (Alternative 1)

Item	Unit	Maximum Sewerage Option (Baht/a)	Minimum Sewerage Option (Baht/a)	Small Bore Sewerage Option/Septic Tank Option (Baht/a)
Technician	3,000 Baht/month	36,000	36,000	36,000
Labourer	2,000 Baht/month	24,000	48,000	48,000
Water quality analysis		15,000	15,000	15,000
Treatment plant maintenance		10,000	20,000	24,000
Total Operating Cost		85,000	119,000	123,000

Location of Septage Treatment Plant

The septage treatment plant shall be located in the same site of the municipal wastewater treatment plant.

BOD_5 and Fecal Coliforms Removal

LIU (1986) found that the BOD_5 removal in an anaerobic pond (retention time = 10 d) is approximately 90%. The anaerobic digester in this study has a retention time of 40 days. Hence the efficiency of BOD_5 removal should be better in the anaerobic digester than in the anaerobic pond. For design purposes, a BOD_5 reduction of 90% was selected. The calculation example for Maximum Sewerage Option is presented as follows:

Septage flow rate	= 2.3 m^3/d
BOD_5 of septage	= 1,700 mg/l
BOD_5 removal in anaerobic digester	= 90%
BOD_5 of supernatant effluent and filtrate from sludge drying beds	= 170 mg/l
Inflow to facultative pond	= 70% of septage flow rate (assumption)
	= 1.6 m^3/d

BOD_5 load to facultative pond $= \frac{170 \times 1.6}{1,000} = 0.27$ kg/d

Surface organic loading rate to facultative pond = 70 kg/(ha.d)

(In tropical climates, the surface organic loading rate ranging from 200 to 300 kg/(ha.d) is generally applicable. Due to high fluctuation in septage characteristics, the lower value, i.e. 70 kg/(ha.d), was chosen, which includes about 3 to 4 times of the safety factor.)

Pond area required $= \frac{0.27 \times 10,000}{70} = 38.6\ m^2$

Use - pond volume = 60 m^3

pond depth = 1.5 m

pond surface area = 40 m^2

retention time = 60/2.3 = 26.1 d

BOD_5 removal in facultative pond

= 0.725 x (surface organic loading rate) + 10.75 (McGARRY and PESCOD, 1970)

= 0.725 x 70 + 10.75

= 61.5 kg/(ha.d)

BOD_5 removal efficency $= \frac{61.5 \times 100}{70} = 87.9\%$

BOD_5 in effluent of facultative pond = 170 x 0.121 = 20.6 mg/l

Maximum fecal coliforms in septage = 4.9×10^7 MPN/100 ml

Fecal coliforms removal is assumed to follow first-order kinetics with a removal rate (k) of 4.0 d^{-1}.

Fecal coliforms in effluent of anaerobic digester, $N_e = \frac{N_i}{1 + kt}$

where: N_i = influent concentration, 4.9×10^7 MPN/100 ml

N_e = effluent concentration, MPN/100 ml

k = 4 d^{-1}

t = 40 d

$$N_e = \frac{4.9 \times 10^7}{1 + 4 \times 40} = 3.04 \times 10^5 \text{ MPN/100 ml}$$

Fecal coliforms in effluent of facultative pond, $N_e = \frac{N_i}{1 + kt}$

where: N_i = influent concentration, 3.04×10^5 MPN/100 ml

N_e = effluent concentration, MPN/100 ml

t = 26.1 d

$$N_e = \frac{3.04 \times 10}{1 + 4 \times 26.1} = 2{,}884 \text{ MPN/100 ml}$$

The fecal coliforms concentration is within the acceptable level (5,000 MPN/100 ml) as suggested by MARA (1976).

6.1.3 Septage Treatment - Alternative 2 (Anaerobic pond, facultative pond)

As shown in Figure 6.1, there are three parallel anaerobic ponds which shall be operated in sequence. The hydraulic retention time (HRT) of each anaerobic pond is taken to be 10 days. Septage shall be pumped daily from the sump into only one anaerobic pond for about one month. At the HRT of 10 days, it was found that a one-month sludge accumulation occupies approximately 35% of the pond volume (LIU, 1986). After one month of septage feeding, the pond shall be subject to sludge drying, while the incoming septage will be loaded into the next anaerobic pond. After about one to two months, the pond mud should be dewatered and sun-dried to some extent. The sludge cake shall be transferred manually to the pond dike for further drying and later collected by the nearby farmers. The anaerobic pond effluent shall be treated further in the facultative pond.

Design Criteria (Based mostly on MARA, 1976 and LIU, 1986)

Anaerobic pond retention time = 10 d

BOD_5 removal in anaerobic pond = 90%

Surface organic loading rate to facultative pond = 70 kg BOD_5 /(ha.d)

Fecal coliforms removal in anaerobic and facultative ponds follows first-order kinetics with a removal rate (k) of 4.0 d^{-1}.

Construction Material

All ponds shall be earthen without bottom lining. There shall be one-phased construction in all 4 sewerage treatment options considered.

Sizing of Septage Treatment Plant

The sizing of septage treatment units (Alternative 2) and their associated costs are summarized in Table 6.4. The total estimated cost includes material and labor cost with about 10% allowance for cost fluctuation.

Table 6.4 Sizing of Septage Treatment Units and Associated Costs (Alternative 2)

Item	Unit	Maximum Sewerage Option	Minimum Sewerage Option	Small Bore Sewerage Option/Septic Tank Option
Septage quantity	m^3/a	840	4,845	6,414
	m^3/d	2.3	13.3	17.6
Size of sump	m^3	3	6	9
Sump cost (including screening)	Baht	6,000	12,000	18,000
Anaerobic pond volume required	m^3	23	133	176
Use-anaerobic pond volume	m^3	25	140	180
Pond unit cost	Baht/m^3	50	50	50
Anaerobic pond cost	Baht	1,250/pond x 3 ponds	7,000/pond x 3 ponds	9,000/pond x 3 ponds
BOD_5 load to facultative pond (Influent BOD_5 = 170mg/l)	kg/d	0.39	2.26	2.99
Facultative pond area required for BOD_5 removal	m^2	56	323	427
Use-facultative pond volume (1.5 m depth)	m^3	150	850	1,130
Retention time of facultative pond	d	65.2	63.9	64.2
Facultative pond cost	Baht	7,500	42,500	56,500
Estimated cost of piping work	Baht	1,000	2,000	3,000
Estimated cost of pumps	Baht	5,000/set x 2 sets	5,000/set x 2 sets	5,000/set x 2 sets
Total construction cost (including 10% allowance)	Baht	31,000	96,000	126,000
Land requirement	ha	0.03	0.15	0.19
Land cost	Baht	28,000	141,000	178,000
Total Cost of Septage Treatment Plant	Baht	67,000	261,000	336,000

Remark: *The 25% increase in total construction cost is added for construction works, i.e. tax, profit, construction supervision and other related expenses.

Operating Cost

The operating cost of septage treatment plant (Alternative 2) is given in Table 6.5.

Table 6.5 Operating Cost (Alternative 2)

Item	Unit	Maximum Sewerage Option (Baht/a)	Minimum Sewerage Option (Baht/a)	Small Bore Sewerage Option/Septic Tank Option (Baht/a)
Technician	3,000 Baht/month	36,000	36,000	36,000
Labourer	2,000 Baht/month	-	24,000	24,000
Water quality analysis		15,000	15,000	15,000
Treatment plant maintenance		3,000	8,000	10,000
Total operating Cost		54,000	83,000	85,000

BOD_5 and Fecal Coliforms Removal

The calculation example for Maximum Sewerage Option is presented as follows:

Septage flow rate = 2.3 m^3/d

BOD_5 of septage = 1,700 mg/l

BOD_5 removal in anaerobic pond = 90% (LIU, 1986)

BOD_5 in effluent of anaerobic pond = 1,700 x 0.1 = 170 mg/l

Inflow to facultative pond = 2.3 m^3 /d

BOD_5 load to facultative pond = 0.39 kg/(ha.d)

Surface organic loading rate = 70 kg/(ha.d)

Pond area required = 55.7 m^2

BOD_5 removal in facultative pond = 87.9% (referred to Alternative 1)

BOD_5 in effluent of facultative pond = 20.6 mg/l

Fecal coliforms in effluent of anaerobic pond,

$$N_e = \frac{N_i}{1 + kt}$$

where: N_i = 4.9×10^7 MPN/100 ml

k = $4\ d^{-1}$

t = 10 d

$$N_e = \frac{4.9 \times 10^7}{1 + 4 \times 10} = 1.2 \times 10^6 \text{ MPN/100 ml}$$

Fecal coliforms requirement in effluent of facultative pond is at most equal to 5,000 MPN/100 ml. Hence,

$$5{,}000 = \frac{1.2 \times 10^6}{1 + 4t}$$

where: t = retention time of facultative pond, d

= 59.8 d

Use - pond volume = 150 m^3
- pond depth = 1.5 m
- pond surface area = 100 m^2
- retention time (t) = 150/2.3 = 65.2 d

6.1.4 Cost Evaluation of Alternatives

Alternative 2 (anaerobic pond, facultative pond) has lower construction and operating costs, hence this alternative is selected for all options.

6.2 Economic Analysis of Fish Culture in Waste Stabilization Ponds for the Selected System Options of Waste Treatment

6.2.1 Introduction

The primary objective of this section is the financial analysis of septage and sewage reuse in Chonburi as a case study to determine their financial viability. The technical feasibility of septage reuse has been assessed by means of a pilot demonstration project at the Asian Institute of Technology (AIT). In fact, much of the data in this section was based on actual experimental data obtained during the demonstration project, the text of which has been published by AIT. (EDWARDS et al., 1987)

The concept of septage or sewage reuse is one whereby human waste (excreta) is recycled by fish which are bred for animal feed or for direct human consumption. Septage or sewage reuse combines the waste stabilization pond method of sewage/septage treatment, which in its conventional form consists of anaerobic, facultative, and maturation ponds, with the traditional Asian system of using excreta as a fish pond fertilizer. Septage and sewage reuse exploit the fact that algae produced in stabilization ponds are a potential source of high-protein food for herbivorous fish such as tilapia which can be cultivated in these ponds.

6.2.2 Waste Treatment Alternatives

Five possiblė alternatives involving waste stabilization ponds for septage/sewage treatment of which four alternatives are with fish (tilapia) cultivation and one for septage/sewage treatment without fish cultivation, were considered in this study. Schematic pond layouts for the five alternatives using a septage loading of 20 m^3/d are given in Figure 6.2. The five alternatives are as follows :

Alternative 1

Anaerobic pond, facultative pond, and maturation pond, designed solely for septage/sewage treatment without fish culture.

Alternative 2

Anaerobic pond, facultative pond, and maturation pond, designed primarily for septage/sewage treatment but with fish culture in the maturation pond.

Alternative 3

Anaerobic pond and facultative pond, as in Alternatives 1 and 2, with the maturation ponds designed without effluent to optimize fish culture in the maturation ponds.

Alternative 4

Anaerobic and maturation ponds only, designed without effluent to optimize fish culture in the maturation ponds.

Alternative 5

Maturation ponds only, designed without effluent to optimize fish culture.

For septage-loaded (from septic tanks) waste stabilization ponds, Alternative 1 has been found to be the most economical (for Bangkok, using a 20 m^3/d septage loading) and therefore shall be used as the proposed system for septage-loaded ponds. Comparing Alternative 1 with Alternatives 2, 3, 4, and 5, it is generally found that operating revenues earned through tilapia culture are worth less than the additional capital and operating costs borne due to the use of maturation ponds for tilapia culture (EDWARDS et al.,1987). The main factors contributing to this situation are the low market prices of tilapia for use as animal feed and the high cost of labor.

For sewage-loaded ponds, Alternative 2 shall be considered (although no actual research has been conducted on sewage reuse). The reasons are that, firstly, the design of waste stabilization ponds is based on Alternatives 1 and 2 only and, secondly, preliminary calculations indicate that this alternative is viable because of the large total production of tilapia from such large maturation ponds.

6.2.3 Design Assumptions

The following assumptions were used in the financial analysis of the various sanitation options (Maximum Sewerage Option , Minimum Sewerage Option, Septic Tank Option, and Small Bore Sewerage Option), as proposed in chapter 3.

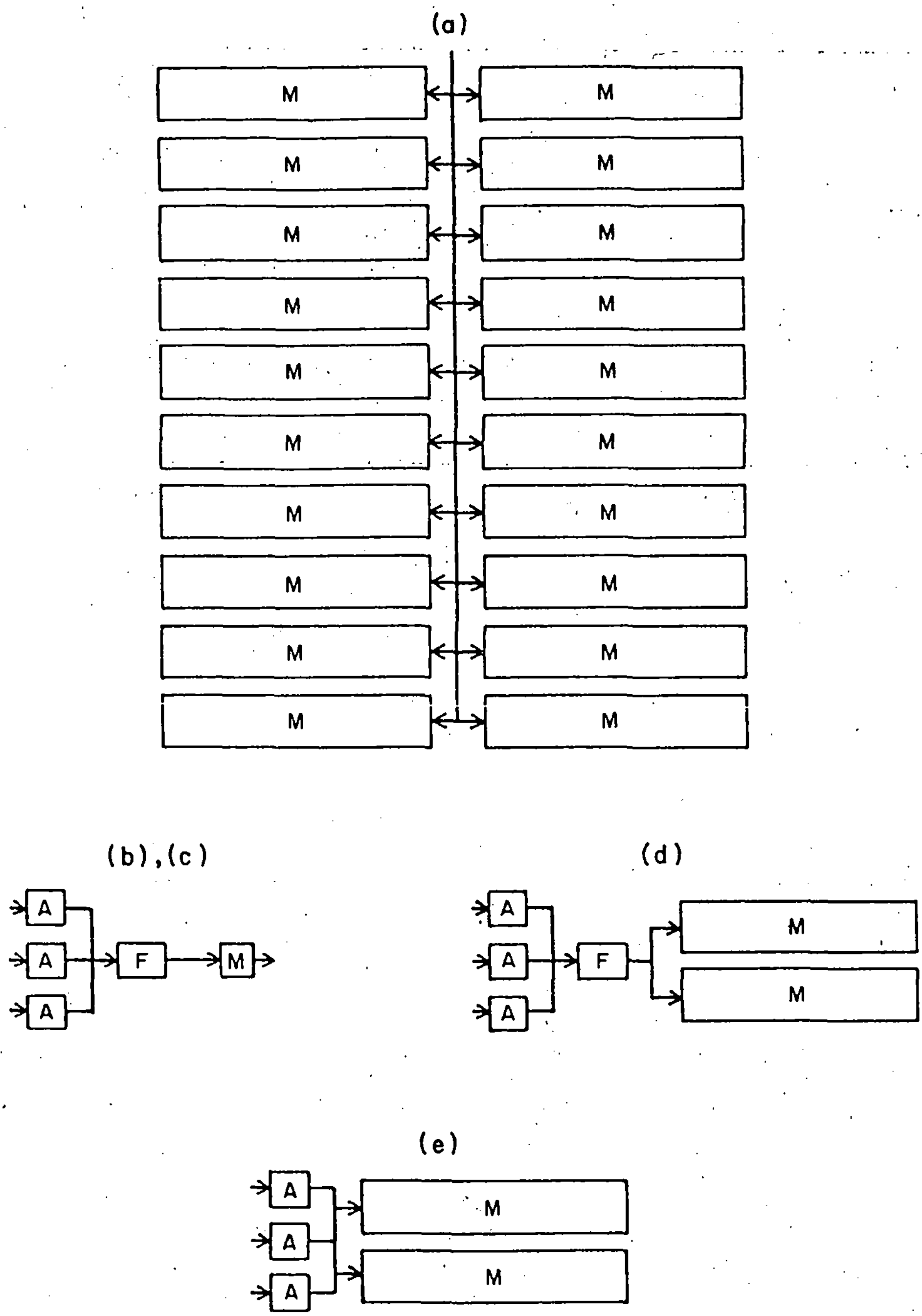

Figure 6.2 Schematic flow diagrams of the various systems of septage treatment and treatment/reuse considered in the study

(a) Maturation fish pond system
(b) Anaerobic, facultative and maturation ponds designed solely for septage treatment
(c) As for (b) but with fish culture in the maturation pond
(d) Anaerobic and facultative ponds design as in (b) and (c) but the maturation ponds designed without an effluent to optimize fish culture
(e) As for (d) but without a facultative pond

A = anaerobic pond, F = facultative pond, M = maturation pond.
Muturation fish pond system (a) based on experimental data but alternative septage stabilization pond systems 1-4 (b-3) are hypothetical. Drawn to scale.

For septage-loaded ponds, the design and costs of the stabilization ponds (based on Alternative 1) used for septage treatment have been covered in Chapter 6.1.2. Fish culture is not economically feasible for septage-loaded ponds for reasons stated above. Furthermore, the stabilization pond system proposed does not include maturation ponds, the only type of stabilization pond in which fish culture is feasible.

For sewage-loaded ponds, only the cost and revenues associated with fish (tilapia culture) in maturation ponds were considered, i.e. for costs, purchase of tilapia fingerlings and hire of labor; and for revenues, sale of tilapia as animal feed and for human consumption. Other costs and revenues associated with the waste ponds, such as pond excavation, piping, and land rent/cost, can be found in Chapter 6.1.

The project organization to manage and operate the waste ponds is the Chonburi municipality. Wage rates for hired manual labor were thus fixed at public sector rates.

Prices and rates quoted on fingerlings, labor, and tilapia were extracted from EDWARDS et al.(1987).

In sewage-loaded ponds, fish (tilapia) shall be cultivated only in maturation ponds. The yield, in the absence of data, is assumed to be the same as in the AIT pilot project on septage reuse, i.e. at 7,000 kg/(ha.a). Harvesting of tilapia shall be done monthly by buyers who use their own labor and harvesting equipment. Stocking shall be done once every five years and the stocking density shall be 1 fingerling/ m^2 of pond area.

There would be negligible sludge accumulation in the maturation ponds and thus there would be no need to drain the ponds for sludge removal. However, for practical purposes, it was assumed that draining shall be done once every five years for general cleaning and restocking of tilapia.

For sewage-loaded ponds, the sizes of maturation ponds are very large (see Table 6.6). In practice, if such sizes were to be used for fish culture, they should ideally be divided into a number of smaller ponds of about 2,000 m^2. This would involve the redesign of the layout of the entire waste stabilization pond system and would also mean the recalculation of extra land and construction costs. But for the sake of simplicity, the need for redesign and recosting was not considered in this report.

The harvested tilapia can be sold as animal feed, for example, pelleted or meal feed for feeding carnivorous fish. Experimental results obtained during the pilot project on septage reuse at AIT indicated that tilapia fed on septage had relatively low concentrations of aerobic bacteria in their fish muscle and no fecal coliforms. For waste ponds based on Alternative 2, tilapia were not raised directly in sewage fed ponds but in maturation ponds which received the effluent from sewage-fed anaerobic and facultative ponds. Although no experimental research has been conducted on sewage fed waste ponds, concentrations of bacteria and coliforms would probably be similar to those in septage-loaded ponds. Thus, the tilapia raised in maturation ponds of Alternative 2 may be sold for direct human consumption based on public health considerations. But in Thailand, there is a social acceptability problem so this option of direct consumption by humans is best left as an academic possibility in this report.

Table 6.6 Population Served, Sewage/Septage Loading, and Maturation Pond Sizes of Sanitation Options under Consideration

Santitation option	Population served	Sewage/ septage load(m^3/d)	Waste stabilization pond system proposed		
			Type of system	Fish culture (Yes/No)	Maturation pond size (m^2)
Maximum Sewerage Option					
Sewer	88,870	20,663	Alternative 2	Yes	68,900
Septic Tank	16,900	2.3	Alternative 1	No	-
Minimum Sewerage Option					
Sewer	38,000	5,651	Alternative 2	Yes	18,800
Septic Tank	67,770	13.3	Alternative 1	No	-
Septic Tank Option					
Sewer	-	-	-	-	-
Septic Tank	105,770	17.6	Alternative 1	No	-
Small Bore Sewerage Option					
Sewer	88,870	20,663	Alternative 2	Yes	68,900
Septic Tank	16,900	17.6	Alternative 1	No	-

6.2.4 Results

The results obtained from Table 6.7 indicate that an annual operating profit (amount is 116,556 Baht/a for the Maximum Sewerage Option, 14,352 Baht/a for the Minimum Sewerage Option and 116,556 Baht/a for the Small Bore Sewerage Option) in the range of about 0.8 Baht/m^3 to 1.7 Baht/m^3 of pond area and 0.01 Baht/m^3 to 0.02 Baht/m^3 of sewage can be made from tilapia culture in sewage-loaded ponds, even if tilapia were only sold as animal feed at 3 Baht/kg. If sold for human consumption, the annual operating profit would rise to about 9 Baht/m^2 to 10 Baht/m^2 of pond area and 0.08 Baht/m^3 to 0.09 Baht/m^3 of sewage.

Assuming that tilapia can only be sold as animal feed in Chonburi, it can be concluded that fish (tilapia) culture in sewage-loaded maturation ponds would be profitable. Fish (tilapia) culture in septage-loaded ponds would not be profitable based on the Thai situation and should not be undertaken. For fish culture in sewage-fed ponds, only minimal additional capital and operating costs would be necessary. In terms of amount of profit made from fish culture alone, the Maximum Sewerage Option and the Small Bore Sewerage Option would be the best options for tilapia culture. However, this conclusion is confined to fish (tilapia) culture as a unit of analysis by itself. As to which of the stabilization pond systems proposed among the sewerage treatment options fares best as a system by itself, costs and revenues must be analyzed in their totality.

6.3 Conventional Wastewater Treatment

6.3.1 Design Criteria for Wastewater Treatment Facilities

6.3.1.1 General Considerations

Three different treatment processes namely the activated sludge process, aerated lagoon system (aerated lagoon followed by maturation ponds), and stabilization pond system (anaerobic pond followed by facultative and maturation ponds) were considered. The three selected processes respectively represent a technical, a half-technical, and a natural process, which are each substantially different with respect to their requirements for land, electro-mechanical equipment, and operation. The design of these treatment systems was based on the following assumptions:

Wastewater flow rate according to section 4.1.1.6

Infiltration/inflow = 20%

Per capita BOD_5 contribution = 50 g/(c.d)

Influent bacterial concentration = 10^7 FC/100 ml

Minimum mean monthly temperature = 25° C

Effluent standards for disposal to sea:

BOD_5 < 30 mg/l
FC/100 ml < 4000

The per capita BOD_5 contribution of 50 g/(c.d) includes an allowance for industrial and commercial activities.

Table 6.7 Determination of Annual Costs and Revenues of Tilapia Culture in Maturation Ponds

		Operation & Maintenance Costs							Annual Operating Revenues						Annual Operating Profit					
		Labour			Fingerlings			Grand Total	Tilapia (animal feed)			Tilapia (human food)			Tilapia (animal feed)			Tilapia (human food)		
Sanitation option	Waste stabil. pond system	Unit cost (Baht/month)	Q'ty	Total cost (Baht/a)	Unit cost (Baht/kg 5-a)	Q'ty (kg)	Total Cost (Baht/a)	(Baht/a)	Unit price (Baht/kg)	Q'ty (kg/a)	Total revenue (Baht/a)	Unit price (Baht/kg)	Q'ty (kg/a)	Total revenue (Baht/a)	Amount (Baht)	By Area (Baht/m²)	By Loading (Baht/m³)	Amount (Baht)	Pond Area (Baht/m²)	Loading (Baht/m³)
<u>Maximum Sewerage Option</u>																				
Sewer	Alternative 2	2000	1	24000	0.3	68900	4134	28134	3	48230	144690	15	48230	723450	116556	1.69	0.02	695316	10.09	0.09
Septic tank	Alternative 1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<u>Minimum Sewerage Option</u>																				
Sewer	Alternative 2	2000	1	24000	0.3	18800	1128	25128	3	13160	39480	15	13160	197400	14352	0.76	0.01	172272	9.16	0.08
Septic tank	Alternative 1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<u>Septic Tank Option</u>																				
Sewer	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Septic tank	Alternative 1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<u>Small Bore Sewerage Option</u>																				
Sewer	Alternative 2	2000	1	24000	0.3	68900	4134	28134	3	48230	144690	15	48230	723450	116556	1.69	0.02	695316	10.09	0.09
Septic Tank	Alternative 1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Notes:

1. It is assumed that harvesting nets and labour for harvesting are not necessary because buyers engage their own workmen and harvesting equipment during harvesting.
2. The labour hire rate is 2000 Baht/month, i.e. 24000 Baht/a.
3. It is assumed that each pond system require 1 labourer for general maintenance such as monitoring water quality and removing dead or diseased fish.
4. Tilapia yield is 7000 kg/(ha.a); farm-gate price (as animal feed) is 3 Baht/kg or 15 Baht/kg (for human consumption).
5. Stocking of tilapia done once every 5 years at density 1 fish/m² of pond area. Price per tilapia fingerling is 0.3 Baht.

6.3.1.2 Site of Treatment Facilities

A study of the topography, rivers, road network, land use, and sewer network layout along with consideration of availibility of the land at reasonable prices in the study area determined the location of the treatment facilities. The site selected is shown in Figure 4.2. According to TISTR (1986), the land price at the chosen site is estimated to average about 150,000 Baht/rai for the whole area. The costs of treatment plants were estimated using this value as one case and a land price of 350,000 Baht/rai as another case. A comparison of costs shows the impact of an eventual increase of land prices, this frequently resulting from heightened development activities.

6.3.1.3 Design Criteria and Assumptions for Pond and Lagoon Systems

The main treatment processes occuring in waste stabilization ponds are sedimentation and aerobic/anaerobic bacterial decomposition. Detention time, temperature, algae concentration, and solar radiation have been identified as significant factors in the operation of pond systems (MARA, 1976; METCALF and EDDY, 1979; ARTHUR, 1983). Design procedures are derived mostly on the basis of either detention time, temperature, or solar radiation and from experience with the operation of a wide variety of individual ponds and pond systems. From among the numerous methods proposed in literature, the design guidelines suggested by ARTHUR (1983) for waste stabilization ponds and aerated lagoon systems were selected for use in this study. ARTHUR recommended the use of temperature-based methods in hot climates, although the relationship between ambient temperature and the reversion of the pond to anaerobic conditions and the subsequent reduction in effluent quality is still not clearly determined. It should be noted that the areal loading rates (kg BOD_5/(ha.d)) in facultative ponds resulting from the design criteria suggested by ARTHUR are considerably higher than those typically suggested by other authors (e.g. METCALF and EDDY, 1979). Also, experience with the operation of pond systems at AIT, Bangkok, suggests that the organic loading rates for facultative ponds, as determined by using the design equations of ARTHUR, are rather critical. However, the design procedures by ARTHUR are widely published and offer, therefore, a preferable basis for comparative studies.

The design criteria used are summarized below:

Anaerobic Ponds

A volumetric organic loading rate of 0.3 kg $BOD_5/(m^3.d)$ was used. A pond depth of 4 m was considered, this being about optimal from the point of view of treatment efficiency in anaerobic ponds.

Facultative Ponds

The design equation suggested by ARTHUR (1983) relates the areal loading rate, expressed in kg BOD_5/(ha.d), with the average minimum monthly temperature:

$$\tau_s = 20\,T - 60 \qquad (6.2)$$

where τ_s is the areal loading rate in kg BOD_5/(ha.d) and T is the average minimum mean monthly temperature. This equation, according to ARTHUR, provides a safety factor of 1.5 before complete failure. With a minimum mean monthly temperature of 25° C, this equation yields an areal loading rate of 440 kg BOD_5/(ha.d). A pond depth of 2 m was considered.

Maturation Ponds

Maturation-ponds were designed with a detention time of 5 days for fecal coliform removal. First order kinetic reaction was assumed for fecal coliform removal and, for simplicity, the rate constant was assumed to be the same in all ponds. The respective equations are as follows :

$$Be = \frac{Bi}{1 + Kb(T) \times t} \tag{6.3}$$

$$\text{and} \quad Kb(T) = 2.6 \times 1.19^{T-20} \tag{6.4}$$

$$= 6.2 \quad 1/d$$

where Be and Bi are the effluent and influent bacterial concentrations in No.FC/100 ml, Kb is the removal rate constant in d^{-1}, T is the temperature in °C, and t is detention time in d. The pond depth was set at 1.5 m.

Aerated Lagoon System

Two partially mixed aerated lagoons in a parallel arrangement followed by short detention period settling ponds which require frequent desludging was considered in the study. A four-day detention time was assumed for the partially mixed aerated lagoon. Power requirements for the aerators were taken as 4 W/m^3. A lagoon depth of 3 m was considered. Three settling ponds with half the total required area each shall be provided in order to facilitate pond desludging. The detention period in the settling ponds, following detention in the aerated lagoon, was assumed to be 2 days. The depth of settling ponds was considered to be 2 m.

6.3.1.4 Design of the Activated Sludge Process

The area requirement for the activated sludge process was taken as 0.3 m^2 per person. No further design criteria were required, since cost evaluation was based on cost statistics from activated sludge plants in Thailand. The related cost functions made use of the daily flow rate and BOD-load as input parameters.

The design criteria of treatment facilities are summarized in Table 6.8.

Table 6.8 Summary of Design Criteria for Wastewater Treatment Facilities

Parameter	Unit	Anaerobic ponds	Facultative ponds	Maturation ponds	Aerated lagoon	Settling pond	Activated sludge process
BOD_5-loading							
- volumetric	$kg/(m^3.d)$	0.3					
- aereal	kg/(ha.d)		440				
Detention time	d			5	4	2	
FC-removal rate	1/d			6.2			
Depth	m	4	2	1.5	3	2	
Power required	W/m^3				4		
Area required	m^2/person						0.3

6.3.2 Design of Conventional Treatment Facilities

Because cost functions depending on the flow rate and BOD load were used for the cost estimate of the activated sludge process, the main factors influencing the cost of pond systems were evaluated. These main factors are the required area, the pond volume as measures of the required excavation volume, and the aerators for the aerated lagoon system. The required pond area, the volume, and the number of ponds allow, furthermore, the evaluation of the length of roads and embankments.

The stabilization pond system consists of an anaerobic pond for pre-treatment, a facultative pond, and a maturation pond. The aerated lagoon system consists of parallel aerated lagoons and settling ponds, the latter designed for a short detention time yet more frequent sludge removal. For all systems, two parallel treatment streets were considered. Exceptions were made in the case of the settling ponds of the aerated lagoon system. Three parallel settling ponds, each with half of the total required capacity, shall be located after two aerated lagoons. The provision of one settling pond more than the required number of aerated lagoons was intended to facilitate the desludging of settling ponds.

The dimensions of the pond systems for the stabilization pond and aerated lagoon system, based on the above assumptions and the design criteria discussed in Chapter 4 are given in Tables 6.9 and 6.10 respectively.

6.3.3 Cost Evaluation

The cost equations for the activated sludge treatment system were obtained from LOOSEREEWANICH (1983). In this report regression equations of capital as well as operation and maintainance costs of several treatment processes were developed after an analysis of 44 activated sludge plants located in the Greater Bangkok area. These cost equations are given as a function of design wastewater flow rate and BOD loading. The cost equations, adjusted so that results reflect 1986 price levels, are as follows:

$$C_c = \exp(9.97 + 0.86 \ln X_1) \tag{6.5}$$

$$C_o = 47{,}980 + 144.1\, X_6 \tag{6.6}$$

where C_c = Capital cost in Baht

C_o = Operation & maintenance costs in Baht/month

X_1 = Design flow rate in m^3/d

X_6 = BOD loading in kg/d

The capital cost derived by equation (6.5) represents the total construction cost. The operation and maintenance cost includes labor costs, costs incurred for energy consumed, and the repair and maintenance costs of the structures and mechanical equipments of the treatment unit.

Table 6.9 Main Dimensions of the Stabilization Pond System

	Unit	Maximum Sewerage Option	Minimum Sewerage Option	Small Bore Sewerage Option
1 Flow rate	m^3/d	20,663	5,651	20,663
2 BOD-Load	kg/d	4,444	1,900	1,777
Anaerobic ponds				
3 Volume (0.3 kg BOD/(m^3.d)	m^3	14,814	6,334	-
4 Detention time	d	0.72	1.12	-
5 Area (Depth = 4 m)	ha	0.38	0.16	-
Facultative ponds				
6 Area (440 kg BOD/(ha.d)) (removal in A) : 60%)	ha	4.04	1.73	4.04
7 Volume (Depth = 2 m)	m^3	80,800	34,600	80,800
8 Detention time	d	3.91	6.12	3.91
Maturation ponds				
9 Be (Kb(T)=6.2 1/d, t=5 d)	FC/100 ml	2,270	1,010	1,240
10 Volume	m^3	103,315	28,255	103,315
11 Area (Depth = 1.5 m)	ha	6.89	1.88	6.89
Total system				
12 Pond area	ha	11.31	3.77	10.93
13 Site area (1/0.75 x (12))	ha	15.07	5.03	14.57
14 Effluent BOD (92% removal)	mg/l	17	27	17

Note : $$Be = \frac{10^7}{\prod_{x=A}^{C} (1 + Kb(T)\ t_x)}$$

where t_x = detention time of anaerobic, facultative, and maturation ponds

Table 6.10 Main Dimensions of the Aerated Lagoon System

	Unit	Maximum Sewerage Option	Minimum Sewerage Option	Small Bore Sewerage Option
1 Flow rate	m^3/d	20,663	5,651	20,663
2 BOD-load	kg/d	4,444	1,900	1,777
Aerated lagoon				
3 Area (t = 4d, depth = 3 m)	ha	2.75	0.75	2.75
4 Power required (4 W/m^3)	kW	330	90.4	330
5 Aerators	No. x kW	10 x 33.6	4 x 22.4	10 x 33.6
Settling pond				
6 Area (t = 2d, depth = 2 m)	ha	2.06	0.565	2.06
7 Provided area (1.5 x (6))	ha	3.1	0.85	3.1
Total system				
8 Pond area	ha	5.85	1.60	5.85
9 Site area (1/0.75 x (9))	ha	7.80	2.13	7.80
10 Effluent BOD (93% removal)	mg/l	15	24	6

The cost of the construction and operation of activated sludge plants according to equations (6.5) and (6.6) respectively are given in Table 6.11. In the case of the Samll Bore Sewerage Option, the cost were reduced by 25% in order to account for the organic matter retained in the interceptor tanks. For the economic evaluation in Chapter 7, it was furthermore assumed that 40% of the construction cost are to be for electro-mechanical equipment. The presented cost estimates exclude land cost.

The construction costs of the stabilization pond and aerated lagoon systems were based on the main dimensions and on the same unit cost rates as for the proposed sewerage systems. The cost of aerators was again obtained from manufacturers.

The cost of the inlet pumping station, for all options and systems, was not included in the cost of treatment plants but was included already in the cost of the sewerage system. The inlet level of the treatment plants was assumed to be 1.2 m above ground level. This should allow gravity flow in the pond systems and would entail pond construction requiring only limited soil transportation to and from the plant site.

Table 6.11 Construction and Operation Costs of the Activated Sludge Plants (Without land cost)

Item	Unit	Maximum Sewerage Options	Minimum Sewerage Option	Small Bore Sewerage Option
BOD	kg/d	4,444	1,900	
Flow rate	m^3/d	20,663	5,651	
Construction cost	Baht	109,639,100	35,952,300	82,229,300
Annual operation cost	Baht/a	8,260,300	3,861,200	6,195,200
Required area (0.3 m^2/c)	ha	2.67	1.14	2.40

The construction and operation costs, minus land cost, of the various pond systems and sanitation options are given in Tables 6.12 to 6.16. Cost estimates including land cost for pond systems and sanitation options are given in Tables 6.17 and 6.18. Construction costs are given on the basis of two different rates for land cost. The higher rate of 350,000 Baht/rai was considered to determine the effect of an increase in land cost which may result from heightened development activities in the study area.

In all wastewater treatment options the aerated lagoon system exhibits an investment cost equal to or slightly lower than that of the stabilization pond system. However, including the annual operation cost which is 8 to 19 times higher for the aerated lagoon system, stabilization ponds are clearly the more economical solution. When the land cost was increased to 350,000 Baht/rai, the investment cost of the stabilization pond system became considerably higher than that of the aerated lagoon system. The resulting differences in investment cost between stabilization ponds and aerated lagoons are 9.8, 5.2, and 7.8 million Baht for the Maximum Sewerage, the Minimum Sewerage, and the Small Bore Sewer Options respectively. However, taking into account the resulting differences in annual operation cost which are 5.2, 1.4, and 5.2 million Baht respectively, stabilization ponds remain the more economical system. Additionally, the land to be occupied by the stabilization pond treatment system would necessarily be owned by the municipality. Any incremental increase, therefore, in the land value of the pond site would accrue to the municipality. The potential income from the resale of land in the future would be highest for the stabilization pond system since they occupy the largest land area. The stabilization pond system is, therefore, considered for further evaluation.

The investment costs of the stabilization pond system for the Maximum Sewerage, the Minimum Sewerage, and the Small Bore Sewerage Options are 275, 245, and 260 Baht per person respectively. Annual operation costs are 3.8, 4.9, and 3.2 Baht per person per annum respectively.

Table 6.12 Cost of Stabilization Pond System for the Maximum Sewerage Option

No.	Description	Unit	Q'ty	Unit Cost (Baht)	Cost (Baht)
	Construction cost				
1.	Plant site office, laboratory, and pump control room	-	-	lump sum	500,000
2.	Laterite road (4 m wide)	m	750	96	72,000
3.	Excavation of ponds, compacted embankment, and disposal of surplus material	m^3	99,270	55	5,459,850
4.	Earth fill over embankment area and well ram with water and consolidate-selected excavated material (0.3 m thick)	m^3	5,972	60	358,320
5.	Interpond pipework, slice gate, etc.	-	-	lump sum	500,000
6.	Mechanical and electrical works	-	-	lump sum	500,000
	Sum				7,390,170
	Total construction cost (With 40% mark up allowance)				10,346,200
	Operation and maintenance costs per annum				
1.	Labor : 4 operators (average salary of 32,000 Baht/a)				128,000
2.	Repair and maintenance of pond structures (2% of total construction cost)				207,000
	Total				335,000

Table 6.13 Cost of Aerated Lagoon System for the Maximum Sewerage and the Small Bore Sewerage Option

No.	Description	Unit	Q'ty	Unit Cost (Baht)	Cost (Baht)
	Construction cost				
1.	Plant site office, laboratory, and pump control room	-	-	lump sum	500,000
2.	Laterite road (4 m wide)	m	750	96	72,000
3.	Excavation of ponds, compacted embankment, and disposal of surplus material	m^3	89,100	55	4,900,500
4.	Earth fill over embankment area and well ram with water and consolidate-selected excavated material (0.3 m thick)	m^3	3,950	60	237,000
5.	Interpond pipework, slice gate, etc.	-	-	lump sum	500,000
6.	Mechanical and electrical works	-	-	lump sum	500,000
7.	Surface aerators with electrical motor and accessories	No	10	500,000	5,000,000
	Sum				11,709,500
	Total construction cost (with 40% mark up allowance)				16,393,300
	Operation and maintenance costs per annum				
1.	Labor : 5 operators (average salary of 32,000 Baht/a)				160,000
2.	Repair and maintenance of lagoon structures (2% of total construction cost)				327,900
3.	Energy consumption of surface aerators (@ 1.55 Baht/kWh)				4,562,200
4.	Repair and maintenance of aerators (10% of energy cost)				456,200
	Total				5,506,300

Table 6.14 Cost of Stabilization Pond System for the Minimum Sewerage Option

No.	Description	Unit	Q'ty	Unit Cost (Baht)	Cost (Baht)
	Construction cost				
1.	Plant site office, laboratory, and pump control room	-	-	lump sum	500,000
2.	Laterite road (4 m wide)	m	500	96	48,000
3.	Excavation of ponds, compacted embankment, and disposal of surplus material	m^3	35,000	55	1,925,000
4.	Earth fill over embankment area and well ram with water and consolidate-selected excavated material (0.3 m thick)	m^3	3,536	60	212,200
5.	Interpond pipework, slice gate, etc.	-	-	lump sum	300,000
6.	Mechanical and electrical works	-	-	lump sum	300,000
	Sum				3,285,200
	Total construction cost (with 40% mark up allowance)				4,599,300
	Operation and maintenance costs per annum				
1.	Labour: 3 operators (average salary of 32,000 Baht/a)				96,000
2.	Repair and maintenance of pond structures (2% of total construction cost)				92,000
	Total				188,000

Table 6.15 Cost of Aerated Lagoon System for the Minimum Sewerage Option

No.	Description	Unit	Q'ty	Unit Cost (Baht)	Cost (Baht)
	Construction cost				
1.	Plant site office, laboratory, and pump control room	-	-	lump sum	500,000
2.	Laterite road (4 m wide)	m	600	96	57,600
3.	Excavation of ponds, compacted backfill, and disposal of surplus material	m^3	24,350	55	1,339,250
4.	Earth fill over backfill and well ram with water and consolidate-selected excavated material (0.3 m thick)	m^3	2,170	60	130,200
5.	Interpond pipework, slice gate, etc.	-	-	lump sum	200,000
6.	Mechanical and electrical works	-	-	lump sum	300,000
7.	Surface aerators with electrical motor and accessories	No	4	400,000	1,600,000
	Sum				4,127,050
	Total construction cost (with 40% mark up allowance)				5,777,900
	Operation and maintenance costs per annum				
1.	Labour: 4 operators (average salary of 32,000 Baht/a)				128,000
2.	Repair and maintenance of lagoon structures (2% of total construction cost)				115,600
3.	Energy consumption of surface aerators (@ 1.55 Baht/kWh)				1,216,600
4.	Repair and maintenance of aerators (10% of energy cost)				121,700
	Total				1,581,900

Table 6.16 Cost of Stabilization Pond System for the Small Bore Sewerage Option

No.	Description	Unit	Q'ty	Unit Cost (Baht)	Cost (Baht)
	Construction cost				
1.	Plant site office, laboratory and pump control room	-	-	lump sum	500,000
2.	Laterite road (4 m wide)	m	700	96	67,200
3.	Excavation of ponds, compacted backfill, and disposal of surplus material	m^3	88,630	55	4,874,650
4.	Earth fill over backfill and wellram with water and consolidate selected excavated material (0.3 m thick)	m^3	5,028	60	301,680
5.	Inter pond pipework, slice gate, etc.	-	-	lump sum	500,000
6.	Mechanical and electrical works	-	-	lump sum	500,000
	Sum				6,743,530
	Total construction cost (with 40% mark-up allowance)				9,440,900
	Operation and maintenance costs per annum				
1.	Labour: 3 operators (average salary of 32,000 Baht/a)				96,000
2.	Repair and maintenance of pond structures (2% of total construction cost)				188,800
	Total				284,800

Table 6.17 Investment Cost of Treatment Facilities

	Maximum Sewerage Option	Minimum Sewerage Option	Small Bore Sewerage Option
Stabilization Pond System			
Area (ha)	15.07	5.03	14.57
Land cost A (350,000 Baht/rai)	32,965,600	11,003,100	31,871,900
Land cost B (150,000 Baht/rai)	14,128,100	4,715,600	13,659,400
Construction cost (Baht)	10,346,200	4,599,300	9,440,900
Total treatment A (Baht)	43,311,800	15,602,400	41,312,800
Total treatment B (Baht)	24,474,300	9,314,900	23,100,300
Aerated Lagoon System			
Area (ha)	7.80	2.13	7.80
Land cost A (350,000 Baht/rai)	17,062,500	4,659,400	17,062,500
Land cost B (150,000 Baht/rai)	7,312,500	1,996,900	7,312,500
Construction cost (Baht)	16,393,300	5,777,900	16,393,300
Total treatment A (Baht)	33,455,800	10,437,300	33,455,800
Total treatment B (Baht)	23,705,800	7,774,800	23,705,800
Activated Sludge Process			
Area (ha)	2.67	1.14	2.40
Land cost A (350,000 Baht/rai)	5,840,600	2,493,800	5,250,000
Land cost B (150,000 Baht/rai)	12,503,100	1,068,800	2,250,000
Construction cost (Baht)	109,639,100	35,952,300	82,229,300
Total treatment A (Baht)	115,479,700	38,446,100	87,479,300
Total treatment B (Baht)	112,142,200	37,021,100	84,479,300

Table 6.18 Annual Operation Cost of Treatment Facilities in Baht per Person per Annum

	Maximum Sewerage Option	Minimum Sewerage Option	Small Bore Sewerage Option
Stabilization pond system	335,000	188,000	284,800
Aerated lagoon system	5,506,300	1,581,900	5,506,300
Activated sludge process	8,260,300	3,861,200	6,195,200

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7. FINANCIAL ANALYSIS

7.1 Introduction

The objective of this chapter is to review the financial implications of each of the alternative sewerage systems under consideration. There are two main aspects to this review; firstly, to examine the cost implications for households covered by the systems; secondly, to identify the funding implications in terms of the required inputs from central government, local government and private individuals. Clearly the two aspects are interrelated in that the charges levied on households will depend on the structure and extent of government contributions to funding. The approach, which is outlined below, was intended to reflect this.

The approach to examining funding consisted of the following stages:

(a) determine the total capital and operating costs of each system;

(b) calculate the total revenue and the levels of charges levied on user-households required to fully cover all costs identified in (a), in the absence of government subsidies;

(c) by considering other charges currently levied on households assess whether users would be able to afford the charges calculated in (b); and

(d) based on the results of (c) and stated government policy on supporting infrastructure projects, determine the likely structure of funding of the project, the degree of government contribution, if any, and the levels of user charges implied by the funding structure.

Each of these stages is discussed in greater detail below.

7.2 Capital Investment and Operating Cost

Capital investment and operating costs are provided for the four alternative systems under consideration, namely:

(i) Maximum Sewerage Option - A conventional mains sewerage system using large bore sewers connected to treatment plants covering all but the areas with the lowest density of housing. Those households not connected to the mains systems will have their own septic tank.

(ii) Minimum Sewerage Option - Similar to the first option but with the coverage of the mains system restricted to the highest density areas. Thus a greater number of households will have their own septic tank.

(iii) Small Bore Sewerage Option - A system based on small bore sewers. Local separator tanks will separate liquid waste, which will flow through the sewers, from solid waste which is collected and removed periodically. The coverage of the main sewerage system is the same as under the Maximum Sewerage Option. Again each household not covered will have an individual septic tank.

(iv) Septic Tank Option - Under this system each household would have an individual septic tank installed.

Basic information on investment and operating costs has been extracted from Chapter 5 of this report. The analysis covers a 30 year period and uses 1986 constant prices. The systems are planned to be implemented over a seven year period to minimize disruption to the town's inhabitants. Results of the analysis are summarized in Table 7.1 and details are presented in Appendix 7.1 to 7.4.

Table 7.1 Capital Investment and Operating Costs

	Maximum Sewerage Option	Minimum Sewerage Option	Small Bore Sewerage Option	Septic Tank Option
Capital Investment (million Baht)	338	322	300	301
- Central system	88%	33%	83%	3%
- Individual septic tank	12%	67%	17%	97%
Operating Cost (million Baht per annum)	4.0	2.4	4.1	1.4
- Central system	94%	58%	67%	9%
- Septic tank	6%	42%	33%	91%

Each system will have two main components, a central sewerage system for areas of high housing density and a septic tank system for those households not covered by the central system. The extent of coverage of the central system depends upon the alternative selected. For example under the Maximum Sewerage Option, investment in the central system accounts for 88% of total expenditure and investment in individual septic tanks accounts for only 12%. Under the Septic Tank Option the central part of the system accounts for only 3% of investment. This will become of significance when the structure of funding of the investment is considered. This is because the central system could be funded by the public sector, whereas individual septic tanks will probably be required to be funded by private individuals.

7.3 Required Revenue and User Charges

The initial method of calculating user charges has been to assume that the project is entirely self financing. That is the total annual revenue was calculated which will be required to fund all the estimated costs of the project over its assumed thirty year life. This is as if an agency were established to implement the project. This agency would be responsible for all expenditures and would be able to levy charges on all users. Under the full cost recovery concept the operating agency must collect revenue from households within the service area to cover investment, operating, maintenance and replacement costs of the system. There is the simplifying assumption in this initial analysis of not including the financing cost of funding the excess of expenditure over income in the early years of the projects.

Table 7.2 shows the required annual revenue necessary to cover all project costs of each option. It analyzes the required revenue into that required to cover the cost of the central system and that required to pay for individual septic tanks.

Table 7.2 Required Revenue

	Maximum Sewerage Option	Minimum Sewerage Option	Small Bore Sewerage Option	Septic Tank Option
Revenue (million Baht per annum)	17	15	16	13
Revenue from				
- Sewer system	88%	41%	72%	0%
- Septic tanks	12%	59%	28%	100%

This will be collected from households as an annual service charge. Under each system the charge will differ for two different groups:

- households served by the central sewerage system
- households using individual septic tanks.

Households are allocated to each group according to the density of buildings in the area in which they are situated. The charge per household is calculated from the total cost of each part of the overall system divided by the number of households covered by that part of the system. The required service charges are set out in Table 7.3. This analyzes the service charge into two parts, one related to the operating costs and one necessary to cover capital expenditure.

Table 7.3 Service Charge per Household per Annum

Service charge per household (Baht per annum) for:	Maximum Sewerage Option	Minimum Sewerage Option	Small Bore Sewerage Option	Septic Tank Option
Households connected to central system				
- Operating cost	274	338	254	-
- Capital cost	911	766	791	-
Total annual service charge	1,185	1,103	1,045	-
Households with septic tank				
- Operating cost	150	150	150	150
- Capital cost	639	639	639	639
Total annual service charge	789	789	789	789

It can be seen that the service charges required to cover all costs of the proposed systems vary from around 800 Baht annually for households with septic tanks to around 1,200 Baht annually for households connected to the main sewers in the maximum sewerage system. Of this between 70% and 80% of the service charge is required to fund capital expenditure. The lowest cost system is the septic tank system which requires a service charge which is 67% of the service charge associated with the most expensive system.

7.4 Affordability of the Proposed Systems

To assess the affordability of the analysed systems the required full cost recovery service charges are compared with the average expenditure on other utilities. According to statistics relating to the Chonburi region, the average expenditure on electricity was 2,130 Baht per household in 1987 and the average expenditure on water was 1,320 Baht. The full cost recovery service charge for the sewerage system would therefore be equivalent to between 37% and 55% of electricity expenses and between 60% and 90% of water expenses, depending on the sewerage system selected. The introduction of the new system would therefore increase household utilities expense by between 23% and 34%, from 3,450 Baht to between 4,239 Baht and 4,635 Baht.

Local government current charges for the collection and disposal of garbage is 120 Baht per annum per household. The necessary service charge for the new sewerage system on a full cost recovery basis is therefore about seven to ten times the current charge for garbage disposal.

The implication of these calculations is that to introduce the proposed systems and set user charges to recover all costs would cause an intolerably high increase in the level of household expenditure on utilities. Considerable community resistance would be likely, particularly since the service charge would be a complete innovation rather than an increase in an existing charge.

7.5 Capital Funding

Based on such considerations, it seems that the implementation of the proposed system on a full cost recovery basis is not affordable by the community. For the implementation to be successful there will therefore need to be financial support from central government, local government and/or aid agencies. The purpose of this section is to estimate the extent of available public sector funding and its impact on the required user charges.

In the 6th National Development Plan, central government set a policy to limit its contribution to local development projects to a maximum of 60% of the investment cost. The balance must be financed locally. Of the local funding the nature of this project implies that some private investment would be required. For example in private areas, lateral sewer connection to households and septic tanks should be paid for privately. It is not practical for public sector to invest in this type of infrastructure.

Therefore it is now assumed that the projects would utilize central government sources of funds as far as possible within the maximum range set by government policy. Private individuals will be responsible for the investment occuring on their property and the balance of capital investment would be funded by local government. Table 7.4 shows the structure of project capital funding which would occur if individuals paid for appropriate investment on their property and the maximum government subsidy were received. The maximum conventional sewerage system could receive a maximum subsidy from central government of 203 million Baht, 60% of project investment cost and a further 33 million Baht, 10% of investment cost, from local government. The remaining 102 million Baht, would be supported by the private sector. The septic tank system will be dominated by investment by the private sector, which must fund 292 million Baht or 97% of total investment, the remaining 9 million Baht coming from the public sector.

Table 7.4 Structure of Capital Funding

	Maximum Sewerage Option	Minimum Sewerage Option	Small Bore Sewerage Option	Septic Tank Option
Funding (million Baht) from:				
- Central government	203	82	169	3
- Municipality	33	8	12	6
- Private sector	102	232	119	292

It is assumed therefore that the total capital cost of each option is fully covered by a combination of central government, local government and support from private sector investment. The annual service charge will therefore be needed only to cover operating expenses. However each household will also be required to make a one off capital payment to make up the private sector contribution to funding. The annual service charge and the contribution to capital required for each household are shown in Table 7.5.

Table 7.5 Annual Service Charge and Contribution to Capital per Household

	Maximum Sewerage Option	Minimum Sewerage Option	Small Bore Sewerage Option	Septic Tank Option
Households connected to central system (Baht)				
- Annual service charge	274	338	254	-
- One-off capital cost	4,815	3,885	6,189	-
Households with septic tank (Baht)				
- Annual service charge	150	150	150	150
- One-off capital cost	14,750	14,750	14,750	14,750

Thus when central government funding is introduced, the service charge for the septic system continues to be the lowest of the four options. However the actual total expenditure by private individuals is highest in the case of the septic tank system because almost all capital expenditure must be funded by private individuals. In the case of the Maximum Sewerage Option almost all capital expenditure is funded by the public sector. Even if the full capital cost of the project is subsidized, the required charge to cover the operating cost of a conventional sewerage service is double the current rate of charge for garbage collection and the required service charge for emptying the septic tank is 25% more.

8. INSTITUTIONAL ASPECTS

8.1 Introduction

The purpose of this chapter is to discuss the institutional factors to be taken into consideration during the construction or enhancement of a sewerage system. In particular the circumstances at the city of Chonburi are discussed, leading to recommendations on the implementation plan for the proposed project in that city. The chapter has been divided into four sections. Firstly, the existing regulations are reviewed, relating to both central and local government, to determine the adequacy of the legal framework to provide authority to implement the recommended system. Secondly, the structure of central and local government and other government agencies are described, including the communication linkages between them as they relate to the current project. Thirdly the steps necessary for the implementation of the system are set out and finally, the main obstacles that may delay that implementation are discussed.

8.2 Regulatory Background

Central government has introduced many laws to protect the environment, including laws to control:

- Pollution of residential, industrial and agricultural areas;
- The discharge of waste into public places; and
- Pollution in canals and other waterways.

The most important laws which have a bearing on public health are:

- National Constitution of 1978, Section 65,
- National Environment Policy Act,
- City Planning Act,
- Cleanliness and Orderliness of the Country Act,
- The Maintenance of Canals Act,
- Navigation in Thai Waters Act.

The principal powers of local government derive from the Public Health Act which was enacted in 1941 for the prevention of diseases and the provision of health care. In section 6, the Act gives authority to local government to issue regulations to:

- provide rubbish and waste collection in public and private places
- set up collection systems
- set collection fees
- prohibit the disposal of rubbish in public places that may reduce health and cleanliness
- undertake any other activities needed for the purposes of proper sanitation.

Municipalities may commission third parties to carry out any of the above activities under municipality supervision.

In Section 16 of the Act, local governments are authorized to give recommendations to land owners to install, enhance or change sewerage systems. The owner must follow these recommendations within 30 days of receiving the notice.

Thus the existing network of laws, and in particular the Public Health Act gives adequate authority to local government to change or improve the sewerage system in Chonburi. No further amendment of regulations is required for the implementation of the recommended system. However, the implementation of the new sewerage system will require the support of the municipality council and this in turn will require that the local community accepts the need for the new scheme.

8.3 Institutional Factors

The proposed sewerage system covers Chonburi Municipality, Bang Sai Sanitary Authority and Ban Suan Sanitary Authority. It is unlikely that local government could take full responsibility for the investment and operation of the sewerage system, raising all the necessary funds by itself from revenues and borrowings. The implementation of this project seems to exceed local government's investment capacity since:

- the project requires capital investment of around 300 million Baht;
- revenue generated by local government is around 50 million Baht per annum;
- 10 million Baht per annum is available for allocation to development projects; and
- local government currently has reserves of 30 million Baht.

On the other hand, it is equally unlikely that central government would take responsibility for all investment and allow local government to operate the system. Central government has established a policy to increase the role of local government in urban development both in project identification and financing and in encouraging the introduction of user charges. This policy would be at variance with central government playing a leading role in the implementation of new infrastructure projects. Therefore the implementation of the proposed sewerage system is likely to be financed by a joint investment requiring the cooperation of both central and local government. This would require the project to be initiated by local government and to receive a subsidy from central government to provide part of the investment. Local government would be responsible for the operation of the system.

Local government may not have sufficient resources and expertise at present to undertake project design and management. Local government's main experience is currently in building construction, roads and drainage systems and they also have a capability in construction supervision. Hence technical assistance from central government or from foreign aid agencies would be required to carry out the system design for this project. The municipality currently has three staff who are responsible for the door to door collection of the service charge for household garbage disposal. The systems currently in use could be enhanced to include collecting revenue for the new sewerage systems.

8.4 Roles of Agencies Involved

As discussed above the proposed new system will require the involvement of both central and local govenment to prepare and finance the project. There will therefore need to be cooperation between several central government agencies as well as the three local government agencies covered. The agencies likely to be concerned will be:

* Central Government Agencies

  - Office of the National Environmental Board (NEB)
  - Office of National Economic and Social Development (NESDB)
  - Ministry of the Interior (MOI)
    Office for Urban Development (OUD)

* Local Government Agencies

  - Province (Changwat) Administration
  - Municipality
  - Sanitary Authorities.

Figure 8.1 presents the communication linkage between central and local government agencies. The main functions of these various agencies as related to the implementation of the proposed sewerage system are discussed below.

The office of the National Environmental Board (NEB) would play a major role in educating local government and the community as to the necessity of the new system; giving technical assistance in evaluating technical specification of treatment plants and drafting new regulations covering implementation. The office would also monitor the operation of the new sewerage system.

The office of National Economic and Social Development Board (NESDB) would coordinate the project feasibility study and would appraise the project for both financial and economic viability. They would consider the project in the context of national development policy based on the national resources and the priority of the project. If appropriate the office will give a recommendation to the Cabinet to support the project.

Ministry of the Interior (MOI) is responsible for the overall administration of the country in accordance with government policy and the provision of law. The governor of each province (Changwat) is appointed by MOI and coordinates between central government and the local governments within the province boundary.

MOI established the Office for Urban Development (OUD) in response to central government's policy of accelerating urban development. As part of this policy, The Regional Cities Development Programme (RCDP) was designed to accelerate growth in urban areas outside Bangkok. In support of this policy, OUD gives guidelines and technical assistance to local government, and serves as a coordinator between central and local government through the governor of each province. The office also administers project feasibility studies, economic and financing studies, arranges financial sources to fund projects and liases with NESDB to obtain approval for the implementation of projects. Since Chonburi is classified as a regional city under RCDP, OUD will play a major role in the implementation of the new sewerage system.

Each Municipality is a form of local government. The municipality council is elected every five years to administer and govern the municipality, give policy guidelines and allocate the budget. The council will appoint senior officers and assistants to supervise and undertake daily administration work. The municipality has authority to issue regulations subject to the approval of the governor.

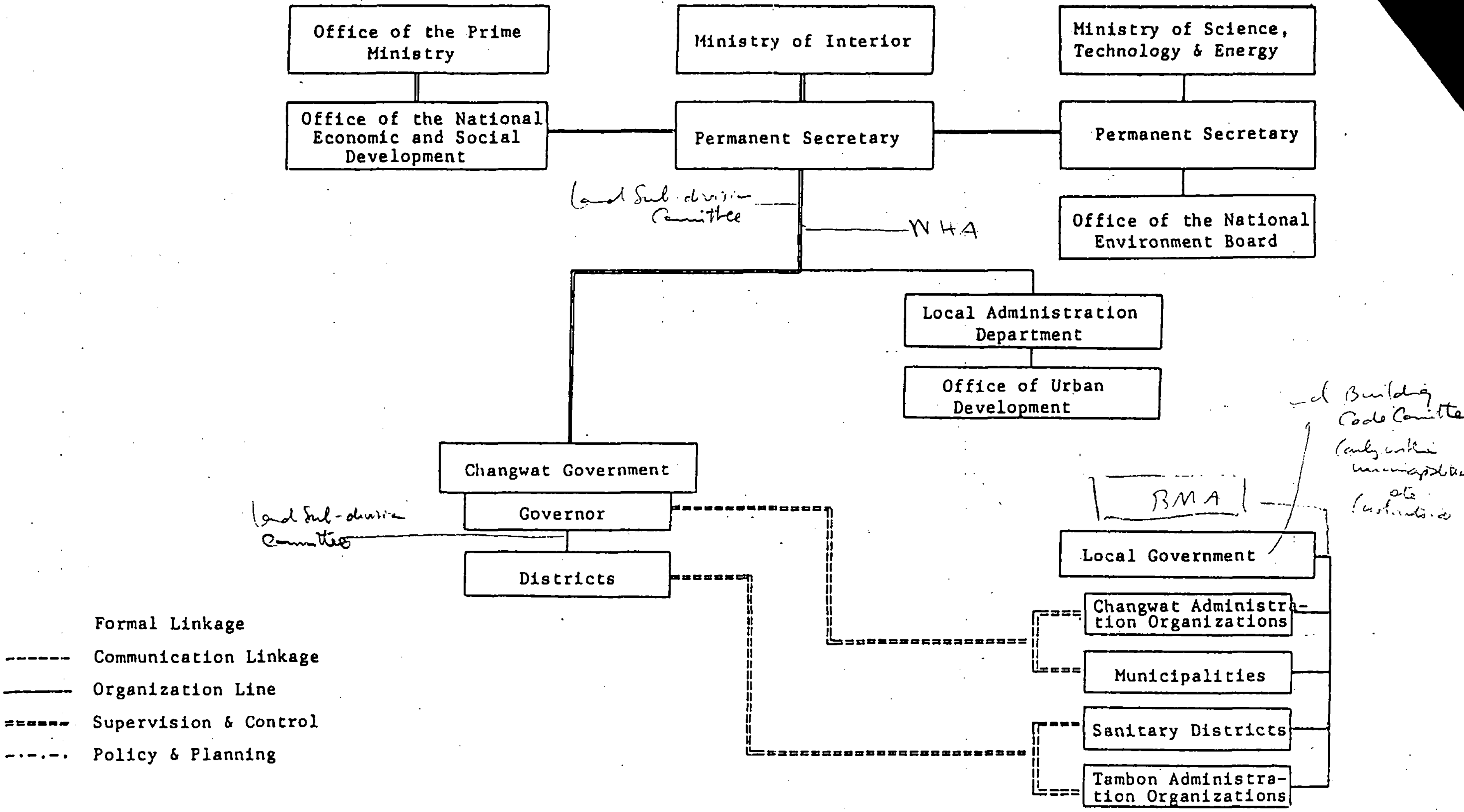


Figure 8.1 Communication Between Government and Changwat Government

A Sanitary Authority is similar to a small municipality. Its functions are similar to those of a municipality. The Sanitary Committee are elected to govern the Authority area. The Sanitary Authority must report to central government through its Amphur (District) authority (a sub-division of the province) and the Provincial Governor.

It can be said that the existing government institutions and regulations are suitable for the proposed project. There is no need to create new agencies or regulations. However a resolution is required to be passed by the local government bodies to allow them to operate the new system and to implement a service charge in accordance with section 16 of the Public Health Act. The resources available to the local government may have to be enhanced before it could take full responsibility for the implementation and running of the new system. In the mean time technical assistance will be required from central government bodies.

8.5 Project Implementation

The major steps in project implementation showing the roles of the various agencies discussed above and how they interact are presented diagramatically in Figure 8.2.

Step 1: The local government development plan for the long and medium terms and the annual plan have been reviewed. These include plans to improve the drainage system but nothing concerning sewerage. A principal early task therefore is to gain the support of local government for the project so that it is included in development planning. NEB must therefore introduce to central and local government the idea of the project and educate them to its direct and indirect benefits. NEB could undertake this step with cooperation from the Department of Health. NEB commitment and support is very important to gain the backing of local government for the project.

Step 2: After local government has accepted the concept of the project, Policy and Planning Division must prepare a brief project description for the local government council to approve the project and integrate it into the long and medium term development plans.

Step 3: Local government can directly apply for funding from central government. The project will be implemented by local government which would apply for a specific subsidy from central government. However in the case of Chonburi, which is a Regional City, an approach through the Office of Urban Development (OUD) would be an easier way to obtain a subsidy from central government. Local government officers would discuss the project with OUD so that it can be included in the Regional City Development Programme (RCDP). OUD will then seek foreign aided technical assistance in conducting a feasibility study of the project covering the technical, economic and financial aspects.

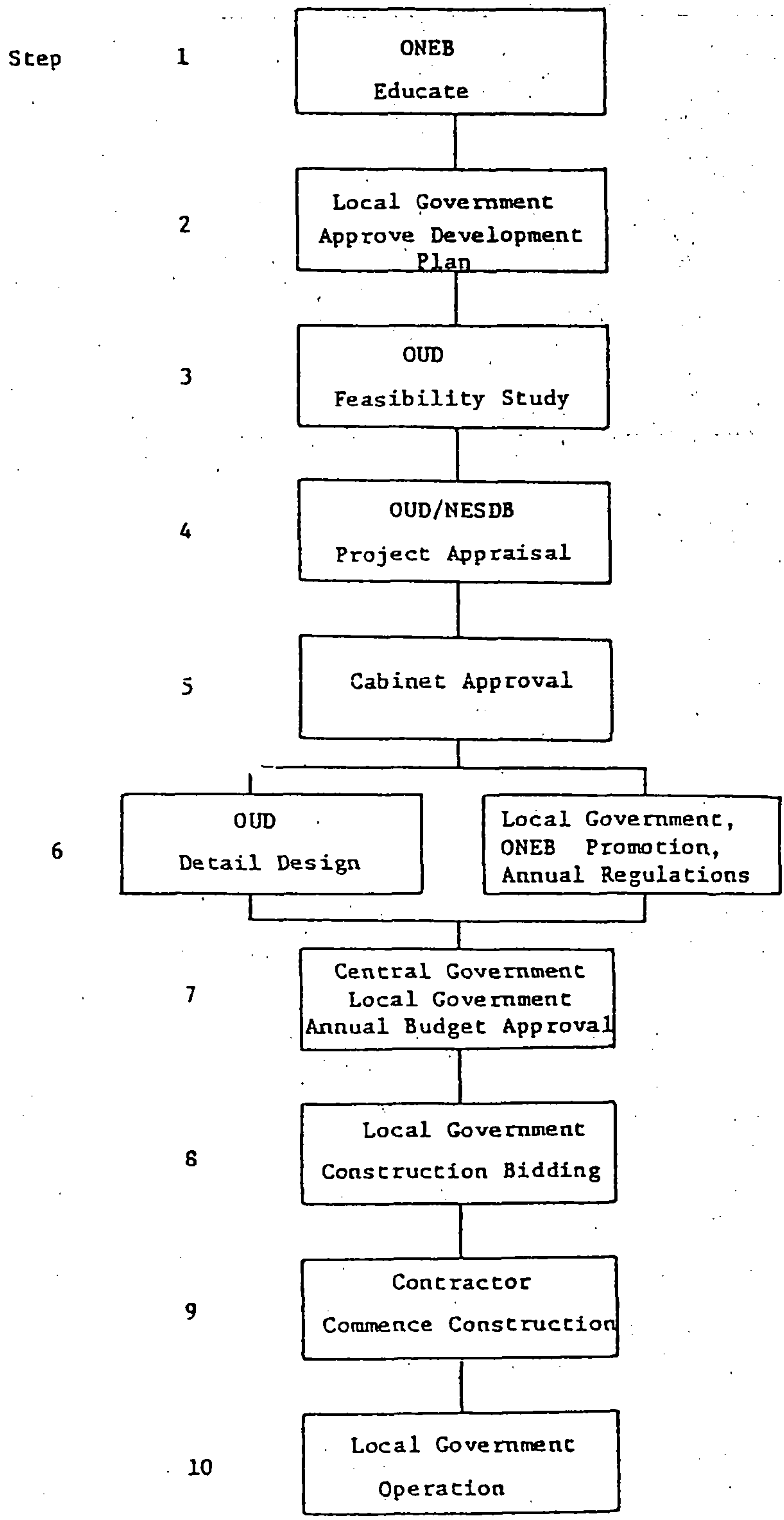


Figure 8.2 Implementation of Sewerage System

Step 4: All projects are subject to project appraisal by NESDB. NESDB will consider individual projects, evaluating their direct and indirect benefits, financial return and economic return. Each project will be assigned priority according to the benefits which it offers. NESDB will then give recommendations to Cabinet to approve the implementation of selected projects, according to the resources available.

Step 5: In response to these recommendations Cabinet will give approval for the implementation of projects. This approval will specify the maximum budget for the project, the proportion of funding to be contributed by central government and local government and sources of financing including for example revenues, reserves, commercial loans and loans from the Municipality Development Fund (MDF).

Step 6: With foreign technical assistance, OUD will undertake the detailed design of the proposed system and obtain a cost estimate for inclusion in the annual budget. At the same time local government can prepare an amendment to its regulations to allow a change to the sewerage system and to enforce community use of the new system after implemention. A promotion programme should be planned to educate the community as to the advantages of the new system and its cost to them. The programme should take account of possible resistance from the community and should identify ways of overcoming that resistance.

Step 7: An annual financial plan, showing sources of financing for the project, will be prepared by both local and central government. OUD must coordinate, through the provincial governor, the annual budget preparation to ensure consistency between central and local government.

Step 8: Local government will carry out a bidding process involving developers interested in project construction. This will involve; preparing a detailed technical specifications of the project; timescale and budget; issuing an invitation to submit bids and evaluating those bids.

Step 9: Selected contractor commences construction under local government supervision according to the agreed specifications.

Step 10: Local government recruit and/or train staff and establish an administrative structure for the operation of the system. This should cover system operations, system maintenance, revenue collection and monitoring of the system. Local government may utilize its garbage disposal revenue collection system to collect service charges for the new sewerage system.

An action plan which lists out all major tasks, responsible agencies, indicative time required and timing of implementation is illustrated in Figure 8.3.

	AGENCIES	ESTIMATED TIME REQUIRED YEAR	Year 1	2	3	4	5	6	7	8	9	10	11	12
I Planning														
1. Initiate Project	NEB	0.5												
2. Approve Development Project	L.G.	0.5												
3. Feasibility	OUD	1.0												
4. Project Appraisal	NESDB	1.0												
5. Project Approval	Cabinet	0.5												
II Implementation														
6. Amend Regulations, Promotion	L.G., NEB	0.5												
Detail Design	OUD	0.5												
7. Approval of Annual Budget	L.G.,C.G.	-												
8. Select Contractor	L.G.	-												
9. Commence Construction	Contractor	7.0												
III Operation														
10. Maintenance and control	L.G.	-												
11. Revenue Collection	L.G.	-												

Note : L.G. = Local Government

C.G. = Central Government

Figure 8.3 Action Plan of Sewage System Implementation

8.6 Major Obstacles to the Implementation of the Proposed System

Four major factors have been identified which will raise obstacles to the progress of the proposed system and which must be addressed if it is to be successfully implemented:

(i) Financial resources in Thailand, as in all countries, are limited. Thailand has identified that it has a particular need for substantial infrastructure investment and therefore has a considerable number of potential projects competing for resources. Any project must therefore be expected to yield outstanding returns when compared with other infrastructure and revenue generating projects before it will obtain approval for implementation.

(ii) This project is quite innovative in the context of Thailand. It will require considerable education of several groups including local government, the community, NESDB and Cabinet to communicate the potential benefits of the project. The project is unlikely to be successful if its direct and indirect benefits are not visible.

(iii) Chonburi is a large and established city. The changing of the whole sewerage system is likely to cause substantial disruption and to involve a long time span. Local government would face considerable disruption to the city and in particular major traffic congestion.

(iv) Local government may face major resistance from the community because the project may require the community to pay a substantial amount towards the cost of the system. Currently no charge is levied on services except for garbage collection and the clearing of septic tanks. However financial analysis has indicated that a considerable annual charge would be necessary if the full cost of the system were to be recovered. Even if there were capital contributions from central and local government, a further capital contribution would be required from each household and a significant annual charge would be levied. It may be expected that local government will therefore be reluctant to implement the system since direct benefits will not be clearly seen but direct costs could cause a negative reaction from the community.

9. CONCLUSIONS

9.1 Summary of Results

The most important facts and figures resulting from the system comparison are shown in Table 9.1. It is to be noted that the Septic Tank Option was not designed as a technically satisfactory solution because the use of on-site facilities alone would be inappropriate in high-density areas with unfavourable soil conditions. However, it was thought to be interesting to compare the economic and institutional consequences of such a theoretical option with those implied in the technically adequate options.

9.2 Conclusions and Suggestions

1. The existing methods of on-site wastewater treatment by cesspool system and direct sullage disposal being practiced in Chonburi municipality are not technically and hygienically effective, resulting in pollution problems to the surrounding soils, ground, water and storm drains. This is due to several reasons such as: the surrounding soil around the cesspool becomes clogged easily; many cesspools have effluent pipes connecting directly to nearby storm drains or canals; and the septage in the cesspool is not regularly removed.

2. The lack on information on the cost of sewerage and wastewater treatment facilities turned out to be an impediment for the planning of sanitation systems. Even cost data from executed projects are a rather unreliable source. Cost differences in the ratio of up to 1:5 were found for the same facilities. Although differences in the local price level are one reason for cost differences, the extreme cost differences originated rather from sub-standard workmanship resulting in very low cost in some instances. Cost information, even when taken from executed projects, can only be used after a careful assessment of the project situation and the quality of construction.

3. On-site wastewater treatment appeared to be more economical than a sewer system with centralized treatment, even in high density areas. The costs of the studied alternative options increase with an increasing part of the area to be sewered (Table 9.1). However, the technical constraints of on-site facilities are to be considered. In areas with a high population density or with limited infiltration capacity of the subsoil, on-site facilities result in surface runoff of wastewater and, thus, constitute a health hazard rather than an improvement of the sanitation conditions.

4. The minimum sewerage option shows 5% lower capital investment and 40% lower annual operating cost than the maximum sewerage option. Thus, there is not one appropriate sanitation technology for the entire town area. Most appropriate is a mix of a sewer system and on- site sanitation, with the sewer system to be built only in those parts of the town where on-site sanitation is infeasible.

Table 9.1 Summary of Costs For Construction And Operation/Maintenance (1,000 Baht)

Description	Maximum Sewerage Option			Minimum Sewerage Option			Small Bore Sewerage Option			Septic Tank Option	
	Treatment alternatives			Treatment alternatives			Treatment alternatives			Trt. alternatives	
	1	2	3	1	2	3	1	2	3	1	2
CONSTRUCTION COST											
1. Household septic tank	35,611			142,801			35,611			222,873	
Institutional septic tank	5,223			67,894			5,223			69,452	
Vaccum truck	420			2,100			2,940			2,940	
Septage treatment	67	177	-	261	798	-	336	1,100	-	336	
Sub total	41,321			213,056			44,110			295,601	1,100
2. Main sewer system	28,580			17,279			24,265			-	
Lateral sewer system	226,881			72,818			169,100			-	
Pumps and pumping stations	5,668			1,818			3,216			-	
Sewage treatment	24,474	23,706	112,142	9,315	7,775	37,021	23,100	23,706	84,479	-	
Sub total	285,603			101,230			219,681			-	
TOTAL	326,924			314,286			263,791			295,601	
OPERATION AND MAINTENANCE COST PER ANNUM											
1. Vacuum truck	177			935			1,280			1,280	
Septage treatment	54	85	-	83	119		85	123	-	85	123
Sub total	231			1,018			1,365			1,365	
2. Sewerage system	3,379			1,176			2,480			-	
Sewage treatment	335	5,506	8,260	188	1,582	3,861	285	5,506	6,195	-	-
Sub total	3,714			1,364			2,765			-	
3. Aquaculture	28			25			28				
TOTAL	3,973			2,407			4,158			1,365	
	Sewer	Septic tank		Sewer	Septic tank		Sewer	Septic tank		Sewer	Septic tank
Total service charge (Baht/household/annum)	1,186	789		1,101	789		1,045	789		-	789
- Operating cost (Baht/household/annum)	274	150		338	150		254	150		-	150
- Capital contribution (Baht/household/annum)	912	639		763	639		791	639		-	639

Notes:

1. Septage treatment
   - Alternative 1 : Anaerobic digester, Facultative pond, Sludge drying bed
   - Alternative 2 : Anaerobic pond, Facultative pond
2. Sewage treatment
   - Alternative 1 : Stabilization pond system
   - Alternative 2 : Aerated lagoon system
   - Alternative 3 : Activated sludge process

5. To improve the existing sanitation conditions in the study area of Chonburi municipality, a sensible option is the use of two-compartment septic tanks and soakage pits to treat some of the household wastewaters on-site, while three-compartment septic tanks and soakage pits should be used for treatment of some of the wastewaters generated from institutional and commercial areas. The remaining wastewaters are collected by the sewerage system and treated at a central wastewater treatment plant. The proposed septic tanks and soakage pit system is expected to provide a satisfactory level of wastewater treatment with respect to pollution control and public health protection.

6. Comparing the cost of a conventional sewer system versus a small bore sewer system, considerable cost savings are possible by the application of a small bore sewer system. The construction cost of the small bore sewer system were about 15% lower than those for a conventional sewer system. This figure applies to the assumption that a completely new system is to be built. When existing on-site facilities were used as interceptor tanks for small bore sewers, the cost savings in this case increased to about 25%. In the assessment of these savings it is to be taken into account, that they are derived for an entire town area and not for a small catchment area only. Since only limited experience is available yet for large areas, the design criteria for the small bore sewer system were rather restrictive and on the safe side.

7. Small bore sewer systems are particularly advantageous in areas with a very low population density and in flat areas. The cost savings compared to a conventional sewer system increased in the area with a population density of only 16 persons per hectare to about 29%. Due to the lower slopes required for small bore sewers, less pumping stations were needed resulting in cost savings of about 43% for the construction of pumping stations. Similarly, the annual energy cost of the pumping stations of the small bore sewer systems amounted to only about 2/3 of the annual energy cost of the conventional sewer system.

8. The AIT sewer design program proved a valuable tool for this study. Without the design program, the preliminary design for conventional sewerage, small bore sewerage and different alternatives amoung these systems had not been possible. Since workable design programs are available today, the development of alternative systems and system layouts on a preliminary design level should be considered as an essential requirement of project planning. As a freely available program package, the "Microcomputer Programs for Improved Planning and Design of Water Supply and Waste Disposal Systems" which were jointly issued by the United Nations Development Program and the World Bank should be mentioned.

9. Manhole costs constitute about a quarter of the total cost of the sewer system. This relatively high share of the manhole cost originates mainly from two factors: prefabricated manholes are not available and all manholes are constructed on site resulting in relatively high unit cost. Secondly, modern cleaning and maintenance equipment is generally not available, thus, limiting the feasible manhole distance and increasing the number of required manholes.

10. Sewer systems are a technology which is not yet fully adopted by the local industry, resulting in economic losses and unreliable operation. This is to be taken into account when deciding for a certain technology in a specific project situation. Where sewer systems turn out to be the most appropriate solution, a gradual implementation should be envisaged which allows the local industry to built up sufficient experience and to adopt this technology in all its components.

11. The cost of the sewer system per person or per household differ at a ratio of up to 1:10 depending on the population density. Two conclusions may be drawn from this dependence of the sewerage cost on the population density: first, data on sewerage cost without stating the population density, as frequently found in the literature, are incomplete. Particularly comparisons between sewer systems and other sanitation technologies are rather meaningless if the population density of the area of the sewer system is not given. Secondly, if a sewer system is financed by a system which imposes the same contribution on all users, as frequent in developing countries, then, actually, the population of high density areas is subsidizing the population in low density areas.

12. Because the collected septage still contains high organic matters, solid as well as pathogenic contents, it was proposed to be treated further by two alternatives: alternative 1 involves anaerobic digester, facultative pond and sludge drying bed; and alternative 2 involves anaerobic pond and facultative pond in series. It is apparent from an economic view that alternative 2 would result in cheaper investment and operating costs.

13. For central wastewaster treatment, pond systems were considerably more economical than technical treatment processes. This was even the case, when the land cost were more than doubled compared to the present price level. Considering furthermore the operational advantages of ponds, a thorough investigation of the feasibility of a pond system should be an essential part of any project planning.

14. No information is available yet on the influence of a small bore sewer system on the design of a central treatment plant. Easily settleable material is retained in the interceptor tanks at each house prior to discharge to the public system. Although the fraction of the organic material retained in the sedimentation chambers may roughly be estimated, the characteristics of the remaining part, its treatability and eventual effects on the design of treatment plants are rather unknown. Studies analyzing this aspect are recommended.

15. Fish ponds, although technically feasible, offered only negligible cost advantages compared to ponds without fish. Considering the possibility of increased organisational requirements, fish ponds may not appear to be economically attractive. However, it is to be noted that in the project scenario of this study, the market value of fish raised in wastewater treatment ponds is very low because it can only be sold as animal feed due to anticipated social acceptance problems of direct consumption for human food. The economics of septage fed aquaculture should be much more economically attractive in other countries with lower labour costs and higher market prices for sewage raised fish, particularly if such fish are accepted for direct human consumption.

16. The transition from on-site sanitation to centralized systems naturally involves a shift of the cost from private users to the public authorities. For example, under the maximum conventional sewerage option, investment in the central system accounts for 88% of total expenditure and investment in individual septic tanks accounts for only 12%. Under the septic tank option the central part of the system accounts for only 3% of the total investment. Similarly the annual operation cost for the central system of the two options account for 94% and 9% respectively. Under this aspect, also the small bore sewer system is advantageous compared to the conventional sewer system. As compared to the 88% and 94% for the capital investment and the operating cost, respectively, for the central system of the maximum sewerage option, the central system of the small bore sewerage option accounts for 83% and 67% of the cost respectively.

17. The lowest cost system overall would be the septic tank system with a required annual charge over the life of the project of 789 Baht, excluding financing charges. The introduction of such a charge would increase household utility expenditure by around 20% and would be likely to meet very strong resistance from consumers. The alternative systems, with even higher service charge would clearly meet even higher resistance.

18. Assuming that public sector funding was possible and that all capital expenditure was paid for separately from the service charge the septic tank system would again have the lowest service charge. However because of the actual nature of the expenditure it would require the highest private sector contribution to capital investment of around 14,750 Baht per household which again would be likely to meet considerable resistance. The maximum conventional sewerage system would have the highest public sector contribution and the lowest overall private sector contribution but would still require a substantial service charge of 274 Baht per year.

19. Even with a public sector contribution there are still likely to be difficulties because of the introduction of significant charges, and because a significant capital payment would be required from households. Under all alternatives some households, which are not connected to a central sewerage system, would have to make a capital contribution of nearly 15,000 Baht as well as paying a service charge. Those households which are connected to the

central system would also face a significant capital contribution, as well as having to pay a service charge.

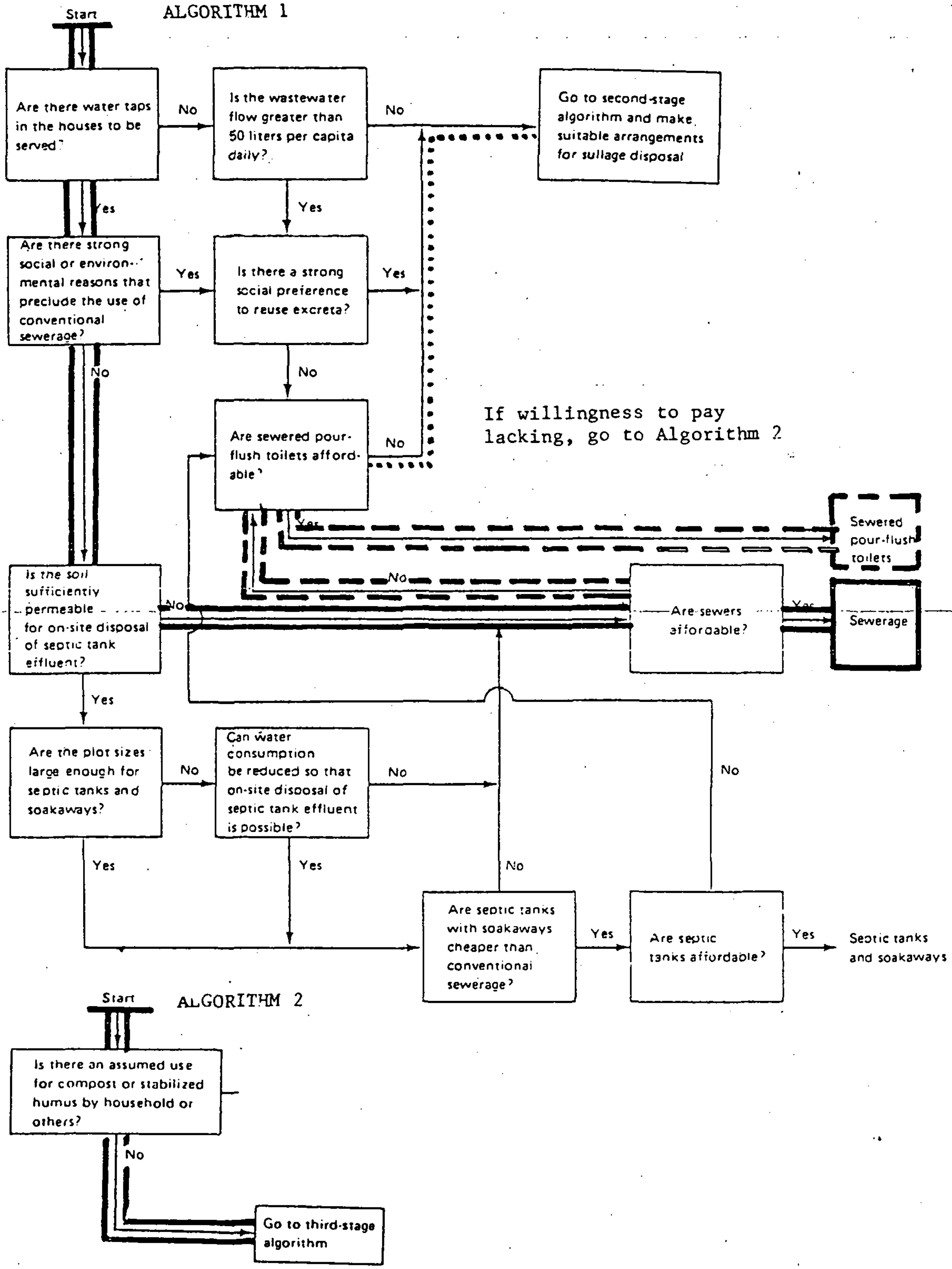
20. A sanitation system consisting of a mix of septic tanks and a sewerage system in high density areas seems to be affordable, although the required charges will most likely meet strong resistance by the users. The crucial question of affordability would thus be determined by the users' willingness, rather than their ability to pay the required charges. Under these circumstances, three future scenarios appear to be possible, as demonstrated by the flow diagrams in Figures 9.1 and 9.2.

(i) With increasing willingness to pay, a sewerage system combined with septic tanks (in the lower density areas) will become feasible

(ii) If the users are not ready to meet the required charges, a vault system would be the logical consequence. However, such a solution would be socially unacceptable as well as organizationally questionable

(iii) The present system is continued, resulting in further deterioration of hygienic and environmental conditions.

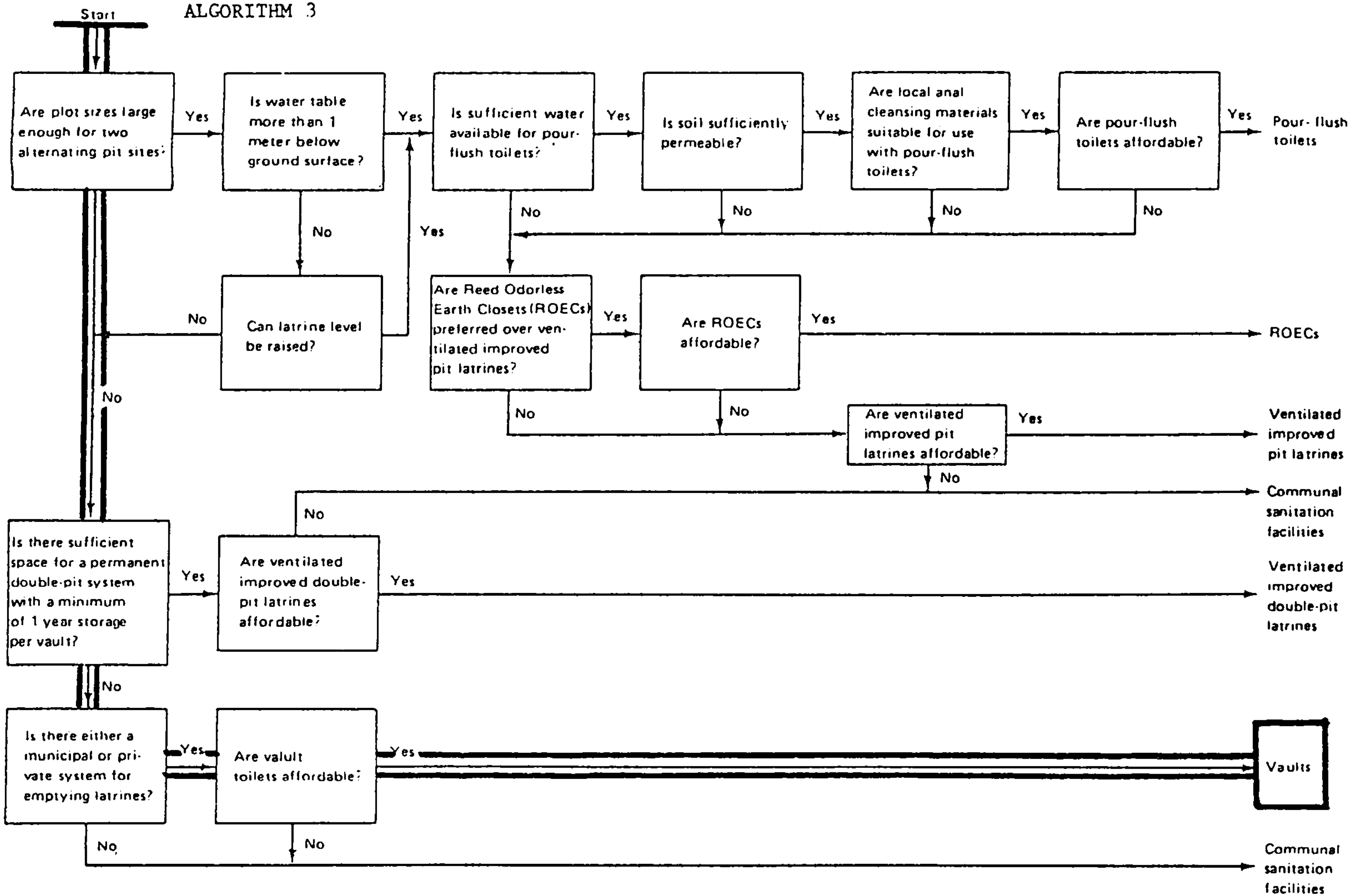
21. The existing institutional framework is adequate to permit the implementation of the scheme with only minor amendments to the regulations at the local authority level. The project itself will require the cooperation of several agencies and will need to be promoted vigourously by OUD as the lead agency. The success of the project will require that a number of obstacles are overcome. Most particularly it will be necessary to educate several groups as to the potential long term benefits to be gained from the scheme.



Source: KALBERMATTEN et al. (1980)

Figure 9.1 Selection of Sanitation Technology
Scenario 1: Willingness to Pay - Sewerage
Alternative: Sewered PF Toilets

ALGORITHM 3



Source: KALBERMATTEN et al. (1980

Figure 9.2 Selection of Sanitation Technology
Scenario 2: Unwillingness to Pay - Vault System
(socially and organizationally

APPENDIX TO CHAPTER 2

APPENDIX 2.1 RELEVANT BACKGROUND STUDIES ON CHONBURI

(a) Regional Development:

(i) COOPERS & LYBRAND Associates et al./NESDB, Eastern Seaboard Study, Final Report, 3 vols.
Bangkok, October 1982

(ii) ___________, Eastern Seaboard Study, Project Reports 1 and 2,
Bangkok, September 1982

(iii) ___________, Eastern Seaboard Study, Sector Studies,

- Vol. 3 (Industry, Tourism, Other Basic Activities, Employment)
- Vol. 5 (Transport, Water and Utilities)
- Vol. 6 (Urban Development)
- Vol. 7 (Implementation, Finance)

Bangkok, September 1982

(b) Urban Land Use Development:

(i) Town and Country Planning Department, General Plan for Chonburi 1988
Bangkok, 1966 (in Thai)

(ii) ___________, General Plan for Chonburi 1998,
Bangkok, 1978 (in Thai)

(iii) ___________, Draft General Plan for Chonburi,
Bangkok, 1983 (in Thai)

(iv) ROBERT R. NATHAN Associates/NESDB/USAID, <u>Land Use Programming for Chonburi, Siracha and Phanat Nikom, Thailand</u>,
Final Report, 2 vols.
Washington D.C., 1980

(c) <u>Sewerage and Excreta Disposal</u>:

SEATEC International/WHO/Department of Public Works, <u>Urban Sewerage and Excreta Disposal Plan</u>, 2 vols.
Bangkok, April 1983

(d) <u>Drainage and Flood Control</u>:

ENGINEERING CONSULTANCY Services Center/Institute of Scientific and Technological Research (TISTR), <u>Feasibility Study and Detailed Design for Drainage and Flood Control of Chonburi Regional City</u>, 2 vols.
Bangkok, June 1985

(e) <u>Water Supply</u>:

KOCKS Consult GmbH/THAI PROFESSIONAL Engineering Consultants Co.Ltd./Provincial Waterworks Authority, <u>Chonburi Water Supply Project</u>,

- Phase I (Immediate Improvements)
- Phase II (Masterplan)
- Phase III (Feasibility Study)

Bangkok, 1984/1985

APPENDIX 2.2 THE THAI CESSPOOL

Source: UNITED NATIONS Centre for Human Settlements (HABITAT) (1986), Community Participation in Low-Cost Sanitation, Training Module, Nairobi, Kenya, pp. 62-63

Background The cesspool as it is now found in the slum areas of Bangkok, Thailand, is a much simplified version of the double-pit latrine which was introduced by the Ministry of Health in the early seventies. It consists of a single pit made out of a set of rings forming a shaft down into the ground. It has a squatting plate with a water seal. The tank sometimes barely enters into the soil; it rises through the surrounding water up to the floor of the house, which is usually built on stilts.

Several factors have facilitated the rapid acceptance of this type of latrine in the slums of Bangkok. Sanitation is not a controversial subject in Thailand. Most of the taboos surrounding the subject existing in other countries are unknown here. The effective water seal of the cesspool prevents unpleasant smells; therefore, the vicinity of toilet in these densely populated areas no longer provokes any strong negative reactions from neighbours. However, as most of the slum areas of Bangkok are regularly flooded, the pollution caused by these pits is considerable. The untreated fluids from the pit leach directly into the surrounding surface water.

Community participation

The construction of the latrine is very simple. The entire latrine is available in prefabricated parts from a multitude of suppliers at a very low cost. Almost all hardware shops in Bangkok have a small workshop in their backyards where components are produced from steel moulds.

All a client has to do is to decide to buy one and call a contractor. The cesspool can be easily assembled. A complete unit can be installed by a mason in a few hours time. The system is so cheap that many households build a second latrine instead of emptying the original one. Authorities do not need to generate participation in order to promote the use of the system.

Implementation

Users often complain about the problems created by the latrines of their neighbours rather than by their own latrines. The main complaint concerns the pollution caused by the careless emptying of the tank, especially the de-sludging, done by breaking the tank and spilling its content on the surrounding land.

Since the existing method is satisfactory to the user, improved systems are likely to meet with considerable resistance. Within the Government, little concern has been shown for the special problems in sanitation. Roads, water supply and garbage disposal are seen as far more urgent infrastructural needs.

Conclusions

A purely commercial implementation system has succeeded in covering almost the entire slum population of Bangkok without any noticeable governmental involvement.

Although the system is in fact unsuitable for areas with a high watertable and causes severe pollution, all surveys show considerable satisfaction with the system. People feel that sanitation is adequate as it is. Public health and environmental considerations are not considered issues within their control, and therefore fail to draw their attention. The absence of smells gives the people a false sense of security.

APPENDIX TO CHAPTER 4

APPENDIX 4.1

Design Criteria, Sewer Network Data and Sewer Design for Maximum Sewerage Option I

Design Criteria for Maximum Sewerage Option I

MIN. SLOPE FOR CONSTRUCTION	=	0.001
MINIMUM COVERING	=	2.00 m
MAX. EXCAVATION	=	5.00 m
MANNING ` n '	=	0.013
MINIMUM VELOCITY	=	0.50 m/s
MAXIMUM VELOCITY	=	3.00 m/s
WASTE WATER PEAK FACTOR	=	1.75**
RAINFALL CONSTANT K2	=	32.00

NO. OF AVAILABLE PIPES = 8

AVAILABLE PIPE DIAMETER ARE:

0.400 m	0.700 m	1.000 m
0.500 m	0.800 m	1.200 m
0.600 m	0.900 m	

** - Composite peak factor considering Peak Flow and Infiltration based on 2 Q.

Sewer Network Data for Maximum Sewerage Option I
From Manholes 1A1 & 1A4 to Manhole 28B1

****** SEWER NETWORK DATA ******

(U - UPSTREAM , D - DOWNSTREAM , Q - AVERAGE FLOW)
(ELE in m, LENGTH in m, Q in l/s)

U. NODE	D. NODE	U. ELE	D. ELE	LENGTH	Q
1A1	2B1	8.37	6.00	80.0	0.1
2B1	3B1	6.00	5.70	80.0	0.0
3B1	4B1	5.70	4.35	80.0	1.8
4B1	1J3	4.35	3.03	80.0	2.0
1A4	2B4	10.00	9.52	75.0	0.4
2B4	3B4	9.52	9.04	75.0	0.4
3B4	4B4	9.04	8.56	75.0	0.4
4B4	5B4	8.56	8.08	75.0	0.4
5B4	6B4	8.08	7.60	75.0	1.0
6B4	7B4	7.60	7.12	75.0	1.0
7B4	8B4	7.12	6.64	75.0	0.4
8B4	9B4	6.64	6.16	75.0	0.4
9B4	10B4	6.16	5.68	75.0	0.4
10B4	11B4	5.68	5.20	75.0	0.4
11B4	12B4	5.20	5.04	75.0	0.4
12B4	13B4	5.04	4.88	75.0	0.4
13B4	14B4	4.88	4.77	50.0	0.4
14B4	15B4	4.77	4.67	50.0	0.4
15B4	16B4	4.67	4.54	60.0	0.4
16B4	17B4	4.54	4.43	50.0	0.4
17B4	18B4	4.43	4.33	50.0	0.4
18B4	19B4	4.33	4.17	75.0	0.4
19B4	20B4	4.17	4.02	72.0	0.0
20B4	21B4	4.02	3.86	72.0	0.0
21B4	22B4	3.86	3.71	72.0	0.8
22B4	23B4	3.71	3.56	72.0	0.0
23B4	24B4	3.56	3.43	60.0	0.8
24B4	25B4	3.43	3.31	60.0	0.0
25B4	26B4	3.31	3.18	60.0	0.8
26B4	1J3	3.18	3.03	70.0	0.0
1J3	6B1	3.03	2.92	66.0	6.6

DETAIL OF THIS 2 BRANCHES JUNCTION
FROM NODE: 4B1 / 26B4

Sewer Network Data for Maximum Sewerage Option I
From Manholes 1A1 & 1A4 to Manhole 28B1

U. NODE	D. NODE	U. ELE	D. ELE	LENGTH	Q
6B1	7B1	2.92	2.81	66.0	2.8
7B1	8B1	2.81	2.70	66.0	2.8
8B1	9B1	2.70	2.58	66.0	1.8
9B1	10B1	2.58	2.52	72.0	1.8
10B1	11B1	2.52	2.47	72.0	2.8
11B1	12B1	2.47	2.42	72.0	2.8
12B1	13B1	2.42	2.37	72.0	4.8
13B1	14B1	2.37	2.31	72.0	2.8
14B1	15B1	2.31	2.26	72.0	0.0
15B1	16B1	2.26	2.26	64.0	0.6
16B1	17B1	2.26	2.26	64.0	2.6
17B1	18B1	2.26	2.26	64.0	2.0
18B1	19B1	2.26	2.26	64.0	2.0
19B1	20B1	2.26	2.34	56.0	2.0
20B1	21B1	2.34	2.42	56.0	0.6
21B1	22B1	2.42	2.50	56.0	2.6
22B1	23B1	2.50	2.58	56.0	2.6
23B1	24B1	2.58	2.68	66.0	0.0
24B1	25B1	2.68	2.77	66.0	2.6
25B1	26B1	2.77	2.86	66.0	3.0
26B1	27B1	2.86	2.95	66.0	1.8
27B1	28B1	2.95	3.25	72.0	3.0

Sewer Network Data for Maximum Sewerage Option I
From Manhole 28B1 to Manhole 2J3

****** SEWER NETWORK DATA ******

(U - UPSTREAM , D - DOWNSTREAM , Q - AVERAGE FLOW)
(ELE in m, LENGTH in m, Q in l/s)

U. NODE	D. NODE	U. ELE	D. ELE	LENGTH	Q
1A1	29B1	3.25	3.50	72.0	70.5
29B1	30B1	3.50	3.35	76.0	1.0
30B1	31B1	3.35	3.21	76.0	4.6
31B1	32B1	3.21	3.07	76.0	3.0
32B1	33B1	3.07	2.92	76.0	3.0
33B1	34B1	2.92	3.01	72.0	3.0
34B1	35B1	3.01	3.10	72.0	3.0
35B1	36B1	3.10	3.20	72.0	3.0
36B1	37B1	3.20	3.29	72.0	2.0
37B1	38B1	3.29	3.11	72.0	1.6
38B1	39B1	3.11	2.94	72.0	0.0
39B1	40B1	2.94	2.44	80.0	5.6
40B1	41B1	2.44	1.94	80.0	0.0
41B1	42B1	1.94	1.87	70.0	0.0
42B1	43B1	1.87	1.80	70.0	0.0
43B1	44B1	1.80	1.73	70.0	0.0
44B1	2J3	1.73	1.65	70.0	0.0

Sewer Network Data for Maximum Sewerage Option I
From Manhole 1A2 to Manhole 2J3

****** SEWER NETWORK DATA ******

(U - UPSTREAM , D - DOWNSTREAM , Q - AVERAGE FLOW)
(ELE in m, LENGTH in m, Q in l/s)

U. NODE	D. NODE	U. ELE	D. ELE	LENGTH	Q
1A2	2B2	2.00	1.89	60.0	2.6
2B2	3B2	1.89	1.78	60.0	2.4
3B2	4B2	1.78	1.67	56.0	2.4
4B2	5B2	1.67	1.55	56.0	2.4
5B2	6B2	1.55	1.44	60.0	2.4
6B2	7B2	1.44	1.33	60.0	3.4
7B2	8B2	1.33	1.22	60.0	3.4
8B2	9B2	1.22	1.11	60.0	2.4
9B2	10B2	1.11	1.00	56.0	1.2
10B2	11B2	1.00	1.00	78.0	1.2
11B2	12B2	1.00	1.00	78.0	1.2
12B2	13B2	1.00	1.00	78.0	4.6
13B2	14B2	1.00	1.00	78.0	4.6
14B2	15B2	1.00	1.00	78.0	6.2
15B2	16B2	1.00	1.00	78.0	0.0
16B2	17B2	1.00	1.00	60.0	1.6
17B2	18B2	1.00	1.00	60.0	1.6
18B2	19B2	1.00	1.00	52.0	1.6
19B2	20B2	1.00	1.00	52.0	3.0
20B2	21B2	1.00	1.00	60.0	3.0
21B2	22B2	1.00	1.00	60.0	3.0
22B2	23B2	1.00	1.00	60.0	3.0
23B2	24B2	1.00	1.00	60.0	3.0
24B2	25B2	1.00	1.00	52.0	3.0
25B2	26B2	1.00	1.22	52.0	4.4
26B2	27B2	1.22	1.44	60.0	1.6
27B2	2J3	1.44	1.65	60.0	1.6

Sewer Network Data for Maximum Sewerage Option I
From Manholes 1A3 & 1A6 to Manhole 3J3

****** SEWER NETWORK DATA ******

(U - UPSTREAM , D - DOWNSTREAM , Q - AVERAGE FLOW)
(ELE in m, LENGTH in m, Q in l/s)

U. NODE	D. NODE	U. ELE	D. ELE	LENGTH	Q
1A3	2B3	13.37	13.33	66.0	15.2
2B3	3B3	13.33	13.30	66.0	0.0
3B3	4B3	13.30	13.27	66.0	0.0
4B3	5B3	13.27	13.23	66.0	0.0
5B3	6B3	13.23	12.67	72.0	2.0
6B3	7B3	12.67	12.12	72.0	0.0
7B3	8B3	12.12	11.56	72.0	2.0
8B3	9B3	11.56	11.01	72.0	0.0
9B3	10B3	11.01	10.59	80.0	2.0
10B3	11B3	10.59	10.15	80.0	0.0
11B3	12B3	10.15	9.70	80.0	2.0
12B3	13B3	9.70	9.30	80.0	0.0
13B3	14B3	9.30	8.87	80.0	2.0
14B3	15B3	8.87	8.44	80.0	0.0
15B3	16B3	8.44	8.02	80.0	2.2
16B3	17B3	8.02	7.59	80.0	0.0
17B3	18B3	7.59	7.16	80.0	2.2
18B3	4J3	7.16	6.73	80.0	1.6
1A6	2B6	13.84	13.15	50.0	0.6
2B6	3B6	13.15	12.47	50.0	0.0
3B6	4B6	12.47	11.77	50.0	0.0
4B6	5B6	11.77	10.98	56.0	0.0
5B6	6B6	10.98	9.98	88.0	0.6
6B6	7B6	9.98	9.47	80.0	0.0
7B6	8B6	9.47	8.96	80.0	0.6
8B6	9B6	8.96	8.57	60.0	1.0
9B6	10B6	8.57	8.21	56.0	0.6
10B6	11B6	8.21	7.85	60.0	0.6
11B6	12B6	7.85	7.49	56.0	2.0
12B6	13B6	7.49	6.70	60.0	0.0
13B6	4J3	6.70	6.73	64.0	8.6
4J3	20B3	6.73	6.29	64.0	0.6

DETAIL OF THIS 2 BRANCHES JUNCTION
FROM NODE: 18B3 / 13B6

Sewer Network Data for Maximum Sewerage Option I
From Manholes 1A3 & 1A6 to Manhole 3J3

U. NODE	D. NODE	U. ELE	D. ELE	LENGTH	Q
20B3	21B3	6.29	5.85	64.0	0.8
21B3	22B3	5.85	5.41	64.0	0.8
22B3	23B3	5.41	5.37	75.0	3.0
23B3	24B3	5.37	5.33	75.0	3.0
24B3	25B3	5.33	5.28	75.0	3.4
25B3	26B3	5.28	5.24	75.0	6.8
26B3	27B3	5.24	5.20	75.0	1.6
27B3	28B3	5.20	5.16	75.0	14.4
28B3	29B3	5.16	5.07	69.0	2.4
29B3	30B3	5.07	4.97	69.0	2.4
30B3	31B3	4.97	4.87	69.0	2.4
31B3	32B3	4.87	4.77	69.0	2.4
32B3	33B3	4.77	4.68	69.0	0.0
33B3	34B3	4.68	4.58	69.0	0.6
34B3	35B3	4.58	4.48	90.0	18.2
35B3	36B3	4.48	4.38	90.0	2.2
36B3	37B3	4.38	4.28	90.0	3.0
37B3	38B3	4.28	4.19	90.0	5.2
38B3	39B3	4.19	4.20	56.0	3.2
39B3	40B3	4.20	4.22	56.0	3.6
40B3	41B3	4.22	4.23	56.0	3.8
41B3	42B3	4.23	4.24	56.0	3.0
42B3	43B3	4.24	4.38	64.0	1.4
43B3	44B3	4.38	4.53	64.0	1.4
44B3	45B3	4.53	4.67	64.0	1.4
45B3	46B3	4.67	4.81	64.0	0.6
46B3	47B3	4.81	4.09	88.0	0.6
47B3	48B3	4.09	3.38	88.0	0.0
48B3	49B3	3.38	3.21	76.0	0.6
49B3	50B3	3.21	3.05	76.0	0.0
50B3	51B3	3.05	3.04	75.0	2.8
51B3	52B3	3.04	3.03	75.0	3.0
52B3	53B3	3.03	3.02	75.0	0.8
53B3	54B3	3.02	3.02	75.0	0.0
54B3	55B3	3.02	3.01	75.0	2.8
55B3	56B3	3.01	3.00	75.0	0.0
56B3	57B3	3.00	2.83	85.0	22.6
57B3	58B3	2.83	2.67	85.0	2.8
58B3	59B3	2.67	2.51	85.0	2.8
59B3	60B3	2.51	2.35	85.0	2.8
60B3	61B3	2.35	2.18	85.0	16.0
61B3	3J3	2.18	2.02	85.0	0.0

Sewer Network Data for Maximum Sewerage Option I
From Manhole 2J3 to Manhole 70B1

****** SEWER NETWORK DATA ******

(U - UPSTREAM , D - DOWNSTREAM , Q - AVERAGE FLOW)
(ELE in m, LENGTH in m, Q in l/s)

U.NODE	D.NODE	U.ELE	D.ELE	LENGTH	Q
1A1	46B1	1.45	1.73	61.0	171.1
46B1	47B1	1.73	1.81	61.0	0.0
47B1	48B1	1.81	1.89	61.0	0.0
48B1	49B1	1.89	1.89	61.0	0.0
49B1	50B1	1.89	1.90	61.0	5.0
50B1	51B1	1.90	1.90	54.0	0.0
51B1	52B1	1.90	1.90	54.0	0.0
52B1	53B1	1.90	1.90	61.0	8.0
53B1	54B1	1.90	1.91	61.0	0.0
54B1	55B1	1.91	1.91	61.0	0.0
55B1	56B1	1.91	1.91	61.0	0.0
56B1	57B1	1.91	1.92	54.0	0.0
57B1	58B1	1.92	2.20	60.0	9.0
58B1	59B1	2.20	2.51	60.0	6.2
59B1	60B1	2.51	2.48	84.0	0.0
60B1	61B1	2.48	2.46	84.0	0.0
61B1	62B1	2.46	2.44	63.0	4.4
62B1	63B1	2.44	2.42	63.0	0.0
63B1	64B1	2.42	2.40	63.0	0.0
64B1	65B1	2.40	2.38	63.0	0.0
65B1	66B1	2.38	2.35	63.0	0.0
66B1	67B1	2.35	2.33	63.0	0.0
67B1	68B1	2.33	2.02	56.0	0.0
68B1	69B1	2.02	2.05	64.0	0.0
69B1	70B1	2.05	2.00	1200.0	194.9

Sewer Network Data for Maximum Sewerage Option I
From Manholes 1A1 & 1A4 to Manhole 28B1

DATA Rec.No	PIPE SECTION U.Node	D.Node	GROUND ELE.(m) UPstre.	DOWNstr.	PIPE DIAM (m)	INVERT ELE.(m) UPstre.	DOWNstr.	SLOPE (m/km)	LENGTH (m)	VELOCITY (m/sec)	ACC. COST (Baht)
4	1A1	2B1	8.37	6.00	0.300	6.07	3.65	30.300	80.00	0.50	49,839
5	2B1	3B1	6.00	5.70	0.300	3.65	1.22	30.300	80.00	0.50	104,469
6	3B1	4B1	5.70	4.35	0.300	1.22	0.87	4.420	80.00	0.50	161,580
7	4B1	1J3	4.35	3.03	0.300	0.87	0.66	2.580	80.00	0.50	214,049
8	1A4	2B4	10.00	9.52	0.300	7.70	6.51	15.900	75.00	0.50	48,082
9	2B4	3B4	9.52	9.04	0.300	6.51	5.85	8.800	75.00	0.50	98,005
10	3B4	4B4	9.04	8.56	0.300	5.85	5.35	6.600	75.00	0.50	148,330
11	4B4	5B4	8.56	8.08	0.300	5.35	4.98	4.950	75.00	0.50	198,461
12	5B4	6B4	8.08	7.60	0.300	4.98	4.71	3.590	75.00	0.50	247,934
13	6B4	7B4	7.60	7.12	0.300	4.71	4.50	2.810	75.00	0.50	296,417
14	7B4	8B4	7.12	6.64	0.300	4.50	4.31	2.580	75.00	0.50	343,753
15	8B4	9B4	6.64	6.16	0.300	4.31	3.86	5.970	75.00	0.71	390,432
16	9B4	10B4	6.16	5.68	0.300	3.86	3.38	6.400	75.00	0.73	437,045
17	10B4	11B4	5.68	5.20	0.300	3.38	2.90	6.400	75.00	0.76	483,657
18	11B4	12B4	5.20	5.04	0.300	2.90	2.74	2.133	75.00	0.51	530,270
19	12B4	13B4	5.04	4.88	0.300	2.74	2.58	2.133	75.00	0.52	576,882
20	13B4	14B4	4.88	4.77	0.300	2.58	2.47	2.200	50.00	0.54	607,957
21	14B4	15B4	4.77	4.67	0.300	2.47	2.37	2.000	50.00	0.53	639,032
22	15B4	16B4	4.67	4.54	0.300	2.37	2.24	2.167	60.00	0.55	676,322
23	16B4	17B4	4.54	4.43	0.300	2.24	2.13	2.200	50.00	0.56	707,397
24	17B4	18B4	4.43	4.33	0.300	2.13	2.03	2.000	50.00	0.55	738,472
25	18B4	19B4	4.33	4.17	0.300	2.03	1.87	2.133	75.00	0.57	785,085
26	19B4	20B4	4.17	4.02	0.300	1.87	1.72	2.083	72.00	0.56	829,833
27	20B4	21B4	4.02	3.86	0.300	1.72	1.56	2.222	72.00	0.58	874,581
28	21B4	22B4	3.86	3.71	0.300	1.56	1.41	2.083	72.00	0.58	919,329
29	22B4	23B4	3.71	3.56	0.300	1.41	1.26	2.083	72.00	0.58	964,077
30	23B4	24B4	3.56	3.43	0.300	1.26	1.13	2.167	60.00	0.60	1,001,367
31	24B4	25B4	3.43	3.31	0.300	1.13	1.01	2.000	60.00	0.58	1,038,657

Sewer Design for Maximum Sewerage Option I
From Manholes 1A1 & 1A4 to Manhole 28B1

32	25B4	26B4	3.31	3.18	0.300	1.01	0.88	2.167	60.00	0.61	1,075,947
33	26B4	1J3	3.18	3.03	0.300	0.88	0.73	2.143	70.00	0.61	1,119,452
34	1J3	6B1	3.03	2.92	0.300	0.66	0.56	1.486	66.00	0.53	1,374,745
35	6B1	7B1	2.92	2.81	0.300	0.56	0.44	1.902	66.00	0.60	1,415,996
36	7B1	8B1	2.81	2.70	0.400	0.34	0.27	1.000	66.00	0.56	1,464,488
37	8B1	9B1	2.70	2.58	0.400	0.27	0.18	1.400	66.00	0.65	1,512,850
38	9B1	10B1	2.58	2.52	0.400	0.18	0.11	1.000	72.00	0.57	1,565,578
39	10B1	11B1	2.52	2.47	0.400	0.11	0.04	1.000	72.00	0.56	1,618,373
40	11B1	12B1	2.47	2.42	0.400	0.04	-0.04	1.000	72.00	0.55	1,671,255
41	12B1	13B1	2.42	2.37	0.400	-0.04	-0.12	1.181	72.00	0.57	1,724,250
42	13B1	14B1	2.37	2.31	0.400	-0.12	-0.22	1.348	72.00	0.61	1,777,388
43	14B1	15B1	2.31	2.26	0.400	-0.22	-0.32	1.348	72.00	0.61	1,830,693
44	15B1	16B1	2.26	2.26	0.400	-0.32	-0.40	1.386	64.00	0.62	1,878,314
45	16B1	17B1	2.26	2.26	0.400	-0.40	-0.50	1.553	64.00	0.65	1,926,265
46	17B1	18B1	2.26	2.26	0.400	-0.50	-0.61	1.688	64.00	0.68	1,974,582
47	18B1	19B1	2.26	2.26	0.400	-0.61	-0.73	1.829	64.00	0.71	2,023,295
48	19B1	20B1	2.26	2.34	0.400	-0.73	-0.84	1.976	56.00	0.74	2,066,373
49	20B1	21B1	2.34	2.42	0.400	-0.84	-0.95	2.021	56.00	0.75	2,110,082
50	21B1	22B1	2.42	2.50	0.400	-0.95	-1.08	2.222	56.00	0.78	2,154,384
51	22B1	23B1	2.50	2.58	0.400	-1.08	-1.21	2.433	56.00	0.82	2,199,333
52	23B1	24B1	2.58	2.68	0.400	-1.21	-1.37	2.433	66.00	0.82	2,253,174
53	24B1	25B1	2.68	2.77	0.500	-1.47	-1.54	1.000	66.00	0.65	2,319,984
54	25B1	26B1	2.77	2.86	0.500	-1.54	-1.61	1.000	66.00	0.64	2,387,474
55	26B1	27B1	2.86	2.95	0.500	-1.61	-1.67	1.000	66.00	0.63	2,455,643
56	27B1	28B1	2.95	3.25	0.500	-1.67	-1.75	1.026	72.00	0.62	2,531,268

TOTAL PIPE LENGTH OF THE NETWORK = 3605 m

Manhole cost = ฿1,577,500.-

Sewer Design for Maximum Sewerage Option I
From Manhole 28B1 to Manhole 2J3

DATA Rec.No	PIPE SECTION U.Node	D.Node	GROUND ELE.(m) UPstre.	DOWNstr.	PIPE DIAM (m)	INVERT ELE.(m) UPstre.	DOWNstr.	SLOPE (m/km)	LENGTH (m)	VELOCITY (m/sec)	ACC. COST (Baht)
4	1A1	29B1	3.25	3.50	0.500	0.75	0.67	1.067	72.00	0.63	65,433
5	29B1	30B1	3.50	3.35	0.500	0.67	0.59	1.098	76.00	0.64	135,153
6	30B1	31B1	3.35	3.21	0.500	0.59	0.50	1.244	76.00	0.68	204,593
7	31B1	32B1	3.21	3.07	0.500	0.50	0.39	1.344	76.00	0.70	273,824
8	32B1	33B1	3.07	2.92	0.500	0.39	0.28	1.448	76.00	0.73	342,859
9	33B1	34B1	2.92	3.01	0.500	0.28	0.17	1.555	72.00	0.76	408,646
10	34B1	35B1	3.01	3.10	0.500	0.17	0.05	1.667	72.00	0.79	475,412
11	35B1	36B1	3.10	3.20	0.500	0.05	-0.08	1.782	72.00	0.81	543,219
12	36B1	37B1	3.20	3.29	0.500	-0.08	-0.21	1.862	72.00	0.83	612,101
13	37B1	38B1	3.29	3.11	0.500	-0.21	-0.35	1.926	72.00	0.84	681,417
14	38B1	39B1	3.11	2.94	0.500	-0.35	-0.49	1.926	72.00	0.84	750,561
15	39B1	40B1	2.94	2.44	0.500	-0.49	-0.66	2.161	80.00	0.89	826,441
16	40B1	41B1	2.44	1.94	0.500	-0.66	-0.83	2.161	80.00	0.89	900,594
17	41B1	42B1	1.94	1.87	0.600	-0.93	-1.00	1.000	70.00	0.74	975,601
18	42B1	43B1	1.87	1.80	0.600	-1.00	-1.07	1.000	70.00	0.74	1,050,607
19	43B1	44B1	1.80	1.73	0.600	-1.07	-1.14	1.000	70.00	0.74	1,125,614
20	44B1	2J3	1.73	3.75	0.600	-1.14	-1.21	1.000	70.00	0.74	1,205,850

TOTAL PIPE LENGTH OF THE NETWORK = 1248 m
EXECUTION TIME (EXCLUDE THE TIME FOR FINAL RESULT PRINT OUT) = 00:03:21 (201 SECONDS)

Manhole Cost (39 + 9) x 12,500 = 600,000.-

Sewer Design for Maximum Sewerage Option I
From Manhole 1A2 to Manhole 2J3

DATA Rec.No	PIPE SECTION U.Node	D.Node	GROUND ELE.(m) UPstre.	DOWNstr.	PIPE DIAM (m)	INVERT ELE.(m) UPstre.	DOWNstr.	SLOPE (m/km)	LENGTH (m)	VELOCITY (m/sec)	ACC. COST (Baht)
4	1A2	2B2	2.00	1.89	0.300	-0.30	-0.52	3.590	60.00	0.50	37,464
5	2B2	3B2	1.89	1.78	0.300	-0.52	-0.64	2.141	60.00	0.50	75,132
6	3B2	4B2	1.78	1.67	0.300	-0.64	-0.74	1.650	56.00	0.50	110,291
7	4B2	5B2	1.67	1.55	0.300	-0.74	-0.81	1.363	56.00	0.50	145,355
8	5B2	6B2	1.55	1.44	0.300	-0.81	-0.89	1.212	60.00	0.50	182,790
9	6B2	7B2	1.44	1.33	0.300	-0.89	-0.97	1.412	60.00	0.55	220,121
10	7B2	8B2	1.33	1.22	0.300	-0.97	-1.08	1.833	60.00	0.63	257,411
11	8B2	9B2	1.22	1.11	0.300	-1.08	-1.19	1.833	60.00	0.63	294,701
12	9B2	10B2	1.11	1.00	0.300	-1.19	-1.30	1.964	56.00	0.64	329,505
13	10B2	11B2	1.00	1.00	0.300	-1.30	-1.44	1.855	78.00	0.59	378,293
14	11B2	12B2	1.00	1.00	0.400	-1.54	-1.62	1.000	78.00	0.56	436,177
15	12B2	13B2	1.00	1.00	0.400	-1.62	-1.70	1.000	78.00	0.56	494,395
16	13B2	14B2	1.00	1.00	0.400	-1.70	-1.78	1.000	78.00	0.56	552,949
17	14B2	15B2	1.00	1.00	0.400	-1.78	-1.87	1.152	78.00	0.56	611,862
18	15B2	16B2	1.00	1.00	0.400	-1.87	-1.96	1.152	78.00	0.56	671,161
19	16B2	17B2	1.00	1.00	0.400	-1.96	-2.03	1.245	60.00	0.58	717,047
20	17B2	18B2	1.00	1.00	0.400	-2.03	-2.11	1.342	60.00	0.61	763,190
21	18B2	19B2	1.00	1.00	0.400	-2.11	-2.19	1.442	52.00	0.63	803,402
22	19B2	20B2	1.00	1.00	0.400	-2.19	-2.27	1.640	52.00	0.67	843,844
23	20B2	21B2	1.00	1.00	0.400	-2.27	-2.39	1.851	60.00	0.71	890,831
24	21B2	22B2	1.00	1.00	0.400	-2.39	-2.51	2.074	60.00	0.75	938,207
25	22B2	23B2	1.00	1.00	0.400	-2.51	-2.65	2.310	60.00	0.80	986,018
26	23B2	24B2	1.00	1.00	0.400	-2.65	-2.80	2.559	60.00	0.84	1,034,310
27	24B2	25B2	1.00	1.00	0.400	-2.80	-2.95	2.820	52.00	0.88	1,076,592
28	25B2	26B2	1.00	1.22	0.400	-2.95	-3.12	3.226	52.00	0.94	1,119,639
29	26B2	27B2	1.22	1.44	0.500	-3.22	-3.28	1.028	60.00	0.62	1,181,743
30	27B2	2J3	1.44	1.65	0.500	-3.28	-3.34	1.077	60.00	0.63	1,244,949

TOTAL PIPE LENGTH OF THE NETWORK = 1684 m
EXECUTION TIME (EXCLUDE THE TIME FOR FINAL RESULT PRINT OUT) = 00:04:18 (258 SECONDS)

Manhole Cost = 24 x 10,000 + 43 x 12,500 = 777,500.-

Sewer Design for Maximum Sewerage Option I
From Manholes 1A3 & 1A6 to Manhole 3J3

DATA	PIPE SECTION		GROUND ELE.(m)		PIPE DIAM	INVERT ELE.(m)		SLOPE	LENGTH	VELOCITY	ACC. COST
Rec.No	U.Node	D.Node	UPstre.	DOWNstr.	(m)	UPstre.	DOWNstr.	(m/km)	(m)	(m/sec)	(Baht)
4	1A3	2B3	13.37	13.33	0.300	11.07	10.99	1.146	66.00	0.50	41,084
5	2B3	3B3	13.33	13.30	0.300	10.99	10.92	1.146	66.00	0.50	82.315
6	3B3	4B3	13.30	13.27	0.300	10.92	10.84	1.146	66.00	0.50	123,712
7	4B3	5B3	13.27	13.23	0.300	10.84	10.77	1.146	66.00	0.50	165,256
8	5B3	6B3	13.23	12.67	0.300	10.77	10.37	5.520	72.00	0.98	210.326
9	6B3	7B3	12.67	12.12	0.300	10.37	9.82	7.639	72.00	1.10	255,074
10	7B3	8B3	12.12	11.56	0.300	9.82	9.26	7.778	72.00	1.13	299,822
11	8B3	9B3	11.56	11.01	0.300	9.26	8.71	7.639	72.00	1.14	344.570
12	9B3	10B3	11.01	10.59	0.300	8.71	8.29	5.250	80.00	1.00	394,290
13	10B3	11B3	10.59	10.15	0.300	8.29	7.85	5.500	80.00	1.02	444,010
14	11B3	12B3	10.15	9.70	0.300	7.85	7.40	5.625	80.00	1.05	493,730
15	12B3	13B3	9.70	9.30	0.300	7.40	7.00	5.000	80.00	1.00	543,450
16	13B3	14B3	9.30	8.87	0.300	7.00	6.57	5.375	80.00	1.05	593,170
17	14B3	15B3	8.87	8.44	0.300	6.57	6.14	5.375	80.00	1.05	642,890
18	15B3	16B3	8.44	8.02	0.300	6.14	5.72	5.250	80.00	1.05	692,610
19	16B3	17B3	8.02	7.59	0.300	5.72	5.29	5.375	80.00	1.06	742.330
20	17B3	18B3	7.59	7.16	0.300	5.29	4.86	5.375	80.00	1.07	792,050
21	18B3	4J3	7.16	6.73	0.300	4.86	4.43	5.375	80.00	1.07	841,770
22	1A6	2B6	13.84	13.15	0.300	11.54	10.85	13.800	50.00	0.55	31,075
23	2B6	3B6	13.15	12.47	0.300	10.85	10.17	13.600	50.00	0.54	62,150
24	3B6	4B6	12.47	11.77	0.300	10.17	9.47	14.000	50.00	0.55	93,225
25	4B6	5B6	11.77	10.98	0.300	9.47	8.68	14.107	56.00	0.55	128,029
26	5B6	6B6	10.98	9.98	0.300	8.68	7.68	11.364	88.00	0.61	182,721
27	6B6	7B6	9.98	9.47	0.300	7.68	7.15	6.600	80.00	0.50	232,481

Sewer Design for Maximum Sewerage Option I
From Manholes 1A3 & 1A6 to Manhole 3J3

28	7B6	8B6	9.47	8.96	0.300	7.15	6.66	6.150	80.00	0.56	282,240
29	8B6	9B6	8.96	8.57	0.300	6.66	6.27	6.500	60.00	0.64	319,530
30	9B6	10B6	8.57	8.21	0.300	6.27	5.91	6.429	56.00	0.66	354,334
31	10B6	11B6	8.21	7.85	0.300	5.91	5.55	6.000	60.00	0.68	391,624
32	11B6	12B6	7.85	7.49	0.300	5.55	5.19	6.429	56.00	0.79	426,428
33	12B6	13B6	7.49	6.70	0.300	5.19	4.40	13.167	60.00	1.00	463,718
34	13B6	4J3	6.70	6.73	0.300	4.40	4.33	1.167	64.00	0.50	503,678
35	4J3	20B3	6.73	6.29	0.300	4.33	3.87	7.050	64.00	1.15	1,385,613
36	20B3	21B3	6.29	5.85	0.300	3.87	3.41	7.296	64.00	1.17	1,425,844
37	21B3	22B3	5.85	5.41	0.400	3.31	3.01	4.643	64.00	1.16	1,472,943
38	22B3	23B3	5.41	5.37	0.500	2.91	2.83	1.000	75.00	0.65	1,540,380
39	23B3	24B3	5.37	5.33	0.500	2.83	2.76	1.000	75.00	0.65	1,607,990
40	24B3	25B3	5.33	5.28	0.500	2.76	2.68	1.000	75.00	0.65	1,675,748
41	25B3	26B3	5.28	5.24	0.500	2.68	2.61	1.000	75.00	0.64	1,743,655
42	26B3	27B3	5.24	5.20	0.500	2.61	2.53	1.000	75.00	0.63	1,811,735
43	27B3	28B3	5.20	5.16	0.500	2.53	2.43	1.381	75.00	0.71	1,880,059
44	28B3	29B3	5.16	5.07	0.500	2.43	2.33	1.465	69.00	0.74	1,943,088
45	29B3	30B3	5.07	4.97	0.500	2.33	2.22	1.552	69.00	0.76	2,006,157
46	30B3	31B3	4.97	4.87	0.500	2.22	2.11	1.641	69.00	0.78	2,069,273
47	31B3	32B3	4.87	4.77	0.500	2.11	1.99	1.732	69.00	0.80	2,132,464
48	32B3	33B3	4.77	4.68	0.500	1.99	1.87	1.732	69.00	0.80	2,195,766
49	33B3	34B3	4.68	4.58	0.500	1.87	1.75	1.755	69.00	0.81	2,259,183
50	34B3	35B3	4.58	4.48	0.600	1.65	1.56	1.000	90.00	0.71	2,355,946
51	35B3	36B3	4.48	4.38	0.600	1.56	1.47	1.000	90.00	0.69	2,452,645
52	36B3	37B3	4.38	4.28	0.600	1.47	1.38	1.052	90.00	0.70	2,549,294
53	37B3	38B3	4.28	4.19	0.600	1.38	1.27	1.150	90.00	0.74	2,645,970
54	38B3	39B3	4.19	4.20	0.600	1.27	1.20	1.213	56.00	0.76	2,706,307

Sewer Design for Maximum Sewerage Option I
From Manholes 1A3 & 1A6 to Manhole 3J3

55	39B3	40B3	4.20	4.22	0.600	1.20	1.13	1.285	56.00	0.78	2,766,984
56	40B3	41B3	4.22	4.23	0.600	1.13	1.06	1.364	56.00	0.80	2,828,018
57	41B3	42B3	4.23	4.24	0.600	1.06	0.98	1.428	56.00	0.82	2,889,405
58	42B3	43B3	4.24	4.38	0.600	0.98	0.88	1.458	64.00	0.83	2,960,301
59	43B3	44B3	4.38	4.53	0.600	0.88	0.79	1.489	64.00	0.84	3,032,293
60	44B3	45B3	4.53	4.67	0.600	0.79	0.69	1.520	64.00	0.85	3,105,389
61	45B3	46B3	4.67	4.81	0.600	0.69	0.59	1.533	64.00	0.85	3,179,572
62	46B3	47B3	4.81	4.09	0.600	0.59	0.46	1.547	88.00	0.85	3,280,487
63	47B3	48B3	4.09	3.38	0.600	0.46	0.32	1.547	88.00	0.85	3,377,760
64	48B3	49B3	3.38	3.21	0.600	0.32	0.20	1.560	76.00	0.86	3,460,069
65	49B3	50B3	3.21	3.05	0.600	0.20	0.08	1.560	76.00	0.86	3,542,126
66	50B3	51B3	3.05	3.04	0.600	0.08	-0.04	1.624	75.00	0.88	3,623,292
67	51B3	52B3	3.04	3.03	0.600	-0.04	-0.17	1.694	75.00	0.89	3,705,071
68	52B3	53B3	3.03	3.02	0.600	-0.17	-0.30	1.712	75.00	0.90	3,787,482
69	53B3	54B3	3.02	3.02	0.600	-0.30	-0.42	1.712	75.00	0.90	3,870,555
70	54B3	55B3	3.02	3.01	0.600	-0.42	-0.56	1.779	75.00	0.92	3,954,303
71	55B3	56B3	3.01	3.00	0.600	-0.56	-0.69	1.779	75.00	0.92	4,038,712
72	56B3	57B3	3.00	2.83	0.600	-0.69	-0.89	2.364	85.00	1.06	4,134,846
73	57B3	58B3	2.83	2.67	0.600	-0.89	-1.10	2.442	85.00	1.07	4,231,218
74	58B3	59B3	2.67	2.51	0.600	-1.10	-1.31	2.522	85.00	1.09	4,327,900
75	59B3	60B3	2.51	2.35	0.600	-1.31	-1.53	2.602	85.00	1.11	4,424,933
76	60B3	61B3	2.35	2.18	0.600	-1.53	-1.80	3.089	85.00	1.21	4,522,434
77	61B3	3J3	2.18	2.02	0.600	-1.80	-2.06	3.089	85.00	1.21	4,620,527

TOTAL PIPE LENGTH OF THE NETWORK = 5346 m
EXECUTION TIME (EXCLUDE THE TIME FOR FINAL RESULT PRINT OUT) = 00:35:16 (2116 SECONDS)

Manhole Cost = 92 x 10,000 + (37 + 71) x 12,500 = 2,270,000.-

Sewer Design for Maximum Sewerage Option I
From Manhole 2J3 to Manhole 70B1

DATA Rec.No	PIPE SECTION U.Node	D.Node	GROUND ELE.(m) UPstre.	DOWNstr.	PIPE DIAM (m)	INVERT ELE.(m) UPstre.	DOWNstr.	SLOPE (m/km)	LENGTH (m)	VELOCITY (m/sec)	ACC. COST (Baht)
4	1A1	46B1	1.45	1.73	0.700	-1.25	-1.31	1.045	61.00	0.78	74,428
5	46B1	47B1	1.73	1.81	0.700	-1.31	-1.38	1.045	61.00	0.78	150,001
6	47B1	48B1	1.81	1.89	0.700	-1.38	-1.44	1.045	61.00	0.78	226,250
7	48B1	49B1	1.89	1.89	0.700	-1.44	-1.50	1.045	61.00	0.78	302,985
8	49B1	50B1	1.89	1.90	0.700	-1.50	-1.57	1.107	61.00	0.80	380,052
9	50B1	51B1	1.90	1.90	0.700	-1.57	-1.63	1.107	54.00	0.80	448,561
10	51B1	52B1	1.90	1.90	0.700	-1.63	-1.69	1.107	54.00	0.80	517,319
11	52B1	53B1	1.90	1.90	0.700	-1.69	-1.77	1.210	61.00	0.84	595,303
12	53B1	54B1	1.90	1.91	0.800	-1.87	-1.93	1.000	61.00	0.89	683,486
13	54B1	55B1	1.91	1.91	0.800	-1.93	-1.99	1.000	61.00	0.89	772,000
14	55B1	56B1	1.91	1.91	0.800	-1.99	-2.05	1.000	61.00	0.89	860,822
15	56B1	57B1	1.91	1.92	0.800	-2.05	-2.10	1.000	54.00	0.89	939,729
16	57B1	58B1	1.92	2.20	0.800	-2.10	-2.16	1.000	60.00	0.90	1,028,404
17	58B1	59B1	2.20	2.51	0.800	-2.16	-2.22	1.000	60.00	0.89	1,118,836
18	59B1	60B1	2.51	2.48	0.800	-2.22	-2.31	1.000	84.00	0.89	1,246,910
19	60B1	61B1	2.48	2.46	0.800	-2.31	-2.39	1.000	84.00	0.89	1,375,393
20	61B1	62B1	2.46	2.44	0.800	-2.39	-2.45	1.000	63.00	0.89	1,472,033
21	62B1	63B1	2.44	2.42	0.800	-2.45	-2.52	1.000	63.00	0.89	1,568,897
22	63B1	64B1	2.42	2.40	0.800	-2.52	-2.58	1.000	63.00	0.89	1,665,984
23	64B1	65B1	2.40	2.38	0.800	-2.58	-2.64	1.000	63.00	0.89	1,763,294
24	65B1	66B1	2.38	2.35	0.800	-2.64	-2.71	1.000	63.00	0.89	1,860,802
25	66B1	67B1	2.35	2.33	0.800	-2.71	-2.77	1.000	63.00	0.89	1,958,508
26	67B1	68B1	2.33	2.02	0.800	-2.77	-2.82	1.000	56.00	0.89	2,044,870
27	68B1	69B1	2.02	2.05	0.800	-2.82	-2.89	1.000	64.00	0.89	2,143,147
28	69B1	70B1	2.05	2.00	1.000	-3.09	-4.29	1.000	1200.00	1.02	4,461,844

TOTAL PIPE LENGTH OF THE NETWORK = 2697 m
EXECUTION TIME (EXCLUDE THE TIME FOR FINAL RESULT PRINT OUT) = 00:06:26 (386 SECONDS)

Manhole Cost = 90 x 12,500 = 1,125,000.-

APPENDIX 4.2

Design Criteria, Sewer Network Data and Sewer Design for Maximum Sewerage Option II

Design Criteria for Maximum Sewerage Option II

MIN. SLOPE FOR CONSTRUCTION	=	0.001
MINIMUM COVERING	=	2.00 m
MAX. EXCAVATION	=	5.00 m
MANNING ` n '	=	0.013
MINIMUM VELOCITY	=	0.50 m/s
MAXIMUM VELOCITY	=	3.00 m/s
WASTE WATER PEAK FACTOR	=	1.75**
RAINFALL CONSTANT K2	=	32.00

NO. OF AVAILABLE PIPES = 8

AVAILABLE PIPE DIAMETER ARE:

0.400 m	0.700 m	1.000 m
0.500 m	0.800 m	1.200 m
0.600 m	0.900 m	

** - Composite peak factor considering Peak Flow and Infiltration based on 2 Q.

Sewer Network Data for Maximum Sewerage Option II
From Manhole 1A1 to Manhole 24B1

****** SEWER NETWORK DATA ******

(U - UPSTREAM , D - DOWNSTREAM , Q - AVERAGE FLOW)
(ELE in m, LENGTH in m, Q in l/s)

U. NODE	D. NODE	U. ELE	D. ELE	LENGTH	Q
1A1	2B1	8.37	6.00	80.0	0.1
2B1	3B1	6.00	5.70	80.0	0.0
3B1	4B1	5.70	4.35	80.0	1.8
4B1	1J3	4.35	3.03	80.0	2.0
1A4	2B4	10.00	9.52	75.0	0.4
2B4	3B4	9.52	9.04	75.0	0.4
3B4	4B4	9.04	8.56	75.0	0.4
4B4	5B4	8.56	8.08	75.0	0.4
5B4	6B4	8.08	7.60	75.0	1.0
6B4	7B4	7.60	7.12	75.0	1.0
7B4	8B4	7.12	6.64	75.0	0.4
8B4	9B4	6.64	6.16	75.0	0.4
9B4	10B4	6.16	5.68	75.0	0.4
10B4	11B4	5.68	5.20	75.0	0.4
11B4	12B4	5.20	5.04	75.0	0.4
12B4	13B4	5.04	4.88	75.0	0.4
13B4	14B4	4.88	4.77	50.0	0.4
14B4	15B4	4.77	4.67	50.0	0.4
15B4	16B4	4.67	4.54	60.0	0.4
16B4	17B4	4.54	4.43	50.0	0.4
17B4	18B4	4.43	4.33	50.0	0.4
18B4	19B4	4.33	4.17	75.0	0.4
19B4	20B4	4.17	4.02	72.0	0.0
20B4	21B4	4.02	3.86	72.0	0.0
21B4	22B4	3.86	3.71	72.0	0.8
22B4	23B4	3.71	3.56	72.0	0.0
23B4	24B4	3.56	3.43	60.0	0.8
24B4	25B4	3.43	3.31	60.0	0.0
25B4	26B4	3.31	3.18	60.0	0.8
26B4	1J3	3.18	3.03	70.0	0.0
1J3	6B1	3.03	2.92	66.0	6.6

DETAIL OF THIS 2 BRANCHES JUNCTION
FROM NODE: 4B1 / 26B4

Sewer Network Data for Maximum Sewerage Option II
From Manhole 1A1 to Manhole 24B1

U. NODE	D. NODE	U. ELE	D. ELE	LENGTH	Q
6B1	7B1	2.92	2.81	66.0	2.8
7B1	8B1	2.81	2.70	66.0	2.8
8B1	9B1	2.70	2.58	66.0	1.8
9B1	10B1	2.58	2.52	72.0	1.8
10B1	11B1	2.52	2.47	72.0	2.8
11B1	12B1	2.47	2.42	72.0	2.8
12B1	13B1	2.42	2.37	72.0	4.8
13B1	14B1	2.37	2.31	72.0	2.8
14B1	7J3	2.31	2.26	72.0	0.0
1A2	2B2	2.00	2.04	61.0	2.6
2B2	3B2	2.04	2.08	61.0	2.4
3B2	4B2	2.08	2.13	61.0	2.4
4B2	5B2	2.13	2.17	61.0	2.4
5B2	6B2	2.17	2.21	61.0	2.4
6B2	4J3	2.21	2.26	61.0	3.4
4J3	16B1	2.26	2.26	64.0	0.6

DETAIL OF THIS 2 BRANCHES JUNCTION
FROM NODE: 14B1 / 6B2

U. NODE	D. NODE	U. ELE	D. ELE	LENGTH	Q
16B1	17B1	2.26	2.26	64.0	2.6
17B1	18B1	2.26	2.26	64.0	2.0
18B1	19B1	2.26	2.26	64.0	2.0
19B1	20B1	2.26	2.34	56.0	2.0
20B1	21B1	2.34	2.42	56.0	0.6
21B1	22B1	2.42	2.50	56.0	2.6
22B1	23B1	2.50	2.58	56.0	2.6
23B1	24B1	2.58	2.68	66.0	0.0

Sewer Network Data for Maximum Sewerage Option II
From Manhole 1A3 to Manhole 8B3

****** SEWER NETWORK DATA ******

(U - UPSTREAM , D - DOWNSTREAM , Q - AVERAGE FLOW)
(ELE in m, LENGTH in m, Q in l/s)

U. NODE	D. NODE	U. ELE	D. ELE	LENGTH	Q
1A3	2B3	1.00	1.20	75.0	3.4
2B3	3B3	1.20	1.40	75.0	2.4
3B3	4B3	1.40	1.60	75.0	1.2
4B3	5B3	1.60	1.80	75.0	1.2
5B3	6B3	1.80	2.00	75.0	1.2
6B3	7B3	2.00	2.20	75.0	4.6
7B3	8B3	2.20	2.40	75.0	4.6

Sewer Network Data for Maximum Sewerage Option II
From Manhole 8B3 to Manhole 5J3

****** SEWER NETWORK DATA ******

(U - UPSTREAM , D - DOWNSTREAM , Q - AVERAGE FLOW)
(ELE in m, LENGTH in m, Q in l/s)

U. NODE	D. NODE	U. ELE	D. ELE	LENGTH	Q
1A3	8B3	2.40	2.60	75.0	24.8
8B3	9B3	2.60	2.80	75.0	0.0
9B3	10B3	2.80	2.95	75.0	1.6
10B3	6J3	2.95	3.00	75.0	1.6
1A1	25B1	2.68	2.77	66.0	76.9
25B1	26B1	2.77	2.86	66.0	3.0
26B1	6J3	2.86	2.95	66.0	1.8
6J3	28B1	2.95	3.25	72.0	3.0

DETAIL OF THIS 2 BRANCHES JUNCTION
FROM NODE: 10B3 / 26B1

U. NODE	D. NODE	U. ELE	D. ELE	LENGTH	Q
28B1	29B1	3.25	3.50	72.0	1.4
29B1	30B1	3.50	3.35	76.0	1.0
30B1	31B1	3.35	3.21	76.0	4.6
31B1	32B1	3.21	3.07	76.0	3.0
32B1	5J3	3.07	2.92	76.0	3.0

Sewer Network Data for Maximum Sewerage Option II
From Manhole 1A5 to Manhole 10B5

****** SEWER NETWORK DATA ******

(U - UPSTREAM , D - DOWNSTREAM , Q - AVERAGE FLOW)
(ELE in m, LENGTH in m, Q in l/s)

U. NODE	D. NODE	U. ELE	D. ELE	LENGTH	Q
1A5	2B5	1.00	1.20	64.0	1.6
2B5	3B5	1.20	1.40	64.0	3.0
3B5	4B5	1.40	1.64	64.0	3.0
4B5	5B5	1.64	1.88	64.0	3.0
5B5	6B5	1.88	2.00	64.0	3.0
6B5	7B5	2.00	2.28	64.0	3.0
7B5	8B5	2.28	2.50	64.0	3.0
8B5	9B5	2.50	2.70	64.0	4.4
9B5	10B5	2.70	2.81	32.0	3.2

Sewer Network Data for Maximum Sewerage Option II
From Manhole 33B1 to Manhole 45B1

****** SEWER NETWORK DATA ******

(U - UPSTREAM , D - DOWNSTREAM , Q - AVERAGE FLOW)
(ELE in m, LENGTH in m, Q in l/s)

U. NODE	D. NODE	U. ELE	D. ELE	LENGTH	Q
1A1	34B1	2.92	3.01	72.0	155.9
34B1	35B1	3.01	3.10	72.0	3.0
35B1	36B1	3.10	3.20	72.0	3.0
36B1	37B1	3.20	3.29	72.0	2.0
37B1	38B1	3.29	3.11	72.0	1.6
38B1	39B1	3.11	2.94	72.0	0.0
39B1	40B1	2.94	2.44	80.0	5.6
40B1	41B1	2.44	1.94	80.0	0.0
41B1	42B1	1.94	1.87	70.0	0.0
42B1	43B1	1.87	1.80	70.0	0.0
43B1	44B1	1.80	1.73	70.0	0.0
44B1	45B1	1.73	1.65	70.0	0.0

Sewer Design for Maximum Sewerage Option II
From Manhole 1A1 to Manhole 24B1

DATA	PIPE SECTION		GROUND ELE.(m)		PIPE DIAM	INVERT ELE.(m)		SLOPE	LENGTH	VELOCITY	ACC. COST
Rec.No	U.Node	D.Node	UPstre.	DOWNstr.	(m)	UPstre.	DOWNstr.	(m/km)	(m)	(m/sec)	(Baht)
4	1A1	2B1	8.37	6.00	0.300	6.07	3.65	30.300	80.00	0.50	49,839
5	2B1	3B1	6.00	5.70	0.300	3.65	1.22	30.300	80.00	0.50	104,469
6	3B1	4B1	5.70	4.35	0.300	1.22	0.87	4.410	80.00	0.50	161,579
7	4B1	1J3	4.35	3.03	0.300	0.87	0.66	2.573	80.00	0.50	214,043
8	1A4	2B4	10.00	9.52	0.300	7.70	6.51	15.860	75.00	0.50	48,076
9	2B4	3B4	9.52	9.04	0.300	6.51	5.85	8.770	75.00	0.50	97,982
10	3B4	4B4	9.04	8.56	0.300	5.85	5.36	6.590	75.00	0.50	148,283
11	4B4	5B4	8.56	8.08	0.300	5.36	4.99	4.940	75.00	0.50	198,389
12	5B4	6B4	8.08	7.60	0.300	4.99	4.72	3.590	75.00	0.50	247,834
13	6B4	7B4	7.60	7.12	0.300	4.72	4.51	2.802	75.00	0.50	296,287
14	7B4	8B4	7.12	6.64	0.300	4.51	4.32	2.573	75.00	0.50	343,592
15	8B4	9B4	6.64	6.16	0.300	4.32	3.86	6.075	75.00	0.71	390,255
16	9B4	10B4	6.16	5.68	0.300	3.86	3.38	6.400	75.00	0.73	436,868
17	10B4	11B4	5.68	5.20	0.300	3.38	2.90	6.400	75.00	0.76	483,480
18	11B4	12B4	5.20	5.04	0.300	2.90	2.74	2.133	75.00	0.51	530,093
19	12B4	13B4	5.04	4.88	0.300	2.74	2.58	2.133	75.00	0.52	576,705
20	13B4	14B4	4.88	4.77	0.300	2.58	2.47	2.200	50.00	0.54	607,780
21	14B4	15B4	4.77	4.67	0.300	2.47	2.37	2.000	50.00	0.53	638,855
22	15B4	16B4	4.67	4.54	0.300	2.37	2.24	2.167	60.00	0.55	676,145
23	16B4	17B4	4.54	4.43	0.300	2.24	2.13	2.200	50.00	0.56	707,220
24	17B4	18B4	4.43	4.33	0.300	2.13	2.03	2.000	50.00	0.55	738,295
25	18B4	19B4	4.33	4.17	0.300	2.03	1.87	2.133	75.00	0.57	784,908
26	19B4	20B4	4.17	4.02	0.300	1.87	1.72	2.083	72.00	0.56	829,656
27	20B4	21B4	4.02	3.86	0.300	1.72	1.56	2.222	72.00	0.58	874,404
28	21B4	22B4	3.86	3.71	0.300	1.56	1.41	2.083	72.00	0.58	919,152
29	22B4	23B4	3.71	3.56	0.300	1.41	1.26	2.083	72.00	0.58	963,900
30	23B4	24B4	3.56	3.43	0.300	1.26	1.13	2.167	60.00	0.60	1,001,190
31	24B4	25B4	3.43	3.31	0.300	1.13	1.01	2.000	60.00	0.58	1,038,480

Sewer Design for Maximum Sewerage Option II
From Manhole 1A1 to Manhole 24B1

32	25B4	26B4	3.31	3.18	0.300	1.01	0.88	2.167	60.00	0.61	1,075,770
33	26B4	1J3	3.18	3.03	0.300	0.88	0.73	2.143	70.00	0.61	1,119,275
34	1J3	6B1	3.03	2.92	0.300	0.66	0.57	1.483	66.00	0.53	1,374,557
35	6B1	7B1	2.92	2.81	0.300	0.57	0.44	1.899	66.00	0.60	1,415,801
36	7B1	8B1	2.81	2.70	0.300	0.44	0.28	2.366	66.00	0.67	1,457,158
37	8B1	9B1	2.70	2.58	0.300	0.28	0.11	2.693	66.00	0.71	1,498,703
38	9B1	10B1	2.58	2.52	0.300	0.11	-0.11	3.042	72.00	0.76	1,544,454
39	10B1	11B1	2.52	2.47	0.300	-0.11	-0.37	3.626	72.00	0.82	1,590,938
40	11B1	12B1	2.47	2.42	0.300	-0.37	-0.68	4.261	72.00	0.89	1,638,348
41	12B1	13B1	2.42	2.37	0.400	-0.78	-0.87	1.179	72.00	0.57	1,694,291
42	13B1	14B1	2.37	2.31	0.400	-0.87	-0.96	1.346	72.00	0.61	1,750,377
43	14B1	7J3	2.31	2.26	0.400	-0.96	-1.06	1.346	72.00	0.61	1,806,629
44	1A2	2B2	2.00	2.04	0.300	-0.30	-0.52	3.590	61.00	0.50	38,346
45	2B2	3B2	2.04	2.08	0.300	-0.52	-0.65	2.140	61.00	0.50	77,412
46	3B2	4B2	2.08	2.13	0.300	-0.65	-0.75	1.647	61.00	0.50	117,017
47	4B2	5B2	2.13	2.17	0.300	-0.75	-0.83	1.361	61.00	0.50	157,081
48	5B2	6B2	2.17	2.21	0.300	-0.83	-0.91	1.210	61.00	0.50	197,542
49	6B2	4J3	2.21	2.26	0.300	-0.91	-0.97	1.000	61.00	0.50	238,380
50	4J3	16B1	2.26	2.26	0.400	-1.07	-1.23	2.529	64.00	0.83	2,095,409
51	16B1	17B1	2.26	2.26	0.400	-1.23	-1.41	2.754	64.00	0.87	2,146,403
52	17B1	18B1	2.26	2.26	0.400	-1.41	-1.59	2.933	64.00	0.90	2,198,037
53	18B1	19B1	2.26	2.26	0.400	-1.59	-1.79	3.118	64.00	0.93	2,250,353
54	19B1	20B1	2.26	2.34	0.500	-1.89	-1.95	1.006	56.00	0.61	2,307,003
55	20B1	21B1	2.34	2.42	0.500	-1.95	-2.01	1.024	56.00	0.62	2,364,159
56	21B1	22B1	2.42	2.50	0.500	-2.01	-2.07	1.102	56.00	0.64	2,421,831
57	22B1	23B1	2.50	2.58	0.500	-2.07	-2.13	1.184	56.00	0.66	2,480,035
58	23B1	24B1	2.58	2.68	0.500	-2.13	-2.21	1.184	66.00	0.66	2,549,339

TOTAL PIPE LENGTH OF THE NETWORK = 3701 m

Manhole Cost = 127 x 10,000 + 21 x 12,500 = 1,532,500.-

Sewer Design for Maximum Sewerage Option II
From Manhole 1A3 to Manhole 8B3

DATA	PIPE SECTION		GROUND ELE.(m)		PIPE DIAM	INVERT ELE.(m)		SLOPE	LENGTH	VELOCITY	ACC. COST
Rec.No	U.Node	D.Node	UPstre.	DOWNstr.	(m)	UPstre.	DOWNstr.	(m/km)	(m)	(m/sec)	(Baht)
4	1A3	2B3	1.00	1.20	0.300	-1.30	-1.51	2.810	75.00	0.50	47,460
5	2B3	3B3	1.20	1.40	0.300	-1.51	-1.66	1.940	75.00	0.50	96,479
6	3B3	4B3	1.40	1.60	0.300	-1.66	-1.78	1.687	75.00	0.50	146,885
7	4B3	5B3	1.60	1.80	0.300	-1.78	-1.90	1.512	75.00	0.50	198,610
8	5B3	6B3	1.80	2.00	0.300	-1.90	-2.00	1.391	75.00	0.50	251,609
9	6B3	7B3	2.00	2.20	0.300	-2.00	-2.09	1.167	75.00	0.50	305,829
10	7B3	8B3	2.20	2.40	0.300	-2.09	-2.18	1.236	75.00	0.50	361,246

TOTAL PIPE LENGTH OF THE NETWORK = 525 m
EXECUTION TIME (EXCLUDE THE TIME FOR FINAL RESULT PRINT OUT) = 00:00:25 (25 SECONDS)

Manhole Cost = 21 x 10,000 = 210,000.-

Sewer Design for Maximum Sewerage Option II
From Manhole 8B3 to Manhole 5J3

DATA Rec.No	PIPE SECTION U.Node	D.Node	GROUND ELE.(m) UPstre.	DOWNstr.	PIPE DIAM (m)	INVERT ELE.(m) UPstre.	DOWNstr.	SLOPE (m/km)	LENGTH (m)	VELOCITY (m/sec)	ACC. COST (Baht)
4	1A3	8B3	2.40	2.60	0.300	0.10	-0.05	2.014	75.00	0.61	47,337
5	8B3	9B3	2.60	2.80	0.300	-0.05	-0.20	2.014	75.00	0.61	96,121
6	9B3	10B3	2.80	2.95	0.300	-0.20	-0.37	2.282	75.00	0.65	146,292
7	10B3	6J3	2.95	3.00	0.400	-0.47	-0.55	1.000	75.00	0.56	205,671
8	1A1	25B1	2.68	2.77	0.400	0.28	0.00	4.175	66.00	1.07	48,976
9	25B1	26B1	2.77	2.86	0.400	0.00	-0.29	4.507	66.00	1.11	99,318
10	26B1	6J3	2.86	2.95	0.400	-0.29	-0.60	4.713	66.00	1.14	151,091
11	6J3	28B1	2.95	3.25	0.500	-0.70	-0.90	2.728	72.00	1.00	428,082
12	28B1	29B1	3.25	3.50	0.500	-0.90	-1.10	2.796	72.00	1.02	501,654
13	29B1	30B1	3.50	3.35	0.500	-1.10	-1.32	2.845	76.00	1.03	580,611
14	30B1	31B1	3.35	3.21	0.500	-1.32	-1.55	3.077	76.00	1.07	659,969
15	31B1	32B1	3.21	3.07	0.500	-1.55	-1.80	3.233	76.00	1.09	739,829
16	32B1	5J3	3.07	2.92	0.500	-1.80	-2.06	3.394	76.00	1.12	820,224

TOTAL PIPE-LENGTH OF THE NETWORK = 946 m
EXECUTION TIME (EXCLUDE THE TIME FOR FINAL RESULT PRINT OUT) = 00:02:53 (173 SECONDS)

Manhole Cost = 9 x 10,000 + 29 x 12,500 = 452,500.-

Sewer Design for Maximum Sewerage Option II
From Manhole 1A5 to Manhole 10B5

DATA Rec.No	PIPE SECTION U.Node	PIPE SECTION D.Node	GROUND ELE.(m) UPstre.	GROUND ELE.(m) DOWNstr.	PIPE DIAM (m)	INVERT ELE.(m) UPstre.	INVERT ELE.(m) DOWNstr.	SLOPE (m/km)	LENGTH (m)	VELOCITY (m/sec)	ACC. COST (Baht)
4	1A5	2B5	1.00	1.20	0.300	-1.30	-1.62	4.950	64.00	0.50	40,686
5	2B5	3B5	1.20	1.40	0.300	-1.62	-1.76	2.254	64.00	0.50	82,887
6	3B5	4B5	1.40	1.64	0.300	-1.76	-1.86	1.580	64.00	0.50	126,294
7	4B5	5B5	1.64	1.88	0.300	-1.86	-1.94	1.284	64.00	0.50	170,869
8	5B5	6B5	1.88	2.00	0.300	-1.94	-2.02	1.167	64.00	0.50	216,353
9	6B5	7B5	2.00	2.28	0.300	-2.02	-2.09	1.167	64.00	0.50	262,804
10	7B5	8B5	2.28	2.50	0.300	-2.09	-2.18	1.284	64.00	0.50	310,412
11	8B5	9B5	2.50	2.70	0.300	-2.18	-2.30	1.886	64.00	0.59	359,115
12	9B5	10B5	2.70	2.81	0.300	-2.30	-2.37	2.423	32.00	0.67	383,914

TOTAL PIPE LENGTH OF THE NETWORK = 544 m
EXECUTION TIME (EXCLUDE THE TIME FOR FINAL RESULT PRINT OUT) = 00:00:31 (31 SECONDS)

Manhole Cost = 22 x 10,000 = 220,000.-

Sewer Design for Maximum Sewerage Option II
From Manhole 33B1 to Manhole 45B1

DATA Rec.No	PIPE SECTION U.Node	D.Node	GROUND ELE.(m) UPstre.	DOWNstr.	PIPE DIAM (m)	INVERT ELE.(m) UPstre.	DOWNstr.	SLOPE (m/km)	LENGTH (m)	VELOCITY (m/sec)	ACC. COST (Baht)
4	1A1	34B1	2.92	3.01	0.600	0.32	0.18	1.974	72.00	0.96	76,334
5	34B1	35B1.	3.01	3.10	0.600	0.18	0.03	2.051	72.00	0.98	153,878
6	35B1	36B1	3.10	3.20	0.600	0.03	-0.12	2.129	72.00	1.00	232,685
7	36B1	37B1	3.20	3.29	0.600	-0.12	-0.28	2.182	72.00	1.01	312,780
8	37B1	38B1	3.29	3.11	0.600	-0.28	-0.44	2.225	72.00	1.02	393,461
9	38B1	39B1	3.11	2.94	0.600	-0.44	-0.60	2.225	72.00	1.02	474,065
10	39B1	40B1	2.94	2.44	0.700	-0.70	-0.78	1.045	80.00	0.78	575,128
11	40B1	41B1	2.44	1.94	0.700	-0.78	-0.87	1.045	80.00	0.78	673,626
12	41B1	42B1	1.94	1.87	0.700	-0.87	-0.94	1.045	70.00	0.78	758,699
13	42B1	43B1	1.87	1.80	0.700	-0.94	-1.01	1.045	70.00	0.78	843,788
14	43B1	44B1	1.80	1.73	0.700	-1.01	-1.09	1.045	70.00	0.78	928,894
15	44B1	45B1	1.73	1.65	0.700	-1.09	-1.16	1.045	70.00	0.78	1,013,990

TAL PIPE LENGTH OF THE NETWORK = 872 m
EXECUTION TIME (EXCLUDE THE TIME FOR FINAL RESULT PRINT OUT) = 00:01:53 (113 SECONDS)

Manhole Cost = 29 x 12,500 = 362,500.-

Sewer Design for Maximum Sewerage Option II
From Manhole 2J3 to Manhole 70B1

DATA Rec.No	PIPE SECTION U.Node	PIPE SECTION D.Node	GROUND ELE.(m) UPstre.	GROUND ELE.(m) DOWNstr.	PIPE DIAM (m)	INVERT ELE.(m) UPstre.	INVERT ELE.(m) DOWNstr.	SLOPE (m/km)	LENGTH (m)	VELOCITY (m/sec)	ACC. COST (Baht)
4	1A1	46B1	1.45	1.73	0.700	-1.16	-1.22	1.045	61.00	0.78	74,005
5	46B1	47B1	1.73	1.81	0.700	-1.22	-1.29	1.045	61.00	0.78	149,156
6	47B1	48B1	1.81	1.89	0.700	-1.29	-1.35	1.045	61.00	0.78	224,981
7	48B1	49B1	1.89	1.89	0.700	-1.35	-1.41	1.045	61.00	0.78	301,294
8	49B1	50B1	1.89	1.90	0.700	-1.41	-1.48	1.107	61.00	0.80	377,939
9	50B1	51B1	1.90	1.90	0.700	-1.48	-1.54	1.107	54.00	0.80	446,074
10	51B1	52B1	1.90	1.90	0.700	-1.54	-1.60	1.107	54.00	0.80	514,457
11	52B1	53B1	1.90	1.90	0.700	-1.60	-1.68	1.210	61.00	0.84	592,018
12	53B1	54B1	1.90	1.91	0.700	-1.68	-1.75	1.210	61.00	0.84	669,950
13	54B1	55B1	1.91	1.91	0.700	-1.75	-1.82	1.210	61.00	0.84	748,252
14	55B1	56B1	1.91	1.91	0.700	-1.82	-1.90	1.210	61.00	0.84	826,901
15	56B1	57B1	1.91	1.92	0.700	-1.90	-1.96	1.210	54.00	0.84	896,834
16	57B1	58B1	1.92	2.20	0.700	-1.96	-2.04	1.331	60.00	0.88	975,543
17	58B1	59B1	2.20	2.51	0.700	-2.04	-2.13	1.418	60.00	0.91	1,055,996
18	59B1	60B1	2.51	2.48	0.700	-2.13	-2.25	1.418	84.00	0.91	1,170,196
19	60B1	61B1	2.48	2.46	0.700	-2.25	-2.37	1.418	84.00	0.91	1,285,004
20	61B1	62B1	2.46	2.44	0.700	-2.37	-2.46	1.481	63.00	0.93	1,371,529
21	62B1	63B1	2.44	2.42	0.700	-2.46	-2.55	1.481	63.00	0.93	1,458,409
22	63B1	64B1	2.42	2.40	0.700	-2.55	-2.65	1.481	63.00	0.93	1,545,645
23	64B1	65B1	2.40	2.38	0.700	-2.65	-2.74	1.481	63.00	0.93	1,633,237
24	65B1	66B1	2.38	2.35	0.800	-2.84	-2.90	1.000	63.00	0.89	1,731,764
25	66B1	67B1	2.35	2.33	0.800	-2.90	-2.97	1.000	63.00	0.89	1,830,489
26	67B1	68B1	2.33	2.02	0.800	-2.97	-3.02	1.000	56.00	0.89	1,917,758
27	68B1	69B1	2.02	2.05	0.800	-3.02	-3.09	1.000	64.00	0.89	2,017,070
28	69B1	70B1	2.05	2.00	1.000	-3.29	-4.49	1.000	1200.00	1.02	4,357,776

TOTAL PIPE LENGTH OF THE NETWORK = 2697 m
EXECUTION TIME (EXCLUDE THE TIME FOR FINAL RESULT PRINT OUT) = 00:06:08 (368 SECONDS)

Manhole Cost = 90 x 12,500 = 1,125,000.-

APPENDIX 4.3

Design Criteria, Sewer Network Data and Sewer Design for Minimum Sewerage Option

Design Criteria for Minimum Sewerage Option

MIN. SLOPE FOR CONSTRUCTION	=	0.001
MINIMUM COVERING	=	2.00 m
MAX. EXCAVATION	=	5.00 m
MANNING ` n '	=	0.013
MINIMUM VELOCITY	=	0.50 m/s
MAXIMUM VELOCITY	=	3.00 m/s
WASTE WATER PEAK FACTOR	=	1.75**
RAINFALL CONSTANT K2	=	32.00

NO. OF AVAILABLE PIPES = 8

AVAILABLE PIPE DIAMETER ARE:

0.400 m	0.700 m	1.000 m
0.500 m	0.800 m	1.200 m
0.600 m	0.900 m	

** - Composite peak factor considering Peak Flow and Infiltration based on 2 Q.

Sewer Network Data for Minimum Sewerage Option
From Manholes **1A1 & 1A4 to Manhole 48B1**

****** SEWER NETWORK DATA ******

(U - UPSTREAM , D - DOWNSTREAM , Q - AVERAGE FLOW)
(ELE in m, LENGTH in m, Q in l/s)

U. NODE	D. NODE	U. ELE	D. ELE	LENGTH	Q
1A1	2B1	8.37	6.00	80.0	0.1
2B1	3B1	6.00	5.70	80.0	0.0
3B1	4B1	5.70	4.35	80.0	0.8
4B1	1J3	4.35	3.03	80.0	0.0
1A4	2B4	10.00	9.52	75.0	0.4
2B4	3B4	9.52	9.04	75.0	0.4
3B4	4B4	9.04	8.56	75.0	0.4
4B4	5B4	8.56	8.08	75.0	0.4
5B4	6B4	8.08	7.60	75.0	1.0
6B4	7B4	7.60	7.12	75.0	1.0
7B4	8B4	7.12	6.64	75.0	0.4
8B4	9B4	6.64	6.16	75.0	0.4
9B4	10B4	6.16	5.68	75.0	0.4
10B4	11B4	5.68	5.20	75.0	0.4
11B4	12B4	5.20	5.04	75.0	0.4
12B4	13B4	5.04	4.88	75.0	0.4
13B4	14B4	4.88	4.77	50.0	0.4
14B4	15B4	4.77	4.67	50.0	0.4
15B4	16B4	4.67	4.54	60.0	0.4
16B4	17B4	4.54	4.43	50.0	0.4
17B4	18B4	4.43	4.33	50.0	0.4
18B4	19B4	4.33	4.17	75.0	0.4
19B4	20B4	4.17	4.02	72.0	0.0
20B4	21B4	4.02	3.86	72.0	0.0
21B4	22B4	3.86	3.71	72.0	0.8
22B4	23B4	3.71	3.56	72.0	0.0
23B4	24B4	3.56	3.43	60.0	0.8
24B4	25B4	3.43	3.31	60.0	0.0
25B4	26B4	3.31	3.18	60.0	0.8
26B4	1J3	3.18	3.03	70.0	0.0
1J3	6B1	3.03	2.92	66.0	4.6

DETAIL OF THIS 2 BRANCHES JUNCTION
FROM NODE: 4B1 / 26B4

Sewer Network Data for Minimum Sewerage Option
From Manholes **1A1 & 1A4 to Manhole 48B1**

U. NODE	D. NODE	U. ELE	D. ELE	LENGTH	Q
6B1	7B1	2.92	2.81	66.0	0.8
7B1	8B1	2.81	2.70	66.0	0.8
8B1	9B1	2.70	2.58	66.0	0.8
9B1	10B1	2.58	2.52	72.0	0.8
10B1	11B1	2.52	2.47	72.0	0.8
11B1	12B1	2.47	2.42	72.0	0.8
12B1	13B1	2.42	2.37	72.0	0.8
13B1	14B1	2.37	2.31	72.0	0.8
14B1	15B1	2.31	2.26	72.0	0.0
15B1	16B1	2.26	2.24	64.0	0.0
16B1	17B1	2.24	2.20	64.0	0.0
17B1	18B1	2.20	2.16	64.0	0.0
18B1	19B1	2.16	2.10	64.0	0.0
19B1	20B1	2.10	2.05	56.0	0.0
20B1	21B1	2.05	2.00	56.0	0.0
21B1	22B1	2.00	1.89	60.0	4.8
22B1	23B1	1.89	1.78	60.0	2.4
23B1	24B1	1.78	1.67	56.0	2.4
24B1	25B1	1.67	1.55	56.0	2.4
25B1	26B1	1.55	1.44	60.0	2.4
26B1	27B1	1.44	1.33	60.0	3.4
27B1	28B1	1.33	1.22	60.0	3.4
28B1	29B1	1.22	1.11	60.0	2.4
29B1	30B1	1.11	1.00	56.0	1.2
30B1	31B1	1.00	1.00	78.0	2.4
31B1	32B1	1.00	1.00	78.0	1.2
32B1	33B1	1.00	1.00	78.0	4.6
33B1	34B1	1.00	1.00	78.0	4.6
34B1	35B1	1.00	1.00	78.0	6.2
35B1	36B1	1.00	1.00	78.0	0.0
36B1	37B1	1.00	1.00	60.0	1.6
37B1	38B1	1.00	1.00	60.0	1.6
38B1	39B1	1.00	1.00	52.0	1.6
39B1	40B1	1.00	1.00	52.0	3.0
40B1	41B1	1.00	1.00	60.0	3.0
41B1	42B1	1.00	1.00	60.0	3.0
42B1	43B1	1.00	1.00	60.0	0.0
43B1	44B1	1.00	1.00	60.0	3.0
44B1	45B1	1.00	1.00	52.0	3.0
45B1	46B1	1.00	1.22	52.0	4.4
46B1	47B1	1.22	1.44	60.0	1.6
47B1	48B1	1.44	1.65	60.0	1.6

Sewer Network Data for Minimum Sewerage Option
From Manhole 1A3 to Manhole 3J3

****** SEWER NETWORK DATA ******

(U - UPSTREAM , D - DOWNSTREAM , Q - AVERAGE FLOW)
(ELE in m, LENGTH in m, Q in l/s)

U. NODE	D. NODE	U. ELE	D. ELE	LENGTH	Q
1A3	36B3	4.48	4.38	90.0	2.2
36B3	37B3	4.38	4.28	90.0	2.2
37B3	38B3	4.28	4.19	90.0	3.6
38B3	39B3	4.19	4.20	56.0	0.6
39B3	40B3	4.20	4.22	56.0	0.6
40B3	41B3	4.22	4.23	56.0	2.0
41B3	42B3	4.23	4.24	56.0	1.2
42B3	43B3	4.24	4.38	64.0	0.6
43B3	44B3	4.38	4.53	64.0	0.6
44B3	45B3	4.53	4.67	64.0	0.6
45B3	46B3	4.67	4.81	64.0	0.6
46B3	47B3	4.81	4.09	88.0	0.6
47B3	48B3	4.09	3.38	88.0	0.0
48B3	49B3	3.38	3.21	76.0	0.6
49B3	50B3	3.21	3.05	76.0	0.0
50B3	51B3	3.05	3.04	75.0	0.0
51B3	52B3	3.04	3.03	75.0	0.0
52B3	53B3	3.03	3.02	75.0	0.0
53B3	54B3	3.02	3.02	75.0	0.0
54B3	55B3	3.02	3.01	75.0	0.0
55B3	56B3	3.01	3.00	75.0	0.0
56B3	57B3	3.00	2.83	85.0	0.0
57B3	58B3	2.83	2.67	85.0	0.0
58B3	59B3	2.67	2.51	85.0	0.0
59B3	60B3	2.51	2.35	85.0	0.0
60B3	61B3	2.35	2.18	85.0	0.0
61B3	3J3	2.18	2.02	85.0	0.0

Sewer Network Data for Minimum Sewerage Option
From Manhole 48B1 to Manhole 73B1

****** SEWER NETWORK DATA ******

(U - UPSTREAM , D - DOWNSTREAM , Q - AVERAGE FLOW)
(ELE in m, LENGTH in m, Q in l/s)

U. NODE	D. NODE	U. ELE	D. ELE	LENGTH	Q
1A1	49B1	1.65	1.73	61.0	93.9
49B1	50B1	1.73	1.81	61.0	0.0
50B1	51B1	1.81	1.89	61.0	0.0
51B1	52B1	1.89	1.89	61.0	0.0
52B1	53B1	1.89	1.90	61.0	0.0
53B1	54B1	1.90	1.90	54.0	0.0
54B1	55B1	1.90	1.90	54.0	0.0
55B1	56B1	1.90	1.90	61.0	0.0
56B1	57B1	1.90	1.91	61.0	0.0
57B1	58B1	1.91	1.91	61.0	0.0
58B1	59B1	1.91	1.91	61.0	0.0
59B1	60B1	1.91	1.92	54.0	0.0
60B1	61B1	1.92	2.20	60.0	0.0
61B1	62B1	2.20	2.51	60.0	0.0
62B1	63B1	2.51	2.48	84.0	0.0
63B1	64B1	2.48	2.46	84.0	0.0
64B1	65B1	2.46	2.44	63.0	0.0
65B1	66B1	2.44	2.42	63.0	0.0
66B1	67B1	2.42	2.40	63.0	0.0
67B1	68B1	2.40	2.38	63.0	0.0
68B1	69B1	2.38	2.35	63.0	0.0
69B1	70B1	2.35	2.33	63.0	0.0
70B1	71B1	2.33	2.02	56.0	0.0
71B1	72B1	2.02	2.02	64.0	0.0
72B1	73B1	2.02	2.00	1200.0	16.0

Sewer Design for Minimum Sewerage Option
From Manholes **1A1 & 1A4 to Manhole 48B1**

DATA Rec.No	PIPE SECTION U.Node	PIPE SECTION D.Node	GROUND ELE.(m) UPstre.	GROUND ELE.(m) DOWNstr.	PIPE DIAM (m)	INVERT ELE.(m) UPstre.	INVERT ELE.(m) DOWNstr.	SLOPE (m/km)	LENGTH (m)	VELOCITY (m/sec)	ACC. COST (Baht)
4	1A1	2B1	8.37	6.00	0.300	6.07	3.65	30.300	80.00	0.50	49,839
5	2B1	3B1	6.00	5.70	0.300	3.65	1.22	30.300	80.00	0.50	104,469
6	3B1	4B1	5.70	4.35	0.300	1.22	0.55	8.340	80.00	0.50	162,270
7	4B1	1J3	4.35	3.03	0.300	0.55	-0.11	8.340	80.00	0.50	217,133
8	1A4	2B4	10.00	9.52	0.300	7.70	6.51	15.860	75.00	0.50	48,076
9	2B4	3B4	9.52	9.04	0.300	6.51	5.85	8.770	75.00	0.50	97,982
10	3B4	4B4	9.04	8.56	0.300	5.85	5.36	6.590	75.00	0.50	148,283
11	4B4	5B4	8.56	8.08	0.300	5.36	4.99	4.940	75.00	0.50	198,389
12	5B4	6B4	8.08	7.60	0.300	4.99	4.72	3.590	75.00	0.50	247,834
13	6B4	7B4	7.60	7.12	0.300	4.72	4.51	2.802	75.00	0.50	296,287
14	7B4	8B4	7.12	6.64	0.300	4.51	4.32	2.573	75.00	0.50	343,592
15	8B4	9B4	6.64	6.16	0.300	4.32	3.86	6.075	75.00	0.71	390,255
16	9B4	10B4	6.16	5.68	0.300	3.86	3.38	6.400	75.00	0.73	436,868
17	10B4	11B4	5.68	5.20	0.300	3.38	2.90	6.400	75.00	0.76	483,480
18	11B4	12B4	5.20	5.04	0.300	2.90	2.74	2.133	75.00	0.51	530,093
19	12B4	13B4	5.04	4.88	0.300	2.74	2.58	2.133	75.00	0.52	576,705
20	13B4	14B4	4.88	4.77	0.300	2.58	2.47	2.200	50.00	0.54	607,780
21	14B4	15B4	4.77	4.67	0.300	2.47	2.37	2.000	50.00	0.53	638,855
22	15B4	16B4	4.67	4.54	0.300	2.37	2.24	2.167	60.00	0.55	676,145
23	16B4	17B4	4.54	4.43	0.300	2.24	2.13	2.200	50.00	0.56	707,220
24	17B4	18B4	4.43	4.33	0.300	2.13	2.03	2.000	50.00	0.55	738,295
25	18B4	19B4	4.33	4.17	0.300	2.03	1.87	2.133	75.00	0.57	784,908
26	19B4	20B4	4.17	4.02	0.300	1.87	1.72	2.083	72.00	0.56	829,656
27	20B4	21B4	4.02	3.86	0.300	1.72	1.56	2.222	72.00	0.58	874,404
28	21B4	22B4	3.86	3.71	0.300	1.56	1.41	2.083	72.00	0.58	919,152
29	22B4	23B4	3.71	3.56	0.300	1.41	1.26	2.083	72.00	0.58	963,900
30	23B4	24B4	3.56	3.43	0.300	1.26	1.13	2.167	60.00	0.60	1,001,190
31	24B4	25B4	3.43	3.31	0.300	1.13	1.01	2.000	60.00	0.58	1,038,480

Sewer Design for Minimum Sewerage Option
From Manholes **1A1 & 1A4 to Manhole 48B1**

32	25B4	26B4	3.31	3.18	0.300	1.01	0.88	2.167	60.00	0.61	1,075,770
33	26B4	1J3	3.18	3.03	0.300	0.88	0.73	2.143	70.00	0.61	1,119,275
34	1J3	6B1	3.03	2.92	0.300	-0.11	-0.19	1.165	66.00	0.50	1,380,424
35	6B1	7B1	2.92	2.81	0.300	-0.19	-0.27	1.165	66.00	0.50	1,424,321
36	7B1	8B1	2.81	2.70	0.300	-0.27	-0.35	1.210	66.00	0.50	1,468,103
37	8B1	9B1	2.70	2.58	0.300	-0.35	-0.43	1.234	66.00	0.50	1,511,760
38	9B1	10B1	2.58	2.52	0.300	-0.43	-0.52	1.243	72.00	0.50	1,559,368
39	10B1	11B1	2.52	2.47	0.400	-0.62	-0.69	1.000	72.00	0.54	1,615,034
40	11B1	12B1	2.47	2.42	0.400	-0.69	-0.76	1.000	72.00	0.54	1,670,788
41	12B1	13B1	2.42	2.37	0.400	-0.76	-0.83	1.000	72.00	0.54	1,726,628
42	13B1	14B1	2.37	2.31	0.400	-0.83	-0.91	1.000	72.00	0.55	1,782,536
43	14B1	15B1	2.31	2.26	0.400	-0.91	-0.98	1.000	72.00	0.55	[illegible]
44	15B1	16B1	2.26	2.24	0.400	-0.98	-1.04	1.000	64.00	0.55	1,888,382
45	16B1	17B1	2.24	2.20	0.400	-1.04	-1.11	1.000	64.00	0.55	1,938,374
46	17B1	18B1	2.20	2.16	0.400	-1.11	-1.17	1.000	64.00	0.55	1,988,450
47	18B1	19B1	2.16	2.10	0.400	-1.17	-1.23	1.000	64.00	0.55	2,038,575
48	19B1	20B1	2.10	2.05	0.400	-1.23	-1.29	1.000	56.00	0.55	2,082,450
49	20B1	21B1	2.05	2.00	0.400	-1.29	-1.35	1.000	56.00	0.55	2,126,343
50	21B1	22B1	2.00	1.89	0.400	-1.35	-1.41	1.000	60.00	0.56	2,173,299

Sewer Design for Minimum Sewerage Option
From Manholes **1A1 & 1A4 to Manhole 48B1**

51	22B1	23B1	1.89	1.78	0.400	-1.41	-1.47	1.000	60.00	0.56	2,220,090
52	23B1	24B1	1.78	1.67	0.400	-1.47	-1.52	1.000	56.00	0.56	2,263,601
53	24B1	25B1	1.67	1.55	0.400	-1.52	-1.58	1.000	56.00	0.56	2,306,931
54	25B1	26B1	1.55	1.44	0.400	-1.58	-1.64	1.000	60.00	0.54	2,353,168
55	26B1	27B1	1.44	1.33	0.400	-1.64	-1.71	1.156	60.00	0.56	2,399,255
56	27B1	28B1	1.33	1.22	0.500	-1.81	-1.87	1.000	60.00	0.64	2,455,556
57	28B1	29B1	1.22	1.11	0.500	-1.87	-1.93	1.000	60.00	0.65	2,511,659
58	29B1	30B1	1.11	1.00	0.500	-1.93	-1.98	1.000	56.00	0.65	2,563,829
59	30B1	31B1	1.00	1.00	0.500	-1.98	-2.06	1.000	78.00	0.65	2,636,557
60	31B1	32B1	1.00	1.00	0.500	-2.06	-2.14	1.000	78.00	0.65	2,709,687
61	32B1	33B1	1.00	1.00	0.500	-2.14	-2.22	1.000	78.00	0.66	2,783,218
62	33B1	34B1	1.00	1.00	0.500	-2.22	-2.29	1.000	78.00	0.65	2,857,151
63	34B1	35B1	1.00	1.00	0.500	-2.29	-2.37	1.000	78.00	0.63	2,931,485
64	35B1	36B1	1.00	1.00	0.500	-2.37	-2.45	1.000	78.00	0.63	3,006,221
65	36B1	37B1	1.00	1.00	0.500	-2.45	-2.51	1.000	60.00	0.61	3,063,983
66	37B1	38B1	1.00	1.00	0.500	-2.51	-2.57	1.042	60.00	0.62	3,121,988
67	38B1	39B1	1.00	1.00	0.500	-2.57	-2.63	1.090	52.00	0.64	3,172,463
68	39B1	40B1	1.00	1.00	0.500	-2.63	-2.69	1.184	52.00	0.66	3,223,142
69	40B1	41B1	1.00	1.00	0.500	-2.69	-2.77	1.281	60.00	0.69	3,281,891
70	41B1	42B1	1.00	1.00	0.500	-2.77	-2.85	1.383	60.00	0.72	3,340,956
71	42B1	43B1	1.00	1.00	0.500	-2.85	-2.93	1.383	60.00	0.72	3,400,350
72	43B1	44B1	1.00	1.00	0.500	-2.93	-3.02	1.488	60.00	0.74	3,460,086
73	44B1	45B1	1.00	1.00	0.600	-3.12	-3.18	1.000	52.00	0.74	3,520,544
74	45B1	46B1	1.00	1.22	0.600	-3.18	-3.23	1.000	52.00	0.74	3,581,606
75	46B1	47B1	1.22	1.44	0.600	-3.23	-3.29	1.000	60.00	0.74	3,653,245
76	47B1	48B1	1.44	1.65	0.600	-3.29	-3.35	1.000	60.00	0.74	3,726,064

TOTAL PIPE LENGTH OF THE NETWORK = 4841 m
EXECUTION TIME (EXCLUDE THE TIME FOR FINAL RESULT PRINT OUT) = 00:57:57 (3477 SECONDS)

Manhole Cost = 97 x 10,000 + 95 x 12,500 = 2,157,500.-

Sewer Design for Minimum Sewerage Option
From Manhole 1A3 to Manhole 3J3

DATA Rec.No	PIPE SECTION U.Node	D.Node	GROUND ELE.(m) UPstre.	DOWNstr.	PIPE DIAM (m)	INVERT ELE.(m) UPstre.	DOWNstr.	SLOPE (m/km)	LENGTH (m)	VELOCITY (m/sec)	ACC. COST (Baht)
4	1A3	36B3	4.48	4.38	0.300	2.18	1.82	3.971	90.00	0.50	56,572
5	36B3	37B3	4.38	4.28	0.300	1.82	1.60	2.440	90.00	0.50	114,077
6	37B3	38B3	4.28	4.19	0.300	1.60	1.46	1.545	90.00	0.50	172,000
7	38B3	39B3	4.19	4.20	0.300	1.46	1.38	1.481	56.00	0.50	208,259
8	39B3	40B3	4.20	4.22	0.300	1.38	1.30	1.420	56.00	0.50	244,815
9	40B3	41B3	4.22	4.23	0.300	1.30	1.23	1.260	56.00	0.50	281,648
10	41B3	42B3	4.23	4.24	0.300	1.23	1.16	1.212	56.00	0.50	318,725
11	42B3	43B3	4.24	4.38	0.300	1.16	1.09	1.190	64.00	0.50	361,616
12	43B3	44B3	4.38	4.53	0.300	1.09	1.01	1.167	64.00	0.50	405,283
13	44B3	45B3	4.53	4.67	0.300	1.01	0.94	1.167	64.00	0.50	449,723
14	45B3	46B3	4.67	4.81	0.300	0.94	0.86	1.167	64.00	0.50	494,920
15	46B3	47B3	4.81	4.09	0.300	0.86	0.76	1.146	88.00	0.50	556,085
16	47B3	48B3	4.09	3.38	0.300	0.76	0.66	1.146	88.00	0.50	614,279
17	48B3	49B3	3.38	3.21	0.300	0.66	0.57	1.167	76.00	0.50	663,094
18	49B3	50B3	3.21	3.05	0.300	0.57	0.48	1.167	76.00	0.50	711,590
19	50B3	51B3	3.05	3.04	0.300	0.48	0.40	1.167	75.00	0.50	759,460
20	51B3	52B3	3.04	3.03	0.300	0.40	0.31	1.167	75.00	0.50	807,651
21	52B3	53B3	3.03	3.02	0.300	0.31	0.22	1.167	75.00	0.50	856,161
22	53B3	54B3	3.02	3.02	0.300	0.22	0.13	1.167	75.00	0.50	905,011
23	54B3	55B3	3.02	3.01	0.300	0.13	0.05	1.167	75.00	0.50	954,202
24	55B3	56B3	3.01	3.00	0.300	0.05	-0.04	1.167	75.00	0.50	1,003,713
25	56B3	57B3	3.00	2.83	0.300	-0.04	-0.14	1.167	85.00	0.50	1,059,841
26	57B3	58B3	2.83	2.67	0.300	-0.14	-0.24	1.167	85.00	0.50	1,115,662
27	58B3	59B3	2.67	2.51	0.300	-0.24	-0.34	1.167	85.00	0.50	1,171,198
28	59B3	60B3	2.51	2.35	0.300	-0.34	-0.44	1.167	85.00	0.50	1,226,449
29	60B3	61B3	2.35	2.18	0.300	-0.44	-0.54	1.167	85.00	0.50	1,281,393
30	61B3	3J3	2.18	2.02	0.300	-0.54	-0.64	1.167	85.00	0.50	1,336,030

TOTAL PIPE LENGTH OF THE NETWORK = 2038 m
EXECUTION TIME (EXCLUDE THE TIME FOR FINAL RESULT PRINT OUT) = 00:01:44 (104 SECONDS)
Manhole Cost = 82 x 10,000 = 820,000.-

Sewer Design for Minimum Sewerage Option
From Manhole 48B1 to Manhole 73B1

DATA	PIPE SECTION		GROUND ELE.(m)		PIPE DIAM	INVERT ELE.(m)		SLOPE	LENGTH	VELOCITY	ACC. COST
Rec.No	U.Node	D.Node	UPstre.	DOWNstr.	(m)	UPstre.	DOWNstr.	(m/km)	(m)	(m/sec)	(Baht)
4	1A1	49B1	1.65	1.73	0.600	-0.95	-1.01	1.000	61.00	0.74	64,473
5	49B1	50B1	1.73	1.81	0.600	-1.01	-1.07	1.000	61.00	0.74	129,562
6	50B1	51B1	1.81	1.89	0.600	-1.07	-1.13	1.000	61.00	0.74	195,265
7	51B1	52B1	1.89	1.89	0.600	-1.13	-1.19	1.000	61.00	0.74	261,409
8	52B1	53B1	1.89	1.90	0.600	-1.19	-1.26	1.000	61.00	0.74	327,841
9	53B1	54B1	1.90	1.90	0.600	-1.26	-1.31	1.000	54.00	0.74	386,890
10	54B1	55B1	1.90	1.90	0.600	-1.31	-1.36	1.000	54.00	0.74	446,148
11	55B1	56B1	1.90	1.90	0.600	-1.36	-1.42	1.000	61.00	0.74	513,339
12	56B1	57B1	1.90	1.91	0.600	-1.42	-1.49	1.000	61.00	0.74	580,818
13	57B1	58B1	1.91	1.91	0.600	-1.49	-1.55	1.000	61.00	0.74	648,584
14	58B1	59B1	1.91	1.91	0.600	-1.55	-1.61	1.000	61.00	0.74	716,616
15	59B1	60B1	1.91	1.92	0.600	-1.61	-1.66	1.000	54.00	0.74	777,083
16	60B1	61B1	1.92	2.20	0.600	-1.66	-1.72	1.000	60.00	0.74	845,135
17	61B1	62B1	2.20	2.51	0.600	-1.72	-1.78	1.000	60.00	0.74	914,709
18	62B1	63B1	2.51	2.48	0.600	-1.78	-1.87	1.000	84.00	0.74	1,013,387
19	63B1	64B1	2.48	2.46	0.600	-1.87	-1.95	1.000	84.00	0.74	1,112,420
20	64B1	65B1	2.46	2.44	0.600	-1.95	-2.01	1.000	63.00	0.74	1,186,935
21	65B1	66B1	2.44	2.42	0.600	-2.01	-2.07	1.000	63.00	0.74	1,261,644
22	66B1	67B1	2.42	2.40	0.600	-2.07	-2.14	1.000	63.00	0.74	1,336,546
23	67B1	68B1	2.40	2.38	0.600	-2.14	-2.20	1.000	63.00	0.74	1,411,643
24	68B1	69B1	2.38	2.35	0.600	-2.20	-2.26	1.000	63.00	0.74	1,486,910
25	69B1	70B1	2.35	2.33	0.600	-2.26	-2.33	1.000	63.00	0.74	1,562,349
26	70B1	71B1	2.33	2.02	0.600	-2.33	-2.38	1.000	56.00	0.74	1,628,983
27	71B1	72B1	2.02	2.02	0.600	-2.38	-2.45	1.000	64.00	0.74	1,704,701
28	72B1	73B1	2.02	2.00	0.600	-2.45	-3.65	1.000	1200.00	0.69	3,177,792

TOTAL PIPE LENGTH OF THE NETWORK = 2697 m
EXECUTION TIME (EXCLUDE THE TIME FOR FINAL RESULT PRINT OUT) = 00:08:01 (481 SECONDS)

Manhole Cost = 90 x 12,500 = 1,125,000.-

APPENDIX 4.4

Design Criteria, Sewer Network Data and Sewer Design for Small Bore Sewerage Option

Design Criteria for Small Bore Sewerage Option

MIN. SLOPE FOR CONSTRUCTION	=	0.001
MINIMUM COVERING	=	1.50 m
MAX. EXCAVATION	=	5.00 m
MANNING ` n '	=	0.013
MINIMUM VELOCITY	=	0.30 m/s
MAXIMUM VELOCITY	=	3.00 m/s
WASTE WATER PEAK FACTOR	=	1.25**
RAINFALL CONSTANT K2	=	32.00

NO. OF AVAILABLE PIPES = 10

AVAILABLE PIPE DIAMETER ARE:

0.200 m	0.500 m	0.800 m	1.200 m
0.300 m	0.600 m	0.900 m	
0.400 m	0.700 m	1.000 m	

** - Composite peak factor considering Peak Flow and Infiltration based on 2 Q.

Sewer Network Data for Small Bore Sewerage Option
From Manholes **1A1 & 1A4 to Manhole 34B1**

********* SEWER NETWORK DATA *********

(U - UPSTREAM , D - DOWNSTREAM , Q - AVERAGE FLOW)
(ELE in m, LENGTH in m, Q in l/s)

U. NODE	D. NODE	U. ELE	D. ELE	LENGTH	Q
1A1	2B1	8.37	6.00	80.0	0.1
2B1	3B1	6.00	5.70	80.0	0.0
3B1	4B1	5.70	4.35	80.0	1.8
4B1	1J3	4.35	3.03	80.0	2.0
1A4	2B4	10.00	9.52	75.0	0.4
2B4	3B4	9.52	9.04	75.0	0.4
3B4	4B4	9.04	8.56	75.0	0.4
4B4	5B4	8.56	8.08	75.0	0.4
5B4	6B4	8.08	7.60	75.0	1.0
6B4	7B4	7.60	7.12	75.0	1.0
7B4	8B4	7.12	6.64	75.0	0.4
8B4	9B4	6.64	6.16	75.0	0.4
9B4	10B4	6.16	5.68	75.0	0.4
10B4	11B4	5.68	5.20	75.0	0.4
11B4	12B4	5.20	5.04	75.0	0.4
12B4	13B4	5.04	4.88	75.0	0.4
13B4	14B4	4.88	4.77	50.0	0.4
14B4	15B4	4.77	4.67	50.0	0.4
15B4	16B4	4.67	4.54	60.0	0.4
16B4	17B4	4.54	4.43	50.0	0.4
17B4	18B4	4.43	4.33	50.0	0.4
18B4	19B4	4.33	4.17	75.0	0.4
19B4	20B4	4.17	4.02	72.0	0.0
20B4	21B4	4.02	3.86	72.0	0.0
21B4	22B4	3.86	3.71	72.0	0.8
22B4	23B4	3.71	3.56	72.0	0.0
23B4	24B4	3.56	3.43	60.0	0.8
24B4	25B4	3.43	3.31	60.0	0.0
25B4	26B4	3.31	3.18	60.0	0.8
26B4	1J3	3.18	3.03	70.0	0.0
1J3	6B1	3.03	2.92	66.0	6.6

DETAIL OF THIS 2 BRANCHES JUNCTION
FROM NODE: 4B1 / 26B4

Sewer Network Data for Small Bore Sewerage Option
From Manholes **1A1 & 1A4 to Manhole 34B1**

U. NODE	D. NODE	U. ELE	D. ELE	LENGTH	Q
6B1	7B1	2.92	2.81	66.0	2.8
7B1	8B1	2.81	2.70	66.0	2.8
8B1	9B1	2.70	2.58	66.0	1.8
9B1	10B1	2.58	2.52	72.0	1.8
10B1	11B1	2.52	2.47	72.0	2.8
11B1	12B1	2.47	2.42	72.0	2.8
12B1	13B1	2.42	2.37	72.0	4.8
13B1	14B1	2.37	2.31	72.0	2.8
14B1	15B1	2.31	2.26	72.0	0.0
15B1	16B1	2.26	2.26	64.0	0.6
16B1	17B1	2.26	2.26	64.0	2.6
17B1	18B1	2.26	2.26	64.0	2.0
18B1	19B1	2.26	2.26	64.0	2.0
19B1	20B1	2.26	2.34	56.0	2.0
20B1	21B1	2.34	2.42	56.0	0.6
21B1	22B1	2.42	2.50	56.0	2.6
22B1	23B1	2.50	2.58	56.0	2.6
23B1	24B1	2.58	2.68	66.0	0.0
24B1	25B1	2.68	2.77	66.0	2.6
25B1	26B1	2.77	2.86	66.0	3.0
26B1	27B1	2.86	2.95	66.0	1.8
27B1	28B1	2.95	3.25	72.0	3.0
28B1	29B1	3.25	3.50	72.0	1.4
29B1	30B1	3.50	3.35	76.0	1.0
30B1	31B1	3.35	3.21	76.0	4.6
31B1	32B1	3.21	3.07	76.0	3.0
32B1	33B1	3.07	2.92	76.0	3.0
33B1	34B1	2.92	3.01	72.0	3.0

Sewer Network Data for Small Bore Sewerage Option
From Manhole 1A2 to Manhole 2J3

****** SEWER NETWORK DATA ******

(U - UPSTREAM , D - DOWNSTREAM , Q - AVERAGE FLOW)
(ELE in m, LENGTH in m, Q in l/s)

U. NODE	D. NODE	U. ELE	D. ELE	LENGTH	Q
1A2	2B2	2.00	1.89	60.0	2.6
2B2	3B2	1.89	1.78	60.0	2.4
3B2	4B2	1.78	1.67	56.0	2.4
4B2	5B2	1.67	1.55	56.0	2.4
5B2	6B2	1.55	1.44	60.0	2.4
6B2	7B2	1.44	1.33	60.0	3.4
7B2	8B2	1.33	1.22	60.0	3.4
8B2	9B2	1.22	1.11	60.0	2.4
9B2	10B2	1.11	1.00	56.0	1.2
10B2	11B2	1.00	1.00	78.0	1.2
11B2	12B2	1.00	1.00	78.0	1.2
12B2	13B2	1.00	1.00	78.0	4.6
13B2	14B2	1.00	1.00	78.0	4.6
14B2	15B2	1.00	1.00	78.0	6.2
15B2	16B2	1.00	1.00	78.0	0.0
16B2	17B2	1.00	1.00	60.0	1.6
17B2	18B2	1.00	1.00	60.0	1.6
18B2	19B2	1.00	1.00	52.0	1.6
19B2	20B2	1.00	1.00	52.0	3.0
20B2	21B2	1.00	1.00	60.0	3.0
21B2	22B2	1.00	1.00	60.0	3.0
22B2	23B2	1.00	1.00	60.0	3.0
23B2	24B2	1.00	1.00	60.0	3.0
24B2	25B2	1.00	1.00	52.0	3.0
25B2	26B2	1.00	1.22	52.0	4.4
26B2	27B2	1.22	1.44	60.0	1.6
27B2	2J3	1.44	3.45	60.0	1.6

Sewer Network Data for Small Bore Sewerage Option
From Manhole 34B1 to Manhole 57B1

****** SEWER NETWORK DATA ******

(U - UPSTREAM , D - DOWNSTREAM , Q - AVERAGE FLOW)
(ELE in m, LENGTH in m, Q in l/s)

U.NODE	D.NODE	U.ELE	D.ELE	LENGTH	Q
1A1	35B1	1.29	3.10	72.0	88.1
35B1	36B1	3.10	3.20	72.0	3.0
36B1	37B1	3.20	3.29	72.0	2.0
37B1	38B1	3.29	3.11	72.0	1.6
38B1	39B1	3.11	2.94	72.0	0.0
39B1	40B1	2.94	2.44	80.0	5.6
40B1	41B1	2.44	1.94	80.0	0.0
41B1	42B1	1.94	1.87	70.0	0.0
42B1	43B1	1.87	1.80	70.0	0.0
43B1	44B1	1.80	1.73	70.0	0.0
44B1	45B1	1.73	1.73	70.0	0.0
45B1	46B1	1.73	1.73	61.0	0.0
46B1	47B1	1.73	1.81	61.0	70.8
47B1	48B1	1.81	1.89	61.0	0.0
48B1	49B1	1.89	1.89	61.0	0.0
49B1	50B1	1.89	1.90	61.0	5.0
50B1	51B1	1.90	1.90	54.0	0.0
51B1	52B1	1.90	1.90	54.0	0.0
52B1	53B1	1.90	1.90	61.0	8.0
53B1	54B1	1.90	1.91	61.0	0.0
54B1	55B1	1.91	1.91	61.0	0.0
55B1	56B1	1.91	1.91	61.0	0.0
56B1	57B1	1.91	1.92	54.0	0.0

Sewer Network Data for Small Bore Sewerage Option
From Manhole 1A3 & 1A6 to Manhole 3J3

****** SEWER NETWORK DATA ******

(U - UPSTREAM , D - DOWNSTREAM , Q - AVERAGE FLOW)
(ELE in m, LENGTH in m, Q in l/s)

U. NODE	D. NODE	U. ELE	D. ELE	LENGTH	Q
1A3	2B3	13.37	13.33	66.0	15.2
2B3	3B3	13.33	13.30	66.0	0.0
3B3	4B3	13.30	13.27	66.0	0.0
4B3	5B3	13.27	13.23	66.0	0.0
5B3	6B3	13.23	12.67	72.0	2.0
6B3	7B3	12.67	12.12	72.0	0.0
7B3	8B3	12.12	11.56	72.0	2.0
8B3	9B3	11.56	11.01	72.0	0.0
9B3	10B3	11.01	10.59	80.0	2.0
10B3	11B3	10.59	10.15	80.0	0.0
11B3	12B3	10.15	9.70	80.0	2.0
12B3	13B3	9.70	9.30	80.0	0.0
13B3	14B3	9.30	8.87	80.0	2.0
14B3	15B3	8.87	8.44	80.0	0.0
15B3	16B3	8.44	8.02	80.0	2.2
16B3	17B3	8.02	7.59	80.0	0.0
17B3	18B3	7.59	7.16	80.0	2.2
18B3	4J3	7.16	6.73	80.0	1.6
1A6	2B6	13.84	13.15	50.0	0.6
2B6	3B6	13.15	12.47	50.0	0.0
3B6	4B6	12.47	11.77	50.0	0.0
4B6	5B6	11.77	10.98	56.0	0.0
5B6	6B6	10.98	9.98	88.0	0.6
6B6	7B6	9.98	9.47	80.0	0.0
7B6	8B6	9.47	8.96	80.0	0.6
8B6	9B6	8.96	8.57	60.0	1.0
9B6	10B6	8.57	8.21	56.0	0.6
10B6	11B6	8.21	7.85	60.0	0.6
11B6	12B6	7.85	7.49	56.0	2.0
12B6	13B6	7.49	6.70	60.0	0.0
13B6	4J3	6.70	6.73	64.0	8.6
4J3	20B3	6.73	6.29	64.0	0.6

DETAIL OF THIS 2 BRANCHES JUNCTION
FROM NODE: 18B3 / 13B6

Sewer Network Data for Small Bore Sewerage Option
From Manhole 1A3 & 1A6 to Manhole 3J3

U. NODE	D. NODE	U. ELE	D. ELE	LENGTH	Q
20B3	21B3	6.29	5.85	64.0	0.8
21B3	22B3	5.85	5.41	64.0	0.8
22B3	23B3	5.41	5.37	75.0	3.0
23B3	24B3	5.37	5.33	75.0	3.0
24B3	25B3	5.33	5.28	75.0	3.4
25B3	26B3	5.28	5.24	75.0	6.8
26B3	27B3	5.24	5.20	75.0	1.6
27B3	28B3	5.20	5.16	75.0	14.4
28B3	29B3	5.16	5.07	69.0	2.4
29B3	30B3	5.07	4.97	69.0	2.4
30B3	31B3	4.97	4.87	69.0	2.4
31B3	32B3	4.87	4.77	69.0	2.4
32B3	33B3	4.77	4.68	69.0	0.0
33B3	34B3	4.68	4.58	69.0	0.6
34B3	35B3	4.58	4.48	90.0	18.2
35B3	36B3	4.48	4.38	90.0	2.2
36B3	37B3	4.38	4.28	90.0	3.0
37B3	38B3	4.28	4.19	90.0	5.2
38B3	39B3	4.19	4.20	56.0	3.2
39B3	40B3	4.20	4.22	56.0	3.6
40B3	41B3	4.22	4.23	56.0	3.8
41B3	42B3	4.23	4.24	56.0	3.0
42B3	43B3	4.24	4.38	64.0	1.4
43B3	44B3	4.38	4.53	64.0	1.4
44B3	45B3	4.53	4.67	64.0	1.4
45B3	46B3	4.67	4.81	64.0	0.6
46B3	47B3	4.81	4.09	88.0	0.6
47B3	48B3	4.09	3.38	88.0	0.0
48B3	49B3	3.38	3.21	76.0	0.6
49B3	50B3	3.21	3.05	76.0	0.0
50B3	51B3	3.05	3.04	75.0	2.8
51B3	52B3	3.04	3.03	75.0	3.0
52B3	53B3	3.03	3.02	75.0	0.8
53B3	54B3	3.02	3.02	75.0	0.0
54B3	55B3	3.02	3.01	75.0	2.8
55B3	56B3	3.01	3.00	75.0	0.0
56B3	57B3	3.00	2.83	85.0	22.6
57B3	58B3	2.83	2.67	85.0	2.8
58B3	59B3	2.67	2.51	85.0	2.8
59B3	60B3	2.51	2.35	85.0	2.8
60B3	61B3	2.35	2.18	85.0	16.0
61B3	3J3	2.18	2.02	85.0	0.0

Sewer Network Data for Small Bore Sewerage Option
From Manhole 57B1 to Manhole 70B1

******** SEWER NETWORK DATA ********

(U - UPSTREAM , D - DOWNSTREAM , Q - AVERAGE FLOW)
(ELE in m, LENGTH in m, Q in l/s)

U. NODE	D. NODE	U. ELE	D. ELE	LENGTH	Q
1A1	58B1	1.92	2.20	60.0	193.1
58B1	59B1	2.20	2.51	60.0	6.2
59B1	60B1	2.51	2.48	84.0	0.0
60B1	61B1	2.48	2.46	84.0	0.0
61B1	62B1	2.46	2.44	63.0	4.4
62B1	63B1	2.44	2.42	63.0	0.0
63B1	64B1	2.42	2.40	63.0	0.0
64B1	65B1	2.40	2.38	63.0	0.0
65B1	66B1	2.38	2.35	63.0	0.0
66B1	67B1	2.35	2.33	63.0	0.0
67B1	68B1	2.33	2.02	56.0	0.0
68B1	69B1	2.02	2.05	64.0	0.0
69B1	70B1	2.02	2.05	64.0	194.4

Sewer Design for Small Bore Sewerage Option
From Manholes 1A1 & 1A4 to Manhole 34B1

DATA	PIPE SECTION		GROUND ELE.(m)		PIPE DIAM	INVERT ELE.(m)		SLOPE	LENGTH	VELOCITY	ACC. COST
Rec.No	U.Node	D.Node	UPstre.	DOWNstr.	(m)	UPstre.	DOWNstr.	(m/km)	(m)	(m/sec)	(Baht)
4	1A1	2B1	8.37	6.00	0.200	6.67	4.30	29.625	80.00	0.38	59,320
5	2B1	3B1	6.00	5.70	0.200	4.30	3.32	12.220	80.00	0.30	120,131
6	3B1	4B1	5.70	4.35	0.200	3.32	2.65	8.405	80.00	0.58	180,941
7	4B1	1J3	4.35	3.03	0.200	2.65	1.33	16.500	80.00	0.93	240,261
8	1A4	2B4	10.00	9.52	0.200	8.30	7.82	6.400	75.00	0.34	55,613
9	2B4	3B4	9.52	9.04	0.200	7.82	7.34	6.400	75.00	0.42	111,225
10	3B4	4B4	9.04	8.56	0.200	7.34	6.86	6.400	75.00	0.46	166,838
11	4B4	5B4	8.56	8.08	0.200	6.86	6.38	6.400	75.00	0.50	222,450
12	5B4	6B4	8.08	7.60	0.200	6.38	5.90	6.400	75.00	0.58	278,063
13	6B4	7B4	7.60	7.12	0.200	5.90	5.42	6.400	75.00	0.64	333,675
14	7B4	8B4	7.12	6.64	0.200	5.42	4.94	6.400	75.00	0.66	389,288
15	8B4	9B4	6.64	6.16	0.200	4.94	4.46	6.400	75.00	0.67	444,900
16	9B4	10B4	6.16	5.68	0.200	4.46	3.98	6.400	75.00	0.68	500,513
17	10B4	11B4	5.68	5.20	0.200	3.98	3.50	6.400	75.00	0.70	556,125
18	11B4	12B4	5.20	5.04	0.200	3.50	3.34	2.133	75.00	0.47	611,738
19	12B4	13B4	5.04	4.88	0.200	3.34	3.18	2.133	75.00	0.48	667,350
20	13B4	14B4	4.88	4.77	0.200	3.18	3.07	2.200	50.00	0.49	704,425
21	14B4	15B4	4.77	4.67	0.200	3.07	2.97	2.000	50.00	0.48	741,500
22	15B4	16B4	4.67	4.54	0.200	2.97	2.84	2.167	60.00	0.50	785,990
23	16B4	17B4	4.54	4.43	0.200	2.84	2.73	2.200	50.00	0.51	823,065
24	17B4	18B4	4.43	4.33	0.200	2.73	2.63	2.000	50.00	0.49	860,140
25	18B4	19B4	4.33	4.17	0.200	2.63	2.47	2.133	75.00	0.51	915,753
26	19B4	20B4	4.17	4.02	0.200	2.47	2.32	2.083	72.00	0.51	969,141
27	20B4	21B4	4.02	3.86	0.200	2.32	2.16	2.222	72.00	0.52	1,022,529
28	21B4	22B4	3.86	3.71	0.200	2.16	2.01	2.083	72.00	0.51	1,075,917
29	22B4	23B4	3.71	3.56	0.200	2.01	1.86	2.083	72.00	0.51	1,129,305
30	23B4	24B4	3.56	3.43	0.200	1.86	1.73	2.167	60.00	0.52	1,173,795

Sewer Design for Small Bore Sewerage Option
From Manholes **1A1 & 1A4 to Manhole 34B1**

31	24B4	25B4	3.43	3.31	0.200	1.73	1.61	2.000	60.00	0.50	1,218,285
32	25B4	26B4	3.31	3.18	0.200	1.61	1.48	2.167	60.00	0.52	1,262,775
33	26B4	1J3	3.18	3.03	0.200	1.48	1.33	2.143	70.00	0.52	1,314,680
34	1J3	6B1	3.03	2.92	0.300	1.23	1.12	1.667	66.00	0.59	1,594,145
35	6B1	7B1	2.92	2.81	0.300	1.12	1.01	1.667	66.00	0.60	1,633,349
36	7B1	8B1	2.81	2.70	0.300	1.01	0.90	1.667	66.00	0.60	1,672,553
37	8B1	9B1	2.70	2.58	0.300	0.90	0.78	1.818	66.00	0.62	1,711,757
38	9B1	10B1	2.58	2.52	0.300	0.78	0.67	1.554	72.00	0.54	1,754,628
39	10B1	11B1	2.52	2.47	0.400	0.57	0.54	0.328	72.00	0.30	1,805,505
40	11B1	12B1	2.47	2.42	0.400	0.54	0.52	0.340	72.00	0.31	1,856,280
41	12B1	13B1	2.42	2.37	0.400	0.52	0.47	0.694	72.00	0.46	1,907,004
42	13B1	14B1	2.37	2.31	0.400	0.47	0.41	0.833	72.00	0.51	1,957,728
43	14B1	15B1	2.31	2.26	0.400	0.41	0.36	0.694	72.00	0.44	2,008,452
44	15B1	16B1	2.26	2.26	0.400	0.36	0.31	0.707	64.00	0.44	2,053,619
45	16B1	17B1	2.26	2.26	0.400	0.31	0.26	0.792	64.00	0.47	2,098,956
46	17B1	18B1	2.26	2.26	0.400	0.26	0.21	0.861	64.00	0.49	2,144,478
47	18B1	19B1	2.26	2.26	0.400	0.21	0.15	0.933	64.00	0.51	2,190,203
48	19B1	20B1	2.26	2.34	0.400	0.15	0.09	1.008	56.00	0.53	2,230,515
49	20B1	21B1	2.34	2.42	0.400	0.09	0.03	1.031	56.00	0.53	2,271,249
50	21B1	22B1	2.42	2.50	0.400	0.03	-0.03	1.134	56.00	0.56	2,312,415

Sewer Design for Small Bore Sewerage Option
From Manholes **1A1 & 1A4 to Manhole 34B1**

51	22B1	23B1	2.50	2.58	0.400	-0.03	-0.10	1.241	56.00	0.58	2,354,033
52	23B1	24B1	2.58	2.68	0.400	-0.10	-0.18	1.241	66.00	0.58	2,403,685
53	24B1	25B1	2.68	2.77	0.500	-0.28	-0.31	0.500	66.00	0.30	2,465,224
54	25B1	26B1	2.77	2.86	0.500	-0.31	-0.35	0.500	66.00	0.30	2,527,299
55	26B1	27B1	2.86	2.95	0.500	-0.35	-0.38	0.500	66.00	0.30	2,589,910
56	27B1	28B1	2.95	3.25	0.500	-0.38	-0.42	0.523	72.00	0.44	2,659,307
57	28B1	29B1	3.25	3.50	0.500	-0.42	-0.46	0.545	72.00	0.45	2,730,194
58	29B1	30B1	3.50	3.35	0.500	-0.46	-0.50	0.560	76.00	0.46	2,805,475
59	30B1	31B1	3.35	3.21	0.500	-0.50	-0.55	0.635	76.00	0.48	2,880,256
60	31B1	32B1	3.21	3.07	0.500	-0.55	-0.60	0.686	76.00	0.50	2,954,587
61	32B1	33B1	3.07	2.92	0.500	-0.60	-0.65	0.739	76.00	0.52	3,028,462
62	33B1	34B1	2.92	3.01	0.500	-0.65	-0.71	0.794	72.00	0.54	3,098,575

TOTAL PIPE LENGTH OF THE NETWORK = 4053 m
EXECUTION TIME (EXCLUDE THE TIME FOR FINAL RESULT PRINT OUT) = 00:16:11 (971 SECONDS)

Manhole Cost = 61 x 10,000 + 32 x 12,500 = 1,010,000.-

Sewer Design for Small Bore Sewerage Option
From Manhole 1A2 to Manhole 2J3

DATA Rec.No	PIPE SECTION U.Node	D.Node	GROUND ELE.(m) UPstre.	DOWNstr.	PIPE DIAM (m)	INVERT ELE.(m) UPstre.	DOWNstr.	SLOPE (m/km)	LENGTH (m)	VELOCITY (m/sec)	ACC. COST (Baht)
4	1A2	2B2	2.00	1.89	0.200	0.30	0.19	1.833	60.00	0.37	44,490
5	2B2	3B2	1.89	1.78	0.200	0.19	0.08	1.833	60.00	0.43	88,980
6	3B2	4B2	1.78	1.67	0.200	0.08	-0.03	1.964	56.00	0.49	130,504
7	4B2	5B2	1.67	1.55	0.200	-0.03	-0.15	2.143	56.00	0.52	172,028
8	5B2	6B2	1.55	1.44	0.300	-0.25	-0.36	1.833	60.00	0.54	207,668
9	6B2	7B2	1.44	1.33	0.300	-0.36	-0.47	1.833	60.00	0.58	243,308
10	7B2	8B2	1.33	1.22	0.300	-0.47	-0.58	1.833	60.00	0.60	278,948
11	8B2	9B2	1.22	1.11	0.300	-0.58	-0.69	1.833	60.00	0.62	314,588
12	9B2	10B2	1.11	1.00	0.300	-0.69	-0.80	1.964	56.00	0.64	347,852
13	10B2	11B2	1.00	1.00	0.400	-0.90	-0.94	0.500	78.00	0.30	402,887
14	11B2	12B2	1.00	1.00	0.400	-0.94	-0.98	0.500	78.00	0.30	458,089
15	12B2	13B2	1.00	1.00	0.400	-0.98	-1.02	0.500	78.00	0.30	513,458
16	13B2	14B2	1.00	1.00	0.400	-1.02	-1.04	0.328	78.00	0.30	568,966
17	14B2	15B2	1.00	1.00	0.400	-1.04	-1.09	0.588	78.00	0.40	624,627
18	15B2	16B2	1.00	1.00	0.400	-1.09	-1.13	0.588	78.00	0.40	680,485
19	16B2	17B2	1.00	1.00	0.500	-1.23	-1.25	0.221	60.00	0.30	733,339
20	17B2	18B2	1.00	1.00	0.500	-1.25	-1.26	0.225	60.00	0.30	786,246
21	18B2	19B2	1.00	1.00	0.500	-1.26	-1.29	0.500	52.00	0.30	832,166
22	19B2	20B2	1.00	1.00	0.500	-1.29	-1.31	0.500	52.00	0.30	878,176
23	20B2	21B2	1.00	1.00	0.500	-1.31	-1.34	0.500	60.00	0.30	931,375
24	21B2	22B2	1.00	1.00	0.500	-1.34	-1.37	0.500	60.00	0.30	984,693
25	22B2	23B2	1.00	1.00	0.500	-1.37	-1.40	0.500	60.00	0.30	1,038,130
26	23B2	24B2	1.00	1.00	0.500	-1.40	-1.43	0.500	60.00	0.30	1,091,686
27	24B2	25B2	1.00	1.00	0.500	-1.43	-1.46	0.500	52.00	0.30	1,138,196
28	25B2	26B2	1.00	1.22	0.500	-1.46	-1.49	0.501	52.00	0.43	1,185,174
29	26B2	27B2	1.22	1.44	0.500	-1.49	-1.52	0.525	60.00	0.44	1,240,364
30	27B2	2J3	1.44	1.65	0.500	-1.52	-1.55	0.549	60.00	0.45	1,296,533

TOTAL PIPE LENGTH OF THE NETWORK = 1684 m
EXECUTION TIME (EXCLUDE THE TIME FOR FINAL RESULT PRINT OUT) = 00:02:05 (125 SECONDS)

Manhole Cost = 13 x 10,000 + 23 x 12,500 = 417,500.-

Sewer Design for Small Bore Sewerage Option
From Manhole 34B1 to Manhole 57B1

DATA Rec.No	PIPE SECTION U.Node	PIPE SECTION D.Node	GROUND ELE.(m) UPstre.	GROUND ELE.(m) DOWNstr.	PIPE DIAM (m)	INVERT ELE.(m) UPstre.	INVERT ELE.(m) DOWNstr.	SLOPE (m/km)	LENGTH (m)	VELOCITY (m/sec)	ACC. COST (Baht)
4	1A1	35B1	1.29	3.10	0.500	-0.71	-0.77	0.851	72.00	0.56	66,726
5	35B1	36B1	3.10	3.20	0.500	-0.77	-0.84	0.909	72.00	0.58	138,291
6	36B1	37B1	3.20	3.29	0.500	-0.84	-0.91	0.950	72.00	0.59	210,626
7	37B1	38B1	3.29	3.11	0.500	-0.91	-0.98	0.983	72.00	0.60	283,078
8	38B1	39B1	3.11	2.94	0.500	-0.98	-1.05	0.983	72.00	0.60	355,034
9	39B1	40B1	2.94	2.44	0.500	-1.05	-1.13	1.102	80.00	0.64	433,636
10	40B1	41B1	2.44	1.94	0.500	-1.13	-1.22	1.102	80.00	0.64	510,064
11	41B1	42B1	1.94	1.87	0.500	-1.22	-1.30	1.102	70.00	0.64	576,003
12	42B1	43B1	1.87	1.80	0.500	-1.30	-1.38	1.102	70.00	0.64	641,976
13	43B1	44B1	1.80	1.73	0.500	-1.38	-1.45	1.102	70.00	0.64	707,982
14	44B1	45B1	1.73	1.73	0.500	-1.45	-1.53	1.102	70.00	0.64	774,182
15	45B1	46B1	1.73	1.73	0.600	-1.63	-1.71	1.213	61.00	0.76	841,832
16	46B1	47B1	1.73	1.81	0.600	-1.71	-1.78	1.213	61.00	0.76	909,978
17	47B1	48B1	1.81	1.89	0.600	-1.78	-1.85	1.213	61.00	0.76	978,796
18	48B1	49B1	1.89	1.89	0.600	-1.85	-1.93	1.213	61.00	0.76	1,048,112
19	49B1	50B1	1.89	1.90	0.600	-1.93	-2.01	1.285	61.00	0.78	1,117,781
20	50B1	51B1	1.90	1.90	0.600	-2.01	-2.08	1.285	54.00	0.78	1,179,760
21	51B1	52B1	1.90	1.90	0.600	-2.08	-2.14	1.285	54.00	0.78	1,242,008
22	52B1	53B1	1.90	1.90	0.600	-2.14	-2.23	1.405	61.00	0.81	1,312,662
23	53B1	54B1	1.90	1.91	0.600	-2.23	-2.32	1.405	61.00	0.81	1,383,712
24	54B1	55B1	1.91	1.91	0.600	-2.32	-2.40	1.405	61.00	0.81	1,455,158
25	55B1	56B1	1.91	1.91	0.600	-2.40	-2.49	1.405	61.00	0.81	1,526,977
26	56B1	57B1	1.91	1.92	0.600	-2.49	-2.56	1.405	54.00	0.81	1,590,885

TOTAL PIPE LENGTH OF THE NETWORK = 1511 m
EXECUTION TIME (EXCLUDE THE TIME FOR FINAL RESULT PRINT OUT) = 00:00:25 (25 SECONDS)

Manhole Cost = 30 x 12,500 = 375,000.-

Sewer Design for Small Bore Sewerage Option
From Manholes **1A3 & 1A6 to Manhole 3J3**

DATA Rec.No	PIPE SECTION U.Node	D.Node	GROUND ELE.(m) UPstre.	DOWNstr.	PIPE DIAM (m)	INVERT ELE.(m) UPstre.	DOWNstr.	SLOPE (m/km)	LENGTH (m)	VELOCITY (m/sec)	ACC. COST (Baht)
4	1A3	2B3	13.37	13.33	0.300	11.57	11.53	0.606	66.00	0.36	39,204
5	2B3	3B3	13.33	13.30	0.300	11.53	11.50	0.455	66.00	0.31	78,408
6	3B3	4B3	13.30	13.27	0.300	11.50	11.47	0.455	66.00	0.31	117,612
7	4B3	5B3	13.27	13.23	0.300	11.47	11.43	0.606	66.00	0.36	156,816
8	5B3	6B3	13.23	12.67	0.300	11.43	10.87	7.778	72.00	1.03	199,584
9	6B3	7B3	12.67	12.12	0.300	10.87	10.32	7.639	72.00	1.02	242,352
10	7B3	8B3	12.12	11.56	0.300	10.32	9.76	7.778	72.00	1.05	285,120
11	8B3	9B3	11.56	11.01	0.300	9.76	9.21	7.639	72.00	1.04	327,888
12	9B3	10B3	11.01	10.59	0.300	9.21	8.79	5.250	80.00	0.92	375,408
13	10B3	11B3	10.59	10.15	0.300	8.79	8.35	5.500	80.00	0.94	422,928
14	11B3	12B3	10.15	9.70	0.300	8.35	7.90	5.625	80.00	0.97	470,448
15	12B3	13B3	9.70	9.30	0.300	7.90	7.50	5.000	80.00	0.93	517,968
16	13B3	14B3	9.30	8.87	0.300	7.50	7.07	5.375	80.00	0.97	565,488
17	14B3	15B3	8.87	8.44	0.300	7.07	6.64	5.375	80.00	0.97	613,008
18	15B3	16B3	8.44	8.02	0.300	6.64	6.22	5.250	80.00	0.99	660,528
19	16B3	17B3	8.02	7.59	0.300	6.22	5.79	5.375	80.00	0.99	708,048
20	17B3	18B3	7.59	7.16	0.300	5.79	5.36	5.375	80.00	1.01	755,568
21	18B3	4J3	7.16	6.73	0.300	5.36	4.93	5.375	80.00	1.02	803,088
22	1A6	2B6	13.84	13.15	0.200	12.14	11.45	13.800	50.00	0.50	37,075
23	2B6	3B6	13.15	12.47	0.200	11.45	10.77	13.600	50.00	0.50	74,150
24	3B6	4B6	12.47	11.77	0.200	10.77	10.07	14.000	50.00	0.51	111,225
25	4B6	5B6	11.77	10.98	0.200	10.07	9.28	14.107	56.00	0.51	152,749
26	5B6	6B6	10.98	9.98	0.200	9.28	8.28	11.364	88.00	0.58	218,001
27	6B6	7B6	9.98	9.47	0.200	8.28	7.77	6.375	80.00	0.46	277,321
28	7B6	8B6	9.47	8.96	0.200	7.77	7.26	6.375	80.00	0.52	336,641
29	8B6	9B6	8.96	8.57	0.200	7.26	6.87	6.500	60.00	0.61	381,131

Sewer Design for Small Bore Sewerage Option
From Manholes 1A3 & 1A6 to Manhole 3J3

30	9B6	10B6	8.57	8.21	0.200	6.87	6.51	6.429	56.00	0.62	422,655
31	10B6	11B6	8.21	7.85	0.200	6.51	6.15	6.000	60.00	0.64	467,145
32	11B6	12B6	7.85	7.49	0.200	6.15	5.79	6.429	56.00	0.73	508,669
33	12B6	13B6	7.49	6.70	0.200	5.79	5.00	13.167	60.00	0.95	553,159
34	13B6	4J3	6.70	6.73	0.300	4.90	4.87	0.428	64.00	0.30	591,276
35	4J3	20B3	6.73	6.29	0.300	4.87	4.49	5.978	64.00	1.13	1,432,481
36	20B3	21B3	6.29	5.85	0.300	4.49	4.05	6.875	64.00	1.21	1,470,497
37	21B3	22B3	5.85	5.41	0.300	4.05	3.61	6.875	64.00	1.21	1,508,513
38	22B3	23B3	5.41	5.37	0.400	3.51	3.44	0.937	75.00	0.51	1,561,413
39	23B3	24B3	5.37	5.33	0.400	3.44	3.36	1.050	75.00	0.54	1,614,455
40	24B3	25B3	5.33	5.28	0.400	3.36	3.27	1.187	75.00	0.57	1,667,658
41	25B3	26B3	5.28	5.24	0.400	3.27	3.16	1.485	75.00	0.64	1,721,089
42	26B3	27B3	5.24	5.20	0.400	3.16	3.04	1.560	75.00	0.65	1,774,825
43	27B3	28B3	5.20	5.16	0.500	2.94	2.89	0.705	75.00	0.51	1,841,001
44	28B3	29B3	5.16	5.07	0.500	2.89	2.84	0.748	69.00	0.53	1,901,825
45	29B3	30B3	5.07	4.97	0.500	2.84	2.78	0.792	69.00	0.54	1,962,458
46	30B3	31B3	4.97	4.87	0.500	2.78	2.73	0.837	69.00	0.56	2,022,891
47	31B3	32B3	4.87	4.77	0.500	2.73	2.67	0.884	69.00	0.57	2,083,140
48	32B3	33B3	4.77	4.68	0.500	2.67	2.60	0.884	69.00	0.57	2,143,233
49	33B3	34B3	4.68	4.58	0.500	2.60	2.54	0.895	69.00	0.58	2,203,173
50	34B3	35B3	4.58	4.48	0.500	2.54	2.43	1.292	90.00	0.69	2,281,291

Sewer Design for Small Bore Sewerage Option
From Manholes **1A3 & 1A6 to Manhole 3J3**

51	35B3	36B3	4.48	4.38	0.500	2.43	2.31	1.345	90.00	0.71	2,359,520
52	36B3	37B3	4.38	4.28	0.500	2.31	2.18	1.419	90.00	0.72	2,437,894
53	37B3	38B3	4.28	4.19	0.500	2.18	2.04	1.552	90.00	0.76	2,516,498
54	38B3	39B3	4.19	4.20	0.500	2.04	1.95	1.636	56.00	0.78	2,565,687
55	39B3	40B3	4.20	4.22	0.500	1.95	1.85	1.734	56.00	0.80	2,615,279
56	40B3	41B3	4.22	4.23	0.500	1.85	1.75	1.841	56.00	0.83	2,665,298
57	41B3	42B3	4.23	4.24	0.500	1.75	1.64	1.927	56.00	0.84	2,715,743
58	42B3	43B3	4.24	4.38	0.500	1.64	1.51	1.968	64.00	0.85	2,774,205
59	43B3	44B3	4.38	4.53	0.500	1.51	1.38	2.009	64.00	0.86	2,833,817
60	44B3	45B3	4.53	4.67	0.500	1.38	1.25	2.051	64.00	0.87	2,894,590
61	45B3	46B3	4.67	4.81	0.500	1.25	1.12	2.069	64.00	0.87	2,956,511
62	46B3	47B3	4.81	4.09	0.500	1.12	0.94	2.087	88.00	0.88	3,040,887
63	47B3	48B3	4.09	3.38	0.500	0.94	0.75	2.087	88.00	0.86	3,122,176
64	48B3	49B3	3.38	3.21	0.500	0.75	0.59	2.105	76.00	0.88	3,191,035
65	49B3	50B3	3.21	3.05	0.500	0.59	0.43	2.105	76.00	0.88	3,259,869
66	50B3	51B3	3.05	3.04	0.500	0.43	0.27	2.191	75.00	0.90	3,328,180
67	51B3	52B3	3.04	3.03	0.500	0.27	0.10	2.285	75.00	0.92	3,397,271
68	52B3	53B3	3.03	3.02	0.500	0.10	-0.08	2.310	75.00	0.92	3,467,166
69	53B3	54B3	3.02	3.02	0.500	-0.08	-0.25	2.310	75.00	0.92	3,537,894
70	54B3	55B3	3.02	3.01	0.500	-0.25	-0.43	2.400	75.00	0.94	3,609,472
71	55B3	56B3	3.01	3.00	0.500	-0.43	-0.61	2.400	75.00	0.94	3,681,891
72	56B3	57B3	3.00	2.83	0.500	-0.61	-0.88	3.189	85.00	1.09	3,764,726
73	57B3	58B3	2.83	2.67	0.500	-0.88	-1.16	3.295	85.00	1.10	3,848,162
74	58B3	59B3	2.67	2.51	0.500	-1.16	-1.45	3.402	85.00	1.12	3,932,337
75	59B3	60B3	2.51	2.35	0.500	-1.45	-1.75	3.511	85.00	1.14	4,017,242
76	60B3	61B3	2.35	2.18	0.500	-1.75	-2.10	4.167	85.00	1.24	4,103,052
77	61B3	3J3	2.18	2.02	0.500	-2.10	-2.46	4.167	85.00	1.24	4,189,924

TOTAL PIPE LENGTH OF THE NETWORK = 5346 m
EXECUTION TIME (EXCLUDE THE TIME FOR FINAL RESULT PRINT OUT) = 00:28:25 (1705 SECONDS)

Manhole Cost = 59 x 10,000 + 60 x 12,500 = 1,340,000.-

Sewer Design for Small Bore Sewerage Option
From Manhole 57B1 to Manhole 70B1

DATA Rec.No	PIPE SECTION U.Node	D.Node	GROUND ELE.(m) UPstre.	DOWNstr.	PIPE DIAM (m)	INVERT ELE.(m) UPstre.	DOWNstr.	SLOPE (m/km)	LENGTH (m)	VELOCITY (m/sec)	ACC. COST (Baht)
4	1A1	58B1	-0.46	2.20	0.700	-2.66	-2.70	0.679	60.00	0.63	76,343
5	58B1	59B1	2.20	2.51	0.700	-2.70	-2.74	0.723	60.00	0.65	159,741
6	59B1	60B1	2.51	2.48	0.700	-2.74	-2.80	0.723	84.00	0.65	277,740
7	60B1	61B1	2.48	2.46	0.800	-2.90	-2.95	0.500	84.00	0.30	410,222
8	61B1	62B1	2.46	2.44	0.800	-2.95	-2.98	0.500	63.00	0.30	509,670
9	62B1	63B1	2.44	2.42	0.800	-2.98	-3.01	0.500	63.00	0.30	609,178
10	63B1	64B1	2.42	2.40	0.800	-3.01	-3.04	0.500	63.00	0.30	708,746
11	64B1	65B1	2.40	2.38	0.800	-3.04	-3.07	0.500	63.00	0.30	808,374
12	65B1	66B1	2.38	2.35	0.800	-3.07	-3.10	0.500	63.00	0.30	908,035
13	66B1	67B1	2.35	2.33	0.800	-3.10	-3.14	0.500	63.00	0.30	1,007,730
14	67B1	68B1	2.33	2.02	0.800	-3.14	-3.16	0.500	56.00	0.30	1,095,724
15	68B1	69B1	2.02	2.02	0.800	-3.16	-3.20	0.500	64.00	0.30	1,195,627
16	69B1	70B1	2.02	2.00	1.000	-3.40	-4.00	0.500	1200.00	0.30	3,513,432

TOTAL PIPE LENGTH OF THE NETWORK = 1986 m
EXECUTION TIME (EXCLUDE THE TIME FOR FINAL RESULT PRINT OUT) = 00:23:27 (1407 SECONDS)

Manhole Cost = 40 x 12,500 = 500,000.-

APPENDIX TO CHAPTER 7

APPENDIX 7.1 :MAXIMUM SEWERAGE OPTION
Cashflow projection

1986 Constant Price
Unit : Thousand Baht

	Total	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	28	29	30
CAPITAL INVESTMENT																			
Household septic tank	35,611	5,087	5,087	5,087	5,087	5,087	5,087	5,087											
Institutional septic tank	5,223	746	746	746	746	746	746	746											
Vacuum truck	1,260	0	420	0	0	0	0	0	0	0	0	0	420	0	0	0	0	0	0
Septage treatment	87	67	0	0	0	0	0	0	0	0	0	10	0	0	0	0	0	0	0
Main sewers system	28,580	5,460	4,905	4,035	3,677	3,609	3,571	3,324											
Lateral sewers system	226,882	16,388	28,665	43,865	52,773	47,164	26,153	11,875											
Pump and pumping station	15,636	0	5,668	0	0	0	0	0	0	0	0	0	4,984	0	0	0	0	0	0
Stabilisation pond	25,474	14,128	10,346	0	0	0	0	0					500						
Aquaculture	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total investment cost	338,753	41,877	55,838	53,733	62,283	56,606	35,557	21,031	0	0	0	10	5,904	0	0	0	0	0	0
OPERATING COST																			
Vacuum truck	4,917		115	126	136	146	156	167	177	177	177	177	177	177	177	177	177	177	177
Septage treatment	1,566		54	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54
Sewers and pumping stations	68,036			611	1,090	1,654	2,162	2,459	2,611	2,611	2,611	2,611	2,611	2,611	2,611	2,611	2,611	2,611	2,611
Energy cost	17,964			97	220	387	561	649	698	698	698	698	698	698	698	698	698	698	698
Maintenance and repair of pumps	1,796			10	22	39	56	65	70	70	70	70	70	70	70	70	70	70	70
Stabilisation pond	9,380			335	335	335	335	335	335	335	335	335	335	335	335	335	335	335	335
Aquaculture	788			28	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28
Total operating cost	104,448	0	169	1,260	1,885	2,643	3,353	3,757	3,973	3,973	3,973	3,973	3,973	3,973	3,973	3,973	3,973	3,973	3,973
TOTAL CASH OUTFLOW	443,200	41,877	56,007	54,993	64,168	59,249	38,910	24,788	3,973	3,973	3,973	3,983	9,877	3,973	3,973	3,973	3,973	3,973	3,973
OPERATING INCOME																			
Septic tank	10,556		58	116	174	232	290	348	406	406	406	406	406	406	406	406	406	406	406
Aquaculture	4,051			145	145	145	145	145	145	145	145	145	145	145	145	145	145	145	145
Service charge - septage treatment	41,045		226	451	677	902	1,128	1,353	1,579	1,579	1,579	1,579	1,579	1,579	1,579	1,579	1,579	1,579	1,579
Service charge - sewer system	387,548			2,086	4,756	8,347	12,099	13,996	15,055	15,055	15,055	15,055	15,055	15,055	15,055	15,055	15,055	15,055	15,055
TOTAL OPERATING INCOME	443,200	0	284	2,798	5,751	9,625	13,661	15,842	17,184	17,184	17,184	17,184	17,184	17,184	17,184	17,184	17,184	17,184	17,184
CASH FLOW	0	(41,877)	(55,724)	(52,195)	(58,417)	(49,624)	(25,249)	(8,946)	13,211	13,211	13,211	13,201	7,307	13,211	13,211	13,211	13,211	13,211	13,211
CUMULATIVE CASHFLOW		(41,877)	(97,600)	(149,795)	(208,212)	(257,836)	(283,084)	(292,031)	(278,819)	(265,608)	(252,397)	(239,196)	(231,888)	(218,677)	(205,466)	(192,255)	(26,422)	(13,211)	0

Service Charge :Full cost recovery	Sewer	Septic	
- operating cost	274	150	Baht/household/year
- private sector	187	639	Baht/household/year
- government	622	0	Baht/household/year
- municipality	103	0	Baht/household/year
Total service charge	*1,186*	*789*	*Baht/household/year*

APPENDIX 7.1 :MAXIMUM SEWERAGE OPTION
Assumptions

1986 Constant Price
Unit : Thousand Baht

	Total	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	28	29	30
# of people use septic tank	16,900	2,414	2,414	2,414	2,414	2,414	2,414	2,414											
Household septic tank - # of unit	2,414	345	345	345	345	345	345	345											
- cum. unit		345	690	1,035	1,380	1,724	2,069	2,414	2,414	2,414	2,414	2,414	2,414	2,414	2,414	2,414	2,414	2,414	2,414
- % cum. # of household		14	29	43	57	71	86	100	100	100	100	100	100	100	100	100	100	100	100
- unit cost	14.750 Thousand Baht																		
Inst. septic tank -# of unit	57	8	8	8	8	8	8	8											
- cum. unit		8	16	24	33	41	49	57	57	57	57	57	57	57	57	57	57	57	57
-unit cost	91.625 Thousand Baht																		
Vacuum truck- inv. plan		0%	100%	0%	0%	0%	0%	0%	0%	0%	0%	0%	100%	0%	0%	0%	0%	0%	0%
- unit cost	420.000 Thousand Baht																		
- maintenance	21.000 Thousand Baht/yr.																		
- fuel	72.000 Thousand Baht/yr.																		
- driver	36.000 Thousand Baht/yr.																		
- labourers	48.000 Thousand Baht/yr.																		
- household revenue	363.000 Thousand Baht/yr.																		
inst. revenue	43.000 Thousand Baht/yr.																		
Septage treatment- const. plan	100%	100%																	
- land	28.000 Thousand Baht																		
- plant construction	38.750 Thousand Baht																		
- maintenance	3.000 Thousand Baht/yr.																		
- water analysis	15.000 Thousand Baht/yr.																		
- technician	36.000 Thousand Baht/yr.																		
- equipment(10 yr.lifetime)	10.000 Thousand Baht																		
Household in service	12,696	334	1,425	2,251	3,028	3,164	1,600	893											
Cum. # household in service		334	1,759	4,011	7,039	10,203	11,803	12,696	12,696	12,696	12,696	12,696	12,696	12,696	12,696	12,696	12,696	12,696	12,696
% Cum. # household in service		3	14	32	55	80	93	100	100	100	100	100	100	100	100	100	100	100	100
Maintenance cost of sewer system	*1% of capital Cost*																		
Pump and pumping station - const. plan PS1																			
- const. plan PS2			100%										100%						
- const. plan PS3			100%										100%						
	PS1	PS2	PS3																
- pumping station cost	0	162.856	521.622																
- pump cost	0	504.000	4,480.000																
- energy consumption(kWh)	0	34,767	415,451																
- energy cost	1.55 Baht/kWh																		
- maintenance & repair	10%of energy cost																		
Stabilisation pond - const. plan	100%	0%	100%	0%	0%	0%	0%	0%											
- % cum.		0%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
- land	14,128.100 Thousand Baht																		
- construction cost	10,346.200 Thousand Baht																		
- operating	335.000 Thousand Baht/yr.																		
- equipment(10 yr.lifetime)	500.000 Thousand Baht																		
Aquaculture - inv. plan																			
- labourer	24.000 Thousand Baht/yr.																		
- fingerling	4.134 Thousand Baht/yr.																		
- revenue	144.690 Thousand Baht/yr.																		
Number of population in household	7 people																		
Government fund	60%of capital investment																		

APPENDIX 7.1 :MAXIMUM SEWERAGE OPTION
MAIN SEWERS AND MANHOLE : CONSTRUCTION COST

1986 Constant Price
Unit : Thousand Baht

From	To	Total	Year 1	2	3	4	5	6	7
MAIN SEWERS									
1A1,1A4	28B1	3,544	0	0	0	0	1,496	0	2,048
28B1	2J3	1,688	0	596	0	1,092	0	0	0
1A2	2J3	1,743	0	1,017	0	0	726	0	0
1A6,1A3	3J3	6,469	0	0	2,706	1,368	0	2,395	0
2J3	70B1	6,247	4,361	1,886	0	0	0	0	0
Total main sewers		19,690	4,361	3,498	2,706	2,461	2,222	2,395	2,048
Manhole									
1A1,1A4	28B1	2,209	0	0	0	0	932	0	1,276
28B1	2J3	840	0	296	0	544	0	0	0
1A2	2J3	1,089	0	635	0	0	454	0	0
1A6,1A3	3J3	3,178	0	0	1,329	672	0	1,176	0
2J3	70B1	1,575	1,100	475	0	0	0	0	0
Total manhole		8,890	1,100	1,407	1,329	1,216	1,386	1,176	1,276
GRAND TOTAL		28,580	5,460	4,905	4,035	3,677	3,609	3,571	3,324

MAIN SEWERS AND MANHOLD : CONSTRUCTION PLAN
DATA MEASURED FROM FIGURE 4.2

Unit : Centimetre

From	To	Total	Year 1	2	3	4	5	6	7
1A1,1A4	28B1	13.5					5.7		7.8
28B1	2J3	5.1		1.8		3.3			
1A2	2J3	6.0		3.5			2.5		
1A6,1A3	3J3	20.8			8.7	4.4		7.7	
2J3	70B1	10.6	7.4	3.2					
Total		56.0	7.4	8.5	8.7	7.7	8.2	7.7	7.8

APPENDIX 7.1 :MAXIMUM SEWERAGE OPTION
BASIC COST OF LATERAL SYSTEM AND NUMBER OF HOUSEHOLD

PLANNING CELL	LAND USE CATEGORY	BUILT-UP AREA OF PLANNING CELL FROM BASE DATA HA	%OF BUILT-UP AREA CONSIDERED OF BUILT-UP FOR SEWERAGE %	BUILT-UP AREA CONSIDERED FOR SEWERAGE HA	BASIC COST HOUSE CONNECTION B/HA	COST PER HA LATERAL SYSTEM B/HA	TOTAL HOUSE CONNECTION BAHT	COST OF LATERAL SYSTEM BAHT	POPULATION NUMBER PER HA	TOTAL POPULATION	NUMBER OF HOUSEHOLD
(1)	(2)	(3)	(4)	(5)=(3)x(4)	(6)	(7)	(8)=(6)x(5)x1.4	(9)=(7)x(5)x1.4	(10)	(11)=(5)*(10)	(12)=(11)/7
Year 1											
30	Institutional	123.0	40	49.2	62,738	237,921	4,321,393	16,387,998	48	2,340	334
	Total year 1	123.0	40	49.2	87,833	333,089	4,321,393	16,387,998	48	2,340	334
Year 2											
9	Residential I	22.0	50	11.0	98,381	339,272	1,515,067	5,224,789	250	2,750	393
10	Residential I	44.0	50	22.0	98,381	339,272	3,030,135	10,449,578	244	5,375	768
29	Institutional	39.0	100	39.0	62,738	237,921	3,425,495	12,990,487	47	1,850	264
	Total year 2	105.0	69	72.0	110,704	398,123	7,970,697	28,664,853	139	9,975	1,425
Year 3											
21	Commercial I	30.0	100	30.0	59,397	256,098	2,494,674	10,756,116	180	5,400	771
22	Commercial II	17.0	100	17.0	104,832	365,356	2,495,002	8,695,473	265	4,500	643
27	Mixed	58.0	40	23.2	70,433	247,079	2,287,664	8,025,126	152	3,520	503
30	Institutional	123.0	40	49.2	62,738	237,921	4,321,393	16,387,998	48	2,340	334
	Total year 3	228.0	52	119.4	97,142	367,376	11,598,733	43,864,713	132	15,760	2,251
Year 4											
10	Residential I	44.0	50	22.0	98,381	339,272	3,030,135	10,449,578	244	5,375	768
11	Residential II	32.0	80	25.6	21,612	227,013	774,574	8,136,146	16	400	57
20	Commercial I	28.4	100	28.4	59,397	256,098	2,361,625	10,182,456	182	5,157	737
20	Commercial II	9.6	100	9.6	104,832	365,356	1,408,942	4,910,385	182	1,743	249
25	Mixed	32.0	100	32.0	70,433	247,079	3,155,398	11,069,139	156	5,000	714
27	Mixed	58.0	40	23.2	70,433	247,079	2,287,664	8,025,126	152	3,520	503
	Total year 4	204.0	69	140.8	92,460	374,807	13,018,338	52,772,830	151	21,195	3,028
Year 5											
7	Residential I	22.0	50	11.0	98,381	339,272	1,515,067	5,224,789	250	2,750	393
8	Residential I	33.0	100	33.0	98,381	339,272	4,545,202	15,674,366	250	8,250	1,179
9	Residential I	22.0	50	11.0	98,381	339,272	1,515,067	5,224,789	250	2,750	393
18	Commercial I	6.0	100	6.0	59,397	256,098	498,935	2,151,223	183	1,100	157
19	Commercial I	7.7	50	3.9	59,397	256,098	320,150	1,380,368	183	706	101
19	Commercial II	10.3	50	5.2	104,832	365,356	755,839	2,634,217	183	944	135
23	Mixed	66.0	50	33.0	70,433	247,079	3,254,005	11,415,050	114	3,750	536
24	Mixed	20.0	50	10.0	70,433	247,079	986,062	3,459,106	190	1,900	271
	Total year 5	187.0	60	113.0	118,498	417,380	13,390,327	47,163,908	196	22,150	3,164
Year 6											
19	Commercial I	7.7	50	3.9	59,397	256,098	320,150	1,380,368	183	706	101
19	Commercial II	10.3	50	5.2	104,832	365,356	755,839	2,634,217	183	944	135
23	Mixed	66.0	50	33.0	70,433	247,079	3,254,005	11,415,050	114	3,750	536
24	Mixed	20.0	50	10.0	70,433	247,079	986,062	3,459,106	190	1,900	271
26	Mixed	21.0	100	21.0	70,433	247,079	2,070,730	7,264,123	186	3,900	557
	Total year 6	125.0	58	73.0	101,189	358,258	7,386,785	26,152,863	153	11,200	1,600
Year 7											
6	Residential I	14.0	100	14.0	98,381	339,272	1,928,268	6,649,731	250	3,500	500
7	Residential I	22.0	50	11.0	98,381	339,272	1,515,067	5,224,789	250	2,750	393
	Total year 7	36.0	69	25.0	137,733	474,981	3,443,335	11,874,520	250	6,250	893
Total		605.0	98	592.4	103,190	382,987	61,129,609	226,881,686	150	88,870	12,696

APPENDIX 7.2 :MINIMUM SEWERAGE OPTION
Cashflow projection

1986 Constant Price
Unit : Thousand Baht

	Total	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	28	29	30
CAPITAL INVESTMENT																			
Household septic tank	142,801	20,400	20,400	20,400	20,400	20,400	20,400	20,400											
Institutional septic tank	67,894	9,699	9,699	9,699	9,699	9,699	9,699	9,699											
Vacuum truck	6,300	0	420	420	420	0	420	420	0	0	0	0	420	420	420	0	0	0	0
Septage treatment	281	261	0	0	0	0	0	0	0	0	0	10	0	0	0	0	0	0	0
Main sewers system	17,279	4,205	3,485	3,018	2,857	3,714	0	0											
Lateral sewers	72,818	0	31,349	8,695	20,899	11,875	0	0											
Pump and pumping station	4,618	0	1,818	0	0	0	0	0	0	0	0	0	1,400	0	0	0	0	0	0
Stabilisation pond	9,915	4,716	4,599	0	0	0	0	0	0	0	0	0	300	0	0	0	0	0	0
Aquaculture	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total investment cost	321,906	39,281	71,770	42,233	54,275	45,688	30,519	30,519	0	0	0	10	2,120	420	420	0	0	0	0
OPERATING COST																			
Vacuum truck	24,871		187	374	561	561	748	935	935	935	935	935	935	935	935	935	935	935	935
Septage treatment	2,407		83	83	83	83	83	83	83	83	83	83	83	83	83	83	83	83	83
Sewers and pumping stations	24,676			409	526	763	919	919	919	919	919	919	919	919	919	919	919	919	919
Energy cost	6,281			100	128	196	234	234	234	234	234	234	234	234	234	234	234	234	234
Maintenance and repair of pumps	628			10	13	20	23	23	23	23	23	23	23	23	23	23	23	23	23
Stabilisation pond	5,264			188	188	188	188	188	188	188	188	188	188	188	188	188	188	188	188
Aquaculture	704			25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25
Total operating cost	64,831	0	270	1,189	1,524	1,836	2,221	2,408	2,408	2,408	2,408	2,408	2,408	2,408	2,408	2,408	2,408	2,408	2,408
TOTAL CASH OUTFLOW	386,737	39,281	72,040	43,422	55,799	47,523	32,740	32,927	2,408	2,408	2,408	2,418	4,528	2,828	2,828	2,408	2,408	2,408	2,408
OERATING INCOME																			
Septic tank	52,260		287	574	861	1,149	1,436	1,723	2,010	2,010	2,010	2,010	2,010	2,010	2,010	2,010	2,010	2,010	2,010
Aquaculture	1,105			39	39	39	39	39	39	39	39	39	39	39	39	39	39	39	39
Service charge-septage treatment	173,112		951	1,902	2,853	3,805	4,756	5,707	6,658	6,658	6,658	6,658	6,658	6,658	6,658	6,658	6,658	6,658	6,658
Service charge-sewer system	160,260			2,556	3,264	4,995	5,978	5,978	5,978	5,978	5,978	5,978	5,978	5,978	5,978	5,978	5,978	5,978	5,978
TOTAL OPERATING INCOME	386,738	0	1,238	5,072	7,019	9,987	12,209	13,447	14,685	14,685	14,685	14,685	14,685	14,685	14,685	14,685	14,685	14,685	14,685
CASH FLOW	0	(39,281)	(70,802)	(38,350)	(48,780)	(37,536)	(20,531)	(19,480)	12,277	12,277	12,277	12,267	10,157	11,857	11,857	12,277	12,277	12,277	12,277
CUMULATIVE CASHFLOW		(39,281)	(110,083)	(148,433)	(197,213)	(234,749)	(255,281)	(274,761)	(262,483)	(250,206)	(237,929)	(225,661)	(215,504)	(203,646)	(191,789)	(179,511)	(24,555)	(12,277)	0

Service Charge :Full cost recovery	Sewer	Septic
- operating cost	338	150 Baht/household/year
- private sector	145	639 Baht/household/year
- government	567	0 Baht/household/year
- municipality	52	0 Baht/household/year
Total service charge	1,101	789 Baht/household/year

APPENDIX 7.2 :MINIMUM SEWERAGE OPTION
Assumptions

1986 Constant Price
Unit : Thousand Baht

	Total	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	28	29	30
# of people use septic tank	67,770	9,681	9,681	9,681	9,681	9,681	9,681	9,681											
Household septic tank - # of unit	9,681	1,383	1,383	1,383	1,383	1,383	1,383	1,383											
- cum. unit		1,383	2,766	4,149	5,532	6,915	8,298	9,681	9,681	9,681	9,681	9,681	9,681	9,681	9,681	9,681	9,681	9,681	9,681
- % cum.# of household		14	29	43	57	71	86	100	100	100	100	100	100	100	100	100	100	100	100
- unit cost	14.750	Thousand Baht																	
Inst. septic tank -# of unit	741	106	106	106	106	106	106	106											
- cum. unit		106	212	318	423	529	635	741	741	741	741	741	741	741	741	741	741	741	741
- unit cost	91.625	Thousand Baht																	
Vacuum truck- # of truck			1	1	1		1	1					1	1	1				
- cum. unit.			1	2	3	3	4	5	5	5	5	5	5	5	5	5	5	5	5
- # of driver			1	1	1		1	1											
- cum. unit			1	2	3	3	4	5	5	5	5	5	5	5	5	5	5	5	5
- # of labourer			2	2	2		2	2											
- cum. unit			2	4	6	6	8	10	10	10	10	10	10	10	10	10	10	10	10
- unit cost	420.000	Thousand Baht																	
- maintenance	21.000	Thousand Baht/yr.																	
- fuel	82.000	Thousand Baht/yr.																	
- driver	36.000	Thousand Baht/yr.																	
- labourers	24.000	Thousand Baht/yr.																	
- household revenue	1,454.000	Thousand Baht/yr.																	
inst. revenue	556.000	Thousand Baht/yr.																	
Septage treatment-const.plan	100%	100%																	
- land	141.000	Thousand Baht																	
- plant const.	120.000	Thousand Baht																	
- maintenance	8.000	Thousand Baht/yr.																	
- technician	36.000	Thousand Baht/yr.																	
- labourers	24.000	Thousand Baht/yr.																	
- water analysis	15.000	Thousand Baht/yr.																	
- equipment(10yr. lifetime)	10.000	Thousand Baht																	
Household in service	5,429	0	2,321	643	1,571	893													
Cum. # household in service		0	2,321	2,964	4,536	5,429	5,429	5,429	5,429	5,429	5,429	5,429	5,429	5,429	5,429	5,429	5,429	5,429	5,429
% Cum. # household in service		0	43	55	84	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Maintenance cost of sewer system	1% of capital Cost																		
Pump and pumping station - const. plan PS1																			
- const. plan PS2			100%										100%						
- const. plan PS3			100%										100%						
	PS1	PS2	PS3																
- pumping station cost	0	200.256	217.724																
- pump cost	0	560.000	840.000																
- energy consumption(kWh)	0	46,111	105,044																
- energy cost	1.55 Baht/kWh																		
- maintenance & repair	10%of energy cost																		
Stabilization pond - const. plan	100%	0%	100%																
- % cum.		0%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
- land	4,715.600	Thousand Baht																	
- construction cost	4,599.300	Thousand Baht																	
- operating	188.000	Thousand Baht																	
- equipment(10yr. lifetime)	300.000	Thousand Baht																	
Aquaculture																			
- labourer	24.000	Thousand Baht																	
- fingerling	1.128	Thousand Baht																	
- revenue	39.480	Thousand Baht																	
Number of population in household	7 people																		
Government fund	60%of capital Investment																		

APPENDIX 7.2 :MINIMUM SEWERAGE OPTION
MAIN SEWERS AND MANHOLE : CONSTRUCTION COST

1986 Constant Price
Unit : Thousand Baht

From	To	Total	Year 1	2	3	4	5	6	7
MAIN SEWERS									
1A1,1A4	48B1	5,216	0	1,055	0	1,809	2,352	0	0
48B1	73B1	4,449	3,106	1,343	0	0	0	0	0
1A3	3J3	1,870	0	0	1,870	0	0	0	0
Total main sewers		11,536	3,106	2,398	1,870	1,809	2,352	0	0
MANHOLE									
1A4,1A1	42B1	3,021	0	611	0	1,048	1,362	0	0
48B1	73B1	1,575	1,100	475	0	0	0	0	0
1A3	3J3	1,148	0	0	1,148	0	0	0	0
Total manhole		5,744	1,100	1,087	1,148	1,048	1,362	0	0
GRAND TOTAL		17,279	4,205	3,485	3,018	2,857	3,714	0	0

MAIN SEWERS AND MANHOLE : CONSTRUCTION PLAN
Data measured from figure 4.4

Unit : Centimetre

From	To	Total	Year 1	2	3	4	5	6	7
1A1,1A4	48B1	17.3		3.5		6.0	7.8		
48B1	73B1	10.6	7.4	3.2					
1A3	3J3	8.7			8.7				
Total		36.6	7.4	6.7	8.7	6.0	7.8	0.0	0.0

APPENDIX 7.2 :MINIMUM SEWERAGE OPTION
BASIC COST OF LATERAL SEWER SYSTEM AND NUMBER OF HOUSEHOLD

CELL (1)	LAND USE CATEGORY (2)	BUILT-UP AREA OF PLANNING CELL FROM BASE DATA HA (3)	AREA CONSIDERED OF BUILT-UP FOR SEWERAGE % (4)	AREA CONSIDERED BUILT-UP FOR SEWERAGE HA (5)=(3)x(4)	AVERAGE COST PER HA HOUSE CONNECTION B/HA (6)	SEWER SYSTEM B/HA (7)	TOTAL HOUSE CONNECTION BAHT (8)=(6)x(5)x1.4	COST OF SEWER SYSTEM BAHT (9)=(7)x(5)x1.4	POPULATION NUMBER PER HA (10)	TOTAL POPULATION (11)=(5)*(10)	NUMBER OF HOUSEHOLD (12)=(11)/7
Year 1											
	Total year 1	0.0	0	0.0	0	0	0	0	0	0	0
9	Residential I	22.0	100	22.0	98,381	339,272	3,030,135	10,449,578	250	5,500	786
10	Residential I	44.0	100	44.0	98,381	339,272	6,060,270	20,899,155	244	10,750	1,536
	Total year 2	66.0	100	66.0	137,733	474,981	9,090,404	31,348,733	246	16,250	2,321
Year 3											
22	Commercial II	17.0	100	17.0	104,832	365,356	2,495,002	8,695,473	265	4,500	643
	Total year 3	17.0	100	17.0	146,765	511,498	2,495,002	8,695,473	265	4,500	643
Year 4											
7	Residential I	22.0	50	11.0	98,381	339,272	1,515,067	5,224,789	250	2,750	393
8	Residential I	33.0	100	33.0	98,381	339,272	4,545,202	15,674,366	250	8,250	1,179
	Total year 4	55.0	80	44.0	137,733	474,981	6,060,270	20,899,155	250	11,000	1,571
Year 5											
6	Residential I	14.0	100	14.0	98,381	339,272	1,928,268	6,649,731	250	3,500	500
7	Residential I	22.0	50	11.0	98,381	339,272	1,515,067	5,224,789	250	2,750	393
	Total year 5	36.0	69	25.0	137,733	474,981	3,443,335	11,874,520	250	6,250	893
Year 6											
	Total year 6	0.0	0	0.0	0	0	0	0	0	0	0
Year 7											
	Total year 7	0.0	0	0.0	0	0	0	0	0	0	0
Total		605.0	25	152.0	138,743	479,065	21,089,011	72,817,881	250	38,000	5,429

APPENDIX 7.3 :SMALL BORE SEWERAGE OPTION
Cashflow projection

1986 Constant Price
Unit : Thousand Baht

	Total	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	28	29	30
CAPITAL INVESTMENT																			
Household septic tank	35,612	5,087	5,087	5,087	5,087	5,087	5,087	5,087											
Institutional septic tank	5,223	746	746	746	746	746	746	746											
Vacuum truck	8,820	0	840	420	420	840	420	0	0	0	0	0	840	420	420	840	0	0	0
Septage treatment	356	336	0	0	0	0	0	0	0	0	0	10	0	0	0	0	0	0	0
Interceptor tanks	24,133	635	2,709	4,280	5,756	6,015	3,041	1,697											
Main sewers system	24,265	4,569	4,840	3,238	2,988	3,011	2,866	2,752											
Lateral sewers	169,100	12,187	21,408	32,659	39,112	35,285	19,550	8,899											
Pump and pumping station	8,817	0	3,217	0	0	0	0	0	0	0	0	0	2,800	0	0	0	0	0	0
Stabilisation pond	24,100	13,659	9,441	0	0	0	0	0	0	0	0	0	500	0	0	0	0	0	0
Aquaculture	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total investment cost	300,425	37,220	48,287	46,430	54,109	50,985	31,711	19,183	0	0	0	10	4,140	420	420	840	0	0	0
OPERATING COST																			
Vacuum truck	34,743		366	549	731	1,097	1,280	1,280	1,280	1,280	1,280	1,280	1,280	1,280	1,280	1,280	1,280	1,280	1,280
Septage treatment	2,465		85	85	85	85	85	85	85	85	85	85	85	85	85	85	85	85	85
Sewers and pumping stations	51,214			462	821	1,242	1,625	1,849	1,966	1,966	1,966	1,966	1,966	1,966	1,966	1,966	1,966	1,966	1,966
Energy cost	12,010			65	147	259	375	434	467	467	467	467	467	467	467	467	467	467	467
Maintenance and repair of pumps	1,201			6	15	26	37	43	47	47	47	47	47	47	47	47	47	47	47
Stabilisation pond	7,974			285	285	285	285	285	285	285	285	285	285	285	285	285	285	285	285
Aquaculture	788			28	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28
Total operating cost	110,395	0	451	1,480	2,113	3,022	3,715	4,004	4,157	4,157	4,157	4,157	4,157	4,157	4,157	4,157	4,157	4,157	4,157
TOTAL CASH OUTFLOW	410,819	37,220	48,738	47,910	56,221	54,007	35,427	23,187	4,157	4,157	4,157	4,167	8,297	4,577	4,577	4,997	4,157	4,157	4,157
OPERATING INCOME																			
Septic tank	73,244		183	530	1,000	1,587	2,194	2,567	2,834	2,834	2,834	2,834	2,834	2,834	2,834	2,834	2,834	2,834	2,834
Aquaculture	4,051			145	145	145	145	145	145	145	145	145	145	145	145	145	145	145	145
Service charge -septage treatment	41,046		226	451	677	903	1,128	1,353	1,579	1,579	1,579	1,579	1,579	1,579	1,579	1,579	1,579	1,579	1,579
Service charge -sewer system	292,478			1,574	3,589	6,299	9,131	10,563	11,362	11,362	11,362	11,362	11,362	11,362	11,362	11,362	11,362	11,362	11,362
TOTAL CASH INFLOW	410,819	0	409	2,700	5,411	8,933	12,598	14,628	15,919	15,919	15,919	15,919	15,919	15,919	15,919	15,919	15,919	15,919	15,919
CASH FLOW	0	(37,220)	(48,329)	(45,210)	(50,811)	(45,074)	(22,829)	(8,559)	11,762	11,762	11,762	11,752	7,622	11,342	11,342	10,922	11,762	11,762	11,762
CUMULATIVE CASHFLOW		(37,220)	(85,549)	(130,759)	(181,570)	(226,643)	(249,473)	(258,032)	(246,270)	(234,507)	(222,745)	(210,993)	(203,371)	(192,028)	(180,686)	(169,764)	(23,524)	(11,762)	0

Service Charge :Full cost recovery	Sewer	Septic
- operating cost	254	150 Baht/household/year
- private sector	240	639 Baht/household/year
- government	515	0 Baht/household/year
- municipality	37	0 Baht/household/year
Total service charge	1,045	789 Baht/household/year

APPENDIX 7.3 :SMALL BORE SEWERAGE OPTION
Assumptions

1986 Constant Price
Unit : Thousand Baht

	Total	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	28	29	30
# of people use septic tank	16,900	2,414	2,414	2,414	2,414	2,414	2,414	2,414											
Household septic tank - # of unit	2,414	345	345	345	345	345	345	345											
- cum. unit		345	690	1,035	1,380	1,725	2,069	2,414	2,414	2,414	2,414	2,414	2,414	2,414	2,414	2,414	2,414	2,414	2,414
- % cum. # of household		14	29	43	57	71	86	100											
- unit cost	14.750 Thousand Baht																		
Inst. septic tank -# of unit	57	8	8	8	8	8	8	8											
- cum. unit		8	16	24	33	41	49	57	57	57	57	57	57	57	57	57	57	57	57
- unit cost	91.625 Thousand Baht																		
Vacuum Truck- cum.#household	15,167	687	2,465	5,070	8,451	11,968	13,921	15,167	15,167	15,167	15,167	15,167	15,167	15,167	15,167	15,167	15,167	15,167	15,167
- # of truck			2	1	1	2	1						2	1	1	2			
- cum. unit			2	3	4	6	7	7	7	7	7	7	7	7	7	7	7	7	7
- # of driver			2	1	1	2	1												
- cum. unit			2	3	4	6	7	7	7	7	7	7	7	7	7	7	7	7	7
- # of labourers			4	2	2	4	2												
- cum. unit			4	6	8	12	14	14	14	14	14	14	14	14	14	14	14	14	14
- unit cost	420.000 Thousand Baht																		
- maintenance	21.000 Thousand Baht/yr.																		
- fuel	77.857 Thousand Baht/yr.																		
- driver	36.000 Thousand Baht/yr.																		
- labourers	24.000 Thousand Baht/yr.																		
- household revenue	363.000 Thousand Baht/yr.																		
inst. revenue	43.000 Thousand Baht/yr.																		
Septage Treatment- const. plan	100%	100%																	
- land	178.000 Thousand Baht																		
- plant construction	157.500 Thousand Baht																		
- maintenance	10.000 Thousand Baht/yr.																		
- technician	36.000 Thousand Baht/yr.																		
- labourers	24.000 Thousand Baht/yr.																		
- water analysis	15.000 Thousand Baht/yr.																		
- equipment(10 yr lifetime)	10.000 Thousand Baht																		
Household in service	12,696	334	1,425	2,251	3,028	3,164	1,600	893											
Cum. # household in service		334	1,759	4,011	7,039	10,203	11,803	12,696	12,696	12,696	12,696	12,696	12,696	12,696	12,696	12,696	12,696	12,696	12,696
% Cum. # household in service		3	14	32	55	80	93	100	100	100	100	100	100	100	100	100	100	100	100
- revenue	1,903.000 Thousand Baht																		
Inst. storage tank - # of unit	701	100	100	100	100	100	100	100											
- cum. unit		100	200	300	401	501	601	701	701	701	701	701	701	701	701	701	701	701	701
- revenue	525.000 Thousand Baht																		
Interceptor tanks																			
- unit cost per household	1.901 Thousand Baht																		
Maintenance cost of sewer system	1% of capital Cost																		
Pump and pumping station - const. plan PS1																			
- const. plan PS2																			
- const. plan PS3			100%										100%						
	PS1	PS2	PS3																
- pumping station cost	0	0	416.763																
- pump cost	0	0	2,800.000																
- energy consumption(kWh)	0	0	300,996																
- energy cost	1.55 Baht/kWh																		
- maintenance & repair	10%of energy cost																		
Stabilization pond - const. plan	100%	0%	100%																
- % cum.		0%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
- land	13,659.400 Thousand Baht																		
- construction cost	9,440.900 Thousand Baht																		
- operating	284.800 Thousand Baht																		
- equipment(10yr. lifetime)	500.000 Thousand Baht																		
Aquaculture																			
- labourer	24.000 Thousand Baht																		
- fingerling	4.134 Thousand Baht																		
- revenue	144.690 Thousand Baht																		
Number of population in household	7 people																		
Government fund	60%of capital Investment																		

APPENDIX 7.3 :SMALL BORE SEWERAGE OPTION
MAIN SEWERS AND MANHOLE : CONSTRUCTION COST

1986 Constant Price
Unit : Thousand Baht

From	To	Total	Year 1	2	3	4	5	6	7
MAIN SEWER									
1A1,1A4	34B1	4,338	0	0	0	745	1,517	0	2,076
1A2	2J3	1,815	0	1,059	0	0	756	0	0
34B1	57B1	2,227	0	1,934	0	293	0	0	0
1A3,1A6	3J3	5,866	0	0	2,454	1,241	0	2,172	0
57B1	70B1	4,919	4,000	919	0	0	0	0	0
Total main sewers		19,165	4,000	3,912	2,454	2,279	2,273	2,172	2,076
Manhole									
1A4,1A1	34B1	1,414	0	0	0	243	494	0	677
1A2	2J3	585	0	341	0	0	244	0	0
34B1,2J3	57B1	525	0	456	0	69	0	0	0
1A6,1A3	3J3	1,876	0	0	785	397	0	694	0
57B1	70B1	700	569	131	0	0	0	0	0
Total manhole		5,100	569	928	785	709	738	694	677
GRAND TOTAL		24,265	4,569	4,840	3,238	2,988	3,011	2,866	2,752

MAIN SEWERS SYSTEM : CONSTRUCTION COST
Data measured from figure 4.5

Unit : Centimetre

From	To	Total	Year 1	2	3	4	5	6	7
1A4,1A1	34B1	16.3				2.8	5.7		7.8
1A2	2J3	6.0		3.5			2.5		
34B1,2J3	57B1	3.8		3.3		0.5			
1A6,1A3	3J3	20.8			8.7	4.4		7.7	
57B1	70B1	9.1	7.4	1.7					
Total		56.0	7.4	8.5	8.7	7.7	8.2	7.7	7.8

APPENDIX 7.3 :SMALL BORE SEWERAGE OPTION
BASIC COST OF LATERAL SEWERS SYSTEM AND NUMBER OF HOUSEHOLD

CELL	LAND USE CATEGORY	BUILT-UP AREA OF PLANNING CELL FROM BASE DATA HA	AREA CONSIDERED OF BUILT-UP FOR SEWERAGE %	AREA CONSIDERE BUILT-UP FOR SEWERAGE HA	AVERAGE COST PER HA HOUSE CONNECTION B/HA	AVERAGE COST PER HA SEWER SYSTEM B/HA	TOTAL HOUSE CONNECTION BAHT	COST OF SEWER SYSTEM BAHT	POPULATION NUMBER PER HA	TOTAL POPULATION	NUMBER OF HOUSEHOLD
(1)	(2)	(3)	(4)	(5)=(3)x(4)	(6)	(7)	(8)=(6)x(5)x1.4	(9)=(7)x(5)x1.4	(10)	(11)=(5)*(10)	(12)=(11)/7
Year 1											
30	Instituional	123.0	40	49.2	55,876	176,929	3,848,739	12,186,870	48	2,340	334
	Total year 1	123.0	40	49.2	78,226	247,701	3,848,739	12,186,870	48	2,340	334
9	Residential I	22.0	50	11.0	87,620	254,269	1,349,348	3,915,743	250	2,750	393
10	Residential I	44.0	50	22.0	87,620	254,269	2,698,696	7,831,485	244	5,375	768
29	Institutional	39.0	100	39.0	55,876	176,929	3,050,830	9,660,323	47	1,850	264
	Total year 2	105.0	69	72.0	98,595	297,327	7,098,874	21,407,551	139	9,975	1,425
Year 3											
21	Commercial I	30.0	100	30.0	52,901	188,948	2,221,842	7,935,816	180	5,400	771
22	Commercial II	17.0	100	17.0	93,366	274,625	2,222,111	6,536,075	265	4,500	643
27	Mixed	58.0	40	23.2	62,730	184,732	2,037,470	6,000,095	152	3,520	503
30	Institutional	123.0	40	49.2	55,876	176,929	3,848,739	12,186,870	48	2,340	334
	Total year 3	228.0	52	119.4	86,517	273,525	10,330,162	32,658,856	132	15,760	2,251
Year 4											
10	Residential I	44.0	50	22.0	87,620	254,269	2,698,696	7,831,485	244	5,375	768
11	Residential II	32.0	80	25.6	19,248	161,850	689,848	5,800,704	16	400	57
20	Commercial I	28.4	100	28.4	52,901	188,948	2,103,344	7,512,572	182	5,157	737
20	Commercial II	9.6	100	9.6	93,366	274,625	1,254,839	3,690,960	182	1,743	249
25	Mixed	32.0	100	32.0	62,730	184,732	2,810,304	8,275,994	156	5,000	714
27	Mixed	58.0	40	23.2	62,730	184,732	2,037,470	6,000,095	152	3,520	503
	Total year 4	204.0	69	140.8	82,347	277,783	11,594,502	39,111,811	151	21,195	3,028
Year 5											
7	Residential I	22.0	50	11.0	87,620	254,269	1,349,348	3,915,743	250	2,750	393
8	Residential I	33.0	100	33.0	87,620	254,269	4,048,044	11,747,228	250	8,250	1,179
9	Residential I	22.0	50	11.0	87,620	254,269	1,349,348	3,915,743	250	2,750	393
18	Commercial I	6.0	100	6.0	52,901	188,948	444,368	1,587,163	183	1,100	157
19	Commercial I	7.7	50	3.9	52,901	188,948	285,136	1,018,430	183	706	101
19	Commercial II	10.3	50	5.2	93,366	274,625	673,169	1,980,046	183	944	135
23	Mixed	66.0	50	33.0	62,730	184,732	2,898,126	8,534,618	114	3,750	536
24	Mixed	20.0	50	10.0	62,730	184,732	878,220	2,586,248	190	1,900	271
	Total year 5	187.0	60	113.0	105,538	312,259	11,925,760	35,285,219	196	22,150	3,164
Year 6											
19	Commercial I	7.7	50	3.9	52,901	188,948	285,136	1,018,430	183	706	101
19	Commercial II	10.3	50	5.2	93,366	274,625	673,169	1,980,046	183	944	135
23	Mixed	66.0	50	33.0	62,730	184,732	2,898,126	8,534,618	114	3,750	536
24	Mixed	20.0	50	10.0	62,730	184,732	878,220	2,586,248	190	1,900	271
26	Mixed	21.0	100	21.0	62,730	184,732	1,844,262	5,431,121	186	3,900	557
	Total year 6	125.0	58	73.0	90,122	267,815	6,578,913	19,550,463	153	11,200	1,600
Year 7											
6	Residential I	14.0	100	14.0	87,620	254,269	1,717,352	4,983,672	250	3,500	500
7	Residential I	22.0	50	11.0	87,620	254,269	1,349,348	3,915,743	250	2,750	393
	Total year 7	36.0	69	25.0	122,668	355,977	3,066,700	8,899,415	250	6,250	893
Total		605.0	98	592.4	91,904	285,449	54,443,649	169,100,184	150	88,870	12,696

APPENDIX 7.4 :SEPTIC TANK OPTION
Cashflow projection

1986 Constant Price
Unit : Thousand Baht

	Total	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	28	29	30
CAPITAL INVESTMENT																			
Household septic tank	222,873	31,839	31,839	31,839	31,839	31,839	31,839	31,839											
Institutional septic tank	69,452	9,922	9,922	9,922	9,922	9,922	9,922	9,922											
Vacuum truck	8,820	0	420	420	420	420	420	420	420	0	0	0	420	420	420	420	420	0	0
Septage treatment	356	336	0	0	0	0	0	0	0	0	0	10	0	0	0	0	0	0	0
Total investment cost	301,500	42,096	42,181	42,181	42,181	42,181	42,181	42,181	420	0	0	10	420	420	420	420	420	0	0
OPERATING COST																			
Vacuum truck	33,280		183	366	549	731	914	1,097	1,280	1,280	1,280	1,280	1,280	1,280	1,280	1,280	1,280	1,280	1,280
Septage treatment	2,465		85	85	85	85	85	85	85	85	85	85	85	85	85	85	85	85	85
Total operating cost	35,745		268	451	634	816	999	1,182	1,365	1,365	1,365	1,365	1,365	1,365	1,365	1,365	1,365	1,365	1,365
TOTAL CASH OUTFLOW	337,245	42,096	42,448	42,631	42,814	42,997	43,180	43,363	1,785	1,365	1,365	1,375	1,785	1,785	1,785	1,785	1,785	1,365	1,365
OPERATING INCOME																			
Septic tank	73,684		405	810	1,215	1,619	2,024	2,429	2,834	2,834	2,834	2,834	2,834	2,834	2,834	2,834	2,834	2,834	2,834
Service charge-septage treatment	263,561		1,448	2,896	4,344	5,793	7,241	8,689	10,137	10,137	10,137	10,137	10,137	10,137	10,137	10,137	10,137	10,137	10,137
TOTAL OPERATING INCOME	337,245	0	1,853	3,706	5,559	7,412	9,265	11,118	12,971	12,971	12,971	12,971	12,971	12,971	12,971	12,971	12,971	12,971	12,971
CASH FLOW	0	(42,096)	(40,595)	(38,925)	(37,255)	(35,585)	(33,915)	(32,245)	11,186	11,606	11,606	11,596	11,186	11,186	11,186	11,186	11,186	11,606	11,606
CUMMULATIVE CASHFLOW		(42,096)	(82,692)	(121,617)	(158,872)	(194,457)	(228,372)	(260,617)	(249,431)	(237,825)	(226,219)	(214,623)	(203,437)	(192,251)	(181,065)	(169,879)	(23,212)	(11,606)	0

Servic Charge :Full cost recovery — Septic
- operating cost — 150 Baht/household/year
- private sector — 639 Baht/household/year

Total service charge — 789 Baht/household/year

APPENDIX 7.4 :SEPTIC TANK OPTION
Assumptions

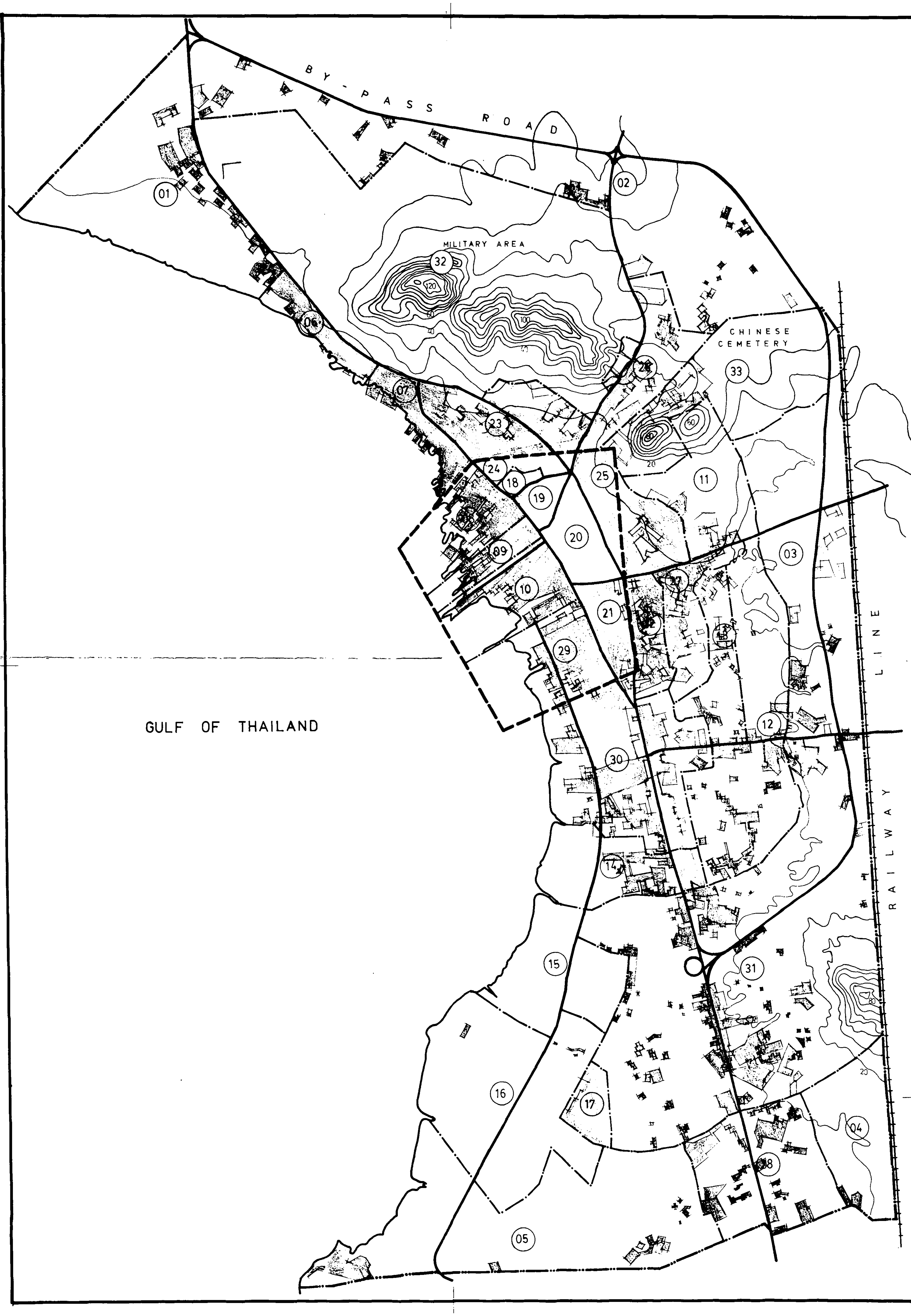
1986 Constant Price
Unit : Thousand Baht

	Total	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	28	29	30
# of people use septic tank	105,770	15,110	15,110	15,110	15,110	15,110	15,110	15,110											
Household septic tank - # of unit	15,110	2,159	2,159	2,159	2,159	2,159	2,159	2,159											
- cum. unit		2,159	4,317	6,476	8,634	10,793	12,951	15,110	15,110	15,110	15,110	15,110	15,110	15,110	15,110	15,110	15,110	15,110	15,110
- % cum. of # household		14	29	43	57	71	86	100	100	100	100	100	100	100	100	100	100	100	100
- unit cost	14.750	Thousand Baht																	
Inst. septic tank -# of unit	758	108	108	108	108	108	108	108											
- cum. unit		108	217	325	433	541	650	758	758	758	758	758	758	758	758	758	758	758	758
- unit cost	91.625	Thousand Baht																	
Vacuum Truck- # of truck			1	1	1	1	1	1	1				1	1	1	1	1		
- cum. unit			1	2	3	4	5	6	7	7	7	7	7	7	7	7	7	7	7
- # of driver			1	1	1	1	1	1	1										
- cum. unit			1	2	3	4	5	6	7	7	7	7	7	7	7	7	7	7	7
- # of labourer			2	2	2	2	2	2	2										
- cum. unit			2	4	6	8	10	12	14	14	14	14	14	14	14	14	14	14	14
- unit cost	420.000	Thousand Baht																	
- maintenance	21.000	Thousand Baht/yr.																	
- fuel	77.857	Thousand Baht/yr.																	
- driver	36.000	Thousand Baht/yr.																	
- labourers	24.000	Thousand Baht/yr.																	
- household revenue	2,266.000	Thousand Baht/yr.																	
inst. revenue	568.000	Thousand Baht/yr.																	
Septage treatment- const. plan	100%	100%																	
- land	178.000	Thousand Baht																	
- plant construction	157.500	Thousand Baht																	
- maintenance	10.000	Thousand Baht/yr.																	
- technician	36.000	Thousand Baht/yr.																	
- labourers	24.000	Thousand Baht/yr.																	
- water analysis	15.000	Thousand Baht/yr.																	
- equipment(10 yr. lifetime)	10.000	Thousand Baht																	
Number of population in household	7	people																	

APPENDIX 7.5 : CAPITAL FUNDING

1986 Constant Price
Unit: Thousand Baht

	Total	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	28	29	30
MAXIMUM SEWERAGE OPTION																			
Private																			
- Septic tank	40,833	5,833	5,833	5,833	5,833	5,833	5,833	5,833											
- Sewer household conn.	61,130	4,321	7,971	11,599	13,018	13,390	7,387	3,443											
Public																			
- Government	203,252	28,660	37,977	32,798	39,240	33,774	20,182	10,620											
- Municipality	33,538	3,061	4,057	3,503	4,191	3,608	2,156	1,134	0	0	0	10	5,904	0	0	0	0	0	0
Loan																			
Total capital inflow	338,753	41,877	55,838	53,733	62,283	56,606	35,557	21,031	0	0	0	10	5,904	0	0	0	0	0	0
MINIMUM SEWERAGE OPTION																			
Private																			
- Septic tank	210,695	30,099	30,099	30,099	30,099	30,099	30,099	30,099											
- Sewer household conn.	21,089	0	9,090	2,495	6,060	3,443	0	0											
Public																			
- Government	82,502	9,182	32,581	9,639	18,116	12,145	420	420											
- Municipality	7,620	0	0	0	0	0	0	0	0	0	0	10	2,120	420	420	0	0	0	0
Loan																			
Total capital inflow	321,906	39,281	71,770	42,233	54,275	45,688	30,519	30,519	0	0	0	10	2,120	420	420	0	0	0	0
SMALL BORE SEWERAGE OPTION																			
Private																			
- Septic tank	40,834	5,833	5,833	5,833	5,833	5,833	5,833	5,833											
- Sewer household conn.	54,444	3,849	7,099	10,330	11,595	11,926	6,579	3,067											
- interceptic tank	24,133	635	2,709	4,280	5,766	6,015	3,041	1,697											
Public																			
- Government	168,154	26,902	32,646	25,987	30,925	27,211	16,258	8,585											
- Municipality	12,500	0	0	0	0	0	0	0	0	0	0	10	4,140	420	420	840	0	0	0
Loan																			
Total capital inflow	300,425	37,220	48,287	46,430	54,109	50,985	31,711	19,183	0	0	0	10	4,140	420	420	840	0	0	0
SEPTIC TANK OPTION																			
Private																			
- Septic tank	292,324	41,761	41,761	41,761	41,761	41,761	41,761	41,761											
Public																			
- Government	2,856	336	420	420	420	420	420	420											
- Municipality	6,320	0	0	0	0	0	0	0	420	0	0	10	420	420	420	420	420	0	0
Loan																			
Total capital inflow	301,500	42,096	42,181	42,181	42,181	42,181	42,181	42,181	420	0	0	10	420	420	420	420	420	0	0



BY-PASS ROAD
MILITARY AREA
CHINESE CEMETERY
GULF OF THAILAND
RAILWAY LINE
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Map No. I

Base Map of the Study Area

Study Area

Municipality Area

(12) Planning Cell

Built-up Area

Major Road

Source : Based on Land Use Maps by Town and Country Planning Department (1983) and Flood Control and Drainage Study (1984)

0 250 500 750 1000 2000M

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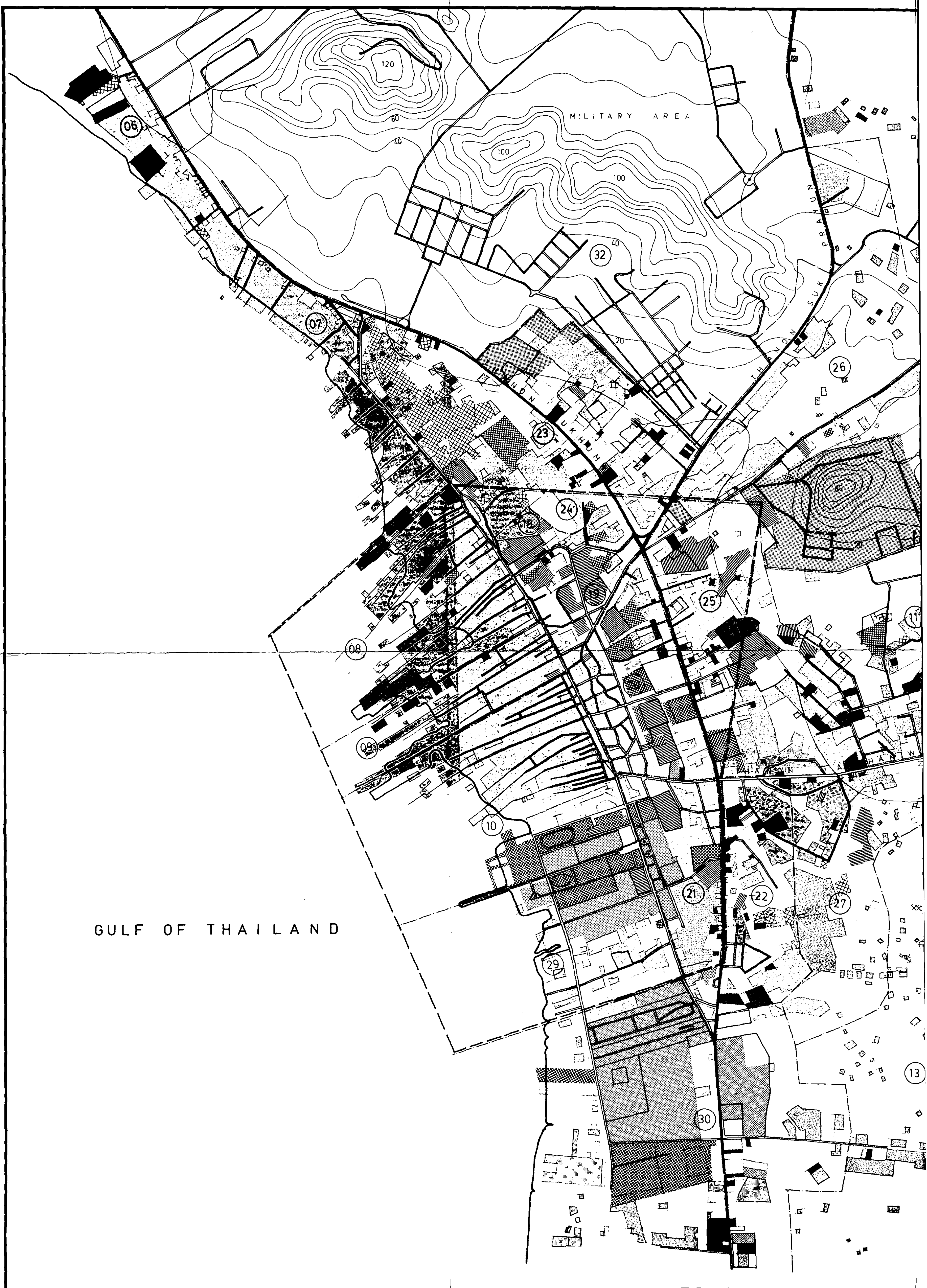

MILITARY AREA
GULF OF THAILAND
THANON SUKHUMVIT
THANON SUKHUMVIT PRAMUN
120
100
60
40
20
06
07
08
09
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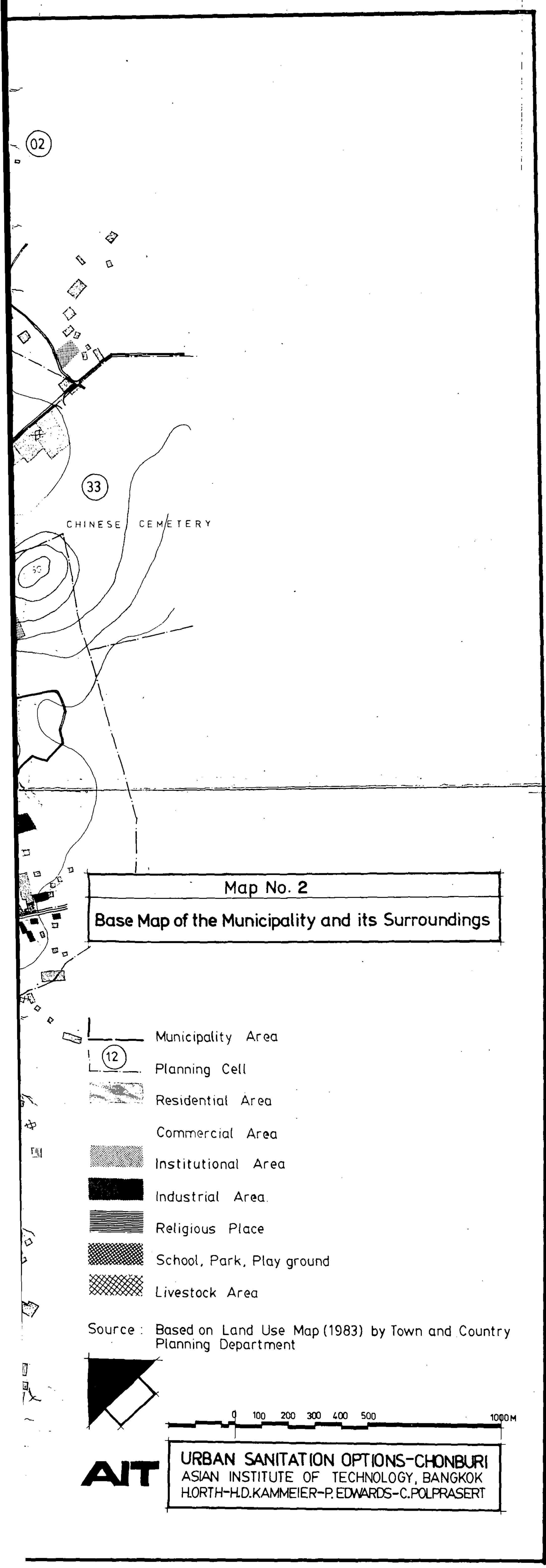

02
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CHINESE CEMETERY
Map No. 2
Base Map of the Municipality and its Surroundings
Municipality Area
12
Planning Cell
Residential Area
Commercial Area
Institutional Area
Industrial Area
Religious Place
School, Park, Play ground
Livestock Area
Source : Based on Land Use Map (1983) by Town and Country Planning Department
0 100 200 300 400 500 1000M
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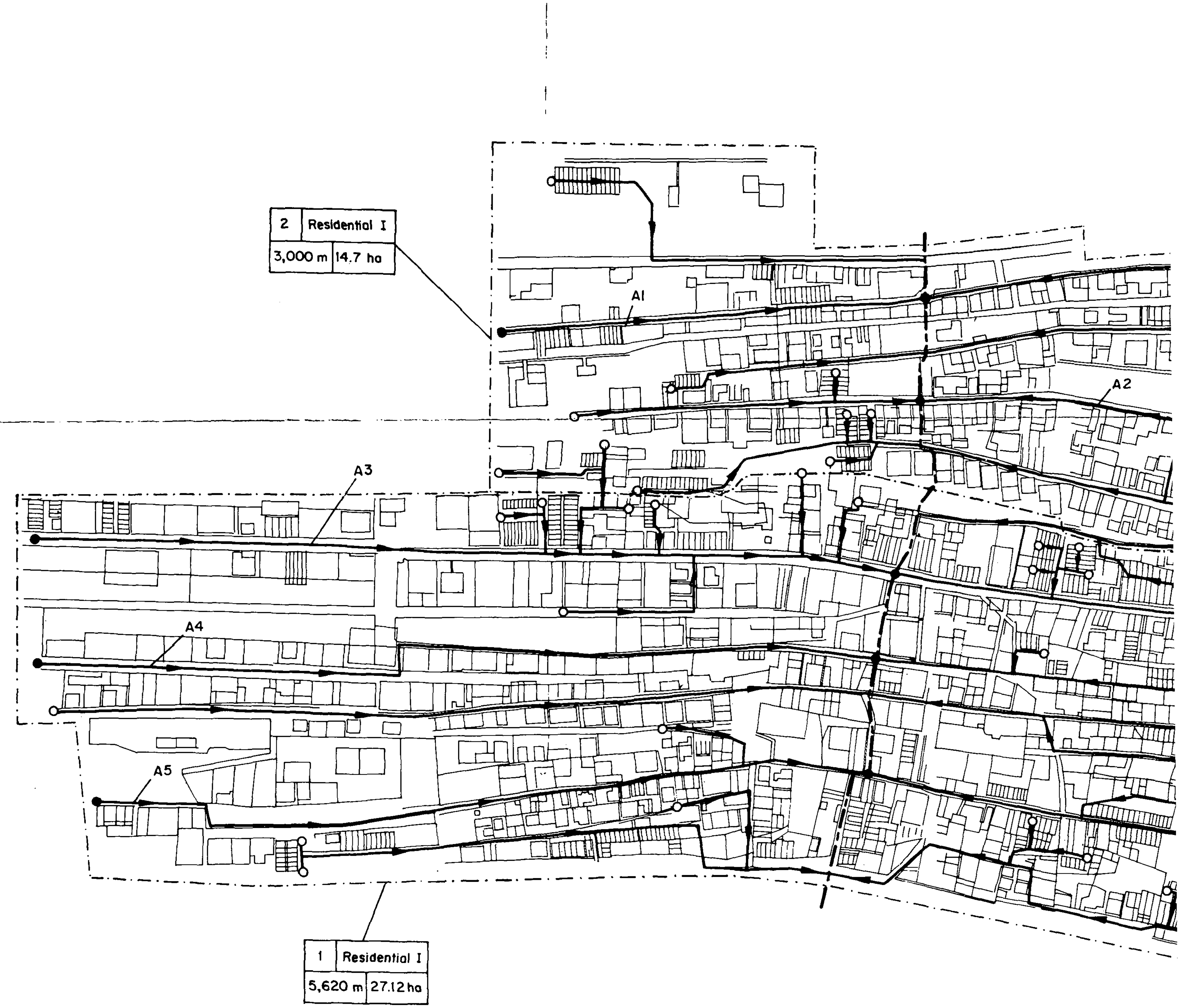
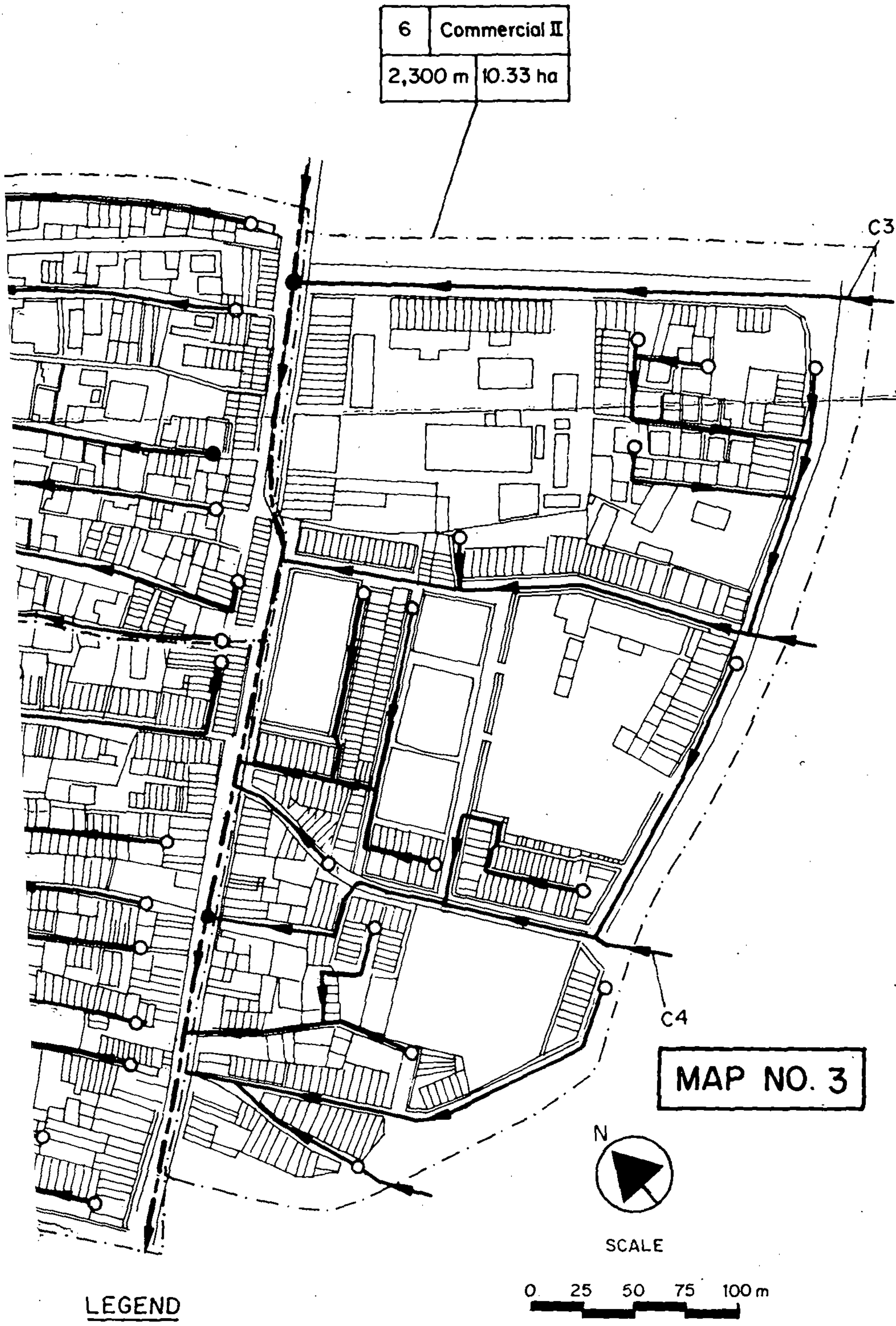


Map 3 : Secondary sewer : network in planning cells 8, 9 and 19



LEGEND

-·-·-·-	Boundary of land use category
o	Beginning of each sewer
— — — —	Trunk sewer
——►——	Secondary sewer
A1 ●——●	Illustrated critical sewer A1
Residential I / 620 m / 27.12 ha	Illustrated representative area no. 1 of 'Residential I' landuse category having sewers of total length 5,620 m over a gross area of 27.12 ha

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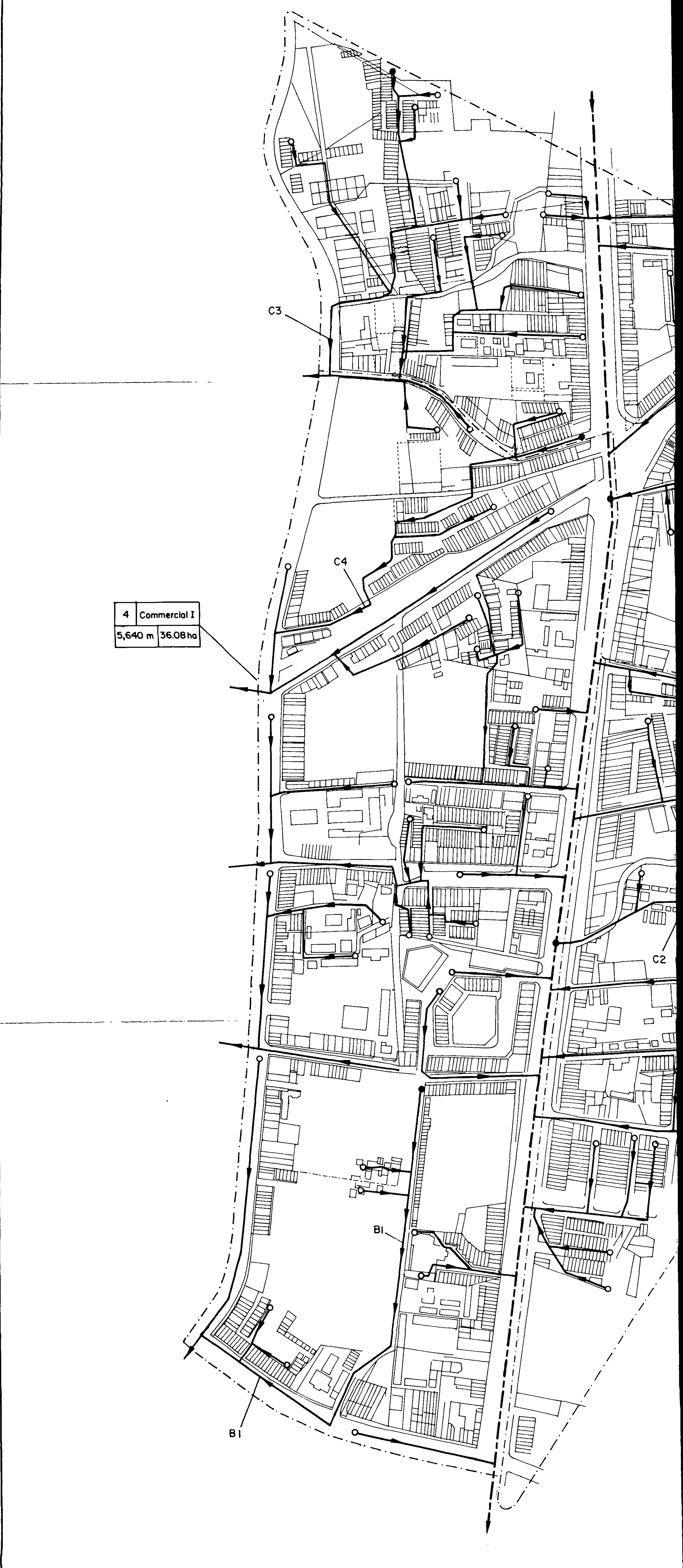
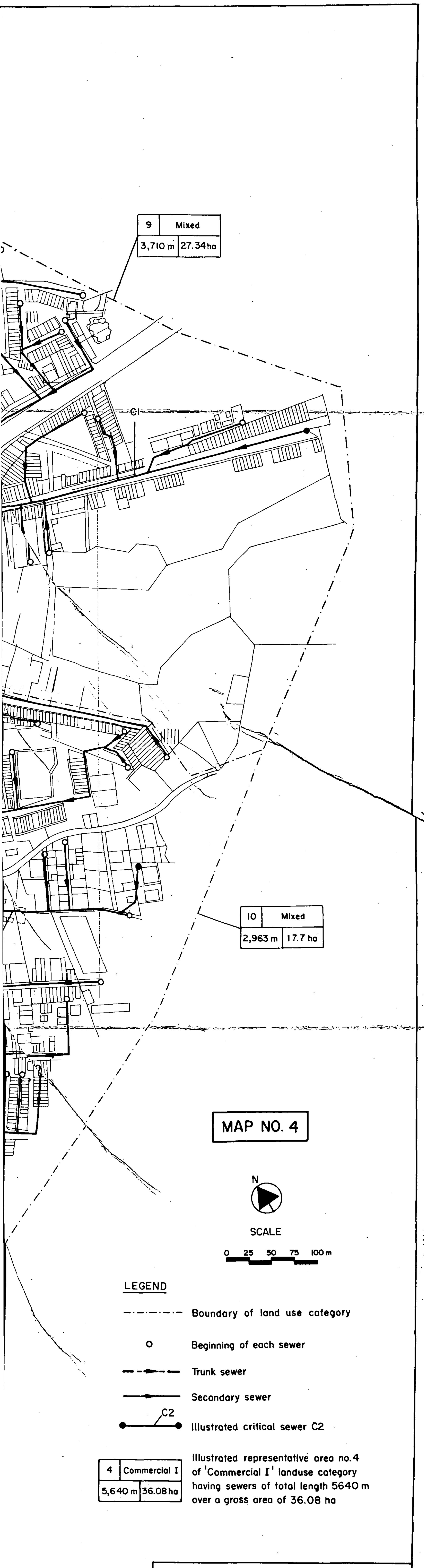


Map 4 : Secondary sewer network in planning cells 19, 20, 24 and 25



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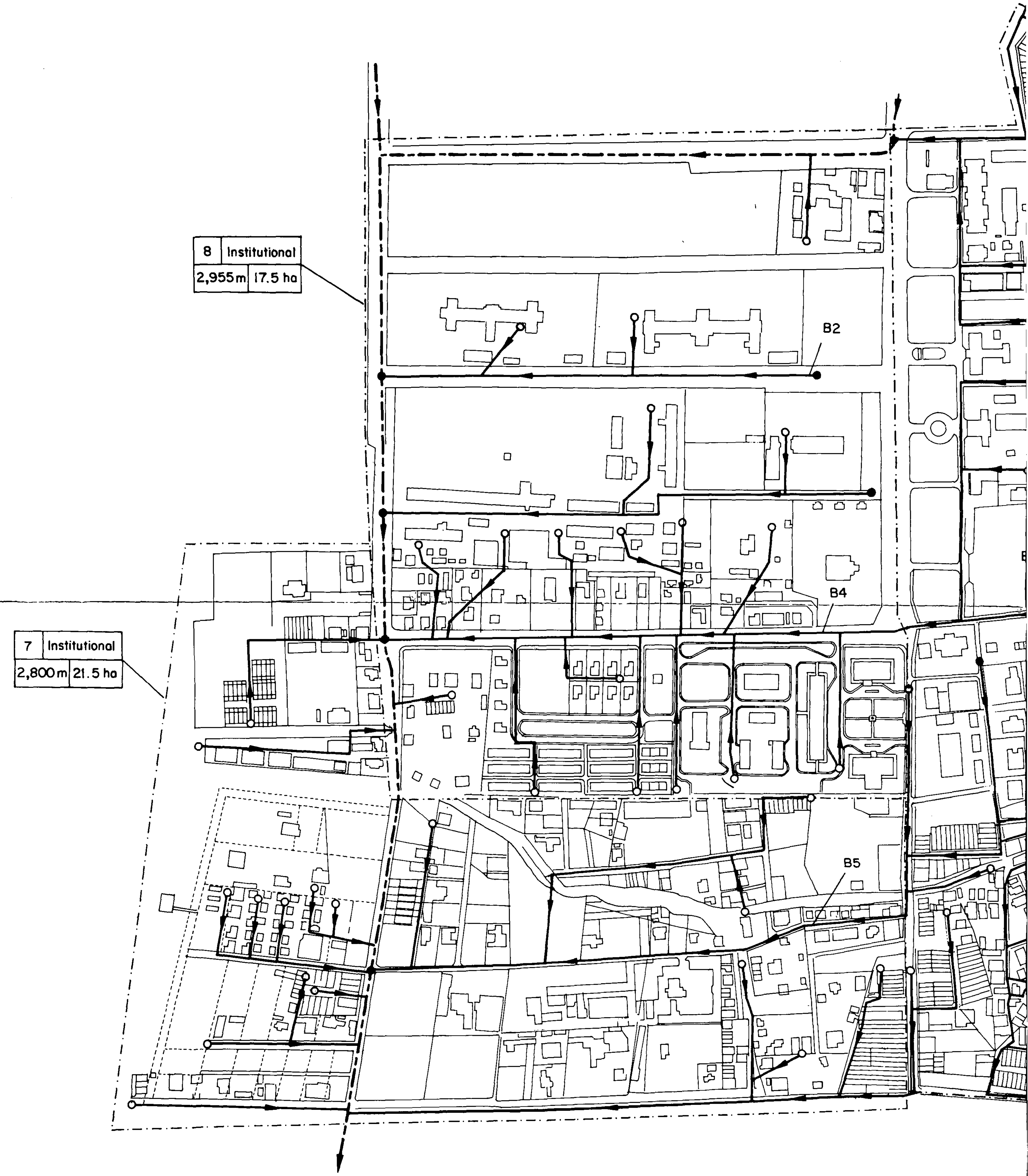
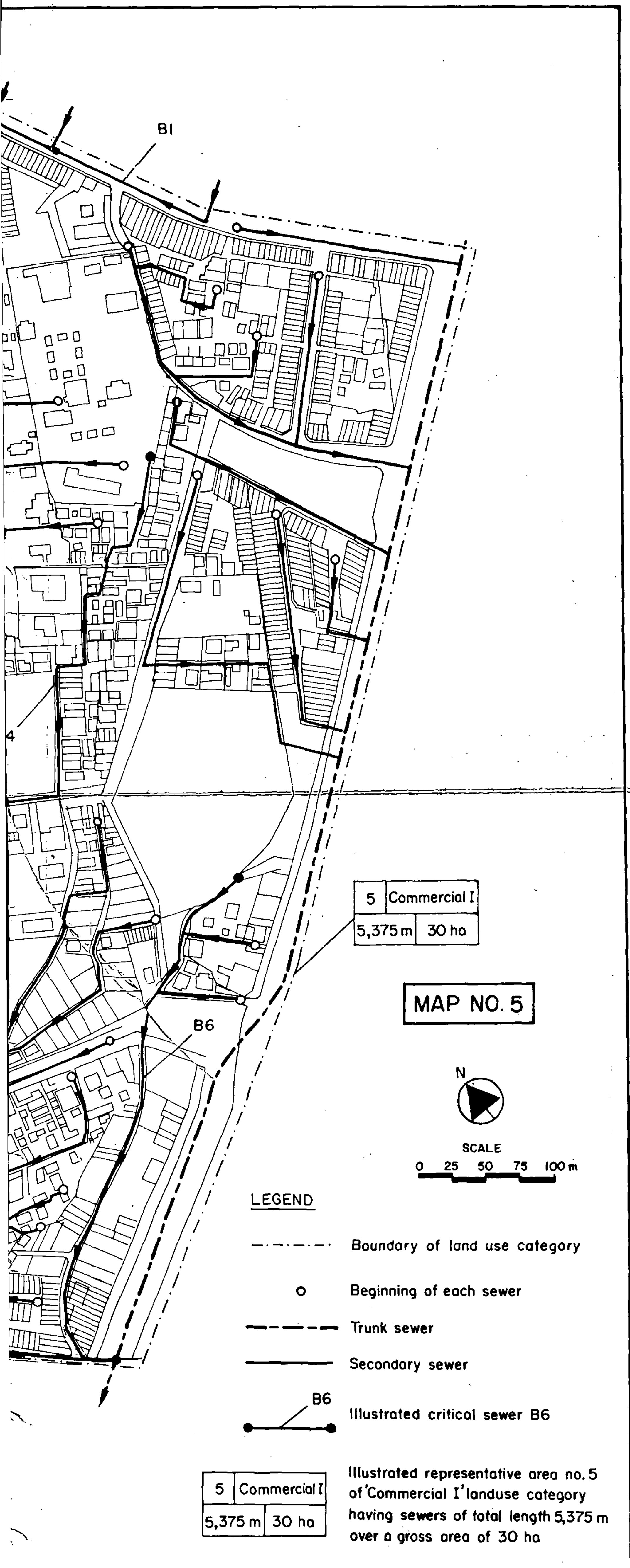


Map 5 : Details of secondary sewer network in planning cells 21 and 29 .



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