Report

December 1990

Municipality of Phnom-Penh
Sewerage Department

NOVIB
Netherlands Organization for
International Development
Cooperation

Drainage Study of Beng Salang Drainage Basin

Phnom-Penh, Cambodia

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Consultancy Group for
Watersupply, Sanitation,
Agriculture and Watermanagement

Utrecht, The Netherlands

IHE DELFT

International Institute for
Hydraulic and Environmental
Engineering

Delft, The Netherlands

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I Table of Contents

Appendices

Figures

Tables

II Summary of conclusions and recommendations

1. Proposed construction work in the Beng Salang drainage basin

- The following work should be carried out to prevent flooding of the Psar Depot 2 area:
  - provision of a discharge culvert (6.0 m wide, 2.0 m high) through the dike of the Beng Salang drainage basin,
  - construction of a 1.2 km open channel in Beng Salang lake,
  - construction of a 1.8 km box culvert from Psar Depot 2 to the lake,

  Details of the proposed conduit are given in Figures 5-2 and 5-3.
  The final design of the proposed system is determined by the outcome of soil investigations and the results of the proposed study on the water management of Beng Tempen polder.
- The discharge channel in the Beng Tempen polder need to be dredged prior to the implementation of the work in the Beng Salang drainage basin.
- Waste water interceptors around the Beng Salang lake should be constructed to collect all waste water from the distilleries, residences and sewers discharging into the lake.
  The final design of the proposed interceptors is determined by the outcome of a study on the disposal of waste water from the Beng Salang drainage basin.

- The estimated costs of the proposed works in the Beng Salang drainage basin are:

main sewer, 1820 m box culvert	Dfl 5600,000	US $ 3100,000
open channel, including culverts	Dfl 3300,000	US $ 1800,000
waste water interceptors	Dfl 800,000 +	US $ 500,000 +
total:	Dfl 9700,000	US $ 5400,000

  This cost estimate includes the provision of one backhoe/loader, two dump trucks, one dredger (hydraulic grab), three barges with one pushboat and one dredge pump with 540 m pipeline. The cost of the equipment including training, provision of spare parts, etc. is Dfl 2180,000 (US $ 1210,000).
- The studies indicated before have to be completed before construction work starts. The sequence of the proposed activities should be as given in Chapter 5, Table 5-2.

- More than one hundred thousand people residing in the Beng Salang drainage basin will benefit indirectly from the proposed scheme when considering that flood levels in the basin are reduced. More than 7000 people will be directly and immediately involved, when they are connected to the sewer system. This number will increase gradually with the connection of residential areas to the sewer system, for example, with the implementation of the pilot water supply and sanitation project Psar Depot 2.

2. Institutional requirements/technical assistance

- The provision of adequate equipment and training of staff for the design, construction and maintenance of sewers is urgently needed.
  The proposed project should include a technical assistance component for the provision of equipment and on-the-job training to the Sewerage Department.
- It is recommended that a resident engineer be appointed to assist the Municipality with the implementation of the project. The appointment could first be for a period of three years. The resident engineer will be responsible for the implementation of the technical assistance component. An engineer will be appointed for a period of 12 to 18 months to assist with the supervision of the construction of the combined sewer (box culvert).
- The duration of the project is expected to be between four and six years. The estimated cost for foreign staff is Dfl 1,000,000 if the project duration is limited to 5 years.

3. Community participation

- The conflicting use of surface water for the disposal of waste water and horticulture is a serious public health hazard and needs to be studied.
- The implementation of the proposed works requires the co-operation of the local population, particularly with regard to the water supply and sanitation facilities around the Beng Salang lake.
- The local population should be involved with the planning and implementation of sanitation systems, such as sewer connections, replacement of pit latrines by pour-flush units, etc. The financing of the house-owners' component should be investigated. The people should also be involved with the improvement of the water supply system.

4. Dredging in Beng Tempen polder

- To reduce flood levels in the Beng Salang lake and Beng Tempen polder and to allow dewatering of the proposed open channel in the Beng Salang drainage basin, it is recommended that the Beng Tempen lake and discharge channel in the polder be dredged. This measure will also greatly improve the drainage characteristics of the sewer systems in the Beng Salang drainage basin.

5. Special studies

- Soil investigations should be carried out for the final design of the proposed construction work as well as for the required dredging work in Beng Tempen polder and Beng Salang lake.
- The disposal of waste water from the Beng Salang drainage basin should be investigated for the final design of the proposed waste water interceptors.
- The water management of the Beng Tempen polder needs to be studied in detail to be based on a detailed survey of the discharge channel and lake. The proposed study should consider the increased run-off from the Beng Salang drainage basin resulting from an improved sewerage system in the basin, as well as the functioning and up-keep of the Beng Tempen pumping station. The study should address environmental and social impacts of the conflicting use of the discharge channel for horticulture and human waste disposal. The proposed engineering study will therefore include a major component for community involvement.

6. Completion of sewerage records

- The planning and design of sewerage systems should be based on up-to-date plans and records indicating the exact location, slope, diameter, invert and ground elevations of sewers as well as the location of house connections. Sewerage records should preferably be on a scale of 1 : 1000. It is recommended that for the completion of sewerage records a set of suitable base maps be prepared, as-built drawings of sewer construction be made and survey results be transferred to the sewerage records. Sewerage records should be kept up-to-date.
- Levelling work for the planning, design and construction of drains should be based on an adequate benchmark system. It is recommended that the provision of benchmarks be continued and existing benchmarks be maintained.
- Adequate surveying equipment and skilled staff for the design and construction of drains are not available within the Sewerage Department. The consultants recommend the urgent provision of surveying equipment and training of surveyors.

7. Master Planning

- A comprehensive Master Plan Study on Urban Drainage for the entire city is needed. This study should include the completion of sewerage records, an integrated study of the sewerage network by considering, among others things, alternative conveyance systems, waste water disposal, micro-drainage, operation and maintenance procedures, financial requirements, institutional requirements, environmental and social impact assessment and community involvement. The Study should also take into consideration the measures that will be taken for the improvement of the water supply facilities. A Master Plan study should also include the following investigations:
  - financial feasibility of alternative types of sewer systems,
  - determination of run-off coefficient rainfall and run-off measurements,
  - hydrological studies rainfall data, river water levels).
- Considering the destruction of urban services during a long period of wars, shortage of skilled personnel and the lack of financial resources, financial and technical assistance from the international and bi-lateral agencies is urgently needed for the rehabilitation and development of the drainage, water supply and sanitation facilities of Phnom Penh. Assistance should include the training of staff at all levels.

8. Existing sewerage facilities

- The Beng Salang pumping station is redundant, because storm water from the Beng Salang drainage basin can be discharged by gravity into the Beng Tempen polder. A culvert should be provided for the direct discharge of storm water from the drainage basin into the Beng Tempen polder.
- The sewerage system in Phnom Penh is of insufficient capacity and of inadequate construction. Blocked drains and the non-availability of drains create an important health problem.
- The construction of sewers (in Beng Salang drainage basin) is below standards. The slope of the sewer invert is not uniform, causing grit to settle in drains.
  The limited infiltration capacity of the soil do not permit the provision of on-site sanitation systems. The combination of septic tanks and combined sewers does not function and should be abolished immediately.
  Municipal by-laws regulating the location of buildings and urban infrastructure need to be enforced.
  The operation of the Beng Tempen pumping station is seriously affected by the limited supply of energy. The flood levels in the polder can be reduced by starting full pump operation at the beginning of a heavy rainfall and by maintaining a minimum water level in the lake as much as possible.

9. Type of sewer system

- The discharge of waste water should not be allowed into surface ditches, open channels or lakes within the built-up area.
- The separate sewer system is the most suitable type of system for the Beng Salang drainage basin; it is cheaper to build, it functions better and it involves less public health risks than a combined sewer system. The system will consist of a piped sanitary sewer system and a low-cost solution for storm water drainage. Storm water will be transported in surface ditches and open channels in streets and alleys and through underground drains in main roads.

10. Design of proposed facilities

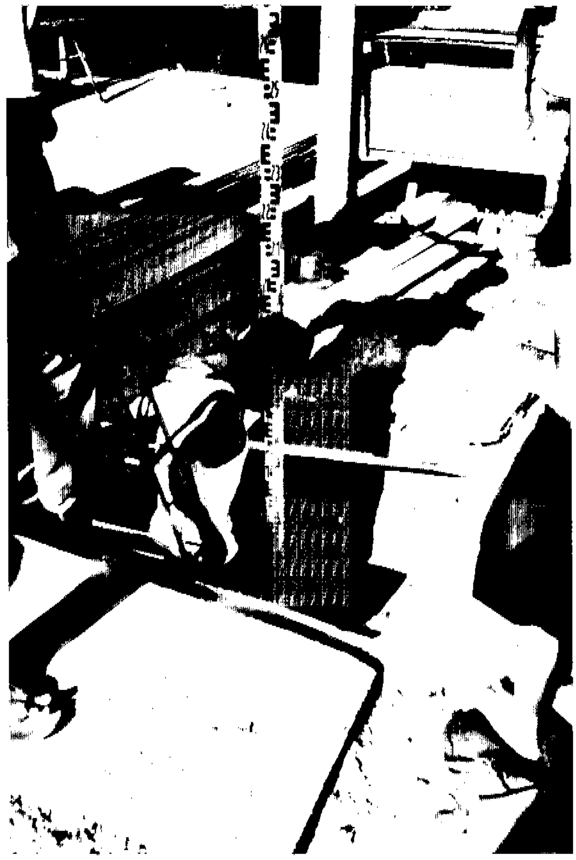
- The proposed main sewer from Psar Depot 2 to the Beng Salang lake has been designed as a combined sewer to follow the policy of the Sewerage and Urbanization Departments, but it can also function as a storm water drain of the separate system, when a separate sanitary sewer is laid parallel to the drain.
  The proposed open channel should be constructed as a "dry" channel which empties completely after a heavy rainfall.
- It is recommended that the rational method be used for the determination of the storm water quantities.
  The calculation procedure can be performed by local staff.
  It is recommended that the drainage system of the Beng Salang drainage basin be designed on a run-off coefficient of 70% and on rainfalls expected to occur or to be exceeded once a year.
- The derived rainfall depth-duration-frequency curves for Phnom Penh are based on incomplete data. The results are acceptable for the underlying study, but more hydrological investigations are required if the data will be used for the entire city of Phnom Penh (see Chapter 4, Figure 4-3).
- The minimum required gradients of sewers should be determined on the basis of sediment transport. The recommended minimum required slopes of sewers for the combined and separate system are given in Chapter 4, Table 4-5.

III Acknowledgement

The consultants would like to express their gratitude to all who contributed with their information to the report.

IV Terminology

BM B	temporary benchmark, no B .. (established by Consultants)
BM BSL	permanent benchmark in Beng Salang drainage basin, no BM .. BSL (established by Consultants)
BM NGK	national benchmark NGK (refer NGK), no BM .. NGK
consultants	IHE-SAWA - Mr. L.A. van Duijl and Mrs. L. van Goor
Dfl	Dutch guilder
ha	hectare(s)
IHE	International Institute for Hydraulic and Environmental Engineering
IRC	International Reference Centre
km	kilometre(s)
L/s	litre(s) per second
L/cap/day	litre(s) per head of population (capita) and per day
m	metre(s)
m^3/scubic	metre(s) per second
min	minute(s)
mm	millimetre
NGK	Nivellement General Khmer; NGK is the national benchmark system of which the naught is related to "normal" sea level. + 2.00 m means NGK + 2.00 m
NGO	non-governmental organization
NOVIB	Netherlands Organization for International Development Cooperation
Par.	paragraph; Par. 4-1 = refer to paragraph number in report
polder	drainage basin with a controlled water level
Psar Depot 2	NOVIB's pilot project in Beng Salang Drainage Basin for the provision of local urban infrastructure
Ref.	refer to number of reference given in chapter 7, "List of References"
SAWA	Consultancy Group for Watersupply, Sanitation, Agriculture and Watermanagement
$^{o}/_{oo}$	gradient, 1 m per 1000 m



Picture 1 Measuring culvert in waste water

Picture 2 Measuring main sewer

Picture 3 Water supply and sanitation in Beng Salang lake

1 Introduction

The Netherlands Organization for International Development Cooperation (NOVIB) supports the municipality of Phnom Penh with the implementation of a pilot project to test and develop an integrated approach for the improvement of living conditions and reducing health risks in low-income residential areas in Phnom Penh. The project includes the provision of drainage and sanitation facilities. The activities are concentrated in two areas, one of which, Psar Depot 2, is located in the Beng Salang drainage basin in Phnom Penh.

The pilot project area Psar Depot 2 is densely populated. A serious public health risk is caused by waste water flowing in surface ditches or in the middle of roads. Drainage and adequate sanitation facilities are absent. The unhygienic conditions are particularly dangerous when it rains.

Psar Depot 2 is severely flooded when it rains, because it also receives storm water from the upper catchment areas, which can not be transported by existing drains along the boundaries of the pilot area (see Figure 2-3). The provision of drainage facilities within the pilot area should, therefore, be preceded by an improvement of the existing transport and disposal system.

The International Institute for Hydraulic and Environmental Engineering (IHE) was invited to submit a proposal for a drainage study of the Beng Salang drainage basin. The invitation included a project description indicating a project duration of four months.

Together with SAWA Consulting Group for Water Supply, Sanitation, Agriculture and Water Management, IHE submitted a proposal (dated April 1990) for a drainage study based on an integrated approach to include, in addition to technical aspects, environmental and institutional aspects. A counterpart contribution composed of one surveying team, one community organizer and one or two engineers would be needed.

The consultants were requested, during their first meeting with NOVIB on 22 May 1990, to cancel the proposed institutional and some technical activities. A modified work plan (dated 31 May 1990) was submitted.

The scope and the contents of the drainage study changed completely during the second meeting with NOVIB on 26 June 1990. The consultants were instructed by the Resident Engineer from Phnom Penh to design the pumping and water storage facilities for the Beng Salang drainage basin. The drainage system needed only to be investigated with regard to the determination of the required pumping capacity. The consultants were informed that sufficient data (contour maps, sewer records) are available. There would be no need to investigate the disposal of storm water nor to study the social and environmental impacts of the proposed measures. The input of experts was reduced to two months.

The second modified proposal (dated 11 July) has been accepted. A description of the proposed activities is given in Appendix 1. The study has been carried out by Mrs. L. van Goor (SAWA) and Mr. L.A. van Duijl (IHE).

Mrs. van Goor was in Phnom Penh from 3 August through 4 October to conduct an inventory of the existing facilities, to carry out the surveying work (Photo 1 and 2) and to process the collected data. Mr. van Duijl was in Phnom Penh between 17 and 24 August to analyze the drainage conditions from the surveyed data and to adapt the work plan as needed for the surveying work. In Bangkok on 27 and 28 August he collected rainfall and river water level data and in Phnom Penh from 17 September through 4 October he completed the study and design work.

The consultants concluded in August that the Beng Salang pumping station is not needed; the station should be replaced with a discharge culvert for a gravity discharge of storm water. The improvement of the drainage facilities in the Beng Salang drainage basin is accordingly related to the water management of the Beng Tempen polder. It was also found that an integrated approach is needed when considering the social and environmental impact of the required measures. The water supply and sanitation conditions in the Beng Salang lake (Photo 3) and the disposal of waste water need to be studied. A survey of the existing drainage facilities, particularly between Psar Depot 2 and the Beng Salang lake, is required. The work plan was adapted to allow the preparation of a preliminary plan of the required works in the Beng Salang drainage basin.

The results of the study were discussed with the three municipal Departments for Sewerage, Pumping Stations and Urbanization during a series of three meetings in September and October. An agreement was reached on the selected alternatives, design criteria and the final recommendations.

The construction procedures and the required types of excavation equipment were further investigated in The Netherlands with assistance from SAWA and IHE staff, and discussions were held with equipment manufacturers and individuals who have carried out similar works in developing countries. The drawings of the design work and the final reporting were completed in The Netherlands.

Table 2-1 Climatic data for Phnom Penh

Month	Precipitation	Evaporation (Class-A pan)	Temperature	Relative humidity
	mm	mm/day	°C	%
January	8.6	5.9	26.0	71.1
April	78	7.8	29.3	72.2
July	153	5.4	27.4	82.8
October	232	4.6	27.1	83.3
Annually	1365			
Annual average:		5.9	27.5	

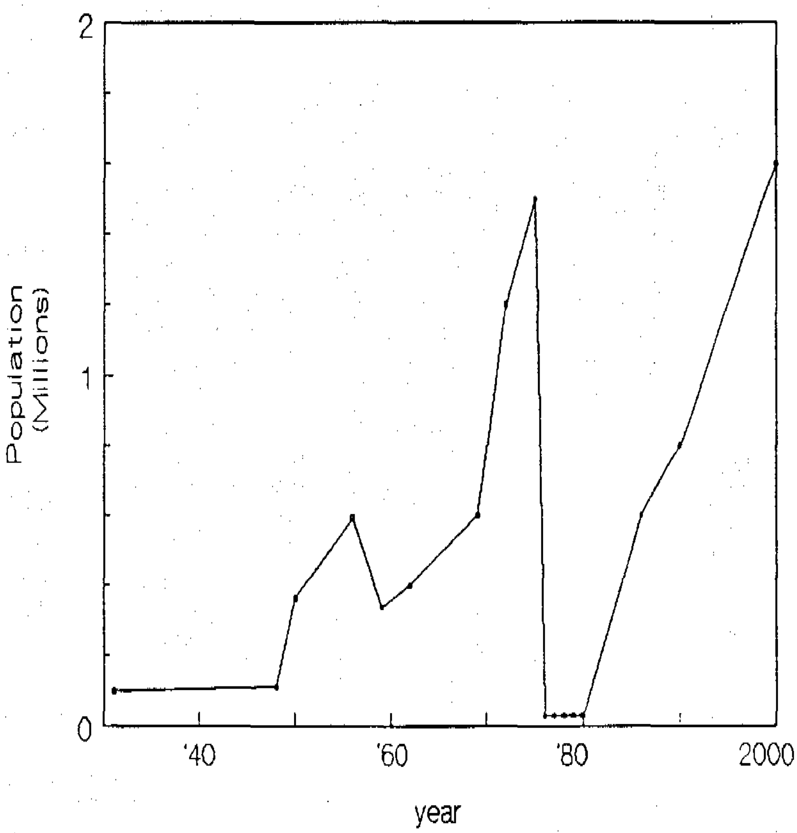


Figure 2-2 Population of Phnom Penh

2 Existing facilities

2.1 Existing situation in Phnom-Penh

a) Climate and soil

The climate is tropical with an uneven distribution of rainfall over the year. It is determined by a dry north-east monsoon with little precipitation and a south-west monsoon with tropical rainfalls. The dry season includes the period December - April. An excellent description of the climate is given by Overkamp (ref 7). A summary is presented in Table 2-1.

The city is subjected to severe rain storms with high intensity rainfalls. These intensities are approximately of equal magnitude to those in the city of Bangkok, or four times as high as those in The Netherlands (Figure 4-2).

With regard to the soil characteristics, a distinction is made between the river banks composed of sand and the backswamp areas of clay precipitated during the rainy season when the backswamps are flooded. The artificial landfilling in the central and old residential areas of Phnom Penh consists of sand. The clay layer is lying on a sandy layer; both layers may reach a depth of 10 m.

b) Land reclamation

The city of Phnom Penh, located at the confluence of the rivers Mekong, Tonle Sap and Bassac, is situated in a typical deltaic area that, with the exception of the high elevated river banks, is flooded during the rainy season. The oldest part of the city was established on the west bank of Tonle Sap. As a result of a phased land reclamation project through the construction of ring-dikes since 1920, the urban area has gradually increased from 400 ha to 3600 ha over a period of 50 years, as shown in Figure 2-1. After a new ring-dike for the extension of the urban area had been completed, the inner dikes were levelled off for the provision of major ring-roads or boulevards (Figure 2-1).

In 1972, an area of 6400 ha was reclaimed through the construction of three dikes (Figure 2-1). This area,used for agricultural purposes, includes the airport and the polder Beng Tempen, expected to be urbanized in the near future. Since 1987 the water management of this polder has been separated from the remainder of the reclaimed area.

The urban services suffered from overloading and improper use from 1970-75, when a vast number of refugees settled in the capital. The refugees came from the western part of the country, which was heavily bombed during the Vietnam war, and later from other parts of the country terrorized by the Khmer Rouge. The urban services deteriorated drastically during the subsequent holocaust of the town population by the Pol Pot regime, when the city was forcibly evacuated and, with the exception of 30,000 soldiers, entirely empty until 1979. The urban services were partly removed or destroyed and the city was inundated during the rainy season.

After the liberation of the country, the functioning of the urban services was restored. It is remarkable that in spite of the lack of skilled personnel (murdered during the Pol Pot period), all drainage pumping stations are functioning quite well, although the equipment is in a bad state of repair. The impact of the assistance rendered by the Vietnamese and Russian Governments and western NGO's has been quite considerable, but little could be done on the rehabilition and development of the drainage, water supply and sanitation facilities. Assistance from western international and bi-lateral agencies is needed to rehabilitate and develop the drainage, water supply and sanitation sector.

c) Urban planning

Trends of population growth are presented in Figure 2-2 (Ref. 5). The present growth of nearly 10% per year is extremely high because of a high rate of natural increase and migration. This growth coincides at present with intense business and building activities. The price of land and particularly of ground-floor establishments in the centre of the city are extremely high. It is impossible to give a reliable estimate of the future population. A low estimate for the year 2000 based on a 4% annual growth rate is 1.2 million inhabitants, but if the present population continues to grow at a rate of 10% per year, Phnom Penh would number 2 million inhabitants in the year 2000. These figures are possibly too conservative; after peace is made in Cambodia many refugees will settle in Phnom Penh.

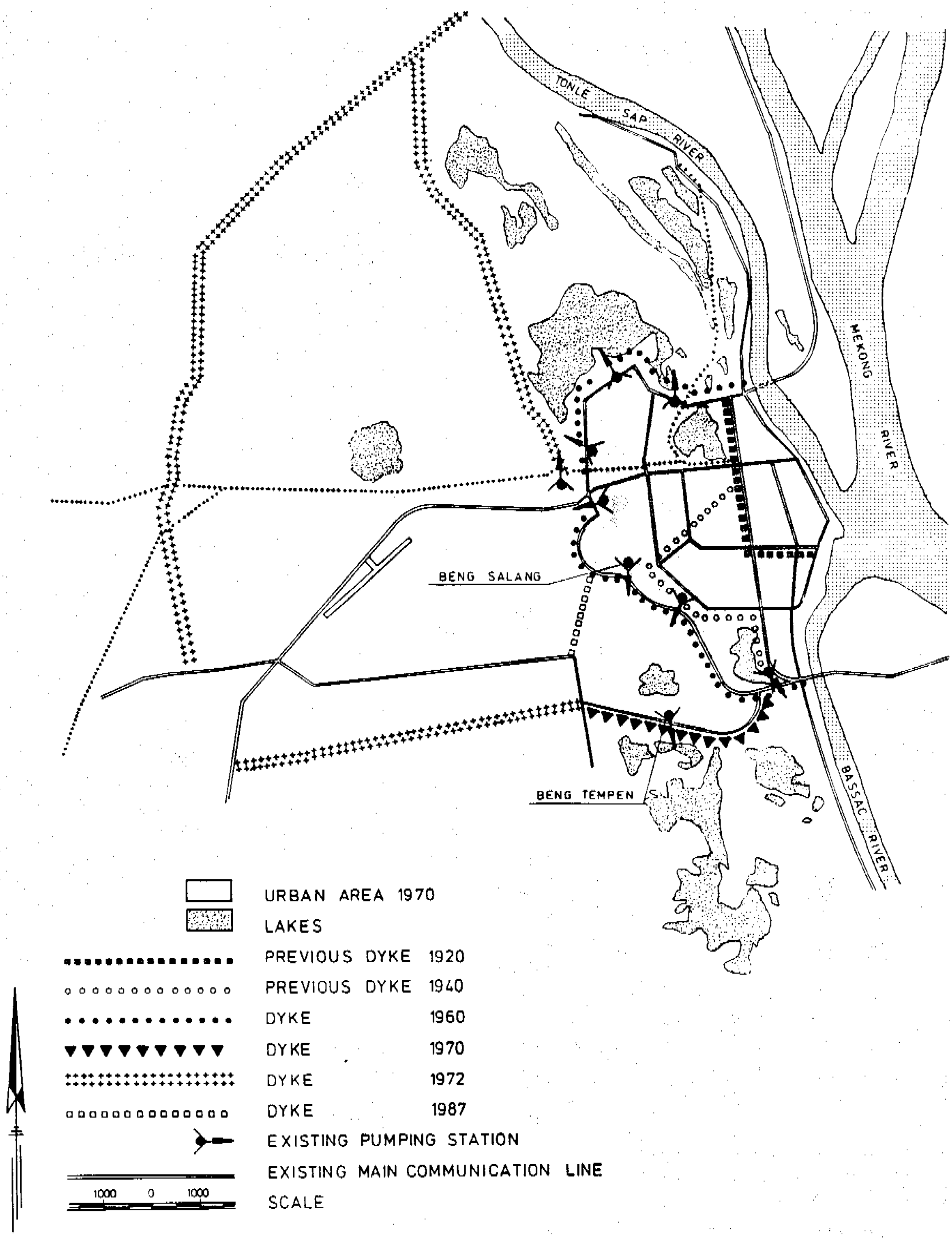


Figure 2-1 Land reclamation in Phnom Penh

The central part of the city is fully developed but the outer residential areas are comparatively less developed. The area covered with buildings and paved surfaces in relation to the total area varies accordingly between 10% and 100%.

Considering an assumed population of 750,000 within the limits of the present urban area, the average density of population amounts to 220 capita per hectare, which is extremely high in view of the existing open spaces. Many residential buildings appear to be overcrowded. The density of population could be as high as 500 to 800 capita per hectare.

Building regulations are hardly enforced. As a result of haphazard development, buildings are constructed above existing urban services in alleys and roads. Measures are now being taken to limit the illegal construction of buildings.

d) Drainage

The river water levels at Phnom Penh vary more than 7 m during the year; they are between + 1.0 m and + 2.0 m in the dry season, increasing to + 7.0 m or + 9.0 m at the end of the wet season. All elevations are reduced to the national bench mark system NGK (see Par. 3-2). Extremely high water levels nearly reached the top of the dikes at + 10.0 m. The central business centre and the old part of the capital built on the west bank of Tonle Sap and the adjacent filled-up land are at an elevation of + 10.0 m to 12.0 m. The ground elevation of the residential areas is generally between + 5.5 m and + 8.0 m. Surface water flows by gravity to the low-lying areas. There are three lakes for the storage of storm water: Beng Trabek, Beng Salang and Beng Tempen. Rain water collected in the low-lying areas or lakes is pumped over the dikes as shown in Figure 2-1.

There is an overland run-off of storm water in the city caused by blocked sewers and the non-availability of drains. As a result, nearly the entire city is flooded when it rains, although, with the exception of the (topographical) depressions, flooding usually disappears within three hours of a heavy rainfall. The depth of flooding is determined by the topographical conditions; it varies between 5 and 30 cm.

Overkamp (ref 6) concluded that the main drains of the Beng Trabek Drainage Basin are of sufficient capacity, provided that the deposits in the drains are removed. The conclusion was based on the connection of a comparatively small part of the tributary drainage areas. The consultants found that the main drainage system is of an insufficient capacity. Because of blocked street drains or the non-availability of drains, water is stored in the yards and streets, thus limiting the problem of flooding along main sewers.

Waste water is discharged into the drainage system, which is considered a combined system for the conveyance of storm water and waste water. Blocked drains and the non-availability of drains create an important public health problem.

Neither details of slope, invert levels, exact location, etc. of sewers nor locations of house connections are available. Sewerage records are urgently needed for design and maintenance work.

The drainage system does not function properly because of inadequate invert slopes. Large quantities of deposits are found in the system which are difficult to remove.

A comprehensive Master Plan Study of the storm water disposal for the entire city is urgently needed. This study should include the completion of sewerage records, an integrated study of the network by considering among others alternative conveyance systems, waste water disposal, micro-drainage, operation and maintenance procedures, financial requirements, institutional requirements, environmental impact assessment and community involvement.

e) Water supply and sanitation

Water supply

The water supply facilities are in very bad condition. The supply of water is restricted to only ten hours per day. Broken pipes and the insufficient capacity of the distribution network further limit the provision of water. The water pressure developed in the system in the Beng Salang drainage basin is just below or above ground level. Consumers install a pump in the house connection to lift the water into their houses. Water is accordingly supplied either by pumping from the distribution network into a ground- or roof reservoir or by gravity to a ground reservoir or concrete well.

Ground-water will infiltrate into the network at times of no flow, but also when pumping if a negative pressure develops in the pipes. The ground-water is usually heavily polluted because of seepage from drains and septic tanks.

The gravity-fed concrete wells are often constructed in the pavement. These wells are open, generally used by several consumers and severely polluted.

The specific water consumption is low, particularly in the Beng Salang drainage basin, as most people collect their water with buckets. It is assumed that the specific amount of water consumption is only 35 L/c/d.

Sewerage
The comparatively high population density, high ground-water during the rainy season and the limited permeability of the clay layers do not permit the infiltration of (treated) sewage effluent into the underground. Generally speaking, on-site sanitation systems are, therefore, not feasible in Phnom Penh.

The original concept of waste water disposal in Phnom Penh is a combination of septic tanks and a combined sewer system. Waste water is subjected to sedimentation in septic tanks before discharging it into the sewer system. The biologically degraded sludge would be removed from the septic tanks by means of vacuum trucks. There are thus two systems: a pipe transport of settled sewage and a road transport for the disposal of sewage sludge. This concept was applied in the central part of the city. The drainage system would benefit as it would be free from sewage sludge.

The consultants reject the combined sewer - septic tank option because of malfunctioning of the system. Desludging septic tanks is not controlled, as this is the sole responsibility of the home-owners. There is in fact no need for desludging when the septic tanks are full of sludge, because sewage sludge can easily pass these tanks and subsequently enter the drainage system. The removal of septic tank sludge is accordingly neglected.

An important disadvantage of the combined sewer - septic tank option is the discharge of anaerobic septic tank effluent into sewers, which severely affects the system. The anaerobic condition of the waste water generates hydrogen sulfide which is responsible for the corrosion of concrete sewer pipes.

The specific amount of waste water production is extremely low, particularly in the Beng Salang drainage basin, and is assumed to be 30 L/cap/day.

Urban drainage in Phnom Penh includes the disposal of waste water and is accordingly affected by the improvement of the water supply facilities. A "Master Plan Study on Urban Drainage" should include an integrated study on "Waste Water Disposal" and take into consideration the measures that will be taken for the improvement of the water supply facilities. Alternative systems for the disposal of storm water and waste water must be investigated to find a technically and financially feasible solution.

It is noted that institutional constraints such as the legal provision of water by individuals or small organizations to consumers in apartment blocks and the illegal provision of water free of charge may hamper the development of the water distribution network.

Solid wastes
The streets are quite clean. Domestic wastes are collected in containers and transported by compacter trucks. This system has been functioning adequately for a few years. A well-functioning solid wastes collection system is a prerequisite for the development of the urban drainage system.

2.2 Beng Salang Drainage Basin

Most of the run-off from the city flows to the lakes Beng Trabek and Beng Salang (Figure 2-1). The watershed between the drainage basins of both lakes is indicated in Figure 2-3.

The location of the watershed is determined by the lay-out of the existing drainage facilities. A different lay-out of the system could change the size of the basins completely. In this regard it is noted that the topographical conditions of the northwestern part of the existing Beng Trabek drainage basin would allow the run-off from this area to flow towards Beng Salang, if the drainage systems of both basins would be linked together and/or the outfall drain to lake Beng Trabek would be blocked. Finding optimum solutions for the lay-out of the drainage system should be included in a "Master Plan Study on Urban Drainage" indicated in Par. 2.1-d.

The total area of the basin is 560 ha. The areas adjacent to the major roads and the Psar Depot 2 area are fully developed. The western and southern parts of the basin consist of low-density and open areas. The surfaced area (asphalt, roofs, concrete backyards, etc.) related to the total area of the basin is less than 30%; classification of areas is estimated in Table 2-2.

The entire area slopes towards Beng Salang Lake with the exception of a small unsewered area in Tuk Laak which is drained through a separate pumping station (Figure 2-1). Contours of the area are presented in Figure 3-1. The slope of the natural ground is generally 0.7 °/oo. Although the natural ground slope is not uniform, it creates sufficient hydraulic gradient for the transport of sediments in large drains. This slope, however, is not sufficient for the smaller diameter drains needing steeper slopes for the transport of sediments. As a consequence main drains will have to be constructed at greater depths to create sufficient gradient for the upper ends of the drainage system.

As described in Par. 2.1-d, the drainage basin is flooded when it heavily rains because of an inadequate drainage system. During the rainy season, when the soil is saturated with rain water, most of the surface water is drained overland, as a result of which flooding disappears within three hours after a storm. The depth of flooding varies

Type of Area	Surfaced Area	Area (ha)
high density	> 70% (fully built-up)	80 ha
medium density	20 - 70 %	200 ha
low density	< 20% (open areas)	180 ha
average	< 30 %	560 ha

Table 2-2 Classification of drainage area

between 5 and 20 cm.

Local depressions are subjected to greater depth and prolonged periods of flooding. These low-lying areas should be connected directly to a main drain.

The existing situation of the Beng Salang lake is shown in Figure 2-4. The plan is the result of a survey described in Par. 3-1. The water collected in the lake is evacuated through two culverts (diameter 1.0 and 0.6 m) and a pumping station. The pumping station is equipped with one diesel-driven pump with an assumed capacity of 700 L/s (ref. 7). Fuel was not available when the consultants visited the station. Fuel is provided by the municipality, only after the water levels of the lake have risen considerably.

At times of dry weather during the observed period of August-September 1990, the water level on both sides of the culverts was generally at an elevation of + 4.75 m. With heavy rains, the water level of the lake increased by 0.3 to 0.5 m. The maximum water level determined from the information given by the local population is usually + 5.60 m during the rainy season, although extreme levels of + 6.50 m occurred in previous years. The houses generally constructed on poles are free from flooding, but the access to the buildings is regularly inundated (see Figure 2-4). It is remarkable that the inundation that occurred in buildings in the drainage basin (see Par. 2.1-d) did not exist in the low-lying area around the lake.

The inflow to the lake, when rains are heavy, is between 2 and 4 m^3/s. This inflow may continue for several hours, when water is stored in the drainage basin. The rising water level in the lake creates a level difference between both sides of the culverts which is less than 0.8 m. Therefore, the contribution delivered by the pumping station appears to be of little value, since the 1.0 m diameter culvert was constructed in 1987/88. An enlargement of the discharge culvert will make the pumping station entirely redundant.

Since the introduction of a separate water control system for Beng Tempen Polder in 1987 (Par. 2.1b), flood levels are below + 5.60 m in this polder. This peak level is exactly the same as the usual maximum water level of Beng Salang Lake. There is accordingly no need for a pumping station at Beng Salang. The consultants recommend lowering the (maximum) water levels in the lake by increasing the cross-sectional dimensions of the culvert(s) through the dike and to terminate the functioning of the Beng Salang pumping station. The system's ability to transport storm water and sediments will be greatly enhanced by lowering the water level of the lake.

The pumping equipment may be used at other sites for other basins.

Evaporation and seepage bring down the water level of the lake during the dry season. Pools or ponds are created at different locations and levels. The lowest water level is reached at the end of the dry season; the lowest water level at the culverts is apparently + 3.80 m or approximately 0.25 m below the invert level of the culvert.

The disposal of waste water into the lake, which is used for the cultivation of a (water)vegetable, is an important public health hazard, as this vegetable is eaten raw. Waste water enters the lake through the drainage system or through house connections and on-site sanitation systems directly connected to the lake. Three distilleries discharge black waste water with a high concentration of organic pollution into the lake.

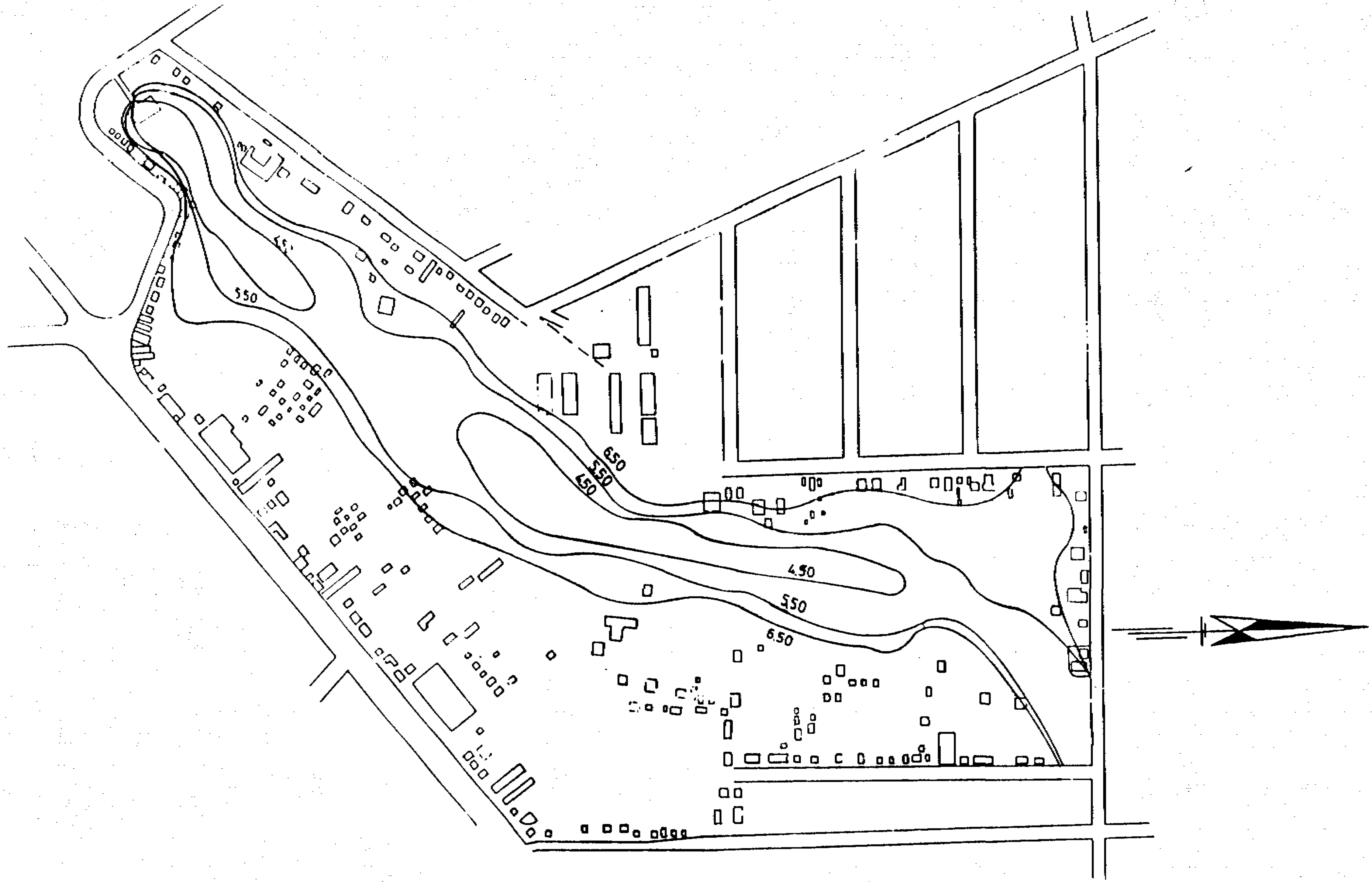


Figure 2-4 Present situation in Beng Salang Lake.

2.3 Existing drainage system

The lay-out of the existing main drainage system is presented in Figure 2-3. The plan is based on information obtained from the Sewerage Department, on field inspections made at specific inspection chambers to find diameter and condition of sewer and on a detailed survey of the interceptor from Psar Depot 2 to Beng Salang Lake (see Par. 3-1). All underground drains consist of concrete pipes. The diameter is usually 1.0 m. The top of the drains is 1.0 m below ground (street) level.

Street drains are not indicated on the map. The area north and east of Psar Depot 2 has been provided with street drains partly blocked by sediments. The diameter of the street drains is mostly 0.6 m and sometimes 0.3 m or 0.4 m. Because of malfunctioning of the street drains, Psar Depot 2 receives the surface run-off from the upper part of the drainage basin. The slope of the natural ground of the unsewered Psar Depot 2 area is excellent for surface run-off, but the main road on the western side of the pilot area functions as a barrier.

It was found during the survey of the interceptor, that the construction of sewers is below standards (Appendix 3-2 and Figure 3-1). The slope of the sewer invert is not uniform and sometimes negative, which can easily be detected from the survey results in Appendix 2 (for example,inspection chamber 2.3, 2.4, 2.9 etc. of sewer 2-2'). The irregular invert slopes cause grit to settle in drains.

The longitudinal profile of the interceptor from Psar Depot 2 to lake Beng Salang (of the eastern side of the road) is presented in Figure 2-5. The slope of the sewer invert is extraordinarily irregular. The relation between state of maintenance and sewer gradient is clearly visible. The depth of the grit and sludge deposition varies between 0.25 m and 0.60 m in the 1.0 m diameter pipe. Self-cleansing velocities would have been created if the sewer had been constructed at a uniform slope.

A gravity flow in the drainage system needed for the transport of sediments is obstructed by the high water levels and sludge elevations in the lake, as shown in Figure 2-5 (see Appendix 3 and Figure 3-1 for survey results). The top of the underground drains is just below the highest sludge levels of the lake. Two sludge levels in the open channels and lake are indicated as described in Par. 3-1: top and "bottom" level of the mud layer. The bottom elevation of the mud layer is usually at + 3.0 m to + 3.5 m (see Appendix 3). It is noted that the reduced sludge elevations in the open channel are the result of recent cleaning.

The drainage characteristics of the basin will be greatly enhanced by dredging the sludge from the lake and channel and by lowering the maximum water levels in the lake from + 6.50 m to, for example, + 5.0 m.

As most roads are unsurfaced, large quantities of grit enter the drainage system. Inspection chambers with a deepened bottom for the collection of grit have been found at a few locations. These sandboxes do not function in Cambodia because of the large quantities of grit entering the drainage system.

2.4 Beng Tempen Polder

The water management of the Beng Tempen polder needs to be studied in detail, because the water levels in the Beng Salang lake are controlled by the Beng Tempen pumping station and lake (Figure 2-1; see Par. 2.1b). The consultants have surveyed the water levels and flood elevations in Beng Tempen polder at the discharge inlet from Beng Salang. This inlet is located near the upper end of a natural "**discharge channel**" situated on a former river bed carrying the collected run-off to the pumping station. The pumping station was surveyed to find a relation between the water levels at the upper and downstream ends of the discharge channels. It was found that the measuring staff fixed at the pumping station is based on NGK. Further study is needed, including a detailed survey of the waterway and lake.

On-site sanitation systems are discharging directly into the discharge channel, which is already heavily polluted by the waste water received from the Beng Salang drainage basin. This is an important public health hazard, as the discharge channel is also used for the cultivation of a water vegetable eaten raw. The proposed engineering study on the water management of the polder should include a major component for community involvement to address environmental and social impacts, as a solution should be found for the on-site sanitation systems and the horticultural use of the discharge channel.

The ground elevations of the polder are between + 4.0 m and + 9.0 m. It is noted that ground elevations below + 5.5 m are not shown on the available contour map which has a scale of 1 : 5000. The water level in the polder at the pumping station is generally + 3.30 m in the dry season, increasing to approximately + 5.4 m during the wet season, as shown in Figure 2-7 for the year 1989. Large areas are flooded during prolonged periods, affecting quite a number of people, as the density of population in the polder is rather high for an agricultural area. The inundation contined for three weeks in September/October 1989 (Figure 2-7). The floors of the houses usually built on poles are above flood level, but access to the houses and agricultural use of the land is hampered during flooding.

The pumping station is equipped with three diesel and four electric driven pumps discharging polder water at an elevation of + 8.95 m into the river.
All pumps are in working condition, but not all of them are put into operation when needed because of a limited supply of electricity and diesel. The pumps have a capacity of 725 L/s each (Ref 7). Figure 2-8 presents the daily utilized capacity in relation to the full capacity of the pumping station for the critical period September - October 1989 (by indicating the number of operating pumps in relation to the number of installed pumps. Electric and in particular diesel driven pumps did not start immediately when the water level in the polder was increasing rapidly in mid-september 1989 (from 13/9). Only one and sometimes two diesel pumps had been in operation.

The provision of energy to the pumping station is limited by the municipality because of a shortage of fuel and limited capacity of the electricity supply. The flood levels in the polder can be reduced by starting full pump operation at the beginning of a rainfall and by maintaining a minimum water level in the lake as much as possible.

The water level in the polder at the upper end of the waterway is during the wet season approximately + 4.70 m. This level can be reduced to + 3.25 m by dredging the waterway. The Beng Salang drainage basin can accordingly be drained to a level of + 3.25 m if a properly designed culvert is constructed through the dike of the basin.

There are no drawings of the pumping station, nor manuals for the operation and maintenance of the equipment. Although replacement of equipment is needed, the pump operators manage quite well to keep the equipment in good working condition. The lay-out of the station is shown in Figure 2-9. It is quite possible that with increased run-off from the Beng Salang drainage basin, the capacity of the pumping station has to be enlarged. The water management study of the Beng Tempen Polder should include a detailed investigation of the pumping station.

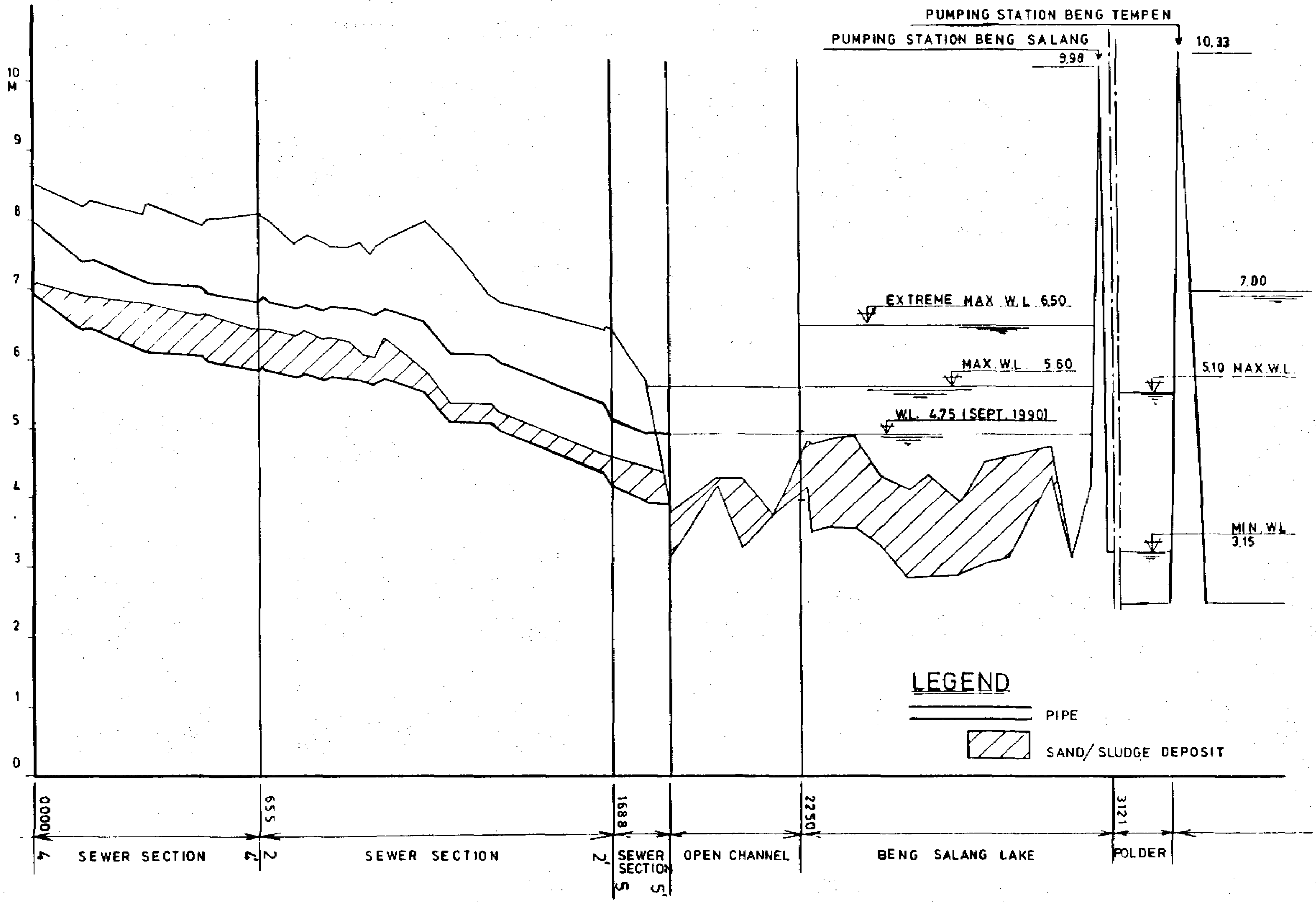


Figure 2-5 Longitudinal profile of existing main drain.

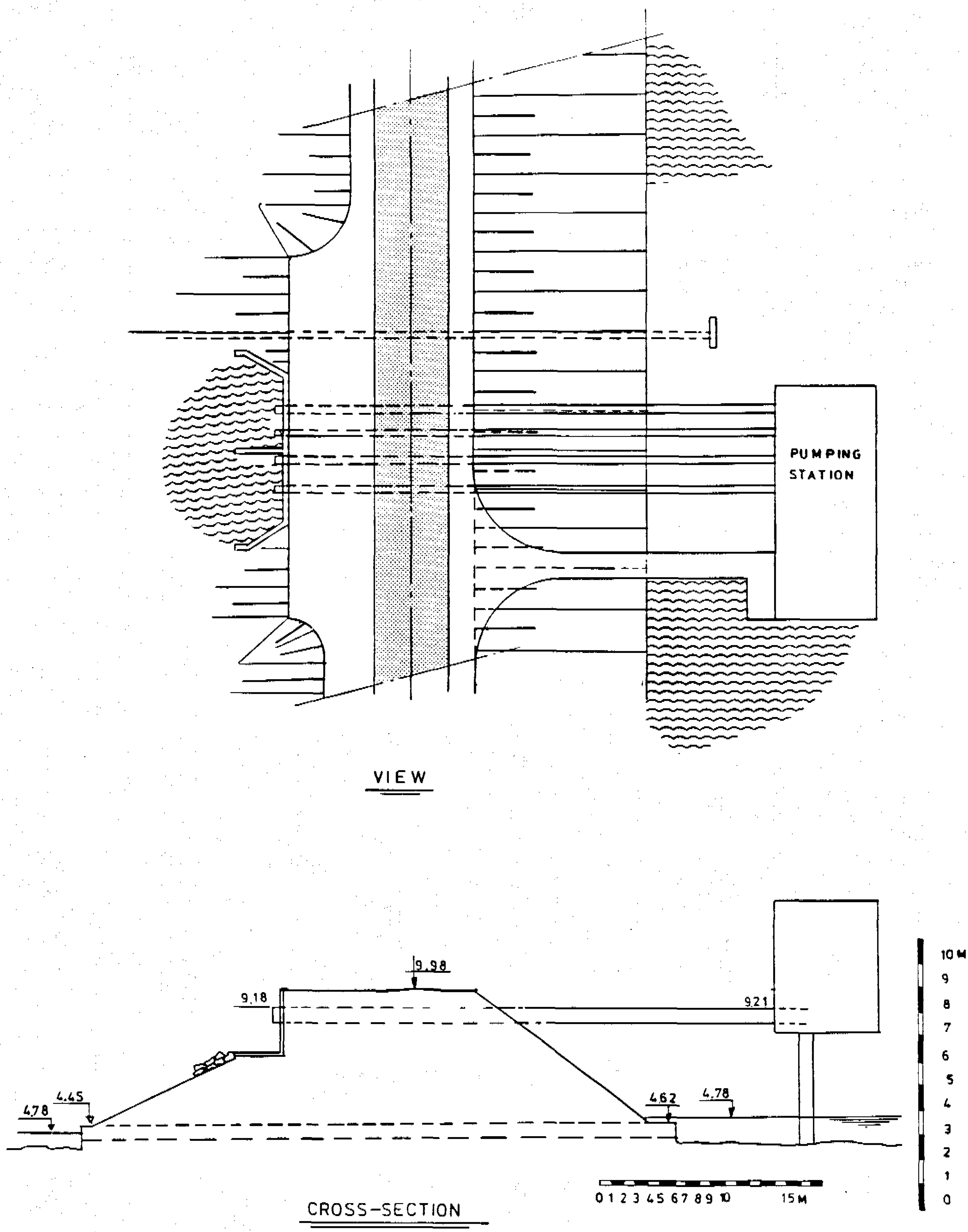
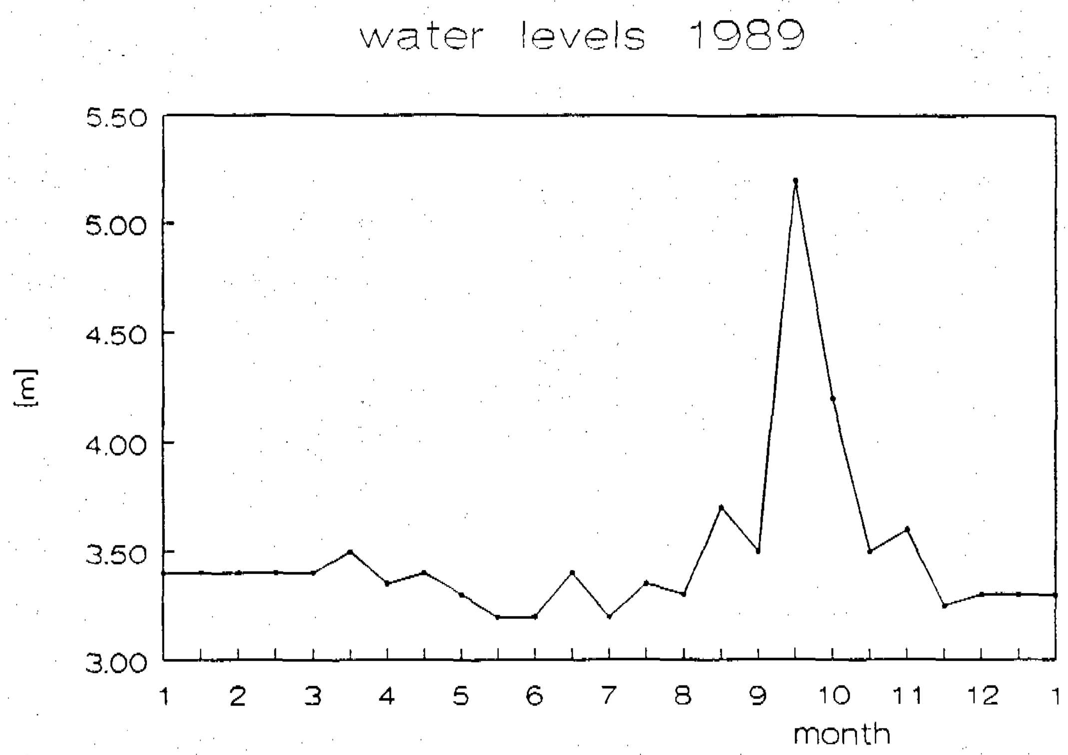


Figure 2-6 Beng Salang Pumping Station. Existing lay-out.



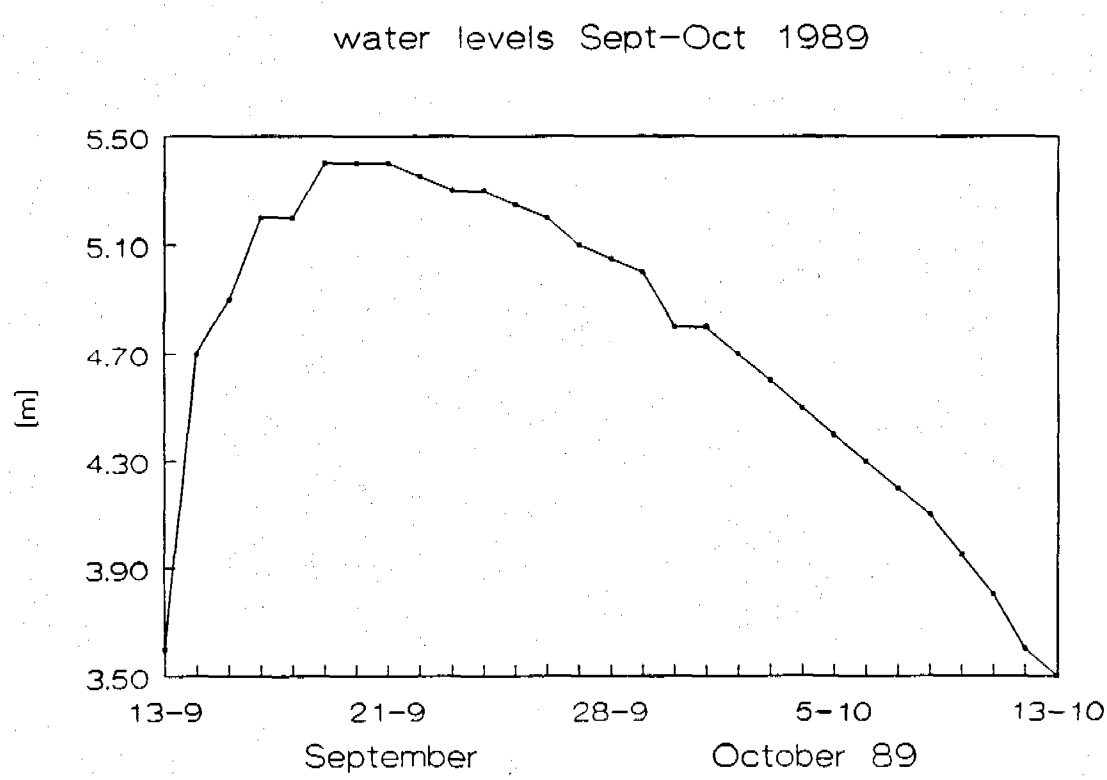


Figure 2-7 Polder water levels at Beng Tempen Pumping Station.

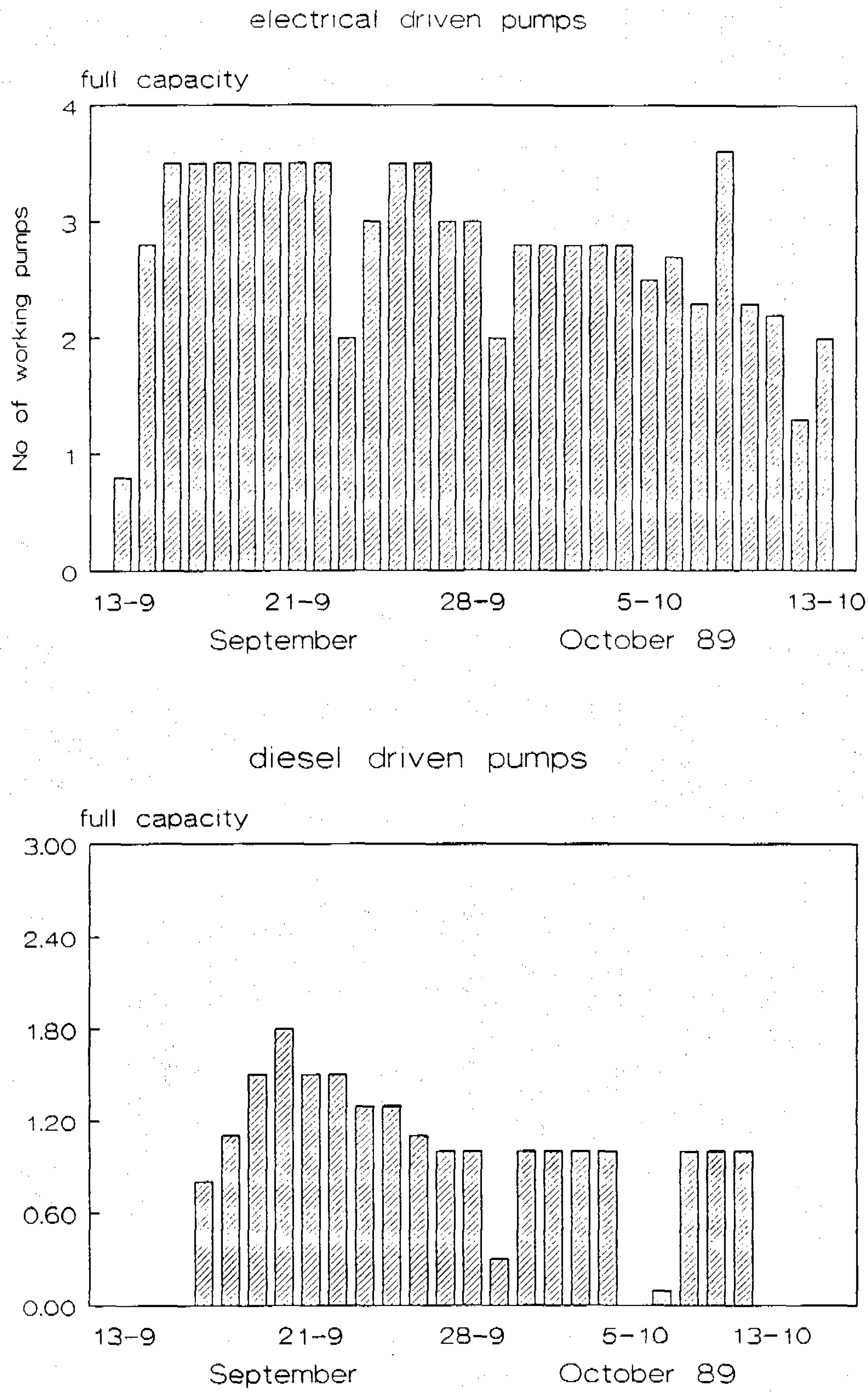


Figure 2-8 Utilized capacity of Beng Tempen Pumping Station.

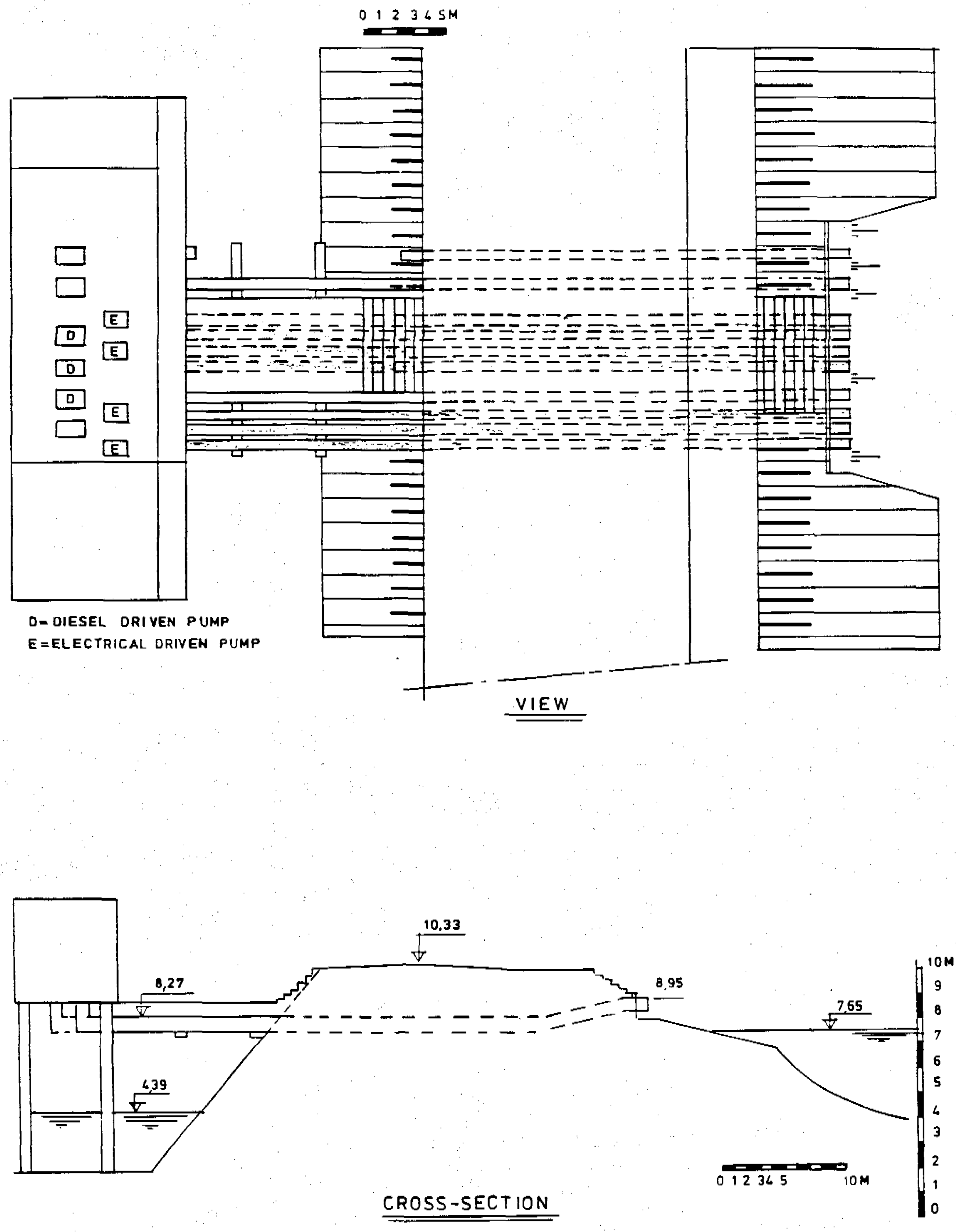


Figure 2-9 Beng Tempen Pumping Station. Existing lay-out.

2.5 Conclusions

- The Beng Salang pumping station is redundant, because storm water from the Beng Salang drainage basin can be discharged by gravity into the Beng Tempen polder. Although the storm water from the basin is discharged by gravity through two existing culverts, pumping is effected at high water levels in the lake.

- To reduce flood levels in the Beng Salang lake, the consultants recommend that an enlarged culvert be provided for the direct discharge of stormwater from the lake into the Beng Tempen polder.

- The conflicting use of the Beng Salang lake for the disposal of waste water and horticulture is a serious public health hazard and needs to be studied.

- To reduce flood levels in the Beng Salang lake and Beng Tempen polder and to allow dewatering of the lake, the consultants recommend that the Beng Tempen lake and discharge channel in the polder be dredged. This measure will also greatly improve the drainage characteristics of the sewer systems in the Beng Salang drainage basin, because a gravity flow in the drainage system required for the transport of sediments is at present obstructed by the high sludge elevations and water levels in the lake.

- The water management of the Beng Tempen polder needs to be studied in detail to be based on a detailed survey of the discharge channel and lake. The proposed study should consider the increased run-off from the Beng Salang drainage basin resulting from an improved sewerage system in the basin, as well as the functioning and up-keep of the Beng Tempen pumping station. The study should address environmental and social impacts of the conflicting use of the discharge channel for horticulture and human waste disposal. The proposed engineering study will therefore include a major component for community involvement.

- A comprehensive Master Plan Study on Urban Drainage for the entire city is needed. This study should include the completion of sewerage records, an integrated study of the sewerage network by considering, among others things, alternative conveyance systems, waste water disposal, micro-drainage, operation and maintenance procedures, financial requirements, institutional requirements, environmental and social impact assessment and commmunity involvement. The Study should also take into consideration the measures that will be taken for the improvement of the water supply facilities.

- Considering the destruction of urban services during a long period of wars, shortage of skilled personnel and the lack of financial resources, financial and technical assistance from the international and bi-lateral agencies is urgently needed for the rehabilitation and development of the drainage, water supply and sanitation facilities of Phnom Penh. Assistance should include the training of staff at all levels.

- The sewerage system in Phnom Penh is of insufficient capacity and of inadequate construction. Blocked drains and the non-availability of drains create an important health problem.
  The construction of sewers (in Beng Salang drainage basin) is below standards. The slope of the sewer invert is not uniform, causing grit to settle in drains.

- The limited infiltration capacity of the soil do not permit the provision of on-site sanitation systems. The combination of septic tanks and combined sewers does not function and should be abolished immediately.

- Municipal by-laws regulating the location of buildings and urban infrastructure need to be enforced.

- The operation of the Beng Tempen pumping station is seriously affected by the limited supply of energy. The flood levels in the polder can be reduced by starting full pump operation at the beginning of a heavy rainfall and by maintaining a minimum water level in the lake as much as possible.

3 Preparation of sewerage records

3.1 Plans and records of existing facilities

A general plan to a scale of 1 : 10 000 indicating diameter and approximate location of sewers is available, but sewerage records do not exist. There are no plans and drawings indicating the exact location, slope, invert and ground levels of sewers in Phnom Penh, which are needed for planning and design work and daily maintenance activities.

The available contour map (1 : 5000) and available plan of the sewer lay-out (1 : 10 000) are not sufficient for the design of drains. Records of the existing sewers of the Beng Salang drainage basin are needed for the underlying study. Within the limited time that was available, the Consultants carried out a detailed survey of the interceptor(s) from Psar Depot 2 to the outlet of the basin. The survey included underground drains on both sides of the roads within the built-up area, an open channel outside the built-up area and the lake.

The lay-out of the surveyed drains is presented in Figure 3-1. Details of the existing drains taken at each inspection chamber are given in Appendix 2.
The inspection chambers are numbered in relation to the numbering of sewer sections. The surveyed details are:
- *structural details*:
  - diameter of incoming, outgoing and branch sewers
  - invert levels of incoming, outgoing and branch sewers
  - ground (street) level of manhole covers
  - distance between inspection chambers
- *state of system*:
  - thickness of bottom deposits in main and branch sewers
  - condition of manhole cover
  - condition of sewer pipe.

The existing situation of the open channel and lake system was surveyed by taking cross-sections and by measuring the exact location of these cross-sections in relation to existing roads. Figure 3-1 presents the existing situation. The cross-sections are given in Appendix 3. The location of buildings and floor elevations were also determined. Flood levels were determined by asking the inhabitants whether their houses were flooded (information which is quite reliable) and/or depth of flooding in roads or footpaths (information which is not so reliable). The discharge of waste water through existing drains and on-site sanitation systems into the lake and open channel and particularly the floating of human wastes near the shore line made it necessary to wear longboots when taking measurements in the water.

Two levels of sludge in the open channel and lake are indicated in the cross-sections (Appendix 3). Both levels are determined by the degree of resistance experienced when pressing the measuring staff into the mud (top level: little resistance; bottom level: maximum resistance).

Maps (transparents) to a suitable scale (preferably 1 : 1000) are needed for the preparation of sewerage records which, however, are not available. A set of base maps can be prepared from the existing contour map 1 : 5000 by upscaling the map to a scale of 1 : 1000.

The structural details given in Appendix 2 and 3 should be transferred to the record maps of the sewerage system. An example for the presentation of sewerage details on record maps is given in Figure 3-2.

3.2 Benchmarks

A system of benchmarks placed at regular distances is needed for the planning, design and construction of drains. All plans, drawings and sewerage records must be related to an adequate bench mark system. Accurate levelling work is required for the design and construction of drains, particularly because little hydraulic gradient is available for the disposal of storm water in Phnom Penh. The availability of an adequate benchmark system is a prerequisite for the integrated design and construction of drainage facilities, such as the disposal of storm water from the Beng Salang drainage basin through the Beng Tempen Polder to Mekong River.

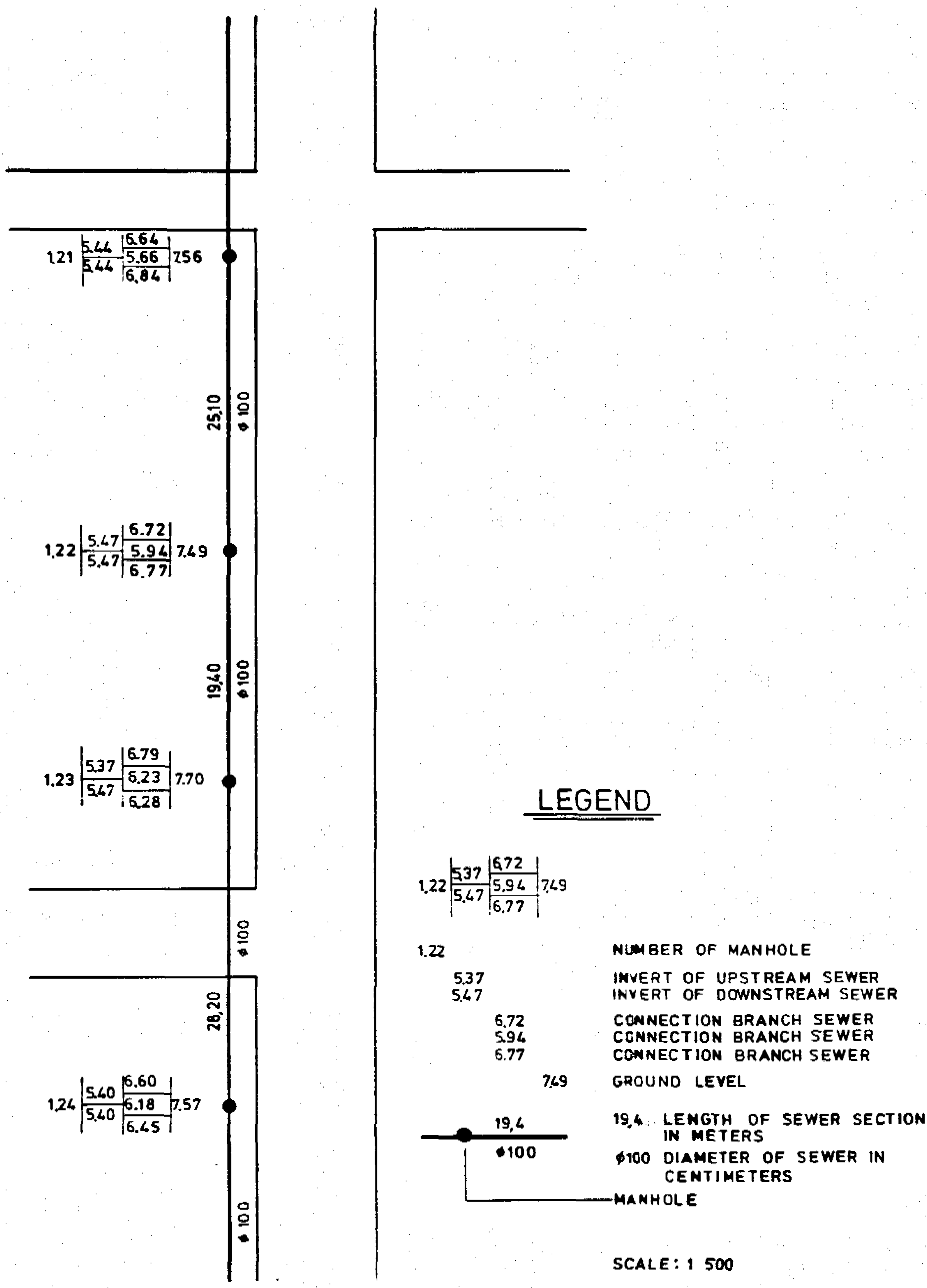


Figure 3-2 Sample of sewer record.

The consultants have established a set of benchmarks needed for the surveying work, as no benchmark system exists in Phnom Penh. Two types of benchmarks were fixed: 5 permanent and 20 temporary. Permanent benchmarks consist of an iron bolt fixed in a concrete or masonry wall of a building. Temporary benchmarks that were used for the daily surveying work consist of steel rods poured in concrete blocks along roads.

All levelling work is related to the national benchmark system NGK (Nivellement General Khmer) and all levels are reduced to this system. The naught of NGK is related to "normal" sea level. It is noted that the elevations of the contour map 1 : 5000 and the published river water levels from the Mekong Committee are based on the NGK system. Three NGK benchmarks are available in Phnom Penh: in the city centre, at the Soviet hospital and in the roundabout Khbal Thnal.

The benchmarks for the underlying study are given in Table 3-1. The location of the benchmarks is indicated in Figure 3-1. Details regarding the location of the NGK and permanent benchmarks are given in Figure 3-3.
The national benchmark BM1 NGK is located in the roundabout Khbal Thnal at the intersection of the southern exit road and the road bridge over the river Bassac; this benchmark is at a distance of a few km from the Beng Tempen pumping station.
The national benchmark BM1 NGK is located at the Soviet hospital which is at a distance of 1000 m from the Beng Salang pumping station.
The permanent benchmarks located in the Beng Salang drainage basin have been fixed in walls of existing buildings.

Table 3-1 Benchmark data.

Benchmark	Elevation	Location
National BM		
BM 1 NGK	+ 11.145 m	N = 1,274.320 roundabout Khbal Thnal E = 0,492.915
BM 2 NGK	+ 8.228 m	N = 1,275.915 Sovjet hospital E = 0,490.110
Permanent BM		
BM1	+ 10.470 m	Beng Salang pumping station
BM2	+ 10.816 m	road, east of Beng Salang lake/channel
BM3	+ 8.377 m	road, east of open channel
BM4	+ 9.379 m	road, western boundary of Psar Depot 2
P1	+ 9.098 m	Beng Tempen pumping station
Temporary BM		Distance from previous benchmark
M1	+ 9.788 m	
M2	+ 7.200 m	61.74 m
M3	+ 7.435 m	149.57 m
M4	+ 7.611 m	97.97 m
M5	+ 6.940 m	47.85 m
M6	+ 6.366 m	74.30 m
M7	+ 6.908 m	202.16 m
M8	+ 6.928 m	134.02 m
M9	+ 6.603 m	40.06 m
P10	+ 6.244 m	101.85 m
M11	+ 6.580 m	153.22 m
M12	+ 6.735 m	252.40 m
M13	+ 7.244 m	100.95 m
M14	+ 6.966 m	105.87 m from road
M15	+ 6.325 m	45.40 m
M16	+ 6.494 m	
M17	+ 7.268 m	373.45 m
M18	+ 7.909 m	365.70 m

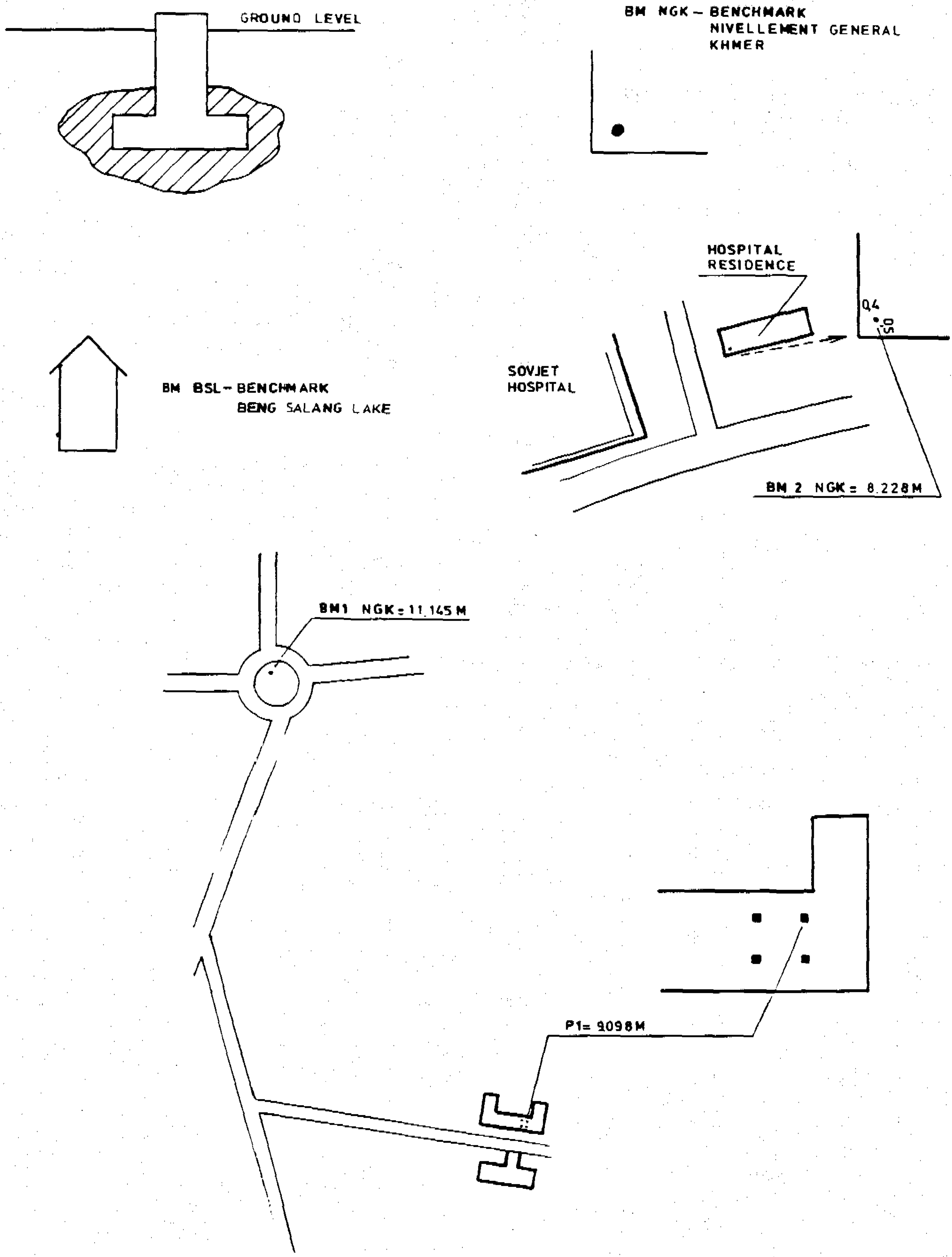


Figure 3-3 Details of NGK and BSL benchmarks.

3.3 Conclusions and recommendations

- The planning and design of sewerage systems should be based on up-to-date plans and records indicating the exact location, slope, diameter, invert and ground elevations of sewers as well as the location of house connections. Sewerage records should preferably be on a scale of 1 : 1000.
  The Consultants recommend that for the completion of sewerage records a set of suitable base maps be prepared, as-built drawings of sewer construction be made and survey results be transferred to the sewerage records. Sewerage records should be kept up-to-date.

- Levelling work for the planning, design and construction of drains should be based on an adequate benchmark system. The consultants recommend that the provision of benchmarks be continued and existing benchmarks be maintained.

- Adequate surveying equipment and skilled staff for the design and construction of drains are not available within the Sewerage Department. The consultants recommend the urgent provision of surveying equipment and training of surveyors.

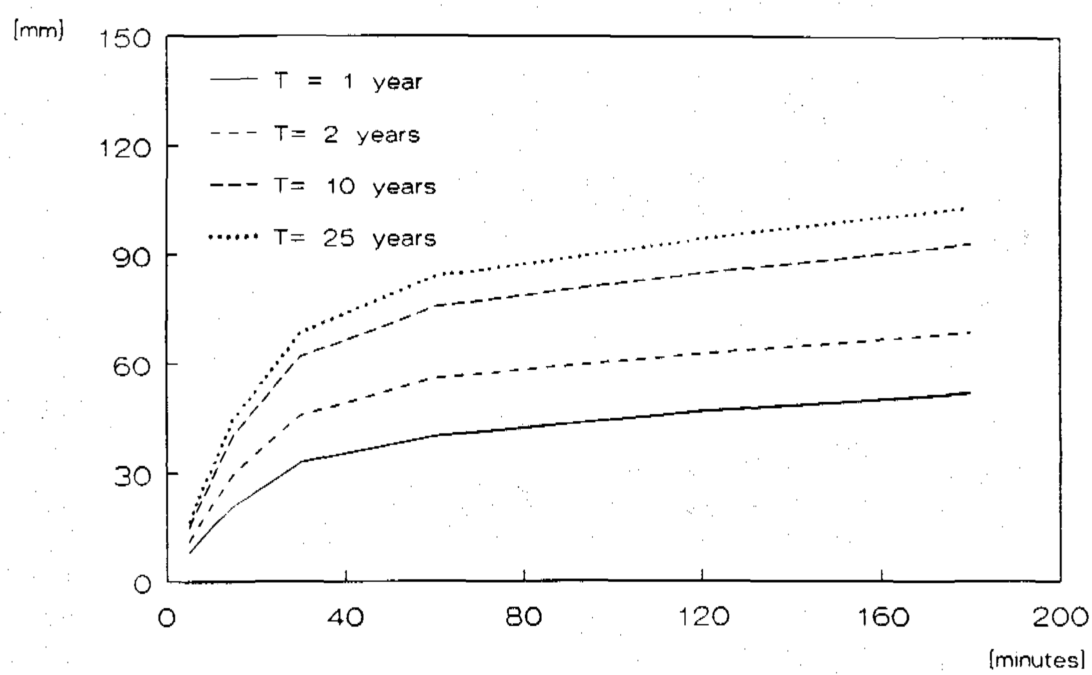


Figure 4-1 Rainfall depth-duration-occurence for Phnom Penh.

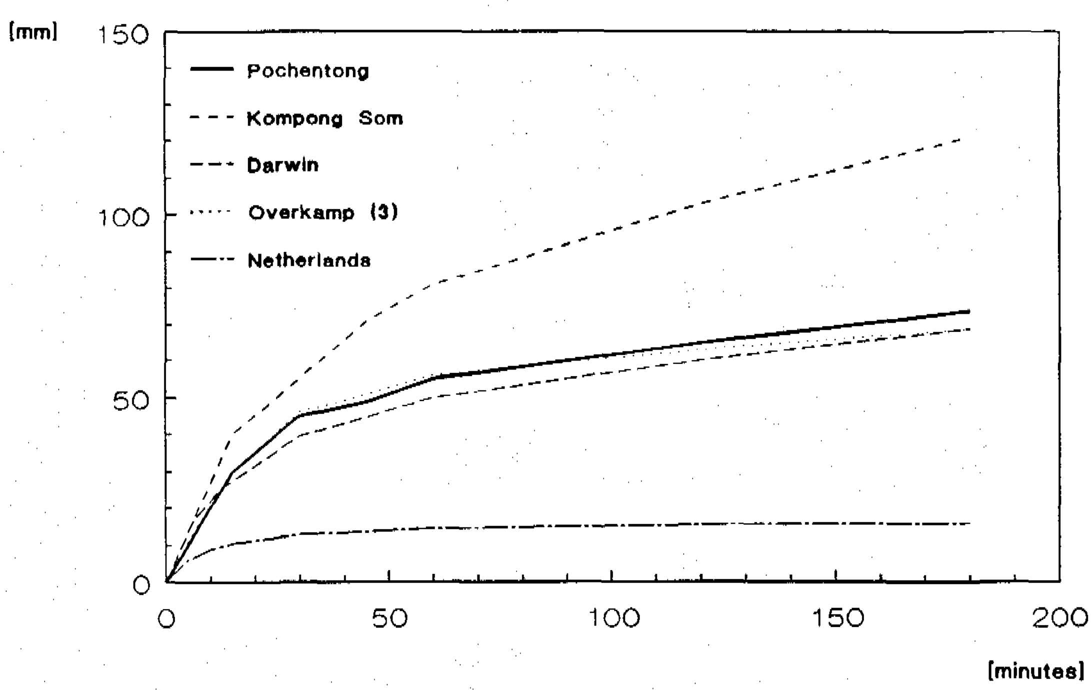


Figure 4-2 Comparison of rainfall curves for T = 2 years.

4 Design Criteria

The consultants have developed criteria for the design of sewers, as suitable design criteria did not yet exist. The collection and analysis of data, however, were restricted by the limited time that was available. Further study is needed when the Beng Tempen pumping station (Par. 2-5) is investigated in detail or within the scope of a Master Plan Study.

4.1 Hydrological Criteria

The storm water quantities have been determined with the rational method which is quite suitable for conditions in Phnom Penh and applicable for a connected area not exceeding 200 hectares. The calculation procedure is conveniently arranged and can be performed by local staff.

The rational method is based on the rainfall intensity-duration-frequency relationship. Rainfall intensity-duration-frequency curves, which are needed for sewer design, did not exist for Phnom Penh. Previous studies were based on assumed relationships.

Rainfall data from observations in Cambodia in the period 1960-70 were collected from the Hydrology Department in Phnom Penh and the Mekong Secretariat in Bangkok (Ref. 2, 3 and 4). The records include monthly maxima of rainfalls with a duration of 15, 30, 45, 60, 120 and 180 minutes from Observations of autographic rainfall recorders and the daily rainfalls at a large number of locations, but the records are incomplete. The derived rainfall depth-duration-frequency curves for Pochentong (Phnom Penh airport) are presented in Figure 4-1. Further investigations are needed, as the curves are based on incomplete data.

There is an amazing similarity between the rainfall intensities of Phnom Penh, Bangkok and Darwin, when comparing short duration rainfalls for an occurrence of two years. The data are presented in Table 4-1 and in Figure 4-2. The three cities have similar climatic conditions (tropical, seasonal) and elevations above sea-level. It is also noted that the cities of Bangkok and Phnom Penh are both located at a distance of approximately 40 km from the sea and both have a mountain range to the east of the city. The data for Bangkok were obtained from the Metropolitan Bangkok Administration, Bureau of Drainage and those for Darwin from John Tuite through the Mekong Secretariat.

The rainfall curve derived for Kompong Som is given Figure 4-2. The intensities are approximately 35% higher than in Phnom Penh, which is explicable because Kompong Som is situated on the coast and close to a high mountain range.

Overkamp formulated a theoretical rainfall curve for Phnom Penh (Ref. 6) which matches quite well with the rainfall curve based on rainfall observations.

Table 4-1 Rainfall heights for an occurrence of 2 years.

Duration of rainfall (minutes)	Rainfall height in mm		
	Phnom Penh	Bangkok	Darwin
12			25
15	30	28	
30	45	43	39.5
60	55	61	50
120	65	71	60
180	74	79	69

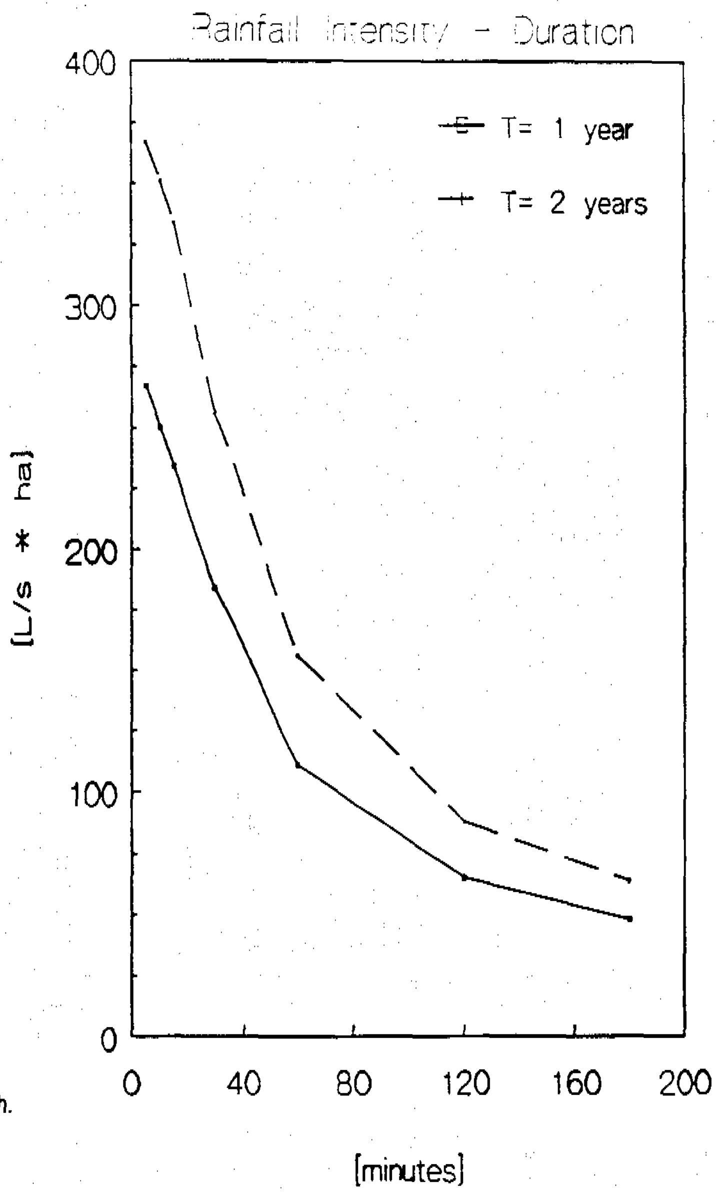


Figure 4-3 Rainfall intensities for Phnom Penh.

Table 4-3 Waste water quantities.

Situation	Existing		Future	
Population density (c/ha)	200	500	200	500
Waste water production: Litres per capita and day average flow, L/sxha*	 30 0.07	 30 0.17	 100 0.23	 100 0.58
* L/sxha = Litres per second and hectare				

Table 4-4 Hydraulic wall roughness.

Conduit, material	Colebrook-White mm	Strickler $m^{1/3}/s$	Manning $s/m^{-2/3}$
concrete pipes, culverts and channels	1,5	75	0.013
earth channels, 10 - 30 m wide, lined sides		35	0.03

Urban drains in Phnom Penh should be designed for rainfalls expected to occur or to be exceeded once a year or once every two years. Higher return periods would require larger conduits, which financially are not justified when considering the amount of damage caused by local flooding. The rainfall intensity-duration curves for Phnom Penh are presented in Figure 4-3.

The storm water flow in a sewer section is calculated as follows:

$$Q = \psi \times i_t \times A$$

where: Q = amount of storm water in L/s (Litres per second)
ψ = run-off factor
i_t = rainfall intensity in L/sxha (Litres per second and hectare)
A = tributary area contributing storm water to the sewer section concerned, in ha (hectares)

The rainfall intensity is determined by the duration of rainfall and design frequency of rainfall (Figure 4-3). The duration of rainfall is assumed to be equal to the time of concentration, which is the time required to collect storm water from the entire connected drainage area at the point of calculation. The time of concentration is thus equal to the sum of inlet and flow time. The inlet time, the time required for storm water to enter the sewer system, is assumed at 10 minutes. The flow time in a sewer is determined by the velocity of flow.

The run-off factor indicates the amount of rainfall expected to enter a sewer in relation to the total amount of rainfall. Water "losses" are infiltration of water into the soil and evaporation of surface water. The determination of the run-off factor should be based on flow and rainfall measurements by comparing both for the same catchment area, which should be included in a Master Plan Study.

The run-off coefficient of the tributary areas was determined by considering topography, land use, building construction (roof type) and by estimating the extent of paved area in relation to total area based on field inspections of the areas concerned. The amount of run-off will increase with duration and intensity of rainfall, but decrease with surface water storage and soil infiltration capacity. The highest values are accordingly reached at the end of the rainy season when the soil is saturated with ground water.

The topography of the Beng Salang drainage basin, absence and malfunctioning of street drains and an overland run-off will allow a considerable storage of storm water before entering the drainage system. The water stored will be transported at a later time, thus reducing the peak flow.

At present, the run-off coefficient varies considerably from area to area, probably between 70% for the Psar Depot 2 area to 10% for the southern and eastern peripheral areas. The average for the entire basin is possibly below 20%. The run-off factor will increase in future with increasing population densities and with the improvement of the drainage system. Alternative calculations are made by considering a return period of two years and a run-off coefficient of:

I Psar Depot 2 area: 70 % other areas: 30 %
II Psar Depot 2 area: 70 % other areas: 50 %

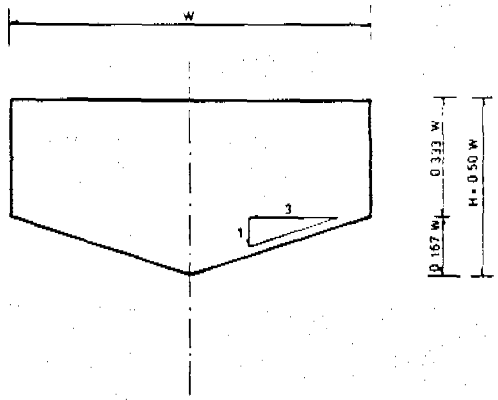
After discussions with the Sewerage Department and the Urbanization Department it was decided to base the design of drains on a run-off factor of 70% for the entire drainage area and on rainfalls expected to occur or to be exceeded once a year. The rainfall intensities for a return period of one year are given in Table 4-2.

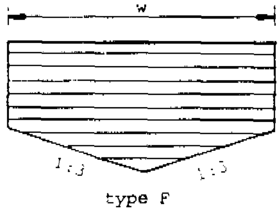
Table 4-2 Rainfall intensities for Phnom Penh (basis of design).

Duration of rainfall (minutes)	15	30	60	120	180
Rainfall intensity (L/sxha)	234	184	111	65	48

4.2 Waste water quantities

The present daily amount of waste water of 30 litres (see par. 2.1e) produced per head of population may increase to 100 litres in future. The peak flow is assumed to be twice the average flow. The specific quantities of waste water flow per hectare related to the density of population are given in Table 4-3.





$\frac{h}{H}$	Type F $\frac{Rp}{Rf}$	$\frac{Vp}{Vf}$	$\frac{Qp}{Qf}$
0.05	0.0776	0.18	0.00082
0.1	0.155	0.29	0.005
0.2	0.310	0.46	0.033
0.3	0.465	0.60	0.097
0.4	0.680	0.77	0.216
0.5	0.892	0.93	0.37
0.6	1.072	1.05	0.56
0.7	1.227	1.15	0.73
0.8	1.361	1.23	0.93
0.9	1.478	1.30	1.14
1.0	1.00	1.00	1.00

DIMENSIONS				HYDRAULIC PROPERTIES		
Type No.	W x H cm	A m^2	R m	v m/s	Q l/s	Note: v and Q calculated for s = 1 ‰.
F_{150}	150 x 75	0.937	0.230	0.89	830	$A = 0.417\ w^2$
F_{210}	210 x 105	1.837	0.322	1.11	2 040	$P = 2.721\ w$
F_{270}	270 x 135	3.037	0.413	1.29	3 920	$R = 0.153\ w$
F_{330}	330 x 165	4.537	0.505	1.47	6 670	
F_{390}	390 x 195	6.337	0.597	1.63	10 330	
F_{450}	450 x 225	8.437	0.689	1.77	14 930	

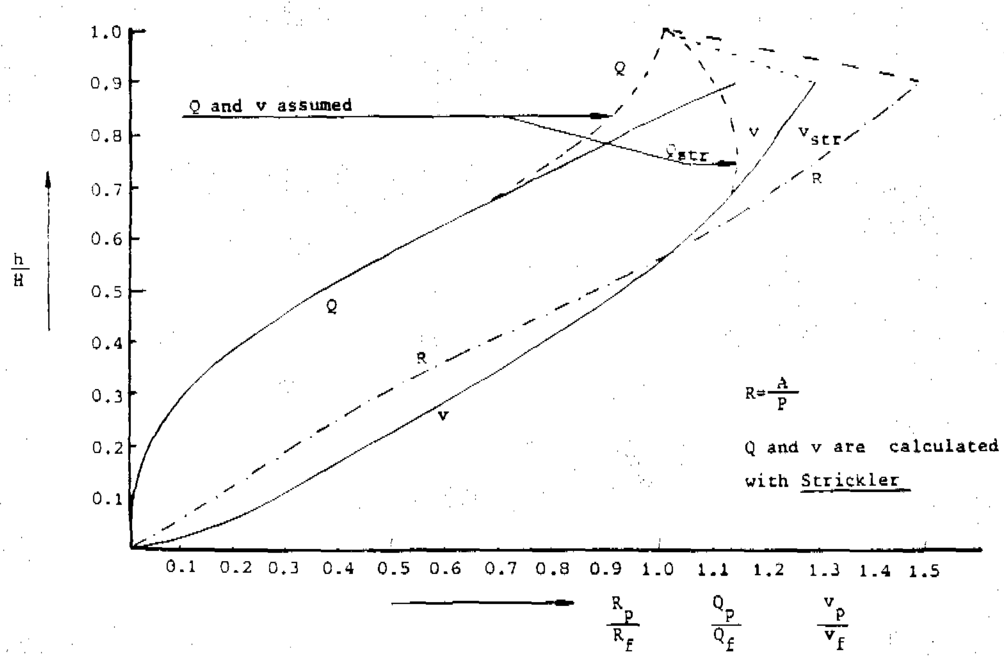


Figure 4-4 Proposed box profile, partial flow diagram.

4.3 Hydraulic Criteria

a) Conduit capacity and selected profiles

The hydraulic calculation of conduits was carried out with the flow formulae of (Prandtl)-Colebrook-White, Strickler or Manning with the friction constants in Table 4-4.

Circular profiles are used up to a diameter of 1.5 m. A flattened type of box profile with a triangular bottom is proposed for the larger conduits as shown in Figure 4-4. The hydraulic capacity of the proposed culvert is larger than the capacity of a pipe with the same construction height (diameter). The width of the culvert (W) is twice the total heigth (H) of the culvert. The bottom is constructed at a slope of 1:3. The triangular bottom is needed to confine the low flows at times of dry weather and accordingly allow sufficient transporting capacity for the transport of sediments.

The hydraulic design of conduits can be made by using tables or graphs. A set of tables for circular conduits flowing full and partial flow diagrams for pipes and the proposed box profiles have been handed over to the Sewerage Department, Section Planning and Design.

b) Grades of sewers

Sewers should be designed on the basis of sediment transport and a sieve analysis of the sediments. The minimum gradients of sewers is thus determined by the grit particles that have to be transported, which in Phnom Penh appear to be rather fine. The consultants propose for the underlying study that a scouring force of 0.8 N/m^2 be created at average flow conditions, enabling a grit transport of 0.8 mm. This corresponds with grit sizes of 0.5 or 0.6 mm at "minimum" flow conditions.

The required minimum gradients of sewers is determined as follows:

$$\tau = \rho_w \times g \times R \times S$$

where: τ = tractive force of the flow in N/m^2
ρ_w = density of grit = 2500 kg/m^3
R = hydraulic radius of the wetted section
S = sewer gradient

The hydraulic radius is determined by the cross-sectional dimensions of the conduit and the filling rate (partial flow in relation to full flow).
Although the filling rate of storm water drains of the separate sewer system varies between o and 100%, a rate of 10% is assumed, as there is little erosion with smaller flows.
With regard to the sanitary sewers of the separate system, a conduit capacity of five times the average flow is selected, also to allow for accidental entrance of storm water. The filling rate will accordingly increase from 6% at present to 20% in future. 10% is assumed.

The filling rate of combined sewers during the dry season is the relation between average dry weather flow and storm flow as the latter determines the pipe capacity. Considering a storm flow of 30 and 60 minutes and a run-off factor of 70%, the filling rate (determined from Table 4-2 and 4-3) increases from 0.1% or 0.2% at present to 0.4% or 0.6% in future and is simply assumed at one percent.

The required minimum gradients of some circular and the selected box profiles are given in Table 4-5.
There are no requirements with regard to the maximum gradients of sewers.

c) Hydraulic losses

Turbulance losses in sewers with gradients larger than 1.0 $^o/_{oo}$ are included in the friction factor provided the cross-sectional profiles of the sewers are not reduced in size.

The design of sewers and open channels with gradients smaller than 1.0 $^o/_{oo}$ is based on the energy grade line by considering turbulance and friction losses separately. The water levels indicated in columns 24 and 25 are determined by substracting the velocity head ($v^2/2g$) from the calculated energy level.

Open channels at intersections with roads or a dike, for example, are usually reduced in size, causing increased friction losses and turbulence losses. Friction losses are calculated with the usual flow formula given in Par. 4a. The inlet and exit losses of road culverts are determined by the velocity of flow in the culvert v_2 and the velocity in the open channel at the exit side of the culvert v_3. Inlet losses are also determined by the shape of the culvert inlet. The recovery of velocity head at the exit of a road culvert is neglected. Inlet and exit or retardation losses

Table 4-5 Minimum grades of sewers.

	Combined system	Separate system
Filling rate:	0.01	0.10
Pipes, hydraulic radius	R = 0.0439 D	R = 0.1265 D
F box profiles, ,,	R = 0.22 R_{full}	R = 0.49 R_{full}
Pipe culverts: dia 0.25 m	7.4 ‰	2.6 ‰
dia 0.50 m	3.7 ‰	1.3 ‰
dia 1.00 m	1.8 ‰	0.7 ‰
dia 1.50 m	1.3 ‰	0.4 ‰
Box culverts: F150	1.6 ‰	0.7 ‰
F210	1.1 ‰	0.5 ‰
F270	0.9 ‰	0.4 ‰
F330	0.7 ‰	0.3 ‰
F390	0.6 ‰	0.3 ‰
F450	0.6 ‰	0.25 ‰

are calculated as follows:

entrance losses: $0.4\, v_2^2/2g$
exit losses: $(v_2 - v_3)^2/2g$

The turbulence losses caused by bends are determined by the velocity of flow in the drain v and the shape of the bend. It is assumed that:

bend losses: $0.4\, v^2/2g$

The discharge capacity of the culvert through the dike is determined either by the upstream and downstream water levels in case of a "drowned overflow" or by the upstream water level alone in case of a "free discharge". The calculation of the hydraulic losses for a drowned overflow is similar to what was discussed earlier for the road culverts. The coefficient for the inlet losses may be assumed at 0.1 when considering the design of the culvert in Figure 5-5. With regard to a free discharge, the upstream water level is determined with the formula:

$$Q = 1.7 \times b \times H^{3/2}$$

where: Q = discharge in m^3/s
b = width of culvert in m
H = upstream channel water depth + velocity head in m.

4.4 Conclusions and recommendations

- It is recommended that the rational method be used for the determination of the storm water quantities. The calculation procedure can be performed by local staff.

- It is recommended that the drainage system of the Beng Salang drainage basin be designed on a run-off coefficient of 70% and on rainfalls expected to occur or to be exceeded once a year.

- The derived rainfall depth-duration-frequency curves for Phnom Penh are based on incomplete data. The results are acceptable for the underlying study, but more hydrological investigations are required if the data will be used for the entire city of Phnom Penh.

- The run-off coefficient should be determined from rainfall and run-off measurements, which should be included in a Master Plan study on urban drainage.

- The minimum required gradients of sewers should be determined on the basis of sediment transport. The recommended minimum slopes of sewers for the combined and separate system are given in Table 4-5.

5 Proposed facilities

The objective of the proposed facilities is to keep Psar Depot 2 free from flooding, which is achieved by a gravity transport of the run-off from Psar Depot 2 and upper catchment areas to Beng Tempen polder (Figure 2-3). Pumping of storm water from the Beng Salang drainage basin is not needed (Par. 2.2). A discharge culvert is proposed to allow a free discharge of storm water from the Beng Salang lake into the Beng Tempen polder. The lake will be incorporated in the drainage system, but needs to be deepened. An entirely new main sewer from Psar Depot 2 to the lake is proposed, because the existing facilities are of an insufficient and inadequate construction (Par. 2.3).

5.1 Type of sewer system

The existing drainage system receives sewage and storm water in one conduit. In Phnom Penh the system is accordingly considered a combined system. The alternative is a separate system with separate conduits for storm water (storm drainage system) and waste water (sanitary sewer system).

The technical feasibility and financial aspects of both types of systems are discussed hereafter. The financial feasibility of both types of systems should be investigated in a Master Plan Study on Urban Drainage.

Availability of existing facilities and financial resources

The existing level of service in the Beng Salang drainage basin is low. Street drains are absent or blocked (Par. 2-3). The present system of waste water disposal in the drainage basin is a public health hazard. The existing main drains, half-full with deposits, transport waste water but they are not suitable for this purpose (Par. 2-3).

The existing system, however, can be improved for the conveyance of storm water through the provision of open street drains and a number of underground main drains. Surface drains may be unlined, but preference is given to lined drains in built-up areas. Paved roads may be provided with a curb and channel construction, or roll-over-curbs, as needed for the collection and transport of run-off. There is accordingly a great flexibility in the improvement and provision of storm water drainage.

A separate system in Phnom Penh would thus consist of the improvement of the existing facilities for storm water drainage and the provision of an entirely new sanitary sewer system for the collection and transport of waste water.

With regard to the combined system, an entirely new sewer network is needed, as all drains will have to be replaced because of insufficient depth to collect waste water, inadequate gradients and sub-standard construction.

Underground sewers collecting waste water should be available in each road or alley for hygienic reasons. A sanitary sewer system requires comparatively small diameter pipes, but combined sewers have considerable sizes because the storm water flow in combined sewers is 100 to 200 times the flow in sanitary sewers (see chapter 4).

A combined system, a high cost solution, is obviously more expensive than a separate system which includes low-cost solutions for storm water drainage. In addition, the separate system allows more flexibility in the allocation of funds for the construction of sewers, as priorities for storm drainage and waste water disposal can be dealt with separately. The limited availability of financial resources for urban infrastructure in Phnom Penh favours the provision of a separate system.

Waste water disposal

A combined system discharges waste water into Lake Beng Salang and the surface waters of Beng Tempen polder, which is not acceptable, as the surface waters are used for the cultivation of a water vegetable and also because of the high rate of densification around the Beng Salang lake. Special measures are needed to deal with the problem of waste water.

A separate system carries the waste water to convenient locations.

House connections
The illicit connection of storm water to sanitary sewers will cause flooding of sewers and illicit connection of waste water to storm drains will cause pollution of Beng Salang lake and other surface waters. This favours the provision of a combined system. Illicit connections should be controlled through a system of building/sewer connection permits and field inspections.

Climate
The tropical climate in Phnom Penh with a seasonal rainfall produces large storm water flows of short duration and prolonged periods of dry weather. Combined sewers carry small amounts of waste water at times of dry weather. Combined sewers are therefore not practical, as large diameter sewers will have to be laid at comparatively steep gradients to create self-cleansing velocities at times of dry weather, as found in Par. 4-2. In flat areas gradients are reduced to limit the depth of sewer construction, resulting in putrefaction of waste water in sewers, particularly during the dry season.

Erosion
Roads in Phnom Penh are generally not paved. Large quantities of erosion products may enter the system. These products should be discharged into a river, lake or open channel system where it can be dredged, which is quite possible for storm water drains of the separate system, but not at all for combined sewers because of their construction depth. Combined sewers are not suitable for the transport of large quantities of grit.

Selected system
Waste water can not be discharged on-site, certainly not in future with the increasing building density. Off-site disposal requires an underground transport system for hygienic reasons. Underground transport of storm water is required in main roads (boulevards) and business streets, but open channels or surface ditches would suffice in secondary roads and alleys.

Obviously a separate system that consists of a low-cost storm water system and a piped sanitary sewer system is the most feasible system. A separate system is also the most suitable system when considering the heavy rainfalls and long duration of dry periods which occur in Phnom Penh, as well as the present erosion from unpaved roads and the existing use of rain water for horticulture.

Nevertheless the proposed main sewer from Psar Depot 2 to Beng Salang lake has been designed as a combined sewer to follow present policy and practice. Also the Sewerage and Urbanization Departments held the view that a combined sewer should be constructed.

The design of the proposed sewer allows a flexible operation. The sewer can also be used as a separate storm water drain when a separate sanitary sewer is laid parallel to the drain.

5.2 Design of proposed facilities

The proposed sewer, composed of underground conduits and open channels, is divided into sections for design purposes. These sections and the tributary areas contributing storm water to the sections are shown in Figure 5–1. The sewer sections are indicated by the points of calculation. The tributary areas are numbered. The surface area of the tributary areas has been determined with the contour map (1:5000) and is given in Figure 5-1.

The design of the main sewer system between points 6 and 16 has been based on a detailed survey (see Par. 3–1), because this part of the system is needed immediately to eliminate flooding of Psar Depot 2. The design of the upper part of the main sewer (between points 2 and 6) is preliminary and should be verified through a survey.

With regard to the selection between open and underground drains, open drains are cheaper to construct, but no space is available in main roads for the provision of open drains if future traffic flows are considered. The consultants were informed that open drains are not allowed along main roads within the built-up area.
Open drains are proposed outside the built-up area. It was found that sufficient space is available for the improvement of the existing open channel between points 14 and 15.

Alternative locations for the proposed main sewer were inspected in the field and discussed with the Sewerage Department and the Urbanization Department. It was found that the route of the proposed main sewer between points 6 and 14 should be similar to the existing system (see Figure 2-3).
The vacant land north of calculation point 14 would be ideal for an extension of the existing open channel to the north, which would be an alternative to an underground sewer in the main road between points 12 and 13. The zoning of the vacant land, however, does not permit the provision of open drains.

The Beng Salang lake is situated between points 15 and 16. In spite of increasing building activities around and in the lake, the present open area is still available for drainage use (see Figure 2-4). The storage function of the lake cannot be continued in future because of the limited space that is available for the storage of storm water

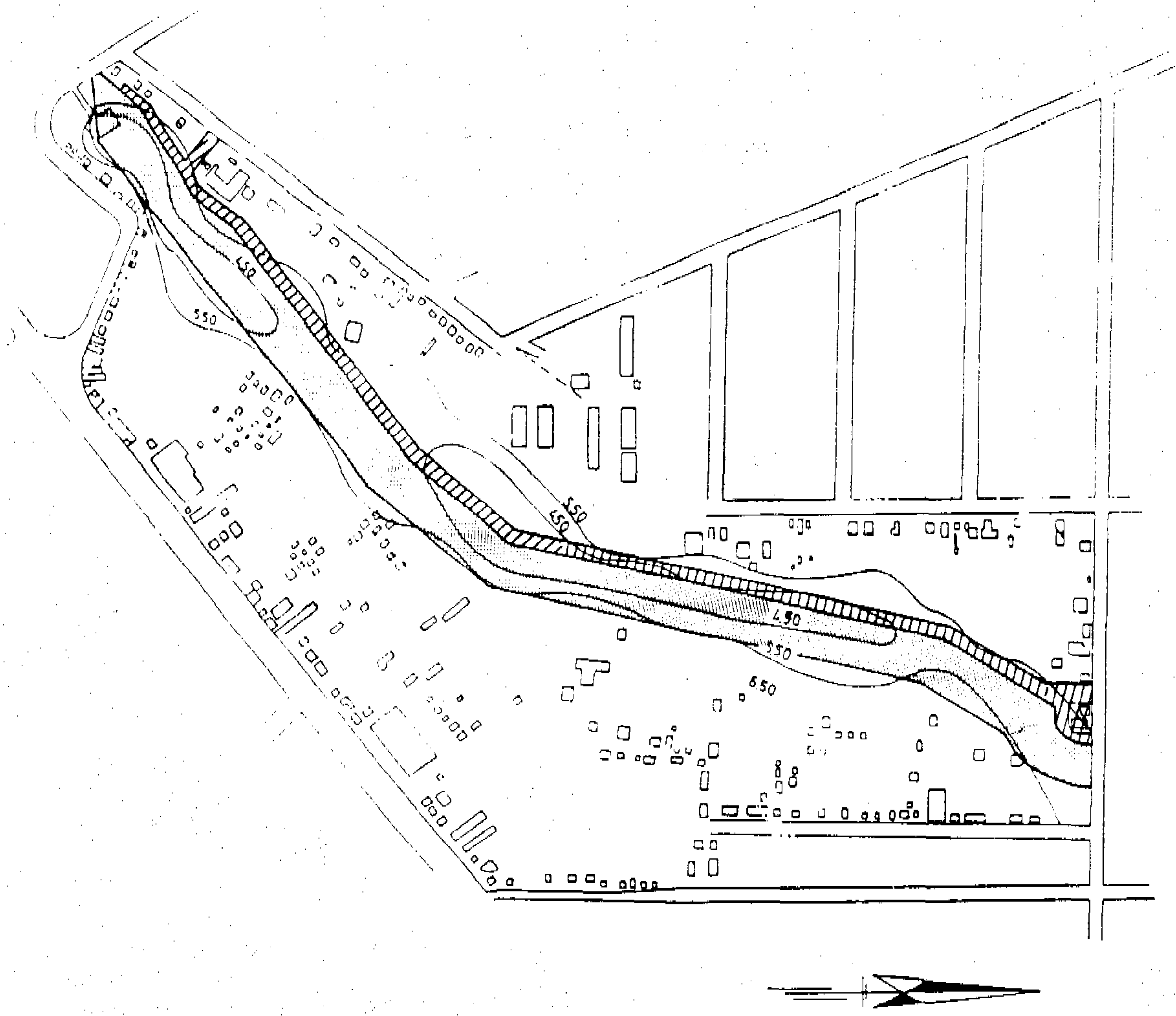
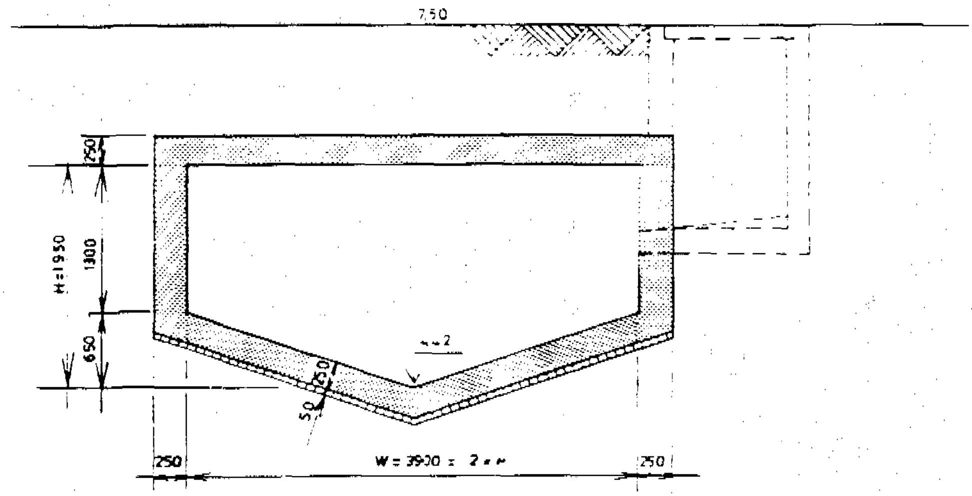
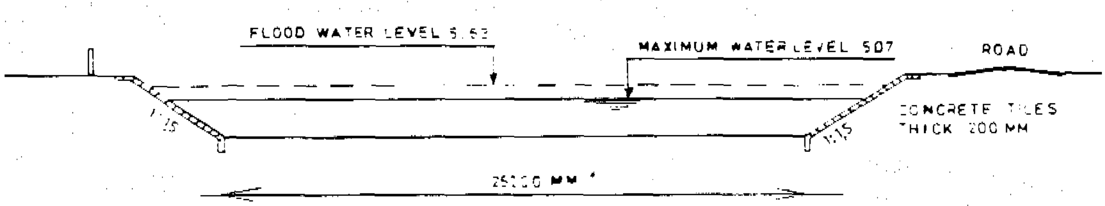


Figure 5-3 Proposed open channel in Beng Salang Lake.

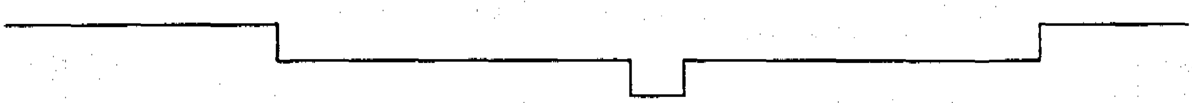


CROSS SECTION MAIN SEWER AT POINT 11 (SCALE 1:50)



CROSS SECTION OPEN CHANNEL AT POINT 15 (SCALE 1:250)

Figure 5-4 Typical profiles for proposed drains.



when it rains heavily. The available area is just sufficient for the provision of a wide low-velocity open channel. A road should be provided along the entire length of the channel between points 14 and 16 to facilitate inspection, cleaning and repair of the channel.

A dry open channel (emptying completely after a rainfall) is proposed to avoid the nuisance of stagnant water in a densely populated area and to prevent the direct disposal of waste water into the channel. Hence the bottom level of the channel should be above the downstream polder water level that occurs during dry weather periods. This water level may be assumed at + 3.25 m, if the proposed dredging of the polder canal is carried out (see Par. 2.4).

The design calculations of the proposed main sewer are presented in Table 5-1 for a run-off factor of 70%. The design is based on the design criteria in chapter 4 and on the lay-out of the tributary areas in Figure 5-1. The table is self-explanatory. The hydrological calculations for the different sewer sections are performed in columns 4 to 10. The time of concentration is first assumed in column 8 and later verified in columns 26 to 28 for the selected design. The results of the hydraulic design are given in columns 12 to 18 and presented in Figure 5-2 and Figure 5-3. The hydraulic characteristics of the selected box profile in Figure 5-4 is discussed in Par. 4.2a.

The sewer sections between points 3 and 11 include the existing 1.0 m diameter pipe that will carry the overflow from the box culvert. These sections will consist of two parallel conduits. Present connections to the existing sewer should be disconnected. All sewer discharges will have to be made into the proposed combined sewer with its invert at 3.0 m below ground level. The velocities of flow, which are different in the parallel conduits, are noted in column 19. The piezometric velocity in column 22 and the flow time in column 26 are determined from the weighted average of the velocities in both parallel conduits.

An invert level of + 8.0 m was selected at point 2, the upper end of the culvert, to allow the connection of adjacent areas to the sewer. The invert level at point 14, the downstream end of the box culvert, is + 3.46 m. The proposed culvert with invert slopes above 1.2 $^{\circ}/_{\infty}$ is self-cleansing, creating sufficient capacity for the transport of sediments.

The performance of the underground sewer at low-flow conditions is remarkable. The "dry weather" flow, which is composed of waste water and probably some infiltration of groundwater, is usually below one percent of the conduit capacity when running full ($Q : Q_{full} = 0.01$). A flow velocity of 0.59 m/s is created at a flow rate of one percent; the tractive force equals 1.6 N/m^2, allowing grit particles of 1.6 mm to remain in suspension.

The calculated discharge level at point 14, the downstream end of the box culvert, is + 5.80 m, allowing hardly any freeboard at a ground level of + 6.0 m. The energy grade line is even at + 6.07 m. The maximum water levels are expected to be much lower when considering the safe assumptions made for the design of the culvert.

The drain at point 14, a road crossing, gradually widens from 4.5 m (culvert) to 10 m at the road intersection and finally to a bottom width of 25 m for the open channel. A wide open channel has been selected to minimize hydraulic losses in the channel and to allow some "storage" of storm water. The channel is narrowed at point 15, another road crossing, to again 10 m. Limited space is available for the provision of an open channel at points 14 and 15, where the channel intersects with the existing roads, along one side of the roads concerned. Either one house has to be demolished at each intersection, or the narrow section has to be extended for an assumed distance of 10 m.

The consultants recommend that measures be taken to prevent the erection of new buildings within the area needed for drainage.

The rectangular profiles at the road intersections are made of concrete.

The open channel has a trapezoid profile with an earth bottom. No provision has been made for the transport of waste water which should not be allowed into the channel and should be diverted through a separate pipe. The channel sides are lined to facilitate maintenance work as well as adequate control against illegal use of the channel. The slopes of the channel sides, which are determined by the soil conditions, are assumed to be 1 : 1.5. Soil investigations are needed before the design of the channel is finalized. This is even more urgent for the design and construction of the road along the open channel and for determining the required dredging equipment.

The discharge culvert through the dike has a total width of 6.0 m, which controls the water depths in the open channel.

The velocity of flow in the open channel will be 0.59 m/s at a maximum water depth of 2.3 m. Much smaller water depths are expected because of safe design assumptions, as noted before with regard to the underground culvert. It is also possible to reduce water depth in the open channel by widening the discharge culvert through the dike.

The open channel is designed on a storm flow of 35 m^3/s by simply considering the time of concentration at point 16. The present flows are much less, with peak rates of only 4 m^3/s, resulting in unfavourable flow conditions in the wide open channel. To improve the flow conditions for the present flows a special profile, that includes a narrowed section as shown schematically hereafter, may be considered. Although this is an excellent profile to facilitate the large difference between present and expected future flows, the elevated part of the channel, however, may be subject to illegal use by the people.

The hydraulic or piezometric gradient of the underground culverts is more than 1.0 $^{o}/_{oo}$, while the hydraulic or water level gradient of the open channel is only 0.1 $^{o}/_{oo}$. The existence of the open channel, the former Beng Salang lake, and the reduced bottom level of the channel has considerably improved the drainage characteristics of the entire basin.

A preliminary design of the proposed culvert through the dike is presented in Figure 5-5. The culvert consists of two box profiles, each 3.0 m wide and 2.0 m high. The culvert is accessible and can easily be maintained. The existing pipe culverts of 0.6 and 1.0 m diameter and the existing pumping mains through the dike should be removed.

Soil investigations are needed to finalize the design of the culvert with regard to seepage and foundation. Although little seepage is expected, provision should be made to prevent seepage along the concrete construction through sheetpiles. A gate at the downstream end on the culvert is provided to cope with unexpected high water levels in the Beng Tempen polder. Grooves to facilitate stop logs are provided at both sides of the culvert. Concrete floor tiles are provided at the upstream and downstream end of the culvert to prevent erosion of the bottom. Provisions should be made to localize the hydraulic jump at the outlet of the culvert.

5.3 Waste water

Waste water cannot be discharged into the open channel section of the proposed main sewer, because the channel is within a developed area with a lot of building activity. Therefore, a separate sanitary sewer has to be provided to intercept the waste water from combined sewers discharging into the proposed open channel as well as to collect the waste water from distilleries and residences around the Beng Salang lake. The proposed interceptors will have to be laid in existing roads: one on the western and one on the eastern side of the open channel. For a lay-out of the channel see Figure 5-2 (between points 14 and 16) and Figure 5-3 (detailed lay-out between points 15 and 16).

In future the interceptors will carry the waste water from the entire drainage basin. The required piping is provisionally determined as follows (see Par. 4-2):

average specific waste water production:	0.35 L/sxha
peak rate (for main sewers):	0.60 L/sxha
sewered area, total:	560 ha
total design flow:	340 L/s

	eastern interceptor	western interceptor
design flow:	220 L/s	120 L/s
proposed pipe capacity:	400 L/s	216 L/s
required pipe diameter:	0.80 m	0.60 m
minimum required slope:	1.0 $^{0}/_{00}$	1.25 $^{0}/_{00}$
length of sewer:	1400 m	1200 m

The interceptors receiving combined sewage will carry, in addition to waste water, a certain amount of storm water. The amount of storm water that will be transported with the waste water is probably between 5 to 8 times the average dry weather flow. However, a forecast of the future water consumption and waste water production is so uncertain that the provision of the required future transport capacity should not be done immediately, but be implemented in phases, for example by doubling main sewers in future. Therefore, it is suggested that initially a pipe capacity of three times the future average waste water flow be provided.

The waste water cannot be discharged directly into the Beng Tempen polder, because of the present use of the surface water in the polder. A special study is needed to investigate the disposal of waste water and to finalize the design of the sanitary sewers.

5.4 Community involvement

An excellent example of community participation in Phnom Penh was realized immediately after the Pol Pot period when the new town population was involved in initiating the infrastructure. At present the community is still responsible for street drainage in residential areas, but technical and financial assistance is not available. This would be the responsibility of the District Offices as all contacts with the communities are channelled through these offices.

The consultants were informed that the local communities had not yet been involved with the planning and implementation of the pilot water supply and sanitation projects.

The project that will evolve from the underlying report will fail completely without community involvement. The existing water supply and sanitation system in Beng Salang lake as shown in Photo 3 clearly demonstrates that an alternative must be found for the extraction of shallow ground water as well as for the direct disposal of human waste into the surface water. The local population must be involved with the preparation, implementation and financing of the alternative solutions, such as a piped water supply, water supply through tankers, pour-flush cisterns to be connected to the sanitary sewer system, etc. Financial assistance is likely needed, for example with the replacement of pit latrines by pour-flush units. Between 1000 and 7000 people residing around the proposed open channel system will be involved directly; probably many more people from adjacent streets desire a sewer connection.

The provision of house connections to the main sewer system also requires active participation of the community. This will likely occur in business streets where the consultants found that the local population is extremely active in connecting their waste water to the drainage system. The existing sanitation systems in the city are a problem because of the limited availability of water.

5.5 Implementation of proposed scheme

a) Scope of work

Manual excavation and ox-cart transport of materials is not feasible because of the large quantities involved. The amounts of excavation and concrete work are as follows:

main sewer, 1820 m long:	
excavation:	27,000 m^3
transportation of excavated material:	18,000 m^3
backfilling of excavated material:	9,000 m^3
reinforced concrete:	8,700 m^3.
dike culvert and road crossings (open channel):	
excavation:	4,500 m^3
reinforced concrete	550 m^3
open channel (lake (Beng Salang), 1130 m long:	
excavation:	70.000 m^3
transport of excavated material:	70.000 m^3
lining of channel slopes:	8.000 m^3
road along channel:	between 10.000 m^3 and 40.000 m^3

Before any construction work in the Beng Salang drainage basin is undertaken, dredging work has to be carried out in the Beng Tempen polder (see Par. 2.4). Estimated quantities are:

Beng Tempen polder (provisional):	
channel, 3.8 km long, excavation:	300.000 m^3
channel, transportation of excavated material:	300.000 m^3
lake Beng Tempen, excavation:	500.000 m^3
lake, transportation of excavated material:	500.000 m^3

Ancillary works include the provision of access to the channel to facilitate maintenance. Not all dredging work is needed immediately, as long as the channel in the Beng Tempen polder is dredged.

b) Required equipment

The different soil and working conditions require different types of earthmoving equipment. A wheel mounted backhoe/loader with different attachments for multi-purpose use will be required for sewer excavation in busy traffic roads. The machine can be used for excavation and backfilling, but also for loading materials or laying conduits. The machine should have sufficient lifting capacity for the laying of box culverts or large diameter pipes, for example, a 90 hp machine with a safe load of 5000 kg at a distance of 4.5 m.

The excavator will be equipped with a 700 litre bucket allowing a production of 30 to 40 m^3 per hour. The required amount of net working hours for a production of 30 m^3 per hour is estimated as follows:

excavation (including carting away excess material):	900 hours
backfilling of sewer trench:	300 hours
crane operation for sewer construction:	600 hours +
total:	1800 hours

The time required to complete the work, based on 30 effective working hours per week and on 35 effective working weeks per year, equals 20 months or nearly two years. The construction period could be much shorter if sufficient skilled staff is available to operate the equipment, but allowance should be made for unfavourable weather conditions, maintenance of equipment, etc.

Three or four trucks are required for the transportation of the excavated material. The vehicles should be able to operate in cross-country conditions. Proposed are 160 hp, all-wheel drive, rear-dump trucks with a payload of 10 tons. Care should be taken not to overload the hauling units. It would be advisable to limit the hauling capacity to 5 or 6 m^3. The vehicles will also be used for the transport of materials for the concrete work. Two trucks will have to be purchased, if the Sewerage Department can provide the required other two hauling units.

The site of the proposed open channel is not accessible to the backhoe and dump trucks, not even if the excavator would be track-mounted. The cheapest solution would be a dismountable cutter dredger equipped with a dredge pump and a discharge pipeline. The pipeline is composed of a flexible floating pipeline and a light-weight flexible shore pipeline. The dredged material is mixed with water to permit pipe transport of the material. A dump site fully equipped with special dewatering boxes and effluent discharge has to be arranged at the end of the pipeline for the dewatering and drying of the mud. The dump site can be made temporary by carting away the dried material.

The dredged material is pumped over a maximum distance of 1500 m; sometimes a distance of 2000 m is possible, which also would not be sufficient for the excavation work in Beng Salang lake, as no suitable dump site can be found in the vicinity of the lake. A booster pumping station would be needed for a longer pipeline.

The cutter dredger, however, can deal neither with the water hyacinth nor with heavy clay. The water hyacinth is found everywhere in the Beng Salang lake (see Photo 3). The plant and roots will block the cutter completely. Heavy clay cannot be cut or is unsuitable when clay balls blocking the pipeline are created. Soil investigations and, in particular, the dredger's own experience are needed to determine whether the cutter dredger can be applied below the root zone of the hyacinth.

A floating crab-crane may be considered as an alternative to the cutter dredger. A wheeled crane or backhoe, which operates on land, is installed on a floating pontoon. The machine can embark and disembark on its own power. Stability is provided by detachable side pontoons. The excavated material will have to be transported over land (or over water and land) to a dump site. Although the excavator will be able to collect the water hyacinth plant on the surface of the water, the power of the machine is limited to the weight of the bucket, 400 kg, because no additional power can be exerted from the floating pontoons. It is doubtful whether this machine can deal with the materials in Beng Salang lake and in Beng Tempen polder.

Therefore, a 75 hp excavator fixed on a pontoon with four movable legs is proposed. The machine can move itself from land into water and vice versa. The grab dredger can operate in water, in marsh conditions and on land. The legs provide a stable foundation during excavation as a result of which a power of 1300 kg can be exerted by the hydraulic grab for the removal of clay etc. There will be sufficient work to do in future for this machine when considering the large amount of dredging work in the Beng Tempen polder.

The capacity of the grab dredger with a bucket of 700 litres will be between 30 and 50 m^3 per hour. Based on a production of 30 m^3 per hour, 30 effective working hours per week and 35 effective working weeks per year, it will take two years to complete the excavation work for the open channel. An efficient operation, longer working hours (if two teams are available for the operation of a machine) and efficient organization may half the required construction period.

The dredged material is transported by ship and by truck to a suitable dump site. Directly loading into trucks is rarely possible. The backhoe proposed for the sewer excavation will be used to transfer the dredged material from ships into trucks. Three barges and a pusher craft are required to handle the dredged material, because the barges are simultaneously loaded (by the grab dredger), moved and unloaded (by the backhoe). Three or four hauling units are required for road transport of the dredged material.

Other equipment is needed, for example, for mixing concrete, etc. They are not listed separately, but their cost are included in the unit cost rates.

Although dredging in the Beng Tempen polder is not the subject of the underlying report, it is noted that a cutter dredger will operate efficiently in the polder, because the dredged material can be dumped nearby.

c) Construction of box culvert

The cost estimate of the underground sewer is based on in-situ construction. A more effective quality control, a much shorter construction period and a somewhat cheaper solution is obtained through a prefabricated construction.

Two cranes are needed for the transport of the prefab elements: one for loading and one for unloading the trucks. It is assumed that one crane can be made available by the municipality if needed for short periods.

It is however extremely difficult to obtain an adequate foundation for the prefabricated conduit sections when placing the culvert sections. Unequal soil resistance can be disastrous for the box culvert. Another disadvantage concerns the weights of the culverts, which for in-situ poured concrete would be between 9000 and 12000 kg per meter length.

The bottom of the culvert should be made of in-situ poured concrete, but the walls and the topslab may be composed of separate prefabricated elements. There are different possibilities to connect the walls to the floor through the reinforcement. At the upper side the walls should be supported by prefabricated horizontal beams which can also be used to support the topslab.

d) Scheduling of works

The required sequence of the proposed works is determined by constructional and operational considerations. The construction sites will be subject to flooding by storm water if no measures are taken to drain the sites by gravity. It is accordingly neccessary to start downstream and to proceed against the stream.

This construction procedure is confirmed by operational considerations. The final design of the discharge culvert and the open channel of the Beng Salang drainage basin and the functioning of this system are determined by the water levels that can be maintained immediately downstream of the culvert.

Also the effective combination of construction works should be considered, such as the use of excess material from sewer excavation for the construction of a road along the open channel.

The environmental and social impacts of the proposed works demand particular attention. Before construction work in the Beng Salang drainage basin is started, a solution must be found for the environmental problems existing in Beng Salang lake and in Beng Tempen polder, such as the disposal of waste water from distilleries and on-site sanitation systems into the lake. The community need to be involved when preparing and constructing sewer connections or investigating alternative solutions for the water supply and sanitation systems before any work on the main drainage system is started. No data are yet available from the ongoing pilot sewerage projects.

The proposed sequence of the needed activities is given in Table 5-2.

Table 5-2 Proposed sequence of required activities.

1. Required studies: (including community involvement) water management of Beng Tempen polder soil investigations water supply and sanitation around the Beng Salang lake waste water disposal micro-drainage (sewerage pilot project)
Construction work: 2. Preparation of dump site for dredged material from Beng Tempen polder. 3. Dredging of main channel in Beng Tempen polder. 4. Construction of discharge culvert (Beng Salang). 5. Construct sewer interceptors around the Beng Salang lake. 6. Preparation of dump site for dredged material from Beng Salang lake. 7. Dredging of open channel in Beng Salang drainage basin. 8. Construction of road crossings. 9. Construction of main sewer (box culvert) and road alongside open channel (material from sewer excavation) 10. Completion of open channel construction.

More than one hundred thousand people residing in the Beng Salang drainage basin will benefit indirectly from the proposed scheme when considerering that flood levels in the basin are reduced. More than 7000 people will be directly involved, as they are immediately connected to the sewer system. This number will increase gradually with the connection of residential areas to the main sewer system, such as Psar Depot 2.

5.6 Estimate of cost

Provision is made for a considerable amount of spare parts in order to avoid delays caused by unforeseen repair work as much as possible. A training component covering operation and regular and preventive maintenance of equipment has been included.

Exchange rate: US $ 1.00 = Dfl 1.80 (Dutch guilders)

Equipment to be purchased for excavation:

	Dfl	US $
backhoe/loader, 90 pk, wheel mounted	320,000	177,000
spare parts for excavator, 4 years	120,000	67,000
2 dump trucks, 160 pk, payload 10 ton, wheel-mounted, @ Dfl 150.000	300,000	167,000
spare parts for 2 dump trucks, 4 years	120,000	67,000
dredger (hydraulic grab on pontoon with movable legs), 75 hp	500,000	278,000
spare parts for dredger (2 years)	100,000	56,000
three barges and one pushboat	250,000	139,000
spare parts for pushboat, barges	20,000	11,000
dredge pump with 40 m floating pipeline and 500 m shore pipeline	150,000	84,000
transport of equipment (overseas)	110,000	61,000
insurance of equipment, during transport	20,000 +	11,000 +
subtotal:	2,010,000	1,118,000
On-the-job training:		
backhoe, trucks: 6 weeks, 2 trips	50,000	28,000
dredger: 16 weeks, 3 trips	120,000 +	67,000 +
Total:	2,180,000	1,213,000

Equipment cost allocated to sewer construction:	Dfl 500,000
Equipment cost allocated to open channel construction:	Dfl 1680,000

The backhoe and trucks will be used for the sewer and open channel excavation. The purchase cost of this equipment is allocated to both types of construction work. The equipment will be available for other sewerage works after the completion of the proposed works.

The purchase cost of the dredger and barges is allocated to the open channel construction, although this equipment will first operate in Beng Tempen polder. It is expected that, in addition to the movable pontoon dredger, at least one dismountable cutter dredger will be needed to meet the dredging requirements in Beng Tempen polder. The purchase cost of a cutter dredger is:

Equipment:		
dismountable cutter dredge	Dfl	510,000
floating pipeline, 100 m		55,000
shore pipeline, 1500 m (light weight)		350,000
spare parts (4 years)		80,000
transport (overseas)		30,000
insurance during transport		14,000 +
subtotal	Dfl	1,039,000
On-the-job training, maintenance:		91,000 +
Total:	Dfl	1,130,000

The estimated construction cost are as follows:

Main sewer:
box culvert, 1820 m long (from Psar Depot 2 to lake Beng Salang)

	Dfl	US $
Excavation:		
provision of excavation and hauling units	500,000	278,000
insurance of equipment on site	20,000	11,000
spare parts for 2 trucks, Sewerage Dept.	40,000	22,000
fuel, 55.000 litres diesel @ Dfl 0.90	50,000	28,000
lubrication, grease	5,000	3,000
labour, 2 years	30,000	17,000
various (relocate water supply pipes, repair road surface, etc.	20,000 +	11,000 +
sub-total	665,000	370,000
dewatering of trenches, temporary sheet piling (provisional):	200,000	111,000
concrete: 8.700 m3 @ Dfl 200,-	1,740,000	967,000
steel reinforcement: 750.000 kg @ Dfl 2,50	1,875,000	1,042,000
shuttering: 18.000 m2 @ Dfl 60,-	1,080,000	600,000
screed:450 m3 @ Dfl 100	45,000 +	25,000 +
Total:	5,605,000	3,115,000

Open channel:
1170 m long, includes discharge culvert and two road crossings

	Dfl	US $
Excavation for open channel and culverts:		
equipment for dredging, transport, etc.:	1,680,000	933,000
insurance of equipment on site	50,000	28,000
spare parts for 2 trucks, Sewerage Dept.	40,000	22,000
fuel, 155.000 litres diesel @ Dfl 0.90	140,000	78,000
lubrication, grease	14,000	8,000
labour, 2 years	32,000 +	18,000 +
sub-total	1,956,000	1,087,000
preparation of dump site (provisional)	150,000	83,000
lining of channel slopes,including filterconstruction, 8000 m² @ Dfl 80,-	640,000	356,000
road construction (provisional)	160,000	89,000
various: repair paving, etc.	20,000	11,000
concrete: 540 m³ @ Dfl 220,-	120,000	67,000
steel reinforcement: 50.000 kg @ Dfl 2,60	130,000	72,000
shuttering: 1540 m² @ Dfl 80,-	120,000	67,000
screed: 40 m³ @ Dfl 100	4,000 +	2,000 +
Total:	3,300,000	1,834,000

The estimated cost of the waste water interceptors (2600 m) based on the purchase of plastic piping is Dfl 800.000.

Soil investigations are needed for the final design of the proposed works. The estimate of cost may have to be adapted when the results of the soil investigations are available.

The estimate of cost for the box culvert is made for in-situ poured concrete, although the quality of a prefabricated construction will be better and the cost probably lower.

The total cost for the proposed works in the Bang Salang drainage basin are:

main sewer, 1820 m box culvert	Dfl 5,600,000	US $ 3,100,000
open channel, including culverts	Dfl 3,300,000	US $ 1,800,000
waste water interceptors	Dfl 800,000 +	US $ 500,000 +
total:	Dfl 9,700,000	US $ 5,400,000

It is noted that the estimate of cost does not include the measures required for the disposal of waste water, the dredging work in Beng Tempen polder nor any study that is needed before any construction work in the Beng Salang drainage basin is undertaken.

5.6 Conclusions and recommendations

- The following work should be carried out to prevent flooding of the Psar Depot 2 area:
  - dredging of the main drainage channel in Beng Tempen polder,
  - provision of a discharge culvert (6.0 m wide, 2.0 m high) through the dike of the Beng Salang drainage basin,
  - construction of a 1.2 km open channel in Beng Salang lake,
  - construction of a 1.8 km box culvert from Psar Depot 2 to the lake.

- Details of the proposed main sewer are given in Figures 5-2 and 5-3. The box culvert has a net width between 3.3 and 4.5 m. The open channel has a bottom width of 25 m; it should be constructed as a "dry" channel which empties completely after a heavy rainfall. The open channel includes two road crossings with a net width of 10 m.

- The discharge of waste water should not be allowed into surface ditches, open channels or lakes within the built-up area.

- Sanitary sewers intercepting waste water from the combined sewers and collecting waste water from the distilleries and residences around the Beng Salang lake should be provided to eliminate the discharge of waste water into the existing lake or the future open channel system.

- The disposal of waste water should be investigated for the final design of the proposed waste water interceptors.

- Soil investigations should be carried out for the final design of the discharge culvert, the open channel and the combined sewer (box culvert) as well as for the required dredging work in Beng Tempen polder and Beng Salang lake. The final design of the channel and drainage system is determined by the outcome of soil investigations and the results of the proposed study on the water management of Beng Tempen polder.

- The estimated costs of the proposed works in the Beng Salang drainage basin are:

main sewer, 1820 m box culvert	Dfl 5,600,000	US $ 3,100,000
open channel, including culverts	Dfl 3,300,000	US $ 1,800,000
waste water interceptors	Dfl 800,000 +	US $ 500,000 +
total:	Dfl 9,700,000	US $ 5,400,000

- This cost estimate includes the provision of one backhoe/loader, two dump trucks, one dredger (hydraulic grab), three barges with one pushboat and one dredge pump with 540 m pipeline. The cost of the equipment including training, provision of spare parts, etc. is Dfl 2,180,000 (US $ 1,210,000).

- The cost estimate does not include dredging in the Beng Tempen polder, the measures required for the disposal of waste water from the Beng Salang drainage basin nor for studies which have to be completed before contruction work starts (see Table 5-2).

- The sequence of the proposed activities should be as given in Table 5-2.

- More than one hundred thousand people residing in the Beng Salang drainage basin will benefit indirectly from the proposed scheme when considering that flood levels in the basin are reduced. More than 7000 people will be directly and immediately involved, when they are connected to the sewer system. This number will increase gradually with the connection of residential areas to the main sewer system, such as, for example, with the implementation of the pilot water supply and sanitation project Psar Depot 2.

- The local population should be involved with the planning and implementation of sanitation systems, such as sewer connections, replacement of pit latrines by pour-flush units, etc. The financing of the houseowners' component should be investigated. The people should also be involved with the improvement of the water supply system.

- The separate sewer system is the most suitable type of system for the Beng Salang drainage basin; it is cheaper to build, it functions better and it involves less public health risks than a combined sewer system. The system will consist of a piped sanitary sewer system and a low-cost solution for storm water drainage. Storm water will be transported in surface ditches and open channels in streets and alleys and through underground drains in main roads.

- The financial feasibility of alternative types of sewer systems should be investigated within the framework of a Master Plan Study on Urban Drainage.

- The proposed main sewer from Psar Depot 2 to the Beng Salang lake has been designed as a combined sewer to follow the policy of the Sewerage and Urbanization Departments, but it can also function as a storm water drain of the separate system, when a separate sanitary sewer is laid parallel to the drain.

6 Institutional Requirements

6.1 Inventory of existing needs

Two departments are responsible for the administration, operation and maintenance of the sewerage system: the Sewerage Department is responsible for the sewer mains and the Pumping Stations Department for the pumping stations. In fact a third department is involved: the Municipal Workshops, responsible for the maintenance of municipal vehicles.

The limited institutional capability of the Sewerage Department is obvious. Adequate surveying equipment needed for sewer construction and data collection is not available nor equipment for planning and design work. There is a shortage of staff, skills and knowledge. The Sewerage Department is responsible for the sewer mains, but no time is available to take care of street sewers in secondary roads and in alleys. No counterpart staff at the engineering level nor surveyors could be made available during the mission to work with the consultants. The shortage of staff is partly caused by a low remuneration. An adequate pay would enhance the availability of existing staff considerably.

Skills in the design and construction of sewers are insufficient. As a consequence of inadequate surveying equipment and limited skills, sewers are constructed below standards, resulting in difficult and inadequate cleaning of sewers (see Par. 2-3). There is accordingly an urgent need for the provision of adequate equipment and on-the-job training for the activities that are performed by the Sewerage Department. This training includes the planning and design of sewers, standardization of materials, conduits, appurtenances, etc., local fabrication of conduits and appurtenances, making and maintaining sewer records, recording and maintaining benchmarks as needed for design and construction work, cleaning and repair of sewers.

A specialist should be appointed to assist the Sewerage Department with their daily activities through on-the-job training. Assistance is also needed with special activities which at present can not yet be handled by the Sewerage Department such as the establishment of sewer records, fixing of benchmarks, or the special studies mentioned in Table 5-2.

Some studies cover the fields of different Departments, for example, the study on the "water management of Beng Tempen polder" largely affects the Urbanization and Pumping Stations Departments, but the Hydrology Department within the Ministry of Agriculture and the Sewerage Department should also be involved with this study. Tuite (Ref.7) proposed, with regard to the implementation of a pumping stations project, the installation of a co-ordinating group to facilitate communication between the organizations involved and to co-ordinate a joint approach. A co-ordinating group would be extremely useful to support the specialist assigned to the Sewerage Department and would enable the specialist to assist other organizations with sewerage or related activities, for example, the planning, design and construction of pumping stations.

6.2 Project Implementation

Sewer construction is at present carried out under municipal control. Expertise will be required for the implementation of the proposed construction works, particularly with regard to the planning and organization of the works and the application of construction procedures. A project or resident engineer is needed to assist the Municipality with the implementation of the complete project as set out in Table 5-2. He should also assist with the completion of the required studies, for example, with finding long/short term consultants as needed, or even assist with preparatory work when consultants have to be found for a "master plan study on urban drainage in Phnom Penh".

The job requirements for the Specialist mentioned in the previous paragraph are quite different from those for the resident engineer. For the implementation of the construction works a practical person with an organizational ability and wide experience in construction management is needed. The specialist, however, should have experience of design, sewer construction, operation and maintenance work. Experience of construction obtained during supervision is quite acceptable.

Both jobs should be carried out by the same person. This person should have the qualifications required for the so-called resident engineer, and he will, when needed, hire specialists for short missions.

It will take approximately 4 years to execute the proposed works in the Beng Salang drainage basin, as set forth in Paragraph 5.5. The total duration of the project will be much longer, because prior to the implementation of the proposed works, special studies will have to be performed and dredging work in the Beng Tempen polder will have to be carried out (see Table 5-2).

The determination of the construction period was based on a conservative production estimate of the excavation and handling equipment. The project duration can be reduced by an efficient organization, but also by carrying out several works simultaneously through the provision of building trenches with dewatering devices. A project period of four to six years should be sufficient.

The resident engineer should be able to hire consultants as needed for special studies but he should also acquire the services of an engineer during a period of 12 to 18 months to assist with the time-consuming supervision of the construction of the combined sewer (box culvert).

6.3 Conclusions and recommendations

- The provision of adequate equipment and training of staff for the design, construction and maintenance of sewers is urgently needed.

- The proposed project should include a technical assistance component for the provision of equipment and on-the-job training to the Sewerage Department.

- It is recommended that a resident engineer be appointed to assist the Municipality with the implementation of the project.
  The appointment could first be for a period of three years.
  The resident engineer will be responsible for the implementation of the technical assistance component.

- An engineer will be appointed for a period of 12 to 18 months to assist with the supervision of the construction of the combined sewer (box culvert).

- The duration of the project is expected to be between four and six years.

- The estimated cost for foreign staff is Dfl 1,000,000 if the project duration is limited to 5 years.

7 References

1 Chhim Sun Fong, Kry Beng Hong, Tan Thanh, Planning Strategy for Phnom Penh, University College London School of Environmental Studies, 1973.

2 Mekong Secretariat, Intensité de Précipitations, Intensité Maxima de Précipitations, 1960-1970

3 Mekong Secretariat, Lower Mekong Hydrological Yearbooks, 1961 - 1974, Volumes I, II, Committee for Co-ordination of Investigations of the Lower Mekong Basin

4 Mekong Secretariat, Modele mathematique du Delta du Mekong,
Volume III-1, (Cambodge): Campagne de Mesures 1963,
Volume III-2, (Cambodge): Campagne de Mesures 1964,
Volume III-4, (Cambodge): Campagne de Mesures 1965

5 Municipality of Phnom Penh, The Functions of a City, Conference " Families in the Face of Urbanization", New Delhi, December 1985.

6 Overkamp J.(Jack), Le Drainage de Phnom Penh, 1987, NOVIB.

7 Tuite J.(John), Phnom Penh Drainage System, Feasibility Study Report, 1989.

Appendix 1

WORKPLAN (Adapted 10 July 1990)

Description of activities

Technical Activities:

1. Collect and examine data in the Netherlands (kind of data are indicated in activity 2).

2. Establish appropriate contacts with municipal and governmental departments, NGO's and other organizations in Phnom Penh.
   Collect and examine data as needed for the proposed engineering study with respect to:
   - base maps with contours (maps 1 : 5000 are avbailable)
   - survey sheets, land-use maps, town planning maps (also location of industries and commercial establish ments)
   - existing records of sewerage and drainage networks
   - population development from statistical records
   - growth and trends considering housing, population densities, proposed development schemes
   - climatic and meteorologic data
   - hydrological data
   - soil conditions (infiltration capacity)
   - local cost for labour, materials, power, fuel and specific construction cost
   - quantity of waste water in drains
   - refuse collection and sanitation practice.

3. Conduct surveying for the completion of records of the existing balancing lake, drainage canal and adjacent sewers of the Beng Salang Drainage Basin.

4. Conduct levelling work and establish a benchmark system as needed for the survey in Activity 4.

5. Check the condition of the balancing lake with regard to storage available, (illicit) housing, vegetation, sedimentation, etc.
   Check state of drainage canal and adjacent sewers with particular attention to materials used, shape, kind of construction, occurrence of blockages, velocity of flow and state of repair.
   Determine and locate shortcomings of these facilities.
   Check roughly, as needed for the engineering study, the state of the existing drainage facilities in the Beng Salang Basin.

6. Check the state of maintenance of the main drainage pumping station (machinery, pumps, piping, specials, other mechanical equipment, building work, etc.). Collect data on pump operation, availability of electricity, fuel, hydraulic conditions.
   Check the suitability of the existing building and concrete work for the installation of pumps and machinery.

7. Collect data on flooded areas with regard to frequency of flooding, depth of flooding and flooded surface area. Collect data on possible damage to housing etc. that may occur.

8. Examine and analyse hydrological data as needed for the computation of peak discharges, pumping and storage requirements. Estimate run-off factors (in relation to land use, density of buildings, etc).

9. Establish basic hydrological and hydraulic design criteria for the pumping station, balancing lake (storage) and the drainage canal.
   Establish, as needed, design criteria for the drainage facilities. The results will be discussed with the Resident Engineer (NOVIB) and the Sewerage Department.

10. Investigate from the base maps, sewer records and field data the drainage characteristics of the catchment area (Beng Salang Basin).
    Determine or estimate run-off quantities needed for the determination of pumping and storage requirements. Consider the results of the NOVIB pilot projects for the integrated provision of local area services (micro-drainage).

11. Investigate alternative solutions of pumping requirements in relation to storage requirements and frequency of flooding.
    Consider alternative types of pumping stations.
    The results will be discussed with the Sewerage Department.

12. Complete the preliminary design of the proposed pumping station, and the final design of the balancing lake (storage reservoir) and drainage canal. The designs will include: engineering drawings, schedule of quantities and specifications for pumping and dredging equipment as needed. The availability of manpower and skills will be considered when drawing up specifications.
    The project will be developed to a sufficient level of detail that the Municipality/NOVIB can purchase the necessary equipment and implement the works required.
    The results will be discussed with the Resident Engineer (NOVIB) and the Sewerage Department.

13. Estimate construction cost.
    Assess the local availability of materials, construction equipment and skills and the local capacity for construction.

Training Activities

14. To train counterpart staff in the activities that are performed, as far as counterpart staff is available to participate in the activities.

Appendix 2

SURVEY RESULTS OF EXISTING DRAINS

The location of the surveyed main sewers and inspection chambers are indicated in Figure 3-1. The main sewers are numbered.

Sewerage records
Indicated are: sewer diameter (of ongoing and branch sewers), distance between inspection chambers, ground levels (top of inspection chamber) and invert levels of ongoing sewers and branch sewers.

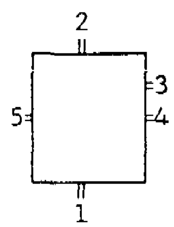
State of system
Indicated are depth of sludge in sewer, condition of cover of inspection chamber and, if possible, condition of sewers.

Legend

3.11 Number of inspection chamber (IC)

Note: The number of IC is related to the number of the main sewer, 3 = number of main sewer 3-3'.

Numbering of sewer lines at inspection chambers:



=2	surveyed sewer, upstream
=3,4,5	branch sewer or house connection
=1	surveyed sewer, downstream

Records existing system (tables):

I.C.,No	Number of inspection chamber
Sewer line, No	Number of connected sewer (ongoing, branch)
dia	diameter of sewer
dist	distance between inspection chambers
Invert level	invert level of sewer
Ground level	top of inspection chamber (frame)

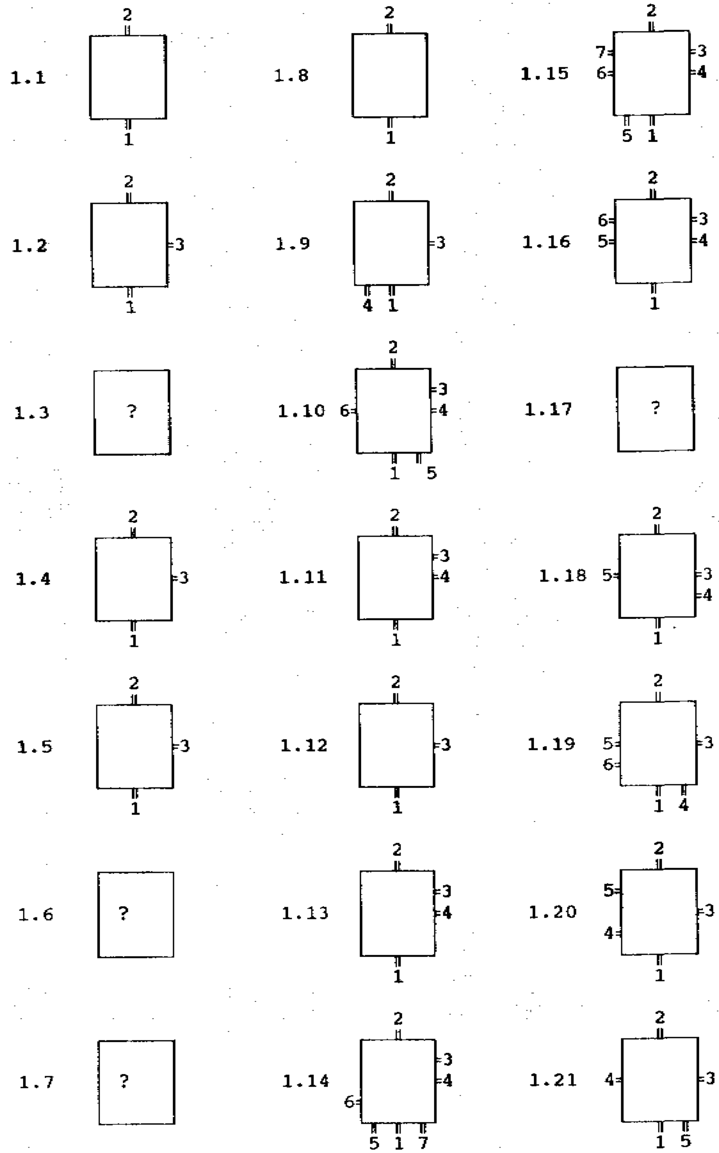
State of system (tables):

Bottom sludge	depth of sludge in sewer (line)
I.C. Cover	cover of inspection chamber
sc, sb	sand catch, sand box
rp	storm water connection

EXISTING SYSTEM

I.C. No	SEWER LINE No	DIA. [m]	DIST. [m]	INVERT LEVEL [m]	GROUND LEVEL [m]
SEWER 1-1'					
1.1	1	0.6		6.35	9.04
	2	0.3	20.7	8.32	
1.2	1	0.6		5.95	8.78
	2	0.6	33.7	5.95	
	3	0.3		8.33	
1.3			20.0	8.56	8.56
1.4	1	0.6		6.00	8.42
	2	0.6	71.5	6.01	
	3	0.3		7.74	
1.5	1	0.6		-	8.32
	2	0.6	44.5	5.99	
	3	0.3		7.63	
	4	0.25		6.72	
1.6	1	-			8.37
	2	-			
1.7	1	-			8.18
	2	-			
1.8	1			6.59	8.26
	2		18.2	6.57	
1.9	1	0.6		5.77	8.04
	2	0.6	37.7	5.73	
	3	0.3		7.41	
	4	0.3		7.06	
1.10	1	1.0		5.77	8.02
	2	1.0	51.5	5.80	
	3	0.6		6.26	
	4	0.3		7.25	
	5	0.15		7.72	
	6	0.3		6.39	
1.11	1	1.0		5.70	7.64
	2	1.0		5.67	
	3	0.3	52.8	6.85	
	4	0.2		7.34	
1.12	1	1.0	31.8	5.62	7.54
	2	1.0		5.62	
	3			6.94	
1.13	1	1.0		5.54	7.51
	2	1.0		5.54	
	3	0.1	23.5	6.85	
	4			7.31	
1.14	1	1.0		5.51	7.68
	2	1.0		5.48	
	3	0.3		6.76	
	4	0.25		7.33	
	5	0.3		6.23	
	6	0.25		6.81	
	7	0.3	29.4	7.07	

SEWER 1-1'

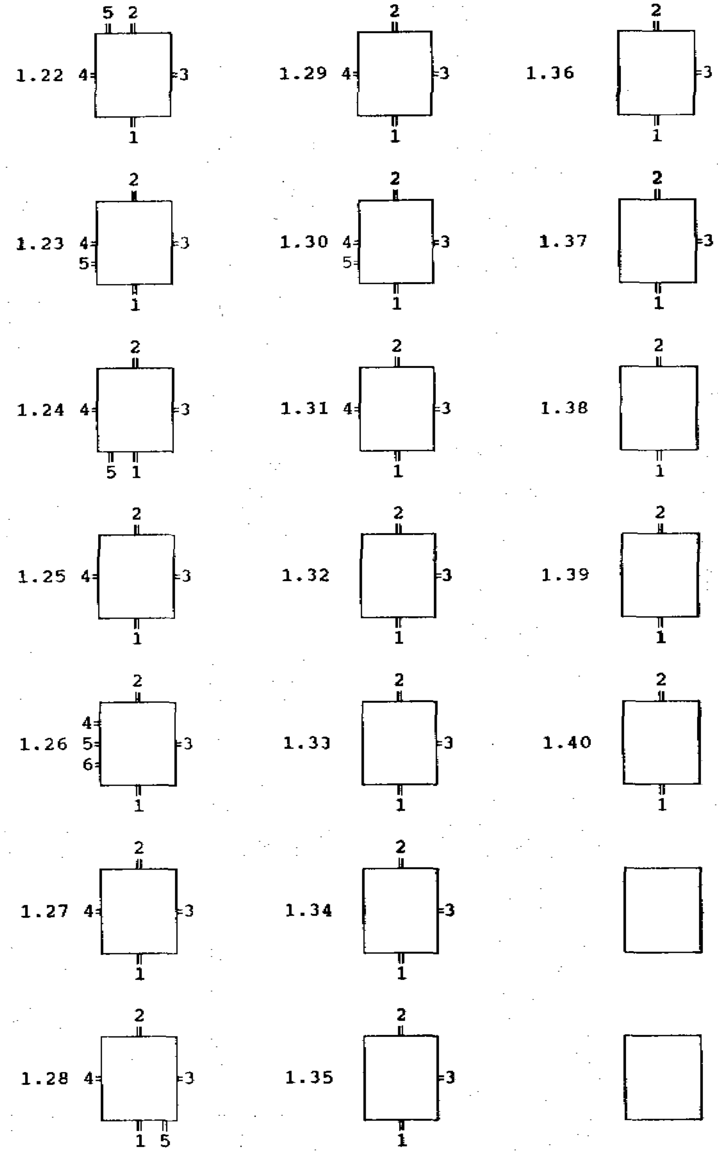


EXISTING SYSTEM

I.C. No	SEWER LINE No	DIA. [m]	DIST. [m]	INVERT LEVEL [m]	GROUND LEVEL [m]
SEWER 1-1'					
1.15	1	1.0		5.56	7.67
	2	1.0	17.6	5.55	
	3	0.3		6.75	
	4	0.25		7.22	
	5	0.25		6.31	
	6	0.15		7.02	
	7	0.25		6.72	
1.16	1	1.0		5.5	7.64
	2	1.0	44.0	5.57	
	3	0.3		6.82	
	4	0.1		7.44	
	5	0.25		6.67	
	6	0.2		6.37	
1.17				0	
1.18	1	1.0	20.1	5.5	7.64
	2	1.0		5.5	
	3	0.3		6.75	
	4	0.2		7.34	
	5	0.2		6.75	
	6	0.2		6.82	
1.19	1	1.0		5.49	7.61
	2	1.0	20.4	5.49	
	3	0.3		5.76	
	4	0.2		5.81	
	5	0.25		6.04	
	6	0.3		6.0	
1.20	1	1.0		5.48	7.56
	2	1.0	27.7	5.45	
	3	0.3		5.59	
	4	0.25		6.19	
	5	0.2		6.24	
1.21	1	1.0		5.44	
	2	1.0	25.1	5.44	
	3	0.3		6.64	
	4	0.6		5.66	
	5	0.3		6.84	
1.22	1	1.0		5.47	7.49
	2	1.0	19.4	5.47	
	3	0.25		6.72	
	4	0.3		5.94	
	5	0.25		6.77	
1.23	1	1.0		5.47	7.7
	2	1.0	28.2	5.37	
	3	0.3		6.79	
	4	0.3		6.23	
	5	0.3		6.28	

EXISTING SYSTEM

I.C. No	SEWER LINE No	DIA. [m]	DIST. [m]	INVERT LEVEL [m]	GROUND LEVEL [m]
SEWER 1-1'					
1.24	1	1.0		5.40	7.57
	2	1.0	24.9	5.40	
	3	0.4		6.60	
	4			6.18	
	5	0.35		6.45	
1.25	1	1.0		5.52	8.02
	2	1.0	30.7	5.51	
	3	0.3		7.28	
	4	0.3		7.01	
1.26	1	1.0		5.18	7.92
	2	1.0	22.6	5.18	
	3	1.0		5.40	
	4	0.6		5.42	
	5			6.71	
	6	0.25		6.97	
1.27	1	1.0		5.04	7.66
	2	1.0	22.2	5.01	
	3	0.3		6.85	
	4	0.6		5.32	
1.28	1	1.0		4.61	7.47
	2	1.0	22.4	5.08	
	3	0.3		6.73	
	4			6.35	
	5	0.25		6.75	
1.29	1	1.0		5.21	7.46
	2	1.0	26.7	5.19	
	3	0.3		6.77	
	4	0.2		6.09	
1.30	1	1.0		5.24	7.41
	2	1.0	50.0	5.23	
	3	0.3		6.76	
	4	0.25		6.86	
	5	0.2		6.09	
1.31	1	1.0		5.04	7.04
	2	1.0	59.3	5.03	
	3	0.3		6.37	
	4	0.25		5.69	
1.32	1	1.0		4.79	6.93
	2	1.0	35.7	4.87	
	3	0.25		6.26	
1.33	1	1.0		4.87	6.95
	2	1.0	44.9	4.85	
	3			6.6	
1.34	1	1.0		4.73	6.83
	2	1.0	49.8	4.69	
	3	0.35		6.13	



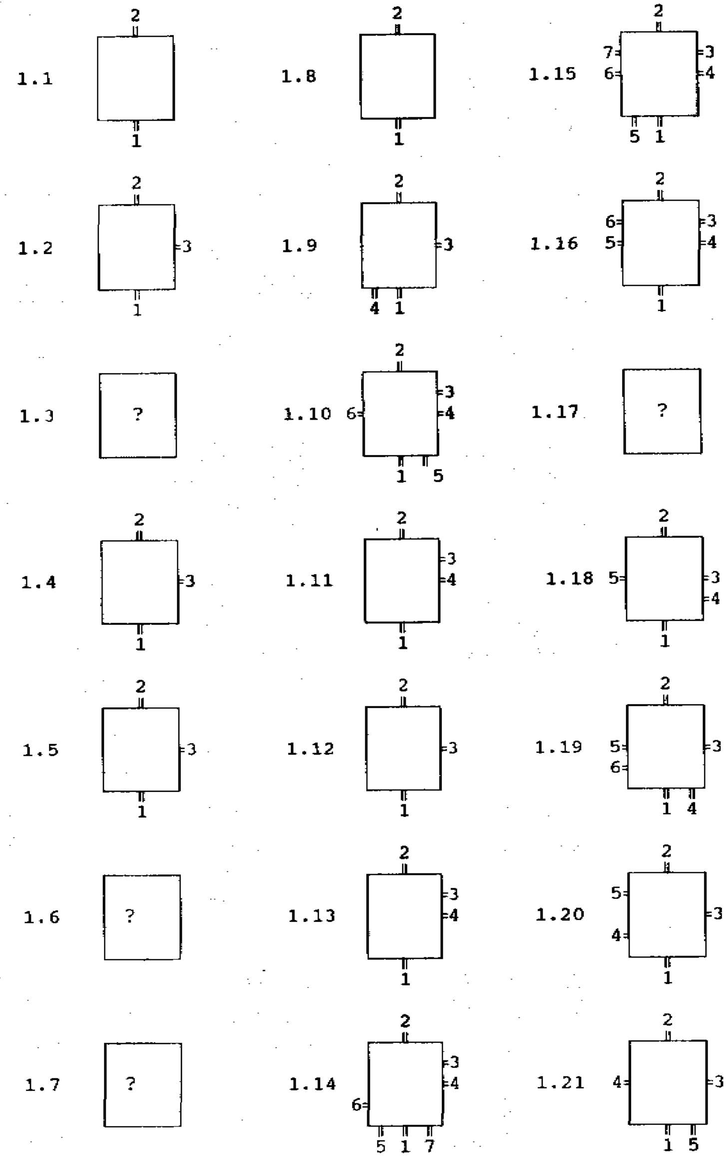
EXISTING SYSTEM

I.C. No	SEWER LINE No	DIA. [m]	DIST. [m]	INVERT LEVEL [m]	GROUND LEVEL [m]
SEWER 1-1'					
1.35	1	1.0		4.67	6.71
	2	1.0	39	4.61	
	3	0.1		6.21	
1.36	1	1.0		4.42	6.61
	2	1.0	26.1	4.36	
	3	0.25		5.99	
1.37	1	1.0		4.32	6.57
	2	1.0	31.3	4.32	
	3	0.2		6.02	
1.38	1	1.0		4.14	6.36
	2	1.0	35.2	4.21	
1.39	1	1.0		4.33	6.45
	2	1.0	43.0	4.28	
1.40	1	1.0		4.25	6.37
	2	1.0		4.2	

STATE OF SYSTEM (Aug '90)

I.C. No	SEWER LINE No	BOTTOM SLUDGE [m]	I.C. COVER	REMARKS
SEWER 1-1'				
1.1	1	0.3		
	2			sc
1.2	1	0.2	broken	
	2	0.2		
	3			sc
1.3				full sand
1.4	1	0.6	good	
	2	0.6		
	3			
1.5	1	0.6	good	
	2	0.6		
	3			sc
	4			
1.6	1	unknown	good	
	2	,,		
1.7	1	,,		
		,,		
1.8	1			
	2			
1.9	1	0.6		
	2	0.6		
	3			sc
	4			
1.10	1	0.74		
	2	0.74		
	3	0.2		sc
	4			rp
	5			
	6			
1.11	1	0.72		
	2	0.73		
	3			sc
	4			open
1.12	1	0.75		
	2	0.75		
	3			
1.13	1	0.8	good	
	2	0.82		
	3			
	4			
1.14	1	0.75		no sce
	2	0.75		
	3			sc
	4			rp,open
	5			
	6			
	7			

SEWER 1-1'

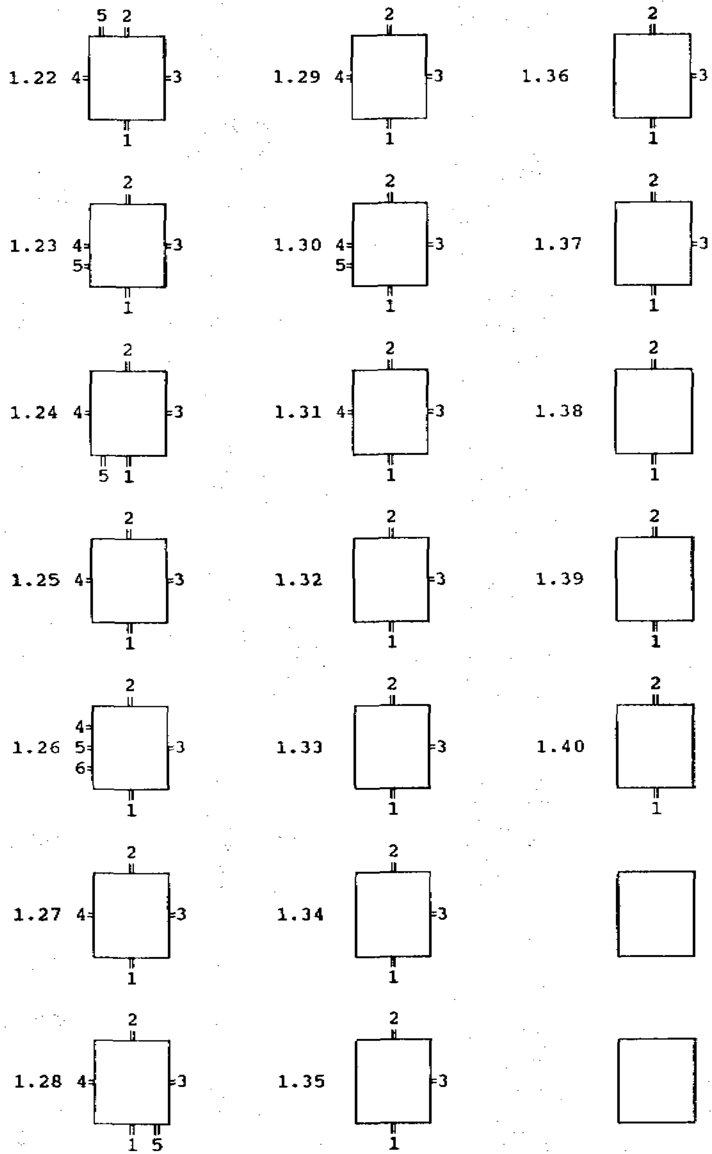


STATE OF SYSTEM (Aug '90)

I.C. No	SEWER LINE No	BOTTOM SLUDGE [m]	I.C. COVER	REMARKS
SEWER 1-1'				
1.15	1	0.72		
	2	0.72		
	3			sc
	4			rp
	5			
	6			
	7			
1.16	1	0.71	good	
	2	0.7		
	3			sc
	4			rp
	5			
	6			
1.17				no data
1.18	1	0.62	good	sc
	2	0.7		
	3			sc
	4			rp
	5			
	6			
1.19	1	0.65	good	
	2	0.65		
	3			no sc
	4			
	5			
	6			
1.20	1	0.62	good	
	2	0.67		
	3			
	4			
	5			
1.21	1	0.55	good	
	2	0.62		
	3			
	4			
	5			
1.22	1	0.65	broken	
	2	0.62		
	3			
	4			
	5			
1.23	1	0.55		
	2	0.62		
	3			
	4			
	5			

STATE OF SYSTEM (Aug '90)

I.C. No	SEWER LINE No	BOTTOM SLUDGE [m]	I.C. COVER	REMARKS
SEWER 1-1'				
1.24	1	0.7	good	
	2	0.64		
	3			
	4			
	5			
1.25	1	0.55	good	
	2	0.5		
	3			
	4			
1.26	1	0.62		
	2	0.65		
	3	0.52		
	4			
	5	0.05		
	6			
1.27	1	0.64		
	2	0.65		
	3			
	4	0.42		
1.28	1	0.68	broken	
	2	0.68		
	3			
	4			
	5			
1.29	1	0.62	good	
	2			
	3			
	4			
1.30	1	0.5		
	2	0.57		
	3			broken, open
	4			
	5			
1.31	1	0.62	broken	
	2	0.62		
	3			
	4			
1.32	1	0.62	good	
	2	0.62		
	3			broken,open
1.33	1	0.71	no	
	2	0.67		
	3			broken, open
1.34	1	0.65	good	
	2	0.65		
	3			



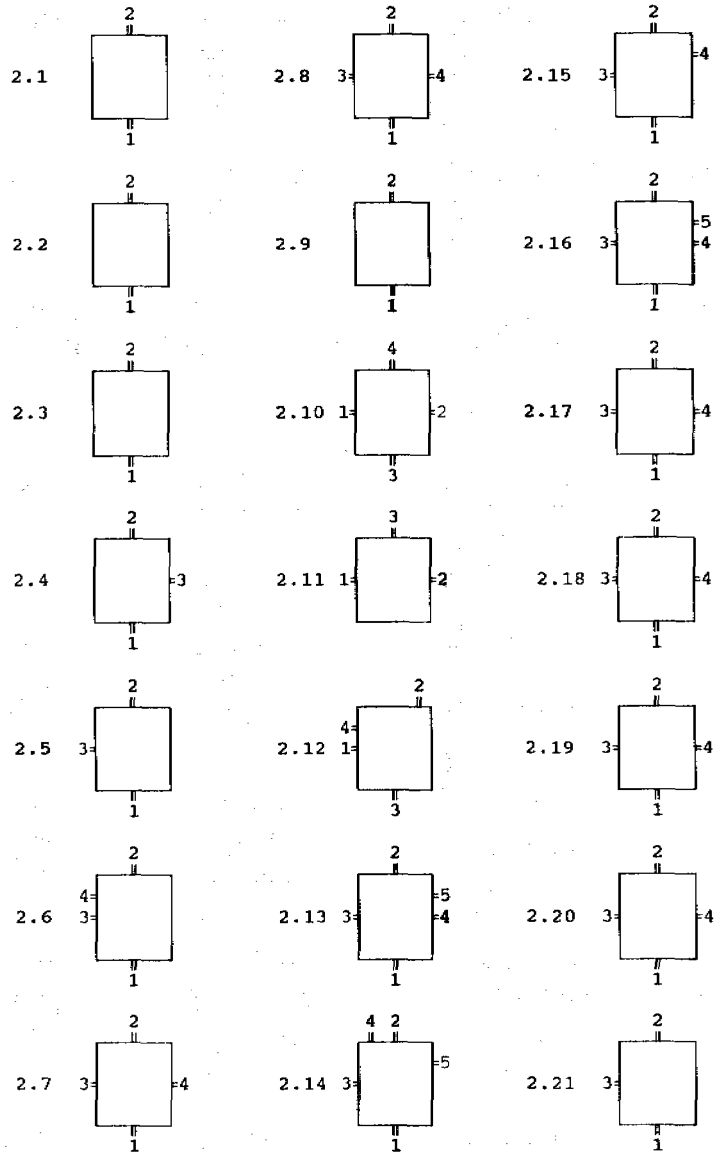
STATE OF SYSTEM (Aug '90)

I.C. No	SEWER LINE No	BOTTOM SLUDGE [m]	I.C. COVER	REMARKS
Sewer 1-1'				
1.35	1	0.6	no	
	2	0.45		
	3			
1.36	1	0.62	good	
	2	0.63		
	3			
1.37	1	0.71	good	broken sewer
	2	0.75		
	3			
1.38	1	0.65	no	
	2	0.65		
1.39	1	0.75	broken	
	2	0.71		
1.40	1	0.47	good	
	2	0.5		

EXISTING SYSTEM

I.C. No	SEWER LINE No	DIA [m]	DIST [m]	INVERT LEVEL [m]	GROUND LEVEL [m]
SEWER 2-2'					
2.1	1	0.4		9.2	10.71
	2	0.4	40.35	9.2	
2.2	1	0.4		8.22	10.10
	2	0.4	89.15	8.19	
2.3	1	0.4		6.89	8.71
	2	0.4	23.0	6.98	
	3	0.4		7.05	
2.4	1	0.4		6.85	8.58
	2	?	32.1	7.25	
	3	0.3		7.05	
2.5	1	0.6		6.57	8.32
	2	0.6	19.6	6.57	
	3	0.2		8.02	
2.6	1	0.6		6.55	8.22
	2	0.6	19.6	6.5	
	3	0.6		6.55	
	4	0.2		7.92	
2.7	1	0.6		6.53	8.16
	2	0.6	27.0	6.53	
	3	0.6		6.53	
	4	0.2		7.86	
2.8	1	0.6		6.52	8.08
	2	0.6	12.1	6.49	
	3	0.25		6.96	
	4	0.25		6.76	
2.9	1	0.6		6.5	7.87
	2	?	11.3	7.1	
2.10	1	1.0		6.95	7.95
	2	1.0	21.7	6.01	
	3	0.3		6.68	
	4	0.6		6.2	
2.11	1	1.0		5.83	7.98
	2	1.0	6.1	5.78	
	3	0.3		7.06	
2.12	1	1.0		5.88	8.03
	2	1.0	21.1	5.86	
	3	1.0		5.82	
	4	0.3		7.28	
2.13	1	1.0		5.8	7.9
	2	1.0	24.2	5.75	
	3	0.3		7.1	
	4	0.3		6.5	
	5	0.2		7.48	
2.14	1	1.0		5.75	7.71
	2	1.0	19.9	5.75	
	3	0.3		6.96	
	4	0.3		6.49	
	5	0.25		6.94	

SEWER 2-2'

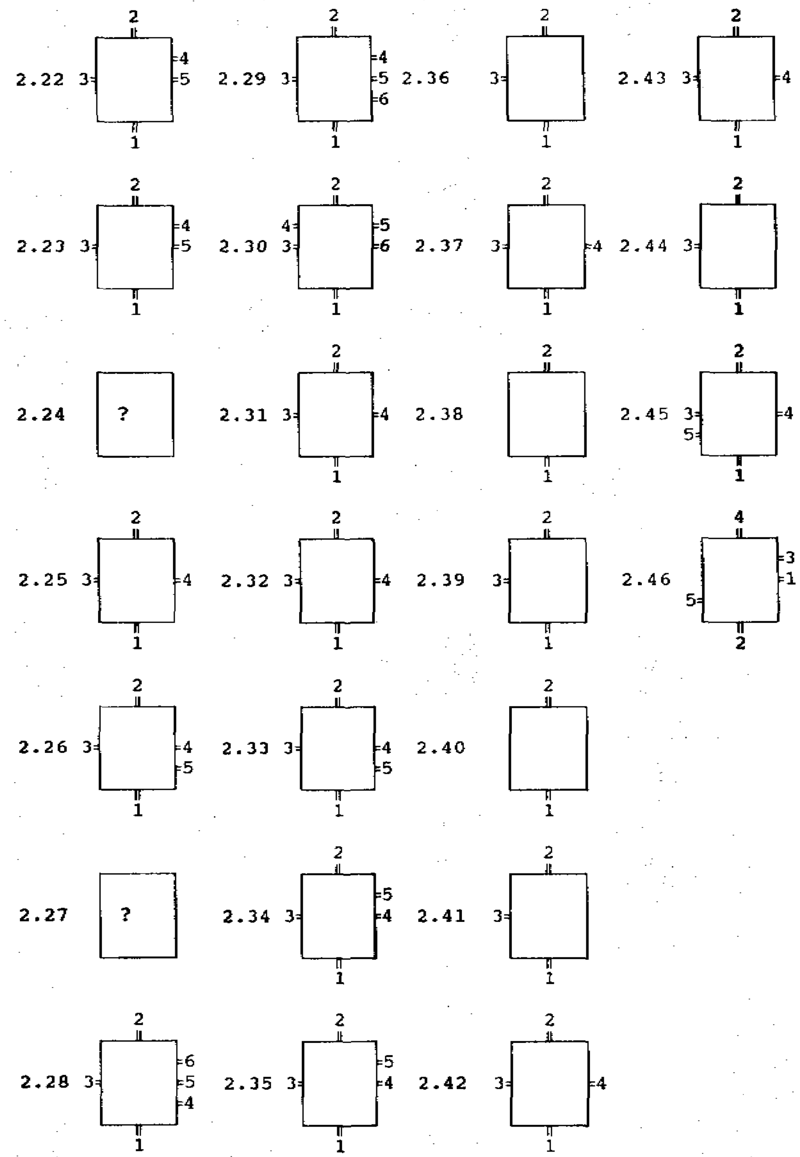


EXISTING SYSTEM

I.C. No	SEWER LINE No	DIA [m]	DIST [m]	INVERT LEVEL [m]	GROUND LEVEL [m]
SEWER 2-2'					
2.15	1	1.0		5.68	7.64
	2	1.0	29.1	5.68	
	3	0.3		6.95	
	4	0.3		6.62	
2.16	1	1.0		5.64	7.88
	2	1.0	12.9	5.76	
	3	0.3		6.98	
	4	0.4		6.93	
	5	0.3		6.36	
2.17	1	1.0		5.72	7.65
	2	1.0	29.8	5.68	
	3	0.3		6.75	
	4	0.25		6.8	
2.18	1	1.0		6.77	7.77
	2	1.0	23.2	5.75	
	3	0.3		6.42	
	4	0.3		6.75	
2.19	1	1.0		5.73	7.8
	2	1.0	30.4	5.73	
	3	0.3		6.78	
	4	0.25		6.88	
2.20	1	1.0		5.68	7.66
	2	1.0	16.1	5.68	
	3	0.3		6.71	
	4	0.3		6.81	
2.21	1	1.0		5.71	7.63
	2	1.0	32.2	5.71	
	3	0.3		6.81	
2.22	1	1.0		5.67	7.64
	2	1.0	22.9	5.67	
	3	0.3		6.74	
	4	0.3		6.64	
	5	0.3		6.36	
2.23	1	1.0		5.68	7.68
	2	1.0	18.9	5.61	
	3	0.3		6.83	
	4	0.25		6.58	
	5	0.25		6.25	
2.24				0	
2.25	1	1.0	53.2	6.42	7.42
	2	1.0	29.2	5.6	
	3	0.3		6.7	
	4	0.4		6.52	
2.26	1	1.0		5.66	7.61
	2	1.0	48.1	5.62	
	3	0.3		6.79	
	4			6.29	
	5			7.09	

EXISTING SYSTEM

I.C. No	SEWER LINE No	DIA [m]	DIST [m]	INVERT LEVEL [m]	GROUND LEVEL [m]
SEWER 2-2'					
2.27	no data			0	
2.28	1	1.0	21.2	5.66	7.64
	2	1.0	21.1	5.64	
	3	0.3		7.0	
	4	0.3		6.39	
	5	0.3		6.39	
	6	0.25		7.19	
2.29	1	1.0		5.62	7.67
	2	1.0	22.3	5.62	
	3	0.3		7.05	
	4	0.3		6.23	
	5	0.2		6.37	
	6	0.1		7.25	
	7	0.2		7.27	
2.30	1	1.0		5.8	7.94
	2	1.0	55.5	5.79	
	3	0.3		7.18	
	4	0.15		7.69	
	5	0.25		6.67	
	6	0.15		7.12	
2.31	1	1.0		5.5	7.96
	2	1.0	23.0	5.5	
	3	1.0		5.84	
	4	0.8		5.75	
	5	0.2		7.34	
2.32	1	1.0		5.11	7.63
	2	1.0	37.6	5.08	
	3	0.3		7.03	
	4	0.3		5.95	
2.33	1	1.0		5.05	7.31
	2	1.0	42.0	5.01	
	3	0.3		6.59	
	4	0.3		6.06	
	5	0.25		6.14	
2.34	1	1.0		5.16	7.18
	2	1.0	41.2	5.14	
	3	0.3		6.58	
	4	0.25		6.06	
	5	0.25		6.36	
2.35	1	1.0		5.02	6.95
	2	1.0	39.8	4.99	
	3	0.2		6.55	
	4	0.25		5.86	
	5	0.25		5.93	



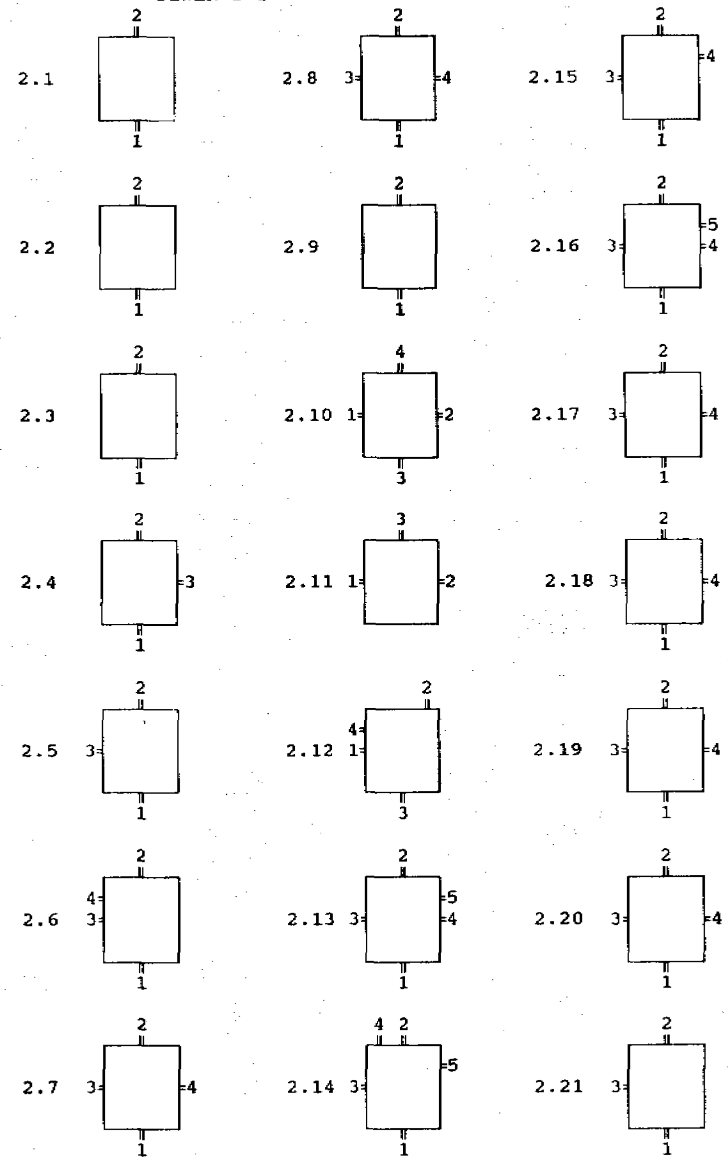
EXISTING SYSTEM

I.C. No	SEWER LINE No	DIA [m]	DIST [m]	INVERT LEVEL [m]	GROUND LEVEL [m]
SEWER 2-2'					
2.36	1	1		5.07	6.94
	2	1	31.6	5.07	
	3	0.3		6.27	
2.37	1	1		4.99	6.81
	2	1	91.5	4.94	
	3	0.4		6.04	
	4	0.6		5.19	
2.38	no data			0	
2.39	1	1		4.85	6.72
	2	1	29.45	4.85	
	3	0.2		6.07	
2.40	1	1		4.91	6.79
	2	1	30.75	4.81	
	3	0.2		6.24	
2.41	1	1		4.58	6.73
	2	1	31.1	4.61	
	3	0.4		6.13	
2.42	1	1		4.59	6.5
	2	1	30.5	4.55	
	3	0.15		6.15	
	4	0.2		5.9	
2.43	1	1		4.44	6.41
	2	1	31.2	4.28	
	3	0.35		5.86	
	4			6.16	
2.44	1	1		4.54	6.55
	2	1	64.5	4.41	
	3	0.3		6.05	
2.45	1	1		4.37	6.43
	2	1	21	4.37	
	3	0.25		5.91	
	4			6.16	
	5	0.8		4.73	
2.46	1	1		4.29	6.44
	2	1		4.32	
	3	1		4.29	
	4	0.6		4.27	
	5	1		4.43	

STATE OF SYSTEM (Aug '90)

I.C. No	SEWER LINE No	BOTTOM SLUDGE [m]	I.C. COVER	REMARKS
SEWER 2-2'				
2.1	1		good	
	2			
2.2	1		good	
	2			
2.3	1	0.3	good	
	2	0.3		
	3	0.2		
2.4	1	0.3	good	
	2	0.2		
	3	0.2		
2.5	1	0.5	no	sb
	2	0.5		
	3			
2.6	1	0.4	good	sb
	2	0.4		
	3	0.4		
	4			
2.7	1	0.3	broken	sb
	2	0.3		
	3	0.3		
	4			
2.8	1	0.4	broken	
	2	0.4		
	3		full	
	4	0.1	open rp	
2.9	1	0.2	bad sewer	
	2	0.2		
2.10	1	0.3		
	2	0.3	good	
	3			
	4	0.3		
2.11	1	0.6		
	2	0.6		
	3		closed	
2.12	1	0.7		
	2	0.7		
	3	0.5		
	4		closed	
2.13	1	0.7	good	
	2	0.7		
	3			closed
	4	0.1		
	5			
2.14	1	0.8	good	
	2	0.8		
	3			closed
	4			
	5			

SEWER 2-2'

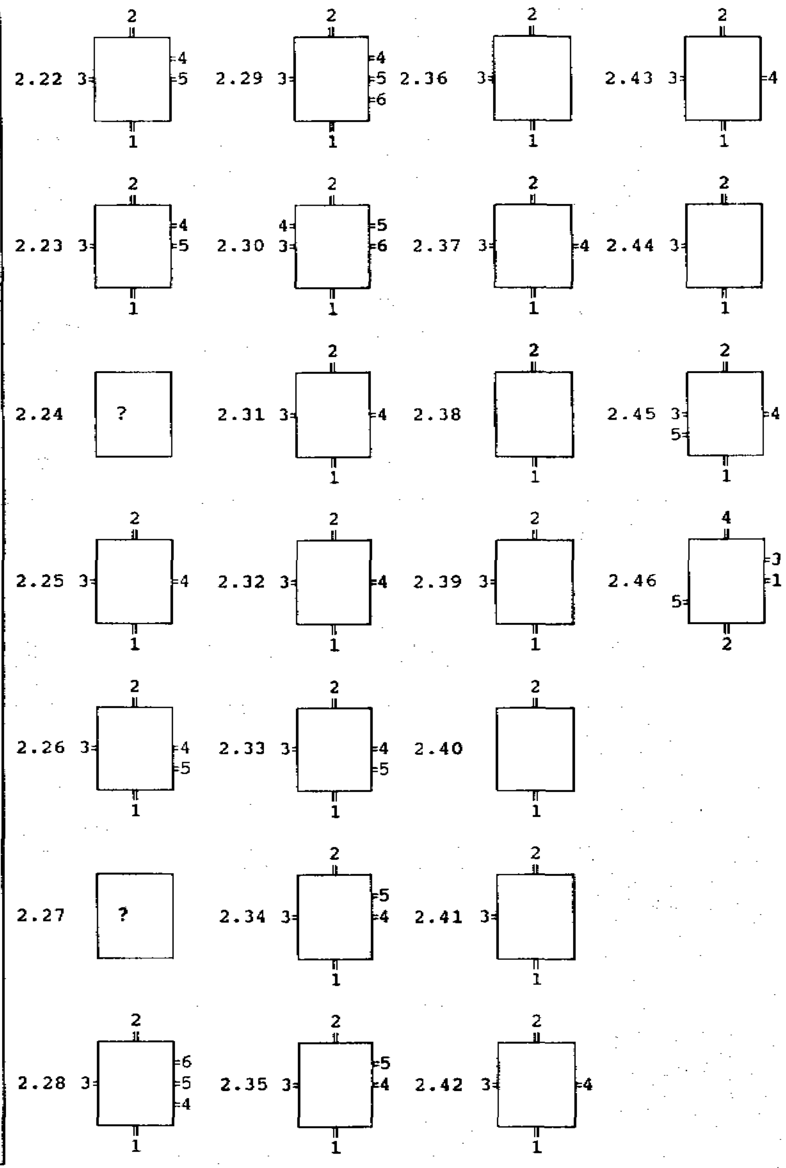


STATE OF SYSTEM (Aug '90)

I.C. No	SEWER LINE No	BOTTOM SLUDGE [m]	I.C. COVER	REMARKS
SEWER 2-2'				
2.15	1	0.8	good	
	2	0.7		
	3			closed
	4			
2.16	1	0.6	good	
	2	0.7		
	3			closed
	4	0.4		
	5	0.1		
2.17	1	0.6		
	2	0.6		
	3			closed
	4			full
2.18	1	0.65		
	2	0.7		
	3			closed
	4			
2.19	1	0.6	good	
	2	0.6		
	3			closed
	4			
2.20	1	0.6	good	
	2	0.6		
	3			closed
	4			
2.21	1	0.6	broken	
	2	0.55		
	3			closed
2.22	1	0.55	broken	
	2	0.55		
	3			closed
	4			
	5			
2.23	1	0.55	good	
	2	0.55		
	3			closed
	4			
	5			
2.24				no data
2.25	1	0.4		
	2	0.45		
	3			
	4			

STATE OF SYSTEM (Aug '90)

I.C. No	SEWER LINE No	BOTTOM SLUDGE [m]	I.C. COVER	REMARKS
SEWER 2-2'				
2.26	1	0.4		
	2	0.4		
	3			closed
	4	0.4		
	5	0.25		
2.27				
2.28	1	0.4	good	
	2	0.5		
	3			closed
	4			
	5			
	6			
2.29	1	0.5	broken	
	2	0.4		
	3			
	4			full
	5			
	6			
	7			
2.30	1	0.4	good	
	2	0.35		
	3			closed
	4			
	5			
	6			
2.31	1	0.3		
	2	0.3		
	3	0.1		
	4	0.2	0.8	
	5			open rp
2.32	1	0.15	good	
	2	0.3	good	
	3			sc
	4			broken
2.33	1	0.35	broken	
	2	0.25		
	3	0.3		sc
	4			
	5			
2.34	1	0.25	good	
	2	0.2		
	3			sc
	4			
	5			
2.35	1	0.1	good	
	2 no			
	3			open sc



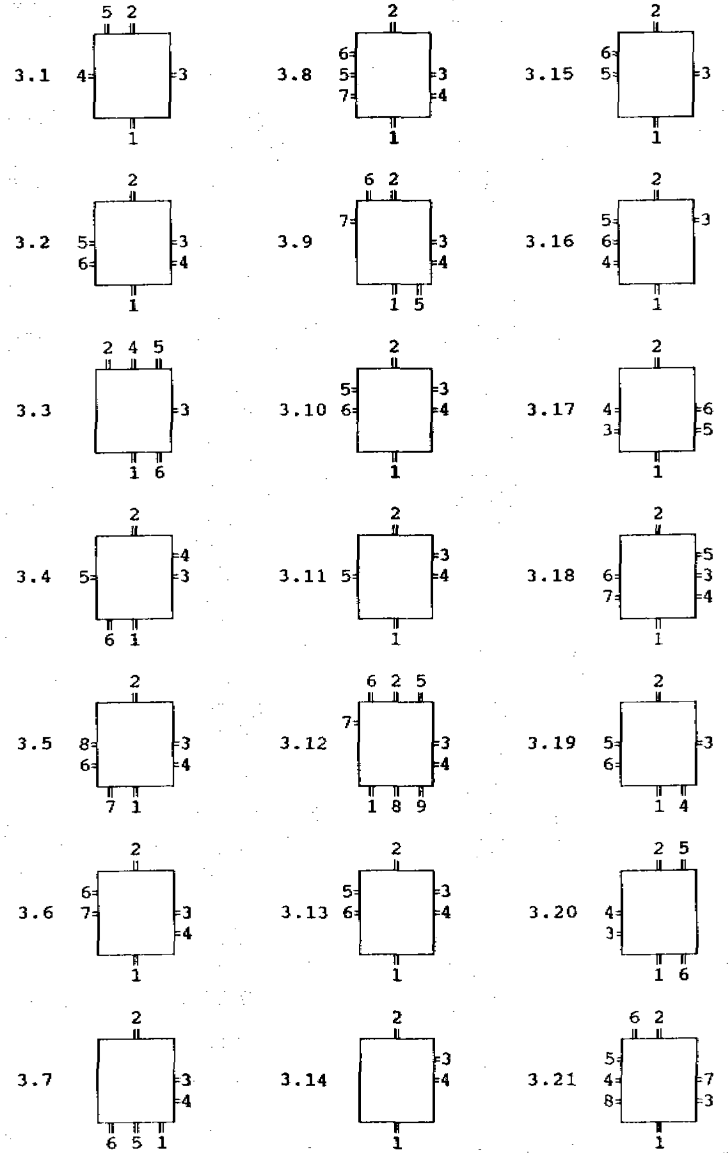
STATE OF SYSTEM (Aug '90)

I.C. No	SEWER LINE No	BOTTOM SLUDGE [m]	I.C. COVER	REMARKS
SEWER 2-2'				
2.36	1	0.3	good	
	2	0.25		
	3			sc, no cover
2.37	1	0.15		
	2	0.25		
	3			sc
	4			
2.38	no data			
2.39	1	0.3	good	
	2	0.25		
	3			sc
2.40	1	0.15	good	
	2	0.3		
	3			sc
2.41	1	0.2	good	
	2	0.1		
	3			sc
2.42	1	0.3	no	
	2	0.25		
	3			sc,no cover
	4			
2.43	1	0.2	no	
	2	0.2		
	3			sc,no cover
	4	0.3		
2.44	1	0.2	no	
	2	0.3		
	3			broken
2.45	1	0.2	good	
	2	0.25		
	3			sc,no tap
	4	0.25		
	5			
2.46	1		good	
	2	0.3		
	3			
	4			
	5	0.2		

EXISTING SYSTEM

I.C. No	SEWER LINE No	DIA [m]	DIST [m]	INVERT LEVEL [m]	GROUND LEVEL [m]
SEWER 3-3'					
3.1	1	1.0		6.83	8.57
	2	1.0		6.77	
	3	0.3	22.7	7.86	
	4	0.6		7.12	
	5	0.3		7.92	
3.2	1	1.0		6.67	8.52
	2	1.0		6.67	
	3	0.3		7.52	
	4	0.2		8.32	
	5	0.2	22.5	7.67	
	6	0.15		7.97	
	7	0.25		7.62	
3.3	1	1.0		6.17	8.48
	2	1.0		6.16	
	3	0.3		7.33	
	4	0.2	25.1	7.38	
	5	0.25		7.34	
	6	0.25		7.35	
3.4	1	1.0		6.11	8.42
	2	1.0		6.09	
	3	0.3		7.27	
	4	0.15	21.6	8.27	
	5	0.2		7.47	
	6	0.25		7.32	
3.5	1	1.0		6.13	8.46
	2	1.0		6.11	
	3	0.3		7.23	
	4	0.35		8.11	
	5	0.3	29.9	7.08	
	6	0.2		7.5	
	7	0.2		7.55	
3.6	1	1.0		6.16	8.31
	2	1.0		6.07	
	3	0.3		7.23	
	4	0.25		7.28	
	5	0.2	14.6	7.33	
	6	0.2		7.31	
	7	0.2		7.56	
3.7	1	1.0		6.13	8.26
	2	1.0		6.11	
	3	0.3		7.21	
	4	0.2	27.6	8.06	
	5	0.2		7.75	
	6	0.6		5.71	

SEWER 3-3'

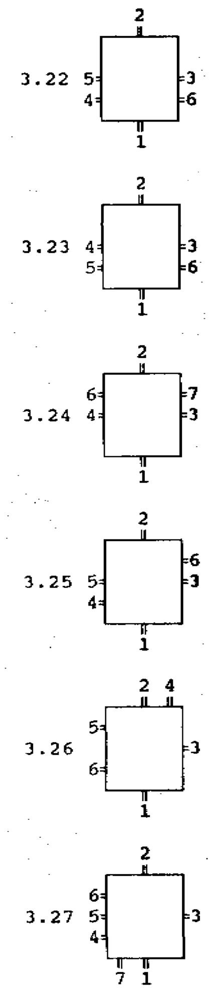


EXISTING SYSTEM

I.C. No	SEWER LINE No	DIA [m]	DIST [m]	INVERT LEVEL [m]	GROUND LEVEL [m]
SEWER 3-3'					
3.8	1	1.0		6.15	8.24
	2	1.0		6.11	
	3	0.3		7.09	
	4	0.35		7.89	
	5	0.3	26.9	7.39	
	6	0.6		6.09	
	7	0.25		7.29	
3.9	1	1.0		6.16	8.29
	2	1.0		6.11	
	3	0.3		7.09	
	4	0.2		8.09	
	5	0.25	23.7	7.32	
	6	0.25		7.17	
	7	0.2		7.46	
3.10	1	1.0		6.11	8.22
	2	1.0		6.06	
	3	0.3		7.14	
	4	0.4		7.72	
	5	0.25	24.9	7.37	
	6	0.25		7.24	
	7	0.25		7.55	
3.11	1	1.0		6.12	8.33
	2	1.0		6.07	
	3	0.3	22.7	7.04	
	4	0.3		8.03	
	5	0.25		7.04	
3.12	1	1.0		6.07	8.25
	2	1.0		6.05	
	3	0.3		7.07	
	4	0.2		8.05	
	5	0.3		7.23	
	6	0.25		7.08	
	7	0.2	25	7.1	
	8	0.25		7.48	
	9	0.25		7.25	
3.13	1	1.0		6.22	8.22
	2	1.0		6.12	
	3	0.3		7.12	
	4	0.2	18.6	8.08	
	5	0.2		7.31	
	6	0.15		7.82	
3.14	1	1.0		6.14	8.06
	2	1.0		6.07	
	3	0.3	17.1	6.99	
	4	0.3		7.76	
	5	0.6		6.84	

EXISTING SYSTEM

I.C. No	SEWER LINE No	DIA [m]	DIST [m]	INVERT LEVEL [m]	GROUND LEVEL [m]
SEWER 3-3'					
3.15	1	1.0		6.19	8.1
	2	1.0		6.12	
	3	0.3		6.97	
	4	0.2	18.4	7.9	
	5	0.1		7.35	
	6	0.6		6.18	
3.16	1	1.0		6.09	8.03
	2	1.0		6.08	
	3	0.3		7.06	
	4	0.25	19.95	7.13	
	5	0.25		7.23	
	6	0.1		7.83	
3.17	1	1.0		6.15	8.18
	2	1.0		6.13	
	3	0.3		7.03	
	4	0.3	24.95	7.88	
	5	0.25		7.08	
	6	0.15		7.78	
3.18	1	1.0		6.15	8.2
	2	1.0		6.11	
	3	0.3		7.0	
	4	0.15		7.7	
	5	0.1	21.5	8.1	
	6	0.3		7.54	
	7	0.15		7.4	
3.19	1	1.0		6.12	7.97
	2	1.0		6.12	
	3	0.3	15.6	7.22	
	4	0.25		7.72	
	5	0.2		7.25	
3.20	1	1.0		6.16	8.12
	2	1.0		6.1	
	3	0.3		7.32	
	4	0.2	36	7.92	
	5	0.3		6.97	
	6	0.3		7.47	
3.21	1	1.0		6.12	8.19
	2	1.0		6.12	
	3	0.3		7.15	
	4	0.25		7.14	
	5	0.25		6.9	
	6	0.25	18.4	7.16	
	7	0.2		7.99	
	8	0.2		7.84	



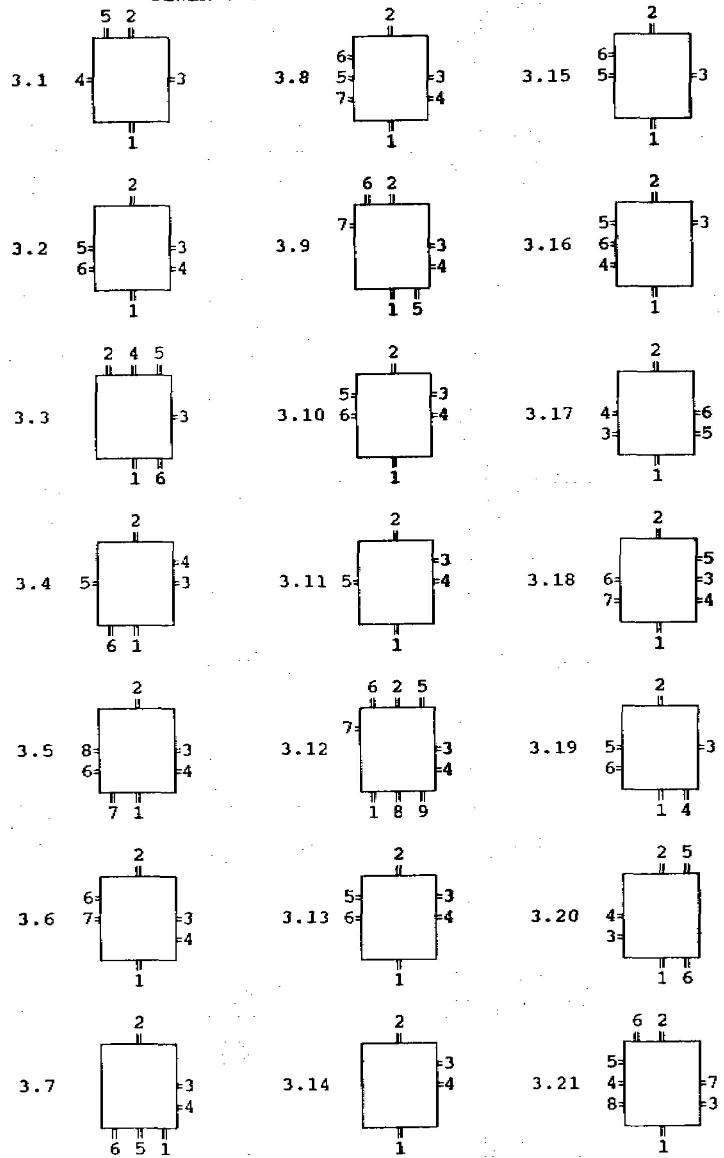
EXISTING SYSTEM

I.C. No	SEWER LINE No	DIA [m]	DIST [m]	INVERT LEVEL [m]	GROUND LEVEL [m]
SEWER 3-3'					
3.22	1	1.0		6.07	8.04
	2	1.0		6.07	
	3	0.3		7.27	
	4	0.6	25.9	6.42	
	5	0.25		7.49	
	6	0.25		7.74	
3.23	1	1.0		6.15	8.07
	2	1.0		6.02	
	3	0.3		7.22	
	4	0.6	29.5	6.45	
	5	0.2		6.7	
	6	0.25		7.72	
3.24	1	1.0		6.14	7.96
	2	1.0		6.04	
	3	0.3		7.06	
	4	0.3		7.26	
	5	0.2	26.6	7.18	
	6	0.25		6.85	
	7	0.2		7.76	
3.25	1	1.0		6.07	8.04
	2	1.0		6.02	
	3	0.3		7.09	
	4	0.25	40.25	7.07	
	5	0.25		7.02	
	6	0.15		7.89	
3.26	1	1.0		6.09	8.15
	2	1.0		6.05	
	3	0.3		7.15	
	4	0.2		7.41	
	5	0.2	22.45	7.27	
	6	0.2		7.1	
	7	0.2		7.75	
3.27	1	1.0		6.06	8.13
	2	1.0		6.06	
	3	0.3		7.13	
	4	0.2		7.14	
	5	0.25		6.81	
	6	0.25		7.01	
	7	0.2		7.83	

STATE OF SYSTEM (Aug '90)

I.C. No	SEWER LINE No	BOTTOM SLUDGE [m]	I.C. COVER	REMARKS
SEWER 3-3'				
3.1	1	0.4	good	
	2	0.45		
	3			open. sc
	4	0.2		
	5			
3.2	1	0.4	good	
	2	0.35		
	3			closed, no s
	4			open rp
	5			
	6			
	7			
3.3	1		good	
	2			
	3			closed, no s
	4			
	5	0.75		
	6	0.75		
3.4	1	0.6	good	
	2	0.8		
	3			closed, no s
	4			open rp
	5			
	6			
3.5	1	0.6	good	
	2	0.7		
	3			closed, no s
	4			open rp
	5			
	6			
	7			
3.6	1	0.65	good	
	2	0.65		
	3			closed, no s
	4			open rp
	5			
	6			
	7			
3.7	1	0.6	good	
	2	0.6		
	3			closed, no s
	4			open rp
	5			
	6	0.6		

SEWER 3-3'

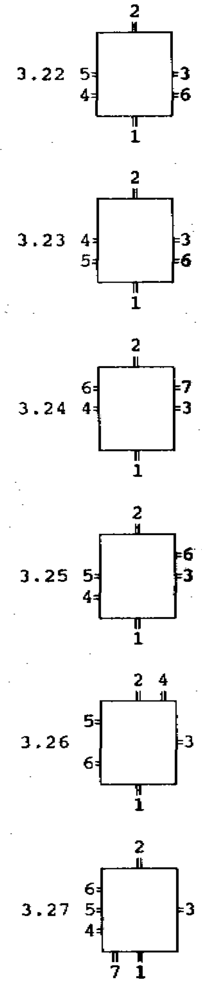


STATE OF SYSTEM (Aug '90)

I.C. No	SEWER LINE No	BOTTOM SLUDGE [m]	I.C. COVER	REMARKS
SEWER 3-3'				
3.8	1	0.65	good	
	2	0.7		
	3			closed, no s
	4			open rp
	5			
	6			street
	7			
3.9	1	0.7	good	
	2	0.7		
	3			closed, no s
	4			open rp
	5			
	6			
	7			
3.10	1	0.7		
	2	0.7		
	3			closed, no s
	4			open rp
	5			
	6			
	7			
3.11	1	0.6	good	
	2	0.7		
	3			closed, no s
	4			open rp
	5			
3.12	1	0.5	good	
	2	0.6		
	3			closed, no s
	4			open rp
	5			
	6			
	7			
	8			
	9			
3.13	1	0.55	good	
	2	0.7		
	3			closed, no s
	4			open rp
	5			
	6			
3.14	1	0.5	no	
	2	0.5		
	3			
	4			open rp
	5	0.1		

STATE OF SYSTEM (Aug '90)

I.C. No	SEWER LINE No	BOTTOM SLUDGE [m]	I.C. COVER	REMARKS
SEWER 3-3'				
3.15	1	0.5	good	
	2	0.55		
	3			closed,no sc
	4			open rp
	5			
	6	0.4		
3.16	1	0.45	good	
	2	0.65		
	3			closed, no c
	4			
	5			
	6			
3.17	1	0.6	good	
	2	0.6		
	3			closed,no sc
	4			open rp
	5			
	6			
3.18	1	0.55	good	
	2	0.7		
	3			
	4			
	5			open rp
	6			
	7			
3.19	1	0.65	good	
	2	0.6		
	3			closed, no s
	4			open rp
	5			
3.20	1	0.5	good	
	2	0.6		
	3			closed,no sc
	4			
	5			
	6			broken
3.21	1	0.55	good	
	2	0.7		
	3			
	4			
	5			
	6			
	7			open rp
	8			



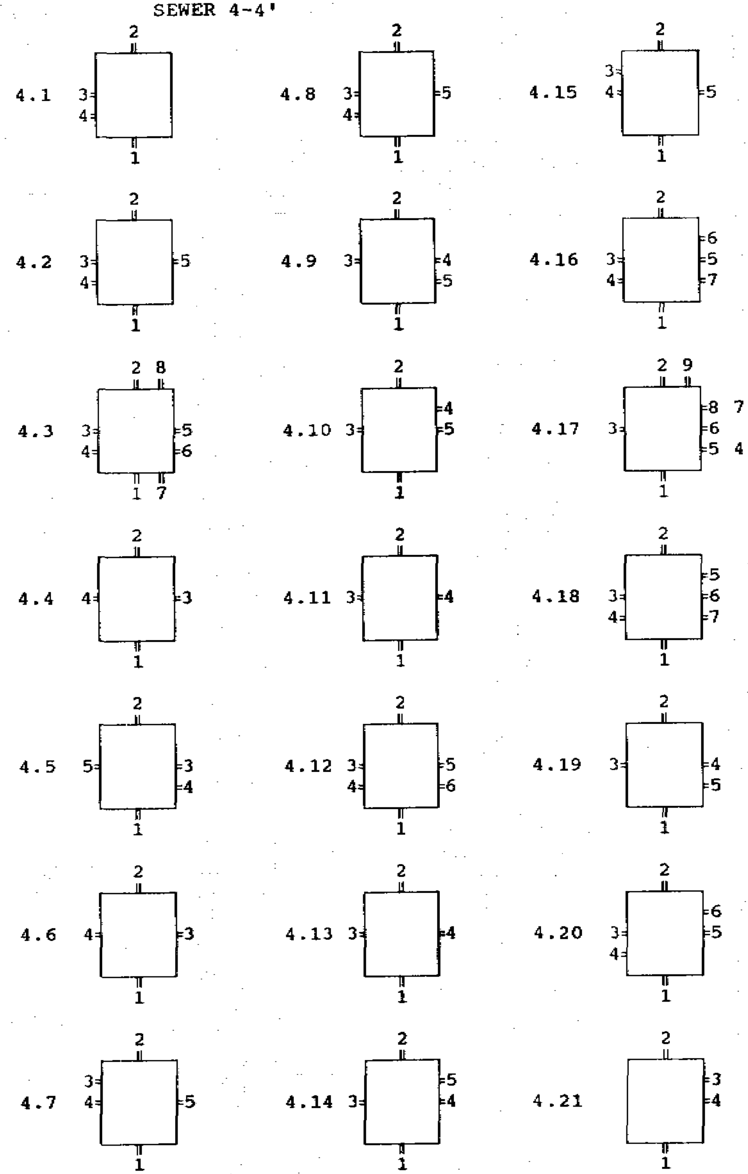
STATE OF SYSTEM (Aug '90)

I.C. No	SEWER LINE No	BOTTOM SLUDGE [m]	I.C. COVER	REMARKS
SEWER 3-3'				
3.22	1	0.4	good	
	2	0.6		
	3			closed, no s
	4	0.1		
	5			
	6			open rp
3.23	1	0.55	good	
	2	0.6		
	3			
	4	0.3		
	5			
	6			open rp
3.24	1	0.5	good	
	2	0.6		
	3			
	4			
	5			
	6			
	7			
3.25	1	0.35	good	
	2	0.3		
	3			closed, no s
	4			
	5			
	6			open rp
3.26	1	0.55	good	
	2	0.55		
	3			closed,no sc
	4			
	5			
	6	0.5		
	7			open rp
3.27	1	0.4	good	
	2	0.6		
	3			closed,no sc
	4			
	5			
	6			
	7			

EXISTING SYSTEM

I.C. No	SEWER LINE No	DIA [m]	DIST [m]	INVERT LEVEL [m]	GROUND LEVEL [m]
SEWER 4-4'					
4.1	1	1.0		6.94	8.49
	2	1.0		6.89	
	3	0.3	23.95	7.44	
	4	0.2		8.19	
4.2	1	1.0		6.96	8.51
	2	1.0		7.02	
	3	0.3	30.95	7.83	
	4	0.2		8.31	
	5	0.2		7.36	
4.3	1	1.0		6.53	8.5
	2	1.0		6.47	
	3	0.3	20.25	7.68	
	4	0.2		8.3	
	5	0.3		7.64	
	6	0.2		7.2	
	7	0.2		7.47	
	8	0.25		7.53	
4.4	1	1.0		6.45	8.56
	2	1.0		6.42	
	3	0.25		8.31	
	4	0.25	21.25	7.45	
	5	0.2		7.41	
	6	0.2		7.48	
4.5	1	1.0		6.28	8.43
	2	1.0		6.28	
	3	0.3	23	7.51	
	4	0.25		8.18	
	5	0.25		7.29	
4.6	1	1.0		6.38	8.33
	2	1.0		6.38	
	3	0.2	22.9	8.03	
	4	0.5		7.08	
4.7	1	1.0		6.38	8.18
	2	1.0		6.38	
	3	0.3		7.38	
	4	0.25	18.2	7.93	
	5	0.4		6.92	
4.8	1	1.0		6.39	8.25
	2	1.0		6.39	
	3	0.3	21.2	7.5	
	4	0.25		8.0	
	5	0.4		6.75	
4.9	1	1.0		6.37	8.33
	2	1.0		6.33	
	3	0.25		8.08	
	4	0.3	12.9	7.23	
	5	0.3		7.21	
	6	0.25		7.13	

SEWER 4-4'

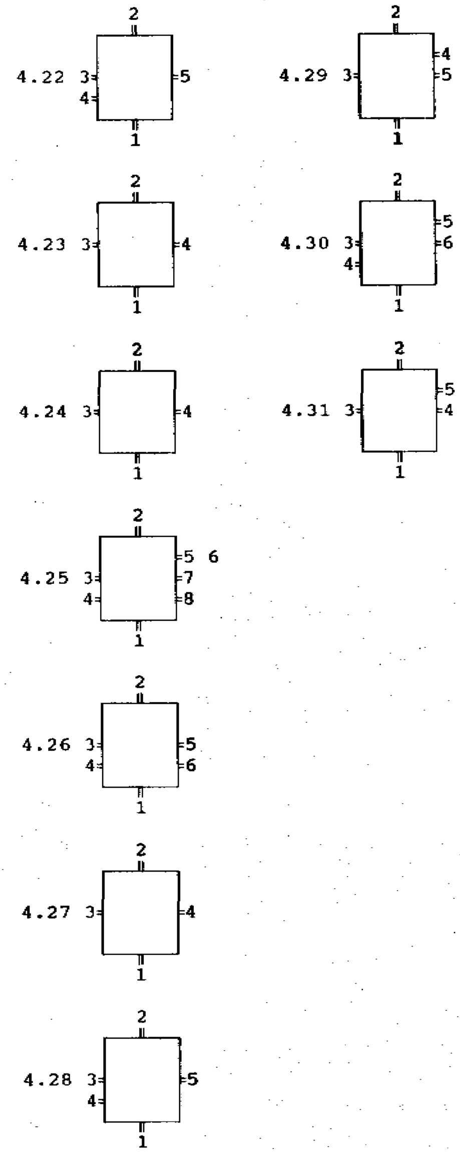


EXISTING SYSTEM

I.C. No	SEWER LINE No	DIA [m]	DIST [m]	INVERT LEVEL [m]	GROUND LEVEL [m]
SEWER 4-4'					
4.10	1	1.0		6.31	8.28
	2	1.0		6.32	
	3	0.4	33.3	7.88	
	4	0.3		7.04	
	5	0.3		6.98	
4.11	1	1.0		6.28	8.25
	2	1.0		6.25	
	3	0.3	19.15	7.95	
	4	0.3		7.0	
4.12	1	1.0		6.2	8.2
	2	1.0		6.2	
	3	0.3		7.3	
	4	0.3		7.9	
	5	0.3	20.25	6.8	
	6	0.2		6.9	
4.13	1	1.0		6.24	8.22
	2	1.0		6.22	
	3	0.2	20.3	8.02	
	4	0.4		6.92	
4.14	1	1.0		6.23	8.27
	2	1.0		6.21	
	3	0.2		8.07	
	4	0.25	26.1	6.9	
	5	0.2		7.01	
4.15	1	1.0		6.18	8.05
	2	1.0		6.18	
	3	0.3		7.15	
	4	0.2	14.15	7.85	
	5	0.2		6.75	
4.16	1	1.0		6.15	8.23
	2	1.0		6.18	
	3	0.3		7.13	
	4	0.15	19.1	8.08	
	5	0.2		7.07	
	6	0.5		6.41	
4.17	1	1.0		6.19	8.22
	2	1.0		6.19	
	3	0.15		8.07	
	4	0.2		7.0	
	5	0.3	20.3	6.96	
	6	0.1		7.62	
	7	0.25		7.0	
	8	0.15		6.97	
	9	0.15		7.9	

EXISTING SYSTEM

I.C. No	SEWER LINE No	DIA [m]	DIST [m]	INVERT LEVEL [m]	GROUND LEVEL [m]
SEWER 4-4'					
4.18	1	1.0		6.19	8.13
	2	1.0		6.17	
	3	0.3		7.31	
	4	0.25		7.88	
	5	0.2		6.9	
	6	0.25	20.15	6.88	
	7	0.2		7.07	
	8	0.25		6.89	
4.19	1	1.00		6.15	8.13
	2	1.00		6.14	
	3	0.45		7.68	
	4	0.25	20.3	6.88	
	5	0.25		6.84	
4.20	1	1.0		6.02	8.08
	2	1.0		6.06	
	3	0.3	20.5	7.31	
	4	0.22		7.86	
	5	0.2		7.05	
	6	0.2		6.89	
4.21	1	1.0		6.02	7.94
	2	1.0		6.02	
	3	0.3	18.95	6.65	
	4	0.3		6.69	
4.22	1	1.0		6.07	8.0
	2	1.0		6.05	
	3	0.3		7.27	
	4	0.15	20.4	7.75	
	5	0.25		7.32	
4.23	1	1.0		6.06	7.94
	2	1.0		6.01	
	3	0.15	16.95	7.69	
	4	0.3		6.5	
4.24	1	1.0		6.04	7.91
	2	1.0		5.99	
	3	0.3		6.98	
	4	0.3	16.9	6.59	
	5	0.25		6.42	
4.25	1	1.0		5.94	7.99
	2	1.0		5.94	
	3	0.3		6.96	
	4	0.2	27.9	7.79	
	5	0.25		7.04	
	6	0.6		6.14	
	7	0.25		6.92	
	8	0.15		6.77	



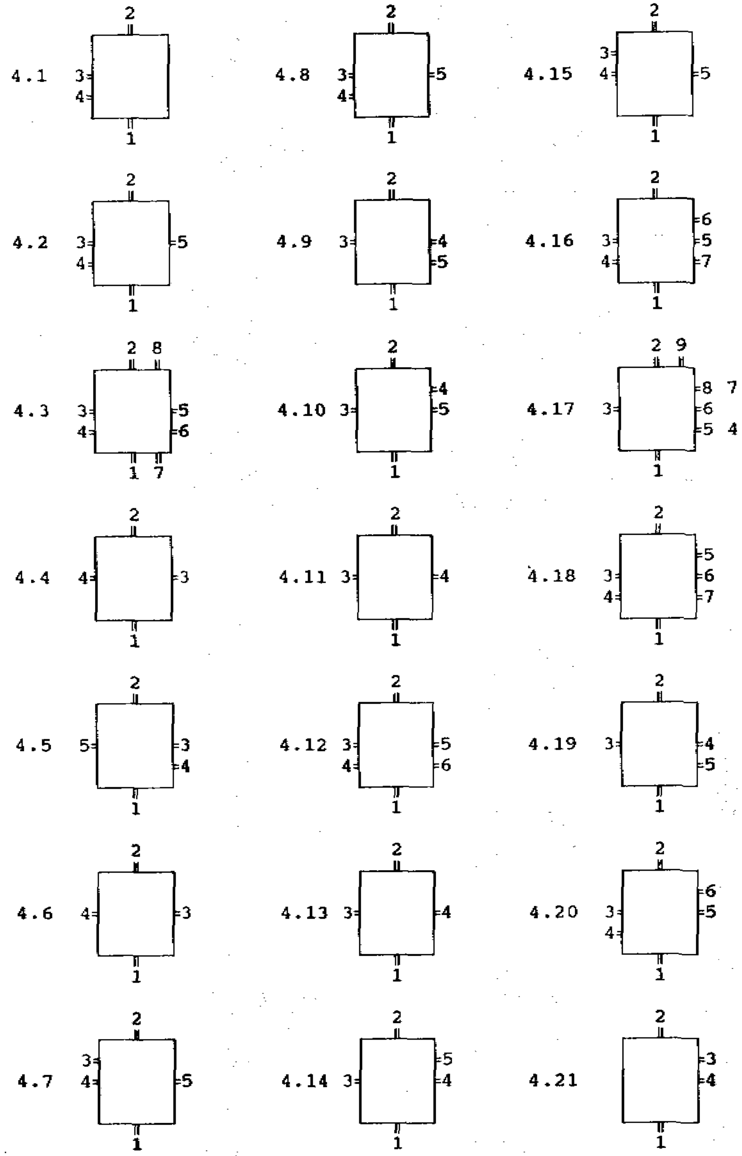
EXISTING SYSTEM

I.C. No	SEWER LINE No	DIA [m]	DIST [m]	INVERT LEVEL [m]	GROUND LEVEL [m]
SEWER 4-4'					
4.26	1	1.0		5.91	8.03
	2	1.0		5.86	
	3	0.3		7.13	
	4	0.3	20.6	7.73	
	5	0.3		6.58	
	6	0.3		6.58	
4.27	1	1.0		5.91	8.06
	2	1.0		5.91	
	3	0.4		7.66	
	4	0.2	20.2	6.61	
	5	0.2		6.61	
4.28	1	1.0		5.87	8.11
	2	1.0		5.87	
	3	0.3		7.21	
	4	0.4	19.1	7.71	
	5	0.3		6.82	
	6	0.25		6.75	
4.29	1	1.0		5.9	8
	2	1.0		5.86	
	3	0.4	20.1	7.6	
	4	0.3		6.65	
	5	0.25		6.82	
4.30	1	2.0		5.83	7.98
	2	2.0		5.73	
	3	0.3		7.03	
	4	0.35	30.1	7.63	
	5	0.3		6.58	
	6	0.25		6.83	
4.31	1	1.0		5.82	8.07
	2	1.0		5.77	
	3	0.4		7.67	
	4	0.2		6.77	
	5	0.25		6.68	

STATE OF SYSTEM (Aug '90)

I.C. No	SEWER LINE No	BOTTOM SLUDGE [m]	I.C. COVER	REMARKS
SEWER 4-4'				
4.1	1	0.2	good	
	2	0.35		
	3			open, sc
	4			rp, covered
4.2	1	0.3	good	
	2	0.3		
	3			closed, no s
	4			open rp
	5			broken
4.3	1	0.4	good	bad manhole
	2	0.45		
	3			closed, no s
	4			open rp
	5			
	6			
	7			
	8			
4.4	1	0.6	good	
	2	0.5		
	3			open rp
	4			
	5			
	6			
4.5	1	0.6	good	
	2	0.7		
	3			closed, no s
	4			open rp
	5			
4.6	1	0.5	good	
	2	0.5		
	3			open rp
	4			
4.7	1	0.5	good	
	2	0.55		
	3			closed, no s
	4			open rp
	5			
4.8	1	0.6	good	
	2	0.5		
	3			closed, no s
	4			open rp
	5	0.2		
4.9	1	0.5	good	
	2	0.5		
	3			
	4			open rp
	5			
	6			

SEWER 4-4'

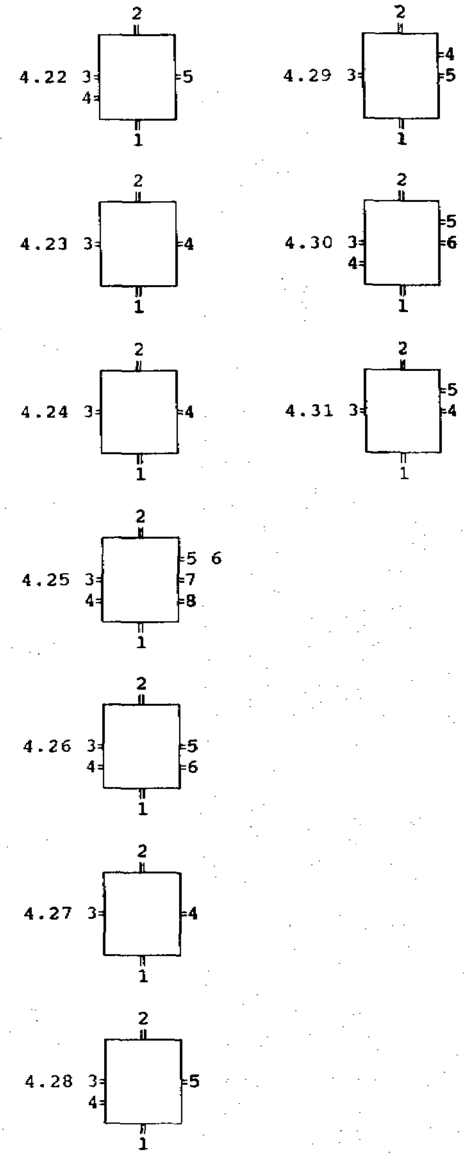


STATE OF SYSTEM (Aug '90)

I.C. No	SEWER LINE No	BOTTOM SLUDGE [m]	I.C. COVER	REMARKS
SEWER 4-4'				
4.10	1	0.5	good	
	2	0.4		
	3			open rp
	4			
	5			
4.11	1	0.8	good	
	2	0.8		
	3			
	4			
4.12	1	0.7	good	
	2	0.7		
	3			closed, no s
	4			open rp
	5			
	6			
4.13	1	0.7	good	
	2	0.7		
	3			open rp
	4			
4.14	1	0.75	good	
	2	0.7		
	3			
	4			
	5			
4.15	1	0.7	good	
	2	0.7		
	3			closed, no s
	4			open rp
	5			
4.16	1	0.7	good	
	2	0.7		
	3			closed, no s
	4			open rp
	5			
	6			
4.17	1	0.7	good	
	2	0.7		
	3			open rp
	4			
	5			
	6			
	7			
	8			
	9			

STATE OF SYSTEM (Aug '90)

I.C. No	SEWER LINE No	BOTTOM SLUDGE [m]	I.C. COVER	REMARKS
SEWER 4-4'				
4.18	1	0.7	good	
	2	0.75	good	
	3			closen,no sc
	4			open rp
	5			
	6			
	7			
	8			
4.19	1	0.7	good	
	2	0.75		
	3			open rp
	4			
	5			
4.20	1	0.7	good	
	2	0.7		
	3			closed, no s
	4			open rp
	5			
	6			
4.21	1	0.6	good	
	2	0.6		
	3			
	4			
4.22	1	0.6	good	
	2	0.7		
	3			closed, no s
	4			open rp
	5			
4.23	1	0.5	good	
	2	0.8		
	3			open rp
	4			
4.24	1	0.6	good	
	2	0.7		
	3			closed no sc
	4			
	5			
4.25	1	0.7	good	
	2	0.7		
	3			closed, no s
	4			open rp
	5			
	6			
	7			
	8			



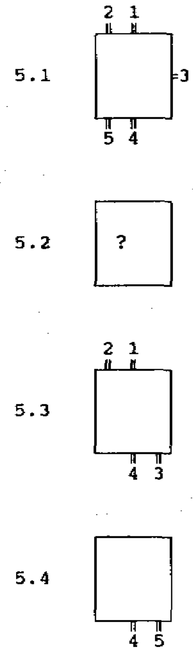
STATE OF SYSTEM (Aug '90)

I.C. No	SEWER LINE No	BOTTOM SLUDGE [m]	I.C. COVER	REMARKS
SEWER 4-4'				
4.26	1	0.6	good	
	2	0.8		
	3			closed, no s
	4			open rp
	5			
	6			
4.27	1	0.6	good	
	2	0.6		
	3			open rp
	4			
	5			
4.28	1	0.6	good	
	2	0.6		
	3			closed, no s
	4			open rp
	5			
	6			
4.29	1	0.6	good	
	2	0.6		
	3			open rp
	4			
	5			
4.30	1	0.6	good	
	2	0.6		
	3			closed, no s
	4			open rp
	5			
	6			
4.31	1	0.6	good	
	2	0.6		
	3			open rp
	4			
	5			

EXISTING SYSTEM

I.C. No	SEWER LINE No	DIA [m]	DIST [m]	INVERT LEVEL [m]	GROUND LEVEL [m]
SEWER 5-5'					
5.1	1	1.0		4.17	6.39
	2	1.0		4.17	
	3	0.6		4.27	
	4	1.0		4.32	
	5	1.0		4.32	
5.2	no data				
5.2	no data				
5.3	1	1.0	96	4	5.7
	2	1.0		4	
	3	1.0		3.93	
	4	1.0		3.93	
5.4	1	1.0	154	3.9	
	1	1.0		3.88	

SEWER 5-5'



STATE OF SYSTEM (Aug '90)

I.C. No	SEWER LINE No	BOTTOM SLUDGE [m]	I.C. COVER	REMARKS
SEWER 5-5'				
5.1	1	0.35	broken	
	2	0.3		
	3	0.4		
	4	0.5		
	5	0.7		
5.2	no data			
5.2	no data			
5.3	1			
	2			
	3			
	4			
5.4	1			outlet pipes
	1			no I.C.

Appendix 3

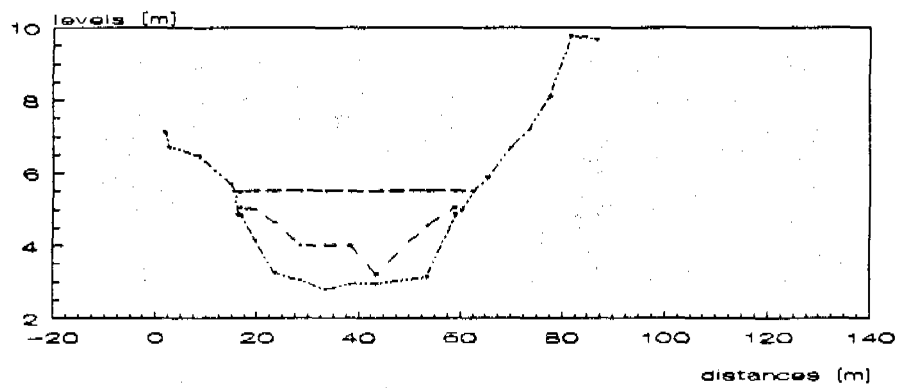
Survey of Beng Salang lake: cross-sections

Existing situation of Beng Salang lake and the open channel

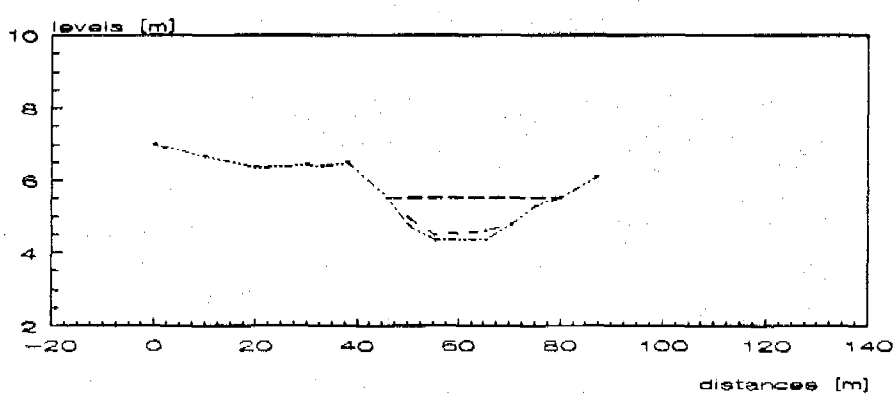
August - September 1990

Indicated are: distances from temporary benchmarks
ground elevations (dottet line)
water level (horizontal line at + 5.50 m
bottom of lake or top of sludge layer (broken line)
bottom of mud layer (dotted line)

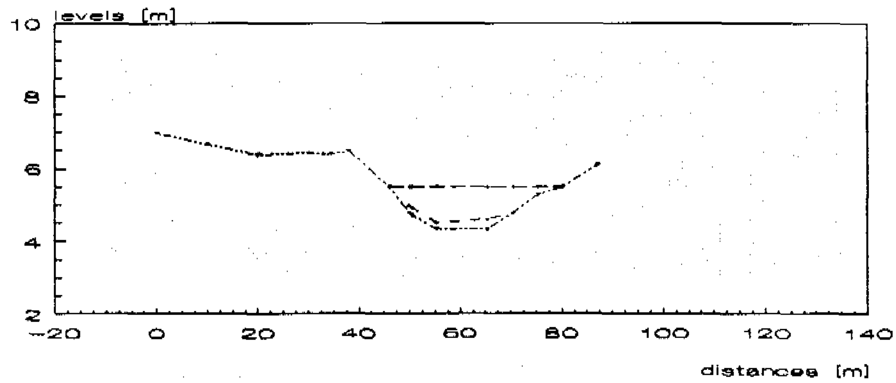
The location of the temporary benchmarks are indicated in Figure 3-1.
All elevations are reduced to the national benchmark system NGK.
Two levels of sludge are indicated in the cross-sections: bottom and top levels of sludge layer. Both levels are determined by the degree of resistance experienced when pressing the measuring staff into the mud.



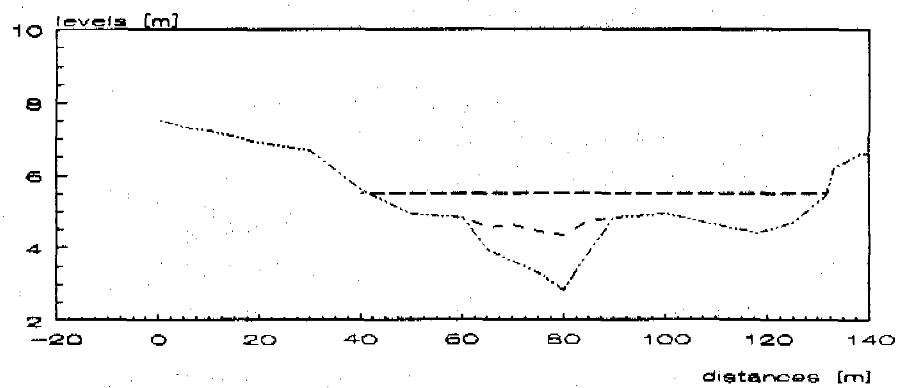
Cross-section 1-1'



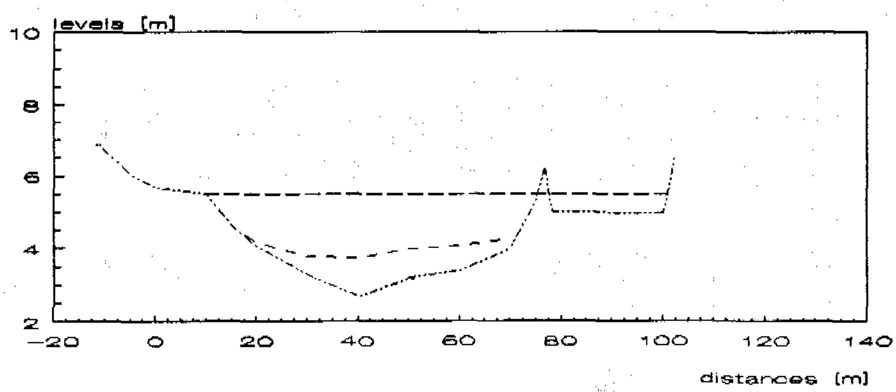
Cross-section 2-2'



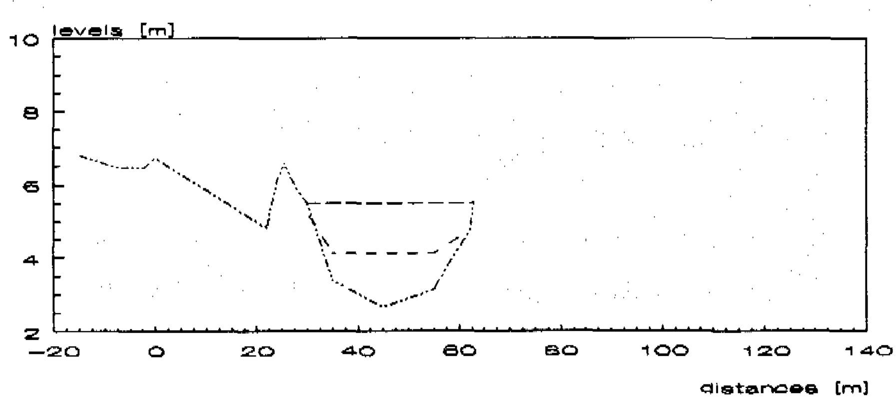
Cross-section 3-3'



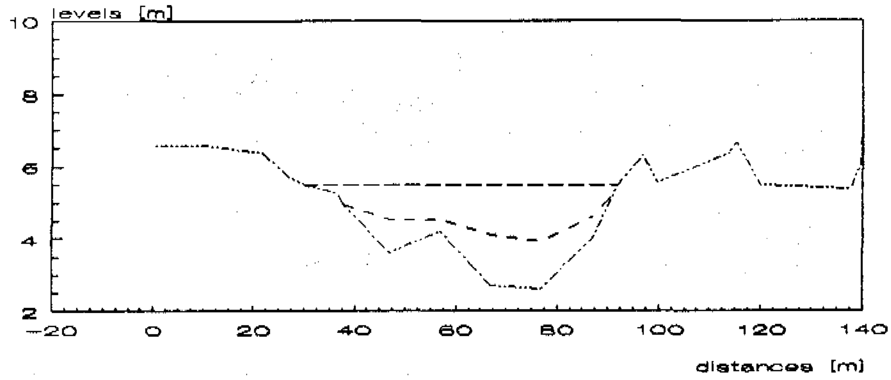
Cross-section 4-4'



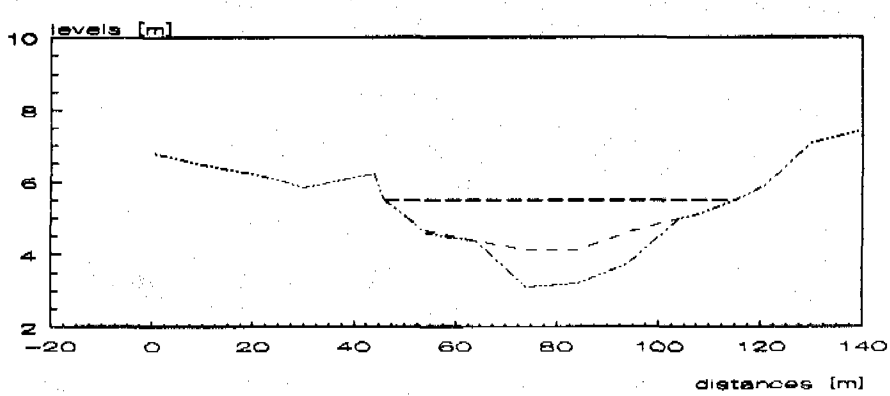
Cross-section 5-5'



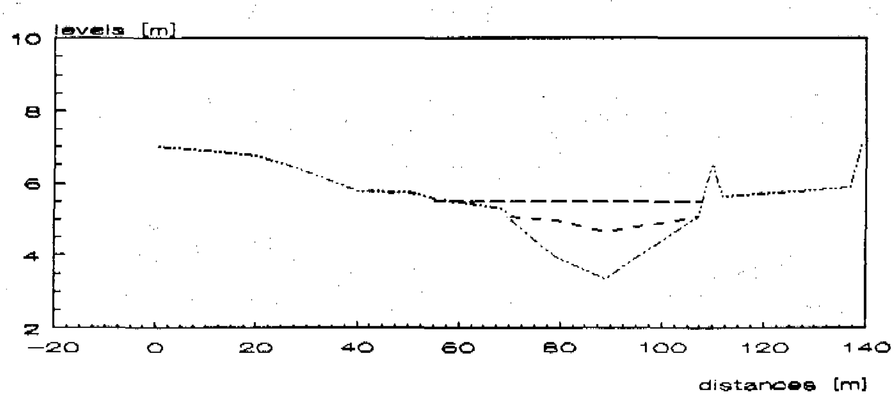
Cross-section 6-6'



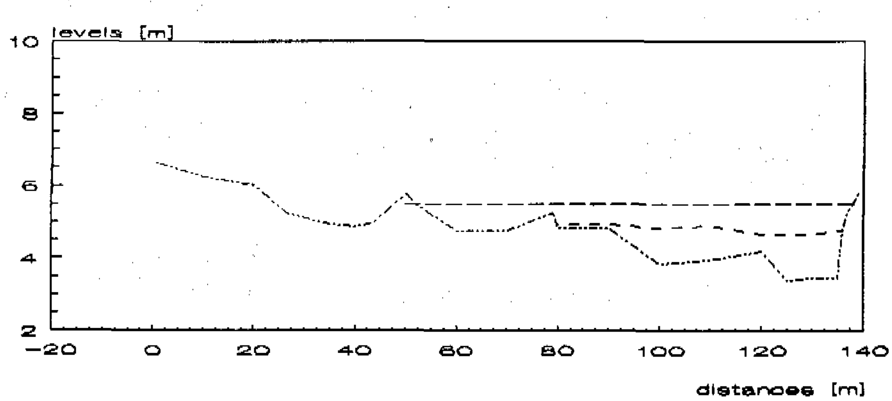
Cross-section 7-7'



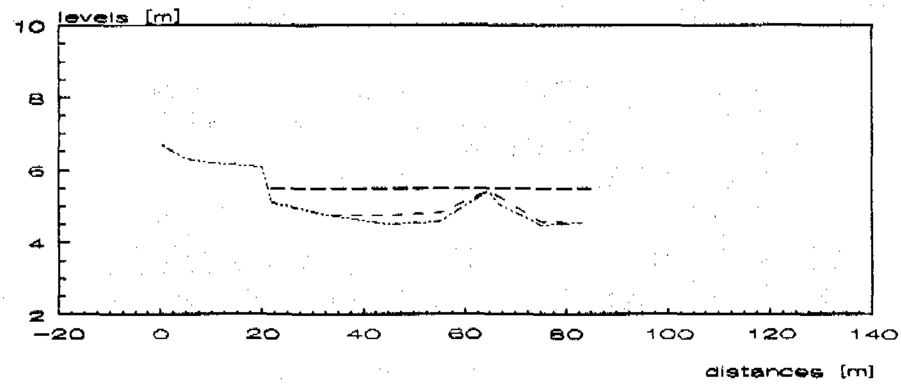
Cross-section 8-8'



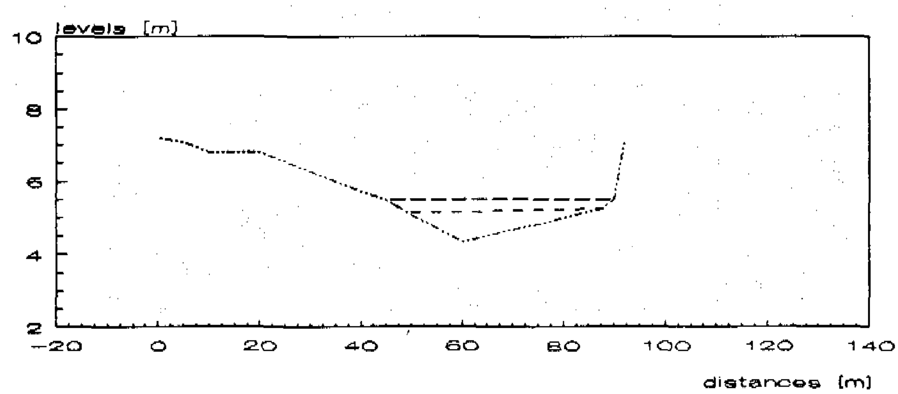
Cross-section 9-9'



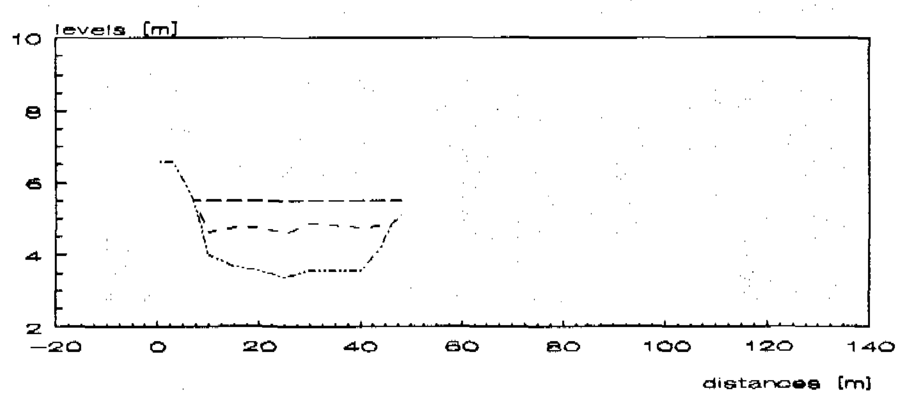
Cross-section 10-10'



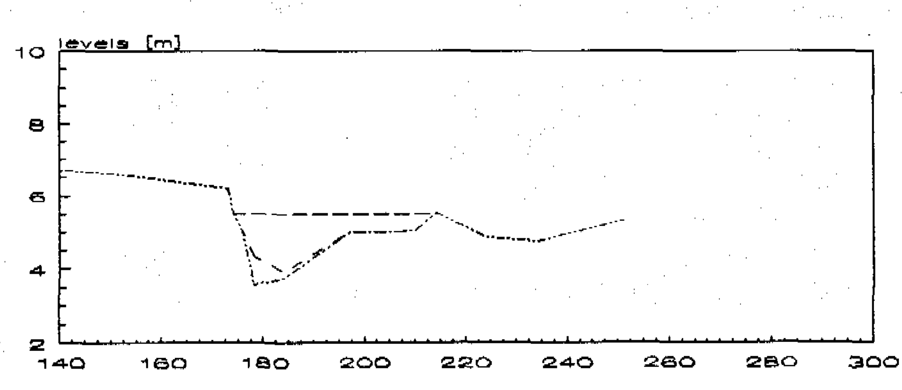
Cross-section 11-11'



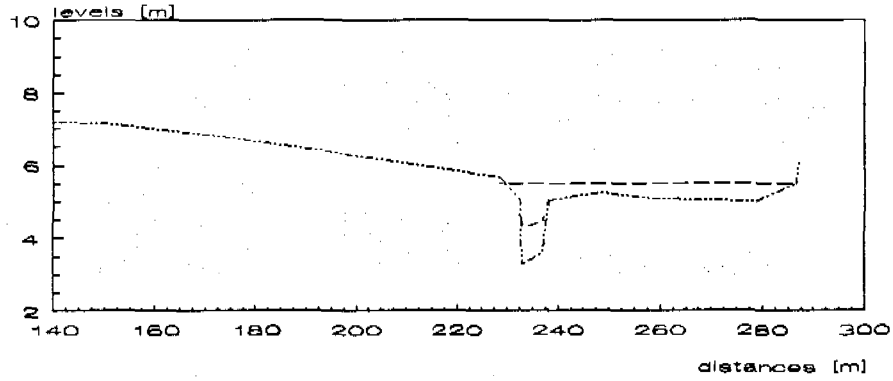
Cross-section 12-12'



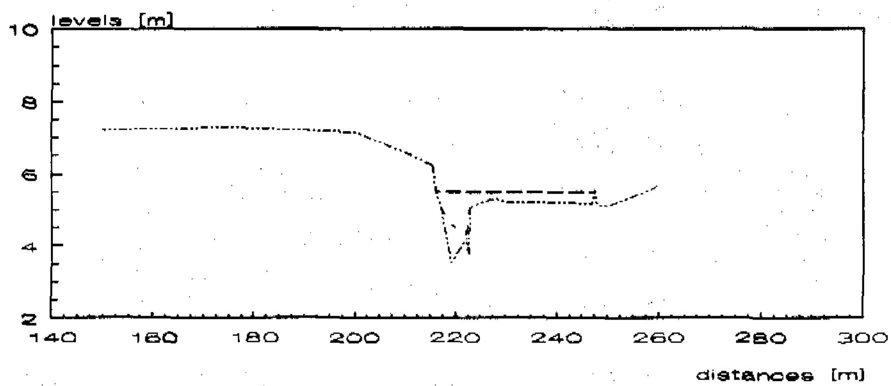
Cross-section 13-13'



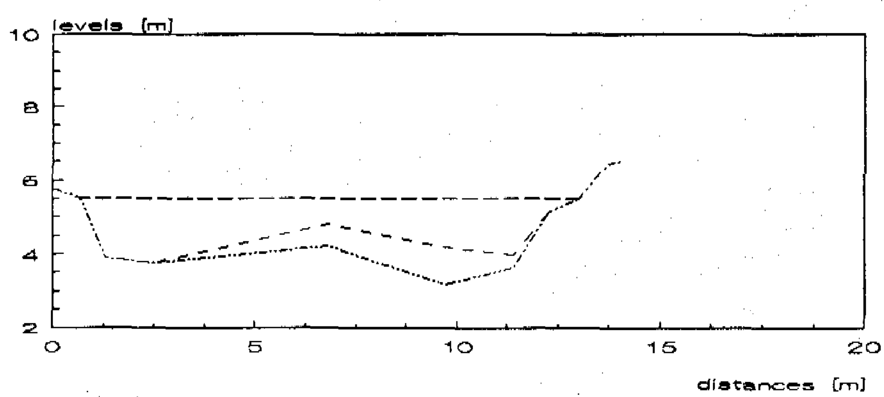
Cross-section 14-14'



Cross-section 15-15'



Cross-section 16-16'



Cross-section 17-17'

Appendix 4

Organizations visited and people met

Municipal Government
Mr. Hok Lundi, mayor of Phnom Penh
Mr. Pum Sichan, member of People's Committee

Municipal Department of Communications
Mr. Sok Pin, director

The Municipal Department of Sewerage
Mr. Chim Khim, director of the Department
Mr. Meung So Pann, vice director for Technical Planning
Mr. Noen Peng Khieng, chief of Planning

The Municipal Department of Pumping Stations
Mr. Ouek Vann, director of the Department
Mr. Mey Twol, chief of Planning
Mr. Ein Sotha, chief of Workshop

The Municipal Department of Urbanization & Construction
Mr. Kry Beng Hong, assistant director

The Municipal Department of Public Works
Mr. Var Nguon, Chief

Hydrology Department
Section Land Surveying, Library (Ministry of Agriculture)

NOVIB's pilot project
Mr. Stephen Greenhalgh, Resident Engineer
Mr. Meng Phou **Marith**, counterpart (technical assistant, Sewerage Department)
Counterpart team
Jo Smet, Internatinal Reference Centre
C. Woutje van Suijlekom, NOVIB

CIDSE (NGO)
Mr. Joop Schaap
Mr. Henk van de Wal

Mekong Secretariat, Bangkok
Mr. John Harrison, Senior Technical Adviser and Division Co-ordinator
Mr. Somboon Somabha, senior Navigation Specialist

Appendix 5

Itinary Mr. L.A. (Bert) van Duijl

15 Aug	Departure from Schiphol (Amsterdam) at 15.05 hrs, Flight TG 911 to Bangkok.
16 Aug	Transit Bangkok 7.30 - 14.00 hrs, Flight VN 852 to Ho Chi Minh. Arrival Ho Chi Minh at 15.30 hrs. Visa arrangements for Cambodia 16.00 - 20.00 hrs.
17 Aug	Departure from Ho Chi Minh airport at 8.00 hrs, Flight MP 392 to Phnom Penh.Arrival Phnom Penh at 9.00 hrs. Discussions with Steve Greenhalgh (Resident Engineer, Novib) and Lenie van Goor. Visit to balancing lake of Beng Salang Drainage Basin, Pumping stations Beng Salang, Beng Tempen and Tuk Laak (with Steve and Lenie). Analysis of survey results.
18 Aug	Padek Office, study reports. Analysis of survey results. Discussion with project staff of SAWA.
19 Aug	Public Holiday Visit to central and surrounding residential areas.
20 Aug	Office moved from Padek to Novib's Office. Visit to Municipal Department of Sewerage (with Steve and Lenie). Discussions with Steve Greenhalgh. Investigate collected data of Beng Salang Drainage Basin.
21 Aug	Visit to the Hydrology Department (Ministry of Agriculture) to collect data on national benchmarks, extreme rainfalls and on extreme river water levels (with Henk van de Wal, SAWA). Visit to Municipal Department of Pumping Stations (with Mr Pann fron Sewerage Department and Lenie van Goor). Study reports.
22 Aug	Visit to balancing lake of Beng Salang Drainage Basin (with Lenie and counterpart Meng Phou Marith). Discussions with Steve Greenhalgh. Analysis of collected data on rainfalls.
23 Aug	Writing Interim Report (including Plan of Operation for Study Team). Visit to pilot area of Padek to inspect local sanitation problems. Discussions with Mr Pann from Sewerage Department.
24 Aug	Departure from Phnom Penh at 11.30 hrs, Flight QV 525 to Vientane. Arrival Vientane at 17.30 hrs. Study reports.
25 Aug	Departure from Vientane at 14.00 hrs, Flight QV 416 to Bangkok. Arrival Bangkok at 15.30 hrs.
26 Aug	On holiday.
27 Aug	Visit to Toshiba Computer Service Centre to collect printer cartridges. Finalize travel arrangements. Analysis of collected rainfall data.
28 Aug	Visit to Mekong Committee to collect additional data on short duration rainfalls and high river water levels at Phnom Penh. Discussion (by telephone) with John Tuite in Australia on his report regarding the proposed pumping facilities for Beng Salang. Analysis of collected data on rainfall.

29 Aug - 15 Sep	On holiday
16 Sep	Departure from Bangkok at 12.25 hrs, Flight AF 174 to Ho Chi Minh. Arrival Hoh Chi Minh at 14.30 hrs.Analysis of rainfall data.
17 Sep	Departure from Ho Chi Minh at 8.00 hrs. Flight VN 941 to Phnom Penh. Arrival Phnom Penh at 11.00 hrs. Study results of survey on sewer system and pumping stations.
18 Sep	Discussions with Steve Greenhalgh.Visit to pilot area of Padek. Analysis of data on pump operation (collected by Lenie).
19 Sep	Public holiday (in Cambodia). Analysis of data on pump operation and main sewer system.
20 Sep	Field inspection of Beng Tempen Pumping Station, Beng Salang sewer system and drainage area. Formulation of design criteria.
21 Sep	Field inspection of Beng Salang Pumping Station, sewer system and drainage area. Visit to alternative locations for possible main sewers. Discussions with Steve Greenhalgh. Design work.
22 Sep	Recalculation of existing system (with regard to functioning of balancing lake and pumping station).
23 Sep	Public holiday. Visit to typical residential areas (after heavy rainfall during previous night), river (tributaries) and lakes in Phnom Penh.
24 Sep	Meeting with the Municipal Departments of Sewerage and of Pumping Stations (discussion on alternative solutions). Finalize design criteria.
25 Sep	Meeting with Mr Kry Beng Hong, Municipal Department of Urbanization. Finalize lay-out of drainage system. Design work.
26 Sep	Visit to Beng Tempen Polder. Consider alternatives for transport and storage of urban drainage water. Design Work.
27 Sep	Discussions with Steve Greenhalgh. Design work.
28 Sep	Design work.
29 Sep	Meeting with the Municipal Departments of Sewerage and Urbanization. Finalize design criteria. Finalize design solutions.
30 Sep	Public Holiday. Visit to rural areas around Phnom Penh.
1 Oct	Visit to Mayor and a municipal council member of Phnom Penh (with Steve, Lenie, Jo Smet (IRC), representative Padek), attended by Sewerage Department. Design work. Report writing
2 Oct	Discussions with Stephe Greenhalgh. Design work. Report writing.
3 Oct	Design work. Report writing. Discussions with Sewerage Department (Mr Pann). Finalize recommendations. Closing session: dinner.
4 Oct	Report writing. Departure from Phnom Penh airport at 15.00 hrs, Flight MP 391 to Ho Chi Minh. Transit. Departure from Ho Chi Minh at 20.00 hrs, Flight AF 175 to Bangkok. Transit, departure from Bangkok at 23.40 hrs, Flight TG 916 to Amsterdam.
5 Oct	Arrival Amsterdam at 5.50 hrs.

Appendix 6

Itinary Mrs. H.G.M. (Lenie) van Goor

1 Aug	Departure from Amsterdam at 15.05 hrs, flight TG 911 to Bangkok.
2 Aug	Transit Bangkok 7.30 -13.30 hrs, Flight VN 852 to Ho Chi Minh. Arrival Ho Chi Minh at 15.30 hrs.
3 Aug	Departure from Ho Chi Minh at 8.00 hrs, Flight MD 392 to Phnom Penh. Arrival Phnom Penh at 9.30 hrs. Meeting at Padek office with Novib Sanitation team. Introduction workplan. Planning and organisation for the first two weeks.
4 Aug	Meeting with Sewerage Department. Introduction workplan.
5 Aug	Public Holiday. Lunch with personnel of Sewerage Department.
6 Aug	Check surveying instruments. Visit to Beng Salang lake. Meeting with Mr. Tuol Kork, head of district, and the chiefs of the sub-districts (chefs de Quartiers) of Beng Salang and Psar Depot 2.
7 Aug	Beng Salang lake: determine location of benchmarks. Meeting with Mr. Kry Beng Hong, vice-director of Urbanization and Construction Department.
8 Aug	Beng Salang lake: installation of benchmarks.
9 Aug	Beng Salang Lake: levelling benchmarks.
10 Aug	Beng Salang lake: levelling benchmarks. Padek- office: processing surveyed data.
11 Aug	Beng Salang lake: surveying. Padek office: processing surveyed data.
12 Aug	Public Holiday.
13 - 16 Aug	Beng Salang lake: surveying cross-sections of lake.
17 Aug	Beng Salang lake: surveying cross-sections of lake. Discussions with Mr. Bert van Duijl and Mr. Steve Greenhalgh, resident engineer (arrival Bert van Duijl). Visit to Beng Salang Drainage Basin, Pumping stations Beng Salang, Tuk Laak and Beng Tempen (with Bert and Steve).
18 Aug	Beng Salang lake: surveying cross-sections of lake.
19 Aug	Public Holiday.
20 Aug	Office moved from Padek to Novib's office. Beng Salang lake: surveying cross-sections of lake.
21 Aug	Beng Salang lake: surveying cross-sections of lake. Visit to Pumping Stations Department (with Mr. Pann from Sewerage Department and Bert van Duijl).
22 Aug	Beng Salang lake: measuring existing culverts through dike between Beng Salang lake and polder Beng Tempen. Visit to department of Hydrology for collecting data of the national benchmark system NGK (Le Nivellement General Khmer).

23 Aug	Beng Salang lake: surveying cross-sections of lake. Processing surveyed data.
24 Aug	Beng Salang lake: levelling benchmarks: reduce benchmarks to NGK.
25 Aug	Beng Salang lake: surveying cross-sections of lake. Processing surveyed data.
26 Aug	Public Holiday.
27 Aug - 1 Sep	Establishing benchmark system along existing open channel and main sewer between Beng Salang lake and Psar Depot 2. Surveying cross-sections of open channel. Processing surveyed data.
2 Sep	Public Holiday.
3 - 8 Sep	Inspection sewer lines 0, 1, 2 and 5 between Psar Depot 2 and Beng Salang lake. Levelling sewer system between Psar Depot 2 and Beng Salang lake. Processing surveyed data.
9 Sep	Public Holiday
10 Sep	Inspection sewer lines 3 and 4.
11 Sep	Levelling serwer lines 3 and 4.
12 Sep	Surveying Pumping Station Beng Trempen. Processing of surveyed data.
13 Sep	Levelling existing road culverts Beng Salang lake and open channel.
14 Sep	Measuring location of existing buildings along Beng Salang lake. Checking lay-out of roads in Beng Salang drainage basin on maps.
15 Sep	Drawing lay-out sewer system and Pumping Station Beng Tempen.
16 Sep	Public Holiday.
17 Sep	Measuring location of existing buildings along Beng Salang lake. Processing surveyed data.
18 Sep	Surveying Pumping Station Beng Salang. Drawing pumping station.
19 Sep	Public Holiday (in Cambodia). Drawing existing situation Beng Salang lake.
20 Sep	Field inspection of Beng Tempen Pumping Station, Beng Salang sewer system and drainage area. Drawing longitudinal profile main sewer and disposal system.
21 Sep	Field inspection of Beng Salang drainage area, sewer system and pumping station. Drawing work.
22 Sep	Measuring location of existing buildings along Beng Salang lake.
23 Sep	Public Holiday.
24 Sep	Meeting with Sewerage Department. Drawing contour lines Beng Salang lake.
25 Sep	Measuring location of existing buildings along Beng Salang lake. Drawing surveyed data.
26 Sep	Field inspection main drainage channel in Beng Tempen polder. Drawing surveyed data.
27 Sep	Drawing work.
28 Sep	Data processing: rainfall curves.

29 Sep	Meeting with Sewerage Department. Writing report.
30 Sep	Public Holiday.
1 Oct	Writing Report. Meeting with Mrs. Woutje vam Suijlekom, Novib project-coordinator for Cambodia. Meeting with the Mayor of Phnom Penh.
2 Oct	Data processing.
3 Oct	Meeting with Sewerage Department. Presentation of results of the study. Data processing.