FEDERATION OF MALAYSIA

FEASIBILITY REPORT
THE FLOOD FORECASTING AND WARNING SYSTEM
IN
SABAH AND SARAWAK

JULY 1980

JAPAN INTERNATIONAL COOPERATION AGENCY

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PREFACE

It is with great pleasure that I present this Feasibility Study Report on the Flood Forecasting and Warning System in Sabah and Sarawak to the Government of Malaysia.

This report embodies the result of a technical feasibility survey which was carried out in the Kinabatangan River Basin and the Sadong River Basin in Sabah and Sarawak States from October 26 to December 17, 1979 by the Japanese survey team commissioned by the Japan International Cooperation Agency following the request of the Government of Malaysia to the Government of Japan.

The survey team, headed by Mr. Akira Yuasa, had a series of discussions with the officials concerned of the Government of Malaysia and Sabah and Sarawak States and conducted an extensive field survey and data analyses.

I sincerely hope that this report will be useful as a basic reference for development of the two States and Malaysia at large.

I wish to express my deep appreciation to the officials concerned of the Government of Malaysia and Sabah and Sarawak States for their close cooperation extended to our team.

July, 1980

Keisuke Arita
President
Japan International
Cooperation Agency

LETTER OF TRANSMITTAL

To: Mr. Keisuke Arita, President
Japan International Cooperation Agency

We are pleased to submit herewith the final report on the feasibility study of the flood forecasting and warning system project in the Kinabatangan river basin, Sabah and in the Sadong river basin, Sarawak of the Federation of Malaysia, compiled after six months of field survey, research and analysis since October, 1979.

These two river basins, situated within the Northeast Asian monsoon region, are not subject to the direct influence of typhoons, but suffer each year damages from minor floods during the rainly seasons of November through March. In addition to this, major floods occuring once in several years have done inestimable damages to the lives and properties of the people living in these areas, washing away houses, crops and livestock. In these river basins, most of the villages are located along the rivers, reflecting the close link between the people's lives and the rivers. This, however, has made them all the more vulnerable to the violence of floods.

The proposed flood forecasting and warning system is projected to reduce the flood damages as well as to improve the safety and welfare of the local people's lives. Furthermore, the implementation of the two systems will surely contribute to the future socio-economic advancement of these generally unexploited areas of the country.

Therefore it is our ardent hope that this project be carried into execution as early as possible with the full understanding and cooperation by the Malaysian Government.

Finally, on behalf of all members of the Mission who have engaged in the field survey and the report preparation, I would like to express my heartfelt gratitude to the Authorities concerned of the Malaysian Government, the States of Sabah and Sawarak and the United Nations Typhoon Committee Secretariat for their cooperation.

July, 1980

Akira Yuasa
Team Leader,
Flood Forecasting and Warning System
Project in Sabah and Sarawak

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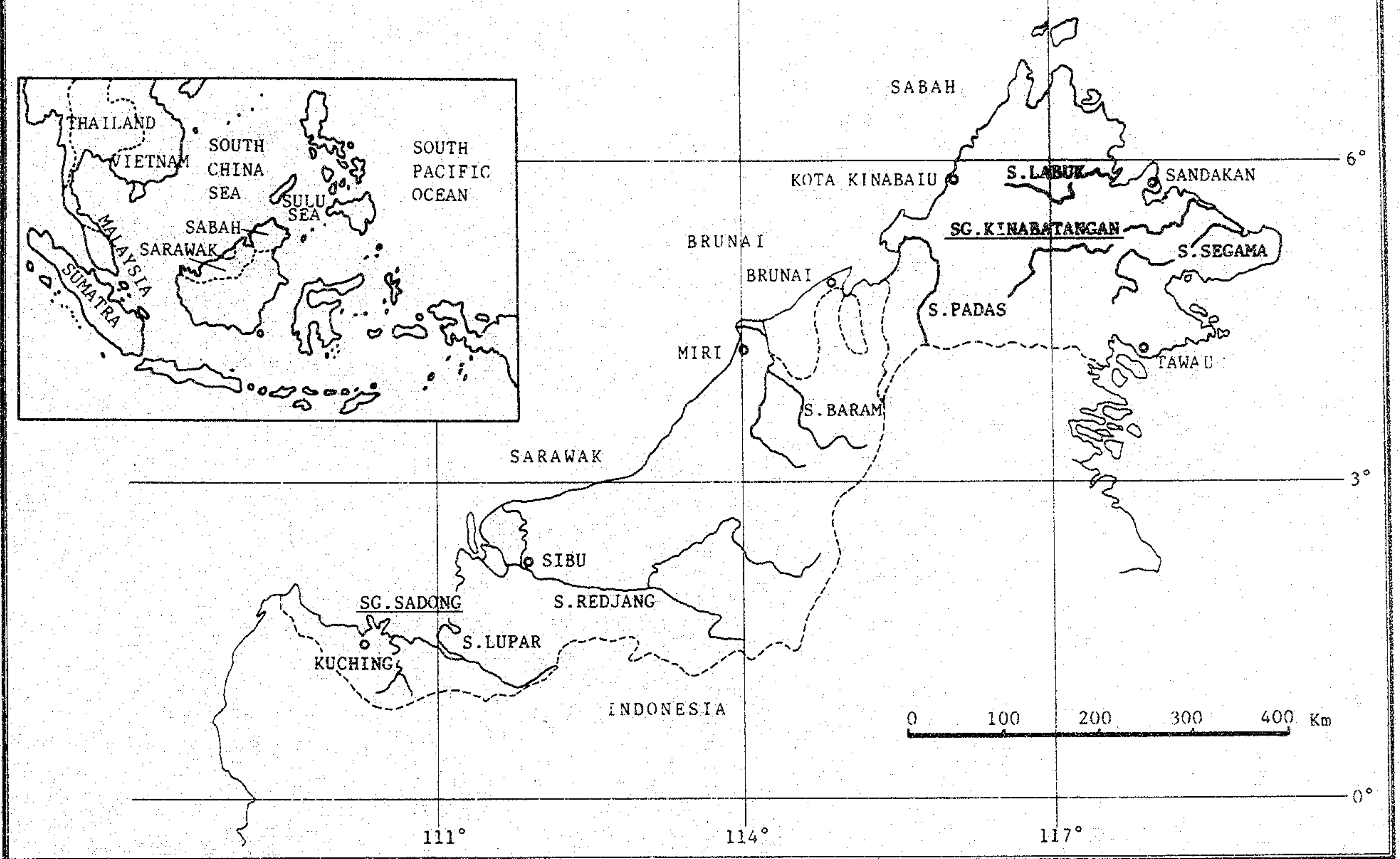


SECTION I OUTLINE

CHAPTER 1 INTRODUCTION

1.1 Background and Purpose of Project

The Federation of Malaysia has been a member of ESCAP/WHO Typhoon Committee (a UN organization whose membership includes Japan, China, Korea, Philippines, Vietnam, Laos, Cambodia and Thailand) for two years. Malaysia, situated within the Northeast Asian monsoon region, is not subject to the direct influence of typhoons. The country, however, suffers each year of flood damages caused by localized torrential downpours and continuous rainfalls during the rainy season.

The Malaysian Government, has been taking intensive care to protect the private properties and social infrastructures by compiling a large sum of budget for the flood control and river management to support the country's social and economic development. As a part of its efforts, flood forecasting and warning system established on the four major rivers of the Peninsular Malaysia (Kelantan, Terengganu, Pahang, Perak) has so far proved quite effective in reducing the damages from floods. This is a fruit of the joint project undertaken by the UNDP and WMO from 1971 through 1974. The Government now plans to establish such flood forecasting and warning system on the rivers of Sabah and Sarawak which are considered key areas of Malaysia's natural resources development. The purpose of the project is to mitigate as much as possible the flood damages during the November - March monsoon in these parts of the country.

The Japanese Government, upon request made by the Malaysian Government, conducted a preliminary survey of the flood forecasting and warning system for the Kinabatangan River in Sabah and the Sadong River in Sarawak from October to November, 1977. As a result, it was determined that the flood forecasting and warning system for each of these rivers was feasible. Then a team of experts was dispatched to these areas to conduct a technical feasibility survey from October through December of 1979.

The following report has been compiled based on the findings of the technical feasibility study conducted by the above-mentioned survey team.

1.2 Scope of the Study

1.2.1 Assignments of Survey

Based on the Preliminary Survey Report and the Scope of Works followed, the survey team conducted a field survey for the technical feasibility study of the flood forecasting and warning system in the Sadong river basin and the Kinabatangan river basin, respectively. The principal assignments involved in this study program included:

Preparation Before Departure:

- Analysis of preliminary survey report
- Preparation of survey schedule

Field Survey:

- Determination of observation and warning points
- Cross-sectional surveying of river at observation and warning points (with simplified sketches)
- Determination of gauging equipment and methodology
- Data collection and radio propagation analysis
- Radio wave propagation test
- Determination of target area

Data Analysis and Conclusion

- Construction plan of flood forecasting and warning system
- Operation and maintenance of flood forecasting and warning system
- Collection of other related data
- Hydrological analysis
- Other necessary analysis

This technical feasibility study, with the assignments as listed above, does not include the investigation into the social and economic benefit which could be brought about by the flood forecasting and warning system.

1.2.2 Organization of Survey Team

The survey team was organized as follows:

Field Survey Team

Name	Designation	Affiliation
Akira Yuasa	Team Leader	C.T.I. Eng. Co., Ltd.
Noboru Sakuma*	Hydrology	Ministry of Construction
Tatsuo Hamaguchi**	"	"
Toyoharu Hiruma	River Planning	C.T.I. Eng. Co., Ltd.
Yasuo Koiwai	Telecommunication	Ministry of Construction
Hiroomi Nakao	"	"
Teiji Maeda	"	Association of Electrical & Engineering
Yoshiharu Nakagawa	"	"
Takashi Ushijima	Liaison Officer	C.T.I. Eng. Co., Ltd.

NOTE: * Survey member of Sadong River Basin in Sarawak

** Survey member of Kinabatangan River in Sabah

Data Analysis and Conclusion

Data analysis and conclusion assignments in the survey operation were taken up by the members listed above as well as following members:

Name	Designation	Affiliation
Hisataka Suganuma	River Planning	C.T.I. Eng. Co., Ltd.
Hiroshi Inoue	Hydrology	"
Osamu Tsumura	Telecommunication	Association of Electrical Engineering
Shuji Suga	Telecommunication	"
Yumio Ishii*	Hydrology	C.T.I. Eng. Co., Ltd.

* Presentation of draft final report

1.2.3 Survey Itinerary

The study was conducted according to the following itinerary.

Field Survey

- Kinabatangan River Basin, Sabah

No.	Month	Day	Week Day	Telecommunication Group	Hydrology Group
1	Oct.	26	Fri.	Tokyo --->	Kota Kinabalu
2		27	Sat.	Courtesy call	
3		28	Sun.	Siting of MFFC	Data Collection
4		29	Mon.	Siting of MFFC	Data Collection
5		30	Tun.	Meeting DID,	EPU, TD
6		31	Wed.	Data Collection	Data Collection
7	Nov.	1	Thu.	Data Collection	Data Collection
8		2	Fri.	Kota Kinbalu --->	Sandakan
9		3	Sat.	Data Analysis	Data Analysis
10		4	Sun.	Free	
11		5	Mon.	Relay Station Siting	Station Siting
12		6	Tue.	Relay Station Siting	Station Siting
13		7	Wed.	Test Equipment Set-up	Station Siting
14		8	Thu.	Radio Propagation test	Data Analysis
15		9	Fri.	Radio Propagation test	Data Analysis

- Kinabatangan River Basin, Sabah (cont'd)

No.	Month	Day	Day	Itinerary: Telecommunication Group	Itinerary: Hydrology Group
16	Nov.	10	Sat.	Radio Propagation Test	Data Analysis
17		11	Sun.	Radio Propagation Test	Data Analysis
18		12	Mon.	Radio Propagation Test	Data Analysis
19		13	Tue.	Data Analysis	Data Analysis
20		14	Wed.	Data Analysis	Station Siting Data Analysis
21		15	Thu.	Data Analysis	Data Analysis
22		16	Fri.	Radio Propagation Test	Data Analysis
23		17	Sat.	Radio Propagation Test	Station Siting
24		18	Sun.	Radio Propagation Test	Station Siting
25		19	Mun.	Radio Propagation Test	Report Preparation
26		20	Tue.	Radio Propagation Test	Report Preparation
27		21	Wed.	Data Analysis	Report Preparation
28		22	Thu.	Data Analysis	Report Preparation
29		23	Fri.	Report Preparation	Report Preparation
30		24	Sat.	Report Preparation	Report Preparation
31		25	Sun.	Sandakan ---------> Kota Kinabalu	
32		26	Mon.	Report Preparation	
33		27	Tue.	Report Preparation	
34		28	Wed.	Meeting D.I.P.	
35		29	Thu.	Meeting D.I.P. Kota Kinabalu ----> Kuching	

- Sadong River Basin, Sarawak

No.	Month	Day	Week Day	Itinerary: Telecommunication Group	Itinerary: Hydrology Group
1	Nov.	29	Thu.	Kota Kinabalu ----> Kuching	
2		30	Fri.	Courtesy Call: D.I.D. Schedule meeting: D.I.D., T.D. Survey at Mt. Serapi Relay Station, T.D.	
3	Dec.	1	Sat.	Preliminary Survey	Station Siting
4		2	Sun.	Free	

- Sadong River Basin, Sarawak (cont'd)

No.	Month	Day	Week Day	Itinerary: Telecommunication Group	Itinerary: Hydrology Group
5	Dec.	3	Mon.	Courtesy Call: D.I.D. Relay Station Siting	
6		4	Tue.	Preliminary Survey	Station Siting
7		5	Wed.	Preliminary Survey	Station Siting
8		6	Thu.	Preliminary Survey	Station Siting
9		7	Fri.	Radio Propagation Test	Data Analysis
10		8	Sat.	Radio Propagation Test	Data Analysis
11		9	Sun.	Free	
12		10	Mon.	Radio Propagation Test	Data Analysis
13		11	Tue.	Radio Propagation Test	Data Analysis
14		12	Wed.	Report preparation	
15		13	Thu.	Report preparation	
16		14	Fri.	Report Preparation	
17		15	Sat.	Meeting: D.I.D., T.D.	
18		16	Sun.	Free	
19		17	Mon.	Kuching ----------> Kuala Lumpur	

- In Kuala Lumpur

No.	Month	Day	Week Day	Itinerary
1	Dec.	17	Mon.	Kuching ---> Kuala Lumpur
2		18	Tue.	Meeting: Embassy of Japan
3		19	Wed.	Courtesy Call: D.I.D., Study of Peninsular Malaysia flood forecasting and warning system.
4		20	Thu.	Meeting: D.I.D., E.P.U., T.D.
5		21	Fri.	Free
6		22	Sat.	Meeting: D.I.D.
7		23	Sun.	Kuala Lumpur ---> Tokyo

(The duration of survey - 59 days)

Reporting Schedule

Reports on data analysis and conclusion of the survey will be prepared in accordance with the following schedule:

October, 1979	Preparation of Inception Report
January-February, 1980	Preparation of Draft Final Report
March, 1980	Submission of Draft Final Report
April - June, 1980	Preparation of Final Report
July, 1980	Submission of Final Report

1.3 Acknowledgements

The survey team acknowledges its indebtedness to the following officials for their great help in conducting this survey:

1.3.1 Malaysian government officials concerned participating in the technical feasibility survey on the Flood Forecasting and Warning System.

- Drainage and Irrigation Department (DID)

(Federal DID)
Mr. Cheong Chup Lim
Mr. S.H. Thavaraj
Mr. Sieh Kok Chi
Mr. Teh Siew Keat
Mr. Ahmad Fuad b.Embi
Mr. Tan King Seng
Mr. Masashi Tanimoto

(Sabah DID)
Mr. Joseph Yeoh Hoh Hoh
Mr. Daniel Wong
Mr. Paul Hii
Mr. Stanley Chin
Mr. Vun Yee Kyun
Mr. Chin Foo Fah

- Drainage and Irrigation Department (DID) (cont'd)

(Sarawak DID)

Mr. Foong Ka Nim

Mr. Joseph Ting

Mr. Ngo Tok Pin

Mr. Tserng Goong Farn

Mr. Then Thiat Khiong

Mr. Lin Joo Hui

Ms. Jennifer Goh

- Economic Planning Unit (EPU)

(Federal EPU)

Mr. Mohd. Aminuddin
Hashim

(Sabah EPU)

Mr. Azizan Bin Husain

Mr. Vincent Gadalon

Ms. Maznah Ghani

(Sarawak EPU)

Mr. Mohamed Aminurashid

- Telecom Department (TD)

(Federal TD)

Mr. Ruslibin Habib

Mr. Xavier Goh

Mr. Khen Wah

Mr. Chong Beng Tiat

Mr. Ong Hai Seng

(Sabah TD)

Mr. Harold Read

Mr. Leslie Chong

Mr. Liew Sak Lim

(Sarawak TD)

Mr. Chan Hick Ping

Mr. Ronny Ong Tiang Lin

1.3.2 The survey team is also indebted to Mr. Hidetomi Oi of the U.N. Typhoon Committee Secretariat, who tendered advice to us in conducting the survey.

1.3.3 We would like to extend our thanks to Mr. Kazuhiko Takayama, Team Leader, and Mr. Osamu Machida and Mr. Hideaki Yokouchi of the preliminary survey team for tendering advice and providing indispensable information and references.

CHAPTER 2 SUMMARY OF CONCLUSION

Based on the field survey and data analysis of the Kinabatangan river basin (Sabah) and the Sadong river basin (Sarawak), the survey team has reached the following conclusion as to the flood forecasting and warning system to be established in each of these basins.

2.1 Target Area of Flood Forecasting and Warning System

2.1.1 Kinabatangan River Basin

Target Area

The target area is to be the major Kinabatangan river flood plain, particularly the area inundated by the flood of February, 1971. The target area, therefore, covers the riparian area from the junction of the Milian and the Kuamut river to the Kampung of Bilit.

Warning Points

The major Kampungs of Kuamut, Balat, Pintasan, Lamag, Bukit Garam and Bilit within the target area are to be the location of warning points.

Forecasting Points

The flood forecasting model for the Kinabatangan river basin was formulated based on the hydro-meteorological and socio-economic conditions in the area as well as the result of the radio wave propagation test conducted. The following three points were selected as the forecasting points:

- Kuamut
- Balat
- Bukit Garam

Fig. 2.1 Target Area for Flood Forecasting and Waring System in Kinabatangan River Basin

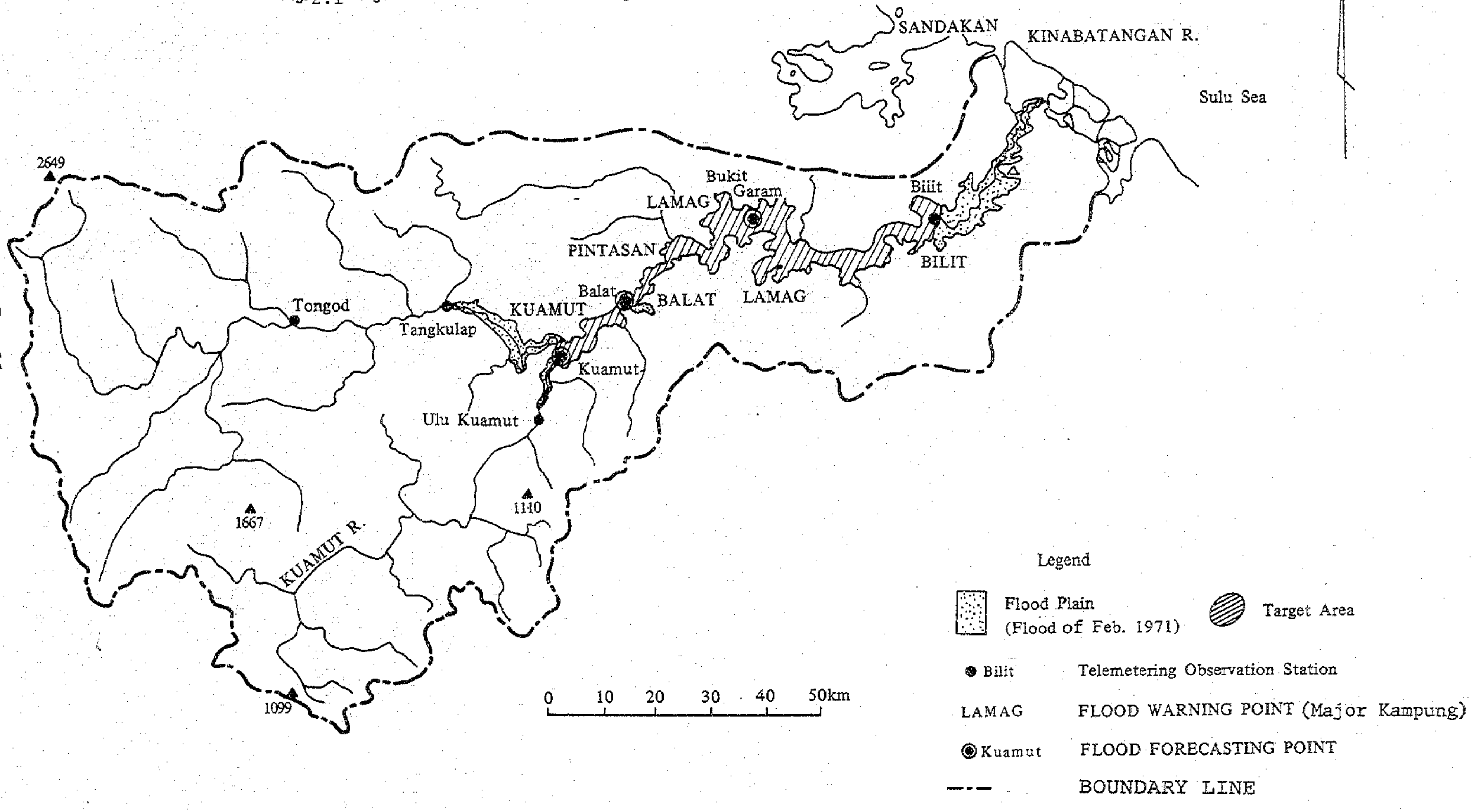
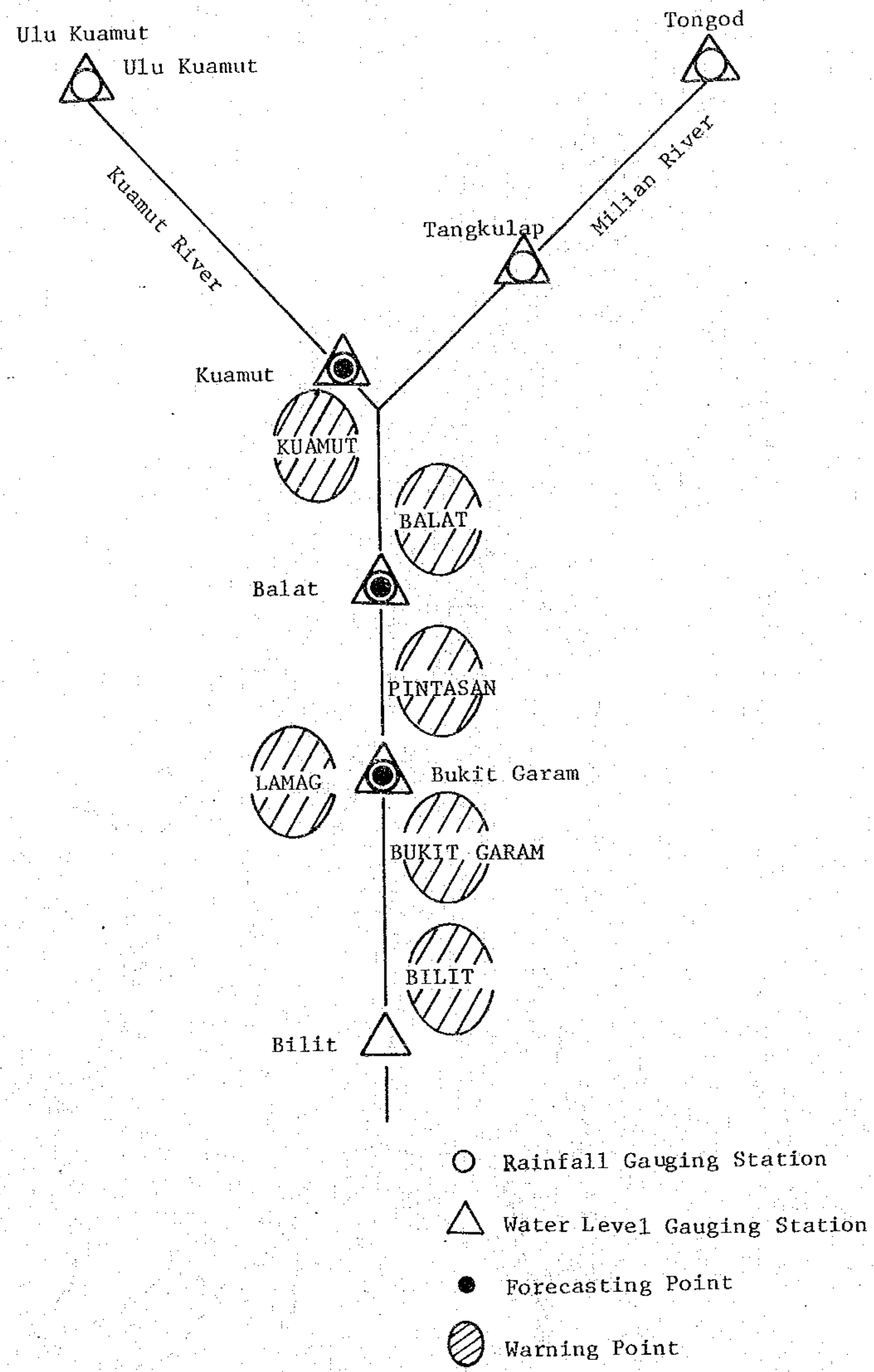


Fig.- 2.2 Flood Forecasting Model

(Kinabatangan River)



2.1.2 Sadong River Basin

Target Area

Target area is to be the entire flood plain of Sadong River. Kampung of Tebakang, Serian, Tanah Puteh, Sebanban and Gedong are to be included which was severely inundated by the 1976 flood.

Warning Point

The warning points are to be the major Kampungs of Tebakang, Serian, Tanah Puteh, Sebamban and Gedong within the target area.

Gedong, which has not had remarkable influence of flood is to be designated a warning point since future basin development and river improvement work is very sure to enhance the influence of floods.

Forecasting Point

The flood forecasting model for the Sadong river basin was formulated based on the hydro-meteorological and socio-economic conditions in the area as well as the result of the radio wave propagation tests conducted. According to this model, the following two points were selected as the forecasting points:

- Serian
- Gedong

Fig. 2.3 Target Area for Flood Forecasting and Warning System in Sadong River Basin

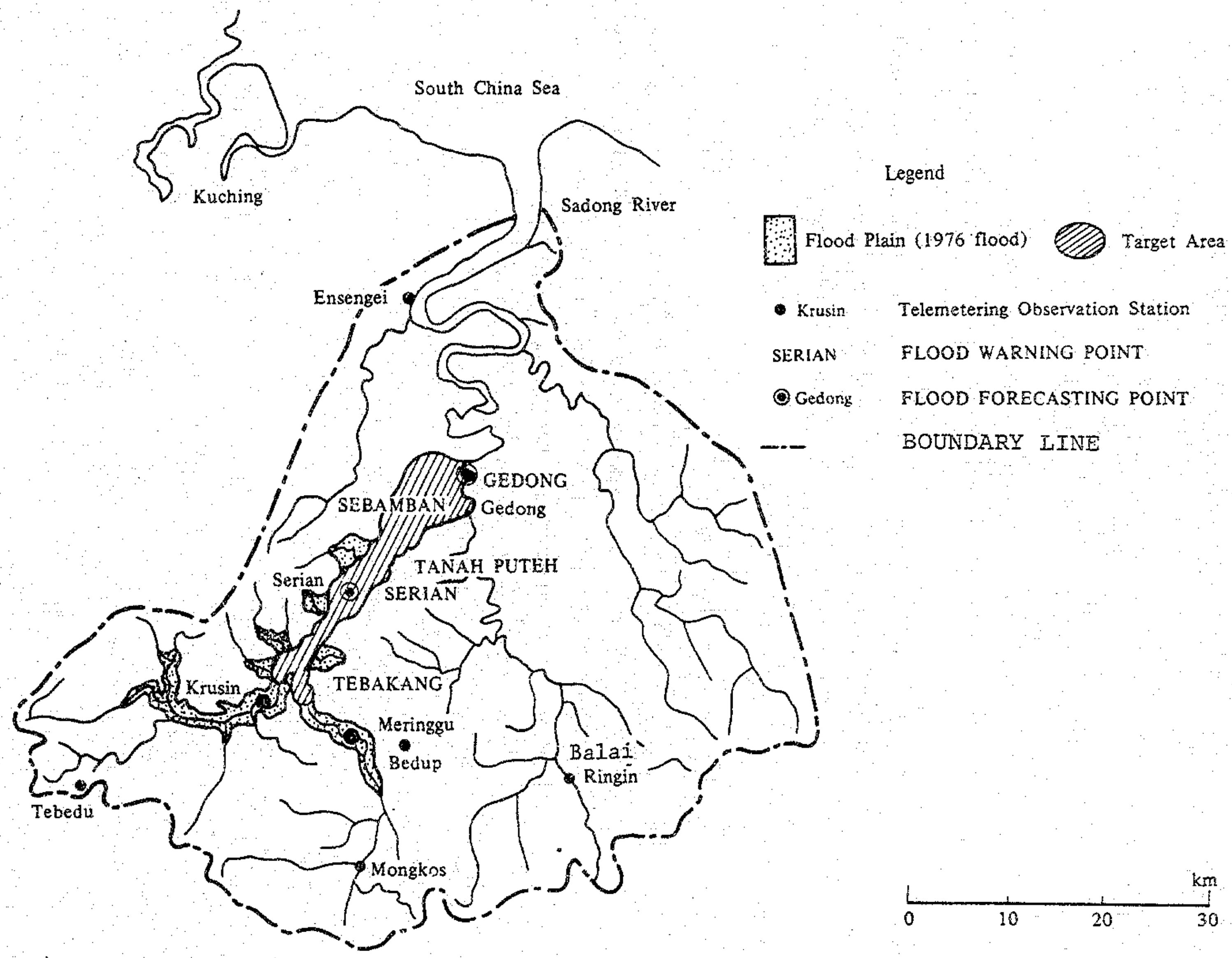
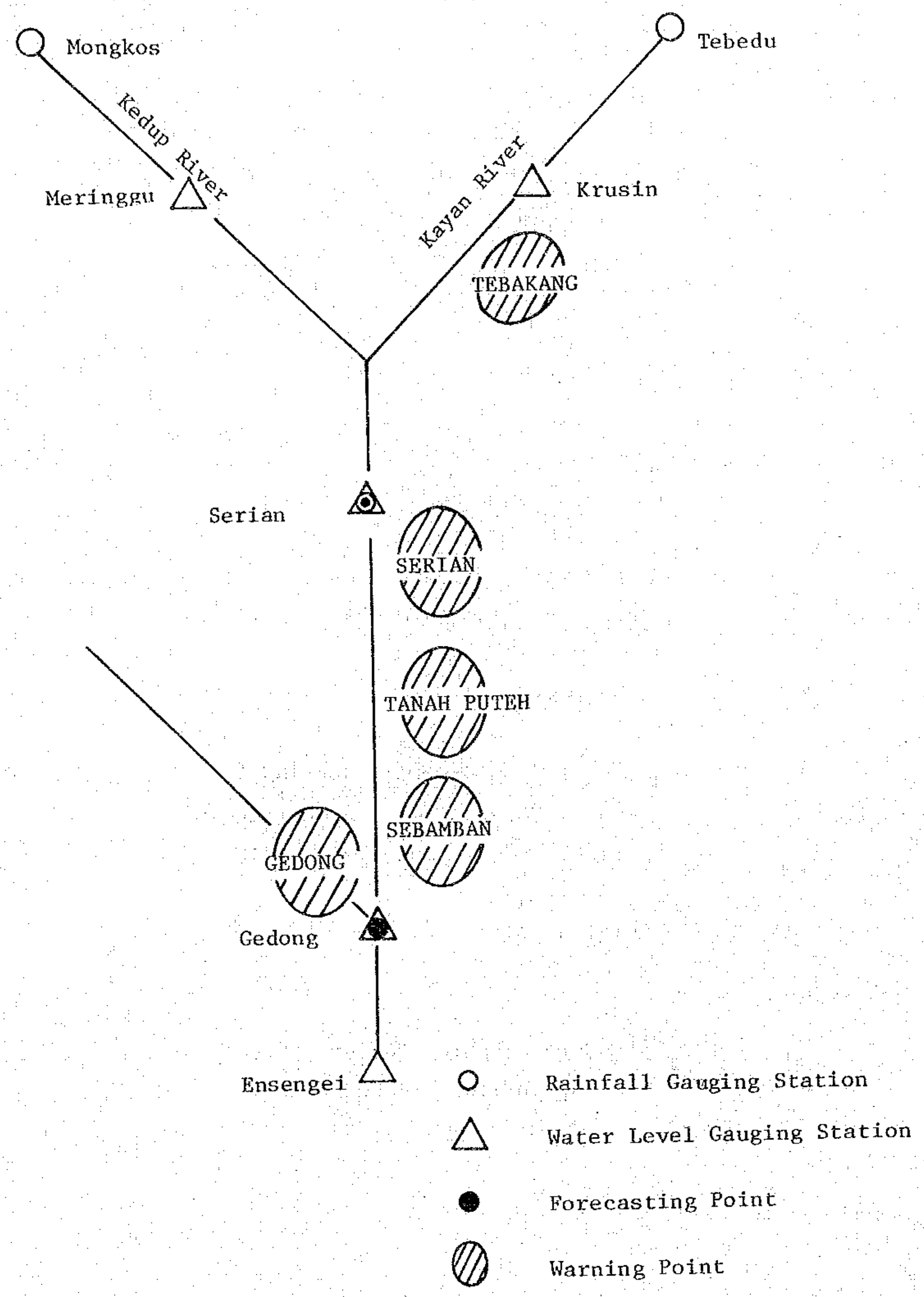


Fig.-2.4 Flood Forecasting Model

(Sadong River)



2.2 Observation and Telecommunication Network

The following observation and telecommunication networks are to be established to accomplish the purpose of this flood forecasting and warning system:

2.2.1 Kinabatangan River

- Telemetry Observation Station .... 7 locations
  Tongod, Tangkulap, Ulu Kuamut,
  Kuamut, Balat, Bukit Garam, Bilit

- Relay Station .... 2 locations
  Mt. Balat, Trig Hill

- Monitoring Center .... 1 location
  Sandakan

- Flood Forecasting Center .... 1 location
  Kota Kinabalu (Inanam)

2.2.2 Sadong River

- Telemetry Observation Station .... 7 locations
  Tebedu, Mongkos, Krusin, Meringgu,
  Serian, Gedong, Ensengei

- Relay Station .... 1 location
  Mt. Serapi

- Flood Forecasting Center .... 1 location
  Kuching (D.I.D. Bintawa Depot)

Fig.2.5 Telecommunication Network
(Kinabatangan River)

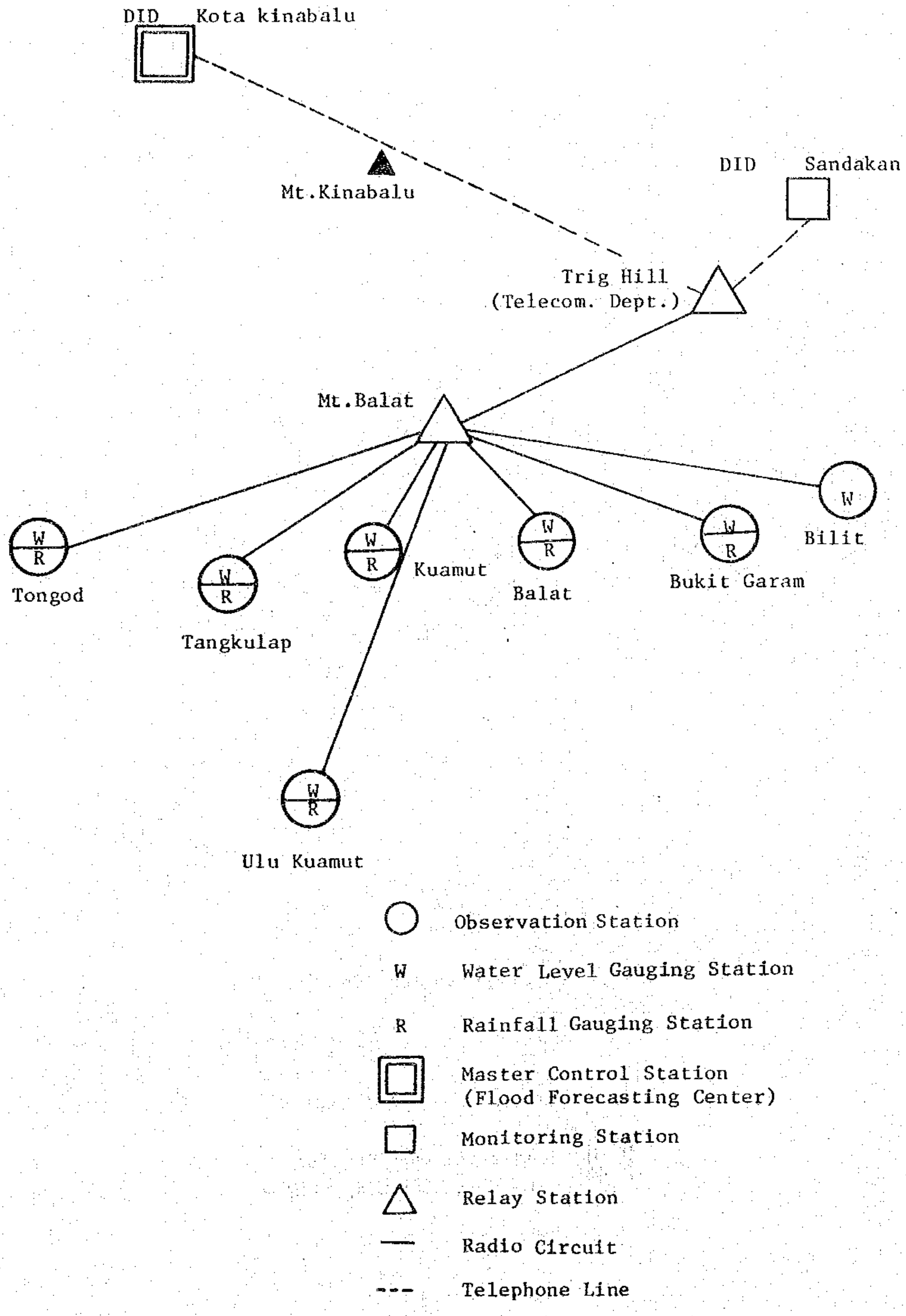
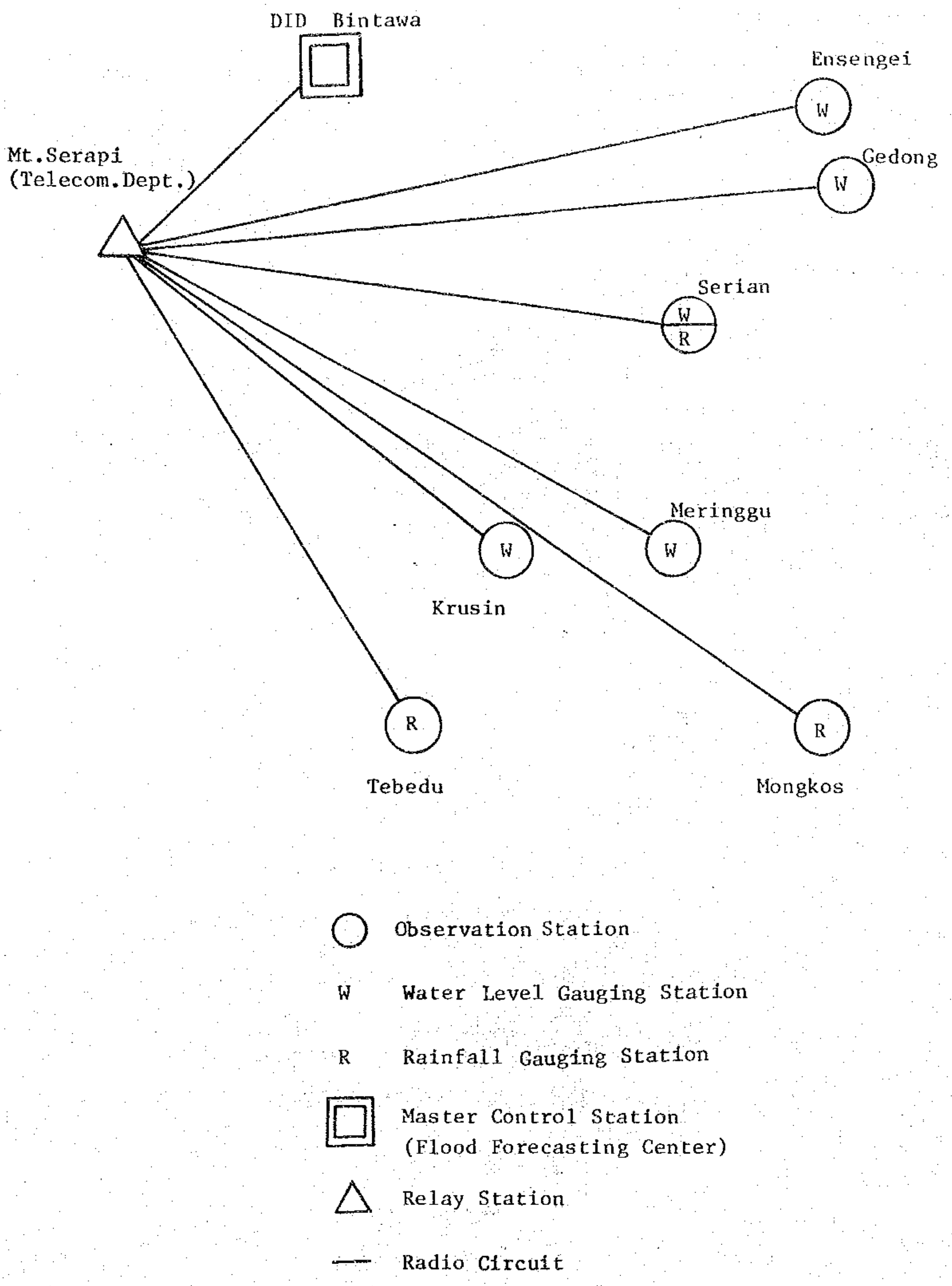


Fig. 2.6 Telecommunication Network
(Sadong River)



2.3 Function and Organization of Flood Forecasting and Warning System

2.3.1 Function of Flood Forecasting Center

- Collection of rainfall and water level data sent from telemetry stations

- Short-term flood forecasting based on hydrological observation data collected

- Prediction of long-term flooding prospects based on short-term flood forecast and meteorological forecasts made by the Meteorological Services and conveyance of the information to the Flood Control Center (F.C.C.)

- Reporting of current and expected conditions of flooding to agencies concerned

- Study to improve forecasting methodology

- Operation and maintenance of equipments and facilities at telemetry stations

- Training of personnel

To achieve its full function, the Flood Forecasting Center (F.F.C.) is to be manned by four hydrology engineers and four telecommunication engineers, namely, one chief, one supervisor and two engineers of hydrology and one supervisor, one engineer and two technicians of telecommunication.

2.3.2 Assignment of Personnel

Number of Personnel

For the efficient operation of the system, the following personnel are to be assigned. The above-mentioned personnel, namely, four hydrology engineers and four telecommunication engineers, are to be assigned before the commencement of the operation.

Training Program

Since it is most desirable that the personnel are fully experienced in the respective fields, it is required to choose and send the personnel at least one hydrology engineer and one telecommunication engineer for training at agency with experience in advanced operation of flood forecasting and warning system. For an example of training program, refer to APPENDIX.

On-the-job Training

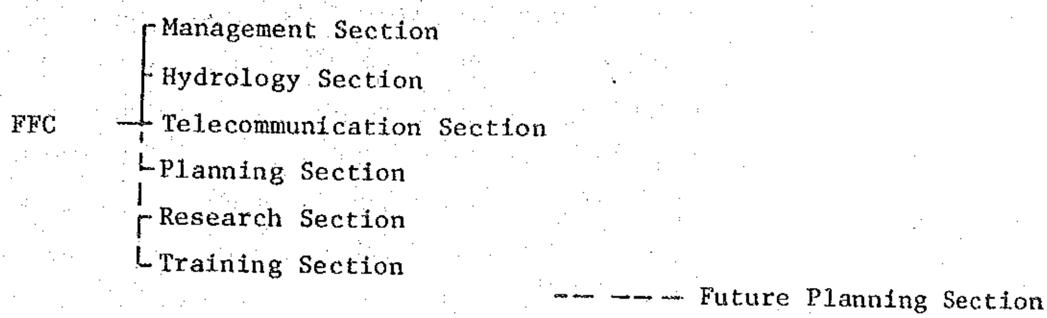
Upon completion of the system network, on-the-job training for operation and maintenance of the system shall be provided by civil engineering consultants during a rainy season (three to four months duration).

2.3.3 Organization

Organization of Flood Forecasting Center

A number of experienced engineers as well as a sum of expenses for management would be required to optimize the function of the flood forecasting and warning system. Therefore, it is recommended that the Flood Forecasting Center be set up as a part of Government Agency and provided an independent personnel assignment program and budget. The survey team would appreciate that Malaysian Government further investigate the above-mentioned recommendation for its development.

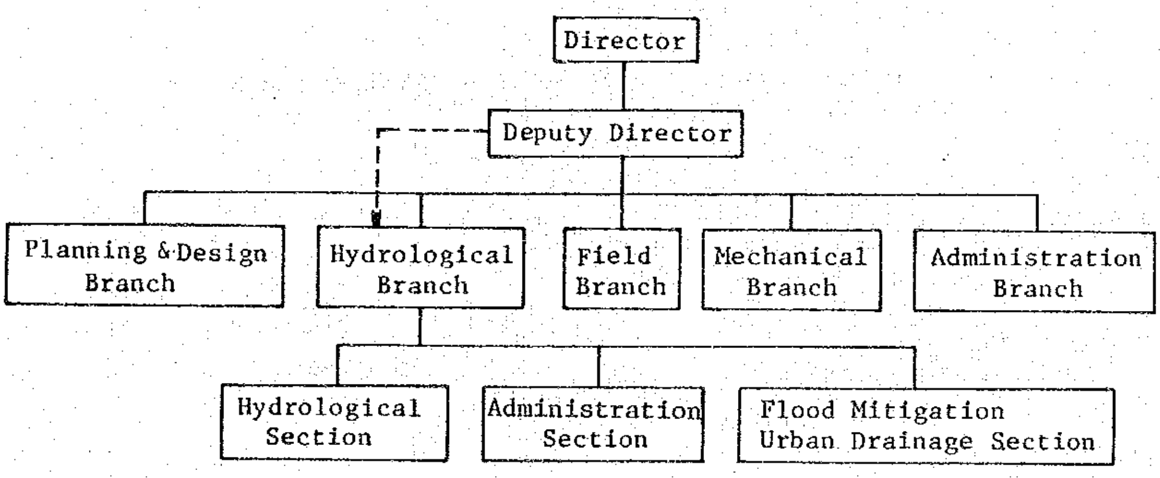
Organization Chart of Flood Forecasting System



Position in Administrative Organization

1) Flood Forecasting Center of the Sadong River in Sarawak

Fig. 2.7 D.I.D. Sarawak Organization Chart



The Flood Forecasting Center can be positioned in the above administrative Organization as follows:

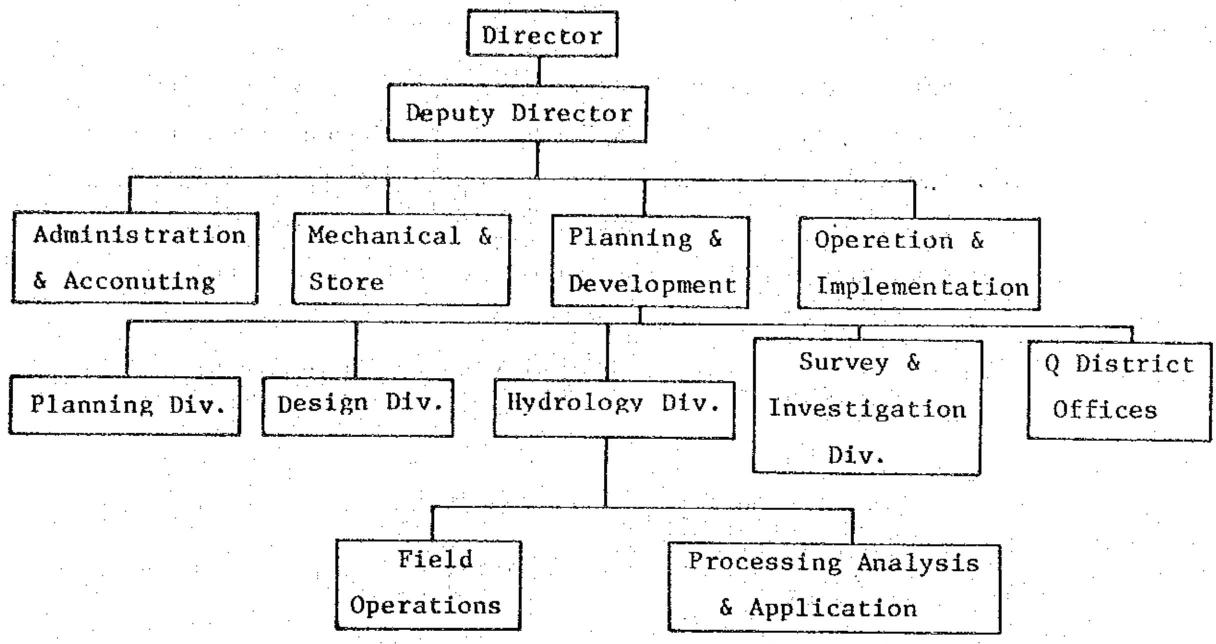
- Initial stage : Upon completion of the system, the Flood Forecasting Center could be located in the Hydrological Section or the Flood Mitigation Urban Drainage Section under the Hydrological Branch. This is recommended in the initial stage until the assignment of personnel, budget scheme and routine operations (management, maintenance, data collection, etc.) have been established, because these two sections are experienced in the related field.

- Intermediate stage : As its operations enlarge with the system the rivers covered extended to other river basins, the Flood Forecasting Center shall be promoted to be a Section under the Hydrological Branch, with independent staff schedule and budget scheme.

- Final stage : It is recommended that the Flood Forecasting Center, with independent personnel and budget, becomes one of the Branches of the D.I.D. or an organization directly under the D.I.D. Director capable of acting as a task force.

2) Flood Forecasting Center of the Kinabatangan River in Sabah

Fig.2.8 D.I.D. Sabah Organization Chart



The Flood Forecasting Center can be positioned in the above administrative Organization as follows:

- Initial stage : Upon the completion of the system, the Flood Forecasting Center should be placed under the Hydrology Division until its staff program, budget scheme and operation procedures have been firmly established.

- Intermediate stage : As its procedures of operations become firmly established and the system extended to other river basins, the Flood Forecasting Center should be promoted to be a Division under the Planning & Development Branch, having its own personnel and budget program.

- Final stage : It is recommended that the Flood Forecasting Center, with independent personnel and budget, becomes one of the Branches of the D.I.D. or an organization directly under the D.I.D. Director capable of acting as a task force.

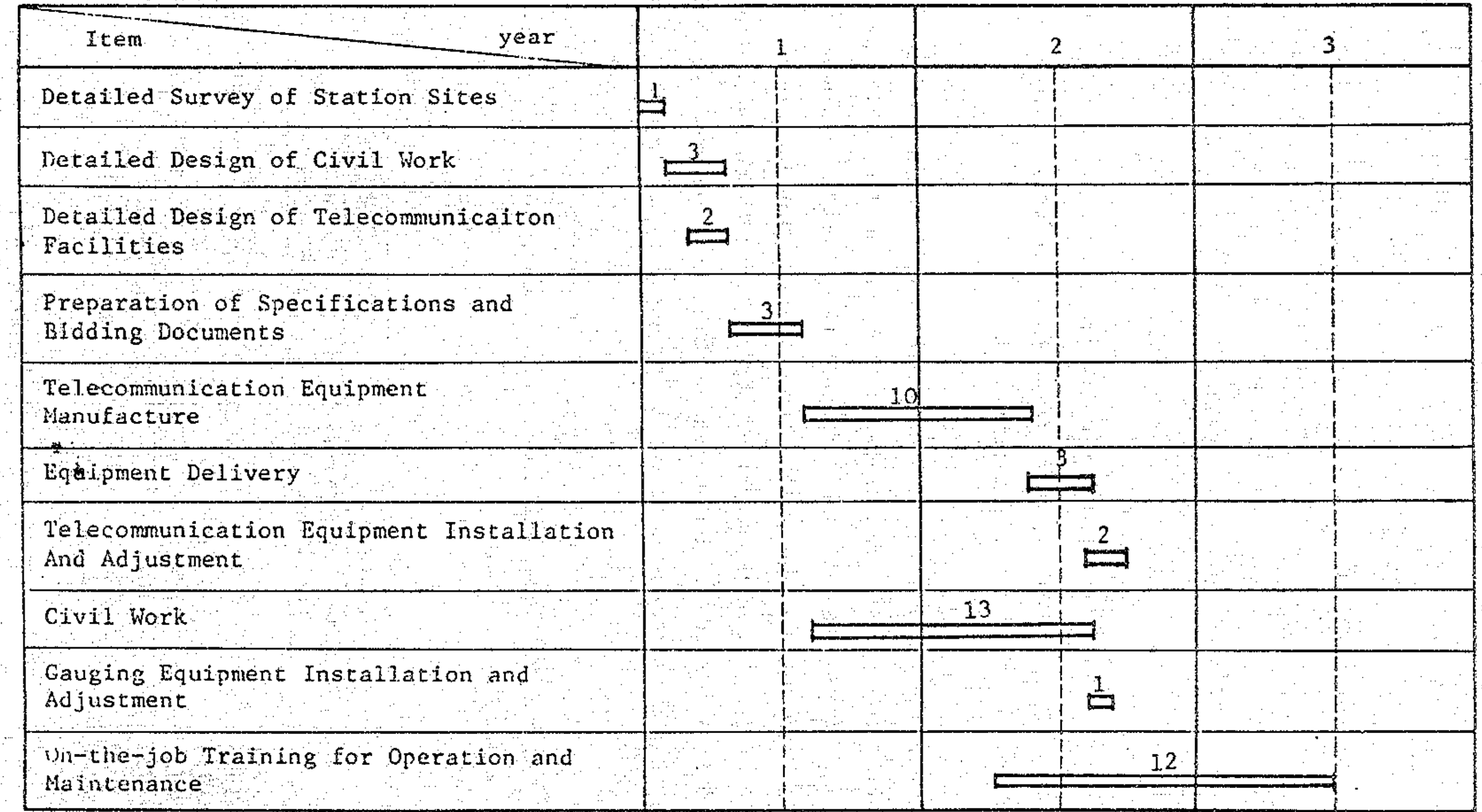
2.4 Implementing Schedule

Both of the flood forecasting and warning system for the Kinabatangan river basin in Sabah and the Sadong river basin in Sarawak could be constructed according to the schedule shown below. It follows then that the system will come into full operation 2.5 years after the commencement of construction.

Periods of time required for each work section of implementation are as follows:

- Detailed survey of station sites	1 month
- Detailed design of civil works	3 months
- Detailed design of telecommunication facilities	2 months
- Preparation of specification and contract documents	3 months
- Telecommunication equipment manufacture	10 months
- Delivery of equipments	3 months
- Telecommunucation equipment installation and adjustment	2 months
- Civil work	13 months
- Installation and adjustment	1 month
- On-the-job training for operation and maintenance	12 months

Fig.2.9 WORK SCHEDULE



2.5 Cost Estimate

The project cost for the establishment of the flood forecasting and warning systems for the Kinabatangan river basin in Sabah and the Sadong river basin in Sarawak are as follows: The cost is to be appropriated for construction (hydrological observation facilities, flood forecasting and warning system facilities), technical assistance, training program, and administration of project implementation.

Further, to carry out an orderly implementation of the flood forecasting and warning system, it is recommended the project be worked out in stage implementation.

The project cost has been estimated based on the current price as of February, 1980. The prices quoted has no indication of inflation rates since it was difficult to estimate it since no defite origin of the equipments and services could be given. In this context the indicated prices may be referred to as the initial cost to be incurred at the commencement of the construction implementation. The project cost may be adjusted by inflation index at detailed design phase of the project implementation for more accurate price estimate. At any rate the duration of construction is expected to be three years or less. The following in an example of deflator scale.

	Equipment	Facility
	National Expenditure Deflator	Civil Works Deflator*
1971	106.9	102.7
1972	112.7	109.0
1973	127.0	137.8
1974	151.9	172.6
1975	167.0	175.1
1976	181.1	188.0
1977	192.7	198.6

100 @ 1970
*May differ in types of construction

Table 2.1 Total Cost (Kinabatangan River Basin)

(US$)

Item	Observation Station	Flood Forecasting System	Total	Remarks
Equipments	176,530	612,900	789,430	
Facilities	248,000	198,000	446,000	
Sub-total	424,530	810,900	1,235,430	
Contingency	42,470	81,100	123,570	
Total	467,000	892,000	1,359,000	

Consulting Services	273,000
° Training	
Training Overseas	41,000
On-the-job Training	95,000
° Supervising	
Detailed Design	82,000
Contract and Procurement	14,000
Design Modification	41,000

(US$ @=¥ 220)

Table 2.2 Total Cost (Sadong River Basin)

(US$)

Item	Observation Station	Flood Forecasting System	Total	Remarks
Equipments	100,800	367,800	468,600	
Facilities	58,600	142,600	201,200	
Sub-total	159,400	510,400	669,800	
Contingency	15,600	51,600	67,200	
Total	175,000	562,000	737,000	

Consulting Services	147,000
° Training	
Training Overseas	22,000
On-the-job Training	52,000
° Supervising	
Detailed Design	44,000
Contract and Procurement	7,000
Design Modification	22,000

(US$ @=¥ 220)

Table 2-3 Cost of Flood Warning System
(Kinabatangan River Basin)
- Radio Receiver System -

($US)

Item	Flood Warning System	Remarks
Equipment	221,480	
Sub-total	221,480	
Contingency	24,520	
Total	246,000	
	Consulting services	44,000

($US @Yen 220)

Table 2-4 Cost of Flood Warning System
(Sadong River Basin)
- Radio Receiver System -

($US)

Item	Flood Warning System	Remarks
Equipment	145,080	
Sub-total	145,080	
Contingency	13,920	
Total	159,000	
	Colsulting services	21,000

($US @Yen 220)

The working machinery of the warning system involves formulation of governmental organization which has to be placed within the existing set-up of governmental agencies. The cost indicated above is of approximate figures which needs further examination by study composed of radio propagation test and population distribution survey for more accurate estimates.

SECTION II KINABATANGAN RIVER BASIN (SABAH)

SECTION II KINABATANGAN RIVER BASIN (SABAH)

CHAPTER 1 OUTLINE OF RIVER BASIN

The Kinabatangan river basin is situated in the eastern part of Sabah, or 4°30'-5°45' N. Latitude and 116°25'-118°40' E. Longitude. The river is the biggest in Sabah with approximately 17,000 km^2 of drainage area and 500 km of main river length.

The river basin stretches about 250 km from east to west and is 40 to 100 km wide having somewhat oblong shape.

1.1 Natural Environment

Starting at the confluence of the Milian River flowing out of the western mountain region and the Kuamut River flowing out of the southern mountain region, the Kinabatangan River winds its way through a vast alluvial plain and flows into the Sulu Sea. The mountainous districts forming divides, consist of Mt. Trus Madi (2,600 m) and other 500-2,000 m high mountains, and the entire river basin is covered with tropical rain forests. The river meanders markedly through the middle and lower reaches, which are a vast and flat alluvial plain. The gradient of the river channel is therefore moderate, estimated at 1/20,000-1/40,000. The width is 150-200 m in the lower reaches and 80-100 m in the middle reaches.

Because of the moderate gradient of the river, the tidal effect reaches as far as Lamag, almost 200 km from the river mouth. Particularly at the height of the rainy season, the flat land along the river is often inundated extensively by the combined effect of the water level increased by tides and the highly developed meandering of the river. So far, no river improvement work has been provided.

The geological feature of this river basin is such that weathered soil, alluvial clay soil and humid forest soil cover the base rock of sandstone, mudstone, etc., and acidic soil and mudstone soil are distributed in the coastal area and marshland.

As for the vegetation, tropical rain forests cover almost all the area, where lumbering for timber export is carried out at various placed.

Tropical rainforest climate dominates the region and the rainfall during the monsoon season of November through March account very much for the region's annual rainfall, which reaches as high as 2,000-3,000 mm.

1.2 Socio-economic Condition

1.2.1 Population of River Basin

According to the 1970 census, the population of the Kinabatangan District was counted as 14,177, or 2.2 per cent of the total population of 653,264 in Sabah.

Eighty per cent of the population, or 11,283 people, are indigenous people, namely, "Orang Sungai".

The population of Sabah as a whole had nearly doubled during the 20 years from 1951 to 1970, whereas the "Orang Sungai" increased at a slower rate of 1.3 times during the same period of time. The populations of major kampongs along the Kinabatangan River are as follows:

Bilit	3,000
Kuamut	2,000 - 2,500
Tangkulap	200
Pintasan	500
Lamag	3,000 (including Bukit Garam)
Balat	200
Tongod	1,500 - 2,000

1.2.2 Agriculture

Principal agricultural products in this river basin are rubber, coconuts, oil palms, paddy and cocoa. Other agricultural products include maize, coffee, fruit, potatoes, tapioca, sweet potatoes, ground nuts, soybeans and other vegetables. In terms of area planted as of 1976, oil palm amounted to 8,532 acres, dry paddy 3,280 acres, coconut 2,266 acres, rubber 2,068 acres and wet paddy 305 acres.

The planted area of these principal products had increased in the range of 1.4 to 2.6 times during the period of 1970 through 1976.

1.2.3 Industry, Transportation, Electric Power and Water

The Kinabatangan river basin, situated in the southern part of Sandakan Residency of Sabah, occupies more than half the area of the residency. Outside the cities, Sandakan Residency, accounting for over one third of the total area of Sabah, is less developed than other residencies. Overall resources development program is literally non-existent except for the lumbering in the tropical rain forests covering the entire area of the river basin. The lumber from the Kinabatangan river basin seems to occupy a considerable proportion of the timber export of Sabah, which amounted to M$1,212,950,000 in 1976.

The transportation within the river basin consists mainly of navigation on the Kinabatangan River. The land-bound transportation is limited to the road from Sandakan and Bukit Garam and timber roads scattered here and there in the basin.

No area in the river basin is supplied with electric power by the Sabah Electricity Board, Kerosine lamps are widely used in areas other than such Kampongs as Bukit Garam which have independent power plants. Because there are no waterworks, people in the basin area utilize rain water and river water.

1.2.4 Income

The gross domestic product (GDP) of Sabah in 1976 was M$1,529 million, or M$2,340 per capita. The personal income in the Kinabatangan river basin is estimated to be lower than the state average.

1.2.5 Damages from Flood

The monsoon rainy season in this river basin is November through March, when minor floods occur along the river almost every year. Once in several years, a large-scale flood causes great damages to livelihood of the people, inflicting heavy losses of houses, crops and livestock. Although actual extent of damage based on statistical survey is not available, the flood of February, 1971 is said to have been the greatest in the past ten years. The damages from floods of the Kinabatangan River in the past decade are reported as follows:

1967	Houses, washed-away	193
	Houses, damaged	700
	Sufferers	8,000
	Loss	M$ 2,000,000
1968	No record, though there were floods	
1971	Inundation of more than 15 feet deep at Lamag	
	Loss	M$ 1,000,000
1974	Inundation of more than 3 feet deep at Lamag	
	Loss	No record
1976	13 dead in extensive flooding	

1977	Houses damaged 100, 50, 3 and 20 in kampungs of Batuputeh, Bilit, Sukau and Abai, respectively	
	Families evacuated	60
	Houses, washed-away	30
	Inundation of more than 8 feet at Bukit Garam	
	Inundation of more than 4 feet at Kuamut	

1.2.6 River Basin Development Plan

As an economic development plan, the Malaysian Government is now implementing its Third Malaysia Plan (1976-1980). In this scheme, the state of Sabah will put an end to the economy solely dependent on its lumber resources by realizing an agricultural program designed to increase the production of such principal products as palm oil, cocoa and coconuts, and by abolishing earning differentials between races as well as social strata. The Kinabatangan river basin has attached a particular attention for the future development, because more than 90 per cent of the population are indigenous people engaged in low-income jobs and there is virtually no industry other than lumbering.

As a part of the agricultural development efforts, a minor settlement scheme of 2,000-acre plantation of coconuts, cocoa and other primary products started in 1970 at Kuamut in the middle reaches of the river, and so far 500 acres of planting has been completed.

At Bukit Garam, a 750 ha paddy field, developed during the period of 1972-1976, suffered a great flood damage and is now abandoned. Aside from the above mentioned program, a development scheme by private sector of 11,000-acre oil palm plantation near Bukit Garam is said to have been conceived.

There is also an overall river basin development plan which is centered on a multi-purpose dam of about 40 m in height for flood control, irrigation and power generation to be constructed near Balat in the middle reaches of the river. Currently a preliminary survey of the river and basin is being conducted, and a thorough investigation will start in the near future.

CHAPTER 2. TARGET AREA OF FLOOD FORECASTING AND WARNING

2.1 Target Area of Flood Forecasting and Warning

The following area in the Kinabatangan river basin is proposed to be the target area of flood forecasting and warning:

Major Kinabatangan River flood plain including such Kampungs as Kuamut, Balat, Pintasan, Lamag, Bukit Garam and Bilit

Due consideration was given to the population and property distribution, current and future land use pattern, expected flood damages and other socioeconomic features as well as the hydro-meteorological, topographical and run-off characteristics of the basin area.

2.2 Flood Forecasting Points

Representative locations for flood forecasting selected for the above target area are as follows:

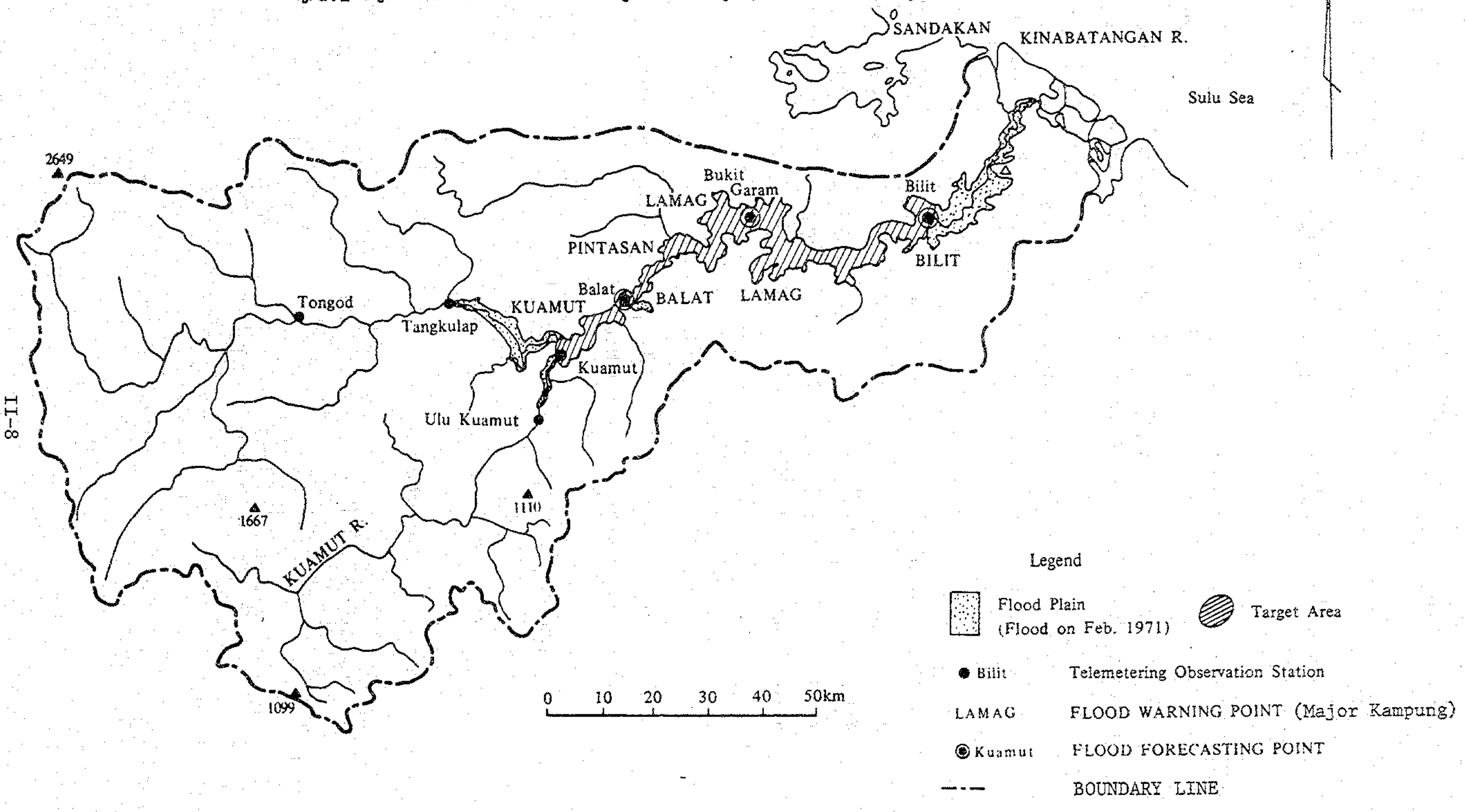
- Kuamut
- Balat
- Bukit Garam

2.3 Flood Warning Points

The major flood warning points selected for the above target area are as follows:

Major Kampungs along the Kinabatangan River of Kuamut, Balat, Pintasan, Lamag, Bukit Garam, Bilit

Fig. 2.1 Target Area for Flood Forecasting and Waring System in Kinabatangan River Basin



2.4 Location of Telemetry Stations

2.4.1 Rainfall Gauging Stations

It is desirable that the area be divided as such the rainfalls over respective areas are about equal to one another and rainfall gauging station placed in each area. Actual locations of stations, however, must be determined based not only on such a hydrological viewpoint but with consideration given to ease of construction, maintenance and management of stations. Other important criteria for station siting are as listed below:

- Accuracy in collecting rainfall distribution in the basin area

- Availability of rainfall information of the area upstream of the flood forecasting point

- Easy operation, inspection and maintenance of equipment

Table 2.1 and Fig. 2.2 show the location of the rainfall telemetry stations determined after the findings of data analysis and field survey conducted with due regard to the above criteria.

2.4.2 Water Level Gauging Stations

Actual locations of the water level gauging stations are to be determined with due regard to the following criteria:

- Availability of river stage data with high correlation to that of above-mentioned forecasting points, which facilitate accurate forecasting. In addition to this, enough time lag for forecasting should be secured.

- Nearness to existing gauging station so as to effectively use existing data

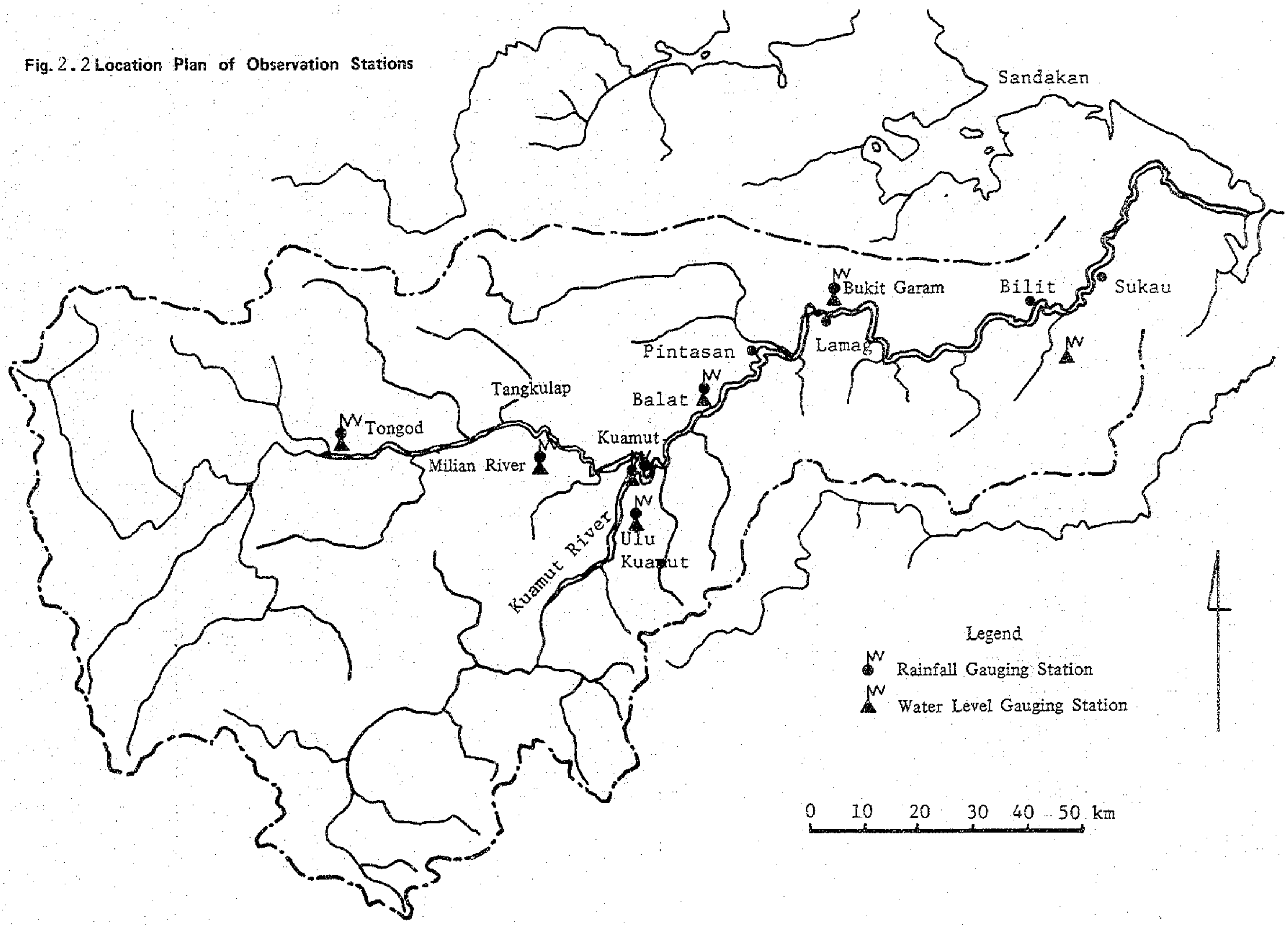
- Easy operation and maintenance irrespective of water level

Table 2.1 and Fig. 2.2 show the location of the water level telemetry stations determined on the basis of the data analysis and field survey conducted with due regard to the above criteria. For actual location of telemetry observation stations, refer to CHAPTER 5, FACILITIES and APPENDIX.

Table 2.1 List of Hydrological Gauging Stations (Kinabatangan River)

Station	River Basin	Station Type	Remarks
1. Tongod	Milian River	Rainfall, water level	Rainfall gauging of upper reaches of Kinabatangan River and water level gauging for downstream flood forecast
2. Tangkulap	Milian River	Rainfall, water level, discharge	Rainfall, water level and discharge gauging at upsteram end of target area
3. Ulu Kuamut	Kuamut River	Rainfall, water level, discharge	Rainfall, water level and discharge gauging of middle reaches of Kuamut River, a major tributary
4. Kuamut	Kuamut River	Rainfall, water level	Flood forecasting point
5. Balat	Kinabatangan River	Rainfall, water level, discharge	Flood forecasting point
6. Bukit Garam	Kinabatangan River	Rainfall, water level	Flood forecasting point
7. Bilit	Kinabatangan River	Water level	Tidal level observation

Fig. 2.2 Location Plan of Observation Stations



2.4.3 Selection of Discharge Gauging Points

The following three locations were selected for discharge observation of flood forecasting purpose:

Table 2.2 List of Discharge Observation Stations

Station	Normal-time observation method	Flood-time observation method
Ulu Kuamut	Current meter	Float
Tangkulap	Current meter	Float
Balat	Current meter	Float

Discharge observation is to be carried out in the vicinity of the water level gauging station. Measurements with the current meter are to be taken from the boat, whereas floats are to be dropped from the cable way.

The location proposed in Fig. 2.2 for discharge observation have wire facilities already installed. In operation of float dropper, however, hazards such as floating logs or travelling boats may be expected. Operation would be difficult during floods. In such cases methods other than float dropper may be adopted. For Kinabatangan River as is discussed later, stage correlation method for flood forecasting would be appropriate for the time being. Under such conditions wire facilities are not in immediate demand.

Along with the future development of the river basin, a more accurate forecasting incorporating rainfall data will have to be introdoced. Subsequently, discharge rating curve will have to be prepared which would inevitably calls for discharge observation. Expensive float dropper could be shared in use by the stations. The main purpose of this observation is to take flow velocity at high water for preparing discharge rating curve.

The following methods may be used to substitute the use of float dropper:

1) Projecting floats from river bank either handthrown or with aid of compressed gas or air.

2) Floats may be dropped from a helicopter when observation location is difficult to approach by boat. Refer to APPENDIX for reference of river gauging by helicopter.

2.4.4 Expansion Program for Future Location Plan of Hydrological Station Network

There are now only several reinfall gauging stations and four water level gauging stations in the Kinabatangan river basin whose drainage area is as spacious as 17,000 km^2. It is necessary to increase by far the number of recording-type gauging stations at new locations not only to raise the accuracy of flood forecasting but also to provide fundamental for the future river development plan.

The characteristic rainfall pattern of the target basin is dipicted best when the gauges are installed in each divided section having uniform distribution. As is expected this distribution pattern is very difficult to be detected. It has been stated in the Japanese Engineering Regulations for Sabo and River that rainfall gauging station are to be placed in every 50 km^2 area.

Another example is the AMEDAS* system operated by Japan Meteorological Agency which collects rainfall data of segmented area separated by grids 17 km apart. (Segment Area: Approx. 300 km^2)

Both of the above standards are for highly developed river basin where basic rainfall data are required for overall river management. In the Kinabatangan River Basin, however, siting conditions are presumably different from the ones stated above and at the present development stage, the number indicated in Fig. 2.3 would suit the purpose of the proposed flood forecasting and warning system.

Such data collection system are to be adopted and enhanced as the gradual development of the area proceeds. At present, extensive system with very high cost does not seem to benifit very much.

For the siting of water level gauges, locations assumed important for river management as well as river improvement program are to be selected. For example the gauges may be placed at confluence of tributaries with main river, upper and lower reaches of river structures such as gates and weirs, bottleneck of river channel, and in the vicinity of lakes, inner basin, estuary and other locations as may cause phenomenal hydrological effects.

In the Kinabatangan River basin one or two water level gauging stations may be required in the tributaries of primary importance for accurate data collection.

At present stage of economical development, the locations shown in Fig. 2.3 would serve the purpose of collecting data for flood forecasting and warning. This extension is to complement the present system which will have to be enhanced greatly as the development in the basin area proceeds.

(* Automated Meteorological Data Aquisition System)

2.5 Relay Station and Flood Forecasting Center

2.5.1 Relay Station

Two relay stations would be required to send the collected hydrological data from observation stations to the flood forecasting center. From the field survey conducted, one station atop Mt. Balat would serve the purpose very well and it would be very efficient if another one would be placed within the Department of Telecoms' Trig Hill radio facilities.

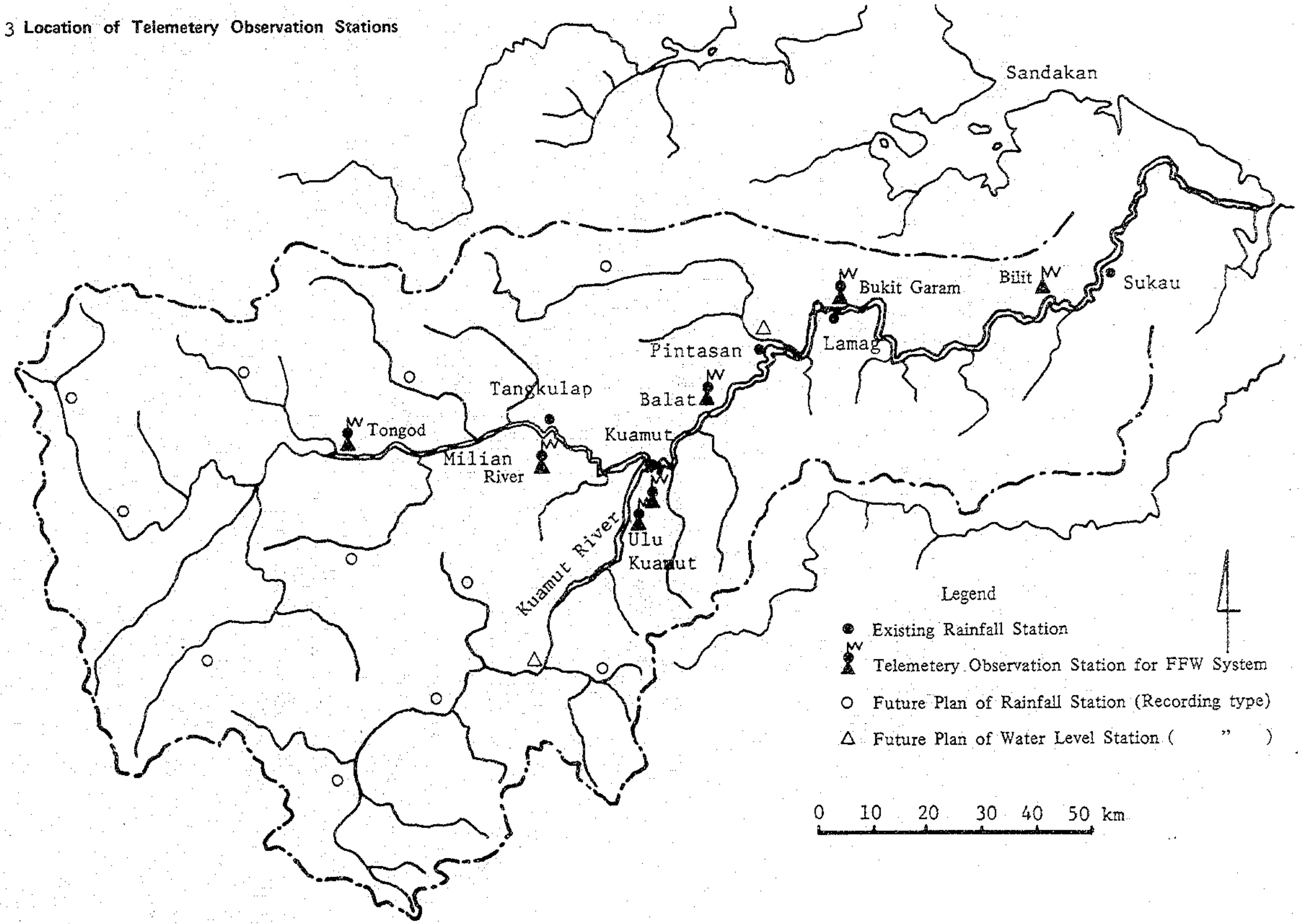
2.5.2 Flood Forecasting Center

Flood Forecasting Center is to be placed in Kota Kinabalu, the capital city of Sabah. The center is to serve as the vital organ of the Kinabatangan River Flood Forecasting System by keeping close watch on the whole system. The facilities are to be constructed within DID Inanam Office.

2.5.3 Monitoring Station

Since the Kinabatangan River basin is remote from Kota Kinabalu, the proposed location of Flood Forecasting Center, a monitoring station is to be placed within DID Sandakan Office which is in relatively closer location from the river basin.

Fig. 2.3 **Location of Telemetery Observation Stations**



CHAPTER 3 FLOOD FORECASTING

3.1 Hydrological Data

3.1.1 Rainfall Data

Rainfall Gauging Stations

There are eight rainfall gauging stations in and around the Kinabatangan river basin as shown in Fig. 3.1 . The stations scattered within the river basin are located in Kampung along the river which serves as primary means of transportation. The number of the rainfall gauging stations is less than adequate in view of the extensive area of the Kinabatangan river basin.

Arrangement of Data

Rainfall data of each rainfall gauging station have already been gathered and arranged by the preliminary survey team. The daily rainfall data and hourly rainfall data at Kuamut, Tangkulap, Ulu Kuamut and Lamag from 1969 through 1975 are presented in the preliminary survey report. Table 3.1 shows the periods when the daily rainfall data and hourly rainfall data of the existing rainfall gauge stations are available. These data, however, are not considered sufficient for determining an accurate rainfall distribution in the river basin, because there are apparently quite many periods without data and the number of rainfall gauging station is too small for the large basin area.

3.1.2 Water Level Data

Water Level Gauging Stations

Water level gauging stations at Barik Manis (moved to Balat in 1978), Ulu Kuamut and Tangkulap have been in operation since 1969. Recently the water level observation exclusively for flood-period have started at Barik Manis (Bukit Garam) and Pagar (Kuamut) on the recommendation of the first Japanese Survey Team in December, 1978.

Arrangement of Data

In the same way as the rainfall data are arranged, daily water level data at Tangkulap, Ulu Kuamut and Kuamut from 1969 to 1975 are presented in the preliminary survey report. The hourly water level values shown in the same report are of the automatic recording taken during the flood in February, 1971 at Tangkulap, Ulu Kuamut and Barik Manis.

The peak water levels at above three locations have been reported for the period of 1969 through 1975. The peak hours, however, which have not been shown clearly, are determined by correlating the peak-time with them and shown in Table 3.2.

Table 3.1 List of Rainfall Data Available

Daily Rainfall Data

Name of Station	Station Number	Period of Data Available						
		1969	1970	1971	1972	1973	1974	1975
Kuamut	5274201							
Tangkulap	5272001							
Ulu Kuamut	5174001							
Lamag	5478001							

Hourly Rainfall Data

Ulu Kuamut

1971 2/1 ~ 2/11
1974 2/12 ~ 2/20
1975 2/20 ~ 3/2
1975 10/28 ~ 10/31
1975 11/1 ~ 11/5

Tangkulap

1971 2/1 ~ 2/11
1972 2/14 ~ 2/29
1972 3/30 ~ 3/31
1974 2/12 ~ 2/15
1975 2/20 ~ 3/2
1975 10/28 ~ 10/31
1975 11/1 ~ 11/4

Kuamut

1971 2/2 ~ 2/7
1972 2/14 ~ 2/29
1972 3/30 ~ 3/31
1972 4/1 ~ 4/7
1974 2/12 ~ 2/15
1975 2/20 ~ 3/2
1975 10/30 ~ 10/31
1975 11/1 ~ 11/4

Lamag

1972 2/14 ~ 2/29
1974 2/12 ~ 2/15
1975 10/28 ~ 10/31
1975 11/1 ~ 11/4

Fig. 3.1 Location of Existing Observation Station

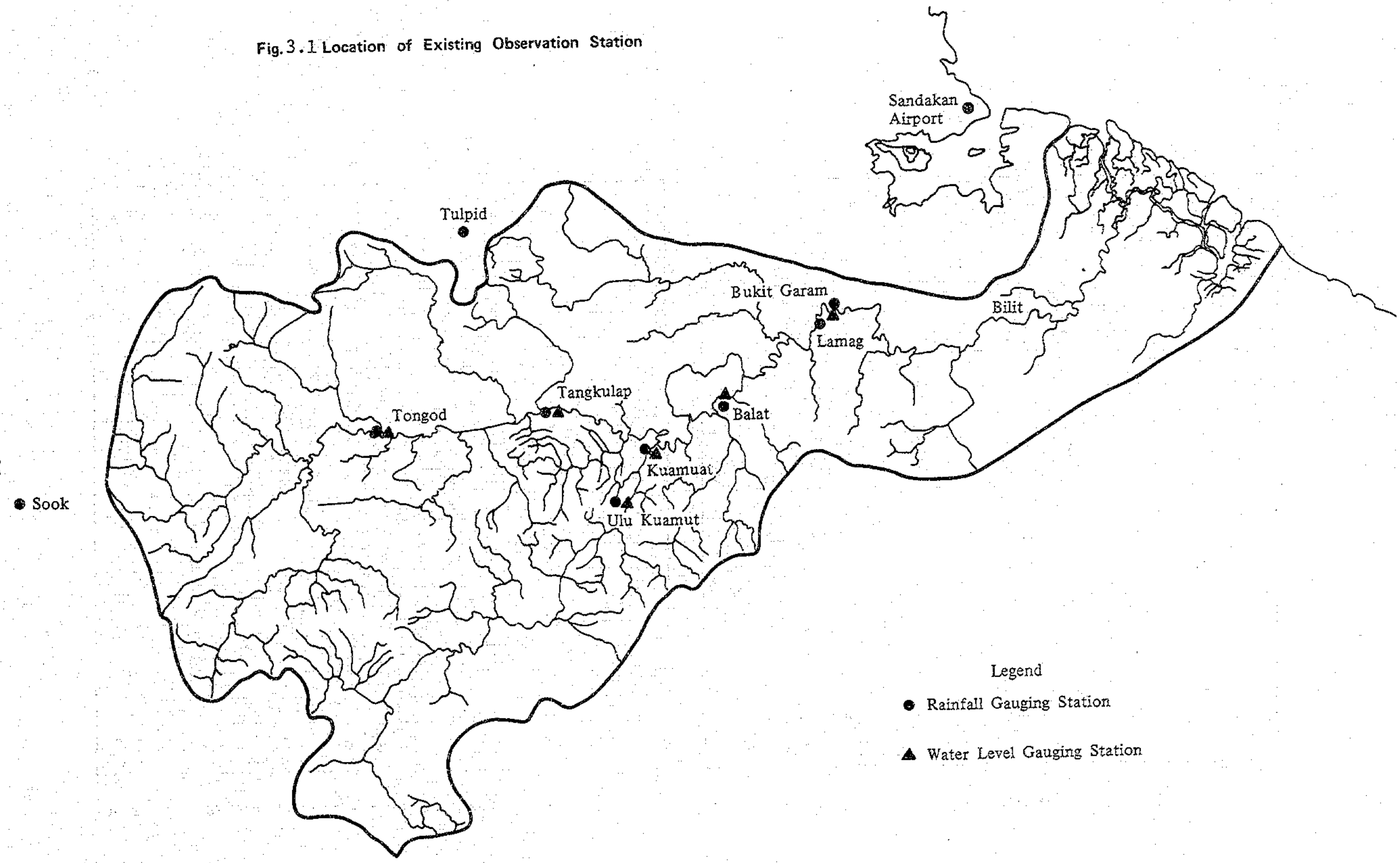


Table 3.2 Peak Water Level Correlation Data Check Sheet (1)

unit : feet

Year Month	Station	Peak Water Level (p174-175)	Collected Data (from Record Paper)	Date, hour	Remarks
1 1970 June	Barik Manis	30	–	–	
	Bangkulap	38	–	–	
	Ulu Kuamut	18	18.6	24, 10h	
2 1970 Sept.	B.M.	23	23.5	23, 17h	
	T	24	24.3	22, 8h	
	U.K.	17	17.3	21, 9h30m	
3 1970 Sept.	B.M.	25	25.8	29, 10m	
	T	24	25.0	28, 13h	
	U.K.	17	17.8	28, 4h	
4 1970 Oct.	B.M.	27	27.6	13, 8h	
	T	26	27.0	11, 9h	
	U.K.	21	21.0	10, 6h	
5 1971 Feb.	B.M.	43	43.5	4, 13h	
	T	31	31.5	2, 0h	
	U.K.	18	18.4	1, 20h30m	
6 1971 Feb.	B.M.	49	–	–	
	T	–	62.1	10, 10h	
	U.K.	45	42.0	9, 22h	
7 1971 July	B.M.	27	27.9	6, 4h	
	T	25	25.9	4, 3h	
	U.K.	24	24.2	3, 3h30m	

Peak Water Level Correlation Data Check Sheet (2)

unit : feet

Year Month	Station	Peak Water Level (p174-175)	Collected Data (from Record Paper)	Date, hour	Remarks
8 1971 Aug.	B.M.	27	27.5	27, 9h	
	T	29	29.1	27, 17h	
	U.K.	15	12.2	26, 22h	
9 1971 Feb.	B.M.	40	–	–	
	T	33	33.4	18, 18h	
	U.K.	27	27.9	17, 9h	
10 1972 May	B.M.	26	26.9	Jun. 2, 0h	
	T	25	25.5	31, 17h	
	U.K.	16	16.3	31, 5h	
11 1973 July	B.M.	21	21.8	4, 20h	
	T	19	19.9	3, 23h	
	U.K.	18	18.8	3, 11h30m	
12 1973 July	B.M.	21	21.9	27, 8h	
	T	23	23.2	26, 8h	
	U.K.	18	18.0	25, 16h	
13 1974 Dec.	B.M.	21	21.6	12, 15h	
	T	22	22.3	10, 6h	
	U.K.	16	16.4	11, 8h	
14 1975 Jan.	B.M.	24	24.8	17, 6h	
	T	17	17.7	16, 21h	
	U.K.	21	21.7	16, 0h	

Remarks

Peak Water Level Correlation Data Check Sheet (3)

unit : feet

Year Month	Station	Peak Water Level (p174-175)	Collected Data (from Record Paper)	Date, hour	Remarks
15 1975 Feb.	B.M.	29	–	–	
	T	35	35.5	26, 8h	
	U.K.	25	25.6	24, 23h	
16 1976 Oct.	B.M.	19	19.5	17, 13h	
	T	17	17.4	16, 23h	
	U.K.	15	15.2	15, 23h30m	
17 1976 Oct.	B.M.	22	22.8	Nov.1, 21h	
	T	29	27.9	31, 14h	
	U.K.	15	15.1	30, 4h30m	

3.2 Hydrological Examination of Telemetry Station Locations

3.2.1 Rainfall Gauging Stations

Siting Criteria

The rainfall gauging (telemetry) stations is to located in such positions that the rainfall characteristics in the target river basin area can be acquired with accuracy. For this purpose, surveys and analyses should be conducted based on the available hydrological data.

In the Kinabatangan river basin, however, there is not enough recorded data for such surveys and analyses. Therefore, the locations of rainfall gauging stations are to be decided by estimating the hydrological characteristics of the basin by the existing hydrological data, map and topographical characteristics made known by field surveys.

Location

The more the rainfall gauging stations, the higher the accuracy will be with which the rainfall distribution in the river basin could be known. The Kingbatangan river basin, with its size, may require dozens of rainfall telemetry stations, which is virtually impossible from the financial point of view. Moreover undeveloped forest covering the most part of the river basin does not allow easy installation and operation of the facilities and this naturally limits the number of location points. Thus, the sites chosen for the telemetry stations are the existing rainfall gauging locations as follows:

Tongod, Tangkulap, Ulu Kuamut, Kuamut, Balat, Bukit Garam

The number of the rainfall gauging stations at these locations will not suffice the data required for adequate flood forecasting. In the future, more telemetry stations are to be installed in the upper reaches of major rivers in this basin.

3.2.2 Water Level Gauging Stations

Siting Criteria

The water level gauging (telemetry) stations are to be placed with due consideration for the following hydrological and hydraulic criteria:

(1) They make it possible to predict the water levels in the flood warning points of Kuamut, Balat, Pintasan, Lamag, Bukit Garam and Bilit.

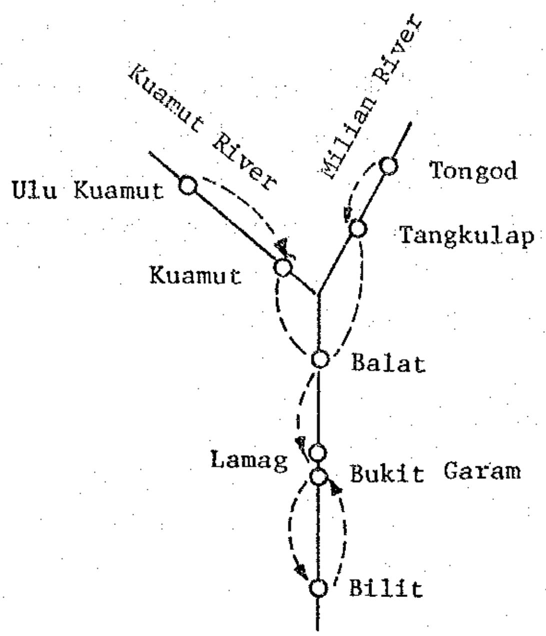
(2) They are located as such they provide enough time-lag for flood forecasting and warning operations.

Location

Currently there are five water level gauging stations located at Tangkulap, Ulu Kuamut, Pagar, Balat, Barik Manis.

Recently, the water level observation exclusively for flood periods have started at Barik Manis (Bukit Garam) and Pagar (Kuamut) on the recommendation of the first Japanese Survey team in December, 1978.

The relative position of these water level gauging stations and the target area for flood forecasting and warning could be illustrated as follows:



The flood warning point along the Milian River is to be Tangkulap and the one along the Kuamut River, Kuamut. Water level gauging stations are therefore required to be located at some point upstream of these warning points. The existing water level gauging station at Ulu Kuamut along the Kuamat River shall be used for this purpose. The one to be installed upstream of Tangkulap could be placed at Tongod which is also a proposed location for a rainfall telemetry station, where the operation and maintenance would be facilitated. The prediction of flooding at Balat shall be made from Tangkulap and Kuamut. The predictions of flooding at Lamag and Bukit Garam, which are subject to the influence of tidal waves, will have to be made from Balat situated upstream and Bilit downstream. The prediction of flooding at Bilit could be made from the water level variation at Bukit Garam and the regular tide level variation at Bilit.

With due consideration for the above, the following seven locations were selected for water level gauging station:

> Tongod, Tangkulap, Ulu Kuamut, Kuamut, Balat, Bukit Garam, Bilit

3.3 Flood Forecasting Methods

3.3.1 Flood Forecasting Methods

Principal flood forecasting methods used today are as follows:

Table 3.3 Classification of Flood Forecasting Method

Input	Output	Forecasting Process
Water level or discharge	Water level or discharge	Channel flow condition
Water level or discharge and basin rainfall	Water level or discharge	Residual basin run-off to channel flow
Basin rainfall	Discharge	Run-off from basin

3.3.2 Classification by Calculation Method

Correlation Method (correlation chart, coaxial correlation chart, correlation formula)

Using the existing hydrological data, the output factors (water level or discharge) of the forecasting point are projected through correlation analysis of the input factors (water level, discharge or rainfall) available at the data-collection point, taking the flood travel time between these points into consideration.

The output factors at the forecasting point are determined approximately by processing the input information gathered during floods using quantitatively-processed correlation charts or correction formulas. In some cases, the prediction accuracy could be improved by including as auxiliary parameters the water level (discharge) of major tributaries and the rainfall in the residual basin area between the data-collection point and the forecasting point.

In using this method, either the water level (discharge) versus water level (discharge) correlation or rainfall versus water level correlation is generally employed.

- Water level (discharge) Versus Water Level (discharge) Correlation

  In the main stream channel of a large river, water level forecasting for a downstream point could be made on the basis of the water level (discharge) correlation and the flood travel time between the two points. This widely used method of flood forecasting can also be applied to the dam, which has a relatively long upstream channel extension (catchment area of more than 500 km^2). In many cases, the prediction of flow conditions with higher accuracy may be possible by introducing auxiliary parameters prepared with attention to the hydrological characteristics of the river basin (e.g., causes of rainfall, rainfall distribution, tributary runoff).

  The velocity of flood wave in the river channel is estimated to be 10-20 km/hr in the upper and middle reaches and 5-10 km/hr in the middle and lower reaches. This would serve as the basis of forecasting time-lag.

- Rainfall Versus Water Level (discharge) Correlation

  In this method which has also been used widely, the runoff and the hour when it will take effect are predicted by means of correlation diagram and simple correlation formulas. Though it is generally inferior in accuracy to the above correlation method (a), it could be both convenient and effective when advance forecasting is required.

The coaxial correlation method is the developed type of correlation method, in which the runoff phenomenon is evaluated using such auxiliary parameters as rainfall and various other conditions of the river basin. This method could be fairly accurate with the adequate choice of parameters and reliable statistical data.

Runoff Analysis (runoff function method, tank mode method, unit hydrograph)

In this method, the runoff characteristics in the basin area upstream of the forecasting point are converted into constants for the runoff calculation formulas by analyzing the existing hydrological data (rainfall and discharge). Then, at the time of flooding, the available rainfall data is put to computation with the runoff calculation formula to predict the discharge at the forecasting point.

This method, when compared with the correlation method, features much longer time-lag of forecasting and an improved prediction accuracy. Particularly when a flood runoff is supposed to be affected by flood control facilities, it is desirable that the predictions be made using a series of runoff analysis models prepared beforehand.

When this calculation method is to be employed, discharge gauging at the forecasting point and one on two additional rainfall gauging stations at each major tributary would be required. Furthermore, complex computation of some sophisticated runoff calculation models would call for the use of electronic computer.

3.3.3 Proposal of Flood Forecasting Method

The correlation method for flood prediction is recommended as an initial step of the flood forecasting system operation, view of the existing hydrological data, the number and location of proposed telemetry stations, the flood information available and required forecasting time-lag.

However, the future increase in population and properties within the warning area would require an improved prediction accuracy and longer forecasting time-lag and moreover the installation of flood control structure in the basin area would make it necessary to switch to the runoff analysis for flood forecasting.

As preparatory steps for the switchover to the runoff calculation method, therefore, it would be necessary to gather and analyze the hydrological data, conduct discharge observation and longitudinal and cross-sectional surveying of the river channel, and to increase and telemetrize the rainfall gauging stations.

3.4 Preparation of Flood Forecasting Models

3.4.1 Flood Forecasting Models

The following table shows the proposed flood forecasting models for the Kinabatangan river basin. With the accumulation of hydrological data, however, it would be necessary to continue to examine and analyze the validity of forecasting models, particularly the correctness of correlation, the necessity of parameters and the prediction accuracy.

Table 3.4 Flood Forecasting Model

Forecasting Model	Forecast Point	Input Factors	Forecasting Time-lag	Application
Model K-1 (Rainfall, water level - water level)	Kuamut	Ulu Kuamut (Rainfall Water Level	5-10 hrs	Basic model for water level prediction of Kuamut
Model BA-1	Balat	Tangkulap (Rainfall Water Level Kuamut (Rainfall Water Level	5-10 hrs	Basic model for water level prediction of Balat
Model BA-2	Balat	Tongod (Rainfall Water Level Ulu Kuamut (Rainfall Water Level	10-20 hrs	Water level at Tangkulap and Kuamut is estimated using rainfall and water level data of Tongod and Ulu Kuamut. These estimated values are put into model BA-1 to predict water level at Balat. Though accuracy is not very high, long term prediction is possible.
Model BU-1	Bukit	Balat Water Level Bilit Water Level	10-20 hrs	Though actual water level data are basically required for prediction, long term forecasting is possible using Balat water level predicted by above model and Bilit water level predicted at the same hour.

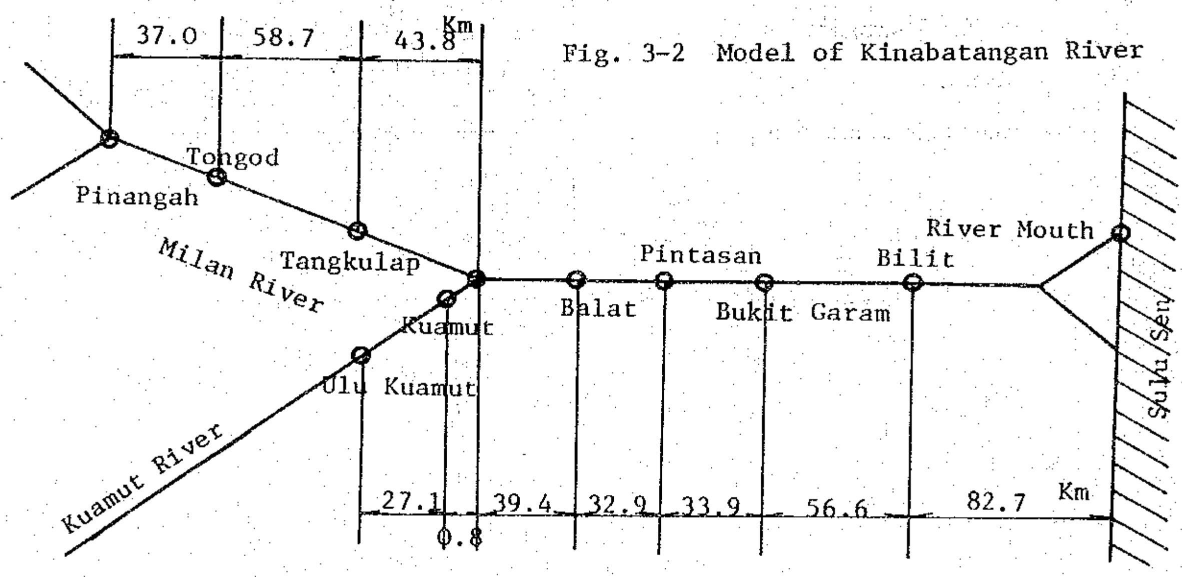
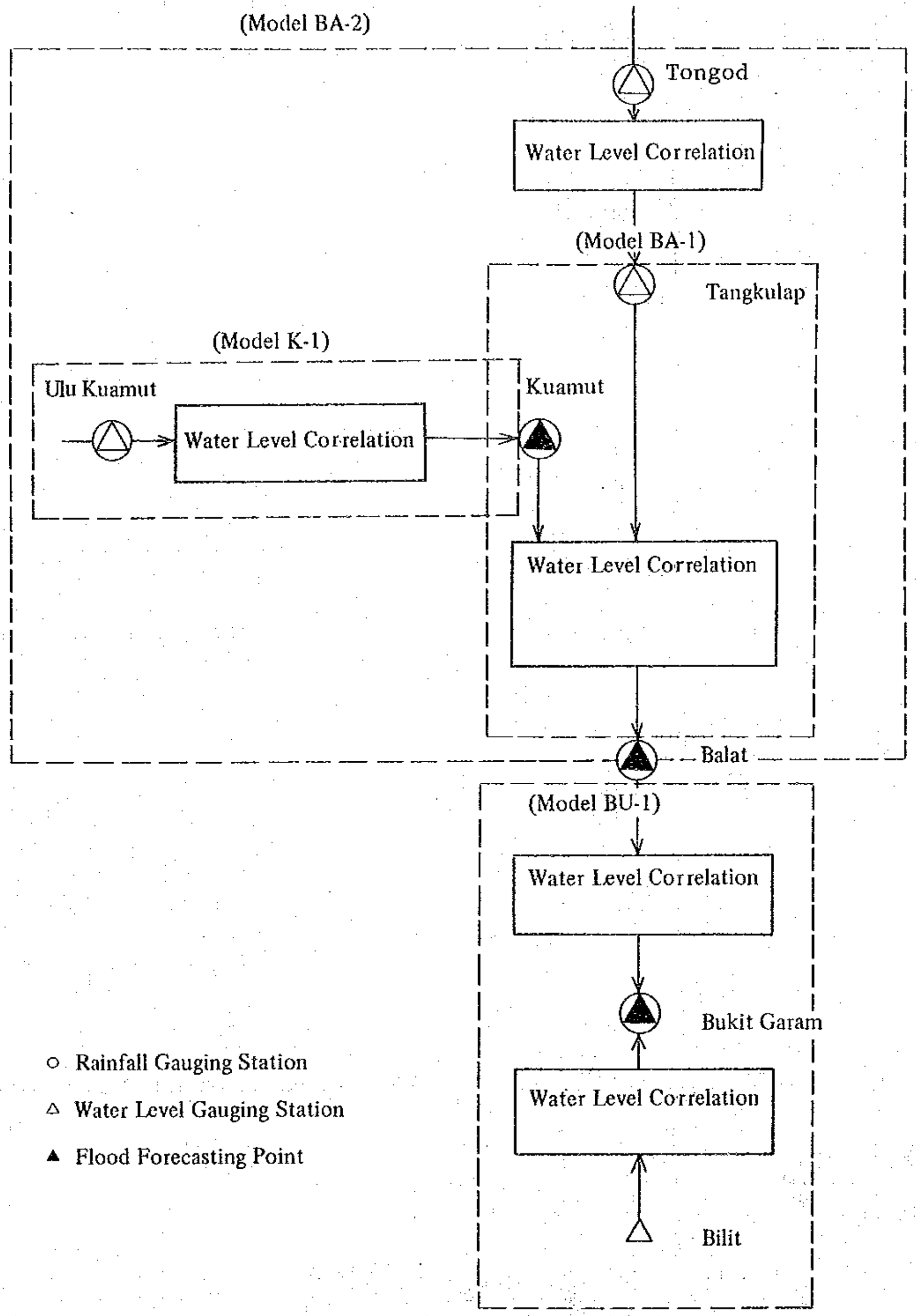


Fig. 3-2 Model of Kinabatangan River

Fig. 3.3 **Flood Forecasting Model**

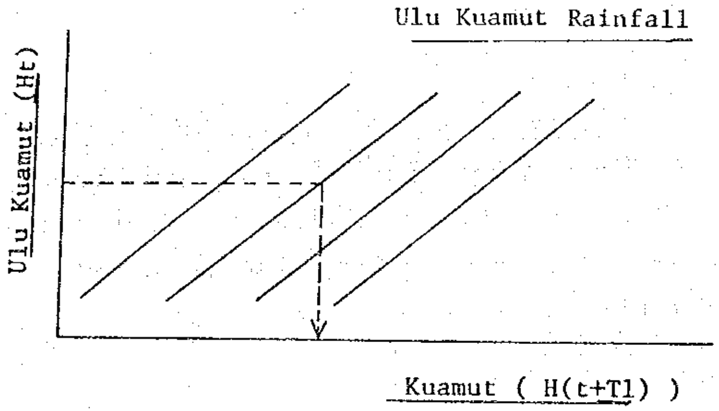
(Kinabatangan River)



3.4.2 Procedures for Preparing Flood Forecasting Models

Forecasting Model K-1 (Ulu Kuamut Rainfall and Water Level into Kuamut Water Level)

The water level at Kuamut is predicted from the rainfall and water level at Ulu Kuamut, using the correlation chart which is shown in a simplified from below.



The correlation charts are to be prepared by the following procedure:

- The flood travel time t1 between the two points (Ulu Kuamut and Kuamut) is calculated from the flood velocity estimated on the basis of discharge data and hydraulic calculation, or the stage correlation between the two points. This is to represent the forecasting time-lag.

- Hourly rainfall and water level of Ulu Kuamut and water level data of Kuamut with the t1 time difference, are plotted as follows:

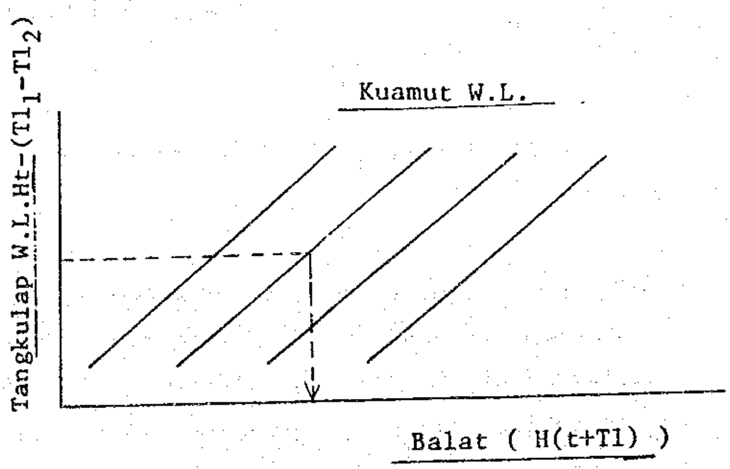
- The water level correlation curve between the two locations is drawn either interpolation or extrapolation.

The rainfall data of Ulu Kuamut may be used as the sole parameter of water level correlation. The rainfall data of Kuamut may also be included as an additional parameter if the experience from actual correlation analyses in the future requires so.

Hour	Ulu Kuamut rainfall(rt)	Ulu Kuamut water level(Ht)	Kuamut water level(t+tl)
1	r1	H1	H(1+tr)
2	r2	H2	H(2+tr)
3	r3	H3	H(3+tr)
4	r4	H4	H(4+tr)

Forecasting Model BA-1 (Tangkulap Rainfall and Water Level Kuamut Rainfall and Water Level into Balat Water Level)

The water level at Balat is predicted from the rainfall and water level data of Tangkulap and Kuamut, using the correlation diagram as shown below.



The correlation chart is to be prepared by the following procedure:

- The flood travel times tl_1 and tl_2 between Tangkulap and Balat and between Kuamut and Balat respectively are calculated in the manner described in Model K-1. tl_2, the shorter of the two flood travel times, is to be used as the forecasting time.

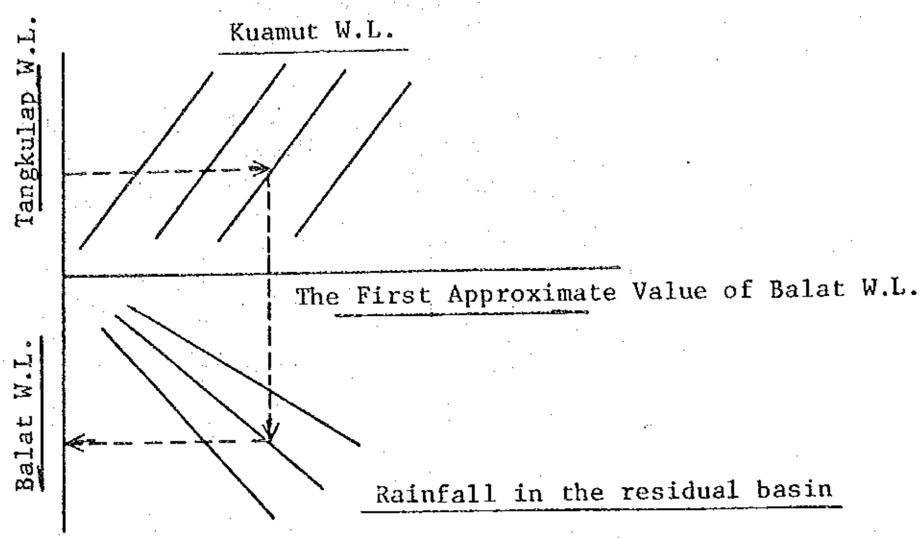
- The water level data, taking the flood travel time into account, are plotted as follows:

Hour (t)	Tang Kulap Water Level ($Ht-tl_1$)	Kuamut Water Level ($Ht-tl_2$)	Balat Water Level (Ht)
1	TH_1-tl_1	KH_1-tl_2	BH_1
2	TH_2-tl_1	KH_2-tl_2	BH_2
3	TH_3-tl_1	KH_3-tl_2	BH_3
4			
5			

- The water level correlation curve is drawn by means of the water level at Kuamut converted into parameters by either interpolation or extrapolation.

In this flood forecasting by the correlation chart, special attention has to be paid to the fact that there is a difference in the flood travel time from these two points. Therefore, the input data at the forecasting hour t are the water level Ht at Kuamut at the hour t and the water level $H(+l_1-tl_2)$ at Tangkulap at the hour $t-(tl_1-tl_2)$.

If the forecasting with the above correlation chart produces much error and when this error is considered to be caused by the runoff from the residual basin area between the three points, then it would be necessary to compensate the error with the available rainfall data as shown below.



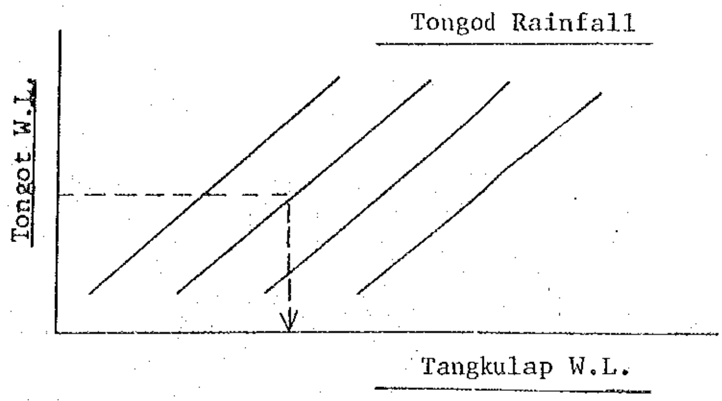
Usable observation data for estimation of rainfall in the residual basin area will be collected from above three gauging stations. They are to be examined for their validity against hydrological correlation established by actual hydrological data.

Forecasting Model BA-2 (Tongot Rainfall and Water Level into Tangkulap Water Level with Ulu Kuamut Rainfall and Water Level into Kuamut Water Level into Balat Water Level)

The water level at Balat is predicted from the hydrological data of Tongot at the upstream end of the network and Ulu Kuamut. The Tangkulap water level predicted by newly prepared Tongot - Tangkulap correlation chart and the Kuamut water level predicted by the forecasting model K-1 are put into the forecasting model BA-1.

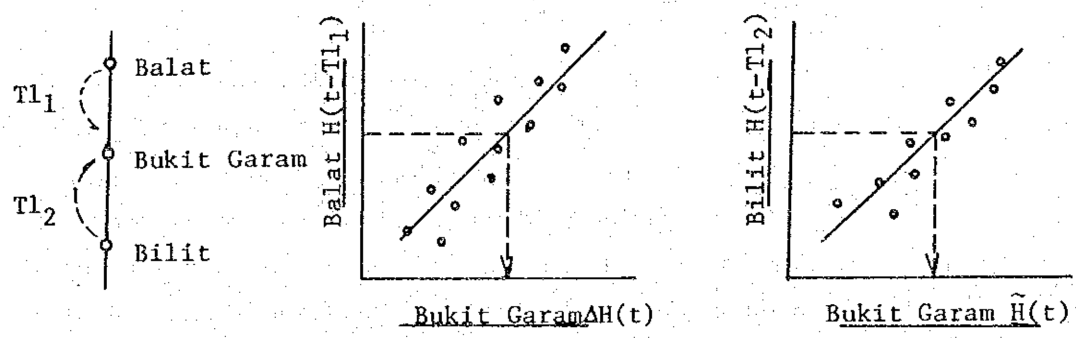
Though the forecasting accuracy is not very high, the long-term forecasting is possible.

The Tongot - Tangkulap forecasting model are to be prepared in the same manner as the forecasting model K-1.



Forecasting Model BU-1 (Bukit Garam Water Level, Balat Water Level and Bakit Garam into Bukit Garam)

The water level forecast for Bukit Garam, which is subject to the influences of tidal waves, is made on the basis of the water level at Balat upstream of Bukit Garam and the water level at Bilit downstream.

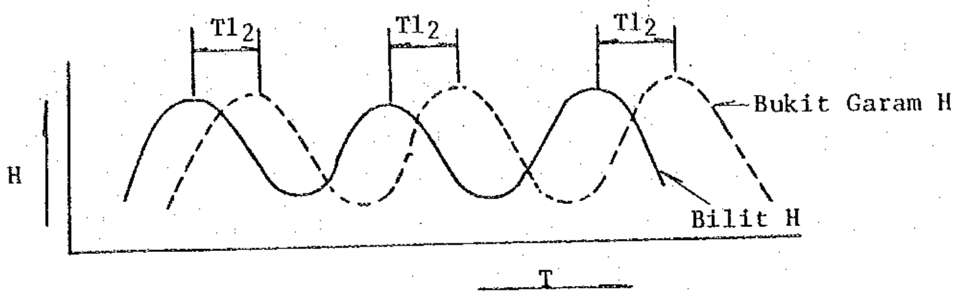


$$\text{Bukit Garam } H(t) = \text{Bukit Garam } \tilde{H}(t) + \text{Bukit Garam } \Delta H(t)$$

The above charts are to be prepared as follows:

- Correlation between Bilit Water Level and Bukit Garam Water Level

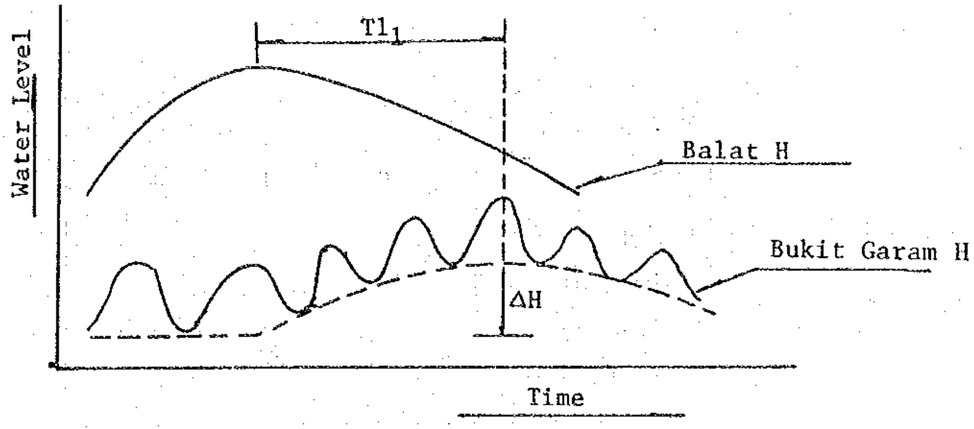
  The correlation between the Bilit water level and the Bukit Garam water level may be represented as follows:



The correlation chart must be prepared based on the correlation between the Bilit water level and Bukit Garam water level determined from normal time data, as shown above.

- Correlation between Balat Water Level and Bakit Garam Water Level

At normal time, it could be assumed that no correlation exists between the water levels at Balat and Bakit Garam because of the serious effects of the tidal waves. At flood-period, however, the increased discharge will markedly affect the water level. The correlation between the water levels at Balat and Bakit Garam is to be established by determining the water level rise at Bakit Garam due to the flood discharge is to be examined for its correspondence with the water level at Balat for preparation of correlation diagram.



The flood time water level at Bukit Garam can thus be forecast from above-mentioned correlation methods.

3.5 Verification of Flood Forecasting Models

3.5.1 Preparation of Forecasting Formula

Correlation Diagram of Peak Water Level

Because of insufficiency of the available hydrological data of the Kinabatangan River, the correlation diagram is to be prepared using the peak water levels at Tangkulap, Ulu Kuamut and Barik Manis recorded during the floods between 1969 and 1975.

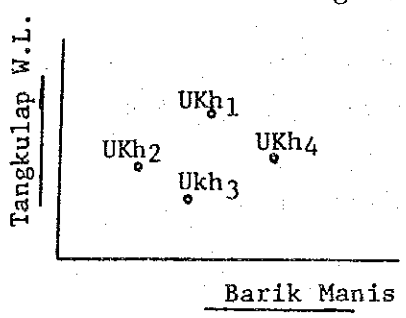
The correlation charts are to be prepared as follows:

- Arrangement of Peak Water Level Data of Flood Period

  The peak water levels at floods at Tangkulap, Ulu Kuamut and Barik Manis must be arranged as follows:

Location \ Item	Peak Water Level	Peak Level Time	Remarks
Flood Data			
Tangkulap	Th_1	Tt_1	
Ulu Kuamut	UKh_1	UKt_1	
Barik Manis	BMh_1	BMt_1	
Flood Data			
Tangkulap	Th_2	Tt_2	
Ulu Kuamut	UKh_2	UKt_2	
Barik Manis	BM_2	BMt_2	

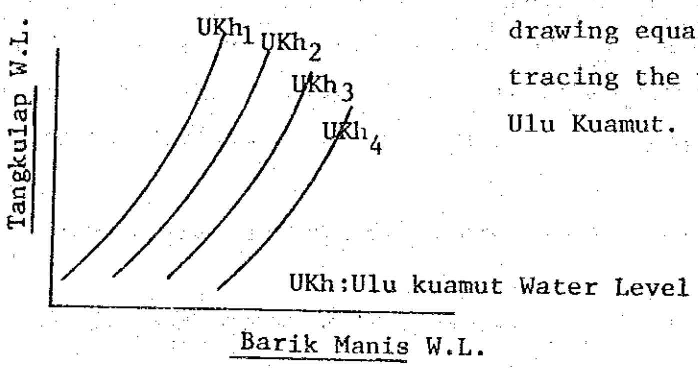
- Plotting of Peak Water Levels



Plot the peak water levels at Tangkulap and Barik Manis as shown left and enter the water levels at Ulu Kuamut in the cordinate system.

- Preparation of Correlation Diagram

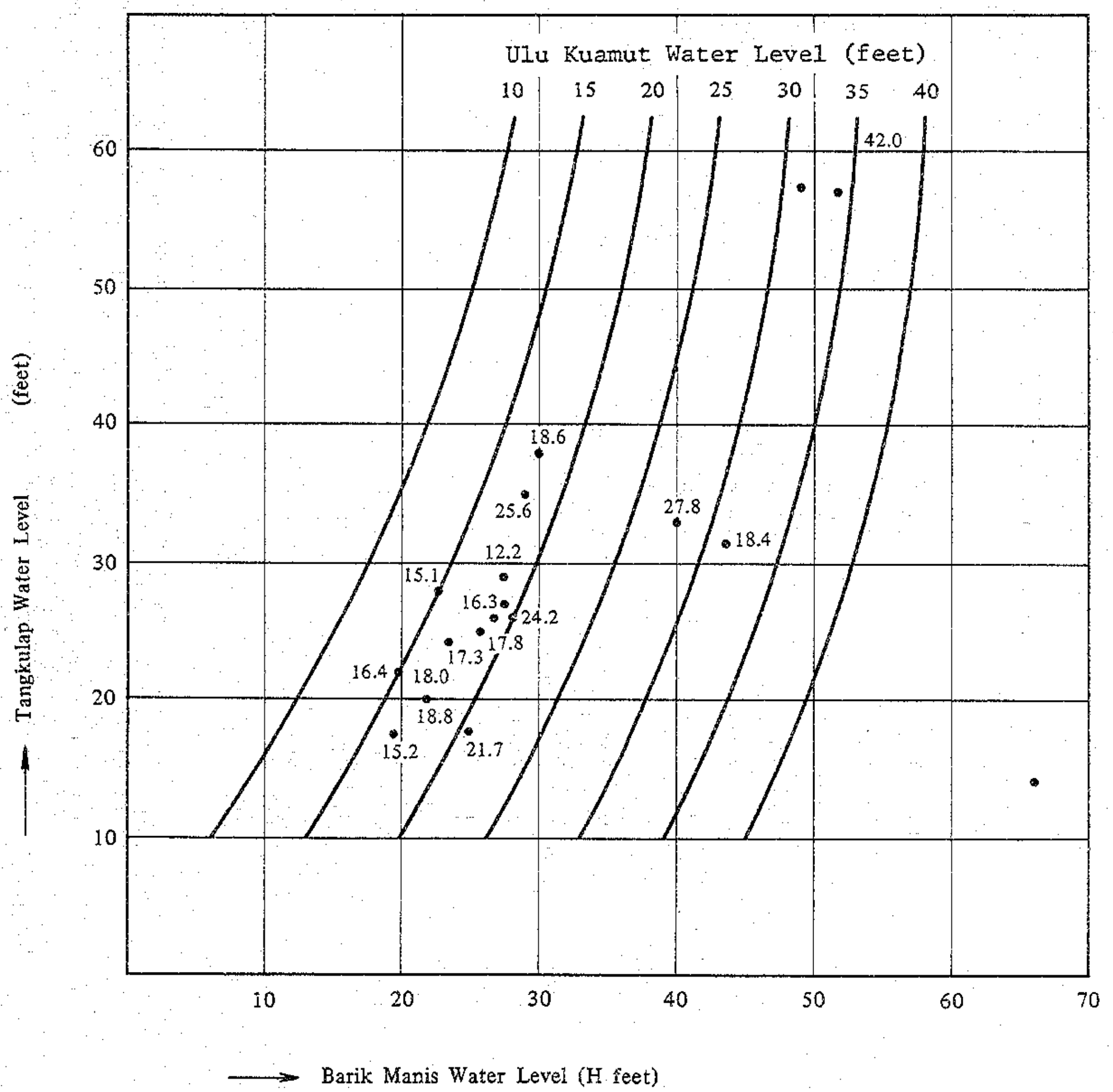
Prepare the correlation diagram by drawing equal water level lines tracing the plotted values of Ulu Kuamut.



The average flood travel time from Tangkulap and Ulu Kuamut to Barik Manis are estimated to be as follows:

Tangkulap	- Barik Manis	33 hours
Ulu Kuamut	- Barik Manis	51 hours

Fig.3.4 Correlation of Water Level between Tangkulap, Ulu Kuamut and Barik Manis



3.5.2 Verification of Forecasting Formula

To verify the accuracy of the correlation chart prepared as specified in the previous paragraph, the actual measurements and predicted values of the water level at Barik Manis are listed in the following table to see the nature of forecasting error.

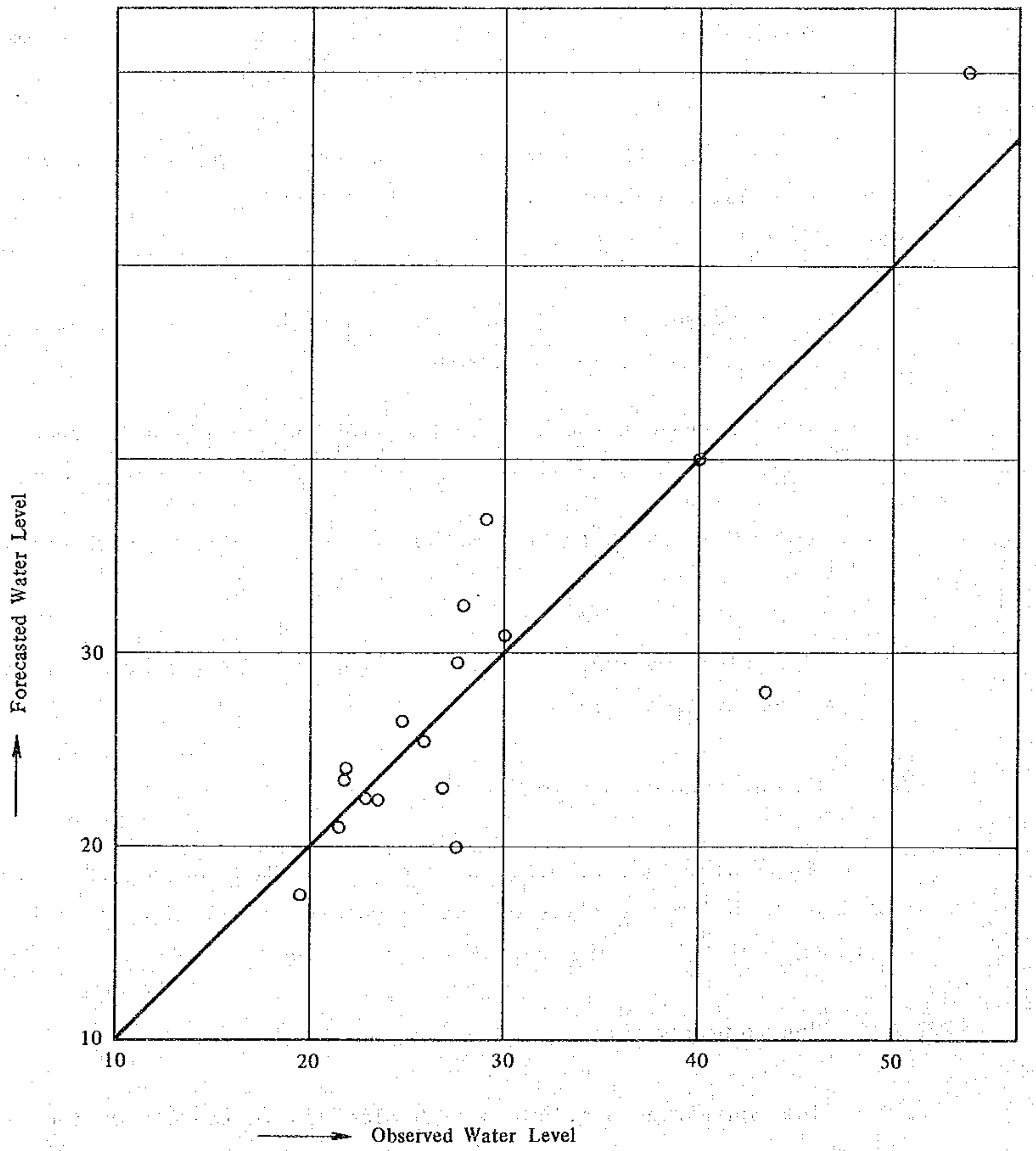
Table 3.5 Forecast Errors of Water Level at Barik Manis

Flood Date	Actual Measurement (ft)	Forecast Value (ft)	Error (ft)
1970 June	30	31	+1.0
1970 Sept.	23.5	22.5	-1.0
1970 Sept.	25.8	25.5	-0.3
1970 Oct.	27.6	29.5	+1.9
1971 Feb.	43.5	28	-15.5
1971 Feb.	54 or more	60	+6
1971 July	27.9	32.5	+4.6
1971 Aug.	27.5	20	-7.5
1972 Feb.	40	40	0
1972 May	26.9	23	-3.9
1973 July	21.8	23.5	+1.7
1973 July	21.9	24	+2.1
1974 Dec.	21.6	21	-0.6
1975 Jan.	24.8	26.5	+1.7
1975 Feb.	29	37	+8.0
1976 Oct.	19.5	17.5	-2.0
1976 Oct.	22.8	22.5	-0.3

The errors in the table are in a range of 3 feet except a few cases in which forecast values are calculated from inaccurate data of recording gauges which had suffered such conditions as breakdown or blurred marking. Therefore this correlation diagram is considered adequate for use in the proposed flood forecasting and warning system from the accuracy point of view. Up-grading of correlation diagram is to be conducted as soon as new observation data are available for the sake of higher accuracy.

Fig. 3.5 Comparison Water Level of Observation and Forecasting

Barik Manis



CHAPTER 4 TELECOMMUNICATION SYSTEM

4.1 Outline

This survey has been conducted in accordance with the telemetry system plan recommended in the preliminary survey report.

In dealing with the telecommunication network of the telemetry system, consideration was given to the following points cited in the preliminary survey report:

- The network is to incorporate any usable facilities of the Telecommunication Department
- A VHF radio network is to be established in view of the stability, reliability and economy of the system
- The network is to be capable of accommodating future extension program

The telecommunication network of the telemetry system consists of the following stations:

4.1.1 Master Control Station

The Master Control Station is to be located in the DID Office of Inanam in the outskirts of Kota Kinabalu where the Flood Forecasting Center is also proposed to be located.

4.1.2 Monitoring Station

The Monitoring Station is to be located in the DID Office at Sandakan.

4.1.3 Relay Station

Two relay stations are required for the telecommunication network of this system. The first relay station is to be placed on top of Mt. Balat (about 275 m) near Balat. This location, about 15 minutes drive from Balat, was chosen out of four candidates from the result of the field survey because it was found to facilitate most the access to facilities and therefore maintenance of equipment.

There were originally two candidate locations for the Second Relay Station - namely, the foot of Mt. Kinabalu where a new station is to be built and Trig Hill near Sandakan where the existing Telecommunication Department's relay station could be used. From the result of the field survey, Trig Hill was chosen as the site for the Second Relay Station for the following reasons:

- The Telecommunication Department has its relay station on Trig Hill. Structures, tower, access road and power supply are already established thus providing a financial advantage by avoided newly construction.

- It is advantageous from the maintenance point of view because it is near to the center of Sandakan.

- It will easily accommodate future extensions of the telemetry system.

As for the data transmission from Trig Hill to Kota Kinabalu and Sandakan two plans were proposed. In one proposal, the public telephone system was to be used from Trig Hill. In the other, a VHF radio circuit was to be established between Trig Hill and Sandakan and the public telephone was to be used between Sandakan and Kota Kinabalu. Considerations for reliability of radio circuits and the relative position of Sandakan DID Office within the whole flood forecasting and warning organization eventually led to the selection of the first proposal.

4.1.4 Observation Stations

- Water level gauging station

  Bilit

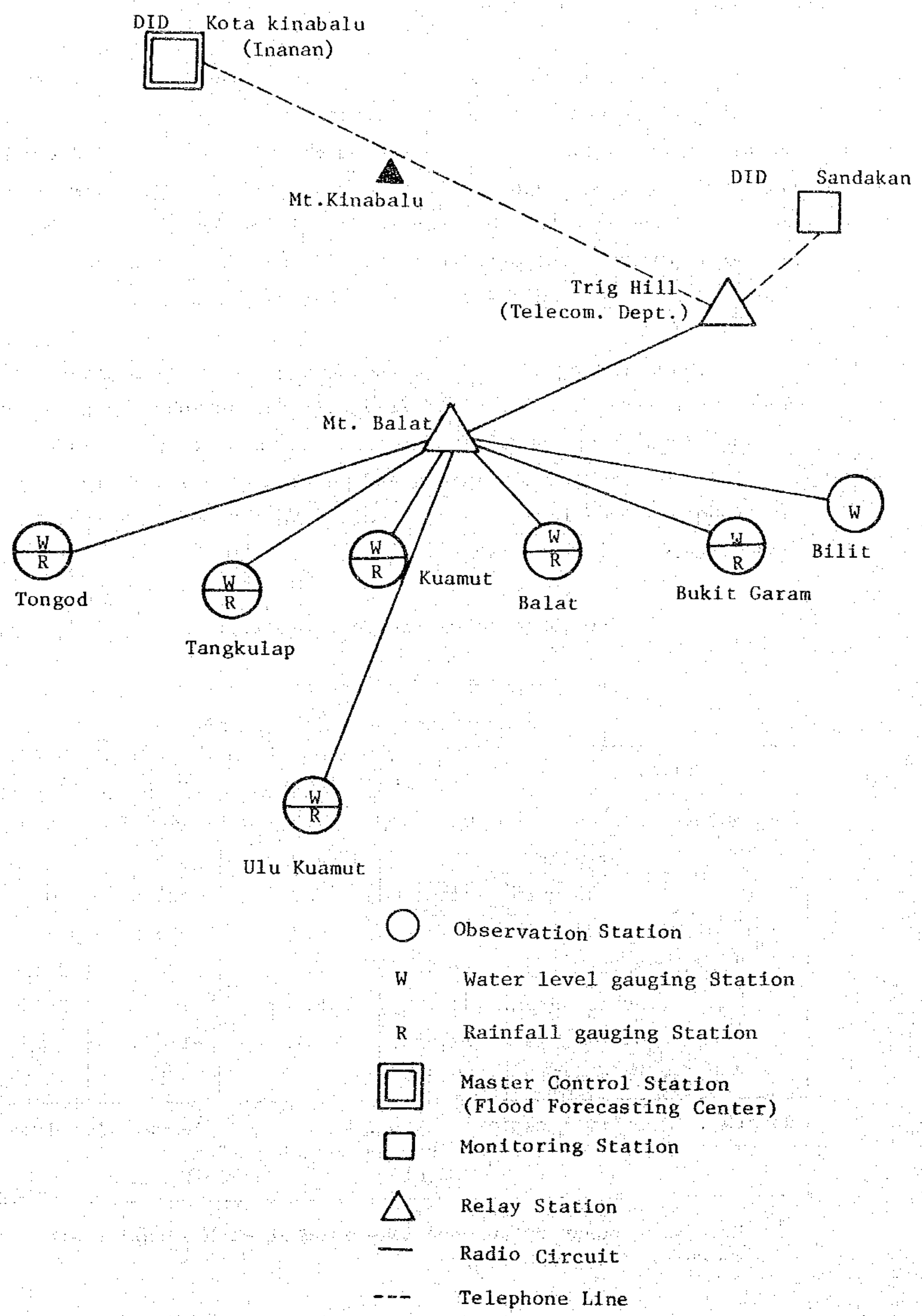
- Rainfall & water level gauging stations

  Tongod
  Tangkulap
  Ulu Kuamut
  Kuamut
  Balat
  Bukit Garam

Fig. 4.1 shows the telecommunication network of the telemetry system.

The field survey, radio wave propagation test and circuit design have been conducted to determine whether the proposed telemetry system is suitable for the flood forecasting purpose.

Fig.- 4.1 Telecommunication Network
(Kinabatangan River)



4.2 Radio Wave Propagation Test and Noise and Interference Test

4.2.1 Radio Wave Propagation Test

The radio wave propagation test included the measurement of the receiving power and direction of arriving waves as well as the actual communication tests. The total circuit loss of the tested span was calculated, and the stability of arriving waves was tested. The test items therefore covered the receiving power, the fluctuation in receiving power due to different position and direction of the antenna equipment, and the quality of communication.

As shown in Fig 4.2 , the radio wave propagation tests were conducted between Mt. Balat and Trig Hill and between Mt. Balat and the individual proposed sites for observation stations. Table 4.2 and Fig. 4.3 show the equipment and instruments used in the tests. The frequency used in these radio wave propagation tests was 70.380 MHz.

The following table shows the test results:

Table 4.1 Result of Propagation Test
(Kinabatangan River Basin)

Span	Distance	Transmitting Power	Receiving Power	S/N Reading
Mt. Balat - Tongod	68.0 km	7.5 W	-114 dBm	10.5 dB
" - Tangkulap	31.1	8.0	-103	22
" - Ulu Kuamut	31.3	7.7	-105.5	20
" - Kuamut	15.3	6.7	-83.5	41
" - Balat	1.5	7.5	-94	30.5
" - Bukit Garam	32.9	8.0	-101	24.5
" - Bilit	70.0	8.2	-117.5	5.5
" - Trig Hill	80.2	8.2	-78	43

Remarks: At every location: Antenna - 3 Element YAGI Type
Antenna Height - 10 m
Cable - 5D-2V, 16 m

Receiving power by antenna direction at each location are shown on Fig. 4.4 - 4.6

4.2.2 Noise and Interference Test

The noise and interference test of about 10 minutes duration was conducted at each proposed station location. The noise level was so low in all cases that no special concern in this respect is needed in the circuit design.

Similarly, there was no interference detected.

Fig.- 4.2 Radio Wave Propagation Test Network

(Kinabatangan River Basin)

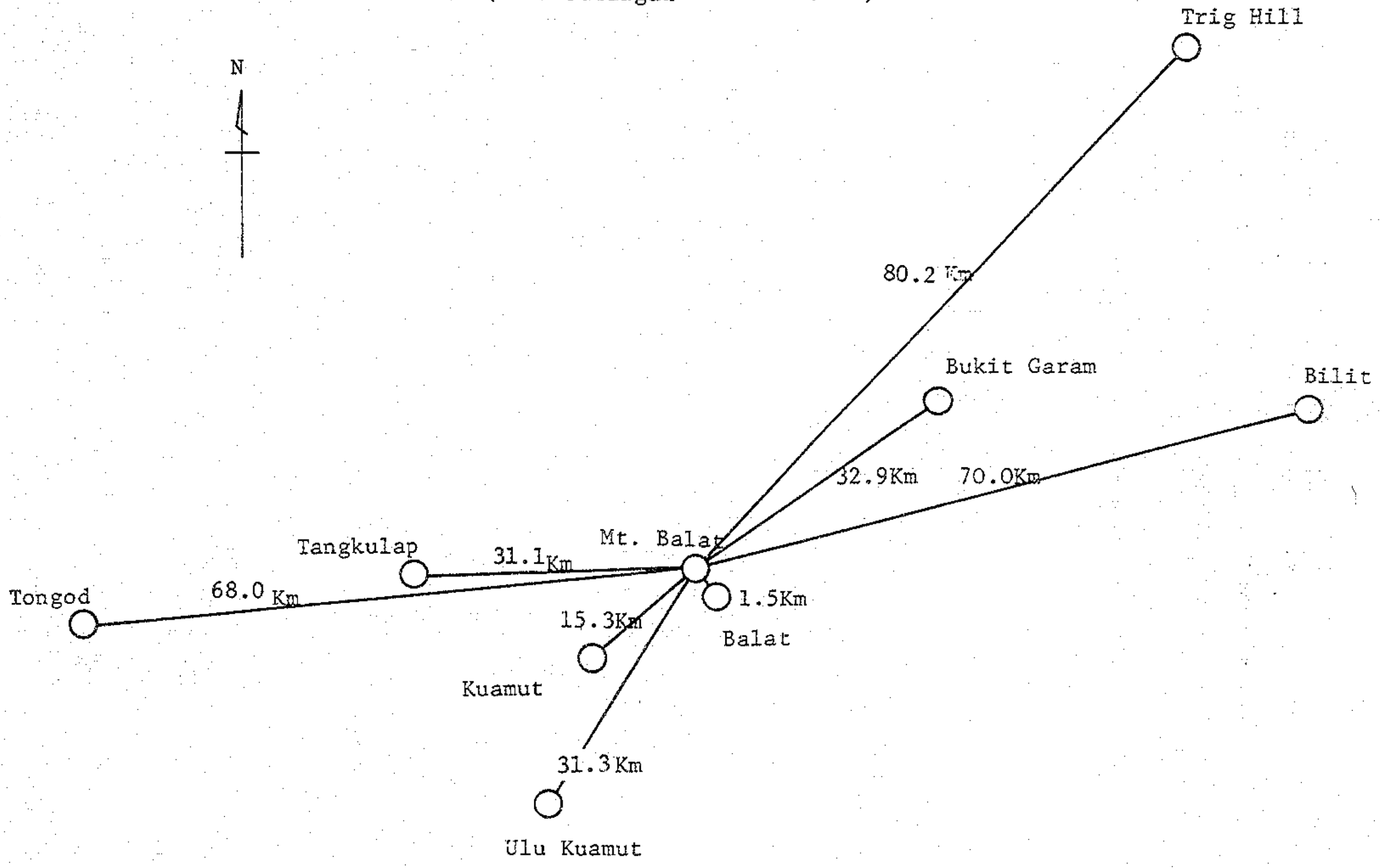
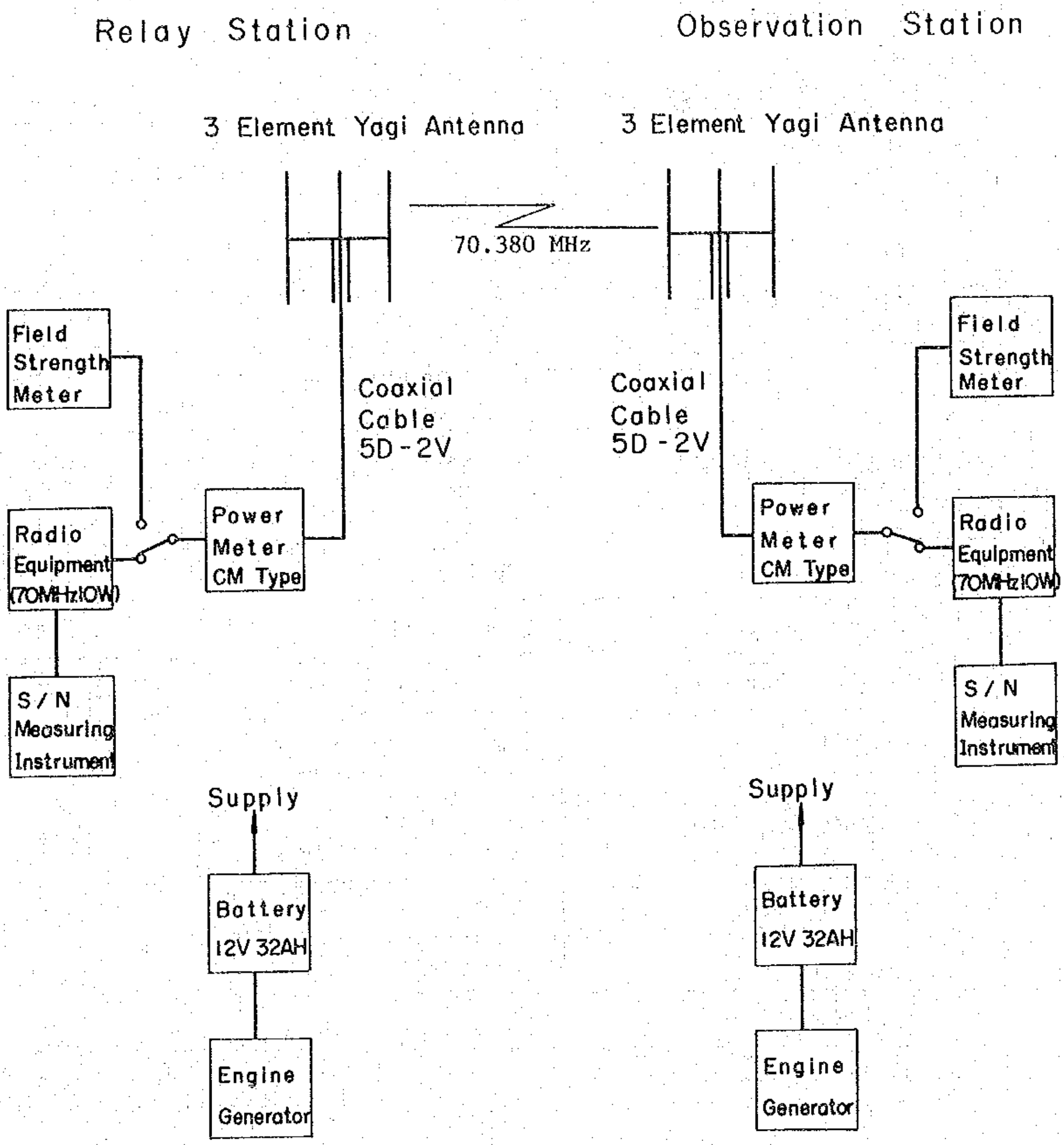


Table 4.2 Equipment and Instruments used in Radio Wave Propagation Test (Kinabatangan River Basin)

	Description of Goods	Rating	Quantity
1	Radio Equipment	CRI-06, 70.380 MHz, 10 W	4 sets
2	Antenna	3 Element Yagi	3 sets
3	Field Strength Meter	M-321G, 25 - 250 MHz	2 sets
4	Power Meter	CM Type, 70 MHz Band, 15 W	3 sets
5	"	Terminal Type, 70 MHz Band 15 W	3 sets
6	Quasi-Peak Meter	MH 33 A	1 set
7	Pen Recorder	VP 6723 A	1 set
8	S/N Measuring Instrument	KCD-1	3 sets
9	Storage Battery	12 V, 32 AH	5 sets
10	Engine Generator	EM 300, 300 W	1 set
11	Charger	Input AC 100 - 115 V Output DC 15V, 8A	1 set
12	Voltage Regulator	Input 220 V Output 0 - 230 V, 10A	1 set
13	Coaxial Cable	5D-2V, 15m	6 sets
14	Tester	TL - 700	3 sets
15	Tool Set		3 sets
16	Spares & Accessories		1 set

Fig. 4.3 Discription of the Equipment of Radio Wave Propagation Test.



4.3 Circuit Design

The desk circuit design to be examined by the radio wave propagation test was first made using 1/50,000 topographical maps, and the propagation loss (free space loss + additional loss)* was calculated. Then the difference between this desk design value and the actual propagation loss measured in the test was used as the compensation value in designing the actual operation circuit.

The design of the operation circuit was so conducted as to secure 30 dB or more of standard S/N and 0 dB or more of margin relative to threshold level at fading. However, when S/N of 30 dB could not be secured for a span, it was designed to be at least 25 dB. The service frequency assumed in the design work was 70 MHz band.

* Additional loss consists of diffraction loss and topography coefficient. This coefficient was estimated according to the conditions of the propagation path.

4.3.1 Desk Circuit Design

- Profile maps of propagation paths were prepared using 1/50,000 topographical maps and the additional loss of each path was calculated.

- Based on the additional loss thus obtained, the transmitting power and the type of antenna equipment, the desk circuit was designed.

The standard S/N is calculated by the following formula:

Standard S/N (dB) = Transmitting power (dBm)
+ Transmitting antenna gain (dB)
+ Receiving antenna gain (dB)
- Antenna equipment branch loss (3.5 dB)*

- Feeder loss (dB)
- Free space loss (dB)
- Additional loss (dB)**
- Receiving noise power (-55 dBm)**
+ S/N improvement factor (12 dB)**

For example, the standard S/N between Mt. Balat and Kuamut is calculated as follows:

Transmitting power = 30 dBm (1W)
Transmitting antenna gain = 8 dB (3 Element YAGI)
Receiving antenna gain = 7 dB (5 Element YAGI, 38°(-4))
Feeder loss = 2 dB (10D-2V, 50 m)
Free space loss = 93 dB (15.3 km)**
Additional loss = 30 dB**

Standard S/N = 30 + 8 + 7 - 3.5 - 2 - 93 - 30 (-115) + 12
= 43.5 dB

* Two 5-element Yagi antenna equipments are to be installed on Mt. Balat, one directed to Tongod and another Bilit. Therefore, the branch loss of 3.5 dB shall be taken into account.

**Calculations are shown in APPENDIX.

- The results of desk circuit design are shown in Table 4.4.

4.3.2 Calculation of Compensation Value

- The compensation value of propagation loss is calculated by the following formula, using the transmitting power, antenna equipment performance used in the radio wave propagation test and the actual measurement of receiving power:

Compensation value (dB) = Transmitting power (dBm)
+ Transmitting antenna gain (dB)
+ Receiving antenna gain (dB)
- Feeder loss (dB)
- Free space loss (dB)
- Additional loss (dB)
- Measured receiving power (dBm)

For example, the compensation value of propagation loss between Mt. Balat and Kuamut is calculated as follows:

Transmitting power = 38.3 dBm (6.7 W)
Transmitting antenna gain = 8 dB (3 Element YAGI)
Receiving antenna gain = 8 DB (3 Element YAGI)
Feeder loss = 3.2 dB (5D-2V, 32 m)
Free space loss = 93 dB (15.3 km)**
Additional loss = 32.5 dB**
Measured receiving power = -83.5 dBm

Compensation value = 38.3 + 8 + 8 - 3.2 - 93 - 32.5 - (-83.5)
= 9.1 dB

The compensation value calculated for individual spans are shown in Table 4.5.

** Calculations are shown in APPENDIX.

4.3.3 Circuit Design

Based on the compensation values of propagation loss mentioned above, the transmitting power, and the type of antenna equipment, the operational circuit was designed.

The receiving power, the standard S/N and the margin relative to threshold level at fading are derived by the following formula respectively:

Receiving power (dBm) = Transmitting power (dBm)
+ Transmiting antenna gain (dB)
+ Receiving antenna gain (dB)
- Antenna equipment branch loss (3.5 dB)
- Feeder loss (dB)
- Free space loss (dB)
- Additional loss (dB)
- Compensation value (dB)

Standard S/N (dB) = Receiving power (dBm)
- Receiving noise power (-115 dBm)
+ S/N improvement factor (12 dB)

Margin relative to threshold level at fading (dB)
= Receiving power (dBm)
- Threshold level (-106 dBm)
- Fading loss (dB) (0.1 dB/km x distance)

For example, the receiving power, standard S/N and margin relative to threshold level at fading for the span between Mt. Balat and Kuamut are calculated as follows:

Transmitting power = 30 dBm (1 W)
Transmitting antenna gain = 8 dB (3 Element YAGI)
Receiving antenna gain = 7 dB (5 Element YAGI, 38°(-4))
Feeder loss = 2 dB (10D-2V, 50 m)
Free space loss = 93 dB (15.3 km)
Additional loss = 30 dB
Compensation value = 9.1 dB
Fading loss = 0.1 x 15.3 = 1.5 dB

Receiving power = 30 + 8 + 7 - 3.5 - 2 - 93 - 30 - 9.1
= -92.6 dBm

Standard S/N = -92.6 - (-115) + 12 = 34.4 dB

Margin relative to threshold level at fading
= -92.6 - (-106) - 1.5
= 11.9 dB

Fig. 4.4 shows the horizontal-direction characteristic pattern of the 5-element Yagi antenna equipment used in the design work.

The results of the circuit design are shown in Table 4.6, the summary of which is shown on the following table.

Table 4.3 Summary of Circuit Design

Station	Transmitting Power	Antenna	Antenna Height	Receiving Power	Standard S/N	Margin at Fading
Tongod	20 W	5 EL Yagix2	30 m	-98.9 dBm	28.1 dB	0.3 dB
Tangkulap	20	5 EL Yagi	10	-92.3	34.7	10.6
Ulu Kuamut	20	5 EL Yagi	30	-95.5	31.5	7.4
Kuamut	1	3 EL Yagi	10	-92.6	34.4	11.9
Balat	3	5 EL Yagi	10	-91.3	35.7	14.5
Bukit Garam	20	5 EL Yagi	10	-94.3	32.7	8.4
Bilit	20	5 EL Yagi	30	-96.7	30.3	2.3
Trig Hill	1	3 EL Yagi	10	-88.4	38.6	9.6
Mt. Balat	20	5 EL Yagi 5 EL Yagi	30	-	-	-

Mt. Balat's antenna equipment is bidirectionally branched toward Tongod (265° from north) and Bilit (75° from north).

As it is clear from the above table, the standard S/N for every span is over 30 dB except for Tongod and the margin relative to threshold level at fading is above 0 dB for all span. Therefore, establishment of good circuits could be expected.

While the standard S/N of Tongod does not reach 30 dB, it is above 25 dB, which makes it possible to establish a circuit there.

Under normal condition, fluctuation in receiving power may be caused by seasonal changes and other meteorological phenomena. In design of actual operational circuit, this decrease in receiving power has already been taken into account.

For stations Tongod, Ulu Kuamut and Bilit, the radio propagation tests have revealed that 10m high antenna incorporated in the circuit design would not facilitate standard level of receiving power.

Hence, in the design of circuits to be established for the above three stations, antenna of 30m high were used instead. Moreover the values of standard S/N as well as that of margin relative to threshold level at fading are barely within the tolerable limit leaving only a slight margin.

The foregoing statement on circuit design, however, is based on the data acquired by the radio propagation tests of short duration and thus the values given by the standard design might not be achieved throughout the year.

For this reason extensive radio tests using 30m high antenna are highly desirable to be conducted before equipment installation so that the receiving power mentioned above could be assured.

For stations Tangkulap, Kuamut, Balat, Bukit Garam and Trig Hill, standard S/N and margin relative to threshold level at fading are both well above required level and therefore good circuits are expected to be established with 10m high antenna.

4.3.4 Service Frequencies

Two frequencies of the 70 MHz band are required to manage this telemetry system. These two frequencies are to be set apart by more than 2 MHz to avoid interference at the relay station

Aside from the above-mentioned interference, investigation is to be made into the mutual interference between these frequencies and the frequency currently in use by the Telecommunication Department at Trig Hill.

Fig. 4.5 shows the relay system of this telecommunication network.

Table 4.4 Desk Circuit Design Table (Kinabatangan River Basin)

Item \ Span		Tongod –Mt. Balat (68.0km)		Tangkulap –Mt. Balat (31.1km)		Ulu Kuamut –Mt. Balat (31.3km)		Kuamut –Mt. Balat (15.3km)		Balat –Mt. Balat (1.5km)		Bukit Garam –Mt. Balat (32.9km)		Bilit –Mt. Balat (70.0km)		Trig Hill –Mt. Balat (80.2km)	
Transmitting Paper	dBm	43	20W	43	20W	43	20W	30	1W	34.8	3W	43	20W	43	20W	30	1W
Transmitting Antenna Gain	dB	13.5	5EL Yagi x 2	11	5EL Yagi	11	5EL Yagi	8	3EL Yagi	11	5EL Yagi	11	5EL Yagi	11	5EL Yagi	8	3EL Yagi
Receiving Antenna Gain	dB	11	5EL Yagi	11	5EL Yagi 3° (0 dB)	2	5EL Yagi 53°(-9dB)	7	5EL Yagi 38°(-4dB)	2	5EL Yagi 53°(-9dB)	10	5EL Yagi 20°(-1dB)	11	5EL Yagi	9	5EL Yagi 31°(-2dB)
Branch Loss	dB	(-) 3.5		(-) 3.5		(-) 3.5		(-) 3.5		(-) 3.5		(-) 3.5		(-) 3.5		(-) 3.5	
Feeder Loss	dB	(-) 2.8	10D-2V 35+35m	(-) 2	10D-2V 15+35m	(-) 2.8	10D-2V 35+35m	(-) 2	10D-2V 15+35m	(-) 2	10D-2V 15+35m	(-) 2	10D-2V 15+35m	(-) 2.8	10D-2V 35+35m	(-) 2	10D-2V 15+35m
Free Space Loss	dB	(-)106.0	70 MHz 68.0km	(-)99.2	70 MHz 31.1km	(-)99.2	70 MHz 31.3km	(-)93.0	70 MHz 15.3km	(-)72.9	70 MHz 1.5km	(-)99.7	70 MHz 32.9km	(-)106.2	70 MHz 70.0km	(-)107.4	70 MHz 80.2km
Additional Loss	dB	(-)45.5		(-)44.5		(-)37.7		(-) 30		(-) 53		(-)45		(-) 42		(-) 15	
Receiving Power	dBm	-90.3		-84.2		-82.2		-83.5		-35.7		-86.2		-89.5		-80.9	
Receiving Noise Power	dBm	-115		-115		-115		-115		-115		-115		-115		-115	
Radio Frequency S/N (C/N)	dB	24.7		30.8		32.8		31.5		79.3		28.8		25.5		34.1	
S/N Improvement Factor	dB	12		12		12		12		12		12		12		12	
Standard S/N	dB	36.7		42.8		44.8		43.5		91.3		40.8		37.5		46.1	
Fading Loss	dB	(-) 6.8	0.1dB/km	(-) 3.1	0.1dB/km	(-) 3.1	0.1dB/km	(-) 1.5	0.1dB/km	(-) 0.2	0.1dB/km	(-) 3.3	0.1dB/km	(-) 7.0	0.1dB/km	(-) 8.0	0.1dB/km
S/N at Fading	dB	29.9		39.7		41.7		42.0		91.1		37.5		30.5		53.1	
Threshold Level	dBm	-106		-106		-106		-106		-106		-106		-106		-106	
Fading Margin Relative to Threshold Level	dB	15.7		21.8		23.8		22.5		70.3		19.8		16.5		25.1	
Margin Relative to Threshold Level at Fading	dB	8.9		18.7		20.7		21.0		70.1		16.5		9.5		32.1	

Table 4.5 Circuit Design Table at Test Condition (Kinabatangan River Basin)

Item \ Span		Tongod –Mt. Balat (68.0km)		Tangkulap –Mt. Balat (31.1km)		Ulu Kuamut –Mt. Balat (31.3km)		Kuamut –Mt. Balat (15.3km)		Balat –Mt. Balat (1.5km)		Bukit Garam –Mt. Balat (32.9km)		Bilit –Mt. Balat (70.0km)		Trig Hill –Mt. Balat (80.2km)	
Transmitting Power	dBm	38.8	7W	39	8W	38.9	7.7W	38.3	6.7W	38.8	7.5W	39	8W	39.1	8.2W	39.1	8.2W
Transmitting Antenna Gain	dB	8	3EL Yagi	8	3EL Yagi	8	3EL Yagi	8	3EL Yagi	8	3EL Yagi	8	3EL Yagi	8	3EL Yagi	8	3EL Yagi
Receiving Antenna Gain	dB	8	3EL Yagi	8	3EL Yagi	8	3EL Yagi	8	3EL Yagi	8	3EL Yagi	8	3EL Yagi	8	3EL Yagi	8	3EL Yagi
Feeder Loss	dB	(-) 3.2	5D-2V 16+16m	(-) 3.2	5D-2V 16+16m	(-) 3.2	5D-2V 16+16m	(-) 3.2	5D-2V 16+16m	(-) 3.2	5D-2V 16+16m	(-) 3.2	5D-2V 16+16m	(-) 3.2	5D-2V 16+16m	(-) 3.2	5D-2V 16+16m
Free Space Loss	dB	(-) 106	70 MHz 68.0km	(-)99.2	70 MHz 31.1km	(-)99.2	70 MHz 31.3km	(-) 93	70 MHz 15.3km	(-)72.9	70 MHz 1.5km	(-)99.7	70 MHz 32.9km	(-)106.2	70 MHz 70.0km	(-)107.4	70 MHz 80.2km
Additional Loss	dB	(-) 51		(-)47.5		(-)49.5		(-)32.5		(-)65		(-)45		(-) 56		(-) 15	
Compensation Value	dB	(-) 8.6		(-) 8.1		(-) 8.5		(-) 9.1		(-) 7.7		(-) 8.1		(-) 7.2		(-) 7.5	
Receiving Power	dBm	-114		-103		-105.5		-83.5		-94		-101		-117.5		-78	

Table 4.6 Circuit Design Table (Kinabatangan River Basin)

Item	Span	Tongod –Mt. Balat (68.0km)		Tangkulap –Mt. Balat (31.1km)		Ulu Kuamut –Mt. Balat (31.3km)		Kuamut –Mt. Balat (15.3km)	
Transmitting Power	dBm	43	20W	43	20W	43	20W	30	1W
Transmitting Antenna Gain	dB	13.5	5EL Yagi x 2	11	5EL Yagi	11	5EL Yagi	8	3EL Yagi
Receiving Antenna Gain	dB	11	5EL Yagi	11	5EL Yagi 3°(0 dB)	2	5EL Yagi 53°(-9dB)	7	5EL Yagi 38°(-4dB)
Branch Loss	dB	(-) 3.5		(-) 3.5		(-) 3.5		(-) 3.5	
Feeder Loss	dB	(-) 2.8	10D-2V 35+35m	(-) 2	10D-2V 15+35m	(-) 2.8	10D-2V 35+35m	(-) 2	10D-2V 15+35m
Free Space Loss	dB	(-)106.0	70 MHz 68.0km	(-)99.2	70 MHz 31.1km	(-)99.2	70 MHz 31.3km	(-)93.0	70 MHz 15.3km
Additional Loss	dB	(-)45.5		(-)44.5		(-)37.7		(-) 30	
Compensation Value	dB	(-) 8.6		(-) 8.1		(-) 8.3		(-) 9.1	
Receiving Power	dBm	-98.9		-92.3		-95.5		-92.6	
Receiving Noise Power	dBm	-115		-115		-115		-115	
Radio Frequency S/N (C/N)	dB	16.1		22.7		19.5		22.4	
S/N Improvement Factor	dB	12		12		12		12	
Standard S/N	dB	28.1		34.7		31.5		34.4	
Fading Loss	dB	(-) 6.8	0.1dB/km	(-) 3.1	0.1dB/km	(-) 3.1	0.1dB/km	(-) 1.5	0.1dB/km
S/N at Fading	dB	21.3		31.6		28.4		32.9	
Threshold Level	dBm	-106		-106		-106		-106	
Fading Margin relative to Threshold Level	dB	7.1		13.7		10.5		13.4	
Margin relative to Threshold Level at Fading	dB	0.3		10.6		7.4		11.9	

Item	Span	Balat –Mt. Balat (1.5km)		Bukit Garam –Mt. Balat (32.9km)		Bilit –Mt. Balat (70.0km)		Trig Hill –Mt. Balat (80.2km)	
Transmitting Power	dBm	34.8	3W	43	20W	43	20W	30	1W
Transmitting Antenna Gain	dB	11	5EL Yagi	11	5EL Yagi	11	5EL Yagi	8	3EL Yagi
Receiving Antenna Gain	dB	2	5EL Yagi 53°(-9dB)	10	5EL Yagi 20°(-1dB)	11	5EL Yagi	9	5EL Yagi 31°(-2dB)
Branch Loss	dB	(-) 3.5		(-) 3.5		(-) 3.5		(-) 3.5	
Feeder Loss	dB	(-) 2	10D-2V 15+35m	(-) 2	10D-2V 15+35m	(-) 2.8	10D-2V 35+35m	(-) 2	10D-2V 15+35m
Free Space Loss	dB	(-)72.9	70 MHz 1.5km	(-)99.7	70 MHz 32.9km	(-)106.2	70 MHz 70.0km	(-)107.4	70 MHz 80.2km
Additional Loss	dB	(-) 5 3		(-) 45		(-) 42		(-) 15	
Compensation Value	dB	(-) 7.7		(-) 8.1		(-) 7.2		(-) 7.5	
Receiving Power	dBm	-91.3		-94.3		-96.7		-88.4	
Receiving Noise Power	dBm	-115		-115		-115		-115	
Radio Frequency S/N (C/N)	dB	23.7		20.7		18.3		26.6	
S/N Improvement Factor	dB	12		12		12		12	
Standard S/N	dB	35.7		32.7		30.3		38.6	
Fading Loss	dB	(-) 0.2	0.1dB/km	(-) 3.3	0.1dB/km	(-) 7.0	0.1dB/km	(-) 8.0	0.1dB/km
S/N at Fading	dB	35.5		29.4		23.3		30.6	
Threshold Level	dBm	-106		-106		-106		-106	
Fading Margin relative to Threshold Level	dB	14.7		11.7		9.3		17.6	
Margin relative to Threshold Level at Fading	dB	14.5		8.4		2.3		9.6	

Fig. 4.4 Horizontal-Direction Characteristic 5-Element Yagi Antenna
(Kinabatangan River Basin) from Balat Relay Station

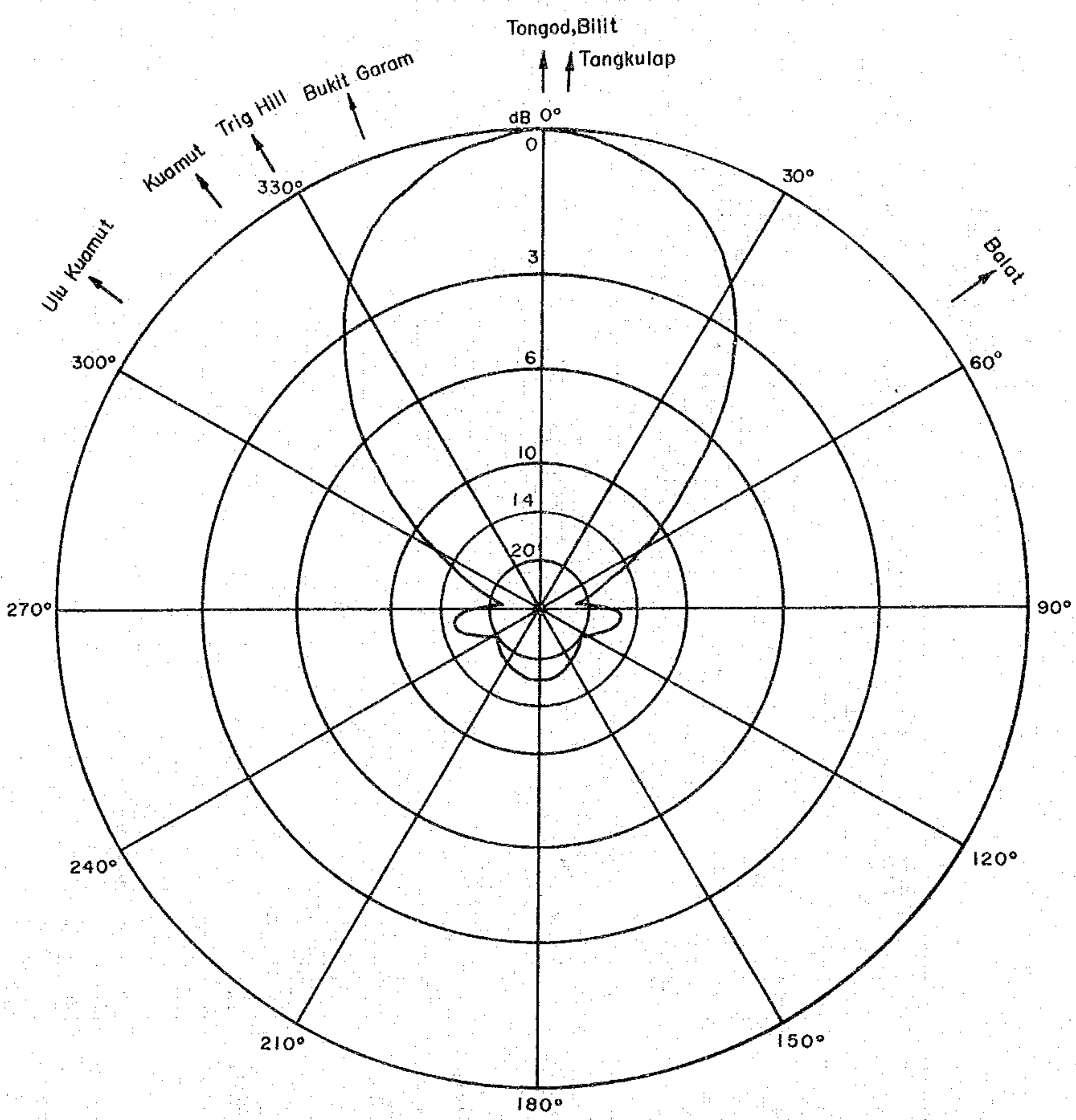
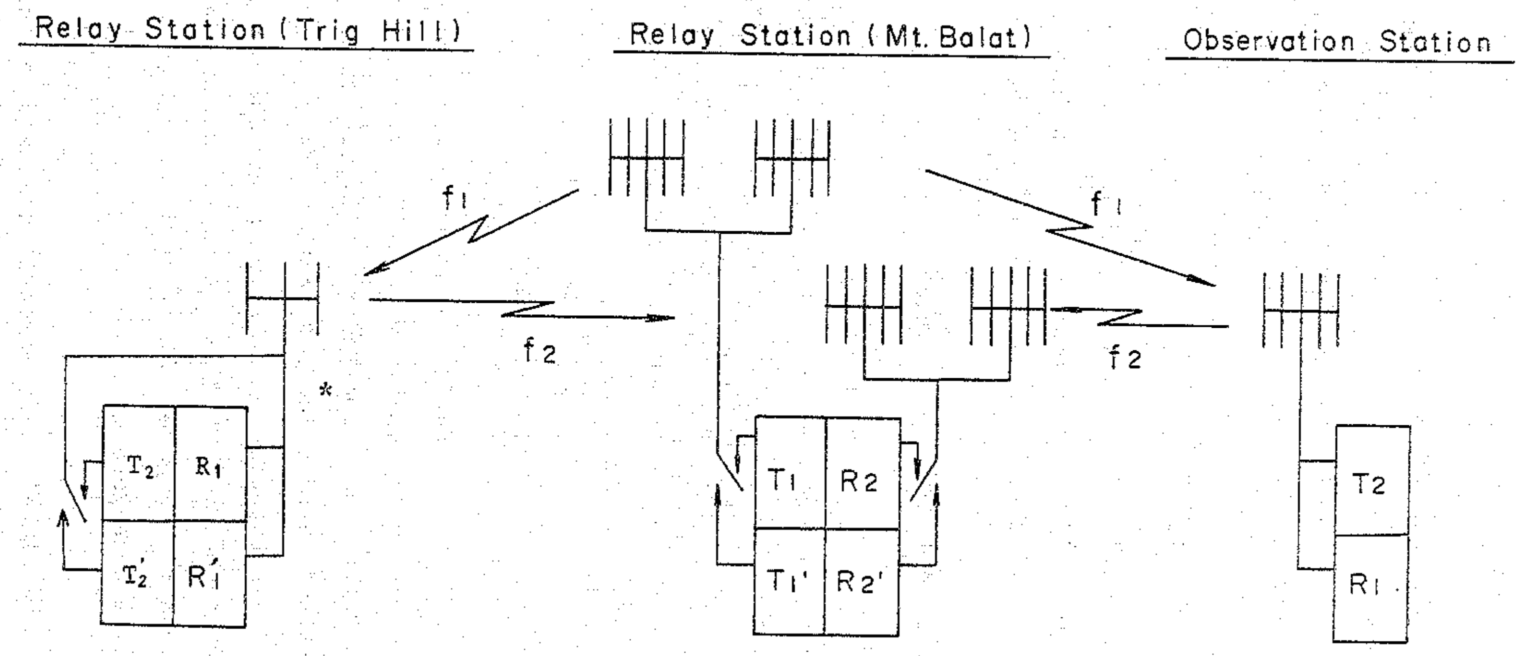


Fig. 4.5 Relay System of Telecommunication Network
(Kinabatangan River Basin)



* Parallel Receiving for Combined gain

T : Transmitter

R : Receiver

f1 f2 : 70MHz Band Radio Frequency

4.4 Sitting Conditions of Stations

4.4.1 Master Control Station

The DID Office in Inanam, situated in the outskirts of Kota Kinabalu, is now connected with Sandakan by SSB radio link. The premises are wide enough to accommodate the Master Control Station.

4.4.2 Monitoring Station

Sandakan's existing DID Office occupies a room in the joint administrative building, therefore the minimum required space for the Monitoring Station is to be secured.

4.4.3 Trig Hill Relay Station

Located on the hill 2.5 km to the west of Sandakan city center, it has a clear perspective in the direction of Mt. Balat. There is a Telecommunication Department's relay station here with its structure, steel tower, access road and power supply. Making use of these facilities offers a great advantage in construction and maintenance.

4.4.4 Mt. Balat Relay Station

This relay station is located on top of Mt. Balat (275 m above see level) which could be reached by driving 15 minutes on a timber road from Balat. Situated almost in the center of scattered observation stations, it is considered to be in a favorable location. The site is now surrounded by 20 to 25 m high treees, but it will not constitute any problem if the antenna is raised or the trees are cleared. It will, however, require some leveling.

The timber road, which is now used as the temporary access road, may have to be secured for extended use.

4.4.5 Tongod Rainfall & Water Level Gauging Station

This gauging station is to be located at the uppermost point in the proposed network and on the left bank of the Kinabatangan River. Since there are lots of trees growing along the river, some of them will have to be felled and the land leveled. Though the place relatively opens out in the direction of Mt. Balat, a mountain is in between hindering a clear connection. Therefore it is necessary to raise the antenna equipment as high as practically possible.

4.4.6 Tangkulap Rainfall & Water Level Gauging Station

This gauging station is located about 30 km west of Balat. There are many tall trees surrounding the existing station. It is therefore desirable that the new station be placed at a clearing in front of the shop house on the right bank a little downstream.

4.4.7 Ulu Kuamut Rainfall & Water Level Gauging Station

There is an existing station here on the right bank of the Kuamut River some 15 km upstream of Kuamut. Though the place opens out in the direction of Mt. Balat, there are tall trees around. Therefore it is necessary to raise the antenna equipment as high as practically possible.

4.4.8 Kuamut Rainfall & Water Level Gauging Station

This station is situated about 15 km upstream of Balat. The existing DID Field Office there will greatly facilitate the maintenance operation. The premises are wide enough and fairly open to the direction of Mt. Balat.

4.4.9 Balat Rainfall & Water Level Gauging Station

There is an existing water level gauging installation on the left bank of the Kinabatangan River at the foot of Mt. Balat. Since there are many trees growing around the proposed location, it may be necessary to fell some of the trees at the time of construction.

4.4.10 Bukit Garam Rainfall & Water Level Gauging Station

The station is located about 33 km downstream of Balat. There are many houses around it but not many trees. Siting it on the left bank will facilitate construction greatly.

4.4.11 Bilit Water Level Gauging Station

This water level gauging station is located at the most downstream point of the Kinabatangan River in the proposed telemetry system, some 70 km from Balat. An open space on the left bank with houses around will provide the site for the station. But with tall trees standing in the direction of Mt. Balat, it is necessary to raise the antenna equipment high enough for good radio circuit.

4.5 Proposed Telemetry System

As already mentioned, it is considered possible to establish an adequate telecommunication circuit for the flood forecasting and warning system in the Kinabatangan river basin. The following is the outline of the proposed telemetry system.

4.5.1 Master Control Station

The Master Control Station performs supervision and control of the telemetry system, which includes the calls to observation stations, supervision of the operation of relay stations and typewriter print-out of hydrological data sent from observation stations. In addition, it is to have a function of computing at least the hourly rainfalls and indicating the hydrological conditions thus obtained of the entire basin area on the display unit.

The floor space required for the telecommunication equipment of the Master Control Station will be about $20m^2$. Refer to Appendix 'M' for example of master control station plan.

4.5.2 Monitoring Station

The Monitoring Station is to watch for the hydrological data as it is being gathered by the Master Control Station. Also, it is to have a functional capability for communication with the Master Control Station and observation stations to facilitate the maintenance operation. The floor space required for the telecommunication equipment of the Monitoring Station will be about $10\ m^2$.

4.5.3 Relay Stations

The Relay Stations together with the Master Control Station, is the mainstay of the telemetry system. Therefore they are to be equipped with two sets of radio equipments consisting of a transmitter and a receiver each. To protect the equipments from lightening hazards entering from the antenna equipment, they are to be equipped with coaxial arresters.

At Trig Hill, power supply is available from the relay station of the Telecommunication Department. However, at the time of commercial power failure, power is to be supplied to the relay equipment from the DC power supply which consists of a rectifier and a storage battery. At Mt. Balat, the power supply is to be of direct current provided by the combination of solar cells and a storage battery.

The installation space required for the telecommunication equipments to be placed at the Trig Hill relay station is to be about 1 m (W) x 1 m (D) x 2 m (H).

The floor space required for the Mt. Balat relay station is to be about 5 m x 5 m.

4.5.4 Observation Stations

Upon receiving a call signal from the Master Control Station, a observation station will automatically read the hydrological data and encode them into pulse signals for transmission to the Master Control Station.

The extended distance between the water level gauge and the telemetry equipment at a water level gauging station tends to invite lightning damage. In such cases, some countermeasures are to be taken to cope with lightning hazards. Also, to provide for the protection against such lightning entering from the antenna equipment, a coaxial arrester is to be installed.

As for the power source, it is desirable that each station be supplied with DC power which consists of solar cells and a storage battery.

The floor space required for a observation station will be about 2.5 m x 2.5 m.

4.5.5 Fig. 4.6 shows the configuration of the proposed telemetry system. Fig. 4.7 shows the telecommunication network of the proposed telemetry system.

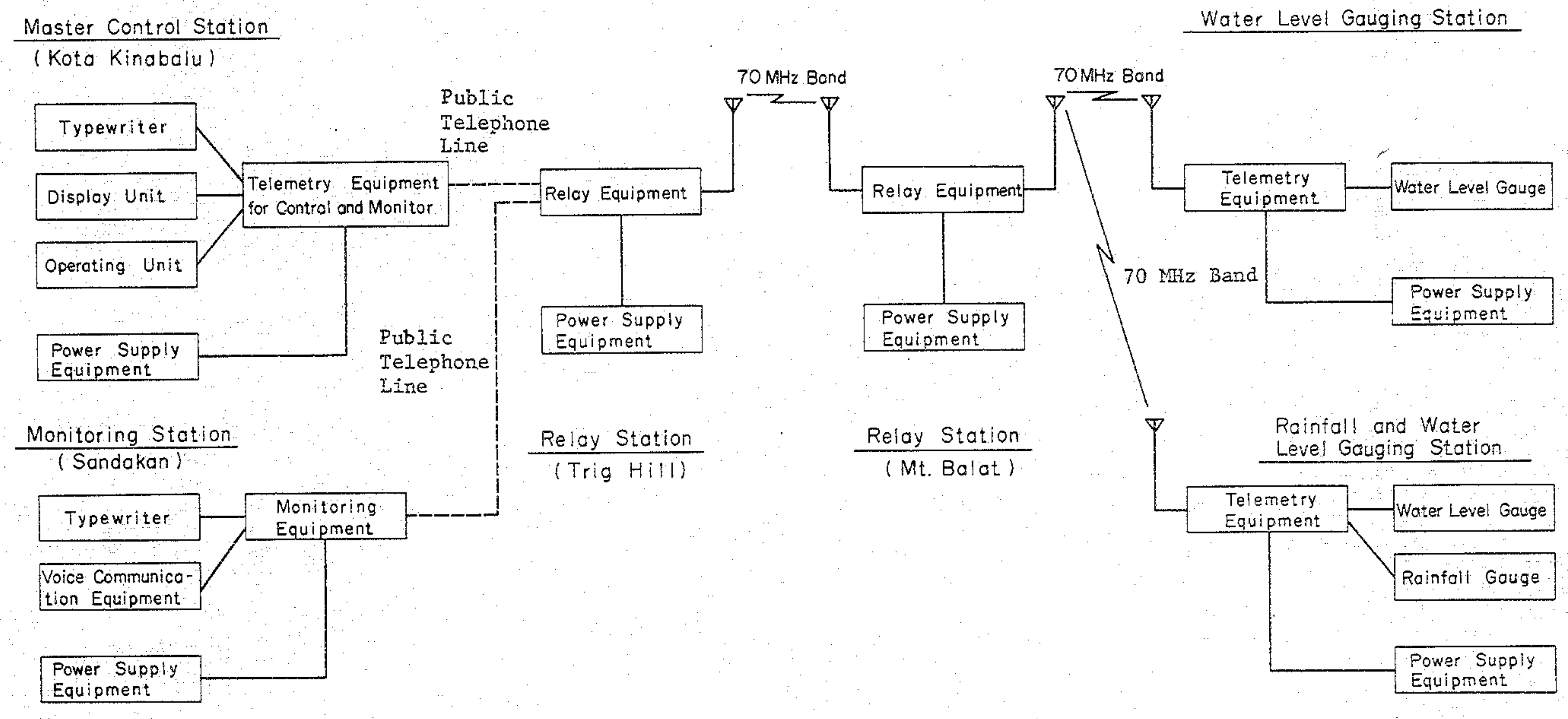
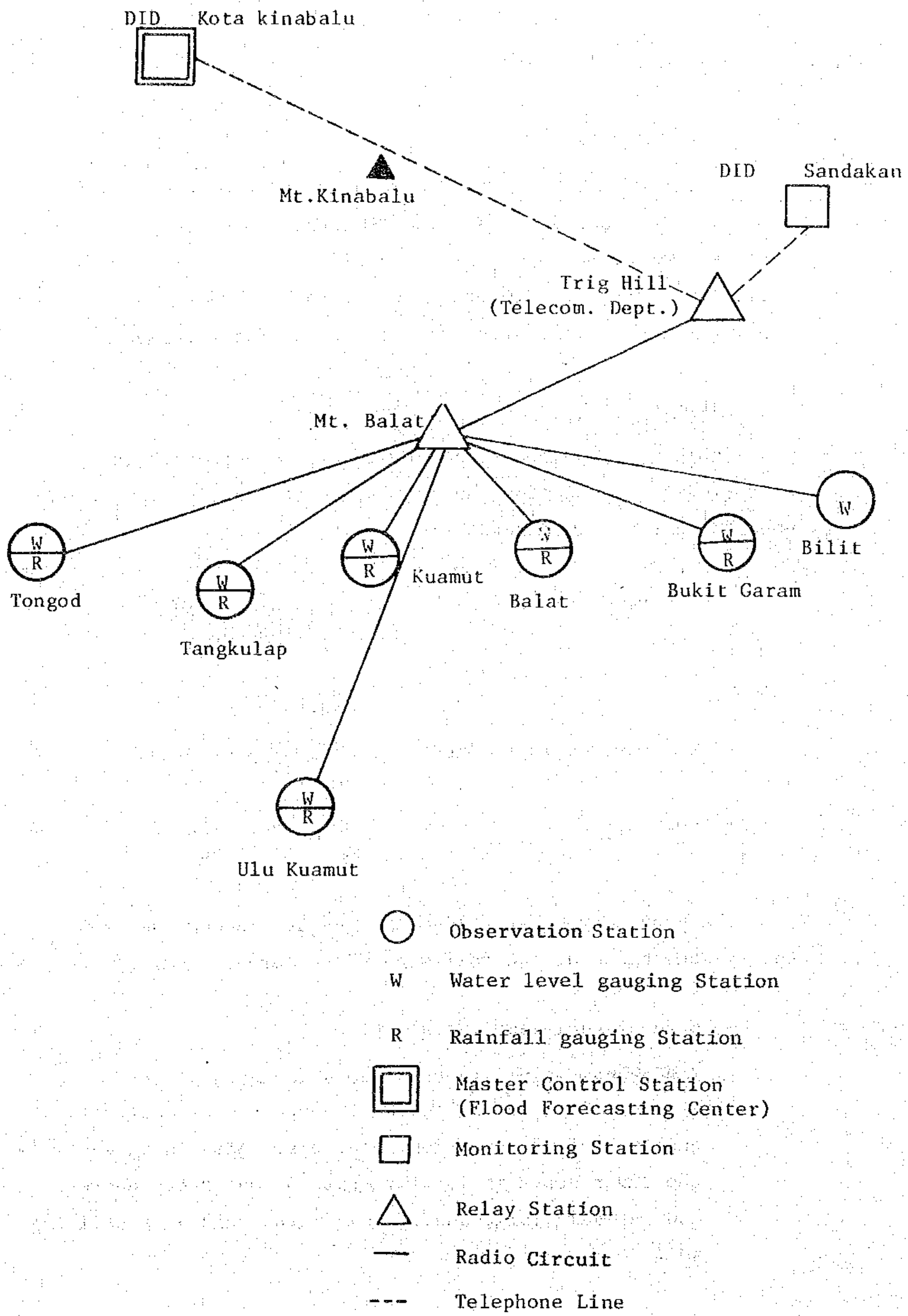


Fig. 4.6 Configuration of Proposed Telemetry System (Kinabatangan River Basin)

Fig. 4.7 Telecommunication Network of Proposed Telemetry System (Kinabatangan River)



CHAPTER 5 FACILITIES

5.1 Design of Gauging Facilities

5.1.1 Selection of Gauges

Rainfall Gauge

The rainfall gauges most commonly used are recording rain gauges. They come in such types as tipping-bucket type, tank type and weight measure type, according to the sensor configurations. For ready telemeterization, the recording-type tipping-bucket rain gauges are recommended for this system.

Water Level Gauge

Table 5.1 shows the type of water level gauges. In selecting the gauges for the system, the following conditions need to be taken into account:

- Instrumental features : Analogue or digital, easy reading
- Environmental conditions : Waves, riverbed fluctuation
- Data processing method : Necessity of manual operation
- Cost : Cost including installation and maintenance

The bubble type water level gauges are recommended for the system, based on the following field survey results:

- Ease of Equipment Installation

  Topographically disadvantageous location of the stations does not allow the transport of a large quantity of construction materials. Also in view of the river shape it is difficult to construct, operate and maintain large-scale facilities, such as a stilling well.

- Wide Range of Water Level Gauging

  The water level to be measured at the gauging points varies greatly (large difference between minimum and maximum water levels). Therefore if the float type water level gauges were employed, construction of the stilling well would be very difficult in terms of both the technical and the financial matter.

- Riverbed Evolution

  The riverbeds at the gauging points are supposed to be fluctuating greatly. It is therefore necessary to select the facilities capable of coping with such riverbed fluctuation.

- Experience

  Since the existing water level gauging stations along the Kinabatangan River have been using the bubble type gauges, the employment of the same type of gauges for the proposed system will be of greater convenience for operation and maintenance.

Table 5.1 Types and Features of Water Level Gauges

a. Float type	This type of water level gauge requires a stilling well for waveless water level measurement and a horizontal conduit (or side hole) to lead water to it. In this gauging system, a float is in the stilling well and a wire leading from the float hangs from the pulley. As the water level goes up and down, the wire moves up or down to turn the pulley, which in turn moves the pen of the recorder.

b. Pressure type	With these water level gauges, the pressure-sensitive part is positioned in the water and the stilling well is not necessary. There are water pressure type and bubble type. (i) Water pressure type The water pressure is measured by the pressure-sensitive part in a bell-shaped protective container in the water. The measurements are brought to the recorder by means of two pipes for temperature compensation. The recorder with a 40-day roll of paper can be put in a watertight container. (ii) Bubble type A very small amount of gas is sent out from a pipe opening in the water. When the gas pressure balances with the water pressure, the water level can be determined by measuring the gas pressure.
c. Sensor pole type	With this type of water level gauge, the sensor pole is lowered slowly until it reaches the water surface and the pulley rotations required are detected electrically. In the other type, the water surface is always followed with one of the sensor poles kept in contact with the water and the other kept apart from it.

d.	Reed switch type	This water level gauge has a pipe standing in the water which incorporates reed switches placed at intervals of 1 cm. As a magnet attached to a float moves up and down within the pipe, the reed switches open or close, indicating the water level. This water level gauge features the recording of limitless height range, (cm minimum reading, print-out or cassette tape type and 3-month long recording period at 10-min. interval.

5.1.2 Design of Gauging Facilities

Siting of Station Housings

1) Rainfall gauging stations

It is desirable that the area projected in this system be divided as such the rainfalls over respective areas are about equal to one another and one rainfall gauging station located in each area. Actual siting of the stations, however, should be made according to the following criteria:

- Availability of easy access to station for operation and maintenance of gauges and other equipment

- No hazard from winds and other factors that would affect observation data

- Availability of place with enough floor space for (minimum 2.5m x 2.5m) and enough housing site (min. 10m x 10m)

- No possibility of inundation

Appendix shows the proposed sites of the rainfall fauging stations in the Kinabatangan river basin selected according to the above criteria by the field survey team.

2) Water level gauging stations

Water level gauging stations are to be located in areas considered necessary for the flood forecasting purpose. Actual siting of the stations, however, should be made according to the following criteria:

- Easy operation and maintenance of gauges and other equipment
- Slow riverbed evolution
- Safe observation during flood
- Possibility of observation during low-water period
- Protection from flood hazards, such as waves and driftwood

Appendix shows the proposed sites of the water level gauging stations in the Kinabatangan river basin selected according to the above criteria by the field survey team.

Though the siting conditions for the rainfall gauging stations and the water level gauging stations have been described separately, all the hydrological gauging stations proposed in the Kinabatangan river basin are the rainfall as well as water level gauging stations except the one at Bilit which is designed for water level observation only.

Therefore it is considered both economical and advantageous from the view of operation and maintenance if the rainfall gauge is installed at the water level gauging station and the same telecommunication equipment is used for both observations.

Design Standard for Equipment Housing

1) Housing

Each telemetering station is to have a housing for the hydrological gauging equipment and telecommunication equipment.

The housing for the water level gauging station as well as the rainfall and water level gauging station is to be a reinforced concrete structure of 2.5m x 2.5m considered suitable for the placement of the various devices to be housed.

The equipment housing needs to be located where it is safe from inundation, i.e., the housing floor level must be determined giving sufficient clearance from the maximum water level expected.

Where there is a stout levee against flooding, the housing is to be set up on the bank. In locations where the bank does not have enough levee free-board, it must be constructed on top of a steel tower of about 10 m.

The telemetering stations and their equipment housing locations are as follows:

Station	Housing Location
1. Tongod	River bank
2. Tangkulap	Steel tower
3. Ulu Kuamut	River bank
4. Kuamut	Steel tower
5. Balat	River bank
6. Bukit Garam	Steel tower
7. Bilit	Steel tower

2) Tele-pole and triangular steel tower

The telemetering stations at Tangkulap, Kuamut, Balat and Bukit Garam are to be provided with a 10 meter-high steel pole for the antenna.

Those at Tongod, Ulu Kuamut and Bilit are to be provided with a 30 meter-high triangular steel tower for the antenna (The tower height is subject to change after detailed design.).

5.1.3 Designing of Relay Stations

Two relay stations for telemetry net work are required to be set up to secure good radio wave propagation paths because each telemetering station is remote from the Flood Forecasting Center.

One relay station is to be located on top of Mt. Balat where the equipment will be newly installed within the station housing, whereas another station is to be installed within the existing Telecommunication Department structure on Trig. Hill.

The equipment housing to be built newly for relay station will have a floor space of 5m x 5m.

5.1.4 Flood Forecasting Center

Flood Forecasting Center is to be placed at Kota Kinabalu, the state capital of Sabah. The center is to have the function of master control station for the proposed flood forecasting and warning system, serving as the mainstay of the whole system. The facility is proposed to be placed within D.I.D. Inanam Office which would occupy 20 m^2 of floor space.

5.2 Design of Telemetry Facilities

Telemetry stations proposed for the flood forecasting and warning system are classified and listed as follows:

Table 5.2 Telemetry Station

Classification	Station	Quantity
Master Control Station	Kota Kinabalu	1
Relay Station	Trig Hill, Mt. Balat	2
Water-level Gauging Station	Bilit	1
Water-level and Rainfall Gauging Station	Tongod, Tangkulap, Kuamut, Ulu Kuamut, Balat, Bukit Garam	6
Monitoring Station	Sandakan	1

Each facilities of telemetry station classfied are stated in the following sections.

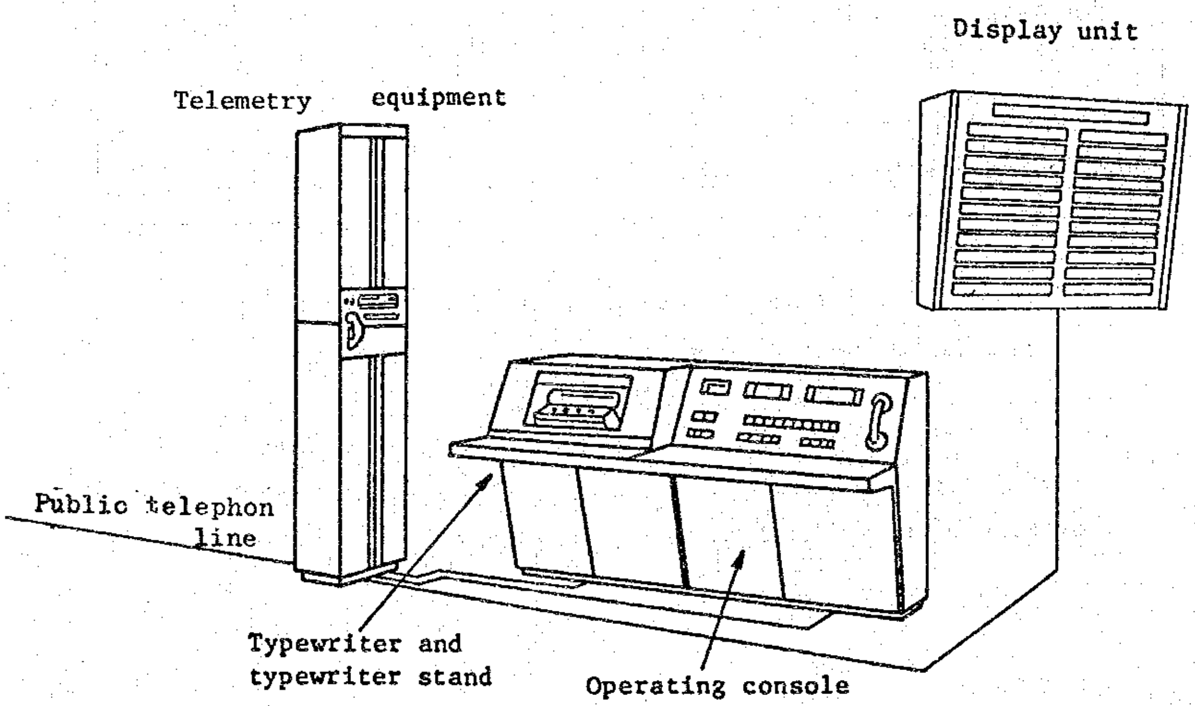
Further, representative specifications of telemetry facilities and example of capacity calculation for solar cell and storage battery are described in Appendix.

5.2.1 Master Control Station Equipment

Composition

The master control station consists of the following equipment :

- Telemetry equipment for control
- Operating console
- Typewriter and typewriter stand
- Display unit
- Clock
- Power supply equipment

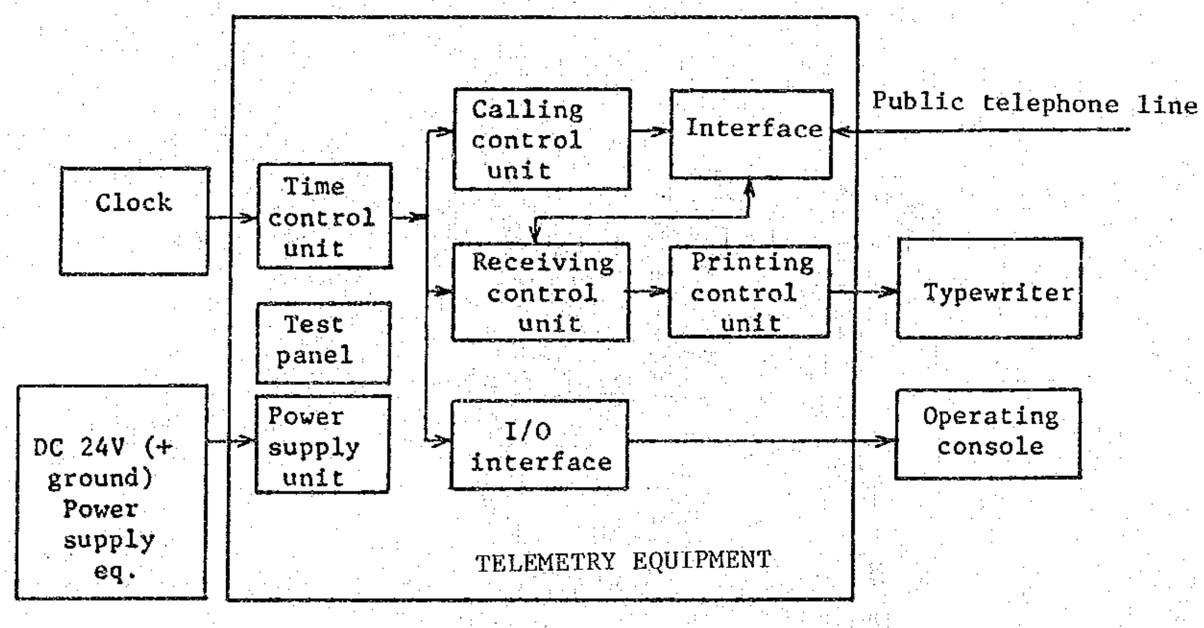


Master Control Station Equipment Composition

Telemetry Equipment

This equipment is a sheet iron bay type having exterior dimensions of approximately 2350 mm x 520 mm x 250 mm. A calling control unit, receiving control unit, printing control unit, relay control unit, power supply unit, and test panel are housed in this bay. Each unit is of plug-in type for convenient inspection, except the power supply unit and test panel.

The block diagram of the telemetry equipment for Master Control Station is given below.



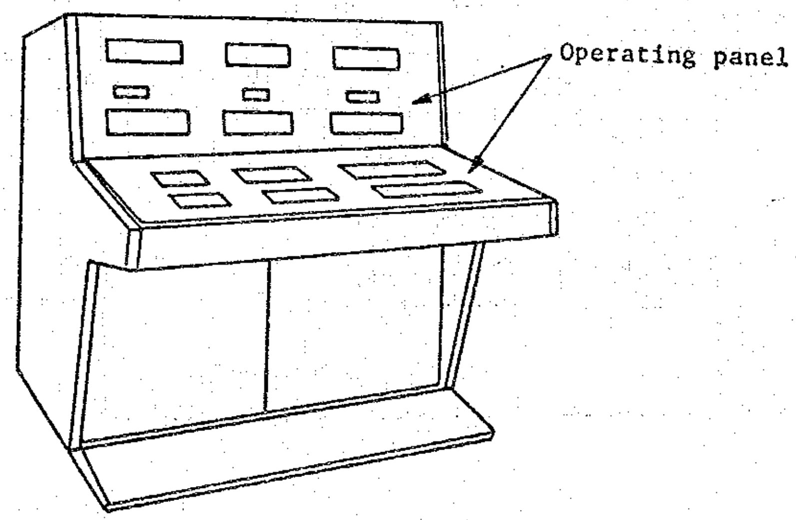
Telemetry Equipment for Master Control Station
Block Diagram

Operating Unit

Operating unit is a console type and has the following functions:

Operation items and display items

- Calling time interval setting
- Manual measurement (all or individual calling control)
- Gauging station operation display and receiving failure display
- Measured value digital display
- Relay station start, stop, switching control
- Relay station status display
- Equipment operation and status display
- Alarm sounding at a failure and stopping
- Voice communication by handset and speaker
- Volume control



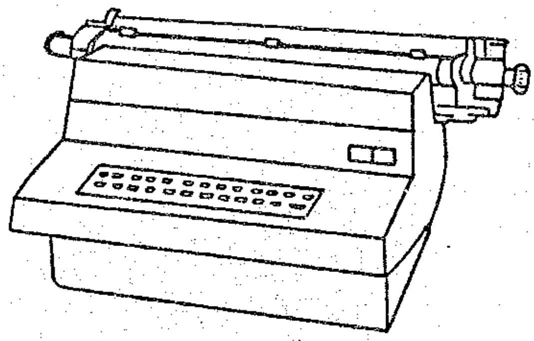
Exterior View of Operating Console

Typewriter

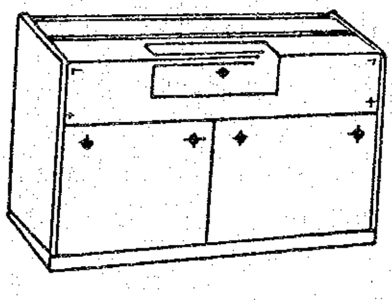
A 24 inches platen typewriter is used. Standard printing speed and character size are as follows:

Printing speed:	250ms/char or less
Character size:	12 chars/inch

The typewriter is normally housed in a typewriter stand such as that shown below for dustproofing and soundproofing.



(a) Exterior view of typewriter

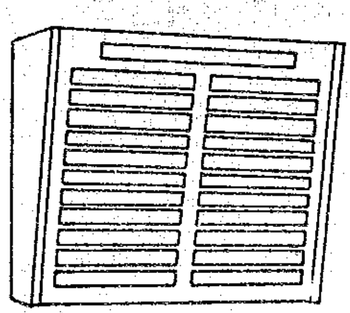


(b) Exterior view of typewriter stand

Display Unit

This unit displays the collected data by a wall-mount type numerical display. Water-level rising, falling or abnormal water-level, etc. may also be displayed. A display unit is not always necessary, but has many advantages such as:

- Data can be grasped simultaneously by a large number of persons.
- Status in river basins can be grasped at a glance.
- Back-up when trouble occurs at the typewriter.



Wall-mount type

Exterior View of Display Unit

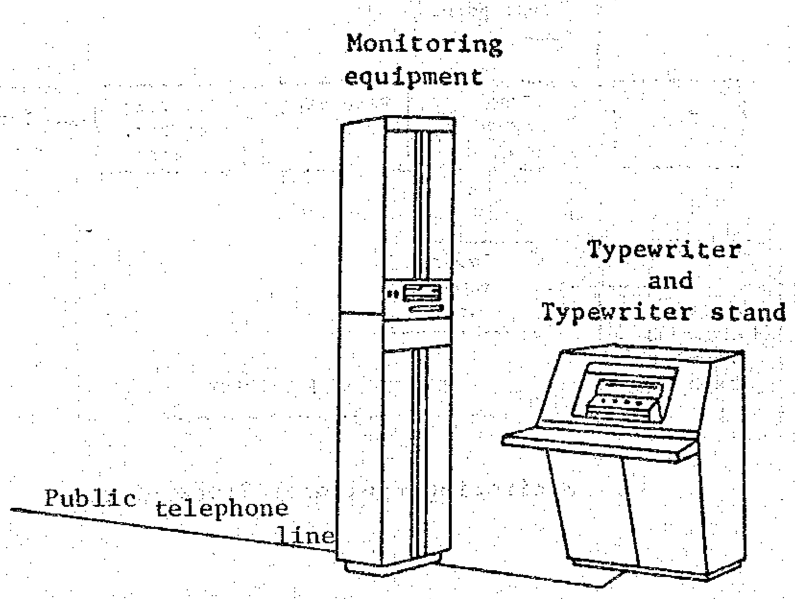
5.2.2 Monitoring Station Equipment

This equipment is installed to monitor the measured data collected by the master control station.

Composition

The monitoring station equipment consists of the following:

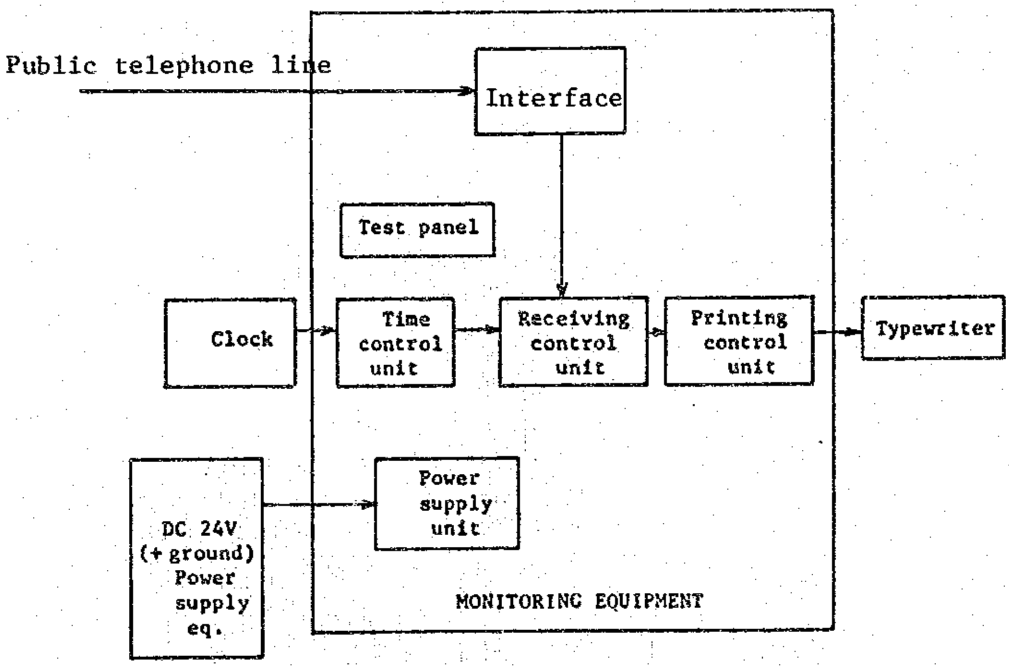
- Monitoring equipment
- Typewriter and typewriter stand
- Voice communication equipment
- Clock
- Power supply equipment



Monitoring Station Equipment Composition

Monitoring equipment

The monitoring equipment consists of the telemetry equipment for master control station without the calling function but with unique monitoring station circuits added. The test panel has data monitoring and units check functions. The block diagram of the monitoring equipment is given below.



Monitoring Equipment Block Diagram

5.2.3 Relay Station Equipment

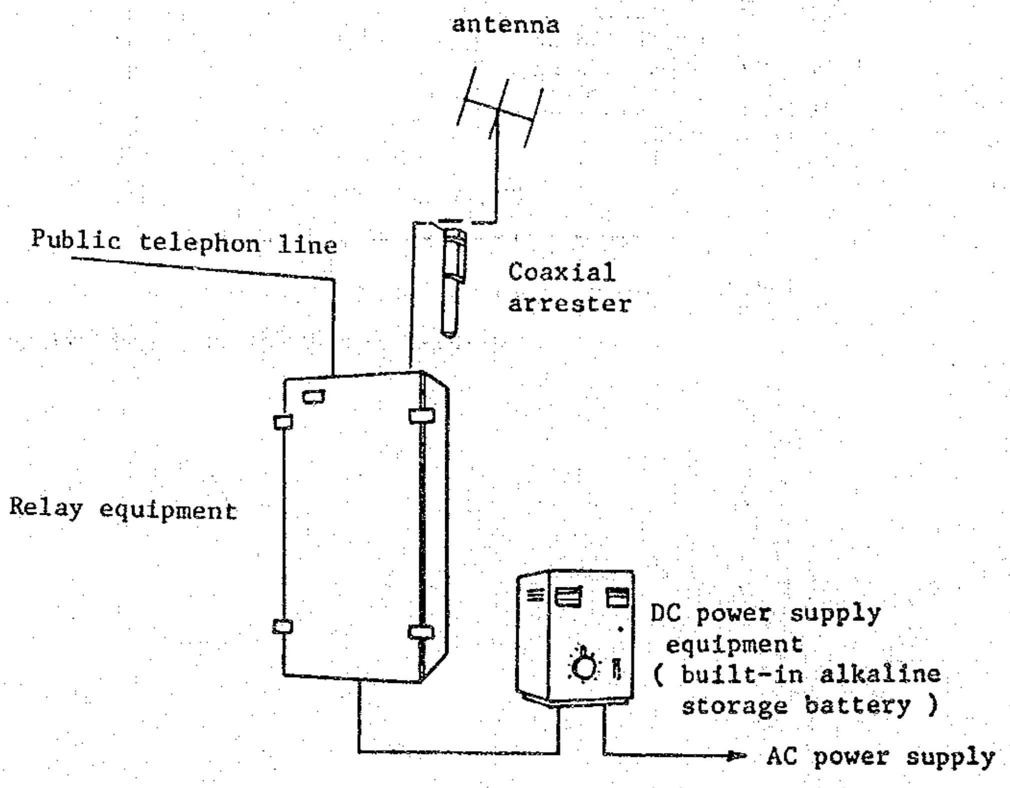
Trig Hill Relay Station Equipment

The Trig Hill relay station equipment has the following two main functions:

- Relay between master control station and Mt. Balat relay station
- Remote control and self-check of relay station

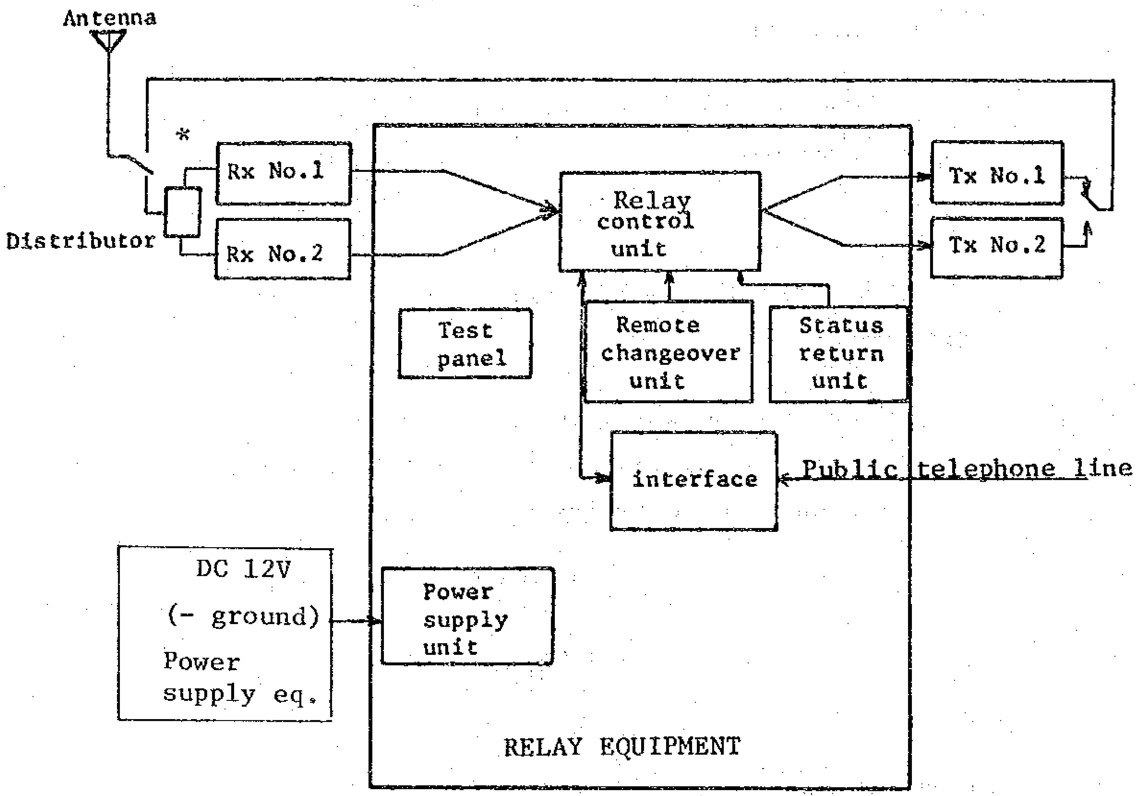
The Trig Hill relay station equipment consists of the following:

- Relay equipment (containing radio equipment)
- Antenna equipment (with coaxial arrester)
- Power supply equipment



Trig Hill Relay Station Equipment Composition

The block diagram of the Trig Hill relay equipment is given below.



Trig Hill Relay Equipment Block Diagram

* Parallel receiving for combined gain

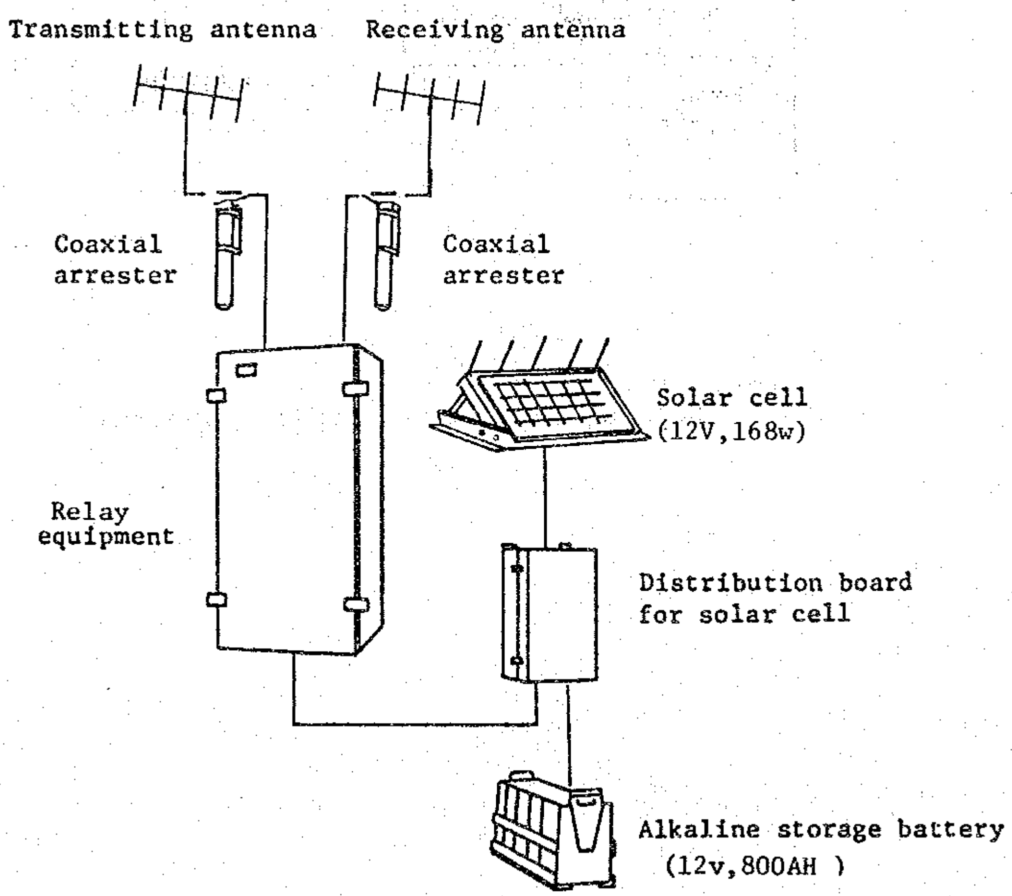
Mt. Balat Relay Station Equipment

The Mt. Balat relay station equipment has the following two main functions:

- Relay between Trig Hill relay station and each gauging station.
- Remote control and self-check of relay station.

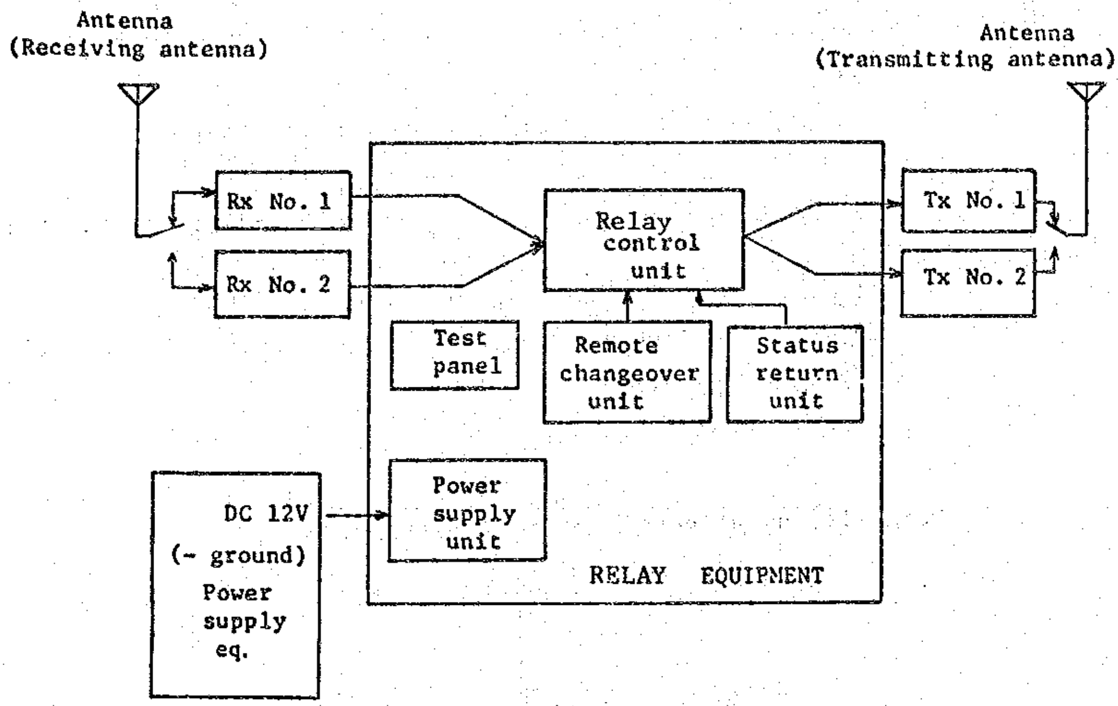
The Mt. Balat relay station equipment consists of the following:

- Relay equipment (containing radio equipment).
- Antenna equipment (transmitting, receiving, 1 each, with coaxial arrester).
- Power supply equipment.



Mt. Balat Relay Station Equipment Composition

The block diagram of the Mt. Balat relay equipment is given below.



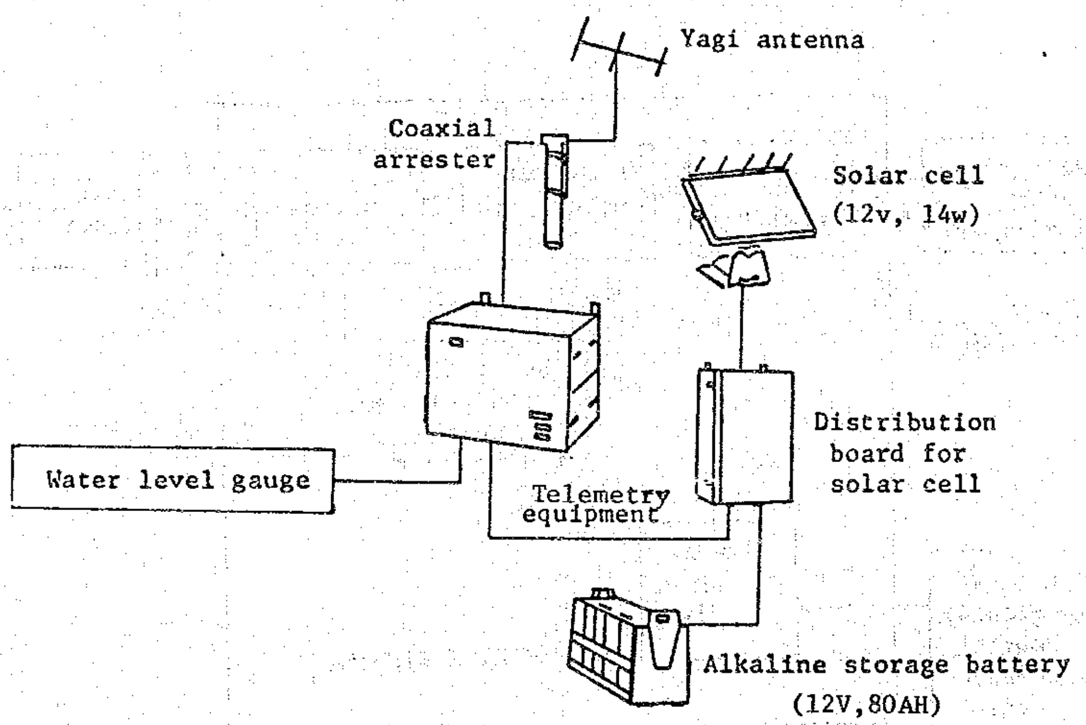
Mt. Balat Relay Equipment Block Diagram

5.2.4 Water Level Gauging Station Equipment

Composition

The water level gauging station equipment consists of the following equipment:

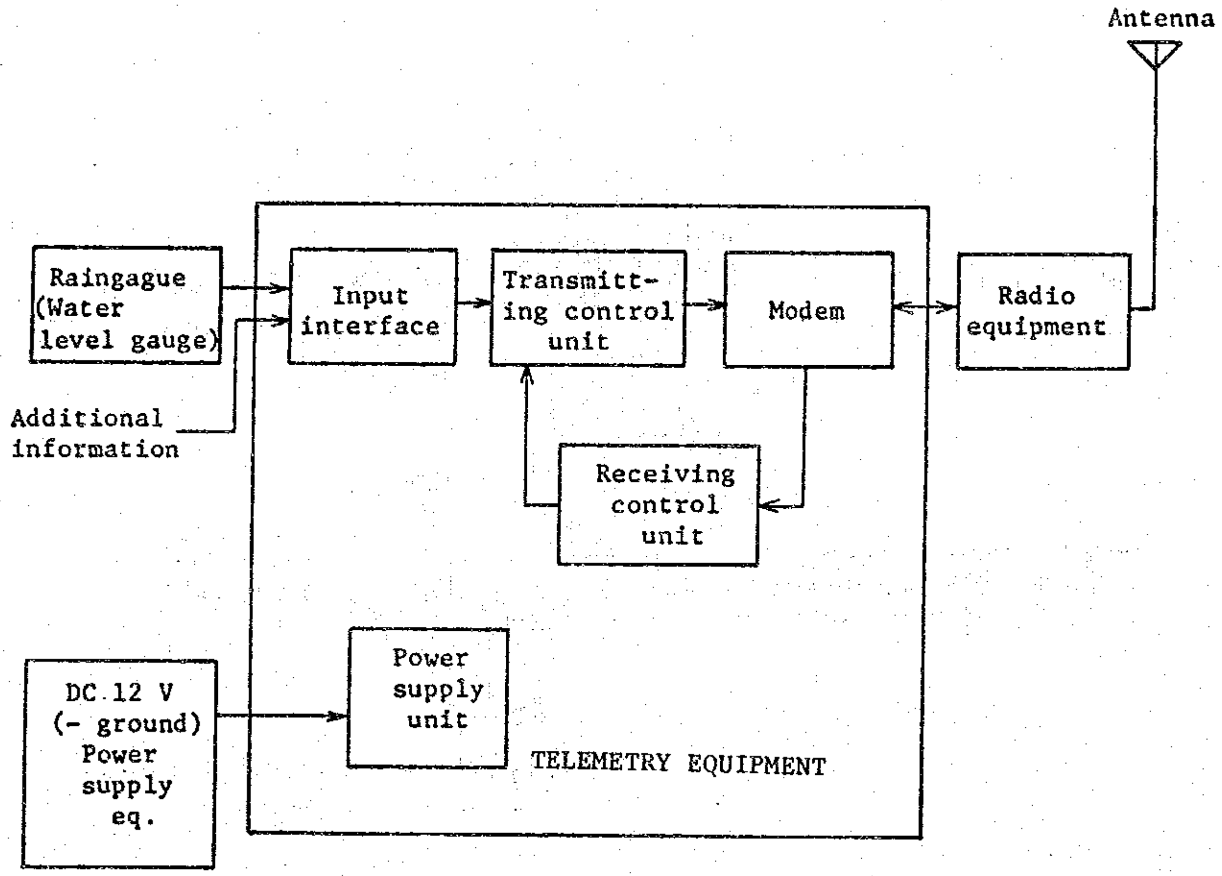
- Telemetry equipment (containing radio equipment)
- Water level gauging equipment
- Power supply equipment
- Antenna equipment (with coaxial arester)



Water Level Gauging Station Equipment Composition

Telemetry Equipment

This is the main part of the gauging station equipment, and includes a modem, transmitting and receiving control unit, input interface and power supply unit.
All circuits are accommodated on plug-in printed circuit boards for convenient inspection.
Since the installation site is unmanned and frequently humid, a moistureproof construction must be amply considered.
The block diagram of the gauging station equipment is given below.



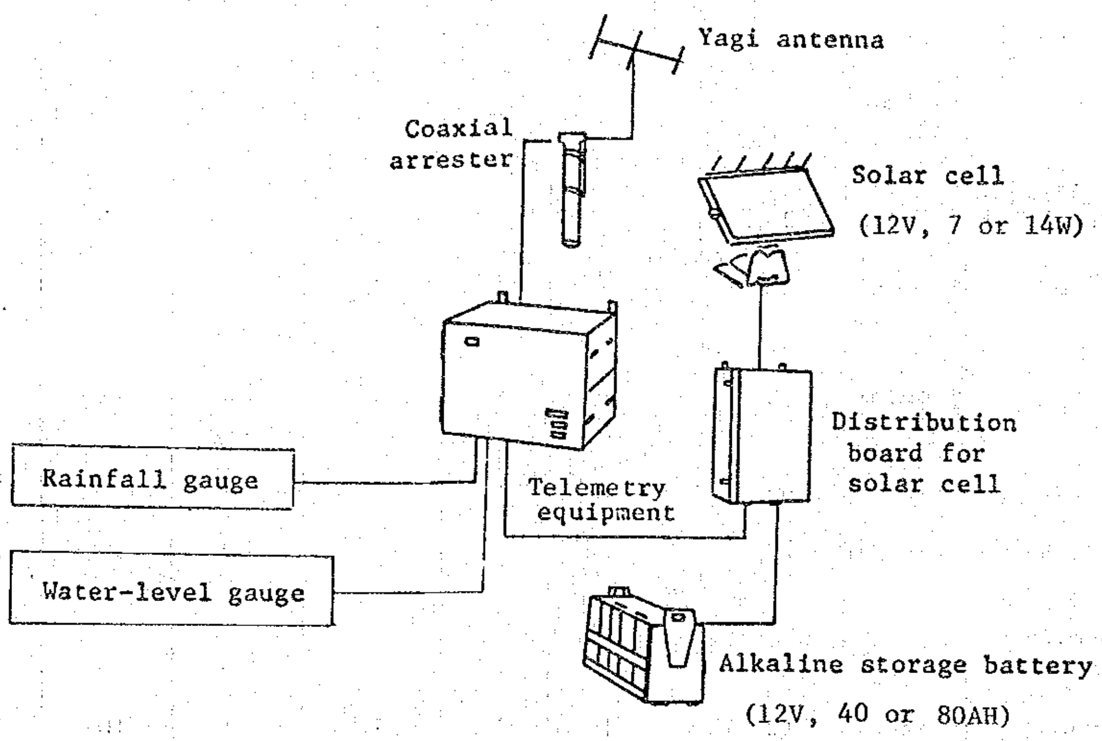
Telemetry Equipment Block Diagram

5.2.5 Rainfall and Water Level Gauging Station Equipment

Composition

The rainfall and water level gauging station equipment consists of the following equipment:

- Telemetry equipment (containing radio equipment)
- Rainfall gauging equipment
- Water level gauging equipment
- Power supply equipment
- Antenna equipment (with coaxial arrester)



Rainfall and Water Level Gauging Station Equipment Composition

5.3 System Component

5.3.1 Civil Work

Table 5.3 Flood Forecasting and Warning System Facilities (Kinabatangan River)

No.	Station	Housing Space	Equipment (2) Antenna	Rainfall	Water Level	Float Dropper	Current Meter	Tower for Housing	Staff Gage	Access (3)
			m	set	set	set	set	m	m	set
1	FFC Kota Kinabalu	$20m^2$	-	-	-	-	-	-	-	-
2	Monitoring Sandakan	$10m^2$	5	-	-	-	-	-	-	-
3	Relay St. Trig Hill	(1) 1x1 (Height 2m)	-	-	-	-	-	-	-	-
4	Relay St. Mt. Balat	5x5	30	-	-	-	-	-	-	1
5	Tongod	2.5x2.5	30	1	1	-	-	-	15	1
6	Tang-kulap	2.5x2.5	10	1	1	-	-	10	10	1
7	Ulu Kuamut	2.5x2.5	30	1	1	-	-	-	15	1
8	Balat	2.5x2.5	10	1	1	-	-	-	15	1
9	Bukit Garam	2.5x2.5	10	1	1	-	-	10	10	1
10	Kuamut	2.5x2.5	10	1	1	1	1	10	10	1
11	Bilit	2.5x2.5	30	-	1	-	-	10	10	1

(1) Only equipment for telecommunication will be installed at the Trig Hill Station.

(2) Antenna Steel Tele pole H = 10.0m
Triangular tower H = 30.0m

(3) Access facilities such as roads and steps are installed for maintenance of gauging stations.

5.3.2. Telemetry Facilities

Table 5.4 List of Telemtry System Components (Kinabatangan River Basin)

Item	Station	KotaKinabalu (Master Control)	Sandakan (Monitoring)	Trig Hill (Relay)	Mt. Balat (Relay)	Tongod (Rainfall & Water Level)	Tangkulap (Rainfall & Water Level)	Ulu Kuamut (Rainfall & Water Level)	Kuamut (Rainfall & Water Level)	Balat (Rainfall & Water Level)	Bukit Garam (Rainfall & Water Level)	Bilit (Water Level)	Total
		Quantity	Quantity	Quantity	Quantity	Quantity	Quantity	Quantity	Quantity	Quantity	Quantity	Quantity	Quantity
Telemetry Equipment	for Control	1											1
Telemetry Equipment	for Water Level Gauge with Protective Device											1	1
Telemetry Equipment	for Rainfall & Water Level Gauge with Magnetic Counter, Protective Device					1	1	1	1	1	1		6
Monitoring Equipment			1										1
Relay Equipment	μ - V Relay			1									1
Relay Equipment	V-V Relay				1								1
Operating Unit	Console Type	1											1
Typewriter	24 inches	1	1										2
Display Unit	Wall-mount Type	1											1
Radio Equipment	70 MHz, 20W				2	1	1	1			1	1	7
Radio Equipment	70 MHz, 3W									1			1
Radio Equipment	70 MHz, 1W			2					1				3
Antenna Equipment	5 Element Yagi with Coaxial Arrester				4	2	1	1		1	1	1	11
Antenna Equipment	3 Element Yagi with Coaxial Arrester			1					1				2
Branch Unit					2								2
Solar Cell	168W, with Distribution Board				1								1
Solar Cell	14W, with Distribution Board					1	1	1			1	1	5
Solar Cell	7W, with Distribution Board								1	1			2
Battery Charger	24V, 30A	1	1										2
Battery Charger	12V, 30A			1									1
Alkaline Storage Battery	24V, 150AH	1	1										2
Alkaline Storage Battery	12V, 800AH				1								1
Alkaline Storage Battery	12V, 150AH			1									1
Alkaline Storage Battery	12V, 80AH					1	1	1			1	1	5
Alkaline Storage Battery	12V, 40AH								1	1			2
Automatic Voltage Regulator	10KVA, 220V	1											1
Automatic Voltage Regulator	5K VA, 220V		1										1
Automatic Voltage Regulator	1K VA, 220V			1									1
Engine Generator	300VA, 220V				1								1
Surge Absorb Transformer	10K VA, 220V	1											1
Surge Absorb Transformer	5K VA, 220V		1										1
Cable		1	1	1	1	1	1	1	1	1	1	1	11
Spares & Accessories		1	1	1	1	1	1	1	1	1	1	1	11

CHAPTER 6 OPERATION AND MAINTENANCE

6.1 Hydrological Observation Facilities

6.1.1 Maintenance of Hydrological Gauging Equipment

To conduct the hydrological observation with accuracy, it is essential to maintain the gauging equipment in perfect order. For this purpose, it is desirable that one maintenance man be appointed for each telemetry station who carries out weekly inspection and maintenance.

In this regular inspection, he is to repair troubles and supply consumables without fail in accordance with the inspection manual. In addition, he will be required to perform a thorough inspection and maintenance of equipment and facilities before the rainy season and after each flood.

Assignments are further discussed in APPENDIX.

6.1.2 Discharge Observations

Discharge observations are to be conducted with the purpose of establishing water level-discharge correlation formula at respective telemetery points.

Discharge measurements are to be taken for both low and high water stages at various timings and frequencies. The greater the frequency of observation, the higher the accuracy will be with which the correlation between the water level and discharge could be determined. The observations personnel are to stand by particularly for the very infrequent high water-level observation.

Observation personnel recommended to be assigned to station are:

Low water-level observation (current meter)	2 - 3 men/group
High water-level observation (float drop)	7 - 10 men/group

When the high water-level observation lasts long, two or three groups of observation personnel will be required. These observation personnel will have to be trained beforehand using the discharge observation manual. Also, the cross-sectional surveying of the river at the discharge observation points are to be conducted periodically (2 - 3 times per year - before and after a rainy season) to observe riverbed.
Another surveying is recommended immediately following a large flood for observing riverbed fluctuation.

Assignments are further described in APPENDIX.

6.1.3 Arrangement of Observation Data

Observation data are to be arranged after ample scouting and then offered as basic data for statistical as well as hydrological analyses.

The basic data are to be kept on file for a long period of time.

6.2 Maintenance of Telecommunication System

For the flood forecasting and warning system to function efficiently, it is essential that the telemetry equipment and all other equipment used in the system are always maintained in a perfect order and the maintenance personnel are always stationed ready and trained for higher techniques. It is also very important that the budget enough for the adequate maintenance and operation is appropriated.

The necessary maintenance personnel include one supervisor-engineer, one engineer and two electrical technicians. They are to be stationed at the Master Control Station and Minitoring Station and are assigned to perform such functions as the preparation and execution of maintenance plan, regular check plan, improvement plan, repair plan, parts and materials supply plan, gauges repair plan, etc. They also have to repair troubles when they have arisen and maintain parts, expendables and gauges in good repair.

The equipment to be used in this system are generally designed to withstand about 10 years of use. Therefore the equipment renewal plan should also be taken into account.

Though it depends on the years of service after the start of system operation, the maintenance cost will be about 5% of the installation cost at least. In addition, about M$175 per mile rental charge of a year will have to be paid for the public telephone use.

6.3 Maintenance of Mt. Balat Relay Station Access Road

The proposed location of the Mt. Balat Relay Station is atop a hill of 275m high located approximately 2.5 km from Balat. Presently a timber track leading from Balat would serves as access road, conecting the two locations by 15 minutes drive. When the timber development cease in the future, however, maintenance of the track would pose some problem. The maintenance cost is difficult to estimate since there are variety of construction possible for this purpose. For example, when gravel is laid for improvement of track (width 4.0m, layer 0.3m), the cost may be estimated as:

$$4.0m \times 0.3m \times 2{,}500m \times 10US\$/m^3 = 30{,}000\ US\$/year$$

When this cost proves to be difficult to be appropriated for periodical inspection on monthly or bi-monthly basis, the station could be well maintained and more economically by reaching the site on foot or by a helicopter.

6.4 Operation of Flood Forecasting and Warning System

6.4.1 Function of Flood Forecasting Center

The Flood Forecasting Center in the proposed flood forecasting and warning system will perform the following fuctions:

- Collection of rainfall and water level data sent from telemetering stations

- Short-term flood forecast based on hydrological observation data collected

- Prediction of Long-term prediction of flooding prospects, based on above-mentioned short-term flood forecast and meteorological forecasts by the meteorological services. This long-term prospect will be conveyed to the Flood Control Center (FCC).

- Reporting of current and expected conditions of flooding to agencies concerned

- Research of improving prediction methodology

- Maintenance and management of equipments at telemetry stations

- Training of personnel

6.4.2 Functions of Monitoring Center

Since the target basin of Kinabatangan is remote from Kota Kinabalu, the proposed location of flood forecasting center, a monitoring station is to be placed within Sandakan D.I.D. Office for better management of the system. The monitoring station is to have the following fuctions:

- To watch for orderly function of telemetry system which collects and sends the data from observation station to flood forecasting center

- To assure prompt repair of equipments and facilities hit by sudden trouble

- To conduct routine maintenance for gauging and telecommunication equipments and facilities

- To arrange for training program and to prepare manual for operation and maintenance of the system

6.4.3 Personnel Organization

The following personnel are to be stationed at the Flood Forecasting Center and the Monitoring Center for the smooth performance of their respective functions:

Hydrology:	Chief	1
	Supervisor	1
	Engineer	2
Telecommunication:	Supervisor	1
	Engineer	1
	Technician	2

6.4.4 Assignment of Personnel

<u>Number of Personnel</u>

For the efficient management of the system, the abovementioned personnel, namely, four hydrology engineers and four telecommunication engineers are required to be assigned before the system goes into operation.

Training Program

Since it is most desirable that the personnel are fully experienced in their respective fields, trainers (at least one hydrology engineer and one telecommunication engineer) are to be chosen and sent for training at some agency that has enough experience with advanced flood forecasting and warning. For training components, refer to APPENDIX.

On-th-job Training

On completion of the Construction of the system, on-the-job training for operation and maintenance is to be necessary to hold an education and training session for the duration provided by civil engineering consultants during a rainy season (3 to 4 months).

The staff to be assigned for operation and maintenance of the system (Chief-1, Supervisor-2, Engineer-3, Technician-2) does not necessarily be stationed at the flood forecasting center. The common pool of personnel may be used provided they are fully aware of the nature of the flood forecasting and warning system. For detailed items of assignment, refer to APPENDIX.

6.4.5 Budget for Operation of Flood Forecasting and Warning System

In order to maintain all the gauges and equipment used in the flood forecasting and warning system in perfect order and continue studies and make improvements for the efficient operation of the system, it will be necessary to have a sufficient number of maintenance personnel and a study program for advanced techniques. At the same time, however, it is very important to have an independent budget appropriated for the necessary maintenance and operation of the system.

While maintenance cost for equipment will vary with the years in service after installation, about five per cent of the initial installation cost is to be appropriated for this purpose.

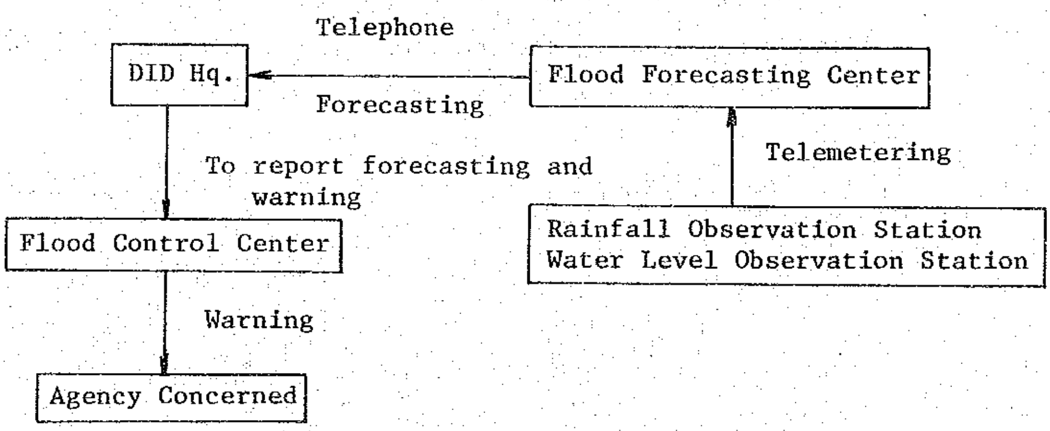
6.5 Flood Warning System

6.5.1 Organization of Flood Warning System

The Drainage and Irrigation Department (D.I.D.) of Sabah is the direct administrator of this flood forecasting and warning system. Therefore, the Flood Forecasting Center will be incorporated in the organization of Branches under it.

In the existing flood forecasting and warning mechanism, the D.I.D. has been taking charge of flood forecasting and the Flood Control Center (FCC) of each state has issued orders for evacuation and relief operations. Hence, the proposed flood forecasting and warning system will have to be incorporated in either the existing or already planned flood disaster relief control machinery.

Fig. 6.1 Conception of Flood Warning System



On the flood forecasting and warning system already established in Peninsular Malaysia, the warning system is being operated as shown on the flow chart of Fig. 6.2. It is desirable that the same system be established as early as possible in the state of Sabah.

6.5.2 Methodology of Flood Warning System

There is no established methodology for a flood warning system, for there are variety of methods suitable for different characteristics of the river basin such as population and property distribution and the traffic network as well as the organization of the flood forecasting and warning system to be adopted.

In many cases, however, residents are warned of the flood prospect in the following ways:

- The Flood Control Center contacts the concerned administrative agencies, which in turn warn the residents in each community through their respective organizations.

- Alarm installations (sirens, speakers, flashlights, etc.) set up in the target area warn the residents by means of sound or light signals.

- Patrol vehicles and boats are used to warn the residents in the target area by voice, sound or light means.

- Chiefs of major villages or the branch offices of administrative agencies are provided with radio receivers through which the flood warning is conveyed. In this case, either a general broadcast network, or a newly established radio network for exclusive use in flood warning could be used.

Construction cost estimate of warning systems mentioned in the above three plans are as follows:

Type	Construction Cost (Incl. Consultancy Fee)
Warning Apparatus	1,564,000
Patrol Vehicle and Boat	769,000
Radio Receiver	290,000

($US)

For detailed items of the above plans, refer to APPENDIX. The cost mentioned above are of approximate estimate which are to be throughly examined after extensive radio test and population distribution survey for selection of appropriate receiver equipments. Above figures are meant for reference only.

6.6 Organization and Position in Administrative Offices

6.6.1 Organization of Flood Forecasting Center

A number of experienced engineers as well as a sum of expenses for management would be required to optimize the function of the flood forecasting and warning system.
Therefore, it is recommended that the Flood Forecasting Center be set up as a part of Government Agency and provided an independent personnel assignment program and budget. The survey team would appreciate that Malaysian Government further investigate the above-mentioned recommendation for its development.

F.F.C.
- Management Section
- Hydrology Section
- Telecommunication Section
- Planning Section
- Research Section
- Training Section

----- Organized in Future

FIG.-6.2 FLOW CHART OF THE
FLOOD DISASTER RELIEF CONTROL MACHINERY

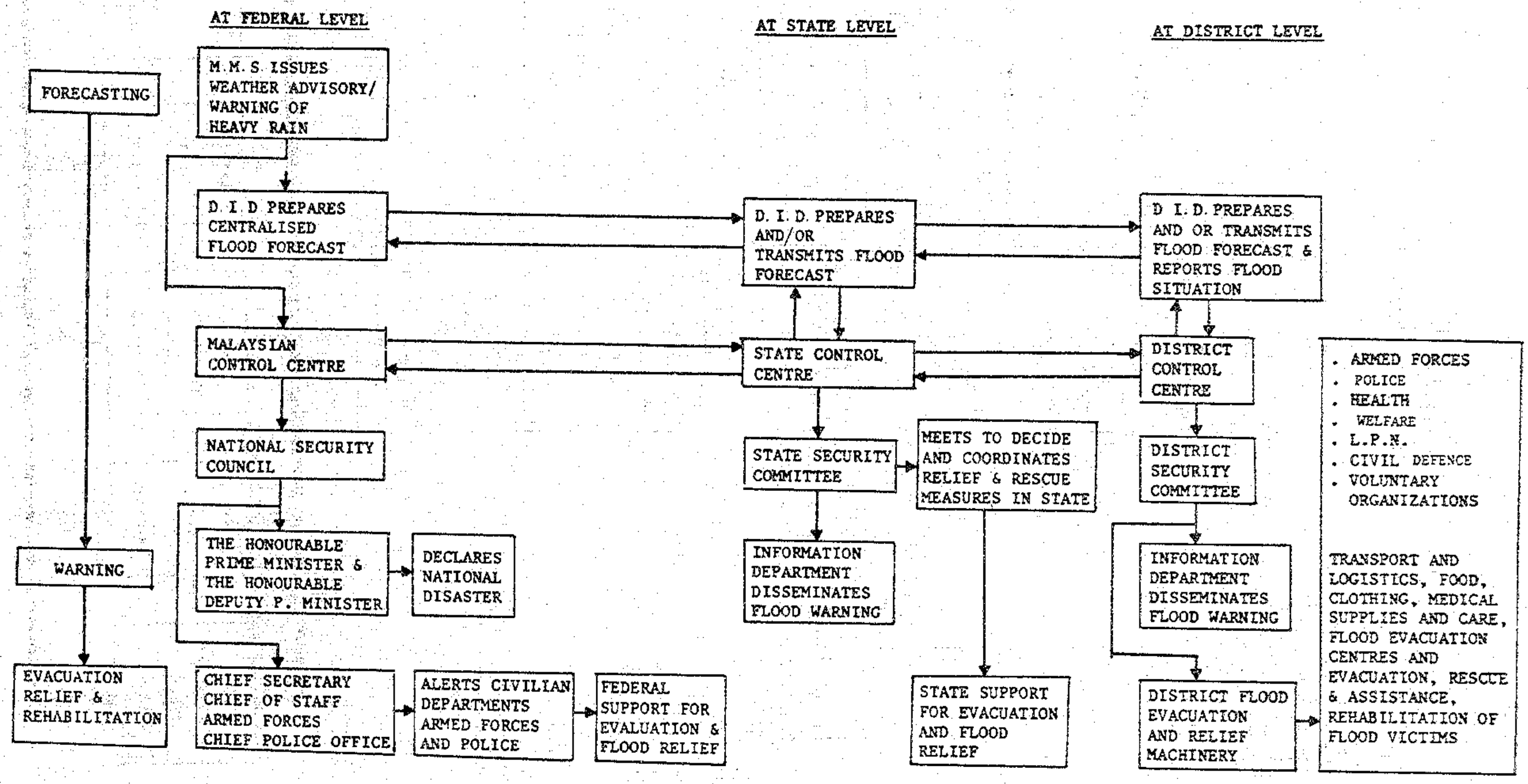
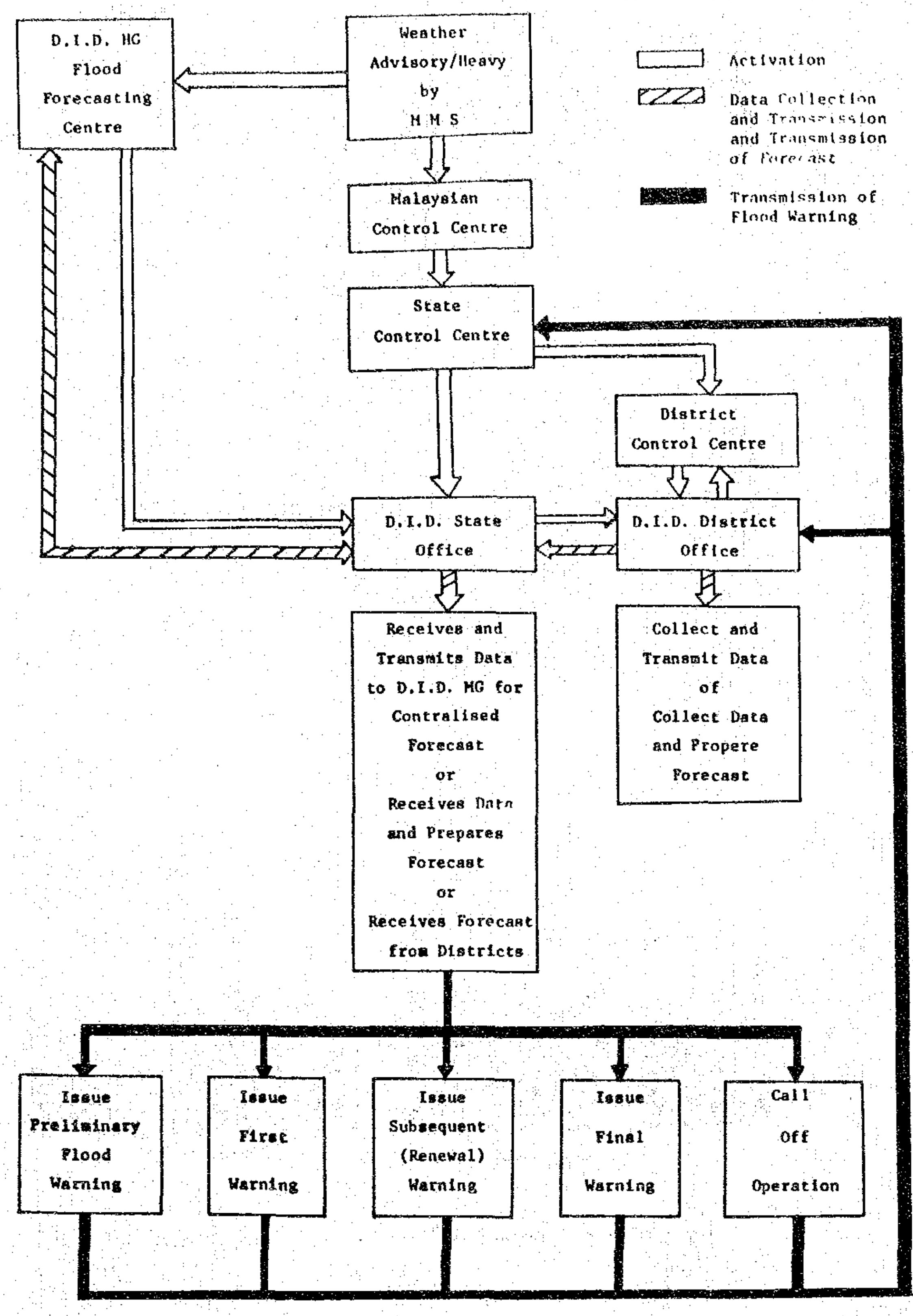


Fig.6.3 **FLOW CHART OF PROCEDURE FOR REAL-TIME OPERATIONS**



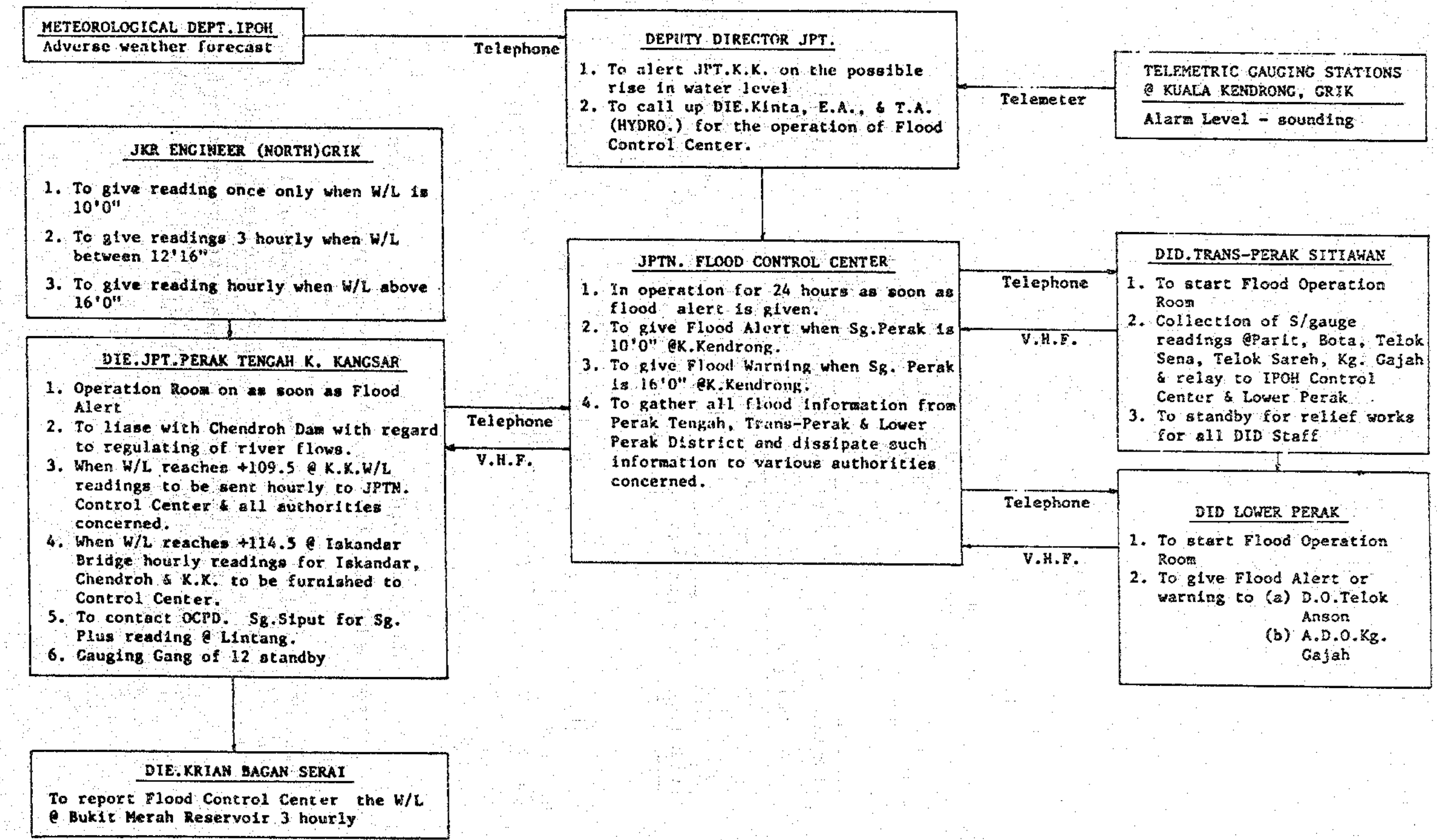


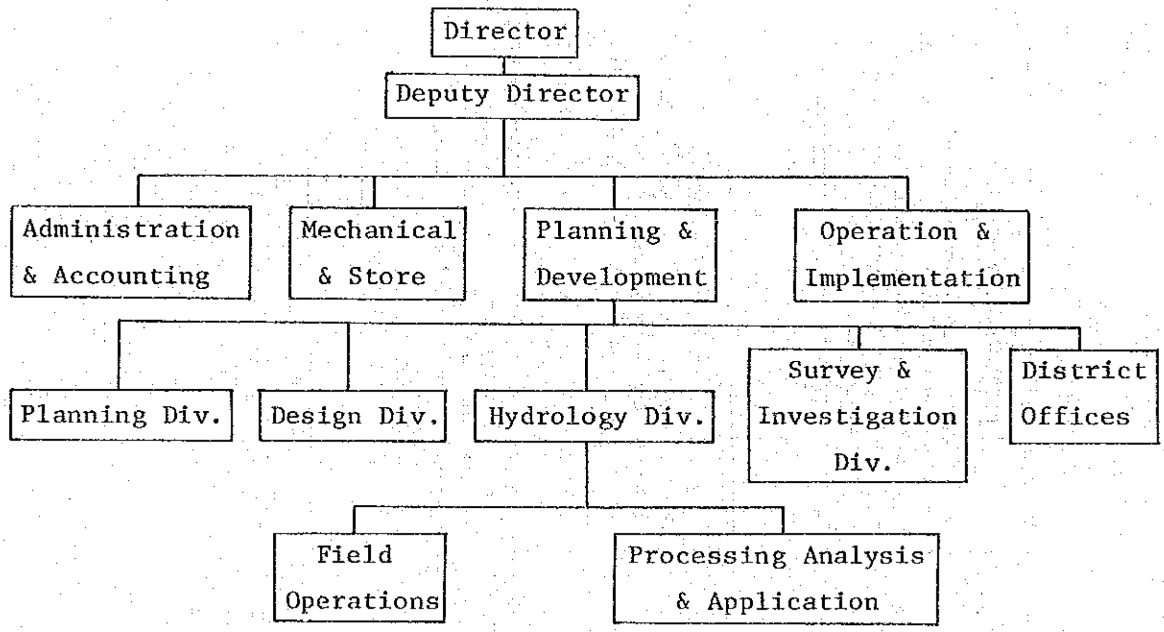
Fig.6.4 Flood Warning Procedure for Sungei Perak

6.5.2 Position in Administrative Offices

Flood Forecasting Center of the Kinabatangan River in Sabah

The organization of the D.I.D., Sabah is as shown below:

Fig. 6.5 D.I.D. Sabah Organization Chart



The Flood Forecasting Center can be positioned in the above administrative Organization as follows:

- Initial stage : Upon the completion of the system, the Flood Forecasting Center should be placed under the Hydrology Division until its staff program, budget scheme and operations have been firmly established.

- Intermediate stage : As its procedures of operations become firmly established and the system extended to other river basins, the Flood Forecasting Center should be prompted to be a Division under the Planning & Development Branch, having its own personnel and budget program.

- Final stage : It is recommended that the Flood Forecasting Center, with independent personnel and budget, becomes one of the Branches of the D.I.D. or an organization directly under the D.I.D. Director capable of acting as a task force.

CHAPTER 7 COST ESTIMATE

7.1 Implementing Schedule

Construction of the flood forecasting center and the system network will start at once. Technical supervision for operation and maintenance will take a period of one year. Hence the system will come into operation in two and a half year after the commencement of construction. Each work section of the implementation will cover the period as stated below.

1.	Detailed Survey of Station Sites	1 month
2.	Detailed Design of Civil Work	3 months
3.	Detailed Design of Telecommunication Facilities	2 months
4.	Preparation of Specifications and Bidding Documents	3 months
5.	Telecommunication Equipment Manufacture	10 months
6.	Equipment Delivery	3 months
7.	Telecommunication Equipment Installation and Adjustment	2 months
8.	Civil Work	13 months
9.	Gauging Equipment Installation and Adjustment	1 month
10.	On-the-job Training for operation and Maintenance	12 months

Fig.7.1 WORK SCHEDULE

Item \ year	1	2	3
Detailed Survey of Station Sites	1		
Detailed Design of Civil Work	3		
Detailed Design of Telecommunicaiton Facilities	2		
Preparation of Specifications and Bidding Documents	3		
Telecommunication Equipment Manufacture	10		
Equipment Delivery		3	
Telecommunication Equipment Installation And Adjustment		2	
Civil Work		13	
Gauging Equipment Installation and Adjustment		1	
On-the-job Training for Operation and Maintenance		12	

7.2 Cost Estimate

7.2.1 Conditions for Estimate

Project cost of the System is estimated on conditions stated below:

i) Price quoted is the standard as of February 1980.

ii) Ten(10) percent of the total cost of civil work and equipment is added to the total implementation cost as contingency, which may be used as the cost of technical supervision for operation and maintenance.

iii) All housing for gauging and radio equipments are to be newly constructed. Land acquisition for these housing is to be undertaken by Malaysian Government.

iv) All equipments (rain gauges, water level gauges, telemetry equipments and accessories) are to be provided by foreign supplier.

v) Installation and adjustment of equipments is to be conducted by foreign technical assistance personnel.

vi) Technical Assistance Cost is to include overseas training fee for Malaysian technical staff, supervision fee for detailed design, design modification, contract and procurement as well as fee to be appropriated for on-the-job training. Twenty percent of the total construction cost is to be appropriated. The proportion of each item would be:

Training	Training Overseas	15%
	On-the-job Training	35%
Supervision	Detailed Design	30%
	Contract and Procurement	5%
	Design Modification	15%

* Technical assistance is required in the civil works phase in case that the detailed design is modified in accordance with the latest conditions of the construction sites.

vii) Cost for housing of the Flood Forecasting Center is to cover only the floor space required. In other words, the Flood Forecasting Center is to occupy some rooms of the building to be constructed for purpose other than the proposed flood forecasting and warning system.

viii) Monitoring station is to occupy a room in Sandakan D.I.D. office. Trig Hill Relay Station is to be included within telecon department facility.

ix) Maintenance vehicles and boats are not included in this estimate.

x) Price of land lot required for housing construction is not estimated.

xi) Technical Assistance Fee is appropriated only for foreign personnel.

Fees to be paid to local consultants for construction supervision, specification writing, contract document preparation, detailed design as well as cost to be incurred for training overseas of Malaysian hydrology and telecommunication staff is to be estimated separately.

7.2.2 Total Cost

Total cost to be incurred for the implementation of the flood forecasting and warning system in the Kinabatangan River basin is as follows. Construction cost for the warning system is not included in this estimate.

Table 7.1 Total Cost (Kinabatangan River Basin)

(US$)

Item	Observation Station	Flood Forecasting System	Total	Remarks
Equipments	176,530	612,900	789,430	
Facilities	248,000	198,000	446,000	
Sub-total	424,530	810,900	1,235,430	
Contingency	42,470	81,100	123,570	
Total	467,000	892,000	1,359,000	

Consulting Services	273,000
° Training	
Training Overseas	41,000
On-the-job Training	95,000
° Supervising	
Detailed Design	82,000
Contract and Procurement	14,000
Design Modification	41,000

(US$ 1=¥ 220)

The project cost has been estimated based on the current price as of February, 1980. The prices quoted has no indication of inflation rates since it was difficult to estimate due to no definite origin of shipment. In this context the indicated prices may be referred to as the initial cost to be incurred at the commencement of the construction implementation.

7.2.3 Breakdown of Construction Cost

Unit Price

Table 7.2 Unit Price of Hydrological Observation Equipment

Item	Unit	Equipment	Indirect Cost	Total	Remarks
Rainfall Gauge (new)	per unit	4,100	1,300	5,400	Including optional parts
Rainfall Gauge (modified)	"	2,000	1,000	3,000	
Water Level Gauge (bubble)	"	10,500	3,500	14,000	
Water Level Gauge (float)	"	5,000	1,500	6,500	
Water Level Gauge (float, modified)	"	7,000	1,500	8,500	
Staff Gauge	10 m 15 m	390 570	150 220	540 790	
Current Meter	per unit	4,600	1,000	5,600	
Float Dropper	"	32,000	4,000	36,000	

Table 7.3 Unit Price of Observation and Telemetry Station Facilities

Item	Unit	Equipment	Indirect Cost	Total	Remarks
Tele-pole	5 m 10 m	4,500 9,200	500 900	5,000 10,100	
Triangular Tower	per unit	18,500	5,400	23,900	H=30 m
Station Housing (2.5mx2.5m)	per site			6,000	Housing re-building: 600
Station Housing (20mx10m)	"			30,000	
Station Housing (5mx5m)				15,000	
Tower for Housing	"			15,000	
Cableway	"			16,000	
Staff Gauge Support	"			2,000	
Access Facility	"			10,000	Ladders and piers
Land Grading	"			2,000	300 sq. m

Table 7.4 Unit Price of Telemetry Equipment

US$

Item		Unit Price
Telemetry Equipment	for Control	46,000
"	for Water Level Gauge;with Protective Device	7,000
"	for Rainfall & Water Level Gauge;with Magnetic Counter, Protective Device	7,500
Monitoring Equipment		34,000
Relay Equipment	μ - V Relay	16,400
"	V - V Relay	16,000
Operating Unit	Console Type	15,700
Typewriter	24 inches	6,500
Display Unit	Wall-mount Type	32,000
Radio Equipment	70 MHz, 20 W	5,000
"	70 MHz, 3 W	2,400
"	70 MHz, 1 W	2,100
Antenna Equipment	5 Element Yagi; with Coaxial Arester	800
"	3 Element Yagi; with Coaxial Arester	700
Branch Unit		600
Solar Cell	168 W, with Distribution Board	22,000
"	14 W, with Distribution Board	2,400
"	7 W, with Distribution Board	1,200
Battery Charger	24 V, 30 A	6,000
"	12 V, 30 A	4,100
Alkaline Storage Battery	24 V, 150 AH	6,400
"	12 V, 800 AH	21,000
"	12 V, 150 AH	3,300
"	12 V, 80 AH	2,000
"	12 V, 40 AH	1,000
Automatic Voltage Regulator	10 KVA, 220 V	6,700
"	5 KVA, 220 V	5,500
"	1 KVA, 220 V	2,300
Engine Generator	300 VA, 220 V	500
Surge Absorb Transformer	10 KVA, 220 V	2,000
"	5 KVA, 220 V	1,700

Table 7.5 Breakdown of Observation Station Construction Cost
(Kinabatangan River Basin)

(US $)

	Station / Item	Tongod		Tangkulap		Ulu Kuamut		Kuamut		Balat		Bukit Garam		Bilit		Total	
		Q'ty	Amt.	Q'ty	Amt.	Q'ty	Amt.	Q'ty	Amt.	Q'ty	Amt.	Q'ty	Amt.	Q'ty	Amt.	Q'ty	Amt.
Equipments	Raingauge	1	5,400	1	5,400	1	5,400	1	5,400	1	5,400	1	5,400			6	32,400
	Waterlevel gauge (bubble)	1	14,000	1	14,000	1	14,000	1	14,000	1	14,000	1	14,000	1	14,000	2	98,000
	Staff gauge	15	790	10	540	15	790	10	540	15	790	10	540	10	540	75	4,530
	Current meter									1	5,600					1	5,600
	Float dropper									1	36,000					1	36,000
	Sub-total		20,190		19,940		20,190		19,940		61,790		19,940		14,540		176,530
Facilities	Station housing	1	6,000	1	6,000	1	6,000	1	6,000	1	6,000	1	6,000	1	6,000	7	42,000
	Access facility	1	10,000	1	10,000	1	10,000	1	10,000	1	10,000	1	10,000	1	10,000	7	70,000
	Housing tower			1	15,000			1	15,000			1	15,000	1	15,000	4	60,000
	Land grading	1	2,000	1	2,000	1	2,000	1	2,000	1	2,000	1	2,000	1	2,000	7	14,000
	Staff gauge support	1	2,000	1	2,000	1	2,000	1	2,000	1	2,000	1	2,000	1	2,000	7	14,000
	Float dropper cableway			1	16,000	1	16,000			1	16,000					3	48,000
	Sub-total		20,000		51,000		36,000		35,000		36,000		35,000		35,000		248,000
Total			40,190		70,940		56,190		54,940		97,790		54,940		49,540		424,530

(US$ 1 = ¥ 220)

2) Breakdown of Telemetry Facilities

Table 7.6 Breakdown of Telemetry Facilities (Kinabatangan River Basin)

US$

Item	Station	Kota Kinabalu (Master Control)		Sandakan (Monitoring)		Trig Hill (Relay)		Mt. Balat (Relay)		Tongod (Rainfall & Water Level)		Tangkulap (Rainfall & Water Level)		Ulu Kuamut (Rainfall & Water Level)		Kuamut (Rainfall & Water Level)		Balat (Rainfall & Water Level)		Bukit Garam (Rainfall & Water Level)		Bilit (Water Level)		Total	
		Q'ty	Amount	Q'ty	Amount	Q'ty	Amount	Q'ty	Amount	Q'ty	Amount	Q'ty	Amount	Q'ty	Amount	Q'ty	Amount	Q'ty	Amount	Q'ty	Amount	Q'ty	Amount	Q'ty	Amount
Telemetry Equipment	for Control	1	46,000																					1	46,000
Telemetry Equipment	for Water Level Gauge with Protective Device																					1	7,000	1	7,000
Telemetry Equipment	for Rainfall & Water Gauge with Magnetic Counter, Protective Device									1	7,500	1	7,500	1	7,500	1	7,500	1	7,500	1	7,500			6	45,000
Monitoring Equipment				1	34,000																			1	34,000
Relay Equipment	μ- V Relay					1	16,400																	1	16,400
Relay Equipment	V-V Relay							1	16,000															1	16,000
Operating Unit	Console Type	1	15,700																					1	15,700
Typewriter	24 inches	1	6,500	1	6,500																			2	13,000
Display Unit	Wall-mount Type	1	32,000																					1	32,000
Radio Equipment	70 MHz, 20W							2	10,000	1	5,000	1	5,000	1	5,000					1	5,000	1	5,000	7	35,000
Radio Equipment	70 MHz, 3W																	1	2,400					1	2,400
Radio Equipment	70 MHz, 1W					2	4,200									1	2,100							3	6,300
Antenna Equipment	5 Elements Yagi with Coaxial Arrester							4	3,200	2	1,600	1	800	1	800			1	800	1	800	1	800	11	8,800
Antenna Equipment	3 Elements Yagi with Coaxial Arrester					1	700									1	700							2	1,400
Branch Unit								2	600															2	600
Solar Cell	168W, with Distribution Board							1	22,000															1	22,000
Solar Cell	14W, with Distribution Board									1	2,400	1	2,400	1	2,400					1	2,400	1	2,400	5	12,000
Solar Cell	7W, with Distribution Board															1	1,200	1	1,200					2	2,400
Battery Charger	24V, 30A	1	6,000	1	6,000																			2	12,000
Battery Charger	12V, 30A					1	4,100																	1	4,100
Alkaline Storage Battery	24V, 150AH	1	6,400	1	6,400																			2	12,800
Alkaline Storage Battery	12V, 800AH							1	21,000															1	21,000
Alkaline Storage Battery	12V, 150AH					1	3,300																	1	3,300
Alkaline Storage Battery	12V, 80AH									1	2,000	1	2,000	1	2,000					1	2,000	1	2,000	5	10,000
Alkaline Storage Battery	12V, 40AH															1	1,000	1	1,000					2	2,000
Automatic Voltage Regulator	10K VA, 220V	1	6,700																					1	6,700
Automatic Voltage Regulator	5K VA, 220V			1	5,500																			1	5,500
Automatic Voltage Regulator	1K VA, 220V					1	2,300																	1	2,300
Engine Generator	300VA, 220V							1	500															1	500
Surge Absorb Transformer	10K VA, 220V	1	2,000																					1	2,000
Surge Absorb Transformer	5K VA, 220V			1	1,700																			1	1,700
Cable		1	2,300	1	2,300	1	1,000	1	1,000	1	1,000	1	1,000	1	1,000	1	1,000	1	1,000	1	1,000	1	1,000	11	13,600
Spares & Accessories		1	3,600	1	2,800	1	2,000	1	2,000	1	2,000	1	2,000	1	2,000	1	2,000	1	2,000	1	2,000	1	2,000	11	24,400
Installation and Adjustment		1	37,000	1	16,000	1	15,000	1	25,000	1	14,000	1	12,000	1	12,000	1	12,000	1	11,000	1	9,000	1	12,000	11	175,000
Total			164,200		81,200		49,000		101.300		35,500		32,700		32,700		27,500		26,900		29,700		32,200		612,900

MCS: Master Control Station
MS: Monitoring Station
RS: Relay Station
GS: Gauging Station

Table 7.7 Breakdown of Flood Forecasting System Facilities Cost

(US$)

Item \ Station	Kota Kinabalu (MCS)	Sandakan (MS)	Trig Hill (RS)	Mt.Balat (GS)	Tongod (GS)	Tangkulap (GS)	Ulu Kuamut (GS)	Kuamut (GS)	Balat (GS)	Bukit Garam (GS)	Bilit (GS)	Total
Tele-pole	5,000					10,100		10,100	10,100	10,100		45,400
Triangurar Tower				23,900	23,900		23,900				23,900	95,600
Station Housing	20,000	10,000		15,000								45,000
Access Facility				10,000								10,000
Land Grading				2,000								2,000
Total	25,000	10,000		50,900	23,900	10,100	23,900	10,100	10,100	10,100	23,900	198,000

7.2.4 Foreign and Local Currency Allocation

Table 7.8 Currency Allocation of Hydrological Observation Equipment

Conversion Rate: 1US$=2.1M$=220Yen

Item	Unit	Total (US$)	Foreign (US$)	Local (M$)	Remarks
Rainfall Gauge (new)	per unit	5,400	4,100 (78%)	2,730	Frgn: Equipment, Shipping Local: Installation, Delivery
Rainfall Gauge (modified)	"	3,000	2,000 (67%)	2,100	Frgn: Modification, Optional Parts Local: Installation, Delivery
Water Level Gauge (bubble)	"	14,000	10,950 (78%)	6,405	Frgn: Equipment, Shipping Local: Installation, Delivery
Water Level Gauge (float)	"	6,500	5,100 (78%)	2,940	"
Water Level (float, modified)	"	8,500	6,600 (78%)	3,990	Frgn: Modification, Optional Parts Local: Installation, Delivery
Staff Gauge	10m 15m	540 790	440 640 (80%)	210 315	Frgn: Material, Shipping Local: Installation, Delivery
Current Meter	per unit	5,600	4,900 (87%)	1,470	Frgn: Equipment, Shipping Local: Delivery
Float Dropper	"	36,000	31,300 (")	9,870	"

Table 7.9 Currency Allocation of Observation and Telemetry Stations Facilities

Item	Unit	Total (US$)	Foreign (US$)	Local (M$)	Remarks
Tele-pole	5m 10m	5,000 10,100	1,500 3,000 (30%)	7,350 14,910	Frgn: Equipment, Shipping Local: Installation, Delivery
Triangular	per unit	23,900	15,600 (65%)	17,430	"
Station Housing (2.5mx2.5m)	per site	6,000	0 (0%)	12,600	Local: Material, Shipping Installation
Housing (5mx5m)	"	15,000	0 (0%)	31,500	"
Housing (20mx20m)	"	30,000	0 (0%)	63,000	"
Tower for Housing(H=10m)	"	15,000	10,000 (67%)	10,500	Frgn: Tower Material Local: Foundation Material
Cableway	"	16,000	0 (0%)	33,600	Local: Material, Installation
Staff Gauge Support	"	2,000	"	4,200	"
Access Facility	"	10,000	"	21,000	"
Land Grading	"	2,000	"	4,200	"

Table 7.10 Currency Allocation of Total Cost
(Kinabatangan River Basin)

Item	Foreign Currency[1] (US$)		Local Currency (M$)		Remarks
	Observation Station	Flood Forecasting System	Observation Station	Flood Forecasting System	
Equipments	141,528	612,900	73,505	-	
Facilities	40,000	75,760	436,800	256,704	
Sub-total	181,528	688,660	510,305	256,704	
Contingency	18,471	69,340	50,695	25,296	
Total	200,000	758,000	561,000	282,000	
Consulting Services	273,000				
° Training					
Training Overseas	41,000				
On-the-job Training	95,000				
° Supervising					
Detailed Design	82,000				
Contract and Procurement	14,000				
Design Modification	41,000				

(US$ 1=M$ 2.1=¥ 220)