gauging stations in the Sakae Krang River Basin are subject to the data transmission system newly provided.

6.2.2 Data Transmission

Planning Conditions

(1) Quantity of Transmission Data

Hydrological data in the whole basin could be obtained on the daily basis at the 31 water level gauging stations and at the 34 rainfall gauging stations. These data will be transmitted to the RID Head Office, and after processing, the results will be disseminated to the related agencies, as well as RID's related regional offices.

(2) Telecommunication Link to be Established

Hydrological data observed at the gauging stations under RID's Regional Offices are to be transmitted to the O&M Division through the Communications Division, and those of MD and EGAT are to be collected at their head offices in Bangkok by their own telecommunication systems. Planning of a new telecommunication network will be done on the concept that the above-said existing systems would be utilized to the maximum extent. Thus, the line to be connected in the system will cover the portions between RID's head office and the following:

(a) Hydrological gauging stations managed by RID's Hydrology Division, for data collection;

(b) Head offices of related agencies, for collection of data and dissemination of prediction results; and

(c) Tidal gauging station of PAT, for data collection (refer to the Study on Telecommunication Network mentioned later).

Study on Applicable Facilities

The applicable facilities have been decided from the viewpoint of intermediation of manpower, the updated on-line system and the existing off-line system. The telecommunication system for the Step 1 Flood Forecasting System will utilize the presently existing offline system, in accordance with the concept mentioned in Chapter 4. In this connection, the applicability of transmission link, transmission media and transmission frequency has been studied and the findings are described hereinafter.

(1) Transmission Link

The wired line is subject to accidental interruption due to heavy rainfall or strong wind. In this connection, the radio link is applicable to this flood forecasting system in view of its reliability during flood time.

(2) Transmission Media

Voice communication system is applied as the transmission media from the viewpoint of economical advantage over the character transmission system. The latter system costs more because of additional facilities with a new HF frequency.

(3) Radio Equipment

From the technical point of view, superiority of VHF or HF/SSB is generally dependent on the distance of communication, i.e., HF/SSB is suitable for long distance communication and VHF, for short distance communication. The turning point appears at about 30 km in terms of the required cost, namely, HF/SSB is selected for communication of more than 30 km, while VHF is for less than this distance, although it must be recognized that the distance of this turning point varies according to topographic conditions.

Study on Alternatives of Telecommunication Network

The main study on the proposed telecommunication link is regarding the transmission of data managed by RID's Hydrological Division. This link is firstly discussed hereunder.

The existing telecommunication network of RID is provided primarily for communication among its head office, regional offices and project offices. To effectively utilize the existing telecommunication network and save on initial investment, the study is firstly made on the possibility of installing additional facilities to link the hydrological observation stations to the nearest project office.

In connection with the above study, it is pointed out that the reliability of data transmitted, as well as operation and maintenance cost, is influenced by the number of relay points. Therefore, to keep the reliability of transmitted data higher and at the same time save on operation and maintenance cost, a telecommunication network directly connecting the observation stations to the regional office concerned or the RID Head Office, regardless of the distance, is also considered.

In the above consideration, alternatives are provided as follows (refer to Fig. 6-2):

Case 1. Telecommunication network connecting the hydrological observation stations to the nearest project office of RID.

Case 2. Telecommunication network connecting the hydrological observation stations to the nearest regional office.

Case 3. Telecommunication network connecting the hydrological observation stations directly to the RID Head Office.

Table 6-6 shows the results of comparison among the three alternatives. In view of the economical superiority and higher reliability of transmitted data, Case 3 is selected as the suitable telecommunication network for hydrological data collection and transmission.

The head office of other related agencies (MD, EGAT, LAD and BMA) and the RID Head Office will be directly connected to the network because of no other applicable line. As for the tidal gauging station under PAT, it is more practical to transmit the tidal data to the RID Head Office than transmitting them by way of PAT's head office because radio communication is not available between this station and PAT's head office.

Optimum Telecommunication Network

On the basis of the aforementioned study results, the telecommunication network is proposed as tabulated below and illustrated in Fig. 6-3.

Related Agencies	Portions of Network				
	Gauging Station	====	Head Office of Related Agency	=====	Head Office of RID
MD		HF/SSB*		VHF**	Data collection /2
PAT			HF/SSB** /1		-do-
RID (O&M Division)		VHF; HF/SSB*		VHF; HF/SSB*	-do-
RID (Hydrology Division)			HF/SSB** /1		-do-
LAD				VHF**	Dissemination /2
BMA				VHF**	-do-
EGAT				VHF**	Data Collection/ Dissemination /2

Note: * Existing; ** Proposed
/1 Direct connection between gauging station and RID Head Office.
/2 Contents of communication.

In addition to the above network, the existing telecommunication line of RID connecting its Head Office to its regional and project offices is also utilized for hydrological data collection, dissemination of flood prediction results, communication of necessary instructions for countermeasures, and so on.

6.2.3 Data Management

Functions

The data management system is essentially formulated to satisfy the following functions of an effective flood forecasting system; namely, real time data filing and processing, real time flood forecasting, hydrological analysis, displaying visual information and monitoring basin condition.

However, the system for Step 1 which utilizes the existing facilities is formulated to execute functions of data filing and processing by manual operation, flood forecasting, hydrological analysis and displaying computation results.

Data to be Managed

The data to be managed by the flood forecasting system are those for flood forecasting computation and formulation of the flood control plan listed in Table 6-7. The data for flood forecasting computation such as rainfall, water level and tidal level, which are selected as a result of hydrological study, shall be managed.

The data and information for flood protection work are as follows:

(1) Other meteo-hydrological data;
(2) Inundation area, depth and duration;
(3) Flood damage;
(4) Record of flood protection work;

(5) Land use map, topographic map, and river cross-section longitudinal section;

(6) Land subsidence; and

(7) Features of river structures and operation rule.

The above data excluding item (5) are filed in the data base. Item (5) will be filed in an ordinary drawer.

Facilities

To establish the data management system, the suitable computer system consisting of the hardware and the software will be selected. The hardware shall be composed of the engineering work station (EWS) suitable for specific use such as the flood forecasting system, and its peripherals such as the data storage equipment, the printer, coler hard copy unit and the video projector.

The configuration of the data management system is illustrated in Fig. 6-4. The specifications of the hardwares are shown in Table 6-8, which have been determined taking into consideration the following:

(1) Ability of data filing, data processing, flood forecasting and display of output results;

(2) Possible expansion of the system in accordance with the future increase of software library and data base; and

(3) Compatibility with the existing computer system of IEC since data base and application program will be held in common.

Softwares consist of an operating system and programs. The specifications of softwares are shown in Table 6-10, and the flow chart of the analysis system for flood forecast is shown in Fig. 6-5. The application programs for the flood forecasting system should be prepared during or after installation of the data management facilities. The main application programs to be prepared are presented in Table 6-9.

6.2.4 Data Dissemination

The flood prediction results consist of the daily and hourly water stages during the flood prediction time at the flood prediction points, as shown in Table 6-10. The information will be disseminated on the daily basis to the related government agencies such as RID Regional Office Nos. 7 and 8, LAD, BMA and EGAT.

The dissemination of flood information will help the above agencies to execute the flood protection work such as flood control, flood fighting, etc. The outline of data dissemination system is shown in Fig. 6-4.

6.3 Manner of Flood Prediction

The results of flood prediction at the respective prediction points are calculated in terms of either the daily average or hourly average water levels and discharges on the basis of the different combinations of the gauged data and the flood prediction models, as described hereinafter.

Prediction of Daily Average Water Level and Discharge

The prediction of the daily average water level/runoff discharge is to be provided to the prediction points except Bangkok. To perform the prediction, water level and the one-day rainfall data are to be collected from the hydrological gauging stations selected in the upper reaches from Bang Sai where the tidal influence is nil during the flood season. The hydrological data need to be simultaneously gauged once everyday and transmitted to the Bangkok Head Office within two days. The gauging time is herein assumed at every 9:00 o'clock in the morning.

After collecting the data, the gauged water level and one-day rainfall are to be respectively processed to the runoff discharges (through rating curves) and the areal average rainfall. Subsequently, the runoff discharges generated from rainfall are to be predicted for each subbasin through the Basin Runoff Prediction Model (refer to Subsection 5.3.2). Further, the flood routing calculations along river channels and flood plains are to be made through the Channel Routing Model and the Flood Plain Routing Model (refer to Subsection 5.3.3 and 5.3.4). Correspondingly, the daily average runoff discharges are predicted in advance of the actual flood runoff occurrence at the respective prediction points.

Prediction of Hourly Average Water Level

Bangkok, the first priority prediction point, is located along the estuary of the Chao Phraya River where the hourly water level is predicted by the Unsteady Flood Prediction Model with special attention to the tidal fluctuation (refer to Subsection 5.3.5).

In the Unsteady Flow Prediction Model, it is first required to calibrate the initial condition, i.e., the water level profile along the river stretch from the river mouth to Bang Sai on the time before starting the model calculation. Due to the required calibration, the hourly observed water levels are needed. Therefore, it is proposed to record the hourly gauged water levels by the automatic recorder at the existing four gauging stations, namely, Fort Phra Chul, Memorial Bridge (Sta. C4), RID Samsen Office (Sta. C12) and RID Pakred Office (Sta. C22) along the estuary. The manner of gauging is assumed in such a way that the hourly water levels are recorded for every 24 hours until 9:00 o'clock in the morning and transmitted to the Bangkok Head Office within two days. The following boundary conditions are also to be provided to perform the flood prediction:

(1) Runoff discharges at Bang Sai which are predicted as the daily variables by the Basin Runoff Prediction Model and the Channel Routing Model and the Flood Plain Routing Model mentioned before; and

(2) Tidal levels in the Gulf of Thailand which are predicted as the hourly variables by the Harmonic Analysis.

In the premises of the aforesaid data collection, calibration and boundary conditions, the hourly water level is predicted through the Unsteady Flow Prediction Model for the optional points along the estuary of the Chao Phraya River.

6.4 Effectiveness of Flood Prediction

The accuracy of 6-day advanced flood prediction has been examined through simulations using the hydrological gauging data recorded in 1978, 1980 and 1983 at the gauging stations to be selected for the Step 1 Flood Forecasting System. The term of 6 days approximately corresponds to the required flood prediction time. The accuracy of simulation results is evaluated as below.

Prediction of Daily Average Discharge in the Upper Reaches from Bang Sai

The flood discharge hydrographs are predicted for the prediction points of Nakhon Sawan, Chai Nat and Angthong where the observed discharge records are available. The prediction was made through the combination of the Basin Runoff Prediction Model, the Channel Routing Model and the Flood Plain Routing Model. The results of the prediction are as shown in Fig. 6-6 and Table 6-11. In this connection, the following evaluations were made.

(1) Prediction for Nakhon Sawan and Chai Nat

As shown in Table 6-11, the annual peak discharges are predicted 6 days in advance subject to the maximum difference of about 300 m^3/s in comparison with the observed value. Considering that the difference of 300 m^3/s in discharge is equivalent to a difference of about 15 cm in water level, the results of prediction are evaluated to be rather available.

(2) Prediction for Ang Thong

The results of prediction are evaluated to be usable for the practical flood forecasting works as shown in Table 6-11 and Fig. 6-6(3/3). It is however noted that compared with the prediction results of Nakhon Sawan and Chai Nat, the errors of prediction are rather large. One of the causes of the errors will be attributed to the reliability of discharges observed at Ang Thong where the period of field discharge measurement is quite limited. Accordingly, it is necessary to accumulate more sufficient data of field discharge measurement and further verify the effectiveness of the proposed flood prediction model.

Prediction of Hourly Average Water Level for Tidal Compartment

The one-day maximum water levels are predicted 6 days in advance through the Unsteady Flow Prediction Model for several points along the estuary and compared with the observed water level as shown in Table 6-12. In this prediction, the following premises are given:

(1) The data for prediction were set on the days when the annual maximum discharges were observed at Bang Sai in 1978, 1980 and 1983.

(2) The upstream boundary conditions were given from the daily average discharges predicted at Bang Sai 6 days in advance.

(3) The downstream boundary conditions were given from the hourly average tidal levels which are predicted through the Harmonic Analysis by using the preceeding years tidal records of Fort Phra Chul (located about 1.0 km upstream from the river mouth).

The errors in the 6 day prediction range approximately from 10 cm to 30 cm and the maximum error of 30 cm occurred in the prediction for Sathu Pradit (located about 40 km upstream from the river mouth) on October 21, 1978 as shown in Table 6-13.

Expected Flood Lag Time

By integrating the observed and simulated flood traveling time (refer to Table 6-13), the following flood lag time is estimated to be possible for the respective flood prediction points:

(1) Nakhon Sawan

A term of about 8 days is estimated as the possible flood lag time which is governed by the flood in the Ping River Basin.

(2) Chai Nat, Sing Buri, Lop Buri and Ang Thong

A term of about 6 days is estimated as the possible flood lag time which is governed by the flood in the Sakae Krang River Basin.

(3) Ayutthaya

In the area along the downstream of Pasak River from the Rama VI Dam, a term of about 4 days is expected as the possible flood lag time which is governed by the flood in the Pasak River Basin. As for the area along the Chao Phraya River, the flood lag time of more than 10 days is expected due to the retarding effects in the upper reaches.

(4) Bangkok

In the same way as the prediction for Ayutthaya along the Chao Phraya River, the runoff discharge at Bang Sai can be predicted more than 10 days in advance. Further, the tidal prediction for the Gulf of Thailand can also be predicted through the Harmonic Analysis about one year in advance. Due to the said possible prediction, the water level for Bangkok can be predicted about 10 days in advance.

Applicability of the Proposed System

As described in the foregoing Subsection 6.4.1, a rather applicable accuracy of prediction results is expected in the proposed Step 1 Flood Forecasting System. It is also expected that the flood lag time at most prediction points will make it possible to secure the time for the short term prediction required for the Step 1 Flood Forecasting System. It is herein noted that the short term prediction time required for the Step 1 Flood Forecasting System is assumed to be almost equal to 5.5 days, the minimum value required under the present condition (refer to Subsection 5.2.1). It is, however, noted that the flood lag time at Ayutthaya is estimated at only about 4 days in case of a flood occurring in the Pasak River Basin which does not cover the required flood prediction time. Due to the above, one of the major objectives in the succeeding Step 2 Flood Forecasting System will be placed on the development of the measures for data collection and processing so as to shorten the above necessary flood prediction time.

6.5 Preliminary Design, Implementation Schedule and Cost Estimates

6.5.1 Preliminary Design

The existing rainfall and water level gauging stations are to be utilized for the proposed system. Therefore, the preliminary design of only the proposed telecommunication and data processing facilities are made, as mentioned hereunder.

Telecommunication Facilities

The major telecommunication facilities comprise the radio equipment and housing, as outlined hereunder.

(1) Radio Equipment

The specifications of equipment to be installed at VHF and HF radio stations are as follows:

(a) VHF Radio Equipment

RF Output Power	:	10 watts
Frequency Band	:	150 MHz
Antenna	:	3-element YAGI antenna
Antenna Height	:	20 m or less

(b) HF Radio Equipment

RF Output Power	:	100 watts
Frequency Coverage	:	3 - 15 MHz
Antenna	:	Dipole
Antenna Height	:	15 m or more

(2) Housing

The housing for the VHF and HF facilities of all the proposed gauging stations will be newly constructed with an area of around 3 m^2 for the installation of radio equipment and operation. However, as for the head office concerned, the unused space of its office will be utilized for installation of the related equipment and performance of its activities.

The general scheme of housing is preliminarily designed in Figs. 6-7 to 6-9.

Data Processing Facilities

The data processing facilities consist of the equipment shown in Fig. 6-10. These equipment will be installed in the RID Head Office, and the required specifications of the data processing facilities are as follows:

(1) Engineering Work Station

CPU	:	32 bit
Main Memory	:	5 MB or more
Cycle Time	:	200 nsec or more

(2) Hard Disk Drive

Capacity	:	100 MB or more

(3) Magnetic Tape Drive

Capacity	:	2400 ft
Data Density	:	1600 BPI

(4) CRT Display

CRT	:	17-inch or more, color
Resolution	:	24 lines x 80 characters or more

(5) Printer

Type	:	Dot matrix impact
Printing Speed	:	180 cps or more
Character Set	:	128 ASCII standard

(6) Operating System

Language	:	FORTRAN, Assembler, C
Utility	:	Backup, Editor, Security

(7) Video Projector

Display Size	:	100 inch

(8) CVCF

Capacity	:	3 KVA

6.5.2 Implementation Schedule

The flood forecasting system project can be classified broadly into two phases, namely, installation of flood forecasting system and the development of the system. The total implementation time required for the proposed project is 36 months, as shown in the proposed implementation schedule in Fig. 6-11.

The establishment of the flood forecasting system, which includes detailed design, pre-construction, construction/installation, preparation of operation and maintenance manual and flood prediction programming, will require 12 months. Although the system will be operational after its establishment, it has to be developed to attain precision of forecasting.

The development of the system including training of the staff concerned will also require 24 months. This development phase will cover calibration and modification of flood prediction models, on-the-job training and overseas training.

6.5.3 Cost Estimates

For the estimation of project cost, careful consideration and evaluation have been made on items such as local availability of equipment, contractor, their prices, and other necessary items relevant to system construction.

The total construction cost of the system comprise costs of purchase of equipment, construction/installation, adjustment, and engineering services; plus 10% physical contingency and 3% price contingency. The reference time for estimation is set at December 1987, and the currency conversion rate is based on the average rate for 10 days in the same month and year, i.e., US$1.00 : 25.5 Bahts : 130 Yen.

The total cost of the proposed system is estimated at US$2,786,000 composed of the cost of establishment of the system and the cost of development amounting to US$1,731,000 and US$1,055,000, respectively. The breakdown of equipment cost is as follows.

<u>Establishment of the System</u>

(1)	Telecommunications (Refer to Tables 6-14 and 6-15)	US$ 960,360
(2)	Data Management	203,120

(3)	Engineering Services	179,300
	- Foreign Engineers (4 M/M) - Local Engineers (19 M/M)	
(4)	Programming of Flood Prediction Model Including Preparation of O&M Manual	231,000
	Sub-Total	US$1,573,780
(5)	Contingency	157,220
	Total	US$1,731,000

Development of the System

(1)	Calibration/Modification of the Flood Prediction Mode;	US$ 805,200
	- Foreign Engineers (24 M/M) - Local Engineer (12 M/M)	
(2)	Training	154,000
	- On-the-Job Training - Overseas Training	
	Sub-Total	US$ 959,200
(3)	Contingency	95,800
	Total	US$1,055,000
	Grand Total	US$2,786,000

6.6 Administrative Structure for System Operation and Maintenance

Organizational Setup

The proposed organizational setup is presented in Fig. 6-12. The appropriate administrative structure for the proposed flood forecasting system has been formulated based on the existing organization of RID, with the enhancement of some of RID's activities. In this connection, a Flood Forecasting Committee is proposed to be set up in RID for the purpose of managing the system and rendering decisions on the predicted flood data; thus, providing prompt response to flood fighting.

The members of the Committee are appointed in consideration of their qualifications and present responsibilities, as shown in Table 6-16.

A Chairman will be needed to manage the Committee and its flood forecasting activities. It is proposed for the Chairman to be well-versed in flood control and flood fighting which are the main objectives of flood frecasting. He should also be in a respectable position to be able to coordinate the activities of the related divisions of RID.

The Committee Secretariat should be familiar with the hydrological analysis and flood prediction on natural mainstreams which are the primary works of flood forecasting. The other members are either related to the executing divisions mentioned hereunder or closely involved in flood control and flood fighting.

Operation and maintenance of the flood forecasting system are to be carried out by the existing divisions in RID such as the Hydrology Division, the O&M Division, the Communications Division, the Data Processing Division and the Regional Offices. With regard to the other related institutions, meteorological information, scheduled dam discharge volume and some hydrological data are to be collected from MD, EGAT and PAT. Predicted flood data are to be furnished to EGAT for reference on dam control, and to BMA and LAD for the flood fighting in metropolitan and provincial areas. Response to inquiries from these related agencies and others concerned in the predicted flood data shall be made.

Assignment of Required Activities

The existing and required activities for the flood forecasting system are tabulated in Table 6-17. The assignment of required activities to the related offices, as described in detail in the supporting report, is proposed in consideration of the existing activities.

6.7 Project Evaluation

With the establishment of the flood forecasting system, hydrological data covering the vast area of the Chao Phraya River Basin will be collected and processed in a more precise manner with a larger quantity and a higher quality. As a result, it will actually be possible to predict the flood discharges and water stages at several target points on the Chao Phraya River, and based on such a method of prediction, a flood mitigation system will be established for the purpose of reducing the area and volume of inundation by flood.

As mentioned in Section 2.10, the Chao Phraya River and its tributaries have caused serious flood damages in the past to immovable and movable properties, business activities and traffic. Such damages are expected to be reduced by establishing the system for flood mitigation.

Immovable Properties

Damage to immovable properties such as buildings, roads, railways, river structures and facilities, and agricultural crops will be reduced by raising levees temporarily and by strengthening protection to buildings and other facilities, as well as by advancing the harvest time for some field crops, before the onset of flood season.

Movable Properties

Movable properties such as livestock and household effects will be saved from damage by transferring them to safer places in advance of the inundation.

Business Activities

Some business activities of people and corporations in and around the inundated area will be suspended during the inundation period. However, by giving the information on flood in advance, a part of the business activities is expected to be performed in advance of the beginning of inundation and thus reduce business losses.

Traffic

During the period of traffic interruption in the inundation area, passengers and freights to be transported by cars or trains will be waiting or making detours on other roads until the restoration of road and/or railway traffic. By giving advance information on flood, however, some of such passengers and freights may also be transported in advance of the beginning of inundation without waiting or making detours. This means that the loss due to traffic interruption will be reduced.

Table 6-1. INVENTORY OF WATER GAUGING STATIONS (STEP 1)

Code No.	River System	Station Number	Location				Type of Gauge /1	Administration Office /2
			District	Province	Latitude	Longitude		
W-H.1	Wang	W10A	Chae Hon	Lampang	18°31'16"	99°37'52"	V	HyD
W-H.2	Wang	W3A	Thoen	Lampang	17°38'29"	99°14'04"	F	HyD
W-H.3	Wang	W4A	Sam Ngao	Tak	17°12'22"	99°06'08"	F	HyD
W-H.4	Ping	P12	Sam Ngao	Tak	17°14'30"	99°00'45"	F	HyD
W-H.5	Ping	P7A	Muang	Kamphaeng Phet	16°28'38"	99°31'06"	V	HyD
W-H.6	Yom	Y20	Song	Phrae	18°35'03"	100°09'17"	B	HyD
W-H.7	Yom	Y14	Si Satchanalai	Sukhotai	17°35'42"	99°43'08"	V	HyD
W-H.8	Yom	Y4	Muang	Sukhotai	17°00'18"	99°49'31"	V	HyD
W-H.9	Yom	Y17	Sam Ngam	Phichit	16°30'50"	100°12'40"	V	HyD
W-H.10	Nan	N33	Nam Pat	Uttaradit	17°43'05"	100°34'32"	F	HyD
W-H.11	Nan	N12A	Tha Pla	Uttaradit	17°44'10"	100°32'28"	F	HyD
W-H.12	Nan	N27A	Phrom Phiram	Phitsanulok	17°01'54"	100°11'05"	B	HyD
W-H.13	Nan	N5A	Muang	Phitsanulok	16°49'15"	100°15'49"	B	HyD
W-H.14	Nan	N40	Wat Bot	Phitsanulok	17°13'14"	100°21'10"	V	Hyd
W-H.15	Nan	N24	Wang Thong	Phitsanulok	16°50'35"	100°31'20"	B	HyD
W-H.16	Nan	N10A	Taphan Hin	Phichit	16°12'42"	100°25'01"	F	HyD
W-H.17	Pasak	S9	Kaeng Khoi	Saraburi	14°37'33"	101°01'00"	F	HyD
W-H.18	Pasak	S5	Muang	Ayutthaya	14°21'32"	100°35'02"	B	HyD
W-H.19	Sakae Krang	Ct8	Thap Than	Uthai Thani	15°29'30"	99°56'28"	V	HyD
W-H.20	Chao Phraya	C2	Muang	Nakhon Sawan	15°40'15"	100°06'45"	F	HyD
W-H.21	Chao Phraya	C13	Sanphaya	Chai Nat	15°09'57"	100°11'32"	V	HyD
W-H.22	Chao Phraya	C3	Muang	Sing Buri	14°53'44"	100°24'14"	V	HyD
W-H.23	Lop Buri	L2A	Muang	Lop Buri	14°47'37"	100°36'34"	V	HyD
W-H.24	Chao Phraya	C7A	Muang	Angthong	14°35'05"	100°27'12"	V	HyD
W-H.25	Chao Phraya	C29	Bang Sai	Ayutthaya	14°11'33"	100°30'23"	V	HyD
W-H.26	Chao Phraya	C22	Pakred /3	Nonthaburi	13°53'47"	100°29'39"	F	HyD
W-H.27	Chao Phraya	C12	Dasit /4	Bangkok	13°47'14"	100°30'56"	F	HyD
W-H.28	Chao Phraya	C4	Thon Buri	Bangkok	13°44'15"	100°29'55"	F	HyD
W-PAT	Chao Phraya	Fort Phra Chul	Pom Phra Chulachomklao	Bangkok	13°32'50"	100°34'58"	F	PAT
W-M1	Pasak	Lom Sak	Lom Sak	Phetchabun	16°46'25"	101°14'58"	V	MD
W-M2	Pasak	Wichian Buri	Wichian Buri	Phetchabun	15°39'25"	101°06'30"	V	MD

Note: /1 V = Vertical Staff Gauge; F = Recorder, Float Gauge; B = Recorder, Bubble Gauge
/2 HyD = Hydrology Division, RID; PAT = Port Authority of Thailand; MD = Meteorological Department
/3 RID Pakred Office
/4 RID Bangkok Office

Table 6-2. INVENTORY OF RAINFALL GAUGING STATIONS (STEP 1)

Code No.	Location					Type of Gauge /1	Administration Office /2
	River Basin	District	Province	Latitude	Longitude		
R-H.1	Ping	Khlong Lan	Kamphaeng Phet	16°20'03"	99°16'29"	R	HyD
R-H.2	Ping	Khlong Khlung	Kamphaeng Phet	16°04'22"	99°24'18"	R	HyD
R-H.3	Ping	Khanu	Kamphaeng Phet	15°54'10"	99°28'45"	R	HyD
R-H.4	Sakae Krang	Lat Yao	Nakhon Sawan	15°47'01"	99°40'55"	NR	Hyd
R-H.5	Sakae Krang	Lat Yao	Nakhon Sawan	15°38'23"	99°32'20"	R	HyD
R-H.6	Sakae Krang	Lam Sak	Uthai Thani	15°31'38"	99°28'10"	R	HyD
R-H.7	Yom	Song	Phrae	18°35'03"	100°09'17"	R	HyD
R-H.8	Yom	Satchanalai	Sukhotai	17°35'42"	99°43'08"	R	HyD
R-H.9	Nan	Tha Pla	Uttaradit	17°44'10"	100°32'28"	R	HyD
R-H.10	Nan	Muang	Phitsanulok	16°49'15"	100°15'52"	R	HyD
R-H.11	Nan	Wang Thong	Phitsanulok	16°50'35"	100°31'20"	R	HyD
R-H.12	Ping/Yom/Nan	Muang	Nakhon Sawan	15°40'15"	100°06'45"	NR	HyD
R-O.1	Wang	Muang	Lampang	18°26'16"	99°38'04"	R	RO
R-O.2	Nan	Muang	Uttaradit	17°37'38"	100°06'33"	NR	RO
R-O.3	Nan	Phrom Phiram	Phitsanulok	17°02'50"	100°10'52"	NR	RO
R-O.4	Pasak	Khlong Phrieo	Saraburi	14°31'34"	100°56'08"	NR	RO
R-M.1	Wang	Muang	Lampang	18°17'23"	99°30'27"	R	MD
R-M.2	Wang	Thoen	Lampang	17°36'39"	99°13'08"	R	MD
R-M.3	Ping	Sam Ngae	Tak	17°14'30"	99°03'45"	R	MD
R-M.4	Ping	Muang	Tak	16°52'50"	99°07'36"	R	MD
R-M.5	Ping	Muang	Kamphaeng Phet	16°28'56"	99°31'26"	NR	MD
R-M.6	Yom	Song	Phrae	18°28'06"	100°11'11"	NR	MD
R-M.7	Yom	Muang	Phrae	18°08'44"	100°08'42"	R	MD
R-M.8	Yom	Muang	Sukhothai	17°00'21"	99°49'36"	NR	MD
R-M.9	Yom	Sam Ngam	Phichit	16°30'25"	100°12'23"	NR	MD
R-M.10	Nan	Muang	Uttaradit	17°37'32"	100°05'57"	R	MD
R-M.11	Nan	Muang	Phitsanulok	16°49'24"	100°15'45"	R	MD
R-M.12	Nan	Taphan Hin	Phichit	16°12'44"	100° 25'23"	NR	MD
R-M.13	Pasak	Lom Sak	Phetchabun	16°46'42"	101°14'45"	NR	MD
R-M.14	Pasak	Muang	Phetchabun	16°25'00"	101°09'35"	R	MD
R-M.15	Pasak	Nong Phai	Phetchabun	15°59'13"	101°03'53"	NR	MD
R-M.16	Pasak	Wichianburi	Phetchabun	15°39'20"	101°06'37"	R	MD
R-M.17	Pasak	Bua Chum	Lop Buri	15°15'50"	101°11'00"	R	MD
R-M.18	Pasak	Chai Badam	Lop Buri	15°02'12"	101°08'11"	NR	MD

Note: /1 R = Recording Raingauge; NR = Non-Recording Raingauge
/2 HyD = Hydrology Division, RID; RO = Regional Office, RID; MD = Meteorological Department

Table 6-3. WATER LEVEL GAUGING STATIONS TO MONITOR AND CALIBRATE (STEP 1)

River System	Monitor and Calibration Items	Station Code No.	Location
Ping	Discharge	W-H.5	Kamphaeng Phet (P7A)
Wang	Discharge	W-H.2	Thoen (W3A)
Wang	Discharge	W-H.3	Wang Khrai (W4A)
Yom	Discharge	W-H.7	Si Satchanalai (Y14)
Yom	Discharge	W-H.8	Sukhotai (Y4)
Yom	Discharge	W-H.9	Sam Ngam (Y17)
Nan	Discharge	W-H.12	Lower Naresuan Dam (N27A)
Nan	Discharge	W-H.13	Phitsanulok (N5A)
Nan	Discharge	W-H.16	Thaphan Hin (N10A)
Sakae Krang	Discharge	W-H.19	Thap Than (Ct8)
Pasak	Discharge	W-M.2	Wichian Buri
Pasak	Discharge	W-H.17	Saraburi (S9)
Pasak	Water Level	W-H.18	Ayutthaya (S5)
Chao Phraya	Discharge/Water Level	W-H.20	Nakhon Sawan (C2)
Chao Phraya	Discharge/Water Level	W-H.21	Lower Chao Phraya Dam Dam (C13)
Chao Phraya	Discharge/Water Level	W-H.22	Sing Buri (C3)
Lop Buri	Discharge/Water Level	W-H.23	Lop Buri (L2A)
Chao Phraya	Discharge/Water Level	W-H.24	Angthong (C7A)
Chao Phraya	Discharge/Water Level	W-H.25	Bang Sai (C29)
Chao Phraya	Water Level	W-H.26	Pakred (C22)
Chao Phraya	Water Level	W-H.27	RID Bangkok Office
Chao Phraya	Water Level	W-H.28	Memorial Bridge
Chao Phraya	Water Level	W-PAT /1	Fort Phra Chul (Gulf)

Note: /1 The observed water level is also used to predict the tidal level in the Gulf of Thailand.

Table 6-4. WATER LEVEL GAUGING STATIONS TO INPUT THE OBSERVED DISCHARGE AS BOUNDARY CONDITION (STEP 1)

Item of Prediction		Applied Gauging Station		
Prediction Time	Target Point	River System	Station Code No.	Location
Short	Bangkok Metropolis	(1) Chao Phraya	W-H25	Bang Sai (C29)
Short	Ayutthaya	(1) Chao Phraya	W-H21	Lower Chao Phraya Dam (C13)
		(2) Pasak	W-M2	Wichian Buri
Short	Chai Nat, Sing Buri, Lop Buri and Angthong	(1) Ping	W-H5	Kamphaeng Phet (P7A)
		(2) Yom	W-H9	Sam Ngam (Y17)
		(3) Nan	W-H16	Thaphan Hin (N10A)
Short	Nakhon Sawan	(1) Ping	W-H4	Lower Bhumibol Dam (P12)
		(2) Wang	W-H3	Wang Khrai (W4A)
		(3) Yom	W-H9	Sam Ngam (Y17)
		(4) Nan	W-H13	Phitsanulok (N5A)
		(5) Nan	W-H15	Kehk River (N24)
Long	All Target Points	(1) Ping	W-H4	Lower Bhumibol Dam (P12)
		(2) Wang	W-H1	Lower Kiu Lom Dam (W10A)
		(3) Yom	W-H6	Ngao Sak (Y20)
		(4) Nan	W-H11	Lower Sirikit Dam (N12A)
		(5) Nan	W-H10	Nan Pat River (N33)

Table 6-5. RAINFALL GAUGING STATIONS APPLIED TO BASIN RUNOFF PREDICTION MODEL (STEP 1)

Objective Basin		Applied Gauging Station		
Basin Code No. /1	River System	Station Code No. /Location	Station Code No. /Location	Station Code No. /Location
BS-2	Wang	R-O.1/Lampang	R-M.1/Lampang	R-M.2/Thoen
BS-3	Wang/ Ping	R-M.3/Sam Ngam	R-M.4/Tak	R-M.5/Kamphaeng Phet
BS-4	Ping	R-M.5/Kamphaeng Phet R-H.1/Khlong Lan	R-H.2/Khlong Klung	R-H.12/Nakhon Sawan
BS-5	Yom	R-M.7/Phrae	R-H.8/Satchanalai	R-M.6/Song
BS-6	Yom	R-H.8/Satchanalai	R-M.8/Sukhothai	
BS-8	Nan	R-H.9/Tha Pla R-H.10/Phitsanulok (R-M.11/ Phitsanulok) /2	R-O.2/Uttaradit (R-M.8/ Uttaradit) /2	R-O.3/Phrom Phiram
BS-9	Nan	R-H.11/Wang Thong	R-H.10/Phitsanulok (R-M/11/Phitsanulok)	
BS-10	Nan/ Yom	R-M.8/Sukhotai R-M.9/Sam Ngam	R-M.12/Taphan Hin	R-H.12/Nakhon Sawan
BS-11	Sakae Krang	R-H.3/Khanu R-H.4/Lat Yao	R-H.5/Lat Yao	R-H.6/Lan Sak
BS-12	Tha Pla Pai	R-H.12/Nakhon Sawan		
BS-13	Pasak	R-M.10/Lom Sak	R-M.11/Phetchabun	R-M.12/Nong Phai
BS-14	Pasak	R-M.13/Wichian Buri R-M.14/Bua Chun	R-M.15/Chai Badam	R-O.4/Khlong Phrieo

Note: /1 Step 1 Flood Forecasting System does not cover the upper reaches of Bhumibol and Sirikit dams which correspond to Basin Code Nos. 1 and 7.

/2 Gauging station in parenthesis is applied as secondary station to supplement lacking data of the main station.

Table 6-6. COMPARISON OF COST, RELAY POINTS AND COMMUNICATION VOLUME AMONG ALTERNATIVES (STEP 1)

Comparison Item	Case 1	Case 2	Case 3
Construction Cost and O&M Cost (US$103)	1,048	1,036	1,029
- Construction Cost	935	948	960
- O&M Cost for 10 years	113	88	69
Repeating Point	2	1	0
Communication Volume (Transmitted Data Volume/Day) /1	104	74	41

Note: /1 One unit of communication volume is one hydrological data transmitted from one place to another, i.e., from hydrological observation station to project office, from project office to regional office, etc.

Table 6-7. LIST OF DATA TO BE MANAGED (STEP 1)

Classification	Data
(1) Data for Flood Forecasting Calculation	
	° Rainfall data
	° Water level, discharge, tide
	° Discharge from main water control structures
(2) Data for Flood Control Plan	
	° Meteorological data (atmospheric depression, wind velocity, etc.)
	° Flood inundation data (inundation area, depth and duration)
	° Flood damage data (house, household effects, public facilities, agricultural products, etc.)
	° Topographic map, land use map, etc.
	° River cross-section, longitudinal profile, etc.
	° Design features of water control structures and operation rule
	° Land subsidence

Table 6-8. SPECIFICATIONS OF COMPUTER HARDWARE (STEP 1)

1.	Engineering Work Station	
1.1	Central Processing Unit (CPU)	1 set
	Type/Size	32 bit central processor
	Capacity/Memory	5 MB main memory minimum
1.2	CRT Graphic Display/Keyboard	1 set
	Type/Size	19 inches diagonal, 16 kinds of color
	Resolution	24 lines x 80 characters per line;
2.	Data Storage Equipment	
2.1	Hard Disk Drive	1 set
	Type/Size	Winchester Type
	Format Capacity	100 MB
2.2	Magnetic Tape Drive	1 set
	Type/Size	High-Speed, Single Density, Inter-Block Cap 0.60 inches
	Format Capacity	100 MB
3.	Printer	1 set
	Type/Size	Line Printer, 132 characters/line
	Capacity/Speed	600 LPM (Line Per Minute)
4.	Video Projector	1 set
	Size	100 inches
	Resolution	RGB in-out 100 lines, 25 lines x 80 characters/line

Table 6-9. SPECIFICATIONS OF COMPUTER SOFTWARE (STEP 1)

(1) OPERATING SYSTEM/SOFTWARE

1. Virtual storage/memory operating system
2. Interactive operating system
3. Multiple jobs
4. Data management system (DMS)
5. Automatic Data Compaction
6. Automatic Print Spooling
7. Background Processing
8. Multiple Language (FORTRAN, C, Assembler, etc.)
9. Data base
10. Spread sheet
11. Graphics
12. Security System

(2) UTILITY

1. Backup	6. Data entry/Control
2. Sort, Merge, Select	7. Create File
3. Copy	8. Editor
4. Tapecopy	9. Security
5. Display	10. etc.

(3) APPLICATION PROGRAM

1. Hydrological and flood information data bases
2. Statistic analysis
   (probable rainfall and probable flood)
3. Correlation analysis
   (rainfall-rainfall, rainfall-water level and water level-water level)
4. Discharge rating curve
5. Flood prediction model
6. Runoff analysis
7. River information display model /1
   (rainfall condition, water level condition and dam data)

Note: Above specification should be modified in detailed design.
/1: Item 7 is prepared at the stage of Step 2.

Table 6-10. DATA DISSEMINATION (STEP 1)

Agencies for Data Dissemination	Items for Dissemination	Flood Prediction Point
BMA	Hourly Water Stage	Memorial Bridge, RID Samsen, RID Pakred
LAD	Daily Water Stage	Nakhon Sawan, Chai Nat, Singburi, Lop Buri, Angthong, Ayutthaya
EGAT	Daily Water Stage	Nakhon Sawan, Chai Nat
	Hourly Water Stage	Memorial Bridge, RID Samsen, RID Pakred
RID (Regional and Project Office)	Daily Water Stage	Ang Thong and Ayutthaya

Table 6-11. ANNUAL PEAK DISCHARGE PREDICTED AT TARGET POINT (STEP 1)

Target Point	Year	Observed		Predicted 6 Days in Advance	
		m^3/s	Date	m^3/s	Date
Nakhon Sawan	1978	3,540	Oct. 07	3,228	Oct. 08
Chai Nat	1978	3,741	Oct. 11	3,408	Oct. 11
Angthong	1978	2,550	Oct. 10	2,693	Oct. 12
Nakhon Sawan	1980	4,320	Oct. 09	4,580	Oct. 09
Chai Nat	1980	3,795	Oct. 10	3,796	Oct. 10
Angthong	1980	3,115	Oct. 15	3,011	Oct. 11
Nakhon Sawan	1983	2,290	Oct. 23	2,348	Oct. 24
Chai Nat	1983	3,290	Oct. 25	3,139	Oct. 27
Angthong	1983	2,482	Oct. 24	2,477	Oct. 28

Table 6-12. ONE-DAY MAXIMUM WATER LEVEL PREDICTED FOR TIDAL COMPARTMENT (STEP 1)

Observation/ Prediction Date /1	Objective Point		Observed		Predicted 6 Days in Advance	
	Location Name	Distance from River Mouth (km)	Water Level (m. MSL)	Time	Water Level (m. MSL)	Time
Oct. 21 1978	Bangkok Port	27	1.73	10:00	1.52	11:00
	Satha Pradit	40	1.77	10:00	1.47	11:00
	Memorial Bridge	48	1.89	10:00	1.86	10:00
	RID Samsen	54	2.03	12:00	1.83	11:00
	Pakred	70	2.15	12:00	1.88	12:00
Oct. 27 1980	Bangkok Port	27	1.77	09:00	1.69	10:00
	Satha Pradit	40	Data Missing		1.65	11:00
	Memorial Bridge	48	1.92	10:00	2.06	10:00
	RID Samsen	54	2.01	10:00	2.00	11:00
	Pakred	70	2.21	11:00	2.30	12:00
Oct. 31 1983	Bangkok Port	27	1.97	15:00	1.72	16:00
	Satha Pradit	40	1.87	16:00	1.60	17:00
	Memorial Bridge	48	1.82	16:00	1.97	16:00
	RID Samsen	54	1.94	17:00	1.73	17:00
	Pakred	70	2.05	18:00	1.90	19:00

Note: /1 Date of observation of annual maximum discharge at Bang Sai.

Table 6-13. FLOOD LAG TIME (STEP 1)

(1) Downstream Point	(2) Upstream Point	(3) Flood Year	(4) Date of Qmax Predicted at (2)	(5) Date of Qmax Observed at (2)	(6) Date of Qmax Observed at (1)	(7) Concentration time (5)-(4) (day)	(8) Traveling Time (6)-(5) (day)	(9) Flood Lag Time (6)-(4) (day)
Nakhon Sawan	Sta. W-H.5	1978	29 Sep	02 Oct	07 Oct	3	5	8
(Sta. W-H.20)	Ping River	1980	02 Oct	04 Oct	10 Oct	2	6	8
		1983	15 Oct /1	20 Oct	23 Oct	5	3	8
	Sta. W-H.7	1978	23 Sep	26 Sep	07 Oct	3	11	14
	Yom River	1980	07 Sep	08 Sep	10 Oct	1	31	32
		1983	04 Oct	06 Oct	23 Oct	2	18	20
	Sta. W-H.13	1978	23 Sep	25 Sep	07 Oct	2	12	14
	Nan River	1980	07 Sep	09 Sep	10 Oct	2	31	33
		1983	05 Oct	07 Oct	23 Oct	2	16	18
Chai Nat	Sta. W-H.14	1978	06 Oct	-	11 Oct	-	-	5
(Sta. W-H.21)	Sakae Krang River	1980	06 Oct /1	-	12 Oct	-	-	6
		1983	18 Oct /1	-	25 Oct	-	-	7
Ayutthaya (1)	Sta. W-H.17	1978	30 Sep	03 Oct	03 Oct	3	0	3
(Sta. W-H.17	Pasak River	1980	01 Oct	05 Oct	05 Oct	4	0	4
		1983	10 Oct /1	14 Oct	14 Oct	4	0	4
Ayutthaya (2)	Sta. W-H.21	1978	-	11 Oct	17 Oct /2	-	6	6
(Sta. W-H.18)	(Chai Nat Dam)	1980	-	13 Oct	28 Oct /2	-	15	15
	Chao Phraya River	1983	-	25 Oct	01 Nov /2	-	7	7
Bang Sai	Sta. W-H.21	1978	-	11 Oct	27 Oct	-	16	16
(Sta. W-H.24)	(Chai Nat Dam)	1980	-	13 Oct	01 Nov	-	20	20
	Chao Phraya River	1930	-	25 Oct	05 Nov	-	11	11

Note: /1 Date of the maximum one day rainfall is substituted.
/2 Date of the predicted discharge is substituted.

Table 6-14. BREAKDOWN OF COST OF TELECOMMUNICATION AND DATA MANAGEMENT FACILITIES (STEP 1)

Cost Item	Quantity	Unit Cost	Amount (US$)
Telecommunication Facilities			
HF Radio Station			
With Housing	30	26,020	780,600
VHF Radio Station			
With Housing	4	24,540	98,160
Without Housing	4	20,400	81,600
Total			960,360

Cost Item	Quantity	Unit Cost	Amount (US$)
Data Management Facilities			
Equipment			202,390
Mini-Computer with CRT Display	1 set		49,170
Hard Disk Drive	1 set		24,640
Magnetic Tape Drive	1 set		12,320
Line Printer	1 set		49,170
Operating System	1 set		12,320
Video Projector	1 set		36,950
CVCF	1 set		12,320
Spare Parts and Accessories	1 set		5,500
Installation and Adjustment of Equipment	L.S.		250
Miscellaneous Cost	L.S.		230
Total			202,870

Table 6-15. UNIT COST OF TELECOMMUNICATION FACILITIES (STEP 1)

Cost Item	Unit Cost (US$)
HF Radio Station	
Equipment	
HF Radio Equipment (3-15 MHz; 100W)	2,340
Antenna, Mast and Materials	7,400
Engine Generator	3,200
Spare Parts and Accessories	240
Installation and Adjustment of Equipment	4,300
Miscellaneous Cost	4,380
Sub Total	21,860
Station Housing	
Material and Installation	3,440
Miscellaneous Cost	720
Sub Total	4,160
Grand Total	26,020
VHF Radio Station	
Equipment	
VHF Radio Equipment (150 MHz; 10W)	2,900
Antenna, Mast and Materials	7,500
AC Power Supply Unit	700
Engine Generator	1,200
Spare Parts and Accessories	400
Installation and Adjustment of Equipment	4,300
Miscellaneous Cost	3,400
Sub Total	20,400
Station Housing	
Material and Installation	3,440
Miscellaneous	700
Sub Total	4,140
Grand Total	24,540

Table 6-16. MEMBERS OF THE FLOOD FORECASTING COMMITTEE IN RID (STEP 1)

	Position in RID	Position in Committee	Existing Related Activity
1.	Deputy Director General for O&M	Chairman	Management of the O&M Division and Regional Offices
2.	Director of Hydrology Division	Member and Secretary	Hydrological observation and analysis of main natural stream of Chao Phraya River.
3.	Director of O&M Division	Member	Management of water flow control
4.	Director of Communications Division	- do -	Telecommunication service
5.	Director of Data Processing Division	- do -	Data compilation by computer
6.	Director of Project Planning Division	- do -	Monitoring and evaluation of projects in RID for future project planning.
7.	Director of Design Division	- do -	Design of riparian structures for flood protection.
8.	Directors of Regional Offices (Nos. 7 and 8) /1	- do -	Flood fighting for agricultural areas.

Note: /1 Directors of Regional Offices shall serve as members upon instructions of the Chairman in accordance with predicted flood area and scale.

Table 6-17. ASSIGNMENT IN RID OF REQUIRED ACTIVITIES FOR THE FLOOD FORECASTING SYSTEM IN THE CHAO PHRAYA RIVER BASIN (STEP 1)

Office	Existing Related Activity	Required Activity
Hydrology Division	Hydrological data observation and storage to study and analyze hydrological phenomena in the Chao Phraya River; repair of gauging facilities	Hydrological data observation /1; collection of hydro-meteorological information; flood prediction; basic data collection for formulation of flood control including flood forecasting; and inspection of gauging stations /2
O&M Division	Public response regarding flood and water flow control of Chao Phraya River	Public response regarding predicted flood data
Communications Division	Communication services for RID offices and other related agencies by radio and telephone including repair and maintenance	Hydrological data transmission /3 ; dissemination of predicted data; maintenance of tele-communication facilities /4
Data Processing Division	Processing and compilation of RID's data by computer	Data input and compilation by computer; and maintenance of computer facilities.
Regional Offices	Hydrological data observation	Hydrological data observation /1

Note: Administrative affairs and training are performed by all the divisions of RID mentioned above for their respective personnel.

/1 Presently executed by the Hydrology Division and Regional Offices of RID, MD and PAT.

/2 Periodical special inspection of gauging stations under Regional Offices are executed by the Hydrology Division, since there are only a few gauging stations in Regional Offices: one recording raingauge and three non-recording raingauges.

/3 All related hydrological data including those of RID, MD, PAT and EGAT are transmitted by this division.

/4 Maintenance of new telecommunication facilities to be installed in RID, MD, BMA, EGAT, LAD and PAT are carried out by the Communications Division.

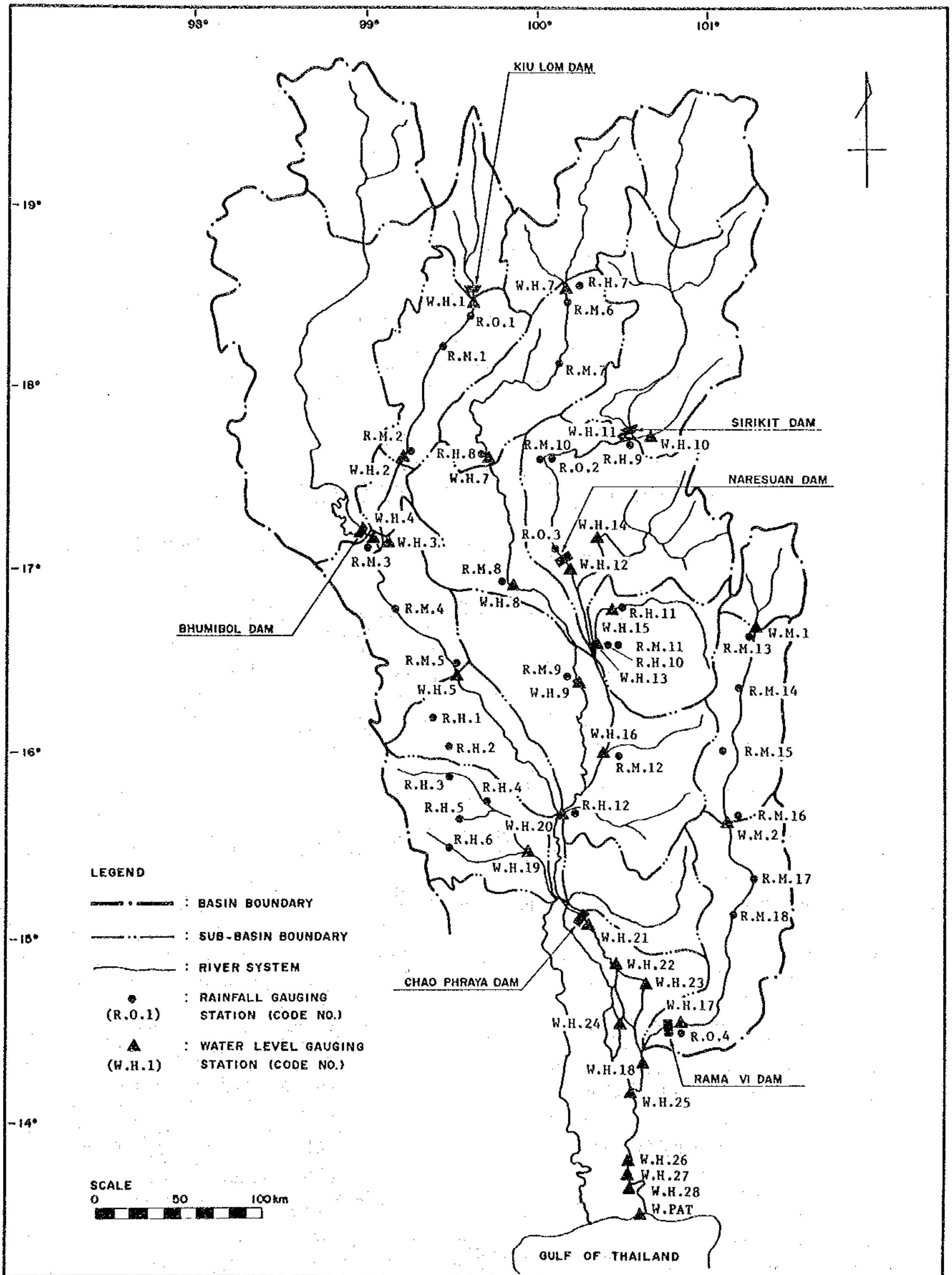

Fig. 6-1. HYDROLOGICAL GAUGING STATIONS (STEP 1)

FLOOD FORECASTING SYSTEM IN THE CHAO PHRAYA RIVER BASIN

JAPAN INTERNATIONAL COOPERATION AGENCY

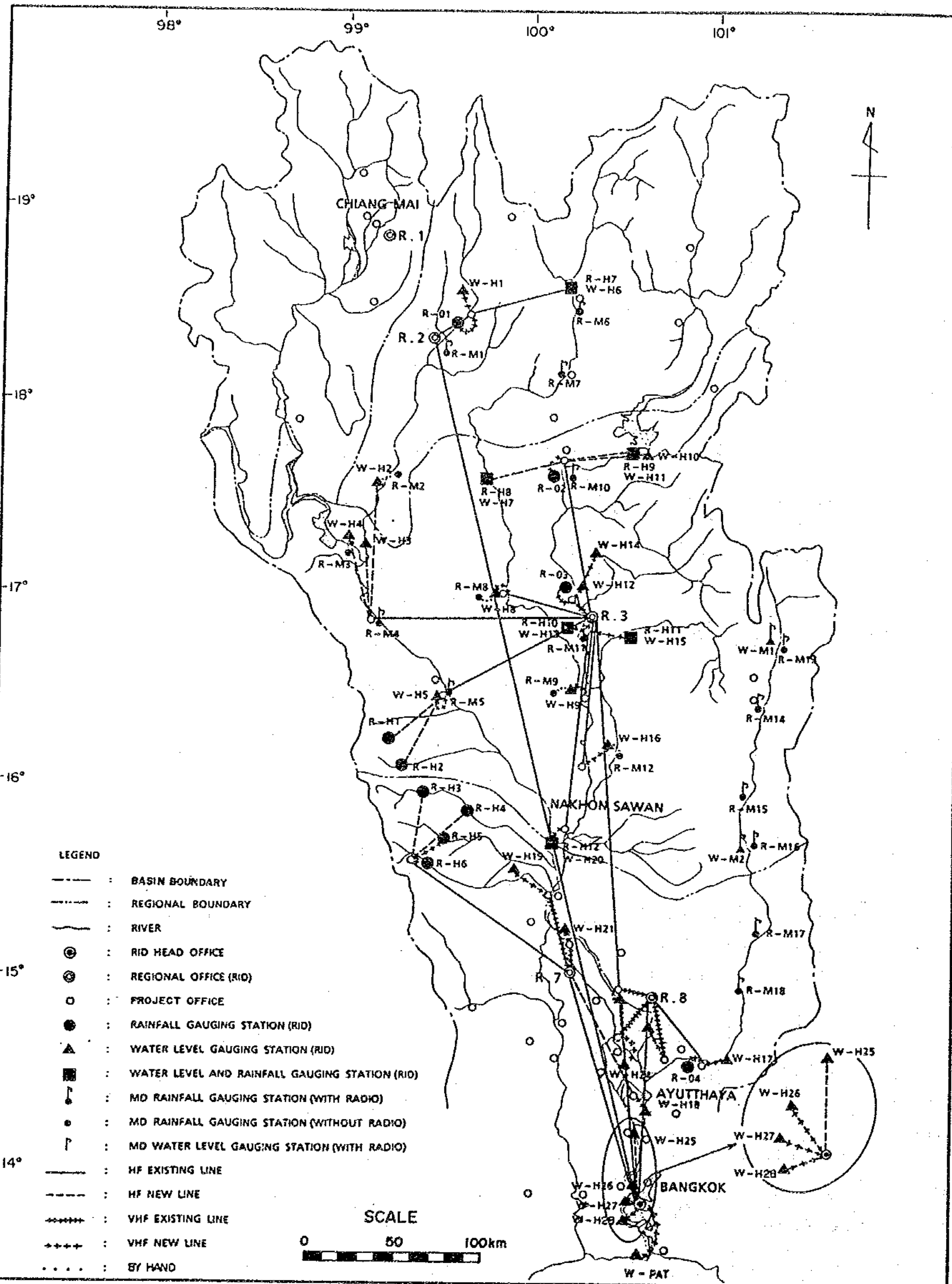

Fig. 6-2(1/3). TELECOMMUNICATION NETWORK (STEP 1: ALTERNATIVE CASE 1)

FLOOD FORECASTING SYSTEM IN THE CHAO PHRAYA RIVER BASIN

JAPAN INTERNATIONAL COOPERATION AGENCY

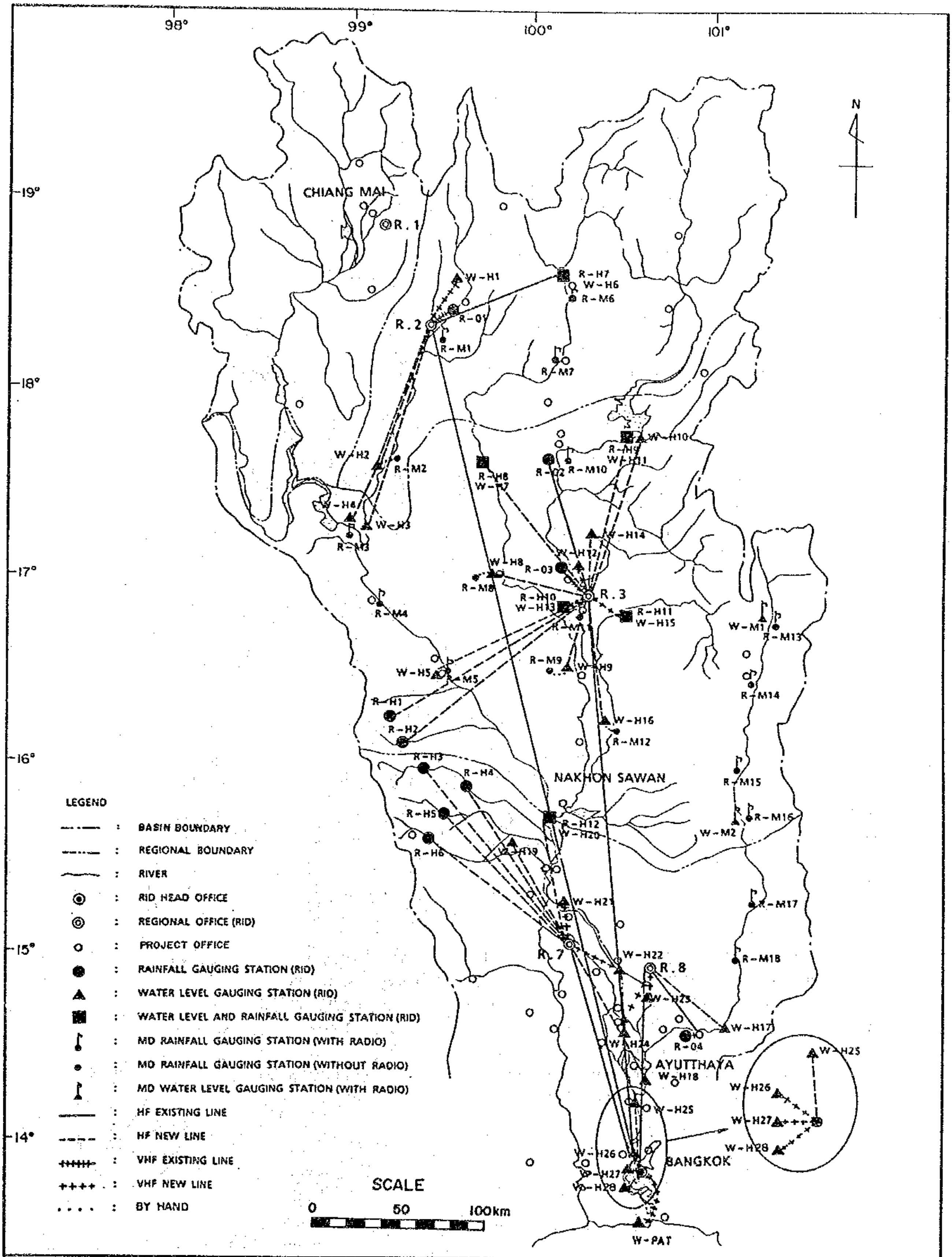

Fig. 6-2(2/3). TELECOMMUNICATION NETWORK (STEP 1: ALTERNATIVE CASE 2)

FLOOD FORECASTING SYSTEM IN THE CHAO PHRAYA RIVER BASIN

JAPAN INTERNATIONAL COOPERATION AGENCY

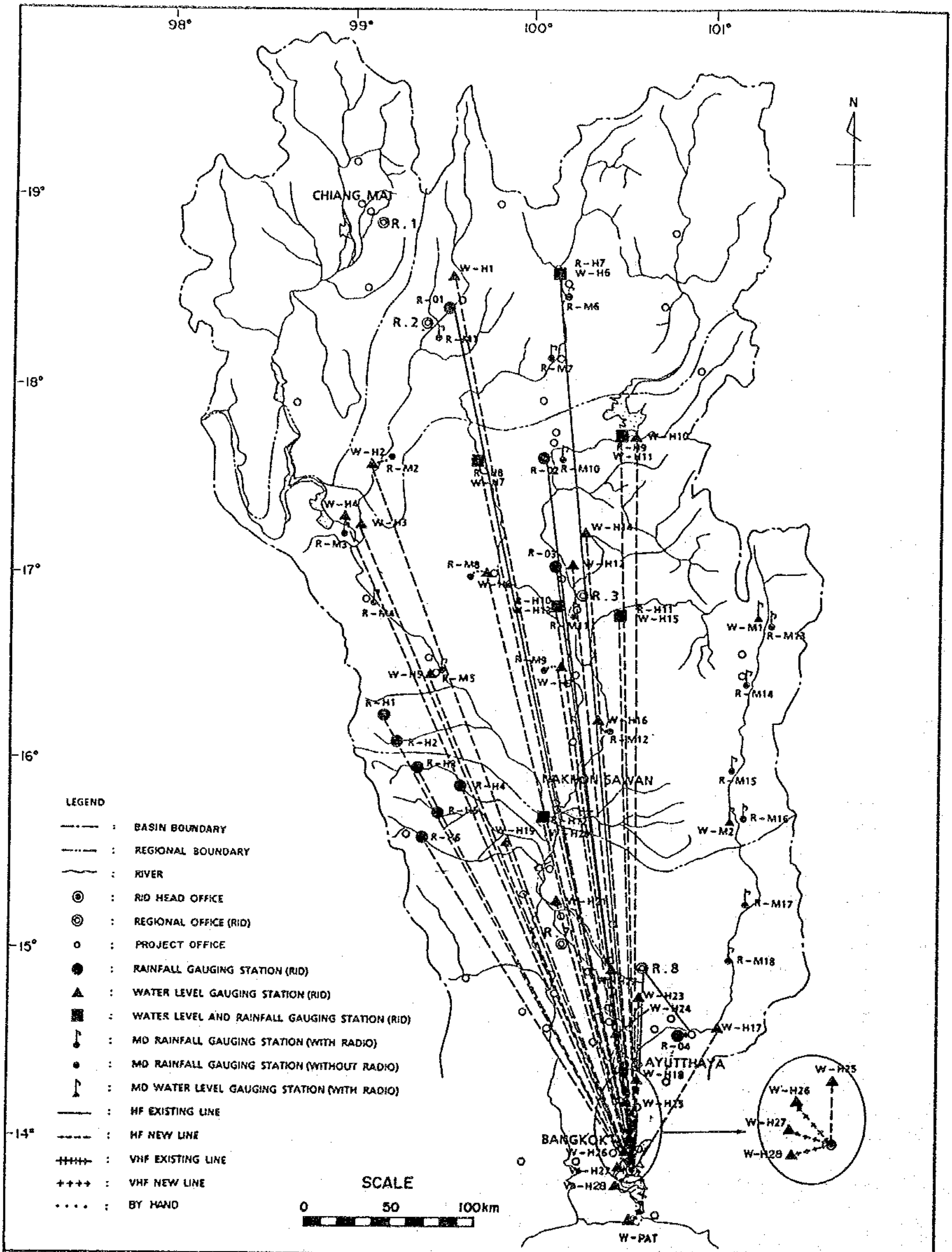

Fig. 6-2(3/3). TELECOMMUNICATION NETWORK (STEP 1: ALTERNATIVE CASE 3)

FLOOD FORECASTING SYSTEM IN THE CHAO PHRAYA RIVER BASIN

JAPAN INTERNATIONAL COOPERATION AGENCY

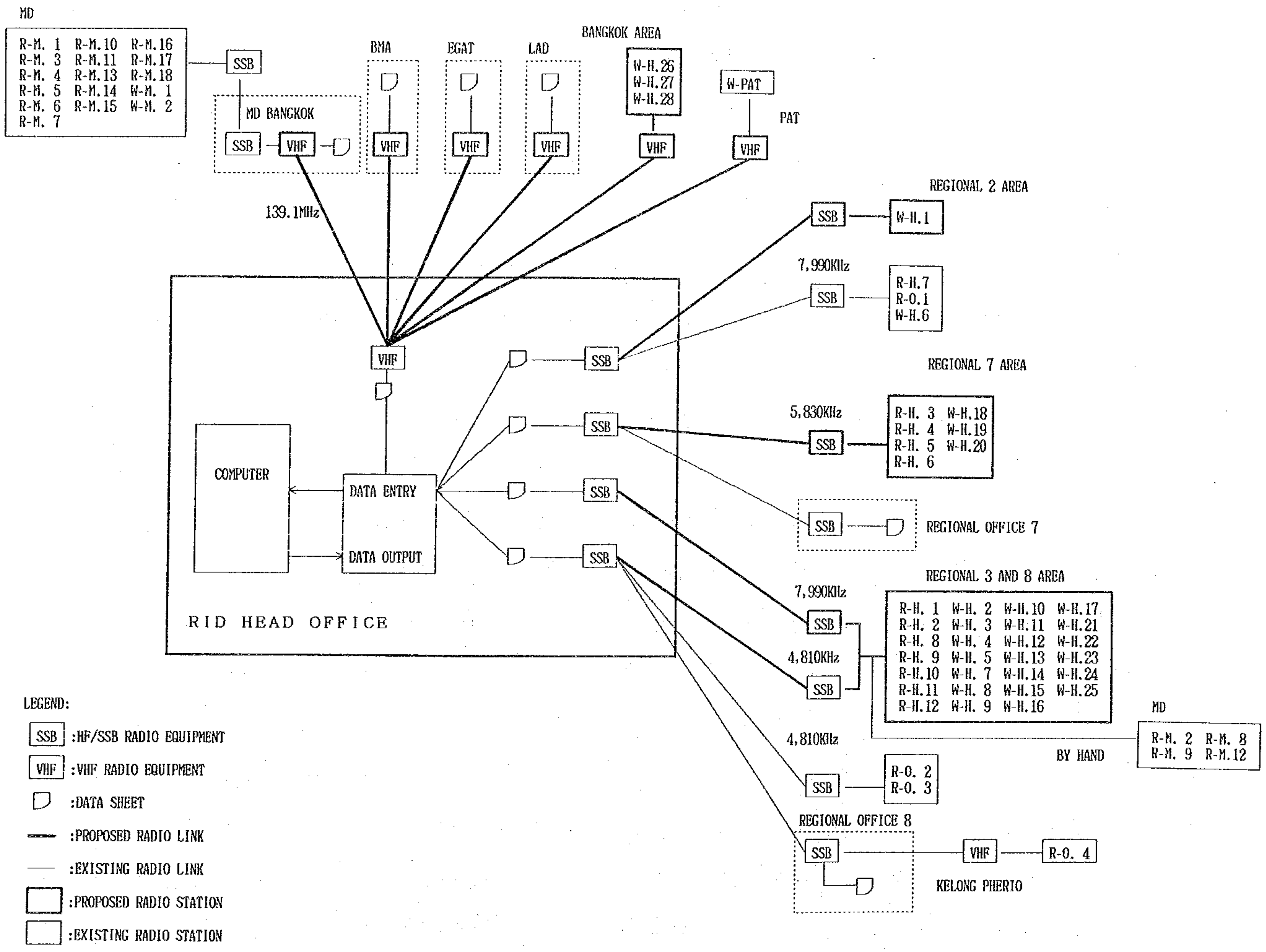

Fig. 6-3. PROPOSED TELECOMMUNICATION NETWORK (STEP 1)

FLOOD FORECASTING SYSTEM IN THE CHAO PHRAYA RIVER BASIN

JAPAN INTERNATIONAL COOPERATION AGENCY

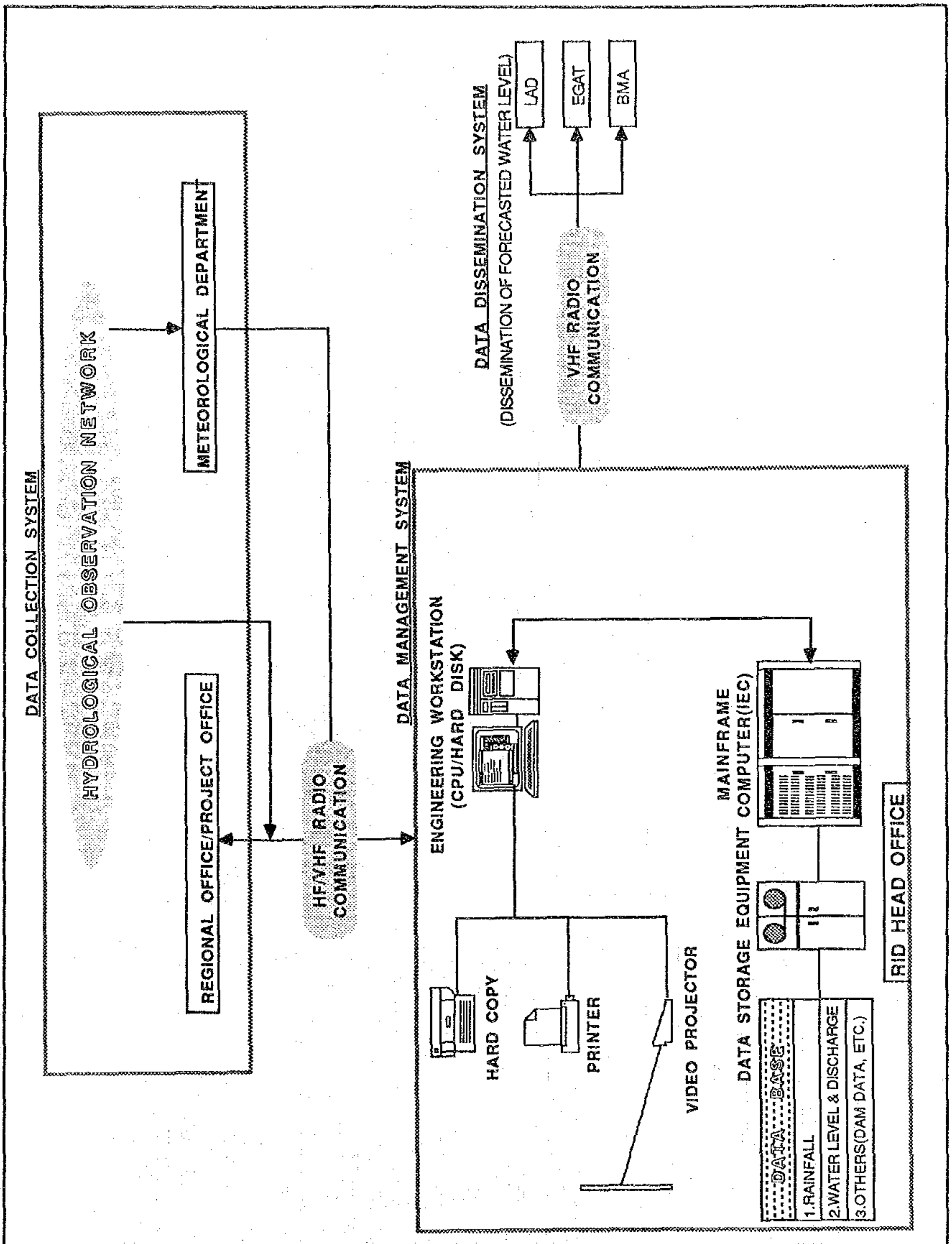

Fig. 6-4. BLOCK DIAGRAM OF DATA MANAGEMENT SYSTEM (STEP 1)	FLOOD FORECASTING SYSTEM IN THE CHAO PHRAYA RIVER BASIN JAPAN INTERNATIONAL COOPERATION AGENCY

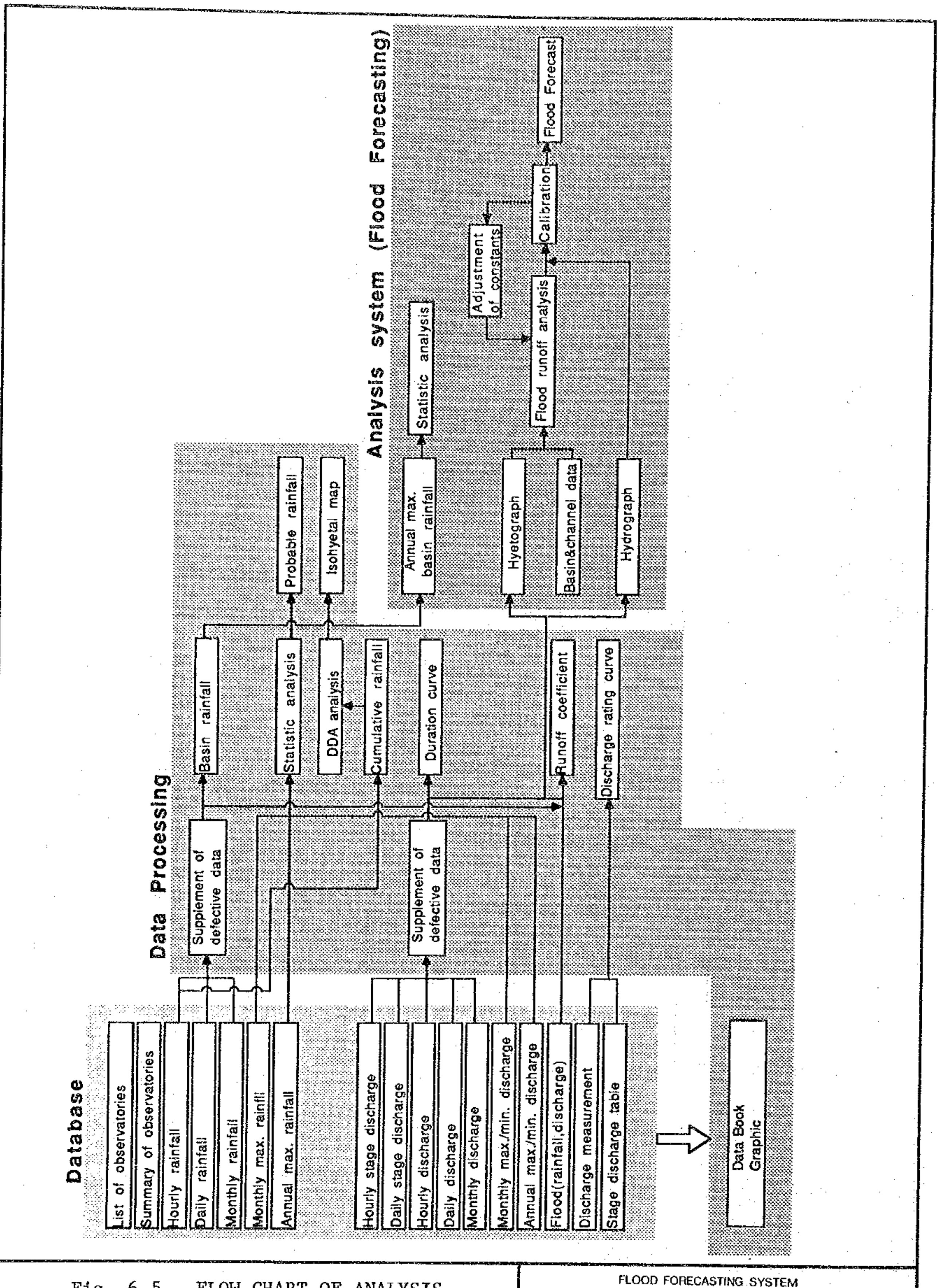

Fig. 6-5. FLOW CHART OF ANALYSIS SYSTEM (STEP 1)

FLOOD FORECASTING SYSTEM
IN THE CHAO PHRAYA RIVER BASIN

JAPAN INTERNATIONAL COOPERATION AGENCY

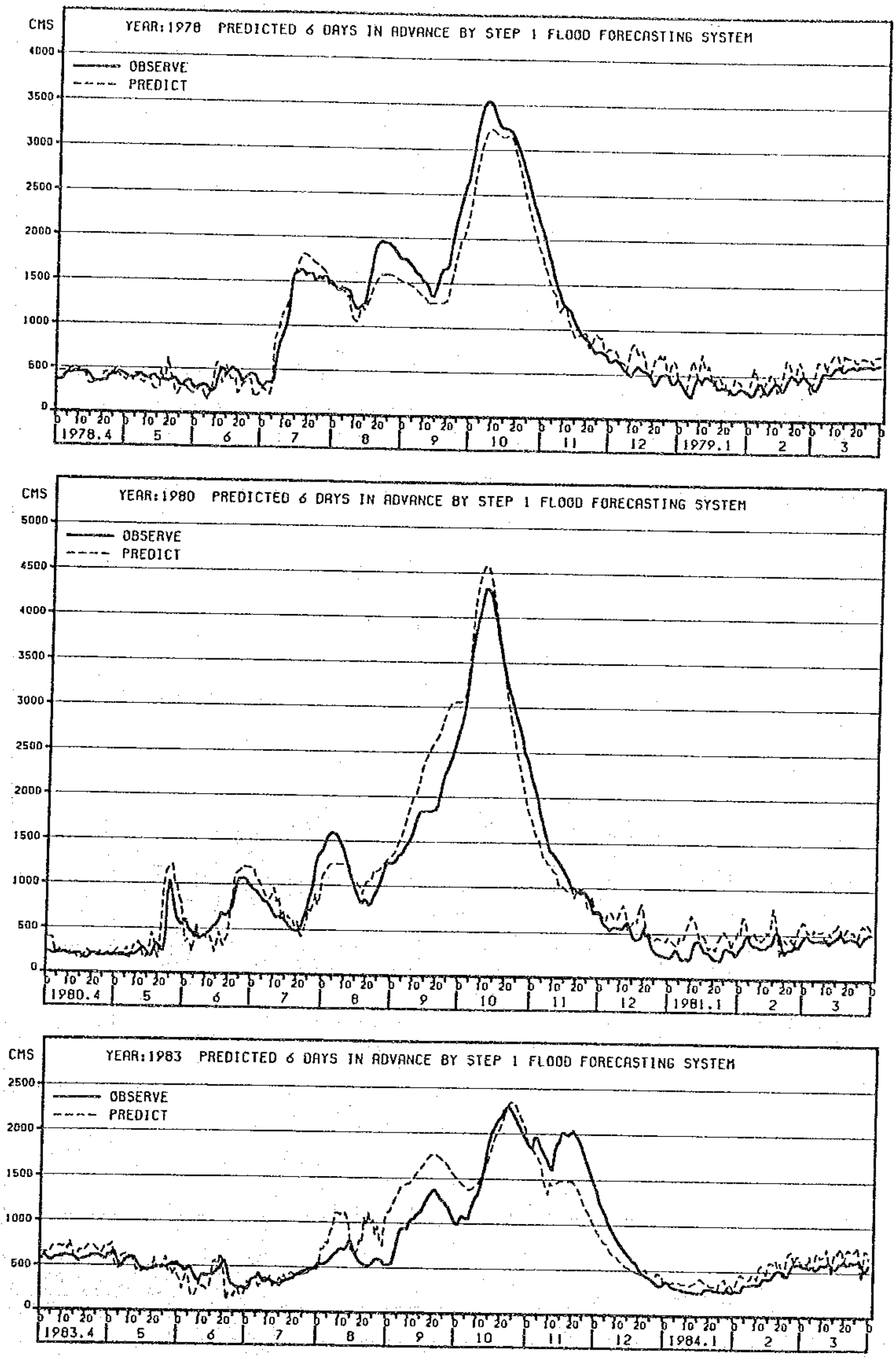

Fig. 6-6(1/3). DISCHARGE HYDROGRAPH PREDICTED 6 DAYS IN ADVANCE AT NAKHON SAWAN (STEP 1)

FLOOD FORECASTING SYSTEM IN THE CHAO PHRAYA RIVER BASIN

JAPAN INTERNATIONAL COOPERATION AGENCY

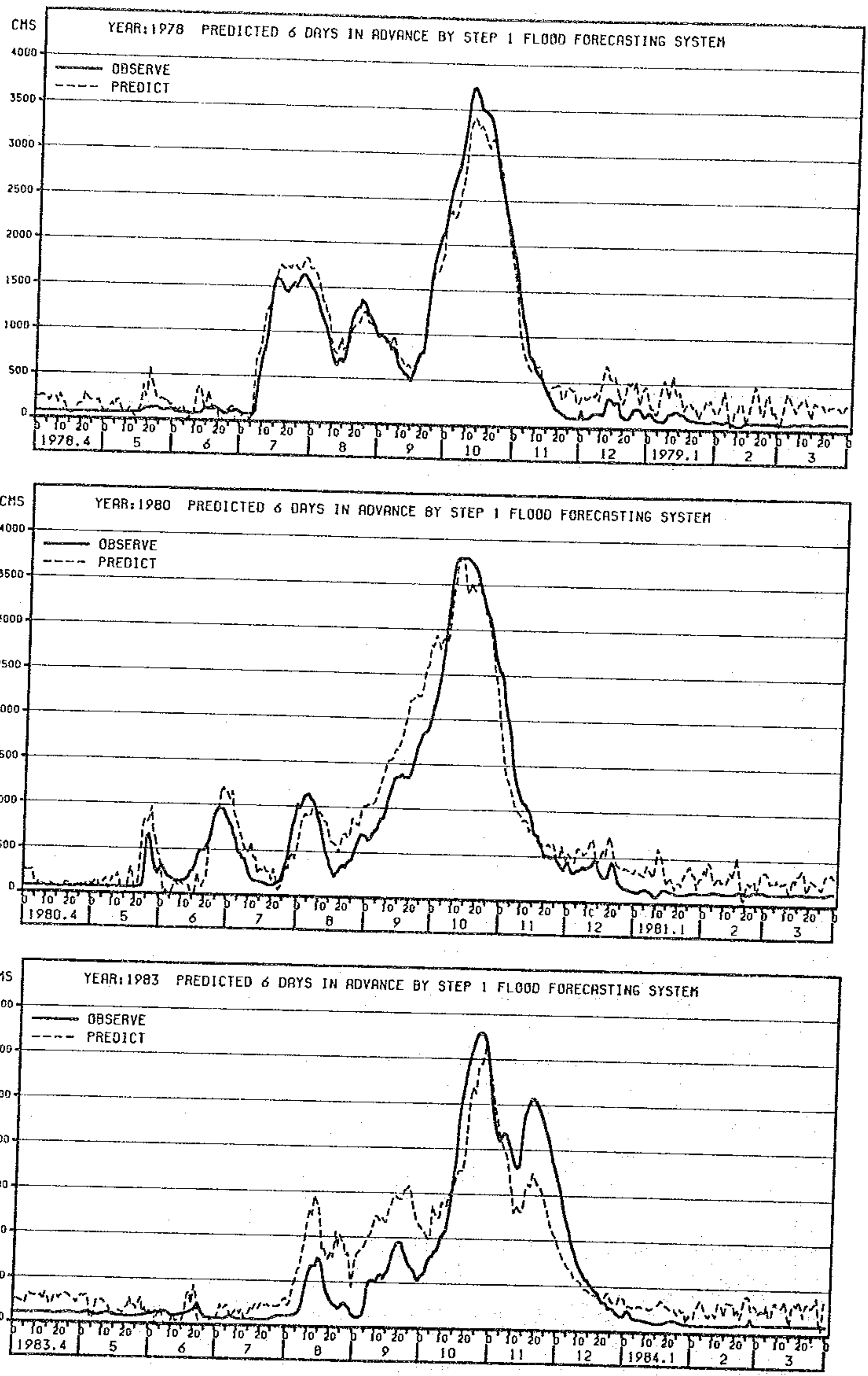

Fig. 6-6(2/3). DISCHARGE HYDROGRAPH PREDICTED 6 DAYS IN ADVANCE AT CHAI NAT (STEP 1)

FLOOD FORECASTING SYSTEM IN THE CHAO PHRAYA RIVER BASIN

JAPAN INTERNATIONAL COOPERATION AGENCY

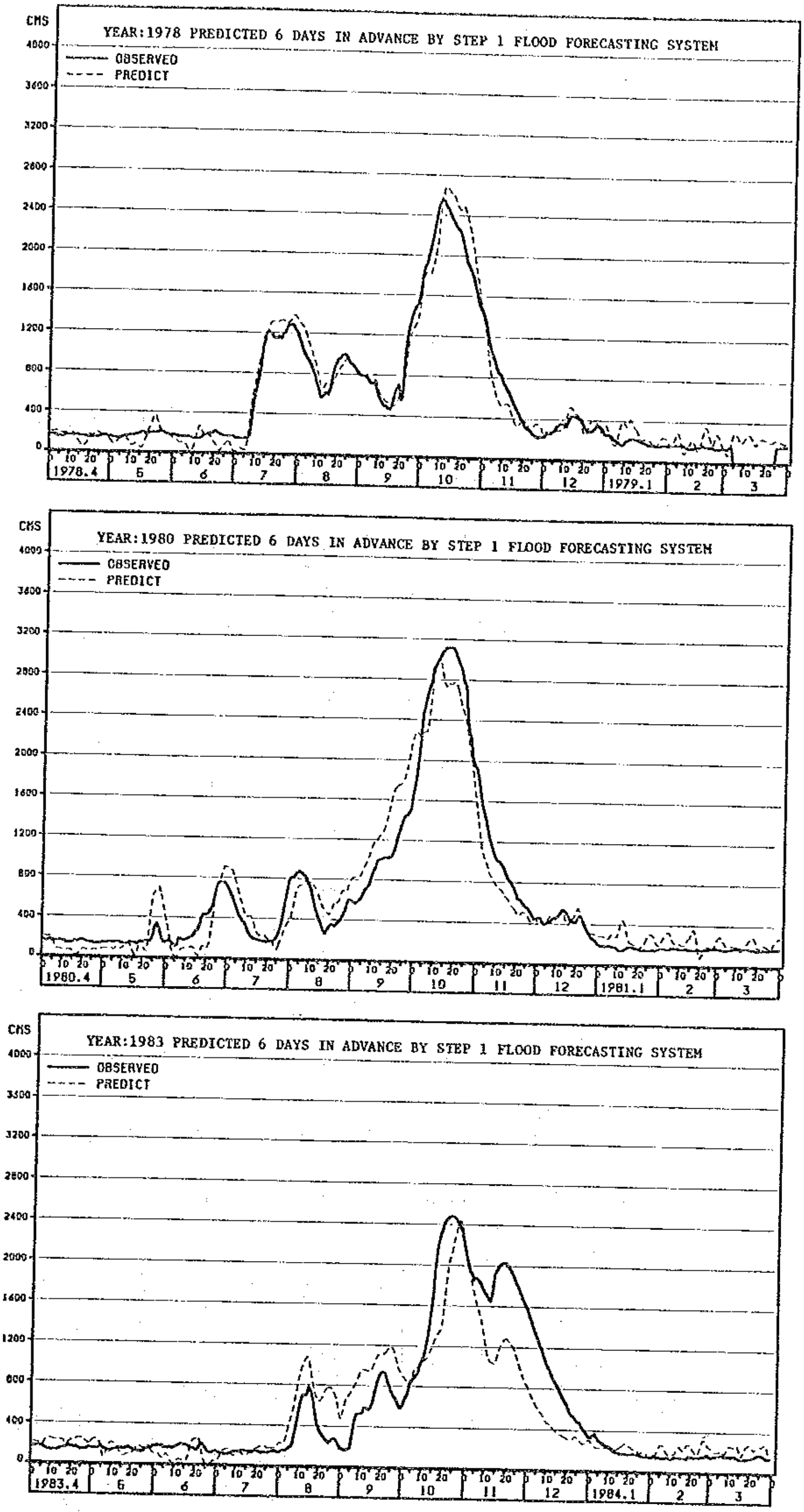

Fig. 6-6(3/3). DISCHARGE HYDROGRAPH PREDICTED 6 DAYS IN ADVANCE AT ANG THONG (STEP 1)	FLOOD FORECASTING SYSTEM IN THE CHAO PHRAYA RIVER BASIN JAPAN INTERNATIONAL COOPERATION AGENCY

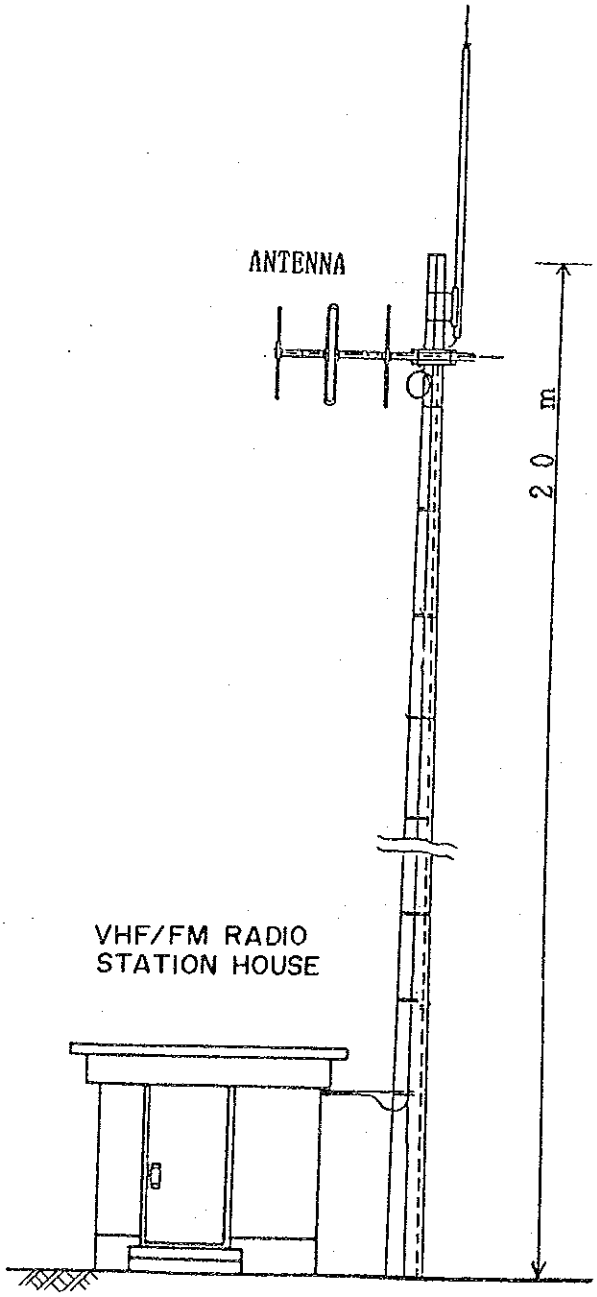

Fig. 6-7. STANDARD DRAWING OF VHF/FM RADIO STATION (STEP 1)

FLOOD FORECASTING SYSTEM
IN THE CHAO PHRAYA RIVER BASIN

JAPAN INTERNATIONAL COOPERATION AGENCY

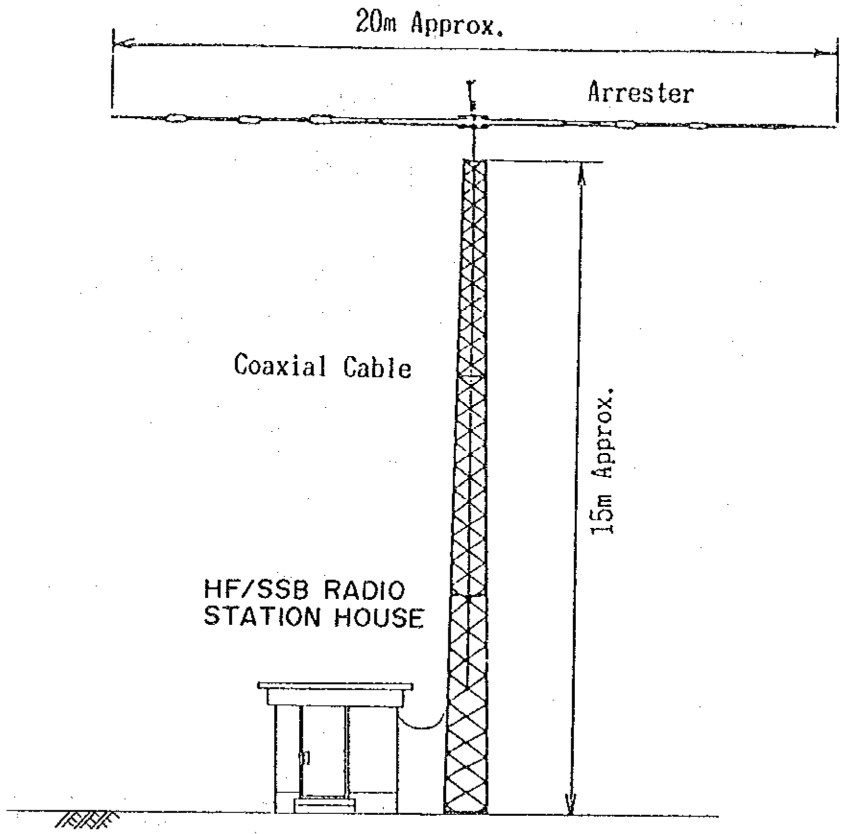

Fig. 6-8. STANDARD DRAWING OF HF/SSB RADIO STATION (STEP 1)

FLOOD FORECASTING SYSTEM IN THE CHAO PHRAYA RIVER BASIN

JAPAN INTERNATIONAL COOPERATION AGENCY

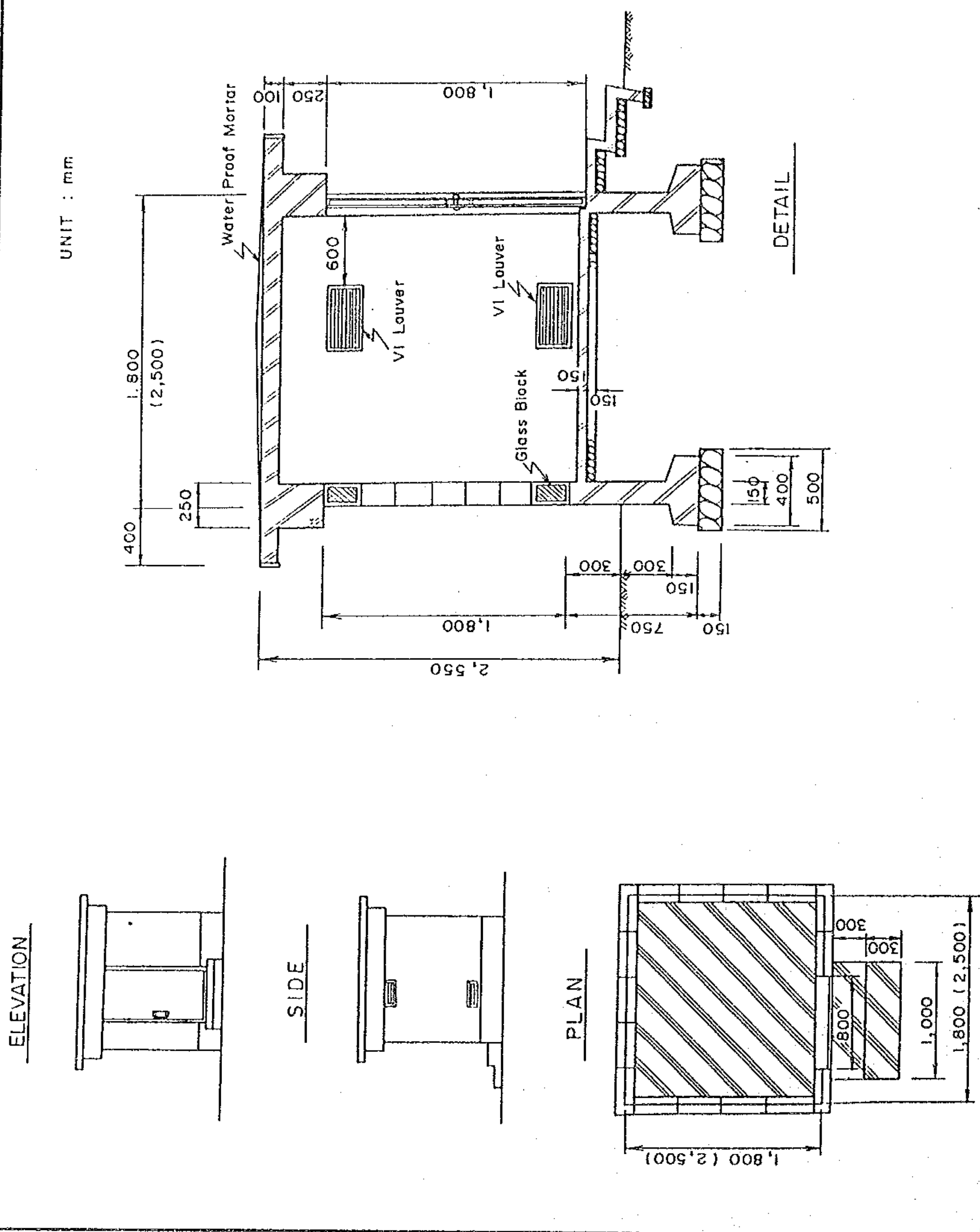

Fig. 6-9. STANDARD DRAWING OF RADIO STATION HOUSING (STEP 1)

FLOOD FORECASTING SYSTEM IN THE CHAO PHRAYA RIVER BASIN

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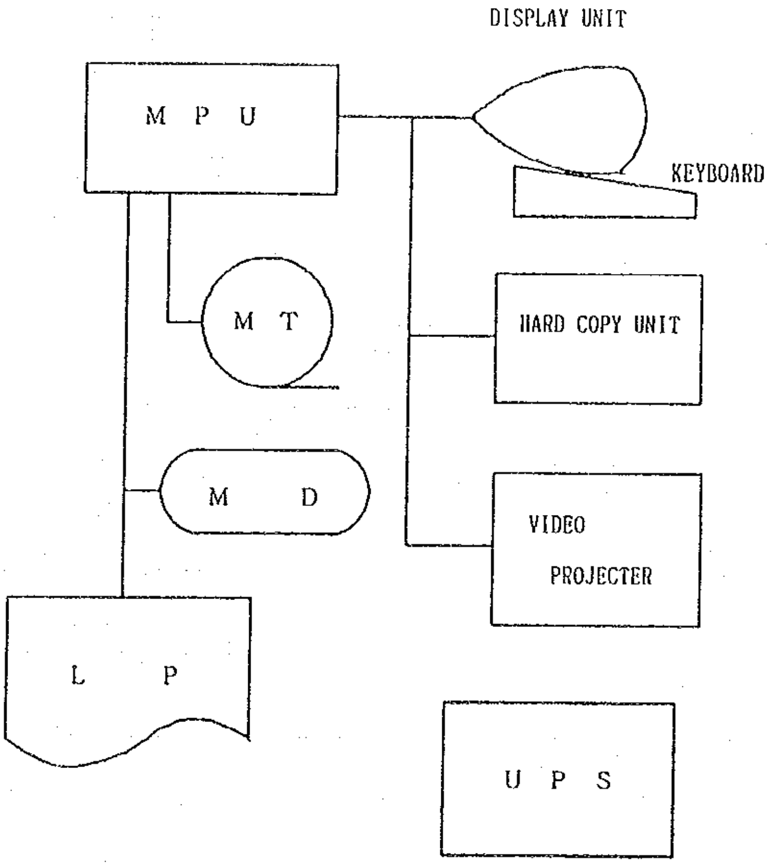

MPU : MAIN PROCESSING UNIT

M T : MAGNETIC TAPE

M D : MAGNETIC DISK

L P : LINE PRINTER

UPS : URGENT POWER SUPPLY

Fig. 6-10. DIAGRAM OF DATA PROCESSING FACILITY (STEP 1)

FLOOD FORECASTING SYSTEM IN THE CHAO PHRAYA RIVER BASIN

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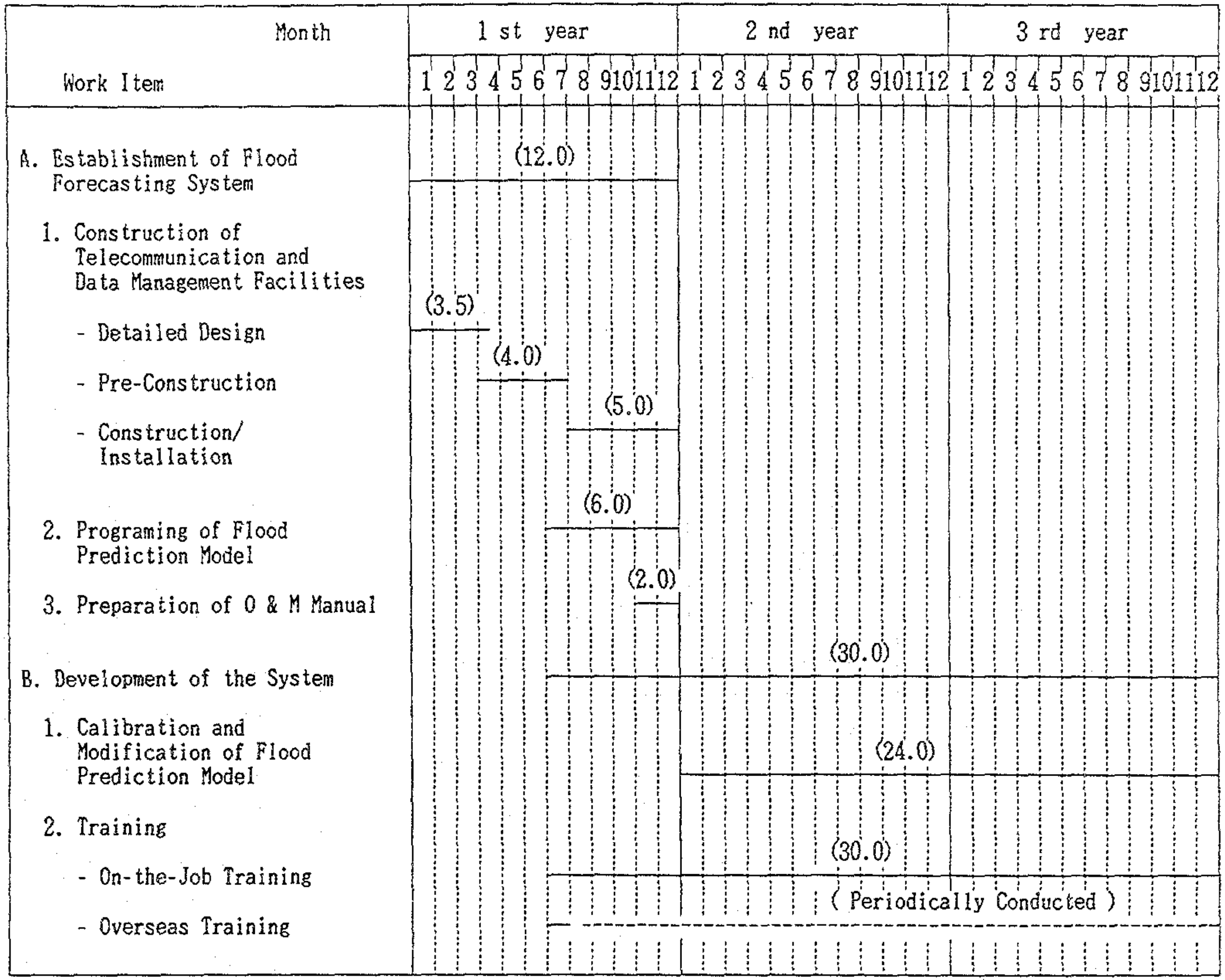

Fig. 6-11. IMPLEMENTATION SCHEDULE (STEP 1)

FLOOD FORECASTING SYSTEM
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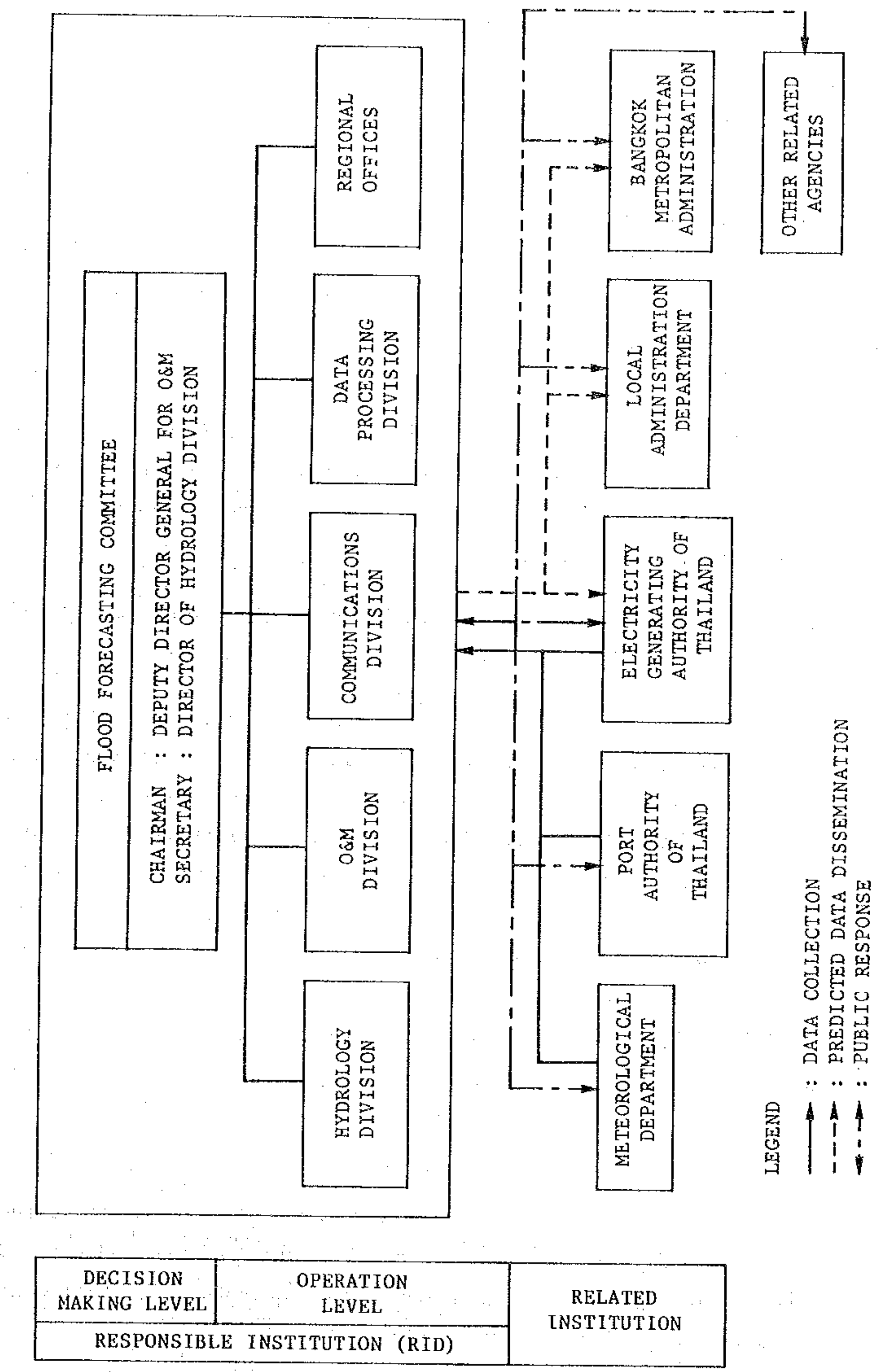

Fig. 6-12. PROPOSED ORGANIZATION CHART OF FLOOD FORECASTING SYSTEM (STEP 1)

FLOOD FORECASTING SYSTEM IN THE CHAO PHRAYA RIVER BASIN

JAPAN INTERNATIONAL COOPERATION AGENCY

CHAPTER 7. FLOOD FORECASTING SYSTEM BASED ON UPDATED FACILITIES (STEP 2)

7.1 Principles of Formulation

The Step 1 Flood Forecasting System has been formulated to cope urgently with the flood damage, and it cannot adequately cover the Chao Phraya River Basin. The Step 2 Flood Forecasting System is, therefore, formulated to include the following considerations in addition to the concepts mentioned in Chapter 4.

(1) The Step 2 Flood Forecasting System is formulated as a master plan, and further detailed study is expected to be performed in coordination with the ongoing water management study.

(2) The Step 2 system is formulated on the basis of updated facilities, all of which are newly introduced.

(3) It will take quite a long time to establish a system that can cover the whole basin, and it is not practical to implement the works for a wide area at the same time in a short period. Therefore, it is proposed to execute the project stepwisely in accordance with the priority of the target area, with more emphasis on short term flood prediction based on the emergency of the situation.

7.2 Formulation of Proposed Flood Forecasting System

7.2.1 Data Collection

The Step 2 gauging system is herein formulated to increase the accuracy of flood prediction results and protract the flood prediction time. To achieve this purpose, the following measures are taken into account:

(1) To propose the most appropriate gauging measures in consideration of the latest models of gauging equipment;

(2) To propose the appropriate number and coverage of the hydrological gauging stations, the selections of which are made purely from the viewpoint of hydrological significance in location for flood simulation works; and

(3) To arrange the order of priority in the installation of gauging stations so as to propose the stepwise development plan in line with the staged extension programs of the target area (refer to Section 5.1).

Objectives of Gauging

Rainfall and water level are the essential items required in calculations for the proposed flood prediction model. The objectives of gauging are as described below.

(1) Objectives of Rainfall Gauge

The coverage of the Step 1 gauging network is limited to within the lower reaches from the Bhumibol and Sirikit dams, while the Step 2 gauging network is expanded to the catchment areas of the two dams. Depending on the expansion of gauging coverage, a longer flood prediction time can be adopted for the downstream target areas. It is further expected that more effective use for potential flood control function can be realized of the dam operation in accordance with the real-time flood forecasting information so as to reduce the flood peak discharges in the target areas.

(2) Objectives of Water Level Gauge

In addition to the sites proposed in the Step 1 Flood Forecasting System, gauging sites related to the existing major river structures are newly proposed in the Step 2 Flood Forecasting System as described herein.

Since the runoff discharge in the dam catchment area is included as an object of flood prediction, it is newly proposed to gauge the reservoir water level at the Bhumibol and the Sirikit dams and also to gauge the stream flow discharges along Ping and Nan rivers in the upper reaches from the dams. The proposed gauging data will provide the boundary conditions in terms of runoff discharge observed in the upstream and monitor the inflow discharges to the dam reservoirs.

It is further proposed to monitor the water level at existing regulators in the major canals which are related to the operation of the Chao Phraya Dam. In accordance with the gauging information, the results of flood prediction will reflect immediately to the integrated control of inflow and outflow discharges of these regulators, as well as the Chao Phraya Dam.

Rainfall Gauge Measure

Gauging measures are roughly classified into two types, the point rainfall gauge type and the radar gauge type.

The point rainfall gauge type has been commonly applied, and this type is employed in the Step 1 gauging system. As described in Section 5.4, the point rainfall gauge is available to predict flood discharges of more than 3,000 m^3/s at Nakhon Sawan. The availability may be attributed to the wide hyetal region and the long flood travelling time of such large-scale flood.

The radar gauge type is recently being developed with the advance of computer systems which can process a large amount of data scanned by the radar into the actual rainfall volume. The major advantages of radar are that one radar gauge has the potential to measure areal rainfall directly within a radius of about 120 km regardless of the size of rainfall area. Radar gauging is, however, performed subject to the real-time calibration using the point rainfall gauge for the reason that the relationship between "the actual rainfall rate" and "the radar reflecting energy" is varied depending on the raindrop size, the intensity of precipitation, etc. Further, a rather long training period will be required to acquire the meteo-hydrological knowledge concerned in the operation of radar rainfall gauge. Facilities for one radar gauge system will also require an enormous cost.

In accordance with the above evaluation, it is recommended to apply both the point rainfall gauge and the radar gauge measures for the Step 2 hydrological gauging system, subject to the following conditions:

(1) The point rainfall gauging network shall be primarily established prior to the radar gauge network. The equipment of point rainfall gauge is herein assumed to be the tipping bucket type which is generally applied to the on-line data transmission system.

(2) Succeedingly, the radar gauge network shall be installed to supplement the accuracy of areal rainfall estimation, subject to the real-time calibration of point rainfall gauge.

Water Level Gauge Measure

It is desirable to select the appropriate gauging equipment for each gauging point among the various alternative types such as the float type, the pressure type and the lead switch type, taking account of each river channel condition. However, the selection subject to the confirmation of the whole channel conditions in the Chao Phraya River Basin is virtually difficult during this study stage. Further, the alternative equipment types have neither an excessive difference in their installation and equipment costs nor an extreme change of the gauging data transmission network.

Due to the above conditions, the equipment for water level gauge is assumed equally to all gauging points as the float type which enables the most flexible installation for various river channel conditions.

Location and Number of Rainfall Gauging Stations

Rainfall gauging stations are to be installed in the proposed 14 subbasins where basin runoff discharge is predicted through the simulation model (refer to Fig. 5-3). As stated before, it is recommended to establish the point rainfall gauge network, and afterwards the radar gauge network. The gauging stations for point rainfall gauge and radar gauge networks are selected as described hereinafter.

(1) Point Rainfall Gauging Station

The necessary density of rainfall gauging points was primarily examined through simulations of rainfall discharges in 1978, 1980 and 1983. The simulation was made on the basis of rainfall data and with gauge densities varying from 1,000 km2 to 1,800 km2 per gauging station in the upper reaches of (1) Nakhon Sawan, (2) Bhumibol Dam, and (3) Saraburi (Sta. S9 in the Pasak River Basin). As the results of simulation, a substantial difference is detected in the observed and simulated discharge hydrographs when the assumed rainfall gauging density is more sparse than 1,200 km2 per station, as shown in Fig. 7-1. The difference is further clarified by the comparison of either the annual peak discharges or the annual discharge volumes, as shown in Table 7-1.

Due to the above verification, the installation density of gauging station is proposed at about 1,200 km2 per station. Further, the location of gauging stations are arranged so as to be equally distributed in the respective subbasin, and also to be nearby the existing gauging stations as far as possible taking into account of the continuity of the gauging period. The exceptional manner of arrangement for gauging stations is, however, applied to the Tha Pla Pi Subbasin (Basin Code No. B-12), where the installation density of about 2,000 km2 per station is available since the basin runoff discharges are simulated to scarcely contribute to the stream flow of the Chao Phraya River.

Based on the aforesaid arrangement, 84 rainfall gauging stations were selected for the Step 2 hydrological gauging network. The location and inventory of these gauging stations are as shown in Fig. 7-2 and Tables 7-2 and 7-3, respectively. The estimation of basin average rainfall has been made on the basis of the gauging stations classified in Table 7-4.

Among the selected gauging stations, 19 stations are to be used in common with the water level gauging stations, and another 65 stations are used purely for rainfall gauging.

(2) Radar Raingauge Station

Among the 14 subbasins regarded as objects of the Basin Runoff Prediction Model, 6 subbasins (Basin Code Nos. BS-4, 9, 10, 11 and 12) in the lower reaches of Ping, Yom, Nan, Pasak and Sakae Krang river basins are adjacent to the downstream target points (refer to Fig. 5-3), and specially characterized as below:

(a) Rainfall prediction for the subbasins is required to perform flood prediction of the target areas due to the short time difference between the occurrence of rainfall in the subbasin and the occurrence of the corresponding runoff discharges at the target points. The time difference is assumed to be less than 3 days in the proposed flood prediction model (refer to Figs. 5-5 and 5-6). Thereby, the radar raingauge is useful to overview the movement of rainfall areas and to predict the time series trend of the rainfall intensity and hyetal region.

(b) Rainfall in the subbasins contributes to the runoff discharges at the target points more sensitively than the rainfall in the other upper subbasins. In this connection, it is desirable to apply the radar gauge so as to catch even the small scale rainfall which is not practically gauged by the point rainfall gauge station.

Due to the above characteristics, two radar raingauge stations are proposed to cover the aforesaid 6 subbasins subject to the available coverage of one radar raingauge station to be about 120 km in radius (refer to Fig. 7-3). The radar stations are to be located approximately in 14°40'N latitude and 100°30'E longitude (south of Lop Buri), and in 16°15'N latitude and 100°15'E longitude (near Taphan Hin).

Number and Location of Water Level Gauging Stations

The water level gauging points were selected due to the following necessities of their gauging data:

(1) To monitor and calibrate the discharge and water level calculated through flood prediction model;

(2) To input the boundary conditions in terms of runoff discharges observed in the upper reaches;

(3) To accommodate the basic data for the tidal prediction in the Gulf of Thailand; and

(4) To monitor the inflow and outflow discharge of major canals at existing regulators.

Correspondingly, 45 water level gauging stations which include one tidal gauging station were selected. The inventory and location of the selected gauging stations are shown in Tables 7-3 and 7-5 and Fig. 7-2, respectively. According to gauging purpose, the selected gauging stations are further classified in Tables 7-6 to 7-8.

Among the water level gauging stations for the Step 2 system, 27 gauging stations were selected at the same locations as those of the Step 1 system for the reason of continuity of cumulative gauging data to be stored, as well as the hydrological significance in location for the calculation of flood prediction.

In addition to the above, the following gauging stations are newly proposed in the Step 2 system:

(1) Four (4) gauging stations in the upper reaches from the Bhumibol and the Sirikit dams, two of which are to gauge the water level of dam reservoirs and the other two, which are located at Chiang Mai and Nan, to gauge the upstream runoff discharges; and

(2) Twelve (12) gauging stations in the lower reaches from Chai Nat Dam, to gauge the water level of Chai Nat-Pasak Canal, Chai Nat-Ayutthaya Canal, Noi River and Suphan River so as to monitor the inflow and outflow discharge at major regulators (refer to Table 7-7).

Installation Priority of Gauging Stations

The installation priority of gauging stations was primarily conceived in accordance with the staged extension programs of the target areas and the expected flood prediction time (refer to Subsection 4.3.2). The priorities were further adjusted from the viewpoint of installation volume.

Through the aforesaid conditions, the installation priorities are divided into five stages as below (refer to Table 7-9 and Fig. 7-2).

(1) As the first priority, it is proposed to install 37 gauging stations in the lower reaches from Nakhon Sawan along the main channel of the Chao Phraya River and in the lower reaches from Wichian Buri along the Pasak River. These gauging stations will enable short term

prediction (prediction time is 3 days) for the target areas except Nakhon Sawan.

(2) As the second priority, it is proposed to install 29 gauging stations in the lower reaches of Ping, Yom and Nan rivers and the upper reaches of Pasak River. The gauging stations will enable short term prediction for Nakhon Sawan as well as 6-day prediction for other target areas.

(3) As the third priority, 21 gauging stations are to be installed in the upper reaches of Ping, Yom and Nan rivers, except the catchment areas of the Bhumibol and Sirikit dams. Provided that the dominant rainfall area covers the installation areas, the flood prediction will be done about 6 days in advance for Nakhon Sawan and more than 6 days in advance for other target areas.

(4) As the fourth priority, 23 gauging stations are to be installed in the catchment areas of Bhumibol and Sirikit dams. Thereby, the gauging network will enable a longer flood prediction time, so that a certain flood mitigation effect may be expected for the respective target areas through the effective use of flood control functions attached to the Bhumibol and Sirikit dams.

(5) As the fifth priority, two radar stations are to be installed so as to facilitate the rainfall prediction measures and improve the accuracy of areal rainfall estimation.

7.2.2 Data Transmission

Planning Conditions

(1) Transmission Data for Flood Prediction

The number of hydrological stations and time interval of data transmission for flood prediction are (a) four water level gauging stations at one-hour interval; (b) 22 water level, 65 rainfall and 19 water level/rainfall gauging stations at 6-hour interval; and (c) two radar rain gauges at five-minute interval. Data processed at the Flood Forecasting Center (FFC) in RID Head Office (refer to Section 7.6) are disseminated to the related agencies in the form of predicted water stage at 6-hour interval.

(2) Telecommunication Facilities

The telecommunication facilities for this flood forecasting system were selected under the following considerations:

(a) The radio transmission link for exclusive use is employed to assure reliability and speed of data transmission;

(b) The on-line system with data transmission is used to prevent occurrence of error due to manual intervention; and

(c) The mutual exchange of information and instruction is made by means of voice communication.

(3) Telecommunication Network and Number of Channels

(a) Formation of Telecommunication Network

Since there are a considerable number of hydrological stations to be linked on the telecommunication network, it is advisable to divide the whole Chao Phraya River Basin into subbasins and to provide substations to collect and manage the hydrological data from each subbasin. For convenience in operating and maintaining the facilities, substations are installed in every RID Regional Office.

The telecommunication network for this flood forecasting system is composed of trunk lines and branch lines for data transmission and communication. Trunk lines will be provided between FFC and substations, and branch lines for data collection will be installed between substations and hydrological gauging stations. Branch lines for data dissemination will be provided between FFC and related agencies.

(b) Number of Channels

- Trunk Line

Two channels will be provided for the communication between FFC and substations: one for data transmission and one for telephone/ facsimile communication. For instructions by hot line, FFC will be connected by one additional channel each to Regional Office Nos. 7 and 8; and, two channels for the radar gauge will be used between FFC and Regional Office Nos. 3 and 8. The number of channels for the trunk lines are shown in Table 7-10.

- Branch Line

  Since the polling system is applied to data collection, one channel is allocated to each branch line connecting substations to hydrological gauging stations. Two channels are allocated for communication between FFC and related agencies; namely, BMA, LAD and EGAT.

Study on Alternatives

A comparative study was done on the formation of telecommunication network putting more emphasis on trunk lines because of several possible alternatives. Some studies on branch lines were conducted, considering the limitations of location and distance.

(1) Trunk Line

Four case alternatives are studied from the aspect of applicable line as explained below. (Refer to Fig. 7-4.)

Case 1: Trunk Line Based on the TOT Long Distance Telephone Line

Since the TOT long distance telephone line connects Bangkok and the main cities where substations are provided, the trunk line can be completed by the provision of only the following supplemental works.

To connect the substations and FFC to the terminal station of the TOT line, RID has to provide a radio line as approach line with no exchanger so as to assure exclusive use by the flood forecasting system. With this line connection, RID will be released from the burden of high initial investment, as well as operation and maintenance cost, though RID has to pay the rental charge of the TOT line.

Case 2: Trunk Line Provided by RID

This trunk line is to be newly provided to directly connect FFC to all substations. In comparison with the other alternative cases, this trunk line is to be constructed on the following conditions: (a) among the frequency bands, UHF band is applied because of the superiority from the aspect of reliability and cost; and (b) multiplex transmission system is adopted to cope with the required number of channels according to the planning conditions.

Since this trunk line is operated and managed by RID itself, maintenance and repair is assured, together with flexibility in future expansion.

Case 3: Trunk Line Based on the CAT Satellite

CAT has a master station in Bangkok and five satellite earth stations (SES) linking the main cities in the Chao Phraya River Basin by way of the INTELSAT satellite. Therefore, the trunk line based on the CAT satellite line can be completed through the provision of an exclusive line connecting these five SES to substations. As in Case 1, RID will be released from the burden of high initial investment, as well as operation and maintenance cost.

Case 4: Trunk Line Based on the PTD Satellite Line

Since PTD rents out only the transponders of PALAPA satellite of Indonesia for communication, the SES must be provided by the user itself, although its location can be freely selected. Therefore, the trunk line using the voice channel of the PTD satellite line can be completed through the provision of the SES installed directly at substations without any approach line.

In this connection, RID must bear the initial investment cost for the construction of five SES, as well as operation and maintenance cost, in addition to the rental charge of the PTD satellite line. Since the rental system of PTD satellite lines is still being developed, this system includes several uncertain items such as rental charge of the line and allocation of available channels of satellite.

Construction cost and operation/maintenance cost for ten (10) years of the four alternatives are summarized in the following table. (Refer to Table 7-11.)

Unit: US$$10^3$

Alternative	Construction Cost	O&M /1 Cost	Total
Case 1 (TOT)	3,169	1,531	4,700
Case 2 (RID)	12,504	2,986	15,490
Case 3 (CAT)	3,305	6,865	10,170
Case 4 (PTD)	4,102	2,286	6,388

/1 The cost includes rental charge for the public radio link.

In this comparative study, the trunk line based on the TOT line (Case 1) is selected as the optimum one because this trunk line has economical advantages over the other cases and the TOT on-land communication system has already acquired sufficient experience in long time operation with reliable performance.

(2) Branch Line

The formation of branch lines for local telemetering and data dissemination are shown in Fig. 7-4.

(a) Branch Line for Local Telemetering between Gauging Stations and Substation

The radio line route for the branch line in this section is subject to the location of repeater stations decided from the topographic condition. Thus, the radio line route is preliminarily selected. The VHF band by simplex line is applied from the economical viewpoint.

(b) Branch Line for Data Dissemination between FFC and Related Agencies

Since the communication distance for this section is very short, the radio line route will directly connect both stations without any repeater station. Multiplex line in the UHF band is applied to the transmission line since the distance is short and two data transmission methods can be employed: by telephone/facsimile and by computer.

Optimum Telecommunication Network

On the basis of the study results, the optimum telecommunication network is proposed as summarized in Fig. 7-5.

7.2.3 Data Management

(1) Functions

The data management system for Step 2 is formulated to satisfy the functions required of an effective flood forecasting system as mentioned in the Subsection 6.2.3. Reinforced functions from those of Step 1 are real-time data filing and processing, real-time flood prediction, displaying visual information, and monitoring basin condition.

(2) Data to be Managed

As in Step 1, data to be managed are classified into two categories: data for flood forecasting and data for flood control. Out of the two categories, data for real-time flood forecasting calculation, as tabulated below, are to be collected anytime.

Type of Data	No. of Data	Collection Interval
Rainfall	84	6 hours
Water Level	42	6 hours
Tide	1	1 hour
Reservoir Water Level	2	6 hours
Radar Rainfall	2	5 minutes

In addition, information on other flood conditions is to be collected from the flood area by off-line data collection system for reference on flood protection work. The data and information to be managed are the same as in Step 1, as shown in Table 6-7.

All the data are to be filed in data bases for necessary analysis and dissemination. The output format of data processing and flood forecasting analysis are presented in the Supporting Report. They will be designed in the appropriate graphic form to provide visual information.

(3) Facilities

Hardwares arranged in FFC are the Engineering Work Station (EWS), Data Storage Equipment, Printer and Color Hard Copy Unit, and Video Projector.

The configuration of the data management system is illustrated in Fig. 7-6, and the specifications of the hardwares are shown in Table 7-12. As for EWS, 3 sets will be placed because real-time flood forecasting, real-time data processing and retrieval of data bases will be conducted simultaneously.

Generally, telemetering data are to be monitored to check basin condition and data error. Information on flood conditions which cannot be arranged in a certain format are to be collected by audio visual equipment and scanner. They will be stored in a specific filing system, and the following equipment will be employed for this purpose: (1) Mimic Board; (2) Electronic Filing System; and (3) Video Tape Recorder.

The specifications of the software are shown in Table 6-9. The application programs for the river information should be prepared during or after installation of the data management facilities. The additional application programs from Step 1 are to be prepared, namely, river information display model (rainfall condition, water level condition and dam data).

7.2.4 Data Dissemination

The related government agencies and regional offices for data dissemination are the same as in Step 1. The facilities to be provided at the agencies concerned and at Regional Office Nos. 7 and 8 are: (1) Remote Terminal Computer, (2) Facsimile/Telephone, and (3) Hot Line Telephone.

The outline of data dissemination system is shown in Fig. 7-8. The information to be disseminated in a manner of visual information consist of the predicted water level at prediction points and the present basin condition. The authorized predicted water level at respective points presented in the form of hydrographs will be disseminated by facsimile, since it is necessary to get approval of an authority responsible for flood control work.

Flood prediction points and kind of predicted water level are the same as in Step 1 in accordance with the agencies concerned. The present basin conditions are to be disseminated through remote terminal computer not only to grasp present conditions but also to predict immediate future conditions. Telephone is to be used for communication between FFC and the agencies concerned; hot line telephone is to be used for communication between FFC and Regional Office Nos. 7 and 8 only.

7.3 Manner of Flood Prediction

Flood prediction at respective prediction points is to be carried out through different combinations of flood prediction models by using the real-time gauged data. Thereby, the results of flood prediction are to be calculated in terms of either the daily average or the hourly average water levels/discharges more than three days in advance for the respective prediction points. The calculations are to be done every six hours on the basis of the gauged data newly collected on the real-time basis so as to update the results of prediction (refer to Section 5.3). The details of the contents of flood prediction are described hereinafter.

Prediction of Daily Average Water Level and Discharge

Predictions are to be made for the target areas except Bangkok on the basis of real-time gauged data collected from the gauging stations in the upper reaches fron Bang Sai. The gauged data are to be continuously and automatically input to the data processing unit, so that they can be successively processed to the runoff discharges, as well as areal average rainfall, and stored by the data memory unit. The gauged data thus processed and stored are to be used for the calculation of flood prediction which has to be made every six hours through the combination of the Basin Runoff Prediction Model, the Channel Routing Model, and the Flood Plain Routing Model. Correspondingly, both water level and runoff discharge are to be predicted in terms of daily average values subject to the renewal of prediction results at every 6-hour interval.

Prediction of Hourly Average Water Level

The results of prediction are to be provided for the Bangkok Metropolitan area which is located along the estuary and strongly influenced by tidal fluctuation. The calculation for prediction has to be made every six hours through the Unsteady Flow Prediction Model by using the following initial condition and boundary conditions.

(1) The water level gauge data are to be collected on the real-time basis from the five (5) gauging stations located along the estuary from the river mouth up to Bang Sai. The collected water level gauge data are to be processed into the water level profile for tidal compartment which is to be used as the initial condition for the time before the start of model calculation.

(2) The upstream boundary conditions for the model calculation are to be given in terms of daily average runoff discharges predicted at Bang Sai.

(3) The hourly average tidal levels are to be predicted through the Harmonic Analysis, using the real-time gauged data of tidal levels at the river mouth. The results of prediction will be used as the downstream boundary conditions of the Unsteady Flow Prediction Model.

7.4 Effectiveness of Flood Prediction

The effectiveness of flood prediction has been examined through simulations using the hydrological gauging data recorded in 1978, 1980 and 1983 at the gauging stations located nearby the gauging points to be selected for the Step 2 Flood Forecasting System. The simulations were carried out subject to the 3 and 6-day advanced predictions; the 3-day prediction corresponds to the short term prediction primarily required of the Step 2 Flood Forecasting System.

The prediction time longer than 6 days has not been examined in this study, since such prediction time essentially requires rainfall prediction, the practical measure of which could not be developed during this study period, specially for the upstream prediction points such as Nakhon Sawan and Chai Nat. It is, however, noted that the advanced prediction time is possibly extended up to about 10 days for the prediction at Bangkok situated at the lowest prediction point due to the long flood lag time (refer to Table 6-13).

The results of simulations are as shown in Tables 7-13 and 7-14 and Figs. 7-7 to 7-12. Compared with the results of flood prediction in the Step 1 Flood Forecasting System (refer to Tables 6-11 and 6-12 and Fig. 6-6), appreciable improvements were recognized for the Step 2 Flood Forecasting System, especially in the results of prediction at Nakhon Sawan and Bangkok. The details are described hereinafter.

Prediction of Daily Average Discharge in the Upper Reaches from Bang Sai

The flood discharge hydrographs were predicted at Nakhon Sawan, Chai Nat and Ang Thong where the observed discharge records are available. The prediction was made through the combination of the Basin Runoff Prediction Model, the Channel Routing Model and the Flood Plain Routing Model.

(1) Prediction for Nakhon Sawan

As shown in Table 7-13 and Fig. 7-7 and 7-8, the results of both 3 and 6-day predictions well coincide with the observed hydrographs in the portion of more than 3,000 m^3/s which is in dangerous condition of overbanking and regarded as the primary object of prediction. However, it is rather difficult to predict the runoff discharges of less than 2,000 m^3/s especially 6 days in advance. The difficulty is attributed to the errors of areal average rainfall estimated from the point rainfall gauge for the small hyetal regions.

(2) Prediction for Lower Chai Nat Dam

As in the prediction for Nakhon Sawan, the results of 3 and 6-day predictions well coincide with the observed discharges, when the runoff discharges are over 2,000 m^3/s (refer to Table 7-13 and Figs. 7-9 and 7-10).

(3) Prediction for Ang Thong

Compared with the prediction results for Nakhon Sawan and Chai Nat, the difference between the observed and predicted discharges is rather large (refer to Table 7-13 and Figs. 7-11 and 7-12). One of the causes is the reliability of observed discharges at Ang Thong where the period of field discharge measurement is quite limited. Accordingly, it is necessary to accumulate sufficient data of field discharge measurements and make further verifications on the model's effectiveness.

Prediction of Hourly Average Water Level for Tidal Compartment

The one-day maximum water levels were predicted 3 days and 6 days in advance through the Unsteady Flow Prediction Model for several points along the estuary and compared with the observed water levels. In this prediction, the following premises are given:

(1) The dates for prediction are set on the days when the annual maximum discharges were observed at Bang Sai in 1978, 1980 and 1983.

(2) The upstream boundary conditions are given from the daily average discharges predicted at Bang Sai either 3 days or 6 days in advance. Thereby, the Step 2 Flood Forecasting System enables improvement of the accuracy of boundary conditions due to the increment of gauging points in the upper reaches from Bang Sai.

(3) The downstream boundary conditions are given from the hourly average tidal levels at Fort Phra Chul which are

predicted through the Harmonic Analysis. Due to the real-time and on-line data collection system, the Step 2 Flood Forecasting System enables updating of the results of tidal prediction at short intervals so as to increase their accuracy. Table 7-14 shows the results of 6-day advanced tidal level prediction to be made subject to everyday updating of results which is assumed to be practical in the Step 2 Flood Forecasting System. The said results of prediction well coincide with the observed values compared with the other results of prediction which were made subject to the updating of results at one year interval (refer to Table 5-11).

In accordance with the aforesaid improvement, the Step 2 Flood Forecasting System improves the results of water level prediction for tidal compartment. As shown in Table 7-15, the 3-day prediction is derived to make the errors of less than 20 cm for all prediction points. As for the 6-day prediction, the errors are also within 20 cm, except in the prediction at Memorial Bridge on October 31, 1983 where the error of 30 cm was calculated.

7.5 Preliminary Design

<u>Facilities to be Provided in Gauging Station</u>

(1) Telecommunication Equipment

The specifications of major telecommunication equipment in rainfall gauging stations, water level gauging stations and rainfall/water level gauging stations are as follows:

- Raingauge

Type	:	tipping bucket type with recorder
Diameter of Inlet	:	200 mm

- Water Level Gauge

Type	:	float type with recorder

- Telemetering Equipment

Transmission Speed	:	50 bps

- Radio Equipment

Frequency Band	:	150 MHz
RF Output Power	:	10 W
Antenna	:	3-element YAGI

- Power Supply Equipment

Solar Cell	:	12V, 8.5W
Battery Capacity	:	DC 12V, 40 AH

(2) Housing and Tower

The typical scheme of housing for proposed rainfall gauging stations, water level gauging stations and rainfall/water gauging stations is shown in Fig. 7-13. Each station housing should have a floor area of at least 3 m^2, considering the size of equipment and space for maintenance activity. A tower of about 20 m in height is installed in each station, and the antenna equipment is set on the top of the tower.

Facilities to be Provided in Radar Raingauge Station

(1) Telecommunication Equipment

The specifications of major telecommunication equipment for the radar raingauge system are given below:

- Radar Transmitter/Receiver

Transmitting Frequency	:	5,300 MHz band
Transmitting Power	:	250 kW or more

- Antenna

Antenna Size	:	3 m Ø parabola

- Signal Processor

Quantization for Range	:	3 km
Quantization for Azimuth	:	2.8° (within 120 km), 1.4° (beyond 120 km)

- Multiplex Radio Equipment

Frequency Band	:	1.5 GHz band
RF Output Power	:	1.0 W
Antenna	:	8-element YAGI

- Multiplex Terminal Equipment

Channel Capacity	:	4 ch

- Power Supply Equipment

Output Voltage	:	AC 220V, 50 Hz
Output Capacity	:	200 kVA

(2) Housing

The typical scheme of housing for radar sites is shown in Fig. 7-13. Such housing will be designed in three-story buildings, so that the radio waves can cover a larger observation area and to provide space for operation and maintenance. The antenna for data transmission will be installed at the side of the housing.

Facilities to be Provided in Repeater Station

(1) Telecommunication Equipment

The specifications of major telecommunication equipment in repeater station are as follows:

- Repeater Equipment

Type	:	Hot/standby automatic change-over and remote changeover
Repeater	:	VHF-VHF repeater

- Radio Equipment

Frequency	:	150 MHz
RF output power	:	10 W
Antenna	:	3-stage Colinear

- Power Supply Equipment

Solar Cell	:	12V, 20W
Battery Capacity	:	DC 12V, 80 AH

(2) Housing and Tower

The typical scheme of housing for repeater stations is shown in Fig. 7-13. A tower of about 30 m in height is installed in each repeater station, and the antenna equipment is set on top of the tower.

Facilities to be Provided in Substation (Regional Office)

(1) Telecommunication Equipment

The telecommunication equipment in substaions consist of those for trunk lines, and branch lines connected to gauging stations or radar sites. The specifications of the major equipment are as follows:

Trunk Line

- Multiplex Radio Equipment

Frequency Band	:	1.5 GHz band
RF Output Power	:	1.0 W
Antenna	:	8-element YAGI

- Multiplex Terminal Equipment

Channel Capacity	:	5 ch or less

Branch Line for Collecting Hydrological Data

- Telemetering Supervisory Equipment

Transmission Speed	:	50 bps

- Radio Equipment

Frequency Band	:	150 MHz
RF Output Power	:	10 W
Antenna	:	3-stage Colinear

- Operating Unit/Console

Operation Function	:	Gauging station selection; Calling interval setting; Voice communication for maintenance

Display Item : Received data;
Received failure;
Date and Time

Branch Line for Collecting Radar Rain Gauge Data (Regional Offices 3 and 8)

- Radar Supervisory/Controller

  Supervisor : 20 items or more
  Controller : 20 items or more

- Brightness Monitor

  Display : 19 inch, color

- Multiplex Radio Equipment
  (same as that for trunk line)

- Multiplex Terminal Equipment
  (same as that for trunk line)

Equipment for Common Use

- Power Supply Equipment

  Output Voltage : AC 220V, 50 Hz
  Output Capacity : 75 kVA or more

(2) Housing and Tower

The typical schemes of housing which will be newly constructed for substations in each regional office are shown in Fig. 7-14. The required floor area is about 100 m^2, considering the size of equipment and space for operation and maintenance. A tower of about 30 m in height is installed in each substation, and the antenna is set on top of the tower as shown in Fig. 7-14.

Facilities to be Provided in TOT Terminal Station

The proposed equipment to be installed in TOT terminal stations are as follows. The space for the installation of equipment will be provided by TOT and electric power consumption by the equipment is included in the rental charge.

- Multiplex Radio Equipment

Frequency Band	:	1.5 GHz band
RF Output Power	:	1.0 W
Antenna	:	8-element YAGI

- Multiplex Terminal Equipment

Channel Capacity	:	5 ch or less

Facilities to be Provided in FFC (RID Head Office)

(1) Telecommunication Equipment

The specifications of the major equipment are shown below:

Trunk Line

- Multiplex Radio Equipment

Frequency Band	:	1.5 GHz band
RF Output Power	:	1.0 W
Antenna	:	8-element YAGI

- Multiplex Terminal Equipment

Channel Capacity	:	16 ch

- Communication Control Unit

Transmission Speed	:	1200 bps or more

- Data Conversion Unit

  Memory : 200 kB or more

Branch Line (For Collecting Hydrological Data in Bangkok Area)

- Telemetering Supervisory Equipment

  Transmission Speed : 50 bps

- Radio Equipment

  Frequency Band : 150 MHz
  RF Output Power : 10 W
  Antenna : 3-stage Colinear

- Operating Unit/Console

  Operation : Gauging station selection; Calling interval setting; Voice communication for maintenance

  Display : Received data; Received failure; Date and Time

Branch Line (For Data Dissemination to Related Agencies)

- Multiplex Radio Equipment (Multi-Direction Type)

  Frequency Band : 1.5 GHz band
  RF Output power : 1.0 W
  Antenna : 3-stage Colinear

- Multiplex Terminal Equipment (Multi-Direction Type)

  Channel Capacity : 3 ch for each station

Equipment for Common Use

- Power Supply Equipment

  Output Voltage : AC 220V, 50 Hz
  Output Capacity : 200 kVA or more

(2) Data Management Equipment

- Engineering Work Station

  CPU : 32 bit
  CRT Graphic Display: 19 inch, color

- Hard Disk Drive

  Capacity : 100 MB or more

- Magnetic Tape Drive

  Density : 1,600 bit/inch
  Transfer Speed : 120 kB/sec

- Printer

  Printing Width : 132 characters/line
  Printing Speed : 180 characters/sec.

- Video Projector

  Size : 100 inch

(3) Housing and Tower

The typical schemes of proposed housing for FFC in the Head Office is shown in Fig. 7-14. The required space is about 600 m^2, considering the size of equipment and space for operation and maintenance activities. A tower of about 30 m in height is installed in FFC, and the antenna is set on top of the tower.

Facilities to be Provided in Related Agencies

Electric power and space for the equipment will be provided by the related agencies such as BMA, LAD and EGAT. The main specifications of the equipment are shown below:

- Multiplex Radio Equipment (Multi-Direction Type)

Frequency Band	:	1.5 GHz band
RF Output Power	:	1.0 W
Antenna	:	8-element YAGI

- Multiplex Terminal Equipment (Multi-Direction Type)

Channel Capacity	:	3 ch for each station

- Terminal Monitor

CRT Graphic Display	:	14 inch, color

7.6 Implementation Schedule and Cost Estimates

7.6.1 Implementation Schedule

Due to the large work volume and execution capability, as shown in Fig. 7-15, the implementation period of each item of work is to be 1.5 years for integrated study, 1.5 years for acquisition of necessary funds, 0.5 year for procurement of Consultant, 2.0 years for detailed design, 0.5 year for pre-construction and 5.0 years for construction of facilities and installation of equipment.

As for the manufacturing and construction work, stepwise completion of the facilities/equipment is considered to be feasible and justified to acquire quicker output in more important areas. Therefore, the proposed work shall be implemented in five phases based on the study results on installation priority of gauging stations described in Section 7.2.1 (refer to Table 7-16). The required period for each phase shall be 12 months, including the period of 8 months for procurement of equipment and 4 months for installation and adjustment. The civil works of 8 months can be implemented within the period of procurement of equipment (refer to Fig. 7-16).

7.6.2 Cost Estimates

Construction Cost

For the estimation of project cost, careful consideration and evaluation have been made on items such as local availability of equipment, their prices, and other necessary items relevent to system construction. The total construction cost of the system comprise costs of purchase of equipment, construction, installation/adjustment, and engineering services; plus 10% physical contingency. The reference time for estimation is set at December 1987, and the currency conversion rate is based on the average rate for 10 days in the same month and year, i.e., US$1.00 : 25.5 Bahts : 130 Yen. The total cost of the proposed system is estimated at US$55,947,500, as shown in Table 7-17.

In case of stagewise implementation, the cost for each phase is shown in Table 7-18 and summarized as follows:

Detailed Design	:	US$ 3,882,800
Phase 1 Construction Works	:	US$11,582,000
Phase 2 Construction Works	:	US$ 5,249,500
Phase 3 Construction Works	:	US$ 5,212,400
Phase 4 Construction Works	:	US$ 5,222,500
Phase 5 Construction Works	:	US$24,798,300

Operation and Maintenance Cost

The operation and maintenance costs consist of the rental fee of the TOT line, personnel costs, costs for spare parts and consummables and other miscellaneous expenses. The annual maintenance and administration costs is estimated at the amount of US$1,688,600 after the completion of the system and its breakdown is shown in Table 7-19.

7.7 Administrative Structure for System Operation and Maintenance

Organizational Setup

Setting up of an integrated organization in RID is desirable for the systematic execution of flood forecasting. The proposed organization chart consisting of the Flood Forecasting Center (FFC) and other related agencies and offices is presented in Fig. 7-17.

A Chairman with adequate knowledge on flood control and flood forecasting and who is in a responsible position to coordinate the activities of related offices in RID will be needed to manage the Flood Forecasting Center.

An Advisory Committee under the Chairman will be established to evaluate predicted flood data and to promptly provide adequate flood fighting activities. The members of the Advisory Committee are to be recruited from the existing related divisions and offices in RID.

Table 7-20 presents the members and their existing related activities. The Flood Prediction Section under the FFC which will execute primary works on flood forecasting shall serve as Secretariat of the Committee.

In accordance with the instructions of the Chairman, the actual operation and maintenance of the flood forecasting system shall be carried out by some sections under the FFC such as the Administrative Section, the Flood Prediction Section, the Communications Section and the Data Processing Section, in consideration of the required activities mentioned in detail in the supporting report.

Assignment of Required Activities

The assignment in the FFC of the required activities is tabulated in Table 7-21. The substations to be set up in regional offices (Nos. 1, 2, 3, 7 and 8) for the inspection of telecommunication facilities such as telemetering, radar and