〈기술정보〉

－인도네시아의 습지개발에 따른 수문분석－
Hydrological Study for the Swamp Areas in Indonesia

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주 : 본고는 필자가 3개월간 인도네시아의 습지개발에 따른 수문용역을 마치고 작성한 보고서 내용을 요약한 것임.

1. INTRODUCTION

Many rivers and canals cross the swamp areas in which the schemes are situated during their course from the upstream of catchment areas. In period of low discharge, the tidal influence may extend as far as inland which land is essentially level and the streams through it are at or below the elevation of high tide at the proposed swamp area. Some smaller rivers originated from the swamps themselves. They are tributaries to the biggest rivers or flow directly to the sea. The rivers in their lower sections form branches and deltas. The Barito river which located near the Tamban and Jelapat project area is one of the large river in the Kalimantan Province(Fig.1).

The whole Indonesia is divided into 90 river basins. The Barito river basin which catchment area having about 61,000㎢ is one of them and further divided into seven sub-basins i.e. S. Barito, S.Kapuas, S.Murung, Martapura, S. Riam Kanan, S.Riam and S.Negara. Alalak river is also a kinds of tributary river of Barito river system having about 945.8㎢ catchment basin and Jejangkit project area is located near the this river. According to the Terms of reference, hydrological studies contains all available hydro-meteorological data collection and processing for carrying out the feasibility study on the selected areas, assess of flood water level of tidal movement, and establish from empirical calculations of the volume of excess water to be evaluated in the drainage area. Also asses for the quality of hydrological network and make recommendations for improving hydrological data collection procedures, and mathematical river modelling or the drainage areas under the tidal influence. Further, the hydrology consultant services are review of data and report, field studies to collect local information to formulation and evaluation of existing condition of all hydrological phenomena in the project. Over whole of the swamp areas in the projects are contains a lot of plenty water also there was no constructed reservoir to supply for irrigation water.

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The Tamban and Jelapat areas have been supplied for irrigation water by tide back water movement so called tidal irrigation system and Jejangkit area was irrigated by rainy paddy system. These system cause by a plenty of water during the wet season but there was some difficulty problem during the dry season even though drinking water. In this study, above mentioned problems are treated at the level of feasibility study and some of solution method be provided for next design procedure.

2. HYDRO-METEOROLOGICAL INVESTIGATION

The climate in the project area is characterized by typical tropical monsoon climate. The north-west monsoon gives heavy rainfall to the study area from November to April of next year(wet season). Dry months occur between May and October by influence of south-east monsoon (dry season). In general the average number of rainy days during the wet seson is rather large and about 72% of annual rainfall concentrates in this period. By the and of April and until November, wind becomes gradually more southerly. Particularly during the period of three months from July to September, there are often long spells of drought.

The meteorological data, rainfall, sunshine

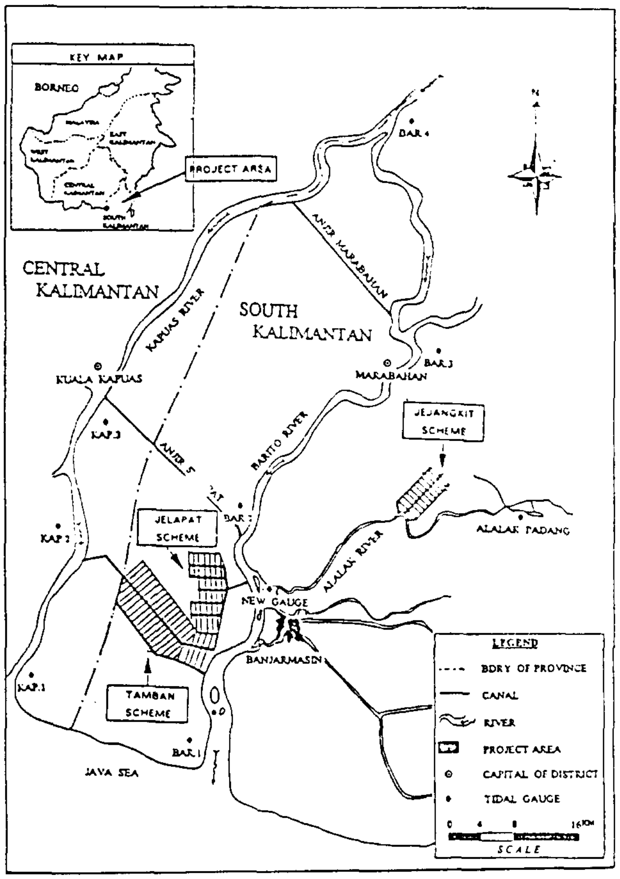

Fig.1 Map of Project Location

hour, temperature, relative humidity, wind velocity and evaporation, which are collected in the standard meteorological stations by the survey team and be presented from the counter parts as below.

The data of rainfall for a considerable long period are available near the project as named the meteorological station of Banjarbaru and Syamsudin Noor(Airport). Seasonal patterns of rainfall observed at each stations are presented in clearly in Fig.2.1, more than 70% of the annual rainfall is concentrated from November to April of next year. There are also some stations to measure only the rainfall but the positions of each stations are not coincided and the data has not timely continuity.

The annual average rainfall is calculated 2580mm in this project. But it varies widely from year to year ranging between 1400mm and 4300 mm. The monthly rainfall amount is expressed by 214mm in average and varying from 64.8mm in July to 378.2mm in January. The difference between wet and dry season is approximately estimated to 1000mm. It can be seen that there is a clear trend in rainfall pattern despite the fact that there is a marked difference in the yearly rainfalls.

The annual average temperature is 26.3℃ that is similar with 26℃ of average value of Indonesia. The variation of monthly temperature was represented as shown in Fig.2.2.

Average value of relative humidity is represented about 85% and varying from 79 up to 89% monthly variation. The difference between dry and wet season shows approximately 10%. This high humidity means that this project belongs to a tropical rain forest climate.

Open-pen evaporation tool is used for daily evaporation records. Collected period of the Banjarbaru station was 1977 to 1992 having 16 year records. The annual mean evaporation is about 1,200mm and maximum value is recorded 1,500mm in a year.

There is not so great variation which indicated in monthly average value of wind velocity. This country is located near the quator zone, wind speed is not so speedy compare with more Northern and Southern part of another country. The difference range is about 0.5km/day.

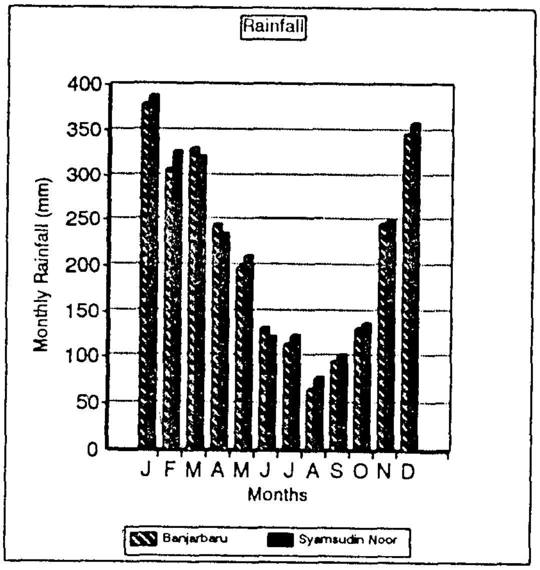

Fig.2.1 Monthly Rainfall

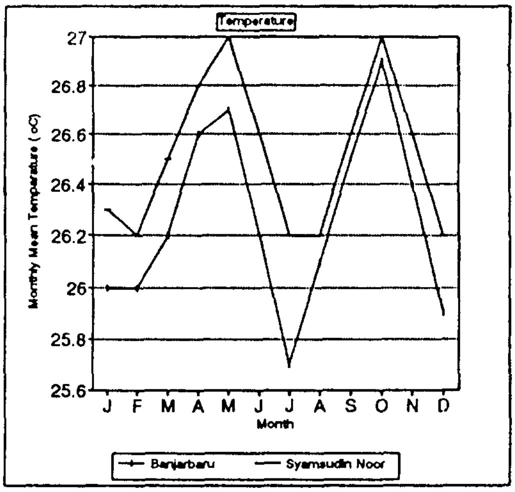

Fig.2.2 Temperature

3. TIDE

3.1 Salt Intrusion

Salt intrusion can take place by saline river water entering the drainage system and fiooding the rice fields or by saline groundwater fiow. Therefore, the distance from the project area to the sea as well as to the river is of major importance. When considering the reclamation of an area, the first question to be answered is whether the area to be reclaimed consists of strongly saline soils and/or is subject to flooding with saline river water. The reclamation strategy as well as the soil and water management to be followed depend on it.

In case the area is under influence of permanent dry and wet season saline river water conditions, rice-fields have to be protected against salinity intrusion. Exclusion of saline tidal flooding and desalinisation of the land by empoldering is the only possible way to reclaim these areas. When the area is only subject to salt river water intrusion during the dry season or when the river water is fresh during the whole year other reclamation and management techniques can be practiced. Fig.3.1 Shows the salt intrusion boundary in the river system which denoted tidal river section.

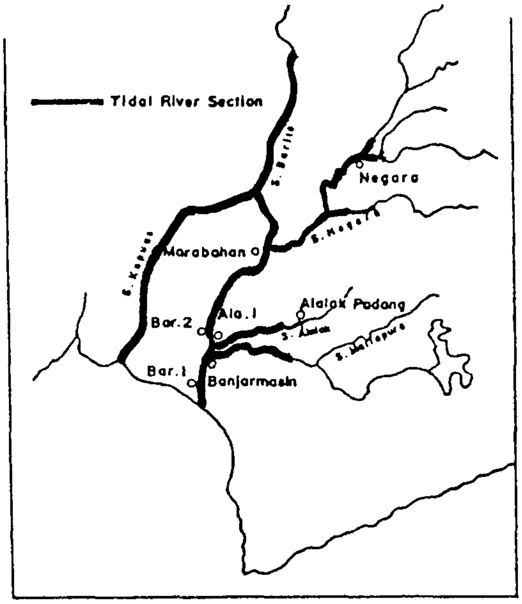

Fig.3.1 Boundary of Tidal River Section

3.2 Data Collection and Analysis

Three selected project areas are located within the tidal river boundary. According to the information of local government, tidal effect on the Barito river has faded around 150km upstream from estuary. Because the flow in a river subject to tidal movement is non-stationary, a measurement programme in such circumstances will vary greatly from the every kinds of methods. Therefore Ala.1 Station is installed and observed 31 days the tidal water level during the consulting period (Jan.-Apr. 1993) as the water level variation for Alalak river mouth. According to collected data from the stations of BAR1, BAR2 as shown Table 3.1, this project has a diurnal tide movement.

For the Harmonic analysis of the tide in this project, 30 days of January, 1981 data are collected at each stations. Fig. 3.2 and Fig. 3.3 show the sampling of tide variation at the two stations, BAR1, BAR2, for the comparison of dry and wet seasons.

Consequently the tide type of selected stations which near the project area are confirmed the diurnal tide based on harmonic constants.

Table 3.1 Selected Stations for the Harmonic Analysis

Station	Location	Latitude-S	Longitude-E	Collected date
BAR1	S. Barito, di Muara Barito	3° 29'	114° 30'	1981, Jan.
BAR2	S. Barito, di Ujung Pantai	3° 14'	114° 31'	1981, Jan.

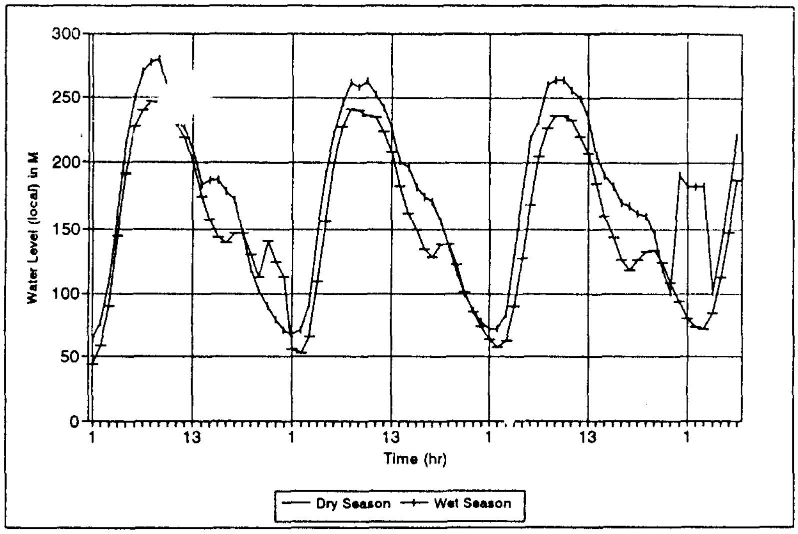

Fig.3.2 Sampling Tide Variation at BAR1

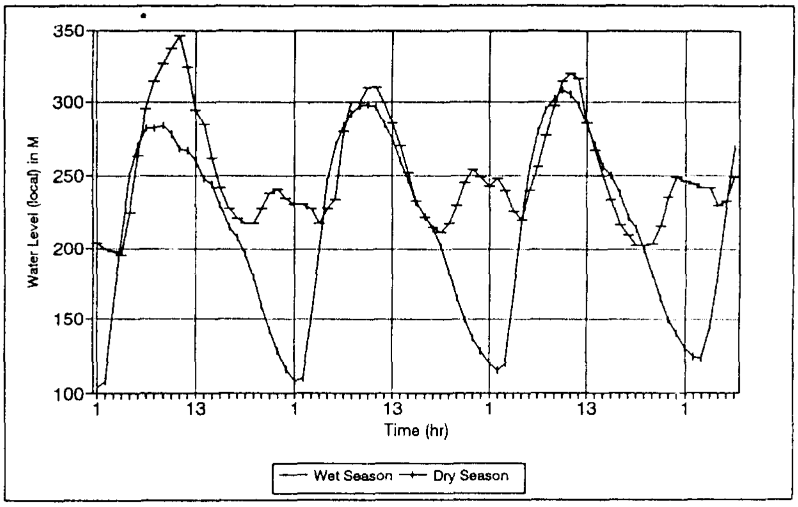

Fig.3.3 Sampling Tide Variation at BAR2

4. FLOOD RUNOFF ANALYSIS FOR THE ALALAK RIVER

4.1 Methodology

There are many methods for the flood runoff estimation. The common used methods in the world are originally by observed Rainfall–Runoff hydrological data and then drive certain Rainfall–Runoff model for the estimation of design flood runoff.

For the Tamban and Jelapat drainage area, it's located near the big Barito river and also affected by influence of tidal movement. Therefore the analysis of flood water level of related river for the drainage problem, tidal water level variation could be apply from harmonic analysis of tide or river modelling with hydrological flood routing method. For the Jejangkit swamp area, Alalak river located near the project area. During the flood seasons, there is no response of tidal motion of the Barito river conjunction wherein the recorded data of the Alalak Padang which is automatic water level gauging station. In order to apply rainfall-runoff model to the Jejangkit area of the Alalak river, there isn't H-Q (water level-discharge) curve at the Alalak Padang station. Causing lack of rainfall -runoff data, following alternative method could be adopted. Estimate catchment parameters by subjective estimation based on pysical consideration such as land use. This approach required familiarity with the catchment and judgment are required. This method is more attractive if the rainfall- runoff model chosen provide good indicative guide-line such as the SCS curve number in HEC-1 (The Hydrological Engineering Center, US Army Corp. of Engineer, 1985). For the completeness of study, above method of deriving flood discharges were undertaken in this study.

4.2 Rainfall Analysis

A probability analysis on the extreme value of rainfall is conducted for 1-day and consecutive rainfalls of two and three days, based on the rainfalls data obtained at the Banjarbaru and Syamsudin Airport meteorological stations. The data are processed theoretically for the frequency analysis of rainfall by applying the Gumbel Type-I method, which is one of the popular statistical analysis method. It has not been authorized yet what consecutive rainfall should be applied as a design flood rainfall. However, it is customary to use two day consecutive rainfall for such a basin as the S. Alalak river basin with drainage area of less than 10,000 sq.km.

4.3 Depth-duration Analysis

Depth-duration analysis is made to determine the hourly distribution pattern of storm rainfall. Hourly distribution of two-day consecutive rainfall was, then determined by the following procedures.

(1) Examined that there was no particular distribution pattern of rainfall in the past.

(2) Picked up one day maximum rainfall which would occur once in a certain return period, and divided it into hourly components using Japanese formula expression as shown in Fig.4.1.

(3) Constant of K of Mononobe formular K is determined from observed hourly record by employing the least square method and 0.4 is obtained for constant K where in the Alalak river basin.

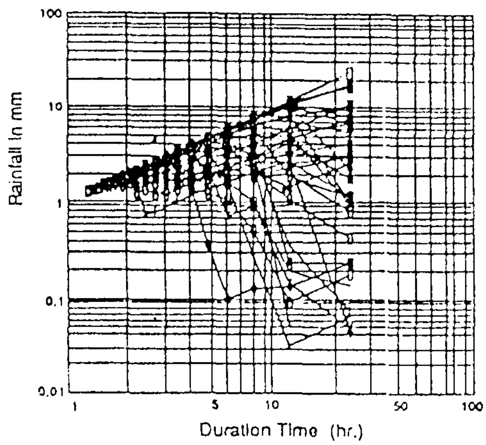

Fig.4.1 Rainfall Depth-Duration

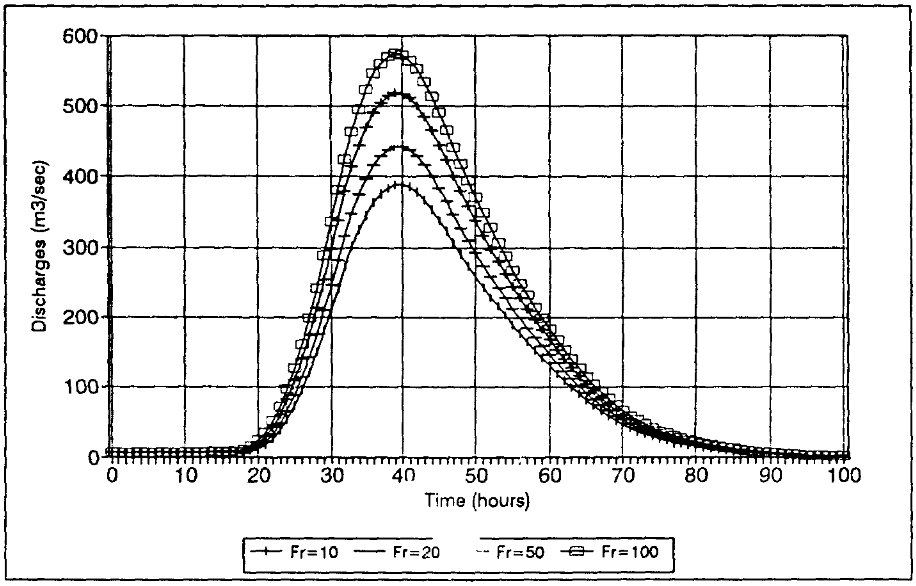

Fig. 4.2 Flood Hydrograph of Each Year Probability

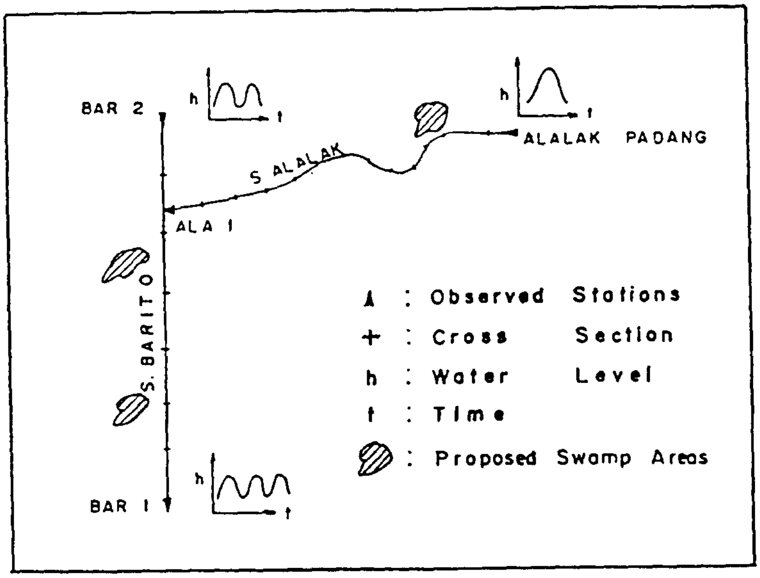

Fig. 5.1 Simple Diagram of River Modelling

4.4 Calculation Results

For flood hydrograph estimated of the ungauged catchment basin, SCS method is another tool by using assigned Hydrological Ruoff Curve Number determined from land use pattern. The flood estimation study is performed based on from 10yr. to 100yr. probability flood for Alalak Padang Station as shown in Fig.4.2.

5. RIVER MODELLING FOR THE SELECTED SWAMP AREAS

5.1 Introduction

The stagnant water in the swamp area can be drained by gravity, if the flood water level with the related project is low than the inside water level of drainage basin. However, river water stages fluctuate hour by hour due to tidal effects of the Barito and the Alalak rivers. Taking this condition into account, the design flood water level for inundation condition of the selected swamp area is estimated by mathematical simulation model. In this study, Dynamic Wave method is usually used to solve for flow and water level movements in large river. There are several approaches to a numerical solution of the set of differential equations: one can solve all equations simultaneously ; one can solve the flow equation first and then the water level; one can solve all equations simultaneously with the assumption that flow rate does not change rapidly, and thus the flow discharges can be introduced as a step function, neglecting the effect of unsteadiness; or one can solve the flow equation first and then the another equation with the assumption that flow rate does not change rapidly.

For the river modelling of the this project, Network Model (Modified DWOPER, Dynamic Wave Operational Model), Developed by Hydrologic Research Laboratory, National Weather Service, USA, to be applied where backwater effect and mild bottom slopes are most troublesome for hydrologic routing methods.

5.2 Data Collection

As shown in Fig. 5.1, the related rivers with these project areas(Tamban, Jelapat and Jejangkit) are Barito and Alalak river. From the review of collected data at the BAR1 and BAR2 water level station, some data are missing for the analysis in BAR2 and some data are changed the reference bottom elevation at the BAR1 station. Therefore the collected data for modelling of each river are selected from the special report of survey for Hydraulic and Hydrometry S.Barito and S.Kapuas(Sep.1985). In this report, there are only 8-cross sections for the Barito river which linked Bench Mark system between BAR1 to BAR2 station. The cross section of S.Alalak couldn't collected and then during the consultant period in hydrologist, the cross sections of related river are surveyed by local consultant.

5.3 Computed Result for the Three Swamp Areas

The Barito river was considered only one tributary river inflow as named Martapura and Alalak river has 4-tributaries lateral inflow exception the upstream boundary condition as used the water level of Alalak Padang station. For the catchment area of Barito river, it is too big for the rainfall-runoff analysis in comparison with drainage basin. Concerning the proposed three swamp areas, the most upstream water level station is BAR3 which near the Marabahan, and there isn't any rating curve(H-Q) data along the Barito and Alalak rivers. Therefore the design flood water levels for the three swamp areas are estimated by Hydraulic river routing using the above mentioned data and then determined the flood water level nearest the mouth of main canal for each projects. Fig. 5.2 shows the flood water level of related swamp areas for analysis of drainage problem for inland basin.

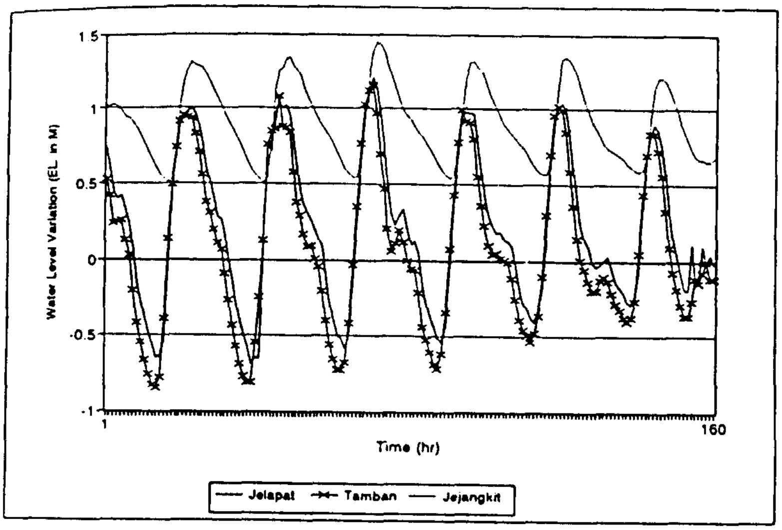

Fig. 5.2 Flood Water Level for the Three Swamp Areas

6. FLOOD RUNOFF FOR THE PROPOSED THREE SWAMP AREAS

6.1 Introduction

In some of the major deltas with a strong seasonal fluctuation in river discharge, there is a broad zone that is alternately fresh and saline. The land is flooded by fresh water to shallow or moderate depth, desalinized, and used for single wetland rice crop in the wet season. During the dry season, it remains fallow and subject to tidal inundation by saline water. For the drainage requirements of the proposed three project areas (Tamban, Jelapat, Jejangkit), flood runoff for a certain design criterion is need for the hydrological analysis. Selected three project areas are not so hilly and consolidated as plane land, tidal movement and high water level of related river (Barito and Alalak) would be affect during the dry and wet seasons.

Even though main drainage channel was constructed before farm land reclamation, proposed project areas are flooded at the present day without polder dike system. In his chapter, runoff analysis in the three project areas for drainage improvement is studied within inland of swamp areas.

6.2 Methodology of Flood Runoff

In various existing models to predict surface runoff, Kinematic wave method was selected for the plane area. This method has three conceptual element: flow planes, collector channels, and a main channel. The Kinematic wave technique transforms rainfall excess into subbasin outflow. This section deals with the application of the Kinematic wave equations in HEC-1 (The Hydrologic Engineering Center, US Army Corps of Engineers, 1985). Refer to HEC, for details on development of the Kinematic wave equations.

6.3 Rainfall Frequency Analysis

The Riam Kanan Irrigation Project(Feasibility Report; Sep. 1979) and Negara River Basin Overall Irrigation plan study(June,1989) select 3-days consecutive rainfall of 10 years frequency values for design rainfall to the swamp drainage area but the report of investgations on Existing Swamp Development for upgrading in Jambi, South Sumatra, Central and South Kalimantan Provinces by Nedeco-Euroconsult (June,1984) was taken the criterion for excessive rainfall should be 6-days rainfall to drain main canal, with a recurrence period of 5-years, within 6-days.

This criterion was developed for rice fields where water retention measures would provide a water layer on the field. In practice this water layer is not present, especially in Barambai where water is used for flushing. Hence, the fields will be able to store an extra amount of without causing trouble to the crop. For this reason a storage of 50㎜ for non-supplied fields was deducted from the design rainfall. In this study for three project areas, the design rainfall is collected total amount of 3-days consecutive rainfall(Table 6.1) with the probability of once per 10-years at the Banjarbaru station data. For the design of daily distribution of rainfall, consecutive 3-days rainfall depth ratio applied bring from the source of statistical mean value of collected data as shown Fig.6.1.

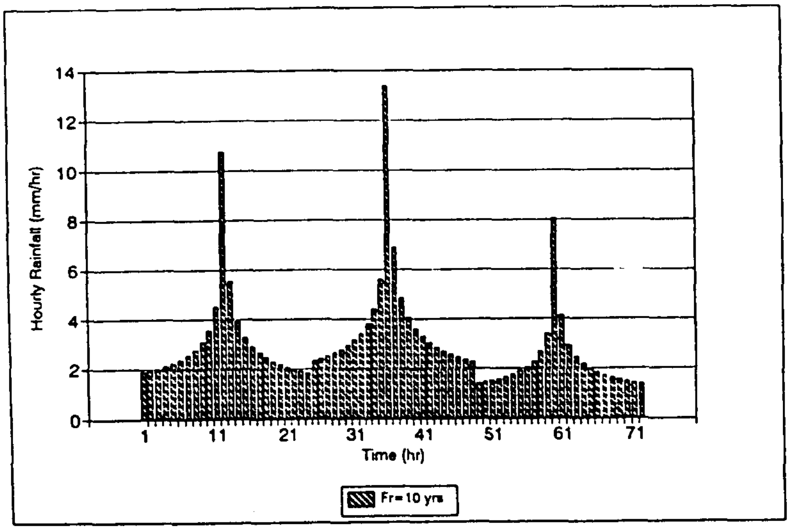

Fig. 6.1 Hourly Distribution of Design Rainfall

Table 6.1 Probable of 3-days Consecutive Rainfall

T(yr)	R(mm)	T(yr)	R(mm)	Remark
2	156.4	50	269.0	Where :
5	192.5	80	284.1	T=Return Period
10	216.4	100	291.3	Method :
15	229.9	200	313.4	Gumbel Type I
20	239.3	250	320.5	
25	246.6	300	326.3	
30	252.5	400	335.5	
40	261.8	500	342.6	

6.4 Modelling Result for Drainage Basin

The use of Kinematic wave option is to start first modelling of drainage basin for each swamp areas and two elements represent separately the impervious or pervious areas of subbasin. The infiltration data is specified only

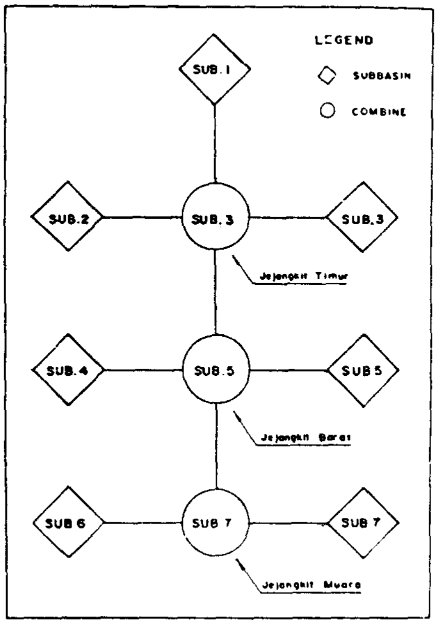

Fig. 6.2 Schematic Diagram of Jejangkit Basin

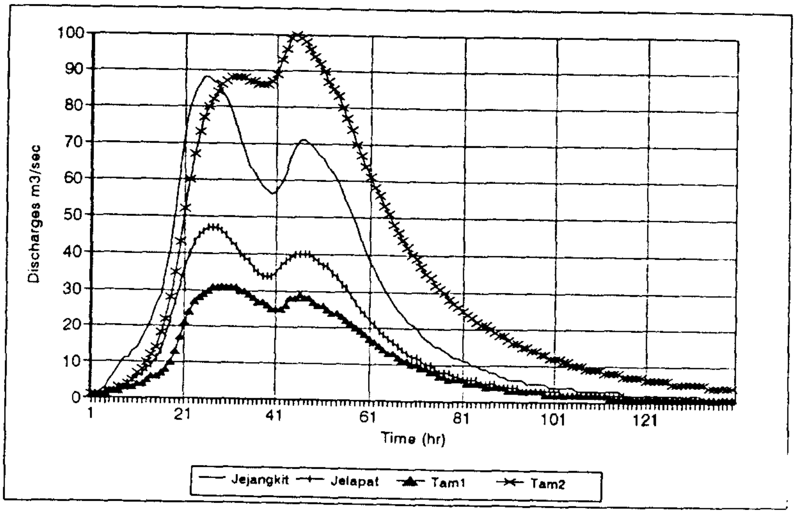

Fig. 6.3 Runoff Hydrograph of design Rainfall for the Three Swamp Areas

once, assumed to apply for all subsequent runoff computations by program input conventions. Fig.6.2 shows the schematic diagram of the Kinematic wave model for drainage basin of the Jejangkit area and Fig.6.3 is represented the hourly flood runoff discharges which covered whole basin area of the three swamp projects.

7. DRINKING WATER

7.1 Introduction

Drinking water of the selected project area is also one of the important problem for the local people life. According to the interview with farmers who live in the three swamp areas, the most serious condition is situated in the Tamban area. The Jejangkit area which located as a little upstream of the Alalak river, the people who lives in the there is directly use from the main canal and the water quality is no problem by the simple treatment. In the Jelapat area also they use the main channel water but they withdrawal only upper freshwater layer causing salt wedge intrusion.

Originally the river water near the tidal effect boundary is influenced the stratified flow by the salinity differences. They use this kinds of hydraulic mechanism for daily life from the long historical experience. Investigation of salinity intrusion along the Barito river was carried out in October 1978. According to this survey, saline intrusion penetrates up to the about 60km upstream from the river mouth. Therefore selected three swamp areas are free from the salinity at all. Fig.7.1 shows the profile of saline intrusion along the Barito river.

7.2 Water Quality

Quality of river or swamp water and even though drinking water have not been checked until now. As before mentioned above, all of the peoples in the selected three project areas take their drinking water from the main canal by the simple treatment using settlement method for

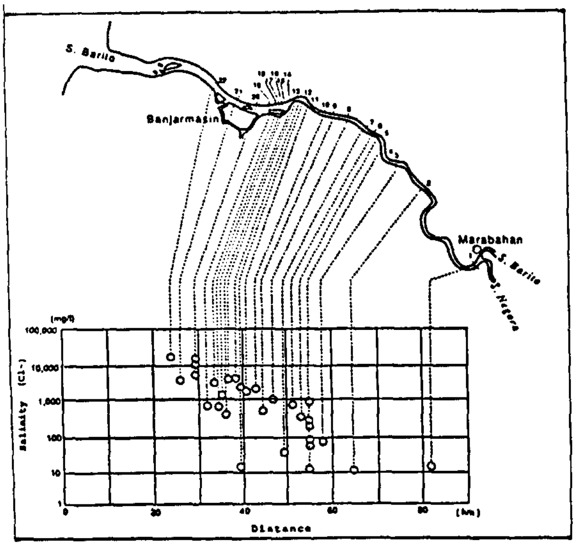

Fig. 7.1 Saline Intrusion Profile Along the Barito River

suspended sediment and chemical additional. In the Jejangkit area, three kinds of sampling source water are selected for drinking water test which are canal, rain and irrigated water. The most good quality of water was rain catchment harvested water. PH was higher value in the upstream of the main canal causing the soil acidification. Even though the canal water, pH value was normal value for drinking water after simple treatment. Also in the Jelapat and Tamban area, all of the local people takes their drinking water by the two kinds of method which one is from the main canal and the other is took from rain-water harvesting system by using the house roof. Especially in the Tamban area, some peoples bring their drinking water from the Banjarmasin city which one made from drinking water factory so called Aqua.

8. DRAINAGE IMPROVEMENT

8.1 Soil Characteristics of the Tropical Region.

Flooding irrigation for rice cultivation, usually eliminates acidity, but iron toxicity and possibly sulphide or other toxicities may then occur. In recent coastal plains and inter-tidal swamps, there are an estimated 12 million ha of potentially acid sulphate soils, mostly in the tropics. There is probably a much greater area of these soils covered by a shallow layer of non-acid peat or alluvium.

Inland, acid sulphate soils have developed naturally as a result of changes in hydrology or relative sea level. The best known example is the Bangkok plain in Thailand, where these siols occupy an estimated 600,000 ha. Fig.8.1 summarizes the known occurrence of actual and potentially acid sulphate soils in south-east and east Asia. Two-thirds of the total amount of 6.7 million ha is found in Indonesia, Thailand, and Vietnam. Millions of hectares of shallow peat land in Indonesia underlain by potentially acid sediments are not included.

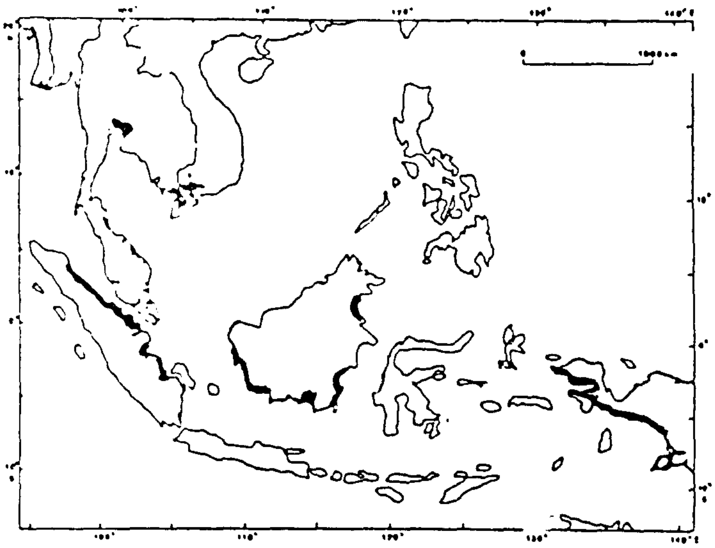

Fig. 8.1 Major Areas of Acid Sulphate Soils in South-east Asia

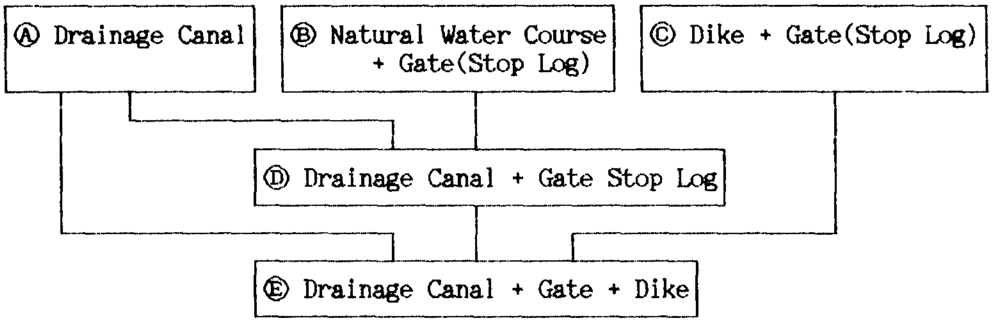

Fig. 8.2 Diagram of Drainage System

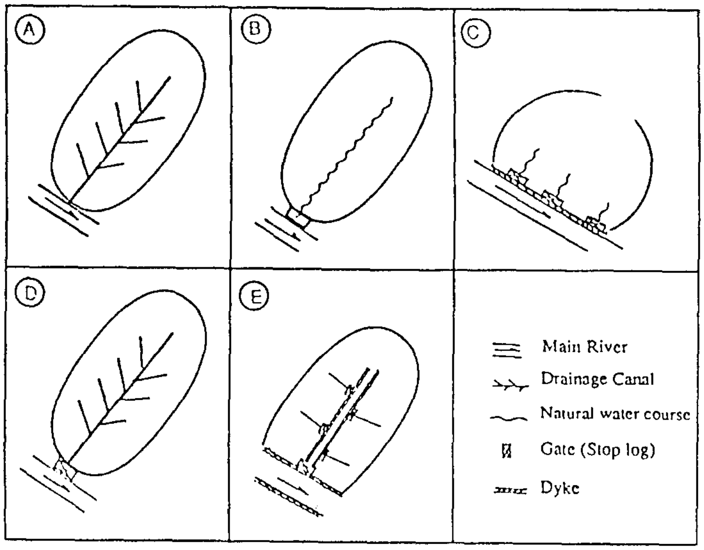

Fig. 8.3 Type of Drainage System

8.2 Features of Schemes

The drainage improvement methods now being implemented by the government of South Kalimantan in the Study Area are classified into five types as illustrated in Fig.8.2 by the Study Team based on a combination of drainage facility types. The features of each type are summarized as follows:

Type A(Independent drainage canal) : This is the simplest system having only excavated draiange canals. This method is not very effective in drainage control.

Type B(Combination of a natural water course and gate(stop log)) : This method aims at taking advantage of natural waterways, by providing a sluice at a conjunction of a natural waterway and the main stream so as to prevent reverse flow and secure adequate water level on paddy field during the growing period of paddy.

Type C(Combination of a dike and gate(stop log)) : In this method, a dike is constructed along the main stream to protect inflow of flood water. The dike is provided with a sluice, at an intersection of a natural waterway and the main stream, which is used for both intake and drainage of water.

Type D(Combination of drainage canals and a gate(stop log)) : This is a combination of newly-cut drainage control. A gate is provided at a conjuntion of a drainage canal and the main stream of a river.

Type E(Combination of drainage canals, gates, and dike)) : This is the ultimate system when natural drainage is a precondition. Drainage control is carried out by newly-cut drainage canals and gates. Gates are equipped at both the end points of primary and secondary drainage canals. The dike is constructed along the main stream of river for protecting flood and further functioning as inspection and access road as shown in Fig.8.3

8.3 Design Drainage

The total amount of 3-day consecutive rainfall with the probability of once per 10-year at two representative rainfall stations in the study area is used. These stations are located in the Banjarbaru and Syamsudin Noor(Airport). The total amount of drainage under the design rainfall is expressed as follows:

If area $\leq$ 400ha $Q=(D/(3\times 8640))\ A$

If area $\geq$ 400ha $Q=1.62(D/(3\times 8640))\ A^{0.92}$

where Q=design drainage capacity(m^3/sec), D=rainfall of 10-year prbability in consecutive three days(mm) A=catchment area(ha).

9. RECOMMENDATIONS

In this sections some recommendations are given for aiming at improving data collection, processing and evaluation.

9.1 Hydrometric Network

All hydrological and water management activities are dependent directly or indirectly on the availability of data, which are include all applications of existing techniques, all development of new techniquse, all decisions concerning technical, administrative or financial matters. So the design of efficient, cost effective hydrological network of station is important.

Despite extensive literature on the project, it could be fairly claimed in 1980 that so full-scale design of a hydrological data network has been accomplished which takes into account the ultimate effects of the data. Thus a flood of interest has resulted in only minimal accomplishment (WMO Operational Hydrology Report No. 19).

It is impossible to define a sufficient number of zones to describe correctly the variety of natural conditions. A limited number of large categories which, because they comprise a variety of cases, must be defined in a more or less vague manner. From the these considerations, some general rules have been adopted for the definition of density norms.

Within Negara catchment area, those all stations do not cover the whole basin as shown in

Fig.9.1 in rainfall stations. This figure shows the observation sphere of each station within mouth of Barito river basin, i.e. one station covers 1,000㎢ for one water level station and 250 ㎢ for one rainfall station. Table 9.2 calculated the density of hydrometric network in the Negara river basin which located near the proposed project.

Table 9.2 Density of Hydrometric Network in the Negara River

Station	Area(㎢)	No.of Station	Density(㎢/station)
Water level	11,000	44	250
Rainfal	11,000	72	153

9.2 Leveling Check

Almost staff gauging stations along the Barito and Alalak river didn't check their reference bottom elevation. During the period of hydrological consult in this study, Tamban, Jelapat and Jejangkit swamp areas are linked by Takisung Bench System(T.S.)and also checked the zero point elevation of Alalak Padang station. It is necessary to have leveling survey works for all staff gauging station in order to perform further hydrological analysis.

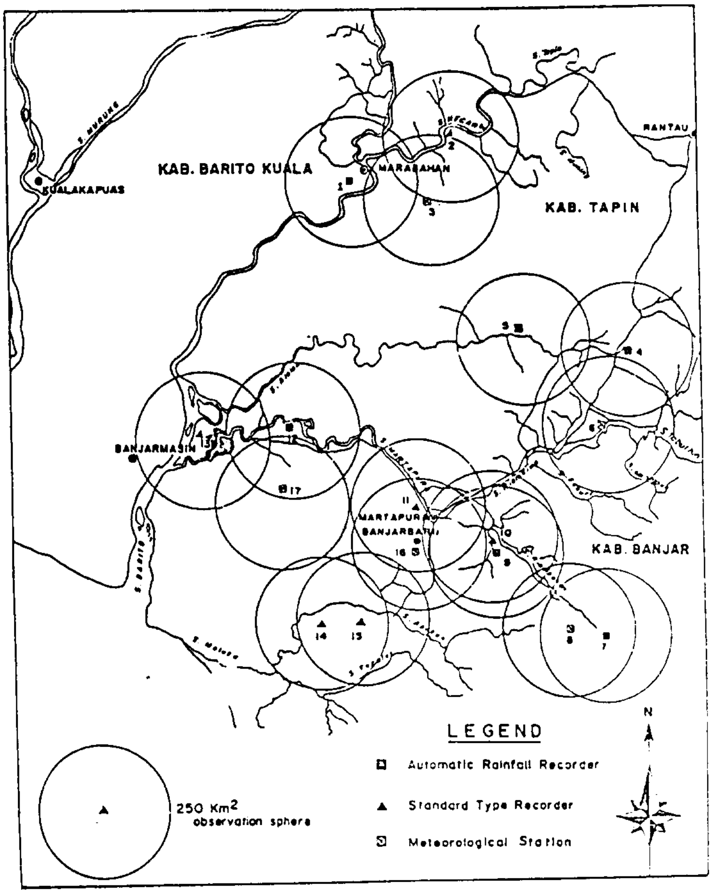

Fig. 9.1 Present Observation Sphere of Rainfall Station

9.3 Data Processing

Until now all of the collected data are raw data which didn't have a manual reference report. Making table and manual processing takes so much time and may results inaccurate data. In order to avoid these kinds of disadvantages, a hydrological data bank should be established even though by personal computer.

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