Table 3.3 LIST OF WATER LEVEL GAUGING STATION AND DATA AVAILABLE PERIOD IN THE WIDAS BASIN

No.	Name of Station	Years	Recording Period	Remarks
1.	Kedungwarak	5	1979 - 1983	
2.	Kedungwarak	3	1982 - 1984	Automatic
3.	Kedungdowo	5	1979 - 1983	
4.	Kedungpedet/Dam Bulakmojo	5	1979 - 1983	
5.	Malangsari	5	1979 - 1983	
6.	Semantok	5	1979 - 1983	
7.	Semantok	1	1983.	Automatic
8.	Kuncir - Widas	4	1979 - 1982	
9.	Kedungsoko - Widas	5	1979 - 1983	
10.	Ngudikan	4	1978 - 1979 1982 - 1983	
11.	K. Bening	3	1976 - 1978	
12.	Confluence of Kedungsoko - Widas	5	1979 - 1983	
13.	Kedungpedet	4	1979 - 1982	
14.	Lengkong - Widas	12	1973 - 1984	Automatic
15.	Lengkong	32	1952 - 1984	1966 no data
16.	K. Ulo	2	1983 - 1984	Automatic
17.	K. Jurang Dandang (Ketandan)	4	1981 - 1984	

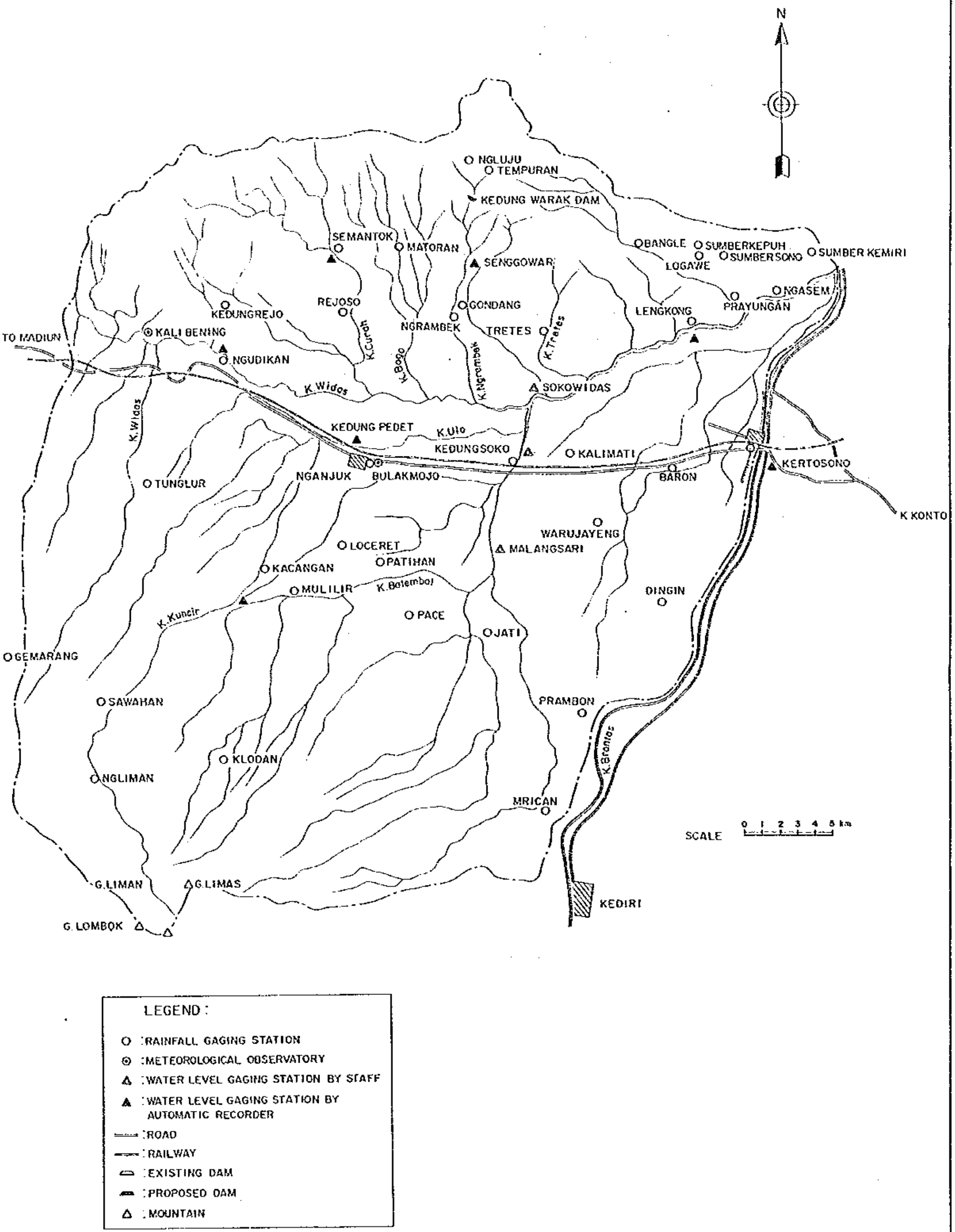

Fig.3.1 LOCATION MAP HYDROLOGICAL GAUGING STATIONS

PART II FLOOD CONTROL AND DRAINAGE PLAN

4. INTRODUCTION

The Widas river basin locates in the north-western part of the Brantas river basin. The total catchment of the basin amounts to 1538 km^2 and the Widas river is the main drainage way in the basin.

The basin, especially Nganjuk and its surrounding area has suffered from recurrent floodings since the beginning of its history. Main trunk highway which connects East Java with Central Java passes through Nganjuk and its surrounding area in the basin. Some basin developments have been proceeded in this decade and as the result, flood damage potential has been increasing. However, comprehensive flood control works have not yet been provided in the basin up to now, although some efforts against flood protection were made in the past. From such viewpoint, implementation of flood control works is strongly required in the basin.

The objectives of this Part II are (i) to clarify present condition in view of flood control and (ii) to conduct feasibility study of Widas flood control and drainage project among those identified in the Master Plan Study which was made in 1985.

This Part II presents the following aspects:

- Present conditions of rivers and related river structures
- Flood flow analysis
- Comparative study on alternative flood control plan
- Proposed flood control plan
- Construction plan and cost estimate
- Evaluation of proposed plan

Detail tables, figures and supplemental explanation which are not incorporated in this Part II are presented in the ANNEXES-2, 4, 5 and 8 in the supporting Report.

CHAPTER 5 PRESENT CONDITIONS OF RIVERS AND RELATED STRUCTURES

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5. PRESENT CONDITIONS OF RIVERS AND RELATED STRUCTURES

5.1 Characteristics of Rivers

5.1.1 Characteristics of rivers

(1) Widas river

The characteristics of the existing channel downstream from the Ngudikan dam site are shown on Fig. 5.1 and in ANNEX-4.

The Widas river has its source on the northern slope of Mt. Liman (EL. 2563 m). From its source, it flows down northerly passing through the mountainous area for some 30 km before turning to the east. The river slope in this reach is very steep more than 1/10 in average and the vegetation in the upper catchment is fairly good (See Figs. 2.1 and 2.5).

At the turning point, the Widas river is joined by the Bening river a left bank tributary. A multipurpose dam called as "Bening dam", is located on this left tributary, contributing to water supply for irrigation and hydroelectric power generation.

After collecting the Bening river, it flows east for a few kilometers towards two existing pondages of the Glatik dam and Ngudikan dam for irrigation intake. The main tributaries in this reach are the Kedungpring river on the left bank and the Awar-awar river on the right bank. This reach of the river is of valley in topography. The total catchment area at the Ngudikan dam site is about 233 km^2.

Downstream from the turning point to the east, the Widas river flows easterly for some 30 km toward the confluence with the Kedungsoko river. The main tributaries in this reach are the left tributaries of the Wotrangkul river, Pelangkeng river and Ngrembek river (or Gondang river). The topography downstream from the Ngudikan dam, changes from valley to plain. The topography on the left is relatively steep, while that on the right bank is flat. The river slope in this reach is from 1/700 to 1/2,000 and channel width varies from 100 m to 50 m. The fine materials of silt or clay prevail on the riverbed. On the left bank near the confluence with the Kedungsoko river, there exists a low dike for about 2.5 km. The total catchment area before the Kedungsoko river confluence is approximately 490 km^2. The lower part of this reach is subject to frequent inundation due to the low flood carrying capacity of the existing channel and backwater at the confluence with the Kedungsoko river. The Kedungsoko river has a catchment area of about 686 km^2. The total catchment area at this confluence is about 1,120 km^2.

From the confulence with the Kedungsoko river, the Widas river flows northeasterly for 25 km towards the confluence with the Brantas river at about 89 km upstream from its estuary. The main tributaries in this stretch are the Tretes river, Ngrempek river and Pohbantu river on the left bank and a drainage canal called as Al canal on the right bank. This canal drains the Warujayeng irrigation area of about 191 km^2 to the lowermost of the Widas river. The total catchment area and river length at the Widas river mouth are about 1,538 km^2 and 85 km respectively.

The river slope of this reach is very flat ranging from 1/3,000 to 1/4,000. The channel width is from 50 m to 40 m. The riverbed is covered mainly by fine materials of silt and clay. The topography on the left bank along this reach is relatively steep one, however that of right bank is flat. In this reach, there has been provided a continuous low dike on the right bank, stretching over nearly 20 km from the confluence with the Kedungsoko river to 8 km point upstream from the Widas river mouth. The Lengkong town is located on the left bank close to the Widas river about 12 km upstream from its river mouth. A low dike partially encloses the Lengkong town area.

The dominant features in this reach are the remarkable meandering of low-water channel, and the two narrows of river width limited by road bridge abutments. One is located just downstream of the confluence with the Kedungsoko river and the other at the Lengkong bridge. Furthermore, the inundation area extends throughout the rainy season over the lowlying lands along the Widas river.

The lowlying area downstream of the Lengkong town is subject to frequent inundation, especially at the Lengkong town. The above lowlying area functions as a natural flood retarding basin in rainy season, attenuating peak discharge in both the Widas river and Brantas river.

(2) Kedungsoko river

The characteristics of the existing Kedungsoko river channel are shown on Fig. 5.2 and in ANNEX-4.

The Kedungsoko river main stream originates on the northeastern slope of Mt. Wilis and flows down in a northeasterly direction, passing through the rich vegetable mountainous area for some 20 km towards the south of Perbek. The Kedungsoko river main stream in this reach is locally known as Bodor river. The river slope of this reach is very steep more than 1/10 in average (See Figs. 2.1 and 2.5).

From the south of Berbek, the Kedungsoko river main stream still known as Bodor river, flows east for about 12 km into the pondage of the Malangsari irrigation dam. The topography in this reach changes from valley to plain and the river slope is 1/200 in average. The main tributaries of this reach are the right ones of the Watulanang river and Genjeng river which originate on the northeastern slopes of the Wilis range. In this reach, there are three dams contributing to the water supply for irrigation. The total catchment area at the lower end of this reach is approximately 146 km^2. The river channel in the lower part of this reach habitually causes inundation in the surrounding area.

At the Malangsari dam site, the main stream of the Kedungsoko river is joined by a right bank triburary of the Bedrek river which originates on the eastern slope of the Wilis range and a small right bank drainage channel which drains the upper Warujayeng irrigation area.

From the Malangsari dam site, the Kedungsoko river flows down straightly in a northerly direction for nearly 10 km towards the confluence with the Widas river. The main tributaries in this reach are the Kuncir river and Ulo river on the left bank. The topography on this reach is plain and the river slope is 1/700 to 1/3300. The materials of clayey sand and silt prevail on the riverbed. The total catchment area and river length of the Kedungsoko river at its river mouth are about 637 km^2 and 42 km respectively.

On this reach, there exist continuous low dikes on the both banks for about 5 km just upstream from the confluence with the Kuncir river. The average width between the both dikes are about 100 m. Furthermore, a continuous low dike has been constructed on the right bank for about 3.5 km upstream from the confluence with the Widas and Kedungsoko rivers. On the upper end of the said right dike, a national highway bridge and a national railway bridge cross over the Kedungsoko river channel.

The dominant features in this reach are that two habitual inundation areas are formed during the rainy season on the both reaches of the middle and the lower Kedungsoko river. One exists on the lowlying land just upstream of the national railway bridge, and other exists on the area where the Ulo river joins the Kedungsoko river. Both function as flood retension area in the rainy season. The another feature of this reach is a narrow of the river width or flow constriction due to bridges of railway and highway. The river width of this narrow is less than 50 m despite that of the upper reach is about 100 m.

(3) Ulo river

The characteristics of the existing channels of the Kuncir kiri and Ulo river are shown on Fig. 5.3 and in ANNEX-4.

The Ulo main stream has its source on the northern slope (EL. 1,500m) of the Wilis range and flows down in a northeasterly direction or in parallel to the river course of the Kuncir for about 14 km towards the Kuncir diversion weir on the Kuncir river which locates about 20.5 km upstream from its river mouth. The river slope in this reach is more than 1/12 (See Figs.2.1 and 2.5).

At the Kuncir diversion weir, the Ulo main stream is connected with the Kuncir river through the two diversion channels. During flood, a part of the flood water in the upper catchment of the Kuncir river is diverted through this 2 diversion channels into the Ulo main stream and the remaining is drained through the Kuncir diversion weir to the lower Kuncir river.

The diversion ratio into the Ulo main stream is reported to be approximately 70%. However, it seems that prompt and accurate weir operation against flood is difficult at present.

From the Kuncir diversion weir, the Ulo mainstream flows down north-north-east for about 12 km before turning into the east. The Ulo main stream of this reach is locally known as the Kuncir kiri. The topography changes from valley to plain at the upper part of this reach and the river slope is about 1/140 in average. The average river width decreases from 100 m to 20 m facing to downstream. The riverbed materials of boulder or cobble stone prevail on the upper part although they change to sand and silt at the lower part. The main tributaries of this reach are the Winong and Secong rivers on the left bank, which originate on the northern slopes of the Wilis range. The Tiripan dam for irrigation use exists before joining the Winong river. Meantime, a continuous low dike has been provided on the right bank for some 2.5 km on this lower reach to protect Nganjuk urban area from flooding. The area near the confluence with the Secong river frequently suffers from inundation. The total catchment area at the confluence with the Secong river or at the turning to east, is about 85 km^2.

From its turning, the Ulo river passes through the outskirts of the Nganjuk urban area for some 3 km and it flows in a easterly direction for about 12 km, collecting some small local drainage channels. It finally joins the Kedungsoko river, 1.5 km upstream of its river mouth. Topography on this reach is plain. The river slope is 1/1,000 to 1/1,700 and the river width is about 20 m in average. The total catchment area and river length at the Ulo river mouth is about 114 km^2 and 41 km respectively. The riverbed in this reach is covered mainly by fine materials of sand and silt.

A national railway and a national highway cross over the Ulo river channel at nearly 15 km upstream from its river mouth.

A low right bank dike with bank protection works has been provided at up and downstream of the national highway bridge for about 2 km to relieve the urban area of Nganjuk from the flooding menace. The Bulakmojo dam for irrigation use exists at about 11 km upstream from the Ulo river mouth. In this reach except near the river mouth partial small dikes have been constructed on the both banks.

As stated previously, the lowlying area of the Ulo river functions as a natural retarding basin in the rainy season. In this reach of the Ulo river which means "snake", the remarkable meandering has been developed. The river of this reach is subject to frequent inundation due to shortage of the carrying capacity of the existing channel and back water from the Kedungsoko main stream.

(4) Kuncir river

The characteristics of the existing channel of the Kuncir river in the plain area are shown on Fig.5.4 and in ANNEX-4.

The Kuncir river has its source on the northern slope of Mt. Wilis, from where it flows down almost in a northeastern direction for about 23 km into the Kuncir diversion weir. The mountainous area of this reach is fairly in good vegetation. The river slope in this reach is steep, more than 1/11 in average (See Figs. 2.1 and 2.5).

There drop structures exist just upstream of the Kuncir diversion weir. The total catchment area is approximately 79 km^2 at the said weir site.

The said Kuncir diversion weir is located about 20.5 km upstream from the Kuncir river mouth. Approximately 70% of the flood water from the upper catchment of the Kuncir river is diverted into the Ulo river main stream and the remaining is discharged through the Kuncir river by the man-power operation of the stoplog gates installed at the weir across the Kuncir river channel. The further explanation of the diversion weir is given in the latter section of flood control facilities.

Downstream from the diversion weir, the Kuncir river flows down northeast for nearly 10 km before turning to the east, collecting some small local drainage channels. The topography in this reach changes valley to plain and the river slope is around 1/120 in average. The river channel width in this reach decreases from 70 m to 20 m and the riverbed materials change from boulder or cobble stones to fine materials of sand or silt. On the lower part of this reach, the urban area of Nganjuk developes. The Kedunggerit dam for irrigation use exists at the upper part of this reach. The river of the lower part of this reach is subject to frequent inundation due to low flood carrying capacity of the existing channel.

From the turning point to the east, the Kuncir river runs through the urban area of Nganjuk and flows in an easterly direction for about 10.5 km and finally, it joins the Kedungsoko river 5.5 km upstream from its river mouth. The main tributary of this reach is the right bank local drainage channel of the Gonggang-Malang river which joins the lowermost of the Kuncir. In this reach, there are two irrigation dams of Tanjung (or Kramat) and Kapas on the Kuncir river channel near the densely populated area of the Nganjuk.

The river slope in this reach is 1/1,900 in average and the river channel width is fairly narrow ranging from 20 m to 10 m. The total catchment area and river length of the Kuncir river at its river mouth are about 141 km^2 and 42 km respectively. The partial small dikes have been provided on the both banks on this reach. The riparian area in this reach suffers frequently from inundation and it can be said the habitual inundation over the Nganjuk urban area is caused mainly by the overbank flow from the Kuncir river.

5.1.2 Characteristics of retarding basins

The lower catchment area of the Widas river basin is the alluvial plain of low topography, especially at major confluences.

The flood flow exceeding channel capacity as well as local rain water, flows into such lowlying areas, and is easily retarded for a long duration, owing to backwater at confluences.

Due to climatic, hydrological and topographical features in the basin as explained later, it is inevitable that inundation occurs over such lowlying areas and the problem is the worst at confluences with the major channels.

Natural three retarding basins of Widas, Ulo and Kedungsoko are prominent ones. The locations of these retarding basins are shown on Fig. 5.5. The habitual inundation area which may be inundated by 2-yr flood for each retarding basin is investigated through hearing on inundation depth from inhabitants as shown in Fig. 5.6. On the other hand, the relationship among elevation, area and storage capacity in each basin is shown on Fig. 5.7 obtained from the topographical maps with a scale of 1/2,500. The habitual retarding area is assumed as shown below based on the data obtained through hearing form local people (See ANNEX-4).

Retarding Basin	Average G.H. (SHVP.m)	Average W.L (SHVP.m)	Area (km)	Storage Volume (10^6m^3)
Widas	37.4	38.0	10.3	7.7
Ulo	44.4	44.9	6.8	7.0
Kedungsoko	44.5	45.0	11.8	9.3

The land in the habitual retarding basins during the rainy season has been utilized as farmland except in the midst of rainy season. Main crops during rainy season are kenaf and paddy. Meantime, those in dry season are such upland crops as corn, water melon, red pepper, etc. The typical cropping patterns of the respective retarding basins are presented in ANNEX-4.

The present features of each retarding basin are given below.

(1) Widas retarding basin

The Widas retarding basin is located just upstream of the river mouth of the Widas river where the Widas river joins the Brantas river.

The Widas retarding basin has functioned as a natural retarding basin of the Widas and the Brantas rivers.

In the downstream reach of the confluence of the Pohbuntu river with the Widas river around 7.1 km upstream of the river mouth, the runoff from the north-eastern area of the Widas river basin flows directly into the Widas retarding basin through small tributaries.

The Widas retarding basin is bounded on the east by the left side dike of the Brantas river, and is bounded on the south by a drainage canal from Warujayeng irrigation area. This canal is called A1 canal in this report.

Local run-off between the Widas river and Al canal flows into the Widas retarding basin from the west. In the Widas retarding basin, the Widas river has no dike on the both banks. On the southren boundary of the Widas retarding basin, Al canal has its own dike with a height of around 1.5 m to 2.0 m on the right bank. This right side dike is connected with the left side dike of the Brantas river.

According to farmers living near Al canal, inundation water in the Widas retarding basin has never overtopped the right side dike of Al canal, but it intrudes the southern area of Al canal through several sluices on the dike, due to deterioration of the sluice gates. And once this area is inundated, the inundation duration is longer than that in the Widas retarding basin because of the bad drainage conditions.

In the Widas retarding basin, there exist 4 hamlets and the total number of houses including sheds is 632 nos. according to the topographical map. The detail is given in ANNEX-4.

The villagers of Dk. Kedungtunggak and Dk. Bolowono located in the center of the retarding basin have to cross a bamboo bridge to go over the Widas river. This bridge is so narrow that people can not cross the bridge with a motor bicycle, but can cross with a bicycle on the shoulder.

A car road along the right side dike of the Widas river leads to Dk. Ngrengket located in the south-western part of the retarding basin from Lengkong city.

According to the people, the duration of habitual inundation in the retarding basin is around one to two weeks, and for more than one month in the east-southern part of the retarding basin where the inundation is drained to Al canal, not directly to the Widas river.

They say the inundation occurs most often in February and March, and the groundwater level rises to about 1 meter below the ground surface in rainy season and lowers to about 2 meters or so below the ground surface in dry season.

Groundwater levels observed at the existing wells in the retarding basin are shown on Fig. 5.8 (ref. to ANNEX-4). According to the figure, the groundwater levels rise fairly high during rainy season while they lower rapidly by 2 to 4 meters below the ground surface in locations during dry season. This implies less possibility of utilization of retarding basin as water supply reservoir.

The Widas retarding basin is utilized as farmland. From the end of rainy season they begin to raise paddy. In dry season, they cultivate mostly corn and watermelon, and partly red pepper and cassava.

Some people say that they can't raise any crops in the midst of rainy season due to inundation.

They water dry season crops by pumping up the river water of the Widas river, Al canal and the groundwater in the basin.

For domestic use of water such as drinking, cooking, washing and bathing, they take groundwater from wells. The surface flow of the Widas river and A1 canal is utilized for watering crops and as a public convenience.

(2) Ulo retarding basin

The Ulo retarding basin is located upstream of the confluence of the Kedungsoko river with the Widas river.

The Ulo retarding basin has functioned as a natural retarding basin for the flood from all the Widas, the Kedungsoko and the Ulo rivers.

The Ulo retarding basin is bounded by the Widas river on the north, by the Kedungsoko river on the east and by the national highway between Kertosono and Nganjuk on the south. The Ulo river inflows into the Ulo retarding basin from the west.

In the adjacent reach to the Ulo retarding basin, the Widas river has a low dike on the left bank, but has no dike on the right bank that is the part of the Ulo retarding basin. In the Ulo retarding basin, the Ulo river has no dike on the both banks. In the reach along the Kedungsoko river between the national highway and the confluence with the Widas river, the Kedungsoko river has a low dike on the right bank.

According to some people in the Ulo retarding basin near the Kedungsoko river, the inundation last for four days when a flood occurs in the Kedungsoko river only. But when a flood occurs in the Widas and the Kedungsoko rivers at the same time, then the inundation continues for many days. Besides, the inundation continued for many days before the construction of right side dike of the Kedungsoko river. But after the construction of right side dike of the Kedungsoko river, the duration of inundation in the Ulo retarding basin has become long.

When a flood occurs in the Widas, the Kedungsoko and the Ulo rivers at the same time, the duration of inundation is one week through one month depending on the places and the rainfall conditions.

In the habitual inundated area in the Ulo retarding basin, there exist some 10 hamlets and the total number of houses including sheds is about 1200 nos. according to the topographical map. The detail is given in ANNEX-4.

In the Ulo retarding basin, public roads have been well located, but people say that during heavy inundation, they have to rely on boats as a means of transportation.

The Ulo retarding basin is also utilized as farmland and people pump up the river water and the groundwater for watering crops in dry season.

For domestic water use they take the groundwater from wells.

According to villagers in the retarding basin, they mostly cultivate corn and partly sugarcane in dry seasons. From around August to January they cultivate kenaf because in January kenaf is already tall enough to stand inundation. In the lowlying area of the Ulo retarding basin, they say they start to raise paddy in April or May after the end of rainy season. But in other areas they say they raise paddy in around November or December to February.

According to the villagers the inundation is the severest in March.

(3) Kedungsoko retarding basin

The Kedungsoko retarding basin is located just upstream of the railway and the national highway bridges over the Kedungsoko river.

The Kuncir river flows into the Kedungsoko retarding basin from the west. The Kedungsoko river flows into the retarding basin from the south. Some drainage canals from the Warujayeng irrigation area flow into the retarding basin from the east. The Kedungsoko retarding basin is bounded on the north by the railway embankment.

Flood water from these rivers is retarded in this Kedungsoko retarding basin due to the constriction of the Kedungsoko river by the railway and the national highway bridges, and due to the river condition that there is no dike in the just upstream reach of the constriction.

The duration of inundation varies depending upon the ground height according to the villagers in the retarding basin. In the most lowlying area, they say that the inundation lasts for about 20 to 25 days in every rainy season with the depth of about 0.6 to 0.7 meters. Accordingly they begin to raise paddy around in May after the end of rainy season. In December, January and February they cultivate nothing. In around February they try to raise paddy but the paddy sometimes dies out due to the inundation in the end of rainy season. In dry season they cultivate mostly corn.

But in the area of rather higher elevation in the retarding basin, people say that the inundation continues for about one or two weeks. Accordingly they raise paddy from December to February and try the second paddy in the end of rainy season. In dry season they cultivate corn, sugarcane and soybean. Here they water crops through irrigation canal.

According to the people, the inundation is most often in March and the groundwater level varies about 1 meter below the ground surface in rainy season to 4 or 5 meters under the ground height in dry season.

In the Kedungsoko retarding basin, there exist some 19 hamlets and the total number of houses including sheds is about 2500 nos. according to the topographical map. The detail is given in ANNEX-4.

5.2 Carrying Capacity of River Channel

5.2.1 Cross-sections and longitudinal profiles of river channel

The river cross-sections for the main channels have been surveyed by BRBDEO supervised by the Study Team during the Part I Study period from 1985 to 1986. The objective rivers surveyed are the Widas, Kedungsoko, Ulo and Kuncir rivers, including these tributaries. The intervals of the surveyed cross-sections are 500 m in average, and outline of the survey works is given below.

River	Extent	Length (km)	Nos. of Section
Widas river	River mouth to Ngudikan dam	52	104
Kedungsoko river	River mouth to Malangsari dam	10	21
Ulo river	River mouth to Kuncir diversion weir	28	41
Kuncir river	River mouth to Kuncir diversion	20.5	33
Secondary tributary	River mouth to 2 or 3 km upstream	25	35
Total		135.5	234

The typical cross-sections surveyed of each river are shown in ANNEX-4. Based on the surveyed cross-sections, longitudinal profiles of the main channels are prepared and shown on Figs. 5.1 to 5.4 respectively and those details are shown on ANNEX-4.

5.2.2 Carrying capacity of river channels

The carrying capacity of the existing channels is estimated for the Widas, Kedungsoko, Ulo and Kuncir rivers by the non-uniform flow method.

The estimated bankfull carrying capacities are shown on Figs. 5.1 to 5.4. The above figures show that the estimated capacities are relatively higher in the upper reaches of respective rivers whereas those in the lower reaches are much reduced. Those are summarized below.

River	Bankfull Capacity (m^3/s)
1. Widas river	
River mouth to Kedungsoko conf.	130 - 200
Kedungsoko conf. to Ngudikan dam	100 - 600
2. Kedungsoko river	
River mouth to national highway bridge	80 - 120
National highway bridge to Malangsari dam	50 - 120
3. Ulo river	
River mouth to Bulakmojo weir	10 - 50
Bulakmojo weir to Tiripan dam	40 - 200
Tiripan dam to Kuncir diversion weir	more than 300
4. Kuncir river	
River mouth to Kapas dam	5 - 30
Kapas dam to 14.5 km point	30 - 300
14.5 km point to Kuncir diversion weir	more than 300

5.3 Flood Control Facilities and Related River Structure

5.3.1 Flood control facilities

(1) Kuncir diversion weir

The Kuncir diversion weir is located at the upper Kuncir river about 20.5 km upstream from its river mouth. The location is shown on Fig. 5.9.

The diversion weir consists of an overflow weir across the Kuncir river channel and two diversion weirs into the Ulo main stream (Kuncir Kiri). The weir is operated and maintained by DPU East Java (Seksi Nganjuk). The major dimensions of the above weir are presented below and on Fig. 5.10.

Kuncir Weir

Total effective width	15.0 m
Nos. of opening	2
Net span width of opening	7.5 m
Height of opening	4.0 m
Gate	stoplog

Kuncir Kiri Weir (Ulo main stream)

Upper weir	
Total effective width	12.0 m
Nos. of opening	3
Net span width of opening	4.0 m
Height of opening	4.3 m
Gate	-

Lower weir

Total effective width	15.0 m
Nos. of opening	2
Net span width of opening	7.5 m
Height of opening	5.4 m
Gate	stoplog

The stoplog gates are operated by manual-driven lifting equipment. Accofding to the administrative office, such stoplog operation has not been made for these recent years. Three pieces of stoplogs have been retained as presently installed on the Kuncir weir. On the other hand, stoplogs of the Kuncir Kiri weir have not been used. Under such condition approximately 70% of flood water coming from the upper catchment is said to be diverted into the Kuncir Kiri (Ulo main stream) and the remaining is discharged through the Kuncir weir into the lower Kuncir river.

Because of no available data on weir structure, the details of the structure are still unknown. However, it is assumed that main body of weir is of wetmasonry structure with direct footing.

More than 50 years have been passed since its construction in 1928 and some rehabilitations of the main body were made in 1978. According to visual inspection, it can be expected that main body of weir itself seems to be still strong and durable against flood force although slab and girder of the inspection bridge which is also used by local people are fairly supperannuated.

(2) River dike

The river dikes have been provided on the right bank of the lower Widas and Kedungsoko rivers and partially on the left bank and on the right bank of the upper Ulo river close to the Nganjuk urban area. The dikes are earth embankment. The existing river dikes are outlined below and those locations are shown on Fig. 5.9.

Location of existing dike		Length (km)	Dike height (m)	Crown width (m)	Dike slope
Widas river					
Right	Kendungsoko conf. to downstream of Lengkong bridge	20.0	1.0 - 2.0	1.5 - 1	1:1
Left	Upstream of the Kedungsoko conf.	2.5	0.5 - 1.5	1.5 - 2	1:1
	Around Lengkong Urban area	5.2	1.0 - 1.5	2.5	1:1
Kedungsoko river					
Right	Upper Kedungsoko	5.0	1.0 - 2.0	2 - 2.5	1:1.5
	National highway bridge to the Widas conf.	3.7	1.5 - 2.0	2 - 2.5	1:1.5
Left	Upper Kedungsoko	5.0	1.0 - 2.0	2 - 2.5	1:1.5
Ulo river					
Right	Upper Ulo	3.0	1.0 - 2.0	1.5 - 2.0	1:1.5

In addition to the above, small and low dikes have been locally constructed on the both river banks of the Ulo and Kuncir.

(3) Bank protection works

The bank protection works are concentrately provided around national highway bridge on the Ulo river and around Tanjung (Kramat) dam on the Kuncir river in the urban area of Nganjuk, and locally on the left bank of the lower Widas river close to the Lengkong town. The wetmasonry type revetments have been employed to the bank protection works. The locations of the major bank protection works are shown on Fig. 5.9.

5.3.2 Related river structure

There are many related river structures across and along the major river channels, especially on the middle reaches of the both Ulo and Kuncir rivers. Based on the topographic maps (1/2,500 in scale) and the results on inventory survey made by the Study Team, the outline of the existing related structures are schematically shown on Fig. 5.11 to 5.14 and those major dimensions are presented in Table 5-1. Such related structures are summarized below.

Structure	River				Total
	Widas R.	Kedungsoko R.	Ulo R.	Kuncir R.	
Objective reach	River mouth to Ngudikan weir	River mough to Malangsari dam	River mouth to Kuncir weir	River mouth to Kuncir weir	
Bridge					
Railway	-	1	1	-	2
Road					
National	-	1	1	-	2
Provincial	1	-	1	4	6
Rural	6	2	16	15	39
Others	2	-	3	-	5
Intake dam (Irrigation head works)	1	1	2	3	7
Syphon	-	-	1	1	2

Among the above bridges, the national railway bridges and national highway bridges across over the river channels of the both Kedungsoko and Ulo, are the largest in scale. Those structural figures are given on Fig. 5.15. The intake dams for irrigation have been constructed across the major river channels of the Kedungsoko, Ulo and Kuncir rivers. Major intake dams are presented on Fig. 5.16. The detail dimensions of the related river strusctures are presented in ANNEX-4.

5.4 Inundation due to Past Flood

5.4.1 Causes of inundation

The basin is situated in the inter tropical convergence zone with the two distinct monsoon periods of the west and the east and characterized by topographic features of steeper slope in the upper catchment. The west monsoons or wet season prevail from November to April during which 80% of the annual rainfall is expected. The east monsoons or dry season prevail from May to October, bringing about slightly cooler and less humid conditions. Much of the upper catchment of the Widas river basin belongs to the range of Mt. Wilis and the rivers in the upper catchment are steeper and deeply incised but there is a distinct transition to the very flat alluvial plain where carrying capacity of the channel is much reduced.

Such climatic and topographical features bring inevitably about inundations on the lowlying areas of the Widas river basin. As soon as heavy rain falls in the upper catchment, the water stage rises rapidly in the middle reaches as well as in the lower reaches and it can be said that flood coming from the upper catchment is torrential. The flood water overtops river banks exceeding its channel capacity. Such overbank flow and local rain water flow into the lowlying area and those flood water is not drained quickly due to insufficient drainage channels. Those are severe at each area of the lowermost of the Widas and Ulo rivers and of just upstream of the national highway bridge over the Kedungsoko river. Thus flood inundation in these areas has continued for long duration, Fig.5.17 shows the flood prone area and typical flooding flow direction.

The flooding in the plain thus may be caused mainly by the following factors:

(a) Overbank flow of flood water of the rivers
(b) Insufficient capacity of the river channels
(c) Back water of flood in a river to another
(d) Combinations of the above

5.4.2 Inundations due to the past flood

The basin has experienced inundation almost every year. According to the information obtained from local people, it can be said that low-lying areas near major confluences habitually suffer from inundation at least three to five times with longer duration during the rainy season. The observed annual max. discharges at Lengkong bridge on the lower Widas are presented in ANNEX-4, although those indicate discharges attenuated by overbank flow on their upper reaches.

Inundation damage due to the past floods in this decade is presented in Table 5.2. The Mar. 1976 flood, Jan. 1979 flood, April 1979 flood, Jan. 1984 flood and april 1985 flood were the major ones in view of the extent of the inundation area and damage. Among others, the Jan. 1979 flood is the largest since 1931. Ten-days total rainfall observed at Bulakmojo station near Nganjuk and at Mrican is presented in ANNEX-4 for the last 11 years from 1973 to 1983. According to the above table, total rainfall at Bulakmojo for the period of the Jan. 1979 flood, exceeded 500 mm in depth. This historical flood brought about 20 casulaties and other serious damage into the basin. More than 9000 ha of beneficial area was inundated. The inundation area by the said flood is shown on Fig. 5.18. It has been reported that basinwide flood fighting was vigorously continued for 3 days by parties of authority concerned and community mutual help organization. The features of the Jan. 1979 flood are presented in Table 5.2.

As mentioned previously, the lowlying areas near confluences form habitually natural retarding basins in the rainy season. Such inundations seem to have occurred in different locations and with different scales depending on the regional meteorological conditions. Based on the collected inundation data and information obtained from local people, habitual inundation area caused by flood that possibly occurs once in two years, is shown on Fig. 5.18. The total inundation area is estimated at approximately 40 km^2 out of 40 km^2 inundation area, about 29 km^2 is habitual inundation area which is caused by 2 yr probable flood, according to data obtained thorugh hearing from local people.

Table 5.1 EXISTING MAJOR RIVER STRUCTURE IN THE WIDAS BASIN (1/2)

Bridge

Name	Purpose	Location		Administrative Office	Specification			Remarks
					Length (m)	Width (m)	Lowest Elevation of girder (m, SHVP)	
K. Widas								
	Footpath	3.9 + 100	4.10 K		20.0	-	-	Bamboo
Lengkong	Highway	11.5 + 130	12.46 K		65.0	4.6	-	RC and PC
Karangsemi	Highway	24.7 + 150	25.90 K		63.0		-	Steel
	Highway	32.1 + 300	33.25 K		42.15	5.60	47.50	RC
	Highway	34.6 + 350	33.80 K		40.30	2.0	50.92	Steel
	Footpath	37.1 + 120	38.05 K		31.80	2.25	-	Steel
	Highway	38.6 + 250	39.7 K		38.80	5.80	53.22	RC
	Highway	43.1 + 300	44.25 K		50.25	5.60	59.04	RC
	Light Railway	48.1 + 200	49.15 K		46.70	2.75	65.93	RC
	Highway	48.6 + 200	49.65 K		47.00	2.70	64.74	Steel
K. Ulo								
	Highway	U- 1.5 + 200	1.7		15.50	2.25	44.76	Wooden
	Highway	U- 5.5 + 350	5.85		16.60	2.0	47.16	Wooden
	Hihgway	U- 6.5 + 330	6.83		21.80	4.0	48.14	RC
	Highway	U- 10 + 70	10.07		15.3	3.90	49.76	Steel
	Highway	U- 11 + 50	11.50		24.60	6.20	-	RC
	Highway	U- 13 + 200	13.2		25.20	8.6	52.80	RC
	Highway	U- 13.5 + 300	13.8		22.00	2.5	-	Steel
	Highway	U- 14 + 250	14.25	Bina Marga	46.0	7.3	53.49	RC
	Railway	U- 14.5 + 250	14.75	PJKA	51.60	(1.067)	54.58	Steel
	Highway	U- 16 + 300	16.30		25.0	8.8	55.74	RC
	Highway	U- 18 + 300	18.3		27.8	8.9	58.88	RC
	Highway	U- 18.5 + 50	18.55		12.2	3.3	57.275	Steel
	Footpath	U- 19.5 + 250	19.75		20.40	1.5	-	Bamboo
	Highway	U- 20.5 + 200	20.70		36.0	3.6	-	Wet masonry
	Highway	U- 21 + 200	21.20		15.20	3.4	-	Wooden
	Footpath	U- 22.5 + 110	22.61		9.40	1.8	-	Steel
	Highway	U- 24 + 440	24.44		15.40	3.0	-	Steel
	Aqueduct	U- 24 + 480	24.48		21.20	1.5	-	Wet masonry
	Footpath	U- 24.5 + 300	24.80		11.1	2.0	-	Steel
	Highway	U- 25 + 300	25.3		22.6	2.5	-	Wooden
	Highway	U- 25.5 + 430	25.93		14.1	2.0	-	Wooden
	Highway	U- 26 + 400	26.40		28.10	2.0	-	Steel
	Footpath	U- 27 + 300	27.30		31.40	1.0	-	Bamboo
K. Kuncir								
	Footpath	Kc - 0 + 50	0.05		10.0	-	-	Bamboo
	Footpath	Kc - 0.5 + 70	0.57		10.0	-	-	Bamboo
	Highway	Kc - 1.0 - 50	0.95		5.5	3.2	-	Bamboo
	Highway	Kc - 1.5 + 0	1.50		6.8	2.5	-	Bamboo
	Footpath	Kc - 1.5 + 350	1.85		10.0	-	-	Bamboo
	Footpath	Kc - 2.0 + 200	2.20		10.0	-	-	Bamboo
	Footpath	Kc - 2.5 + 120	2.62		14.20	1.5	47.67	Bamboo
	Highway	Kc - 4 + 250	4.25		14.40	4.8	49.06	RC
	Highway	Kc - 5.5 + 0	5.50		11.20	3.1	49.47	Wooden
	Footpath	Kc - 7.5 + 220	7.72		10.00	-	-	Bamboo
	Highway	Kc - 8 + 150	8.15		20.25	2.6	52.39	Steel
	Highway	Kc - 8 + 450	8.45		13.85	3.65	52.26	Steel
	Highway	Kc - 9.5 + 150	9.65		19.0	8.20	53.36	RC
	Aqueduct	Kc -10.0 + 400	10.40		0.6	-	-	Steel(Aqueduct)
	Highway	Kc -10.5 + 0	10.50		20.50	10.50	55.82	Steel and RC
	Highway	Kc -10.5 + 350	10.85		25.50	2.6	56.55	Steel
	Footpath	Kc -12 + 120	12.12		26.00	1.5	59.10	Bamboo
	Highway	Kc -12.5 + 50	12.55		22.00	2.0	60.18	Steel
	Highway	Kc -13 + 80	13.08		22.00	6.2	62.40	RC
	Highway	Kc -14.5 + 0	14.50		17.80	3.5	66.81	Steel
	Highway	Kc -16.5 + 180	16.68		10.00	2.5	-	Steel
	Highway	Kc -17 + 250	17.25		14.50	2.5	-	Steel
	Highway	Kc -17 + 400	17.40		21.00	6.2	-	RC
	Highway	Kc -18.5 + 150	18.65		28.00	2.0	-	Steel
	Highway	Kc -20.5	20.50		40.00	3.6	-	Steel
K. Kedungsoko								
	Highway	K - 3.5 + 200	3.7	Bina Marga	50.8	8.5	45.62	Steel
	Railway	K - 3.5 + 220	3.72	PJKA	82.0	(1.067)	45.29	Steel
	Highway	K - 7 + 250	7.25		40.00	-	48.76	Wooden
	Footpath	K - 8 + 100	8.10		41.00	-	-	Bamboo
	Highway	K - 10 + 150	10.15		40.80	-	48.61	RC

Note : 1) Administrative office except Binamarga and PJKA are regional one.

2) - denotes that dimension was not surveyed.

3) Width in ( ) show rail gauge.

4) Highway / railway means highway bridge / railway bridge.

Table 5.1 EXISTING MAJOR RIVER STRUCTURE IN THE WIDAS BASIN (2/2)

Gate or Dam

Name	Purpose	Location		Specification			
		Distance from river-mouth (km)	Left/ Right bank	Total Width (m)	Gate Height (m)	Nos. of Span	Crest Elevation (m, SHVP)
K. Widas							
Ngudikan Dam	Irrigation	51.45	-	45	2.5	2	-
Glatik Dam	Irrigation	53.5	-	54	3.75	4	74.6
K. Kedungsoko							
Sluice	Drainage	1.00	R	φ 0.4		1	-
Sluice	Drainage	1.25	R	1.5	2.3	1	-
Sluice	Drainage	3.30	R	0.3	0.5	1	-
Sluice	Drainage	5.25	R	1.2	1.5	1	-
Sluice	Drainage	6.50	L	φ 0.8		1	-
Malangsari Dam	Irrigation	10.15	-	37	4.0	4	45.8
K. Ulo and Kuncir Kiri							
Dorongeneng Syphone	Irrigation	8.8	-	-	-	-	-
Bulakmojo Weir	Irrigation	10.8	-	23	3	9	-
Dangdet Dam (Sluice)	Irrigation	14.0	-	1.5	1.0	1	-
Sluice	Drainage	16.75	L	0.5	0.8	1	-
Tripan Dam	Irrigation	20.7	-	10	2.2	2	-
K. Kuncir							
Sluice	Drainage	1.90	L	0.5	1.0	1	-
Sluice	Drainage	2.20	L	0.5	0.8	1	-
Sluice	Drainage	2.20	R	0.5	0.8	1	-
Sluice	Drainage	3.65	L	0.3	0.3	1	-
Sluice	Drainage	4.55	L	φ 0.3		1	-
Kapas Dam	Irrigation	6.5	-	18	2.2	4	-
Syphone	Irrigation	8.65	-	φ 2		2	-
Tanjung Dam (Kramat)	Irrigation	9.65	-	9.5	2.6	2	-
Sluice	Drainage	10.95	L	2.5	2	1	-
Kedunggerit Dam	Irrigation	17.58	-	18.3	6	2	-
Kuncir Diversion Weir	Flood Diversion	20.5	-	33	2	4	-

Source : Topo map with a scale of 1/2,500, inventory survey by Study Team and data obtained from Irrigation Nganjuk Office

Table 5.2 INUNDATION DAMAGE DUE TO REMARKABLE PAST FLOOD

Flood	Total Rainfall (mm) *1	Inundation Area (Ha)					Average Duration (day)	Maximum Inundation Depth (m)	Inundated Houses (nos)	Destroyed Facilities				Damage (Rp. 10^6)*2
		Paddy	Upland	Yard	Others	Total				House (nos)	Bridge (nos)	Levee (m)	Road (km)	
1976 Feb. 29 to Mar. 8	114	2,859	487	180	118	3,644	9	-	872	-	-	100	-	7.5
1977 Jan. 19 to Jan. 20	73	192	10	10	-	212	2	1.00 (at Pace)	70	-	-	28	-	1.0
1978 Feb. 15	59													
1979 Dec. 27 to Jan. 7	260	5,824	2,044	870	499	9,237	12	3.00 (at Lengkong)	14,178	68	8	930	9.20	195.0
Apr. 12 to Apr. 16	188	1,657	580	-	-	2,237	5	0.60 (at Sukomoro)	1,707	11	-	12	9.50	2.5
1980 Dec. 24	35	527	-	-	-	527	1	0.75 (at Sukomoro)	-	-	-	-	-	-
1982 Jan. 25 to Jan. 27	51	742	218	-	-	960	3	0.80 (at Prambon)	441	-	1	14	-	1.5
1983 Mar. 12 to Mar. 14	114	311	38	-	-	349	3	0.75 (at Sukomoro)	-	-	-	-	-	-
1984 Jan. 31	-	919	244	89	-	1,252	10	1.50 (at Lengkong)	2,138	-	-	-	-	25.0
Apr. 12 to Apr. 16	-	937	129	7	-	1,073	3	1.50 (at Sukomoro)	-	-	-	-	-	-
1985 Apr. 21 to Apr. 24	-	1,104	192	10	23	1,329	4	1.00 (at Nganjuk)	-	-	-	-	-	-

Source : DPU East Java Sakai I Pengairan Nganjuk

Note : *1 Averaged total rainfall (Sawahan., Pace, Ngudikan and Lengkong stations)
*2 Current Price

FEATURES OF THE JAN., 1979 FLOOD

1. Duration : December 27, 1978 to January 7, 1979

2. Meteo-Hydrological features

Rainfall.

Maximum Daily Rainfall Depth : 169 mm at Glatik station (Dec., 31)
Maximum Hourly Rainfall Depth : 50 mm at Ngudikan station (Dec., 31)
59 mm at Nganjuk station (Dec., 31)
40 mm at Mricen station (Dec., 31)

River Discharge

Peak Discharge : 268 m^3/s at Lengkong Bridge (Widas, AH 6, Jan., 1)

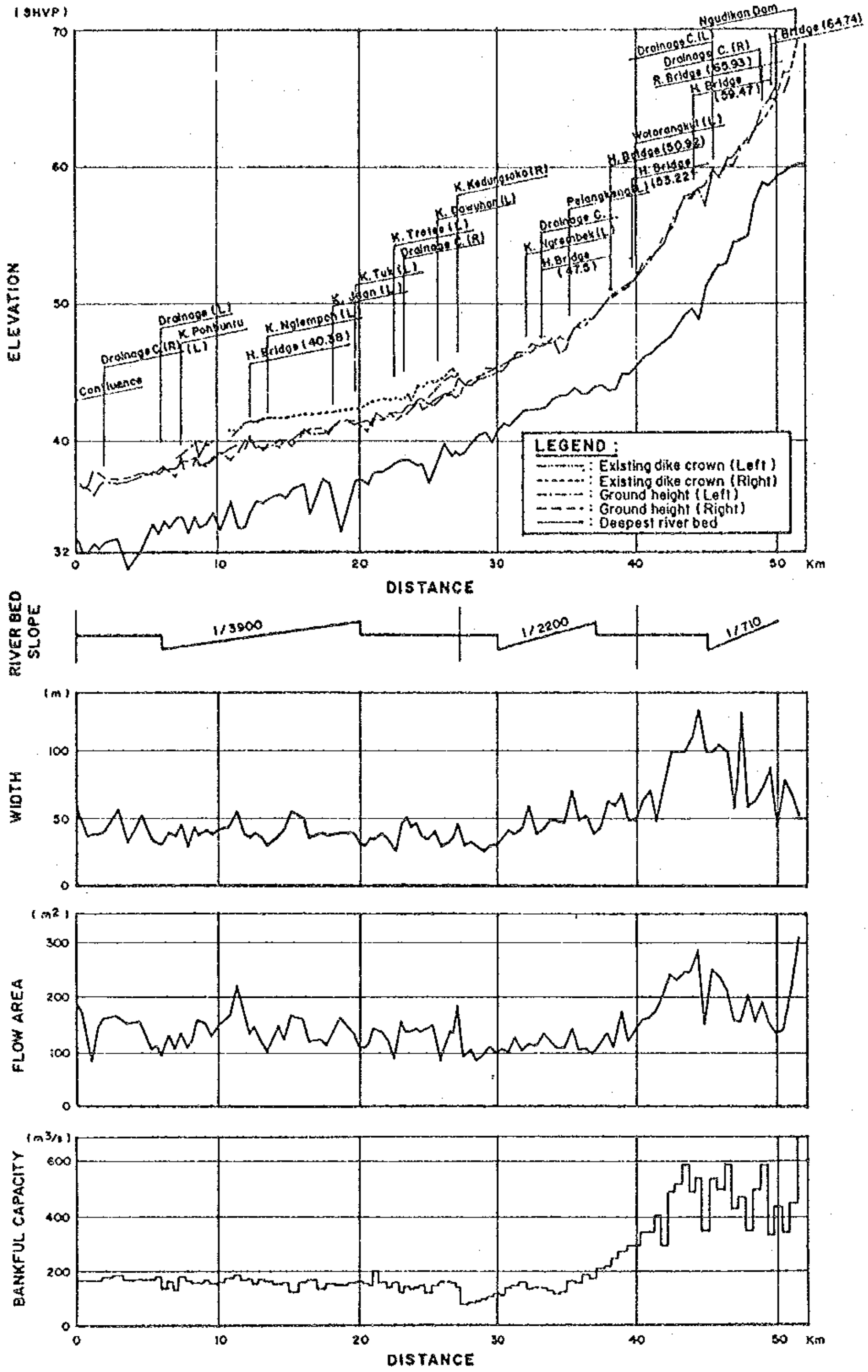
Inundation

Total Inundation Area : 9,200 Ha (Except non-cultivated or swamp area)
Maximum Duration : about 2 weeks
Maximum Inundation Depth : about 3 m

3. Damage

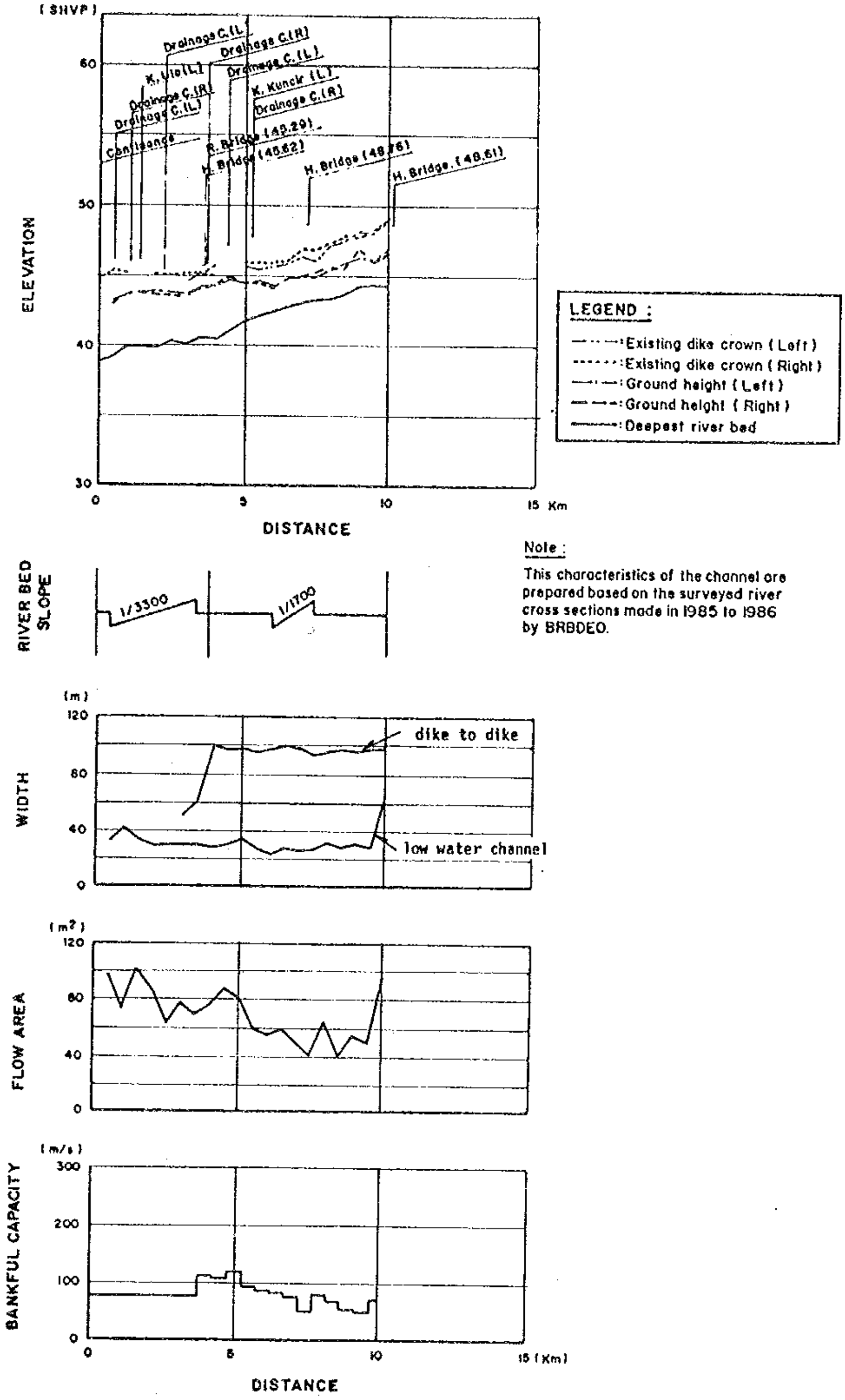
Casualty : 20 death
Destroyed Facility : House : 68 nos; Bridge : 8 nos; Levee : 930 m; Road : 9.2 km
Inundation Farm Land : Paddy Field : 5,900 Ha; Upland Crop Area : 870 Ha.
Total Direct Damage Amount : Rp. 10^6 x 195 (1979 current price)

Source : DPU East Java, Sakai I Pengairan Nganjuk and BRBDEQ.



Note : This characteristics of the channel are prepared based on the surveyed river cross sections made in 1985 to 1986 by BRBDEO.

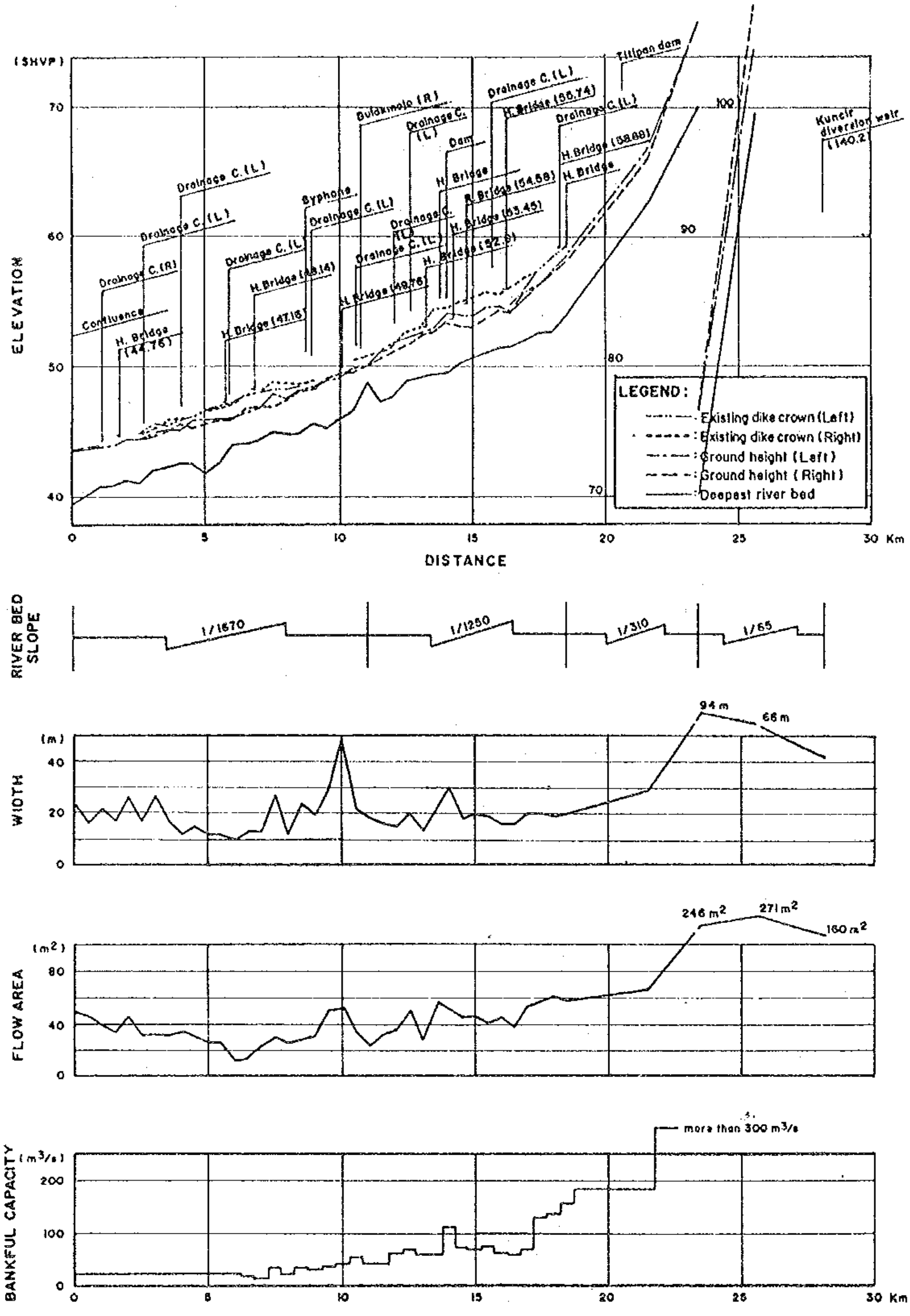
Fig. 5.1. CHANNEL CHARACTERISTICS OF THE EXISTING K. WIDAS



Note :

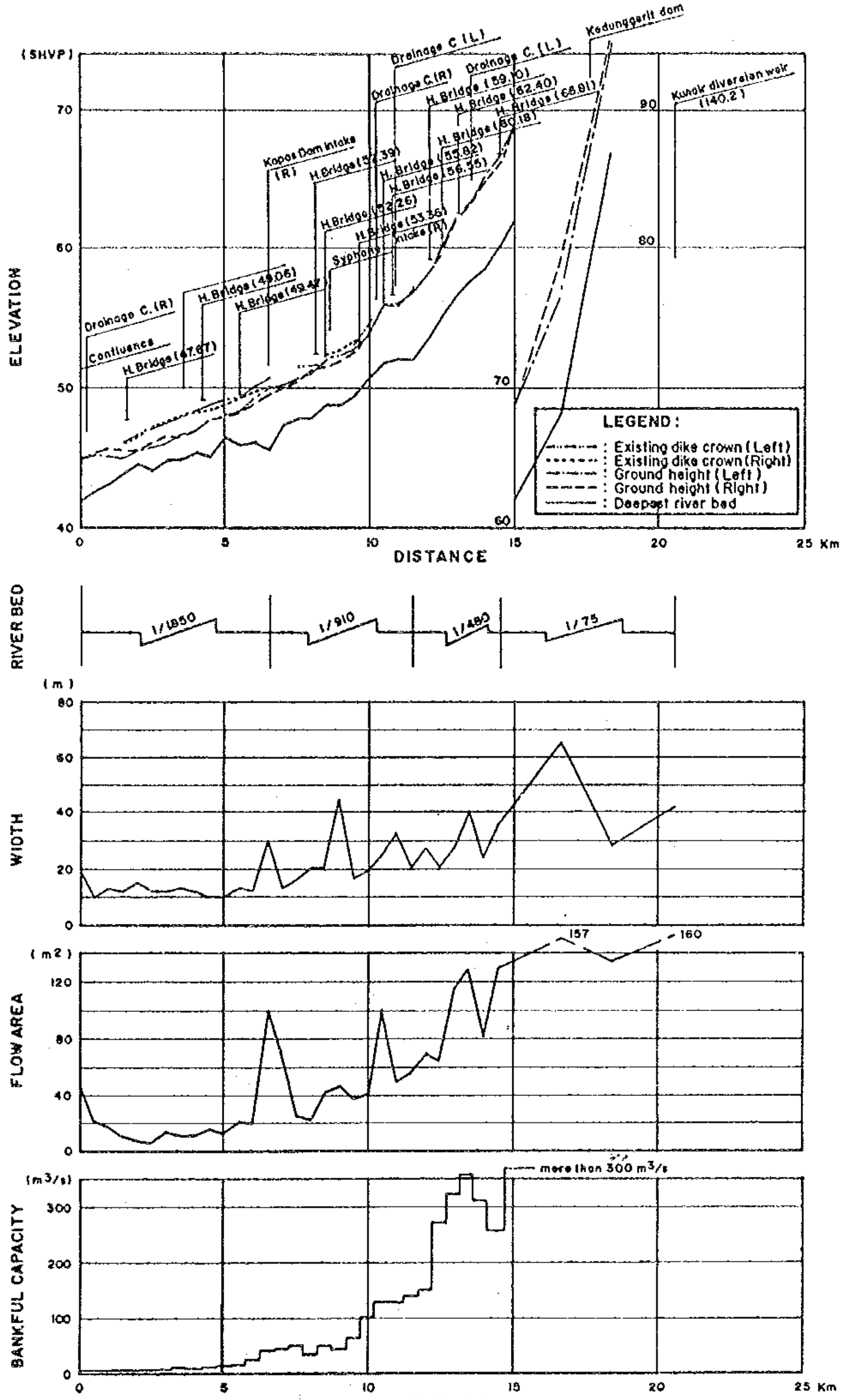
This characteristics of the channel are prepared based on the surveyed river cross sections made in 1985 to 1986 by BRBDEO.

Fig. 5.2 CHANNEL CHARACTERISTICS OF THE EXISTING K. KEDUNGSOKO



Note : This characteristics of the channel are prepared based on the surveyed river cross sections made in 1985 to 1986 by BRBDEO.

Fig. 5.3. CHANNEL CHARACTERISTICS OF THE EXISTING K. ULO



Note : This characteristics of the channel are prepared based on the surveyed river cross sections made in 1985 to 1986 by BRBDEO.

Fig. 5.4. CHANNEL CHARACTERISTICS OF THE EXISTING K. KUNCIR

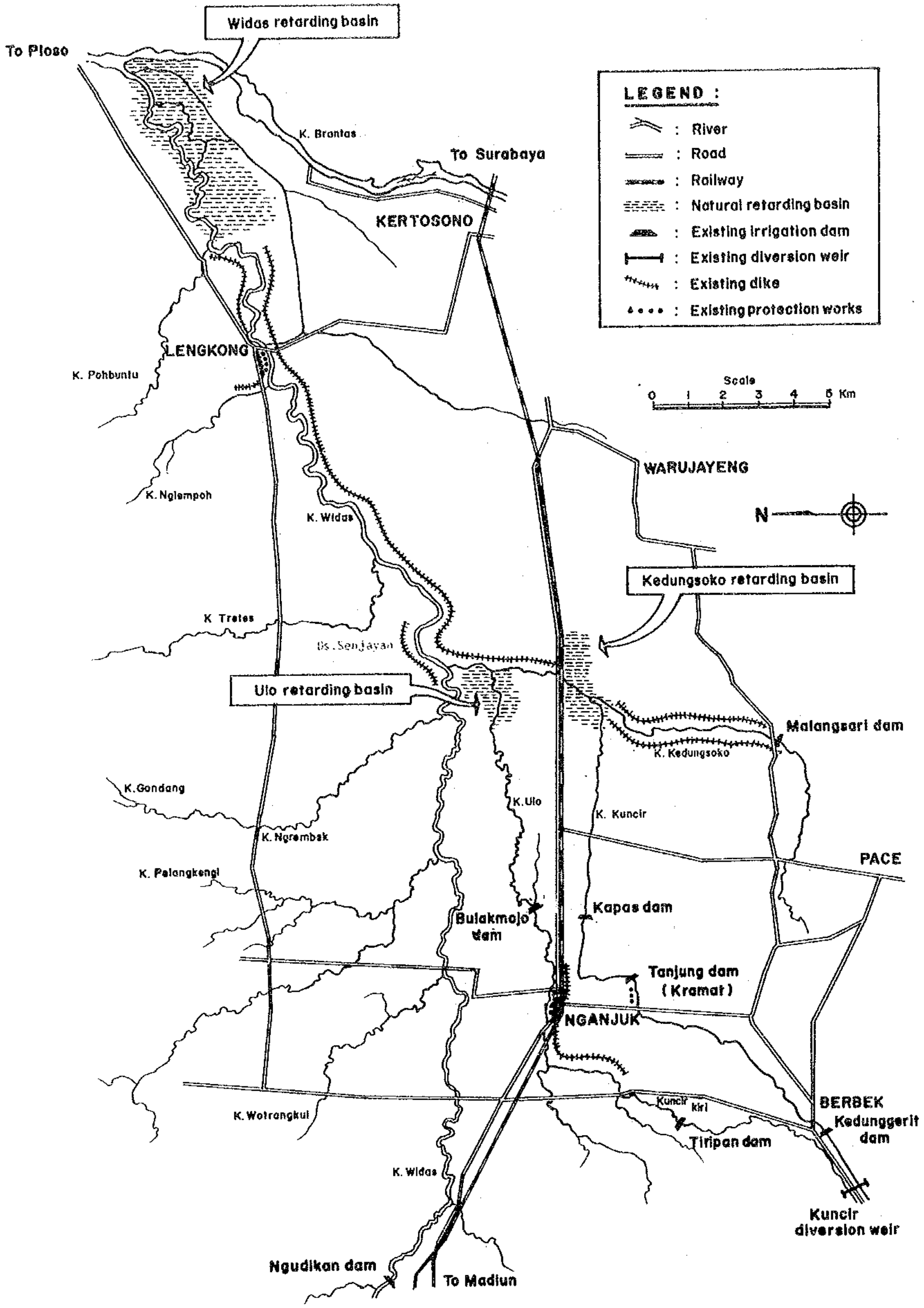


Fig. 5.5. LOCATIONS OF NATURAL RETARDING BASIN

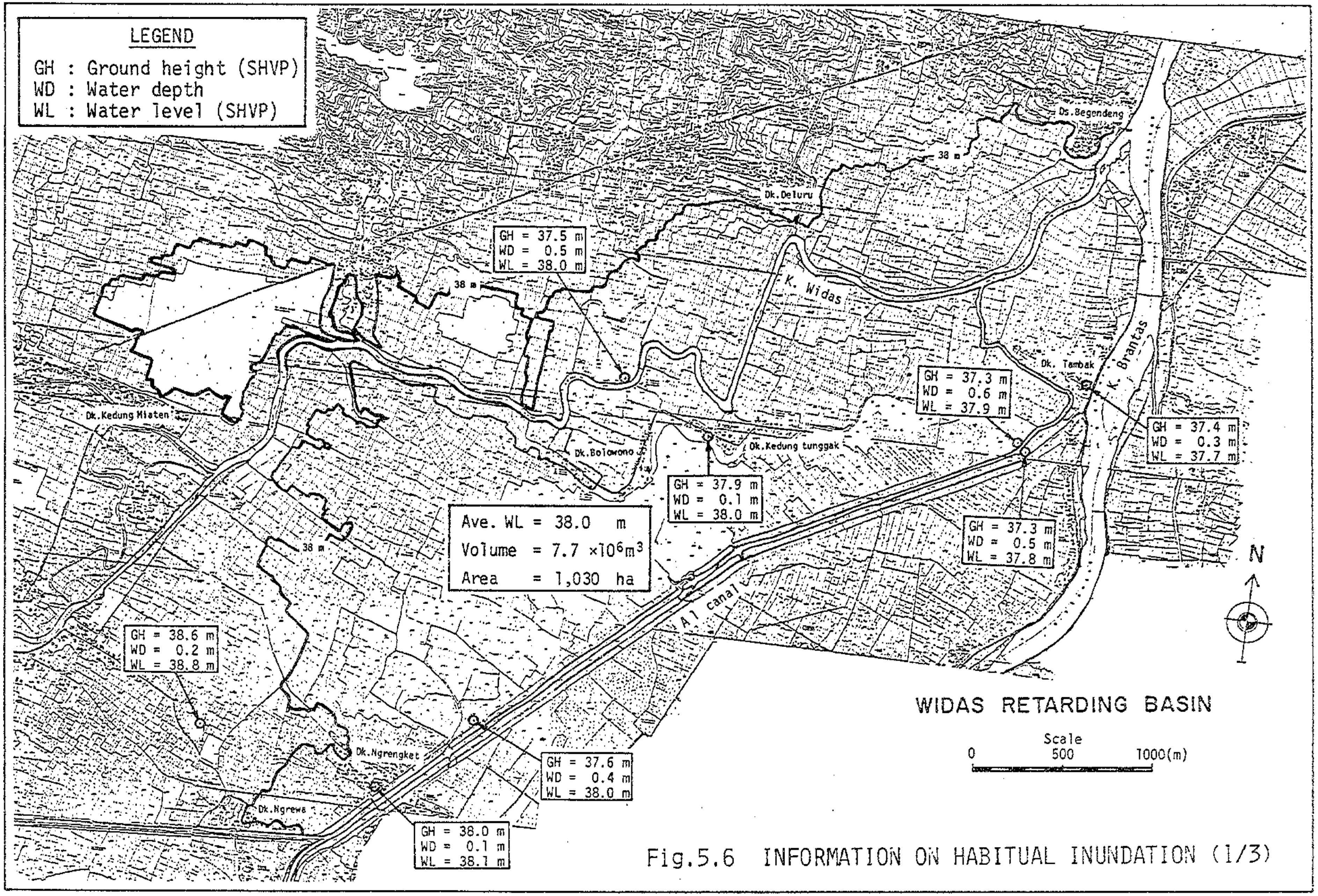


Fig.5.6 INFORMATION ON HABITUAL INUNDATION (1/3)

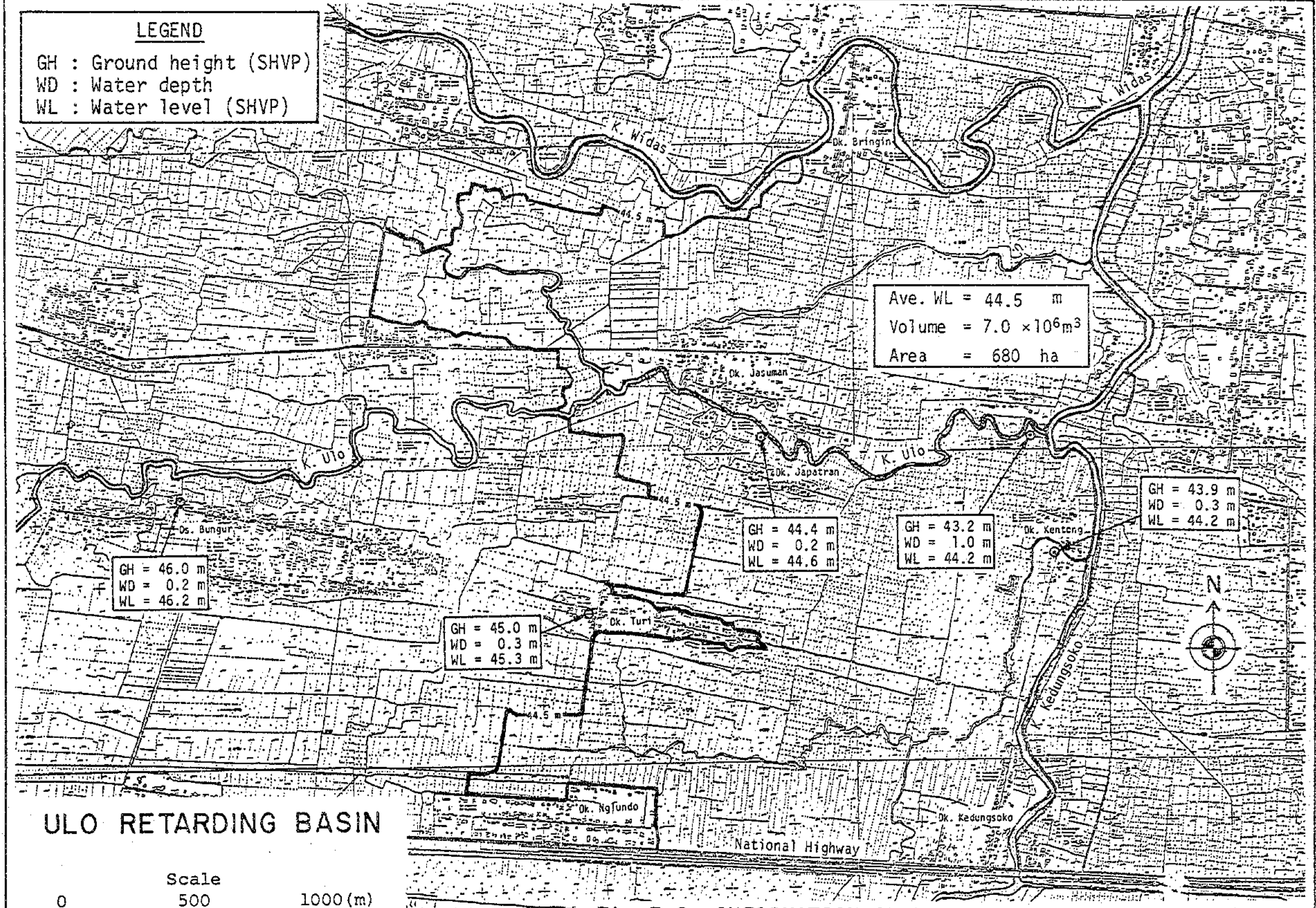


Fig.5.6 INFORMATION ON HABITUAL INUNDATION (2/3)

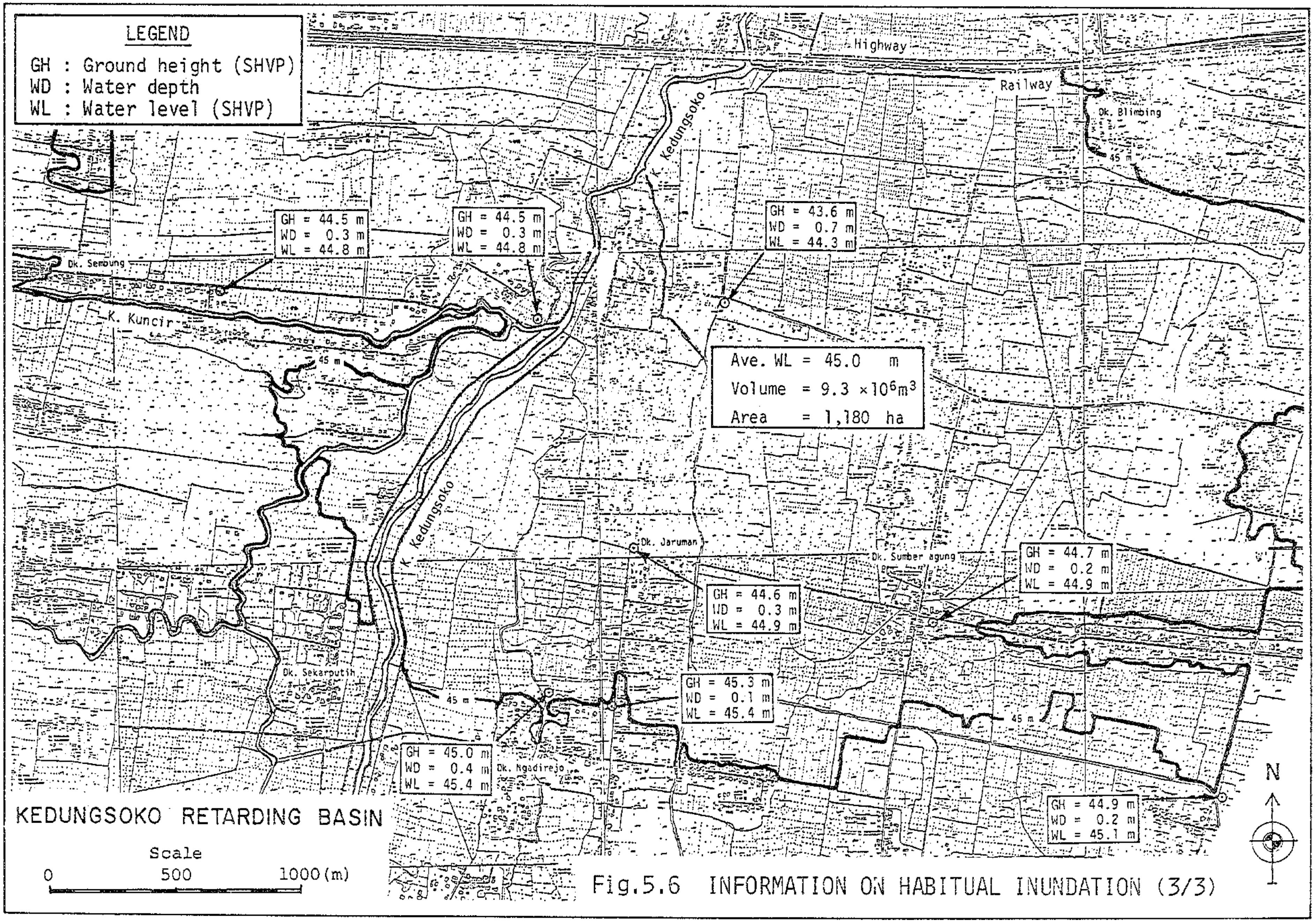


Fig.5.6 INFORMATION ON HABITUAL INUNDATION (3/3)

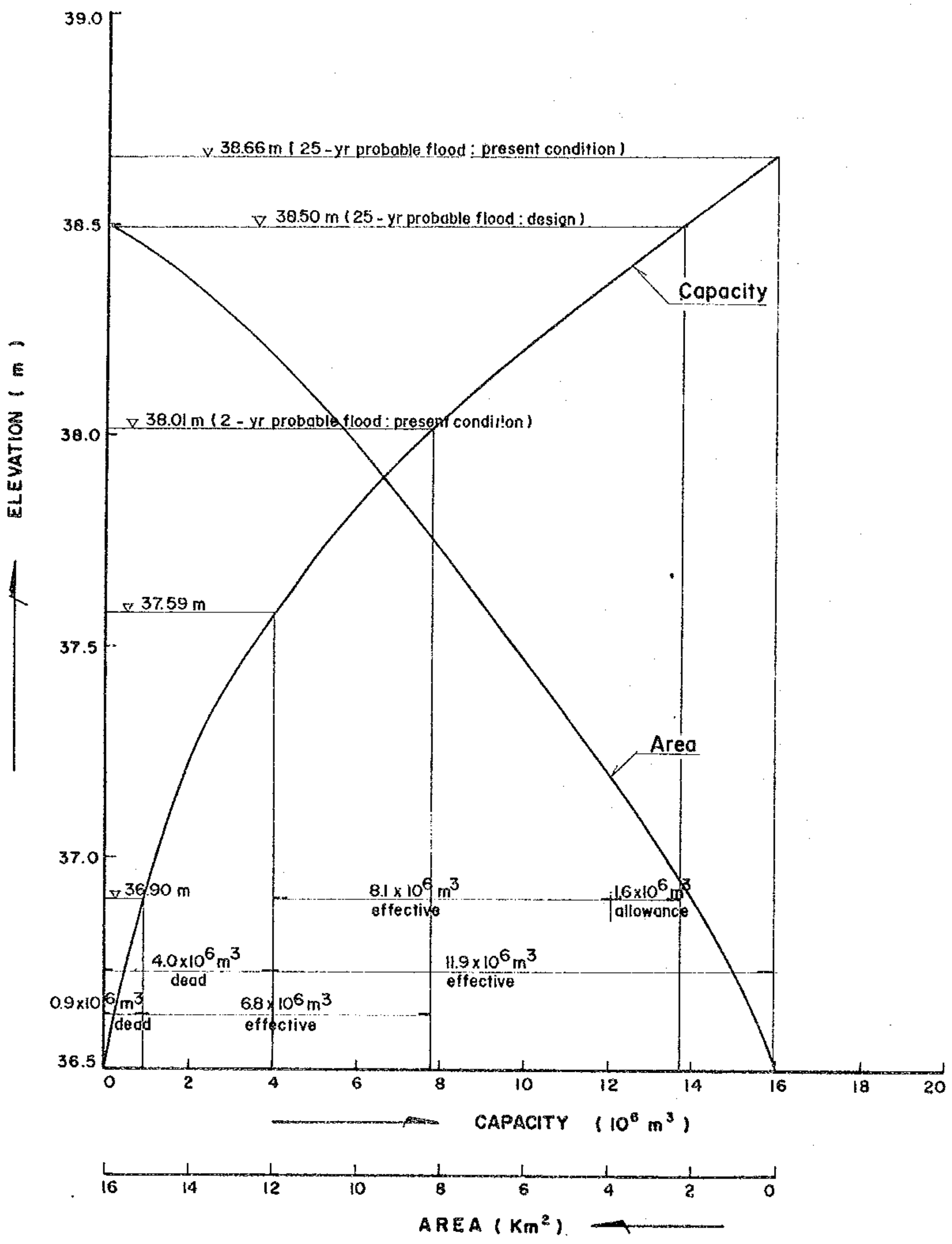


Fig. 5.7. RELATIONSHIP AMONG AREA , CAPACITY AND ELEVATION IN WIDAS RETARDING BASIN (1/3)

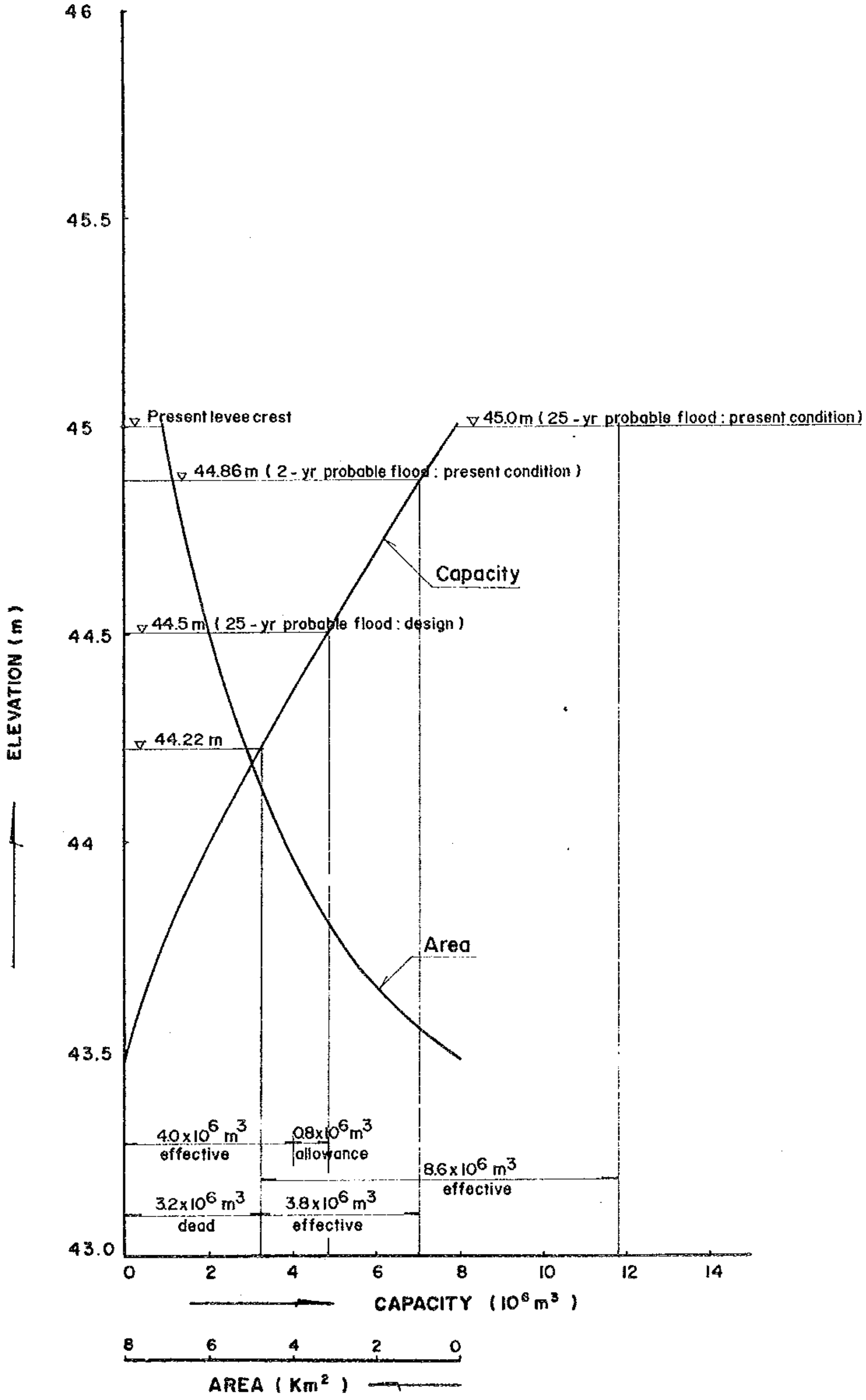


Fig. 5.7. RELATIONSHIP AMONG AREA, CAPACITY AND ELEVATION IN ULO RETARDING BASIN (2/3)

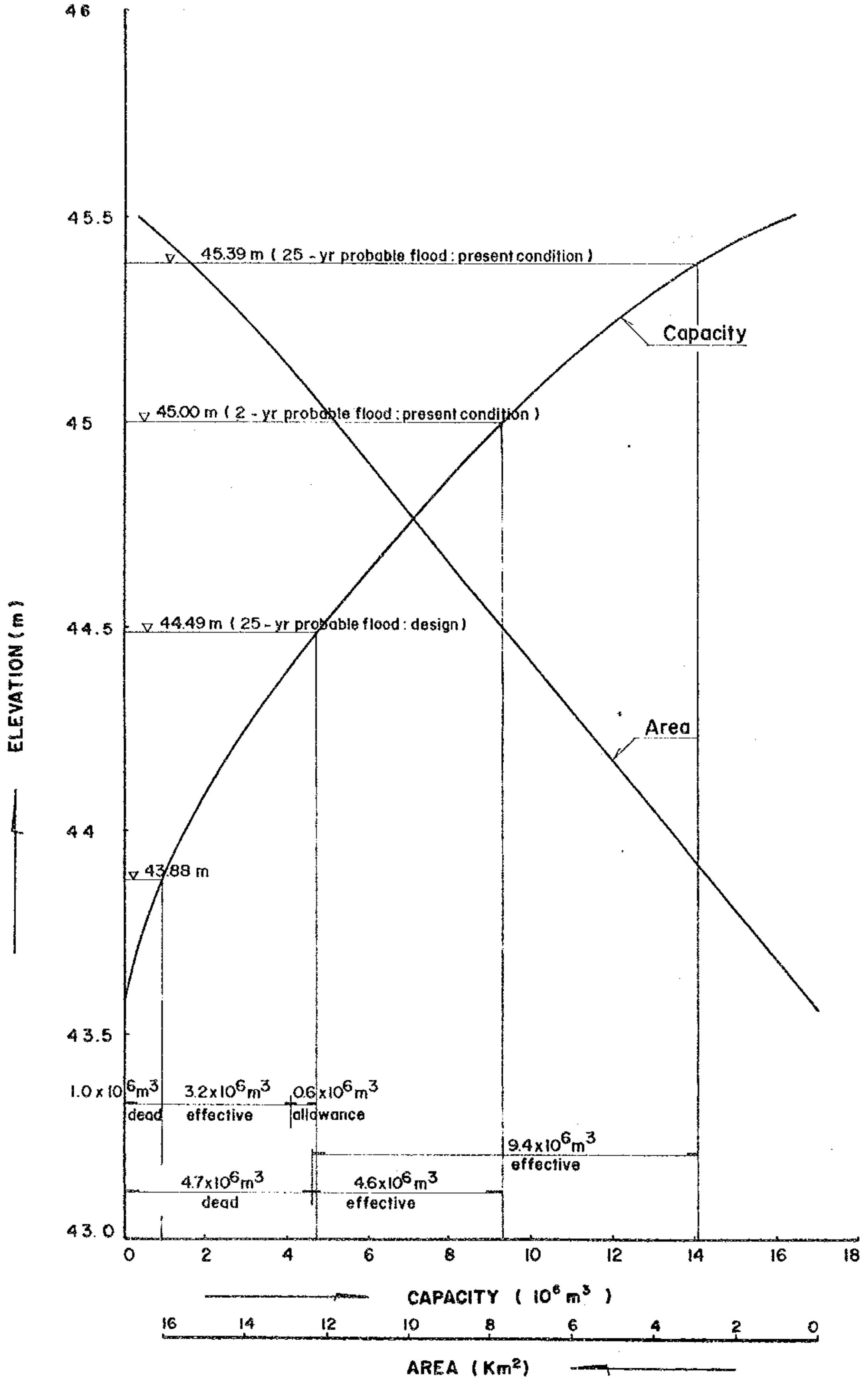
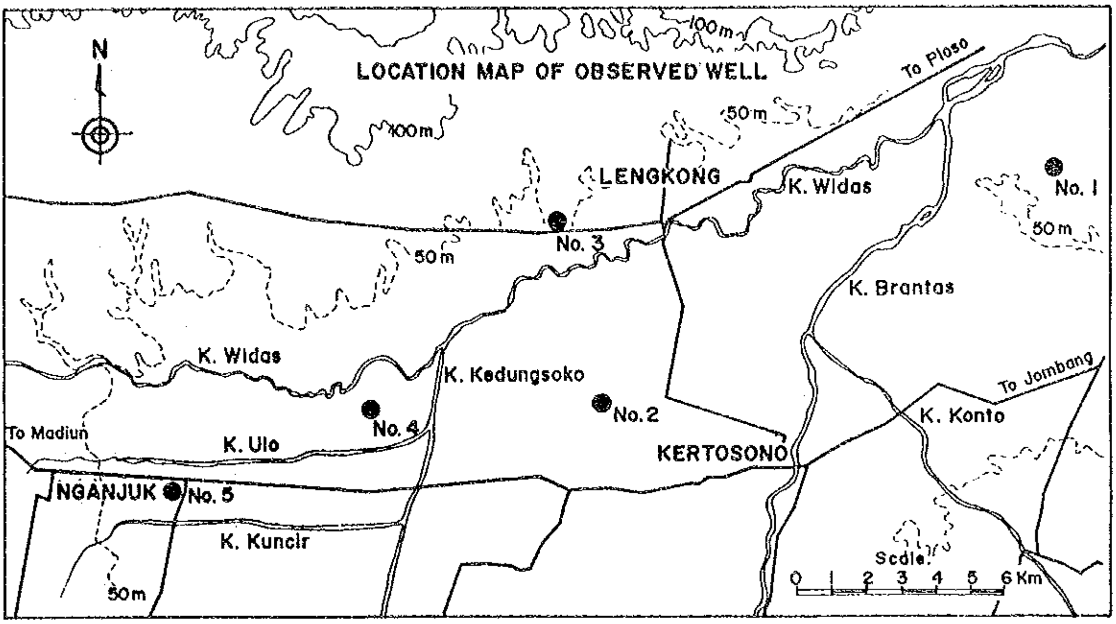


Fig. 5.7. RELATIONSHIP AMONG AREA, CAPACITY AND ELEVATION IN KEDUNGSOKO RETARDING BASIN (3/3)

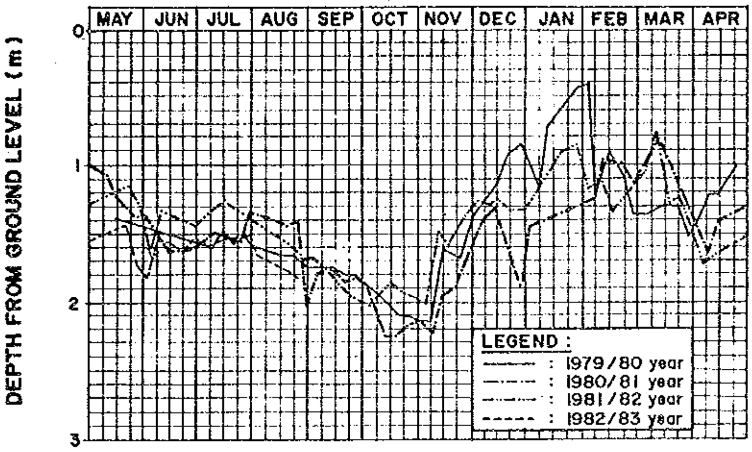


Source : Groundwater Development Project , by I.B.R.D.

DESCRIPTION

GROUND WATER LEVEL HYDROGRAPH

Observed well : No. 1
Type of well : Dug well
Depth of well
from ground level : 2.63 m
Ground elevation : 34 m SHVP



Observed well : No. 2
Type of well : Dug well
Depth of well
from ground level : 3.44 m
Ground elevation : 40 m SHVP

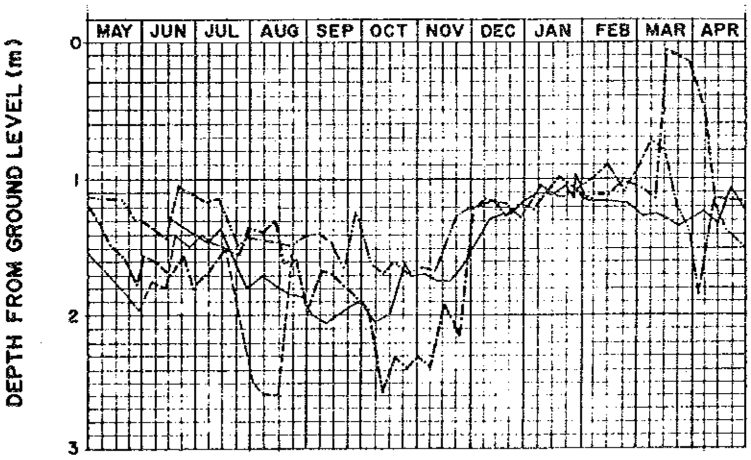
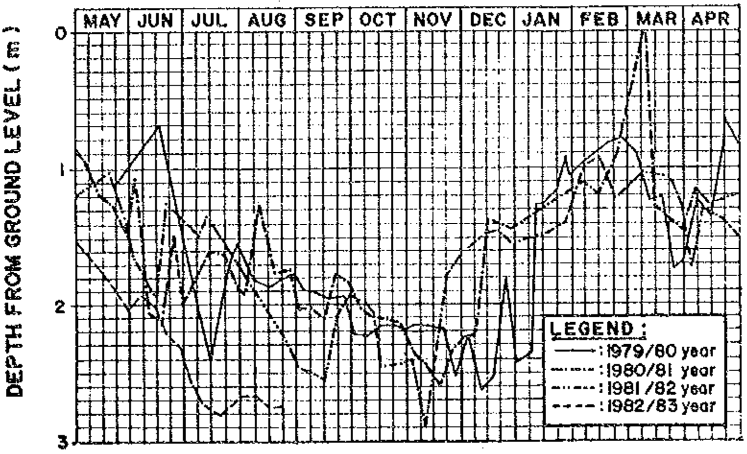


Fig. 5.8. GROUND WATER LEVEL HYDROGRAPH IN AND AROUND K. WIDAS BASIN (1/2)

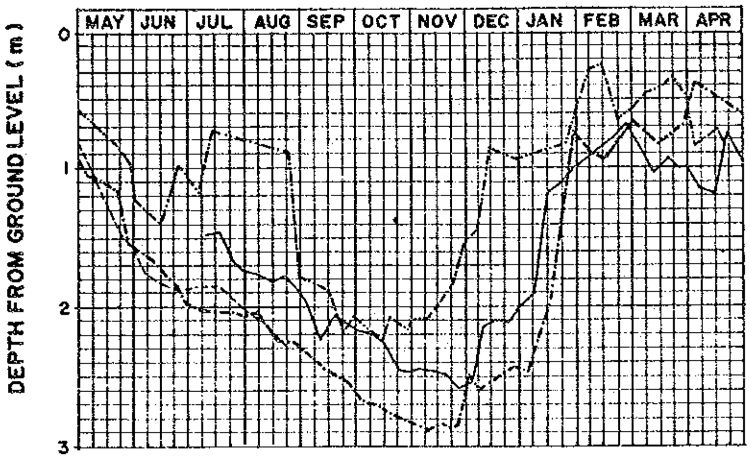
DESCRIPTION

GROUND WATER LEVEL HYDROGRAPH

Observed well : No. 3
Type of well : Dug well
Depth of well
from ground level : 6.74 m
Ground elevation : 50m SHVP



Observed well : No. 4
Type of well : Dug well
Depth of well
from ground level : 3.97 m
Ground elevation : 44m SHVP



Observed well : No. 5
Type of well : Dug well
Depth of well
from ground level : 4.64 m
Ground elevation : 46m SHVP

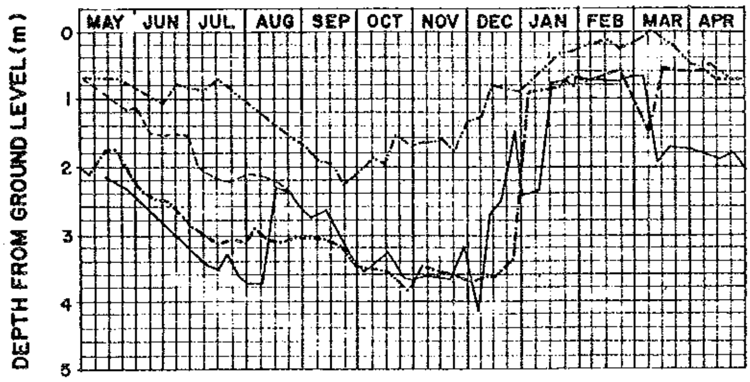


Fig. 5.8. GROUND WATER LEVEL HYDROGRAPH IN AND AROUND K. WIDAS BASIN (2/2)

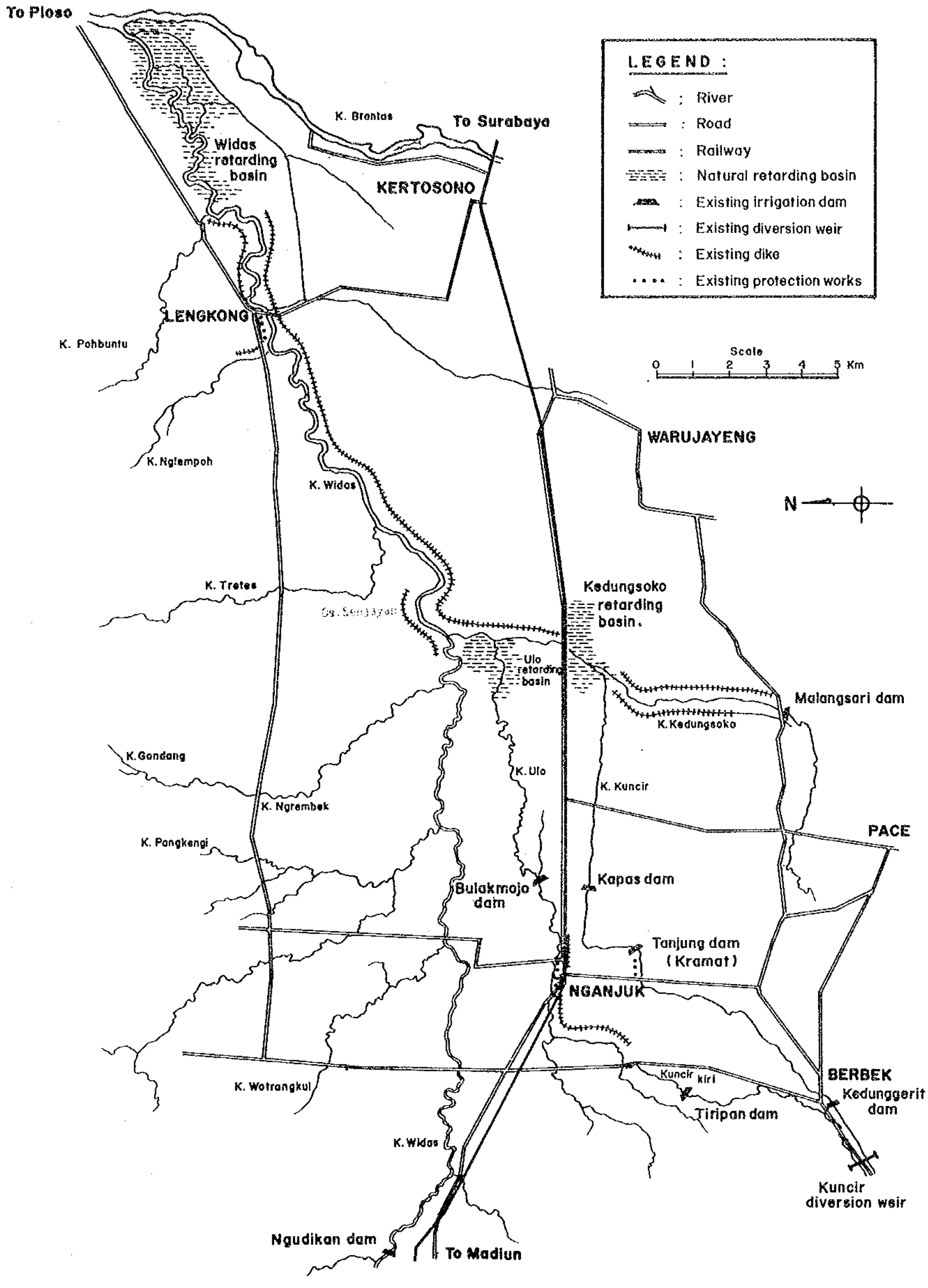
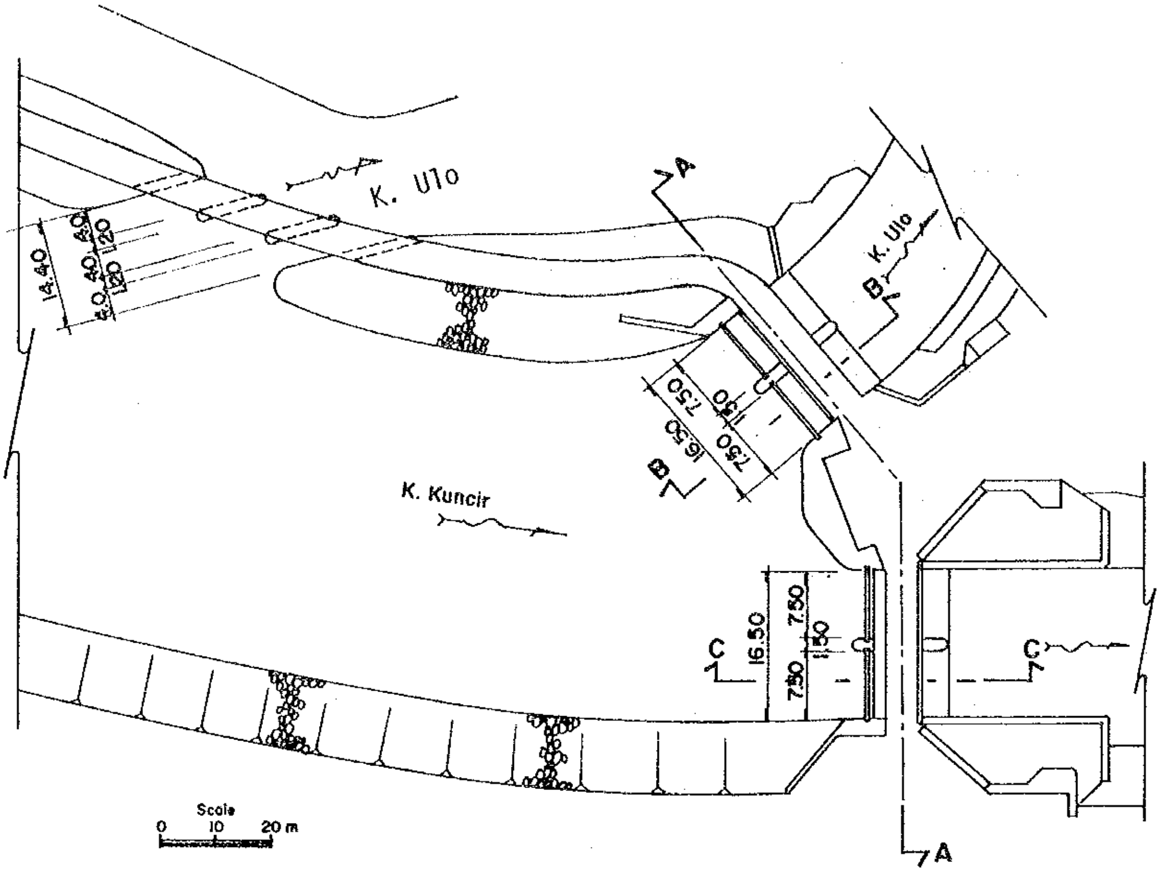


Fig. 5.9. LOCATIONS OF MAJOR FLOOD CONTROL FACILITIES AND RELATED RIVER STRUCTURES



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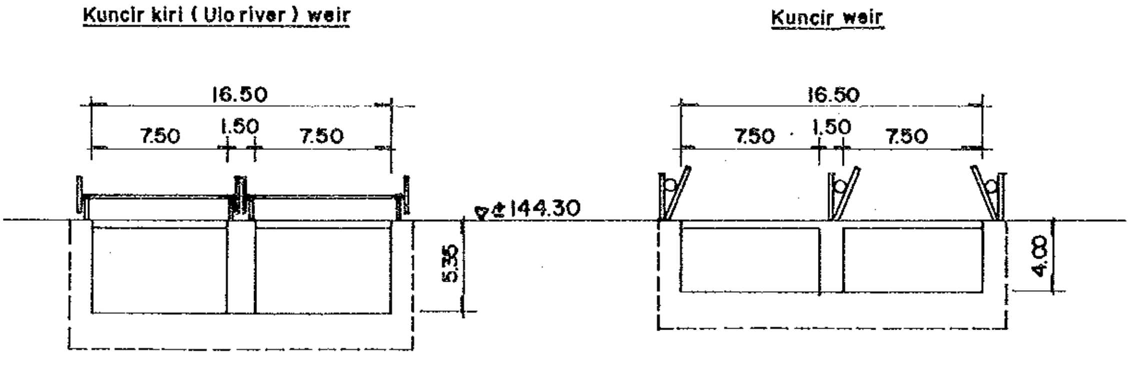
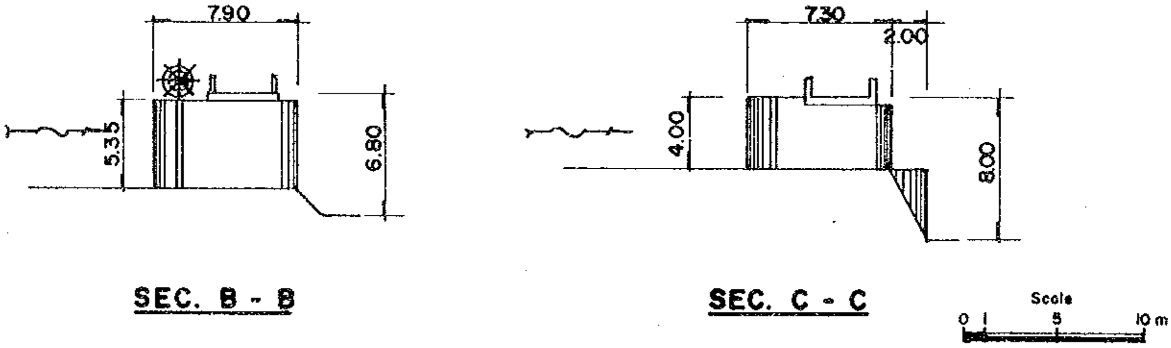


SEC. A - A

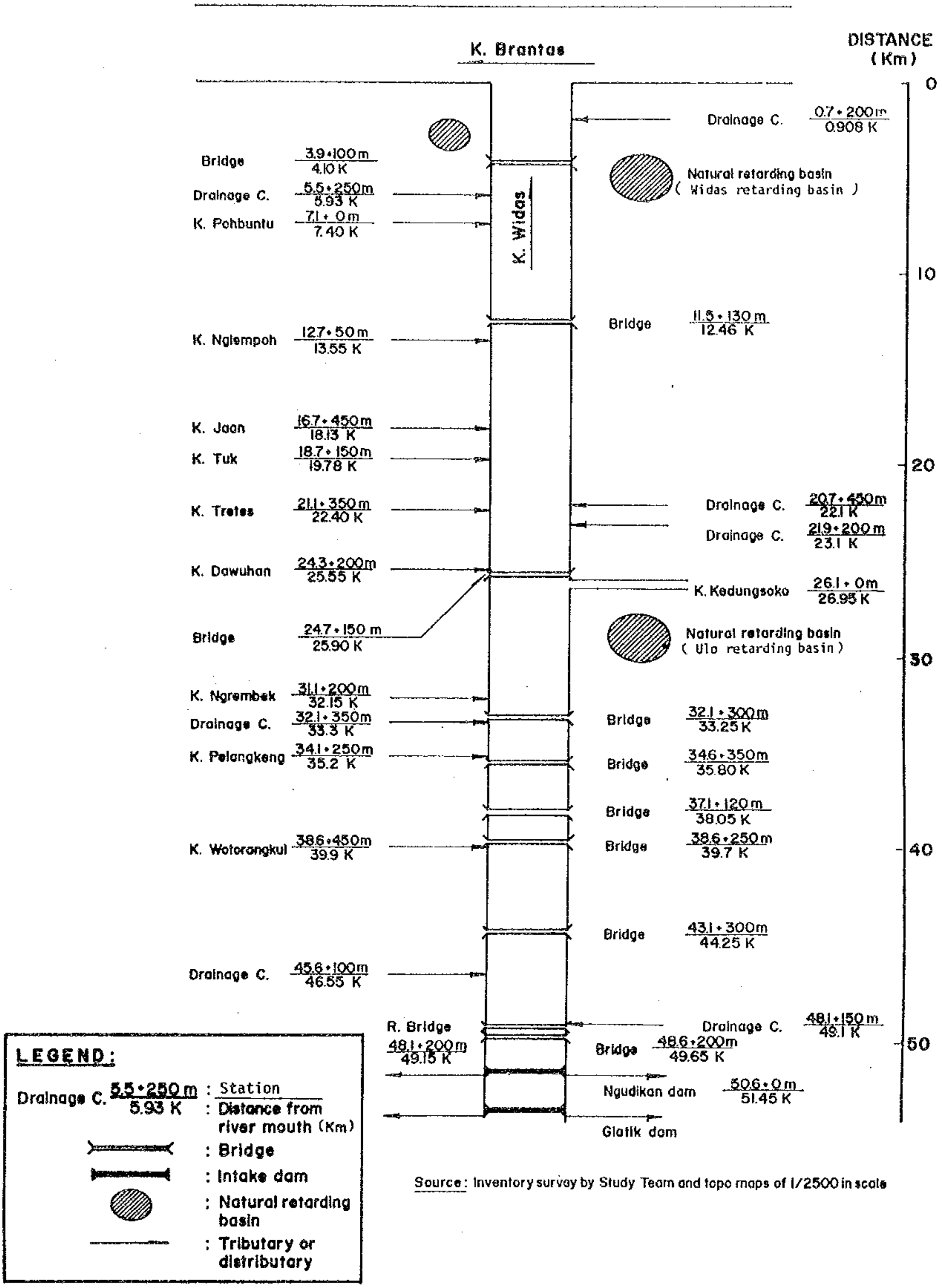


SEC. B - B

SEC. C - C

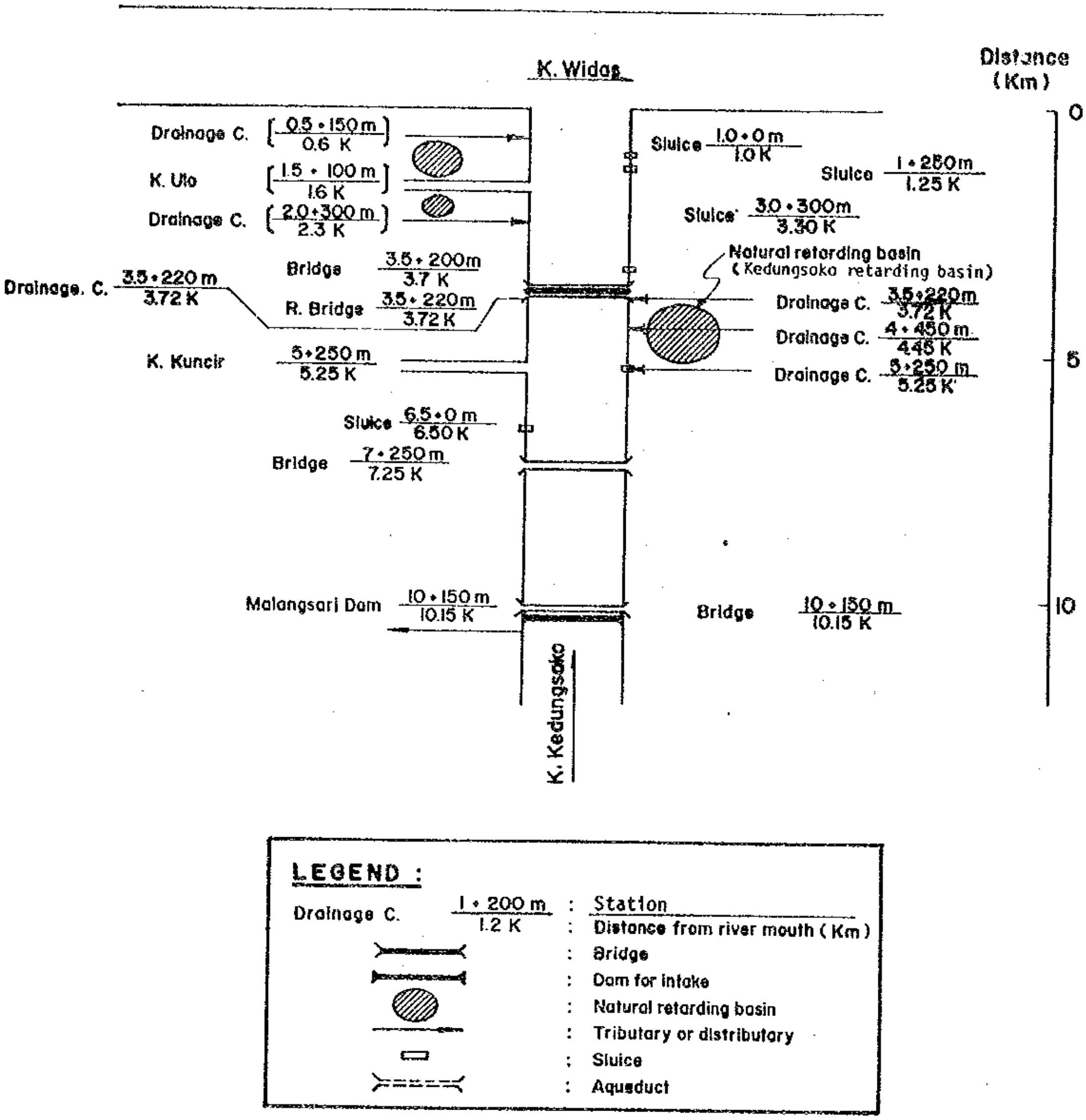
Note : Foundation structure is based on data collected at Pengairan Seksi Nganjuk office.

Fig. 5.10. SKETCH OF KUNCIR DIVERSION WEIR



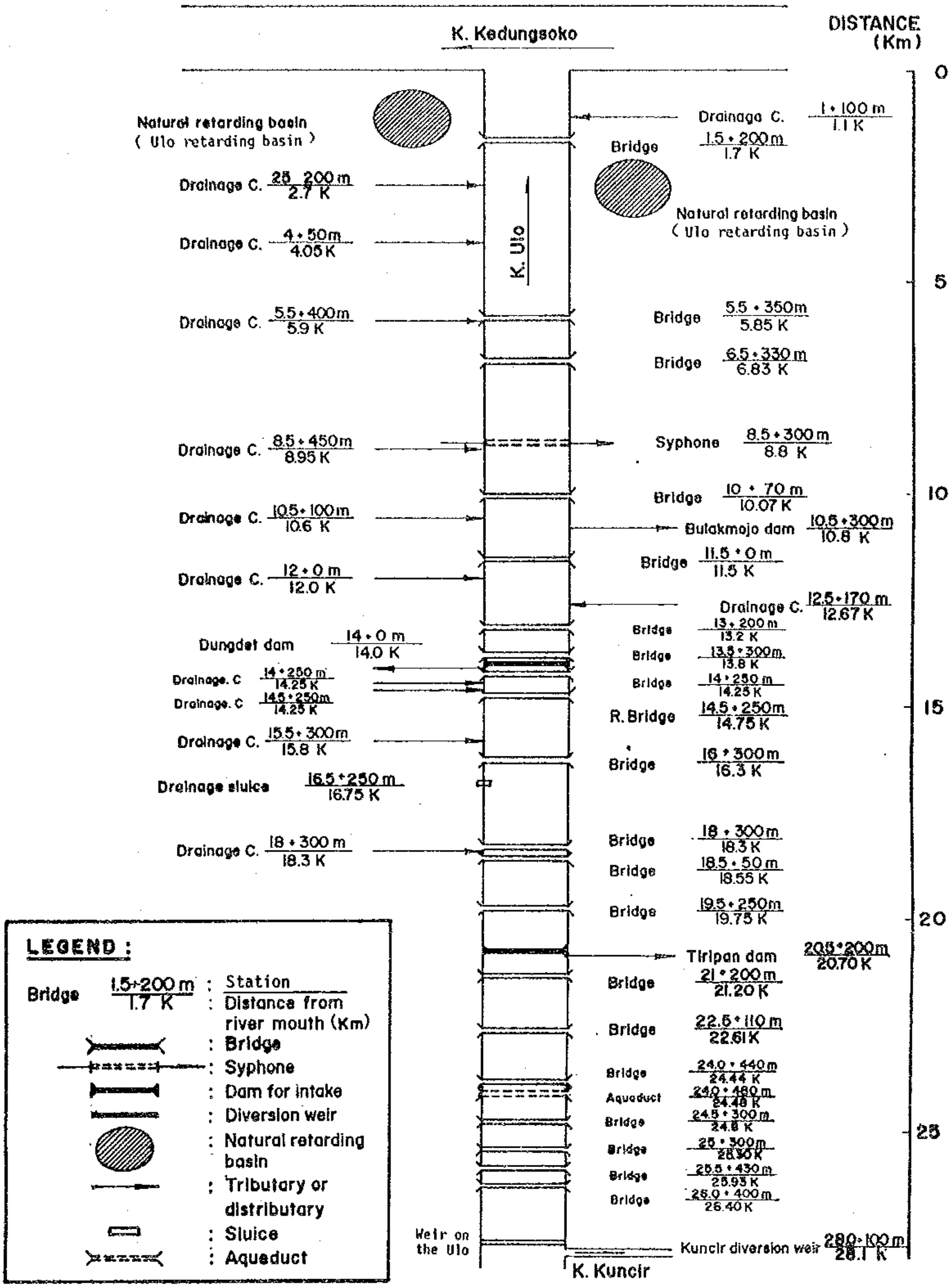
Source: Inventory survey by Study Team and topo maps of 1/2500 in scale

Fig. 5.11. RIVER SYSTEM AND RELATED RIVER STRUCTURES IN THE K. WIDAS



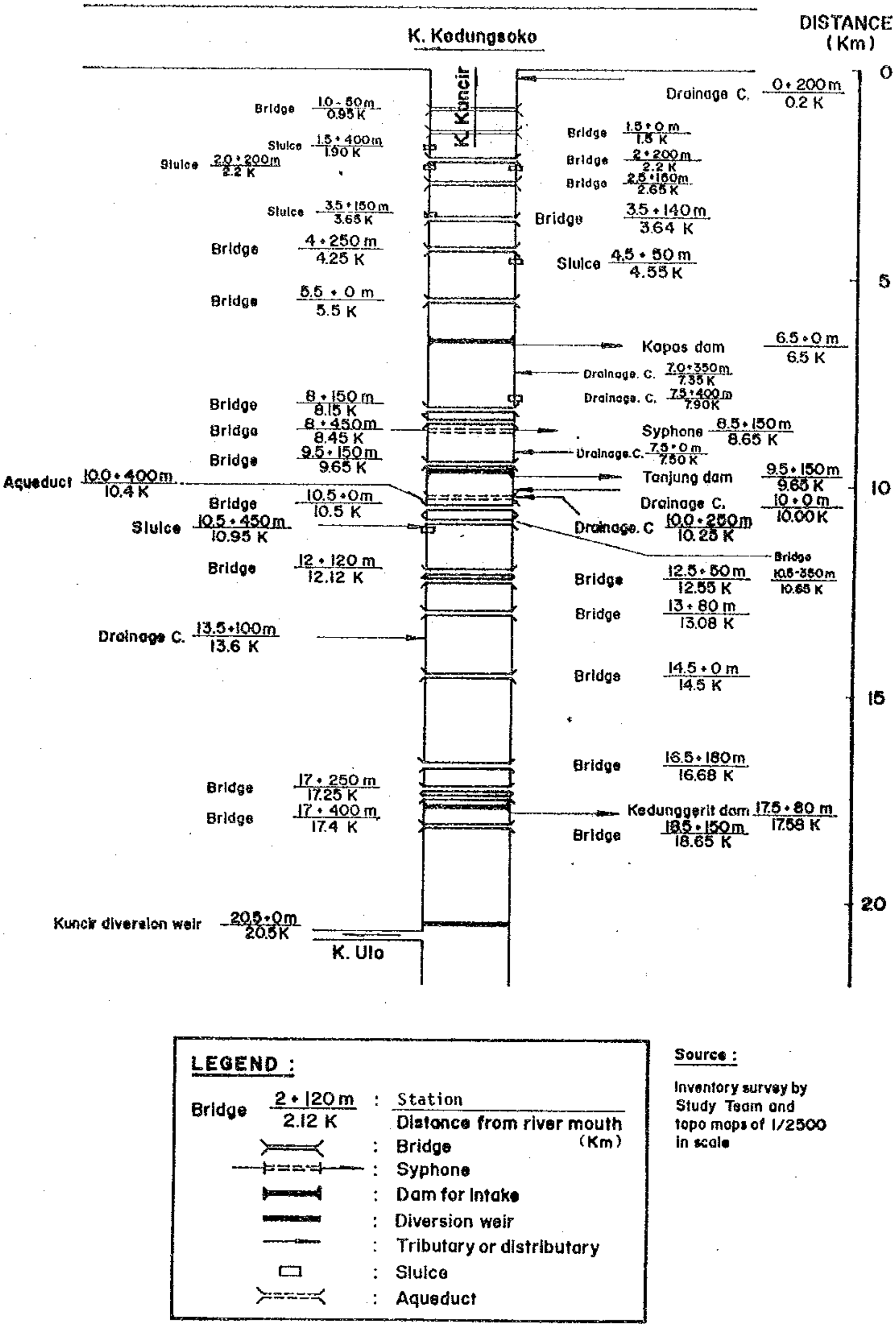
Soure : Inventory survey by Study Team and topo maps of 1/2500 in scale

Fig. 5.12. RIVER SYSTEM AND RELATED RIVER STRUCTURES IN THE K. KEDUNGSOKO



Source : Inventory survey by Study Team and topo maps of 1/2500 in scale

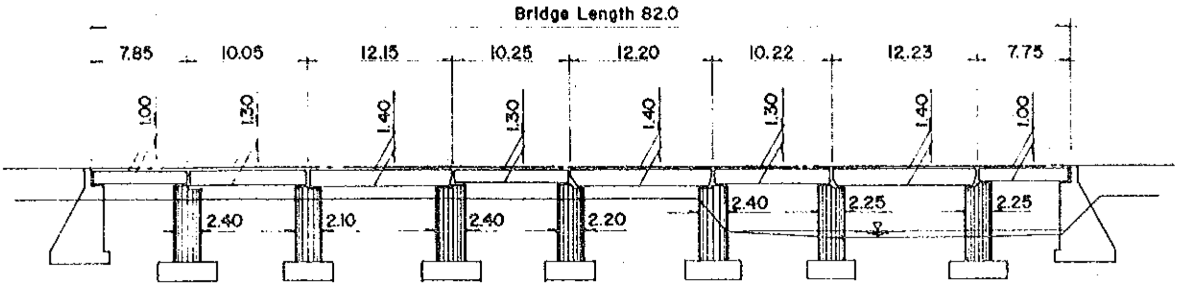
Fig. 5.13. RIVER SYSTEM AND RELATED RIVER STRUCTURES IN THE K. ULO



Source :

Inventory survey by
Study Team and
topo maps of 1/2500
in scale

Fig. 5.14. RIVER SYSTEM AND RELATED RIVER STRUCTURES IN THE K. KUNCIR



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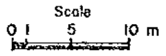

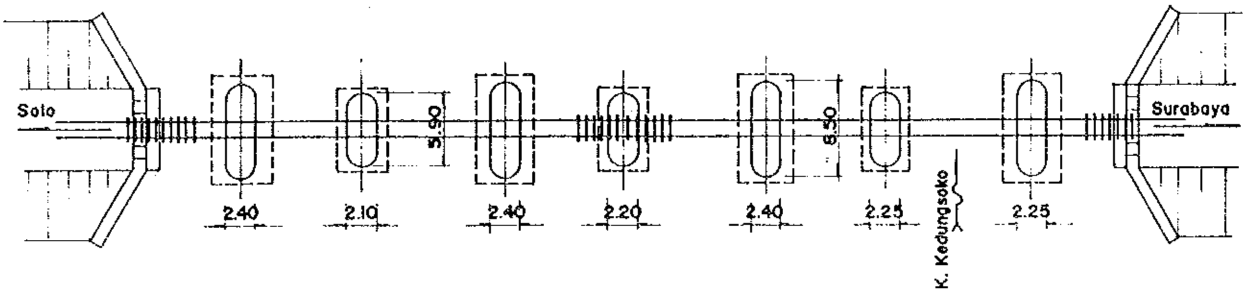

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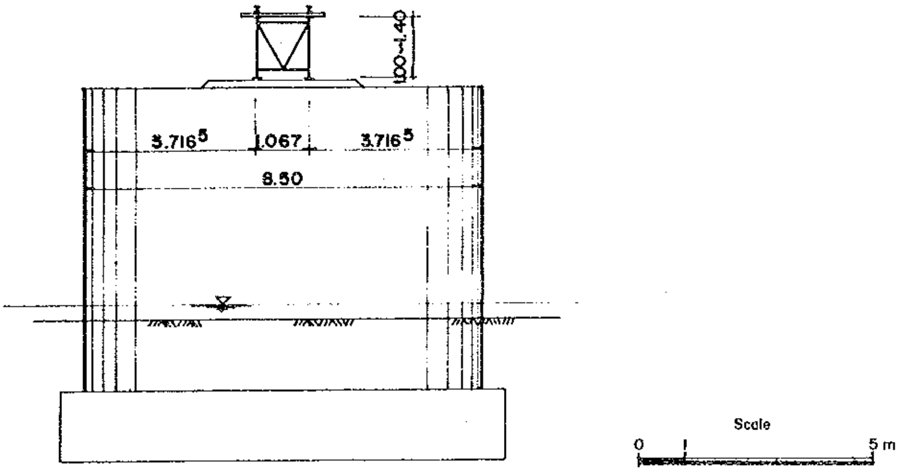
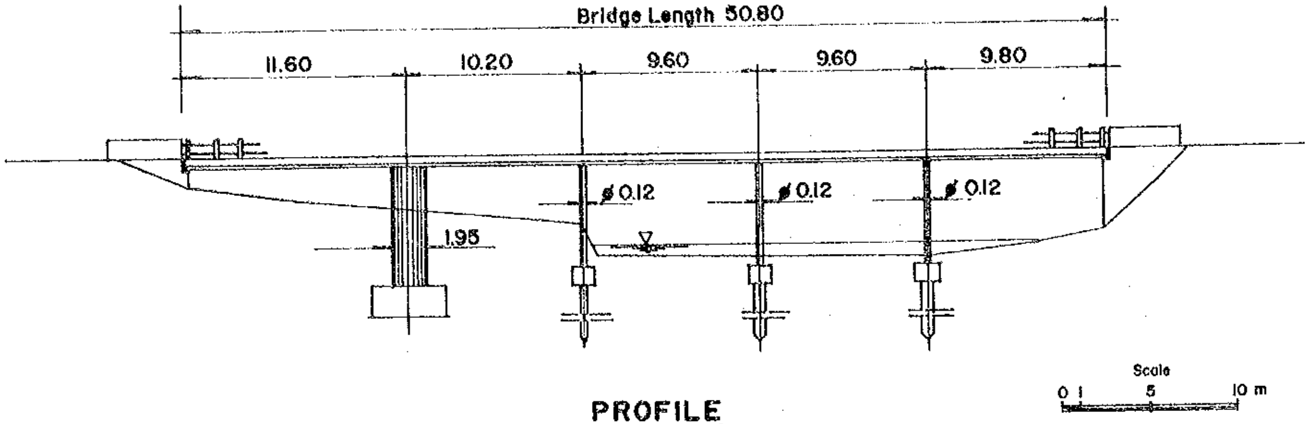


CROSS SECTION

Note : Foundation structure is based on data collected at PJKA office and data obtained from WaruJayeng Project.

Fig. 5.15. K. KEDUNGSOKO RAILWAY BRIDGE (1/5)



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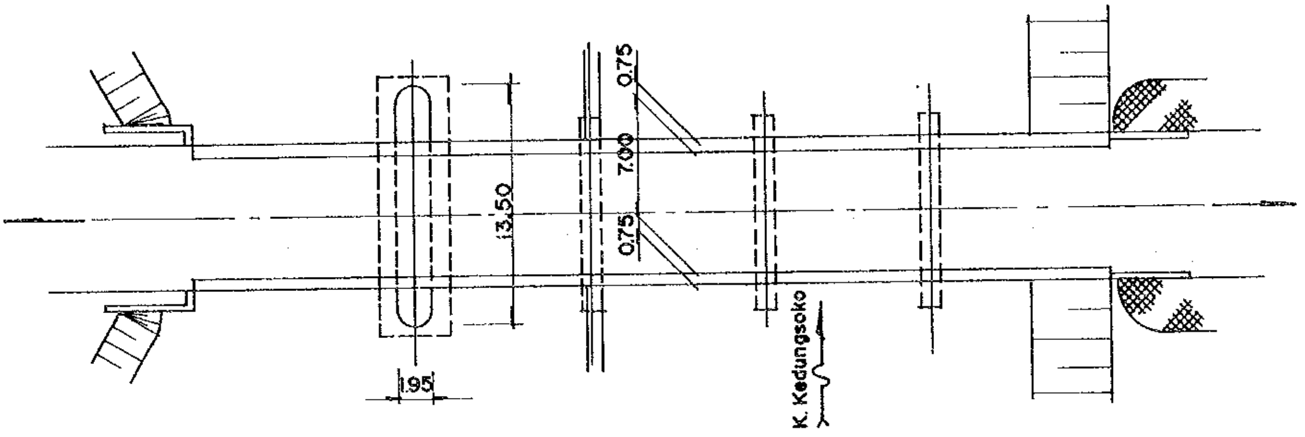

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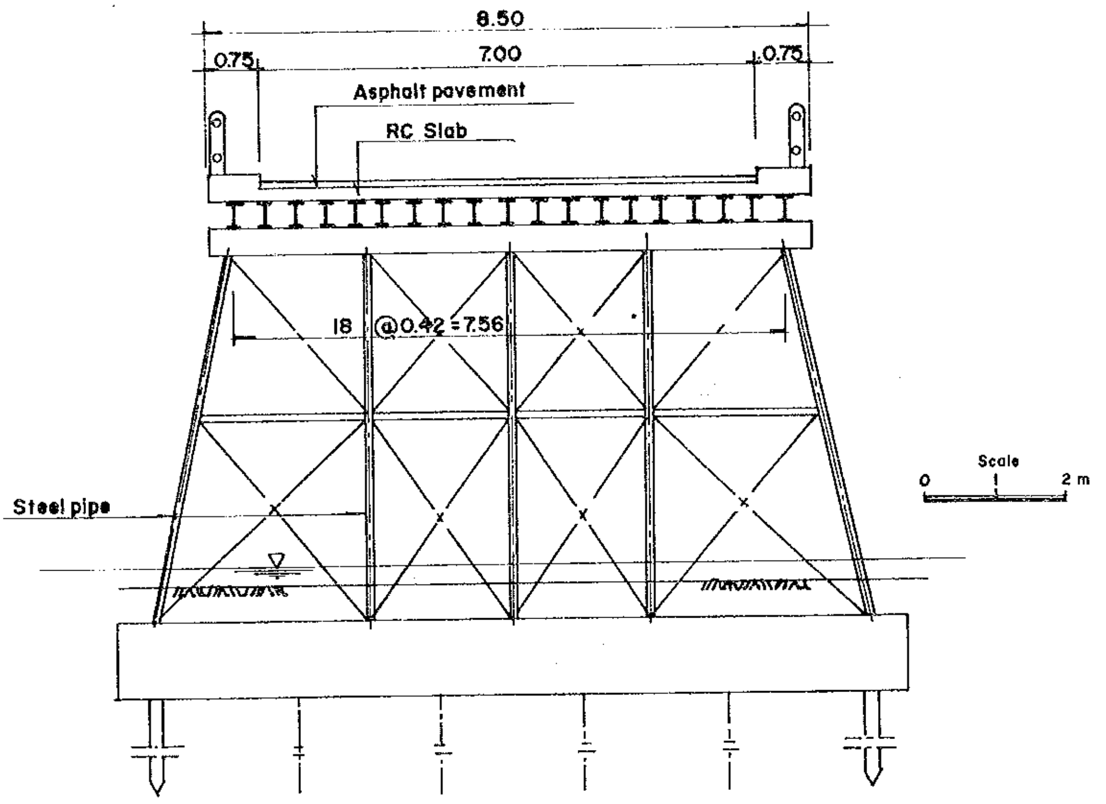
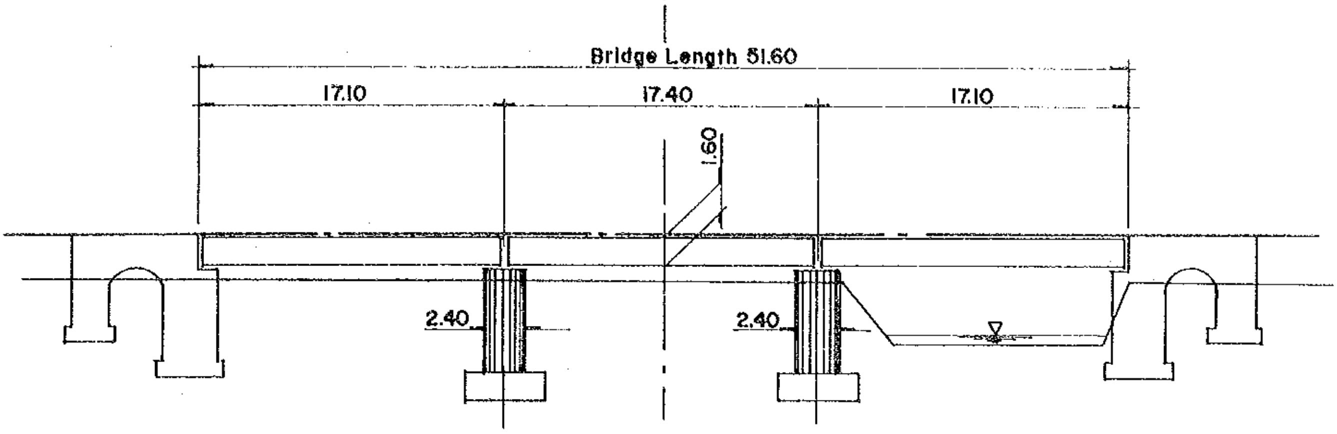


CROSS SECTION

Note : Foundation structure is based on data collected at Binamarga office.

Fig. 5.15. K. KEDUNGSOKO HIGHWAY BRIDGE (2/5)



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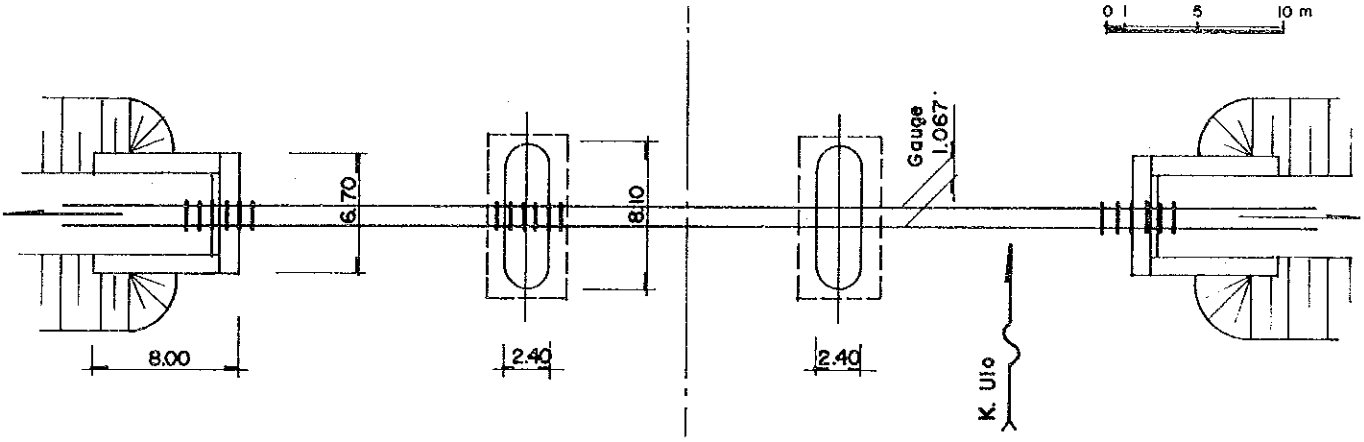

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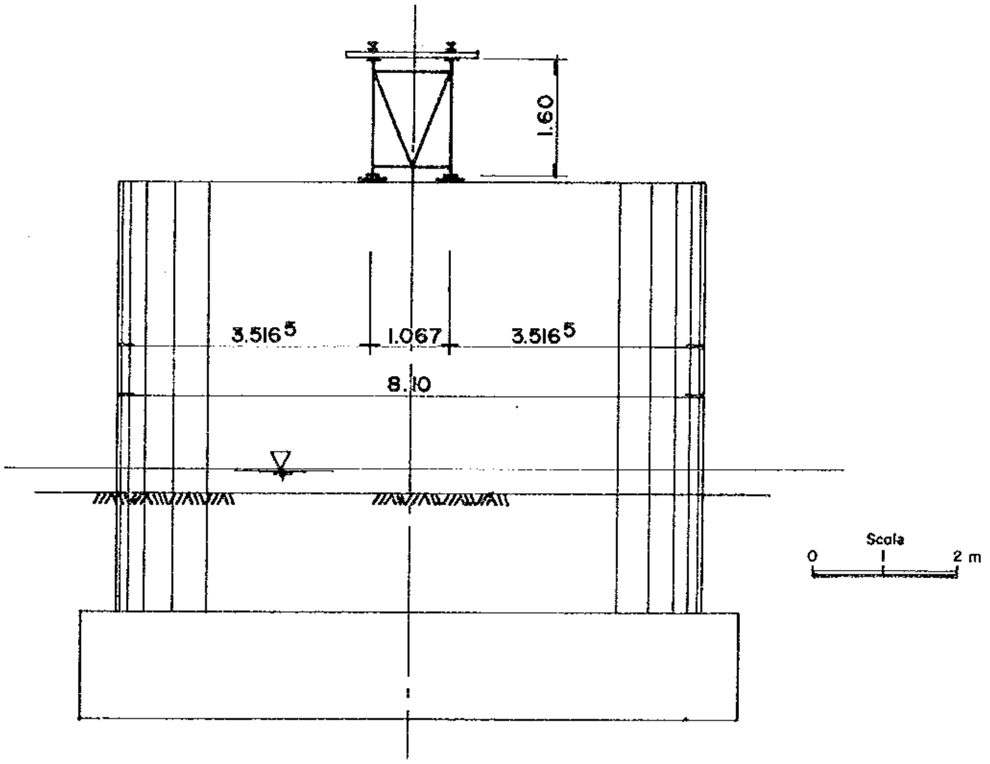
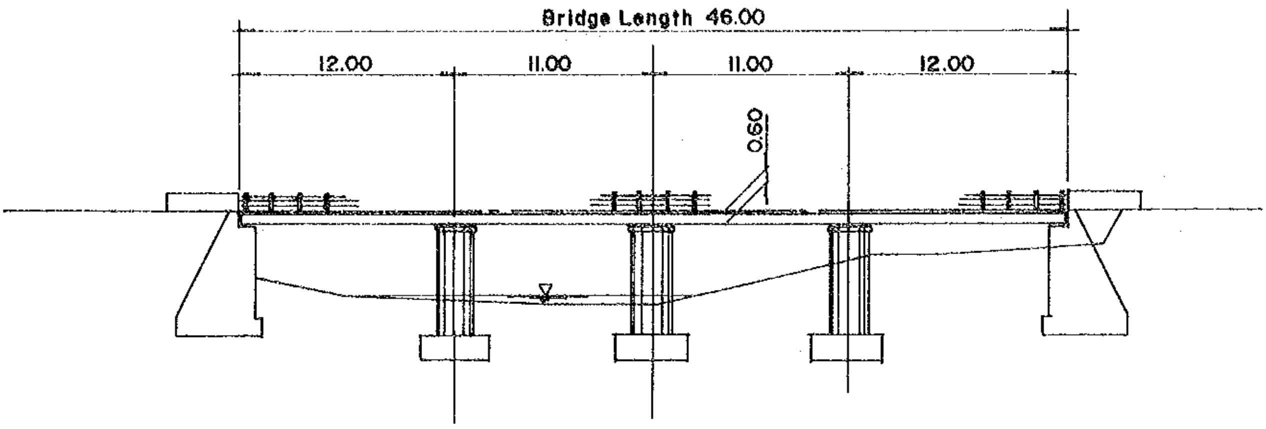


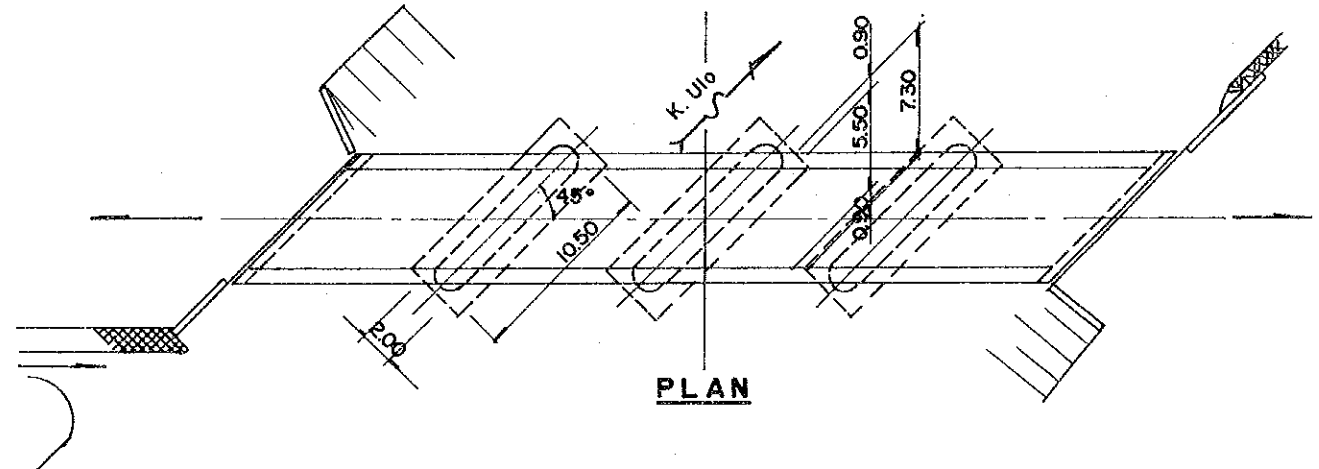
CROSS SECTION

Note : Foundation structure is based on data collected at PJKA office.

Fig. 5.15. K. ULO RAILWAY BRIDGE (3/5)



PROFILE



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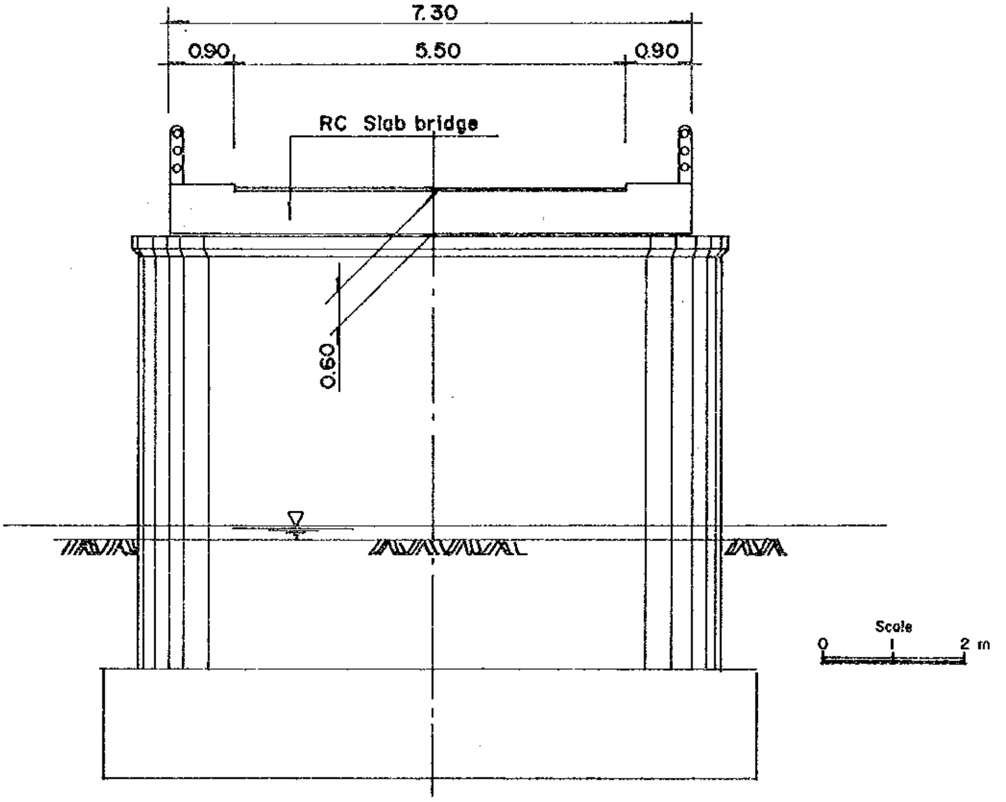
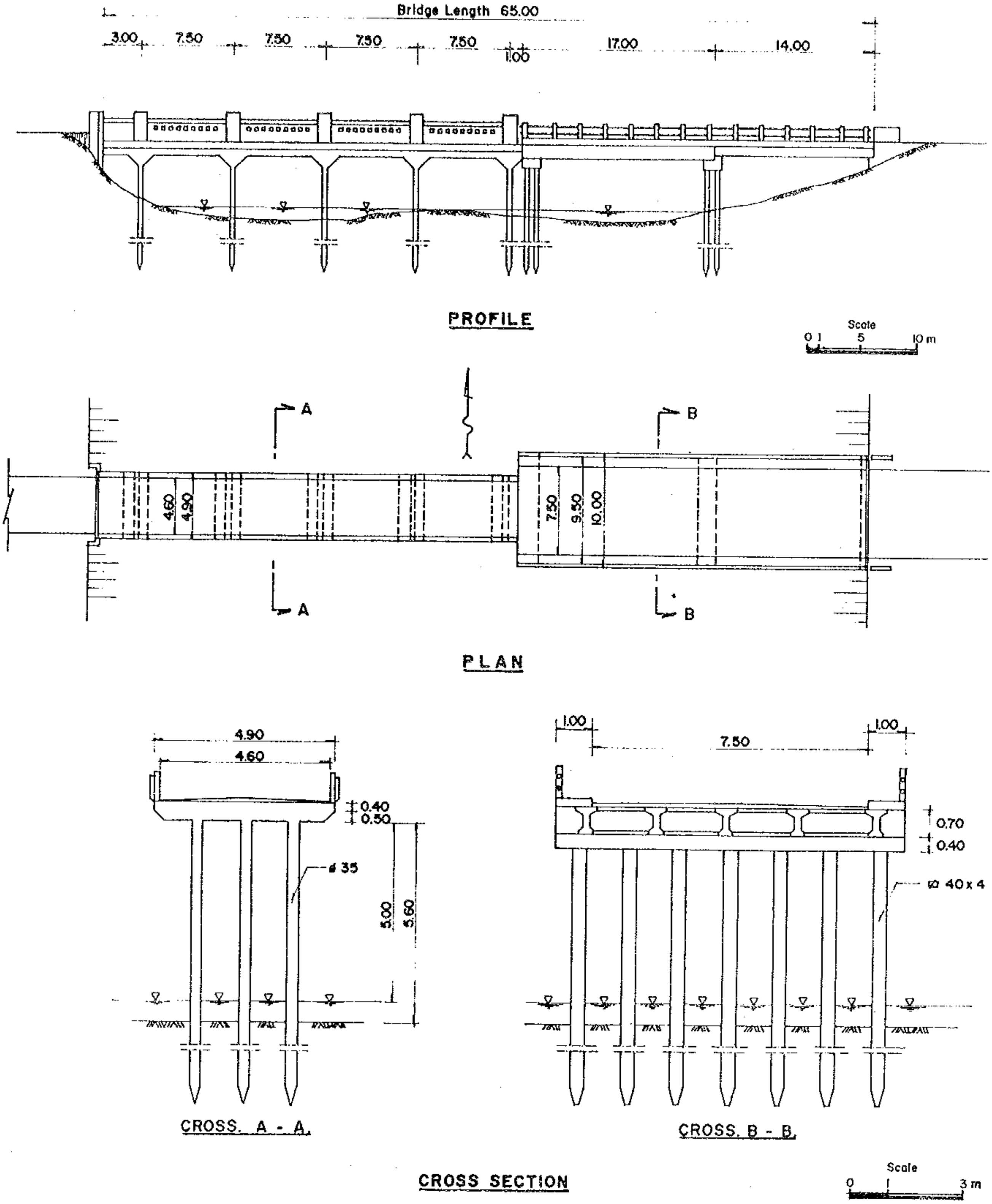


CROSS SECTION

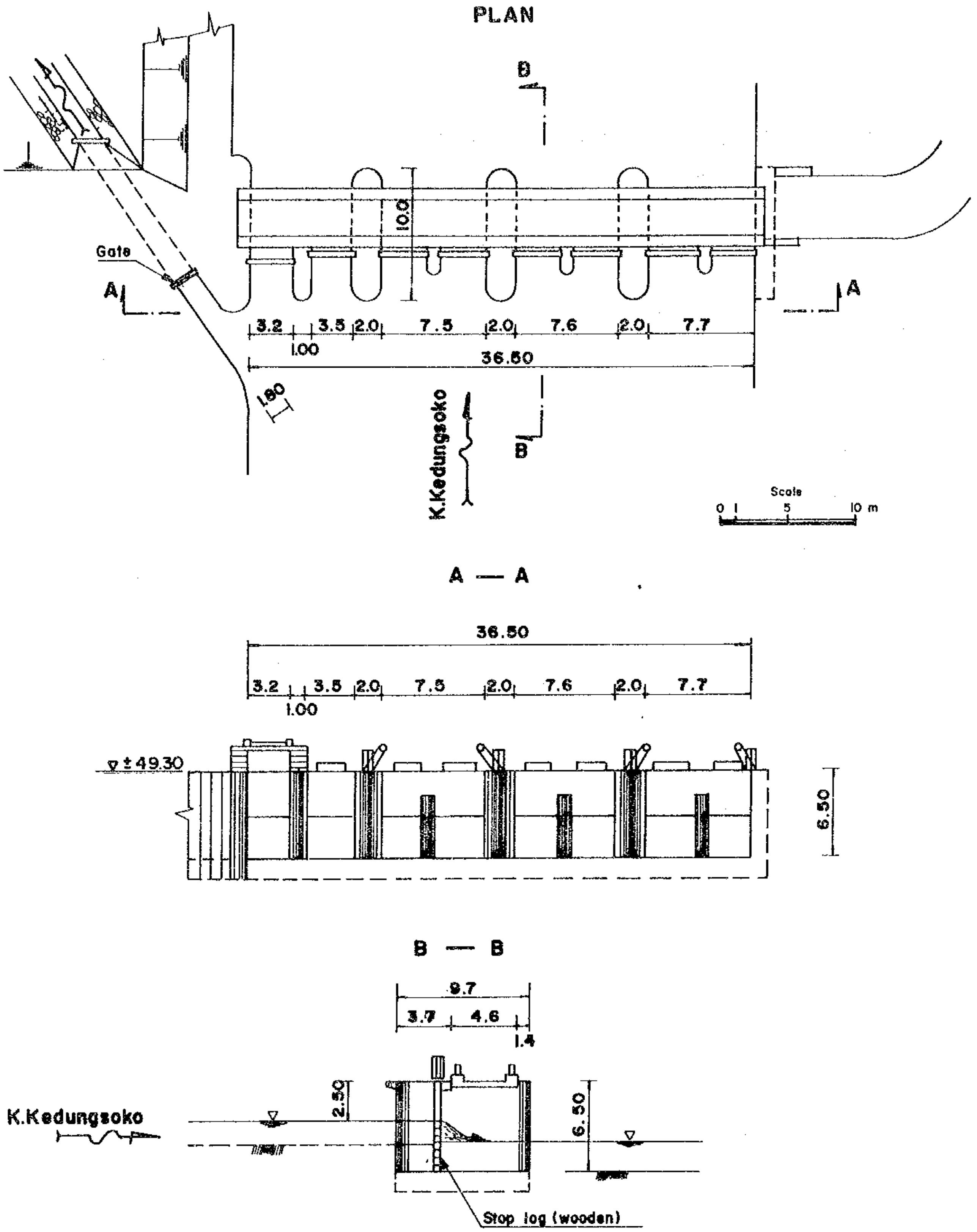
Note : Foundation structure is based on data collected at Binamarga office.

Fig. 5.15. K. ULO HIGHWAY BRIDGE (4/5)



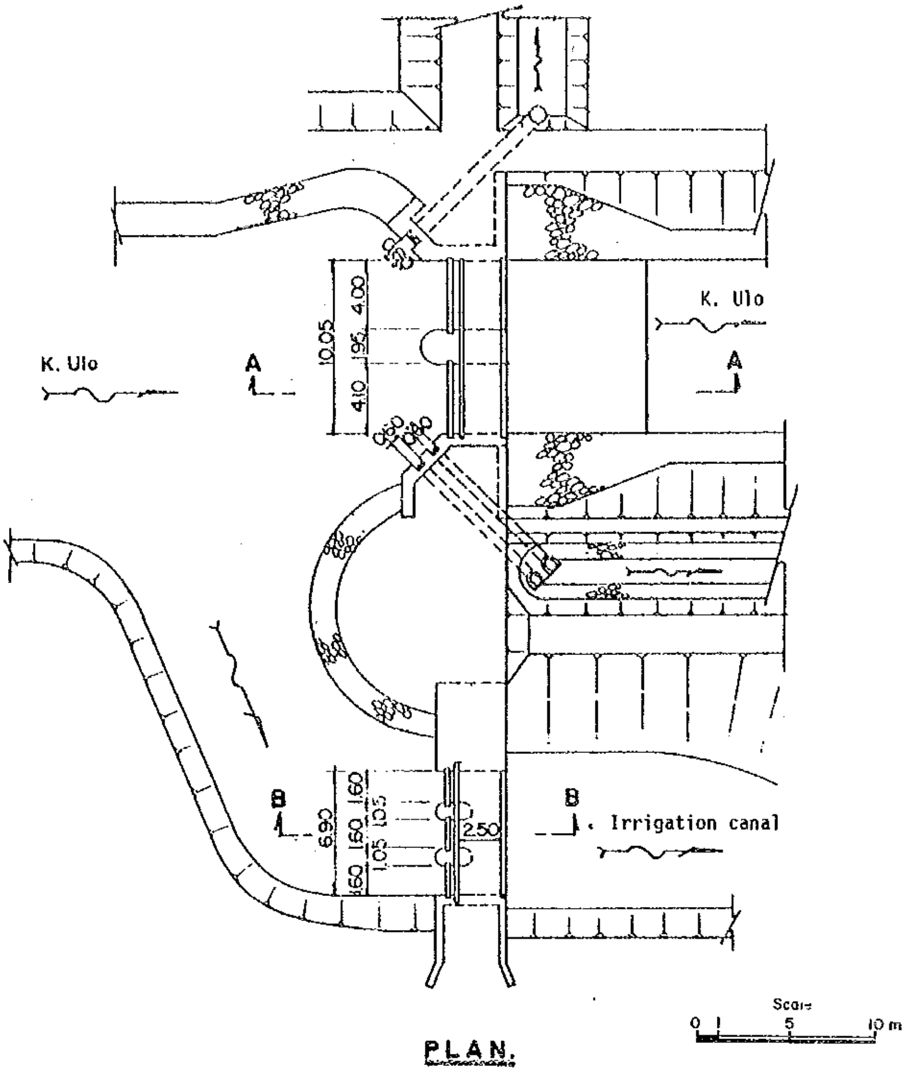
Note : Foundation structure is based on data collected at Binamarga office.

Fig. 5.15. LENGKONG HIGHWAY BRIDGE (5/5)

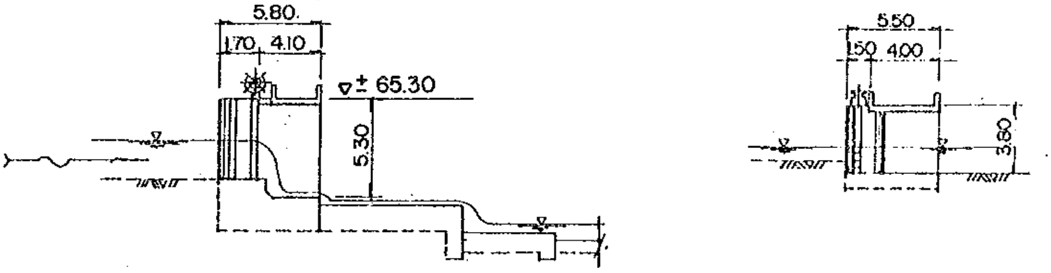


Note : Foundation structure is based on data collected at Pengairan Seksi Nganjuk office.

Fig. 5.16. SKETCH OF MALANGSARI DAM (1/2)



PLAN.



SEC. A - A.

SEC. B - B.

Note : Foundation structure is based on data collected at Pengairan Seksi Nganjuk office.

Fig. 5.16. SKETCH OF TIRIPAN DAM (2/2)

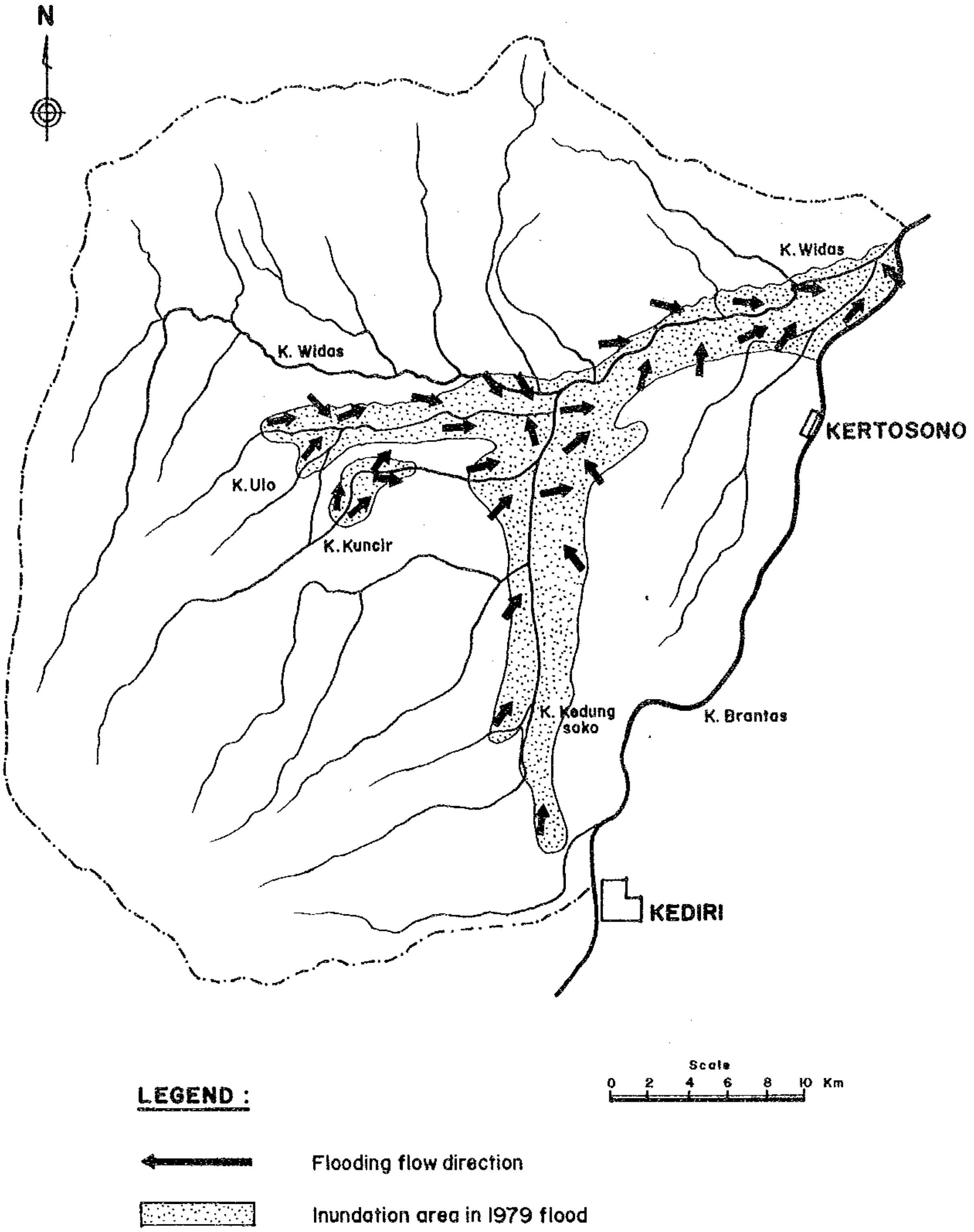
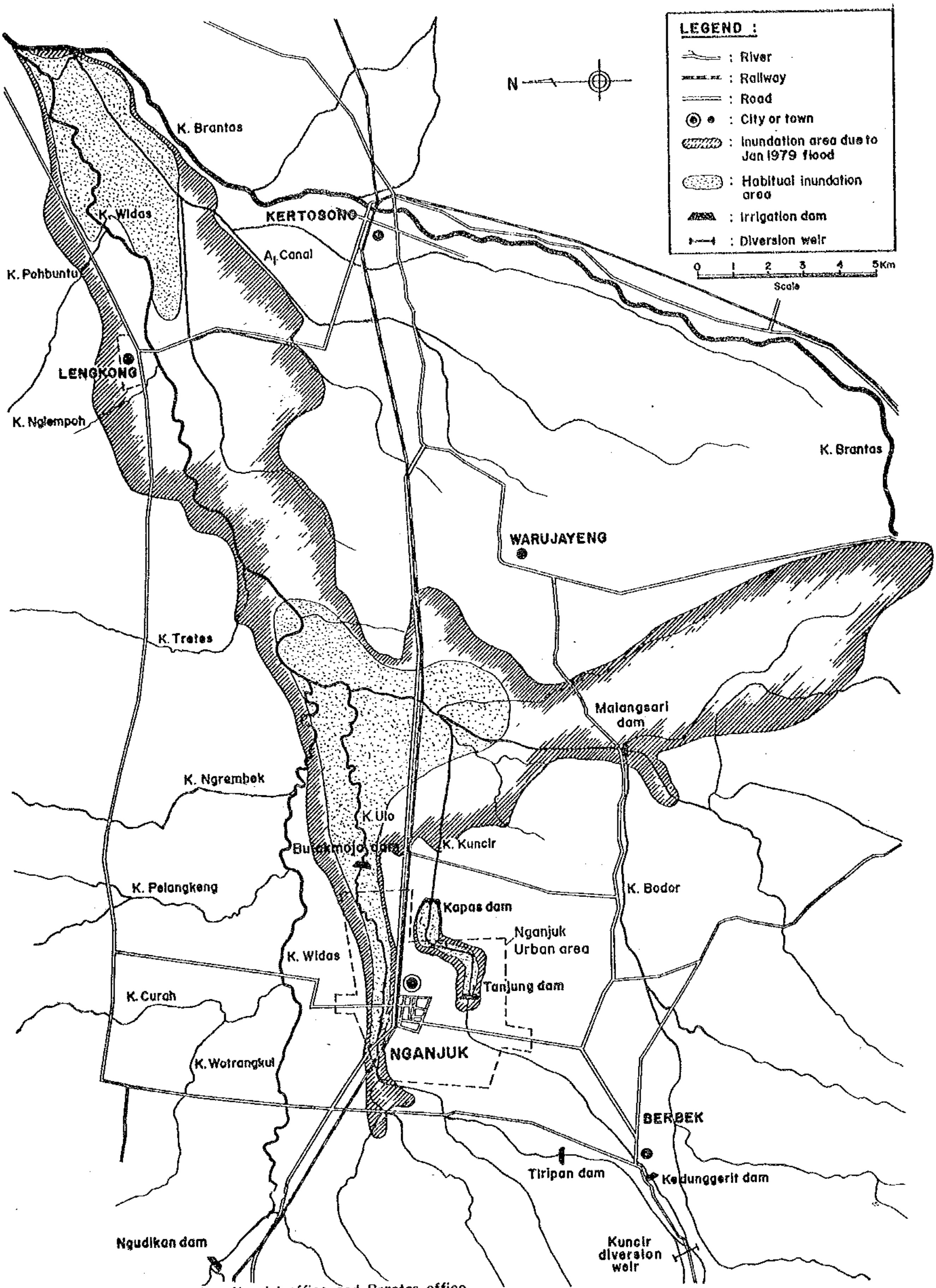


Fig. 5.17. TYPICAL FLOODING FLOW DIRECTIONS



Source ; Pengairan Nganjuk office and Brantas office

Fig. 5.18. INUNDATION AREA OF THE WIDAS RIVER BASIN

CHAPTER 6 FLOOD FLOW ANALYSIS

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6. FLOOD FLOW ANALYSIS

6.1 Introduction

Flood flow analysis for the Widas river basin was once made in the PART I STUDY in order to work out the probable flood flow distribution in the main Brantas and to find out an orientation of possible flood control works in the Widas river basin, based on the selected hydrological data. In the Part II Study, flood flow analysis for the Widas river basin is carried out incorporating more hydrological data specific to the basin. Since flood discharge data available are not sufficient, probable flood discharges are estimated from probable storm rainfalls. For converting the probable storm rainfalls into the probable flood discharges, the storage function method is used, since the method is flexible to assess basin lag time, retarding effects in the river channel, etc. The flood flow analysis consists of construction of a river system model, rainfall analysis and simulation of probable flood flows. The general procedures of the flood flow analysis are presented on Fig.6.1.

6.2 Rainfall - Runoff Model

(1) River system

The river system of the K. Widas is constructed with 26-sub-basins and 11 river channels as illustrated in Fig. 6.2. The natural retarding basins on K. Kedungsoko, K. Ulo and K. Widas are included in river channel. The diversion ratio at the existing Kuncir flood diversion weir to the downstream reaches of K. Kuncir and K. Ulo is taken at 30% and 70% respectively according to the information from the gate keepers. The Bening and K. Warak reservoirs are not accounted for flood regulation in the K. Widas because the reservoir has little particular flood control capacity. Fig. 6.3 shows the river system for flood flow analysis in the entire K. Widas basin.

Base points for probable flood estimate are set at the location just upstream and downstream the confluences with the tributaries and flood control facilities to be considered in the development plan.

(2) Rainfall analysis

The length of the Widas river is about 85 km. A design rainfall duration time would therefore be sufficient one day or two days for flood flow analysis, if there is no retarding basins. However, the flooding in the basin has prolonged to one or two weeks by the retarding basins. Therefore the design rainfall duration time of six days is selected, on the basis of duration of continuous rain storm observed at Nganjuk, Sawahan, Ngluyu, Ngrembek and Semantok rainfall gauging station as shown in Fig.3.1.

Hourly/daily basin mean rainfall in sub-basin and a basin upstream of a base point is estimated by Thiesen's method of which the polygon and weight for rainfall gaging station are shown in ANNEX-2.

Probable basin mean rainfalls at each base point for a period of one day to six days are calculated by Gumbel's method using the annual maximum basin mean rainfall from 1950 to 1983 for each duration as listed in Table 6.1.

Probable hourly rainfall distribution and total amount in each sub-basin in design rainfall duration time are derived from the hourly rainfall patterns recorded on January 23 - 28 and February 3 - 8 1982, and January 26 - 31 1984 as shown on Figs. 6.4 and 6.5 by multiplying the ratio of probable rainfall to the observed in the duration time into the observed. Then, the probable hourly rainfall intensity and total amount in each sub-basin are compared with the possible 1-hour rainfall and 1-day rainfall in a sub-basin which are estimated by Mononobe's formula and Horton's law respectively. If 1-hour or 1-day rainfall in probable rainfall distribution exceed the above limit, probable hourly rainfall is modified by distributing excess rainfall to other hour or basin. Details of procedure for making rainfall distribution is described in ANNEX-2.

(3) Flood flow analysis

(a) Storage function of sub-basin and river channel

River system of K.Widas river basin is consisted of 18 sub-basins in mountainous area, 8 sub-basins in alluvial plain and 11 river channels. These components are newly constructed from PART I STUDY considering the additional base points.

Since storage function of river basin in PART I STUDY is examined as that in mountainous area, results of PART II STUDY are applied to the above 18 sub-basins. As for sub-basin in alluvial plain, it is required to study on coefficient of storage function. However, discharge data in this area are not available. Therefore, an empirical formula, which has been derived from studies on 6 rivers in flat plains in Japan, is used for 8 sub-basins in alluvial plain.

For 11 river channels, the coefficients are estimated by means of the uniform/non-uniform flow calculation under the assumption that the water level on the K. Brantas is set design at water level of EL37.15 m which has been adopted in the Middle Reach River Improvement Project, second stage.

Reliability of the above storage function model is examined by comparing probable flood simulated from probable rainfall with that estimated by frequency analysis using observed flood runoff.

(b) Flood runoff coefficient

Relationships between storm rainfall and flood runoff depth at the Karangkates and Serorejo damsites and Ngudikan water level station are shown on Fig. 6.6, which are drawn based on the data at these damsites in 1981, 1982 and 1984 and the water level station in 1976. From this figure, the direct flood run-off coefficient is set at 0.3. The maximum limit of rainfall to completely saturate the ground surface, depression, etc. is set at 200 mm, taking into account the geological, soil and vegetation conditions in the basin.

(c) Base flow

The base flow, which is the runoff just before the increase in discharge due to flood, is expected high in wet season. Therefore, the base flow for probable flood estimate is simulated by using this rainfall - runoff model and hourly rainfall in a month. Monthly rainfall pattern in Jan, 1983 when the total was about 380 mm, corresponding to the average of annual maximum monthly rainfall, is applied for the simulation. Fig. 6.7 shows the rainfall pattern and runoff hydrograph under the present river condition. From the result, the design base flow distribution is set at the flow hydrograph in the period from 16th to 21st just after the base flow becomes the maximum of 94 m^3/sec.

6.3 Probable Flood Discharge

Probable flood discharge is studied under the present river condition and under the condition confining the non-diked area. The latter is called as basic high flow discharge hereinafter.

1. Present condition

Fig. 6.8 shows the probable flood peak discharges with different return period at each base point. The probable flood peak discharges at the principle base points with the recurrence period of 25 years are summarized below.

	Catchment (km^2)	Flood Peak Discharge (m^3/sec)
Confluence with K. Brantas	1,538	257
Upstream of K. Widas	490	487
K. Kuncir	141	85
K. Ulo	112	165
K. Kedungsoko	686	98
Kuncir Flood Diversion	79	188

In the present condition, the existing retarding basins contribute to the flood retardation as shown below.

Name of Retarding Basin	Discharge (m^3/sec) Inflow	Discharge (m^3/sec) Outflow	Retarded Volume ($10^6 m^3$)
Kedungsoko	458	87	9.4
Ulo	195	98	8.6
Widas	456	257	11.9

The retarding volume in the Widas retarding basin excludes the retarded volume of 4.0 x 10^6 m^3 for flood discharge of the Main Brantas in the above table.

For the examination of the reliability of the results, the simulated flood discharge for the Lengkong site is compared with the probable flood discharge based on the frequency analysis of the flood records from 1973 to 1984 at Lengkong. The frequency curve of annual maximum discharge at Lengkong - Widas is illustrated in Fig. 6.9. The 25-year probable floods are estimated to be 330 m^3/sec by the frequency analysis by means of Iwai Method and 355 m^3/sec by the simulation. The difference of 25 m^3/sec between the above results in less than 10% to the flood based on frequency analysis. From the above, it is judged that this simulation model is applicable for the flood discharge distribution analysis of the alternative schemes in the flood control plan.

Under the present river condition, the inundation in the K. Widas occurs habitually. The examination for grasping the area and the volume of the habitual inundation is carried out on both the simulation using the runoff - rainfall model and 2-year probable rainfall, and the hearing from the inhabitants in the retarding basins. The results of this examination are shown below.

Retarding Basin	Retarded Volume for 2-year Flood (10^6 m^3)	Average W.L. (m)	By Hearting Retarded Volume (10^6 m^3)	Difference of Volume (10^6 m^3)
Widas	6.8	38.0	7.7	0.9
Ulo	3.8	44.9	7.0	3.2
Kedungsoko	4.6	45.0	9.3	4.7

As seen in the table, the difference of the retarded volume is not so small. However, it is considered that this difference is caused by the dead storage in the local depressions within the retarding basin and assumption of the level inundation on estimating the retarded volume by hearing, especially in the Keundgsoko and Ulo retarding basin.

The retarded volume in each inundation area for the simulated 25-year flood including the dead volume is estimated below.

Retarding Basin	Net Volume for 25-year Flood (10^6 m^3)	Dead Volume (10^6 m^3)	Total (10^6 m^3)	W.L. (m)
Widas	11.9	4.0 /1	15.9	38.9
Ulo	8.6	3.2	11.8	45.0
Kedungsoko	9.4	4.7	14.1	45.4

/1: Retarded volume by the flood of the Main Brantas

2. Basic high flow discharge

In the present condition, flood discharge inundates the non-diked reaches. In case of confining these reaches, it is expected to increase the flood peak discharge. The 25-year probable flood peak discharge are presented on Fig. 6.10. The following table shows the comparison of the flood peak in the present and confined condition.

	Flood Peak Discharge (m^3/sec)		Difference (m^3/sec)
	Present	Basic High Flow	
Kedungsoko R.B	87	392	305
Ulo R.B	98	488	390
K. Widas after the confluence with K. Kedungsoko	387	612	225
Confluence with K. Brantas	257	579	322

As shown in the above table, the increase in the flood peak discharge by full confinement is expected to be from 200 m^3/sec to 390 m^3 /sec.

6.4 Flood Analysis for Alternatives

Design floods for alternative flood control schemes against 25 yr probable flood are estimated based on the storage functions and other coefficients obtained throughout basic study mentioned in the previous sections.

The detail conditions for each alternative are described in the succeeding CHAPTER 7. The required retarding capacity is estimated herein simply assuming peak-cut-method against each alternative capacity. For Widas retarding basin, the required retarding capacity to reduce outflow from Widas into the main Brantas to 270 m^3/sec is estimated adopting the peak-cut-method.

The results for alternative schemes are presented in ANNEX-4 as design discharge distribution.

In case first stage plan against 10 yr probable flood, design discharge is estimated for only the selected plan against 25 yr probable flood as is explained in the succeeding chapter. Hydrological study for 10 yr probable flood is conducted considereing full utilization of proposed capacity of the retarding basin designed for 25 yr probable flood. Maximum outflow from the Widas into main Brantas is also limited to 270 m^3/s that equals to distribution for the selected plan against 25 yr probable flood.

The results of the first stage plan are presented on Fig. 8.12 as design discharge distribution.

Hydraulic calculation on the controllable retarding basin for the selected plan is explained in ANNEX-4.

Table 6.1 PROBABLE BASIN MEAN RAINFALL AT BASE POINTS (1/3)

Unit : mm

Return Period	Rainfall Duration 1 - day	2 - day	3 - day	4 - day	5 - day	6 - day
(1) Ngudikan						
1.05	54	71	88	113	121	133
2	73	97	120	140	158	176
5	87	118	142	165	185	209
10	98	133	157	183	206	234
25	111	151	176	205	231	263
50	120	265	190	221	249	284
100	129	178	204	237	267	306
(2) K. Widas before the confluence with K. Kedungsoko						
1.05	46	69	84	100	113	125
2	64	91	111	131	146	159
5	78	110	133	155	172	186
10	89	123	149	173	192	707
25	102	140	168	194	215	231
50	111	152	182	210	232	249
100	120	163	196	225	249	266
(3) K. Widas after the confluence with K. Kedungsoko						
1.05	44	67	87	98	110	121
2	55	80	99	117	134	148
5	63	91	112	131	153	170
10	70	99	122	142	166	186
25	77	108	133	155	183	206
50	83	115	142	164	195	220
100	88	122	151	174	207	234
(4) Confluence with K. Brantas						
1.05	38	59	75	92	104	113
2	51	75	92	109	126	139
5	60	86	104	124	143	159
10	67	95	113	135	156	173
25	75	105	124	148	171	190
50	81	113	132	157	183	203
100	87	120	140	167	194	216

Table 6.1 PROBABLE BASIN MEAN RAINFALL AT BASE POINTS (2/3)

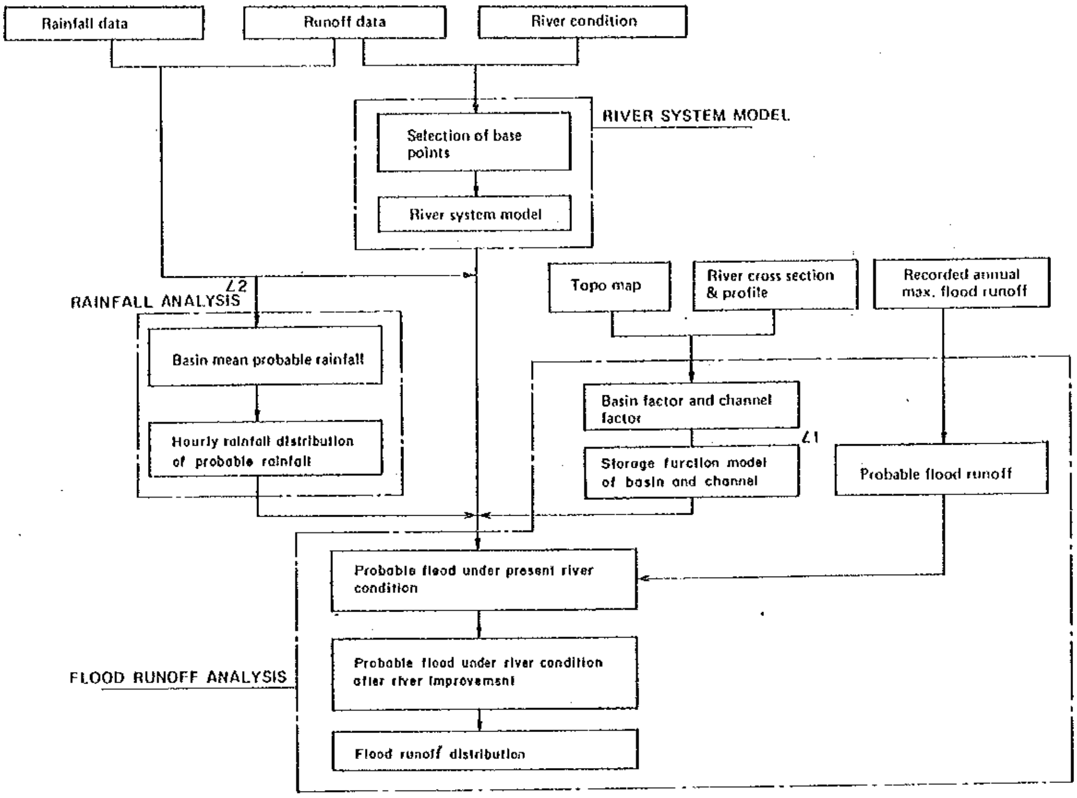
Unit : mm

Return Period	Rainfall Duration 1 - day	2 - day	3 - day	4 - day	5 - day	6 - day
(5) K. Kedungsoko before the confluence with K. Kuncir						
1.05	50	71	88	100	115	123
2	64	91	111	128	146	160
5	74	108	130	151	172	189
10	82	120	143	169	191	211
25	91	135	159	189	213	237
50	98	146	171	204	230	256
100	105	156	183	219	247	275
(6) K. Kedungsoko before the confluence with K. Ulo						
1.05	46	67	83	96	110	121
2	60	87	106	123	140	154
5	70	103	124	144	163	181
10	78	114	137	159	181	202
25	87	128	153	178	201	225
50	94	138	165	191	216	243
100	100	149	176	205	231	261
(7) K. Kedungsoko before the confluence with K. Widas						
1.05	46	67	83	97	110	122
2	59	84	103	121	138	154
5	69	99	120	140	160	179
10	77	110	133	154	176	198
25	86	123	148	170	195	220
50	93	132	159	182	210	236
100	100	142	170	195	224	253

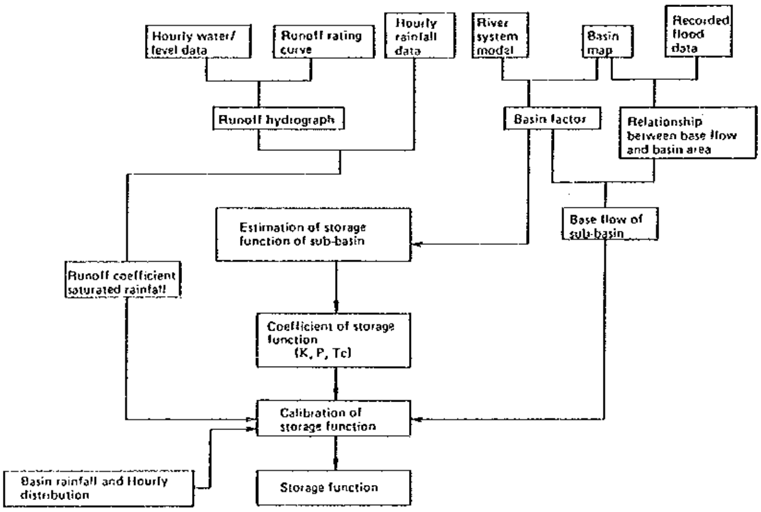
Table 6.1 PROBABLE BASIN MEAN RAINFALL AT BASE POINTS (3/3)

Unit : mm

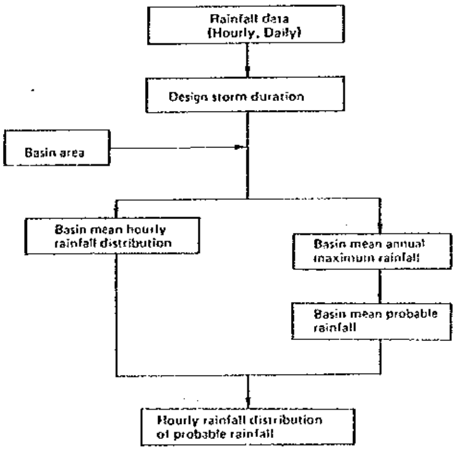
Return Period	Rainfall Duration 1 - day	2 - day	3 - day	4 - day	5 - day	6 - day
(8) Kuncir Flood Diversion						
1.05	62.5	83	100	121	142	154
2	88	118	143	170	190	210
5	108	146	177	209	228	255
10	122	168	202	238	257	238
25	140	193	232	272	290	327
50	153	211	254	297	315	356
100	166	230	276	322	340	385
(9) K. Kuncir before the confluence with K. Kedungsoko						
1.05	50	69	90	104	115	127
2	64	93	115	133	149	166
5	76	111	135	154	177	197
10	84	125	150	171	197	221
25	94	142	168	190	221	248
50	101	154	181	205	239	268
100	109	166	194	219	256	288
(10) K. Ulo before the confluence with K. Kedungsoko						
1.05	54	73	93	109	121	193
2	70	96	118	140	157	175
5	82	113	137	164	186	208
10	91	125	151	182	208	234
25	102	140	168	203	233	263
50	110	151	180	219	252	285
100	118	162	192	235	270	307



GENERAL FLOW CHART OF FLOOD ANALYSIS



Z1. STORAGE FUNCTION MODEL
OF BASIN AND CHANNEL



Z2. RAINFALL ANALYSIS

Fig.6.1 GENERAL PROCEDURE

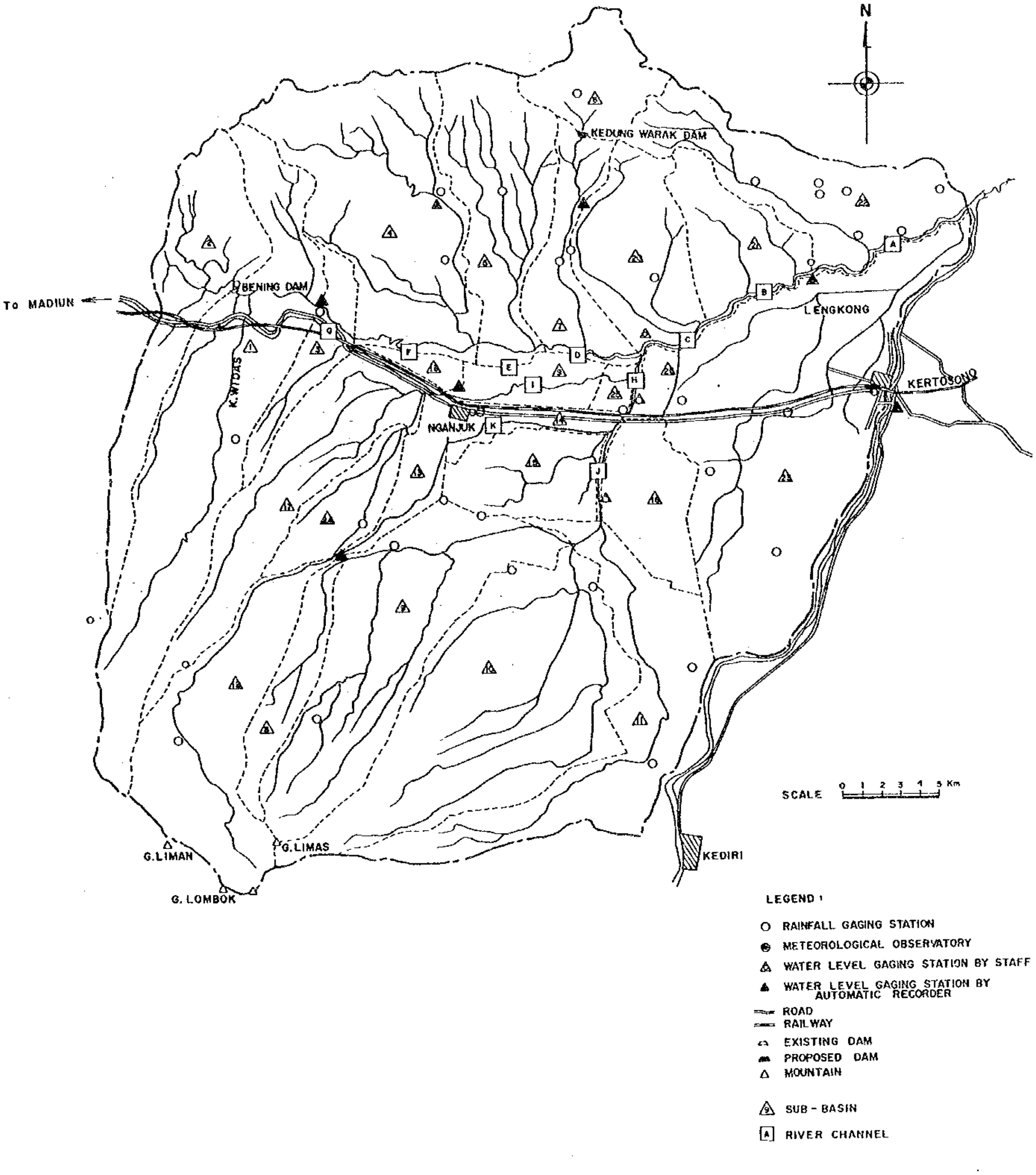
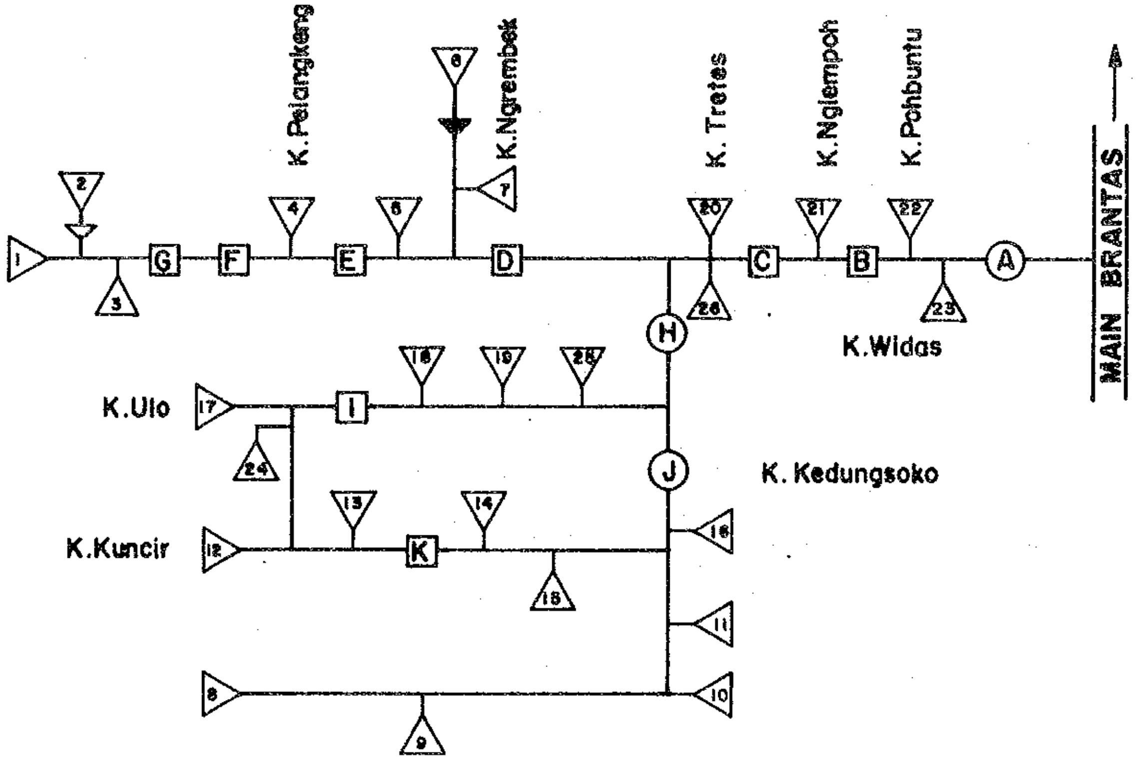


Fig. 6.2 SUB-BASIN AND RIVER CHANNEL



LEGEND

△ : Sub basin

□ : River channel

○ : Natural retarding basin

▲ : Proposed dam

△ : Existing dam

Fig. 6.3 RIVER SYSTEM MODEL OF K.WIDAS UNDER PRESENT RIVER CONDITION

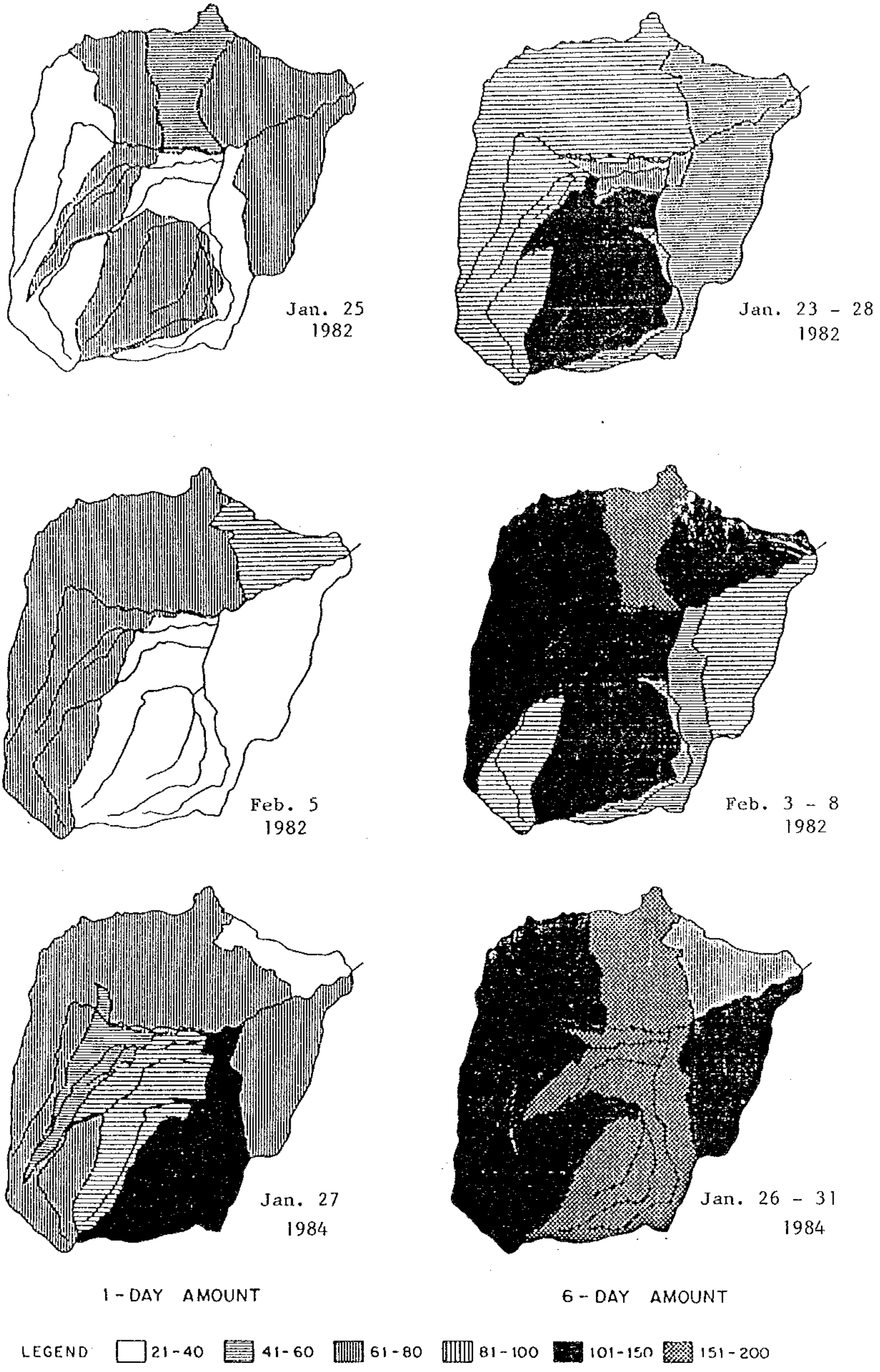


Fig. 6.4 1-DAY/6-DAY RAINFALL AMOUNT ON JAN/FEB. 1982, AND JAN. 1984

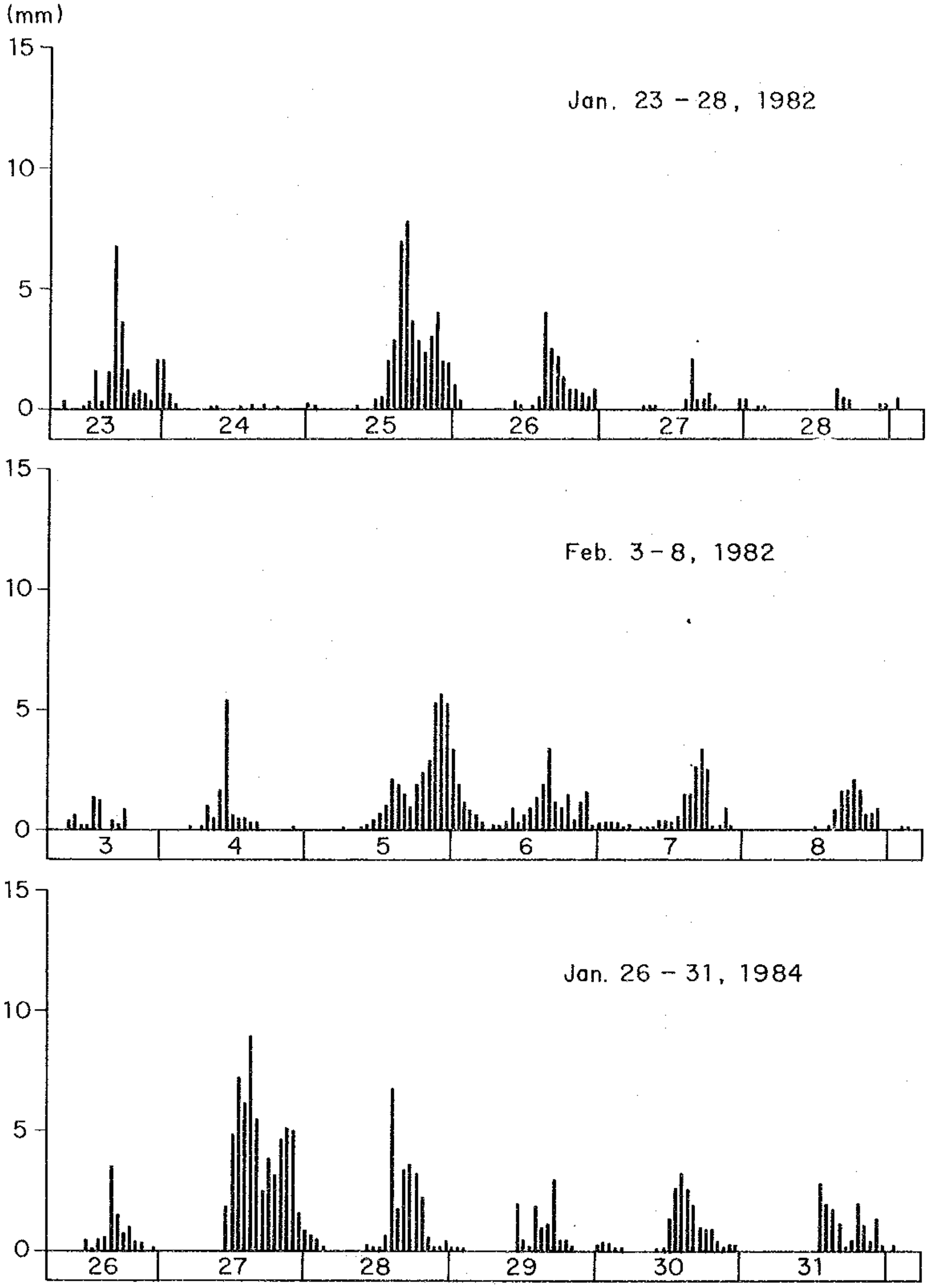


Fig.6.5 BASIN MEAN HOURLY RAINFALL DISTRIBUTION IN ENTIRE WIDAS RIVER BASIN

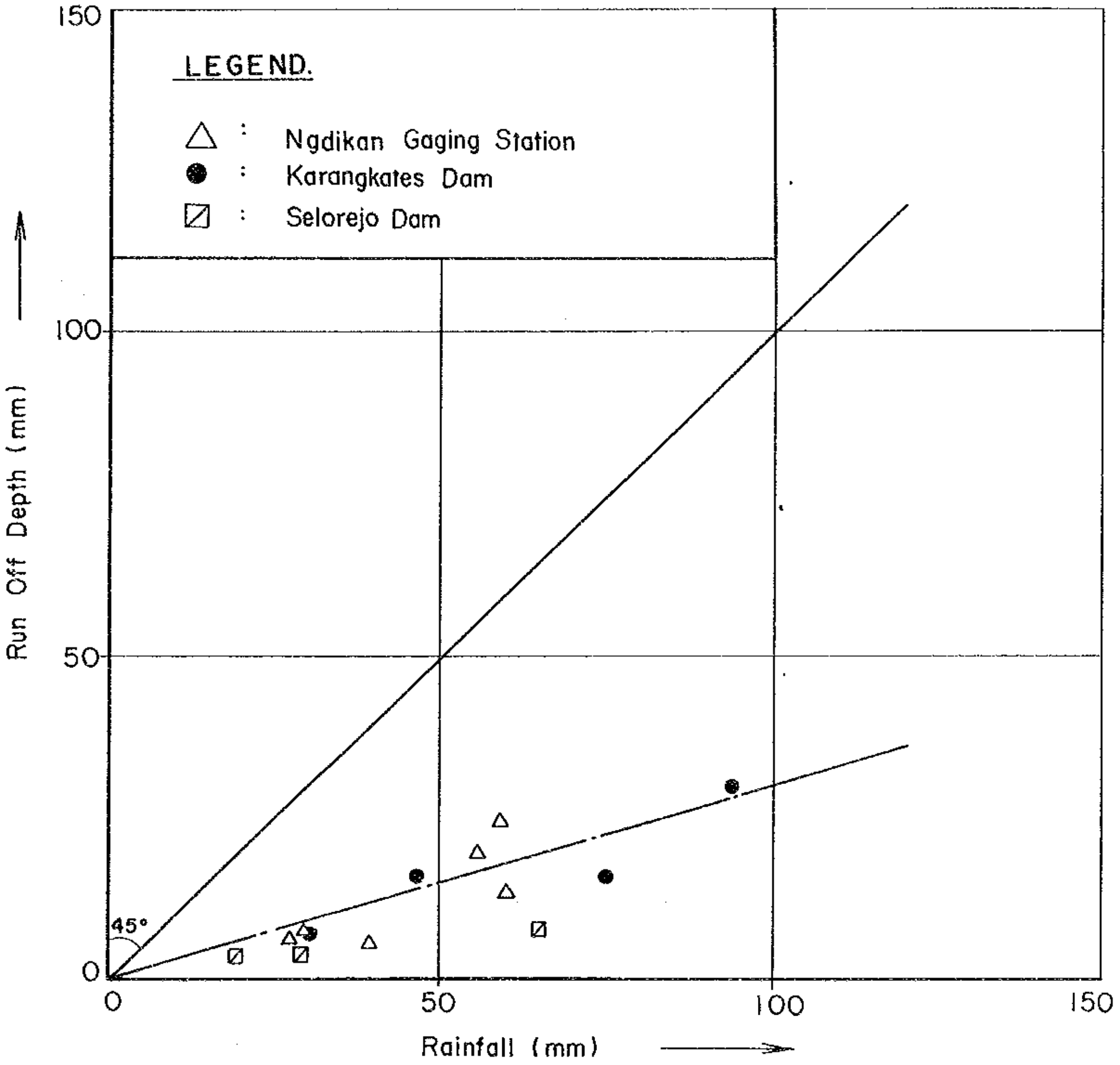


Fig. 6.6 RELATION BETWEEN RUN-OFF DEPTH AND RAINFALL AMOUNT DURING FLOOD

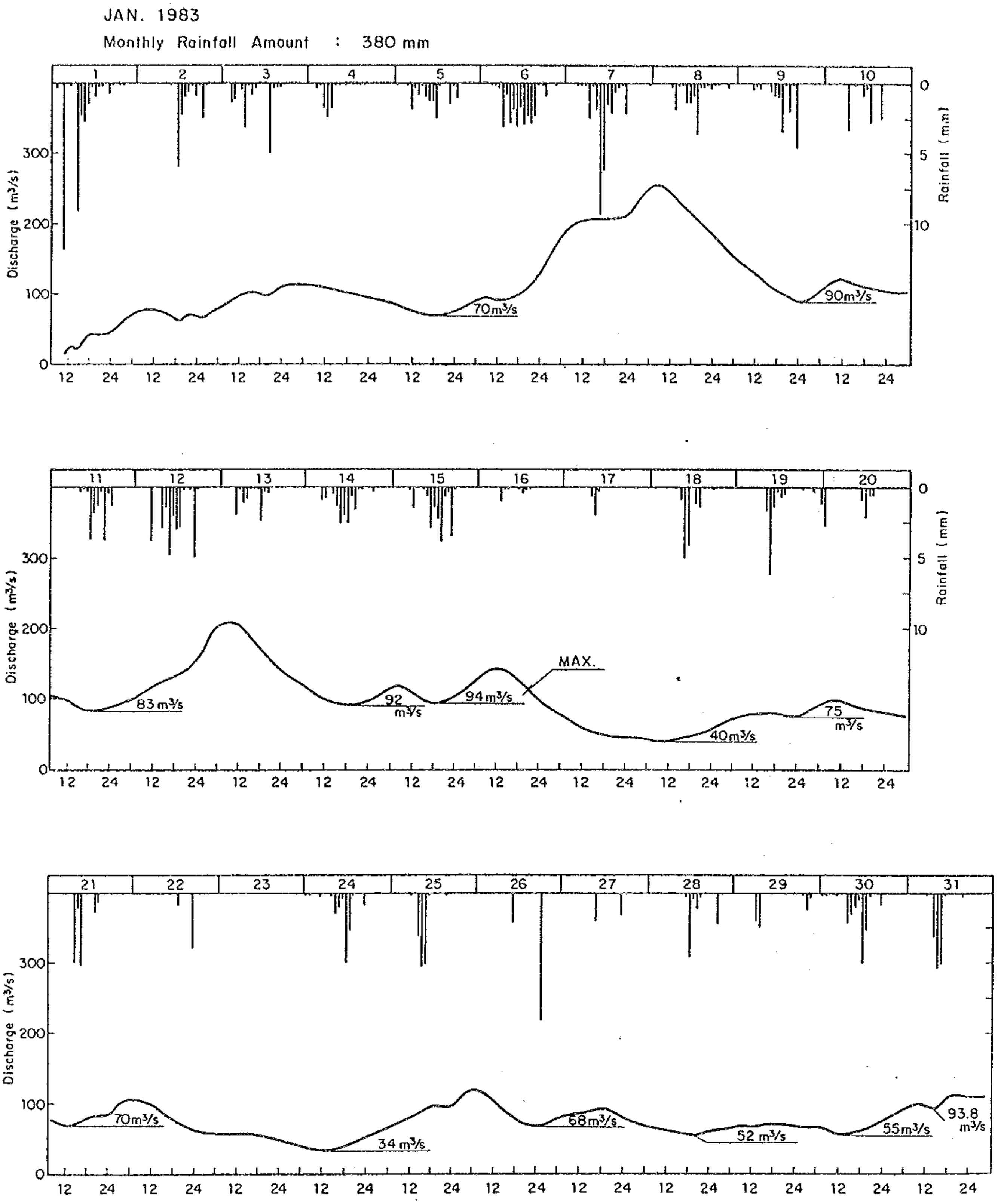
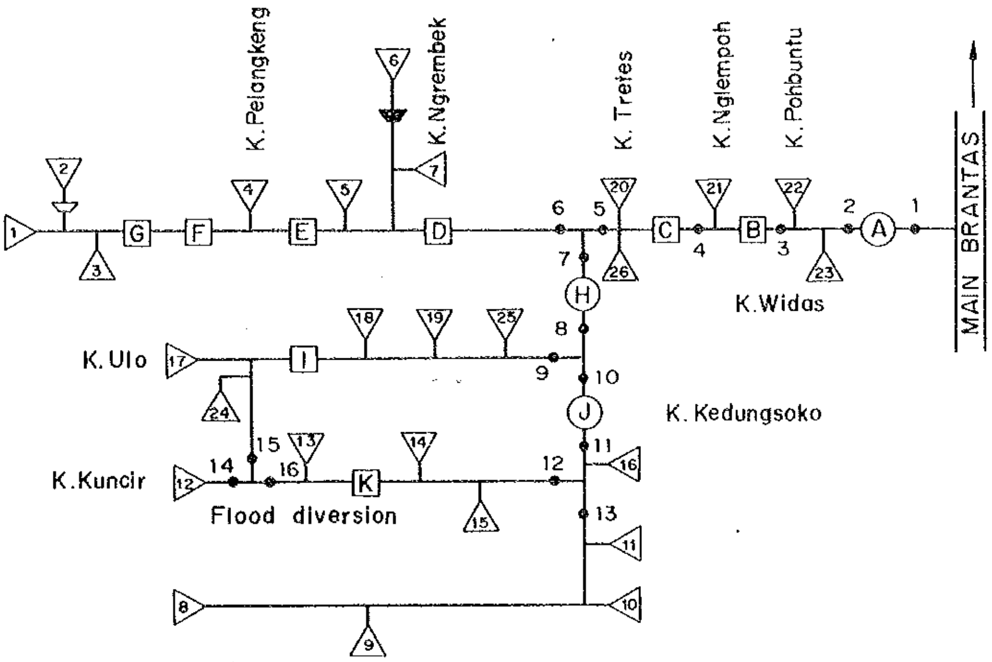


Fig. 6.7 BASIN MEAN MONTHLY RAINFALL PATTERN AND BASE FLOW



(Unit : m^3/sec)

POINT NO.	RETURN PERIOD (YEAR)						
	1.05	2	5	10	25	50	100
1	139	187	213	236	257	273	289
A ∠.1	5.1	6.8	8.4	10.3	11.9	13.0	15.2
2	238	319	374	411	456	492	530
3	196	263	295	321	355	379	404
4	214	268	308	338	377	405	432
5	219	274	317	352	387	420	448
6	220	292	367	425	487	533	581
7	59	75	84	89	98	104	112
H ∠.1	3.0	3.8	5.3	6.6	8.6	10.2	12.0
8	108	138	157	174	195	224	264
9	67	87	110	128	165	223	290
10	57	74	80	84	87	92	109
J ∠.1	3.5	4.6	6.0	7.0	9.4	10.2	11.0
11	219	285	354	402	458	508	557
12	30	39	53	67	85	97	104
13	218	279	346	400	461	510	557
14	78	110	140	162	188	211	236
15	55	77	98	113	132	148	165
16	23	33	42	49	56	63	71

∠.1 Retarded volume (10^{6}m^3) in retarding basin

Fig. 6.8 PROBABLE FLOOD PEAK DISCHARGES AT BASE POINTS UNDER PRESENT CONDITION

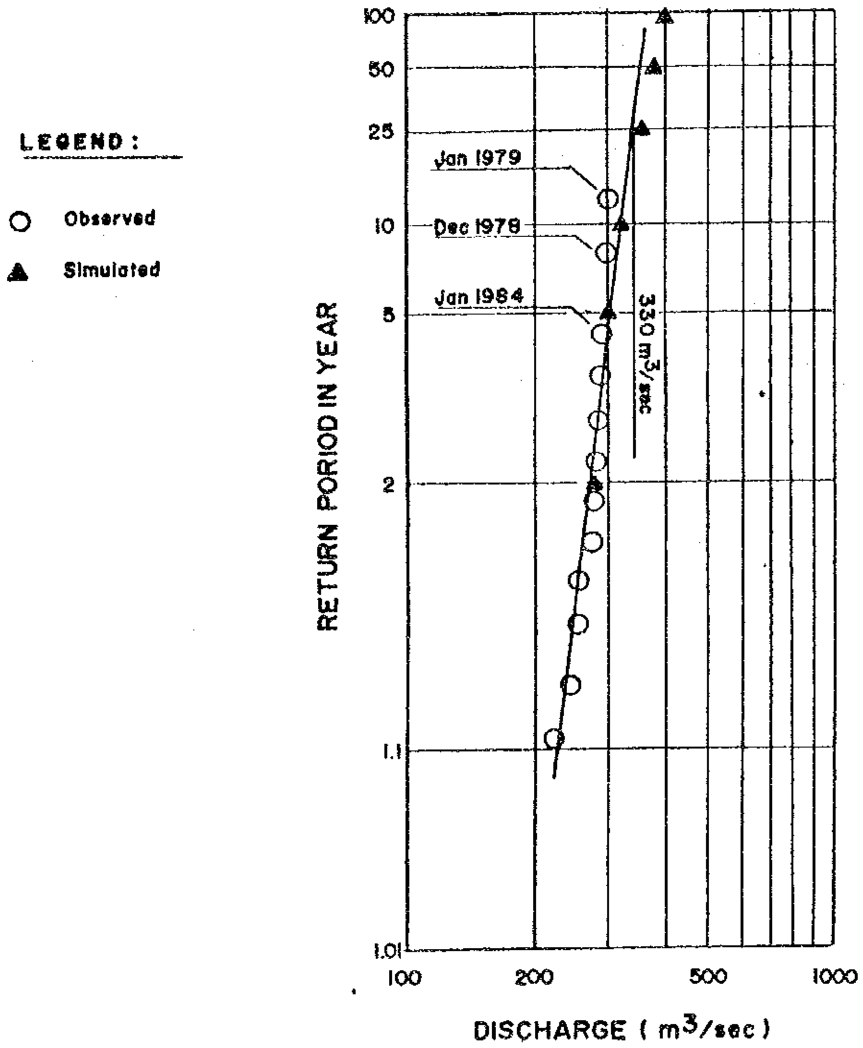


Fig. 6.9 FREQUNCY CURVE OF ANNUAL MAXIMUM DISCHARGE AT LENGKONG

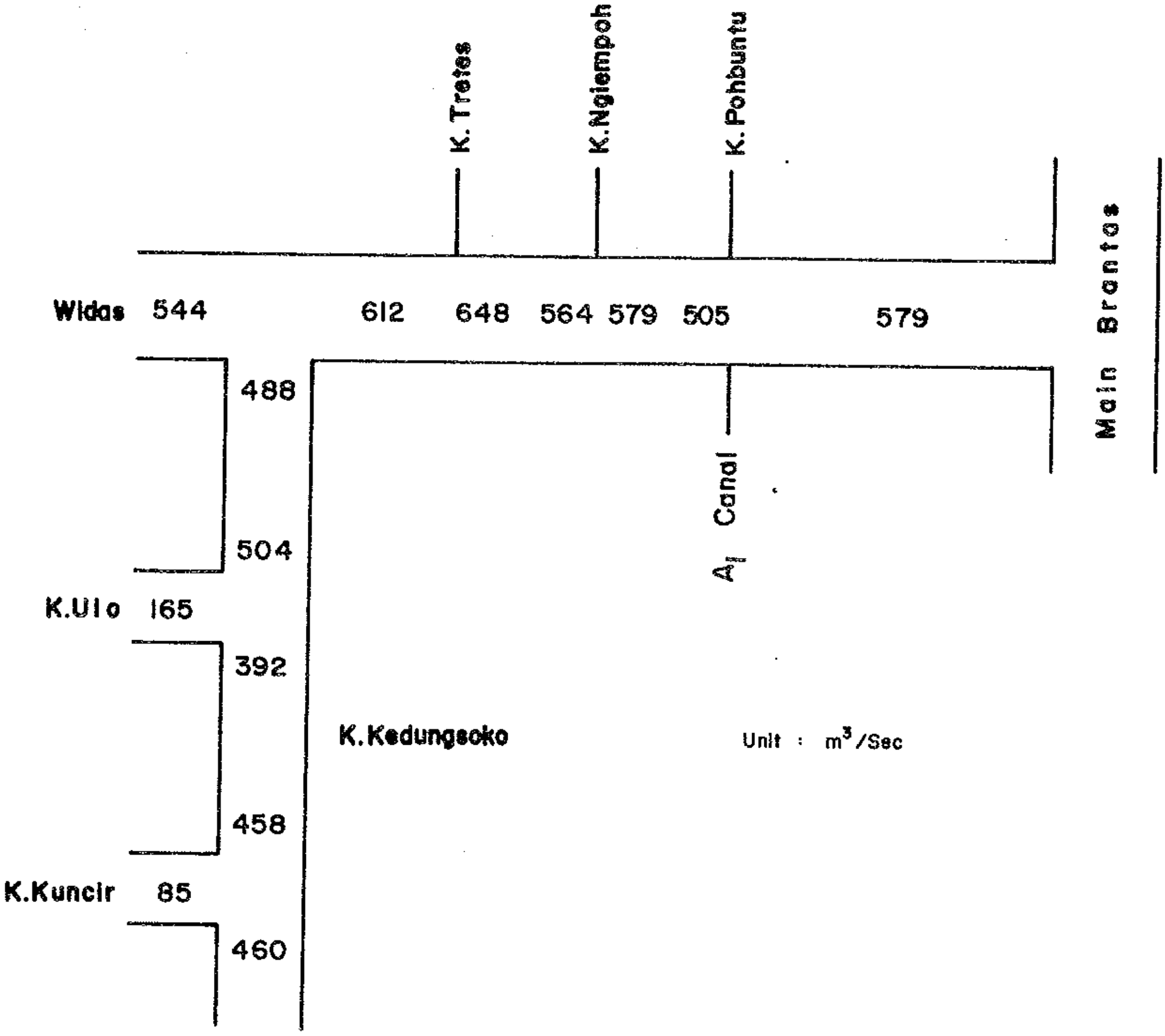


Fig. 6.10 25-YEAR BASIC HIGH FLOW DISCHARGES

CHAPTER 7 COMPARATIVE STUDY ON ALTERNATIVE FLOOD CONTROL PLAN

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7. COMPARATIVE STUDY ON ALTERNATIVE FLOOD CONTROL PLAN

7.1 General

The Nganjuk town and its hinterland have severely suffered from recurrent flooding since the beginning of their history. While, irrigation and other developments have been proceeded intensively in the past, especially in the last decade. As the result of such developments, the risk of flood damage in the basin has been increasing.

With recognition of the current flooding problem and need of further equitable regional development, a basinwide flood control project is required aiming to protect Nganjuk urban area and its surrounding area of agricultural land as well as land in the habitual inundation areas at major confluences.

The objective of the present study is to select a comprehensive flood control and drainage plan among alternatives and subsequently, to conduct a feasibility study on the selected plan as the optimum one, and to provide a priority project which is to be formulated as the 1st stage within the selected comprehensive plan for immediate implementation. Firstly, the optimum flood control and drainage scheme is selected thorough a comparative study in this chapter and the results are explained below.

7.2 Basic Condition of the Flood Control Plan

In the PART I Study, the flood distribution in the main Brantas river was studied, including possible elimination of the existing natural retarding basins on the main stream and in the tributary basin. It was confirmed that such elimination would require large increase in the dischange capacity of the main Brantas beyond the present design capacity, and accordingly huge costs. The huge costs for reimprovement of the main Brantas would offset the benefits anticipated from elimination. Then, the elimination is not economically justifiable.

The maximum outflow from the Widas river into the main Brantas was estimated at 270 m^3/s as a balance of discharges at the upstream and downstream of the confluence of the Widas river, from the viewpoint of the entire Brantas river basin. The peak outflow of 25-year flood from the Widas river under the fully confined condition is estimated at 579 m^3/s as shown in Chapter 6. The difference between 270 m^3/s and 579 m^3/s was to be regulated within the Widas river basin. The PART I Study found that there was no suitable site for effective and economical flood control dam in the watershed areas of the Widas river owing to the topographic reason. Then it is obliged to regulate the flood flow by the natural retarding basins existing in the plain area.

From the above backgrounds, the basic conditions for the study on the flood control and drainage plan in the Widas river basin are set as follows;

(a) The Widas flood control works should be conducted independently of the improvement works of the main Brantas, i.e. the Widas river flood control should not bring about any flood discharge increase in the main Brantas.

(b) Maximum outflow from the Widas river into the main Brantas is to be limited to 270 m^3/s which is the estimated maximum in the present flood distribution plan of the main Brantas.

(c) Design flood for comprehensive flood control scheme is taken at 25-yr probable flood.

(d) Stagewise implementation is considered. The first stage plan is formulated with 10-yr probable flood, considering design values currently being applied to rivers in Indonesia (See Table 7.1 and Fig. 7.1).

(e) River channel improvement, full utilization of existing flood retarding swamp area and/or new flood diversion channel construction are superior to the flood control by dams from economic viewpoint.

In line with the above principle, the study is made with special attentions on the protection of Nganjuk urban area and its hinterland from flooding and the effective utilization of existing natural flood retarding basin area. The flood control plan covers the Widas main stream and its major tribuatries of the Kedungsoko, Ulo and Kuncir. Those objective stretches are determined with due consideration of the present river condition as summarized below.

River	Stretch	Length (km)
Widas river	River mouth to Ngudikan dam	42
Kedungsoko river	River mouth to Malangsari dam	10
Ulo river	River mouth to Kuncir diversion weir	24
Kuncir river	River mouth to Kuncir diversion weir	20

Note: Length to be improved

7.3 Conceivable Alternatives

With due consideration for the present basin and its river condition, the alternative flood control schemes are studied in the following. The alternative schemes consist of three controllable retarding basin schemes which are respectively incorporated with three river system improvements. The basic ideas of each component are explained below.

Three conceivable methods of river system imporvement are considered and those consist of:

(a) Channel improvement of all the objective river channels

(b) Channel improvement of the Widas and Kedungsoko rivers and full utilization of the existing Ulo river as a main floodway to discharge out from the Upper Ulo and the Upper Kuncir

(c) Channel improvement of the Widas and Kedungsoko rivers and construction of a new flood diversion channel aiming at diverting flood from the upper Kuncir and Ulo directly into the upper Widas river (same as trans-basin).

To attenuate the flood peak at the confluence with the Brantas river to the allowed maximum, utilization of natural retarding basin is to be considered. The study on retarding basin scheme is made on the basis of the following recognition and consideration.

(a) The land use of the existing retarding basins as farmland is not so active due to recurrent inundations. Among the three, the efficiency of land use of the Widas is the lowest and followed by that of Ulo. That of Kedungsoko is most active among the three basins.

(b) In the Widas river and its tributaries, sediment problem is not so serious as in the main Brantas river. Suspended sediment load prevails in the Widas basin. According to a preliminary study on sediment load (See ANNEX-4), it seems that content of suspended load is relatively small. Sedimentation in the retarding basin is considered not to affect the storage capacity of the retarding basin. This is further explained in ANNEX-4.

(c) In the retarding basin scheme, surrounding dike or ring levees along the proposed retarding basin is not provided because of the following reasons. Further explanation is given in ANNEX-4.

- Local drainage from the surrounding area of the retarding basin becomes difficult due to employment of surrounding dike. To treat this problem, new drainage system is to be constructed.

- In case with surrounding dike, the house in the retarding area are to be removed. The total numbers of houses to be removed exceed 3000 houses.

(d) The retarding at present occurs at the non-dike stretches and the stored water returns to the river through the non-dike stretch. Such natural phenomena can be put under artificial control.

Flood water coming from the upper reaches is controlled by fixed side-overflow dike and the stored water in the retarding basins is drained by gated drainage sluice.

Conceivable alterantive plans of the flood control thus taken up are explained below.

Scheme I

In the scheme I, only the Widas retarding basin is employed as controllable one. The other two retarding basins areas are retained by confining dikes. Furthermore, this scheme is divided into the following three cases of river system improvements (See Fig. 7.2).

Case 1: Existing four river channels are improved involving excavation of low-water channel and construction of flood dike.
At the Kuncir diversion weir, 50% of the flood coming from upper catchment is diverted into the Ulo main stream and the remaining is discharged into the Kuncir river.

Case 2: Ulo river channel is fully utilized as the main of the Upper Kuncir and the Ulo floodway. During flood, the diversion weir of the Kuncir is closed and the existing lower Kuncir is slightly improved for the local drainage. The existing Widas and Kedungsoko river channels are improved by excavation of low-water channel and construction of flood dikes.

Case 3: Ulo diversion channel is newly constructed aiming at diverting the flood coming from the upper catchments of the Kuncir and Ulo to the Widas. The lower reaches of the Kuncir and Ulo are slightly improved for local drainage. The Widas and Kedungsoko rivers are improved by excavation of low-water channel and construction of flood dike.

In all cases in the above, it is necessary to provide a large discharge capacity to the Lower Wides in order to convey flood to the Widas retarding basin.

Scheme II

In this scheme II, the Widas and Ulo retarding basins are employed to attenuate flood peaks. This scheme II is further divided into the following three cases of river system improvements which are same as that of scheme I (See Fig. 7.3).

Case 1: Same as scheme I

Case 2: Same as scheme I

Case 3: Same as scheme I

For the above respective cases, the Ulo retarding basin is comparatively studied of its different four retarding capacities incorporated with the Widas retarding basin as shown below.

Comparative cases (Ulo retarding volume) : Required net retarding volume = 0×10^6 m^3 (without retarding basin).
$V = 2 \times 10^6$ m^3
$V = 4 \times 10^6$ m^3
$V = 6 \times 10^6$ m^3

In this Scheme, the required discharge capacity of the Lower Widas is depend on the storage capacity of the Ulo retarding basin.

Scheme III

In this scheme III, all the three retarding basins of the Widas, Ulo and Kedungsoko are employed. The scheme III is further divided into the following three cases of river system improvement which are same as those of scheme I and II (See Fig. 7.4).

Case 1: Same as scheme I and II

Case 2: Same as scheme I and II

Case 3: Same as scheme I and II

For the above respective cases, the following three cases capacities of Kedungsoko retarding basin are combined with the above comparative case study of scheme II, based on the following consideration.

(a) Limited carrying capacity at railway and highway bridges on the Kedungsoko river : $Q = 145$ m^3/s. (round up by 150 m^3/s).

In this case, the existing both bridges are remained as they are and a net retarding capacity of 4.8×10^6 m^3 is allocated in the Kedungsoko retarding basin.

(b) $Q = 195$ m^3/s (round up to 200 m^3/s)

In this case, the existing both bridges and low-water channel are locally improved and reformed, and a net retarding capacity of 3.2×10^6 m^3 is allocated in the Kedungsoko retarding basin.

(c) $Q = 300$ m^3/s

In this case, existing both bridges are completely reconstructed and a net retarding capacity of 1.6×10 m^3 is allocated in the Kedungsoko retarding basin.

In this Scheme, the required discharge capacity of the Lower Widas is depend on the storage capacities of the Ulo and Kedungsoko retarding basin.

The retarding basins which are improved from passive retarding to positive flood control are defined as controllable retarding basin herein under.

7.4 Conditions of Comparative Study

The following are the basic conditions adopted to comparative study.

(1) Map and river cross-section

The following are applied to preliminary design of river channel improvement and controllable retarding basin.

A series of the topography maps of 1/5,000 and partially 1/10,000 is used for the design of channel, dike alignment and controllable retarding basin. The river cross-sections surveyed by BRBDEO and Study Team are used for the design of river channel.

(2) Design discharge distributions

Design flood discharges for respective alternative schemes are estimated based on the results of flood analysis and presented in ANNEX-4. Max. outflow into the Brantas main stream is limited to 270 m^3/s as the basic condition.

(3) Adopted condition to preliminary design

(a) Alignment of channel

The existing river channels, especially on the Widas and Ulo rivers meander in several locations. It is planned to moderate such excessive meandering by means of cut-off channel to secure stability of the channel.

(b) Cross section of river channel

The compound cross-section of channel consisting of low-water and high-water channels is adopted in principle with due consideration of large seasonal fluctuation of river water level. For the new flood diversion channel, the single cross-section with banquette is adopted.

The design cross-sectional area is estimated based on the uniform flow calculation. With regard to Manning's coefficient of roughness for the flow calculation, 0.03 for low-water channel and 0.05 for high-water channel are adopted with due consideration of the present river condition.

(c) Dike section

The following are adopted to the design of dike section as standard. The standard dike section is shown on Fig. 7.5.

Discharge m^3/s	Free Board (m) not less than	Crown Width (m) not less than	Slope	
			w/o protection	w/protection
Less than 200	0.6	3	1:2	1:1.5
200 to 500	0.8	3	1:2	1:1.5
500 to 2000	1.0	4	1:2	1:1.5

(d) Longitudinal profile of channel

The longitudinal profiles of river channel are planned based on the existing profiles of river bed and ground surface on river banks as shown below.

River	Slope of Profile
Widas	1/3,400 - 1/890
Kedungsoko	1/2,800 - 1/1,950
Ulo	1/1,430 - 1/400
Kuncir	1/1,380 - 1/690
Diversion channel	1/1,180

The design high water levels are determined on the basis of the water levels calculated by uniform flow method and shown in ANNEX-4 as standard one for attenuations.

The water level at the confluence with the Brantas river is set at 37.59 m in SHVP designed for 50-yr probable flood by Brantas Middle Reach Improvement Project.

(e) Controllable retarding basin

Control facilities to be employed in the controllable retarding basin consists of side-overflow dikes, drainage sluice and some small drainage canals in the basin. Surrounding dike is not provided as explained previously.

Required retarding capacity is estimated herein simply assuming peak-cut-method, namely flood water which equals to the proposed retarding capacity is attenuated into the basin by means of side-overflow dike, discharging a certain constant flow as base flow into the lower reach.

(f) Kuncir diversion weir

The diversion weir is to be replaced and the gate of the diversion weir on the Kuncir channel is to be improved to motor-driven gate so as to control flood water in time of flood according to assumed diversion rates.

(g) Irrigation head works

Also the gates of the irrigation head works are to be replaced by motor-driven one so as to pass flood water timely.

(h) Bridges

Major bridges are to be improved to secure necessary flow area and clearance against its design discharge.

(i) The land for the planned low-water channel, high-water channel and dike site are to be acquired.

(4) Selection method of optimum plan

Preliminary designs for respective alternatives are made aiming to estimate construction cost for respective ones and to select an optimum flood control plan. Since the flood control plan is formulated under the condition of 25-yr return period, benefit accured from flood damage reduction can be assumed to be same one for all alternatives. Accordingly, the optimum plan is selected as the least cost one among alternatives by considering negative cost (land enhancement) to be accured from the project.

(5) Adopted unit construction cost and compensation cost

The construction costs for respective alternatives are estimated based on the provisional unit construction cost for flood control works. Those are given in Table 3.1 in CHAPTER 3.

7.5 Result of Comparative Study

7.5.1 Preliminary construction cost

The preliminary construction costs inluding those of land acquisition and building compensation are estimated for each alternative and those results are summarized in Table 7.2.

7.5.2 Selection of optimum plan

Based on the required work quantities for alternatives and unit construction costs for flood control works, total construction costs are estimated for each alternative. In this flood control plan, some inundation areas are converted into farmland which can be utilized with higher intensity owing to decrease of inundation by flood mitigation depending on schemes take up. For such areas, increase in crop production is considered as negative cost.

Based on the estimated construction cost and negative cost for alternatives, the net present values for alternatives are calculated considering the project life of 50 years and the discount rate of 12%. The result are shown in Table 7.2.

According to the estimated net present values as shown in Table 7.2, the case 3 in scheme III is the least cost case among alternatives. Namely, flood control method by construction of new flood diversion channel and channel improvement of the Widas and Kedungsoko combined with utilization of three controllable retarding basins of Widas, Ulo and Kedungsoko, is selected as the least cost case (See Figs. 7.4, 7.6 and 7.7).

In selecting optimum retarding volume among the different retarding volume schemes, one of the major factors is the treatment of the existing railway bridge on the Kedungsoko river. This railway bridge is largely contributing to transportation as a trunk line between East Jawa and Central Jawa. The carrying capacity at the existing railway bridge is limited to about 200 m^3/s, even the sediment under the bridge is completely removed.

In order to pass more than the said 200 m^3/s by keeping the clearance under the bridge, the replacement of the bridge including rising of formation level of the bridge and adjustment of approach railway over long distance is required. However, such replacement is not an appropriate countermeasure from the viewpoint of social and technical aspects as well economic aspect.

On the contrary, in case of less than the said 200 m^3/s (carrying capacity at the existing highway bridge: 150 m^3/s), the inundation condition in the existing Kedungsoko retarding area which is highly utilizable for agriculture among the three retarating bains is not so much improved even though the flood control works are carried out.

Therefore, the design discharge at the existing railway bridge is considered reasonable to be proposed at 200 m^3/s which estimated under the existing railway bridge.

Among the selected case with a design discharge of 200 m^3/s at the existing railway bridge (required net Kedungsoko retarding volume: 3.2 x 10^6 m^3), the least cost case and the second least cost case are as follows, respectively.

Least cost case

Required net retarding basin volume (10^6 m^3)		
Kedungsoko	Ulo	Widas
3.2	6.0	7.4

Second least cost case

Required net retarding basin volume (10^6 m^3)		
Kedugnsoko	Ulo	Widas
3.2	4.0	8.1

For the above 2 cases, the proposed retarding volume is estimated below. However, required net retarding volume is estimated herein simply assuming peak-cut-method. Therefore, proposed retarding volume should be slightly more than estimated one for actual flood operation. Some allowance are taken into account for required net retarding volume. The dimension of the retarding basin of the above 2 cases thus estimated are as follows.

Least cost case

	Proposed dimensions of retarding basin (x10^6 m^3)					
		Allowance				
	Required net retarding volume	for actual flood operation *1	for dead storage	Total	Proposed dimension	Water level (m.SHVP)
K. soko						
- Limited carrying capacity at bridges	Q = 200 m^3/s (round up for planning)					
- Retarding capacity	3.2	0.6	1.0	4.8	5	44.5
Ulo retarding capacity	6.0	1.2	0 *2	7.2	8	44.9
Widas retarding capacity	7.4	1.5	4.0	12.9	13	38.5
Present worth of cost	Rp. 37,100x10^6					

Second least cost case

	Proposed dimensions of retarding basin (x10^6 m^3)					
		Allowance				
	Required net retarding volume	for actual flood operation *1	for dead storage	Total	Proposed dimension	Water level (m.SHVP)
K. soko						
- Limited carrying capacity at bridges	Q = 200 m^3/s (round up for planning)					
- Retarding capacity	3.2	0.6	1.0	4.8	5	44.5
Ulo retarding capacity	4.0	0.8	0 *2	4.8	5	44.5
Widas retarding capacity	8.1	1.6	4.0	13.7	14	38.5
Present worth of cost	Rp. 37,700x10^6					

Note : *1 20% of the estimated capacity

*2 No dead storage for local flow is considered due to improvement of local drainage

As is seen in the above table for the least cost case, the water level of the Ulo retarding basin is far higher than those of the Kedungsoko retarding basin and design high water level at the confluence with the Kedungsoko and Widas (SHVP 44.5 m).

Such condition will be troublesome in view of actual flood operation in the retarding basin and river administration during flood season. The proposed retarding volume should be well-ballanced one. For this reason, it is considered much appropriate to lower/decrease the water level/retarding volume in the Ulo retarding basin. For the Widas retarding basin, it is fully utilized to attenuate flood peaks in the lower Widas by the basic outflow condition of 270 m^3/s into the main Brantas river.

From the above, the second least cost case is proposed as the well-ballanced retarding volume in the selected flood control scheme. The proposed dimensions thus selected are shown on Fig.5.11.

7.5.3 Selected optimum plan

In conclusion, it is considered reasonable to select the case 3 in scheme III for the comprehensive flood control and drainage plan in the widas basin. The main flood control components of the above consist of:

(a) Construction of new flood diversion channel,

(b) Channel improvement of the Widas, Keudngsoko and upper Ulo rivers, and minor channel improvement of the lower Kuncir river, and

(c) Utilization of three existing natural retarding basins as controllable ones.

The concept of the selected comprehensive flood control and drainage plan and its design discharge distribution are presented on Fig. 7.6 and Fig. 7.7 respectively. The selected plan is further studied as feasibility study in the following chapter.

7.6 Possiblity of Utilization of Widas Retarding Basin Reservoir for Water Supply

From the following reasons, it can be said that there is little possibility of utilizing the retarding basin as a reservoir for water supply.

(1) Volume capacity

Principally the retarding basin is planned as one of flood control facilities to reduce flood peaks. Accordingly the storage capacity should be reserved for storage of flood water. When it is clear that the rainy season has ended and the available streamflow is still sufficient, it might be possible to store the river water in the retarding basin. But according to the hydrological analysis, the recorded one day basin mean rainfalls at the end of rainy season are as follows.

One day mean rainfall		Average river discharge in lower Widas
March	66 mm	385 m^3/s
April	63 mm	376 m^3/s
May	48 mm	311 m^3/s

These values show that there is a possibility that flood with peak discharge more than 270 m^3/s occures even in March and April in the Widas retarding basin. The Widas retarding basin has to reserve storage capacity for the peak reduction of such flood even in April and/or May. Accordingly it is very risky to store flood water in rainy season for water supply.

(2) Permeability

According to the geological investigation, permeability in the retarding basin areas especially in the Widas retarding basin is quite high.

As explained in the preceding section on the present condition of the retarding basins, the groundwater level is very liable to variation. At some wells, the groundwater level varies by 1 meter or 2 meters within one month even in a rainy season.

This means that the water stored in a rainy season in a retarding basin will be soon lost before being needed for water supply in a dry season.

Accordingly some countermeasures would be needed for utilizing the existing retarding basin as a reservoir for water supply in view of the permeability. Setting of blanket is one of the methods. In this case, the retarding basin can not be utilized as farmland, and villages in the basin have to be relocated. Considering such aspects, it should be said that the reservoir scheme is not economically viable.

(3) Others

In addition to the above, evaporation in the reservoir is expected to be fairly high in dry season. Water quality might be worsened day by day and some mechanical countermeasures are required to maintain water quality in reasonable condition.

Table 7.1 DESIGN DISCHARGE AND ITS SCALE CURRENTLY BEING APPLIED TO RIVERS IN INDONESIA

No.	Name of River	Province	Catchment Area (km^2)	Design Flood (m^3/s)	Specific Discharge ($m^3/s/km^2$)	Return Period (yr)
1.	Cimanuk	West Java	3,006	1,440	0.48	25
2.	Serang	Central Java	937	900	0.96	25
3.	Citandui	West Java	3,680	1,900	0.52	25
4.	Ular	North Sumatra	1,080	800	0.74	25
5.	Pemali	Central Java	1,228	1,300	1.06	25
6.	Cipanas	West Java	220	385	1.75	25
7.	Solo	Central/East Java	3,400	1,500	0.44	10 *1
				2,000	0.59	40 *2
8.	Madiun	East Java	2,400	1,100	0.46	10 *1
				2,300	0.96	40 *2
9.	Wampu	North Sumatra	3,840	1,320	0.34	20
10.	Arakundo	Aceh	5,495	1,800	0.33	20
11.	Kring Aceh	Aceh	1,775	1,300	0.73	20
12.	Brantas	East Java	10,000	1,350	0.14	10 *1
				1,500	0.15	50 *2
13.	Bah Bolon	North Sumatra	2,776	1,220	0.44	20
14.	Walanae	South Sulawesi	3,190	2,900	0.91	20
15.	Bila	South Sulawesi	1,368	1,900	1.39	20
16.	Jeneberang	South Sulawesi	729	3,700	5.08	50
17.	Ciujung	West Java	1,850	1,100	0.59	10 *1
				1,600	0.86	50 *2
18.	Kuranji	West Sumatra	213	870	4.08	25 *1
				1,000	4.69	50 *2
19.	Air Dingin	West Sumatra	131	600	4.58	25 *1
				700	5.34	50 *2
20.	Marmoyo	East Java	290	230	0.79	20
21.	Surabaya	East Java	631	370	0.59	50

Note *1 : 1st stage plan

*2 : Comprehensive plan and/or overall plan

Table 7.2 RESULTS OF COMPARATIVE STUDY (1/2)

Scheme I

Case	Construction cost (Rp.10^6)						Present value at 12 % discount (Rp.10^6)		
	Total	Widas	K.soko	Ulo	Kuncir	Diversion C.	Cost	Negative cost	Net
Case 1	65,085	29,416	12,980	13,315	9,374	-	46,924	3,094	43,830
2	65,791	29,423	12,983	15,503	7,882	-	47,433	3,074	44,359
3	59,728	30,493	12,441	4,639	7,882	4,273	43,061	3,054	40,007

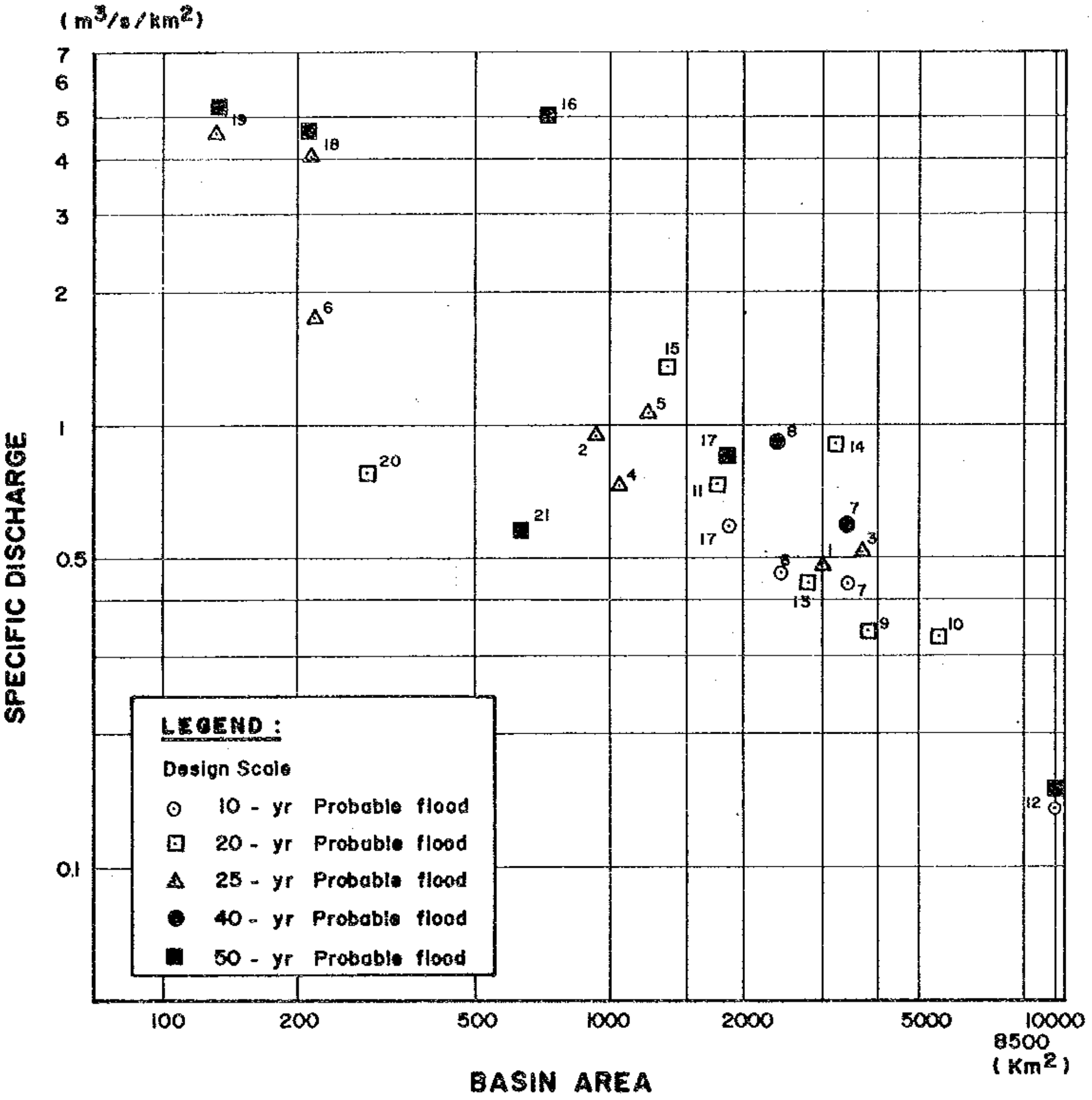
Scheme II

Case			Construction cost (Rp.10^6)						Present.value at 12 % discount (Rp.10^6)		
			Total	Widas	K.soko	Ulo	Kuncir	Diversion C.	Cost	Negative cost	Net
Case 1 : Channel improvement of existing rivers											
Retarding capacity (10^6 m^3)											
	Ulo	Widas									
	0	9.2	65,085	29,416	12,980	13,315	9,374	-	46,924	3,094	43,830
	2	9.2	63,106	28,843	12,277	12,612	"	-	45,497	2,385	43,112
	4	9.2	62,810	28,547	"	"	"	-	45,283	2,175	43,108
	6	8.4	61,824	27,561	"	"	"	-	44,573	2,174	42,399
Case 2 : Ulo main floodway and channel improvement											
	Ulo	Widas									
	0	9.3	65,791	29,423	12,983	15,503	7,882	-	47,433	3,074	44,359
	2	9.3	63,646	28,979	12,258	14,527	"	-	45,886	2,365	43,521
	4	9.3	63,347	28,680	"	"	"	-	45,671	2,151	43,520
	6	8.7	62,679	28,012	"	"	"	-	45,189	2,121	43,068
Case 3 : New diversion channel and channel improvement											
	Ulo	Widas									
	0	9.4	59,728	30,493	12,441	4,639	7,882	4,273	43,061	3,054	40,007
	2	9.4	58,672	29,647	12,258	4,612	"	"	42,300	2,345	39,955
	4	9.3	58,203	29,178	"	"	"	"	41,962	2,151	39,811
	6	8.6	57,316	28,291	"	"	"	"	41,323	2,141	39,182

Table 7.2 RESULTS OF COMPARATIVE STUDY (2/2)

Scheme III

Case		Construction cost (Rp.10^6)						Present value at 12% discount (Rp.10^6)		
		Total	Widas	K.soko	Ulo	Kuncir	Diversion C.	Cost	Negative cost	Net
Case 1 : Channel improvement of existing rivers										
K.soko limitted carrying capacity at K.soko bridges Q=145 m^3/s. Capacity of K.soko retarding basin V=6.7x10^6 m^3										
Retarding capacity ($10^6 m^3$)										
Ulo	Widas									
0	6.4	59,395	27,409	9,297	13,315	9,374	-	42,821	1,926	40,895
2	6.4	57,906	26,828	9,092	12,612	"	-	41,748	1,217	40,531
4	6.4	57,506	26,428	"	"	"	-	41,460	1,003	40,457
6	5.7	56,391	25,313	"	"	"	-	40,656	924	39,732
K.soko limitted carrying capacity at K.soko bridges Q=195 m^3/s. Capacity of K.soko retarding basin V=4.2x10^6 m^3										
Ulo	Widas									
0	7.4	60,667	28,063	9,915	13,315	9,374	-	43,738	2,220	41,518
2	7.4	58,790	27,422	9,382	12,612	"	-	42,385	1,511	40,874
4	7.3	58,394	27,026	"	"	"	-	42,100	1,306	40,794
6	6.3	57,270	25,902	"	"	"	-	41,289	1,280	40,009
K.soko limitted carrying capacity at K.soko bridges Q=300 m^3/s. Capacity of K.soko retarding basin V=1.9x10^6 m^3										
Ulo	Widas									
0	8.9	63,170	28,608	11,873	13,315	9,374	-	45,543	2,461	43,082
2	8.9	61,422	28,347	11,089	12,612	"	-	44,283	1,752	42,531
4	7.4	60,474	27,399	"	"	"	-	43,599	1,775	41,824
6	7.4	59,926	26,851	"	"	"	-	43,204	1,626	41,578
Case 2 : Ulo main floodway and channel improvement										
K.soko Q = 145 m^3/s ; V = 4.8 x 10^6 m^3										
Ulo	Widas									
0	7.2	61,041	27,900	9,756	15,503	7,882	-	44,008	2,141	41,867
2	7.2	58,965	27,355	9,201	14,527	"	-	42,511	1,432	41,079
4	7.2	58,657	27,047	"	"	"	-	42,289	1,217	41,072
6	6.7	57,773	26,163	"	"	"	-	41,652	1,138	40,514
K.soko Q = 195 m^3/s ; V = 3.2 x 10^6 m^3										
Ulo	Widas									
0	8.0	61,781	28,356	10,040	15,503	7,882	-	44,542	2,325	42,217
2	8.0	59,724	27,913	9,402	14,527	"	-	43,059	1,616	41,443
4	8.0	59,423	27,612	"	"	"	-	42,842	1,402	41,440
6	7.4	58,606	26,795	"	"	"	-	42,253	1,346	40,907
K.soko Q = 300 m^3/s ; V = 1.6 x 10^6 m^3										
Ulo	Widas									
0	9.0	64,203	28,911	11,907	15,503	7,882	-	46,288	2,507	43,781
2	9.0	62,173	28,671	11,093	14,527	"	-	44,824	1,798	43,026
4	9.0	61,869	28,367	"	"	"	-	44,605	1,583	43,022
6	8.4	61,154	27,652	"	"	"	-	44,090	1,547	42,543
Case 3 : New diversion channel and channel improvement										
K.soko Q = 145 m^3/s ; V = 4.8 x 10^6 m^3										
Ulo	Widas									
0	7.5	55,244	29,105	9,345	4,639	7,882	4,273	39,829	2,111	37,718
2	7.5	53,960	27,992	9,201	4,612	"	"	38,903	1,402	37,501
4	7.4	53,444	27,476	"	"	"	"	38,531	1,197	37,334
6	6.7	52,504	26,536	"	"	"	"	37,853	1,128	36,725
K.soko Q = 195 m^3/s ; V = 3.2 x 10^6 m^3										
Ulo	Widas									
0	8.2	55,714	29,313	9,607	4,639	7,882	4,273	40,168	2,290	37,869
2	8.2	54,719	28,550	9,402	4,612	"	"	39,450	1,590	37,860
4	8.1	54,227	28,058	"	"	"	"	39,095	1,389	37,706
6	7.4	53,332	27,163	"	"	"	"	38,450	1,346	37,104
K.soko Q = 300 m^3/s ; V = 1.6 x 10^6 m^3										
Ulo	Widas									
0	9.2	58,197	29,899	11,504	4,639	7,882	4,273	41,958	2,467	39,491
2	9.2	57,204	29,344	11,093	4,612	"	"	41,242	1,758	39,484
4	9.1	56,712	28,852	"	"	"	"	40,887	1,550	39,337
6	8.4	55,855	27,995	"	"	"	"	40,269	1,547	38,722

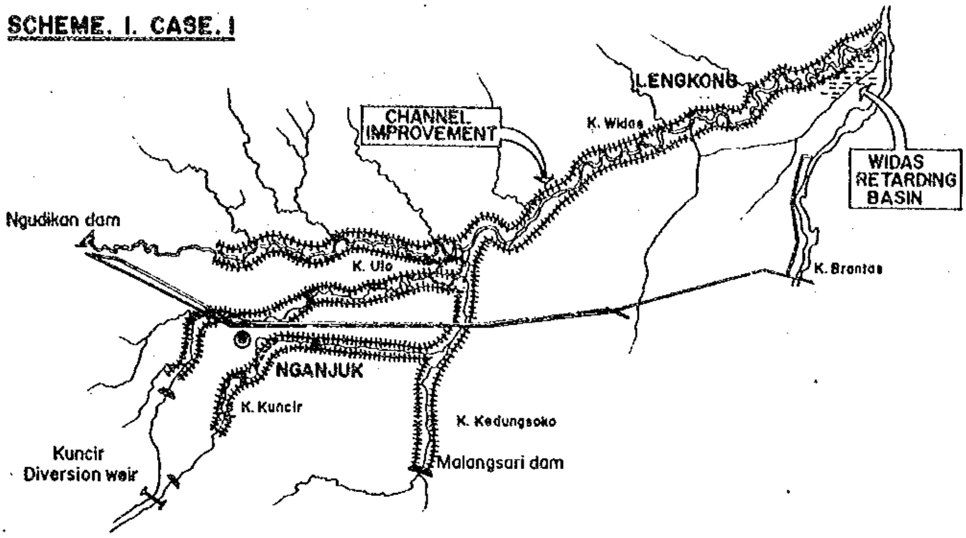


LEGEND :

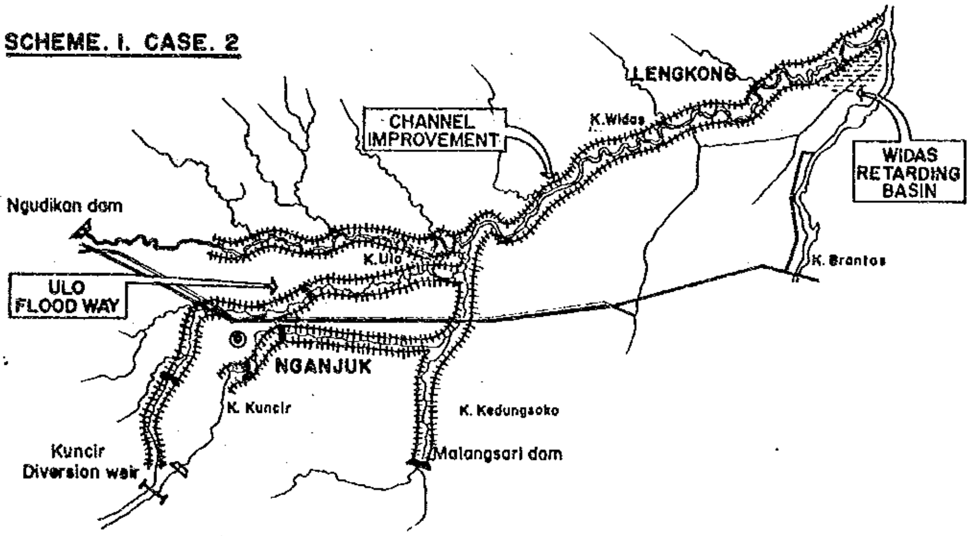
1. Cimanuk r.
2. Serang r.
3. Citandui r.
4. Ular r.
5. Pemali r.
6. Cipanas r.
7. Solo r.
8. Madiun r.
9. Wampu r.
10. Arakundo r.
11. Aceh r.
12. Brantas r.
13. Bah. Bolon r.
14. Walanae r.
15. Bila r.
16. Jeneberang r.
17. Ciujung r.
18. Kuranji r.
19. Air Dingin r.
20. Marmoyo r.
21. Surabaya r.

Fig. 7.1. RELATIONSHIP BETWEEN SPECIFIC DISCHARGE AND BASIN AREA CURRENTLY BEING APPLIED TO RIVERS IN INDONESIA

SCHEME. I. CASE. I



SCHEME. I. CASE. 2



SCHEME. I. CASE. 3

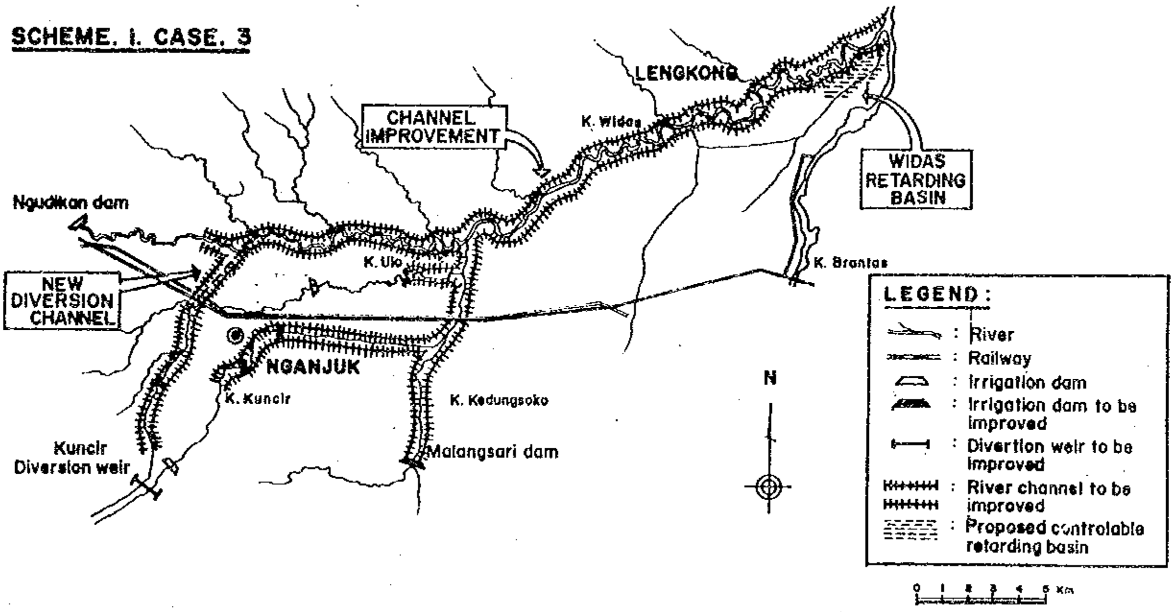
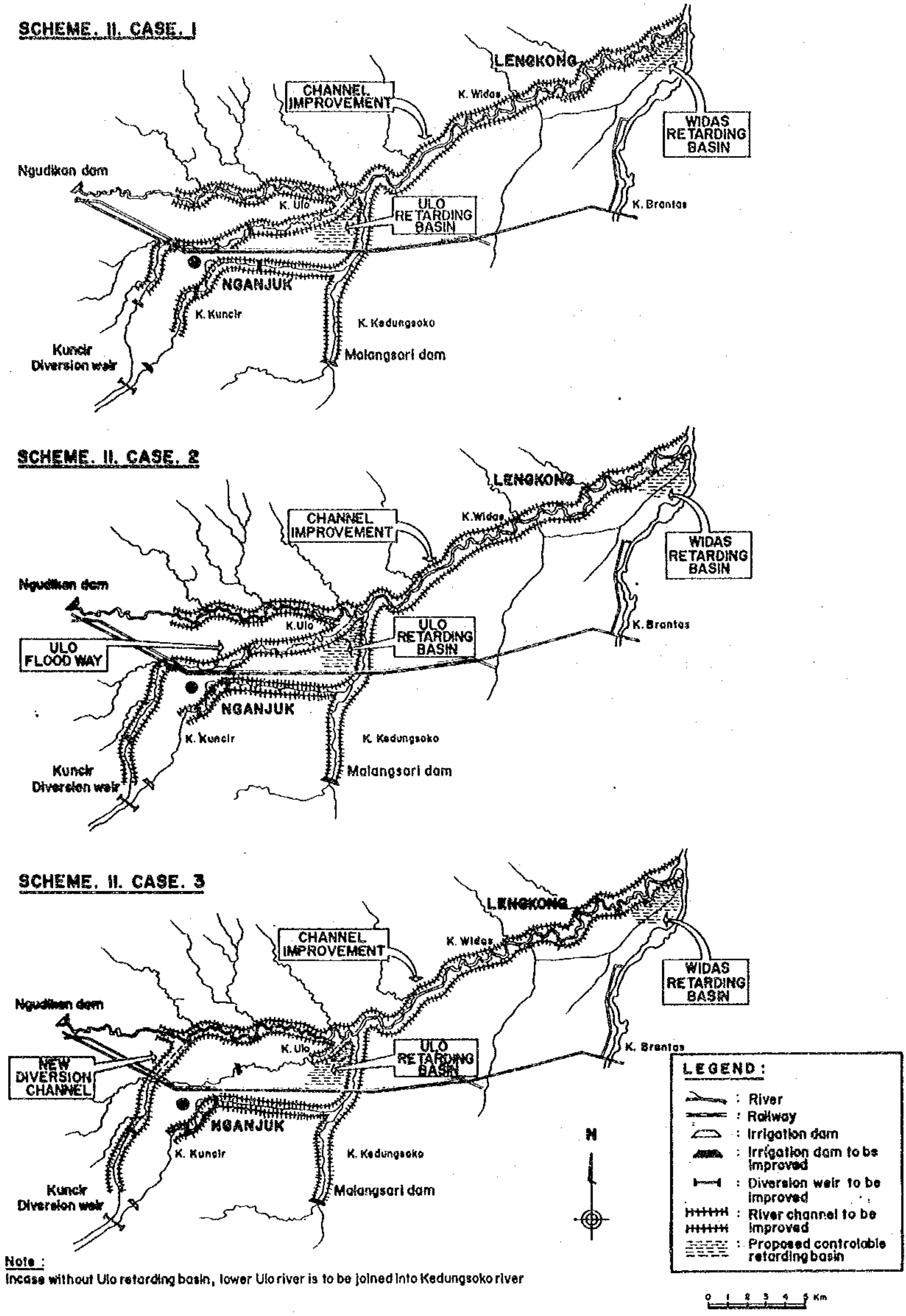


Fig. 7. 2 ALTERNATIVE SCHEMES OF FLOOD CONTROL PLAN (SCHEME. I.)



SCHEME. II. CASE. 1

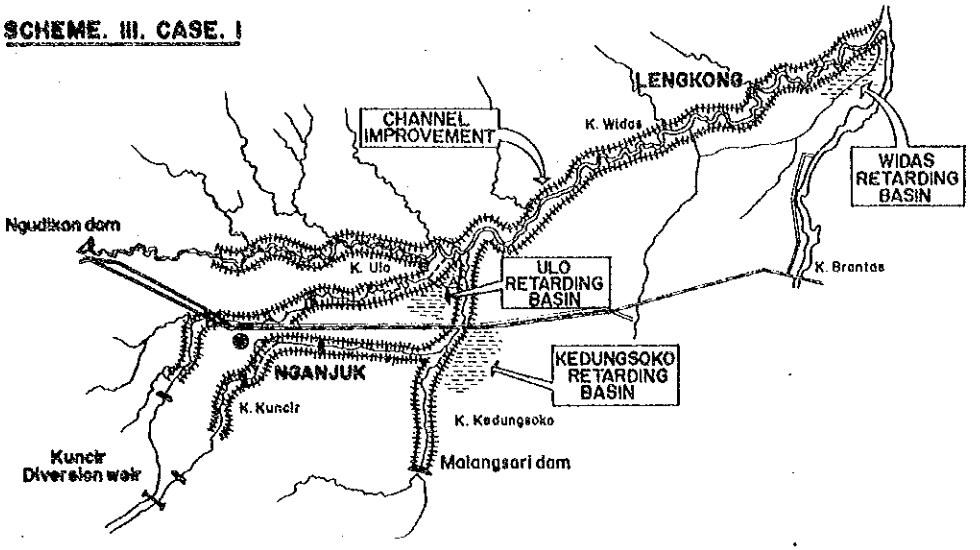
SCHEME. II. CASE. 2

SCHEME. II. CASE. 3

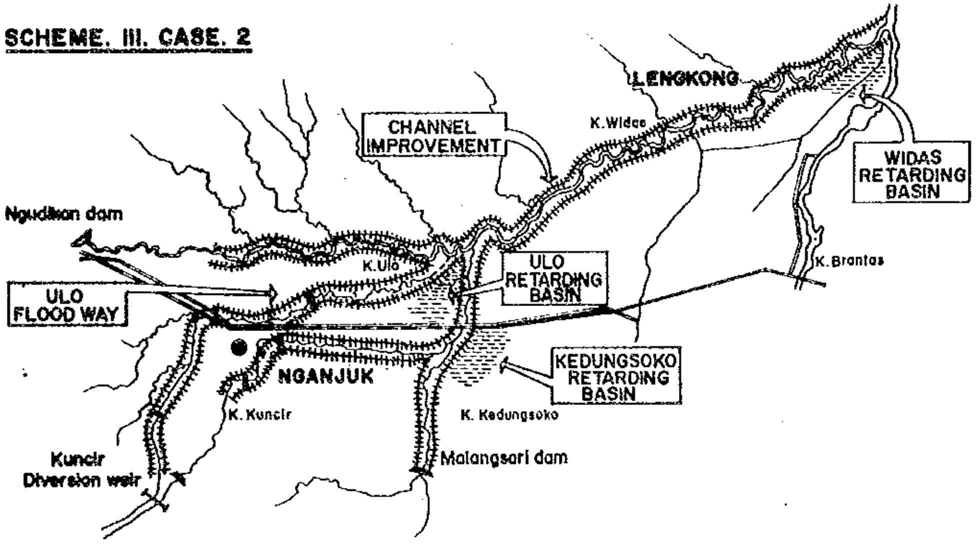
Note :
Incase without Ulo retarding basin, lower Ulo river is to be joined into Kedungsoko river

Fig. 7.3 ALTERNATIVE SCHEMES OF FLOOD CONTROL PLAN (SCHEME. II.)

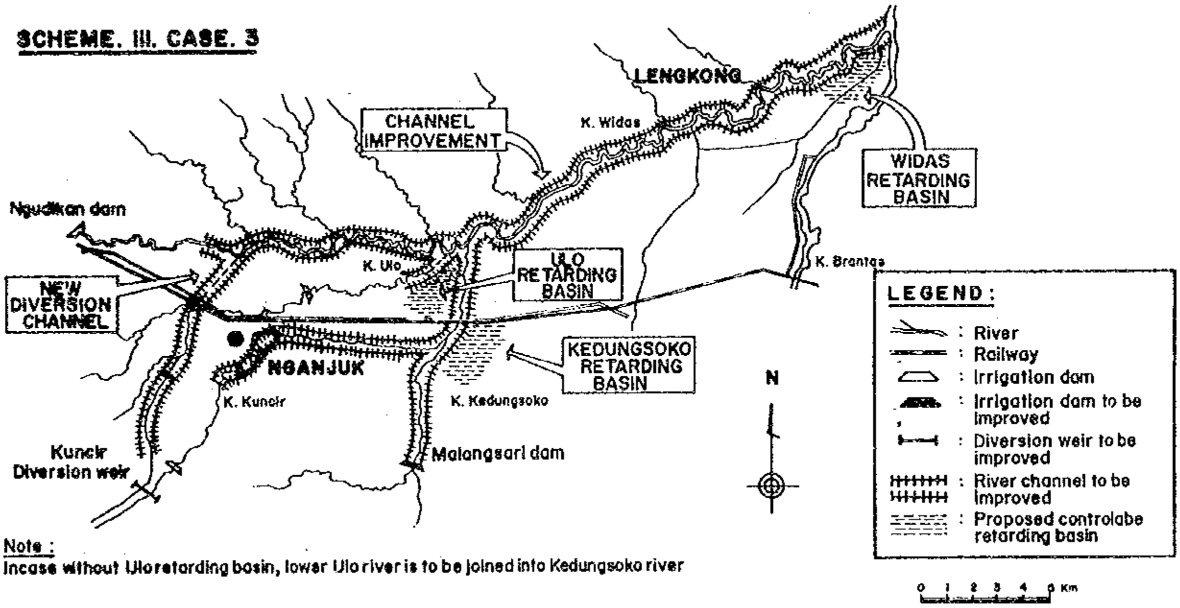
SCHEME. III. CASE. 1



SCHEME. III. CASE. 2



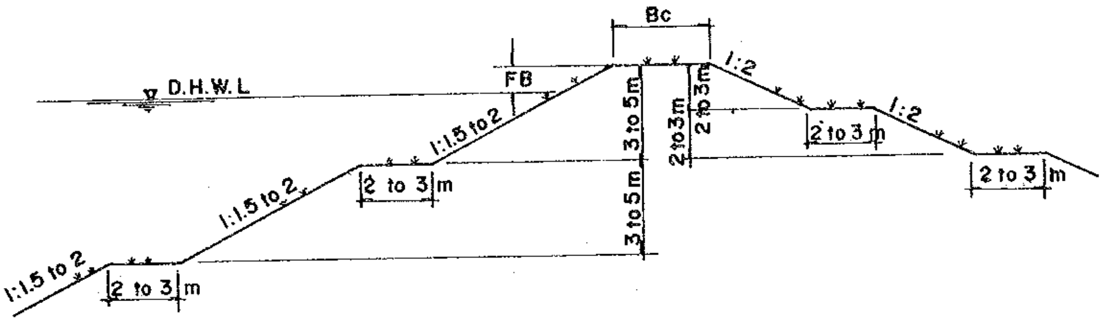
SCHEME. III. CASE. 3



Note :
Incase without Ulo retarding basin, lower Ulo river is to be joined into Kedungsoko river

Fig. 7.4 ALTERNATIVE SCHEMES OF FLOOD CONTROL PLAN (SCHEME. III.)

DIKE SECTION



STANDARD VALUES

Designed Discharge Q(m³/s)	Free - board FB (m) not less than	Crown width BC (m) not less than
200	0.6	3
200 to 500	0.8	3
500 to 2.000	1.0	4

Fig. 7.5. STANDARD DIKE SECTION

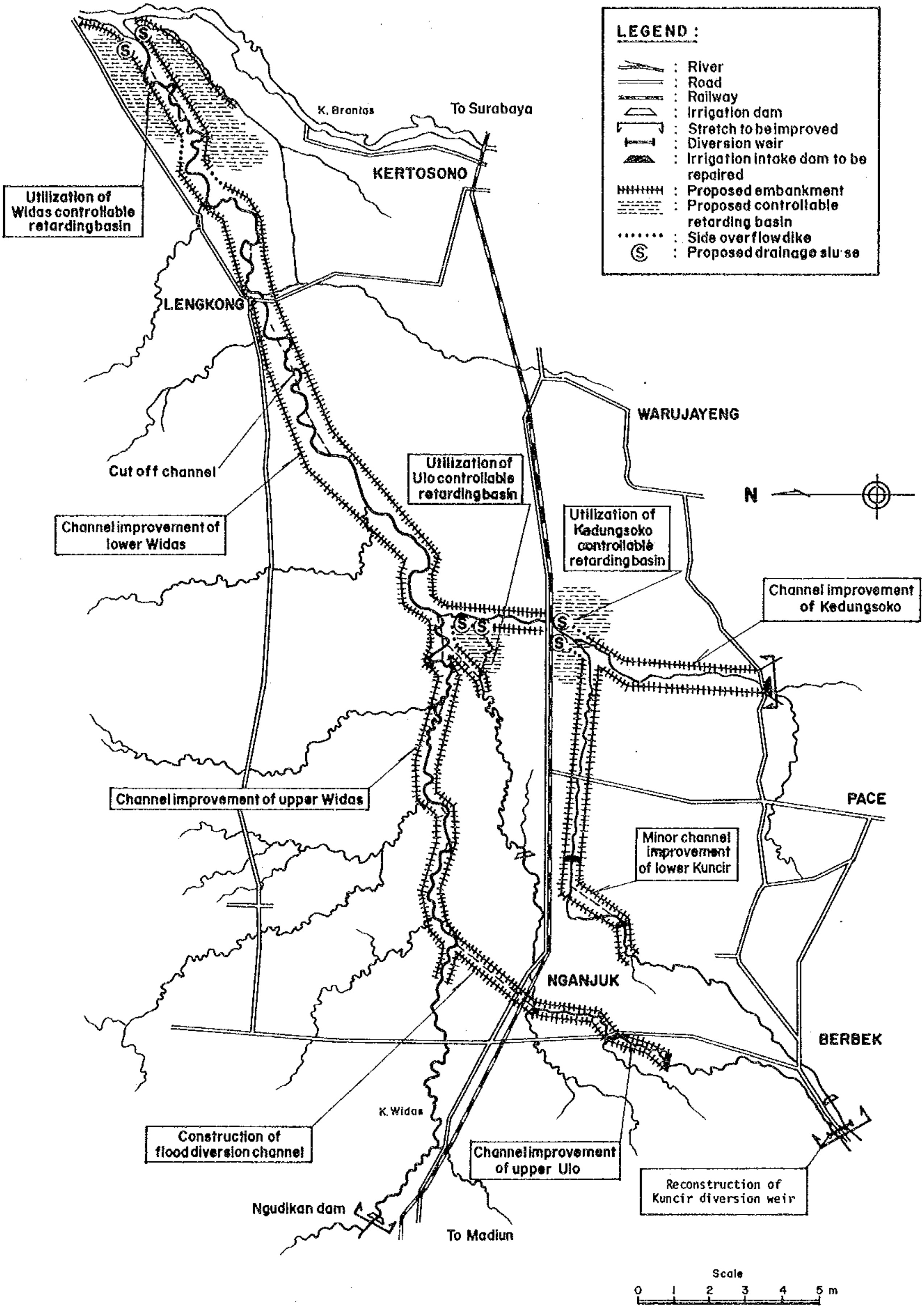
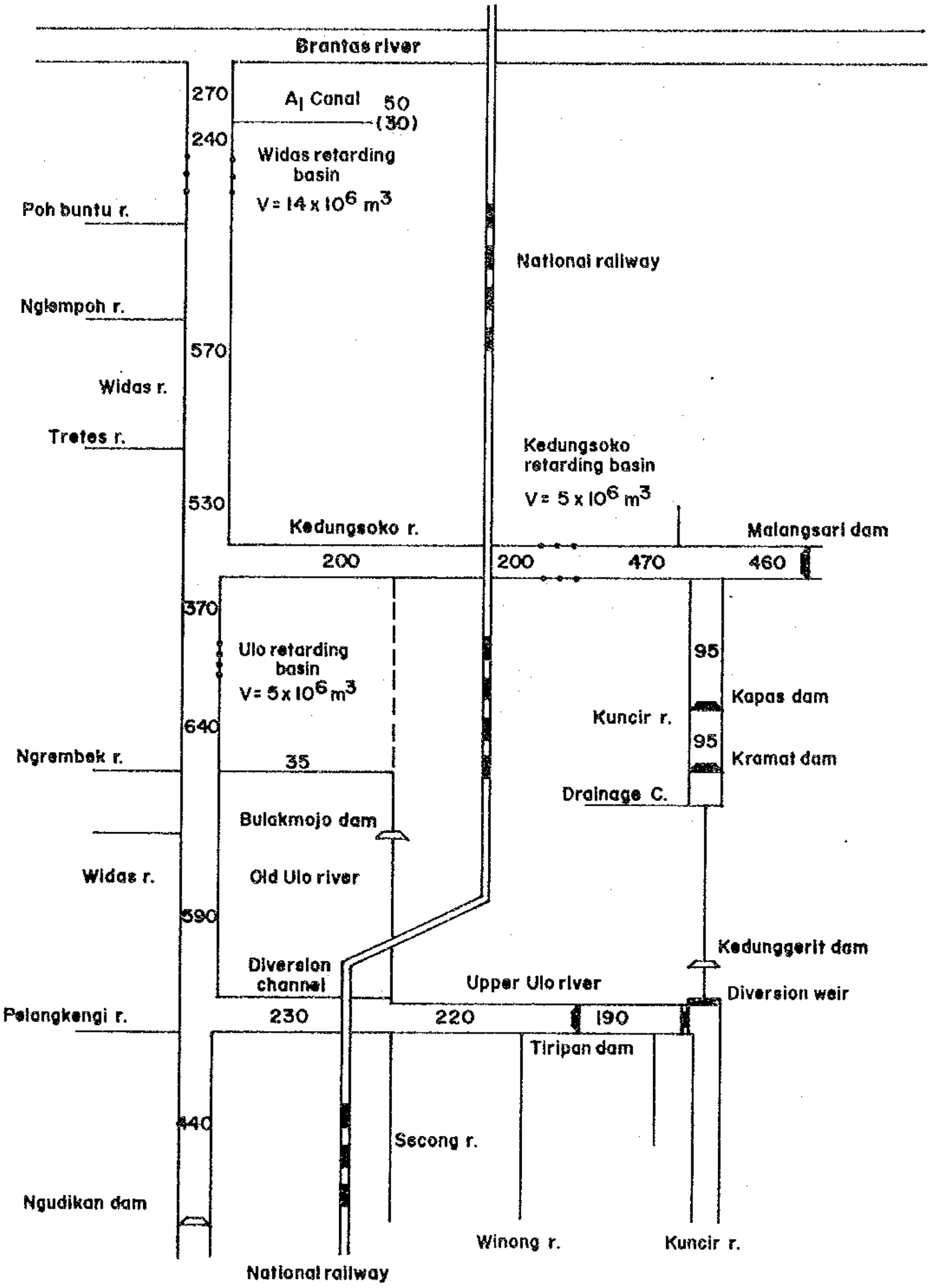


Fig. 7.6. OUTLINE OF OPTIMUM FLOOD CONTROL PLAN



Note : Unit m^3/s

▬ Irrigation head works to be repaired

(30) Inflow at peak stage in the Widas

-•-•- Side overflow dike

Fig. 7.7. DESIGN DISCHARGE DISTRIBUTION OF OPTIMUM FLOOD CONTROL PLAN