2.3.5 Sabo Facility Location Plan

The sabo facilities are to be provided in such a way as to satisfy the requirements of the sediment desposal plan, described in 2.3.4 with the works and structural planning described in the following paragraphs.

1) Selection of Works

a) Check dams should be selected in the following cases:

(1) Cases where storage of sediment by check dams is to raise riverbeds for prevention of erosion of riverbeds and banks.

(2) Cases in which the sediment discharged is to be controlled.

b) Consolidation dams should be selected in the following cases:

(1) Cases in which the present riverbed height is to be maintained and the riverbed and banks are to be fixed.

(2) Cases in which the flow of the river channel is to be corrected or the direction of flow regulated.

(3) Cases in which the deposited sediment is to be spread more evenly by preventing deep downward erosion within the river course and keeping the riverbed surface flat.

c) Training levees should be used as follows:

Cases in which lahar flooding is to be prevented and guided.

d) Valley mouth fixation works should be chosen as follows:

Cases in which valley mouths are to be fixed by a combination of check dams and training levees.

e) Embankments and bank protection works should be selected in the following cases:

(1) In the vicinity of points where there is danger of flooding.

(2) In cases where the difference in height between the riverbed and the river banks is insufficient for drainage of flood waters.

(3) In cases where such difference is sufficient, bank protection works are to be provided.

(4) In cases where there is marked riverbed variation or where the works are to be temporary, gabion or other such works are to be provided.

(5) In cases where there is danger of overflow over the top of the embankments, embankments of the three-sided wet masonry type are to be used.

f) Channel works should be selected in the following cases:

(1) Cases in which it is necessary to fix the course of flow with a combination of riverbed fixation works and bank protection works.

(2) Cases in which the degree of socio-economic importance is high.

g) Groins should be used as follows:

Cases in which flow direction regulation, protection of the riverbank at corners, or at the foot of revetment and groin is necessary.

h) Sand pockets should be used as follows:

Cases in which it is necessary to reduce sediment discharge through storage.

i) Bridges should be selected in the following cases:

(1) Cases in which bridges represent bottlenecks decreasing flood discharge capacity.

(2) Cases in which bridges are needed for evacuation or control, or from the standpoint of regional development.

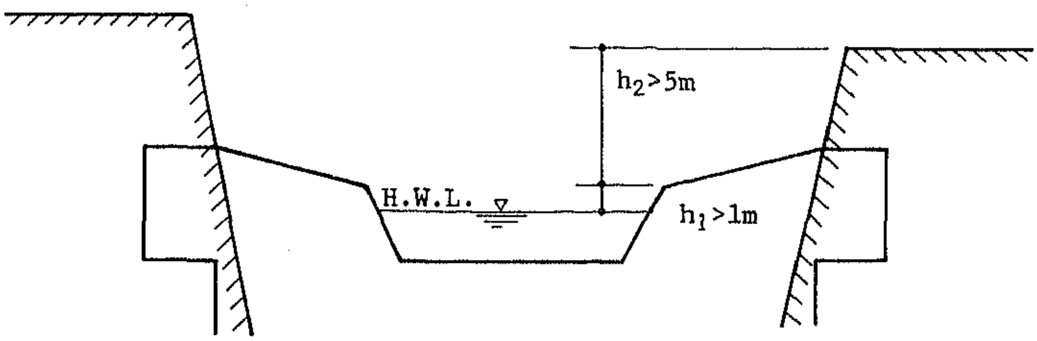
2) Structural Planning Policy

a) Height of Check Dams

The around base for the foundations of the check dams consists mostly of unsolidified lahar deposits and nuée ardente deposits, and generally the ground bearing capacity is low and the permeability is large; it is scoured easily. In short, the ground base for such foundations is not very good. Accordingly, the height of the check dams can be no more than 15 m. If a height of more than 15 m is necessary, a second dam will have to be built on top of the stored sediment of the dam, and since this ground or foundation base will be even less ideal, its height cannot exceed 10 m. Furthermore, if there is insufficient bearing capacity or creep length, the base of the dam will have to be widened and aprons and cutoffs increased.

b) Freeboard of Check Dams, Consolidation Dams, Embankments, and Bank Protection Works

In determining the amount of freeboard, such factors as the proposed amount of high water flow and the riverbed gradient are taken into account. In the area in question it will have to be 1 meter in view of the marked riverbed fluctuation and other circumstances. Furthermore, in order to prevent lahar from flowing over the top of the check dams, the crowns of the wings of the dams and the bank height are to be at least 5 meters.



c) Scouring Prevention Works for Check Dams and Consolidation Dams

Because of decline in sediment load and other changes in hydrological conditions due to check dams and other facilities, downword scouring of the foot of such facilities is inevitable, particularly in view of the fact that the riverbed matter consists of fine particles. Accordingly, from the outstart sufficient provision must be made for scouring prevention works, including provision of a second apron in most cases.

d) Foot Protection Works for Revetment and Groin

Foot protection works are to be provided at places where revetment groins can be expected to be scored. Furthermore, revetment works will be needed where groins are installed.

e) Protection Works for Wings of Check Dams

Since the wings of dams are easily damaged by the impact of lahar flow, banking and bank protection works will be necessary to protect the wings from the direct impact of the lahar flow.

f) Protection of Crowns of Check Dams and Consolidation Dams

Since the crowns of the dams will be subject to great deal of abrasion from the sediment load, they will have to be reinforced with rock materials, intensive concrete, and other such materials.

g) Materials and Implementation of Construction

For economy and from the standpoint of providing local employment opportunities, such materials as rock, earth and sand, bamboo, and wood are to be used for the structures and the construction is to be done mostly manually.

h) Flexible Multi-Stage Implementation of Plan

Sabo works have a great influence on sediment load, riverbed variation, and so on. Since there are many phenomena that cannot be foreseen at the time of planning, it is necessary to carry out the construction work in a flexible manner while observing actual river conditions. For instance, construction of a dam might be divided into two stages: stopping after the construction of the first stage to observe the effects of it before proceeding with the second stage, and if advisable, even adding a dam that was not originally planned for between the first and second stage.

i) Multipurpose Use of the Sabo Facilities

These facilities are to be planned in such a way that they can also be used for irrigation water intakes and other purposes. This means that as a rule intakes and approach channels are to be provided as a part of the check dams and consolidation dams. Passageways, washing places, and other everyday facilities for use by local residents are also to be provided.

3) River Characteristics and Facility Location Plan

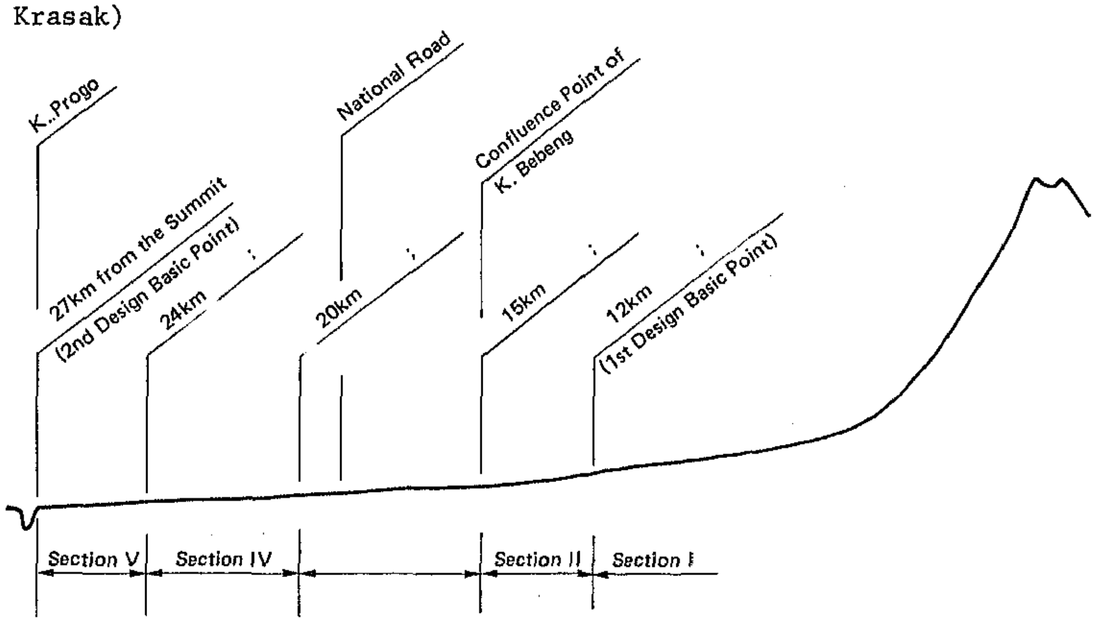
a) K. Krasak

i) River Characteristcs

Since the 1969 eruption K. Krasak has been subject to the direct influence of eruptions, and the river in the area covered by the plan now has the most sediment production and discharge. Because of the large amounts of volcanic debris, there are frequent lahar flows which cause pronounced erosion of the river valleys. As a result, there is considerable discharge of sediment downstream, which causes major rises in the riverbed, large-scale flooding, and substantial damage. Although the amount of sediment discharge has been gradually declining since 1969, sediment deposits in the middle and downstream sections that have thus far been discharged have widened the river and reduced the riverbed gradient so that the riverbed continues to rise year after year, increasing the danger of flooding.

Based on river characteristics, K. Krasak should be divided into the following five sections:

(k. Krasak)



Section I (upstream from the first design basic point)

(1) This section is the sediment production area, the valley being U-shaped and 20 - 30 m deep and marked erosion being both lateral and downward.

(2) Up until 1969, the main course of the upstream section of the river was K. Krasak, but the eruption of that year blocked the valley at that section and the main course became K. Bebeng.

(3) K. Krasak proper now has a deep, wide valley, and there is now very little sediment production there.

(4) With a future eruption, however, the main course could become K. Krasak proper again, or, as in 1930, it could continue to be K. Batang.

Section II (from the 1st design basic point to the confluence point of K. Bebeng)

(1) This is where lahar deposits stop. The length is about 3 km, with a maximum width of about 700 m. The area is fan-shaped, and there are a great number of sediment deposits.

(2) Presently the riverbed is 2 - 3 m below the ground base of the area around it, but at times of major flooding, the riverbed rises, and the direction of flow switches back and forth at the apex of the fan (a phenomenon called "head shaking"), and there is considerable danger of flooding.

(3) The shape of the river is deep and wide, and the riverbed is tending to lower.

Section III (from the confluence point of K. Bebeng to the 20 km point)

(1) This section is mainly characterized by conveyance of sediment, but deposits are increasing because of rise of the riverbed in Section IV.

(2) In the vicinity of the national road there is considerable bending, which gives rise to bank collapse and impedes smooth drainage of flood waters.

Section IV (from the 20 km point to the 24 km point)

Over this section the riverbed gradient gets more gentle, the width of the river widens, tractive force declines sharply, and there is a great deal of depositing of sediment. There are embankments on both sides, but flooding danger is increasing the riverbed rises each year.

Section V (from the 24 km point to the 2nd design basic point)

Over this section the width of the river is a narrow 40 - 50 m, and the riverbed gradient is high. At the 26 km point there is an unused intake that is a bottleneck for the sediment load. Furthermore, there is considerable danger of bank collapse and flooding in the vicinity of the point where the Mataram main irrigation canal crosses the river by means of a siphon.

ii) Sabo Facilities Location Plan

Sabo facilities will be provided in the manner described below so as to ensure safety at times of eruption no matter whether the lahar flows down the K. Bebeng river system or down the K. Krasak river system.

(Facilities for Reducing Sediment Production)

These facilities will be provided as follows in Section I:

(1) Valley Mouth Fixation Works

Considering past conditions of nuée ardente and lahar flooding, a No. 1 training levee will be provided near the 9 km point from the crater and a No. 2 training levee near the 10 km point in order to keep the river course in its present channel. Training levees will also be provided at points where there is danger of flooding (see Fig. 12).

(2) Check Dams and Consolidation Dams

For prevention of erosion nine check dams and a series of five consolidation dams will be provided along K. Bebeng.

Six check dams will be provided along K. Krasak proper.

Facilities for Reducing Sediment Discharge

(1) Over Section II sand pockets with a total sediment storage area of 1,780 x 10^3 m^2 will be provided.

Since the sediment is to be deposited evenly over this sediment storage area, four consolidation dams will also be provided.

River Course Improvement Facilities - Section III

(1) Embankments and bank protection works are to be provided chiefly at points where there is danger of flooding.

(2) The normal line at the bend near the national road bridge is to be improved.

River Course Improvement Facilities - Sections IV and V

Over these sections tractive force is to be increased so that sediment will be carried to K. Progo right away instead of being deposited.

(1) Lowering the Height of Intake Weir (Section V)

By reducing the height of the intake weir by about 3 m it will be possible to lower the riverbed and increase the riverbed gradient so as to increase tractive force. At the same time it will be necessary to provide protective works (consolidation dam) for the siphon of the Mataram irrigation canal (where it crosses the river) as well as protective works (underpinning) for the abutment of the bridge.

(2) Reduction of River Width and Fixation of Low Water Course (Section IV)

Embankments and bank protection works are to be provided for a river width of about 100 m, and a low water course of approximately 40 m is to be fixed by groin so that the riverbed will become about 2 m lower. The order of the construction work will be (i) reduction of width of intake weir, (ii) temporary works, and (iii) permanent works (see Fig. 13).

Since it will be necessary to undertake works for prevention of flooding before completion of the works upstream for reduction of sediment production and discharge, the river channel is to be fixed for the time being by means of temporary works, and the permanent works for this purpose are to be carried out after the river course is stabilized.

The temporary works should be simple and inexpensive structures provided with flexible construction methods in order to cope with riverbed variation. Possibilities in this respect include bamboo gabions, wood and bamboo skeleton works for reducing the riverbed variation.

It will be necessary to retain the present river course even in the permanent works stage since there is no telling how the river configuration might change. The embankments are also to be completely lined with revetment work or other such materials in order to prevent damage to them by overflowing resulting from riverbed rise or other cause.

(3) Bank Protection Works (Sections IV-V)

For protection of the Mataram main canal and other facilities, bank protection works are to be provided as far as the 24 km or 26 km point.

iii) Alternative Plans for K. Bebeng

Three alternative plans were considered for the section upstream of the 8.6 km point in the case of K. Bebeng, and Alternative-1 (described above) was chosen on the basis of a comparative study which is summarized in Appendix B.

b) K. Batang

i) Characteristics of the River

K. Batang experienced a large amount of lahar flow in 1930, but in 1961 the upstream section was blocked by lahar, and there is now little sediment production or riverbed fluctuation. There is, however, considerable danger of reoccurrence of lahar as a result of future eruptions.

Section I (from the summit to 12 km point (1st design basic point))

This section is characterized by sediment production, but since the valley is presently blocked and the basin is narrow, there is very little erosion of the shallow valley.

Section II (from 1st design basic point to the 17 km point (national road))

Although the riverbed is getting lower, the valley is relatively deep, with many boulders and sandbar-like deposits, and the course of flow is unstable giving rise to danger of bank collapse and flooding.

Section III (from national road to the 20 km point)

There was considerable flooding here in 1930, and even now the riverbed is shallow, with considerable danger of flooding.

Section IV (from the 20 km point to 2nd design basic point)

(1) Although the riverbed is relatively deep here, there is some localized danger of bank collapse and flooding.

(2) About 100 m upstream of the junction with K. Progo the Mataram main canal crosses the river by means of a siphon. The consolidation dams protecting the siphon, however, are damaged and present a flooding danger; the canal on the right bank side also presents considerable flooding danger.

ii) Sabo Facilities Location Plan

Facilities for reducing sediment production and facilities for reducing sediment discharge

Over Section I such facilities are to be provided as follows:

(1) At the 8.7 km and 10.3 km points, check dams and training levees are to be provided for fixation of the valley mouth.

(2) The valley is to be completely filled by sediment storage at the dams for greater effect of prevention of erosion.

(3) By filling the valley, an area of $2,090 \times 10^3$ m^2 enclosed by the dams and training levees is to be turned into sand pockets.

(4) At the 11 km point two consolidation dams are to be provided for reduction of erosion.

Facilities for River Course Improvement

(1) At dangerous spots in Section II, three riverbed fixation works and bank protection works are to be provided.

(2) In Section III, there are to be 3,000 m of river channel works in which both consolidation dams and bank protection works are to be used.

(3) In Section IV, 600 m of river channel works are to be provided for protection of the Mataram main canal.

c) K. Putih

i) Characteristics of the River

K. Putih ranks second to K. Krasak in terms of sediment production and riverbed variation. At present the sediment discharge is declining, but the small cross-sectional area of the river in the vicinity of the national road represents a bottleneck that is causing the riverbed to rise upstream of it, which in turn has resulted in flooding.

Section I (upstream from the 1st design basic point 19 km from the summit)

(1) This section is characterized by considerable sediment production, frequent occurrence of lahar, and pronounced river channel piracy.

(2) The valley is shallower than in the case of K. Krasak, and there is less erosion.

(3) There is the possibility of a change in the river channel to K. Blongkeng.

Section II (from the 1st design basic point to the 11 km point, Ngepos bridge)

(1) This is an area of lahar deposits and flooding, the sediment deposits being distributed in a fan shape.

(2) There is the possibility of change in the river channel to K. Batang.

Section III (from the 11 km point to the 17.5 km point, national road)

(1) In the vicinity of the national road the river is narrow, making for insufficient drainage capacity and causing riverbed rise upstream of that point as well as flooding.

(2) Flooding is also caused by the many sudden narrowings and sharp bends in the river course.

Section IV (from national road to the 24 km point, confluence point of K. Blongkeng)

Here the river is deep, and are few problems except for some localized danger of bank collapse and flooding.

ii) Sabo Facilities Location Plan

(Facilities for reducing sediment production and facilities for reducing sediment discharge)

Such facilities will be provided in Sections I and II as follows:

(1) Valley mouth fixation works are to be provided at the 7 km, 7.6 km, 8.9 km, 9.4 km, and 10.4 km points in the form of check dams and traning levees.

(2) The particular aim is prevention of change of the river channel to K. Blongkeng.

(3) $1,410 \times 10^3\ m^2$ of sand pockets are to be provided between the 10.4 km and 6.7 km points.

(Facilities for Improvement of the River Course)

(1) Downstream of the sand pockets in Section II, three consolidation dams and bank protection works are to be provided.

(2) A shortcut is to be made in the vicinity of the national road in Section III to increase drainage capacity and lower the riverbed. It will involve 2,400 m of river course works in the form of consolidation dams and bank protection works.

(3) Embankments and bank protection works will be provided upstream of the shortcut.

(4) Bank protection works and groin works are to be provided at flooding danger spots in Section IV.

d) K. Blongkeng

i) Characteristics of the River

A great deal of lahar occurred in 1930, and in 1969 the river course was taken over by K. Putih at Jurang Jero, so that there is now little sediment production or riverbed fluctuation. Nevertheless, there is still danger of lahar occurring again as a result of eruptions.

Section I (upstream from the 1st design basic point, the 9 km point)

(1) Although this is a sediment production area, there is not very much erosion.

(2) There is danger of K. Putih changing its course and flowing into this section.

Section II (from the 1st design basic point is the 10 km point)

There is wide distribution in this section of past lahar deposits.

Section III (from the 10 km point to the 19 km point)

A considerable amount of the deposits from the 1930 eruption have been washed away because of the great amount of flow, but boulders and sandbar-like sediment deposits remain and the course of flow is unstable, resulting in bank collapse and flooding.

Section IV (from the 19 km point to the 2nd design basic point, the 26 km point)

(1) There is a broad deposit area for about 2 km downstream of the national road, the river course being deep downstream of that, with some localized danger of bank collapse and flooding.

(2) Sediment is being discharged into K. Progo in a fan shape, and there are signs of K. Progo having been temporarily blocked.

(K. Lamat)

(1) This is a branch of K. Blongkeng (right side) that is classified as a Type-I area and which is not now subject to any direct influence from eruptions.

(2) Although the valley is deep and there is little sediment production at present, there could be sediment discharge at the time of major flooding.

ii) *Sabo Facilities Location Plan*

Although K. Lamat is a tributary of K. Blongkeng, it has been treated separately for facility planning purposes.

(Facilities for reducing sediment production and facilities for reducing sediment discharge)

(1) The plan assumes the case that the lahar of K. Putih would flow into the main river.

(2) The works for deterring inflow of lahar from the section downstream of the 6 km point have been included in the facility planning for K. Putih, although the effect thereof is accounted for by K. Blongkeng as well.

(3) Since construction of facilities is impossible upstream of the 6 km point, valley mouth fixation works are to be provided at the 3.7 km and 9.85 km points in the form of check dams and training levees to guard against inflow of lahar from there. *In this section there will also be 660 x* 10^3 m^2 *of sand pockets.*

(4) A check dam will be provided at the 10.3 km point in the case of K. Lamat.

(Facilities for Improvement of the River Course)

(1) Six consolidation dams and bank protection works are to be provided at flooding danger spots in Sections II and III.

(2) River channel works are to be provided for at an interval of approximately 2 km in the vicinity of the national road for protection of it and the urban developed areas of Muntilan.

(3) Bank protection works and groin works are to be provided for localized flooding danger spots in Section IV.

(4) At the point where the river flows into K. Progo training levees are to be provided so that the angle of confluence will be acute.

e) K. Woro

i) Characteristics of the River

This river ranks behind K. Krasak and K. Putih in Type-I areas in terms of the amount of sediment discharged. There is little direct influence from eruptions, with probably only an outflow of volcanic ash from the top part of the mountain (above elevation 2,000 m). The sediment production and discharge takes place chiefly in the 10 km interval from the top of the mountain. Most of the sediment is produced from past lahar deposits, which are largely terraced. When there is a lot of water, lahar can occur, but in normal years there is not much production or discharge of sediment.

K. Dengkeng, into which it flows, has a gentle riverbed gradient and very little sediment load capacity. As a result, the sediment supplied from upstream is deposited at the middle and downstream sections, forming large fan-shaped areas. Downstream there have long been sand pockets and embankments for preservation of farmland, and the level of the riverbed is quite a bit higher than the surrounding land. Recently, the riverbed of K. Dengkeng has risen as much as 2 m, but has returned to its original level a few years afterwards.

At about the 11 km point from the top of the mountain the riverbed of K. Woro comes up to the level of its banks, and from that point on downstream, the riverbed is higher than the surrounding land. For this reason there is a long history of frequent flooding from the vicinity of the head the fan-shaped area on downstream. Moreover, the flooding has tended to occur frequently for a long-term after a big flood because of the sediment action caused by the flood.

Section I (upstream from the 1st design basic point, the 10 km point)

(1) This is a sediment production area, where the valley is U-shaped and has a depth of 30 - 50 m.

(2) The sediment production is due mainly to crosswise erosion of terraced deposits.

(3) At a point about 7 km from the top of the mountain the river width decreases sharply by several meters, and the riverbed there rises sharply by about 20 m. As a result, there is still a large amount of unstable sediment upstream of that point. The soil conditions at that point consist of solidified strata of volcanic debris which could collapse in the future, resulting in substantial sediment production upstream of that point.

Section II (from the 1st design basic point to the entrance of sand pocket, 14 km point)

Lahar flows down in this area, and because of the shallowness of the riverbed, there is danger of flooding. There are stone masonry embankments already, but they are severely damaged.

Section III (from the 14 km point to the 14 km point)

(1) This is a sediment deposit area. Lahar is deposited in the sand pockets upstream, and these deposits gradually flow out and are deposited at the check dam downstream.

(2) The riverbed is high at the sand pockets and the sediment storage areas of the check dams, and there is therefore considerable danger of flooding.

(3) There are river course works linking the sand pockets and the check dams, and the riverbed is now getting lower there.

Section IV (from the 24 km point to the 2nd design basic point)

(1) At this section there is very little sediment load capacity, which makes it a deposit area, with the riverbed higher than the ground base of the surrounding land. If the embankments should break, there would be a major disaster.

(2) Recently there has been quarrying at the check dam and downstream of it, and in the vicinity of the national road the riverbed is getting lower.

ii) Land Erosion and Volcanic Debris Control Facilities Location Plan

(Facilities for Reducing Sediment Production)

Starting at the 10 km point, where there is considerable erosion, consolidation dams are to be provided at two places and check dams at nine places in a stairway fashion for prevention of erosion of riverbed deposits and the river bank terraces.

(Facilities for Reducing Sediment Discharge)

The existing sand pockets and check dams are to be improved and reinforced for the purpose of reducing sediment discharge, the sediment storage area being 2,650 x 10^3 m^2. In order to have the sediments deposited evenly in the sand pockets, three consolidation dams are to be provided, and embankments and bank protection works are to be reinforced and groin works provided.

(Improvement of River Courses)

(1) Embankments and bank protection works are to be reinforced.

(2) In order to increase the Tractive force at Section IV bank protection works are to be provided for fixation of the low-flow channel.

(Measures for Handling the Amount of Sediment Discharged in Normal Years)

(1) In normal years the river bed rises because of the low sediment load capacity, the problem section being Section IV. The amount of sediment flowing into it in a normal year is 24,000 m^3/year. Since the sediment load capacity at the point of confluence with K. Dengkeng is 6,000 m^3/year, the difference between these two figures, or 18,000 m^3 is the amount of sediment deposited annually at this section.

(2) Among the possible measures for coping with this situation are (a) removing the deposit by excavation (b) provision of sand pockets, (c) raising the height of embankments, (d) increasing the sediment load capacity of K. Dengkeng (by such means as low-flow channel works), or (e) switching over to the K. Opak river system.

(3) Of these possibilities, the last two are not recommendable since they would result in an increase in sediment discharge into K. Dengkeng and K. Opak. Nor is the third measure advisable in view of the fact that it would cause the riverbed to rise still more.

(4) The first two measures, however, would be appropriate, but since 50,000 - 100,000 m^3/year of sediment is being quarried in the vicinity of the national road for use as construction materials, there is no problem at the present time. Furthermore, such quarrying could continue to be encouraged through administrative guidance and, if necessary, even assisted in the form of subsidies or provision of conveniences with respect to excavation and loading.

f. K. Gendol

i) Characteristics of the River

K. Gendol, like K. Woro, is a Type-II area river, and it is second only to K. Woro in terms of amount of sediment discharge and riverbed variation. It differs from K. Woro, however, in that the riverbed gradient of the main river into which it flows, K. Opak, is greater than that of K. Dengkeng, into which K. Woro flows, making for greater sediment load capacity and less sediment deposits downstream.

There is a higher degree of flooding danger, however, because of fewer and less adequate disaster prevention facilities than in the case of K. Woro.

Section I (upstream from the 1st design basic point the 13 km point)

(1) This is a sediment production area.

(2) The main ways in which the sediment is produced are erosion of riverbed deposits and bank terraces upstream of the existing check dams and bank collapse due to scouring.

(3) Downstream of the existing dams the riverbed is getting lower.

Section II (from the 1st design basic point to the 2nd design basic point, the 18 km point)

(1) Starting at the first Design basic point (13 km from the top of the mountain) the river widens, and the area consists of deposits. In the vicinity of the 14 km point the riverbed is higher than the ground base of the surrounding land, which is a very dangerous situation encouraging flooding.

(2) For about 4.5 km from the 13 km point there are already consolidation dams and revetment works, and the state of the river course is good.

(3) Downstream of the terminal point of the existing revetment works, there is widespread sediment flooding.

(4) Downstream of the flooding area, the land that suffered disaster damage in 1973 has already been restored to paddy fields. The river is flowing naturally in the lowest course, but there is considerable danger of recurrence of flooding here at times of major flood waters.

(5) Downstream of the flooding area the width of the river gets to be about 5 m, and a tributary flows in from the left.

(6) In the vicinity of where K. Gendol flows into K. Opak the latter has a high sediment load capacity, the riverbed trend is down, and the river configuration is stable.

ii) Land Erosion and Volcanic Debris Control Facilities Location Plan

(Facilities for Reducing Sediment Production)

(1) Upstream of the existing dam, in Section I, seven check dams are to be provided in series in staircase fashion.

(2) Downstream of the existing dam are to be provided in the same kind of series to fix the riverbed deposits and prevent bank collapse.

(Facilities for Reducing Sediment Discharge)

(1) Downstream of the 13 km point sand pockets with a sediment storage area of 660 x 10^3 m^2 are to be provided.

(2) Downstream of the 16 km point sand pockets with a sediment storage area of 260 x 10^3 m^2 are to be provided.

(River Course Improvement Facilities)

(1) Starting at the 18 km point about 1 km of river course works are to be provided.

(2) Groin works are to be provided along the section with existing bank protection works.

(3) In the vicinity of the Prambanan archeological monuments, the bank protection works for K. Opak are to take into account the need to preserve scenic beauty in accordance with archelogical park plan. Furthermore, the environmental surruoundings are also to be improved.

g) K. Boyong

i) Characteristics of the River

For a long while this river has not been directly influenced by eruptions, and as a result of past erosion its valley is deep and there is presently little sediment production. The riverbed has been armored, and the particle size of the riverbed materials is large. Upstream, however, there are terraced deposits of past sediment discharges that could flow down at times of major flood waters. Furthermore, in view of the fact that this and other rivers in Type-III areas have recently experienced little disaster damage, there is considerable development along their banks, which gives them a high degree of socio-economic importance.

Section I (upstream from the 1st design basic point, 13 km point)

(1) The erosion occurs chiefly between the 5 km and 13 km points.

(2) Past lahar deposits are a source of sediment production, and there are a relatively large number of riverbed deposits.

(3) Lahar could occur at times of major flooding, but in normal years there is little sediment movement.

Section II (from the 1st design basic point to the 18 km point)

(1) In this section the drainage capability is low because of the relatively gentle riverbed gradient due to sediment deposits from lahar that occurred in the past.

(2) The large sized particles from past sediment discharges remain in sandbar fashion, causing instability of river course flow and localized bank collapse.

(3) Since there is little sediment discharged in normal years, the riverbed is getting lower. Because of the instability of river course flow and bottlenecks at bridges, however, there is some flooding.

Section III (from the 18 km point to confluence point of K. Opak, the 42 km point)

From the 18 km point to the other side of the urbanly developed part of Yogyakarta, the river has cut a deep valley that presents no danger of flooding at the present time. In Yogyakarta, however, there are many houses on low terraces that would be in danger if a disaster occurred.

ii) Sabo Facilities Location Plan

(Facilities for Reducing Sediment Production)

Five check dams are to be provided between the 8 km and 13 km points to prevent erosion of riverbed and river bank sediment.

(Facilities for Reducing Sediment Discharge)

Sediment discharge is to be controlled to the capacity of the above-mentioned check dams.

(River Course Improvement Facilities)

(1) Improvement of River Course

There are to be localized provision of two consolidation dams and revetment works at places where there is danger of flooding or of bank collapse.

(2) Improvement of Bridges

At points where bridges form bottlenecks, they are to be improved.

(3) Because of the fact that there is frequent flooding along the river inside Kota Yogyakarta, where there many houses near the low-flow river course, an effort is to be made to keep the riverbed there from rising any higher than the present level. In the future these houses should be relocated and the areas in question made into riverside parks from the standpoint of both safety and improvement of the urban environment.

h) K. Kuning

i) Characteristics of the River

Like K. Boyong, K. Kuning is characterized by little sediment discharge.

Section I (upstream from the 1st design basic point, the 13 km point)

(1) Up until about the 5.5 km point there is exposed rock in the riverbed in the shape of a rock trough. The fine particles of the sediment deposits have been washed away, leaving only larger rocks and boulders.

(2) The sediment production is mainly based on erosion of riverbed deposits remaining in sandbar fashion and of terraced hills.

Section II (from the 1st design basic point to the 2nd design basic point)

(1) Starting at the 13 km point the river gets narrow, and there is considerable conveyance of sediment. Because of intake weir and bridge bottlenecks, however, the riverbed has risen, causing flooding.

(2) Starting at about the national road, the river becomes shallow, and the course of flow unsteady. As a result, there is danger of bank collapse in the vicinity of Yogyakarta airport.

ii) Land Erosion and Volcanic Debris Control Facilities Location Plan

(Facilities for Reduction of Sediment Production and Facilities for Control of Sediment Discharge)

Three check dams are to be provided in Section I downstream of the existing dam to reduce sediment production and control sediment discharge.

(Riverbed Improvement Facilities)

(1) Bank protection works are to be provided mainly in the vicinity of points where there is danger of flooding.

(2) One bridge is to be remodelled since it represents an obstacle to drainage of flood waters.

(3) Bank protection works are to be provided at places in the vicinity of the airport where thre has been bank collapse.

h) K. Pabelan

i) Characteristics of the River

Although K. Pabelan is also classified as a Type-III area river, like K. Boyong and K. Kuning, it is somewhat different in character. In the period 1953 - 1956 there was outflow of volcanic debris into K. Pabelan proper. Since, however, there is a large basin area of 103 km^2 (and basins not on G. Merapi) which have little sediment discharge, the large amount of flow at all times is accommodated by the large sediment load capacity. Consequently, the riverbed is getting lower, and the size of the particles of the riverbed matter is getting larger through armoring. Although there seems to have been a great deal of sediment discharge in the past, there is relatively little at present.

Section I (upstream from the 1st design basic point)

(1) At the 12 km point (the distance measured along K. Trising from the mountain top) K. Pabelan and K. Trising run together, with K. Senowo running in at the 13 km point.

(2) There is considerable sediment production in this section, with descending amounts produced by K. Senowo, K. Trising, and K. Pabelan respectively.

(3) Most of the sediment production is due to secondary erosion of lahar deposits and bank collapse where there is considerable impact from the river flow.

(4) On the left bank downstream of the vicinity of the point of confluence with K. Senowo there is a fan-shaped sediment deposit area due to flooding in 1972.

Section II (from the 1st design basic point to the national road, the 23 km point)

(1) The finer particles of sediment discharged in the past have been washed away, leaving larger sized sediment which has been armored.

(2) Although the river is relatively wide, there is danger of flooding at bends because of the small difference in the height between the riverbed and the banks.

Section III (from the national road to the 2nd design basic point)

The river course is stable over this section, but at some places on the right bank there is danger of flooding because the height of the banks is low at the bends.

ii) Sabo Facilities Location Plan

(Facilities for Reduction of Sediment Production and Facilities for Control of Sediment Discharge)

Nine check dams are to be provided in Section I to reduce sediment production and control sediment discharge.

(River Course Improvement Facilities)

(1) Consolidation dams are to be provided downstream of the first design basic point and at the 18 km point to correct the river course and control the direction of flow.

(2) Embankments and bank protective works are to be provided for a section of approximately 1 km upstream of the consolidastion dams of the first design basic point in order to prevent flooding.

(3) A bridge is to be provided above the consolidation dams.

This point is important in terms of evacuation, management of land erosion and volcanic debris control facilities, and regional development since there are markets and important roads on both banks.

(4) Revetment works are to be provided at the place near the 20 km point where there is danger of flooding.

(5) At the places downstream of the national road where there is danger of flooding the banks are to be protected by means of groin works.

4) Summary of the Plans for Coping With Sediment

Table 12 shows the calculated amounts by which sediment is to be reduced or controlled by means of the proposed facilities, and Fig. 15 give the sediment discharge balances for both the case in which such facilities are provided and the case in which they are not provided. The results indicate that the plans described above for coping with sediment satisfy the requirements that were mentioned. The sand pockets that are to be provided will have double the sediment discharge control capacity necessary to cope with the scale of eruptions envisioned so that they should be effective for at least 50 years considering the periodicity of major major eruptions which is based on the following factors:

(1) Major eruption cycle: 12.5 years

(2) Cycle of influence on the rivers of major eruptions: 25 years

This cycle is based on the assumption at each river will be affected by about every other major eruption, as in the past.

5) Summary of Sabo Facilities

The table below lists the total number of check dams, consolidation dams, the total length of embankments, revetments, training levees, groin work bridges and others for all the sabo facilities in the project. The locations of the existing and proposed sabo works is shown in Fig. 14.

Summary List of Sabo Facilities

Area Type	Facilities / River Name	Check dam (No.)	Consoli-dation dam (No.)	Embankment and Revetment (m)	Training Levee (m)	Groin (m)	Bridge (m)	Others (m)
Type-1	K.Krasak	15	10	22,200	7,140	4,500	-	1
	K.Batang	2	17	13,330	2,520	900	-	-
	K.Putih	4	14	16,380	4,600	1,980	-	-
	K.Blongkeng	3	12	14,430	2,230	1,560	-	-
	Sub-Total	24	53	66,340	16,490	8,940	-	1
Type-II	K.Woro	10	5	20,920	-	3,000	-	-
	K.Gendol	7	17	8,750	-	780	-	-
	Sub-Total	17	22	29,670	-	3,780	-	-
Type-III	K.Boyong	5	2	6,960	-	-	2	-
	K.Kuning	3	-	7,700	-	-	1	-
	K.Pabelan	9	2	5,400	-	90	1	-
	Sub-Total	17	4	20,060	-	90	4	-
Total		58	79	116,070	16,490	12,810	4	1

Table 13 Review of Sediment Disposal Plan

Unit: $10^3 m^3$/year

Name of River	Proposed Excess Amount of Sediment (H)	Volume of Sediment Reduction by Type				Excess Sediment Capacity After Reduction of Sediment Discharge Q=H-(B+E)	Evaluation		
		Reduction of Production (B)	Reduction of Discharge (D)	Control of Discharge (E)	Total (T)		T≧H	D/Q	Type-I D/Q>2 Type-II D/Q>1
K. Blongkeng	2,120	869	2,920	-	3,789	1,251	O.K	2.33	O.K
(K. Lamat)	64	24	-	41	65	-	O.K	-	-
K. Putih	2,170	1,328	5,640	-	6,968	842	O.K	6.70	O.K
K. Batang	9,031	5,962	8,360	-	14,322	3,069	O.K	2.72	O.K
K. Krasak *	8,455	5,081	7,120	-	12,201	3,374	O.K	2.11	O.K
Sub-total	21,840	13,264	24,040	41	37,345	8,536			
K. Gendol	2,480	1,179	1,580	-	2,759	1,301	O.K	1.21	O.K
K. Woro	3,725	1,737	2,650	-	4,387	1,988	O.K	1.33	O.K
Sub-total	6,205	2,916	4,230	-	7,146	3,289			
K. Pabelan	2,427	660	-	1,776	2,436	-	O.K	-	-
K. Boyong	824	515	-	310	825	-	O.K	-	-
K. Kuning	1,074	622	-	456	1,078	-	O.K	-	-
Sub-total	4,325	1,797	-	2,542	4,339	-	O.K	-	-
Total	32,370	17,977	28,270	2,583	48,830	11,825			

*Alternative to pass through upper K. Krasak, not K. Bebeng.

	8,455	5,196	7,120	-	12,316	3,259	O.K	2,18	O.K

Table 14 Reduction Amount and Controlled Amount of Sediment

(1) K. Krasak

Unit: $10^3 m^3$

No.	Facility	Reduced Volume of Sediment Production	Reduced Volume of Sediment Discharge	Controlled Volume of Sediment Discharge	Remarks
	BE - C.1		S.P. 7,120 (C.1–C.4)		S.P.= Sand Pocket
	C.2				
	C.3				
	C.4				
	C.5	1			
	C.6	1			
	C.7	2			
	C.8	18			
	C.9	47			
	BE - D.1	252	(144)		
	D.2	155	(8)		
	D.3	298	(98)		
	D.4	175	(107)		
	D.5	138	(33)		
	D.6	138	(23)		
	D.7	212	(49)		
	D.8	350	(62)		
	D.9	171	(38)		
	BE - T.1	3,123 (T.1–T.4)			
	T.2				
	T.3				
	T.4				
	KR - D.1	270*	(950)		
	D.2	264*	(178)		
	D.3	210*	(31)		
	D.4	48*	(12)		
	D.5	159*	(61)		
	D.6	48*	(25)		
	KR - T.1	4,197* (T.1–T.5)			
	T.2				
	T.3				
	T.4				
	T.5				
	Total	5,081 5,196*	7,120		*Passing through upper K. Karasak

*

Table 14 Reduction Amount and Controlled Amount of Sediment

(2) K. Batang

Unit: $10^3 m^3$

No.	Facility	Reduced Volume of Sediment Production	Reduced Volume of Sediment Discharge	Controlled Volume of Sediment Discharge	Remarks
	BA - D.1	1,254	S.P. 1 3,960		
	D.2	1,523	S.P 2 4,400		
	BA - C.16	31			
	C.17	31			
	BA - T.1 T.2 T.3 T.4 T.5	3,123			
	Total	5,962	8,360		

Table 14 Reduction Amount and Controlled Amount of Sediment

(3) K. Putih

Unit: $10^3 m^3$

No.	Facility	Reduced Volume of Sediment Production	Reduced Volume of Sediment Discharge	Controlled Volume of Sediment Discharge	Remarks
	PU - D.1		(104)		
	D.2		(160)		
	D.3	27			
	Salamsari Dam (Lower)	25			
	Salamsari Dam (Middle)	45			
	PU - D.4	90			
	Salamsari Dam (Upper)	327			
	PU - T.1	814 (T.1 – T.8)	S.P 1 1,680		
	T.2		S.P 2 560		
	T.3		S.P 3 440		
	T.4		S.P 4 880		
	T.5		S.P 5 2,080		
	T.6				
	T.7				
	T.8				
	Total	1,328	5,640		

Table 14 Reduction Amount and Controlled Amount of Sediment

(4) K. Blongkeng

Unit: $10^3 m^3$

No.	Facility	Reduced Volume of Sediment Production	Reduced Volume of Sediment Discharge	Controlled Volume of Sediment Discharge	Remarks
	BL - D.1		(57)		
	D.2	19	(190)		
	Slamsari Dam	36	(105)		
	BL - T.1 T.2 T.3 T.4	814	S.P. 1 2,400 S.P. 2 520		
	Total	869	2,920		

(5) K. Lamat

No.	Facility	Reduced Volume of Sediment Production	Reduced Volume of Sediment Discharge	Controlled Volume of Sediment Discharge	Remarks
	LA - D.3	24	(108)	41	
	Total	24		41	

Table 14 Reduction Amount and Controlled Amount of Sediment

(5) K. Woro

Unit: $10^3 m^3$

No.	Facility	Reduced Volume of Sediment Production	Reduced Volume of Sediment Discharge	Controlled Volume of Sediment Discharge	Remarks
	WO - C.1		S.P. 1 570		
	C.2		S.P. 2 2,080		
	C.3				
	C.4	28			
	C.5	19			
	WO - D.1	88	(70)		
	D.2	61	(21)		
	D.3	138	(294)		
	D.4	115	(142)		
	D.5	377	(46)		
	D.6	153	(35)		
	D.7	188	(111)		
	D.8	137	(18)		
	D.9	335	(260)		
	D.10	98	(25)		
	Total	1,737	2,650		

Table 14 Reduction Amount and Controlled Amount of Sediment

(6) K. Gendol

Unit: $10^3 m^3$

No.	Facility	Reduced Volume of Sediment Production	Reduced Volume of Sediment Discharge	Controlled Volume of Sediment Discharge	Remarks
	GE - D.1	92	(254)		
	D.2	150	(224)		
	D.3	88	(91)		
	D.4	117	(272)		
	D.5	193	(150)		
	D.6	56	(163)		
	D.7	56	(91)		
	GE - C.5				
	C.6		S.P. 1 260		
	C.7				
	C.8				
	C.9		S.P. 2 1,320		
	C.10	54			
	C.11	54			
	C.12	35			
	C.13	23			
	C.14	34			
	C.15	58			
	C.16	78			
	C.17	91			
	Total	1,179	1,580		

Table 14 Reduction Amount and Controlled Amount of Sediment

(7) K. Boyong

Unit: $10^3 m^3$

No.	Facility	Reduced Volume of Sediment Production	Reduced Volume of Sediment Discharge	Controlled Volume of Sediment Discharge	Remarks
	BO - D.1	68	(43)	67	
	D.2	83	(22)	30	
	D.3	156	(35)	35	
	D.4	140	(58)	82	
	D.5	68	(39)	54	
	Kaliurang Dam	-	(435)	42	
	Total	515		310	

Table 14 Reduction Amount and Controlled Amount of Sediment

(8) K. Kuning

Unit: $10^3 m^3$

No.	Facility	Reduced Volume of Sediment Production	Reduced Volume of Sediment Discharge	Reduced Volume of Sediment Discharge	Remarks
	KU - D.1	85	(74)	110	
	D.2	154	(50)	231	
	D.3	383	(71)	55	
	Ngipiksari Dam	-	(300)	60	
	Total	622		456	

Table 14 Reduction Amount and Controlled Amount of Sediment

(9) K. Pabelan

Unit: $10^3 m^3$

No.	Facility	Reduced Volume of Sediment Production	Reduced Volume of Sediment Discharge	Reduced Volume of Sediment Discharge	Remarks
	PA - D.1	58	(360)	257	
	D.2	47	(82)	55	
	Pendem Dam	-	(110)	77	in K. Pabelan
	Tlatar Dam	-	(72)	44	"
	Sukoguo Dam	-	(50)	30	in K. Trising
	TR - D.1	60	(138)	203	
	D.2	89	(61)	135	
	D.3	62	(116)	69	
	D.4	56	(81)	35	
	SE - D.1	100	(73)	205	
	Tutup Dam	-	(136)	215	in K. Senowo
	SE - D.2	75	(50)	94	
	D.3	113	(72)	357	
	Total	660		1,776	

Table 15 Proposed Amount of Deposit at Sand Pockets

Unit: $10^3 m^3$

Type	Name of Rivers	Facility Number	Distance from the Summit (km)	Deposit Amount: Area ($10^3 m^2$)	Deposit Amount: Depth (m)	Deposit Amount: Volume ($10^3 m^3$)	Proposed Discharge Sediment: Volume ($10^3 m^3$)	Proposed Discharge Sediment: Depth (m)
Type-I	K. Krasak	1	12 ∿ 15	1,780	4	7,120	3,374	1.9
	K. Batang	1	8.7∿10.3	990	4	3,960	1,454	1.47
		2	7 ∿ 8.7	1,100	4	4,400	1,615	1.47
		Sub-total		2,090		8,360	3,069	
	K. Putih	1	9.4∿10.4	420	4	1,680	251	0.60
		2	8.9∿ 9.4	140	4	560	84	0.60
		3	8.3∿ 8.9	110	4	440	66	0.60
		4	7 ∿ 7.6	220	4	880	131	0.60
		5	6 ∿ 7	520	4	2,080	310	0.60
		Sub-total		1,410		5,640	842	
	K. Blongkeng	1	8.7∿9.85	600	4	2,400	1,028	1.71
		2	8.2∿ 8.7	130	4	520	223	1.71
		Sub-total		730		2,920	1,251	
Type-II	K. Woro	1	20.5∿23.7	570	1	570	428	0.75
		2	14 ∿17	2,080	1	2,080	1,560	0.75
		Sub-total		2,650		2,650	1,988	
	K. Gendol	1	16.3∿18	260	1	260	199	0.77
		2	12.7∿13.7	660	2	1,320	1,102	1.67
		Sub-total		920		1,580	1,301	
Total				9,580		28,270		

Table 16 Sediment Balances of Before and After Master Plan Implementation

(1) K. Krasak

Unit: $10^3 m^3$/year

Distance from the Summit	Before			After Implementation of the Plan					Remarks
	Proposed Volume of Sediment by Types			Proposed Volume of Sediment by Types					
(Km)	Produced (A)	Controlled (C)	Discharged (G = Σ(A-C))	Production Reduced ΣB (B)	Discharged (I = G - ΣB)	Discharge Reduced (D)	Controlled (E)	Discharged (J=I-Σ(D+E))	
3	1,235		1,235	-	1,235	-	-	1,235	
7	4,278	1,359	4,154	-	4,154	-	-	4,154	
8	2,127	188	6,093	521	1,606	-	-	1,606	
9	1,311	267	7,173	4,132 (3,611)	3,041	-	-	3,041	
10	1,848	432	8,553	4,760 (628)	3,793	-	-	3,793	
11	890	112	9,331	5,059 (299)	4,272	-	-	4,272	
12	71	91	9,331	5,081 (22)	4,230	-	-	4,230	1st Design Basic Point
13			9,331	5,081	4,230	-	-	4,230	
15	44*		9,355	5,081	4,274	3,374		900	K. Krasak + K. Bebeng
17.6			9,355	5,081	4,274	3,374		900	National Road
20			9,355	5,081	4,274	3,374		900	
24			9,355	5,081	4,274	3,374		900	
27			9,355	5,081	4,274	3,374		900	2nd Design Basic Point

*from Upper K. Krasak

(2) K. Batang

Unit: $10^3 m^3$/year

Distance from the Summit	Before			After Implementation of the Plan					Remarks
	Proposed Volume of Sediment by Types			Proposed Volume of Sediment by Types					
(Km)	Produced (A)	Controlled (C)	Discharged (G = Σ(A-C))	Production Reduced ΣB (B)	Discharged (I = G - ΣB)	Discharge Reduced (D)	Controlled (E)	Discharged (J-I-Σ(D+E))	
3	1,235	-	1,235	-	1,235	-	-	1,235	
7	4,278	1,359	4,154	-	4,154	-	-	4,154	
8	2,127	188	6,093	-	6,093	-	-	6,093	
9	1,311	267	7,173	1,523	5,650	1,615	-	4,035	
10	1,848	432	8,553	1,523 -	7,030	1,615	-	5,415	
11	890	112	9,331	5,962 (4,439)	3,369	3,069 (1,454)	-	300	
12	71	91	9,311	5,962 -	3,349	3,069	-	280	
13			9,311	5,962	3,349	3,069	-	280	
17			9,311	5,962	3,349	3,069	-	280	
25			9,311	5,962	3,349	3,069	-	280	

Table 16 Sediment Balances of Before and After Master Plan Implementation

(3) K. Putih

Unit: $10^3 m^3$/year

Distance from the Summit (Km)	Before: Proposed Volume of Sediment by Types			After Implementation of the Plan: Proposed Volume of Sediment by Types					Remarks
	Produced (A)	Controlled (C)	Discharged (G = Σ(A-C))	Production Reduced ΣB (B)	Discharged I = G - ΣB	Discharge Reduced (D)	Controlled (E)	Discharged (J=I-Σ(D+E))	
3	2,480		2,480	-	2,480	-	-	2,480	
5	750	2,480	750	-	750	-	-	750	
6	1,202	310	1,642	-	1,642	-	-	1,642	
7	1,210	387	2,465	327	2,138	310	-	1,828	
8	334	362	2,437	462 (135)	1,975	441 (131)	-	1,534	
9	84	91	2,430	1,328 (866)	1,102	507 (66)	-	595	
10	-	-	2,430	1,328	1,102	591 (84)	-	511	
11	-	-	2,430	1,328	1,102	842 (251)	-	260	
12	-	-	2,430	1,328	1,102	842	-	260	
13	-	-	2,430	1,328	1,102	842	-	260	
14	-	-	2,430	1,328	1,102	842	-	260	
15	-	-	2,430	1,328	1,102	842	-	260	
16	-	-	2,430	1,328	1,102	842	-	260	
17	-	-	2,430	1,328	1,102	842	-	260	
24	-	-	2,430	1,328	1,102	842	-	260	

(4) K. Blongkeng

Unit: $10^3 m^3$/Year

Distance from the Summit (Km)	Before: Proposed Volume of Sediment by Types			After Implenentation of of the Plan: Proposed Volume of Sediment by Types					Remarks
	Produced (A)	Controlled (C)	Discharged (G = Σ(A-C))	Production Reduced ΣB (B)	Discharged (I = G - ΣB)	Discharge Reduced (D)	Controlled (E)	Discharged (J=I-Σ(D+E))	
3	2,480	-	2,480	-	2,480	-	-	-	
5	750	2,480	750	-	750	-	-	-	
6	1,202	310	1,642	-	1,642	-	-	-	
7	1,210	387	2,465	-	2,465	-	-	-	
8	334	362	2,437	-	2.437	223	-	-	
9	84	91	2,430	55	2,375	1,251 (1,028)	-	2,152	
10	-	-	2,430	869 (814)	1,561	1,251	-	310	
11	-	-	2,430	869	1,561	1,251	-	310	
12	-	-	2,430	869	1,561	1,251	-	310	
13	-	-	2,430	869	1,561	1,251	-	310	
14	-	-	2,430	869	1,561	1,251	-	310	
15	-	-	2,430	869	1,561	1,251	-	310	
16	-	-	2,430	869	1,561	1,251	-	310	
17	-	-	2,430	869	1,561	1,251	-	310	
18	-	-	2.430	869	1,561	1,251	-	310	
26	-	-	2,430	869	1,561	1,251	-	310	

Table 16 Sediment Balances of Before and After Master Plan Implementation

(4') K. Lamat

Unit: $10^3 m^3$/year

Distance from the Summit	Before			After Implementation of the Plan					Remarks
	Proposed Volume of Sediment by Types			Proposed volume of Sediment by Types					
(Km)	Produced (A)	Controlled (C)	Discharged (G =Σ(A-C))	Production Reduced ΣB (B)	Discharged (I = G -ΣB)	Discharge Reduced (D)	Controlled (E)	Discharged (J=I-Σ(D+E))	
4	-	-	-	-	-	-	-	-	
5	30	-	30	-	30	-	-	30	
6	50	15	65	-	65	-	-	65	
7	89	20	134	-	134	-	-	134	
8	40	25	149	-	149	-	-	149	
9	60	30	179	-	179	-	-	179	
10	100	40	239	-	239	-	-	239	
11	50	45	244	-	244	-	-	244	
12	40	50	234	24	210	-	41	169	
20	-	-	234	24	210	-	41	169	

(5) K. Woro

Unit: $10^3/m^3$/year

Distance from the Summit	Before			After Implementation of the Plan					Remarks
	Proposed Volume of Sediment by Types			Proposed Volume of Sediment by Types					
(Km)	Produced (A)	Controlled (C)	Discharged (G = Σ(A-C))	Production Reduced ΣB (B)	Discharged (I = G - ΣB)	Discharge Reduced (D)	Controlled (E)	Discharged (J-I- Σ(D+E))	
3	1,157	4	1,153	-	1,153	-	-	1,153	
4	133	20	1,266	-	1,266	-	-	1,266	
5	468	40	1,694	98	1,596	-	-	1,596	
6	806	52	2,448	433 (335)	2,015	-	-	2,015	
7	659	62	3,045	911 (478)	2,134	-	-	2,232	
8	559	80	3,524	1,403 (492)	2,121	-	-	2,219	
9	253	144	3,663	1,602 (199)	2,031	-	-	2,129	
10	184	86	3,731	1,737 (135)	1,994	-	-	2,092	
14	-	-	3,731	1,737	1,994	-	-	2,092	
17	-	-	3,731	1,737	1,994	1,560	-	384	
24	-	-	3,731	1,737	1,994	1,988 (428)	-	6	
28.5	-	-	3,731	1,737	1,994	1,988	-	6	

Table 16 Sediment Balances of Before and After Master Plan Implementation

(6) K. Gendol

Unit: $10^3 m^3$/year

Distance from the Summit	Before			After Implementation of the Plan					Remarks
	Proposed Volume of Sediment by Types			Proposed Volume of Sediment by Types					
(Km)	Produced (A)	Controlled (C)	Discharged (G = Σ(A-C))	Production Reduced ΣB (B)	Discharged (I = G - ΣB)	Discharge Reduced (D)	Controlled (E)	Discharged (J-I-Σ(DE))	
5	1,333	24	1,309	-	1,309	-	-	1,309	
6	149	34	1,424	112	1,312	-	-	1,312	
7	515	54	1,885	305 (193)	1,580	-	-	1,580	
8	403	72	2,216	510 (205)	1,706	-	-	1,706	
9	185	66	2,335	752 (242)	1,583	-	-	1,583	
10	109	32	2,412	752 (-)	1,660	-	-	1,660	
11	214	56	2,570	921 (169)	1,649	-	-	1,649	
12	116	60	2,626	1,071 (150)	1,555	-	-	1,555	
13	134	70	2,690	1,179 (108)	1,511	-	-	1,511	
14	-	-	2,690	1,179	1,511	199		1,312	
15	-	-	2,690	1,179	1,511	199		1,312	
16	-	-	2,690	1,179	1,511	199		1,312	
17	-	-	2,690	1,179	1,511	199		1,312	
18	-	-	2,690	1,179	1,511	1,301 (1,102)		210	
19	-	-	2,690	1,179	1,511	1,301		210	

(7) K. Boyong

Unit: $10^3/m^3$/year

Distance from the Summit	Beofre			After Implementation of the Plan					Remarks
	Proposed Volume of Sediment by Types			Proposed Volume of Sediment by Types					
(Km)	Produced (A)	Controlled (C)	Discharged (G = Σ(A-C))	Production Reduced ΣB (B)	Discharged (I = G - ΣB)	Discharge Reduced (D)	Controlled (E)	Discharged (J=I-Σ(D+E))	
5	79	-	79	-	79	-	-	79	
6	75	20	134	-	134	-	-	134	
7	414	80	468	-	468	-	-	468	
8	94	55	507	-	507	-	42	465	
9	189	78	618	68	550	-	96 (54)	454	
10	271	65	824	364 (296)	460	-	213 (117)	247	
11	107	75	856	447 (83)	409	-	243 (30)	166	
12	118	63	911	447 -	464	-	243 -	221	
13	90	87	914	515 (68)	399	-	310 (67)	89	
42	-	-	-	-	-	-	-	-	

Table 16 Sediment Balances of Before and After Master Plan Implementation

(8) K. Kuning

Unit: $10^3 m^3$/year

Distance from the Summit	Before			After Implementation of the Plan					Remarks
	Proposed Volume of Sediment by Types			Proposed Volume of Sediment by Types					
(Km)	Produced (A)	Controlled (C)	Discharged (G =Σ(A-C))	Production Reduced ΣB (B)	Discharged (I = G - ΣB)	Discharge Reduced (D)	Controlled (E)	Discharged (J=I-Σ(D+E))	
5	488	-	488	-	488	-	-	488	
6	133	25	596	-	596	-	-	596	
7	99	33	662	-	662	-	-	662	
8	64	67	659	-	659	-	60	599	
9	213	105	767	383	384	-	115 (55)	269	
10	207	150	824	537 (154)	287	-	346 (231)	0	
11	118	135	807	537	270	-	346	0	
12	173	130	850	622 (85)	228	-	456 (110)	0	
13	349	85	1,114	622	492	-	456	36	
23	-	-	1,114	622	492	-	456	36	
30	-	-	1,114	622	492	-	456	36	

(9) K. Pabelan

Unit: $10^3 m^3$/year

Distance from the Summit	Before			After Implementation of the Plan					Remarks
	Proposed Volume of Sediment by Types			Proposed Volume of Sediment by Types					
(Km)	Produced (A)	Controlled (C)	Discharged (G = (A-C))	Production Reduced ΣB (B)	Discharged (I = G - ΣB)	Discharge Reduced (D)	Controlled (E)	Discharged (J=I-Σ(D+E))	
4	1,088	-	1,088	-	1,088	-	-	1,088	
5	535	60	1,563	56	1,507	-	35	1,472	
6	498	70	1,991	56	1,935	-	35	1,900	
7	484	130	2,345	56	2,289	-	35	2,254	
8	298	195	2,448	169 (113)	2,279	-	392 (357)	1,887	
9	414	150	2,712	306 (137)	2,406	-	555 (163)	1,851	
10	263	170	2,805	395 (89)	2,410	-	905 (350)	1,505	
11	310	278	2,837	613 (218)	2,224	-	1,647 (742)	577	
12	301	305	2,833	660 (47)	2,173	-	1,776 (129)	397	
13	19	20	2,832	660	2,172	-	1,776	396	
14	-	65	2,767	660	2,107	-	1,776	331	
23	-	-	2,767	660		-	1,776	331	
30	-	-	2,767	660		-	1,776	331	

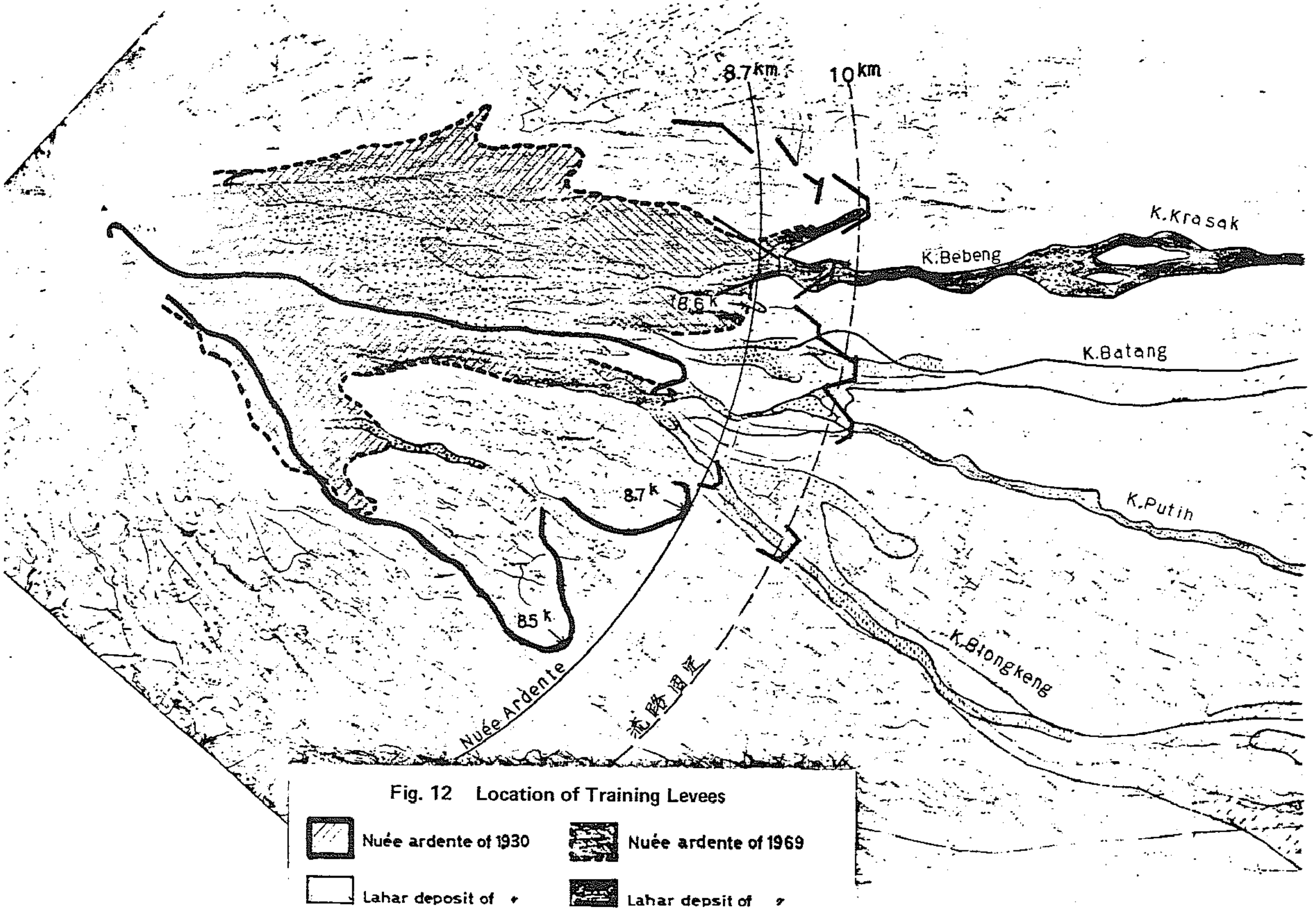
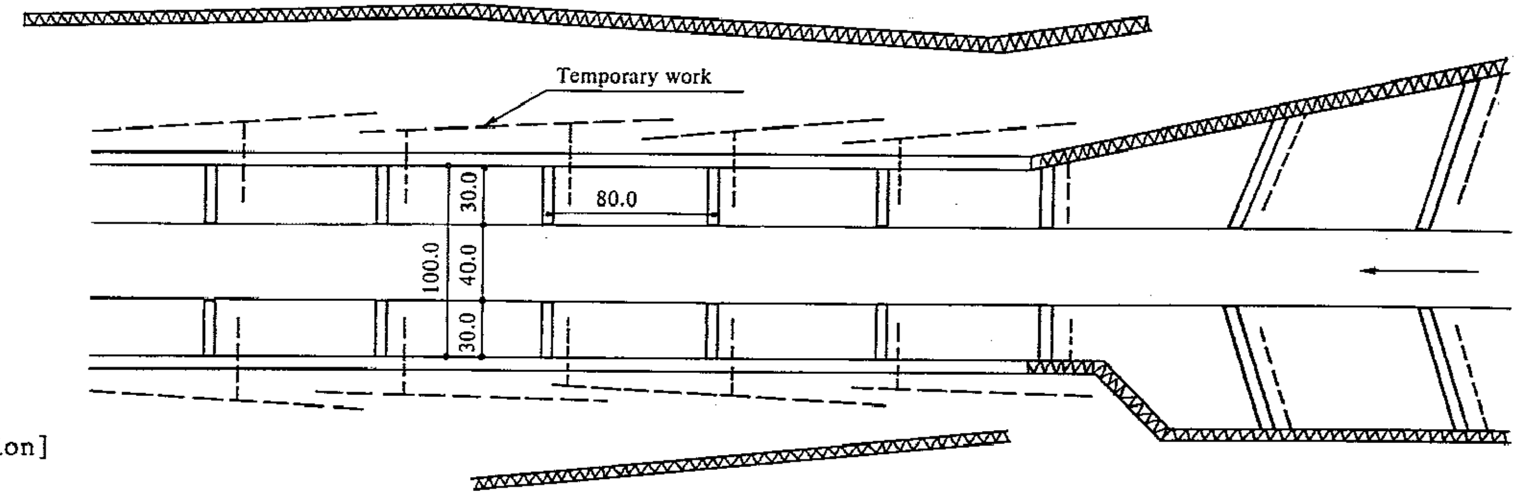


Fig. 12 Location of Training Levees

Fig. 13 River Course Improvement Plan (between 20km and 24km)

[Location]



[Cross Section]

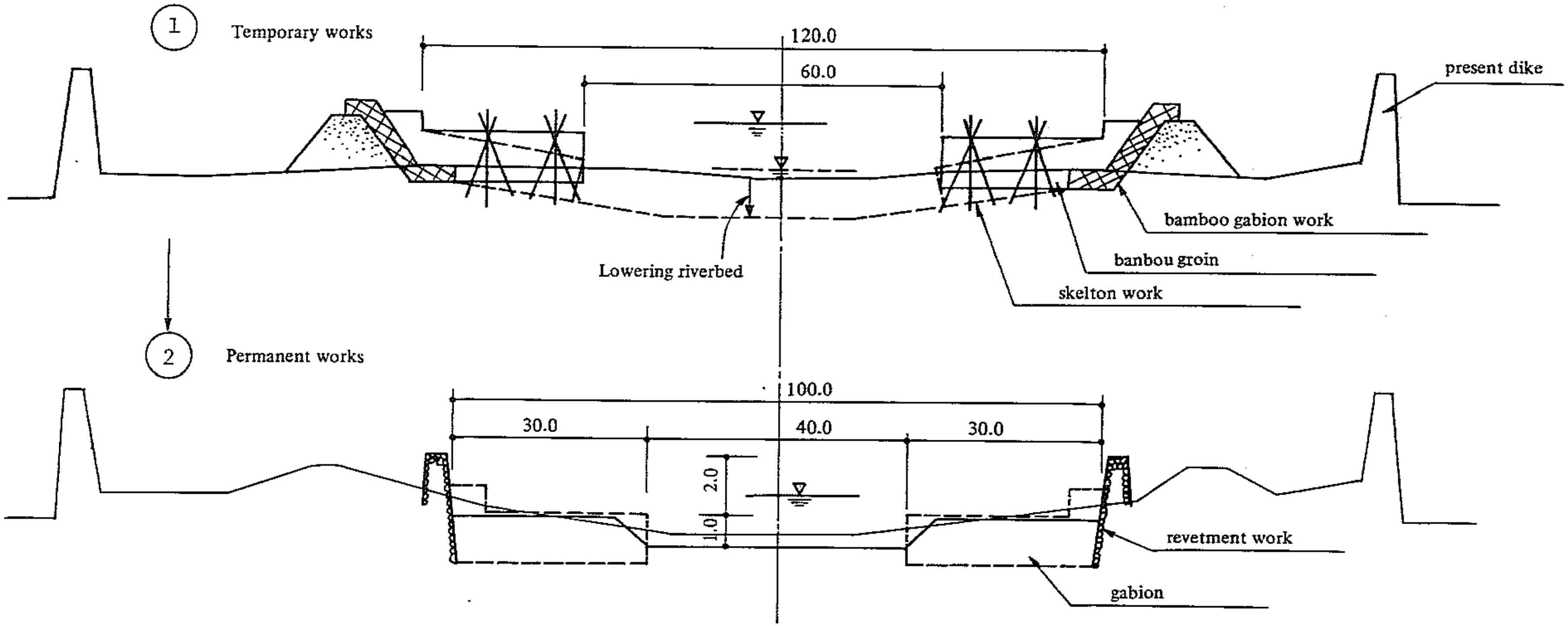
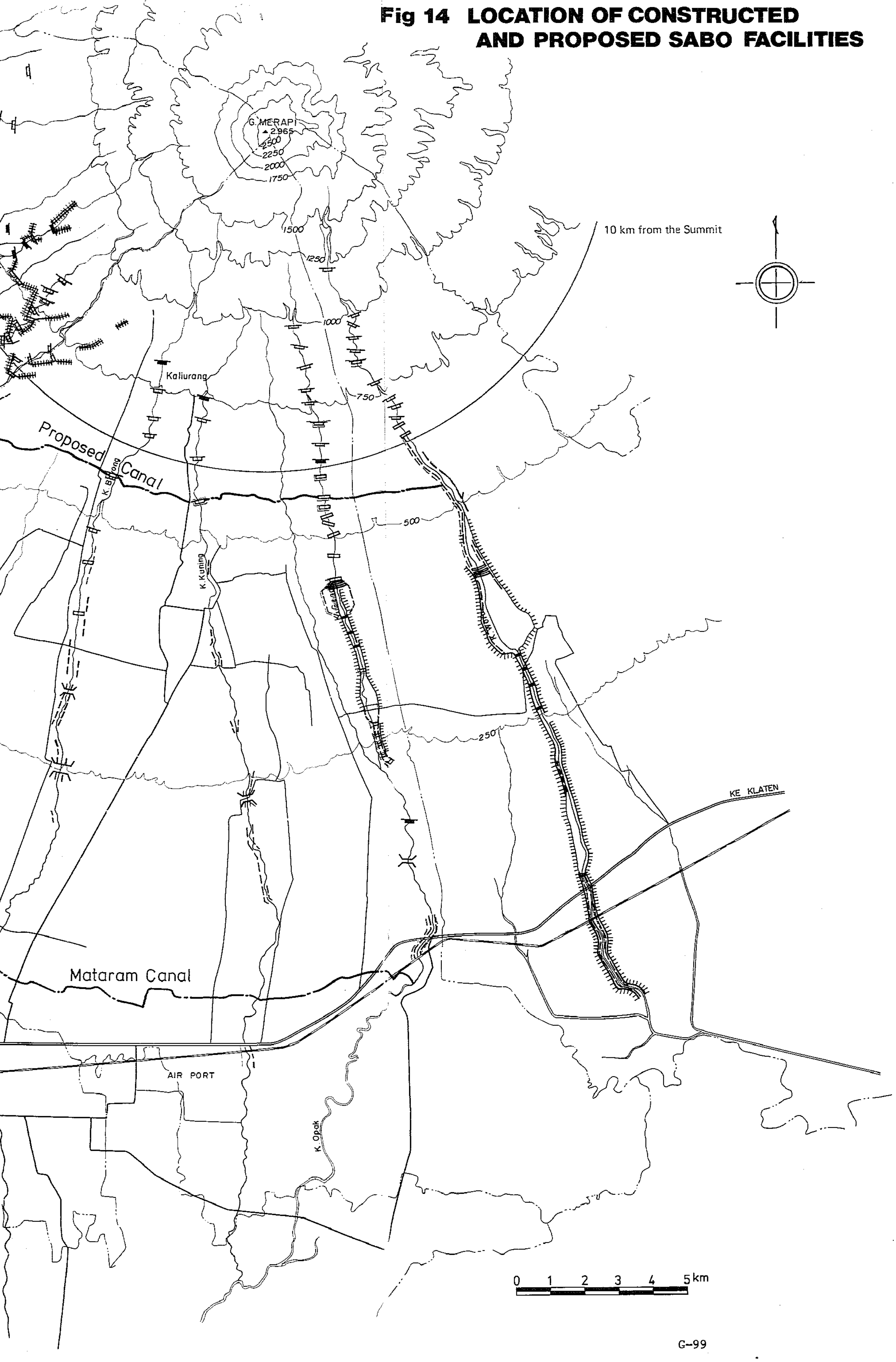


Fig 14 LOCATION OF CONSTRUCTED AND PROPOSED SABO FACILITIES



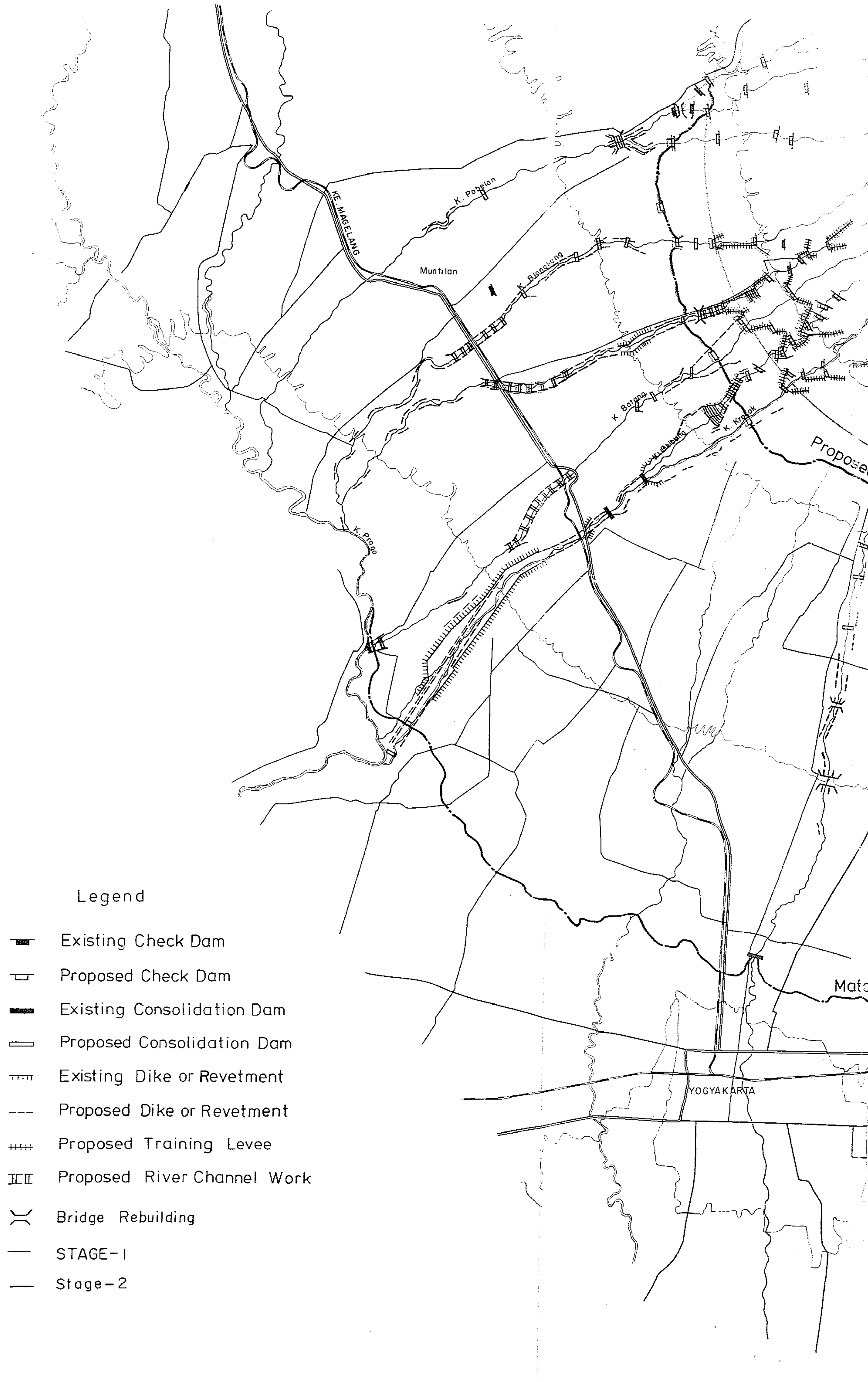
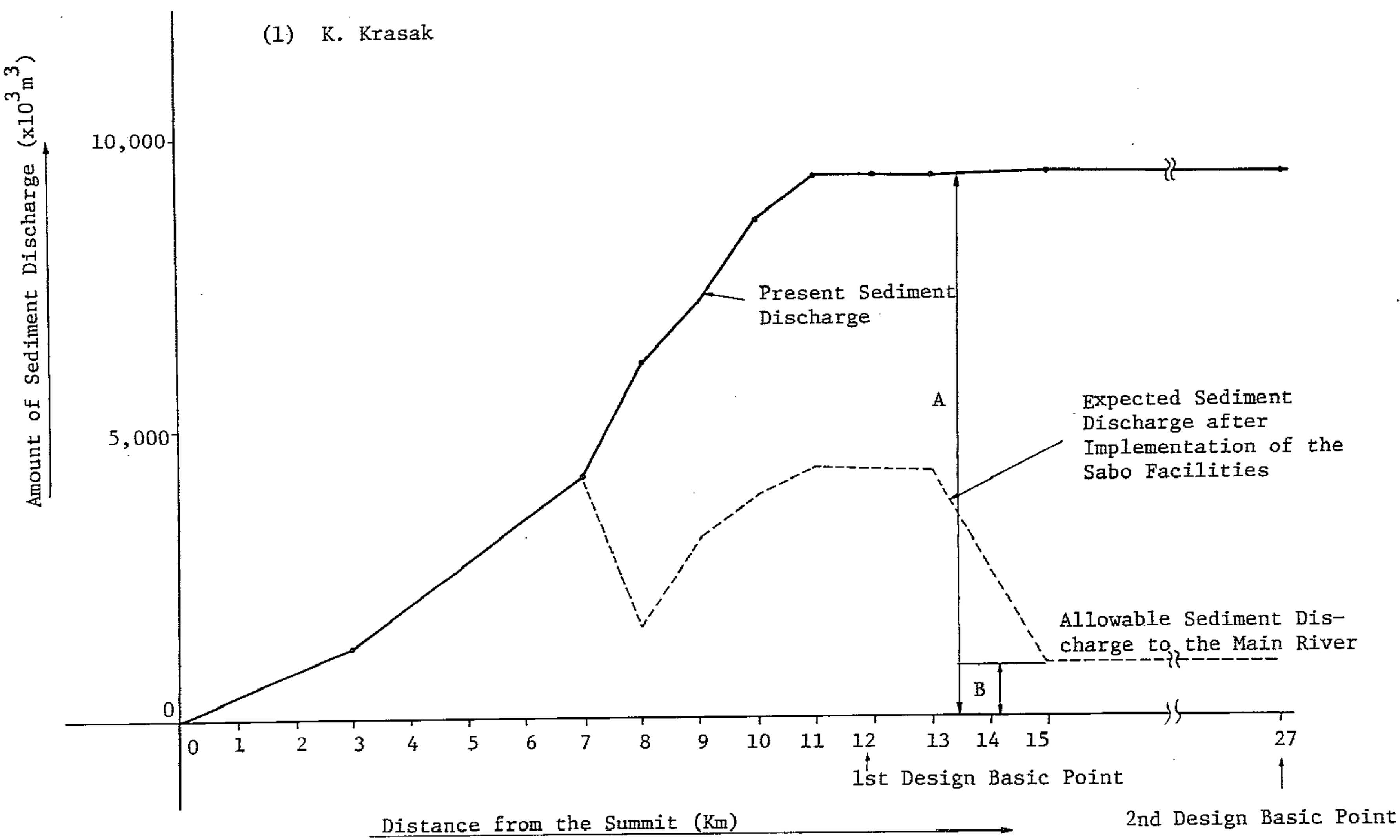

KE. MAGELANG
K. Pabelan
Muntilan
K. Blongkeng
K. Batang
K. Krasak
K. Progo
Propose
Mata
YOGYAKARTA
Legend
Existing Check Dam
Proposed Check Dam
Existing Consolidation Dam
Proposed Consolidation Dam
Existing Dike or Revetment
Proposed Dike or Revetment
Proposed Training Levee
Proposed River Channel Work
Bridge Rebuilding
STAGE-1
Stage-2

Fig. 15 Effect of Sabo Facilities on Sediment Discharge

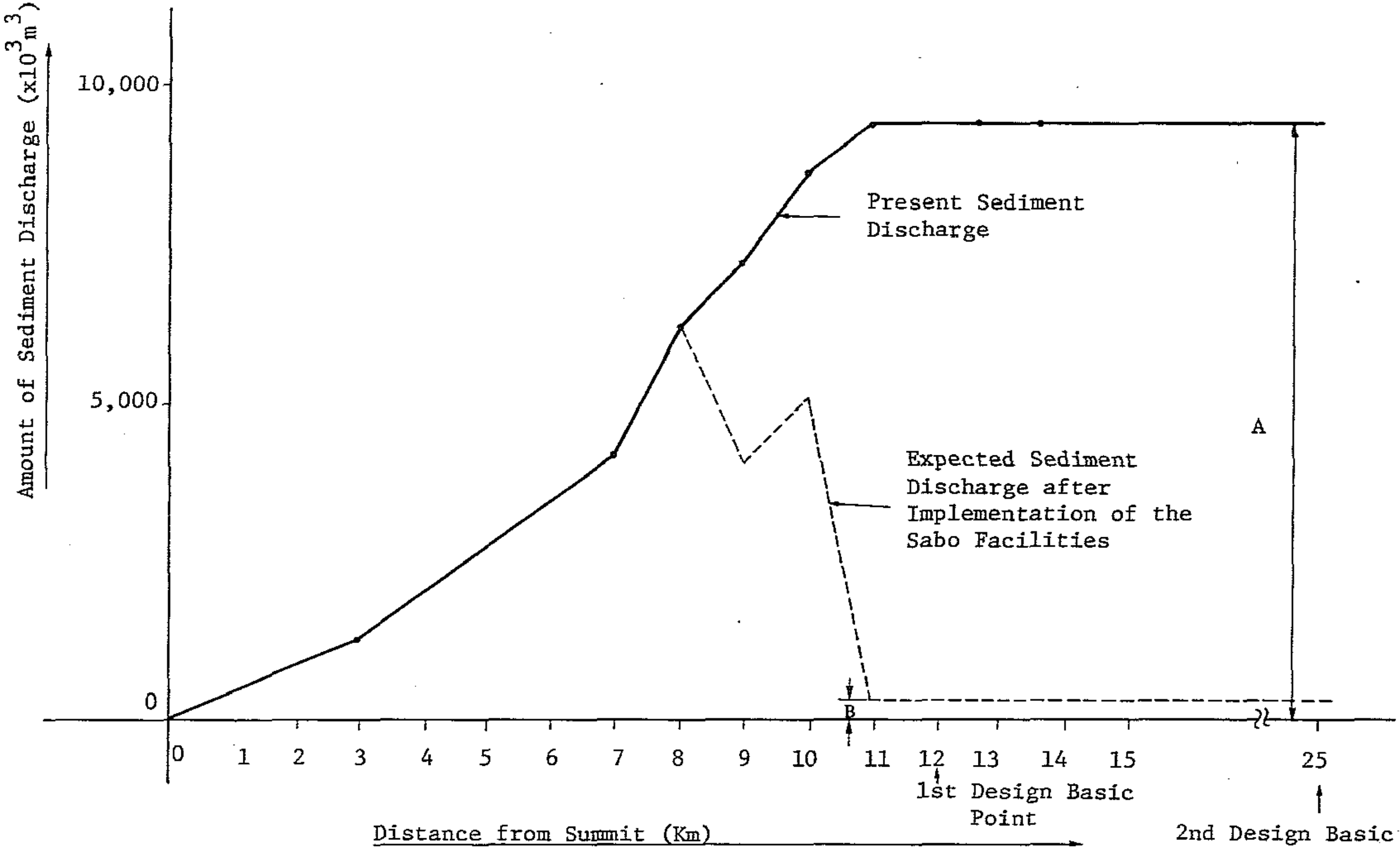
(1) K. Krasak



A: Proposed Amount of Sediment to be produced
B: Allowable Amount of Sediment Discharge to the Main River

Fig. 15 Effect of Sabo Facilities on Sediment Discharge

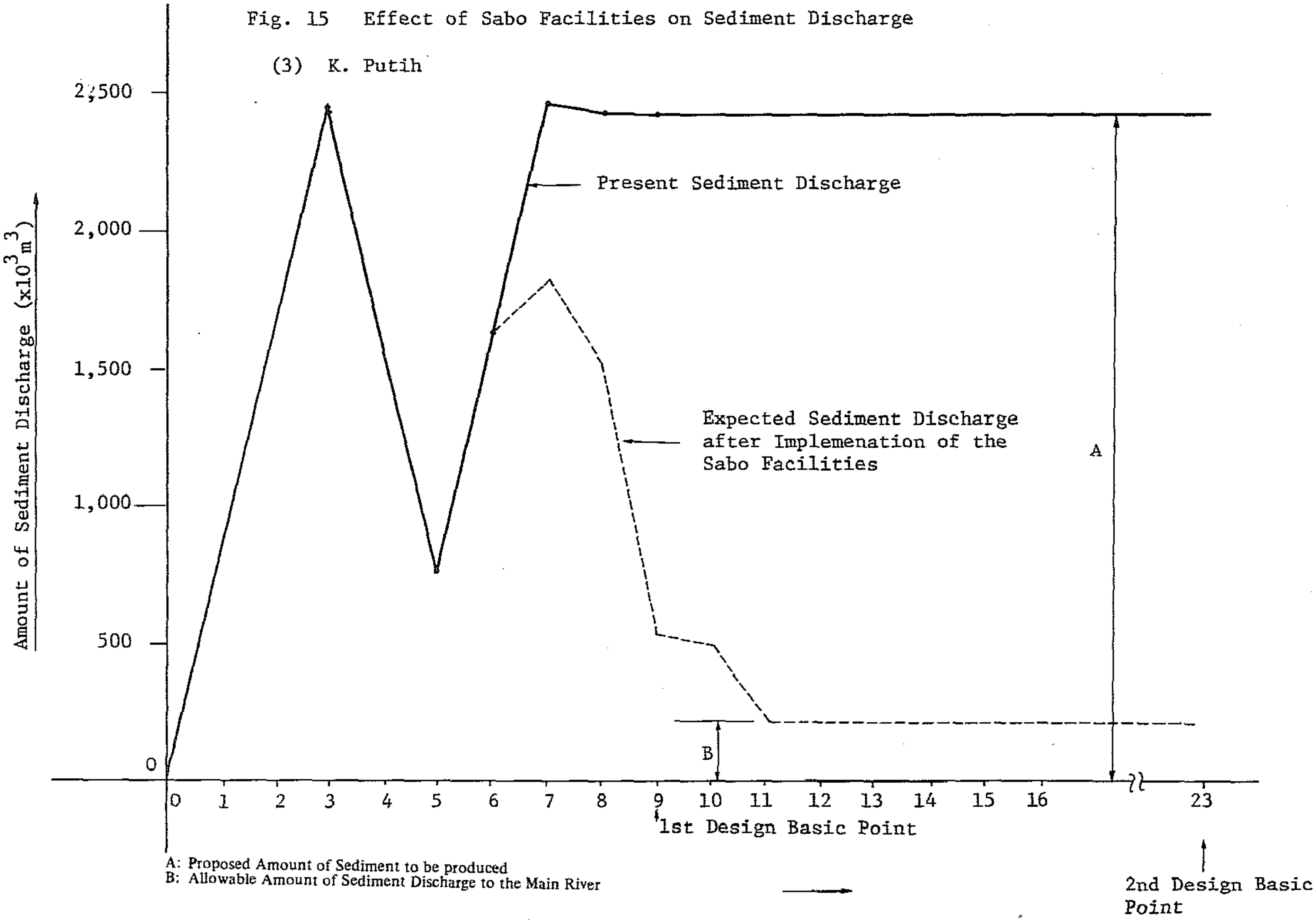
(2) K. Batang



A: Proposed Amount of Sediment to be produced
B: Allowable Amount of Sediment Discharge to the Main River

Fig. 15 Effect of Sabo Facilities on Sediment Discharge

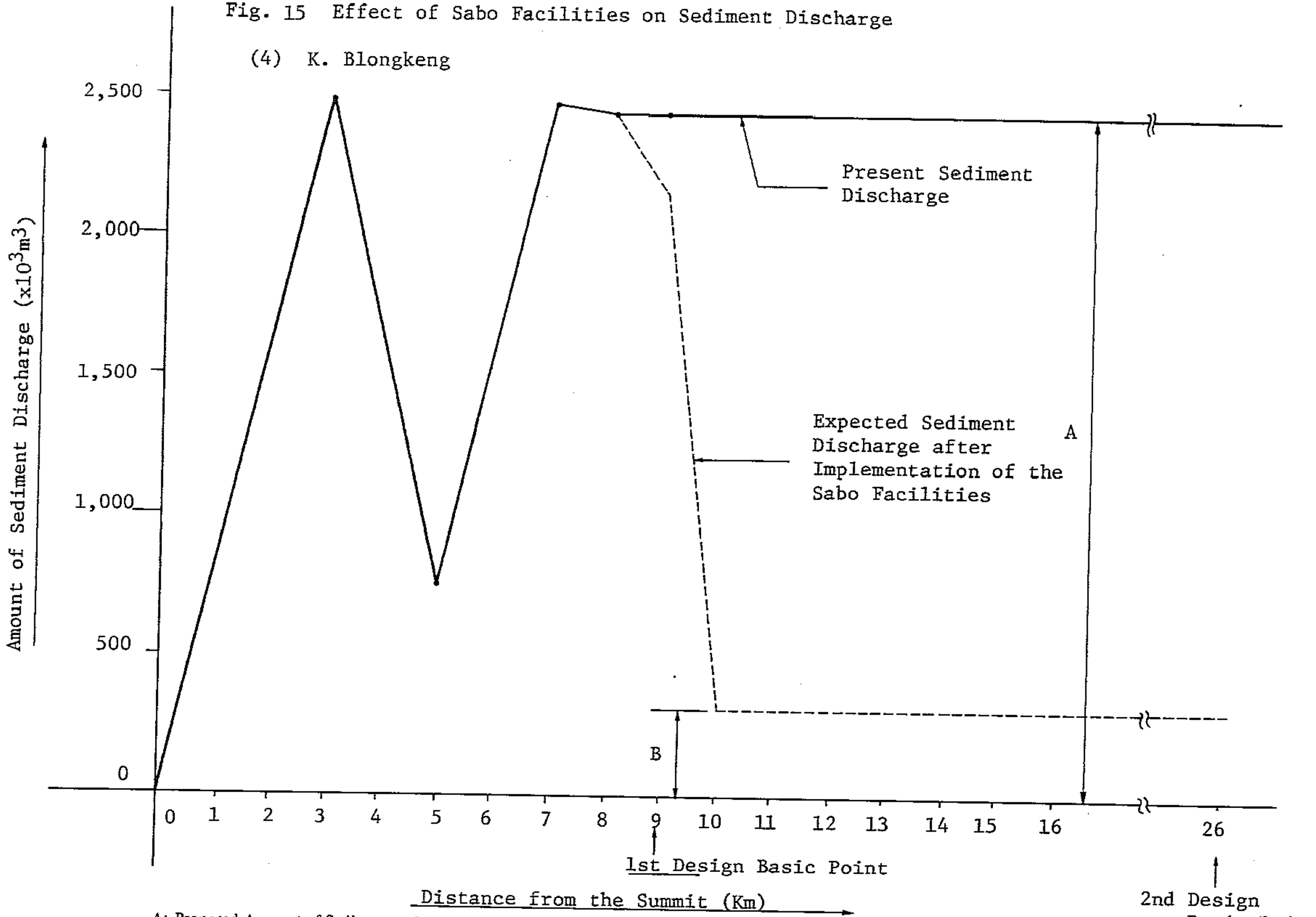
(3) K. Putih



A: Proposed Amount of Sediment to be produced
B: Allowable Amount of Sediment Discharge to the Main River

Fig. 15 Effect of Sabo Facilities on Sediment Discharge

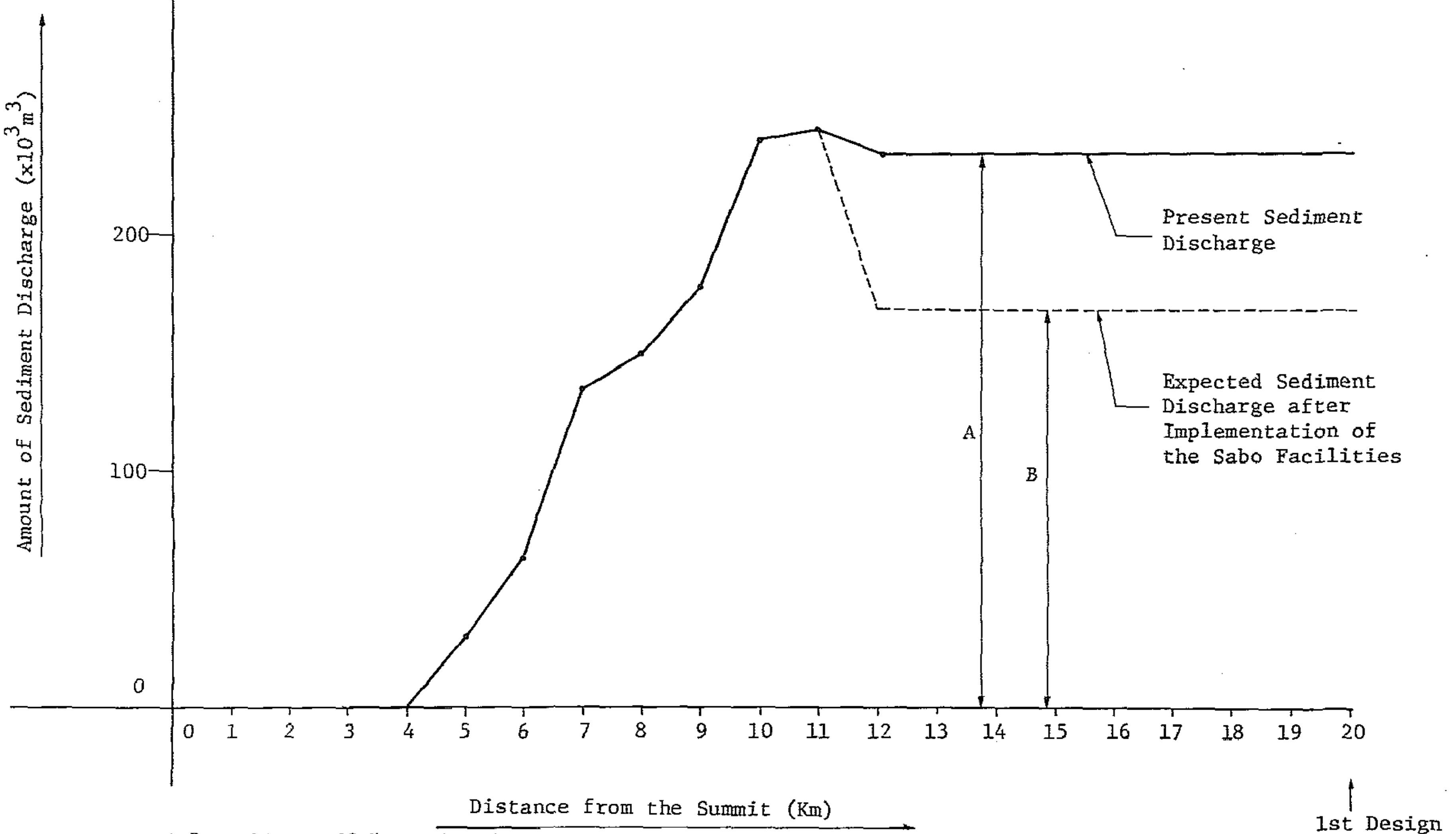
(4) K. Blongkeng



A: Proposed Amount of Sediment to be produced
B: Allowable Amount of Sediment Discharge to the Main River

Fig. 15 Effect of Sabo Facilities on Sediment Discharge

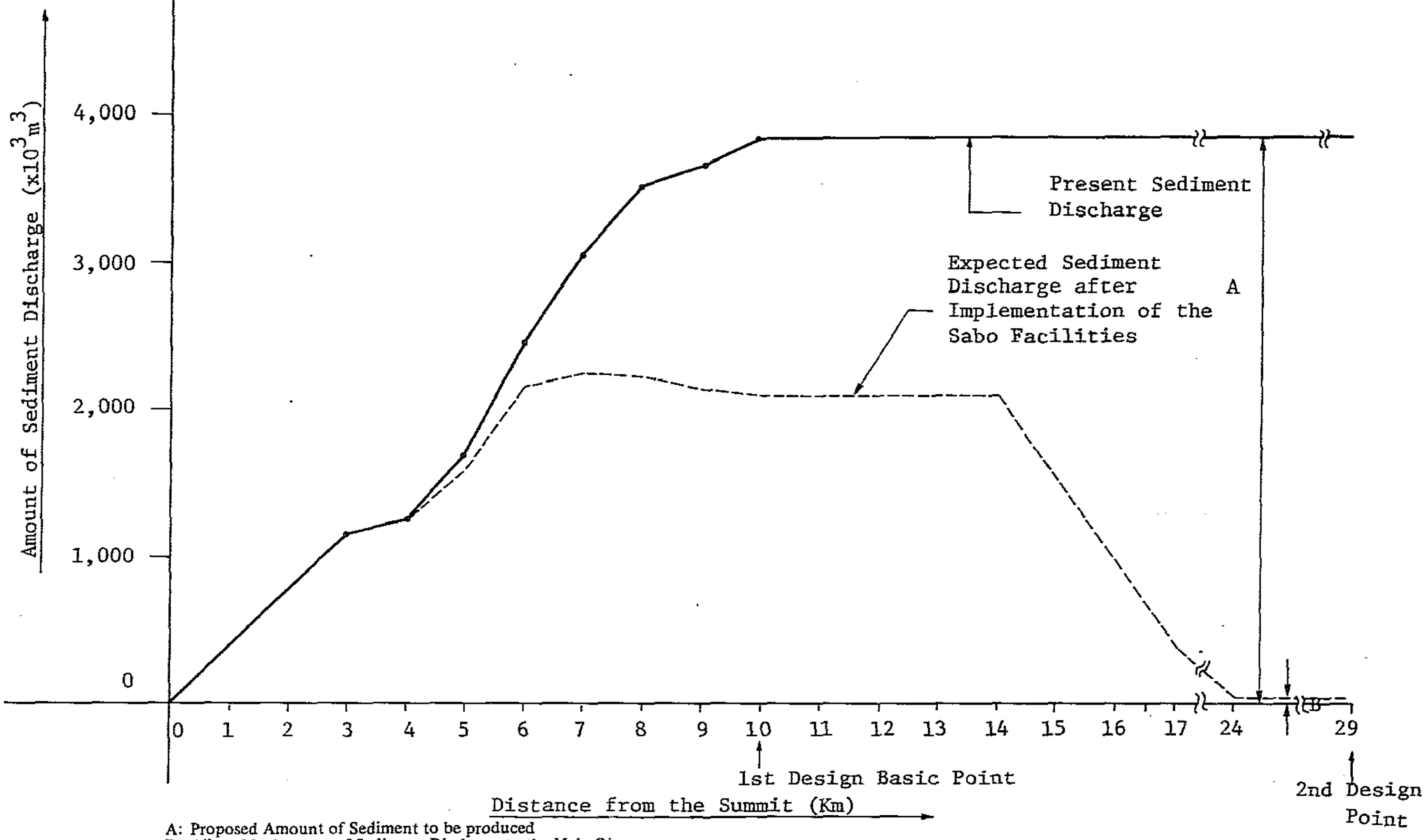
K. Lamat



A: Proposed Amount of Sediment to be produced
B: Allowable Amount of Sediment Discharge to the Main River

Fig. 15 Effect of Sabo Facilites on Sediment Discharge

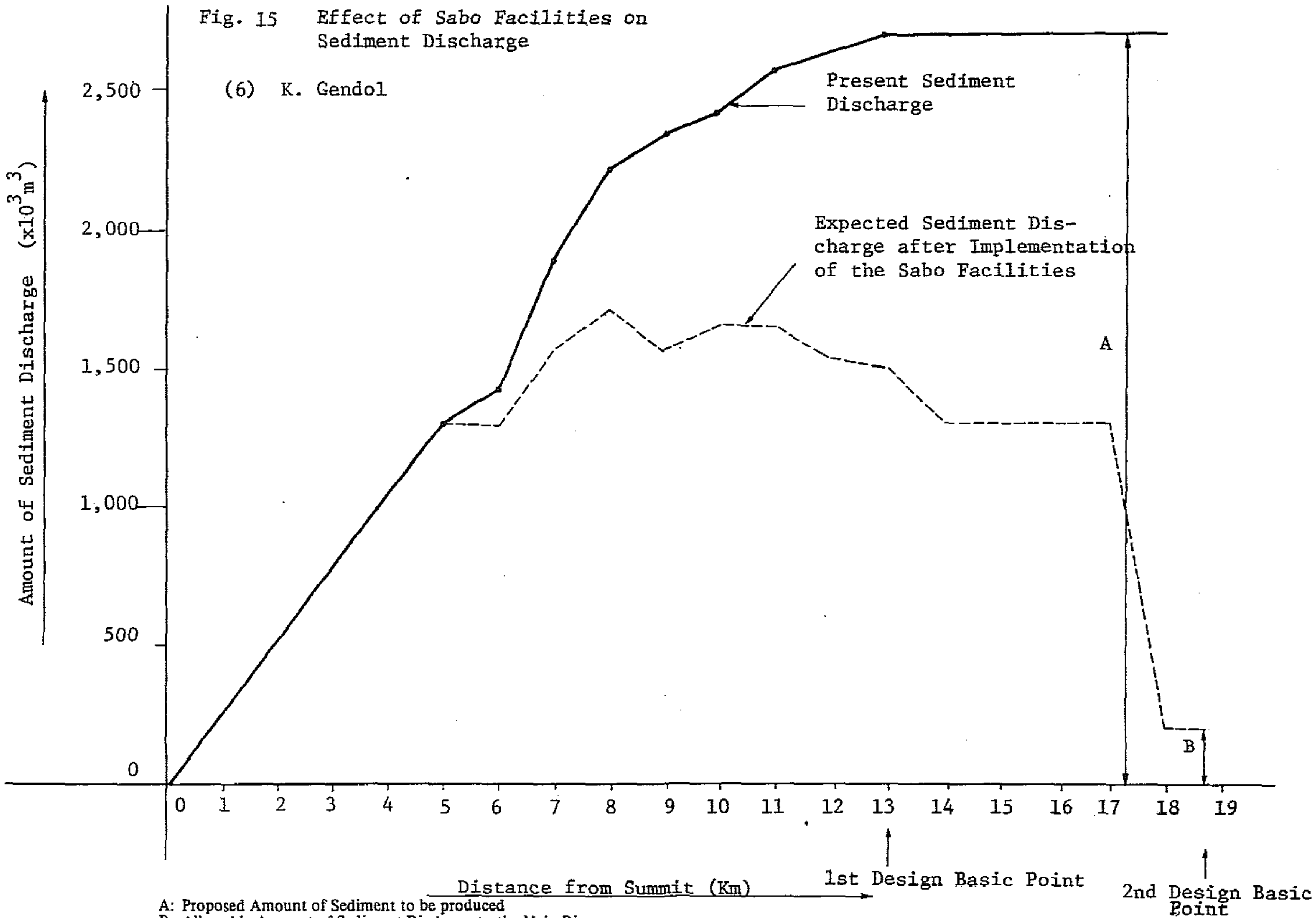
(5) K. Woro



A: Proposed Amount of Sediment to be produced
B: Allowable Amount of Sediment Discharge to the Main River

Fig. 15 Effect of Sabo Facilities on Sediment Discharge

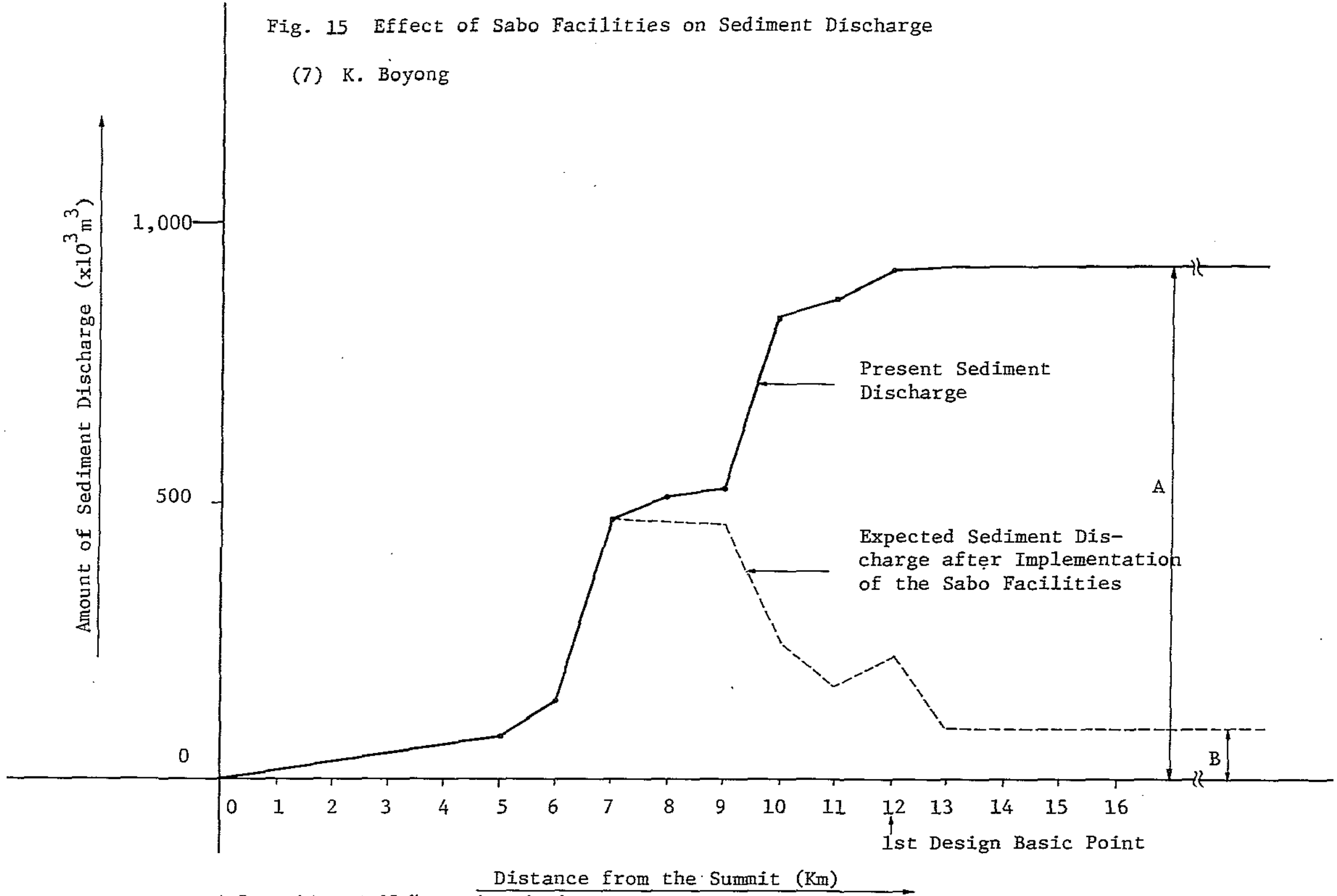
(6) K. Gendol



A: Proposed Amount of Sediment to be produced
B: Allowable Amount of Sediment Discharge to the Main River

Fig. 15 Effect of Sabo Facilities on Sediment Discharge

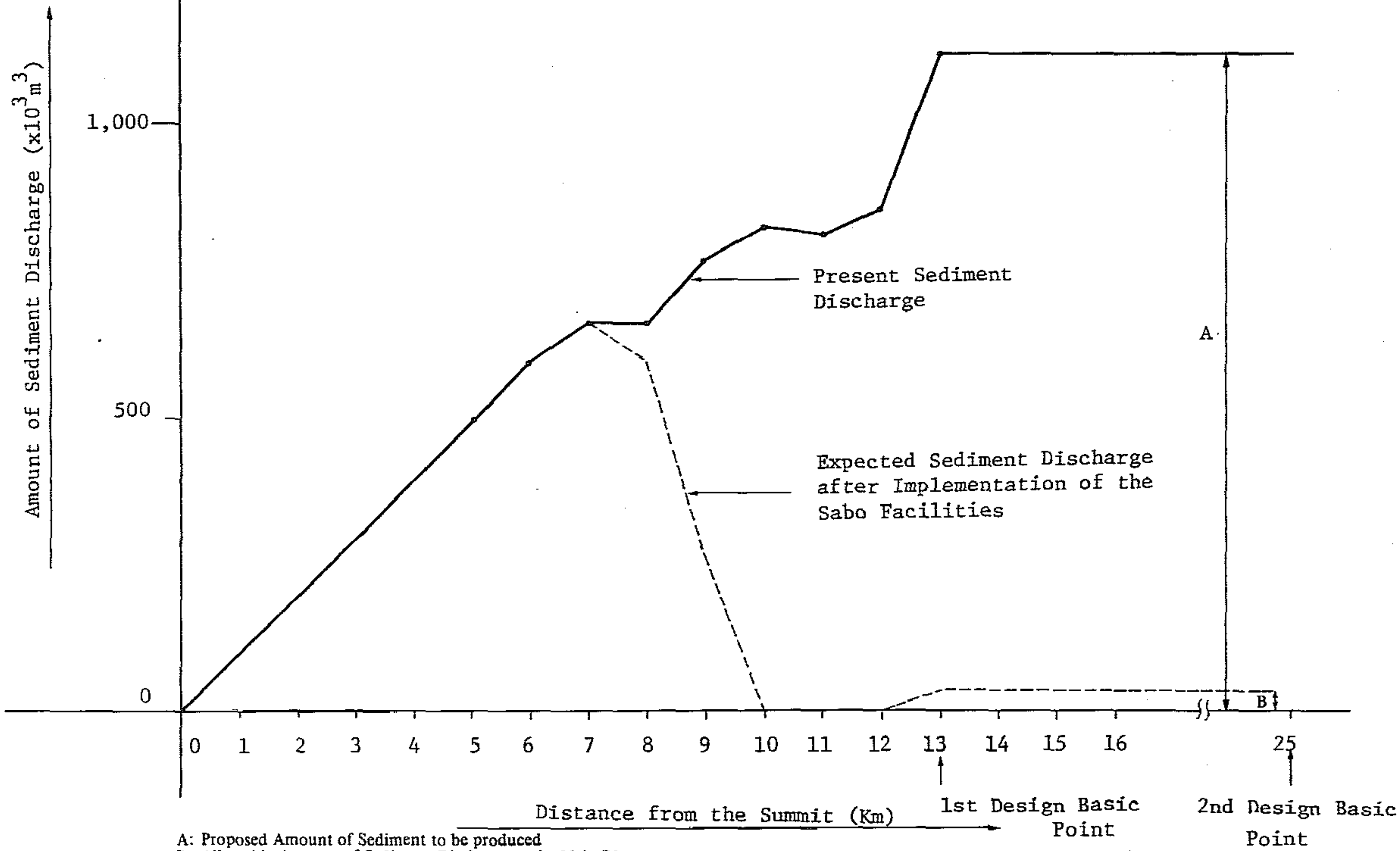
(7) K. Boyong



A: Proposed Amount of Sediment to be produced
B: Allowable Amount of Sediment Discharge to the Main River

Fig. 15 Effect of Sabo Facilities on Sediment Discharge

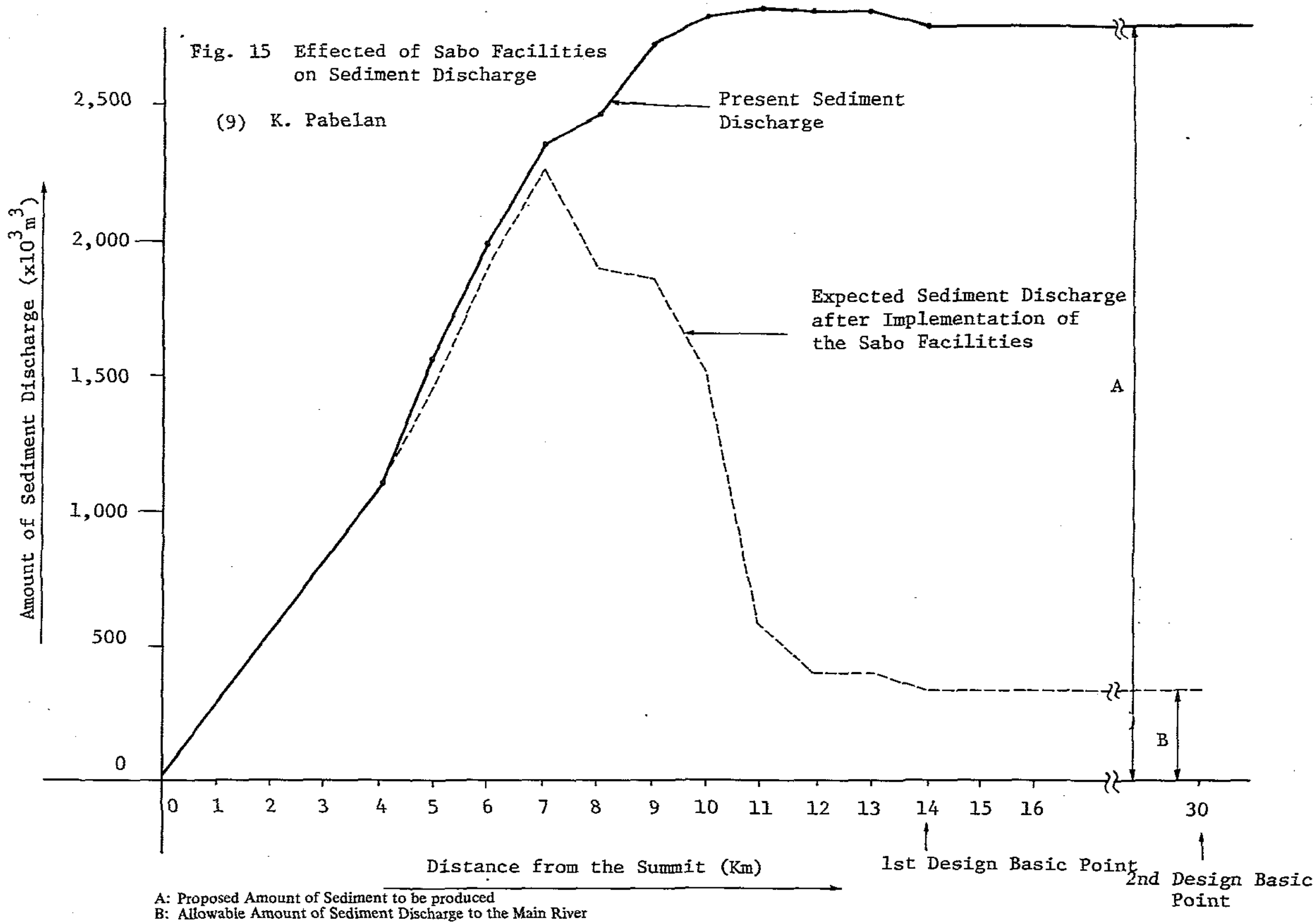
(8) K. Kuning



A: Proposed Amount of Sediment to be produced
B: Allowable Amount of Sediment Discharge to the Main River

Fig. 15 Effected of Sabo Facilities on Sediment Discharge

(9) K. Pabelan



2.3.6 Effects for Reducing Sediment Discharge and Decreasing Hazand Areas

The effects are summarized in Tables 17 and 18 and Fig. 16.

1) Reducing effects of Sediment discharge by the plan.

a) Reduction Amount in total tributaries Area After the construction of sabo facilities

The present amount of possible sediment discharge 34,976 x 10^3 m^3 will be reduced 92.5 % to 2,606 x 10^3 m^3.

b) Reduction Amount to K. Progo and K. Opak.

By the implementation of sabo facilities at tributaries area, the amounts of sediment discharge will be decreased 84 ∿ 93 %. (See Table 17)

(1) K. Progo

The scale of major sediment discharge, 12,715 x 10^3 m^3 from the type 2 area will be reduced 2,090 x 10^3 m^3.

(2) K. Opak

The scale of major sediment discharge of 4,718 x 10^3 m^3 from K. Boyong, K. Kuning and K. Gendol will be decreased 93 % to 340 x 10^3 m^3.

(3) K. Dengkeng

In the case of K. Dengkeng, sabo facilities are planned to maintain the effects of existing sand pockets with which Amounts of sediment discharge from K. Woro are controlled or reduced to the allowable amount for K. Dengkeng. The reduced amounts of sediment discharge are not estimated.

2) Reducing effects in hazard Area.

After the implementation of the facilities, the possible hazard areas of depress 4 and 5 will be safe and the zone-3 hazard area of 286 km^2 will be decreased approximately 47 % to 134.6 km^2. (See Table 18 and Fig. 16)

Table 17 Amount of Sediment discharge to the Main Rivers

unit: $10^3 m^3$

Name of Rivers		Sediment Discharge from Tributaries Estimated			
		Before Implementation	After Implementation	Reducted Amount	Ratio of Reduction
K. Progo	K.Pabelang	340	340	0	- (%)
	K.Blongkeng	310	310	0	-
	K.Putih	2,430 1/	260	2,170	89
	K.Batang	280	280	0	-
	K.Krasak	9,355 1/	900	8,455	90
	Total	12,715	2,090	10,625	84
K. Opak	K.Boyong	914	90	824	90
	K.Kuning	1,114	40	1,074	96
	K.Gendol	2,690	210	2,480	92
	Total	4,718	340	4,378	93

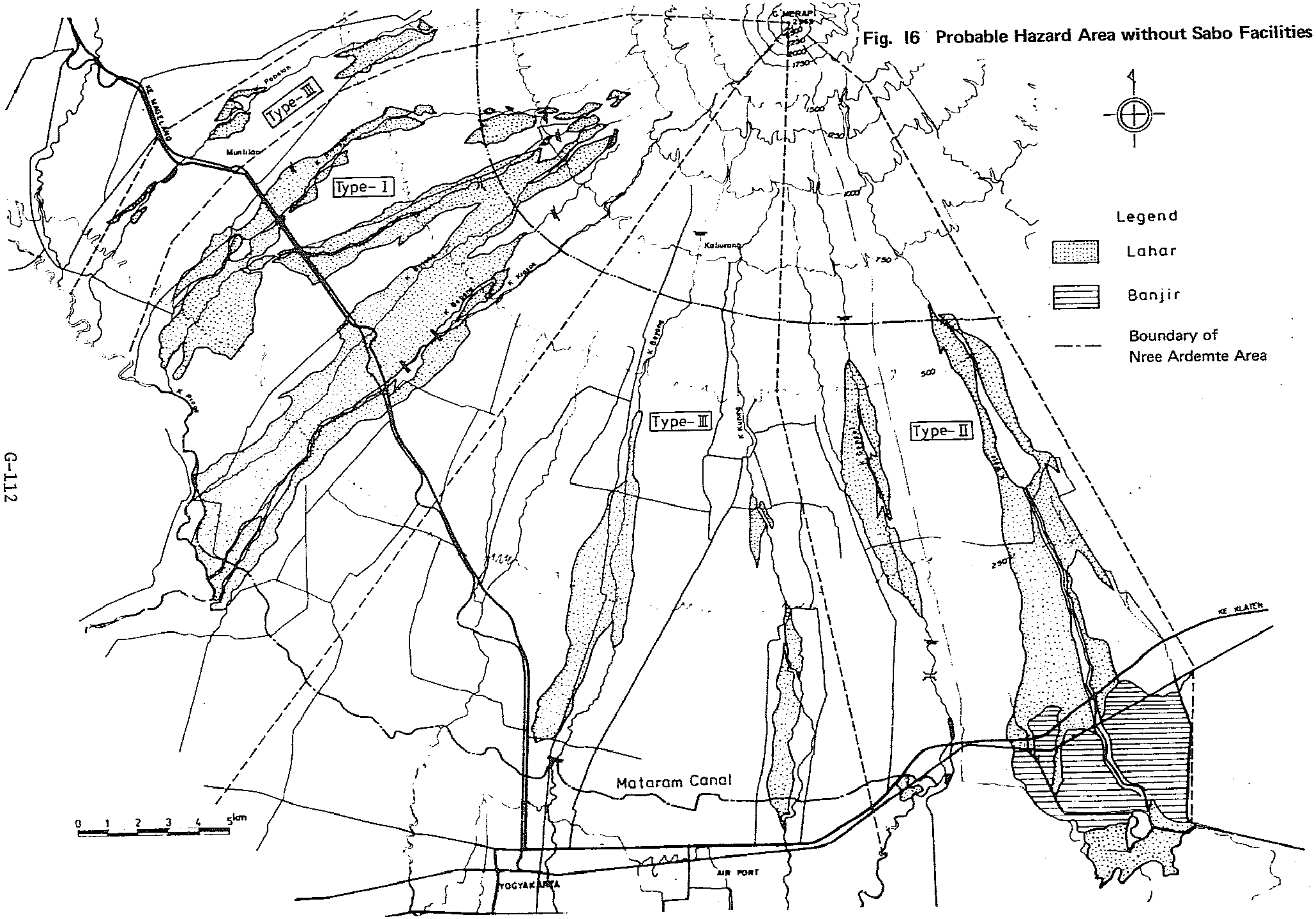
Note:

1/ Proposed amount of Sediment discharged assumed from K.Krasak and K.Putih since flooding will follow either the K.Putih - K.Krasak system or K.Pabelan - K.Blongkeng - K.Batang system.

Table 18 Probable Hazard Areas without Sabo Facilities

	Name of Rivers	Degree of Danger-5 (x 10^3 m^2)	Degree of Danger-4 (x 10^3 m^2)	Total (x 10^3 m^2)
Type-I	K.Krasak	13,836	4,402	18,238
	K.Batang	11,439	6,661	18,100
	K.Putih	8,329	6,688	15,017
	K.Blongkeng	2,283	8,261	10,544
	Sub-Total	35,887	26,012	61,899
Type-II	K.Woro	45,702	-	45,702
	K.Gendol	6,936	-	6,936
	Sub-Total	52,638	-	52,638
Type-III	K.Poyong	11,481	-	11,481
	K.Kuning	4,475	-	4,475
	K.Pabelan	4,153	-	4,153
	Sub-Total	20,109	-	20,109
	Total	108,634	26,012	134,646

Fig. 16 Probable Hazard Area without Sabo Facilities



2.3.7 Construction Cost Estimates

1) General

The construction costs of the present plan have been estimated as follows for the purpose of economic assessment of the plan:

a) The construction costs are based on the quantities of materials to be used, and the prices of labor and materials those cited by the Merapi Office for fiscal 1979.

b) The only contigency costs that have been considered are those for construction quantities, at a rate of 15 % of direct construction costs. In other words, no contingency costs have been considered for rise in the prices of materials purchased due to inflation.

c) *Expenses for Administrative/Overhead, and Consulting Services* have each been taken as 10 % of the sum of the direct construction costs and the contingency costs referred to in b) above.

d) The total construction cost has been taken as the sum of a), b), and c) above.

e) Maintenance and management costs have been taken as the annual average (one-fifteenth) of the total construction costs, starting from the sixteenth year and for a duration of 35 years.

2) Estimated Figures

The total construction cost for the disaster prevention facilities has been estimated at Rp 39,379 million (see Table 19 for details), and the annual maintenance and management cost has been estimated at Rp 394 million.

Table 19 Summary of Constraction Costs of Sabo Facilities

unit: Rp.1,000

	Name of Rivers	Check Dams	Consolida-tation Dams	Embank-ments and Revements	Training Levee	Groin	Bridges	Others	Civil Work Sub-Total	Contin-gencies	Administ-ration and Overhead	Consulting Services	Total
Type-I	K. Krasak	3,579,000	620,760	1,429,220	1,049,580	310,500	–	13,380	7,002,440	1,050,360	805,280	805,280	9,663,360
	K. Batang	623,000	953,600	925,890	370,440	62,100	–	–	2,935,030	440,260	337,530	337,530	4,050,350
	K. Putih	670,600	783,600	982,880	676,200	136,620	–	–	3,249,900	487,490	373,740	373,740	4,484,870
	K. Blongkong	479,000	888,000	832,300	327,810	107,640	–	–	2,634,750	395,210	302,990	302,990	3,635,940
	Sub-Total	5,351,600	3,245,960	4,170.290	2,424,030	616,860	–	13,380	15,822,120	2,373,320	1,819,540	1,819,540	21,834,520
Type-II	K. Woro	2,486,400	367,100	1,046,350	–	207,000	–	–	4,106,850	616,030	472,290	472,290	5,667,460
	K. Gendol	1,825,600	850,280	611,800	–	53,820	–	–	3,341,500	501,230	384,270	384,270	4,611,270
	Sub-Total	4,312,000	1,217,382	1,658,150	–	260,820	–	–	7,448,350	1,117,260	856,560	856,560	10,278,730
Type-III	K. Boyong	729,400	170,800	264,440	–	–	100,000	–	1,264,640	189,700	145,430	145,430	1,745,200
	K. Kuning	586,600	–	573,250	–	–	50,000	–	1,209,850	181,480	139,130	139,130	1,669,590
	K. Pabelan	2,238,400	100,800	345,600	–	6,210	100,000	–	2,791,010	418,650	320,970	320,970	3,851,600
	Sub-Total	3,554,400	271,600	1,183,290	–	6,210	250,000	–	5,265,500	789,830	605,530	605,530	7,266,390
Total		13,218,000	4,734,940	7,011,730	2,424,030	883,890	250,000	13,380	28,535,970	4,280,410	3,281,630	3,281,630	39,379,640

Table 19-1 Sabo Facilities Construction Sosts

(1) K. Krasak

No.	Facility	Element: Type	Element: Height (m)	Element: Length (m)	Element: Volume (m^3)	Construction Cost (Rp x 1,000)	Remarks
1	BE- D.1	Check Dam			1,100	15,400	Sub Dam
2	D.2	"	6.5	85	6,000	84,000	
3	D.3	"	11.0	134	13,400	187,600	
4	D.4	"	11.5	140	18,600	260,400	
5	D.5	"	10.9	80	10,500	147,000	
6	D.6	"	7.5	88	7,800	109,200	
7	D.7	"	10.0	104	12,800	179,200	
8	D.8	"	11.0	100	12,500	175,000	
9	D.9	"	12.5	140	13,300	186,200	
10	EE- C.1 *	Consolidation Dam	4.0	630	10,500	115,500	
11	C.2 *	"	"	550	9,200	101,200	
12	C.3 *	"	"	425	7,100	78,100	
13	C.4	"	"	108.	4,100	57,400	
14	C.5	"	3.0	111	3,100	43,400	
15	C.6	"	4.0	"	3,200	44,800	
16	C.7	"	3.5	"	3,700	51,800	
17	C.8	"	4.5	118	4,100	57,400	
18	C.9	"	4.0	61	2,400	33,600	
19	BE- R.1	Revetment, Dike (B-4)	5.0	1,230		118,080	
20	R.2	(")	"	950		91,200	
21	R.3	(B-3)	3.0	600		55,800	
22	R.4	(")	"	570		53,010	
23	R.5	(D-4)	5.0	420		20,160	
24	R.6	(B-5)	3.0	750		36,000	
25	R.7	(D-3)	5.0	220		12,540	
26	BE- T.1	Training Levee	6.0	630		92,610	
27	T.2	"	"	1,000		147,000	
28	T.3	"	"	950		139,650	
29	T.4	"	"	1,070		157,290	
30	KR- D.1 **	Check Dam	14.0	190	35,400	672,600	
31	D.2	"	"	190	35,400	495,600	
32	D.3	"	14.5	178	34,600	484,400	
33	D.4	"	8.0	143	11,900	166,600	
34	D.5	"	"	155	17,200	240,800	
35	D.6	"	10.0	128	12,500	175,000	
36	KR- R.1	Revetment, Dike (D-1)	3.0	1,950		89,700	
37	R.2	(")	"	2,050		94,300	
38	R.3	(A, F)	3.0	1,100		97,900	
39	R.4	(")	"	2,050		182,450	
40	R.5	(B-1)	"	1,600		102,400	
41	R.6	(")	"	2,400		153,600	
42	R.7	(")	"	"		153,600	
43	R.8	(D-2)	"	450		17,100	
44	R.9	(")	"	330		12,540	
45	R.10	(")	"	1,140		43,320	
46	R.11	(B-5)	"	350		16,800	
47	R.12	(")	"	230		11,040	
48	R.13	(")	"	580		27,840	
49	R.14	(")	"	430		20,640	
50	R.15	(")	"	200		9,600	
51	R.16	(")	"	"		9,600	
52	KR- T.1	Training Levee	6.0	400		58,800	
53	T.2	"	"	550		80,850	
54	T.3	"	"	540		123,480	
55	T.4	"	"	840		183,750	
56	T.5	"	"	1,250		66,150	
57	KR-C.1	Consulidation Dam	4.1	69	2,100	37,560	Protection
58	KR-G	Groin	–	4,500		310,500	Work for
59	–	(Chipping the crest of head work)			13,380	13,380	Sypnone.
						7,002,440	

* unit cost : Rp.11,000/m^3

** " : Rp.19,000/m^3

(2) K. Batang

No.	Facility	Element				Construction Cost (Rp x 1,000)	Remarks
		Type	Height (m)	Length (m)	Volume (m^3)		
1	BA- D.1	Check Dam	13.0	300	22,600	316,400	
2	D.2	"	11.0	400	21,900	306,600	
3	BA- C.1	Consolidation Dam	3.0	80	4,400	61,600	
4	C.2	"	3.0	100	3,800	53,200	
5	C.3	"	3.0	80	4,400	61,600	
6	C.4	"	3.0	100	3,800	53,200	
7	C.5	"	3.0	80	3,500	49,000	
8	C.6	"	3.0	80	3,500	49,000	
9	C.7	"	3.0	100	3,800	53,200	
10	C.8	"	3.0	80	3,500	49,000	
11	C.9	"	3.0	80	3,500	49,000	
12	C.10	"	3.0	80	3,500	49,000	
13	C.11	"	3.0	100	3,800	72,200	
14	C.12	"	3.0	100	3,800	72,200	
15	C.13	"	4.0	130	4,900	68,600	
16	C.14	"	5.0	70	4,300	60,200	
17	C.15	"	4.0	70	3,500	49,000	
18	C.16	"	4.0	80	3,700	51,800	
19	C.17	"	4.0	80	3,700	51,800	
20	BA- R.1	Revetment, Dike (D-2)	3.0	450	–	24,750	
21	R.2	(D-2)	3.0	600	–	22,800	
22	R.3	(D-1)	3.0	400	–	18,400	
23	R.4	(B-2)	3.0	3,000	–	165,000	
24	R.5	(B-2)	3.0	3,100	–	170,000	
25	R.7	(D-3)	3.0	350	–	19,950	
26	R.8	(B-3)	5.0	100	–	9,300	
27	R.8	(B-3)	5.0	880	–	81,840	
28	R.9	(B-3)	5.0	850	–	79,050	
29	R.10	(B-3)	5.0	1,500	–	139,500	
30	R.11	(B-3)	5.0	1,500	–	139,500	
31	R.12	(B-3)	5.0	600	–	55,800	
32	BA- T.1	Tranining Levee	7.0	280	–	41,160	
33	T.2	"	7.0	700	–	102,900	
34	T.3	"	7.0	480	–	67,620	
35	T.4	"	7.0	520	–	76,440	
36	T.5	"	7.0	560	–	82,320	
37	BA- G	Groin	–	900	–	62,100	
	Total					2,935,030	

(3) K. Putih

No.	Facility	Element				Construction Cost (Rp. x 1,000)
		Type	Height (m)	Length (m)	Volume (m^3)	
1	PU - D.1	Check Dam	10.0	250	16,300	228,200
2	D.2	"	11.0	80	10,700	149,800
3	D.3	"	9.0	150	13,300	186,200
4	D.4	"	8.0	90	7,600	106,400
5	PU - C.1	Consolidation Dam	3.0	80	4,400	61,600
6	C.2	"	3.0	80	3,500	49,000
7	C.3	"	3.0	100	3,800	53,200
8	C.4	"	3.0	80	3,500	49,000
9	C.5	"	3.0	80	3,500	49,000
10	C.6	"	3.0	80	3,500	49,000
11	C.7	"	3.0	80	3,500	49,000
12	C.8	"	5.0	100	6,200	86,800
13	C.9	"	3.0	100	3,800	53,200
14	C.10	"	4.0	110	4,500	63,000
15	C.11	"	4.0	110	4,500	63,000
16	C.12	"	5.0	110	5,300	74,200
17	C.13*	"	6.0	270	3,600	39,600
18	C.14*	"	6.0	300	4,000	44,000
19	PU - R.1	Revetment (D-1)	3.0	130	-	5,980
20	R.2	(D-1)	3.0	180	-	8,280
21	R.3	(D-1)	3.0	430	-	19,780
22	R.4	(D-3)	5.0	250	-	14,250
23	R.5	(D-3)	5.0	450	-	25,650
24	R.6	(D-1)	3.0	350	-	16,100
25	R.7	(D-1)	3.0	190	-	8,740
26	R.8	(D-1)	3.0	800	-	36,800
27	R.9	(D-1)	3.0	350	-	16,100
28	R.10	(B-1)	3.0	2,400	-	110,400
29	R.11	(B-1)	3.0	2,400	-	153,600
30	R.12	(B-1)	3.0	2,050	-	131,200
31	R.13	(B-1)	3.0	2,050	-	131,200
32	R.14	(B-1)	3.0	1,400	-	89,600
33	R.15	(B-1)	3.0	1,750	-	112,000
34	R.16	(B-4)	5.0	600	-	51,600
35	R.17	(B-4)	5.0	600	-	51,600
36	PU - T.1	Training Levee	7.0	1,100	-	161,700
37	T.2	"	7.0	700	-	102,900
38	T.3	"	7.0	630	-	92,610
39	T.4	"	7.0	220	-	32,340
40	T.5	"	7.0	500	-	73,500
41	T.6	"	7.0	100	-	14,700
42	T.7	"	7.0	1,050	-	154,350
43	T.6	"	7.0	300	-	44,100
44	PU - G	Groin	-	1,980	-	136,620
						3,249,900

* unit cost: Rp.11,000/m^3

(4) K. Blongkeng

No.	Facility	Element				Construction Cost
		Type	Height (m)	Length (m)	Volume (m^3)	(Rp. x 1,000)
1	BL - D.1	Check Dam	7.0	85	6,500	91,000
2	D.2	"	10.0	110	11,700	163,800
3	LA - D.1**	"	12.0	70	11,800	224,200
4	BL - C.1	Cons. Dam	3.0	90	4,900	68,600
5	C.2	"	3.0	90	3,900	54,600
6	C.3	"	3.0	110	4,300	60,200
7	C.4	"	3.0	90	3,900	54,600
8	C.5	"	3.0	90	3,900	54,600
9	C.6	"	5.0	150	7,900	110,600
10	C.7	"	4.0	120	6,000	84,000
11	C.8	"	4.0	110	5,600	78,400
12	C.9	"	4.0	140	5,200	72,800
13	C.10	"	4.0	120	4,700	65,800
14	C.11	"	5.0	120	5,800	81,200
15	C.12**	"	4.0	150	5,400	102,600
16	BL - R.1	A	2.0	250	-	147,750
17	R.2	(D - 1)	3.0	260	-	11,960
18	R.3	(D - 1)	3.0	160	-	7,360
19	R.4	(D - 1)	3.0	250	-	11,500
20	R.5	(D - 1)	3.0	400	-	18,400
21	R.6	(D - 1)	3.0	950	-	43,700
22	R.7	(D - 3)	5.0	1,150	-	65,550
23	BL - R.8	(D - 1)	3.0	2,000	-	92,000
24	R.9	(D - 2)	3.0	2,050	-	77,900
25	R.10	(D - 2)	3.0	950	-	36,100
26	R.11	(B - 1)	3.0	1,200	-	76,800
27	R.12	(B - 3)	5.0	250	-	23,250
28	R.13	(B - 1)	3.0	1,450	-	92,800
29	R.14	(B - 1)	3.0	400	-	25,600
30	R.15	(B - 1)	3.0	600	-	38,400
31	R.16	(B - 3)	5.0	250	-	23,250
32	R.17	(B - 3)	5.0	200	-	18,600
33	R.18	(B - 3)	5.0	300	-	27,900
34	R.19	(B - 3)	5.0	100	-	9,300
35	R.20	(B - 3)	5.0	500	-	46,500
36	R.21	(B - 3)	5.0	300	-	27,900
37	R.22	(B - 3)	5.0	80	-	7,440
38	R.23	(B - 3)	5.0	100	-	9,300
39	R.24	(B - 3)	5.0	280	-	26,040
40	BL - T.1	Training Levee	7.0	300	-	44,100
41	T.2	"	7.0	1,450	-	213,150
42	T.3	"	7.0	180	-	26,460
43	T.4	"	7.0	300	-	44,100
44	BL - G	Groin	-	1,560	-	107,640
						2,634,750

** unit cost: Rp.19,000/m^3

(5) K. Woro

No.	Facility	Element				Construction Cost
		Type	Height (m)	Length (m)	Volume (m^3)	(Rp. x 1,000)
1	WO - C.1*	Consolidation Dam	5.0	360	6,000	66,000
2	C.2*	"	"	320	5,400	59,400
3	C.3*	"	"	318	5,300	58,300
4	C.4	"	"	130	5,000	70,000
5	C.5	"	7.0	125	8,100	113,400
6	WO - D.1	Check Dam	10.0	135	13,200	184,800
7	D.2	"	"	120	12,300	172,200
8	D.3	"	13.5	125	17,500	245,000
9	D.4	"	12.0	"	17,700	247,800
10	D.5	"	13.0	97	15,300	214,200
11	D.5'	"	7.0	162	19,700	275,800
12	D.6	"	13.0	55	11,300	158,200
13	D.7	"	12.0	158	18,200	254,800
14	D.8	"	8.0	70	7,500	105,000
15	D.9.A	"	14.5	141	16,300	228,200
16	D.9.B	"	10.0	148	19,100	267,400
17	D.10	"	"	72	9,500	133,000
18	WO - R.1	Revetment, Dike (D - 1)	3.0	2,500		115,000
19	R.2	(")	"	"		115,000
20	R.3	(")	"	"		115,000
21	R.4	(")	"			115,000
22	R.5	(B - 2)	"	230		12,650
23	R.6	(")	"	600		33,000
24	R.7	(")	"	580		31,900
25	R.8	(B - 5)	"	1,050		50,400
26	R.9	(")	"	1,570		75,360
27	R.10	(")	"	650		31,200
28	R.11	(")	"	1,070		51,360
29	R.12	(")	"	1,900		91,200
30	R.13	(B - 1)	"	3,270		209,280
31	WO - G	Groin	"	3,000		207,000
						4,106,850

* unit cost: Rp.11,000/m^3

(6) K. Gendol

No.	Facility	Element				Construction Cost
		Type	Height (m)	Length (m)	Volume (m^3)	(Rp. x 1,000)
1	GE - D.1	Check Dam	14.5	80	20,900	292,600
2	D.2	"	14.0	90	20,800	291,200
3	D.3	"	10.0	75	10,000	140,000
4	D.4	"	14.5	100	23,000	322,000
5	D.5	"	14.0	70	19,000	266,000
6	D.6	"	14.5	"	19,900	278,600
7	D.7	"	"	40	16,800	235,200
8	GE - C.1	Consolidation Dam	3.0	70	2,100	29,400
9	C.2	"	"	"	"	29,400
10	C.3	"	"	"	"	29,400
11	C.4	"	"	"	"	29,400
12	C.5	"	"	"	"	29,400
13	C.6	"	"	250.	7,400	103,600
14	C.7	"	"	110	3,200	44,800
15	C.8*	"	4.0	200	"	35,200
16	C.9*	"	"	280	4,480	49,280
17	C.10	"	"	60	4,700	65,800
18	C.11	"	5.0	70	3,600	50,400
19	C.12	"	6.0	75	3,200	44,800
20	C.13	"	5.0	70	3,600	50,400
21	C.14	"	4.0	80	3,200	44,800
22	C.15	"	6.0	70	4,600	64,400
23	C.16	"	7.0	60	5,500	77,000
24	C.17	"	"	50	5,200	72,800
25	GE - R.1	Rivetment, Dike (D-5)	3.0	1,150		65,550
26	R.2	(")	"	"		65,550
27	R.3	(B-1)	"	1,300		83,200
28	R.4	(")	"	700		44,800
29	R.5	(")	"	350		22,400
30	R.6	(D-1)	"	850		39,100
31	R.7	(B-1)	"	650		41,600
32	R.8	(B-4)	5.0	1,300		124,800
33	R.9	(")	"	"		124,800
34	GE - G.1	Groin	-	390		26,910
35	G.2	"	-	390		26,910
						3,341,500

* unit cost: Rp.1,000/m^3

(7) K. Boyong

No.	Facility	Element				Construction Cost
		Type	Height (m)	Length (m)	Volume (m^3)	(Rp. 1,000)
1	BO - D.1	Check Dam	8.0	61	7,900	110,600
2	D.2	"	7.0	130	8,300	116,200
3	D.3	"	11.0	120	14,300	200,200
4	D.4	"	"	75	11,300	158,200
5	D.5	"	"	80	10,300	144,200
6	BO - C.1	Consolidation Dam	5.0	74	6,100	85,400
7	C.2	"	"	"	"	85,400
8	BO - R.1	Revetment, Dike (D - 2)	3.0	160		6,080
9	R.2	(")	"	350		13,300
10	R.3	(")	"	"		13,300
11	R.4	(")	"	300		11,400
12	R.5	(")	"	450		17,100
13	R.6	(")	"	980		37,240
14	R.7	(")	"	190		7,200
15	R.8	(")	"	"		7,200
16	R.9	(")	"	200		7,600
17	R.10	(")		1,340		50,920
18	R.11	(")	"	1,150		43,700
19	R.12	(")	"	1,300		49,400
20	BO - B.1	Bridge				50,000
21	B.2	"				50,000
						1,264,640

(8) K. Kuning

No.	Facility	Element				Construction Cost (Rp. 1,000)
		Type	Height (m)	Length (m)	Volume (m^3)	
1	KU - D.1	Check Dam	12.0	100	14,100	197,400
2	D.2	"	13.0	145	18,400	257,600
3	D.3	"	10.0	70	9,400	131,600
4	KU - R.1	Rivetment, Dike (D-1)	3.0	600		27,600
5	R.2	(")	"	700		32,200
6	R.3	(B-3)	5.0	2,400		223,200
7	R.4	(B-1)	3.0	400		23,600
8	R.5	(B-3)	5.0	800		74,400
9	R.6	(B-1)	3.0	100		6,400
10.	R.7	(")	"	50		3,200
11	R.8	(")	"	650		41,600
12	R.9	(")	"	300		19,200
13	R.10	(")	"	300		19,200
14	R.11	(B-3)	5.0	450		41,850
15	R.12	(B-1)	3.0	300		19,200
16	R.13	(")	"	450		28,800
17	R.14	(")	"	200		12,800
18	KU - B	Bridge				50,000
						1,209,850

(9) K. Pabelan

No.	Facility	Element				Construction Cost (Rp. x 1,000)
		Type	Height (m)	Length (m)	Volume (m^3)	
1	PA - D.1**	Check Dam	14.5	110	22,600	429,400
2	D.2	"	8.0	130	10,400	145,600
3	PA - C.1	Consolidation Dam	5.0	70	3,600	50,400
4	C.2	"	5.0	67	3,600	50,400
5	PA - R.1	Rivetment, Dike (B-1)	3.0	700		44,800
6	R.2	(")	"	1,300		83,200
7	R.3	(")	"	900		57,600
8	R.4	(A)	"	1,300		83,200
9	R.5	(B-1)	"	800		51,200
10	R.6	(")	"	400		25,600
11	PA - G	Groin		90		6,210
12	PA - B	Bridge				100,000
13	SE - D.1**	Check Dams	14.5	65	19,300	336,700
14	D.2	"	13.0	80	12,700	177,800
15	D.3	"	13.5	130	17,400	243,600
16	TR - D.1**	Check Dams	14.5	94	22,300	423,700
17	D.2	"	10.0	60	8,800	123,200
18	D.3	"	12.0	96	13,800	193,200
19	D.4	"	12.0	70	11,800	165,200
						2,791,010

** unit cost: Rp.19,000

Table 20 Unit Cost of Construction Works

Work	Type	Unit Cost (1,000 Rp.)	Remarks
Check Dam and Consolidation dam	Concrete + cobble	$14/m^3$	Contain of cobble: much
	Concrete + cobble	$19/m^3$	" : less
	Crib works	$11/m^3$	
Revetment and Dike	A	59/m	
	B - 1	64/"	
	B - 2	55/"	
	B - 3	93/"	
	B - 4	96/"	
	B - 5	48/"	
	C	59/"	
	D - 1	46/"	
	D - 2	38/"	
	D —	57/"	
	D - 4	48/"	
	D - 5	57/"	
	E	$11/m^3$	
	F	30/m	
Training Levee		147/m	
Groin		69/m	

2.3.8 Implementation Planning

1) General

The implementation of the sabo facilities plan has taken into account present conditions in the area covered by the plan, the characteristics of the other plans, the present state of implementation as well as the interrelationships between the plans and ways of enhancing their socio-economic effect. Two alternatives have been considered and studied. The construction work is to be implemented over a period of fifteen years, with a 5-year first stage and a 10-year second stage.

Two alternatives considered are outlined as follows:

Alternative A: All main sediment control works are to be constructed in the first stage and minor works are to be constructed in the second phase.

Alternative B: Main sodiment control works in ype-I Area are to be constructed in the first phase and minor works in Type-I and all works in Type-II and -III are to be constructed in the second stage.

From the technical point of view, Alternative A was selected for the master plan.

2) Implementation of Sabo Facilities

Of the facilities proposed by this plan, some need to be urgently provided in view of present disaster hazards and others should be provided over a longer period on the basis of observation of sediment discharge conditions and riverbed fluctuation conditions. Consequently, this plan should be implemented in two stages, with provision of urgent facilities, facilities of basic importance in dealing with sediment discharge, and facilities important in connection with the associated facilities in the first stage and the rest in the second stage.

Small-scale irrigation facilities for direct intake from check dams and other disaster prevention facilities are incorporated in this disaster prevention facilities plan.

The implementation policy for each of the two stages is outlined below:

a) Stage 1 (5 years)

(1) Completion of facilities for reducing and controlling sediment production and discharge (referred to hereunder as basic facilities) in Type-I areas.

(2) Completion of river course improvement facilities in Type-I areas at places of particular danger or importance.

(3) Completion of those basic facilities in Type-II and -III areas that are particularly important or that are connected with the associated facilities.

(4) Completion of those river course improvement facilities in Type-II and -III areas that are particularly important in terms of the danger involved and the places where they are to be located.

b) Stage 2 (10 years)

Over this period the remaining disaster prevention facilities are to be provided.

Although a schedule for sabo works has not been undertaken at this stage, the following order of construction is recommended.

CATEGORY	PRIORITY		
Sabo Works	1	- Valley mouth fixation works for fixation of flow courses	
	2	- River course improvement facilities at places of urgency and importance	
	3	- Check dams (in the direction from downstream to upstream)	
	4	- Consolidation dams	
	5	- Embankments and revetments ·	
Location	1	K. Krasak	Type - I
	2	K. Putih	
	3	K. Batang	
	4	K. Blongkeng	
	5	K. Gendol	Type - II
	6	K. Woro	
	7	K. Pabelan	Type - III
	8	K. Boyong	
	9	K. Kuning	

Since sabo works have a great influence on sediment load, riverbed variation and since there are many phenomena that cannot be foressen at the time of planning, it is necessary to carry out the construction work in a flexible manner while observing actual river conditions.

Since the associated facility plans depend on the sabo facility plan, the construction work for the intakes and the siphons and bridges for crossing the main tributaries will be carried out at the same time as that of the sabo facilities themselves, but the construction work for the main irrigation canal and some other associated facilities will take place later. This is because it is better for such facilities to be provided after area stability has been enhanced by the disaster prevention facilities.

For considerations of economy and employment opportunities in the project area, maximum use should be made of locally available materials such as rocks, bamboo, and wood and of construction methods that are labor-intensive. Moreover, structure and construction methods should be flexible in view of such circumstances as riverbed fluctuation. In addition, every effort should be made to use trees and ground covering for protection against erosion wherever possible. As for the kinds of construction machinery, use should be made of hand winches and other machinery to improve the efficiency of labor, vibrators and other machinery for improvement of quality, and some heavy machinery such as that needed for urgent or emergency excavation.

2.4 Associated Works

2.4.1 General

1) Purpose of Study

The development of the area around volcanic G. Merapi in Central Java is being impaired by damage caused directly and indirectly by volcanic sediment discharge after eruptions. Particularly affected has been agriculture, the area's chief industry, which is at a low level because of a vicious cycle of disaster damage, instability of irrigation water supply, and failure to improve the production infrastructure. The domestic environment, too has its problems. For instance, in upstream areas of K. Woro on the east side of the mountain there is a serious shortage of water which has made it necessary to rely on collected rainwater even for drinking water.

The purpose of this study is to plan for effective sabo facilities in the context of overall planning for promotion of the region. Consequently, the same facilities used to stabilize the area in the disaster plan will be designed to be used to improve the production infrastructure during the second phase of regional development.

2) Area Covered by Study

The study area consists of about 510km^2 enclosed by K. Woro on the east, K. Pabelan on the west, the line connecting the planned disaster prevention facilities on the north, and the Mataram canal on the south.

The area downstream of the Mataram canal has not been included because the production infrastructure is much better there and that area will not be directly connected with the planned sabo facilities.

3) Items Covered by and Method of Study

a) Study of Existing Conditions

Both field surveys and collection of information and data were used in order to get an accurate picture of existing conditions in the study area. Such activities took place primarily in Indonesia.

(1) Field Surveys

Field surveys were carried out mainly at the scheduled locations of the planned sabo facilities, at the locations of existing disaster prevention facilities, and in the vicinity of irrigation intake points for the purpose of determining cross sections, flow conditions, and irrigation conditions as information to be taken into account in considering intake possibilities, irrigation plans, and so on. At the same time, fields were observed to get an idea of the land-use pattern and the state of growth of crops.

(2) Collection of Information and Data

Information was collected with respect to the following items from other projects in the vicinity of the area covered by this project: rainfall, acreage and yield for different crops, unit duty of water, dry period water discharge, irrigation systems, soil conditions, supply of electricity, etc.

b) Associated Facility Plans

Associated plans listed below have been made possible by use of the sabo facilities:

(1) Irrigation Plan

Planning of primary canals, the area of farmland that can be irrigated by them, and the main structures connected with them.

(2) Road Plan

Planning of road system involving use of roads for maintenance and management of primary canals.

(3) Micro Hydro-electric Power Station Plan

Planning of micro generation of hydroelectric power through use of main irrigation canal heads.

(4) Other Associated Works Plans

Presentation of basic ideas regarding plans for fishery nurseries and supply of water for everyday use and a plan for comprehensive model of rural village improvement.

(5) Implementation Plan

Planning of implementation or construction of the related facilities.

(6) Estimated Construction Costs

Estimation of cost of construction of the related facilities.

(7) Conclusion

Summary of the effects of the related facility plans and description of remaining tasks.

2.4.2 Existing Conditions in the Study Area

In the following paragraphs, descriptions are made of conclusions reached regarding conditions in the study area from the standpoint of the related facility plans based on existing information and data and the survey of existing conditions.

1) Present State of Agriculture

a) Land Use and Unit Yield of Rice

Table-21 and Fig. 17 are concerned with the land use pattern and the unit yield of rice, the most important crop in the area, in different kacamatan.

(1) Ratio of Paddy Field in Landuse

The priority land use is paddy fields, which exist wherever there is enough water for them. There are groundwater springs in the vicinity of the land use boundary between paddy fields and rice fields in the upstream area, and downstream of that boundary the groundwater level is generally high. The approximate elevation of this boundary is 1,000m in the case of K. Pabelan, 700m in the case of K. Krasak, and 400m in the case of K. Woro, after which the elevation declines rapidly toward the east.

Upstream where the groundwater level is lower, the paddy field production rate is generally low. There are also places downstream where the paddy field rate is also low. These are flood plains where the soil has a mixture of gravel and the elevation is somewhat higher than that of the surrounding land.

The main dry field crops are maise, sweet potatoes, and cassava in the upstream area and groundnuts and soybeans in the downstream area.

(2) Rice Intensity

Rice intensity varies greatly from place to place, the range being 1.0-2.5 times per year. On the average, two full rice crops a year are not possible since the cultivated area during the dry season is smaller than during the rainy season. Furthermore, on the whole the cropping pattern does not often consist of consecutive rice crops.

This figure is lower for upstream areas than downstream areas and lower in Kab. Magelang than elsewhere, the reason being the unstable supply of irrigation water.

(3) Mean Yield

The lowest mean yield, a low 3 tons/ha, is in Kecamatan Dukan, Srumbung and Ngluwar of Kab. Magelang between K. Pabelan and Krasak. Elsewhere the mean yield is roughly 4 ton/ha, with little variation between different areas. Besides the difference in irrigation water there are also differences in terms of agricultural roads, the size of fields, the slope of the terrain and other aspects of the production infrastructure between upstream areas and downstream areas, but nevertheless there is hardly any difference in yield which is low everywhere. This is a good indication of how much room there is for improvement of agricultural technology in this area.

Table 21 Annual Rice Growing Intensity and Yield of Paddy

		Land Use		Ratio of Paddy field (%)	Annual rice intensity	Mean yield of paddy (t/ha)
		Paddy field	Dry field			
KODYA	Yogyakarta	543	42	92.8	2.11	4.26
BANTUL	Sewon	1,781	21	98.8	1.23	4.06
	Kasihan	1,006	202	83.3	1.06	3.98
	Piyungan	1,532	626	71.0	1.06	3.98
	Banguntapan	1,718	76	95.8		
SLEMAN	Sleman	1,958	26	98.7	1.62	3.96
	Mlati	1,461	118	92.5	2.36	4.09
	Gamping	1,375	43	97.0	1.88	4.07
	Godean	1,518	97	94.0	1.45	4.09
	Moyudan	1,479	30	97.9	2.32	4.01
	Minggir	1,506	26	98.3	2.34	4.12
	Seyegan	1,551	53	96.7	2.20	3.92
	Tenpel	1.945	84	95.9	1.42	3.98
	Turi	1,622	473	77.4	1.29	3.83
	Pakem	1,785	1,129	61.3	1.08	3.82
	Cangkringan	1,188	730	61.9	2.06	3.84
	Ngaglik	2,141	776	73.4	1.58	3.75
	Depot	907	577	61.1	2.23	3.96
	Kalasan	1,943	221	89.8	2.57	4.02
	Berbah	1,481	891	62.4	1.67	3.83
	Pranbanan	1,682	220	88.4	1.92	4.08
	Ngenplak	2,207	425	83.9	1.74	4.07
	(Total)	(27,749)	(5,919)	(82.4)		
KLATEN	Jogonalan	1,641	17	99.0	1.31	3.92
	Prambanan	1,483	114	92.9	1.24	3.91
	Gantiwarno	1,722	63	96.5	1.36	4.10
	Manisrenggo	1,725	245	87.6	1.15	3.89
	Karangnongko	757	892	45.9	2.02	4.03
	Kenalang	54	2,145	2.5	1.83	3.59
MAGELANG	Muntilan	1,985	955	67.5	1.48	3.66
	Dukun	2,399	1,148	67.6	1.32	3.06
	Salan	1,963	348	84.9	1.10	3.76
	Srumbung	2,536	661	79.3	0.93	3.05
	Ngluwar	1,456	32	97.8	1.51	3.15

Source: Proyek Gunung Merapi - Yogyakarta - 1977 -
Present Land Use
Yield of Food Crops

- Landuse : Data in 1976
- Ratio of Paddy Field: $\frac{\text{Paddy field}}{\text{Paddy field + Dry field}} \times 100$ (%)
- Rice Growing Intensity : $\frac{\text{Mean yield area (1975∿1976)}}{\text{Paddy field area}}$
- Mean yield of Paddy : Mean yield of paddy in three years (1974∿1976).

b) Irrigation Conditions

(1) Classification of Irrigation Systems

Fig. 18 shows the classification of irrigation systems in the area covered by the disaster prevention plan.

The Mataram canal serves as a sort of dividing line in this respect, the areas south of it being technical areas and those north of it on the periphery of G. Merapi being semi-technical and non-technical areas for the most part. Looking only at the area covered by the study, one sees that the main irrigation facilities are located in the downstream parts of the rivers where the river courses are stable. Most of these facilities, however, are primitive natural intakes, with technical areas representing only 3,900ha of paddy fields versus a total of 19,700ha in the study area, the other 80% or so being semi-technical or nontechnical areas.

(2) Unit Duty of Water

In the case of the K. Progo irrigation project, the unit duty of water and the amounts of evaporation were as follows:

Unit Duty of Water and Amount of Evaporation

(Unit: ℓ/s/ha, mm/day)

Area \ Month		1	2	3	4	5	6	7	8	9	10	11	12
Mataram	West	1.21	0.70	1.03	0.95	0.93	0.98	0.97	0.80	0.83	1.12	1.35	1.31
	East	1.54	0.96	1.27	1.18	1.19	1.27	1.12	0.86	0.82	1.12	1.47	1.57
K. Opak	Left bank	0.97	0.59	0.70	0.65	0.75	0.74	0.65	0.66	0.67	0.78	1.09	1.11
	Right bank	1.09	0.63	0.81	0.78	0.71	0.82	0.95	0.80	0.91	1.12	1.28	1.03
Evaporation		4.6	4.7	4.8	4.5	4.2	3.9	4.1	4.7	5.2	5.5	5.0	4.9

(Source: K. Progo Irrigation Project - 1977)

Although there is some variation in time and place a unit duty of water of 1ℓ/s/ha will be adequate for planning purposes. Since this is equivalent to 8.6mm/day, about one-half of the unit duty of water is evaporated.

Setting the unit duty of water at 1ℓ/s/ha does not necessarily mean that the amount of irrigation water will be the same. This is because part of the unit duty of water remains after subtraction of the amount evaporated or is otherwise lost and will once again flow into the irrigation canals and fields downstream to be used again. Accordingly, the design duty of irrigation water in the Mataram canal plan is 0.32-0.62ℓ/s/ha. The validity of this figure, was substantiated by a survey of the actual water balance in the Wonogiri area which estimated the water consumption at 0.3-0.6ℓ/s/ha. (Reference: Feasibility Report on the Wonogiri Irrigation Project--1976, JICA.)

(3) Rainfall and Runoff

Fig. 19 gives the mean monthly rainfall for 26 years (1950-1969 and 1971-1976) at Yogyakarta and Kaliurang, and the 1/5 and 1/10 low values on the basis of probability evaluation.

The mean annual rainfall at Kaliurang is approximately twice that at Yogyakarta. The probability evaluation, however, shows that even at Kaliurang, which is upstream, not much rainfall can be expected in the dry period from June to October.

Although there is no actually measured data available for the area covered by the plan, the runoff was measured and analyzed for a period of 58 months (1962-1968) at Kranggan with a catchment area of $424km^2$ (see Fig. 20).

These measurements show that the amount of runoff is very small in August, September, and October which is an indication of the fact that runoff is a constraining factor on wet paddy cultivation in the dry season.

It is extremely important for irrigation planning that the drought level runoff be accurately assessed. The Kranggan data indicates that the shortfall was in the range of $0.6-4.0m^3/s/100km^2$. Furthermore, in the Wonogiri area it was estimated at $3m^3/s/100km^2$. Since rainfall tends to increase as the elevation gets higher, the shorfall should be somewhat greater in the study area. Moreover, since there is not enough water in the dry season for irrigation of all the paddy fields, it is urgent to determine the exact amount of water which is available then.

(4) Irrigation Area

The actual amount of irrigation acreage in the dry season has been estimated for Kab. Sleman from the monthly figures for wet rice acreage in 1975 and 1976 on the basis of a cultivation period of 4.5 months (see Fig. 21).

As can be seen from Fig. 21, the amount of wet rice acreage differs from year to year. The wet season rice crop is started in October-November and harvested in February-April of the next year, immediately after which the transplanting of the dry season crop begins, followed by harvesting again before September.

In the rainy season almost all of the paddy fields are planted with rice, but in the dry season the rice acreage is reduced. Because of this, only about 55% of the paddy field acreage required irrigation in the dry season in 1975 and only about 30% in 1976.

2.4.3 Irrigation Plan

Main irrigation canals are planned for the purpose of stabilizing the irrigation water supply, upgrading semi-technical and

1) Background of Plan

The following is the rationale which has resulted in the adoption of disaster prevention facilities for irrigation purposes as well.

a) Irrigable Acreage

Since the basin area in the area covered by the disaster prevention plan is approximately 530km^2, this means that in the dry period the irrigable acreage will be 5,300-15,900ha,(with a relative dry period flow in the range of 1-3m^3/s/100km^2, the total drought level flow will be 5.3-15.9m^3/s) which is about 30-80% of the present paddy field area. Actually, however, it should be possible to cover a greater area considering the fact that some of the water will spill over to be used again further down in the irrigation system.

Although it will not be possible to supply enough irrigation water for consecutive wet rice crops on all of the paddy field acreage, it should be possible to average 2 crops a year if the water intake is stabilized and a cropping pattern is established which is geared to the irrigation water supply capability.

b) Technical Feasibility

The check dams and consolidation dams proposed in the disaster prevention facilities plan can also be used from the standpoint of water intake in the context of the irrigation plan. If such facilities were to be proposed solely from the standpoint of irrigation, they would hardly be feasible either technically or economically considering the difficult topography and the large size of the facilities for the amount of water intake that would be involved. Since they are going to be built as basic facilities for the disaster prevention plan, however, it will be not only technically feasible but also very economical to use them for the purpose of irrigation intake as well since this will involve only structural changes.

c) Irrigation Systems

By using the check and consolidation dams for irrigation water intake purposes, it will be possible to integrate the many temporary weirs on the main tributaries and make them permanent structures. Furthermore, it should be possible to upgrade the irrigation systems to technical systems on the basis of such facilities.

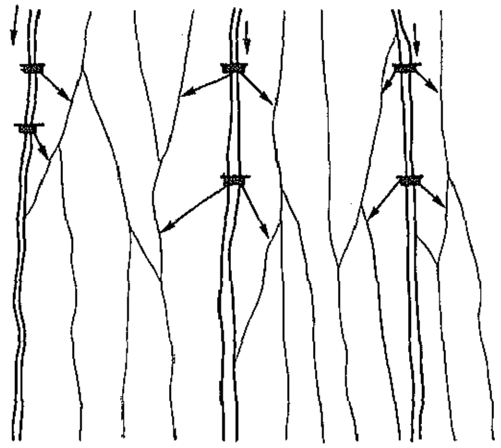
2) Irrigation Plan

The alternative features for the irrigation plan for the study area, prepared on the basis of the disaster prevention plan, are discussed in the following dimensions:

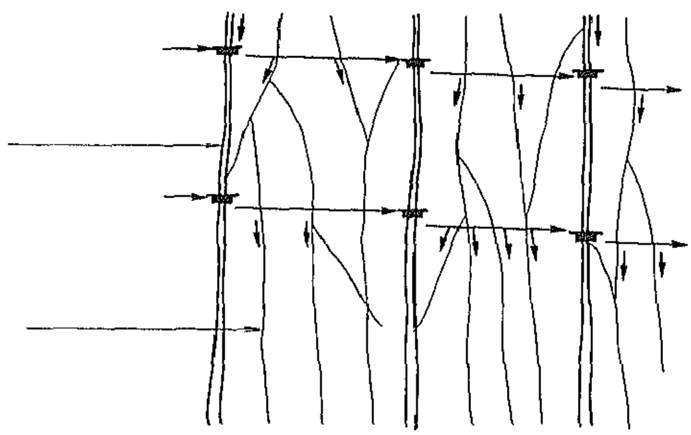
a) Water Supply Method

If the disaster prevention facilities mentioned are also to be used for irrigation water intake, there will have to be irrigation canals leading from them. The following are two possible patterns for such canals:

(A) Provision of new canals to connect the intakes with existing irrigation canals.



(B) Provision of canals for lateral linkage of the disaster prevention facilities thereby enabling supply of irrigation water to areas in which there is a shortfall by repeated intake and sharing.



Because of the regional imbalance of irrigation water in the study area (K. Pabelan on the west side having a larger intake capacity and the K. Woro basin on the east side having a shortage of irrigation water), pattern B is the more appropriate of the two in terms of supplementary irrigation.

b) Routing of Irrigation Canals

The planned routes for the main irrigation canals as described in the following paragraphs are shown in Fig. 23.

(1) Off-limits Zone (Nuée Ardente Zone)

The main irrigation canals are to pass through safe areas on the downstream side of the off-limits zone.

(2) Sabo Facilities

The check dams and consolidation dams, disaster prevention facilities are to be made maximum use of since only Main Canal-1 meets this requirement. Main Canal-2 and Main Canal-3 will have to be restudied as future possibilities.

(3) Function of Canals

As already stated, the canals are to be multipurpose. Therefore they have been designed to meet this requirement in the following specific ways:

- To avoid fast flow speed for the sake of use for supply of water for everyday use and for fishery nurseries, and to irrigate a greater acreage, a low canal gradient is planned.

- To design an appropriate head for micro hydroelectric stations.

(4) Canal System

Since Main Canal-1 will have a considerable intake capacity, it should be sufficient by itself if facilities are provided for the secondary and tertiary levels as well. If, however, provision of facilities for the secondary and tertiary levels is still unfeasible, as in the present stage, and considering the fact that the amount of intake will not be enough for the whole area covered by the plan, Main Canals-1 and -2 would be very effective as an irrigation system, even for the supply of irrigation water throughout the area on the basis of efficient repeated use of the same water. As already mentioned, however, these canals are only a future possibility in view of the fact that they do not make use of disaster prevention facilities.

(5) Use of Existing Roads

The roads for maintenance and management of the canals which are also to be used as development roads are described below. If the canals are planned along existing roads, there will be a savings in construction costs.

c) Intake Capability

The areas upstream of the main canal (Main Canal-1) have been divided into different basins for each main tributary with intakes for the purpose of estimating intake capacities during the dry period

At the present stage in which there are as yet no survey results regarding the dry period water discharge in the area covered by the plan it is better to be on the safe side and consider lower values with respect to irrigation effectiveness. However, in the case of the present plan since the dry fields in the upstream areas of K. Woro are to be converted to paddy fields, and since the irrigation canals are to be used for hydroelectric power stations as well, a considerable amount of water will be required. Accordingly, it is better in this case that higher values such as those given in Table 23 be used in the irrigation canal design.

Table 23 Available Amount of Water in Dry Season

	Catchment area (km^2)	Available amount	
		$q=1m^3/s/100km^2$	$q=3m^3/s/100km^2$
K. Pabelan	64.8	0.65	1.94
K. Blongkeng	7.6	0.08	0.23
K. Putih	9.9	0.10	0.30
K. Batang	5.0	0.05	0.15
K. Krasak, K. Bebeng	18.1	0.18	0.54
K. Boyong	9.6	0.10	0.29
K. Kuning	10.0	0.10	0.30
K. Gendol	11.0	0.11	0.33
K. Woro	8.1	0.08	0.24
Sub-Total	144.1	1.44	4.32
Other tributaries	45.7	0.46	1.37
Total	189.8	1.90	5.69

d) Design Irrigation Area

It has been assumed that 0.6ℓ/s/ha will be supplied by the main canal, with dependence on repeated use of spillover and on small rivers, other than main tributaries, for the remaining 0.4ℓ/s/ha. Accordingly, with use of the planned irrigation canals the acreage that can be planted with wet rice in the dry season and still be able to count on a stable supply of irrigation water will be in the range 2,400-7,200ha.

As for the 760ha of dry fields below the planned irrigation canal in the upstream area of K. Woro, they can be used as paddy fields in the rainy season, but not in the dry season.

e) Design of Structures

In the following paragraphs, standard drawings and design and planning policies are given for the main canal structures, which are the intakes, crossings for main tributaries, the canals themselves, and crossings for small rivers.

(1) Intakes

The following is a description in outline of the intakes, the standard cross sections for which are given in Fig. 24.