(a) Crossings for River

Across the main tributaries, Hume concrete pipes will be laid in the check and consolidation dams for siphon flow.

(b) Intakes for Groundwater

In order to increase the amount of intake, water collection ducts will be laid on the upstream side of the dams so that there can also be intake of the water held back by the dams.

(c) Sediment remover will be installed to dispose of deposits in front of the intakes.

(2) Irrigation Canals

The following is a description in outline of the irrigation canals, the standard cross sections for which are given in Fig. 25.

(a) Velocity of Flow

Since the main canals are to be for multipurpose use, the velocity of flow should not be too fast. Since, however, the cross section of the canal will have to be large if the velocity of flow is too low, a range of V=0.5-1.0m/s should be a correct compromise value.

(b) Lining

The lining of the canals is to be masonry for the following reasons:

- To keep the site width as narrow as possible, a smaller roughness coefficient is better.
- To keep loss as small as possible considering the length of the canals.
- To maintain the stability of the roads planned along the canals.

(3) Crossing of Small Rivers

Besides the main tributaries there are many small rivers requiring facilities for the crossing of irrigation canals. As indicated in Fig. 24, the standard structure of such crossings will be of the aqueduct type, with roads running above the aqueducts.

2.4.4 Road Plan

The road planned to connect K. Pabelan with K. Woro along the planned main canal is discussed in detail below.

a) Background of the Road Plan

A main road is to be made by widening the maintenance and management road along the main canal so that it can be used as a main route in the upstream part of the area covered by the plan. This will be much more economical than building a new road and will be very effective, as explained below.

The main technical and economic problems of road construction are the points where this road crosses the main tributaries. There is, however, the possibility of using the check and consolidation dams planned as disaster prevention facilities for this purpose by building the substructure of the bridges into the dams. This is, of course, technically feasible and much more economical then building separate bridges.

This whole idea presupposes that the road will be planned together with the canal. If it is to be separate from it, the problem of bridges will have to be restudied.

b) Effects of the Road

The effects that can be expected of this road are listed as follows:

(1) Provision of an Agricultural Road Network

This road will make it possible to improve the inadequate agricultural road network in upstream areas. Although any lengthening or increase of the number of agricultural roads will represent only a very small increase per unit of area, one can expect auxiliary connecting roads will be built once this road is provided.

(2) More Contacts between Isolated Areas

With this road, there will be an increase in contacts between areas hitherto cut off from one another by rivers.

(3) Raising Development Potential

By connecting different parts of this homogeneous area in which agriculture is the central occupation running along an isometric line, this road can be expected to raise the regional development potential.

(4) Evacuation Route

As a road running parallel to isometric lines and crossing rivers perpendicularly, this road will be important for emergency evacuation at times of Lahar and other dangers.

2.4.5 Plan for Micro Hydro-electric Power Stations

Micro hydro-electric power stations are to be built on main irrigation canals.

1) Background of Plan

A supply of electricity to the areas on the slopes of Mt. Merapi include in the area covered by the plan from the Yogyakarta power supply system cannot be expected at least in the near future. It will therefore be very effective in terms of raising the potential of such areas to provide micro hydro-electric power stations on main irrigation canals as related facilities in the context of provision of disaster prevention facilities. As for technical feasibility, use of German Osberger turbines is possible in the range of flow of 20-9,000 ℓ/s and head of 1-200 m, and the flow and head of the main irrigation canal in this case fall within this range.

2) Construction Locations

Since hydro-electric power generation utilizes only head and does not consume the water itself, micro-power stations could be set up anywhere along main irrigation canal on the mountain slopes. However, it would be most efficient to set them up in the vicinity of intake works, which inevitably have head, since there would otherwise be a reduction in the irrigation acreage because of too much head (see Fig. 24). In other words, there is a head of 5-10 m between the level of the water that crosses check dams or consolidation dams by siphon and the level of intake water from these dams. With such an arrangement it would be possible to set up eleven micro hydro-electric power stations on Main Canal-1.

3) Generation Capacity

The amount of power that can be generated can be calculated as follows:

$$P = 9.8\eta_1\eta_2 QH,$$

Where P : Amount of Power (KW)
Q : Amount of water flow (m^3/s)
η_1: Turbine efficiency (0.79 if $P<100KW$)
η_2: Generator efficiency (0.91 if $P<100KW$)

Assuming an average water flow of $Q = 1.0\ m^3/s$ and an average effective head of $H = 6m$, the average amount of power (P/per station) would be as follows:

$$P = 9.8 \times 0.79 \times 0.91 \times 6 = 42\ (KW)$$

Accordingly, the total power generation capacity comes to 462 KW (42 KW x 11), which means that the area as a whole could expect to have a power supply of roudily 400-500 KW. With a maximum consumption per household of 100 W, this would be enough to supply 4,000-5,000 households in the area with electricity.

c) Structure and Cross Section

Fig. 25 shows the structure and cross section of this road, and Fig. 24 generalizes the bridges and canal crossing.

Since this road will function not only as a canal maintenance and management road but also as a main agricultural road and hence as a regional development road, it should have a width of at least 4m.

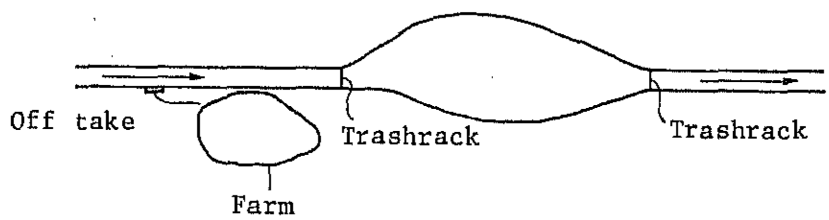
2.4.6 Other Associated Works Plans

In addition to the related facility plans making use of the sabo facilities (i.e., the irrigation plan (main canal), the road plan, and the micro hydroelectric power station), other uses exist to which these related facilities can be used, thereby increasing their effectiveness.

1) Fishery Nurseries

At present ponds in the yards of farm households and even paddy fields are being used to raise fish as a valuable source of cash income and animal protein.

The main canal will be very important in terms of developing fishery nurseries in this area. It will be possible both to raise fish in ponds dug on the way from the main canal to the fields and to use the main canal itself as a fishery nursery by widening it at selected places.



2) Supply of Domestic Water

In areas where farmland is presently being used mainly as paddy fields, the groundwater level is generally high, and there is no problem supplying the water needed for use in daily life. In upstream areas where the farmland is mostly dry fields, however, the shortfall of water gets to be very serious during the dry season. In the K. Woro basin upstream of the 400m elevation, for instance, groundwater level is low, and the people have a hard time getting enough water for daily use in the dry season. Presently at some places spring water is piped from quite a distance upstream for use at public water points, and at other places, rainwater is stored in reservoir ponds, but the amount is still insufficient, and not all the hamlets get a sufficient share. Furthermore, the stored water leaves much to be desired from the standpoint of sanitation.

A new supply of water in such areas can be expected to help considerably in raising the standard of living of the people.

3) Demonstration of Comprehensive Rural Village Improvement

Demonstration areas should be designated and a comprehensive rural village improvement plan should be formulated in order that all of the related facilities, that have been described above, be efficiently utilized and that the systems involved, spread as broadly as possible throughout the area covered by the plan, thereby raising the standard of living of all of its residents.

a) Selection of Demonstration Areas

Considering the size of the area covered by the plan, at least two demonstration areas should be designated within it. Hamlets along the main canal near K. Pabelan and K. Krasak would be the best choices for such demonstration areas in that the two rivers are sufficiently far from one another, they can be expected to provide larger water intakes than other rivers, and it should be possible to install many different kinds of associated facilities.

b) Size of Demonstration Areas

The larger the demonstration areas, the greater visible effect they will have; however, in view of the fact that none of the related facilities will be on a large scale, the most appropriate size for each of the demonstration areas is a kelurahan, with about 150-200ha of farmland.

c) Description of Demonstration Comprehensive Rural Village Improvement Plan

The following improvements will be made in the demonstration rural villages, using the related facilities described above as basic facilities.

(1) Improvement of Irrigation Canal Network

The irrigation canal systems in the demonstration villages are to be developed to the secondary and tertiary levels from the main canal.

(2) Improvement of Agricultural Road Network

The canal maintenance and management roads in the demonstration villages are to be improved along with the network of agricultural roads associated with the canal system.

(3) Introduction of Small Industry

Cottage industries and other small-scale industry are to be introduced, making use of the electricity produced by micro hydroelectric stations.

(4) Introduction of Fishery Nurseries

Fishery nurseries are to be introduced by making use of the main canal.

(5) Hamlet Improvement

Road networks, irrigation canal networks, livestock sheds, etc. within the hamlets are to be improved, and the level of the living environment within them is to be raised.

(6) Model Farms

Model farms are to be studied within the model villages for the following purposes:

(a) Tests and research on rice cultivation methods.

(b) Training and retraining of agricultural extension workers.

(c) On-the-job training and classroom audio-visual instruction regarding the main work involved in crop cultivation: seed preparation, sowing, plowing, weeding, insecticide spraying, application of additional fertilizer, harvesting, and crop management.

(d) Production and distribution of superior seeds.

2.4.7 Construction Cost Estimation

The construction cost of associated works is estimated as Rp.3 billion.

Irrigation canals	Rp.1,693,092,000
Bridges	778,320,000
Sub-total	2,471,412,000
Micro hydro-electric power station	330,000,000
Total	Rp.2,801,412,000

Table 24 Construction Cost of Main Canal-1

(Unit: Rp.1,000)

Works	Unit Cost	1 K. Pabelan ∫ K. Blongkeng Qty	Const. Cost	2 K. Blongken ∫ K. Putih Qty	Const. Cost	3 K. Putih ∫ K. Batang Qty	Const. Cost	4 K. Batang ∫ K. Krasak Qty	Const. Cost	5 K. Krasak ∫ K. Boyong Qty	Const. Cost	6 K. Boyong ∫ K. Kuning Qty	Const. Cost	7 K. Kuning ∫ K. Gendol Qty	Const. Cost	8 K. Gendol ∫ K. Woro Qty	Const. Cost	Total Qty	Const. Cost
IRRIGATION CANAL																			
Intakes	10,720	3	32,160	2	21,440	1	10,720	2	21,440	1	10,720	1	10,720	1	10,720	1	10,720	12	128,640
Siphon	13,500	3	40,500	1	13,500	1	13,500	2	27,000	1	13,500	1	13,500	1	13,500	–		10	135,000
Main Canal	23	6,000	138,000	2,300	52,900	1,600	36,800	1,800	41,400	5,300	121,900	2,300	52,900	3,800	87,400	3,600	82,800	26,700	614,100
Aqueduct	5,290	7	37,030	9	47,610	5	26,450	6	31,740	12	63,480	8	42,320	9	47,610	10	52,900	66	349,140
(Sub-total)			247,690		135,450		87,470		121,580		209,600		119,440		159,230		146,420		1,226,880
Contingencies			37,154		20,318		13,121		18,237		31,440		17,916		23,885		21,963		184,034
Administration and Overhead			28,484		15,577		10,059		13,981		24,104		13,735		18,311		16,838		141,089
Consulting Services			28,484		15,577		10,059		13,981		24,104		13,735		18,311		16,838		141,089
Sub-Total			341,812		186,922		120,709		167,779		289,248		164,826		219,737		202,059		1,693,092
BRIDGES																			
Construction Cost	47,000	4	188,000	1	47,000	1	47,000	2	94,000	1	47,000	1	47,000	1	47,000	1	47,000	12	564,000
Contingencies			28,200		7,050		7,050		14,100		7,050		7,050		7,050		7,050		84,600
Administration and Overhead			21,620		5,405		5,405		10,810		5,405		5,405		5,405		5,405		64,860
Consulting Services			21,620		5,405		5,405		10,810		5,405		5,405		5,405		5,405		64,860
Sub-Total			259,440		64,860		64,860		129,720		64,860		64,860		64,860		64,860		778,320
TOTAL			601,252		251,782		185,569		297,499		354,108		229,686		284,597		266,919		2,471,412

Unit Cost for Construction works

(1) Main Canal (per meter)

Earth work	Rp. 1,500
Concrete work	R 21,500
Total	Rp.23,000

(2) Bridge (H-shaped steel beam: 25 m length, 4 m width)

Sub-structure work	Rp.12,000,000
Bridge work	35,000,000
Total	Rp.47,000,000

(3) Intake

Gate work (ø1,000, ø600)	Rp.1,720,000
Pipe work (ø1,000, ø600)	8,040,000
Concrete work	250,000
Earth work	710,000
Total	Rp.10,720,000

(4) Siphon

Pipe work (ø1,000)	Rp.10,912,000
Mason work	2,199,000
Earth work	389,000
Total	Rp.13,500,000

(5) Aqueduct

Concrete work	Rp.3,220,000
Gate work (600mm x 600mm)	750,000
Mason work	1,270,000
Earth work	50,000
	Rp.5,290,000

(6) Micro-electric power station

D = 50 kw	Rp.30,000,000

2.4.8 Implementation Plan

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 disaster prevention facilities themselves, but the construction work for the main 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 sabo facilities. As for Main Canals-1 and -2, which have been left for future consideration, they will be evaluated after it is seen how effective Main Canal-1 and the model area activities have been.

Table 25 summarizes the construction work schedule for the related facilities.

Table 25 Implementation Plan for Associated Works

Works \ Stage / Year	1st Stage (0–5)	2nd Stage (5–10)	2nd Stage (10–15)	3rd Stage (15–20)	3rd Stage (20–25)
Main Canal- 1 (Alt. a)	—				
Main Canal- 1 (Alt. b) *	—	—	—		
Main Canal- 2				—	
Main Canal- 3					—
Micro-electric Power Station	—		—		
Demonstration Model Farm Plan		—	—	—	

* : 1st Stage: K. Pabelan ∿ K. Krasak
2nd Stage: K. Krasak ∿ K. Woro

2.4.9 Conclusion

1) Effectiveness of Associated Facilities

As a project principle, the planning of the associated facilities depends on the check dams and consolidation dams. With these facilities, the existing primitive intakes will be integrated, and linkage of these facilities in the direction of isometric lines will possibly also make use of the same routes as main canals and trunk roads in upstream areas. Among the effects that can be expected are increase in agricultural production through stabilization of irrigation, supply of badly needed water for everyday use to areas with severe shortages, and more contacts between areas that have hitherto been isolated from one another by lack of river crossings. The canals can also be effectively used for generation of electric power by micro hydro-electric power stations and for fishery nurseries. All these uses and effects are summarized by a chart (see Fig. 26).

Only the production boosting effect of Main Canal-1 has been considered in quantifying the economic effects of the associated facilities. With stabilization of the supply of irrigation water, it will be possible to raise the average rice yield (3.5t/ha) and rice intensity (1.4) in the upstream areas to the same levels as downstream (4.0t/ha and 2.0), and about 4,800ha of farmland should benefit from this effect, assuming a relative flow in the dry period of $=1.0m^3/s/100km^2$ to be on the safe side.

2.4.10 Further Study Required

The following items will require further study in order to raise the precision of the master plan for the related facility plans presented herein:

(1) Determination of Dry Period Flow

As there is no data yet available concerning dry period flow which is one of the most basic factors in irrigation planning for the study area, it will be necessary to generate flow and rainfall statistics in the basin of K. Pabelan, the largest in terms of area in the study area, during a dry period.

(2) Use of Groundwater

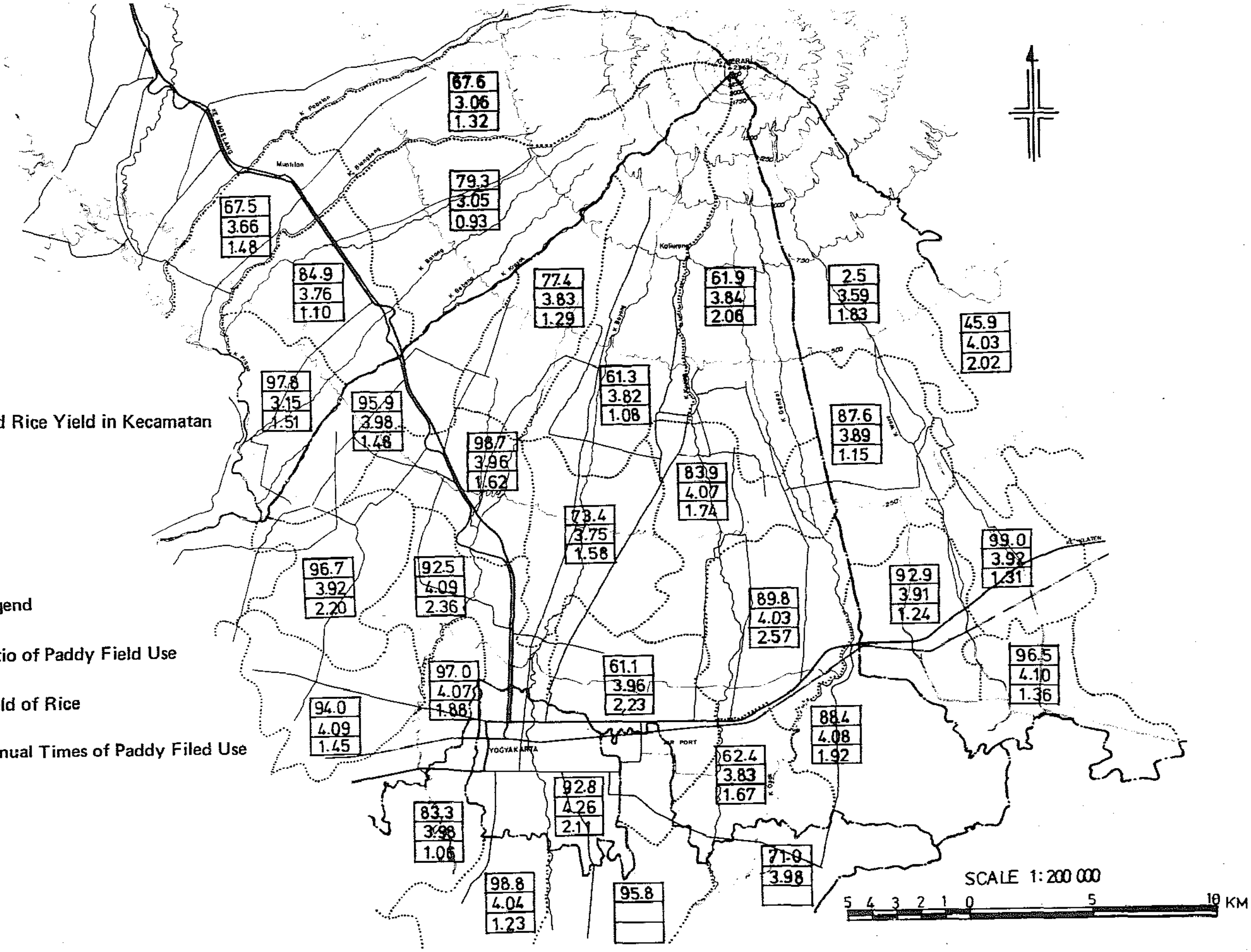
For more effective use of groundwater, which in general appears to have a high level in the paddy field parts of the study area, it is necessary that the groundwater level be surveyed throughout the year.

(3) Determination of the Exact Area to be Covered by the Irrigation Plan

In view of the fact that the water supplies vary considerably between different parts of the study area, it will be necessary to determine exactly where the shortages exist for irrigation planning purposes.

Fig. 17

Land Use and Rice Yield in Kecamatan



Legend

: Ratio of Paddy Field Use

: Yield of Rice

: Annual Times of Paddy Filed Use

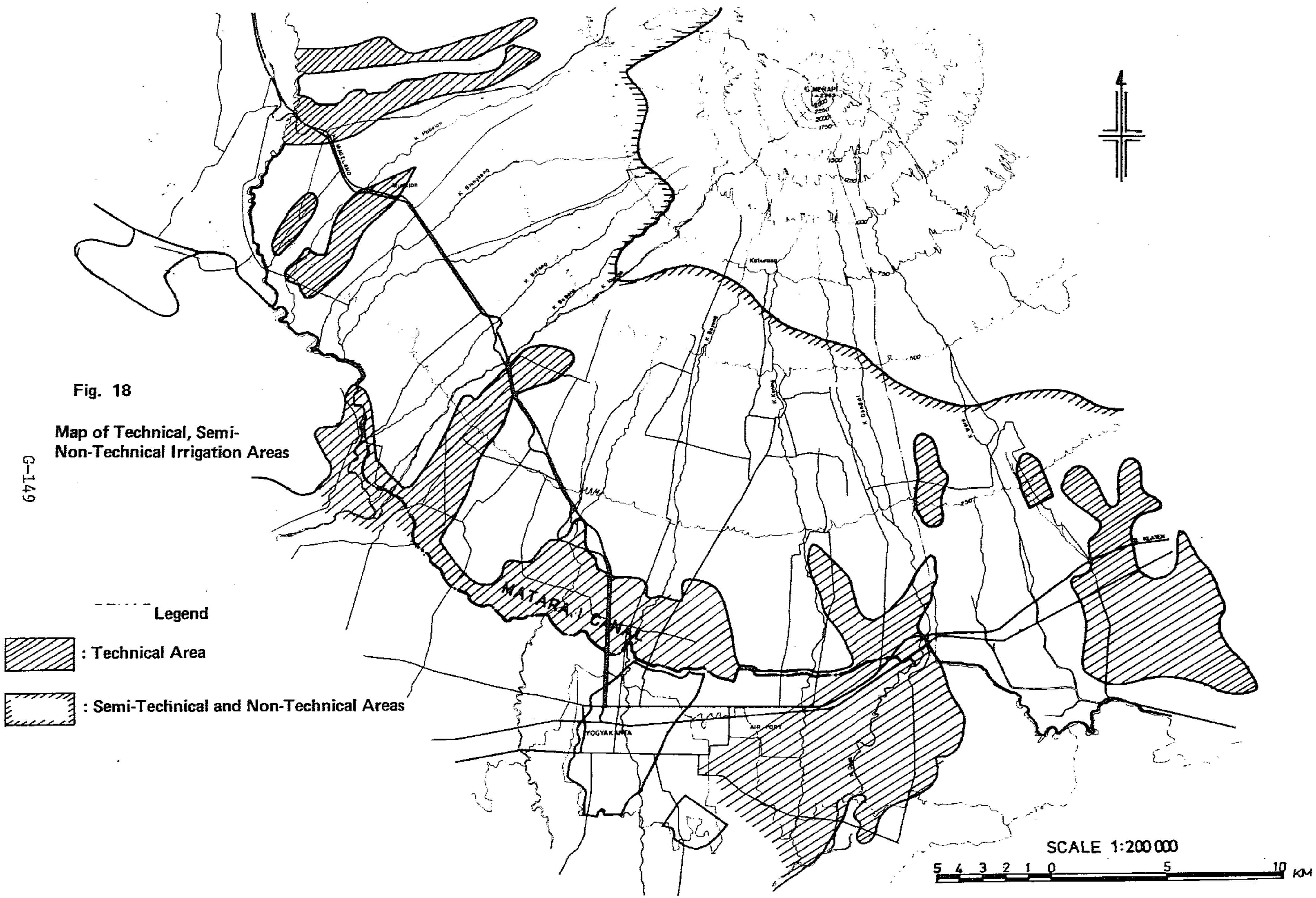
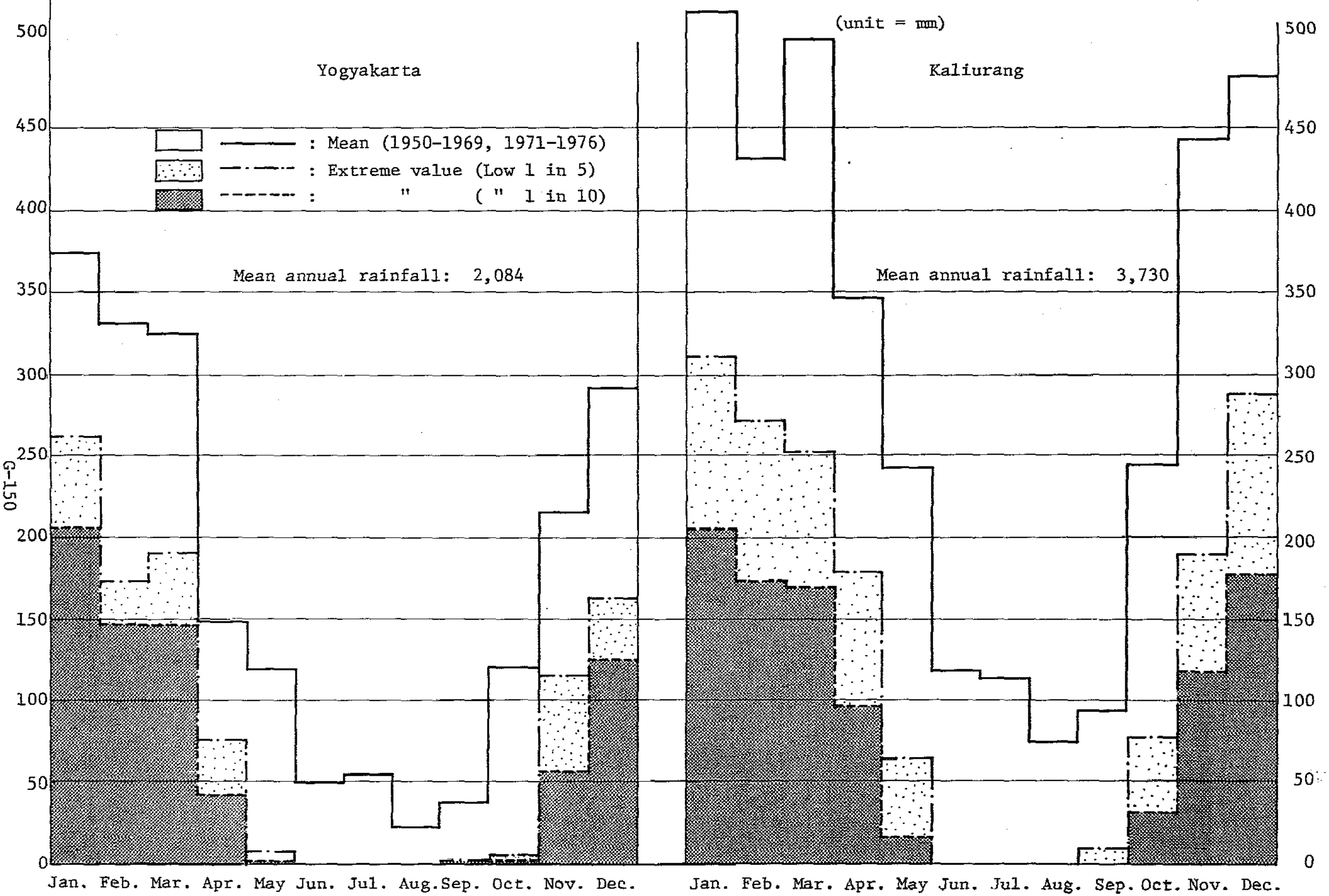


Fig. 18

Map of Technical, Semi-
Non-Technical Irrigation Areas

Fig. 19 Monthly Rainfall at Yogyakarta and Kaliurang



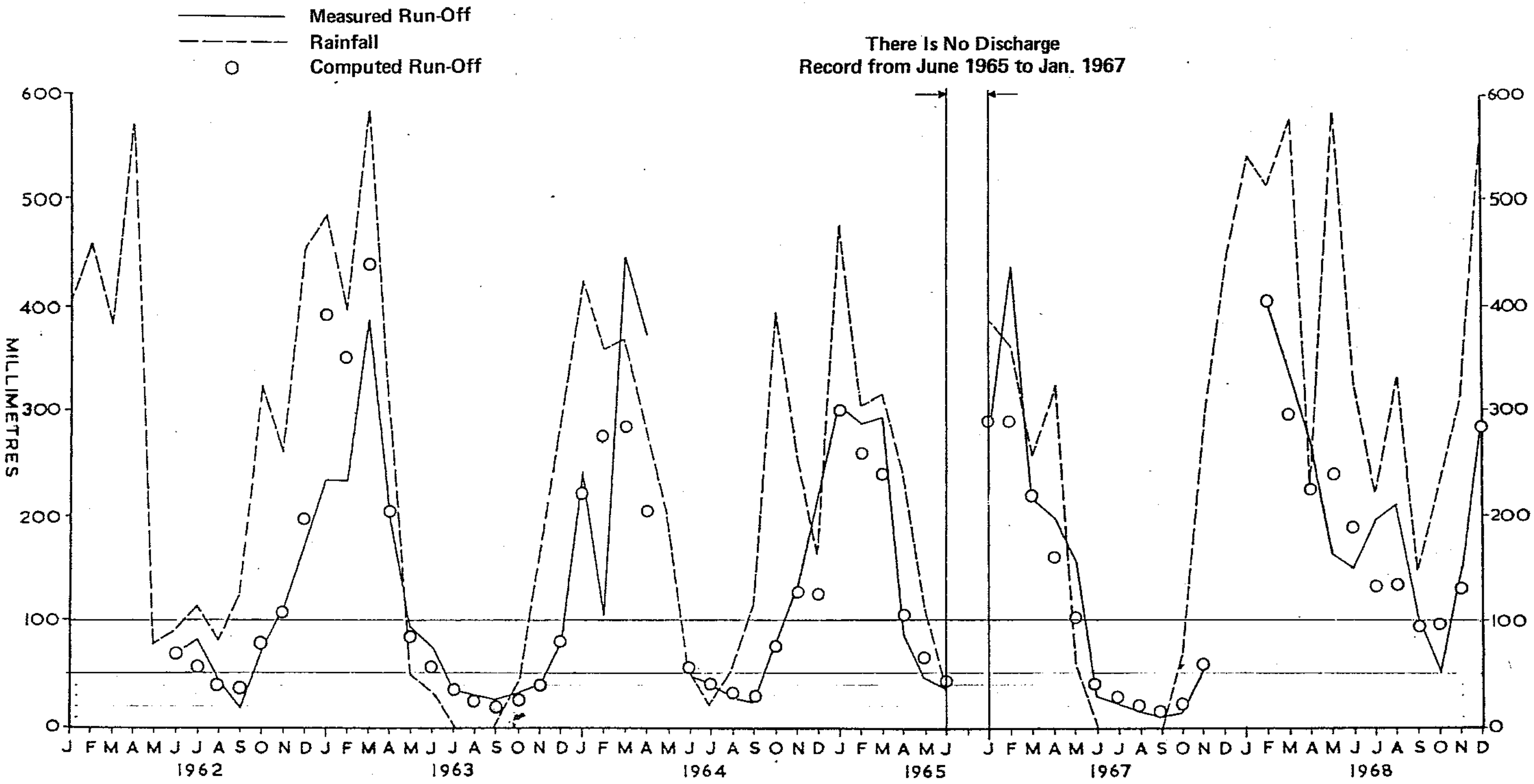


Fig. 20 Comparsion of Computed and Measured Run-Off for Kali Progo at Kranggan

Fig. 21 Area of Wetland Rice Harvested and Irrigated in Sleman

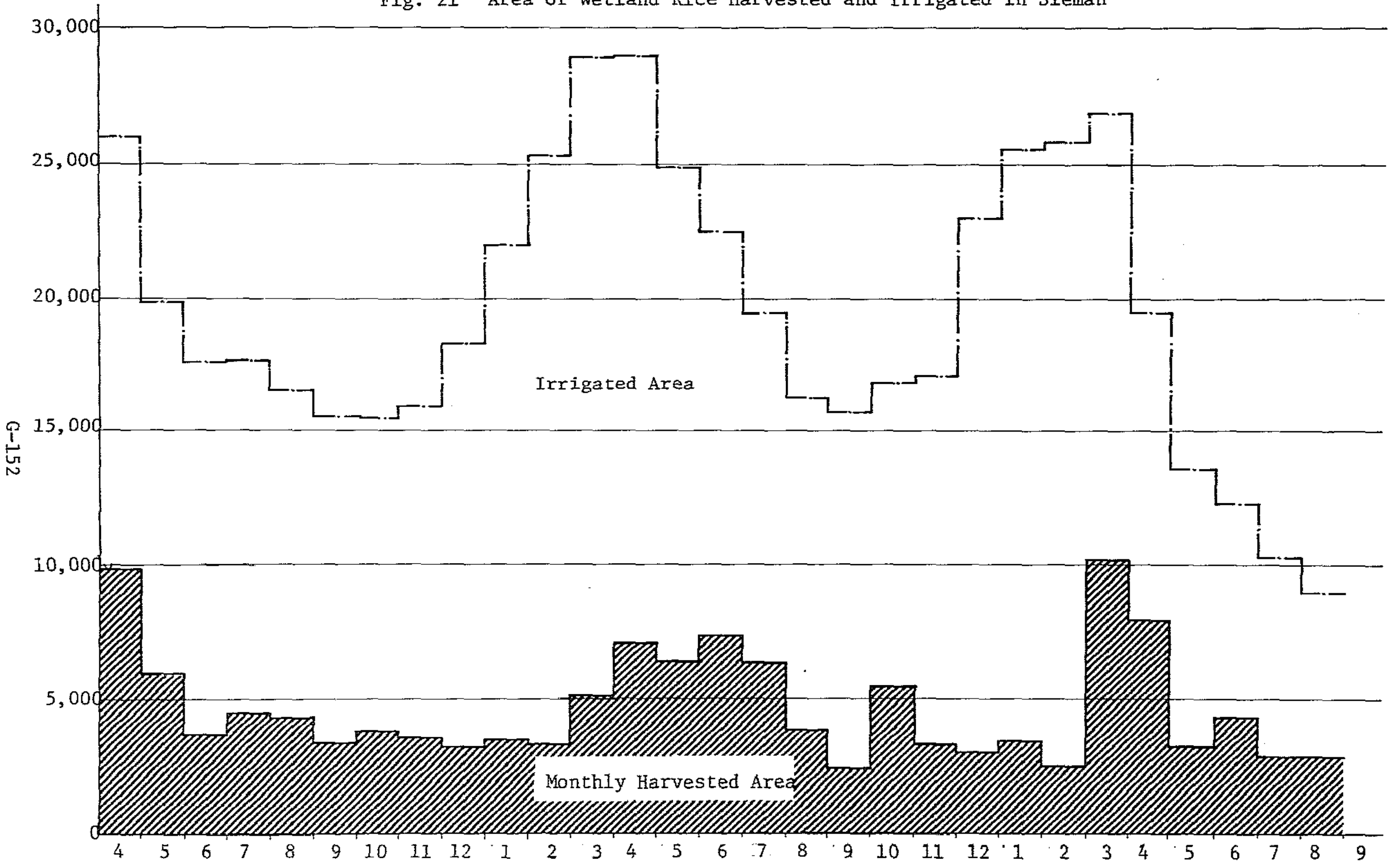
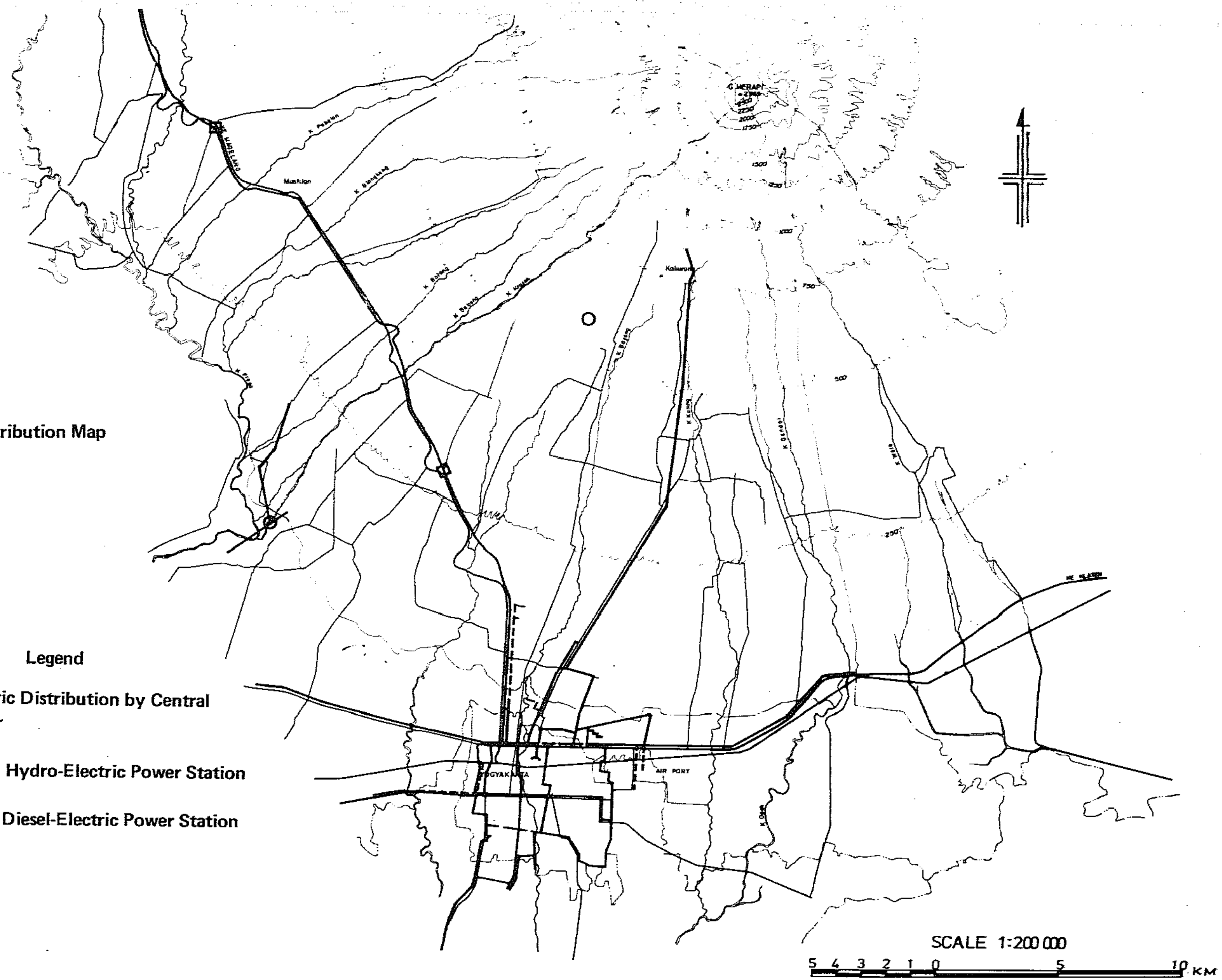


Fig. 22

Electric Power Distribution Map



Legend

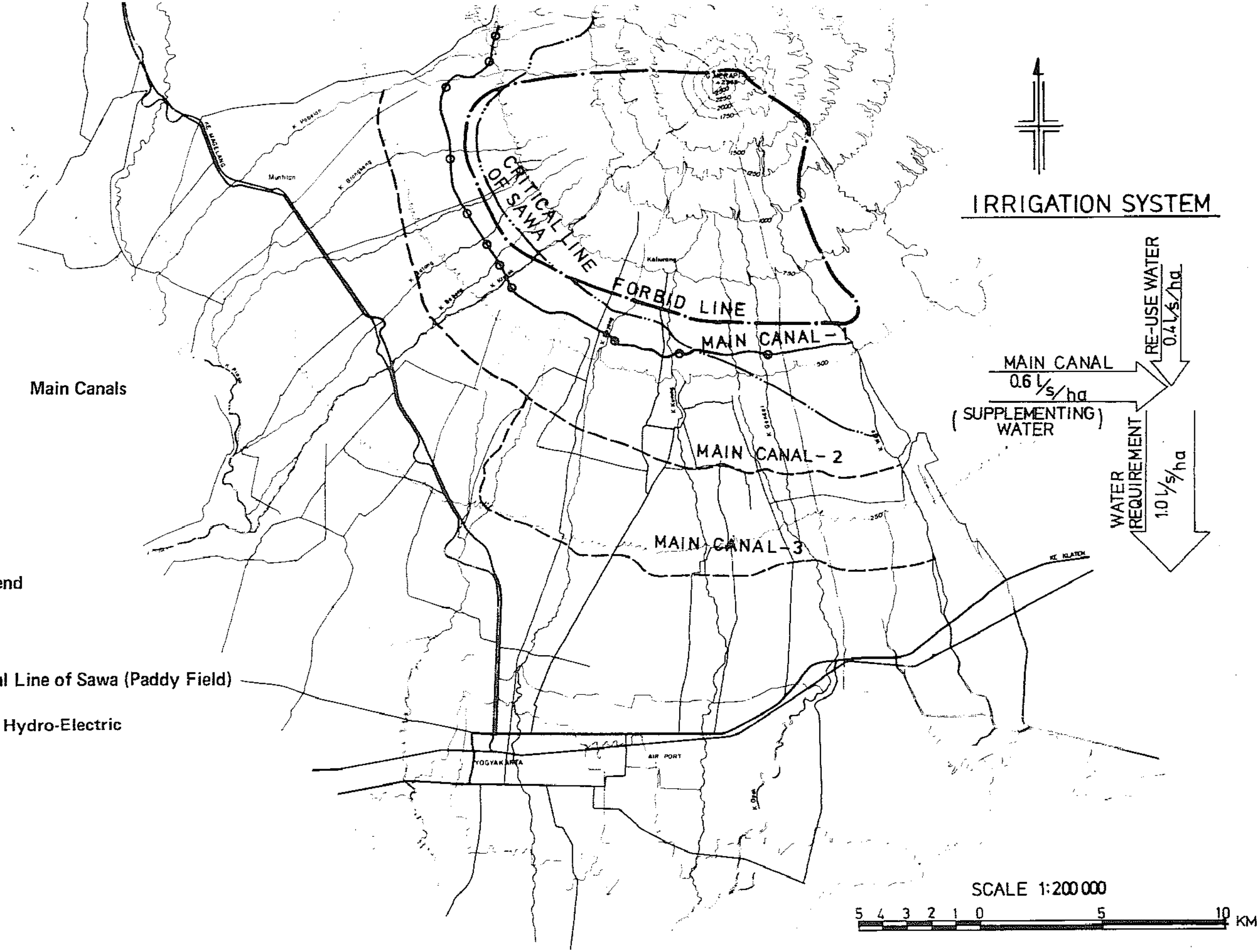
——— : Electric Distribution by Central Power

○ : Micro Hydro-Electric Power Station

□ : Micro Diesel-Electric Power Station

Fig. 23

Routes of Main Canals



Legend

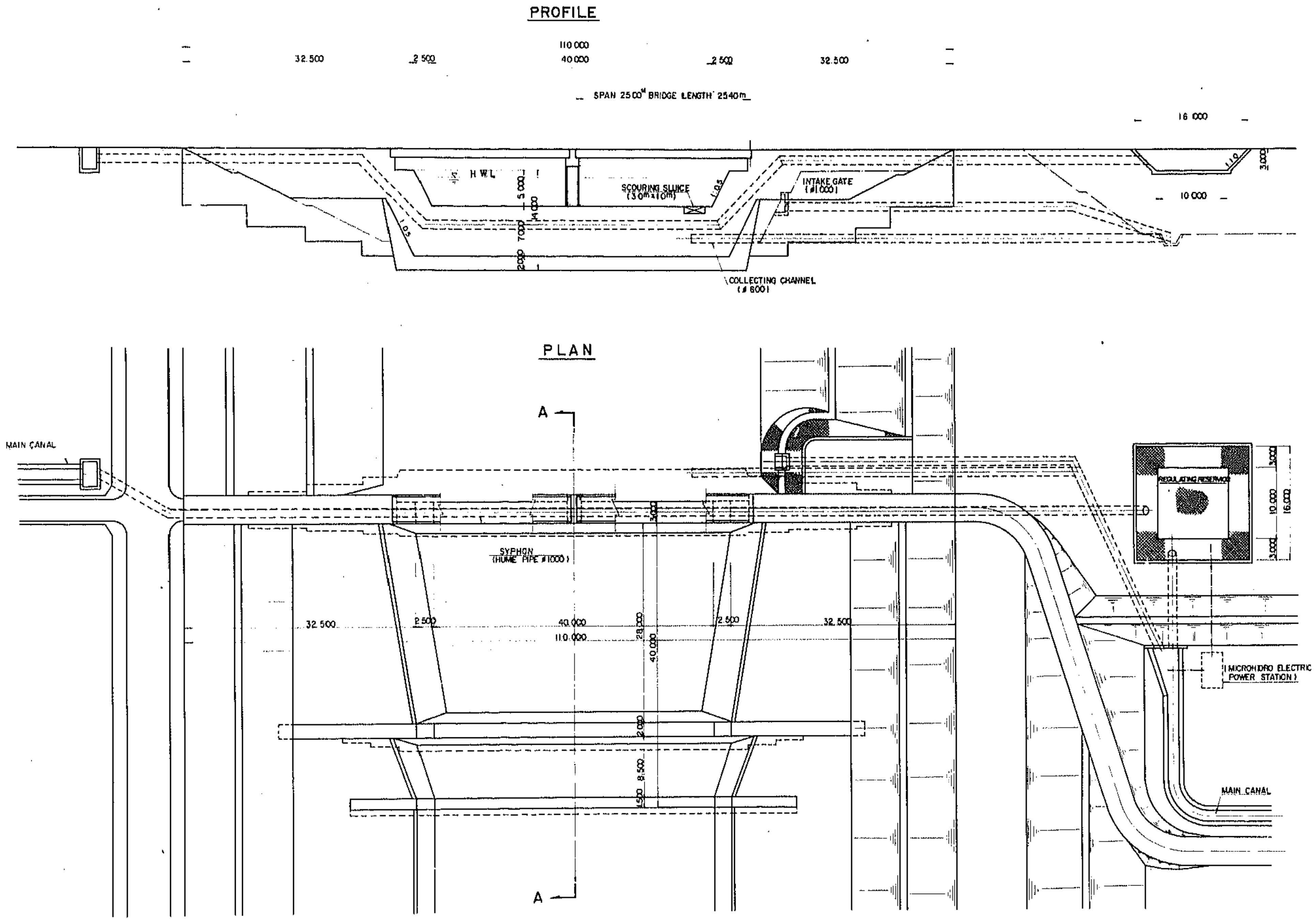
—·— : Off

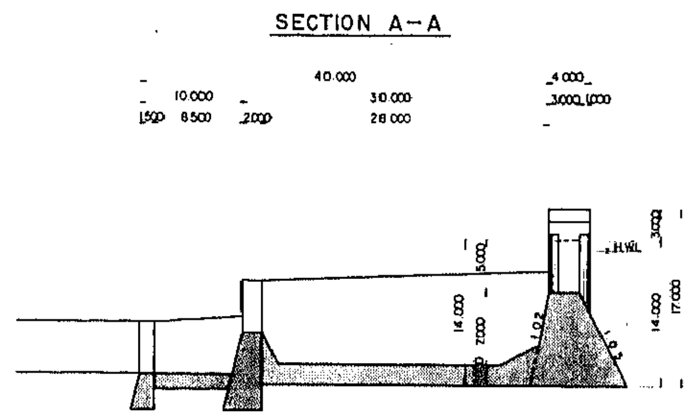
—··— : Critical Line of Sawa (Paddy Field)

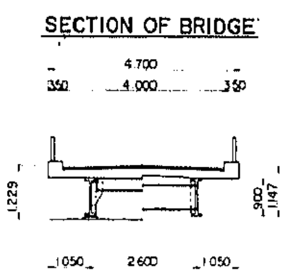
—o— : Micro Hydro-Electric

Fig. 24 Standard Cross Sections of Intakes

DIVERSION WORKS
AND CROSS WORKS FOR MAIN TRIBUTARIES

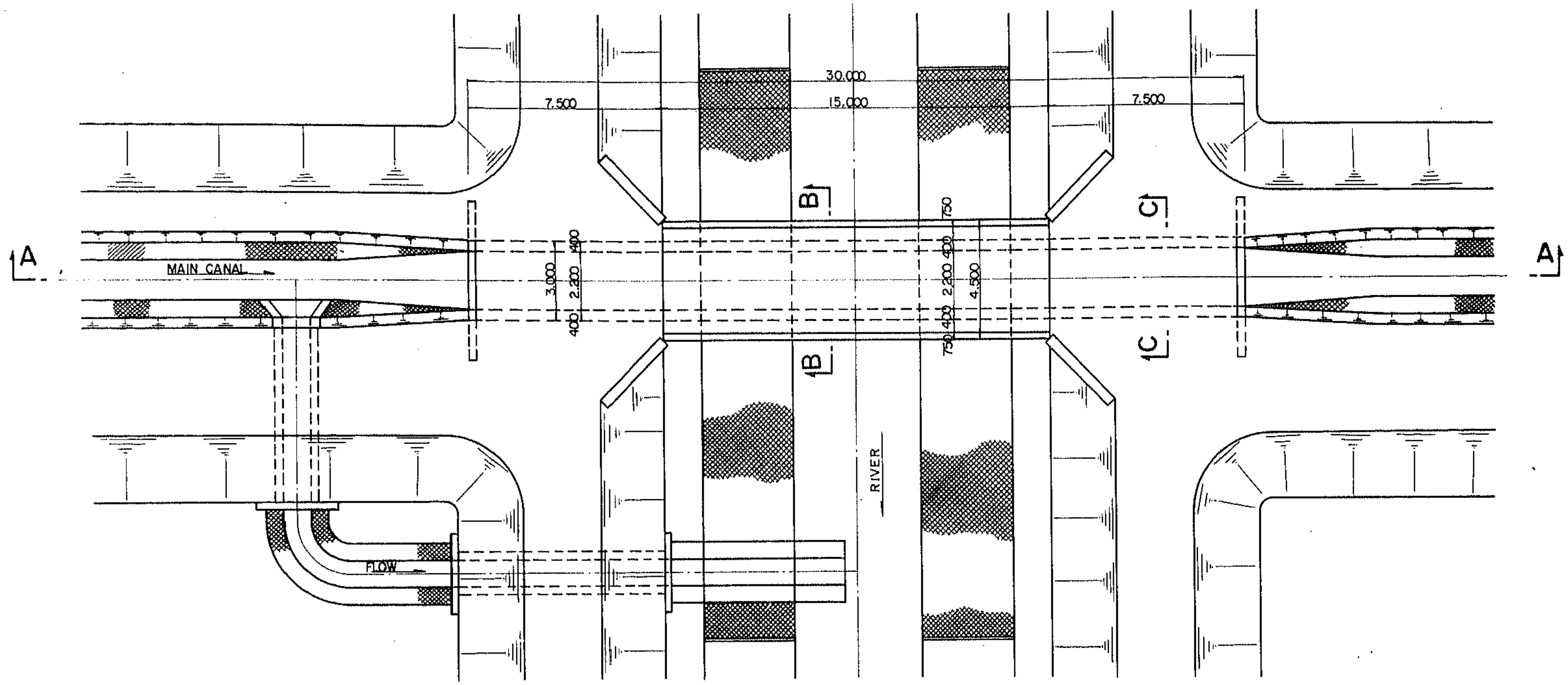




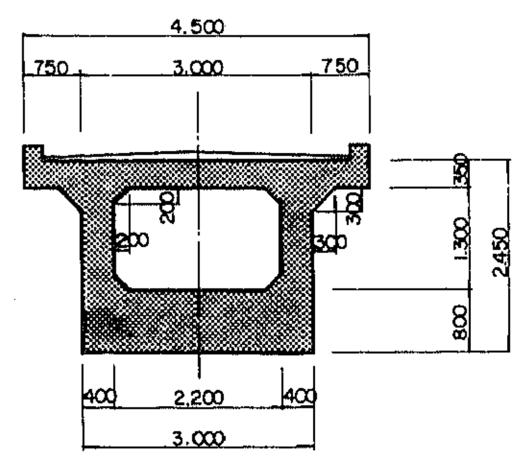


AQUEDUCT

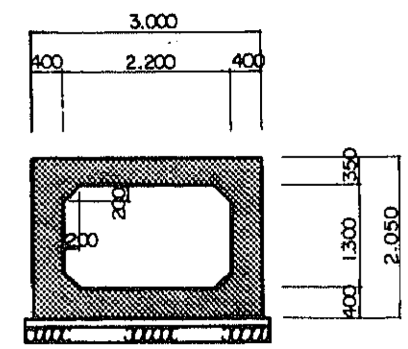
PLAN



SECTION B-B



SECTION C-C



SECTION A - A

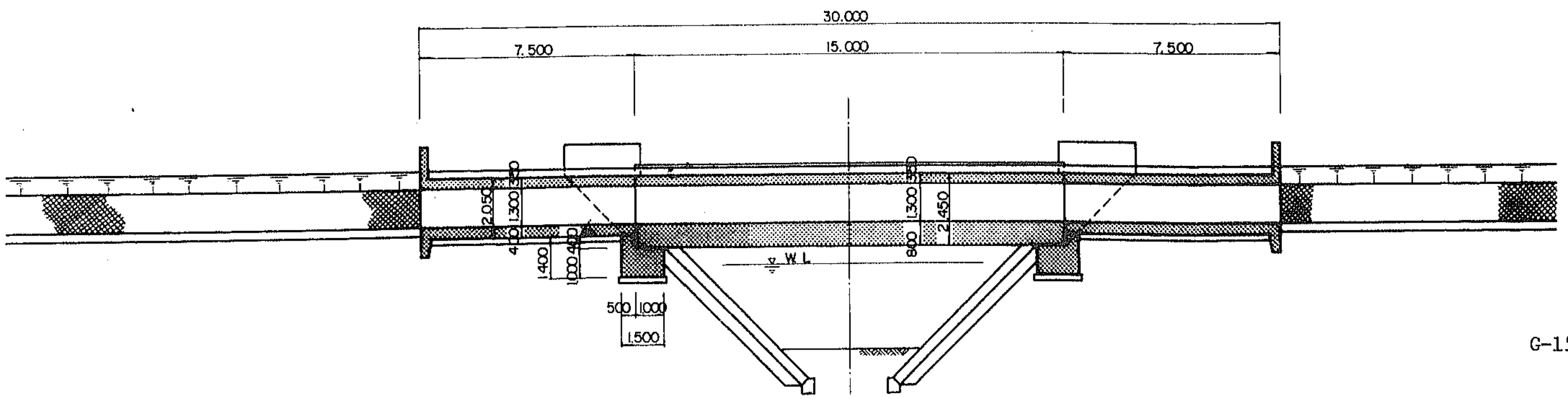
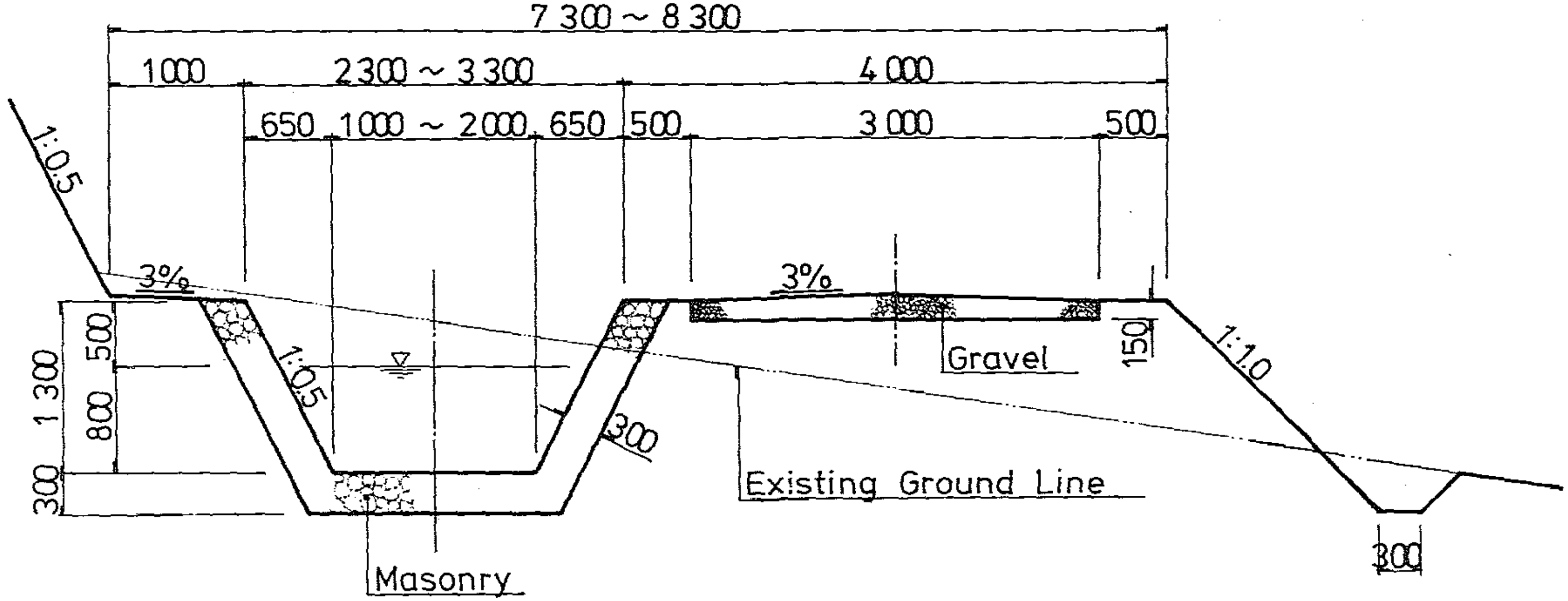


Fig. 25 Standard Main Canal Section

S = 1/50

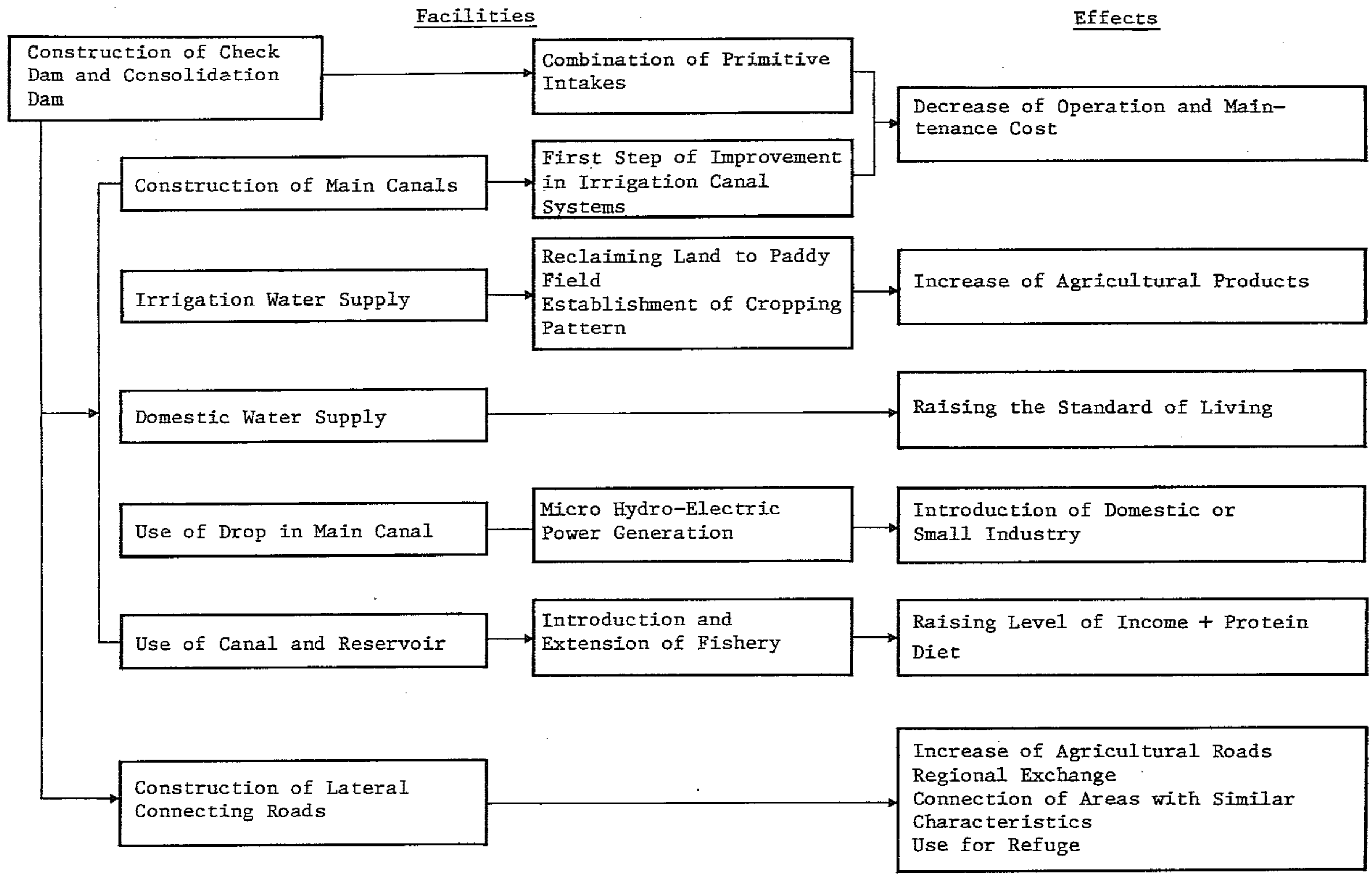


$Q = 1.0 \sim 2.0\ m^3/s$

$I = 1/1\,000 \sim 1/2\,000$

$V = 0.5 \sim 1.0\ m/s$

Fig. 26 Outline of Effects of Multi-Purpose Facilities



CHAPTER 3 SOCIO-ECONOMIC EVALUATION

3.1 Purpose and Methodology

3.1.1 General

The purpose of this chapter is to analyze the present disaster prevention plan from economic, social, and financial angles to determine the feasibility of the plan.

Generally land erosion and volcanic debris control works have a number of different effects. In this chapter a cost-benefit analysis is to be made of these anticipated effects that relate to economic efficiency.
In addition, a qualitative and quantitative analysis is to be made of the main social effects expected. The financial significance of implementation of the plan is to be considered from the standpoint of procurement of dunds. Finally, an overall analysis is to be made of the results of these economic, social, and financial analysis, taking into account congruency with the goals of Repelita-III on the national level and the level of Central Java Province and D.I. Yogyakarta, so as to assign priorities to the alternatives.

3.1.2 Economic Effects

The economic effects of the project which can be directly expected from the planned sabo facilities and the associated works excluding those effects from K. Progo, K. Opak and Matarum Canal include the following:

(1) Damage reduction effects by way of sabo facilities.

(2) Effects from stabilization of the rivers and agriculture in the area, and

(3) Development effects resulting from the multi-purpose use of sabo facilities: use of the associated facilities.

The standard of evaluation in the economic analysis is to be internal rate of return (IRR).

In estimating the amount of damage incurred annually, use has been made of various statistics and of the results of the socio-economic survey carried out locally instead of predicting the future amount of damage on the basis of past trends since, for one thing, there is too little data available on past damage. The estimated damage incurred in the case of farmland and yards has been based on the annual net income from them; in the case of houses and private assets it is based on the average net worth per household; and in the case of roads, it is based on the construction costs involved in restoring them to their original condition after such damage. As for the area it is impossible to estimate it on a probability basis in connection with eruptions of G. Merapi and rainfall. Instead, therefore, damage has been estimated based on the amounts of area involved in past damage and the amounts of sediment that would be deposited if the area was not to be protected by disaster prevention facilities over a period of 25 years for Type-I area, 50 years for Type-II areas and over a period of 100 years for Type-III areas. Accoordingly, in the event that the plan were not implemented 1/25th of the area protected by the disaster prevention facilities in Type-I areas can be expected to suffer damage each year on the average, 1/50th of the same in Type-II areas, and 1/100th in Type-III areas. Since it can be expected to take a great deal of time and cost to restore farmland and yards that have suffered sediment damage to their original state and get them back on into production, it has been assumed that it would not be possible to start cultivation again within the life of the project, and that the estimated not lost income of farmers from such farmland and yards would be taken as the extent to which damage will be reduced by implementation of the plan.

In the case of houses and private assets and roads, the number of houses and the length of roads included in the amounts of land that as expected to suffer damage each year have been estimated, and the average worth in assets of each household and the construction cost of restoration of each unit of road multiplied respectively by these figures have been taken as the extent to which damage would be reduced by implementation of the plan. From the conditions of damage sustained in the past in the case of K. Krasak, however, it has been assumed that only about 25% of the houses on the area of land concerned would actually be destroyed.

3.1.3 Social Effects

This project has a very high feasibility in the besides its direct economic benefits, it can be expected to contribute greatly to the balanced development of the area through such social effects as protection of life and property, increase of development potential through enhancement of safety, increase of food production, creation of more employment opportunities, narrowing of the regional income gap, improvement of social infrastructure and living standards, and mitigation of population pressure by resettlement.

In the social evaluation, consideration has been given to the following:

(1) increase in production of food,

(2) employment opportunities

(3) income distribution,

(4) resettlement, and

(5) other social effects.

In addition to these, there are a number of other socio-economic benefits for the region: improvement of the standard of living as a by-product of road construction, electrification from installation of micro hydroelectric generator, supply of water for daily domestic use, diversification of agriculture through introduction of improved technology, and introduction of cottage industry.

3.2 Economic Evaluation

3.2.1 Benefits

1) Effect of Reducing Damage

Table 26 gives the estimated annual amount of damage that could be expected in the case of each river if the plan were not to be implemented. For the net income from farmland the net earnings perhectare from farmland in the kabupaten in which the particular river is located has been used. In the case of K. Krasak, however, which runs through both Kab. Magelang and Kab. Sleman, the proportion of the area involved in each (Magelang 45%, Sleman 55%) was taken into account in calculating the average net income on this basis.

It is not easy to estimate the extent to which flooding of farmland will reduce crop yields in view of the fact that many factors, including the time of year the following occurs, the duration of the flooding, and the depth of the flood waters, have a bearing on it. In the flood protection plan in North Sumatra, the following rates were adopted for reduction of wet rice yields owing to flooding:

Depth of flood water (m)	Rate of reduction in yields (%)
0.0 ∿ 0.5	20
0.5 ∿ 1.0	60
1.0	100

In this report it has been assumed that the flooding of paddy, which is the most generally grown crop in the rainy season, to a depth of 0.5 ∿ 0.99 m and for a duration of 1 ∿ 2 days would cause a 25% reduction in the yield.

2) Effect of Increasing Production Through Its Stabilization

Implementation of the disaster prevention plan can be expected to stabilize production in the area benefiting from it as well as securing a stable supply of irrigation water with intake facilities making use of check dams. Accordingly, an increase in production can be expected over that would result in the case in which the plan were not implemented.

In reports of several agricultural projects near the area covered by this plan the estimated annual rates of increase in paddy production that would result without the project are 2.1 ∿ 2.8% in the first 5 years and 0.7 ∿ 1.0% from the sixth to the twentieth year; it is also anticipated that these rates can be raised to 6.8 ∿ 7.3% and 1.4 ∿ 1.7%, respectively, with project implementation. This means a difference of 4.2 ∿ 5.1% in the first five years and 0.4 ∿ 1.0% in the next fifteen years between the two case, i.e., the case of non-implementation and the case of implementation of the agricultural project in question. For the first three years the accumulative difference would be 13.1 ∿ 16.1%, for the first five years it would be 22.8 ∿ 28.2%, and for the entire twenty-year period it would be 34 ∿ 43%.

In the local questionnaire surveys that were carried out in the case of the present project, most of the respondents said that they expected an increase of at least 10% in agricultural production as a result of implementation of the plan, and some even expected an increase of 100%.

It has therefore been adopted that the average increase in production would be 15% over the present level in the third year after completion of the project construction work, and 20% in the fifth year.

Table 27 gives the estimated figures for increase in production owing to implementation of the project in the third year after completion of the construction work (the 18th year from commencement of the construction work) and in the fifth year (the 20th year from commencement).

3) Effect of Increase in Production of the Associated Facilities

The net increase in income per hectare through increase in production of paddy made possible by provision of a main irrigation canal for stabilization of irrigation water supply has been calculated as follows:

Of the paddy fields presently being supplied with irrigation water, 4,800 ha are to be additionally supplied with water by means of the new main irrigation canal. At present they have an average yield of 3.5 tons/ha, and on average they are used for cultivation of 1.4 paddy crops per year. With the additional supply of irrigation water, it will be possible to raise the yield to 4.0 tons/ha and the average number of paddy crops per year to 2.0; this will bring about a gross increase in earnings of Rp.300,700/ha. Subtracting the increase in cultivation cost of Rp.40,755/ha due to the increase in the number of crops planted a year, the net increase in earnings comes to Rp. Rp.259,945/ha, or Rp.1,248 million for the 4,800 ha in question.

In addition, 760 ha of dry crop fields can be converted to paddy fields as a result of the new supply of irrigation water. The gross earning from them, assuming a yield of 4.0 tons/ha and two paddy crops a year, will be Rp.776,000/ha. Subtracting the cost of Rp.135,850/ha and the loss of Rp.210,800/ha from reduction in cultivation of cassava and sweet potatos, the net earnings of such new paddy fields comes to Rp.430,150/ha, or Rp.327 million for the 760 ha in question. It has been assumed that such an effect of increase in production will arise at the beginning in the third year after completion of the construction work.

3.2.2 Costs

As stated in the section on construction cost estimate, the total investment involved in the implementation of the present disaster prevention plan will be Rp.39,379,640,000 at 1979 prices.

The construction period is to be fifteen years, with a 5-year first phase and a 10-year second phase. Since the order of construction of the facilities within each phase has not yet been decided, the annual construction cost for each year has been taken as one-fifth of the total construction cost for the first phase (in the case of each of the first five years) and one-tenth of the total construction cost of the second phase (in the case of each of the ten years after that).

As for the investment cost of the associated facilities, the total construction cost of the main irrigation canal has been estimated at Rp.1,693,092,000, and the first alternative calls for its completion within the first construction phase. The construction cost for it each year, therefore, would be one-fifth of its total construction cost in that case. The third alternative, however, calls for completion of the section be tween K. Pabelan and K. Krasak during the first phase and the rest, i.e., the section from Krasak to K. Woro, in the second phase. Accordingly, the annual construction cost for it would be one-fifth of its total construction cost of Rp.817,222,000 in the first phase (for the first five years), and one-tenth of its total construction cost Rp.875,870,000 in the second phase (for each of the ten years thereafter).

The annual maintenance and management costs of the disaster prevention facilities and the associated facilities taken together after completion of their construction have been taken as 1% of their total construction costs, and the duration of such maintenance and management costs has been taken from the year after completion of the construction works to the end of the life of the project.

The life of the works has been taken as fifty years, starting rrom commencement of the construction works in view of the durability of the structures. Furthermore, the salvage value of the structures after the end of the life of the works has been taken as zero.
Table 28 gives the annual construction costs for each of the four alternatives.

3.2.3 Evaluation

The calculated internal rates of return for the four alternatives are as follows:

	with sabo facilities	Total (sabo facilities with associated works)
Alternative-1	7.7	11.4
Alternative-2	7.7	7.7
Alternative-3	7.3	10.6
Alternative-4	7.3	7.3

Interms of economic efficiency, therefore, the order of priority of the alternatives is: Alternative-1, Alternative-3, Alternative-2, and Alternative-4.

Sensitivitity analysis was performed on the internal rates of return for the following cases: a structure life of 40 years, 10% higher construction costs, and 10% lower construction costs. The results have bee been calculated as follows:

	Alternative 1	Alternative 2	Alternative 3	Alternative 4
Structure life of 40 years	11.2	7.2	10.4	6.7
10% higher construction costs	10.1	6.7	9.4	6.6
10% lower construction costs	12.7	8.9	11.7	8.3

3.3 Social Evaluation

3.3.1 General

Protection of production infrastructure, domestic infrastructure, transportation infrastructure and social infrastructure such as cultural assets, educational and medical care facilities, mosques and other religious facilities, and meeting places and other public buildings is very important in terms of regional stability and enhancement of development potential. Consequently, the disaster prevention facilities should be assessed not only in terms of their economic effect but also in terms of their social or socio-economic effect. The following is a quantitative and qualitative analysis of this latter effect.

3.3.2 Evaluation

1) Increase in Food Production

With implementation of the plan, the farmland and irrigation facilities in the area covered by it will be protected from lahar and banjir, and the amount of intake of irrigation water will be stabilized with stabilization of the river courses. As a result, damage to agricultural crops will be reduced, and there will be production of more food as agricultural production is stabilized. This is very important in view of the high population density of the area and government policy of increasing its population supporting capacity. Table 29 gives estimated figures for the amount of rice production in the area that will result from implementation of the plan.

2) Employment Opportunities

Implementation of the disaster prevention plan will mean creation and availability of employment opportunities. Temporary employment will be increased by the jobs available in the construction of the disaster pre-ention facilities and the related facilities and in the supply of materials for use in such construction work; permanent employment will be increased by the jobs available in m maintenance and management of the facilities after they are completed, in afforestation and other planting activities for conservation and land use improvement purposes, and in agriculture as a result of further intensification of agricultural production. Furthermore, protection of farmland from damage due to lahar will be of great significance in terms of stabilizing employment opportunities in agriculture.

Since there is already a considerable surplus labor force in rural communities of the area covered by the plan and the population of working age will continue to increase in view of the age structure of the population, and it should be easy to secure the amount of labor needed in the implementation of the plan and as a result of it. Furthermore, the creation of job opportunities is one of the main goals of Repelita III.

Table 30 gives figures regarding the amount of employment that will be available in the construction of the disaster prevention facilities and the related facilities. These estimated figures are based on an assumed average worker wage of 600 rupiah a day and 200 working days a year. Alternative-1 and Alternative-3 would both create 164,300 man-years of direct employment over a period of 15 years, and Alternative-2 and Alternative-4 would both create 157,520 man-years of direct employment over the same period. Alternative-1 and Alternative-2, however, are the ones that would have the greatest employment creation effect in the early years.

As for the amount of employment that would be created in the agricultural sector, it has been estimated in terms of rice cultivation, the most important facet of agriculture in the area. According to a report of the K. Progo Project, 1,500 ∿ 2,400 man-hours are required to work 1 ha of paddy field, and the daily amount of labor per worker is 3.5 ∿ 4 hr. Assuming an average requirement of 2,000 man-hours and a working day of 4 hrs, two people would be required for 1 ha of rice cultivation annually. On this basis the amount of employment lost by lahar damage and the amount of employment created by the associated facilities have been estimated (see Table 31). If the plan were not to be implemented, the amount of employment lost would be equivalent to 319 workers per year, or nearly 4,800 persons over a period of 15 years. As for the amount of employment that would be created by the associated facilities, it would be about 1 person per hectare in the case of increased production of rice on the existing 4,800 ha of paddy fields, and 4 persons per hectare in the case of creation of 760 ha of new paddy fields. Subtracting 2 persons per hectare from this latter figure as the amount of employment already existing in cassava and sweet potato cultivation on this land before its conversion to paddy fields, one gets a net increase in employment of 2 persons per hectare in the case of these 760 ha. Furthermore, employment opportunities for 30 ∿ 40 persons per hectare will be provided in the afforestation program for land-use improvement.

3) Income Distribution

In the economic evaluation, consideration has already been given to the amount of reduction in damage to farmland, yards, and houses and the amount of increase in farm income resulting from stabilization of agricultural income and increase in yields due to related facilities that would be derived as benefits to the area covered by the plan from the implementation of it. Besides contributing to the economy of the area as a whole, these effects will have a social effect in terms of income distribution.

In the area covered by the plan the overwhelming majority of the farmers have less than 0.3 ha of farmland, and therefore the average income per household is quite low. Furthermore, there is a considerable surplus of labor. Through implementation of the plan, money will be pumped into the local economy in the form of wages of the workers employed at the construction sites of the facilities and after completion of such facilities farm income can be expected to increase through higher yields of agricultural products.

Of the total estimated construction cost of the project of RP.39,380 million, Rp.23,630 million (60%) will be for labor costs, and a very substantial part of that can be expected to go into the pockets of residents of the area.

Fig. 27 gives figures on the amount of increase in farm household income that can be expected per person with respect to the 164,000 persons living in the areas that will protected by the disaster prevention facilities after they are completed (based on a 1% annual increase in population). In the case of Alternative-1 or -3 this per-capita increase can be expected to be Rp.12,550 over twenty years, or 20% of the per-capita income for D.I. Yogyakarta in 1976. As local residents get to be better off economically as a result of such income distribution, they will become more interested in development, and there will be a higher potential for cottage industry and diversified farming.

4) Resettlement

The resettlement of 50,400 persons presently residing in Planning Zone-1 and Zone-2 areas will not only reduce the danger to life, but also help to relieve the population pressure of the area covered by the plan. Without such resettlement, the present population of 1,300,000 could be expected to increase to 1,510,000 in 15 years at an annual rate of increase of 1%. Resettlement of these 50,400 persons, who would grow to 58,500 in the same period at the same rate of increase outside the area, will have the effect of lowering the annual rate of population increase of the area from 1% to 0.74%.

5) Other Social Effects

By their very nature, land erosion and volcanic debris control works are more often than not carried out in remote mountain area.

Since there is little social overhead capital in such areas, there tends to be a considerable gap between them and other areas. The various effects of disaster prevention works of this kind go a long way toward bridging this gap, particularly when they are provided as long-term programs as in this case. The following is a brief summary of other major social effects of such works in addition to those already taken into account.

(1) Construction and Evacuation Roads

Construction roads, facility management roads after completion of the works, and evacuation roads improve local communications and raise development potential in addition to their basic functions. Access to markets will stipulate economic activity, and better communication between local areas will have many positive social and cultural effects.

(2) Transfer of Technology

A long-term 15-year disaster prevention project of this kind provides an excellent opportunity for transfer of technology to unskilled workers in the area.

(3) Social Effect of the Related Facilities

Micro Hydroelectric plants: Besides raising the standard of living of local residents, the supply of electricity by this means could very well stimulate handcraft or domestic industry.

Fishery nurseries: Promotion of this activity will not only income in the area, but also help to improve the diet of local residents by providing more animal portein.

Household water supply: A stable supply of water for this purpose will greatly improve local sanitation conditions.

3.4 Financial Evaluation

3.4.1 Procurement of Funds

As already stated, the cost estimates of Rp.39,379,640,000 for construction of the sabo facilities and Rp.1,693,092,000 for construction of the associated irrigation canal facilities are based on 1979 prices. Possible future inflation has not been taken into account in these figures, but it will have to be taken into account in the procurement of funds.

Table 32 shows the amount of dunds that each alternative would require in the first 5-year construction stage if the works were to commence in 1981, and Table 33 gives the annual budgets of the Merapi Office for fiscal 1969 through fiscal 1978. For the five years from 1973 to 1978, there was a tremendous average annual increase of 35% in that budget.

Furthermore, this budget accounted for 1.7% of the total budget for River Bureau works in fiscal 1978. Accordingly, in the first year of implementation of the plan, funds equivalent to three times the Merapi Office budget of fiscal 1978 will be needed.

The budget of the Merapi Office continues to increase at the rate of 5 ∿ 15% a year. Therefore much preparation will be necessary in order to ensure that the funds needed can in fact be procured.

3.4.2 Present Value of the Amount of Investment

The total investment entailed by Alternative-1 or Alternative-3 over the 15-year period at 1979 prices will be Rp.41,072,732,000, and that of Alternative-2 or Alternative-4 will be Rp.39,379,640,000. However, the necessary flow of funds for the different stages will be different between the two alternatives of each pair. Accordingly, it is necessary to determine the extent of the fiscal burden that such investment will entail by considering the present value thereof for each alternative. Table 34 gives the figures for the present value of such investment in the case of each alternative on the basis of discount rates of 8% and 10%.

Table 26 Estimated Annual Damage Amount

(1) Type-I

Items \ Rivers	K. Krasak	K. Batang	K. Putih	K. Blongkeng
1. Estimated damage area (ha)	1,823.8	1,516.7	1,370.9	1,054.4
2. Land use				
farmland (%)	64.4	64.4	64.4	64.4
yard (%)	28.0	28.0	28.0	28.0
road (m/ha)	118.4	118.4	118.4	118.4
3. House	5,289	4,398	3,976	3,058
4. Income and Assets				
farm income (Rp./ha)	523,900	260,600	260,600	260,600
yard income (Rp./ha)	188,500	188,500	188,500	188,500
house and assets	1,000,000	1,000,000	1,000,000	1,000,000
road construction cost (Rp./m)	13,500	13,500	13,500	13,500
5. Estimated annual damage area (ha)	73.0	60.7	54.8	42.2
farmland (ha)	47.0	39.1	35.3	27.2
yard (ha)	20.4	17.0	15.3	11.8
house	53	44	40	
road (m)	8,643	7,187	6,488	4,996
6. Estimated annual damage area				
farmland (million Rp)	25	10	9	7
yard (")	4	3	3	2
house and assets (")	53	44	40	31
road (")	117	97	88	67

(2) Type-II

Items \ Rivers	K. Woro	K. Gendol	
1. Estimated damage area (ha)	2,894.6 (1,675.6)	693.5	
2. Land use			
famland (%)	63.4	63.4	
yard (%)	31.8	31.8	
road (m/ha)	57.5	57.5	
3. House	8,105 (4,692)	1,942	
4. Income and Assets		739,300	
farm income (Rp./ha)	550,300	739,300	
yard income (")	81,600	81,600	
house and assets	1,000,000	1,000,000	
road construction cost (Rp./m)	13,500		
5. Estimated annual damage area (ha)	57.9(33.5)	13.9	
farmland (ha)	36.7(21.2)	8.8	
yard (ha)	18.4(10.7)	4.4	
house	41 (23)	10	
road (m)	3,341(1,933)	799	
6. Estimated annual damage area			
farmland (million Rp)	20 (3)	7	
yard (")	2 (-)	-	
house and assets (")	41 (6)	10	
road (")	45 (-)	11	

( ) Banjir damage

(3) Type-III

Items \ Rivers	K. Boyong	K. Kuning	K. Pabelan
1. Estimated damage area (ha)	1,148.1	447.5	409.0
2. Land use			
farmland (%)	70.6	70.6	70.6
yard (%)	21.0	21.0	21.0
road (m/ha)	55.7	55.7	55.7
3. House	1,952	761	695
4. Income and Assets			
farm income (Rp./ha)	739,300	739,300	260,600
yard income (Rp./ha)	71,700	71,700	188,500
house and assets	1,000,000	1,000,000	1,000,000
road construction cost (Rp./m)	13,500	13,500	13,500
Estimated annual damage area (ha)	11.5	4.5	4.1
farmland (ha)	8.1	3.2	2.9
yard (ha)	2.4	0.9	0.9
house	5	2	2
road (m)	641	251	228
6. Estimated annual damage area			
farmland (million Rp)	6	2	1
yard (")	-	-	-
house and assets (")	5	2	2
road (")	9	3	3

Table 27 Estimated figures for Increase in Agricultural Production

(unit: million Rp)

Type		3rd Year After the Project	5th Year After the Project
Type-I	K. Krasak	106	142
	K. Batang	50	67
	K. Putih	46	60
	K. Blongkeng	35	46
Type-II	K. Woro	257	343
	K. Gendol	52	69
Type-III	K. Boyong	93	123
	K. Kuning	36	48
	K. Pabelan	13	18

Table 28 Annual Construction Costs of four Altanative Plans

(unit: million Rp)

Altanative	Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Altanative - 1	Sabo Facilities	4,092	4,092	4,092	4,092	4,092	1,892	1,892	1,892	1,892	1,892	1,892	1,892	1,892	1,892	1,892
	Associated Works	339	339	339	339	339	-	-	-	-	-	-	-	-	-	-
	Total	4,431	4,431	4,431	4,431	4,431	1,892	1,892	1,892	1,892	1,892	1,892	1,892	1,892	1,892	1,892
Altanative - 2	Sabo Facilities	4,092	4,092	4,092	4,092	4,092	1,892	1,892	1,892	1,892	1,892	1,892	1,892	1,892	1,892	1,892
Altanative - 3	Sabo Facilites	3,105	3,105	3,105	3,105	3,105	2,386	2,386	2,386	2,386	2,386	2,386	2,386	2,386	2,386	2,386
	Associated Works	163	163	163	163	163	88	88	88	88	88	88	88	88	88	88
	Total	3,268	3,268	3,268	3,268	3,268	2,474	2,474	2,474	2,474	2,474	2,474	2,474	2,474	2,474	2,474
Altanative - 4	Sabo Facilities	3,105	3,105	3,105	3,105	3,105	2,386	2,386	2,386	2,386	2,386	2,386	2,386	2,386	2,386	2,386

Table 28 Expected Growth in Paddy Production in the Hazard Area Without and With Project

Unit: ton

	Without Project	With Project			
		Alter-native-1	Alter-native-2	Alter-native-3	Alter-native-4
0	44,853	44,853	44,853	44,853	44,853
5	35,396	54,354	45,970	50,318	45,665
10	30,573	70,323	49,363	60,526	48,502
15	25,749	72,946	51,986	68,879	50,717
20	20,927	74,783	53,823	74,783	53,823

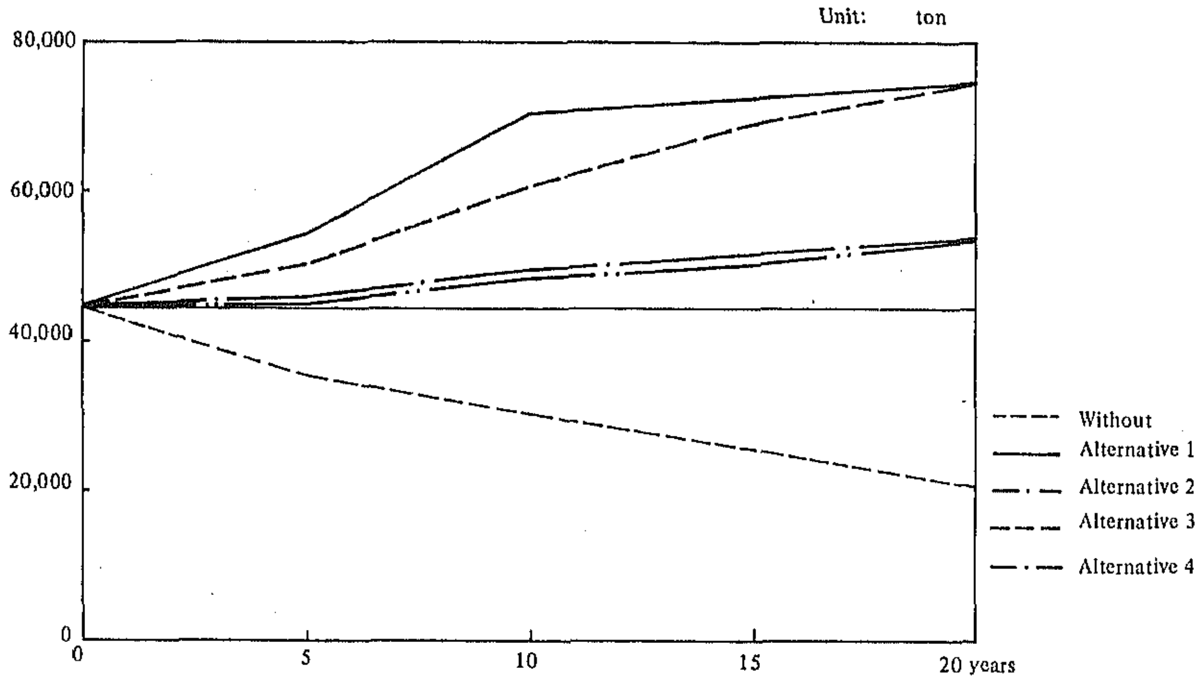


Table 30 Expected Increase of Employment Opportunities with Sabo Works and Associated Works

(1) Construction

Unit: man-year

Year	Alter-native-1	Alter-native-2	Alter-native-3	Alter-native-4
1 ~ 5	88,620	81,840	65,360	62,100
6 ~ 10	37,840	37,840	49,470	47,710
11 ~ 15	37,840	37,840	49,470	47,710
1 ~ 15	164,300	157,520	164,300	157,520
Average	10,953	10,501	10,953	10,501

(2) Maintenance

unit: man-year

Year	Alternative-1 and -3	Alternative-2 and -4
16 ∿ 50	1,640	1,575

Table 31 Expected Increase of Employment Opportunities in Agriculture

1) Expected Decrease in Paddy field Hazarded by Lahar

(unit: person)

Type-I	Type-II	Type-III	Total
231	65	23	319

2) Expected Increase in Paddy Field Improved by Associated Works

(Unit: person)

By Improvement of Irrigation System	By Improving Dry Field to Paddy Field	Total
4,800	1,520	6,320

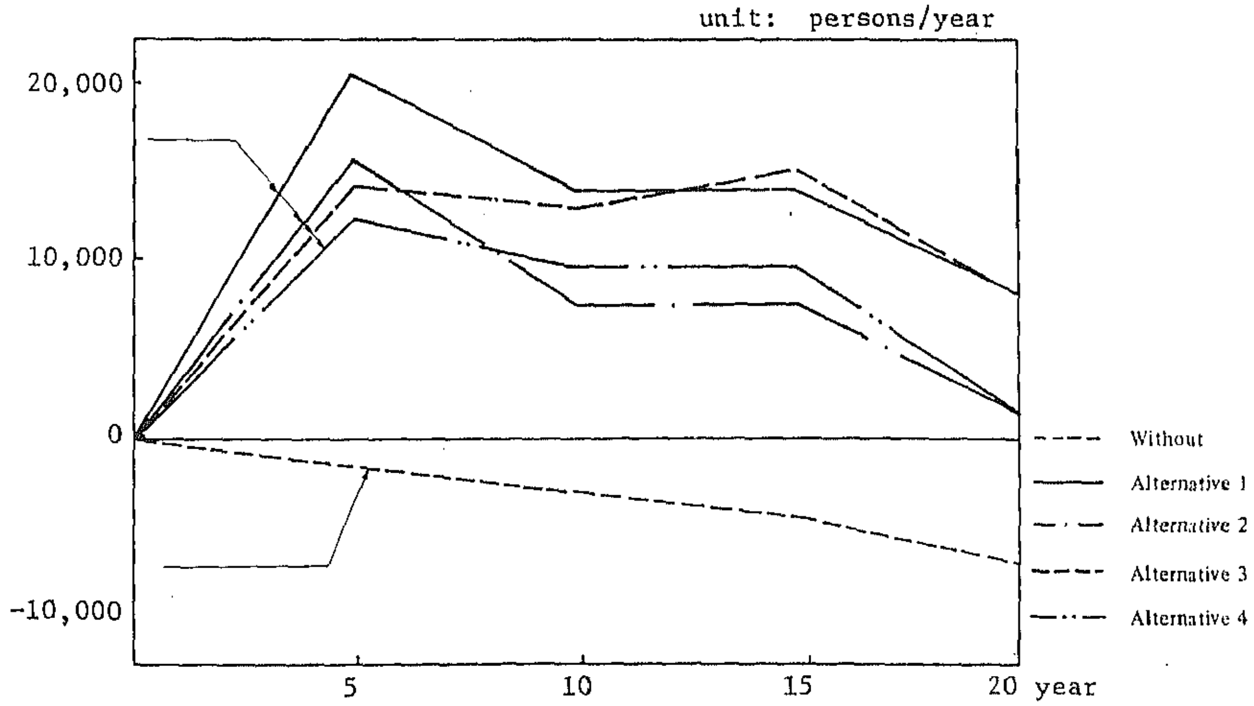


Fig. 27 Expected Increase in Personal Income

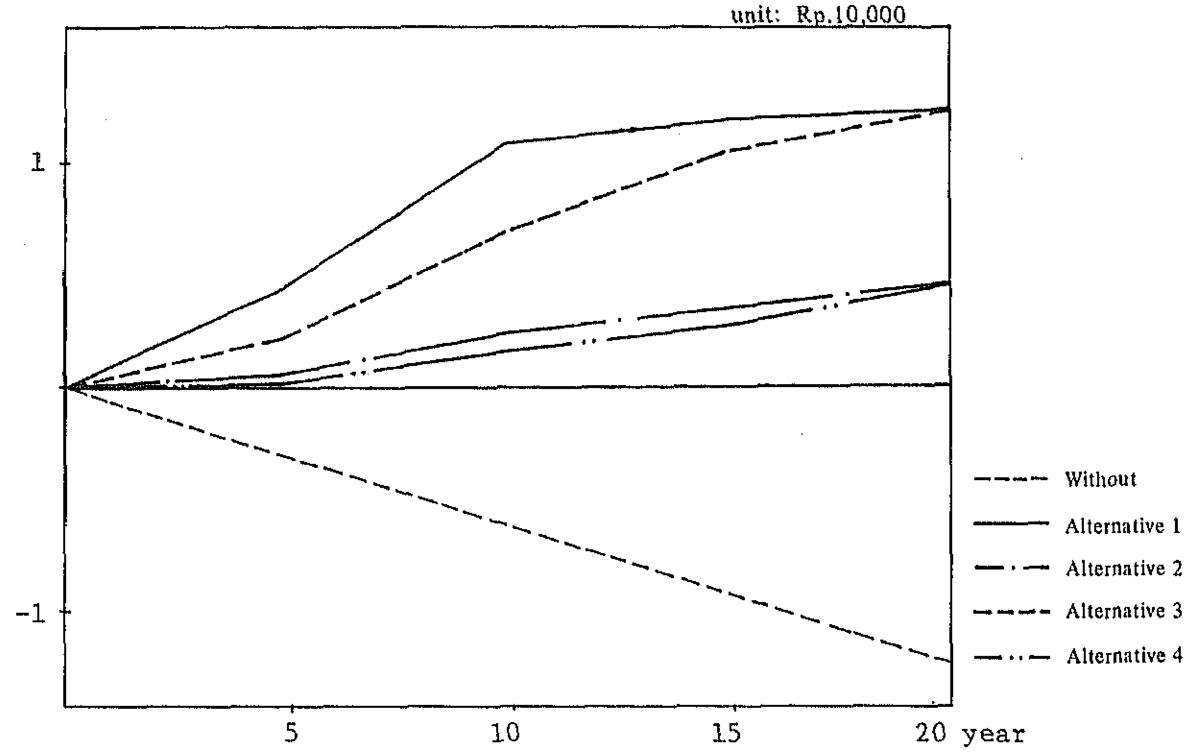


Table 32 Procurement of Funds

(Unit: Rp. 1,000,000)

Item \ Year	1981	1982	1983	1984	1985
Alternative-1	5,361	5,897	6,486	7,135	7,848
Alternative-2	4,951	5,446	5,991	6,590	7,249
Alternative-3	3,954	4,350	4,785	5,263	5,789
Alternative-4	3,757	4,133	4,546	5,001	5,501

(Note:) Expected rate of inflation is assumed to be 10% yearly.

Table 33 Yearly Budget of Merapi Project Office

Year	Construction		Operation/ Maintenance		Total (Rp)	%
	Cost (Rp)1/	%	Cost (Rp)	%		
1969-'70	(98,000,000) 134,900,999	58.4	96,100,000	41.6	231,000,000	100
'70-'71	131,773,000	73.2	48,227,000	26.8	180,000,000	100
'71-'72	110,550,000	71.3	44,450,000	28.7	155,000,000	100
'72-'73	122,800,000	79.2	32,200,000	20.3	155,000,000	100
'73-'74	129,100,000	83.3	25,900,000	16.7	155,000,000	100
'74-'75	224,600,000	86.4	35,400,000	13.6	260,000,000	100
'75-'76	325,500,000	87.8	45,300,000	12.2	370,800,000	100
'76-'77	290,400,000	78.8	78,200,000	21.2	368,600,000	100
'77-'78	234,500,000	79.1	88,500,000	20.9	423,000,000	100
'78-'79	528,000,000	88.0	72,000,000	12.0	600,000,000	100
Total	2,332,123,000 (80.5%)		566,277,000 (19.5%)		2,898,400,000 (100%)	

Note: 1/ An Amount for Pre-Project expenses was added in brackets in the First Year; however precentages were calculated without it.

Table 34 Present Value of Project Investment

(Unit: Rp. 100,000)

	Alter-native-1	Alter-native-2	Alter-native-3	Alter-native-4
8%	30,759	29,066	27,610	26,394
10%	28,447	26,823	25,095	23,979

CHAPTER 4 PROJECT EVALUATION

Table 35 integrates the results of the economic, social, and financial assessments in score card form. As can be seen, Alternative-1 ranks best in every respect except the fiscal burden, with respect to which it ranks last.

The project was evaluated in terms of internal rate of return (IRR) calculated on the basis of the following direct effects expected from the planned sabo facilities and the associated irrigation canal-1 works, excluding those effects from K. Progo and K. Opak and Mataram Canal;

(1) Sediment damage reduction effects by way of sabo facilities,

(2) Effects from stabilization of the rivers and agricultural in the area, and

(3) Development effects resulting from the multi-purpose use of sabo facilities; use of the associated irrigation canal-1 facilities.

Four alternative implementation proposals were considered in determining the effects for the project. The results of the comparison are shown in Table 35 and indicate that alternative-1 would bring the greatest amount of benefits to the project area in terms of economic and social effects.

In addition to direct economic benefit, the project implementation can be expected to contribute greatly to the balanced development of the area through such social effects as protection of life and property, increase of development potential through enhancement of safety and quantifiable benefits such as the following;

(1) An increase in rive production in the foothills of G. Merapi by 9 ∿ 21%,

(2) A creation of employment opportunities on sabo construction works and agricultural stability and development for 10,500 ∿ 11,000 persons/year

(3) An increase in the income level in the sabo-protected area to Rp.12,550/person/year

(4) A decline of the population growth rate by 0.26% as a result of resettlement of residents from the nuee ardente danger area (Zones 1 and 2)

In summary the project is highly recommendable not only to solve regional problems, but to establish a firm foundation for regional growth and achievement of regional development targets.

Table 35 Summary of Socio-economic Analysis

Item	Alternative-1	Alternative-2	Alternative-3	Alternative-4
1. Economic Evaluation (IRR)	1 (11.4%)	3 (7.7%)	2 (10.6%)	4 (7.3%)
2. Social Evaluation				
Protected and Stabilized Area in 5 years	1 (5875.9)	1 (5875.9)	3 (4609.2)	3 (4609.2)
Increase in Paddy Production in 15 years (Unit: ton)	1 (72,946)	3 (51,986)	2 (68,879)	4 (50,717)
Increase in Employment Opportunity (Unit: person)	1 (14,001)	4 (7,568)	2 (12,843)	3 (9,542)
Increase in Personal Income in 10 years (Unit: Rp.)	1 (12,147)	3 (3,858)	2 (10,768)	4 (3,674)
Improvement of Social Environment and Increase of Potentiality for Regional Development	1	3	2	4
3. Present Value of Investment (Discount Rate: 10%) (Unit: million Rp.)	4 (28,447)	3 (26,823)	2 (25,095)	1 (23,979)
4. Total Project Evaluation	1	3	2	4

Legend: Rank

(Value) (Unit: Rp million unless otherwise indicated)

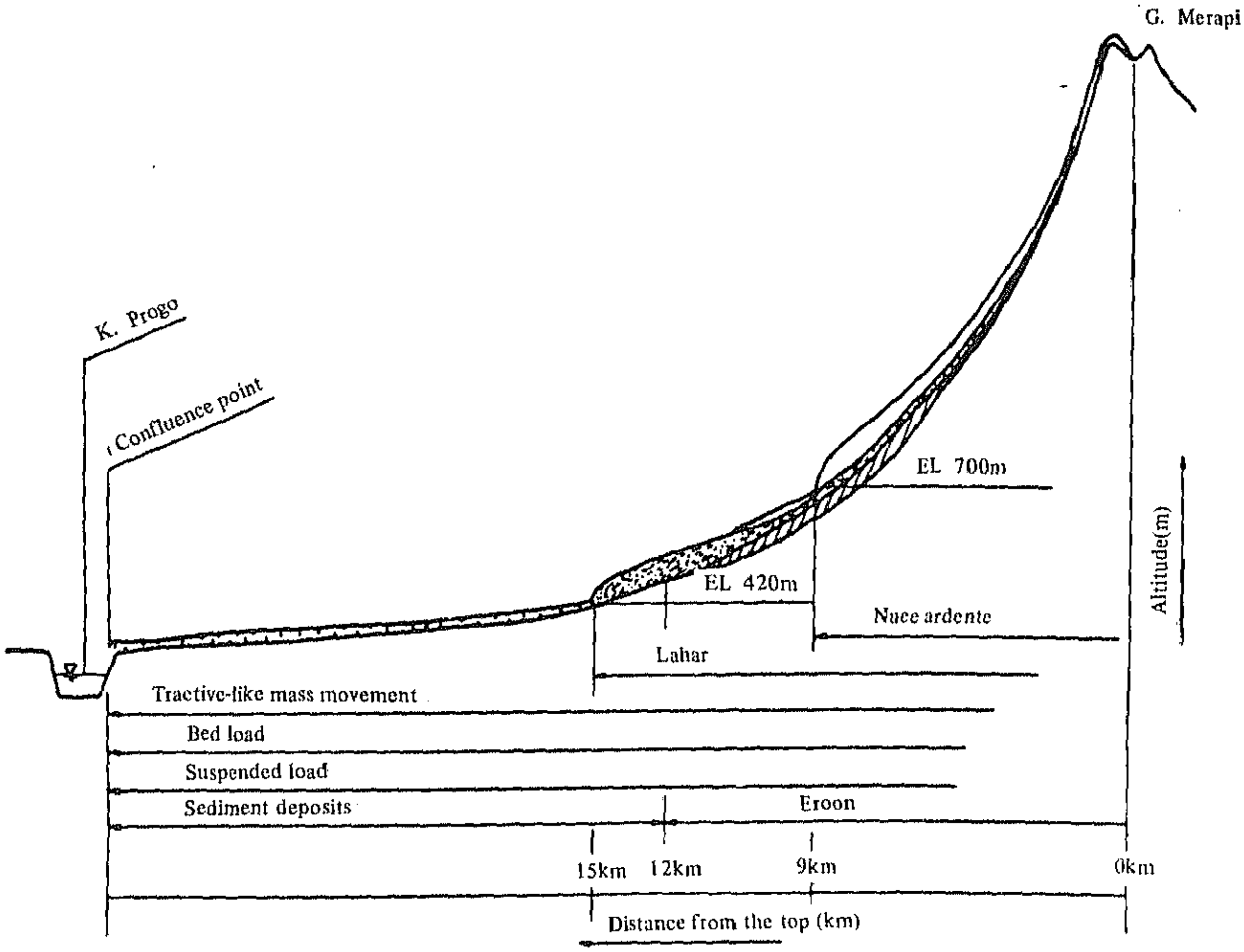
where 1 = Highest
5 = Lowest

Note: 1. IRR: Internal Rate of Return

APPENDIX - A Form of Sediment Transportation in K. Krasak

There is considerable variation in the form of sediment transportation according to changes in hydraulic conditions. Forms of sediment transport are classified as follows:

Mass movement	Mud flow →	Lahar
	Tractive-mass movement →	Banjir
Individual movement	Bed load →	Banjir
	Suspended load and wash load →	Banjir

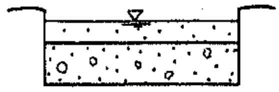


1) Tractive Massive Transport

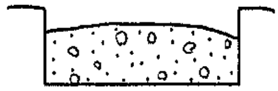
While the sediment and water flow separately, the sediment flows with tractive mass movement.

° Individual movement
(bed load suspended load)

° Tractive mass movement



° mass movement
(mud flow)



The equation of conditions of occurrence of tractive-massive movement is explained as follows:

$$I = \left[\frac{C^*(\gamma - \rho)}{C^*(\gamma - \rho) + \rho(1 + \frac{h}{\sigma})}\right] \tan\phi$$

where C^* : unit sediment amount (%)
h : water depth
d : diameter of particle
I : (tan I) stream gradient
σ : density of particle
ρ : density of water
$\tan\phi$: angle of internal friction

Using this equation, the minimum water depth of tractive massive transport in the vicinity of the river mouth of K. Krasak, was calculated as 60 ∿ 70 cm.

When the flood stage is 1.5 ∿ 2.0 m in depth for the deisgn discharge, the form of sediment becomes completely the tractive-mass movement.

2) Suspended Load

The river bed consists of fine particles, the influence of suspended load is the great. At Blaburan in the downstream area of K. Krasak, where the mean diameter of bed materials is 0.457 mm, sediment become suspended load when the rate of flow is over the value of 250 m^3/s. With a design flood discharge of 560 m^3/s and probability of 100 years, the load will be completely suspended load.

3) Grain Size of Riverbed Materials in K. Krasak

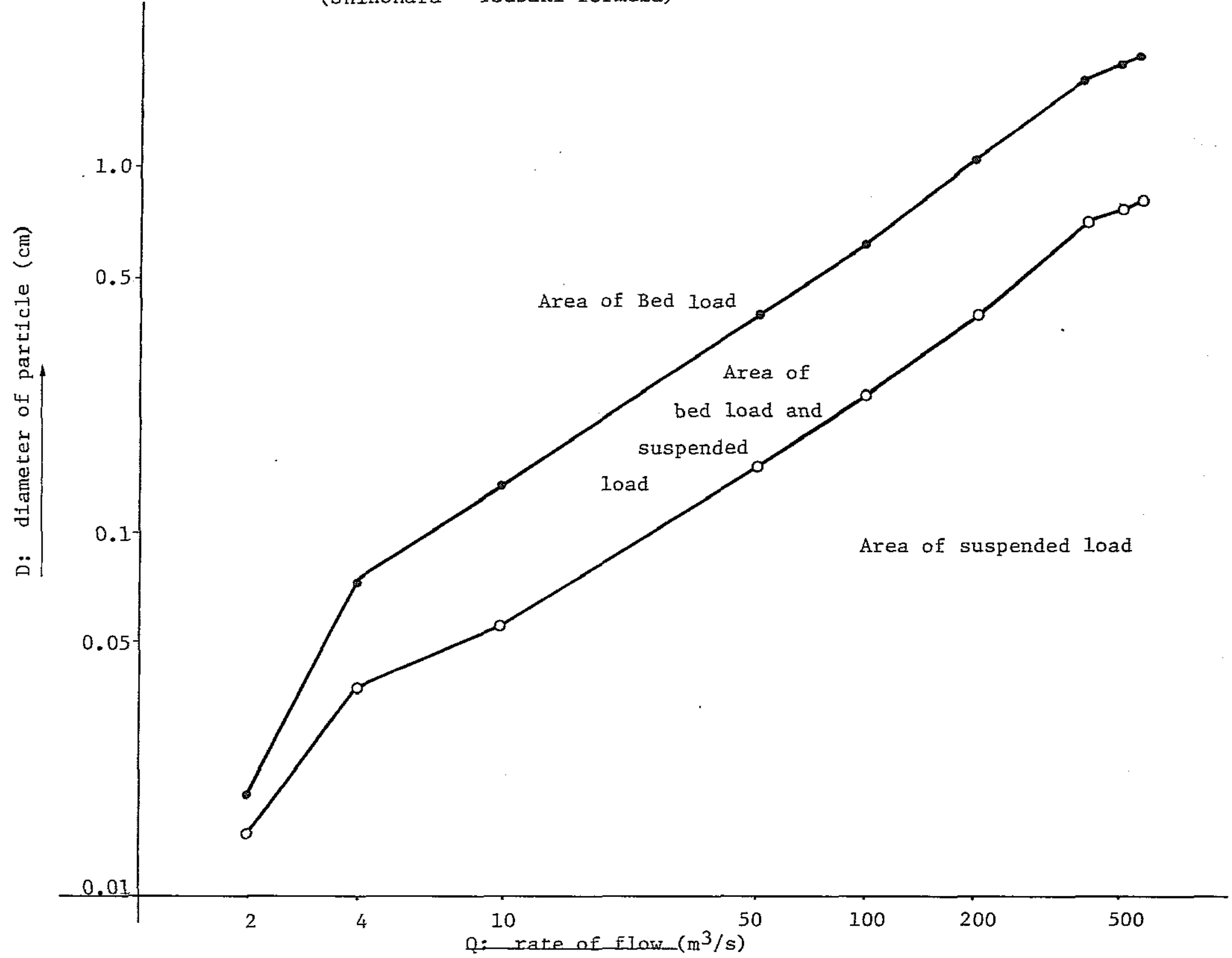
Although the average particle diameter (dm_1) of the riverbed materials deposited during the flood in 1976 averages 0.7 mm. The average particle diameter (dm_2) of present riverbed materials in the downstream area averages 4.75 mm or 6.8 times larger than dm_1.

Since particle diameter is inversely propotional to the amount of sediment load calculated with Brown's formula, the sediment load during the flood in 1976 was 6.8 times larger than that during ordinary times.

It is estimated that during a flood, a large amount of fine materials might be produced by erosion and discharged to the downstream areas.

In order to solve the problems of sediment discharge during floods and to evaluate the effects of decreasing values of average particle diameter of sediment by reducing sediment production with sabo faciliites, observation of sediment discharge during floods should be carried out.

Fig. A.1 Relation between Forms of Sediment Load and Rates of Flow at Blaburan
(Shinohara - Tsubaki formula)



APPENDIX - B <u>Alternative Sabo Facilities Location Plans for K. Bebeng</u>

1) Case - 1: Prevention of downward and lateral erosion with low step dams

a) Check Dams

Four check dams (Be.D.6 ∿ Be.D.9) of 7.5 ∿ 12.5 m in height are to be planned it steps at the upper stream of the 8.6 km point from the summit.

b) Sand Pockets

The sand pockets between the 12 and 15 km points are to be improved with the provision of three consolidation dams and gabions to ensure that the deposits in the sand pocket are well dispersed by leveling.

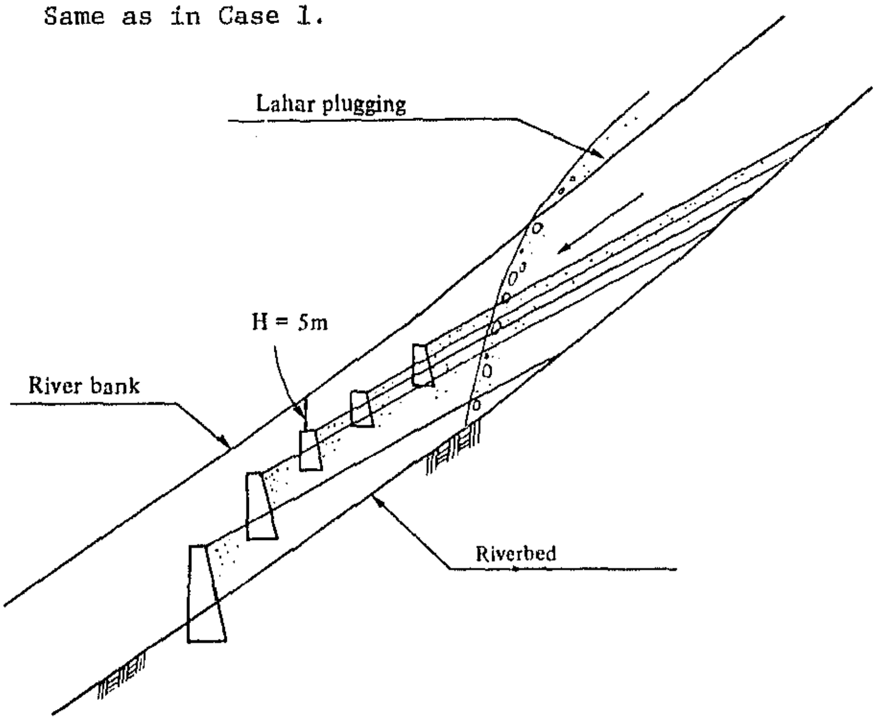
2) Case - 2: Prevention of downward and lateral erosion by Means of increasing riverbed

a) Check Dams

Construction of a dam with a height of 9 m on the deposit area of the Be-D.6 dam at the 8.6 km point after deposition. Provision of three other dams increasing heights to raise the riverbed as high as possible (but not to the extent that there would be lahar overflow) and about 5 m below the river bank. The aim is to prevent erosion subsequent to possible stoppage of the valley by Lahar.

b) Sand Pockets:

Same as in Case 1.



3) Case - 3: Dispersal of Lahar flow by raising the riverbed in the upper slope area to the level of the bank

a) Check Dams

Four dams in a line (Be-D.6A ∿ Be-D.6D), each on the deposit of the preceding one, should be constructed until the riverbed is brought up to the level of the bank.

The Lahar overflow will also be directed in to the present river course by means of the training levees of the valley mouth fixation works.

b) Sand Pockets

1,000 x 10^3 m^3 of sediment will be controlled in the sand pockets of 500 x 10^3 m^3 in the upper stream of the Be-D.6 dams. As for remaining amount, it will be controlled with sand pockets between the 12 and 15 km points, as in case 2.

4) Determination of the Final Plan

Based on a comparative study of the three cases, case - 1 was selected because of are its superiority is terms of safety and low construction costs.

Table B.1 Proposed Sediment Amount of Along K. Krasak

Unit: 10^3 m^3

		Case-1	Case-1 Amount	Case-2	Case-2 Amount	Case-3	Case-3 Amount	Remarks
Excess amount of sediment			8,455		8,455		8,455	
Reduction amount of sediment	Fixing valley Mouth	(1) 1	(4,197) 3,123	1 1	3,123	1	3,123	
	Check dams and consolidation dams	(6) 14	(999) 1,958	15	2,207	14	2,332	
	Subtotal	(7) 15	(5,196) 5,081	16	5,330	15	5,455	
	Sand pocket	(1) 1	(3,259) 3,374	1	3,125	2	1,000 2,000	
	Depth		(1.9 m)		1.8 m	8.4 km 12~15 km	2 m 1.1 m	
	Total	(1)	(3,259) 3,374	1 1	3,125	2	2,625	
Total		(8) 16	(8,455) 8,455	17	8,455	17	8,455	

( ): Pass through upper K. Krasak

APPENDIX - C The Process of Calculating Reduction Volume of Sediment Production

The process of calculating the unit reduction volume of sediment production is shown in Tables - C.1 and C.2.

Table - C.1 (1) Unit Reduction Volume of Sediment Production (K. Bebeng)

Distance from the Summit (km)	Sediment Volume to be Produced: (1) 1969-'76 ($x10^3m^3$)	(2) Proposed Sediment Amount to be Produced =(1)x0.6 ($x10^3m^3$)	(3) Proposed Sediment Amount to be Produced in case of passing through the Present Channel =(2)x0.5 ($x10^3m^3$)	Unit Reduction Volume: (4) Case-1 =(3)x0.7 (m^3/m)	(5) Case-2 =(3)x0.9 (m^3/m)	(6) Case-3 =(3)x1 (m^3/m)	Remarks
7 - 8	3,545	2,127	1,064	745	958	1,064	
8 - 9	2,185	1,311	656	459	590	656	
9 - 10	3,079	1,848	924	647	-	-	( ):
10 - 11	1,484	890	445	(156) 312		-	Consolidation
11 - 12	118	71	35	(12) 25	-	-	Dam (4) x 0.5
Total	10,411	6,247	3,124				

Table - C.1 (2) Unit Reduction Volume of Sediment Production (K. Krasak)

Distance from the Summit (km)	Distance (m)	Sediment Voluem to be produced ($x10^3m^3$)	Unit Reduction Volume (m^3)	Remarks
Main Channel				
7-8	1,000	150	150	
8-9	1,000	220	220	
9-10	1,000	340	340	
10-12	2,000	600	300	
Sub Total	5,000	1,310		
R.T.-I				
7-7.6(I-1)	600	84	140	
7-7.6(I-2)	600	108	180	
7.6-8	400	80	200	
8-9	1,000	240	240	
9-9.4	400	120	300	
Sub Total	3,000	632		
R.T.-II				
9.4-9.7	300	48	160	
9.7-10	300	60	200	
Sub Total	600	108		
Total	8,600	2,050		

Table - C.1 (3) Unit Reduction Volume of Sediment Production (K. Woro)

Distance from the Summit (km)	Sediment Accumulated on the River Bed ($x10^3m^3$)	Sediment Accumulated of the Lower Terrace ($x10^3m^3$	Sediment Accumulated of the Middle and the Upper Terrace (70%) ($x10^3m^3$)	Total ($x10^3m^3$	Reduction Volume per Unit Distance (m^3/m)	Remarks
0 - 3						
3 - 4	10		69	79	79	
4 - 5	20		305	325	325	
5 - 6	40		519	559	559	
6 - 7	40	178	291	509	509	
7 - 7.25	339	17	21	377	838	Length of Channel 450 m
7.25 - 8	28	39	48	115	151	" 760 m
8 - 9	60	106	43	209	209	( ): Consolidation Dam
9 - 10	100	84		184	(92) 184	184 x 0.5
Total	637	424	1,296	2,357		

Table - C.2 (1) Reduction Volume of Sediment Production (K. Begeng)
- Check and Consolidation Dam -

Facility	Reduction District (km)	Reduction Length (m)	Unit Reduction Volume (m^3/m)	Reduction Volume ($x10^3m^3$)	Remarks
1 Case - I					
C-5	11.6-11.5	100	12	1	
C-6	11.5-11.4	100	12	1	
C-7	11.4-11.2	200	12	2	
C-8	11.2-10.9	300		18	
	11.2-11	200	12	2	( ) Item
	11-10.9	100	156	16	
C-9	10.9-10.6	300	156	47	
D-1	10.6-9.9	700		252	
	10.6-10	600	312	187	
	10-9.9	100	647	65	
D-2	9.9-9.66	240	647	155	
D-3	9.66-9.2	460	647	298	
D-4	9.2-8.9	300		175	
	9.2-9	200	647	129	
	9-8.9	100	459	46	
D-5	8.6-8.6	300	459	138	
Sub Total				1,087	
D-6	8.6-8.3	300	459	138	
D-7	8.3-7.9	400		212	
	8.3-8	300	459	138	
	8-7.9	100	745	74	
D-8	7.9-7.43	470	745	350	
D-9	7.43-7.2	230	745	171	
Sub Total				871	
Total				1,958	

Table - C.2 (1) Continued

Facility	Reduction District (km)	Reduction Length (m)	Unit Reduction Volume (m^3/m)	Reduction Volume ($x10^3m^3$)	Remarks
2 Case - II					
C.5 - C.9 D.1 - D.5				1,087	Same as Case-I
D-6A - E	8.6-7.2	1,400		1,120	
	8.6-8 8-7.2	600 800	590 958	354 766	
Total				2,207	
3 Case - III					
C.5 - C.9				1,087	Same as Case-I
D.6A - D	8.6-7.2	1,400		1,245	
	8.6-8 8-7.2	600 800	656 1,064	1,394 851	
Total				2,332	

Table - C.2 (2) Reduction Volume of Sediment Production
(K. Krasak)
- Check and Consolidation Dam -

Facility	Reduction District (km)	Reduction Length (m)	Unit Reduction Volume (m^3/m)	Reduction Volume ($x10^3m^3$)	Remarks
KR-D-1	Main Channel				
	11.5-10.6			270	
	11.5-10.6	900	300	270	
KR-D-2	10-9.4	900		264	
	10-9.4	600	340	204	
	R.T. - II 10-9.7	300	200	60	R.T.: Right Tributary
KR-D-3	9.4-9.05	700		210	
	9.4-9.05	350	300	105	
	R.T. - I 9.4-9.05	350	300	105	
KR-D-4	9.05-8.85	200		48	
	9.05-9	50	300	15	
	9-8.85	150	220	33	
KR-D-5	R.T. - I 9.05-8.4	650		159	
	9.05-9	50	300	15	
	9-8.4	600	240	144	
KR-D-6	R.T. - II 9.4-9.7	300	160	48	
Total				999	

Table - C.2 (3) Reduction Volume of Sediment Production (K. Woro) - Check and Consolidation Dam -

Facility	Reduction District (km)	Reduction Length (m)	Unit Reduction Volume (m^3/m)	Reduction Volume ($x10^3m^3$)	Remarks
C-4	9.7-9.4	300	92	28	
C-5	9.4-9.2	210	92	19	
D-1	9.2-8.7	480	184	88	
D-2	8.7-8.5	290	209	61	
D-3	7.9-8.5	660	209	138	
D-4	7.9-7.25	760	151	115	
D-5	7.25-7	450	838	377	
D-6	7-6.8	300	509	153	
D-7	6.8-6.2	370	509	188	
D-8	6.2-6	270	509	137	
D-9	6-5.4	600	559	335	
D-10	4.4-4.1	300	325	98	
Total				1,737	

APPENDIX - D Expression of Degrees of Danger and Importance with a Grid-Square System

1) Grid-Square System

The grid-square system has been used for evaluation of degree of danger and importance in the area for the following reasons:

(1) In making a comparative study of different areas, it is necessary to disregard administrative boundaries and to standardize zone size. The grid system offers the advantages of dividing the area into geometrically equal shapes and displaying data visually.

(2) Since the area of each mesh in a grid system is the same, the mesh area functions as a common demonstrator for making area comparisons.

(3) Since a grid system is not influenced by variation in administrative area, topography, land use, etc., historical comparisons are facilitated.

(4) Since each area has the same shape, grids more easily show the relationship between location and shape of area phenomena.

(5) Informaiton from standard surveys can make up for gaps in existing information for a particular zone since the grid areas are divided into equal parts.

(6) A broad statistical approach can be taken using accurate high-speed electronic computers.

(7) Since data on terrain, land use, and other conditions will be expressed in terms of mesh squares measuring 0.5 km on a side, the system of coordinates can easily be converted to coordinates of longitude and latitude.

2) Basic Data

Evaluation of present conditions is based on the following sources of information:

Type of Information	Statistical Source
(1) Population	Population density data (1976)
(2) Land productivity	Crop yield indices data (1971) " (1976) Yield of paddy data (1976) Projection of paddy yield data (1981)
(3) Land use	Social division (land use map) Economic division (land use map) Form of irrigation map

(4)	Social infrastructure and other important facilities	Roads, irrigation facilities, etc.
(5)	Topographical conditions	Slope grade map
(6)	Volcanic damage	Type of volcanic material (nuee ardente, lahar, and banjir area map). Volcano frequency (direction of eruption and river types map). Degree of possible flooding map.

The basic data is expressed in Figs. D.1 ∿ D.9.

(1) Population density division (1976) (Fig. D.1)

(2) Crop yield division (Fig. D.2)

(3) Yield of paddy division (1976) (Fig. D.3)

(4) Present tendency of yield of paddy division (1981) (Fig. D.4)

(5) Social land use division (Fig. D.5)

(6) Economic land use division (Fig. D.6)

(7) Irrigation areas division (Fig. D.7)

(8) Possible hazard area division (Fig. D.8)

(9) Slope grades division (Fig. D.9)

3) Statistics of Degree of Danger and Importance

(1) Possible hazard area division (Fig. D.10)

a. 1) Possible hazard area division (Fig. D.8)

b. 2) Damage divisions: nuee ardente, lahar and banjir (10)

c. 3) Damage frequency

$$\log(10) = \frac{1}{3}(\log(a) + \log(b) + \log(c))$$

(2) Degree of social importance classification (Fig. D.11)

d. Population density division (1976)

e. Social land use division

f. Distribution of social infrastructure and other important facilities. (11)

$$\log(11) = \frac{1}{3} (\log(d) + \log(e) + \log(f))$$

(3) Degree of economic importance classification (Fig. D.12)

g. Crop yield index division

h. Paddy productivity division (12)

i. Economic land use division

$$\log(12) = \frac{1}{2} \{(\frac{1}{2}(\log(g) + \log(h) + \log(i)\}$$

(4) Degree of future economic importance classification (Fig. D.13)

j. Crop yield index division

k. Future productivity of yield of paddy division (13)

l. Economic land use division

$$\log(13) = \frac{1}{2} \{(\frac{1}{2} (\log(j) + \log(k) + \log(l)\}$$

Notes: (1) Present tendency of paddy yield division (1981)

The estimated yield of paddy in 1881 are obtained from the following equation:

$$\bar{Y} = a + bt + u$$

where Y: Estimated yield (q/ha)

a. The present level of paddy yield in 1976 (q/ha)

b. The increasing or decreasing tendency (q/ha/year)

t: time Period (year) ... 5

u: Error term .... Estimated as "0"

(2) Damage divisions: Nuee ardente zone, Lahar zone and Banjir zone. Divisions and values determined for each zone are as follows:

. Nuee Ardente Zone 5
. Lahar Zone 4
. Banjir Zone 3
. Others 1

(3) Damage frequency
The hazard areas have been divided into four types divisions and values determined as follows:

. Type - I area 5
. Type - II area 3
. Type - III area 2
. Type - IV* area 1

* Type - IV area indicates land outside the proposed hazard area.

3) Zoning Areas and their Countermeasures

The study area is zoned to the following form zone on the basis of danger and importance degree classifications as follows:
(The hazard area from nuée ardente)

Zone - 1	Type - I
Zone - 2	Type - II Type - III
Zone - 3	(other areas)

Zonal Range of Degree of Danger and Importance

	Degree of Danger					Degree of Socio-economic importance				
	1	2	3	4	5	1	2	3	4	5
Zone - 1	o					o	o	o	o	o
Zone - 2		o	o	o	o	o	o	o	o	o
Zone - 3			o	o	o			o	o	o

(Zone - 1) and (Zone - 2) Where the inhabitant should be protected only by relocation outside area.

From the stand-point of protecting human life first, habitation in nuée ardente hazard zone of type - I should be prohibited and the present inhabitants should be immediately relocated.

(Zone - 3) The inhabitants and property should be protected by Sabo works.

In order to reduce the damage and stabilizing the channels, the possible lahar/banjir hazard areas should be protected to some extent by abo works.

(Zone - 4) The hazard possibilities from the lahar/banjir are very small in this area because it lies outside the hazard zone and therefore it should be eccluded from the objectives of sabo works at this time.

Fig. D General Location Map of Grid Square System

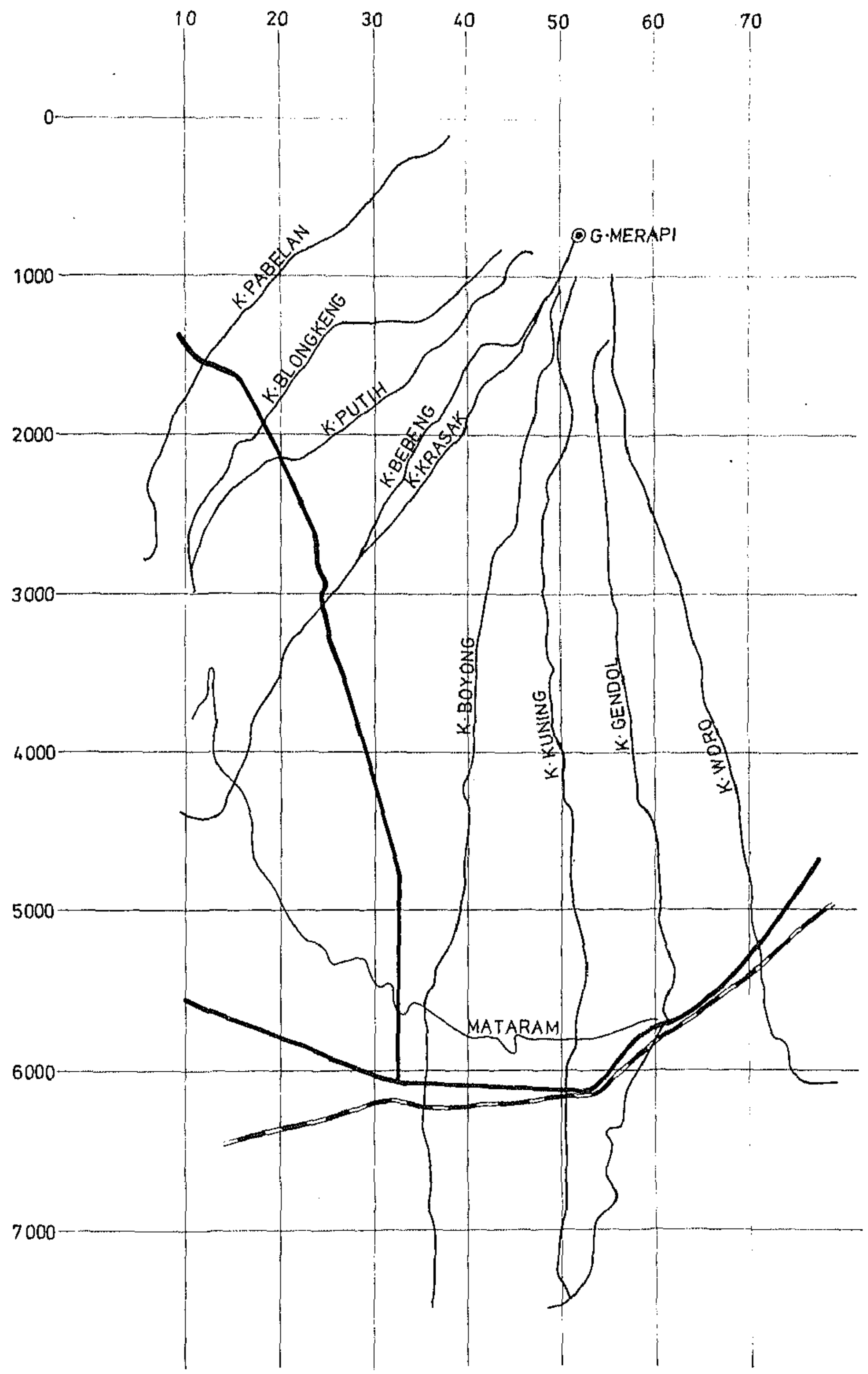


Fig. D.1 Poputation Density Division of 1976

NUMBER LEVEL	SIGN	NUMBER	Number of		
0	x	581	Pop. density below	500	1 sq. km
1	x	1019	"	in 500 - 1,100	"
2	x	1548	"	in 1,100 - 1,700	"
3	H	383	"	in 1,700 - 2,300	"
4	■	404	"	over 2,300	"
	ERROR	1763			

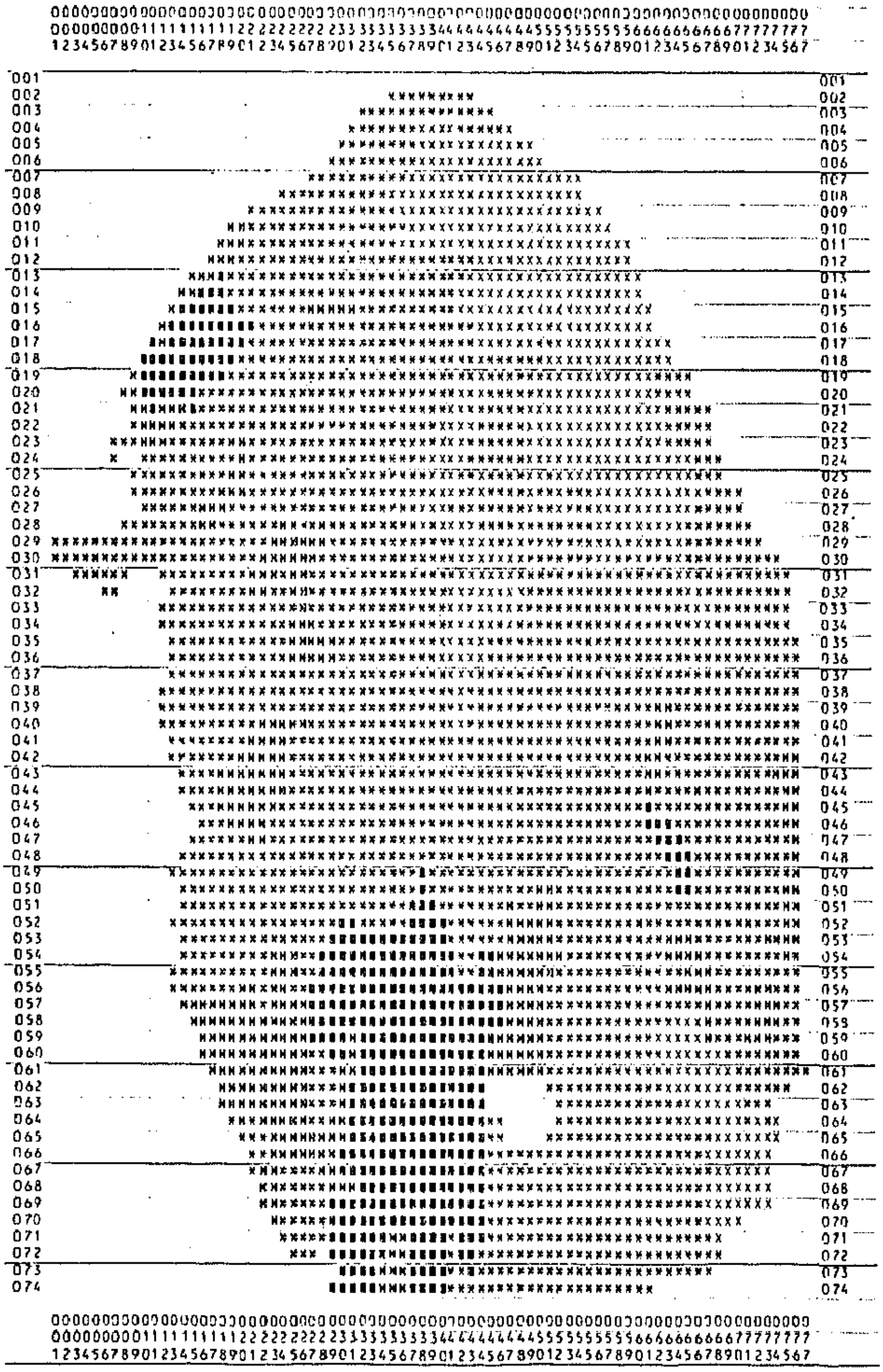


Fig. D.2 Crop Yield Division

NUMOER

LEVEL	SIGN	NUMBER	
0	x	203	Very Low level of land productivity both 1971 and 1976
1	¥	844	Low level of land productivity both 1971 and 1976
2	¥	127	Land productivity decreasing—more than 100% in 1971 but less than 100% in 1976
3	H	1574	Land productivity increasing—less than 100% in 1971 but more than 100% in 1976
4	■	987	High level of land productivity both in 1971 and 1976
	ERROR	1763	

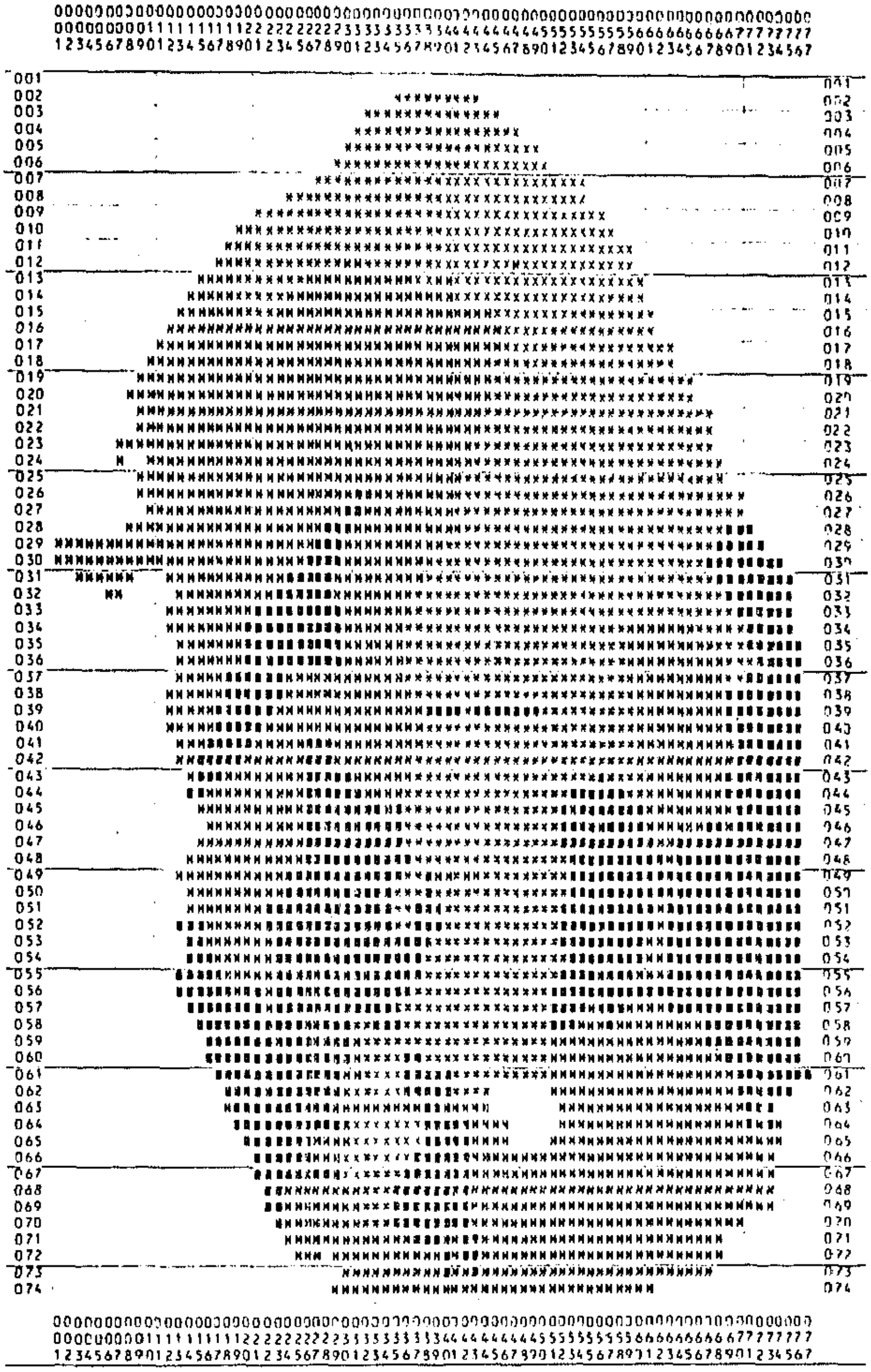


Fig. D.3 Yield of Paddy Division (1976)

NUMBER

LEVEL	SIGN	NUMBER	
0	x	213	below 37.5 q/ha
1	*	1127	in 37.5 — 42.5 q/ha
2	*	1816	in 42.5 — 47.5 q/ha
3	H	373	in 47.5 — 52.5 q/ha
4	#	406	above 52.5 q/ha
	ERROR	1763	

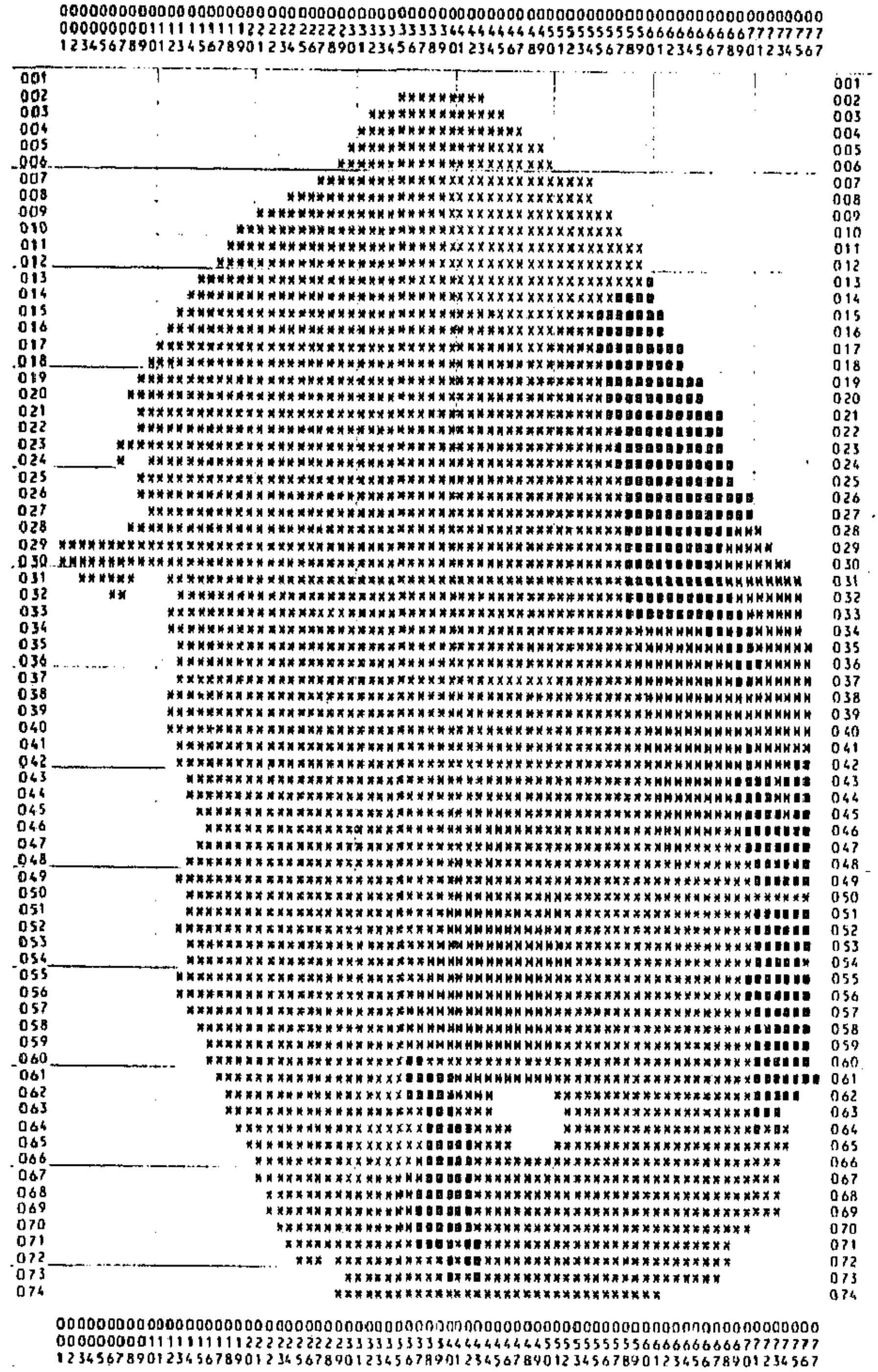


Fig. D.4 Present Tendency of Yield of Paddy Division (1981*)

NUMBER

LEVEL	SIGN	NUMBER	
0	X	346	below 37.5
1	*	245	In 37.5 – 42.5 q/ha
2	*	1095	In 42.5 – 47.5 q/ha
3	H	1655	In 47.5 – 52.5 q/ha
4	■	594	above 52.5 q/ha
	ERROR	1763	

* Values of the Paddy yield estimated from the equation — Y = a + bt (t = 5)

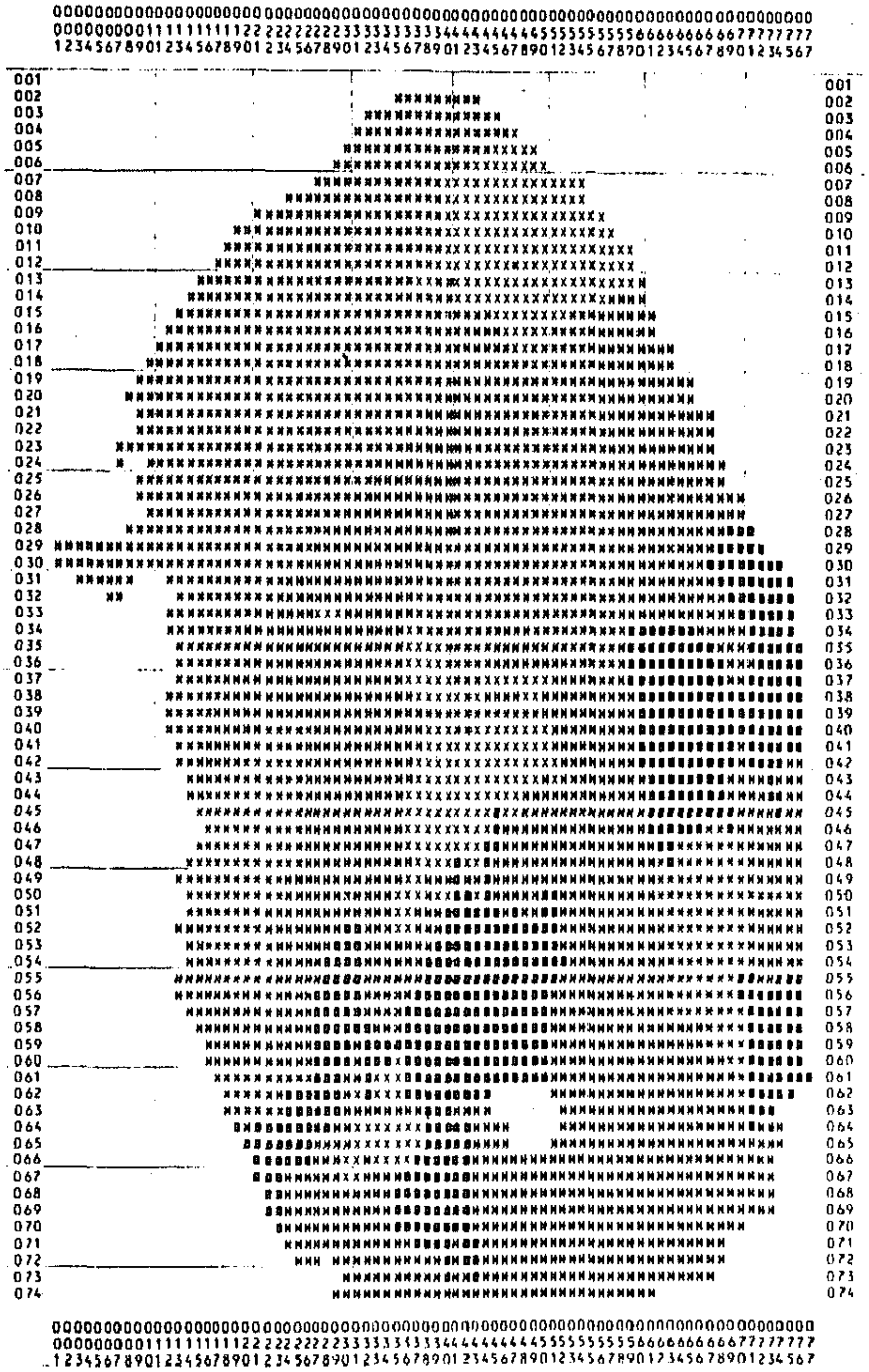


Fig. D.5 Social Land Use Division

NUMBER

LEVEL	SIGN	NUMBER
0	x	123
1	*	132
2	x	2875
3	X	698
4	■	107
	ERROR	1763

Others
Forest or grass land
Farm land
Yard areas or semi-important structure are existing
Urban areas or important structures-national road, trunk channel etc—one existing

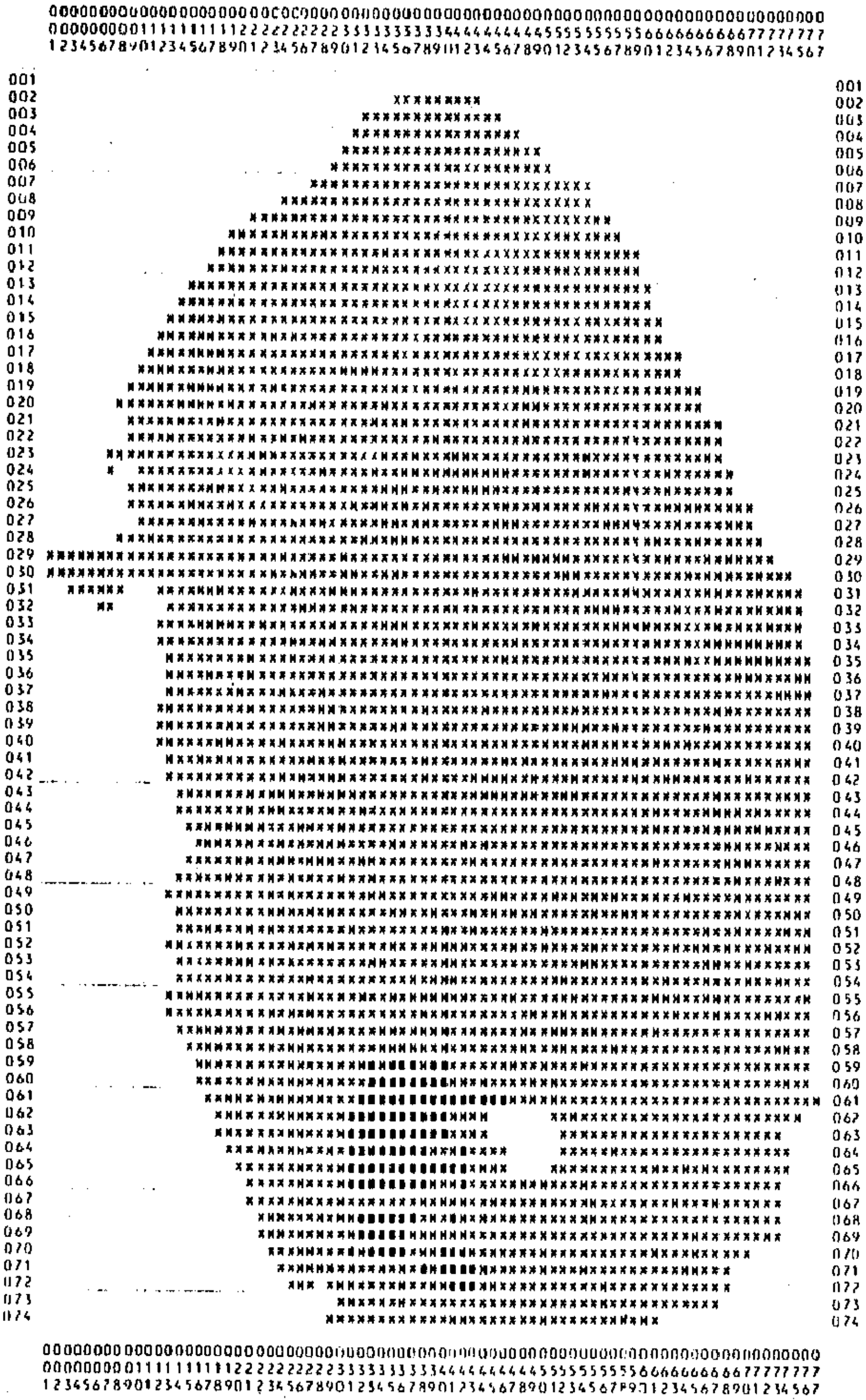


Fig. D.6 Economic Land Use Division

NUMBER

LEVEL	SIGN	NUMBER	
0	x	85	Forest or glass land and others.
1	x	137	Dry field (in 25–50%)
2	x	499	Dry field (in 50–100%)
3	x	675	Yard or Paddy field (in 25–50%)
4	▮	2139	Urban area or paddy field (in 50–100%)
ERROR		1765	

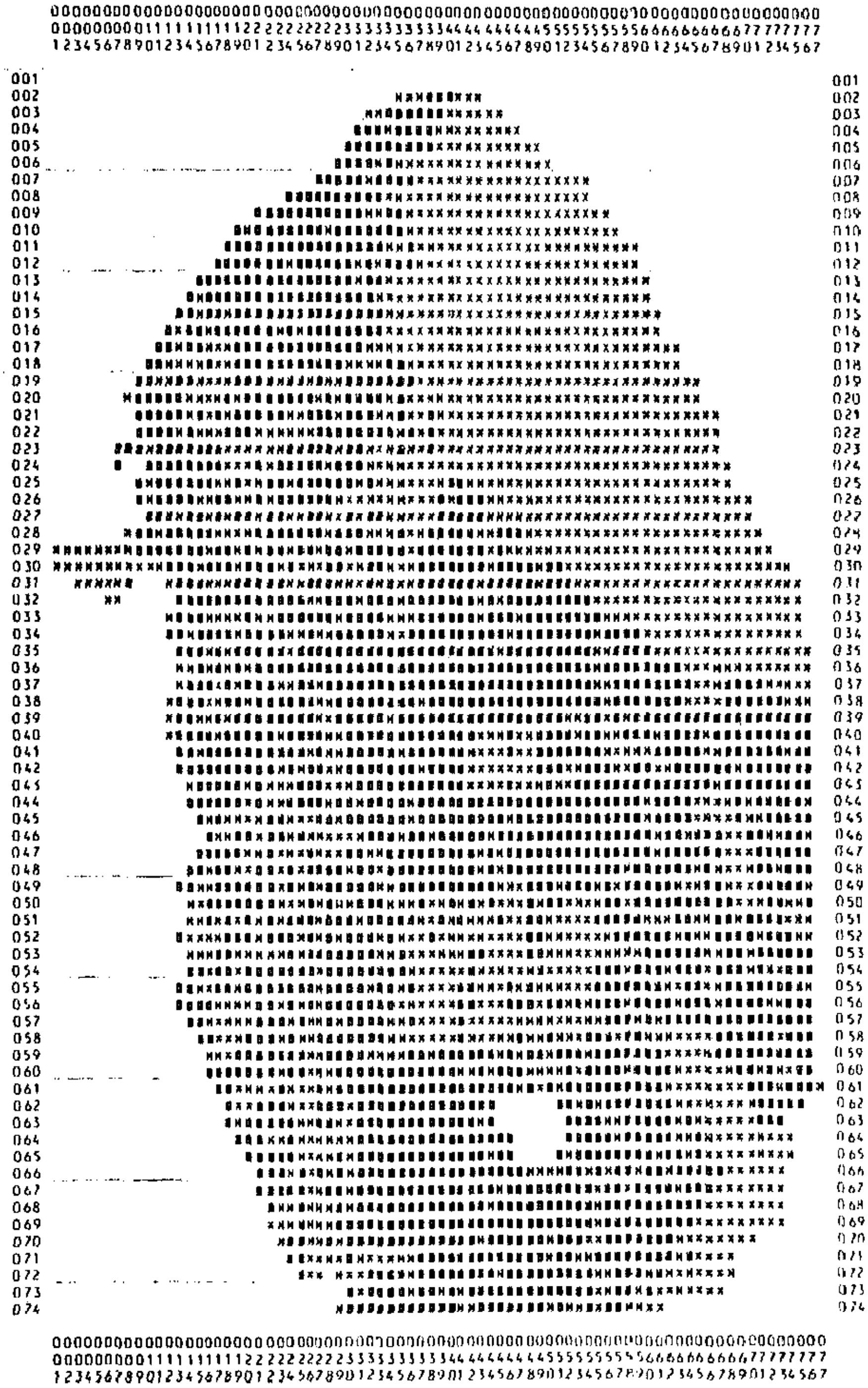


Fig. D.7 Irrigation Areas Division

NUMBER

LEVEL	SIGN	NUMBER	
0	x	816	Dry field or forest etc.
1	×	1041	Primitire or non–technical irrigation area
2	x	1262	Semi–technical irrigation area
3	M	0	
4	▮	816	—
	ERROR	1765	Technical irrigation area

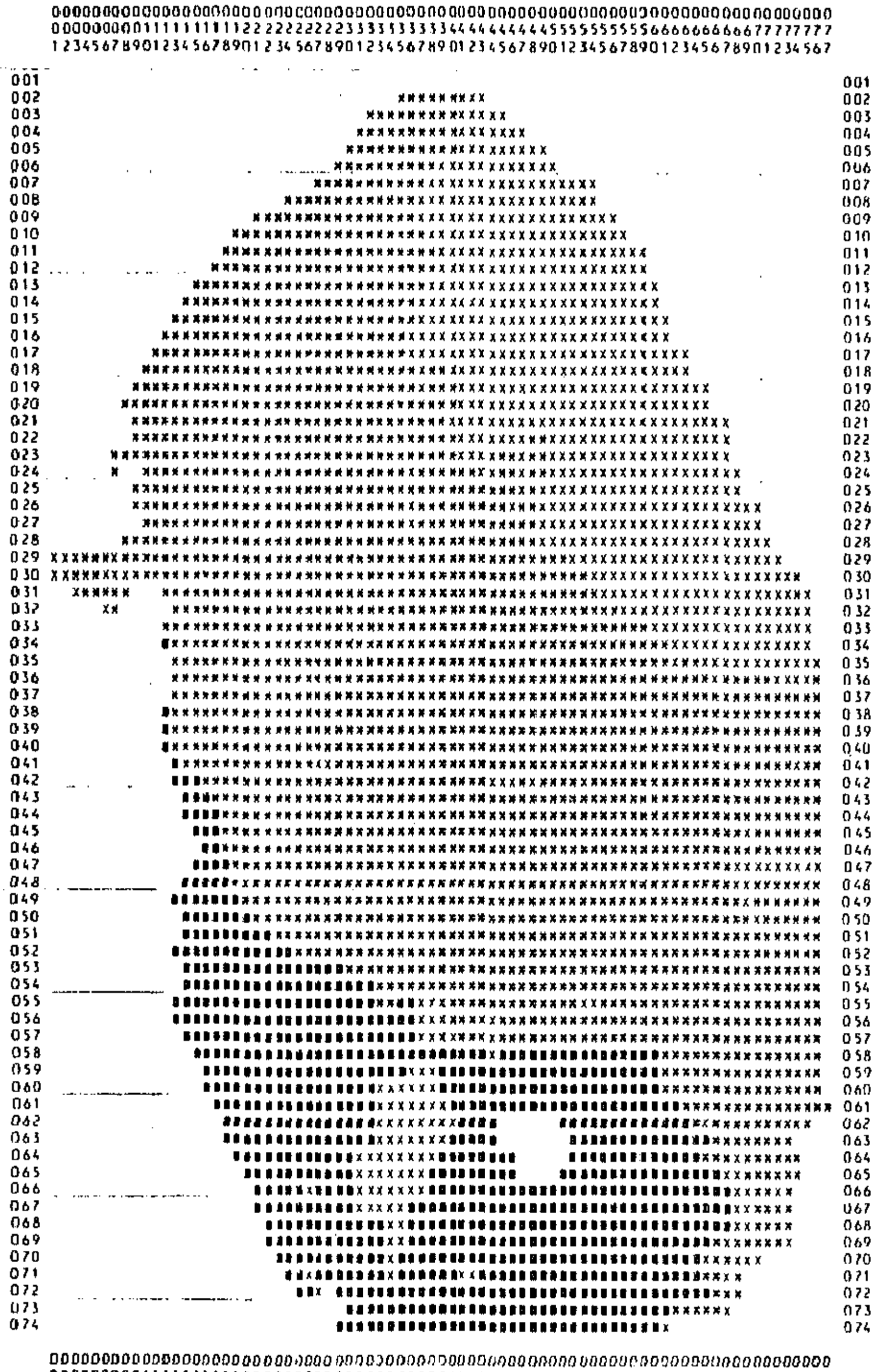


Fig. D.8 Possible Hazard Areas Division
(From geomorphic aspects)

NUMBER

LEVEL	SIGN	NUMBER		
0	x	2246	Where outside of the hazard areas.	
1	ж	25	Where the hights of bank of flooding point	over 20 meter
2	ж	95	"	in 10 – 20 meter
3	ж	257	"	in 5 – 10 meter
4	▮	1112	"	in 0 – 5 meter, or nuee ardente zone
	ERROR	1763		

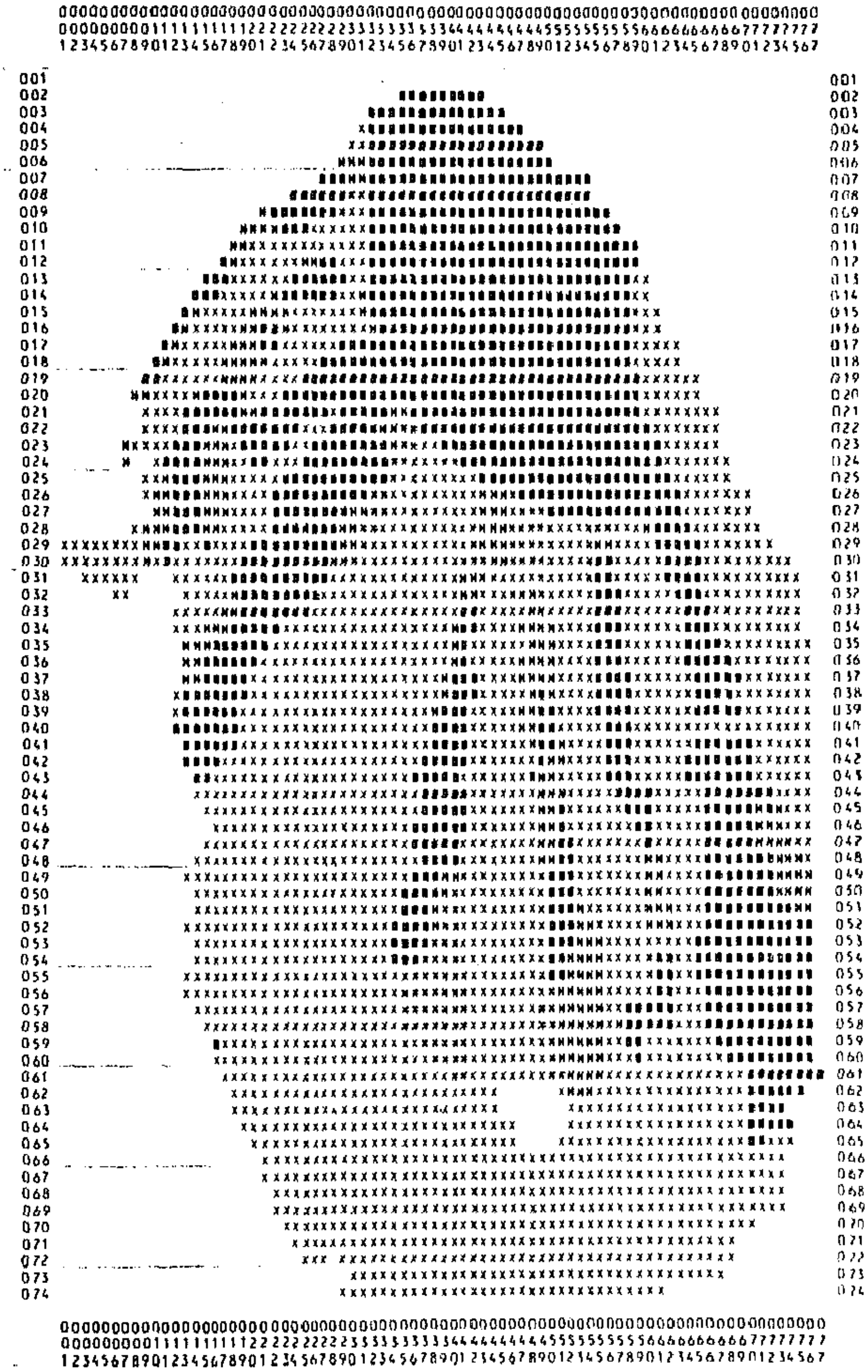


Fig. D.9 Slope Grades Division

NUMBER

LEVEL	SIGN	NUMBER
0	x	202
1	x	33
2	x	155
3	x	731
4	▮	2764
	ERROR	1763

Slope gradient	over	25	degrees
"	in	15 – 25	"
"	in	8 – 15	"
"	in	3 – 8	"
"	in	0 – 8	"

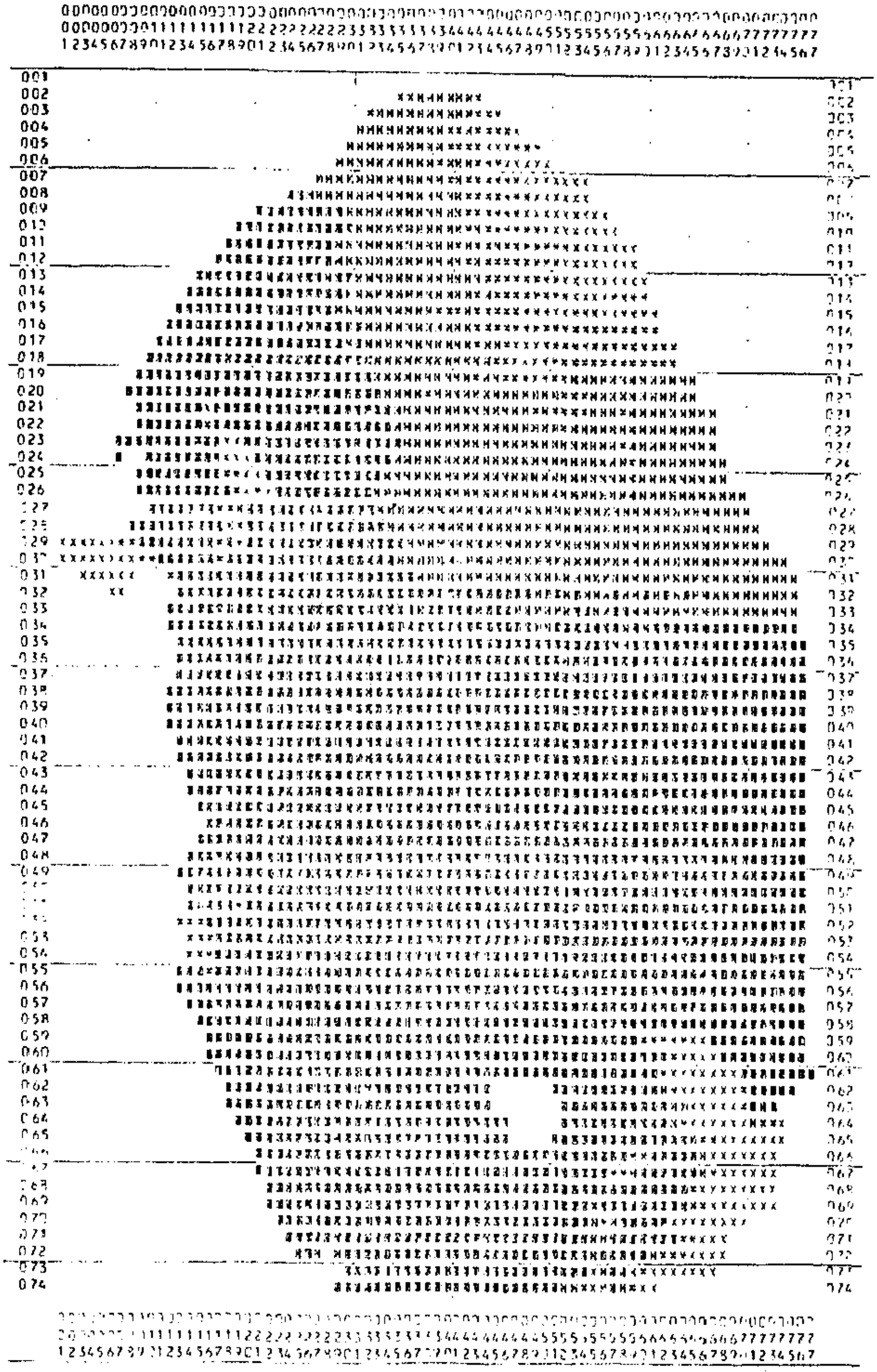


Fig. D.10 Degree of Danger Classification

NUMBER

LEVEL	SIGN	NUMBER		
0	x	2225	Degree 1 of danger classification	(least dangerous area)
1	*	106	" 2 "	
2	*	476	" 3 "	
3	H	715	" 4 "	
4	#	413	" 5 "	(most dangerous area)
	ERROR	1763		

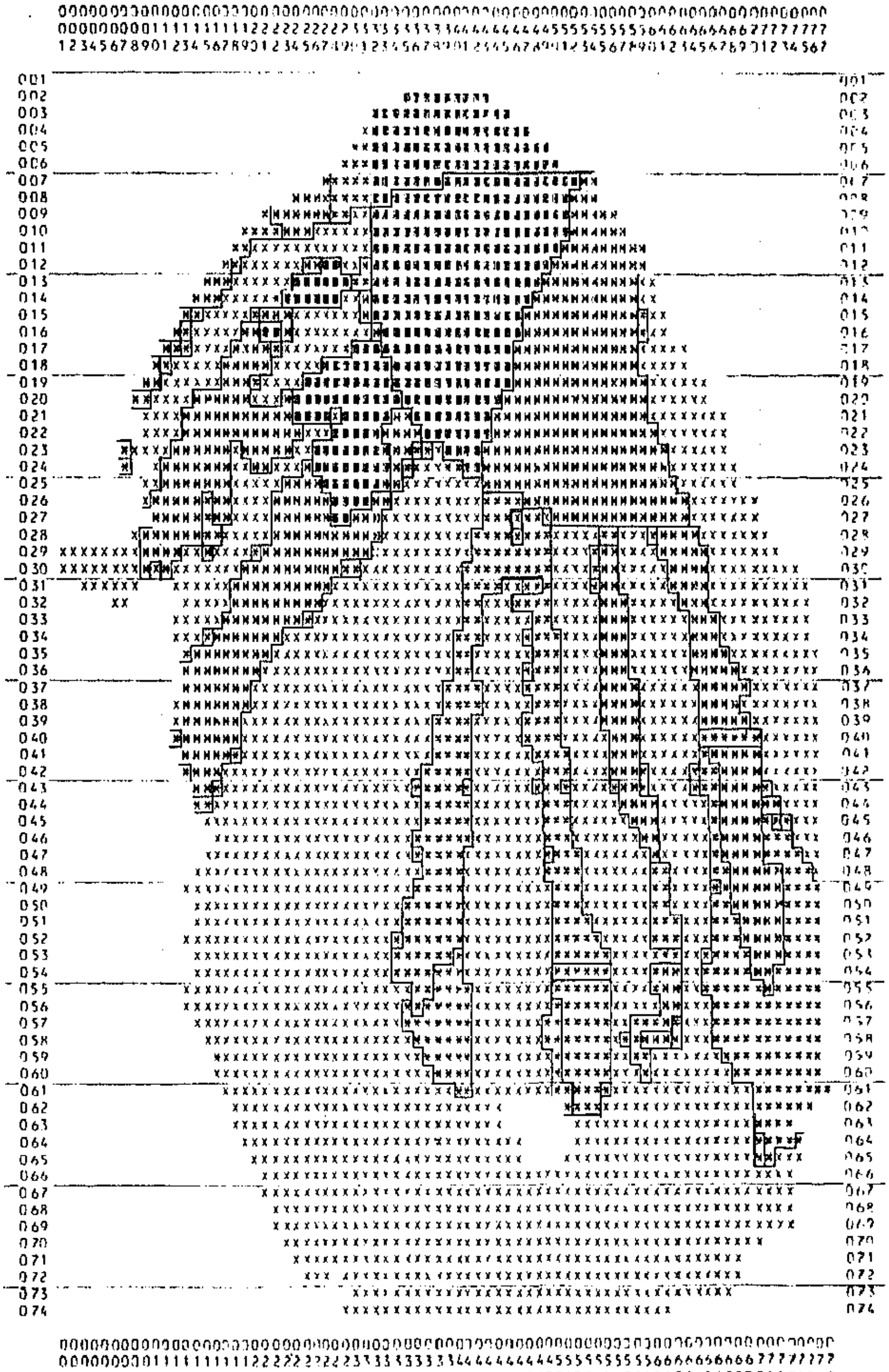


Fig. D.11 Degree of Social Importance Classification and Hazard Areas

NUMBER

LEVEL	SIGN	NUMBER		
0	x	233	Degree 1	of soial importance classification (least important area)
1	+	636	" 2	"
2	*	2229	" 3	"
3	H	517	" 4	"
4	■	113	" 5	" (most important area)
	ERROR	1763		

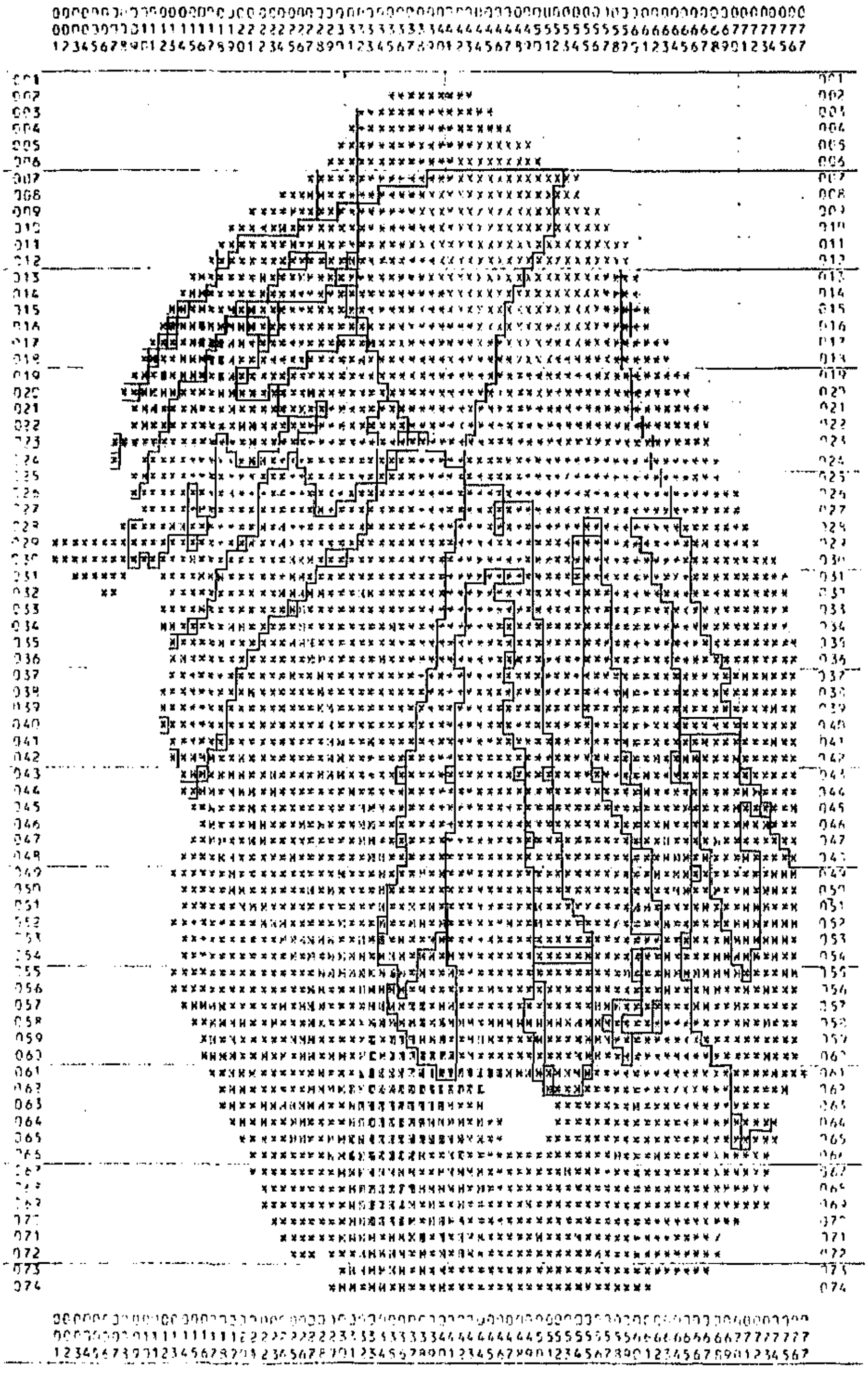


Fig. D.12 Degree of Economic Importance Classification and Hazard Areas

NUMBER

LEVEL	SIGN	NUMBER		
0	x	170	Degree 1 of economic importance classification	(least important area)
1	*	145	" 2 "	
2	*	1383	" 3 "	
3	*	2027	" 4 "	
4	*	210	" 5 "	(most important area)
	ERROR	1763		

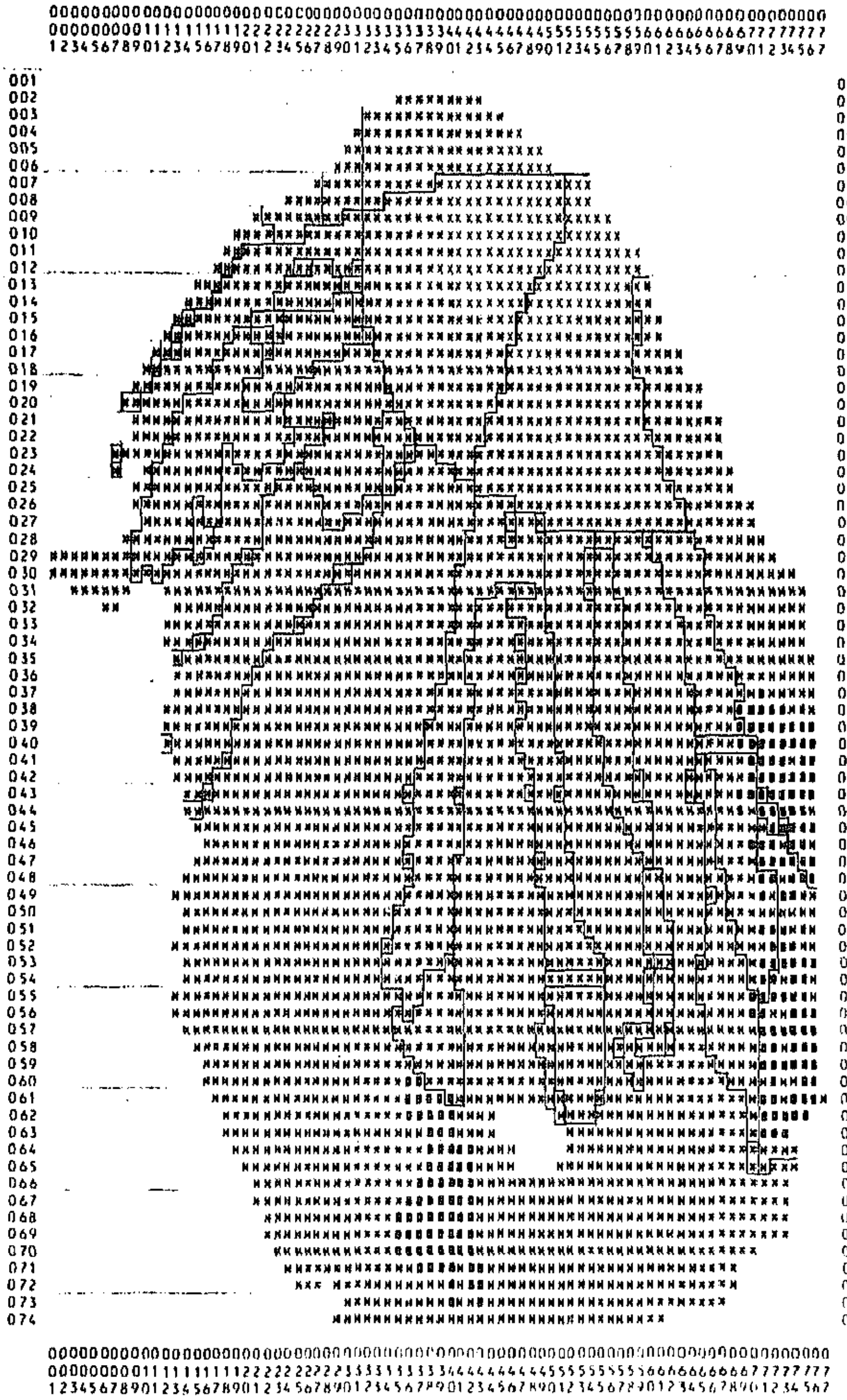


Fig. D.13 Degree of Future Economic Importance Classification and Hazard Areas

NUMBER LEVEL	SEGN	NUMBER
0	x	169
1	ж	118
2	ж	1174
3	ж	1837
4	■	637
	ERROR	1765

Degree 1 of future economic importance classification (least important area)
" 2 "
" 3 "
" 4 "
" 5 " (most important area)