ANNEX - V

IRRIGATION AND DRAINAGE

LHUNTSHI AND MONGAR
INTEGRATED AGRICULTURAL DEVELOPMENT PROJECT

ANNEX-V IRRIGATION AND DRAINAGE

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

1. GENERAL

In order to grasp the present conditions of irrigation and drainage in the study area, the following field surveys have been carried out by the study team.

(1) First Survey (Dec. 1987 - Mar. 1988)

1) Field reconnaissance throughout 16 project areas.
2) Data collections of existing related facilities.
3) Meteorological and hydrological data collections.
4) Canal survey in the proposed model project areas.
5) Installation of gauging stations for automatic recording of rainfall and runoff water level.

(2) Second Survey (Jul. 1988 - Sep. 1988)

1) Detailed field survey in the model project areas.
2) Additional detailed survey for the project planning.
3) Percolation test at paddy fields.

2. PRESENT CONDITION

2.1 Present Condition of the Study Area

2.1.1 General

The irrigation facilities in Bhutan have been developed as a small scale project in the limited area. In the southern foot hills near the border of India, medium or large scale irrigation projects were developed, introducing the new technology recently.

The progress of the development in the study area is much behind in comparison with that of other districts in Bhutan, due to inferior geophysical and topographical conditions. No substantial irrigation facility in the area had been developed up to 1960s, except for small scale private projects covering small irrigation block.

The existing irrigation schemes in Lhuntshi and Mongar Districts developed since 1970 are shown in Table V.2.1, and the number of schemes is 43 with 2,298 ha of the command area. Most of the schemes were completed in the last 10 years.

The irrigation blocks in the area are scattered on the hillside as small as about 50 ha on average, and blocks of paddy land are composed of extremely small terraces. Therefore, existing irrigation schemes were provided very small scale facilities, and established based on traditional technologies and construction methods.

Government of Bhutan intends to put emphasis on the renovation works for the existing schemes, because these are necessary to be executed urgently and benefits from the implementation of renovation works can be yielded instantly.

Many new irrigation schemes are planned by the Government in the 6th Plan started from 1987/88, as shown in Table V.2.2. These schemes are scheduled to be completed by the year of 1993.

The Irrigation Division formally named as Irrigation Cell in Department of Agriculture was set up in 1967 to undertake the nationwide development and the operation and maintenance for the irrigation schemes. The District Irrigation Engineers are assigned to every district offices to carry out their duties of the promotion of new projects, the execution of renovation works and the operation and maintenance of the facilities for the existing schemes.

The implementation of irrigation projects is carried out according to the following procedures and manners:

1) The project formulation is made by the Department of Agriculture in compliance with the request from the beneficiaries headed by the Gup.

2) The survey, planning and preliminary design are made by District Irrigation Engineers under the control of the District Administrator. The detailed design, cost estimate and implementation schedule are made by the Irrigation Division in Thimphu.

3) The construction costs are shared in the following manners:

   - All the costs are borne by the Government for new schemes.

   - Costs for materials, equipment and skilled labour wages are borne by the Government for renovation works.

   - Unskilled labour wages are borne by the beneficiaries for renovation works. (Labour forces are contributed by the farmers usually.)

   - Engineering and supervision expenses are borne by the Government for all the schemes.

The implementation of the irrigation project are generally completed within three years after the commencement of the construction works. However, the renovation works on the facilities are unavoidable to be carried out in a short time duration after the completion of the construction, because these construction works were executed with considerably economical costs, even though the site conditions were unfavorable.

The construction works are relatively small scale, so that the works are carried out by the manner of force account and the beneficiaries are engaged in the construction works as common labour forces in most cases.

In general, these irrigation schemes were designed by the Irrigation Division, Department of Agriculture in Thimphu, and constructed under the control and supervision of the District Irrigation Engineers, based on the design manual issued by Department of Agriculture. Major design criteria are stipulated hereunder.

1) The standard irrigation water requirement of 2.25 lit/sec/ha may be applied for all the schemes.

2) The intake weir is made of natural boulders and/or random stone filling in combination with log frame and/or wet masonry.

3) The canal alignment is made along the contour line of the original ground surface, and all structures are constructed on the cutting ground, not on the embankment.

4) The standard gradient of the canal is about 0.3%. The main canal is designed as earth canal in relatively flat area and masonry lining canal in steep slope area. At the critical places such as gully, exposed rock and extremely steep slope, wooden flume gouged out from a large log is used.

2.1.2 Water Management

The water management and the operation and maintenance of the scheme are executed by the Gup with the supporting of the District Administration Office staff.

The Government has a plan to establish the Water Users' Association in order to carry out these works throughout the country, but it is not organized yet up to date. However, there are a some sort of organizations in some schemes which have been established and are functioning efficiently already. Actually, these operation staffs consist of the Gup, his assistants and water distributors who are elected among the beneficiaries democratically.

The irrigation area is divided into rotation blocks to apply the rotation irrigation system in order to get high irrigation efficiency in most of schemes. This rotation system is controlled by the Gup.

During the land preparation for transplanting, available water is insufficient in many cases. The rotational irrigation method is applied in such cases as the water distribution practice.

In 1979, the Government has decided to impose the water charge of 5 Ngultrum per acre per year on irrigation schemes all over the country, but it was not practically realized still. Expenditures of the operation and maintenance are borne by beneficiaries themselves.

2.1.3 Irrigation Facilities

(1) General

Kuri chu is the greatest river in the area. The river originates in Great Himalaya and flows north to south through Lhuntshi and Mongar Districts. The river is possessed of abundant water

resources throughout the year, however, the runoff water of this river is unavailable for gravity-irrigation. The irrigation water level requires some 100s meter higher than the river water level. On the other hand, many small tributaries of Kuri chu have a lot of available gravity-irrigation water. The irrigable lands are developed as many small plots of terraced paddy field on steep slopes, ranging from 5 to 35 degrees. All terraced plots are reclaimed along the original ground contour line. The width of plots are as narrow as 2 to 3 m in most cases, and it is very rare case to be greater than 10 m in width. The irrigation area is less than 15% of the cultivated farm land and all of them belong to small irrigation scheme.

The irrigation water is taken from the small tributaries directly, and conveyed to the paddy field with open canal system in all schemes. There is no water impounding reservoir to regulate the canal discharge. Most of the irrigation schemes in the study area have not permanent intake and regulating facilities such as cross-drainage structure and spillway for canal protections. The existing canals are 3 to 10 km long approximately, but major parts are unlined and water distribution structures are poorly provided, and secondary and tertiary irrigation facilities are undeveloped. Furthermore, most of these irrigation systems do not function entirely and not secure adequate water supply during the land preparation period mainly from May to June.

There is no on-farm irrigation facility. Actual field irrigation is carried out by plot to plot irrigation method, because many steps of small terraces are extended from lower place to upper place in the wide range of some 100s meter of different altitude. Under these field situations, it is very difficult to conduct modernized irrigation systems from the physical and economical viewpoints.

Since there is no lower land suffering from drainage problem such as high ground water table land or swampy area in Bhutan, no scheme with serious drainage problem exist at present. At the limited area along river, some farm lands are flooded in rainy season. An instant construction of flood protection dike will be considered for the flood control work in said area. But there is no applicable project site in the study area.

(2) Present Condition of Irrigation Facilities

The present conditions of sixteen (16) irrigation schemes which were investigated by the study team are as follows:

1) Lhuntshi District

a. Pang Khar Project Area

This project was constructed in 1984, but was destroyed by heavy rain in 1987. The renovation works are not carried out yet due to relatively large scale landslide. The canal is 3 km long and most of them are earth canal except for minor parts of masonry lining.

The water source was taken from a small hillside spring at an altitude of EL. 2,200 m approximately without any intake facility. Accordingly, the amount of water was not sufficient, furthermore the law suit of water right is still disputing between the water users and the land owner. Therefore, the water users intend to find an alternative water resource. The viability of the existing canal renovation may be very low.

b. Gangzoor Project Area

This is a very small scale of the irrigation scheme with 16 ha of command area and 2.5 km of main canal. The canal was constructed in 1972.

The canal mostly consists of earth canal with 50 m of wooden flume, 20 m of masonry lining and 30 m of concrete pipe. Two wooden flumes are installed at the very steep ground and the concrete pipe is embedded at the landslide zone lately.

The intake weir is made of random stone fill to be repaired before every irrigation seasons.

The renovation and/or small repairings of the canals have been made every year. These are caused by over-topping of the canal discharge due to insufficient operation and maintenance practices.

It is very hard to provide the permanent facilities at the landslide zone. The installation of pipe at the landslide zone shall be considered as re-renovation work in near future due to unstable canal bed.

c. Tangmachhu Project Area

This is the biggest area in Lhuntshi District. This scheme is composed of two canal systems of Tangmachhu Canal and Gorgan Canal, the length of canals being 8.6 km and 4.1 km respectively.

Intakes of both canals are located in Begang Sher and Ngeh chu, but their positions are at quite different altitude of EL. 2,240 m for Tangmachhu Canal and of EL. 1,960 m for Gorgan Canal approximately. The Tangmachhu Canal has 14 other inlets to obtain the water from small mountain streams along the canal route as subsidiary water resources.

Both intakes have very poor structures made of random stone fill weir which need to be repaired every year. Especially, Tangmachhu intake is located at a considerably disadvantageous site.

The renovation works of this project were completed in 1985. Most of main canals are earth canal and some particular parts are lined with stone masonry.

Where there is no space of the canal bed at gully or steep slope, 2 Nos. and 3 Nos. of wooden flumes are installed in Tangmachhu and Gorgan canal respectively.

A large scale of landslide having about 200 m wide exists at Gorgan Canal route. This renovation work shall be introduced together with new canal construction technology such as the inverted pipe syphon to keep away the canal route from the landslide zone, since ordinary open canal can not be provided on the moving ground as a permanent facility.

There are many other places to be renovated and/or repaired due to small scale landslides or land collapses on the canal.

These landslides and collapses might be triggered by over-topping due to excessive discharge in rainy season, and these sort of repairing works must be carried out every year repeatedly.

In general, maintenance of the canals are inadequate, and operation and maintenance roads like foot pathes are not provided appropriately.

d. Minji Project Area

Minji project consists of upper Minji Canal and lower Lekpa chu Canal. Both the intakes are located in the same river of Narigan chu at an altitude of EL. 2,200 m and EL. 1,700 m approximately. The canal lengths are 5.6 km for Minji and 5.5 km for Lekpa chu. The construction works of these projects have completed in 1984 and 1985 respectively.

Intake weirs were made of huge boulders only, but both of them are situated at fairly good locations. They might fulfill their function sufficiently even with such simple structures, and may not need to pay much maintenance cost.

On the other hand, both the main canals involve many problems to be solved. The Minji Canal is mostly earth canal excepting 35 m of masonry lining and 14 Nos. of wooden flumes at the critical points. About 2 km of main canal adjoining the intake is in poor conditions due to the landslide and collapse caused by the heavy rainfall in 1986. Many small mountain streams along the main canal contribute the supplemental irrigation water instead of Narigang chu at the moment, but amount of the water resources are not sufficient.

Moreover, there are many minor damages on the canal berm caused by cattle passing. These small damages are to be considered as an indirect cause of the canal collapse.

The Lekpa chu Canal consists of 1.5 km of earth canal, 4 km of masonry lining canal and 12 Nos. of wooden flumes at critical points. Also, there are many sites of small scale landslide and collapse to be repaired.

The Lekpa chu Canal involves a large scale drop structure of about 20 m head. In case a new canal is extended about 2 km long from the drop head, about 40 ha of additional command area can be created.

In both canals, O&M roads are very poor and maintenance of the main canal is not either well performed. Major renovation and repairing works at Minji and Lekpa chu Canal are needed at 4 places and 9 places respectively.

e. Menjibi Project Area

This project was completed in 1982. The intake is located in Began chu at an altitude of EL. 1,900 m approximately, and the intake weir is made of random stone fill as a

temporary facility. Some improvement may be necessary to this weir in order to secure the intake water in drought year.

The canal consists of 3.7 km of earth canal and 0.4 km of masonry lining canal, involving 2 Nos. of wooden flumes.

Since in the absence of maintenance road, the canal maintenance is very poor, and major collapse portions to be renovated are at 3 places. These collapses might have occurred due to over-topping of the canal water. In general, this irrigation scheme is not operated and maintained in appropriate manners.

f. Kupinesa Project Area

This project was completed in 1984, but it was functional only in 1985 and subsequently a heavy rainfall destroyed the upper portion of the canal in 1986. The intake and about 1 km of the upper portion of main canal have not been available since 1986. Irrigation water is collected from 6 small mountain streams along the canal at present.

The intake structure is provided in Dungkhar chu at an altitude of EL. 2,100 m approximately. The intake weir is composed of huge boulders but no substantial problem exist with this facility.

The main canal consists of 6.3 km of earth canal and 0.6 km of masonry canal, involving 10 Nos. of wooden flumes at critical points.

The renovation at the landslide portions shall be provided with the pipe syphon system having 100 m long approximately.

There is a natural valley drop in main canal. The height of drop is 140 m approximately. This is a big potentiality for the utilization of the mini-hydro-power.

The maintenance of the canal is extremely poor, and many damages on the berm were caused by cattle passing. Notwithstanding many inlets were provided to take the water into the canal from mountain streams, only sole spillway was furnished. The spillway structure to waste the excessive water is essentially important in order to control the canal discharge in rainy season.

g. Wambur Project Area

This is the best irrigation scheme from the viewpoint of performance of the construction works as well as operation and maintenance of the facilities investigated in Lhuntshi District. This project was completed in 1984.

The intake structure is provided in Kheba chu at an altitude of EL. 2,300 m approximately with the boulder weir same as others. The site and the structural conditions on the intake have no problem.

Six Nos. of inlets are provided to add the water into the canal as subsidiary water resources from small mountain streams.

The canal consists of 2.2 km of earth canal and 3 km of masonry lining canal, involving 2 Nos. of wooden flumes and a masonry drop. Near the end point of the canal, there is a big drop utilizing an exposed rock. As the drop has about 70 m head, the development of mini-hydro-power is available.

The foot pass for the canal maintenance is kept in good condition in most parts of the canal, and collapsed canal to be renovated area at 3 places only.

2) Mongar District

a. Chali Project Area

This project is the biggest scale in this district. The project was completed in 1983 and the canal renovation work was carried out by Tashigang and Mongar Area Development Project in 1987. This project also has been scheduled to be constructed a new feeder road shortly in the area.

The intake is located in Thruwan chu at an altitude of EL. 1,700 m approximately. All the 5.5 km long canal are lined with masonry and kept in good situation except for 2 landslide places. These renovation works are to be carried out in the above project.

The maintenance of the facilities is also fairly good.

b. Karbithang Project Area

This project was renovated in 1974. In comparison with other schemes, the facilities are considerably deteriorated because the facilities are rather old and maintenance of the

canal is very poor, having no maintenance road along the canal.

The intake is located in Shongjari chu at an altitude of EL. 819 m approximately. The intake weir is made of boulders and cobbles together with some of logs, as a temporary structure to be repaired every year.

The canal consists of 1.7 km of earth canal and 0.1 km of masonry lining canal involving a wooden over chute crossing above Shongjari chu and 2 Nos. of special flumes with wooden beams and G.I. sheets at collapsed sections. The masonry lining is applied mainly at steep gradient canal sections.

Annual maintenance cost seems to be high considering the scale of the project, because these facilities are deteriorated already.

A new Karibee project area can be planned to be supplied irrigation water by means of extension of this canal. In that case, the intake and some parts of Karbithang canal shall be renovated and the new canal shall be extended to the Karibee Area.

c. Karibee Project Area

There is no irrigation facility for the area at present, but there is a possibility of the extension of Karbithang Irrigation canal to supply the water to the area. In this connection, Karbithang project will need renovation of the facilities since there is no other water resource near the Karibee Area.

d. Masangdaza Project Area

This project is composed of two canal systems of upper Masangdaza canal and lower Bongdima canal. Both intakes are constructed in the same river of Shongjari chu, at approximately an altitude of EL. 919 m and EL. 804 m (just below the Karbithang Intake) respectively.

The canal lengths are 3.3 km for Masangdaza canal and 4.6 km for Bongdima canal, and both canals are lined with masonry except earth canal provided within short distance in relatively flat paddy lands.

The Masangdaza canal and the Bongdima canal were completed in 1982 and 1984 respectively, and these canals were renovated in 1986.

The intake weir of Masangdaza is made of masonry and Bongdima's one is composed of boulders and logs.

Most of the facilities including the two intakes have no substantial problems at present, except for 4 landslide places in Masangdaza canal and many collapsed places in the lower part of Bongdima canal.

It shall be considered as renovation works to apply the inverted pipe syphon because of no suitable foundation space for the open canal in the area.

Bongdima canal water has been utilized as domestic water supply for Animal Husbandry Farm and Public Road Construction Camp (DANTAK) at the downstream of the canal, and the existing water supply system is not accommodated with water treatment facility.

Furthermore, the amount of the irrigation water is insufficient at the end point of the Bongdima canal, because the lower part of the canal has a lot of leakage water and the above mentioned domestic water is taken predominantly.

In order to solve these problems, the renovation of the Bondima canal need to increase the water supply capacity of canals together with quality control measure.

e. Gyelposhing Project Area

This project was constructed for the new settlement area in 1979 and renovated in 1982, but 3 places of canal have been destroyed owing to the land collapse in 1987. The intake and its adjacent portion of some 100 m of canal must be repaired every year, because the ground surface near the intake is in extremely unstable situations. The ground surface including the river bed and both banks near the intake are collapsed continuously. Permanent facility shall not be constructed on the moving area.

The intake is located in Drodi ri at an altitude of EL. 730 m approximately, and it is a temporary structure by above reason. A lot of leakage water exist at the intake and in the adjacent canal since they are imperfect structures.

The canal is constructed 3.7 km long with all masonry lining. The collapse of the canal may be caused by over-topping of excess water. To avoid such collapses, the covered canal or pipe canal shall be provided.

To secure the adequate amount of intake water constantly, the intake site may be relocated to upperstream of the river and the connection pipe from the new intake to the existing canal shall be embedded under the stable ground.

f. Kalapang Project Area

The construction work for this irrigation canal has commenced in 1987, but it was interrupted due to unfavorable site conditions for the construction works. The canal site is a very steep and big amount of rock must be excavated. The command area is as very small as 14 ha only. According to these circumstances, the resumption of the construction works is very hard.

g. Yadi Project Area

The irrigation canal is the sholder ditch of national highway between Mongar and Tashigang. The irrigation water is taken from 5 small mountain streams along the highway. The gradient of the canal is 3 to 5% same as the gradient of the highway. This is a too steep slope as a canal. The canal bottom was scoured at many places due to the inappropriate curing of the concrete and too steep gradient.

This canal has no potentiality to be improved and there is no more irrigation land to be extended.

h. Chaskhar Project Area

This project is under implementation of the Tashigang and Mongar Area Development Project, same as Chali project area. The canal was completed in 1985 and renovation works are under progress.

Two intakes are located in Goda ri and Loda ri at an altitude of EL. 1,980 m and EL. 1,960 m respectively. To take supplemental water, 18 small mountain streams along the canal are utilized.

The canal is 6.3 km long with 0.6 km of earth canal and 5.6 km of masonry lining canal at present. All canals are going to be lined and renovated together with construction of additional related canal structures and feeder road by the said project.

2.2 Present Condition of the Model Project Area

2.2.1 General

(1) Tangmachhu Area

This area has a largest scale of paddy farming in the East Bhutan. About 220 ha of wet land has been developed on the comparatively gentle slope, extending 3 km from south to north and 2.5 km from east to west approximately. The difference of altitude is estimated at about 800 m from the lowest place to the highest.

The wet paddy farming in the area was originated some hundreds years ago, utilizing the Gorgan Irrigation System which was constructed by the Ruler of the area. Then, it was extended gradually over whole Tangmachhu area due to the good adaptability of paddy farming in geographical, meteorological and soil conditions.

The paddy fields have been developed with many small terraces on the slope. It is very rare case that a plot of the paddy fields has bigger than 0.1 ha. Most plots of paddy field have 2 to 3 m width and they are extending along the contour line of the original ground. The height of terraces are 0.3 to 0.6 m usually, but they increase to 1 m or more sometimes. There is no protection such as masonry wall on these terraces, even the difference of terrace levels is more than 2 m. The width of terrace levees are as narrow as 15 to 20 cm.

(2) Masangdaza Integrated Area

This area consists of small paddy blocks which are scattered on both banks downstream of main water resource, Songjari chu. They belong to existing irrigation schemes of Masangdaza, Karbithang, Bongdima and three other old schemes. Karibee area is now left as rainfed cultivated area which will be included as a new irrigation area.

Most of Masangdaza area are developed with many small terraced paddy fields on the considerable steep hillside. Bongdima, Karbithang and the lower part of Masangdaza areas are developed with comparatively flat paddy fields on a river terrace along Shongar chu. Some paddy fields have a nature of high permeability due to the low clay content in the soil.

Irrigation schemes of Masangdaza and Bongdima were implemented in 1976 as a new land reclamation and settlement program by Government. But the development of wet paddy field are only as small scale as less than 10% of original plan and it results in insufficient of irrigation facilities and shortage of labour forces for the land reclamation.

The paddy fields in Karbithang area was developed about 30 years ago, and the paddy fields belonging to most upstream of the existing Bongdima Canal in Masangdaza area was developed about 50 years ago. No records exist as to the development on three other old schemes.

These irrigation projects can be expanded the command area up to 80 ha in total, when these irrigation facilities are completed to be renovated and strengthened. Existing maize fields in Masangdaza, Bongdima and Karibee areas will change to wet paddy fields in future.

2.2.2 Irrigation System

(1) Tangmachhu Area

This area involves two irrigation systems consisting of two intakes and two main canals. Tangmachhu system covers upper part of the area, and Gorgan system covers lower part of the area. These two canals located about 200 m difference altitude, and run in the same direction in parallel on the hillside.

The water distribution system of secondary and tertiary canal networks are not developed enough and no farm ditches are provided in most parts of paddy fields.

(2) Masangdaza Integrated Area

There are major three irrigation systems in this area, comprising three intakes and three main canals, i.e., Masangdaza, Bongdima and Karbithang Canals, and three other old systems with intakes and canals exist in three old irrigation area at present. No irrigation system is provided in Karibee area.

Masangdaza system covers the upper part of Masangdaza area and Bongdima system supplies the water to the lower part of Masangdaza area and Bongdima area. Three other old systems distribute the water respectively to three old irrigation areas.

Masangdaza intake is located at upper position in Shongjari chu, Bongdima intake at lower and Karbithang intake at middle. Intakes for old systems are situated in lower places than Karbithang intake. Masangdaza and Bongdima Canals run mostly northeastward in parallel on the hillside to Bongdima area. Karbithang Canal is lead mostly northward on the hillside from intake up to the boundary between Karbithang and Karibee areas.

No secondary and tertiary canals are provided except Karbithang system, which has very short and poor secondary canal.

2.2.3 Irrigation Facilities

(1) Tangmachhu Area

Two temporary intake facilities are established in Begang Sher and Ngeh chu. The altitudes of these intakes are 2,240 m and 1,960 m, and the altitudes of canal tails are 1,960 m and 1,840 m respectively. The canal lengths are about 8.6 km and 4.0 km respectively.

There are no permanent intake facilities. The intake weirs are made of random filled stone and boulder. These temporary facilities have been repaired every after flood and have a lot of seepage losses. Neither regulating facility for discharge control are provided nor releasing facility for sedimented materials.

The main canals were constructed along the contour line on hillside with the slope of 30 to 40 degree slope of hillside. Most of canals are earth canal without lining. The masonry lining canals were constructed at limited area of steep hillside or rocky area.

The canal gradients are about 1/100 in most of routes. It has more steep gradient at rocky area or steep slope area, and more gentle gradient in paddy field or flat area.

Gorgan Canal crosses the large scale landslide area extending over about 200 m wide in Nebi Village. This part of canal has to be repaired frequently, because the seepage water from the canal makes it more unstable ground.

At the place of gully and land collapse, wooden flumes made of big logs are provided. One flume was provided respectively in Tangmachhu and Gorgan Canal. These flumes become bottleneck causing the reduction of the canal capacity.

Trunouts to divert the required water to fields are provided in poor conditions. Spillways, waste ways or retaining walls for canal protection are not accommodated enough. Cross drainage structures to cut the inflow surface water into the canal in rainy season are not provided adequately. The canals are therefore collapsed at many places due to overtopping of the water and the shortage of water supply occurs. Moreover, it is considered to increase the repairing cost for the collapsed canals due to insufficient O&M practice with the lack of O&M roads.

Secondary and tertiary canals are very poor. Most of them are the excavated earth trenches only and they have no regulating facility for the discharge control. This is one of reasons of low irrigation efficiency.

Secondary Canals of Tangmachhu-1st and Tangmachhu-2nd have been provided perpendicularly with about 400 m long on the extremely steep slope. It is very difficult to realign the secondary and tertiary irrigation network according to field conditions of the steep ground surface. Though it is not a problem substantially because these distribution canals are short length in general, it should not be left as present situation, because canals have been eroded remarkably in this case. Ngumaling Secondary Canal which belong to the end of Tangmachhu Canal is not useful at the moment owing to the destroyed aqueduct at crossing point of a valley in 1986.

It is not necessary to provide the drainage facilities in this area due to terraced paddy on the hillside. The surplus irrigation water can be released by plot to plot system and released water is reused at lower paddy at present.

(2) Masangdaza Integrated Area

All irrigation water for each area are taken from Songjari chu. Three intake facilities have been installed in the order from upstream of the river for Masangdaza, Karbithang and Bongdima areas. The altitude of intakes are 919 m, 819 m, and 804 m respectively. Three other intakes are located at about 50 to 100 m lower positions than Bongdima Intake.

All intake weirs are made of the random arrangement of stone and boulder combined with log frames except Masangdaza intake weir which is made of wet masonry. These temporary facilities are to be repaired every after flood. Neither regulating facility for discharge control are provided nor releasing facility for sedimented materials.

The canal lengths are 3.3 km of Masangdaza, 1.6 km of Karbithang and 4.5 km of Bongdima, and altitudes of each canal end are 906 m, 741 m, 640 m respectively. Three other canals are some hundreds m long each.

Masangdaza and Bongdima canals have been renovated already. They have mostly masonry lining sections, but Karbithang canal have earth canal in most of sections except a short rocky section. Notwithstanding some sand traps and spillways are provided in renovated canals, they do not function practically. It is very hard to walk along Karbithang canal due to poor O&M road and there is no walking space beside three old canals.

The gradients of canal are 1/100 in most canal routes, while 1/1,000 in paddy field area and steep chute at rock area.

In Masangdaza Canal, a 10 m long aqueduct made of GI sheet flume reinforced by log beam and a 6 m long wooden log flume have been

installed at land collapsed places. At the crossing point over Songjari chu and in Karbithang Canal, a 8 m long wooden over chutes have been installed. Two GI sheet aqueducts using the same materials as above, 22 m and 6 m long each have been provided at land collapsed places in Karbithang Canal. Three aqueducts made of wooden log flume, 13 m, 8 m, 5 m long each, have been provided in Bongdima Canal. All these aqueducts are temporary facilities and their discharge capacities are insufficient due to lack of section areas of flow as a canal.

There are no drainage facilities in the area and these are not necessary due to the same reason as Tangmachhu area.

2.2.4 Water Management

In Tangmachhu area, there is no nominated Chusumpa for the water management. A Chusumpa was once appointed as a responsible person and tried to undertake the water management of the system, but it could not function well, and no one reappointed. The present key staffs for the operation and maintenance of the facilities are composed of 1 Chimi, 1 Gup and 4 Mangups informally. No responsible man to undertake water distribution control is appointed exclusively at the moment. Every farmer carries out irrigation water control to their own paddy without the regulation.

In Masangdaza area, they are in different situations depending on schemes. The water management of Masangdaza and Bongdima Canal have been undertaken by each Chusumpa, but no other Chusumpa is appointed for other canals. The former Gup carries out the water distribution practice for Karbithang Canal practically at present. Actual operation and maintenance and water management for the irrigation facilities in Masangdaza area are carried out by one Chimi, one Gup and one Mangup.

In accordance with the regulation in Bhutan, the operation and maintenance of the irrigation facilities is undertaken by Government within 5 years after the completion of the construction works. After that, beneficiaries have to carry out everything with their own expenses except renovation projects controlled by Government. Actual renovation works and annual maintenance works are executed under the leadership and the control by Gup in all the area.

Annual maintenance works are mainly the repairing of intake weir, the removal of sedimented materials from the canal and minor repairing of the canal. Large scale of destructions are repaired by the manner of renovation project.

There are no any records of used budgets or labour forces for the operation and maintenance performed. But the rough estimation for

the annual average forces to be contributed to the maintenance for each irrigation system is about 200 to 400 man-days, and the labour forces for the considerable large scale renovation works are about 2,000 to 3,000 man-days.

2.2.5 Constraints

These projects were implemented under the unfavorable economical conditions and are very small scales. The project areas are located in remote area and the road network is poorly developed. Irrigation facilities are constructed on the steep slope ground. It is very difficult to transport construction equipment and materials to sites. These matters are constraints for the development and reasons not to be introduced modernized facilities yet.

These facilities were constructed utilizing local materials and local labours mostly. The construction equipment was not employed. Therefore, it can not say that existing facilities have enough functions due to the limited application of the new design and the construction technologies.

The followings are matters to be improved or considered on the renovation of the facilities.

(a) Existing temporary intake weirs require considerable maintenance costs and are impossible to avoid seepage loss. These are not provided with discharge control devices.

(b) The canal alignment are zigzaged from place to place and dropped at rocky areas.

(c) Most parts of main and secondary canals are earth canals. Therefore there exist much amount of seepage water and it is necessary to pay much amount of maintenance cost.

(d) Temporary aqueducts made of log or GI sheet necessiate the repairing work every year and their capacities are not enough for required discharge.

(e) There are no canal protection facilities such as spillway, waste way and discharge facility for sedimented materials.

(f) Over chute and cross drainage are not provided enough to cut the inflow water into the canal.

(g) There are no retaining walls and covers for canal protection against land collapse or stone falling.

(h) O&M roads are provided insufficiently or nothing.

3. IRRIGATION DEVELOPMENT PLAN ON THE MODEL PROJECT AREA

3.1 General

Government of Bhutan established the nationwide renovation plans for existing irrigation schemes in 6th Plan. Several renovation schemes in the study area are also involved in this Plan. Because most of existing irrigation facilities are not sufficient in the capacity and have been already deteriorated in many cases. Therefore, this development plan was set up as the renovation projects for existing schemes in order to meet with the national requirement and to achieve the high beneficial efficiency in a short time.

The following project areas are proposed as the model areas for the renovation projects, taking into considerations of local conditions in many aspects together with the construction work volume and the construction period.

(a) Tangmachhu Project Area in Lhuntshi District
- Tangmachhu area
- Gorgan area

(b) Masangdaza Project Area in Mongar District
- Masangdaza area (including two old systems)
- Bongdima area
- Karbithang area (including one old system) and Karibee area

The major irrigation facilities to be renovated are intake structures, main canals and their related facilities.

All these construction works are scheduled to be completed within two off-irrigation seasons except the construction period of feeder roads and the bridge.

3.2 Beneficial Area

The proposed irrigation areas in each model project area is as follows, based on the available land resources and water resources:

(a)	Tangmachhu Model Project Area		220 ha in total
	- Tangmachhu area	(Covered by Tangmachhu Canal)	86 ha
	- Gorgan area	(Covered by Gorgan Canal)	134 ha
(b)	Masangdaza Model Project Area		80 ha in total
	- Masangdaza area	(Covered by Masangdaza Canal)	37 ha
		(Covered by Bongdima Canal)	20 ha
	- Bongdima area	(Covered by Bongdima Canal)	7 ha

- Karbithang area (Covered by Karbithang Canal) 11 ha
- Karibee area (Covered by Karbithang Canal) 5 ha

3.3 Irrigation Water Requirement

Rice will be the principal crop in the model project area and upland crops such as wheat and mustard are also recommended as consumable and profitable crops for the Project. The study of irrigation water requirement was made for these crops.

The estimates of irrigation water requirement are made on 10-day basis, according to the proposed cropping pattern of the above crops.

3.3.1 Irrigation Water Requirement for Paddy

(1) Crop Water Requirement (CWR)

The crop water requirement is defined as the amount of water needed to meet the consumptive demand of crop for optimum growth from seeding to harvesting. It consists of nursery, puddling and field crop requirements as shown below:

$$CWR = Kn \times NU + Kp \times PU + Kf \times FC$$

where, CWR : Crop water requirement (mm/day)
Kn : Area factor of nursery
NU : Nursery requirement (mm/day)
Kp : Area factor of puddling
PU : Puddling requirement (mm/day)
Kf : Area factor of planted main field
FC : Field crop requirement (mm/day)

(a) Nursery requirement (NU)

The nursery requirement is the amount of water necessary for nursery preparation and growth of seeding until it is transplanted to main yield.

The nursery requirement was estimated under the following conditions:

- Area required for nursery bed : 1/20 of main field
- Nursery period : 40 days

$$NU = Sn/N + Kc \times ETo + P$$
$$Sn = Ds \times (Sc - Mc)/100$$

where,
- NU : Nursery requirement (mm/day)
- Sn : Soil saturation requirement (mm)
- Ds : Depth of soil saturation (300 mm)
- Sc : Soil saturation capacity (% in volume)
- Mc : Soil moisture content before water supply (% in volume)
- N : Nursery period
- Kc : Crop coefficient (Kc = 1.0)
- ETo : Potential evapotranspiration (mm/day)
- P : Percolation rate (mm/day)

The soil textures in respective project areas are generally silty clay in Tangmachhu area and clay loam in Masangdaza area. In the above equation, the rates of Sc and Mc are determined according to the soil textures as shown below:

Soil Texture	Sc (%)	Mc (%)
Silty clay	66	30
Clay loam	66	27

The percolation rate will be dependent on the soil characteristics and topography encountered. The irrigation design manual, published by Department of Agriculture, shows that an allowance of 2 mm/day could be used as a guide. The measurement data on percolation rate are not available in the project areas. In order to estimate the percolation rate, the actual field measurement was carried out by the Study Team during the second field survey period. The result of field measurement indicates that the average percolation rate is 1.8 mm/day in Tangmachhu area and 20.2 mm/day in Masangdaza area as shown in Table V.3.1.

However, it is considered that the percolation loss in upper terraces shall be reused in lower terraces due to the special features of terraced fields on steep hillslopes. The rate of percolation adopted for this study is decreased by 50% and is taken as 1.0 mm/day in Tangmachhu area and 10 mm/day in Masangdaza area.

(b) Puddling requirement (PU)

The puddling requirement is defined as the amount of water needed to saturate the soil prior to the initial breaking and pond the paddy field for transplanting, and needed evaporation and percolation in the paddy field.

$$PU = (Sn + Sp)/N + Ev + P$$

where, PU : Puddling requirement (mm/day)
Sn : Soil saturation requirement (mm)
Sp : Depth of ponding for transplanting (50mm)
N : Puddling period (20 days)
Ev : Evaporation (mm/day)
P : Percolation rate (mm/day)

(c) Field crop requirement (FC)

The field crop requirement is the amount of water consumed by the crop during the period from transplanting to 20 days before harvesting and the needed percolation in the paddy field.

$$FC = Kc \times ETo + P$$

where, FC : Field crop requirement (mm/day)
Kc : Crop coefficient
ETo : Potential evapotranspiration (mm/day)

The crop coefficient at each growth stage of rice is derived from Irrigation Design Manual published by DAO and shown in Fig. V.3.1.

The potential evapotranspiration is estimated by Blaney-Criddle method using the monthly mean air temperature data obtained at Tangmachhu and Lingmethang Meteorological Stations, since the available meteorological date are limited to air temperature, relative humidity and rainfall. The estimted potential evapotranspiration is shown in Fig. V.3.2. The evaporation is assessed from the potential evapotranspiration by the relationship of Ev=ETo/0.85, referred to FAO, Irrigation and Drainage Paper, No. 24.

(2) Farm Water Requirement (FWR)

The farm water requirement was assessed on 10-day basis, deducting the effective rainfall from crop water requirement as follows:

$$FWR = CWR - RE$$

where, FWR : Farm water requirement (mm/10-day)
CWR : Crop water requirement (mm/10-day)
RE : Effective rainfall (mm/10-day)

The effective rainfall was estimated by the daily water depth balance method as follows:

(i) The year of daily rainfall adopted for this calculation is 1985 for Tangmachhu and 1986 for Masangdaza, since the total rainfall during the planting period based on the proposed cropping pattern is minimum for three years with available rainfall records.

(ii) The design daily rainfall (RD), which is adopted for the effective rainfall calculation, was determiend as follows:

$R(i) < RI : RD(i) = 0$
$R(i) > RI : RD(i) = R(i)$

where, RD(i) : Design daily rainfall (mm/day)
R(i) : Daily rainfall in 1985 and 1986 (mm/day)
RI : Ineffective rainfall (5mm)
i : Day considered

(iii) The daily water depth calculation was made as follows, assuming the field outlet height of 100mm:

$$PWL(i) = PWL(i-1) - CWR(i) + RD(i)$$

where, PWL(i) : Water level in paddy field (mm)
CWR(i) : Crop water requirement (mm/day)
RD(i) : Design daily rainfall (mm/day)
i : Day considered.

(iv) Using abvoe equation, a overflow comes about when the computed PWL(i) exceeds the field outlet height. The amount of effective rainfall was therfore calculated as follows:

Without overflow : $RE(i) = RD(i)$
With overflow : $RE(i) = FOH - PWL(i-1) + CWR(i)$

where, RE(i) : Effective daily rainfall (mm/day)
RD(i) : Design daily rainfall (mm/day)
FOH : Field outlet height (100mm/day)
PWL(i) : Water level in paddy field (mm)
CWR(i) : Crop water requirement (mm/day)

The estimated design rainfall on 10-day basis is shown in Table V.3.2. The calculated results of effective rainfall and farm water requirement are shown in Table V.3.3.

(3) Unit Diversion Water Requirement (DWR)

The diversion water requirement is defined as the amout of farm water requirement plus allowances for application loss, operation loss and conveyance loss, and calculated as below:

$$DWR = FWR/EF/100$$

where, DWR : Diversion water requirement (mm/10-day)
FWR : Farm water requirement (mm/10-day)
EF : Overall irrigation efficiency (%)

Due to no data available on irrigation efficiences of existing irrigation project in Bhutan, the irrigation efficiency shall be determiend based on the guidelines developed by ICID. These guidelines reported that overall irrigation efficiency adopted to each project ranges from 50% to 85%, but ICID concludes that it is not possible to predict the efficiency within an accuracy of 15% with its best effort.

The following efficiencies were adopted in assessing the diversion water requirement, taking into account the special feature of terraced paddy fields on steep hillsides where surplus irrigation water flows down to lower terraces and is not completely wasted.

Item	Efficiency (%)
Conveyance efficiency	90
Operation efficiency	80
Application efficiency	85
Overall efficiency	60

The unit diversion water requirement was estimated by use of the above efficiency on 10-day basis as shown in Table V.3.4. The peak requirement of 1.49 l/s/ha for Tangmachhu and 2.85 l/s/ha for Masangdaza occurs in last 10-day of June and second 10-day of August respectively.

3.3.2 Irrigation Water Requirement for Upland Crops

(1) Crop Water Requirement (CWR)

The crop water requirement comprises land preparation requirement and field crop requirement.

$$CWR = LP + FC$$

where, CWR : Crop water requirement (mm/day)
LP : Land preparation requirement (mm/day)
FC : Field crop requirement (mm/day)

(a) Land preparation requirement (LP)

The land preparation requirement is the amount of water necessary for making satisfactory field for seedlings of crop.

$$LP = De \times (Fc - Mc) \times As/(100 \times N)$$

where, LP : Land preparation requirement (mm/day)
De : Depth of effective root zone (mm)
FC : Field capacity (% in weight)
Mc : Soil moisture content before water supply (% in weight)
As : Apparent specific gravity
N : Land preparation period (20 days)

The soil texture is generally classified as silty clay in Tangmachhu area and clay loam in Masangdaza area and the values of Fc, Mc and As are determined as follows:

Soil Texture	Fc (%)	Mc (%)	As
Silty day	31	23	1.30
Clay loam	27	20	1.35

The root zone for each crop (De) is determined as below:

Crops	Effective Root Zone (De)
Wheat	1,200 mm
Mustard	500 mm

(b) Field crop requirement (FC)

The field crop requirement is the amount of water consumed by crops during the period from seeding to harvesting.

$$FC = Kc \times ETo$$

where, FC : Field crop requirement (mm/day)
Kc : Crop coefficient
ETo : Potential evapotranspiration (mm/day)

The crop coefficient at each growth stage of crops is derived from FAO, Irrigation and Drainage Paper, No.24 and shown in Fig. V.3.3 and Fig. V.3.4.

(2) Farm Water Requirement (FWR)

The farm water requirement is obtained on 10-day basis, deducting the effective rainfall from crop water requirement as shown below:

$$FWR = CWR - RE$$

where, FWR : Farm water requirement (mm/10-day)
CWR : Crop water requrement (mm/10-day)
RE : Effective rainfall (mm/day)

The estimate of effective rainfall is made by daily moisture level balance method as below:

(i) The year of daily rainfall adopted for this calculation is 1985/86 for both project areas.

(ii) The water holding capacity after 24 hours from soil saturation in the root zone is estimated, based on the method of FAO, Irrigation and Drianage Paper, No. 24, as shown in Table V.3.5.

(iii) The daily moisture level in the root zone is calculated by use of the following equation:

$$ML(i) = ML(i-1) - CWR(i) + RD(i)$$

where, ML(i) : Moisture level in the effective root zone (mm)
CWR(i) : Crop water requirement (mm/day)
RD(i) : Design daily rainfall (mm/day)

(iv) The effective rainfall was obtained from daily moisture level in the root zone and the estimated water holding capacity as follows:

In case of $ML(i) < MH_{24}$: $RE(i) = RD(i)$
In case of $ML(i) > MH_{24}$: $RE(i) = MH_{24} - ML(i-1) + CWR(i)$

where, RE(i) : Effective daily rainfall (mm/day)
MH_{24} : Water holding capacity (mm)
ML(i) : Moisture level in the root zone (mm)
CWR(i) : Crop water requirement (mm/day)

The calculated results of effective rainfall and farm water requirement on 10-day basis for each crop are shown in Table V.3.3.

(3) Unit Diversion Water Requirment

The diversion water requirement is defined as the amount of farm water requirement plus allowance for irrigation losses.

$$DWR = FWR/EF/100$$

where, DWR : Diversion water requirement (mm/10-day)
FWR : Farm water requirement (mm/10-day)
EF : Overall irrigation efficiency (%)

The overall irrigation efficiency for upland crops was roughly assumed to be 55%. The unit diversion requirement was roughly computed from farm water requirement in conformity with the above efficiency and their results are shown in Table V.3.4. The peak requirements for each crop are as follows:

Crops	Tangmachhu Area		Masangdaza Area	
	Peak Unit Diversion Requirement (l/s/ha)	Period 10-day	Peak Unit Diversion Requirement (l/s/ha)	Period 10-day
Wheat	1.32	Nov. 2nd	0.95	Nov. 3rd
Mustard	0.85	Dec. 2nd	0.76	Mar. 2nd

3.3.3 Irrigable Area

The irrigation water requirement for each crop varies throughout the year and river discharge also fluctuates from day to day. There is difference in time of occurrence between the abundant flows of the tributaries and the peak irrigation water requirement. In order to assess the irrigable area guaranteed by the river flows, the water balance calculation between the drought discharge at lower prospective intake site and the unit diversion water requirement was made on 10-day basis as shown in Table V.3.6, assuming that the cropping intensity of both wheat and mustard is 25% respectively. In this calculation, the available discharge for Masangdaza area was deducted the amount of 10 l/s which should be supplied to Animal Husbandary Farm and Public Road Construction Camp (DANTAK) for their domestic water.

As a result of the water balance calculation, the irrigable areas for respective crops guaranteed by the drought discharge are summarized as follows:

Crops	Tangmachhu Area	Masangdaza Area
Rice	221	148
Upland crops	334	473

3.4 Proposed Irrigation System

3.4.1 Basic Consideration

The irrigation water is taken from comparatively small rivers which are tributaries of Kuri chu. The amount of available water resources are limited except in rainy season and existing irrigation facilities have insufficient capacity to supply the required water, while every farmer intends to expand paddy as much as possible.

According to these situations, the basic considerations on the proposed irrigation development:

- To improve the efficiency of intake water
- To increase the canal capacity
- To reduce repairing and O&M costs

And the following technical matters are fundamentals in the formulation of irrigation development:

- The intake structures shall be a permanent facility and the intake loss of water shall be minimized.
- The main canals shall be lined in order to reduce the water conveyance loss.
- An adequate structures such as syphon and aqueduct shall be provided at the land slided or collapsed area in order to keep sufficient water supply.
- The permanent turnouts shall be arranged at every diversion points to control the water distribution more effectively.
- The suitable canal protection facilities such as cross drain, retaining wall or canal cover shall be installed to cut the inflow water in rainy season or against the collapse and the stone fall.
- The operation and maintenance roads shall be arranged in order to save the repairing and O&M cost.

3.4.2 Distribution Method of Irrigation Water

The existing irrigation water distribution in the paddy fields is done by plot to plot. As the terraced paddy fields are developed with extreme small sized plots on the steep hillside, it is very difficult to provide the modernized water distribution network in the area.

The water distribution method could not be changed to the new method. However it shall be considered to improve the water management system. The control device of water distribution will be provided at each turnout in this system in order to rise up the water distribution efficiency.

3.4.3 Irrigation System

Tangmachhu area will involve two irrigation systems i.e. Tangmachhu and Gorgan systems as shown in Fig. V.3.5 and Masangdaza area will include three irrigation systems, that is, Masangdaza, Bongdima and Karbitang systems as shown in Fig. V.3.5.

The each irrigation system will consist of the intakes provided in small river, main canals provided on the hillside from intake site to irrigation area, their related structures and partially some distribution canals such as secondary and tertiary canals.

This development plan was made on the basis of the renovation project. It is very hard to change the existing irrigation system in the area because the paddy fields are much undulated on the hillside. Therefore, the proposed irrigation systems will be basically followed by the existing systems, except the following revisions:

- Locations of the intakes will be changed near the existing site except Karbithang Intake.
- The alignment of main canals will be mostly same as the existing one except some particular routes.
- The upper part of about 400 m long in Tangmachhu Secondary Canal will be changed to one pipeline from existing two open earth canals.
- Karbithang and Bongdima Intake will be unified in sole structure, then the upper part of Karbithang Canal will be relocated to lower parts.
- The end of Karbithang Canal will be relocated to 7 m higher place than the existing canal so as to supply the water to New Karibee Area.

- Among three old irrigation systems, one system will be involved in Karbithang system and two others in Bongdima system.

3.5 Preliminary Design of Irrigation Facilities

3.5.1 Basic Concepts on Design

It is the biggest problem on the planning to introduce the modernized facilities most adaptable to the local conditions. Existing facilities were constructed based on the traditional construction technics and by full use of local materials and labour forces. But these facilities are very low level in quality in comparison with the present worldwide construction technologies. It is necessary to apply the suitable new technologies for the area, taking into account the particular geographical, social and economical local conditions in East Bhutan. The following concepts as considered on the design.

(a) Design criteria of Bhutan Standard issued by DOA shall be applied as much as possible and supplemented by Indian Civil Engineer's Handbook.

(b) All facilities shall correspond with the small scale project.

(c) All facilities shall be provided in a narrow space on the steep slope.

(d) Due to the unfavorable transportation conditions, it is necessary to use local materials and small sized construction equipment as far as possible.

(e) The mechanized construction method shall be applied due to the difficulty of labour recruitment.

(f) The sophisticated facilities are unsuitable due to the difficulty of O&M.

(g) The construction works for irrigation facilities shall be completed within two off-irrigation seasons except feeder road construction works.

The major proposed irrigation facilities are as follows:

(a) Tangmachhu Area

New construction, intake	Tangmachhu intake No.1	1 no.
	Tangmachhu intake No.2	1 no.
	Gorgan intake	1 no.
Renovation, main canal	Tangmachhu canal	8.6 km
	Gorgan canal	4.0 km
New const'n, secondary canal	Tangmachhu secondary canal	0.4 km
(two secondary canals, No.1 and No.2 canal will be unified)		
Renovation, secondary canal	Ngunmaling secondary canal	0.3 km
	Tangmachhu secondary No.2 canal	0.2 km

(b) Masangdaza Area

New construction, intake	Masangdaza intake	1 no.
	Bongdima, Karbithang intake	1 no.
	(Existing two intakes will be unified)	
Renovation, main canal	Masangdaza canal	3.3 km
	Bongdima canal	4.5 km
	Karbithang canal	0.7 km
New const'n, main canal	Karbithang canal	0.9 km
New const'n, secondary canal	Karibee secondary canal	0.2 km
	Tshanglungshing secondary canal	0.2 km

3.5.2 Intake Structure

(1) Basic Design Conditions

Three intake structures will be constructed in Tangmachhu area and two intake structures in Masangdaza area. The fixed weir with wet masonry type will be provided across the river at each site. The plan and design of intake structure was carried out on the basis of topographic survey results on intake sites. The following design conditions were applied to the design of intake structures.

Project Area	Name of Intake	Design Intake Discharge (m^3/s)	Design Flood Discharge (m^3/s)	Catchment Area (km^2)	Average Slope of River Bed
Tangmachhu	Tangmachhu No.1	0.13	15.2	5.4	1/15
	Tangmachhu No.2	0.23	9.8	4.5	1/15
	Gorgan	0.20	30.4	15.1	1/10
Masangdaza	Masangdaza	0.11	30.6	15.2	1/50
	Bongdima/Karbithang	0.14	41.4	22.0	1/15

Note: Design flood discharge with 25-year return period was applied.

(2) Design of Intake Structure

The intake structure consists of weir, sluice way and intake. The weir comprises the overflow section and nonoverflow section. The design of intake structure on the basis of above conditions is described hereinafter. The general feature of each intake structure are summarized in Table V.3.7 and typical drawing for Tangmachhu intake No.1 is shown in Fig. V.3.6.

(a) Overflow Section

i) Length of weir

The length was determined by the following formula, considering the topographic conditions of existing river site as below:

$$Q = C \times L \times H^{3/2}$$

where, Q : Design flood discharge (m^3/s)
C : Coefficient of overflow
L : Length of overflow section (m)
H : Overflow depth (m)

Name of Intake	Overflow Depth (m)	Length (m)
Tangmachhu No.1	1.5	4.9
Tangmachhu No.2	1.5	3.2
Gorgan	2.0	6.4
Masangdaza	2.0	6.4
Bondima/Karbithang	2.0	8.7

ii) Length of apron (Lu and Ld)

The length of upstream apron was determined to be more than twice of upstream water depth at the time of design flood discharge, taking into account the characteristics of river bed rock and functions of intake and sluice way.

The length of downstream was decided by the following formula.

$$Ld \geqq 0.9 \times C \times \sqrt{D_1}$$

where, Ld : Length of downstream apron (m)
C : Coefficient of Bligh method
D_1 : Height from the crest to surface of the end of apron (m)

Name of Intake	Upstream Apron (m)	Downstream Apron (m)
Tangmachhu No.1	6.0	7.5
Tangmachhu No.2	6.0	7.5
Gorgan	6.0	7.5
Masangdaza	6.0-9.0	6.0
Bondima/Karbithang	7.5	8.5

iii) Thickness of apron

The thickness of downstream apron was determined by the following formula:

$$t \geqq S \times (\Delta H \times Hf)/(r-1)$$

where, t : Thickness of apron at the considered point (m)
ΔH : Difference between upstream and downstream water level (m)
Hf : Head loss of seepage water up to the considered point (m)
r : Apparent specific gravity of materials of apron and weir (t/m^3)
S : Safety factor (4/3)

The thickness of upstream apron was estimated to be 50 cm, corresponding to half thickness of downstream apron.

iv) Crest width and slope of weir

The weir body will be made of wet masonry with upstream slope of vertical and downstream slope of 0.8. The crest width was determined to be 1.5 m by following formula:

$$B = 0.552 \times (\sqrt{H} + \sqrt{h_1})$$

where, B : Crest width (m)
h_1 : Overflow depth at the time of flood (m)
H : Weir height (m)

(b) Nonoverflow Section

The height of nonoverflow section is the value of freeboard plus upstream water depth of weir at the time of design flood. The freeboard to be applied are as follows:

Discharge (m^3/s)	Freeboard (m)
$Q \leqq 200$	0.6
$200 < Q \leqq 500$	0.8

The weir body of this section will be made of wet masonry, while the part of gate sill and operation deck will be made of reinforced concrete.

(c) Sluice way

i) Width

The width of sluice way was determined by the following formula:

$$Bs \leqq Qs/qe$$

$$Qs = qm \times Br$$

$$qe = \sqrt{(20 \times d)^3/g^2}$$

where, Bs : Width of sluice way (m)
Qs : River discharge for flushing grain size D_{60} (m^3/s)
qm : River discharge in terms of unit width for flushing grain size D_{60} ($m^3/s/m$)
Br : River width (m)
qe : River discharge in terms of unit width for flushing grain size Dmax ($m^3/s/m$)
d : Maximum grain size of bed materials (m)
g : Acceleration of gravity (9.8 m/sec)

Project Area	qe ($m^3/s/m$)	qm ($m^3/s/m$)	Br (m)	Qs ($m^3/s/m$)	Bs (m)	Adapted Width of Sluice Way (m)	Height (m)
Tangmachhu	0.102	0.026	7.0	0.182	1.82	1.5	1.2
Masangdaza	1.5	0.82	5.0	4.1	2.73	2.0	1.2

ii) Guide wall

The guide walls will be provided for the purpose of the stability of river course and the protection of influence for intake. The height of guide walls was determined to be the same as the design intake water level.

(d) Intake

The bed elevation of intake will be 1.0 m higher than the existing river bed elevation. The method of intake water will be the overflow type during the period of drought and ordinary water level, while it will be orifice type during the period of abundant water level. The major features of intake gate are as follows:

	No.	Type	Width (m)	Height (m)
Tangmachhu No.1	1	Sluice gate	0.65	0.50
Tangmachhu No.2	1	Sluice gate	0.75	0.50
Gorgan	1	Sluice gate	0.75	0.50
Masangdaza	1	Sluice gate	0.70	0.50
Bondima/Karbithang	1	Sluice gate	0.60	0.50

(e) River Bed Protection Works

The protection works of river bed at the downstream of the weir consist of reinforced concrete lattice frame with cobble stones filled in frames. The length of protection works will be 6.0 m for Tangmachhu No.1 and No.2 because of small design flood discharge. Gorgan and Bongdima/Karbithang intakes will have those of 9.0 m long due to large design discharge. Masangdaza intake will not be provided protection works, considering the characteristics of sound river bed and the existence of drop.

3.5.3 Irrigation Canal and Related Structure

(1) Design of Main Canal

Main irrigation canals were in principle designed as wet masonry canals with rectangular section. The design of the main canals are carried out based on the basic design criteria described below:

i) Design discharge

The design discharge for irrigation canals were estimated, based on the irrigation water requirement and the command area. Irrigation diagram for the proposed irrigation system is shown in Fig. V.3.7.

There is a possibility to generate the hydropower in Tangmachhu area. Since there exist 170 m different height between Tangmachhu canal and Gorgan canal at the point of 5 km downstream of Tangmachhu canal. Providing Tangmachhu canal with the discharge of 0.1 m^3/sec, about 120 kW of

electric power will be available without extra construction cost for water conveyance except very small cost of canal enlargement. It has no adverse effects on the proposed irrigation system. Therefore, Tangmachhu irrigation system involved the extra discharge of 0.1 m^3/s and was provided with diversion facilities to power plant for the future hydropower development.

ii) Velocity

The maximum permissible velocity of canals was determined so as not to cause scouring of canal. The minimum permissible velocity was determined so as not to induce the growth of aquatic plant and moss, and not to cause the sedimentation in canal. Permissible velocity of each canal was determined as follows:

Materials	Min.	Max.
Masonry	0.6 m/s	2.0 m/s

iii) Hydraulic calculation

The hydraulic analysis for the canal section is based on Manning's formula which is expressed as:

$$B = 1/n \times R^{2/3} \times S^{1/2}$$

where, R : Hydraulic radius of the canal (m) (wetted area + wetted perimeter)

S : Slope of the canal

n : Manning's coefficient of roughness (adopted as 0.026 for both earth and masonry canals within the project area)

The discharge for the canal is the estimated by using the Law of Continuity which is given as:

$$Q = A \times V$$

where, Q : Discharge of the canal (m^3/s)

A : Wetted area of the canal (m^2)

V : Velocity of flow in the canal (m/s)

iv) Freeboard

The freeboard for the canal was decided, taking into account both the rising up of waer surface in the curved canal and

ratio of maximum canal capacity against the design discharge.

The rising up of water surface in the curved canal is calculated by following formula:

$$\Delta H = b/2 \times \tan \phi_c$$

$$\tan \phi = 2 \times V^2/(g \times R)$$

where, ΔH : Rising up height of water surface (m)
b : Width of canal (m)
ϕ_c : Gradient of water surface in the curved canal
v : Velocity of flow (m/s)
R : Radius of curvature (m)
g : Acceleration of gravity (9.8 m/s^2)

The ratio of maximum canal capacity against the design discharge shall be more than 1.5, in case there exist the direct inflow water to the canal. As a result, the freeboard for canal is calculated at 0.15 m.

v) Canal section

The following four types of typical cross sections as shown in Fig. V.3.8 will be applied to main canals.

Type-1 This is a most common wet masonry canal to be applied in the comparatively gentle area. The masonry wall is provided for protection of berm shoulder against the cattle walking.

Type-2 This is a variation of Type-1, being added a retaining wall on the cutting face and will be applied at the collapsible place such as the paddy field area.

Type-3 This is a covered canal to be used as a O&M road on the top space. This type will be applied at the steep slope or locky area.

Type-4 This is a special one reformed from the existing masonry canal. The existing canal section shall be enlarged and the O&M road will be newly constructed.

The canal lengths of each type are presented in Table V.3.8.

(2) Related Structure

Various structures are required in conjunction with irrigation canals for conveyance, regulation and measurement of irrigation water and protection of canal system as follows:

(a) An inverted pipe syphons is provided at the place of big scale landslide or collapse. The pipes to be used are steel pipes due to the high water pressure.

(b) A pipe aqueducts are provided at the places of small scale landslide, collapse and gully or rocky cliff. The pipes are corrugated galvanized steel pipe combined with steel beams and supports.

(c) In order to prevent the overtopping of water which is the biggest reason of the canal destruction, a spillway and/or a waste way is provided. The locations of these structures shall be just before the syphon, culvert, covered canal and at about 1 km intervals of the continuous open canal.

(d) In order to cut the inflow into the canal, over chute or cross drain is provided at all required places. At the crossing point with small mountain streams, drain inlet is installed to take the supplemental water into the canal in dry season.

(e) Diversion structure to distribute the water to both Bongdima and Karbithang systems is provided just downstream of intake facilities.

(f) Two types of turnouts are provided at all points with a water control gate or a valve in the small case. The locations of turnouts are in principle same position as existings except some particular removal one.

(g) The O&M roads with 1.5 to 2.0 m wide are provided beside all canals.

(h) At the place of stone falling and land collapse, the canal shall be covered with the reinforced concrete plates.

(i) Cascade and drop structures are constructed to convey the water from a higher to a lower elevation and dissipate excess energy resulting from steep slopes.

The number of related structures for respective project areas are presented in Table V.3.8.

(3) Secondary Canal

Ngunmaling Secondary Canal of about 200 m long is renovated and steel pipe aqueduct of 10 m long and 300 mm in diameter is installed at the end of canal.

The upper part of about 400 m in Tangmachhu 1st and 2nd Secondary Canal located on the steep slope are proposed to be changed one steel pipeline (ϕ450 mm) and the turnout box is provided at the end of pipeline for the water distribution to two secondary canals.

Tangmachhu 2nd Secondary Canal of about 200 m long from the turnout box is renovated and provided with corrugated steel pipe (ϕ400 mm) aqueduct of 10 m at the end portion.

Karibee Secondary Canal is newly constructed with about 200 m long from the end of Karbithang Canal which is relocated 7 m higher position than the existing. A steel pipe syphon with 200 mm in diameter is installed at the crossover point with valley.

Table V.2.1 EXISTING IRRIGATION SCHEME

	Block	Number of Scheme	Comand Area (ha)	Canal Length (Km)	Beneficiary House-hold	Year of Construction
LHUNTSHI DISTRICT						
1	Dungkhar	1	121	3	50	-
2	Gangzoor	4	150	10	144	1984-1885
3	Khoma	3	128	6	104	1983
4	Minji	4	231	23	153	1983
5	Tangmachhu	4	321	19	293	1982
6	Metsho	2	45	3	60	1984
7	Jarrey	-	-	-	-	-
8	Chengkhar	3	150	10	121	1985
	Total	21	1,146	74	925	-
MONGAR DISTRICT						
1	Chakaling	4	416	11.3	280	1974-1983
2	Chamang	-	-	-	-	-
3	Chaskhar	1	292	6.81	332	1984-1985
4	Demchi	3	48.8	22.1	60	1973-1985
5	Ngatshang	3	66	5.85	172	1974-1978
6	Gongdu	3	104	3.93	12	1975-1985
7	Kengkhar	-	-	-	-	-
8	Mongar	3	123	6.72	177	1977-1979
9	Salling	5	102	14.4	83	1974-1984
10	Silambi	-	-	-	-	-
11	Thangrong	-	-	-	-	-
	Total	22	1,152	71.2	1,116	-

Table V.2.2 IRRIGATION DEVELOPMENT PLAN UNDER 6TH PLAN

Block	Scheme	Command Area (ha)	Canal Length (Km)	Category	Remarks
LHUNTSHI DISTRICT					
Tangmachhu	Tangmachu	121	10	Renovation	-
Tangmachhu	Gorgan	91	4	Renovation	1987/88
Minji	Minji	75	5.64	Renovation	1987/88
Minji	Lekpachu	44	5.45	Renovation	1987/88
Chengkhar	Wambur	80	5.18	Renovation	1987/88
Chengkhar	Domkhar	30	3.48	Renovation.	
Minji	Kupinesa	40	6.86	Renovation.	
Tangmachhu	Menjibi	102	N.A.	Renovation	
Gangzoor	Nagar & Janpo	66	N.A.	Renovation	
Kurtey	Thumbi Rulling & Jasabi	82	N.A.	Renovation	
Jarrey	Nangay & Umchey	30	N.A.	Renovation	
Gangzoor	Nagar Samling	90	N.A.	New Construction	
Chengkhar	Chengkhar	121	9	New Construction	
Kurtey	Dungkhar	64	N.A.	New Construction	
Metsho	Gortshan	30	N.A.	New Construction	
Jarrey	Yabi	32	N.A.	New Construction	
MONGAR DISTRICT					
Dremtshi	Rollong	30	2	Renovation	1987/88
Mongar	Tailing	4	0.23	Renovation	1987/88
Mongar	Gyelposhing	75	3.72	Renovation	1987/88
Dremtshi	Yayung	28	2.4	Renovation	1987/88
Salling	Masangdaza	80	3.48	Renovation	1988/89
Salling	Bongdima	16	4.76	Renovation	1988/89
Dremtshi	Gomchu	52	2.5	New Construction	
Ngatshang	Muhung	56	2.2	New Construction	
Salling	Thridangbi	N.A	N.A	New Construction	
Chakaling	Chali	N.A	N.A	New Construction	

Table V.3.1 PERCOLATION TEST RESULT

(Unit: mm)

No.	Date	Tangmachhu Area		Masangdaza Area	
		A	B	A	B
1	88-7-18	-	-	-	
2	19	-	-	26	26
3	20	-	-	12	24
4	21	-	-	13	11
5	22	-	-	23	16
6	23	1	1	16	16
7	24	3	3	18	14
8	25	-	-	18	13
9	26	-	-	13	17
10	27	-	-	23	16
11	28	-	-	31	13
12	29	3	4	23	23
13	30	1	1	-	33
14	31	1	1	-	34
15	88-8-1	2	1	22	36
16	2	3	2	19	42
17	3	1	1	19	22
18	4	2	3	16	17
19	5	3	1	19	22
20	6	1	1	18	29
21	7	2	1	19	14
22	8	2	3	14	15
23	9	1	4	17	18
24	10	4	1	17	28
25	11	1	1	18	17
26	12	1	1	-	-
27	13	1	1	-	-
28	14	1	5	-	-
29	15	1	1	-	-
Average		1.75	1.85	18.8	21.5
		1.80		20.2	

Table V.3.2 DAILY RAINFALL (R) AND DESIGN RAINFALL (RD)

Area		Tangmachhhu Area				Masangdaza Area			
Crop		Rice		Upland		Rice		Upland	
Month	Day	R	RD	R	D	R	RD	R	RD
Jan.	1 - 10			0	0			0	0
	11 - 20			0	0			0	0
	21 - 30			0	0			0	0
Feb.	1 - 10			0	0			1	0
	11 - 20			0	0			7	5
	21 - 28			0	0			0	0
Mar.	1 - 10			10	7			8	6
	11 - 20			1	0			8	0
	21 - 31			0	0			0	0
Apr.	1 - 10			26	22			20	17
	11 - 20			23	21			34	33
	21 - 30	62	56	11	0			71	65
May	1 - 10	45	34	53	43	6	0	6	0
	11 - 20	10	6			24	14	24	14
	21 - 31	5	0			0	0		
Jun.	1 - 10	21	14			7	0		
	11 - 20	5	5			34	26		
	21 - 30	10	5			199	191		
Jul.	1 - 10	54	43			52	49		
	11 - 20	42	37			59	50		
	21 - 31	56	39			65	58		
Aug.	1 - 10	28	14			23	18		
	11 - 20	1	0			15	9		
	21 - 31	34	28			61	59		
Sep.	1 - 10	26	22			22	22		
	11 - 20	19	14			55	54		
	21 - 30	19	6			30	22		
Oct.	1 - 10	7	0			42	40		
	11 - 20	71	62			29	23	77	72
	21 - 31	16	12	16	12			1	0
Nov.	1 - 10			11	11			13	8
	11 - 20			8	8			0	0
	21 - 30			3	0			0	0
Dec.	1 - 10			1	0			3	0
	11 - 20			1	0			4	0
	21 - 31			10	10			17	17

Table V.3.3 EFFECTIVE RAINFALL (RE) AND FARM WATER REQUIREMENT (FWR)

(Unit: mm/10-day)

Area		Tangmachhu Area						Masangdaza Area					
Crop		Rice		Wheat		Mustard		Rice		Wheat		Mustard	
Month	Day	RE	FWR	RE	FWR	RE	FWR	RE	FWR	RE	FWR	RE	FWR
Jan.	1 - 10			0	21	0	16			0	20	0	23
	11 - 20			0	24	0	10			0	23	0	14
	21 - 30			0	29	0	13			0	28	0	13
Feb.	1 - 10			0	32	0	17			0	36	0	19
	11 - 20			0	33	0	20			5	32	5	18
	21 - 28			0	27	0	19			0	29	0	21
Mar.	1 - 10			7	33	7	27			6	34	4	30
	11 - 20			0	37	0	37			0	38	0	36
	21 - 31			0	38	0	41			0	37	0	40
Apr.	1 - 10			22	8	22	15			17	13	17	19
	11 - 20			21	2	21	10			33	0	30	5
	21 - 30	56	1	0	9	0	15			65	0	33	1
May	1 - 10	34	1	8	1	43	0	0	1	0	6	0	10
	11 - 20	6	13					14	3	14	0	11	2
	21 - 31	0	43					0	40				
Jun.	1 - 10	14	54					0	102				
	11 - 20	5	68					26	136				
	21 - 30	5	77					123	82				
Jul.	1 - 10	43	50					49	145				
	11 - 20	37	51					50	119				
	21 - 31	39	41					58	115				
Aug.	1 - 10	14	50					18	137				
	11 - 20	0	65					9	148				
	21 - 31	28	45					59	116				
Sep.	1 - 10	22	38					22	131				
	11 - 20	14	37					54	87				
	21 - 30	6	33					22	82				
Oct.	1 - 10	0	26					40	41				
	11 - 20	62	0					23	16	42	6		
	21 - 31	12	5	12	17					0	32		
Nov.	1 - 10			11	46					8	35		
	11 - 20			8	63					0	42	0	7
	21 - 30			0	56	0	11			0	45	0	20
Dec.	1 - 10			0	24	0	30			0	39	0	26
	11 - 20			0	14	0	40			0	25	0	28
	21 - 31			10	10	10	28			17	7	17	21

Table V.3.4 UNIT DIVERSION WATER REQUIREMENT

(Unit: l/s/ha)

Area		Tangmachhu Area			Masangdaza Area		
Month	Day	Rice	Wheat	Mustard	Rice	Wheat	Mustard
Jan.	1 - 10		0.45	0.34		0.42	0.48
	11 - 20		0.51	0.20		0.48	0.31
	21 - 30		0.56	0.25		0.53	0.25
Feb.	1 - 10		0.68	0.35		0.75	0.40
	11 - 20		0.70	0.42		0.67	0.38
	21 - 28		0.70	0.50		0.77	0.56
Mar.	1 - 10		0.70	0.57		0.72	0.63
	11 - 20		0.79	0.77		0.80	0.76
	21 - 31		0.72	0.78		0.70	0.76
Apr.	1 - 10		0.17	0.32		0.28	0.40
	11 - 20		0.05	0.21		0.00	0.10
	21 - 30	0.01	0.19	0.31		0.00	0.02
May	1 - 10	0.02	0.01	0.00	0.02	0.13	0.21
	11 - 20	0.26			0.06	0.00	0.03
	21 - 31	0.75			0.69		
Jun.	1 - 10	1.04			1.96		
	11 - 20	1.30			2.63		
	21 - 30	1.49			1.57		
Jul.	1 - 10	0.97			2.79		
	11 - 20	0.98			2.29		
	21 - 31	0.73			2.02		
Aug.	1 - 10	0.96			2.65		
	11 - 20	1.26			2.85		
	21 - 31	0.79			2.03		
Sep.	1 - 10	0.73			2.54		
	11 - 20	0.71			1.67		
	21 - 30	0.64			1.58		
Oct.	1 - 10	0.50			0.79		
	11 - 20	0.00			0.30	0.13	
	21 - 31	0.08	0.36			0.67	
Nov.	1 - 10		0.96			0.74	
	11 - 20		1.32			0.88	0.14
	21 - 30		1.18	0.24		0.95	0.41
Dec.	1 - 10		0.51	0.62		0.81	0.55
	11 - 20		0.29	0.85		0.53	0.58
	21 - 31		0.19	0.53		0.13	0.40

Table V.3.5 WATER HOLDING CAPACITY

Crops	Root Zone (mm)	Friction of Available Soil Water	Water Holding Capacity (mm)			
			Field Capacity (% in Volume)	ETcrop < 3mm x1.3 (mm)	3mm < ETcrop < 8mm x1.0 (mm)	8mm < ETcrop x0.7 (mm)
Tangmachhu						
Wheat	1,200	0.55	40	343	264	185
Mustard	500	0.45	40	117	90	63
Masangdaza						
Wheat	1,200	0.55	36	309	238	167
Mustard	500	0.45	36	105	81	57

Table V.3.6 WATER BALANCE CALCULATION

Project Area		Tangmachhu Area					Masangdaza Area				
Month	Day	Drought Discharge (l/s)	Diversion Req. (l/s/ha) Rice	Wheat	Mustard	Irrigable Area (ha)	Drought Discharge (l/s)	Diversion Req. (l/s/ha) Rice	Wheat	Mustard	Irrigable Area (ha)
Jan.	1 - 10	159		0.45	0.34	803	221		0.42	0.48	982
	11 - 20	162		0.51	0.20	910	225		0.48	0.31	1,141
	21 - 30	143		0.56	0.25	708	199		0.53	0.25	1,021
Feb.	1 - 10	149		0.68	0.35	581	208		0.75	0.40	723
	11 - 20	146		0.70	0.42	523	203		0.67	0.38	775
	21 - 28	131		0.70	0.50	438	181		0.77	0.56	546
Mar.	1 - 10	133		0.70	0.57	419	184		0.72	0.63	544
	11 - 20	134		0.79	0.77	345	186		0.80	0.76	476
	21 - 31	125		0.72	0.78	334	173		0.70	0.76	473
Apr.	1 - 10	157		0.17	0.32	1,282	219		0.28	0.40	1,287
	11 - 20	133		0.05	0.21	2,044	184		0.00	0.10	7,344
	21 - 30	190	0.01	0.19	0.31	1,409	267		0.00	0.02	53,440
May	1 - 10	187	0.02	0.01	0.00	8,322	263	0.02	0.13	0.21	2,503
	11 - 20	254	0.26			976	360	0.06	0.00	0.03	5,327
	21 - 31	266	0.75			354	377	0.69			547
Jun.	1 - 10	285	1.04			274	406	1.96			207
	11 - 20	287	1.30			221	408	2.63			155
	21 - 30	331	1.49			222	472	1.57			301
Jul.	1 - 10	444	0.97			458	637	2.79			228
	11 - 20	468	0.98			478	672	2.29			293
	21 - 31	471	0.73			645	676	2.02			335
Aug.	1 - 10	447	0.96			466	641	2.65			242
	11 - 20	323	1.26			256	461	2.85			162
	21 - 31	291	0.79			369	415	2.03			204
Sep.	1 - 10	264	0.73			362	375	2.54			148
	11 - 20	290	0.71			408	412	1.67			247
	21 - 30	258	0.64			403	366	1.58			232
Oct.	1 - 10	245	0.50			489	346	0.79			438
	11 - 20	236	0.00			-	333	0.30	0.13		1,002
	21 - 31	278	0.08	0.36		1,634	395		0.67		2,357
Nov.	1 - 10	243		0.96		1,013	344		0.74		1,861
	11 - 20	240		1.32		728	340		0.88	0.14	1,333
	21 - 30	242		1.18	0.24	681	342		0.95	0.41	1,006
Dec.	1 - 10	214		0.51	0.62	759	302		0.81	0.55	889
	11 - 20	196		0.29	0.85	689	276		0.53	0.58	995
	21 - 31	171		0.19	0.53	948	239		0.13	0.40	1,801

Table V.3.7 GENERAL FEATURE OF INTAKE STRUCTURE

Item	Unit	Tangmachhu Area			Masangdaza Area	
		Tangmachhu-No. 1	Tangmachhu-No. 2	Gorgan	Masangdaza	Karbithang-Bongdima
1) Type of Structure		Masonry	Masonry	Masonry	Masonry	Masonry
2) Weir Length						
Whole Length	m	7.4	5.7	8.9	9.4	11.7
Overflow Section	m	4.9	3.2	6.4	6.4	8.7
3) Weir Height						
Non-overflow Section	m	3.6	4.1	4.1	4.1	4.1
Overflow Section	m	1.5	1.5	1.5	1.5	2.5
4) Intake						
Water Level	m	El. 2,233.7	El. 2,206.7	El. 1,957.8	El. 920.5	El. 802.3
Discharge	m3/s	0.13	0.23	0.20	0.11	0.14
5) Flood Discharge	m3/s	15.20	9.80	30.40	30.60	40.40
6) Gate						
Sluice Way (H x W)	mm	1,200 x 1,500	1,200 x 1,500	1,200 x 1,500	1,200 x 2,000	1,200 x 2,000
Intake (H x W)	mm	500 x 650	500 x 750	500 x 750	500 x 700	500 x 600

Table V.3.8 IRRIGATION CANAL AND RELATED STRUCTURE

Facilities		Unit	Tangmachhu Area		Masangdaza Area		
			Tangmachhu	Gorgan	Masangdaza	Karbithang	Bongdima
1) Intake		No.	2	1	1	1	
2) Main Canal							
Open Canal	Type-1	m	5,151.5	654.8	934.0	1,296.0	1,304.0
	Type-2	m	430.0	1,064.8	-	-	-
	Type-3	m	1,712.5	1,150.0	66.0	129.0	-
	Type-4	m	-	-	2,285.0	-	3,142.7
Syphon	Steel Pipe	m	-	251.2	-	-	-
Aqueduct	Corrugated Pipe	m	54.3	10.0	16.0	93.0	26.3
Cascade		m	1,201.7	889.0	-	125.0	30.0
Total Length of Main Canal		m	8,550.0	4,019.6	3,301.0	1,643.0	4,503.0
3) Related Structures							
Spillway		No.	11	2.0	4	1	3
Wasteway		No.	-	-	1	-	-
Sand Trap		No.	2	3.0	3	-	1
Drop		No.	21	12	-	3	4
Cross-drain		No.	3	-	2	3	1
Drain Inlet		No.	3	1.0	-	-	-
Over Chute		No.	1	3.0	8	1	7
Road Crossing (Footpath)		No.	20	3.0	6	1	2
Turnout	Type-A	No.	6	21.0	6	-	11
	Type-B	No.	8	2.0	8	3	1
	Diversion	No.	0	1.0	-	-	-
4) Secondary Canal		m	300	600.0	-	200	200

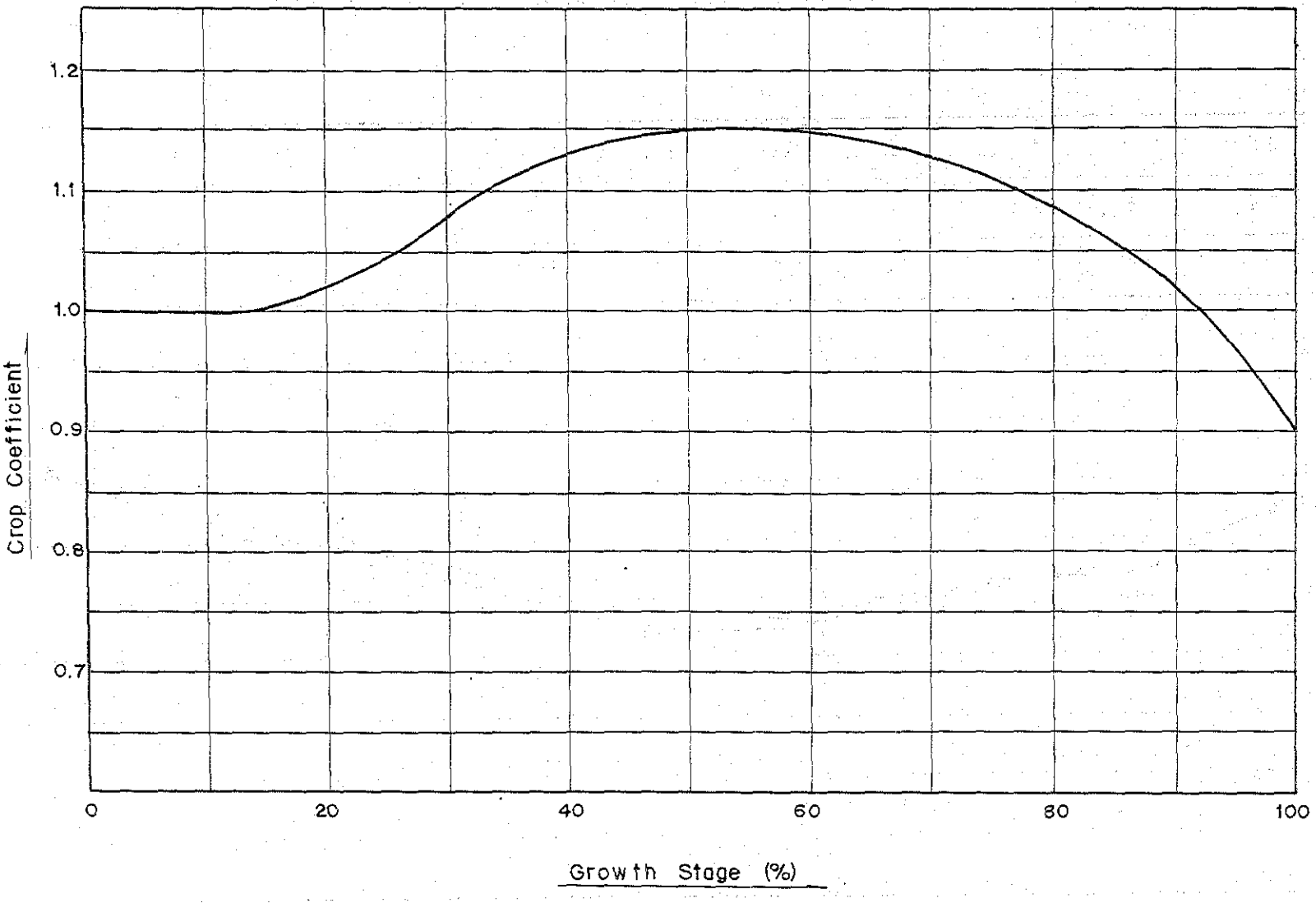
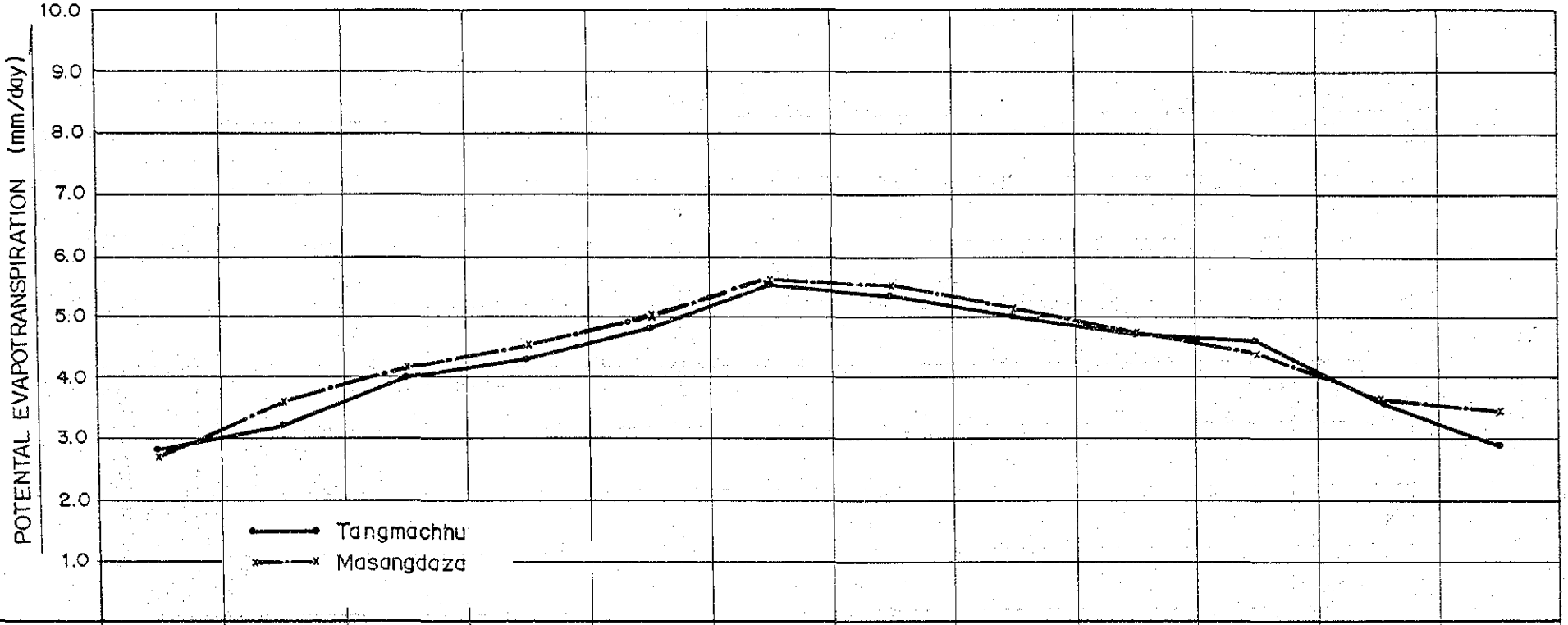


Fig. V. 3. 1 CROP COEFFICIENT CURVE FOR PADDY



Month	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Tangmachhu	2.8	3.2	4.0	4.3	4.8	5.5	5.3	5.0	4.7	4.6	3.6	2.9
Masangdaza	2.7	3.6	4.1	4.5	5.0	5.6	5.5	5.1	4.7	4.4	3.6	3.4

Fig. V. 3.2 POTENTIAL EVAPOTRANSPIRATION
(BLANEY - CRIDDLE METHOD)

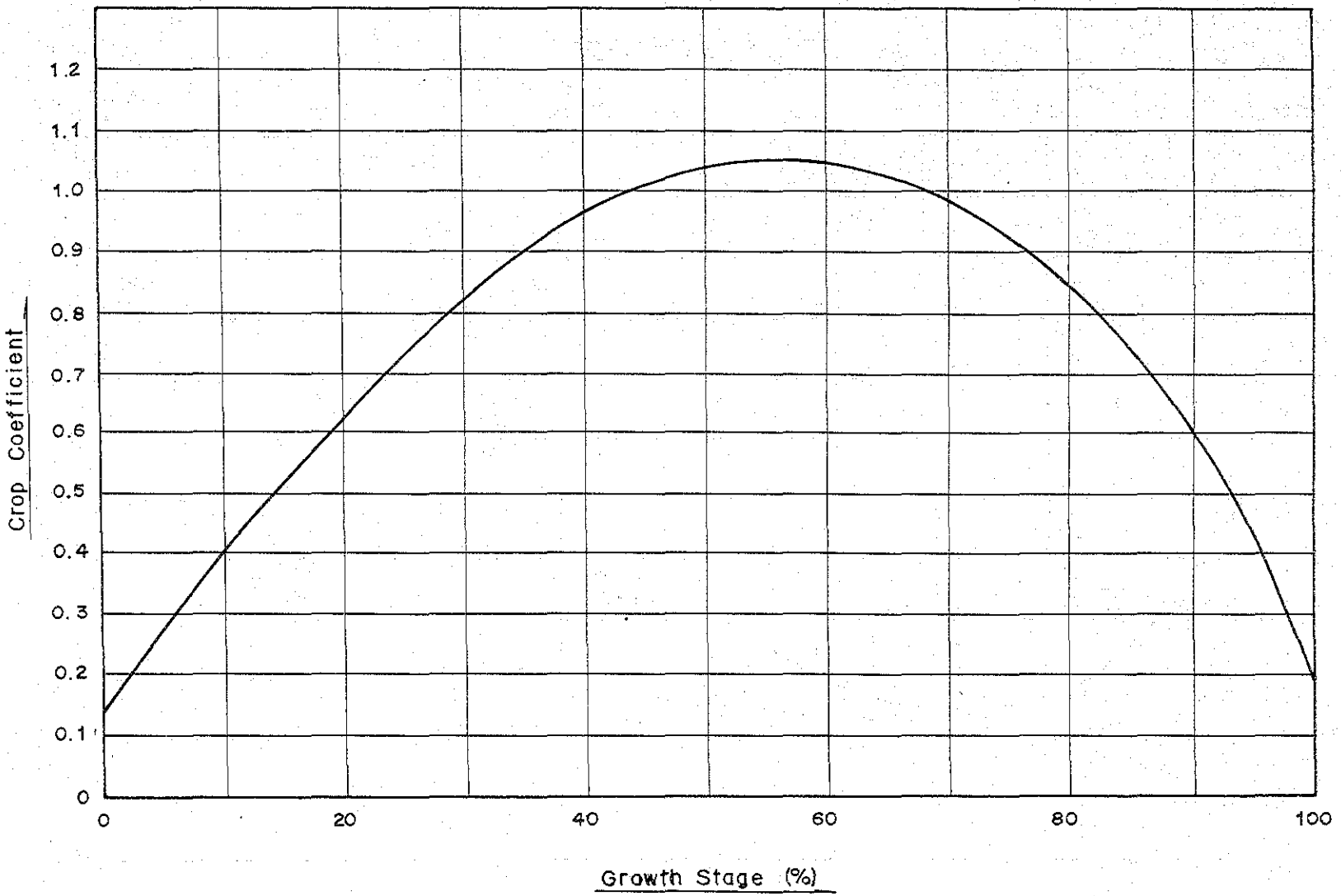


Fig.V.3.3 CROP COEFFICIENT CURVE FOR WHEAT

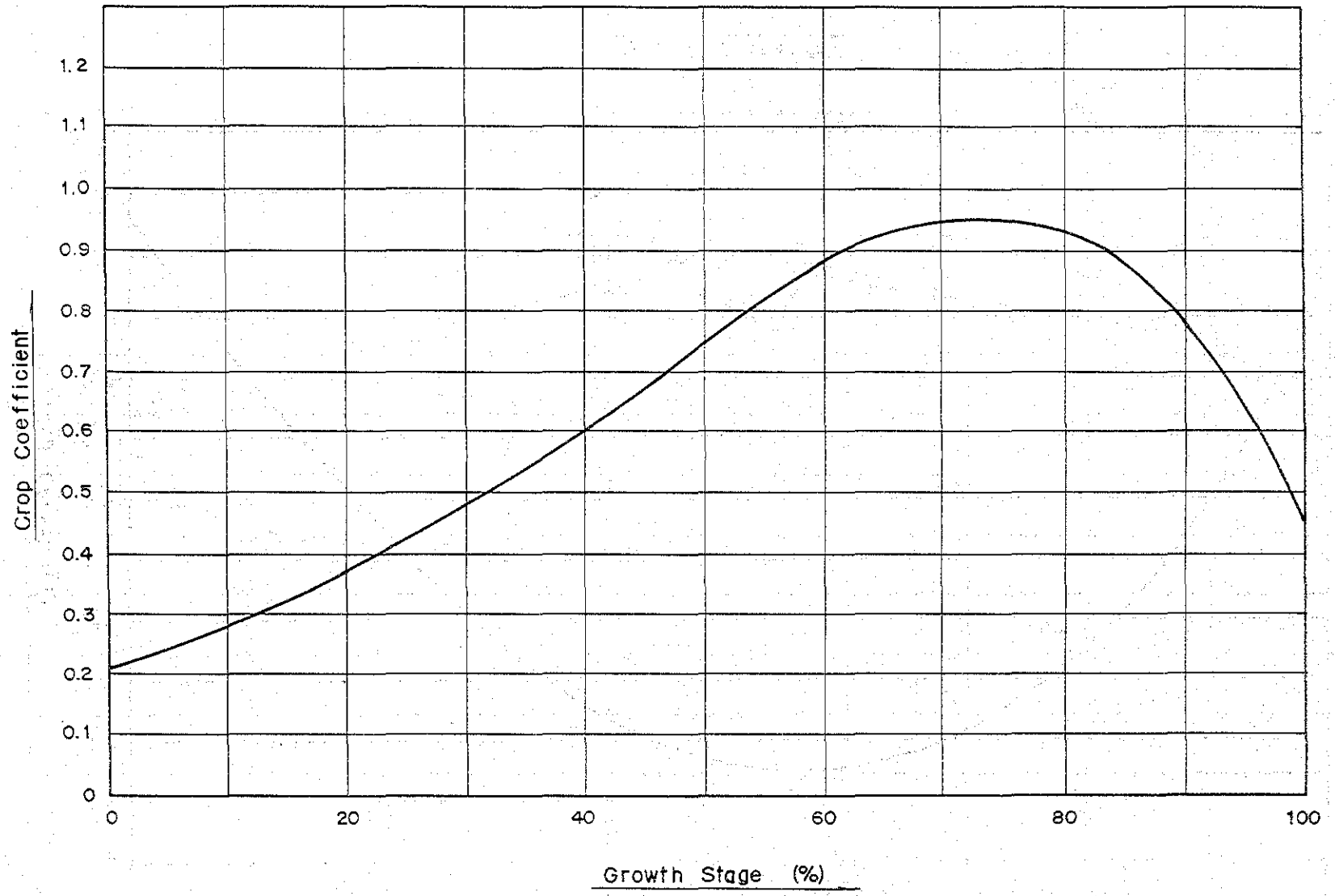


Fig. V. 3.4 CROP COEFFICIENT CURVE FOR MUSTARD

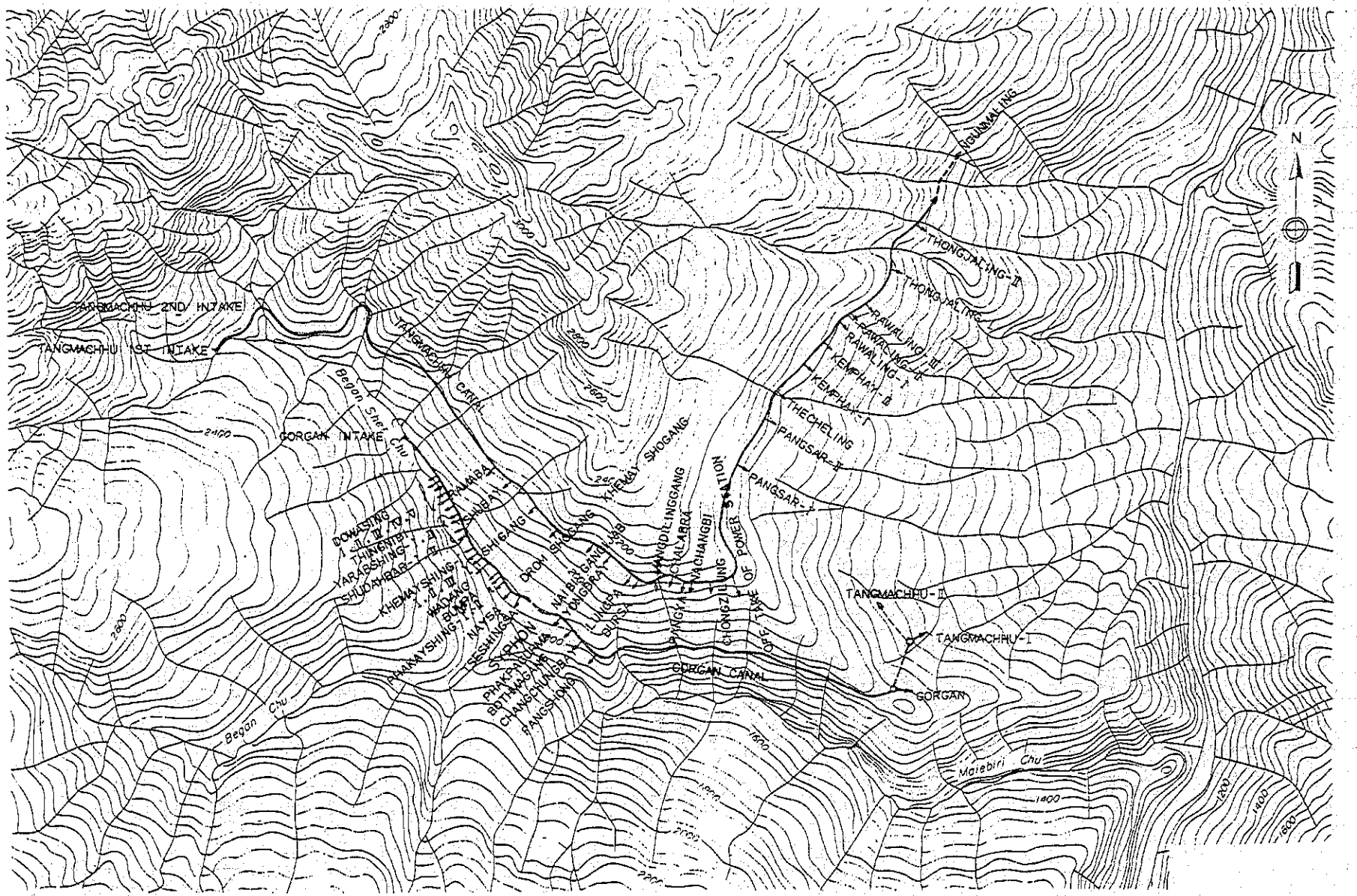


Fig.V.3.5 GENERAL PLAN OF IRRIGATION SYSTEM (1/2)

(TANGMACHHU AREA)

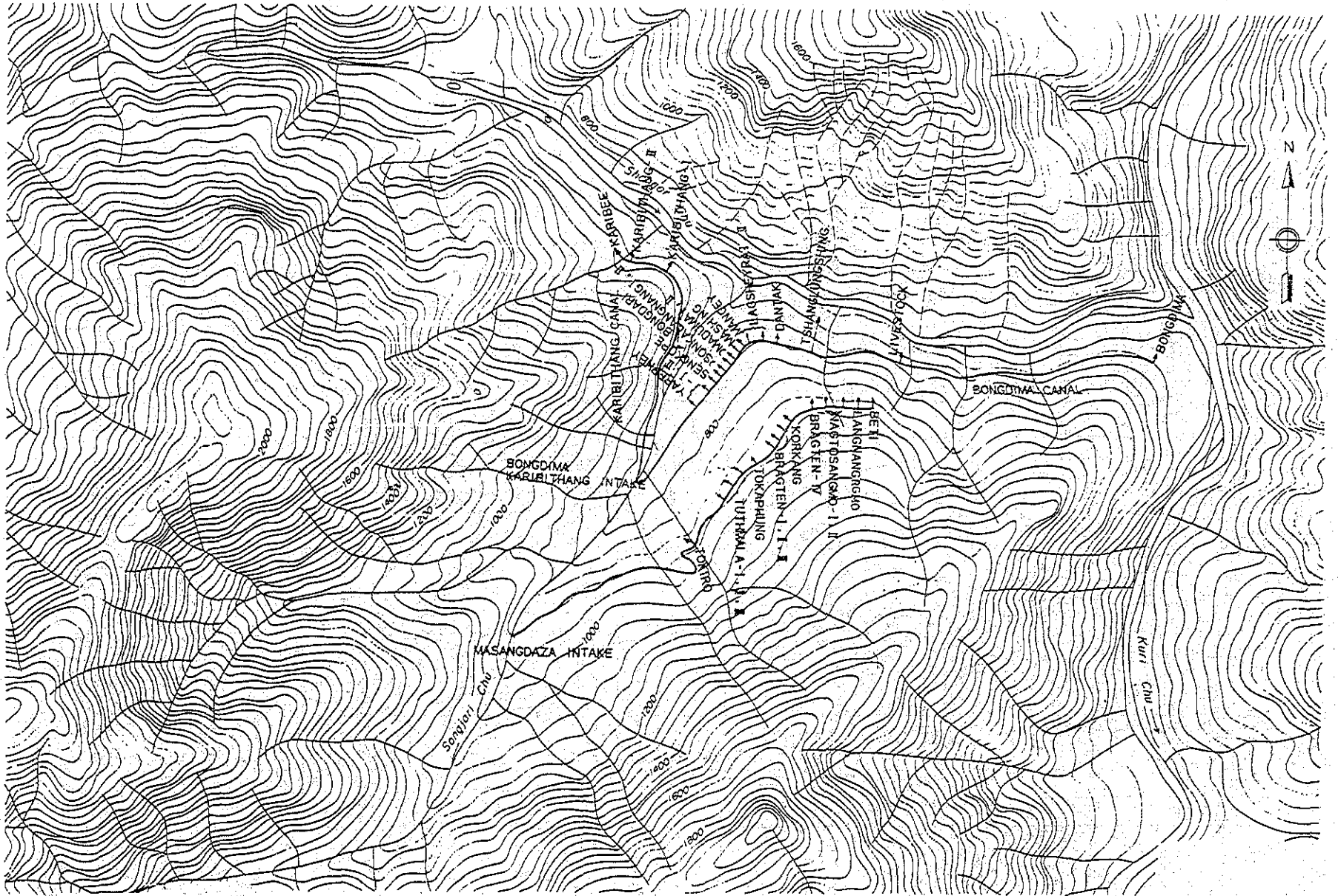


Fig.V.3.5 GENERAL PLAN OF IRRIGATION SYSTEM (2/2)
(MASANGDAZA AREA)

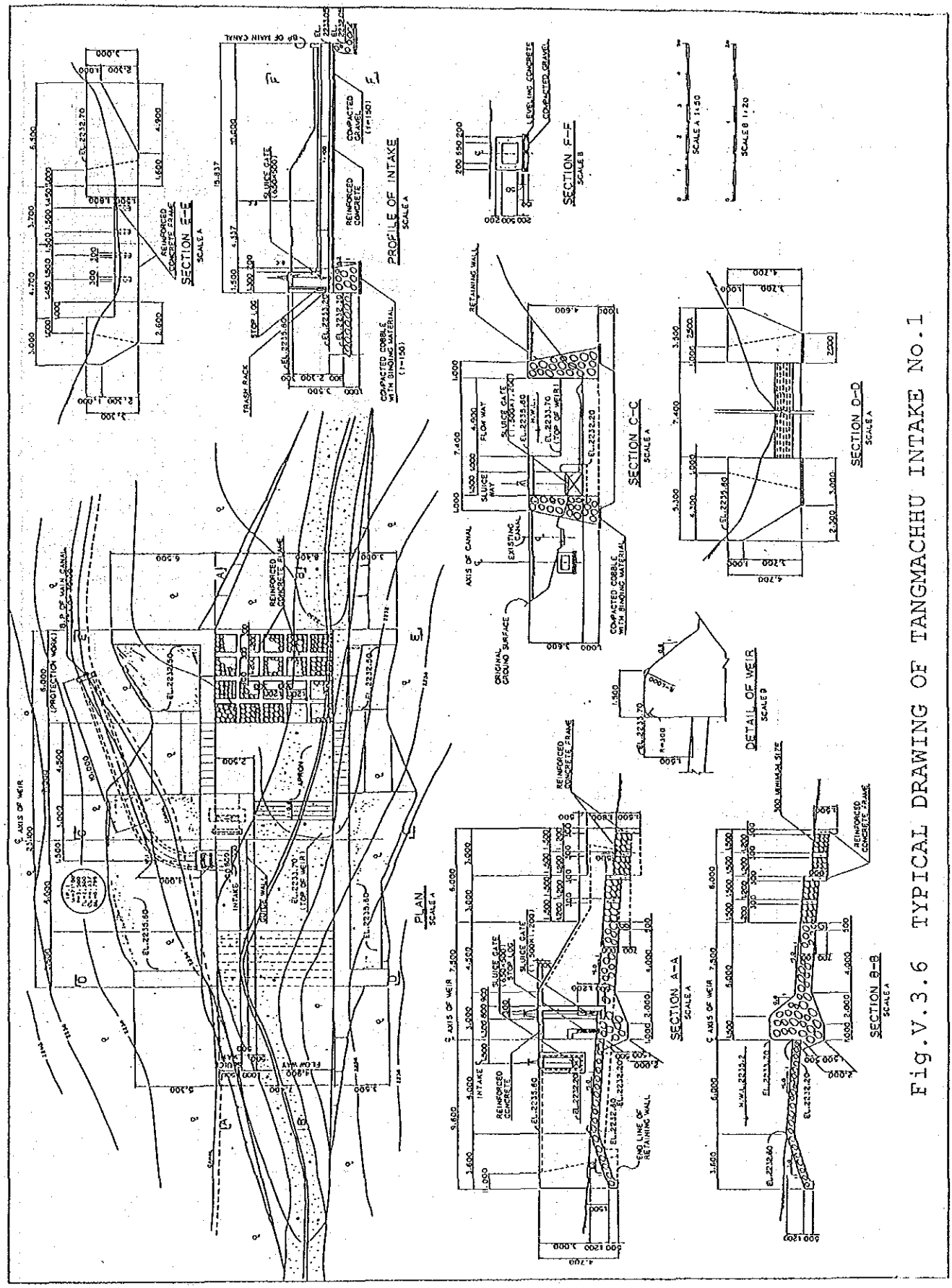
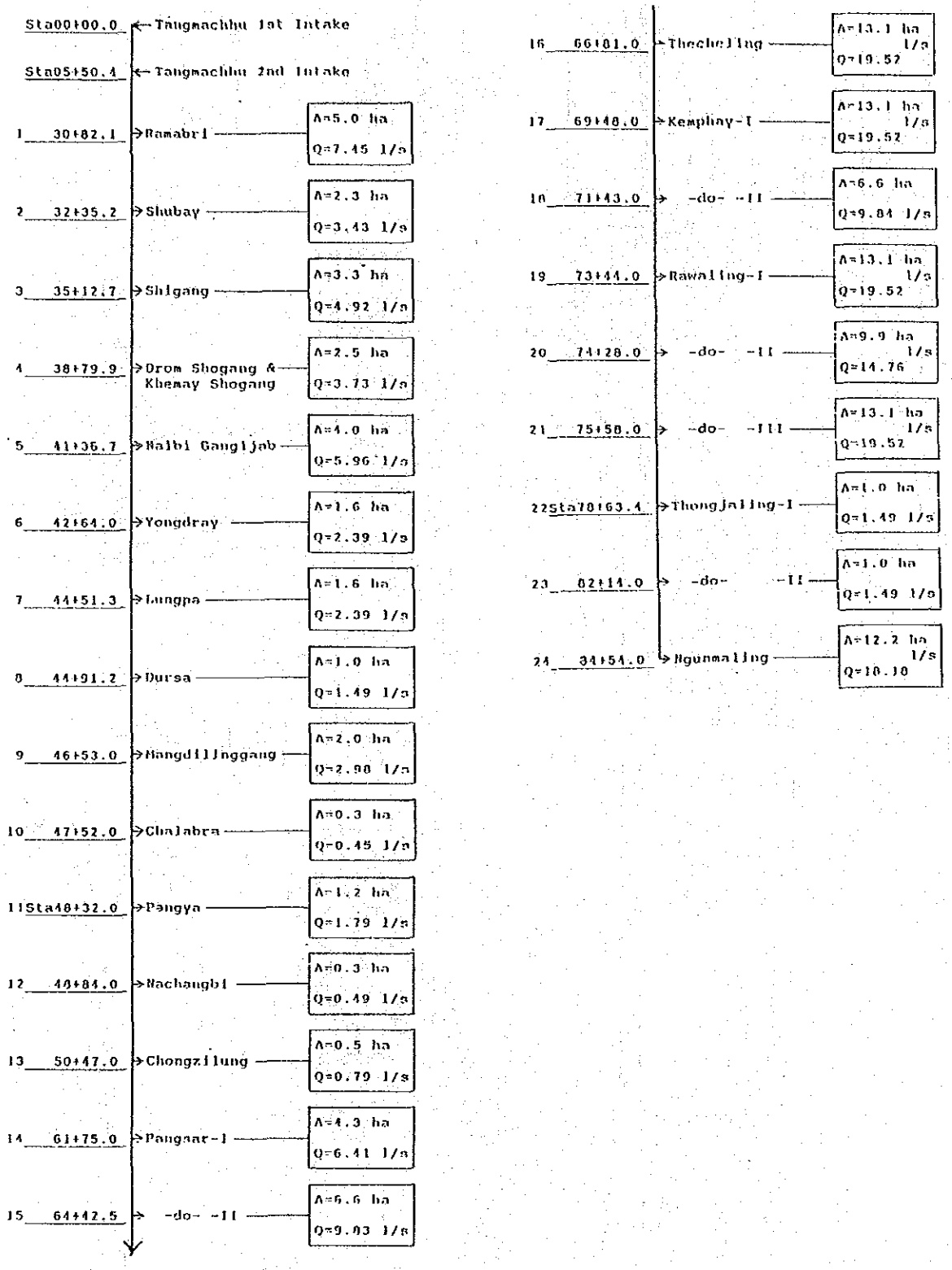
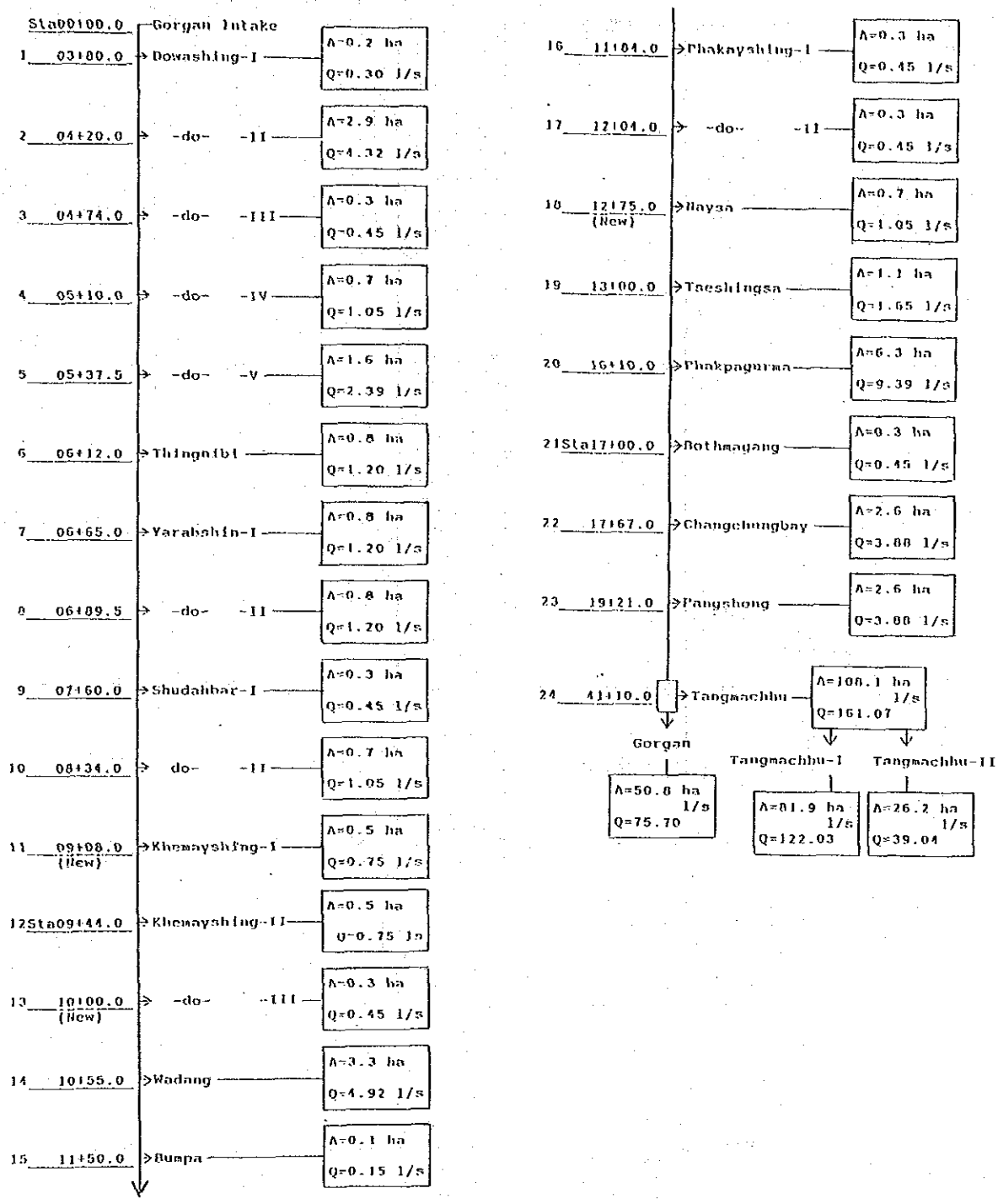


Fig.V.3.6 TYPICAL DRAWING OF TANGMACHHU INTAKE No.1



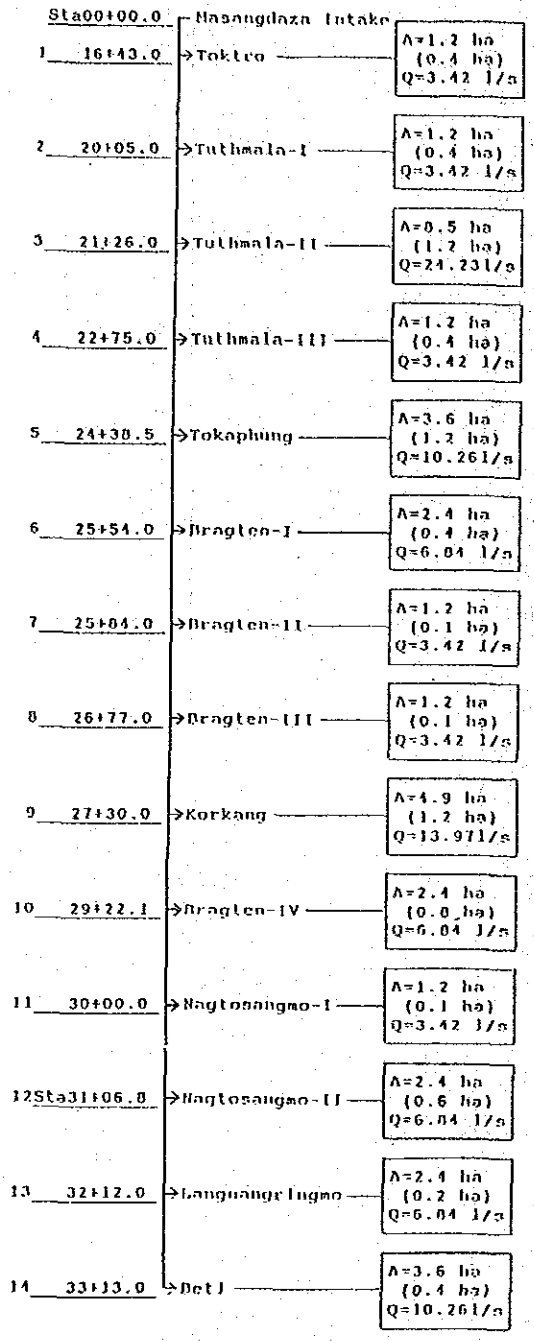
Note:Water Duty is given as an average value of 1.49 l/sec/ha for all turnouts.

FIG.V.3.7 IRRIGATION DIAGRAM (1/4)
(TANGMACHHU CANAL)



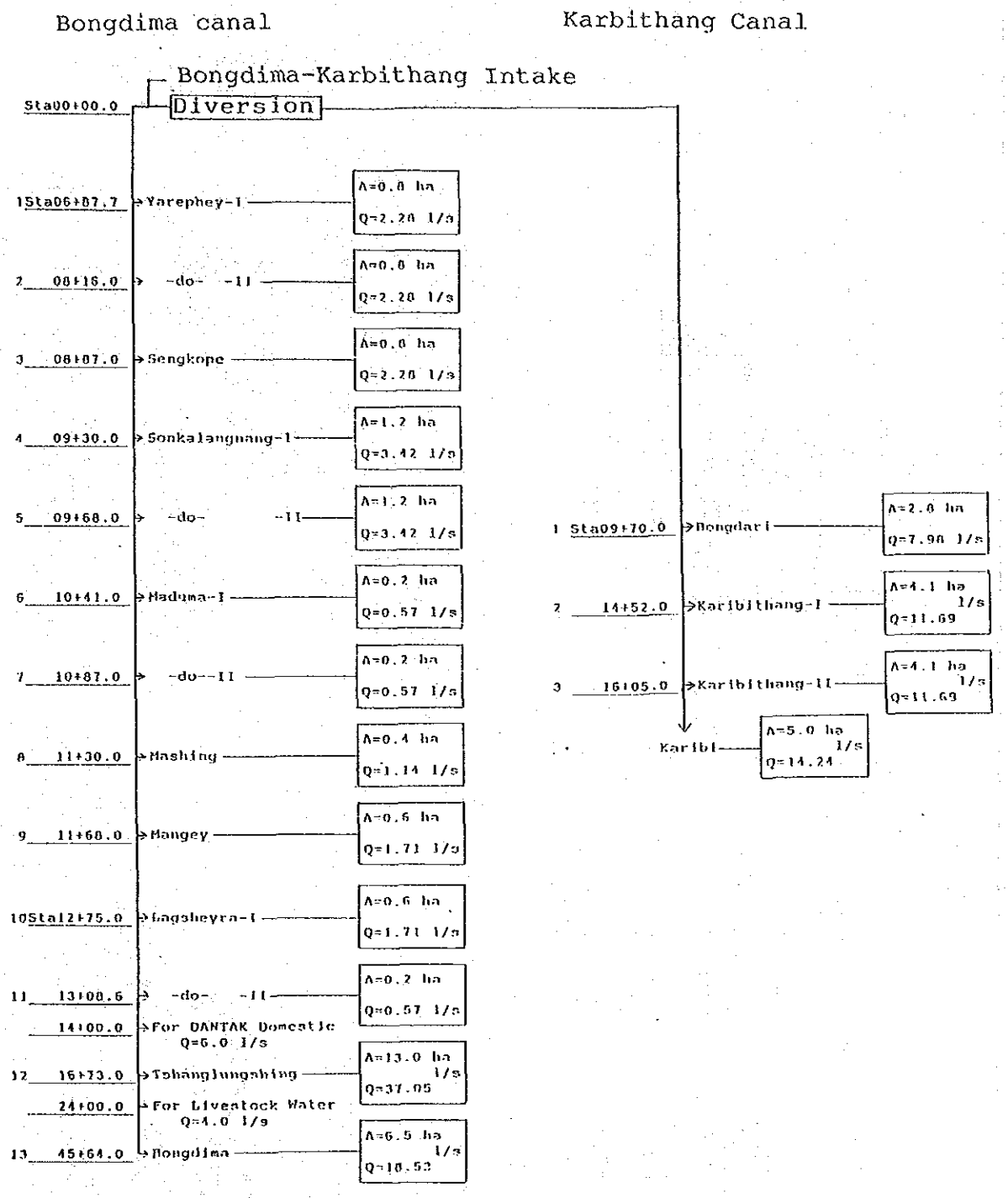
Note:Water Duty is given as an average of 1.49 l/sec/ha for all turnouts.

FIG.V.3.7 IRRIGATION DIAGRAM (2/4)
(GORGAN CANAL)



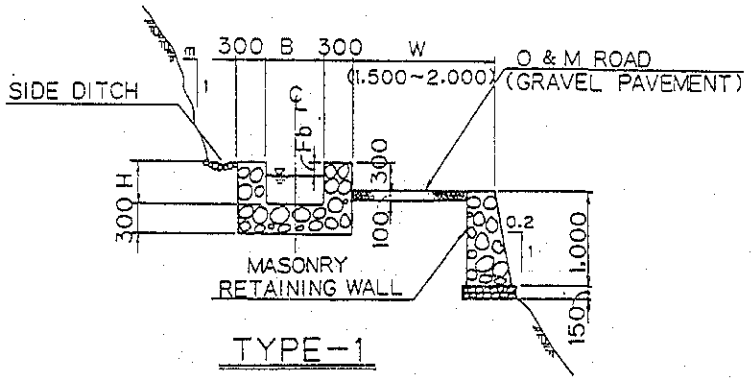
Note:(1)Water Duty is given as an average of 2.85 l/sec/ha for all turnouts.
(2)All <A> include future extension areas. Existing acreages are shown in each parentheais.

FIG.V.3.7 IRRIGATION DIAGRAM (3/4)
(MASANGDAZA CANAL)

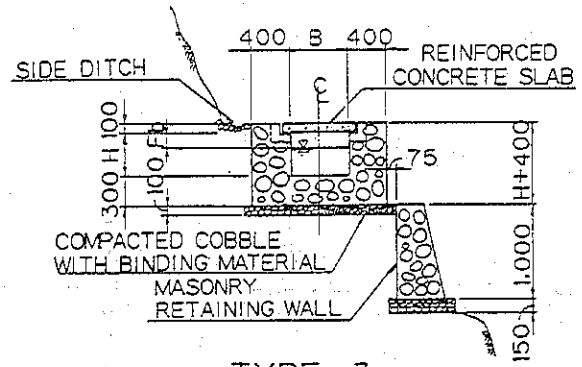


Note:(1)Water Duty is given as an average value of 2.85 l/sec/ha for all turnouts.
(2)Tshanglungshing Turnout involves 12.2 ha of private 2 systems.
(3)Bongdari Turnout involves 1.2 ha of a private system at Duptho.
(4)Karibi Turnout is for the future extension area.

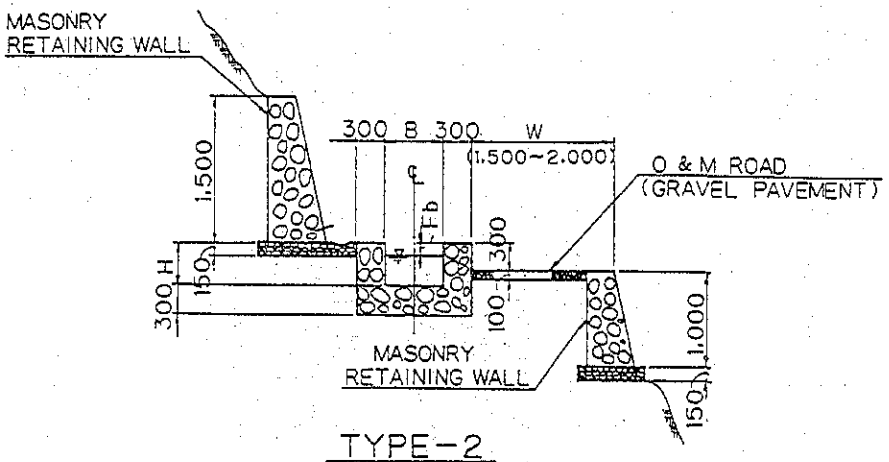
FIG.V.3.7 IRRIGATION DIAGRAM (4/4)
(BONGDIMA AND KARBITHANG CANAL)



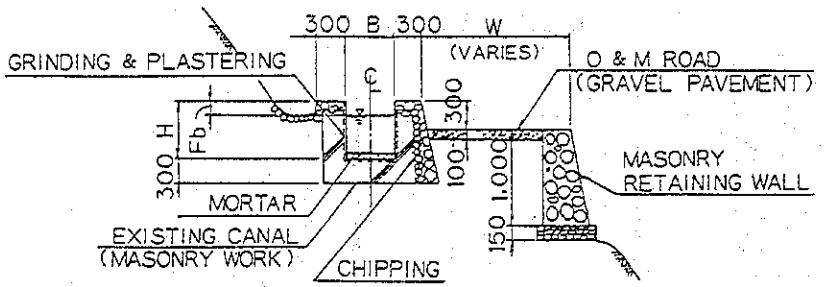
TYPE-1



TYPE-3



TYPE-2



TYPE-4

Fig.V.3.8 TYPICAL CROSS SECTION OF MAIN CANAL

ANNEX - VI

OTHER RURAL FACILITIES

LHUNTSHI AND MONGAR
INTEGRATED AGRICULTURAL DEVELOPMENT PROJECT

ANNEX-VI OTHER RURAL FACILITIES

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

1. GENERAL

This annex report is the supporting report on the rural facilities other than the irrigation facilities in the study area as well as the model project areas. This report describes the present condition and the development plans. The present condition includes the general status of the rural facilities in the study area and the model project areas. The development plans contains feeder roads, agro-industry, agricultural mechanization, workshop and extension center.

Together with the field survey, data collection and interview survey were conducted for the following government authorities:

1) Lhuntshi Districts
2) Mongar Districts
3) Department of Agriculture
4) Public Work Department
5) Ministry of Home Affairs
6) Department of Power

2. PRESENT CONDITION

2.1 Present Condition of the Study Area

2.1.1 Road

The east-west national road linking Thimphu and Tashigang goes through Mongar District. Lhuntshi District is solely connected to the district capital from Mongar along the Kuri-chu. Existing national road length and their origin and destination in both districts are as follows:

	Origin-Destination	Length (km)
I. Lhuntshi		
(i) Lhuntshi-Mongar Road	Lhuntshi-Rewangchu	47
II. Mongar		
(i) East-West Road	Thumsingla-Mongar	109
	Mongar-Gomchu	68
(ii) Lhuntshi-Mongar Road	Mongar-Rewangchu	20

The national road is all paved except in landsliding and/or sinking areas, of which the part of Chakaling block, especially Chali village, in Lhuntshi-Mongar road is sinking severely. Road conditions are normally good during the dry season, while road traffic during the rainy season in June to September is often stopped by collapses and/or landslide. These roads are linked with non-permanent prefabricated steel truss bridges which may have less than 18 t of loading capacity. All the roads are available to use medium size truck up to 10 t loading capacity due to the small curvature of the road alignment.

Road repair and maintenance, which are implemented by the Indian Border Roads Organization under the Indian Ministry of Transportation and the Bhutan Public Works Department, require continuous efforts and large funds.

Both the districts have one motorable feeder road each, to Tangmachhu with 7 km in Lhuntshi, and to Demchi with 18 km in Mongar. Other feeder roads are steep and narrow foot paths. Most of the villages are scattered on the mountain slopes, located at several hours' walk or horse riding from the national road. Foot paths are often destroyed during the rainy season and accessibility becomes worse. Social solidarity, agricultural extension activities, marketing of local products and the other rural development efforts suffer from such access constraints.

The following road developments in the study area are included in the Sixth Plan:

Program	Phase	Length (km)
I. Lhuntshi		
i) Tangmachu Feeder Road	Improvement	7
II. Mongar		
i) Mongar-Kuri chu Manas Confluence	New	40
(Gyelposhing-Nganglam through Pema Gatshel)		(60)
ii) Demchi Feeder Road	Improvement	18
iii) Chali Feeder Road*1	New	7
iv) Chaskhar Feeder Road*1	New	12

Note: *1; Included in Tashigang and Mongar Area Development Project founded by IFAD.

2.1.2 Electrification

Power supply in the study area largely depends on micro hydropower generation. Location and installed capacity of the power stations are summarized as follows:

Location	Installed Capacity (Kw)
I. Lhuntshi	
(i) Gangzoor, Gangzoor Block	20
II. Mongar	
(i) Khalanzi, Chakaling Block	390
(ii) Yadi, Ngatshang Block	30

Micro hydro power stations listed above supply only one out of 53 villages in Lhuntshi and 4 out of 115 villages in Mongar. Number of households supplied are 55 in Lhuntshi and 340 in Mongar which correspond to only one (1) and three (3) percents of the total households respectively. It is clear that electrification in the study area remains at these specific areas.

There are no programs on the construction of micro power stations under the Sixth Plan except the Kuri chu power station with 11.5 MW at Gyelposhing in Mongar, which is now under the feasibility study. However, electricity supply to the study area is not included in the Kuri-chu power project.

2.1.3 Rural Water Supply

A rural water supply project was begun in the mid-1970s with UNICEF assistance. Continuous supply of safety water is very effective for the improvement of rural health condition and the security of rural livelihood. Construction of water supply facilities is presently done by voluntary village labour under the technical supervision of the Dzongkhag (District) engineer. The government does not imposed water charges at present. The materials such as pipes and cement are supplied free of charge.

Present condition of rural water supply in the study area is summarized as follows:

Item	Lhuntshi	Mongar
I. No. of villages		
- With facility	36 (68%)	67 (56%)
- Without facility	17 (32%)	52 (44%)
Total	53 (100%)	119 (100%)
II. Population		
- Beneficiary	4,800 (11%)	13,300 (17%)
- Non-beneficiary	37,300 (89%)	63,900 (83%)
Total	42,100 (100%)	77,200 (100%)

Rural water supply beneficiaries in Lhuntshi and Mongar Districts are still less than 20% of the total population. Under the Sixth Plan, the construction and rehabilitation of water supply facilities are programed as follows:

Item	Lhuntshi	Mongar
I. Construction		
- No. of scheme	37	32
- Beneficiary	4,800	2,900
II. Rehabilitation		
- No. of scheme	15	23
- Beneficiary	2,600	3,400

If the present population growth of 2% per annum continues and the programs are completed, beneficiaries in the study area will increase to over 20% by the end of the year 1992 of the Sixth Plan.

2.1.4 Communications

The civil wireless network covers the whole country with 34 stations. The study area has 3 stations, Lhuntshi has one station at the district capital and Mongar has two stations at the district capital and Kurizampa. Messages are transmitted using transceivers by voice or by Morse code. This wireless network is the sole nationwide communication means at present. A nationwide telephone system by microwave linkage is still under planning and will be constructed in the near future.

Both of districts have one post office at each district capital. Of branch post office, which are operated by officials of other departments on a part-time basis, there are two in Lhuntshi and three in Mongar as shown in Fig. VI.2.1.

2.1.5 Education Facilities

The education system in Bhutan consists of 8 years of primary grades including 2 years of pre-primary education, 2 years of junior high school grade, 2 years of high school grade, 2 years of junior college, and 3 years to obtain a degree. Lhuntshi and Mongar Districts have four and six primary schools respectively which are managed under the district office. Junior high school which is under the Ministry of Social Services exists at each district capital, while there are no other schools in the study area.

Primary schools in the study area are not established at each block as shown in Fig. VI.2.1, hence some schools have hostels for the students from remote areas. The government provides free textbooks and supplies, as well as free food and board. Nevertheless, enrollment of primary education in the study area is at the low level of 27% as compared with the national average of 54% in 1986. The scattered settlements of villages, significant distances to school, and poor transportation facilities, together with the necessities for children's help on household and agricultural work, make school attendance difficult.

2.1.6 Medical Facilities

The most common diseases in the study area are (i) diarrhea (30% of total patients), (ii) helminthic infection (18%), (iii) acute respiratory infection (17%), (iv) skin diseases (15%), (v) eye infection (8%), and (vi) nutritional deficiency (3%). The medical facilities and their staffs in the study area have been improved under the assistance of UNICEF, a mission body and others. However, the medical care is not sufficient due to shortage of beds, drugs, equipment and instruments in addition to the shortage of trained medical personnel.

The location of medical facilities in the study area is show in Fig. VI.2.1 and their condition is summarized as follows:

Item	Lhuntshi	Mongar
I. Hospital		
- Number	1	1
(Location)	(Lhuntshi capital)	(Mongar capital)
- No. of Doctors	1	2
- No. of Nurses	4	24
- No. of Beds	16	50
II. Basic Health Unit		
- Number	5	6
- No. of Paramedical Personnel	9	18
III. Dispensary		
- Number	2	3
- No. of Paramedical Personnel	2	4

2.2 Present Condition of the Model Project Area

2.2.1 Road

(1) Tangmachhu Area

The existing feeder road passes through in the area from the lowest place to the Heli-port of altitude 1,850 m approximately. There is no bridge on this line, but many bridges having the restriction of the loading weight have been installed on the National Highway to reach the area. The maximum loading capacities are about 18 to 20 t. An average gradient of the feeder road is 1 to 15. More steep slope is existed at some places. It is very hard to use large vehicles because the small curvatures seem to be 10 to 15 m approximately.

This feeder road is terminated at the near Gorgan Canal end. There is no more road in the construction area except narrow foot paths for pedestrian and horse. O&M road along the canal having 30 to 50 cm of the width are possible to pass with a few exceptions at the upper most of both canals.

There is no any farm road in the area for the transportation of farming equipment and materials. Small foot paths which are using as distribution ditches together exist at some places. All transportation shall be carried out by manpower and/or horse. The existing feeder road is scheduled to be paved by the end of June, 1989 by PWD.

(2) Masangdaza Area

This area is to be access from the National Highway, Bumthang-Mongar line. No bridge exist on the crossing point of the Shongar chu, a tributary of the Kuri chu. There is a wooden bridge which is a traditional cantilever type at Duptho, but it is not possible to use for the transportation of heavy materials and equipment. Even the foot path network is not provided sufficiently in the area.

O&M roads having about 50 cm width are provided along the canal at the most parts of Masangdaza and the upper part of Bongdima. No passable O&M road exist along other canals.

2.2.2 Other Rural Facilities

(1) Electrification

Tangmachhu and Masangdaza project areas have no electric power supply at present.

The capital area in Lhuntshi District is solely supplied by the Ganzoor micro hydro station with the installed capacity of 20 kW. The power distribution from the Ganzoor to Tangmachhu is impossible due to the small capacity. If the Kuri-chu power station in Mongar District is installed in the future, this electric power can cover the Lhuntshi District. While, from short and medium term visions, a new micro hydro station is needed to be built in and around the Tangmachhu area.

The Kalangzi power station with the installed capacity of 390 kW in Mongar District has a surplus power of around 100 kW at present, and supplies to Lingmethang village which is located at the opposite side of Masangdaza after crossing the Shongar chu. Hence a power distribution from Lingmethang to the Masangdaza can be made.

(2) Rural Water Supply

Beneficiaries of rural water supply are estimated at 900 in Tangmachhu and 400 in Masangdaza which are about 37% and 80% of total population respectively.

Masangdaza project area has a sufficient water resources; two tributaries of the Shongar chu and other many streams are crossing the project area, therefore rural water supply is easy to be done. On the other hand, villages in Tangmachhu lie scattered between the elevation of 1,200 m and 2,000 m and there are no tributaries using for a year-round rural water resource. Rural water supply in Tangmachhu depends mainly on spring waters.

A rural water resource for "Development Service Center" in Takila, Tangmachhu mentioned in the section 2.2.11 of Annex IV is needed to get from the Began chu which is an irrigation water resources of the Tangmachhu project area.

(3) Other Facilities

In Tangmachhu area, a primary school and a basic health unit together with an agricultural extension center and a veterinary center are established. They will be renovated under the "Development Service Center Project" in Takila, Tangmachhu.

There are no primary school and other public facilities in Masangdaza area. While those public facilities are at Lingmethang next to the Masangdaza area.

Both project areas are located at the center of each block, therefore the public facilities are developed than the average.

3. OTHER RURAL FACILITIES DEVELOPMENT PLAN

3.1 Feeder Road Facilities

3.1.1 General

The National Road is situated near both project areas, but the proper feeder road networks has not been arranged yet. The inconvenience of the traffic and the ill communication systems are the biggest constraints for the rural development. The development of road networks is the great concern with the Government officials and inhabitants. So that the proper road networks are the essential problem for the rural development in order to transport necessary materials and equipment for the agriculture, or carry out agricultural products. It is also needed for the execution of the construction works.

The geographical and topographical conditions in the area are disadvantageous to the development of the road networks. It takes an enormous budget and the long construction period, and it is more remarkable for the new bridge construction. Accordingly following proposal is a minimum requirement on the feeder road development taking into consideration of the all aspects of the local conditions in the area.

The design criteria of the feeder road are based on the standard of DOA Bhutan. But some appurtenant structures are slightly revised in order to make more safety facilities against the flood or the land collapse.

3.1.2 Tangmachhu Area

At the moment there is a feeder road passing through the area from national road to the heli-port. About 5.4 km long new feeder road is planned to extend from the heli-port to Nebi village. This road is passed through the tail point of Gorgan canal and climbed up about 200 m high to the middle part of Tangmachhu canal taking the zigzag course on the ridge. The road reach to center of the village approximately.

The some temporary road may be necessary for the construction works from the end point of the feeder road to the 2 intake sites. This temporary road is estimated about 4.5 km long and it may remove after finishing the construction works.

This feeder road is available to use not only inhabitants of Tangmachhu and Nebi but back areas of Shungkhar and Tongling village also. The road has a potentiality to be connected to Minjibi village in future.

The location of the proposed feeder road is shown on Fig. VI.3.1. The typical cross-section and structure of the proposed feeder road are shown on Fig. VI.3.2.

3.1.3 Masangdaza Area

There is no motorable access road to the area from the national road across the Shongar chu. Since a bridge construction takes a considerable budget and construction times, a new feeder road was planned from the national road to the existing wooden foot bridge in the original idea, but it is not possible to transport equipment and heavy materials to the area across the river. Other temporary transporting facility may be necessary for the construction works.

After due consideration the Bailey type bridge is applied to across the river at the most closed point of the national road and the river. This type of bridge is easy to manufacture, transport and fabricate. The bridge is 60 m long with 2 spans of 30 m each. Substructures of 2 abutments and 1 pier having 8 m high are constructed with masonry.

The feeder road involves above bridge and 200 m access road from the national road and 2 km of new road along Shongar chu in the area. The temporary road for the construction may be considered to Masangdaza intake along the Songjari chu.

The location of the proposed feeder road is shown on Fig. VI.3.3. The typical crossection and the structure of the proposed feeder road are shown on Fig. VI.3.4.

3.1.4 Beneficiary of the Road

There are many small villages scattered in the bihind of areas. Up to date these villagers have no possibility to use motorable transportation method for agricultural inputs and outputs. The proposed feeder roads may contribute a great impact to the rural development. The beneficial populations with proposed feeder roads are given hereunder.

Beneficial Population

Village	Population	Household
Tangmachhu		
Project Area	2,427	253
Shungkhar	513	76
Menjibi	552	61
Total	3,492	390
Masangdaza		
Tidambi	393	79
Chanzabi	160	40
Rolambi	6	29
Brogsar	125	13
Manglang	48	5
Project Area (Excluded Bongdima)	420	86
Total	1,152	252

These feeder road have another important role on the construction schedule of the project. These roads would be available to use the transportation of construction equipment and materials for the projects. Without feeder roads the mechanized construction method can not be applied and construction materials will be obliged to carry by man powers or horses by extreme poor foot paths in a long distance. As a result, it will take as long as the double construction times or more. Therefore this project will not be finalized within the proper construction period without proposed feeder road.

3.2 Small Scale Agro-Industry

3.2.1 General

For introduction of the cash crops, the following small scall agro-processing facility will be established in the Tangmachu area;

(i) Building for processing plant — 1 building

(ii) Processing plant

- Chilli powder unit — 1 set
- Mustard oil unit — 1 set
- Multi-purpose dryer — 1 set

Multi-purpose dryer will be utilized to dry part of maize, soyabean, paddy and chilli, which are harvested in the rainy season, to prevent deterioration by moisture.

3.2.2 Capacity of the Facility

Capacity of the facility is basically estimated on the basis of the requirements in the Tangmachu model project area. Besides, farmers in the sorrounding areas will utilize this processing facility in considering the present condition of the surrounding areas. Accordingly, capacity of the facility will have some allowance over the requirments in the Tangmachu area.

(1) Chilli Powder Unit

After the completion of the model project, about 114 t of dry chilli will be harvested druing July to September. Out of chilli harvested, 108 t will be marketable, and a part of the marketable amount will be milled into powder to sell. Accordingly, the capacity of powder mill is estimated at 20 kg per hour including the requirements of the surrounding area.

(2) Mustard Oil Unit

After the completion of the model project, 67 t of mustard seeds will be harvested in the Tangmachu area. The peroid of harvesting mustard seeds will be from February to April for about 80 days, and 850 kg per day will be processed on average. Accordingly, the processing capacity of about 100 kg of seeds per hour is enough to expel oil.

(3) Multi-purpose Dryer

Part of maize, soyabean, chilli and paddy will be harvested during rainy season, and some of them might be spoiled because of high moisture content. Especially, soyabean and chilli are the main cash crops in the Tangmachu area, therefore, these should be increase the quality. The capacity of dryer is estimated at about 5 m^3 per day.

(4) Building

The building required for agro-processing facilities would be as follows:

a.	Floor space	- 90 m^2 (18 m x 5 m), concrete floor
b.	Maximum height	- 3.5 m
c.	Foundation	- cobble and concrete
d.	Structure	- masonry wall and slate roofing
e.	Design	- window frames and pillars designed according to the traditional style in Bhutan

f. No. of rooms
- 4 rooms (mustard oil unit, chilli powder unit and dryer, diesel engine generator, and office)
- Each room has a space for temporary storage of material and products.

Preliminary design and general layout of the facility are illustrated in Fig. VI.3.5. Outline of facilities are shown in Table VI.3.1.

3.2.3 Proposed Location

Based on the available land and convenient transpotation, two alternative locations of the above processing plants is proposed as follows;

(i) the proper Tangmachu in the middle of the model project area,

(ii) the area within the Development Service Center propsed by the Ministry of Home Affairs

3.2.4 Operation and Maintenace

While the Lhuntshi District office will basically have the responsibility for operation and maintenace of the processing facility, it is practical to operate the facility through organizing the association of farmers or on lease to the progressive farmers. It is recommended that DOA would prepare a manual for operation and maintenace of the processing facility.

3.3 Agricultural Mechanization

3.3.1 General

As mentioned in the labour balance study of the Annex IV, all the labour force is almost fully engaged at present, and no other labour force can be found in the model project areas. After the implementation of model projects, it is necessary to reduce the peak labour requirement for land preparation, transplanting and harvesting, to grow two crops in a year and to promote modernized farming in the irrigated land.

In addition to this, proposed farming practices are formulated by introducing improved tools and agricultural machinery to utilize the available labour force efficiently. Therefore, agricultural mechanization is essential to the model project areas. Based on the basic integrated agricultural development plan, the improved tools and machinery are selected as follows;

Improved tools	sickles, planting ropes, rotary weeders, improved steel ploughs and hollows for bullock draft power, hand sprayers, hand dusters, etc.
Machinery	pedal threashers, manual winnowers, manual rice husker, manual rice polishers, manual maize hullars, power tillers, etc.

3.3.2 Requirements of Tools and Machinery

(1) Improved Tools

Improved tools should be owned by individual farmers, because farmers use these tools every day and these tools are not so costly. However, farmers are not familiar to use improved tools, and it is necessary to demonstrate by the extension workers. In this regard, these tools will be introduced for demonstration purpose, and will be included in the equipments for demonstration as mentioned in section 3.5.

(2) Machinery

The number of machines required in the model project areas is basically estimated on the basis of their working capacity and requirements in the areas as shown in Table VI.3.2. The total numbers of machinery are estimated as followed;

Machinery item	Tangmachu	Masangdaza	Total
- Pedal threasher	40	22	62
- Manual winnower	40	22	62
- Manual paddy separator	9	4	13
- Manual rice husker	9	4	13
- Manual rice polisher	9	4	13
- Manual maize huller	8	4	12
- Power tiller (3-4 Hp)	14	8	22

3.3.3 Operation and Maintenace

The Agricultural Mechanization Center (AMC) will provide these machinery to farmers on lease, and AMC will have the responsibility of maintenace and repair. Practically, farmers who operate the machinery will repair the machinery. Therefore, it is recommended that DOA would prepare a lease manual of machinery.

3.4 Branch Office of AMC (Workshop)

3.4.1 General

The distribution of improved farm tools, agricultural powered machines and processing machines in the project area is quite low; there no rice mills in Masangdaza project area, and no oil mills and power tillers in the both project areas. This low extension is mainly due to lack of support services on agricultural mechanization in the area. There are no workshop for maintenance and repair of farm tools and machines.

The Agricultural Mechanization Center (AMC) at Paro under DOA is a executive body in Bhutan. Any branch offices under AMC proposed by the Master Plan on Agricultural Mechanization have not been constructed due to the budget constraints.

Agricultural mechanization is indispensable not only for the extension of labour saving farming practices but also for the increase in cropping intensity and cash crop production. Especially promotion of second cropping of cash crops after paddy is one of the essential development directions in the area. In addition to agricultural mechanization, strengthening of the present operation and maintenance activities for feeder road and irrigation facilities will be important for the continuation of the project benefits. Hence O&M equipments have to be prepared by the projects. The promotion of agricultural mechanization and strengthening of O&M activities will be achieved through the following activities by a workshop:

1) Transfer of technology on operation and maintenance of agricultural tools, machines, and O&M equipments.
2) Timely support services for repair.
3) Promotion of agricultural mechanization and strengthening O&M activities through the above two activities.

For an effective agricultural mechanization and strengthening O&M activities in the project areas, a mobile workshop which is a motor truck with tools and machines for repair would be recommended together with a stationary workshop.

3.4.2 Facility

The facilities required for the workshop would consist of two categories, i.e. a stationary workshop and a mobile workshop.

(1) Stationary Workshop

The stationary workshop is composed of a building and equipments. The building will have the spaces such as an office, a meeting room, a tools and material room, a cubicle room, repairing space, machine shed, garage for a mobile workshop. Equipments are repair tools and machines.

The building for the stationary workshop is as follows:

a.	Floor space	- 400 m^2, concrete floor
b.	Maximum height	- 6 m
c.	Foundation	- cobble and concrete
d.	Structure	- masonry wall and slate roofing
		- reinforced concrete (repairing and maintenance room)
		- masonry (other rooms)
e.	Design	- same as the agro-processing factory
f.	No. of rooms	- 7 rooms (office, meeting room, tools and materials room, spare parts room, cubicle room, repair and maintenance room and machine shed)

(2) Mobile Workshop

a. Truck equiped with container
b. Repair tools and machines

(3) Operation and Maintenance Equipment

a. Bulldozer, and backhoe
b. Truck, pickup and motor cycle
c. Pump
d. Spare parts, others

Preliminary design of the workshop building are shown in Fig. IV.3.6.

3.4.3 Proposed Location

Most suitable site of a workshop is within the Mongar District according to the Master Plan on Agricultural Mechanization. Possible locations are the Mongar District Capital, Lingmethang together with extension center and Kilikhar from about 4 km from the Capital towards Tashigang.

3.4.4 Operation and Maintenance

The workshop will be managed under the Agricultural Mechanization Program which is one of the Central Programs of DOA.

This workshop will be a branch office of the Agricultural Mechanization Center at Paro.

3.5 Improvement of Agricultural Extension Center

3.5.1 General

The enhancement of agricultural extension services are essential to implement the model projects successful. These services includes the technical guidance and training for farmers, demonstration and trials of improved farming, and farm input supply.

The facilities of the extension services are small and deteriorated at present. Besides, shortage of equipments for extension service is serious. In this regard, it is necessary to improve the extension center.

In the Tangmachu area, the Development Service Center (DSC) is planned to establish in 1988 by the Government of Bhutan. This DSC includes the agricultural extension center, therefore, the technical service and input supply service will be provided by the DSC in the Tangmachu area in the near future. Accordingly, the following extension facilities is necessary to improve:

(a) New building space of the extension center in Masangdaza in stead of the present facility,

(b) Establishment of plots and supply of equipments necessary for demonstration and trials in both model project areas.

3.5.2 Scale and Requirements

(1) Masangdaza Extension Center

New extension building will include office space, meeting room and storage. Storage should have the capacity to store farm inputs and equipments for supply and demonstration. Meeting room will accomodate the capacity of 20 persons. This capacity will cover about 20% of households in the Masangdaza model project area, also cover the number of the villages in the Salling Block. One room space will be enough for the office space for the extension worker.

The building for agricultural extension center would be as follows:

a. Floor space - 62 m^2, concrete floor
b. Maximum height - 3 m
c. Foundation - cobble and concrete
d. Structure - masonry wall and slate roofing

e. Design - same as the agro-processing factory

f. No. of rooms - 4 rooms (office, meeting room, store for machines and fertilizer, and store for agro-chemicals)

General layout of the extension center is shown on Fig. VI.3.7.

(2) Plots and Equipments for Demonstration and Trials

Demonstration and trial plots will be established in the both model project areas based on the natural and social conditions as follows:

Location	Irrigated Farming	Rainfed Farming
Tangmachu	3 plots	1 plot
Masangdaza	2 plots	1 plot

Equipments for demonstration and trials are listed in Table VI.3.3 and are summarized as follows:

Tools - improved steel plough and hurrow for bullock draft power, rotary weeder, and other improved hand tools,

Machinery - Pedal threasher, Manual winnower, Manual paddy separator, Manual rice husker, Manual rice polisher, Manual maize sheller, Power tiller (3-4 Hp).

3.5.3 Location

A new extension center has to be located at a convenient place not only for the Masangdaza medel project area and but also for the whole Salling Block. Considering the available land and transportation from the national road and the Masangdaza model project area, the altenative sites are identified as follows:

(a) the area within the Lingmethan Dantak Camp which will be transfered to PWD near future,

(b) the area within the Animal Husbandry Farm in Lingmethan,

3.5.4 Operation

The building of the extension center, demonstration and trial plots, and equipments for demonstration and trial will be maintained or operated by the extension worker under the District administration.

Table VI.3.1 GENERAL FEATURE OF AGRO-PROCESSING FACILITY

1.	Chilli Powder Unit		
	(1) Capacity	:	20 kg/hr. on dried chilli
	(2) Pre-processing	:	rough crashing before milling
	(2) Mill		
	a) type	:	milling by the impact force generated by high speed rotating rings
	b) power source	:	electricity by diesel generator
	(3) Sifter		
	a) function	:	separation by fine powder, rough powder and mixture of fine and rough powder
	b) component	:	layers of flat sieves with gyratory movements, inlet with supporting post, outlets, and motor
	c) power source	:	electricity by diesel generator
2.	Mustard Oil Unit		
	(1) Capacity	:	100 kg/hr. on mustard
	(2) Process	:	1) to roll material by roller 2) to heat up and dry material by cooker 3) to press material by oil expeller 4) to clean oil the filter
	(3) Component		roll, cooker, oil expeller, oil tank, oil pump, filter press, oil tank, base, electricity control panel, diesel generator set, flow back boiler, other necessities
3.	Multi-purpose Dryer		
	(1) Type	:	box type, batch system, fun operated
	(2) Flat space	:	2 m x 3 m approx.
	(3) Holding capacity	:	5 m^3
	(4) Fuel	:	kerocene burnt

Table VI.3.2 ESTIMATION OF REQUIREMENTS OF AGRICULTURAL MACHINERY (1/3)

(1) Capacity of Machinery

Machinery	Original Capacity	Efficiency	Estimated Capacity
1. Threaser and winnower/1			
	115 kg/hr.	80%	90 kg/hr.
Pedal threasher	: 1		
Manual winnower	: 1		
2. Husker, separator and rice polisher/2			
	240 kg/hr.	80%	190 kg/hr.
Manual husker	: 1		
Manual separator	: 1		
Manual rice polisher	: 5		
3. Manual maize sheller	100 kg/hr.	50%	50 kg/hr.
4. Power tiller (2.5 - 5.0 Hp)			
Rotary/ploughing	40 hrs./ha	80%	50 hrs./ha
Puddling	40 hrs./ha	80%	50 hrs./ha

/1 : Capacity is estimated on the basis on the smallest machinery.
/2 : Capacity is estimated on the basis on the smallest machinery. Required no. of rice polisher is estimated at 5 in one set, by which ammount of rice in one time can be polished during the intervals of husking.

(2) Required working volume

1. Threasher and winnower (paddy)

(Tangmachu area)

-Expected harvest amount of paddy	:	220 ha x 5.0 ton = 1,100 ton,
-Harvesying period	:	60 days x 85% = 51days
-Paddy to process in 1 day	:	1,100ton/51days = 21.6ton/day
-Working hour pre day	:	6 hrs/day
-Paddy to process in 1 hour	:	3.6 ton/hr.
-Required number od machine (pedal threasher and manual winnower)	:	40 sets

(Masangdaza area)

-Expected harvest amount	:	80 ha x 5.0 ton = 400 ton
-Harvesying period	:	40 days x 85% = 34 days
-Paddy to process in 1 day	:	400ton / 34days = 11.8ton/day
-Working hour pre day	:	6 hrs/day
-Paddy to process in 1 hour	:	1.97 ton/hr.
-Required number od machine (pedal threasher and manual winnower)	:	22 sets

Table VI.3.2 ESTIMATION OF REQUIREMENTS OF AGRICULTURAL MACHINERY (2/3)

2. Husker, separator and rice polisher (paddy)/3

(Tangmachu area)

-Paddy to process in 1 day	:	1,100ton/102days = 10.8ton/day
-Working hour pre day	:	6 hrs/day
-Paddy to process in 1 hour	:	1.8 ton/hr.
-Required number od machine (manual rice husker and manual separator)	:	9 sets

(Masangdaza area)

-Paddy to process in 1 day	:	400ton / 102days = 3.92ton/day
-Working hour pre day	:	6 hrs/day
-Paddy to process in 1 hour	:	0.65 ton/hr.
-Required number od machine (manual rice husker and manual separator)	:	4 sets

/3 : Basically husking will carried out 2 times a week, but polishing will be made 4 times a week.

3. Maize (shellar)

(Tangmachu area)

-Expected harvest amount of paddy	:	58 ha x 1.5 ton = 87 ton
-Harvesying period	:	60 days x 80% = 48 days
-Paddy to process in 1 day	:	87 ton / 48 days = 1.8 ton/day
-Working hour pre day	:	5 hrs./day
-Paddy to process in 1 hour	:	0.36 ton/hr.
-Required number od machine maize sheller	:	8

(Masangdaza area)

-Expected harvest amount	:	32 ha x 1.5 ton = 48 ton
-Harvesying period	:	70 days x 80% = 56 days
-Paddy to process in 1 day	:	48 ton / 56 days = 0.86ton/day
-Working hour pre day	:	5 hrs./day
-Paddy to process in 1 hour	:	0.17 ton/hr.
-Required number od machine maize sheller	:	4

Table VI.3.2 ESTIMATION OF REQUIREMENTS OF AGRICULTURAL MACHINERY (3/3)

4. Power tiller

(Tangmachu area)

-Expected area of paddy cultivated by power tiller	:	220 ha x 10 % = 22 ha
-Period for operation	:	60 days x 80% = 48 days
-Area to be cultivated in 1 day	:	22 ha / 48 day = 0.46 ha/day
-Working hour per day	:	5 hrs.
-Working efficiency in 1 day	:	0.1 ha / day / unit
-Time of operation	:	3 times (2 ploughing, 1 puddling)
-Required number od machine	:	14

(Masngdaza area)

-Expected area of paddy cultivated by power tiller	:	80 ha x 10 % = 8 ha
-Period for operation	:	40 days x 80% = 32 days
-Area to be cultivated in 1 day	:	8 ha / 48 day = 0.25 ha/day
-Working hour per day	:	5 hrs.
-Working efficiency in 1 day	:	0.1 ha / day / unit
-Time of operation	:	3 times (2 ploughing, 1 puddling)
-Required number of machine	:	8