GOVERNMENT OF MALAYSIA

FEASIBILITY STUDY
ON
THE TANJONG KARANG IRRIGATION DEVELOPMENT AND MANAGEMENT PROJECT

MAIN REPORT

JUNE 1987

JAPAN INTERNATIONAL COOPERATION AGENCY

GOVERNMENT OF MALAYSIA

FEASIBILITY STUDY
ON
THE TANJONG KARANG IRRIGATION DEVELOPMENT AND MANAGEMENT PROJECT

MAIN REPORT

JUNE 1987

JAPAN INTERNATIONAL COOPERATION AGENCY

LIST OF VOLUMES

MAIN TEXT

ANNEXES

Annex	A	Hydrology and Water Resources
Annex	B	Agriculture and Agro-economy
Annex	C	Water Demand and Water Balance
Annex	D	Characteristics of Flow in Concrete Conduit
Annex	E	Institutional Framework and Improvement Schemes in PBLS Area
Annex	F	Manual for Operation and Maintenance of Tanjong Karang Irrigaion Project

PREFACE

It is with great pleasure that I present this feasibility study report on the Tanjong Karang Irrigation Development and Management Project to the Government of Malaysia.

This report embodies the result of an in-depth survey in the Tanjong Karang Irrigation area. The survey was carried out from June 1986 to March 1987 by a Japanese survey team commissioned by the Japan International Cooperation Agency following the request of the Government of Malaysia to the Government of Japan.

The survey team, headed by Mr. Kunio Irie of the Nippon Koei Co. Ltd., had a series of close consultation on the project with the officials concerned of the Government of Malaysia, and conducted a wide scope of field survey for a period of 10 months starting from June, 1986. After the team returned to Japan, further studies were made and the present report has been prepared.

I hope that this report will be useful as a basic reference for development of the Project and contribute to the promotion of friendly relations between our two countries.

I wish to express my deep appreciation to the officials concerned of the Government of Malaysia for their close cooperation extended to the team.

June 1987

Keisuke Arita
President
Japan International
Cooperation Agency

June 1987

Mr. Keisuke Arita
President
Japan International
Cooperation Agency
Tokyo

Dear Sir,

LETTER OF TRANSMITTAL

We are pleased to submit to you the Final Report of Feasibility Study on the Tanjong Karang Irrigation Development and Management Project prepared for consideration by the Government of Malaysia in implementing irrigation development and management to overcome water-related problems prevailing in the project area.

This report consists of two separate volumes: Main Report summarises the results of the study and presents the conclusion and recommendations; Annexes provide more detailed informations and procedures as well as operation and maintenance manual.

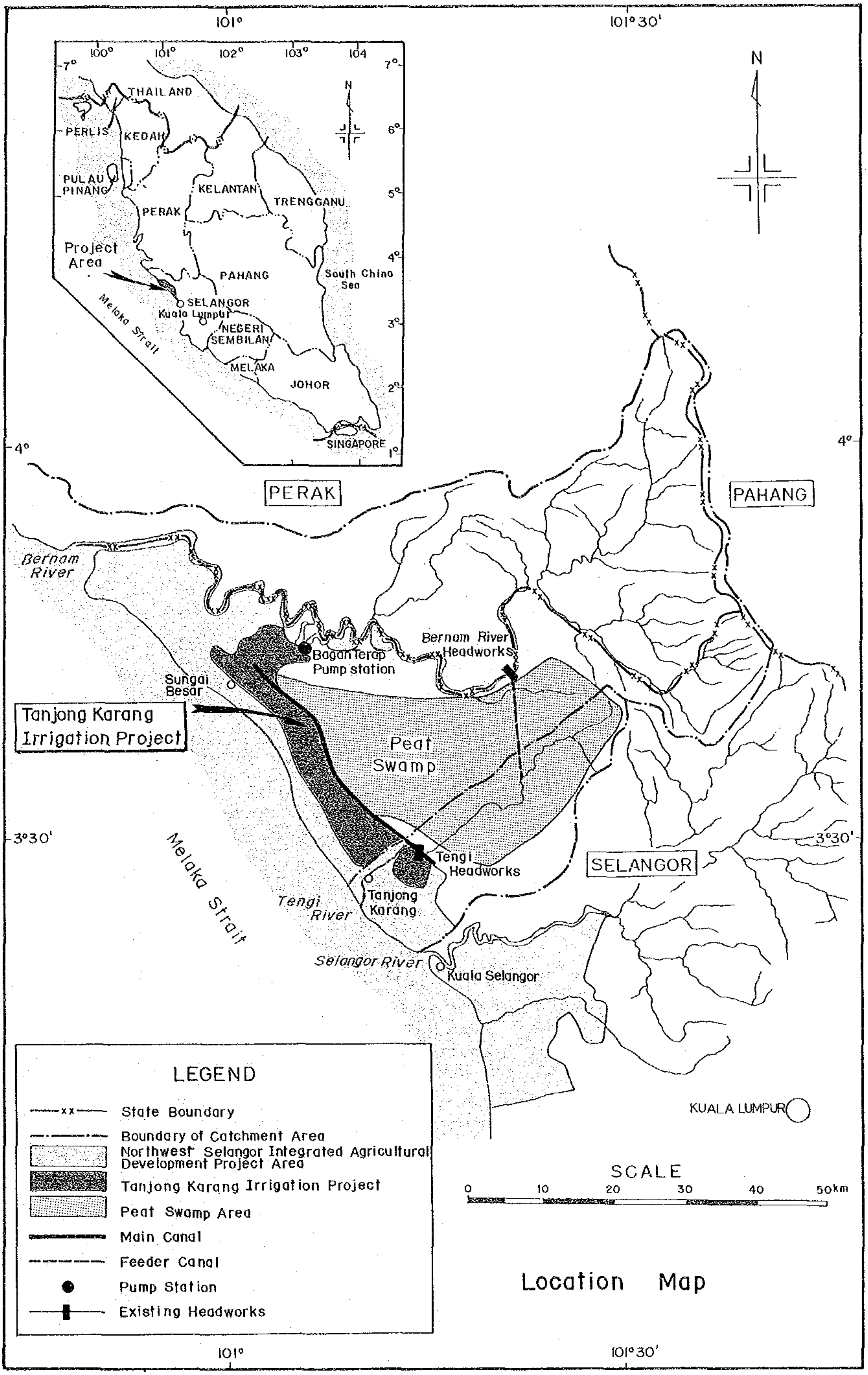
This study was carried out in line with the keynote agreed by both countries as below:

> "A solution to the water-related problems identified in the project area should, in the first instance, be found by looking for weakness in the management and operation of the project with the view of promoting low-cost solutions involving as much as possible institutional improvements. Investments on major infrastructural development additional to existing facilities shall only be explored as a last report."

All members of the Study Team wish to express grateful acknowledgement to the personnel of your Agency, Advisory Committee, Ministry of Foreign Affairs, Ministry of Agriculture, Forestry and Fisheries and Embassy to Malaysia as well as officials and individuals of Malaysia for their assistance extended to the Study Team. The Study Team sincerely hopes that the study results would contribute to the future irrigation development and management in granaries of Malaysia in particular and to her socio-economic development and well-being in general.

Yours sincerely,

Kunio Irie
Team Leader


101°
101°30'
100°
101°
102°
103°
104
7°
6°
5°
4°
3°
2°
1°
THAILAND
PERLIS
KEDAH
PULAU PINANG
KELANTAN
TRENGGANU
PERAK
Project Area
PAHANG
South China Sea
SELANGOR
Kuala Lumpur
Melaka Strait
NEGERI SEMBILAN
MELAKA
JOHOR
SINGAPORE
N
4°
PERAK
PAHANG
Bernam River
Bagan Terap Pump station
Bernam River Headworks
Sungai Besar
Tanjong Karang Irrigation Project
Peat Swamp
3°30'
Melaka Strait
Tengi Headworks
SELANGOR
Tanjong Karang
Tengi River
Selangor River
Kuala Selangor
LEGEND
State Boundary
Boundary of Catchment Area
Northwest Selangor Integrated Agricultural Development Project Area
Tanjong Karang Irrigation Project
Peat Swamp Area
Main Canal
Feeder Canal
Pump Station
Existing Headworks
KUALA LUMPUR
SCALE
0 10 20 30 40 50km
Location Map

FEASIBILITY STUDY ON THE TANJONG KARANG
IRRIGATION DEVELOPMENT AND MANAGEMENT PROJECT

SUMMARY

1. **This Feasibility Study** on the Tanjong Karang Irrigation Development and Management Project was undertaken by the Japan International Cooperation Agency with the guidance of a Technical Committee set up by the Government of Malaysia. The Study concentrated on identifying water-related problems in the project area and on developing low-cost solutions based as far as possible on institutional improvements. Investment on major infrastructural development additional to existing facilities has been regarded as a last resort.

2. ***The main constraints on the water source of the project*** are the recession of runoff of the Bernam river and the negligible contribution of the Tanjong Karang swamp. The runoff of the Bernam river has decreased in recent years. This is mainly due to a decrease in the basin rainfall which has become apparent since the middle of 1970s. The decrease in runoff closely matches that in basin rainfall. The average annual runoff has been 1,150 mm for the 10 years from 1974 to 1983 compared with 1,820 mm for the 13 years from 1961 to 1973, i.e. a decrease of about 37% in the recent 10 years.

The function of Tanjong Karang swamp was examined through various investigations and studies. In the dry season the groundwater table is more than 30 cm below the ground surface. Rainfall is retained in the peat soil layer and never reaches groundwater level. In the rainy season, however, the groundwater table reaches the soil surface at the time of heavy rainfall and surface runoff starts. If there is no rain, the groundwater level gradually decreases at a rate of about 11 mm per day on average, while the groundwater level rises 3 mm with a unit rainfall of 1 mm. The above figure of 11 mm means that the free surface water decreases by 3.7 mm per day. This would be more or less the value of evapotranspiration from a swamp forest. It is estimated, therefore, that seepage from the peat soil layer is very limited even in the rainy season, and that the swamp should be neglected as a water source for the project.

3. **Paddy production** in the project area is still low as compared with the target of the Northwest Selangor Integrated Agricultural Development Project (PBLS). Double cropping has been promoted under PBLS. However, the cropping intensity has never reached 2.0. Delay in cropping in one season greatly affects the cropping schedule in the next. About 80% of paddy cultivation area of 17,510 ha has missed one to two crop seasons for the last four years between 1983 and 1986. The present cropping intensity is 1.77 on average in the whole project area.

The unit yield of paddy in the past five years has been 2.9 ton/ha in the first (dry) season and 3.4 ton/ha in the second (rainy) season. The final target of PBLS is to increase paddy yield to 4.7 ton/ha in the off-season (dry season) and 4.4 ton/ha in the main season (rainy season). Such a low yield of paddy is derived from the existence of orgaic acid soils in upstream part of the project area where no intensive soil improvement has been carried out. Although soils in downstream part of the project area have high yield potential in rice cultivation, but the prevailing traditional transplanting method coupled with unstable irrigation water supply forms the main cause of low yield.

4. **Changes in farming practices** require a lot of improvements in present irrigation facilities. Recently, direct seeding methods have been spreading over the project area. Once these are introduced, the peak water requirement increases during the presaturation period. The capacity of present tertiary canals, however, is designed to meet the requirements of the transplanting method, and it is insufficient to meet the increased peak water requirement. The necessity for land leveling has also increased with the introduction of direct seeding method. Although the State DOA has emphasized land leveling work through its "Field Improvement Scheme", the number of farm lots to which its funds have been allocated is still limited.

5. **Structural defects of the main conveyance system** were found as follows:

a. The intake at Bernam River Headworks (BRH) is badly affected by rubbish which accumulates in front of the screens of the intake.

b. The revised design discharge of 30.6 cu.m/s (1,080 cusec) cannot be diverted without raising the height of the radial gates by 15 cm (0.5 ft).

c. The present flow capacity of the Main Canal is insufficient in all reaches of the Main Canal. It is estimated at 54% to 69% of the revised design discharge.

d. Significant leakage is found along the Main Canal. The total amount of leakage is estimated at 7.9 cu.m/s (280 cusec), which corresponds to 28% of the present design discharge.

e. The pumping capacity of the Bagan Terap pumphouse has decreased to 70% of its designed capacity.

f. The existing cross regulator constricts flow in the Main Canal.

g. The height of the existing banks in lower reaches of the Main Canal and the secondary canal c-c line is about 15 to 50 cm lower than the designed height. The full supply level (FSL) cannot maintained in these reaches.

6. **Structural defects of the distribution network** were discovered through trial operations and hydraulic simulation analyses, as follows:

a. Significant amounts of rubbish and aquatic weeds flow into the tertiary canals, because the screens have been removed and no operation decks have been provided at the offtakes.

b. The flow capacity of conduits is insufficient to cope with the peak water requirements during presaturation.

c. Water leaks from joints in the concrete conduits.

d. Field offtake pipes have not always been installed properly. This prevents even water distribution to each farm lot.

e. Cleaning of concrete conduits is difficult, because water remains in the conduits, even after the water supply is completely stopped. It is coupled with the following problems.

- Check gates cannot be lowered.
- Many checks have been damaged by farmers or removed by DID.
- Most of the slots have disappeared.

f. No drainage controls have been provided in old drains. This makes the control of water levels in the drainage canals difficult.

g. About a half of the farm lots have no direct access to existing farm roads. Farming machinery crosses and damages batas.

7. **Institutional problems** in the O&M organization in relation to water management may be enumerated as follows:

a. The number and grades of the assigned Engineers are insufficient in the PBLS area.

b. The Engineer in charge of planning and operation and maintenance of the irrigation system in the PBLS area has not been appointed. This results in inadequate coordination of water management of the project.

c. Engineers, Tanjong Karang and Sungai Besar, administer both irrigation and drainage areas of PBLS. As a result, the irrigation area is not properly supervised.

d. The enforcement of decisions on irrigation matters is delegated to the Chief Irrigation Inspector, who does not have powers of administration and financial control.

e Demarcation of responsibilities among the Chief Irrigation Inspector and Engineers is not clear.

f. The project area is divided into two groups of irrigation compartments with supposedly one Senior Irrigation Inspector and associated irrigation staff for each group. As one Senior

Irrigation Inspector has not been appointed, the Chief Irrigation Inspector has to administer four upstream compartments. In the circumstances he cannot give enough time to supervision of the whole irrigation area.

g. Operation and maintenance staff of the main conveyance system other than BRH are attached to the Irrigation Inspector in different compartments. There is no effective coordination of these staff.

h. Water management in tertiary canals is based on the experience of the respective Irrigaion Inspectors and again there is no coordination between them.

i Due to limitations of staff, maintenance of the project facilities is inadequate, especially in the tertiary canals.

8. Problems of the present water management of the main conveyance system *may be summarized as follows:*

a. A minimum of 6.2 cu.m/s (220 cusec) is always released through the BRH scour sluice even when severe drought occurs in the project area.

b. The intake gates at BRH are almost always open in order to divert as much river water as possible. The excessive intake aggravates silt intrusion and sedimentation in the Feeder Canal.

c. It is impractical to monitor the discharge in the main conveyance system, because the discharge in every section of the system is greatly influenced by changes in water level.

d. FSL cannot be maintained because water levels in the Main Canal fluctuates considerably in all sections of the Main Canal.

9. Problems of water management in the distribution network may be summarized as follows:

a. The supply of water to tertiary canals is scheduled for 12 hours a day during normal irrigation period. This is impractical and nobody can comply.

b. It takes a long time to adjust the discharge at an offtake and control of diversion is not properly carried out.

c. Most of check gates cannot be lowered due to siltation in the well chamber and distribution to upstream farm lots is about 40% larger than that to downstream farm lots.

d. If the check gates are removed, the distribution to upstream farm lots becomes about half of that to downstream lots.

e. The present flow capacity of tertiary canals is inadequate due to siltation and rubbish deposited on the bottom of the canal.

10. The agricultural development plan was formulated by setting the target of agricultural development for the project to achieve irrigated double cropping of paddy with the minimum inputs of manpower and production costs, and to get the maximum output.

Future land use is proposed. Changes in land use from paddy to tree crops is proposed in 450 ha covered with organic acid soils. Out of the total project area of 20,400 ha, the irrigation area is 18,980 ha, comprising 18,320 ha for paddy cropping and 660 ha for vegetable cultivation. The remaining 1,420 ha are used for non-irrigated tree crops, reserves and home yards.

Direct seeding methods are recommended in view of the advantages in saving labour and in curtailing production costs. The dry direct seeding method is proposed for off-season cropping and the wet direct seeding method for main season cropping.

The proposed cropping schedule of the project is recommended taking into account various hydro-meteorological and agronomic factors. These factors are the best use of the available water source, annual and seasonal patterns of rainfall, farming practices, the growing period of paddy, timing of harvesting and out-breaks of insects.

11. An irrigation schedule is proposed to match the proposed cropping schedule. The project area is divided into three Irrigation Schedule Areas (ISA). Each ISA is staggered 30 days. Presaturation supply for ISA-1 is commenced on 21st February for the off-season cropping and on 11th August for main season cropping. The supply of water is stopped 25 days before harvesting.

During the presaturation period, the intensity of the irrigation water requirement is higher for the direct seeding method. In order to fulfill the increased requirement without making any changes in the present concrete conduits, the introduction of rotational irrigation is proposed in the distribution network. The area commanded by a tertiary canal is divided by the existing cross bunds into three blocks. Water for presaturation would be supplied in rotation starting from the upstream block for about 10 days for each block. The presaturation for one tertiary canal can be completed within 30 days. For the normal irrigation period, irrigation water would be supplied continuously for 24 hours daily. Use of syphons is also recommended during the presaturation period.

12. The water demand for the project comprises the demand for irrigation use and the demand for domestic and industrial use. The irrigation water demand is estimated for both paddy and vegetables, based on the cropping schedule, net irrigation water requirement and irrigation efficiencies. The irrigation efficiency in tertiary canals is assumed at 75% for paddy and 52% for vegetables. The irrigation efficiency in the main conveyance system is estimated at 90% taking into account conveyance and operation efficiencies under the proposed water management. The water demand for domestic and industrial use is estimated at 27,300 cu.m/day (6 mgd) forecasting future water requirements. The peak water demand is estimated at 30.6 cu.m/s, which should be diverted to the project area at BRH.

13. A water balance study was made based on the proposed land use, cropping schedule and water management plans. Among many factors, the amount of water released through the scour sluice at BRH has a great influence on the results of the study. Three alternative cases were considered and a water balance study was made for each case. The study put stress on the water balance during dry periods and, therefore, discharges from the swamp were neglected. Since the runoff of the Bernam river and rainfall in the project area have decreased in recent years, the study was based on the conditioins of the 10 year from 1975 to 1984. The required dependability of irrigation water supply was set at 80%.

14. **Alteration to the present irrigation system** is proposed as a result of the water balance study. The most realistic and economical plan for water use is that all the irrigable area in eight irrigation compartments should be served by BRH. The Bagan Terap pumphouse will not normally be used. It is operated only in case of water shortage. With this change in irrigation network, the water released through the scour sluice may be reduced to 1.5 cu.m/s (53 cusec) and the area of 1,520 ha presently served by the Bagan Terap pumphouse will be commanded by the Main Canal.

15. **An improvement plan for the project facilities** was formulated. In order to overcome the present structural defects in the project facilities and to cope with the proposed use of water, the following improvements are recommended.

(1) Bernam River Headworks

a. Increase in height of the radial gates
b. Provision of electrically driven hoists to the intake
c. Replacement of screens, and provision of support for a chain block and an operation deck in front of the screens

(2) Main Canal

a. Enlargement of canal sections
b. Construction of an additional cross regulator
c. Improvement of existing cross regulator
d. Stopping leakage of water

(3) Secondary canal

a. Construction of the d-d line
b. Banking of the c-c line

(4) Tertiary canals

a. Construction of concrete conduits in the Sawa Sempadan and Sungai Nipah irrigation compartments and the Panchang Bedena extension area
b. Provision of screens at offtake structures
c. Improvement of check gates and slots
d. Change in location of offtake pipes

(5) Drainage facilities

a. Construction of drainage controls
b. Construction of bridges

(6) Construction of farm roads

(7) Installation of a radio communication network

16. **Water management proposals** were formulated with the basic concepts of; (1) necessity for keeping to a fixed irrigation schedule, (2) importance of maintenance, (3) effective use of the Bernam river water, (4) measures to be taken during water shortage, and (5) monitoring for proper water management. The present operation manual was totally reviewed, and the revised operation and maintenance manual was prepared.

Automatic gates, to keep upstream water levels constant, are proposed at cross regulators No. 1 and No. 2. The upstream water level at these two cross regulators would be maintained at FSL automatically. Operation of BRH would also aim to maintain the water level in the c-c line of Panchang Bedena at FSL. The scour gate at BRH will remain as now normally fully opened, but when water shortages occur the gate will be closed to reduce the release of water to 1.5 cu.m/s (53 cusec).

In the distribution network, it is necessary to introduce rotational irrigation in the tertiary canals, and the use of syphons during the presaturation period is imperative. For the normal irrigation supply, check gates and slots are needed to be adjusted to predetermined positions and water to be supplied continuously for 24 hours a day. The water level must then be maintained at the normal supply level (NSL) in the tertiary canals to achieve even and equitable distribution of water.

17. **Improvement of the O&M organization** is proposed to overcome problems in the institutional set-up and in the distribution of functions among the existing staff. Recommendations include the appointment of an Engineer in charge of irrigation; filling of the vacant post of Senior Irrigation Inspector, Tanjong Karang; creation of the Main Conveyance System Operation and Maintenance Unit (MOMU) with one Engineer as a head; and addition of Irrigation Inspector either to Sungai Burong or to Panchang Bedena. The number of Engineers should be 12 in the PBLS area, including those in charge of drainage areas. Establishment of MOMU in particular would have a significant effect in improving water management. It will be responsible for monitoring and regulating water levels as well as for operation and maintenance of related facilities. The newly assigned Engineers, jointly with the Chief Irrigation Inspector, will provide more timely coordination to the irrigation staff throughout the project area.

18. **The proposed monitoring system** will cover operation both of the monitoring of the main conveyance system and of the distribution network. Monitoring of the main conveyance system will be carried out by MOMU, and of the distribution system by the Irrigation Inspector of each irrigation compartment.

In order to facilitate prompt action to rectify water problems and to promote proper on-farm water management practices, it is important to monitor the day-to-day water situation throughout distribution network. The water level in the tertiary canals will be monitored and recorded for each tertiary canal by the Irrigation Inspector of each compartment. For the proper water management of the project, it is of utmost importance to keep to a fixed irrigation schedule. Thus, farming activities which affect water management will also be monitored to pinpoint water-related problems in the project area. Weekly monitoring of farming activities will be done for each farm lot.

19. Trials of water management in tertiary canals should be conducted by the existing Water Management Extension Pilot Project team, in order to identify effective practices for sufficient and equitable supply of irrigation water into farm lots. The targets for investigation are as follows:

a. Clarification of constraints to water management
b. Clarification of structural defects in the system
c. Identification of urgent improvement work
d. Identification of operation and maintenance of the system during the presaturation and normal irrigation periods
e. Finding effective ways of extending the practices throughout the project area

The investigation results should be spreaded over the whole project area, through the Engineers to be newly appointed. Structural defects will have to be corrected by the Federal DID staff allocated to PBLS at the request of the Senior Engineer, Kuala Selangor. Farmers will be encouraged to participate in clearing work in the tertiary canals.

20. Proper implementation of the project is of the utmost importance in realizing the proposed water management. Major items for implementation of the project should be completed within three years from 1987, namely:

a. Improvement of facilities,
b. Procurement of equipment for O&M,
c. Institutional improvement,
d. Establishment of monitoring system,
e. Water management pilot project,
f. Extension of water management,
g. Training programme, and
h. Follow-up programme.

21. Total investment costs will amount to M$27 million composing M$25 million for improvement of facilities and M$2 million for procurement of O&M equipment. **Annual O&M costs** for the project, based on the O&M budget of PBLS in 1987, are estimated at M$2.5 million excluding salaries for DID staff.

22. **Project benefits** will be derived from the increase in unit yield of paddy and cropping intensity. The targeted yield of PBLS will be attained. The present low yield of paddy, 6.3 ton/ha a year will be raised to 9.1 ton/ha a year. The present cropping intensity of 1.77 will be raised to 2.0 with consistent double cropping of paddy by keeping to the fixed irrigation schedule. As a result, the annual production of paddy in the project area will increase from 99,600 to 167,000 tons. *Stabilizing and sustaining* rice production in the project area contribute to intensification of national granaries.

CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABBREVIATIONS

Plans

5MP	:	Fifth Malaysia Plan, 1986-1990

Irrigation Compartment

BT	:	Bagan Terap
PB	:	Panchang Bedena
PP	:	Pasir Panjang
SB	:	Sungai Burong
SK	:	Sekinchan
SL	:	Sungai Leman
SN	:	Sungai Nipah
SS	:	Sawah Sempadan

Organizations

AICPLC	:	Area Inter-agency Coordination, Planning and Liaison Committee
BPM	:	Agricultural Bank of Malaysia (Bank Pertanian Malaysia)
DICPLC	:	District Inter-agency Coordination, Planning and Liaison Committee
DID	:	Drainage and Irrigation Department
DOA	:	Department of Agriculture
EPU	:	Economic Planning Unit
FAMA	:	Federal Agricultural Marketing Authority
FDC	:	Farmers Development Center
FDSc	:	Farmers Development Sub-center
FO	:	Farmer's Organization
FOA	:	Farmer's Organization Authority
JICA	:	Japan International Cooperation Agency
JKR	:	Jabatan Kerja Raja
JPT	:	Jabatan Parit dan Tali Air (DID)
KADA	:	Kembu Agricultural Development Authority
LPN	:	National Paddy and Rice Board

MARDI	:	Malaysian Agricultural Research and Development Institute
MOA	:	Ministry of Agriculture
MADA	:	Muda Agricultural Development Authority
PBLS	:	Northwest Selangor Integrated Agricultural Development Project
PMP	:	Farm Mechanization Center, FOA
MOMU	:	Main Conveyance System Operation and Maintenance Unit
NWMTC	:	National Water Management Training Centre, DID

CONVERSION FACTORS

	Metric to Imperial	Imperial to Metric
Length	1 cm = 0.394 inch 1 m = 3.28 feet 1 km = 0.621 mile	1 inch = 2.54 cm 1 feet = 30.48 cm 1 mile = 1.609 km
Area	1 sq.m = 10.76 sq.ft 1 ha = 2.471 acres 1 sq.km = 0.386 sq.mile	1 sq.ft = 0.0929 sq.m 1 acre = 0.4047 ha 1 sq.mile = 2.59 sq.km
Volume	1 lit = 0.22 gal (imp) 1 cu.m = 35.3 cu.ft 1 mil cu.m = 811 acre-ft	1 cu.ft = 28.32 lit 1 gal (imp) = 4.55 lit 1 acre-ft = 1,233.5 cu.m
Weight	1 kg = 2.20 lb 1 ton = 0.984 long ton	1 lb = 0.4536 kg 1 long ton = 1.016 ton
Derived Measures	1 cu.m/s = 35.3 cusec 1 ton/ha = 891 lb/acre 1 cu.m/s = 19.0 mgd	1 cusec = 0.0283 cu.m/s 1 lb/acre = 1.12 kg/ha 1 mgd = 0.0526 cu.m/s
Temperature	°C = (°F - 32) x 5/9	°F = 1.8 x °C + 32
Local Measures	1 lit = 0.22 gantang 1 kg = 1.65 kati 1 ton = 16.5 pikul	1 gantang = 4.55 lit 1 kati = 0.606 kg 1 pikul = 60.6 kg

1. INTRODUCTION

1.1 Objectives of the Study

The objectives of the Feasibility Study on the Tanjong Karang Irrigation Development and Management Project (the Study) are to identify water-related problems faced in the Tanjong Karang Irrigation Scheme, and to recommend solutions to these problems in order to stabilize and sustain rice production in the project area as a national "granary".

1.2 Scope of the Study

In response to the request of the Government of Malaysia, the Government of Japan sent the preliminary survey team for the Study through the Japan International Cooperation Agency (JICA) in March 1986. The Scope of Work for the Study was agreed between the Economic Planning Unit (EPU) of the Prime Minister's Department and JICA, and minutes of meeting were prepared and signed on March 14, 1986. The Scope of Work for the Study is attached in APPENDIX A of this report. The Study was carried out in line with the keynote agreed by both sides as mentioned below.

> "A solution to the water-related problems identified in the project area should, in the first instance, be found by looking for weakness in the management and operation of the project with the view of promoting low-cost solutions involving as much as possible institutional improvements. Investments on major infrastructural development additional to existing facilities shall only be explored as a last resort."

1.3 Performance of the Study

In May 1986, JICA dispatched a study team headed by Mr. Kunio Irie, to carry out the Study. Counterpart officials were appointed by the Government of Malaysia to participate in the Study, led by the chief counterpart, Mr. Tan Jiak Kim, Senior Engineer, Drainage and Irrigation

Department (DID), Kuala Selangor. The Study was guided by the Technical committee chaired by Mr. Cheong Chup Lim, Deputy Director General, DID. An Advisory Committee was established by JICA to advise the Study Team. These committees have maintained close liaison by meeting to exchange views and opinions on the Study. Members who have directly involved and concerned to the Study are as listed in APPENDIX B.

The Study was carried out in two phases: Phase I Study from June to October 1986 and Phase II Study from November 1986 to March 1987. At the beginning of Phase I Study, the Inception Report was submitted by the Study Team. The Steering Committee met at EPU followed by official discussions on the Inception Report at DID. The direction and schedule of the Study were agreed by both sides. During the field work of Phase I Study, water-related problems were revealed and clarified. After three months of field work, the Progress Report was prepared by summarizing the results of survey and investigations. Home work was then done in Japan for two months. The Pre-feasibility Study Report was submitted at the end of October 1986, which marked the completion of the Phase I Study.

A meeting was held on November 4, 1986 at DID Headquarters among the representatives of the Malaysian Government, the Advisory Committee and the Study Team, to discuss the Pre-feasibility Study Report and to confirm the direction of Phase II Study. Field work of Phase II Study was carried out over two and a half months to supplement data and to confirm findings and solutions to the water-related problems. At the end of the field work in Phase II, the Interim Report was submitted, summarizing all the results of field work, basic concepts of agricultural development and institutional arrangements, and proposed solutions to the water-related problems. Further studies have been continued in Japan from January to March 1987. All the conclusion and recommendation drawn from the Phase II Study were compiled in the Draft Final Report.

After sending the Draft Final Report for preliminary review by the Malaysian Government, JICA dispatched the Advisory Committee and the Study Team in the middle of March to discuss this report. At meetings held on March 18 and 19, 1987 at DID and EPU, respectively, discussion was made focusing on the proposed plan for the solution of water-related problems and the improvement of project facilities with its implementation schedule. Several comments were recorded in the minutes of the meeting and further comment on institutional aspects was submitted in a written form in April. The Study Team finalized the Draft Final Report in due consideration of these comments.

The Final Report (the Report) here submitted presents all the results of Phase I and Phase II Studies. The Report comprises two volumes: Volume 1; Main Report, and Volume 2; Annexes including Operation and Maintenance Manual.

1.4 Acknowledgement

In undertaking the Study, the Study Team has attached great importance to the incorporation of the views of departments and agencies of the Government of Malaysia relating to the various aspects covered by the Study. The contribution to the Study by the officials of both the Federal and State Governments and other individuals who have provided information and data, participated in discussions, given valuable advices and provided other forms of assistance to the Study are greatly acknowledged. A heartful gratitude is made to the officials of the Ministry of Foreign Affairs, Ministry of Agriculture, Forestry and Fishery, and Embassy to Malaysia of the Government of Japan, the JICA Malaysia Office and Japanese Colombo Plan Experts who have given advices, directly participated in the Study and provided various supports in performing the Study. In reality, the Study can be regarded as a joint effort by the Malaysian and Japanese officials and individuals concerned and the Study Team. The Study Team sincerely hopes that this joint effort would contribute to the future improvement of the Project and to raise living standard of farmers in the project area.

2. BACKGROUND

2.1 Agricultural Policy in Malaysia

In 1984, the National Agricultural Policy (NAP) announced guidelines for agricultural development towards 2000. The objective of NAP is to maximize income from agriculture through efficient utilization of the country's resources and revitalization of the sector's contribution to overall economic development of the country. In NAP, the target of self-sufficiency in rice, the staple food in Malaysia, is set at a level of 80 to 85% in due consideration of the high cost of rice production and the need for the national food security. In order to achieve and sustain the above self-sufficiency level, rice production is being intensified through the provision and improvement of drainage and irrigation facilities, use of high-yielding varieties, and adoption of modern farming practices.

In the Fifth Malaysia Plan (5MP, 1986-90), the Government has made special efforts to rationalize investment and the extent of its involvement in paddy production. In order to realize economical and effective paddy production, efforts will be concentrated in the existing eight granary areas of Muda, Kembu, Besut, Northwest Selangor, Krian-Sungai Manik, Trans-Perak, Kemasin-Semarak and Seberang Prai. The self-sufficiency of rice will mainly depend on output from the granary areas which cover about 218,000 ha in total. The present production of these granary areas is equivalent to 55 to 60% of domestic requirements.

Irrigation development will be focused on intensification and better use of irrigation facilities in the eight granary areas. DID has a pressing need to strengthen its staff quantitatively and qualitatively for proper water management.

2.2 History of the Project

The project area was developed from virgin jungle by DID through a series of programmes beginning in 1936. Water was first provided for a single wet-season paddy crop by a weir on the Tengi river via a 40-km main canal along the border of the project area. In order to augment the water supply for double-cropping, a diversion barrage was constructed in 1957 on the Bernam river, and a 15-km feeder canal was excavated through the peat swamp area to transport water to the Tengi river. A pumphouse was constructed in 1962 on the lower reaches of the Bernam river at Bagan Terap to provide a more assured water supply for the northern portion of the area. The diversion barrage on the Bernam river was reconstructed to the present Bernam River Headworks (BRH) in 1964.

The irrigation facilities still suffered from several deficiencies. The capacity of some reaches of the main canal was inadequate. Command head of distributary canals was inadequate, causing slow inundation of fields and late transplanting. Problems were exacerbated by the fact that water had to travel one-half mile across farm lots with low density of distributaries. Depressions were filled with water to undesirable depths and substantial amounts of both water and fertilizers were wasted. These inadequacies led to a situation where large areas of paddy were continually out of phase.

The situation could not be solved by piecemeal engineering work depending on routine allocation of budgets for operation and maintenance. Aiming at consistent annual double cropping of paddy, the Government decided to implement the North-west Selangor Integrated Agricultural Development Project (PBLS), with a financial aid from the World Bank. PBLS was carried out from 1978 to 1985. With its completion, the distribution network has been upgraded and intensified, giving each farmer direct access to canals and drains. To sustain the annual double cropping, the fixed irrigation schedule has been proposed.

2.3 Necessity of the Project

Even after the completion of PBLS, water is not evenly distributed in the project area. Water is frequently short. Delay in cropping from the schedule is chronic. As a result, the targeted yield of PBLS has not been attained. Furthermore, the production of rice is in decreasing trend. It has become necessary to identify water-related problems in the project area and to develop suitable solutions to these problems. Thus, both the Governments of Malaysia and Japan have agreed to conduct the feasibility study on the Tanjong Karang Irrigation Development and Management Project (the Project).

3. PRESENT CONDITIONS IN THE PROJECT AREA

3.1 Physical Conditions

3.1.1 Location and topography

The project area is located on a flat coastal plain in the northwestern corner of the State of Selangor. The area covers about 20,000 ha extending over a length of 40 km along the coast with a width of 5 km on average. The main irrigation and drainage canals run parallel with the coast. The gradient of ground surface is as gentle as 1 to 2,000 to 1 to 6,000 descending toward the coast. The Bernam river, the water source for the project area, meanders northwestward and forms the boundary between the States of Selangor and Perak. The project area is divided into eight irrigation compartments for project management purpose comprising two of them, Sawah Sempadan and Sungai Burong, in the District of Kuala Selangor and the remaining six, Sekinchan, Sungai Leman, Pasir Panjang, Sungai Nipah, Panchang Bedena and Bagan Terap, in the District of Sabak Bernam as shown in Fig. 1.

The Tanjong Karang peat swamp (the Swamp) lies adjacent to the Main Canal and extends eastward. The Bernam river forms the northern boundary of the Swamp. The Tengi river flows southwestward through the Swamp. The Swamp is mostly covered with primary forest. The topography in the Swamp is very gentle with minor undulation and the ground elevation gradually rises eastward with the average land slope of about 1 to 2,000. The total area of the Swamp is 720 sq.km, of which 250 sq.km are the catchment of the Main Canal, 230 sq.km of the Feeder Canal and the Tengi river, and the remaining 240 sq.km of the the Bernam river, respectively.

3.1.2 Climate

(1) Rainfall

The project area has a humid tropical climate characterized by two rainy seasons annually. The annual rainfall averages 1,800 mm in the project area. It gradually increases toward the mountainous area in the east and reaches about 3,000 mm in the most upstream basin of the Bernam river. The annual distribution of rainfall is influenced by two monsoons, the northeast monsoon prevailing October to March and the southwest monsoon May to September. The wet months are October to November and April to May. The dry months are February to March and June to July. Monthly distribution of rainfall is shown in Fig. 2. Rainfall during January to August is unreliable. This requires supplemental irrigation for cropping rice in these months.

Based on the rainfall data covering 23 years from 1961 to 1983, an isohyetal map was prepared. It was compared with an isohyetal map made by DID, as shown in Fig. 3. The DID's map is based on the old rainfall data for 26 years from 1950 to 1975. It is clear from these maps that the average annual rainfall decreased about 200 mm in recent years.

(2) Other climatic factors

Temperature and humidity are consistently high all the year round. The monthly mean temperature is about 28°C with a daily variation of about 8°C. The monthly mean humidity is 77% on average. The annual average daily sunshine is 6.2 hours. The wind is calm for most of the time. The annual average daily wind run is 89 km/day. The annual pan evaporation is about 1,850 mm. Climate factors in the project area are summarized in Fig. 4. There are no major climatic constraints to paddy cultivation.

3.1.3 Water sources

The main water source of the Project is the runoff of the Bernam river. The Bernam river water is taken at BRH and the Bagang Terap pumphouse. BRH is located at 130 km upstream of the estuary of the Bernam river and the pumphouse is at 62 km upstream. The catchment area of the river is 1,260 sq.km at BRH and 1,960 sq.km at the pumphouse.

(1) The runoff at BRH

Reliable discharge records are available at the existing river station No. 3813411 (so-called SKC bridge station) 17 km upstream of BRH. The relationship of runoff between the SKC bridge station and BRH is examined as shown in Fig. 5. The Bernam river runoff at BRH can be estimated by multiplying the discharge at the SKC bridge station by 1.1. The average monthly discharge for the recent 10 years from 1975 to 1984 is shown below.

(Unit: cu.m/s)

Jan	Feb	Mar	Apr	May	June	July
33.4	30.5	33.8	46.3	49.6	37.6	32.7

Aug	Sep	Oct	Nov	Dec	Annual Mean
26.3	42.1	60.8	72.7	61.4	43.9

As seen in the above table, the monthly mean discharges fluctuate between peaks in May and November. The low flow seasons last from January to March and from June to August.

Frequency analysis on the annual drought runoff was carried out based on the data of 24 years from 1961 to 1984. The result of analysis is shown in Fig. 6 and summarized below.

Return Period (years)	Probable Drought Runoff (cu.m/s)
2	24
5	16
10	12
20	11
30	9

(2) Base flow from the catchment area between BRH and the pumphouse

The runoff of a tributary meeting with the Bernam river at 12 km upstream of the pumphouse was measured twice at the low tide time in the driest month, September in 1986. This runoff is regarded as the base flow of the catchment. Based on these observation data, the base flow from the catchment area of about 700 sq.km between BRH and the Bagan Terap pumphouse is estimated at about 2.0 cu.m/s.

3.1.4 Flood runoff at Bernam River Headworks

Discharge records at the SKC bridge station were used to estimate the probable flood runoff at BRH. The probable flood runoff at the SKC bridge station was calculated by the Gumbel method and it was converted to that at BRH using Creager's equation. The results of calculation are summarized below.

Return Period (years)	Probable Flood at BRH (cu.m/s)
20	560
50	720
100	800

3.1.5 Water quality

Water was collected for the quality analyses from the Main Canal, drainage canals and the Swamp. The samples were analyzed at the Ampang Research Station of DID. The results of analyses are shown in Table 1.

(1) The pH value

The pH value of water sampled from both the Main Canal and drainage canals ranges between 5.8 and 6.3. On the other hand, the pH value of swamp water shows a quite acid value of 3.8. Such acid water would badly influence the paddy cultivation. However, the swamp water is not directly used for irrigation. It is diluted with the river water taken at BRH. As a result, the pH value of water in the Main Canal shows 5.8 to 6.1. There would be no problem for its use for irrigation.

(2) Electric conductivity

Electric conductivity (EC) of the samples ranges from 35 μS/cm in the Main Canal to 205 μS/cm in the drainage canal in Panchang Bedena compartment.

EC of river water was also measured along the reaches between Bagan Terap and BRH. It shows considerably high values in the lower reaches. It varies from time to time due to a tidal effect. EC at Bagan Terap was about 3,000 µS/cm at the high tide and 1,000 µS/cm at the low tide, as shown in Fig. 7. The results of EC measurement along the river reaches are shown in Fig. 8. EC decreased toward upstream and it became 64 µS/cm at the 112 km upstream point from the estuary.

In order to examine the effect of the released water from BRH, EC was continually measured at Bagan Terap in the driest month in 1986. Measurements were made both before and after closure of the scour gate at BRH. The results of continual measurement of EC of river water at Bagan Terap are shown in Table 2. Before the gate was closed, the highest EC was around 2,200 µS/cm, but after closure it significantly increased to 4,000 µS/cm. Complete closure of the scour gate thus results in deteriorating the water quality downstream.

It is said that, if EC of irrigation water is less than 2,000 µS/cm, no effect will take place for paddy production. But, the production would bereduced to 75% if EC exceeds 3,400 µS/cm. EC of the river water at Bagan Terap is normally less than 2,000 µS/cm. The water is suitable for irrigation of paddy. However, it does exceed 2,000 µS/cm at periods of high tide in a severe drought season. If water is pumped at such times, paddy will be damaged and the yield reduced to some extent.

(3) Suspended load

The relationship between the river runoff at the SKC bridge station and the content of suspended load is shown in Fig. 9. The content of suspended load increases in proportion to the increase in the river runoff. It is 120 mg/lit when the runoff is 20 cu.m/s and 220 mg/lit when 30 cu.m/s. In order to prevent the excessive intrusion of suspended load into the Feeder Canal, the intake of water at BRH should be controlled taking into consideration the project requirements.

The water was sampled from the intake channel of the Bagan Terap pumphouse and the content of suspended load was measured. It is remarkably affected by tide. During the low tide period, it is about 1,100 mg/lit and about 5,000 mg/lit during the high tide, as shown in Table 3.

3.1.6 Soil

Soils in the project area are composed of mineral soils and organic soils. The former are developed on the marine alluvium along the coast, and the reverine alluvium along the Bernam river. The latter are transitional soils between the mineral soils and the peat soils in the Swamp. They comprise Brown Clay Soils derived from brackish water deposits and Organic Clay and Muck Soils originated from the peat soils. Distribution of these soils is illustrated in Fig. 10.

The mineral soils are fairly heavy alluvial soils and are suited for rice cultivation. The Organic Clay and Muck Soils are, however, strongly acidic and deficient in nutrition. If no soil improvement is made, the paddy yield will be as low as 1.5 to 1.6 ton/ha, while it can be doubled with proper soil amelioration and nutrient management. The Organic Clay and Muck Soils extend to 950 ha in Sungai Burong, 327 ha in Sekinchan and 646 ha in Sungai Leman, gradually tapering off in Pasir Panjang with an area of 90 ha : the area covered is 2,013 ha in total. This corresponds to about 10% of the total project area.

3.1.7 Land use

The project area is 19,857 ha in gross. Present land use in the project area is shown in Table 4 and in Fig. 11. In total, 610 ha of land are used for non-agricultural purposes such as houses, public reserves, schools, mosques, canals and roads. Rice is cultivated on 17,510 ha of land. Vegitables are planted on 760 ha of land, while permanent crops including oil palm, coconut and mango occupy 460 ha . The remaining 517 ha of land lie fallow and are defined as idle land. Both the cropped area and the idle land are regarded as irrigable and amount to 19,247 ha.

Vegetable cultivation is usually practiced during several crop seasons as one of the steps for improving the Organic Clay and Muck Soils. Such practice under dry field condition is effective in decomposing rapidly soill organic matter with application of lime and fertilizers containing micronutrients. The area covered with the Organic Clay and Muck Soils comprises 745 ha for paddy, 330 ha for vegetables, 460 ha for permanent crops and 478 ha for idle land.

3.2 Existing Infrastructure

3.2.1 Irrigation facilities

The existing irrigation system comprises the main conveyance system and distribution canal systems. The main conveyance system includes a diversion headworks on the Bernam river, the Feeder Canal connecting the Bernam river to the Tengi river and the Main Canal. The Bagan Terap pumphouse commands an area of 1,520 ha (3,800 acres) located at the extreme end of the system. The location of these irrigation facilities is illustrated in Fig. 12.

(1) Main conveyance system

The Bernam River Headworks is composed of a diversion barrage 30 m (100 ft) wide constructed across the Bernam river, an intake which diverts water into the Feeder Canal, and a scour sluice on the left side of the barrage. It is located at about 39 km (24.5 miles) upstream from the Tengi Headworks. The diversion barrage is provided with three sets of radial gates, each 9.1 m wide. The gates back up the water level to 9.4 m (+31.0 ft). Six sluice gates at the intake divert a maximum of 28.3 cu.m/s (1,000 cusec) of water to the Feeder Canal. The scour sluice gate is always open and a minimum 6.2 cu.m/s (220 cusec) of water is allowed to flow down through the scour sluice.

The Feeder Canal conveys the water diverted from BRH to the Tengi river. It runs some 14.5 km (9 miles) through virgin jungle along the eastern side of the Swamp. The improved Tengi river runs a further 24.5 km (15 miles) through the jungle swamp to the Tengi Headworks and the Main Canal. In order to increase the flow capacity in both the Feeder Canal and Tengi river, expansion work was carried out by the O&M section of DID Kuala Selangor by using a steam driven dredger. The dredger was old and its working efficiency was very low. However, the work was completed by August 1986. With this expansion work, the flow capacity has been increased, and the present design discharge of 28.3 cu.m/s (1,000 cusec) can be easily passed.

The Main Canal runs southward 3.3 km long irrigating the Sawah Sempadan compartment, and 34.6 km northward along the remaining compartments. The total length of the Main Canal is 37.9 km.

The Tengi Headworks backs up the water in the Main Canal to the required full supply level (FSL) so that it can command the irrigation area. Flood relief measures are provided in the Main Canal by means of two spillways. One spillway near the Tengi Headworks has a capacity for discharging 72 cu.m/s (2,550 cusec) into the Tengi river and the other at Haji Dorani High Level Drain 35 cu.m/s (1,250 cusec) into the sea. The present flow capacity of the Main Canal is insufficient for the design discharge and significant leaks are found at 33 places along the Main Canal between Sawah Sempadan and Sungai Nipah.

The Bagan Terap pumphouse is located about 63 km (39 miles) upstream from the estuary of the Bernam river. It was constructed in 1962 to supply irrigation water from the Bernam river to part of the Bagan Terap compartment. The area commanded by the pumphouse was originally 2,800 ha (7,000 acres) in Bagan Terap. When PBLS was completed in 1985, the area served by the pumphouse was reduced from 2,800 ha to 1,200 ha (3,000 acres) in Bagan Terap and added the Sungai Panjang area of 320 ha (800 acres) as an extension area. The present command area is thus 1,520 ha (3,800 acres) in total. The pumphouse accommodates three units of mixed flow pump with diesel engines. The design capacity of each pump is 1.56 cu.m/s (55 cusec) of water with a maximum static head of 4.6 m (15 ft). However, the present capacity is about 70% of the designed one, due to deterioration of the pumps. The amount of water which can be delivered by each pump is about 1.25 cu.m/s (45 cusec) under full operation.

(2) Distribution network

Distribution canal network is composed of secondary and tertiary canals. Secondary canals are found in three compartments, namely Sawah Sempadan, Panchang Bedena and Bagan Terap. They command a number of tertiary canals. In other compartments, the tertiary canals are spaced at 400 m intervals at about right angles to and taking off directly from the Main Canal. A typical layout of tertiary canals is shown in Fig. 13. Most of the present distribution network consists of concrete conduits. Tertiary canals in Sawah Sempadan are exceptional. Six are concrete lined canals of trapezoidal shape, and another six and all the tertiary canals in Sungai Nipah are made of Glass Reinforced Polyester (GRP) flume. GRP is not strong enough and frequently bends and breaks. The leakage is significant and farmers can easily make holes in the flume. They are found in many parts of the flume which makes it quite difficult to distribute sufficient water to the downstream reaches of the flume. It is planned that these GRP flumes be replaced by concrete conduits.

Each tertiary canal is provided with an offtake at its head. The offtake is either a constant head orifice offtake (CHO) or an adjustable weir offtake. The total number of offtakes is 140, out of which 129 are CHO and the remaining 11 are adjustable weir offtakes. The function of offtakes is to divert the required water to tertiary canals following the irrigation schedule. CHO consists of an orifice gate and a turnout gate separated by a stilling chamber. Typical features of CHO are shown in Fig. 14. An adjustable weir offtake consists of a screwdown gate upstream and a slide gate at the downstream end. A typical adjustable weir offtake is shown in Fig. 14.

A check structure is equipped at each cross bund. It consists of a well chamber and an inlet with an adjustable slide gate. A typical drawing of a check structure is shown in Fig. 15. The water level in the tertiary canal is controlled by means of checks and slots provided along the tertiary canal. It is designed so that each 1.2 ha (3 acres) farm lot is provided with a 2-inch offtake pipe which is placed 30.5 cm (12 inches) below the top of the conduit and 20.3 cm (8 inches) below FSL. The pipe will deliver 2.83 lit/s (0.1 cusec) of water.

3.2.2 Drainage facilities

The drainage network in the project area consists of field ditches with an outlet pipe in each farm lot, tertiary drains and main drains. A tertiary drain collects water from field ditches and disposes of it to a main drain. The main drain is connected with the coastal belt drain. The excess water is finally released by gravity to the sea through the tidal gates provided on the coastal belt drain. Figure 16 shows the present drainage network.

A field ditch of 30.5 cm (1 ft) wide and 45.7 cm (1.5 ft) deep is constructed along the batas in each farm lot. Polyvinyl chloride (PVC) pipe of 15 cm (6 inches) in diameter is provided at the end of the field ditch to drain excess water from the farm lot into a tertiary drain. Under PBLS, old tertiary canals were transformed into tertiary drains, and additional tertiary drains were constructed tertiary canal and drain. This provides a tertiary drain spacing of 400 m, which permits evacuation of a five-year probable rainfall in 72 hours. At each cross bund and at the end of the tertiary drain, drainage control gates are provided. At the end of a main drain, an end control gate is constructed. These control gates are mainly used for maintaining water level, therefore, preventing excess seepage as well as for back-flooding irrigation. The excess water from the project area is drained from the end control gates into the coastal belt drains. The main features of the end control gates are given in Table 5.

3.2.3 Farm roads

The project area is bordered by the Main Canal on the east and by the Tanjong Karang-Sungai Besar main road on the west. There is a bund about 5 m wide along the left side of Main Canal. The asphalt paved roads at intervals of 1.6 km connect the bund and the main road. These roads are about 6 m wide with two lanes. They are well maintained by the Public Works Department (JKR). Between the asphalt roads, there is a 3 m wide road paved with laterite. Under PBLS, access paths 1.8 m wide were constructed between the asphalt and the laterite roads. Thus there are farm roads at intervals of 400 m.

Four to three cross bunds are placed at intervals of 1.6 km which inter-connect with the above roads. They are named No.1 to No.4 or No.3 from the west. The cross bunds are 3 m wide and paved with laterite.

3.3 Operation of Project Facilities

3.3.1 Water supply schedule

Out of the total irrigation area of 18,270 ha, 17,070 ha are served by the Main Canal at present and 1,200 ha are supplied with water from the Bagan Terap pumphouse.

According to DID's operation manual, the project area is divided into three Irrigation Schedule Areas (ISA) with cropping schedules phased 20 days apart. Irrigation Schedule Area No. 1 (ISA 1) comprises Sawah Sempadan (2,310 ha), Sungai Burong (3,122 ha) and Sekinchan (1,778 ha), totalling 7,210 ha. Irrigation Schedule Area No. 2 (ISA 2) consists of Sungai Leman (1,765 ha), Pasir Panjang (1,484 ha) and Sungai Nipah (1,938 ha), totalling 5,187 ha. Irrigation Schedule Area No. 3 (ISA 3) includes Panchang Bedena (3,260 ha) and part of Bagan Terap (1,413 ha), totalling 4,673 ha. The remaining area in Bagan Terap area is commanded by the Bagan Terap pumphouse. The location of ISA is shown in Fig. 17.

At the start of each irrigation season, ISA-1 receives presaturation supply in the first 20 days, while ISA-2 and ISA-3 do not get any supply. In the next 20 days, ISA-1 gets normal irrigation supply, while presaturation supply is let into ISA-2. There is no supply to ISA-3. In the following 20 days, ISA-1 and ISA-2 get normal irrigation supply while ISA 3 gets the presaturation supply. After 60 days, all areas receive the normal irrigation supply. The normal irrigation supply is for 120 days each and the supply is stopped during the drainage period. By operating the offtakes at the head of tertiary canals, the supply of water to tertiary canals can be controlled and the depth of water in the farm lots can be kept at 10 to 15 cm (4 to 6 inches).

The supply of water follows the fixed irrigation schedule. However, actual cropping is always behind the schedule. In all the compartments except Sekinchan, several crop seasons have been missed during the last decade, due to prolonged staggering of cropping. The commencement of irrigation supply is now individually determined compartment by compartment by the Paddy Planting Schedule Committee. This causes many water-related problems in the project area.

3.3.2 Operation of main conveyance system

(1) Operation of BRH

Three kinds of gates are installed at BRH. There are three sets of radial gates provided on the barrage, six sets of sluice gates on the intake and one sluice gate on the scour culvert. These gates are operated by a special-grade Irrigation Overseer stationed at BRH, with the orders of the Chief Irrigation Inspector.

The radial gates of the barrage are closed most of the time so that water is backed up and diverted into the Feeder Canal through the intake.

The excess flow spills over the diversion barrage down the Bernam river under normal conditions. The radial gates of the barrage are only opened when there are excessive flows in the Bernam river during the rainy season, and also when there is a possibility of flooding in the project area. Six sets of sluice gates installed at the intake are almost always fully opened in order to intake as much water as possible. It is designed so that a maximum of 28.3 cu.m/s (1,000 cusec) can be diverted through the intake into the Feeder Canal.

Of the three kinds of gates, the gate at the scour culvert has closed till recently, and a minimum of 6.2 cu.m/s (220 cusec) of water has been allowed to flow down through the sluiceway in order to prevent the accumulation of silt in front of the intake. However, it has became clear that no sedimentation problem will occur in the vicinity of the barrage when the river flow decreases to about 14 cu.m/s (500 cusec). Consequently, when facing a severe water shortage, the gate was closed for the first time in August 1986.

The record of operation of gates at BRH is shown in Fig.18 for a period of one year from June 1985 to May 1986. The radial gates are opened when the water level upstream of BRH reaches about +10.1 m (+33.0 ft). The gates were opened for 89 days during the above period. When the radial gates were opened, the opening of the intake gates was decreased. It is noted, however, that the operation of intake gates was less frequent than that of radial gates. The intake gates were completely closed for only two days and partially closed for 54 days during the said period.

(2) Operation of the Main Canal

According to the operation manual, the water level along the Main Canal is to be maintained at the following FSL:

Location	FSL	Structures
Tengi Headworks	+4.3 m (+14.0 ft)	Tengi Headworks and Spillway
Haji Dorani	+3.7 m (+12.0 ft)	Haji Dorani Spillway

In order to maintain FSL at the location stated above, it is important to control and regulate the withdrawal of water from the Main Canal. Withdrawal of water for irrigation is only carried out through the offtakes provided at the head of the tertiary canals. The amount of water withdrawn for a particular tertiary canal should be as designed, and the time and duration of withdrawal are regulated in accordance with the irrigation schedule. However, it is quite difficult to follow the irrigation schedule stipulated in the operation manual, due to the delay in actual cropping. At present, the irrigation schedule is determined compartment by compartment for each season by the Paddy Planting Schedule Committee. The compartment located upstream has greater advantages in withdrawing water than those located downstream. Together with insufficient flow capacity of the Main Canal and much leakage from the Main Canal, a chronic water shortage occurs in the three downstream compartments, Sungai Nipah, Panchang Bedena and Bagan Terap.

Figure 19 shows the daily changes in water level of the Main Canal at the Tengi Headworks during 1985/6, together with the record of operation of gates at the Tengi Headworks and Spillway. The daily and seasonal fluctuation in the water level is considerable. During the drought season from July to September, the water level seldom reaches FSL, but the water level is kept above FSL during the remaining months of the year. The gates of the spillway are frequently opened to control the water level of the Main Canal, so that the water never overflows the canal embankment. The gates of the spillway are opened when the water level at the Tengi Headworks exceeds +4.45 m (+14.60 ft).

(3) Operation of the Bagan Terap pumphouse

The pumphouse is located about 63 km (39 miles) upstream from the estuary of the Bernam river. The location is influenced by a tidal effect. At the time of high tide, a control gate which is provided at the head of the intake channel is opened to let water flow into the channel. When the tide reaches its peak, the gate is closed. Such operation is repeated twice a day. The present daily running hours of the pumps vary from 22 hours during the spring tide to eight hours during the neap tide, the average being about 16 hours per day.

3.3.3 Operation of distribution network

The required amount of water to be diverted into each tertiary canal is regulated and controlled by an offtake provided at the head of each tertiary canal. However, it is difficult in practice to regulate the discharge only by means of the gate opening. The regulation of discharge is therefore made by adjusting the water level in the tertiary canal to FSL by Irrigation Inspectors and Irrigation Overseers. The results of a questionnaire survey show that operation of offtakes is conducted regularly or occasionally. The water level in the Main Canal fluctuates considerably. This requires frequent operations of the offtakes to keep the water levels in tertiary canals at suitable levels.

The present maintenance condition of all the offtakes in the project area was investigated. The results are summarized in Table 6. The gates of offtakes are normally locked and most of offtakes are functioning well. Steering wheels are not equipped in 37 offtakes, but the wheels were kept by gatekeepers. In Sekinchan, however, five gates out of a total of eight have been damaged or removed. According to the Irrigation Inspector in charge, the offtake gates are often damaged by farmers who cultivate vegetables, when the water supply is stopped for harvesting paddy. The water supply for vegetables should also be taken into account.

In order to control the water level in tertiary canals, checks are provided at the cross bunds and slots are placed 300 m (1,000 ft) apart along the canal. However, both checks and slots are not used effectively to control water levels in the canal. Slots are lost and many check gates are removed.

During the presaturation period, many farmers use syphons to get more water within a short time. It seems that syphons are more widely used in farm lots where direct seeding is practiced. DID treats the use of syphon as illegal. However, the main reason for the use of syphons is the insufficient flow of water in the tertiary canals during the presaturation period. Reasonable use of syphons should be taken into consideration to cope with farmers' requirements.

3.3.4 Operation of the drainage network

Water in a drain is regulated by drainage control structures installed at each cross bund and at the end of a tertiary drain. The structure comprises a screw-down gate at the upstream and fixed weirs at the sides. During the irrigation period, the water level in tertiary drains is maintained close to the water level in farm lots to prevent excessive seepage as well as to supply water to the farm lots by back-flooding. The screw-down gate is lowered to its fullest extent and the excess water spills over the weirs. During heavy rainfall and prior to harvesting, the screw-down gate is opened so that the water level in the drain can be lowered.

According to the operation manual, the water level in drains is measured and recorded at the major points of the drainage network. The water level records at the Haji Dorani drainage control are shown in Fig. 20 and the followings are made clear from the figure.

a. During the presaturation period, the end control gate is closed and water is stored in the drains as much as possible.
b. When transplanting is started, the gate is opened and water level in the drain is lowered. This will create comfortable working conditions for transplanting.
c. After transplanting, the gate is again closed and the water level in drains is kept about 10 cm (0.3 ft) below the ground surface.
d. When a heavy rain falls, the gate is opened. However, this operation is sometimes delayed because forecasting of rainfall is difficult. The operation is usually made one day after heavy rain. This causes flood damage in the depression area.
e. During normal irrigation period, the water level in drains fluctuates considerably.
f. About one month before harvesting, the gate is opened and the ponding water is released.

For managing the water in a farm lot, a 6-inch PVC pipe is installed at the end of field ditch. It is located at about 45 cm (1.5 ft) below the ground surface. On instructions of the State DID, each farmer has to provide a plank of about 20 cm (8 inches) wide to close the pipe. However, most of the pipes are not closed with such a plank, but by using weeds or other means.

3.4 Maintenance of Project Facilities

3.4.1 Present conditions of maintenance

There has been no fixed maintenance programme, so far. The work is carried out as the necessity arises. Present maintenance work is summarized below.

(1) BRH

Operation and maintenance (O&M) of BRH is carried out by two gatekeepers. The main task is clearing rubbish and debris, greasing mechanical parts of gates and reading water level in the Bernam river. Painting of metal and concrete surfaces is done every year.

The lifting cables for the radial gates are replaced every four or five years, often after they have snapped. The rubber seals of radial gates are also changed after leaks became significant. One was changed in 1986 after operating for 10 years. Special maintenance work is carried out by DID Tanjong Karang. Since construction, none of the gates at BRH nor the screens for the intake structure have ever been replaced.

A dragline excavator with a bucket capacity of 0.4 cu.m is stationed at BRH to maintain the Feeder Canal in the 2 km reach from BRH to the confluence of the Sungai Dusun and the Bernam river about 300 m upstream reach of BRH. The excavator desilts sediments in the canal and river, and trims slopes. It normally takes four months to complete the above work and the work is repeated.

Clearing and grass cutting around BRH are done by five DID labourers using a rotary cutter pulled by a tractor. One labourer is the operator of the tractor, two others cut and clear the slopes where the tractor cannot reach. Two other labourers clear grasses on the slopes and banks of the Feeder Canal.

(2) Feeder Canal and Tengi river

About 7 km of the Feeder Canal downstream of the Sungai Dusun was desilted in 1984/85. The Tengi river is maintained by the steam driven dredger. Maintenance work from the Tengi Headworks to the Feeder Canal was carried out under force account of PBLS for three years from 1984 to 1986. Before this operation, no scheduled maintenance work had been carried out. The dredger had worked at places where maintenance was urgently needed.

(3) Main Canal and related structures

Clearing and weeding of the bund of the Main Canal are done regularly three times a year on a contract basis. The left side of the Main Canal is cleared by machine, whereas, the right side is difficult to maintain properly because there is no bund for the access of equipment. The right side has to be cleaned manually. Desilting work is not done regularly. The last desilting was done from 1979 to 1983, using departmental excavators under force account.

The topping of the bund along the Main Canal was done under PBLS. Normal maintenance work comprising patching and grading is normally done by DID equipment. Laterite for the work is brought from the DID quarry in Batang Berjuntai, Kuala Selangor. There are four bridges for logging and one DID's concrete bridge across the Main Canal. Logs are floated in the Main Canal and collected upstream of these bridges. This constricts the flow in the Main Canal. Maintenance of the Tengi Headworks and two spillways is carried out to the same standard as that of BRH.

(4) Distribution network

DID gatekeepers and labourers clean offtakes, concrete conduits and chambers of check structures every season prior to the supply of water. All the maintenance work have to be carried out by DID. Leakages and damages are also repaired by DID. This brings about farmers' throwing weeds and other materials into the system more, resulting in heavy work load for clearing. The present maintenance of distribution network being undertaken by DID is not sufficient, and it is clear that part of the maintenance work should be entrusted to the farmers.

(5) Drainage canals

Weeding and clearing of drainage canals are done four times a year on a contract basis. The contract is given to the village chief. The chief employs villagers to complete the work. Unit costs vary with the width of drains. These unit costs are fixed by the State Financial Officer. Because of this system, drainage canals are normally properly maintained. The annual expenditure for this maintenance work is estimated at about M$500,000. Desilting of drainage canals is conducted once in three to four years also on a contract basis.

(6) Farm roads

Resurfacing of existing farm roads is normally done on a contract basis. The frequency of maintenance depends on the intensity of use, normally once in three years. Bridges on farm roads are repaired only when damaged.

3.4.2 Annual maintenance costs

Up to 1985, all the annual maintenance cost for the project were allocated from the State of Selangor. In 1986, part of the maintenance cost was borne by the Federal Government. This contribution by the Federal Government will continue, until the project is completed. According to the current Agreement, the project maintenance will be carried out by the State Government once the project is completed. However, this issue has not been settled yet i.e. whether the Federal Government should continue with some amount of the contribution or otherwise. The annual maintenance cost is allocated for both irrigation and drainage areas. Some items like materials and maintenance of vehicles and equipment are used for both areas. It is, therefore, difficult to clearly divide the costs used only for the irrigation area. The annual maintenance costs of the irrigation area excluding salaries for the DID staff are estimated for three years from 1984 to 1986 as shown in Table 7.

About 18% of the annual maintenance costs spent on maintaining GRP will not be necessary after GRP in Sawah Sempadan and Sungai Nipah is replaced by concrete conduit by 1989.

3.4.3 Existing equipment for maintenance

In DID Tanjong Karang, there are a number of pieces of heavy equipment available for maintenance of both irrigation and drainage areas. The list of equipment is shown below. There is no equipment exclusively used for irrigation area, except for the old steam driven dredger and an amphibious excavator. Present equipment is insufficient for the use both in irrigation and drainage areas. It is necessary to provide additional equipment for an exclusive use in the irrigation area as listed below.

	Type	Present Equipment	Additional Equipment
1.	Tractor	15	-
2.	Loader	3	-
3.	Grader	3	-
4.	Backhoe loader	3	2
5.	Tippers	6	-
6.	Hydraulic excavator	6	2
7.	Dragline excavator	11	-
8.	Dredger	1	1
9.	Roller	2	-
10.	Boat	3	-
11.	Aquatic weed cutter	-	2

Maintenance of this equipment is done in the workshop of the State DID, Tanjong Karang. Major overhaul for hydraulic and dragline excavators is carried out in the workshop of Federal DID, Ipoh. When the equipment is sent for overhaul, a replacement is provided. No shortage will occur due to overhaul.

3.4.4 Present condition of communication

DID offices in Kuala Selangor, Tanjong Karang, Sungai Besar and BRH are all equipped with very high frequency (VHF) radiophone sets. VHF sets fitted on vehicles are also available at the three offices. The system available in the project area is part of the system for the State of Selangor, but it is used mainly for flood monitoring and warning. It is maintained by the Hydrology section of Selangor State DID, Shah Alam. However, the system has not been working well, especially the set in BRH. There is also the public telephone system, but this is sometimes interrupted and lines are often busy. As it is difficult to maintain constant communications, information and instructions have to be sometimes conveyed by vehicles.

3.5 Agriculture and Agro-economy

3.5.1 Social background

(1) Demographic situation

In PBLS area, there are 19,500 farm households, out of which 14,500 obtain their income from paddy cultivation. According to the the monitoring survey by the PBLS Office, the average family size is 6.0 persons. The population connecting to paddy cultivation is estimated at 87,000, in which 38% are under 15 years and 8% over 60 years in age. The Chinese population is largely concentrated in town areas along the coastal belt. All the paddy farmers in Sekinchan are composed of Chinese. The labour force in one household is 3.2 persons on average. About 60% is over 50 years old, while only 5% is under 30. Paddy farmers in the project area have become old.

(2) Land tenure and holding size

The paddy farmers in the project area are classified into four types from the viewpoints of land tenure; (1) owner operator, 68%; (2) partially owner operator, 12%; (3) owner non-operator, 2% and (4) tenant operator, 18%. The holding size of farm land ranges from 0.6 to 2.4 ha. About 83% of paddy farmers still hold 1.2 ha (3 acres), which has continued from the beginning of the settlements.

3.5.2 Paddy cultivation

(1) Cropping schedule

A cropping schedule is proposed by the PBLS Office aiming at double cropping of paddy in every year. Off-season cropping is to start from 1st February, and main season cropping from 1st August. Each cropping period is fixed at 201 days with the staggering of 40 days.

Even after the irrigation system was upgraded, the proposed cropping schedule has not been realized. Water supply schedule was adjusted for every season in each compartment by the Paddy Planting Schedule Committee chaired by the PBLS Office, to take into account performances in the preceding season and available irrigation water resources. Farmers' request is also reflected in determining the water supply schedule. The cropping schedule is determined individually for each compartment. Past performances are summarized in Fig. 21. In compartments other than Sawah Sempadan and Sekinchan, one to two crop seasons have been missed in four years from 1983 to 1986. Due to the chronic delay in cropping, the PBLS office has defined paddy sown during the first six months as the first season crop and for the second six months as the second season crop.

(2) Farming practices

Two different kinds of paddy planting are prevailing in the project area. One is traditional transplanting and another is the newly introduced direct seeding. In case of the traditional transplanting, paddy is transplanted twice. The first transplanting starts from the 7th to 10th day after the seeding. It is done by hands. The second one is made use of the "Kuku Kambing" or forked sticks, which begins at about 30th day from the first transplanting.

Direct seeding was introduced firstly to Sekinchan in 1979. The method has been spreading in other compartments since 1982. In the first season of 1986, it was practiced in about 35% of the whole project area. The situation of its application is summarized in Table 8. In Panchang Bedena and Bagan Terap, it has been never practiced. Most of the farmers in other compartments have already had the experiences. The three methods of direct seeding are employed, which are as follows:

a. **Mechanized dry seeding**: It is done by a seed driller attached to a tractor, and applied in dry condition to the field. In order to make even and reliable germination of seeds, rotavating and land leveling are required. Seeding is carried out five to ten days before water supply.

b. **Manual dry seeding**: This is applied in the uneven lot. Seeding is conducted five to ten days before water supply.

c. **Manual wet seeding**: This is applied if the lot is in wet condition. Pre-germinated seeds are used for this method. The more precise control of water is necessary if compared with the two methods above.

Land preparation and harvesting have already been mechanized in the project area. Land preparation is usually done by 4-wheeled tractors with 20 to 80 HP on a contract basis. Most farm lots are rotavated twice. For the harvesting, large-scale harvesters of 32 to 220 HP are used on a contract basis. Field drains have been provided in the selected area, along 'batas' or farm ridges under the Field Improvement Scheme of the Department of Agriculture (DOA). This improves drainage conditions in the farm lot and makes the movements of heavy machinery easier. Paddy stalks remaining after harvesting are slashed and burnt in the farm lot.

Varieties of paddy being cultivated in the project area are composed of mostly the improved varieties such as MR1, MR10, MR52, MR71, MR73 and MR77. Seeding rates are 20kg/ha in the transplanting and 80kg/ha in the direct seeding. About 60% of the required amount of seeds comes from the retention in the preceding harvest. The certified seeds are contributed for the remaining 40%, which are provided from DOA to farmers directly or through the Farmers' Organization.

Fertilizers as well as agro-chemicals are distributed to farmers through Area Farmers' Organizations. Fertilizers are subsidized by the Government, completely free of charge. If farmers feel necessity, they use additional amount on their own expense. Urea of 100 kg/ha and compound fertilizer of 200 kg/ha are subsidized in one crop season. Total content of nitrogen is 80 kg/ha. Agro-chemicals are sold to the farmers. With the extension of direct seeding, the need for weed control has been encouraged. There are two kinds of weeds, *Echinochloa crusgalli* and *Echinochloa colona*, which grow faster than the rice plant. As the weed control by chemicals is costly, the transplanting tends to be repracticed by farmers as a cheaper measure. The State DOA is promoting land preparation exclusively for the purpose of weed control without use of so much chemicals.

Since the late 1970s, the brown plant hopper (BPH) has become a serious threat to paddy cultivation in the project area. Damage of BPH was recorded in Sungai Leman in 1977 first, and in Sungai Burong in 1978, the next. These were the first records for the country. Overuse of chemicals destroys the delicate ecological balance, leading to the outbreaks of BPH. The amount of chemicals used is especially much in Sekinchan, which becomes the area of BPH source. Buildup of BPH takes place in the period from the end of June to the beginning of July. If the heading stage of paddy falls in this period, the severe outbreak of BPH would take place. About 10% of the project area is monitored in each crop season by the State DOA. When the outbreak of BPH recognized, the stocked pesticides are released to farmers, free of charge. In 1986, the funds totaling M$175,100 were allocated for this purpose, and the damages of BPH have become not so severe.

(3) Production of paddy

The average cropped area was 15,460 ha in the first season and 16,400 ha in the second season for the past five years from 1981 to 1985, as shown in the following table. Cropping intensity of paddy was 1.77.

	Cropped Area (ha)	Unit Yield (ton/ha)	Production (ton)
First season	15,460	2.89	44,680
Second season	16,400	3.35	54,950
Total	31,860		99,630
Cultivable area of paddy /1	18,027		
Cropping intensity /2	1.77		

Remarks: /1 = Including idle land (517 ha)
/2 = Total cropped area / Cultivable area of paddy

The records of unit yield in each compartment are summarized for the above five years in Table 9. The unit yield was unstable and on a decreasing trend. The average unit yield of the first season paddy was 2.89 ton/ha and that of the second season paddy 3.35 ton/ha. These yields are lower than the target yield for 1990 projected by PBLS; 3.7 ton/ha in the first season and 3.8 ton/ha in the second season. Total paddy production in the project area is 99,630 tons on average.

(4) Processing and marketing

In the PBLS area, there are four rice mills. The paddy produced in the project area is dried and milled at these rice mills. The maximum working hour of these four mills is 20 hours per day, and present capacities of drying and milling are assumed to be 1,940 and 410 tons per day, respectively. The rice mills are managed by the National Paddy and Rice Board (LPN).

LPN is responsible for marketing rice, maintaining the national stockpile, and importing rice. Paddy is usually sold to LPN through the licensed dealers without drying. The licensed dealers are Farmers' Cooperatives or private agents. Small amount of paddy is also sold directly to LPN. After milled at the rice mills of LPN, the rice is sold to wholesalers, and then marketed on the open market. Some amount of milled rice is delivered for the stockpile of the Government.

Procurement price of paddy is controlled by the Government through LPN. In 1986, the purchasing price of clean dry paddy at the mill gate was M$66.15/100 kg for long grain and M$62.84/100 kg for medium grain, both including Government paddy subsidy of M$16.54/100 kg. The market price of rice depends on supply and demand situations, though the price at the open market is controlled indirectly by the Government's adjustments of the national stockpile.

3.5.3 Present crop budget

Based on the monitoring survey by the PBLS Office, the analysis is made to clarify production cost, gross income and net return for paddy cultivation in the project area. The results are as shown in Tables 10 and 11. The crop budget can be summarized below.

	1980	1981	1982	1983	1984	1985	Average
First season (M$/ha)							
Production cost/1	-	1,283	1,286	1,117	1,249	1,192	1,225
Gross income	-	1,539	2,094	1,261	1,570	1,306	1,554
Net return	-	256	808	144	321	114	329
Second season (M$/ha)							
Production cost/1	1,361	1,366	1,246	1,230	1,210	-	1,283
Gross income	2,170	2,469	1,720	1,598	1,576	-	1,907
Net return	809	1,103	474	368	366	-	624
Production cost of rice (M$/ton)							
First season	-	850	624	901	811	931	823
Second season	639	562	737	783	781	-	700
Average							762

Remarks: /1= Including costs for seed, fertilizer, agro-chemicals, hired and family labours, farm machinery, and land and water charges.

As shown in the table above, net returns have not substantially increased. Its averages were M$329/ha in the first season and M$624/ha in the second season, accounting for 21% and 33% of the gross income, respectively. The average production cost of rice was M$762/ton in the past 10 crop seasons. During 1985, LPN imported 429,500 tons of rice with unit value of M$608/ton. The production cost of rice in the project area is in excess of the import price.

3.5.4 Farmers' economy

In order to identify the farmers' economy, farm budget was analyzed for the years 1984 and 1985 for a typical farmer holding farm land of 1.2 ha. The farm budget, two years' average, is summarized below.

(Unit : M$)

	7 Compartments Excluding Sekinchan	Sekinchan
A. Gross Income	4,600	8,637
1) Farm income	3,755	5,940
- Paddy	2,963	4,111
- Other crops and activities	792	1,829
2) Off-farm income	845	2,697
B. Gross Outgo		
1) Production cost	1,589	2,192
2) Land rent	1,007	1,975
3) Land and water charges	17	17
C. Living Expenses and Net Reserve		
1) Owner operator/1	2,994	6,428
2) Tenant operator/2	2,004	4,470

Remarks: /1 = (A)-(B.1)-(B.3) /2 = (A)-(B.1)-(B.2)

The gross income of farmers in the seven compartments other than Sekinchan is lower than the median gross household income of M$7,150 for rural areas of Peninsula Malaysia in 1984. Farmers in Sekinchan had higher living expenses and net reserve than those in other compartments. Earnings from paddy cultivation account for 48% of the gross income in Sekinchan and 64% in the other compartments. Off-farm income mainly consists of the remittances from family members working in the outside of the project area and wages earned from non-farm activities.

3.6 Agricultural Support System

3.6.1 Outline of existing organizations

The institutional framework established in the project area under PBLS remains, and coordination in terms of agricultural support services is still effective. The coordinating body is the Project Office (PBLS Office) which chairs committees at various levels with the representation of:

a. DID,
b. Department of Agriculture,
c. Farmers' Organization Authority (FOA),
d. Agricultural Bank Malaysia (Bank Pertanian Malaysia, BPM), and
e. Malaysian Agricultural Research and Development Institute(MARDI).

Construction, operation and maintenance of irrigation and drainage facilities are the major roles of DID, while agricultural extension services are provided by DOA. A sole agency concerning with the development of the Farmers' Organizations (FOs) is FOA, and institutional credit facilities have been provided to individual farmers by BPM. Specialized research in paddy cultivation technology is the task of MARDI, which also acts as a breeder of stock seeds of paddy.

The coordinative committee set-up for PBLS implementation is as follows:

a. Steering Committee
b. Implementation Committee
c. District Inter-agency Coordination, Planning and Liaison Committee (DICPLC)
d. Area Inter-agency Coordination, Planning and Liaison Committee (AICPLC)
e. Technical-Social Advisory Committee

The Steering Committee is a superior-level policy-making body; the

Secretary General of MOA and the State Secretary, Selangor, share the chairmanship. The Project Director of PBLS chairs the Implementation Committee and the Paddy Planting Schedule Committee. A chairman of DICPLC is the Deputy Project Director of PBLS, and that of AICPLC is the assigned coordination officers. The Technical and Social Advisory Committee has been established to make sure an inter-agency coordination in particular areas.

3.6.2 Extension services in paddy area

Agricultural extension services are provided by the State DOA staff. The head is the Agriculture Officer in one District. The following are PBLS Area divisions connected to paddy growing areas and the involved Extension Blocks for which one Agriculture Technician is responsible.

PBLS Area	Extension Block
Kuala Selangor North:	Sawah Sempadan I-III
	Sungai Burong I-IV
Sabak Bernam South:	Sekinchan I and II
	Sungai Leman I and II
	Pasir Panjang I and II
	Sungai Nipah I-III
Sabak Bernam Central:	Panchang Bedena I - IV
	Bagan Terap I - IV

One Assistant Agriculture Officer is responsible for coordinating and supervising the extension activities of all Agriculture Technicians at Area level. These DOA extension staff are usually stationed at Farmers' Development Centre (FDC) or Farmers' Development Sub-centres (FDScs) established by PBLS. Table 12 shows the staffing pattern and the office locations.

In addition to assistance of the Federal DOA staff, financial support has been provided within the State DOA. Under the District Agriculture Officer, one Assistant Agriculture Officer and a few Agriculture Technicians are in charge of development, and one to two Agriculture Technicians have been attached to the Area Assistant Agriculture Officer for the same purpose. These development staff allocate and disburse the funds for "Field Improvement Scheme".

Objectives of DOA extension services are (1) to guide and train farmers with progressive agricultural technology, and (2) to introduce more systematic crop production methods and farming practices. The training and visit (2L) system was applied formerly, in which extension Agriculture Technicians visit a group of farmers once in every two weeks and training of staff is conducted when the time is available at the quarters. However, it has been revised to a "group farming approach" since 1983 (refer to Annex E).

3.6.3 Farmers' Organization

Any kind of FO must be registered with FOA, as required under the "Farmers' Organization Act, 1973 (Act 109)" jointly promulgated with the "Farmers' Organization Authority Act, 1973 (Act 110)". Otherwise, it cannot carry on business. On this legal basis, FOs have been set up at Area, State, and National levels. FO is a business body established by the farmers under the supervision of FOA.

Five Area FOs are in existence, of which three are situated in paddy growing areas: (1) Area FO, Tanjong Karang; covering Sawah Sempadan and Sungai Burong, (2) Area FO, Pasir Panjang; for Sekinchan, Sungai Leman, Pasir Panjang and Sungai Nipah, and (3) Area FO, Sabak Bernam; for Panchang Bedena and Bagan Terap. Policies vary, but organizational structure and activities are almost identical.

Members of Area FO are categorized into two types: namely, individual farmers through Farmers' Unit, and Agro-business Cooperative Societies. Each of the above Area FOs has the following membership as of June 30, 1986: (1) Area FO, Tanjong Karang; 3,100 farmers through 22 Farmers' Units and 10 Agro-business Cooperative Societies, (2) Area FO, Pasir Panjang; 1,906 farmers through 18 Farmers' Units and 12 Agro-business Cooperative Societies, and (3) Area FO, Sabak Bernam; 2,047 farmers through 32 Farmers' Units and 12 Agro-business Cooperative Societies.

Farmers' participation to Area FO starts in attending the general meeting at each Farmers' Unit once a year. In this general meeting, representatives are selected and sent to the representative meeting in which around 10 Board of Directors are elected in each year. The Board of Directors is the decision-maker in terms of policy and financial measures. The management of Area FO is guided by these decisions.

The management of an Area FO consists of a (General) Manager and Assistant Section Heads, all of whom are FOA officers seconded. The number of seconded FOA officers is usually eight to ten. Area FO has its own staff under these officers, providing with clerical work and labour. Activities and division of work may be summarized as follows:

Organization:
: Registration of member farmers. Supervision of Farmers' Units.

Credit:
: Credit facilities with its own funds from members' shares and from business profit, in the form of agricultural inputs (maximum amount: M$1,000 and interest rate: Tanjong Karang FO; 6 % per season, Sabak Bernam FO; 8% per annum, Pasir Panjang FO; no system).

Agro-business:
: Selling agricultural inputs (FO members have a discounted price of around 5% less). Wholesale of consumer commodities consisting of milk, suger, rice, flour and cooking oil (Tanjong Karang FO only). Retail of consumer goods (Sabak Bernam FO only). Transportation services with lorries.

Special Projects:
: Paddy Mini-estate (refer to Annex E)
: Vegetable Mini-estate
: Oil-palm nursery
: Distribution of fertilizer subsidy

Apart from these business activities, lower level units of Area FO have been inactive. The roles of Farmers' Units are either purchasing agricultural inputs through Area FO or selling paddy through active Agro-business Cooperative Societies. Active Agro-business Cooperative Societies are seen only when they are nominated as LPN agents for purchasing paddy.

3.7 Organization and Management

3.7.1 Operation and maintenance staff of DID

All the PBLS facilities have been constructed by the Federal DID staff with Federal funds. Once completed, they are handed over to the State DID for operation and maintenance. In case of irrigation facilities, it is normally after two seasons of defects and liability period from the completion. The situation of handing over as of the end of second season in 1986 is as follows:

Already handed over :
Sawah Sempadan, Sungai Burong, Sekinchan, Sungai Leman, Pasir Panjang, and Sungai Nipah
Not yet handed over :
Panchang Bedena and Bagan Terap

Operation of irrigation facilities in the last two compartments has already started with the State DID personnel, prior to the official verification.

The State DID has its Headquarters at Shah Alam and the State Director is the head. Principal office in the PBLS area is located at Kuala Selangor where the Senior Engineer is stationed. In addition to this principal office, the State DID has two offices at Tanjong Karang and Sungai Besar. The head of each office is the Engineer who administers the irrigation area as well as drainage area. Figure 22 shows an outline of organization under the Senior Engineer, Kuala Selangor. His staff number around 600 persons including departmental labourers in the field.

The head of the irrigation staff is the Chief Irrigation Inspector directly under the Senior Engineer, Kuala Selangor. He is stationed at the Tanjong Karang DID office, but maintenance support and administrative control are provided from the Engineers, Tanjong Karang and Sungai Besar. Personnel management of the irrigation staff is also undertaken by these Engineers. The Senior Engineer is responsible for policy making in irrigation water management, and enforcement is carried out by the Chief Irrigation Inspector. Distribution of water from the source is also entrusted to the Chief Irrigation Inspector.

Of 600 persons of the State DID in the PBLS area, nearly 150 are the irrigation staff. There are eight irrigation compartments in the PBLS area, in two groups: Sawah Sempadan to Sungai Leman, and Pasir Panjang to Bagan Terap. Each of the compartment group is administered by the Engineer, Tanjong Karang or Sungai Besar. Under each Engineer, one post of the Senior Irrigation Inspector has been approved by the State Government; however, as the arrangement of an appropriate personnel has been failed, only one post of Sungai Besar is filled at the moment. As a result, the Chief Irrigation Inspector supervises upstream compartments from Sawah Sempadan to Sungai Leman, and the downstream compartments are controlled by the Senior Irrigation Inspector, Sungai Besar.

The irrigation staff in each irrigation compartment consist of one Irrigation Inspector, two to four Irrigation Overseers and a force of irrigation gatekeepers and a few drainage gatekeepers. Operation of irrigation facilities is carried out by irrigation gatekeepers under orders of the Irrigation Overseer who is instructed by the Irrigation Inspector. Maintenance work of facilities is usually done by contractors except for departmental machinery work. Irrigation staff, especially Irrigation Overseers, supervise these contract works.

The other irrigation staff are: BRH team (one special-grade Irrigation Overseer, two gatekeepers, one operator, one greaser, two drivers and three labourers; under the Chief Irrigation Inspector), Water Management Extension Pilot Project team for TASB4 (one Engineer, one Irrigation Inspector, one Irrigation Overseer, one gatekeeper and two labourers; under the Senior Engineer), two operators and two greasers in Bagan Terap pumphouse (under the Irrigation Inspector, Bagan Terap), two secondary canal gatekeepers (under the Irrigation Inspector, Panchang Bedena), two operators for the Tengi Headworks and Spillway (under the Irrigation Inspector, Sawah Sempadan), and one operator for the Haji Dorani Spillway (under the Irrigation Inspector, Panchang Bedena).

The organizational structure and staffing pattern of the irrigation staff are summarized in Table 13 and Fig. 22.

3.7.2 Water supply procedures

The water supply schedule is determined first at a meeting of the

Paddy Planting Schedule Committee chaired by the Project Director of PBLS. Attendants at the meeting are mostly the members of the Implementation Committee. Out of the irrigation staff, the Chief Irrigation and Senior Irrigation Inspectors attend together with the Senior Engineer with a draft time table for water supply.

Irrigation staff usually have a preparatory period of one month after the announcement of the schedule. During this period, their activities are concentrated on inspection and repair of the irrigation system. Although attendance at the following meeting is of importance, priority is placed on such preparatory work.

a. DID internal meeting
b. DICPLC meeting
c. AICPLC meeting
d. Meeting with all the Ketua Bloks in PBLS Area (see Annex E)

In each irrigation compartment, the DID irrigation staff alone operate the irrigation system. Before water supply, the Irrigation Inspector has to make sure that the water level in the Main Canal be adequate. If the water level is lower than FSL, the Irrigation Inspector informs the Chief or Senior Irrigation Inspector to get instructions. If water level is high enough, instruction is given to Irrigation Overseers to instruct gatekeepers to open the gates of offtakes. After the water supply started, Irrigation Overseers inspect every tertiary canal to look into the water level. The Irrigation Inspector carries out spot-checks, according to reports from his subordinates. If the water level in tertiary canals is not enough, the Irrigation Inspector directs Irrigation Overseers to instruct gatekeepers to operate the gates of offtakes. All these adjustment measures are taken in consultation with the Chief or Senior Irrigation Inspector. At the final stage of water supply, the Irrigation Inspector gives orders to Irrigation Overseers to instruct gatekeepers to close offtake gates, for meeting the scheduled closing date. The Irrigation Inspector has to make sure that all the offtakes are closed. After he confirmed this, he directs Irrigation Overseers to instruct drainage gatekeepers to open the drainage control gates. The Chief and Senior Irrigation Inspector look after the overall water supply situation throughout the areas in charge, respectively. The Chief Irrigation Inspector also controls the staff for BRH, cross regulators and spillways.

4. EXISTING WATER-RELATED PROBLEMS

4.1 Water Resources

4.1.1 Recession in the runoff of the Bernam river

(1) Basin rainfall

The annual rainfall at three representative stations in the Bernam river basin was used to study the changes in rainfall and runoff in recent years. Average annual rainfalls as shown in Fig. 23 indicate that annual rainfall has apparently decreased since the middle of 1970s. The average rainfall at the above three stations was 2,350 mm for the 10 years from 1974 to 1983, but 2,900 mm for the 13 years from 1961 to 1973; a decrease of about 550 mm or 19% in the recent 10 years.

(2) Runoff of the Bernam river

The runoff of the Bernam river at the SKC bridge station has also decreased in recent years. The past five-year thru-mean of runoff was calculated for the same periods as the rainfall as shown in Fig. 23. The changes in runoff were quite similar to those in the basin rainfall. The average runoff at the SKC bridge station was 1,150 mm for the recent 10 years from 1974 to 1983, and 1,820 mm for the 13 years from 1961 to 1973. The runoff has decreased about 670 mm or 37% in the recent 10 years, compared with the average annual runoff for the 13 years from 1961 to 1973.

It is obvious that the recession in the runoff is mainly due to the decrease in the basin rainfall. Recession in runoff is not peculiar to the Bernam river basin. A similar recession has been noted in the runoff of rivers in North Sumatra as shown in Fig. 24.

4.1.2 Function of the Tanjong Karang Swamp

It had previously been considered that the Swamp made an important contribution as a water source to the project area when the runoff of the

Bernam river becomes less than the project requirements, and that the Swamp would act as a storage reservoir for the project area, the extractable water being stored in the upper layer which is computed to hold 148 million cu.m (120,000 acre-ft) of live storage.

The function of the Swamp was examined through various investigations and studies, but these all showed that its function was extremely small in the dry months. It is concluded that the function of the Swamp as a water source for the project should be neglected.

(1) The relationship between rainfall and the groundwater level

A line of 1 km long and perpendicular to the Main Canal was cleared through the swamp forest, and three sets of water level recorders, two gauging staff and an automatic rain gauge were installed. Continuous records of both rainfall and groundwater table at five points on the line were obtained over five months from August to December, 1986. The results of observations are shown in Fig. 25.

From the above observations, it may be seen that there is no relationship between the groundwater level in the Swamp and the water level in the Main Canal. The changes in groundwater level are simply influenced by rainfall, while the water level in the Main Canal fluctuates depending on the water balance in the Main Canal. It is also noticeable that the groundwater level is always higher than the water level in the Main Canal. It is impossible therefore that the water in the Main Canal could intrude into the Swamp.

The relationship between rainfall and the groundwater level was also examined. In dry months, the groundwater level was constant and not affected by rainfall. It was more than 30 cm below the ground surface. In September and afterward, the groundwater level rose sharply after rainfall. It closely corresponded to the rainfall within a short time lag of about one hour. The groundwater level reached the ground surface twice during the observation period. Table 14 summarizes the changes in groundwater level after the heavy rainfall of more than 20 mm. The increase in the groundwater level was about three times bigger than the depth of rainfall. These findings indicate that rainfall in the dry season is retained in pore spaces of the peat soil layer. It never reaches the groundwater table. The pore spaces are gradually filled with rain water in the beginning of the rainy season. After further rain, the groundwater level rises sharply. If the rain is heavy enough, the groundwater level reaches the soil surface and runoff starts.

If no rain follows, the groundwater level gradually decreases. The daily rate of decrease in groundwater level was examined at the four points where the water level recorders were installed. The groundwater level decreased daily by 9 to 13 mm, 11 mm on average, as summarized in Table 15. While the groundwater level rises 3 mm with the unit rainfall of 1 mm, the above figure of 11 mm means that the free surface water decreases by 3.7 mm. This is more or less the value of evapotranspiration from a swamp forest. Seepage from the peat soil layer would be negligible throughout a year.

(2) pH value of irrigation water

The pH value of the water was measured at four points along the main conveyance system together with that of the swamp water. The pH value of the water in the Swamp was consistently around 3.7 in the dry season, 1986. The water in the main conveyance system becomes gradually more acid towards the end of the system as summarized below.

Location	pH value
BRH	6.7
Tengi Headworks	6.3
Middle of the Main Canal	6.0
Upstream of Cross Regulator	5.9

This is because water diverted at BRH is mixed with the swamp water in the main conveyance system. In order to estimate the quantity of the water derived from the Swamp entering the main conveyance system, the water was sampled both at the intake of BRH and the Tengi Headworks in July 1986. The sampled water was mixed with the swamp water at various mixing ratios, and the pH value of the mixed water measured. The relationship between the mixing ratio and pH value is shown in Fig. 26.

It may be seen from the figure that, between BRH and the Tengi Headworks, the amount of water derived from the Swamp is equivalent to about 5.5% of the amount of water diverted at BRH. Between the Tengi Headworks and the existing cross regulator, 2.7 to 7.9% of the water in the Main Canal comes from the Swamp. It is roughly estimated that water derived from the Swamp to the main conveyance system in the dry season is equivalent to about 11 % of the diverted water at BRH.

(3) Discharge measurement in the existing drain in the Swamp

Discharge in the Swamp was measured in the existing drain provided along the timber transportation road. The drain is about 12 km long, 2.5 m wide and 1.5 m deep at the measuring site. In order to know the minimum amount of seepage from the Swamp, the measurements were carried out several times during continuous no rain days. The minimum flow was 0.025 cu.m/s, equivalent to 2.1 lit/s/km. It is judged that the amount of seepage flow from the Swamp is very limited in the dry season. Even if the water source of the Swamp were developed by digging drains, it would be necessary to construct about 476 km of drains to extract 1.0 cu.m/s. This would be uneconomical and unfeasible.

(4) Estimate of seepage flow from the Swamp

In order to know the coefficient of permeability of the peat soils, permeability tests were carried out at eight points in the Swamp. At each point, a hole was dug by a hand auger and cased by a PVC pipe. The groundwater in the hole was drained and the time taken for the groundwater to recover its original level was measured. The coefficient of permeability of peat soils was estimated based on the observed data. It ranges from 1.2×10^{-3}cm/s to 1.2×10^{-4} cm/s, an average of 2.5×10^{-3}cm/s.

Seepage flow from the Swamp can be estimated by applying the Hooghoudt's formula as shown in Annex A. It was estimated at 0.77 lit/s/km for the main conveyance system and 3.56 lit/s/km for the existing drain. As a result, the seepage flow from the Swamp was estimated at 131 lit/s in total for the dry season in 1986 as shown below.

Seepage flow along the Main Canal :		
	0.77 lit/s/km x 36 km =	28 lit/s
Seepage flow along the Feeder Canal and Tengi river :		
	0.77 lit/s/km x 39 km x 2 =	60 lit/s
Seepage from the existing drain		
	3.56 lit/s/km x 12 km =	43 lit/s
	Total seepage flow	**131 lit/s**

4.2 Paddy production

4.2.1 Low level of production

The paddy production in the project area is still low against the target of PBLS. From agricultural viewpoints, two factors have adversely affected the paddy production in the project area: low cropping intensity and low unit yield.

Annual paddy cropped area is dependent on the intensity of cropping. In the PBLS area, double cropping has been promoted. However, the cropping intensity has never attained 2.0. Delay in cropping in one season greatly affects the cropping schedule for the succeeding season. In six compartments except for Sawah Sempadan and Sekinchan, one to two crop seasons were missed for four years from 1983 to 1986. The present cropping intensity is about 1.77 for the whole project area. As a result, the cropped area has not covered what is required for the target of paddy production under PBLS.

The average unit yield of paddy in the past five years from 1981 to 1985 was 2.89 ton/ha in the first season and 3.35 ton/ha in the second season. Under PBLS, the target yield was projected at 4.7 ton/ha for the off-season crop and 4.4 ton/ha for the main season crop. It has recently been revised in line with the progress of PBLS. The newly projected yield for 1990 is 3.7 ton/ha in the first season and 3.8 ton/ha in the second season. There are several reasons why the present average yield is below these project levels. One is to exist organic acid soils such as the Brown Clay Soils and the Organic Clay and Muck Soils, in part of Sungai Burong, Sungai Leman and Pasir Panjang. As no soil improvement work has been practiced, these areas are low in soil productivity for rice cultivation. Another reason is derived from the prevailing traditional method of transplanting. In this method, the transplanting is done twice; the first transplanting is 10 days and the second one 40 days after seeding. The second transplanting is carried out when seedlings are in the initial tillering stage with around 50 cm in height. Since the supply of irrigation water is unreliable, farmers try to keep water depth as high as possible against the water shortage. The traditional method is suitable under deep water condition. However, the number of tillers is considerably less than that of an ordinary transplanting method in which seedlings are transplanted only once. As a result, the yield of paddy decreases. Despite high soil productivity in the downstream compartments, Sungai Nipah to Bagan Terap, the present yield is low by the effect of traditional transplanting method.

4.2.2 Change in farming practices

Recently, direct seeding methods have been spreading over the project area. In the first season of 1986, 35% of the paddy cultivation area was under direct seeding methods. The introduction of direct seeding methods requires a lot of improvement in the present irrigation facilities. The capacity of tertiary canals is designed to meet the requirements for the transplanting method. Once the direct seeding methods are introduced, the irrigation water has to be supplied for presaturation within a shortest period in order to realize an even germination of seeds and an effective control of weeds. The peak water requirement is increased during presaturation with the introduction of direct seeding methods. If farmers start paddy cultivation all at once following the fixed irrigation schedule, the flow capacity of tertiary canals is insufficient to meet the increased peak water requirement. The fixed irrigation schedule proposed by PBLS would not be able to adhered to.

More precise land leveling is necessary for the direct seeding methods than that required in the transplanting method. If the land leveling is not properly done, it will lead to unreliable and uneven germination of seeds. The necessity of land leveling has been increased with the introduction of direct seeding methods. Although the State DOA has emphasized the land leveling work through the Field Improvement Scheme, the number of farm lots on which its fund has been allocated is still limited. In order to promote the direct seeding method, land leveling work should be promoted in the project area.

4.2.3 Farm mechanization

The present labour force is 3.2 per farm household. Since the end of 1970's, young generation has found jobs other than agriculture. Young people have migrated to urban areas such as Kuala Lumpur, Klang and Petaling Jaya for study or work. As they are still registered as family members in the PBLS area, actual labour force is less than the figure and deteriorates its quality.

Mechanized farming has been spreading over the project area in the course of the above change in quantity and quality of manpower. It is accelerated owing to difficulties in hiring the required labour for farming as well as high labour cost in the project area. Land preparation and harvesting have already been fully mechanized. The existing machinery in the project area comprise 113 tractors, 65 harvesters, 113 rotavators and 52 slashers. Most machinery are operated by private owners on a contract basis. If the paddy cropping is practiced following the schedule set by PBLS, the required machines would be 190 tractors, 67 harvesters, 143 rotavators and 53 slashers as shown in Table 16. The number of existing tractors and rotavators is definitely insufficient. This also becomes one of the reasons why delay in cropping occurs.

4.3 Structural Defects of Project Facilities

4.3.1 Bernam River Headworks

According to the operation manual, a maximum of 28.3 cu.m/s (1,000 cusec) can be diverted to the Feeder Canal when the water level upstream of BRH is kept at FSL +9.45 m (+31.00 ft). However, it has been recognized since long ago that the design discharge cannot be taken even when the water level is kept at FSL. A hydraulic model test was carried out to investigate the reasons for not achieving the design discharge in the Feeder Canal in 1982. The test showed that the minimum river discharge that would give 28.3 cu.m/s (1,000 cusec) diversion would be about 37 cu.m/s (1,300 cusec), and the corresponding river head should be +9.63 m (+31.60 ft).

The amount of discharge diverted to the Feeder Canal has been measured by DID weekly in the Feeder Canal downstream of the intake of BRH. As pointed out above, the diverted discharge cannot reach the designed discharge even if the water level upstream of BRH is kept at FSL, 9.4 m (31.0 ft). The relationship between the diverted discharge and the water level upstream of BRH is shown in Fig. 27. In order to grasp the flow conditions at the intake, a trial operation of the existing gates was carried out. Three sets of radial gates on the weir were opened and six sets of intake gate were closed. As the water level upstream of BRH became lower and lower, a lot of rubbish and pieces of wood deposited in front of the screens came into view. These had prevented the flow into the intake. All rubbish and wooden pieces were cleared away and the screens were removed. The flow pattern to the intake changed dramatically. It always showed a perfect overflow pattern and a large amount of water entered into the intake.

The diverted discharge measured without screens is also shown in Fig. 27. Close correlation is found between the water level and the diverted discharge. If the water level is at the present FSL, 9.4 m (31.0 ft), the diverted discharge is 26.5 cu.m/s. As mentioned in Section 5.3, the revised design discharge is 30.6 cu.m/s. This can be diverted, if the water level is kept at 9.6 m (31.4 ft).

It is important to maintain the screens clean. The intake gates are necessary to be closed for cleaning screens. The operation of intake gates are now carried out manually by the limited number of staff. If the gates are under water, the operation becomes very difficult. This prevents the frequent and timely operation. The existing screens are old and damaged, and there is no operation deck.

4.3.2 Main Canal

(1) Insufficient flow capacity of the Main Canal

The flow capacity of the Main Canal is insufficient. Even when sufficient water is taken at the intake of BRH, enough water cannot be conveyed to downstream. The water level and discharge in the Main Canal just downstream of the Tengi Headworks are compared as shown in Fig. 28. As the section is influenced by a back water effect, no distinct relation is found between the water level and the discharge. The figure shows, however, that the maximum flow capacity of the Main Canal is more or less 14 cu.m/s (500 cusec).

The present flow capacity of the Main Canal was also estimated by means of a back-water calculation. For the calculation, the latest result of cross sectional survey was used and a Manning's coefficient of roughness of 0.03 was adopted. The present flow capacity was calculated in all reaches of the Main Canal between the Tengi Headworks and the existing cross regulator at Panchang Bedena. The results of the calculation are summarized below and illustrated in Fig. 29.

Location		Present Capacity (A) (cu.m/s)	Design Discharge (B) (cu.m/s)	Ratio (A/B) (%)
Upstream	: Tengi H/W to TASB 13	15.0	27.6	54
	: TASB 13 to TASL 10	14.0	23.0	61
Middle	: TASL 10 to TAPP 12	12.6	18.3	69
Downstream	: TAPP 12 to TASN 18	8.8	16.4	54

The present flow capacity of the Main Canal is insufficient in all reaches of the Main Canal. It is 54 to 69% of the revised design discharge.

There are three timber bridges and one DID's concrete bridge crossing the Main Canal between Sungai Burong and Sungai Leman. These bridges prevent the flow in the Main Canal. Moreover, the water course of the Main Canal is used for transporting timber. The timber is stored in front of the bridges and obstructs the flow in the Main Canal.

(2) Leakage of water from the Main Canal

Much leakage of water was found in many places along the Main Canal. Leakage was significant especially from old structures which are not used at present. The leakage had been recognized for a long time. However, it was assumed to be negligible and left as it was.

Significant leakage was found at 33 places along the Main Canal between Sawah Sempadan and Sungai Nipah as shown in Fig. 30. Discharges were measured just downstream of such places of leakage. The results of measurements are shown in Table 17. The total amount of leakage was 7.9 cu.m/s (280 cusec), which corresponded to 28% of the present design discharge for the project area. It is noted that this amount did not include any spilled water from structures, as the water level in the Main Canal was low when the measurement was carried out.

It was found that there were five 4-inch PVC pipes and one culvert installed under the embankment to divert the canal water into drains. The leaked water is used for domestic purposes by the people living along the drains. The leakage cannot be simply stopped, because this would lead to social problems.

(3) Cross regulator

The existing cross regulator at Panchang Bedena restricts the flow in the Main Canal. Its function is to regulate the water level in the Main Canal. The water level is controlled by a sluice gate placed on a fixed weir. The design discharge downstream of the cross regulator is 8.8 cu.m/s (310 cusec) at present, and the allowable head losses at the regulator are limited to be 0.02 m (0.06 ft). However, when the discharge becomes about 3.7 cu.m/s (130 cusec), the head losses exceed 0.02 m (0.06 ft), even when the gate is fully opened. Accordingly, the design discharge cannot be passed. This is because the sill of regulator is too high to meet the design discharge and hydraulic losses at the regulator are excessive.

(4) Insufficient height of canal embankment

The height of the existing banks in the lower reaches of the Main Canal is about 15 to 50 cm lower than the designed height. One bank of the c-c line is the asphalt paved road and firm enough. However, the opposite bank is small and its height is insufficient to maintain the proposed FSL. Water overtops at five places on the bank, when the water level is near to FSL. This should be improved by raising the banks to provide allowing a freeboard of 60 cm above FSL.

4.3.3 Bagan Terap pumphouse

The Bagan Terap pumphouse commands an area of 1,200 ha in Bagan Terap and 320 ha in Sungai Panjang. The maximum water requirement for these areas is 3.55 cu.m/s (125 cusec). The Bernam river water is taken through the intake channel and pumped up to the irrigation canal. The existing pumps and diesel engines have been in operation for 23 years since 1964. Their economic useful life has already passed. Spare parts are difficult to get in the market. One of diesel engines has been left without repair for about one year. The pumping efficiency has decreased to about 70 % of the original one, as shown in Fig. 31. The amount of water delivered from the pumphouse is about 2.5 cu.m/s (90 cusec) with two pumps under full operation.

The Bernam river water carries a suspended sediment load of about 3,500 to 5,000 mg/lit during the high tide and 1,100 mg/lit during the low tide. Silts accumulate severely in both the intake channel and irrigation canal. Desilting work is carried out by two draglines stationed along the intake channel and one excavator along the irrigation canal. The cost for desilting is extremely high. In 1985, about M$50,000 was spent for desilting the irrigation canal alone.

Another problem of the Bagan Terap pumphouse is the intrusion of seawater into the intake channel. The intrusion is significant when the tide is high and the Bernam river flow becomes extreme low. When the gate of the scouring sluice was closed and the water supply from BRH was stopped, the intrusion of seawater became even more serious. The domestic water to Sungai Besar town areas is also taken from the intake channel by the Selangor State Waterworks Department. Special attention should be paid to intrusion of seawater not only for irrigation use but also for domestic water use.

4.3.4 Tertiary canals

The tertiary canals are made of concrete conduit. The related structures of the tertiary canal are the offtake, check structures, slots and offtake pipes. Structural defects of these structures are summarized below.

(1) Concrete conduit

In order to study existing conditions of the concrete conduit, two canals were selected from each compartment and the elevation of the top of the conduit at each offtake pipe was surveyed. The results of the survey were compared with the design. It was found that most of the concrete conduits were properly constructed as designed. However, the conduits in Pasir Panjang have settled unequally. The conduit leans significantly and there is a difference of up to 5 cm between left and right top of the conduit.

Water leaks from the joints of the conduits. Leakages are found in all compartments. The average number of leak points is about 2 points/km. The amount of leakage is usually bigger than the discharge from an offtake pipe. A lot of water is wasted.

There is much silt and rubbish deposited on the bottom of the conduit. Once rubbish is thrown into the conduit, the rubbish is conveyed downstream and deposited there. The flow in the conduit is greatly influenced by the silt and rubbish. However, it is difficult to remove these from the conduit. The bottom elevation of conduit rises at the point where the canal section is reduced. Water therefore remains in the conduit, even after the water supply is completely stopped at the offtake. This remaining water makes cleaning of the conduit difficult.

With the expansion of direct seeding practices in the project area, the peak water requirement during the presaturation period has increased. The amount of water required for presaturation under direct seeding is 280 mm in depth. It is desirable for farmers to presaturate the farm lot in the shortest period, preferably within 10 days at the longest. This requires the supply of water at a rate of 28 mm/day, which corresponds to 3.24 lit/s/ha. The design discharge of a concrete conduit is based on the traditional transplanting method, i.e. 30 acres/cusec for 20 days. This is equivalent to 20.1 mm/day or 2.33 lit/s/ha. Thus, the flow capacity of a conduit is insufficient to cope with the water requirements of the direct seeding method.

If presaturation for direct seeding is made simultaneously within 10 days in an area commanded by a tertiary canal, the existing conduit should be reconstructed and its flow capacity increased by 1.39 times. In order to make the best use of the present conduit, rotational irrigation should be undertaken. In addition, the flow capacity of the offtake pipe is insufficient to cope with the peak water requirement of presaturation for dry direct seeding. The use of syphons will be imperative during the presaturation period.

(2) Offtake

CHO was originally equipped with vertical and horizontal screens in front of the gate. Weeds and rubbish choked these screens, and it was impossible for gatekeepers to clean them, because the location and shape of screens were not suitable, and no operation deck was provided for removing weeds and rubbish, as shown in Fig. 14. As a result, the design discharge could not be diverted. All the vertical screens were removed in 1984 to 1985. The amount of water that can be diverted has been increased, but the flow of rubbish and aquatic weeds into a tertiary canal has become significant, and has caused new problems. There is a lump of silt in front of some offtakes. This was placed during construction and has not been removed. Due to this, the flow capacity is still insufficient even after the removal of screens.

It was designed that the water should be measured at the head of tertiary canal. For this purpose, a staff gauge is provided in front of the offtake and water level measuring devices are installed upstream and downstream of the orifice gate. About 16% of the staff gauges cannot be read now. Almost all the water level measuring devices have already been removed or damaged and discharge measurements have not been made by any gatekeeper.

As a trial, both orifice and turnout gates of CHO were operated following the procedures stipulated in the present operation manual. Correct control of discharge could not be performed because of the fluctuations in water level both in the Main Canal and in the tertiary canal. It would be possible to estimate the discharge when both water levels are steady. However, it takes long time to adjust the discharge at CHO to a target amount. Frequent control of gates is necessary to precisely adjust the discharge. Once gates are adjusted to obtain a difference of 6 cm (0.2 ft) in water level between up and downstream of the orifice gate, it would be necessary to wait about two hours until the flow in the tertiary canal becomes steady. Such adjustments have to be repeated at least three times to obtain the targeted discharge. It takes at least six hours to adjust one CHO. This would not be practical for gatekeepers.

(3) Check structure

The crest elevation of check gates is too high to control the water level in a tertiary canal. The functioning of check gates in six compartments was investigated. The results are summarized in Table 18. Out of 199 check gates in total, 51 gates have been removed and seven damaged. The remaining 141 gates or about 71% of the total are still functioning well. Of these 141 check structures, a more detailed survey was made. The gate was put down as low as possible and the top elevation of the gate was measured. The result of survey is shown in Table 19. For 101 check structures, the gates could not be lowered to the bottom of the well chamber. This was because of rubbish, weeds and other materials deposited in the well chamber. The upstream water level of these check structures is backed up too high and enough water cannot conveyed to downstream. This is the reason why many check gates are damaged by farmers or removed by DID.

At present, more than half of the volume of the well chamber is filled with rubbish. Various kinds of rubbish and debris are found in the well chamber. These are silts, weeds, paddy stalks, leaves of banana and mango trees, wooden pieces, stones, pieces of broken concrete, glasses, bags of fertilizer and insecticides, buckets and sometimes snakes. A considerable amount of these are weeds, paddy stalks and soils attached to them. They are thrown into canals by farmers and never come out unless the canal is cleaned by the DID staff.

A check structure is provided with a water level measuring device for estimating discharge. However, almost all of these devices have been removed or are non-functional.

(4) Slot

Most of the slots have already disappeared. Only the slot equipped at the end of tertiary canal still remains. The distance between check structures is so long that the installation of slots is imperative to adjust the water level suitably in all sections of the canal. The effective use of slots should be studied and the suitable location and height of slot should be determined for each tertiary canal.

(5) Offtake pipe

Discharge from a field offtake pipe greatly influences the distribution of irrigation water to each farm lot. The discharge from offtake pipes was measured by filling the water from the pipe into a box and by measuring the time taken for filling it. The box is rectangular in shape and its volume is 72.4 lit. From five compartments, 15 offtake pipes were selected at random and the discharge was measured under various water depth. A summary of measurement is given in Fig. 32. The coefficient of discharge was also calculated as summarized below.

Compartment	Name of Canal	Coeff. of Discharge	Time of Completion
Panchang Bedena	TAPB 1a	0.84	Oct., 1985
	TAPB 1a	0.87	Oct., 1985
Sungai Leman	TASL 1	0.77	Dec., 1983
	TASL 1	0.81	Dec., 1983
	TASL 2	0.74	Dec., 1983
	TASL 2	0.79	Dec., 1983
	TASL 5R	0.76	Dec., 1983
Sungai Burong	TASB 1	0.73	Sept.,1983
Sekinchan	TAS 1	0.84	Aug., 1983
	TAS 1	0.83	Aug., 1983
	TAS 2	0.75	Aug., 1983
	TAS 2	0.81	Aug., 1983
Pasir Panjang	TAPP 7	0.82	Sept.,1982
	TAPP 8	0.84	Sept.,1982
	TAPP12	0.75	Sept.,1982

As seen in the above table, the coefficients of discharge vary significantly from a minimum of 0.73 at TASB 1 to a maximum of 0.87 at TAPB 1a. The averaged coefficient of discharge is 0.80. The reason for the variation is not clear. It could be (1) slime inside the pipe, (2) the shape of the entrance to the offtake pipe, (3) distortion of the pipe or (4) errors in measurement.

Assuming that the coefficient of discharge is 0.80, the required water depth to obtain a normal irrigation discharge of 1.07 lit/s for a farm lot of 1.2 ha (3 acres) is calculated at 1.9 cm (0.8 inch) by applying the following equation.

$$Q = C\,A\,\sqrt{2gh}/1000$$

where,
- Q : Discharge (lit/s)
- C : Coefficient of discharge (C=0.80)
- A : Flow area (A=22.1 sq.cm)
- g : Acceleration of gravity (g=980 cm/sec^2)
- h : Water depth (cm)

The discharge from the offtake pipe was calculated under various conditions of water depth as shown below. In order to attain an irrigation efficiency of more than 75%, it would be necessary to keep the water depth less than 3.8 cm (1.5 inches) at each offtake pipe.

Water Depth (cm)	(inch)	Discharge from Offtake pipe (lit/s)
2.5	(1.0)	1.2
3.8	(1.5)	1.5
5.1	(2.0)	1.8
6.4	(2.5)	2.0
7.6	(3.0)	2.2

The location of an offtake pipe (i.e. depth) directly influences the discharge from a pipe. The location of 1,750 offtake pipes on 11 tertiary canals was surveyed. The result of survey is summarized in Fig. 33. The location of a pipe should be at 30.5 cm (12 inches) from the top of conduit. The survey revealed that about 94% of pipes are properly installed within an error of plus or minus 2.5 cm (1 inch). The remaining pipes are installed considerably apart from the designed value. The difference between the maximum and minimum height is 19.7 cm (7.75 inches). Such a discrepancy adversely influences equitable distribution of water. Such offtake pipes should be replaced.

4.3.5 Drainage network

Present drainage problems in the project area are limited to part of the Bagan Terap compartment. Inundation occurs in the depression areas at times of heavy rainfall. The inundation is seen in a lowland area of about 530 ha surrounded by the secondary canal c-c line, cross bund No.1, TABT 3 and TABT 11 in the center part of the compartment, as shown in Fig. 34. Rain water is drained into the main drain along c-c line which is connected with the tidal gate in Sungai Besar. Back-flooding irrigation is practiced in Bagan Terap. As no drainage controls are provided in old drains, the end control gate of the main drain is closed for back-flooding. The main drain is, therefore, filled with water during the planting season. When heavy rain comes, the gate should be opened. However, the gate is seldom opened for fear of a water deficit which may occur afterwards. This causes a local flood in the depressed area. Once the depressed area is flooded, it takes long time to drain the water because the distance from the depressed area to the end control gate is long. The inundation lasts for about one week with a standing water depth of about 0.6 m (2 ft).

A road cross, either a culvert or a bridge, is provided on the main drain. The culverts are old and their dimensions are small compared with the cross sectional area of the drain. They have insufficient flow capacity and prevent the smooth drainage of floods from the depression area. There are seven such culverts on the main drain.

Among the existing end control gates, three gates, No. 28, 29 and 30 as indicated in Fig. 16, are not functioning well. There is a depressed area in downstream of gates, No.28 and 29. The release of water from these gates badly influences the depressed area and the release is not allowed by the people living there. In case of gate No. 30, the downstream drain of about 400 m long has not yet been constructed. This makes it difficult to drain excess water in the vicinity of the northern corner of Panchang Bedena compartment.

4.3.6 Farm roads

With the completion of PBLS, an access path of 1.8 m (6 ft) wide was constructed along the additional drain, and the farm roads are now spaced at an interval of 400 m. The typical layout of farm roads before and after PBLS is shown in Fig. 35 The access to each farm lot has been much improved. About a half of the total number of farm lots in the project area, however, still have no direct access to existing farm roads. The width of access path constructed by PBLS is too narrow to allow the passage of heavy farm machinery. With the increasing need for farm roads, DID has started the improvement of the existing farm road network by widening the access path from the present 1.8 m (6 ft) to about 2.4 m (8 ft) and constructing new roads in addition.

4.4 Water Management

4.4.1 Bernam River Headworks

BRH is properly maintained and all gates and other related facilities are functioning well. The main problems of water management are (1) the constant release of a minimum of 6.2 cu.m/s (220 cusec) water from the scour sluice, and (2) the operation of the intake gates.

(1) Release of a minimum of 6.2 cu.m/s water

The gate of the scour culvert has never been closed and a minimum of 6.2 cu.m/s water has been released throughout a year in order to prevent the accumulation of silt in front of the intake. If the release of water could be stopped to use the water for irrigation at times of water deficit, the water could be counted as an additional water source for the Project.

The original BRH was constructed in 1956. It consisted of a fixed weir with a width of 30 m (100 ft) and a crest elevation set at 25.0 ft, and an intake consisting of six square culverts (1.5 m x 1.5 m or 5 ft x 5 ft) tapping water from the river into the Feeder Canal at 6.7 m (22.0 ft). The level of the upstream apron of the weir was set at 5.5 m (18.0 ft) and that of the downstream one at 5.2 m (17.0 ft). When the original BRH was put into operation, no afflux was noticed and the weir was drowned under all conditions of flow. After the first season, excessive silt was being drawn into the Feeder Canal through the intake, and by 1961 the upstream and downstream river beds of the weir had risen from 5.5 m (18.0 ft) and 5.2 m (17.0 ft) to about 7.0 m (24.0 ft). This silting extended for a considerable distance both upstream and downstream reaches of the weir. It was not known why there was no afflux at the weir and the reason for the excessive accumulation of silt.

In order to find means of preventing excessive silt being drawn into the intake and to enable the diversion of river flow up to 28.3 cu.m/s (1,000 cusec) into the intake, hydraulic model tests of the weir were carried out in 1964. Various devices were tried to induce the accumulated silt in the vicinity of the intake to flush over the weir. Many methods did not prove effective at all. The raising of the invert of the intake and FSL in the river, however, showed some improvement over the others, and finally the following solution was recommended:

a. to provide the weir with three radial gates to raise the water level in the river to 12.5 m (31.0 ft);

b. to raise the invert of the sill of intake with its axis in line with the centre line of the river; and

c. to provide three port hole openings 0.9 m x 0.9 m (3 ft x 3 ft) square on the vertical side of the intake culvert nearest the river and evenly spaced along the barrel. The downstream end of the culvert is to be opened on the downstream side of the weir.

It was also recognized that the amount of silt drawn in was further diminished if uniform scour was produced around the inlet of the intake by adjusting the spacing and size of the scour ports. Various sizes, positions and numbers of scour ports were tried out, and the final acceptable shape and arrangement were adopted in the present BRH. The constant flushing discharge through the scour culvert during dry weather flow was found to be 6.2 cu.m/s. Since then, the gate for the scour culvert has been fully opened and a minimum of 6.2 cu.m/s of water has been released throughout the year.

Concerning the accumulation of silt in the vicinity of the intake, a hydraulic model test was again carried out in 1982, and a quantitative study of silt in the Feeder Canal was carried out with three river discharges of 14.2, 28.3 and 34.0 cu.m/s. The amount of sediment being brought into the Feeder Canal and also the amount that was brought to the downstream reach of BRH through scour sluice was simulated for the respective river discharges. The results of the hydraulic model test are summarized below.

Discharge		Sediment (mg/lit)		Proportion
cu.m/s	(cusec)	Feeder Canal	Scour Culvert	F/C : S/C
14.2	(500)	*	*	-
28.3	(1,000)	72	665	1 : 9.3
34.0	(1,200)	359	799	1 : 2.2

Remark : * = Insignificant amount of sediment

It is clear from the above table that the silting problem is negligible when the river discharge is less than 14.2 cu.m/s and significant amount of sediment can be flushed out through the scour culvert when the river discharge reaches 28.3 cu.m/s.

According to the data collected at the SKC bridge station, the suspended solids in the river water are under 120 mg/lit when the discharge of the river is less than 20 cu.m/s (710 cusec), as shown in

Fig. 9. The result of sedimentation analysis carried out during low flow period in August 1986 shows that suspended solids contained in the river water at BRH is 123 mg/lit. From these figures, it is concluded that no silting problem will occur during low flow of less than about 20 cu.m/s, even if the scour gate is closed.

From these facts, it is judged that the gate of the scour culvert could be closed when the river discharge becomes less than 20 cu.m/s and the released water of 6.2 cu.m/s could be used for irrigation as an additional water source. It is proposed to close the gate of scour culvert, if the project requirement exceeds the amount of water diverted at BRH. Even if sedimentation in front of the intake becomes significant with this operation, it could be flushed downstream with periodic opening of both the scour and radial gates. It will be necessary, however, to ensure that stopping the release of water will not cause any adverse effects in the downstream reaches of the Bernam river.

(2) Operation of intake gates

The six sluice gates installed at the intake are almost always fully open in order to divert as much as possible river water to the Feeder Canal. The gates are only closed when there is a possibility of flooding in the project area. This operation role is based on the following assumption. Namely, when the rainfall and the diversion are in excess of demand, the excess water is stored in the Swamp. Conversely, when the above two sources are insufficient in a drought period, the deficit is made by withdrawal of water from the Swamp.

However, it has become clear that the possible amount of withdrawal from the Swamp is extremely small in the dry months and should be neglected as a water source for the project. It is, therefore, proposed that the intake of water at BRH should be so determined as to meet the project requirement and excessive intake should be prohibited to minimize the flow of silt into the Feeder Canal.

4.4.2 Feeder Canal and the Tengi river

In order to monitor the distribution of water in the main conveyance system, DID measures the discharge once a week at the key points of the system. Since the Feeder Canal and the Tengi river pass through the Swamp in most of their reaches, the discharge is assumed to increase downstream. However, past records of discharge measurement show that the downstream discharge is not always larger than the upstream one. In particular the discharge observed upstream of the Tengi Headworks was often smaller than the diverted discharge at BRH in the dry months of 1986. The records of discharge measurement at (1) the Feeder Canal at about 1 km from the JKR bridge downstream, so-called Sungai Dusun station and (2) the Tengi river just upstream of the Tengi Headworks are compared as shown in Table 20. In order to discover the cause of the decrease in discharge, both banks of the channel were carefully inspected. No escape was found along the channel. However, it was noticed that the fluctuation in the water level of the Main Canal greatly influences the discharge of the Tengi river.

The longitudinal sections of the Feeder Canal and the Tengi river are shown in Fig. 36. The hydraulic gradients of the Feeder canal and the Tengi river are 1 to 5,500 and 1 to 10,000, respectively. The gradient especially of the Tengi river is so gentle that the back water effect caused by a change in water level in the Main canal reaches far upstream course of the river. It can be assumed that the river has a certain storage capacity and functions as a storage reservoir. In order to assess the water balance in the Feeder and the Tengi river, a simple model was assumed as shown in Fig. 37. Water enters a reservoir through an inlet and goes out through an outlet. The inlet corresponds to the intake of BRH, and the outlet to the confluence of the Tengi river with the Main Canal. The reservoir has a surface area of about 1.3 million sq.m, assuming the average width of the channel is 35 m and the total length is 38,000 m. The inflow to the reservoir (Q1) is supplied from the intake of BRH. The discharge from the Tengi river to the Main Canal (Q3) corresponds to the outflow of the reservoir. There is another inflow (Q2) to the reservoir. It is seepage or runoff from the Swamp. This is so small in dry months that it is neglected in the model.

The inflow (Q1) is perfect overflow and is not affected by the water level in the reservoir, while the outflow is affected by a change in water level in the Main Canal. If the water level in the Main Canal decreases, the stored water starts to flow out and the discharge through the outlet of the reservoir increases, and vice versa. If the water level in the Main Canal is kept constant, Q3 would be the same as Q1. The relationship between the water level in the Main Canal and discharges Q1 and Q3 are illustrated in Fig. 37. The figure shows that if the water level in the Main Canal is decreasing, Q3 is larger than Q1, and vice versa. If the water level in the Main Canal drops 1 cm per hour, an increase in discharge (q) at the outlet would be 3.6 cu.m/s as calculated below. This would greatly influence to the result of discharge measurement upstream of the Tengi Headworks.

$$q = 1{,}300{,}000 \times 0.01 / 3{,}600 = 3.6 \text{ cu.m/s}$$

The above was confirmed by past records of discharge measurements. An automatic water level recorder is installed at the upstream of the Tengi Headworks. Using the recording sheets from May to September, 1986, daily changes in water level in the Main Canal were examined on the days when the discharge measurement were conducted. Five cases which showed significant daily change in water level were selected for analysis. Every three hours, the water level was read from the recording sheets. The change in discharge (q) was calculated for every three hours. Then, the upstream discharge at the Tengi Headworks was estimated by adding the diverted discharge (Q1) and q. This was compared with the observed discharge (Qo). The result of the analysis is shown in Table 21. The estimated discharges change significantly. It is noted, however, that the estimated discharge at the time of discharge measurement is similar to the observed discharge.

It is considered that discharge measurements upstream of the Tengi Headworks in the past were made at arbitrary points on the line Q3 in Fig. 37. Under these considerations, the followings are concluded.

a. The diverted discharge at BRH is not affected by the water level in the Feeder Canal.

b. The downstream discharge of the Tengi river is greatly influenced by change in water level in the Main Canal.

c. No relationship is found between the diverted discharge at BRH and the downstream discharge of the Tengi river, if both discharges are compared concurrently.

The above facts indicate that it would be impractical to monitor the distribution of water by measuring the discharge in the main conveyance