CHAPTER C4 IRRIGATION AND DRAINAGE PLAN OF POR CANAL REHABILITATION SUB-PROJECT

C4.1 Irrigation and Drainage Plan

(1) Basic Plan

1) Demarcation of Sub-project area

The Sub-project area is selected and determined based on the present land use, topography, and in proportion to the estimated water potential irrigation area in the Moung Russei River basin as a whole with rehabilitation of Bassac reservoir. The area which is lower than EL. 11.0 m is excluded from the Sub-project area due to habitual inundation by high water level of Lake Tonle Sap.

2) Intake for the Sub-project

The existing intake of the Sub-project is located near the proposed headworks of Ream Kon Sub-project on the Moung Russei River. Accordingly, the headworks of the Ream Kon Sub-project can be commonly used by Por Canal Sub-project. The intake of the Por Canal Sub-project is to be reconstructed at the existing site because of severe cracks of concrete, severe corrosion and lack of reinforcing bars which directly affect strength of the structure, no functioning gates. The intake water level is determined at EL. 15.0 m to enable gravity irrigation in all of the Sub-project area.

3) Irrigation water requirement

The irrigation water requirement is assumed as same as that for Ream Kon Sub-project (refer to section C3.1 (2) because they are located close to each other. The peak water requirement for tertiary and field canals is figured out at 2.00 lit/sec/ha in August including irrigation efficiency of 85%.

The unit diversion water requirement is at 1.41 lit/sec/ha for early wet season paddy in April taking into accound the overall irrigation efficiency of 66%

4) Water Balance Study in the Moung Russei River Basin

The water balance study in the Moung Russei River is conducted and described in the previous section C3.1.

(2) Sub-project area and canal layout proposed

The irrigation area of the Sub-project is determined 1,940 ha. The Sub-project area and irrigation canal layout are proposed as shown in Figure C3-1 as well as Ream Kon Sub-project. Two main canals are proposed to irrigate western half and eastern half of the Sub-project area each. General features are summarizes in Table C3-2 together with other Sub-projects. The irrigation area diagram is shown in Figure C4-1.

(3) Drainage plan

In order to protect the Sub-project area from flood from surrounding areas, drainage plan is made as follows.

i) The drainage water from Prek Taam irrigation area is collected by proposed collector drain (CD-1) which flows along National Road No.5. The collector drain meets the western edge of the Sub-project, and flows to north to join existing stream (Stueng Moung).

ii) Another collector drain (CD-2) is proposed to intercept the drainage water from western area located between National Road No.5 and the Sub-project area. The CD-2 flows to north, and finally joins with the CD-1 above.

The general feature of drainage plan is summarized in Table C3-2 together with other Sub-projects. The drainage area diagram is presented in Figure C4-2.

(4) Drainage water requirement

1) Drainage water requirement from paddy field

The unit drainage water requirement from paddy field is calculated at 7.17 lit/sec/ha based on the annual maximum rainfall in the 3 consecutive days at one in 5 years return period. The procedure is described in the previous section C3.2 (8).

2) Drainage water requirement from other type of land

The unit diversion water requirement is calculated for the area less than 100 ha and more than 100 ha. The procedure is described in the previous section C3-2 (8).

Qpeak=0.025m^3/sec/ha from the area less than 100 ha

Qpeak=0.019m^3/sec/ha from the area more than 100 ha

The above unit drainage water requirement is applied to drainage canals and collector drains shown in Figure C4-2

C4.2 Rehabilitation and Improvement of Facilities

The facilities of the Sub-project are divided into 3 categories; (1) headworks (diversion weir and intake(s)) and major related structures, (2) irrigation facilities for main and secondary systems, (3) drainage facilities for main and secondary systems, respectively.

C4.2.1 Headworks and Major Related Structures

(1) Basic Consideration

The Moung Russei Headworks is planned to rehabilitated in the Ream Kon Sub-project as explained in the previous section. In Por Canal Sub-project (1,940 ha), an intake (Q=2.74 m^3/sec) is to be rehabilitated in order to supply irrigation water to this Sub-project.

(2) Por Canal Intake

1) Summary of Design Condition and Result:

Design condition and result for Por Canal Intake are summarized as follows:

Summary for Design of Por Canal Intake

Design Parameter	Condition	Remarks
Design Intake Discharge rate:	Q: 2.74 m^3/sec	Por Canal Sub-project A=1,940 ha
Irrigation Water Level WL1:	WL. 15.50 m	Top of Gate
Irrigation Water Level WL1':	WL. 15.70 m	WL1+max. Overflow depth=0.2m
Elevation at Inlet (River bed):	EL. 11.70 m	
Elevation at Inlet (Intake):	EL. 14.20 m	≥ 14.00 OK
Gate Sill Elevation:	EL. 14.20 m	
Width, Height and Length	Width: 3.5 m Height: 3.6 m Length: 8.0 m (+ Apron length)	Breast wall is installed between EL.15.4 m and EL.17.8 m to prevent The entrance of flood water.
Gate Type and Gate Size, nos.	Slide gate, B:1.0 x H:1.2 x 2 nos.	
Bridge	Total width 4.0 m	

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2) Design Elevation of Intake Inlet:

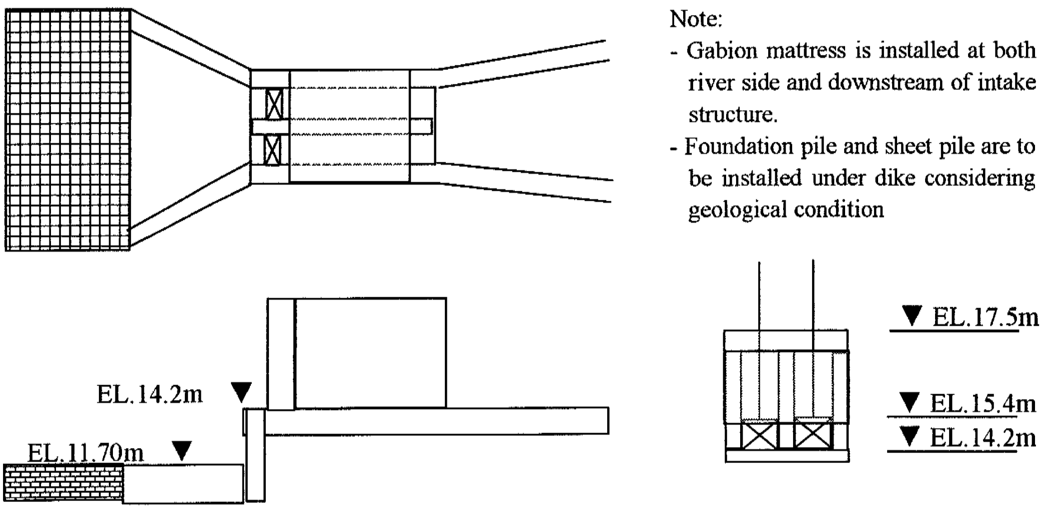
Elevation of an intake is to be designed, considering the design water depth of the both river and intake at inlet, in order to reduce and minimize the entrance of suspended particle (sediment). Water depth at inlet of intake is desirable to be within upper 0.4 of that of river (referring to Japanese design criteria for headworks):

- Water depth at river, H: 3.8 m (= NWL .15.50 m – EL.11.70 m)

  Elevation of intake inlet ≥ NWL - 0.4 x H=15.50 –0.4 x 3.8 = 14.0 m

- Water depth at intake, h: 1.20 m (refer to "rehab. of irrigation and drainage facilities")

  Elevation of intake inlet = NWL- head loss – h = 15.50 –0.1 –1.2 = 14.2 > 14.0 OK



Note:
- Gabion mattress is installed at both river side and downstream of intake structure.
- Foundation pile and sheet pile are to be installed under dike considering geological condition

Prepared by JICA Study Team

Schematic Drawing of Por Canal Intake

3) Design of Gate:

Design of intake gate (gate size and numbers of gate) is given as follows:

(reference: "Booklet of Hydraulic Formula", 1999 edition, Japanese Society of Civil Eng.,pp.255)

- Discharge rate Q (m^3/sec) for 1 gate leaf (N=1):

$$Q = C\,a\,B\,(2\,g\,h0)^{1/2}$$

$$= 0.51 \times 0.56 \times 1.0 \times (2 \times 9.8 \times 1.2)^{1/2} = 1.38\ (m^3/sec)$$

- Discharge rate Q' (m^3/sec) for 2 gate leaf (N=2):

Q' = 2 x 1.38 = 2.76 > 2.74 (m^3/sec) = Design discharge rate OK

- Gate size and number(N): B=1.0m, H=1.2 m, N=2

Where,

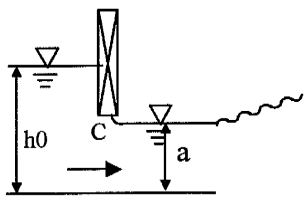
C: coefficient (C=0.51, when a / h0 =2)

a: gate opening (m)

B: width of gate (m)

g: gravity acceleration (m/sec^2)

h0: water depth (river side)



C4.2.2 Irrigation and Drainage Facilities

(1) Irrigation Facilities

1) Design Plan of Irrigation Facilities

Design plan of irrigation facilities is discussed in section C3.3.2 (1).

2) Rehabilitation and Improvement of Irrigation Facilities

a) Design of Irrigation Canal

In the Por Sub-Project, 2 main canals and 12 secondary canals are preliminarily designed. Out of 14 main and secondary canals, 2 main and 8 secondary canals have canal sections to be rehabilitated.

Frequent rehabilitation works have been carried out to the main and some secondary canals. These rehabilitation works were funded by carious sources, such as commune fund, SEILA program, ECOSORN, etc.

In this study, rehabilitation and improvement design includes these canals, because a comprehensive rehabilitation and improvement plan would be necessary to utilize these canals effectively Water levels of the existing canal sections of the Main Canal 1 are calculated by the equation for non-uniform flow condition. Water levels and flow velocity of the other canals are estimated by the Manning's formula.

The following shows the canal dimensions designed preliminarily in this study.

Summary of Irrigation Canal Design

Irrigation Canal	Canal Length				Design			
	Total	Rehab.	New	Design Q(m3/s)	Bottom Width	Height	Left Bank Top Width	Right Bank Top Width
Main Canal 1	6,600	6,600	0	2.74 - 0.21	8.0 m - 4.0 m	3.3 m - 1.4 m	1.5 m - 1.0 m	4.0 m
S1 - 1	1,700	1,700	0	0.25	1.1 m	1.0 m	4.0 m	1.0 m
S1 - 2	1,600	1,600	0	0.24	1.0 m	1.0 m	4.0 m	1.0 m
S1 - 3	600	600	0	0.14	0.8 m	0.9 m	4.0 m	1.0 m
S1 - 4	1,000	1,000	0	0.23	1.0 m	1.0 m	4.0 m	1.0 m
S1 - 5	1,600	1,600	0	0.27	1.1 m	1.0 m	4.0 m	1.0 m
S1 - 6	1,700	1,700	0	0.17	0.9 m	1.0 m	4.0 m	1.0 m
S1 - 7	1,500	0	1,500	0.21	1.0 m	1.0 m	4.0 m	1.0 m
Total of S1	9,700	8,200	1,500					
Main Canal 2	6,100	5,100	1,000	1.20 - 0.28	4.0 m - 2.0 m	1.7 m - 1.3 m	1.5 m - 1.0 m	4.0 m
S2L - 1	500	0	700	0.14	0.8 m	0.9 m	4.0 m	1.0 m
S2L - 2	1,000	0	500	0.18	0.9 m	1.0 m	4.0 m	1.0 m
S2L - 3	1,500	0	700	0.28	1.1 m	1.1 m	4.0 m	1.0 m
S2L - 4	1,600	0	500	0.24	1.0 m	1.0 m	4.0 m	1.0 m
S2L - 5	1,500	0	700	0.28	1.1 m	1.1 m	4.0 m	1.0 m
Total of S2	6,100	0	3,100					

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b) Design of Irrigation Canal Related Structure

Five types of irrigation related structure are preliminarily designed for the Por Canal Sub-project. Types employed are the same as those of the Ream Kon Sub-project.

The following table shows the required types and numbers.

List of Irrigation Canal Related Structures

Structure	nos.	Structure	nos.
Turnout	54	Foot Path Bridge	5
Check	31	Bridge	2
Terminal Structure	14		

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The function and feature of drainage canal related structures are described in the previous section C3.3.2(2) except for a footpath bridge.

Footpath Bridge

Five footpath bridges across the drainage canal MD-1 would be required to enter the Main Canal 2 areas from the main canal 1. A footpath bridge would have effective width of 2.2 m with a parapet.

(2) Drainage Facilities

1) Design Plan of Drainage Facilities

Design plan of Drainage facilities is discussed in section C3.3.2 (2)-1).

2) Rehabilitation and Improvement of Drainage Facilities

a) Design of Drainage Canal

Drainage canals are all new canals. Structural and hydraulic designs are the same as the Ream Kon Sub-project.

The following table summarizes design parameters for drainage canal.

Summary of Drainage Canal Design

Drainage Canal	Canal Length			Design	
	Total	Rehab.	New	Bottom Width	Height
MD 1	9,300	0	9,300	13.0 m - 1.6 m	2.7 m - 0.9 m
CD-1	5,400	0	5,400	8.0 m - 7.0 m	2.6 m - 2.2 m
CD-2	4,600	0	4,600	2.8 m - 1.2 m	1.6 m - 0.7 m
Sub-Total	19,300	0	19,300		
SD-1	1,700	0	1,700	2.2 m	1.2 m
SD-2	1,800	0	1,800	2.6 m	1.5 m
SD-3	1,900	0	1,900	2.4 m	1.4 m
SD-4	1,100	0	1,100	2.0 m	1.1 m
SD-5	1,200	0	1,200	2.6 m	1.4 m
SD-6	1,800	0	1,800	2.6 m	1.4 m
SD-7	1,500	0	1,500	2.6 m	1.4 m
SD-8	1,500	0	1,500	2.6 m	1.5 m
SD-9	1,400	0	1,400	2.2 m	1.2 m
SD-10	900	0	900	2.0 m	1.1 m
Total of SD	14,800	0	13,900		
Grand Total	34,100	0	33,200		

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b) Design of Drainage Canal Related Structure

New secondary drainage canals would require 9 drainage culvers to cross the existing roads in the Main Canal No.1 area.

Type and Number of Drainage Structures

Structure	nos.	Structure	nos.
Drainage Culvert	9		

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C4.3 On-farm Development Plan

In accordance with the topography and the concept mentioned in section C2.3, 42 tertiary blocks are proposed in the Por Canal Sub-project (1,940 ha) in total. The average size of the tertiary block is figured out 46.2 ha. The typical length of a tertiary canal is 1.3 km on average in accordance with the topography. The total length of the tertiary canals is assumed at 55 km in the Sub-project.

The typical length of one water course and number of water courses in the Sub-project are assumed at 360 m and 168 numbers, respectively.

C4.4 Water Management and Operation & Maintenance of Irrigation Facilities

(1) Responsible Organization

The share of responsibility of water management and O&M activities is proposed as follows taking into consideration the policy above, size of the Sub-project, importance of facility for the Sub-project management.

Level / Activities	Moung Russei Headworks*1	Main Canal-1 & Main Canal-2	Secondary canals	Tertiary canals	Water courses	Field canals
Preparation of annual O&M plan	PDOWRAM	PDOWRAM	FWUG	Sub-FWUG	WUG	-
Preparation of cropping schedule	-	-	FWUC/ FWUG	Sub-FUWG	WUG	Household
Operation of facilities	PDOWRAM	PDOWRAM	FWUG	Sub-FUWG	WUG	Household
Maintenance work	PDOWRAM	PDOWRAM	FWUG	Sub-FUWG	WUG	Household

*1 The Headworks is commonly used by Ream Kon Sub-project (refer to C3.5 (1)).

Note O&M Manuals shall be prepared by MOWRAM/PDOWRAM and be hand over to the respective agencies responsible during hand-over period.

Prepared by JICA Study Team

(2) Water Management and Operation

1) Moung Russei Headworks and Main Canal-1 and Main Canal-2

Por Canal Sub-project uses Moung Russei Headworks commonly with Ream Kon Sub-project. O&M of the Headworks is under responsibility PDOWRAM, Battambang.

The required water level at the intake is to be EL. 15.00m which is lower than required water level for Ream Kon Sub-project (EL. 15.50m). Should the water level is kept at EL. 15.5m for at Moung Russei Headworks, the water level is enough high for the Por Canal Sub-project.

The peak diversion water requirement is designed at 2.45 m^3/sec. However, the amount of water taken to the Main Canal-1 is controlled by intake gates in accordance with irrigation service plan which is to be prepared by PDOWRAM Battambang. The intake gates are controlled by readings of staff gauges which are installed upstream and downstream of the intake gates. The gate opening rule shall be set up based on the relationship between water level, gate opening and discharge.

Main Canal-2 branches off from Main Canal-1. The peak discharge of Main Canal-1 and Main Canal-2 are designed at 1.25 m^3/sec and 1.20 m^3/sec respectively. The water taken at intake is to be divided by the two main canals above in accordance with the above proportion. In order to this, H-Q curve shall be developed at the diversion structure. Water supply to the Main Canal-1 and Main Canal-2 shall be continuously made throughout a year except for maintenance period which is set in March and April.

Other water management activity, as listed below is described in the section C3.5 (2).

- Operation of check gates and turnout gates
- Water level in the canal,
- Continuous water flow in the canal,

2) Secondary Canals

The water management in the secondary canal is described in the previous section C2.4 (3)

3) Tertiary Canals

The water management in the tertiary canal is described in the previous section C2.4 (3)

4) Water courses and Field Canals

The water management in the tertiary canal is described in the previous section C2.4 (3)

(3) Maintenance Work

The water management in the tertiary canal is described in the previous section C2.4 (4)

CHAPTER C5 IRRIGATION AND DRAINAGE PLAN OF DAMNAK AMPIL REHABILITATION SUB-PROJECT

C5.1 Water Balance Study in the Pursat River Basin

(1) Necessity of water balance study

The Pursat River has abundant water resource. MOWRAM and PDOWRAM have a plan to develop irrigation development in the Pursat River Basin and Svay Don Keo River Basin. A conjunctive water balance study is executed to confirm the water potential area in the Pursat River and Svay Don Keo River basins in order to confirm the water potential areas in the two rivers.

(2) River Runoff and Water Requirements

The 5-day river runoff in the Pursat River at Damnak Ampil Headworks and that in the Svay Don Keo River at Svay Don Keo Water Level Station are estimated in Volume III Appendix A. Meteorology and Hydrology. The domestic and industrial water, river maintenance flow in the two river basins which were estimated in Volume II Appendix D Irrigation and Drainage are used in the study. The irrigation water requirement is estimated in accordance with the procedure described in the following paragraphs is applied to the two river basins.

(3) Irrigation water requirement

1) Basic conditions

The irrigation water requirement is estimated similar procedure with that described in the section D2.3 in Volume-II Appendix-D Irrigation and Drainage. The basic condition and figures applied to the Pursat River Basin are same with those in the same section D2.3 Volume-II Appendix-D Irrigation and Drainage, and extracted as follows:

i) Meteorological data; average of mean monthly data at Pursat station

ii) Percolation rate 2.5 mm/day based on the observed data

iii) Rainfall data; Daily rainfall data at Boeung Khnar, Pursat, Boeung Kantout stations

iv) Transplanting method is practiced in the Sub-project area

v) Overall irrigation efficiency 66%

- In the tertiary unit, low water loss can be achieved by farmers, so low water loss rate of 15 % is applied, efficiency=100-15 %=85 %
- In the secondary canal, it will take some time to train farmers and to disseminate water technology, so high water loss rate of 15 % similarly with that at current condition is conservatively applied, efficiency=100-12 %=88 %
- In the main canal, as explained in b) above, same efficiency× 100-12 %=88 %
- Overall efficiency can be figured out by multiplying the above efficiency conjunctively. Overall irrigation efficiency = 85 × 88 × 88 % = 65.8 % = 66 %

The irrigation water requirement is estimated based on the proposed cropping pattern described in the Volume-III Appendix-B Agriculture. The sample calculation for wet season paddy is presented in Table C5-1. This table is applied to three Sub-projects in the Pursat River Basin, i.e Damnak Ampil, Wat Long, and Wat Chre Sub-projects.

The above figure is applied to planning of irrigation facilities. On the contrary, in the water balance study, a half of irrigation loss or 17% (=(100-66)÷2) from upstream irrigation area and or a system was conservatively assume to be re-used in the downstream irrigation system. Accordingly, the irrigation efficiency of 83% (=66+17) was applied in the water balance study.

2) Irrigation water requirement for tertiary and field canals

The rotational irrigation proposed for equitable and effective water distribution in the secondary canal command area. Tertiary canal blocks are divided into a few rotation blocks. The irrigation water is supplied to each rotation block in turn. The tertiary and field canals are to have a peak flow capacity to supply water smoothly in turn. The peak water requirement is figured out at 1.91 lit/sec/ha for wet season paddy in August including irrigation efficiency of 85% at tertiary level.

3) Diversion water requirement for headworks, main canal, and secondary/sub-secondary canals

On the contrary, the flow in the headworks, main and secondary canals are almost constant. The 5-day water requirement is calculated in accordance with staggered cropping calendar. The peak diversion water requirement in the Sub-project as a whole is figured out at 1.36 lit/sec/ha by wet season paddy in August taking into account the overall irrigation efficiency of 66%. This number is used for design of the intake, main and secondary canals.

(3) Inventory Irrigation Area

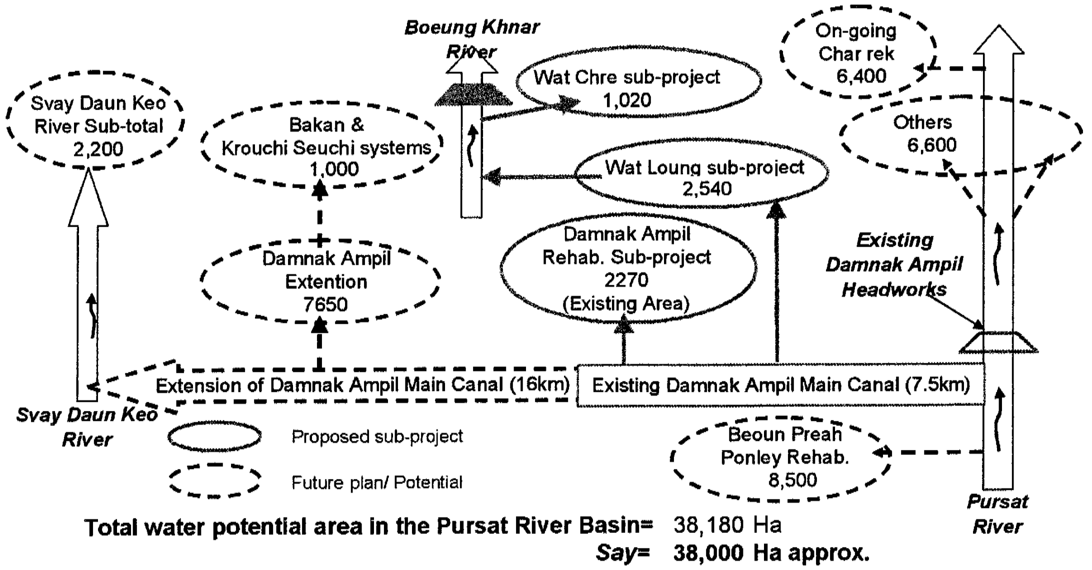
The total area of the existing irrigation systems amounts about 41,000 ha in total in accordance with the JICA Inventory Survey 2006.

(4) Result of Water Balance Calculation

In the water balance study a 5-day river runoff in the Pursat River is compared to water requirements. The following figure shows the results. The result shows the potential irrigation areas in the Pursat River Basin which are to be approximately 38,000 ha in 1/5 year return period of drought. The potential irrigation of the Damnak Ampil Headworks is to be at 14,480 ha[1] in the Pursat River Basin and 2,200 ha in the Svay Don Keo River Basin (supplemental water supply of 1.5 m^3/sec).

[1] Including Damnak Ampil Rehabilitation Sub-project, Wat Loung and Wat Chre Sub-projects, Damnak Ampil Extension area, Bakan and Krouchi Seuchi systems

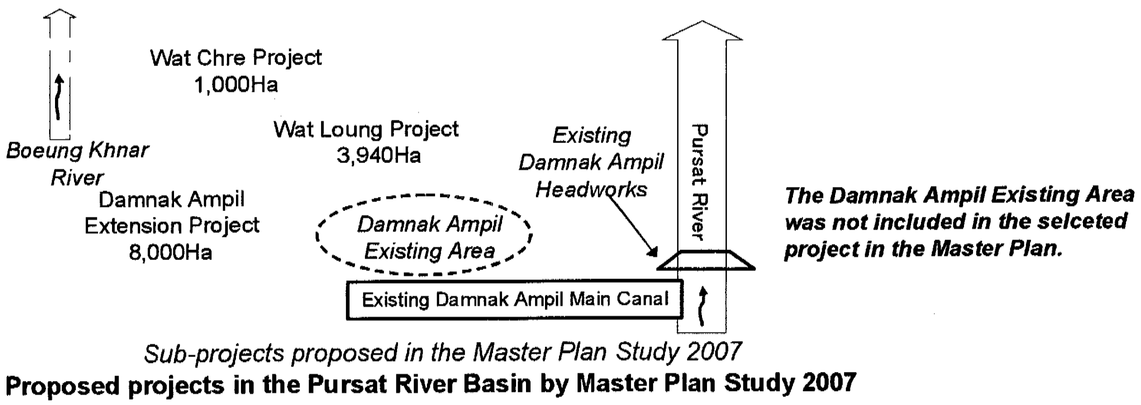
In future, the flow capacity of the Damnak Ampil Main Canal is to be extended up to about 21 m^3/sec in order to irrigate the all command areas.



Potential Irrigation Areas in the Pursat River Basin

C5.2 Change of Sub-project

(1) 3 Sub-projects proposed by Master Plan 2007 in the Pursat River Basin



Proposed projects in the Pursat River Basin by Master Plan Study 2007

3 Sub-projects proposed in the Master Plan Study 2007

The above figure shows the location of 3 Sub-projects which were proposed by Master Plan Study 2007 in the Pursat River Basin. The irrigation water supply was proposed to be supplied by the existing weir and intake (herein after called as the Damnak Ampil Headworks) to these Sub-projects. Of them, Damnak Ampil Extension Sub-project (herein after called as the Extension Sub-project) was proposed to cover 8,000 ha in the downstream of the existing Damnak Ampil Main Canal. The existing Damnak Ampil main canal was considered to be expanded in order to irrigate the Extension Sub-project.

(2) Revision of irrigation areas of Sub-projects

The irrigation area of the Sub-projects is revised by the present study based on the information obtained from ortho-photographs and field survey.

	Damnak Ampil Extension Sub-project	**Wat Loung Sub-project**	**Wat Chre Sub-project**
Area in M/P (ha)	8,000	3,940	1,000
Revised area (ha)	7,650	2,540	1,020
Balance (ha)	-350	-1,400	+20
Reason	Measured by using ortho-photographs (1 to 10,000)	Measured by using ortho-photographs (1 to 10,000) Bakan and Krouchi Seuchi Irrigation Areas are excluded due to high ground surface elevation. These areas can be irrigated by expanded canal from the Damnak Ampil Extension area.	Measured by using ortho-photographs (1 to 10,000)

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The area of Extension Sub-project is measured and revised at 7,650 ha as shown above. Further, the following systems are found to be take out from Wat Loung Sub-project, and considered to be irrigated from the Extension Sub-project taking into account the topography.

- Bakan and Krouchi Seuchi Irrigation Systems: 1,000 ha (as described in the above table)

(3) Present condition of the Existing irrigation area

There is the existing irrigation area located between Damnak Ampil Headworks and the Extension Sub-project. The existing area is measured at 2,270 ha by using ortho-photographs. The existing area was excluded from the Extension Sub-project in the priority Sub-projects since the area was considered developed in 2006. However, the irrigation activity in the existing area is performed in the very limited part due to the following reasons:

- There are three secondary canals but not functioning, need rehabilitation, however, PDOWRAM does not have a plan to rehabilitate these canals in near future
- A FWUC was established but not registered nor active due to few irrigation water supply due to malfunction of the flood gates of the Headworks
- Farmers in the existing irrigation area do not have experience of irrigated agriculture except those along the main canal

In summary, the development in the existing area still requires the rehabilitation of facilities and soft components such as agricultural extension service and FWUC

(4) Flow capacity of the existing main canal

The flow capacity of the existing main canal in the existing irrigation area is checked in the present study. The results are summarized as follows as well as possible measures to increase the flow capacity.

Comparison of flow capacity increase by canal type and canal base width

Description	Case-1 (Existing)	Case-2	Case-3	Case-4
Canal type	Earth	Concrete lined	Earth	Concrete lined
Canal base width (m)	7.0	7.0	11.0	11.0
Roughness coefficient for Manning's formula	0.027	0.015	0.027	0.015
Canal bed slope	0.0002 (1/5000)			
Water depth (m)	1.5			
Canal inside slope	1 to 1.5			
Velocity (m/sec)	0.57	1.02	0.60	1.08
Flow capacity (m^3/sec)	8.0	14.3	12.0	21.5

Prepared by JICA Study Team

Based on the above result, the existing main canal does not have enough capacity to supply irrigation water to the all command areas (14,480 ha). The main canal and related structures which have been rehabilitated in 2006 has to be enlarged further in order to develop the Extension Sub-project.

(5) Change of the Sub-project

The following difficulties are expected if the Extension Sub-project is developed without improvement of the current situation of the Existing area:

- The main canal and structures which have been constructed in 2006 shall be enlarged or improved again in order to flow water for the Extension Sub-project area
- Should the rehabilitation and soft components would not be executed in the existing area, the whole irrigation area of the Damnak Ampil Headworks may not perform smoothly.
- The total area of the existing area and the extension area amounts 14,480 ha, and shares more than a half of the total area of 6 Sub-projects. Due to undeveloped situation of the existing irrigation area, the development in the both existing and extension all at once will have a high risk in on-farm development, water management and agricultural extension.

Based on the above, a phased development is considered in the Damnak Ampil existing area and extension area. The rehabilitation of the existing area is proposed as the first phase. The development of the extension area should be studied based on the performance and outputs of the first phase. Accordingly, the Extension Sub-project is changed to Rehabilitation Sub-project as follows.

- Damank Ampil Rehabilitation Sub-project 2,270 ha
- Wat Loung Rehabilitation Sub-project 2,540 ha
- Wat Chre Rehabilitation Sub-project 1,020 ha

The irrigation water to the above three Sub-projects is supplied by Damnak Ampil Headworks. The detailed reason and water supply route are described in the following sections C6.1 and C7.1.

C5.3 Irrigation and Drainage Plan

(1) Headworks

The existing Damnak Ampil Headworks have been constructed by MOWRAM in 2006, and are used for irrigation water supply to the three Sub-projects. The capacity of intake is designed for 8.0 m^3/sec, and considered to be enough for three Sub-projects provided that the existing automatic flood gates are to be improved so as to keep adequate water level at intake.

(2) Main Canal

The existing Main Canal (7.3 km) was rehabilitated by MOWRAM to have a flow capacity of 8.0 m^3/sec in 2006, and is used by the Sub-project.

(3) The Sub-project area and canal layout proposed

The Damnak Ampil Rehabilitation Sub-project area is determined at 2,270 ha. The diversion water requirement is figured out at 3.09m^3/sec. The area is covered by the existing main canal. The irrigation and drainage canal layout is proposed as shown in Figure C5-1 together with Wat Loung and Wat Chre Sub-projects. General features are summarizes in Table C3-2 together with other Sub-projects. The irrigation area diagram is shown in Figure C5-2A.

(4) Irrigation Area by Portable Pump

The water level at intake is designed at EL.17.0 m. The ground height of upstream area of each secondary canal is higher than water level in the Main Canal. The raising water level in the Main Canal is not economical because it requires raising the headworks by about 1.0 m which requires high cost, and causes inundation in the upstream of the Pursat River. The pump irrigation is inevitable in about 500 ha out of 2,270 ha. Those areas are located along with the Main Canal, and the farmers are now executing pump irrigation at present. Accordingly no serious problems are expected.

(5) Drainage plan

The excess water in the Sub-project area is proposed to be drained by gravity. Field drain collects water from paddy fields and other type of land, and flows into a tertiary drain. Tertiary drains flow into a secondary drain due to the topography. Secondary drains flow to Ou Bakan river. In the northwest border of the Sub-project, a small stream so called as Stueng Chambot is also used as one of the secondary drain.

The general feature of drainage plan is summarized in Table C3-2 together with other Sub-projects. The drainage area diagram is presented in Figure C5-2B.

(6) Drainage water requirement

1) Drainage water requirement from paddy field

The unit drainage water requirement from paddy field is calculated at 6.32 lit/sec/ha based on the annual maximum rainfall in the 3 consecutive days at one in 5 years return period.

$q=0.164\times 10,000\div(3\times 86400)\times 1000=6.32$

where, 0.164 is a probable 3 consecutive days rainfall at Moung Russey station q is the drainage water requirement (lit./sec/ha)

2) Drainage water requirement from other type of land

The Sub-project area consists of paddy field and other type of land which are house yard, upland, right of way of irrigation canals, etc. Those lands are located adjacent to the paddy field, and are assumed at 15% of the paddy field. Those lands do not have storage function as paddy field, and runoff characteristics from those lands are different from that from paddy field. The unit drainage water requirement from those lands is calculated by Rational formula and annual maximum one day rainfall at one in 5 years return period (110 mm/day).

The unit diversion water requirement is calculated for the area less than 100 ha and more than 100 ha.

Qpeak=0.25 m^3/sec/ha from the area less than 100 ha
Qpeak=0.18 m^3/sec/ha from the area more than 100 ha

The above unit drainage water requirement is applied to drainage canals shown in Figure C5-2B.

C5.4 Rehabilitation and Improvement of Facilities

The facilities of the Sub-project are divided into 3 categories; (1) headworks (diversion weir and intake(s)) and major related structures, (2) irrigation facilities for main and secondary systems, (3) drainage facilities for main and secondary systems, respectively.

C5.4.1 Headworks and major related structures

(1) Basic Consideration

In the Damnak Ampil Sub-project, mainly two components are considered to the existing Damnak Ampil Diversion Weir; improvement of the gate system and newly installation of fish ladder on the right bank side of the existing weir.

1) Summary of Design Condition:

Design condition for improvement of the Damnak Ampil Headworks is summarized as follows:

Summary of Design Condition for Improvement of Damnak Ampil Headworks

Design Parameter	Condition	Remarks
Design River Bank Elevation	EL. 19.00 - 20.00 m	around Weir site
Design Irrigation Water Level WL1:	WL. 17.00 m	Top of Gate
	(WL. 17.20 m)	WL1+max. Overflow depth=0.2m
Design River bed Elevation (Upstream):	EL. 12.00 m	
Design River bed Elevation (Downstream):	EL. 12.00 m	
Design Gate Sill Elevation:	EL. 13.50 m	

Prepared by JICA Study Team

2) Condition for flood:

The flood discharge for the Damnak Ampil Diversion Weir was estimated based on the observation data at Bac Trakoun and Khum Viel stations as explained in the section A6.5, in Appendix A, Volume III.

- Flood discharge (Q_F): Q_F =1,560 m^3/sec (equivalent to 100 year return period)

3) Design condition for Irrigation:

The design conditions for Irrigation are summarized as follows:

-Design water level for irrigation (WL1): 17.00 m

(WL1 + overflow depth 0.20 m =17.20 m)

-Design Discharge for irrigation (Q_I1'): 7.93 m^3/sec (See Section C.3.1)

-Design Discharge for maintenance flow (Q_M): 4.48 m^3/sec (for CA=4,480 km^2)

-Design Discharge for domestic, industrial use ($Q_{D\&I}$): = 0.26 m^3/sec (refer to M/P)

(2) Improvement of Gate System

Improvement of gate system for the Damnak Ampil Divrsion Weir is summarized as follows:

- Installation of new hoisting system for assisting flood gate lifting;
- Improvement of bushing of flood gate:
- Installation of new hoisting system for gate lifting assistance:

1) Hoisting system for flood gate:

Flood gate has mainly two objectives, which are controversial, and it is complicated to accomplish both tasks by only counterweight:

- Lifting of gate leaves to maintain water depth for irrigation
- Flap down of gate leaves to discharge flood water

In the improvement works, existing counterweight will be used for flapping down the flood gate, and new hoisting system is proposed to assist lifting of gate leaf after flood events, which is quite difficult to control only by counter weight since it does not allow gate to lift up until water level completely falls down to a certain level. Therefore, a new hoisting system has a clutch system for switching "automatic gate flap down by counter weight" and "motorized mechanical gate lifting". From "flood management" viewpoint, it is very important to switch back to "automatic flap" mode after every "gate lift" event. Image drawings for the improvement works are shown in the following figure.

Summary of Improvement of Damnak Ampil Flood Gate System

Items	Contents	Remarks
Installation of new hoist system (Replacement of present hoist)	7 sets	1 motor-2 drum winch type with clutch for counter weight Local control panels w/ cable network system, Hoist deck Generator 75 kVA Lightening rods with earthing network
Exchange of bushing (Replacement of present bushing)	7 sets	Bushing with larger diameter and oil-less bearing for long durability

Prepared by JICA Study Team

2) Hoisting system for flood gate:

At present, 4 sets of slide gate with dimension of about 2 m by 3.5 m are installed for scouring sluice gate, and they are very heavy to lift up manually. Therefore, new hoisting system with motor is proposed to be installed as follows:

Summary of Improvement of Damnak Ampil Flood Gate System

Items	Contents	Remarks
Installation of new hoist system (Replacement of present hoist)	4 sets	Rack type hoist with motor Local control panel

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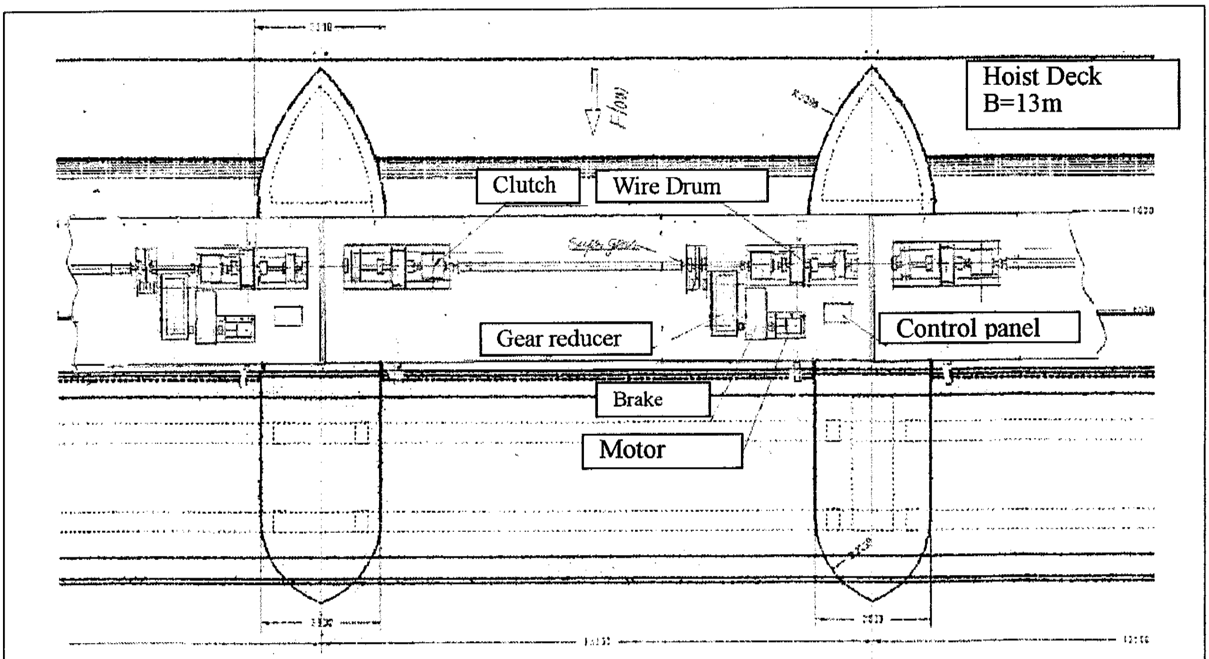
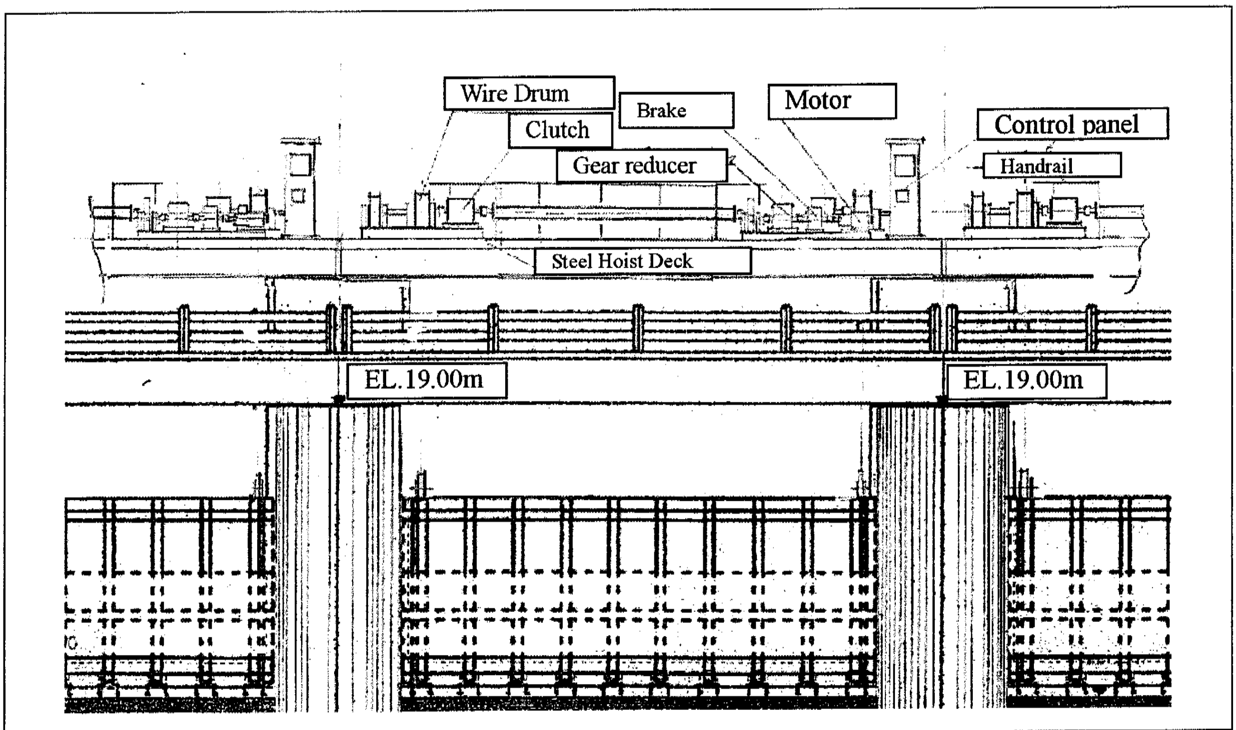
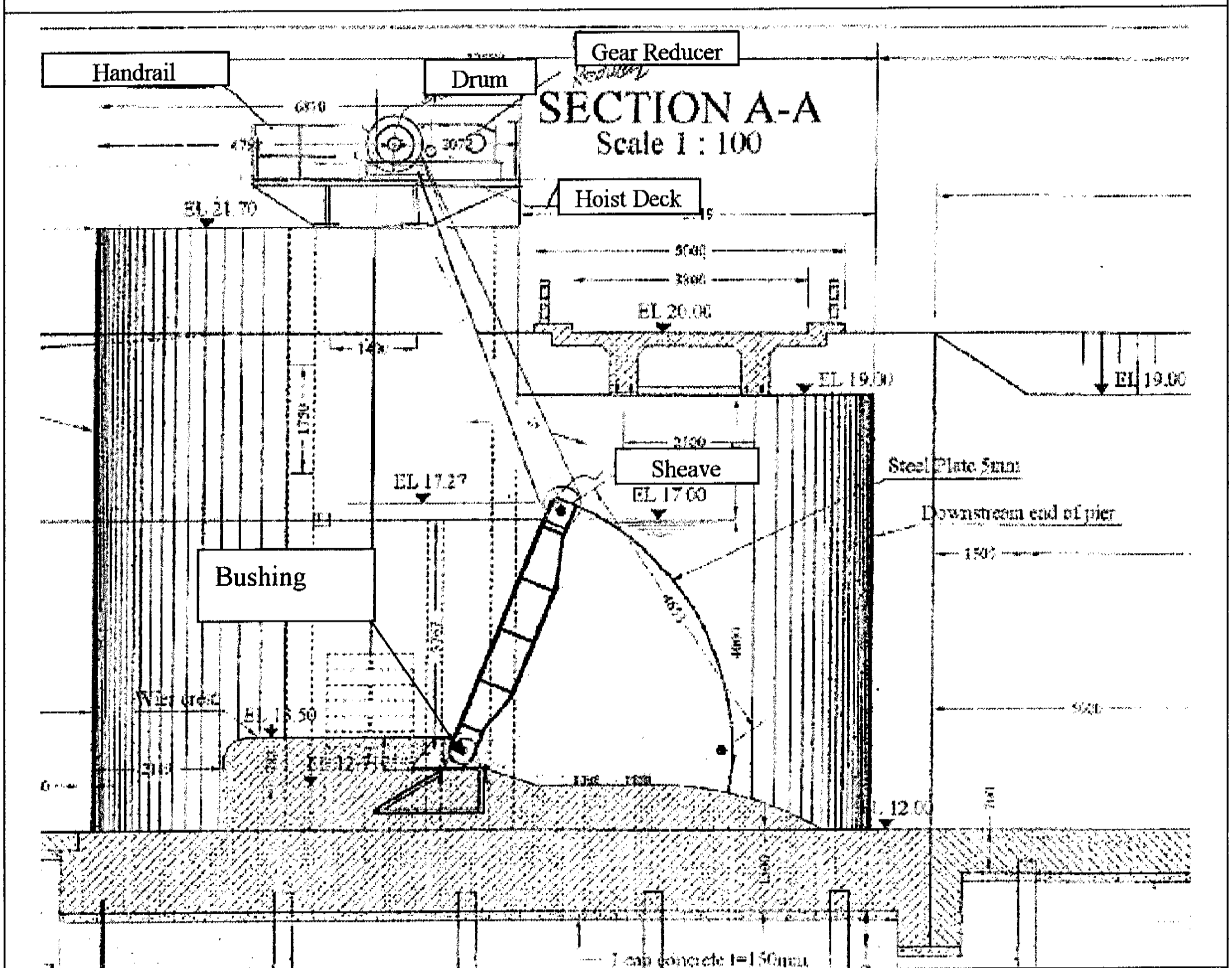


Prepared by JICA Study Team based on Original Source
'Project Proposal for Rehabilitaion of Damnak Ampil Irrigtion Project in Pursat Province", MOWRAM, 2004

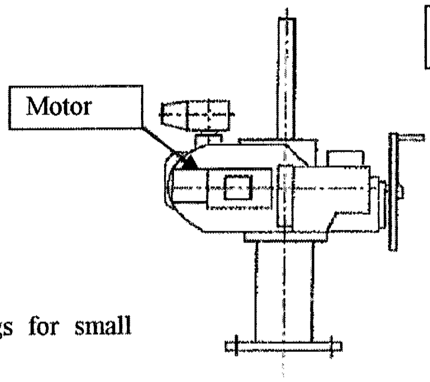
Schematic Drawing of New Hoisting System for Damnak Ampil Diversion Weir (Flood gate)(1/2)





Prepared by JICA Study Team based on Original Source
"Project Proposal for Rehabilitaion of Damnak Ampil Irrigtion Project in Pursat Province", MOWRAM, 2004

Schematic Drawing of New Hoisting System for Damnak Ampil Diversion Weir (Flood gate)(2/2)

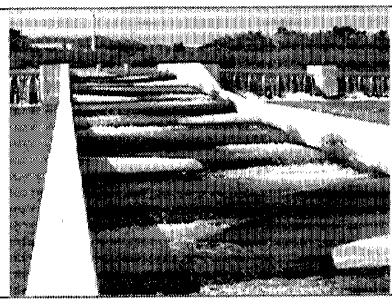


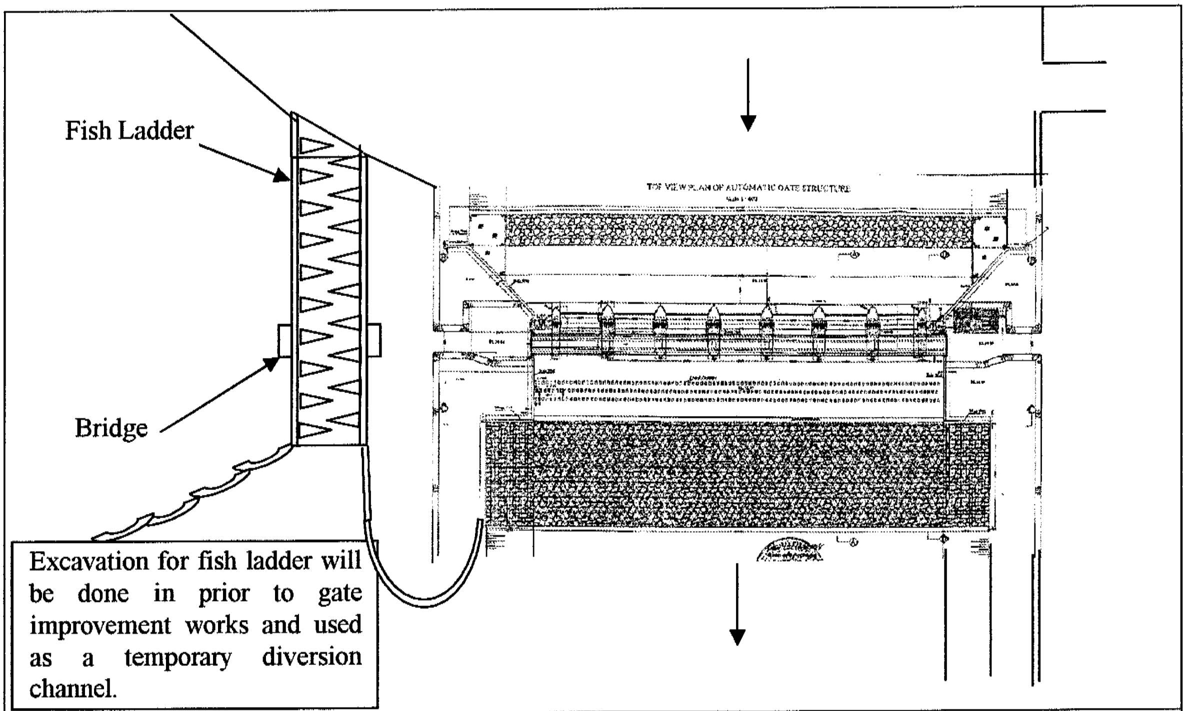
Source: Standard drawings for small scale gate, MAFF of Japan

Sample Drawing of New Hoisting System for Scouring sluice gate

3) Installation of Fish ladder:

Installation of fish ladder is proposed on the right bank of the existing diversion weir. Type of fish ladder is planned to be "half-cone type" or "grouted riprap cascade type", since these types creates a variety of water depth and flow velocity, so that fish is able to choose suitable course, water depth and flow velocity in accordance with its size and swimming ability.

- discharge: 4.71 m^3/sec (maintenance flow + D&I flow) + residual - Width: B=5.0m (common for above types) - Slope: I = 1/10 (commonly for above types) - Height: H=4.4m (Gate height-inlet water depth) - Length: L6=44 m (=4.4/(1/10))	 Image: half-cone type fish ladder



Prepared by JICA Study Team based on Original Source
"Project Proposal for Rehabilitaion of Damnak Ampil Irrigtion Project in Pursat Province", MOWRAM, 2004

Image Drawing of Installation of Fish ladder

C5.4.2 Irrigation and Drainage Facilities

(1) Irrigation Facilities

1) Design Plan of Irrigation Facilities

Design plan of irrigation facilities is discussed in section C3.3.2(1).

2) Rehabilitation and Improvement of Irrigation Facilities

a) Design of Irrigation Canal

Three secondary canals exist in the rehabilitated section of the Damnak Ampil Main Canal. This study conducts the rehabilitation and improvement designs of these canals.

These canals change their depth and width section by section. Therefore, canal designs are carried out by applying the Bernoulli's theorem under non-uniform condition.

Water source of these canals is the Damnak Ampil Main Canal. The designed water level of the Main Canal is set at 17.0 m at the intake site. Water levels of secondary canals are designed to connect to the water level of the main canal.

Summary of Irrigation Canal Design

Irrigation Canal	Canal Length			Design				
	Total	Rehab.	New	Design Q (m3/s)	Bottom Width	Height	Left Bank Top Width	Right Bank Top Width
S1	4,800	4,800	0	1.07	11.0m - 2.0m	1.8m - 1.0m	4.0 m	1.0 m
S2	5,000	5,000	0	0.79	6.0m - 0.8m	1.4m - 1.0m	4.0 m	1.0 m
S3	7,800	7,800	0	0.98	11.0m - 2.0m	1.8m - 0.9m	4.0 m	1.0 m
Total of S	17,600	17,600	0					

Prepared by JICA Study Team

b) Design of Irrigation Canal Related Structure

Five types of irrigation related structure are preliminarily designed for the Damnak Ampil Sub-project. The following table shows the required types and numbers of structures.

Type and Number of Irrigation Related Structures

Structure	nos.	Structure	nos.
Turnout	62	Road Culvert	32
Check	15	Regulator (Temporary)	1
Terminal Structure	3		

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The function and feature of drainage canal related structures are described in the previous section C3.3.2 (1) except for a regulator on a temporary basis.

Regulator (provided on a temporary basis)

This structure with stop-logs would function as a regulator to keep main canal water level high enough for the secondary canal No.3. This regulator would be constructed temporarily in consideration of a future extension plan of the Damnak Ampil rehabilitation project.

(2) Drainage Facilities

1) Design Plan of Drainage Facilities

Design plan of Drainage facilities is discussed in section C3.3.2 (2).

2) Rehabilitation and Improvement of Drainage Facilities

a) Design of Drainage Canal

Four secondary drainage canals would be necessary in the Sub-project area. Three secondary drainage canals, namely SD-1, SD-2 and SD-3, would be new canal, and SD-4 would be an existing stream. This study designed to utilize an existing stream as SD-4 without rehabilitation.

Summary of Drainage Canal Design

Drainage Canal	Canal Length			Design	
	Total	Rehab.	New	Bottom Width	Height
SD-1	6,400	0	6,400	2.2 m - 1.8 m	1.1 m - 1.0 m
SD-2	6,800	0	6,800	5.5 m - 2.0 m	2.0 m - 1.0 m
SD-3	7,800	0	7,800	5.0 m - 2.0 m	1.8 m - 1.0 m
SD-4	7,200	7,200	0	-	-
Total	28,200	7,200	21,000		

Prepared by JICA Study Team

b) Design of Drainage Canal Related Structure

Nine drainage culverts are preliminarily designed on secondary canals. Moreover, 26 drainage culverts would be necessary in tertiary blocks.

Type and Number of Drainage Structures

Structure	nos.	Structure	nos.
Drainage Culvert	35		

Prepared by JICA Study Team

C5.5 On-farm Development Plan

In accordance with the topography and the concept above mentioned, 50 tertiary blocks are proposed in the Damnak Ampil Sub-project (2,270 ha) in total. The average size of the tertiary block is figured out 45.4 ha. The typical length of a tertiary canal is 1.7 km on average in accordance with the topography. The total length of the tertiary canals is assumed at 85 km in the Sub-project.

The typical length of one water course and number of water courses in the Sub-project are assumed at 270 m and 200 numbers respectively.

C5.6 Water Management and Operation & Maintenance of Irrigation Facilities

(1) Responsible Organization

The share of responsibility of water management and O&M activities is proposed as follows taking into consideration the policy above, size of the Sub-project, importance of facility for the Sub-project management.

Activities \ Level	Damnak Ampil Headworks	Main Canal	Secondary canals	Tertiary canals	Water courses	Field canals
Preparation of annual O&M plan	PDOWRAM	PDOWRAM	FWUG	Sub-FWUG	WUG	-
Preparation of cropping schedule	-	-	FWUC/ FWUG	Sub-FUWG	WUG	Household
Operation of facilities	PDOWRAM	PDOWRAM	FWUG	Sub-FUWG	WUG	Household
Maintenance work	PDOWRAM	PDOWRAM	FWUG	Sub-FUWG	WUG	Household

Note O&M Manuals shall be prepared by MOWRAM/PDOWRAM and be hand over to the respective agencies responsible during hand-over period.

Prepared by JICA Study Team

(2) Water Management and Operation

1) Damnak Ampil Headworks

PDOWRAM, Pusrsat is responsible for water management and O&M of Damnak Ampil Headworks and Main Canal including related structures.

The water level at the intake is designed at EL.17.00 m. Sluice gates are controlled to keep the design water level except for flood time. The water level shall be observed by reading a staff gauge which are installed at upstream of weir site and intake site.

The Damank Ampil Headworks is a main water source for three Sub-projects proposed, i.e., Damnak Ampil Rehabilitation, Wat Loung Rehabilitation, Wat Chre Rehabilitation (refer to section C5.1(4)). The intake of the Damnak Ampil Headworks is located at 640 m downstream of the main canal, and is called as the regulator. The peak diversion water is designed at 7.93m^3/sec. The amount of water taken to the Main Canal, however, is to be controlled by the gates installed at the regulator in accordance with irrigation service plan of the 3 Sub-projects, which is to be prepared by PDOWRAM, Pursat. The regulator gates are controlled by readings of staff gauges which are installed upstream and downstream of the gates. The gate opening rule shall be set up based on the relationship between water level, gate opening and discharge.

2) Damnak Ampil Main Canal

Damnak Ampil Main Canal shall supply water to Wat Loung Main Canal which branches off at the first turnout (800 m downstream from Headworks). The peak design discharge in the Damnak Ampil Main Canal and Wat Loung Main Canal is 3.09 m^3/sec and 4.84 m^3/sec respectively. The water distribution of the two canals above is to be executed in proportion with the peak design discharge by controlling the turnout gates. In order to this, H-Q curve shall be developed at the turnout. Water supply to the two canals shall be continuously made throughout a year except for maintenance period which is set in March and April.

In the main canal, check gates are fully opened in case the design discharge flows. However, check gates should be operated if discharge in the main canal is lower than the design discharge in order to maintain the water level in the main canal for gravity irrigation. In this connection, turnout gates shall be operated carefully in order to avoid overtaking of water.

Water level in the main canal shall not be suddenly down except emergency case like danger to human life. This rule shall be observed to prevent the slipping of inside slopes of canal bank. And also, when water supply starts after completion of maintenance period, intake discharge shall be gradually increased up to the water demand.

In the maintenance period, the intake gates of the Headworks shall be totally closed and main canal shall be dried up for the purpose of annual maintenance. The maintenance works of Headworks and main canal are to be executed by PDOWRAM including related structures.

3) Secondary Canals

The water management in the secondary canal is described in the previous section C2.4 (3)

4) Tertiary Canals

The water management in the tertiary canal is described in the previous section C2.4 (3)

5) Water courses and Field Canals

The water management in the tertiary canal is described in the previous section C2.4 (3)

(3) Maintenance Work

The water management in the tertiary canal is described in the previous section C2.4 (4)

CHAPTER C6 IRRIGATION AND DRAINAGE PLAN OF WAT LOUNG REHABILITATION SUB-PROJECT

C6.1 Irrigation and Drainage Plan

(1) Basic Plan

1) Headworks

The existing headworks (Damnak Ampil Headworks) is used by the Sub-project as described in the previous section. The reasons are:

- The reconstruction of diversion weir and intake requires high cost.
- The Damnak Ampil Headworks is located only 3.5 km downstream of the Wat Loung Sub-project.
- The existing Damnak Ampil Headworks and Main Canal have enough capacity (8.0 m^3/sec) to carry water for Wat Loung Sub-project and others too.

2) Wat Loung Main Canal

The new Wat Loung Main Canal branches from Damnak Ampil Main Canal at cumulative distance of 800 m from Damnak Ampil Headworks. It runs about 7.6 km along with rural road and joins with the existing main canal. After joining, the existing main canal is used until it joins with the Boeung Khnar River (12.7 km).

3) Irrigation water supply to Wat Chre Sub-project

The Wat Loung Main Canal is used to supply irrigation water to Wat Chre Sub-project. The reason is explained in the following section C7.1.

(2) Proposed cropping pattern and irrigation water requirement

The proposed cropping pattern for irrigation and irrigation water requirement of the Sub-project are considered same as those of Damnak Ampil Rehabilitation Sub-project since these Sub-projects are located in the similar climatic and other natural conditions.

The peak water requirement for tertiary and field canals is figured out at 1.91 lit/sec/ha in August including irrigation efficiency of 85%.

The peak diversion water requirement in the Sub-project is figured out at 1.36 lit/sec/ha for wet season paddy in August taking into account the overall irrigation efficiency of 66%.

(3) Sub-project area and canal layout proposed

The Wat Loung Sub-project area is determined at 2,540 ha. The diversion water requirement is estimated at 3.45 m^3/sec. The existing main canal is improved and used in the Sub-project. As described above, the main canal carries irrigation water to Wat Chre Sub-project (1.39 m^3/sec) too. Accordingly the Wat Loung Main Canal has a flow capacity of 4.84m^3/sec. The irrigation and drainage canal layout is proposed as shown in Figure C5-1 together with Damnak Ampil and Wat Chre Sub-projects. General features of the Sub-project is summarizes in Table C3-2 together with other Sub-projects. The irrigation area diagram is shown in Figure C6-1.

(4) Irrigation Area by Pump

The ground height of upstream area of Wat Loung Main Canal is higher than water level in the canal. The raising water level in the main canal is not economical because it requires raising Damnak Ampil Headworks by about 1.0 m which requires high cost, and causes inundation in the upstream of the Pursat River. The pumping irrigation is inevitable in about 800 ha out of 2,540 ha. Those areas are located along with the Wat Loung Main Canal, and farmers are familiar with pumping irrigation.

(5) Drainage plan

The excess water in the Sub-project area is proposed to be drained by gravity. Field drain collects water from paddy fields and other type of land, and flows into a tertiary drain. Tertiary drains flow into a secondary drain due to the topography. Secondary drains flow to the Boeung Khnar River in downstream.

The general feature of drainage plan is summarized in Table C3-2 together with other Sub-projects. The drainage area diagram is presented in Figure C6-2.

(6) Drainage water requirement

1) Drainage water requirement from paddy field

The unit drainage water requirement from paddy field is calculated at 6.32 lit/sec/ha based on the annual maximum rainfall in the 3 consecutive days with one in 5 years return period. The procedure is described in the previous section C5.3 (6).

2) Drainage water requirement from other type of land

The unit diversion water requirement is calculated for the area less than 100 ha and more than 100 ha. The procedure is described in the previous section C5.3 (6).

Qpeak=0.25m^3/sec/ha from the area less than 100 ha

Qpeak=0.18m^3/sec/ha from the area more than 100 ha

The above unit drainage water requirement is applied to drainage canals shown in Figure C6-2.

C.6.2 Rehabilitation and Improvement of Facilities

The facilities of the Sub-project are divided into 3 categories; (1) headworks (diversion weir and intake(s)) and major related structures, (2) irrigation facilities for main and secondary systems, (3) drainage facilities for main and secondary systems, respectively.

C.6.2.1 Irrigation and Drainage Facilities

(1) Irrigation Facilities

1) Design Plan of Irrigation Facilities

Design plan of irrigation facilities is discussed in section C3.3.2 (1).

2) Rehabilitation and Improvement of Irrigation Facilities

a) Design of Irrigation Canal

The Wat Loung Main Canal would originate from the Damnak Ampil Main Canal. The intake site of the Wat Loung would be located at just downstream section of the first gated regulator with bridge of the Damnak Ampil Main Canal.

The canal would be designed to have a flow capacity that would cover the Wat Loung and the Wat Chre Sub-projects.

The new main canal of the Wat Loung of first approximately 2.7 km section, which would connect two main canals, would run the left bank of existing trunk road along the Pursat River. The canal section would be deep excavated ones.

The new canal would meet the existing Wat Loung Main Canal at 4.5 km point from the existing main canal mouth on the Pursat River.

Summary of Irrigation Canal Design

Irrigation Canal	Canal Length			Design				
	Total	Rehab.	New	Design Q (m3/s)	Bottom Width	Height	Left Bank Top Width	Right Bank Top Width
Main Canal	20,300	17,200	3,100	4.84 - 1.39	11.0m - 4.0m	3.8 m - 1.2 m	4.0 m	1.5 m
S - 1	6,700	0	6,700	0.57	1.8 m	1.1 m	1.0 m	4.0 m
S - 2	2,600	0	2,600	0.23	1.0 m	1.0 m	1.0 m	4.0 m
S - 3	5,600	0	5,600	0.39	1.2 m	1.1 m	1.0 m	4.0 m
S - 4	3,600	0	3,600	0.34	1.2 m	1.1 m	1.0 m	4.0 m
S - 5	3,000	0	3,000	0.35	1.2 m	1.1 m	1.0 m	4.0 m
S - 6	1,600	0	1,600	0.19	1.0 m	1.0 m	1.0 m	4.0 m
S - 7	2,000	0	2,000	0.37	1.2 m	1.1 m	1.0 m	4.0 m
S - 8	1,800	1,800	0	0.20	1.0 m	1.0 m	1.0 m	4.0 m
S - 9	2,400	0	2,400	0.24	1.0 m	1.0 m	1.0 m	4.0 m
S - 10	1,800	0	1,800	0.24	1.0 m	1.0 m	1.0 m	4.0 m
Total of S	31,100	1,800	29,300					

Prepared by JICA Study Team

b) Design of Irrigation Canal Related Structure

Seven types of irrigation related structure are preliminarily designed for the Sub-project. The following table shows the required types and numbers.

The function and feature of drainage canal related structures are described in the previous section C3.3.2 (1) except for a syphon.

<u>Syphon</u>

The new main canal would cross the Ou Bakan at approximately 2.5 km point from the beginning. In order to cross the natural stream safely, a syphon, which is a closed conduit designed to run full under pressure, is designed.

Type and Number of Irrigation Related Structures

Structure	nos.	Structure	nos.
Turnout	64	Bridge	4
Check	34	Footpath Bridge	8
Terminal Structure	6	Syphon	1
Road Culvert	14		

Prepared by JICA Study Team

The conduit would be a box concrete type with an effective inner dimension of 2.5 m x 2.5 m. Conduit length would be 60 m.

(2) Drainage Facilities

1) Design Plan of Drainage Facilities

Design plan of Drainage facilities is discussed in section C3.3.2 (2).

2) Rehabilitation and Improvement of Drainage Facilities

a) Design of Drainage Canal

Drainage canals would be new canals. Structural and hydraulic designs are the same as the Ream Kon Sub-project.

The following table summarizes design parameters for drainage canal. Water depth and flow velocity are calculated by the Manning's formula.

Summary of Drainage Canal Design

Drainage Canal	Canal Length			Design	
	Total	Rehab.	New	Bottom Width	Height
SD-1	2,700	0	2,700	6.0 m - 2.4 m	2.3 m - 1.4 m
SD-2	3,300	0	3,300	5.5 m - 2.4 m	2.2 m - 1.4 m
SD-3	4,200	0	4,200	5.0 m - 2.4 m	1.9 m - 1.2 m
SD-4	4,500	0	4,500	4.5 m - 3.0 m	1.7 m - 1.6 m
SD-5	3,700	0	3,700	2.2 m	1.2 m
SD-6	6,100	0	6,100	7.5 m - 5.0 m	2.4 m - 1.8 m
SD-7	9,500	0	9,500	5.5 m - 4.5 m	2.2 m - 1.7 m
SD-8	3,700	0	3,700	4.5 m	1.6 m
Total	37,700	0	37,700		

Prepared by JICA Study Team

b) Design of Drainage Canal Related Structure

<u>Drainage Culvert</u>

Five drainage culverts across the main canal would be necessary to drain out excessive water from the southern area. Nine drainage culverts are designed to cross existing trunk roads.

Footpath Bridge

There are lots of footpaths, which are not shown in the topographic map, in secondary canal commanding areas. Eight footpath bridges are designed for these footpaths to cross natural stream or depressions. Locations of these footpath bridges would be investigated in a next stage.

Type and Number of Drainage Structures

Structure	nos.	Structure	nos.
Drainage Culvert	13	Footpath Bridge	8

Prepared by JICA Study Team

C6.3 On-farm Development Plan

The concept of on-farm development plan for the Wat Loung Rehabilitation Sub-project such as irrigation method, command area by a tertiary block, etc., are discussed in section C.3.4.

In accordance with the topography and the concept above mentioned, 54 tertiary blocks are proposed in the Wat Loung Rehabilitation Sub-project (2,540 ha) in total. The average size of the tertiary block is figured out to be 47.0 ha. The typical length of a tertiary canal is 1.5 km on average in accordance with the topography. The total length of the tertiary canals is assumed to be 81 km in the sub-project. The typical length of one water course and number of water courses in the Sub-project are assumed to be 320 m and 216 numbers, respectively.

C6.4 Water Management and Operation & Maintenance of Irrigation Facilities

(1) Responsible Organization

The share of responsibility of water management and O&M activities is proposed as follows taking into consideration the policy above, size of the Sub-project, importance of facility for the Sub-project management.

Activities \ Level	Damnak Ampil Head works/ Main Canal *1	Wat Loung Main Canal	Secondary canals	Tertiary canals	Water courses	Field canals
Preparation of annual O&M plan	PDOWRAM	PDOWRAM	FWUG	Sub-FWUG	WUG	-
Preparation of cropping schedule	-	-	FWUC/ FWUG	Sub-FWUG	WUG	Household
Operation of facilities	PDOWRAM	PDOWRAM	FWUG	Sub-FWUG	WUG	Household
Maintenance work	PDOWRAM	PDOWRAM	FWUG	Sub-FWUG	WUG	Household

Note O&M Manuals shall be prepared by MOWRAM/PDOWRAM and be hand over to the respective agencies responsible during hand-over period.

*1 Wat Loung Sub-project commonly uses the Damnak Ampil Headworks and Main Canal (about 700m) together with Damnak Ampil Sub-project and Wat Chre Sub-project.

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(2) Water Management and Operation

1) Damnak Ampil Headworks and Main Canal

Damnak Ampil Main Canal shall supply water to Wat Loung Main Canal at the first turnout as described in section C5.6 (2).

2) Wat Loung Main Canal

PDOWRAM, Pusrsat is responsible for water management and O&M of Wat Loung Main Canal including related structures.

The peak design discharge in the Wat Loung Main Canal is 4.84m^3/sec respectively. The Wat Long Main Canal is proposed to transport irrigation water to Wat Chre Sub-project safely. The design discharge above contains 1.39 m^3/sec which shall be supplied to Wat Chre Sub-project. At the end of the Wat Loung Main Canal where the canal meets the Boeung Khnar River, the 1.39m^3/sec shall flow into Boeung Khnar River. The water is taken by Wat Chre Headworks which is proposed at about 9 km downstream. Water supply to the Wat Chre Sub-project shall be continuously made throughout a year except for maintenance period which is set in March and April.

The canal base of Wat Loung Main Canal is designed to vary from place to place to use the existing canal section for cost saving, the flow in the main canal is not a uniform flow but non-uniform flow. Accordingly, check gates shall be operated in order to maintain the water level in the main canal for gravity irrigation. In this connection, turnout gates shall be operated carefully in order to avoid overtaking of water.

Water level in the Main Canal shall not be suddenly down except emergency case like danger to human life. This rule shall be observed to prevent the slipping of inside slopes of canal bank. And also, when water supply starts after completion of maintenance period, intake discharge shall be gradually increased up to the water demand.

In the maintenance period, the intake gates of the Headworks shall be totally closed and main canals shall be dried up for the purpose of annual maintenance. The maintenance works of Headworks and main canals are to be executed by PDOWRAM including related structures.

3) Secondary Canals

The water management in the secondary canal is described in the previous section C2.4 (3)

4) Tertiary Canals

The water management in the tertiary canal is described in the previous section C2.4 (3)

5) Water courses and Field Canals

The water management in the tertiary canal is described in the previous section C2.4 (3)

(3) Maintenance Work

The water management in the tertiary canal is described in the previous section C2.4 (4)

CHAPTER C7 IRRIGATION AND DRAINAGE PLAN OF WAT CHRE REHABILITATION SUB-PROJECT

C7.1 Irrigation and Drainage Plan

(1) Basic Plan

1) Wat Chre Headworks

The new headworks site is proposed at 1.6 km upstream from the existing site in the Boeung Khnar River to avoid climbing canal bed slope. The river bed and river bank is about EL.9.5 m and EL.13.0 m, respectively. The river width is about 30m. The intake water level is determined taking into consideration the lowest existing bank height in the upstream and paddy field elevation in the irrigation area:

- Paddy field elevation = EL. 13.2m approx at highest point
- Bank height = EL. 13.0m approx at lowest point

In order to irrigate all area by gravity, the water level at Headwork is to be higher than 13.5 m. It requires raising the existing river dike by about 1.0 m. The height of existing rive dike ranges between EL.12.4 m and EL.14.2 m. The heightening of the dike requires high construction cost and land acquisition. Based on this, the intake water level at Wat Chre Headworks is determined at EL. 13.0 m taking into consideration these conditions.

2) Wat Chre Main Canal

Wat Chre Main Canal is proposed to start at new Wat Chre Headworks. A new canal is to be constructed at the first 500 m to connect to the existing main canal. After this, the main canal runs toward northeast following the existing canal route. The existing main canal which runs toward northwest is used as a secondary canal, so that the current uphill canal base can be reversely used downhill.

(2) Proposed cropping pattern and irrigation water requirement

The proposed cropping pattern for irrigation and irrigation water requirement of the Sub-project are considered same as those of Damnak Ampil Sub-project since these Sub-projects are located in the similar climatic and other natural conditions.

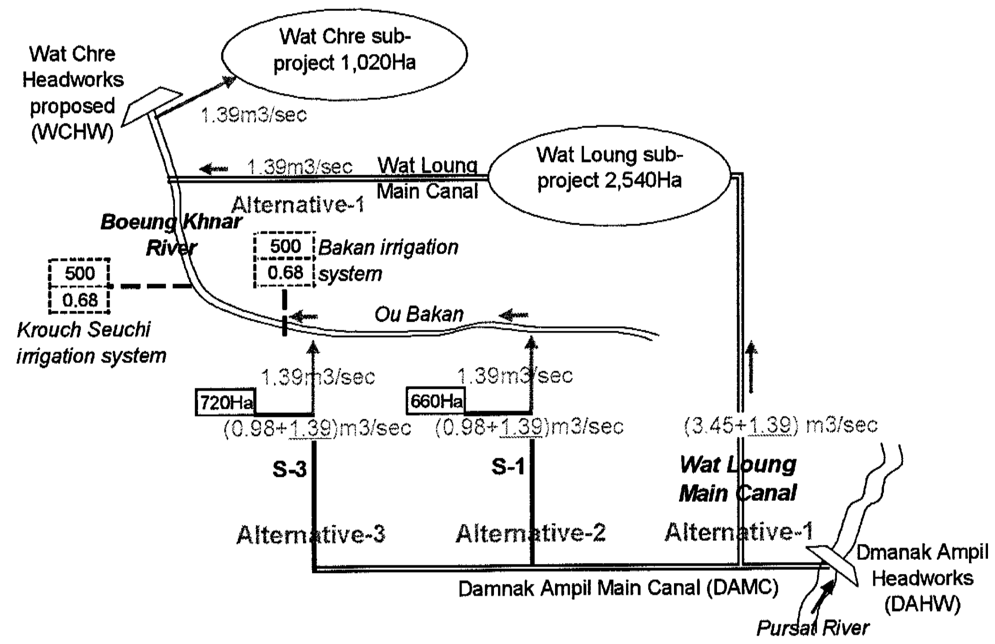
The peak water requirement for tertiary and field canals is figured out at 1.91 lit/sec/ha in August including irrigation efficiency of 85%.

The peak diversion water requirement in the Sub-project is figured out at 1.36 lit/sec/ha for wet season paddy in August taking into account the overall irrigation efficiency of 66%.

(3) Water conveyance plan from Damnak Ampil Headworks to the Wat Chre Headworks

The water source of Wat Chre Sub-project is the Boeung Khnar River. The river does not have stable and enough runoff due to (i) its catchment area is small (180 km^2 approx.) and is located in the plain area in which rainfalls are not much, (ii) the most of its runoff is drainage water from Damnak Ampil Sub-project area.

The irrigation water for Wat Chre Sub-project is to be supplied from Pursat River which has abundant water. Since the Sub-project area is more than 20 km far from Damnak Ampil Headworks (DAHW) in a beeline, the water taken at DAHW is to be conveyed by canals and the Boeung Khnar River upto Wat Chre Headworks proposed (WCHW). A few alternatives are studied to determine the water conveyance plan to the Sub-project.



Alternatives plans for water supply to Wat Chre Sub-project

Alternative study of irrigation water supply from Damnak Ampil to Wat Chre Sub-project

Description	Alternative-1	Alternative-2	Alternative-3
Discharge to be conveyed	1.39 m^3/sec	1.39 m^3/sec	1.39 m^3/sec
Conveyance route	DAHW→ DAMC→ Wat Loung Main Canal→ Boeung Khnar River	DAHW→ DAMC→ DA Secondary Canal-1→ Boeung Khnar River	DAHW→ DAMC→ DA Secondary Canal-3→ Boeung Khnar River
Total length of canals to be used for conveyance	DAMC= 0.8 km Wat Loung Main Canal= 20.3 km, Total=21.3 km	DAMC= 3.1 km DA Secondary Canal-1= 5.2 km, Total= 8.3 km	DAMC= 6.3 km DA Secondary Canal-3= 8.4 km, Total=14.7 km
Length of Boeung Khnar River up to WCHW	9.0 km	36.0 km	26.0 km
Total distance of the conveyance	30.3 km Shortest	44.3km Longest distance	40.7km 2nd shortest
Flow capacity of the conveyance canals	- Wat Loung Main Canal needs to increase capacity from 3.45 m^3/sec to 4.84 (140%)	- DA Secondary Canal-1 needs to increase capacity from 1.07 m^3/sec to 2.46 (230%)	- DA Secondary Canal-3 needs to increase capacity from 0.98 m^3/sec to 2.37 (240%)
Necessity of additional land acquisition	- Existing Wat Loung Main Canal has enough right-of-way for 4.84 m^3/sec,	- Additional land acquisition is required for DA Secondary Canal-1	- Additional land acquisition is required for DA Secondary Canal-3

Description	Alternative-1	Alternative-2	Alternative-3
	no land acquisition is required		
Necessity of water route improvement of Boeung Khnar River	Not necessary, water route is clear.	Necessary in 27 km due to unclear water route	Necessary in 17 km due to unclear water route
Possibility of unauthorized water-taking in the Boeung Khnar River before WCHW	No irrigation system exists between joining point and WCHW; no unauthorized water-taking is anticipated.	- Two irrigation systems exist (Bakan and Krouch Seuchi) between canal's joining point and WCHW; unauthorized water-taking is anticipated.	- Two irrigation systems exist (Bakan and Krouch Seuchi) between joining point and WCHW; unauthorized water-taking is anticipated.
Cost for conveyance facilities	Low, because increase of flow capacity of main canal is required only	High, because increase of flow capacity of secondary canal and water route improvement are required	High, because increase of flow capacity of secondary canal and water route improvement are required

Note: DAHW means Damnak Ampil Headworks
DAMC means Damnak Ampil Main Canal
DA means Damnak Ampile
WCHW means Wat Chre Headworks proposed

As the result of comparison described above, Alternative-1 is selected to convey irrigation water to Wat Chre Sub-project. Accordingly, Wat Loung Main Canal has to have a flow capacity of 4.84 m^3/sec. Wat Loung Main Canal joins with Boeung Khnar River, and supplies 1.39 m^3/sec to the river. The Boeung Khnar River conveys the 1.39 m^3/sec to the Wat Chre Headworks proposed.

(4) Sub-project area and canal layout proposed

The Wat Chre Sub-project area is determined at 1,020 ha. The area is divided into right and left sides by Boeung Khnar River. A secondary canal must cross the Boeung Khnar River to irrigate left side of the River. The irrigation and drainage canal layout is proposed as shown in Figure C5-1 together with Damnak Ampil and Wat Loung Sub-projects. General features are summarizes in Table C3-2 together with other Sub-projects. The irrigation area diagram is shown in Figure C7-1.

(5) Irrigation Area by portable pump

Out of 1,020 ha, about 400 ha requires pump irrigation in the upstream area of the main canal due to topography. The raising water level in the main canal is not economical as describe in the above section.

(6) Drainage plan

The excess water in the Sub-project area is proposed to be drained by gravity. Field drain collects water from paddy fields and other type of land, and flows into a tertiary drain. Tertiary drains flow into a secondary drain due to the topography. Secondary drains flow to the Boeung Khnar River.

The general feature of drainage plan is summarized in Table C3-2 together with other Sub-projects. The drainage area diagram is presented in Figure C7-2.

(7) Drainage water requirement

1) Drainage water requirement from paddy field

The unit drainage water requirement from paddy field is calculated at 6.32 lit/sec/ha based on the annual maximum rainfall in the 3 consecutive days with one in 5 years return period. The procedure is described in the previous section C5.3.

2) Drainage water requirement from other type of land

The unit diversion water requirement is calculated for the area less than 100 ha and more than 100 ha. The procedure is described in the previous section C5.3 (6).

Qpeak=0.25m^3/sec/ha from the area less than 100 ha

Qpeak=0.18m^3/sec/ha from the area more than 100 ha

C7.2 Rehabilitation and Improvement of Facilities

C7.2.1 Headworks and Major Related Structures

The facilities of the Sub-project are divided into 3 categories; (1) headworks (diversion weir and intake(s)) and major related structures, (2) irrigation facilities for main and secondary systems, (3) drainage facilities for main and secondary systems, respectively.

(1) Basic Consideration

The Wat Chre Headworks is planned to supply irrigation water only to Wat Chre Sub-project area (1,020 ha). Components of the Wat Chre Headworks are as follows:

a) Re-construction of Wat Chre Diversion Weir

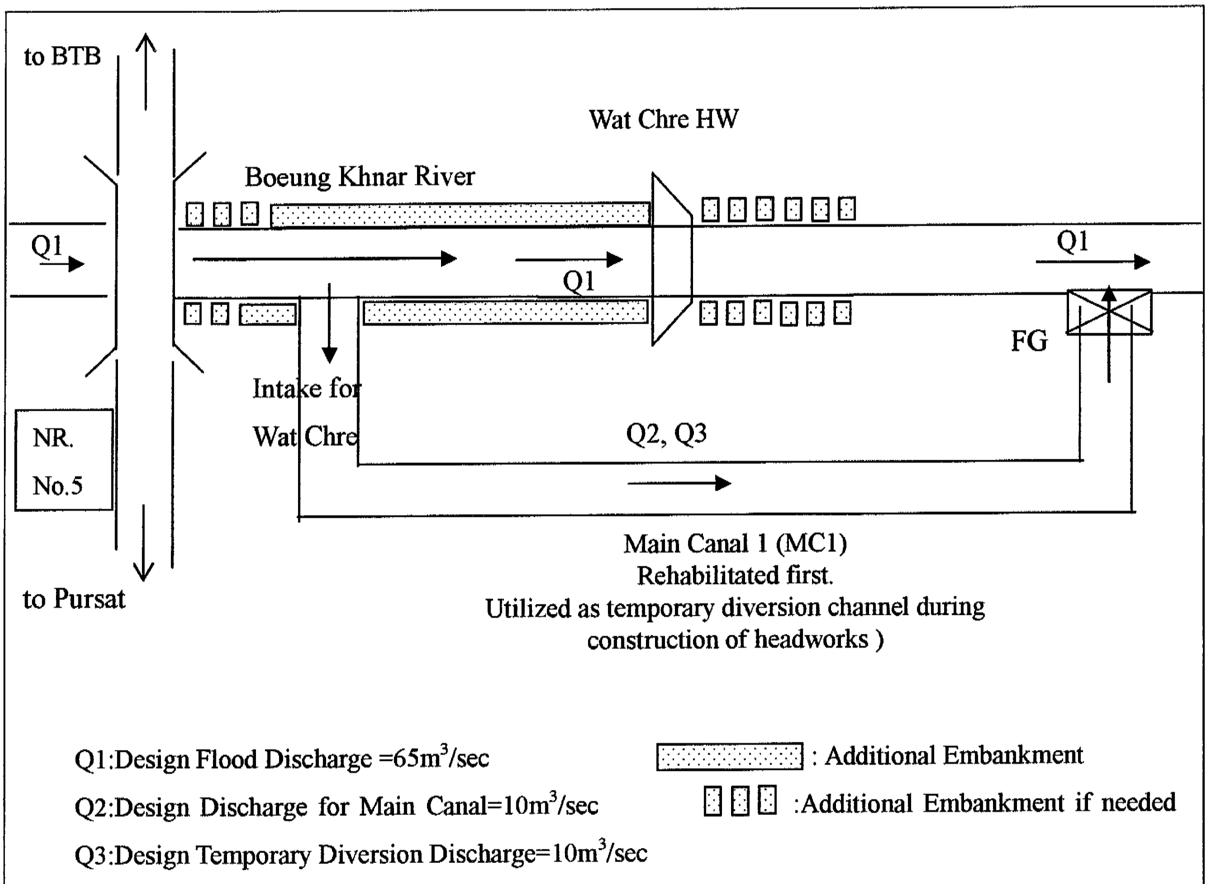
b) Re-construction of Wat Chre Intake

In addition, the following facilities are also planned to be rehabilitated in order to improve the system of the Wat Chre Sub-project. These facilities are depicted in the following schematic diagram:

c) Additional embankment of river bank and excavation of river

It is noted that:

- Additional embankment of 0.5m - 1.0 m is needed on both river banks along the river between Wat Chre Headworks and National Road No.5, since the design flood water level reaches up to around EL.13.5 m - 14.1 m at design flood discharge of 65 m^3/sec.
- The size of the Boeng Khnar River course as well as the Main Canal (MC) should be rehabilitated with consideration of present land use; i.e., since villagers live along both the river and the canal, their size should fit into present river or canal boundary, in order to avoid resettlement.
- During the construction of Wat Chre Headworks in the dry season, Main Canal (MC) will be utilized as a temporary diversion channel in order to reduce construction cost. Therefore, MC will be rehabilitated (excavated) first, in prior to the construction of headworks. Excavated soil will be utilized for additional embankment along the river and MC.



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Schematic Diagram of Wat Chre Headworks and Wat Chre Sub-Project

(2) Design Condition for Headworks

1) Summary of Design Condition:

Design condition proposed for Wat Chre Headworks is summarized as follows:

Summary of Proposed Design Condition for Wat Chre Headworks

Design Parameter	Condition	Remarks
Design Flood Discharge Q_F:	65 m^3/sec	T=100 year return period
Design Flood Water Level WL_F1:	WL. 13.6 m	at Weir site
Design Flood Water Level WL_F2:	WL. 14.2 m	at NR. No.5 w/o diversion
Design River Bank Elevation	EL. 14.30 - 15.00 m	betw/ Weir site and NR. No.5
Design Irrigation Water Level WL1:	WL. 13.00 m	Top of Gate. Overflow depth=0.2m
	(WL. 13.20 m)	WL1+Overflow depth:0.2m
Design River bed Elevation (Upstream):	EL. 9.60 m	
Design River bed Elevation (Downstream):	EL. 9.60 m	
Design Gate Sill Elevation:	EL. 9.60 m	

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2) Design condition for flood:

Design flood discharge of Boeng Khnar River for Wat Chre Headworks is determined, based on the following manner. Calculated result is shown in the following table:

-Design flood discharge (Q_F): Q_F =65 m^3/sec (equivalent to 100 year return period)

a) Design flood discharge Qp at T=100 year return period for Damnak Ampil is used and divided by its catchment area of CA=4,479 km^2 to estimate the unit discharge rate q' per km^2 (refer to section A.6.5, Appendix-A, in Volume III).

b) To obtained Design flood discharge Qp' at T=100 year return period, the unit discharge rate per km^2 is multiplied by the catchment area of CA1=180 km^2, which is for the Boeng Khnar River at the location of the Wat Chre Weir site.

c) The estimated discharge above for Boeng Khnar River is applied to non-uniform flow hydraulic calculation along Boeng Khnar River, between upstream of weir site and bridge on National Road No.5 (NR No.5) to insure the safety condition of the bridge.

Estimation of Design Flood Discharge for Boeng Khnar River
(T=100 year return period)

	Damnak Ampil	
CA(km^2)	4,479	
Qp (m^3/s)	1,560	T=100year
q' (m^3/s/km^2)	0.3483	Qp/CA
CA1(km^2)	180	Wat Chre
qp' (m^3/s)	63	q' x CA1

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As shown, the flood discharge at T=100 year return period for Wat Chre is estimated at 63m^3/sec, therefore, the design flood discharge at 100 year return period is determined as Q_F=65 m^3/sec.

-Design flood water level (HWL_F): HWL_F1=13.6m at weir site,

HWL_F2=14.2m at bridge on NR No.5.

Design flood water level (HWL_F) at two locations were determined as follows:

a) Weir site: HWL_F1=13.6m, based on non-uniform flow hydraulic calculations at design flood discharge of Q_F =65 m^3/sec for several weir size which satisfy the conditions (see "3)" for detail).

b) Bridge site: HWL_F2=14.2m, based on non-uniform flow hydraulic calculations at design flood discharge of Q_F =65 m^3/sec for determined weir size in above. It is noted that the elevation at the slab-bottom of the bridge on NR No.5 is EL.16.465 m, desirable allowable maximum water level of WL.15.66 m, hence it is high enough compared with HWL_F2=14.2 m and is able to deal with the design flood discharge.

3) Design condition for irrigation:

Design water level (WL1) and design discharge (Q_I1, Q_I2) for irrigation is determined as follows for each Sub-project site (refer to sub-section "5.5.1 Irrigation and Drainage Plan". In addition, "maintenance flow" discharge (Q_M) is determined by unit discharge of 0.1 m^3/sec per 100km^2 and catchment area at the location of headworks (=180 km^2):

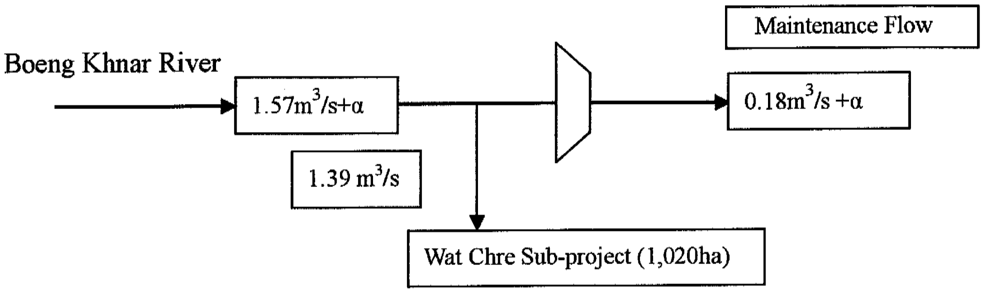
- WL1=13.00m (=elevation for top of the gate of the weir)

  (WL1+ maximum allowable overflow water depth of h: 0.2 m = 13.20 m)

- Q_I1 =1.39 m^3/sec for Wat Chre (1,020 ha)

- Q_M =0.18 m^3/sec =Maintenance flow discharge for downstream through "fish ladder"

  (=0.1m^3/sec/100 km^2 x Catchment Area=180 km^2)



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Design Condition for Irrigation

(3) Preliminary Design of Headworks

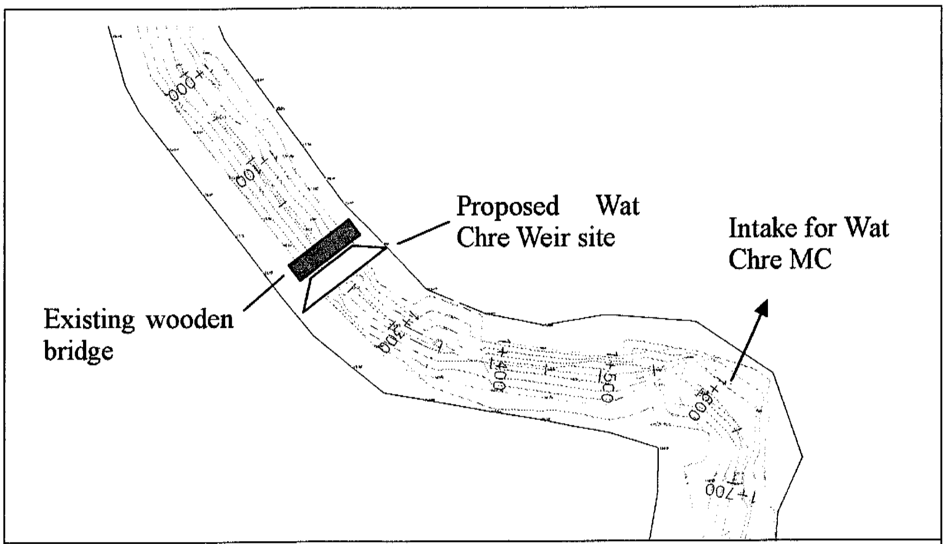
1) Location:

It is proposed to re-construct Wat Chre Diversion Weir for Headworks at upstream of the existing weir, which is severely damaged and currently not in use.

The weir site is proposed at slightly upstream of existing wooden bridge, where the shape of river-course is rather straight compared to that of near the intake for the Sub-project, with consideration for the structural and hydraulic stability of the weir. The location of Wat Chre Diversion Weir is shown in the figure on next page

2) Preliminary Design of River Course:

Based on the topographic survey data, longitudinal section of the river would be rehabilitated with the river bed slope of I=1/3,000. By employing the uniform flow calculation, it is proposed to rehabilitate the river course of Boeng Khnar River with the following dimension to deal with the flood discharge of Q_F=65m^3/sec, also to fit the river section into the present section of about 35 m.



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Proposed Location of Wat Chre Diversion Weir and Intake Structure

Hydraulic Calculation Result (Uniform flow) of River Section

Item	Symbol	Unit	Equation	Case-1	Case-2	Case-3
Design discharge	Q1	(m3/s)	<Input>	65.000	65.000	65.000
Base width	B1	(m)	<Input>	15.000	15.000	15.000
Water depth	h	(m)	<Input>	3.946	3.809	3.694
Canal bed slope	I		<Input>	1/3000	1/3000	1/3000
Roughness coef.	n		<Input>	0.050	0.050	0.050
Side slope	αL		<Input>	2.00	2.50	3.00
Side slope	αR		<Input>	2.00	2.50	3.00
Wet-perimeter	P	(m)	$B+[(1+\alpha L^2)^{0.5}+(1+\alpha R^2)^{0.5}]*h$	32.646	35.514	38.363
Cross-section area	A	(m2)	$B\cdot h+0.5\alpha h^2$	90.323	93.417	96.346
Hydr. Mean depth	R	(m)	A/P	2.767	2.630	2.511
Velocity	v	(m/s)	(R^(2/3)×I^(1/2))/n	0.720	0.696	0.675
Calc. discharge	Q	(m3/s)	A·v	65.000	65.000	65.001
Free board	Fb	(m)	<Input>	0.800	0.000	0.000
Canal total height	H	(m)	h+Fb	4.700	3.900	3.700
Canal total width	B2	(m)	B1+2*α*H	33.800	34.500	37.200
Remarks				Flood (100yr)	Flood (100yr)	Flood (100yr)

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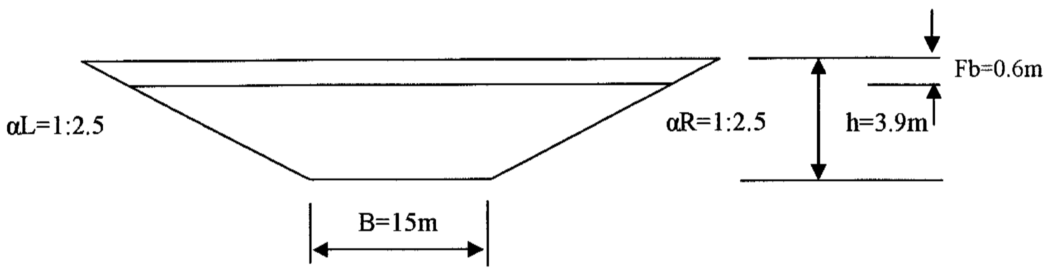

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Proposed Typical Cross Section of Boeng Khnar River

3) Weir Type

Weir type is determined as "floating type" in the preliminary design, due to lack of geological information along the river and the weir site. In addition, movable weir with gate is proposed in order to maintain an adequate water level along the upstream reach of the river during floods.

4) Gate Type

Five gate types were considered for flood gate; slide gate, fixed wheel gate, flap gate (=automatic gate, steel type, rubber textile type), radial gate. These gate types are compared from technical and economical viewpoints as shown below. As a result, fixed wheel type gate is selected for flood gate, in particular for its high reliability under influence of downstream back water from Lake Tonle Sap, as well as its easy operation, since those factors are important for facility management of the Project.

Selection of Gate Type for Wat Chre Diversion Weir

Item	Slide Gate		Fixed Wheel Gate		Flap Gate (Steel)		Flap Gate (Rubber Textile)		Radial Gate	
	Charac-teristic	Judge	Charac-teristic	Judge	Charac-teristic	Judge	Charac-teristic	Judge	Charac-teristic	Judge
Downstream water level	No influence	◎	No influence	◎	Influence	△	Influence	△	Influence	△
Operation	So difficult	△	Easy	◎	Easy	◎	Easy	○	Easy	◎
Maintenance	Easy	◎	Slightly difficult	○	Slightly difficult	○	Slightly difficult	○	Slightly difficult	○
Pier height	High	△	High	△	Low	◎	Low	◎	Low	◎
Cost	Low	◎	High	○	High	○	Moderate	○	High	○
Hoisting load	Large	△	Moderate	○	Large	△	Large	△	Light	◎
Vibration	No	◎	No	◎	Moderate	○	Moderate	○	Occurence	△
Reliability	High	◎	High	◎	Low	△	Low	△	Low	△
Height/width ratio	No influence	◎	No influence	◎	Influence	△	Influence	△	Influence	△
Over-all Evaluation	Hoisting load becomes large for large sized gate leaf and operation will be difficult		Reliability is high and hoist load is relatively low for large sized gate		Reliability is low under influence of downstream water level/ back water of Lake Tonle Sap		Reliability is low under influence of downstream water level/ back water		Reliability is low under influence of downstream water level/ back water	
			◎							

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For sluice scouring gate, slide gate is selected, owing to its high reliability and relatively small the gate size compared to the flood gate, thus it could be operated with lower hoisting load with ease.

5) Dimension of Weir

Dimension of the Wat Chre Diversion Weir will be proposed as the followings, based on the criteria shown in table below:

Dimension of Wat Chre Diversion Weir

Items	Dimension	Remarks
Weir Type	Floating Type Movable Weir	See i), iii)
Design Water Level	WL1: 13.0 m (Irrigation) WL_F1:13.6 m (Flood)	See 2) i) - iii)
Design Flood Discharge	Q_F=65.0m^3/sec	See 2) (T=100 year Return period)
Total Clear Width of Weir	ΣB=27.5 m	Flood gate: 12.5 x 1 + 2 x 2=16.5m Sluice gate: 2 x 2 + 1 x 2 = 6m Fish ladder: 5.0 m
Elevation of gate sill	EL1.= 9.60 m	Longitudinal design of river bed
Total Height of Weir	Dp:8.8 m	Based on Japanese design criteria above; (EL2.=18.4m) - (EL1.=9.6m) = 10.9
Length of Weir	L1=13.0m(Body Spillway) L2=25.0m (Downstream) L3=10.0m (Upstream) L4=30.0m (DS Riprap) L5=10.0m (US Riprap)	See schematic drawing on next page.
Gate type (Flood Gate)	Fixed wheel gate	See iv)
Gate Dimension	Clear Height H:3.4 m, Clear Span B:12.5 m	H:3.4m = WL1=13.00m – EL.9.60m (Sill) B: Refer to weirs in Cambodia, Japanese design criteria for headworks and hydraulic calculation
Number of Gate	1 nos.	
Number of Pier and width	0 nos. (Pier for counter weight)	Referrence: weirs w/ counter weight (Damnak Ampil, Roleang Chrey, Kandal Steung)
Gate type (Sluice scouring)	Slide gate	See iv)
Gate Dimension	H:2.0m, B:2.0 m	Referred to Damnak Ampil w/ consideration of river size
Number of Gate	2 nos.	
Fish Ladder	B:5.0m (Half cone type) Δh=3.3m L=33m	EL. difference Δh=(13.0-0.1)-9.6=3.3m Slope for ladder=1:10, L=Δh/(1/10)=3.3/0.1=33m

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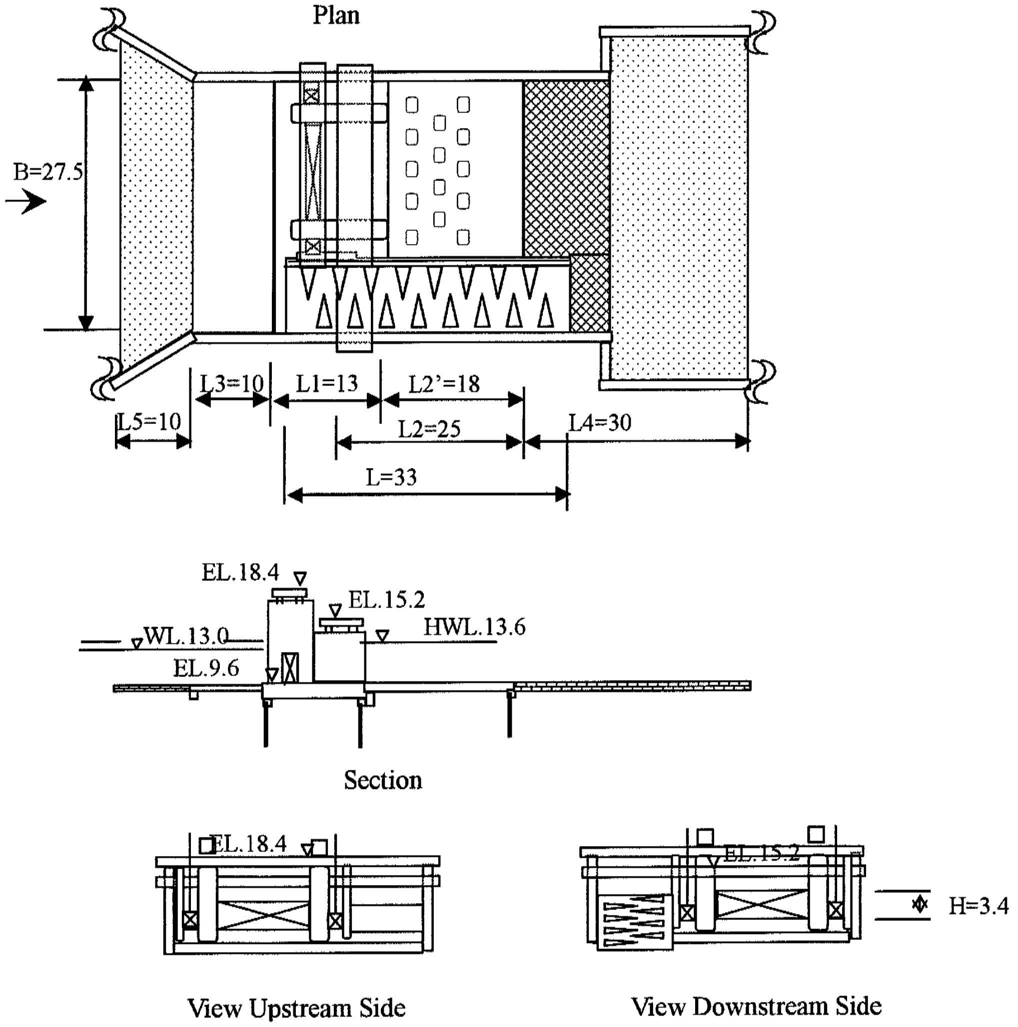
a) Design criteria employed for Span Length, Clear Span

Based on the river size of within 35 m and design flood discharge condition (Q_F=65m^3/sec), the number of gate is anticipated to 1. Therefore, the minimum span length of 12.5 m or more is applied to Wat Chre Weir. (referred to Japanese design criteria for headworks (and the River Control Structural Ordinance).

- Span length =clear span of gate leaf +Σ(1/2 pier width)

=10.5 + 1/2 x (2.0 (side pier) x 2) =12.5 $\geqq$ 12.5 OK

However, it is proposed to employ the minimum gate width of 12.5 m (Span length=14.5 m) or more, by taking in to account for the change in cross-sectional area and flow velocity of the river and the weir.



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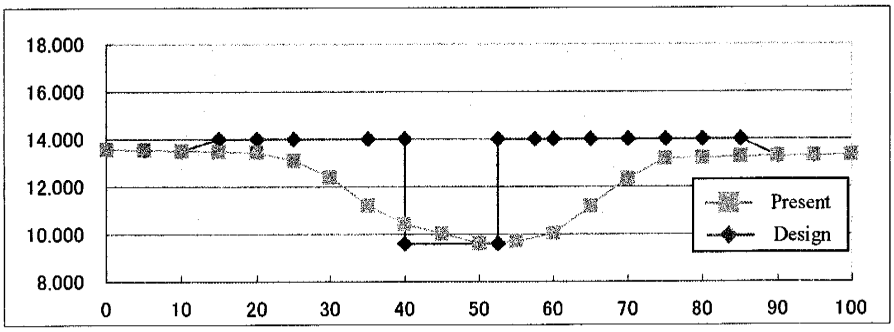
Schematic Drawing of Wat Chre Diversion Weir

- Hydraulic Calculation:

Trial is conducted for clear span: 12.5 m, 15 m, 20 m, with the number of leaf: one.



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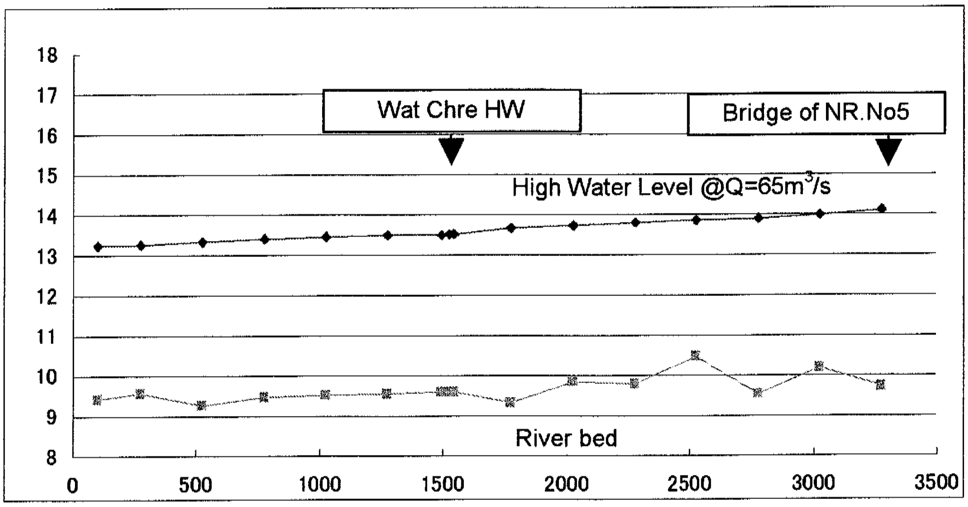
Trial Cross-Section of Wat Chre Diversion Weir (Clear Span=12.5m)



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Hydraulic Calculation Result of Non-uniform flow for Proposed Weir Section at $Q=65m^3/sec$

- Determination of Dimension:

A total of three trial results are shown in table below, with the maximum gate clear span of 20.0 m, considering total clear width of structure (including fish ladder) and present river section with top width of about 40m. The result shows that design high water level at weir WL_F1=13.51-13.60m, and did not change significant for larger size, however the situation does not improve by widening the clear span of gate. Hence, "one gate with clear span of B=12.5m" is selected for Wat Chre Weir.

Summary of Trial Calculation Result

Gate Nos.	Clear Span	Span Length	PierObst. Ratio	Total Clear Width	Elevation of Gate sill	Water level (m) at weir, upstream and downstream			Remarks WL<=15.66m
	(m)	(m)	(%)	(m)	EL. (m)	250mDS	Weir	Bridge	
2	12.50	14.50	-	27.50	9.60	13.50	13.51	14.11	OK
	15.00	17.00	-	30.00	9.60	13.50	13.52	14.09	OK
	20.00	22.00	-	35.00	9.60	13.50	13.56	14.08	OK

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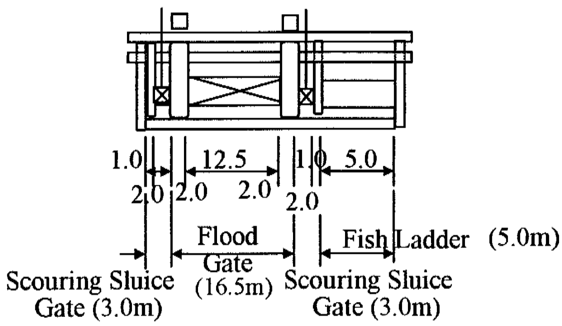

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Schematic Drawing of Moung Russei Diversion Weir (Upstream View)

d) Length of Weir

- Body Spillway : L1 = Operation deck and miscellaneous width + Bridge width

  = (7.0m + 6.0m) =13.0 m

  Slab thickness t1 = 1.4 m

- Downstream (D.S) Apron: L2 = 0.9 C (D) $^{1/2}$ =

  = 0.9 x 15 x (3.4) $^{1/2}$ = 25.0 m

  Slab thickness t2 = 0.9 m

  Where, C: Bligh's coefficient (C=15 for fine sand), D: Gate height 3.4 m

- Upstream (U.S) Apron: L3 = 2 h2

  = 2 x 4 =8.0 m (Where, h2: water depth in U.S)

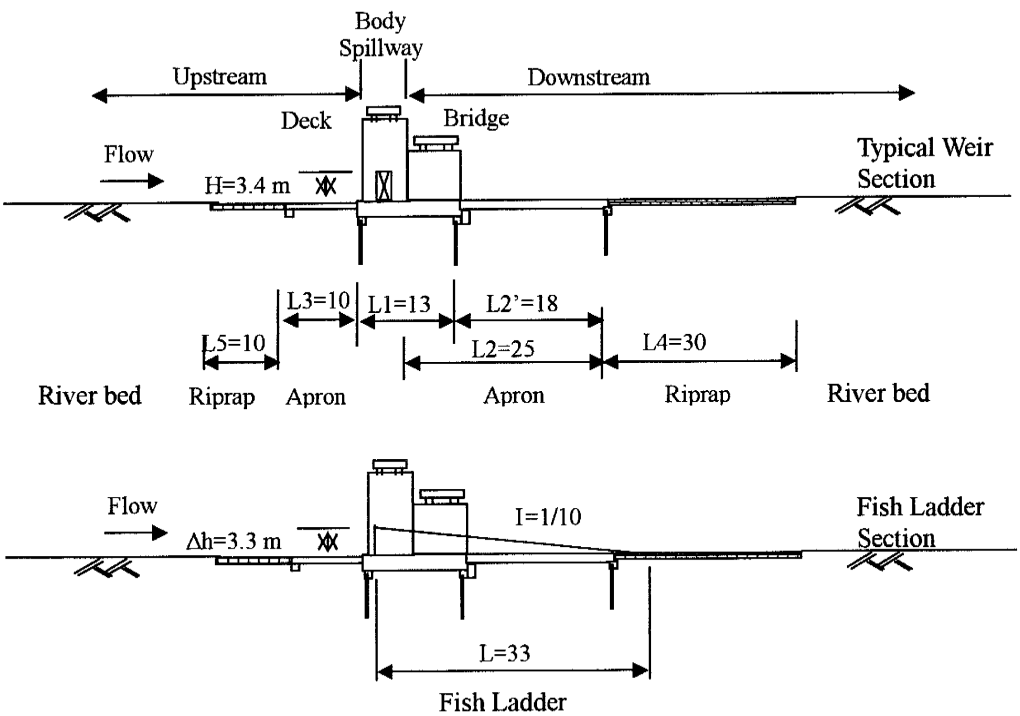
  Slab thickness t3 = 0.7 m

- DS Riprap:

  L = 6 x h3 =6 x 4 = 24 m

- US Riprap: L5 = L3 = 11.0 m

It is noted that for the lengths of DS apron and DS riprap, "Bligh's equation" has been applied since it was slightly longer and safer than the lengths calculated by USBR Type equation.



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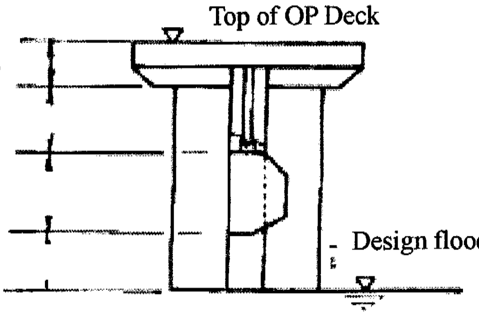
Schematic Drawing (Section) of Wat Chre Diversion Weir

e) Total Height of Weir

- Total height : Dp = (HWL_F1 + Fb1 + gate height + Fb2) – gate sill EL.

= 13.6 + 0.6 + 3.4 + 0.8 – 9.60 = 8.8m



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Explanatory Profile for Crest Elevation of Pier

f) Thickness of Pier

- Pier for counter weight: 2.5 m (Roleang Chrey, Kandal Steung) – 3.1 m (Damnak Ampil)

tp = 2.5 m > 1.7 m OK

- range of thickness: tp = 0.12 x (Dp + 0.2 Bi) ± 0.25

= 0.12 x (8.8+ 0.2 x14.5) ± 0.25

=1.2 m < tp < 1.7 m

Where, Bi = Span Length (m)

g) Bridge

A concrete slab bridge is installed over the weir with a total span of about 40m. The elevation of slab bottom is to be EL. 14.6m, by adding a freeboard of 1.0 m to the design flood (high water) level WL_F1=13.6m at weir site. The effective width and total width of the bridge are 3.8m and 5.0m, respectively, referred to the bridge of the Damnak Ampil Weir, with regarding the adjacent provincial road class.

h) Foundation works

Due to lack of geological information for preliminary design, concrete piles with 30 cm x 30 cm (or dia. 30 cm) x L = 6.0 m are to be installed at a maximum spacing of 3.0 m under body spillway, upstream and downstream apron and fish ladder. In addition sheet piles of L = 6.0 m are also to be installed near the edge of body spillway.

i) Fish Ladder:

Fish ladder is planed on right bank side of the weir. Type of fish ladder is planned to be "half-cone type" or "grouted riprap cascade type", since these types creates a variety of water depth and flow velocity, so that fish is able to choose suitable course, water depth and flow velocity in accordance with its size and swimming ability.

- discharge: 0.18m^3/sec (maintenance flow) + residual
- Width: B=5.0m (common for above types)
- Slope: I = 1/10 (commonly for above types)
- Height: H=3.3m (Gate height-inlet water depth)
- Length: L6=33 m (=3.3/(1/10))

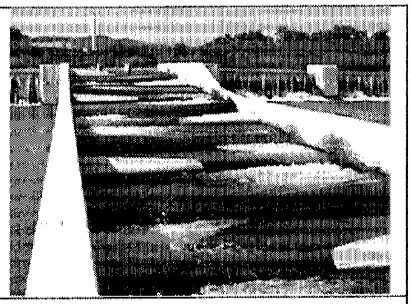


Image: half-cone type fish ladder

(4) Wat Chre Intake

1) Summary of Design Condition and Result:

Design condition and result for Wat Chre Intake are summarized as follows:

Summary for Design of Wat Chre Intake

Design Parameter	Condition	Remarks
Design Intake Discharge rate:	Q: 1.39 m^3/sec	Wat Chre Sub-project A=1,020 ha
Irrigation Water Level WL1:	WL. 13.00 m	Top of Gate
	(WL. 13.20 m)	WL1+max. Overflow depth=0.2m
Elevation at Inlet (River bed):	EL. 9.60 m	
Elevation at Inlet (Intake):	EL. 12.10 m	
Gate Sill Elevation:	EL. 12.10 m	
Width, Height and Length	Width: 1.0 m Height: 2.4 m Length: 6.0 m (+ Apron length)	Breast wall is installed between EL. 13.1m and EL.14.5m to prevent the entrance of flood water.
Gate Type and Gate Size, nos.	Slide gate, B:1.0 x H:1.0 x 1 nos.	
Bridge	Total width 2.0 m	

Prepared by JICA Study Team

2) Design Elevation of Intake Inlet:

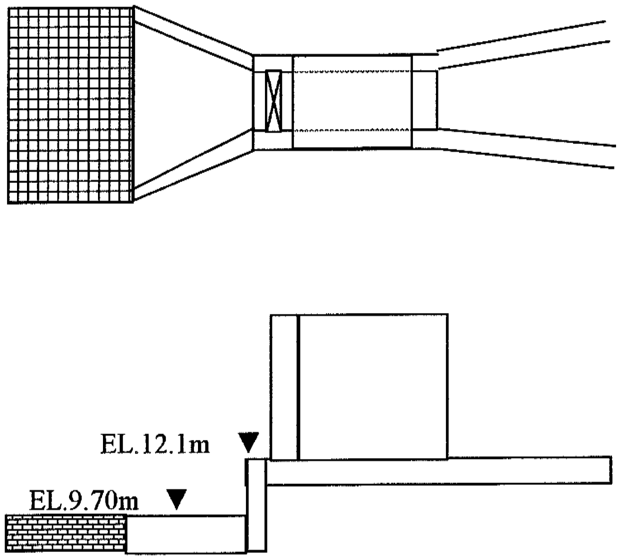
Elevation of an intake is to be designed, considering the design water depth of the both river and intake at inlet, in order to reduce and minimize the entrance of suspended particle (sediment). Water depth at inlet of intake is desirable to be within upper 0.4 of that of river (referring to Japanese design criteria for headworks):

- Water depth at river, H: 3.3 m (= NWL .13.00m – EL.9.60 m)

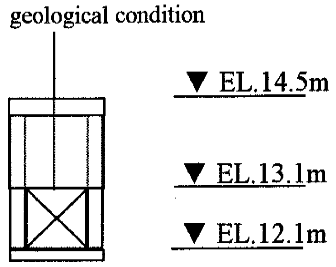
  Elevation of intake inlet ≥ NWL - 0.4 x H=13.00 –0.4 x 3.3 = 11.7

- Water depth at intake, h: 0.8 m (refer to "rehab. of irrigation and drainage facilities")

  Elevation of intake inlet = NWL- head loss – h = 13.00 –0.1 –0.8 = 12.1 > 11.7   OK



Note:
- Gabion mattress is installed at both river side and downstream of intake structure.
- Foundation pile and sheet pile are to be installed under dike considering geological condition



Prepared by JICA Study Team

Schematic Drawing of Wat Chre Intake

3) Design of Gate:

Design of intake gate (gate size and number of gate) is given as follows:

(reference: "Booklet of Hydraulic Formula", 1999 edition, Japanese Society of Civil Eng.,pp.255)

- Discharge rate Q (m^3/s) for 1 gate leaf (N=1):

$$Q = C\,a\,B\,(2\,g\,h0)^{1/2}$$

$$= 0.5 \times 0.71 \times 1.0 \times (2 \times 9.8 \times 0.8)^{1/2}$$

$$= 1.405\ (m^3/sec) > 1.39\ (m^3/sec) = \text{Design discharge rate} \quad \text{OK}$$

- Gate size and number: B=1.0m,   H=1.0 m,   N=1

Where,

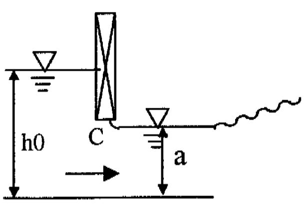
C: coefficient   (C=0.51,   when a / h0 =2)

a: gate opening (m)

B: width of gate (m)

g: gravity acceleration (m/sec^2)

h0: water depth (river side)



(5) Main Canal for Temporary Diversion during Construction

1) Summary of Design Condition and Result:

Design condition and result of Main Canal (MC) for temporary diversion use are summarized as follows. It is noted that the construction period for the Wat Chre Weir is anticipated between mid-November and late-May, thus the discharge rate for temporary diversion during construction is estimated at 3.0m^3/s, which is the maximum discharge of the above period in last five years:

Summary for Design of Main Canal (MC)

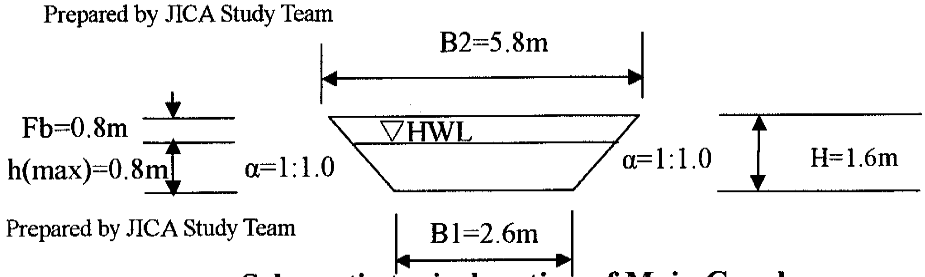
Design Parameter	Condition	Remarks
Design Discharge rate:	Q1: 1.39 m^3/sec	Maximum discharge for irrigation
Design Temporary Discharge	Q2: 3.0 m^3/sec	Max. during Mid-Nov. – End. May
Canal bed Inclination	1/ 3,000	Refer to landscape
Canal Base width, top width	B1:2.6 m, B2:5.8 m	Irrigation canal dimension
Canal Side Slope, Maning's n coefficient Freeboard	m : 1:1.0 n : 0.025 Fb: 0.8 m	MOWRAM design criteria for Irr. main canal class with sandy soil applied.
Canal Height,	H: 3.0m,	Present condition
Water Depth	h1: 0.81m (Q1=1.39 m^3/s) h2: 1.25m (Q2=3.0 m^3/s) hmax:1.6 m(Qmax=7.1 m^3/s)	hmax: Fb=0

Prepared by JICA Study Team

Hydraulic Calculation Result (Uniform flow) of Main Canal Section

Item	Symbol	Unit	Equation	Case-1	Case-2	Case-3
Design discharge	Q1	(m3/s)	<Input>	1.390	3.000	3.000
Base width	B1	(m)	<Input>	2.600	2.600	2.600
Water depth	h	(m)	<Input>	0.814	1.252	1.600
Canal bed slope	I		<Input>	1/3000	1/3000	1/3000
Roughness coef.	n		<Input>	0.025	0.025	0.025
Side slope	αL		<Input>	1.00	1.00	1.00
Side slope	αR		<Input>	1.00	1.00	1.00
Wet-perimeter	P	(m)	B+ [(1+αL^2)$^{0.5}$+ (1+αR^2)$^{0.5}$]*h	4.902	6.143	7.125
Cross-section area	A	(m2)	B･h+0.5αh^2	2.779	4.825	6.720
Hydr. Mean depth	R	(m)	A/P	0.567	0.786	0.943
Velocity	v	(m/s)	(R^(2/3)×I^(1/2))/n	0.500	0.622	0.702
Calc. discharge	Q	(m3/s)	A･v	1.390	3.000	4.720
Free board	Fb	(m)	<Input>	0.800	0.000	0.000
Canal total height	H	(m)	h+Fb	1.600	1.300	1.600
Canal total width	B2	(m)	B1+2*α*H	5.800	5.200	5.800
Remarks				Intake Div.	Flood (dry)	Max. Div.Fb=0

Prepared by JICA Study Team



Prepared by JICA Study Team

Schematic typical section of Main Canal

Discharge Observation data for Pursat River and Estimated discharge for Boeng Khnar River in Dry Season (Top 5 in Mid Nov. to following End of May)

No.	Discharge (m^3/s) Observed at Damnak Ampil Weir in Dry season of 2001-2005	Conversion Factor for Catchment Area CA2/CA1	Estimated Discharge at Wat Chre Weir in Dry season	Remarks (November 15th- May 30th)
1.	73.2	0.041 CA1:4,479 ha CA2:180 ha	3.0	Nov, 2005
2.	71.6		2.9	Nov, 2005
3.	38.6		1.6	March, 2001
4.	35.3		1.5	Nov, 2002
5.	34.7		1.4	May, 2005

Prepared by JICA Study Team, based on Table A.6.4.1 in Appendix A

C7.2.2 Irrigation and Drainage Facilities

(1) Irrigation Facilities

1) Design Plan of Irrigation Facilities

Design plan of irrigation facilities is discussed in section C3.3.2 (1).

2) Rehabilitation and Improvement of Irrigation Facilities

a) Design of Irrigation Canal

One main and five secondary and one sub-secondary canals are preliminary designed.

The first section of 700m of the Wat Chre Main Canal is designed as a new canal with the design discharge of 1.39 m^3/sec. The remaining 4,000 m of the main canal would utilize the existing secondary No.2 by making improvement.

Secondary No.1 would run in the canal section of existing right main canal. After crossing the Boeung Khnar River by means of a syphon, the secondary would flow in the section of existing left main canal for the distance of 700m. In the beneficiary area, the canal would be a new canal. The SS-1 is designed in the canal section of existing let main canal. The existing left main canal would be rehabilitated. Secondary canals No. from 2 to 4 would be new canals. Secondary No.5 would utilize an existing canal.

The following shows the canal dimensions designed preliminarily in this study.

Summary of Canal Design

Irrigation Canal	Canal Length			Design				
	Total	Rehab.	New	Design Q (m3/s)	Bottom Width	Height	Left Bank Top Width	Right Bank Top Width
Main Canal	4,700	4,000	700	1.39 - 0.31	8.0m - 2.6m	2.0m - 1.7m	4.0 m	1.5m - 1.0m
S - 1	6,100	1,700	4,400	0.46- 0.20	1.4m - 1.0m	1.2m - 1.0m	1.0 m	4.0 m
SS - 1 -1	1,300	1,300	0	0.18	1.0 m	1.0 m	1.0 m	4.0 m
S - 2	1,200	0	1,200	0.08	0.7 m	0.8 m	4.0 m	1.0 m
S - 3	2,900	0	2,900	0.23	1.0 m	1.0 m	4.0 m	1.0 m
S - 4	1,700	0	1,700	0.14	0.8 m	0.9 m	4.0 m	1.0 m
S - 5	1,500	1,500	0	0.24	1.0 m	1.0 m	4.0 m	1.0 m
Total of S	14,700	4,500	10,200					

Prepared by JICA Study Team

b) Design of Irrigation Canal Related Structure

Six types of irrigation related structure are preliminarily designed. The following table shows the required types and numbers.

Type and Number of Irrigation Related Structures

Structure	nos.	Structure	nos.
Turnout	31	Road Culvert	3
Check	17	Bridge	1
Terminal Structure	4	Syphon	1

Prepared by JICA Study Team

The function and feature of drainage canal related structures are described in the previous section C3.3.2 (1) except for a syphon.

Syphon

The secondary No.1 would require a pipe type syphon with 0.6 m in diameter to cross the Stung Kambot safely.

(2) Drainage Facilities

1) Design Plan of Drainage Facilities

Design plan of Drainage facilities is discussed in section C3.3.2 (2).

2) Rehabilitation and Improvement of Drainage Facilities

a) Design of Drainage Canal

Secondary drainage canals are designed as new ones except SD-2. The SD-2 would utilize an existing canal alignment.

The following table summarizes design parameters for drainage canals. Water depth and flow velocity are estimated by the Manning's formula.

Summary of Drainage Canal Design

Drainage Canal	Canal Length			Design	
	Total	Rehab.	New	Bottom Width	Height
SD-1	2,200	0	2,200	2.2 m	1.2 m
SD-2	2,200	0	2,200	2.8 m	1.5 m
SD-3	3,500	0	3,500	2.8 m	1.5 m
SD-4	2,100	0	2,100	1.8 m	1.0 m
SD-5	1,500	0	1,500	1.8 m	1.0 m
SD-6	1,800	0	1,800	2.8 m	1.5 m
SD-7	1,500	0	1,500	1.8 m	0.9 m
Total	14,800	0	14,800		

Prepared by JICA Study Team

b) Design of Drainage Canal Related Structure

Fourteen drainage culverts are designed at the crossing point with existing roads. At the end point of SD-3, existing culvert would be utilized.

Type and Number of Drainage Structures

Structure	nos.	Structure	nos.
Drainage Culvert	14		

Prepared by JICA Study Team

C7.3 On-farm Development Plan

In accordance with the topography and the concept above mentioned, 27 tertiary blocks are proposed in the Wat Chre Sub-project (1,020 ha) in total. The average size of the tertiary block is figured out 37.8 ha. The typical length of a tertiary canal is 1.0 km on average in accordance with the topography. The total length of the tertiary canals is assumed at 27 km in the Sub-project.

The typical length of one water course and number of water courses in the Sub-project are assumed at 380 m and 189 numbers respectively.

C7.4 Water Management and Operation & Maintenance of Irrigation Facilities

(1) Responsible Organization

The share of responsibility of water management and O&M activities is proposed as follows taking into consideration the policy above, size of the Sub-project, importance of facility for the Sub-project management.

Level / Activities	Damnak Ampil Head works/Main Canal, Wat Loung Main Canal *1	Wat Chre Headworks	Wat Chre Main Canal	Secondary canals	Tertiary canals	Water courses	Field canals
Preparation of annual O&M plan	PDOWRAM	PDOWRAM	PDOWRAM	FWUG	Sub-FWUG	WUG	-
Preparation of cropping schedule	-	-	-	FWUC/ FWUG	Sub-FWUG	WUG	House hold
Operation of facilities	PDOWRAM	PDOWRAM	PDOWRAM	FWUG	Sub-FWUG	WUG	House hold
Maintenance work	PDOWRAM	PDOWRAM	PDOWRAM	FWUG	Sub-FWUG	WUG	House hold

Note O&M Manuals shall be prepared by MOWRAM/PDOWRAM and be hand over to the respective agencies responsible during hand-over period.

*1 Wat Chre Sub-project commonly uses the Damnak Ampil Headworks/Main Canal (about 700m), and Wat Loung Main Canal together with Damnak Ampil Sub-project and Wat Chre Sub-project.

Prepared by JICA Study Team

(2) Water Management and Operation

1) Damnak Ampil Headworks/Main Canal, Wat Loung Main Canal

Irrigation water for Wat Chre Sub-project is supplied from Damnak Ampil Headworks/Main Canal, and Wat Loung Main Canal. The water for Wat Chre Sub-project flows from Wat Loung Main Canal to the Boeung Khnar River, and is taken at Wat Chre Headworks proposed. The peak irrigation water requirement for Wat Chre Sub-project is estimated at 1.39m3/sec. Water management of Damnak Ampil Headworks and Main Canal is described in section C5.6. Water management of Wat Loung Main Canal is described in section C6.3 (2).

2) Wat Chre Headworks and Main Canal

PDOWRAM, Pusrsat is responsible for water management and O&M of Wat Chre Headworks and Wat Chre Main Canal including related structures.

The water level at the intake is designed at EL.13.00. Sluice gates are controlled to keep the design water level except for flood time. The water level shall be observed by reading a staff gauge which are installed at upstream of weir site and intake site.

The amount of water taken to the Wat Chre Main Canal is controlled by intake gates in accordance with irrigation service plan which is to be prepared by PDOWRAM, Pursat. The intake gates are controlled by readings of staff gauges which are installed upstream and downstream of the intake gates. The gate opening rule shall be set up based on the relationship between water level, gate opening and discharge.

The canal base of Wat Chre Main Canal is designed to vary from place to place to use the existing canal section for cost saving, the flow in the main canal is not a uniform flow but non-uniform flow. Accordingly, check gates shall be operated in order to maintain the water level in the main canal for gravity irrigation. In this connection, turnout gates shall be operated carefully in order to avoid overtaking of water.

Water level in the Main Canal shall not be suddenly down except emergency case like danger to human life. This rule shall be observed to prevent the slipping of inside slopes of canal bank. And also, when water supply starts after completion of maintenance period, intake discharge shall be gradually increased up to the water demand.

Water supply to the main canal shall be continuously made throughout a year except for maintenance period which is set in March and April. In the maintenance period, the intake gates of the Headworks shall be totally closed and main canals shall be dried up for the purpose of annual maintenance. The maintenance works of Headworks and main canals are to be executed by PDOWRAM including related structures.

3) Secondary Canals

The water management in the secondary canal is described in the previous section C2.4 (3)

4) Tertiary Canals

The water management in the tertiary canal is described in the previous section C2.4 (3)

5) Water courses and Field Canals

The water management in the tertiary canal is described in the previous section C2.4 (3)

(3) Maintenance Work

The water management in the tertiary canal is described in the previous section C2.4 (4)

CHAPTER C8 IRRIGATION AND DRAINAGE PLAN OF LUM HACH REHABILITATION SUB-PROJECT

C8.1 Irrigation and Drainage Plan

(1) Sub-project area

The Sub-project area is determined at 3,100 ha of paddy fields taking into the topography and present land use based on the ortho-photographs and field survey.

(2) Irrigation water requirement

1) Basic conditions

The irrigation water requirement is estimated similar procedure with that described in the section D2.3 in Volume-II Appendix-D Irrigation and Drainage. The basic condition and figures applied to the Boribo River Basin are same with those in the same section D2.3 Volume-II Appendix-D Irrigation and Drainage, and extracted as follows:

i) Meteorological data; average of mean monthly data at Pochentong International Airport in Phnom Penh

ii) Percolation rate 3.0 mm/day based on the observed data

iii) Rainfall data; Daily rainfall data at Boeung Kantout and Bamnak stations

iv) Paddy is cultivated by transplanting method in all over Sub-project area

v) Irrigation efficiency in the tertiary unit= 85 %

vi) In the secondary canal and main canal= 88 %, respectively

vii) Overall efficiency= 85 × 88 × 88 % = 65.8 % = 66 %

The irrigation water requirement is estimated based on the proposed cropping pattern described in the Volume-III Appendix-B Agriculture. The sample calculation for wet season paddy is presented in Table C8-1.

The above figure is applied to planning of irrigation facilities. On the contrary, in the water balance study, a half of irrigation loss or 17% (=(100-66)÷2) from upstream irrigation area and or a system was conservatively assume to be re-used in the downstream irrigation system. Accordingly, the irrigation efficiency of 83% (=66+17) was applied in the water balance study.

2) Irrigation water requirement for tertiary and field canals

The peak water requirement is figured out at 2.40 lit/sec/ha for Early Wet Season Paddy in April including irrigation efficiency of 85% at tertiary level.

3) Diversion water requirement for headworks, main canal, and secondary/sub-secondary canals

The peak diversion water requirement in the Sub-project as a whole is figured out at 2.13

lit/sec/ha by Wet Season Paddy in July taking into account the overall irrigation efficiency of 66%.

(3) Water Balance Study for Sub-project

1) Necessity of water balance study

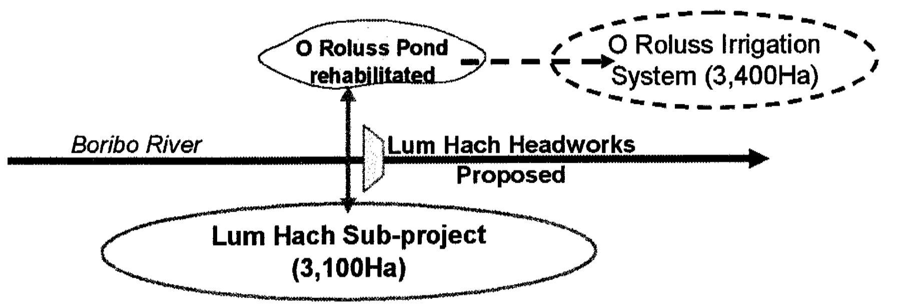
The most affective factor in determination of Sub-project area is water. The water source of the Sub-projects is the Boribo River. The water balance study is executed in order to estimate irrigable area in the Sub-project by cropping season.

2) River Runoff and Other Water Requirements

The main water source of the Lum Hach Sub-project is the Boribo River. The 5-day river runoff in the Boribo River is estimated in Volume III Appendix A Meteorology and Hydrology.

The irrigation water requirement described in the above paragraph is used in the calculation. The domestic and industrial water, river maintenance flow which were estimated in the Volume II Appendix D Irrigation and Drainage are used in the water balance calculation. The other factors such as evaporation and seepage loss from the reservoir which were estimated in the Volume II Appendix D Irrigation and Drainage are also used in the present study.

3) Water Distribution to on-going O Roluss Irrigation System



Irrigation areas by Lum Hach Headworks proposed (Total 6,500Ha)

The above figure shows water distribution plan to the Sub-project and O Roluss Irrigation System which is located at left side of the Boribo River, and has an irrigation area of 3,400 ha. PDOWRAM started rehabilitation of O Roluss Irrigation System which is located at left side of the Boribo River. The irrigation system expects a main water supply from the Boribo River though it has a small pond. The proposed Lum Hach Headworks will be the best water source facility to the system owing to the topographic condition. Accordingly, the water distribution to the O Roluss Irrigation System is to be considered in the water balance study. Accordingly, the irrigation area by the Lum Hach Headworks proposed is to be 6,500 ha in total.

4) Water balance calculation

The possible irrigation area by Lum Hach Headworks is studied by changing high water level at the Headworks. The fluctuation of water volume in the Headworks was checked by comparing inflow and water requirements i.e., domestic and industrial water, river maintenance flow, and irrigation water requirement. These water requirements which were used in the Master Plan Study in 2007 are also used in the present study.

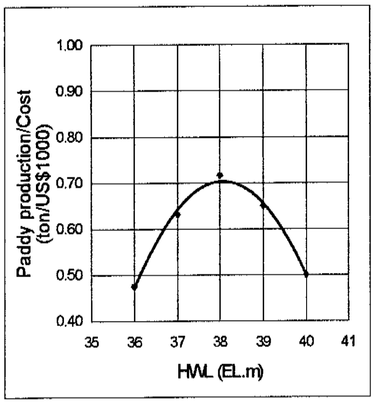
Based on the result of calculation, relationship between high water level at Lum Hach Headworks and possible irrigation area was obtained by cropping seasons. The Wet Season Paddy can be irrigated in the Sub-project area all. On the contrary, the Early Wet Season Paddy and Dry Season Paddy vary depending on the available water at the Headworks respectively. Accordingly the annual irrigation area varies depending on high water level. An incremental paddy production is calculated for each possible irrigation area.

5) Comparative study

Construction cost of the Sub-project was estimated by changing high water level at Headworks including land acquisition cost in the storage area. The incremental paddy production was divided by construction cost and paddy production per US$ was obtained as shown below.

Case study of Water Level of Lum Hach Headworks

Description	Case				
	1-1	1-2	1-3	1-4	1-5
HWL (EL.m)	36.0	37.0	38.0	39.0	40.0
LWL (EL.m)	36.0	36.0	36.0	36.0	36.0
Eff. Storage (MCM)	0.00	0.45	1.24	2.46	6.37
Development area (Ha)	3,100	3,100	3,100	3,100	3,100
Irrigable area - Early wet season (ha)	500	1,200	1,600	1,900	2,800
- Wet season (ha)	3,100	3,100	3,100	3,100	3,100
- Dry season (ha)	0	100	300	500	900
Annual irrigation area (Ha)	3,600	4,400	5,000	5,500	6,800
Annual paddy production (ton)	10,800	13,200	15,000	16,500	20,400
Incremental production (ton)	6,716	9,116	10,916	12,416	16,316
Cost - Headworks (10^3US$)	4,813	5,077	5,869	9,486	22,791
- Canals & drains*1 (10^3US$)	9,326	9,326	9,326	9,326	9,326
- Land acquistion for pond (10^3US$)	14.5	36.5	57.5	306.0	486.0
Total Cost (10^3US$)	14,154	14,440	15,253	19,118	32,603
Paddy production?Cost (ton/US$$10^3$)	0.47	0.63	0.72	0.65	0.50

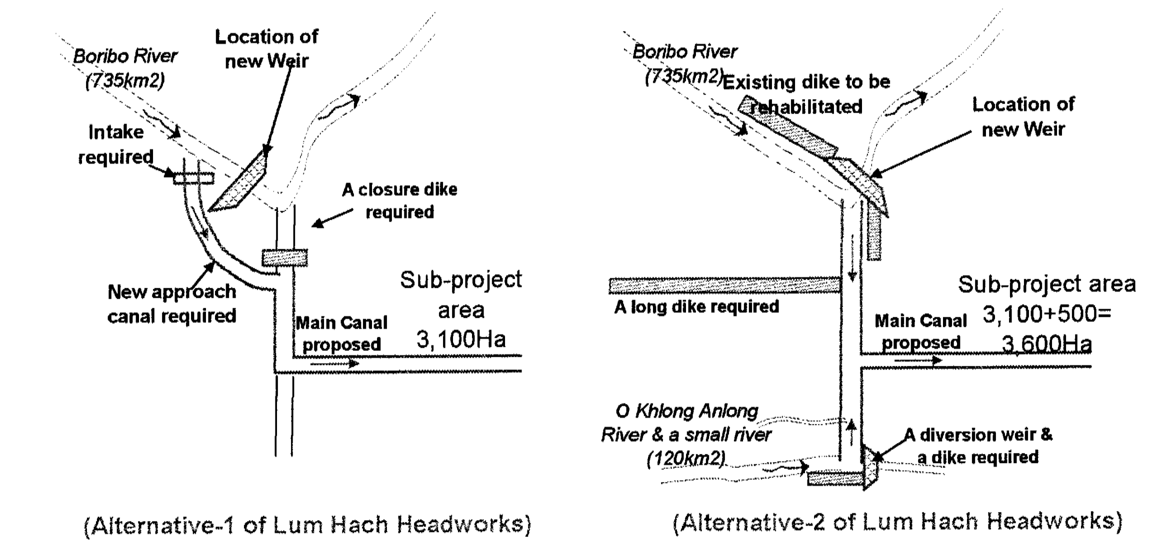


Water Level and Incremental Paddy Production per Construction Cost

As shown in the above figure, the high water level at EL. 38.0 m gives the largest incremental benefit per cost, and is the most economical (Case 1-3). Therefore, construction of Headworks at upstream site at high water level EL. 38.0 m is recommendable for the Sub-project. The cropping area of each season is estimated at 1,600 ha, 3,100 ha and 300 ha for Early wet season paddy, Wet season paddy, and Dry season paddy, respectively.

(4) Alternative study of the Headworks site

The Sub-project requires a headworks on the Boribo River, the headworks is tentatively called as Lum Hach Headworks.



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Concept of Alternative Sites

The above figure shows two alternatives of Lum Hach Headworks site. These alternatives are conceived taking into the topography, the potential irrigable area by the Sub-project, the existing facilities, etc.

Alternative-1: Located at upstream where the Boribo River is narrow

Alternative-2: Located at about 500 m downstream from Alternative-1, near the previous weir site.

1) Engineering comparison of alternative sites

The two alternatives are compared and evaluated qualitatively from engineering point of view as follows:

	Alternative-1	**Alternative-2**
Location:	Upstream	Downstream, very near the previous washed-away headworks site
Topography:	River is straight and narrow, River bed EL.33.7m approx.,	The river is wide, and curves at just upstream of the site, - River bed EL.29.7m approx.,
Development area in Ha	3,100 ha	3,600 ha because 500 ha of irrigation area is now irrigated by Khlong Anlong river.
Merit:	River course will be stable.	Water in the O Khlong Anlong river and other stream (120km^2) can be used for irrigation, Sub-project area increases by 500 ha.
Demerit:		- The erosion will cluster on one side of the Boribo river due to the curve, resulting in less stability of the headworks, - The water flows alternately resulting in difficulty of water management
Engineering evaluation:	Preferable for headworks	Less preferable from engineering view point,

2) Cost and benefit comparison

The major structures required are listed for each alternative as follows:

	Alternative-1	Alternative-2
Major structures required	- Flood discharge 430m^3/sec, - HWL = EL.38.0m, LWL = EL.36.0m - Weir (h=5m approx.), - Intake on the Boribo river, - Approach canal 0.75km, - Closure dike on 7th January Canal, - Rehabilitation of 7th January Canal 3.5km	- Flood discharge 430m^3/sec, - HWL = EL.38.0m, LWL = EL.36.0m - Weir (h=9m approx.), - 3 dikes about 5km in total along the Boribo river, - Rehabilitation of 7th January Canal 7.3km, - Weir and dike on the Khlong Anlong river

The irrigable area in each cropping season is calculated comparison of 5-day daily mean discharge at the headworks site and water requirements such as irrigation, domestic, maintenance flow, etc.

The construction cost and benefit are estimated for comparison as shown below:

Item	Unit	Alternative-1	Alternative-2
Development Area	ha	3,100	3,600
Irrigable area in Early wet season	ha	1,600	1,600
Irrigable area in Wet season	ha	3,100	3,600
Irrigable area in Dry season	ha	300	400
Annual irrigation area	ha	5,000	5,600
Annual paddy production	Ton	15,000	16,800
Incremental production	Ton	10,916	12,057
Construction cost - Headworks	10^{3}US$	5,869	9,346
- Canals & drains	10^{3}US$	9,326	9,686
- Total cost	10^{3}US$	15195	20,166
Incremental paddy production/Cost	ton/US$	0.72	0.60

As shown in the above table, the incremental production of paddy per construction cost is higher in Alternative-1 than in Alternative-2. Further, the site of Alternative-1 is more preferable from the civil engineering view point. Accordingly, the Alternative-1 is selected.

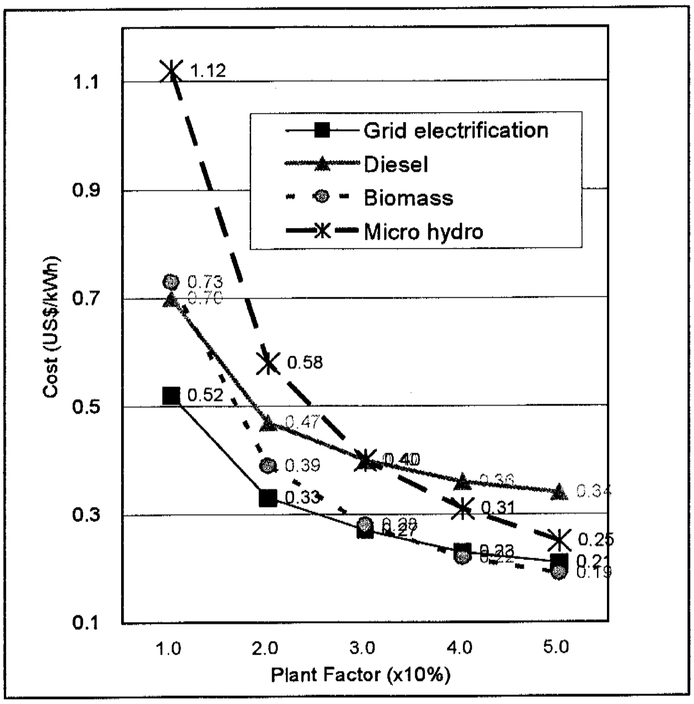
(5) Power source of gates of the Lum Hach Headworks

The construction cost of the headworks remarkably increases if the high water level exceeds EL.38.0m. Accordingly movable flood gates are recommended rather than a overflow weir to keep the flood water level lower than EL.38.0 m. Since the water depth at the flood gates is nearly 4m, the gates are to be operated by electric power. The required power for one gate operation is assumed at about 5kW to 10kW on condition that the flood gates are operated one by one.

A possible electric power source of gates is considered as follows for the Lum Hach Headworks:

- Grid electrification
- Diesel generator
- Micro-hydro power using flood water in the river

The right figure shows unit costs of electricity at the consumer's end with its plant factor prepared by other study in Cambodia. The plant factor is read as a ratio of the actual power generation and the possible power generation at one power plant. Grid electrification is the cheapest and the diesel generation becomes the second cheapest when the plant factor is lower than 10%.



Plant Factor and Unit Costs of Electricity at the Consumer End
Source: Extracted from Final Report Master Plan Study on Rural Electrification by Renewable Energy in the Kingdom of Cambodia, JICA

Since the Lum Hach Headworks is located far from grid electrification, the grid electrification is not feasible. The annual operation time of gates will be far less than 10% of annual hours (365 days=8,760 hrs/year) because the flood gates are operated at flood time only, and the other gates such as sand sluice and intake are operated periodically but not every day.

Based on the above consideration, the diesel generator is the most feasible power source for gates of Lum Hach Headworks.

(6) Canal layout proposed

The Sub-project area is determined at 3,100 ha. The proposed canal layout of irrigation and drainage is shown in Figure C8-1. The upstream reach (3.5 km) of the existing 7th January Canal is used for the main canal of the Sub-project though it requires improvement. The existing Secondary Canal No.2 which branches from the 7th January Canal at 3.5km point is used as the main canal too. On the contrary, the further downstream of the existing main canal is not used. General features are summarized in Table C3-2 together with other Sub-projects. The irrigation area diagram is shown in Figure C8-2A.

(7) Irrigation Area by Portable Pump

The command areas by Secondary Canals No. 1 and No. 2 are high elevated (EL.35.0 m to 39.3 m approx.). In order to irrigate these areas by gravity raising water level at headworks is required up to EL. 41.0 m. On the contrary, about 820 ha will be submerged at the same water level. Comparing the increase of gravity irrigation area and the submerged land, pump irrigation is recommendable. The pumping irrigation area is estimated at about 410 ha.

(8) Drainage plan

The excess water in the Sub-project area is proposed to be drained by gravity. Field drain collects water from paddy fields and other type of land, and flows into a tertiary drain. Tertiary drains flow into a secondary drain or main drain due to the topography. Secondary drains and main drains flow to the Boribo river or other small streams.

In order to protect the Sub-project area from flood from surrounding areas, drainage plan is made as follows.

i) The Boribo River is the main drain of the Sub-project.

ii) The existing streams such as Ou Kab Chen, Ou Khang Tuol, Stueng Si, etc., are used for secondary drain.

iii) Water in the Boribo River sometimes flow into the Sub-project area when the Boribo River has high water level. A drainage gate is proposed at the junction point of secondary drains and the Boribo River in order to control water inflow from the Boribo River.

The general feature of drainage plan is summarized in Table C3-2 together with other Sub-projects. The drainage area diagram is presented in Figure C8-2B.

(10) Drainage water requirement

1) Drainage water requirement from paddy field

The unit drainage water requirement from paddy field is calculated at 6.83 lit/sec/ha based on the annual maximum rainfall in the 3 consecutive days with one in 5 years return period.

$q=0.177\times 10{,}000\div(3\times 86400)\times 1000=6.83$

where, 0.177 is a probable 3 consecutive days rainfall at Kampong Chhnang station

q is the drainage water requirement (lit./sec/ha)

2) Drainage water requirement from other type of land

The Sub-project area consists of paddy field and other type of land which are house yard, upland, right of way of irrigation canals, etc. Those lands are located adjacent to the paddy field, and are assumed at 15% of the paddy field. Those lands do not have storage function as paddy field, and runoff characteristics from those lands are different from that from paddy field. The unit drainage water requirement from those lands is calculated by Rational formula and annual maximum one day rainfall with one in 5 years return period (118 mm/day).

The unit diversion water requirement is calculated for the area less than 100 ha and more than 100 ha.

Qpeak=0.027 m^3/sec/ha from the area less than 100 ha

Qpeak=0.019m^3/sec/ha from the area more than 100 ha

The above unit drainage water requirement is applied to drainage canals and collector drains shown in Figure C8-2B

C8.2 Rehabilitation and Improvement of Facilities

The facilities of the Sub-project are divided into 3 categories; (1) headworks (diversion weir and intake(s)) and major related structures, (2) irrigation facilities for main and secondary systems, (3) drainage facilities for main and secondary systems, respectively.

C8.2.1 Headworks and major related structures

(1) Basic Consideration

The Lum Hach Headworks is planned to supply irrigation water to Lum Hach Sub-Project area (3,100 ha), and an existing "O Roluss Canal Irrigation System (3,440 ha)", respectively. Therefore, the components of the Lum Hach Headworks are as follows:

a) Construction of Lum Hach Diversion Weir

b) Construction of Lum Hach Intake

c) Construction of O Roluss Intake

In addition, the following appurtenant facilities are also planned to be rehabilitated/ newly constructed at the Lum Hach headworks site in order to improve the system of the Lum Hach Sub-Project. These facilities are depicted in the following schematic diagram:

d) Construction of Lum Hach Approach Canal from intake to 7th January Canal

e) Construction of an overflow dike at outlet of 7th January Canal to the Boribo River

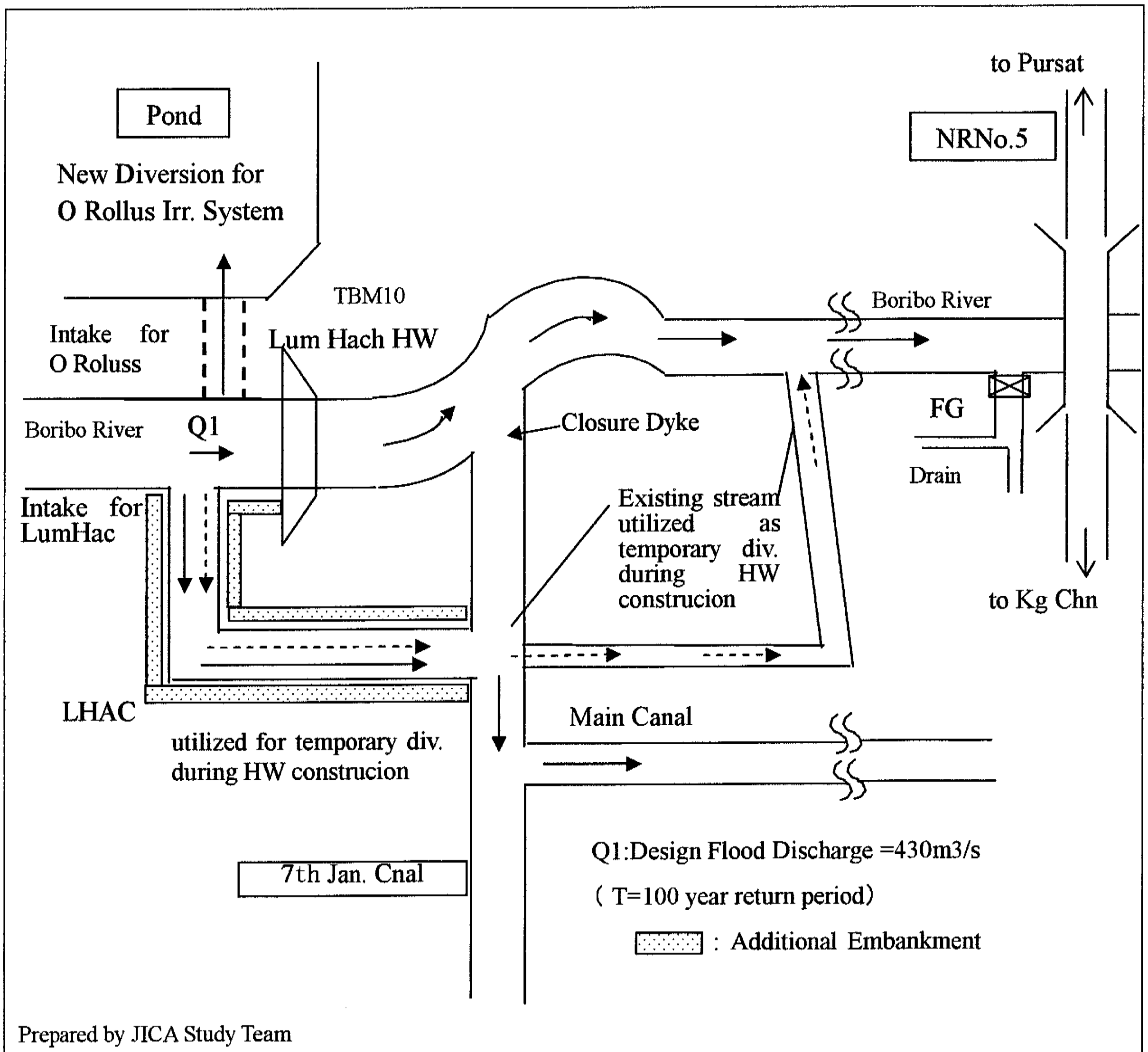
f) Additional excavation of river and embankment of river bank

It is noted that:

- Additional excavation of river is needed for the downstream of the new headworks on the right bank side, and excavated material is used for an additional embankment on the right bank.
- Lum Hach Approach Canal (LHAC) is planned to connect and deliver irrigation water to 7th January Canal.
- During the construction of Lum Hach Headworks in the dry season, Lum Hach Approach

Canal (LHAC) will be utilized as a temporary diversion channel in order to reduce construction cost. Therefore, LHAC will be excavated first, in prior to the construction of headworks with a cross-section for design temporary diversion discharge of 30.0m^3/sec. Excavated soil will be utilized for additional embankment along the river and LHAC.

- Temporary diverted water is conveyed by LHAC, then short distance by 7th January canal and finally thrown into Boribo river through an existing stream.



Schematic Diagram of Lum Hach Headworks and Lum Hach Sub-Project

(2) Design Condition for Headworks

1) Summary of Design Condition:

Design condition proposed for Lum Hach Headworks is summarized as follows:

Summary of Proposed Design Condition for Lum Hach Headworks

Design Parameter	Condition	Remarks
Design Flood Discharge Q_F:	430 m^3/sec	T=100 year return period
Design Flood Water Level WL_F1:	WL. 38.00 m	at Weir site
Design River Bank Elevation	EL. 39.00 m	betw/ Weir site and LHAC
Design Irrigation Water Level WL1:	WL. 38.00 m	Top of Gate
	(WL. 38.20 m)	WL1+max. Overflow depth=0.2m
Design River bed Elevation (Upstream):	EL. 11.70 m	
Design River bed Elevation (Downstream):	EL. 11.70 m	
Design Gate Sill Elevation:	EL. 34.00 m	

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2) Design condition for flood:

-Design flood discharge (Q_F): Q_F =430 m^3/sec (T=100 year return period, refer to the section A.7.5, Appendix-A in Volume III)

3) Design condition for irrigation:

Design water level (WL1) and design discharge (Q_I1, Q_I2) for irrigation is determined as follows for each Sub-project site (refer to sub-section "C.8.1 Irrigation and Drainage Plan". In addition, "maintenance flow" discharge (Q_M) as well as "Industry and Domestic use flow" discharge ($Q_{D\&I}$) are determined by unit discharge rate of 0.1 m^3/s per 100km^2 and catchment area at the location of headworks (=735 km^2) and based on M/P, respectively:

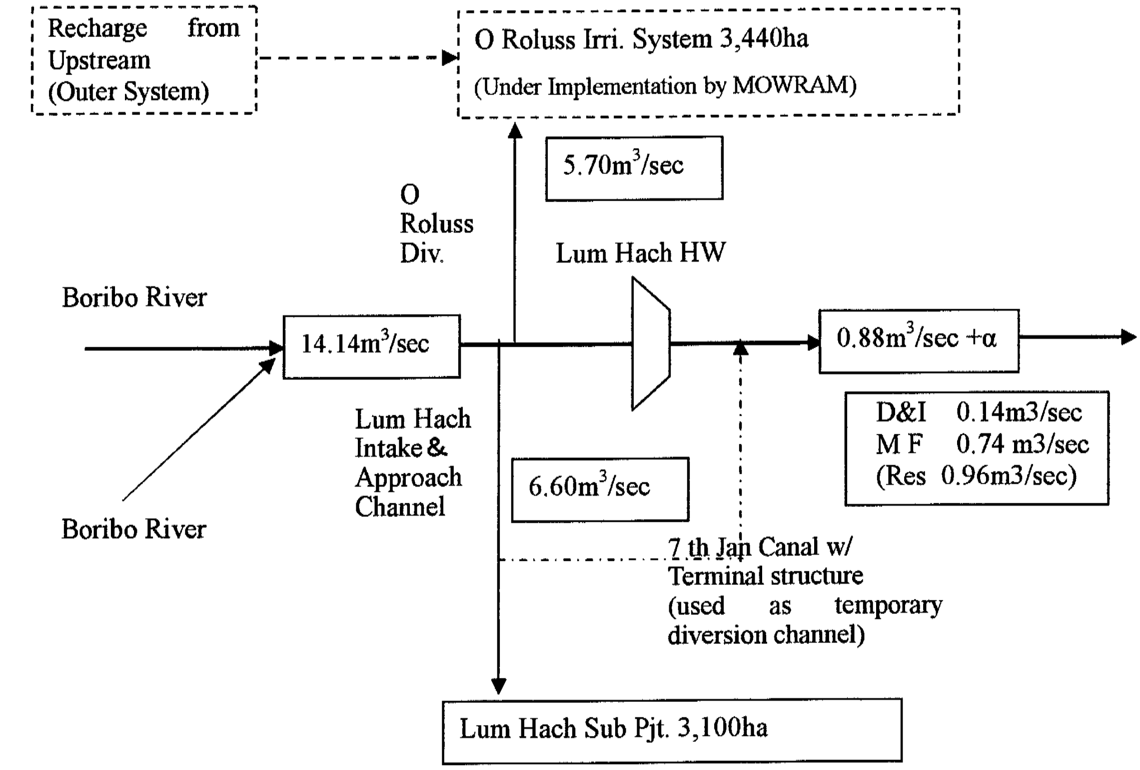
- WL1=38.00 m (=elevation for top of the gate of the weir)

  (WL1+ maximum allowable overflow water depth of h: 0.2m =38.2 0m)

- Q_I1 =6.60 m^3/sec for Lum Hach (3,100 ha)
- Q_I2 =5.70 m^3/sec for O Roluss (3,440 ha)
- Q_M =0.74 m^3/sec =Maintenance flow discharge for downstream through "fish ladder"

  (=0.1m^3/s/100 km^2 x Catchment Area=735 km^2)

- $Q_{D\&I}$ =0.14 m^3/sec = Industry and Domestic use discharge for downstream through "fish ladder"



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Design Condition for Irrigation Lum Hach Haedworks and Sub Project

(3) Preliminary Design of Headworks

1) Location:

It is proposed to re-construct Lum Hach Diversion Weir for Headworks at near TBM 10 as explained in the alternative study in Section C.8.1.

2) Preliminary Design of River Course:

Based on the topographic survey data, longitudinal section of the river would be rehabilitated with the river bed slope of I=1/250. By employing the uniform flow calculation, it is proposed to rehabilitate the river course of Boribo River, downstream section of the new weir with the following dimension to deal with the flood discharge of Q_F=430m^3/sec. It is noted that the river bank on the left side is to be remained as present condition as possible due to its steep landscape, and only right bank is to be excavated for the enlargement of the river section.

Hydraulic Calculation Result (Uniform flow) of Typical River Section

Item	Symbol	Unit	Equation	Case-1
Design discharge	Q1	(m3/s)	<Input>	430.000
Base width	B	(m)	<Input>	25.000
Water depth	h	(m)	<Input>	3.974
River bed slope	I		<Input>	1/250
Roughness coef.	n		<Input>	0.035
Side slope	αL		<Input>	0.4
Side slope	αR		<Input>	1.0
Wet-perimeter	P	(m)	$B+[(1+\alpha L^2)^{0.5}+(1+\alpha R^2)^{0.5}]*h$	34.901
Cross-section area	A	(m2)	$B\cdot h+0.5\alpha h^2$	110.418
Hydr. Mean depth	R	(m)	A/P	3.164
Velocity	v	(m/s)	(R^(2/3)×I^(1/2))/n	3.894
Design EL.(Bed)	EL1		<Input>	32.900
Design water level	H	(m)	h+EL1	36.874
Calc. discharge	Q	(m3/s)	A·v	430.000
Remarks				Flood (T=100)

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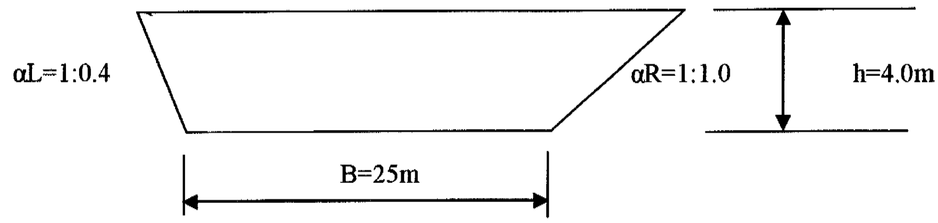

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Proposed Cross Section of Boribo River in Downstream of the Weir

3) Weir Type:

Weir type is determined as "floating type" in the preliminary design, due to lack of geological information along the river and the weir site. In addition, movable weir with gate is proposed to be constructed at "the mouth" of the junction of Boribo River and its tributary. Since the location above is too wide comparing to the size of the weir, an additional conarete dyke is to be placed for closure of the mouth, in order to maintain an adequate water level.

Moreover, it is difficult to find the land elevated at EL.39.0 m or higher on the right bank side in the vicinity of the "mouth", hence the high water level for irrigation as well as flood water level is designed to be at WL. 38.0m, so that to prevent river water from overtopping the concrete dyke around the mouse. Non-uniform flow hydraulic calculation also shows that it may enhance the overtopping when an overflow crest weir is installed at the mouth.

4) Gate Type:

Five gate types were considered for flood gate; slide gate, fixed wheel gate, flap gate

(=automatic gate, steel type, rubber textile type), radial gate. These gate types are compared from technical and economical viewpoints as shown below. As a result, fixed wheel type gate is selected for flood gate, in particular for its high reliability as well as its easy operation, since those factors are important for facility management of the Project.

For sluice scouring gate, slide gate is selected, owing to its high reliability and relatively small the gate size compared to the flood gate, thus it could be operated with lower hoisting load with ease.

Selection of Gate Type for Lum Hach Diversion Weir

Item	Slide Gate		Fixed Wheel Gate		Flap Gate (Steel)		Flap Gate (Rubber Textile)		Radial Gate	
	Charac-teristic	Judge	Charac-teristic	Judge	Charac-teristic	Judge	Charac-teristic	Judge	Charac-teristic	Judge
Downstream water level	No influence	◎	No influence	◎	Influence	△	Influence	△	Influence	△
Operation	So difficult	△	Easy	◎	Easy	◎	Easy	○	Easy	◎
Maintenance	Easy	◎	Slightly difficult	○	Slightly difficult	○	Slightly difficult	○	Slightly difficult	○
Pier height	High	△	High	△	Low	◎	Low	◎	Low	◎
Cost	Low	◎	High	○	High	○	Moderate	○	High	○
Hoisting load	Large	△	Moderate	○	Large	△	Large	△	Light	◎
Vibration	No	◎	No	◎	Moderate	○	Moderate	○	Occurence	△
Reliability	High	◎	High	◎	Low	△	Low	△	Low	△
Height/width ratio	No influence	◎	No influence	◎	Influence	△	Influence	△	Influence	△
Over-all Evaluation	Hoisting load becomes large for large sized gate leaf and operation will be difficult		Reliability is high and hoist load is relatively low for large sized gate		Reliability is low under influence of downstream water level/ back water of Lake Tonle Sap		Reliability is low under influence of downstream water level/ back water		Reliability is low under influence of downstream water level/ back water	
			◎							

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5) Dimension of Weir:

Dimension of the Moung Russei Diversion Weir will be proposed as the followings, based on the criteria shown in table below:

Dimension of Lum Hach Diversion Weir

Items	Dimension	Remarks
Weir Type	Floating Type Movable Weir	See i), iii)
Design Water Level	WL1: 38.0 m (Irrigation) WL_F1:38. 0m (Flood)	See 2) i) - iii)
Design Flood Discharge	Q_F=430.0 m^3/sec	See 2) ii) (T=100 year Return period)
Total Clear Width of Weir	ΣB=65.0 m	Flood gate: 15.0x3+2.5x 2+ 2 x 2=54.0m Sluice gate: 2 x 2 + 1 x 2 = 6m Fish ladder: 5.0 m
Width of Concrete dyke	ΣB=64.0 m	

Elevation of gate sill	EL1.= 34.00 m	Longitudinal design of river bed
Total Height of Weir	Dp:10.0 m	Based on Japanese design criteria above; (EL2.=44.0m) - (EL1.=34.0m) = 10.0
Length of Weir	L1=14.0m(Body Spillway) L2=25.0m (Downstream) L3=12.0m (Upstream)	See Schematic Drawing of Lum Hach Diversion weir
	L4=30.0 m (DS Riprap) L5=12.0 m (US Riprap)	
Gate type (Flood Gate)	Fixed wheel gate	See iv)
Gate Dimension	Clear Height H:4.0 m, Clear Span B:15.0 m	H:4.0m = WL1=38.00m – EL.34.00m (Sill) B: Refer to weirs in Cambodia, Japanese design criteria for headworks and hydraulic calculation
Number of Gate	3 nos.	
Number of Pier and width	2 nos. tp = 2.5 m (Pier for counter weight)	Referrence: weirs w/ counter weight (Damnak Ampil, Roleang Chrey, Kandal Steung)
Gate type (Sluice scouring)	Slide gate	See iv)
Gate Dimension	H:2.0m, B:3.0 m	Referred to Damnak Ampil w/ consideration of river size
Number of Gate	2 nos.	
Fish Ladder	B:5.0m (Half cone type) Δh=3.8 m L=38 m	EL. difference Δh=(38.0-0.2)-34.0=3.8m Slope for ladder=1:10, L=Δh/(1/10)=3.8/0.1=38m

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a) Design criteria employed for Span Length, Clear Span

Span length, clear span and number of gate leaf is first referred to existing large weirs in Cambodia, such as Damnak Ampil, Roleang Chrey and Kandal Steung, and then determined by employing Japanese design criteria for headworks (and the River Control Structural ordinance), coupled with non-uniform flow hydraulic calculations for design flood (high water) discharge of 430 m^3/s as follows:

Existing large weirs in Cambodia: Clear span of 10-15m with plural gate leaves;

Japanese design criteria for headworks (and the River Control Structural Ordinance);

- Span length (=distance between the center lines of adjoining piers of the weir):

  For rivers with design flood (high water) discharge of less than 500 m^3/sec

  Minimum Span length =15m (for weirs with movable portion length $\geqq$ 30m)

- Obstruction ratio of pier (total width of pier(s) to movable portion length of weir):

  For all rivers, Obstruction ratio of pier $\leqq$ 0.1 (10 %)

b) Determination of Span Length, Clear Span

Based on the above criteria and regarding the present size of the river (top-width 40-50 m), it is assumed that number of gate leaf is two, clear span is 15.0m as follows:

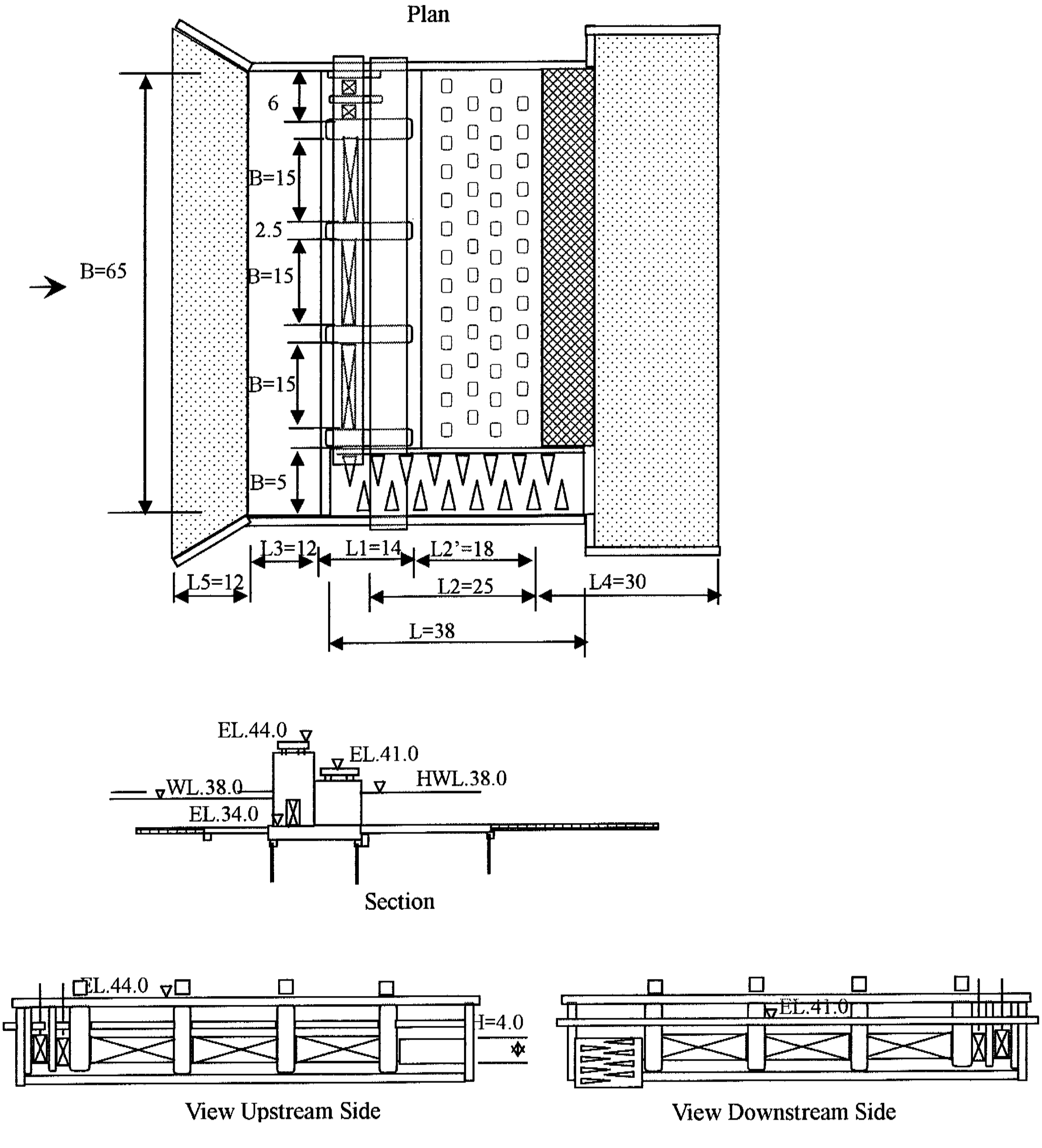
- Disturbance ratio of pier =Σ pier width /(Movable portion length including Σ pier)

= ((2.5 x2) / (3 x 15.0 + 2.5 x2) =0.10 ≦ 0.1 OK

Thus, minimum clear span = 15.0m

- Span length =clear span of gate leaf +Σ(1/2 pier width)

=15 + 1/2 x (2.5 (center pier) x 2) =17.5 > 15.0 OK



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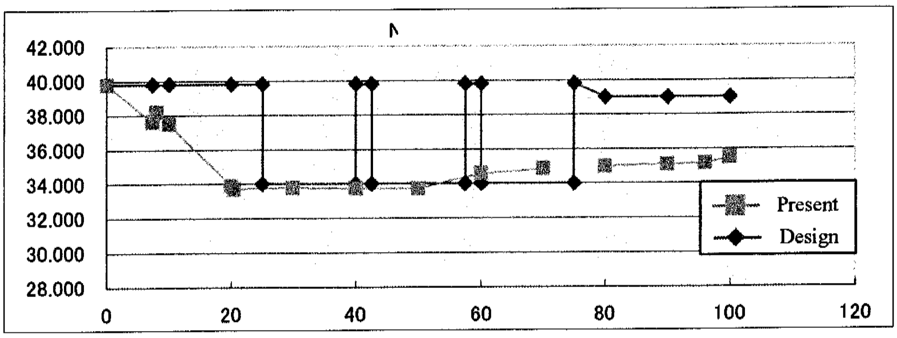
Schematic Drawing ofLum Hach Diversion Weir

c) Hydraulic Calculation:

First trial is conducted for clear span: 15m, number of gate leaf: three, pier: 2 (width 2.5m). The result shows that design high water level at weir and its upstream are in the range of WL_F1=36.9-37.5m < 38.00m (maximum design high water level).



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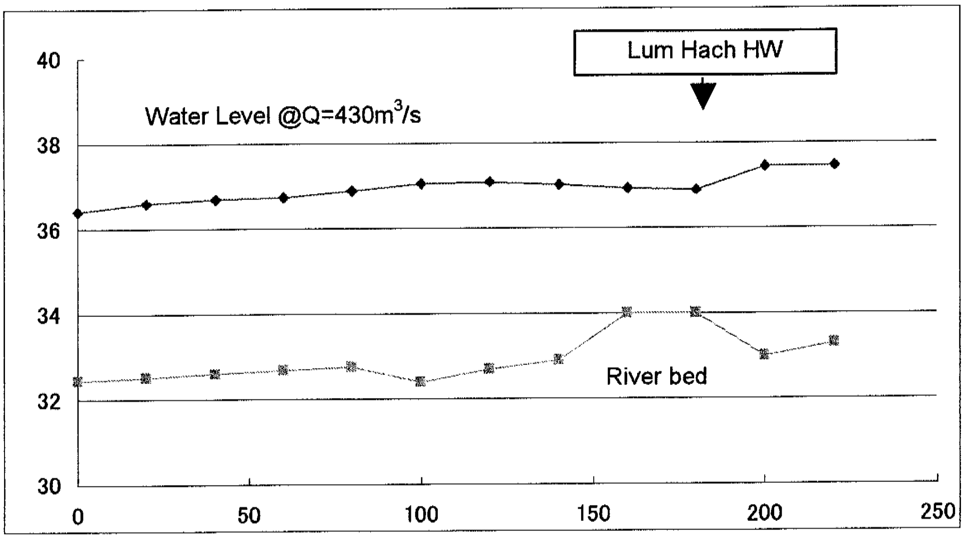
Trial Cross-Section of Lum Hach Diversion Weir



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Hydraulic Calculation Result of Non-uniform flow for Proposed Weir Section at Q=430m^3/sec

- Determination of Dimension:

Considering gate size of the existing weirs mentioned above, a total of three trials are carried out with the maximum gate clear span of 15.0 m. The results are shown in table below, considering total clear width of structure (including fish ladder) and present river section with top width of about 65m. The results show that:

-for the case of "3 gates with clear span 15m", design high water level at the weir and its upstream, downstream ranges between WL_F1=36.9 -37.46m, which is below the maximum allowable water level of 38.00m.

-however, for the case of "2 gates with 'clear span 12.5m' and '15m", design high water level at the upstream of the weir ranges between WL_F1=38.8-38.2, which is higher than the maximum allowable water level of 38.00m.

Therefore, "3 gates with clear span of 15.0m" is selected for the Lum Hach Weir.

Summary of Trial Calculation Result

Gate Nos.	Clear Span	Span Length	PierDist Ratio	Total Clear Width	Elevation of Gate sill	Water level (m) at weir, up and downsteram			Remarks WL<=17.82m
	(m)	(m)	(%)	(m)	EL. (m)	60mDS	Weir	40mUS	
2	12.50	14.75	9.1	42.50	34.00	37.09	37.11	38.79	NG
	15.00	17.25	7.7	47.50	34.00	37.09	36.87	38.23	NG
3	15.00	17.50	10.0	65.00	34.00	37.09	36.90	37.46	OK

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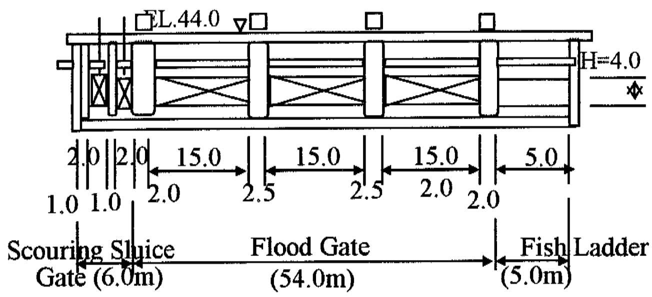

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Schematic Drawing of Lum Hach Diversion Weir (Upstream View)

d) Length of Weir

- Body Spillway : L1 = Operation deck and miscellaneous width + Bridge width

= (7.0m + 7.0m) =14.0 m

Slab thickness t1 = 1.8 m

- Downstream (D.S) Apron: L2 = $0.9\ C\ (D)^{1/2}$ =

= $0.9 \times 12 \times (4.0)^{1/2}$ = 25.0 m

Slab thickness t2 = 1.0 m

Where, C: Bligh's coefficient (C=12 for coarse sand), D: Gate height 4.0 m

- Upstream (U.S) Apron: L3 = 2 h2

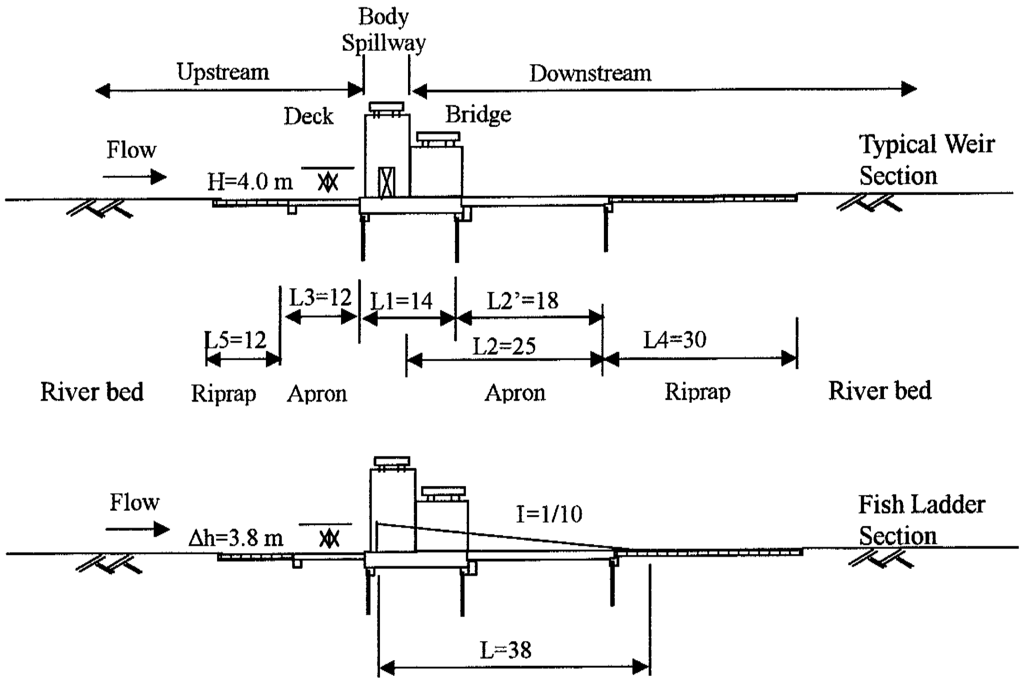
= 2 x 3.5 =7.0 -> 10m (Where, h2: water depth in U.S)

Slab thickness t3 = 0.8 m

- DS Riprap: L4 = 6 x h2 = 6 x 4.4=26.4 -> 30 m

- US Riprap: L5= L3 = 12.0 m

It is noted that for the lengths of DS apron and DS riprap, "Bligh's equation" has been applied since it was slightly longer and safer than the lengths calculated by USBR Type equation.



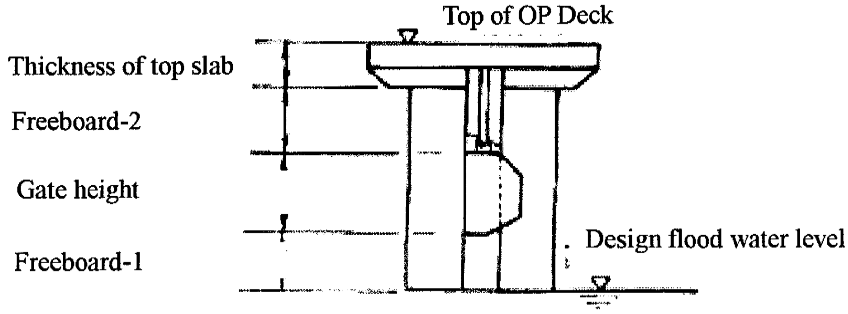
Prepared by JICA Study Team

Schematic Drawing (Section) of Lum Hach Diversion Weir

e) Total Height of Weir

- Total height : Dp = (HWL_F1+ Fb1 + gate height + Fb2) – gate sill EL.

  = 38.0 + 0.8 + 4.0 + 1.0 + 0.2 – 34.00 =44–34= 10.0m



Prepared by JICA Study Team
Originaal source in Japanese Design Criteria for Headworks

Explanatory Profile for Crest Elevation of Pier

f) Thickness of Pier

- Pier for counter weight: 2.5 m (Roleang Chrey, Kandal Steung) – 3.1 m (Damnak Ampil)

  tp = 2.5 m > 1.9 m OK

- range of thickness: tp $= 0.12 \times (Dp + 0.2\ Bi) \pm 0.25$

  $= 0.12 \times (10 + 0.2 \times 17.5) \pm 0.25$

  $= 1.4\ m < tp < 1.9\ m$

  Where, Bi = Span Length (m)

g) Bridge

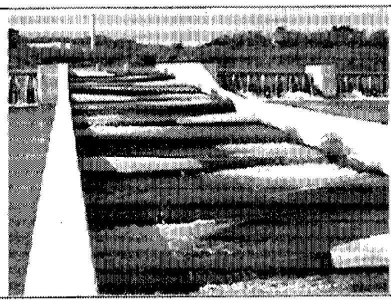
A concrete slab bridge is installed over the weir with a total span of about 40m. The elevation of slab bottom is to be EL. 39.7m, by adding a freeboard of 1.5 m to the design irrigation water level $WL_I 1'$=38.2m at weir site. The effective width and total width of the bridge are 3.8m and 5.0m, respectively, referred to the bridge of the Damnak Ampil Weir, with regarding the adjacent provincial road class.

h) Foundation works

Due to lack of geological information for preliminary design, concrete piles with 30 cm x 30 cm (or dia. 30 cm) x L = 6.0 m are to be installed at a maximum spacing of 3.0 m under body spillway, upstream and downstream apron and fish ladder. In addition sheet piles of L = 6.0 m are also to be installed near the edge of body spillway.

i) Fish Ladder:

Fish ladder is planed on right bank side of the weir. Type of fish ladder is planned to be "half-cone type" or "grouted riprap cascade type", since these types creates a variety of water depth and flow velocity, so that fish is able to choose suitable course, water depth and flow velocity in accordance with its size and swimming ability.

- discharge: 0.88m^3/s (maintenance flow0.74 +Industry & Domestic flow o.14) + residual - Width: B=5.0m (common for above types) - Slope: I = 1/10 (commonly for above types) - Height: H=3.8m (Gate height-inlet water depth) - Length: L6=38 m (=3.8/(1/10))	 Image: half-cone type fish ladder

(4) Lum Hach Intake

1) Summary of Design Condition and Result:

Design condition and result for Lum Hach Intake are summarized as follows:

Summary for Design of Lum Hach Intake

Design Parameter	Condition	Remarks
Design Intake Discharge rate:	Q: 6.60 m^3/sec	Lum Hach Sub-project A=3,100 ha
Irrigation Water Level WL1:	WL. 36.00 - 38.00 m	Top of Gate: EL. 38.00
	(WL. 38.20 m)	WL1+max. Overflow depth=0.2m
Elevation at Inlet (River bed):	EL. 34.00 m	
Elevation at Inlet (Intake):	EL. 35.20 m	
Gate Sill Elevation:	WL. 35.20 m	
Width, Height and Length	Width: 7.1 m Height: 3.8 m Length: 9.5 m (+ Apron length)	Breast wall is installed between EL. 36.7 and EL.39.0 to prevent The entrance of flood water.
Gate Type and Gate Size, nos.	Slide gate, B:1.5 x H:1.5 x 3 nos.	
Bridge	Total width 4.0 m	

Prepared by JICA Study Team

2) Design Elevation of Intake Inlet:

Elevation of an intake is to be designed, considering the design water depth of the both river and intake at inlet, in order to reduce and minimize the entrance of suspended particle (sediment). Water depth at inlet of intake is desirable to be within upper 0.4 of that of river (referring to Japanese design criteria for headworks):

- Water depth at river, H: 2.0 m (= NLWL .36.00m – EL.34.00 m)

  Elevation of intake inlet $\geqq$ NLWL - 0.4 x H=36.00 –0.4 x 2.0 = 35.2

- Water depth at intake, h: 0.80 m (refer to "rehab. of irrigation and drainage facilities")

  Elevation of intake inlet = NLWL– h = 36.00 –0.8 = 35.2 $\geqq$ 35.2 OK

3) Design of Gate:

Design of the drainage gate (gate size and numbers of gate) is given as follows:

(reference: "Booklet of Hydraulic Formula", 1999 edition, Japanese Society of Civil Eng.,pp.255)

- Discharge rate Q (m^3/sec) for 1 gate leaf (N=1):

$$Q = C\,a\,B\,(2\,g\,h0)^{1/2}$$

$$= 0.5 \times 0.75 \times 1.5 \times (2 \times 9.8 \times 0.8)^{1/2} = 2.227\ (m^3/sec)$$

- Discharge rate Q' (m^3/s) for 3 gate leaf (N=3):

$$Q' = 3 \times 2.227 = 6.68 > 6.6\ (m^3/sec) = \text{Design discharge rate} \quad \text{OK}$$

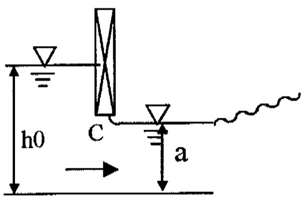
- Gate size and number(N): B=1.5m, H=1.5 m, N=3

Where,

C: coefficient (C=0.5, when a / h0 =1)

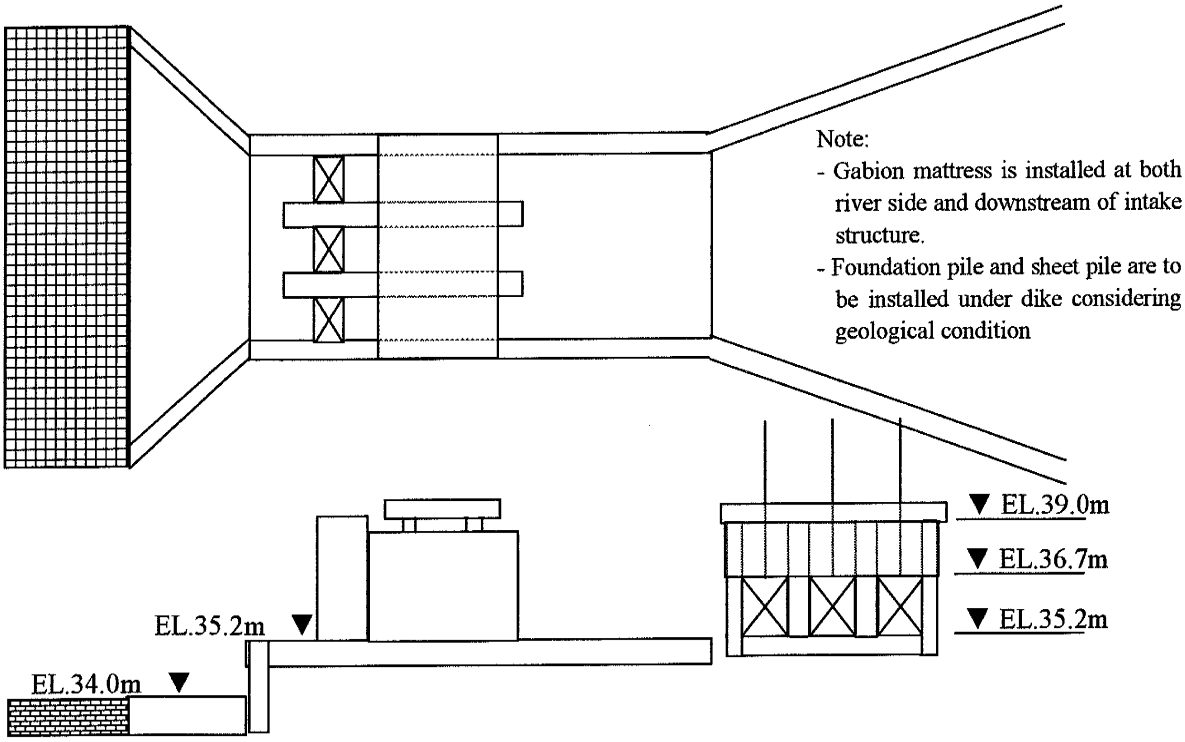
a: gate opening (m)

B: width of gate (m)



g: gravity acceleration (m/sec^2)

h0: water depth (river side)



Prepared by JICA Study Team

Schematic Drawing of Lum Hach Intake

(5) O Roluss Intake

1) Summary of Design Condition and Result:

Design condition and result for O Roluss Intake are summarized as follows:

Summary for Design of O Roluss Intake

Design Parameter	Condition	Remarks
Design Intake Discharge rate:	Q: 5.70 m^3/sec	O Roluss Irr.-System A=3,440 ha
Irrigation Water Level WL1:	WL. 36.00 - 38.00 m	Top of Gate: EL. 38.00m
	(WL. 38.20 m)	WL1+max. Overflow depth=0.2m
Elevation at Inlet (River bed):	EL. 34.00 m	
Elevation at Inlet (Intake):	EL. 35.20 m	
Gate Sill Elevation:	WL. 35.20 m	
Width, Height and Length	Width: 5.7 m Height: 4.8 m Length: 15.0 m (+ Apron length)	Breast wall is installed between EL. 36.7 and EL.39.0 to prevent The entrance of flood water.
Gate Type and Gate Size, nos.	Slide gate, B:2.0 x H:1.5 x 2 nos.	
Bridge	Total width 4.0 m	

Prepared by JICA Study Team

2) Design Elevation of Intake Inlet:

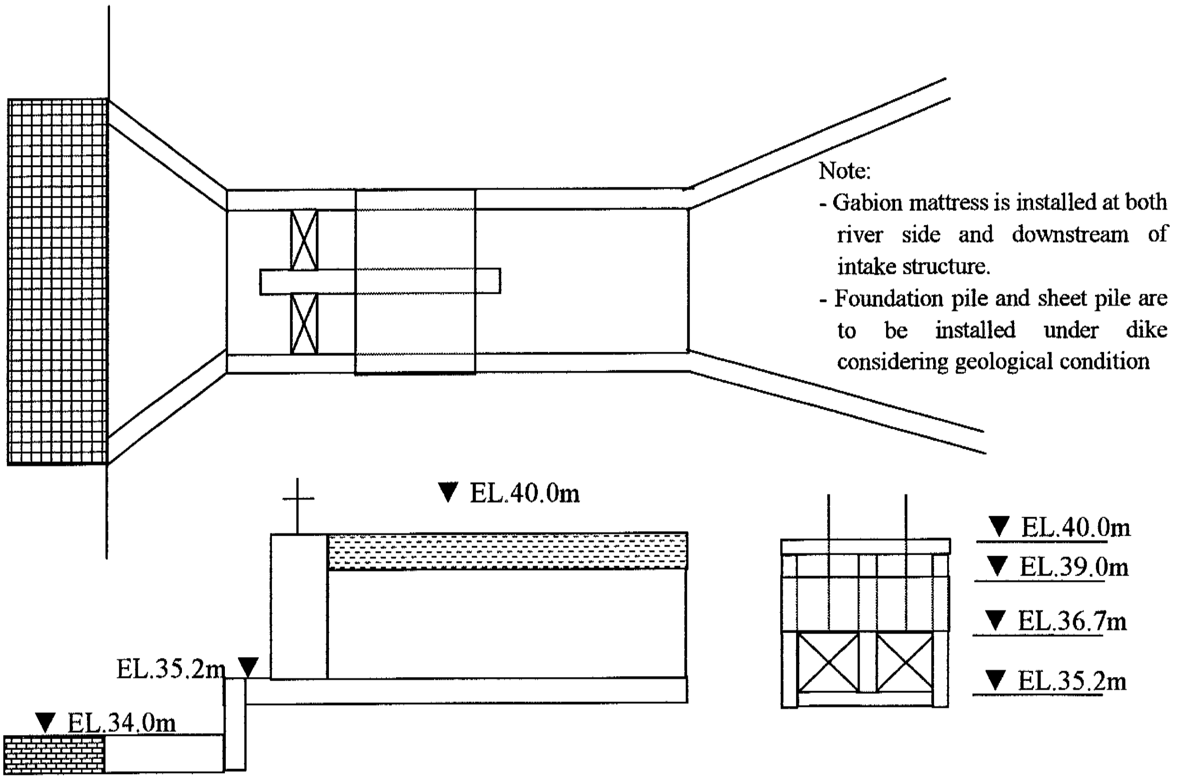
Elevation of an intake is to be designed, considering the design water depth of the both river and intake at inlet, in order to reduce and minimize the entrance of suspended particle (sediment). Water depth at inlet of intake is desirable to be within upper 0.4 of that of river (referring to Japanese design criteria for headworks):

- Water depth at river, H: 2.0 m (= NLWL .36.00m – EL.34.00 m)

  Elevation of intake inlet ≧ NLWL - 0.4 x H=36.00 –0.4 x 2.0 = 35.2

- Water depth at intake, h: 0.80 m (refer to "rehab. of irrigation and drainage facilities")

  Elevation of intake inlet = NLWL– h = 36.00 –0.8 = 35.2 ≧ 35.2   OK



Prepared by JICA Study Team

Schematic Drawing of O Roluss Intake

3) Design of Gate:

Design of the drainage gate (gate size and numbers of gate) is given as follows:

(reference: "Booklet of Hydraulic Formula", 1999 edition, Japanese Society of Civil Eng.,pp.255)

- Discharge rate Q (m^3/sec) for 1 gate leaf (N=1):

$$Q = C\,a\,B\,(2\,g\,h0)^{1/2}$$

$$= 0.5 \times 0.72 \times 2.0 \times (2 \times 9.8 \times 0.8)^{1/2} = 2.851\ (m^3/sec)$$

- Discharge rate Q' (m^3/sec) for 2 gate leaf (N=2):

$Q' = 3 \times 2.85 = 5.70 \geqq 5.7\ (m^3/s)$ = Design discharge rate OK

- Gate size and number(N): B=2.0m, H=1.5 m, N=2

Where,

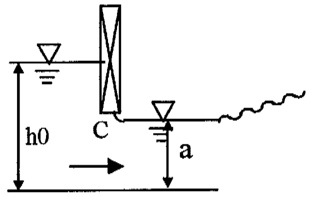
C: coefficient (C=0.5, when a / h0 =1)

a: gate opening (m)

B: width of gate (m)

g: gravity acceleration (m/sec^2)

h0: water depth (river side)



(6) Lum Hach Approach Canal (LHAC)

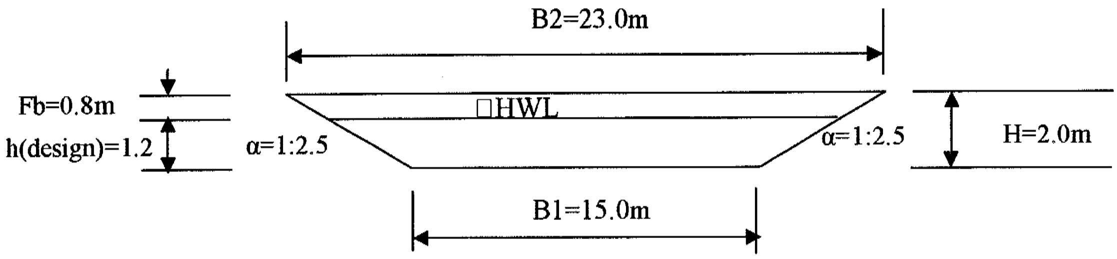
1) Summary of Design Condition and Result:

Design condition and result of Lum Hach Approach Canal (LHAC) are summarized as follows. It is noted that the construction period for the Lum Hach Weir is anticipated between early-November and late-May, thus the discharge rate for temporary diversion during construction is estimated at $30.3 m^3/sec$, which is the maximum discharge of the above period in last five years:

Summary for Design of Lum Hach Approach Canal (LHAC)

Design Parameter	Condition	Remarks
Design Discharge rate:	Q1: 6.6 m^3/sec	Maximum Intake discharge
Design Temporary Discharge	Q2: 30.3 m^3/sec	Max. during Early-Nov. – End. May
Canal bed Inclination	1/ 4,000	Refer to landscape
Canal Base width, top width	B1:15.0 m, B2:23.0 m	Considering economic size
Canal Side Slope, Maning's n coefficient Freeboard	m : 1:2.0 n : 0.025 Fb: 0.8 m	MOWRAM design criteria for Irr. main canal class with Q=5-10m^3/sec sandy soil applied .
Canal Height,	H: 2.0m,	Present condition
Water Depth	h1: 0.79m (Q1=6.6 m^3/s) h2: 1.92m (Q2=30.3 m^3/s) hmax:2.0 m(Qmax=37 m^3/s)	hmax: Fb=0

Prepared by JICA Study Team



Prepared by JICA Study Team

Schematic typical section of Lum Hach Approach Canal

Hydraulic Calculation Result (Uniform flow) of Lum Hach Approach Canal Section

Item	Symbol	Unit	Equation	Case-1	Case-2
Design discharge	Q1	(m3/s)	＜Input＞	30.000	6.600
Base width	B1	(m)	＜Input＞	15.000	15.000
Water depth	h	(m)	＜Input＞	1.916	0.792
Canal bed slope	I		＜Input＞	1/4000	1/4000
Roughness coef.	n		＜Input＞	0.025	0.025
Side slope	α		＜Input＞	2.0	2.0
Wet-perimeter	P	(m)	$B+[(1+\alpha L^2)^{0.5}+(1+\alpha R^2)^{0.5}]*h$	23.567	18.541
Cross-section area	A	(m2)	$B \cdot h+0.5\alpha h^2$	36.072	13.133
Hydr. Mean depth	R	(m)	A/P	1.531	0.708
Velocity	v	(m/s)	(R^(2/3)×I^(1/2))/n	0.840	0.503
Canal EL.(Inlet)	EL1	(m)	＜Input＞	35.200	35.200
Design water level	WL1	(m)	EL1+h	37.116	35.992
Calc. discharge	Q	(m3/s)	A·v	30.300	6.600
Free board	Fb	(m)	＜Input＞	0.000	0.800
Canal total height	H	(m)	h+Fb	2.000	1.600
Canal total width	B2	(m)	B1+2*α*H	23.000	21.400
Canal bank-top EL.	EL2	(m)	EL1+h+Fb	37.116	36.792
Canal Length	L1	(m)		750.000	750.000
Change in canal EL.	⊿EL	(m)	L1·I	0.188	0.188
Canal EL.(outlet)	EL3	(m)	EL1-⊿EL	35.013	35.013
Water level(outlet)	WL2	(m)	EL3+H	36.928	35.804
Remarks				Flood (dry)	Intake disch.

Prepared by JICA Study Team

Discharge Observation data for Boribo River in Dry Season (Top 5 in Early Nov. to following End of June)

No.	Discharge (m^3/s) Observed at Damnak Ampil Weir in Dry season of 2001-2005	Remarks (November 1st-June 30th)
1.	30.3	Nov, 2002
2.	29.7	April, 2005
3.	21.1	Nov, 2002
4.	16.5	June, 2007
5.	14.7	April, 2005

Prepared by JICA Study Team, based on Table A.4.2-5 in Appendix A

(7) Closure Dyke at Outlet of 7th January Canal

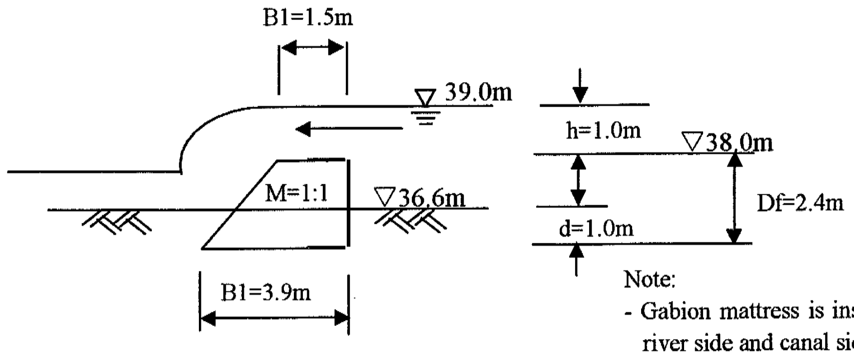
1) Summary of Design Condition and Result:

Design condition and result of closure dyke at the outlet of 7 th January Canal in Lum Hach Sub-project are summarized as follows:

Summary for Design of Closure Dyke for 7 th January Canal

Design Parameter		Condition	Remarks
Type of Structure		Concrete Dyke	
Elevation of Dyke	Overflow section	EL1.: 38.0 m	> HWL_F1.= 38.00 m
Elevation of Canal Base		EL2.: 36.6 m	
Elevation of Dyke Bottom		EL3.: 35.6 m	EL2. – 1.0 m
Height of Dyke	Overflow section	H1: 2.4 m (1.4 m)	Apparent height in ( )
Width	Top of Overflow section Top of Bottom of section	B1: 1.5 m B2: 3.9 m	Slope M=1:1.0
Length	Top of Overflow section	L1: 40.0 m	Actual length 34 m + 3.0 x both side
Design Maximum Overflow depth		h : 1.0 m	WL. 39.0 m

Prepared by JICA Study Team



Note:
- Gabion mattress is installed at doth river side and canal side of structure for bed protection.
- Foundation pile are to be installed under dike considering geological condition

Prepared by JICA Study Team

Schematic typical section of Closure Dyke at Outlet of 7th January Canal

C8.2.2 Irrigation and Drainage Facilities

(1) Irrigation Facilities

1) Design Plan of Irrigation Facilities

Design plan of irrigation facilities is discussed in section C3.3.2 (1).

2) Rehabilitation and Improvement of Irrigation Facilities

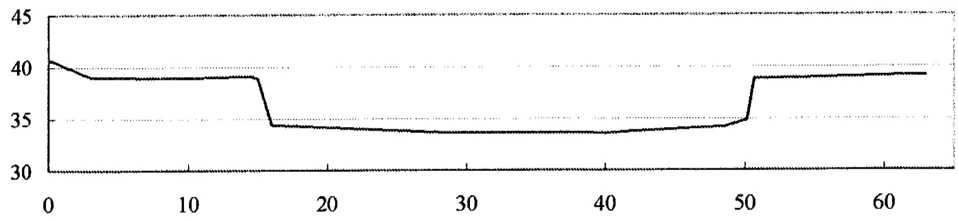
a) Design of Irrigation Canal

One main, nine secondary and two sub-secondary canals are designed preliminarily. The main canal would flow in the existing 7 th January canal and the existing "secondary No.2". The 7 th January canal would act as a conveyance canal.

The main canal would start from the junction between the approach channel of the proposed headworks and the existing 7 th January canal.

At the 750m section from the beginning point, dispersible soil can be observed. This section is quite big for the design discharge of 6.6 m^3/sec. The width of the section reaches to 50 m and bank height ranges from 5.0 m to 8.0 m. Moreover, the section has a big opening on its left bank. It might be one of the old river courses of the Ou Lea Pong.

In this study, the section is designed as a regulating pond in the main canal closing the opening by an embankment dyke system. As a result of hydraulic calculation under a non-uniform flow condition, flow velocity would be less than 10cm/sec in this section.



Prepared by JICA Study Team

Cross section at 750 m point

After passing afore-discussed section, the main canal would start excavation because of higher bottom elevation of the existing canal than the designed water surface level.

Secondary canals would be all new canals.

The following shows the canal dimensions designed preliminarily in this study.

Summary of Canal Design

Irrigation Canal	Canal Length			Design				
	Total	Rehab.	New	Design Q(m3/s)	Bottom Width	Canal Height	Left Bank Top Width	Right Bank Top Width
Main Canal	16,400	11,400	5,000	6.6 - 0.83	50.0m - 4.0m	3.7 m - 1.7m	4.0 m	1.5 m
S - 1	500	0	500	0.23	1.0 m	1.0 m	1.0 m	4.0 m
S - 2	1,000	0	1,000	0.26	1.0 m	1.1 m	1.0 m	4.0 m
S - 3	800	0	800	0.23	1.0 m	1.0 m	1.0 m	4.0 m
S - 4	900	0	900	0.23	1.0 m	1.0 m	1.0 m	4.0 m
S - 5	2,000	0	2,000	0.43	1.2 m	1.2 m	1.0 m	4.0 m
S - 6	11,300	0	11,300	0.58	1.8 m	1.2 m	1.0 m	4.0 m
S - 7	11,800	0	11,800	1.51	2.8 m	1.4 m	4.0 m	1.0 m
SS7 -1	3,400	0	3,400	0.26	1.0 m	1.1 m	1.0 m	1.0 m
SS7 -2	2,700	0	2,700	0.34	1.2 m	1.1 m	4.0 m	1.0 m
S - 8	2,400	0	2,400	1.15	2.4 m	1.3 m	4.0 m	1.0 m
S - 9	5,600	0	5,600	0.83	2.2 m	1.2 m	4.0 m	1.0 m
Total of S	42,400	0	42,400					

Prepared by JICA Study Team

b) Design of Irrigation Canal Related Structure

Six types of irrigation related structure are designed preliminarily. The following table shows the required types and numbers.

Type and Number of Irrigation Related Structures

Structure	nos.	Structure	nos.
Turnout	81	Road Culvert	26
Check	38	Bridge	2
Terminal Structure	10	Syphon	1

Prepared by JICA Study Team

The function and feature of drainage canal related structures are described in the previous section C3.3.2 (1).

(2) Drainage Facilities

1) Design Plan of Drainage Facilities

Design plan of Drainage facilities is discussed in section C3.3.2 (2).

2) Rehabilitation and Improvement of Drainage Facilities

a) Design of Drainage Canal

SD-8 and SD-10 are to be rehabilitated. Other drainage canals are designed as new canals.

Summary of Drainage Canal Design

Drainage Canal	Canal Length			Design	
	Total	Rehab.	New	Bottom Width	Height
SD-1	4,000	0	4,000	7.0 m - 4.0 m	2.2 m - 1.6 m
SD-2	6,400	0	6,400	4.5 m	1.6 m
SD-3	6,400	0	6,400	4.0 m	1.5 m
SD-4	4,500	0	4,500	4.0 m	1.6 m
SD-5	3,200	0	3,200	4.0 m	1.5 m
SD-6	2,800	0	2,800	4.5 m	1.6 m
SD-7	3,300	0	3,300	4.0 m	1.5 m
SD-8	6,100	6,100	0	min. 2.4 m	min. 1.2 m
SD-9	3,000	0	3,000	2.0 m	1.1 m
SD-10	10,300	10,300	0	min. 2.8 m	min. 1.5 m
SD-11	3,900	0	3,900	4.0 m	1.5 m
Total	53,900	16,400	37,500		

Prepared by JICA Study Team

b) Design of Drainage Canal Related Structure

Three types of drainage related structure are preliminarily designed. The following table shows the required types and numbers.

<u>Drainage Culvert</u>

Nine culvers are designed to cross proposed irrigation canals and sixteen drainage culver are designed to cross existing roads.

Type and Number of Drainage Related Structures

Structure	nos.	Structure	nos.
Drainage Culvert	25	Footpath Bridge	120
Drainage Gate	1		

Prepared by JICA Study Team

Drainage Gate

A drainage gate is designed at the end-point of the SD-1 for releasing drainage water to the Boribo River. Total effective width of the flow section would be 7.0m equipped with 3 slide gates.

Footpath Bridge

A footpath bridge would be provided for each household along SD-2 and SD-3 to cross a drainage canal.

C8.3 On-farm Development Plan

In accordance with the topography and the concept above mentioned, 67 tertiary blocks are proposed in the Lum Hach Sub-project (3,100 ha) in total. The average size of the tertiary block is figured out 46.3 ha. The typical length of a tertiary canal is 1.0km on average in accordance with the topography. The total length of the tertiary canals is assumed at 67 km in the Sub-project.

The typical length of one water course and number of water courses in the Sub-project are assumed at 470 m and 268 numbers respectively.

C8.4 Water Management and Operation & Maintenance of Irrigation Facilities

(1) Responsible Organization

The share of responsibility of water management and O&M activities is proposed as follows taking into consideration the policy above, size of the Sub-project, importance of facility for the Sub-project management.

Level / Activities	Lum Hach Headworks	Main Canal	Secondary canals	Tertiary canals	Water courses	Field canals
Preparation of annual O&M plan	PDOWRAM	PDOWRAM	FWUG	Sub-FWUG	WUG	-
Preparation of cropping schedule	-	-	FWUC/ FWUG	Sub-FUWG	WUG	Household
Operation of facilities	PDOWRAM	PDOWRAM	FWUG	Sub-FUWG	WUG	Household
Maintenance work	PDOWRAM	PDOWRAM	FWUG	Sub-FUWG	WUG	Household

Note O&M Manuals shall be prepared by MOWRAM/PDOWRAM and be hand over to the respective agencies responsible during hand-over period.

Prepared by JICA Study Team

(2) Water Management and Operation

1) Lum Hach Headworks and Main Canal

PDOWRAM, Kompong Chhnang is responsible for water management and O&M of Lum Hach Headworks and Main Canal including related structures.

The water level at the Headworks is to be kept at EL. 38.0m by controlling sluice gates which are installed at the Headworks, except for flood time. The water level shall be observed by reading a staff gauge which are installed at upstream of weir site and intake site.

The peak diversion water requirement is designed at 6.6m^3/sec. The amount of water taken to the Main Canal is controlled by intake gates in accordance with irrigation service plan which is to be prepared by PDOWRAM, Kompong Chhnang. The intake gates are controlled by readings of staff gauges which are installed upstream and downstream of the intake gates. The gate opening rule shall be set up based on the relationship between water level, gate opening and discharge. Water supply to the Main Canal shall be continuously made throughout a year except for maintenance period which is set in March and April.

The canal base of Main Canal is designed to vary from place to place to use the existing canal section for cost saving, the flow in the main canal is not a uniform flow but non-uniform flow. Accordingly, check gates shall be operated in order to maintain the water level in the main canal for gravity irrigation. In this connection, turnout gates shall be operated carefully in order to avoid overtaking of water.

In the maintenance period, the intake gates of the Headworks shall be totally closed and main canals shall be dried up for the purpose of annual maintenance. The maintenance works of Headworks and main canals are to be executed by PDOWRAM including related structures.

2) Secondary Canals

The water management in the secondary canal is described in the previous section C2.4 (3)

3) Tertiary Canals

The water management in the tertiary canal is described in the previous section C2.4 (3)

4) Water courses and Field Canals

The water management in the tertiary canal is described in the previous section C2.4 (3)

(3) Maintenance Work

The water management in the tertiary canal is described in the previous section C2.4 (4)