IRRIGATION AND POWER DEPARTMENT
GOVERNMENT OF PUNJAB
THE ISLAMIC REPUBLIC OF PAKISTAN

BASIC DESIGN STUDY REPORT
ON
MITHAWAN HILL TORRENT PILOT PROJECT
IN
THE ISLAMIC REPUBLIC OF PAKISTAN

SEPTEMBER 1997

JAPAN INTERNATIONAL COOPERATION AGENCY
NIPPON GIKEN INC.
CTI ENGINEERING CO,. LTD.

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PREFACE

In response to a request from the Government of the Islamic Republic of Pakistan the Government of Japan decided to conduct a basic design study on Mithawan Hill Torrent Pilot Project in the Islamic Republic of Pakistan and entrusted the study to the Japan International Cooperation Agency (JICA).

JICA sent to Pakistan a study team from 19 October to 3 November, 1995, from 25 January to 2 February, 1996 and from 1 July to 13 August, 1996.

The team held discussions with the officials concerned of the Government of Pakistan, and conducted a field study at the study area. After the team returned to Japan, further studies were made. Then, a mission was sent to Pakistan in order to discuss a draft basic design, and as this result, the present report was finalized.

I hope that this report will contribute to the promotion of the project and to the enhancement of friendly relations between our two countries.

I wish to express my sincere appreciation to the officials concerned of the Government of the Islamic Republic of Pakistan for their close cooperation extended to the teams.

September, 1997

Kimio Fujita
President
Japan International Cooperation Agency

September, 1997

Letter of Transmittal

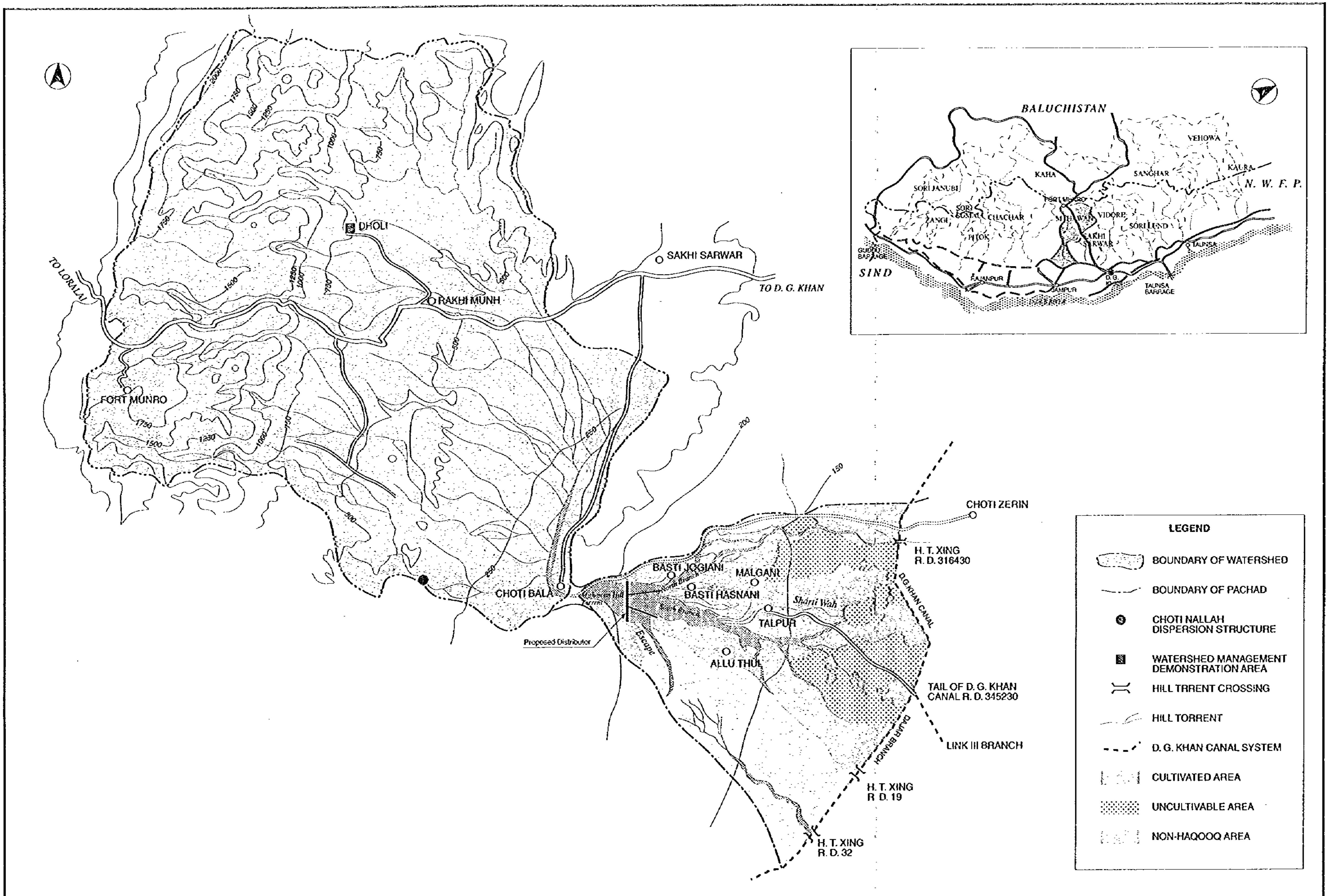
We are pleased to submit to you the basic design study report on Mithawan Hill Torrent Pilot Project in the Islamic Republic of Pakistan.

The study was conducted by Nippon Giken Inc. and CTI Engineering Co., Ltd., under a contract to JICA, during the period from 13 October, 1995 to 29 March, 1996 (Phase I), from 14 June, 1996 to 31 March, 1997 (Phase II) and 10 June to 22 September, 1997 (Phase III). In conducting the study, we have examined the feasibility and rationale of the project with due consideration to the present situation of Pakistan and formulated the most appropriate basic design for the project under Japan's grant aid scheme.

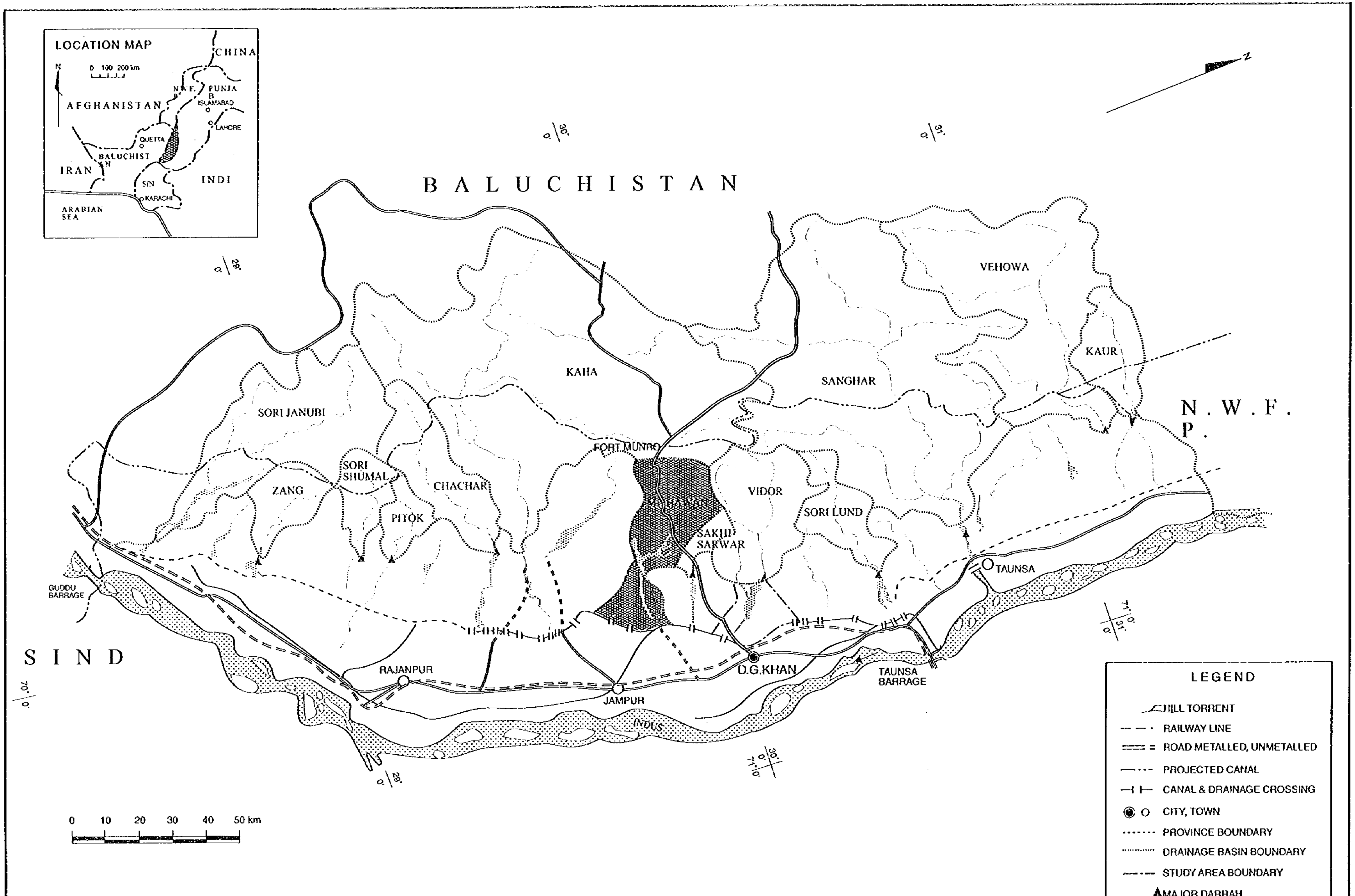
Finally, we hope that this report will contribute to further promotion of the project.

Very truly yours,

Yoichi Kishi
Project manager,
Basic design study team on
Mithawan Hill Torrent Pilot Project
Nippon Giken Inc.
CTI Engineering Co., Ltd.,

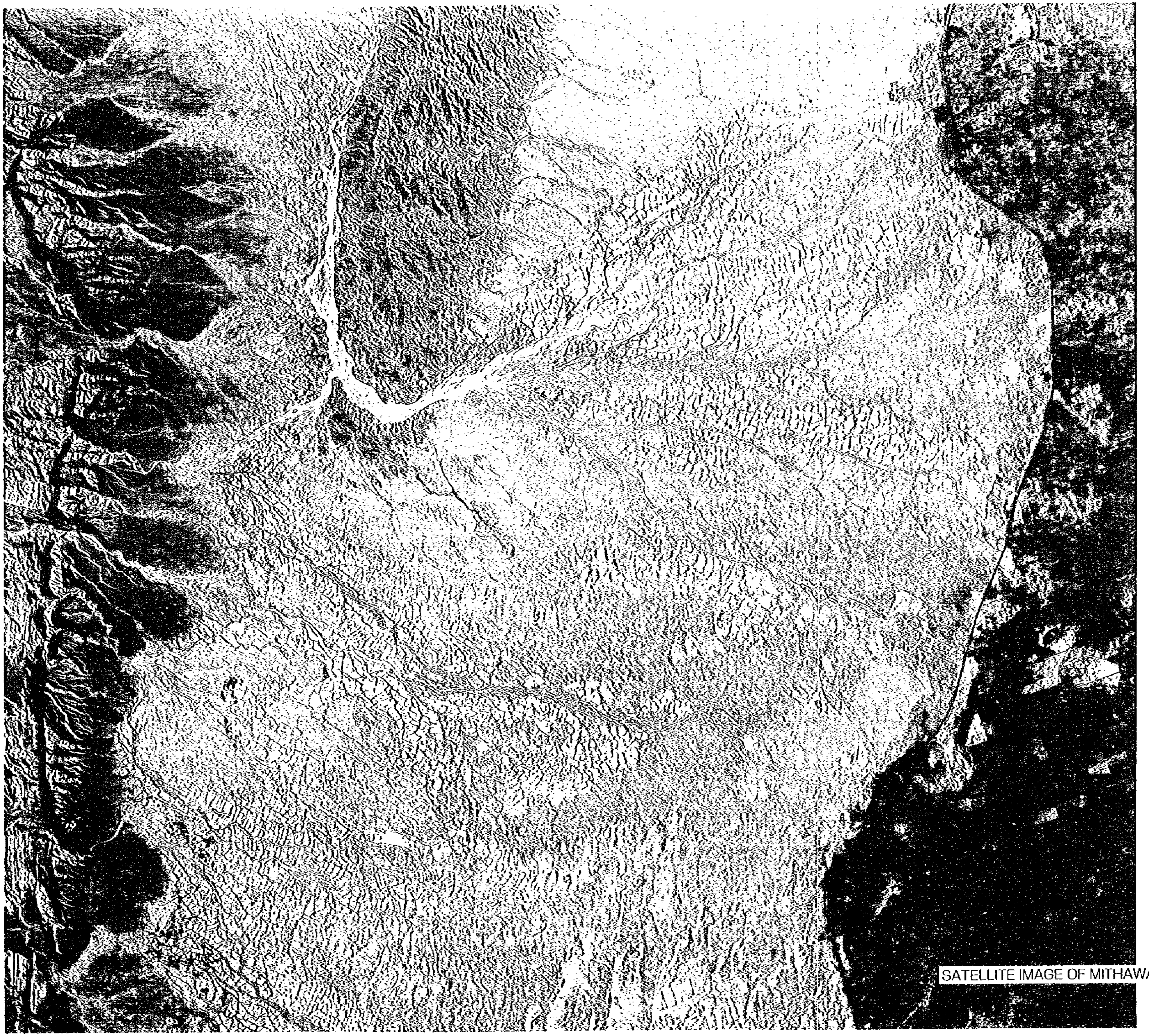


GENERAL PLAN OF THE PROJECT
MITHAWAN HILL TORRENT PILOT PROJECT



GENERAL MAP OF D.G.KHAN HILL TORRENT

MITHAWAN HILL TORRENT PILOT PROJECT



SATELLITE IMAGE OF MITHAWAN PACHAD

Terms (1)

Hill Torrent	– A ephemeral stream in semi-arid and arid area.
Ephemeral stream	– A stream or portion of a stream which flows only in direct response to precipitation and whose channel is completely dry at certain times.
Haqooq	– The area or channel having water rights on flood flows of hill torrents
Non-haqooq	– The area or channel having no water rights on flood flows of hill torrents.
Ghair-haqooq	– The area or channel having no water rights on flood flows of hill torrents as Non-haqooq
Saropa Paina	– The upper fields on a hill torrent are called Saropa and have prior rights while the lower fields are called Paina and have secondary right over flood flows. This is a relative term and is used for all the fields on a hill torrent with respect to their location to each other.
Tarot	– Flood water flowing down after breach of diversion bund to areas having secondary or no right.
Lath	– Earthen embankment constructed around the fields to flood water for basin irrigation
Bund	– Field surround by earthen embankments (Lath)
Gandah	– Any obstruction constructed across the bed of torrent or its branch for diverting flood flows.
Wakra	– Any obstruction constructed in wah or wahi for basin irrigation of fields.
Maqasma	– The works constructed for distribution of flood flows according to shares of various off-takes at any distribution site.
Shakh	– A natural channel off-taking from main hill torrent.
Wahi	– A natural channel off-taking from wah.
Darrah	– The site or the place at which a torrent or a Nallar comes out of hills. Below darrah the torrent fans out into different branches.
Pachad	– It means west side of any reference line.
Pachad Area	– The area lying on the western side of the reference line. In D. G. khan and Rajanpur districts, the area lying on the western side of Canal System upto the toe of hills is called Pachad Area.
Kala pani	– Perennial flow of a hill torrent.
Rhod kohi	– Hill Torrent

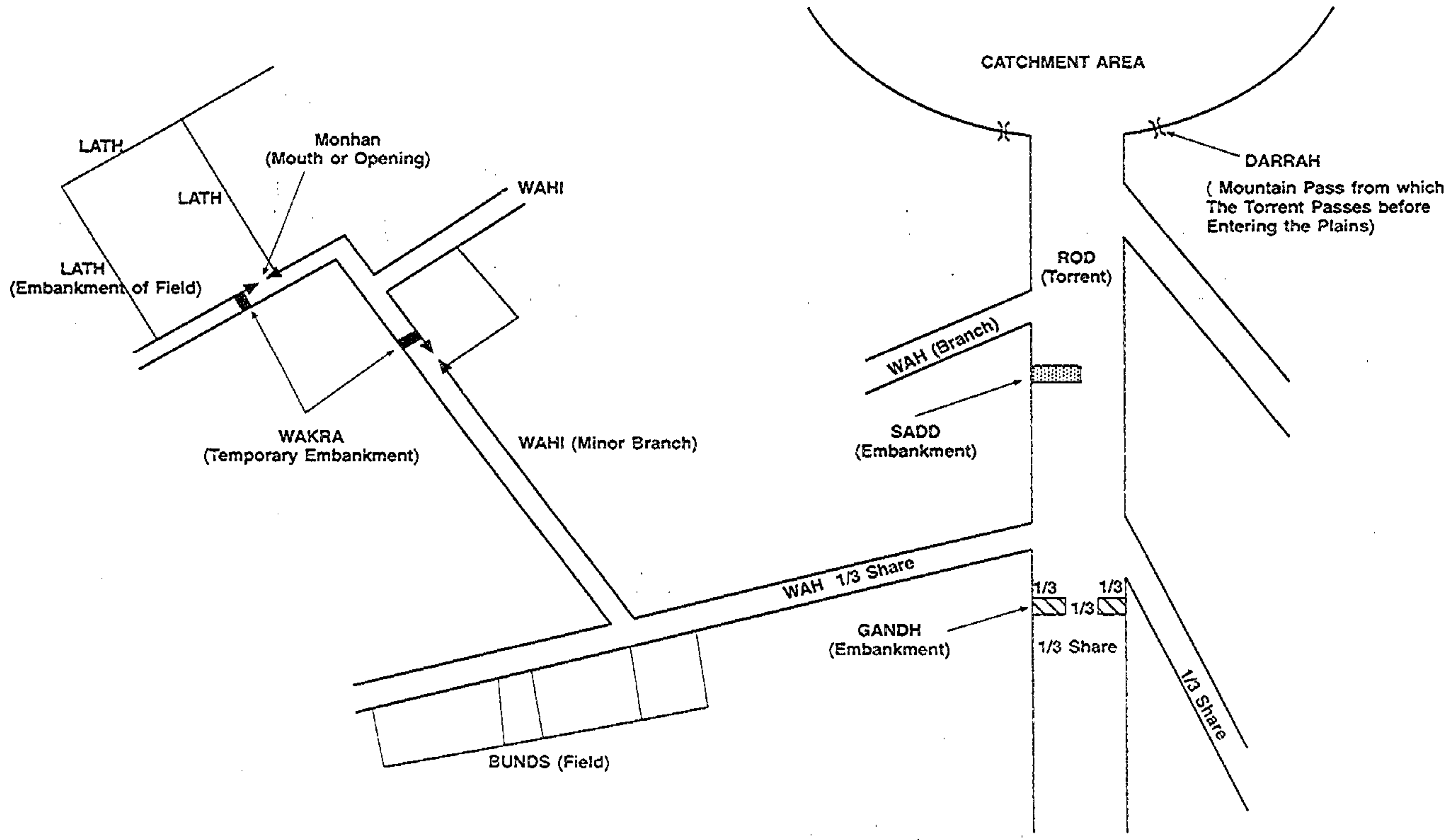
Terms (2)

Kamara System	– A system prevalent in D. G. khan areas where work for diversion of flood flows is carried out on self help basis in accordance with the share fixed under Minor Canal Act of 1905.

Technical Terms

Bed material load	– That part of the sediment load which consists of grain sizes represented in the bed.
Bed load	– 1.) Sand, silt, gravel, or soil and rock detritus carried by a stream on or immediately above its bed. The particles of this material have a density or grain size such as to preclude movement far above or for a long distance out of contact with the stream bed under natural conditions of flow. 2.) The quantity of silt, sand, gravel, or a steam detritus load rolled along the bed of a stream, often expressed as weight or volume per unit of time.
Suspended load	– Particles moving outside the bed layer. The weight of suspended particles is continuously supported by the fluid.
Wash load	– Suspended material of very small size (generally clays and colloids) originating primarily from erosion on the land slopes of the drainage area and present to a negligible degree in the bed itself.

q_s	– Volume of sediment transported per unit time per unit width.
u_*	– Shear velocity ($=\sqrt{(s \cdot h \cdot i)}$
τ_*	– Dimensionless shear stress ($=u_*^2 / \sqrt{(s \cdot g \cdot d)}$)
d	– Diameter of river bed material
g	– Acceleration due to gravity
s	– ($=(\sigma/\rho-1)$)
h	– flow depth
i	– Bed slop
σ	– Density of sand
ρ	– Density of water
q_s	– Volume of sediment transported per unit time per unit width.



Local Terminology and Irrigation System of Hill Torrents

Weights and measures

Millimeter	mm	0.03937 inches
Centimeter	cm	0.3937 inches
Meter	m	3.2808 feet
		1.0936 yards(yd)
Kilometer	km	0.62137 miles
Inches	in.	25.4 mm
		5.54 cm
foot	ft.	0.3048 m
Miles	mil	1.60934 km
Reduced distance	RD	1000.0 feet
		304.8 m
Square meters	m^2	10.7639 sq. ft
Square kilometers	km^2	0.3861 sq. miles
Hectares	ha	2.471 acre
Square feet	sq. ft	0.092903 Square meters
Square miles	sq. mil.	2.58999 km^2
Acre	A	0.404685 ha
Cubic meters	cu. meters, cum, m^3	35.3147 cu. ft
Liters	lit	0.0353 cu. ft
Million cubic meters	MCM	810.71 acre feet
Cubic feet	cu. ft	0.028317 m^3
		28.317 lit
Acre feet		1233.48 m^3
		0.001233 MCM
Kilograms	kg	2.20462 lb
Pounds	lb	0.45359 kg
Cumec	cum/s, m^3/s	35.310 cusec (cfs, cu ft/sec)
Cusec	cfs, cu ft/sec	0.028317 cumec (cum/s, m^3/s)

List of Figures

List of Tables

TABLE OF CONTENTS

CHAPTER 1 BACKGROUND OF THE PROJECT

Economy of Pakistan is based on agriculture sector, that contributes 25 % of the gross domestic product (GDP) and absorbs about 50 % of the total labor force of the nation. About 60 % of the territory, however, including main crop production area of Sind and Punjab belongs to the dry region where annual rainfall is less than 250 mm. Irrigation is very important for the crop production, and Pakistan is the distinguished irrigated country in the world having 16 million hectares of irrigated land that is equivalent to 20 % of the territory of 800,000 square km or 76 % of cultivated land consequently. The major target of the nation is to maximize effective use of limited water for irrigation.

The government of Pakistan places the major goal of policy in water resources development to be that of uplifting the agro-based economy of the country by maximizing crop production in the Eighth Five Year Plan (EFYP) for 1993 to 1998. The strategy is utilizing flood water for augmenting water availability for irrigation in backward regions through flood irrigation schemes, delay action dams, small irrigation schemes, etc., along with improvement of irrigation systems, improvement of O&M by farmer's participation, exploitation of good quality ground water, and protection from water-logging and salinity.

The area called D. G. Khan hill torrent belt including Mithawan area is located in the west-most part of Punjab. There are 13 major and more than 200 minor hill torrents coming from the Suleiman range to the Indus plains. The alluvial fan, called Pachad, has been created along eastern hill foot of Suleiman by the hill torrents, and the local people have cultivated using hill torrent floods for irrigation for crop cultivation. On the other hand, D. G. Khan canal which constructed in 1960's along the edge of the alluvial fan has been suffered from flood damage by the hill torrent floods and its irrigated area occasionally has been inundated by the flood.

The Federal Flood Commission (FFC) and Irrigation and Power Department of Punjab (IPD) conducted the study of flood management for D. G. Khan hill torrent in 1984 aiming at minimizing flood damage in irrigated areas and enhancing crop production in Pachad areas, in which Mithawan area was selected for the pilot project. The government of Pakistan (GOP) requested the government of Japan (GOJ) to conduct the feasibility study on the irrigation development over the D. G. Khan hill torrent belt excluding Mithawan and Kaha and the study conducted in 1991 and 1992 by the Japan International Cooperation Agency (JICA).

On the basis of their above study of 1984 by FFC and IPD, the GOP requested the Japan's grant aid assistance for the implementation of Mithawan Pilot Project on September in 1992. Requested components were followings :

(a) Main Dispersion Structure in Mithawan Hill Torrent,
(b) Improvement of Bhattiwala Bund,
(c) Dispersion Structure in Choti Nallah,
(d) Improvement of Distributor in Nangar Nallah,
(e) Watershed management in Dholi, and
(f) Improvement of existing road.

On the basis of the request, JICA sent preliminary study team on May in 1993, then basic design study team on August in 1993. As the result of these studies, above (c), (e) and (f) components were constructed by Japan's grant aid assistance called "The Project for Watershed Management and Irrigation Development in Mithawan" in the period from September in 1994 to March in 1996.

The dispersion structure in Choti Nallah was constructed to promote flood irrigation for crop lands of the upstream hill foot area by cutting about 10 % of total runoff of the Mithawan hill torrent flood. Further, the project for watershed management being conducted by FAO is still the stage of pilot project and its area is limited. Therefore, it will take more time for the project to be effective over the whole area.

The GOP hopes to achieve all the components in their request since the project has regarded as a pilot project for development of the wide-spread hill torrent area over the territory along with promotion on the crop production in the rainfed area which is a one of the important target in the EFYP. The completed Mithawan Hill Torrent Pilot Project was regarded being unable to remove the flood damage in the D. G. Khan canal irrigated area and in the Pachad immediately, so that the GOP requested strongly the construction of the main dispersion structure in Mithawan hill torrent and improvement of Bhattiwala bund which expand flood irrigation area and reduce flood damage directly.

Despite planned and carried out several projects for flood protection by means of flood irrigation in Pakistan, they have been technical and economical problems and consequently the GOJ reviewed the project carefully. In the review of the project, it was found that experience is not much to construct such a huge structure and topographical and geographical data are short for the design and the GOJ sent the preliminary study team to collect additional information and the details of the structure and to explore the topographical and geographical conditions.

Succeeding the preliminary study, the basic design for the Mithawan Pilot project for the construction of the Mithawan main dispersion structure commenced on October in 1995. The first field study on October in 1995 aimed to determine the conditions of the hydraulic model test and the first series of hydraulic model tests has been done in Japan from November in 1995 to March in 1996. On January in 1996, the second field study conducted. The study and hydraulic test concluded that operation and maintenance is inevitable issue to support the flood irrigation and additional hydraulic model test is necessary to understand the characteristics of the sandy riverbed during flood.

The study team submitted interim report to the GOP and collected additional information for the hydraulic test and studied existing organization for the flood irrigation and social soundness as the third field study on July in 1996. The second hydraulic model test was done from August to December in 1996. Finally, the study team concluded that construction of the main dispersion structure in Mithawan hill torrent is not feasible by the Japan's grant aid assistance.

On June in 1997, the mission was sent to Pakistan to convey the conclusion of the basic design study on the Mithawan Pilot Project. The mission explained that implementation of the project was not feasible, and that the promotion of the watershed management was basic necessity for the area development for an alternative instead. Pakistan side understood it. However, they insisted to construct the flexible structure in Mithawan hill torrent by themselves, because the works on the watershed management take very long time to be effective. Then, Pakistan side requested Japan the assistance on the watershed management and construction of the flexible structure. The mission mentioned that the Japan's grant aid assistance cannot be applied to the flexible structure because it lacks durability, reliability and stability. Nevertheless, the mission expressed their willingness to move forward the request by advising the GOJ to send a project formation study team to Pakistan.

CHAPTER 2 CONTENTS OF THE PROJECT

2.1 Objectives

The construction project for Mithawan main distributor will expand flood irrigation over Mithawan alluvial fan, so called Pachad, as well, mitigate of flood damage in D. G. Khan canal irrigated area.

The Project is a part of Mithawan Pilot Project aiming at flood control and water resources development, that was planned by Irrigation and Power Department (IPD) of Punjab. The Mithawan Pilot Project has three major components, which are (1) watershed management by recovering vegetationin upstream mountain area and construction of minor structures in the ravines, (2) construction of distributors in tributaries on the upstream hill foot, and (3) construction of Mithawan main distributor to distribute flood flows over Pachad.

The objective of the Project is the third component, construction of Mithawan main distributor. As to the first component of watershed management, the small-scale structures have been constructed at and around Dholi, model area, under Japan's grant aid program, and the watershed management program is in progress under participatory approach assisted by FAO. The second component, construction of distributors has been realized on Choti Nallah under Japan's grant aid program. The extension of the first component will be important in the overall implementation of the Mithawan Pilot Project in future.

2.2 Basic Concept of the Project

2.2.1 Development Concept

(1) Previous Studies

Four feasibility studies have been conducted on construction of detention dam or bund construction in Mithawan hill torrent since 1945. All the proposals, however, were abandoned because immense amount of sedimentation was estimated.

In 1984, another feasibility study conducted by IPD proposed the following alternatives on flood control.

1) Construction of aqua-duct cross drainage works on D. G. Khan canal system for disposal of flood flows to the Indus river by means of drains in the canal command area,

2) Disposal of flood flows to D. G. Khan canal and Dajal branch,

3) Disposal of flood flows to the Indus river newly constructed drains along the right side of D. G. Khan canal, and

4) Management of flood flows in the sub-mountainous and Pachad area.

Among them, the alternative 4) was selected, because the alternative 1) of construction of aqua-duct was estimated very costly, the alternative 2) of disposal to D. G. Khan canal was technically impossible and the alternative 3) of new drain was technically difficult and costly.

Plans for proposed Mithawan distributor by IPD are shown in Fig.-2.1 and Fig.-2.2. Hydraulic model test was conducted to decide the width and the elevation of outlets of the distributor to assure the required shares of flood flow.

Design in the feasibility study, however, had not considered following technical points. The model test showed development of sand bars upstream of the structure, which suggested the possibility of unequal shares of flood distribution. Proposed narrow outlets of the distributor would increase flow velocity which would cause severe scouring resulting collapse of the distributor. Fixed shares of flood distribution to the water right area would result distorted fan formation making the area higher than non-water right area and would make it difficult to keep the fan in equilibrium.

(2) The Project Area

The basic design study has revealed that integrated solution is indispensable taking account of both characteristics of alluvial fan and social conditions of the area.

1) Natural Conditions: Deterioration of vegetation cover caused by long term over-grazing, hot and dry climate that weathers rocky ground surface and rare torrential rain all together erode the ground surface and transport to the lower alluvial fan. Such conditions are forming Mithawan alluvial fan. An alluvial fan on the forming process shows considerable change of the surface accompanied by severe scouring of the channel bed, concentration of flood flows, formation of secondary fan downstream, shifting of channels, etc.

2) Social Conditions: Livelihood of the people in the Pachad relied only on flood irrigation farming in old days. After the completion of D. G. Khan canal, people in the Pachad observed that their farming by flood irrigation was

exceedingly unstable compared with that of the canal irrigated area. Furthermore, their small farm land holdings caused by the land inheritance system of the tribal have made it difficult to keep their livelihood. Eventually, they began to migrate from the Pachad to the canal irrigated area or work away to the Middle East countries. Shortage of labor force caused by migration resulted less maintenance for the flood irrigation facilities which needed usual repair.

(3) Completed Works in the Area

At the beginning of 1980's, Hadwari bund and Chitri bund pitched with durable stones were built in Mithawan Pachad with the assistance of the government as the substitute for the traditional sand embankment which needed frequent restoration works. However, it was resulted that Hadwari bund brought concentration of flood flows into Talha wah and its river bed degradation. Besides, Chitri bund left Sharti wah being severely scoured and malfunctioning as an irrigation channel. This means that the technique brought from outside does not fit the requirement of the fan being on its formation process.

(4) Principle of the Project

Change of the surface condition is inevitable on the fan of forming process. Therefore, fan management is necessary to keep balanced change over the fan minimizing excess local variation to assure sustainable use. Fan management is dispersing flood flow uniformly over the fan at the apex and maintaining channels on the fan as irrigation channels.

To keep uniform flows dispersion, the structure which ceases horizontal shift of the channel and assures equal distribution to the channels downstream is essential. For maintaining channels for irrigation, people's organization is necessary for the purpose of monitoring and quick restoration works to undesirable variation in the channels.

Since both constructions of the distributor and fan management are required for sustainable use of the fan which is expected as a productive area, the basic concept of the Project is carrying forward both of them simultaneously. The request by the Pakistan government was the construction of the distributor at the apex and Bhattiwala bund. The latter, however, would not be necessary when flood flows are dispersed by the distributor. Therefore, the study excludes Bhattiwala bund.

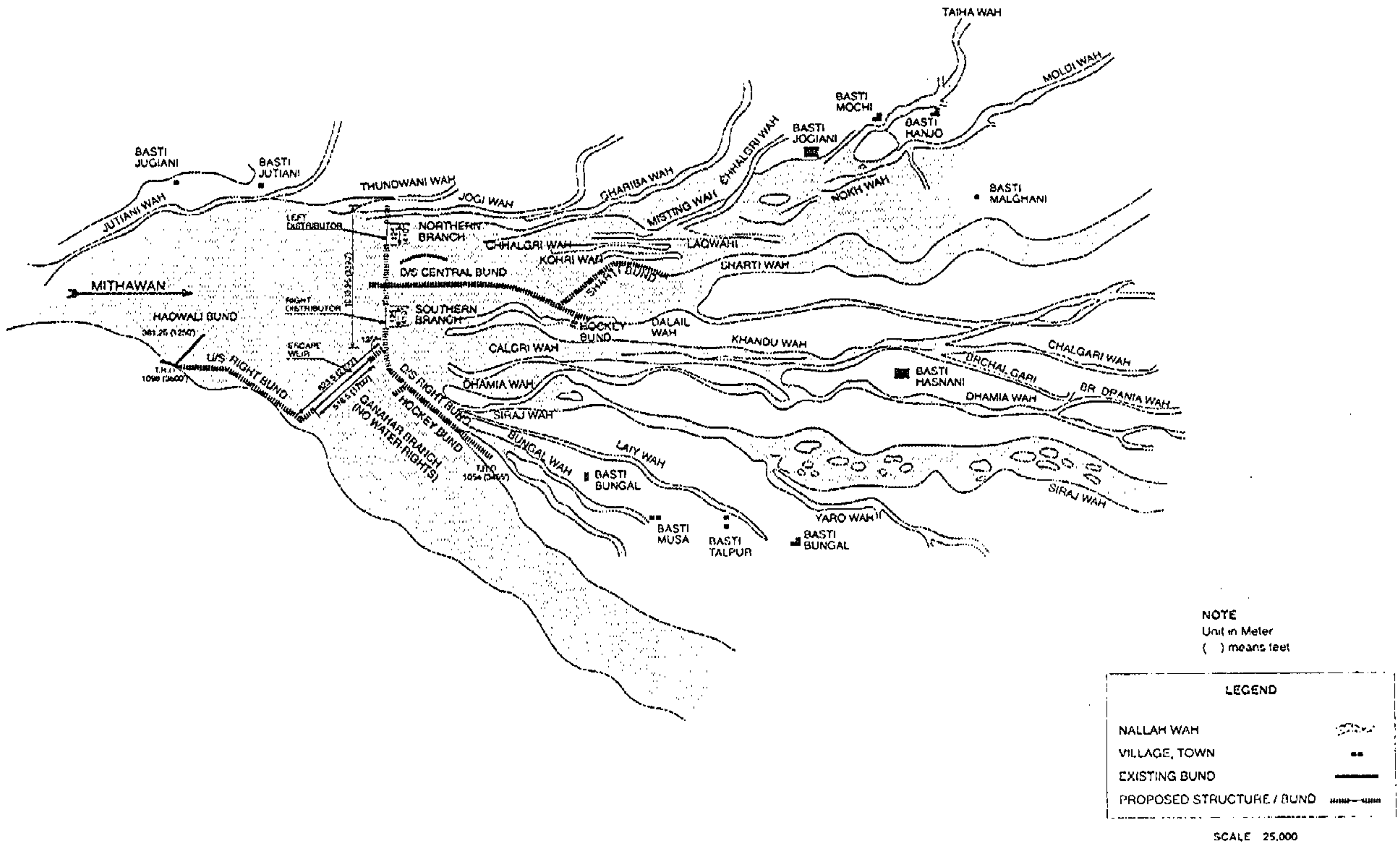


Fig. 2.1 Layout of Mithawan Distributor by IPD, Punjab

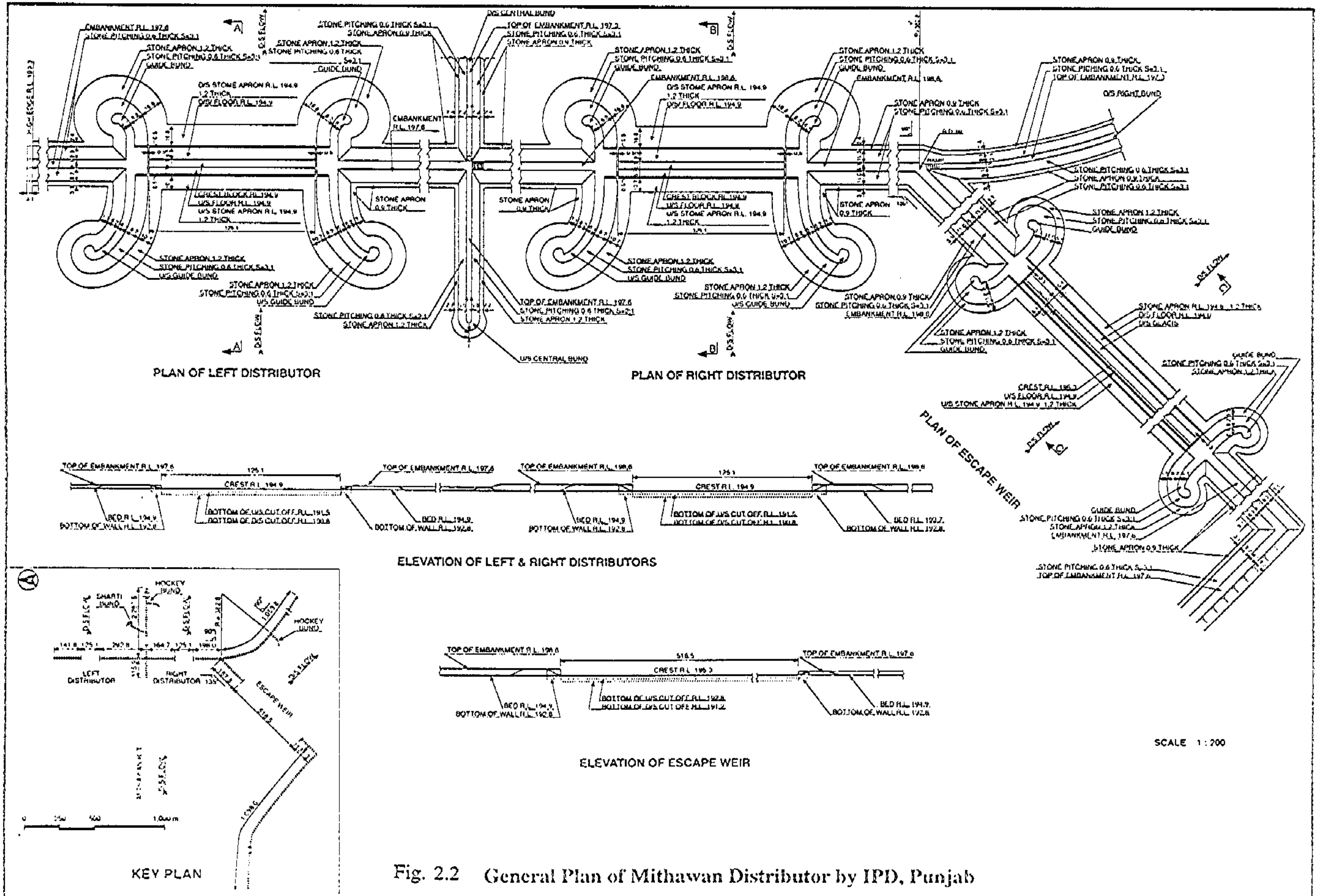


Fig. 2.2 General Plan of Mithawan Distributor by IPD, Punjab

2.2.2 Design Conditions

Mithawan alluvial fan is on the forming process by immense supply of eroded materials from the upper reaches. To maintain sustainable flood irrigation on the alluvial fan, it is necessary to keep equal distribution of flood flows and sediment over the alluvial fan protecting excess scouring and flood concentration in a channel and local surface variation.

Prior to designing the structure for equal distribution of flows and sediment, hydraulic model tests had been executed to clarify whether the existing Hadwari bund was performing for equal distribution, and to determine the location and the type of the structure for preventing the shift of channel at the fanhead and for assuring stable shares of distribution.

The structure is designed on the assumption, because much of the necessary basic data, such as rainfall, flood discharge, foundation condition, aerial photos, etc., are unavailable. However, the design is aimed at the possible safest structure.

(1) Design Conditions

Probable peak floods at various return periods are shown in Table-2.1, which are based on the observed data at Mithawan Nallah. Probable rainfalls in Kaha project shown in Table-2.2 are also referred to decide the design peak flood. Flood discharge of 25-year return period is applied, because it is used for a design flood for hill torrents.

Peak flood was estimated 2,880 cumecs (102,000 cusecs) at 25-year return period for original drainage area of 729 sq. km (180,000 acres). Drainage area at present, however, has reduced to 640 sq. km (158,000 acres), because the flood from Choti Nallah has been drained to neighboring valley. As a result, the design peak flood in Mithawan hill torrent is reduced to 2,500 cumecs (88,000 cusecs) in proportion to decrease of drainage area.

Table-2.1 Probable Flood Peak at Mithawan Nallah

Return Period	Peak Flood (cumecs)	Return (cusecs)	(year) Period	Peak Flood (cumecs)	(m3/sec) (cusecs)
2	917	32,384	20	2,721	96,091
3	1,257	44,390	25	2,880	101,706
5	1,658	58,552	30	3,040	107,357
10	1,952	68,934	50	3,450	121,836

Table-2.2 Probable Rainfall in Mountainous Area (in mm/day)

Basin	Location	Return Period					
		2	5	10	20	25	50
Kaha	Z. Sheru	50	66	76	86	89	100
Vidore	Beweta	22	35	43	52	55	64
Mithawan	F. Munro	33	58	75	90	95	112
Mithawan	estimated						
	(mm)	29	48	60	72	76	87
	(inches)	1.14	1.89	2.36	2.83	2.99	3.43

River bed in Mithawan Nallah is composed mostly with fine sand. Fine sand layer was confirmed down to 5 m by JICA's preliminary exploration. Drilling log of deep well shows the same material at least 90 m (300 ft) thick in Basti Jogiani about 2 km (1.2 miles) downstream from the proposed site. Thickness of the sand at the site deposit is estimated about 35 m (116 ft) by the log and geological structure.

(2) Cultivate Area and Shares of Flood Distribution

Shares of distribution of flood flows are decided by the area irrigated by each channel or actual capacity of the channels. Table-2.3 shows flood irrigated area on the fan by each branch. Maximum flow capacity of each main channel is shown in Table-2.4.

Shares of distribution of flood flows on the original plan were North: South: Escape = 3 : 3 : 4. Prior to the Phase-1 hydraulic model test, shares of the distribution changed to North: South: Escape = 3 : 4 : 3 by the cropping area and carrying capacity of the channels. The Phase-1 hydraulic model test showed that the shares cannot maintain (Case-5 in the Phase-1 hydraulic model study).

Shares of distribution of flood flows for the design are North: South: Escape = 1 : 1 : 1 based on the capacity of existing channels and the result of hydraulic model test on the condition of amendment of water right extending to the non-haqooq area.

Table-2.3 Land Use in Pachad

Branch		Flood Irrigated		Pump Irrigated	Channels & Wasted	Total
		Cultivated	Uncultivated			
North	(ha)	2,112	1,778	253	1,469	5,612
	(acre)	5,219	4,393	625	3,630	13,867
South	(ha)	3,200	2,590	455	1,508	7,753
	(acre)	7,907	6,400	1,124	3,726	19,157
Escape	(ha)	1,297	1,394	125	8,172	10,988
	(acre)	3,205	3,445	309	20,193	27,123
Total	(ha)	6,609	5,762	833	14,149	24,353
	(acre)	16,331	14,238	2,058	34,962	60,175

Table-2.4 Capacity of Major Branches

Branch	Capacity (cumecs)	of Major Branches (cusecs)
North	500	17,700
South	550	19,400
Escape	480	16,900
Total	1,530	54,000

Estimated flood discharge of 60 MCM (48,662 acre feet) at the design flood needs 8,600 ha (21,250 acres) of farm land to store. It is easy to obtain the area since total available flood irrigated area is counted more than 12,000 ha (29,650 acres) at present.

(3) Shift and Vertical Variation of Channels on Mithawan Alluvial Fan

A horizontal variation or a swinging movement of the channel is prone to occur at the fanhead in its formation process of the alluvial fan. Moreover, degradation or aggradation of channel is inevitable.

1) Chronological shift of Sharti wah

Horizontal shift of Sharti wah was studied using old topo-maps (Fig.-2.3 and 2.4) issued in 1968, and in 1986 from Survey of Pakistan, topo-map of Mithawan feasibility study by IPD (Fig.-2.5) in t1984 and satellite image (Fig.-2.6) in May of 1992.

Before 1968, Sharti wah was still minor channel. After the flood of 1976 upper reaches at the wah widened as same as at present, but it flowed toward north and joined with Behu and Moldi wahs. In 1984 it flowed toward west and lengthened to near D. G. Khan canal in 1992. The change of the water course after 1979 has been caused by slope sliding and/or farmer's restoration works raising bed by filling flood water into the channel since Chitri bund was built to stop flood concentration into Sharti wah in 1979.

Aerial photo taken in 1950's shows that sand deposition had already covered farm land in the middle reaches of Sharti wah. It means that flood flows were concentrating on Sharti wah at the time. It is said that the degradation of the channel bed of Sharti wah developed down to 4 to 5 m by the 1976's flood.

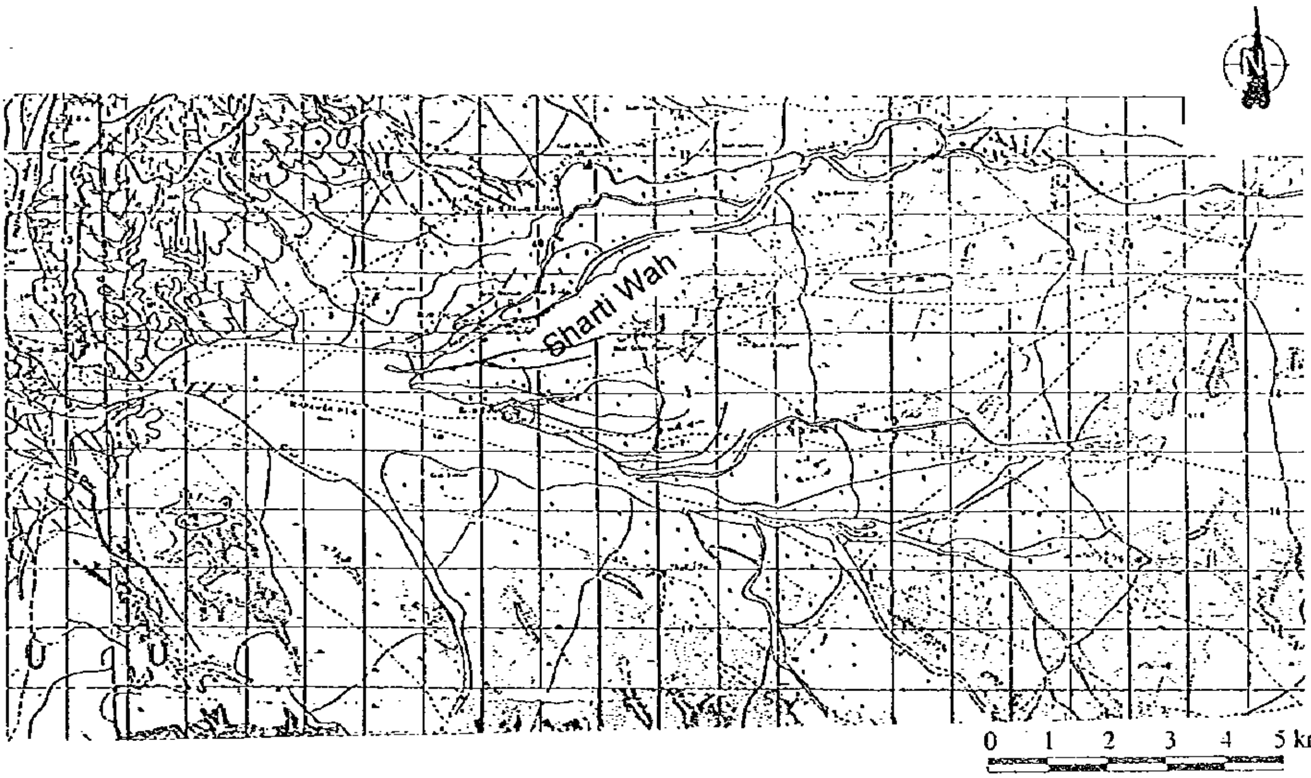


Fig. 2.3 Water Course of Sharti Wah (1950's)

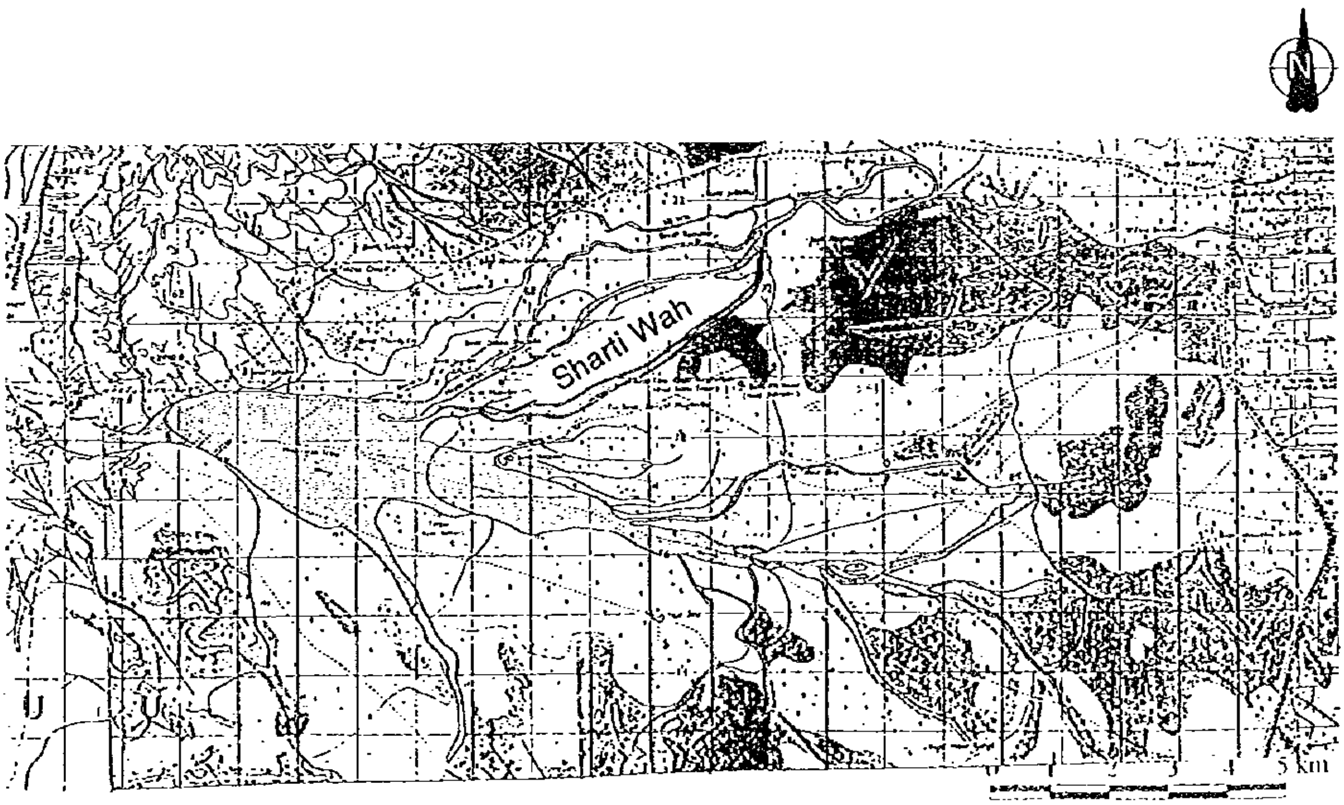


Fig. 2.4 Water Course of Sharti Wah (1970's)

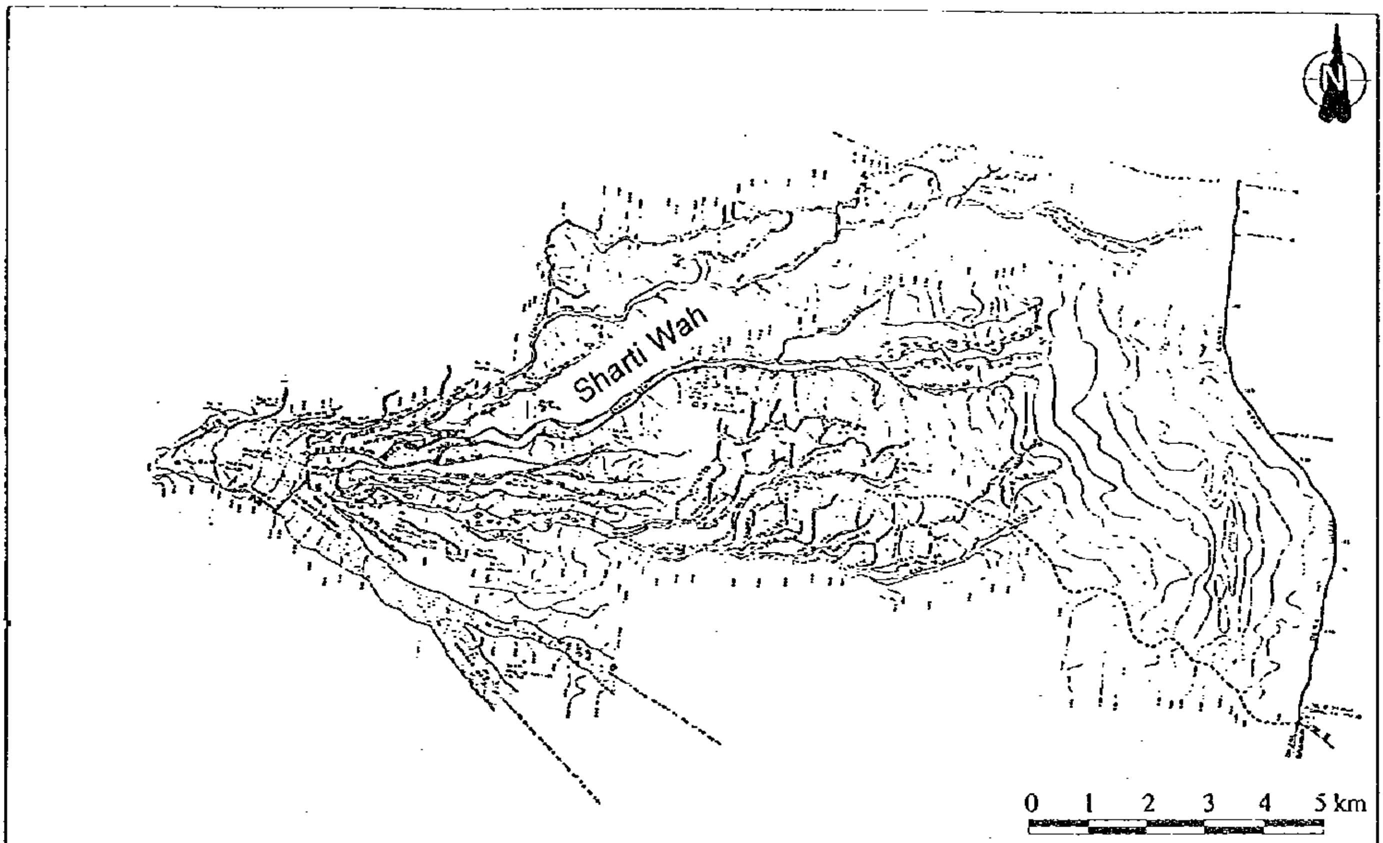


Fig. 2.5 Water Course of Sharti Wah (1980's)

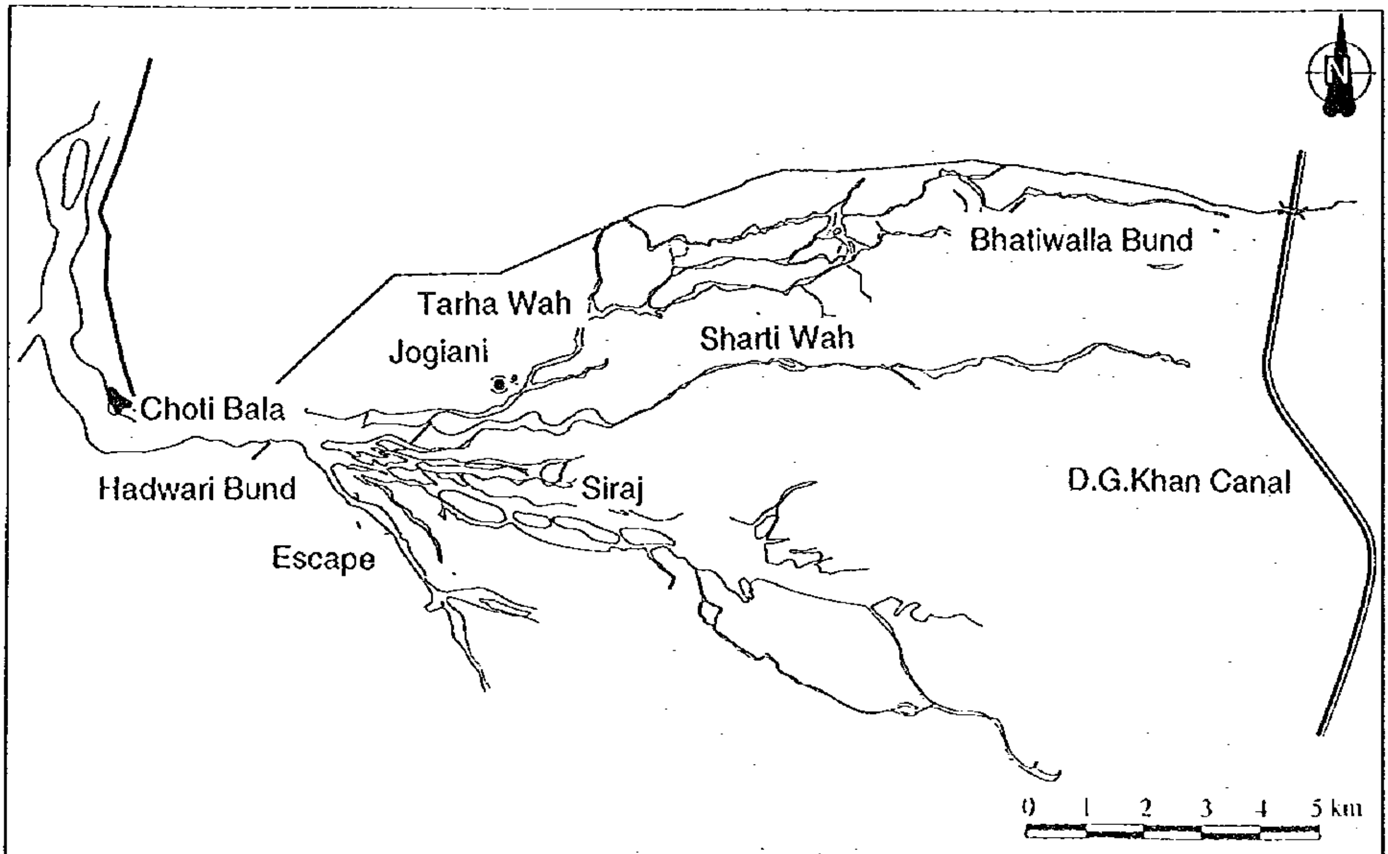


Fig. 2.6 Water Course of Sharti Wah (May 1992)

2) Vertical change of channel bed

Channels in the fanhead: There are major channels, namely North and South Branches and Escape, in the fanhead of Mithawan fan. They are predicted to develop extreme river bed variation during flooding since the bed material is composed of fine particles having mean diameter of 0.3 mm including suspended load.

River bed degradation reached down to 4 - 5 m deep in Sharti wah by 1976 flood and it reached 3 - 4 m deep in upper reaches of Talha wah by 1994 flood.

Bed lowering was so severe in the first phase hydraulic model tests in 1995 that it could not be analyzed and forecast by existing engineering knowledge about the bed variation. The second phase hydraulic model test in 1996 was executed to solve bed variation experimentally. The test showed that bed slope and bed configuration of the models agreed with those of the site. This means that river bed alteration could be forecast by the test result. Changes of bed in the major channels were computed as shown in Table-2.5. Degradation of the channel

Branch	Bed Lowering

bed reached 3.5 m in North and South branches and 5.8 m in Escape. The test result indicates development of sand bars in the site.

Table-2.5 Degradation of River Bed

North Branch	3.5 m
South Branch	3.5 m
Escape	5.8 m

Channels in the midfan: In the midfan, minor channels are there called 'wah', which are 1.5 - 2.5 m deep and about 10 m wide with capacity of 40 - 60 m^3/sec.

Relation between the channel width and bed alteration at a constant sediment concentration is shown in Fig.-2.7. Bed alteration by the variation of discharge increases when channel becomes narrower. Fig.-2.8 shows bed alteration by the change of discharge and sediment concentration in 10 m wide channel. Increase of discharge accelerates bed lowering and increase of sediment concentration makes the river bed high. The river bed in the channels about 10 m wide varies responding quickly with change of discharge in the midfan

The cross embankment dikes called 'wakra' are constructed in the channels. Every farming plot has its own wakra which will be removed when the field will be filled with water. Besides, most wakras are washed away in high floods. Discharge and velocity of flood flows in the channels fluctuate much and influence river bed alteration.

When discharge is smaller than 10 cumecs and it possible to draw into the field, medium to coarse sand particles deposit in the channels and finer particles of silt and clay flow into the field. High flood with discharge over 10 cumecs washes wakras away by over-topping or seepage, and flood with high velocity of about 3 m/sec erodes the channel bed carrying eroded material to the lower reaches.

Wakras reduce sediment transportation when they function well. However, even during low flood, small wahs might be scoured when wakras are collapsed. Degradation of a wah by scouring results increase of flow capacity of the wah, then more flood flowing into the wah accelerates degradation of the wah. When bank of the wah reaches high enough to fall down, the wah becomes wider because of banks collapse resulting retarding degradation. Capacity of channel enlarges and repeated same process widens the channels more.

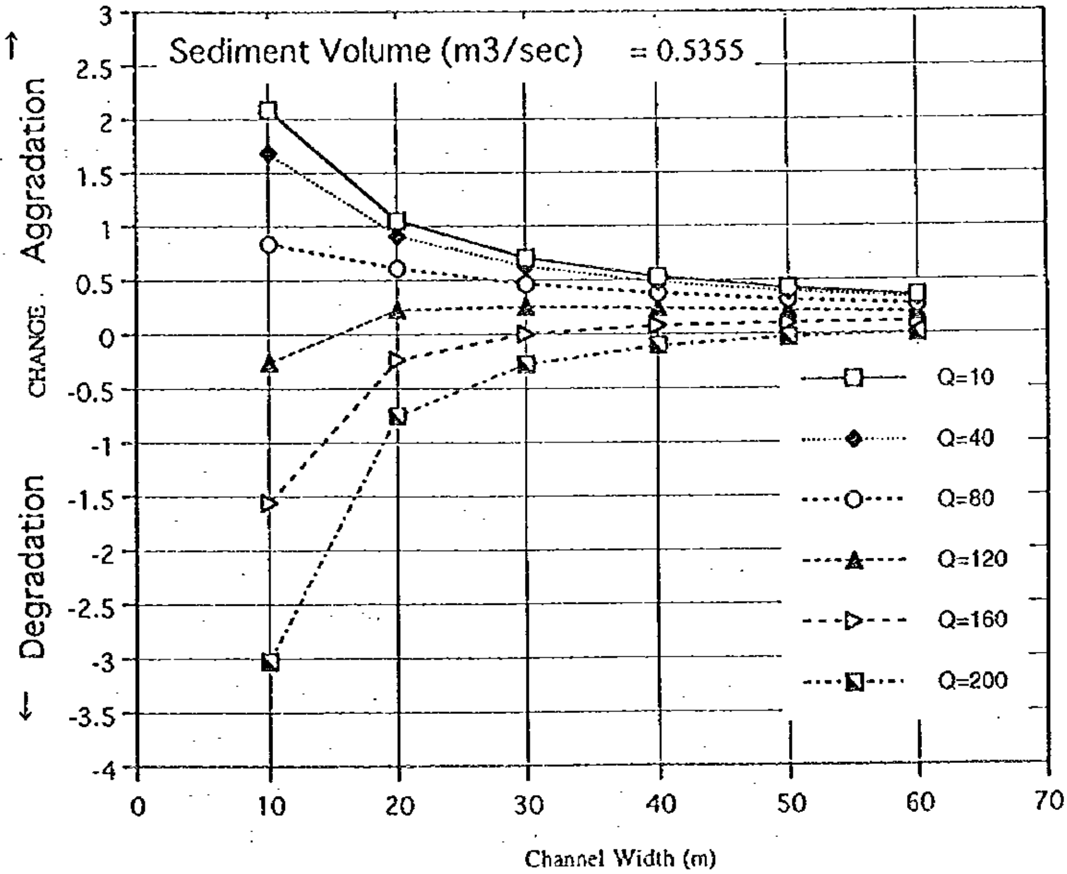


Fig. 2.7 Relations between Bed Alteration and Channel width (Sediment Concentration)

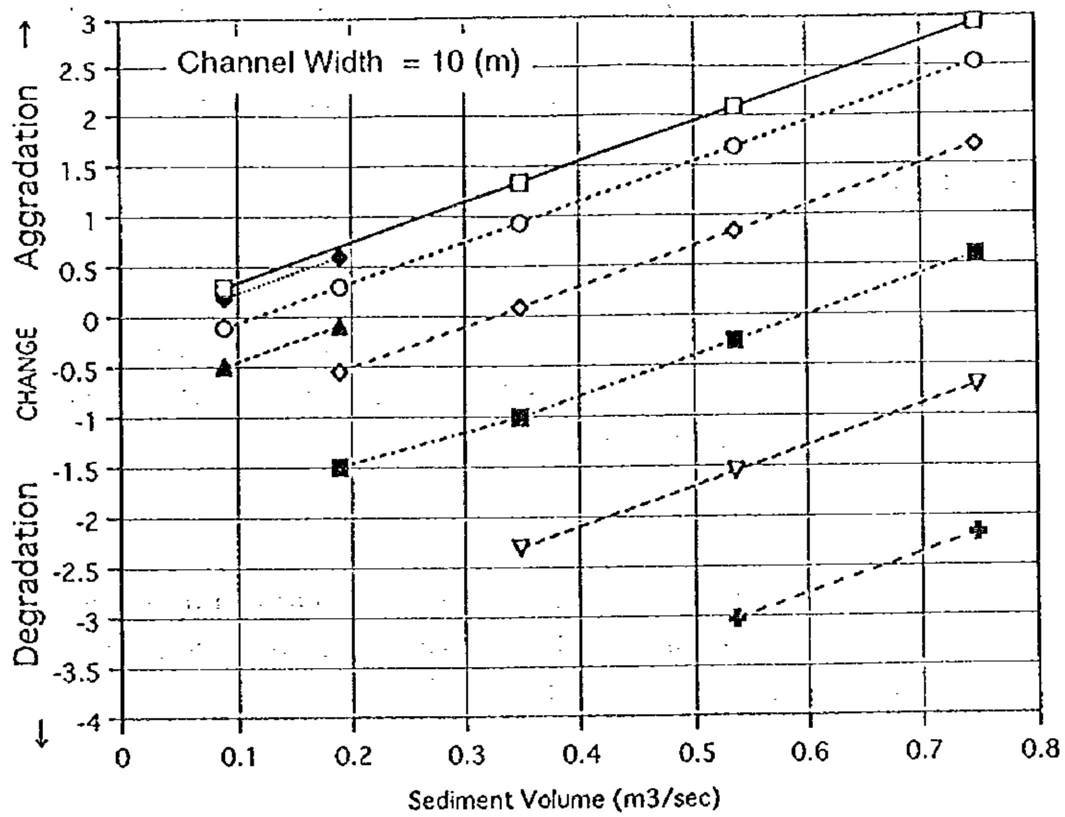


Fig. 2.8 Relations between Bed Alteration and Channel width (Channel width 10m)

3) Formation of Secondary Fan

During low floods, most part of wash load and suspended load flow into the fields and bed load remains on the channel bed. Therefore, no secondary fan is developed and all the eroded material in the upper reaches remain on the fan. On the other hand, sediment from the upper reaches and eroded material in the wah deposits intersection point downstream in high floods, and forms secondary fan. Bed load remains on the secondary fan and suspended load and wash load flow downstream.

About 25 years before the catastrophic degradation in Sharti wah (there had been a sign of lowering of channel bed), in the aerial photo taken in 1950's indicated development of minor secondary fan along the wah in the mid-fan. It suggests that formation of a large secondary fan takes tens of years.

A considerable large secondary fan has formed in the lower reaches of Sharti wah near D. G. Khan canal. The satellite image shows that the areas covered with secondary fan are not cultivated at present because wahs have shifted and intake from the wah has been inoperative addition to deposition of sand on the farm land.

Degradation of wahs and formation of secondary fans develop tens of years in natural condition. If the changes of the channels are monitored and appropriate measures stopping unfavorable changes of the channel are taken, formation of secondary fans and large scale degradation could be regulated.

(4) Hydraulic Model Test

1) Necessity of the Test

A series of hydraulic model test was conducted to evaluate effectiveness and function of the distributor considering sediment transportation that is difficult to solve by numerical analysis.

2) The First Phase Test

Objectives of the test: Objectives in the first phase of the test were firstly to confirm effectiveness of Hadwari bund and secondly to determine the most suitable location of the distributor.

The points of the test are to confirm the planned shares of distribution to North and South Branches and Escape at 1,500 cumecs (52,000 cusecs) of 5-year flood and diversion of flood flows to Escape when discharge is beyond 400 cumecs (14,000 cusecs) which is supposed to be occurred every year.

Result of the test: The test showed that removal of Hadwari bund is preferable to increase outflow to Escape and to approach actual shares of distribution to that of planned.

A section of alteration of longitudinal bed slope and branches of the channel where scouring or siltation occurs, could be a control section of channel bed alteration where the directions of diverted flows and bed alteration could be regulated easily so that it must be the most appropriate site for placing the distributor. There are, therefore, two proposed sections for constructing the distributor. One is section M2 + 100 where river bed slope alters and another is section M2 + 800 which is branch of the channel as shown Fig. 2.9 and 2.10. Hydraulic model test had done firstly at the section M2 + 800 as it needs shorter guide bank and secondary at the section M2+100. Shares of distribution were confirmed being same to the design proportion and diversion to Escape began at 400 cumecs (14,000 cusecs) in the rigid bed model test.

The mobile bed test exhibited that channel bed was formed ripples mostly but dunes and flat bed were developed in the flow concentrated portion of the channel. It means river bed configuration is different between the prototype and the model. It suggests the test result by the mobile bed test will not indicate actual phenomena in site, such as bed alteration, shares of distribution and local scouring around the structure, so that the result could not be applied for designing the distributor.

Above-mentioned technical issues can be solved only through the hydraulic model test using distorted model which has different reduced scale between vertical and horizontal planes to keep similarity of bed configuration.

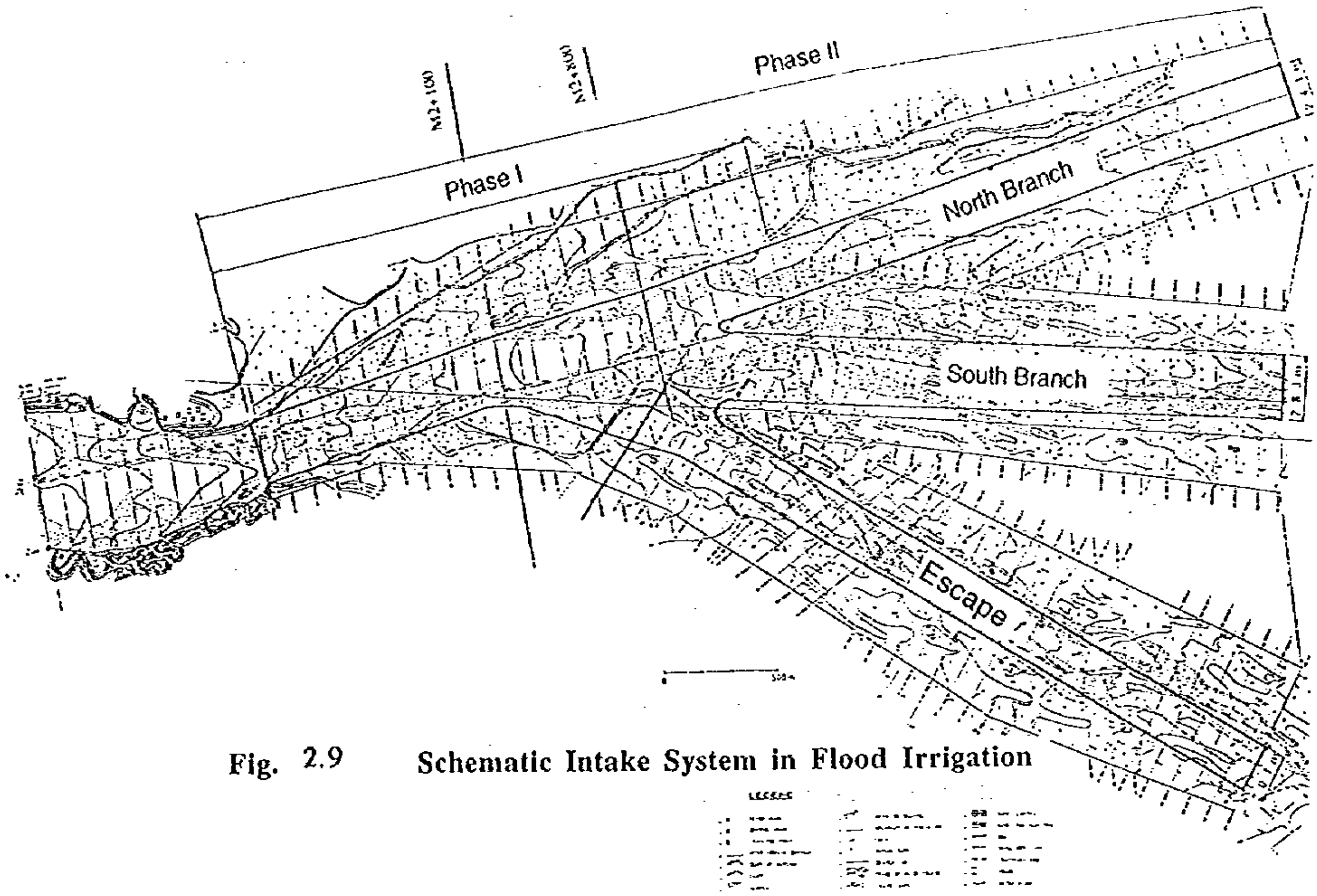


Fig. 2.9 Schematic Intake System in Flood Irrigation

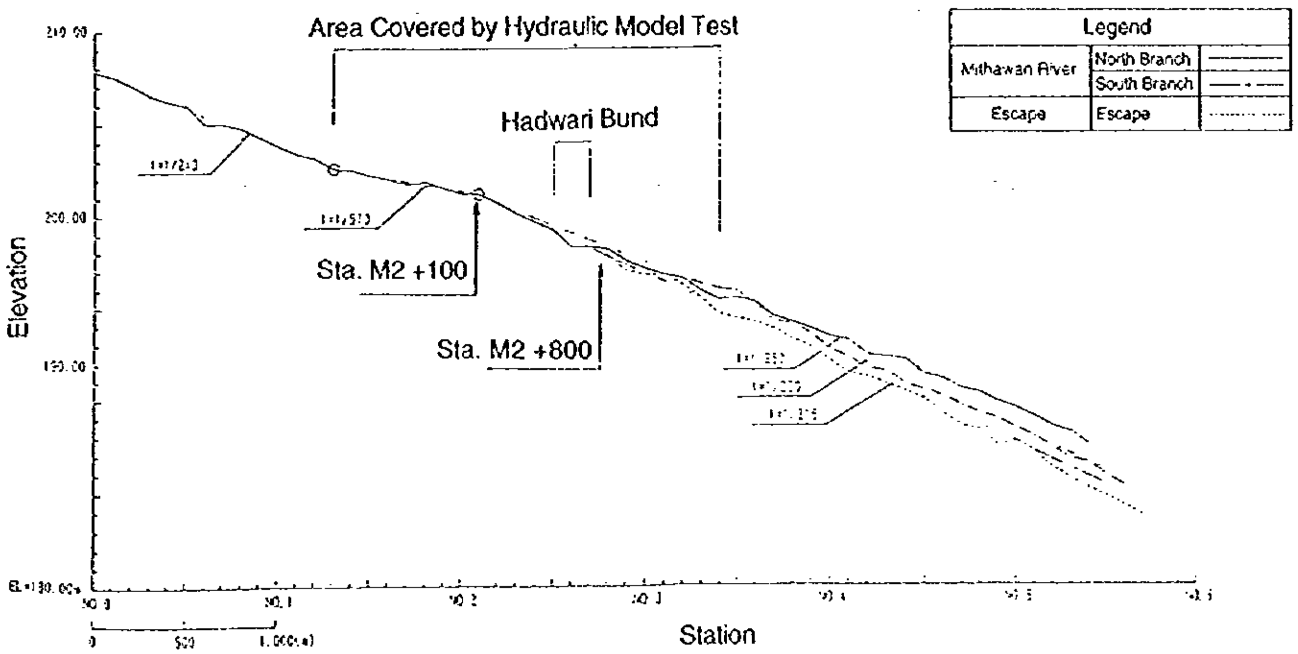


Fig. 2.10 Longitudinal Section of River Bed and Proposed Site for Mithawan Distributor

3) The Second Phase Test

Distorted mobile bed model was applied through the second phase test for forecasting bed alteration, location and type of structure and share of distribution. Additionally, the local scouring around the structure was checked by extra-model.

Dimensions of local scouring will be enlarged in the distorted model, then structure to be designed matching to the test result must be safer side. Long term bed alteration of the channels on the fan and its time dependent variation are important factor to design safe and durable structure. The test was conducted using distorted model which can keep similarity on the bed alteration for the safe design consequently. The test, however, was regarded as a conceptual model test since the change of bed by local scouring in the distorted model would not indicate actual dimension, and its purpose was to understand bed alteration in the channels qualitatively.

Test results are following.

a) Type of the structure

Without structure, main part of the flow oscillated between South branch and North branch in the initial stage of the test caused by the bed alteration in the widened area of the channel and it gradually converged to Escape with the passage of time. Maximum share into a particular channel reached 80 % of total flow.

A distributor of cross structure with guide walls showed longer period of oscillation of flow direction than other types. It maintained necessary shares of distribution for two times of flood under similarity on sediment transportation at the discharge of 1,000 cumecs (2-year return period) (35,000 cusecs). Monitoring of bed alteration and flattening of bed or removal of sand bars upstream would be necessary to keep the required shares of distribution.

A distributor of guide walls without cross structure showed longer period of oscillation of flow direction than the case without structure. It is, however, difficult to forecast to which channel flood flow will concentrate in the first flood since there is no cross structure to fix the channel bed. This type structure has an effect to regulate inflow, because maximum inflow to each branch was smaller than that of no structure, but there was possibility of flooding downstream in some of the channels.

b) Location of the structure

Two axes were tested to select suitable site of the structure.

One was at the starting point of horizontal variation of channel and another was at the point where the channel forked into three branches. When the structure was built at the former point, distribution of flood flows was uniform at an initial stage of flooding and period of oscillation of flow direction was rather longer. On the contrary, the latter case showed similar variation, because the case without structure and shares of distribution varied more than the former case.

The reason is that the share of distribution to each channel was regulated by bed alteration in the widened zone where the flow direction varies much so that the latter case, distributor placed downstream of the widened zone, could not regulate the share of distribution.

The hydraulic model test resulted the starting point of horizontal variation of channel was more suitable location for the distributor than the point where the channel forked into three branches. River bed upstream of the distributor rose about 0.5 m because of the cross structure, then the starting point of change of flow direction shifted toward upstream. It means that shares of distribution could not hold constantly even the structure constructed at the starting point of horizontal variation of the channel.

c) Local Scouring

<u>In Upstream Cross Structure:</u>

Cross structure is designed 0.5 m higher than original river bed making uniform flow over the cross structure. It causes partial secondary flow which results local scouring, but it is impossible to point out the location where scouring occurs and its extent because local scouring develops depending on hydraulic condition of upstream the cross structure. Scoured portion is visible during early stage of flooding and it is filled with sediment that reaches to the cross structure following stage. Dimensions of scoured portion are 1.5 to 3.8 m deep from top of the cross structure and 4 to 8 m long toward upstream from the structure.

Local Scouring in Downstream the Cross Structure:

Scale of scoured depth and length became larger with lowering of channel bed. Maximum scoured depth was 2.5 m and length 15 m when channel bed did not lower. When channel bed lowered down to 3.75 m, scoured portion enlarged 18 m deep and 48 m long. When gabion bed protection was placed on the 3.75 m lowered bed, scoured depth reduced to 7.5 m and scoured length was 8 m from the end of gabion protection.

Cause of enlarging of scale of scouring is that flood water falls downward when channel bed lowered. Safety of the distributor could be kept by maintaining flow direction as horizontal as possible placing bed protection work to downstream of the cross structure consequently. Since flexible gabion protection tends to be settled by bed lowering and local scouring, the protection works must be long enough having no effect on the cross structure.

2.2.3 Concept on Operation and Maintenance

Variation of the fan on its formation process is intense and massive. Fan control through uniform distribution of flood water and sediment is necessary for sustainable use of the area for crop production.

(1) Methodology for Fan Management

Traditional maintenance methods for channels and crop lands which have been conducted by the local farmers through observing variation in the channels and minimizing harm events are important basic techniques for the future maintenance on the fan. Good maintenance would be realized through the measures below.

a) To avoid concentration of flood flows into a specific channel by dispersing flows over the fan by means of distributor on the fanhead,

b) To divert flood flows into the bund in a secure manner, and

c) To assure storage in each bund.

In addition, the followings are recommended to use flood flows effectively and to decrease flood damage.

d) To strengthen the right bank of D. G. Khan canal for prevention of flooding in the canal irrigated area,

e) To provide reservoir area on the mid-fan for effective use of the water by expanding available duration to use flood flows, and

f) To reduce discharge at the apex to keep effective flood distribution and to decrease channel bed alteration.

(2) Managing Organization

Conventional farmers' organization for flood irrigation, so-called as Kamara, is functioning well to maintain traditional flood irrigation practices. The perspective of management on overall fan by controlling variation of channels and change on the fan is indispensable for managing the fan on formation process. Existing Kamaras never think of controlling overall fan. Besides, they are loosing management ability over the fan area recently. Individual village basis Kamaras are well working, however, no coordinating capacity from higher viewpoint. Local population requests higher coordinating body to be formed are there. In this sense, it is needed to make the organization to manage overall Mithawan fan.

The organizations which have been created by needs of people have flexibility to change their rules depending on the situation and have sustainability. On the contrary, government organizations are lacking such flexibility to change the rules and their application and to recognize the local conditions.

In Mithawan hill torrent area, farmers associations are functioning well. It is recommended to promote farmer's participation and to request their duty to the Project from its very beginning in the planning or implementing with their experience in the area. They must have the sense of ownership to the Project because they are the direct beneficiaries.

(3) Role of the Government Agencies Concerned

The agencies concerned to the flood irrigation in Pachad are Irrigation and Power Department of Punjab (IPD) in technical aspect and Rod Kohi Department (RKD) under Deputy Commissioner in administration. At present, the problems are brought into the government offices when the people can not solve them, and such manner comes from the traditional social custom in the area.

From technical view, IPD had to take necessary measures against hill torrent floods since existing flood irrigation practice have not ceased any flood damages during high flood. The Leadership of the government agencies with respecting local tradition are requested to promote construction of the distributor dispersing flood flows and to train and strengthen existing local associations to keep good maintenance for flood irrigation practice on the fan.

(4) Monitoring and Quick Action

They say that people can not be a farmer without knowledge of selection on the suitable location, structure, construction and rehabilitation practice for the flood irrigation. They have maintained their channels by themselves.

Monitoring technique is very important capability for the local farmers to keep the facilities being operational during sudden flood. The techniques are established to provide the bunds at appropriate location with suitable structure by forecasting the flow condition during flood for sure diversion to the fields. They recognize the limitations in their flood controlling techniques that their gandas/wakras can not persist to high flood because of weak sand structure.

It is expected that steady maintenance works are required for tens of years until the channel bed conditions being in equilibrium as floods seldom flow in ephemeral stream.

Local population owns the basic idea and practice on monitoring and measures necessary to unfavorable change. Technical support and advice by outside resources should be granted to improve their techniques reliable.

(5) Revision of the Water Right

The method and shares on the flood irrigation have changed to meet with existing situation of the channels. It was confirmed through interview to the farmers that they wanted to change the water right to the existing condition.

It is recommended to recognize the water right in non-haqooq area to expand flood irrigation over the fan for decrease of flood damage in downstream canal irrigated area.

(6) Financial Assistance by the Government

Construction of the distributor makes additional public ought to the farmers in Pachad to maintain flood irrigation for reduction of flood damage in the canal irrigated area. It means that maintenance works in the flood irrigation need to be of higher quality and more expensive.

It is supposed that the quality of maintenance might become lower and flood damage would not reduce unless the government subsidize for the people's activity to fight against floods, as the people in Pachad are suffering from overburden for the maintenance even at present.

(7) Limitations of Local Practice and Introduction of Outside Technique

Local practice can manage low flood but cannot control high floods so well as they could not stop the large degradation in Sharti wah. Outside techniques were introduced when the situation became serious. Such manner must be improved in future.

The purpose of the Project is to manage overall alluvial fan, but local farmers' practice has no such sense. Regarding individual water use, they might have forecasting share of flood, for example the farmers in Althul making embankments in Talha wah about 10 km far from their village. Since flooding duration of hill torrent flood is short, every farmer is eager to draw water only for his field and do not think about the status of downstream. The local farmers have little sense on water management on the fan.

In pachad area, there have been no huge facilities to control hill torrent flood. They have little experience to operate and maintain such structure and cannot afford the cost for maintenance. Then, outside techniques and funds are necessary to do it.

(8) Technical Assistance and Training

Overall fan management to control change of channels and surface feature on the fan is necessary, although the local population lacks such sense. Monitoring on the channel condition and structures with quick action against unfavorable change is indispensable for fan management. Observational management has been done only for diverting the floods. They can manage the area using future improved techniques as they have basic idea and practice in flood irrigation.

The Project as the pilot hill torrent development project is hard to push forward with limited data for planning and designing. Therefore, it is recommended to collect data regarding natural conditions and the behavior of constructed structures.

It is necessary to conduct technical support and training covering the following items.

(a) Training of O&M technique and Organization management for the local organizations and offices concerned.

(b) Training of leaders.

(c) Improvement of water management, and

(d) Collection basic data.

2.3 Basic Design

2.3.1 Design Concept

The structures for the Project are designed based on the following design concept.

(1) Stability of the Structure

The Mithawan hill torrent locates on the alluvial fan which is still on the process of the fan formation. Therefore, the design works shall take into account the characteristics of sedimentation and scouring mainly derived from the fine riverbed material (average grain size is 0.3 mm) on the steep riverbed gradient (1/215 to 1/250). However, as the riverbed alteration has not been clarified yet, the proposed design aims at delineating the stable structure for one pass of design flood discharge.

(2) Esteeming Hydraulic Model Test Results

Various hydraulic model tests have been executed to define sediment transportation mechanism, analysis for stabilized riverbed, effective distributor, riverbed alteration after construction of the proposed structure and local scouring nearby the structures, which are difficult to analyze through the case history or numerical analysis. The design works have been carried out holding these results in high esteem.

(3) Additional Survey

The hydraulic model test revealed that the proposed distributor it will become huge structure and then it will need to be safer. Consequently. available data which prepared during JICA's preliminary study are limited and less accurate to design the distributor as required in the test

Therefore, the design factors of foundation of the structure are derived from assumption. Moreover, precision on the survey of topography and longitudinal and cross sections was too poor to design the structure. Therefore, the works of this basic design have to be reviewed and revised during detailed design period with additional geotechnical exploration and survey works.

(4) Construction Material

Local materials and practices in construction works shall be applied as much as possible in the work, except locally unavailable particular cases.

(5) Responsibility of the IPD

In the downstream from the area where the flood flows become stable after dispersion structure, the structures such as training dikes, secondary dispersion structures and intake structures are expected to be designed and constructed by the Pakistan agencies in cooperation with the local people. Therefore, these structures are not included in this design. Design works are also executed under the condition that the below works will be executed by the Pakistan agencies and the local people:

a. The maintenance works of locally scoured portions shall be executed immediately after the flood.

b. In the case of serious degradation of riverbed, the ground sill for recovering the original riverbed elevation shall be constructed at the downstream of the proposed cross structure.

2.3.2 Basic Design

(1) Results of the Hydraulic Model Test

Followings are conditions for the execution of the hydraulic model test;

a) Design flood discharge is set at 25 years return period of 2,500 cumecs (88,300 cusecs) estimated by the obtained hydrological data and field observation.

b) The number of outlets of the distributor are set three, which lead flood flows to channels named North branch, South branch and Escape, respectively on the basis of the land use analysis of the downstream area.

c) As the surplus flood water has been used even in the non-haqooq area, proposed distributor is designed to distribute the water not only to the haqooq area but also to the non-haqooq area. Therefore, the top elevation of the cross structure of the distributor for each channels is set the same, if the cross structure is judged to be necessary.

The major conclusion conditions obtained from the results of the hydraulic model test in view of the structural design are as follows.

1) Necessary Structures for Flood Dispersion

To attain the objectives of the Project, two kinds of structures are considered to be employed, which are cross structure and longitudinal structures (revetment and guide wall). The combination of these facilities are the following three types;

a) cross structure + longitudinal structures,
b) cross structure only, and
c) longitudinal structures only.

For each case, the distorted model test was carried out and above cases b) and c) could not attain the required shares of distribution of flood flows. Only the case a) could attain the required share though it shows a variation of the shares around 10%.

2) Shares of distribution of Flood Flows

On the basis of the downstream agricultural land proportion, shares of distribution are derived as North branch : South branch : Escape = 3 : 4 : 3. However, the distorted model test shows that the proposed structure has some variation of the shares of distribution. Therefore, the shares of distribution has set at North branch : South branch : Escape = 1 : 1 : 1.

3) Location of the Cross Structure

Based upon the distorted model tests with the cross structure at Sta.2+100 and Sta.2+800, the followings are found out;

a) in the case of that cross structure is located at the downstream of the Sta. 2+100, the drift current caused by the sand bars occurs and shares of distribution becomes fluctuate,

b) in the case of that the cross structure is located at the upstream from the Sta. 2+100, the length of the guide wall becomes long. In this care, the construction cost shall increase.

Therefore, the location of the cross structure is decided at the Sta. 2+100.

4) Installation of the Longitudinal Structure

Installation of the longitudinal structure is set between the upstream portion of the cross structure where the riverbed is relatively good condition and 1000 m downstream of the dispersion structure where the flow condition becomes stable.

5) Demolition of Hadwari Bund

Hadwari bund is hydraulic obstruction for guiding the flood water to non-haqooq area smoothly. Therefore, Hadwari bund is proposed to be demolished.

6) Flood Discharge to Each Channel

In the hydraulic model test, the drift flow occurred by the influence of the sand bar in the upstream portion. Therefore, discharge in each channel in the lower reaches of the cross structure is set at the 70 % of design flood discharge of 1,750 cumecs (61,800 cusecs) for rhw estimate of the average depth of riverbed degradation and local scouring.

7) Proposed Longitudinal Gradient of each Channel

The longitudinal gradients of each channel in downstream of the cross structure are different at present. The average longitudinal gradient of 1/230 is applied as the design gradient of the longitudinal section since the future riverbed alteration is not clear. Present longitudinal profile is shown in Fig. -2.11.

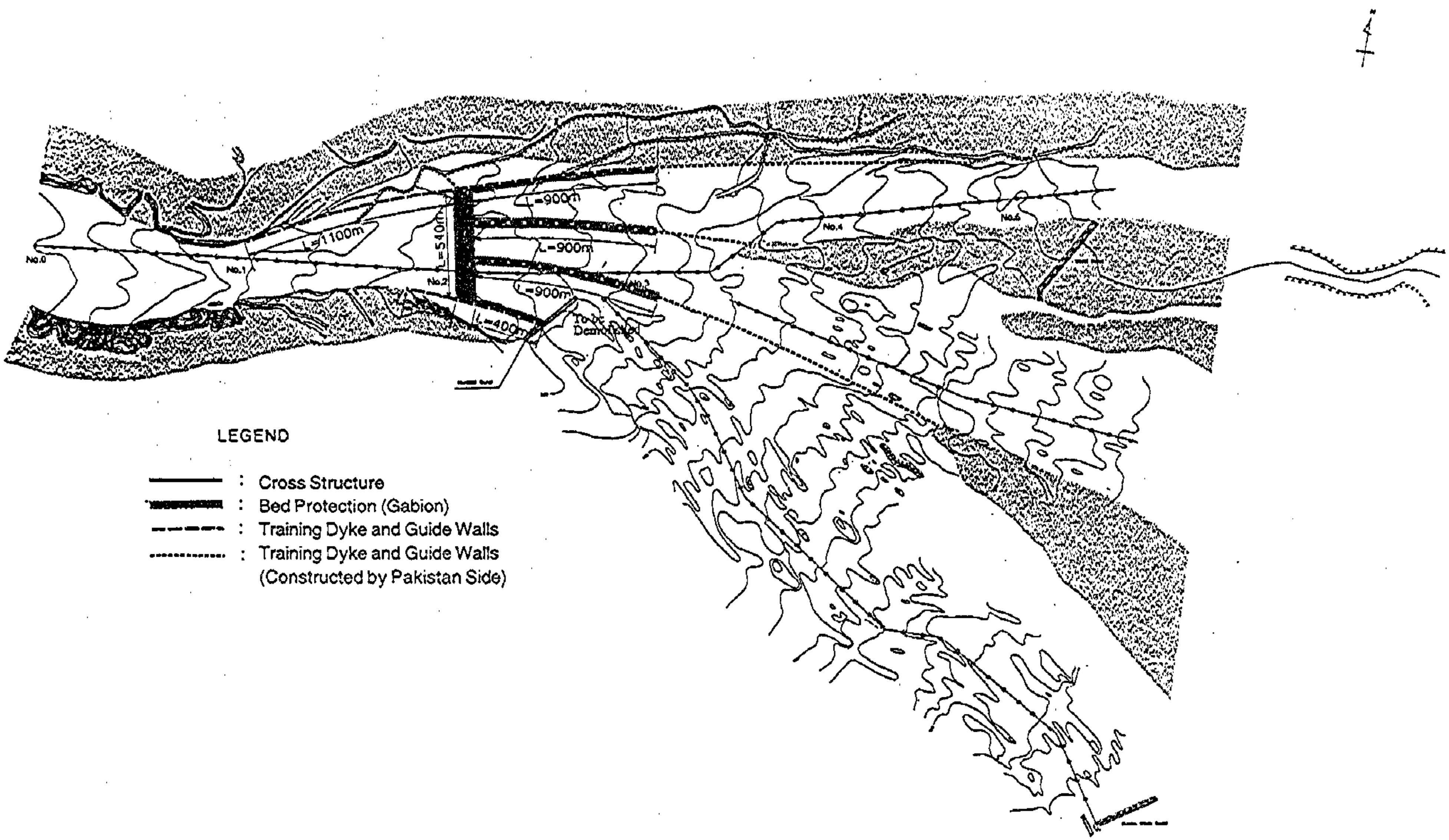


Fig. 2.11 General Layout for Proposed Mithawan Distributor

8) Average Water Depth of Flood

Average water depth of design flood is estimated at 2.5 m based upon the results of the hydraulic model test and the uniform flow calculation.

9) Average Riverbed Degradation

Average riverbed degradation by the design flood discharge in downstream of the cross structure is set 4 m deep through the distorted model test results. In upstream of the cross structure, no riverbed lowering is observed.

10) Local Scouring in Downstream of the Cross Structure

The cross structure is designed on the conditions that immediate rehabilitation works shall be commenced when damage occurs at any portion around the structure. Therefore, the depth of the local scouring is assumed based on the riverbed-protection which corresponds to the extra model test case No. 5 (riverbed elevation downstream is lowered 3.75m from the end-sill elevation of cross structure and with protection of gabion).

In addition, scouring is neglected under the gabions since geotextile membrane is proposed to be spread out under the gabions.

11) Local Scouring Upstream of the Cross Structure

The local scouring upstream of the cross structure may be reduced when the riverbed protection placed. However, reduction of the scouring depth by the riverbed protection is not evaluated because upstream cutoff is planned to be utilized as the anchor to the downstream cutoff.

12) Local Scouring along the Longitudinal Structure

Local scouring depth is estimated along the longitudinal structure using following empirical equation for scouring depth along sand bar.

$$Hmax/Hm = 1+\Delta Z/Hm = 1+0.8Hs/Hm$$

where, "Hmax" is water depth at mean annual maximum flood, "Hm" is mean water depth, "ΔZ" is difference between mean bed elevation and bottom elevation at most scoured portion, and "Hs" is height of sand bar.

In this case, local scouring depth of 4 m is obtained assuming Hs/Hm = 2.

13) Lowering of Channel Bed

Channel bed is lowered by degradation of the bed and by local scouring. Since these two may occur simultaneously, design depth of cutoff is based on the accumulated depth of degradation and local scouring depth.

(2) Determination of Dimensions of the Structure and Material

Dimesions of the structure and its material have determined applying above mentioned design criteria and the result of the hydraulic model test. Details of the structure are shown in Fig.-2.12, 2.13 and 2.14. Earthquake load is not applied because no earthquake has reported in the area.

1) Dimensions of the Cross Structure

Objectives of the cross structure are to secure shares of distribution, to obtain stabilized river bed, to prevent development of a particular water course, etc. Therefore, the structure is necessary to produce a hydraulic control point, such as a structure with the drop between the upstream and downstream water surface. In this case, the drop is limited 2 m at most by the site condition. The length of hydraulic jump is computed, then the dimensions of the model is decided. Proposed structure with such dimensions are confirmed its effect by the hydraulic model test.

2) Materials used for the Cross Structure

Local materials, such as gabion mattress, gabion cylinder and stone works are inapplicable for the proposed cross structure because they lack durability, reliability and accord with other materials of other parts. Therefore, reinforced concrete is recommended to be used for the cross structure with friction piles against uneven settlement.

3) Dimensions of the Longitudinal Structure

The top elevation of the guide wall is determined by the water surface at the maximum flood discharge to secure the dispersion. The top elevation of the revetment is set also to the water surface at the maximum flood discharge without any free board because the purpose of this structure is expected to be the guide wall to distribute flood toward each channel on the flat plane. Top of these structures keeps same height on the riverbed over whole area.

4) Material for the Longitudinal Structures

Steel sheet piles are chosen for the material of rivetment and guide walls. Because long steel sheet piles work itself as a protection against scouring and these piles are not eroded even if flood flows over them during high flood because of without any free board.

5) Countermeasure to the Local Scouring

At the upstream and downstream of the cross structure and along the longitudinal structures, local scouring as well as riverbed degradation occurs. The structures made by wet masonry could not give the sufficient stability to the riverbed degradation and local scouring, because the depth of these scouring and degradation is estimated very deep. Therefore, sheet piles are necessary to be utilized to attain the stability of the structures.

There are a few kinds of sheet piles, typically steel sheet piles and concrete sheet piles. But concrete sheet piles cannot be recommended because they are incapable to maintain water tightness because of the openings between the piles.

The structure should be watertight to stop the movement of fine sand particles through the sheet piles.

Penetration length of the steel sheet piles are to be average depth of riverbed degradation plus local scouring depth. Following table shows length of steel sheet piles applied in the design.

Table-2.6 Steel Sheet Piles applied in the Design

	Bed Lowering m(feet)			Design Length of the Steel Sheet pile m (feet)
	Average Riverbed Degradation	Local Scouring	Total	
Upstream of the Cross Structure	0	5.5 (18)	5.5 (18)	11 (36)
Downstream of the Cross Structure	4 (13)	6.5 (20)	10.5 (35)	24 (80)
Revetment Upstream of the Cross Structure	0	4 (13)	4 (13)	12 (40)
Revetment Downstream of the Cross Structure	4 (13)	4 (13)	8 (26)	22 (73)
Guide Walls	4 (13)	4 (13)	8 (26)	22 (73)

Length of the steel sheet piles for the guide walls and revetment except the portion close to the cross structure is to be same throughout the structure, since the deepest portions on the riverbed after flood have same depth from initial riverbed at any section of the channels.

6) Riverbed Protection and Foot Protection

As for the design of protection, installation of a gabion mattress with sufficient thickness and length is proposed as the gabion mattress has flexibility to follow the settlement of riverbed. In addition, the geotextile membrane is proposed to be used on the foundation for the gabion.

Installation area of riverbed protection and foot protection are set as follows;

- Length of riverbed protection is set double of the scoured depth without protection toward upstream and downstream from the cross structure.
- Width of foot protection for the longitudinal structure is set to be extended on the riverbed portion which falls down to scoured depth on the assumption that the slope of the scoured portion is to be 30 degree which is the angle of repose of fine sand.

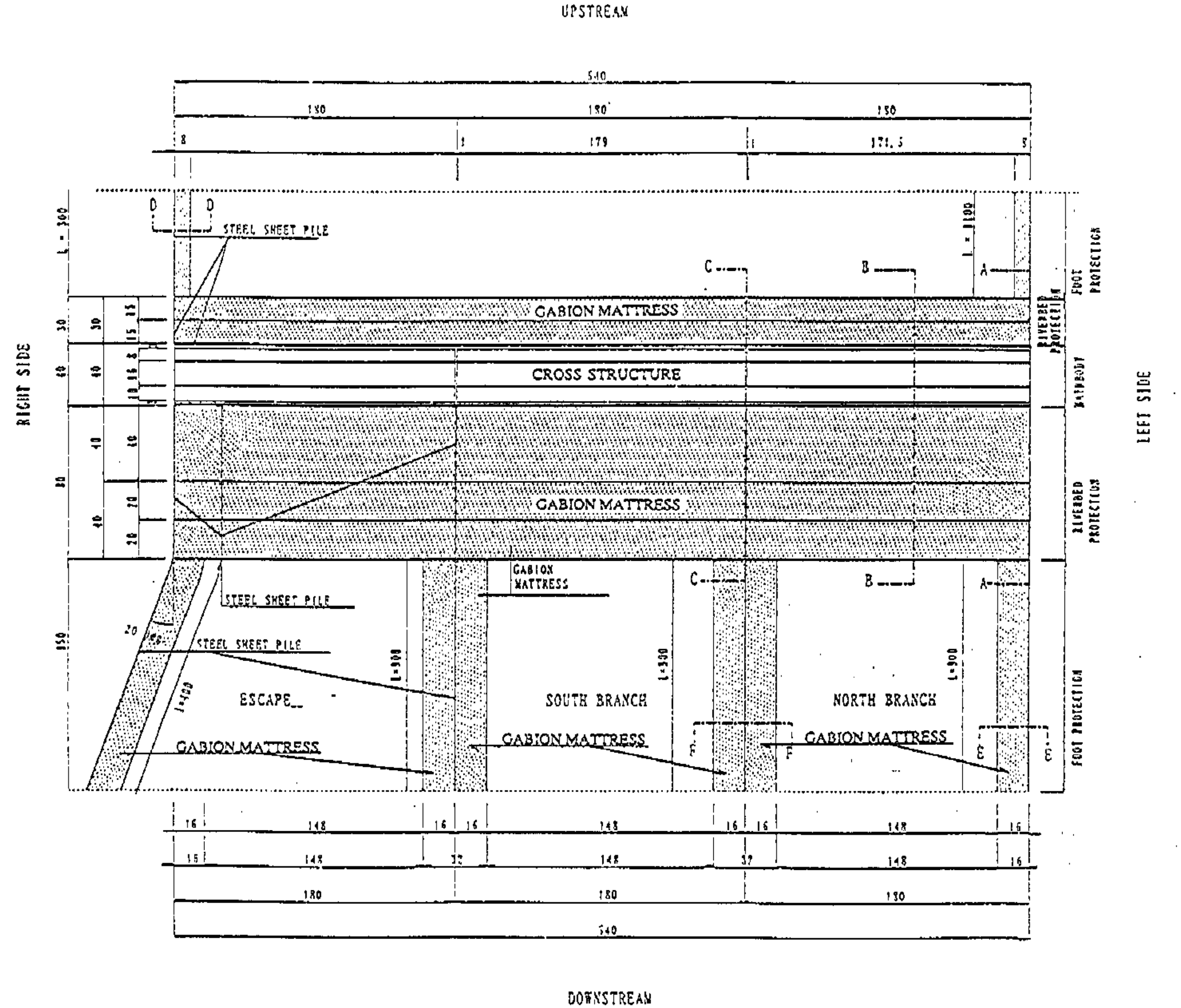


Fig. 2.12 Plan of Mithawan Cross Structure

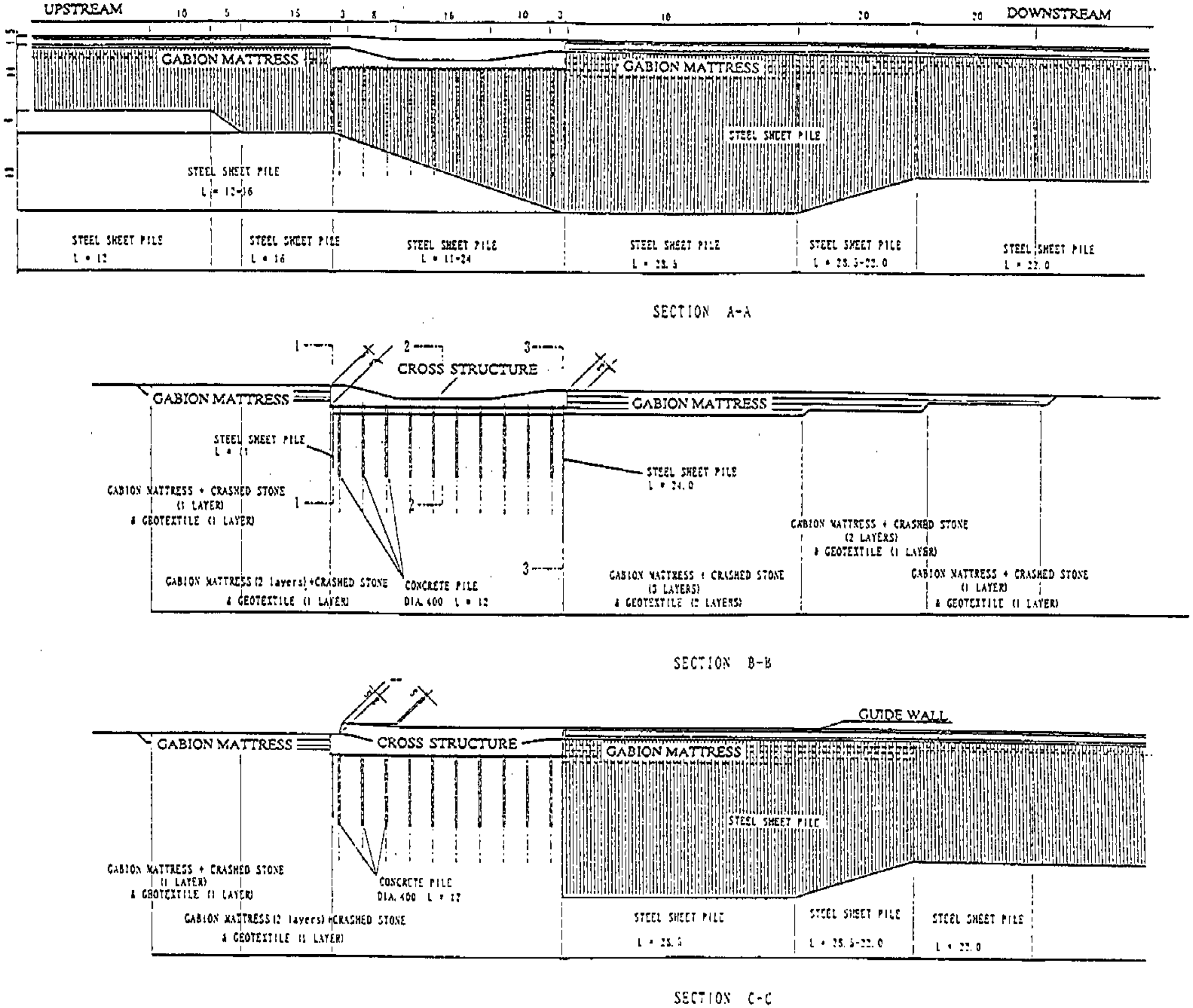


Fig. 2.13 Longitudinal Section of Mithawan Cross Structure

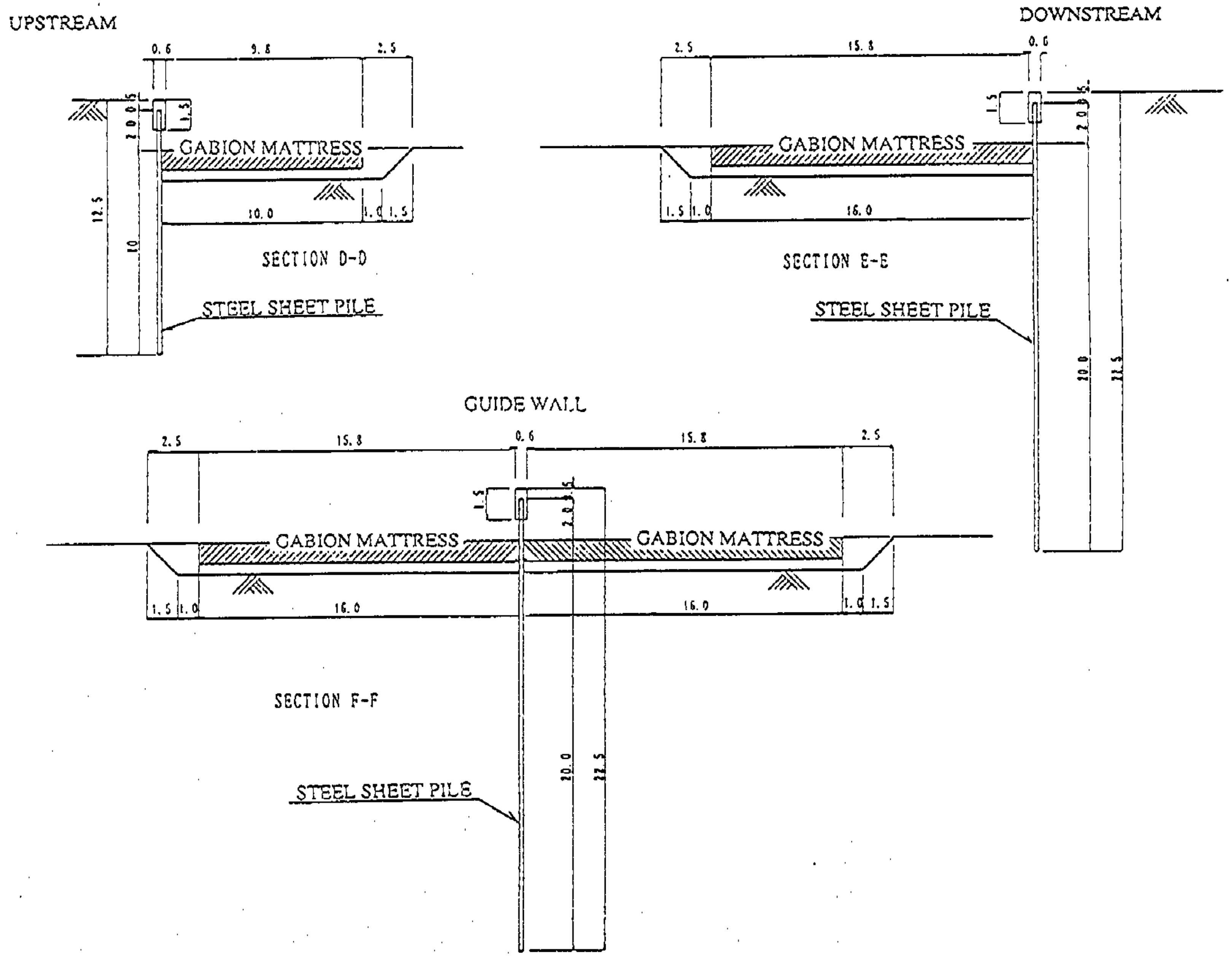


Fig. 2.14 Cross Section of Guide Walls