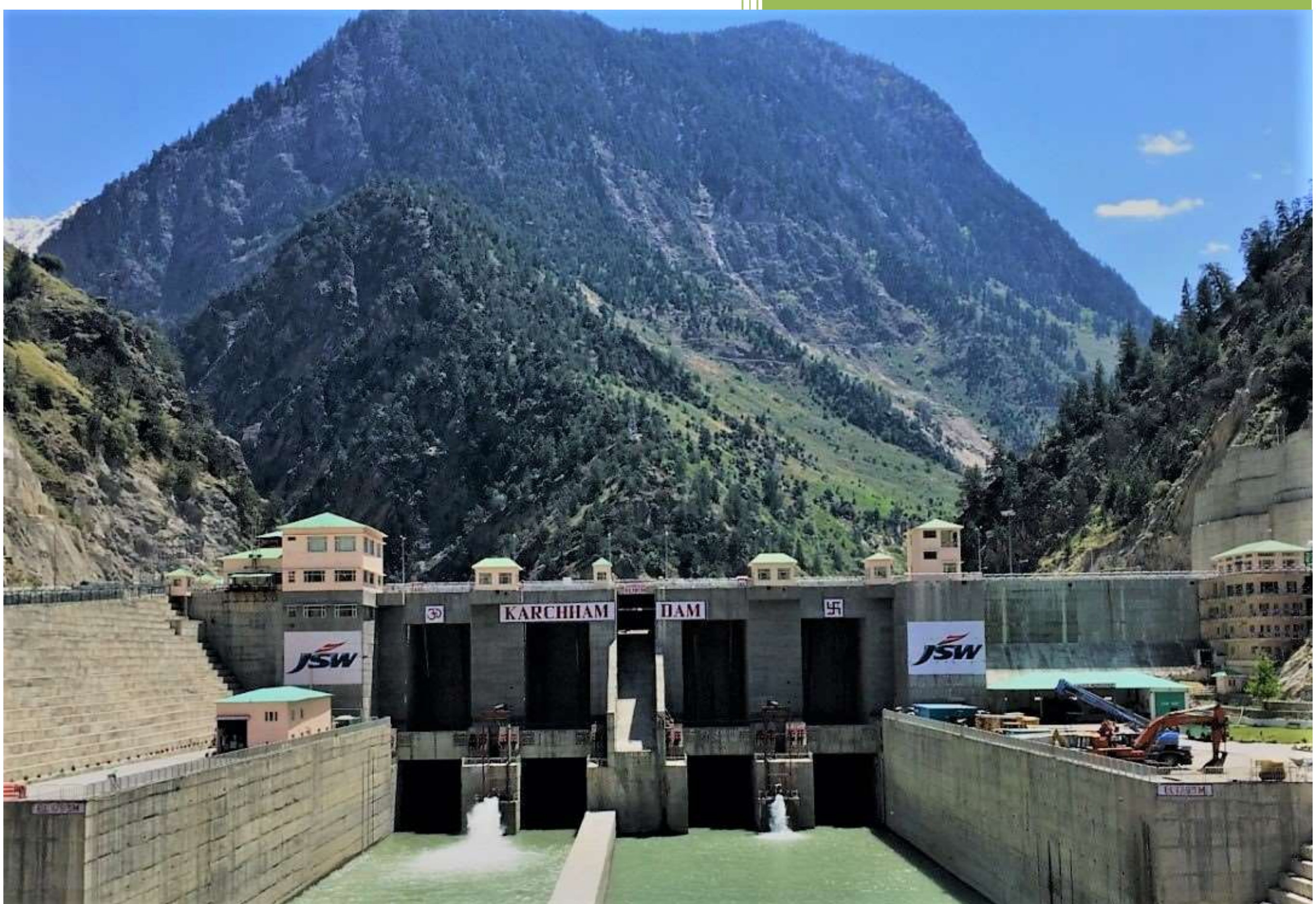
KARCHAM WANGTOO H.E.P
(1000 MW)
DISTRICT KINNAUR (H.P.)

Emergency Action Plan (EAP)

Project Identification Code of Dam HP43HH0013



JANUARY 2017 (REV-03)

Safety 1st IS A PRACTICE, NOT A CHOICE

Prepared By:

JSW HYDRO ENERGY LIMITED

JSW Energy

KARCHAM DAM

Project Identification Code of Dam HP43HH0013

District Kinnaur

This is the First Edition of Emergency Action Plan for **KARCHAM DAM** prepared in line with the "CWC Guidelines, 2016 for Developing Emergency Action Plans for Dams".

Disclaimer

Every effort has been taken to estimate the severity of flooding and inundation areas likely to be affected by KARCHAM DAM in an emergency condition. These estimates are based on available primary and secondary data. Every effort has been made to foresee varied emergency possibilities and develop appropriate notification procedures for timely rescue and relief operations. However, implementation of the Emergency Action Plan (EAP) involves many agencies, who are required to work in a coordinated manner to reduce the consequences of the emergency triggered by the dam site condition. Effectiveness of the rescue and relief operations depend on many factors including the adequacy and accuracy of the estimation of the severity of flooding, coordinated efforts of all the agencies involved in rescue and relief efforts and availability of facilities like power, telephones, road communications, etc. EAP Developer may therefore, not be held responsible for the efficacy of the EAP.

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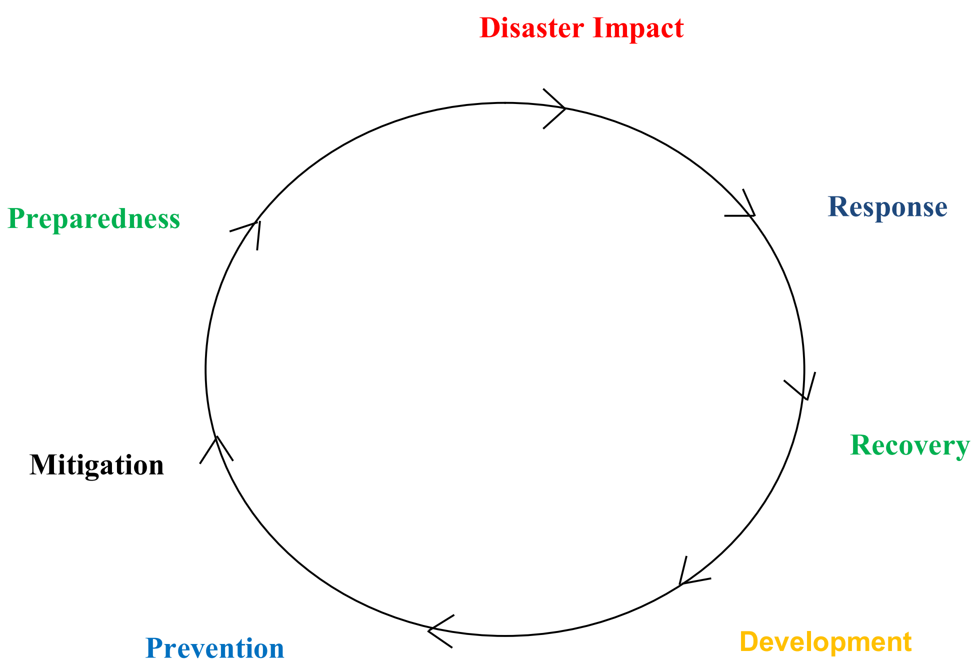
PREFACE

For the progress and prosperity of a society, the increased industrialization in planned manner is necessary. Every work that we do involves some degree of hazard. Exposure to an uncontrolled hazard over a sufficiently long period of time can give rise to adverse conditions such as ill-health and industrial accidents. Therefore, in case of the Large Dams the design, construction, operation, maintenance, and inspection of dams are intended to minimize the risk of dam failures. Despite adequacies of the safety measures and their implementations, situations may develop sometimes leading to dam failures – structural or operational. In order to ensure the total protection of the workers, preventive measures have to be adopted in controlling the hazards and to prevent accidents. Hence, this **EAP (EMERGENCY ACTION PLAN)** has been developed for **THE KARCHAM DAM** following the Guidelines of Central Water Commission (CWC),2016.
This EAP encourages and facilitates dam safety practices that will help reduce the risk to lives and property from the consequences of potential dam failures



PROCESS FLOW DURING EMERGENCY SITUATION

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NOTIFICATION FLOW CHART

What is a Notification Flowchart?

A Notification Flowchart identifies who is to be notified in case of a dam safety incident, by whom, and in what order. The information on the flowchart is very critical and it is provided for the timely notification to those who are responsible for taking emergency actions. For ease of use during an incident, this EAP includes Notification Flowcharts that clearly present the information listed below. A set of three notification charts are used depending on the complexity of the hazards associated with the dam and the potentially affected downstream areas. Notification chart contains following

- Emergency level
- Individuals who will notify JSWHEL representatives and local administration (emergency management authorities).
- Prioritization of notifications.
- Individuals who will be notified.

The Notification Flowchart includes appropriate contact information such as names, positions, telephone number. Supplemental contact information is included in the list of table of emergency contacts and communication.
The Notification Flowchart must be mobilised according to the needs and notification priorities.

The notification flowcharts for the various Emergency Levels are as follows

EMERGENCY ACTION PLAN (Rev.03) KARCHAM DAM (Rev.03_25.12.2021)

a) Watch Condition Notification Flowchart

Emergency Level BLUE

(Non-Emergency Unusual event, slowly developing situations)

Name of Project : KARCHAM WANGTOO HEP (1045 MW)

Summary Sheet For :- DAM EAP, Emergency Level BLUE

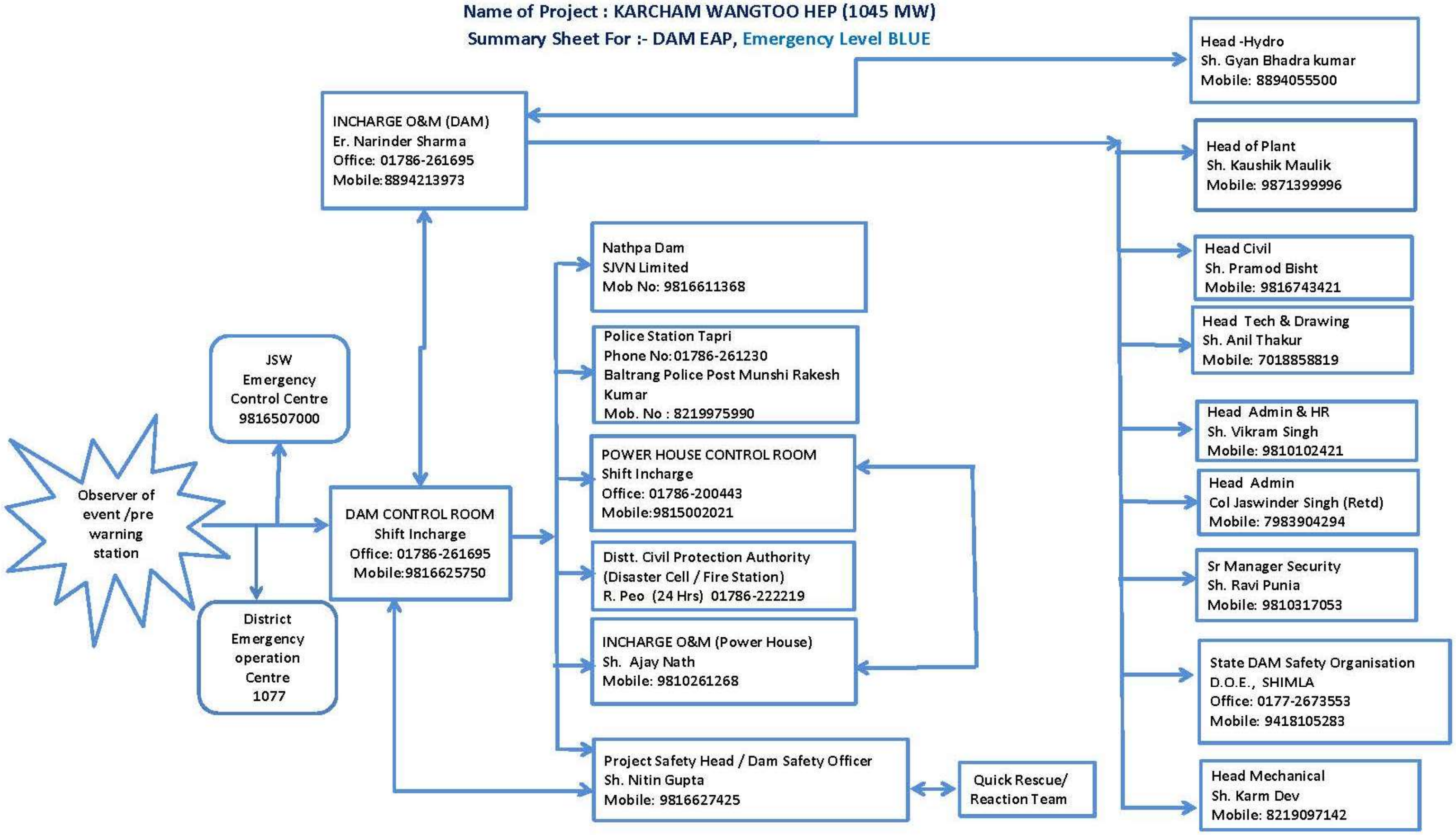


Fig. : Watch Condition Notification Flowchart

EMERGENCY ACTION PLAN (Rev.03) KARCHAM DAM (Rev.03_25.12.2021)

b) Potential Failure Notification Flowchart

Emergency Level ORANGE

(Emergency event, potential dam failure situation; rapidly developing) External Alert

Name of Project : KARCHAM WANGTOO HEP (1045 MW)

Summary Sheet For :- DAM EAP, Emergency Level ORANGE

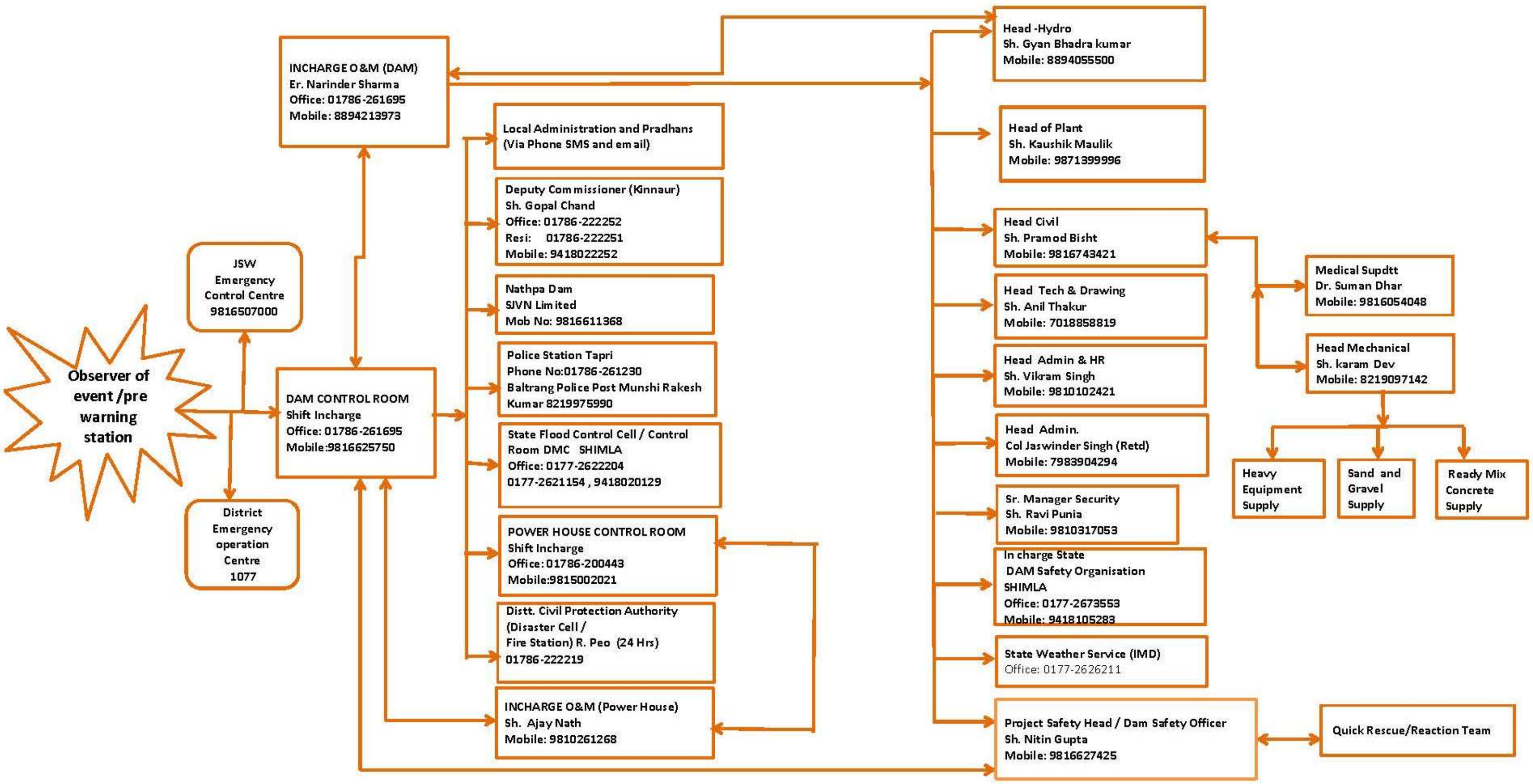


Fig. : Potential Failure Notification Chart

EMERGENCY ACTION PLAN (Rev.03) KARCHAM DAM (Rev.03_25.12.2021)

c) Failure Condition Notification Flowchart

Emergency Level RED

(Emergency event, potential dam failure situation; rapidly developing) External Alert

Name of Project : KARCHAM WANGTOO HEP (1045 MW)

Summary Sheet For :- DAM EAP, Emergency Level RED

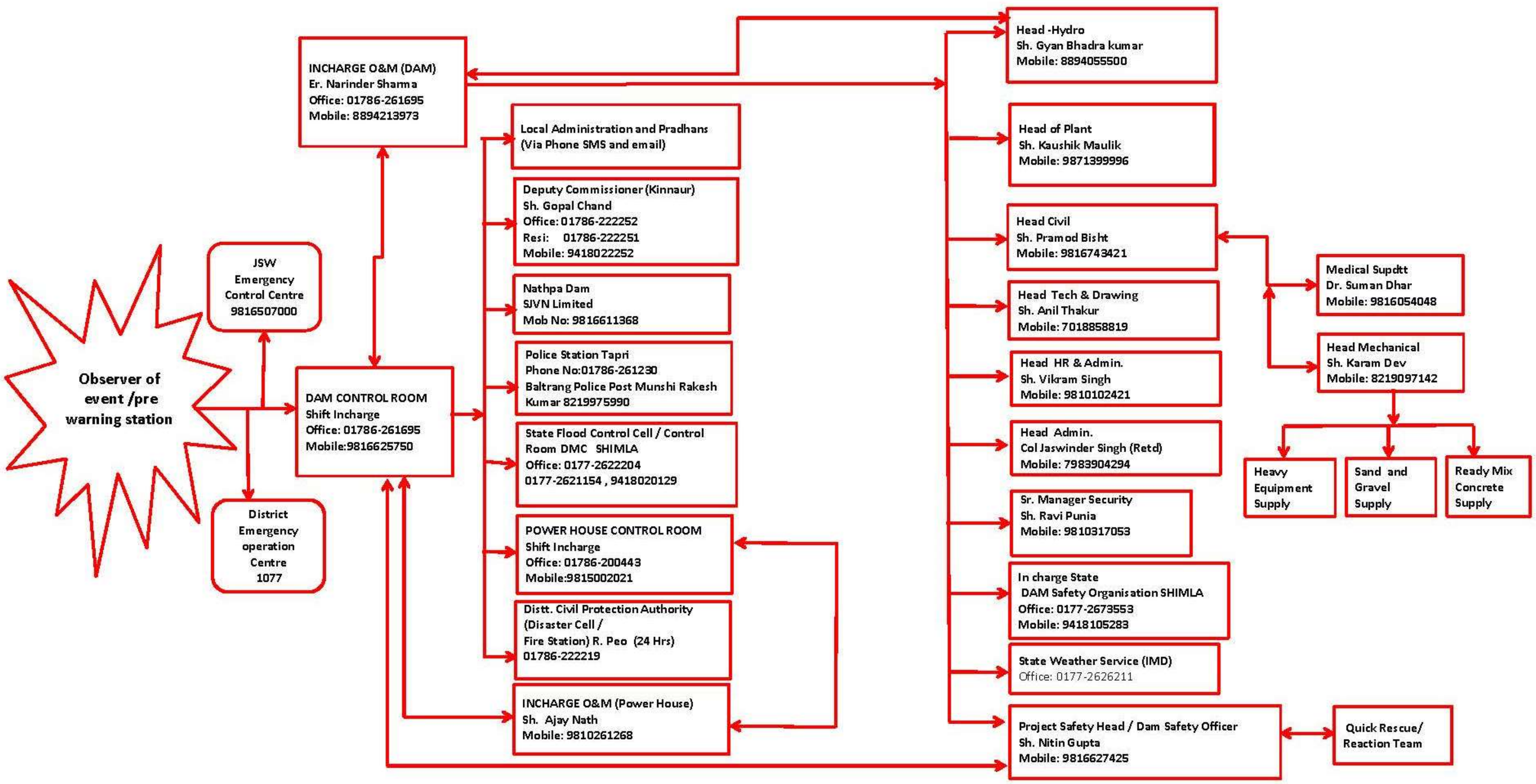


Fig. : Failure Condition Notification Chart

EAP DISTRIBUTION LIST

KARCHAM DAM
PROJECT ID CODE - Dam ID [HP43HH0013]

A copy of EAP has been provided to the people as shown on the EAP Distribution List:

Sl. No.	Name, Title	Phone	Address
1	Gyan Bhadra Kumar, HOH	8894055500	JSWHEL, Sholtu
2	Perveen Kumar Puri, HoP	9805009201	-do-
3	Pramod Kumar Bisht	9816743421	-do-
4	Anil Kumar Thakur	7018858819	-do-
5	Narinder Sharma, A.G.M, In Charge O&M Dam	8894213973	-do-
6	Ajay Nath, A.G.M, Incharge O&M PH	9810261268	-do-
7	Vikram Singh, D.G.M, Head HR & Admin	9810102421	-do-
8	Sudhir Kumar, Sr. Manager, Head Safety	9238003935	-do-
9	Dam Control Room	9816625750	-do-
10	Emergency Control Centre (ECC)	9816507000	-do-
11	D.C (Kinnaur) at Reckong Peo	9418022252	DC- Office, Reckong Peo
12	SDM, Kalpa at Reckong Peo	9418036271	SDM office at , Reckong Peo
13	SDM, Nichar at Bhabanagar	9459318171	SDM Officer, Bhabanagar
14	Chief Engineer (Authority), Directorate of Energy (DOE), GoHP	0177-2673553	Shimla, H.P
15	State Dam Flood Control Cell (Ctrl Room DMC), GoHP	0177-2622204	Shimla, H.P
16	Executive Engineer, HPPWD, GoHP	01786-263303	Sholding, District Kinnaur, H.P
17	SE, HPPWD, NH Division, GoHP	01782-233044	Rampur, District Shimla, HP
18	Regional Chief Engineer, CWC, MOWR, GoI	0172-2741766	Indus Basin Organisation, Chandigarh
19	HOP NJHPS, SJVN Limited Jhakri	01782-275052	Jhakri, Distt. Shimla, H.P

PROJECT ID CODE - Dam ID [HP43HH0013]

LOG SHEET OF CHANGES

The following changes have been made to the EAP and revisions have been provided to the people shown on the EAP Distribution List:

DATE	CHANGES MADE	SIGNATURE
18-04-2017	Revised according to CWC Guidelines, 2016	
25-02-2020	Revised according to CWC Guidelines, 2016 (Rev-01)	

KARCHAM DAM

PROJECT ID CODE - Dam ID [HP43HH0013]

APPROVAL AND IMPLEMENTATION

This Emergency Action Plan is hereby approved. This plan is effective immediately and supersedes all previous editions.

Perveen Kumar Puri
Vice President & Head of Plant
(JSW Hydro Energy Limited)

Date:

Copy No: _______________

I have received a copy of this Emergency Action Plan (EAP) and concur with the notification procedures.

Signature

Name and title of person(s) in-charge of Emergency Response Date

Emergency Action Plan
KARCHAM DAM
PROJECT ID CODE - Dam ID [HP43HH0013]

CHAPTER 1

PURPOSE

The purpose of this Emergency Action Plan (EAP) is

1. To identify emergency situations that could threaten the **KARCHAM DAM**.
2. To plan for an expedited & effective response to prevent failure of the dam and warn downstream residents of impending danger.
3. To define the notification procedures to be followed in the event of a potentially hazardous situation.
4. Intended to protect lives and prevent damage from an excessive release of water from the dam spillways or an uncontrolled outflow of water from the breached portion of dam.

EAP outlines "**who does what, where, when and how**" in an emergency situation or unusual occurrence affecting the dams.

CHAPTER – 2

DAM DESCRIPTION

2.1 General

Brief Description of Project

Karcham Dam and Reservoir are owned and operated by JSW Hydro Energy Ltd (JSWHEL), a unit of JSW Energy Ltd. It is located on river Satluj in District Kinnaur, HP. Satluj river originates from Mansarovar Lake in Tibet, traverses a distance of about 350 kms before entering Indian territory @ Shipkila. Subsequently it travels a further distance of about 75 kms upto Karcham Dam. The Dam was completed in the year 2010 and was constructed as part of Karcham-Wangtoo Hydroelectric Project (1000 MW), the largest Hydro Power Project in the Private Sector in India. The reservoir was constructed to create storage for generation of hydro-electricity using the head available between Karcham Dam and Wangtoo Powerhouse location.

A vicinity map showing the location of the dam is mentioned in **Table-1**. Inundation maps showing the areas subject to flooding as a result of dam failure are provided in **Table-2**. The inundation area is described in further details in the Dam Breach Sensitivity Analysis (Enclosed as **Annexure-I**). Lastly, a description of dam, its spillways and other features are outlined in the Dam Description in **Table-3**.

2.2 Reservoir Operations

Reservoir operation manual is as given in **Annexure-II.**

CHAPTER – 3

RESPONSIBILTIES

3.1 Dam Owner's Responsibilities

The dam owner **JSW Hydro Energy Limited (JSWHEL)** is responsible for all dam operation and maintenance.

Assistant General Manager-In charge Karcham Dam is the first line of dam observers and is the person responsible for initiating implementation of the EAP.

Assistant General Manager- In-charge Karcham Dam is responsible for collecting weather forecasts and the inflow forecasts and alerting of any potential emergency situation.

Assistant General Manager- In-charge Karcham Dam is responsible for conducting routine dam maintenance, such as annual weed control, conducting dam integrity inspections, and notifying **Head of Hydro** (HoH) (JSW Hydro Energy Limited) and **Head of Plant** (HoP) of any potential emergency situations.

Assistant General Manager- In-charge Karcham Dam is responsible for contacting emergency personnel should a dam failure be imminent.

Assistant General Manager- In-charge Karcham Dam is responsible for **updating the EAP** with approval from HoP and HOH. An annual EAP review will be conducted to ensure that contact names and numbers are current on the Notification Flowcharts.

Assistant General Manager- In-charge Karcham Dam is responsible for directing specific, incident appropriate actions during an emergency, such as opening or closing water outlets and remedial construction activities such as earthmoving etc.

3.2. Responsibilities for Notification

Assistant General Manager- In-charge Karcham Dam is responsible for inspecting the dam in a potential emergency such as the potential threat of high waters or a tropical cyclone. He will contact the District Magistrate/Collector, Local Police, affected Gram Panchayats, SJVN Limited and other administrational Officials.

If warranted, Assistant General Manager- In-charge Karcham Dam will notify the State and District Disaster Management Authorities as per emergency situation and respective Notification Flowchart.

District Administration or Local Police will notify downstream residents.

3.3. Emergency Operation Centre

In the event of a failure condition, Head of Plant (HoP) will activate the Emergency Operation Centre to serve as the main distribution centre for warning and Evacuation activities with **Head Safety (Dam Safety Officer)**.

The Emergency Operations Centre will be established at Sholtu. HoP will be responsible for initiating actions from this location in coordination with Emergency/ Disaster Management Team.

3.4. Responsibilities for Evacuation

The Kinnaur District Disaster Management Authority or Kinnaur district Police are responsible for initiating evacuations.

3.5. Responsibilities for Duration, Security, Termination, and Follow-up

1. Assistant General Manager- In-charge Karcham Dam is responsible for monitoring of emergency situations and keeping local authorities and downstream Project authorities and habitat informed, based on the Notification Flowcharts.
2. Assistant General Manager- In-charge Karcham Dam and District Magistrate/ Collector are responsible for declaring that an emergency is terminated. Applicable authorities will be notified based on the Notification Flowcharts.
3. HoP (JSWHEL) will ensure that a follow-up evaluation is completed by all participants after the emergency. The results of the evaluation should be documented in a written report and filed with the EAP.

3.6 Communications

Local officials and downstream residents will be notified by JSWHEL through by landline telephone/ cell phones. Any other type of communication like SMS, email alerts and Public Announcements through P.A System shall be add-on only.

The various networks for emergency use include the networks of the following:

- District Magistrate - (Chairman, DDMA)
- Superintending of Police
- Superintending Engineer (PWD)
- Superintending Engineer (I&PH)
- Superintending Engineer (MPP & Power)
- Chairperson of Zila- Parishad
- In charge-Nathpa Dam

The sample public announcements appear in, **Table 4.**

Verification or authentication of the situation can be made by contacting Assistant General Manager- In-charge Karcham Dam and Kinnaur District disaster management officials.

Television, Radio and bulk SMS facilities of the local mobile network operators shall be used as much as possible to notify area residents of the possible dangers.

Public announcements are to be issued by Kinnaur district disaster management officials or the Administration wing of **JSWHEL**.

At JSWHEL, Patrolling Team visit different Locations initiating alarm by blowing up Sirens-

Team A --- Kilba to Choling via Karcham

Team B --- Sholtu to Choling and Sholtu to Adit-4

Team C--- Kaksthal to Adit 4 and Kaksthal to Outfall TRT

The Sirens are installed at:

1. Karcham Dam .... 0 KM
2. Kilba Camp ....4 KM
3. Sholtu .... 9 KM
4. Kaksthal ....18 KM

CHAPTER-4

EMERGENCY DETECTION, EVALUATION AND CLASSIFICATION

4.1 Emergency Detection

A. Situations

Many dam conditions can lead to emergency situations, not all of which will necessitate the Implementation of the EAP. However, if any of them occur, the appropriate actions must be taken.

- Severe Storms/Inclement Weather: Although generally not in themselves a threat to the dam, severe storms and other inclement weather conditions can contribute to an existing problem and hinder any remediation efforts. Severe storms also cause the uncontrolled release of floodwater, and increase flow in already rain-swollen areas.
- Tropical cyclones: Tropical cyclones do occur in the area, with the potential for structural damage to the dam, possibly resulting in its failure. If a tropical cyclone has struck in the area, an inspection of the dam for any signs of damage will be appropriate.
- Earthquakes: Karcham Dam is located in the seismic zone IV. An earthquake is a possibility, and appropriate post-earthquake inspections should be performed.
- Sabotage: In case a threat to damage the dam has been made, appropriate actions must be taken to protect the dam.

B. Signs of Failure

Assistant General Manager- In-charge Karcham Dam is responsible for conducting routine inspections and identifying conditions that could indicate the onset of problems leading to a dam failure. The early identification of potentially dangerous conditions can allow time for the implementation of EAPs. It is important to understand how distress can develop into failure. With appropriate action, distress need not lead to a catastrophic failure of the dam. The following sections describe some of the different types of failure which could lead to a dam failure.

- Seepage Failure: Although all earthen embankments allow some minor seepage through the dam or the foundation, excessive, uncontrolled seepage can result in piping (the movement of embankment material in the seepage flow) and lead to failure. Piping can occur for years at a slow rate. If the piping has progressed to a dangerous level, it will be evident by increased flow or the discharge of muddy water (or both). At that stage, immediate action to stop the piping is needed. Fully developed piping is difficult to control and is very likely to result in failure. A whirlpool in the reservoir is a sign of uncontrollable piping and necessitates immediate emergency action.
- Embankment or Foundation Sliding: Sliding is usually first apparent when cracks or bulges in the embankment appear. Slides with progressive movement can cause failure of the embankment.
- Structural Failure: The structural failure or collapse of any non-overflow portion of the dam, spillway or spillway gates could result in loss of the reservoir. A structural failure of a portion of the spillway could cause piping and possibly embankment failure.
- Overtopping Failure: Overtopping of the embankment results in erosion of the dam crest. Once erosion begins, it is very difficult to stop.

4.2. Emergency Evaluation and Classification

This section lists the conditions and actions which may be used to classify the level of emergency response, as a guide for Assistant General Manager- In-charge Karcham Dam. Specific dam observations and corresponding emergency classification levels can be found in the evidence of distress in **Table 5.**

Internal Alert Condition BLUE – A "watch" condition. A problem has been detected at the dam that requires constant monitoring. At this time, the distress condition is manageable by dam personnel. The Assistant General Manager- In-charge Karcham Dam will be responsible for monitoring and repair as soon as possible and implementing the appropriate Notification Flowchart. The following is a list of conditions that would initiate this condition:

- Cloudy or dirty seepage or seepage with an increase in flow, boils, piping, or bogs
- Seepage around conduits
- Large sinkholes with corresponding seepage anywhere on the embankment or downstream from the toe
- Any slide that degrades the crest of the embankment or that is progressively increasing in size
- Cracking or movement of any concrete structure
- An increase in the reservoir level leading to engagement of the emergency spillway
- Exceptionally heavy rainfall in the catchment of the dam reservoir

External Alert Condition ORANGE– This is indicative of a dam condition that is progressively getting worse; and there is a high probability of dam failure. Although there is no immediate danger, the dam could fail if conditions continue to deteriorate. Assistant General Manager- In-charge Karcham Dam will be responsible for initiating immediate repairs, including lowering the reservoir if appropriate and implementing the appropriate Notification Flowchart. The following is a list of conditions that would initiate this condition:

- Large boils, increasing in size and flow rate, especially if there is flowing muddy water
- Significantly increasing seepage, especially flowing muddy water
- Slides involving a large mass of material that impairs the crest of the dam and is continuing to move
- Sinkholes with seepage flowing muddy water
- Large cracks, movement or failure of a portion of any major concrete structure that forms an integral part of the dam
- An increase in the reservoir level to near the top of the dam
- Overtopping of a dam that is not designed for overtopping
- Near to 'Design Flood' inflow forecast

External Alert Conditions RED – These are "failure" conditions. Either the dam is in immediate danger of failing or has already failed. No time remains to implement measures to prevent failure. Evacuate immediately. Evacuation efforts will continue until the situation is stabilized.

Assistant General Manager- In-charge Karcham Dam is responsible for implementing the appropriate Notification Flowchart.
The following is a list of conditions that would initiate "imminent dam failure" or "dam failure" conditions:

- Rapidly increasing boils or the presence of new, significantly flowing boils, particularly muddy ones near previously identified ones
- Rapidly increasing seepage, especially flowing muddy water
- Slides involving a large mass of material or which have degraded the crest of the embankment
- to a level that approaches the water surface level, or if significant seepage is observed through the slide area
- Settlement that is predicted to degrade to the reservoir level
- Cracks that extend to the reservoir level
- Significant movement or failure of any structure that forms an integral part of the dam
- Overtopping of an earthen dam
- Uncontrollable release of the reservoir

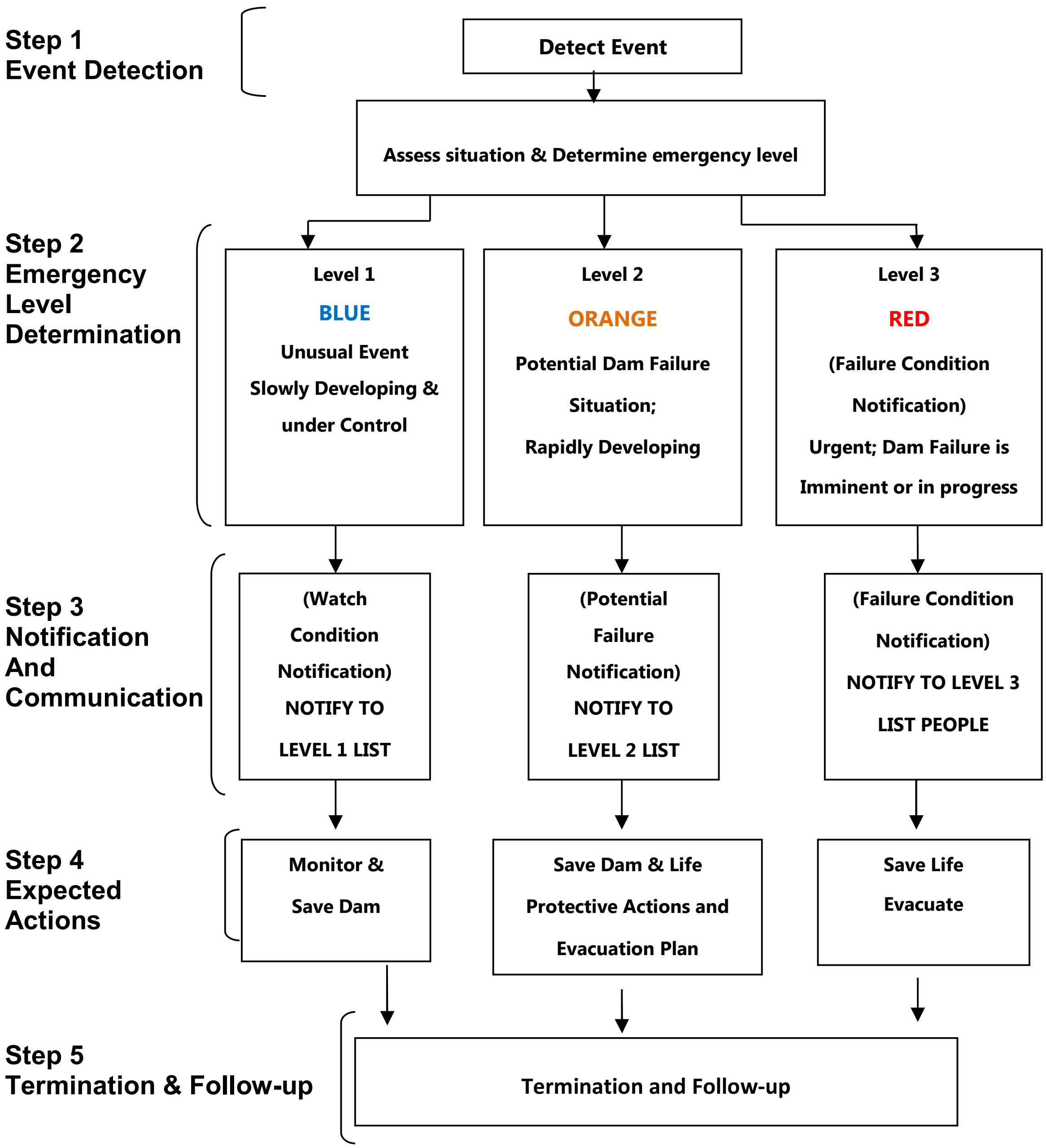
DETERMINING THE LEVEL OF EMERGENCY

Event	Situation	Emergency Level
Earth spillway flow	Reservoir water surface elevation at auxiliary spillway crest or spillway is flowing with no active erosion	1
	Spillway flowing with active gully erosion	2
	Spillway flow that could result in flooding downstream	2
	Spillway flowing with an advancing head cut that is threatening the control section	3
	Spillway flow that is flooding people downstream	3
Embankment overtopping	Overtopping flow not eroding the embankment slope; reservoir level expected to lower	2
	Overtopping flow eroding the embankment slope	3
	Overtopping flow not eroding the embankment slope; reservoir level expected to rise	3
Seepage	New seepage areas in or near the dam	1
	New seepage areas with cloudy discharge or increasing flow rate	2
	Seepage with discharge greater than 10 gallons per minute	3
Sinkholes	Observation of new sinkhole in reservoir area or on embankment	1
	Rapidly enlarging sinkhole	2
Embankment Cracking	New cracks in the embankment greater than ¼-inch wide without seepage	1
	Cracks in the embankment with seepage	2
Embankment Movement	Visual movement/slippage of the embankment slope	1
	Sudden or rapidly proceeding slides of the embankment slope	3
Instruments	Instrumentation readings beyond predetermined values	1
Earthquake	Measurable earthquake felt or reported on or within 50 miles of the dam	1
	Earthquake resulting in visible damage to the dam or appurtenances	2
	Earthquake resulting in uncontrolled release of water from the dam	3
Security Threat	Verified bomb threat that, if carried out, could result in damage to dam	2
	Detonated bomb that has resulted in damage to the dam or appurtenances	3
Sabotage / Vandalism	Damage to dam or appurtenances with no impacts to the functioning of the dam	1
	Modification to the dam or appurtenances that could adversely impact the functioning of the dam	1
	Damage to dam or appurtenances that has resulted in seepage flow	2
	Damage to dam or appurtenances that has resulted in uncontrolled water release	3

Figure 1

4.3. Previously Known Problems

No such problems observed in the past.



Five Step Response process of EAP, Detection to Termination Activities

Figure 2

CHAPTER-5

PREPAREDNESS

Preparedness actions are to be taken both before and following the development of emergency conditions and should identify ways of preparing for an emergency, increasing response readiness in a uniform and coordinated manner, and helping to reduce the effects of a dam failure.

The following are some steps that could prevent or delay failure after an emergency is first discovered.

Surveillance: Assistant General Manager- In-charge Karcham Dam will monitor the dam during emergency situations such as a severe storm event.

Response on forecast of excessive inflow: Assistant General Manager- In-charge Karcham Dam will respond to situation of excessive inflow forecast by way of controlled spillway releases after ascertaining the reliability of the forecast.

Response during weekends and holidays: Assistant General Manager- In-charge Karcham Dam will be available for emergency response during weekends and holidays and can be present at the dam site within [30 minutes maximum] of detection of an emergency condition.

Response during periods of darkness and adverse weather: Assistant General Manager- In-charge Karcham Dam will arrange for access to generators and lights to adequately monitor the situation. Assistant General Manager- In-charge Karcham Dam will be able to access the site during adverse weather conditions on foot.

Access to the site: Alternate access routes should be planned in the event of an emergency at the dam.
Access from both right and left banks to Karcham Dam is available.

Preventive measures can be taken in an emergency to prevent the catastrophic failure of the dam, but such repairs should be undertaken with extreme caution. The repairs are only temporary, and a permanent repair should be designed by an engineer as soon as possible.

The following actions should only be undertaken under the direction of a professional engineer or contractor. In all cases, the appropriate Notification Flowchart must be implemented and the personnel of the SDSO at DOE Shimla must be notified.

Consider the following preparedness actions if the dam's integrity is threatened by:

Seepage Failure

- Plug the flow with whatever material is available (hay, bentonite, or plastic) if the entrance is in the reservoir.

- Lower the water level in the reservoir by using the low flow outlet and pumping if necessary, until the flow decreases to a non-erosive velocity or until it stops. Place an inverted filter (a protective layer of sand and gravel) on the exit area to hold the material in place.
- Continue operating at a lower level until a repair is made.

Embankment or Foundation Sliding

- Lower the water level in the reservoir by using the low flow outlet and pumping if necessary at a rate and to an elevation considered safe, given the slide condition.
- Stabilize the slide, if on the downstream slope, by weighting the toe area below the slide with soil, rock, or gravel.
- Continue operating at a lower level until a repair is made.

Structural Failure

- Implement temporary measures to protect the damaged structure, such as placing rock riprap in the damaged area.
- Lower the water level to a safe elevation through the low flow outlet and by pumping if necessary.

CHAPTER 6

SUPPLIES AND RESOURCES

6.1. Contracts

Should JSWHEL personnel and resources prove to be inadequate during an emergency, requests will be made for assistance from other local jurisdictions, other agencies, and industry, as needed. Such assistance may include equipment, supplies, or personnel. All agreements will be entered into by authorized officials and should be in writing whenever possible. HoP / Assistant General Manager- In-charge Karcham Dam shall have the authority to enter into agreements as deemed necessary to prevent the failure of the dam.

6.2. Equipment and Supplies

Equipment that is available for use and local contractors that can be contacted to provide equipment during an emergency event are listed in Table 6.

6.3. Reports

Technical Data

Pre-monsoon and post-monsoon inspections of the dam will be made to evaluate its structural safety, stability, and operational adequacy.
In the event of an abnormal occurrence, reference to these reports, particularly the photographs, can be beneficial in the evaluation of a potential problem.
Technical records such as drawings and inspection reports should be stored and carefully maintained at the JSWHEL Site offices.
Alternate personnel will be familiar with the location of the documents in the event of an emergency situation.

Emergency Operations Centre Activity Log

Any unusual or emergency condition should be documented, including the following:

- Activation or deactivation of emergency facilities
- Emergency notifications to other local governments and to state and central government agencies
- Significant changes in the emergency
- Major commitments of resources or requests for additional resources from external sources
- Telephone calls should be recorded in chronological order
- Issuance of protective action recommendations to the public
- Evacuations
- Casualties
- Termination of the incident

Costs of the Emergency Operations Centre

For major emergencies, the emergency operations centre will maintain detailed records of costs expended. These records may be used to recover costs from the responsible party or insurers, or as a basis for requesting financial assistance for certain allowable response and recovery costs from the state or central government.
Documented costs should include:

- Personnel costs, especially overtime
- Equipment operation
- Equipment leasing and rental
- Contract services to support emergency operations
- Specialized supplies expended in emergency operations

CHAPTER 7

INUNDATION AREA

The inundation map illustrates the areas subject to flooding from a failure of the dam and can be found in **Table-2.** The map was prepared using the results of the Dam Breach Analysis.

After examining the results of the Karcham Dam Breach Analysis, it has been determined that no village will get submerged even in case of extreme flood of 11467 cumecs (against PMF of 6744 cumecs) in the event of any dam break/dam breach. Only a portion of the road near Sholtu gets submerged with about 1m to 1.6 m depth of water for a short period.

The breach analysis contains profiles of the peak flood levels expected, as well as an estimation of the time from the beginning of the breach to the peak flood elevations. A comparison of the areas that are likely to be flooded with the plots showing the times from the start of the breach to the flooding shows the areas of evacuation and the time constraints involved. Figures in the breach analysis includes information on the estimated impact of flooding on the bridges along the Satluj river.

7.1. Local Evacuation Plan

If imminent failure of the dam with uncontrolled downstream flooding is anticipated, local disaster management and law enforcement personnel should notify those downstream, for evacuation in the most expedient manner possible. The organizations and personnel on the Notification Flowchart should be contacted immediately. Local law enforcement officials, along with local mobile network operators, radio and television stations can best spread the notice for evacuation.
The immediate impact will be to areas along Satluj river downstream of the dam. For sunny-day and design flood breaches, the following actions should be taken:

- Barricading all bridges that could possibly be flooded to prevent access to the affected area. These bridges include the Satluj crossings of NH-5.
  See the Inundation Map in **Table-2** to determine appropriate barricade locations.
- The District Disaster Management office can assist with the notification of all persons and agencies involved, with the possibility of additional support—including contacting others not accessible by radio or telephone.
- District officials are generally familiar with developed areas in their jurisdiction. Such knowledge, coupled with the requirements of state law that they respond to disasters, make them the logical officials to be notified and to spread the warning message to all areas subject to flooding.

CHAPTER 8

IMPLEMENTATION

8.1. Development

The draft EAP is being sent to the SDSO (DOE, GoHP) for review and their comments shall be incorporated into this document, a copy of which is currently on file with the SDSO.
The EAP was approved by SDSO vide their letter dated 01/04/17.

8.2. Updating

Copies of the EAP shall be provided to the appropriate persons and the EAP shall be approved and signed by the owner and the person(s) in charge of emergency response, as shown on the Distribution List and Approval and Implementation sheets at the front of the report. This plan will be reviewed and updated annually by JSWHEL and personnel from local disaster management agencies in conjunction with Assistant General Manager- In-charge Karcham Dam 's annual maintenance inspection of the dam. Assistant General Manager- In-charge Karcham Dam will review and complete all items on the Annual EAP Evaluation Checklist in **Table-7**. After the annual update is complete, a new Approval and Implementation sheet will be attached and the annual update will be documented on the Plan Review and Update sheet in **Table- 8.**

If revisions to the EAP are made as a result of the annual update, such changes will be recorded on the Log Sheet of Changes form at the front of the report. A copy of the updated portions of the EAP will be sent to the SDSO and all other concerned as per the EAP Distribution List. If the EAP was reviewed and revisions were not required, JSWHEL will submit written notification to all concerned that no updates to the EAP have been adopted or implemented.

8.3. Testing

A table top drill will be conducted at least once every five years. The table top drill involves a meeting of Assistant General Manager- In-charge Karcham Dam with local and state disaster management officials in a conference room. The drill begins with a description of a simulated event and proceeds with discussions by the participants to evaluate the EAP and response procedures, and to resolve concerns regarding coordination and responsibilities. Any problems identified during a drill should be included in revisions to the EAP. Records of training and drills will be maintained in **Table-9**.

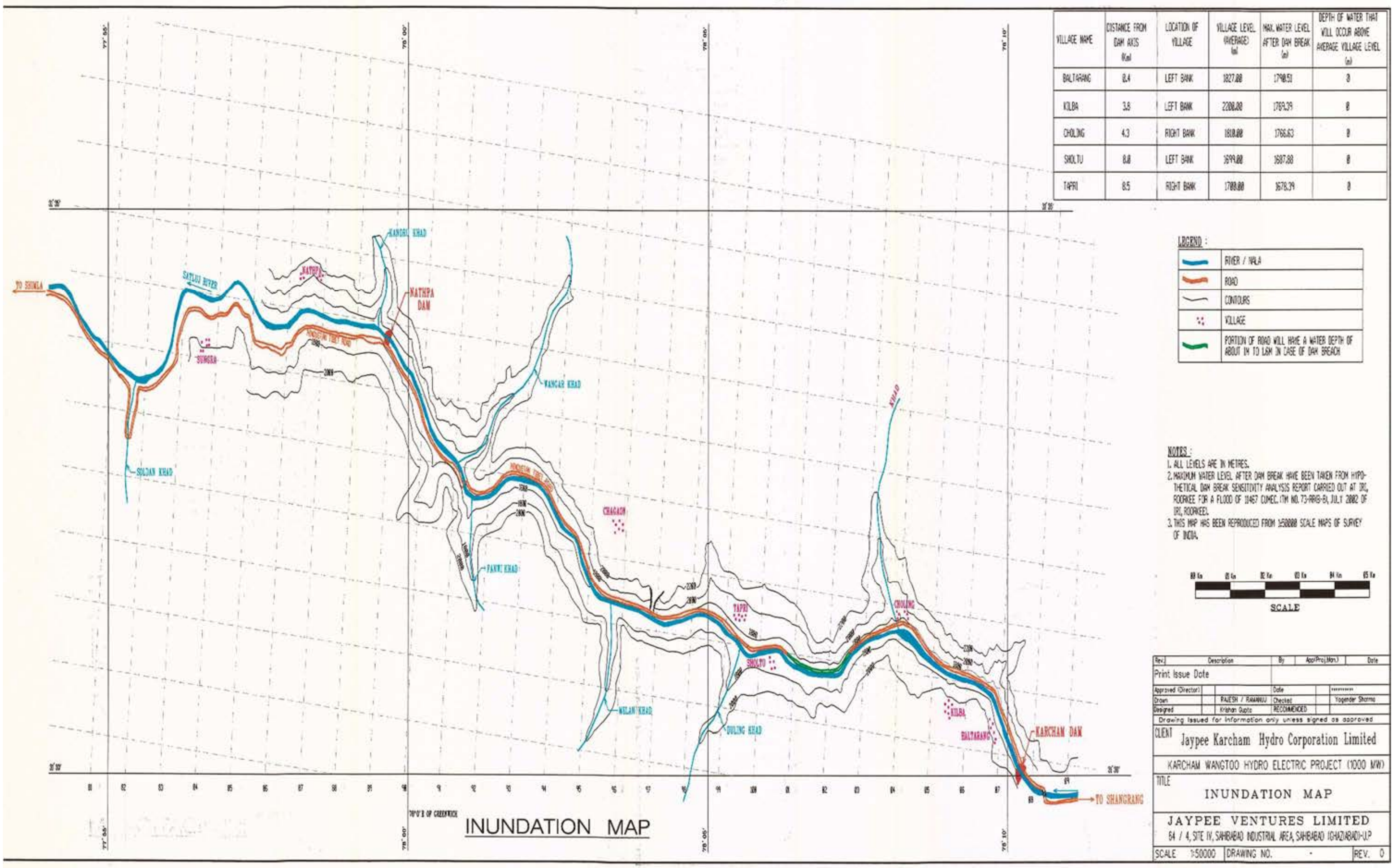
8.4. Training

All people involved in the EAP will be trained to ensure that they are thoroughly familiar with its elements, the availability of equipment, and their responsibilities and duties under the plan. Personnel will be trained in problem detection, evaluation, and appropriate corrective measures.

This training is essential for proper evaluation of developing situations at all levels of responsibility. Training records will be maintained in **Table-9**.

Table- 1
Vicinity Map

Table-2
Inundation Map



VILLAGE NAME	DISTANCE FROM DAM AXIS (Km)	LOCATION OF VILLAGE	VILLAGE LEVEL (AVERAGE) (m)	MAX. WATER LEVEL AFTER DAM BREAK (m)	DEPTH OF WATER THAT WILL OCCUR ABOVE AVERAGE VILLAGE LEVEL (m)
BALTARANG	8.4	LEFT BANK	1827.00	1790.51	0
KILBA	3.8	LEFT BANK	2200.00	1769.39	0
CHOLING	4.3	RIGHT BANK	1610.00	1766.63	0
SHOLTU	8.8	LEFT BANK	1699.00	1687.88	0
TAPRI	8.5	RIGHT BANK	1700.00	1678.39	0

Table- 3
DAM DESCRIPTION

SALIENT FEATURES

LOCATION		
State		Himachal Pradesh
District	:	Kinnaur
River	:	Satluj
Vicinity	:	Approx. 200km. from Shimla
Latitude	:	($31^0$30'00.26" N)
Longitude	:	($78^0$10'39.54"E)
PROJECT CODE OR DAM ID	:	**HP43HH0013**
HYDROLOGY		
Catchment area at Dam site	:	48755 Sq Km
Snow Catchment	:	38760 Sq Km
Design Flood : PMF	:	5660 cumecs
RIVER DIVERSION WORK		
Diversion Tunnel	:	±10.15m dia
Length	:	541 m
COFFER DAM		
Type	:	Rock fill with Concrete wall
Upstream	:	16.50m high
Down Stream	:	6.5m high
Cut off for Coffer Dam	:	Jet grouted columns
DIVERSION DAM		
Type	:	Concrete gravity
Top of Dam	:	EL 1813m
No. of Blocks	:	10
HT from foundation level	:	88m
Total length at top	:	182.50m
Minimum foundation level	:	EL 1725m
Maximum Pond level	:	EL 1810 m
Live Storage capacity	:	544.97 Hectare metre.

MAIN SPILL WAY

No. of bays	:	4
Size of each gate	:	10m(W) x 10.5m(H)
Crest elevation	:	EL 1778 m
Type of gates	:	Radial Gates (top sealing)
Discharge capacity of sluices	:	7400 cumecs.
Maximum flood level	:	EL 1810 m.

AUXILARY SPILL WAY

No. of bays	:	1
Crest elevation	:	EL 1807 m
Size of gate	:	6m x 6m
Type of gate	:	Fixed wheel gate

INTAKE

No. of bays	:	4
Size of bay	:	16m (W) x 17.50m(H)
Sill level	:	EL 1793 m
Discharge through each bay	:	126 cumecs
Size of each gate	:	7.5m (W) x 4.0m(H)

SEDIMENTATION CHAMBERS

No. of chambers	:	4
Design discharge	:	126 cumecs
Size of each chamber	:	424m(L) x 18m(W) x 32.50m(H) & 70m long U/S and D/S transitions
Flushing Discharge of each chamber	:	20.75 cumecs
Size of Gate Operating Gallery	:	217m(L) x 7.5m(W) x 9m(H)

FLUSHING TUNNEL

Size	:	5m(W) x 7.3m(H)
Length	:	5.232 Km
Invert level at outfall	:	EL 1741.50 m
Size of Gate Operating Gallery	:	210m(L) x 7.5m(W) x 8.00m((H)

HEAD RACE TUNNEL

Size and type	:	10.48m dia circular
Length	:	16.925 Km
Design discharge	:	421 cumecs
Velocity	:	4.88 m/sec
Slope	:	0.210
No. of Adits	:	7, 7.50m D-Shaped and 3124m in length

SURGE SHAFT

Type	:	Restricted Orifice
Dia	:	16m / 27m
Bottom Elevation	:	EL 1713.24m
Top Elevation	:	EL 1860m
Maximum Up surge	:	EL 1850.01m

PRESSURE SHAFTS

No. and type	:	4, steel lined
Dia meter	:	5 m
Length	:	I & IV : 695m
		II & III : 657m
Steel of liners	:	ASTM - 517, Grade -F

VALVE CHAMBER

Size	:	104m(L) x 10m(W) x 19.075m(H)
Type of valve	:	Butterfly Valve
Dia of Valve	:	4.60m
EOT Crane	:	1x80/10 T

POWER HOUSE

Size of Cavern	:	188 m(L) x 22m(W) x 52.50m(H)
No. of units	:	4, 250MW each
Gross Head	:	293.00
Net Head	:	269m

TRANSFORMER HALL

Size of Cavern	:	162m(L) x 16.00m(W) x 22.60m(H)

D/S SURGE CHAMBER

Size of Chamber	:	220m(L) x 12.50m(W) x 13.50m(H)
Maximum Surge Level	:	1528.54m
Minimum Surge Level	:	1502.69m

DT GATE OPERATING GALLERY

Size of Gallery	:	107m(L) x 7.5m(W) x 10.60m(H)

TAIL RACE TUNNEL

Size and type	:	10.48m dia circular
Length	:	1270m
Invert level of out fall	:	1502.50m

Table-4
Sample Public Announcements

Communication Message (English & Hindi)

"This is , Dam Owner, KARCHAM DAM (JSW ENERGY LTD.) delivering to notify you all, that we have an emergency condition at KARCHAM DAM in the Kinnaur District of Himachal Pradesh, located at ______ Km (east/west/north/south) of ________________.

We have activated the Emergency Action Plan (EAP)for this dam and are currently under the Emergency Level 2situation that could result in the dam failure.

We are implementing the pre-determined actionsto respondto rapidly developing condition which could also lead to failure of the dam.

(So, you are requested to please prepare for the evacuation of the low lying downstream portions along __________________).

Please refer the evacuation map (Annexure-XX) in your copy of EAP. We will be advising you regularly as the condition is resolved or if it gets worse."

"मैं………………………, (जे० एस० डब्लयू० एनर्जी लिमिटेड) के करच्छम बांध का प्रमुख, आप सबको सूचित कर रहा हूँ, कि हम हिमाचल प्रदेश के जिला किन्नौर……….कि.मी. (पूर्व/पश्चिम/उत्तर/दक्षिण) …………..स्थित करच्छम बांध में एक आपातकालीन स्थिति में हैं।

हम ने आपातकालीन कार्रवाई योजना (EAP) इस बांध के लिए सक्रिय कर ली है और हम वर्तमान में आपातकालीन स्थिति स्तर-2 पर हैं जिसका परिणाम बांध की विफलता भी हो सकती है।

तेजी से विकसित होने वाली स्थिति, जिसके कारण बांध विफल हो सकता है, हम उसके प्रतिसाद पूर्व निर्धारित क्रियाएँ लागू कर रहे हैं।

(तो, आप से यह अनुरोध है कि, कृपया बांध के अनुप्रवाह निचले क्षेत्रों में स्थित ……………को खाली कराने की तैयारी करें।)

कृपया अपनी EAP की प्रतिलिपि में निकासी मानचित्र (Annexure-XX) देखें। हम आपको स्थिति के सुधरने और बिगडने का निरन्तर दिशा निर्देश देते रहेंगे।

Table-5

Evidence of Distress

General Observation	Specific observation	Emergency condition level	Emergency action	Equipment, material and Supplies	Data to record
Boils	Small boils, no increase of water flow, flowing clear water.	**BLUE**	Closely check all of downstream toe, especially in the vicinity of boil for additional boils, wet spots, sinkholes, or seepage. Closely monitor entire area for changes or flow rate increases.	None	Site and location, approximate flow
	Large or additional boils near previously identified ones, without increasing flow rate, but carrying small amount of soil particles.	**BLUE**	Initiate 24-hour surveillance. Monitor as described above. Construct sandbag ring dikes around boils, to cover them with water to retard the movement of soil particles. Filter cloth may be used to retard soil movement, but do not retard the flow of water.	Sandbags, filter cloth	Site and location, approximate flow
	Large or additional boils near previously identified ones, in-creasing flow rate, carrying soil particles.	**ORANGE**	Continue 24-hour surveillance. Continue monitoring and remedial action as described above. Initiate emergency lowering of the reser-voir. Issue a warning to downstream residents.	Sandbags, pump	Site and location, approximate flow
	Rapidly increasing size of boils and flow increasing and muddy water.	**RED**	Downstream evacuation. Employ all available equip-ment to attempt to construct a large ring dike around the boil area.	Dozer, shovels, source of earth fill	Site and location, approximate flow
	Minor seepage of clear water at toe, on slope of em-	**BLUE**	Closely check entire embankment for other seepage areas. Use wooden stakes	Wooden stakes, flagging	Site, location, approximate flow

Seepage	bankment, or at the abutments.		or flagging to delineate seepage area. Try to channel and measure flow. Look for upstream whirlpools.		
Seepage	Additional seepage areas observed flowing clear water and /or increasing flow rate.	**BLUE**	Initiate 24-hour surveillance. Monitor as described above. Construct measuring weir and channel all seepage through weir. Attempt to determine source of seepage.	Dozer, shovels	Site, location, approximate flow
	Seriously or rapidly increasing seepage, under-seepage, or drain flow.	**ORANGE**	Continue 24-hour monitoring and remedial action as described above. Initiate emergency lowering of the reservoir. Construct a large ring dike around the seepage area.	Dozer, shovels, source of fill material	Site location, approximate flow
	Additional seepage areas with rapid in-crease in flow and muddy water.	**RED**	Downstream evacuation. Employ all available equip-ment to attempt to construct a large ring dike around the seepage area.	Dozer, shovels, source of fill material	Site location, approximate flow
Slides or severe erosion	Skin slide or slough on slope of em-bankment. No further movement of slide and embankment crest not de-graded.	**BLUE**	Examine rest of embankment for other slides. Place stakes in slide material and adjacent to it for determining if further movement is taking place.	Stakes, tape measure	Distance between stakes
	Slide or erosion in-volving large mass of material, crest of embankment is degraded,	**BLUE**	Initiate 24-hour surveillance. Mobilize all available resources and equipment for repair operations to increase freeboard and to protect the	Dozer, shovels, sources of fill material, sandbags	Distance between stakes

	no movement or very slow continuing movement.		exposed embankment material. Start filling sandbags and stockpile near slide area.		
	Slide or erosion involving large mass of material, crest of embankment is degraded, progressively increasing in size.	ORANGE	Continue monitoring and remedial actions as described above. Place additional material at the toe of the slope to stop the slide.	Dozer, shovels, source of fill material, pump	Distance between stakes
	Slide or erosion involving large mass of material, crest of embankment is severely degraded; movement of slide is continuing and may reach pool level.	RED	Downstream evacuation. Utilize all available equipment and personnel to sandbag the degraded slide area to prevent it from overtopping.	Dozer, shovels, sandbags, pump	Distance between stakes
Sinkholes	Sinkholes anywhere on the embankment or within 150 metres downstream from the toe.	BLUE	Carefully walk the entire embankment and downstream area looking for additional sinkholes, movement, or seepage.	Stakes, flagging	Size, location
	Large sinkholes with corresponding seepage anywhere on the embankment or downstream from the toe.	ORANGE	Continue monitoring and remedial action as described above. Utilize sandbags to increase the freeboard on the dam if necessary.	Sandbags, dozer, pump	Size, location

	Sinkholes rapidly getting worse, seep-age flowing muddy water and increasing flow.	**RED**	Downstream evacuation. Utilize all available equip-ment and personnel to attempt to construct a large ring dike around the area.	Dozer, shovels, pump	Size, location

Settlement	Obvious settlement of the crest of the embankment, especially adjacent to concrete structures.	**BLUE**	Look for bulges on slope or changes in crest alignment.	None	Size, location
	Settlement of crest of embankment that is progressing, especially adjacent to concrete structures or if any corre-sponding seepage is present.	**BLUE**	Initiate 24-hour surveillance. Mobilize all available resources for repair operations to increase freeboard. Fill and stockpile sandbags. Identify any boils near settlement points for flowing material and pursue action for boils.	Sandbags, dozer, shovels, source of fill material	Size, location
	Settlement of crest of embankment that is rapidly progressing especially adjacent to concrete structures or if any correspondin g seepage is flowing mud-dy water or increasing flow.	**ORANGE**	Continue monitoring and remedial actions as described above. Use sandbags to in-crease the freeboard on the dam if necessary.	Sandbags, shovels, dozer, source of fill material	Size, location

	Progressing settlement that is ex-pected to degrade the embankment to reservoir level.	**RED**	Downstream evacuation. Utilize all available equipment and personnel to build up the crest in the area that is settling. Identify any boils near settlement points for flowing material and pursue action for boils.	Dozer, shovels, source of fill material , sandbags	Size, location

Cracking	Cracks in the embankment crest or on slopes.	**BLUE**	Walk on entire crest and slope and check for additional cracking.	Stakes, tape measure	Size, location
	Numerous cracks in crest that are enlarging, especially that perpendicular to the centreline of the dam.	**BLUE**	Initiate 24-hour surveillance. Carefully monitor and measure cracking to determine the speed and extent of the problem. Mobilize to fill cracks. Cracks parallel to the centerline indicate a slide. Follow remedial action for slides.	Stakes, tape measure, dozer, shovels, source of fill material	Size, location
	Large cracks in the crest that is rapidly enlarging, especially that perpendicular to the centerline of the dam.	**ORANGE**	Continue monitoring and remedial action as described above.	Dozer, shovels, source of fill material	Size, location
	Cracking that extends to pool eleva-tion.	**RED**	Downstream evacuation. Continue remedial actions as described above.	Dozer, shovels, source of fill material	Size, location

Cracking or movement of concrete structure	Minor cracking and/or movement.	**BLUE**	Immediately install measuring device to monitor movement.	Crack Monitors, stakes, tape measure	Size, location
	Significant cracking and /or movement.	**BLUE**	Initiate 24-hour surveillance. Lower burlap on upstream face of crack to reduce flow of soil particles. Dump large rock on downstream of moving concrete structure monolith to resist the movement.	Burlap, rock, dozer, shovels	Size, location, flow rate
	Serious cracking and /or movement	**ORANGE**	Prepare for evacuation. Continue monitoring and reme-dial action as described above.	Dozer, rock, burlap, crack monitors	Size, move-ment, flow rate
	Major cracking and /or movement	**RED**	Downstream evacuation. Dam failure is imminent. Continue monitoring andremedial actions as described above.	Dozer, shovels, rock	Size, location flow rate
Upstream whirlpool	Whirlpool in the lake in the vicinity of the embankment	**RED**	Downstream evacuation. Attempt to plug the entrance of the whirlpool with riprap from the slope of the embankment. Search downstream for an exit point and construct a ring dike to retard the flow of soil particles.	Dozer, fill material, sandbags, filter cloth, straw, rocks	Size, location, flow rate
Malfunction of gate	Structural member of a gate or gate operator broken or severely damaged so as to prevent operation of the gate	**ORANGE**	Initiate 24-hour surveillance. Immediately place stop logs in front of gate and initiate necessary actions to get gate repaired.	Crane and welder	Type of problem, location

Rapidly rising lake	Lake level rising and rain continuing	**BLUE**	Initiate 24-hour surveillance of lake level and rainfall. Generate inflow forecasts every 12 hours.		Lake level, rainfall
Overtopping	Water flowing over the dam and lake continuing to rise. No significant erosion of downstream embankment.	**ORANGE**	Prepare for evacuation. Continue monitoring. Generate inflow forecasts every 3 hours.	Dozer, fill material, sandbags, filter cloth, rocks	Lake level, rainfall
	Water flowing over the dam, the lake continuing to rise, and significant erosion of downstream embankment with development of head-cuts encroaching on the dam crest, or significant movement of sections of concrete or masonry portions of the dam.	**RED**	Immediate evacuation. Dam failure is imminent or ongoing.	Cameras.	Status of breach formation. Width of breach as it enlarges.

Table-6

TABLE OF SUPPLIES AND RESOURCES

Equipment/ Supplies	Quantity/ Nos.	Location
EXCAVATOR	3	[JSWHEL, Sholtu]
EXCAVATOR CUM LOADER	3	**-do-**
WHEEL LOADER	4	**-do-**
DOZER	2	**-do-**
VIBRATORY COMPACTOR	1	**-do-**
CONCRETE PUMP	1	**-do-**
CRAWLER DRILL MACHINE	2	**-do-**
AIR COMPRESSOR	5	**-do-**
MOBILE CRANE	2	**-do-**
DIESEL WELDING MACHINE	2	**-do-**
DIESEL FORK LIFT	2	**-do-**
BATCHING PLANT 30 CUM/H	1	**-do-**
AGGREGATE PROCESSING PLANT 120TPH	1	**-do-**
FABRICATED PLATFORM	1	**-do-**
TIPPER	8	**-do-**
TRUCK	2	**-do-**
TRANSIT MIXTURE	1	**-do-**
AMBULANCE	4	**-do-**

Table-7

ANNUAL EAP EVALUATION CHECKLIST

Was the annual dam inspection conducted?	□ Yes □ No	If yes, has the EAP been revised to include any signs of failures observed during the inspection?	□ Yes □ No
Was weed clearing, animal burrow removal, or other maintenance required?	□ Yes □ No	If yes, describe actions taken and date:	
Was the outlet gate operable?	□ Yes □ No	If no, describe actions taken and date:	
Does the Notification Flowcharts require revision? (Note that revision of the contact information will not require EAP approval; however, the revised contact information pages will need to be redistributed as replacement pages.)	□ Yes □ No	If yes, list the dates of the contact information revision and redistribution:	
Was annual training or a table top drill conducted?	□ Yes □ No	Circle: training drill Date conducted:	
Are inspection and training records included in the EAP?	□ Yes □ No		
Was the EAP reviewed?	□ Yes □ No	If yes, review date:	
Were changes required to the EAP?	□ Yes □ No	If yes, date of revised EAP approval:	

Table-8

PLAN REVIEW AND UPDATE

This plan will be reviewed and updated annually and table top drills will be carried out at least once every five years. Reviews will be documented as below.

Date of review: --Participants:

Date of review: --Participants:

Date of review: --Participants:

Date of review: --Participants:

Date of table top drill: ---------------------------------------Participants:

Table-9

TABLE FOR TRAINING RECORD

This form will be to record training sessions. File the completed form in the appropriate Tab of the EAP. All items in the EAP should be thoroughly reviewed during training. Appropriate JSWHEL employees and EAP team members should attend a training session annually (or participate in a simulated drill).

TRAINING LOCATION:	
DATE: TIME: INSTRUCTOR:	
CLASS:	SIGNATURE:
Type of Simulation Conducted:	Circle Emergency Type: Emergency water release Watch condition Possible dam failure Imminent dam failure Actual dam failure
Comments, Results of Drill	
Revisions Needed to EAP Based on Results of Drill? □ Yes □ No If yes, list revisions required:	

Appendix. A
GLOSSARY OF TERMS FOR DAM SAFETY

The purpose of this glossary is to establish a common vocabulary of dam safety terms for use within and among Central and State Government agencies. Terms have been included that are generic and apply to all dams, regardless of size, owner, or Location-**Abutment –** The part of the valley side against which the dam is constructed. The left and right abutments of a dam are defined with the observer looking downstream from the dam.

Appurtenant work – Structures associated with the dam including the following:

a) Spillways, either in the dam or separate therefrom;
b) Reservoir and its rim;
c) Low-level outlet works and water conduits such as tunnels, pipelines or penstocks, either through the dam or its abutments or reservoir rim;
d) Hydro-mechanical equipment including gates, valves, hoists, and elevators;
e) Energy dissipation and river training works; and
f) Other associated structures acting integrally with dam body.

Auxiliary spillway – Any secondary spillway that is designed to be operated infrequently, possibly in anticipation of some degree of structural damage or erosion to the spillway that would occur during operation.

Barrage – While the term barrage is borrowed from the French word meaning "dam" in general, its usage in English refers to a type of low-head, dam that consists of a number of large gates that can be opened or closed to control the amount of water passing through the structure, and thus regulate and stabilize river water elevation upstream for use diverting flow for irrigation and other purposes.

Boil – A disruption of the soil surface due to water discharging from below the surface. Eroded soil may be deposited in the form of a ring (miniature volcano) around the disruption.

Breach – An excavation or opening, either controlled or a result of a failure of the dam, through a dam or spillway that is capable of completely draining the reservoir down to the approximate original topography so the dam will no longer impound water, or partially draining the reservoir to lower impounding capacity. An uncontrolled breach is generally associated with the partial or total failure of the dam.

Breach analysis – The determination of the most likely uncontrolled release of water from a dam (magnitude, duration, and location), using accepted engineering practice, to evaluate downstream hazard potential.

Breach inundation area – An area that would be flooded as a result of a dam failure.

Chimney drain – A vertical or inclined layer of pervious material in an embankment to facilitate and control drainage of the embankment fill.

Cofferdam – A temporary structure enclosing all or part of the construction area that construction can proceed in the dry. A diversion cofferdam diverts a stream into a pipe, channel, tunnel, or other watercourse.

Compaction – Mechanical action that increases soil density by reducing voids.

Concrete lift –The vertical distance between successive horizontal construction joints.

Conduit – A closed channel to convey water through, around, or under a dam.

Construction joint – The interface between two successive placements or pours of concrete where bond, and not permanent separation, is intended.

Construction – Building a proposed dam and appurtenant structures capable of storing water.

Contact grouting – Filling, with cement grout, any voids existing at the contact of two zones of different materials, i.e., between a concrete tunnel lining and the surrounding rock.

Core wall – A wall built of relatively impervious material, usually of concrete or asphaltic concrete in the body of an embankment dam to prevent seepage.

Cutoff trench – A foundation excavation later to be filled with impervious material so as to limit seepage beneath a dam.

Cutoff wall – A wall of impervious material usually of concrete, asphaltic concrete, or steel sheet piling constructed in the foundation and abutments to reduce seepage beneath and adjacent to the dam.

Dam – Any artificial barrier including appurtenant works constructed across rivers or tributaries thereof with a view to impound or divert water; includes barrage, weir and similar water impounding structures but does not include water conveyance structures such as canal, aqueduct and navigation channel and flow regulation structures such as flood embankment, dike and guide bund.

Dam failure – Failures in the structures or operation of a dam which may lead to uncontrolled release of impounded water resulting in downstream flooding affecting the life and property of the people.

Dam incident – All problems occurring to a dam that have not degraded into 'dam failure' and including the following:

a) Structural damage to the dam and appurtenant works;
b) Unusual readings of instruments in the dam;
c) Unusual seepage or leakage through the dam body;
d) Change in the seepage or leakage regime;
e) Boiling or artesian conditions noticed below an earth dam;
f) Stoppage or reduction in seepage or leakage from the foundation or body of the dam into any of the galleries, for dams with such galleries;
g) Malfunctioning or inappropriate operation of gates;
h) Occurrence of any flood, the peak of which exceeds the available flood discharge capacity or 70% of the approved design flood;
h) Occurrence of a flood, which resulted in encroachment on the available free board, or the approved design free board;
j) Erosion in the near vicinity, up to five hundred meters, downstream of the spillway, waste weir, etc.; and
k) Any other event that prudence suggests would have a significant unfavorable impact on dam safety.

Dam inspection – On site examination of all components of dam and its appurtenances by one or more persons trained in this respect and includes examination of non-overflow portion, spillways, abutments, stilling basin, piers, bridge, downstream toe, drainage galleries, operation of mechanical systems (including gates and its components, drive units, cranes), interior of outlet conduits, instrumentation records and record-keeping arrangements of instruments.

Dam owner – The Central Government or a State Government or public sector undertaking or local authority or **company** and any or all of such persons or organisations, who own, control, operate, or maintain a specified dam.

Dam safety – The practice of ensuring the integrity and viability of dams such that they do not present unacceptable risks to the public, property, and the environment. It requires the collective application of engineering principles and experience, and a philosophy of risk management that recognizes that a dam is a structure whose safe function is not explicitly determined by its original design and construction. It also includes all actions taken to identify or predict deficiencies and consequences related to failure, and to document, publicize, and reduce, eliminate, or remediate to the extent reasonably possible, any unacceptable risks.

Design water level – The maximum water elevation, including the flood surcharge, that a dam is designed to withstand.

Design wind – The most severe wind that is reasonably possible at a particular reservoir for generating wind setup and run-up. The determination will generally include the results of meteorological studies that combine wind velocity, duration, direction and seasonal distribution characteristics in realistic manner.

Diversion dam – A dam built to divert water from a waterway or stream into a different watercourse.

Earth-fill dam – An embankment dam in which more than 50% of the total volume is formed of compacted earth layers.

Effective crest of the dam – The elevation of the lowest point on the crest (top) of the dam, excluding spillways.

Embankment dam – Any dam constructed of excavated natural materials, such as both earth-fill and rock-fill dams, or of industrial waste materials, such as a tailings dam.

Embankment zone – An area or portion of an embankment dam constructed using similar materials and similar construction and compaction methods throughout.

Emergency action plan (EAP) – A written document prepared by the dam owner or the owner's professional engineer describing a detailed plan to prevent or lessen the effects of a failure of the dam or appurtenant structures.

Emergency condition level – The following three emergency condition levels are considered:

a) **BLUE** – An event has taken place that is developing slowly and needs to be monitored closely. Immediate correction action is required.

b) **ORANGE** – Dam failure is highly probable but might be avoided with corrective actions.

c) **RED** – Dam failure is imminent or ongoing. **Emergency repairs –** Any repairs that are considered to be temporary in nature and that are necessary to preserve the integrity of the dam and prevent a possible failure of the dam.

Emergency spillway – An auxiliary spillway designed to pass a large, but infrequent, volume of flood flow, with a crest elevation higher than the principal spillway or normal operating level.

Failure mode – A potential failure mode is a physically plausible process for dam failure resulting from an existing inadequacy or defect related to a natural foundation condition, the dam or appurtenant structures design, the construction, the materials incorporated, the operations and maintenance, or aging process, which can lead to an uncontrolled release of the reservoir.

Fetch – The-straight-line distance across a body of water subject to wind forces. The fetch is one of the factors used in calculating wave heights in a reservoir.

Filter – One or more layers of granular material graded (either naturally or by selection) so as to allow seepage through or within the layers while preventing the migration of material from adjacent zones.

Flap gate – A gate hinged along one edge, usually either the top or bottom edge. Examples of bottom-hinged flap gates are tilting gates and fish belly gates so called from their shape in cross section.

Flashboards – Structural members of timber, concrete, or steel placed in channels or on the crest of a spillway to raise the reservoir water level but intended to be quickly removed, tripped, or fail in the event of a flood.

Flip bucket – An energy dissipater located at the downstream end of a spillway and shaped so that water flowing at a high velocity is deflected upwards in a trajectory away from the foundation of the spillway.

Flood hydrograph – A graph showing, for a given point on a stream, the discharge, height, or other characteristic of a flood with respect to time.

Freeboard – Vertical distance between a specified Stillwater (or other) reservoir sur-face elevation and the top of the dam, without camber.

Gabion – Rectangular-shaped baskets or mattresses fabricated from wire mesh, filled with rock, and assembled to form overflow weirs, hydraulic drops, and overtopping protection for small embankment dams. Gabion baskets are generally stacked in a stair-stepped fashion, while mattresses are generally placed parallel to a slope. Gabions have advantages over loose riprap because of their modularity and rock confinement properties, thus providing erosion protection with less rock and with smaller rock sizes than loose riprap.

Gallery – A passageway in the body of a dam used for inspection, foundation grouting, and/or drainage.

Gate – A movable water barrier for the control of water.

Geo-membrane – An essentially impermeable geo-synthetic composed of one or more synthetic sheets.

Geo-synthetic – A planar product manufactured from polymeric material used with soil, rock, earth, or other geotechnical engineering related material as an integral part of a man-made project, structure, or system.

Geotextile – Any fabric or textile (natural or synthetic) when used as an engineering material in conjunction with soil, foundations, or rock. Geotextiles have the following uses: drainage, filtration, separation of materials, reinforcement, moisture barriers, and erosion protection.

Gravity dam – A dam constructed of concrete and/or masonry that relies on its weight and internal strength for stability.

Grout – A fluidized material that is injected into soil, rock, concrete, or other construction material to seal openings and to lower the permeability and/or provide additional structural strength. There are four major types of grouting materials: chemical; cement; clay; and bitumen.

Grout blanket – An area of the foundation systematically grouted to a uniform shallow depth.

Grout cap – A concrete filled trench or pad encompassing all grout lines constructed to impede surface leakage and to provide anchorage for grout connections.

Grout curtain – One or more zones, usually thin, in the foundation into which grout is injected to reduce seepage under or around a dam.

Hazard potential – The possible adverse incremental consequences that result from the release of water or stored contents because of failure or incorrect operation of the dam or appurtenances. Impacts may be for a defined area downstream of a dam from flood waters released through spillways and outlet works of the dam or waters released by partial or complete failure of the dam. There may also be impacts for an area upstream of the dam from effects of backwater flooding or landslides around the reservoir perimeter.

Hazard potential classification – A measure of the potential for loss of life, property damage, or economic impact in the area downstream of the dam in the event of a failure or malfunction of the dam or appurtenant structures. The hazard classification does not represent the physical condition of the dam.

Height of dam – The difference in elevation between the natural bed of the watercourse or the lowest point on the down-stream toe of the dam, whichever is lower, and the effective crest of the dam.

Hydraulic fracturing – Hydraulic fracturing in soils is a tensile parting that is created because of increased fluid pressure. Initiation and/or propagation cracks in the core sections of earthen dams because of hydraulic fracturing affect adversely structural safety of the dams.

Hydraulic gradient – The change in total hydraulic pressure per unit distance of flow.

Hydrology – One of the earth sciences that encompasses the natural occurrence, distribution, movement, and properties of the waters of the earth and their environmental relationships.

Hydrometeorology – The study of the atmospheric and land-surface phases of the hydrologic cycle with emphasis on the interrelationships involved.

Hydrostatic pressure – The pressure exerted by water at rest.

Inclinometer – An instrument, usually consisting of a metal or plastic casing inserted in a drill hole and a sensitive monitor either lowered into the casing or fixed within the casing. This measures at different points the casing's inclination to the vertical. The system may be used to measure settlement.

Inflow design flood –The flood hydro-graph used in the design of a dam and its appurtenant works particularly for sizing the spillway and outlet works and for determining maximum storage, height of dam, and freeboard requirements.

Instrumentation – An arrangement of devices installed into or near dams that provide for measurements that can be used to evaluate the structural behavior and performance parameters of the structure.

Internal erosion – A general term used to describe all of the various erosional processes where water moves internally through or adjacent to the soil zones of embankment dams and foundation, except for the specific process referred to as 'backward erosion piping'. The term internal erosion is used in place of a variety of terms that have been used to describe various erosional processes, such as scour, suffusion, concentrated leak piping, and others.

Inundation map – A map showing areas that would be affected by flooding from releases from a dam's reservoir. The flooding may be from either controlled or uncontrolled releases or as a result of a dam failure. A series of maps for a dam could show the incremental areas flooded by larger flood releases. For breach analyses, this map should also show the time to flood arrival, and maximum water-surface elevations and flow rates.

Large dam – A dam which is above 15 m in height, measured from the lowest portion of the general foundation area to the top of dam; or a dam between 10 m to 15 m in height and that satisfies at least one of the following, namely

a) The length of crest is not less than 500 m;
b) The capacity of the reservoir formed by the dam is not less than one million cubic meters;
c) The maximum flood discharge dealt with by the dam is not less than 2000 m^3/s;
d) The dam has particularly difficult foundation problems; or e) The dam is of unusual design.

Liquefaction – A condition whereby soil undergoes continued deformation at a constant low residual stress or with low residual resistance, due to the buildup and maintenance of high pore-water pressures, which reduces the effective confining pressure to a very low value. Pore pressure buildup leading to liquefaction may be due either to static or cyclic stress applications and the possibility of its occurrence will depend on the void ratio or relative density of a cohesion less soil and the confining pressure.

Loss of life – Human fatalities that would result from a failure of the dam, without considering the mitigation of loss of life that could occur with evacuation or other emergency actions.

Low level outlet (bottom outlet) – An opening at a low level from a reservoir generally used for emptying or for scouring sediment and sometimes for irrigation releases.

Maintenance – Those tasks that are generally recurring and are necessary to keep the dam and appurtenant structures in a sound condition and free from defect or damage that could hinder the dam's functions as designed, including adjacent areas that also could affect the function and operation of the dam.

Maintenance inspection – Visual inspection of the dam and appurtenant structures by the owner or owner's representative to detect apparent signs of deterioration, other deficiencies, or any other areas of concern.

Masonry dam – Any dam constructed mainly of stone, brick, or concrete blocks pointed with mortar. A dam having only a masonry facing should not be referred to as a masonry dam.

Maximum storage capacity – The volume, in millions of cubic meters (Mm^3), of the impoundment created by the dam at the effective crest of the dam; only water that can be stored above natural ground level or that could be released by failure of the dam is considered in assessing the storage volume; the maximum storage capacity may decrease over time due to sedimentation or increase if the reservoir is dredged.

Maximum wind – The most severe wind for generating waves that is reasonably possible at a particular reservoir. The determination will generally include results of meteorological studies that combine wind velocity, duration, direction, fetch, and seasonal distribution characteristics in a realistic manner.

Meteorology – The science that deals with the atmosphere and atmospheric phenomena, the study of weather, particularly storms and the rainfall they produce.

Normal storage capacity – The volume, in millions of cubic meters (Mm^3), of the impoundment created by the dam at the lowest uncontrolled spillway crest elevation, or at the maximum elevation of the reservoir at the normal (non-flooding) operating level.

Outlet – A conduit or pipe controlled by a gate or valve, or a siphon, that is used to release impounded water from the reservoir.

Outlet gate – A gate controlling the flow of water through a reservoir outlet.

Outlet works – A dam appurtenance that provides release of water (generally controlled) from a reservoir.
Parapet wall – A solid wall built along the top of a dam (upstream or downstream edge) used for ornamentation, for safety of vehicles and pedestrians, or to prevent overtopping caused by wave run-up.

Peak flow – The maximum instantaneous discharge that occurs during a flood. It is coincident with the peak of a flood hydro-graph.

Penstock – A pressurized pipeline or shaft between the reservoir and hydraulic machinery.

Phreatic surface – The free surface of water seeping at atmospheric pressure through soil or rock.

Piezometer – An instrument used to measure water levels or pore water pressures in embankments, foundations, abutments, soil, rock, or concrete.

Piping – The progressive development of internal erosion by seepage.

Plunge pool – A natural or artificially created pool that dissipates the energy of free falling water.

Pressure relief pipes – Pipes used to relieve uplift or pore water pressure in a dam foundation or in the dam structure.

Probable Maximum Flood – The flood that may be expected from the most severe combination of critical meteorological and hydrologic conditions that are reasonably possible in the drainage basin under study.

Probable Maximum Precipitation – Theoretically, the greatest depth of precipitation for a given duration that is physically possible over a given size storm area at a particular geographical location during a certain time of the year.

Principal spillway – The primary or initial spillway engaged during a rainfall runoff event that is designed to pass normal flows.

Proposed dam – Any dam not yet under construction.

Radial gate – A gate with a curved upstream plate and radial arms hinged to piers or other supporting structure. Also known as tainter gate.

Repairs – Any work done on a dam that may affect the integrity, safety, and operation of the dam.

Reservoir – Any water spread which contains impounded water.

Reservoir Storage – The retention of water or delay of runoff in a reservoir either by planned operation, as in a reservoir, or by temporary filling in the progression of a flood wave. Specific types of storage in reservoirs are defined as follows:

a) Active storage – The volume of the reservoir that is available for some use such as power generation, irrigation, flood control, water supply, etc. The bottom elevation is the minimum operating level.
b) Dead storage – The storage that lies below the invert of the lowest outlet and that, therefore, cannot readily be withdrawn from the reservoir.
c) Flood surcharge – The storage volume between the top of the active storage and the design water level.
d) Inactive storage – The storage volume of a reservoir between the crest of the invert of the lowest outlet and the minimum operating level.
e) Live storage – The sum of the active-and the inactive storage. f) Reservoir capacity – The sum of the dead and live storage of the reservoir.
g) Surcharge – The volume or space in a reservoir between the controlled retention water level and the maximum wa-

ter level. Flood surcharge cannot be retained in the reservoir but will flow out of the reservoir until the controlled retention water level is reached.

Riprap – A layer of large rock, precast blocks, bags of cement, or other suitable material, generally placed on an embankment or along a watercourse as protection against wave action, erosion, or scour.

Risk analysis – A procedure to identify and quantify risks by establishing potential failure modes, providing numerical estimates of the likelihood of an event in a specified time period, and estimating the magnitude of the consequences. The risk analysis should include all potential events that would cause unintentional release of stored water from the reservoir.

Risk assessment – The process of deciding whether existing risks are tolerable and present risk control measures are adequate and, if not, whether alternative risk control measures are justified. Risk assessment incorporates the risk analysis and risk evaluation phases.

Rock anchor – A steel rod or cable placed in a hole drilled in rock, held in position by grout, mechanical means, or both. In principle, the same as a rock bolt, but usually the rock anchor is more than 4 meters long.

Rock bolt – A tensioned reinforcement element consisting of a steel rod, a mechanical or grouted anchorage, and a plate and nut for tensioning or for retaining tension applied by direct pull or by torqueing.

Rock reinforcement – The placement of rock bolts, un-tensioned rock dowels, pre-stressed rock anchors, or wire tendons in a rock mass to reinforce and mobilize the rock's natural competency to support itself.

Rock-fill dam – An embankment dam in which more than 50% of the total volume is comprised of compacted or dumped cobbles, boulders, rock fragments, or quarried rock generally larger than 3-inch size.

Roller compacted concrete dam – A concrete gravity dam constructed by the use of a dry mix concrete transported by conventional construction equipment and compacted by rolling, usually with vibratory rollers.

Rubble dam – A stone masonry dam in which the stones are not shaped or coursed.

Saddle dam (or dike) – A subsidiary dam of any type constructed across a saddle or low point on the perimeter of a reservoir.

Safe manner – Operating and maintaining a dam in sound condition, free from defect or damage that could hinder the dam's functions as designed.

Scour – The loss of material occurring at an erosional surface, where a concentrated flow is located, such as a crack through a dam or the dam/foundation contact. Continued flow causes the erosion to progress, creating a larger and larger eroded area.

Seepage – The internal movement of water that may take place through a dam, the foundation or the abutments, often emerging at ground level lower down the slope.

Seiche – An oscillating wave in a reservoir caused by a landslide into the reservoir or earthquake-induced ground accelerations or fault offset or meteorological event.

Settlement – The vertical downward movement of a structure or its foundation.

Sinkhole – A depression, indicating subsurface settlement or particle movement, typically having clearly defined boundaries with a sharp offset.

Significant wave height – Average height of the one-third highest individual waves. May be estimated from wind speed, fetch length, and wind duration

Siphon – An inverted U-shaped pipe or conduit, filled until atmospheric pressure is sufficient to force water from a reservoir over an embankment dam and out of the other end.

Slide – Movement of a mass of earth down a slope on the embankment or abutment of a dam.

Slide gate – A gate that can be opened or closed by sliding in supporting guides.

Spillway – A structure over or through which flow is discharged from a reservoir. If the rate of flow is controlled by mechanical means, such as gates, it is considered a controlled spillway. If the geometry of the spillway is the only control, it is considered an uncontrolled spillway.

Stilling basin – A basin constructed to dissipate the energy of rapidly flowing water, e.g., from a spillway or outlet, and to protect the riverbed from erosion.

Stillwater level – The elevation that a water surface would assume if all wave actions were absent.

Stop logs – Large logs, timbers, or steel beams placed on top of each other with their ends held in guides on each side of a channel or conduit so as to provide a cheaper or more easily handled means of temporary closure than a bulkhead gate.

Toe drain – A system of pipe and/or pervious material along the downstream toe of a dam used to collect seepage from the foundation and embankment and convey it to a free outlet.

Toe of dam – The junction of the downstream slope or face of a dam with the ground surface; also referred to as the downstream toe. The junction of the upstream slope with ground surface is called the heel or the upstream toe.

Top thickness (top width) – The thickness or width of a dam at the level of the top of dam (excluding corbels or parapets). In general, the term thickness is used for gravity and arch dams, and width is used for other dams.

Trash rack – A device located at an intake to prevent floating or submerged debris from entering the intake.

Uplift – The hydrostatic force of water exerted on or underneath a structure, tending to cause a displacement of the structure.

Vicinity map – A map that shows the location of the dam and surrounding roads that provide access to the dam. This map should display the location of the dam in relation to major roads and streets, and should include a north arrow and scale bar.

Volume of dam – The total space occupied by the materials forming the dam structure computed between abutments and from top to bottom of dam. No deduction is made for small openings such as galleries, Adits, tunnels, and operating chambers within the dam structure. Portions of power plants, locks, spillway, etc., are included only if they are needed for structural stability of the dam.

Watershed – The area drained by a river or river system or portion thereof. The watershed for a dam is the drainage area upstream of the dam.

Watershed divide – The divide or boundary between catchment areas (or drainage areas).

Wave protection – Riprap, concrete, or other armoring on the upstream face of an embankment dam to protect against scouring or erosion due to wave action.

Wave run-up – Vertical height above the Stillwater level to which water from a specific wave will run up the face of a structure or embankment.

Weir – A barrier across a stream designed to alter its flow characteristics. In most cases, weirs take the form of obstructions smaller than conventional dams, pooling water behind them while also allowing it to flow steadily over their tops.

Weir, broad-crested – An overflow structure on which the nappe is supported for an appreciable length in the direction of flow.

Weir, measuring – A device for measuring the rate of flow of water. It generally consists of a rectangular, trapezoidal, triangular, or other shaped notch, located in a vertical, thin plate over which water flows. The height of water above the weir crest is used to determine the rate of flow.

Weir, ogee – A reverse curve, shaped like an elongated letter "S.” The downstream faces of overflow spillways are often made to this shape.

Wind setup – The vertical rise in the still-water level at the face of a structure or embankment caused by wind stresses on the surface of the water.

Appendix. B
List of Acronyms

AAR	After Action Report
CDSO	Central Dam Safety Organization
CWC	Central Water Commission
DDMA	District Disaster Management Authority
DOE	Directorate of Energy
DRIP	Dam Rehabilitation and Improvement Project
DTM	Digital Terrain Model
EAP	Emergency Action Plan
HOH	Head of Hydro
HOP	Head of Plant
SDMA	State Disaster Management Authority
LIDAR	Light Detection and Ranging
PAR	Population at Risk
SDSO	State Dam Safety Organization
ECC	Emergency Control Centre

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Hypothetical Dam Breach Sensitivity Analysis for Karcham Dam(H.P.)

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Irrigation Research Institute
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SYNOPSIS

The post failure study of dams is generally required to assess the flood magnitudes and its behaviour in the downstream river portion so that a preparatory plan can be made to safeguard the lives and properties on the flood plains of the river downstream of the dam. With this aim, a hypothetical Dam Breach Sensitivity Analysis for Karcham Dam was referred by M/S Jai Prakash Industries Ltd., New Delhi. The study has been carried out with the help of **MIKE-11** software, developed by the Danish Hydraulic Institute, Denmark. Various combinations of Breach Widths and Breach Development Times have been considered in the study and results are presented in the report. The results indicate that instantaneous failure of the dam is worst failure case and the effect of change of breach width is more significant than the breach development time.

Key Words: Dam Break, Breach Width, Breach Time	
Subject : Dam Break Modelling	
Project: Karcham Wangtoo Hydro-electric Project	

Research Officer
Basic Research Division

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1.0 INTRODUCTION

Many large dams have been built in India to cater to the irrigation, hydropower and flood control needs of the country and many more are under construction and planning/investigation stages. Assured water resource facility and flood protection provided by the dam has led to various developmental activities in the downstream of the dam. The floods and droughts are the two sides of a coin which can not be checked fully but managed to a certain extent, so that loss of human lives and properties can be brought down to the minimum. When a dam fails, very high floods are generated in comparison to that when the dam had not been there. Therefore it can be said that the dam break floods are more man-made than the natural event and in the event of dam failure, the disaster would be catastrophic. Therefore, it is the responsibility of the organisations involved for the safety of dams to plan preventive measures so that the disaster would be minimum in the event of failure of dam.

One of the preventive measures in dam failure disaster is by issuing flood warning to the public of downstream when there is a failure of dam. It is quite difficult to analyse dam failure and determine the warning time at the time of disaster. Therefore, predetermination of the warning time assuming various hypothetical dam break situations is a needed exercise in dam safety measures.

Generally the study of dam failure using the mathematical models pose various problems to simulate actual failure of the dam and suitable assumptions are made to suit the model. A dam break study consists of the following components.

- Modelling of River Setup and Structures.
- Identification of Inflow hydrograph for the reservoir at the time of failure.
- Development of failure conditions of the Dam such as Overtopping, Breaching incorporating Breach width and Breach time etc.
- Obtaining Outflow hydrograph through the Breach Section.
- Propagation of Flood wave downstream to determine Maximum Discharge, Water Levels and Travel Time etc.

Generally, when a dam fails by overtopping due to severe storm with high inflow into the reservoir, at that time, either the flow measurements are not made or the gauging sites are washed away resulting in no information. Therefore, in many cases, the only available information is the maximum water level marks at the time of passing of the flood wave. Time of breach development is also a major component in deciding the dam break flood hydrograph but generally an approximate value is available.

2.0 OBJECTIVE OF THE STUDY

There are number of villages and bridges in the downstream of proposed Karcham Dam on the banks of river Satluj, which may be affected by the floods generated by the failure of the Karcham Dam. Therefore a hypothetical dam breach sensitivity analysis for Karcham Dam has been carried out to study the effect of dam breach in the event of failure of Karcham Dam. The flood propagation has been simulated in the downstream at various locations where the cross sections are available.

3.0 KARCHAM DAM AND STUDY AREA

1000 MW Karcham-Wangtoo Hydroelectric Project with 98.0 m high concrete dam is proposed to be constructed across river Satluj near village Karcham in Himachal Pradesh. The index map is shown in Fig.1. The prominent villages, downstream of the dam, on the left bank of the river Satluj are *Baltrang* at Ch. 0.40 km, *Kilba* at Ch. 3.80 km and *Sholtu* at Ch. 8.00 km. The villages on the right bank of river Satluj include *Choling* at Ch. 4.30 km and *Tapri* at Ch. 8.50 km. The ropeway Bridge at Sholtu Colony at Ch. 8.365 km(Photograph-1), 120.0 m Shatrujit Bridge at Ch.18.317 km(Photograph-2) and 132.0 m Wangtoo Bridge at Ch.18.677 km(Photograph-3) also cross the river Satluj in the downstream of the dam. 177.80 m long Karcham Dam consists of a concrete section with top of the dam at an elevation 1813.0 m. The maximum height of the dam above the deepest foundation level is 98.0 m. Six sluices (9.0mX9.0m) have been proposed in the central portion of the dam to spill the flood discharge. River valley cross section, hypothetically assumed breach section and typical non-overflow section and sluices are shown in Fig. 2.

3.1 Salient features

3.1.1 Location

i.	State	Himachal Pradesh
ii.	River	Satluj
iii.	Vicinity	Dam near village Karcham and Power House near village Wangtoo on NH-22 about 186 km from Shimla.

3.1.2 Diversion Dam

i.	Type	Concrete Gravity

ii.	Top of Dam	EL 1813.00 m
iii.	Height from deepest foundation level	98.00 m
iv.	Total length of Dam	177.80 m
v.	Total No. of Blocks	12
vi.	Deepest foundation Level	EL 1715.00 m
vii.	Maximum Reservoir Level	EL 1810.00 m
viii.	Minimum Reservoir Level	EL 1799.00 m
ix.	Live Storage capacity	544.97 Ha-m

3.1.3 Main Spillway (Sluices)

i.	Location	Block Nos. 5 to 10 of Dam
ii.	Number of Bays	6
iii.	Size of Each Sluice	9.0m X 9.0m
iv.	Crest Level	1782.00 m
v.	Maximum Reservoir Level	EL 1808.00 m
vi.	Discharge Capacity of Sluices	8260 cumec

3.1.4 Auxiliary Spillway

i.	Location	Block No. 3 of Dam
ii.	Number of Bays	1
iii.	Width of Each Bay	8.0m
iv.	Crest Level	1803.00 m
v.	Maximum Discharge Capacity	549 cumec

4.0 DAM BREAK SIMULATIONS

A Concrete dam is expected to fail in blocks between two transverse joints and can fail partially between blocks, or completely and almost instantaneously or in a time dependent manner. The type of failure for a concrete dam has been considered linear depending on the development of breach size, shape and breach time. In the present study, since Karcham Dam is a concrete dam, a rectangular breach width, has been assumed to carry out the analysis. The distance between contraction joints has been specified as 15.0 m by the sponsors, M/S Jai Prakash Ltd., New Delhi and therefore rectangular breach width has been considered as 15.0 m, 30.0 m, 45.0 m and 60.0 m. The breach depth has been taken as 31 m i.e. upto the bottom of the sluice level, which is only 12.0 m above the river bed level, as suggested by the sponsors. The breach development time of 1.00 hr, 0.50 hr, 0.25 hr and 0.01 hr have been considered in the study. Instantaneous failure case (i.e. Breach Development Time = 0.01 hr) has been considered in the study because it is the most critical failure, which may happen in case of Concrete Dams. The various dam breach parameters considered in the study are shown in Table 1.

Table 1 - Breach Parameters

Sl. No.	Rectangular Breach, m		Breach Time,hr	Remark
	Width	Depth		
1.	15.0	31.00	1.00	
2.	15.0	31.00	0.50	
3.	15.0	31.00	0.25	
4.	15.0	31.00	0.01	Instantaneous Failure
5.	30.0	31.00	1.00	
6.	30.0	31.00	0.50	
7.	30.0	31.00	0.25	
8.	30.0	31.00	0.01	Instantaneous Failure
9.	45.0	31.00	1.00	
10.	45.0	31.00	0.50	
11.	45.0	31.00	0.25	
12.	45.0	31.00	0.01	Instantaneous Failure
13.	60.0	31.00	1.00	
14.	60.0	31.00	0.50	
15.	60.0	31.00	0.25	
16.	60.0	31.00	0.01	Instantaneous Failure

5.0 MATHEMATICAL MODELLING FOR DAM BREAK STUDY

Development of Personal Computers marked a revolutionary step in the mathematical modelling techniques. **MIKE-11** is a personal computer based powerful menu driven software package developed by the Danish Hydraulic Institute, Denmark. MIKE-11 consists of basic module and a series of additional modules which can be used for flood forecasting, reservoir operation etc. Hydrodynamic module of MIKE-11 has been used for the dam break simulation study of Karcham Dam.

5.1 Hydrodynamic Module

MIKE-11 is a one dimensional unsteady flow modelling package capable of modelling unsteady flows in open channel systems through a numerical solution of the one dimensional St. Venant Equation. Dam break is one particular case of the general flow conditions. The module provides a choice between the following three different flow descriptions :

- Kinematic Wave Approach - The flow is calculated from the assumptions of balance between the friction and gravity forces. This simplification implies that the kinematic wave approach can not simulate backwater effects.

- Diffusive Wave Approach - In addition to the friction and gravity forces, the hydrostatic gradient is included in this description. This allows the user to take downstream boundaries into account and thus simulate backwater effects.

- Dynamic Wave Approach - Using the full momentum equation, including acceleration force, the user is able to simulate fast transients, tidal flows etc. in the system.

The Dynamic Wave Approach has been used in the present study.

MIKE-11 uses the following two basic flow equations associated with the hydraulic resistance.

5.1.1 Continuity Equation

$$\frac{\partial Q}{\partial x} + \frac{\partial A}{\partial t} = q \qquad \ldots (1)$$

5.1.2 Momentum Equation

$$\frac{\partial Q}{\partial t} + \frac{\partial}{\partial x}\left[\propto \frac{Q^2}{A}\right] + gA\frac{\partial h}{\partial x} + \frac{gQ|Q|}{C^2AR^*} = 0 \ldots (2)$$

Where

A = Flow area (m^2)
C = Chezy's resistance coefficient ($m^{½}s^{-1}$)
g = acceleration due to gravity (ms^{-2})
h = Stage above horizontal reference level (m)
Q = discharge (Cumec)
R^* = Hydraulic radius(m)
$\propto$ = Momentum distribution coefficient
q = Lateral inflow (Cumec)

5.1.3. Solution Technique

The transformation of Eqs. 1 and 2 to a set of implicit finite difference equations is performed in a computational grid consisting of alternate Q and h-points i.e. points where the discharge Q and water level h, respectively, are computed at each time step(Fig.3). Q-points are always placed midway between neighbouring h-points, while the distance between h-points may differ. The discharge, as a rule, is defined as positive in the positive x-direction (increasing chainage). The solution technique adopted in MIKE-11 is a 6 point Abbott-Scheme as shown in Fig.4).

6.0 DIGITAL MODEL

The model set up needs to describe the complete river system, consisting of a single or several Channels, Dam Structure, Auxiliary Dam Structures like Spillway etc. Further the downstream river portion may have Dams, Barrages, Bridges etc. Due to highly unsteady nature of the dam break flood propagation, it is necessary that the river course be described through the use of as many cross-sections precisely as necessary, particularly where the cross sections varies rapidly.

6.1 Digital River Model Setup

The river model setup(Fig. 5) for the dam breach study consists of the following three branches :

6.1.1 DAM Branch

The DAM branch is arbitrarily taken as 0.20 km long. The dam branch is represented by two **h-points**, one at ch 0.0 km, where the reservoir surface area is described in the cross-section data base(Fig.7) and second at ch 0.20 km, which is the junction point of SATLUJ branch. The Dam structure at an intermediate chainage 0.15 km has been defined as Q point.

6.1.2 SPILLWAY Branch

The SPILLWAY branch simulates the flow through the Spillway. The length of this branch is also kept same as Dam Branch. Two cross-sections at ch. 0.0 km and ch. 0.20 km were described to make two **h-points** so that spillway structure can be introduced at an intermediate ch. 0.16 km as *Q-point.* The upstream h-point was connected to the h-point of upstream dam branch and downstream h-point to ch 0.20 km of SATLUJ branch.

6.1.3 SATLUJ Branch

SATLUJ Branch in the setup is 21.80 km long and runs from ch. 0.20 km to 22.00 km i.e. upto Nathpa Dam. The length of the SATLUJ branch has been represented by twenty three cross-sections.

The longitudinal profile of Satluj river, Surface Area Elevation Curve for Reservoir are shown in Fig. 6 and 7 respectively. Twenty three cross-sections at different chainages along the downstream of river Satluj are shown in Fig. 8.

6.2 Control Structures

The control structures such as Dam and Spillway etc. are also located with the river name and chainages. In the present study, Karcham Dam and Spillway are the control structures defined in the setup.

6.2.1 Karcham Dam

Dam Break Structure was located in DAM Branch at ch. 0.15 km in the mathematical model. The crest level was kept equal to the top of the breaching section i.e. 1813.0 m and length of dam as 177.80 m. The other details of breaching such as breach width, breach development time were varied as listed in Table 1.

6.2.2 Spillway

The Spillway structure was located at ch.0.16 km in the SPILLWAY branch in the digital model set-up. The hydraulic characteristics of spillway described in salient features were entered along with the spillway rating curve, (Fig.9) as input in the special weir. Auxiliary Spillway has not been considered in the modelling.

6.3 Boundary Conditions

For the dam break simulation MIKE-11 needs boundary conditions to be specified at the first upstream h-point and at the farthest down stream cross-section of the river valley. Apart from these, Dams, Spillways, Weirs etc. form the internal boundary conditions because they help in modifying the flow condition in the branch.

6.3.1 Upstream Boundary Condition

Upstream boundary is generally specified as time dependent inflow in the reservoir. In the present study, an inflow into the reservoir at ch. 0.01 Km. in the dam branch has been specified in the form of design flood hydrograph supplied by the Jai Prakash Industries Ltd. as shown in Fig. 10.

6.3.2 Downstream Boundary Condition

The Downstream Boundary Condition should be generally independent of any changes within the model. MIKE-11 can accept varying water level boundary or a time dependent discharge or a Q-H relation. In the present study, Q-H relationship has been used as a downstream boundary condition. The Q-H relation at the d/s boundary was developed using Manning's equation with the help of cross section area, hydraulic radius for different levels from the processed data at ch. 22.0 Km. for n=0.07 and average slope of river as 1/73 (Fig.11).

6.4 Supplementary Data

6.4.1 Initial Conditions

Initial conditions in the form of water level and corresponding discharge at the start time of computation, calculated from cross-sections using Manning's equation were specified at various locations along the river.

6.4.2 Resistance Numbers

There was no direct information available on the roughness characteristics of the study reach. River bed conditions, as seen from the Photograph-4 and the comparison of river bed conditions with the conditions proposed by Chow[1], the resistance number value of 14.3 (n=0.07) was adopted for the entire length of the river, as suggested by the sponsors.

7.0 EXECUTION OF MODEL

The dam breach flood propagation modelling in the Satluj river in the event of Karcham dam failure requires the river setup to represent the actual physical initial hydraulic conditions prevalent at the moment of breach of dam.

7.1 Steady State Condition

In some cases, a dam failure may occur on a dry river bed downstream of the dam. However, such initial conditions are not executable in MIKE-11, which requires a finite depth of water to be present throughout the entire model to ensure connectivity of finite difference algorithm. Hence, before a dam break is actually simulated, it is necessary to create a steady state Hot Start file which can be used for subsequent dam break simulations.

As per the guidelines outlined in the Dam Break Modelling Manual[2], initial conditions (i) zero inflow into the reservoir (ii) a constant inflow of 3000 cumec (iii) the failure mode by overtopping was specified to create a hotstart file.

7.2 Full Reservoir Condition

Using the hotstart file, design flood hydrograph (Fig. 10) was introduced at chainage 0.01 Km. (i.e. u/s boundary of river setup) and the model was again run for a sufficient long time with the failure mode as overtopping. From the results, it was observed that the water levels first decreased and then started building up and reached a maximum value of 1798.33 m at 0 hr 23 min. on an arbitrary date say 30.7.2000 and the dam did not fail. From the above result file, a short file using the same set up and boundary conditions was made by running the model for a short simulation time of 4 hrs starting from 0 hrs on 30.7.2000 to be used for dam break simulation studies, thereby saving time.

7.3 Dam Breach Cases

The Karcham Dam failure was specified as 0 hr.23 min on 30.7.2000 in each case to coincide with the reservoir attaining maximum water level under FRL condition. The linear failure mode, applicable to concrete dam failures was specified, to study the worst case. The sensitivity analysis for dam breach parameters, specified in Table-1 was carried out to study the effect on dam breach flood and behaviour of flood wave during its travel downstream. The Flood hydrographs and Water Levels for Breach Widths of 15.0m, 30.0m, 45.0m and 60.0m for Breach Time of 1.00 hr, 0.50 hr, 0.25 hr and 0.01 hr are shown in Figs. 12 to 15 respectively. The maximum discharge at various locations along with the travel time after breach for 15.0m, 30.0m, 45.0m and 60.0m Breach Widths for different Breach Times are shown in Tables 2, 4,6 and 8 respectively. The maximum water levels attained at various locations along with the travel time after breach for 15.0m, 30.0m, 45.0m and 60.0m Breach Widths for different Breach Times are also shown in Tables 3, 5,7 and 9 respectively.

8.0 SENSITIVITY ANALYSIS

The effect of breach width and breach development time on maximum discharge and maximum water level of the dam break module on the simulated flood results was studied considering the linear failure mode. The various parameters considered in the study are as :

Crest Level	-	1813.00 m
Crest Length	-	177.80 m
Resistance Number	-	14.30
Roughness Co-efficient	-	0.07
Start Breach Level	-	1813.00 m
Final Breach Level	-	1782.00 m
Shape of Breach	-	Rectangular
Breach Width	-	15.0, 30.0, 45.0 and 60.0 m
Breach Development Time	-	1.00, 0.50, 0.25 and 0.01 hr
Hypothetical Failure Moment	-	30-7-2000 **0:23 hrs**

8.1 Effect of Breach Development Time

8.1.1 15.0 m Breach Width

Four simulations by varying breach development time to 1.00 hr, 0.50 hr, 0.25 hr and 0.01 hr were carried out for rectangular breach width 15.0 m and depth 31.0 m. The Maximum Discharge and Maximum Water Level at various locations along with the travel time for different Breach Times are shown in Tables 2 and 3 respectively. The variation of Maximum Discharge for different Breach Times and rise in Maximum Water Level w.r.t. 1.00 hr Breach Time are shown in Figs. 16 and 24 respectively.

From Fig. 16, it has been inferred that the maximum discharge increases nearly 4.3 % at the dam site and 1.3 % near the downstream boundary with the decrease in breach development time from 1.00 hr to 0.50 hr. However, when the breach time is further reduced the increase is not phenomenal in the downstream of the river.

Perusal of Fig. 24 indicates that the rise in maximum water level near the dam site is 0.30 m w.r.t. 1.00 breach time, when the breach time is decreased from 1.00 hr to 0.50 hr and the rise in maximum water level is about 0.10 m from ch. 4.00 to 22.00 km. It is also observed that when the breach time is reduced further to 0.25 hr, the rise in maximum water level near the dam site is 0.12 m w.r.t. 0.50 hr breach time and 0.03 m from ch. 4.00 to 22.00 km in the downstream of the river.

8.1.2 30.0 m Breach Width

Four simulations by varying breach development time to 1.00 hr, 0.50 hr, 0.25 hr and 0.01 hr were carried out for rectangular breach width 30.0 m and depth 31.0 m. The Maximum Discharge and Maximum Water Level at various locations along with the travel time for different Breach Times are shown in Tables 4 and 5 respectively. The variation of Maximum Discharge for different Breach Times and rise in Maximum Water Level w.r.t. 1.00 hr Breach Time are shown in Figs. 17 and 25 receptively.

From Fig. 17, it has been inferred that the maximum discharge increases sharply (nearly 8.5 %) at the dam site and 1.95 % near the downstream boundary with the decrease in breach development time from 1.00 hr to 0.50 hr. However, when the breach time is further reduced the increase is not phenomenal in the downstream of the river.

Perusal of Fig. 25 indicates that the rise in maximum water level near the dam site is 0.58 m w.r.t. 1.00 breach time, when the breach time is decreased from 1.00 hr to 0.50 hr and the rise in maximum water level is about 0.16 m from ch. 5.00 to 22.00 km. It is also observed that when the breach time is reduced further to 0.25 hr, the rise in maximum water level near the dam site is 0.40 m w.r.t. 0.50 hr breach time and 0.07 m from ch. 5.00 to 22.00 km in the downstream of the river.

8.1.3 45.0 m Breach Width

Four simulations by varying breach development time to 1.00 hr, 0.50 hr, 0.25 hr and 0.01 hr were carried out for rectangular breach width 45.0 m and depth 31.0 m. The Maximum Discharge and Maximum Water Level at various locations along with the travel time for different Breach Times are shown in Tables 6 and 7 respectively. The variation of Maximum Discharge for different Breach Times and rise in Maximum Water Level w.r.t. 1.00 hr Breach Time are shown in Figs. 18 and 26 respectively.

From Fig. 18, it has been inferred that the maximum discharge increases sharply (nearly 12.75 %) at the dam site and 2.45 % near the downstream boundary with the decrease in breach development time from 1.00 hr to 0.50 hr. However, when the breach time is further reduced the increase is not phenomenal in the downstream of the river.

Perusal of Fig. 26 indicates that the rise in maximum water level near the dam site is 0.87 m w.r.t. 1.00 breach time, when the breach time is decreased from 1.00 hr to 0.50 hr and the rise in maximum water level varies from 0.28 m to 0.20 m in the downstream from ch. 4.00 to 22.00 km. It is also observed that when the breach time is reduced further to 0.25 hr, the rise in maximum water level near the dam site is 0.52 m w.r.t. 0.50 hr breach time and 0.10 m from ch. 4.00 to 22.00 km in the downstream of the river.

8.1.4 60.0 m Breach Width

Four simulations by varying breach development time to 1.00 hr, 0.50 hr, 0.25 hr and 0.01 hr were carried out for rectangular breach width 60.0 m and depth 31.0 m. The Maximum Discharge and Maximum Water Level at various locations along with the travel time for different Breach Times are shown in Tables 8 and 9 respectively. The variation of Maximum Discharge for different Breach Times and rise in Maximum Water Level w.r.t. 1.00 hr Breach Time are shown in Figs. 19 and 27 respectively.

From Fig. 19, it has been inferred that the maximum discharge increases nearly 16.85 % at the dam site and 2.9 % near the downstream boundary with the decrease in breach development time from 1.00 hr to 0.50 hr. When the breach time is further reduced from 0.50 hr to 0.25 hr, the maximum increase in discharge at the dam site is 12.95 % and 0.9 % at the downstream boundary.

Perusal of Fig. 27 indicates that the rise in maximum water level near the dam site is 1.17 m w.r.t. 1.00 breach time, when the breach time is decreased from 1.00 hr to 0.50 hr and the rise in maximum water level varies from 0.36 m to 0.26 m in the downstream from ch. 4.00 to 22.00 km. It is also observed that when the breach time is reduced further to 0.25 hr, the rise in maximum water level near the dam site is 0.68 m w.r.t. 0.50 hr breach time and 0.10 m from ch. 11.00 to 22.00 km in the downstream of the river.

8.2 Effect of Breach Width

8.2.1 1.00 Hour Breach Development Time

Four simulations by varying breach width to 15.0 m, 30.0 m, 45.0 m and 60.0 m were carried out for breach development time of 1.00 hour. The variation of Maximum Discharge for different Breach Widths and rise in Maximum Water Level w.r.t. 15.0 m Breach Width are shown in Figs. 20 and 28 respectively.

From Fig. 20, it has been inferred that the maximum discharge increases nearly 5.3 % at the dam site and 3.7 % near the downstream boundary with the increase in breach width from 15.0 m to 30.0 m. When the breach width is increased from 30.0 to 45.0 m, the increase in maximum discharge at the dam site is 2.70 %.

Perusal of Fig. 28 indicates that the rise in maximum water level near the dam site is 0.49 m w.r.t. 15.0 m breach width, when the breach width is increased from 15.0 m to 30.0 m and the rise in maximum water level is about 0.20 m from ch. 4.00 to 22.00 km. It is also observed that when the breach width is further increased to 45.0 m, the rise in maximum water level near the dam site is 0.28 m w.r.t. 30.0 m breach width and 0.15 m from ch. 4.00 to 22.00 km in the downstream of the river.

8.2.2 0.50 Hour Breach Development Time

Four simulations by varying breach width to 15.0 m, 30.0 m, 45.0 m and 60.0 m were carried out for breach development time of 0.50 hour. The variation of Maximum Discharge for different Breach Widths and rise in Maximum Water Level w.r.t. 15.0 m Breach Width are shown in Figs. 21 and 29 respectively.

From Fig. 21, it has been inferred that the maximum discharge increases nearly 9.7 % at the dam site and 4.3 % near the downstream boundary with the increase in breach width from 15.0 m to 30.0 m. When the breach width is increased from 30.0 to 45.0 m, the increase in maximum discharge at the dam site is 6.5 %.

Perusal of Fig. 29 indicates that the rise in maximum water level near the dam site is 0.78 m w.r.t. 15.0 m breach width, when the breach width is increased from 15.0 m to 30.0 m and the rise in maximum water level is about 0.30 m from ch. 4.00 to 22.00 km. It is also observed that when the breach width is further increased to 45.0 m, the rise in maximum water level near the dam site is 0.56 m w.r.t. 30.0 m breach width and 0.20 m from ch. 4.00 to 22.00 km in the downstream of the river.

8.2.3 0.25 Hour Breach Development Time

Four simulations by varying breach width to 15.0 m, 30.0 m, 45.0 m and 60.0 m were carried out for breach development time of 0.25 hour. The variation of Maximum Discharge for different Breach Widths and rise in Maximum Water Level w.r.t. 15.0 m Breach Width are shown in Figs. 22 and 30 respectively.

From Fig. 22, it has been inferred that the maximum discharge increases nearly 12.9 % at the dam site and 4.5 % near the downstream boundary with the increase in breach width from 15.0 m to 30.0 m. When the breach width is increased from 30.0 to 45.0 m, the increase in maximum discharge at the dam site is 10.5 %.

Perusal of Fig. 30 indicates that the rise in maximum water level near the dam site is 0.96 m w.r.t. 15.0 m breach width, when the breach width is increased from 15.0 m to 30.0 m and the rise in maximum water level is about 0.30 m from ch. 17.00 to 22.00 km. It is also observed that when the breach width is further increased to 45.0 m, the rise in maximum water level near the dam site is 0.78 m w.r.t. 30.0 m breach width and 0.20 m from ch. 17.00 to 22.00 km in the downstream of the river.

8.2.4 0.01 Hour Breach Development Time

Four simulations by varying breach width to 15.0 m, 30.0 m, 45.0 m and 60.0 m were carried out for breach development time of 0.01 hour. The variation of Maximum Discharge for different Breach Widths and rise in Maximum Water Level w.r.t. 15.0 m Breach Width are shown in Figs. 23 and 31 respectively.

From Fig. 23, it has been inferred that the maximum discharge increases nearly 14.0 % at the dam site and 4.6 % near the downstream boundary with the increase in breach width from 15.0 m to 30.0 m. When the breach width is increased from 30.0 to 45.0 m, the increase in maximum discharge at the dam site is 13.7 %.

Perusal of Fig. 31 indicates that the rise in maximum water level near the dam site is 0.90 m w.r.t. 15.0 m breach width, when the breach width is increased from 15.0 m to 30.0 m and the rise in maximum water level is about 0.31 m from ch. 17.00 to 22.00 km.

It is also observed that when the breach width is further increased to 45.0 m, the rise in maximum water level near the dam site is 1.07 m w.r.t. 30.0 m breach width and 0.20 m from ch. 17.00 to 22.00 km in the downstream of the river.

9.0 CONCLUSION

In the present study, a hypothetical case of failure of the Karcham Dam, proposed to be constructed on the river Satluj in Himachal Pradesh was studied. In the digital model, 22.0 km long river reach from the proposed Karcham Dam, upto Nathpa Dam was simulated with the help of three branches and twenty three cross-sections. The Dam and the Spillway were located on a separate branch. The upstream boundary was taken as time varying discharge in the form of inflow into the reservoir, whereas d/s boundary was taken as a Q-H relation at ch. 22.00 km. The spillway was described in the model by specifying discharge and water level relationship.

Total 16 Dam Breach Simulations were carried out by considering linear failure mode by varying the various breach parameters within the probable domain. The parameters considered were breach width and breach development time. The instantaneous failure of the dam which is a special case of the linear failure with a breach development time of 0.01 hr was also studied.

The following conclusions can be drawn from the above study :

- Based on the hypothetical dam break simulations, Figs. 12 to 31 and Tables 2 to 9 provide the necessary information for working out a disaster management plan.

- The instantaneous failure of the dam is the worst failure case. The maximum discharge from the dam is of the order of 11467 cumec, when rectangular breach width is 60.0 m, breach depth 31.0 m and breach development time 0.01 hour. Out of 11467 cumec, 5134 cumec will pass through breach section and balance 6333 cumec through Spillway.

- The three bridges at Ch. 8.365, 18.317 and 18.677 km in the downstream of river Satluj will not be submerged during the worst case of failure adopted in the study (i.e. breach width=60.0 m, breach depth=31.0 m, breach development time =0.01 hour). The maximum water levels at these locations do not cross the deck level of bridges.

- It is observed that the NH-22 road on the right bank of the river Satluj at Ch. 7.00 km will have a water depth of about 1.00 - 1.60 m during all the dam breach simulations for few hours.

- It can be clearly seen that the effect of change in the breach width is more significant than the breach development time. Both maximum discharge and maximum water levels increase with the increase in breach width and the peaks are attained earlier.

- With the increase in breach development time both maximum discharge, maximum water level decreases and the peak is also delayed. But the effect is not so significant in comparison to the change in breach width except in case of instantaneous failure of the dam.

10.0 ACKNOWLEDGEMENT

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11.0 REFERENCES

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2. ————(1992) *Lecture Notes on Dam Break Modelling*, Course organised by Central Water Commission, New Delhi at Irrigation Design Organisation, Roorkee, Jan. 20 - Feb. 1.

PHOTOGRAPHS

Photograph 1 - Ropeway Bridge at Sholtu Colony at Ch. 8.365 km

Photograph 2- 120.0 m Shatrujit Bridge at Ch. 18.317 km

Photograph 3- 132.0 m Wangtoo Bridge at Ch. 18.677 km

Photograph 4 - Gravel Material along the Left Bank of river Satluj

TABLES

Table 2 - Maximum Discharge at Different Locations for Breach Width = 15.0 m

Chainage km	Maximum Discharge, cumec / *Travel Time after Breach, hour-min*				
	Breach Time, Hour				
	1.00	**0.50**	**0.25**	**0.01**	
0.15	1122 / 1-0'	1209 / 0.30'	1268 / 0.15'	1325 / 0.0'	DAM BREACH
0.16	5933 / 1-0'	6151 / 0.30'	6293 / 0.15'	6429 / 0.01'	SPILLWAY
0.60	7033 / 1.01'	7308 / 0.31'	7478 / 0.16'	7624 / 0.03'	
1.50	7007 / 1.01'	7232 / 0.32'	7333 / 0.18'	7380 / 0.05'	
2.50	6983 / 1.03'	7170 / 0.34'	7244 / 0.20'	7276 / 0.08'	
3.50	6966 / 1.04'	7137 / 0.36'	7203 / 0.23'	7231 / 0.10'	
4.50	6938 / 1.06'	7083 / 0.38'	7137 / 0.25'	7158 / 0.13'	
5.50	6926 / 1.08'	7065 / 0.40'	7115 / 0.27'	7134 / 0.15'	
6.50	6922 / 1.09'	7059 / 0.42'	7108 / 0.29'	7127 / 0.17'	
7.50	6913 / 1.10'	7045 / 0.43'	7091 / 0.30'	7110 / 0.19'	
8.50	6909 / 1.12'	7038 / 0.45'	7084 / 0.33'	7103 / 0.20'	
9.50	6900 / 1.13'	7024 / 0.47'	7068 / 0.34'	7085 / 0.22'	
10.50	6895 / 1.15'	7016 / 0.48'	7058 / 0.35'	7075 / 0.23'	
11.50	6889 / 1.16'	7007 / 0.50'	7048 / 0.37'	7064 / 0.25'	
12.50	6884 / 1.18'	6998 / 0.51'	7037 / 0.38'	7054 / 0.27'	
13.50	6880 / 1.19'	6991 / 0.52'	7030 / 0.40'	7046 / 0.28'	
14.50	6875 / 1.20'	6985 / 0.54'	7022 / 0.41'	7038 / 0.30'	
15.50	6869 / 1.22'	6976 / 0.56'	7012 / 0.43'	7026 / 0.31'	
16.50	6865 / 1.23'	6969 / 0.57'	7005 / 0.45'	7019 / 0.33'	
17.50	6862 / 1.25'	6964 / 0.58'	6999 / 0.46'	7013 / 0.34'	
18.50	6858 / 1.26'	6959 / 1-0'	6993 / 0.47'	7007 / 0.36'	
19.50	6852 / 1.28'	6950 / 1-02'	6982 / 0.49'	6996 / 0.38'	
20.50	6846 / 1.29'	6941 / 1-04'	6972 / 0.51'	6984 / 0.39'	
21.50	6835 / 1.32'	6924 / 1-05'	6954 / 0.54"	6965 / 0.42'	

Table 3 - Maximum Water Level at Different Locations for Breach Width = 15.0 m

Chainage km	Maximum Water Level, m / *Travel Time after Breach, hour-min*			
	Breach Time, Hour			
	1.00	**0.50**	**0.25**	**0.01**
0.20	1788.54 / 1-0'	1788.84 / 0-31'	1788.96 / 0-16'	1789.00 / 0-03'
1.00	1784.91 / 1-01'	1785.14 / 0-32'	1785.23 / 0-18'	1785.26 / 0-07'
2.00	1778.99 / 1-02'	1779.18 / 0-34'	1779.25 / 0-20'	1779.28 / 0-08'
3.00	1772.58 / 1-04'	1772.72 / 0-36'	1772.77 / 0-22'	1772.79 / 0-10'
4.00	1767.20 / 1-06'	1767.30 / 0-38'	1767.34 / 0-25'	1767.36 / 0-14'
5.00	1761.77 / 1-07'	1761.88 / 0-40'	1761.92 / 0-28'	1761.93 / 0-15'
6.00	1735.35 / 1-08'	1735.46 / 0-41'	1735.50 / 0-29'	1735.52 / 0-16'
7.00	1700.69 / 1-09'	1700.79 / 0-42'	1700.83 / 0-30'	1700.84 / 0-17'
8.00	1686.69 / 1-10'	1686.82 / 0-44'	1686.87 / 0-32'	1686.88 / 0-19'
9.00	1667.99 / 1-11'	1668.09 / 0-46'	1668.12 / 0-33'	1668.14 / 0-22'
10.00	1654.29 / 1-15'	1654.42 / 0-48'	1654.46 / 0-35'	1654.48 / 0-23'
11.00	1641.07 / 1-15'	1641.20 / 0-50'	1641.24 / 0-37'	1641.26 / 0-25'
12.00	1628.21 / 1-17'	1628.33 / 0-50'	1628.38 / 0-39'	1628.39 / 0-26'
13.00	1615.14 / 1-18'	1615.25 / 0-52'	1615.29 / 0-40'	1615.30 / 0-27'
14.00	1594.75 / 1-19'	1594.86 / 0-53'	1594.90 / 0-40'	1594.92 / 0-29'
15.00	1577.85 / 1-21'	1577.99 / 0-55'	1578.04 / 0-43'	1578.05 / 0-30'
16.00	1565.34 / 1-23'	1565.46 / 0-57'	1565.50 / 0-44'	1565.52 / 0-32'
17.00	1554.68 / 1-24'	1554.75 / 0-57'	1554.78 / 0-46'	1554.79 / 0-34'
18.00	1528.35 / 1-24'	1528.43 / 0-59'	1528.45 / 0-46'	1528.46 / 0-34'
19.00	1512.75 / 1-26'	1512.84 / 1-02'	1512.86 / 0-48'	1512.88 / 0-38'
20.00	1500.85 / 1-28'	1500.95 / 1-03'	1500.98 / 0-50'	1501.00 / 0-40'
21.00	1491.92 / 1-31'	1492.03 / 1-06'	1492.06 / 0-53'	1492.08 / 0-42'
22.00	1489.06 / 1-33'	1489.14 / 1-06'	1489.17 / 0-54'	1489.19 / 0-43'

Table 4 - Maximum Discharge at Different Locations for Breach Width = 30.0 m

Chainage km	Maximum Discharge, cumec / *Travel Time after Breach, hour-min*				
	Breach Time, Hour				
	1.00	**0.50**	**0.25**	**0.01**	
0.15	1927 / 1-0'	2198 / 0-30'	2404 / 0-15'	2622 / 0-01'	DAM BREACH
0.16	5503 / 1-0'	5877 / 0-30'	6134 / 0-15'	6397 / 0-01'	SPILLWAY
0.60	7408 / 1-0'	7966 / 0-31'	8364 / 0-16'	8680 / 0-03'	
1.50	7370 / 1-1'	7831 / 0-32'	8074 / 0-17'	8204 / 0-04'	
2.50	7331 / 1-2'	7702 / 0-33'	7861 / 0-20'	7929 / 0-07'	
3.50	7304 / 1-3'	7637 / 0-35'	7776 / 0-22'	7833 / 0-10'	
4.50	7261 / 1-5'	7531 / 0-37'	7637 / 0-24'	7679 / 0-12'	
5.50	7241 / 1-6'	7493 / 0-39'	7588 / 0-26'	7626 / 0-14'	
6.50	7234 / 1-8'	7478 / 0-40'	7571 / 0-27'	7606 / 0-15'	
7.50	7220 / 1-9'	7453 / 0-42'	7338 / 0-29'	7572 / 0-17'	
8.50	7213 / 1-10'	7438 / 0-43'	7521 / 0-30'	7554 / 0-19'	
9.50	7198 / 1-12'	7411 / 0-45'	7487 / 0-32'	7518 / 0-21'	
10.50	7189 / 1-13'	7396 / 0-47'	7470 / 0-34'	7499 / 0-22'	
11.50	7179 / 1-15'	7378 / 0-48'	7448 / 0-36'	7476 / 0-24'	
12.50	7170 / 1-16'	7362 / 0-50'	7429 / 0-37'	7455 / 0-25'	
13.50	7162 / 1-17'	7349 / 0-51'	7414 / 0-39'	7439 / 0-27'	
14.50	7155 / 1-19'	7336 / 0-53'	7400 / 0-40'	7424 / 0-28'	
15.50	7145 / 1-20'	7319 / 0-54'	7379 / 0-42'	7402 / 0-30'	
16.50	7137 / 1-22'	7307 / 0-56'	7365 / 0-43'	7386 / 0-31'	
17.50	7132 / 1-23'	7298 / 0-57'	7353 / 0-44'	7375 / 0-33'	
18.50	7125 / 1-24'	7287 / 0-58'	7343 / 0-46'	7363 / 0-34'	
19.50	7116 / 1-26'	7271 / 1-00'	7323 / 0-48'	7343 / 0-36'	
20.50	7105 / 1-28'	7254 / 1-02'	7304 / 0-50'	7323 / 0-38'	
21.50	7087 / 1-30'	7225 / 1-04'	7271 / 0-52'	7287 / 0-41'	

Table 5 - Maximum Water Level at Different Locations for Breach Width=30.0 m

Chainage km	Maximum Water Level, m / *Travel Time after Breach, hour-min*			
	Breach Time, Hour			
	1.00	**0.50**	**0.25**	**0.01**
0.20	1789.03 / 1-0'	1789.62 / 0-31'	1789.92 / 0-16'	1789.90 / 0-05'
1.00	1785.32 / 1-1'	1785.77 / 0-32'	1785.97 / 0-18'	1786.04 / 0-05'
2.00	1779.36 / 1-2'	1779.73 / 0-33'	1779.90 / 0-20'	1779.96 / 0-08'
3.00	1772.86 / 1-3'	1773.12 / 0-35'	1773.22 / 0-22'	1773.26 / 0-09'
4.00	1767.44 / 1-5'	1767.63 / 0-38'	1767.71 / 0-25'	1767.74 / 0-13'
5.00	1762.01 / 1-5'	1762.21 / 0-39'	1762.28 / 0-26'	1762.31 / 0-14'
6.00	1735.60 / 1-6'	1735.80 / 0-40'	1735.87 / 0-27'	1735.90 / 0-15'
7.00	1700.93 / 1-9'	1701.10 / 0-42'	1701.16 / 0-29'	1701.19 / 0-17'
8.00	1686.99 / 1-9'	1687.21 / 0-43'	1687.29 / 0-31'	1687.32 / 0-19'
9.00	1668.22 / 1-11'	1668.38 / 0-44'	1668.44 / 0-32'	1668.46 / 0-20'
10.00	1654.60 / 1-12'	1654.82 / 0-47'	1654.89 / 0-33'	1654.92 / 0-21'
11.00	1641.38 / 1-14'	1641.58 / 0-48'	1641.66 / 0-36'	1641.68 / 0-23'
12.00	1628.52 / 1-15'	1628.73 / 0-50'	1628.80 / 0-37'	1628.82 / 0-25'
13.00	1615.41 / 1-16'	1615.59 / 0-51'	1615.65 / 0-38'	1615.68 / 0-27'
14.00	1595.04 / 1-18'	1595.22 / 0-52'	1595.29 / 0-40'	1595.31 / 0-27'
15.00	1578.21 / 1-20'	1578.42 / 0-54'	1578.50 / 0-42'	1578.53 / 0-30'
16.00	1565.65 / 1-21'	1565.84 / 0-55'	1565.91 / 0-43'	1565.93 / 0-31'
17.00	1554.87 / 1-22'	1554.99 / 0-57'	1555.03 / 0-44'	1555.04 / 0-32'
18.00	1528.55 / 1-23'	1528.67 / 0-58'	1528.71 / 0-45'	1528.72 / 0-33'
19.00	1512.98 / 1-25'	1513.11 / 0-59'	1513.16 / 0-48'	1513.17 / 0-35'
20.00	1501.12 / 1-27'	1501.27 / 1-01'	1501.32 / 0-49'	1501.34 / 0-37'
21.00	1492.22 / 1-29'	1492.39 / 1-04'	1492.44 / 0-52'	1492.46 / 0-37'
22.00	1489.31 / 1-30'	1489.45 / 1-05'	1489.49 / 0-52'	1489.51 / 0-41'

Table 6 - Maximum Discharge at Different Locations for Breach Width = 45.0 m

	Maximum Discharge, cumec / *Travel Time after Breach, hour-min*				
Chainage	Breach Time, Hour				
km	**1.00**	**0.50**	**0.25**	**0.01**	
0.15	2504 / 1-01'	2998 / 0-30'	3418 / 0-15'	3891 / 0-01'	DAM BREACH
0.16	5127 / 1-01'	5607 / 0-30'	5980 / 0-15'	6365 / 0-01'	SPILLWAY
0.60	7618 / 1-01'	8470 / 0-30'	9131 / 0-16'	9735 / 0-02'	
1.50	7582 / 1-01'	8294 / 0-31'	8725 / 0-17'	8966 / 0-04'	
2.50	7544 / 1-01'	8112 / 0-33'	8375 / 0-19'	8480 / 0-07'	
3.50	7516 / 1-03'	8011 / 0-35'	8235 / 0-21'	8326 / 0-09'	
4.50	7468 / 1-04'	7863 / 0-36'	8029 / 0-23'	8091 / 0-11'	
5.50	7443 / 1-05'	7808 / 0-38'	7950 / 0-25'	8007 / 0-13'	
6.50	7433 / 1-06'	7784 / 0-40'	7919 / 0-27'	7974 / 0-15'	
7.50	7417 / 1-08'	7746 / 0-41'	7869 / 0-28'	7916 / 0-16'	
8.50	7407 / 1-09'	7725 / 0-42'	7842 / 0-30'	7889 / 0-18'	
9.50	7388 / 1-11'	7685 / 0-44'	7792 / 0-31'	7834 / 0-20'	
10.50	7377 / 1-12'	7663 / 0-46'	7766 / 0-33'	7805 / 0-21'	
11.50	7364 / 1-13'	7637 / 0-47'	7733 / 0-35'	7770 / 0-23'	
12.50	7352 / 1-15'	7613 / 0-49'	7706 / 0-36'	7740 / 0-24'	
13.50	7343 / 1-16'	7596 / 0-50'	7682 / 0-37'	7715 / 0-26'	
14.50	7333 / 1-17'	7576 / 0-51'	7662 / 0-39'	7694 / 0-27'	
15.50	7320 / 1-19'	7553 / 0-53'	7632 / 0-41'	7662 / 0-29'	
16.50	7310 / 1-20'	7534 / 0-54'	7612 / 0-42'	7639 / 0-30'	
17.50	7302 / 1-21'	7522 / 0-56'	7596 / 0-43'	7622 / 0-31'	
18.50	7295 / 1-23'	7508 / 0-57'	7580 / 0-45'	7607 / 0-33'	
19.50	7281 / 1-24'	7486 / 0-59'	7553 / 0-47'	7578 / 0-35'	
20.50	7269 / 1-26'	7463 / 1-01'	7526 / 0-48'	7549 / 0-37'	
21.50	7245 / 1-28'	7423 / 1-03'	7481 / 0-51'	7500 / 0-39'	

Table 7 - Maximum Water Level at Different Locations for Breach Width = 45.0 m

Chainage km	Maximum Water Level, m / *Travel Time after Breach, hour-min*			
	Breach Time, Hour			
	1.00	**0.50**	**0.25**	**0.01**
0.20	1789.31 / 1-0'	1790.18 / 0-31'	1790.70 / 0-16'	1790.97 / 0-02'
1.00	1785.56 / 1-0'	1786.24 / 0-31'	1786.57 / 0-17'	1786.69 / 0-05'
2.00	1779.59 / 1-01'	1780.15 / 0-33'	1780.40 / 0-19'	1780.50 / 0-07'
3.00	1773.03 / 1-02'	1773.40 / 0-34'	1773.56 / 0-21'	1773.63 / 0-09'
4.00	1767.59 / 1-04'	1767.87 / 0-37'	1767.98 / 0-24'	1768.02 / 0-12'
5.00	1762.17 / 1-05'	1762.45 / 0-38'	1762.55 / 0-25'	1762.60 / 0-13'
6.00	1735.76 / 1-05'	1736.04 / 0-39'	1736.15 / 0-26'	1736.19 / 0-14'
7.00	1701.07 / 1-07'	1701.31 / 0-41'	1701.40 / 0-28'	1701.43 / 0-16'
8.00	1687.18 / 1-09'	1687.48 / 0-42'	1687.59 / 0-29'	1687.63 / 0-17'
9.00	1668.37 / 1-10'	1668.59 / 0-44'	1668.67 / 0-31'	1668.70 / 0-19'
10.00	1654.80 / 1-12'	1655.09 / 0-45'	1655.20 / 0-33'	1655.24 / 0-21'
11.00	1641.57 / 1-13'	1641.85 / 0-47'	1641.95 / 0-35'	1641.98 / 0-22'
12.00	1628.72 / 1-15'	1628.99 / 0-48'	1629.09 / 0-36'	1629.12 / 0-24'
13.00	1615.59 / 1-16'	1615.82 / 0-50'	1615.90 / 0-37'	1615.93 / 0-25'
14.00	1595.22 / 1-16'	1595.47 / 0-51'	1595.55 / 0-38'	1595.59 / 0-27'
15.00	1578.43 / 1-19'	1578.71 / 0-53'	1578.81 / 0-40'	1578.85 / 0-29'
16.00	1565.85 / 1-20'	1566.10 / 0-54'	1566.18 / 0-42'	1566.21 / 0-30'
17.00	1554.99 / 1-20'	1555.14 / 0-55'	1555.20 / 0-43'	1555.21 / 0-31'
18.00	1528.67 / 1-21'	1528.83 / 0-57'	1528.88 / 0-44'	1528.90 / 0-33'
19.00	1513.12 / 1-23'	1513.30 / 0-59'	1513.35 / 0-46'	1513.37 / 0-34'
20.00	1501.29 / 1-25'	1501.49 / 1-01'	1501.55 / 0-48'	1501.57 / 0-36'
21.00	1492.41 / 1-28'	1492.62 / 1-03'	1492.69 / 0-51'	1492.71 / 0-39'
22.00	1489.47 / 1-29'	1489.64 / 1-03'	1489.70 / 0-51'	1489.72 / 0-39'

Table 8 - Maximum Discharge at Different Locations for Breach Width = 60.0 m

	Maximum Discharge, cumec / *Travel Time after Breach, hour-min*				
Chainage	Breach Time, Hour				
km	**1.00**	**0.50**	**0.25**	**0.01**	
0.15	2889 / 1-00'	3636 / 0-30'	4318 / 0-15'	5134 / 0-01'	DAM BREACH
0.16	4802 / 1-00'	5350 / 0-30'	5830 / 0-15'	6333 / 0-01'	SPILLWAY
0.60	7688 / 1-00'	8854 / 0-30'	9740 / 0-16'	10771 / 0-02'	
1.50	7674 / 1-00'	8653 / 0-31'	9229 / 0-17'	9591 / 0-04'	
2.50	7669 / 1-01'	8418 / 0-32'	8785 / 0-19'	8926 / 0-06'	
3.50	7647 / 1-02'	8313 / 0-34'	8608 / 0-21'	8727 / 0-09'	
4.50	7600 / 1-03'	8134 / 0-36'	8351 / 0-23'	8437 / 0-11'	
5.50	7575 / 1-05'	8056 / 0-38'	8247 / 0-25'	8321 / 0-13'	
6.50	7566 / 1-06'	8027 / 0-39'	8206 / 0-26'	8261 / 0-15'	
7.50	7548 / 1-07'	7974 / 0-41'	8139 / 0-28'	8202 / 0-16'	
8.50	7538 / 1-08'	7950 / 0-42'	8106 / 0-29'	8166 / 0-17'	
9.50	7517 / 1-10'	7898 / 0-44'	8031 / 0-30'	8076 / 0-18'	
10.50	7506 / 1-11'	7872 / 0-45'	7951 / 0-33'	7976 / 0-21'	
11.50	7491 / 1-12'	7837 / 0-46'	7926 / 0-35'	7953 / 0-23'	
12.50	7477 / 1-14'	7809 / 0-48'	7904 / 0-36'	7929 / 0-25'	
13.50	7467 / 1-15'	7786 / 0-49'	7884 / 0-37'	7912 / 0-26'	
14.50	7456 / 1-16'	7762 / 0-51'	7860 / 0-39'	7891 / 0-27'	
15.50	7441 / 1-18'	7732 / 0-52'	7827 / 0-40'	7856 / 0-29'	
16.50	7430 / 1-19'	7709 / 0-54'	7800 / 0-41'	7832 / 0-30'	
17.50	7421 / 1-20'	7694 / 0-55'	7782 / 0-43'	7812 / 0-31'	
18.50	7412 / 1-22'	7676 / 0-56'	7763 / 0-44'	7791 / 0-33'	
19.50	7397 / 1-23'	7648 / 0-58'	7730 / 0-46'	7756 / 0-34'	
20.50	7382 / 1-25'	7620 / 1-00'	7695 / 0-48'	7722 / 0-36'	
21.50	7355 / 1-27'	7570 / 1-02'	7639 / 0-50'	7661 / 0-39'	

Table 9 - Maximum Water Level at Different Locations for Breach Width = 60.0 m

Chainage km	Maximum Water Level, m / *Travel Time after Breach, hour-min*			
	Breach Time, Hour			
	1.00	**0.50**	**0.25**	**0.01**
0.20	1789.44 / 1-00'	1790.61 / 0-30'	1791.29 / 0-16'	1791.60 / 0-03'
1.00	1785.69 / 1-00'	1786.60 / 0-31'	1787.05 / 0-17'	1787.25 / 0-04'
2.00	1779.72 / 1-01'	1780.47 / 0-33'	1780.80 / 0-19'	1780.93 / 0-07'
3.00	1773.13 / 1-01'	1773.63 / 0-34'	1773.84 / 0-21'	1773.92 / 0-09'
4.00	1767.69 / 1-03'	1768.05 / 0-36'	1768.20 / 0-23'	1768.26 / 0-12'
5.00	1762.27 / 1-04'	1762.63 / 0-37'	1762.78 / 0-25'	1762.83 / 0-13'
6.00	1735.87 / 1-05'	1736.23 / 0-39'	1736.37 / 0-26'	1736.42 / 0-14'
7.00	1701.17 / 1-06'	1701.48 / 0-40'	1701.59 / 0-27'	1701.64 / 0-16'
8.00	1687.30 / 1-07'	1687.69 / 0-42'	1687.83 / 0-29'	1687.88 / 0-17'
9.00	1668.47 / 1-10'	1668.75 / 0-43'	1668.85 / 0-31'	1668.90 / 0-19'
10.00	1654.93 / 1-10'	1655.31 / 0-45'	1655.50 / 0-33'	1655.60 / 0-21'
11.00	1641.70 / 1-12'	1642.05 / 0-46'	1642.15 / 0-35'	1642.17 / 0-23'
12.00	1628.85 / 1-13'	1629.20 / 0-48'	1629.30 / 0-36'	1629.33 / 0-25'
13.00	1615.70 / 1-14'	1616.00 / 0-49'	1616.09 / 0-37'	1616.12 / 0-26'
14.00	1595.35 / 1-16'	1595.65 / 0-50'	1595.75 / 0-38'	1595.78 / 0-27'
15.00	1578.58 / 1-18'	1578.93 / 0-52'	1579.05 / 0-40'	1579.08 / 0-28'
16.00	1565.98 / 1-18'	1566.29 / 0-53'	1566.39 / 0-41'	1566.43 / 0-30'
17.00	1555.07 / 1-19'	1555.26 / 0-54'	1555.32 / 0-42'	1555.34 / 0-30'
18.00	1528.76 / 1-21'	1528.95 / 0-56'	1529.01 / 0-44'	1529.03 / 0-32'
19.00	1513.22 / 1-22'	1513.43 / 0-57'	1513.50 / 0-45'	1513.52 / 0-34'
20.00	1501.41 / 1-25'	1501.64 / 0-59'	1501.72 / 0-48'	1501.74 / 0-36'
21.00	1492.54 / 1-27'	1492.80 / 1-02'	1492.88 / 0-50'	1492.91 / 0-39'
22.00	1489.58 / 1-28'	1489.79 / 1-03'	1489.86 / 0-51'	1489.88 / 0-39'

FIGURES

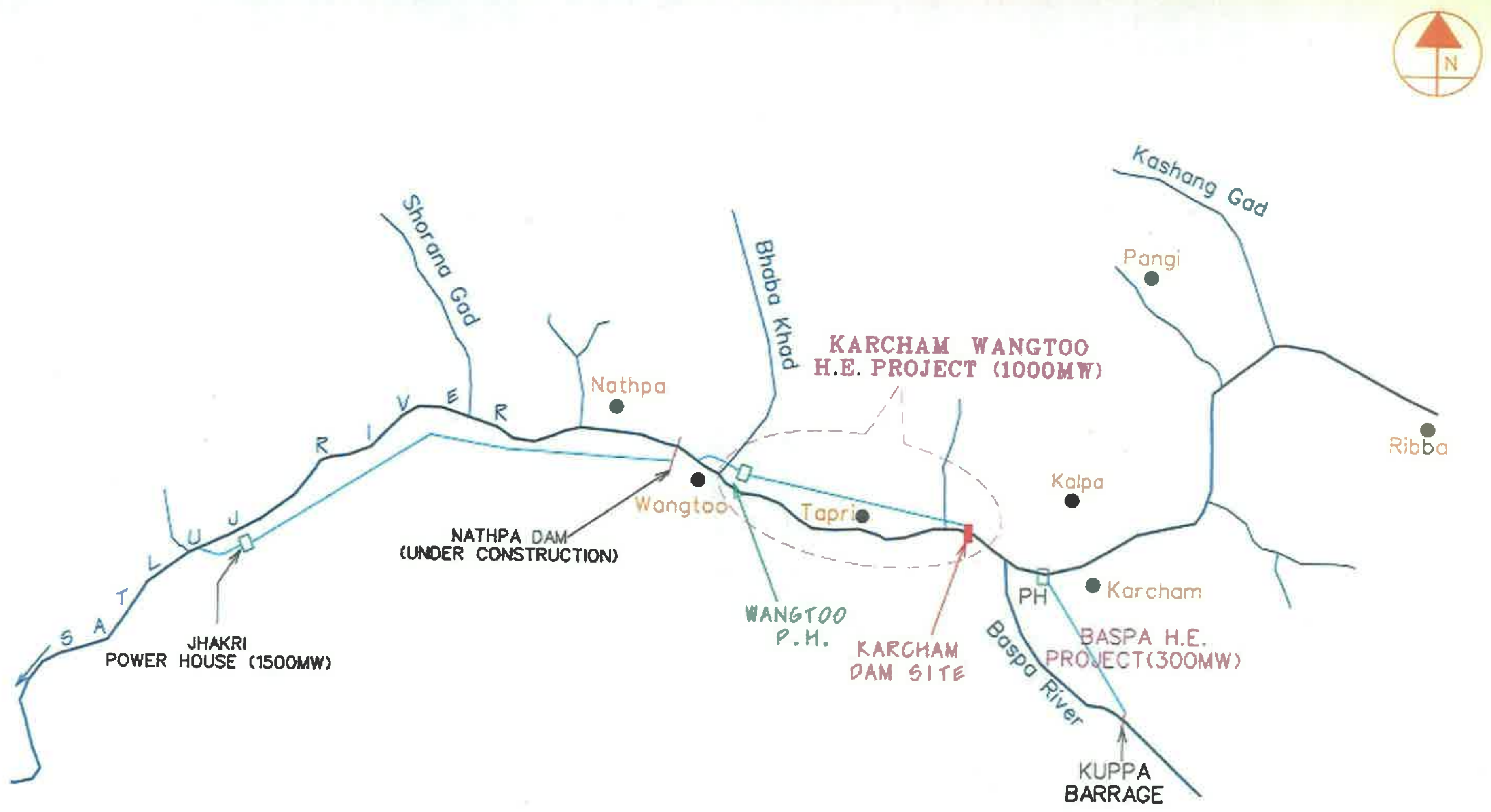
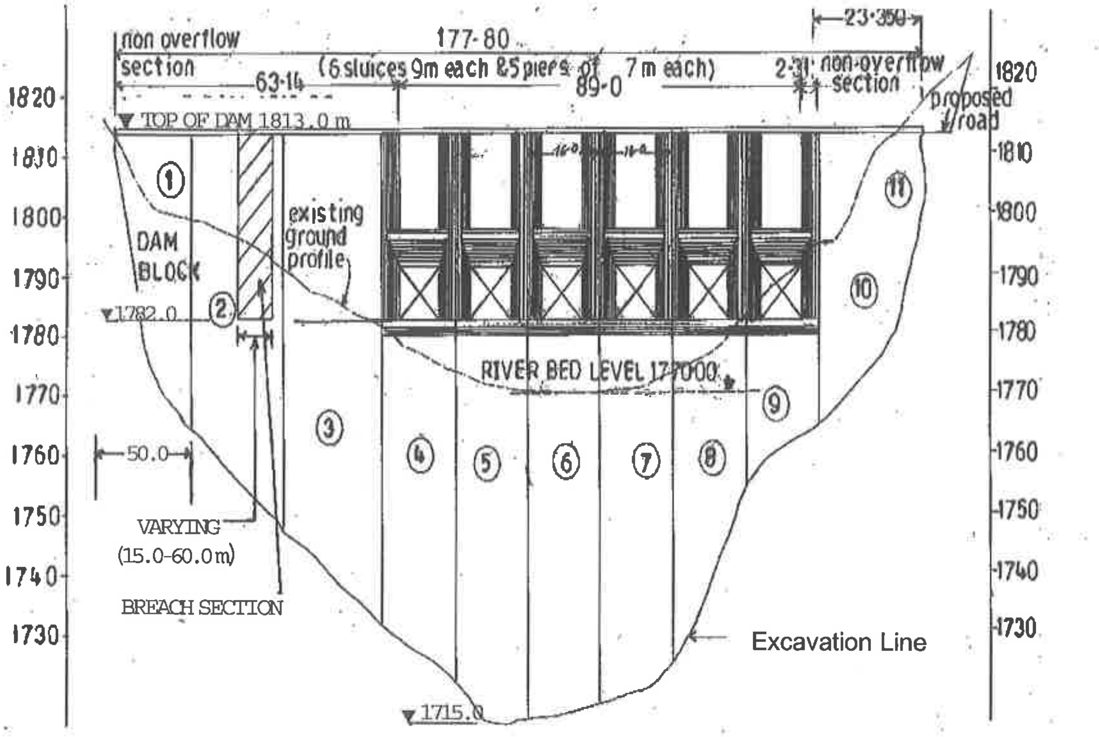
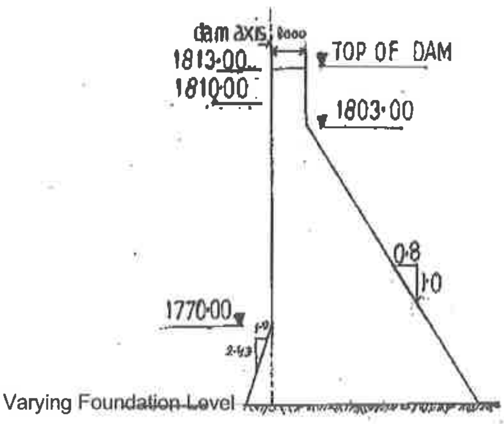


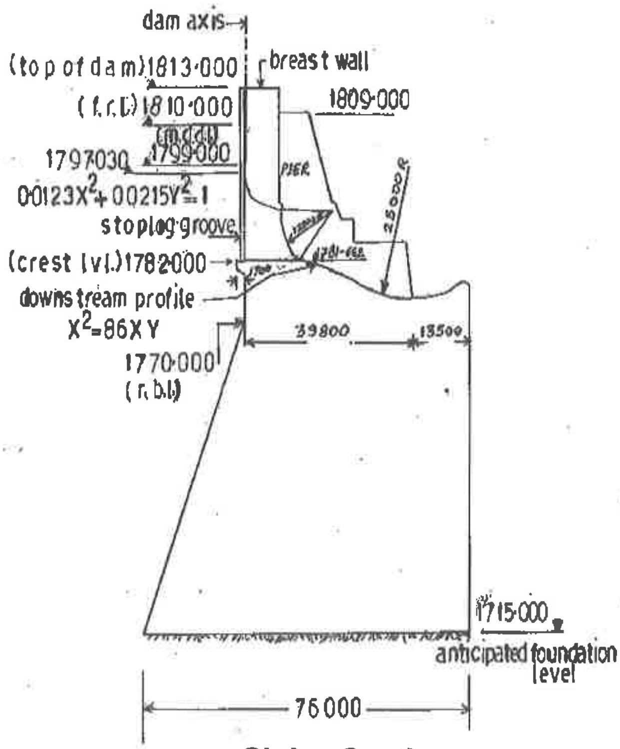
FIG.-1 - INDEX MAP OF KARCHAM-WANGTOO HYDRO-ELECTRIC PROJECT (1000MW)



Cross-Section of River Valley



Typical Non Overflow Section



Sluice Section

Fig. 2 - Cross-Section of River Valley at Karcham Dam Site

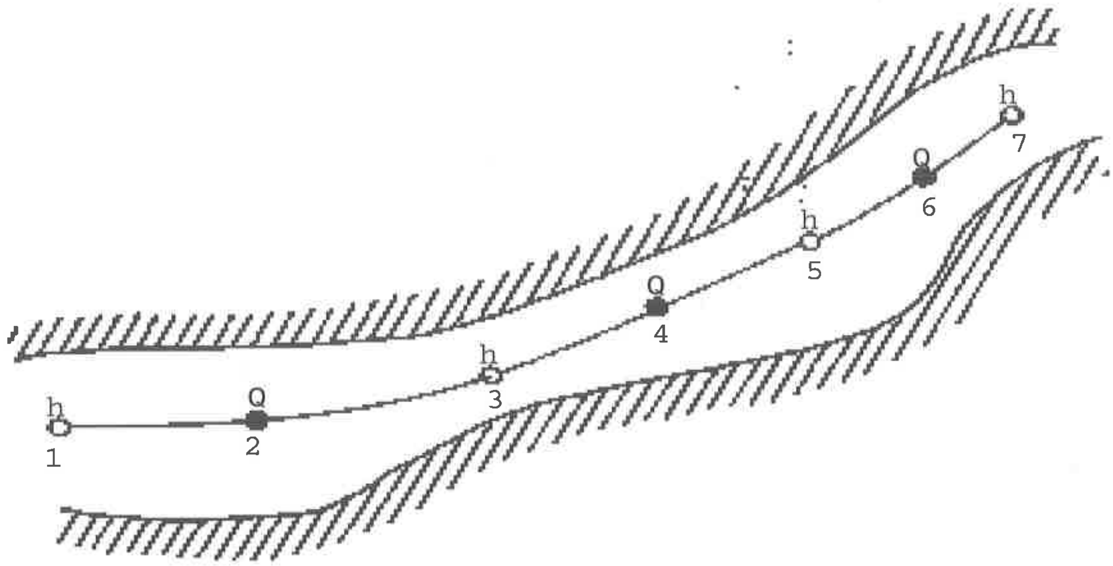


Fig. 3 - Channel Section with Computational Net

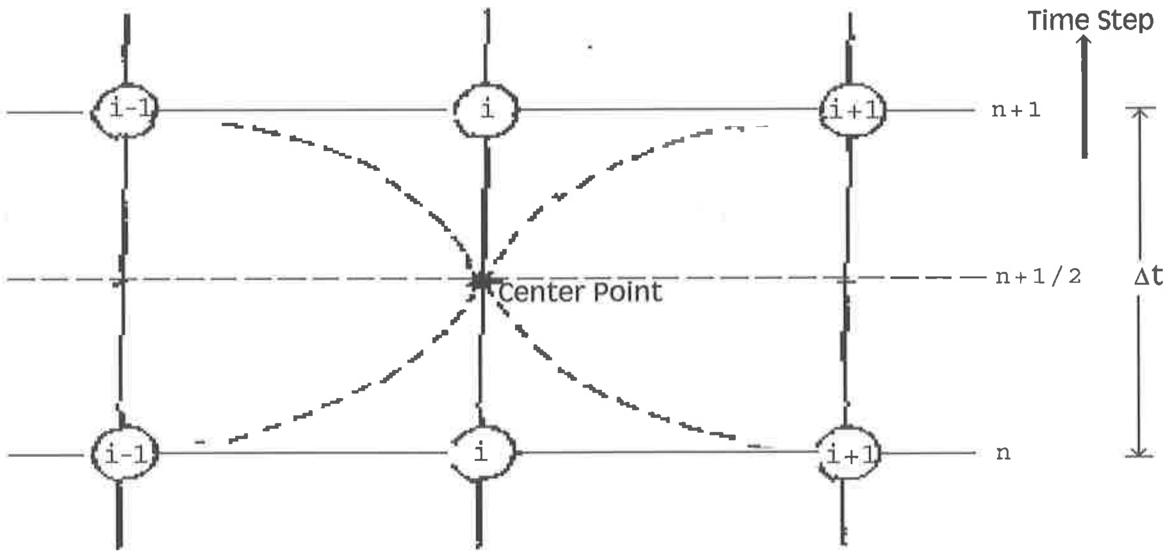


Fig. 4 - Centered 6-Point Abbott Scheme

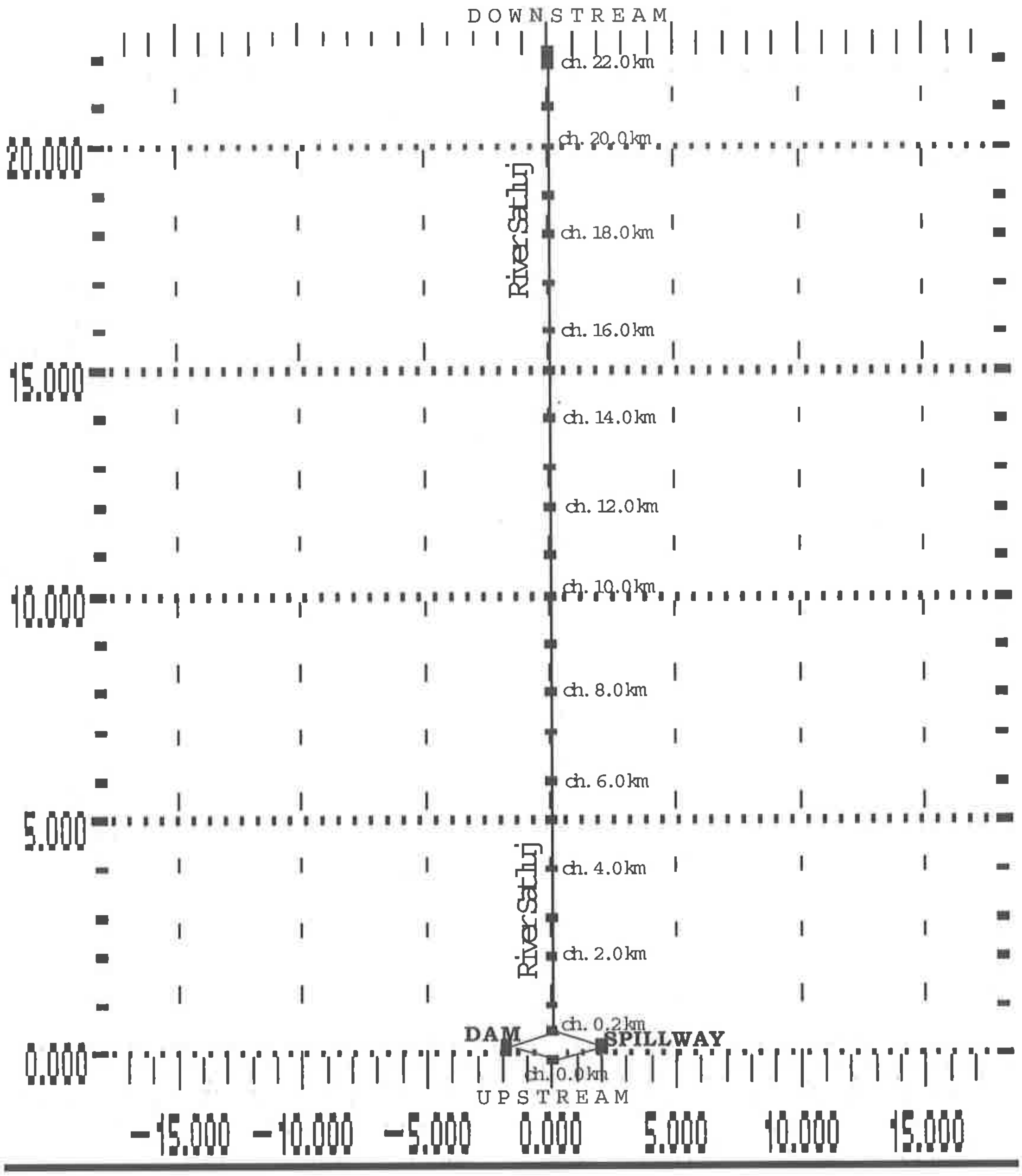


Fig. 5 - River Model Setup for Dam Break Study

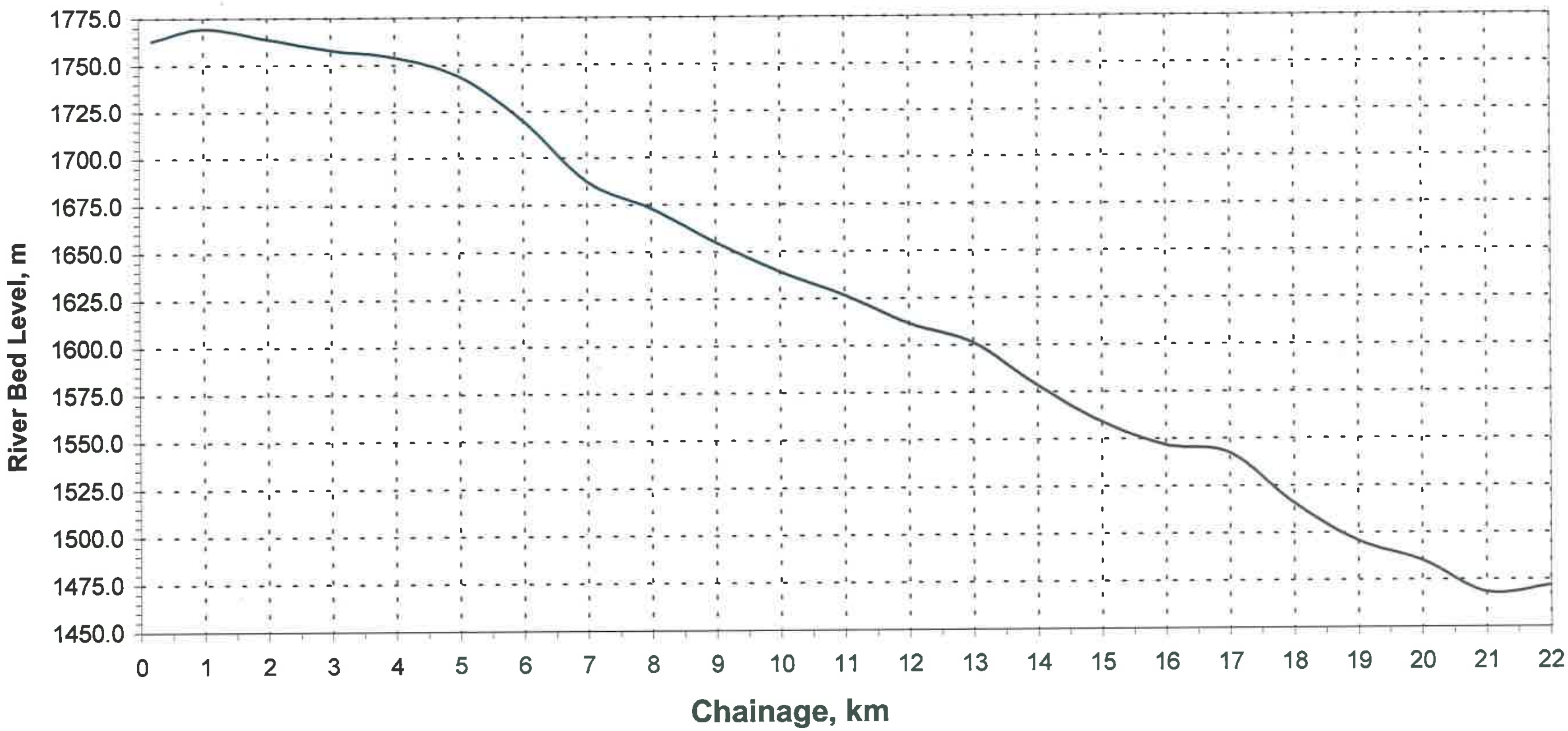


Fig. 6 - Longitudinal Profile of River Satluj

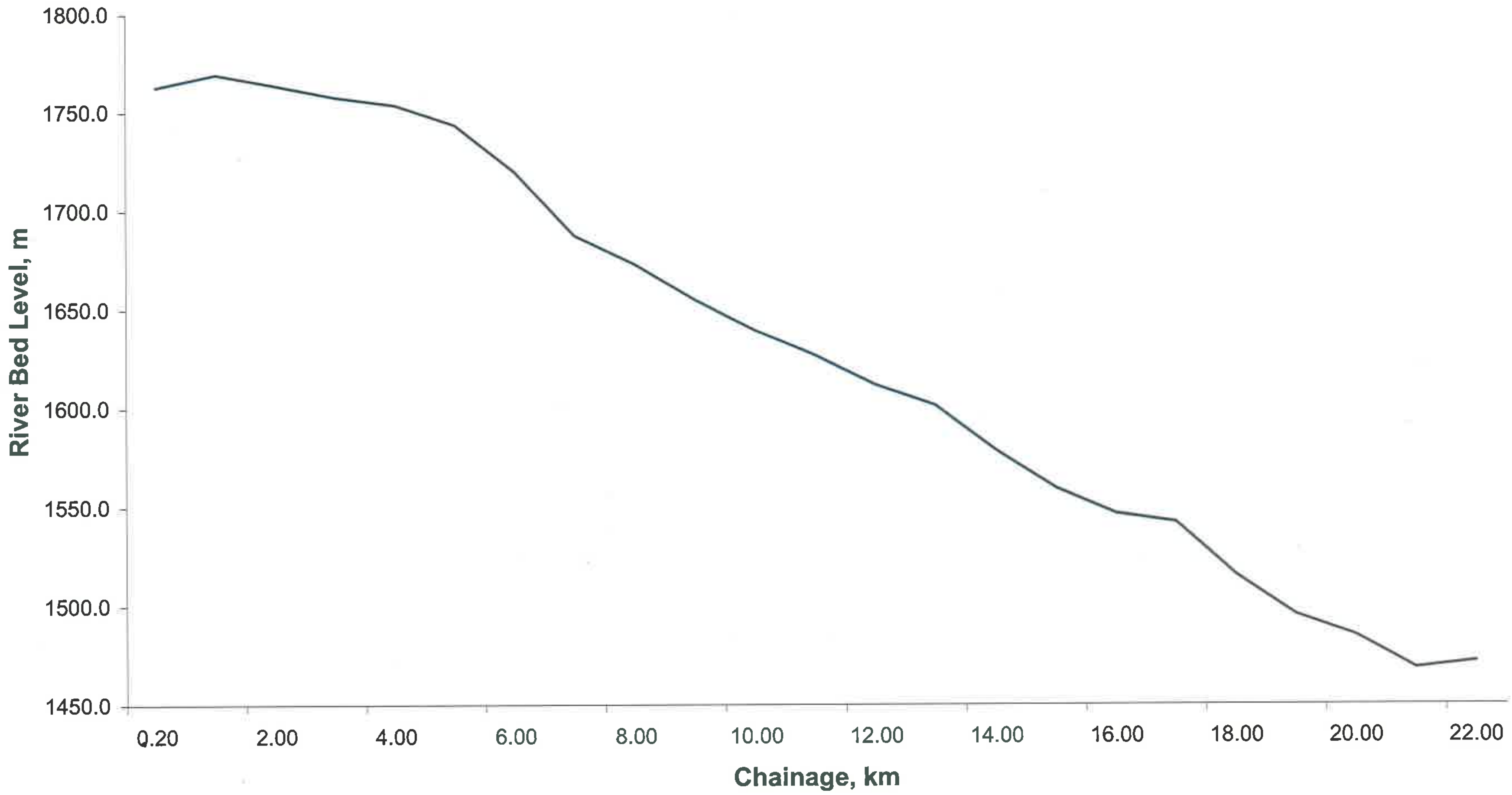


Fig. 7 - L-Section of River Satluj

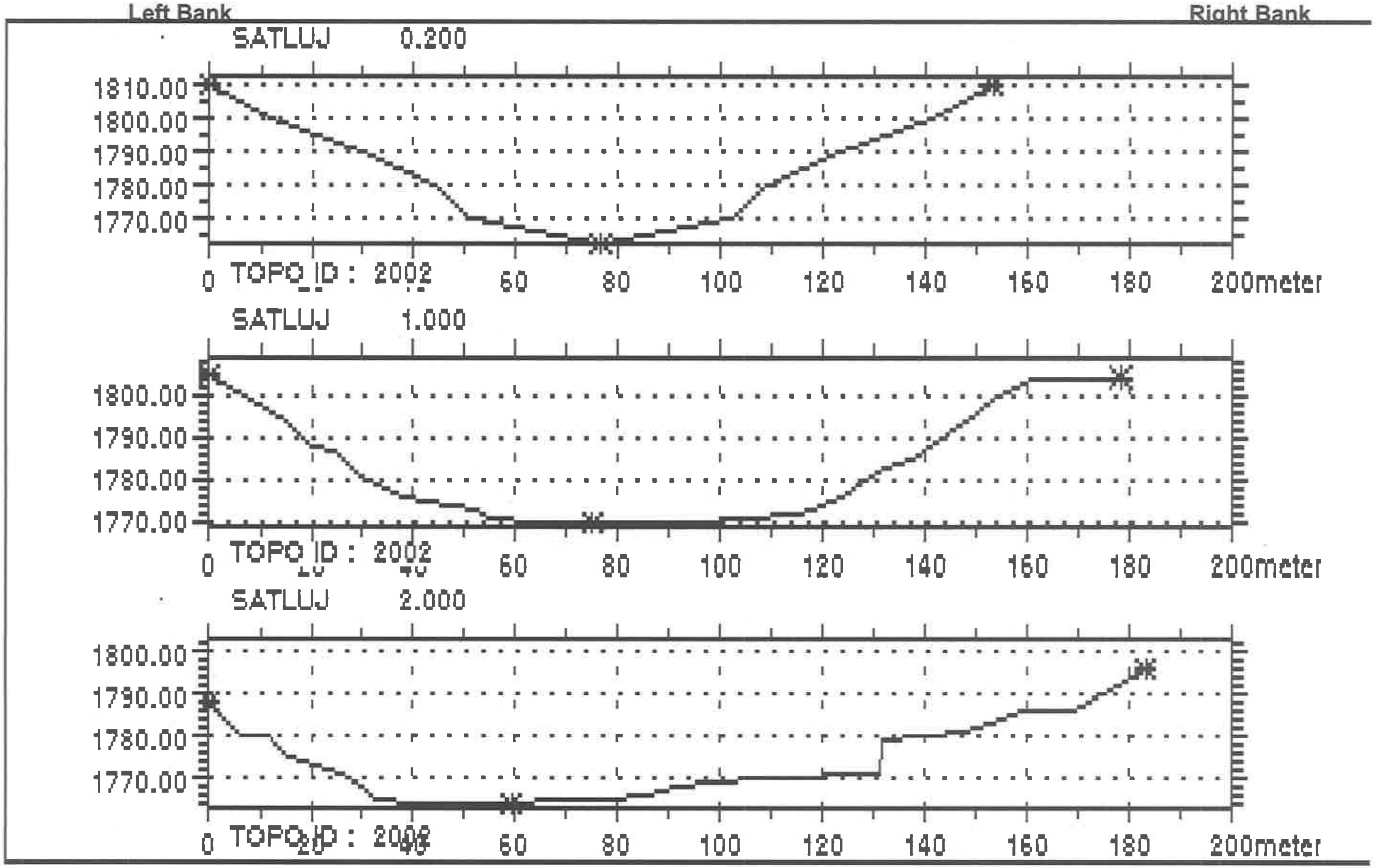


Fig. 8 - Cross-Sections of river Satluj at Chainage 0.20 km, 1.00 km and 2.00 km

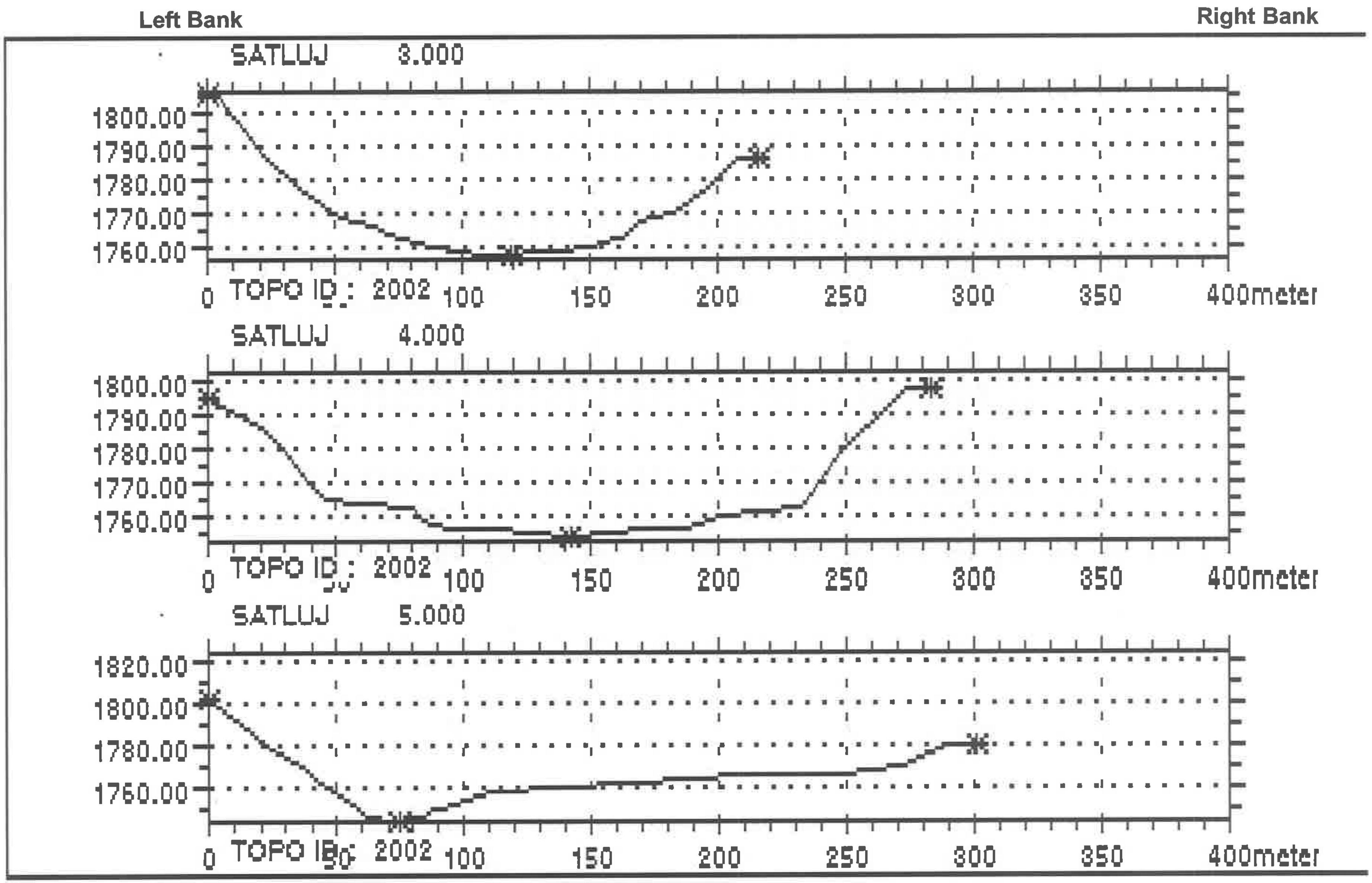


Fig. 8 - Cross-Sections of river Satluj at Chainage 3.00 km, 4.00 km and 5.00 km

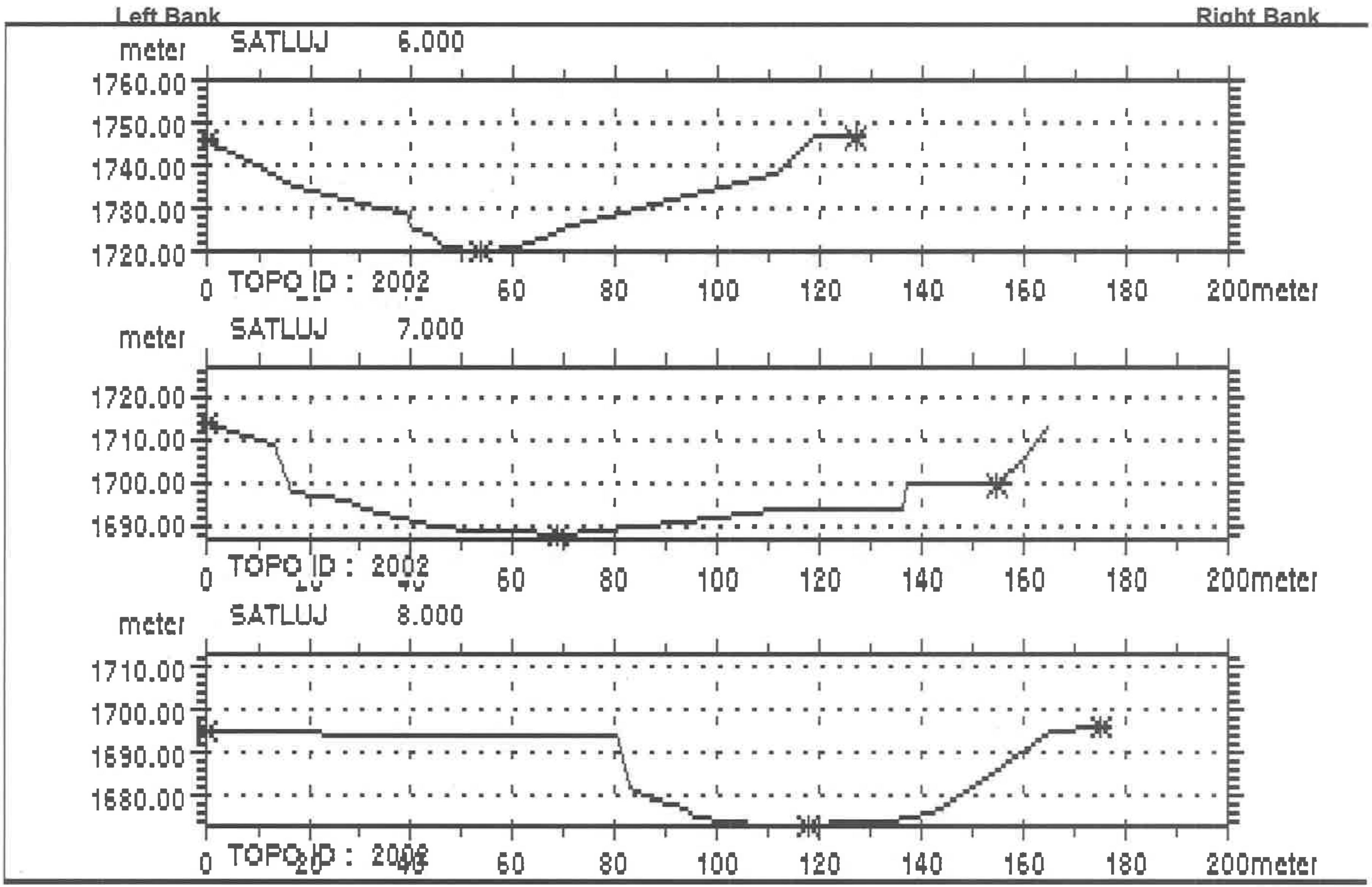


Fig. 8 - Cross-Sections of river Satluj at Chainage 6.00 km, 7.00 km and 8.00 km

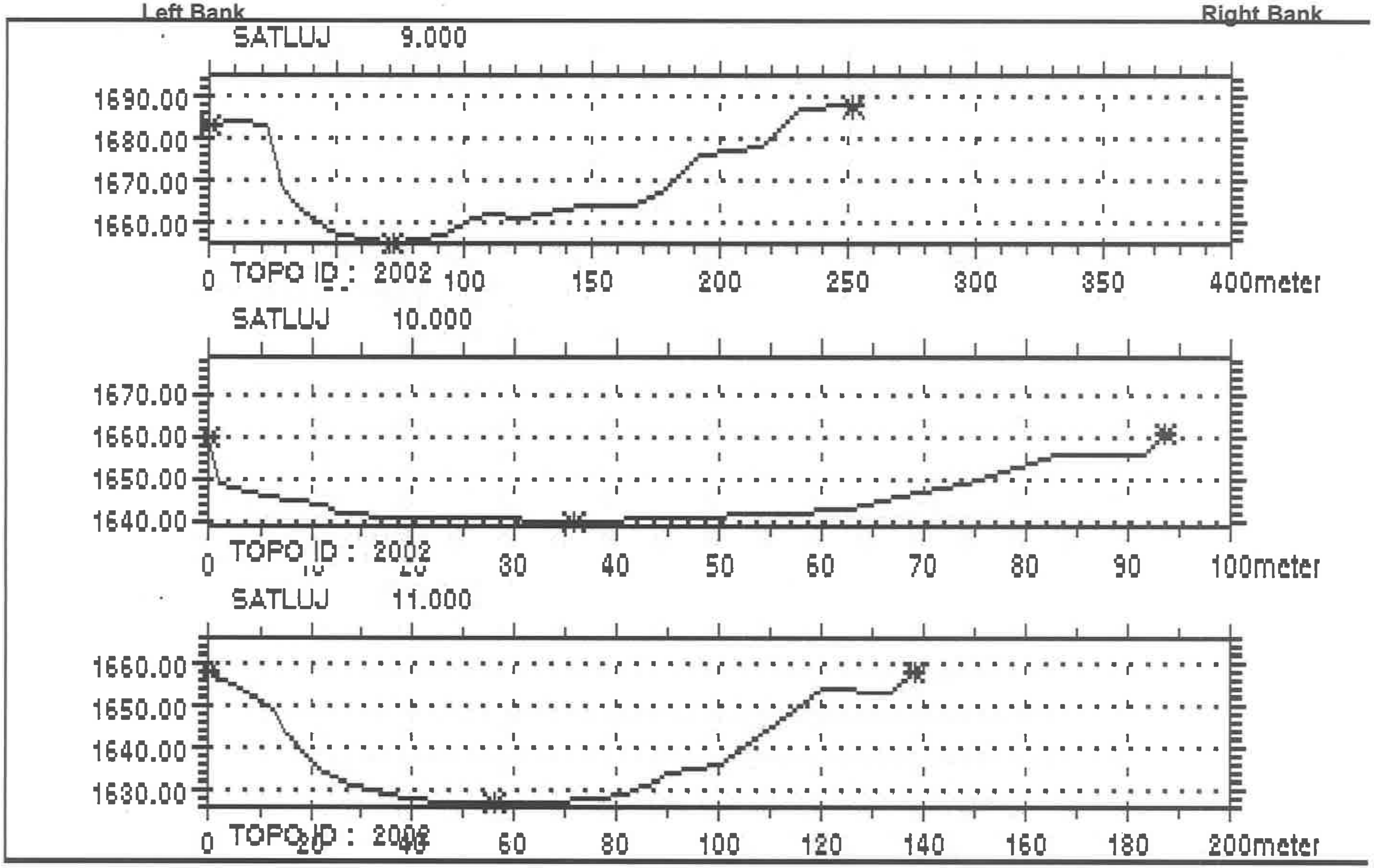


Fig. 8 - Cross-Sections of river Satluj at Chainage 9.00 km, 10.00 km and 11.00 km

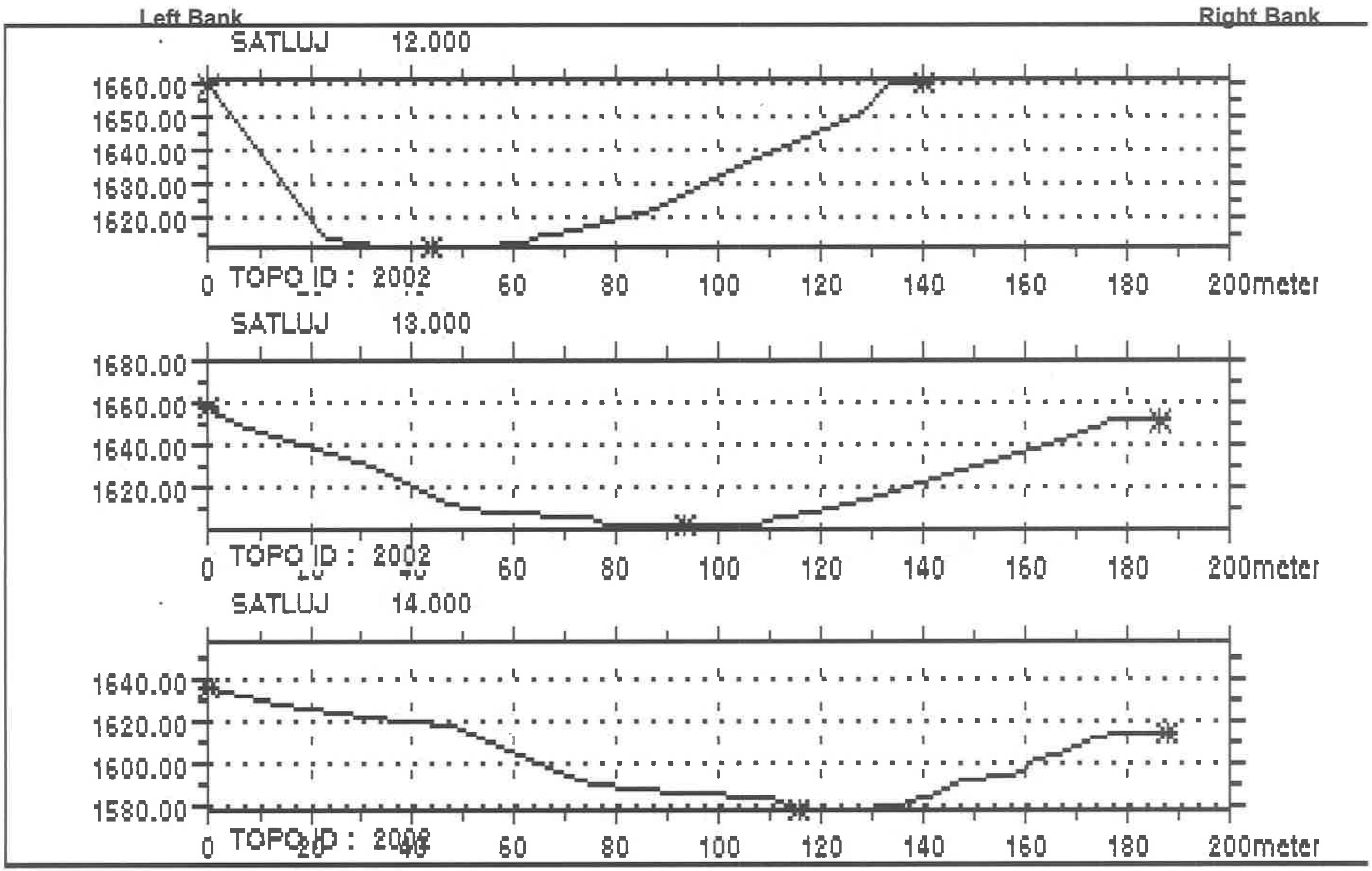


Fig. 8 - Cross-Sections of river Satluj at Chainage 12.00 km, 13.00 km and 14.00 km

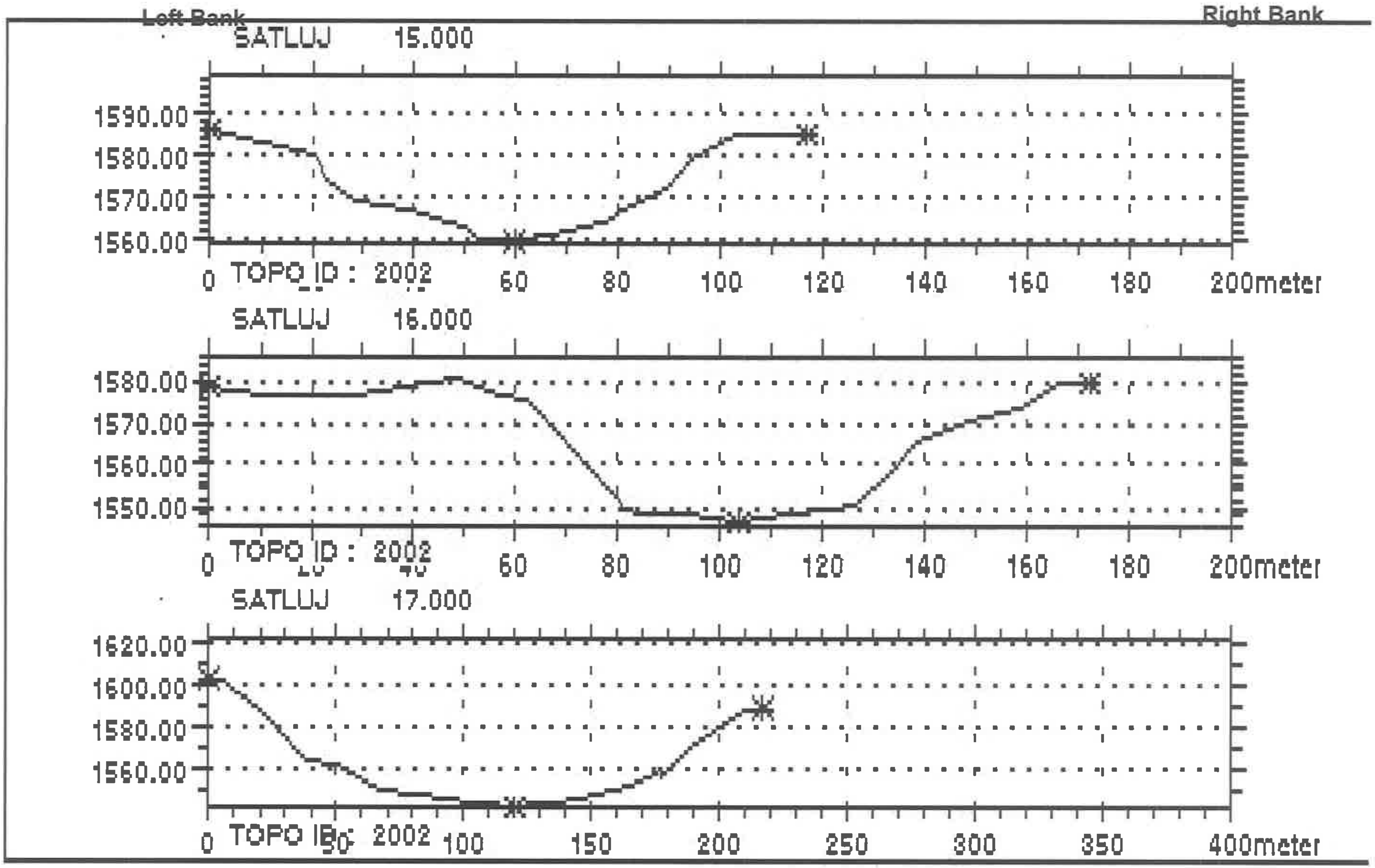


Fig. 8 - Cross-Sections of river Satluj at Chainage 15.00 km, 16.00 km and 17.00 km

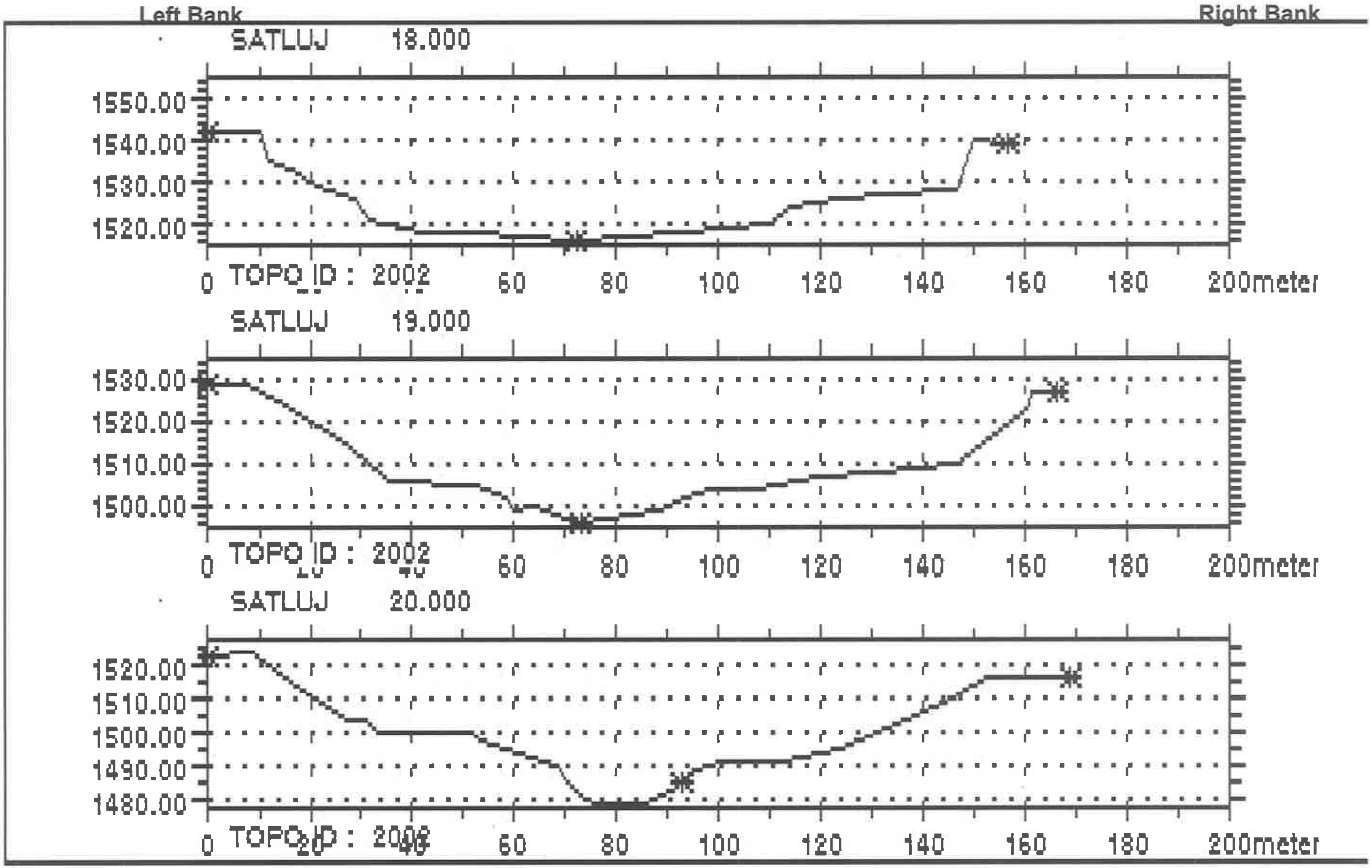


Fig. 8 - Cross-Sections of river Satluj at Chainage 18.00 km, 19.00 km and 20.00 km

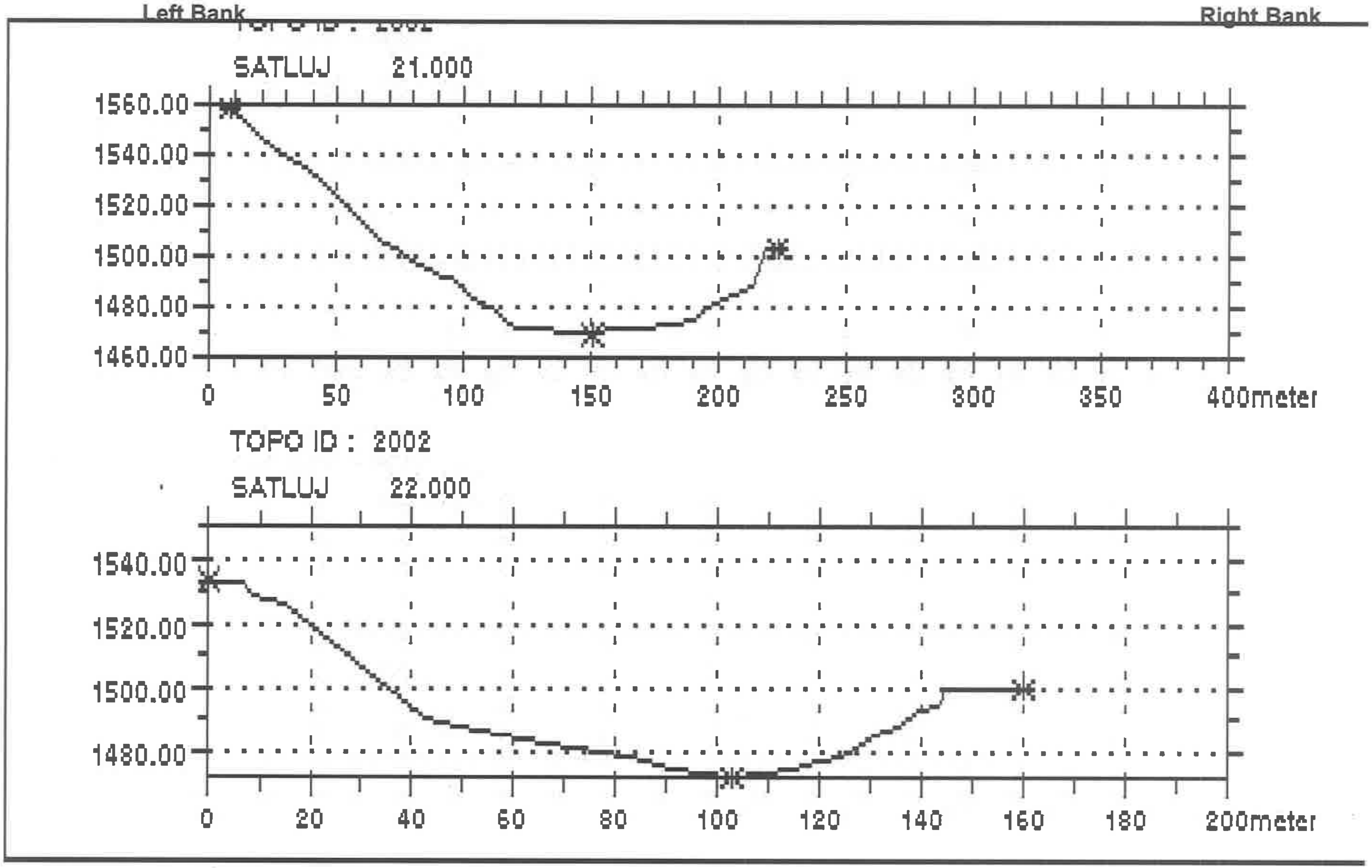


Fig. 8 - Cross-Sections of river Satluj at Chainage 21.00 km and 22.00 km

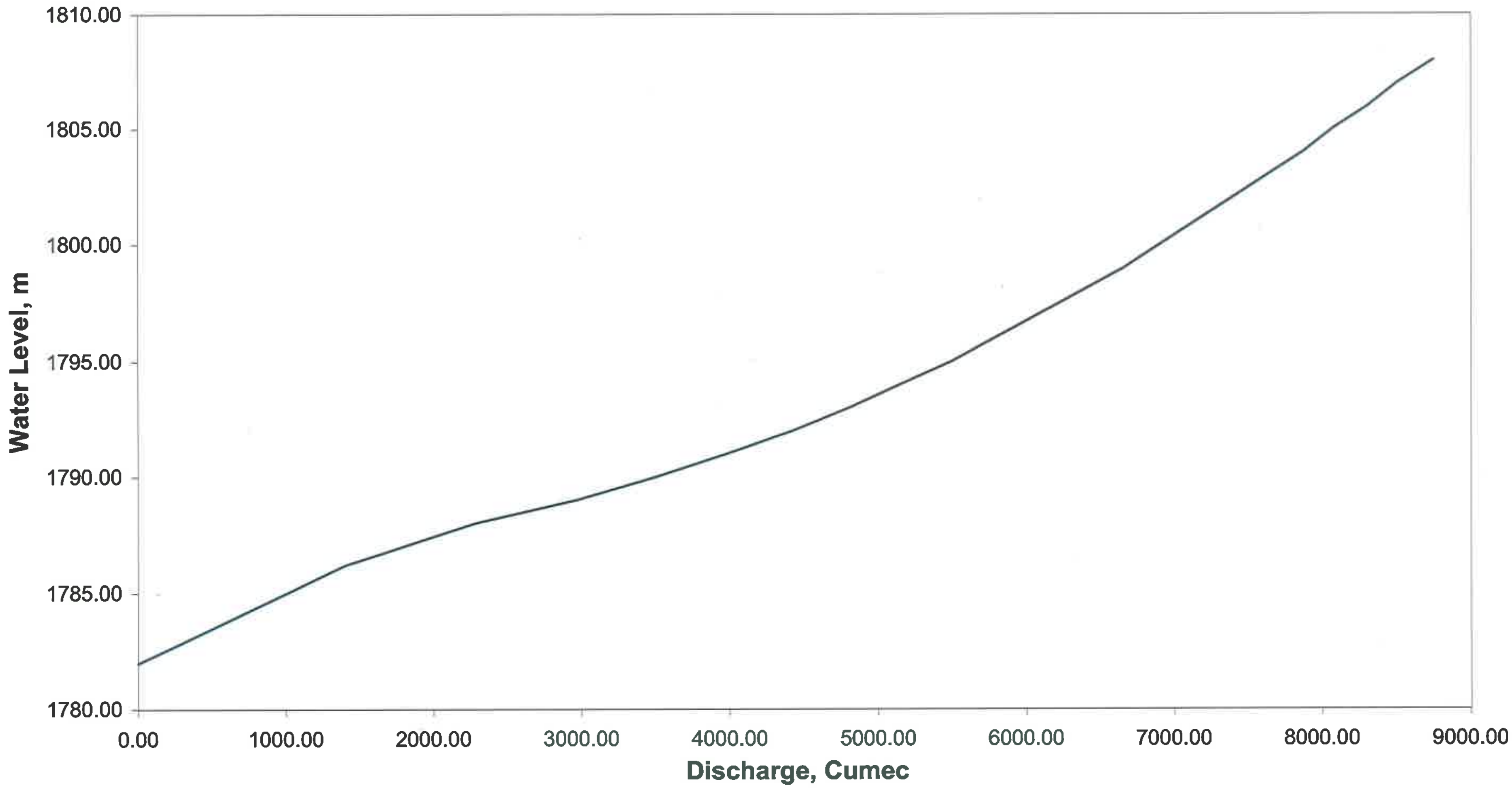


Fig. 9 - Spillway Rating Curve

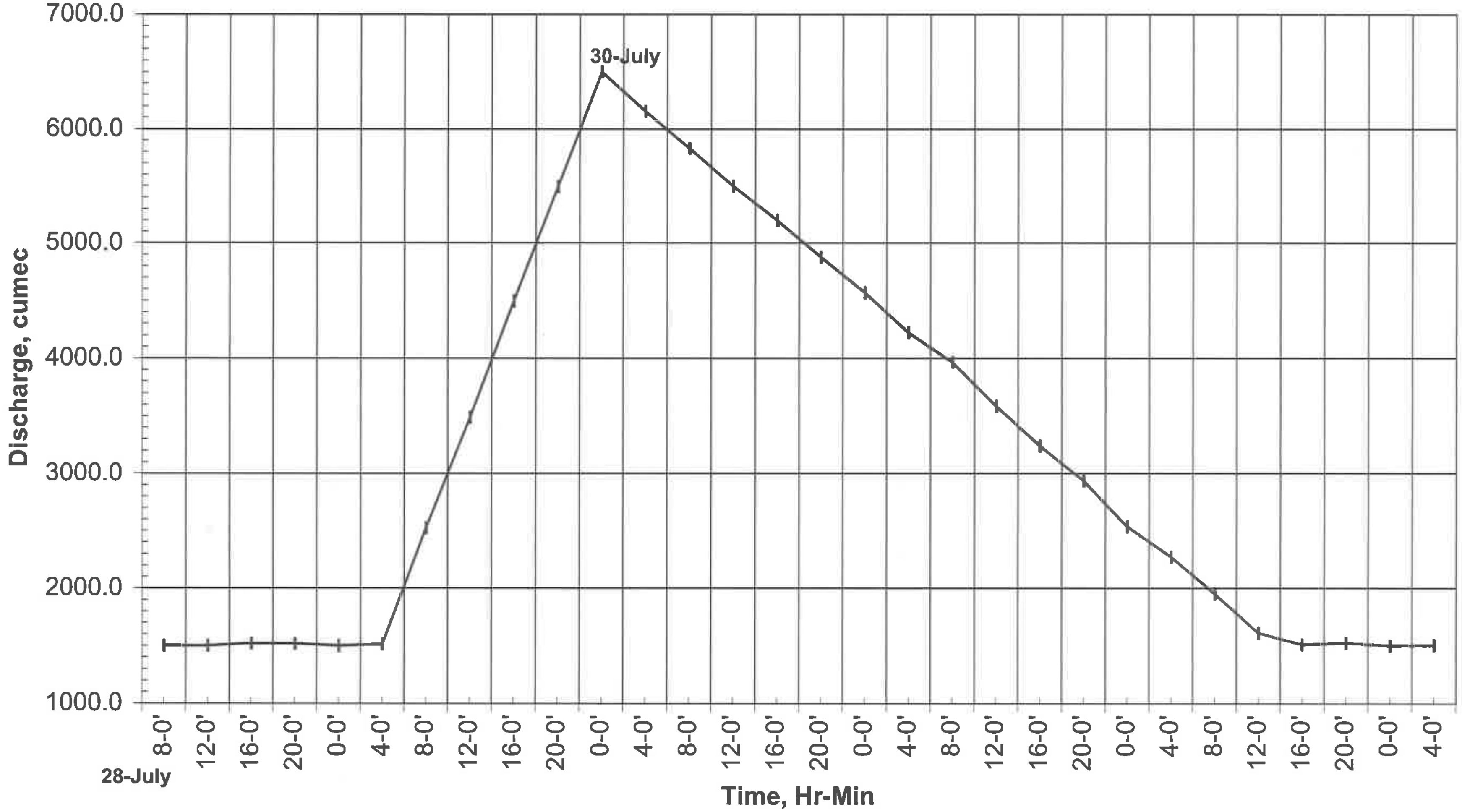


Fig. 10 - Design Flood Hydrograph

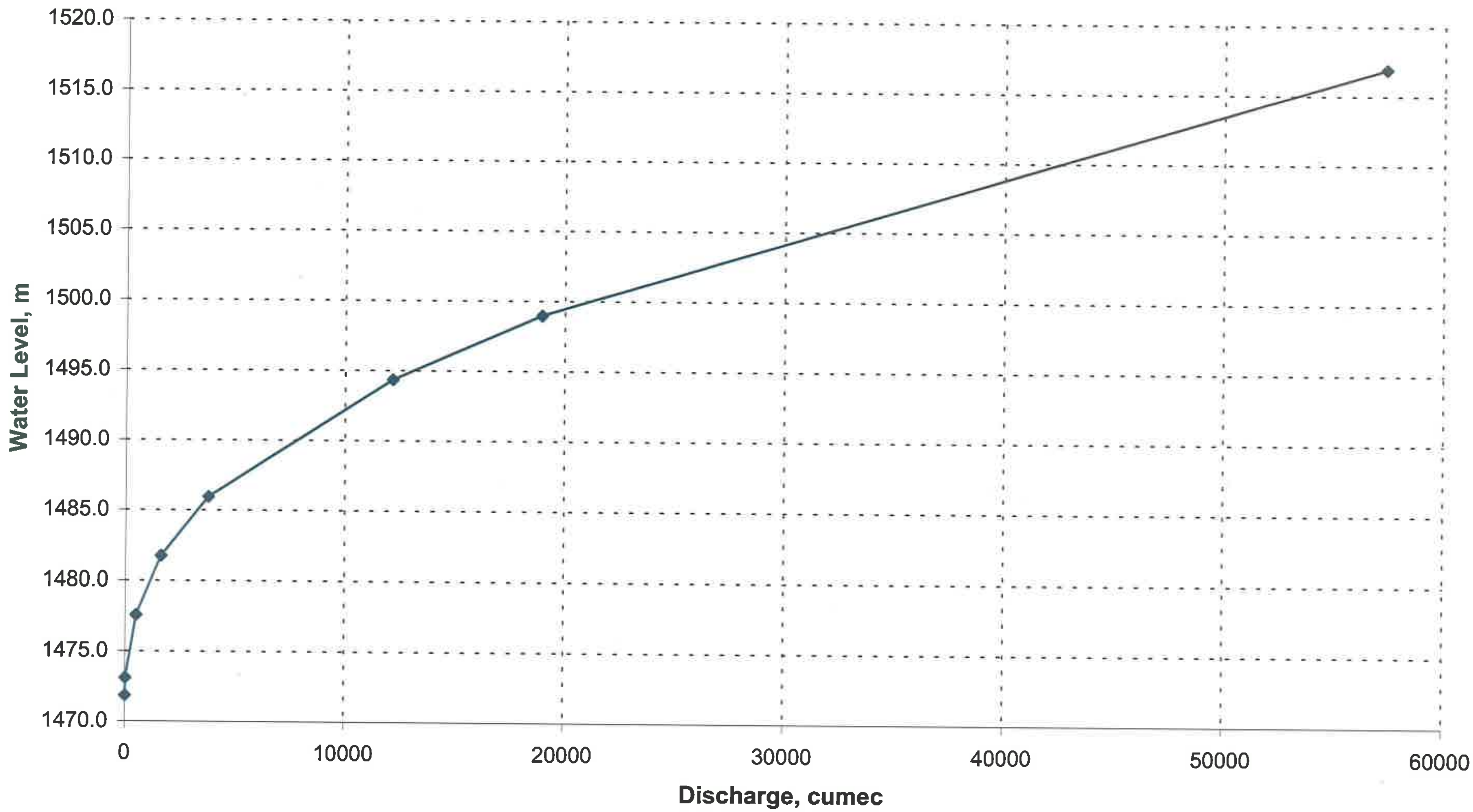


Fig. 11 - Q-H Relationship at Downstream Boundary at Chainage 22.00 km

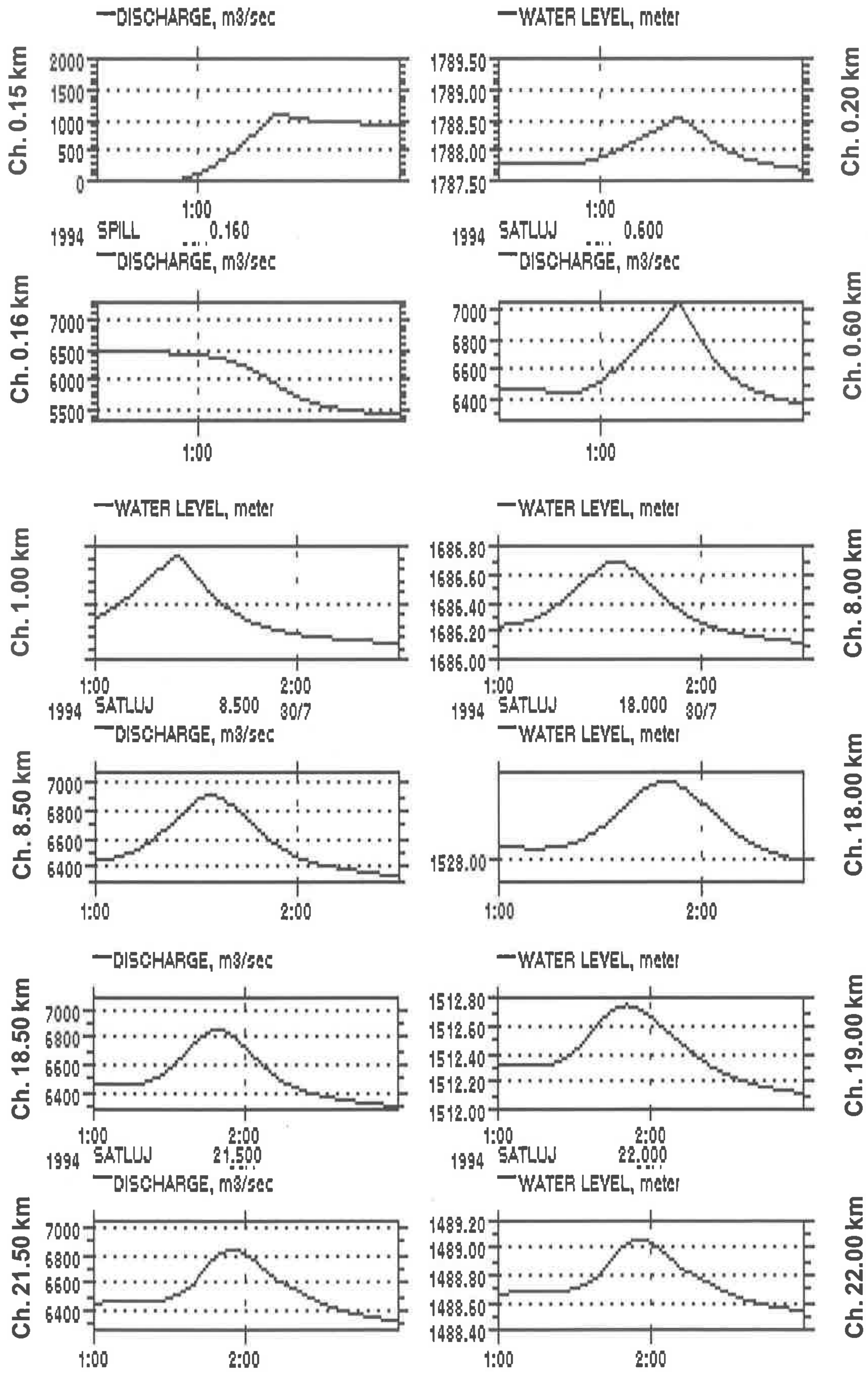


Fig. 12(a) - Flood Hydrographs and Water Level Curves for Breach Width = 15.0 m and Breach Time = 1.00 Hour

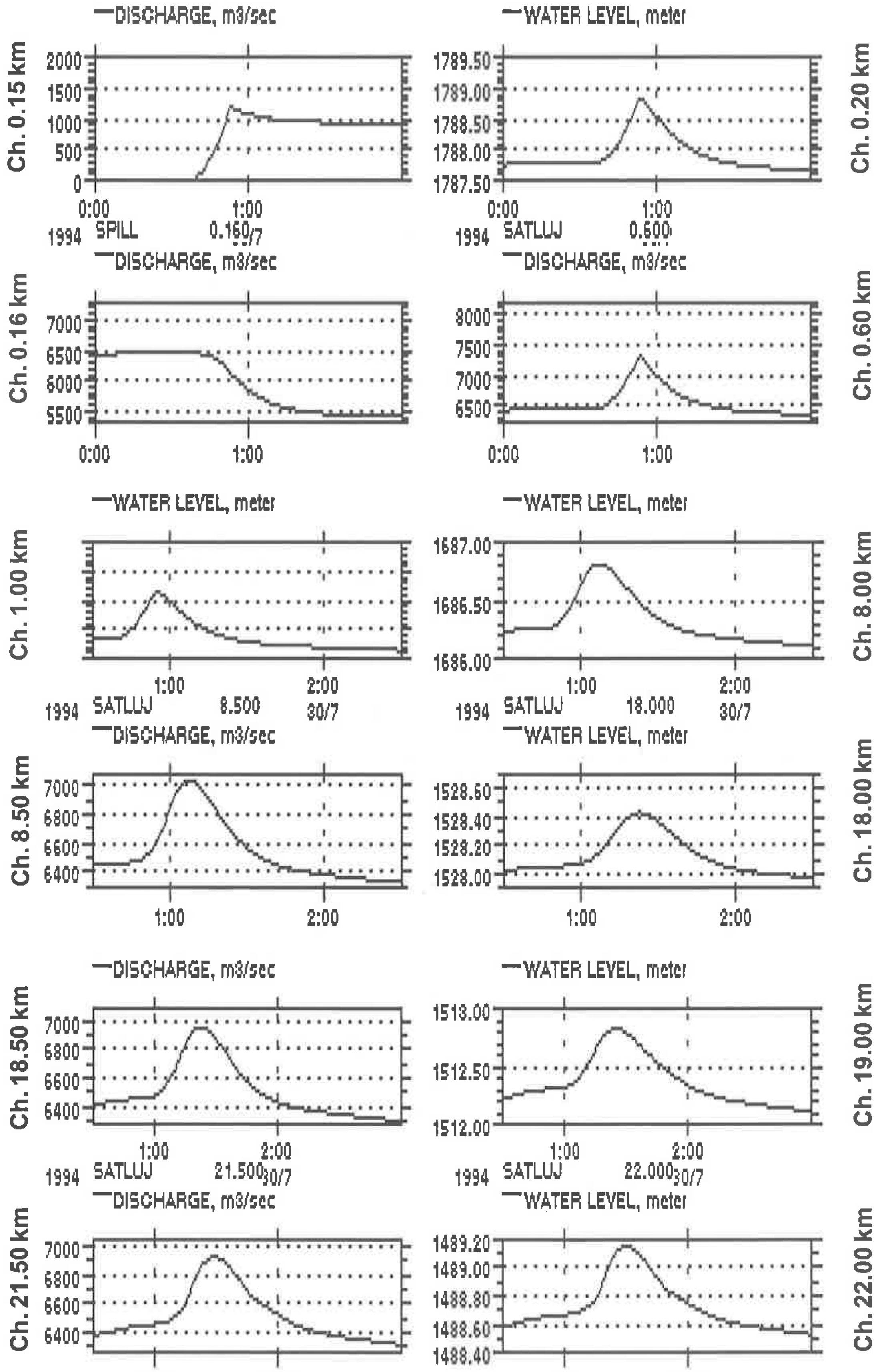


Fig. 12(b) - Flood Hydrographs and Water Level Curves for Breach Width = 15.0 m and Breach Time = 0.50 Hour

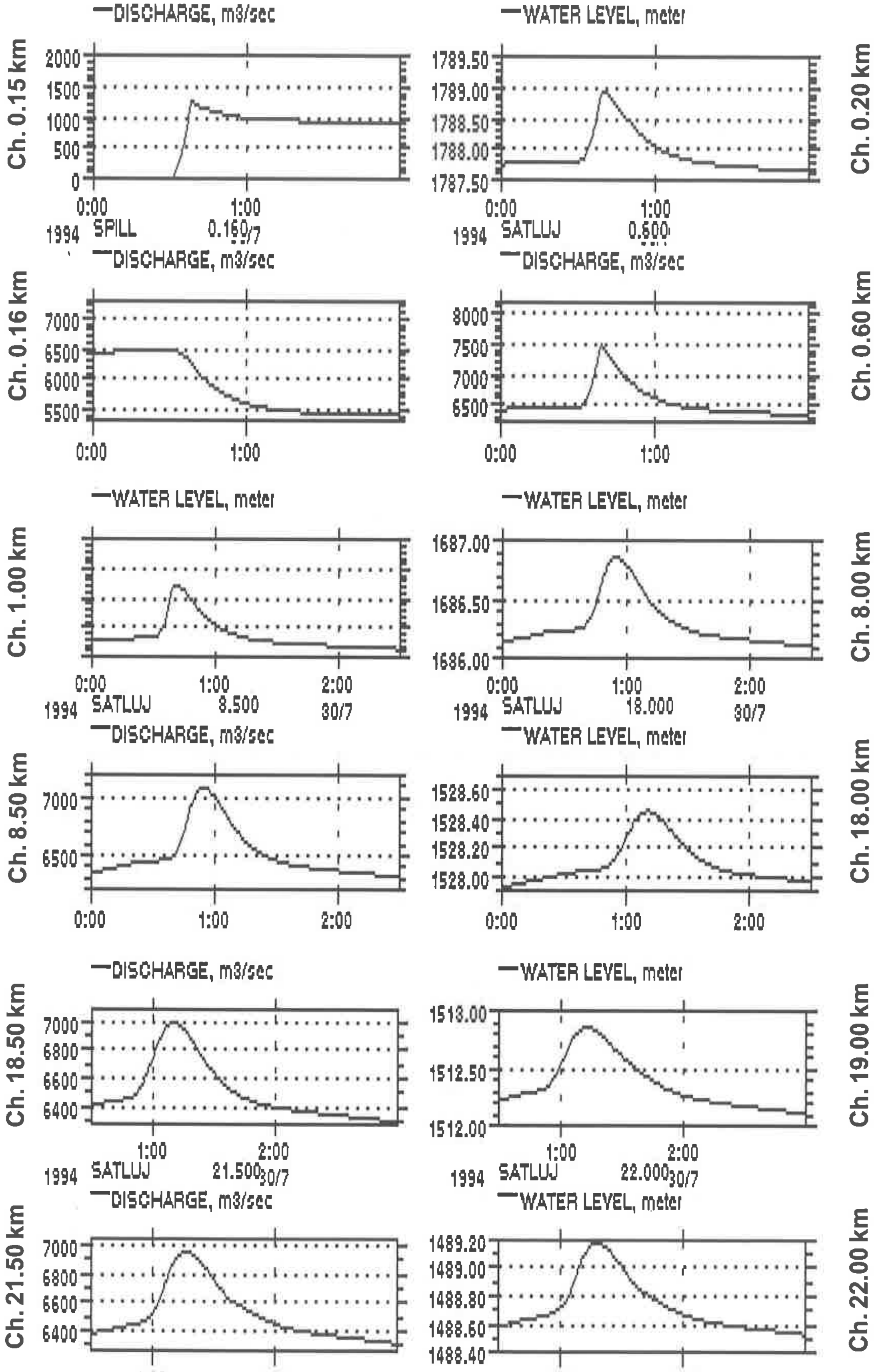


Fig. 12(c) - Flood Hydrographs and Water Level Curves for Breach Width = 15.0 m and Breach Time = 0.25 Hour

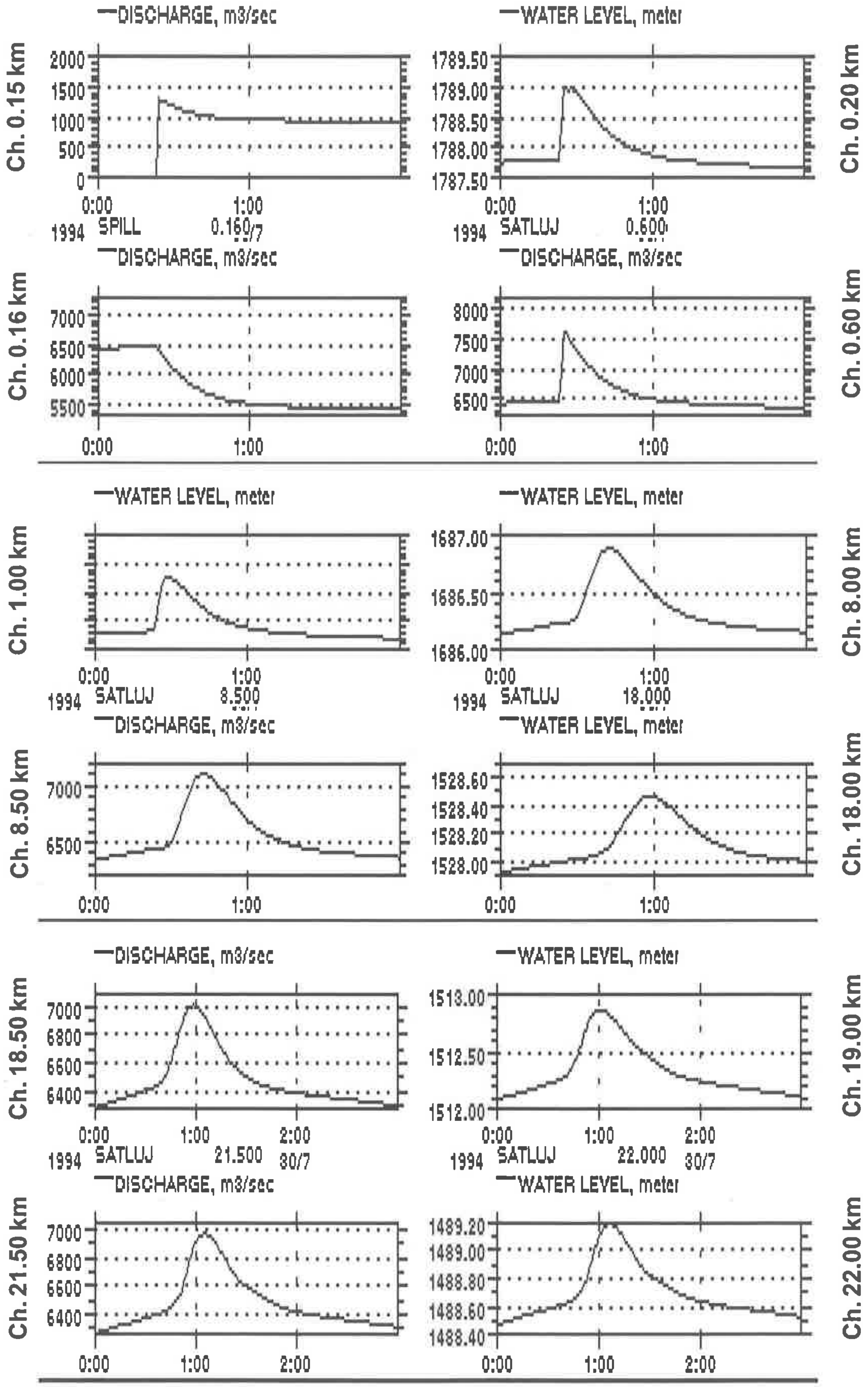


Fig. 12(d) - Flood Hydrographs and Water Level Curves for Breach Width = 15.0 m and Breach Time = 0.01 Hour

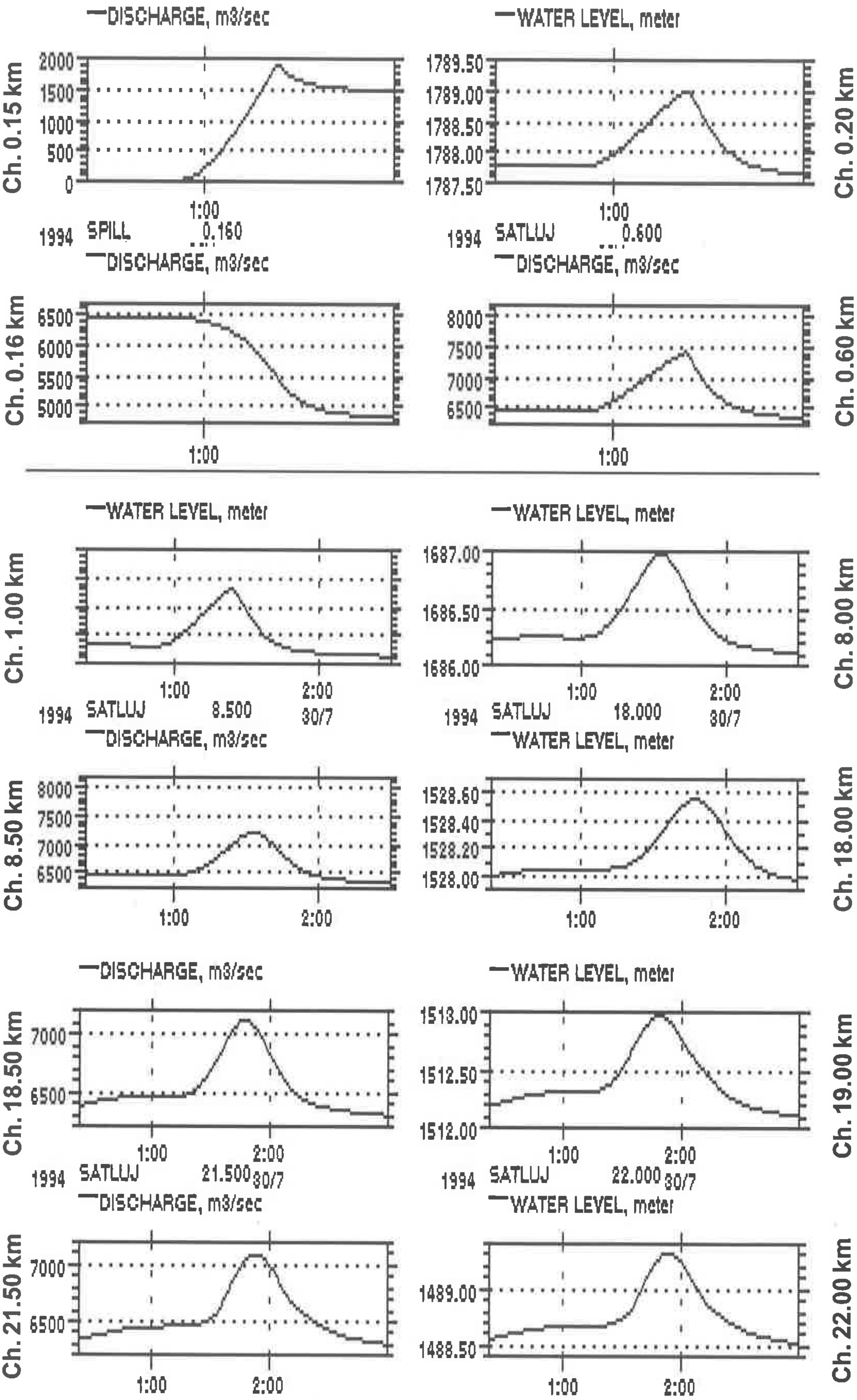


Fig. 13(a) - Flood Hydrographs and Water Level Curves for Breach Width = 30.0 m and Breach Time = 1.00 Hour

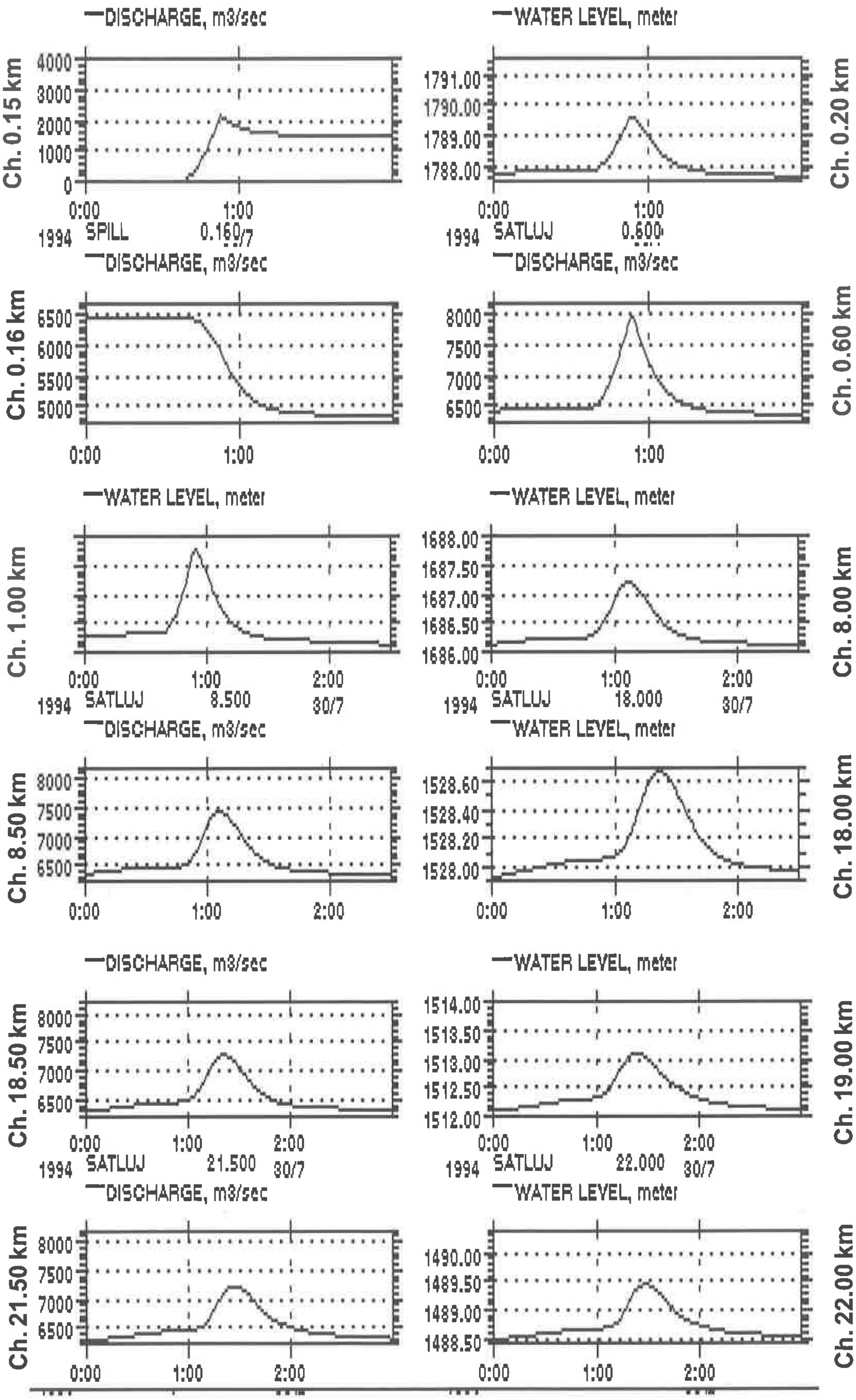


Fig. 13(b) - Flood Hydrographs and Water Level Curves for Breach Width = 30.0 m and Breach Time = 0.50 Hour

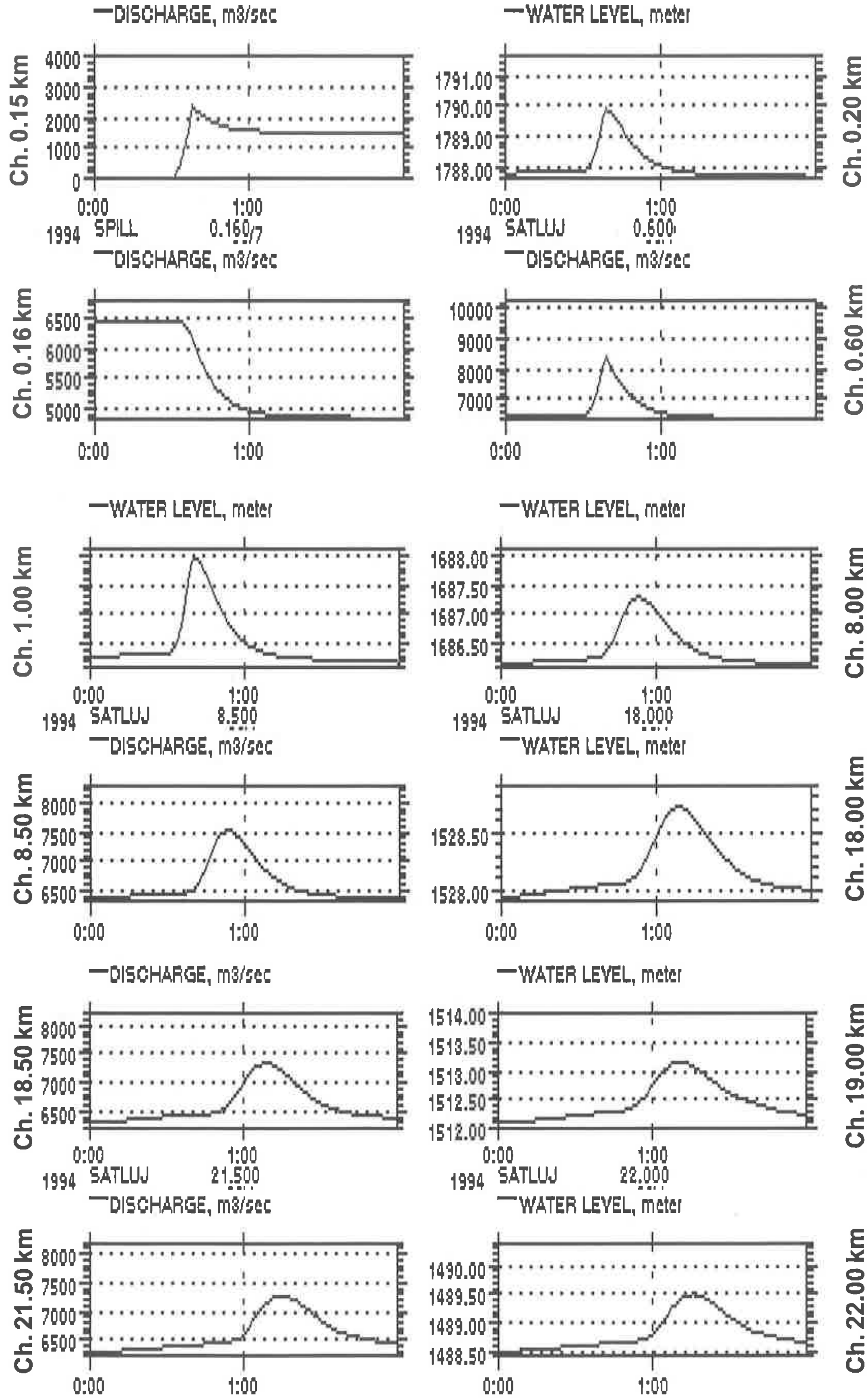


Fig. 13(c) - Flood Hydrographs and Water Level Curves for Breach Width = 30.0 m and Breach Time = 0.25 Hour

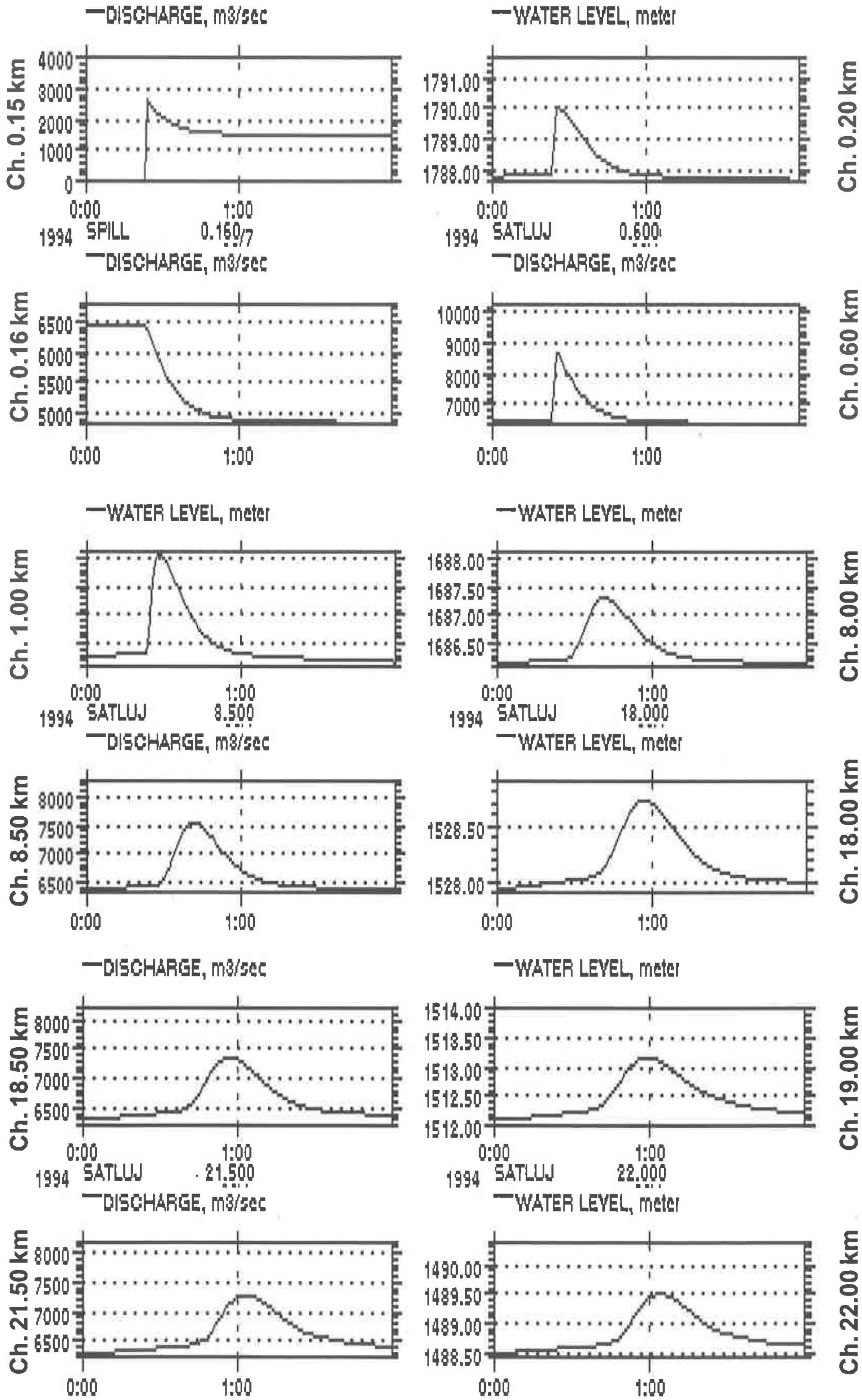


Fig. 13(d) - Flood Hydrographs and Water Level Curves for Breach Width = 30.0 m and Breach Time = 0.01 Hour

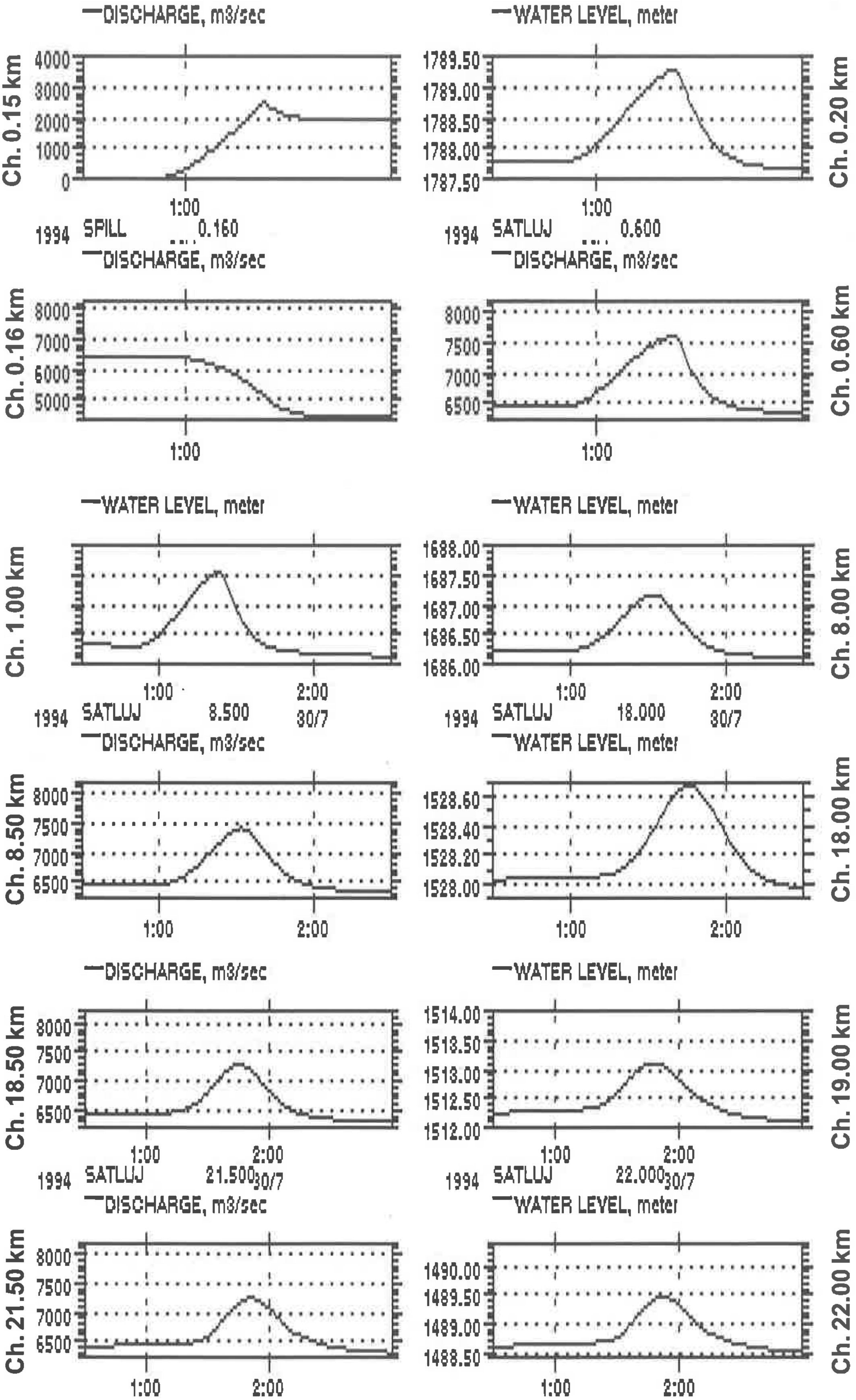


Fig. 14(a) - Flood Hydrographs and Water Level Curves for Breach Width = 45.0 m and Breach Time = 1.00 Hour

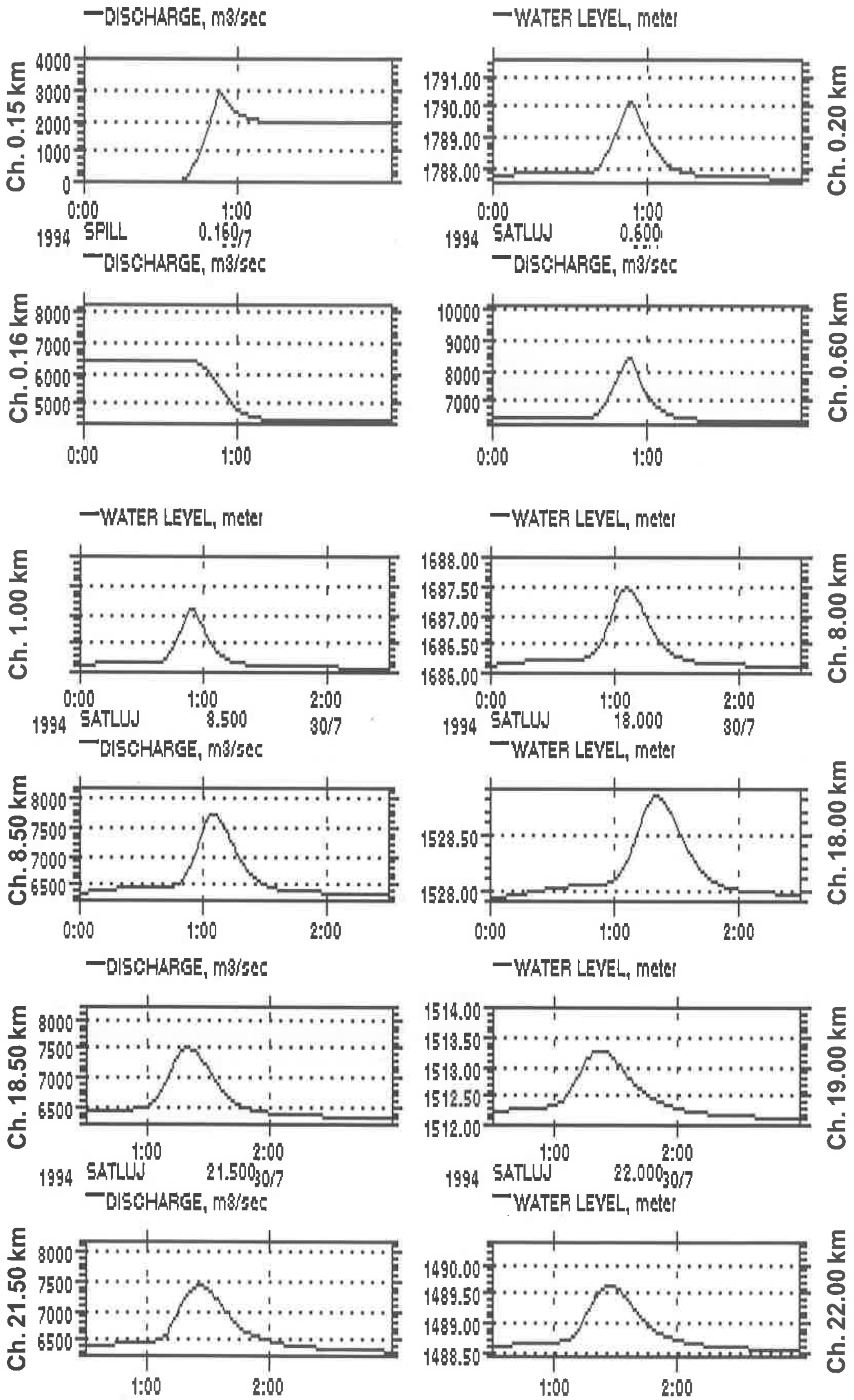


Fig. 14(b) - Flood Hydrographs and Water Level Curves for Breach Width = 45.0 m and Breach Time = 0.50 Hour

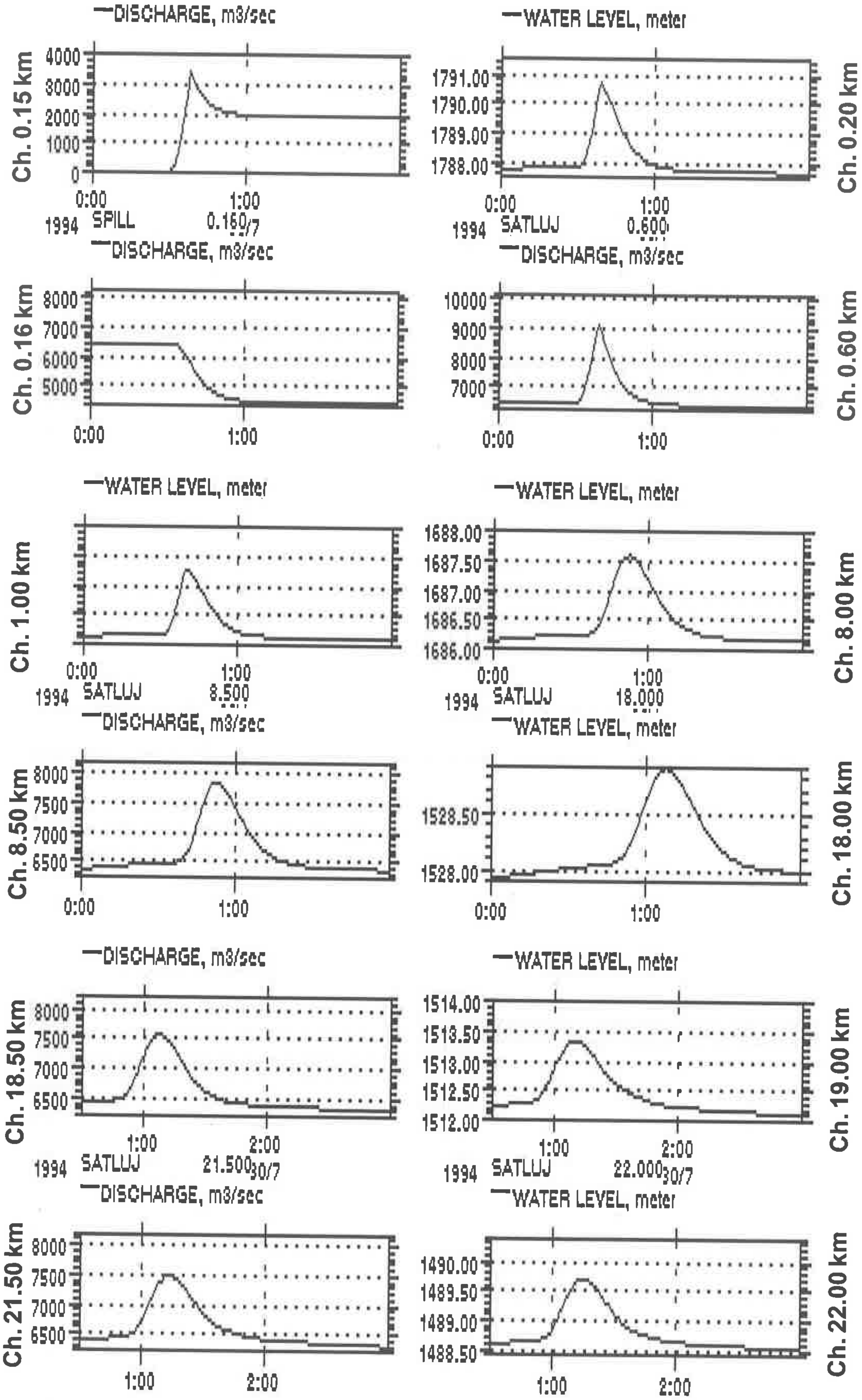


Fig. 14(c) - Flood Hydrographs and Water Level Curves for Breach Width = 45.0 m and Breach Time = 0.25 Hour

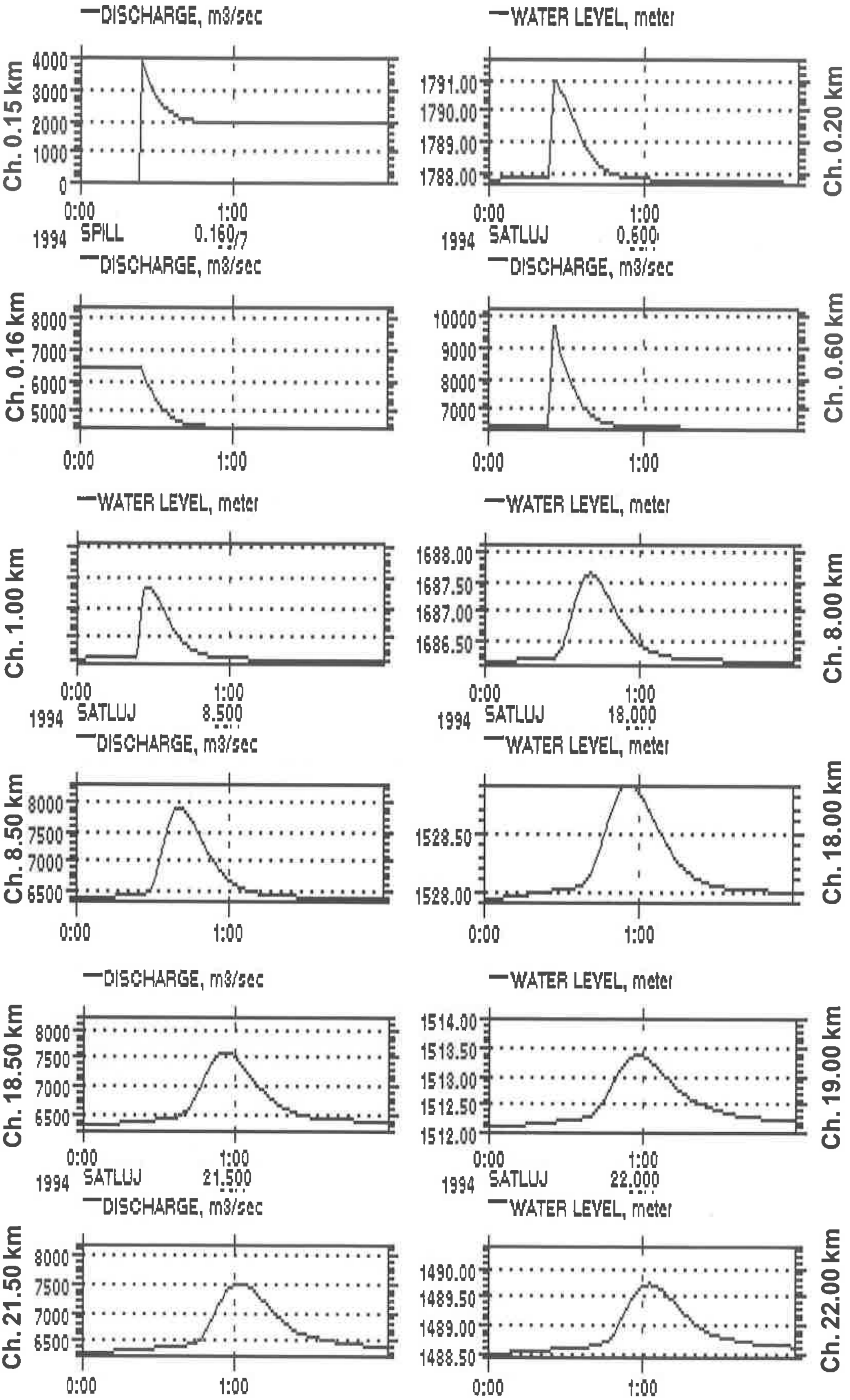


Fig. 14(d) - Flood Hydrographs and Water Level Curves for Breach Width = 45.0 m and Breach Time = 0.01 Hour

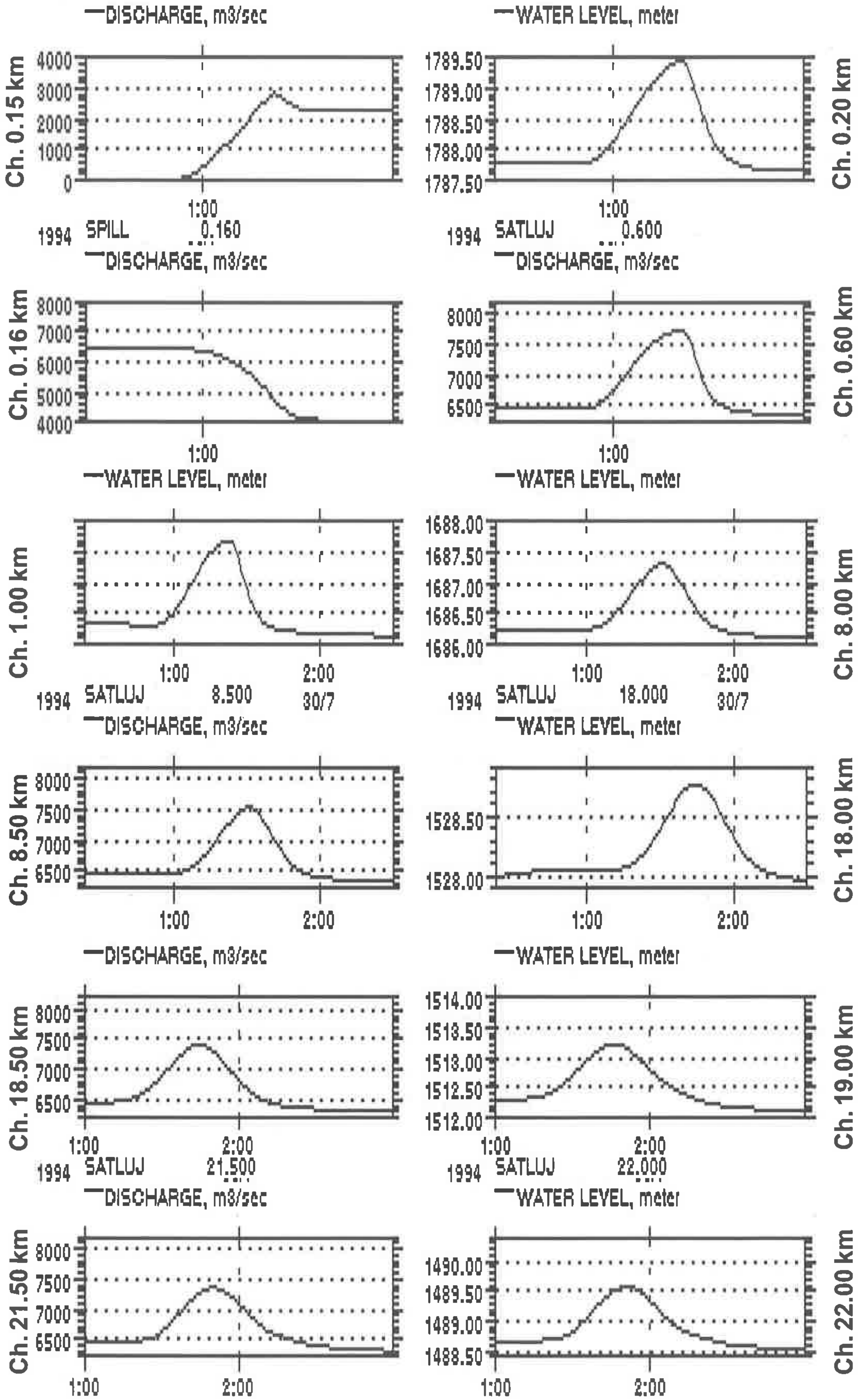


Fig. 15(a) - Flood Hydrographs and Water Level Curves for Breach Width = 60.0 m and Breach Time = 1.00 Hour

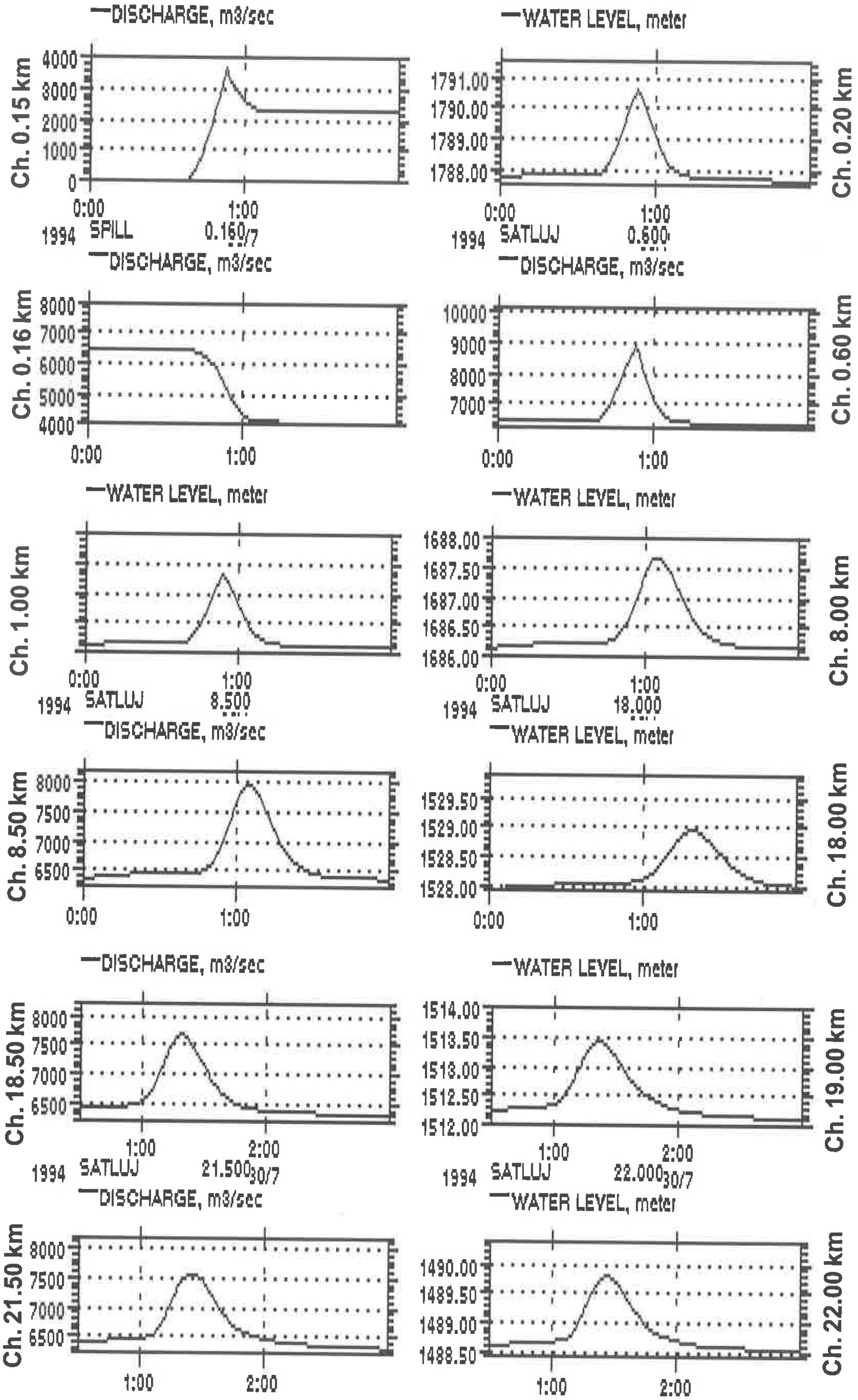


Fig. 15(b) - Flood Hydrographs and Water Level Curves for Breach Width = 60.0 m and Breach Time = 0.50 Hour

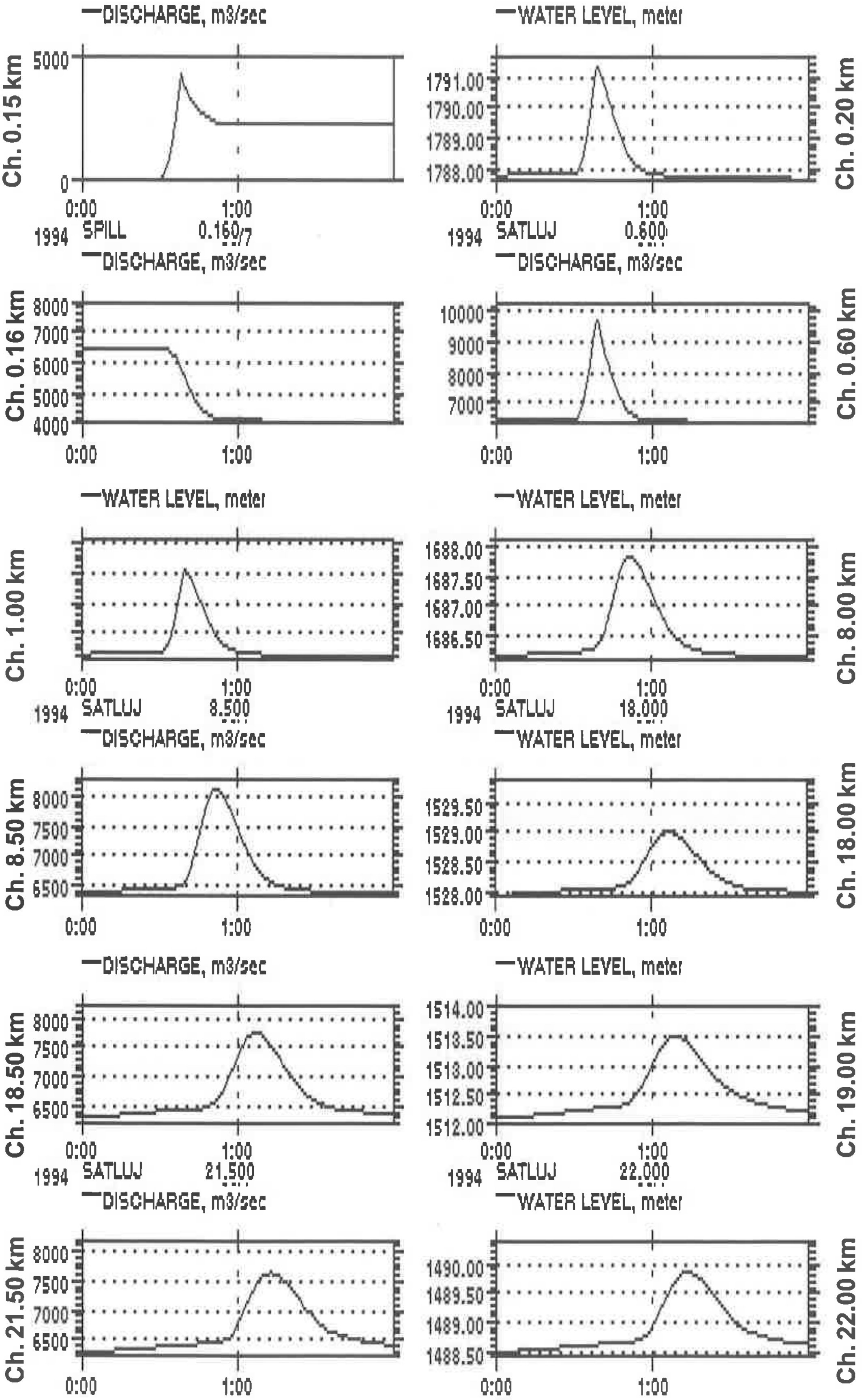


Fig. 15(c) - Flood Hydrographs and Water Level Curves for Breach Width = 60.0 m and Breach Time = 0.25 Hour

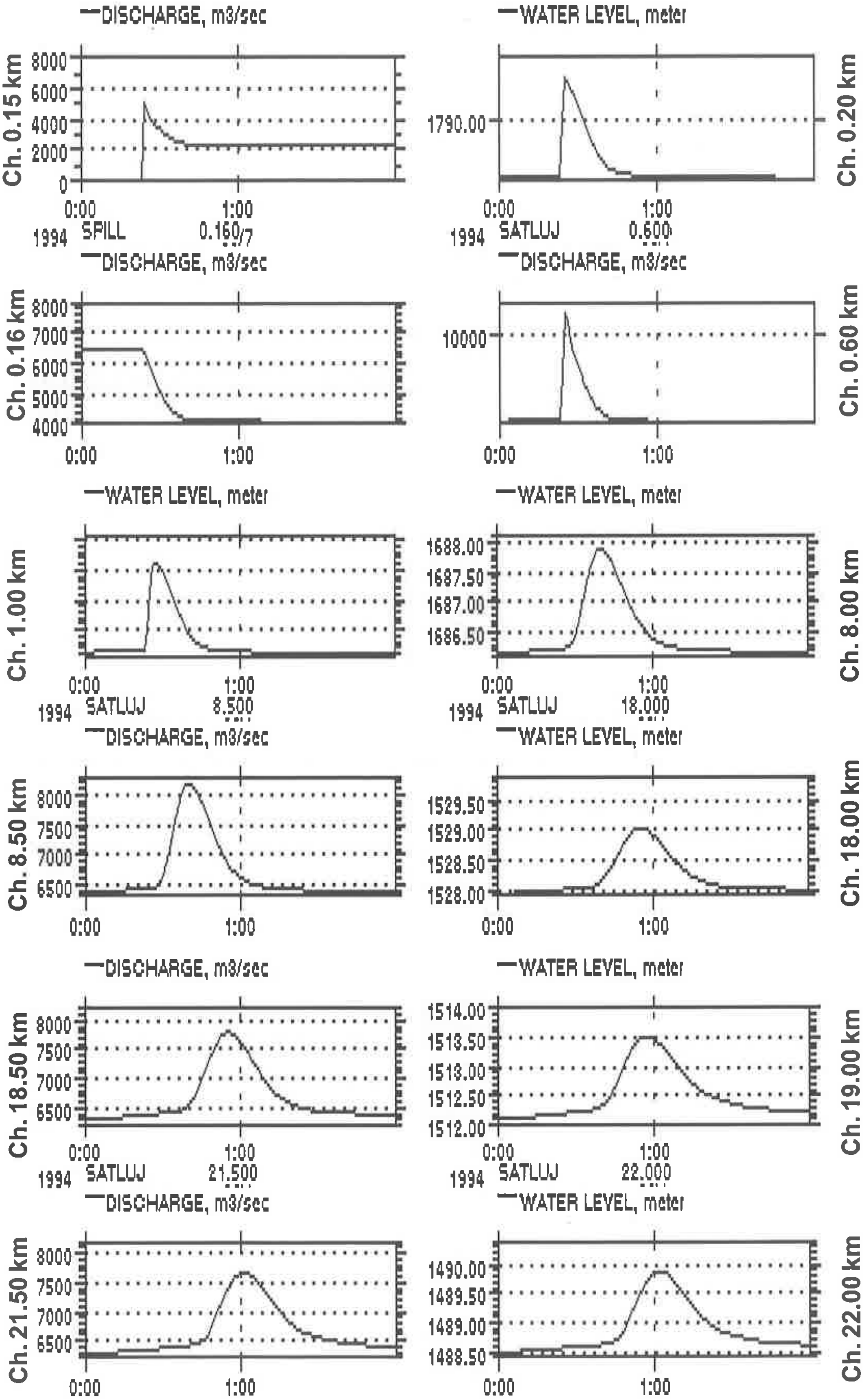


Fig. 15(d) - Flood Hydrographs and Water Level Curves for Breach Width = 60.0 m and Breach Time = 0.01 Hour

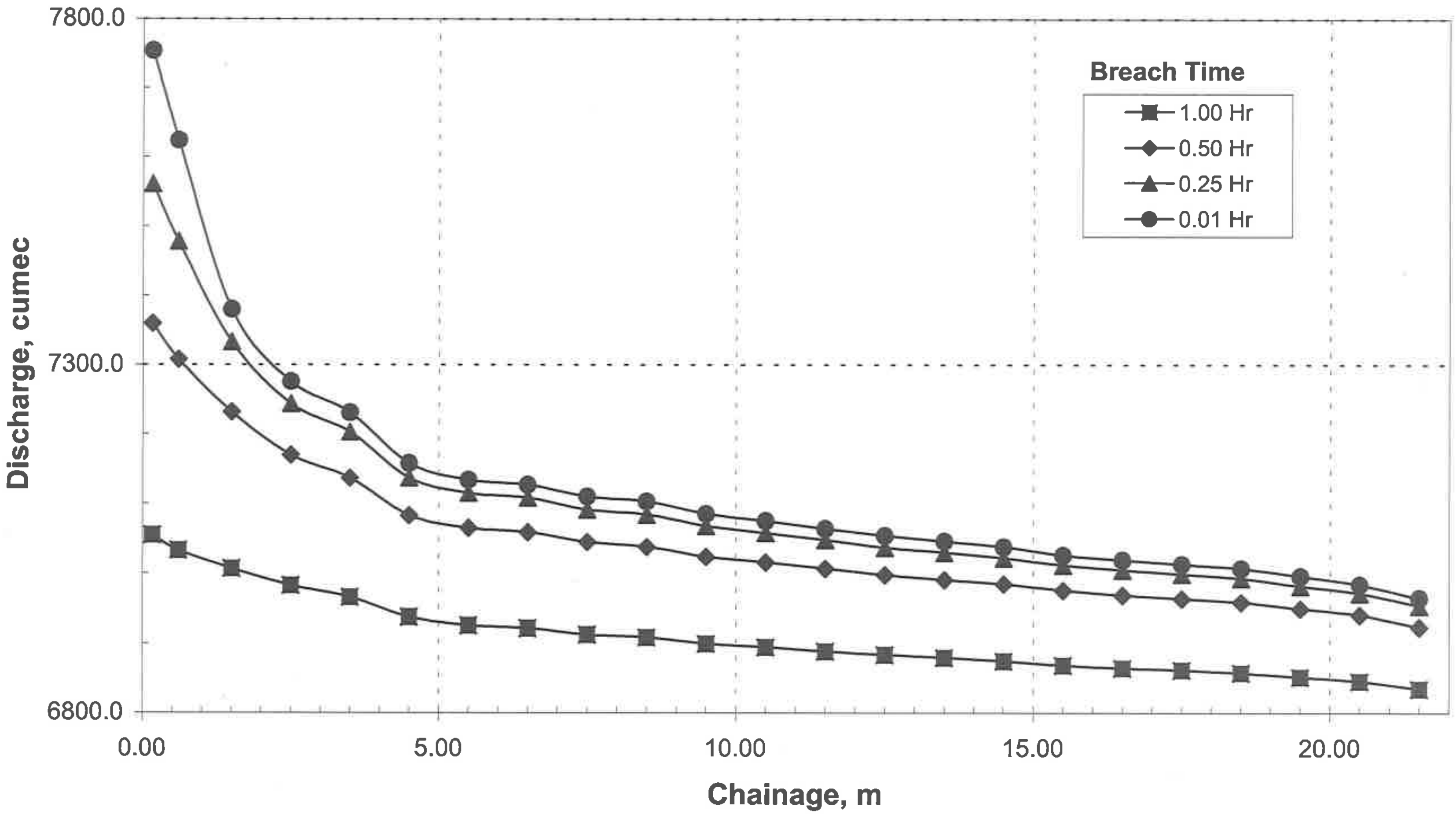


Fig. 16 - Variation of Maximum Discharge for Different Breach Times for Breach Width = 15.0 m

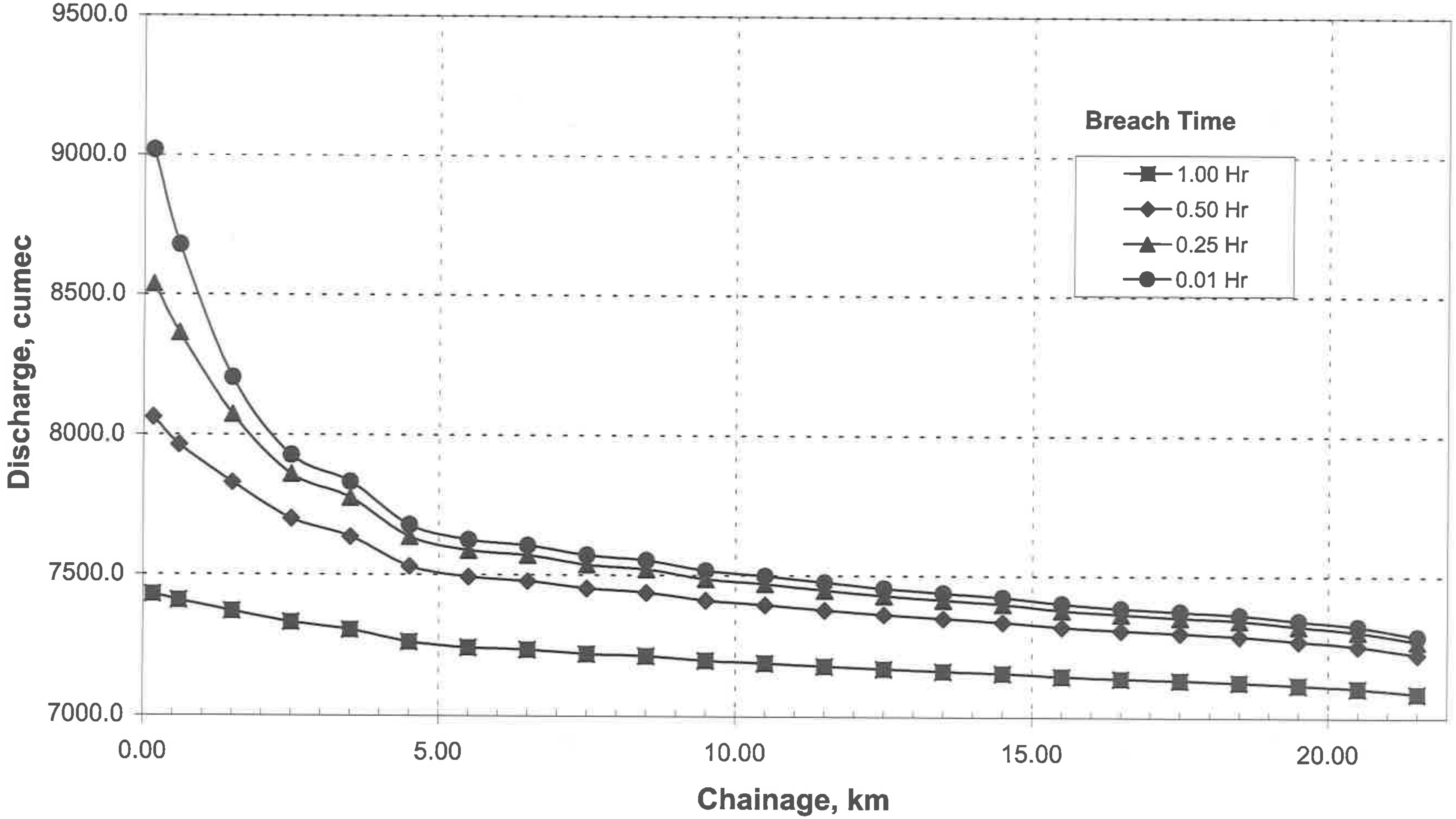


Fig. 17 - Variation of Maximum Discharge with Different Breach Times for Breach Width = 30.0 m

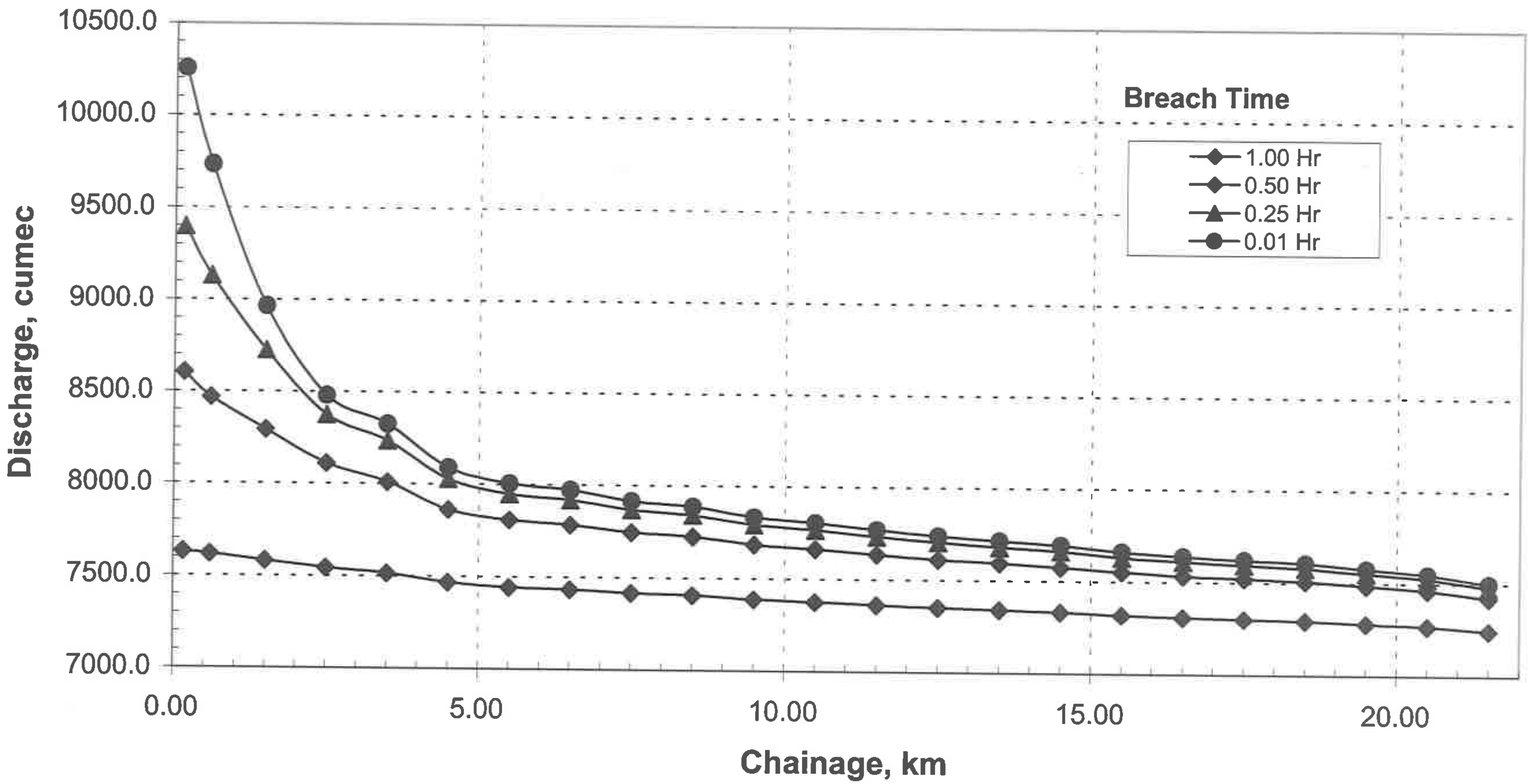


Fig. 18 - Variation of Maximum Discharge with Diiferent Breach Times for Breach Width = 45.0 m

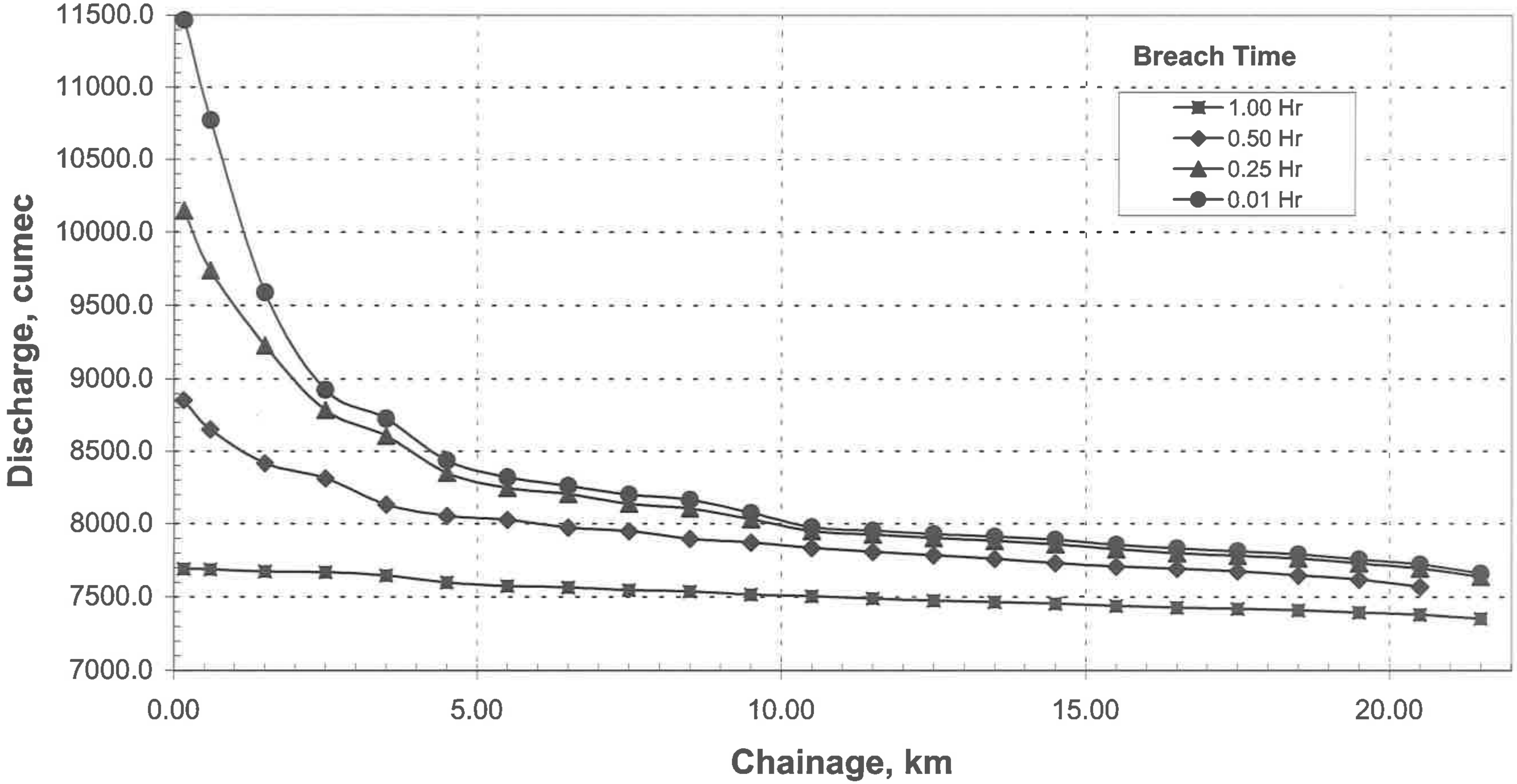


Fig 19 - Variation of Maximum Discharge with Different Breach Times for Breach Width = 60.0 m

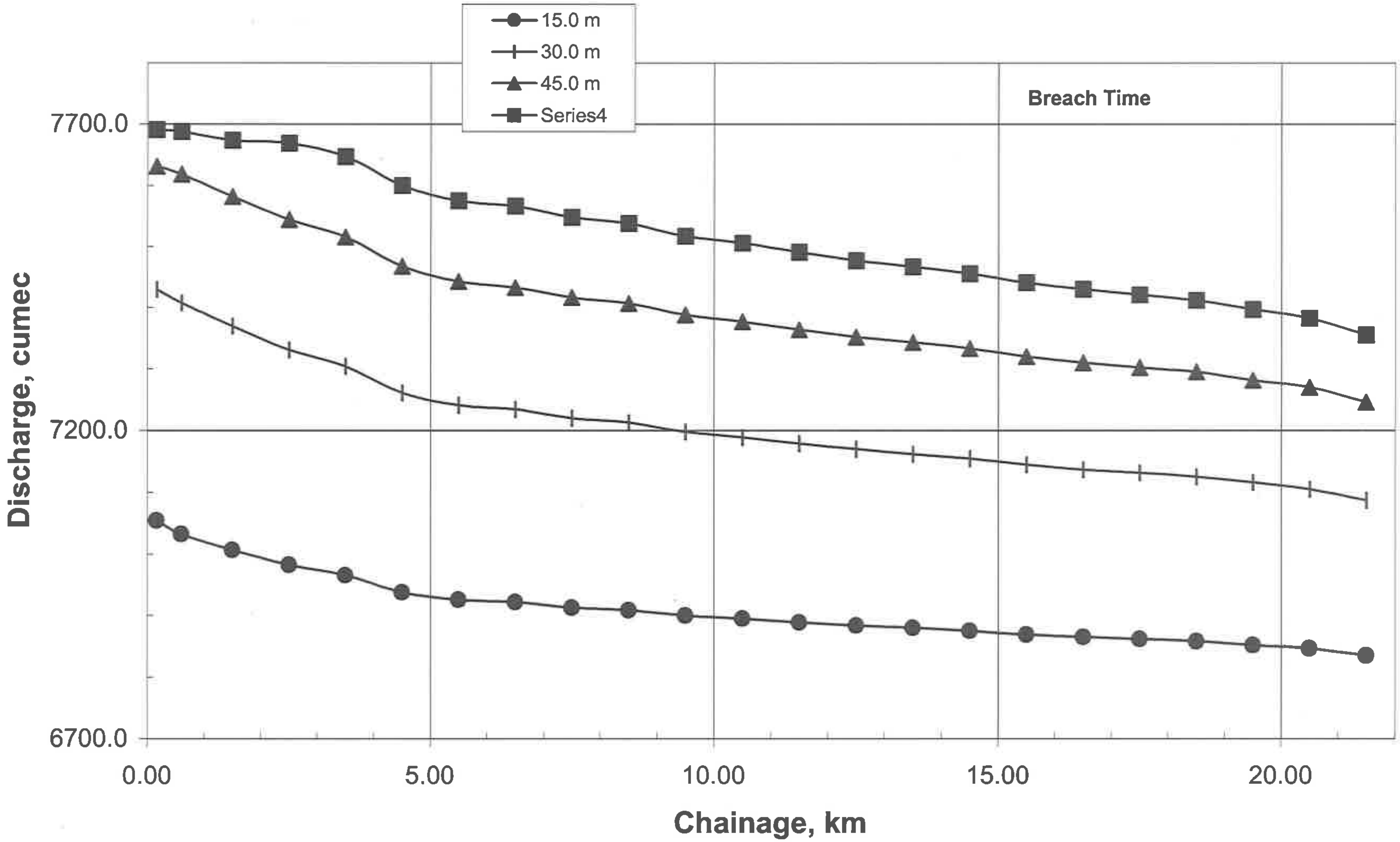


Fig. 20 - Variation of Maximum Discharge for Different Breach Widths for Breach Time =1.0 Hour

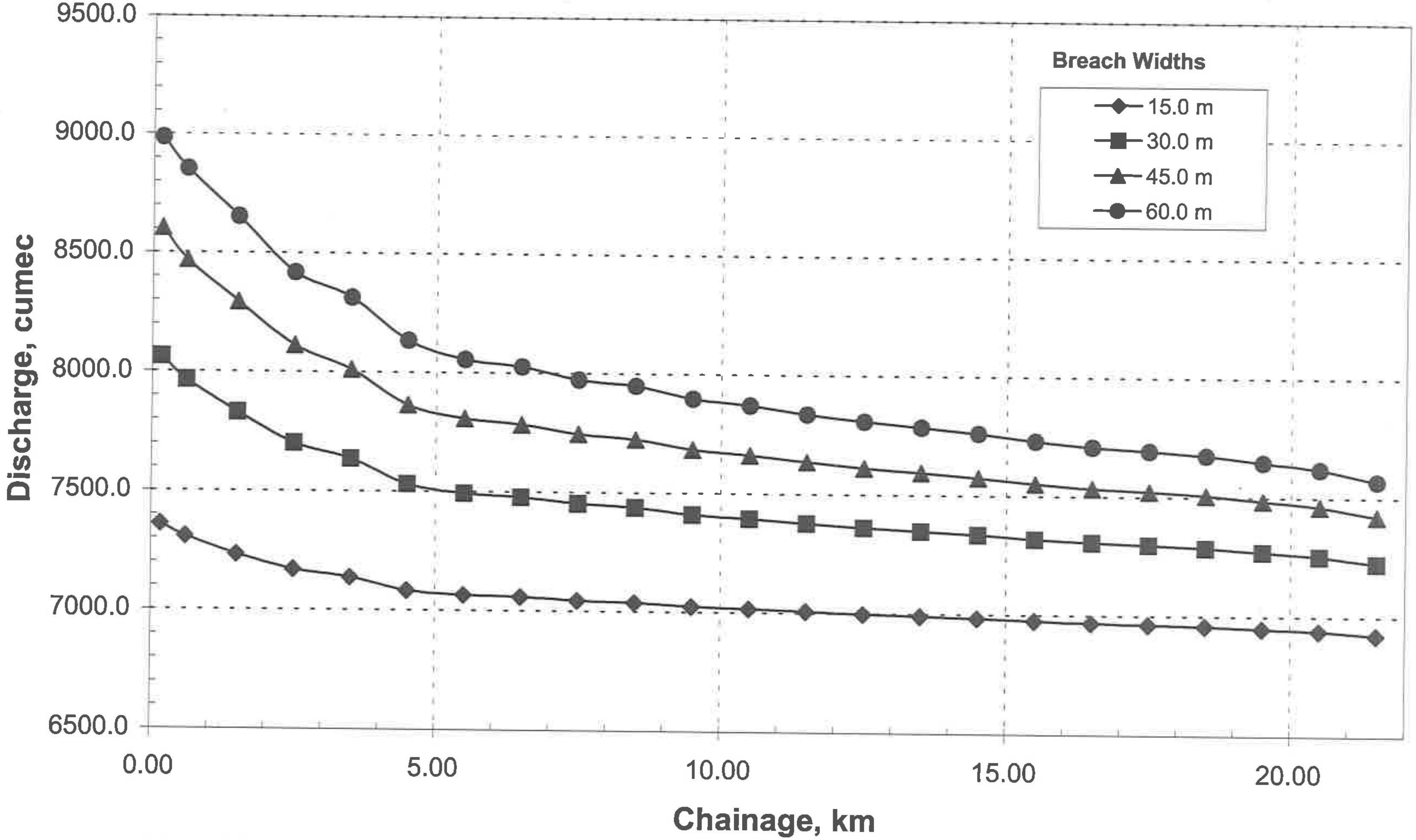


Fig. 21 - Variation of Maximum Discharge for Different Breach Widths for Breach Time = 0.50 Hour

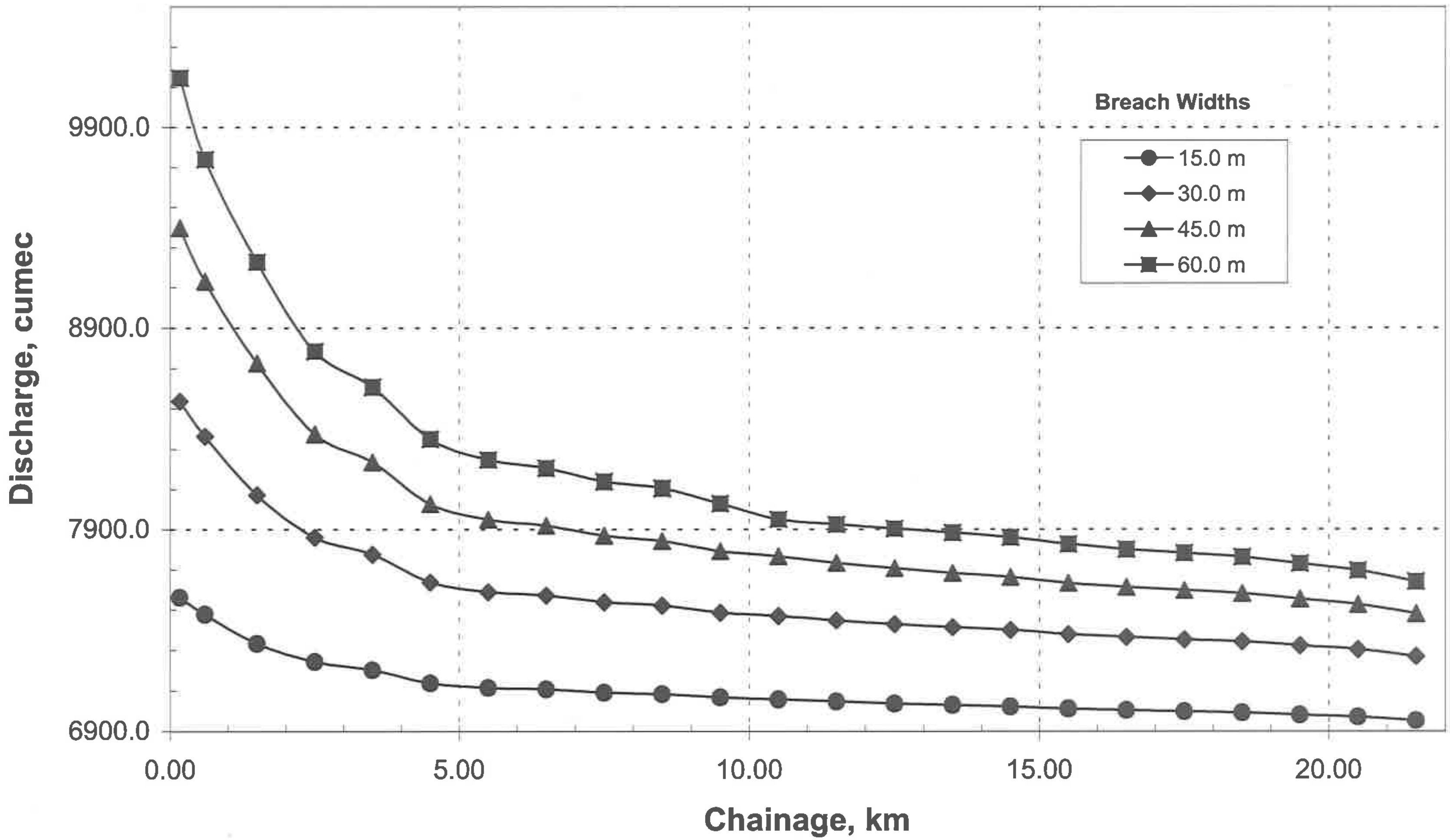


Fig. 22 - Variation of Maximum Discharge for Different Breach Widths for Breach Time = 0.25 Hour

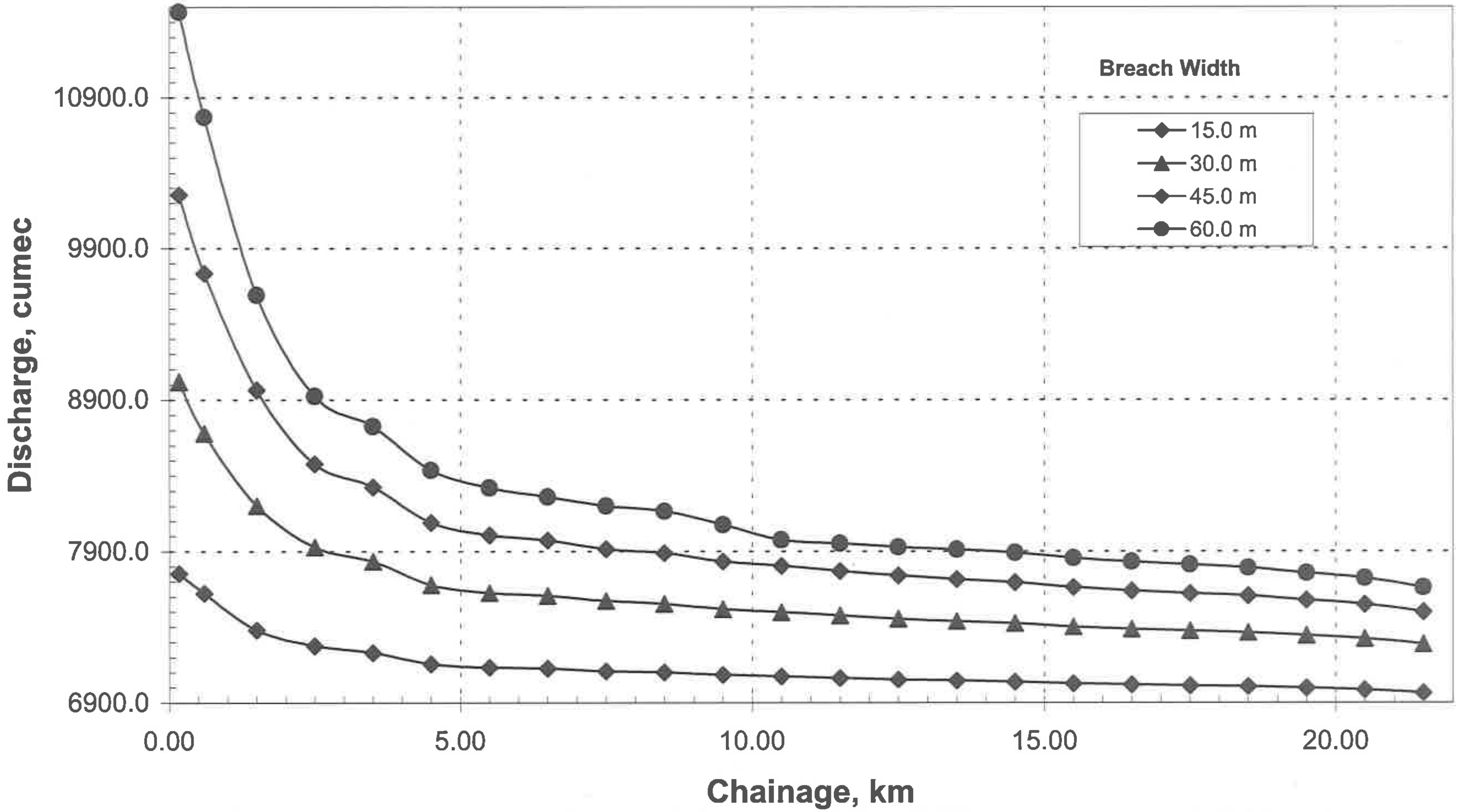


Fig. 23 - Variation of Maximum Discharge for Different Breach Widths for Breach Time = 0.01 Hour

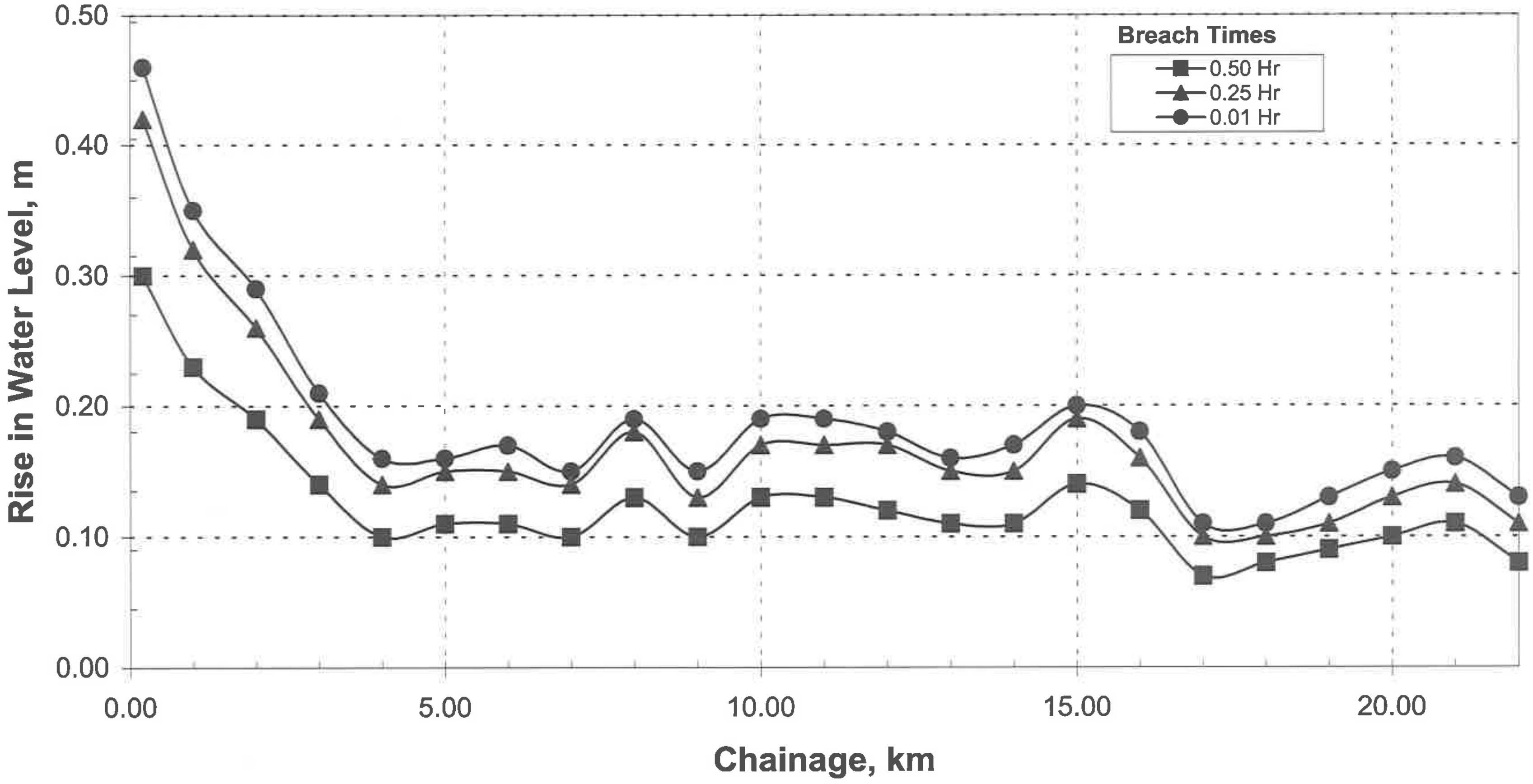


Fig. 24 - Rise in Maximum Water Levels w.r.t. 1.0 Hr Breach Time for Diiferent Breach Times(Breach Width = 15.0 m)

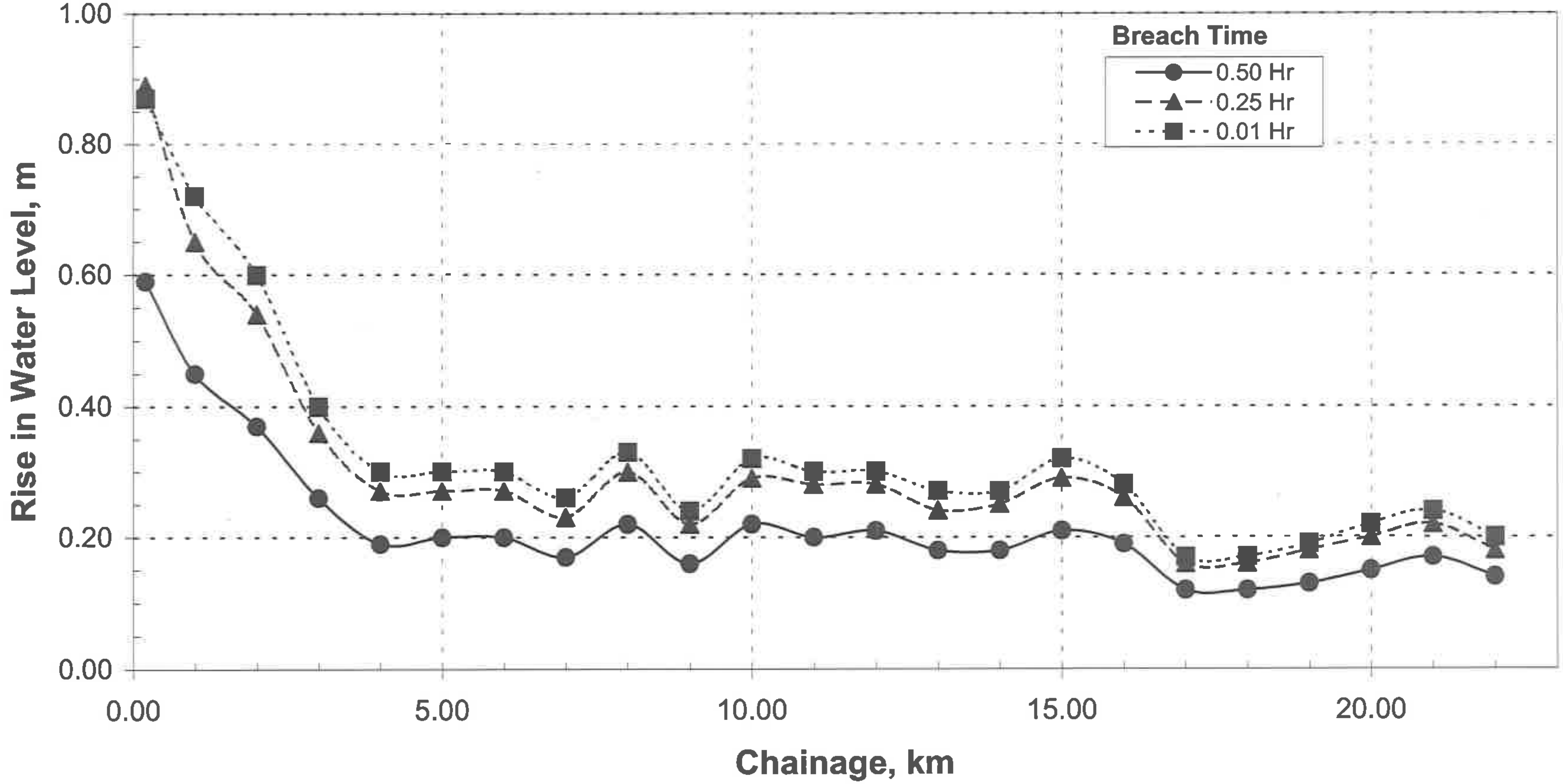


Fig. 25 - Rise in Maximum Water Levels w.r.t. 1.0 Hr Breach Time for Different Breach Times(Breach Width = 30.0 m)

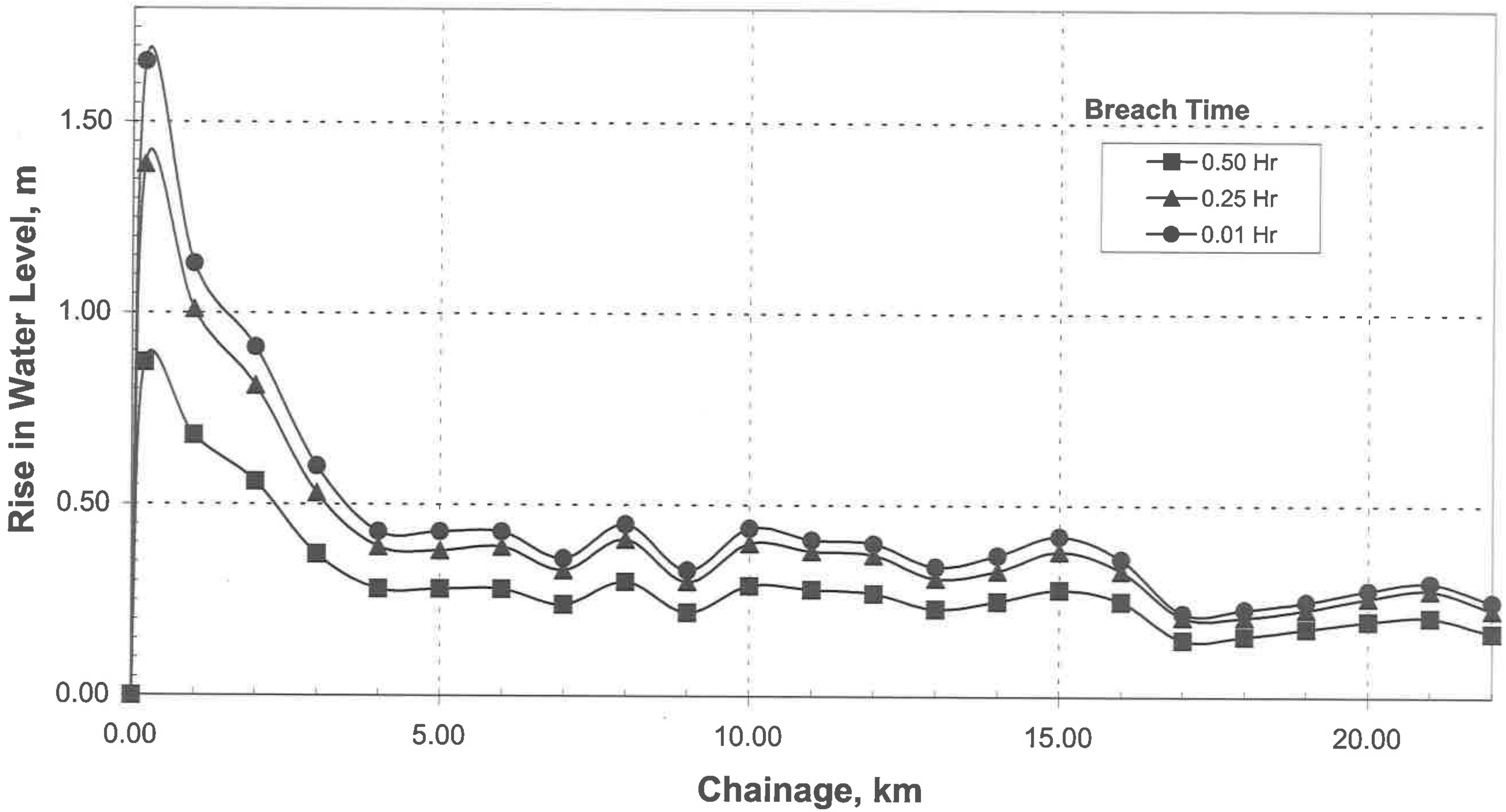


Fig. 26 - Rise in Maximum Water Levels w.r.t. 1.0 Hr Breach Time for Different Breach Times (Breach Width = 45.0 m)

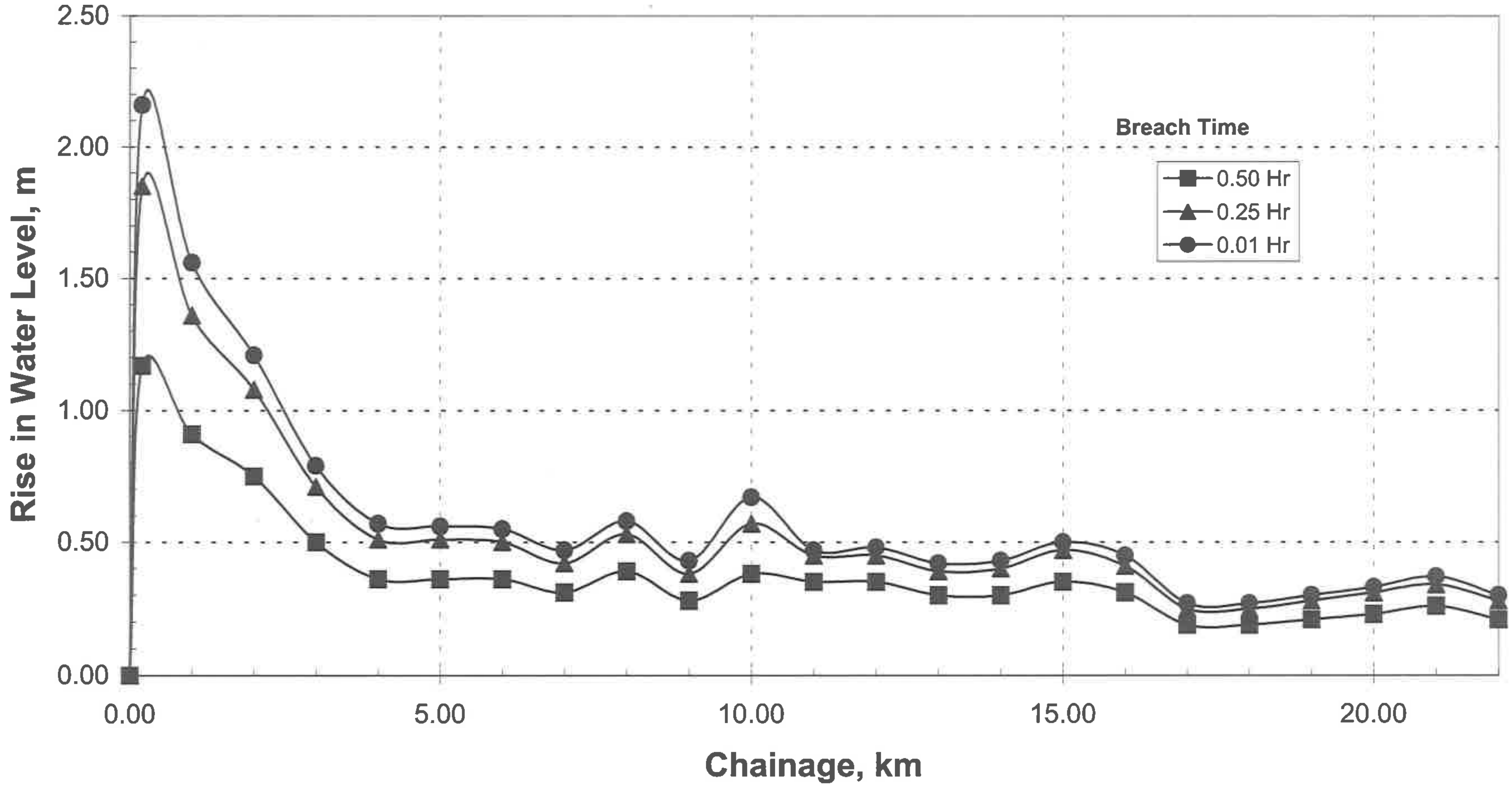


Fig. 27 - Rise in Maximum Water Levels w.r.t. 1.0 Hr Breach Time for Different Breach Times (Breach Width = 60.0 m)

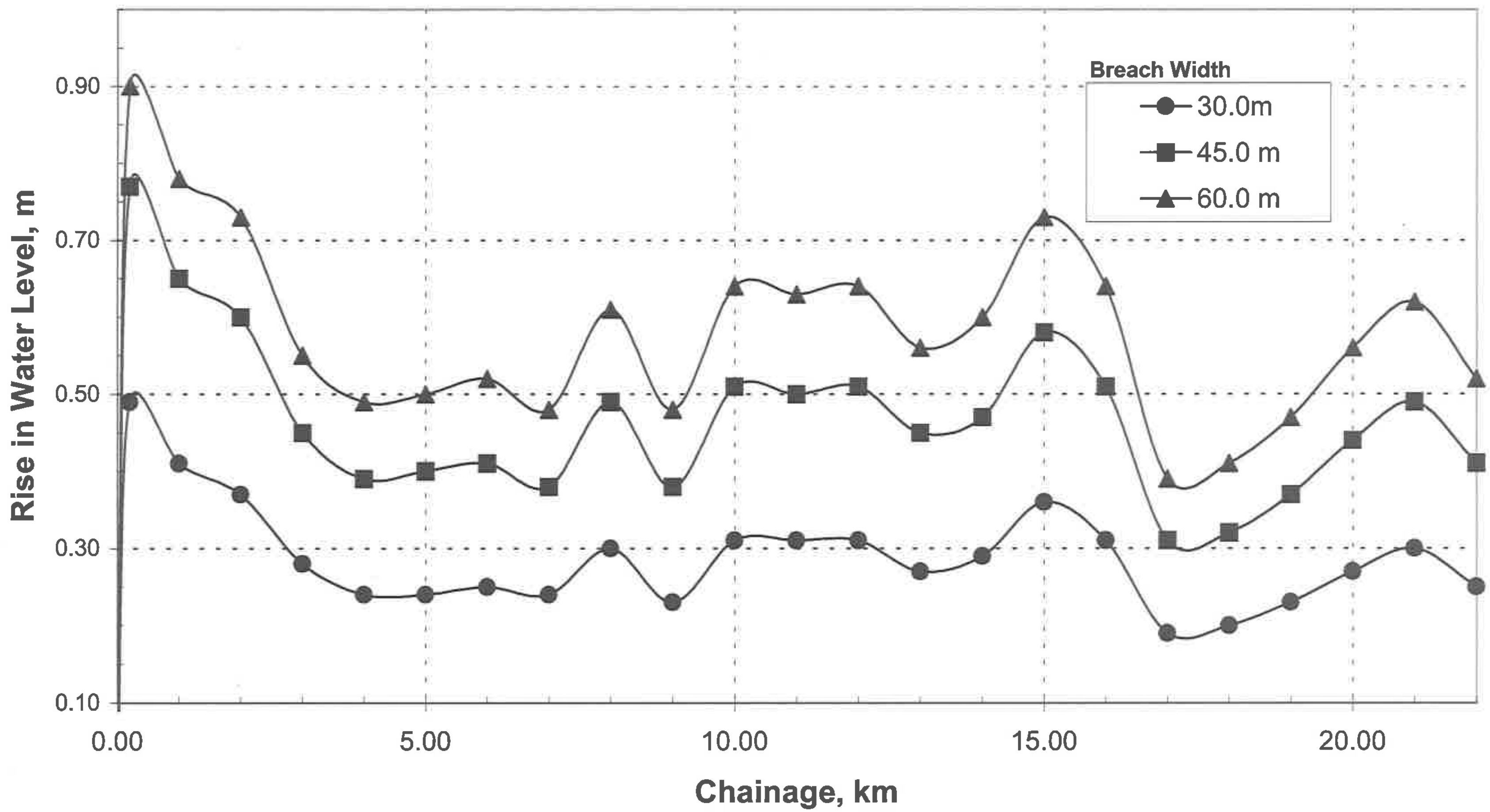


Fig. 28 - Rise in Maximum Water Levels w.r.t. 15.0 m Breach Width for Breach Time = 1.00 Hour

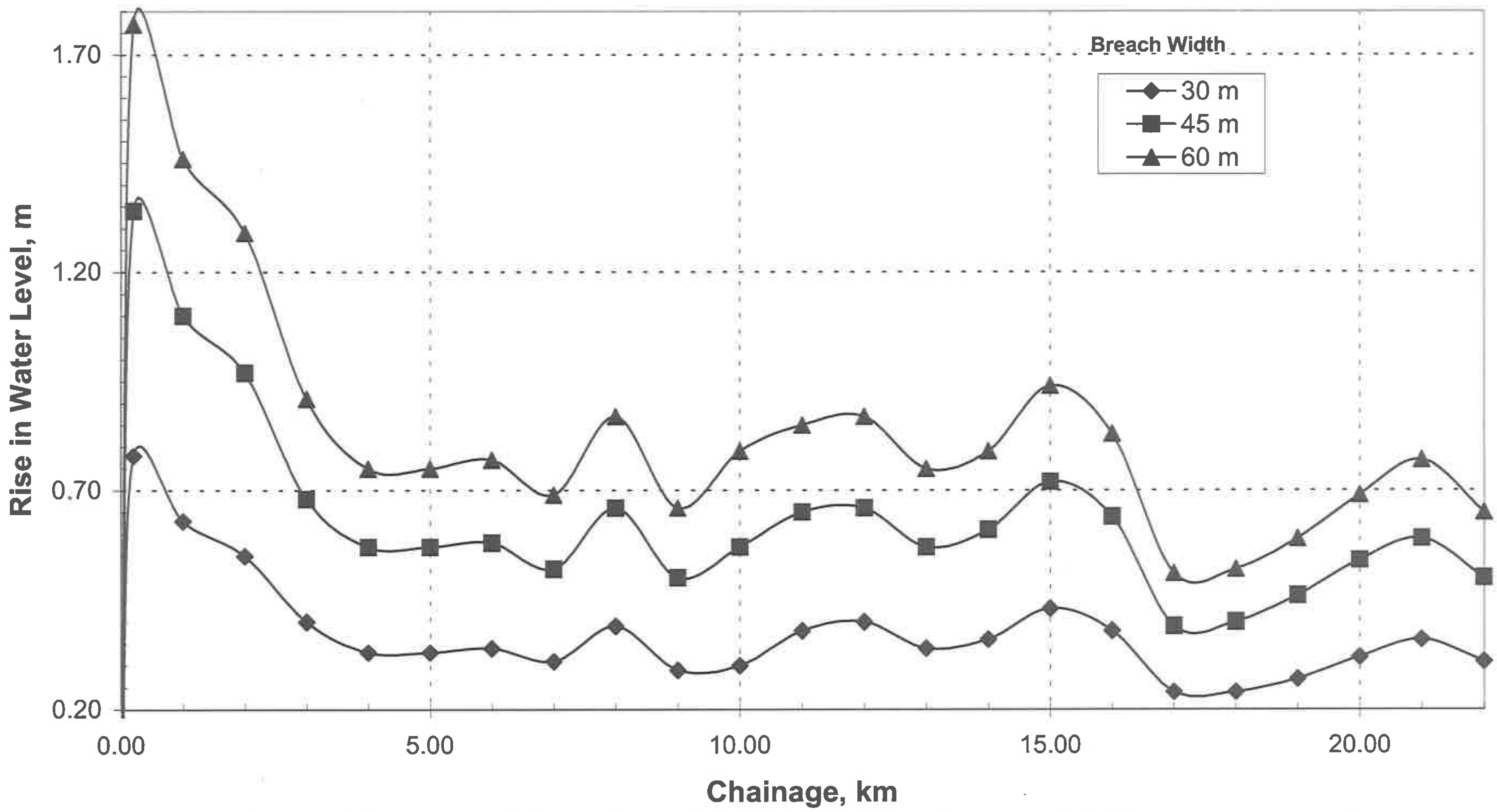


Fig. 29 - Rise in Maximum Water Levels w.r.t. 15.0 m Breach Width for Breach Time = 0.50 Hour

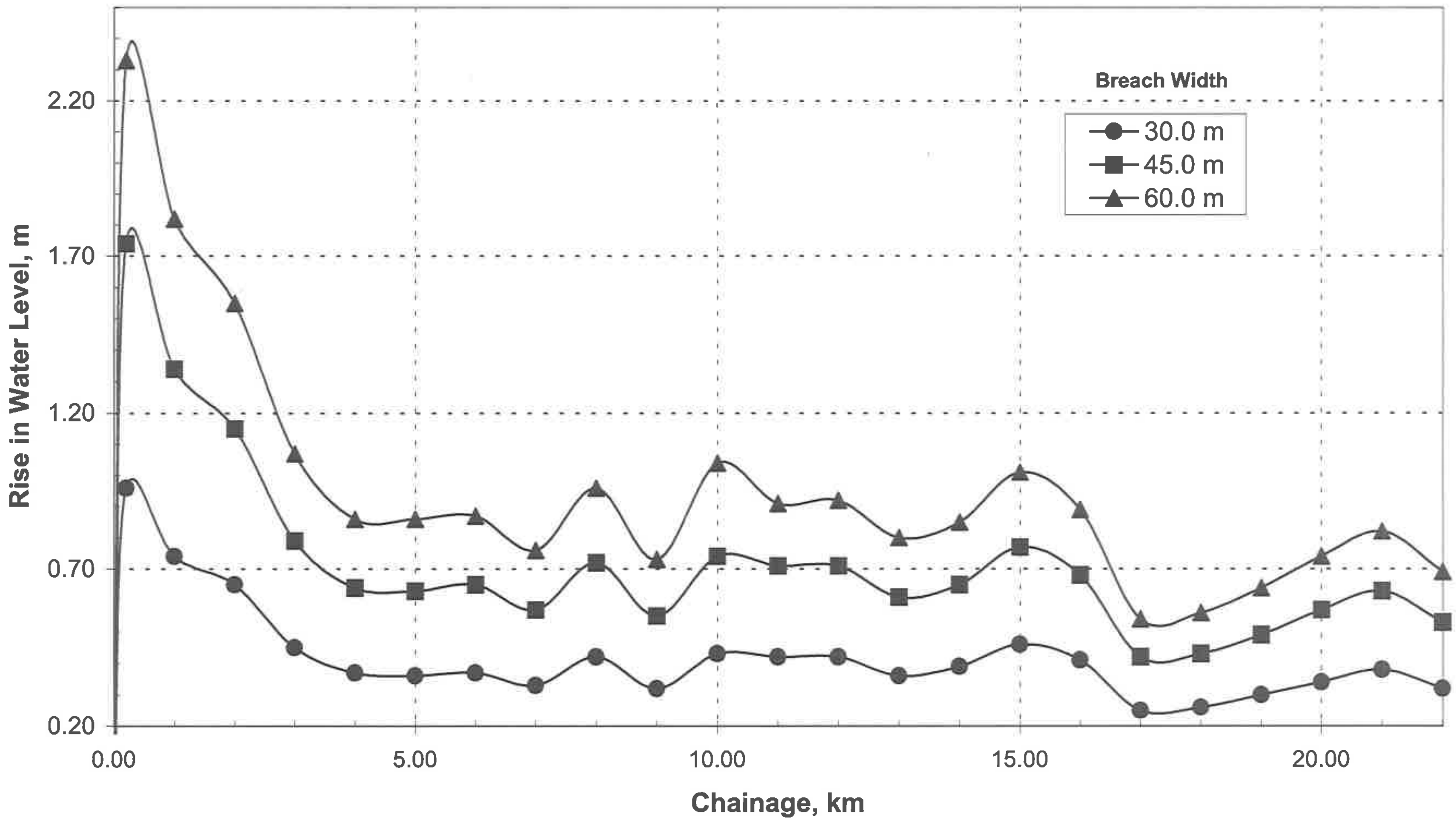


Fig. 30 - Rise in Maximum Water Levels w.r.t. 15.0 m Breach Width for Breach Time = 0.25 Hour

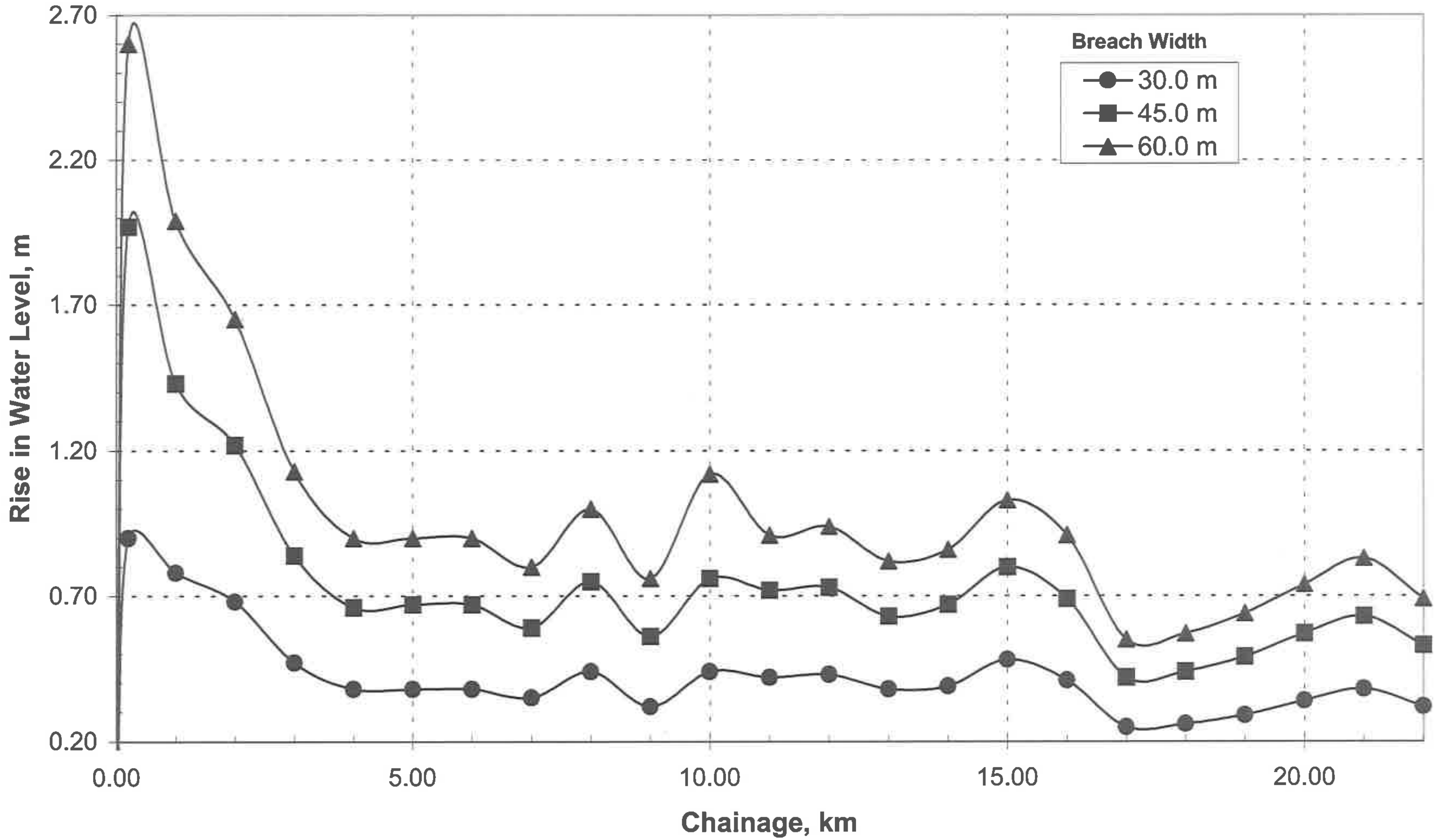


Fig. 31- Rise in Maximum Water Levels w.r.t. 15.0 m Breach Width for Breach Time = 0.01 Hour

KARCHAM-WANGTOO H.E. PROJECT (1000 MW) IN H.P.

DISASTER MANAGEMENT PLAN

Karcham-Wangtoo H.E. Project (1000 MW)
Disaster Management Plan

1.0 Hazard Potential of Dams

Dam serves as an important source of several benefits and facilities to the region downstream. However, such dams also form a potential source of hazard in the event of any mishap. The hazard potential of a dam lies in sudden release of the stored water in the form of a flood wave which has a potential to sweep away all the life and property coming within its course. The hazard potential of a dam is related to the possible extent of loss of life and damage to the property that is likely to be caused in addition to the loss of facility in the event of its failure. Hence in view of inherent hazard potential in dams, the following requirement should be fulfilled.

i) To evaluate the hazard potential of the dam
ii) To formulate and implement emergency action / Disaster Management Plan

2.0 Emergency Action Plan

Hypothetical Dam break sensitivity analysis for KARCHAM dam has been carried out by Irrigation Research Institute (IRI), Roorkee. The aim of Emergency Action Plan is to identify in advance the types of emergencies which are likely to occur in connection with operation of reservoir. This includes identification of probable areas, population or structures and installations likely to be affected adversely due to the water stored in the reservoir or due to the floodwater let out from the reservoir. This plan further includes making advance planning and preparations for handling efficiently and to the best extent possible the expected situations especially trying to avoid loss of human life.

The important purpose of the dam break study is to prepare an Emergency Action Plan that will lessen or mitigate its impact upon human habitations and properties. The thrust area of action plan will be as follows:

ii) To prepare an inundation map and to evaluate risk at downstream habitations, potential areas etc.
iii) To prepare a disaster management plan.

3.0 Inundation map and risk at downstream Habitation / Potential Areas:

An inundation map on the scale 1 : 50,000 has been prepared on the basis of Table 2 to 9 of the Dam Break Sensitivity Analysis (pp 18 to 25) for the worst case of breach involving a flood of 11467 cumec. From this map it could be seen that villages in the area between Karcham Dam & Nathpa Dam along with maximum depth of water that will occur are as follows:

Table A

Village Name	Distance from Dam Axis (km)	Location of Village with reference to Sutlej river	Village level (m) (Average)	Max. water level after dam break (m)	Depth of water that will occur above average village level (m)
Baltarang	0.4	Left bank	1827.0	1790.51	0
Kilba	3.8	Left bank	2200.0	1769.39	0
Choling	4.3	Right bank	1810.0	1766.63	0
Sholtu	8.0	Left bank	1699.0	1687.88	0
Tapri	8.5	Right bank	1700.0	1678.39	0

From Table A, it can be seen, that no village will get submerged even in case of extreme flood of 11467 cumec in the event of any dam break / dam breach. However, a portion of the road near Sholtu gets submerged with about 1 m to 1.6 m depth of water for a short period. The Disaster Management Plan takes with account the flood levels of the year 2000.

Nathpa Dam across river Sutlej is about 22 km downstream of Karcham Dam with its top at El. 1498.50 m. During dam breach, the flood water level at this location works out to 1489.88 m. It may be mentioned that Sutlej river from Karcham to Nathpa dam site flows within the steep river banks. No agricultural land falls within the flood levels calculated as above.

4.0 Disaster Management Plan

In the event of any breach, it is to be ascertained that losses to lives and properties could be kept at minimum by administering the feasible measures. To achieve this, non-structural measures are found to be substantially effective. The important measures are:

i) To provide flood forecasting services and quick dissemination of forecasts to important and heavily populated towns, villages, including other potential areas
ii) To formulate flood proof communication system, and
iii) To form a disaster mitigation network / system, including relief fund.

Along with the above, few important structural measures are to be adopted in case of break / dam breach are:

(i) Time to time vetification of gates, sluices etc.
(ii) A schedule of opening and closing the gates to limit the reservoir levels to the present gauges. This schedule shall be strictly followed.
(iii) Increased vigilance for the dam during the following periods.
    a) First filling of the reservoir in different stages of filling
    b) Period of excessive rainfall in the catchment of dam
    c) Period of excessive flood
    d) Period of about a month following critical earth quake event in the region
    e) In the Dam with signs of adverse behaviour till the deficiencies are rectified and normal behaviour is confirmed.

5.0 Flood forecasting Network

For the extreme occurrence of flood, in the event of any dam break / breach, either due to structural failure or due to weather hazard, a timely warning will help to reduce / mitigate the downstream losses. As shown in Table A, no village shall be submerged even in the extreme occurrence of flood. However, as decided in the Meeting of State Level EIA & Monitoring Committee, Govt. of H.P. held on 17.3.2005 at Shimla, early flood warning system alongwith VSAT communication shall be provided at the following locations:

Sl. No.	Station	Types of wireless set	Extension line to :
1.	Samdoh	V-sat	Local Administrative Head
2.	Khab	V-sat	Local Administrative Head
3.	Pooh	V-sat	Local Administrative Head
4.	Moorang	V-sat	Local Administrative Head
5.	Powari	V-sat	Local Administrative Head
6.	Reckong Peo (Kinnaur)	V-sat	Deputy Commissioner
7.	Karcham	V-sat	In-charge of dam
8.	Wangtoo	V-sat	In-charge of PH
9.	Kilba (desirable)	V-sat	Local Administrative Head
10.	Baltarang (desirable)	V-sat	Local Administrative Head
11.	Sholtu/ Tapri	V-sat	Local Administrative Head
12.	Bhabha Nagar	V-sat	Local Administrative Head
13.	Nathpa dam	V-sat	In-charge of dam

As mentioned earlier, Nathpa dam being constructed under Nathpa Jhakri H.E. Project, is about 22 km downstream of Karcham Dam Site. The time taken for flood waters to travel from Karcham dam to Nathpa dam shall be about 40 minutes. During this period, a warning regarding occurrence of any extreme flood, shall be communicated to Nathpa Dam authorities also so that regulation of spillway gates is done accordingly to safely pass the flood in the downstream of Nathpa Dam.

6.0 Disaster Management Committee

It is suggested to constitute one Disaster Management Committee on the following lines, whose main function will be

(i) verification of the functioning of warning network
(ii) assessing the status of river
(iii) assessing the functioning of gates and sluices etc. i.e., the whole system which will work in case of emergency.

The committee is proposed to be constituted with the following representatives:

1.	District Magistrate, Kinnaur	Chairman
2.	Representative from Telecommunication Dept.	Member
3.	Representative from Surface Transport Dept.	Member
4.	Representative from Flood Control Dept.	Member
5.	Representative from Civil Supply Dept.	Member
6.	Representative from Public Health Organisation	Member
7.	Representative from Nathpa Jhakri Power Corporation	Member
8.	Representative from Jaypee Karcham Hydro Corporation Ltd.	Convener

The State Level EIA and Monitoring Committee in its meeting held on 17.3.2005 also decided that an Emergency Operation Centre/ Disaster Management Centre (having State of the Art Computer Infrastructure) shall be put in place in association with Deputy Commissioner, Kinnaur. All information from various VSATs and Early Flood Warning System should flow to this Emergency Operation Centre automatically.

The Committee shall have its meeting at least once in each year after commissioning of the Project.

7.0 Financial Involvement

As the O&M of the V-sat will be a regular and long-term affair, the expenditure towards salary of the operator (Licence Holder) may be charged to Establishment Cost of the Project (Post-Construction). However, for each station, 3 operators may be kept for shift duty @ 8 hrs/day.

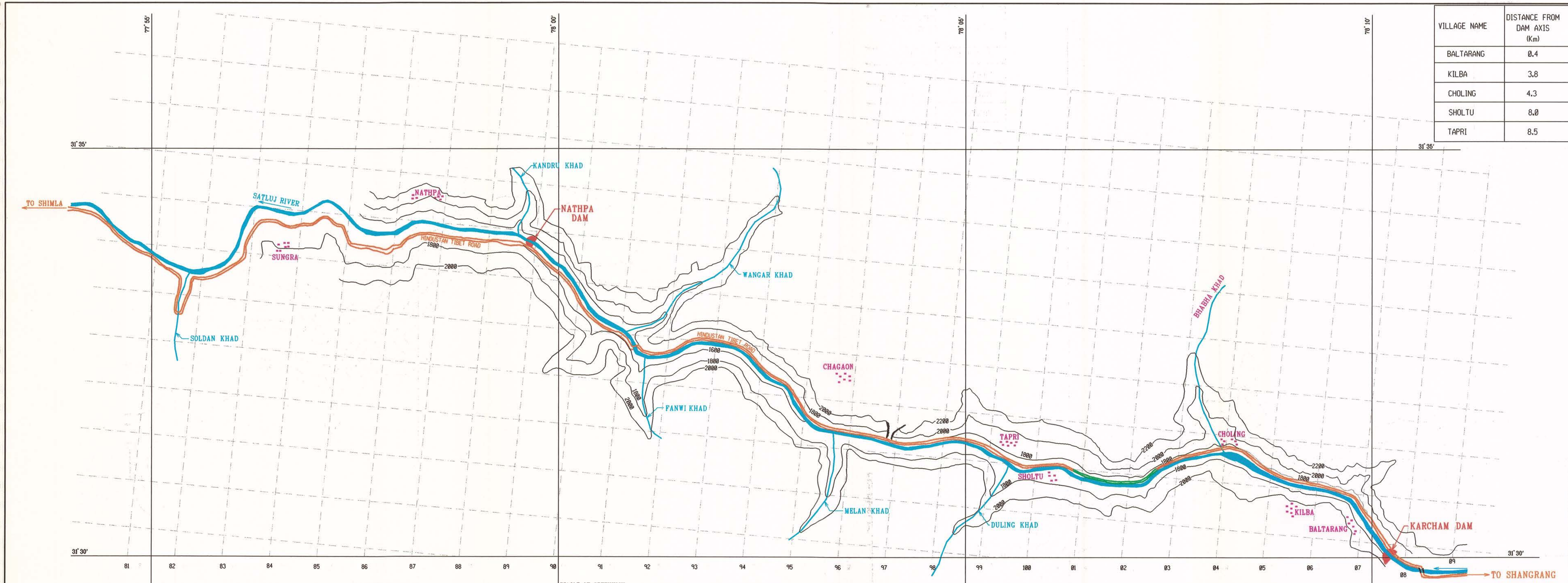
Thus, only the cost of V-sats, their installation charges and buildings will be charged on Disaster Management Plan budget, the financial involvement for which will be as follows:

(i)	Cost of V-sats		
	a)	No. of V-sats required	13 nos.
		Total cost	Rs. 60.00 lakhs
	b)	Power equipment	Rs. 39.20 lakhs
(ii)	Installation charges of V-sats		Rs. 12.00 lakhs
(iii)	Construction of buildings, (13 nos. x 20 sq m x Rs. 4,500/- per sq m)		Rs. 11.70 lakhs
(iv)	Flood Monitoring Stations		Rs. 10.00 lakhs
		Total	**Rs. 132.90 lakhs**

Suitable provision towards cost of V-sats etc. has been made in the Cost estimates of the Project which have been approved by Central Water Commission. In addition to this, Company has provided Rs.100 lacs as Disaster Relief Amount, Rs.25 lacs for Emergency Operation Centre, Rs.20 lacs kept exclusively for relief and rescue equipment and Rs.10 lacs for disaster management equipment.

8.0 Conclusions

Emergency Action Plan / Disaster Management Plan is a very important and effective tool for dam safety programme to handle an emergency situation arising due to likely failure of a dam due to any unforeseen reason. If the plan is adequately implemented, the impact of flooding on people and property can be minimised. However, the success of Plan largely depends upon its successful testing and trial so as to check any loopholes with a view to rectify it.



INUNDATION MAP

VILLAGE NAME	DISTANCE FROM DAM AXIS (Km)	LOCATION OF VILLAGE	VILLAGE LEVEL (AVERAGE) (m)	MAX. WATER LEVEL AFTER DAM BREAK (m)	DEPTH OF WATER THAT WILL OCCUR ABOVE AVERAGE VILLAGE LEVEL (m)
BALTARANG	0.4	LEFT BANK	1827.00	1790.51	0
KILBA	3.8	LEFT BANK	2200.00	1769.39	0
CHOLING	4.3	RIGHT BANK	1810.00	1766.63	0
SHOLTU	8.0	LEFT BANK	1699.00	1687.88	0
TAPRI	8.5	RIGHT BANK	1700.00	1678.39	0

LEGEND :

- RIVER / NALA
- ROAD
- CONTOURS
- VILLAGE
- PORTION OF ROAD WILL HAVE A WATER DEPTH OF ABOUT 1M TO 1.6M IN CASE OF DAM BREACH

NOTES :

1. ALL LEVELS ARE IN METRES.
2. MAXIMUM WATER LEVEL AFTER DAM BREAK HAVE BEEN TAKEN FROM HYPOTHETICAL DAM BREAK SENSITIVITY ANALYSIS REPORT CARRIED OUT AT IRI, ROORKEE FOR A FLOOD OF 11467 CUMEC. (TM NO. 73-RR(B-8), JULY 2002 OF IRI, ROORKEE).
3. THIS MAP HAS BEEN REPRODUCED FROM 1:50000 SCALE MAPS OF SURVEY OF INDIA.

00 Km 01 Km 02 Km 03 Km 04 Km 05 Km

SCALE

Rev.	Description	By	App(Proj.Man.)	Date
Print Issue Date				

Approved (Director)			Date		**********
Drawn		RAJESH / RAMANUJ	Checked		Yogender Sharma
Designed		Krishan Gupta	RECOMMENDED		

Drawing issued for information only unless signed as approved

CLIENT Jaypee Karcham Hydro Corporation Limited

KARCHAM WANGTOO HYDRO ELECTRIC PROJECT (1000 MW)

TITLE INUNDATION MAP

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KARCHAM-WANGTOO HYDROELECTRIC PROJECT (1000 MW)

RESERVOIR OPERATIONS

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RESERVERVOIR OPERATIONS

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KARCHAM-WANGTOO HYDROELECTRIC PROJECT (4x250 MW)

RESERVOIR OPERATIONS

1. GENERAL

This document describes the reservoir operations as well as the operation of silt flushing system. The document covers the following operations:-

i) Operation of Sluice Spillway for passing flood discharges as also for passing surplus water during non-monsoon period.

ii) Operation of Auxiliary spillway to pass low discharges as also passing the floating trash.

iii) Operation of mandatory discharge system for passing the discharge downstream of Dam during lean flood period.

iv) Reservoir sediment flushing.

v) Operation of Intake system (including Trashracks, Blind Trashracks and Trashrack Cleaning Machine (TRCM)) for silt management as also cleaning the Trashracks for reducing head loss across Trashracks.

vi) Operation of Silt Flushing System.

2. PARTICULARS OF CONTROL EQUIPMENT FOR DAM, INTAKE, AND SILT FLUSHING SYSTEM

2.1 Sluice Spillway

4 nos. Top Sealing Radial Gates 10m(W) x 10.5m(H) operated by Hydraulic Hoists (two for each Gate).

2.2 Auxiliary Spillway

1 no. Fixed Wheel Gate of size 6m(W) x 3.3m(H) operated by a Hydraulic Hoist.

2.3 Mandatory Discharge Pipes

2 nos. 800mm dia pipes and Electrically operated Globe Valves (at exit end) for controlling the discharge.

2.4 **Intake**

i) 4 nos. Fixed Wheel Gates of size 7.5m(W) x 4m(H) operated by Hydraulic Hoists.
(The Intake Gates are designed for lowering under unbalanced water head. However, preferably these should be operated under balanced head condition when power house is under shut down. For detailed operation of Intake Gate(s), refer O&M Manual for Intake Gate(s).

ii) Intake Trashracks and Blind Trashracks operated by an Auxiliary Hoist mounted on Trashrack Cleaning Machine (TRCM).

iii) Trashrack Cleaning Machine (TRCM) with Hydraulic Jib Crane for cleaning the Trashracks as also removing heavy trash accumulation near the Intake.

2.5 **Sedimentation Chambers And Flushing Conduits**

i) Bonneted Slide Gates of size 1.5m(W) x 1.5m(H) (one service Gate and one maintenance Gate) for each of the four flushing conduit)

ii) Fixed Wheel Emergency Gate of size 5.0m(W) x 5.5m(H) operated by a Hydraulic Hoist at the outfall of Silt Flushing Tunnel.

iii) Fixed wheel type gates of size 6m(W) x 6m(H) at the end of each of the four sedimentation chambers, operated by a Gantry Crane.

3. OPERATION OF SLUICE SPILLWAY RADIAL GATES

3.1 **Operating Modes**

The operation of Spillway Gates (Sluice Radial Gates as also Auxiliary Spillway Gate) can be carried out from Local Control Panels (mounted in the Local Control Rooms) as well as from the Remote Control Panels located in the Dam Control Room (DCR) located on Right Bank. The operations from Local Control Panels shall be carried out normally for maintenance purpose only. For this operation the selector switch should be in "LOCAL" mode at the Control Panels in Dam Control Room (DCR).

Manual operation of Spillway Gates will be carried out from Remote Control Panels in Dam Control Room (DCR) with selector switch in "Remote" position.

The automatic operation of Sluice Radial Gates for maintaining desired Reservoir level can also be carried out by ARMAC system with selector switch in "Auto" mode.

The Auxiliary Spillway Gate is not part of the ARMAC system and it can be operated in "Local" or "Remote" mode only.

3.2 Spillway Rating Curves

The Graph/Charts 1 to 4 as below gives the Spillway Discharge (per bay) at various reservoir levels and different Gate openings.

Graph/Chart - 1 - Spillway Top Sealing Radial Gates - Discharge Curves for different Gate openings and Reservoir levels

Graph/Chart - 2 - Spillway Top Sealing Radial Gates - Table of Discharges for different Gate openings and Reservoir levels

Graph/Chart - 3 - Auxiliary Spillway Gate - Discharge Curves for different Gate openings and Reservoir levels

Graph/Chart - 4 - Auxiliary Spillway Gate - Table of Discharges for different Gate openings and Reservoir levels

3.3 Spillway Regulatory Graphs

The Graph/Chart 5 below give the reservoir capacity. Graph/Chart 6 gives the inflow in the reservoir knowing the rate of rise of reservoir and actual outflow from the Spillway.

Graph/Chart - 5 - Reservoir capacity curve

Graph/Chart - 6 - Reservoir inflow/outflow from rate of rise/fall of reservoir

3.4 Operating Procedure

3.4.1 The manual operation of the Spillway is based on the following information :-

a) Rate of Rise/Fall of the Reservoir

b) Current outflow from the Gate settings

c) Current Reservoir level

3.4.2 The following procedure will be used to workout the Gate settings to maintain the required reservoir level.

a) By knowing the Gate openings of all the Spillway Top Sealing Radial Gates, workout the outflow (a) from each Gate by using Control Graphs (Graphs/Charts 1 and 2). The total outflow will be nil if all the Gates are closed.

b) By knowing the rate of rise or fall during the preceding inter sample interval, find out the additional inflow (b) in storage using Control Graphs (Graph/Chart 6). The total inflow will be the (a) + (b) i.e. total outflow from the Radial Gates and additional inflow in storage.

c) The new total inflow as above will be the new total outflow required to maintain the reservoir level.

d) Workout the outflow required for each Gate by distributing the total outflow between the Gates in operation. Any Gate which is out of operation and is in fully closed shall not be considered.

e) Find out the new settings for each Gate by using Control Graphs (Graph/Chart 1 and 2).

f) If the rate of rise/fall during any inter sample interval (i.e. time interval after which Gate position(s) are to be adjusted) is less than 1.0 cm per minute it is not necessary to adjust the Gate openings. However this rate of rise/fall shall be added to the rate of rise/fall for the next inter sample interval for adjusting the Gate settings to achieve the required reservoir level.

g) If the rate of rise/fall is more than 2.5 cm/minute, the Gate settings will be adjusted immediately.

Important Note:

3.4.3 The inter sample interval will be 15 minutes during monsoon period and 30 minutes during non-monsoon period or as set in the ARMAC System.

3.5 Sequence of Gate Operation

3.5.1 The sequence of operation of Spillway Radial Gates for passing the flood discharge will be as below: (The set sequence in ARMAC is 4,1,3,2 – 3,2,4,1 – 2,4,1,3 and 1,3,2,4).

a) Spillway Discharge upto 2000 cumec. It shall be as per Table 1 below.

Table-1

Sl. No.	Discharge to be passed through Spillway (cumec)	Gate Nos. to be used	Dam Block nos. in which Gates are located	Maximum Reservoir Level to be maintained (meters)
1.	0-250	4	7	El 1809.0
2.	250-500	4 and 1	7 and 4	El 1809.0
3.	500-750	4,1 and 3	7, 4 and 6	El 1809.0
4.	750-2000	4,1, 3 and 2	7, 4, 6 and 5	El 1809.0

The above table-1 is for first sequence set in the ARMAC which shall be most effective in removing the silt deposited in front of the Intake. However other sequences should also be followed at least once in a week for equal duty on all four Radial Gates. The balance between effective flushing and distribution of equal duty on the gates shall be made by the site.

Note: If any designated Gate is out of operation, the next Gate in order mentioned above can be used.

b) Spillway Discharge above 2000 cumec

i) For discharge above 2000 cumec, reservoir level shall be gradually depleted till free flow condition is achieved. Thereafter all the Spillway Gates will be fully opened. This will be done by overriding Automatic control system (ARMAC) and will be carried out by manual control operation of all the Sluice Spillway Radial Gates and Auxiliary Spillway Gate from DCR.

ii) If at any discharge ARMAC system is not responding to the commands due to any reason then before reaching the permissible reservoir limits, the control system should immediately be switched over to the 'Remote Mode' to operate the gates.

3.6 Reservoir Levels to be maintained

3.6.1 Non-Monsoon Period (16th Oct to 31st May)

a) The reservoir level will be maintained between El 1809.5 and El 1799.0 m to meet the peaking requirements. The free board of 0.5m shall be useful to accumulate the inflow during sudden shutdown of power house / increased river inflow. This will also avoid loss of water due to automatic operation of Spillway Gates. This will provide suitable response time to Shift Incharge to inform concerned authorities before spilling the water.

b) In case reservoir is full i.e. El 1809.5m and excess water is required to be discharged into river, first Silt Flushing conduit Gates shall be opened to discharge water upto 83 cumec. If additional discharge is to be spilled into river, then Spillway Gate no. 4 will be used to maintain the reservoir level at El 1809.5m.

c) In case of sudden tripping of Power Station (when operating at El 1809.5 m) there may be loss of water due to automatic operation of Spillway Gates. To save the spilling of this water, the Gates should be put in "Remote" mode and closed fully. The reservoir level can be allowed to raise upto El 1810 m and maintained at El. 1810 m. For excess water discharge, follow para 3.6.1 (b). The Gates can again be put in Auto mode when scheduled generation resumes and reservoir level lowers to El 1809.5 m.

d) Normally operation from Dam Control Room (DCR) shall be carried out to maintain the reservoir level by ARMAC or Remote Mode. In case of any fault or in case of emergency, operation from Local Control Panels can also be carried out under permission from Shift Incharge.

e) When the Spillway Gates are in "Auto mode" the ARMAC System will maintain reservoir at El 1809.5 m.

3.6.2 Monsoon Period (1stJune to 15th Oct)

a) The monsoon period has been considered from 1st June to 15th October. However, actual dates based on onset of monsoon and recede of monsoon can be considered based on forecast of IMD.

b) The reservoir will be maintained between El 1808.0 and El 1809m during the monsoon period in order to provide suitable response time in case of a sudden flood or sudden tripping of power station and ensuring that the reservoir level does not rise above El 1810.0 m.

c) The above level is a guide for satisfactory operation of the reservoir. However, this level can be reviewed based on experience on annual basis.

d) The sequence of operation of Gates will be as given in Para 3.5.

e) The operation of Spillway Gates shall be done in such a way that the opening of Gate(s) in operation is almost equal.

f) The operation of Gates will be carried out by 'Remote' operation for Dam Control Room (DCR) as per procedure described in Para 3.4.

g) ARMAC system can also be used to maintain the reservoir level with Selector Switch in 'AUTO' mode. For using ARMAC system the maximum and minimum levels to be maintained shall be fixed in advance and software shall be programmed accordingly. The difference between the maximum level and minimum level can be fixed as per Clause 3.6.2(b).

h) When Blind Trash racks are in position, the following minimum water level shall be maintained for the various loads:-

Table – 2

Sr. No.	Load	Minimum reservoir water level to be maintained
1	>920MW	EL: 1805m
2	>860MW upto 920MW	EL:1804.5m
3	>780MW up to 860MW	EL:1804m
4	>700 MW upto 780MW	EL: 1803.5m
5	≤ 700MW	EL: 1803m

Reservoir level should not go below above mentioned levels while generating load as per above table.

3.7 ARMAC System

3.7.1 ARMAC system has been installed at the Dam Control Room (DCR) and it can be used to maintain the reservoir level as required.

In this system PLC will control the operation of Sluice Radial Gate as per program.

The points to be noted for using this system are as below:

a) Selector switch shall be at 'AUTO' when using this system.

b) ARMAC System will workout the inflow based on rate of rise of reservoir and hence the discharge passing through the Intake will not be taken into account.

c) The difference between maximum and minimum levels to be maintained by ARMAC system should be 1 meter as per para 3.6.2(b).

3.7.2 For flood discharge of above 2000 cumec the ARMAC system shall not be used and all Spillway Gate(s) shall be fully opened by .manual control, which will override ARMAC System. Aux. Spillway gate shall also be kept fully open as per para 4 below.

4.0 OPERATION OF AUXILIARY SPILLWAY

4.1 The Auxiliary Spillway will be used for passing the floating trash and debris. For carrying out this operation, reservoir level shall be maintained above El 1808.0 m. The operation will be carried out from Remote Control Panel in Dam Control Room (DCR).

4.2 The frequency of this operation will depend upon the extent of accumulation of floating trash in the reservoir.

4.3 The Auxiliary Spillway can also be used during non-monsoon period for passing the excess water upto 50 cumec.

4.4 During monsoon period when flood discharge is above 2000 cumec, the Auxiliary Spillway Gate will be kept in fully open position.

5.0 OPERATION OF MANDATORY DISCHARGE SYSTEM

5.1 Two no. pipes of 800mm dia are provided in Dam Block nos. 5 and 6. The flow through these pipes is controlled by electrically operated Globe Valves provided at the exit end of each pipe.

These pipes will be used for passing the mandatory discharge as per guidelines downstream of the Dam during lean period i.e. when all the Spillway Gates are closed and no water is passing through the Spillway.

The following Graph/Chart will be used for determining the Valve openings for passing the required discharge.

(1) Graph/Chart - 7 - Discharge curve for each Mandatory Discharge Pipe at max. reservoir level at El 1810.0

(2) Graph/Chart - 8 - Discharge curve for each Mandatory Discharge Pipe at mean reservoir level at El 1804.5

(3) Graph/Chart-9 - Discharge curve for each Mandatory Discharge Pipe at minimum reservoir level at El 1799.0

(4) Graph/Chart-10 - Table of discharges from each Globe Valve at different openings of Valve and reservoir level at El 1810, El 1804.5 and El 1799.0

5.2 During monsoon period when excessive discharge is being passed through the Spillway and Mandatory Discharge Pipes are not being used, it is important that

Maintenance Gates at the Inlet end of mandatory discharge pipes are placed in closed position by using the Auxiliary Hoist on the Spillway Gantry Crane.

The Globe Valves at the exit end of mandatory discharge pipes should also be closed and Electric Actuators of the Valves should be removed by using the handling arrangement provided for this purpose.

This procedure will avoid deposition of silt in the pipes during floods, which can create problems in re-commissioning the system after monsoons.

6.0 RESERVOIR SEDIMENT FLUSHING:

6.1 Reservoir sediment flushing is required from time to time to take care of following aspects:-

a) *To maintain and restore the reservoir capacity*

b) When silt load in the water level is very high and PPM content at Intake gates crosses the threshold limits for safe operation of the generating units (Refer Anenxure-1), the generating units are required to be shut down, and water spilled from the reservoir to prevent deposit of sediments in the reservoir, which can seriously affect the capacity of the reservoir. It is important that sediment flushing is done when PPM content in the river inflow is high (as per Protocol-Annexure-1) and river inflows are also exceeding 750 cumecs.

c) During high flood condition (River inflow exceeding 2000 cumec)

6.2 Sediment flushing operations as below are envisaged:-

a) It is mandatory to carryout Silt flushing towards end of the monsoon season when the river discharge desending and is approaching about 800 cumecs. This will help restore the reservoir capacity for peaking purpose during non-monsoon period.

b) Reservoir flushing when PPM contents at Intake are very high.

c) Refer para 6.1.(c).

6.3 A joint protocol for reservoir flushing has been signed between JPVL, NRLDC and SJVNL for regulating generation and shut down of the units followed by reservoir flushing. A copy of the protocol is enclosed at Annexure-1. Necessary action shall be ensured according to this protocol.

6.4 Communication to various District Authorities, NRLDC and NJPC shall also be ensured as per the established communication protocols. A copy of the communication protocol / 'Standard Operating Procedure' is enclosed at Annexure-2.

6.5 During the flushing operations it will be necessary to keep all the generating units in Power House stopped. The flushing operation will last till PPM content at Powari will fall to 9000 PPM or below. During the flushing all the four radial gates will be opened equally and Gate lip should be at least one meter above the reservoir level (after free flow water conditions are established).

6.6. It will be necessary to carry out cross-sections of river at every 200m after last flushing of reservoir at end of monsoon season. This data will be useful for assessing the reservoir capacity for non-monsoon season and planning peaking operations of Power Station.

6.7. During flushing operations, it is necessary that Trash rack and Blind Trashracks are thoroughly cleaned of any trash and flushing debris embedded between racks and/or deposited on the top or side of the trash rack and its grooves. This is important so that Trashrack units are removed easily without any problem. Any deposition of trash on the top of Trash rack units will interfere with the engaging of lifting beam.

6.8 The following procedure shall be followed for lowering the Reservoir level for Reservoir flushing and raising the reservoir level after flushing and also when PPM at Intake exceeds 5000PPM and Power house is required to be closed:-

6.8.1 Lowering the Reservoir level for Flushing

a) Stop all the generating units of Power Station. Refer Protocol of operations at Annexure-1

b) First close Silt Flushing Gates and thereafter Intake Gates

c) Silt Flushing conduit Gates shall be re-opened after 45 minutes for a brief period of about 20 minutes. During 45 minutes of closure of Silt Flushing Conduit Gates most of + 0.2mm Silt particles will settle down and will be flushed subsequently during opening of these gates.

d) Close Silt Flushing Conduit Gates after 20 minutes.

e) Lower the reservoir level till free flow condition is achieved.

f) Reservoir flushing to continue till PPM content at Powari reduces below 9000 PPM and it has a reducing trend

g) After the reservoir level has been depleted and free flow condition achieved, all radial gates shall be kept at least one meter above the water level so that floating debris does not hit the radial gates. If floating debris is considerable, open the radial gates fully.

h) When discharge (river inflow) exceeds 2000 cumec, steps to stop all generating unit (s) at Power House should be taken and reservoir flushing commenced following protocol requirements (Annexure-1). During such conditions, PPM silt content will be very high. Reservoir level shall be gradually reduced following the guidelines for same [refer Para 6.8.1]. In this condition, all radial gates should be **fully** opened after.free flow condition is achieved.

i) <u>The rate of lowering of reservoir level should be not more than 3 metre per hour and it should also be ensured that outflow is not more than one and half times the river inflow in order to prevent flooding downstream.</u>

6.8.2. Raising the Reservoir level after completion of Flushing operation

a) Raise the reservoir level upto El 1800 m. The rate of raising the reservoir level can be upto 3m per hour.

b) Open the Intake Gates by 0.15 metre (Crack opening).

c) Open the silt flushing conduit gates by 0.5m and keep these Gates open for about 15 minutes . This will help to flush out the silt settled in the Sedimentation Chambers during flushing operation.

d) Close the Silt Flushing Conduit Gates.

e) Raise the reservoir level upto El 1803 at the rate of not more than 3 metres per hour.

f) Open the Intake Gates fully after balancing at El 1803m.

g) Open the Silt Flushing Regulating Gates.

h) The system is now ready to resume generation. As per reservoir le vel, follow generation limits as per para 3.6.2(h). Inform Power Station.

Note:

i) During raising the reservoir it should be ensured that flow from spillway is not less than half of the river inflow in order to meet water requirement of downstream project.

ii) The raising of reservoir level can be started when silt content in water at Powari is about 9000 PPM.

7. OPERATION OF INTAKE SYSTEM

7.1 Intake Gates

All the Intake Gates will be in fully opened position when all the machines at the Power Station are operating. However, during non-monsoon period when one or more Sedimentation Chambers have been isolated for inspection and maintenance, the corresponding Intake Gate as also the corresponding Sedimentation Chamber Gates will be in fully closed position.

7.2 Monitoring the Head Loss at Trashracks and Cleaning of Trashracks

a) It will be necessary to monitor the head loss at Trashracks by monitoring the water level at the intake and downstream of Trashracks. Radar type level measuring instruments have been installed on u/s and d/s of Intake Trashracks for directly measuring the head loss across the Trashracks.

b) The cleaning of Trashracks by using Trashrack Cleaning Machine (TRCM) shall be continuous round-the-clock during monsoon period to avoid choking of Trashracks and loss of head. Manual means for removing embedded trash / debris between racks shall also supplement the effort.

c) Following head loss limit as per Table 3 below shall be observed:-

Table – 3

Head loss >0.5m	Warning	Také action as per para 7.2 (d)
Head loss >2 m	Alarm	Inform Power House and action as per para 7.2.(d) Reduce generation to 1000 MW.
Head loss >3 m	High Alarm	Initiate action as per Para 7.2(e) and (f) or as per the condition prevailing

d) Lower the reservoir level by about 2 – 2.5 m and remove the trash / debris by manual intervention by using suitable hoisting arrangement. Thereafter, again raise the reservoir level. This will help in reducing the headloss at trash racks.

e) Try to coordinate the reservoir flushing operation due to high silt content and simultaneous cleaning of the trash racks from top to bottom by trash rack cleaning machine and/or manual mechanical means.

f) If it is not possible to coordinate silt flushing and trash rack cleaning operations and head loss across trash racks exceeds 3 meters, resort to partial flushing i.e. decrease water level from 1808 m to 1798 m and simultaneously remove and clean the embedded trash in the trash racks manually and thereafter again raise the level. This process will take around 8 hours and will require all generating unit(s) to be shut down (to reduce load one by one in about one hour) at the start of operation and resume generation one by one in last one hour of the operation. This will ensure minimum outage.

g) All operations for partial flushing shall be carried out following communication protocol as for reservoir flushing (Annexure-1).

7.3 **Use of Blind Trashracks**

a) Two panels of Blind Trashracks are provided for each Trashrack Bay.

b) The purpose of the Blind Trashracks is to raise the entry level at the Intake by about 6 metres during monsoon period so that water entering the intake is taken from the upper layers.

c) The Blind Trashracks will be placed in position before start of monsoon and will be removed after end of monsoon period by using the Auxiliary Hoist mounting on the Trashrack Cleaning Machine (TRCM).

d) While lowering / removing blind trash rack panels, close intake gate behind it, to ensure balanced head condition for lowering / removing of trashrack panels of this bay.

e) During the period the Blind trashracks are in position, water level should be maintained between El 1809.0 and El 1803.0 m as per Clause 3.6.2(h) and load regulated accordingly.

8.0 OPERATION OF SILT FLUSHING SYSTEM

8.1 Low River Inflow (**During Monsoon and non monsoon Period)**
Normally all the four silt flushing ducts shall remain open throughout the monsoons. However, if river inflow is low, procedure outlined in Table-4below shall be adopted.

Table -4

Inflow in Cumec	Average Silt content in PPM at Intake	Frequency of silt flushing from sedimentation chambers
< 503	Less than 250	Once in a week @ 15 minutes per Chamber
<503	>250 but < 500	Alternate day @ 15 minutes per Chamber
<503	>500 but <1000	Once in a day @ 15 minutes per Chamber
<503	>1000 but < 2000	Twice in a day @ 15 minutes per Chamber
<503	>2000 but < 3000	Twice in a day @ 30 minutes per Chamber
<503	3000	Continuous
>503 but <586	Less than 3000	Excess water to be passed through SFT beyond 503 cumecs
	Above 3000	Continuous

Note:

i) 503 cumec discharge corresponds to 10% overload i.e. 1200MW with reservoir level maintained at El 1809.5m.

ii) 586 cumec discharge includes 83 cumec discharge for flushing tunnel.

Important Note:

To pass a discharge of 20.75 cumec from each Flushing Conduit at reservoir El at 1809.0, the Gate opening required for the Flushing Conduit Service Gate is 0.5 metre.

a) When the silt content in the water (sample of water taken from downstream of Trashracks) is more than 5000 PPM, the Power Station will be closed. The power station will be again started when PPM goes down below 4500.

b) When the discharge exceeds 2000 cumec, Power Station will be closed and intake gates will be dropped so that no silt from the river enters the desilting chambers. The silt flushing regulating Gates will also be closed simultaneously. The Flushing Tunnel Outfall Gate will also be closed to prevent entry of river water in Silt Flushing Tunnel. TRT outfall gates shall also be got closed through power house.

c) When the flood recedes, the Power Station can be started again. The Gates will be opened in following sequence:

- Flushing Tunnel Outfall Gate
- Intake Gates
- Silt Flushing Regulating Gates

8.2 During Monsoon Period (1st June to 15th October)

Normally the gates of all the four flushing ducts shall remain open throughout the monsoons. However if river inflow is low, the procedure out lined in (a) and (b) below shall be adopted.

a) When river discharge is less than 503 cumec all the Spillway Gates shall remain closed and reservoir level shall vary between El 1809.00 to 1803.00 m run to run the power station. Silt Flushing conduit Gates shall be opened as per Table-4 in para 8.1.

b) When the river discharge is more than 503 cumec but less than 586 cumec; 503 cumec will be passed into HRT and remaining will be passed through silt flushing ducts, with reservoir level being maintained at El 1809 m.

c) When the river inflow is more than 586 cumec, 503 cumec will enter the tunnel and 83 cumec will be passed through the flushing conduit (20.75 cumec for each conduit) and the reservoir level will be maintained at El 1809.00. The excess discharge will be passed through the Spillway.

d) To pass a discharge of 20.75 cumec from each Flushing Conduit at reservoir El at 1809.00, the Gate Opening required for the Flushing Conduit Service Gate is 0.5 meter.

e) When the river discharge exceeds 2000 cumec, all generating units at Power Station will be shut down and Intake gates are closed so that no silt from the river enters the sedimentation chambers. The Silt Flushing Regulating Gates will also be closed simultaneously. The Flushing Tunnel Outfall Gate will also be closed to prevent entry of river water in silt Flushing Tunnel. TRT Gates also shall be got closed through Power House.

f) When the flood recedes, the Power station can be started again. The Gates will be opened in following sequence:
- Flushing Tunnel Outfall Tunnel Gate (s) and TRT Gate(s)
- Intake Gate(s)
- Silt Flushing Regulating Gates

8.3 **During non-monsoon period**

a) When the river discharge is below 417 cumec water is normally clean, keep Spillway Radial Gates fully closed, and operate reservoir between El 1809.5 and El: 1799.00m for peaking purposes.

Operate silt flushing conduit gates as per Table-4 para. 8.1

9.0 SILT OBSERVATIONS

9.1 For efficient management of silt, a regular observation of silt in river water and exit water from the Turbines is very important.

A small laboratory will be set at the Dam for silt observations and silt analysis. The laboratory shall have necessary equipment such as chemical balance, oven, sampling bottles and filters paper etc. For quick and approximate idea of silt content in river water, silt tubes of one litre capacity will be used.

Silt observations will be taken as below:

During monsoon & during non-monsoon (At Intake):-

Silt content & gradation	Frequency of measurement
Upto 250PPM	After every 4 hours
>250 upto 2000PPM	After every hour

>2000 upto 3000PPM	After every 30Mintues
>3000PPM	After every 15Mintues

During monsoon & during non-monsoon (At Draft tubes):-

Silt content & gradation	Frequency of measurement
Upto 250PPM	After every 4 hours
>250 upto 1000PPM	After every 2 hours
>1000	After every one hours

9.2 Not only silt content but petrographical analysis of silt is also important. The petrographical analysis of silt sample shall be carried out at least once every year during the monsoon period from an established Lab/Institution.

10. OPERATING CRITERIA FOR TRT OUTFALL GATES, SILT FLUSHING TUNNEL OUTFALL GATES AND DRAFT TUBE GATES

10.1 **Tailrace Tunnel (TRT) Out fall gates:-**

TRT Outfall Gates shall be closed in following conditions.

a) When Power house is closed due to any reason and more than 2000 cumecs discharge is being passed through spillways.

Before closing Tailrace Tunnel Outfall Gates it shall be ensured that MIV of all units in Power house are closed.

10.2 Silt Flushing tunnel Out fall Gates:-

Silt flushing Tunnel outfall gates shall be closed when more than 2000 cumecs discharge is being passed through spillways. Ensure Power House has been shut down.

10.3 Draft Tube Gates:-

a) Draft tube gate(s) of all unit(s) shall be closed, if necessary in case of excessive leakage from shaft seal and/or if TRT gates do not seal properly. This decision shall be taken by Shift Incharge of Power House.
b) When river water level at TRT outfall crosses El 1512 m, i.e. 1 m below top of TRT gates, draft tube gates will also be closed.
c) Normally, Draft Tube Gates are to be closed for maintenance purpose of respective unit(s).

Draft Tube gates of all four units shall also be closed when power house is closed and more than 5000 cumec discharge is being released through spillways.

d) During the above condition (b), water level in Draft Tube gallery will start rising due to drainage from the Power House. The level in draft tube gallery will need to be

Time	Milestone	Action by KW HEP as per protocol	Action by Wangtoo -PH	Action by Karcham Dam
30 minutes to 45 minutes	15 minutes after previous action	Trip 2 units one after another over a period of 15 minutes (Inform NRLDC, NJHPS prior to starting the action and confirm after completion)	• Confirm from NJHPS shut down of two units at Jhakri • Inform NRLDC / NJPHS by fax of start of balance two units shut down • Trip on normal shutdown (NSD) third unit followed by 4th unit at 15 minutes interval • Confirm NRLDC / NJHPS by fax of balance two units shut down	-do-
45 minutes to 60 minutes	15 minutes after previous action	Monitor the reservoir level	-	-do- • Monitor reservoir level • Inform District Authorities & Wangtoo Power House • Intimate NRLDC & NJPHS likely time of reservoir flushing. • Complete advance action i.e. closing silt flushing gate and intake gates
60 minutes to 75 minutes	15 minutes after previous action	Monitor the reservoir level		• Monitor Reservoir level • Intimate reservoir level at Karcham Dam to Wangtoo PH and Nathpa Dam of any change in level if applicable.
75 minutes onwards		KWHPS would initiate reservoir flushing after confirming closing down of all units of NJHPS	Confirm all units of NJHPS have stopped and give clearance to Karcham Dam for start of flushing	• Confirm that all units of NJHPS have stopped • Obtain operation code from Wangtoo PH • Start flushing operation at Karcham Dam

Time	Milestone	Action by KW HEP as per protocol	Action by Wangtoo -PH	Action by Karcham Dam
				• Inform NRLDC/NJHPS by fax of start of reservoir flushing and its time • Inform Wangtoo Power House Control of start of Reservoir flushing.

Note:

1.0 If operation code is not received from NRLDC and silt has rising trend, send an SOS for operation code.
2.0 In case of fax not working, use voice / SMS / e-mail

II. **Reservoir Refilling**

.1 After flushing operation has been completed and silt level at Powari has reduced substantially (below 7000 PPM) [Now revised to 9000 PPM] at Powari, Karcham Wangtoo Authorities will take a decision for refilling of the reservoir. A tentative programme comprising following information shall be prepared and sent to NRLDC and NJHPS by Karcham Dam Control by fax.

Programme for Refilling

Sl No	Activity	Activity duration	Expected time
1	Closing of the reservoir / spill way gates and start of pondage of water	5 – 10 min	Hrs
2	Expected time when reservoir level will reach the level to resume generation	07 hrs 30 min	Hrs
3	Raise the intake gates	10 minutes	Hrs
4	Open silt flushing gates	5 minutes	Hrs
5	Time when generation can be resumed considering unit start-up and synchronizing time	10 – 15 minutes	Hrs

This schedule of pondage will depend on the river inflow.

.2 A revised schedule, which shall be more precise, shall be sent to NRLDC for giving unit operation code by KW-PH. Also inform NJHPS.

Jaipraksh Power Ventures Limited
Karcham Wangtoo Hydro Electric Plant (1000 MW)

STANDARD OPERATING PROCEDURE (SOP) FOR COMMUNICATION FOR RELEASING WATER FROM KARCHAM RESERVOIR

1. **Shift Engineer at DCR** shall inform probable time and Quantity of discharge into the river to all concerned as per list below through Fax, E. Mail & on telephone.
2. Before discharge of water Shift Engineer will ensure the sounding of the siren at all 04 location.
3. In case during reservoir flushing operation discharge is likely to exceed 2000 cumecs, ask power house to close TRT gate(s) and confirm back. Power house to ensure all MIV's are closed before TRT gates are dropped.
4. In case river inflow exceeds 2500 cumec, all spillway gates(s) shall be fully raised after free flow condition during reservoir depletion is achieved.

NAME	LAND LINE	FAX NO.	E- MAIL	REMARKS / ACTION BY
Sh.Sanjay Gupta ji				
Sh. Narender Sharma ji				
D C Kinnour	01786222252 (O) / 51 (R)	Fax-01786223342	dc-kin-hp@nic.in	
S P Kinnour	01786222270 (O) / 88 (R)	Fax- 01786222528	sp-kin-hp@nic.in	
SDM Bhawa Nagar	01786263201 (O) / 02 (R)	Fax -01786263201		
Tehsildar Nichar	01786263382 (O) / 512 (R)			
Police Station Baltrang	01786 233321/ 222512			
Sh. Madan Lal, ASI Baltrang				
Sh. Yog Raj, Havaldar Baltrang				
Police Station Tapri	01786 261230			
Flood Control Room, R'Peo	01786 222227	Fax-01786223342		
Sh Tejwant Singhji	01786261253/54/55			
Brig. (Retd) KK Marvah ji	01786261253/54/55		kk.marwah@jalindia.co.in	1.To provide information to concerned officers
Col. (Retd) M. L. Prashar ji				1. Inform Mr. Doulat Negi, Village Pradhan, Kilba 2. Alert all the Security Check posts in Karcham / Kilba area. 3.Announce near Quarry, Kilba. 4.Arrange to sound the siren at Kilba camp
Col. (Retd) G.C.Angiras ji	01786261253/54/55		gc.angiras@jalindia.co.in	1.Make sure that men/machinery/ cattle etc., are moved out from the river bed/banks in Sholtu area. 2.Alert all the Security Posts in Sholtu area. 3 Arrange to sound the siren at sholtu Camp.

Sh. H. R. Thakur ji	01786261253/54/55		hr.thakur@jalindia.co.in	To ensure removal of all men & machinery from nearby areas of the river at karcham, Sholtu and Kakastal.
Power House Control Wangtoo	Hot Line/ V-sat	Fax-1786261241/ 01204196866	kw.powerhouse@jalindia.co.in	
Wirless Control Sholtu	01786261253/54/55	Fax-01786261258		
Sh. Balveer ji, Sholtu	01786261253/54/55		secretarial@jalindia.co.in	
PR Sharma ji (Kaksthal)	9805002021			1.Make sure that men/machinery/ cattle etc., are moved out from the river bed/banks in Kaksthal area. 2.Alert all the Security Posts in Kaksthal area. 3 Arrange to sound the siren at Kaksthal Camp.
NRLDC				
Mr. D K Jain, Dy. GM	9910344127			
Shift Incharge	011-26519406	FAX-011-26853082 / 011-26852747		
NJPHS				
Jhakri Power House Control	01782-234960	Fax-01786234960		
Mobil	9816675194			
Mr. Ajay uppal (AGM)	9418075288			
NATHPA DAM (CONTROL)				
Dam Control Nathpa	9816611368	FAX-01786-263364		
Mr. Nag Raj, Sr. Manager	9418066961			

NOTE:-

1. Action as per this SOP are to be taken by all the concerned including preparation of records regarding massage received/ conveyed.
2. Mobile numbers of all concerns is to be updated every month.
3. The name of officers mentioned above are the officers who are presently deputed. In case any of the officer is changed, then the name and contact details of the new officer shall be metnioned in above annexure.

AUTOMATIC RESERVOIR MONITORING AND CONTROL SYSTEM (ARMAC SYSTEM)

OPERATOR STATION AT DAM CONTROL ROOM (DCR)

A computer based Main Machine Interface (MMI) Station has been provided at the Dam Control Room (DCR) for monitoring and control of ARMAC System. The system basically consists of Personal Computer loaded with WINDOWS and ABB make **SCADA Portal** monitoring software. The operator station is also provided with ABB make **Control Builder M Programming** software for interlock and sequence programme. The Dam Control Room (DCR) operator station is connected to the PLC's at local control panels through Profibus communication network.

With MMI the operator station with perform the following functions:

1. Monitoring and Control the Gate Operation of Sluice Spillway, Auxiliary Spillway Gate and Silt Flushing Regulating Gates
2. Animated plant graphics
3. Real time and Historical trending
4. Data Logging
5. Fault Diagnosis
6. Password Protection

The CPU panel in the Dam Control Room (DCR) contains the following basic equipment:

1. AC 800m Processor
2. Communication modules
3. Analog input/output modules
4. Digital input/output modules
5. Power supply unit
6. Water level indicators with RS 485 communication
7. Head loss indicators with RS 485 communication
8. Water discharge indicators with RS 485 communication

The details of all the instruments are given in Doc No. 1200-0210-023 "Design & Selection of Components for Automatic Reservoir Monitoring and Remote Control System - Spillway, Intake and Silt Flushing Conduit Gates.

The discharge calculations based on Gate openings as also reservoir capacity data based on Graph/Charts 1 to 4 and 6 are fed in the programme. This data is used for obtaining following information required for automatic operation of Sluice Spillway Radial Gates.

1. Total outflow based on the Gate openings of various Gates

2. Rate of rise / fall of the reservoir for calculating the inflow (net inflow)

With the ARMAC System following function can be carried out from Computer Station:-

1. Automatically regulate the combined opening of the Radial Gates to control the outflow of water as required.

2. To change the parameters of response of the Gates to the inflow levels by changing the program. PC based system allows to do flexible programming.

3. To monitor status of all the Spillway, Intake and Silt Flushing Gates.

4. Get indications at the Remote Control Panels regarding the operation and position of each Gate, including the real time display of Gate motion of selected Radial Gate.

5. Obtain audio/visual alarms and indications of various faults in the hydraulic systems of each gate.

6. Provide printouts at periodic intervals (1 Shift – 8 hours) as stipulated regarding the water inflow, outflow, gate levels and fault indications.

7. To operate the gates manually by clicking the mouse button in the computer screen or respective push buttons on Remote Control Panels at Dam Control Room (DCR).

REMOTE CONTROL AND INDICATION SYSTEM FOR SPILLWAY GATES, INTAKE GATES AND SILT FLUSHING GATES AND ARMAC SYSTEM TO MAINTAIN REQUIRED RESERVOIR LEVEL

1. BRIEF DESCRIPTION OF SYSTEM

The system provides the following functions:

i) Remote indication and operation of Sluice Spillway Top Sealing Radial Gates (4 nos.) and Auxiliary Spillway Fixed Wheel Gate (1 no.) from the Dam Control Room.

ii) Remote indication and operation of Intake Fixed Wheel Gates (4 nos.) & Silt Flushing Conduit Gates (4 nos.) from the Dam Control Room.

iii) Indication of Reservoir Water Level and Head Loss through Trashracks at the Dam Control Room.

iv) Automatic operation of Sluice Spillway Top Sealing Radial Gates to maintain the required reservoir level using SCADA Portal at Operator Station at Dam Control Room (DCR).

2. MAIN COMPONENTS OF THE SYSTEM

The main components of the system are:

(1) Gate Position Sensors

Gate position sensors for the Spillway and Intake Gates (Tilt Angle Transmitters for the Radial Gates and Temposonic Sensors for the vertical lift gates i.e. Intake Gates and Auxiliary Spillway Gate and Silt Flushing Conduit Gates) have been provided.

All these instruments provide an Analog signal of 4-20 mA.

(2) Water Level Sensors

Two Radar type water level sensors are mounted on Dam and at Intake for giving reservoir water level. Four water level sensors are mounted on downstream of Trashracks for giving indication of head loss across Trashracks.

(3) **Remote Control Panels in Dam Control Room**

Panel 1 - For 4 nos. Sluice Spillway Radial Gates and one no. Auxiliary Spillway Gate
Panel 2 - For 4 nos. Intake Gates
Panel 3 - For 4 nos. Silt Flushing Regulating Gates

(4) CPU Panel having master CPU and redundant CPU and also containing Digital I/p O/p modules and Analog I/p modules and also having Water Level Indicator, Water Discharge Indicator and Head Loss Indicator.

(5) Operator station (SCADA Portal) at Dam Control Room (DCR) and also at P.H. Control Room.

Note: PLC are provided at the Local Control Panels of all the Gates which will be linked to the CPU at Dam Control Room (DCR) through Profibus network.

3. REMOTE OPERATION OF SPILLWAY AND INTAKE GATES

(1) Remote operation of the Spillway Gates (5 nos.) and Intake Gates (4 nos.) and Silt Flushing Regulating Gates can be carried out from the Remote Control Panels at Dam Control Room (DCR).

(2) **Selector Switch and Push Buttons**

The following Push Buttons (PB), Selector Switches (SS) and Indication Lamps are provided on the Remote Control Panels for all the Gates.

(i) Local/Auto/manual - SS (Auto not applicable for Auxiliary Spillway Gate, Intake Gates and Silt Flushing Gates)
(ii) Gate open PB
(iii) Gate closed PB
(iv) Intermediate Stop PB
(v) Lamp Test PB (one number on each panel)
(vi) Fault Reset PB (one number on each panel)

(3) **Indicating Lamps**

(i) Gate open Ind. Lamp
(ii) Gate close Ind. Lamp
(iii) Gate Stop in Intermediate position Ind. Lamp (only for Radial Gates)
(iv) Local
(v) Remote
(vi) Auto
(vii) System Reading Lamp
(viii) System Fault

(4) **Fault Alarm**

(i) System Fault - Hooter

<u>ANALOG INPUTS</u>

The following Analog Inputs are available for the CPU Panel.

(i) Water Level Sensor on Dam for Reservoir Water Level measurement

(ii) Water Level Sensor on Intake (U/S)

(iii) Head Loss Sensor D/S of Trashracks for Trashracks Head Loss measurement

(5) Remote operation of all the Gates can be carried out by selecting the Local/Remote/Auto key type selector switch. The Auto operation of Auxiliary Spillway Gate and Intake Gates is not provided as these are not part of the ARMAC system.

4. OPERATING MODES

(1) Local Mode

In local mode operation manual operation from Local Control Panels (located in Control rooms near the Gates) can be carried out. Operation from Local Control Panels will only be required when the particular Gate is in maintenance or if there is any fault in the Remote Control System. However, in this mode PLC will monitor the operation and all status information will be available at Local Control Panel as well as the Computer station.

(2) Remote Mode

In remote mode the Gates are operated from the Remote Control Panels at Dam Control Room (DCR) manually by operator. However, PLC will monitor this operation and all status information will also be available at Local Control Panel as also the Computer Station

(3) Auto Mode

PLC will be controlling the operation of Sluice Spillway Radial Gates as per program. Reservoir level and set point will be given in the program.

When the Sluice Spillway Gates are running in AUTO mode local operation from Local Control Panels and Remote operation from Remote Controls Panel will be inhibited.

Redundant CPU will give digital input and output signals to Remote Control Panels for controlling and monitoring all the 13 Gates. Redundant CPU will give digital RS-485 - Profibus communication output for Digital Gate position indicators, Water level indicators, Trashrack head loss indicators and Water discharge indicator (for Spillway Gates) irrespective of mode of operation.

Note: Electrical Circuit for Input and Output Points are given in Electrical Circuit Diagram 150.090-02 contained in Doc No. 1200-0210-023 "Design & Selection of Components for Automatic Reservoir Monitoring and Remote Control System - Spillway, Intake and Silt Flushing Conduit Gates.

5. ARMAC SYSTEM

Two computer based Main Machine Interface (MMI) station one at Dam Control Room (DCR) and one at P.H. Control Room have been provided for monitoring and control by ARMAC system.

However, control of Gates from P.H. Control Room will only be possible with permission from Dam Control Room (DCR).

This system basically consists of Personal computer loaded with Windows Software and ABB make SCADA monitoring software. The Dam Control Room (DCR) station is also provided with ABB software for interlock and sequence control. The Dam Control Room (DCR) operator station shall be connected to CPU Panel via Ethernet communication network. The Power Station is connected to CPU via fiber optic cable.

The Sluice Spillway Gates can be operated both through Dam Control Room (DCR) and P.H. operator station. However, when the Gates are being operated by one station, if one tries to operate from the other station the redundant CPU will give warning message and ask for password for taking over control from the other station.

With the help of MMI station at Dam Control Room (DCR) operator can perform the following functions:-

(1) Monitoring and Control of Gate operation
(2) Animated graphics
(3) Real time and historical trending
(4) Data logging
(5) Fault diagnosis
(6) Password protection

6. REDUNDANT CPU SYSTEM

The Redundancy is offered at CPU level so that any single failure should not effect the Gate operation. There will be two sets of PLC for Gate control. Main CPU (Master CPU) shall normally be controlling the Gate operation and secondary CPU (Slave CPU) shall monitor the operation. Slave CPU shall have current information like gate position, water level etc. updated via communication level with Master CPU. In case of any fault in the Master CPU, Slave CPU will become Master and will take over the control without any manual intervention. Changeover shall be bump-less and operation will not be effected.

Changeover from Mater to Slave shall take place if any of the following conditions occur.

1. Master CPU failure
2. Program corruption in the Master CPU
3. Total cut-off of power to Master CPU System

7. CIRCUIT DIAGRAMS AND PART LISTS

The following diagrams are included in Doc No. 1200-0210-023 "Design & Selection of Components for Automatic Reservoir Monitoring and Remote Control System - Spillway, Intake and Silt Flushing Conduit Gates.

1.	150.090-01	ARMAC Configuration Diagram for Remote Control and ARMAC System and BOM
2.	150.090-02	CPU Panel - GA, Circuit and Bill of Materials (BOM)
3.	150.090-02A	CPU Panel – Circuits
4.	150.029-03	Remote Control Panel - Spillway Gates – GA and BOM
5.	150.029-04	Remote Control Panel - Intake Gates – GA and BOM
6.	150.029-05	Remote Control Panel – Silt Flushing Gates – GA and BOM

8. SIGNALS FOR POWER STATION CONTROL ROOM

The following signals will be available.

A. DIGITAL SIGNALS

Intake Gates 1 to 4

(i)	Intake Gate Closed D/I	Potential free contact

CPU Panel

(i)	Dam Control System Fault D/I	CPU Panel at Dam Control Room (DCR)

B. ANALOG SIGNALS

(i)	Water Level Sensor U/S of Dam	4-20 mA
(ii)	Water Level Sensor U/S of Intake	4-20 mA
(iii)	Head loss Sensor (D/S of Trashracks) Bays 1 to 4	4-20 mA

Important Note:

The Intake Gates will be fully open i.e. hanging hydraulically keeping bottom of gate above the vent opening when Power Station is running.

During this condition following must be observed:-

i) Keep the electric power supply to the Local Control Panels "ON"

ii) Shut off valve on rod side of the hydraulic cylinder be kept fully closed

iii) Ensure that the creep restoration is functioning properly

iv) Ensure that it gives alarm, if excessive creep occurs

This is necessary to ensure that there is no possibility of Intake closing accidentally due to any electrical/mechanical fault.

The operation of Intake Gates can only be carried out from Remote Control Panel at Dam Control Room (DCR) or Local Control Panels. The operation will be carried out only with permission from Power Station Control Room and after opening hand valves slowly.

This arrangement will ensure that the Power Station will not be shutdown if Intake Gate closing signal is received at Power Station Control Room due to any accidental closing of Intake Gate or due to any electrical or mechanical fault, as hand valves on rod side of cylinder remain closed when Power Station is running.

monitored and if necessary flood pumps should be used for drainage purpose. Standstill seal for shaft should be applied to minimise drainage.

11.0 HIGH SILT CONTENT AT DRAFT TUBE

11.1 Whenever silt content in draft tube exceeds 3000 PPM, load on generating units shall be reduced to 1000 MW under intimation to NRLDC.

11.2 Whenever silt content in draft tube is found more than 2500 PPM, frequency of sampling at Intake shall be increased to 15 minutes.

11.3 Intake gates shall be dropped with reservoir level at 1808 m or above when reservoir flushing is undertaken.

Karcham Wangtoo HEP
Action protocol Reservoir Flushing

I. Reservoir Flushing

Time	Milestone	Action by KW HEP as per protocol	Action by Wangtoo -PH	Action by Karcham Dam
	Silt level at KW HPS Intake is $\geq$ 3000 PPM	Inform to NRLDC, NJHPS and customers. Reduce the silt sampling interval to 15 minutes	• Fax to NRLDC & NJHPS stating of increased silt level	• Inform Wangtoo-PH silt results • Silt sampling rate to be reduced to 15 minutes
	Silt level at KW HPS Intake is $\geq$ 4000 PPM	Take operation code from NRLDC and start reducing generation from 1200 MW to 1000 MW and inform NJHPS simultaneously	• Fax / Voice communication / SMS to NRLDC for operation code. • Inform NJHPS-PH Control also by Fax and Voice Communication / SMS • After operation code from NRLDC, reduce load from 1200 MW to 1000 MW • Inform NJHPS by fax	• Inform regularly silt content to KW-PH
0 minutes to 15 minutes	Silt level at KWHPS Intake is $\geq$ 4500 PPM	Trip 2 units one after another over a period of 15 minutes (Inform NRLDC, NJHPS prior to starting the action and confirm after completion)	• Inform NRLDC / NJPHS by fax of start of two units shut down • Trip on normal shutdown (NSD) one unit followed by 2nd unit at 15 minutes interval • Send confirmation to NRLDC / NJPHS by fax of two units shut down	-do-
15 minutes to 30 minutes	15 minutes after previous action	Monitor frequency, hold generation	• Monitor frequency • Maintain generation 500 MW • Monitor Draft Tube Silt level of running unit	-do-

KARCHAM WANGTOO H.E.PROJECT I (1000MW)

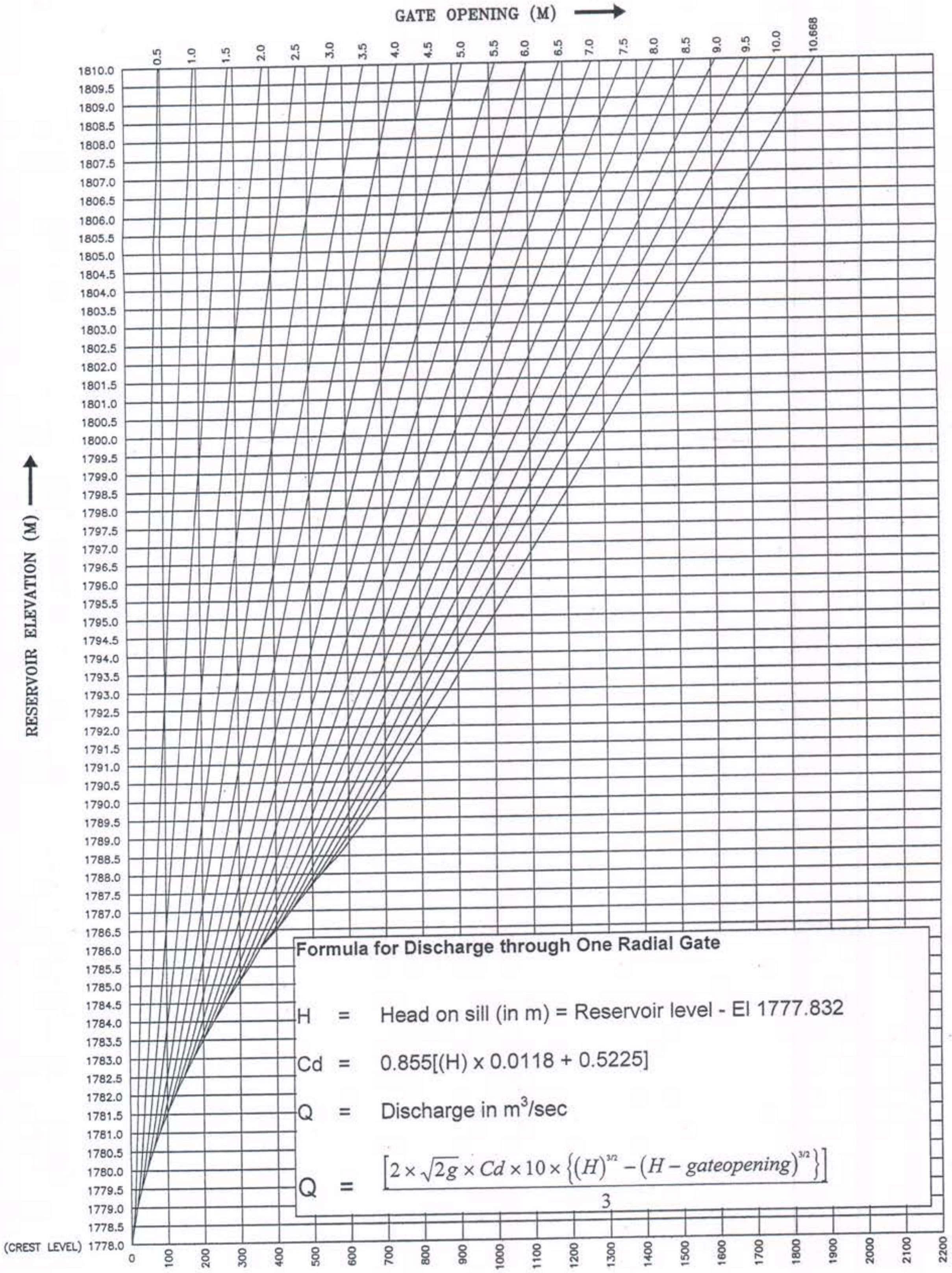
TABLE OF DISCHARGES FOR SPILLWAY/BAY FOR DIFFERENT GATE OPENNINGS AND RESERVOIR LEVELS

Gate opening	0	0.5	1	1.5	2	2.5	3	3.5	4	4.5	5	5.5	6	6.5	7	7.5	8	8.5	9	9.5	10	10.668
Reservoir level																						
1778.00	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		-	-	-
1778.50	0	6																				
1779.00	0	10	16																			
1779.50	0	12	22	28																		
1780.00	0	14	27	36	43																	
1780.50	0	16	31	43	53	60																
1781.00	0	18	34	49	62	72	78															
1781.50	0	20	38	55	69	82	92	99														
1782.00	0	21	41	60	76	91	104	115	121													
1782.50	0	23	44	65	83	100	115	128	139	146												
1783.00	0	24	48	69	90	109	126	141	154	164	171											
1783.50	0	26	51	74	96	117	135	153	168	181	192	199										
1784.00	0	27	53	78	102	124	145	164	182	197	211	221	228									
1784.50	0	29	56	83	108	132	154	175	195	212	228	241	252	259								
1785.00	0	30	59	87	114	139	163	186	207	227	244	260	274	285	292							
1785.50	0	32	62	91	119	146	172	196	219	241	260	278	294	308	319	326						
1786.00	0	33	65	95	125	153	181	207	231	254	276	296	314	330	344	355	363					
1786.50	0	34	67	100	131	160	189	217	243	267	291	313	333	351	367	381	393	400				
1787.00	0	36	70	104	136	167	197	226	254	281	306	329	351	371	390	406	421	432	440			
1787.50	0	37	73	108	141	174	206	236	265	293	320	345	369	391	412	431	447	461	473	481		
1788.00	0	38	75	112	147	181	214	246	277	306	334	361	387	411	433	454	473	489	504	515	523	
1788.50	0	40	78	116	152	188	222	255	288	319	348	377	404	430	454	477	498	517	533	548	560	570
1789.00	0	41	81	120	157	194	230	265	299	331	362	392	421	449	475	499	522	543	562	579	594	609
1789.50	0	42	83	124	163	201	238	274	309	343	376	408	438	467	495	521	546	569	590	609	627	646
1790.00	0	43	86	127	168	208	246	284	320	356	390	423	455	485	515	543	569	594	617	639	658	681
1790.50	0	45	89	131	173	214	254	293	331	368	404	438	471	504	534	564	592	619	644	667	689	715
1791.00	0	46	91	135	179	221	262	302	342	380	417	453	488	522	554	585	615	643	670	696	719	748
1791.50	0	47	94	139	184	227	270	312	352	392	431	468	504	539	573	606	638	668	696	723	749	780
1792.00	0	49	96	143	189	234	278	321	363	404	444	483	521	557	593	627	660	692	722	751	778	812
1792.50	0	50	99	147	194	240	286	330	374	416	457	498	537	575	612	648	682	716	747	778	807	844
1793.00	0	51	101	151	199	247	294	339	384	428	471	512	553	593	631	668	704	739	773	805	836	875
1793.50	0	52	104	155	205	254	302	349	395	440	484	527	569	610	650	689	726	763	798	832	864	905
1794.00	0	54	107	159	210	260	309	358	405	452	497	542	585	628	669	709	748	786	823	858	892	936
1794.50	0	55	109	163	215	267	317	367	416	464	511	556	601	645	688	730	770	810	848	885	920	966
1795.00	0	56	112	166	220	273	325	376	426	476	524	571	617	663	707	750	792	833	872	911	948	996
1795.50	0	58	114	170	225	280	333	385	437	487	537	586	633	680	726	770	814	856	897	937	976	1026
1796.00	0	59	117	174	231	286	341	395	447	499	550	600	649	697	744	790	835	879	922	963	1004	1056
1796.50	0	60	120	178	236	293	349	404	458	511	563	615	665	715	763	811	857	902	946	989	1031	1085
1797.00	0	61	122	182	241	299	356	413	468	523	577	629	681	732	782	831	878	925	971	1015	1059	1115
1797.50	0	63	125	186	246	306	364	422	479	535	590	644	697	749	801	851	900	948	995	1041	1086	1144
1798.00	0	64	127	190	252	312	372	431	490	547	603	659	713	767	819	871	922	971	1020	1067	1114	1174
1798.50	0	65	130	194	257	319	380	441	500	559	616	673	729	784	838	891	943	994	1044	1093	1141	1203
1799.00	0	67	133	198	262	325	388	450	511	571	630	688	745	802	857	911	965	1017	1069	1119	1168	1232
1799.50	0	68	135	202	267	332	396	459	521	583	643	703	761	819	876	932	986	1040	1093	1145	1196	1262
1800.00	0	69	138	206	273	339	404	468	532	595	656	717	777	836	895	952	1008	1063	1117	1171	1223	1291
1800.50	0	71	141	210	278	345	412	478	542	607	670	732	793	854	913	972	1030	1086	1142	1197	1250	1320
1801.00	0	72	143	214	283	352	420	487	553	619	683	747	809	871	932	992	1051	1109	1166	1222	1277	1349
1801.50	0	73	146	217	288	358	428	496	564	631	696	761	825	889	951	1012	1073	1132	1191	1248	1305	1379
1802.00	0	75	148	221	294	365	436	506	574	643	710	776	842	906	970	1033	1094	1155	1215	1274	1332	1408
1802.50	0	76	151	225	299	372	444	515	585	655	723	791	858	924	989	1053	1116	1178	1240	1300	1359	1437
1803.00	0	77	154	229	304	378	452	524	596	667	737	806	874	941	1008	1073	1138	1202	1264	1326	1387	1466
1803.50	0	79	156	233	310	385	460	534	607	679	750	821	890	959	1027	1094	1160	1225	1289	1352	1414	1496
1804.00	0	80	159	238	315	392	468	543	617	691	764	835	906	976	1046	1114	1181	1248	1313	1378	1442	1525
1804.50	0	81	162	242	320	399	476	553	628	703	777	850	923	994	1065	1134	1203	1271	1338	1404	1469	1554
1805.00	0	83	164	246	326	405	484	562	639	715	791	865	939	1012	1084	1155	1225	1294	1363	1430	1497	1584
1805.50	0	84	167	250	331	412	492	571	650	728	804	880	955	1030	1103	1175	1247	1318	1387	1456	1524	1613
1806.00	0	85	170	254	337	419	500	581	661	740	818	895	972	1047	1122	1196	1269	1341	1412	1482	1552	1643
1806.50	0	87	173	258	342	426	509	591	672	752	832	910	988	1065	1141	1217	1291	1364	1437	1509	1579	1672
1807.00	0	88	175	262	348	433	517	600	683	764	845	925	1005	1083	1160	1237	1313	1388	1462	1535	1607	1702
1807.50	0	89	178	266	353	439	525	610	694	777	859	940	1021	1101	1180	1258	1335	1411	1487	1561	1635	1732
1808.00	0	91	181	270	359	446	533	619	705	789	873	956	1038	1119	1199	1279	1357	1435	1512	1588	1663	1761
1808.50	0	92	184	274	364	453	541	629	716	801	887	971	1054	1137	1218	1299	1379	1458	1537	1614	1690	1791
1809.00	0	94	186	278	370	460	550	639	727	814	900	986	1071	1155	1238	1320	1402	1482	1562	1640	1718	1821
1809.50	0	95	189	282	375	467	558	648	738	826	914	1001	1087	1173	1257	1341	1424	1506	1587	1667	1746	1851
1810.00	0	96	192	287	381	474	566	658	749	839	928	1017	1104	1191	1277	1362	1446	1529	1612	1694	1774	1881

GRAPH/CHART-1 R-1

23-03-2011

KARCHAM WANGTOO H.E. PROJECT 1000MW
SPILLWAY TOP SEALING RADIAL GATES



NOTE :- THE BOTTOM DARK CURVE IS THE DISCHARGE CURVE WHEN THE GATE LIP IS ABOVE THE WATER SURFACE PROFILE.

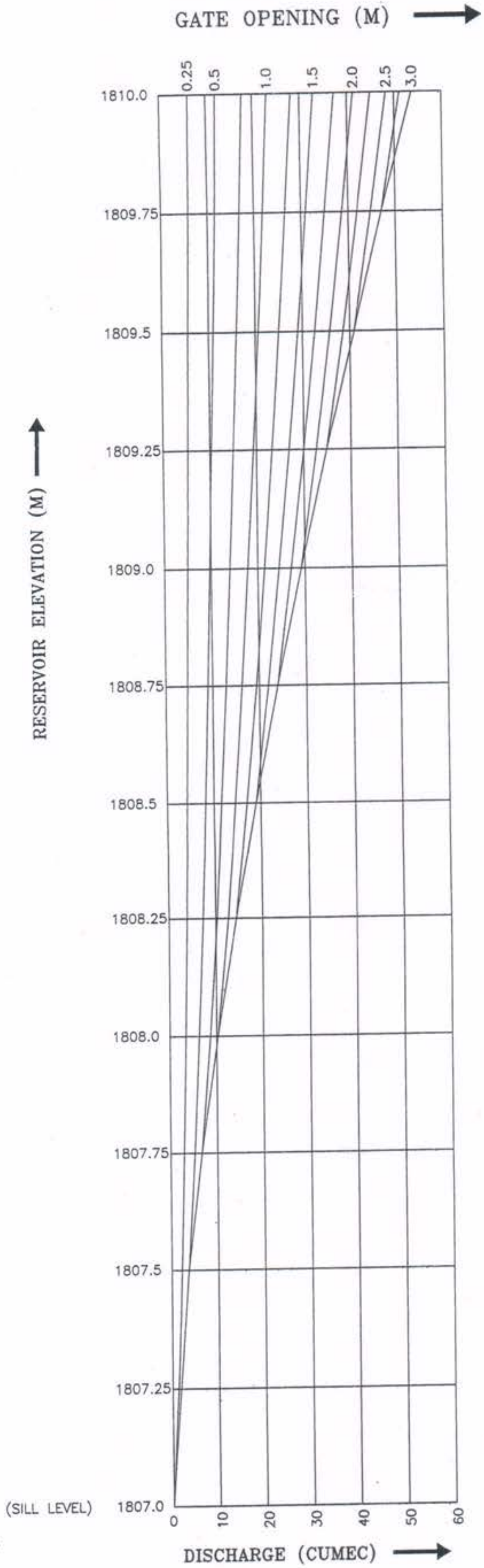
DISCHARGE PER BAY (CUMEC) ⟶

DISCHARGE CURVES FOR DIFFERENT GATE OPENINGS AND RESERVOIR LEVELS

KARCHAM WANTOO H.E. PROJECT (1000MW)

GRAPH/CHART-3

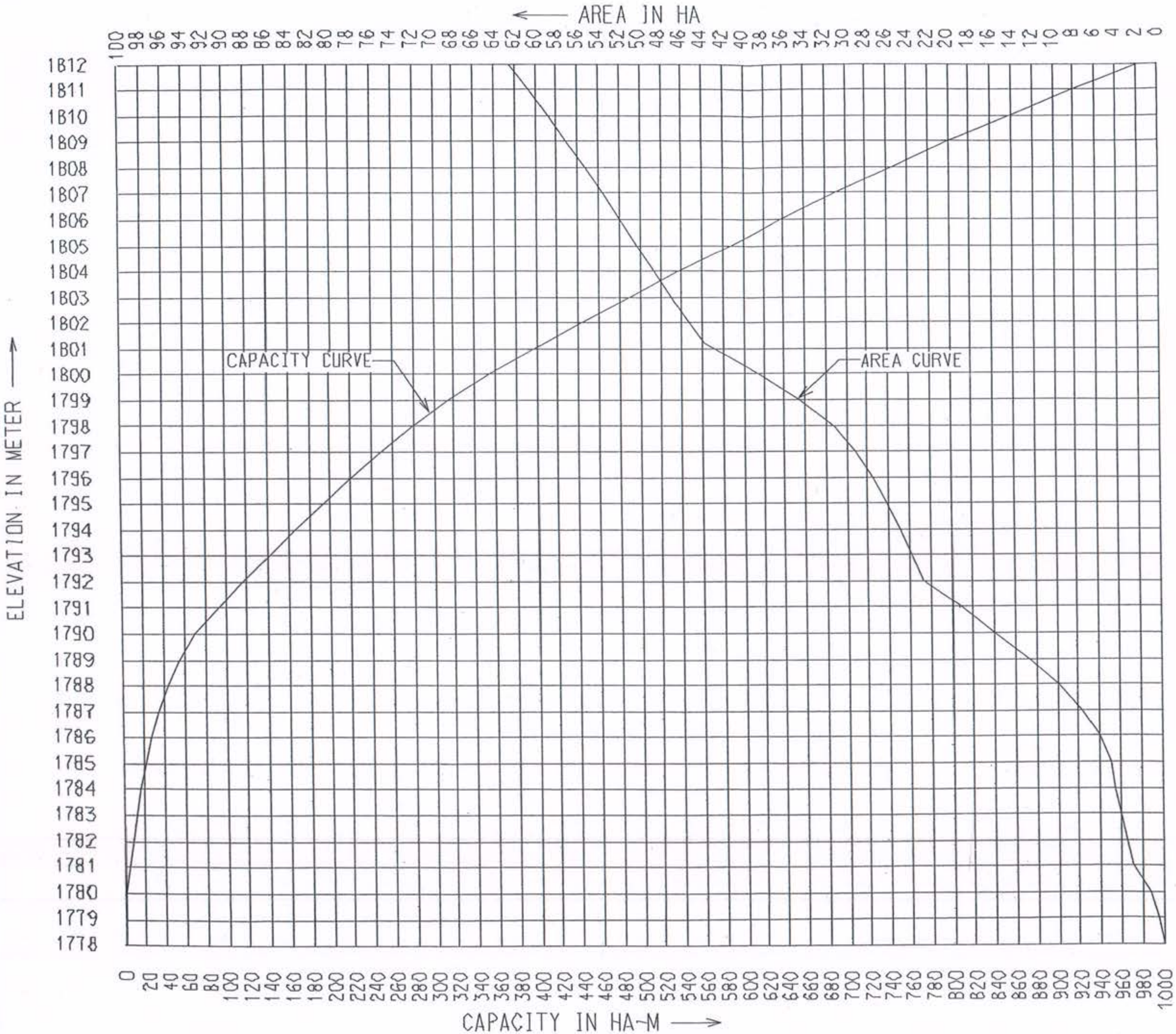
AUXILIARY SPILLWAY GATE



NOTE :- THE BOTTOM CURVE IS THE DISCHARGE CURVE WHEN THE GATE LIP IS ABOVE THE WATER SURFACE PROFILE.

DISCHARGE CURVES FOR DIFFERENT GATE OPENINGS

AND RESERVOIR LEVELS



RESERVOIR CAPACITY CURVE

ELEVA-TION (M)	AREA (HA)	CAPACITY (HA-M)
1778	0.0	0.0
1779	0.44	0.28
1780	1.26	1.31
1781	2.84	4.47
1782	3.44	8.06
1783	4.01	12.08
1784	4.49	16.54
1785	4.98	21.42
1786	6.03	27.16
1787	7.78	34.45
1788	9.99	43.70
1789	12.72	55.32
1790	16.06	69.72
1791	19.29	92.64
1792	22.63	116.39
1793	23.77	140.98
1794	24.95	166.38
1795	26.19	192.60
1796	27.49	220.04
1797	29.28	249.10
1798	31.19	280.10
1799	34.51	313.32
1800	38.60	354.31
1801	45.11	397.93
1802	45.35	443.01
1803	47.05	489.57
1804	48.70	537.59
1805	50.31	587.08
1806	51.97	638.12
1807	53.65	690.74
1808	55.38	744.96
1809	57.09	800.80
1810	58.84	858.29
1811	60.70	919.16
1812	62.61	981.74

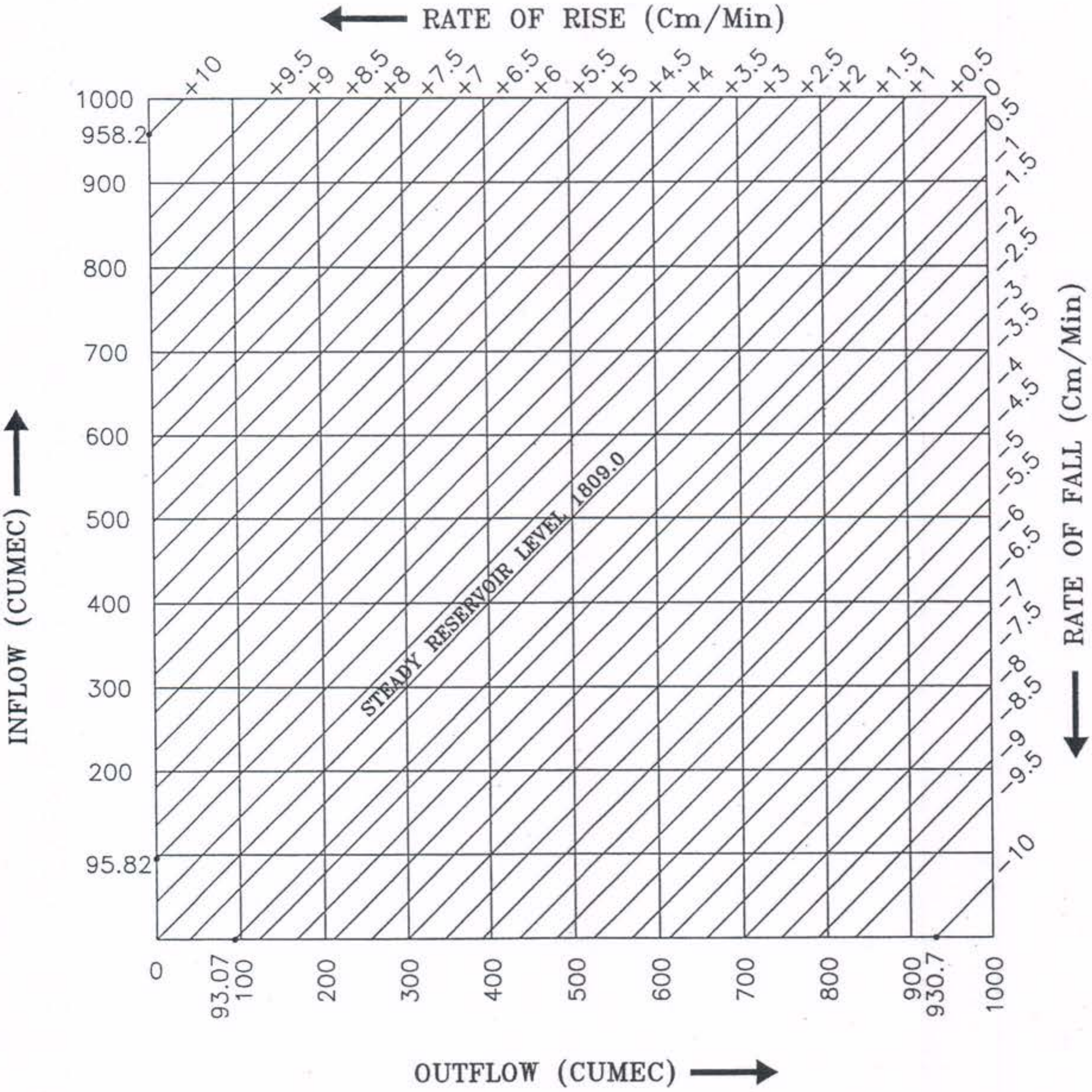
KARCHAM WANGTOO H.E.PROJECT (1000MW)

TABLE OF DISCHARGES FOR AUXILLIARY SPILLWAY GATE AT VARIOUS GATE OPENINGS AND RESERVOIR LEVELS

Gate opening	0	0.25	0.5	0.75	1	1.25	1.5	1.75	2	2.25	2.5	2.75	3
Reservoir level													
1807.00	0												
1807.25	0	1.29											
1807.50	0	2.24	3.65										
1807.75	0	2.89	5.17	6.71									
1808.00	0	3.42	6.33	8.67	10.34								
1808.25	0	3.88	7.31	10.25	12.66	14.44							
1808.50	0	4.29	8.17	11.63	14.62	17.09	18.99						
1808.75	0	4.66	8.95	12.86	16.34	19.38	21.93	23.93					
1809.00	0	5.00	9.67	13.97	17.90	21.43	24.51	27.13	29.23				
1809.25	0	5.33	10.34	15.01	19.34	23.29	26.85	30.00	32.68	34.88			
1809.50	0	5.63	10.96	15.98	20.67	25.02	29.01	32.61	35.80	38.57	40.86		
1809.75	0	5.92	11.56	16.89	21.93	26.64	31.01	35.03	38.67	41.92	44.76	47:14	
1810.00	0	6.20	12.12	17.76	23.11	28.16	32.89	37.29	41.34	45.03	48.34	51.24	53.71

					Cd
					0.5500
					0.5500
					0.5500
					0.5500
					0.5500
					0.5500
					0.5500
					0.5500
					0.5500
					0.5500
	0.000	,839.5			0.5500
	0.000	,839.75			0.5500
	0.537	,840.0			0.5500

GRAPH/CHART 6
(SHEET 1)
(REV.1)
(26-03-2011)

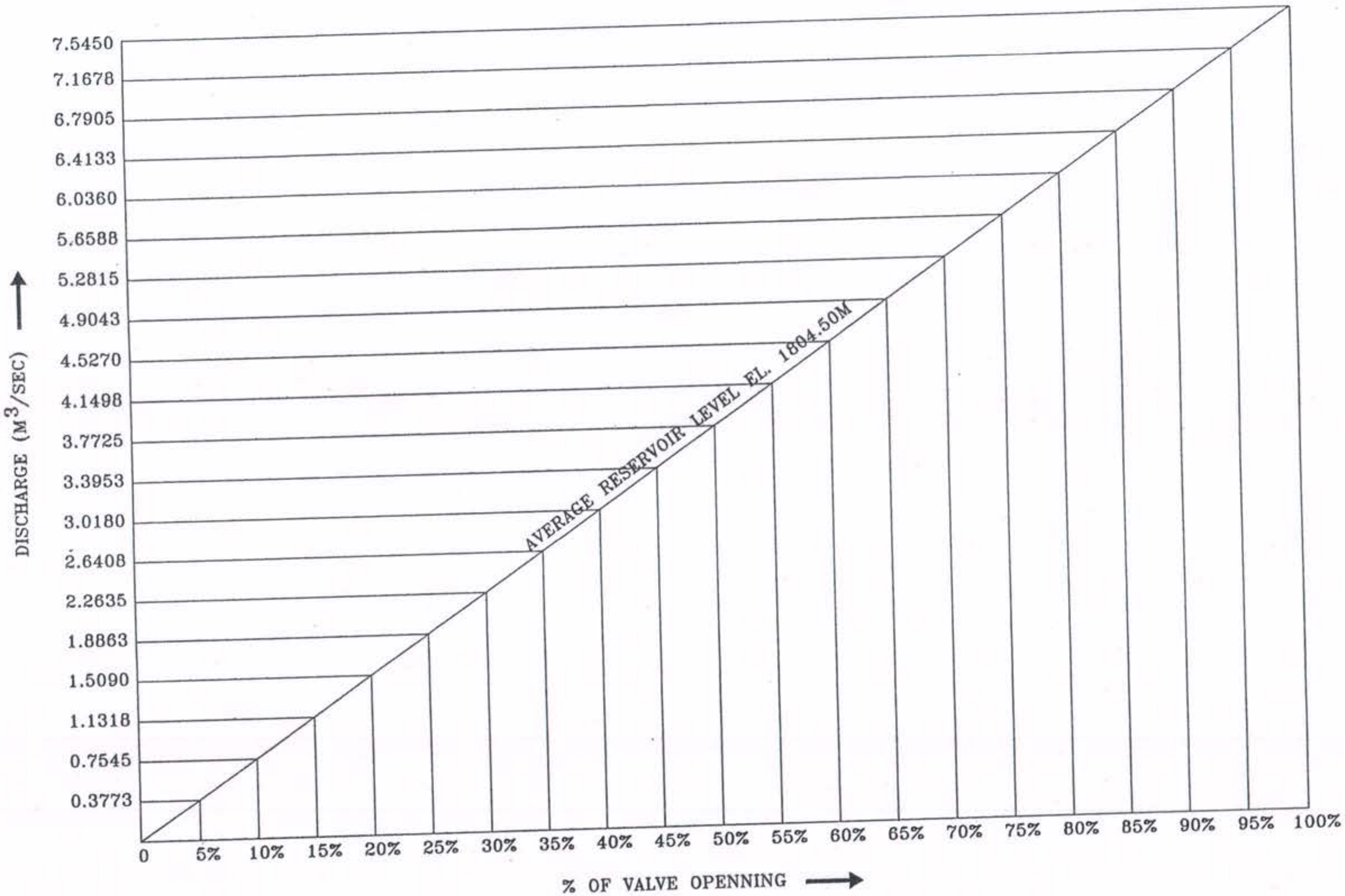


NOTE :- 1. ALL FIGURES RELATE TO RATE OF CHANGE IN LEVEL IN Cm/Min.
2. THE GRAPH IS TO BE USED FOR INFLOW/OUTFLOW UPTO 1000 CUMEC.

GRAPH FOR CALCULATING INFLOW/OUTFLOW FROM RATE OF RISE/FALL OF RESERVOIR LEVEL

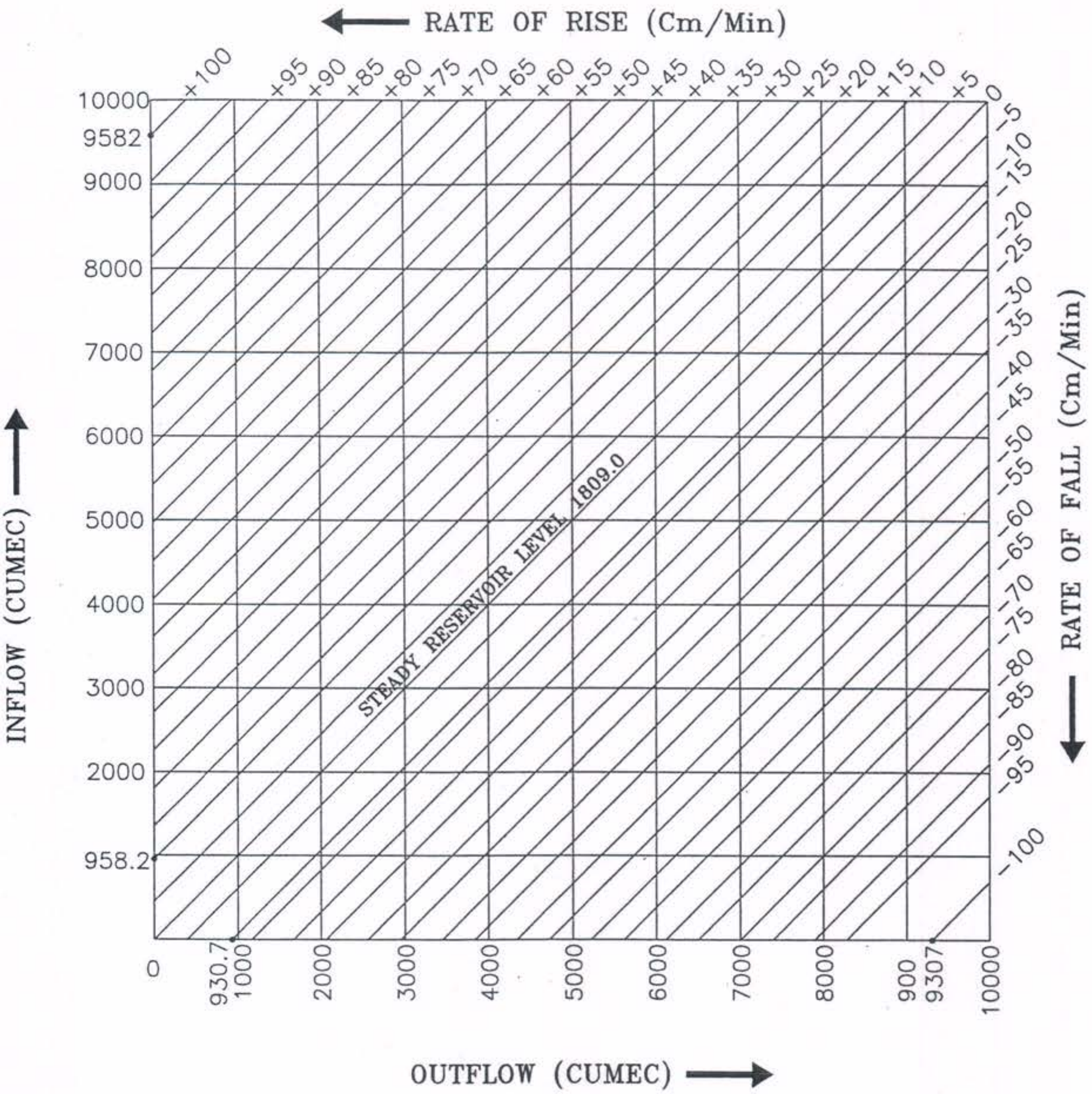
GRAPH/CHART 8

KARCHAM WANGTOO H.E. PROJECT (1000MW)



DISCHARGE CURVE FOR EACH MANDATORY DISCHARGE PIPE AT MINIMUM RESERVOIR LEVEL 1804.50

GRAPH/CHART 6
(SHEET 2)
(REV.1)
(26-03-2011)



NOTE :- 1. ALL FIGURES RELATE TO RATE OF CHANGE IN LEVEL IN Cm/Min.
2. THE GRAPH IS TO BE USED FOR INFLOW/OUTFLOW ABOVE 1000 CUMEC.

GRAPH FOR CALCULATING INFLOW/OUTFLOW FROM RATE OF RISE/FALL OF RESERVOIR LEVEL

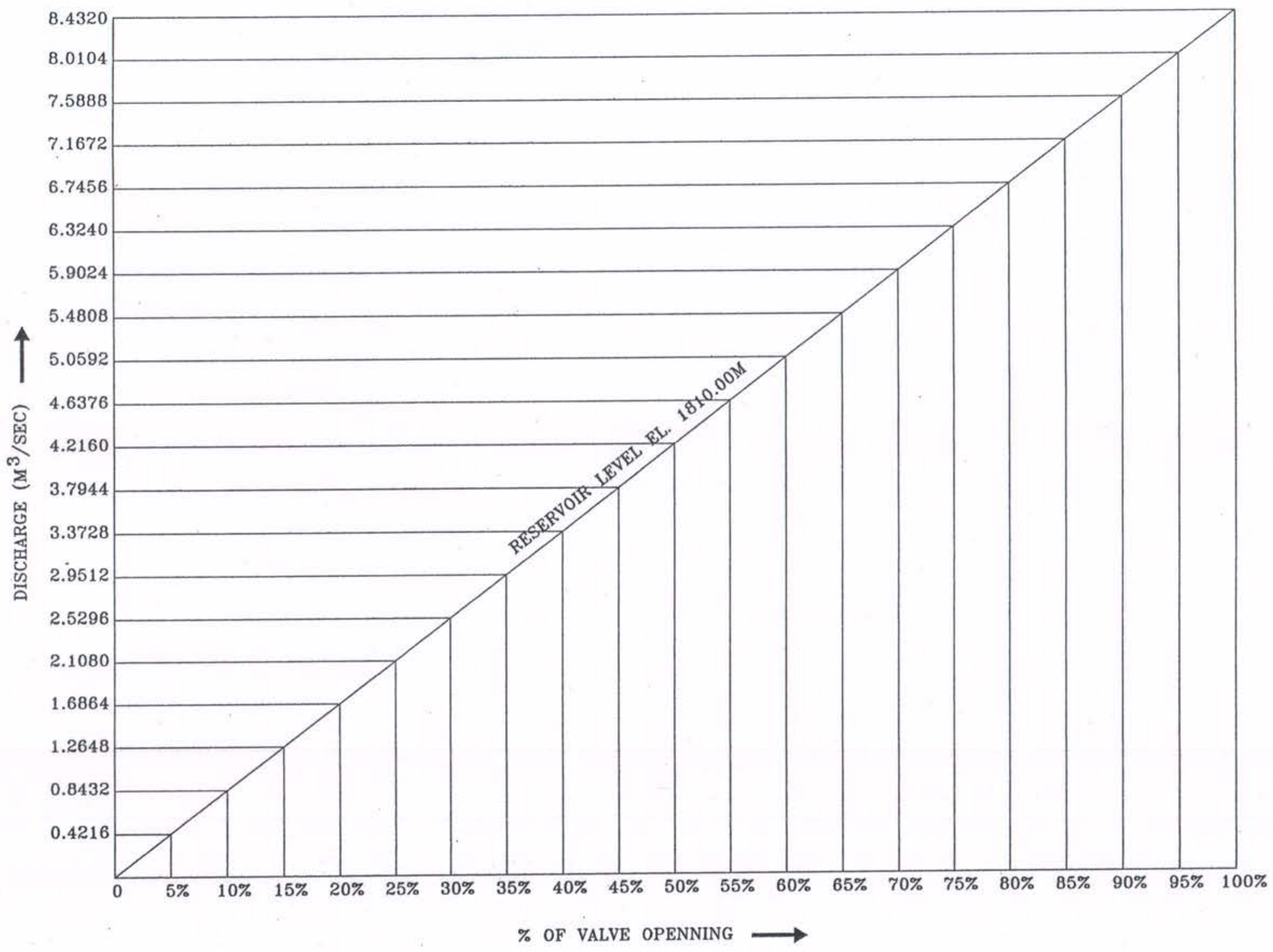
Graph/Chart 6
(Sheet 3)
(26.3.11)

KARCHAM-WANGTOO H.E. PROJECT (1000 MW)

Table showing Inflow/Outflow in the reservoir
based on Rate of Rise / Rate of Fall

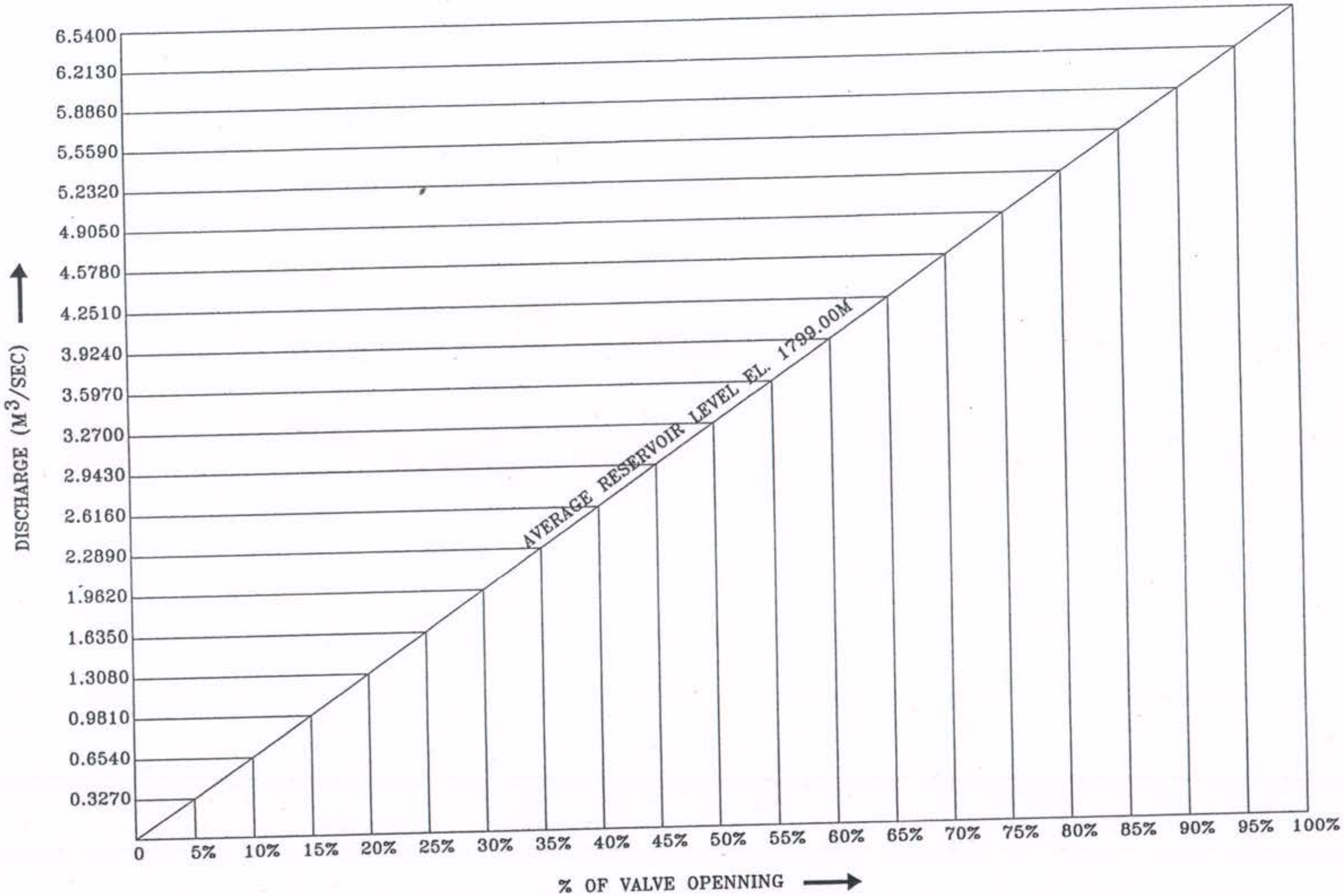
Sl. No.	Rate of Rise (cm/min)	Inflow (cumec)	Rate of Fall (cm/min)	Outflow (cumec)
1	5	479.1	5	465.35
2	10	958.2	10	930.7
3	15	1437.3	15	1396.05
4	20	1916.4	20	1861.4
5	25	2395.5	25	2326.75
6	30	2874.6	30	2792.1
7	35	3353.7	35	3257.45
8	40	3832.8	40	3722.8
9	45	4311.9	45	4188.15
10	50	4791	50	4653.5
11	55	5270.1	55	5118.85
12	60	5749.2	60	5584.2
13	65	6228.3	65	6049.55
14	70	6707.4	70	6514.9
15	75	7186.5	75	6980.25
16	80	7665.6	80	7445.6
17	85	8144.7	85	7910.95
18	90	8623.8	90	8376.3
19	95	9102.9	95	8841.65
20	100	9582	100	9307

KARCHAM WANGTOO H.E. PROJECT (1000MW)



DISCHARGE CURVE FOR EACH MANDATORY DISCHARGE PIPE AT MAXIMUM RESERVOIR LEVEL 1810.00

KARCHAM WANGTOO H.E. PROJECT (1000MW)



DISCHARGE CURVE FOR EACH MANDATORY DISCHARGE PIPE AT MINIMUM RESERVOIR LEVEL 1799.00

KARCHAM WANGTOO H.E. PROJECT(1000MW)			
TABLE OF DISCHARGE FOR EACH GLOBE VALVE AT DIFFERENT OPENINGS OF VALVE AND RESERVOIR LEVEL AT EL. 1810.0, EL.1804.5 & EL. 1799.0			
%OPENING OF VALVE	DISCHARGE AT RESERVOIR LEVEL1810M (CUMEC)	DISCHARGE AT AVG.RESERVOIR LEVEL 1804.5M (CUMEC)	DISCHARGE AT MINIMUM.RESERVOIR LEVEL 1799 M (CUMEC)
0	0.0000	0.0000	0.0000
5	0.4216	0.3773	0.3270
10	0.8432	0.7545	0.6540
15	1.2648	1.1318	0.9810
20	1.6864	1.5090	1.3080
25	2.1080	1.8863	1.6350
30	2.5296	2.2635	1.9620
35	2.9512	2.6408	2.2890
40	3.3728	3.0180	2.6160
45	3.7944	3.3953	2.9430
50	4.2160	3.7725	3.2700
55	4.6376	4.1498	3.5970
60	5.0592	4.5270	3.9240
65	5.4808	4.9043	4.2510
70	5.9024	5.2815	4.5780
75	6.3240	5.6588	4.9050
80	6.7456	6.0360	5.2320
85	7.1672	6.4133	5.5590
90	7.5888	6.7905	5.8860
95	8.0104	7.1678	6.2130
100	8.4320	7.5450	6.5400

Formulae for discharge through each pipe

$$Q(m^3/sec) = 1.605 \times \left(\frac{\%\ of\ valve\ opening}{100}\right)\sqrt{H - H_c}$$

Where H = Reservoir level (m)
Hc = Centre line of pipe
= 1782.4m