CHAPTER-15

DISASTER MANAGEMENT PLAN & RISK ASSESSMENT

15.1 INTRODUCTION

Any hydroelectric project if not designed on the sound principles of design after detailed investigations in respect of hydrology, geology, seismicity etc., could spell a large scale calamity. Thus these are inherent risk to the project like improper investigation, planning, designing and construction which ultimately lead to human catastrophy. Though through detailed field investigations it has been ensured that the dam is founded on firm foundation, designed for suitable seismic design parameters and the spillway has been designed for a routed PMF of 16150 cumecs capacity, yet in view of that uncertain element of "Force Mejure" the eventuality of a disaster cannot be ignored but a rescue plan has to be devised for confronting such an exigency without being caught in the vast realm of unpreparedness.

A disaster is an unwarranted, untoward and emergent situation that culminates into heavy toll of life and property and is a calamity sometimes caused by "force mejure" and also by human error. The identification of all types of disaster in any proposed project scenario involves the critical review of the project vis-à-vis the study of historical past incidents/disasters in the similar situations. The evolution of disaster management plan dwells on various aspects such as provision of evacuation paths, setting up of alarms and warning systems, establishing communicating system besides delineating an Emergency Response Organization with an Effective Response System. Keeping in view the grievous effects a disaster can cause on human or animal population, loss of property and environment in and around the areas of impact. Therefore it is essential to assess the possibility of such failures in context to the present project and formulate a contingent plan.

The proposed Thana Plaun HEP on river Beas comprises of 106.70 m high concrete dam with spillway crest and top of the dam at El 670.0 masl and El 719 masl respectively. The gross and live storage at FRL (El 716 masl) are 78.56 MCM and 44.93 MCM respectively with the reservoir spread being 316.77 ha. There are two other HEP on the Beas river viz. Larji and Pandoh which are 20 km upstream of the proposed Thana Plaun HEP. The hazard classification of the Thana Plaun HEP shall be of relevance for these dams in series. Therefore, a comprehensive monitoring network system has to be established to combat jointly the threat due to failure of any of these schemes. For accomplishing this, a fool-proof "no communication failure" system has to be evolved.

15.2 DAM BREAK INUNDATION ANALYSIS

The outflow flood hydrograph from a dam failure is dependent upon many factors such as physical characteristics of the dam, volume of reservoir and the mode of failure. The parameters which control the magnitude of the peak discharge and the shape of outflow hydrograph include: the breach dimensions, the manner and length of time for the breach to develop, the depth and volume of water stored in the reservoir, and the inflow to the reservoir at the time of failure. The shape and size of the breach and the elapsed time of development of the breach are in turn dependent upon the geometry of the dam, construction materials and the casual agent for failure.

The dam break study given in this chapter has been conducted by SMEC India which is the DPR consultants of this project. A complete DAM Break study is attached as **Annexure-IV** of this report.

15.2.1 Model for Dam Break Analysis

Selection of an appropriate model to undertake dam break flood modeling is essential to ensure to achieve the right balance between modeling accuracy and cost in terms of time spent developing the model setup. In the instant case HEC-RAS version 4.1.0 model released by Hydrologic Engineering Center of U.S. Army Corps of Engineers in January 2010 has been selected. HEC-RAS is an integrated system of software, designed for interactive use in a multi-tasking environment. The system is comprised of a graphical user interface, separate hydraulic analysis components, data storage and management capabilities, graphics and reporting facilities. The model contains the advanced features for dam break simulation.

The dynamic routing method based on the complete equations of unsteady flow is the appropriate technique to route the flood hydrograph through the downstream valley. The method is derived from the original equations developed by St. Venant. The model uses St. Venant's equations for routing dam break floods in channels.

15.2.2 Methodology

HEC-RAS uses an implicit four-point finite difference scheme. The common problem of instability in the case of unsteady flow simulation can be overcome by suitable selection of following;

1. Cross section spacing along the river reach
2. Computational time step
3. Theta weighing factor for numerical solution
4. Solution iterations
5. Solution tolerance
6. Weir and spillway stability factors

Cross section spacing

The river cross sections should be placed at representative locations to describe the change in geometry. Additional cross sections should be added at locations where changes occur in discharge, slope, velocity and roughness. Cross sections must also be added at various levels, bridges, culverts, and other structures. Additional cross sections should be added at locations where changes occur in discharge, slope, velocity, and roughness to describe the change in geometry. Bed slope plays an important role in deciding the cross section spacing. Streams having steep slope require cross sections at a closer spacing say 500 m or so. For larger uniform rivers with flat slope the cross section spacing can be kept from 1000m to 3000m.

Computational time step

Stability and accuracy can be achieved by selecting a computational time step that satisfies the courant condition;

Therefore,

$$\Delta t \le (\Delta x / Vw)$$

Where; Vw : Flood Wave Speed
V : Average velocity of flow
Δx : Distance between the X-sections
Δx : Computational Time Step

For most of rivers the flood wave speed can be calculated as:

$$Vw = dQ/dA$$

However, an approximate way of calculating flood wave speed is to multiply the average speed by a factor. Factors for various channel shapes are given in the Table 15.1

Table 15.1: Factor for Channel shape

S. No.	Channel Shape	Ratio
1	Wide rectangular	1.67
2	Wide parabolic	1.44
3	Triangular	1.33
4	Natural Channel	1.5

Theta weighing factor

Theta is a weighing factor applied to the finite difference approximations when solving the unsteady flow equations. Theoretically Theta can vary from 0.5 to 1.0. Theta of 1.0 provides the most stability, while Theta of 0.5 provides the most accuracy.

Solution iteration

At each time step derivatives are estimated and the equations are solved. All the computational nodes are then checked for numerical error. If the error is greater than the allowable tolerances, the program will iterate. The default number of iterations in HEC-RAS is set to 20. Iteration will improve the solution.

Solution tolerances

Two solution tolerances can be set or changed by the user:

i) Water surface calculation
ii) Storage area elevation. Making the tolerance larger can reduce the stability problem.

Making them smaller can cause the program to go to the maximum number of iterations every time.

Weir and spillway stability factor

Weirs and spillways can often be a source of instability in the solution. During each time step, the flow over a weir/spillway is assumed to be constant. This can cause oscillations by sending too much flow during a time step. One solution is to reduce the time step.

15.2.3 Dam Break Model Set-up for Thana Plaun HEP

For dam break model setup and other hydrodynamic model set up for Thana Plaun HEP, the different components of the project have been represented in the model as following:

Beas River

The Beas River for a length of 30 km downstream of Thana Plaun dam site has been represented in the model by cross sections taken at an appropriate interval. The Beas river cross section at dam axis has been connected to a storage area representing the reservoir. As the dam breach flood levels far exceed the normal flood level marks and the flood spreads beyond the normal river course, the Manning's roughness coefficient for the dam break studies should be assumed normally more than the other hydro-dynamic studies. The Manning's roughness coefficient for this reach of the river has been taken as 0.040 considering the boundary river beds.

Reservoir

The reservoir has been represented in the model by storage area of the graphical editor of the model and its Elevation-volume relationship has been specified therein.

The stage in volume relationship of the reservoir as used in the model set up is given in Table 15.2.

Table 15.2: Flood hydrograph

Elevation, (m)	Cumulative Volume (1000 m3)
634	0
640	1.9
645	101.4
650	502.2
655	1328.3
660	2546.2
665	4204.2
670	6391.7

Elevation, (m)	Cumulative Volume (1000 m3)
675	9214
680	12842.8
685	17425.6
690	23138.1
695	30221.1
700	38742.4
705	61041.7
710	75239.2
715	78560
720	91839.1
725	111290.5

15.2.4 Breach Parameters and Dam Break Simulation

Selection of breach parameters for Dam Break study

For any dam break study it is extremely difficult to predict the chances of failure of a dam, as prediction of the dam breach parameters and timing of the breach are not within the capability of any of the commercially available mathematical models. However, assuming the dam fails, the important aspects to deal with are, time of failure, extent of overtopping before failure, size, shape and time of the breach formation.

Estimation of the dam break flood will depend on these parameters. The breach characteristics that are used as input to the existing dam break models are:

- Final bottom width of the breach,
- Final bottom elevation of the breach,
- Left and right side slope of the breaching section
- Full formation time of breach, and
- Reservoir level at time of start of breach.

The type of breach formation mechanism is to a large extent, dependent on the type of dam and the cause due to which the dam failed. A study of the different dam failures indicate that concrete arch and gravity dams breach by sudden collapse, overturning or sliding away of the structure due to inadequate design or excessive forces that may result from overtopping, earthquakes and deterioration of the abutment or foundation material.

As per the UK Dam Break Guidelines and U.S. Federal Energy Regulatory Commission (FERC) Guidelines, in the case of concrete gravity dams, the breach width should be taken between 0.2 to 0.5 times the crest length of the dam and full breach formation time should be taken instantaneous which may be practically taken as 0.2 to 0.25 hours. The full breach formation time for the dam break simulation of Thana Plaun HEP.

Project has been considered as 12 minutes. The final bottom elevation of the breach for sensitivity analysis has been taken corresponding to relatively weaker locations in the dam, such as location of openings, galleries etc. Further, the final bottom elevation of the breach should be restricted to the reservoir bed level /natural ground level at the dam location due to nil reservoir storage below this level.

The manner in which the failure is to commence can be specified as one of the following:

- At a specified stage (water surface elevation) of the reservoir and duration
- At a specified time
- At a specified stage (water surface elevation) of the reservoir

Critical condition for dam break study

The critical condition for a dam break study is when the reservoir is at Full Reservoir Level (FRL) and design flood hydrograph (PMF in the present case) is impinged. Accordingly, in the present study keeping the reservoir at FRL of 716 m, the reservoir routing has been carried out by impinging the PMF. For opening schedule of spillway gates the elevation controlled algorithm of HEC-RAS model has been used, where the spillway gate opening is controlled with the rise and fall of reservoir water level just upstream of dam. The maximum water level reached in the reservoir during routing is 718.75 m which occurs 34 hours 12 minutes after the impingement of PMF. The corresponding discharge of all the gates has been found is 15722 cumec. The top of dam is at EL 719 m. Hence, it can be said that even initial reservoir level at FRL, the PMF can be safely passed as the spillway capacity is adequate to negotiate the PMF for its one gate i n operative condition. The discharge through spillway gates and the reservoir level as obtained during reservoir routing of PMF is shown in Figure 15.1.

The dates given on the horizontal axis of the plot are the relative dates only, as used in HECRAS model set up.

Figure 15.1: Discharge through spillways and reservoir level during reservoir routing

It can be seen that the PMF can be safely passed through spillway gates. In order to get the maximum discharge through the breach and most critical dam break flood, the dam has been assumed to breach 34 hours 12 minutes after the occurrence of PMF *i.e.* on 21 May 2013 at 10 hours 12 minutes as per simulation period adopted.

15.2.5 Dam Break Flood Hydrograph

The dam break flood hydrograph just downstream of Thana Plaun dam (comprising of total discharge through spillway and dam breach) with peak 34694 cumec is given in Figure 15.2. The time of occurrence of the flood peak is on 21 May 2013 at 10 hours 24 minutes, which is 12 minutes after the start of breach. From the figure, it can be seen that the peak segment of the hydrograph last for about 5 hours only. This is due to quick depletion of reservoir in the event of dam break.

The maximum discharge, bed level of river, maximum water level, velocity of flood wave and travel time of flood at different locations of the Beas River downstream of Thana Plaun dam are given in Table 15.3. From the Table 15.3, it can be seen that the dam breach flood peak just downstream of the dam is 34694 cumec, which reduces to 24585 cumec at the chainage -30000 m of the Beas River downstream of the Thana Plaun dam axis. The velocity of the flood wave is dependent of the river cross section at a particular location. The narrower cross sections will result in higher flood velocity than the wider cross sections.

Further, it can be seen that at the Beas River cross sections located 750 m to 7000 m downstream of the dam axis, the velocity is in the range of 8.1 to 17.1 m/s. The same at the cross sections between -8000 m and -20000 m is in the range of 4.2 to 6.8 m/s, while the cross section at -25000 m velocity is 10.25 m/s.

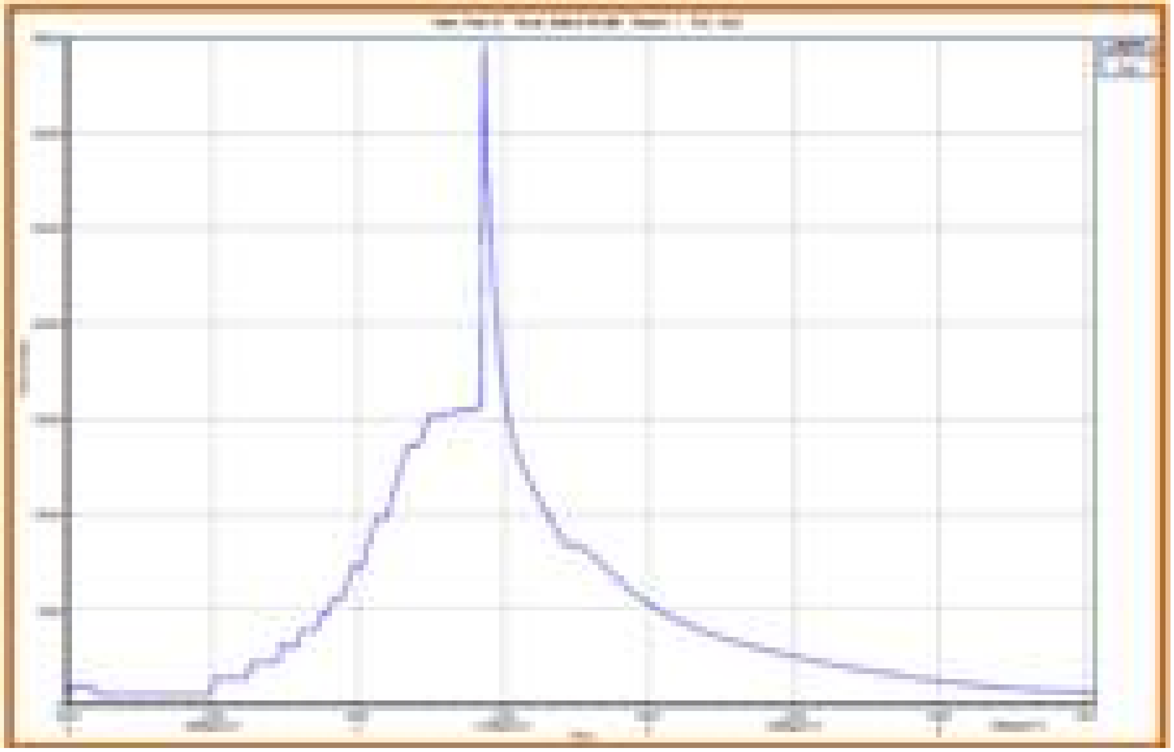
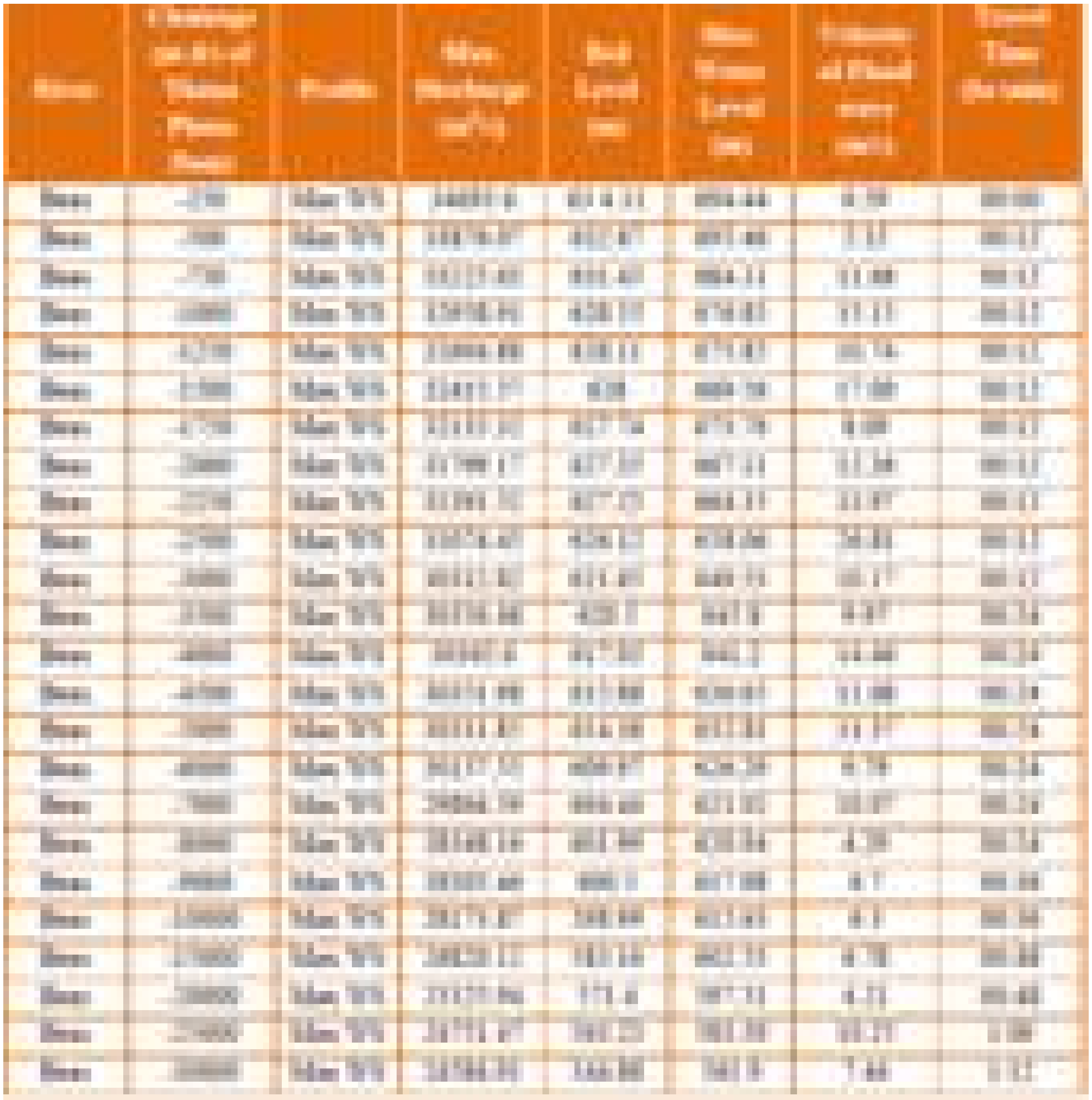


Figure 15.2 : Dam break flood hydrograph due to Thana Plaun dam break

Table 15.3: Maximum discharge, water level and flood wave velocity and travel time at different locations of Beas river for Thana Plaun dam break (breach width 20 m, breach depth 59 m)



The longitudinal profile of the Beas River downstream of Thana Plaun dam for dam break condition is given below in Figure 15.3.

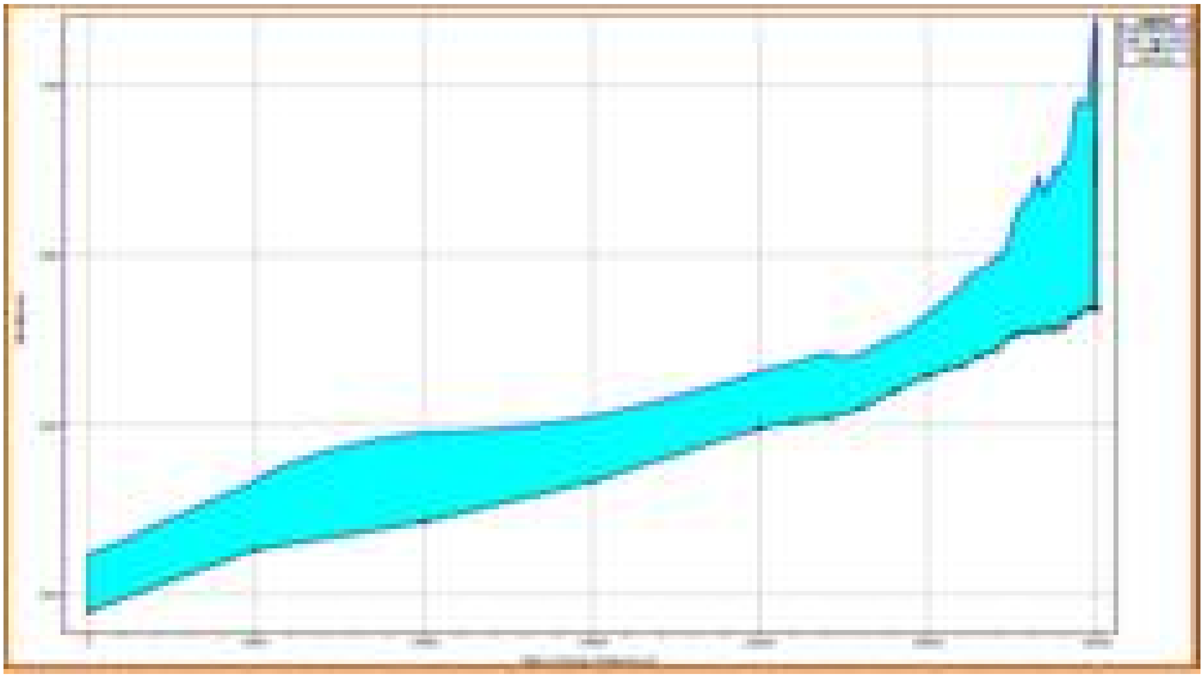


Figure 0.3: Bed profile and maximum water surface profile of Beas River during Thana Plaun dam break

Comparison of maximum water level for different simulated conditions

The maximum water level obtained at different locations of Beas River downstream of Thana Plaun dam axis for different simulated conditions are given below in Table 15.4.

(Note: -500, -3000 etc denote the location of river cross sections 500 m, 3000 m d/s of Thana Plaun dam axis. Same way all the other locations may please be read)

Table 15.4: Comparison of maximum water level for different simulated conditions

River	Chainage (m d/s of Thana Plaun Dam)	Bed Level (m)	Max. Water Level (m) due to occurrence of		
			PMF with dam break	PMF without dam break	PMF in natural condition
Beas	-250	634.11	694.44	673.57	674.40
Beas	-500	632.67	695.46	674.02	674.88
Beas	-750	631.45	684.11	667.07	667.70
Beas	-1000	628.58	676.85	662.57	663.10
Beas	-1250	628.11	675.85	663.66	664.13
Beas	-1500	628.00	669.56	659.37	659.76
Beas	-1750	627.74	673.70	662.00	662.50
Beas	-2000	627.35	667.11	657.43	657.83
Beas	-2250	627.25	664.35	654.44	654.89
Beas	-2500	626.12	658.06	648.73	649.16
Beas	-3000	621.65	649.53	643.12	643.46
Beas	-3500	620.50	645.80	639.27	639.61
Beas	-4000	617.08	643.20	634.49	634.81
Beas	-4500	615.88	636.65	630.86	631.17
Beas	-5000	614.38	632.81	627.07	627.38
Beas	-6000	609.97	626.29	621.05	621.30
Beas	-7000	604.44	621.02	617.09	617.30
Beas	-8000	601.59	620.94	616.14	616.39
Beas	-9000	600.50	617.88	613.45	613.68
Beas	-10000	598.99	615.03	610.99	611.23
Beas	-15000	583.16	602.53	597.66	597.96
Beas	-20000	571.40	597.51	591.89	592.28
Beas	-25000	563.23	583.39	579.31	579.60
Beas	-30000	544.88	561.90	558.92	559.15

Limitations

The uncertainties associated with the breach parameters, specially breach width, breach depth and breach development time may cause uncertainty in flood peak estimation and arrival times.

Further the high velocity flows associated with dam break floods can cause significant scour of channels. This enlargement in channel cross section is neglected since the equations for sediment transport, sediment continuity, dynamic bed form friction etc. are not included among the governing equations of the model. The narrow channels with minimal flood plains are subject to over estimation of water elevation due to significant channel degradation. The dam breach floods create a large amount of transported debris, which may accumulate at very narrow cross sections, resulting water level variation at downstream locations. This aspect has been neglected due to limitations in modeling of such complicated physical process.

15.3 DISASTER MANAGEMENT PLAN

The emergency planning for dam break scenario is devised on the basis of results of dam break analysis mainly the travel time of flood wave to various locations in the downstream stretch of the river. It is inferred from the analysis that in case of main dam failure the flood peak discharge as it prorogates through valley shall inundate downstream stretch of three km within 02 minutes implying that the Triveni Mahadev proposed project, which is located about 5 km d/s of the dam shall be left with just a little reaction time for executing any rescue plan and sending evacuation message to small settlements.

The flood period during monsoon generally is reckoned from June with the onset of monsoon and ends with withdrawal of south-west monsoon by the end of September. Before the onset of monsoon all hydro-mechanical equipments, electrical gadgets, captive power plant and public announcement and communication system should be kept in perfect readiness. The degree of alertness has to enhance during high stage of river manifested with sharp increase in discharge. Though there cannot be very sharp edge demarcation between different levels of emergency yet the following flood conditions have been contemplated and the preventive measures suggested against each as given in Table 15.5.

Table 15.5: Status of emergency

S. No.	Status of emergency	Water Level	Preventive measures
1.	Normal Flood	Below FRL i.e. EL 716 masl and flood discharge below 16150 Cumecs	Utmost vigil observed in regulation of spillway gates

S. No.	Status of emergency	Water Level	Preventive measures
2.	Level –1 Emergency	Rises above EL 716 masl but below MWL EL 718.75 masl	(1) All gates fully operational (2) All the official should attend dam site. Local officials informed and warning system be kept on alert.
3.	Level –2 Emergency	Above MWL i.e. EL 718.75 masl and discharge keeps on rising	Communication & public announcement system should be put into operation and flood warning issued to people.
4.	Level –3 Emergency	Top of dam i.e. EL 719 masl	(1) All staff from dam site, power house & TRC outlets alerted to move to safer places (2) Possibility of dam failure should be flashed to district administration.
5.	Disaster	Rising above EL 719 masl and the breach appears in any form	District Administration and Project authorities be intimated and only life saving measures should be resorted too

15.3.1 Dam Safety and Maintenance Manual

Based on standard recommended guidelines for the safety inspection of dams a manual should be prepared by the project proponents in respect of dam safety surveillance and monitoring aspects. This should be updated with the availability of instrumentation data and observation data with periodical review. The need for greater vigil has to be emphasized during first reservoir impoundment and first few years of operation. The manual should also delve on the routine maintenance schedule of all hydro-mechanical and electrical instruments. It should be eloquent in respect of quantum of specific construction material needed for emergency repair along with delineation of the suitable locations for its stocking and also identify the much needed machinery and equipment for executing emergency repair work and for accomplishing the evacuation plan.

15.3.2 Emergency Action Plan (EAP)

Dam safety programme as indicated above includes the formation of an Emergency Action Plan for the dam. An emergency is defined as a condition of serious nature which develops unexpectedly and endangers downstream property and human life and required immediate attention. Emergency Action Plan should include all potential indicators of likely failure of the dam, since the primary concern is for timely and reliable identification and evaluation of existing of potential emergency.

This EAP presents warning and notification procedures to follow during the monsoon season in case of failure or potential failure of the dam. The objective is to provide timely warning to nearby residents and alert key personnel responsible for taking action in case of emergency.

15.3.3 Administration and Procedural Aspects

The administrative and procedural aspects of the Emergency Action Plan consist of flow chart depicting the names and addresses of the responsible personnel of project proponent and the district administration. In order of hierarchy, the following system will usually be appropriate. In the event that the failure is imminent or the failure has occurred or a potential emergency conditions is developing, the observer at the site is required to report it to the Junior Engineer who will report to the Executive Engineer / Superintending Engineer for their reporting to the Chief Engineer through a wireless system or by any available fastest communication system. The Engineer-in-Charge is usually responsible for making cognizant with the developing situation to the Civil Administration. Each personnel are to acknowledge his/her responsibilities under the EAP in an appropriate format at a priority.

The technical aspects of the EAP consist of preventive action to be taken with regards to the structural safety of the dam. The EAP is drawn at a priority for the regular inspection of the dam. For this purpose, providing an adequate and easy access to the dam site is a necessity. The dam, its sluices, overflows and non-overflow sections should be properly illuminated for effective operations during night time. Whenever sinkholes, boils, increased leakages, movement of masonry rock, gate failure, rapid rise or fall of the level in the reservoir, rise in the level of reservoir beyond the maximum working level, or wave overrun of the dam crest are observed, the personnel on patrol is required to inform immediately to the Junior Engineer (JE) / Assistant Engineer (AE) for initiation of the execution of EAP. They are required to inform the Engineer-in-Charge and the local administrative authorities. It is desirable if the downstream inhabitants are warned using siren, if available, so as to make them aware the likely imminent danger.

The other preventive measures may include availability of sufficient number of sandbags at several selected downstream locations and logs (for holding sandbags) and at the dam site, one tractor, two motor boats, gas lanterns, Manila ropes and life jackets. Areas from where the labour can be mobilized should be chalked out at a priority. In addition to these, public participation in the process of execution of the EAP may further help in amelioration of the adverse impacts of the likely disaster. For this, it is necessary that the public should be made aware of its responsibilities.

15.3.4 Preventive Action

Once the likelihood of an emergency situation is suspected, action has to be initiated to prevent a failure. The point at which each situation reaches an emergency status shall be specified and at that stage the vigilance and surveillance shall be upgraded both in respect of time and level. At this stage a thorough inspection of the dam should be carried out to locate any visible sign(s) of distress.

Engineers responsible for preventive action should identify sources of equipment needed for repair, materials, labour and expertise for use during an emergency. The amount and type of material required for emergency repairs should be determined for dam, depending upon its characteristics, design, construction history and past behavior. It is desirable to stockpile suitable construction materials at appropriate sites. The anticipated need of equipment should be evaluated and if these are not available at the dam site, the exact location and availability of these equipments should be determined and specified. The sources/agencies must have necessary instructions for assistance during emergency. Due to the inherent uncertainties about their effectiveness, preventive actions should usually be carried out simultaneously with the appropriate notification on alert situation or a warning situation.

15.3.5 Communication System

An effective communication system and a downstream warning system are absolutely essential for the success of an emergency preparedness plan. The difference between a high flood and dam-break situation must be made clear to the downstream population.

15.3.6 Evacuations Plans

Emergency Action Plan includes evacuation plans and procedures for implementation based on local needs. These could be:

- Demarcation / prioritization of areas to be evacuated.

- Notification procedures and evacuation instructions.
- Safe routes, transport and traffic control.
- Safe areas/shelters.
- Functions and responsibilities of members of evacuation team.

Any precarious situation during floods will be communicated either by an alert situation or by an alert situation followed by a warning situation. An alert situation would indicate that although failure of flooding is not imminent, a more serious situation could occur unless conditions improve. A warning situation would indicate that flooding is imminent as a result of an impending failure of the dam. It would normally include an order for evacuation of delineated inundation areas.

15.3.7 Evacuation Team

It will comprise of following official / Representative:

- DM / his Nominated officer (To peacefully relocate the people to places at higher elevation with local administration).
- Engineer in charge of the project (Team Leader)
- Superintendent of Police (SP) / Nominated Police Officer (To maintain law and order)
- Chief Medical Officer (CMO), (To tackle morbidity of affected people)
- Affected village Representative to execute the resettlement operation with the aid of state machinery and project proponents.
- Sub committees at village level

The Engineer-in-Charge will be responsible for the entire operation including prompt determination of the flood situation time to time. Once the red alert is declared the whole state machinery will come into swing and will start evacuating people in the inundation areas delineated in the inundation maps. For successful execution, annually demo exercise will be done. The DM is to monitor the entire operation.

15.3.8 Public Awareness for Disaster Mitigation

In addition, guidelines that have to be followed by the inhabitants of flood prone areas, in the event of flood resulting from dam failure, which form part of public awareness for disaster mitigation may also include following:

- Listen to the radio for advance information and advice.
- Disconnect all electrical appliances and move all valuable personal and household goods beyond the reach of floodwater, if one is warned or if one suspects that flood waters may enter the house.
- Move vehicles, farm animals and movables goods to the higher place nearby.
- Keep sources of water pollution i.e. insecticides out of the reach of water.
- Turn off electricity and LPG gas before one has to leave the house.
- Lock all outside doors and windows if one has to leave the house.
- Do not enter floodwaters.
- Never wander around a flood area.

15.3.9 Notifications

Notification procedures are an integral part of any emergency action plan. Separate procedures should be established for slowly and rapidly developing situations and failure. Notifications would include communication of either an alert situation or an alert situation followed by a warning situation. An alert situation would indicate that although failure or flooding is not imminent, a more serious situation could occur unless conditions improve. A warning situation would indicate that flooding is imminent as a result of an impending failure of the dam. It would normally include an order for evacuation of delineated inundation areas.

15.3.10 Notification Procedures

Copies of the EAP that also include the above described inundation map are displayed at prominent locations, in the rooms and locations of the personnel named in the notification chart. For a regular watch on the flood level situation, it is necessary that the flood cells be manned by two or more people so that an alternative person is always available for notification round the clock. For speedy and unhindered communication, a wireless system is a preferable mode of communication. Telephones may be kept for back up, wherever available. It is also preferred that the entire flood cells, if more than one, are tuned in the same wireless channel. It will ensure communication from the dam site to the control rooms. The communication can be established by messenger service in the absence of such modes of communication.

15.3.11 Management after receding of Flood Water

It is to be accepted that in the event of dam break, even with maximum efforts, the loss of human lives, livestock and property would be inevitable. Under such a scenario, a massive effort would be used by various government agencies to provide various relief measures to the evacuees. Formulation of a plan delineating such measures is beyond the scope of work of this document. However, some of the measures which need to be implemented are listed as below:

- Provision of various food items and shelter to the evacuees.
- Provision of fuel for various evacuees.
- Provision of adequate fodder supply.
- Arrangements for potable water supply.
- Commissioning of low cost sewage treatment and sanitation facilities, and disposal of treatment sewage.
- Expeditious disposal of dead bodies human and livestock.
- Immunization programmes for prevention of outbreak of epidemics of various water related diseases.
- Adequate stocks of medicines of various diseases, especially water-related diseases.

15.3.12 Communication between Different Projects

There are two HEPs viz., Largi and Pandoh u/s and two HEPs viz. Triveni Mahadev and Dhaulasidh HEP are in the downstream of the project. These projects shall run in tanden. Therefore, a comprehensive monitoring network system has to be established to combat jointly the threat due to failure of any of these schemes. For accomplishing this full proof “no communication failure” system has to be evolved.

15.3.13 Flood Forecasting

The importance of flood forecasting is paramount in a dam break scenario, by overtopping, when little or no reaction time is left for the people to evacuate to safe places. Effective and accurate flood warning can facilitate the evacuation of people living in flood zone, their property and livestock, opportune maintenance and early alerting of emergency services besides exercising legitimate control by adjusting downstream releases from reservoir / ponds or achieving the balance pond. An advance warning of approaching flood allows suitable reservoir operation for moderating its intensity / peak and also helps in ensuring full storage and for flood relief purposes.

The catchment of the Beas up to the proposed dam site extends approximately 7378 Sq Km in area. River flows are constituted of two main natural components viz., run-off resulting from precipitation and base flow derived from spring flows. Due to mountains topography, the excessive bed slope causes rapid run-off from the contributing hill torrents to the main river. There is no extensive network of meteorological station, rain gauge; snow-gauge; gauge and discharge sites in the catchment area. Many of the sub-watersheds within the catchment are un-gauged. Currently flood warning relies on issuing of alerts when the river level at a few location reaches are within a few meter below the high flood levels observed in the past. Sometime these warnings may be accurate but due to very little lead time between the HFL being very fast approached and the commencement of flooding. Due to the existence of fertile agricultural land and its expansion along the river banks and concentration of population in the region of submergence area, there is a need for developing an operational flood forecasting system as a part of preparedness strategies for disastrous flood events by providing advance warning several days ahead such that the public and the district authorities have adequate time at their disposal without being panicky.

Due to morphological characteristics, the flood plains and the area near to the river / stream banks, classified under land use class agriculture and settlement, are more prone to the flood hazards. In such areas delineation of flood zone and its height besides detecting the characteristics of floods in different return periods is most significant. Thus flood zonation is not only essential in respect of various development activities in the likely inundation area, but also for study of ecological and environment impacts. For the study of flood zonation, within the likely inundation area, for different time periods of 2, 5, 10, 25, 50 and 100 years, topography maps at 1:1000 scale shall have to be developed.

All forms of flood forecasting use some type of trigger mechanism to anticipate when the water level of the river at the flood risk area shall exceed the threshold. When the trigger reaches a predetermined level that is less than the threshold, a warning is triggered. In case of a small river, a rainfall-runoff based model may be adequate within reasonable limits of accuracy. In case of large rivers, like Beas, forecasting of discharge by upstream stages, with a high degree of sophistication is involved. The main aim is to assess the future output at different time as accurately as possible, *i.e.* within narrow error bonds, starting with measurements of present and past input quantities. Interaction between a comprehensive hydrological model and geographical information system (GIS) technique provides a better forecasting tool. The main requirement of a hydrological model is description of flow channel characteristics and land surface as input data to the watershed model. The flood zonation is actualize, development and perfection of the applied engineering hydrology and its aim is to acquire a real time rainfall data and river flow by short wave, radio and satellite network, and using them tin rainfall runoff models to forecast.

For enabling GIS based flood forecasting using hydrological model, a network of meteorological station, rainfall and snowfall gauges, gauge and discharge sites equipped with latest state-of-the-art gadgets, meteorological radar shall have to be established. Survey of inundation area at 1:1000 scales with 1.0 meter shall have to be conducted.

15.3.14 Seismic Concern and Disaster Management

The project area as such falls in the seismic zone-V. The geology and geo-morphological parameters of the study area had been presented in the beginning. The area has experienced earthquakes of moderate to serve intensity in the past. The epicenters of major earthquakes in and around the project area of the project site are related to mega and intermediate lineaments; however, there is no documentation of seismic activity in the project area. Still, form safety point of view, a plan of seismic surveillance of the area by establishing a seismic monitoring station is proposed. Detailed dam site investigations have been conducted from geological point of view and design of dams has been done accordingly.

15.3.15 Reservoir Induced Seismicity

The column of water in a large and deep artificial lake alters in-situ stress along an existing fault or fracture. In these reservoirs, the weight of the water column can significantly change the stress on an underlying fault or fracture by increasing the total stress through direct loading, or decreasing the effective stress through the increased pore water pressure. This significant change in stress can lead to sudden movement along the fault or fracture, resulting in an earthquake. Reservoir-induced seismic events can be relatively large compared to other forms of induced seismicity. Though understanding of reservoir-induced seismic activity is very limited, it has been noted that seismicity appears to occur on dams with heights larger than 330 feet (100 m). The extra water pressure created by large reservoirs is the most accepted explanation for the seismic activity. Induced seismicity is usually overlooked due to cost cutting during the geological surveys of the locations for proposed dams. When the reservoirs are filled or drained, induced seismicity can occur immediately or with a small time lag. The incidence of reservoir induced seismicity (RIS) or some time referred as reservoir triggered seismicity (RTS) is usually confined in both time and space. It has been observed that in some reservoirs seismicity begins immediately after the first filling while at others it is not observed until several years of filling cycles. The differential behavior in spatial and temporal pattern of RIS is attributed to two fundamental mechanisms – one related to rapid increase in the elastic stress due to loading of the reservoir and the other to the more gradual diffusion of water from the reservoir to hypo central depths. Until recently it was surmised that RIS was triggered by the loading of the reservoir and/or by the effect of pore pressure (Pp) in lowering the strength of rocks at hypo central depths. The analysis of case histories accumulated suggest that the latter *i.e.* pore-pressure is the prime factor and a small perturbation in the in situ stress field due to Pp changes triggers the RIS. Pore pressure can play a twofold roles in the seismic process, the first, as mechanical effect as pore pressure, and second, a chemical effect in reducing the co-efficient of friction between the clays in the pre-existing fractures and the rocks that enclose these fractures. This underlines need for routine monitoring of seismic data on dense and local networks. The seismic data so collected shall help to study the mechanism of RIS in particular and the physics of the earthquake process in general.

For mitigation of the seismic hazard, the only option available is to upgrade our knowledge on the co-dynamics of earthquakes and to utilize the state-of-the-art technology to constraint the motion characteristics. This would help in seismic designing of the components of the project. The reservoir induced seismic concerns, however, requires a special emphasis for judging the effect of impoundment of the reservoir on seismic status of the area. It is proposed that a state-of-art seismic observatory may be made compatible with IMD National Grid for recording and analyzing the regional-wide seismic activity. This would not only help the project authorities to plan the disaster management scheme related to the project but will also be helpful for the other projects in the area.

15.4 COST ESTIMATE

A budget allocation of **Rs. 80.00 lacs** is being made towards disaster management plan.