CHAPTER-15
DISASTER MANAGEMENT PLAN

15.1 INTRODUCTION

Any hydro project if not designed on the sound principles of design after detail 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 catastrophe. Though through detailed field investigations it has been ensured that the barrage is founded on firm foundation, designed for suitable seismic design parameters, 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 affects 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 Jakhol Sankri Hydroelectric project envisages the following Civil Structures:

- Barrage across river Supin near Jakhol village having 33 meter length and 17 meter height & having elevation at Top of barrage 1962.20 m.
- 4 number of vertical gates.(Size 5.0 meter width and 4.4 meter Height)
- Design Flood 270 Cumecs.
- Intake, Approach Tunnel and Underground Desilting Chamber on left bank.
- Head Race Tunnel (HRT) on the left bank and terminating at Surge Shaft.
- Underground restricted orifice type Surge Shaft.
- Pressure Shaft & surface Penstock.
- Underground Power House with 2 units of vertical Pelton type turbines near village Sankri.
- Tailrace Tunnel (TRT) & Underground Cavern for GIS

15.2 DAM BREAK INUNDATION ANALYSIS

The outflow flood hydrograph from a dam/Barrage failure is dependent upon many factors such as physical characteristics of the Barrage, 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 causal agent for failure.

For reasons of simplicity, generally, wide applicability and the uncertainty in the actual mechanism, the BOSS DAMBRK model has been used. The model uses failure time interval, terminal size and shape of the breach as the inputs. The possible shapes of the breach that can be accomplished by the model are rectangular, triangular and trapezoidal. The model is capable of adopting either storage routing or dynamic routing methods for routing floods through reservoirs depending on the nature of flood wave movement in reservoirs at the time failure.

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.

15.3 METHODOLOGY

The National Weather Service's DAMBRK model developed by Dr. L. Fread has been used in the study. This model simulates the failure of dam, computes the resultant outflow hydrograph and also simulates movement of the dam break flood wave through the downstream river valley. The model is built around three major capabilities, which are reservoir routing, breach simulation and river routing. However, it does no rainfall-runoff analysis and storm inflow hydrographs to the upstream of reservoir must be developed external to the model. A brief description of the capabilities of the model is described in the following paragraphs.

15.3.1 Reservoir Routing

The storage routing is based on the law of conservation given as:

$$I - Q = dS/dt \quad \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

In which, I is reservoir inflow. Q is the total reservoir outflow which includes the flow spillway, breach, overtopping flow and head independent discharge, and rate of change of reservoir storage volume. Equation (1) can be expressed in finite difference form as :

$$(1 + I') \, 2 - (Q + Q')/2 = \Delta S/\Delta t \text{ -.-----(2)}$$

In which the prime (') superscript denotes the values at the time t - Δt and the notation approximates the differential. The term ΔS may be expressed as:

$$\Delta S = (As + A's)\,(h-h')/2 \text{ ………………(3)}$$

In which, As is the reservoir surface area coincidental with the elevation (h) and is a function of h. The discharge Q which is to be evaluated from equation (2) is a function of h and this known h is evaluated using Newton–Raphson iteration technique and thus the estimation of discharge corresponding to h.

15.3.2 Dynamic Routing

The hydrologic storage routing technique, expressed by equation (2) implies that the water surface elevation within the reservoir is horizontal. This assumption is quite adequate for gradually occurring breaches with no substantial reservoir inflow hydrographs. However, when the breach is specified to form almost instantaneously so as to produce a negative wave within the reservoir, and/or the reservoir inflow hydrograph is significant enough to produce a positive wave progressing through the reservoir, a routing option which simulates the negative and /or positive wave occurring within the reservoir may be used in DAMBRK model. Such a technique is referred to as dynamic routing. The routing principle is same as dynamic routing in river reaches and it is performed using St. Venant's equation. The movement of the dam break flood wave through the downstream river channel is simulated using the complete unsteady flow equations for one dimensional open channel flow, alternatively known as St. Venant's equations. These equations consist of the continuity equation

$$\frac{\partial Q}{\partial t} + \frac{\partial (A + A0)}{\partial t} = q \text{ ……………………………………(4)}$$

and the conservation of momentum equation :

$$\frac{\partial Q}{\partial t} + \frac{\partial (A2/ +A)}{\partial t} + g A \left(\frac{\partial h}{\partial t} + Sf + S e \right) + Lc = 0 \quad \ldots\ldots(5)$$

where,

A = active cross – sectional flow area
A0 = inactive (off-channel storage) cross – sectional area
X = distance the channel
q = lateral inflow or outflow per unit distance along the channel
g = acceleration due to gravity
Q = discharge
H = water surface elevation
Ss = friction slope
Se = expansion – contraction loss slope
Lc = lateral inflow/outflow momentum effect due to assumed flow path of inflow being perpendicular to the main flow.

The friction slope and expansion – contraction loss slope are evaluated by the following equation

$$Sf = \frac{n^3 Q^2}{2.21 A^2 R^{3/4}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(6)$$

and,

$$Se = \frac{K\Delta(Q/A)^2}{2g \Delta X} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(7)$$

where,

n = Manning's roughness coefficient
R = A/B where B is the top width of the active portion of the channel
K = Expansion – contraction coefficient varying from 0.1 to 0.3 for contraction and 0.5 to – 1.0 expansion
$\Delta(Q/A)^2$ = Difference in $(Q/A)^2$ for cross sections at their end of a reach

The non-linear partial differential equations (4) and (5) are represented by a corresponding set of non-linear finite difference algebraic equations and they are solved by the Newton-Raphson method using weighted four point implicit scheme to evaluate Q and h. The initial conditions are given by known steady discharge at the dam, for which steady state non-uniform boundary flow equation are used. The outflow hydrograph from the reservoir is the upstream boundary condition for the channel routing and the model is capable of dealing with fully supercritical flow or fully supercritical flow in the reach or the upstream reach having supercritical flow and downstream reach having subs critical flow. There is a choice of downstream boundary conditions such as internally calculated loop rating curve, user provided single valued rating curve, user provided time dependent water surface elevation, critical depth and dam/barrage which may pass flow via spillways, overtopping and/or breaching.

15.3.3 Statement of the problem

The computation of flood wave resulting from a dam breach basically involves two scenarios which can be considered jointly or separately: (1) the outflow hydrograph from the pond (2) the routing of the flood wave downstream from the breached dam along the river valley and the flood plain. If breach outflow is independent of downstream conditions, or if their effect can be neglected, the reservoir outflow hydrograph is referred to as the free outflow hydrograph. In this case, the computation of the flood characteristics is divided into two distinct phases: (a) the determination of outflow hydrograph with or without the routing of the negative wave the reservoir, and (b) the routing of flood wave downstream from the breached dam. In this study the problem of simulating the failure of “Dam” and computing the free outflow hydrograph from the breached section using storage routing technique’ with the aim of reproducing the maximum water level marks reached during the passage of flood wave is considered. The information regarding inflow hydrograph into the pond due to the storm at the time of failure, the structural and the hydraulic characteristics details of the dam, the time of failure, the channel cross sections details, the maximum water level marks reached in the reservoir at the time of failure and those observed in the downstream reach of the dam to the passage of flood wave etc. are available for the study.

15.3.4 Availability of Data

The input data required can be categorized into two groups. The first data group pertains to the dam and inflow hydrograph into the reservoir and the second group pertains to the routing of the outflow hydrograph through the downstream valley. These are described in the following paragraphs.

- **First Data Group**

With reference to the data group pertaining to the dam, the information on reservoir elevation-volume relationship, spillway details, elevation of bottom and top of dam, elevation of water surface in the pond at the beginning of analysis and at the time of failure, breach description data are required.

- **Second Data Group**

The second group of data pertaining to the routing of the outflow hydrograph through the downstream valley consists of a description of cross-sections, hydraulic resistance coefficients of the reach, steady state flow in the river at the beginning of the simulation and downstream boundary condition. The cross section is specified by location mileage, and tables of top width and corresponding elevation.

15.3.5 Result and Conclusions

A rectangular breach at an El 1962.20 masl with side slope 1:0 and breach formation time as 15 minutes. have been considered in the study for Barrage break analysis of SJHEP. After the breach, immediately below the Barrage, the maximum flow will occur immediately after the start of breach. The magnitude of the simulated outflow hydrograph will be 927.62 cumec corresponding to maximum stage elevation 1962.50 masl, at Km. 2.50 is attenuated to 850.32 cumecs corresponding to maximum stage elevation of 1815.12 masl and at km. 9.32. Further reduced to 394.25 cumecs. The maximum flow and time to maximum stage at various distances d/s of the dam is given in **Table-15.1**

TABLE-15.1
Summary of Wave Profile In The Event Of Dam Break

Distance from Dam (km)	Max Elevation, (masl)	Maximum Flow (cumec)	Time to Maximum Stage, (hrs)	Maximum velocity, m/s
0.0	1962.50	927.62	0.060	10.65
2.25	1844.32	856.30	0.090	10.10
2.50	1815.12	850.32	0.093	9.98
2.75	1796.4	842.87	0.101	9.81
3.00	1788.10	835.50	0.121	9.60
6.25	1582.45	510.11	0.230	6.50
6.50	1566.22	488.96	0.250	6.36
6.75	1552.07	484.23	0.280	6.31
7.00	1539.74	467.83	0.310	6.22
9.30	1499.7	394.25	0.35	5.10

The following conclusions could be drawn from **Table-15.1**:

- Failure of Barrage like the proposed JSHEP, which is designed to the present technical standards and built with adequate quality control, is a very remote possibility.
- The monoliths having the least resistance to withstand the unforeseen loading combinations may give way, which in turn provides a relief and prevents failure of

other monoliths. Under such as situation, the discharge and the water depth will be much lesser than those determined from the study.

15.4 DISASTER MANAGEMENT PLAN

The emergency planning for Barrage 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 Barrage failure the flood peak discharge as it prorogates through valley shall inundate downstream stretch of 9.3 km and the flood wave peak in 0.35 hour implying that a little reaction time for executing any rescue plan. The inundation map is presented in Figure-15.1. The plan is, therefore, based on such measures, which are purely preventive in nature. However in present case no village will be affected.

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-15.2.

TABLE-15.2
Status of Emergency

S. No.	Status of emergency	Water Level	Preventive measures
1.	Normal Flood	Normal Flood	Below FRL i.e. EL 1959.40 masl and flood discharge below 270 cumecs..
2.	Level –1 Emergency	Level –1 Emergency	Rises above FRL 1959.40 masl but below 1961.20masl.
3.	Level –2 Emergency	Level –2 Emergency	Above MWL i.e. EL 1961.20 masl but below top of Barrage
4.	Level –3 Emergency	Level –3 Emergency	Top of Barrage i.e 1962.20masl
5.	Disaster	Disaster	Rising above top of Barrage and the breach appears in any form

15.4.1 Barrage Safety and Maintenance Manual

Based on standard recommended guidelines for the safety inspection of Barrage 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.

15.4.2 Emergency Action Plan (EAP)

Barrage safety programme as indicated above includes the formation of an Emergency Action Plan for the barrage. 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/barrage, 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/barrage. The objective is to provide timely warning to nearby residents and alert key personnel responsible for taking action in case of emergency.

15.4.3 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 Dist. 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 barrage. The EAP is drawn at a priority for the regular inspection of the barrage. For this purpose, providing an adequate and easy access to the barrage site is a necessity. The dam/barrage, 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/barrage 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 barrage 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.

15.4.4 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/barrage 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/barrage, 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/barrage 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.

15.4.5 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.

15.4.6 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/barrage. It would normally include an order for evacuation of delineated inundation areas.

15.4.7 Evacuation Team

It will comprise of following official / Representative:

- District Magistrate (D. M.)/ His Nominated officer (To peacefully relocate the people to places at higher elevation with state administration).
- Engineer in charge of the project (Team Leader)
- Superintendent of Police (S. P.) / Nominated Police Officer (To maintain law and order)
- Chief Medical Officer (C. M. O.), (To tackle morbidity of affected people)
- Head of affected village 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 D.M. is to monitor the entire operation.

15.4.8 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/barrage 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.

15.4.9 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/barrage. It would normally include an order for evacuation of delineated inundation areas.

15.4.10 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 that one, are tuned in the same wireless channel. It will ensure communication from the dam/barrage site to the control rooms. The communication can be established by messenger service in the absence of such modes of communication.

15.4.11 Management after receding of Flood Water

It is to be accepted that in the even of dam/barrage 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.

15.4.12 Reservoir Induced Seismicity

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. With this background, it is proposed that a seismic observatory may be made compatible with IMD National Grid for recording and analyzing the nation-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.

15.5 COST ESTIMATES

The budget for different activities required to be carried out for mitigation and prevention of dam/barrage break hazard exclusively from the barrage is Rs 60.00 lakh as per details given in Table-15.3.

TABLE-15.3

Budget earmarked for implementation of Disaster Management Plan

S. No.	Particular	Cost (Rs. lakh)
1.	Installation of alert system in control room	10.0
2	Setting up of communication between various projects on river Supin /Tons	10.0
3	Setting up of communication system between barrage and d/s settlements	15.0
4	Public information system	15.0
5	Training and miscellaneous expenses	10.0
	Total	**60.0**

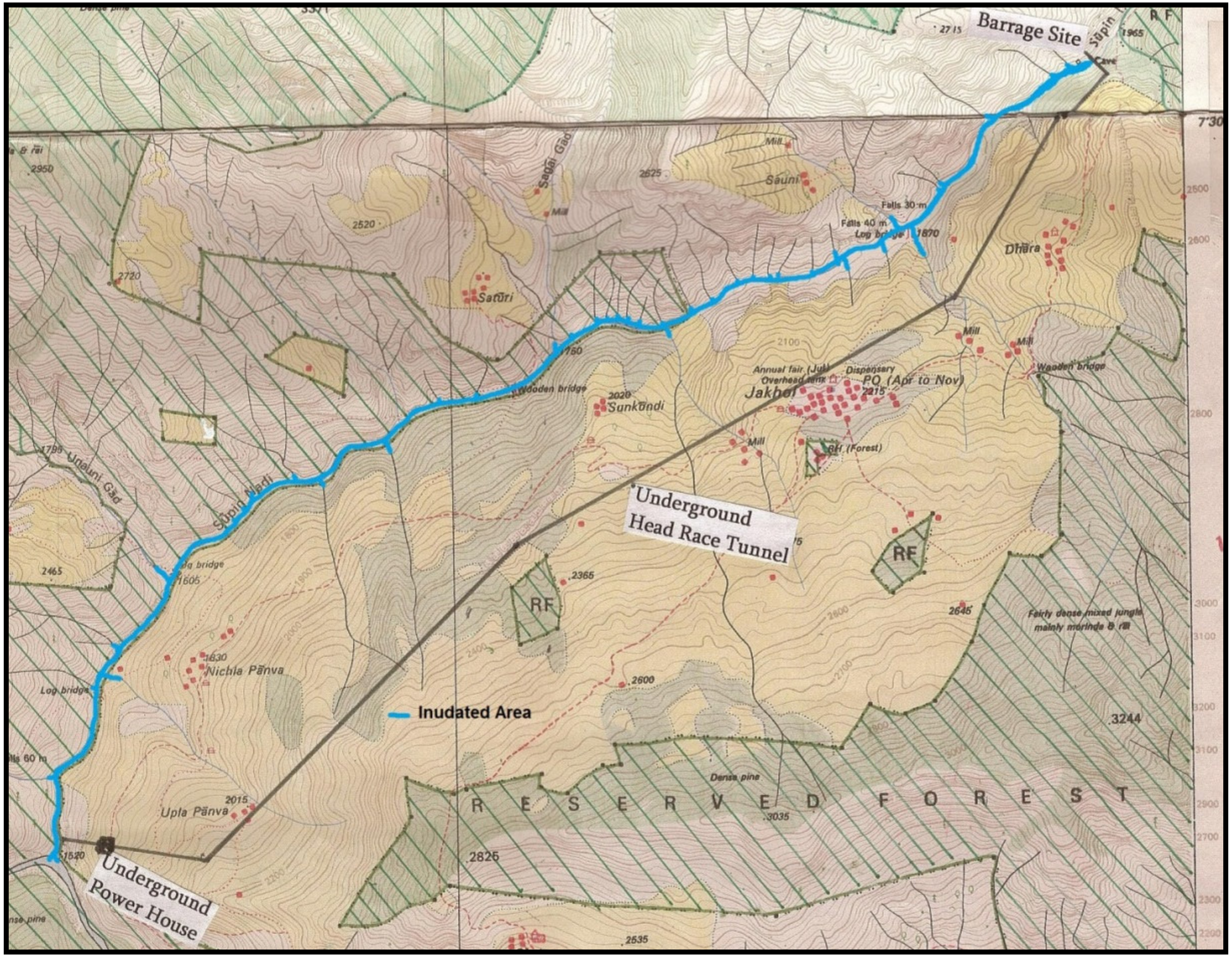

Figure-15.1: Inundation Map