



# Guidelines for Preparing Operation and Maintenance Manual for Dams

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Central Water Commission  
Ministry of Water Resources,  
River Development & Ganga Rejuvenation  
Government of India

**Front Cover Photograph:** Nagarjuna Sagar Dam, Telangana, India.



Government of India  
Central Water Commission  
Central Dam Safety Organization

Guidelines for Preparing Operation  
and Maintenance Manual for Dams

January 2018

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*Guidelines for Preparing Operation and Maintenance Manual for Dams* is one of the several dam safety guidelines being developed under the Dam Rehabilitation and Improvement Project (DRIP)

Disclaimer

*Guidelines for Preparing Operation and Maintenance Manual for Dams* in no way restricts the dam owner in digressing from it. The Central Dam Safety Organization or the Central Water Commission cannot be held responsible for the efficacy of the manuals developed by various dam owners based on these guidelines. Dam owners and operators should exercise appropriate discretion when preparing an operation and maintenance manual for their dams.

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## MESSAGE

The lifespan of any dam can be as long as it is technically safe and operable. In general, if a dam and its appurtenant structures are properly maintained and the ageing processes can be controlled, the condition of a dam can be preserved. Proper maintenance means that there must be a responsible agency, who takes care of a project along with requisite resources, in the absence of which the safety of any infrastructure project will deteriorate rapidly and the structure can become unsafe in a very short time compared to its design life.

An appropriate operation mechanism of dam as per defined protocols with maintenance is essential for controlling the ageing processes that may diminish the safety and shorten the service life. The operation and maintenance can be considered as the key factors in achieving the expected benefits from dams and reservoirs. It is one of the key elements to extend the service life as much as possible.

As India possesses a significant number of large dams, it needs standard operation and maintenance procedures, protocols and regulations to ensure sound health of these assets as well as minimise the potential risk hazards to downstream habitation, property and environment etc. It is a general international practice that Operation and Maintenance (O&M) Manual shall be in place before first filling of any reservoir. However, few dams in India have got such Manuals in place. This document intends to provide a help to all the dam professionals in India, who will find it very useful to develop dam specific Operation and Maintenance Manual.

As every dam is unique, it would require specific O&M Manual for effective operation and maintenance of all its civil and hydro-mechanical components. The current *Guidelines for Preparing Operation and Maintenance Manual for Dams* is expected to fulfil the need of development of dam specific document and will prove an important milestone in moving in the direction of integrated dam safety management.



(S Masood Husain)  
Chairman

Central Water Commission

New Delhi  
January 2018

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## FOREWORD

Presently, India has 5254 large dams in operation and 447 large dams under construction having gross storage of more than 300 billion cubic meter. Approximately 80% of these existing dams are more than 25 years old. Their health and safety are of paramount importance for sustainable use of these existing valuable assets, besides providing protection to the people and property in the downstream areas. The existing operation and maintenance protocols for majority of these dams need to be improved in order to ensure sound health and safety.

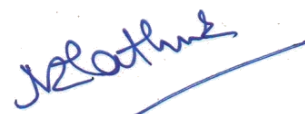
For a healthy dam safety management system, various important components of it needs to be in place. Based on experience of Central Water Commission, it is felt that it is high time for India to put required legislation on Dam Safety in place to address the dam safety sector in a comprehensive and holistic way. It will make mandatory for all stakeholders to perform required activities in the very interest of these assets. There are additional issues beyond maintenance, which have to be considered with time and shall be addressed scientifically.

An Operation and Maintenance Manual is essential for a dam for ensuring its safe functioning and for deriving desired benefits from it. The document is treated as the important guiding force during the whole life cycle of the Project. The present *Guidelines for Preparing Operation and Maintenance Manuals* describe all the elements systematically and comprehensively essential for its operation, inspection, maintenance, instrumentation and monitoring the health of the dam regularly as well as sometimes need based. These guidelines have been framed based on global prevailing practices, individual experiences of the experts, as well as experience derived during the ongoing DRIP.

Central Water Commission is striving to put best practices for dam safety management based on sound judgement and worldwide experiences. The documents need continuous revision based on continuous change in technological advancement in rehabilitation materials, surveillance and monitoring systems, comprehensive dam safety inspection and risk assessment, etc. All dam owners can use this document for developing and revising Operation and Maintenance Manuals for their dams.

I convey my sincere compliment to all the officials and staff who have contributed directly and indirectly in the development of these guidelines under the DRIP project, and extend heartily gratitude for sparing valuable time and resources. Central Water Commission also acknowledges the special support extended by World Bank in accomplishing these objectives and especially thank Mr. Jun Matsmoto, past Task Team Leader, DRIP as well as Dr. C Rajgopal Singh, present Task Team Leader, DRIP and their team for extending excellent support all the time.

New Delhi  
January 2018



(N K Mathur)  
Member (D&R)  
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## PREFACE

An Operation and Maintenance (O&M) Manual is a detailed written document of procedures and protocols for ensuring that a dam is operated and maintained properly and timely to avoid further health deterioration and extend service life of these assets. In India, it would be first of its kind publication to facilitate all dam owners to frame or update their dam specific Operation and Maintenance Manual based on these guidelines. A group of experts from Egis Eau, France (Engineering and Management Consultant supporting Central Water Commission in coordination and implementation of ongoing DRIP) were engaged in bringing the draft for these guidelines and a separate Review Committee comprising of group of national experts was constituted by Central Water Commission to review the guidelines with the intention of preparing a document that was not only more in line with the current thinking but would also be widely adopted and used by practicing dam engineers.

It has not been an easy task for the working experts, and Review Committee members. It took considerable time and efforts to reach consensus on the details, in particular all present chapters for inclusion in this document. Since it's a first of its kind document being published by Central Water Commission, the document is comprehensive covering acceptable practices.

These guidelines provide a basis for framing a new O&M Manual or update an existing O&M Manual for all kind of dams. However, the team preparing O&M Manual for dams should consist of professionals with significant experience who are able to use sound engineering judgement in the application of these Guidelines.

These guidelines comprised of six chapters i.e. General Information, Project Operation, Project Inspection, Project Maintenance, Instrumentation and Monitoring and Updating the Manual. It contains all important details generally required for development of an O&M Manual for any kind of dam. Best global practices have been used in preparation of these guidelines keeping in view their applicability and acceptability.

Central Water Commission would like to thank the members of the Consultant Group as well as Review Committee and all the contributors involved in developing and bringing these guidelines to fruition. This document will be of great assistance to dam engineering professionals in India. A further revision of this document is also recommended based on future development as well as omission of any important practice, in the current document.

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**ABBREVIATIONS**

Acronyms used in this publication are as follows:	
<b>BIS</b>	Bureau of Indian Standards
<b>CDSO</b>	Central Dam Safety Organisation
<b>CWC</b>	Central Water Commission
<b>SDSO</b>	State Dam Safety Organisation
<b>O &amp; M</b>	Operation and Maintenance
<b>DRIP</b>	Dam Rehabilitation and Improvement Project
<b>DSRP</b>	Dam Safety Review Panel
<b>DTM</b>	Digital Terrain Model
<b>EAP</b>	Emergency Action Plan
<b>FMIS</b>	Flood Management Information System
<b>GPS</b>	Global Positioning System (uses GPRS for data transmission like browsing the web)
<b>FRL</b>	Full Reservoir Level
<b>MWL</b>	Maximum Water Level
<b>MDDL</b>	Minimum Draw Down Level
<b>DSL</b>	Dead Storage Level
<b>RT-DAS</b>	Real Time Data Acquisition system
<b>SCADA</b>	Supervisory Control and Data Acquisition
<b>DDMS</b>	Dam Deformation Monitoring System
<b>EDA</b>	Energy Dissipation Arrangement
<b>HM works</b>	Hydro-Mechanical works
<b>DG set</b>	Diesel Generator set
<b>ADAS</b>	Automated Data Acquisition System
<b>RMU</b>	Remote Monitoring Unit
<b>PC</b>	Personal Computer

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## Chapter 1. GENERAL INFORMATION

An Operation and Maintenance (O&M) Manual of a dam is a detailed written description of procedures for ensuring that it functions safely and is kept in a good condition by periodic repairs/maintenance. Timely maintenance is important for the continued safe functioning of the dam and productive use of the dam and reservoir.

The term “O&M” as employed in these guidelines includes operation, maintenance & general repairs of dam components including replacement, as necessary.

The Manual needs to be prepared primarily for the dam operations staff and their supervisors who are assigned the responsibility for the physical operations and maintenance of the dam. It should contain, as a minimum, all information and instructions necessary for them to perform their allotted tasks. In addition to instructions for dam operations staff, the Manual should also include all necessary instructions for other staff directly or indirectly involved in operating and maintaining the dam.

In general, it is a global practice that the O&M Manual is available prior to the initial filling of the reservoir.

### 1.1 Purpose, Location, Description of dam

The following information needs to be included in the Manual:-

- Name of the dam.
- Name of the river on which the dam is built, sub-basin & river basin.
- Location of the dam – Latitude/ Longitude.
- District in which it is located.
- Nearest city/town.
- Nearest railway station & airport.
- Location/Index Plan.
- Project Benefits.
- Salient features of dam.
- Basic drawings of the dam & spillway like plan, elevations, cross-sections, gallery & adits layout etc.
- Brief history of the dam including dam incidents/additions/modifications etc.
- Any special problem encountered during designs and construction.

### 1.2 Assignment of responsibility

This chapter should clearly identify all areas of responsibilities connected with the operation & maintenance of the dam. The officers having responsibility for the following functions needs to be identified by their designation:-

- Project Administration-officer in-charge
- Operations of equipment at the dam.
- Reservoir inflow and flood forecasting.
- Authorizing spillway flood releases
- Authorizing releases for various purposes like irrigation, water supply, hydropower etc.
- Recording reservoir data.
- Routine inspection.
- Maintenance.
- Dam safety surveillance including instrumentation.

Administrative and operational relationships with user organizations should be highlighted. Formal agreements with other State Governments/Agencies/Organizations as well as informal arrangements should be referenced.

Arrangements with other Agencies/ Organizations/State Governments should be readily available.

The responsibilities of operating personnel should be specifically identified in the Manual. This should include regularly scheduled duties which they are required to perform. A typical schedule of duties for operating personnel is given at para 1.9 of this chapter.

### **1.3 Collection & Reporting of Dam and Reservoir Data**

Instructions & standard forms for collection and reporting of dam & reservoir data needs to be included in the Manual.

Routine data for the following is to be collected in separate forms as per frequency prescribed:-

- Reservoir water surface elevation.
- Reservoir inflow.
- Spillway outflow.
- River releases.
- Irrigation, water supply and hydropower releases.
- Weather related data.
- Surveillance and monitoring
- Water quality

Further records of the following operations in a dam needs to be maintained in a chronological manner for reference. These records would be helpful in identifying development of any unusual conditions in the dam.

- Attendance statement during normal operations – both during monsoon and non-monsoon period.
- Operations of the spillway gates and outlet works.
- Operating hours of mechanical equipment's.
- Testing/Operation of spillway gates, stop-logs and associated controls.
- Testing/operation of Outlet gates, valves and associated controls,
- Maintenance activities carried out.
- Reservoir and dam inspections.
- Unusual conditions or occurrences, including acts of vandalism.
- Attendance statement at the dam during emergency operations.
- Changes to normal operating procedures.
- Communication network checks.
- Safety and special instructions.
- Names and addresses of official visitors (e.g. staff carrying out inspection)
- Any other item pertaining to the operation and maintenance of the dam.

### **1.4 Public Utilities and Safety**

As public safety is of prime concern, safety instructions & protection measures at the dam should be included in a supporting document and referenced in the Manual. Signboards need to be provided at appropriate locations of the dam for convenience of the public.

This will include the following:-

- Location of public conveniences near the dam.
- Distance to the nearest medical assistance and police station from the dam.

- Safety equipment available at the dam would be listed here; (first-aid kits, fire extinguisher, self-contained breathing apparatus, air-quality monitors, etc.)
- Any other pertinent information concerning public health and safety.

## 1.5 Restricted Areas

Area of the dam and reservoir with restricted entry for the public should be indicated in a Supporting document and referenced in the Manual. Purpose of restriction should be explained.

Restricted areas which are potentially hazardous could include the following:

- Confined spaces, especially those with no ventilation.
- Spillway approach areas, chutes and stilling basins.
- Control buildings and valve areas.
- Intake or outlet channels adjacent to hydraulic structures subject to surging or rapid changes in water level during releases.
- Active land slide areas.

Suitable warning and restriction signs located at various places around the dam should be referenced in the Manual.

Reference should be made to the Communications Directory for local police assistance, medical and fire services.

## 1.6 Staff position, Communication & Warning System

The number & description of operating unit personnel posted/placed at different locations of the dam should be noted in supporting documents & referenced in the Manual. Staff position will vary according to requirement during monsoon/non-monsoon.

The means of communications both in normal and emergency situations should be identified. All available communication means including landline, mobile phones, wireless sets, & phones/radio facility should be noted.

If no facilities are available at the dam site the location and owner of the nearest phone or radio should be noted.

The actual phone numbers and other communication numbers should be listed in the Communication Directory for the dam. A suitable reference to the Communication Directory should be included in this section of the Manual.

In addition to communication facilities a brief description of the warning systems including alarms at the dam should be mentioned in the Manual. This will include giving information to downstream areas regarding release of flood outflows from the spillway. Basic facilities like communication facilities, sirens, hooters etc. are to be compulsorily provided at all dams.

A notification for strengthening the alarm and warning system for safety of people from sudden release of water from dams issued by the National Disaster Management Authority in October 2015 may be seen at Appendix - A.

## 1.7 Distribution of Operation & Maintenance Manuals

The list of units offices to whom the O&M Manual is required to be distributed needs to be mentioned in the O&M Manual. It must be ensured that revisions of the Manual are also supplied to the same units as per the list.

Page numbering of the Manual should be in form of 1-1, 1-2...for Chapter 1 and 2-1, 2-2...for Chapter 2 etc. for the different chapters to allow for future revision without affecting overall page numbering. It is recommended that while revising a Manual each

revised sheet should clearly show the revision number and date.

## 1.8 Supporting Documents & Reference Material

The O&M Manual is the key instruction document. Supporting documents other than the Manual provide necessary instructions for all phases of the operation & maintenance of the dam, reservoir & appurtenant works. They need to be referenced in the Manual.

The number of supporting documents will vary from project to project & may include the following:-

- Operating criteria for the reservoir, spillway & outlets.
- Emergency action plan.
- Flood forecasting and operating criteria.
- Basin or river operating plan.
- Power station or pumping plant operating instructions.
- Irrigation operating instructions.
- Administrative procedures.
- Dam site security plan
- Reservoir or river pollution contingency plans.
- Major maintenance procedures
- Maintenance schedules
- Manufacturer's instructions & drawings.
- Reservoir management plan (land, recreation, fish and wildlife).
- Regional communications directory for dams
- Instrumentation reports and/or results

## 1.9 Typical Schedule of Duties

The checklist below should be used as a guide in preparing duty schedules for operat-

ing personnel. Depending on the requirements at dam site, size and importance of the dam, the frequency of the duties can be altered. All activities should be recorded in dam log book /site registers.

### 1.9.1 Daily

- Visual inspection of dam
  - Crest of dam (Dam top)
  - Upstream and downstream faces
  - Visible portions of foundation and abutments contacts
  - Galleries
- Record water surface elevation. (during monsoon on hourly basis)
- Record reservoir inflow and spillway discharge. (during monsoon on hourly basis)
- Record releases from outlets /sluices.
- Record seepage from drainage systems- Toe drains, Gallery drains etc. on daily basis (during initial filling of the reservoir)
- Record meteorological data.
- Check security and safety devices.
- Complete logbook / site registers which should include the above information

### 1.9.2 Weekly

#### Electrical System

- Standby generator (DG Sets)
  - Run for 15-30 min to achieve recommended operating temperature
  - Check status of batteries and keep them charged.
  - Check Fuel Supply
- Drainage systems - Toe drains, Gallery drains etc. ( during 1<sup>st</sup> year after initial reservoir filling)

### 1.9.3 Monthly

#### Check condition of

#### Dam and Reservoir

- Critical landslides area (During Monsoon)
- Reservoir periphery (During Monsoon)
- Drainage systems - Toe Drains, Gallery drains etc. (on regular basis from second year onwards after initial reservoir filling)
- Measuring devices/Instruments
- Security and safety devices – rectification, if needed.
- Communication Devices
- Status of Vegetation growth
- Check Sign/Warning display boards near vulnerable locations

#### Mechanical/Electrical System

- Replace fuse light bulbs
- Inspect to maintain ventilation system
- Cleaning of control panel boards

### 1.9.4 Three Monthly

#### Outlet Works

- Availability of updated operating instruction
- Check gate air vents
- Clean gate control switchboxes
- Check operation of gates and valves
- Grease gate hanger / dogging

#### Check

- Check condition of trash rack of intake structure
- Check condition of Outlet works & its Energy Dissipation Arrangement
- Check operation of Valve house

#### Spillway

- Check condition of log and safety boom

- Check for debris in inlet channel
- Check operation of gates
- Check for damages in spillway glacis, energy dissipation arrangement, d/s area etc.
- Check and clear spillway bridge drains
- Clean inside of motor control cabinet

#### Other works

- Check for adherence to instrumentation schedule
- Record pertinent information in Operation Log
- Check condition of V-notch/other seepage measuring devices

### 1.9.5 Six Monthly

#### Spillway & outlet works

- Check paint on gates
- Check lubrication of wire ropes and application of cardium compound.
- Check mechanical hoist bearings and flexible coupling bearings
- Check gear systems
- Exercise gate and valves
- Check oil reservoir level in hydraulic system
- Check pressure release valve
- Lubricate gate rollers
- Check rubber seals and seal clamp bar

#### Electrical System and Equipment

- Change oil in stand by generator
- Check exposed electrical wiring of :
  - Operating equipment's of gates/valves/hoists of Outlet works.
  - Operating equipment's of gates and hoists of Spillway
  - Operating equipment's of any other gates and hoists in dam
  - Spillway bridge

- Dam Galleries
- Check Gate limit switches and adjust

### **1.9.6 Annually**

#### **Spillway & outlet works**

- Paint
  - Metalwork, Gate, Hoists and all exposed metal parts
  - Valves / Control valves
- Hydraulic power pack system
- Exercise Gates and Valves
- Examine stilling basin / energy dissipation arrangement and d/s channel & carry out rectification works, as necessary.
- Check metal welds for damages/cracks in Gates, Hoist platform, Radial Gate Tie flats, Trunnion Girders/supports etc.

#### **Electrical**

- Check electrical conduits, pull-boxes and switches for:
  - Outlet works valve house
  - Gates & hoists
  - Spillway bridge
  - Galleries

### **1.9.7 Five Yearly**

- Inspect intake structures, trash racks and stilling basin / energy dissipation arrangement, which normally are underwater; less frequent, if experience indicates. This may need to be done by carrying out dewatering or by divers/remote operated vehicle, as necessary.
- Review Dam operation procedures and EAP.



## Chapter 2. PROJECT OPERATION

The operation of a dam will involve regulation of its reservoir as per project specific requirements, keeping records and ensuring public safety. Proper operation procedures are crucial for maintaining a safe structure. This chapter provides details on how various elements of a project are to be operated both during normal and emergency situations.

The following basic data in addition to the salient features & basic drawings mentioned in chapter 1 will need to be enclosed under this chapter of O& M Manual:

- Area – Capacity curves.
- Data of the historic floods.
- Latest design flood and flood routing study.
- Sequence of operation of spillway gates during monsoon.
- Discharge through spillway for different reservoir levels with different gate openings.
- Where more than one spillway exist, the sequence of operation of spillways need to be included

### 2.1 Operation Plan

Operation plan consists of step-by-step instructions for operating the dam and reservoir. Operating procedures are developed based on:

- Reservoir operation studies, relevant design documents, hydraulic model studies etc.
- Equipment Operating and Maintenance Instructions (Manufacturers' Instructions)

Operating procedures are to be developed for both normal operations and emergency operations.

### 2.2 Normal Operations

The operating procedures developed for normal or “day-to-day” operation of a dam shall include the following:

- Instructions for operating control mechanisms.
- Instructions for operating the reservoir in accordance with reservoir operation rule curve.
- General instructions for the safe operation of the dam and appurtenances.

The following aspects also need to be included:

- Releases to be made for various purposes round the year including releases to be made as per Inter-State Agreements/MOU's with various States/Agencies/Projects, riparian releases etc.
- Rule curves.
- Inflow forecasting
- Flood release procedure
- Limitation on reservoir drawdown rate to prevent failure of u/s slope of the embankment/landslides along reservoir periphery

Site security is a matter of concern at all major dams. This includes terrorism implications and preventing structural damage by vandals and unauthorized operation of outlet or spillway gates. In most cases restricting public access is essential, and in some instances electronic security devices should be considered.

### 2.2.1 Instructions for Operating Control Mechanisms

The Procedures should provide instructions for operating all necessary equipment associated with a dam including the spillway gates and outlet gates /valves. The gate manufacturer's O&M Manual for Gates & Hoists will however govern the overall Gate operations whenever there is any contradiction with the instructions given in the Manual. The frequency and nature (e.g. flow test, static test, dry test) of operational check testing of the equipment's should be specified. Correct sequence should be emphasized and sketches, drawings and photographs to aid in identifying specific handles, buttons, levers, etc., should be included. Provisions and uses of backup equipment should be outlined.

The correct method and sequence of opening and closing guard gates, gate usage during low and high flow, and openings at which excessive vibration are experienced, and operating problems peculiar to a specific gate should also be listed. For gates/valves, a schematic diagram should be provided showing each component (including backup equipment) and its place in the operating sequence.

An auxiliary power system such as a petrol or diesel-operated generator or other appropriate energy source, is essential if the outlets, spillway gates and other dam facilities are electrically operated. This system should be located at levels higher than the extreme flood levels. Access and lighting during extreme events is essential.

All the spillway and outlet gates should be tested on a regular schedule along with testing of alarms and associated indicators. The test should include use of both the primary and auxiliary power systems.

### 2.2.2 Operation of the Reservoir

Instructions need to be included for the general operation of the reservoir, including

monitoring and regulation of inflow and outflow. Inflows shall consist of flows/ releases from upstream dam, tail race releases into the reservoir, contribution from the intervening catchment etc. as applicable. The surplus flows will be passed as outflow through the spillways in the dam.

Releases from the reservoir will need to be made for irrigation, power generation, or other purposes as per project requirements. Release rate instructions and schedules for the same need to be referenced. Any other required downstream flows should be given. The actual release rates and dates should be recorded and placed in the project files.

Instructions for operating spillways will be based on:

- Gate operation sequence including tables giving discharges for different gate openings and reservoir levels obtained through model studies or otherwise.
- Where more than one spillway exist, the sequence of operation of spillways need to be included

The general instructions should give the maximum pool levels proposed at different times of the year, and the largest and smallest carryover storage volumes. Both reservoir filling and release procedures (Rule Curves) should be available.

Guidelines for drawdown, flushing & sluicing in case of Hydro-power projects need to be referenced.

A typical reservoir operation guidelines for Barna Dam, Madhya Pradesh is given below for reference:

#### *Reservoir Operation Guide Lines*

##### *i) Reservoir Capacities*

*The various important reservoir levels and corresponding capacities are given below:*

Particulars	RL. in meters	Live Capacity in M. Cum
Canal sill level	335.60	-
Minimum draw down level	338.10	-
Crest level	341.70	94.30
Full Reservoir level	348.55	455.50
Maximum water level	351.45	829.00

### ii) Monsoon Yields

In flow data for monsoon months for Barna Dam site calculated on monthly basis from actual observed data at Barna Dam and the same expressed as percentage of live reservoir capacity is given below:

Month	Average yield in M. cu.m.	Average monthly yield as percentage (%) of live reservoir capacity
July	94	19.30
August	282	58.19
September	89	18.46
October	13	2.57
Nov. to June	-	-

### iii) Proposed Reservoir Levels during Monsoon Months

The reservoir levels to be maintained should be such that the reservoir receives the average monsoon yields during the particular month so that it is at FRL by 15th September every year. The yield during 2nd fortnight of September and the month of October is very meagre and cannot be relied upon for filling of reservoir.

The proposed reservoir level, live capacity and percentage filling are given below:

	Reservoir level (m)	Live Capacity (M. Cum.)	% filling
By 31st July	345	234.50	50
By 31st August	347	354.70	77
By 15th September	348.55 FRL	455.80	100

The above capacity and levels have been proposed as per detailed observation made from the year 1977 to 1994. The Executive Engineer located at dam site should use his discretion and judgement to make slight variation in the above arrangement in order to

stagger the out flows from the reservoir with floods in Narmada river due to release from Rani Awanti Sagar and Tawa Projects based upon available data of flood or forecasting etc. to safe guard the flood situation at Hoshangabad.

### iv) Release of Surplus Water

If reservoir levels increase beyond the levels indicated above on or before the prescribed dates, the radial gate shall be cautiously opened by issuing warning by sirens and wireless messages to all concerned authorities as prescribed.

By 15th September the reservoir should be near about FRL as after 15th September, the river discharge reduces considerably and there are little chances of filling the reservoir after this date.

During very high flood when reservoir water is at FRL, the incoming flood will have to be passed over spillway taking care that rate of out flow does not exceed the rate of inflow in the reservoir. The absorption between FRL 348.55 m and MWL 351.45 m is 289 M. cu.m. and the moderated discharge of the spillway is 6825.00 cumec. The rate of rise of reservoir water level may be restricted to 10 cm / hour after FRL so that the flood can be safely moderated and regulated for the prolonged period of about 30 hours, without crossing MWL, thereby reducing spillway discharge and minimizing downstream damages.

### v) Discretion of Field Engineers

The above recommendations shall be treated as guide lines for average monsoon and run-off conditions. The field Engineer should be extremely vigilant and will closely watch the rainfall pattern, storms and resulting yields and floods during the month of August and 1st fortnight of September and take decisions accordingly so that excessive releases are not made nor water is stored more than required, necessitating heavy peak flood releases in panic.

The knowledge, experience and ingenuity of the officer in charge of the reservoir operation blended with fast processing of rainfall and G.D. data of catchment area would provide the best solution for the operation of reservoir.

### vi) Flood Protection and Flood Moderation

The detailed project report (DPR) does not provide for flood protection. However, through judicious and

*cautious reservoir operation, peak flood can be moderated to some extent thereby reducing damage & submergence of life and properties downstream of the dam especially near Bareli Township.*

**vii) PMF & Moderated Flood**

*The designed maximum flood (PMF) is 13557 cumec (4.79 lac. cusec). The moderated flood at MWL is 6825 cumec (2.41 lac. cusec). The FRL & MWL are RL. 348.55 m and RL. 351.45 m. respectively.*

Also typical Rule Curves for Hirakud and Rengali Dams of Odisha at Figures 2-1 & 2-2 may be seen for reference.

Rules curves/Regulatory Plan for reservoirs, if not available, could be developed as per I.S 7323 - Operation of Reservoirs - Guidelines or as per any other suitable reference and included in the O&M Manual.

### 2.2.3 Safety Aspects

The public safety is of paramount importance at all dams and reservoirs. The general instructions in this regard are as under:

- State procedures to be followed for restricting access to the dam or confining traffic to designated areas. Indicate the procedures to be followed when tourists visit the facility.
- Designate speed limits to keep the traffic within acceptable and safe limits.
- Establish standards for maintaining sanitary conditions.
- Prevent contamination or pollution of water for human consumption and/or re-creational use.
- Eliminate safety hazards by:
  - Posting warning signs.
  - Removing unsafe conditions where possible.
  - Restricting public access to chutes, stilling basins, and control rooms.

- Posting safety instructions at visible and key locations.
- Maintaining warning buoys upstream of the dam.
- Providing adequate security.

- Ensure provision of all downstream warning systems like sirens, hooters etc. An adequate system of giving information to downstream areas regarding release of flood outflows from spillway should be there.

At the same time instructions regarding operations, inspection and maintenance need to be strictly followed for ensuring safe operation of the dam.

### 2.2.4 Flood Release Procedure

Surplus waters during floods are released through a service spillway, emergency spillway, fuse plug, outlet works etc. as applicable.

The service (principal) spillway maintains the reservoir at Full Reservoir level (FRL). Its function is to pass expected flood flows past the dam safely. It may be gated or un-gated. It is necessary to ensure that all gates are in working condition. Normally these spillways are standard ogee, chute, or side-channel spillways.

An auxiliary spillway / a fuse plug spillway functions during emergency conditions to prevent overtopping of a dam. A typical auxiliary spillway could be an excavated channel in earth or rock near one abutment of a dam with invert at FRL like a flush bar, or it can be like any other conventional type of spillway as per project planning. An auxiliary spillway should discharge away from the toe of a dam to avoid its erosion.

A fuse plug spillway normally has its crest at a level slightly higher than FRL and is designed to be washed away during large floods after which it is required to be re-constructed. These spillways in conjunction

with service spillway are sized/ designed to convey the so-called “design flood -- the rare, large-magnitude flood used to design the dam/ spillway arrangement.

The gate operation schedule for passing floods safely must be prepared based on the project layout and the results of hydraulic model studies. The following general guidelines may be borne in mind while preparing the gate operation schedule:

- i. The regulation of gates should be based on model studies where such studies have been carried out. Otherwise the regulation can be based on past experience of operation of the gates and design studies carried out for developing the same. The aim will be to ensure safety of the dam structure including the gate components, hoists, energy dissipation arrangement and downstream channel while letting out the desired discharge.
- ii. The end gates shall normally be opened first to prevent cross-flows striking against the walls and junctions.
- iii. At any time during the operation of different gates, the difference in gate opening of any two consecutive bays should not exceed 0.5 meters.
- iv. After opening the end gates, the gates at the centre should be opened and the other gates should be opened in symmetrical manner starting from the centre towards the end through gradual increase in the openings.
- v. While closing the gates, the gate that was opened last should be closed first. The procedure to be followed for closing the gates should be generally reverse of the procedure followed for opening the gates. Complete closure of the gates should be accomplished by gradual lowering of the gates by 0.2 to 0.3 m in the proper sequence.
- vi. In some cases all the gates will be needed to be opened equally especially when the energy dissipation arrangement consists

of a solid roller bucket or slotted roller bucket.

### **2.2.5 Reservoir Capacities**

The important reservoir levels such as sill levels of various outlets in the dam, DSL, MDDL, Spillway Crest level, Full Reservoir Level, Maximum Water Level and corresponding reservoir capacities should be included. (See Figure 2-3) Also it is essential to include Area-Capacity data (both in the form of tables and curves) in the Manual.

The O&M manual should mention that the reservoir capacities may change because of sedimentation that reduces the available storage volume over time. Revised area-capacity curves need to be prepared whenever a new bathymetric survey of a reservoir is carried out. The frequency of this survey will depend upon reservoir siltation rates and other factors as applicable (approx. 10 years).

### **2.2.6 Inflow forecasting**

Inflow forecasting should include instructions and procedure for preparing, periodic estimates of inflow volumes especially for the monsoon season. These estimates provide a basis to plan reservoir and project operations before and during the flood season and to permit optimization and coordination of water supply and other reservoir functions. Also, these estimates will help in planning operating procedures consistent with operating criteria to protect the dam and its appurtenances against failure caused by high reservoir water levels and excessive discharge rates.

The instructions and procedures should be described in sufficient details and completeness in a referenced Supporting Document to enable newly assigned personnel to estimate inflows and to fully implement the procedures. Maps or drawings could be used to show locations of Hydrological stations in the drainage area where data such as river gauge, discharge, rainfall, sediment is collected on a regular basis.

Administrative and technical procedures should be included. Administrative procedures should identify organizations responsible for forecasting estimates and the related collection of data and conversion of forecasts into operating plans. Technical procedures shall include:

- Parameters to be measured / monitored in hydro-meteorological stations.
- Specific correlations, equations, graphical tools, and analytical procedures used in forecasting inflow, such as early warning systems, rule curves, etc.
- Instructions regarding at what frequency forecasts are to be made under various conditions.

The supporting document should include a description of the procedures and criteria used by those agencies and instructions for operating personnel in the use of such forecasts.

Development of inflow forecasting procedures is a continuing process because correlations are subject to revision as more data become available. Hence, instructions in the Supporting document should include a requirement to examine the procedures periodically and to make revisions and improvements where needed.

## 2.3 Emergency Operations

For emergency operations, the Emergency Action Plan (EAP) will have to be invoked. The emergency situations are outlined under 4.2.1 of this document and Guidelines for developing Emergency Action Plans for Dams (Doc No. CDSO\_GUD\_DS\_01\_v2.0), CWC 2016. The EAP will help in minimizing losses to life and property. It will include:

- i) A clear description of the circumstances under which a warning is issued and a list of individuals to whom the warning is issued.

- ii) The names, organizations, telephone numbers (day/night), and alternate communication means for individuals responsible for operating the dam and the sequence by which these individuals should be contacted.

- iii) The names, designations, telephone numbers (day/night) and alternate communication means of the representatives of local, State, and Central agencies and other officials to be contacted, including:

- Concerned District/Revenue Authorities.
- Operators of other affected dams/other facilities.
- Managers/operators of recreational facilities/water sports.

- iv) The materials and equipment to be used for performing emergency dam repairs, including:

- The description and intended use of the materials.
- The description and location of equipment available with dam owner, and the names of the agencies to be contacted.
- The procedures to be used for contacting concerned agencies.

The EAP will be one of the referenced documents of the O&M Manual.

## 2.4 Drawdown Facility

All water release facilities, including outlet works, sluices, gated spillways, and power penstocks should be considered available for evacuation to the extent that their reliability in an emergency situation can be reasonably certain. In the case of canal outlet works, there must be a bypass or waste way in order for such outlet works to be considered available for emergency releases. Otherwise releases through them will be considered equal to the design capacity of the canal.

Reservoir level may be required to be lowered if a critical/emergency condition occurs or for carrying out repairs to the dam on its upstream slope/face in dry condition. For general guidance the ACER Technical Memorandum no. 3 - Criteria and Guideline for evacuating storage reservoirs and sizing low level outlet works & IS: 15472 - Guidelines for planning of low level outlets for evacuating storage reservoirs may be referred to. Care is to be taken to restrict the reservoir drawdown rates to prevent failure of upstream slope of the Embankment/ landslides along reservoir periphery etc. This will vary from dam to dam and project to project. The actual drawdown rates both under normal and emergency conditions have to be decided by the Dam Designers.

The Central Water Commission (CWC) Guidelines on Criteria for Evacuating Storage Reservoirs, Sizing Low Level Outlets and Initial Filling of Reservoirs are at Appendix – B

## **2.5 Initial Filling of Reservoir**

First filling of a reservoir is first indication that the dam is safe and will function as designed. Therefore, first filling of a reservoir should be carefully planned and implemented to ensure safety of the dam and future success of the dam. USBR & USACE (2012) studies indicate that approximately two-thirds of all failures and one-half of all dam incidents occur on first filling or in the first 5 years of reservoir operation. Thus, it is vital for dam operators and engineers to have as much control over the first filling as possible allowing as much time as needed for appropriate surveillance, including the observation and analysis of instrumentation data. Depending on the location, type, size, and intended purpose of a dam, the duration and rate of its first filling can vary. Regardless of how much time it takes, the first filling of a reservoir should be planned, controlled, and closely monitored in order to reduce the risk of failure. The prime consideration in deciding the rate of reservoir rise should be to

allow the dam to adjust to the forces it will experience as the water level behind it increases.

In addition to dam failure, it is common for design, construction, and/or material deficiencies of a new dam to become apparent during the first filling. For example, evidence of seepage, cracking, and erosion are often noted when the reservoir is raised to new levels for the first time. Inspection and assessment of these potentially hazardous conditions prior to the completion of filling is important and it may be necessary to halt filling or in some cases lower the reservoir before the desired operating water level is achieved to investigate signs of seepage, cracking and erosion. Repairs to any project features that did not function as designed can be re-evaluated and modified to ensure the dam operates according to its original design.

All the water release facilities including gated spillways, outlet works, sluices etc. are to be used for control of reservoir levels during initial filling. The O&M Manual should be available before initial filling of the reservoir.

The initial filling criteria for the reservoir shall be available in a separate supporting document which shall be referenced in the O&M Manual.

Before initial filling of the reservoir is taken up, the State Dam Safety Organisation shall arrange for safety inspection of the dam either through its own engineers or by an independent panel of experts, who shall also examine the initial filling program and prepare a detailed report in respect thereof.

Reservoir filling schedule is governed by the Indian Standard, IS: 15472 - Guidelines for planning and design of low level outlets for evacuating storage reservoirs in which the Guidelines regarding initial filling of reservoirs have been described. It stipulates that the filling rates for concrete/masonry dams are much less restrictive than for embank-

ment dams and specify a general initial filling program in respect of embankment dams, which can be suitably modified as necessary, as under:

- a) The first stage consists of filling the reservoir up to MDDL. This filling can be done without restraint as the hazard potential to the public and economic development downstream of the dam is low.
- b) The second stage consists of filling the reservoir from MDDL to the crest of spillway. For earth and rock fill dams this stage filling should be done in two parts.

The reservoir above MDDL should be gradually built at a rate not exceeding 3 m per fortnight and filling should be temporarily stopped at half the height between MDDL and crest of spillway, for a reasonable time in order to assess the behaviour of the structure on the basis of observed values and to take a decision about further storage and remedial measures in case of distress.

After a decision is taken to continue the filling, further building up of the storage should be done in gradual sub-stages of 2 to 3 m per fortnight depending upon the height of the dam and increase in storage capacity. The reservoir should then be temporarily held at the crest level of the spillway for a reasonable time for monitoring and evaluating the performance of the dam and to take a decision about further storage.

- c) The third stage consists of filling above the crest of the spillway up to the full reservoir level (FRL). The rate of reservoir filling above crest of spillway should be restricted to sub-stages of 0.3 m in 48 h. The reservoir should be temporarily held at half the height between FRL and crest of spillway for sufficient time for moni-

toring and evaluating performance of dam and to take a decision about further storage/remedial measures, if any.

**Central Water Commission (CWC)** vide letter no.L25/86-DSS/509 dated 13<sup>th</sup> May 1986 has stipulated reservoir filling schedule in respect of Concrete Dams as under:

The first stage consists of filling the reservoir up to Minimum Draw down Level (MDDL). This filling can be done without restraint.

The second stage consists of filling the reservoir from MDDL to the crest of spillway. The reservoir above MDDL should be gradually built up at a rate not exceeding 3 meters per fortnight depending upon the height of the dam and held at the level of crest of spillway in order to assess the behavior of the structure on the, basis of observed data and to take a decision about further storage.

The third stage consists of filling above the crest of the spillway and up to full reservoir level (FRL). Above the crest level of spillway the building up of water level till FRL should be restricted to 0.3 meter (1 ft.) in 48 hours and the same should be temporarily held at half the height between the crest of spillway and FRL to monitor and assess the behavior of structure before further filling resumed. The period for which the reservoir is held at this level will depend on the instrument response time.

In case of concrete dams having high earthen flanks, the procedure suggested for earthen dams should be followed

## 2.6 Record Keeping

As already suggested, operating a dam should include keeping accurate records of the following items pertaining to project operation:-

- Rainfall and Reservoir Levels – On daily basis during non-monsoon and on hourly basis during monsoon.



- Release through outlet/sluices on daily basis for irrigation, water supply, hydropower etc.
- Outflows through spillway during monsoon on hourly basis and during non-monsoon on daily basis.
- Records of drawdown with reservoir levels, quantity of water released, drawdown rates, reason for drawdown.
- Water Audit register to be maintained on daily basis by accounting all the releases, incremental storage in the reservoir etc.
- Security protocols to be in place along with operating protocols.
- Visitors register with complete details like name, address, designation, purpose etc.
- Other Procedures – Maintain a complete record of all operating procedures.

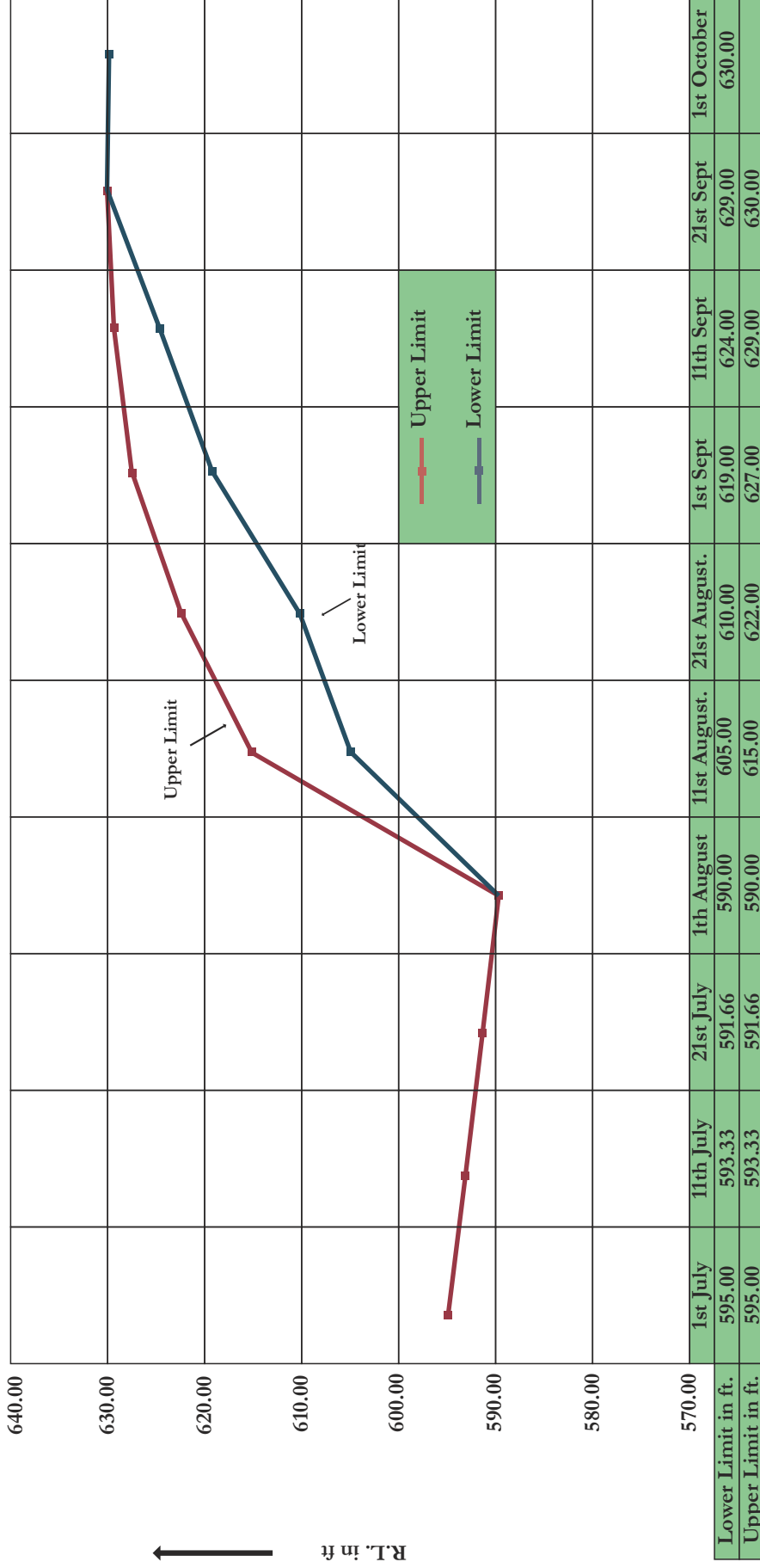


Figure 2-1: Rule Curve of Hirakud Dam (Odisha)

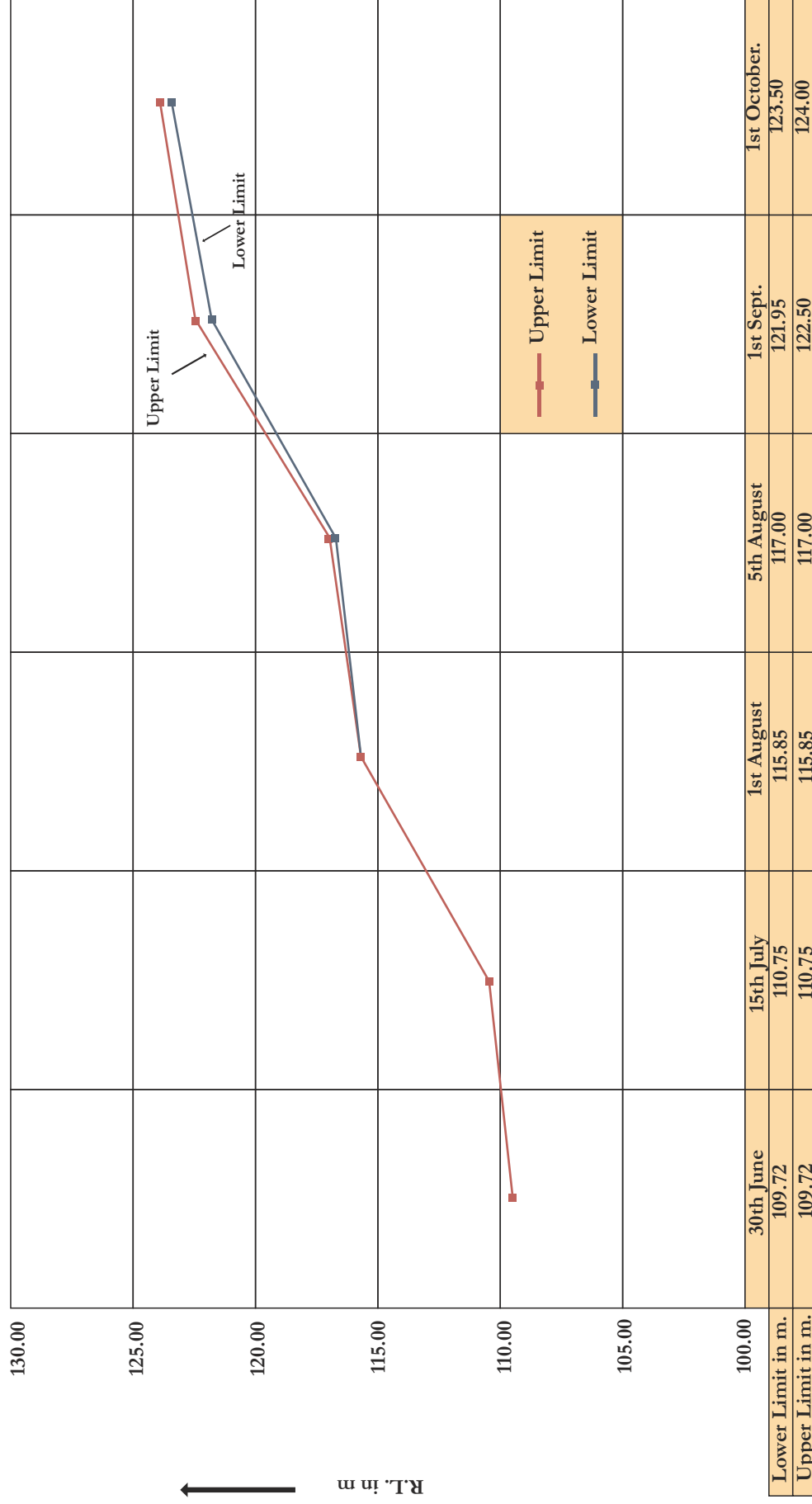


Figure 2-2: Rule Curve of Rengali Dam (Odisha)

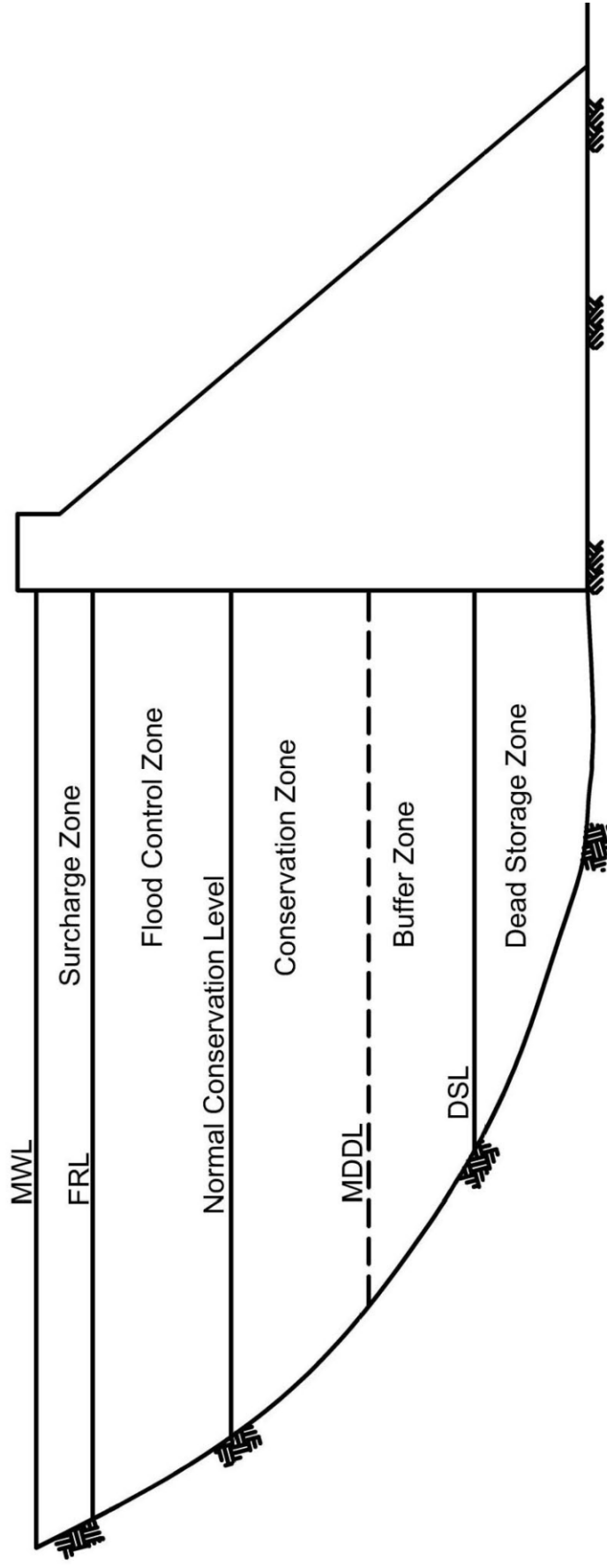


Figure 2-3: Reservoir Storage Allocation Zones

## Chapter 3. PROJECT INSPECTION

An effective inspection program is essential to identify problems and to keep a dam in a good and healthy condition. Detailed description on project inspections is available in the Guideline for Safety Inspection of dams (Doc No. CDSO\_GUD\_DS\_07\_v1.0), CWC 2018. However an overview of the various types of inspections is given below:

### 3.1 Types of Inspections

Four different types of dam safety inspections are carried out for all dams:

1. Informal inspections
2. Scheduled inspections (Pre & Post monsoon inspections & other scheduled inspections)
3. Special (unscheduled) inspections
4. Comprehensive evaluation inspections

The frequency of each type of inspection will depend on the hazard classification of the dam, the condition of the dam, the CDSO regulations etc.

### 3.2 Informal Inspections

An informal inspection is a continuing effort by on-site personnel (dam owners/operators and maintenance personnel) performed during their normal duties. Informal inspections envisage surveillance of the dam periodically and are critical to the proper operation and maintenance of the dam. They consist of frequent observations of the general appearance and functioning of the dam and appurtenant structures.

Normally the dam owners, operators, maintenance crews, or other staff who are posted at dam site will make informal inspections. These people are the “first line of

defense” in assuring safe dam conditions, and it is their responsibility to be familiar with all aspects of the dam. Their vigilance in inspection/surveillance of the dam, checking the operating equipment, and noting changes in conditions may prevent serious mishaps or even dam failures.

Informal inspections are important and should be performed at every available opportunity. These inspections may only cover one or two dam components as the occasion presents itself, or they may cover the entire dam and its appurtenant structures. The informal inspections are not as detailed as comprehensive evaluation, scheduled, and special inspections and will only require that a formal report is submitted to the dam owner’s project files if a condition is detected that might endanger the dam.

### 3.3 Scheduled Inspections

Scheduled inspections shall consist of Pre-monsoon & Post-monsoon inspection and any other inspections carried out by the State Dam Safety Organization/any Expert panels constituted by the dam owner.

These inspections are performed to gather information on the current condition of the dam and its appurtenant works. This information is then used to establish needed repairs and repair schedules, and to assess the safety and operational adequacy of the dam. Scheduled inspections are also performed to evaluate previous repairs.

The purpose of scheduled inspections is to keep the dam and its appurtenant structures in good operating condition and to maintain a safe structure. As such, these inspections and timely maintenance will minimize the long-term costs and will extend the life of the dam. Scheduled inspections are per-

formed more frequently than comprehensive evaluation inspections to detect at an early stage any developments that may be detrimental to the dam. These inspections involve assessing operational capability as well as structural stability and detection of any problems and to correct them before the conditions worsen. The field examinations should be made by the personnel assigned responsibility for monitoring the safety of the dam. If the dam or appurtenant works have instrumentation, the individual responsible for monitoring should analyze measurements as they are received and include an evaluation of that data. Dam Inspection Report or an inspection brief should be prepared following the field visit (Dam Inspection Report is recommended).

Scheduled inspections should include the following four components as a minimum:

1. Review of past inspection reports, monitoring data, photographs, maintenance records, or other pertinent data as may be required;
2. Visual inspection of the dam and its appurtenant works;
3. Preparation of a report or inspection brief, with relevant documentation and photographs.
4. Education and training if someone other than the owner is performing the inspection.

### **3.4 Special (Unscheduled) Inspections**

Special inspections may need to be performed to resolve specific concerns or conditions at the site on an unscheduled basis. Special inspections are not regularly scheduled activities, but are usually made before or immediately after the dam or appurtenant works have been subjected to unusual events or conditions, such as an unusually high flood or a significant earthquake.

Japan Water Agency (JWA) has developed an excellent system of carrying out inspec-

tions after an earthquake event for Ichari Dam, Uttarakhand. For details refer “Inspection Manual for Dam Field Engineers after Seismic Events, Ichari Dam, Uttarakhand (CDSO\_MAN\_DS\_01\_v1.0), January 2018” The threshold acceleration adopted by them for carrying out inspection is when the acceleration recorded at dam foundation exceeds 25 gals (25 cm/sec<sup>2</sup>). It is proposed to adopt their system in our guidelines. The system envisage a quick check within 1 hour after the earthquake event, next i.e. first check within 3 hours and a second check within 24 hrs.

The quick check will envisage:

- Confirming the seismic intensity at the dam site.
- Sending initial report regarding an assessment of a possible dam failure.
- Finding out urgent rescue needs.

The first inspection will envisage:

- Visual observations of leakage/seepage, deformations, cracking in dam, slope failure, collapse of any component, functioning of gates and electrical devices, hill slopes (upstream and downstream of the dam), roads etc.
- Confirming any subsequent action to be taken.

The second inspection will envisage:

- Quantitatively measuring leakage, deformation and other monitoring items.
- Verifying function of facilities by actual movement.

Further the following activities are also recommend to minimize the adverse impacts of an earthquake

- i) Regular field drills at dam site to make the site officials aware of their roles and responsibilities

- during and after an earthquake event and thereby to upgrade the earthquake response system
- ii) Securing communication lines by having a redundancy in the system by way of availability of different types of telecommunication systems (viz. mobile phone, wireless, satellites, telephone etc.) at dam site.
  - iii) Securing adequate fuel for at least 3 days (viz. petrol, diesel) for the emergency power generators and other essential supplies like food, water, fire wood etc.
  - iv) Installation of seismometers in a dam and development of a data sharing system.

### 3.5 Comprehensive Evaluation Inspections

#### 3.5.1 General

For comprehensive dam safety evaluation for each dam an independent panel of experts known as Dam Safety Review Panel (DSRP) needs to be constituted for determining the condition of the dam and appurtenant works. The panel would undertake evaluation of each dam once in 10 years or on occurrence of any extreme hydrological or seismic event or any unusual condition of the dam or in the reservoir rim. The terms of reference of the comprehensive dam safety evaluation shall include but not be limited to;

1. General assessment of hydrologic and hydraulic conditions, review of design flood, flood routing for revised design flood and mitigation measures.
2. Review and analysis of available data of dam design including seismic safety, construction, operation maintenance and performance of dam structure and appurtenant works.
3. Evaluation of procedures for operation, maintenance and inspection of

dam and to suggest improvements / modifications.

4. Evaluation of any possible hazardous threat to the dam structure such as dam abutment slope stability failure or slope failures along the reservoir periphery.

#### 3.5.2 Details to be provided to DSRP before inspection

All relevant details/data/drawings for the dam project to be inspected by the Panel of Experts shall be provided at least 3 months in advance of the proposed visit. This will include:-

##### (a) General Information

1. Scope of project
2. Basic data and salient features
3. Issues related to safety of dam
4. Details of key personnel
5. Emergency preparedness – Communications, Auxiliary Power, Downstream Warning system & Security of site.

##### (b) Hydrology

1. Description of drainage basin
2. Original inflow design flood
3. Spillway capacity at FRL & original MWL
4. Surface area & storage capacity of the reservoir
5. Flood routing criteria & results

##### (c) Geology

1. Dam site geology including geological reports
2. Quality and sufficiency of the geological investigations.
3. Special problems and their treatment
4. Reservoir competency as per geological report.

5. Slope stability issues along reservoir rim.
- (d) Layout including Drawings
1. Dam
  2. Spillway
  3. Junction between Embankment & Concrete/Masonry dams
  4. River/Canal outlets
  5. Instrumentation
- (e) Dam and Spillway
1. Geology
  2. Special problems
  3. Foundation treatment including treatment of faults/shear zones/weak zones, curtain/consolidation grouting, drainage provisions, any other special treatment, cutoff trench, diaphragm walls etc.
  4. Design criteria and result of stability analysis
  5. Special studies (Finite element/Dynamic Analysis etc.)
  6. Adequacy of design – from dam safety considerations
  7. Hydraulic design of Spillway and Energy Dissipation Arrangements including past model study reports.
  8. Instrumentation – analysis and interpretation of instrumentation data including structural behavior reports.
  9. Pre-construction material testing reports including adequacy of field and laboratory investigations, appropriateness of materials selected etc.
  10. Post-construction testing reports, if any.
  11. Seismicity (Seismic Parameters approved by the National Committee for Recommending Seismic Design Parameters for Dams)
- f) Construction history

- g) Dam incidents/failures, remedial measures/modifications undertaken
- h) Reservoir Operation & Regulation Plan
  1. General
  2. Reservoir filling
  3. Water releases – normal and during floods.

### **3.5.3 Field Inspection – Observations & Recommendations regarding Remedial Measures**

Each component of the project is to be inspected, evaluated and specific problems are to be brought out. Recommendations for necessary remedial measures need to be included in the panel's report. Various project components to be inspected shall include but will not be limited to;

- (a) Dam
1. Upstream face
  2. Downstream face
  3. Top of dam
  4. Structural behavior as observed visually and as per evaluation of instrumentation data (any visible cracking, deflections etc.)
  5. Seepage assessment
  6. Condition of natural/excavated slopes in the abutments, both on u/s and d/s of the dam.
  7. Any specific problems/deficiencies
- (b) Spillway
1. Civil structure
  2. Energy Dissipation Arrangements (EDA)
  3. Spill channel, drop structures etc. if any.
  4. Condition of EDA and its performance
  5. Spillway Gates & Hoists



6. Downstream safe carrying capacity of river / channel.
- (c) River / Canal Outlets
1. Civil structures
  2. Outlet Gates, Hoists & Controls
  3. Conducts / Outlets through Embankment dams and sluices through Masonry / Concrete dams (Condition, problems etc.)
  4. Trash racks, if any
  5. Separate energy dissipation arrangements, if any.
- (d) Review of Sedimentation of the Reservoir.
1. Assessment of sedimentation and its effect on flood routing, operation/ life of reservoir.
- (e) Flood Hydrology
1. Extent & sufficiency of data available
  2. Method used for estimating the design flood.
  3. Design flood review study.
  4. Flood routing studies with the revised flood
  5. Adequacy of free board available
- (f) Miscellaneous services / facilities
1. Access Roads / Bridges / Culverts
  2. Elevators
  3. Stand by power arrangements
  4. Flood forecasting arrangements, if any
  5. Communication facilities (Telephone, Satellite, Wireless, Mobile etc.)
- (g) Hydraulic Model studies, if any new studies carried out.
- (h) Earlier reports of experts / DSRP etc., if any, as annexures.
- (i) Photographs of dam project showing problem areas.

### 3.5.4 Components involved

A comprehensive evaluation inspection of a dam will typically consist of five components:

1. Project records review (i.e. study of all design / construction records/drawings, history of the dam's performance, past inspection notes/reports, notes on distress observed/ any rehabilitation measures undertaken earlier etc.).
2. Visual inspection or field examination of the dam and its appurtenant works.
3. Preparation of a detailed report of the inspection.
4. Education and training of the dam owner on the issues observed during dam inspection, identification of potential dam failure modes & to carryout additional field investigations & laboratory testing as required. Dam owners should be made part of the inspection process so that they take ownership of the results and are committed to implementing the recommended remedial measures.
5. Design studies e.g. review of design flood, checking of the adequacy of spillway capacity, freeboard requirements, dam stability, any special study as required & submission of the report.

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## Chapter 4. PROJECT MAINTENANCE

A good maintenance program will protect a dam against deterioration, prolong its life, and greatly reduce the chance of failure. Nearly all the components of a dam and its materials are susceptible to damage and deterioration if not well maintained. Moreover, the cost of a proper maintenance program is small compared to the costs of major repairs, loss of life and property and litigation. Properly maintaining a dam not only protects the dam and its owner but the public as well. If maintenance of a dam is neglected the consequences and costs could multiply.

### 4.1 Maintenance Plan

Timely maintenance assures that a dam and reservoir would remain in a good working condition and prevents more harmful conditions from developing. Individual maintenance tasks should be noted, with a description of the area where the maintenance is to be performed, the schedule for performing the tasks, and reporting procedures. Typical routine maintenance tasks performed at most dams include mowing grass, removing vegetation, bushes and trees, removing litter and other debris, re-grading the crest and/or access roads, repairing fencing to keep livestock off the dam, etc. Other maintenance works that may need to be performed in an Earth dam may include restoration of embankment to its design section, seepage problems, erosion, displaced riprap, cracking in embankment etc. In concrete / masonry dams there may be issues like cracking and disintegration in concrete, choking of drainage holes in dam body/ foundation, damages to spillway glacis/piers/energy dissipaters due to abrasion/ cavitation/unsymmetrical flows, damages to pointing on upstream & downstream faces of masonry dams, heavy seepages through some drains in foundation/inspection galleries etc.

Maintenance program for a dam should be developed primarily based on systematic and frequent inspections.

### 4.2 Maintenance Priorities

Maintenance activities need to be prioritized. In order of priority they need to be clarified under the heads immediate maintenance & preventive maintenance.

#### 4.2.1 Immediate Maintenance

The following conditions are critical and call for immediate attention & reservoir lowering, if warranted. These conditions may include, but are not limited to:

- A dam about to be overtopped or being overtopped during high flood.
- A dam about to be breached by erosion, slope failure etc.
- A dam showing signs of piping or internal erosion indicated by increasingly cloudy seepage or other symptoms.
- A spillway being blocked or with some inoperable gates.
- Evidence of excessive seepage appearing anywhere at the dam site e.g. an Embankment dam becoming saturated, seepage exiting on the downstream face of a dam, increasing in volume.

Although the remedy for some critical problems may be obvious (such as clearing a blocked spillway or repairing the spillway gates so that they are in working condition), the problems listed above generally demand the services of experienced engineers/expert panels familiar with the design, construction and maintenance of dams. An emergency action plan (EAP) should be activated when any of the above conditions are noted.

## 4.2.2 Preventive Maintenance

This can be classified as Condition based Maintenance and Routine Maintenance.

### 4.2.2.1 Condition Based Maintenance

The following maintenance should be completed as soon as possible after the defective condition is noted. These may include but are not limited to:

- Remove all vegetation and bushes from the dam and restoring any eroded areas and to establish a good grass cover.
- Fill animal burrows.
- Repair livestock trails and fences to keep livestock off dam.
- Restore and reseed eroded areas and gullies on embankment dams.
- Repair of defective gates, valves, and other hydro-mechanical equipment.
- Repair any concrete or metal components that have deteriorated.
- Cleaning of the choked drainage holes in the dam body/foundations in concrete/masonry dams.
- Repair any damages on spillway glacis, piers, energy dissipaters, training/ divide walls, downstream areas etc.
- Repairs on the upstream face of masonry dams, in case the pointing is damaged, due to which there is increased seepage.
- Controlling any heavy seepage in the foundation/inspection galleries in Concrete/Masonry dams from drainage holes.
- Repairs of any cracks/cavities/joints in concrete/masonry dams/ structures.

However many of these works will require the services of experienced engineers/expert panels.

### 4.2.2.2 Routine Maintenance

Several tasks should be performed on a continuous basis. These may include but are not limited to

- Routine mowing, restore and reseed eroded areas and gullies on downstream face of embankment dams and general maintenance including repairs/cleaning of surface drains on downstream face & in the downstream areas.
- Maintenance and treatment of any cracks/joints/cavities in Concrete/Masonry dams and spillways based on the recommendations of experienced engineers/expert panels.
- Observation of any springs or seepage areas, comparing quantity and quality (clarity) with prior observations in embankment dams.
- Monitoring of development in the upstream watershed which would materially increase runoff and sediment from storms.
- Monitoring of downstream development which could have an impact on the dam and its hazard category.
- Maintenance of Electrical & Hydro-Mechanical equipment and systems e. g. Servicing of spillway gates & stop logs, hoisting arrangements, gantry crane, gates/hoist of outlet works/sluices & stand by generator.
- Proper lighting at dam top, galleries in dams etc.
- Monitoring of seepage in galleries of concrete/masonry dams.
- Monitoring/cleaning & removal of leached deposits in porous concrete/formed drains in dam body & founda-

tion drainage holes of Concrete/ Masonry dams.

- Maintenance of all dam roads & access roads.
- Operation of electrical and mechanical equipment and systems including exercising gates & valves.
- To keep the gate slots clear of silt/debris.
- Maintenance/testing of monitoring equipment (instruments) and safety alarms.
- Testing of security equipment.
- Testing of communication equipment.
- Any other maintenance considered necessary.

### 4.3 Maintenance Items

The O&M Manual for a dam should include detailed instructions and schedules for performing periodic maintenance works at the site. This should include maintenance of the dam, the appurtenant works, and the reservoir areas.

All needed maintenance works should be listed. Dam maintenance includes all maintenance and repair of issues/works identified during safety inspections and routine dam surveillance. An adequate maintenance program will ensure that the dam and its appurtenant works remain in good working condition and will prevent more harmful conditions from developing.

Individual maintenance tasks should be itemized on the list, with a description of the area where the maintenance is to be performed, the time it takes to complete each task, the equipment that is needed, who will perform the work, the schedule for performing the tasks, and reporting procedures. Adequate O & M Budget should be provided based on the above exercise.

Dam repairs should be scheduled based on severity of the problem, available resources, and weather conditions. For example, if a severe settlement problem (more than envisaged in designs) or cracking is detected on the crest of the dam, it should have a high priority since further degradation could lead to dam breaching. The causes of all major issues/problems should be identified and evaluated by experienced engineers/Expert Panels so that appropriate remedial measures can be finalized. Correcting minor rill erosion on the downstream slope could be assigned a low priority since it is not a dam safety concern. This type of repair will also be weather dependent, since grass can only be planted during specific times of the year, and the embankment should be dry so that more damage is not inflicted to the embankment slopes.

Identification of works/issues which may require periodic maintenance, are summarized in Table 4-1.

#### 4.3.1 Earthwork

The surfaces of an earthen dam may deteriorate due to several reasons. For example, wave action may cut into the upstream slope, vehicles may cause ruts in the crest or slopes, trails left by livestock can result in erosion, or runoff waters may leave erosion gullies on the downstream slope. Other special problems, such as shrinkage cracks or rodent damage, may also occur. Damage of this nature must be repaired constantly.

The maintenance procedures to be described in the O&M Manual will be used for repairs of routine earthwork problems. However, this section is not intended to be a technical guide, and the methods discussed should not be used to solve serious problems. Conditions such as embankment slides, structural cracking, and sinkholes threaten the immediate safety of a dam and require immediate repair under the directions of experienced engineers/Expert panels.

The material selected for repairing embankments should be free from vegetation, organic materials, trash, and large rocks.

If flow-resistant portions of an embankment are being repaired, materials that are high in clay or silt content should be used. If the area is to be free draining or highly permeable (such as pervious shell of an embankment dam) the material should have a higher percentage of sand and gravel. It is usually satisfactory to replace or repair damaged areas with soils like those originally in place.

An important soil property affecting compaction is moisture content. Soils that are too dry or too wet do not compact well. One may test repair material by squeezing it into a tight ball. If the sample keeps its shape without cracking and falling apart (which means it is too dry), and without depositing excess water onto the hand (which means it is too wet), the moisture content is near the proper level.

Before placement of earth, the repair area needs to be prepared by removing all inappropriate material. All vegetation, such as bushes, roots, and tree stumps, along with any large rocks or trash need to be removed. Also, unsuitable earth, such as organic or loose soils, should be removed, so that the work surface consists of exposed, firm, clean embankment material.

Following cleanup, shape and dress the affected area so that the new fill can be compacted to the level specified in the technical specifications. Also it should properly key with the existing fill. Further trim the slopes and roughen the surfaces by scarifying or plowing to improve the bond between the new and existing fill and to provide a good base to compact against.

Place soils in loose layers up to 20 centimeters thick and compact manually or mechanically to form a dense mass free from large rock or organic material. Keep soil moisture in the proper range. The fill should be wa-

tered and mixed to the proper wetness and allowed to dry if too wet.

Erosion is one of the most common maintenance problems at embankment structures. Erosion is a natural process and its continuous forces will eventually wear down almost any surface or structure. Periodic and prompt maintenance is essential to prevent continuous deterioration and possible failure.

Turfing, free from weeds and bushes, is an effective means of preventing erosion.

Rills and gullies should be filled with suitable soil, compacted, and then seeded for growing the turfing. Erosion in large gullies can be slowed by stacking bales of hay or straw across the gully until permanent repairs can be made.

Paths due to pedestrian, livestock, or vehicular traffic (two and four-wheeled) are a problem on many embankments. If a path has become established, vegetation will not provide adequate protection and more durable cover will be required unless traffic is eliminated. Stones may be used effectively to cover such footpaths.

In addition, steps can be provided/ constructed at regular intervals along the length of the dam for going from downstream toe to the dam top. All vehicular traffic, except for maintenance, should be restricted from the dam.

Erosion is also common at the point where an embankment and the concrete walls of a spillway or other structure meet. Poor compaction adjacent to such walls during construction and later settlement can result in an area along the wall that is lower than the grade of the embankment.

Runoff, therefore, often concentrates along these structures, resulting in erosion. People also often walk along these walls, wearing down the vegetative cover. Workable solu-

tions include re-grading the area so that it slopes away from the wall, adding more resistant surface protection, or constructing steps.

#### **4.3.2 Upstream Riprap**

The upstream face of a dam is required to be protected against wave erosion. Rip-rap is normally provided for the purpose with filter layers below.

Nonetheless, erosion can still occur in existing riprap. Water running down the slope under the riprap can erode the embankment. Sections of riprap that have slumped downward are often signs of this kind of erosion.

Effective slope protection must prevent soil from being removed from the embankment.

When erosion occurs on the upstream slope of a dam, repairs should be made as soon as possible. (Refer IS: 8237- Code of practice for protection of Slopes for Reservoir Embankments).

#### **4.3.3 Controlling Vegetation**

Keep the entire dam clear of unwanted vegetation such as bushes or trees. Excessive growth may cause several problems:

- It can obscure the surface of an embankment and not allow a proper inspection of the dam.
- Large trees can be uprooted by high wind or erosion and leave large holes that can lead to breaching of the dam.
- Some root systems can decay and rot, creating passageways for water, and thus causing erosion.
- Growing root systems can lift concrete slabs or structures.
- Trees, bushes, and weeds can prevent the growth of desirable grasses.
- Rodent habitats can develop.

All bushes/trees should be as far as possible removed by roots. The resulting holes should be filled with well compacted earth. It would be desirable to remove the plants/vegetation at their early stage to prevent their growing into big tree/bushes. In cases where trees and bushes cannot be removed, the root systems should be treated with herbicide (properly selected and applied) to retard further growth. Concerned Government Agencies should be consulted for selection of appropriate herbicides & their use for control of vegetation on dam structures.

Further, it is desirable that there are no trees or bushes within 500 m of the toe drain on the downstream side of the dam.

#### **4.3.4 Controlling Animal Damage**

Livestock should not be allowed to graze on an embankment surface. When soil is wet, livestock can damage vegetation and disrupt the uniformity of the surface. Moreover, livestock tend to walk in established paths and thus can promote erosion. Such paths should be re-graded and seeded, and the livestock permanently fenced out of the area.

The burrows and tunnels of burrowing animals (beaver, muskrat, groundhogs and others) weaken earthen embankments and serve as pathways for seepage from the reservoir. Large burrows on an embankment should be filled by mud packing. This simple, inexpensive method involves placing vent pipe in a vertical position over the entrance of the den. Making sure that the pipe connection to the den does not leak, the mud-pack mixture is poured into the pipe until the burrow and pipe are filled with the soil-water mixture. The pipe is removed and more dry earth is tamped into the entrance. As per some US publications, the mud pack is generally made by adding water to 90% earth & 10% cement mixture until a slurry or thin cement consistency is attained. For bigger holes, bentonite coated stones can also be used. All entrances should be plugged with well-compacted earth & vegetation re-established.

Dens should be eliminated without delay. Different repair measures are necessary if a dam has been damaged by extensive small rodent tunneling or large rodent activity. Excavate the area around the entrance and then backfill it with impervious material. This plugs the passage entrance so that water is prevented from saturating the dam's interior.

#### **4.3.5 Controlling Ants and Termites (White Ants)**

Ants and termites have become one of the most serious pests for Embankment dams. They both need water to survive and have been found on most of the embankment dams in India. These insects can create problems in the dam itself and with any of its electrical components.

In some habitats, ants and termites can move as much or more soil as earthworms, thereby reducing soil compaction. Nest galleries can penetrate in a V-shaped pattern below the nest, penetrating as much as more than one meter deep in the soil. These galleries can create pathways for surface water to penetrate in the dam, resulting in internal erosion and collapse of the surface.

Ants and termites left undisturbed can build mounds that can become quite large. These can create problems for mowing. However, frequent mowing can induce the colonies to migrate to neighboring, undisturbed areas.

There are many options for managing ants and termites. Use only pesticides labeled as suitable for the location you want to treat. Make every effort to avoid contaminating water with pesticides.

#### **4.3.6 Controlling Damage from Vehicular Traffic**

As mentioned earlier, vehicles driving across an embankment dam can create ruts in the crest if it is not surfaced with roadway material. The ruts can then collect water and

cause saturation and softening of the dam. Other ruts may be formed by vehicles driving up and down a dam face; these can collect runoff and cause severe erosion.

Vehicles, except for maintenance, should be restricted on the dam top and kept out by fences or barricades. Any ruts should be repaired as soon as possible. .

In the case of existing dams having permission for movement of nearby villagers, heavy traffic movement may be avoided. If possible, separate connectivity may be explored for such cases.

In the case of barrages and dams having provisions for roads of National/State Highways etc., all efforts should be made to restrict the speed of vehicles. Regular maintenance of bridge and roads shall be mandatory.

#### **4.3.7 Masonry/Concrete dams & Spillways**

Various issues/problems that may need maintenance/repairs in Concrete/Masonry dams & Spillways may include but are not limited to:

- Cracking in concrete (potential causes are alkali – aggregate reaction, thermal stresses because of heat of hydration or temperature variations, foundation problems).
- Damages on spillway glacis, spillway piers, training/divide walls, energy dissipaters, downstream areas (probable causes are cavitation, abrasion, un-symmetrical flows, unfavorable downstream conditions)
- Vegetation growth in unattended Auxiliary spillways, spill channel, approach channel etc.
- Seepage in Galleries and on d/s face of the dam.



- Cleaning and removal of leached deposits from choked drainage holes in the dam body/foundations.
- Repair to upstream face of masonry dams in case the pointing is damaged, leading to increased seepage.
- To ensure proper access & lighting in galleries.
- To ensure that the dam is behaving as designed based on instrumentation programs.
- Periodic maintenance should be performed of all concrete surfaces to repair deteriorated areas. Repair deteriorated concrete at the earliest; it is most easily repaired in its initial stages. Deterioration can accelerate and, if left unattended, can result in serious problems or dam failure.

For remedial measures of problems of special nature advice of experienced engineers/ Panel of Experts needs to be obtained

#### 4.3.8 Outlet Works

Outlet conduits should be inspected thoroughly once a year. Circular conduits that are one and a half meter or more in diameter can be entered and visually inspected. Common problems are improper alignment (sagging), separation and displacement at joints, cracks, leaks, surface wear, loss of protective coatings, corrosion, and blockage. Problems with conduits occur most often at the joints. Further collars at joints used to also lead to inadequate compaction. Hence, special attention should be given to them during the inspection. The joints should be checked for gaps caused by elongation or settlement and loss of joint-filler material. Open joints can permit erosion of embankment material or cause leakage of water into the embankment during pressure flow. The outlet should be checked for signs of water seeping along the exterior surface of the pipe. A depression in the soil surface over the pipe may be a sign that soil is being removed from around the pipe.

Listed below are common concerns regarding repairs to outlet works:

- Asphalt mastic is not recommended for other than temporary repairs. Asphalt mastic used as joint filler becomes hard and brittle, is easily eroded, and as per literature survey it may provide a satisfactory seal for only about five years. Mastic should not be used if the conduit is expected to flow under pressure.
- The instructions on the label should be followed when using thermosetting plastics (epoxy). Most of these products must be applied to a clean and dry surface to set up an effective bond. However cementitious materials are to be preferred in view of their UV resistance & longer life.
- Material used as joint filler should be impervious to water and should be flexible throughout the range of expected air and water temperatures.
- The internal surfaces of the conduit should be made as smooth as possible when repairs are made so that high-velocity flow will not damage the repair material.
- Minor cracks in concrete are not considered a dangerous problem. Repair is not necessary unless the cracks widen or leak.

The general practice now is not to go in for pre-cast concrete/MS pipe conduits with collars but to construct RCC conduits at site without any collars and joints. PVC water stops are provided at joints and the exterior faces of the conduits are given a slope to enable better contact at the interface with earth.

#### 4.3.9 Trash Racks

Trash racks at intakes that have become clogged with debris or trash reduce their discharging capacity. The head losses through clogged trash racks also increase.

Maintenance of trash racks includes periodic inspections for rusted and broken sections and repairs are made as needed. Trash racks should be checked during and after floods to ensure that they are functioning properly and to remove accumulated debris.

#### 4.3.10 Gates & Hoisting Equipment

The safe and satisfactory operation of a dam depends on proper operation of its Gates & their Hoisting Equipment. Maintaining spillway gates in working condition is critical for dam safety and is to be assigned the height priority.

If routine inspection of the Hydro-Mechanical Equipment shows the need for maintenance, the work should be completed as soon as possible. The simplest procedure to ensure smooth operation of gates is to operate them through their full range at least once, and preferably twice annually (before monsoon & after monsoon keeping a gap of at least six months). Because operating gates under full reservoir pressure can result in large discharges, exercising of gates should preferably be carried out in dry conditions using stop-logs/ emergency gates.

Commonly used Gates and Hoists including their inspection / maintenance requirements are discussed below.

The O&M manuals of the gates manufacturer's would however govern the overall maintenance of Gates & Hoists whenever there is any contradiction with the instructions given in the Manual.

##### 4.3.10.1 Vertical lift fixed wheel and Slide Gates

These gates are provided in spillways, outlet works, sluices etc. for controlling/regulating the flow. The main components of these gates are as under;

i). Embedded parts:

- Sill beam assembly

- Top and side seal seats
- Roller track
- Side guide
- Dogging arrangement

ii). Gate Parts:

- Skin plate Assembly
- End Verticals
- Horizontal girders
- Vertical Stiffeners
- Roller assembly
- Seal Assembly
- Side guide assembly
- Lifting Arrangement

The aspects to be inspected and maintained periodically for ensuring proper operation of these gates are as under;

- i) The gate slot and bottom platform/sill beam should be cleaned periodically. Scales formed over the embedded parts should be removed. Second stage concrete should be checked for any development of cracks/leakages and repairs should be attended to immediately.
- ii) The gate leaf should be thoroughly cleaned and repainted as and when necessary according to the procedure or guidelines- indicated in IS: 14177 or as per the recommendations of the paint manufacturer. All drain holes provided in the gate assembly should be cleaned.
- iii) Rubber seals should be smoothened, if required, for proper alignment. All nuts and bolts fixing the seal to the gate should be tightened uniformly. Seals, if found damaged or found leaking excessively should be adjusted, repaired or replaced as considered necessary.
- iv) The wheel shall be rotated to check their free movement. Gate roller bearings and guide roller bushes

should be properly lubricated. Whenever necessary these should be opened for rectifications of defects, cleaning and lubrication and should thereafter be refitted. These may be replaced if repairs are not possible.

- v) Hoisting connection of the gate leaf should be lubricated where necessary and defects if any should be rectified.
- vi) All nuts, bolts, check nuts and cotter pins of the lifting devices should be checked periodically.
- vii) All components should be greased and lubricated. Recommended and approved oils and grease only should be used.
- viii) Roller assembly should be adjusted by the eccentricity arrangement to ensure all rollers rest uniformly on the track plates particularly in the closed position of the gate.
- ix) Where filling valves are provided as part of the gate structure, all the nuts, bolts, check nuts etc. should be tightened.
- x) All welds shall be checked for cracks/damages. Any weld that might have become defective should be chipped out and redone following the relevant codal provisions. Damaged nuts, bolts, rivets, screws etc. should be replaced without delay.
- xi) The filling-in valves allow passage of water when it is lifted by lifting beam & crane due to creation of space between stem seat and exit passage liner. The springs and associated components should be checked periodically for damages and replaced if necessary.
- xii) The guide-assemblies, wheel-assemblies and sealing-assemblies shall be cleared off grit, sand or any other foreign material.
- xiii) The wheel pin shall be coated with corrosion resistant compound.

xiv) All nuts and bolts shall be tightened.

#### 4.3.10.2 Radial Gate

The main components of these gates are as under;

##### (a) Embedded Parts:

- Common Anchorages (Bonded Anchorages)
  - Sill beam Assembly
  - Wall plate Assembly
  - Horizontal Anchor Rods
  - Trunnion Girder
  - Trunnion girder chairs
  - Vertical rods
  - Thrust block (If tie between trunnion is not used)
- Independent Anchorages (Unbonded Anchorages)
  - Sill beam assembly
  - Wall plate assembly
  - Anchor girders
  - Load Anchors / Tie flats
  - Yoke girders
  - Rest plate
  - Vertical rods etc.
  - Thrust block (If tie between trunnion is not used).

##### (b) Radial Gate Leaf:

- Common Anchorages (Bonded Anchorages)
  - Skin plate
  - Side guide and seal assembly
  - Vertical stiffeners
  - Horizontal Girders
  - Horizontal Girder Bracings
  - Arm Assembly
  - Trunnion
  - Trunnion pin

- Trunnion Bush
- Trunnion Bracket
- Tie between trunnion and thrust Block
- Independent Anchorages (Unbonded Anchorages)
  - Lifting Bracket
  - Skin plate
  - Side guide and seal assembly
  - Vertical stiffeners
  - Horizontal Girders
  - Horizontal Girder Bracings
  - Arm Assembly
  - Trunnion
  - Trunnion pin
  - Trunnion Bush
  - Trunnion Bracket
  - Tie between trunnion or Thrust block

The aspects to be inspected and maintained periodically for ensuring proper operation of these gates are as under:

#### **i) Rubber Seals**

- Seals shall be inspected for leakages. Locations of excessive leakages shall be recorded for taking remedial measures. Weeping or slight flow in localized area will not require immediate remedial measures. However, measures like tightening of bolts are carried out. Further adjustment is carried out during annual maintenance.
- If leakage is excessive & immediate repair is considered necessary, the stop log gates shall be dropped and seals repaired or replaced.

NOTE: - During monsoon period, stop log gates shall NEVER be lowered in spite of heavy leakage through seals.

#### **ii) Trunnion block assembly and its anchorages**

- All the nuts and bolts of Trunnion block assembly and its anchorages shall be checked for tightness.
- Check all the welds for soundness and rectify defects.
- Check whether the Yoke girder and thrust block is covered or not. If not, cover it with mild steel plates.
- Cover the trunnion pin with anti-corrosive jelly.
- Remove all dirt, grit etc. from trunnion assembly and lubricate trunnion bearings of the gate with suitable water resisting grease as recommended by bearing manufacturers.

#### **iii) Gate structure**

- Check all the welding for soundness and rectify defects.
- Check welding between arms and horizontal girders as well as between latching bracket and skin plate with the help of magnifying glass for cracks/defects and rectify the defects.
- Clean all drain holes including those in end arms and horizontal girders.
- Check all the nuts and bolts and tighten them. Replace damaged ones.
- Check upstream face of skin plate for pitting, scaling and corrosion. Scaling may be filled with weld and grinded. Corroded surface shall be cleaned and painted.

#### **iv) Embedded Parts**

- All the sill beams and wall plates shall be inspected for crack, pit-

ting etc. and defects shall be rectified.

- The guide roller pins shall be lubricated.

#### v) **General Maintenance**

- Defective welding should be chipped out and it should be re-welded duly following the relevant codal provision (IS: 10096, Part-3).
- Damaged nuts, bolts, rivets, screws etc. should be replaced.
- Any pitting should be filled up by welding and finished by grinding if necessary.
- The gate leaf, exposed embedded metal parts, hoists and hoist supporting structure etc., should be thoroughly cleaned and repainted when required keeping in view the original painting system adopted and as per the guidelines contained in IS: 14177.
- Trunnion bearing should be greased as and when required. Keeping trunnion bearings in perfect working condition is very important. All other bolted connections should also be checked up for proper tightness.
- Bolts and trunnion bearing housing should be tightened wherever required.
- The seals of the gate should be checked for wear and tear and deterioration. These should be adjusted/replaced as and when necessary.
- The wall plates, sill beams shall be checked and repaired if necessary.
- Wire ropes should be properly lubricated.

- Oil level in the worm reduction unit should be maintained by suitable replenishment. Oil seals should also be replaced if required. Lubrication of other parts of hoists such as chains, position indicators and limit switches should also be done.
- The stroke of the brake should be reset to compensate for lining wear. Worn out brake linings should be replaced in time.
- Flexible couplings should be adjusted if required.
- Repairs and replacements of all electrical relays and controls should be attended to.
- Maintenance of alternative sources of Power such as Diesel Generating sets and alternative drives wherever provided should be carried out.
- The list of essential spare parts to be kept available should be reviewed and updated periodically. The condition of spares should be checked periodically and protective coating given for use.

#### **4.3.10.3 Electrically operated fixed hoists**

##### a) **General Instructions**

- Operation of fixed hoist without lifting the gate is not possible and need not therefore be attempted. It will be possible to operate the unit and observe operation of load carrying hoist component when gate is being lifted or lowered.
- Never open any bolt or nut on motor, gear boxes, rope drums and other load carrying hoist components when the gate is in raised position. The gate should be fully closed or rested on the gate latches before carrying out any work on hoist compo-

nents including motor brake and other electrical equipment.

#### b) Inspection and Maintenance

The aspects to be inspected and maintained periodically for ensuring proper operation of Rope drum hoists are as under;

- Entrance to all hoist platforms shall be kept locked. All keys shall remain with the shift supervisor.
- A cursory daily inspection shall be made of hoist and gate to ensure that there is no unusual happening.
- Clean all hoisting equipment and hoist platform.
- Check oil level in gearboxes and replenish as and when required with oil of proper grade.
- Apply grease of suitable grade by grease gun.
- Lubricate all bearings, bushings, pins, linkages etc.
- Check all the fuses on the power lines.
- All bolts and nuts on gear boxes, hoist drum and shaft couplings should be checked for tightness.
- Check the supply voltage.
- Drain sample gear oil from each of the gear boxes. If excessive foreign particles or sludge is found, the gear box shall be drained, flushed and filled with new oil.
- All the geared couplings shall be greased.
- Raise and lower the gate by hoist motor and check for smooth, and trouble free operation of gate without excessive vibration.
- Observe current drawn by motor at the time of lifting and check if it is more than normal. If so, stop the hoist and investigate the cause and rectify.
- Check the condition of painting of various components and remove rust wherever noticed and repaint the portion after proper cleaning as per painting schedule.
- All trash, sediments and any other foreign material shall be cleared off the lifting rope and lifting attachment.
- All ropes shall be checked for wear and tear and if broken wires are noticed, the rope shall be replaced.
- All the wire ropes shall be checked and all visible oxidation shall be removed.
- All wire ropes shall be greased with cardium compound.
- Check the overload relays for proper functioning.
- Check all the nuts, bolts, rivets, welds and structural components for hoisting platform and its supporting structure for wear, tear and damage. All damages shall be rectified. All bolts shall be tightened. The portion with damaged painting shall be touched up.
- Check the pulleys, sheaves and turnbuckles.
- Raise and lower the gate for its full lift several time (at least three to four) and observe the following:
  - Check the limit switches and adjust for design limits.
  - The effectiveness and slip of the breaks shall be checked by stopping the gate in raising and lowering operations. The brakes shall be adjusted if needed.
  - When the gate is operated, there should not be any noise or chatter in the gears.

- Adjust the rope tension of wires if unequal.
- Check for all gears and pinions for uneven wear and adjust for proper contact. Grease the gears.
- Repaint the hoist components, hoisting platform and its supporting structures as per requirement.
- The periodic maintenance of commercial equipment like motors, brakes, thrusts etc. shall be carried out as per manufacturers operation and maintenance manual.

#### 4.3.10.3.1 Maintenance of Electrical components of Fixed Rope Drum Hoists

The electrical components to be inspected and maintained periodically are as under;

- i) Starters should be cleaned free of moisture and dust.
- ii) Each individual contactor should be tried by hand to make sure that it operates freely.
- iii) All wearing parts should be examined in order to take note of any wear which may have occurred during operation.
- iv) If the contactor hums, the contact faces should be cleaned.
- v) Examine all connections to see that no wires are broken and no connections are loose.
- vi) Clean the surface of the moving armature and magnet core which comes together when the contactor closes, free of dust or grease of any kind.
- vii) Examine the mechanical interlocks between the reversing contactor and see when the contact tips of one of the contactor units are touching, it is impossible to get the contact tips of the other unit to touch.
- viii) The contact tips should be kept free from burns or pits by smoothing with fine sand paper or emery paper.
- ix) Replace the contact tips which have worn away half-way.
- x) Do not lubricate the contacts.
- xi) Blow out windings thoroughly by clean and dry air to clear air passage in the stator and the rotor of any accumulated dirt. The air pressure shall not be too high to damage the insulation.
- xii) Examine earth connections and motor leads.
- xiii) Examine motor windings for overheating
- xiv) Examine control equipment's
- xv) Examine starting equipment for burnt contacts
- xvi) Check and tighten all nuts and bolts
- xvii) Clean and tighten all terminals and screw connections all contact surfaces shall be made clean and smooth.
- xviii) Lubricate the bearings
- xix) Overhaul the controllers
- xx) Inspect and clean circuit breakers.
- xxi) Wipe brush holders and check bedding of brushes.
- xxii) Blow out windings thoroughly by clean and dry air. The pressure shall not be so high that insulation may get damaged.
- xxiii) Check the insulation resistance of the motor between any terminal and the frame. If the measured resistance is less than the prescribed value, then steps shall be taken to dry- out the motors either by passing a low voltage current through the windings or by placing the stator and rotor only in a warm dry place for a day or so.

**Important:** The complete motor shall never be put in an oven for drying as that may melt the grease out of bearings.

- xxiv) Coat the windings with an approved high temperature resisting insulation enamel or varnish.
- xxv) Over haul the motor, if required.
- xxvi) Check the switch fuse units and renew, if required.
- xxvii) Check resistance or earth connections.
- xxviii) Check air gap.

#### **Solenoids Operated Brakes**

- i) All fixing bolts shall be checked and tightened at least once in three months.
- ii) The magnet stroke should be reset to compensate for wear.
- iii) Re-adjust the brake when the magnet stroke reaches the value given on the instruction plate.
- iv) Brake lining should be checked and replaced when required.
- v) Examine all electrical leads and connections.
- vi) Rubber bushes or couplings should be checked and replaced if defective.
- vii) The pins should be tightened.
- viii) Brake drum shall be cleaned to remove any dust or grease.

#### **4.3.10.4 Stop Logs, Lifting Beam and Gantry Crane**

##### **a) Stop Logs for Spillway Radial Gate**

Generally one or two sets of spillway stop log are planned for Spillway Radial Gates depending upon the number of spillway gate installations.

The set of stop logs shall comprise of more than one unit planned to cover around 200-250 mm above the FRL or the top of spillway gate. These stop logs shall be operated under balanced head conditions (both for raising & lowering) by Gantry Crane to be located at the top of dam over the rails fixed on the roadway over the dam with the provision of an automatic engaging & disengaging lifting beam.

The stop log units being in pieces, the top non-interchangeable unit with unique features as well as the other interchangeable units are stored in the grooves in various spans/bays.

The following aspects are to be considered and attended during maintenance:

- i) Defective/damaged/cracked welding should be chipped out and re-welded.
- ii) Damaged nuts, bolts, screws etc. should be replaced.
- iii) The gate leaf should be thoroughly cleaned and repainted whenever necessary
- iv) Rubber seals should be grinded, if required to bring it in alignment. All nuts and bolts for fixing seals to gate should be tightened uniformly. Seals when damaged or found leaking excessively should be adjusted or replaced as and when considered necessary.
- v) All components should be greased and lubricated with the recommended oil and grease only.
- vi) The roller assembly should be adjusted by the eccentricity provision to ensure that all the rollers rest uniformly on track plates particularly in the closed position of the stop log gate.
- vii) The drain holes in horizontal girders should be cleaned.



- viii) It should be ensured that no bearing is overheated.
- ix) The gate slots should be kept cleaned. The scaling over the embedded parts should be removed.

Since normally the stop logs remain mostly in hanging position, for any routine maintenance, these are required to be raised up to the top of pier or deck level to rest on the dogging beam with the help of gantry crane & lifting beam. Thereafter, if required it is further raised at a slow speed from safety point of view. It is to be ensured that these units do not foul or hit legs/columns of the gantry crane.

Thereafter, the gate can be rested on the deck level for necessary maintenance, servicing, repairs or replacement of its component parts.

After completion of maintenance, the stop log units are shifted back to their original dogging position.

### **b) Lifting Beam**

Lifting beam shall be used for both raising & lowering of Spillway stop log units with the use of Gantry crane.

Lifting Beam shall mainly comprise of two number structural steel channels or fabricated channels with back to back connection to make it a single fabricated structural frame.

Two side guide rollers/shoes shall be provided on each side of the lifting beam. The depth of lifting beam/frame should be sufficient to accommodate to rollers on each side located at sufficient distance from one another to enable proper guided movement. The depth of lifting beam shall not be less than one tenth of the length/span of the lifting beam or 500 mm whichever is more.

Lifting beam hook mechanism shall provide for automatic engagement and release of the equipment to be handled manually by

movement of the hook block. The two hooks shall be mechanically linked together for simultaneous operation.

All rotating parts of the lifting beam shall be provided with corrosion resistant steel pins and aluminum bronze bushing/roller bearings. All nuts, bolts and washers and retaining devices for pins shall be of corrosion resistant steel.

Following issues need to be considered and attended during maintenance;

- i) Bush bearing of lifting attachment and various pulleys/sheaves wheel gears etc. should be properly lubricated.
- ii) Whenever it is felt that friction in the bearing has increased, these should be taken out for cleaning and lubrication and should be refitted properly. These should be replaced, if found beyond repair.

### **c) Gantry Crane**

Hoisting trolley of the Gantry Cranes are generally built on top of a wheeled mobile gantry structure travelling over fixed rails and is used to straddle an object or load over a workspace.

The major component parts of the gantry comprise of the following:

Frame & legs, machinery housing, operator's cabin, walkways, ladders and railings, end buffers, mechanical equipment, wheels and axles, gantry drive unit, wire rope, rope drum, gears and pinions, reduction gear box, shafts for gears and pinions, sheaves and pulleys, bearings, flexible couplings, lifting hook and block, sockets for wire ropes, gear box covers, keys & key ways, counter weight, wrenches and tools, electrical equipment, electric motor, master control equipment, cables and cable reel, wiring, limit switches, miscellaneous components etc.

Following aspects need to be considered and attended to during maintenance;

- Oil level in the gear boxes. It is very important to ensure that the correct oil level is maintained. Over filling causes overheating and leakage, therefore, care should be taken that the breather holes are not clogged by any foreign material like dust, paint etc.
- The insulation resistance of motor winding. In case it is found to have dropped below a prescribed value, the motor should be dried prior to putting back in service. If weak insulation becomes a regular feature, the winding should be given a good coat of insulating varnish after the motor has been dried.
- Checking of all the electrical connections.
- Lubrication of each part of crane
- Removal of any loose/foreign material along the rail track
- Actuating tests of limit switches
- Actuating tests of brakes.
- All fuses in the control panel should be checked and if necessary it should be replaced.
- Necessary terminal connections of motors, brakes etc. is to be checked.
- Overload relay should be checked.
- Visual inspection of wire ropes for any snapped loose wire and its proper lubrication.
- Checking of rope clamps on the drum and tightening of bolts if required.
- Gearbox assembly should not have any leakage of oil.
- Unusual noise/vibration if any should be checked and rectified before operation.

#### 4.3.10.5 Surface Preparation and Painting of HM Works

- i) Protection of painted surfaces is considered essential for protection & enhancement of service life.

Gates, its embedded parts, gate leaf, hoists and its supporting structures need to be protected against corrosion due to climatic condition, weathering, biochemical reaction and abrasion etc. These equipment are likely to deteriorate/damage to any extent that the replacement of parts may become necessary and such replacement may become difficult and costly.

- ii) Surface preparation & Painting requirements.

Painting for hydro-mechanical works is to be carried out as prescribed in IS: 14177 for both newly manufactured as well as old & used gates, hoists and associated works after proper surface preparation. The preparation includes thorough cleaning, smoothing irregular surfaces, rusted surfaces, weld spatters, oil, grease, dirt, earlier applied damaged layers of primers/paint by use of mechanical tools, by use of solvents, wire brush etc. The sand/grit blasting process is used for surface preparation to a level of Sa 2½ of the Swedish standard.

- iii) Surfaces not requiring painting & their protection during surface preparation, painting & transportation process.

- a) The following surfaces are not to be painted unless or otherwise specified:
- Machine finished or similar surface
  - Surfaces which will be in contact with concrete
  - Stainless steel overlay surfaces.
  - Surfaces in sliding or rolling contact
  - Galvanized surfaces, brass and bronze surfaces.
  - Aluminum alloy surfaces

- b) The Surfaces of stainless steel, nickel, bronze and machined surface adjacent to metal work being cleaned or painted shall be protected by using sticky protective tape or by other suitable means over the surfaces not to be painted.
- c) All embedded parts which come in contact with concrete shall be cleaned as detailed above and given two coats of cement latex to prevent rusting during the shipment while awaiting installation.
- iv) Application of primer & finish coats on embedded parts and gates
- a) Embedded parts
- The prescribed primer shall be applied as soon as the surface preparation is complete and prior to the development of surface rusting and within the specified time prescribed by Indian Standards or the Paint Manufacturer. In case there is lapse of considerable time beyond the prescribed time limit, the surfaces shall be again cleaned prior to priming.
  - Two coats of zinc rich primer with epoxy resin shall be applied to all embedded parts surfaces which are not in contact with concrete and shall remain exposed to atmosphere or submerged in water to obtain a dry film thickness of 75 microns.
  - This shall be followed by three coats at an interval of 24hours of coal-tar blend epoxy resin so as to get a dry film thickness of 80 microns in each coat. Total dry film thickness of paint shall not be less than 300 microns.
- b) Gates
- Primer Coat
- Over the prepared surface one coat of inorganic zinc silicate primer giving a dry film thickness of  $70 \pm 5$  microns should be applied. Alternatively two coats of zinc rich primer, which should contain not less than 85% zinc on dry film should be applied to give a total dry film thickness of  $75 \pm 5$  microns.
- Finished paint
- Two coats of solvent less coal tar epoxy paints. These shall be applied at an interval of about 24 hours. Each coat shall give a dry film thickness of  $150 \pm 5$  microns. The total dry film thickness of all the coats including primer coating shall not be less than 350 microns.
- v) Hoist and supporting structure
- a) Structural component
- Primer coats of zinc phosphate primer shall be applied to give a dry film thickness of  $40 \pm 5$  microns.
- Final Coats: One coat of alkalized based micaceous iron oxide paint to give a dry film thickness of  $65 \pm 5$  microns followed by two coats of synthetic enamel paint confirming to IS: 2932 – 1974 to give a dry film thickness of  $25 \pm 5$  microns per coat. The interval between each coat shall be 24hours. The total dry thickness of all coats of paint including the primer coat shall not be less than 175 microns.
- b) Machinery: Except machined surfaces all surfaces of machinery including gearing, housing, shafting, bearing pedestals etc., shall be given:
- Primer coats: One coat of zinc phosphate primer paint to give minimum film thickness of 50 microns. Motors and other bought out items shall be painted if necessary.
- Finished coats: The finished paint shall consists of three coats of aluminum paint confirming to IS: 2339 – 1963 or synthetic enamel paint confirming to IS: 2932 – 1977 to give a dry film thickness of  $25 \pm 5$  mi-

crons per coat to obtain a total minimum dry film thickness of 125 microns.

c) Machined surfaces

All machined surfaces of ferrous metal including screw threads which will be exposed during shipment or installation shall be cleaned by suitable solvent and given a heavy uniform coating of gasoline soluble removable rust preventive compound or equivalent. Machined surfaces shall be protected with the adhesive tapes or other suitable means during the cleaning and painting operation of other components.

vi) Application of paint

Mix the contents thoroughly as directed by paint manufacturer before and during use.

Painting at shop can be done by any of the three methods namely Brush/roller, Conventional spray, Airless spray etc.

The paint can be made to suit the adopted method. But once the gate and equipment is in erected position the general method adopted is only brush / roller. In case of spray lot of precautions are to be taken.

For More details: Refer IS: 14177 Part (II) – 1971.

Appendix A – Brushing of paint

Appendix B – Spraying of paint

Appendix C – Spray painting defects: Causes and remedies.

Removal of old paint / rust and carrying out fresh painting:

The carrying out of fresh painting is to be considered under the following conditions:

- The rusting is noticed all over the surface or
- Rusting is severe or

- Cracking and blistering has damaged the primer coat exposing the metal and is noticed all over the surface or
- The paint film has eroded badly, the scrap of entire paint film to the base metal and carry out fresh painting.

Note: In case of maintenance and renovation: Refer IS: 14177 (Part II) – 1971 for checking and repainting.

vii) Removal of old paint for repainting

Caution should be exercised while removing the old paint. The surfaces shall be de-rusted and descaled by either mechanically by one or more of the methods, namely:

- a) Wire brushing, Scraping, and chipping. Sand papering or cleaning with steel wool or abrasive paper
- b) Power tool cleaning
- c) Flame cleaning
- d) Sand blasting or shot blasting and
- e) Chemical rust removal.

Note: The method of application shall be decided based on conditions existing. After cleaning painting is to be carried out as originally proposed.

Some are painted without removal of old paint and rusting this will amounts to no painting and deteriorate faster than the original one.

viii) Inspection and testing of painting of H. M works

- a) The following steps are involved in inspection of painting:
  - General inspection before and during painting
  - Viscosity test of paints
  - Paint thickness test-using Elcometer.
  - Inspection of general appearance of finished work.

## b) General

The aim of inspection and testing is to ascertain whether the recommended practice is being employed correctly during every stage of application and whether the final results fulfill the object of painting. Any test carried out should be of non – destructive nature or, if it is of destructive nature, it should be either restricted to areas which can be restored without marring the general appearances, or be such that it is possible to restore easily without necessitating a complete repetition of the work.

## c) Inspection of surfaces prior to painting

Inspection methods will depend on whether it is to be painted for the first time or is to be repainted.

## d) New Works (not previously painted).

The following shall be decided by inspection:

- The method of pre cleaning feasible or recommended;
- The intermediate protective treatments to be applied, if found necessary;
- The final painting schedule and the specifications for the paint for ensuring the particular performance;
- The method of application, whether by brush, roller or spray.

## e) Old Work (which requires repainting)

The following shall be decided by inspection:

- Whether the entire existing paint requires removal; and/or

- Whether repainting without paint removal would be adequate.

**4.3.11 Electrical System**

Electricity is typically used at a dam for lighting and to operate the gates, hoists, recording equipment, and other miscellaneous equipment. It is important that the Electrical system be well maintained, including a thorough check of fuses and a test of the system to ensure that all parts are properly functioning. The system should be free from moisture and dirt, and wiring should be checked for corrosion and mineral deposits.

All necessary repairs should be carried out immediately and records of the works kept. Maintain generators used for auxiliary emergency power - change the oil, check the batteries and antifreeze and make sure fuel is readily available.

Monitoring devices usually do not need routine maintenance. Open areas are particularly susceptible to vandalism. As such all electrical fittings like bulbs, lights, loose wires etc. in open areas should be checked routinely and replaced/repared where needed. The recommendations of the manufacturer should also be referred to.

**4.3.12 Metal Component Maintenance**

All exposed, bare ferrous metal of an outlet installation, whether submerged or exposed to air, will tend to rust. To prevent corrosion, exposed ferrous metals must be either appropriately painted (following the paint manufacturer's directions) or heavily greased in respect of moving parts & on surfaces like guides & track seats on which there is movement of gates. When areas are repainted, it should be ensured that paint is not applied to gate seats, wedges, or stems (where they pass through the stem guides), or on other friction surfaces where paint could cause binding. Heavy grease should be

applied on friction surfaces to avoid binding. As rust is especially damaging to contact surfaces, existing rust is to be removed before periodic application of grease.

#### **4.3.13 Access Roads**

For a dam to be operated and maintained, there must be a safe means of access to it at all times. Access road surfaces must be maintained to allow safe passage of automobiles and any required equipment for servicing the dam in any weather conditions. Routine observations of any cut and fill slopes along the sides of the road should be made. If unstable conditions develop assistance of experienced Engineers/Expert Panels should be obtained and remedial measures initiated.

Drains are required to be provided and maintained along roads to remove surface and subsurface drainage. This will prolong the life of the road and help reduce deterioration from rutting. Road surfacing should be repaired or replaced as necessary to maintain the required traffic loadings. In most cases, specialized contractors will be required to perform this maintenance.

#### **4.3.14 General Cleaning**

As already suggested, for proper operation of spillways, sluiceways, approach channels, inlet and outlet structures, stilling basin/energy dissipation arrangements, discharge conduit, dam slopes, trash racks, debris control devices etc., regular and thorough cleaning and removal of debris is necessary. Cleaning is especially important after large floods, which tend to send more debris into the reservoir.

### **4.4 Materials requirements for maintenance during monsoon period**

Materials required during monsoon period for both immediate maintenance and preventive maintenance should be stocked in

adequate quantity depending upon the size of the project and requirements. Needful instructions in this regard need to be enclosed in the O&M Manual. In Indian dams, normally a 24x7 hour patrolling is to be carried out during monsoon period.

The materials normally required to be stocked in sufficient quantity are:-

- Gunny Bags
- Sand
- Boulders/Wire crates
- Bamboos/Balli's
- Baskets
- Ropes
- Petromax Lamps with Spares
- Torches with spare cells
- Kerosene Oil
- Match Boxes
- Rain Coats
- Gum Boots
- Warning sign indicator
- Danger zone lights

### **4.5 Establishment Requirements**

The requirements of annual and monsoon establishment for the operation and maintenance of a dam is to be decided by the Dam Owners on a case to case basis. A typical organization set up for dams as per its height covering supervision staff down to Junior Engineer level is given at Figure 4-1 for guidance. In addition there will be other supporting staff (skilled/unskilled), regular/work charged staff/labour and clerical staff depending upon the requirements in monsoon & non-monsoon period. The staff requirements would vary from project to project depending upon its size, importance and hazard potential.

#### 4.6 Preparation of O&M budget

In order to prepare O&M budget for a dam project all possible costs associated with implementation of O&M Program need to be identified and considered. Typical O&M budget for a project should essentially include but not limited to the following items:

- i) **Establishment Cost of Regular Staff** - Salaries and allowances, Bonus, Medical Reimbursement, LTC, Leave Encashment, pension benefits, etc. (as applicable).
- ii) **Establishment Cost of Work charged Staff** - Salaries and allowances, Bonus, Medical Reimbursement, LTC, Leave Encashment, Pension benefits, TA and DA , etc. (as applicable).
- iii) **Establishment Cost of Daily wage Staff** - Salaries and allowances, TA and DA etc. (as applicable).
- iv) **Office Expenses** – Rent for office, Telephone/Mobile/any other Telecommunication bills, Electricity bills, water bills, Office stationery, Day to day office requirements.
- v) **Motor Vehicles** - Running and Maintenance cost of inspection vehicles, Cost of hiring of vehicles as required
- vi) **Maintenance of Colony** - Maintenance of staff quarters, colony roads, Electricity, Sanitary and Water supply systems etc.
- vii) **T&P** - T&P requirements for offices, colony, works etc. as applicable.
- viii) **Works** - Painting, oiling, greasing, overhauling of HM equipment's, Repair/replacement of gates seals & wire ropes, POL for pumps & generator sets, Electricity charges and maintenance of Electric systems of dam site, specific requirements for all

Civil, H.M & Electrical maintenance works, vegetation removal and mowing of turfing on earth dams, maintenance/cleaning of drains in dam, maintenance of lift/elevators in dam (as applicable), maintenance of access roads & basic facilities, provision for flood contingency works during monsoon, unforeseen events/items (about 10% of the cost of works) etc.

#### 4.7 Apportionment of O&M cost in respect of Inter-State projects

There are many Inter-State projects in our country with benefits accruing to different States. Where there are agreements on sharing of the costs of the project, it would be appropriate that the O&M costs including the costs of special repairs are shared in the same proportion.

Where such agreements do not exist, apportionment of cost among different purposes for Multi-purpose projects could be worked out on notional basis as per IS: 7560 (Guidelines for allocation of cost among different purposes of river valley projects). The cost of O&M can be shared in the same proportion among different purposes. Further, sharing of the cost of the project for each purpose among beneficiary States could be worked out in proportion of the benefits accruing to different States. For the purposes which require consumptive use of water like irrigation or drinking water supply, cost could be worked out in proportion of quantum of water to be utilized by the different States or based on any other agreeable approach. There after the share of O&M cost of different beneficiary States could be worked out in the same proportion as their share cost of the project.

#### **4.8 O&M cost for dams where owner and operator is different**

It has been seen that there are many Hydro-Electric Projects in our country which are under the control of State Electricity Boards and the O&M of their dams and appurtenant works is with the State Water Resources Departments. Very often the O&M of such dams gets neglected due to non-availability of sufficient funds.

As such, it is recommended that in such cases the State Electricity Boards should provide for the O&M cost of their dams and appurtenant works in their annual budget (based on the cost estimates obtained from relevant Water Resources Departments) and transfer the said amount to the Water Resources Departments for the O&M of the dams and appurtenant works.

In cases where the State Electricity Boards are paying levy or water charges to the Water Resources Departments, the same should be utilized for the O&M of the dam.

#### **4.9 Maintenance Records**

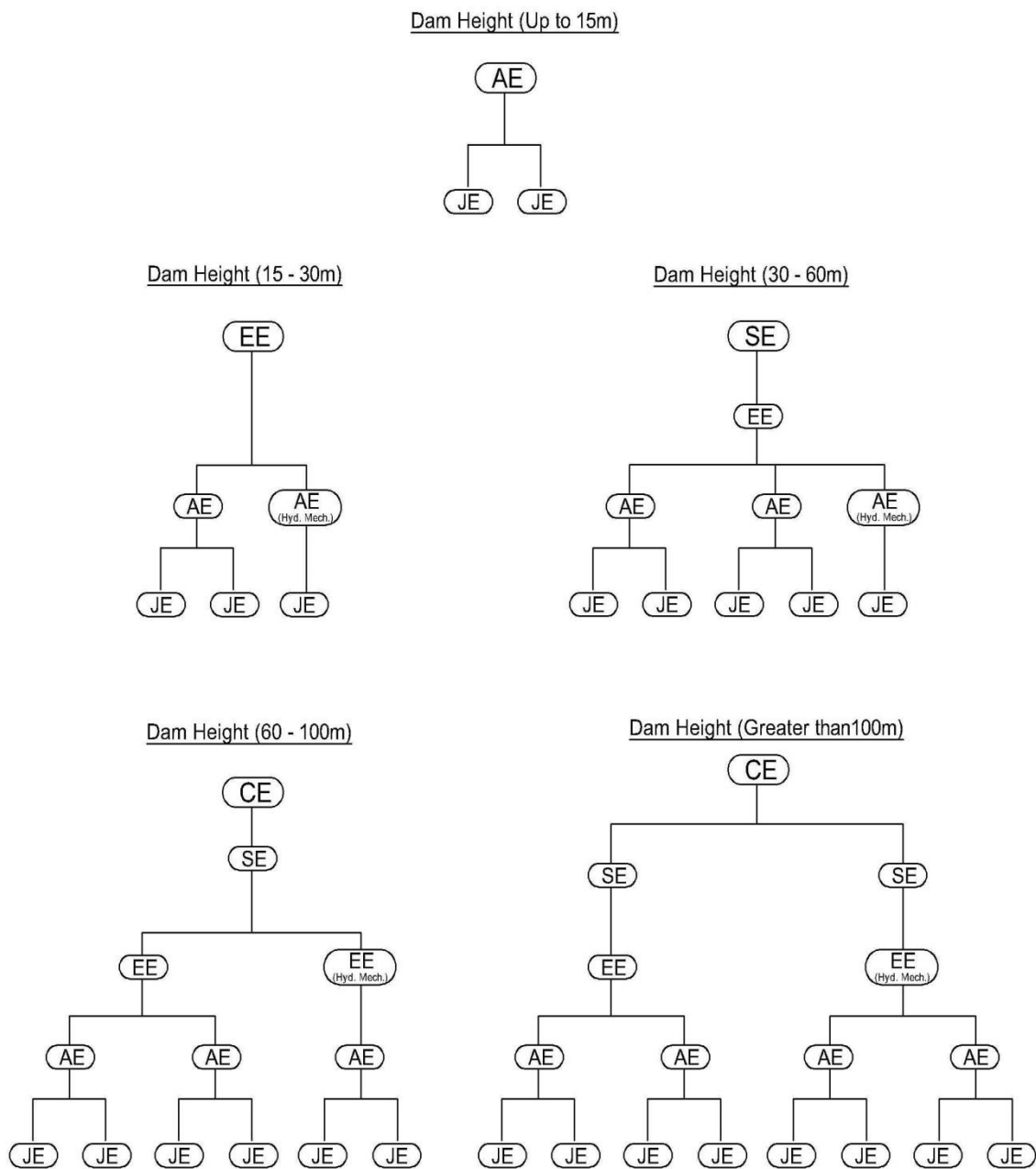
Maintenance records are of utmost importance. A record should be kept of all maintenance activities, both immediate and preventive maintenance works. Information that should be recorded includes the following as a minimum:

- date and time of maintenance,
- weather conditions,
- the type of maintenance,
- name of person or contractor performing maintenance,
- description of work performed,
- the length of time it took to complete the work with dates,
- equipment and materials used, and

- before and after photographs.

The data should be recorded by the person responsible for maintenance.





Note :- The set up shown is only indicative and can be modified as per actual requirements in a project.

**Figure 4-1: Typical Organisation Setup Chart**

**Table 4-1: Maintenance Guidelines Summary**

Required Maintenance Item →	Earthwork	Riprap	Vegetation Removal	Chute/long./toe drains	D/S Rock Toe	Piping Issues	Monitoring Grass Turfing	Seepage Issues	Livestock damage	Rodent damage	Vehicular traffic damage	Mechanical equipment	Electrical equipment	Cleaning	Concrete/Masonry	Metal components
<b>Earth fill/Rock fill Embankment</b>																
Upstream slope	●	●	●			●			●	●				●		
Downstream slope	●		●	●	●	●	●	●	●	●	●			●		
Left/right abutments	●	●	●	●	●	●	●	●	●	●	●					
Crest (Dam Top)	●		●			●			●	●	●			●	●	
Area D/s of Dam	●					●		●						●		
<b>Concrete/Masonry Dams</b>																
Upstream face														●	●	
Downstream face								●						●	●	
Left/right abutments	●	●	●					●	●	●	●					
Crest (Dam top)													●	●	●	
Internal Body Drains								●				●	●	●		●
Foundation drainage holes								●				●	●	●		●
Galleries								●					●	●	●	
Sluice / Controls								●				●	●	●	●	●
<b>Spillways</b>																
Approach channel	●	●	●											●	●	
Control Structure								●						●	●	●
Stilling basin/EDA			●											●	●	
Discharge conduit/channel	●	●	●									●	●	●	●	●
Control Features (Gates, Hoists etc.)								●				●	●	●	●	●
Erosion Protection d/s of EDA	●	●	●											●	●	
Side Slopes	●	●	●					●						●	●	
<b>Outlet</b>																
Outlets	●		●					●				●	●	●	●	●
Stilling basin														●	●	
Trash racks/debris removal												●	●	●		●
<b>General Areas</b>																
Reservoir Surface														●		
Reservoir Periphery	●	●	●											●		

## Chapter 5. INSTRUMENTATION AND MONITORING

A dam's instrumentation furnishes data for deciding if the structure is functioning as intended and provides continuous monitoring to warn of any unsafe developments. Monitoring physical phenomena that can lead to a dam failure may draw information from a wide spectrum of instruments and procedures ranging from simple to complex. Any program of dam safety instrumentation has to be properly planned consistent with project components.

The program must be based on prevailing geotechnical conditions at the dam, and must include consideration of the hydrologic and hydraulic factors present before and after the project is in operation. Instrumentation designed for monitoring potential deficiencies at dams must consider the threat to life and property that the dam presents. Thus, the extent and nature of the instrumentation depends not only on the complexity of the dam and the size of the reservoir, but also on the potential for threat to life and property losses downstream.

An instrumentation program should involve instruments and evaluation methods that are as simple and straight forward as the project will allow. The involvement of personnel with experience in the design, installation, regular monitoring, and evaluation of an instrumentation system is of prime importance to the success of the program. Specific information that an instrumentation program provides is as under:

- warning of a problem, for example, settlement, movement, seepage, stability;
- definition and analysis of a problem, such as finding areas of concern;
- proof that behavior of the dam is as expected; and
- evaluating any remedial actions.

The means and methods available to monitor phenomena that can lead to dam failure include a wide spectrum of instruments and procedures, ranging from simple to complex. Every instrument should have a specific purpose and expected design response.

Continued monitoring is also important to monitor the efficacy of the remedial works carried out. Involvement of personnel with experience in the design, installation, monitoring, and evaluation of an instrumentation system is of prime importance.

Detailed description on instrumentation in dams is available in "Guidelines for instrumentation in dams (CWC, 2018)". However an overview of the same is given below.

### **5.1 Reasons for Instrumentation**

Instrumentation, proper monitoring and evaluation are extremely valuable in determining the performance of a dam. Information that an instrumentation program can provide is outlined in the following subsections.

#### **5.1.1 Warning of a Problem**

Often instruments can detect issues such as the uplift pressures being more than designed in case of Gravity dams, settlements in Earth dams being more than assumed settlements, high tensile stresses in Gravity Dam etc. This monitoring provides warning of any problems which may occur in future.

#### **5.1.2 Analyzing and Defining a Problem**

Instrumentation data are often used for analyzing and defining the extent of a problem. For example, a high value of downstream deflection in a Gravity dam may need to be

analyzed to figure out if the movement is normal or otherwise; whether the movement is in the dam, the foundation, or both; and whether the movement is constant, increasing, or decreasing. Such information can then be used to plan and design corrective measures.

### 5.1.3 Behavior Is as Expected

Instruments installed at a dam can indicate occurrence of any anomalous or problematic behavior. They can show that whether the dam behavior is as per design or otherwise. Actual measurements of uplift pressure in a Gravity dam and comparison with the uplift pressure assumed in original designs is an example.

### 5.1.4 Evaluating Remedial Action Performance

Many dams, particularly older ones, are required to be modified to correct for any deficiency. Instrument readings before and after the change, facilitate in analysis and evaluation of the performance of the modification.

## 5.2 Details to be included in an O&M Manual

The following details may be included;

- Details of instrumentation carried out in the dam including drawings showing instrumentation details and cable layout.
- Frequency at which different instrument readings are to be taken.
- Interpretation of instrumentation data and preparation of structural behavior reports periodically.
- What is to be done in case some of the instruments are not in working condition?

Following are the suggestions in this regard;

- i) In case connecting cables of the non-working instruments are accessible, the manufacturer of the said instruments should be approached for checking and rectification of the installations to make instruments work.
- ii) In case the embedded non-working instruments cannot be repaired, the same are to be abandoned.
- iii) Observations of the following parameters need to be continued;
  - Water levels in the reservoir
  - Hydro-meteorological observations
  - Seepage observations using V-notches/ weirs etc.
  - Displacements in the dam by means of survey observations using prism/paper targets fixed at structures. Tilt meters or repaired plumb lines could also serve the purpose.
  - Uplift pressures at dam base using stand pipes in Gravity dams.

## 5.3 Instrument Types and Usage

A wide variety of instruments and procedures are used to monitor dam behavior. The parameters often monitored by instruments include:

- movements (horizontal, vertical, rotational and lateral);
- pore pressure and uplift pressures;
- water level;
- seepage flow;
- water quality;
- temperature;
- Crack width;
- seismic activity;
- weather and precipitation data; and

- stress and strains.

A thorough treatment of instrument types and their usage is presented in Dunn cliff (1993). Both the U.S. Bureau of Reclamation and the U.S. Army Corps of Engineers have published Manuals on Instrumentation and Monitoring for Concrete & Embankment dams.

### 5.3.1 Movements

Movements occur in every dam. They may increase on account of unstable slopes, low foundation shearing strength, settlement due to compressibility of foundation and dam materials, thrust due to arching, expansion resulting from temperature change, heave resulting from hydrostatic uplift pressures etc.. They can be categorized by direction.

#### 5.3.1.1 Horizontal or Translational Movement

Horizontal or translational movement occurs in an upstream-downstream direction in both embankment and concrete dams. In an Embankment dam, instruments used for measuring such movements include:

- extensometers, including multi-point extensometers,
- inclinometers,
- embankment measuring points,
- shear strips,

For a concrete dam or concrete spillway, instruments for measuring horizontal movements include:

- extensometers, including multi-point,
- inclinometers,
- structural measuring points,
- tape gauges,
- strain meters,
- plumb lines,
- foundation-deformation gauges,

- tilt meters,
- Crack measuring devices,
- two-dimensional (2D) or three-dimensions (3D) joint-movement indicators,

#### 5.3.1.2 Vertical Movement

Vertical movement is a result of consolidation of embankment or foundation materials resulting in settlement of the dam. Another cause is heave (particularly at the heel of a Gravity dam) caused by hydrostatic uplift pressures. In an embankment dam, vertical movements may be measured using:

- settlement plates and sensors,
- extensometers,
- embankment survey monuments,
- inclinometer casing measurements.

In a concrete dam or concrete spillway, vertical movement monitoring devices may include:

- settlement sensors,
- extensometers,
- structural measuring points, and
- foundation deformation gauges.

#### 5.3.1.3 Rotational Movement

Rotational movement occurs generally due to varying foundation levels in dams. This kind of movement may be measured by instruments such as:

- extensometers,
- inclinometers,
- tilt meters,
- surface measurement points,
- crack-measurement devices,
- foundation-deformation gauges, and
- plumb lines (concrete only).

#### 5.3.1.4 Lateral Movement

Lateral movement (parallel with the crest of a dam) is common in Concrete Arch and Gravity dams. The structure of an Arch dam causes reservoir water pressure to be translated into a horizontal thrust against each abutment. Concrete dams also show some lateral movement because of expansion and contraction due to temperature changes. These movements may be detected by:

- structural measurement points,
- tilt meters,
- extensometers,
- crack-measurement devices,
- plumb lines,
- strain meters,
- stress meters,
- inclinometers,
- joint meters, and
- load cells.

#### 5.3.2 Pore Pressure and Uplift Pressure

Water seeps through, under, and around the ends of all dams. It moves through pores in the soil, rock, or concrete as well as through cracks, joints, etc. Water pressure acts uniformly in all directions and is termed pore pressure. The upward force (called uplift pressure) has the effect of reducing the effective weight of the Gravity dam and can materially reduce dam stability. Uplift pressure is measured with uplift pressure cells. Pore pressure in an Embankment dam, reduces the normal force & hence the shear resistance. In addition on account of seepage, if the migration of fines is not effectively intercepted by filters, it may result in progressive internal erosion (piping) or slope failure. Pore pressures can be monitored with piezometers & open wells.

Pore-pressure measurements and monitoring can supply critical information regarding the overall stability of an embankment dam.

#### 5.3.3 Stress and Strain

Measurements of stress and strain are common in Concrete/Masonry dams. Monitoring of tensile stress in Gravity dams is important in assessing its structural safety.

#### 5.3.4 Temperature

The internal temperature of concrete dams is measured both during and after construction. After placement the temperature of concrete rises due to heat of hydration. Thereafter it cools to reservoir temperature on the upstream side and to the ambient air temperature on the downstream side. When the concrete tends to contract due to cooling then due to external/internal restraints which do not permit contraction, tensile stresses are set up, resulting in cracking of concrete. Thermal studies are therefore very important in mass concrete for which measurements of concrete temperatures is important.

After construction is completed and a dam is in operation, significant temperature differentials are common, depending on season to season.

For example, during winter, the upstream face of a dam stays warm because of reservoir-water temperature, while the downstream face of the dam is cold on account of low ambient air temperatures. The reverse is true in summer.

In some concrete dams cracking has been observed on account of tensile stresses due to seasonal temperature variations like Konar dam of the D.V.C. For studying their behavior, temperature measurements are important. Temperature may be measured using various kinds of embedded thermometers or by simultaneous temperature readings in devices such as stress and strain meters,

which allow for indirect measurement of the temperature of the mass.

### 5.3.5 Crack Width

In some concrete dams under distress, monitoring the locations and widths of cracks is important for taking decisions regarding their treatment in order to ensure continued dam safety. It is even more important to know if the width of such openings is increasing or decreasing or whether it has stabilised. Various measuring devices are available for measuring crack widths (both 2D & 3D). Some use simple tape or dial gauge; others use complex electronics.

### 5.3.6 Water Level

For most dams, it is important to monitor the water level in the reservoir and the downstream pool regularly.

Water levels may be measured by simple elevation gauges either by staff gauges or by numbers painted on permanent fixed structures in the dam/reservoir or they may use complex devices that sense water level (Automatic Water Level Recorders).

### 5.3.7 Seepage Flow

Seepage must be monitored on a regular basis to determine if it is increasing, decreasing, or remaining constant as the reservoir level fluctuates. Seepage may be measured using the following devices and methods:

- Weirs (any shape such as V-notch, rectangular, trapezoidal, etc.)
- Flumes (such as a Par shall flume)
- Time-bucket methods

### 5.3.8 Water Quality

As long as the seepage water is clear there is generally no immediate problem. However it is carrying some particles then water quality testing is important.

Dissolution of solids from the dam can often be detected by comparing chemical analyses of reservoir water and seepage water. Such tests are site specific; for example, in a limestone area, one would look for calcium and carbonates; in a gypsum area, calcium and sulfates. Other tests, such as pH, can also sometimes provide useful information on chemical dissolution. Internal erosion in the embankment dam can be detected by comparing turbidity of reservoir water with that of seepage water and can be indicative of a potential undermining/ piping problem.

Further a large increase in turbidity in a masonry dam can be indicative of erosion of mortar between masonry stones.

### 5.3.9 Seismic Activity

Seismic measuring devices record the intensity and duration of large-scale earth movements such as earthquakes. They are provided in some of major dams in India located in seismically active zones.

Seismic instruments can also be used to monitor any blasting conducted near a dam site.

### 5.3.10 Weather Conditions

Monitoring the weather at a dam site can provide valuable meteorological information. A rain gauge, thermometer, wind gauge etc. can be easily purchased, installed, maintained, and monitored at a dam site.

## 5.4 Automated Data-Acquisition Systems

Automation of dam-safety instrumentation is possible using advance sensor technology, data acquisition equipment, and data management that have made data acquisition more reliable, cost-effective, and readily available for broader applications in dam-safety monitoring.

An automated data-acquisition system (ADAS) can range from a simple data logger

temporarily connected to one or more instruments to a permanent system that automates up to several hundred instruments at a dam. An ADAS for dam-safety monitoring includes the following key components:

- Electronic sensors for measuring different parameters like water levels, displacements, temperature etc.
- a remote data logger (permanent or portable)
- a communication link to the dam for remote access (cell phone, landline, radio, or satellite)

An ADAS usually consists of one or more solar-powered remote monitoring units (RMUs) positioned on the dam and connected to key instruments to be automated. The RMUs communicate via radio, hardwire, or cell phone with a central network monitor — a conventional desktop PC with vendor-supplied interface and communication software to provide access to the on-site RMUs by remote users. Typically, the monitor is located at site; however, it can be located at any far away location (such as a district or administration building). Instrument readings are stored in memory for either manual or automatic downloading for plotting and tabular reporting.

These systems can send out an alarm via cell phone, pagers, or e-mail if user defined instrument thresholds are exceeded. More recently, ADASs now incorporate remote digital still or video cameras. Since these systems are employed outdoors, it is important to use only data acquisition equipment that is designed for geotechnical instrumentation and dam safety monitoring.

Special attention need to be paid to lightning protection and grounding, surge protection, and backup power supplies. It would be advisable to contact engineering companies and vendors that are experienced in this area in case ADAS is under consideration for any dam monitoring.

A properly designed and installed ADAS can provide cost-effective and reliable instrumentation data acquisition and presentation to assist dam safety personnel in both long-term monitoring and during safety events. These systems provide the ability to adjust the frequency of instrument readings and to quickly assess trends from remote locations. When coupled with downstream warning sirens, ADAS can give early warning to downstream residents during a safety problem.

## 5.5 Frequency of Monitoring

The frequency of instrument readings or taking observations at a dam depends on several factors including:

- the relative hazard to life and property it represents,
- its height or overall size,
- the relative quantity of water impounded,
- the relative seismic risk at the site,
- its age, and
- the frequency and amount of water level fluctuation in the reservoir.

In general, as each of the above factors increases, the frequency of monitoring should increase. For example, frequent (even daily) readings should be taken during the first filling of a reservoir, and more frequent readings should be taken when water levels are high and after significant storms and earthquakes. As a rule of thumb, simple visual observations should be made during each visit to the dam and not less than monthly. Daily or weekly readings should be made during the first filling. Immediate readings should be taken following a storm or earthquake. Significant seepage, movement, and stress-strain readings should be taken at least monthly. The parameters to be monitored in dams and suggested frequency of measurements are at Tables 5-1 and 5-2 respectively.



These are generally as per the Guidelines on Instrumentation for dams (CWC 2018).

## **5.6 Data Processing and Evaluation**

The steps required to process and evaluate data, whether collected manually or automatically, are the same. Instrument data should be processed and evaluated according to the procedures established by the monitoring program. Accumulation of instrument data by itself does not improve dam safety or protect the public.

### **5.6.1 Data Collection**

Data collected manually should be recorded on the data sheets prepared as part of the monitoring program. Complementary data, such as air temperature, reservoir level, reservoir temperature, recent precipitation, and other information or observations that may be important in evaluating the instrumentation data should be noted on the data sheets.

### **5.6.2 Data Presentation**

All data should be summarised in graphical form. All plots should include sufficient previous data to identify any long-term trends. Furthermore, the plots should be self-explanatory.

### **5.6.3 Data Interpretation**

Data should be reviewed for reasonableness, evidence of incorrectly functioning instruments, and transposed data. Several checks for reasonableness can be made on all data. The magnitude of data should be near the range of previous data. Data that are significantly different may be incorrect. All data will have scatter from instrument error, human error, and from changes in natural phenomena such as temperature, wind, and humidity. The true accuracy of data will not be apparent until a significant number of readings have been taken under a variety of conditions. All data will follow trends, such as decreasing with time or depth, increasing

with time or depth, seasonal fluctuation, direct variation with reservoir or tail water level, direct variation with temperature, or a combination of such trends.

### **5.6.4 Dam Performance Evaluation**

The purpose of instrumentation and monitoring is to maintain and improve dam safety. The data should be used to evaluate whether the dam is performing as expected and whether it provides a warning of developing conditions that could endanger the safety of the dam. All data should be compared with expected behaviour based on the basic engineering concepts. Variations from expected behaviour may suggest development of conditions that should be evaluated. All data should be compared with design assumptions. If no unusual behaviour or evidence of problems is detected, the data should be filed for future reference. If data deviates from expected behaviour or design assumptions, action should be taken. The action to be taken depends on the nature of the problem, and should be determined on a case-by-case basis. Possible actions include:

- Performing detailed visual inspection;
- Repeating measurements to confirm behaviour;
- Re-evaluating stability using new data;
- Increasing frequency of measurements;
- Installing additional instrumentation;
- Designing and constructing remedial measures;
- Operating the reservoir at a lower level; and
- Emergency lowering of the reservoir.

### **5.6.5 Methods of Behavior Prediction**

Each dam is a unique structure and has its own special conditions of siting, design, construction and operation. Rigorous methods

of prediction have been developed over the years. These methods apply the laws of physics to problems of slope stability, foundation stability and rock deformation. Modern solutions use finite element or finite difference models run on computers. Such numerical analyses are expensive and for that reason are generally used only for larger dams. Special analyses are made when investigations reveal weak materials or other anomalies.

## **5.7 Visual Observations**

Observations by on site personnel (dam owners/operators and maintenance personnel) may be the most important and effective means of monitoring the performance of a dam. An inspector, upon each visit to the dam site, should examine it visually - walking along the dam alignment and looking for any signs of distress or unusual conditions.

Table 5-1: Parameters to be Monitored at Dams

Structure Type	Feature	Visual observation	Movements	Uplift and pore pressure	Water levels	Seepage flows	Water quality	Temperature measurement	Crack and joint measurement	Seismic measurement	Stress-strain measurement
Embankment Dams	Upstream slope	●	●	●	●	—	—	—	—	●	—
	Downstream slope	●	●	●	—	●	●	●	●	●	—
	Abutments	●	●	●	—	●	●	●	—	●	—
	Crest (Dam Top)	●	●	●	—	—	—	—	●	●	—
	Internal drainage system	—	—	●	—	●	●	●	—	—	—
	D/s Toe Drains Relief Drain	●	—	●	—	●	●	—	—	—	—
	U/s Riprap and D/s slope protection	●	—	—	—	—	—	—	—	—	—
Concrete and Masonry Dams	Upstream slope	●	●	—	●	—	—	●	●	●	●
	Downstream slope	●	●	●	—	—	—	●	●	●	●
	Abutments	●	●	●	—	●	●	—	—	●	●
	Crest (Dam Top)	●	●	●	—	—	—	●	●	●	●
	Internal drainage system in Dam Body	—	—	●	—	●	—	—	●	—	—
	Foundation drains	●	—	●	—	●	—	—	—	—	—
	Galleries	●	●	—	—	—	—	—	●	●	●
	Sluices / controls	●	—	—	●	—	—	—	—	—	—
Spillways	Approach channel	●	●	—	●	—	—	—	—	—	—
	Control structure	●	●	●	●	●	—	—	●	●	—
	Stilling basin / any other EDA	●	—	—	●	—	—	—	●	—	—
	Discharge conduit/channel	●	—	●	●	—	—	—	—	—	—
	Gate controls	●	—	—	—	—	—	—	—	—	—
	Erosion protection on d/s of EDA	●	—	—	—	—	—	—	—	—	—
	Side slopes	●	●	●	—	●	—	—	—	—	—

Structure Type	Feature	Visual observation	Movements	Uplift and pore pressure	Water levels	Seepage flows	Water quality	Temperature measurement	Crack and joint measurement	Seismic measurement	Stress-strain measurement
<b>Outlets</b>	Control Structure	●	●	●	●	—	—	—	●	●	—
	Stilling basin / any other EDA	●	—	—	—	—	—	—	—	—	—
	Discharge conduit/channel	●	●	●	●	—	—	—	●	—	—
	Trash rack/debris controls	●	—	—	—	—	—	—	—	—	—
<b>General Areas</b>	Reservoir surface	●	—	—	—	—	●	—	—	—	—
	Mechanical/ electrical systems	●	—	—	●	—	—	—	—	—	—
	Reservoir Periphery	●	—	—	—	—	●	—	—	—	—
	Upstream watershed	●	—	—	—	—	●	—	—	—	—
	Downstream channel	●	—	—	—	●	●	—	—	—	—
	Emergency Warning System	●	—	—	—	—	—	—	—	—	—

**Table 5-2: Suggested frequency of readings for specified instruments**

Type of instrument	During Construction		During initial filling	During Period of Operation		
	Construction	Shutdown		Year 1	Years 2 to 3	Regular
Vibrating wire piezometers	W	M	W	BiW	M	M
Hydrostatic uplift pressure pipes	W	M	W	W	BiW	M
Porous-tube piezometers	M	M	W	W	M	M
Slotted-pipe piezometers	M	M	W	W	M	M
Observation wells	W	M	W	W	BiW	M
Seepage measurement (weirs and flumes)	W	M	D	W	M	M
Visual seepage monitoring	W	W	W	W	F	M
Resistance thermometers	W	M	W	W	M	M
Thermocouples	D	M	W	W	M	M
Carlson strain meters	W	W	W	BiW	M	M
Joint meters	W	W	W	BiW	M	M
Stress meters	W	M	W	BiW	M	M
Reinforcement meters	W	M	M	M	M	M
Penstock meters	W	M	M	M	M	M
Deflectometers	W	M	W	W	M	M
Vibrating wire strain gauge	W	M	M	M	M	M
Vibrating-wire total pressure cell	W	M	M	M	M	M
Load cell	W	M	W	BiW	M	M
Pore pressure meters	W	W	D	W	M	M
Foundation deformation meters	W	W	W	BiW	M	M
Flat jacks	D	W	W	BiW	M	M

Type of instrument	During Construction		During initial filling	During Period of Operation		
	Construction	Shutdown		Year 1	Years 2 to 3	Regular
Tape gauges (tunnel)	W	W	W/BiW	BiW	M	M
Whitmore gauges, Avongard crack meter	W	M	W	W	M	M
Wire gauges	W	M	W/M	W/M	M	M/Q
Abutment deformation gauges	W	M	W	W	M	M
Ames dialmeters, differential buttress gauges	W	M	W	W	M	M
Plumblines	D	W	D	W	BiW	M
Inclinometer	W	W	W	W	BiW	M
Collimation	Every two days for a month	M	W	BiW	M	M
Embankment settlement points	-- <sup>c</sup>	--	M	BiM	Q	SA
Level points	M	Q	M	M/Y	BM/Q	BM
Multipoint extensometers	W	M	W	M	M	Q/SA
Triangulation			M	M	Q	SA
Trilateration (EDM)	--	--	BiW/M	M	Q	Q/A
Reservoir slide monitoring systems	--	--	M	M	M	Q
Power plant movement	--	--	M/W	M	M	M/Q
Rock movement	W	M	W	M	M	M
<ol style="list-style-type: none"> <li>1. These are suggested minimums. However, anomalies observed or unusual occurrences, such as earthquakes or floods, will require additional readings.</li> <li>2. D = daily, W = weekly, BiW = bi-weekly, M = monthly, Q = quarterly, SA = semi-annually, A = annually.</li> <li>3. Shutdown is that period during construction when the works remained suspended / stopped, due to any reason.</li> </ol>						

## Chapter 6. UPDATING THE MANUAL

As features of the dam and appurtenant structures change occasionally, the O&M Manual must be edited and portions rewritten to reflect these changes. This important task is often ignored. Updating information in the O&M Manual should be done whenever major changes like construction of an additional spillway, construction of dam on the upstream etc. take place. Aspects to be considered when updating include:

- Increase/decrease in the frequency of an inspection or the maintenance routine based on additional data/ experience acquired.
- Changes in the operation and/or maintenance procedures based on additional data/experience acquired.
- Alterations to the project data because of changes/modifications in the dam by way of additional spillway etc.

All up-dates/revisions of the O&M Manual need to be sent to all the locations/addresses to whom the copies of the original O&M Manual had been sent earlier. It is recommended that O&M Manuals be reviewed/updated after every 10 years by the respective Dam Owners.

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## **APPENDIX A - NOTIFICATION FOR STRENGTHENING OF ALARM AND WARNING SYSTEM FOR SAFETY OF PEOPLE FROM SUDDEN RELEASE OF WATER FROM DAMS ISSUED BY NATIONAL DISASTER MANAGEMENT AUTHORITY (OCTOBER 2015)**

### **Introduction**

Dams are delivering enormous benefits to the nation through flood risk mitigation, navigation, irrigation, hydropower, water supply, fisheries, wildlife conservation and recreation. Dams store large amount of water; and an uncontrolled or excessive outflow of water from dam reservoir may pose unacceptable risks to the lives and property of people downstream of dam. Sometimes, unexpected release of even small quantum of water during day to day operation of dam reservoirs could also catch people unaware, and cause loss of lives - recent Larji dam incident (81 June, 2014) is the tragic example which resulted in drowning of 25 students in the river Beas in Himachal Pradesh. Strengthening of alarm and warning system linked with dam operations can go a long way in ensuring safety of people from sudden release of water through dam spillways.

### **Scope**

This notification is intended to strengthen the alarm and warning system on India's dams for safety of people from sudden release of water through dam spillways/river sluices. It is also expected that the notification will sensitize and guide the dam operating staff in identifying, monitoring, and responding to emergency situation that may arise at any downstream stretch of the river due to sudden release of water from dam.

### **Applicability**

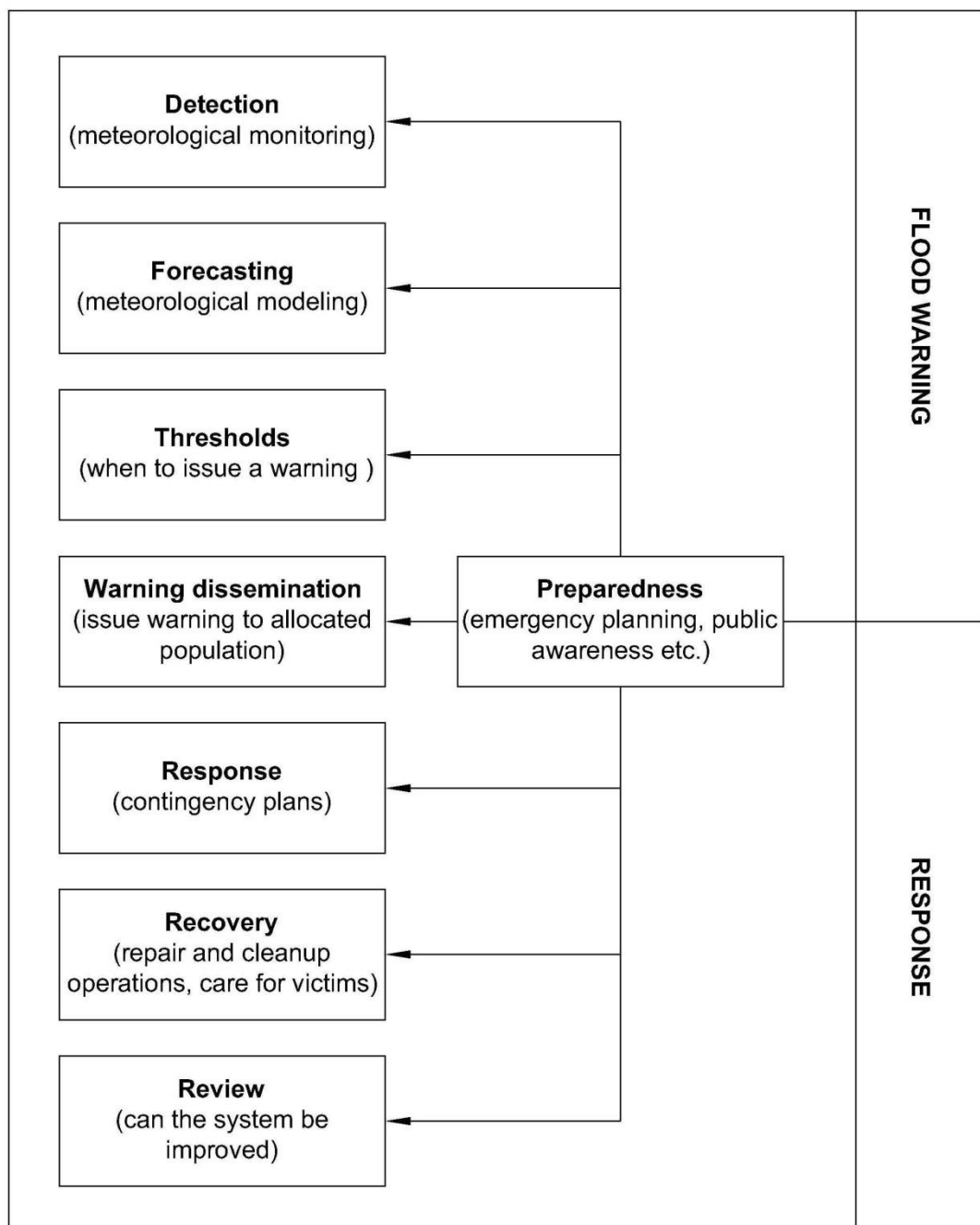
This notification is applicable for enforcement by all dam authorities in charge of operation of the dams. This is particularly applicable to barrages and independent outlet works which are directly discharging into the river.

### **Measures for Strengthening of Alarm and Warning System**

1. Reservoir Operation Manual, prescribing standard operating procedures for the day to day as well as emergency operations of dam, shall be prepared by the concerned project authorities/dam owners (State Governments, Public Sector Undertakings, other government or private agencies). The Operation Manual shall spell out all possible scenarios of operation of spillway gates and other outlet gates keeping in perspective the elevation-storage curve of the reservoir; the annual inflow pattern of the reservoir; the annual water demand pattern of the project; and in case of hydropower projects, the power demand and impact of load rejection on generating units.
2. The concerned project authorities shall carry out hydraulic routing studies for the downstream river reaches for different dam-outflow conditions in order to identify vulnerable areas in terms of depth/level and velocity of flows. In such vulnerable areas, project authorities shall mark danger levels at appropriate places and set up permanent warning posts (in English, Hindi and the local language) visible with naked eyes from reasonable distances. Movable barriers may be installed to prevent the entry of people and vehicles during passage of flood.

3. The purpose of a flood warning service is to detect and forecast threatening flood events so that the public can be alerted in advance and undertake appropriate responses to minimize the impact of flood. The components of a flood warning system can be aptly illustrated in figure below.
4. The vulnerable areas that pose very high risk levels (e.g. river reaches very close to dam locations) shall be fenced to bar free access of people. Development of river front from the point-of-view of tourism shall be allowed only at safe places; and in all such places ample care shall be taken to prominently notify risks associated with sudden release of water from dam.
5. The concerned project authorities shall establish a Control Room to keep watch on probable water inflows so as to have advance information and sufficient lead time for protective measures. A proper coordination regarding releases of water during both normal and emergent conditions shall be ensured with the immediate upstream and other cascading projects. The work of Control Room shall be entrusted to duly qualified persons.
6. A foolproof warning system to alert downstream habitants before release of water shall be put in place. The warning for release of water shall be given through Speakers, Sirens or Hooters adequately in advance of dam releases (minimum 15 minutes); and all such instruments shall be directly connected to the Control Room eliminating dependence on watch-staff stationed at vulnerable areas. The warning system shall be backed up by alternate power sources in Control Room as well as vulnerable locations so as to avoid malfunctioning of system in case of power failures. The Sirens/ Hooters shall be distinguishable from other common sounds like VIP vehicles, fire brigades, ambulance etc. Regular Inspection shall be carried out to ensure all time functioning of sirens, and periodical mock drills shall also be planned for ensuring efficacy of the warning system.
7. Tourists entering the vulnerable zones shall be forewarned of dangers of sudden dam releases. A suitable mechanism shall be developed in consultation with pertinent telecom service providers to send SMSs to such tourists whenever they enter vulnerable zones. Attempts shall also be made to send SMSs related to extreme releases of water to all mobile phones operating in the downstream vicinity of the dam project.
8. For dealing with extreme weather and flood conditions, accurate and reliable hydro meteorological network, inflow forecasting and communication mechanism shall be established by the State Governments. Releases from the storage dams associated with irrigation and flood moderation shall be planned in advance with the help of telemetry data available on real time basis, and advance warnings shall be issued to the people. Such information related to flood estimates and planned releases from dams shall be made available on Project website and through other means of public dissemination.
9. The concerned project authorities shall develop appropriate mechanism to keep local administration informed about the extreme inflows, sudden release of water and any other exigency conditions. Directory of contact numbers of key persons of civil administration, police, ambulance, fire station etc. shall be available with the officials responsible for such communications, and a copy shall also be available in the Control Room. Regular revision/updating of the Directory shall be carried out for its meaningful intent.

10. Preparation of Emergency Action Plan (EAP) for each dam is crucial for minimizing the loss of life and property in the event of occurrence of any emergency situation. A typical EAP contains procedures and information to assist the dam owner in taking necessary actions in time to moderate or alleviate the problems, in addition to issuing early warning and notification messages to responsible authorities, viz., District Magistrate/Collector, Armed forces, Paramilitary forces, Project Authorities and other Central/State Agencies. It also contains inundation maps to identify critical areas for prioritization of relief and rescue actions in case of an emergency. Project Authorities shall ensure preparation and up-dation of the EAPs of their dams as per Central Water Commission's guidelines available on CWC website at [http://www.cwc.gov.in/main/downloads/EAP chapter.pdf](http://www.cwc.gov.in/main/downloads/EAP%20chapter.pdf).



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## **APPENDIX B - CRITERIA AND GUIDELINES FOR EVACUATING STORAGE RESERVOIRS, SIZING LOW LEVEL OUTLETS AND INITIAL FILLING OF RESERVOIR (Central Water Commission, 1986)**

### **General**

All dams should be provided with low level outlets of adequate capacity to lower the reservoir water level to a specified elevation for inspection, maintenance and repair, to control the rate of reservoir pool rise during initial filling and for emergency drawdown.

The drawdown levels, and the evacuation time shall be set forth for each project.

### **Criteria for Evacuating Facilities**

For lowering the water level for inspection and repairs when necessary, the requirement would be to evacuate a major portion of the reservoir in such time so that after the water level is lowered, sufficient time is available for repairs before the water level rises due to higher inflows. For such a consideration the outlets should be at the lowest possible level and sufficient to cater for the anticipated inflows.

### **Other factors to be taken into account are:**

1. To control the rate of reservoir rise during initial filling and if necessary subsequently also.
2. To hold the reservoir at predetermined levels for stage-wise initial filling.
3. Emergency drawdown during initial filling or at a future date when distress conditions are noticed.

The low level outlets should be sized to maintain specific reservoir filling rates and also to hold the reservoir levels reasonably constant at specified elevations during initial filling to accomplish a predetermined monitoring programme. The period during which the initial reservoir filling is to be done has to be decided and a detailed programme drawn up. Flood routing studies with different frequency floods (lower floods) will have to be done. As such the low level outlet works should have discharge capacity sufficient to maintain reservoir filling rate to a pre-specified programme and to hold the reservoir levels reasonably constant for elevations above fifty percent of the height. Inflows in the reservoir should include a reasonable frequency, flood which would be dependent on the anticipated filling period.

The capacity and level of low level outlets for emergency drawdown during initial filling or at a future date when distress conditions are noticed, has to be evaluated in each individual case separately.

For structural safety the reduction in height of water which gives relief is important. For very large reservoirs this would mean very large capacity outlets for prompt evacuation.

Sizing of outlets works should be accomplished in a systematic way, considering the following aspects:

1. Project release requirements.

2. Economic benefits that can be derived from using the outlet works in routing the inflow design flood.

This study may result in increase in outlet works capacity.

3. Initial filling requirement.
4. Evacuation criteria. This study to meet the evacuation criteria may result in future increase in capacity which may in turn be beneficial in routing the inflow design flood.
5. After the above requirements are satisfied, a study to take advantage of the outlet works capacity for diversion requirements during construction and the multistage construction of outlet works is made.

### **Initial Filling of Reservoirs**

Initial reservoir filling is the first test of a dam to perform its intended functions. As the sizing of the outlet works to meet the probable outflow requirements during initial filling has to be fixed during designs, the information on the desired rates of pool rise must also be available at the time the design requirements are established.

In order to monitor reservoir performance, the rate of filling should be controlled to the extent feasible to allow in accomplishing a pre-determined monitoring programme. Low level outlets should be located and sized to provide discharge capacity sufficient to maintain the reservoir filling rates specified by the initial filling criteria to hold reservoir levels reasonably constant for elevation above 50% of the hydraulic height of the dam. Inflow into the reservoir should be assumed as the average of the mean monthly inflow in the selected filling period and reasonable frequency flood.

Reservoir filling criteria are established on a dam to dam basis. In general the objective as already stated above is to provide a planned programme with adequate time for monitoring and evaluating performance of the dam and its foundation as the reservoir is being filled for the first time.

The major factors to be considered in establishing initial filling criteria are as under:

1. Type of Dam – Concrete, earth and rock fill.
2. Geology of the dam foundation and reservoir and land-slide potential along the banks of the reservoir.
3. Hazard potential.
4. Inflow characteristics – controlled or uncontrolled.
5. Hydrology – flood patterns and seasonal based flows.
6. Release provisions for projects requirements, flood release and emergency evacuation.
7. Type of instrumentation and provision for monitoring – reading evaluation time needed and response time.
8. Safe channel capacities – downstream of the dam.
9. Characteristics of reservoir – Storage.

Filling rates for concrete dams are much less restricted and are not normally specified for the bottom half of the depth of the reservoir impounded of the dam. Broadly the stage-wise filling to be done as under:

The first stage consists of filling the reservoir up to MDDL. This filling can be done without restraint as there is no hazard potential to the public and economic development downstream of the dam. The second stage consists of filling of the reservoir from MDDL to the crest of the spillway. The rate of the filling should be controlled and it has to be specified. The third stage consists of filling above the crest of the spillway up to the full reservoir level (FRL) which has also to be conducted in stages.

### **Concrete Dams**

The first stage consists of filling the reservoir up to MDDL. This filling can be done without restraint.

The second stage consists of filling the reservoir from MDDL to the crest of spillway. The reservoir above MDDL should be gradually built up at a rate not exceeding 3 meters per fortnight depending upon the height of the dam and held at the level of crest of spillway in order to assess the behavior of the structure on the basis of observed data and to take a decision about further storage.

The third stage consists of filling above the crest of the spillway and up to full reservoir level (FRL). Above the crest level of spillway the building up of the reservoir should be restricted to 0.3 meter (1 ft.) in 48 hours and the same should be temporarily held at half the height between the crest of spillway and FRL to monitor and assess the behavior of the structure before further filling is resumed. The period for which the reservoir is held at this level will depend on the instrument response time.

In case of concrete dams having high earthen flanks, the procedures suggested for earthen dams should be followed.

### **Earthen Dams**

The first stage consists of filling the reservoir up to MDDL. This filling can be done without restraint.

The second stage consists of filling the reservoir from MDDL to the crest of spillway. In case of earthen and rock fill dam this stage filling shall be done in two parts.

The reservoir above MDDL should be gradually built at a rate not exceeding 3 meters per fortnight, and filling should be temporarily stopped at 50% elevation from MDDL to crest of spillway in order to assess the behavior of the structure on the basis of observed values and to take a decision about further storage.

After decision is taken to continue the filling further building up of the storage should be done in gradual sub-stages of 2 to 3 meters depending upon the height of the dam. Observations of pore pressure cells, uplift pressures, seepage quantum, other instrumentation data should be carried out at each stage after allowing a suitable stabilizing period before going on to the next sub-stage of filling.

The third stage consists of filling above the crest of the spillway up to the full reservoir level (FRL).

The rate of reservoir filling above crest of the spillway should be restricted to 0.3 meters (1 ft.) in 48 hours. The reservoir should be temporarily held at half the height between FRL and crest of spillway for sufficient time for monitoring and evaluating performance of dam, also taking into account instrument response time, and to take a decision about further storage.

### Evacuation Time

Guidelines on this aspect should, generally take into account the assessment of hazard potential and risk potential of the dam. However, in the Indian conditions where population growth in downstream areas is not controllable, the hazard potential at the initial stage and its subsequent increase cannot be assessed. In most cases the dams would come under high hazard category.

Similarly, risk is very difficult to classify because of many combinations of adverse conditions that may be involved at a particular dam site, and the type of dam.

Classification is also recommended to be based on the height of dams so far as determination of risk potential is concerned and dams with a height of more than 50 meters are to be considered more important than those of height less than 50 meters.

For evacuating storage reservoirs and sizing low-level outlets, three categories have been suggested as given in the table below. These assume a general balance between hazard and risk and could be adjusted on the basis of detailed site specific studies.

### Evacuation Time (in Days)

Sl. No.	Depth of Evacuation (from initial pool level)	Degree of Hazard or risk (Evacuation time in days)		
		High	Significant	Low
1.	25%	20	30	50
2.	50%	40	50	70
3.	75%	80	90	100

The above evacuation periods would generally be within the overall requirement to drawdown the reservoir within a period of one to four months, allowing sufficient time for carrying out inspection and repairs, before the water level rises due to higher inflows of monsoon.

In some exceptional cases, it may not be technically possible and economically feasible to provide the required drawdown capability to meet the above criteria because of the size of the project (unusually small or large) or because of some special feature. In such a case, the criteria regarding drawdown level or the evacuation time could be altered to suit the site specific case if the results of studies so indicate.

These Guidelines were evolved by a Panel of Officers of Central Water Commission comprising of Shri K. Madhavan, Member (D&R) & Chairman of the Panel; Shri P. Sen, Chief Engineer (NHPD); Shri V.A. Prakash, Chief Engineer (Designs-II); Shri M.S. Reddy, Chief Engineer (Designs-I); Shri G.S. Narayana, Chief Engineer (DSO); Shri Z. Hasan, Director (ERDD-II) and Shri K.D. Thite, Director (Dam Safety), Member Secretary.

## APPENDIX C - GLOSSARY

**Abutment** — that part of a valley side against which a dam is constructed. Right and left abutments are those on respective sides of an observer looking downstream.

**Air-Vent Pipe** — a pipe designed to provide air to the outlet conduit to reduce turbulence during release of water and safeguard against damages due to cavitation.

**Appurtenant Structures** — ancillary features of a dam, such as the outlet, spillway, energy dissipation arrangement powerhouse, tunnels, etc.

**Arch Dam** — a concrete or masonry dam that is curved to transmit the major part of the water pressure to the abutments.

**Auxiliary Spillway (Emergency Spillway)** — a secondary spillway designed to operate only during exceptionally large floods.

**Backwater Curve** — the longitudinal profile of the water surface in an open channel where the depth of flow has been increased by an obstruction, an increase in channel roughness, a decrease in channel width, or a flattening of the bed slope.

**Base Width (Base Thickness)** — the maximum width or thickness of a dam measured horizontally between upstream and downstream faces and normal (perpendicular) to the axis of the dam but excluding projections for outlets, etc.

**Berm** — a horizontal step or bench in the sloping profile of an embankment dam.

**Bulkhead gate** — a gate used either for temporary closure of a channel or conduit to empty it for inspection or maintenance or for closure against flowing water when the head difference is small, e.g., for diversion tunnel closure. Although a bulkhead gate is usually opened and closed under nearly balanced pressures, it nevertheless may be capable of withstanding a high pressure differential when in the closed position.

**Buttress dam** — a dam consisting of a watertight upstream face supported at intervals on the downstream side by a series of buttresses.

**Cofferdam** — a temporary structure enclosing all or part of a construction area so that construction can proceed in a dry area.

**Concrete Lift** — in concrete works the vertical distance between successive horizontal construction joints.

**Conduit Outlet Works** — a closed conduit for conveying discharge through or under a dam for different project purposes.

**Consolidation Grouting (Blanket Grouting)** — the injection of grout to consolidate a layer of the foundation, resulting in greater impermeability, strength, or both.

**Construction Joint** — the interface between two successive placings or pours of concrete where a bond, not permanent separation, is intended.

**Core Wall** — a wall built of impervious material, usually concrete or asphaltic concrete, in the body of an embankment dam to prevent leakage.

**Crest gate (spillway gate)** — a gate on the crest of a spillway to control overflow or reservoir water level.

**Crest Length** — the length of the dam at its crest (dam top) top of a dam, including the length of the spillway, powerhouse, navigation lock, fish pass, etc., where these structures form part of the length of a dam. If detached from a dam, these structures should not be included.

**Crest of dam** — Used to indicate the “top of dam”. To avoid confusion to indicate the crest *of spillway* and *top of dam* may be used.

**Culvert** — a drain or waterway built under a road, railway, or embankment, usually consisting of a pipe or covered conduits

**Cutoff** — an impervious construction or material which reduces seepage through the foundation material.

**Cutoff trench** — an excavation later to be filled with impervious material to form a cutoff.

**Cutoff wall** — a wall of impervious material (e.g., concrete, asphaltic concrete, steel-sheet piling) built into the foundation to reduce seepage under 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 embankments, dikes, and guide bunds.

**Dam failure** — failures in the structures or operation of a dam which may lead to the 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 has 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;

- i) Occurrence of a flood, which resulted in encroachment on the available free-board, or the adopted 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 visual examination of all components of dam and its appurtenances by one or more persons trained in this respect and includes investigation of the 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.

**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 organizations, 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.

**Dead storage** — the storage that lies below the invert of the lowest outlet and that, therefore, cannot be withdrawn from the reservoir.

**Decommission** — Taking a dam out of service in an environmentally sound and

safe manner, or converting it to another purpose.

**Design flood** — see spillway design flood.

**Design life** — the intended period that the dam will function successfully with only routine maintenance; determined during design phase.

**Diaphragm** — see *membrane*.

**Dike (Levee)** — a long low embankment whose height is usually less than 5 m and whose length is more than 10 times the maximum height. Usually applied to embankments or structures built to protect land from flooding. If built of concrete or masonry, the structure is usually referred to as a *flood wall*. Also, used to describe embankments that block areas on a reservoir rim that are lower than the top of the main dam and that are quite long. In the Mississippi River basin, where the old French word *levee* has survived, the term now applies to flood-protecting embankments whose height can average up to 15 m.

**Distress condition** — the occurrence or potential development of such conditions in the dam or appurtenance or its reservoir or reservoir rim, which if left unattended to, may impede the safe operation of dam for its intended benefits or may pose unacceptable risks to the life and property of people downstream.

**Diversion channel, canal, or tunnel** — a waterway used to divert water from its natural course. These terms are generally applied to temporary structures such as those designed to bypass water around a dam site during construction. “Channel” is normally used instead of “canal” when the waterway is short. Occasionally these terms are applied to permanent structures.

**Documentation** — all permanent records concerning investigation, design, construction, operation, performance, maintenance and safety of dams and includes design memorandum, construction drawings, geological reports, reports of specialized studies simulating structural and hydraulic response

of the dam, changes made in design and drawings, quality control records, emergency action plan, operation and maintenance manual, instrumentation readings, inspection and testing reports, operational reports, and dam safety review reports;

**Drainage area** — an area that drains naturally to a point on a river.

**Drainage layer or blanket** — a layer of permeable material in a dam to relieve pore pressure or to facilitate drainage of fill.

**Drawdown** — the lowering of water surface level due to release of water from a reservoir.

**Earth dam (Earth fill dam)** — An embankment dam in which more than 50 percent of the total volume is formed of compacted fine-grained material obtained from a borrow area.

Earthen dam or earth fill dam — see *embankment dam*.

**Embankment dam (Fill dam)** — any dam constructed of excavated natural materials.

**Emergency Action Plan (EAP)** — a plan of action to be taken to reduce the potential for damage to property and loss of life in the area affected by failure of a dam or other potentially hazardous practice.

**Emergency gate** — a standby or reserve gate which is lowered only for repairing/ servicing of the service gate.

**Emergency spillway** — see *spillway*.

**Face** — the external surface of a structure, e.g., the surface of a wall of a dam.

**Failure** — the uncontrolled release of water from a dam.

**Filter (filter zone)** — A band or zone of granular material that is incorporated into a dam and is graded (either naturally or by selection) to allow seepage to flow across or down the filter without causing the migration of material from zones adjacent to it.

**Fixed wheel gate (fixed-roller gate, fixed-axle gate)** — a gate having wheels or rollers mounted on the end posts of the gate. The wheels move against rails fixed in side grooves or gate guides.

**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 *belly gates*, so called due to their shape in cross-section.

**Flashboards** — a length of timber, concrete, or steel placed on the crest of a spillway to raise the retention water level but that may be quickly removed in the event of a flood, either by a tripping device or by deliberately designed failure of the flashboard or its supports.

**Flood gate** — a gate to control flood release from a reservoir.

**Flood routing** — the determination of the attenuating effect of storage on a flood passing through a valley, channel, or reservoir.

**Flood surcharge** — the volume or space in a reservoir between the controlled retention water level (Full Reservoir Level) and the maximum water level. Flood surcharge cannot be retained in the reservoir but will flow over the spillway until the controlled retention water level is reached.

**Flood wall** — a concrete wall constructed adjacent to a stream to prevent flooding of property on the landward side of the wall, normally constructed in lieu of or to supplement a levee where the land required for levee construction is expensive or not available.

**Floodplain** — an area adjoining a body of water or natural stream that has been, or may be, covered by flood water.

**Floodplain management** — a management program to reduce the consequences of flooding, either by natural runoff or by dam failure, to existing and future properties in a floodplain.

**Foundation of dam** — the natural material on which the dam structure is placed.

**Freeboard** — the vertical distance between a stated reservoir level and the top of a dam. Normal freeboard is the vertical distance between Full Reservoir Level (FRL) and the top of the dam. Minimum freeboard is the vertical distance between the Maximum Water Level (MWL) and the top of the dam.

**Full Reservoir Level (FRL)/Normal water level** — for a reservoir with un-gated spillway it is the spillway crest level. For a reservoir, whose outflow is controlled wholly or partly by movable gates, siphons or other means, it is the maximum level to which water can be stored under normal operating conditions, exclusive of any provision for flood surcharge.

**Fuse-Plug Spillway** — an auxiliary or emergency spillway comprising a low embankment or a natural saddle designed to be overtopped and eroded away during a rare and exceptionally large flood.

**Gallery** — (a) a passageway within the body of a dam or abutment, hence the terms *grouting gallery*, *inspection gallery* and *drainage gallery* (b) a long and rather narrow hall, hence the following terms for a power plant viz. *valve gallery*, *transformer gallery* and *bus bar gallery*.

**Gate** — a device in which a leaf or member is moved across the waterway from an external position to control or stop the flow.

**Gravity dam** — a dam constructed of concrete, masonry, or both that relies on its weight for stability.

**Grout cap** — a pad or wall constructed to facilitate pressure grouting of the grout curtain beneath it.

**Grout curtain (grout cutoff)** — a barrier produced by injecting grout into a vertical zone, usually narrow horizontally, in the foundation to reduce seepage under a dam.

**Guard gate (guard valve)** — a gate or valve that operates fully open or closed. It may function as a secondary device for shutting off the flow of water in case the primary closure device becomes inoperable, but is



usually operated under conditions of balanced pressure and no flow.

**Hazard Classification** — a system that categorizes dams according to the degree of adverse incremental consequences of a failure or improper operation of the dam. CWC classifies dam hazards as “low”, “significant”, or “high”.

**Height above lowest foundation** — the maximum height from the lowest point of the general foundation to the top of the dam.

**Homogeneous earth fill dam** — an embankment dam constructed of similar earth material throughout, except internal drains or drainage blankets; distinguished from a zoned earth fill dam.

**Hydraulic fill dam** — an embankment dam constructed of materials, often dredged, that are conveyed and placed by suspension in flowing water.

**Hydraulic height** — the height to which water rises behind a dam and the difference between the lowest point in the original streambed at the axis of the dam and the maximum controllable water surface.

**Hydrograph** — a graphic representation of discharge, stage, or other hydraulic property with respect to time for a point on a stream. (At times the term is applied to the phenomenon the graphic representation describes; hence a flood hydrograph is the passage of a flood discharge past the observation point.)

**Inclinometer** — an instrument, usually consisting of a metal or plastic tube inserted in a drill hole and a sensitized monitor either lowered into the tube or fixed within it. The monitor measures at different points the tube’s inclination to the vertical. By integration, the lateral position at various levels of the tube may be found relative to a point, usually the top or bottom of the tube, assumed to be fixed. The system may be used to measure settlement.

**Intake** — any structure in a reservoir, dam, or river through which water can be drawn into an aqueduct.

**Internal Erosion** — see *piping*.

**Inundation map** — a map delineating the area that would be inundated in case of a failure.

**Leakage** — Uncontrolled loss of water by flow through a hole or crack.

**Lining** — a coating of asphaltic concrete, reinforced or unreinforced concrete, shotcrete, rubber or plastic on a canal, tunnel etc. to provide water tightness, prevent erosion, reduce friction, or support the periphery of structure. May also refer to lining, such as steel or concrete, of outlet pipe or conduit.

**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** — the recurring activities necessary to retain or restore a dam in a safe and functioning condition, including the management of vegetation, the repair or replacement of failed components, the prevention or treatment of deterioration, and the repair of damages caused by flooding or vandalism.

**Masonry dam** — a dam constructed mainly of stone, brick, or concrete blocks that may or may not be joined with mortar. A dam having only a masonry facing should not be referred to as a masonry dam.

**Maximum cross-section of dam** — a cross-section of a dam at the point of its maximum height.

**Maximum water level** — the maximum water level, including flood surcharge, the dam is designed to withstand.

**Membrane (Diaphragm)** — a sheet or thin zone or facing made of a flexible material, sometimes referred to as a *diaphragm wall* or *diaphragm*.

**Minimum operating level** — the lowest level to which the reservoir is drawn down under normal operating conditions.

**Morning glory spillway** — see *spillway*.

**One-Hundred Year (100-Year) Exceedance Interval** — the flood magnitude expected to be equaled or exceeded on the average of once in 100 years. It may also be expressed as an *exceedance frequency*, i.e. a percent chance of being exceeded in any given year.

**Operation** — the administration, management, and performance of maintenance activities necessary to keep a dam safe and functioning as planned.

**Outlet** — an opening through which water can be freely discharged from a reservoir.

**Outlet gate** — a gate controlling the outflow of water from a reservoir.

**Overflow dam** — a dam designed to be overtopped.

**Parapet Wall** — a solid wall built along the top of a dam for ornament, for the safety of vehicles and pedestrians, or to prevent overtopping.

**Peak Flow** — the maximum instantaneous discharge that occurs during a flood. It coincides with the peak of a flood hydrograph.

**Pervious Zone** — a part of the cross-section of an embankment dam comprising material of high permeability.

**Phreatic Surface** — the top most flow line in an embankment dam.

**Piezometer** — an instrument for measuring pore water pressure within soil, rock, or concrete.

**Piping** — the progressive development of internal erosion by seepage, appearing downstream as a hole or seam discharging water that contains soil particles.

**Pore Pressure** — the interstitial pressure of water within a mass of soil, rock, or concrete.

**Pressure Cell** — an instrument for measuring pressure within a mass of soil, rock, or concrete or at an interface between one and the other.

**Pressure Relief Pipes** — Pipes used to relieve uplift or pore water pressure in a dam's foundation or structure.

**Primary Spillway (Principal Spillway)** — the principal or first-used spillway during flood flows.

**Probable Maximum Flood (PMF)** — a flood that would result from the most severe combination of critical meteorologic and hydrologic conditions possible in the region.

**Probable Maximum Precipitation (PMP)** — the maximum amount and duration of precipitation that can be expected to occur on a drainage basin.

**Program** — any authorized activity used to implement and carry out goals, actions, and objectives contained within the authorizing legislation.

**Program Life** — the period in a contract, conservation plan, or plan during which the conservation practice or conservation system shall be maintained and used for the intended purpose; determined by program requirements.

**Pumped storage reservoir** — a reservoir filled entirely or mainly with water pumped from outside its natural drainage area.

**Radial gate (Tainter gate)** — a gate with a curved upstream plate and radial arms hinged to piers or other supporting structures.

**Regulating dam** — a dam impounding a reservoir from which water is released to regulate

**Rehabilitation** — the completion of all work necessary to extend the service life of the practice or component and meet applicable safety and performance standards.

**Relief well** — vertical wells or boreholes, constructed downstream of an embankment

dam to relieve the pressure from confined pervious layers in foundation overlaid by an impervious layer to arrest boiling.

**Repair** — actions to restore deteriorated, damaged, or failed dam or its component to an acceptable by meeting functional condition.

**Replacement** — the removal of a structure or component and installation of a similar, functional structure or component.

**Reservoir area** — the surface area of a reservoir when filled to controlled retention level.

**Reservoir routing** — the computation by which the interrelated effects of the inflow hydrograph, reservoir storage, and discharge from the reservoir are evaluated.

**Reservoir surface** — the surface of a reservoir at any level.

**Riprap** — a layer of large stones, broken rock, or precast blocks placed randomly on the upstream slope of an embankment dam, on a reservoir shore, or on the sides of a channel as a protection against wave action. Large riprap is sometimes referred to as armoring.

**Risk assessment** — as applied to dam safety, the process of identifying the likelihood and consequences of dam failure to provide the basis for informed decisions on a course of action.

**Rock fill dam** — an embankment dam in which more than 50 percent of the total volume comprises compacted or dumped pervious natural or crushed rock.

**Rock fill Dam** — see *embankment dam*.

**Roll Crete or Roller-Compacted Concrete** - a no-slump concrete that can be hauled in dump trucks, spread with a bulldozer or grader, and compacted with a vibratory roller.

**Rolled fill dam** — an embankment dam of earth or rock in which the material is placed in layers and compacted using rollers or rolling equipment.

**Seepage** — the interstitial movement of water that may take place through a dam, its foundation, or its abutments.

**Service Life** — the actual period after construction of a dam, during which the practice functions adequately and safely with only routine maintenance; determined by on-site review.

**Service/Regulating gate (regulating valve)** — a gate or valve that operates under full pressure and flow to throttle and vary the rate of discharge.

**Shaft Spillway (Morning Glory Spillway)** — a vertical or inclined shaft into which flood water spills and then is conducted through, under, or around a dam by means of a conduit or tunnel. If the upper part of the shaft is splayed out and terminates in a circular horizontal weir, it is termed a “bell mouth” or “morning glory” spillway.

**Side Channel Spillway** — a spillway whose crest is roughly parallel to the channel immediately downstream of the spillway.

**Sill** — (a) A submerged structure across a river to control the water level upstream. (b) The crest of a spillway. (c) A horizontal gate seating, made of wood, stone, concrete or metal at the invert of any opening or gap in a structure, hence the expressions *gate sill* and *stop log sill*.

**Siphon Spillway** — a spillway with one or more siphons built at crest level. This type of spillway is sometimes used for providing automatic surface-level regulation within narrow limits or when considerable discharge capacity is necessary within a short period.

**Slide gate (sluice gate)** — a gate that can be opened or closed by sliding it in supporting guides.

**Slope** — (a) the side of a hill or mountain. (b) The inclined face of a cutting or canal or embankment. (c) Inclination from the horizontal. In the United States, it is measured as the ratio of the number of units of horizontal distance to the number of corre-

sponding units of vertical distance. The term is used in English for any inclination and is expressed as a percentage when the slope is gentle, in which case the term *gradient* is also used.

**Slope Protection** — the protection of a slope against wave action or erosion.

**Sluiceway** — see *low-level outlet*.

**Spillway** — a structure over or through which flood flows are discharged. If the flow is controlled by gates, it is a controlled spillway; if the elevation of the spillway crest is the only control, it is an uncontrolled spillway.

**Spillway Channel (Spillway Tunnel)** — a channel or tunnel conveying water from the spillway to the river downstream.

**Stilling Basin** — a basin constructed to dissipate the energy of fast-flowing water, e.g., from a spillway or bottom outlet, and to protect the riverbed from erosion.

**Stop logs** — large logs or timber or steel beams placed on top of each other with their ends held in guides on each side of a channel or conduit providing a cheaper or easily handled temporary closure than a bulkhead gate.

**Storage** — the retention of water or delay of runoff either by planned operation, as in a reservoir, or by temporary filling of overflow areas, as in the progression of a flood crest through a natural stream channel.

**Tail water Level** — the level of water in the tailrace at the nearest free surface to the turbine or in the discharge channel immediately downstream of the dam.

**Tailrace** — the tunnel, channel or conduit that conveys the discharge from the turbine to the river, hence the terms *tailrace tunnel* and *tailrace canal*.

**Toe of Dam** — the junction of the downstream face of a dam with the ground surface, referred to as the *downstream toe*. For an embankment dam the junction of upstream

face with ground surface is called the *upstream toe*.

**Top of Dam** — the elevation of the uppermost surface of a dam, usually a road or walkway, excluding any parapet wall, railings, etc.

**Top Thickness (Top Width)** — the thickness or width of a dam at the level of the top of the dam. In general, “thickness” is used for gravity and arch dams, “width” for other dams.

**Transition Zone (Semi-pervious Zone)** — a part of the cross-section of a zoned embankment dam comprising material of intermediate size between that of an impervious zone and that of a permeable zone.

**Trash rack** — a screen located at an intake to prevent the ingress of debris.

**Tunnel** — a long underground excavation usually having a uniform cross-section. Types of tunnel include: headrace tunnel, pressure tunnel, collecting tunnel, diversion tunnel, power tunnel, tailrace tunnel, navigation tunnel, access tunnel, scour tunnel, draw-off tunnel, and spillway tunnel.

**Under seepage** — the interstitial movement of water through a foundation.

**Uplift** — the upward pressure in the pores of a material (interstitial pressure) or on the base of a structure.

**Upstream Blanket** — an impervious layer placed on the reservoir floor upstream of a dam. In case of an embankment dam, the blanket may be connected to the impermeable element in a dam.

**Upstream Blanket** — see *blanket*.

**Valve** — a device fitted to a pipeline or orifice in which the closure member is either rotated or moved transversely or longitudinally in the waterway to control or stop the flow.

**Water stop** — a strip of metal, rubber or other material used to prevent leakage through joints between adjacent sections of concrete.

**Weir** — (a) a low dam or wall built across a stream to raise the upstream water level, called *fixed-crest weir* when uncontrolled. (b) A structure built across a stream or channel for measuring flow, sometimes called a *measuring weir* or gauging weir. Types of weir include *broad-crested weir*, *sharp-crested weir*, *drowned weir*, and *submerged weir*.

**Zoned embankment dam** — an embankment dam composed of zones of materials selected for different degrees of porosity, permeability and density.

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# Central Dam Safety Organisation

## Central Water Commission

### Vision

To remain as a premier organisation with best technical and managerial expertise for providing advisory services on matters relating to dam safety.

### Mission

To provide expert services to State Dam Safety Organisations, dam owners, dam operating agencies and others concerned for ensuring safe functioning of dams with a view to protect human life, property and the environment.

### Values

**Integrity:** Act with integrity and honesty in all our actions and practices.

**Commitment:** Ensure good working conditions for employees and encourage professional excellence.

**Transparency:** Ensure clear, accurate and complete information in communications with stakeholders and take all decisions openly based on reliable information.

**Quality of service:** Provide state-of-the-art technical and managerial services within agreed time frame.

**Striving towards excellence:** Promote continual improvement as an integral part of our working and strive towards excellence in all our endeavours.

### Quality Policy

We provide technical and managerial assistance to dam owners and State Dam Safety Organizations for proper surveillance, inspection, operation and maintenance of all dams and appurtenant works in India to ensure safe functioning of dams and protecting human life, property and the environment.

We develop and nurture competent manpower and equip ourselves with state of the art technical infrastructure to provide expert services to all stakeholders.

We continually improve our systems, processes and services to ensure satisfaction of our customers.

