Operation and Maintenance Manual for KUNDALA DAM State of Kerala

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KUNDALA DAM
KSEBL_10_v1.0

Chief Engineer
(Civil DRIP & Dam Safety)
Kerala State Electricity Board

सत्यमेव जयते

Operation and Maintenance Manual for Kundala Dam

Prepared by the Dam Safety Organisation
Kerala State Electricity Board Ltd

(A Government of Kerala undertaking)
State of Kerala

Front Cover Photographs: Upstream and downstream views of Kundala dam.

Operation and Maintenance Manual

Kundala Dam

Prepared

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Approved

Sd/-

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Kerala State Electricity Board Ltd
Pallom, Kottayam.

May 2020

Kerala State Electricity Board Ltd
Dam Safety Organisation

Disclaimer

This Operation and Maintenance Manual for Kundala Dam in no way restricts the dam operators in digressing from her/his responsibilities. The Dam Operators must exercise appropriate discretion and good judgement based on actual site condition when implementing and using the operation and maintenance manual for managing the workings of the dams and appurtenant structures.

The manual was developed for the purpose of organising and managing the operation, inspection and maintenance of the dams for reducing risk and optimizing performance of the dams as a general guide.

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Message

India has more than 5200 large dams. Their health and safety are of paramount importance for sustainable use of the valuable assets, besides providing protection to the people and property in the downstream areas. The Ministry of Water Resources, River Development & Ganga Rejuvenation through the Central Water Commission (CWC), with financial assistance from the World Bank, started the Dam Rehabilitation and Improvement Project (DRIP) to rehabilitate 198 large dam projects in seven states. Kerala State Electricity Board Ltd, through Government of Kerala participated in DRIP to rehabilitate 37 dams under 12 Hydro Electric Projects in the state.

For managing a dam in a sustainable and scientific manner, it is very crucial for each dam owner to have dam specific Operation and Maintenance Manual that lays down procedures for the daily upkeep of the dam. An Operation and Maintenance Manual for a dam is essential for ensuring its safe functioning and for deriving continued benefits. This Operation and Maintenance Manual for Dam has been prepared following the Guidelines for Preparation, Operation and Maintenance Manuals published by CWC in January 2018 under DRIP and covers requirements for project Operation, Inspection, Maintenance, Instrumentation and Monitoring the health of Dam both during monsoon and non-monsoon periods.

I recommend the dam officials to use this manual for the efficient and safe Operation and Maintenance of the Dams on regular basis.

I compliment all the experts who have contributed to the development of this manual and congratulate the Dam Safety Organisation, KSEB Ltd, Pallom and CWC for the initiation of such important policy protocol to address dam safety management in Kerala.

Bibin Joseph,
Director Generation (Civil),
KSEBLtd
Kerala

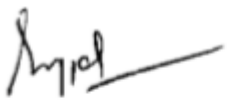
Foreword

Globally, the Operation and Maintenance (O&M) Manual of a dam is one of the most important documents which is supposed to be put in practice right from the initial filling of reservoirs. In order to address the operation and maintenance aspects, ongoing Dam Rehabilitation and Improvement Project (DRIP) has requisite scope to prepare new or update existing O&M manuals for all DRIP dams, which will become very helpful to Dam Owners in addressing the dam specific issues comprehensively in future.

This Operation and Maintenance (O & M) Manual developed is a detailed set of written descriptions with step-by-step procedures for ensuring that the dam is safely operated, frequently inspected and properly maintained. In this era of shrinking budgets, timely inspection and preventative maintenance is necessary for the safe functioning of the dam and continued productive use of the dam and reservoir.

The format of this manual is prepared following the principles published in 2018 CWC Guidelines for Operation and Maintenance of dams for the use by all Dam Owners in developing their own site-specific manuals. Each section of the document provides the necessary instructions to operate inspect and maintain their dams.

It is recommended that all dam officials in charge to use this manual for ensuring that the dam is operated and maintained in a sustainable manner and will continue to derive benefits.



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PREFACE

Operation and Maintenance Manual is a detailed document containing procedures and protocols for ensuring that a Dam is operated and maintained properly and timely to avoid further health deterioration and to extend the service life of these assets. An Operation and Maintenance Manual is essential for a Dam for ensuring its safe functioning and for deriving desired benefits from it by describing all the elements systematically for its operation, inspection, maintenance, instrumentation and monitoring of the health.

Central Water Commission has published the guidelines for the development of new manual and updating of existing manual videCDSO_GUD_DS_03_v1.0 Page xii January 2018. Accordingly Kerala State Electricity Board Ltd is developing and updating the Operation and Maintenance Manual of Dams under their ownership for a healthy Dam Safety management system.

Kundala Dam under KSEBL has no Operation and Maintenance Manual according to the present standards. Hence an attempt is being made here to prepare the manual as per the new guidelines by CWC.

Team Involved in preparing this O & M Manual of Kundala dam

Review and Approval

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Smt. Mini T	Sub Engineer

Field Officers associated in giving Data

Executive Engineer, Asst. Executive Engineer, Assistant Engineer and Sub Engineers of Dam Safety Division, KSEB Ltd., Pambla.

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GENERAL INFORMATION

1.1 Introduction

Pallivasal Hydro Electric Project is the first Hydro Electric project of Kerala with installed capacity 37.5 MW. The project is located in Idukki District and is near to Munnar. The Project comprises of Kundala Dam, Madupetty Dam & R A Head Works constructed in Mudirappuzha stream, a tributary of River Periyar along with a water conductor system and a surface Power House at Chithirapuram. These are cascading structures with Kundala at the upstream and R A Head Works at downstream. RA Head works is located by the side of Aluva – Munnar road just before Munnar. The Madupetty Dam is located at about 15km upstream of R. A. Head works. Kundala Dam is further upstream and is about 12 km from Madupetty Dam. Kundala is comparatively a small reservoir. The water stored in the reservoir is released to the downstream Madupetty reservoir through the river when water level in Madupetty reservoir lowers. The water stored in the Madupetty reservoir is further released to downstream through a Dam Toe Power Station having a capacity of 2MW. The controlled release from Madupetty Dam reaches R A Head Works, a gated diversion structure near Munnar from where, the water is diverted through a water conducting system to the 37.5MW power house of Pallivasal HEP located on the right bank of Mudirapuzha river. After generating power, the tail water is pumped to the balancing reservoir of Sengulam Hydro Electric Project and the surplus water from the sump of pumping station is spilled to the Mudirapuzha river itself.

Kundala dam is also known as Sethuparvathipuram dam after Moolam Thirunal Sethu ParvathiBayi , better known as Amma Maharani of the State of Travancore.

1.2 Purpose, Location & Description of Kundala Dam

Kundala dam is a Masonry gravity dam completed in 1946 as a part of the II stage of the Pallivasal HEP. It is the upstream most dam in Mudirappuzha sub basin with a length of dam is 259 m. The spillway structure has five bays and one lower level outlet is provided in the dam. Nominal bed level is +1733.70 m. The dam is constructed in the upstream reaches of Mudirappuzha sub basin, downstream of the confluence of Chittuvarai, Ellappatti and

Chunduvarai streams, in Periyar Basin in Idukki District. Maduppetty is the immediate downstream dam in the same stream.

Fig 1.1 Kundala Dam – Upstream view

Fig 1.2 Kundala Dam – Downstream view

Location Sketch

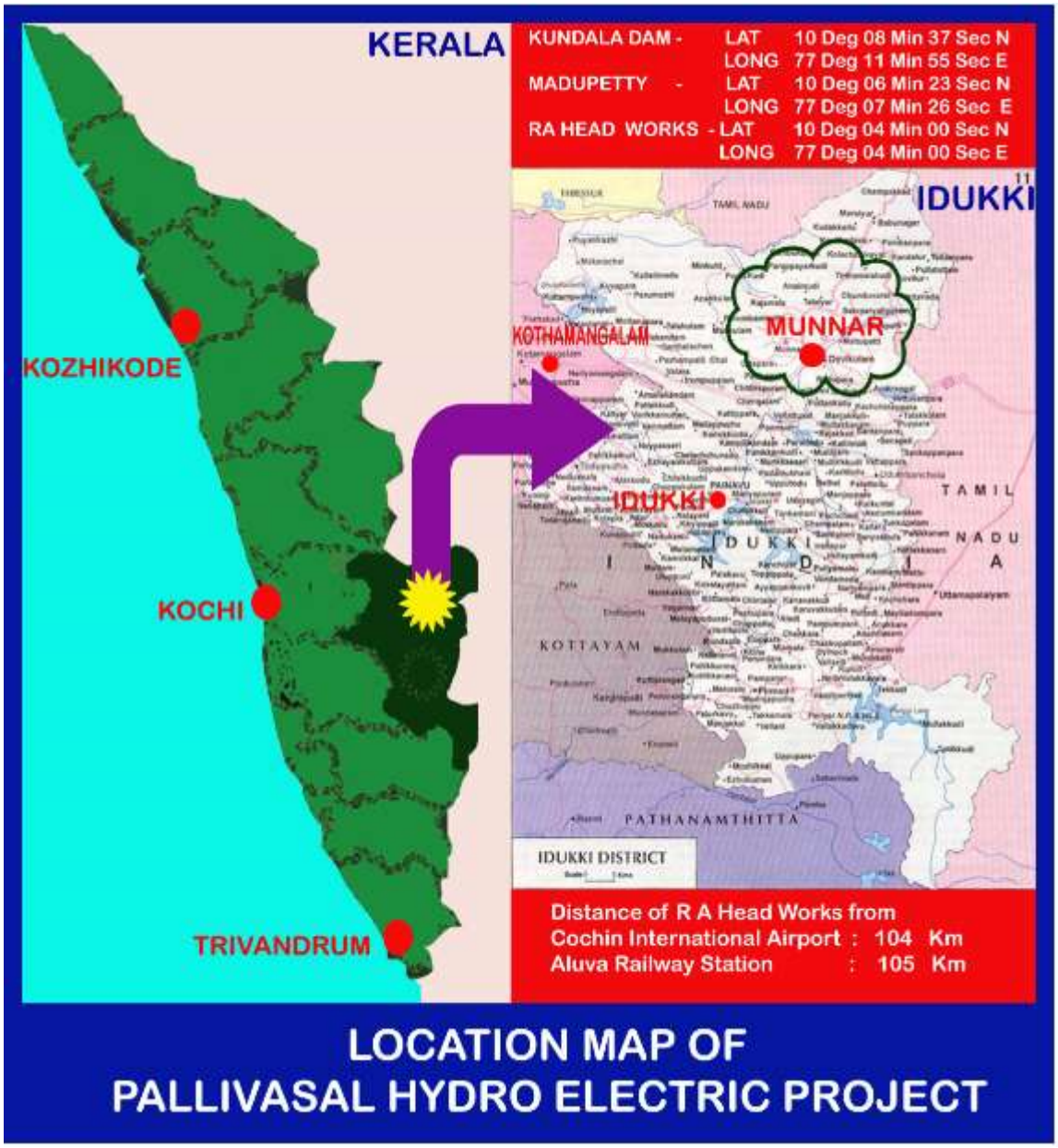

Fig 1.3 Location Map

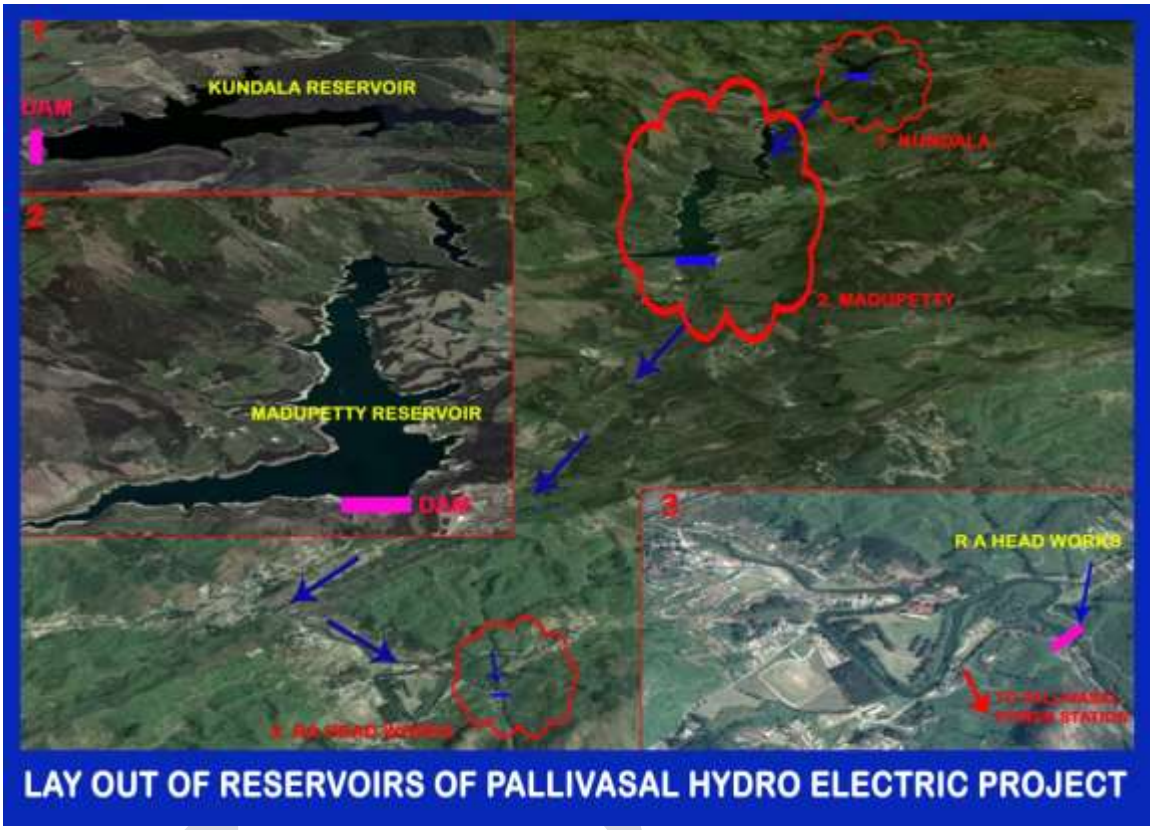

Fig 1.4 Layout of Pallivasal Hydro Electric Project

Fig 1.5 Kundala dam – View from Google Earth

Fig 1.6 Pallivasal Power House – View from Google Earth

1.3 Background Details of the Project

The first stage of the Pallivasal Hydro Electric Scheme with an installed capacity of 13500 KW was commissioned in 1940. The power station, operating on a head of 609.60m, utilised only the run of the river flows of 238.28 sq. km catchment, above the Munnar weir and generated only9000 KW with a flow of 42 cusec (1.19 cumec).

However, since the inauguration of the power generating system, the demand for power rose very steeply throughout the State, and attention was bestowed on the second stage of the Pallivasal Development viz. to regulate the run-off in the catchment by creating storage reservoirs. Various alternative storage sites were examined in the streams above Munnar headworks and finally a combination of two storages, one by constructing a small dam across the Kundala gorge and another by a major dam at the Madupetty gorge were chosen.

1.4 Salient Features of KundalaDam

General		
1	Location	River : Palar River basin : Periyar Sub River basin : Mudirapuzha District : Idukki Panchayat : Devikulam Village : KDH Village Latitude : 10 ° 08'37" N Longitude : 77° 11'55"E
2	Means of Access	The nearest Railway station is Aluva. Nearest Air Port is Cochin International Airport, Nedumbassery, Kochi. Nearest City is Kochi.
Geophysical Features		
1	Catchment area	36.24 sq km
2	Nature of catchment	Comprises of non-absorbent rocky areas with no extensive forest area
3	Mean annual precipitation	2000 mm
4	Geological features at dam site	Rock type - Granitic gneiss, hornblende gneiss and charnockite gneiss
Technical Details of reservoir		
1	Gross Storage Capacity	7.78 Mm^3
2	Live Storage	7.65 Mm^3

3	Dead Storage	0.13 Mm^3
4	Dead Storage Level at MDDL(El.)	+1735.84 m
5	Full Reservoir Level (FRL) (El.)	+1758.69 m
6	Original Maximum Water Level (MWL) (El.)	+1759.30 m
7	Reservoir spread area at FRL	0.65 Sq. km
Dam		
1	Type	Masonry Gravity
2	Nominal Bed Level (El.)	+1733.70 m
3	Spillway Crest level (El.)	+1756.86 m
4	Top Level of Dam	+1759.92 m
5	Length of dam	259m
6	Height above bed level	26.22m
7	Width of Dam at top	3.05 m
8	Type of spillway	Ogee
9	No. of Bays	5
10	Type & size of gates	Vertical Lift gates, 5.18 m (W) X 2.74 m (H)
11	Gate Hoisting Arrangement	Chain and Sprocket type (Manual operation)
12	Spillway capacity	184 m^3/s
13	Energy Dissipation arrangement	Hydraulic Jump type stilling basin
Outlet		
1	No. and Size	1 No. 1.80m dia.
2	Sill level	+1735.84m
3	Maximum Head	22.77m
4	Discharge capacity	14 m^3/s
5	Type of Hoist	Screw operated

Table 1.1 Salient Features of Kundala Dam

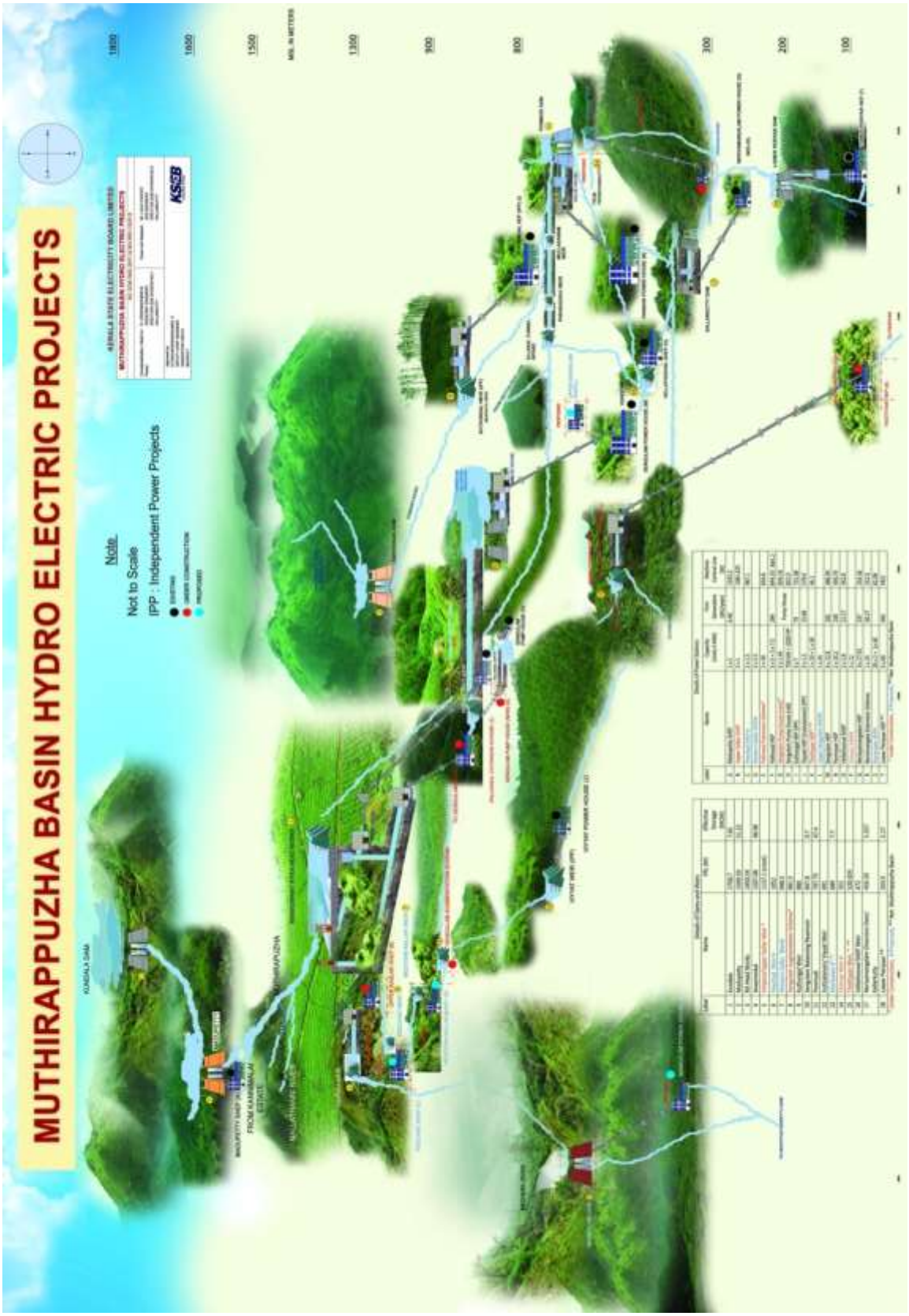

Fig 1.7 Schematic Diagram

1.5 Assignment of Responsibility

Kerala State Electricity Board Ltd is the owner and has the final authority and responsibility for the operation and maintenance of the dam. Identification of all areas of responsibilities connected with the operation and maintenance of the dam are covered in this section. The officer's responsibilities for the various functions (civil, mechanical, electrical, instrumentation etc.) are identified by their designation and, in particular, the responsibilities of operating personnel are specifically identified below, including the regularly scheduled duties, which the staff personnel are required to perform. The same are outlined in the following tables.

Sl. No	Particulars	Remarks
1	Project Administration Officer	Chairman & Managing Director, KSEB Ltd.
2	Chief Controlling Officer	Chief Engineer (Civil – DS&DRIP).
3	Authority of operation of Spillway and Flood releases	Chief Engineer (Civil – DS&DRIP),KSEB Ltd
4	Operation and safety of the dam	Deputy Chief Engineer, Research & Dam Safety Organization & DRIP, KSEB Ltd., Pallom
5	Controlling / Operation Officer at dam site	Executive Engineer, Research & Dam Safety Division No. IV, Pambla.
6	Dam Health Engineer	Executive Engineer, Research & Dam Safety Division No. IV, Pambla.
7	Recording reservoir data, inspection, maintenance	Assistant Executive Engineer, Dam Safety Sub Division, Kallarkutty

Table 1.2 – Overall Responsibilities for Kundala Dam.

1.5.1 Roles and Responsibilities of the AEE and AE during Monsoon

	Flood condition assessment, warning, flood mitigation, and other responsibilities
1	Collect information on the rainfall in the catchment and inflow status and to bring it to the notice of the EE/Dy CE.
2	Assist the EE/ Dy CE /CE to issue notification to the inhabitants downstream in Newspapers, Radio, TV News channel to be alert regarding the flood situation.
3	Assist the EE/ Dy CE /CE to coordinate with the Revenue authorities (District Administration) to alert the downstream inhabitants to evacuate the flood zone to prevent loss of life and livestock.
4	Assist the EE/ Dy CE /CE to coordinate with the CWC flood monitoring authorities on the flood condition
5	Maintain the reservoir water level gauge register and to update on hourly basis during floods and report to EE/ Dy CE /Chief Engineer
6	Assess the inflows in the reservoir as per the approved reservoir operation and to prepare proforma consisting of the status of the reservoir capacity and releases from the reservoir as per the standard Performa and to submit to the EE/ Dy CE /CE
7	Submit to the EE/ Dy CE /CE on the inflows and releases from the reservoir and status of the reservoir twice in the day
8	Maintain the spillway crest gate operation log book
9	Operate the Spillway crest gates for flood mitigation as per the instructions of the EE/ Dy CE /CE and to update the Gate operation Log book
10	Observe and record the seepages and to immediately bring to the notice of the EE/ Dy CE /CE in case of excessive seepage/leakage
11	Observe the gates and see that they are not clogged and floating debris is not deposited in the gate components
12	Monitor the condition of the Welding transformers, gas cutting sets, umbrellas, tool kits, torches, chain blocks, ropes, ballies etc. on daily basis and to see that things are in place to handle any emergency situation
13	Observe the Gates, hoists and handling equipment during operation for the smooth movements and to immediately report any untoward excessive sounds in the motors,

	pumps or vibrations in the gate
14	Observe the dam top, embankment, approach roads are well maintained by housekeeping personnel
15	Observe the performance of the Dam and its appurtenant structures / Gates and Hoists during flood water releases and to report to the EE/ Dy CE /CE in case of any untoward incidents or malfunctioning of the gates or excessive seepages, leakages etc.
16	Assist EE/Dy CE /CE to coordinate with the Generating staff of Pallivasal Power House downstream in the operation and power generation.
17	Assist EE/Dy CE /CE to share the flow data and the reservoir storage details to the Media on day to day basis during flood.

Table 1.3 – Roles & Responsibilities of AEE & AE

1.5.2 Roles and Responsibilities of the DyCE and EE during Monsoon

SL No	Flood condition assessment, warning, flood mitigation, and other responsibilities
1	Conduct Periodical inspections to assess the health of the Dam and to direct the Executive Engineer for the immediate repair and maintenance for the smooth operation.
2	Observe the performance of the Dam and its appurtenant structures / Gates and Hoists before and after monsoon and to issue necessary instructions to the Executive Engineer
3	To issue notification to the inhabitants downstream in Newspapers, Radio, TV News channel to be alert regarding the flood situation
4	Assist the CE to coordinate with the Revenue authorities (District Administration) to alert the downstream villagers to evacuate the flood zone to prevent loss of life and live stock
5	Assist the CE to coordinate with the CWC flood monitoring authorities on the flood condition
6	Submit to the CE the daily inflows and releases from the reservoir and status.
7	Operate the Spillway crest gates for flood mitigation as per the instructions of the CE and to update the Gate operation Log book
8	Observe the seepages and to immediately bring to the notice of the CE in case of

	excessive seepage, leakage
9	Observe the Gates, hoists and handling equipment during operation for the smooth movements and to immediately report any untoward excessive sounds in the motors, pumps or vibrations in the gate
10	Observe the dam top, approach roads are well maintained by housekeeping personnel
11	Observe the performance of the Dam and its appurtenant structures / Gates and Hoists during flood water releases and to report to the CE in case of any untoward incidents or malfunctioning of the gates or excessive seepages, leakages etc.

Table 1.4 – Roles & Responsibilities of DyCE & EE

1.5.3 Roles and Responsibilities of the Chief Engineer during Monsoon

SL No	Flood condition assessment, warning, flood mitigation, and other responsibilities
1	To issue sanction for flood release notification after discussing with Kerala Disaster Management Authority and Revenue Authority (District Administration).
2	Coordinate with the CWC flood monitoring authorities on the flood condition
3	Issue necessary instructions to the Engineers to Operate the reservoir based on the in-flows, rainfall data, releases from the upstream reservoirs and status of the reservoir
4	Observe the performance of the Dam and its appurtenant structures / Gates and Hoists during flood water releases and to issue necessary instructions to the DyCE/EE
5	Coordinate with the Generation wing of KSEBL regarding the power generation requirement.
6	To review and submit the report of Pre and Post Monsoon inspections of the Dam to State Dam Safety Organization with a copy to CWC.

Table 1.5 – Roles & Responsibilities of the Chief Engineer

1.6 Collection & Reporting of Dam and Reservoir Data

Dam Reservoir Data and vital information as below are collected, recorded and documented for the record.

- Reservoir water surface elevation.
- Reservoir inflow.
- Spillway outflow.
- River releases.
- Hydropower releases.
- Weather related data
- Instrumentation data
- Water quality

Sl. No.	Parameter	Frequency of measurement
1	Reservoir water surface elevation	Hourly during monsoon Daily during non-monsoon
2	Reservoir inflow	Hourly during monsoon Daily during non-monsoon
3	Spillway outflow	Hourly during spill
4	River releases	Hourly during monsoon Daily during non-monsoon
5	Hydropower releases	Hourly during monsoon Daily during non-monsoon
6	Weather related data	Daily basis normally During heavy rains at required intervals

Day is defined as from 7 hrs. of the morning of one day to 7 hrs. of morning of the next day.

MWL (m)	FRL (m)	Crest Level (m)	Present Water Level (m)	Previous Year Water Level (m)	Storage (Mm3)	Rainfall (mm)	Generation (Mu)	Spill (Mm^3)	Gate Operation Details

Table 1.6 Daily Reservoir Data

Instruction is given to the Executive Engineer for daily collection and reporting of inflow and outflow data in standard proforma as in **Table 1.6** above to the Deputy Chief Engineer.

On collecting the details in the above format, a daily reservoir status is submitted to the Chief Engineer as in the **Table 1.7.**

Date	Water Level (m)	Previous Year Same day Water Level (m)	Rainfall (mm)	Previous Year Rainfall (mm)	Storage (Mm^3)	Gross Inflow (Mm^3)	Release of water to Madupetty reservoir(Mm^3)	Spill (Mm^3)	Net Inflow (Mm^3)	Remarks

Table 1.7 Daily Reservoir Status

Records/Logbooks of the operations at Kundala Dam are maintained in a chronological manner for reference. These records are also helpful for identifying preventative maintenance measures that may need to be taken up, troubleshooting the cause of potential equipment failure and documenting development of any unusual conditions.

- Date and Time
- Attendance statement during normal operations – both during monsoon and non-monsoon periods.
- Operations of the spillway gates and outlet works.
- Operating hours of mechanical equipment.
- Testing / Operation of spillway gates, and associated controls.
- Maintenance activities carried out.
- Reservoir and dam inspections.
- Unusual conditions or occurrences.
- Safety and special instructions.
- Names of officers and staff carrying out inspections and maintenance.

Periodical collection of Dam and Reservoir Data are done as follows:

Reservoir water surface elevation:	This is collected daily during non-monsoon and hourly during monsoon
Reservoir inflow:	This is calculated daily during non-monsoon and hourly during monsoon
Spillway outflow:	This is calculated during spill
Hydropower releases:	The reservoir water is used for power generation
Weather related data:	Collected and reported daily during non-monsoon and during heavy rains at required intervals
Security arrangements:	Provided in dam and premises round the Clock. CCTV surveillance will be provided soon covering the dam and premises.
Water quality:	The quality of water is to be tested.
Attendance statement during normal operations	Both during monsoon and non-monsoon period maintained at field office
Operations of the spillway gates and outlet works	Take record of actual operations
Operating hours of mechanical equipments	Maintained at field office
Testing/Operation of spillway gates and associated controls	The testing and operation are being carried out as per the manual and maintenance schedule. Other details maintained at field office
Testing/operation of Outlet gates, valves and associated controls	Maintained at field office
Maintenance activities carried out	Details maintained at field office
Reservoir and dam inspections	Periodically inspected and details maintained at field office
Unusual conditions or occurrences, including acts of vandalism	Details maintained at field office
Attendance statement at dam during	Details maintained at field office

emergency operations	
Changes to normal operating procedure	Details maintained at field office
Communication network checks:	Regularly checked and maintained
Safety and special instructions:	Safety equipment provided
Names and addresses of official visitors:	Record of inspections maintained at office.

1.7 Public and Project Staff - Health and Safety

As safety of Project Staff is of prime concern, safety instructions & protection measures at the dam are to be followed by all staff / project personnel. Security personnel are posted for providing public notices of events and status of security of the dam and downstream river conditions.

Access Roads

Kundala dam is about 25km from Munnar. The dam is accessible from Munnar – Top Station highway via Kundala road. The nearest Railway station is Aluva which is at a distance of 133km and can be reached via NH85.Nearest Air Port is Cochin International Airport, Nedumbassery which is at a distance of 131km and can be reached via NH85.Nearest City is Kochi which is at a distance of 152km via NH85.

Location of public utilities / conveniences

Inspection Bungalow is located at Munnar, about 25km from Kundala dam. Nearest police station is located at Munnar. Primary Health Centre is located at Vattavada, 20 km away from dam and can be reached via Munnar – Top Station highway and Koviloor road.

Safety equipment available at the dam: First aid kit and fire extinguishers are available.

1.8 Restricted Areas

Certain areas of the dam and reservoir are restricted for entry of the general public. The purpose of restrictions is for security of the dam, public safety and uninterrupted safe operation of the dam. Restricted areas will include the following:

- Spillway approach areas, chutes and energy dissipation arrangements.

Sign boards are displayed at the prohibited areas of the dam.

1.8.1 Details of the Security arrangements at Kundala Dam Site

Security arrangements are provided through private agency (Ex – Servicemen) in dam and premises round the clock. One security personnel per shift is posted in 3 shifts. Also CCTV surveillance will be provided soon covering the dam and premises.

1.9 Staff Position, Communication & Warning System

An engineering organizational chart for the control and safety of Kundala dam is shown in **Figure 1.8** below. Means of communications both in normal and emergency situations are identified in the Communication Directory. Communication means available include land line, mobile phone and satellite phones.

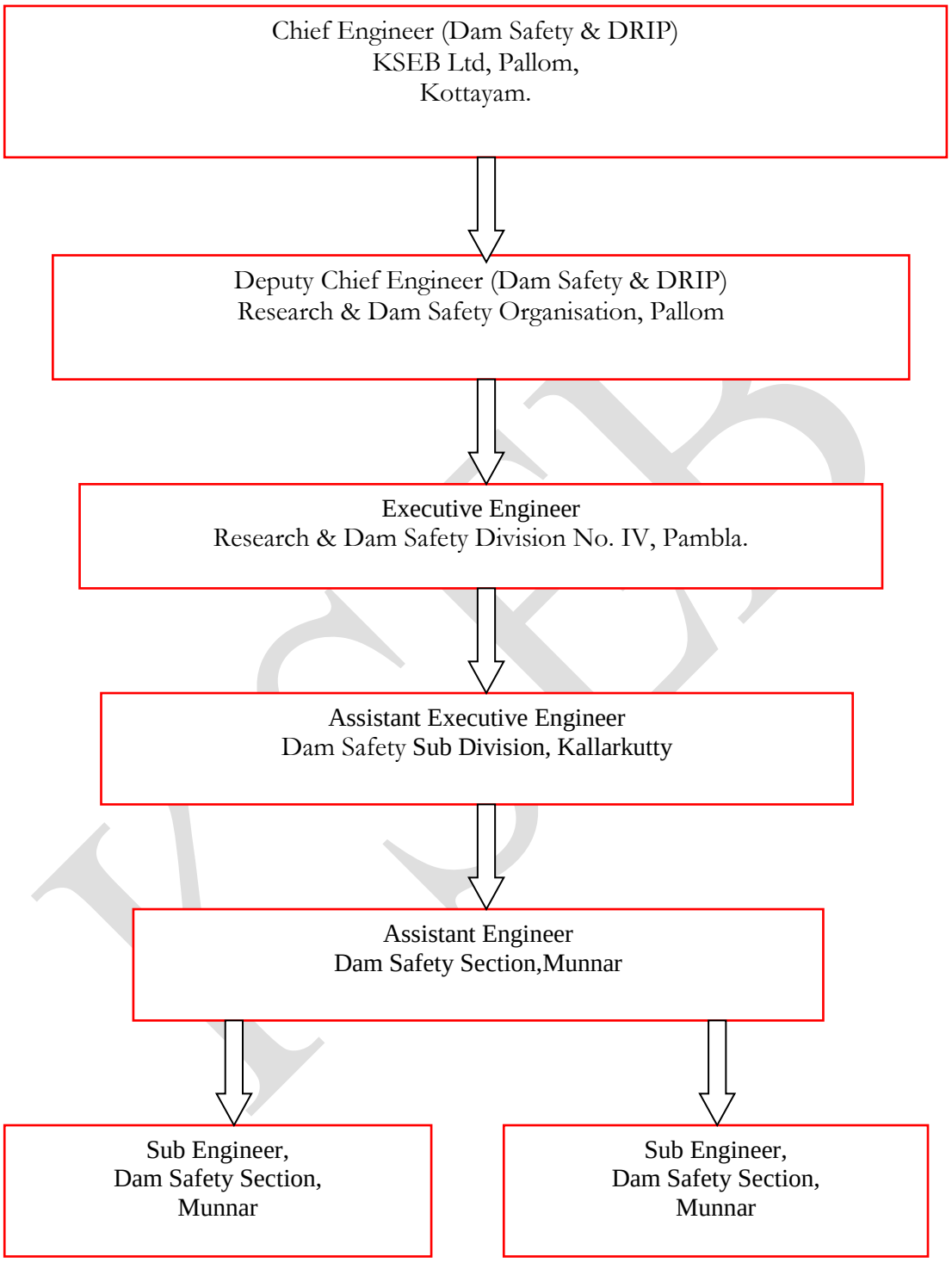

Fig 1.8 – Dam Safety Organisation Structure for Kundala Dam

Present hierarchy of Controlling officers and their contacts are as below:

Chief Engineer Civil (Dam safety & DRIP), KSEBL, DSO Building, Pallom, Kottayam
Phone: 9496018719, e-mail: cedamsafety@gmail.com

Deputy Chief Engineer, Research & Dam Safety Organization, Pallom
Phone: 9446008492, 0481-2432290, 9496011540 e-mail: dirroplm2@gmail.com.

Executive Engineer, Research and Dam Safety Division No.IV, Pambla
Phone: 9446008421, e-mail:eerdspambla@gmail.com

Assistant Executive Engineer, Dam Safety Sub Division, Kallarkutty
Phone: 9496011963, e-mail: aeedskty@gmail.com

Assistant Engineer, Dam Safety Section, Munnar.
Phone: 9496011964

Spillway flood releases

As per the guidelines issued by the Central Water Commission for developing Emergency Action Plan for Dams issued in February, 2016 (Doc. No. CDSO_GUD_DS_01_v2.0), a three colour alert system (Blue, Orange and Red) shall be issued by the dam owner on detecting a distress in the dam according to the nature of the emergency level, to the various statutory authorities in charge of District Administration, Disaster Management etc. in order to take appropriate action to reduce the risk to lives and property from the consequences of potential dam failures. The above guidelines also envisage using the alerts in the case of a large controlled release from the dam due to severe weather and emergency conditions.

For Kundala reservoir, Blue Alert is given as water level reaches +1755m, Orange Alert at +1756m and Red Alert at +1757m for opening of spillway gates. Warnings are given in local media including TV etc. regarding the possible opening of spillway gates continuously up to +1758.69m level (FRL). Also, intimations are given to Disaster Management, District Administration, and Police Department etc. Spillway gates are opened at +1758.69m level (FRL) based on 'Guidelines for Operation of Reservoirs' (IS 7323:1994) and Gate Operation Manual.

The alert level is fixed considering the normal rainfall intensity and for general guidance. In the case of extreme rainfall event or identifying any distress in the dam, appropriate protective action shall be initiated by the Dam managers. Sanction has to be obtained from the District Collector, Idukki for spilling the water. Release from the dam will be contained in the river course and no evacuation is required in normal course.

Release for hydropower

The water stored in Kundala reservoir is released to the downstream Madupetty reservoir through the river when storage in Madupetty reservoir is below 50% (50% level - +1587.90m). The water stored in the Madupetty reservoir plus the water released from Kundala is further released to downstream through a Dam Toe Power Station having a capacity of 2MW. R A Head Works, a gated diversion structure, constructed downstream of Madupetty helps to divert the water released from the upstream reservoir as well as the inflow from own catchment to Pallivasal Power Station with installed capacity 37.5MW for generating power.

Routine inspection

Usually monthly inspection and quarterly inspections as per KDSA are carried out by the operating/controlling officers. Pre-monsoon inspection and Post-monsoon inspection as per CWC guidelines are carried out and reports are supplied to CWC. The pre-monsoon and post-monsoon reports are to be updated in DHARMA web site.

Maintenance

Routine maintenance is carried out for Spillway gates, sluice gate as part of routine maintenance before the onset of monsoon. Details are given under the Chapter, Project Maintenance.

1.10 Typical Schedule of Duties

Sl. No.	Component/ Duty	Frequency	Personnel
1	Visual inspection of dam including Crest of dam (Dam top), Upstream and downstream faces, visible portions of	Daily	Sub Engineer/Dam operators on contract

	foundation and abutments, Spillway and its energy dissipation arrangements		
2	Record water surface elevation, reservoir inflow and spillway discharge.	Daily (Hourly basis during monsoon)	Sub Engineer/Dam operators on contract
3	Record meteorological data, Record releases from outlets /sluices	Daily	Sub Engineer/Dam operators on contract
4	Check security and safety devices, Complete logbook / site register which include the above information.	Daily	Assistant Engineer
5	Record seepage from drainage systems etc. and record meteorological data.	Weekly	Sub Engineer/Dam operators on contract
6	Visual inspection of dam including Crest of dam (Dam top), Upstream and downstream faces, visible portions of foundation and abutments, Spillway and its energy dissipation arrangements	Weekly	Assistant Engineer
7	Check stand by generator (DG Sets), Drainage systems etc.	Weekly	Assistant Engineer
8	Visual inspection of dam including Crest of dam (Dam top), Upstream and downstream faces, visible portions of foundation and abutments, Spillway and its energy dissipation arrangements	Fort nightly	Assistant Executive Engineer
9	Check security and safety devices, logbook and site register which include the above information.	Fort nightly	Assistant Executive Engineer
10	Check stand by generator (DG Sets), Drainage systems, etc.	Fort nightly	Assistant Executive Engineer
11	Measuring devices, communication devices, status of instruments, vegetation growth	Fort nightly	Assistant Executive Engineer
12	Check Sign/Warning display boards near vulnerable locations	Fort nightly	Assistant Executive Engineer
13	Visual inspection of dam including Crest of dam (Dam top), Upstream and downstream faces, visible portions of foundation and abutments,	Monthly	Executive Engineer

	Spillway and its energy dissipation arrangements		
14	Check measuring devices/Instruments, Security and safety devices, Communication Devices, Status of Vegetation growth – rectification, if needed.	Monthly	Executive Engineer
15	Check Sign/Warning display boards near vulnerable locations	Monthly	Executive Engineer
16	Replace fuse light bulbs, Inspect to maintain ventilation system, cleaning of control panel boards.	Monthly	Assistant Engineer
17	Check outlet works, updating operating instruction, check gate air vents, clean gate control switchboxes, check operation of gates, grease gate hanger/dogging	Quarterly	Executive Engineer
18	Check condition of Outlet works and its Energy Dissipation Arrangement	Quarterly	Executive Engineer
19	Check condition of spillway, 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.	Quarterly	Executive Engineer
20	Check for adherence to instrumentation schedule, Record pertinent information in Operation of Gates, Check condition of V-notch/seepage measuring devices, Check hydro mechanical components.	Quarterly	Executive Engineer
21	Inspection of Spillway & outlet works, hydro mechanical components, Check paint on gates and valves, Check lubrication of wire ropes and application of cardium compound, Check lubrication of chains and application of grease, Check mechanical hoist bearings and flexible coupling bearings, Check gear systems, Exercise gates and valves, Check oil	Half yearly (Pre and Post Monsoon)	Deputy Chief Engineer along with Executive Engineer in charge of dam

	reservoir level in hydraulic system, Check pressure release valve, Check lubrication of gate rollers, Check rubber seals and seal clamp bar.		
22	Submission of Pre and Post monsoon Inspection report to State DSO, CWC and uploading into DHARMA.	Half yearly	Chief Engineer/Deputy Chief Engineer
23	Comprehensive inspections of Dam Safety Authority of KSEB.	Annually	Dam Safety Authority along with Dam Owners
24	Inspect dam and gate structures and stilling basin / energy dissipation arrangement, which normally are underwater (by dewatering or by divers/ROV as necessary).	Five Yearly	Chief Engineer/Deputy Chief Engineer
25	Comprehensive inspection of performance of the dam and gate structures and reservoirs and stilling basin/energy dissipation arrangement by DSRP.	Ten Yearly	DSRP
26	Review O&M Manual and EAP and update as necessary	Ten yearly	Executive Engineer

Table 1.8 Schedule of duties/inspections

1.11 Hydro-Mechanical Inspections / Checks

Special duties required to be performed by H-M operating personnel are given in this section. Frequency of inspections / checks for hydro-mechanical components and necessary actions to be taken up during maintenance are as under:

1. Gates

a. Embedded Parts

Sl. No	Embedded Part	Frequency
1	Checking of horizontal and vertical seals beams. Seal Seats, Guide track & all other exposed embedded parts with respect to their	Half Yearly

	alignment, distortion :if any due to continuous use, pitting and un-necessary cracks due to wear & carrying out requisite repairs, rectification by welding, grinding etc.	
2	Removing debris & other foreign material deposited on embedded parts& cleaning the same.	Monthly
3	All cracks & defective weld joints to be ascertained & rectified.	Half Yearly

Gate structure

Sl. No	**Gates and Hoists**	**Frequency**
1	Regular inspection of the gate along with the hoist to be carried out to ensure that there is no unusual development/ observation	Yearly
2	Check all welding/riveting for soundness & rectify defects	Quarterly
3	Check upstream & downstream face of Skin plate for pitting, scaling and corrosion. Scaling formation is to be removed. Pitting shall be filled with weld and corroded surface shall be cleaned & painted.	Yearly
4	Joints of side & bottom metal seals to be checked for their proper alignment and fixing & to be rectified/ adjusted if there is leakage through joints	Yearly
5	The excessive or widespread leakages if any shall be reported to the Engineer in charge. If the seals are required to be replaced the same shall be carried out.	Quarterly
6	The guide roller & thrust roller pin are to be lubricated	Yearly

2. River outlet valve

Sl. No	**Outlet valve**	**Frequency**
1	Regular inspection of components of valve to be carried out to ensure that there is no unusual development/ observation	Yearly
	Metal seals to be checked. If the seals are required to be replaced the same shall be carried out.	Yearly

Table 1.9 Frequency of inspection of Hydro Mechanical components

1.12 Supporting Documents & Reference Material

This O&M Manual is the key instruction document. Supporting documents and necessary instructions for all phases of the operation, inspection and maintenance of the dam, reservoir and appurtenant works shown below are available at the dam control room:

- Emergency Action Plan (EAP)
- Flood forecasting and operating criteria
- Basin or river operating plan
- Administrative procedures
- Reservoir / River pollution contingency plan
- Maintenance schedules
- Gate Manufacturer's instructions and drawings
- Regional communication directory
- Instrumentation reports / results
- Latest dam design flood review and flood routing study report
- All drawings of dam (Civil, Mechanical & Electrical)

1.13 Distribution of Operation & Maintenance Manuals

The list of officers to whom the O&M Manual is required to be distributed is shown in the table below.

Sl. No.	Officer	Number of Manual Distribution
1	Director Generation (Civil), KSEBL, Vydyuthi Bhavan, Thiruvananthapuram	1
2	Chief Engineer Civil (Dam Safety & DRIP), KSEBL, Pallom, Kottayam	1
3	Deputy Chief Engineer, Research & Dam Safety Organization, Pallom	1
4	Executive Engineer, Research & Dam Safety Division No. IV, Pambla	1
5	Assistant Executive Engineer,	1

	Research & Dam Safety Sub Division, Kallarkutty	
6	Assistant Engineer, Research & Dam Safety Section, Munnar	1
7	Dam Operator's Room at Dam Site.	1

Table 1.10 Distribution of O&M Manual and Revisions

CHAPTER 2

PROJECT OPERATION

2.1 Basic Data

The Kundala operation plan contains instructions for operating the dam and reservoir during routine (normal) and emergency conditions. The operating procedures for normal operations are discussed in this chapter including operating criteria for the reservoir, spillway and outlets. The operation of a dam involves regulation of its reservoir as per rule curve/ project specific requirements.

2.1.1 Elevation Capacity curve

The Elevation – Capacity Curve for Kundala Reservoir in tabular and graphical form are shown in **Fig. 2.1** and **Table 2.1**.

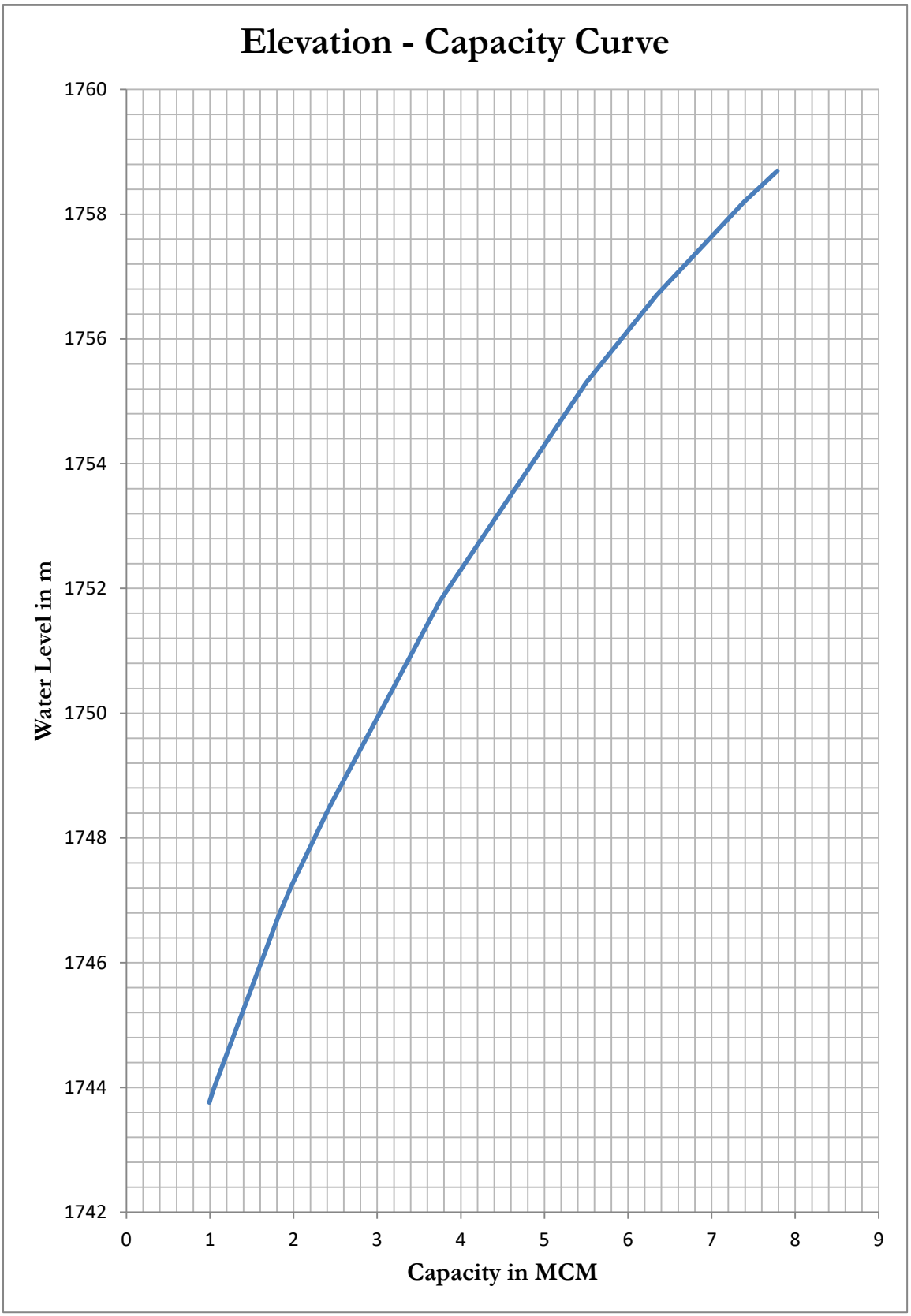

Fig 2.1 - Elevation capacity curve for Kundala Reservoir

ELEVATION - CAPACITY OF KUNDALA RESERVOIR					
Reservoir level in m	**Gross Capacity in MCM**	**Reservoir level in m**	**Gross Capacity in MCM**	**Reservoir level in m**	**Gross Capacity in MCM**
1743.76	0.99	1751.30	3.55	1755.10	5.40
1744.00	1.05	1751.40	3.59	1755.20	5.45
1744.25	1.12	1751.50	3.63	1755.30	5.50
1744.50	1.19	1751.60	3.67	1755.40	5.56
1744.75	1.26	1751.70	3.71	1755.50	5.62
1745.00	1.33	1751.80	3.75	1755.60	5.68
1745.25	1.40	1751.90	3.80	1755.70	5.74
1745.50	1.47	1752.00	3.85	1755.80	5.80
1745.75	1.54	1752.10	3.90	1755.90	5.86
1746.00	1.61	1752.20	3.95	1756.00	5.92
1746.25	1.68	1752.30	4.00	1756.10	5.98
1746.50	1.75	1752.40	4.05	1756.20	6.04
1746.75	1.82	1752.50	4.10	1756.30	6.10
1747.00	1.90	1752.60	4.15	1756.40	6.16
1747.25	1.98	1752.70	4.20	1756.50	6.22
1747.50	2.07	1752.80	4.25	1756.60	6.28
1747.75	2.16	1752.90	4.30	1756.70	6.34
1748.00	2.25	1753.00	4.35	1756.80	6.41
1748.25	2.34	1753.10	4.40	1756.90	6.48
1748.50	2.43	1753.20	4.45	1757.00	6.55
1748.75	2.53	1753.30	4.50	1757.10	6.62
1749.00	2.63	1753.40	4.55	1757.20	6.69
1749.25	2.73	1753.50	4.60	1757.30	6.76
1749.50	2.83	1753.60	4.65	1757.40	6.83
1749.75	2.93	1753.70	4.70	1757.50	6.90
1750.00	3.03	1753.80	4.75	1757.60	6.97
1750.10	3.07	1753.90	4.80	1757.70	7.04
1750.20	3.11	1754.00	4.85	1757.80	7.11
1750.30	3.15	1754.10	4.90	1757.90	7.18
1750.40	3.19	1754.20	4.95	1758.00	7.25
1750.50	3.23	1754.30	5.00	1758.10	7.32
1750.60	3.27	1754.40	5.05	1758.20	7.39
1750.70	3.31	1754.50	5.10	1758.30	7.47
1750.80	3.35	1754.60	5.15	1758.40	7.55
1750.90	3.39	1754.70	5.20	1758.50	7.63
1751.00	3.43	1754.80	5.25	1758.60	7.71
1751.10	3.47	1754.90	5.30	1758.70	7.79
1751.20	3.51	1755.00	5.35		

Table 2.1 Elevation – Capacity of Kundala Reservoir

2.2 Operation Plan

An effective operation plan and schedule is required for the safe project operation for which the project specific features shall be known. Salient features of the Reservoir are given below.

Salient features

Original Maximum Water Level (MWL)	-	+1759.30 m
Full Reservoir Level (FRL)	-	+1758.69 m
Minimum Draw Down Level (MDDL)	-	+1735.84 m
Gross storage	-	7.78 Mm^3
Live storage	-	7.65 Mm^3
Water spread area at FRL	-	0.65 sq km

2.2.1 Data of the historic floods

As per historical records, the maximum flood observed in Western Ghats was during 1924. The centre of the storm of the 1-day rainfall of 17th July 1924 and 2-day rainstorm of July 16-17 was located at Devikulam in Kerala in which rain fall of 484 mm and 751 mm respectively was recorded.

The SW monsoon of the year 2018 in the State was similar to that of 1924Devikulam storm and Kerala experienced an abnormally high rainfall from 1 June 2018 to 19 August 2018 which resulted in severe flooding in 13 out of 14 districts in the State. It is seen that the 2-day and 3-day rainfall depths of 15 -17, August 2018 rainfall in Pamba, Periyar and Bharathapuzha sub-basins are almost comparable to the Devikulam storm of 16-18, July 1924. Out of 758.6 mm rainfall from 1 August 2018 to 19 August 2018, about 414 mm rainfall occurred in just three days viz. 15-17, August 2018, which created severe flooding in the state.

Spill details of the year 2018 are tabulated below in **Table 2.2**.

Date	Water Level	Gross Inflow	Spill	Date	Water Level	Gross Inflow	Spill
	m	MCM	MCM		m	MCM	MCM
17-08-2018	1758.5	1.296	0.216	17-10-2018	1757.65	0.346	0.346
18-08-2018	1758.5	0.216	0.216	18-10-2018	1757.65	0.346	0.346
19-08-2018	1758.4	0.136	0.216	19-10-2018	1757.65	0.346	0.346
20-08-2018	1758.4	0.216	0.216	20-10-2018	1757.65	0.346	0.346

21-08-2018	1758.5	0.188	0.108	21-10-2018	1757.65	0.346	0.346
22-08-2018	1758.5	0.108	0.108	22-10-2018	1757.65	0.346	0.346
23-08-2018	1758.4	0.028	0.108	23-10-2018	1757.65	0.346	0.346
24-08-2018	1758.4	0.108	0.108	24-10-2018	1757.65	0.259	0.259
25-08-2018	1758.3	0.028	0.108	25-10-2018	1757.65	0.259	0.259
26-08-2018	1758.3	0.108	0.108	26-10-2018	1757.65	0.259	0.259
27-08-2018	1758.3	0.108	0.108	27-10-2018	1757.65	0.173	0.173
28-08-2018	1758.3	0.108	0.108	28-10-2018	1757.65	0.130	0.130
29-08-2018	1758.3	0.108	0.108	29-10-2018	1757.65	0.130	0.130
30-08-2018	1758.3	0.054	0.054	30-10-2018	1757.65	0.130	0.130
31-08-2018	1758.3	0.054	0.054	31-10-2018	1757.65	0.086	0.086
01-09-2018	1758.3	0.054	0.054	01-11-2018	1757.70	0.121	0.086
02-09-2018	1758.25	0.014	0.054	14-11-2018	1758.45	0.213	0.173
03-09-2018	1758.25	0.054	0.054	15-11-2018	1758.40	0.306	0.346
04-09-2018	1758.25	0.054	0.054	16-11-2018	1758.40	0.346	0.346
05-09-2018	1758.25	0.054	0.054	17-11-2018	1758.60	0.592	0.432
06-09-2018	1758.25	0.054	0.054	18-11-2018	1758.60	0.346	0.346
07-09-2018	1758.25	0.054	0.054	19-11-2018	1758.55	0.306	0.346
08-09-2018	1758.25	0.054	0.054	20-11-2018	1758.50	0.306	0.346
09-09-2018	1758.25	0.043	0.043	21-11-2018	1758.45	0.306	0.346
10-09-2018	1758.25	0.043	0.043	22-11-2018	1758.45	0.173	0.173
11-09-2018	1758.25	0.043	0.043	23-11-2018	1758.45	0.130	0.130
12-09-2018	1758.25	0.043	0.043	24-11-2018	1758.50	0.170	0.130
13-09-2018	1758.25	0.043	0.043	25-11-2018	1758.50	0.130	0.130
14-09-2018	1758.25	0.043	0.043	26-11-2018	1758.50	0.130	0.130
15-09-2018	1758.20	0.003	0.043	27-11-2018	1758.50	0.130	0.130
16-09-2018	1758.20	0.043	0.043	28-11-2018	1758.45	0.090	0.130
17-09-2018	1758.20	0.043	0.043	29-11-2018	1758.45	0.130	0.130
18-09-2018	1758.20	0.043	0.043	30-11-2018	1758.45	0.130	0.130
19-09-2018	1758.20	0.043	0.043	01-12-2018	1758.45	0.130	0.130
20-09-2018	1758.15	0.008	0.043	02-12-2018	1758.45	0.130	0.130
21-09-2018	1758.15	0.043	0.043	03-12-2018	1758.40	0.090	0.130
22-09-2018	1758.10	0.008	0.043	08-12-2018	1758.65	0.256	0.216
23-09-2018	1758.10	0.043	0.043	09-12-2018	1758.65	0.216	0.216
24-09-2018	1758.10	0.043	0.043	10-12-2018	1758.65	0.216	0.216
25-09-2018	1758.30	0.193	0.043	11-12-2018	1758.60	0.219	0.259
26-09-2018	1758.35	0.083	0.043	12-12-2018	1758.55	0.219	0.259
27-09-2018	1758.35	0.043	0.043	13-12-2018	1758.50	0.176	0.216
28-09-2018	1758.35	0.043	0.043	14-12-2018	1758.45	0.176	0.216
29-09-2018	1758.70	0.320	0.043	15-12-2018	1758.40	0.090	0.130
30-09-2018	1758.60	0.182	0.259	16-12-2018	1758.45	0.126	0.086
01-10-2018	1758.40	0.056	0.216	17-12-2018	1758.45	0.086	0.086
02-10-2018	1758.35	0.176	0.216	18-12-2018	1758.45	0.086	0.086

03-10-2018	1758.30	0.176	0.216	19-12-2018	1758.45	0.086	0.086
04-10-2018	1758.30	0.432	0.432	20-12-2018	1758.45	0.086	0.086
05-10-2018	1758.10	0.282	0.432	21-12-2018	1758.45	0.086	0.086
06-10-2018	1758.00	0.362	0.432	22-12-2018	1758.45	0.086	0.086
07-10-2018	1758.10	0.502	0.432	23-12-2018	1758.45	0.086	0.086
08-10-2018	1758.05	0.181	0.216	24-12-2018	1758.45	0.086	0.086
09-10-2018	1758.05	0.216	0.216	25-12-2018	1758.45	0.086	0.086
10-10-2018	1758.05	0.216	0.216	26-12-2018	1758.45	0.086	0.086
11-10-2018	1758.00	0.181	0.216	27-12-2018	1758.45	0.086	0.086
12-10-2018	1757.80	0.292	0.432	28-12-2018	1758.45	0.086	0.086
13-10-2018	1757.70	0.276	0.346	29-12-2018	1758.45	0.086	0.086
14-10-2018	1757.70	0.346	0.346	30-12-2018	1758.45	0.086	0.086
15-10-2018	1757.65	0.311	0.346	31-12-2018	1758.45	0.086	0.086
16-10-2018	1757.65	0.346	0.346				

Table 2.2 – Spill details

2.2.2 Design Flood and Features Related to Safety

Hydrology

The Pallivasal Project utilises the waters of the Mudirapuzha river, a tributary of the Periyarriver having its source in the High Ranges of the Western Ghats. This river is fed by several streams rising in the surrounding hills. The catchment area above headworks of the project is about 238.28 sq km, and most of this area experiences rains both during south-west and north-east monsoons. Rainfall within this catchment varies annually from 5778mm in certain areas to 1460mm in others with an average per sq km of 1111mm over the entire catchment area. The river flow varies from 849.50 cumec during heavy flood period to a recorded minimum of 1.22 cumec over a period of 3 days in the driest season of an exceptionally dry year. The minimum flow during an average dry year at Munnar Head Works is 1.98 cumec.

The Kundala storage utilises only 38.85 sq km of this catchment in the upper region of Palar stream with an average rainfall of 2000 mm in the catchment. The annual run-off of a normal year is estimated to be 36.10 Mm^3, but the economical storage in Kundala reservoir is only 7.78 Mm^3. The run-off in the catchment depends entirely upon rainfall for the water supply. Owing to lack of extensive forest areas and presence of non-absorbent rocky areas, the run-off is high. The chances of high floods are therefore high.

Climate

The location of the Project is in the High Ranges, above an elevation of 1372m. The climate is healthy and there are three major seasons viz. summer, winter and monsoon as is a general pattern of climate in Kerala. The summer is usually from February to June. The monsoons are from June to October and the winter from November to January in a normal year.

Water Spread:

Water spread area of Kundala reservoir at F.R.L is 0.65 sq. km.

Hydrology Review

The revised design flood of Kundala reservoir (Pallivasal HEP) has been estimated based on unit hydrograph derived as per FER 5 (a) & (b) published by Central Water Commission. The Central Water Commission has approved a revised design flood with peak discharge as 892 m^3/s. The spillway capacity is 184 m^3/s. The revised design flood peak now becomes more than five times that of the spillway capacity. The revised flood PMF is estimated from a PMP value derived after transposing 1 day storm occurred at Devikulum in 1924. According to the criteria of hydraulic head the design storm of the reservoir shall be SPS and design flood shall be SPF. But it will not also help to reduce the design flood peak by more than 30% of the PMF. So far the reservoir never had to tackle a flood more than its original design flood since the project is completed in 1947.

As per studies carried out, the dam gets overtopped with the revised flood. Further the margin between FRL and original MWL is only 60 cm. As such the available provision in the reservoir to hold the water in the reservoir during such an extreme flood condition is limited. Pre-depletion of the reservoir is also not practical as the time travel of the flood peak is less than one hour as the terrain is very steep and equivalent slope is quite large. There is no provision to augment the spill way capacity due to practical constraints and even with larger spillway dimension; the river downstream cannot safely pass the heavy abnormal flood to downstream. Hence for the time being it is proposed to conduct dam break analysis and evolve emergency action plan to take care of extreme scenario resulting from an abnormal flood situation.

2.3 Kundala Dam

Kundala dam is a rubble masonry gravity dam and is curved in plan, aligned to suit the foundation rock and has radii varying from 103.63m to 195.07m. The dam is keyed into the abutment hills by means of masonry core walls 30.48m long on the left bank and 38.10m long on the right bank.

The spillway section in the center is from ch. 105.16m to ch. 138.68m.The abutments on either side from ch. 74.68m to 104.85m and ch. 138.68m to 173.43m are designed as gravity structure with 50% hydro static uplift.

The core walls on the sides have a top width of 1.22m and 1:20 batter on either side. The above construction is of cement mortar 1:4. In the spillway up to +1746.50m, the heel portion up to 1.52m downstream of the vertical face is of cement mortar 1:2 $^{1}/_{2}$ and above RL. 1746.50m of cement mortar 1:3. All the rest of the masonry in this reach is of 1:4 mortar. In all other sections, up to +1746.50m, the front face is of 1:2 $^{1}/_{2}$ mortar, and the rear is with 1:4 mortar. Above +1746.50m, the proportions of mortar changes to 1:3 and 1:5 respectively.

Except for the core wall, the heel side of all other sections had a batter of 1:10 up to El. +1744.67m, 1:17.5 from +1744.67m to +1755.34m and no batter above +1755.34m. On the rear side the spillway has a batter of 0.16m to 0.30m. The abutments with 50% uplift have a batter of 0.18m to 0.30m on the rear. The rest of the section has a batter varying from 0.18m to 0.30m to 0.05m to 0.30m.

The length of dam at top is 259m and width of dam at top is 3.05m. Height above bed level is 26.20 m. There is no inspection gallery in the dam. A 0.91m diameter opening has been provided for collecting drainage water in the dam in place of the gallery.

Fig 2.2 Kundala Dam

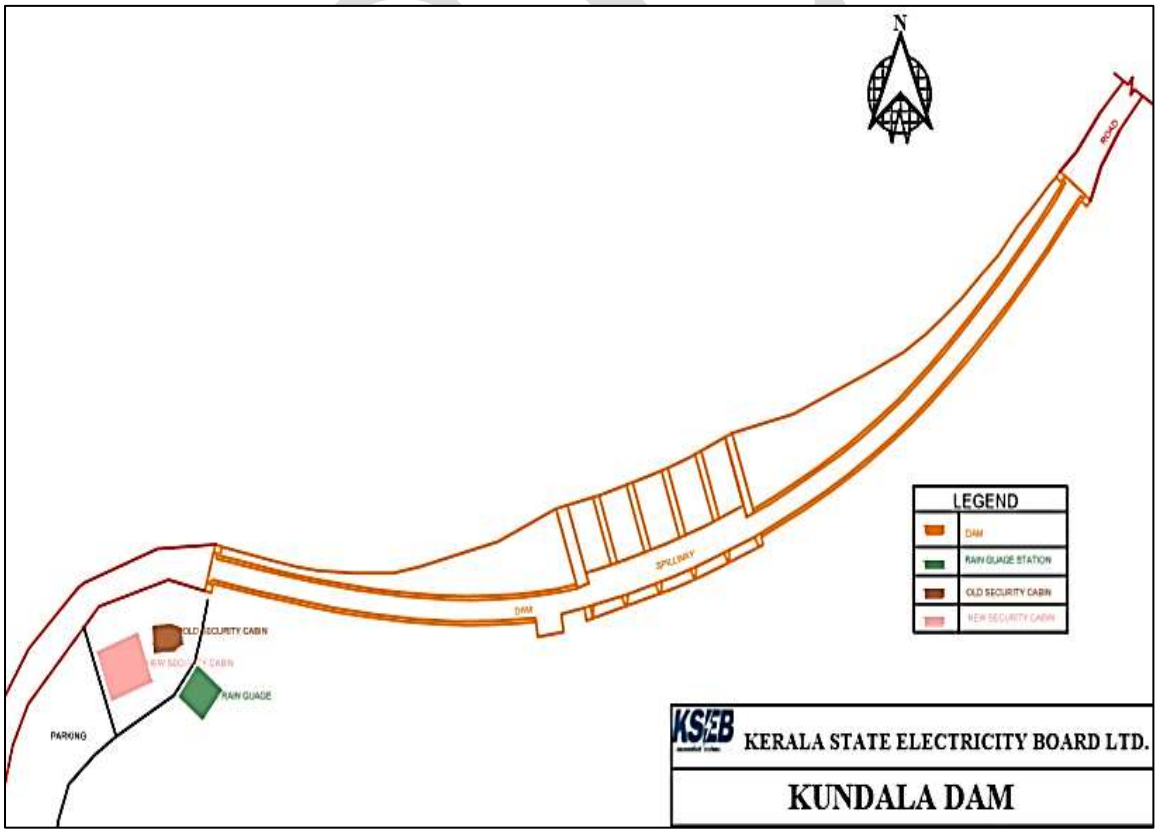

Fig 2.3 Plan of Kundala dam

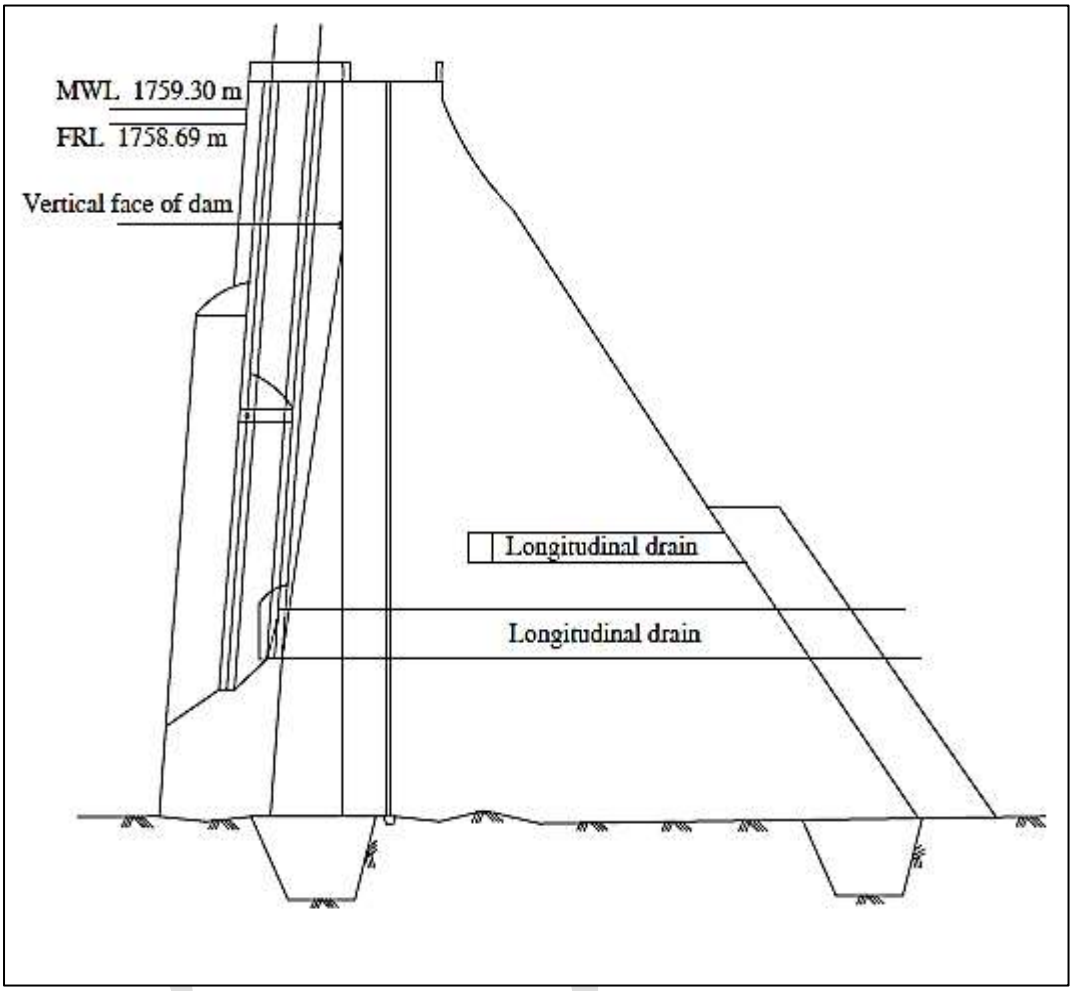

Fig 2.4 Section of Kundala dam

2.3.1 Components

Spillway

Spillway is ogee type with 5 bays. Vertical Lift Gates of size 5.18 m x 2.74 m are installed for controlling the flood discharge. Chain and sprocket type gate hoisting arrangement is provided. Crest level of spillway is +1756.86 m. The Spillway is designed for a maximum discharge of 184cumec. Dissipation of energy of the water falling from the ogee crested spillway is effected by providing hydraulic jump type stilling basin.

The five spillway spans are formed by RCC piers built up from elevation +1754.43m. The piers are about 6.10m across including the cantilever portion (i.e. in direction parallel to flow) and are about 1.22m thick with a slight taper toward the rear. There are masonry training walls on both sides of the spillway on the downstream.

Crest Gates

Five Vertical Lift Gates of size 5.18 m x 2.74 m are installed in the spillway. The gates are of fixed roller type and in the closed position cover elevations from +1755.95m to +1758.70m, providing additional storage of nearly 1.416 Mm^3 above the crest of spillway. The hoists of the gates are of screw type and are operated by manual labour from dam top and are provided with slow and fast gears. The gate is opened by using an operating lever put in position at a stud. There are two studs one for fast mode and the other for slow mode of operation. For opening the gate in fast mode, turn the operating lever in anticlockwise direction and for opening the gate in the slow mode, turn the operating lever in clockwise direction. For closing the gate, turn the lever in the opposite direction as the case is. It takes about 30 to 45 minutes of manual operation of the lever to lift the gate from fully open position to close position. The gates are supplied by M/s Glenfield and Kennedy Ltd., Kilmarnock, Scotland.

Bridge over Spillway

The bridge is built over the spillway with its top level at +1760.22m and its road width is 4.88m. The bridge has five equal clear spans of 5.18m each.

Fig 2.5 Spillway of Kundala dam

Fig 2.6 Downstream channel

Fig 2.7 Screw hoists for vertical lift spillway gates

Fig 2.8 Spillway gate hoisting gear

Outlet Arrangements

One outlet of dia. 1.80m controlled by a variable jet type disperser is provided in the dam. Emergency gate is provided on the upstream side of the outlet and the valve near the downstream end. It is provided at an elevation of +1735.84 m. The discharge capacity of the outlet is 14 m^3/s and the maximum head is 22.77m. The outlet arrangement includes

1. Trash racks
2. Emergency gate
3. Outlet pipe and
4. Disperser valve

Trash Rack

Trash rack is provided in front of the outlet pipe allowing a flow of 0.91m/s through the bars, with an assumed 50% blockage. It consists of 89mm x 9.5mm, flat iron straps with 25mm through bolts and with 25mm C.I. pipe distance pieces 10cm long in between straps. The Trash Rack is in three sections consisting of a section about 1.45m at the bottom and

two sections about 2.67m at the top and middle. The overall area covered is 6.76m x 4.88m. Two flats in the central section are removable and enable entry into the pipe without dismantling the whole section.

A subsidiary trash rack hinged on the R.C. platform at +1741.32m and covering the slot for the emergency gate is also fitted. This trash rack can be lifted up by a wire rope to open the slot for taking out the emergency gate.

Fig 2.9 Trash rack

Emergency Gate

An emergency gate is provided for the outlet to be used for the repairs of the disperser and in any other emergency. This is a roller sluice gate 2.44m x 2.74m made in the Travancore PWD workshops to fit the front of the bell mouth entrance in case of emergency. This is worked by a hand winch with 25mm steel wire rope. For lowering, the rollers work against an angle iron groove fitted in the masonry. For guiding the wheels and preventing the wheels swinging and missing the grooves altogether masonry piers 1.52m x 1.52m is built on either side at the top.

When the gate is lowered and used as a shutter and the reservoir is full, the pressure on the shutter is enormous. Opening by hand operated winch is difficult except by equalising pressure. For this a slot 76mm dia. with a square shutter is available. This shutter can be operated by a small size wire. In order to open the gate, 4 persons are required and it takes 10 to 15 minutes of operation to provide a lift of 1.25m.

Fig 2.10 Emergency gate guiding column

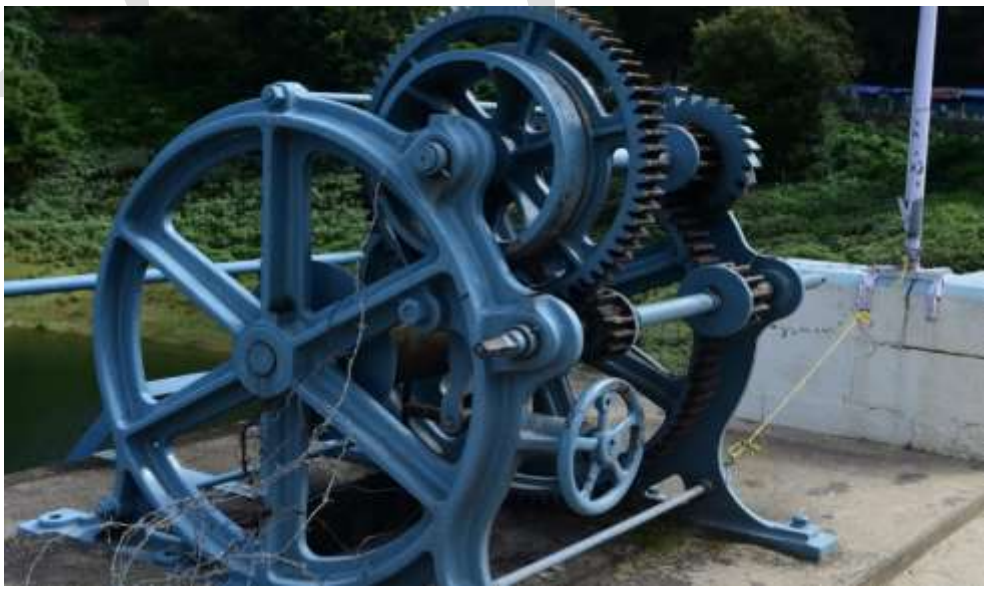

Fig 2.11 Hoist for river outlet emergency gate

Outlet pipe

The outlet pipe is located at chainage +99.10m and consists of

1. first 7.60m length from heel of dam including the bell mouth portion widening from 1.80m to 2.40m dia. built in 0.30m rings of ashlar stones.
2. 26.20m length of 1.80 m dia. steel outlet pipes with 13mm M.S. welded pipes
3. last length of 5.64m by a taper piece in steel tapering from 1.80m dia. to 1.07m to suit the hollow jet disperser.

The outlet pipe is suitably bent in alignment inside the masonry with extra length of pipe to enable the hollow jet discharge over the apron below the spillway just downstream of the baffle wall. The pipes are placed on a downward slope of 1:50.

Disperser Valve

A 1000mm disperser is fitted to the end of the taper piece which is made by the English Electric Co. Ltd. This consists of a taper piece foundation ring connecting to the 5.64m taper piece and enclosed in concrete and a valve portion consisting of a fixed cone with radial vanes. This portion is covered by a movable casing, the operation of which forms a gap along the rim of the cone enabling water to spread in the direction of the cone. A triangular lever and a link converts the vertical motion of the operating rod into the horizontal motion of the casing. The head stock is placed on top of the masonry platform and is of out-door type needing no valve house.

A dial gauge with a maximum indication up to 9 inches is provided which indicates the opening of the valve when the operating lever is turned in anticlockwise direction. For opening the disperser valve first the top part of the trash rack is lifted up and the emergency gate is lifted up. Thereafter the disperser valve is operated for release of water to Madupetty reservoir which is located just downstream or for depletion of reservoir. Discharge Tables of the disperser valve are not available. Usually the operation of the valve is done for full opening of 7 to 8 inches and the valve discharges at an average rate of 6 cumec and the reservoir is emptied in about 2 weeks at this rate of discharge.

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Fig 2.12 Disperser valve

Fig 2.13 Disperser valve hoist dial

Drains

The system of draining the foundation beneath the dam consists of a set of foundation drains at the level of foundation rock. These drains are of size 381mm x 381 mm and are connected by 10 cm risers to the drainage gallery. These vertical risers from the foundation drains are placed at 4.57m intervals and at every contraction joint. The drainage gallery is at EL 1738.29m and consists of a main drain 1.50m from the upstream face extending from Ch. 44.20m to Ch. 206.96m of the dam. The section of this drain is 686mm x 762mm and rectangular in shape. A subsidiary drain 381mm x 381mm exists 6.10m away to the toe side. Cross drains lead from these at Ch. 97.54m and Ch. 143.26m to the outside of the dam, where they are bent and then lead to discharge to the stilling pool. There is an arrangement in the form of a V notch provided at the downstream in an open pit for measuring the seepage water flowing through the drains on either side of spillway. For drainage of seepage water in the masonry 10 cm dia. vertical risers are provided leading from the top of the dam from about EL 1759.32m to the drainage gallery. To drain the foundation effectively, 10cm dia. holes are made in the rock for a depth of 1.83m.

2.4 Operation of the Reservoir

The Gross Storage of Kundala dam is 7.78 Mm3 and live storage is 7.65 Mm3. FRL of the reservoir is 1758.69 m and the MWL is 1759.30 m. Top level of dam is 1759.92 m. There are five vertical gates (falling type), each of size 5.18 m x 2.74 m. Crest level of spillway is 1756.86 m. One lower level outlet of 1.8 m dia. is also provided in the dam. Spillway capacity is 184 m^3/s. The reservoir will be at FRL near the end of monsoon season. When the water level reaches FRL, water is released through spillway gates.

The water stored in the reservoir is released to Maduppetty reservoir, located about 4 km downstream, through the river course usually from April to May when the water level in Maduppetty reservoir falls to less than 50 % of its storage capacity. The reservoir will be empty by the end of May.

Following inputs/information is used to support the reservoir operation.

a) Satellite images of cloud formation.
b) India Meteorological Department (IMD) forecast.
c) Advance information on release from upstream reservoir.
c) Daily rainfall detail of the nearby rain gauge stations.

Discharge through single spillway bay for different gate openings at MWL is tabulated in **Table 2.3**. Discharge (Rating) curve is given in **Fig. 2.7**.

SPILL THROUGH VERTICAL GATES OF KUNDALA DAM (For I gate)													
FRL	1758.69	m	5 Nos vertical type @ 5.18mx2.74m				crest level	1756.86	m				
MWL	1759.30	m	Width between piers 5.18										
Shutter opening in m	Discharge in m3/s	Discharge in Mm3 for hours											
		1	2	3	4	5	6	7	8	9	10	11	12
0.01	0.01	0.00004	0.0001	0.0001	0.0002	0.0002	0.0002	0.0003	0.0003	0.0003	0.0004	0.0004	0.0005
0.05	0.12	0.0004	0.0009	0.0013	0.0017	0.0022	0.0026	0.0030	0.0034	0.0039	0.0043	0.0047	0.0052
0.1	0.34	0.0012	0.0024	0.0037	0.0049	0.0061	0.0073	0.0085	0.0097	0.0110	0.0122	0.0134	0.0146
0.15	0.62	0.0022	0.0045	0.0067	0.0090	0.0112	0.0134	0.0157	0.0179	0.0201	0.0224	0.0246	0.0269
0.2	0.96	0.0034	0.0069	0.0103	0.0138	0.0172	0.0207	0.0241	0.0276	0.0310	0.0345	0.0379	0.0413
0.25	1.34	0.0048	0.0096	0.0144	0.0193	0.0241	0.0289	0.0337	0.0385	0.0433	0.0481	0.0530	0.0578
0.3	1.76	0.0063	0.0127	0.0190	0.0253	0.0316	0.0380	0.0443	0.0506	0.0569	0.0633	0.0696	0.0759
0.35	2.21	0.0080	0.0159	0.0239	0.0319	0.0399	0.0478	0.0558	0.0638	0.0717	0.0797	0.0877	0.0956
0.4	2.70	0.0097	0.0195	0.0292	0.0389	0.0487	0.0584	0.0682	0.0779	0.0876	0.0974	0.1071	0.1168
0.45	3.23	0.0116	0.0232	0.0348	0.0465	0.0581	0.0697	0.0813	0.0929	0.1045	0.1162	0.1278	0.1394
0.5	3.78	0.0136	0.0272	0.0408	0.0544	0.0680	0.0816	0.0952	0.1088	0.1224	0.1360	0.1496	0.1632
1	10.67	0.0384	0.0768	0.1152	0.1536	0.1920	0.2304	0.2688	0.3072	0.3456	0.3840	0.4224	0.4608
1.5	19.56	0.0704	0.1408	0.2112	0.2816	0.3520	0.4224	0.4928	0.5632	0.6336	0.7040	0.7745	0.8449
1.83	26.32	0.0948	0.1895	0.2843	0.3790	0.4738	0.5685	0.6633	0.7580	0.8528	0.9475	1.0423	1.1370
2	30.05	0.1082	0.2164	0.3246	0.4327	0.5409	0.6491	0.7573	0.8655	0.9737	1.0818	1.1900	1.2982
2.29	36.78	0.1324	0.2648	0.3972	0.5296	0.6620	0.7944	0.9268	1.0592	1.1916	1.3240	1.4564	1.5888

Table 2.3 Spill way Discharge

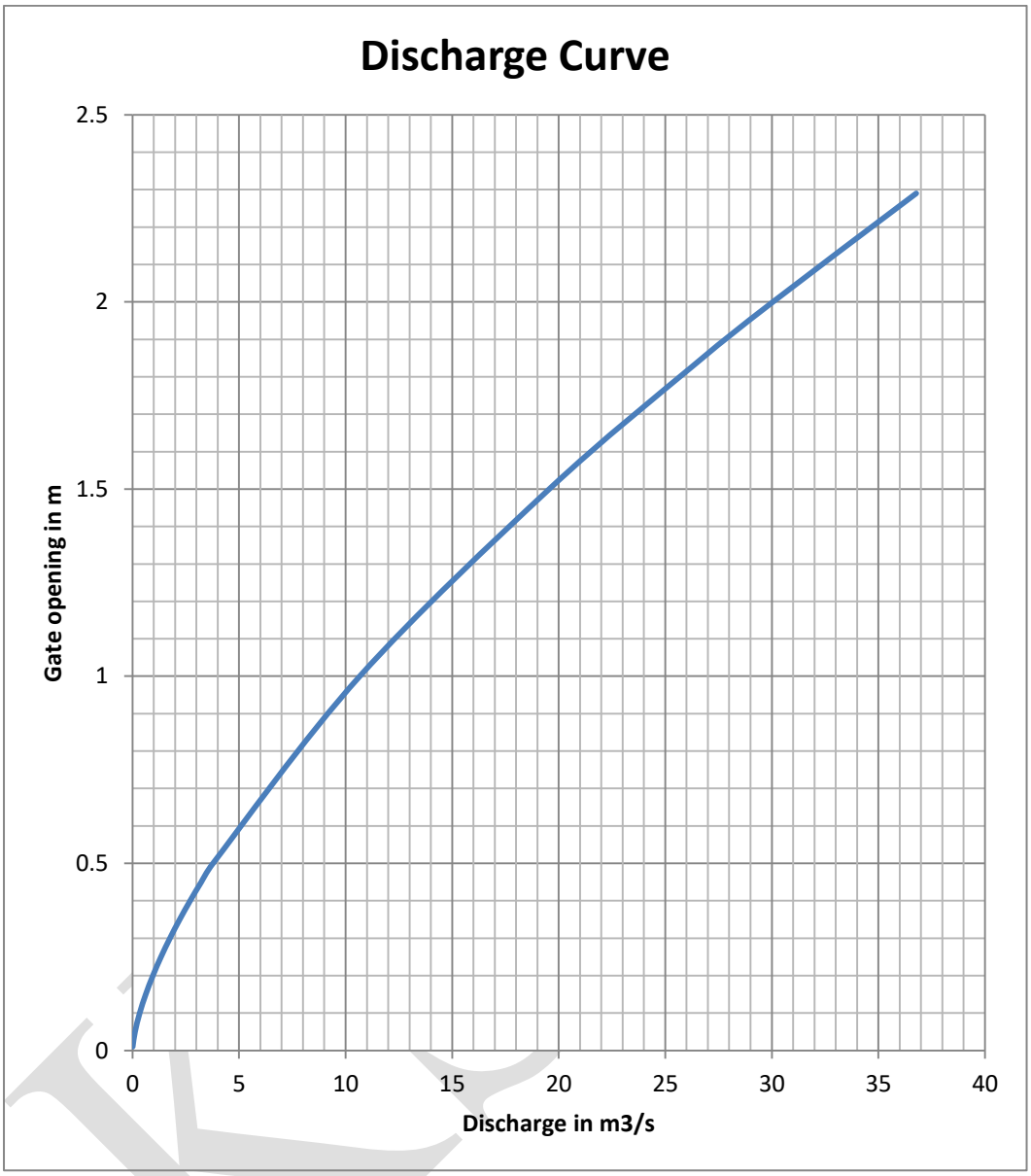

Fig 2.14 Discharge curve

2.4.1 Rule Curve

Kundala is comparatively a small reservoir with a gross storage of7.78 Mm^3 and live storage of 7.65 Mm^3. FRL of the reservoir is 1758.69 m and the original MWL is 1759.30 m. The Kundala storage utilises only 38.85 sq km of the catchment in the upper regions of Palar stream.

The water stored in the reservoir is released to Madupetty reservoir, located about 4 km downstream, through the river course usually from April to May. The reservoir will be empty by the end of May. Near the end of monsoon season, the reservoir will be at FRL. Since the

gross storage of Kundala reservoir is only 7.78 Mm^3, rule levels cannot be formulated and water exceeding FRL will be spilled through spillway gates.

2.4.2 Safety Aspects

The spillway gates are operated step by step after assessing the reservoir water level and inflow and the sequencing is defined in **2.4.3.**

2.4.3 Flood Release Procedure

The flood water is released through spillway gates based on the operation manual of gates and flood inflows. There are five spillway gates. The sequence of operation of spillway gates is Gate no. 3, 2, 4,1,5 i.e. The spillway gate No. 3 is operated first. Thereafter depending on requirement gates on either side of the central gate nos. 2 & 4 are opened. Spillway gates 1 & 5 are operated last. Further opening of gates, if required is done in the same way, keeping the difference in the openings of any two adjacent gates not more than 0.2m. Closing of gates is to be done in reverse order; the gate opened last being closed first.

Fig 2.15 Spillway gates

2.4.4 Reservoir Capacities

Fig 2.16 Kundala Reservoir

The Gross storage of the reservoir is 7.78 Million Cubic Meters and the live storage is 7.65 Million Cubic Meters at FRL of +1758.69m.

2.4.5 Inflow forecasting

Monsoons are from June to October. Owing to lack of extensive forest areas and presence of non-absorbent rocky areas, the run-off is high. The chances of high floods are therefore high and a flood forecasting method is proposed to be implemented.

The floods may lead to problems like people getting displaced from their homes, huge damage to crops and other assets. The floods can have disastrous impact on the environment also. Adequate measures are required to be taken up in advance to control and regulate the flow of water in the river. The following measures are essential for effective management of floods in the river during the monsoons.

1) Nomination of liaising officers for respective reservoirs.
2) Sharing of Sub-basin wise directory of concerned officers responsible for flood management.

3) Exchange of data regarding rainfall, reservoir water levels.

4) Reservoir operation schedules.

During monsoon, daily water releases from the Dams/Barrages at 8 hrs. & 16 hrs. in normal situation and hourly data exchange during heavy floods is necessary.

Flood communication system: The widely time tested communication to reach every corner of the flood affected zones have been radio and television and private media for the people to move to safer places by themselves in an emergency. Communication is very important in such occasions. These days due to revolution in the telecommunication system, networks of mobile phones are widely available. Advantage of this facility will be taken. Mobile numbers of all officers and staff working in Dam operations wing, District Disaster Management, Revenue authorities will be listed and made available to all the personnel who have been assigned duty of disaster management. A satellite phone is provided at the dam site.

2.4.6 Methodology of Flood Regulation at Kundala

2.4.6.1 Inflow Computation

Inflow into reservoirs is normally estimated by the reservoir gauging method (also called the rise and fall method or inflow-outflow method). All the outflows are added together and to it the rate of rise in storage (Positive if the level rises, and negative if it falls) is added. Expressed as an equation, this will be.

Inflow (cumec) = Total outflow (cumec) + Rate of increase in storage (cumec)

The rate of increase or decrease in storage can be determined from the observed rate of increase or decrease in reservoir level and the elevation capacity tables. For easy computation a table can be developed showing the rate of change of storage in the Kundala reservoir for a rate of rise in reservoir level of 1 cm/hour. This table can be put to use for easy interpolation. Once the inflow is known the outflow and gate opening required to maintain the water level can be computed.

2.4.7 Summary of Flood Regulation Procedure

The flood regulation procedures at Kundala can be summarized in the following 5 steps:

1. Observe the reservoir level at 1 hour intervals.

2. Determine the total outflow occurring at all outlets (including river outlet, spillway, release to Madupetty reservoir)
3. Estimate the inflow
4. Determine the gate opening as the case maybe.
5. Open the required number of gates to the extent required to maintain constant reservoir level (i.e., release is equal to the inflow).

2.4.8 Emergency Operation

The purpose of Emergency Action Plan is to identify emergency situations that could threaten Kundala Dam and to plan for an expedited, effective response to prevent failure of the dam and warn downstream residents of impending danger. This plan defines the notification procedures to be followed in the event of a potentially hazardous situation. The procedures are intended to protect lives and prevent property damage from and excessive release of water from the dam spillways or an uncontrolled outflow of water from the breached portion of dam.

Dam owner's responsibilities before and during an Emergency event, Dam Engineers Preparedness& Responsibilities, Responsibilities for Notification, Responsibilities for Evacuation, Responsibilities for Termination and Follow-Up, Communication Networks, Emergency Detection, Evaluation and Classification, Preparedness, Remedial Actions, Emergency Operations Centre, Inundation Areas, Local Evacuation Plan, Implementation, Vicinity Inundation cum Evacuation Maps etc. are provided in the detailed EAP document of Kundala Dam. Summary of Alert Conditions during Emergency are given in **Annexure 6**.

The Emergency operation will be carried out following the Emergency Action Pan (EAP). The Emergency conditions are outlined in Chapter 4 under clause **4.2.1** on Immediate Maintenance. The EAP together with this Manual will be present at site at all times.

2.5 Initial Filling of Reservoir

The initial filling of the reservoir was carried out during 1947.

2.6 Record Keeping

The records regarding dam and appurtenant structures and construction details are kept at the field office. Essential documents as per the dam safety guidelines are kept at dam site office.

Following records of reservoir operations are being maintained:

1. Rainfall record on daily basis throughout the year.
2. Reservoir levels on daily basis during non-monsoon and hourly basis during monsoon.
3. Depth of outflow over the spillway on hourly basis during monsoon.
4. Estimated spillway outflows during monsoon on hourly basis.
5. Power releases.
6. Water audit register to be maintained for estimating the inflows on hourly basis during monsoon and daily basis during non-monsoon by accounting all the releases/outflows and the incremental change in storage in the reservoir.

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CHAPTER 3
PROJECT INSPECTION

An effective inspection program is essential to identify problems and to keep a dam in a good and healthy condition. Inspection details and suggestions are kept at field office and reports are sent to higher offices. The current practice of Inspection at Kundala dam envisages that the Deputy Chief Engineer along with Executive Engineer of the project shall carryout pre-monsoon and post-monsoon inspections as per CWC guidelines in the format issued by CWC. The Chief Engineer will review the inspection report and submit to CWC. The Executive Engineer of the Project will also conduct quarterly inspections and will prepare health reports as per KDSA. The format to be followed as per CWC has been revised during January 2018 and new guidelines have been issued vide Doc No. CDSO_GUD_DS_07_ v1.0, CWC 2018 for Safety Inspection of Dams. The health reports of the dam are to be prepared in the new format meant for incorporating the data in DHARMA. Detailed description on project inspections is available in the Guideline for Safety Inspection of dams. However an overview of the various types of inspections required to be carried out at Kundala dam is given below. Note that for uploading Inspection Data into DHARMA, the Inspection Instructions & Forms given in the above mentioned Guideline for Safety Inspection of Dams must be used.

Guidance for carrying out other inspections is elaborated in the following paras.

3.1 Types of inspections

Four types of dam safety inspections could be carried out at Kundala Dam. These include, but not limited, to the following:

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

The frequency of each type of inspection depends on the condition of the dam and State DSO regulations.

Typical inspection elements and the detail of the safety inspections are provided below. More detailed descriptions are given in the 'Guideline for Safety Inspection of Dams' (CWC

2018). A comprehensive health checklist for recording the status of each item being inspected and the overall condition of the equipment along with any consequential risks on the health of the dam is also to be maintained.

3.2 Comprehensive Evaluation Inspections

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 will undertake evaluation of the 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:

- General assessment of hydrologic and hydraulic conditions, review of design flood, flood routing for revised design flood and mitigation measures.
- Review and analysis of available data of dam design including seismic safety, construction, operation, maintenance and performance of dam structure and appurtenant works.
- Evaluation of procedures for operation, maintenance and inspection of dam and to suggest improvements / modifications.
- Evaluation of any possible hazardous threat to the dam structure such as dam abutment slope stability failure or slope failures along the reservoir periphery.

A comprehensive evaluation inspection of Kundala dam consists of five major parts:

1. Review of project records (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, instrumentation data and its interpretation including.
2. Inspection of the dam and its appurtenant works.
3. To review the results and reports of additional field investigations & laboratory testing as required.
4. Review of design studies, review of design flood, checking of the adequacy of Spillway capacity, freeboard requirements, dam stability and any special study as required.

5. Preparation of a detailed report of the inspection.

3.2.1 Details to be provided to DSRP before inspection.

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

- General information and scope of the project
- Emergency preparedness
- Details of key personnel
- Hydrology original and reviewed
- Reservoir operation and regulation plan
- Basic data and issues related to safety of dam
- Problems, if any, during construction
- Drawings of dam, spillway, gates and appurtenant structures
- Seismicity aspects & details
- Status of the instrumentation
- Construction history
- Geological report including special problems at site and their treatment
- Field Inspection- Observation and recommendation regarding remedial measures
- Dam incidents and reservoir filling details

Problem during construction

Fault zone in foundation and treatment

During construction, a fault zone was discovered in the foundation of the right bank extending right across the dam beneath a thick layer of surface rock. The existence of cavity was noticed from borings for the foundation which revealed a zone 2.44m to 3m deep consisting of voids and thin layers of rock sandwiching loose earth and water. In relation to the dam, the cavity extended from about chainage 170.70m to 213.40m.

Excavation of the cavity was done and filled with cement concrete 1:3:6 with 40mm metal and river sand and was filled from the farthest and lowest point backwards. The lowest levels were grouted after laying a 1.50m layer of concrete.

On the left bank also a similar but small cavity was discovered. This cavity was almost normal to the axis of the dam and contained generally micaceous earth. This cavity was also filled with concrete and grouted from above through a bore hole.

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 long-term costs and will extend the life of the dam. Dam Inspection Report or an inspection brief should be prepared following the field visit.

Scheduled inspections include the following components as a minimum:

- Review of past inspection reports, monitoring data, photographs, maintenance records, or other pertinent data as may be required
- Visual inspection of the dam and its appurtenant works
- Preparation of a report or inspection brief, with relevant documentation and photographs. The report should be filed in the dam owner's project files

3.3.1 Pre & Post Monsoon Checklist and Example of Reporting Proforma

Detailed checklists are to be followed to ensure evaluation of the health of the dam and to ensure that it continues to operate in satisfactory and safe condition. The proforma to be used for inspection should be the one enclosed in the Doc. No. CDSO.GUD.DS07 v 1.0, CWC 2018 on the Guide lines for Safety Inspection of Dams **(Annexure 2)**.

Schedule of undertaking Pre & Post Monsoon Inspections:

Pre-monsoon Inspection to be carried out during	April - May
Post-monsoon Inspection to be carried out during	December - January
Inspecting Officers	Deputy Chief Engineer along with SPMU Executive Engineer, Field Executive Engineer, Concerned field Assistant Executive Engineer and Assistant Engineer
Preparation of Inspection Report	Executive Engineer, Field (Dam Health Engineer)
Submission of Pre-monsoon Inspection Report Submission of Post-monsoon Inspection Report	Before June 30th Before January 15th
Checking and approval of report	Deputy Chief Engineer, SPMU
Uploading corrected document in DHARMA	Executive Engineer, Field

The information in regard to above inspection would be supplied to the Chief Engineer of the Project for further co-ordination with the concerned departments and district Authorities.

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. These inspections are to be carried out by teams to be constituted by State DSO after an initial assessment based on informal inspection carried out by project personnel reveal dam safety related concerns like cracking in the dam, damages, erosion/ scour, undermining/ piping/ sink holes/ liquefaction or any such undesirable feature. A special inspection may also be performed during an emergency, such as an impending dam breach, to evaluate specific areas or concerns. They are also made when the ongoing surveillance program identifies a condition or a trend that appears to warrant a special evaluation. Special inspections should focus on those dam components that are affected by

the unusual event and should include at least three elements: 1) review of relevant files or data, 2) visual inspection, and 3) report preparation.

More detailed site investigations / studies may be required (such as drilling, surveys, or seepage flow estimates) if the special inspection reveals the need for the same. Photographic documentation is to be included as part of the inspection.

3.5 Informal Inspections

An informal inspection, is a continuing effort by on-site personnel (dam owners/operators and maintenance personnel) performed during their routine duties. Informal inspections are critical especially to keep an eye on the proper operation and maintenance of the dam. These inspections consist of frequent observations of the general appearance and functioning of the dam and appurtenant structures.

Operators, maintenance crews, or other staffs who are posted at Kundala dam site are supposed to conduct informal inspections on routine basis(See duty schedules in Chapter 1). 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 while walking across the dam for inspection / surveillance, checking the operating equipment, and noting changes in conditions may prevent serious mishaps or even dam failures.

Informal inspections are important and are performed at every available opportunity. These inspections may only cover one or two dam components as the case may be, or they may cover the entire dam and its appurtenant structures in one go. 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. Report is to be submitted detailing the condition discovered along with photographs, time, reservoir water level, other features etc.

CHAPTER 4
PROJECT MAINTENANCE

A good maintenance program is required to protect a dam against deterioration, prolong its life and reduce the chance of failure. Maintenance program for a dam should be developed primarily based on systematic and frequent inspections. 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 is small compared to the costs of major repairs, loss of life, property and litigation. If maintenance of a dam is neglected the consequences and costs could be enormous.

4.1 Maintenance Plan

A basic maintenance schedule for the various monitoring components based on manual of operating parts, frequent inspections, priority, and interval is attached as **Annexure 5**. This shows the tasks to be performed and how frequently that is to be inspected/observed and repaired.

4.2 Maintenance Priorities

Maintenance activities need to be prioritized. In order of priority they need to be clarified under the head's 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:

- The dam is about to be overtopped or being overtopped during high flood.
- The dam is about to be breached by erosion, slope failure etc.
- A dam showing signs of failure due to aging/cracking, sliding, overturning etc.
- The dam showing signs of piping or internal erosion along shear zones, faults etc. indicated by increasingly cloudy seepage or other symptoms.
- The spillway being blocked or with some inoperable gates.
- Evidence of excessive seepage as on downstream face of the dam.

An EAP is to be activated when any of the above conditions are noted.

4.2.2 Preventive Maintenance

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

4.2.2.1 Condition Based Maintenance

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

- Remove all vegetation and bushes by roots from the dam surface and restoring any eroded areas.
- Repair any concrete or metal components that have deteriorated.
- Cleaning of the choked drainage holes in the dam body/ foundations.
- 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 include but are not limited to the following:

- Any routine repair to concrete or metal component.
- Observation of any springs or seepage areas, comparing the quantity and quality (clarity) with earlier observations.
- 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, hoisting arrangements and gates/valves/hoist of outlet works & stand by generator.
- Maintaining proper lighting at dam top etc.
- Monitoring of seepage in masonry/ concrete dams.
- Monitoring/ cleaning & removal of leached deposits in porous concrete / formed drains in dam body and foundation drainage holes of masonry/ concrete 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 Procedures for Routine Maintenance

4.3.1 Controlling Damage from Vehicular Traffic

Vehicles, except for maintenance, are restricted on the dam top and kept out by fencing or barricades. Any damages are repaired as soon as possible. Also vehicles are to be permitted only after security checking at check posts.

4.3.2 Controlling Vegetation

Removal of vegetation around the dam and its premises is done at least 2 times in a year.

4.3.3 Masonry / Concrete dams & spillways

The following important issues / aspects need to addressed while undertaking the periodic maintenance, but are not be 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, unsymmetrical flows, unfavourable down-stream conditions)
- Vegetation growth in spillways, spill channel, approach channel etc.
- Seepage 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.
- Status of rectification works undertaken from time to time need to be assessed during periodic maintenance.
- To ensure that the dam is behaving as designed based on instrumentation programs.

Periodic maintenance should be performed on all concrete surfaces to repair deteriorated areas. Repair of deteriorated concrete at the earliest following the standard specifications for repair of concrete surfaces and re-pointing of masonry joints etc. 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.

4.3.4 Gates & Hoisting Equipment

The safe and satisfactory operation of Spillway depends on proper operation of its Gates & Hoisting Equipment. Maintaining spillway gates in working condition is critical for dam safety and is to be assigned the highest priority. If routine inspection of the Hydro-Mechanical Equipment reports the need for maintenance, the work should be completed as soon as possible.

The gates are to be operated through their full range twice annually (before monsoon & after monsoon keeping a gap of at least six months). As operating gates under full reservoir pressure can result in large discharges, exercising of gates should preferably be carried out during dry conditions or lean times of the year.

The aspects to be inspected and maintained periodically for ensuring proper operation of gates in general are given below. The O&M manuals of the gates manufacturer's would however govern the overall maintenance of Gate and Hoists whenever there is any contradiction with the inspections given in the Manual.

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 to required torques. 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) 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.

ix) The guide-assemblies, wheel-assemblies and sealing-assemblies shall be cleared off grit, sand or any other foreign material.

x) The wheel pin shall be coated with corrosion resistant compound.

xi) All nuts and bolts shall be tightened.

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

a) **Rubber Seals**:

Seals shall be inspected for leakages. Locations of excessive leakages shall be recorded for taking remedial measures. Appropriate action to replace the damaged seal needs to be taken immediately after monsoon. 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.

b) **Gate structures:**

i) Check all the welds for soundness and rectify defects.

ii) Check welds 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.

iii) Clean all drain holes including those in end arms and horizontal girders.

iv) Check all the nuts and bolts and tighten them. Replace damaged ones.

v) 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.

a) Embedded Parts:

i) All the sill beams and wall plates shall be inspected for crack, pitting etc. and defects shall be rectified.

ii) The guide roller pins shall be lubricated.

b) General Maintenance:

Defective welding should be chipped out and it should be re-welded duly following the relevant codal provision (IS: 10096, Part-3).

i) Damaged nuts, bolts, rivets, screws etc. should be replaced.

ii) Any pitting should be filled up by welding and finished by grinding if necessary.

iii) 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.

iv) Bolts should be tightened wherever required.

v) The seals of the gate should be checked for wear and tear and deterioration. These should be adjusted/replaced as and when necessary.

vi) The wall plates, sill beams shall be checked and repaired if necessary

vii) Wire ropes should be properly lubricated.

viii) 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.

ix) The stroke of the brake should be reset to compensate for lining wear. Worn out brake linings should be replaced in time.

x) Flexible couplings should be adjusted if required.

xi) Repairs and replacements of all electrical relays and controls should be attended to.

xii) Maintenance of alternative sources of Power such as Diesel Generating sets and alternative drives wherever provided should be carried out.

xiii) 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. Ensure availability of essential spare parts at site as per the list of essential spares.

4.3.5 Maintenance of Hoisting System

i) General Instructions:

a) Never open any bolt or nut on 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 components

ii) Inspection and Maintenance

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

i. Entrance to all hoist platforms shall be kept locked. All keys shall remain with the shift supervisor.
ii. A cursory daily inspection shall be made of hoist and gate to ensure that there is no unusual happening.
iii. Clean all hoisting equipment and hoist platform.
iv. Check oil level in gearboxes and replenish as and when required with oil of proper grade.
v. Apply grease of suitable grade by grease gun.
vi. Lubricate all bearings, bushings, pins, linkages etc.
vii. All bolts and nuts on gear boxes, hoist drum and shaft couplings should be checked for tightness.
viii. 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.
ix. All the geared couplings shall be greased.
x. Raise and lower the gate and check for smooth, and trouble free operation of gate without excessive vibration.
xi. Check the condition of painting of various components and remove rust wherever noticed and repaint the portion after proper cleaning as per painting schedule.
xii. All trash, sediments and any other foreign material shall be cleared off the lifting rope and lifting attachment.
xiii. All ropes shall be checked for wear and tear and if broken wires are noticed, the rope shall be replaced.
xiv. All the wire ropes shall be checked and all visible oxidation shall be removed. All chains to be greased.
xv. All wire ropes shall be greased with cardium compound.
xvi. 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.

xvii. Check the pulleys, sheaves and turn-buckles.

xviii. Raise and lower the gate for its full lift several times (at least three to four). When the gate is operated, there should not be any noise or chatter in the gears.

xxiv. Check for all gears and pinions for uneven wear and adjust for proper contact. Grease the gears.

xxv. Repaint the hoist components, hoisting platform and its supporting structures as per requirement.

4.3.6 Maintenance of River Outlet

i) Inspect hydro mechanical components and carry out necessary repair works
ii) Check paint on gates and valves
iii) Wire ropes should be properly lubricated with cardium compound
iv) Inspect mechanical hoist bearings and flexible coupling bearings periodically
v) Exercise gates and valves
vi) Gate rollers should be properly lubricated
vii) Check metal seals

4.3.7 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/repaired where needed. The recommendations of the manufacturer should also be referred to.

4.3.8 Maintenance of Metal Gate Components

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.

4.3.9 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 / slope failure etc. develop, assistance of experienced Engineers/Expert Panels should be arranged 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.

4.3.10 General Cleaning

As already suggested, for proper operation of spillways, sluiceways, approach channels, 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.The dam top road is also to be cleaned regularly.

4.4 Materials and Establishment Requirements during Monsoon

Materials required during monsoon period for both immediate maintenance and preventive maintenance must be stocked in adequate quantities for emergency situations that may arise.

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

At Kundala Dam, round the clock patrol is to be carried out during monsoon period. At the same time the man-power requirements during monsoon period are to be enhanced.

4.5 Preparation of O&M budget

The O&M budget for Kundala Dam should essentially include but not be 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 – 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 stationaries 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 –The 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, 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.

SL. NO.	BUDGET ITEM	PREVIOUS YEAR COST (Rs)	CURRENT YEAR BUDGET (YR _____) (Rs)	REMARKS
A. ESTABLISHMENT				
1	SALARY OF REGULAR STAFF INCLUDING ALL OTHER BENEFITS			
2	TRAVEL EXPENSES			
3	OFFICE EXPENSES			
4	MOTOR VEHICLE EXPENSES			
5	MAINTENANCE OF OFFICE & COLONY COMPLEX			
	SUB-TOTAL - A			
B. WORKS				
1	**CIVIL**			
1.1	MASONRY DAM SPILLWAY & APPURTENANT WORKS			
1.2	PROTECTION WORKS			

	U/S & D/S OF DAM			
1.3	RIVER OUTLET IN CONCRETE / MASONRY DAMS			
1.4	APPROACH / INSPECTION ROADS WITHIN DAM AREA			
2	**HYDRO-MECHANICAL**			
2.1	SPILLWAY GATES & HOISTS			
2.2	RIVER OUTLET IN DAM - EMERGENCY GATE, VALVE&OPERATING MECHANISMS			
3	**ELECTRICAL**			
3.1	ELECTRICAL FITTINGS, MOTORS, CONTROLS FOR ALL GATE HOISTS			
3.2	POWER SUPPLY LINES			
3.3	ELECTRICAL FITTINGS ON DAM TOP, DAM GALLERIES, ETC			
3.4	STANDBY POWER / DIESEL GENERATOR			
3.5	REMOTE CONTROL/CCTV			
4	**INSTRUMENTATION**			
5	**MISCELLANEOUS WORKS**			
6	**SALARY OF WORK- CHARGED STAFF INCLUDING ALL BENEFITS**			
7	**MATERIALS TO BE STORED BEFORE MONSOON**			
	SUB-TOTAL - B			
8	**CONTINGENCY (10%) ON SUB-TOTAL OF A & B**			
9	**TOOLS & PLANTS**			
	SUB-TOTAL- C			
10	**TOTAL ANNUAL COST**			

Table 4.1 O&M Budget Costs (Annual)

4.6 Maintenance Records

Maintenance records are of utmost importance. A record shall be kept for all maintenance activities, both immediate and preventive maintenance works. Information that must be recorded includes, but not limited to, the following**:**

- 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
- Before and after photographs.

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

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 or phenomena that can lead to dam failure.

5.1 Instrument Types and Usage

The instruments installed in Kundala dam are appended below.

LIST OF INSTRUMENTS INSTALLED IN KUNDALA DAM			
Sl. No.	**Name of Instruments**	**Total No installed**	**Frequency of Measurements**
1	V – notch	2	Weekly

Table 5.1 Instrumentation present status in Kundala Dam

5.1.1 Parameters monitored

Water Level

Daily water levels are taken. During monsoon, hourly readings are taken and recorded.

Seepage Flow

Seepage measurements are taken with V notches fitted in the gallery.

Frequency of Monitoring

Water level is monitored daily and seepage measurements are taken weekly.

Water Quality

The quality of water is to be tested.

Seismic Activity

There is no Seismic observatory installed at Kundala Dam.

Weather Conditions

Now the rainfall is measured with rain gauge. But a full equipped weather station can sense all weather conditions. Automated weather station is needed.

5.2 Data Processing, Evaluation& Interpretation

The monthly reports are prepared for evaluation & interpretation done.

CHAPTER 6

REHABILITATION WORKS UNDER DRIP

The rehabilitation works carried out under DRIP include

1. Pressure washing the downstream of dam body and painting parapet
2. Painting of allied structures of dam
3. Construction of security guard room cum control room
4. Maintenance of approach road to dam and construction of drain
5. Protective fencing to dam premises
6. Supply and installation of high mast light
7. Purchase of automatic rain gauge

Fig 6.1 Fencing and road work

Fig 6.2 Security guard room

Fig 6.3 Hoisting mechanism before painting

Fig 6.4 Hoisting mechanism after painting

Fig 6.5 High mast light and parapet painting

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CHAPTER 7
UPDATING THE MANUAL

Whenever features of the dam and appurtenant structures change, the O&M Manual must be edited and portions rewritten to reflect these changes. This 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:

i) Increase/decrease in the frequency of an inspection or the maintenance routine based on additional data/ experience acquired,

ii) Changes in the operation and/or maintenance procedures based on additional data/experience acquired,

iii) Alterations to the project data because of changes/modifications in the dam by way of additional spillway etc.

It is recommended that the O&M Manuals may be reviewed/updated after every 10 years by the respective Dam Owners.