Operation and Maintenance Manual for IDUKKI, CHERUTHONI & KULAMAVU DAMS

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DRIP
Dam Rehabilitation & Improvement Project

KSEB

Chief Engineer
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Kerala State Electricity Board

Government of Kerala

Operation and Maintenance Manual

Of

Idukki, Cheruthoni & Kulamavu Dams

Prepared

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Kerala State Electricity Board Ltd
Pallom, Kottayam.

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Government of Kerala
Kerala State Electricity Board Ltd
Dam Safety Organisation

Disclaimer

This *Operation and Maintenance Manual* for Idukki Reservoir, i.e. Idukki, Cheruthoni and Kulamavu dams 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 dam and appurtenant structures.

The manual is developed for the purposes of organization 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.

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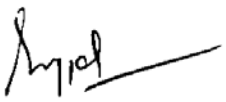
Foreword

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 (O&M) Manual is a detailed written document of procedures and protocols for ensuring that a dam is operated and maintained properly and timely to avoid further health deterioration and extend service life of these assets. 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 vide CDSO_GUD_DS_03_v1.0 Page xii January 2018. Accordingly Kerala State Electricity Board is developing and updating the Operation and Maintenance Manual of Dams under their ownership for a healthy dam safety management system.

Idukki Hydro Electric Project (IHEP) of Periyar basin is the largest hydroelectric project in Kerala. The project was completed with aid from the Government of Canada and the technical consultant was M/s Surveyor, Nenniger and Chenevert. There are three large dams associated with this project viz. Idukki Arch Dam of height 169.16 meters, Cheruthoni Dam of height 138.38 meters and Kulamavu Dam of height 99.97 meters. In addition there are augmentation dams viz. Kallar & Erattayar and Diversion schemes Kuttiyar, Vadakkepuzha, Azhutha and Narakakkanam. Cheruthoni is the spill way dam of Idukki HEP having five radial gates to release the water from the reservoir. Idukki is the largest reservoir in Kerala having a water spread area of 60 Sq km and spreads across Thodupuzha, Peerumedu, and Udumbanchola Taluks in Idukki District. Idukki Underground Power Station located at Moolamattom is a technological achievement of the country having 780 MW installed capacity with six generating units (Vertical Pelton turbines) each of 130 MW capacities. The entry to this power house cavern is through an access tunnel of 599 m length. A 220 KV switchyard is situated outside the powerhouse cavern. After power generation, water from the power station is released to the Thodupuzha River through an underground tunnel, 1220 m in length. The first stage of the project (3 x 130 MW) was dedicated to the nation on 12th February 1976 by the then Prime Minister of India, Mrs. Indira Gandhi. Later in 1986 the 2nd stage of (3 x 130 MW) was also

commissioned. A flow chart of IHEP is given in the next page for reference. There is a detailed O&M Manual (Vol.1 & Vol.2) for Idukki HEP prepared after completion of the project prepared collaboratively by M/s SNC & KSEB Ltd. However as per the revised CWC guidelines 2018, updating of the manual is required after 10 years. Accordingly an updated Operation and Maintenance Manual for Idukki, Cheruthoni and Kulamavu dams is presented here.

This Updated Operation & Maintenance Manual is prepared for Idukki, Cheruthoni and Kulamavu dams of Idukki HEP.

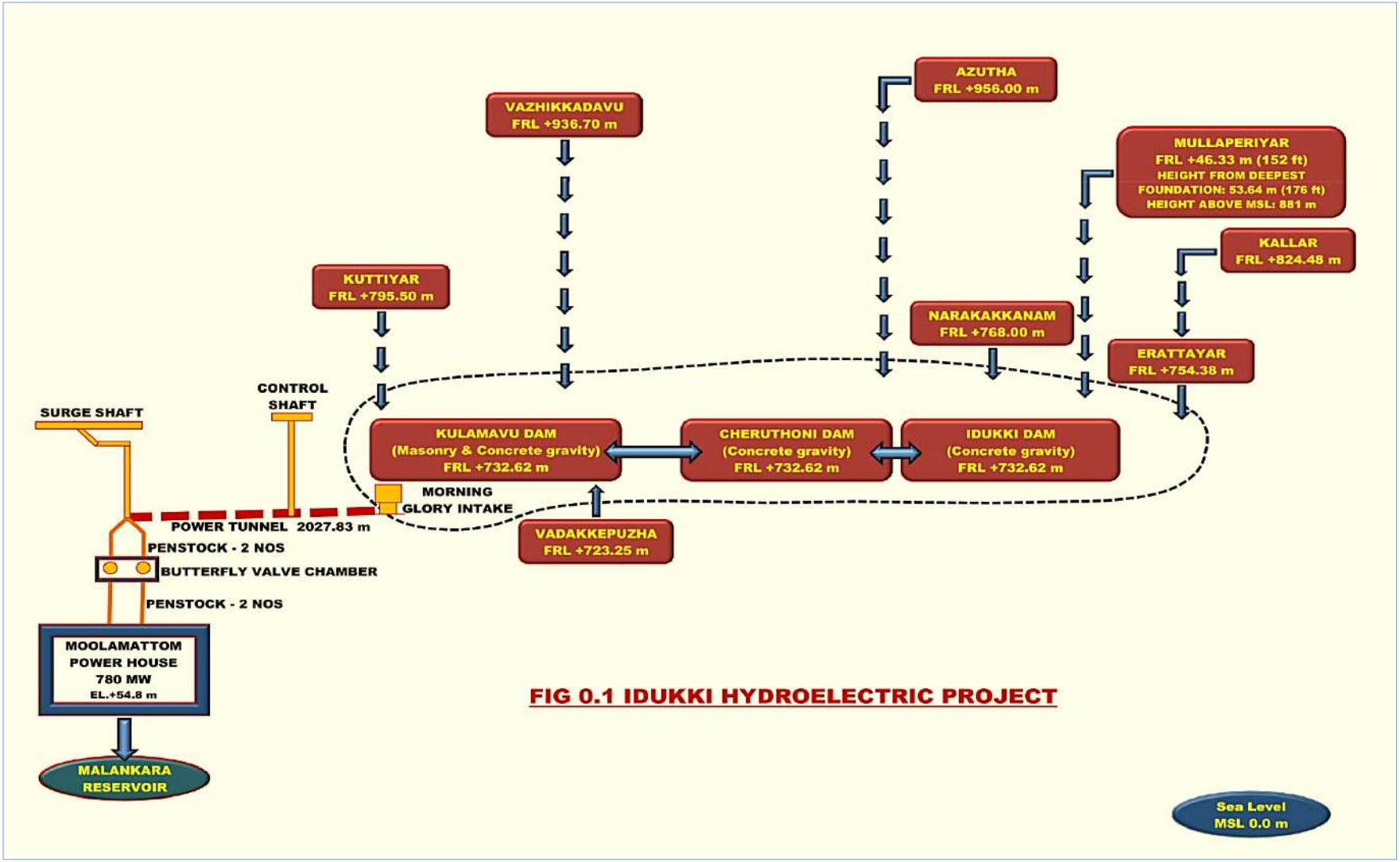

FIG 0.1 IDUKKI HYDROELECTRIC PROJECT

LIST OF ACRONYMS

The following acronyms are used in this publication:

AAR	**Alkali-Aggregate Reaction**
ACI	**American Concrete Institute**
ASTM	**American Society for Testing Materials**
CDSO	**Central Dam Safety Organization**
CWC	**Central Water Commission**
CWPRS	**Central Water and Power Research Station**
DDMA	**District Disaster Management Authority**
DHARMA	**Dam Health and Rehabilitation Monitoring Application**
DRIP	**Dam Rehabilitation and Improvement Project**
EAP	**Emergency Action Plan**
FSCT	**Federation of Societies for Coatings Technology**
HCC	**Hindustan Construction Corporation Ltd**
IS	**Indian Standard**
KERI	**Kerala Engineering Research Institute**
KDSA	**Kerala Dam Safety Authority**
KSEBL	**Kerala State Electricity Board Ltd**
KWA	**Kerala Water Authority**
NCDS	**National Committee on Dam Safety**
NCSDP	**National Committee on Seismic Design Parameters**
PMF	**Probable Maximum Flood**
PMP	**Probable Maximum Precipitation**
RCC	**Reinforced Cement Concrete**
ROUV	**Remotely Operated Underwater Vehicle**
ROV	**Remotely Operated Vehicle**
SDSO	**State Dam Safety Organization**
SISF	**State Industrial Security Force**
UAV	**Unmanned Aerial Vehicle**
USBR	**United States Bureau of Reclamation**
USACE	**United States Army Corps of Engineers**

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2. Operation and Maintenance Manual Vol II Monitoring of Idukki Arch Dam; M/s. Surveyor, Nenniger and Chenevert, Montreal, Canada & KSEB Ltd 1977.

3. Cheruthoni Dam Guidelines for operation of spillway Gates; Chief Engineer Planning KSEB Ltd.

4. Original Drawing Volumes of Idukki HEP (Digital)

5. CWC Guidelines for preparing O & M Manual of Dams CDSO_GUD_DS_03_v1.0 Page xii January 2018.

6. CWC Guidelines for Safety Inspection of Dams CDSO_GUD_DS_07_v2.0 January 2018.

7. 'Guidelines for Operation of Reservoirs' (IS 7323:1994)
8. 'Hydraulic Design of High Ogee Overflow Spillways' (IS 6934:1998)

9. Data Book of Idukki Dam

10. Hydrology Review Idukki Reservoir under DRIP phase 1

11. DSRP Report of Idukki HEP under DRIP phase 1

12. Emergency Action Plan IHEP under phase 1

13.Project Screening Template of IHEP under phase 1

14.Report on Rule Levels for Major Reservoirs of KSEB Ltd May 2019

Chapter 1

General Information

1.1 Introduction

The Idukki Hydro-Electric Project is located in the Western Ghats, 80 km from the Cochin Port, in the Southernmost Indian State of Kerala. The Idukki Hydro Electric Project was developed as a joint undertaking between Canada and India under the Colombo Plan. Farsighted Indian industrialists originally conceived it in 1919, various alternative schemes were envisaged from time to time and cost – benefit studied. Three large dams viz. Idukki, Cheruthoni and Kulamavu forms the reservoir (Idukki) of the Project which generates the major share 780 MW of Kerala Hydel Power. Idukki reservoir is the largest man made reservoir of Kerala. The entire area belongs to Western Ghats at an altitude ranging from 1840 m at originating point to 695 m at Idukki above MSL. The Idukki dam, the premier feature of the gigantic Idukki project is the first arch dam constructed in India. The dam site at Idukki gorge in Periyar River is a place of great constriction hardly 30 feet wide at the bottom. On either side of this narrow gorge stand the wild, un-trodden, untamed, bare and massive steep rocky hills of Kuravan and Kurathi. The first stage of the project was dedicated to the nation by Smt. Indira Priyadarsini, our beloved Late Prime Minister in 1976. The second stage was commissioned in 1986 enhancing the capacity to 780 MW.

1.2 Purpose, Location, Description of the Project

Idukki Hydro Electric Project

Idukki Hydro Electric Project is the largest hydroelectric project of Kerala State located in Idukki District. The project is aimed for power generation. The reservoir of the project, in Periyar river basin, is impounded by constructing three dams viz. Idukki Arch dam (latitude 90^0 50 ’35” N, longitude 76^0 58’ 35” E), Cheruthoni dam (latitude 90^0 50’ 45” N, longitude 76^0 58’ 03” E) and Kulamavu (latitude 90^0 48’ 10” N, longitude 76^0 53’ 08” E). The spill way of this reservoir is provided in Cheruthoni dam. Water from the reservoir is diverted to an underground power house with an installed capacity 780 MW located at Moolamattom through tunnel/pressure shaft etc. The reservoir is augmented by diverting water from adjacent streams like Kallar and Erattayar. There is also diversion from adjacent basins like

Azhutha, Vazhikkadavu, Narakakkanam, Vadakkepuzha etc. to Idukki reservoir. The tail race water after power generation is discharged to Valiar, a tributary of Thodupuzha River in the Muvattupuzha basin and is used for irrigation and drinking purposes.

The nearest city is Kochi, nearest railway station is Aluva about 100 km from dam site and nearest airport is CIAL, Nedumbasserry about 100 km from dam site. The index map and route map of IHEP are given in **Fig 1.1** and **Fig 1.2**.

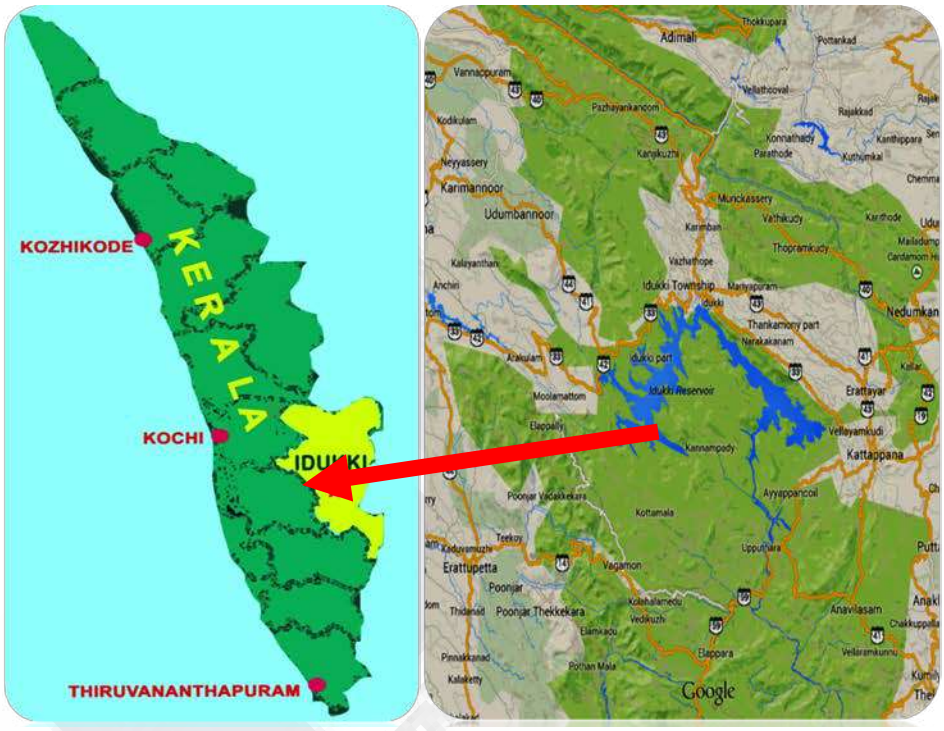


Fig 1.1 Idukki HEP Index Map

The different main components structures of IHEP are:

1. Three main dams viz. Idukki Concrete Arch dam 169.16 m (555 ft) high across river Periyar, Cheruthoni Concrete Gravity dam 138.38 m (454 ft) high across river Cheruthoni, a tributary of Periyar and Kulamavu Masonry-cum-Concrete Gravity dam 99.97 m (328 ft) high across river Killivallithodu, in Muvattupuzha basin and a leading channel which connects this reservoir formed to the Periyar basin.
2. Intake Tower 'Morning-glory' type, a reinforced concrete structure.
3. A concrete lined horseshoe shaped power tunnel of length 2027.83 m (6653 ft).

4. Two steel lined underground penstocks having a maximum inside diameter of 12' 6" and each approximately 3200' long.
5. An underground powerhouse installed with (6 x 130) MW, 6 jet Pelton Turbines.
6. A 26' dia D shaped tailrace tunnel 4000' long which transfers the tail race water to Muvattupuzha basin after power generation.
7. Several miscellaneous open channels and associated structures.
8. A double circuit 220 KV transmission line to Load Dispatch Station Kalamassery.
9. Single circuit 220 KV lines to each Pallom and Mysore.

Fig 1.2 Idukki HEP Google Route Map

A schematic diagram of the project is outlined below in **Fig 1.3**. The project in general and salient features of its component structures are given below.

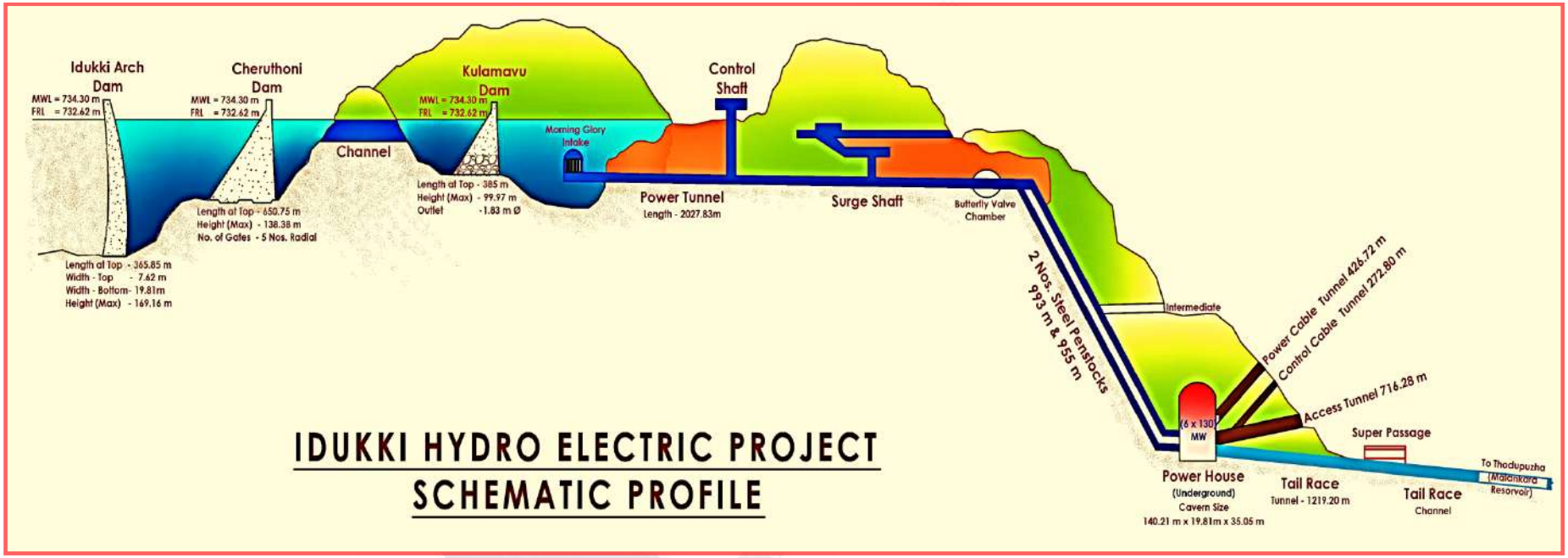


Fig 1.3 Schematic diagram of the project

MAIN FEATURES OF IDUKKI HE PROJECT

A	**Hydrology and Power Potential**	
1	Total Catchment Area	650 Sq km (527 Sq km for Idukki-Cheruthoni +123 Sq km for Kulamavu)
2	Average Annual rainfall	3628 mm
3	Average Annual runoff	824.112 Mm^3
5	Firm power at 100% L.F	280.20 MW
6	Annual Average Power generation	2398 MU
7	Maximum rate of diversion to power station	147 m^3/s
B	**Idukki Dam**	
1	Type	Concrete double curvature, Parabolic, thin arch
2	F.R.L	+2403' (732.62 m)
3	M.W.L	+2408.5' (734.3 m)
4	Top of dam	+2415' (736.09 m)
5	Effective Storage above MDDL+2280.0’	51543 Mcft (1459.5 Mm^3)
6	Length of dam at top	1200' (365.85m)
7	Volume of Concrete	0.481 Mm^3
8	(a) Reservoir area at Idukki - Cheruthoni site	59.83 Sq km
	(b) Kulamavu Reservoir area	18.28 Sq km
9	Original Design PMF (1974)	8019.83 m^3/s
10	Revised Design PMF (2014)	9402 m^3/s
11	Height of dam above deepest foundation	555’ (169.16 m)
12	Dead storage below MDDL of +2280’	18957 Mcft (536.79 Mm^3)
C	**Cheruthoni Dam**	
1	Type	Straight gravity concrete
2	F.R.L	+2403' (732.62 m)
3	M.W.L	+2408.5' (734.3 m)
4	Top of Dam	+2415' (736.09 m)
5	Length of Dam at Top	+2135’ (650.75 m)
6	Volume of masonry and concrete in Dam	1.722 Mm^3
7	Height of Dam above deepest foundation	454’ (138.38 m)

8	No. and size of radial gates	5 Nos. 40' x 34' (12.19 m x 10.36 m) Rope Drum Hoist of capacity 60 T
9	Crest level of spillway	2373.00' (723.29 m)
10	Spillway Capacity at FRL	3875 m^3/s
11	Spillway Capacity at MWL	5000 m^3/s
12	Lower level outlets in the dam	2 Nos (3.05 m x 6.5 m) Vertical Gate with Rope Drum Hoist Capacity 170 T
13	Discharge capacity of Outlets at MWL (2 Nos)	Each 557.5 m^3/s
D	**Kulamavu Dam**	
1	Type	Masonry, Straight gravity
2	F.R.L	+2403' (732.62 m)
3	M.W.L	+2408.5' (734.3 m)
4	Top of Dam	+736.28 m
5	Length of Dam at Top	1263' (384.96 m)
6	Volume of masonry and concrete in Dam	0.474 Mm^3
7	Height of Dam above deepest foundation	328' (99.97 m)
8	Kulamavu H B Valve	60' dia valve of capacity 48.85 cumec in Block 7 of the dam C/L El. 2210.00, Chainage 660.
D1	**Kulamavu Saddle Dams**	
a	**Right bank saddle dam - Strengthening**	
1	Type	Rolled earth fill
2	Slope	3:1 (upstream only)
3	Road width at top	30' (9.14 m)
4	Max. height	90' (27.43 m)
5	Volume	73,750 m^3
b	**Saddle near Kulamavu Junction - Strengthening**	
1	Type	Rolled earth fill
2	Road width at top	40' (12.19 m)
3	Max. height	60' (18.29 m)
4	Upstream slope	3:1
5	Downstream slope	2.5:1
6	Crest length	1,500' (457.2 m)

E	**Kulamavu Channel**	
1	Length of channel	6,825' (2080.26 m)
2	Bottom width	50' (15.24 m)
3	Max. top width	650' (198.12 m)
4	Slope of channel	1 in 3000
5	Bed level at downstream end	2,263'
6	Maximum velocity assumed	5'/s. (1.524 m/s)
7	Maximum design discharge at MDDL	5,760 cusecs (163.10 cumecs)
8	Side slopes	1:1 in rock
		2:1 and 2.5:1 in soil.
F	**Spillway for Idukki Reservoir at Cheruthoni Dam**	
1	Original design Flood (1974)	8019.83 m^3/s
2	Revised design Flood approved by CWC	9402 m^3/s including the flood contribution of 90.3 m^3/s from diversion schemes
3	Width of Spillway	240' (73.2 m)
4	Length of Spillway Channel	149.35 m
5	No. and size of radial gates	5 Nos. 40' x 34' (12.19 m x 10.36 m) Rope Drum Hoist of capacity 60 T
6	Spillway Discharge Capacity	3875 m^3/s at FRL
		5000 m^3/s at MWL
7	Slope of Spillway Channel	1/100
8	El. of Spillway Crest	2373.00' (723.29 m)
9	Clear roadway at Spillway bridge	4.572 m
10	El. of the top of Hoist Bridge	+986.49 m
11	Total width of Hoist Bridge	3.66 m
12	Dead storage at MDDL	536.81 Mm^3
G	**Diversion Schemes**	
a.	**Kallar Diversion Weir**	
1	Type	Concrete
2	Length of Dam at Top	57.91 m
3	Width of Dam at Top	3.50 m
4	Height above deepest foundation	12.19 m
5	Main Spillway Arrangement:	
	(i) Type of Spillway	Ogee

	(ii) No. of Bays	4
	(iii) Type of Gate	Radial
	(iv) Size of Gate:	
	Height	6.10 m
	Width	7.62 m
	(v) Total Spillway Capacity of all bays	1014 m^3/s
	(vi) Gate Hoisting Arrangement	Rope-Drum Type, 25 T capacity
6	Catchment Area at Dam site	187 Sq km
7	Maximum Water Level	824.5 m
8	Full Reservoir Level	824.5 m
9	Minimum Draw Down Level	816.86 m
10	Live Storage Capacity	0.76 Mm^3
11	Gross Storage Capacity at FRL	0.79 Mm^3
12	Reservoir Spread Area at FRL	0.25 Sq km
b.	**Erattayar Diversion Weir**	
1	Type	Concrete
2	Length of Dam at Top	146.30 m
3	Width of Dam at Top	4.70 m
4	Height above deepest foundation	19.81 m
5	Volume Content of Dam (10^3)	465 m^3
6	Main Spillway Arrangement:	1263' (384.96 m)
	(i) Type of Spillway	Ogee
	(ii) No. of Bays	2
	(iii) Type of Gate	Radial
	(iv) Size of Gate:	
	Height	6.10 m
	Width	7.62 m
	(v) Total Spillway Capacity of all bays	507 m^3/s
	(vi) Gate Hoisting Arrangement	Rope Drum Type, 25 T capacity
	(viii) Energy Dissipation Arrangement	Ski jump
6	Catchment Area at Dam site :	68.80 Sqkm
7	Maximum Water Level	754.40 m
8	Full Reservoir Level	754.40 m
9	Outlet Levels	741 m

10	Gross Storage Capacity at FRL	5.35 Mm^3
11	Reservoir Spread Area at FRL	0.96 Sq km
II	**POWER SYSTEM**	
A	**Headrace Tunnel**	
1	**Intake Tower**	
	Type	"Morning-glory" reinforced concrete structure
	Exterior diameter	64’ (19.507 m)
	Top of slab El.	2271.25’ (692.277 m)
	Sill elevation	2245’ (684.276 m)
	Invert elevation	2200’ (670.56 m)
	Inside diameter	23’ (7.01 m)
	Trash racks	16 units, 10’ x 22’ (3.048 m x 6.706 m) each
	Concrete quantity	1743.185 m^3
2	**Headrace Tunnel**	
	Type	Horse shoe shaped, concrete lined pressure tunnel
	Total length	6653’ (2027.834 m)
	Excavation diameter	26’ (7.925 m)
	Lined diameter	23’ (7.01 m)
3	**Surge Shaft and Expansion Chambers**	
	Type	Inclined surge shaft with upper and lower expansion chambers and with restricting orifice.
	Vertical shaft	
	Inside diameter	23’ (7.01 m)
	Orifice diameter	11’ (3.353 m)
	Lower Horizontal Expansion Chamber	
	Inside diameter	23’ (7.01 m)
	Length	166’ (50.59 m)
	Inclined Shaft	
	Excavation diameter	31.5’ (9.601 m)
	Length	250’ (76.2 m)

	Inclination	53°
	Upper Expansion Chamber	
	Section	23’ (7.01 m) - D shaped
	Length	464’ (141.427 m)
4	**Penstocks**	
	Type	Underground, steel lined pressure conduits.
	Length	Penstock No. 1: 3259 ft (993.34 m)
		Penstock No. 2: 3136 ft (955.85 m)
	External diameter	12'-7 7/8" (3.86 m) at top, reduced to 12'-2 1/2" (3.72 m) at bottom
	Maximum design head	2453 ft (747.674 m) (incl. 10% water hammer)
	Assumed rock participation	50%
	Quality of steel: Penstock No. 1	
	Above El. 1680	Mild Steel, ASTM A-285
	Plate thicknesses	13/16 - 1 in (0.021 m - 0.0254 m)
	Below El.1680	Intermediate grade steel: Lukens 36 and ASTM A-537
	Plate thicknesses	13/16 - 2 in (0.021 m - 0.051 m)
5.	**Wyes**	
	Type	Bifurcations strengthened with horseshoe girder and tie rod.
	Max. design head	2453 ft (747.674 m)
	Rock participation	0%
	Quality of Steel	High tensile: FG 47
	Plate thicknesses	Shell: 41 - 73 mm (1 5/8 - 2 7/8 in)
		Horseshoe girder: 150 mm (5 7/8 in)
	Elevation of centre of pipes	180.0 ft (54.86 m)
6.	**Manifolds**	
	External diameters	9'-10" (2.74 m) between the wyes and 7'-1" (2.16 m)downstream of wyes
	Rock participation	0%
	Quality of steel	FG 47 between wyes and ASTM A-537 downstream of wyes.
	Plate thicknesses	60 mm (2 3/8 in) between wyes

		51 mm (2 in) downstream of wyes
	Elevation of centre of pipes	180.0 ft (54.864 m)
7.	**Butterfly Valve Chamber**	
	Type	Underground main chamber with 3 side chambers, excavated in rock.
	Main chamber dimensions**:**	
	• Length	145 ft (44.196 m)
	• Width	32 ft (9.754 m)
	• Height	38.5 ft (11.735 m)
	• Overhead crane: Capacity	40 T
	• Butterfly valves	Two 12'6" (3.81 m) diameter
	• Elevation of centerline of valves	2157.46 ft (657.594 m)
B	**Powerhouse**	
	Type	Underground single main chamber, excavated in solid rock.
	Length	460 ft (140.21m)
	Width	65 ft (19.81 m)
	Height	115 ft (from crown of roof to bottom of turbine pit) (35.05 m)
	Valves	6 spherical valves, 63 in (1.60 m) diameter
	Turbines	3 vertical Pelton turbines with 6 jets, 375 rpm, 130 MW each.
		(1st stage)
	Generators	3 units 130 MW, 11 kV (1st stage)
	Transformers	9 units 48 MVA each (1st stage)
	Overhead cranes	Two 150 T capacity each
The Turbines, Generators, Transformers capacity are doubled in the second stage of the Project in 1986 enhancing the total capacity to 780 MW.		
C	**Cooling Water System**	
1	**Water Reservoir**	
	Length	92 feet (28.042 m)
	Width (average)	16 feet (4.877 m)
	Bottom El.	322 feet (98.146 m)

	Capacity	184,940 U.S. Gallons (700.0741 m^3)
D	**Tailrace**	
1	**Tailrace Tunnel**	
	Type	'D' shaped concrete lined free flow tunnel (only the sides and bottom are lined)
	Total length	4,000 ft (1219.2 m)
	Excavated area	635 Sq ft (58.99 m^2)
	Finished area:	26' x 24' (7.92 m x 7.32 m)
	Bed slope	1 in 1000
2	**Open Channel**	
	Length of open channel from tailrace tunnel exit to the outer face of upstream through wall of super passage	959 ft (292.303 m)
	Shape	Trapezoidal, concrete lined.
	Bottom width	26 ft (7.92 m)
	Side slopes	1 H to 8 V
	Bed slope for first 360'	1 in 1,000
	After Ch. 360'	1 in 4,000
	Depth for maximum flow	16 ft (4.88 m)
	Sill level of open channel exit	148.01 ft (45.11 m)
	Sill level of channel beneath super passages	147.5 ft (44.96 m)
3	**By-pass Channel**	
	Shape	Trapezoidal, concrete lined
	Depth of flow max.	16 ft (4.88 m)
	Side slope	1 H to 8 V
	Length	2,800 ft (853.44 m)
	Bottom width	35 ft (10.67 m)
	Bed slope	1 in 4,000
4	**Super Passage at Chainage 959'**	
	Width of flow of Nachar	69 ft (21.03 m)
	Width of structure between outside faces of trough walls	71 ft (21.64 m)
	Thickness of trough wall	1 ft (0.3048 m)
	Height of trough	9 ft (2.74 m)

	Floor level of S.P. trough	178
	Max. depth of flow	8' (2.44 m)
	Length	80' (24.38 m)
E	**Switchyard and Cable Tunnels**	
1	**Switchyard**	
	Switchyard area	821' x 282' (250.241 m x 85.95 m)
	Switchyard level	+550 ft (167.64 m)
	Cables from Powerhouse to switchyard	9 Nos, single phase oil filled.
	Bus arrangement	Double bus
	Transmission lines	One double circuit line to Kalamassery and one single circuit line each to Mysore and Pallom.
2	**Cable Tunnels**	
	No. of tunnels	2
	Sectional area	68 Sq ft (6.32 m^2) (2.44 m x 2.59 m)
	Length	1,400 ft (426.72 m)
F	**Access Roads, Access Tunnels and Moolamattom Colony**	
1	**Access to Project**	
	Nearest harbor	Cochin
	Nearest airport	Cochin
	Nearest railhead	Angamali and Ettumanoor
	Road distance from nearest town to Moolamattom	87 km from Ernakulam (Cochin) and 81 km from Kottayam
	Road distance from Moolamattom to Kulamavu	18 km
	Road distance from Kulamavu to Idukki	27 km
2	**Access Tunnel to Powerhouse**	
	Length	2,350
	Section	24' x 20' (7.32 m x 6.096 m)

The Reservoir

The Idukki reservoir is formed in Periyar River basin by constructing three dams viz. Idukki, Cheruthoni & Kulamavu and two diversion dams/weirs across Kallar and Erattayar streams. The layout map of the project and reservoirs under the project are shown in **Fig 1.4** and **Fig 1.5**. A Google map view of the reservoir is also given in **Fig 1.6.**

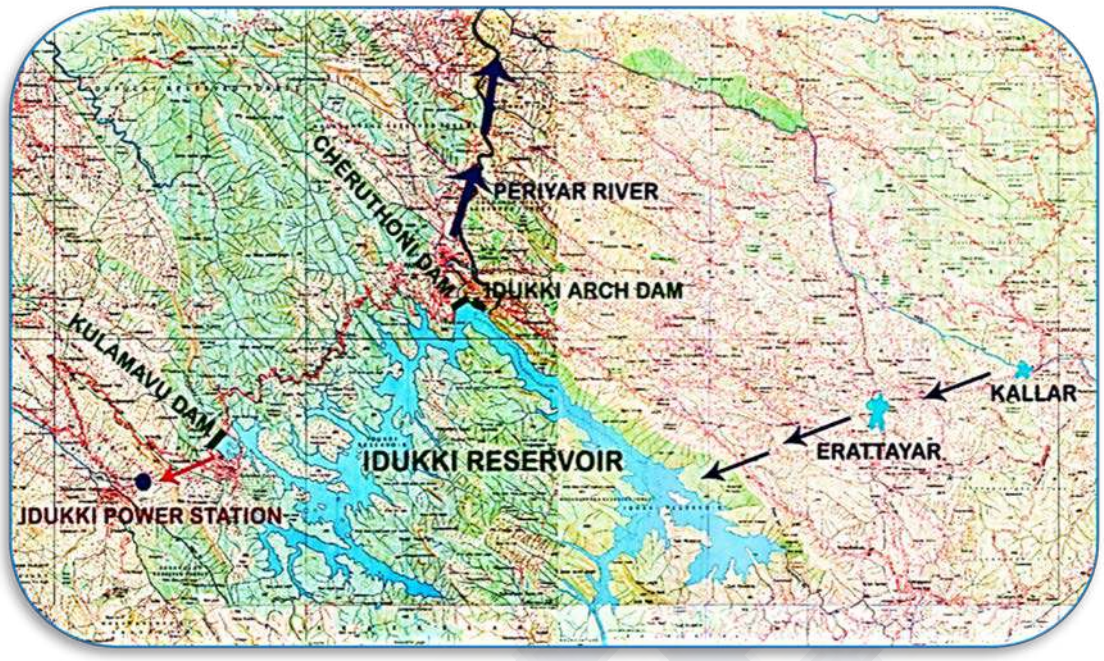


Fig 1.4 Reservoir Layout of IHEP

The spill way of the reservoir is provided in Cheruthoni concrete gravity dam. There are 5 nos. of radial gates. The size of gate is 12.19 m x 10.36 m. The spill water flows to Periyar River. There are two lower level outlets provided for the dam. Elevation at the C/L of low level outlet is 673.45 m. The bed profile varies from 598 m to 736 m.

The following Augmentations schemes are completed construction to divert more waters from neighboring streams to increase the power potential of the project.

Project	**Energy addition**
Idukki Stage III	376 MU
Narakakkanam	7 MU
Vazhikkadavu	25 MU
Vadakkepuzha	12 MU
Kuttiyar	44 MU
Azhutha	57 MU
Total addition	**521 MU**

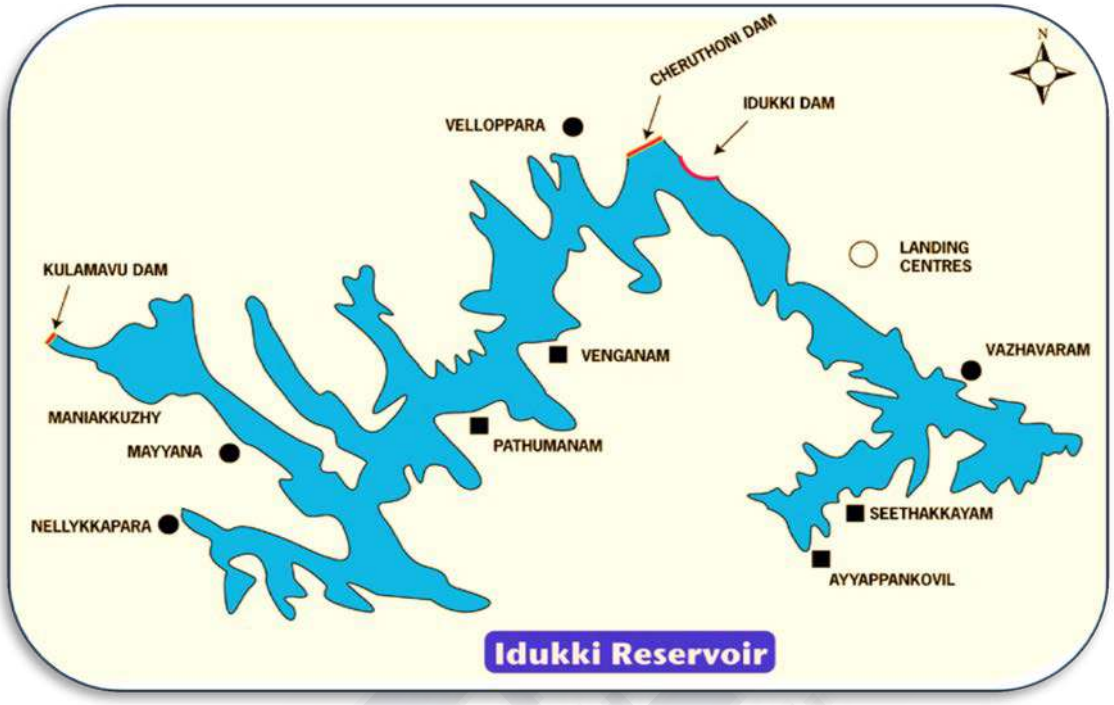


Fig 1.5 IHEP Reservoir

Fig 1.6 Google map view of the reservoir

1.3 Background Details of the Project

History of the project dates back to the year 1919 when a small and modest scheme to harness Periyar waters was proposed with a small dam across Periyar at Idukki and to lead the impounded waters through a tunnel and pipe line to a power house to be located on the banks of the same river lower down, to utilize a head of 236.3 m (775 ft) for power generation. Later, in 1932, a proposal for a trans-basin diversion of Periyar for hydro-power development was brought to the notice of the erstwhile Government of Travancore. This scheme, contemplated the construction of two high dams, one across Periyar at Idukki 182.9 m (600 ft) high, the other across Cheruthoni, a tributary of Periyar 152.4 m (500 ft) high to create a common reservoir of 88 sq km (34 sq miles) water spread and to divert the waters through a long tunnel at El. 685.8 m (2,250 ft) to a power house to be located at Arakkulam at El. 45.7 m (150 ft) to generate power.

In 1937, two Italian Engineers, Mr. Angelo Omedeo and Mr. Claudeo Marcelle were commissioned by the Government of Travancore to assess the hydro-power potential of the State. They studied the available data and proposed a small scheme to harness Periyar waters by two dams, one in Periyar at Idukki and other in Cheruthoni interconnected by means of a tunnel and to generate power in a power house to be located on the banks of Periyar itself. It was during 1949, that a preliminary report on the project was submitted to the then Government of Travancore-Cochin by the Electricity Department. As the magnitude of the project became more clearly defined and resources of the small State was found inadequate to take up further works, the Government of India took up the detailed investigation studies at the request of the State Government. Formal inauguration of the investigation of Idukki Project was done in September 1956 by Sri. Gulzarilal Nanda, the then Minister for Irrigation and Power, Government of India.

The Central Water and Power Commission investigated the scheme in detail, utilizing the services of Central and State Engineers. Based on the scheme prepared and finalized by them in September 1961 the Planning Commission sanctioned a project for Rs. 49.23 cores in January 1963. The proposal approved by the Planning Commission comprised the creation of a single reservoir by three dams, viz., 164.6 m (540 ft) high concrete non-overflow arch dam at Idukki, 132.6 m (435 ft) high masonry gravity dam across Cheruthoni and 74.7 m (245 ft) high earthen dam across Killivallithodu, one power tunnel, surge shaft, 4 Nos L.P tunnels

commencing from the surge shaft and 8 Nos pen stocks to feed 8 Nos 100 MW generators. Preliminary works of the project were then taken up and simultaneously it was posed for aid assistance from friendly countries. During the pre-construction surveys and studies by the Kerala State Electricity Board, the scope of the project was enlarged and revised. Late Sri. V Ranganathan, who was then Chief Engineer in charge of the project, was responsible for visualizing the project in its present form. The Government of Canada agreed to aid the construction of the project and appointed the Canadian Engineering firm of M/s Surveyor, Nenniger and Chenevert Inc., as Consultants for the project. This resulted in certain modifications to the original project features relating to reservoir levels and choice of the type of structures. A revised Project Report was drawn up in 1966 and this was finally approved by the Planning Commission. An aid agreement was signed between the Governments of Canada and India in 1967; the consulting engineers were assigned the engineering responsibility in respect of Idukki Arch Dam, pressure shaft and the underground power house.

Major Contracts

The contract for the construction of Idukki Arch Dam was awarded to M/s Hindustan Construction Company Ltd during December 1966. The construction of Cheruthoni concrete gravity dam also was entrusted with the same contractors. The contract value of the work carried out through M/s Hindustan Construction Company Ltd., in respect of Idukki Dam was Rs.6.60 Crores against the total estimated cost of Rs.10.44 crores. The cement for concrete was supplied by the State Electricity Board. The Consulting Engineers were Canadian Consultants M/s Surveyer, Nenniger and Chenevert Inc., having specialists in survey, rock mechanics, geology, dam construction, concrete technology, power house equipments etc., and they were stationed at site headed by a Senior Canadian Engineer. The Consulting Engineers from Montreal and their Consultant Geologist and consultant on arch dam design visited the project site at times.

Organisation

The Kerala State Electricity Board's Organisation for the execution of Idukki Project was headed by the Chief Engineer, Civil for all works including designs. KSEB ensured quality control and instrumentation, supplies and services from Angamali. Consultancy services were arranged with Dr. K.V. Swaminathan formerly of IISc Bangalore, Model studies by CWPRS, Pune and for the establishment of the Idukki seismic net. The Geological Survey of India was

also associated with the project. The aerial photographic survey of the Idukki Dam site was done by the Survey of India**.**

1.4 Salient Features of Component Dams of the Project

1.4A IDUKKI DAM

1.4A.1 Geometric Definition of Dam

The dam consists of a non-overflow double curvature concrete arch 560 feet high with a crest length of 1170 feet. The arch is built across a non-symmetrical valley with the right and left banks inclined by 45° and 37° respectively to the horizontal. The arch thickness, which varies with the height, is 24 feet at the crest elevation (2415 ft) and 65 feet at the lowest point (El.1850 ft). It also varies between the crown section and the abutments. The dam is composed of **24** blocks or monoliths separated by helicoidal contraction joints.

The arch dam foundations are blocked by backfill concrete along the valley slopes in a step arrangement as shown on the reference drawings. In addition to anchoring the arch to its foundations, this backfill concrete provides an excellent platform at various elevations for work related to grouting or foundation drainage. For design reasons, the three top left abutment blocks have a special geometry, in which their upstream face is curved along an arc of a circle. The crest incorporates a 22 feet wide roadway with concrete parapets consisting of modular precast elements mounted on upstream and downstream cantilevers.

The geometric definition, plan and cross section of Idukki Arch Dam are given in **Fig 1.7a & Fig 1.7b, Fig 1.8** & **Fig 1.9**. Google view of the dam is given in **Fig 1.10**. The photographs of Idukki dam from upstream and downstream sides are given in Fig **1.11a** & **Fig 1.11b**. The photographs of Idukki dam downstream bottom from central block-01 and downstream view of left & right banks from dam top are given in **Fig 1.12a and Fig 1.12b.**

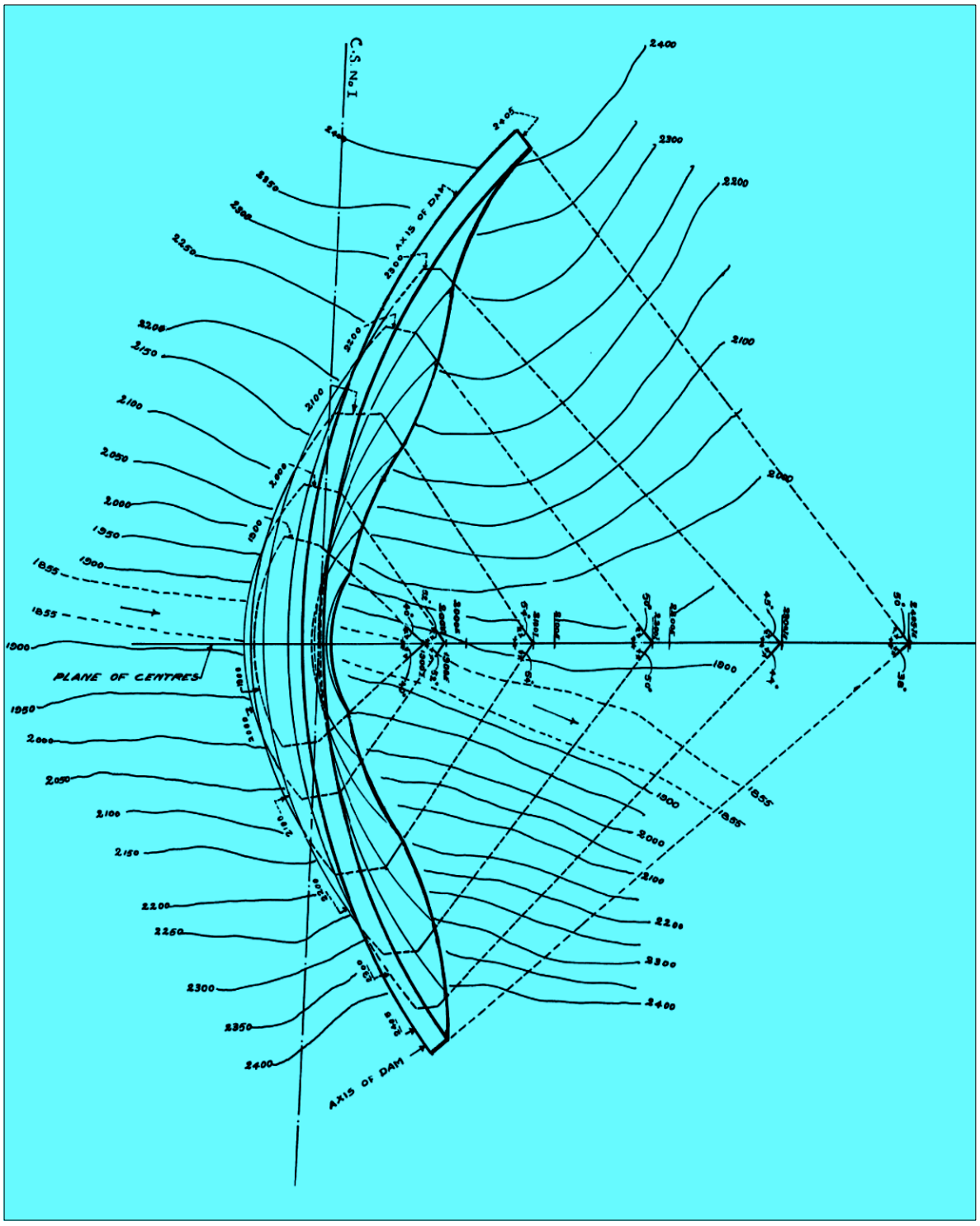


Fig 1.7a Geometric Definition of Idukki Arch Dam

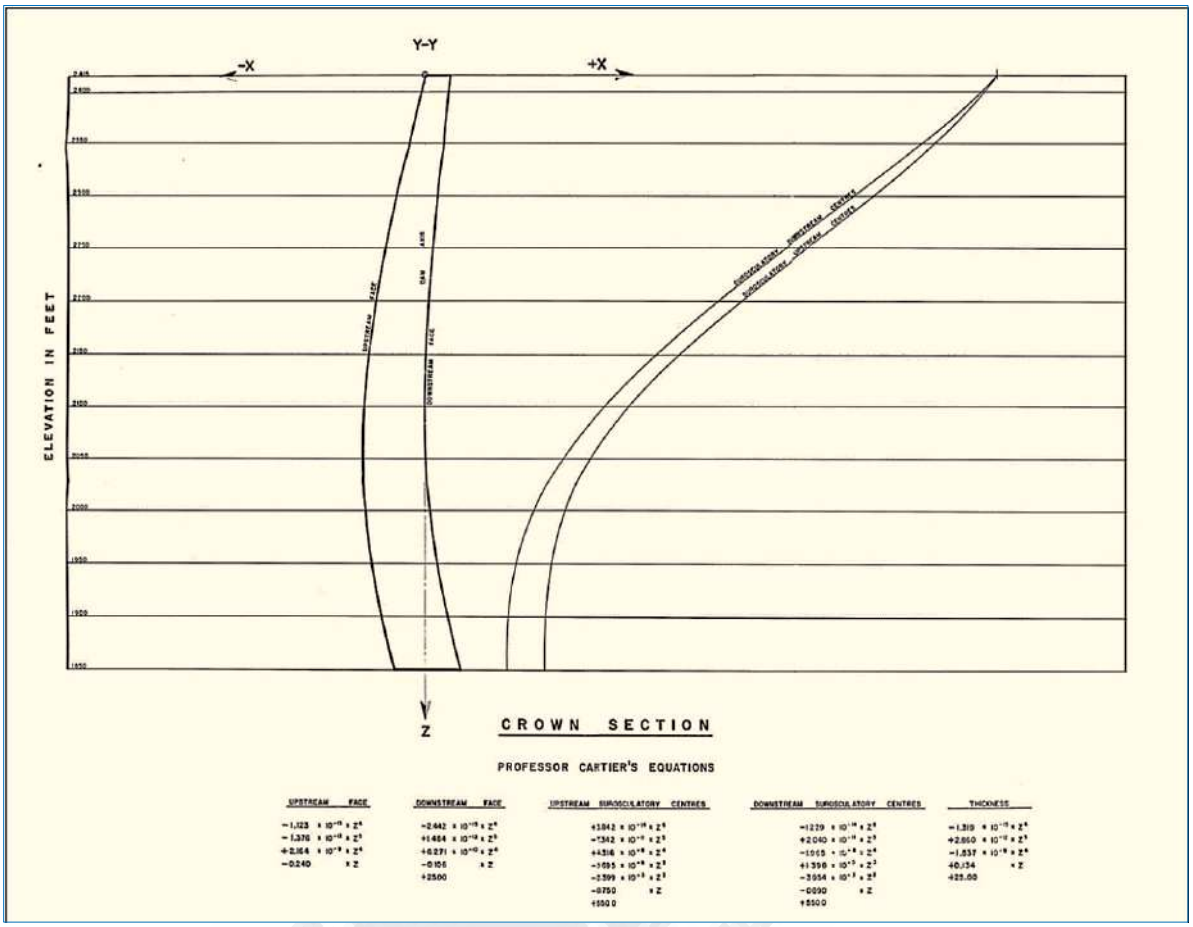


Fig 1.7b Geometric Definition of Idukki Arch Dam

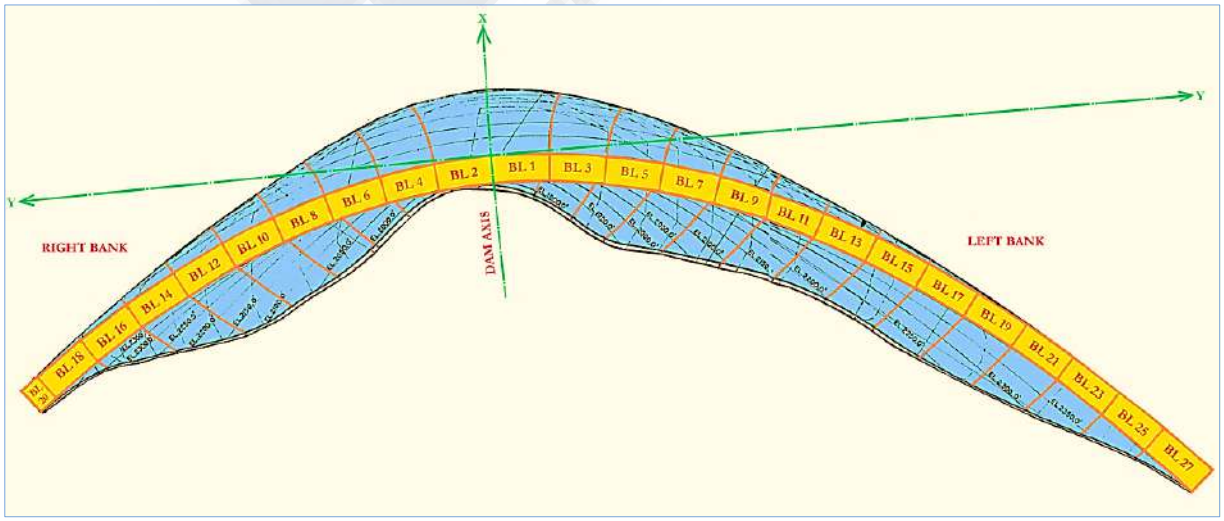


Fig 1.8 Plan of Idukki Arch Dam

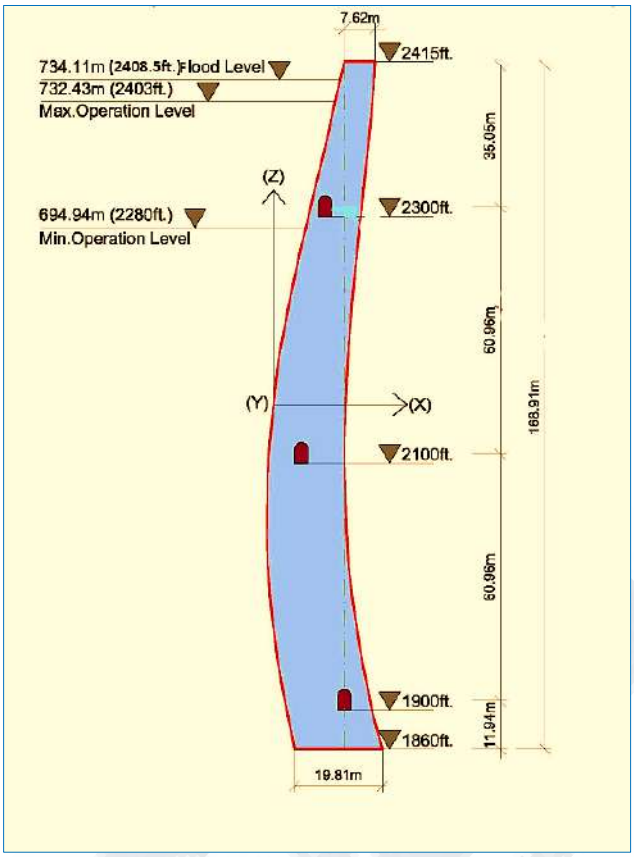


Fig 1.9 Cross Section of Idukki Arch Dam

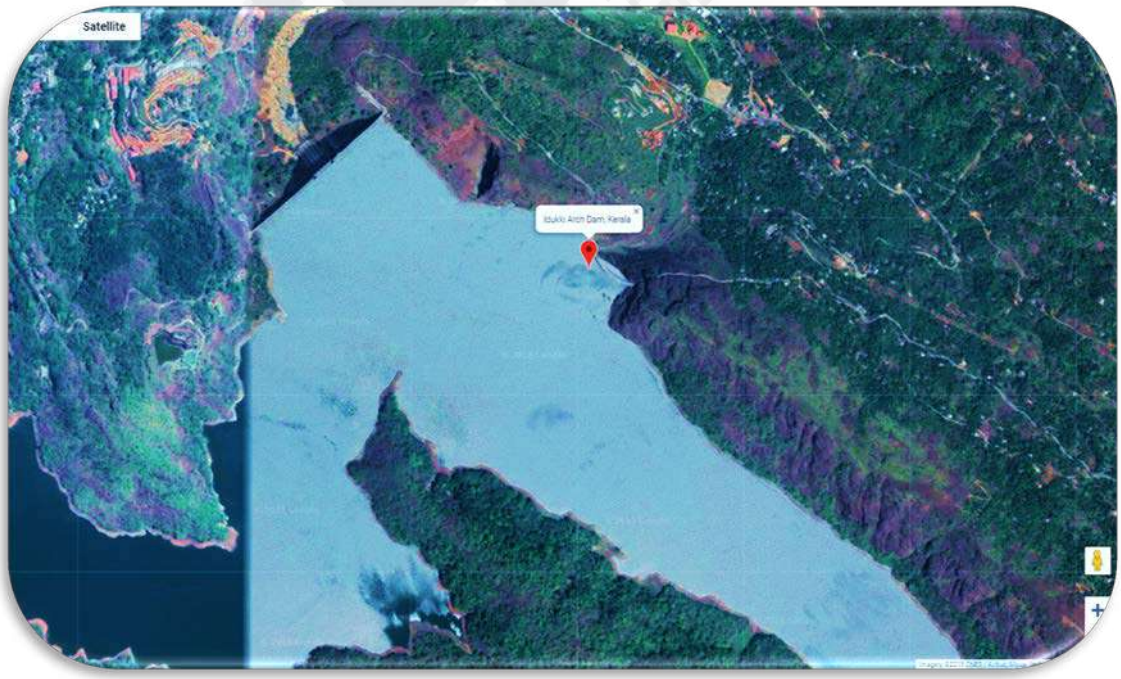


Fig 1.10 Google view of the Idukki dam

Fig 1.11a View of Idukki dam from upstream of reservoir

Fig 1.11b View of Idukki dam downstream

Fig 1.12a View of Idukki dam d/s bottom from central block – 01

Fig 1.12bView of Idukki dam left and right banks (downstream) from dam top

1.4A.2 Galleries and Face Drains

The dam includes a system of 10" drain holes which are designed to intercept and dispose of any leakage that may develop from time to time due to;

1) Defective construction joints (lift joints)
2) Defective water stops
3) Fissures originating at the upstream face of the dam.

Likewise, the dam abutments comprise a system of drain holes which are designed to drain the rock mass which is subjected to the arch thrusts. For the purpose of monitoring the performance of this combined drainage system, the dam and its abutments incorporate a system of galleries designed to collect any leakage flow intercepted by the face drains, the foundation and abutment drains. These galleries also permit the inspection of the surrounding concrete or rock to detect any possible fissuration and leakage points.

Three of these galleries traverse the dam horizontally from one abutment to the next at elevations 1900', 2100' and 2300' and extend into the rock mass by a length sufficient to meet foundation drainage requirements. In the left abutment the length of the rock galleries varies from 220 feet in the gallery at elevation 2300' to 280 feet in the gallery at elevation 1900'. In the right abutment the three rock galleries extend further and merge with an elevator shaft connecting all three galleries to the right bank access tunnel at the crest level. Arch cross sections at the galleries and dam top are given in **Fig 1.13a** and projected elevation from downstream side of the dam is given in Fig**1.13b**.

Photographs showing inspection gallery at El. 2300' & at El.2100' and foundation gallery at El.1900' are given in **Fig 1.14a, Fig 1.14b** and **Fig 1.14c**. In addition to the horizontal galleries, the dam comprises one bottom gallery which traverses the dam periphery near the rock abutments and merges with the 1900' gallery. Stairway landings are provided for every 50' increment in elevation. Also, a vertical 8' shaft is incorporated in the lower left abutment. Each horizontal gallery is formed of a series of straight sections along the curvature of the dam each of which traverses one block of the dam. The gallery extensions, into the rock abutments, are also straight, except for the left and right abutment bottom galleries at elevation 1900' which extend into the rock with one change in direction. A distance of 50' in each rock gallery measured from the rock concrete interface into the rock mass is concrete

lined. Dam cross sections, downstream elevation and General layout showing shafts and galleries are given in **Drg 1.1, Drg 1.2 & Drg 1.3** of **Annexure 1**.

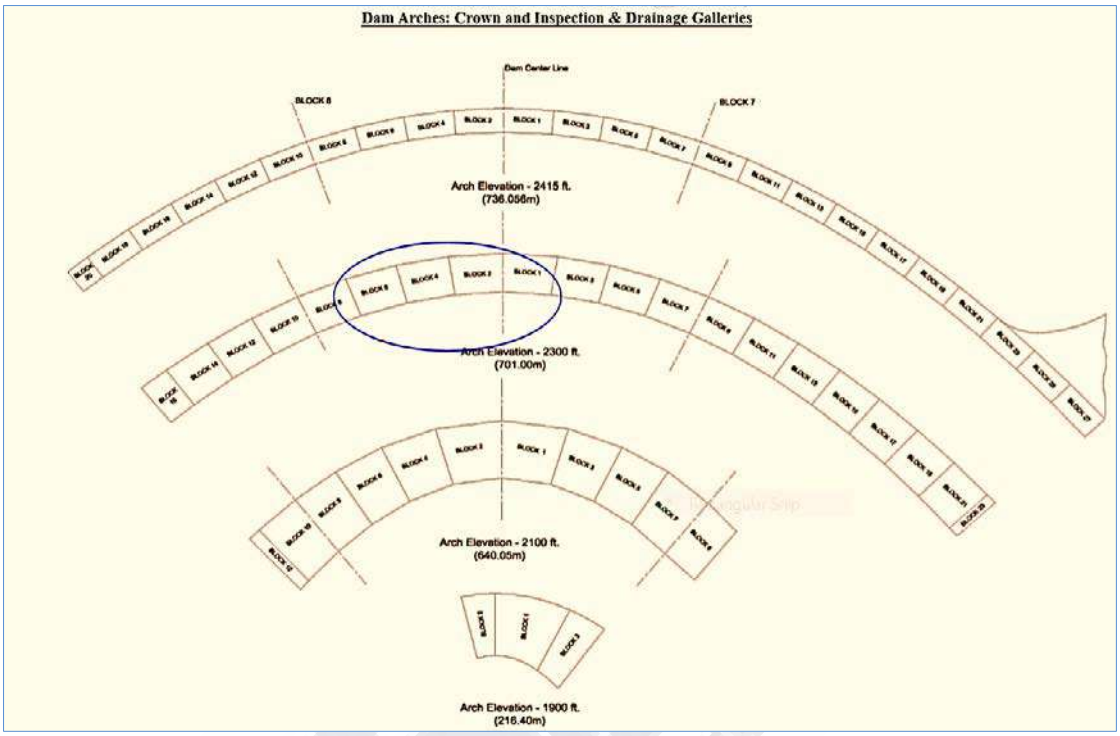


Fig 1.13a Arch cross sections of Idukki dam at elevations 1900', 2100', 2300', 2415'

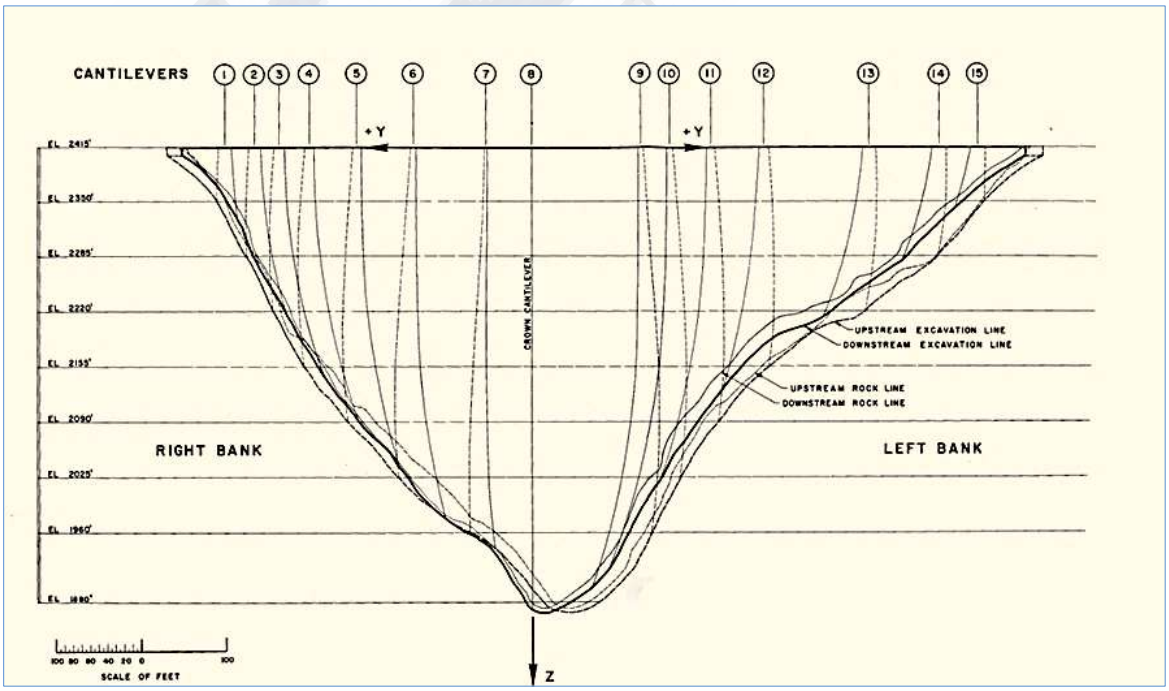


Fig 1.13b Cantilever sections of Idukki dam from downstream

For access, the gallery system is provided with a number of Adits through the downstream face of the dam near both the abutments. These Adits can be reached by a series of footpaths carved on the mountain side. The dam galleries can also be reached by an **elevator** from the right bank access tunnel or through an Adit to rock gallery at El. 1900 in the lower right abutment.

Fig 1.14a Inspection gallery at El. 2300'

Fig 1.14b Inspection gallery at El. 2100'

Fig 1.14c Foundation gallery at El.1900'

The gallery and shaft system also comprise:

1. Three pendulum shafts and one cable shaft in block 1
2. An upstream gutter in each gallery designed to direct collected leakage to the main collector shaft.

The main features of the galleries and shafts are summarized in the following table:

Designation	Location	Nominal elevation (feet)	Length (feet)
Galleries in Dam Structure:			
1900	Dam	1900	75
2100		2100	500
2300		2300	940
Abutment gallery		1900-2300	1530 including 8ft shaft
Galleries in Rock Abutments:			
RG 1900	Right	1900	520
RG 1925	Left	1925	280
RG 2100	Right Left	2100 2100	280 300
RG 2300	Right Left	2300 2300	160 220

Table 1.1 Galleries

Designation	Location	Range (Elevation)	Height (feet)	Diameter(feet)
Elevator Shaft	Right abutment	1900 to 2415	550	13', unlined
P-l	Dam block 8	2100 to 2400	300	2'
P-4	Dam block 1	1900 to 2100	200	2'
P-3		2100 to 2300	200	2'
P-2		2300 to 2400	100	2'
P-5	Rock, under block 1	1900 to 1761.8	138.2	2', above El.1860 8" below El.1860
P-6	Dam block 7	2100 to 2400	300	2'

Table 1.2 Shafts

The drawings containing the main information pertaining to the galleries and shafts, including layout, interconnections, elevations of elevator and stairway landings and concrete and rock Adits are kept as supporting documents at the field office.

1.4A.3 Contraction Joints

The dam comprises **23** contraction joints as noted above. The joints are provided to prevent concrete fissuration during construction and to achieve the overall monolithism of the dam by allowing tightening of the monoliths under cement pressure grouting prior to load application. For this purpose, the contraction joints are equipped with a complete grouting system composed of grouting risers and lines designed to feed cement grout through special grout outlets and grooves to the joints.

Near the upstream face of the dam each joint is provided with two water stops, (also known as sealing strips) embedded in the concrete and spaced one foot apart. The first water stop, located one foot from the upstream face, consists of a Monel metal Z shaped 18" inch wide strip extending from the rock foundation to the crest. This is also provided horizontally at the end of each construction campaign from one abutment to the next. The second type of water stop is made of (Polyvinyl Chloride) 12" inch PVC strip, also extending from the rock to the crest.

To permit joint grouting during construction and to control grouting operations, each contraction joint is divided into compartments by embedding 9" wide PVC strips across every joint horizontally in the upstream-downstream direction, along the downstream face of the joint and around the galleries. A number of compartments, therefore, serve each contraction joint. Every contraction joint is in addition provided with shear keys designed to resist any differential loads acting on the dam blocks and to secure full monolithism of the arch. The upstream and downstream elevation showing details of lift joints are given in **Drg 1.4** and **Drg 1.5** of **Annexure 1**.

Reinforcing Steel

The following parts of the Idukki Dam are provided with reinforced steel:

- the concrete around the galleries
- the upstream and downstream cantilevers at the crest
- the precast crest parapet
- the four buttresses between the top left bank abutment and the main rock knob

The galleries are systematically reinforced as follows:

- horizontally: 12 mm bars at 24"c/c
- vertically: 25 mm bars at 12"c/c

The upstream and downstream cantilevers are each reinforced along the crest arc with 16 mm bars and transversally along the cantilevers with 22 mm bars set 12" apart. The precast concrete elements of the crest parapet are fully reinforced to carry their dead load during initial placing and to withstand vehicle or equipment impact during maintenance operations. Finally, four buttresses are built at the top left abutment as main components of a number of stabilization features which are designed to prevent any motion of the main left bank rock knob. These are reinforced on each face and on the top with 20 mm bars at 12" centers in both directions.

1.4A.4 Rock Mechanics

For the purpose of design, the modulus of deformation for concrete was assumed to be 3 x 10^6 psi and for the rock 3 x 10^6 psi with a Poisson's ratio of 0.2. Compressive strength of charnockite is in the range of 30,000 psi and tensile strength is approximately 800 psi.

a) Stress Measurements:

Vertical and horizontal jack tests in the abutments indicated a modulus of elasticity in the range of 5 x 10^6 psi. Stress measurements by the over coring methods on both flanks gave 1600 psi parallel to the river, and 2000 psi perpendicular to it. Peak stresses of 6000 psi at El. 1900' and 3000 psi at El. 2100' were found to decline abruptly with increase in depth. No tensile stresses were recorded anywhere.

b) Seismic Testing:

Seismic refraction tests revealed two velocity layers, an upper layer 10 ft thick, with a velocity of 12,000 ft/s and a lower layer at 20,000 ft/s.

c) Earthquake Acceleration:

For the design of Idukki arch dam, earthquake acceleration 'a' into consideration was; a = 0.02g and 0.1g in the upstream-downstream (horizontal) direction. Period of vibration parallel to the plane of center = 1.0 second. As per seismic zone chart of India, Idukki arch dam lies in Zone III with soil type 1 giving a possible acceleration of 0.02 and 0.049.

1.4A.5 Rock Drifts and Shafts

a) Road Tunnel

The road tunnel on the right bank at El. 2415 was driven 390 ft through massive charnockite. The crown was reinforced with rock-bolts, wire-mesh and guniting. Photographs showing the view of Idukki dam through road tunnel at right bank and entrance tunnel at right bank are given in **Fig 1.15a** and **Fig 1.15b.**

Fig 1.15a View of Idukki dam from road tunnel at right bank

Fig 1.15b View of road tunnel at right bank

b) Exploratory and Drainage Galleries

The right bank exploration gallery at El. 2105 measures 6' x 7.5' x 100'. It was plugged to its full length with concrete. The exploration gallery on the left bank at El. 2105 was left open

and is now serving as a drainage gallery. Incorporated in the design of foundation drainage are Six Nos (6 ft x 8.5 ft) rock galleries totaling 1664 ft. Instruments to monitor the vertical and horizontal movements of the dam have been placed in all these galleries. **Fig 1.16** shows exploratory drift tunnel at El.1925 (right bank).

Fig 1.16 Exploratory drift tunnel at El.1925 Right bank

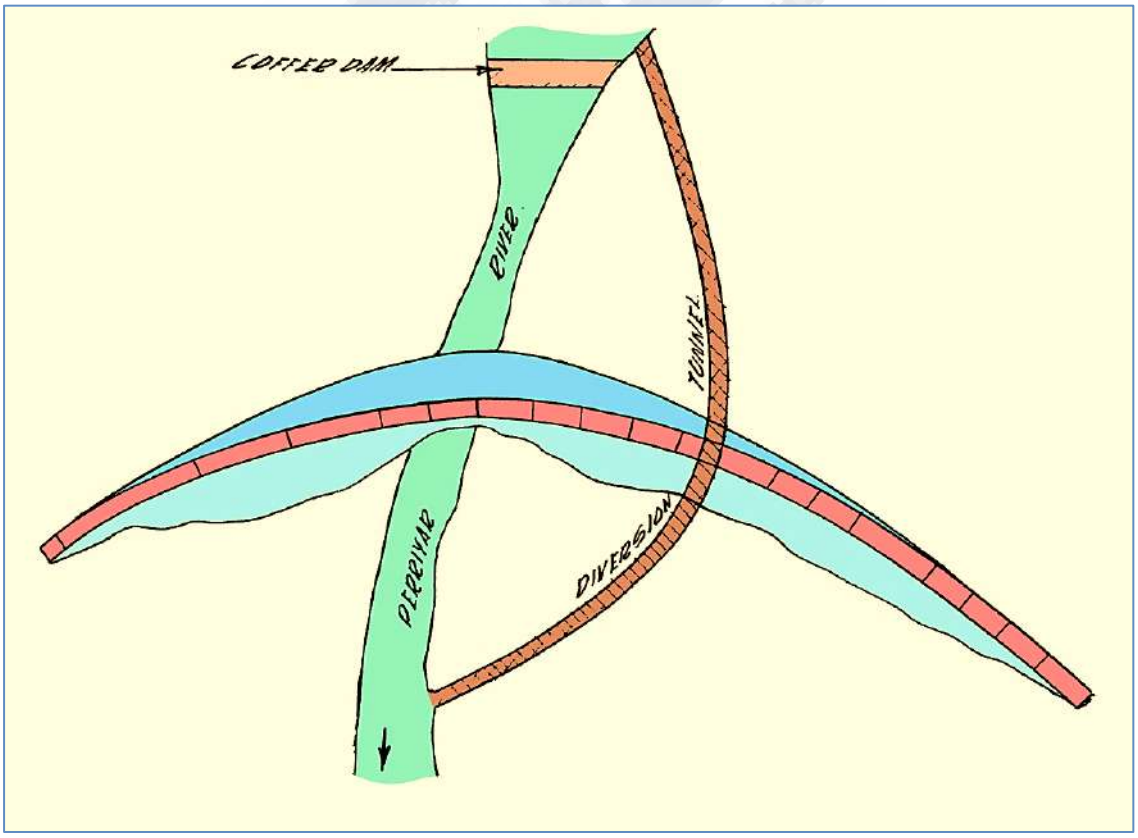


Fig 1.17 Idukki Dam Diversion Tunnel Layout

c) Elevator Shaft

The elevator shaft (**Fig 1.18a**) is vertical, 13 ft circular and 550 ft deep. It is situated on the right bank and opens into the road tunnel. Its purpose is to connect the three rock drainage galleries from the exterior with a modern elevator.

1.4A.6 Diversion Tunnel

The diversion tunnel has 20 ft diameter horseshoe profile and is 813 ft long. The bottom elevation at the inlet is 1888' and at the outlet 1880'. The tunnel was driven through excellent quality charnockite into the left flank, clearing the base of the concrete dam by 98 ft.

It is now plugged. Plugging operations consisted of building three adjacent temporary concrete plugs (two of 15 ft and one of 20 ft) and one permanent plug 40 ft in length. Initial plugging of the Periyar River was done on March 14, 1974 when the four 24" diameter pipes embedded into the second concrete plug were closed. A layout showing diversion tunnel is given in **Fig 1.17.**

1.4A.7 Elevator

The rated capacity of the passenger freight elevator to be installed is 2268 kg. Its travel speed is 30 metres per minute with a constant potential at the controller of 400 volts 3 phase 50 cycles A.C. The size of platform is 2200 mm wide and 2100 mm deep (outside dimensions). The car will travel from El.1905' to El. 2417' (ie. about 156 m) stopping at four floors and serving four openings located on the same side. The elevator is installed in a shaft driven in rock in the right abutment. Photograph showing lift entrance and electrical panel board is given in **Fig 1.18b**.

General Geology

India is divided geologically into three distinct regions:

1. Himalayan Ranges (extra peninsular)
2. Indo-Ganga Alluvial Plains
3. Peninsular Region

The project area is in the Periyar valley of the Kerala State in the peninsular region, a stable land mass which is mostly composed of Precambrian formations. The rocks are products of sedimentary and igneous action and are highly metamorphosed. The project area is under laid with granite gneiss intruded by dykes varying between mafic and felsic forms, and

charnockites of undetermined origin. The regional foliation strikes generally NW and major jointing in a NE direction and both are steep dipping.

Fig 1.18a Vertical shaft at right bank

Fig 1.18bView of lift entrance and electrical panel board

Geology (Idukki)

Geologically the formation of Idukki Gorge is believed to have taken place during the formation of Western Ghats. The site is situated in an Archean group of Precambrian formation of which gneisses and charnockites are predominant. The foundation of Idukki Dam has been carved out of a South East directed mountain of massive coarsely crystalline charnockite. The V-shape gorge, containing the dam through which the Periyar River flowing once at an average rate of 1128 cubic feet per second, is 1100 ft wide by 550 ft deep.

There are no faults except for the two systems of close joints in the area, the most prominent system trending slightly east of north and the less prominent system trending almost East-West. Both systems are steeply dipping, fused and impermeable below the superficial layer. The only characteristic of the rock which warranted careful attention and adjustment in the design was the tendency of charnockite to spall along cohesion less planes. The condition called drumminess of rock is caused due to release of high locked in stresses, crystalline nature of rock and brittleness combined with high modulus of elasticity. Blasting also aggravated drumminess. This was counteracted by carrying excavation without using explosives and immediately before the placement of concrete. No special rock treatment was necessary at depths other than the usual grouting and drainage. Site exploration consisted of making numerous diamond drill holes, permeability tests, surface excavation, seismic and rock mechanic measurements and 8 Adits into the abutments below the dam. The river bottom was found to be well polished and without joints and faults.

Foundation Treatment

The geological exploration of Idukki dam site was carried out in an extensive way. The exploration consisted of making numerous diamond drill holes and logging them, conducting permeability tests, surface excavation, determination of static and dynamic modulus of elasticity of rock and driving of two exploratory drift tunnels into the abutments.

In Idukki dam, contact grouting was systematically done to consolidate the foundation and to fill in the rock concrete interfaces. The design for contact grouting consisted of holes spaced at 3 m (10 ft) centres at the rock concrete contact and to depths varying between 10.5 m to 15 m (35 ft to 50 ft). A total of 824 Nos 50 mm diameter percussion drill holes were made for contact grouting and grouting done at low pressure. Absorption of grout into the rock and at the rock-concrete interface was very little.

A row of 50 mm diameter primary holes drilled 9 m (30 ft) apart, from the foundation gallery at an inclination of 70° to 80° to the upstream side together with secondary and tertiary holes as dictated at site was envisaged for the deep grout curtain of Idukki Dam. The primary grout holes were drilled to a depth equal to nearly 60 percent of the height of the reservoir water. Water testing of the curtain holes drilled revealed that there was practically no absorption except in two or three holes in the left bank and the charnockite rock foundation below the dam is impermeable. Because of this, holes at closer intervals were not drilled and the holes drilled were left open to act as drains and observation holes during the initial filling of the reservoir. Perhaps Idukki Dam is the only dam in operation which has no deep grout curtain barrier established before and after impounding.

For both contact and curtain grouting 'packer grouting' was adopted. The total length of grout holes drilled for Idukki Dam was 19725 m (64700 ft) and the total cement used for grouting was 110 tonnes. This works out to a grout consumption of about 5.6 kg/m of grout hole drilled.

A system of foundation drains is provided in the foundation rock to drain the rock and relieve the uplift pressure. The drainage system consists of two rows of 76 mm (3") diameter holes spaced at 9 m (30 ft) intervals, supplemented with local holes specifically drilled to intersect known fissures. The first row covers the middle part of the foundation and the second row the downstream area. The seepage through drain holes discharge into rock drifts or foundation galleries. Another system of drain holes drilled downstream of the dam toe, ensure relief of pore pressure in the region and thus strengthen the rock mass on the downstream of the dam. The Idukki dam foundation drainage system is made up of 199 holes totaling a length of 7012 m (2300 ft) of drilling.

The plan views of foundation drainage system at left and right bank are given in **Drg 1.6a** and **Drg 1.6b** of **Annexure 1.**

1.4B CHERUTHONI DAM

1.4B.1 Geometric Definition of Dam

This gravity type dam consists of a central overflow section flanked on the two sides by non-overflow sections. The length of spillway section is 240 ft and the non-overflow sections 1895ft. The maximum height of dam above deepest foundation is 454 ft. The thickness of non-overflow section at the top is 30 ft and accommodates a 24 ft clear roadway. The dam

has a downstream slope of 0.74 H to 1 V from El. 2380.00 and an upstream slope of 0.07 H to 1 V from El. 2240. The crest level of spillway is at El. 2373.00. The spillway section has a downstream slope of 0.74 H to 1 V and an upstream slope of 0.07 H to 1 V from El. 2240.00 **(Drg 1.7** of **Annexure 1)**. The energy of the spilling water is dissipated by a flip bucket having a radius of 60 ft. The maximum overflow section and plan of Cheruthoni dam are given in **Drg 1.8** and **Drg 1.9** of **Annexure 1**. A Google view of Cheruthoni dam is given below in **Fig 1.19**.

Fig 1.19 Google view of Cheruthoni dam

The spillway is controlled by 5 radial gates of size 40 ft x 34 ft. The roadway over the spillway is supported on 10 ft wide piers. Two outlets with a total discharging capacity of 30000 cusecs are provided, one on each side of the spillway at El. 2199 and are controlled by an emergency and service gate each. The dam is composed of 39 monoliths or blocks separated by 38 contraction joints. The blocks are numbered consecutively from left bank to right bank. The dam foundations are blocked by backfill concrete in a step arrangement.

Photographs showing downstream and upstream view of Cheruthoni dam are given in **Fig 1.20a and 1.20b**.

Fig 1.20a Downstream view of Cheruthoni dam

Fig 1.20b Upstream view of Cheruthoni dam

1.4B.2 Galleries and Shafts

The dam includes a system of 10 inch diameter drain holes (**Fig 1.21)** designed to intercept and dispose of any leakage which may develop due to defective construction joints (lift joints), defective water stops or Fissures originating at the upstream face of the dam**.**

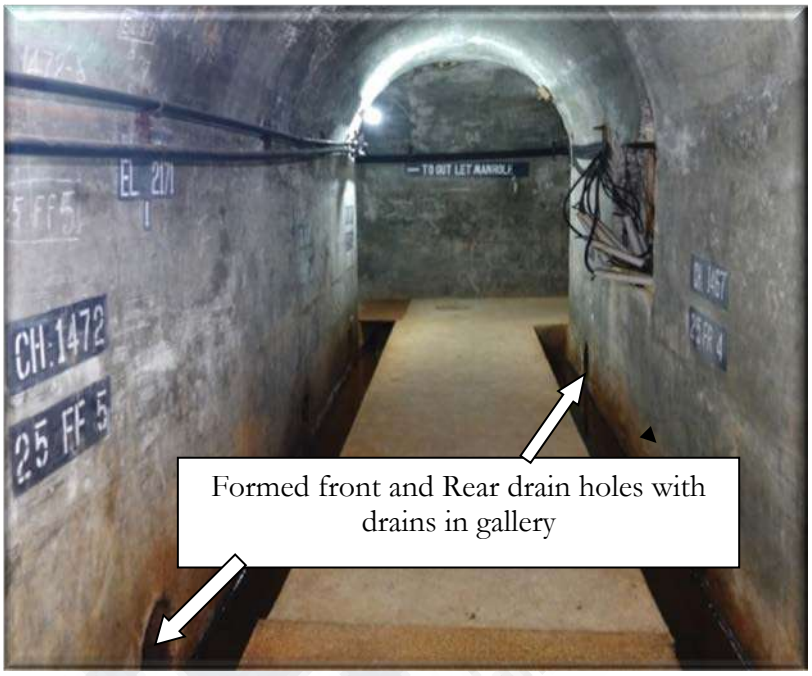


Fig 1.21 Formed drain holes to dispose seepage water

Likewise, the dam foundation contains a system of drain holes to drain foundation and grout holes for consolidating the foundation and to make a grouted cut off curtain beneath the foundation. For the purpose of monitoring the performance of this combined drainage system, to drill and grout the foundation if necessary at a future date, to give access to the outlets, to aid inspection of the dam structure. The dam and its abutments incorporate a system of galleries 6' x 8' size. Five of these galleries traverse the dam horizontally (longitudinally) from one abutment to the other at Elevations 2000 ft, 2004 ft, 2092 ft, 2173 ft, and 2291.5 ft. The gallery at Elevation 2004 ft is located 190 ft downstream of the axis of dam. The one at Elevation 2291.5 ft is at 15'6" and others at 18' 6" from the axis of the dam. There is also a transverse horizontal gallery in block 28 at El. 2070 ft. **Fig 1.22a** and **1.22b** shows inspection gallery and transverse gallery of Cheruthoni dam respectively. The elevation along the centerline of galleries is given in **Drg 1.10** of **Annexure 1**.

Five rock galleries driven for foundation exploration, treatment of abutments and drainage abutments are also connected to this gallery system. The rock galleries at right bank are 660 ft long and at left bank 1050 ft long. The galleries have access by an elevator provided in block 26 and through a number of Adits from the downstream face of the dam near both abutments. These Adits can be reached by a system of roads and footsteps. The downstream elevation, typical section of elevator shaft & inspection gallery is given in **Drg 1.11** of **Annexure 1**.

Fig 1.22a Inspection gallery - Cheruthoni dam **Fig 1.22b Transverse gallery**

In addition to the horizontal galleries the dam has one bottom gallery also which traverses the dam periphery near the rock abutments and merges with the gallery at El. 2000 ft. A similar system is provided for the longitudinal gallery at El. 2004 ft. Stairways and landings are provided in this bottom gallery. The rock galleries are concrete lined, and have a finished section of 6 ft x 8 ft.

The gallery and shaft system also comprise the following:

- Four pendulum shafts, two 18" dia. collector drains, cable ducts, access galleries to pump chamber and outlet manholes, drain culverts and air vents to outlet gates.
- An upstream gutter is provided in each gallery to direct water leakage to the collector drains.

The main characteristics of the galleries and shafts are summarized in the following table **Table 1.3 & Table 1.4**.

Designation		Location	Nominal Elevation (feet)	Length (feet)
Galleries	2000	Dam	2000	195
	2004		2004	164
	2092		2092	542
	2173		2173.5	879
	2291.5		2291.5	1330
	2052	Block 28	2052	85
	2072	Block 28	2072	192
Galleries in Rock Abutments	RG 2131	Right	2131	185
	RG 2026	Right	2026	472
	RG 2026	Left	2026	557
	RG 2121	Left	2121	211
	RG 2213	Left	2213	273
Chambers	Pump Chamber	Block 20	2052	13'.3"x11'x13'
	Sump Pit	"	1992.5	20'x7'6"x7'6"
	Operating Chamber	"	2004	10'x10'x12'

Table 1.3 Galleries

Designation	Location	Range	Height feet	Diameter feet
Elevator Shaft	Block 26	2415 to 2055	360	13'6"x10'0"
Pendulum PI	Block 16	2415 to 2090	325	12"
Pendulum P2	Block 21	2291.5 to 2000	291.5	12"
Pendulum P3	Block 27	2415 to 2065	350	12"
Pendulum P4	Block 33	2415 to 2200	215	12"
Cable duct	Block 2	2415 to 2365	50	3'
Cable duct	Block 22	2291.5 to 2000	291.5	2'
Cable duct	Block 37	2415 to 2320	95	3'
Collector drain	Block 18	2288 to 2050	238	18"
Collector drain	Block 25	2288 to 2050	238	18"
Pump Shaft	Block 20	2052 to 2000	52	4'6"x 6'6"

Table 1.4 Shafts

1.4B.3 Contraction Joints

The dam has **38** vertical transverse contraction joints. These vertical joints are provided for convenience in construction and to provide for contraction of the concrete. 'U' or 'Z' type metal seals are provided for joints around galleries, spillway bucket, spillway training wall and at the joint of concrete and rock at the entrance of rock drifts. The vertical joints in the dam contain two 'U' shaped 24" wide sealing strips of Monel metal fixed near the upstream face of the dam. The first sealing strip (or water stop) is located at 2 feet from the face of the dam and the second at 4 feet. The sealing strips extend from rock foundation to the crest. An asphalt seal of 5 inches square is provided in between the two metal sealing strips.

Reinforcing Steel

The following parts of the Cheruthoni dam are provided with reinforcing steel:

- the concrete around galleries and shafts
- the concrete around outlets and trash racks
- the concrete of the gate hoist structure, spillway face, buckets, guide walls, spillway piers, spillway bridge and gate hoist bridge
- concrete in elevator tower
- concrete in roadway parapet, footpath and kerbs
- concrete around openings of more than 2 ft dia

Reinforcements conform to I.S.: No. 432/1960 and its amendments.

1.4B.3 Outlets

Outlets in Blocks 19 and 24

The purposes of the outlets in Cheruthoni dam are:

(i) Depletion of the reservoir during emergencies such as blockages in headrace tunnel.

(ii) Control of reservoir levels during construction of dams

(iii) Systematic regulation of reservoir elevation for controlled loading of Idukki arch dam above El. 2300 and

(iv) Supplementing the spillway capacity provided in Cheruthoni dam.

The capacity of outlets is dictated by the requirement of reservoir water level control during initial loading of Idukki Arch dam. The elevation of the outlets is dictated by the level of Kulamavu Channel (El. 2260) which leads the water of the main reservoir to the power tunnel intake. The design of the outlets underwent a continuous evolution in respect of their

capacity, type, elevation, location and control arrangements. Model studies on the design of gates, outlet profile and design of steel lining were done at CW & PRS, Pune. Model studies on energy dissipation of outlets were done at Kerala Engineering Research Institute, Peechi. The details of outlet arrangements provided are: -

- The centre line of outlet is El. 2209.5.
- There is a service gate and an emergency gate of the fixed wheel type of size 10' x 21' (high) on the upstream side of the outlet, each outlet with sill level El. 2199 ft and located 23 ft and 31 ft from entrance respectively. The outlet is horizontal up to 50 ft from the face of the dam and then joined by parabola of equation $x^2 = 800$ y at bottom and $x^2 = 635$ y at top, the axes of parabola being titled down to the horizontal by 5°.
- One outlet is provided on either side of the spillway with flip bucket energy dissipation arrangement. The invert of bucket is at El. 2025 ft, the guide walls are curved and the bucket is given a super elevation to deflect the jet to the central portion of the river.
- The discharging capacity is 15900 cusecs at reservoir level 2350 ft for each outlet.
- There is a steel lining for 64 ft from the face of the outlet at inlet on all sides and for 95 ft on the exit curved portion at bottom only.
- The outlet flares in plan with width changing from 10 ft at a distance of 50 ft from entrance to 18 ft at exit.
- The maximum velocity of flow is 115 ft/sec.
- There is a shortened bell mouth at entrance with equation:

$$x^2/(0.55 \times 21)^2 + y^2/(7)^2 = 1 \text{ in section and}$$
$$x^2/(0.55 \times 10)^2 + y^2/(10/3)^2 = 1 \text{ in plan,}$$

  to suit the design and construction of trash rack.
- There is a semicircular reinforced concrete trash rack with 15' 0" radius extending from El. 2174.00 to El. 2258.00 for the two outlets.
- The platform of the gate hoist structure is located at El. 2448.25.

Outlet in Block 10

A 500 mm C.I pipe with an upstream bell mouth and a downstream sluice valve is provided for the water supply arrangement to Idukki District Headquarters Township.

Fig 1.23 shows downstream side view of sluice gate from manhole. The downstream view of sluice opening from inside of outlet is given in **Fig 1.24.**

Fig1.23 Sluice gate downstream side view from manhole

Fig1.24 Downstream view of sluice opening from inside of outlet

1.4B.5 Rock Mechanics

The average value of Young's modulus for the rock by ultrasonic tests was found to be 5.63 x $l0^6$ dynes/cm^2 and the same for poor variety of rock 2.55 x 10^6 dynes/cm^2. The earthquake acceleration taken into consideration for the design of Cheruthoni dam was 0.05 horizontal and 0.025 vertical. All combination of these two was considered in the design. As

per the seismic zoning of India, Cheruthoni dam lies between zones III with soil type 1 giving a possible acceleration of 0.049 and 0.02.

1.4B.6 Rock Drifts

Two exploratory rock drifts (**Fig 1.25**) were driven at El. 2026' at left bank and El. 2026' at right bank. The left bank drift projected into the reservoir for some length. A 65 ft long section of this tunnel is plugged with concrete. The right bank drift has a branch at Ch. 1602.66 and because this branch traversed a fault, a concrete plug has been provided between Chainages 1635 and 1668.18. Three more rocks drifts were driven on the abutments and have been joined to the gallery system. Two drifts are in the left bank at El. 2121' and 2213' and one at El. 2131' on right bank. The total length of all these rock drifts is 1700'.

Fig 1.25 View of Drift tunnel at Cheruthoni dam

1.4B.6 Outlet Gates and Emergency Gates

Two sets of river outlets gates (fixed wheel type) complete with embedded parts, hoisting equipment, controls and dogging devices were supplied by Tungabhadra Steel Products, India. Each set consists of one emergency gate and one service gate with its independent hoist and control equipment. The upstream gate is used as emergency gate, normally it will be kept open, and downstream gate is the service gate which will be either open or closed.

Details of the gates are:

Clear width of gate opening;	10 ft
Clear height of gate opening;	21 ft
Sill elevation:	2199 ft
Maximum static head above sill:	209.5 ft
Deck level	2415 ft
Approximate hoisting speed:	5 ft per min.
Approximate lowering speed	10 ft per min.
Approximate hoisting speed by manual labour:	½ to 1 in/min.

The gates are designed for the following loads:

- The full hydrostatic load on the upstream side when the water is at MWL and no load on the downstream side.
- The total hydrostatic, hydro dynamic and friction forces occurring when the gate is raised lowered or "cracked" open with upstream water level at 2408.5, and 2280 and maximum flow 19000 cfs.

The gates are designed with downstream seal. Each gate is operated by a hoisting equipment of the conventional electric wire rope type with local control equipment working on 400/440 volts 3 phase 50 cycles A.C. The hoisting platform is at El. 2448.25 ft. Two air vents, one of 5 ft dia and one 3 ft dia are provided for each outlet. Model studies on the performance of the gates were done at Central Water and Power Research Station, Pune.

Operating Instructions and Reports:

Model study report of CW & PRS 22/21/71-GVS/23-3-72 and 11-8-72 and Operating instructions of M/s. Tungabhadra Steel Products given in **Annexure 2** are to be strictly followed in the operation and maintenance of service and emergency gates.

1.4B.8 Diversion Tunnel and Open Channel

A 30 ft high coffer dam was constructed on the upstream side of Cheruthoni Dam. Its crest is at El. 2025 ft. The river discharge is diverted to Periyar through a 14 ft x 14 ft D-shaped, 1012 ft long diversion tunnel, with inlet sill level at 1995 ft. The tunnel was aligned across the low saddle between the two rivers. The tunnel is submerged in the reservoir. During earlier construction period the monsoon flow was diverted through the Idukki dam

and diversion tunnel. When Idukki dam reached such a height as not to allow spilling, diversion of monsoon flow was accomplished over Cheruthoni dam and through the outlets.

1.4B.9 Elevator

One passenger cum freight elevator of platform size 3650 mm wide x 2500 mm deep (outside dimensions) is installed in block 26. The car to travel from El. 2066 ft to El. 2415.62 ft i.e. about 107 meters stopping at six floors and serving six openings located on the same side. The elevator's rated capacity is 3628 kg and its travel speed is 30 m/minute with a constant potential at the controller of 400 volts, 9 phases, 50 cycles A.C. Photograph of elevator at Cheruthoni dam is shown in **Fig 1.26.**

Fig 1.26 Elevator at Cheruthoni dam

Geology

The underlying formation is largely granite gneiss and schist associated with subordinate pegmatite dykes and varied according to mafic and more felspathic members. The foliation is generally tilted steeply easterly with strike in a northerly direction to which the principal ridges and intervening valleys conform. Some folding is seen locally. Joint systems in both nearly vertical and also moderately inclined patterns occur in the area. There is a contact with the charnockite dyke higher on the right side. A pattern of minor faults are mapped between elevations 2050 ft to 2150 ft on the right abutment, paralleling the river and dipping

southward. The strongest of these features was encountered at a distance of about 225 ft from the exploratory Adit portal on the right side and was followed in a downstream direction by cross cut for the base width of the dam. The zone composed of sheared and jointed rock and some gorgy material not more than 4 ft wide and has a southerly dip toward the river. The zone was compact and only slightly moist. This zone was properly treated. The pronounced pattern of parallel joints dipping about 20° toward the north found on both abutments and created drummy or slabby rock. All loose slabs were removed before placing concrete. No special rock treatment was necessary at depths other than the usual grouting and drainage. The exploration consisted of making numerous drill holes, permeability tests, surface excavation, and rock mechanic measurements and five rock drifts into the abutments below the dam.

Foundations

Initial excavation of foundation was done in two stages and started on 25.04.1964 and main excavation of foundation completed just a few days prior to initial concreting on 08.03.1969. Light blasting and local smoothening of seating by barring and wedging were done before the concreting operations were started. Excavation averaging a depth of 25 ft was required to assure sound rock. Approximately 220000 m^3 of rock, 14000 m^3 of boulders and 175000 $m^3$of earth were removed.

Foundation Treatment

a) Excavation

At least 50% of the total foundation area was near horizontal having less than 35° slope to sliding in axial direction. A small pocket in block 5 was excavated to sound rock. A fault more than 12" wide was noticed crossing the block from upstream to downstream. A major fault of more than 12" wide crossed the foundation block No. 28 from upstream to downstream. 35 ft deep pocket was excavated at the toe of the dam in block 28 to reach sound rock. This was due to minor faulting and deep weathering. A 5' x 10' shaft was formed in the backfilled concrete of this portion for a depth of 75 ft below the average elevation for fault zone treatment and subsequently filled with concrete. In block 24 there was a seam about 6 inches thick near elevation 2000. This seam was removed and concrete placed on the solid rock under the flat seam.

b) Grout Curtain

The design of grout curtain consisted of a single row of grout holes inclined towards upstream, bored from the upstream side of the gallery of the dam (from the heel for top abutments). The depth of hole varied from 40 ft to 290 ft and the spacing from 10 ft c/c to 40 ft centre to centre depending on the nature of foundation and the hydrostatic head. These holes are designated as 'A' holes. Holes at 20 ft centre to centre and depth varying from 50 to 60 ft designated as 'N' holes suggested by Dr. F.A. Nickell are drilled and grouted from the floor of the gallery. These are vertical holes and staggered with 'A' holes. Holes designated as 'C' holes at 20 ft c/c and depth varying from 45 to 70 ft are drilled and grouted from the heel of the dam inclined downstream and staggered from 'A' and 'N' holes. Grout holes of 30 ft depth spaced 20 ft c/c have been drilled and grouted on the periphery of the rock gallery at El. 2026 on the left bank.

c) Contact and Consolidation Grouting

This is generally applied to the area of heel of the dam although local conditions have dictated other areas of grouting. Holes are spaced 20 ft apart in an 'X' pattern and covered 1/3 of the upstream foundation area. The depth of holes is generally 30 ft and is vertical or inclined. On the right bank and also in some blocks on the left bank more holes have been drilled and grouted. Consolidation holes were generally drilled and grouted before laying concrete.

The consolidation grouting at right bank, left bank, river bottom and curtain grouting are given in **Drg 1.12a, Drg 1.12b, Drg 1.12c** and **Drg 1.13** of **Annexure 1.**

d) Drainage System

- **Foundation Drainage**

As dictated by the design criteria drain holes have been provided in the foundation rock to control uplift pressures. These holes designated as 'D' holes are spaced at 20 ft centre to centre and are inclined towards downstream, (generally 10°). Their depths vary from 40 ft to 225 ft and they have 3" in diameter. Holes designated as 'U' holes have been drilled from drifts for drainage of weak zones and the depth varies from 15 ft to 130 ft. Around rock gallery at El. 2026 ft on the left bank some peripheral drainage holes of 20 ft depth at 20 ft centre to centre have been drilled.

• **Dam Drainage**

To reduce pore pressure inside the body of the dam a system of 10 inches diameter vertical and inclined drains have been located at 14 ft and 26 ft from the axis of the dam and in two rows at regular intervals of 10 ft in each row. These drains as well as the foundation drains discharge into the 12" x 10" drains in the galleries or drifts. This drainage water is taken to the downstream face through three 3'-0 by 4'-6" culverts located at El. 2050 in blocks 18 and 25 and at El. 1992 in block 20. When there is tail water, the drain water collected at El. 1992.5 will be pumped up to El. 2050 to be drained by the culvert in block 18. Provision for a non-return valve (gate) is made in block 20 to prevent the tail water entering into the gallery system.

• **Diversion Tunnel and Open Channel**

A 30 ft high coffer dam was constructed on the upstream side of Cheruthoni Dam. Its crest was at El. 2025. The river discharge is diverted to Periyar through a 14 ft by 14 ft D shaped, 1012 ft long diversion tunnel, with inlet sill level at El. 1995. The tunnel was aligned across the low saddle between the two rivers so that it is submerged in the reservoir.

During earlier construction period the monsoon flow was diverted through Idukki dam and diversion tunnel. When Idukki dam reached such a height as not to allow spilling, diversion of monsoon flow was accomplished over Cheruthoni dam and through the outlets.

1.4C KULAMAVU DAM

1.4C.1 Geometric Definition of Dam

The dam is designed and constructed as a straight gravity structure without any overflow arrangements. Though originally designed as a masonry dam, later constructed as a composite dam with 150000 m^3 of concrete on the top (See **Drg 1.14a** and **Drg 1.14b** of **Annexure 1**). The dam has a length of 1263 ft with a 24 ft wide roadway at the top at level +2415'. The maximum height of the dam at deepest foundation level is 328', Upstream slope of 1 in 20 starts from the level +2345'. Downstream slope is 0.7 H to 1.0 V between levels +2385' & +2225' and 0.75 H to 1.0 V below level +2225'. The cross section of Kulamavu dam is shown in **Fig 1.27**. The 1263 ft long dam is divided into **16** masonry blocks of length varying from 60 ft to 100 ft. Each block is separated from the other by a contraction joint. When masonry construction was stopped and dam construction continued with concrete at a later date, additional contraction joints were provided, limiting the length of blocks between 30 ft

and 60 ft. The blocks are numbered consecutively from left bank to right bank. A 6 ft diameter outlet, controlled by an upstream emergency gate and a downstream hollow jet valve has been installed in block 7. The central line of the outlet is at level + 2207'. The plan of Kulamavu dam is given in **Drg 1.15** of **Annexure 1**.

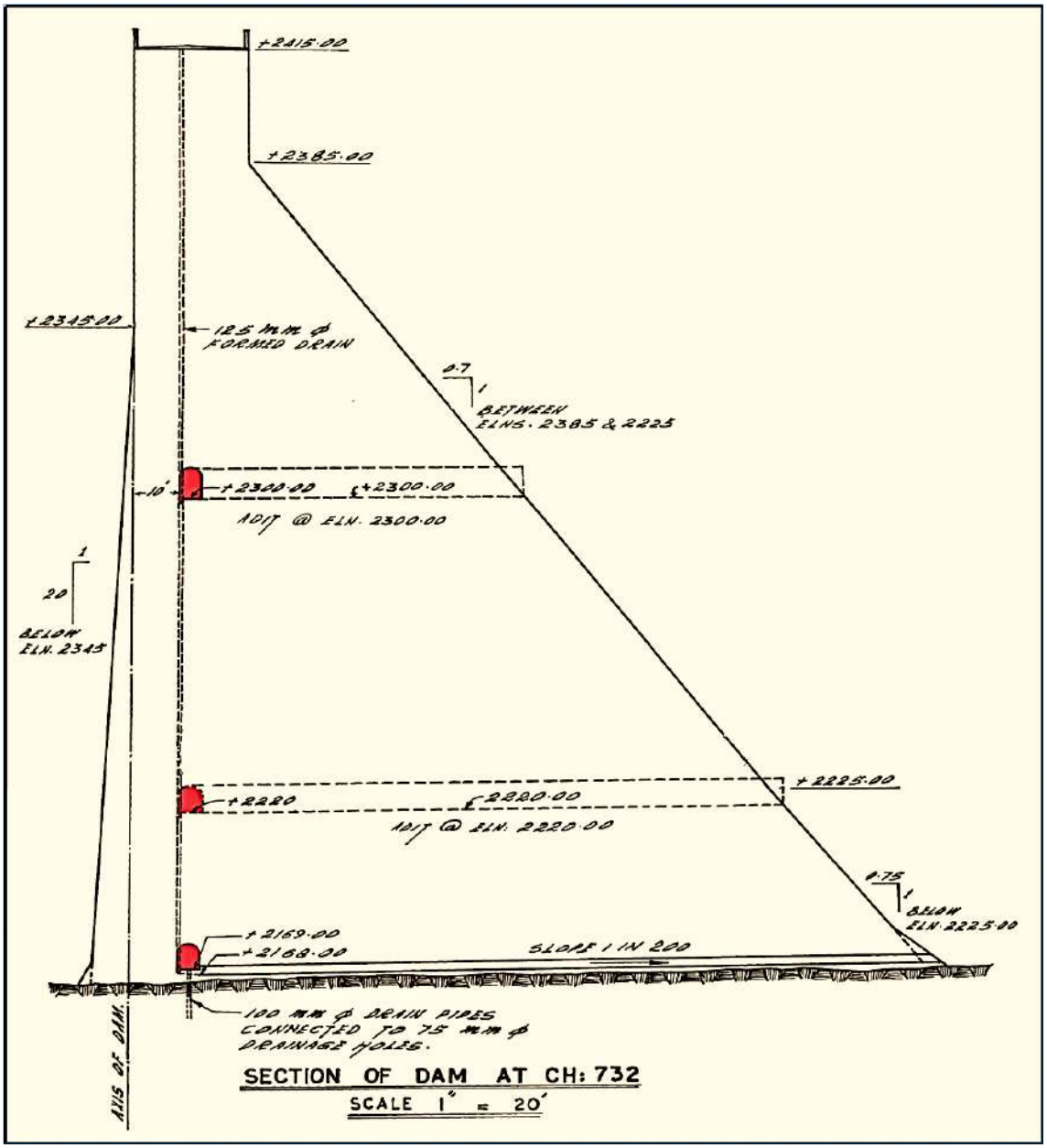


Fig 1.27 Kulamavu Dam Cross Section

A Google view of the Kulamavu dam is shown below in **Fig 1.28**. The dam top and downstream view of Kulamavu dam are given in **Fig 1.29** and **Fig 1.30.**

Fig 1.28 Google view of the Kulamavu Dam

Fig 1.29 Kulamavu Dam Top view

Fig 1.30 Kulamavu Dam Downstream view

1.4C.2 Dam and Foundation Mat

There was a weak zone identified during construction in the foundation of blocks 9 and 10. The fault zone consisted of crushed and fractured material and very soft graphite mica schist which behaved like a plastic material when in contact with water. The advice of expert Engineering Geologist was to confine this deleterious material in the fault seam itself, as it was impossible to scoop out the entire material from the seam or to stabilize the area by grouting alone. For this purpose, two cut off trenches, one at the heel and the other at the toe of the dam were excavated and backfilled with concrete after fixing dowel rods on the sides. Also the plastic materials from the seam in between the cut off trenches were scooped out for a depth of about 30 ft from the general excavation level of 2135 ft and backfilled with concrete. Over that, a reinforced concrete mat of about 35 ft thickness was constructed, covering both sides of the fault and extending from heel to toe of the dam, in order to transmit the load to firm foundations. To prevent any possible differential settlement of the mat at the weak zone, the mat was constructed with two contraction joints with shear keys at the joints and later was grouted, after allowing sufficient time for settlement. The foundation grouting in Block 6 & 7 are given in **Drg 1.16a** and **Drg 1.16b** of **Annexure 1.**

1.4C.3 Galleries and Shafts

The dam includes a system of 125 mm internal diameter porous concrete pipes which are designed to intercept and dispose of any leakage that may develop from time to time due to:

1) Defective construction joints (left joints)
2) Defective water stops
3) Fissures originating at the upstream face of the dam.

Likewise, the dam foundation comprises a system of drain holes to drain foundation and grout holes for consolidating the foundation and to make a grouted curtain beneath the foundation. The dam and its abutments incorporate two main galleries (size 5' x 7'6"), a foundation gallery and an inspection gallery. The foundation gallery is located close to the foundation level. The horizontal inspection gallery is at El. 2327 ft. In addition to these, two transverse galleries and two rows of wing galleries of size 8 ft x 8 ft are also provided in the reinforced concrete mat of the weak zone of blocks 9 & 10. For studying the behavior of the contraction joints in the reinforced concrete in blocks 9 and 10, an observation gallery with wing galleries of size 5 ft x 74 ft has been constructed near the top of the concrete mat. The galleries are connected to the downstream side of the dam by Adits on both banks. These adits are approachable by a system of roads. The inspection gallery traverses the dam horizontally at El. 2327.44. The length of the gallery is 656.25 ft. The purpose of the galleries is to monitor the performance of the drainage system, to aid the inspection of the dam structure and to give access to the outlets.

The gallery and shaft system also comprise

- Pendulum shafts, cable ducts, outlet manholes, drain culverts and air vents to outlet gates.
- An upstream gutter in each gallery designed to direct collected leakage to the collector drains.

Shafts Designation	Location	Range	Height Dia.
Pendulum	Bl. 9	El. 2415 to El. 2137	278' 12" above El. 2170' 2 ft below El.2170'
Inverted Pendulum		2137 to sound rock	6"
Air vent	7		2'9" interval
Float well pipe	8	El. 2200 to El. 2415	2'6"

1.4C.4 Contraction Joints

Vertical transverse contraction joints are provided in the dam for convenience of the construction and to provide for the contraction of the masonry. Additional contraction joints were provided, limiting the lengths of blocks between 30' and 60', when the dam construction continued with concrete. U or Z type metal seals are provided for joints between blocks and around galleries. The joints extend through the full cross section of the dam profile from the foundation. The joint is sealed on the upstream end by installing two lines of copper sealing strips and an asphalt seal in between. The asphalt seal is provided with a steam heating system. In blocks 9 and 10 there was a fault zone in the foundation and the same was excavated and concreted. For monolithic action the joints were grouted.

Reinforcing Steel

The following parts of Kulamavu dam are provided with reinforced steel:

- The concrete around galleries and shafts
- The concrete around outlets trash racks
- Concrete in roadway, parapet, footpath and kerbs
- Concrete around openings of more than 2 ft dia
- Foundation treatment for blocks 9 & 10

Reinforcements conform to I.S.S. No. 412/1960 and its amendments.

1.4C.5 Outlet

A 6 ft diameter outlet, controlled by an upstream emergency gate and a downstream hollow jet valve has been installed in block No. 7 of Kulamavu dam. The central line of the outlet is at level +22010.00'. The emergency gate has a hoist structure on top of dam. Hollow jet valve is approachable on the downstream by a catwalk. The emergency outlet enables lowering the reservoir water level below the Intake level of the power tunnel in case of such necessity would arise. The outlet is lined with thick steel lining for the full length. An upstream bell mouth is provided. Photograph of disperser valve house at the downstream side of Kulamavu dam is shown below in **Fig 1.31**.

Hollow Jet Valve

Kulamavu masonry dam is provided with a bottom discharge outlet to control water level by releasing water into the downstream valley. This outlet consists of 145 feet long steel pipe,

Fig 1.31 Disperser Valve House

6 feet diameter passes through the body of the gravity dam, 205 feet below the crest. To control the water discharge, a hollow jet valve is installed at the downstream end of the pipe. **Fig 1.32** shows the photograph of disperser valve room**.**

The hollow jet valve has a nominal diameter of 60 inches and is able to discharge freely into the atmosphere approximately 1725 cft/s (49 m^3/s) at full opening under the maximum head. The valve can close under full flow and is capable of discharging water at any partial opening without vibration. The valve is operated by a mechanical reducer driving two machine screw actuators which move the stainless steel tubular gate sliding sleeve. The driving mechanism is equipped with a torque limiting device "Limit torque" which protects the valve against any overload resulting from obstruction of foreign material during the seating of the valve. It also assures that the valve is absolutely tight on each closure. The seating thrust may be adjusted by means of a micrometer adjustment of the torque limit switch. Geared limit switches govern the sleeve travel in its opening and closing directions. In case of power failure, the mechanism can be manually operated through a hand wheel control. The sealing of the valve is performed by a bronze ring attached to the valve sleeve which seats against a non-aging rubber sealing ring of the "music note" type, mounted on the cone of the valve body.

Fig 1.32 Disperser Valve Room

Operating Controls

All the controls of the hollow jet valve are housed in a control room located right above the valve at the downstream face of the dam. The controls consist of a push-button station with an adequate number of indicating lamps. A selector switch permits a change from automatic to manual operation. The opening of the valve is performed by pressing the "open" push-button. The valve is automatically stopped at the end of its travel by a limit switch. Any desirable intermediate opening can be obtained by pressing the "stop" button. Pressing the "close" button will bring the valve to full closure and the limit switch will automatically stop the gate after the proper seating of the seal is obtained. For the manual operation of the gate, the selector switch has to be turned to "Manual". The special lever is placed behind the hand crank wheel and is pushed in the direction of the arrow. By turning the hand wheel in the appropriate direction, the valve can be opened or closed. The hollow jet valve and its auxiliary equipment should be operated and maintained in strict accordance with "Operation and Maintenance Instructions" supplied by Canadian Vickers Ltd.

Emergency Gate and Hoist

The emergency gate is part of the Kulamavu discharge works and is located at the upstream face of the dam. This gate is designed to close in emergency against the full flow passing through the outlet works. It also makes it possible to isolate the downstream part of

the discharge works for inspection, maintenance and repairs. Opening of this gate subsequent to a closure is to be done only under balanced pressure conditions. Therefore, prior to opening it completely, the gate is cracked open from 6 to 12 inches, allowing the water to fill the downstream end of the steel pipe. The hollow jet valve remains closed. In normal conditions, the emergency gate is maintained right above the opening, but it can be hoisted to the operating deck for inspection and maintenance. **Fig 1.33** shows photographs of emergency gate hoist.

a) Gate

The gate, 6 feet wide and 8 feet high, consists of a structural steel frame welded to a heavy upstream skin plate. The gate is equipped with 8 Nos 21 inch diameter forged steel wheels mounted on tapered roller bearings. These rollers are fitted on eccentrical shafts to permit precise alignment of the wheel rims. The gate is supplied with brass faced rubber seals which run along the top and vertical sides. The sealing at the bottom is ensured by the contact of the machined surfaces of the gate lip and the sill beam. Spring loaded side rollers mounted on self-lubricated bronze bushings are installed on each side near the top and bottom of the gate to limit its lateral movement.

b) Hoist

The gate hoist is of the conventional wire rope type and consists of a single drum which is driven through a helical gear reducer by an induction motor. Lowering speed of the gate is controlled by a power absorption fan. An additional electro-mechanical brake holds the gate in its open position. The brake is applied automatically when the power is cut off from the motor. In the absence of the electric supply, a hand cranking system allows the manual lifting of the gate. The gate position indicator consists of two dials. One, graduated in feet and in meters, indicates the position of the gate over its full range of travel. The other, graduated in inches, shows the gate position over its first foot of travel. It is used to monitor the "crack opening" for filling the steel pipe.

c) Operating Controls

The emergency gate is controlled from a push button station mounted on the hoist structure above deck elevation. This station includes four pushbuttons, labeled: "Crack", "Raise", "Lower" and "Stop". The complete procedure for the manual operation of the gate and instructions for manual operation are detailed in the "Operation and Maintenance

Instruction" prepared by Canadian Vickers Ltd., the manufacturer of the emergency gate. The emergency gate should be operated and maintained in strict accordance with the "Operation and Maintenance Instructions" supplied by Canadian Vickers Ltd.

Fig 1.33 Emergency gate hoist

Drainage Pumps and Systems

The foundation drain holes and the drain holes provided in the dam discharge into the gallery system. This drainage water is taken to the downstream side of the dam through the transverse gallery at El. 2137 ft and a drain culvert of size 3 ft x 3 ft at El. 2168 ft in block 8. No pumping arrangement is required.

Diversion Conduit (Construction Sluice)

At chainage 705, a construction sluice of size 7' x 5' was provided in the dam for diversion of the flow in Killivallithodu. The entire length of this sluice was plugged with concrete after closing the u/s face with a steel gate, which was also embedded in concrete.

1.4C.6 Saddle Dams

1.4C.6.1 Right Bank Saddle

Kulamavu original ground level was at El. 2430' and the rock level at about El. 2385'. This saddle was found to be insufficient to withstand the water pressure of about 25 ft.

The strengthening on the reservoir side consists of:

- Stripping the original ground for 2 ft to remove vegetation and objectionable materials.
- Laying clayey earth rolled in 6" layers from El. 2345 to El. 2430 with u/s slope 3: 1.
- Laying a filter layer of 24" over the clayey earth with u/s slope 3:1. The filter layer consists of 6" thick graded sand (particle size 0.02 mm to 2 mm), 6" thick graded metal (2 mm to 20 mm) and 12" thick graded metal (20 to 75 mm).
- Laying a 12" thick filter layer below elevation 2345 ft over the stripped ground.
- Laying a rip rap layer of 3 ft thickness over the filter from El. 2370.00 to El. 2430.00 with 8 ft berm at El. 2370.00, and
- A rock fill toe below El. 2370 with u/s slope 2:1 and a berm of 8 ft at El. 2346.00

1.4C.6.2 Saddle Dam of Kulamavu Junction

The second saddle which necessitated strengthening was near the Kulamavu junction. The original ground there was at El. 2405 ft

Strengthening on the reservoir side consists of:

- Stripping original ground for about 1ft.
- Laying earth fill rolled in 6" layers between El. 2370 ft to El. 2418 ft with downstream slope 1 V to 3 H.
- Laying a filter below El. 2408.5 over earth fill consisting of 6" thick graded sand (0.02 mm to 2 mm), 6" thick crushed rock material (2 mm to 20 mm) and 9" thick graded metal (20 mm to 75 mm).
- Laying 1ft thick hand placed rip rap over the filter from El. 2418 to El. 2370 ft and
- A rock fill toe of 3 ft depth at El. 2370 ft

On the downstream side a 14 ft thick rip rap layer was laid with a slope of 2.5 H to 1.0 V up to El. 2405 with a 4 ft thick rock fill toe at El. 2405. The width of the saddle dam at El. 2418 is 40 ft and accommodates a 24 ft roadway.

Geology at Kulamavu dam site

The bed of the stream near Kulamavu dam site is rocky and there are rocky outcrops on the fairly steep left abutments with comparatively little overburden. The right abutment is having gentle and irregular slopes with extensive soil cover and erratic weathering of bedrock surface. The foundation rock is classified as gneissic type and consists of a heterogeneous mixture of different granitic rocks. Gneissic rock permits deep weathering due to varying hardness of the foliation and banding.

In blocks 9 and 10 on the right bank of Kulamavu dam there is a 32 m (105 ft) wide weak zone extending between Ch. 8 - 50 and 10 + 05 and approximately at El. 2140 and 2195 along the axis. The rock types occurring in this area are charnockites, granite gneisses, graphite mica schists and inter banded quartz veins extending from heel to toe i.e. across the dam. The felspathic gneisses and graphite mica schists are highly weathered, decomposed and disintegrated while the charnockite and granitic rocks are closely jointed and only weathered along joint planes.

The shear zone, which is 6 m (20 ft) wide, is located at the contact of the granite and charnockite on the right side. Within this sheared zone there is graphite-mica schist between Ch 8+55 and 8+75. This is highly eroded and fractured and very soft sulphide mineralisation is also observed. This deleterious band required intense treatment.

Foundation

Initial excavation for the foundation was started early in 1965 and was completed in February 1966. Local blasting and removing rock by wedging and barring were done as and when the particular block was taken up for construction. Excavation averaging 25 ft depth was required to assure sound rock and to suitably shape the abutments to provide a saw-tooth seating for the blocks. Loose materials in blocks 9 and 10 were removed as per the directions of the geologist for proper seating of the blocks over the fault zone.

Foundation Treatment

a) Grout Curtain

The design for the grout curtain consisted of a single row of grout holes from the foot of the foundation gallery of the dam. These holes designated as **'A'** holes are inclined upstream. Their diameter is 2.4" and their depth is varying from 40 to 60% of the hydrostatic head and up to 70% in weak zones. The holes were initially drilled at 40 ft c/c and depending on the grout intake; intermediate holes were drilled at 10 to 20 ft c/c and grouted. Another row of holes designated as **'C'** holes were drilled and grouted from the heel of the dam. These holes also have 2.0" dia. but are inclined downstream and were drilled after construction of 20 ft of masonry. The holes are spaced 40 ft c/c. Intermediate holes were drilled and grouted when foundation conditions did warrant. The depth of holes is same as for 'A' holes. Additional holes along the width of the dam were drilled and grouted in blocks 9 and 10 for treatment of fault zone.

b) Contact and Consolidation Grouting

After exposing foundation rock or after construction of masonry for a depth of 15 ft three rows of 'B' holes were drilled and grouted keeping the pressure at 50 psi. The holes are spaced at 40 to 80 ft and if found necessary intermediate holes were drilled and grouted.

c) Drainage

As dictated by the design criteria, drain holes have been provided in the foundation rock to control uplift pressures. The holes are drilled from the foundation gallery after grouting the 'A' holes. The holes are 75 mm in diameter. Their depths vary from 20 to 50% of the hydrostatic head (but not more than 707, of the depth of 'A' holes). Their spacing is 20 ft c/c. The drains discharge into the galleries. Additional drainage holes were drilled from transverse and wing galleries in blocks 9 and 10 for treatment of fault zone.

Idukki HEP Power Generation

The Idukki underground Power House is located at Moolamattom and the cavern is of size (140.21 x 19.81 x 35.05) m installed with **six** vertical Pelton Turbines. The generating units are each of 130 MW with total 780 MW installed capacity. The capacity and date of commissioning are given in **Table 1.5.** 220 KV underground switchyard is located outside the power house with seven 220 KV feeders. The firm annual generation capacity is 2398 MU.

The tailrace water is released to Nachar, a tributary of Thodupuzha River through an underground tunnel of 1220 m length and is used for power generation in Malankara SHEP and for irrigation purpose with Malankara irrigation dam. Google map view, Generator rooms & entrance tunnel and front view of Power House are given below in **Fig 1.34, Fig 1.35 & Fig 1.36**.

Unit	Rating	Date of commissioning
U # 1	130 MW	12.02.1976
U # 2	130 MW	07.06.1976
U # 3	130 MW	24.12.1976
U # 4	130 MW	04.11.1985
U # 5	130 MW	22.03.1986
U # 6	130 MW	09.09.1986

Table 1.5 Power House Generation Capacity

Fig 1.34 IHEP Power House Google View

Fig 1.35 IHEP Power House

Fig 1.36 IHEP Power House Generators

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 are identified by their designation and, in particular, the responsibilities of operating personnel are specifically

identified in below and include regularly scheduled duties which staff personnel are required to perform as outlined.

Project Administration Office	-	Chairman& Managing Director, KSEB Ltd
Chief Controlling Officer	-	Chief Engineer (Civil – DS & DRIP), KSEB Ltd, Dam Safety Organisation, Pallom, Kottayam
Authority of Spillway and Flood releases	-	Chief Engineer (Civil – DS & DRIP), KSEB Ltd, Dam Safety Organisation, Pallom, Kottayam
Operation and safety of the dam	-	Deputy Chief Engineer, Research & Dam Safety Organization, Pallom, KSEB Ltd
Controlling and Operation Officer at dam site	-	Executive Engineer, Dam Safety Division No. II, Vazhathoppe
Recording reservoir data, inspection, maintenance	-	Executive Engineer, Dam Safety Division No. II, Vazhathoppe, Idukki
Dam Health Engineer	-	Executive Engineer, Dam Safety Division No. II, Vazhathoppe, Idukki
Recording reservoir data, inspection, monitoring and maintenance at site	-	Assistant Executive Engineer, Dam Safety Sub Division I, Vazhathoppe, Idukki(For **Kulamavu** dam)
	-	Assistant Executive Engineer, Dam Safety Sub Division II, Vazhathoppe, Idukki (For **Idukki & Cheruthoni** dams)
Dam operating, inspection, monitoring and maintenance at dam site	-	Assistant Engineer, Dam Safety Sub Division I, Vazhathoppe, Idukki (For **Kulamavu** dam)
	-	Assistant Engineer, Dam Safety Sub Division II, Vazhathoppe, Idukki (For **Idukki & Cheruthoni** dams)

1.5.1 Roles and Responsibilities of the AEE and AE during Monsoon

Flood condition assessment, warning, flood mitigation, and other responsibilities

1. Coordinate with the Asst Exe Engineers of other Sub Divisions and get the information on inflow status, reservoir level and to bring it to the notice of the EE/Dy CE.

2. Coordinate with the Engineers of TamilNadu in charge of Mullaperiyar and get the information on inflow status, reservoir level, spill etc. and to bring it to the notice of the EE/Dy CE.

3. Assist the EE/ Dy CE /CE to issue notification to the inhabitants downstream in Newspapers, Radio and TV News channel to alert regarding the flood situation.

4. Assist the EE/ Dy CE /CE to coordinate with the Revenue authorities (District Administration) to alert the downstream inhabitants to evacuate from the flood zone to prevent loss of life and livestock.

5. Assist the EE/ Dy CE /CE to coordinate with the CWC flood monitoring authorities on the flood condition

6. Maintain the reservoir water level gauge register and to update on hourly basis during floods and report to EE/ Dy CE /Chief Engineer

7. 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

8. Submit to the EE/ Dy CE /CE on the inflows and releases from the reservoir and status of the reservoir twice in the day

9. Maintain the spillway crest gate operation log book

10. 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

11. Observe seepages in the drainage Gallery with respect to the reservoir head and record the seepages in the infiltration gallery and immediately bring to the notice of the EE/ Dy CE /CE in case of excessive seepage/leakage in any specific blocks and porous drains.

12. Maintain the pump operation log books for the dewatering pumps in the drainage gallery and to submit to EE/ Dy CE /Chief Engineer

13. Observe the gates and to see that the drain holes are not clogged and floating debris is not deposited in the gate components

14. Monitor the condition of the welding transformers, gas cutting sets, umbrellas, tool kits, torches, chain blocks, ropes etc. on daily basis and to see that things are in place to handle any emergency situation

15. 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
16. Observe the dam top, ensure that embankment, catwalk, approach roads are well maintained by housekeeping personnel

17. 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 of excessive seepages, leakages etc.

18. Assist EE/Dy CE /CE to coordinate with the Generating staff of Moolamattom Powerhouse downstream in the operation and power generation.

19. 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.

1.5.2 Roles and Responsibilities of the Deputy Chief Engineer and Executive Engineer during Monsoon

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. Conduct Pre and Post Monsoon inspections of the Dam and submit the report to CWC.

3. 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

4. Coordinate with the Engineers of the sub divisions & to get the information in the rainfall and inflow status and to bring to the notice of the CE.

5. Coordinate with the Generating staff of Moolamattom Powerhouse downstream in the operation and power generation.

6. Collect information of Mullaperiyar inflow status, reservoir level, spill, rainfall etc. and to bring it to the notice of the CE.

7. To issue notification to the inhabitants downstream in Newspapers, Radio, TV News channel to alert them regarding the flood situation

8. Assist the CE to coordinate with the Revenue authorities (District Administration) to alert the downstream villagers in evacuating the flood zone to prevent loss of life and live stock

9. Assist the CE to coordinate with the CWC flood monitoring authorities on the flood condition.

10. Submit to the CE the daily inflows and releases/Gate operation from the reservoir and status.

11. Observe the seepages in the Drainage Gallery with respect to the reservoir head and record the seepages in the infiltration gallery and immediately bring to the notice of the CE in case of excessive seepage, leakage in any specific blocks and porous drains.

12. 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.

13. Observe the dam top, ensure that the embankment, catwalk, approach roads are well maintained by housekeeping personnel.

14. 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 of excessive seepages, leakages etc.

1.5.3 Roles and Responsibilities of the Chief Engineer during Monsoon

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, releases from the upstream reservoirs (Mullaperiyar) 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 Dy CE/EE.

5. Coordinate with the Generation wing of KSEB Ltd regarding the power generation requirement.

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
- Irrigation, water supply and hydropower releases
- Weather related data
- Instrumentation data
- Water quality

MWL (m)	FRL (m)	Crest Level (m)	Present Water Level (m)	Previous Year Water Level	Percentage Storage	Rainfall (mm)	Generation (Mu)	Spill	Gate operation details

Table 1.6a Daily Reservoir Data

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

Date	Water Level	Previous Year Same day Water Level	Rainfall	Previous Year Rainfall	Storage	Generation	Gross Inflow	PH Discharge + Losses	Spill	Net Inflow	Remarks

Table 1.6b Daily Reservoir Status

On collecting the details in the above format, a daily reservoir status is submitted to the Chief Engineer as in the **Table 1.6b**.

Records/Logbooks of the operations at Idukki reservoir are maintained in a chronological manner for reference. These records are 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.
- Testing/operation of Power outlet gates, valves 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
Reservoir inflow	This is calculated daily
Spillway outflow	This is calculated during spill
River releases	The tail water release is measured at Moolamattom Power house and released to Muvattupuzha basin.
Irrigation, water supply and hydropower releases	The reservoir water is used for power generation at Moolamattom power house. Malankara Irrigation Project, Malankara Generating station and other Irrigation and water supply schemes work under the tail water release of Moolamattom Power house.

Weather related data	Collected and reported daily
Surveillance/Security arrangements	Provided security check posts near dams. The watch and ward of the dam structure and premises is arranged as Police Force under Govt. of Kerala. CCTV surveillance will be provided soon covering the dam and premises.
Water quality	Water sample analysis is also conducting once in a month. Physical & Chemical tests are being conducted at the Regional Analytical Laboratory, Kakkanad, Ernakulam.
Attendance statement during normal operations	Both during monsoon and non-monsoon period maintained at field office.
Operations of the spillway gates and outlet works	The spill way is designed for a safe discharge of 3875 m^3/s at FRL. There are5 no of radial gates for spillway operation. The spillway operations are recorded in the gate operation log book as well as reported to higher offices.
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 are maintained at field Office.
Testing/operation of Outlet gates, valves and 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 as well as forwarded to higher offices and upload in DHARMA
Unusual conditions or occurrences, including acts of vandalism	Details maintained at field office
Attendance statement at dam during emergency operations	Details maintained at field office
Changes to normal operating procedure	Details maintained at field office

Communication network checks	Network available at Dam site but not with full band strength at some locations. Police wireless system regularly checked.
Safety and special instructions	Safety equipments are provided
Names and addresses of official visitors	Record of inspections maintained at office

1.7 Public Utilities 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. IB and Canteen are provided near Cheruthoni and Idukki Dam and premises.

Idukki and Cheruthoni dams are situated in Mariyapuram and Vazhathoppe villages of Idukki district and approachable by Thodupuzha – Puliyamala road at Cheruthoni town. Dams are situated 1.2 km from Cheruthoni town.

Location of public conveniences:

Nearest Airport : CIAL, Cochin – 102 km

Nearest Railway station : Aluva – 102 km

Nearest Sea port : Cochin harbor –130 km

Nearest Police station : Cheruthoni, Idukki – 1.2 km

Nearest Hospital : Medical College Hospital, Idukki – 0.60 km

Nearest Private Hospital : St. Johns Hospital, Kattappana – 28 km

The dams (Idukki & Cheruthoni) can be reached via road from Cheruthoni town; Vellappara – Government Guest house road and alternatively through Medical college road and Kattappana road. It is possible to reach the dam bottom by road. Directional display boards are erected all along the road by state PWD and KSEB Ltd.

To Cheruthoni Dam

Vellappara Junction to Cheruthoni Entrance Gate No.1 - 1.40 km

Medical College Junction to Cheruthoni Gate No.2 - 1.45 km

Medical warehouse Junction to 8th Block of Left bank - 0.38 km

School Junction to Cheruthoni dam bottom Gate - 0.54 km

Medical warehouse Junction to Rain gauge station room - 0.18 km

To Idukki Dam

Cheruthoni right bank to Idukki dam left bank - 1.30 km

Kattappana road junction to Idukki Exit - 0.60 km

Idukki town to dam bottom guard room road - 0.62 km

Idukki town to dam bottom seismic station road - 0.50 km

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 include: confined spaces such as Adits, galleries, spillway approach, chute, energy dissipation arrangements, intake, tunnel etc. Warning boards showing the restricted area are placed at the dam premises.

- By the side of roads leading to dam top and bottom of Idukki and Cheruthoni dams
- Near to entrance of dams
- At a distance of 500 m from the dam premises
- Dam bottom area of both dams, spillway area and downstream of spillway
- Road to 8th Block of Cheruthoni dam
- Spillway gate operating bridge area/tower
- Sluice gate operating bridge area/tower
- Lift to both dams
- Inspection galleries of both dams
- Control rooms and Security cabins meant for dam safety and security
- 500 m upstream of close proximity of dam in the Reservoir
- Tunnel in the Right bank of Arch dam
- Intake gate/bubbler system/surge area/Intermediate Adit tunnel/butterfly valve area/penstock route/Power house/Switch yard/Cable tunnels/Tail race tunnel.

- Any other places declared/decided by the authority for the safety of the project will be a part of restricted area.

Lighting of Dams

In addition to the general lighting on the dam top, bottom and premises, high mast lights are provided at Cheruthoni (5 nos) and Idukki (10 nos) dams respectively. Tourists are visiting the dam area on Saturdays, Sundays and Public holidays and is managed by KHTC, a tourism wing owned/operated by KSEB Ltd. Security check done by Police and KHTC officials with HHMD, DFMD etc. and boating arranged by Forest Department. Service of women Police were utilized for security check for women tourists.

1.8.1 Dam safety surveillance

Security arrangements are provided near dam at security check post. Existing security arrangement is Kerala Police Force as per the structure is given below. Also CCTV surveillance will be provided soon covering the dam and premises.

Security Arrangement Existing	-	Kerala Police Force 3 shifts per day (Head Constable-1 No & Police Constable-3 Nos)
Cheruthoni Dam Top Entrance Guard	-	1 HC and 3 constables – 3 shifts/day
Cheruthoni dam bottom Guard	-	3 constables – 3 shifts/day
Idukki dam top Left bank Guard	-	3 constables – 3 shifts/day
Idukki dam top Right bank Guard	-	3 constables – 3 shifts/day
Idukki dam bottom Guard	-	3 constables – 3 shifts/day

(Total 5 Guard posts)Additional Guard post at Cheruthoni Right bank: (Building is ready but duty not assigned by Police Department. The CI of SHO, station recommended posting the Guard duty at 8th block and right bank of Cheruthoni dam)

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

1.9 Staff position, Communication & Warning System

The number & description of operating unit personnel posted/placed at different locations of the dam are noted in supporting documents and referenced in this Manual. Means of

communications both in normal and emergency situations are identified in the Communication Directory.

A hierarchy of organizational structure for the control and safety of Idukki, Cheruthoni, Kulamavu, Kallar and Erattayar dams is outlined below in **Fig 1.37.** Kulamavu, Kallar and Erattayar dams are under the control of Dam Safety Sub Division No. I. Idukki and Cheruthoni dams are under the control of Dam Safety Sub Division No. II. Means of communications both in normal and emergency situations are identified in the Communication Directory. Available communication means including landline, mobile and satellite phones, wireless sets are provided. Basic warning facilities like mike announcement and siren is provided.

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

Designation and office address	Contact number and e-mail
Chief Engineer Civil (Dam safety & DRIP), KSEB Ltd, Dam Safety Organisation, Pallom, Kottayam	Ph: 9446008005, 9446008964 e-mail: cedamsafety@kseb.in, cedamsafety@gmail.com
Deputy Chief Engineer, Research & Dam Safety Organization, Pallom, Kottayam	Ph: 9446008492, 0481-2432290, 9496011540 e-mail: dirroplm2@gmail.com
Executive Engineer, Dam Safety Division No. II, Vazhathoppe	Ph: 9446008425 e-mail: ddrdskkds@gmail.com
Assistant Executive Engineer, Dam Safety Sub Division No. II, Vazhathoppe (Idukki & Cheruthoni dams)	Ph: 9496011962, 04862 235226 email: aee2.damsafety.vazhathope@gmail.com
Assistant Engineer, Dam Safety Sub Division No. II, Vazhathoppe (Idukki & Cheruthoni dams)	email: aee2.damsafety.vazhathope@gmail.com
Assistant Executive Engineer, Dam Safety Sub Division No. I, Vazhathoppe (Kulamavu dam)	Ph: 9446011961 e-mail: aee1dssd@gmail.com
Assistant Engineer, Dam Safety Sub Division No. I, Vazhathoppe (Kulamavu dam)	e-mail: aee1dssd@gmail.com

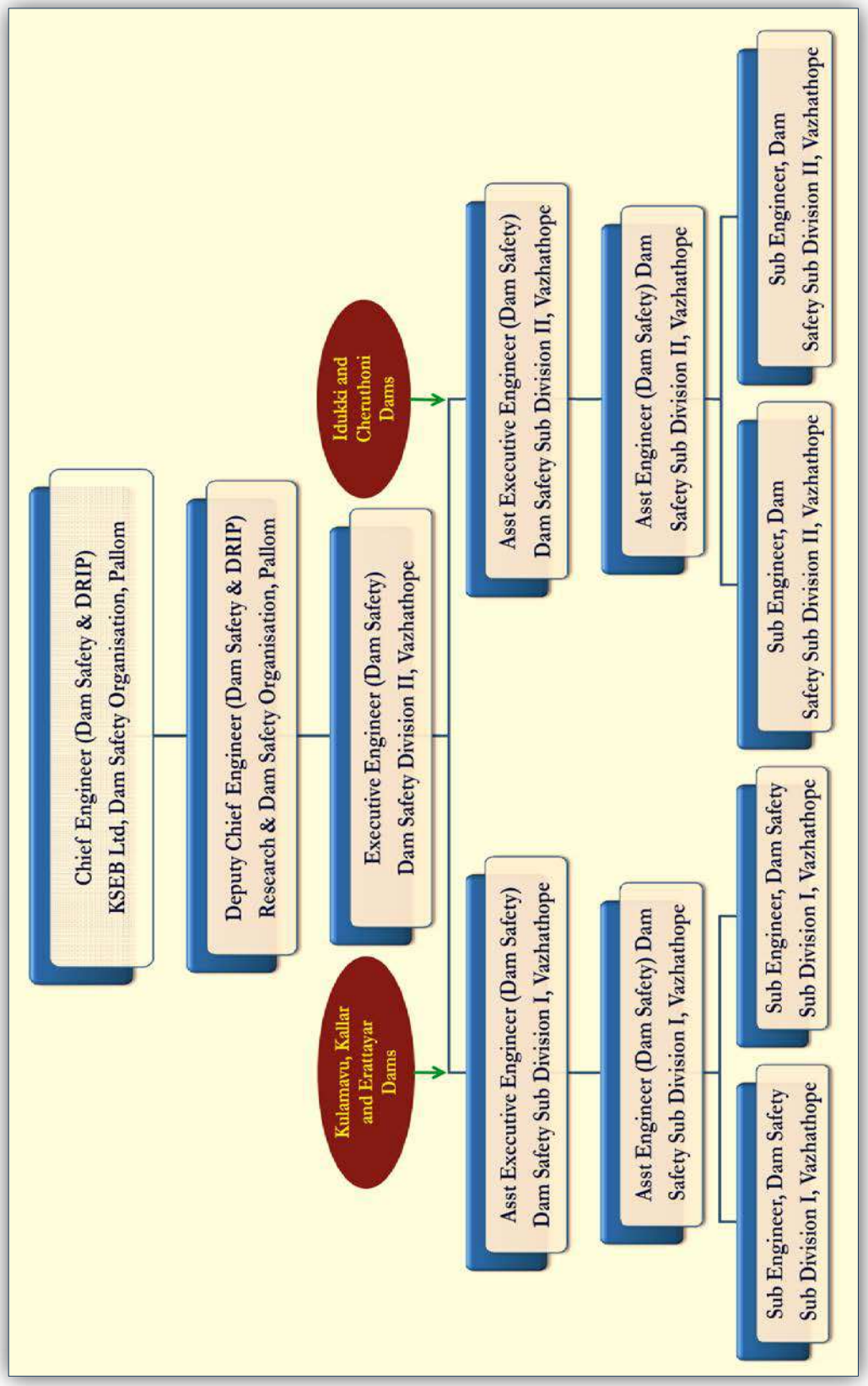


Fig. 1.37 Dam Safety Organisation Structure for Idukki, Cheruthoni, Kulamavu dams

Spillway flood releases

Spillway gates at Cheruthoni were being opened based on 'Guidelines for Operation of Reservoirs' (IS 7323:1994) and Gate Operation Manual. During flood season, Various Alerts at specified levels for opening of spillway gates are given. The first warning **(Blue Alert)** as water level reaches 2395ft (730 m), second warning **(Orange Alert)** as water level reaches 2397 ft (730.60 m) and third warning **(Red Alert)** as water level reaches 2398 ft (730.91 m) are given for opening of spillway gates. After giving warning at +2397 ft (730.60 m) level, further warning is given in local media including TV etc. regarding the possible opening of spillway gates continuously up to +2398 ft (730.91 m) level. Also intimations are given to Disaster Management, District Administration, and Police Department etc. But based on 2018 Kerala Flood, the operation alert levels are revised and details are given in the **Chapter 'Project Operation' Cl. 2.3.5**.

Releases for various purposes like irrigation, water supply and hydropower

The water from Idukki reservoir is mainly used for power generation of 780 MW at Moolamattom underground power house of KSEB Ltd around 46 km from Idukki. The tail water from this power house discharges into the reservoir of Malankara irrigation project in Muvattupuzha basin which irrigates 50000 Hect of land through left and right bank canals. These waters are utilized for power generation at Malankara power house downstream of Malankara irrigation dam on right bank which produces 10.5 (3 x 3.5) MW power and is owned by KSEB Ltd. The tail water is discharged into the Muvattupuzha river basin.

Warning system: Mike announcement, Siren, Newspaper and Television are used for providing warning to the downstream areas during floods.

Routine inspection

Usually monthly inspection and quarterly inspections are carried out by the operating/controlling officers. Pre-monsoon inspection and Post monsoon inspection as per CWC are carried out and reports intimated to CWC. These reports are to be updated in DHARMA web site. Details are given under the **Chapter 'Project Inspection'**.

Maintenance: Routine maintenance is carried out for Spillway gates and hoisting mechanism as part of routine maintenance before the onset of monsoon. Details are given under the **Chapter 'Project Maintenance'**.

1.10 Distribution of Operation & Maintenance Manual

The following officers/ field staff at different levels in the Division under the supervision of Deputy Chief Engineer, Research & Dam Safety Organization, KSEB Ltd, Pallom and administrative control of Chief Engineer, Dam Safety Organization, KSEB Ltd, Pallom are entrusted with the specific responsibility for carrying out O & M activities for Idukki, Cheruthoni and Kulamavu dams.

1) Executive Engineer, Dam Safety Division No. II, Vazhathoppe
2) Asst. Executive Engineer, Dam Safety Sub Division No. I, Vazhathoppe
3) Asst. Executive Engineer, Dam Safety Sub Division No. II, Vazhathoppe
4) Assistant Engineer, Dam Safety Sub Division No. I, Vazhathoppe
5) Assistant Engineer, Dam Safety Sub Division No. II, Vazhathoppe
6) Personnel in charge of works of the Dam

The offices/officers to which the O&M Manual of Idukki dam is to be distributed are:

Sl. No	Unit Officers to whom Manual is to be Distributed	No of Manuals
1	Dam Safety Division No. II, Vazhathoppe	1
2	Dam Safety Sub Division No. I, Vazhathoppe	1
3	Dam Safety Sub Division No. II, Vazhathoppe	2
4	Assistant Engineer, Dam Safety Sub Division No. I, Vazhathoppe	1
5	Assistant Engineer, Dam Safety Sub Division No. II, Vazhathoppe	1
6	Office of Deputy Chief Engineer, Research & Dam Safety Organization, KSEB Ltd, Pallom	2
7	Office of Chief Engineer, Dam Safety Organization, KSEB Ltd, Pallom	1
8	Office of the Director (Generation- Civil), KSEB Ltd, Vydyuthi Bhavanam, Pattom, Thiruvananthapuram.	1
9	Central Dam Safety Organisation	1
10	State Emergency Operation Center, Kerala Disaster Management Authority	1

1.11 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.

- Detailed drawings of the Project
- Emergency Action Plan (EAP)
- Latest Hydrology Review Report
- Latest DSRP Report
- Flood forecasting and operating criteria
- Agreements with user agencies
- Power station operation plan
- Administrative procedures
- Maintenance schedules
- Gate Manufacturer's manual and drawings
- Regional communication directory
- Instrumentation reports / results

1.12 Typical Schedule of Duties

Schedule of duties/inspections to be carried out for the operation and maintenance of the dam by the concerned official are tabulated below in **Table 1.7**.

Sl. No.	Component/ Duty	Frequency	Personnel
1	Visual inspection of dam including Crest of dam (Dam top), Upstream and downstream faces, visible portions of foundation and abutments, Galleries, Spillway and its energy dissipation arrangements, Power intake etc.	Daily	Sub Engineer/Dam operators on contract
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, Gallery drains 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, Galleries, Spillway and its energy dissipation arrangements, Power Intake etc.	Weekly	Assistant Engineer
7	Check stand by generator (DG Sets), Drainage systems, Gallery drains 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, Galleries, Spillway and its energy dissipation arrangements, Power Intake etc.	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, Toe drains, Gallery drains 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, Galleries, Spillway and its energy dissipation	Monthly	Executive Engineer

	arrangements, Power Intake etc.		
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	Regular Inspection and Maintenance of all hydro mechanical equipment (gates, hoist, embedments and allied works including electrical parts and power supply. 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 trash rack of intake structure, condition of Outlet works & its energy dissipation arrangement, Check operation of Valve house	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, Check lubrication of wire ropes and application of cardium compound, Check mechanical hoist bearings and flexible coupling bearings, Check gear systems, Exercise gates and valves, Check lubrication of gate rollers, Check rubber seals and seal clamp bar.	Half yearly (Pre and Post Monsoon)	Deputy Chief Engineer along with Executive Engineer in charge of dam
22	Submission of Inspection report to CWC and uploading into DHARMA.	Half yearly	Chief Engineer/ Deputy Chief Engineer
23	Comprehensive inspections	Annually	Dam Safety Authority along with Dam Owners
24	Inspect dam and gate structures, trash racks and stilling basin/energy dissipation arrangement, which normally are underwater (by dewatering or by divers/ROV as necessary). Review Dam operation procedures, EAP and update.	Five Yearly	Chief Engineer/ Deputy Chief Engineer
25	Comprehensive inspection of performance of the dam and gate structures and reservoirs, trash racks and stilling basin /energy dissipation arrangement.	Ten Yearly	DSRP

Table 1.7 Schedule of duties/inspections

1.13 Hydro-Mechanical Inspections / Checks

Frequent inspections/checks for hydro-mechanical components are to be conducted and necessary action to be taken up during maintenance. Routine maintenance is carried out for Spillway gates and hoisting machinery as part of routine maintenance before the onset of monsoon. Details are given under the Chapter **'Project Maintenance'**.

Chapter 2

Project Operation

The operation of a dam will involve regulation of its reservoir as per project specific requirements, keeping records and ensuring public safety. Proper operation procedures are crucial for normal or day to day operation of a dam for maintaining a safe structure.

2.1 Basic Data

The Idukki HEP operation plan consists of step-by-step instructions for operating the dams 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 and spillway. The operation of a dam involves regulation of its reservoir as per project specific requirements. This includes the use of area capacity curve and design flood.

2.1.1 Spillway Dam

Cheruthoni dam is the spillway dam for Idukki reservoir and is located at Cheruthoni about 4 km NE of Idukki dam. The FRL and MWL are 732.63 m and 734.30 m respectively. The design of Cheruthoni dam was done in consultation with C & MDD of Central Water and Power Commission in 1965.

The crest of the spillway in Cheruthoni Dam is 723.29 m (2373.00 ft), FRL is 732.63m (2403 ft) and there are five radial gates of size 12.19 m x 10.36 m (40 ft x 34 ft) with sill of gates at +722.87m (2371 ft) as finally built. The spillway has a discharge capacity of 3875 m^3/s (1.37 lakh cusecs) at FRL Condition and 5000 m^3/s (176500 cusecs) at MWL condition. The maximum non overflow section of the spillway at Cheruthoni dam is given in **Fig 2.1**. Photographs showing downstream and upstream elevation of spillway at Cheruthoni dam are given in **Fig 2.2a** and **Fig 2.2b**. The downstream elevation showing spillway & outlet, details of spillway bucket and crest at Cheruthoni dam are given in **Drg 2.1, Drg 2.2a** and **Drg 2.2b** of **Annexure 1.**

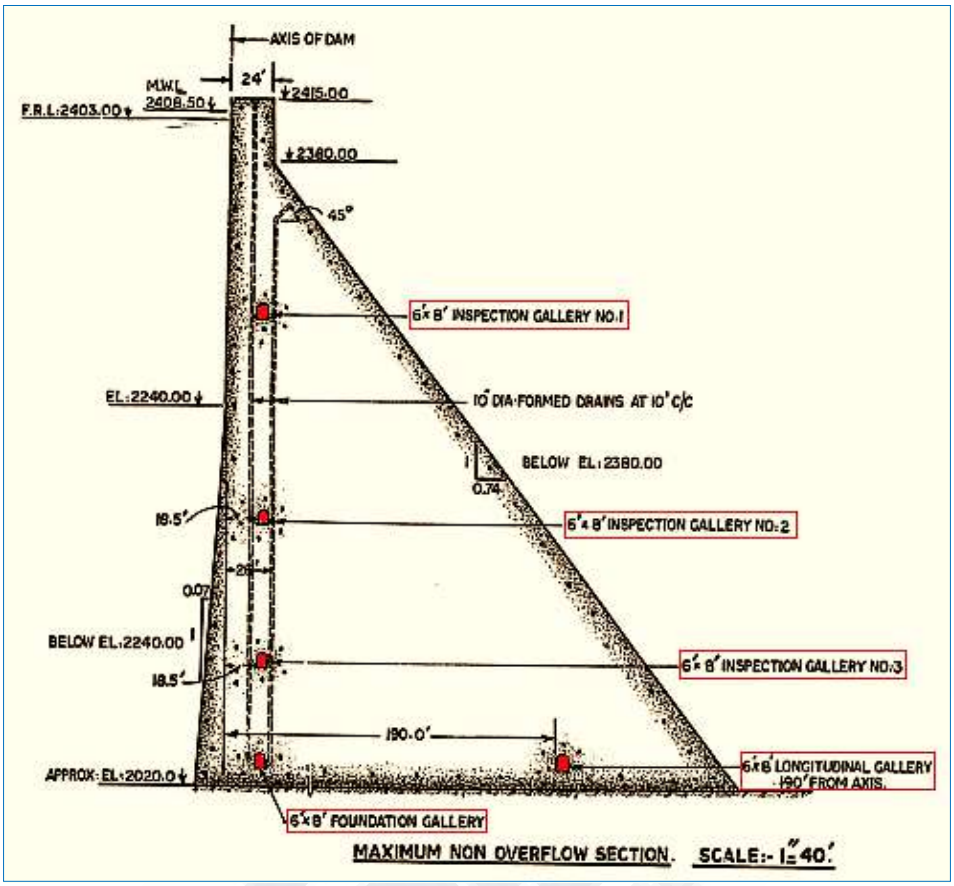


Fig 2.1 Maximum Non Overflow Section of the spillway at Cheruthoni

Fig 2.2a Downstream Elevation of Spillway

Fig 2.2b Upstream Elevation of Spillway

2.1.1.1 Spillway

No openings are provided in the Idukki Dam for flood water releases. It is accomplished through spillway and outlets provided in the adjacent **Cheruthoni** dam. The maximum design flood for the catchment of Idukki reservoir is worked out as 8019 m^3/s (Revised as 9402 m^3/s). Some flood absorption capacity is provided in the Idukki reservoir. The design flood of 283000 cusecs is moderated to 174000 cusecs. Five spillway radial crest gates of sizes 12.19 m x 10.36 m (40 ft x 34 ft) are installed in Cheruthoni Dam.

The spillway is located in the river portion. It has an ogee crest with an upstream lip as control structure and a free flip bucket as terminal structure. The crest of the spillway is at El. 723.29 m (2373 ft) and the bucket sill of the middle three vent ways having a radius of 18.29 m (60 ft) is at El. 609.7 m (2000 ft). The same spillway arrangement is provided on each side with buckets' sill at El. 617.3 m (2025 ft) and 618.8 m (2030 ft) respectively. (Pl refer **Drg 2.1**) Sufficient anchorage, grouting and drainage facilities are provided under the bucket portion to overcome uplift. Longitudinal contraction joints separate the bucket portion from the dam. The spillway gates are operated by hoists located at El. 739.5 m (2426 ft). The platforms for these hoists and the roadway are reinforced concrete constructions and are supported on 10 ft wide piers.

The design for spillway buckets were finalized after conducting hydraulic model studies at the Kerala Engineering Research Institute, Peechi. Idukki Dam does not contain and outlet. However the outlets for the reservoir are located in Cheruthoni Dam and Kulamavu Dam. Two unusually large size outlets 10' x 21' (3.05 m x 6.4 m) are provided in Cheruthoni Dam to meet the following requirements. (1) Emptying the reservoir during emergencies. (2) Control of reservoir levels during constructions of the dam. (3) Systematic regulation of reservoir elevation for controlled loading of Idukki Arch Dam (4) Supplementing the spillway capacity provided. The capacity of the outlets is dictated by requirement (3) mentioned above. It was required to design the outlets for a flow of 424.8 cumecs (15 cusecs) from each when the water surface elevation 716.4 m (2350 ft). This requirement is found out after imposing certain constraints in result of rise in reservoir during flash flood and time evacuating the flash flood during initial loading Idukki Arch Dam. The discharge capacity of each outlet is 15900 cusecs for reservoir elevation 716.4 m (2350 ft) and 20000 cusecs at M.W.L 734.3 m (2408.5 ft).

2.1.2 Spillway operation schedule

The spillway operation schedule as per the guidelines during project execution is reproduced below:

Inflow computation

- Compute the current rate of reservoir rise or fall per hour in metres from observed reservoir level.
- Compute the corresponding storage change in cumecs indicated in figure for current reservoir elevation from reservoir capacity **Table 2.1**.
- The storage equation is Inflow = Outflow ± change in storage. Storage change is expressed in cumecs, the same unit as inflow and outflow. The outflow also includes water utilized for generation and various losses like evaporation, leakage etc.

Gate Operation Schedule

The outflow through spillway gates for different heads and different opening are arrived based on model studies and is given in **Table 2.6**.

- The spill required for maintaining the preferred reservoir operation level may be worked out.
- From **Table 2.6** find out the gate opening to release this inflow and adjust the gate openings accordingly.

A register with the following details is to be maintained to give the details of gate operation.

- Date, Hour
- Reservoir level at the end of the hour (m)
- Rise or fall in reservoir level (m)
- Change in storage (m^3/s)
- Release from the reservoir during the hour (m^3/s)
- Inflow into the reservoir during the hour (m^3/s)
- Release from the reservoir for the next hour (m^3/s)
- Position of gate openings for the next hour (Gate no and opening)

The estimated maximum probable flood for Idukki reservoir is 8019 m^3/sec (Revised as 9402 m^3/s). If this flood impinges when the reservoir is at FRL (+732.63 m) and all the gates are opened fully, the reservoir will attain a maximum water level of +734.3 m (MWL). The assumption here is that the initial inflow of the flood hydrograph which are less than the discharge capacity of the spillway at FRL are released by suitable openings of the spillway gates so that the reservoir level is maintained at FRL.

- Discharges through the outlets in Cheruthoni and Kulamavu dams can also be operated when found necessary to keep the reservoir from rising above MWL.
- Part inflows of Idukki reservoir: Based on rainfall runoff relationships monthly monsoon inflows into Idukki reservoir for the period 1933 to 1957 have been calculated. From 1958 to 1974 the monthly inflows are based on actual observed discharges. The maximum inflow (June to December) has occurred in 1961 and is 77,436 Mcft of which 71643 Mcft has occurred in June to September. In 1971 the total inflow was 70444 Mcft, of which 51632 Mcft occurred in June to September and 18812 Mcft in October to December (in terms of energy, this is about 780 MU). 1933 has an inflow of 21829 Mcft (914 MU) in October - December out of the total of 63446 Mcft.

The possibilities, for the reservoir to get filled up, therefore are

(i) in rich South West monsoon itself (as in 1961)

(ii) by both the monsoons being good (as in 1971)

(iii) with normal South West monsoon and very rich North East monsoon (as in 1933).

Hence strict vigilance for reservoir control is essential throughout the two monsoons.

2.1.3 Elevation Capacity Curve

The area capacity curves for Idukki Reservoir during design are shown in **Fig 2.3.** The elevation capacity (storage) curve for Idukki Reservoir based on **Table 2.1** is shown in **Fig 2.4**.

Idukki Reservoir - Elevation Vs. Storage				
Water level in feet	**Water level in m**	**Storage in Mcft**	**Storage in Mm³**	**Remarks**
1900	579.12	0.520	0.01	
1920	585.22	1.93	0.05	
1940	591.31	8.80	0.25	
1960	597.41	33.16	0.94	
1980	603.50	75.90	2.15	
2000	609.60	138.52	3.92	
2020	615.70	231.05	6.55	
2040	621.79	361.35	10.24	
2060	627.89	541.55	15.34	
2080	633.98	783.25	22.19	
2100	640.08	1093.25	30.97	
2120	646.18	1548.55	43.87	
2140	652.27	2229.95	63.17	
2160	658.37	3151.95	89.29	
2180	664.46	4389.00	124.33	
2200	670.56	6076.00	172.12	
2220	676.66	8304.00	235.24	
2240	682.75	11127.00	315.21	
2260	688.85	14625.00	414.31	
2280	**694.94**	**18957.00**	**537.03**	**MDDL**
2281	695.25	19206.00	544.08	

2282	695.55	19454.00	551.10	
2283	695.86	19703.00	558.16	
2284	696.16	19951.00	565.18	
2285	696.47	20200.00	572.24	
2286	696.77	20460.00	579.60	
2287	697.08	20720.00	586.97	
2288	697.38	20980.00	594.33	
2289	697.69	21240.00	601.70	
2290	697.99	21500.00	609.07	
2291	698.30	21768.00	616.66	
2292	698.60	22036.00	624.25	
2293	698.91	22304.00	631.84	
2294	699.21	22572.00	639.43	
2295	699.52	22840.00	647.03	
2296	699.82	23128.00	655.18	
2297	700.13	23416.00	663.34	
2298	700.43	23703.00	671.47	
2299	700.74	23991.00	679.63	
2300	701.04	24279.00	687.79	
2301	701.34	24601.00	696.91	
2302	701.65	24922.00	706.01	
2303	701.95	25244.00	715.13	
2304	702.26	25566.00	724.25	
2305	702.56	25887.00	733.34	
2306	702.87	26209.00	742.46	
2307	703.17	26531.00	751.59	
2308	703.48	26852.00	760.68	
2309	703.78	27174.00	769.80	

2310	704.09	27496.00	778.92	
2311	704.39	27817.00	788.02	
2312	704.70	28139.00	797.14	
2313	705.00	28460.00	806.23	
2314	705.31	28782.00	815.35	
2315	705.61	29104.00	824.48	
2316	705.92	29425.00	833.57	
2317	706.22	29747.00	842.69	
2318	706.53	30069.00	851.81	
2319	706.83	30390.00	860.91	
2320	707.14	30712.00	870.03	
2321	707.44	31089.00	880.71	
2322	707.75	31466.00	891.39	
2323	708.05	31844.00	902.10	
2324	708.36	32221.00	912.78	
2325	708.66	32598.00	923.46	
2326	708.96	32975.00	934.14	
2327	709.27	33352.00	944.82	
2328	709.57	33730.00	955.52	
2329	709.88	34107.00	966.20	
2330	710.18	34484.00	976.88	
2331	710.49	34861.00	987.56	
2332	710.79	35238.00	998.24	
2333	711.10	35616.00	1008.95	
2334	711.40	35993.00	1019.63	
2335	711.71	36370.00	1030.31	
2336	712.0128	36747.00	1040.99	
2337	712.3176	37124.00	1051.67	

2338	712.6224	37502.00	1062.38	
2339	712.9272	37879.00	1073.06	
2340	713.232	38256.00	1083.74	
2341	713.5368	38690.00	1096.03	
2342	713.8416	39124.00	1108.33	
2343	714.1464	39557.00	1120.59	
2344	714.4512	39991.00	1132.89	
2345	714.756	40425.00	1145.18	
2346	715.0608	40859.00	1157.48	
2347	715.3656	41293.00	1169.77	
2348	715.6704	41726.00	1182.04	
2349	715.9752	42160.00	1194.33	
2350	716.28	42594.00	1206.63	
2351	716.5848	43028.00	1218.92	
2352	716.8896	43462.00	1231.22	
2353	717.1944	43896.00	1243.51	
2354	717.4992	44329.00	1255.78	
2355	717.804	44763.00	1268.07	
2356	718.1088	45197.00	1280.37	
2357	718.4136	45631.00	1292.66	
2358	718.7184	46064.00	1304.93	
2359	719.0232	46498.00	1317.22	
2360	719.328	46932.00	1329.52	
2361	719.6328	47433.00	1343.71	
2362	719.9376	47935.00	1357.93	
2363	720.2424	48436.00	1372.12	
2364	720.5472	48938.00	1386.35	
2365	720.852	49439.00	1400.54	

2366	721.1568	49941.00	1414.76	
2367	721.4616	50442.00	1428.95	
2368	721.7664	50944.00	1443.17	
2369	722.0712	51445.00	1457.37	
2370	722.376	51947.00	1471.59	
2371	722.6808	52448.00	1485.78	
2372	722.9856	52950.00	1500.00	
2373	723.2904	53451.00	1514.19	
2374	723.5952	53953.00	1528.41	
2375	723.9	54454.00	1542.61	
2376	724.2048	54956.00	1556.83	
2377	724.5096	55457.00	1571.02	
2378	724.8144	55959.00	1585.24	
2379	725.1192	56460.00	1599.43	
2380	725.424	56962.00	1613.65	
2381	725.7288	57546.50	1630.21	
2382	726.0336	58131.00	1646.77	
2383	726.3384	58715.50	1663.33	
2384	726.6432	59300.00	1679.89	
2385	726.948	59885.00	1696.46	
2386	727.2528	60469.50	1713.02	
2387	727.5576	61054.00	1729.58	
2388	727.8624	61638.50	1746.13	
2389	728.1672	62223.00	1762.69	
2390	728.472	62807.00	1779.24	
2391	728.7768	63391.50	1795.79	
2392	729.0816	63976.00	1812.35	
2393	729.3864	64560.50	1828.91	

2394	729.6912	65145.00	1845.47	
2395	729.996	65730.00	1862.04	
2396	730.3008	66314.50	1878.60	
2397	730.6056	66899.00	1895.16	
2398	730.9104	67483.50	1911.71	
2399	731.2152	68068.00	1928.27	
2400	731.52	68652.00	1944.82	
2401	731.8248	69268.00	1962.27	
2402	732.1296	69884.00	1979.72	
2403	**732.43**	**70500.00**	**1997.17**	**FRL**
2404	732.7392	71209.00	2017.25	
2405	733.044	71918.00	2037.34	
2406	733.3488	72627.00	2057.42	
2407	733.6536	73336.00	2077.51	
2408	733.9584	74045.00	2097.59	
2408.5	**734.11**	**74400.00**	**2107.65**	**MWL**

Table 2.1 Idukki Reservoir Elevation vs Storage

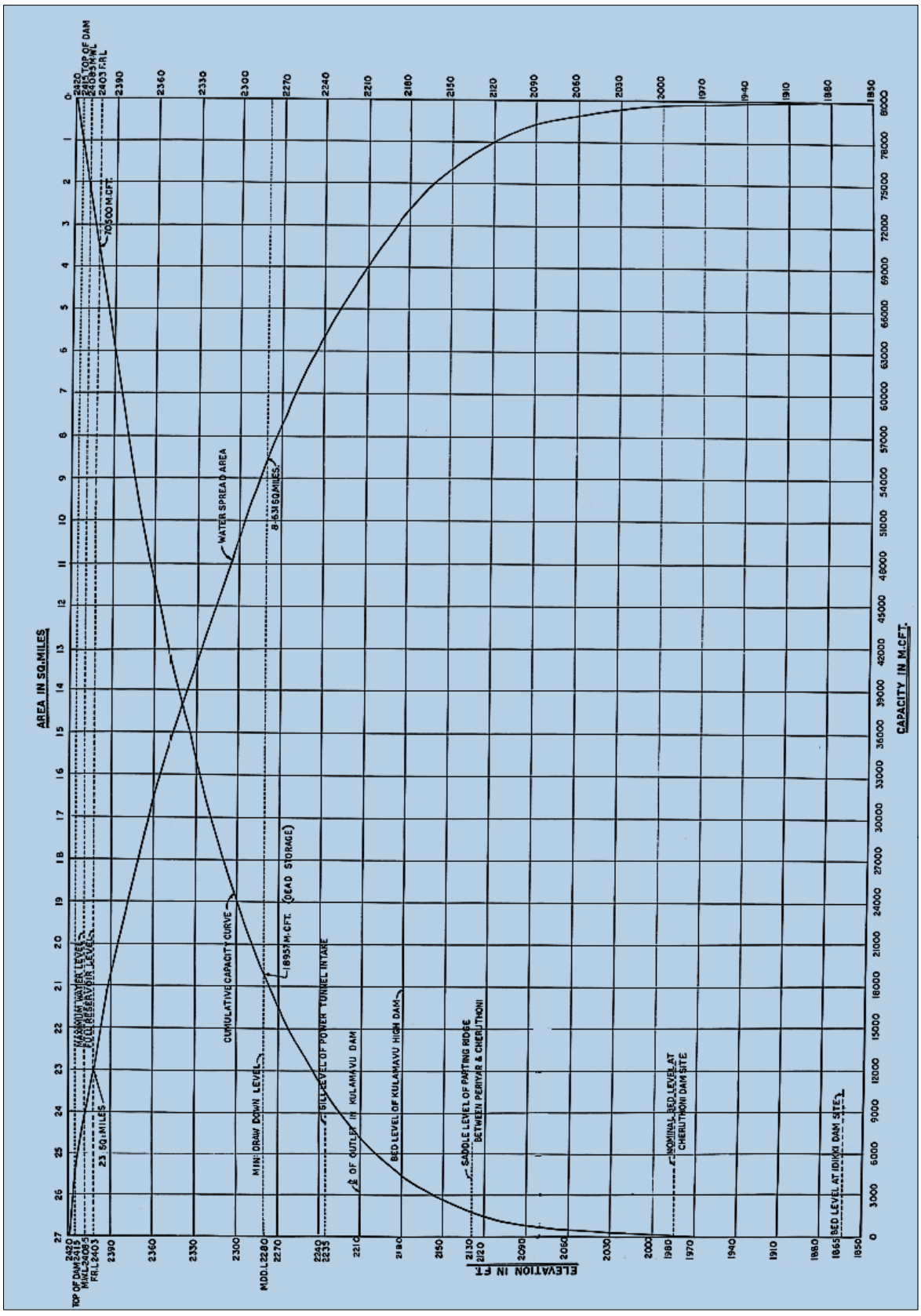


Fig 2.3 Area and Capacity curves

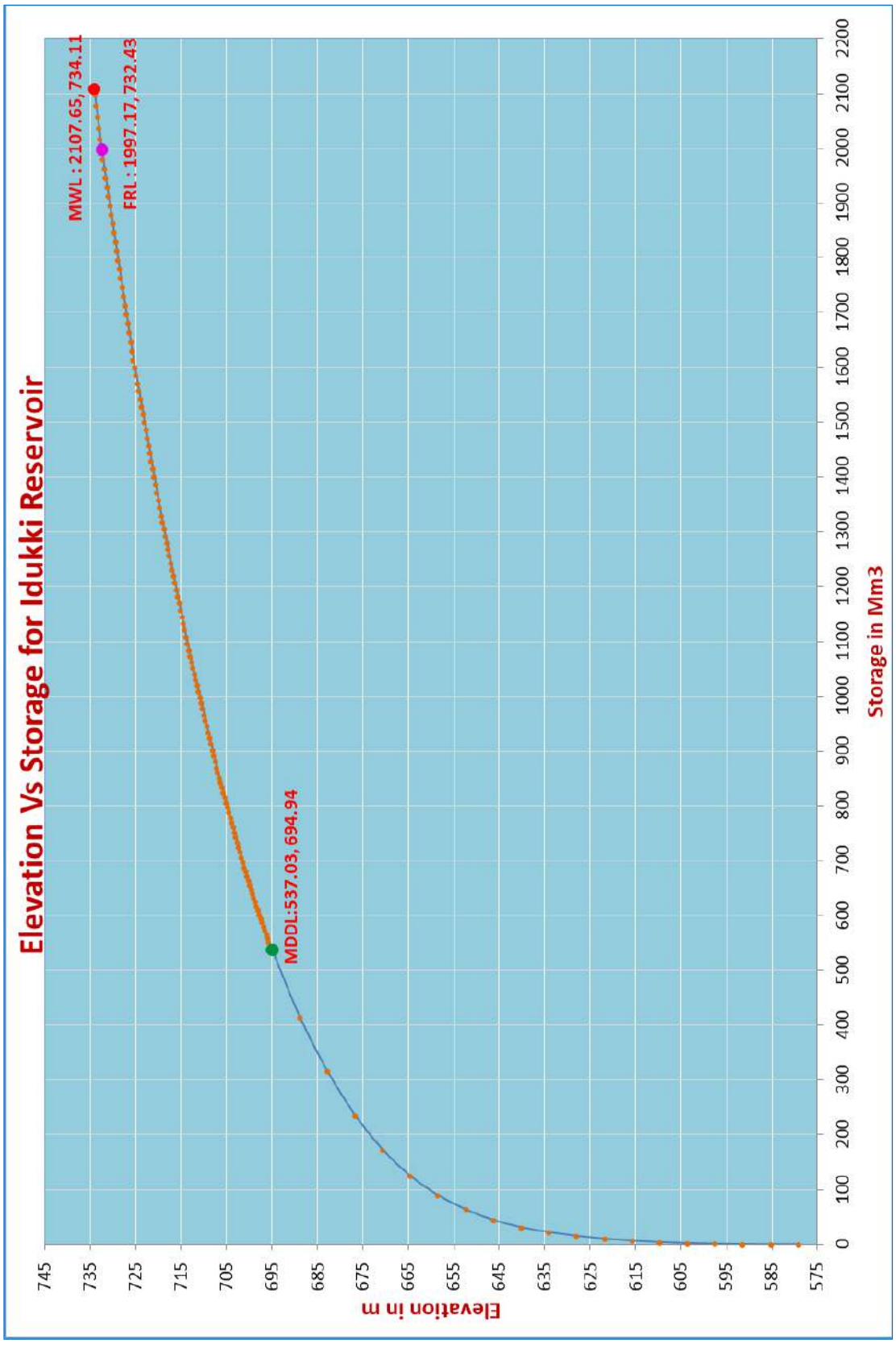


Fig 2.4 Elevation- Capacity Curve

2.1.4 Elevation Area Curve

Elevation Vs. water spread area curve for Idukki Reservoir based on **Table 2.2** is shown in **Fig 2.5.**

Idukki Reservoir - Elevation Vs Water Spread Area				
Water level in feet	**Water level in metre**	**Water spread area in Sq miles**	**Water spread area in Sq km**	**Remarks**
1880.00	573.024	0.0006	0.0016	
1900.00	579.120	0.0013	0.0034	
1920.00	585.216	0.0040	0.0104	
1940.00	591.312	0.0240	0.0622	
1960.00	597.408	0.0670	0.1735	
1980.00	603.504	0.0870	0.2253	
2000.00	609.600	0.1400	0.3626	
2020.00	615.696	0.1940	0.5025	
2040.00	621.792	0.2760	0.7148	
2060.00	627.888	0.3780	0.9790	
2080.00	633.984	0.4980	1.2898	
2100.00	640.080	0.6200	1.6058	
2120.00	646.176	1.0310	2.6703	
2140.00	652.272	1.4240	3.6881	
2160.00	658.368	1.8960	4.9106	
2180.00	664.464	2.5576	6.6242	
2200.00	670.560	3.4980	9.0598	
2220.00	676.656	4.5160	11.6964	
2240.00	682.752	5.6330	14.5894	
2260.00	688.848	6.9380	17.9693	
2280.00	**694.944**	**8.6310**	**22.3542**	**MDDL**
2300.00	701.040	10.4900	27.1690	
2320.00	707.136	12.6200	32.6856	
2340.00	713.232	14.4500	37.4253	
2360.00	719.328	16.6900	43.2269	
2380.00	725.424	19.3400	50.0904	
2400.00	731.520	22.6120	58.5648	
2403.00	**732.434**	**23.0000**	**59.5697**	**FRL**
2420.00	737.616	27.0000	69.9297	

Table 2.2 Water level vs Waterspread area of Idukki Reservoir

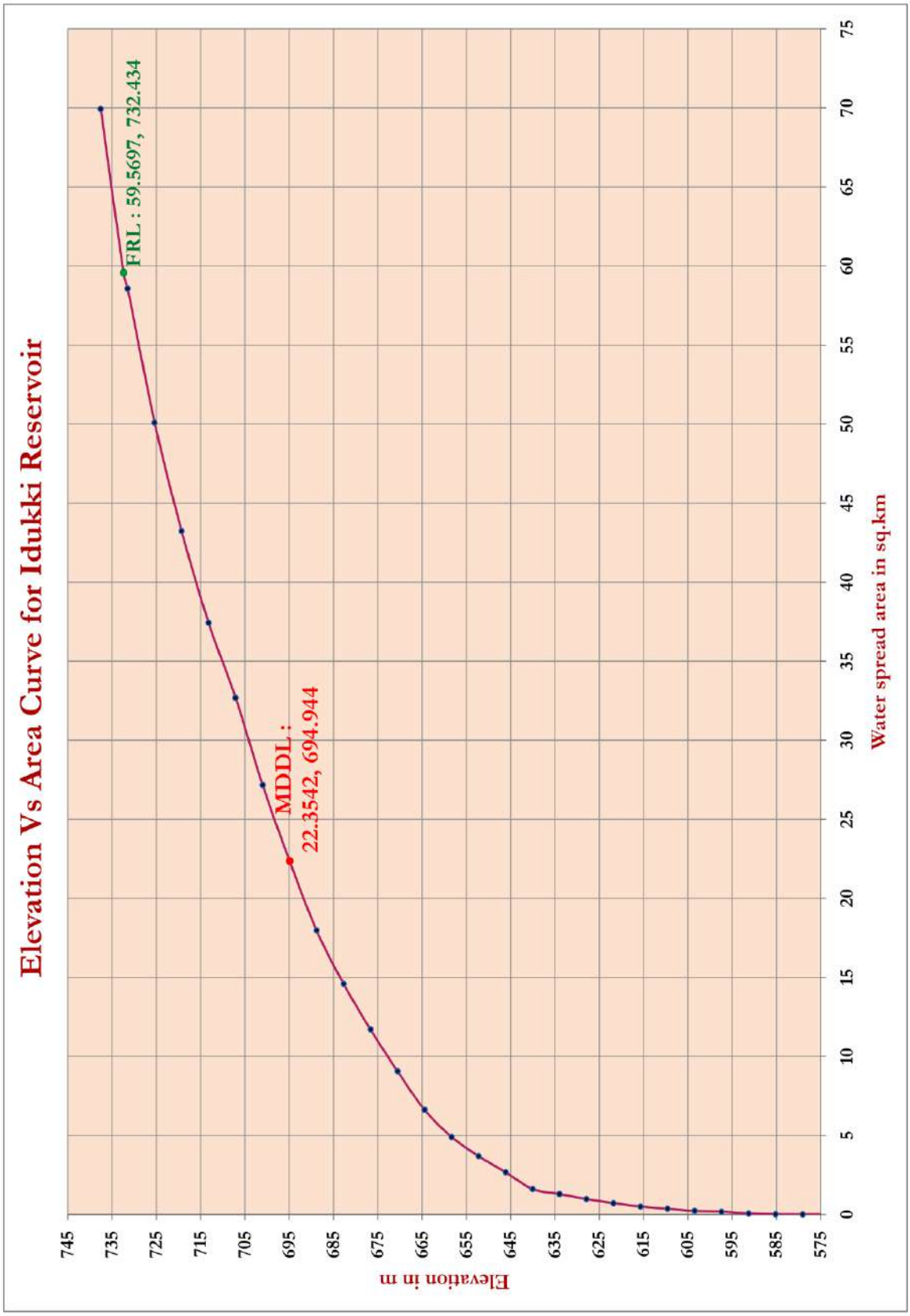


Fig 2.5 Elevation- Waterspread Area Curve

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. The salient features of the dam and reservoir are detailed in **Chapter 1**.

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 rainfall of 484 mm and 751 mm respectively was recorded.

The second historical flood occurred during August 14 to 17 in 2018 is the highest flood recorded in the reservoir. The SW monsoon of the year 2018 in the State was similar to that of 1924 Devikulam storm. Kerala experienced abnormally high rainfall from 1 June 2018 to 19 August 2018 which resulted 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 in Pamba, Periyar and Bharathapuzha sub-basins are almost comparable to the Devikulam storm of 16-18, July 1924. For the entire Kerala, 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, while the same during 16-18, July 1924 was 443 mm. The 3-day rainfall of 15-17, August 2018 at Idukki dam site was 812 mm. The 4 –day rainfall of 15-18, August 2018 at Idukki dam site was 1032 mm which is one of the highest in the State.

Cheruthoni spillway shutters were opened during **1981, 1992 & 2018** for flood control. Spill details of **1981 and 1992** are tabulated below in **Table 2.3**. Spill details of the year 2018 are tabulated below in **Table 2.4**. The rainfall, inflow and reservoir water level of the 1981, 1992 and 2018 are included in **Annexure 3.**

Spill Details in 1981					
Date	**Water level in ft**	**Storage in Mcft**	**Spillway discharge in Mcft/day**	**Daily inflow in Mm^3**	**Spill in m^3/sec**
29.10.1981	2402.17	69988.72	9.901	8.834	3
30.10.1981	2402.23	70025.68	202.147	10.648	66

31.10.1981	2402.57	70235.12	97.152	11.726	32
01.11.1981	2402.99	70493.84	386.4	11.166	127
02.11.1981	2402.98	70487.68	108.72	**14.590**	36
03.11.1981	2402.98	70487.68	40.869	6.891	13
04.11.1981	2403.03	70521.27	11.957	6.497	4
09.11.1981	2403.1	70570.9	197.766	4.972	65
10.11.1981	2403.03	70521.27	35.871	7.423	12
11.11.1981	2403.02	70514.18	17.935	4.728	6
13.11.1981	2403.12	70585.08	112.504	6.877	37
Total spill in 1981 (Mcft)			**1221.222**		
Total spill in 1981 (Mm^3)			**34.585**		
Maximum Inflow observed during spill period in 1981 = 14.590 Mm^3 (on 02/11/1981)					
Maximum Inflow observed during the year 1981 = 51.073 Mm^3 (on 11/08/1981(Water level = 2366.20 ft))					
Spill Details in 1992					
12.10.1992	2401.44	69539.04	203.387	15.547	67
13.10.1992	2401.48	69563.68	215.63	13.449	71
14.10.1992	2401.39	69508.24	213.817	11.697	70
15.10.1992	2401.23	69409.68	213.36	8.523	70
16.10.1992	2401.09	69323.44	77.76	7.278	25
16.11.1992	2402.38	70118.08	170.864	**25.483**	56
17.11.1992	2402.88	70426.08	309.121	23.507	101
18.11.1992	2402.93	70204.32	743.245	14.976	244
19.11.1992	2402.66	70290.56	164.144	12.362	54
20.11.1992	2402.66	70290.56	163.172	10.907	53
21.11.1992	2402.66	70290.56	122.458	10.448	40
22.11.1992	2402.66	70290.56	109.882	7.947	36
23.11.1992	2402.60	70253.6	67.894	5.617	22
Total spill in 1992 (Mcft)			**2774.734**		
Total spill in 1992 (Mm^3)			**78.582**		
Maximum Inflow observed during spill period in 1981 = **25.483** Mm^3 (on 16/11/1992)					
Maximum Inflow observed during the year 1992 = 68.412 Mm^3 (on 28/07/1992 (Water level = 2352.50 ft))					

Table 2.3 Spill details of the year 1981 and 1992

Spill Details in 2018					
Date	**Water level in ft**	**Rainfall in mm**	**Storage in Mm^3**	**Gross Inflow in Mm^3/day**	**Spill in Mm^3**
10/08/18	2401.00	129.80	1961.45	57.451	3.47
11/08/18	2401.10	95.40	1963.20	61.033	49.19
12/08/18	2399.38	25.40	1933.76	45.444	64.80
13/08/18	2397.78	82.00	1907.28	48.443	64.80
14/08/18	2396.88	72.00	1892.38	45.994	50.76
15/08/18	2398.56	235.00	1920.19	84.181	46.26
16/08/18	2401.14	295.40	1963.89	**165.057**	111.24
17/08/18	2402.30	180.20	1984.13	154.960	124.65
18/08/18	2401.52	100.40	1970.52	111.700	115.20
19/08/18	2402.24	45.00	1983.08	92.506	70.16
20/08/18	2401.86	30.20	1976.45	62.880	59.40
21/08/18	2401.02	24.40	1961.80	37.544	42.12
22/08/18	2400.72	6.80	1956.57	29.950	25.38
23/08/18	2400.56	4.80	1953.78	24.597	17.28
24/08/18	2400.16	4.80	1946.80	20.392	17.28
25/08/18	2399.66	0.00	1938.39	18.957	17.28
26/08/18	2399.08	0.00	1928.79	17.772	17.28
27/08/18	2398.42	16.20	1917.87	16.417	17.28
28/08/18	2397.88	41.20	1908.93	18.436	17.28
29/08/18	2397.36	19.80	1900.33	18.705	17.28
30/08/18	2396.66	8.20	1888.74	15.781	17.28
31/08/18	2396.00	4.40	1877.82	15.165	17.28
01/09/18	2395.30	24.20	1866.23	15.830	17.28
02/09/18	2394.50	20.40	1852.97	14.082	17.28
03/09/18	2393.86	20.20	1842.38	8.651	9.00
04/09/18	2393.20	0.00	1831.46	7.953	8.64
05/09/18	2392.56	0.00	1820.87	7.938	8.64
06/09/18	2391.90	0.00	1809.94	7.780	8.64
07/09/18	2391.18	0.00	1798.03	6.960	8.64
08/09/18	2390.72	0.00	1790.41	4.566	2.16
				Total Spill in 2018 (Mm^3)	**1063.23**
Maximum Inflow observed during the year 2018 = 165.057 Mm^3 (on 16/08/2018 (Water level = 2401.14 ft))					

Table 2.4 Spill details of the year 2018

2.2.2 Design Flood and Features Related to Safety

Hydrology during the initial period as available is given below.

Hydrology (Original)

The sites of the Idukki and Cheruthoni dams are situated 54 km downstream of the existing Periyar dam across river Periyar. The free catchment area of 649.30 Sq km downstream of Periyar dam, commanded at Idukki consists of 526.28 Sq km of Periyar and 123.02 Sq km of the Kulamavu. The catchment is generally hilly and is covered with rich vegetation consisting of reserve forests interspersed with tea, coffee, cardamom and pepper estates. The prevailing winds are only due to monsoon currents. 90% of the annual rainfall is received during the two monsoon periods. 2/3rd of this monsoon rainfall is contributed by the south-west monsoon. 38 years mean annual rainfalls (1933 to 1970) for Periyar and Cheruthoni catchments are respectively 301.25 cm and 423.16 cm. Relative humidity in monsoon periods over the catchment is in excess of 90% during the night and early mornings, decreasing to about 40% in midafternoons. During the remaining period, the values are 85% and 30% respectively. The maximum recorded temperature is 100 °F and minimum 51°F.

Rain Gauges' data from a total of 67 rain gauge stations maintained by the Estates, 49 of which are located within the catchment have been made use of for working out the yearly average rainfall. Data from 1930 were available in some of the stations. 7 more stations were added in 1957.

Flow gauges -Gauging weirs were constructed across Periyar and Cheruthoni near the dam sites and gauging records are available from 1958. The weir across Periyar is 1.61 km upstream of the dam site and that across Cheruthoni about 0.8 km downstream of the dam site. Automatic water level recorders of Glenfield and Kennedy make were installed at both sites. Current meter sites were also established for measurement of discharges by area-velocity method. Additional Gauge sites were established in 1959 to facilitate more accurate determination of river slopes. Rating curves were established and weighted mean daily discharge rates have been worked out from the gauges observed.

Hydrographs and Floods

A rainfall run off correlation was established based on the records of upper catchment from 1921 and was used for finding the yield of the catchment. The relationship is:

$$R = -13.71 + 0.741\ P$$

R = Run off in inches over the catchment and

P = Precipitation in inches.

Hydrographs for Periyar and Cheruthoni are available from 1958 onwards. The unit hydrograph method was used for estimation of design flood utilizing available data for the periods June 1958 to August 1958, 15th Oct 1958 to 14th Nov 1958 and from 15th June 1959 to August 1959. For deriving the design flood the Periyar and Cheruthoni catchments have been considered separately, as well as the contribution of the upper catchment. Since the waters of the Cheruthoni & Periyar form a single reservoir and the Periyar has no separate spillway, the spillway for the Idukki project has to cater for the floods for the Periyar & Cheruthoni as well as the releases from the existing Periyar dam upstream. The sum of the two peak discharges of the Cheruthoni and Periyar come to 283000 cusecs (8019 cumecs) which is taken as the design flood for which the spillway of Cheruthoni dam has been provided.

Cheruthoni spillway moderates the peak flood to 1, 74,000 cusecs (4927.13 cumecs). Two outlets are provided in Cheruthoni dam. They have a maximum capacity of 30,000 cusecs (849.50 cumecs) which is determined by the requirement of reservoir water level control during initial impounding of Idukki arch dam and for more flexibility in the control of water levels in the reservoir during construction. One outlet with a discharge capacity of 1,600 cusecs (45.30 cumecs) is provided in Kulamavu dam to deplete the Kulamavu basin in case of an emergency.

Hydrology review carried out in DRIP

As per BIS 11223-1985, Idukki, Cheruthoni & Kulamavu Dams fall under the category of large Dams, i.e., Reservoir Capacity above 60 Mm^3 and Hydraulic head above 30 m. Hence the spillways are designed to carry Probable Maximum Flood. Hence, as a pre requisite for DRIP, design flood was reviewed based on the 1 day PMP value of 500 mm from PMP Atlas published by CWC and was submitted to CWC. Central Water Commission vide letter No.7/Kerala-57/2011- Hyd (S)/243-244 dated 02/04/2014 has approved the revised design flood of Idukki (PMF). The spillway is provided in Cheruthoni dam. The revised peak flood was estimated as 9402 m^3/s. This value exceeds the spillway capacity of the dam at FRL (+732.62 m). But the MWL of the reservoir is + 734.30 m. The storage of reservoir at FRL is 1996 Mm^3. The storage at MWL is 2106 Mm^3. Hence there is provision in the reservoir to absorb the flood volume between FRL and MWL to a certain extent during the occurrence of an extreme flood of magnitude 9402 m^3/s. In order to ascertain extent of absorption of flood volume in the reservoir, routing of PMF flood is carried out treating impingement level of flood as at FRL & at 0.75 m below FRL by Modified Puls method. When flood is routed by

treating the impingement level as FRL, the reservoir water level rises to a maximum of +734.59 m. That is just 29 cm above the MWL. Even then, there is clearance of 1.68 m between MWL and top of dam.

The revised design flood of Idukki was estimated from two day PMP. With the advance information from modern meteorological forecasting systems, the occurrence of a very high rainfall can be very well predicted. In case of the occurrence of PMF, the reservoir level may be kept at low by a small margin in advance by operating the gates and absorbing the flood volume in the reservoir without allowing the water level to exceed MWL. When the PMF is routed with impingement level as 0.75 m below the FRL, the maximum water level in the reservoir is 736.26 m and is below MWL.

2.2.3 Hoisting Arrangements for Radial Crest Gates

As detailed in **Cl 2.1.2,** Cheruthoni dam has 5 spillway radial gates and 2 sluice gates (**Fig 2.6)**. The key plan of Hoist Bridge for the operation of radial crest gates is given in **Drg 2.3a** of **Annexure 1.** Platform of the gate hoist structure is located at El. 2424.25 as in **Drg 2.3b** and radial crest gate in **Drg 2.3c** of **Annexure 1**. The hoisting platform is given in **Fig 2.7**.

Fig 2.6 View of Sluice gates and Radial Gates of Cheruthoni dam from upstream

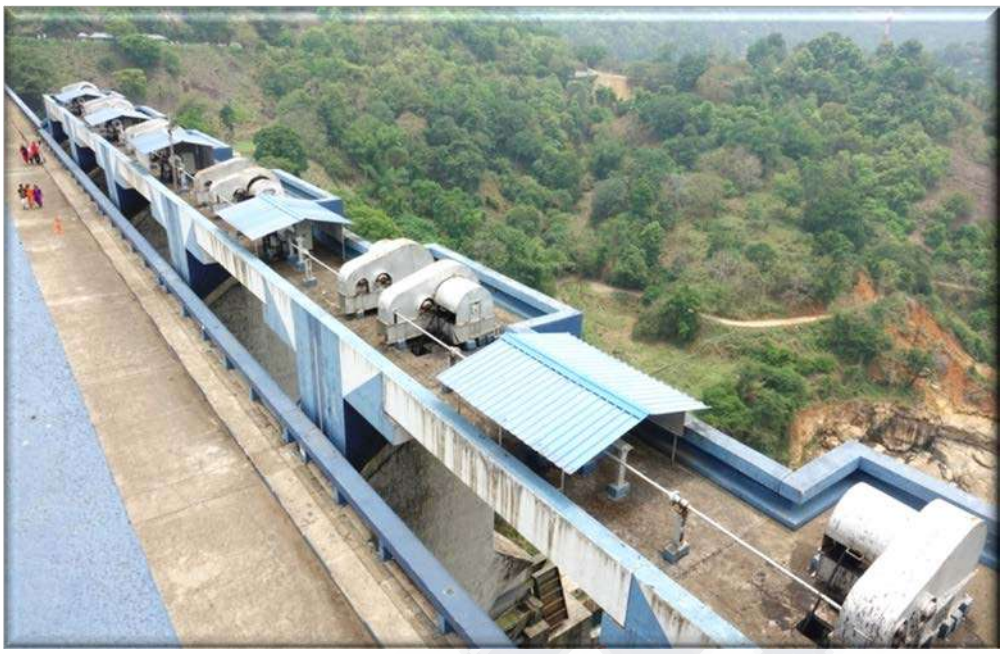


Fig 2.7 View of Spillway Gate Operation Bridge of Cheruthoni dam (Units #1 to #5 Left to Right)

Photographs of spillway bucket from Hoist Bridge and from left bank are shown in **Fig 2.8** and **Fig 2.9**. **Fig 2.10** shows gear mechanism and electric control panel for operating radial gates. Photographs of control panel and measuring scale for the radial gates hoist is given in **Fig 2.11.** The hoisting mechanism with wire rope for radial gates at Cheruthoni dam is given in **Fig 2.12.**

Fig 2.8 View of Spillway bucket from Hoist bridge

Fig 2.9 View of Spillway bucket from Left bank

Fig 2.10 View of Gate operation Gear mechanism and Electric control panel

Fig 2.11 Control panel and measuring scale for the radial gates hoist

Fig 2.12 Hoisting mechanism with wire rope for radial gates

2.3 Normal Operation of the Reservoir

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

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

The following aspects also need to be included:

- Releases to be made for various purposes round the year including releases to be made as per Inter-State Agreements/ MOU with various States/Agencies/Projects, riparian releases etc.
- Rule curves.
- Inflow forecasting
- Flood release procedure

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

2.3.1 Operation of the Reservoir

Idukki reservoir was being operated as per 'Guidelines for Operation of Storage Reservoirs', no spilling of water over the spillway will normally be permitted until FRL is reached. The reservoir water is released through spillway gates on reaching the Full reservoir Level i.e. 2403 ft level. During flood season, various alerts as mentioned in **Chapter 1** were issued for opening of spillway gates. But in the light of the Kerala Flood 2018, the flood release operations of Idukki reservoir based on rule levels are approved by the Board vide B.O (FTD) No. 444/2019 (DGC/AEE-II/Dam Safety/2019 dt 03.06.2019 and is reproduced below in **Table 2.7**. Accordingly, Alerts for spilling of water are fixed as first warning **Blue** (4 ft below the upper rule level), second warning **Orange** (2 ft below the upper rule level) and third warning **Red** (1 ft below the upper rule level). After giving first warning, further warning is given in local media including TV etc., regarding the possible opening of spillway gates continuously up to Rule level. Also intimations are given to Disaster Management, District Administration, and Police Department etc. before opening the Spillway gates. As per the

approved rule upper rule levels, it is proposed to keep the water level at or below 2373 ft (Crest Level of spillway) on June 10th and 2403 ft (FRL) on 30th November.

Spillway Rating Curve

During flood season, the reservoir water is released through spillway gates. The Full Reservoir Level is **2403 ft** and spillway crest level is **2373 ft**. The total spillway discharge (free discharge) through spillway gates (5Nos) for different reservoir levels under full opened condition is tabulated in **Table 2.5** and is given in **Fig 2.13**. Discharge (Rating) curve through single spillway for different reservoir levels with different gate openings is given in **Fig 2.14** and tabulated in **Table 2.6**.

Reservoir Level in m	Spillway discharge through one gate in m^3/s	Total Spillway discharge (5 gates) in m^3/s
723.48	0	0
724	10	50
725	40	200
726	90	450
727	155	775
728	229.89	1149.45
729	320	1600
730	420	2100
731	540	2700
732	660	3300
732.63	757	3785
733	790	3950
734	930	4650
734.11	1000	5000

Table 2.5 Spillway Discharge

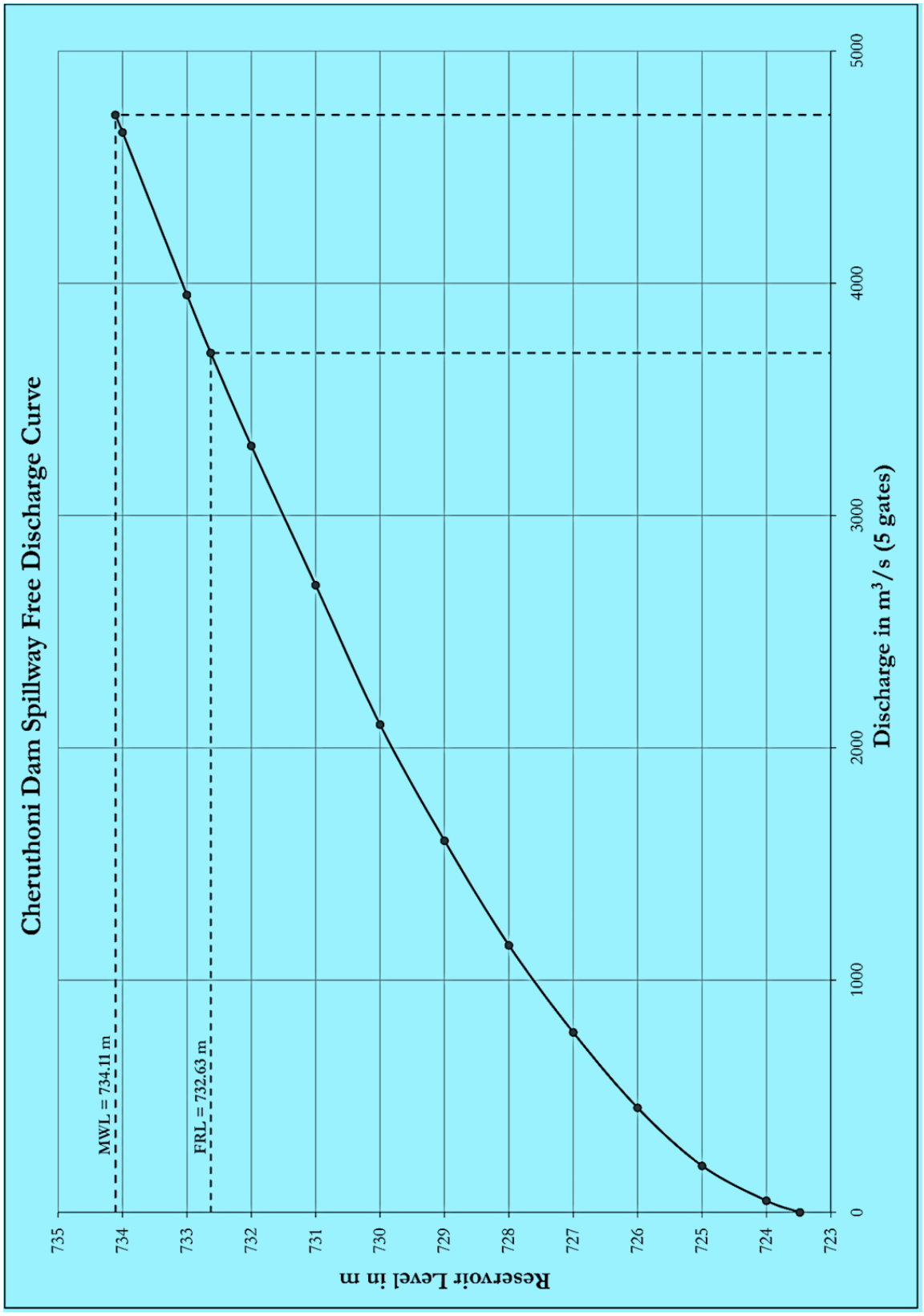


Fig 2.13 Free Discharge curve for Spillway Gates

DISCHARGE THROUGH A SINGLE SPILLWAY GATE FOR DIFFERENT GATE OPENINGS AND POOL LEVEL

Reservoir Level (+m)	GATE OPENING (M)/BOTTOM LEVEL OF GATE (+M)																						
	0.4	**0.8**	**1.2**	**1.6**	**2**	**2.4**	**2.8**	**3.2**	**3.6**	**4**	**4.4**	**4.8**	**5.2**	**5.6**	**6**	**6.4**	**6.8**	**7.2**	**7.6**	**8**	**8.4**	**8.8**	**9.2**
	723.9	724.28	724.68	725.08	725.48	725.88	726.28	726.68	727.08	727.48	727.88	728.28	728.68	729.08	729.48	729.88	730.28	730.68	731.08	731.48	731.88	732.28	732.7
723.48 (Crest)	0																						
724	10.43																						
725	15.87	28.82	38.37																				
726	22.67	42.16	58.20	70.19	79.66	89.85																	
727	27.92	52.81	75.28	94.18	111.27	125.51	137.92	145.64															
728	31.92	60.96	87.77	111.9	134.38	153.56	170.86	184.47	194.41	209.12	229.83												
729	35.73	68.67	99.49	128.53	155.78	179.85	202.6	222.55	240.36	255.55	268.74												
730	39.01	75.17	109.1	141.64	172.66	201.00	227.63	250.71	274.24	295.35	312.18	324.31	348.97	366.28	394.86	416.77							
731	42.23	81.48	118.47	154.47	188.98	221.46	251.81	278.43	306.96	331.66	354.04	370.07	392.64	410.56	440.25	460.4	480.66	503.85					
732	45.24	87.07	126.88	166.22	203.19	239.39	272.83	304.40	335.38	363.35	389.94	413.24	438.54	460.83	477.8	504.4	523.68	544.28	562.13	585.38			
732.63	47.10	90.54	132.10	173.50	212.20	250.50	285.86	320.50	353.00	383.00	412.2	440.00	467.00	492.00	511.00	531.00	550.00	565.00	579.00	590.00	599.00	604.00	

Note:- Calculations are based on plate 7 L for one single gate (12.19 -0.2H)m where 0.2 is 2 times the pier contraction coefficient value of 0.1 and 12.19 is length of one bay (40ft)

Table 2.6 Discharge through single spillway

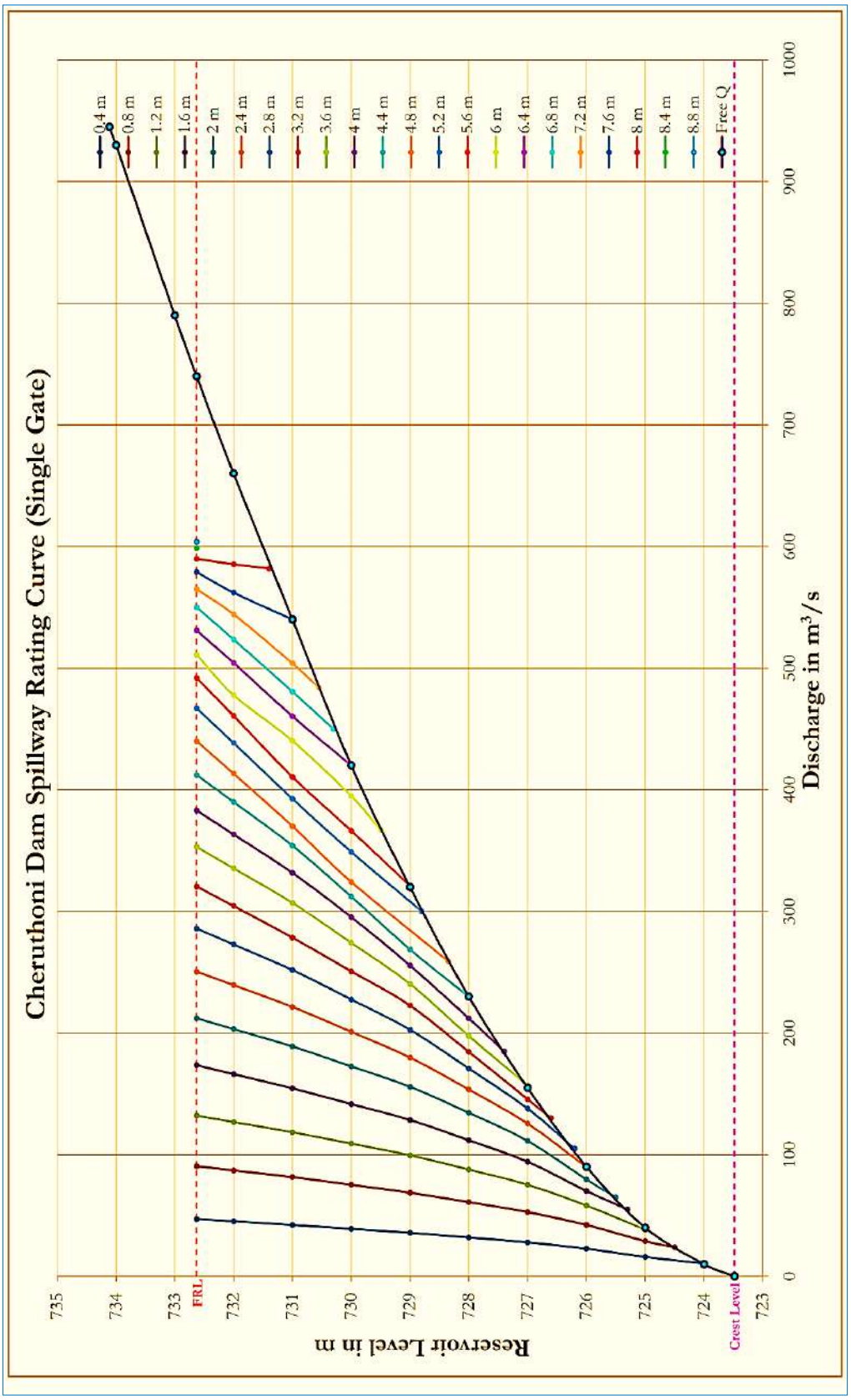


Fig 2.14 Discharge curves for Single Spillway Gate

2.3.2 Operation of Control Mechanisms

Radial Gate Operations

Five radial crest gates with hoisting arrangements were supplied by M/s. Central India Machinery Manufacturing Company Ltd., Bharatpur, India. The details of the radial gates of Cheruthoni dam are given below.

Details of Radial Gates	
Type of Equipment	Electrically operated spillway Radial Gate.
Gate Size	40 ft x 34 ft
Gate Sill	2371 ft
Gate Crest	2373 ft
Hoist Platform	2426 ft
Approx weight of Gate (Assembly)	50 MT
Quantity	5 Sets
Type of hoist	Rope Drum type
Hoist capacity	60 MT
Lifting/Lowering speed of gate by electrical operation	0.3 m/min
Gate speed by manual operation	10 mm/min
Total lift	10.85 m
No. of persons required for manual operation	Two

The gates can be operated electrically or manually. During floods or other-wise the gate/gates shall be operated electrically. In the event of electric power failure, the gate may be operated manually with the help of emergency hand operating mechanism provided with the hoist. The reservoir level for which gate and hoist have been designed is El. 2403 ft. The gates shall be operated and maintained strictly as per the O & Maintenance Manual attached as **Annexure 2**.

Sluice gate operation

There are two outlets in the dam each of size 3.05 m x 6.4 m with inlet sill at 670.43 m (2199 ft) and each having a discharge capacity of (19,700 cusecs) 557.5 m^3/s at MWL Conditions. The section and sectional plan through centerline of outlet is given in **Drg 2.4a** and **Drg 2.4b** of **Annexure 1**. The outlets are controlled by a service and emergency gate (fixed wheel type) each of size 3.05 m x 6.4 m. Hoist Bridge for sluice gate operation is shown in **Fig 2.15.** Hoist drum, gear system and panel board for sluice gate operation are given in **Fig 2.16.** The discharge curve is given in **Fig 2.17.** The section through centerline of outlet at Ch.1400.00 and section at El. 2209.50 is given in **Drg 2.5a** and **Drg 2.5b** of **Annexure 1**.

Fig 2.15 Hoist Bridge for sluice gate operation (Service and Emergency Gates)

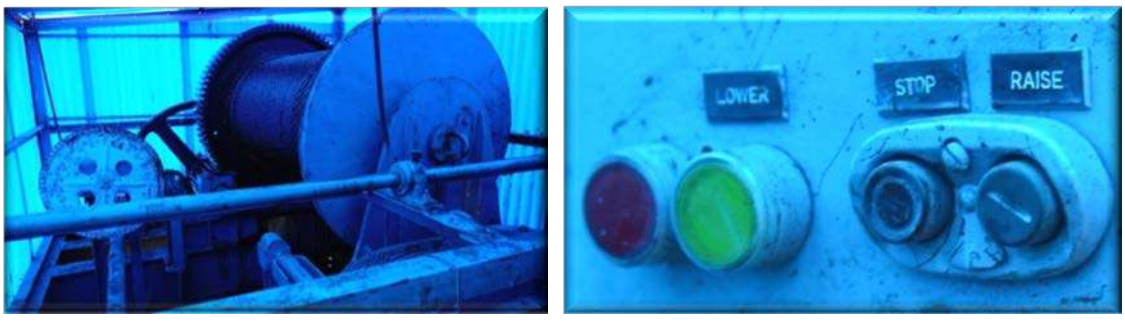


Fig 2.16 Hoist drum, gear system and panel board for sluice gate operation

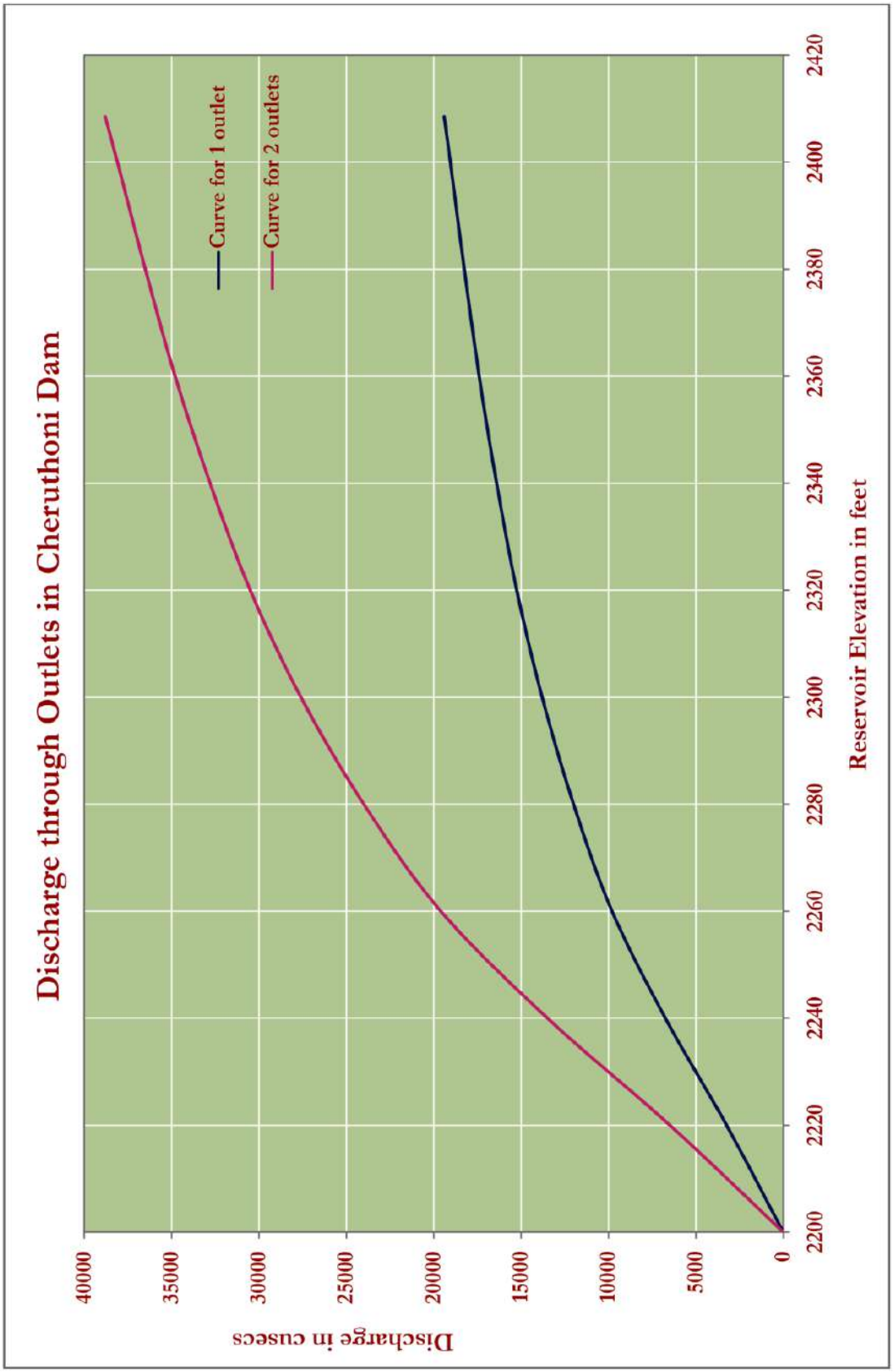


Fig 2.17 Discharge Curve for Outlets in Cheruthoni dam

Valve operation

In addition there is an outlet in Kulamavu Dam controlled by an upstream gate of size 2.44 m x 1.83 m and a downstream hollow jet valve 1524 mm dia having a maximum discharge capacity of 49 m^3/s. The disperser valve shall be operated as per the manual given in **Annexure 2C.2.** The discharge corresponding to each reservoir level at various opening is given in the Annexure. The section along centerline of disperser and downstream elevation of disperser house are given in **Drg 2.6** and **Drg 2.7** of **Annexure1**. The sectional elevation along the centerline of outlet showing trash rack arrangement is given in **Drg 2.8** of **Annexure 1**. The plan of emergency gate hoist house, section along centerline of outlet showing details of emergency gate hoist house and elevation of emergency gate hoist house are given in **Drg 2.9a, Drg 2.9b** and **Drg 2.9c** of **Annexure 1**.

2.3.3 Rule Curve

In the Kerala flood study report of August 2018, CWC has recommended for reviewing the rule curves of major reservoirs in Kerala. The rule curves need to be formulated for both conservation as well as operations during the flood, in case of storage reservoirs also, particularly for the reservoirs having the live storage capacity of more than 200 Mm^3 in order to create some dynamic flood cushion for moderating the floods of lower return periods. Accordingly, rule curve for Idukki reservoir is arrived by the committee constituted vide Order (CMD) No 628/2018 (DGC-AEE- II/Flood/2018) TVPM, dated 20.10.2018. The relevant portion of the report is reproduced below where in the following parameters are considered for fixing the rule levels;

- MWL of reservoir - 2408.5 feet
- FRL of reservoir - 2403 feet
- MDDL - 2280 feet
- Crest level of spillway - 2373 feet
- Maximum generation from power station –780 MW
- At the end of the water year, 31st May, the net storage at Idukki reservoir shall be good enough to generate at least 350 MU. Hence the target level at the end of May is fixed as 2311 feet (704.39 m) for deriving lower rule levels.
- The target level in the reservoir at the end of monsoon season, on November 20th is kept as 2400 feet as decided by the committee.

- Reservoir level shall not fall below 2280 feet.

From the storage corresponding to target level 2400 feet on November 20th, the storage at previous time steps are worked out for the inflow corresponding to 50% dependable inflow and the scheduled releases. From the levels corresponding to 50% dependable inflow, the intermediate upper rule levels are judiciously arrived.

Upper Rule Levels

From the rule levels derived based on 50% dependable inflow, the upper rule levels for the period from June 1st to November 20th is judiciously arrived at by setting the target level in the reservoir on November 20th as 2400 feet. The target level in the initial time step is taken as 2373 feet i.e., the Crest Level of spillway. The storage corresponding to rule level and the flood space available at respective levels is shown in the **Table 2.7** below.

Table 4.10.1 - Upper rule levels of Idukki reservoir

Time Step	Date	Upper Rule Levels	Rule storage	Flood space up to FRL	Percentage Gross Storage
		feet	Mm3	Mm3	%
1	June 10 th	2373	1514	483	76%
2	June 20 th	2375	1542	454	77%
3	June 30 th	2377	1570	426	79%
4	July 10 th	2383	1663	334	83%
5	July 20 th	2385	1696	301	85%
6	July 31 th	2390	1779	218	89%
7	Aug 10 th	2390	1779	218	89%
8	Aug 20 th	2390	1779	218	89%
9	Aug 31st	2392	1812	185	91%
10	Sep 10 th	2393	1828	168	92%
11	Sep 20 th	2394	1845	152	92%
12	Sep 30 th	2395	1861	135	93%
13	Oct 10 th	2395	1861	135	93%
14	Oct 20 th	2395	1861	135	93%

15	Oct 31st	2397	1894	102	95%
16	Nov 10 th	2399	1927	69	97%
17	Nov 20 th	2400	1944	52	97%
18	Nov 30 th	2403	1996	0	100%

Table 2.7 Upper Rule Levels of Idukki reservoir

Though the upper rule level is fixed as above, the operation of the reservoir shall be meticulously planned based on the rainfall forecast. In case of Idukki Reservoir about 50% of the catchment is intercepted by upstream dam. The unscheduled controlled releases from upstream reservoirs are also a critical element in the inflow component especially in a critical hydro-meteorological condition.

In every time step beginning from June, the probable reservoir level shall be estimated in advance, based on the forecasted inflow derived from predicted rainfall, at least for the next two-time steps. If the estimated reservoir level is likely to be exceeded from the rule levels for the next two-time steps, it shall be tried to keep the reservoir level within the rule levels from the current time step itself by increasing generation or by spilling the reservoir. Priority shall be given to maximize the release to power station. If the rate of rise of water level in the reservoir still observes to be steeper than the slope of the upper rule curve, the reservoir shall be allowed to spill to bring the water level within the rule levels during the respective time steps. The process shall be continued till the end of monsoon.

Flood hydrograph with 100 year return period was routed through the reservoir with impinging level as 2395 feet, the rule levels in the active monsoon period. It is found that the reservoir level is not encroaching the FRL after allowing a spill within the spillway capacity. But the rate of spill found to be comparatively higher. If a quality rainfall prediction is in place, the spill can be moderated to a certain extent by forecasting the inflow and operating the reservoir according to the rule levels as there are intermediate control levels.

The reservoir level can be better managed by providing a dynamic cushion to moderate flood through meticulous planning by reviewing the reservoir levels & inflow forecast at all time-steps. It is not prudent to maintain a static cushion in the reservoir to accommodate the flood likely to be happened in case of occurrence of an extreme rainfall.

Lower Rule Levels

The lower rule levels are derived based on 90% dependable inflow series. The target date and level set for deriving lower rule levels are 31st May and 2311 feet. The storage at previous time steps worked out beginning from the target storage. The rule levels arrived at corresponding to the respective storages are tabulated below in **Table 2.8.**

Table 4.11.1 - Lower rule level of Idukki reservoir						
Date	Rule Storage	Rule Level	50% dependable inflow	Water spread area	Reservoir Losses	P H demand
	Mm3	feet	Mm3	Sq km	Mm3	Mm3
June 10th	1472.95	**2370.13**	10.424	46.700	0.140	62.37
June 20th	1430.98	**2367.18**	19.868	45.690	0.138	61.70
June 30th	1408.46	**2365.59**	34.752	45.140	0.137	57.13
July 10th	1417.30	**2366.22**	39.392	45.360	0.129	30.43
July 20th	1441.29	**2367.90**	55.301	45.940	0.130	31.18
July 31st	1468.49	**2369.82**	60.552	46.600	0.131	33.22
Aug 10th	1491.19	**2371.42**	48.222	47.140	0.141	25.39
Aug 20th	1525.33	**2373.82**	60.186	47.970	0.143	25.90
Aug 31st	1540.98	**2374.93**	47.725	48.350	0.144	31.92
Sep 10th	1533.07	**2374.37**	30.419	48.160	0.148	38.18
Sep 20th	1509.61	**2372.72**	23.269	47.590	0.147	46.58
Sep 30th	1494.01	**2371.62**	19.452	47.210	0.146	34.90
Oct 10th	1476.87	**2370.41**	20.210	46.800	0.164	37.20
Oct 20th	1464.04	**2369.51**	23.774	46.490	0.163	36.43
Oct 31st	1440.89	**2367.88**	22.317	45.930	0.162	45.31
Nov 10th	1426.35	**2366.85**	20.729	45.580	0.161	35.11
Nov 20th	1404.64	**2365.32**	15.436	45.050	0.160	36.99
Nov 30th	1379.28	**2363.54**	12.989	44.440	0.158	38.19
Dec 10th	1346.87	**2361.26**	9.556	43.660	0.182	41.79
Dec 20th	1308.82	**2358.36**	6.267	42.750	0.180	44.14
Dec 31st	1271.22	**2355.29**	4.845	41.860	0.177	42.27
Jan 10th	1231.48	**2352.06**	4.538	40.920	0.190	44.09
Jan 20th	1191.37	**2348.79**	3.279	39.970	0.187	43.20

Jan 31st	1148.82	**2345.33**	2.521	38.970	0.183	44.90
Feb 10th	1106.34	**2341.87**	2.349	37.970	0.206	44.62
Feb 20th	1065.62	**2338.34**	2.272	37.030	0.203	42.79
Feb 28th	1036.33	**2335.60**	2.492	36.380	0.200	31.58
Mar 10th	1002.31	**2332.41**	5.290	35.630	0.222	39.09
Mar 20th	968.57	**2329.25**	3.799	34.880	0.218	37.31
Mar 31st	941.20	**2326.69**	5.724	34.270	0.215	32.89
Apr 10th	917.08	**2324.43**	4.138	33.740	0.179	28.07
Apr 20th	895.79	**2322.44**	5.751	33.260	0.177	26.87
Apr 30th	871.58	**2320.17**	6.055	32.730	0.175	30.09
May 10th	849.68	**2317.80**	5.974	32.080	0.134	27.74
May 20th	821.06	**2314.66**	6.939	31.210	0.131	35.43
May 31st	787.69	**2311.00**	7.863	30.200	0.129	41.11

Table 2.8 Lower Rule Levels of Idukki reservoir

Based on the upper and lower rule levels, rule curve arrived for the operation accordingly is shown in **Fig 2.18** and the maximum (storage) water levels of the respective months in **Table 2.7.** The reservoir water exceeding the rule curve level beyond crest level can be spilled or adjusted with power generation. This rule curve can be used till further revision.

2.3.4 Safety Aspects

The spillway gates are operated step by step after assessing the reservoir water level and inflow and as per the sequencing defined in **Cl.2.3.1**. Evacuation will be required only in the case of large release/extreme rainfall event and large release from Mullaperiyar dam upstream.

2.3.5 Flood Release Procedure

The flood water is released through spillway gates as explained in **Cl. 2.3.2** based on the Alert levels approved by the Board and operation manual of gates. There are five spillway gates in Cheruthoni dam. The sequence of operation of spillway gates is Gate no. 3, 2, 4, 1 & 5. Gate No. 3 is first opened to a unit height on the basis of requirement and then Gate No. 2 and Gate No. 4 are opened to the same height. After that as per requirement, Gate No. 1 and Gate No. 5 can be opened. Further opening of gates are also performed in the same manner. Closing of gates is done in the reverse manner as that of opening.

The present Alert levels fixed by KSEB Ltd for the operation of the spillway are **Blue - 8 ft below rule level**, **Orange - 2 ft below rule level** & **Red - 1 ft below rule level**.

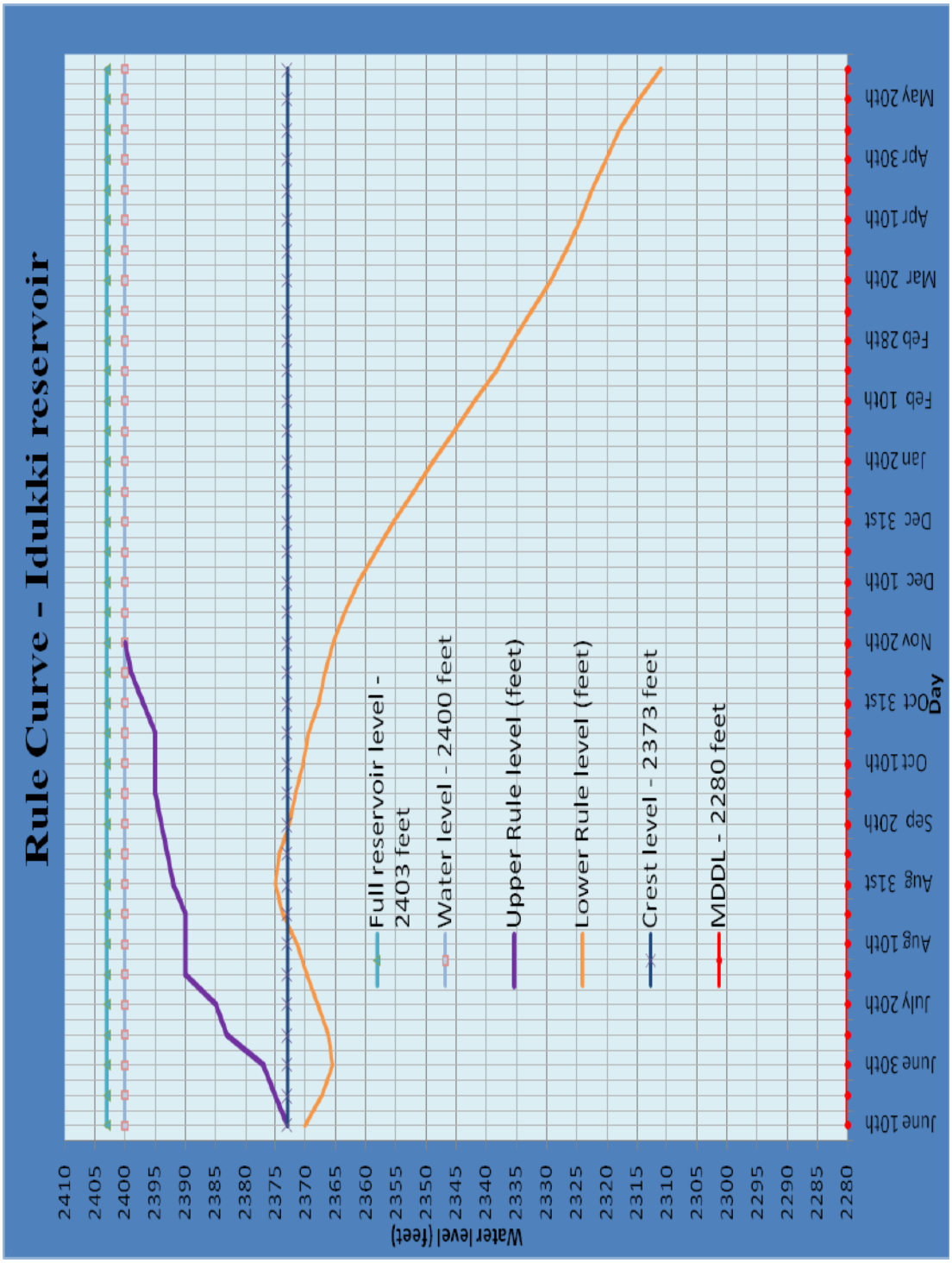


Fig 2.18 Rule Curve for Idukki Reservoir

As per the approved (B O dt 03.06.2019 & G O dt 15.06.2019) upper rule levels vide Table 2.7, it is proposed to keep the water level at or below m (Close to Crest Level) on June 10th and (FRL) on 30 th November. But CWC have adopted a more conservative approach in this rule levels and revised rule levels proposed. Accordingly KSEB Ltd on 08/08/2019 have adopted this modified upper rule levels as suggested by CWC in the wake of heavy monsoon in Kerala as given in Table 2.9 below. This modified rule levels fixed by CWC which is more conservative is approved vide G O Rt.No.64/2020/power dt 21.05.2020 & B O dt 03.06.2020 for operation of Idukki reservoir.)

Upper Rule Levels as Modified by CWC	
Time Step	**Upper Rule Levels (feet)**
June 10th	2373.00
June 20th	2373.00
June 30th	2373.00
July 10th	2375.33
July 20th	2377.95
July 31st	2380.58
Aug 10th	2383.53
Aug 20th	2386.81
Aug 31st	2390.09
Sep 10th	2392.55
Sep 20th	2395.01
Sep 30th	2396.94
Oct 10th	2397.78
Oct 20th	2398.86
Oct 31st	2399.31
Nov 10th	2399.79
Nov 20th	2400.03

Table 2.9 Modified Upper Rule levels of Idukki reservoir by CWC

2.3.6 Climate

The temperature in the plains ranges from 70°F to 80°F, at the foot of the ghat goes up to 5 to 6 degrees, while in the mountains it falls to 50°F by day and to freezing point in winter night. The mean daily range of temperature is less in coastal belt and greater in the interior. There are no well-defined seasons in Kerala State. The south-west monsoon remains active after middle of May up to September, while north-east monsoon between October and middle of December. The period from January to middle of May is generally dry and the months of March and April form a hot summer.

Dams and Reservoir areas are situated above an elevation of +2000 ft. The area of the catchment experiences a temperate climate throughout the year. Heavy rainfall is confined to the period of South-West monsoon. On account of the dense vegetation over the whole of the catchment, surface humidity remains high even during non-monsoon months.

Unlike the reservoir area, Powerhouse and Switchyard areas are located at an elevation of about + 200 and + 550 respectively, the temperature in summer months is high. The average rainfall in the area is about 180" per year and temperature varies from 50°F to 90°F.

2.3.7 Inflow forecasting/Methodology

The methodology followed for working out the inflow is given in **Cl.2.1.2.**

2.3.8 Summary of Flood Regulation Procedure

Flood regulation procedures at Idukki reservoir 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 Power Intake, Spillway, Losses, River Sluices, Hollow Jet Valve and Release for water supply etc.)
3. Estimate the inflow
4. Determine the gate opening as the case may be.
5. Open the required number of gates to the extent required to maintain constant reservoir level. i.e., release is equal to the inflow as per the upper rule curve.

2.3.9 Emergency Operation

The Emergency operation will be carried out following the Emergency Action Plan (EAP) which is available as supporting document. The Emergency conditions are outlined in

Chapter 4 under clause 4.2.1 on Immediate Maintenance. The EAP together with this Manual will be available at site at all times. Summary of Alert conditions during Emergency are given in **Annexure 4**.

2.4 Power Generation

Idukki Hydro Electric Project is the largest hydroelectric project of Kerala State with installed capacity 780 MW. There are six machines with capacity 130 MW. The planned annual generation from this plant is 2398 MU. The tail water of this station is used for power generation, irrigation and drinking water. The spill water of Idukki reservoir flows to Periyar River. There is also diversion from adjacent basins like Azhutha, Vazhikkadavu, Narakakkanam, Kallar, Erattayar, Vadakkepuzha etc. to Idukki reservoir.

2.4.1 Power Outlets

Power Intake

The "Morning-glory" type intake tower is located on the left bank of the Killivallithodu, about ¼th mile upstream of the Kulamavu dam and about 280 ft in a north-easterly direction from the face of the headrace tunnel. The main structural elements of the reinforced concrete intake tower are the following:

The top slab is at El. 2271.25 ft (692.27m). Its diameter is approximately 66.5 ft and is supported by 16 columns, extending down to the sill of the bell mouth intake at El. 2245 ft (684.27 m). The maximum reservoir drawdown is at El. 2280 ft (694.94 m) and consequently the top slab is permanently submerged under normal operating conditions. The columns are connected at mid-height by beams which also serve as trash rack supports. Below the sill of the bell mouth, a vertical shaft stiffened with 16 ribs, leads into a converging 90° elbow, having an exit diameter of 23.0 ft. The tower is built on a sixteen sided foundation mat resting on sound rock. The intake structure was designed for a seismic acceleration of 0.05 g in the horizontal direction and 0.025 g in the vertical direction.

The intake tower is partly surrounded by a horseshoe shaped rock fill dyke as a protection against possible limited slope failures in the vicinity of the intake. No measures have been taken to prevent the disintegration of the laterite overburden lying adjacent to and above the base of the intake tower. However, the finished constructed grade around the intake tower is at El. 2230 ft which is about 15 ft below the sill elevation of the trash rack and thus a nominal

allowance is provided for the accumulation. Photographs of morning glory intake during and after construction are shown in **Fig 2.19.**

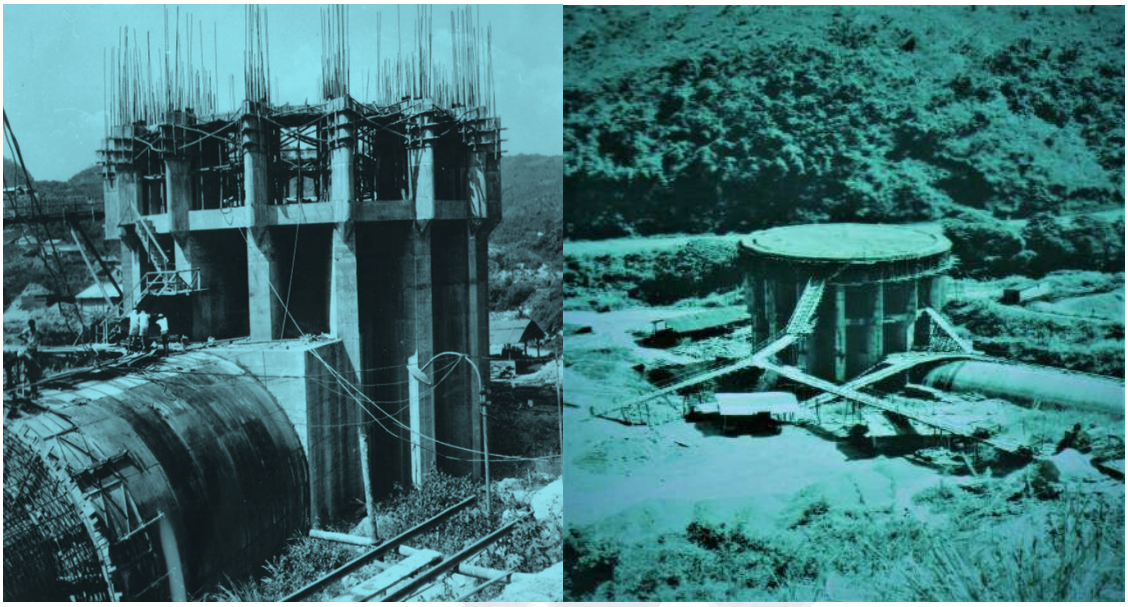


Fig 2.19 Morning Glory Intake during and after Construction

Intake conduit

The intake tower is connected to the headrace tunnel by a reinforced concrete conduit approximately 250 ft (76.2 m) long. The conduit has an inside diameter of 23 ft (7.01 m) and a wall thickness of 4.0 ft (1.22 m). The invert is at El. 2200 ft (670.56 m). The conduit trench is backfilled with laterite. A rock-fill protective berm having a minimum thickness of 5.0 ft (1.524 m) is placed over the conduit. The rock supporting the Intake structure is hard granite gneiss of excellent quality with steep-dipping tectonic joints paralleling the floor of the valley. The drawings of intake tower are given in **Drg 2.10** and **Drg 2.11** of **Annexure 1**.

Trash racks

The intake tower has sixteen trash rack panels, located on the perimeter of a circle having a 30 ft (9.14 m) radius. The individual panels are welded structures with dimensions of approximately 10 ft x 22 ft (3.048 m x 6.706 m). Each trash rack panel consists of two vertical end girders with horizontal stiffener-beams in between. They support 1 in x 1 in vertical steel trash rack bars spaced uniformly at 2.5 in c/c. The steel is of fusion welding quality and conforms to IS: 2062-1962. The steel surfaces are protected by coal tar epoxy coating. The average water velocity through the racks is about 2.5 ft/s (0.762 m/s) at an estimated maximum flow of approximately 5,000 cfs.

Bubbler System For the effective cleaning of trash rack, bubbler system **(Fig 2.20a)** is provided. It consists of one electrically driven Compressor of 350 cfm capacity. 200 HP Induction motor is used to drive the Compressor. The compressed air is stored in two Air tanks. A filter unit is also provided in the Air tank. Whenever the large tank is filled fully, the air can be released using the valve provided. The speed of the motor can be adjusted with the regulator fixed before motor unit. A heater is also provided to heat the pump before starting. A compressor cooling system with water pump also provided. A schematic diagram of the Bubbler system is given in **Fig 2.20b** below.

Fig 2.20 Bubbler System

Operating procedure

- Before starting, check the Electric connection & Oil level in the Compressor.
- Check the Insulation resistance of Motor.
- Heat the windings if Insulation resistance is low.
- Adjust the Regulator to get 400V in Dial gauge.
- Start the motor in 'Star' position. After gaining the required speed, change the liver to 'Delta' position.
- Switch on the Compressor Cooling system Motor.

- Fill Air tank fully up to 10 kg/cm^2
- Release the Valve, allow air to bubble up and agitate the intake tower area for 15 min.

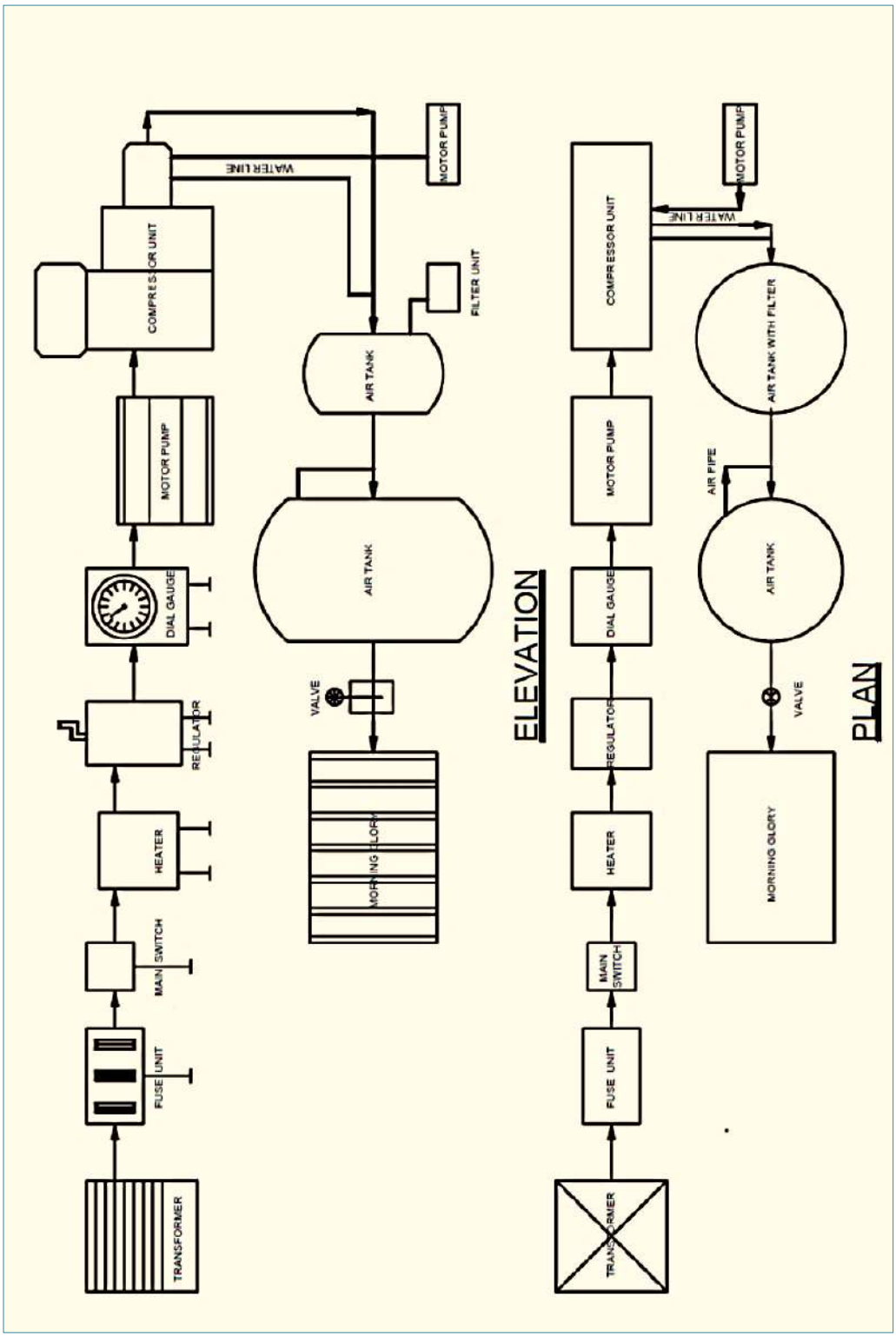


Fig 2.20b Schematic diagram of Bubbler system

2.4.2 Power Tunnel (Headrace Tunnel)

The headrace tunnel is excavated in a generally sound igneous rock. The rock cover varies between approximately 125 ft (38.1 m) (at the Vadakkepuzha depression) and 620 ft (188.98 m). The excavated diameter of the horse shoe shaped tunnel is approximately 26 ft (7.924 m). Exceptions are the transition section at the intake gate and at the tunnel face, where the excavated dimensions exceed 26 ft (7.924 m). The tunnel has a concrete lining of 1.5 ft (0.457 m) minimum thickness. The horseshoe shaped finished sectional area is 441.2 ft^2 (40.988 m^2) (D-23 ft (7.01 m)). The length of the concrete lined tunnel section between the tunnel face and the beginning of the steel liner at the surge shaft inlet is approximately 6600 ft (2011.68 m). The invert elevation at the face is El. 2200 ft, and at the surge shaft inlet approximately El. 2151 ft. The water velocity in the tunnel is about 11.3 ft/s (3.44 m/s), for the maximum flow of approximately 5000 ft^3/sec. At the downstream end of the headrace tunnel, close to the beginning of the steel lined penstock section, a rock trap is provided on the tunnel floor. Its purpose, should the tunnel lining deteriorate, is to prevent particles of concrete or rock from reaching the turbines. The drawing of intake arrangement of power tunnel is given in **Drg 2.12** of **Annexure 1**.

Intake Gate Shaft

A vertical shaft for the intake gate is located in the headrace tunnel, about 2380 ft (725.424 m) from the intake tower (See **Drg 2.12** of **Annexure 1)**. The oval shaped shaft is concrete lined. The excavation dimensions are approximately 14 ft x 24 ft (4.27 m x 7.32 m). The thickness of the liner is about 2.5 ft (0.762 m) below and 1.5 ft (0.457 m) above El. 2320 (707.14 m) respectively. Vertical steel rails are embedded in the concrete liner for guiding the intake gate. Air vents are provided in the lining below El. 2260 (688.85 m) to facilitate air escape during the filling up of the headrace tunnel. The gate platform and supporting structure for the gate hoisting mechanism is located directly above the gate shaft at El. 2423 ft (738.53 m). Photographs of intake gate and hoist are shown in **Fig 2.21a, Fig 2.21b and Fig 2.21c**.

Fig 2.22 shows intake gate hoist wire rope and operating control. Details of Intake gate is given below in table.

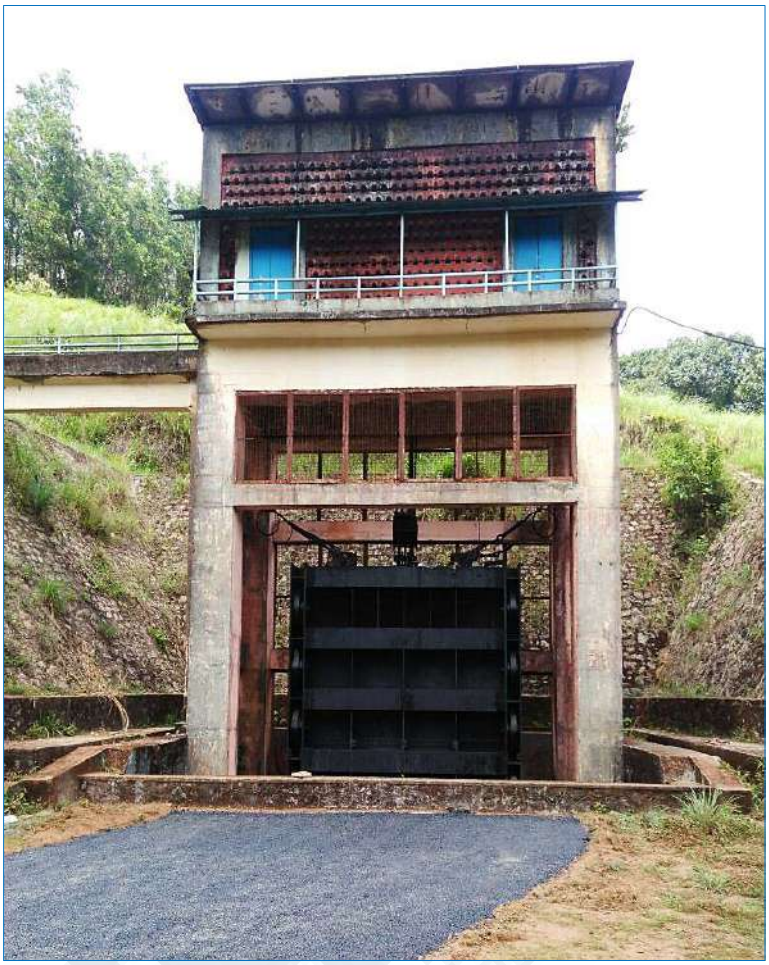


Fig 2.21a Intake gate and Hoist

Details of Intake Gate	
Type of Equipment	Electrically operated Lift Gate.
Gate Size	15 ft x 24 ft 6 in
Quantity	1 Set
Type of hoist	Cable Drum
Sill Level	2174' 8"
Deck Level	2423'
Max static head above sill	233.5 ft
Hoist Motor	40 HP
Lifting speed of gate by electrical operation	5 ft /min
Lowering speed of gate by electrical operation	10 ft /min
Gate speed by manual operation	1 in/min

Fig 2.21b Intake gate

Fig 2.21c Intake Gate Hoist

Fig 2.22 Intake Gate Hoist Wire rope and Operating Control

The intake gate, permitting the closure of the headrace tunnel is installed in a concrete lined vertical shaft. This gate, operating under a head of 222 feet (67.66 m), is designed to close under emergency conditions, against the full flow passing through the power tunnel. Its second function is to isolate the downstream part of the pressure conduit, mainly the steel lined penstocks, during inspection, maintenance and possible repairs. Full opening of this gate subsequent to a closure can only be accomplished under balanced pressure conditions. Therefore, prior to being opened completely, the gate shall be cracked by 6 to 12 inches, allowing the water to fill the downstream end of the penstocks. Under normal conditions, the intake gate shall be hung immediately above the lintel, but can be hoisted periodically up to the operating deck platform for inspection and maintenance.

The gate measures 15 feet wide by 23 feet high and is made of a heavy structural steel frame welded to a skin-plate. The gate is equipped with 12 nos; 34 inch dia forged steel wheels mounted on double spherical roller bearings. The rollers are fitted onto eccentrical axles to permit precise alignment of the wheel rims. The gate is provided with an upstream skin plate and upstream sealing devices. The lateral and top seals are of the "music note" shaped rubber type provided with a Teflon film cladding on the wearing surfaces. The sealing at the bottom is insured by the contact of the machined surfaces of the gate lip and the sill beam. Spring loaded side rollers mounted on self-lubricated bronze bushings are installed on each side near the top and bottom of the gate to limit its lateral movement.

The gate hoist is of the wire rope type and consists of a single drum driven through a helical gear speed reducer by an induction motor. The speed of the gate during lowering is controlled by a power absorption fan brake. An additional electro-mechanical brake holds the gate in its open position. This brake sets automatically by means of spring applied shoes when the current is cut off from the motor. In case of a failure of the electric power supply, a hand cranking system allows the manual lifting of the gate by two men. The gate position indicator consists of two circular dials mounted on the drum shaft extension. One dial, graduated in feet, indicates the position of the gate from the sill to the deck. The second dial indicates, in inches, the gate position over its first foot of travel. It is used to determine the "cracking opening" when filling the penstock.

The intake gate may be controlled from a local push-button station located on top of the hoist supporting structure at the hoist frame level. Provision is also made to close the gate, in case of an emergency, from a control building installed nearby at deck level. However the opening of the gate can be performed only from the local push-button station. This station

includes four push-buttons labeled: "Crack", "Raise", "Stop" and "Lower". Limit switches are provided in the "Raise" and "Lower" control circuit. If required, the gate can be raised to deck level by pushing the "Raise" button to by-pass the "open" limit switch. Indicating lights are provided on the push-button station to indicate the following conditions:

- gate fully open
- gate closed
- penstock filled
- gate operation stopped

Power for the gate operation is provided by a 40 H.P Electric motor located on the input shaft of the reducer.

Access Tunnel

An access tunnel was required during construction to facilitate the headrace tunnel excavation. However, this temporary access has to be blocked after the headrace tunnel is completed. For this purpose a concrete plug was built at the end of the access tunnel about 360 ft up steam of the surge shaft inlet.

An access gallery and a permanent steel door are provided through the concrete plug. The size of the gallery and door is sufficient to permit access of a jeep-sized vehicle and thus facilitate the periodical inspection and maintenance of the headrace tunnel when dewatered.

Access Tunnel Plug

The access tunnel, which was required during the headrace tunnel excavation, is closed by a concrete plug. However, a gallery with a permanent steel door provides access through the concrete plug to the headrace tunnel.

Steel Door

The steel door is located at the upstream end of the access gallery. The clear width and height of door opening is 7 ft. and-8 ft. respectively. The door structure consists of a downstream skin plate, welded to horizontal beams and vertical stiffener ribs. The water pressure keeps the door in the closed position under operating conditions. Molded rubber seals activated by water pressure ensure water-tightness. The structural steel material for the door conforms to IS: 2062-1962, Structural Steel (Fusion Welding Quality).

The steel surfaces susceptible to corrosion are protected by coal tar epoxy coating. The door is designed to withstand a hydrostatic pressure of 18 kips/sqft without excessive deformation.

Operating Control

The door can be opened only after the dewatering of the headrace tunnel. To open the door the six tightening bolts at the door sides shall first be loosened. The two leveling bolts at the sill shall then be unscrewed until contact is lost between the sill plate and bolts and thus the load of the door is transmitted to the door hinges. When the door is closed, the adjusting bolts at the sill shall be turned so as to level and lift up the door slightly. The six bolts at the sides of the door shall then be secured. In case of leakage, it shall be stopped by adjusting the rubber seals, and not by over tightening the bolts. Periodically, the condition of the door has to be checked, and the protective coating renewed to prevent any corrosion.

2.4.3 Surge Shaft and Expansion Chambers

The entrance to the surge shaft is located at the end of the headrace tunnel, about 6930 ft (2112.264 m) from the intake tower. The surge shaft system consists of the following components:

- The upper expansion chamber
- The inclined surge shaft
- The lower expansion chamber
- The restricting orifice

The whole system is located entirely underground excavated in rock. The upper expansion chamber has a 23 ft x 23 ft (7.01 m x 7.01 m) inverted U section. A gallery with approximately 8 ft x 8 ft (2.44 m x 2.44 m) cross section provides access to it from the outside. The length of the upper chamber is about 365 ft (111.25 m). Its downstream end is closed with a wall. Top of the wall is at elevation 2443 (744.626 m), the floor elevation is 2420 ft (737.616 m). The upper chamber is connected to the lower by a circular shaft about 262 ft (79.86 m) long, inclined at 43° to the horizontal and having an excavation dia31.5 ft (9.6 m). The bottom 60 ft (18.288 m) length of the inclined shaft and the lower horizontal chamber have a minimum 1.5 ft (0.457 m) thick reinforced concrete lining. The inside diameter of the lower chamber is 23.0 ft (7.01 m), its length is approximately 165 ft (50.29 m) and the invert is at an elevation of 2205 ft (672.084 m). A rock trap was built at the intersection of the lower horizontal chamber and inclined shaft to catch any rock fragment which may fall from the unlined section of the inclined shaft.

The lower chamber is connected to the headrace tunnel and penstocks by a vertical shaft. Its inner diameter is 23 ft (7.01 m) which is reduced by an orifice to dia 11.0 ft (3.35 m). The

vertical shaft is lined with reinforced concrete. The orifice and a section of the headrace tunnel in the vicinity of the surge shaft entrance are steel lined. The surge shaft and expansion chamber is given in **Drg 2.13** of **Annexure 1**.

Steel Lining

The steel liner for the surge shaft consists of the restricting orifice and the transition pieces between the headrace and penstocks upstream and downstream of the surge shaft entrance. The 23 ft (7.01 m) diameter vertical shaft is reduced to 11 ft (3.35 m) by an orifice. The horizontal section of the orifice lining is a sixteen sided polygon, and the vertical section is approximating a quarter ellipse. The transition piece upstream of the orifice is approximately 38 ft long. It has a 23 ft (7.01 m) diameter circular section at the headrace tunnel end, which gradually changes to a 23 ft x 17.5 ft (7.01 m x 5.33 m) rectangular section below the orifice. Downstream of the orifice the 23 ft x 17.5 ft (7.01 m x 5.33 m) rectangular section is divided 16 ft x 12.6 ft (4.88 m x 3.84 m) rectangular branches, which are in turn connected to the two 12.5 ft (3.81 m) diameter circular penstock branches by 30 ft (9.14 m) long transition pieces. The steel liner is stiffened by ribs and anchor bars welded to the outside face of the shell at about 1.5 ft (0.457 m) c/c. The anchor bars are embedded in the backfill concrete to resist external hydrostatic pressure when the tunnel is dewatered.

Geology Surge Shaft

The exploration by diamond drilling, and by seismic method did indicate that the rock in the area of surge shaft and chambers is of good quality for these structures. This was confirmed by the subsequent excavation also.

a) Upper Expansion Chamber

The rock in the upper chamber is hard pink massive granite gneiss, which is deteriorated near to the rock surface. The steep inclined fissuration, diminishing towards the interior of the mountain, strikes almost normal to the long axis of the chamber. Zones of weakness are along shear zones which have deteriorated through the action of lateritization. Lateritization usually extends not more than 50 ft from the surface into the rock along steep dipping open joint planes. Occasionally, some laterite deterioration extends down to more than 100 ft. in depth.

b) Surge Shaft

The inclined shaft was excavated to a diameter of 31.5 ft to accommodate a concrete lining if the rock conditions would require it. The rock traversed by the shaft is granitic gneiss of mostly excellent quality except for a steep dipping about 6-inch wide, sand-filled fissure which cuts obliquely across the bottom junction of the inclined shaft. Because of this fissure, a concrete lining of the inclined shaft was necessary for a distance of 60 ft from the bottom. The rest of the inclined shaft is unlined.

Rock Treatment of Upper Expansion Chamber

Concreting and Contact Grouting: Concrete lining and grouting were required only in the first 50 ft length of the access gallery at the portal to support the strongly lateritized shear zones.

Rock-Bolting and Guniting: The crown of the upper chamber immediately above the opening of the inclined surge shaft, and in the vicinity of a small fault upstream of the surge shaft opening have been rock-bolted, wire-meshed and Gunited. The rock face above the portal of the entrance to the chamber has also been rock-bolted with 20 ft long bolts for additional protection.

Drainage: No drainage of the cavern was necessary other than in areas covered with Gunited and this was done in order to prevent pressure build-up behind the concrete lining. 5 ft long and 2-inch diameter drain holes were drilled in regular pattern through the guniting lining.

Surge Shaft Water Level Measuring System

A measuring system is provided in order to monitor the fluctuation of the surge shaft water level in the powerhouse. Its main components are as follows: an electronic gauge pressure transmitter which is located on the upstream wall of the butterfly valve chamber. It receives the impulses through a one inch diameter stainless steel pipe running along the penstock in a length of approximately 330 ft (100.58 m). The reference point (zero reading) where the impulse line starts is at the bottom of lower expansion chamber at elevation 2206 ft. A 180° bend is provided at the upstream end of the pipeline to prevent dirt from entering. A valve is provided at the downstream end in the butterfly valve chamber to facilitate cleaning the line by flushing. The gauge pressure transmitter in the butterfly valve chamber is connected by a single pair conductor to a strip chart recorder located in the powerhouse

2.4.4 Penstocks

The water from the headrace tunnel is routed via two underground penstocks to the power house (See **Drg 2.14** of **Annexure 1)**. Geological and economic considerations influenced, to a major extent, the choice of an underground conduit over steel-lined, surface penstocks. The possibility of damage due to landslides caused by the potential instability of the overburden on the steep slopes is thus precluded as well.

Upon completion of concreting, the steel-concrete and concrete-rock interfaces were pressure grouted, thereby ensuring rock participation to assist in withstanding hydraulic loading conditions. Plate thickness and consequently overall quantities of steel were thus reduced on this account. While both shafts have been completely excavated, only one has been steel lined and concreted under the first stage of development. In addition, the steel manifolds of the second shaft adjacent to the powerhouse have been placed and concreted and are in readiness to receive the steel lining to be erected under a subsequent stage.

Leading from the butterfly chamber, both penstocks are approximately parallel and horizontal, spaced 100 feet (30.48 m) apart. The length of this horizontal section is 480 feet (146.304 m). The inside diameter of both penstocks remains constant at 12.5 feet (3.81 m) along this run. The elevation of this section is El. 2155 ft at the end of which the shafts dip down to an elevation of El. 180 ft. Due to the dictates of geological conditions and design requirements, the two shafts do not run parallel to each other within this inclined section. The distance between the two also varies from 80 to 100 feet (24.38 m to 30.48 m).

Penstock No. 1 is inclined at an angle of 51° 02' 32.3" to the horizontal, the length of which is 2540 feet (774.19 m). The inside diameter of the penstock is 12'6" at the elevated end and remains the same for a distance of 1600 feet (487.68 m) before tapering gradually down to 12' (3.66 m) at the lower end. Penstock No. 2 is inclined at an angle of 52° 37' 24.2" to the horizontal and has a total length of 2490 feet. The end diameters and the tapering off are identical to No. 1 penstock. Please see **Drg 2.15** of **Annexure 1**.

The excavation dimensions for both shafts were 16 ft (4.88 m) for the 12.5 ft (3.81 m) dia lining and 15.5 ft (4.72 m) for the 12.0 ft (3.66 m) dia lining. The excavation dimensions were further increased to facilitate liner installation at the bends, intermediate adit and around the wye. The average water velocities in the penstock for maximum flow of 2,500 cusecs are 20.4 and 22.1 ft/second in the 12.5 ft and 12.0 ft diameter sections respectively. At an elevation of 180 ft (54.86 m), each penstock is divided by two wyes into three manifold branches. The

lengths of the manifolds are 50 ft (15.24 m), 70 ft (21.34 m), 95 ft (28.96 m) respectively. The inside diameter of the three manifolds is 6.75 feet (2.057 m). The branch outlets of the bifurcations are strengthened with a horseshoe girder and tie rod. The deflection angle between the main pipe and branch outlets is 60°. Penstock No. 1 is feeding turbines 1, 2 and 3 and penstock No. 2 will supply water to turbines 4, 5 and 6 to be installed later. The average water velocity in the manifold branches is 23.5 ft/second (7.16 m/s).

Steel Lining

The pressure conduit No. 1 is steel lined downstream of the surge shaft. The lining in penstock No. 2 was installed between the surge shaft and butterfly valve as well as in the wyes and manifold branches. The rest of the steel lining was installed in the second stage. The steel liner has an outside diameter of 12'-7 7/8" above and 12'-2 1/2" below the elevation of 920 ft respectively, with a conical transition piece joining the two liners. Two bifurcations (wyes) were installed in each penstock in the first development stage. The outside diameters of the large wye branches are 11'-10 1/2"/9'-10" 7'-1", and those for the smaller wyes are 9'-11"/7'-1" 7'-1". The deflection angle for the bifurcations is 60°. The outside diameter at the manifold branches downstream of the wyes is 7'-1".

Butterfly Valve Chamber

Two 12.5 ft (3.81 m) diameter butterfly valves are installed in the upper horizontal sections of the penstocks in a common underground chamber, excavated in the rock about 300 ft (91.44 m) downstream from the surge shaft orifice. The main chamber has the following dimensions: length - 145 ft (44.196 m), width - 32 ft (9.75 m), and height at crown - 38.5 ft (11.73 m). The floor elevation is at 2148 ft (654.71 m). Three small side chambers were also required during the construction to facilitate the penstock liner erection. The chambers were not lined, but rock bolting and guniting was done on the ceiling. A 40 T capacity overhead electric travelling crane is provided for servicing the butterfly valves. The crane is supported on reinforced concrete columns and girders running along the longitudinal walls of the chamber. The top of the girders is at an elevation of 2173 ft (662.33 m). A 20 ft x 20 ft (6.096 m x 6.096 m) tunnel provides access to the chamber from outside. Please see **Drg 2.14** of **Annexure 1.**

The butterfly valve chamber is provided with one 40 T capacity electric overhead travelling crane of the following specification.

Make Khandelwal	-	Munck
Suppliers	-	Khandelwal Udyog Limited, Bombay
Capacity	-	40 ton
Span	-	30 ft (9.144 m)
Vertical lift	-	25 ft (7.62 m)
Speeds		
a) Hoist	-	5 ft/min
b) Cross travel	-	50 ft/min
c) Long travel	-	100 ft/min
Class/duty	-	Class II, Indoor service
Type of control	-	From cabin, through master controllers
Motors		
a) Hoist	-	20 H.P slip ring 1 hour rated totally enclosed
b) Cross travel	-	3.5 H.P slip ring 1 hour rated totally enclosed
c) Long travel	-	10 H.P slip ring 1 hour rated totally enclosed
End clearance	-	230 mm
Head room	-	1.75 m
Power supply	-	400/440 V. AC. 3 phase 50 cycles

The crane is of double girder welded plate box construction with a steel platform and hand railing on one side and two short platforms on the other side. The cross travel and long travel wheels are of double flanged type of cast steel and move on antifriction bearings. Wooden buffers are provided on either side of end carriage. Electromagnetic brakes are provided on all motions. Foot operated hydraulic brake controlled from cabin is for L.T. motion.

A butterfly valve is installed on each of the horizontal parallel branches of the penstocks. The valves have a diameter of 12'-6" (3.81 m) and are housed in a common underground chamber located about 300 feet (91.44 m) downstream from the junction point of the surge tank with the headrace tunnel.

2.4.5 Initial Filling of Reservoir

The diversion tunnel for the construction of Idukki Dam was closed on 14 March 1974. The reservoir rose to elevation 623.4 m (2045 ft) by the beginning of June 1974 with flow from the date of closure. During the South-West monsoon of 1974, the reservoir went up to El. 679.8 m (2230 ft) with the outlets and low blocks discharging water. By the end of the North-East monsoon in December 1974, the reservoir fell to El. 670.6 m (2200 ft, the sill level of Cheruthoni outlet) and remained more or less steady till the commencement of the South-West monsoon in 1975. The outlet gates were erected by June-July 1975. During the South-West and North-East monsoons of 1975 (from June to December 1975) there was a total inflow of 1670 Mm^3 (59 TMC) raising the level in the reservoir to 704.8 m (2312 ft).

The first generator in Idukki Power House was commissioned on 12 February 1976. There was some initial teething trouble and as a result very little water could be drawn for power generation during the period from February to end of May 1976. The live storage available in the Idukki Reservoir before the beginning of the SW monsoon of 1976 was of the order of 254.8 Mm^3 (9 TMC), reckoning El. 692 m (2270 ft) as the MDDL for running three generators of 130 MW each. During the SW and NE monsoons of 1976, there was a total inflow of 877.8 Mm^3 (31 TMC) from June 1976 to December 1976. Power generation during this period was 641 million units, drawing a total of 436 Mm^3 (15.4 TMC) of water.

The reservoir elevation as on 1 January 1977 was 715.1 m (2346 ft) making the total live storage available in the reservoir for power generation 688 Mm^3 (24.3 TMC).The power generation from January 1977 to end of May 1977 was to the tune of 736 million units, drawing a total of 511.1 Mm^3 (18.05 TMC) of water. The erection of the radial crest gates for Cheruthoni Dam spillways had been completed before the commencement of monsoon rains of 1977. The reservoir level before the beginning of monsoon was 703.4 m (2307.6 ft as on 1 June 1977), holding a live storage of 283.2 Mm^3 (10 TMC) in the reservoir. The monsoon started by the middle of June and by December 1977 the reservoir was at elevation 722.7 m (2371 ft). This was just below the crest of the spillway. Out of the total inflow of 1265.8 Mm^3 (44.7 TMC) from the SW and NE monsoons of 1977; 634.3 Mm^3 (22.4 TMC) was used for power generation. The power generation during the period was 931 million units.

From January 1978 to end of May 1978 a total of 1061 million units of energy was generated drawing 736.2 Mm^3 (26 TMC) of water and bringing down the level of water in the reservoir to 702.8 m (2305.7 ft).The monsoon of 1978 started by this time and the reservoir

level went up to 726.2 m (2382.4 ft) by the middle of November. The total inflow during the monsoons 1978 (June to December) was 1543 Mm^3 (54.5 TMC) of which 736.2 Mm^3 (26 TMC) was drawn to generate 1085 million units of energy. Uncontrolled reservoir rise was permitted up to El. 719.4 m (2360 ft). Above this level up to El. 725.5 m (2380 ft) a rise of 3.05 m (10 ft) per week and above 725.5 m (2380 ft) a rise of 1.5 m (5 ft) per week was insisted.

2.5 Record Keeping

The records regarding dam and appurtenant structures including detailed drawings and construction details are kept at the field office. Essential documents as per the dam safety guidelines are kept at the dam site office. Also the Rainfall data and Reservoir level are available.

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 / releases through outlets.
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.
7. All operating procedures

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 send to higher offices. The current practice of Inspection at Idukki, Cheruthoni and Kulamavu dams includes the Chief Engineer in presence of Deputy Chief Engineer and Executive Engineer at site to carryout pre-monsoon and post-monsoon inspections as per CWC guidelines in the format issued by CWC (**Annexure 5)**. The Deputy Chief Engineer will submit the inspection report to the Chief Engineer for onward transmission to CWC. The Executive Engineer at site will conduct quarterly inspections and will prepare health reports. The format followed as per CWC is now revised during January 2018 and new guidelines issued vide Doc No. CDSO_GUD_DS_07_v1.0, CWC 2018 for Safety Inspection of Dams. Now since the health reports are to be uploaded in DHARMA, the inspection reports are prepared in the new format. Detailed description on project inspections is available in the Guideline for Safety Inspection of dams. However an overview of the various types of inspections to be carried out at Idukki, Cheruthoni and Kulamavu dams are 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. This Chapter provides guidance on carrying out other inspections.

3.1 Types of inspections

Four different types of dam safety inspections are to be carried out at Idukki, Cheruthoni and Kulamavu dams. These include, but not limited, to the following:

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

The frequency of each type of inspection depends on the condition of the dam and State DSO regulations, etc. 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 **(Annexure 6)** 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 required 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 at Idukki, Cheruthoni and Kulamavu dams 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.
4. Review of design studies, review of design flood, checking of the adequacy of Spillway capacity, freeboard requirements, dam stability and any special study.
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 are to be handed over in detail.
- Basic data and issues related to safety of dam
- Problems if any during construction
- Drawings of dam, spillway, gates and appurtenant structures
- Seismicity
- Status of the instrumentation
- Construction History
- Geological Report including special problems at site and their treatment
- Field Inspection- Observation & recommendation regarding remedial measures
- Dam Incidents and Reservoir filling

Dam Incidents and Reservoir filling

The initial filling of the reservoir was done as in **Cl.2.4.5**. To mention specifically no incidents occurred in the dam. But a behavioral change of Idukki Arch dam was noted on loading and unloading of dam, in the deflection which was studied in detail by CWC under DRIP and is included in **Chapter 6**.

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 Organisation/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. Dam Inspection Report or an inspection brief should be prepared following the field visit as per the approved format of CWC as in **Annexure 5.**

Scheduled inspections include the following four 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.

3.3.1 Pre- and Post-Monsoon Checklist and Example of Report Proforma

Detailed checklists are required to ensure 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_DS_07_ v1.0, CWC 2018 on the Guidelines for Safety Inspection of Dams.

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

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

The last type of inspection, 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 to the proper operation and maintenance of the dam. They consist of frequent observations of the general appearance and functioning of the dam and appurtenant structures.

Operators, maintenance crews, or other staffs who are posted at dam sites conduct informal inspections. These people are the 'first-line of defense' in assuring safe dam conditions, and it is their responsibility to be familiar with all aspects of the dam. Their vigilance in walking the dam, 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 occasion presents itself, or they may cover the entire dam and its appurtenant structures. The informal inspections are not as detailed as comprehensive evaluation, scheduled, and special inspections and will only require that a formal report is submitted to the dam owner's project files if a condition is detected that might endanger the dam. Report is to be submitted detailing the condition discovered along with photographs, time, reservoir water level 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 and litigation. Preventative maintenance not only protects the dam and its owner but the public as well. If maintenance of a dam is neglected the consequences and costs will multiply.

4.1 Maintenance Plan

A basic maintenance schedule for the various monitoring components prepared for Idukki, Cheruthoni and Kulamavu dams based on manual of operating parts, frequent inspections, priority, and interval is arrived showing the tasks to be performed and how frequently that is to be inspected/observed and repaired as in **Annexure 7**.

4.2 Maintenance Priorities

Maintenance activities need to be prioritized. In order of priority they need to be clarified under the heads immediate maintenance and 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.
- A dam showing signs of failure due to aging/cracking, sliding, overturning etc.
- The dam showing signs of piping or internal erosion along faults, weak zone etc. indicated by increasingly cloudy seepage or other symptoms.
- The spillway being blocked or with some gates become in operative.
- Evidence of excessive seepage as seen in the gallery/on downstream face of the dam.

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 from the dam and restoring any eroded areas.
- Repair of defective gates, valves, and other hydro-mechanical equipment.
- Repair any concrete or metal components that have deteriorated.
- Cleaning of the choked drainage holes in the dam body/ foundations in concrete dams.
- Repair any damages on spillway glacis, piers, energy dissipaters, training/divide walls, downstream areas etc.
- Controlling any heavy seepage in the foundation/ inspection galleries in Concrete dams from drainage holes.
- Repairs of any cracks/cavities/joints in concrete dams/structures. However many of these works will require the services of experienced engineers/expert panels.
- Repair/Replacement of Hydro mechanical equipment (gate, hoist , valves , DG sets with their embedded parts) or its parts and associated works including electrical with cabling / power supply for any damages/defect

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 quantity and quality (clarity) with prior observations.
- Monitoring of downstream development which could have an impact on the dam and its hazard category.

- Regular Inspection and Maintenance of Electrical & Hydro-Mechanical equipment and systems eg. Servicing of spillway gates, hoisting arrangements, gantry crane, and gates/hoist of outlet works/sluices, Valves, trash racks and its cleaning equipment, Intake gate and hoist & stand by generator and control panels for all gates and valves with all electrical parts, cable and supply.
- Maintaining proper lighting at dam top, galleries, etc.
- Monitoring of seepage in galleries.
- Monitoring/ cleaning & removal of leached deposits in porous concrete / formed drains in dam body and foundation drainage holes.
- 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 fences or barricades. Any damages are repaired as soon as possible**.** Also vehicles were permitted after security checking at check posts.

4.3.2 Controlling Vegetation

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

4.3.3 Masonry / Concrete Dams and Spillways

The following important issues/aspects need to address 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, un-symmetrical flows, unfavorable down-stream conditions)
- Vegetation growth in spillways, spill channel, approach channel etc.
- Seepage in Galleries and on d/s face of the dam.
- Cleaning and removal of leached deposits from choked drainage holes in the dam body/foundations.
- Repair to upstream face of masonry dams in case the pointing is damaged, leading to increased seepage.
- Status of rectification works undertaken from time to time need to be assessed during periodic maintenance.
- To ensure proper access & lighting in galleries.
- To ensure that the dam is behaving as designed based on instrumentation programs.
- Periodic maintenance should be performed 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 need to be obtained.

4.3.4 Outlet Works

The civil and HM components of outlet provided in Cheruthoni & Kulamavu Dams are detailed in **Clause 2.2.4** and the operation and maintenance are detailed out in the manufacturer's manual attached as **Annexure 2.** The outlet conduits should be inspected thoroughly once a year. Circular conduits that are of dia 1.5 m or more can be manually inspected. Common problems are improper alignment (sagging), separation and displacement at joints, cracks, leaks, surface wear and loss of protective coatings, corrosion and blockage. Problems with conduits occur most often at the joints. Further collars at joints used may also lead to inadequate compaction. Hence, special attention should be given to them during inspection. The joints should be checked for gaps caused by elongation or settlement and loss of joint-filler material. Open joints can permit erosion of embankment material or cause

leakage of water to the embankment during pressure flow. The outlet should be checked for signs of water seepage along the exterior surface of the pipe.

As regards to Hydro-mechanical works, appropriate paragraphs in this chapter may be referred. If routine inspection of the Hydro-Mechanical Equipment shows the need for maintenance, the work should be completed as soon as possible.

4.3.4.1 Trash Racks

Trash racks provided in front of the Kulamavu intake may become clogged with debris or trash which reduces their discharging capacity. As per the original manual, the surface of the trash racks should be kept clean of debris. It is recommended to clean these every year, preferably during the period of low reservoir water level, especially in the first few years of operation. Later, if experience has shown that the yearly accumulation of debris on the racks is negligible, the time interval between the cleaning operations may be increased. It is recommended that the racks be inspected at five year intervals. Lifting hooks are provided on each panel to facilitate their removal for inspection and maintenance. Since this is submerged very deep, normally frequent cleaning is not necessitated. However bubbler system is also provided for the same.

Trash racks are also provided in front of the disperser valve at Kulamavu dam. Maintenance of trash rack includes periodic inspections for rusted and broken sections and repairs are made as needed. Trash racks should be checked during and after floods to en-sure that they are functioning properly and to remove accumulated debris periodically as per site requirements.

4.3.4.2 River Outlet

A 6 ft. diameter outlet, controlled by an upstream emergency gate and a downstream hollow jet valve has been installed in Kulamavu dam. The emergency gate has a hoist structure on top of dam. Hollow jet valve is approachable on the downstream by a catwalk.

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

4.3.4.3 Maintenance of HB/ Disperser jet Valve and its operating arrangement.

The Kulamavu masonry dam is provided with a bottom discharge outlet to control water level by releasing water into the downstream valley. The hollow jet valve and its auxiliary equipment should be operated and maintained in strict accordance with "Operation and Maintenance Instructions" supplied by Canadian Vickers Ltd.

4.3.5 Spillway Radial Gates & Hoisting Equipment

The safe and satisfactory operation of a dam 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.

4.3.5.1 Radial Gates

The gates are to be operated through their full range twice annually (before monsoon & after monsoon keeping a gap of at least six months). Because operating gates under full reservoir pressure can result in large discharges, exercising of gates should preferably be carried out 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 Gates & Hoists whenever there is any contradiction with the instructions 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 smoothed, 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 guide wheel shall be rotated to check their free movement. Guide roller pin and bearings 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 and sealing-assemblies shall be cleared off grit, sand or any other foreign material.

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

xi. All nuts and bolts shall be tightened.

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

a) **Rubber Seals**: i) Seals shall be inspected for leakages. Locations of excessive leakages shall be recorded for taking remedial measures. Weeping or slight flow in localized area will not require immediate remedial measures. However, measures like tightening of bolts are carried out. Further adjustment is carried out during annual maintenance.

b) **Trunnion block assembly and anchorages:**

i. All the nuts and bolts of Trunnion block assembly and its anchorages shall be checked for tightness.

ii. Check all the welds for soundness and rectify defects.

iii. Check whether the Yoke girder and thrust block is covered or not. If not, cover it with mild steel plates.

iv. Cover the trunnion pin with anti- corrosive jelly.

v. Remove all dirt, grit etc. from trunnion assembly and lubricate trunnion bearings of the gate with suitable water resisting grease as recommended by bearing manufacturers.

c) **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.

vi. The guide roller pins shall be lubricated

d) **Embedded Parts:**

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

e) **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) Trunnion bearing should be greased as and when required. Keeping trunnion bearings in perfect working condition is very important. All other bolted connections should also be checked up for proper tightness.

v) Bolts and trunnion bearing housing should be tightened wherever required.

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

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

viii) Wire ropes should be properly lubricated.

ix) 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.

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

xi) Flexible couplings should be adjusted if required.

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

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

xiv) The list of essential spare parts to be kept available should be reviewed and updated periodically. The condition of spares should be checked periodically and protective coating given for use.

4.3.5.2 Fixed Wheel Gate

These gates are provided for outlet gates at Cheruthoni Dam, Outlet and Intake Kulamavu Dam for controlling/regulating the flow. The headrace tunnel intake gate should be operated and maintained in strict accordance with the manufacturer's instructions. The complete procedure for the normal operation of the gate and the instructions to be followed in case of a manual operation are detailed in the "Operation and Maintenance Manual" prepared by Davie Shipbuilding Ltd., the manufacturer of the intake gate.

The main components of these gates are as under;

i) Embedded parts:

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

ii) Gate Parts:

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

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

i. The gate slot and bottom platform/sill beam should be cleaned periodically. Scales formed over the embedded parts should be removed. Second-stage concrete should be checked for any development of cracks / leakages and repairs should be attended to immediately.

ii. Rubber seals should be smoothed, 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.

iii. 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.

iv. Hoisting connection of the gate leaf should be lubricated where necessary and defects if any should be rectified.

v. All nuts, bolts, check nuts and cotter pins of the lifting devices should be checked periodically.

vi. All components should be greased and lubricated. Recommended and approved oils and grease only should be used.

vii. Roller assembly should be adjusted by the eccentricity arrangement to ensure all rollers rest uniformly on the track plates particularly in the closed position of the gate.

viii. Where filling valves are provided as part of the gate structure, all the nuts, bolts, check nuts etc. should be tightened.

ix. 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.

x. The filling-in valves allow passage of water when it is lifted by lifting beam & crane due to creation of space between stem seat and exit passage liner. The springs and associated components should be checked periodically for damages and replaced if necessary.

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

xii. The wheel pin shall be coated with corrosion resistant compound.

xiii. All nuts and bolts shall be tightened.

4.3.5.3 Maintenance of Electrically operated fixed hoists

Electrically operated fixed hoists are provided for Spillway Radial gates at Cheruthoni Dam, Outlet and Intake gates at Kulamavu Dam.

1. General Instructions:

a. Never open any bolt or nut on motor, gear boxes, rope drums and other load carrying hoist components when the gate is in raised position. The gate should be fully closed or rested on the gate latches before carrying out any work on hoist components including motor brake and other electrical equipment.

b. 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. Check all the fuses on the power lines.

viii. All bolts and nuts on gear boxes, hoist drum and shaft couplings should be checked for tightness.

ix. Check the supply voltage.

x. 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.

xi. All the geared couplings shall be greased.

xii. Raise and lower the gate by hoist motor and check for smooth, and trouble free operation of gate without excessive vibration.

xiii. Observe current drawn by motor at the time of lifting and check if it is more than normal. If so, stop the hoist and investigate the cause and rectify.

xiv. Check the condition of painting of various components and remove rust wherever noticed and repaint the portion after proper cleaning as per painting schedule.

xv. All trash, sediments and any other foreign material shall be cleared off the lifting rope and lifting attachment.

xvi. All ropes shall be checked for wear and tear and if broken wires are noticed, the rope shall be replaced.

xvii. All the wire ropes shall be checked and all visible oxidation shall be removed. xix. All wire ropes shall be greased with cardium compound.

xviii. Check the overload relays for proper functioning.

xix. 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.

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

xxi. Raise and lower the gate for its full lift several times (at least three to four) and observe the following:

a) Check the limit switches and adjust for design limits.

b) The effectiveness and slip of the breaks shall be checked by stopping the gate in raising and lowering operations. The brakes shall be adjusted if needed.

c) When the gate is operated, there should not be any noise or chatter in the gears.

xxii. Adjust the rope tension of wires if unequal. Check for all gears and pinions for uneven wear and adjust for proper contact. Grease the gears.

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

xxiv. The periodic maintenance of commercial equipment like motors, brakes, thrusts etc. shall be carried out as per manufacturers operation and maintenance manual.

4.3.5.4 Maintenance of Electrical components of Fixed Rope Drum Hoists:

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

xxv. Starters should be cleaned free of moisture and dust.

xxvi. Each individual contactor should be tried by hand to make sure that it operates freely.

xxvii. All wearing parts should be examined in order to take note of any wear which may have occurred during operation.

xxviii. If the contactor hums, the contact faces should be cleaned.

xxix. Examine all connections to see that no wires are broken and no connections are loose.

xxx. Clean the surface of the moving armature and magnet core which comes together when the contactor closes, free of dust or grease of any kind.

i) Examine the mechanical interlocks between the reversing contactor and see when the contact tips of one of the contactor units are touching, it is impossible to get the contact tips of the other unit to touch.

ii) The contact tips should be kept free from burns or pits by smoothening with fine sand paper or emery paper.

iii) Replace the contact tips which have worn away half-way.

iv) Do not lubricate the contacts.

v) Examine earth connections and motor leads.

vi) Examine motor windings for overheating

vii) Blow out windings thoroughly by clean and dry air to clear air passage in the stator and the rotor of any accumulated dirt. The air pressure shall not be too high to damage the insulation.

viii) Examine control equipment

ix) Examine starting equipment for burnt contacts

x) Check and tighten all nuts and bolts

xi) Clean and tighten all terminals and screw connections all contact surfaces shall be made clean and smooth.

xii) Lubricate the bearings

xiii) Overhaul the controllers

xiv) Inspect and clean circuit breakers.

xv) Wipe brush holders and check bedding of brushes.

xvi) Blow out windings thoroughly by clean and dry air. The pressure shall not be so high that insulation may get damaged.

xvii) Check the insulation resistance of the motor between any terminal and the frame. If the measured resistance is less than the prescribed value, then steps shall be taken to dry- out the motors either by passing a low voltage current through the windings or by placing the stator and rotor only in a warm dry place for a day or so.

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

xviii) Coat the windings with an approved high temperature resisting insulation enamel or varnish.

xix) Over haul the motor, if required.

xx) Check the switch fuse units and renew, if required.

xxi) Check resistance or earth connections.

xxii) Check air gap.

b) Solenoid Operated Brakes

i) All fixing bolts shall be checked and tightened at least once in three months.

ii) The magnet stroke should be reset to compensate for wear.

iii) Re-adjust the brake when the magnet stroke reaches the value given on the instruction plate.

iv) Brake lining should be checked and replaced when required.

v) Examine all electrical leads and connections.

vi) Rubber bushes or couplings should be checked and replaced if defective.

vii) The pins should be tightened.

4.3.6 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. 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.

4.3.7 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.

Surface Preparation and Painting of HM Works

i) Protection of painted surfaces is considered essential for protection & enhancement of service life. Gates, their embedded parts, gate leaf, hoists and its supporting structures need to be protected against corrosion due to climatic condition, weathering, biochemical reaction and abrasion etc. This equipment is likely to deteriorate or get damaged to any extent that the replacement of parts may become necessary and such replacement may become difficult and costly.

ii) Surface preparation & Painting requirements:

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

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

a) The following surfaces are not to be painted unless or otherwise specified:

- Machine finished or similar surface
- Surfaces which will be in contact with concrete
- Stainless steel overlay surfaces.
- Surfaces in sliding or rolling contact
- Galvanized surfaces, brass and bronze surfaces.
- Aluminum alloy surfaces

b) The Surfaces of stainless steel, nickel, bronze and machined surface adjacent to metal work being cleaned or painted shall be protected by using sticky protective tape or by other suitable means over the surfaces not to be painted.

c) All embedded parts which come in contact with concrete shall be cleaned as detailed above and given two coats of cement latex to prevent rusting during the shipment while awaiting installation.

iv) Application of primer &finish coats on embedded parts and gates:

a) Embedded Parts:

- The prescribed primer shall be applied as soon as the surface preparation is complete and prior to the development of surface rusting and within the specified time prescribed by Indian Standards or the Paint Manufacturer. In case there is lapse of considerable time beyond the prescribed time limit, the surfaces shall be again cleaned prior to priming.
- Two coats of zinc rich primer with epoxy resin shall be applied to all embedded parts surfaces which are not in contact with concrete and shall remain exposed to atmosphere or submerged in water to obtain a dry film thickness of 75 microns.
- This shall be followed by three coats at an interval of 24hours of coal-tar blend epoxy resin so as to get a dry film thickness of 80 microns in each coat. Total dry film thickness of paint shall not be less than 300 microns.

b) Gates:

- **<u>Primer Coat:</u>**

  Over the prepared surface one coat of inorganic zinc silicate primer giving a dry film thickness of 70 ± 5 microns should be applied. Alternatively two coats of zinc rich primer, which should contain not less than 85% zinc on dry film should be applied to give a total dry film thickness of 75 ± 5 microns.

- **Finished paint:**

  Two coats of solvent less coal tar epoxy paints. These shall be applied at an interval of about 24 hours. Each coat shall give a dry film thickness of 150±5 microns. The total dry film thickness of all the coats including primer coating shall not be less than 350 microns.

v) Hoist and supporting structure:

a) Structural components:

Primer coats of zinc phosphate primer shall be applied to give a dry film thickness of 40±5 microns.

Final Coats: One coat of alkalized based micaceous iron oxide paint to give a dry film thickness of 65 ± 5 microns followed by two coats of synthetic enamel paint confirming to IS 2932 – 1974 to give a dry film thickness of 25 ± 5 microns per coat. The interval between each coat shall be 24hours. The total dry thickness of all coats of paint including the primer coat shall not be less than 175 microns.

b) Machinery: Except machined surfaces all surfaces of machinery including gearing, housing, shafting, bearing pedestals etc., shall be given:

Primer coats: One coat of zinc phosphate primer paint to give minimum film thickness of 50 microns. Motors and other bought out items shall be painted if necessary.

Finished coats: The finished paint shall consists of three coats of aluminum paint confirming to IS2339 – 1963 or synthetic enamel paint confirming to IS 2932 – 1977 to give a dry film thickness of 25±5 microns per coat to obtain a total minimum dry film thickness of 125 microns.

c) Machined surfaces:

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

vi) Application of paint:

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

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

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

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

Appendix A – Brushing of paint

Appendix B – Spraying of paint

Appendix C – Spray painting defects: Causes and remedies.

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

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

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

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

vii) Removal of old paint for repainting:

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

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

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

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

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

a) The following steps are involved in inspection of painting:

- General inspection before and during painting
- Viscosity test of paints
- Paint thickness test – using Elco-meter.
- Inspection of general appearance of finished work.

b) General:

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

c) Inspection of surfaces prior to painting:

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

d) New Works (Not previously painted): The following shall be decided by inspection:

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

e) Old Work (Which requires repainting):

The following shall be decided by inspection:

- Whether the entire existing paint requires removal; and/or
- Whether repainting without paint removal would be adequate.

4.3.8 Access Roads

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/slopes develop blockage of the road, protective works including retaining walls shall be provided as remedial measures. Drains are required to be provided and maintained along roads to remove surface and subsurface drainage. This will prolong the life of the road. Road surfacing should be repaired or replaced as necessary to maintain the required traffic loadings. The maintenance of all access roads is executed under DRIP.

4.3.9 General Cleaning

As already suggested, for proper operation of spillways, sluiceways, approach channels, inlet and outlet structures, stilling basin / energy dissipation arrangements, discharge conduit, dam slopes, trash racks, debris control devices etc., regular and thorough cleaning and removal of debris is necessary. Cleaning is especially important after large floods, which tend to send more debris into the reservoir. The dam top, access roads and galleries are 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. At Idukki, Cheruthoni and Kulamavu Dams, round the clock patrol is carried out. At the same time the additional requirements during monsoon period are also provided.

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

Round the clock patrolling is carried out during monsoon period. Manpower requirements including operating staff (gate operators, workers, electrician, sweepers etc.) are arranged on annual contract basis for the dams.

The departmental regular manpower provided for Idukki, Cheruthoni and Kulamavu Dams are as below:

<table>
<tr><th colspan="5">Present Manpower</th></tr>
<tr><th>Designation</th><th>Idukki Dam</th><th>Cheruthoni Dam</th><th>Kulamavu Dam</th><th>Remarks</th></tr>
<tr><td>Executive Engineer</td><td colspan="3">1</td><td rowspan="5">The dam safety officers and staff concentrate fully on monsoon related dam operation & monitoring works during monsoon period. The dam safety O&M works are generally executed during the off monsoon period.</td></tr>
<tr><td>Assistant Executive Engineer</td><td>1</td><td>1</td><td>1</td></tr>
<tr><td>Assistant Engineer</td><td>2</td><td>2</td><td>1</td></tr>
<tr><td>Sub Engineer</td><td>5</td><td>5</td><td>4</td></tr>
<tr><td>Security Staff</td><td colspan="3">As mentioned in Cl.1.8.1</td></tr>
</table>

4.5 Preparation of O&M budget

The O & M budget for Idukki, Cheruthoni and Kulamavu Dams 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 Staff** - Salaries and allowances, Bonus, Medical Reimbursement, LTC, Leave Encashment, Pension benefits, TA and DA, etc. (as applicable).

iii) **Establishment Cost of Daily Wage Staff** - Salaries and allowances, TA and DA etc. (as applicable)

iv) **Office Expenses**-Telephone/Mobile/any other Telecommunication bills, Electricity bills, water bills, Office stationery, Day to day office requirements.

v) **Motor Vehicles** - Running and Maintenance cost of inspection vehicles, Cost of hiring of vehicles as required

vi) **Maintenance of Colony** - Maintenance of staff quarters, colony roads, Electricity, Sanitary and Water supply systems etc

vii) **T&P**-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 to dams, intake, control shaft and Bubbler system & basic facilities, provision for flood contingency works during monsoon, unforeseen events/items (about 10% of the cost of works) etc.

ix) **Upkeep and maintenance** – Provision for upkeep & maintenance of all gates (Radial, Sluice & Intake) and valves, operation of gates, valves and connected works.

x) **Dam monitoring** - The dam monitoring apparatus is basically geodetic in which triangulation, crest collimation and net leveling are required for Idukki dam. Instrumentation studies and monitoring of Idukki and Cheruthoni dams are required. In addition, the embedded instruments are to be monitored, readings taken for which O & M budget along with seismological and climatological stations required.

A summary table for the O & M budget is given below in **Table 4.1**

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	Vehicle expenses			
5	Maintenance of office & colony complex			
	Sub-total - a			
b.	**Works**			
1	**Civil works**			
1.1	Concrete / masonry dam			
1.2	Sluices in concrete / masonry dams			

1.3	Approach / inspection roads within dam area			
2	**Hydro-Mechanical works**			
2.1	Spillway gates & hoists			
2.3	Sluices in concrete/masonry dams – service/emergency gates & hoists			
3	**Electrical works**			
3.1	Electrical fittings, motors, controls for all 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			
4	**Instrumentation and monitoring**			
4.1	Geodetic Surveying (Triangulation, Crest collimation and Net levelling)			
4.2	Embedded instruments			
4.3	Seismic network			
4.4	Rain gauge stations			
5	**Miscellaneous works**			
5.1	Bubbler System			
5.2	Drainage network			
5.3	Intake Gate and Hoist			
6	**Salary of work charged staff including all benefits**			
7	**Materials to be stored before monsoon**			
	Sub-total - b			
c.	**Contingencies**			
1	Contingency (10%) on Sub-total of **a & b**			
2	Tools & Plants			
	Sub-total - c			
	Total Annual Cost			

Table 4.1 Summary Table for Annual O&M Budget

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, and
- 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 may draw information from a wide spectrum of instruments and procedures, ranging from simple to complex. The program must be based on prevailing geotechnical conditions at the dam, and must include consideration of the hydrologic and hydraulic factors present before and after the project is in operation.

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

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

5.1A Idukki Dam - Instrument Types and Usage

Recognizing the importance for surveillance of a large arch dam for which design extrapolations are considerable, a large scale structural monitoring system to verify the behavior of the dam under conditions of loading complies with safety requirements and design assumptions.

Surveying methods

Geodetic methods, viz. Triangulation, Leveling and Collimation can measure the absolute movement of the dam and foundation rock with respect to fixed points on earth's surface

whereas ordinary plumb lines measure the relative displacements between two points in the dam structure. The reference points for regular observations of the movements of the dam are located within two nets identified as **'area net'** (situated in the area around the reservoir and the dam) and **'dam net'** (located in the immediate vicinity of the dam). The two nets are tied in periodically to determine the amount of ground movement produced by the weight of the dam and the reservoir.

Horizontal Movements

Triangulation Method: First order triangulation techniques are employed to measure horizontal movements of targets fixed on the downstream face of the dam (See **Drg 5.1**of **Annexure 1**). 26 geodetic targets placed on the downstream face of the dam. There are 5 Deformation stations and 5 Safety stations for triangulation.

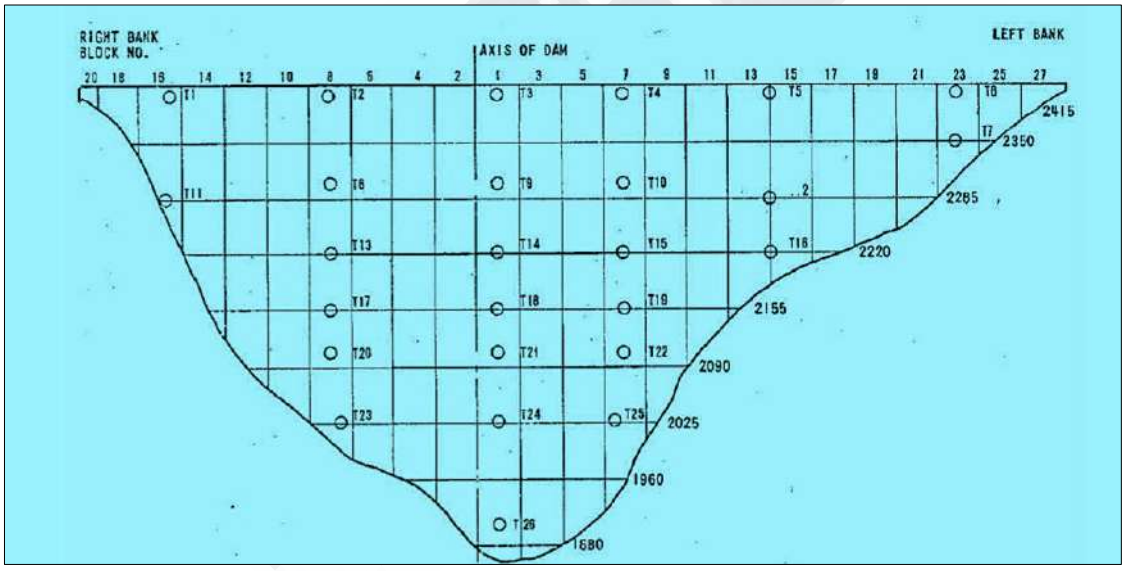


Fig 5.1 Target Stations on downstream face

Pendulums & Deformation stations

There are Five (**P1 to P5**) pendulums from top to bottom embedded in Block numbers 8,1 & 7 for measuring the horizontal deflections. Horizontal displacements relative to a point deep in the foundation rock is measured by means of an inverted pendulum P6. Pendulum locations are given below in **Fig 5.2.** (See **Drg 1.1 & 5.2 of Annexure 1**). There are Five Deformation stations with inverted pendulums distributed along abutments near dam.

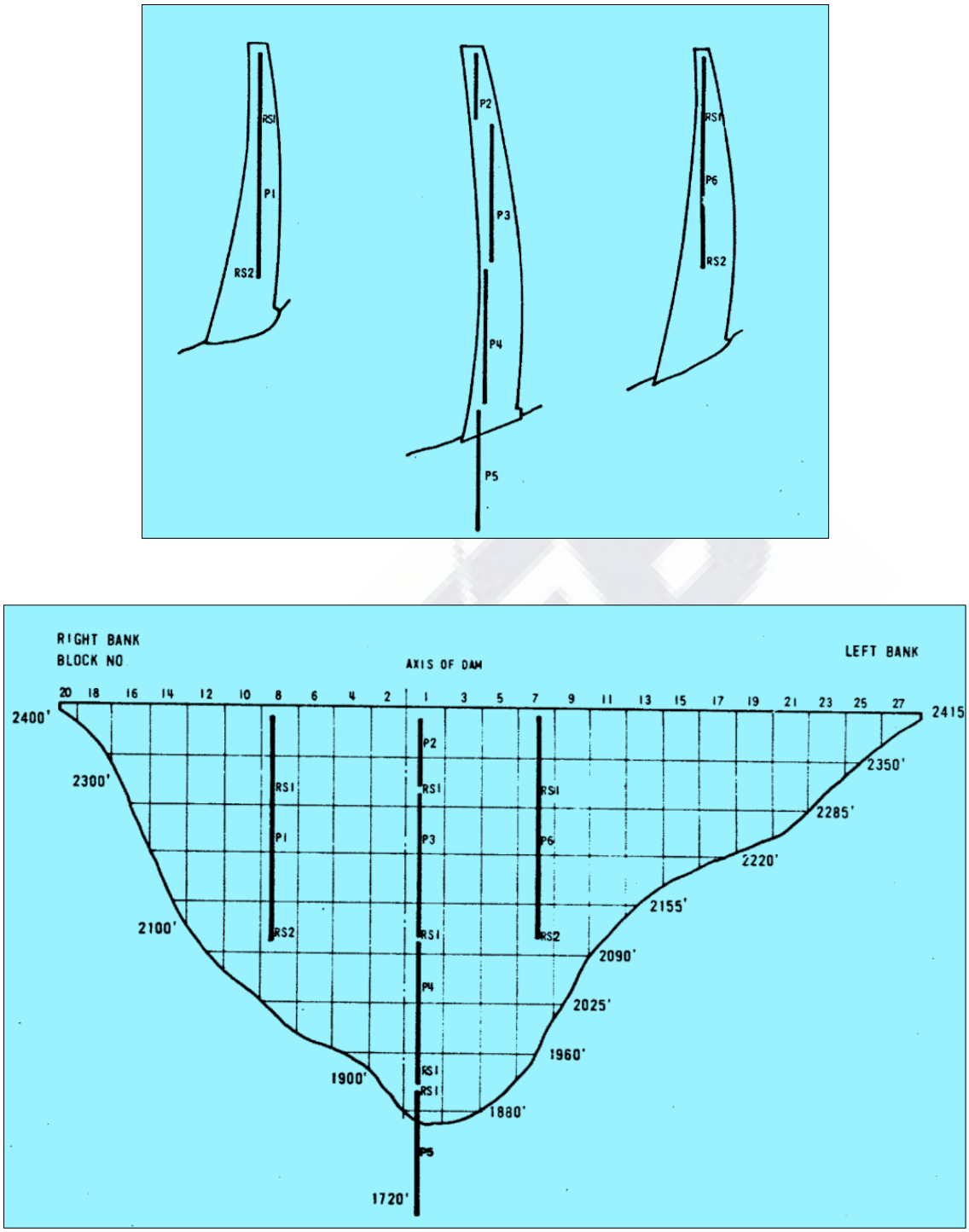


Fig 5.2 Pendulum Locations

Collimation Method is employed to measure the deflection of the crest of the dam. A line of sight passing through two reference points on the right and left abutment rock is established in space and movements of points on the dam crest with respect to the line of

sight are determined. See **Fig 5.3**. There are three crest collimation stations on the crest of the dam.

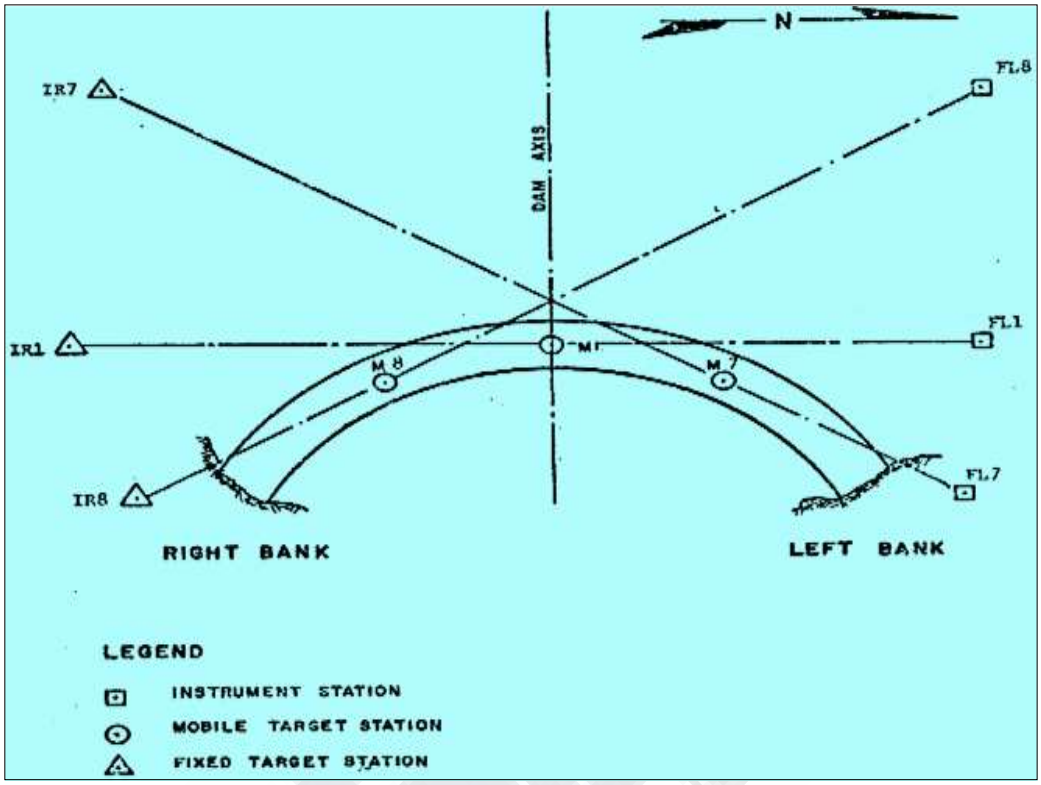


Fig 5.3 Mobile Target and Fixed Target for Crest Collimation

Plumb lines are made use of to measure the relative horizontal displacements of the crest of the arch dam with reference to its base. In addition there are joint meters to measure the horizontal deflection.

Vertical Movements

Precision Leveling: Vertical movements of the dam and its foundation are measured by precision leveling. A network of control bench marks have been established downstream of Idukki Dam to a distance of 8 km which have been connected to points outside the assumed zone of deformation. Bench marks have also been established in the dam galleries and drift tunnels and connected to the downstream control bench marks to find out the vertical deformation.

Foundation

There are four base meters connecting the foundation galleries to the formed galleries. Five rock-targets are there in each of the six rock galleries.

Fig 5.4 View of rock target station at galleries

Rotations

Rotations with reference to vertical or horizontal planes are measured by means of Clinometer. One clinometer is located at the base of the dam.

Geotechnical Methods

Embedded instruments fall within two basic groups, viz., **resistance type** and **vibrating wire type** or acoustic type. These instruments help to measure the response of the dam structure to influences such as temperature, gravity loads, water loads, volume change of concrete, etc. The distribution of the different types of instruments in the dam is so arranged that there is counter check between the readings obtained from one system of instruments and

those obtained from other systems of instruments. Further, the instrument locations cover all critical points and the readings obtained from the instruments can be directly compared with theoretical results. A general layout of instruments in Idukki dam is given in **Fig. 5.5**.

Stress control

Eighty three vibrating wire type strain meter groups totaling 346 No individual strain meters and sixty three thermistors embedded in the concrete. There are 52 Carlson type direct stress meters also.

Foundation drainage network made up of 199 drilled drain holes totaling approximately 7,000 m is monitored regularly for uplift pressure and seepage 'V' notch weirs constructed in the galleries enable measurements of total volume of seepage in the dam and its foundation. Individual seepages from body drains measured separately.

Uplift Pressure

Foundation uplift pressure is measured using expander packer set assembly and bourdon pressure gauge.

Water Level of the reservoir is read every day and regular and detailed visual inspection is carried out for detecting cracks, if any, in the galleries and exposed faces of the dam. See photo below. Water samples are taken for physical and chemical analysis from various locations.

Dam Electrical System

The electric system consists of lighting of the galleries, elevator shaft drift tunnels, plumb bob reading stations, roadway and other openings in the body of dam, ventilating the gallery and elevator shaft by suitable air circulators and exhaust fans, providing power connections to machine room of elevator tower, etc. The illumination level required in the various areas of the dam and related structures is prescribed based on accepted standards.

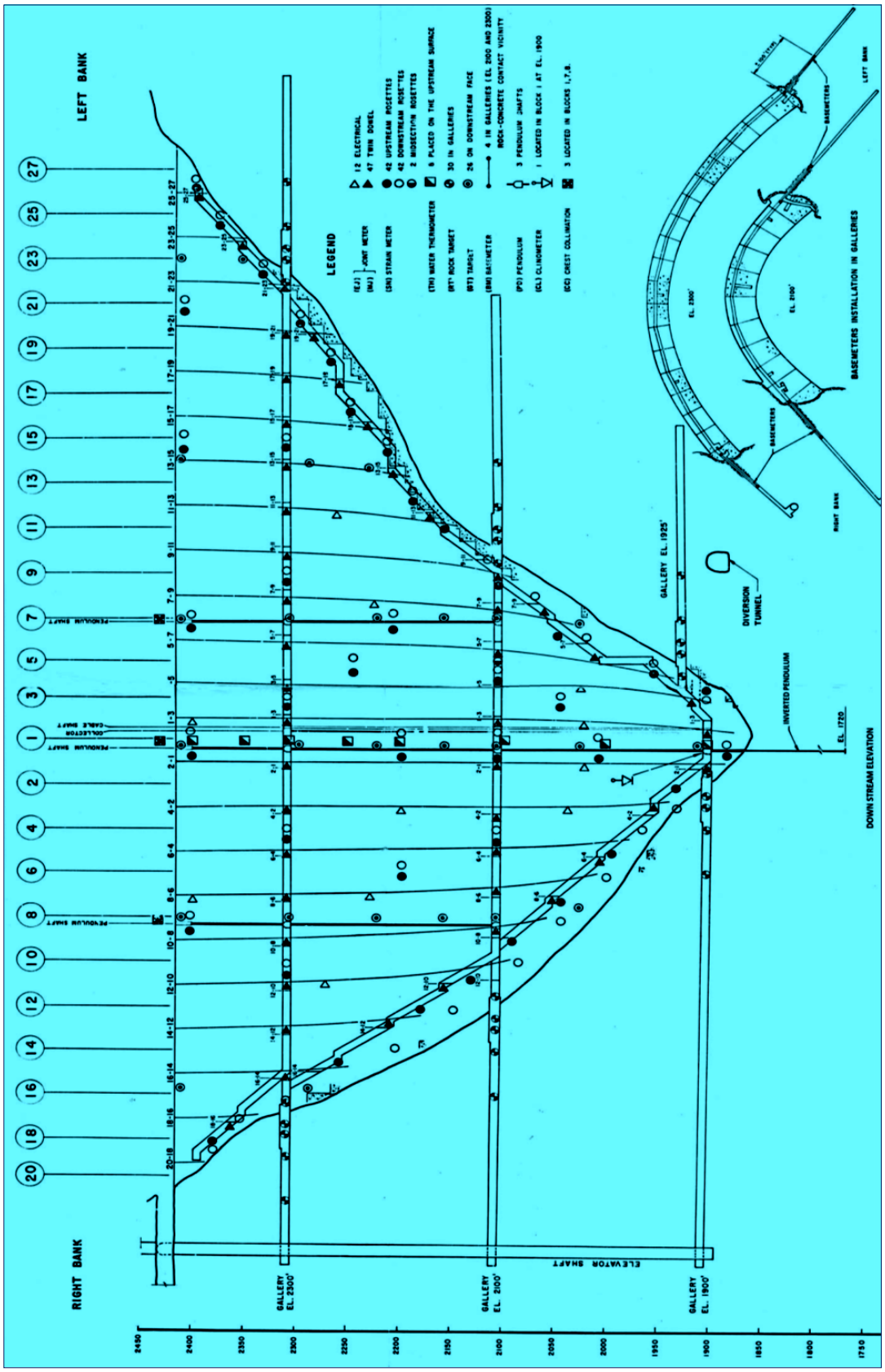


Fig 5.5 Instrument Layout General Arrangement

Arch Dam Monitoring System (AMS)

A computer system called the AMS system was developed by SNC to process the data from 18 instrument group which include embedded electronic instruments, geodetic instruments, and miscellaneous devices to monitor foundation pressures, cracks, temperatures, etc. A two letter code was developed to correspond to each instrumentation function to be performed on the dam.

Code	Instrumentation	Code	Instrumentation
BM	Base Meters	MJ	Mechanical Joint Meters
CC	Crest Collimation	MT	Monument Triangulation
CL	Clinometer	NL	Net Leveling
CR	Cracks	PD	Pendulums
DH	Drain Holes	RT	Rock Targets
EJ	Electrical Joint Meters	SN	Strain Meters
FL	Water Flow	SS	Stress Meters
GL	Gallery Leveling	TH	Temperature
GT	Geodetic Targets	WL	Water Level

A standard 80 column format was developed for field recording the basic data and field data for each instrument within an instrument group. Preprinted forms were prepared in India corresponding to this format such that all readings can be immediately keypunched for computer analysis once the data arrives in Montreal. A description of this data logging system and the method required to complete the forms is given in SNC's report No. 3575-0001 of June 1974, entitled "Idukki Dam Monitoring System, Field Input Coding Forms & Scheduled Reading Dates". The AMS computer was developed to operate on an IBM 1130 computer equipped with 8K memory, single disk and printer. The system is presently being converted over to a larger and faster computer, a Data General NOVA 840 which will replace the IBM 1130 presently installed in SNC's office. The NOVA is equipped with a 56 K memory, two disks, line printer, magnetic tape and plotter.

The status of instrumentation in Idukki dam is given in the **Table 5.1.**

STATUS OF INSTRUMENTATIONS IN IDUKKI DAM			
Sl.No.	**Name of Instruments**	**Total instrument**	**Functioning**
1	Stress meter	52	22
2	Strain meter	83	49
3	Rock Target	30	-
4	Pendulum Upright	5	5
5	Clinometer	1	-
6	Base meter	4	-
7	Joint meter (Electrical)	12	-
8	Joint meter (Mechanical)	47	47
9	Thermometers (Vibrating wire type)	63	31
10	Thermometers (Resistance type)	9	-
11	Instrumented Cylinders	7	-
12	Water Thermometer	8	-
13	Crest collimation of rock target points	3	3
14	Deformation Pendulum inverted	1	1
15	Accelerograph	4	4

Table 5.1 Instrumentation Present Status - Idukki Dam

Note: **Various instruments installed in Idukki dam during construction are not functioning and read out units found faulty/obsolete. Hence based on the study of 'Investigation of Current Behaviour of Idukki Arch dam' by Central Water Commission, Real Time Structural Health Monitoring & Early Warning System (RTSHM & EWS) as detailed in Chapter 6 is being implemented at site. A correct picture of the instrumentation status can be arrived only after the completion of this work and shall be amended.**

The Seepage Details of foundation and body drains of Idukki dam are given in **Table 5.2,** Diversion tunnel in **Table 5.3 &** B9-4 Body drain in **Table 5.4** below**.**

SEEPAGE MEASUREMENT OF IDUKKI DAM						
Date	Water Level in ft	V-Notch Reading in mm		Seepage in litres/min		Total Seepage in litres/min
		I(Body drains)	II(Side drains)	I	II	
18/01/2010	2369.26	159	216	28.36	0.40	28.75
20/02/2010	2364.20	163	215	24.46	0.48	24.94
10/03/2010	2348.36	161	214	26.37	0.57	26.94
14/05/2010	2318.65	160	214	27.35	0.57	27.92
11/06/2010	2308.60	160	214	27.35	0.57	27.92
21/07/2010	2343.70	167	203	20.90	2.33	23.23
08/09/2010	2369.08	155	213	32.61	0.67	33.29
07/10/2010	2380.14	155	206	32.61	1.70	34.31
02/11/2010	2388.40	162	216	25.40	0.40	25.80
02/02/2011	2381.52	158	215	29.39	0.48	29.87
08/03/2011	2365.96	156	217	31.51	0.32	31.84
30/04/2011	2339.44	160	213	27.35	0.67	28.03
27/05/2011	2319.52	156	218	31.51	0.26	31.77
24/06/2011	2337.58	157	210	30.44	1.05	31.49
27/07/2011	2356.24	154	220	33.73	0.15	33.88
28/09/2011	2392.52	155	220	32.61	0.15	32.76
24/10/2011	2385.54	153	215	34.87	0.48	35.35
18/11/2011	2386.64	153	216	34.87	0.40	35.27
22/12/2011	2378.20	155	218	32.61	0.26	32.87
24/01/2012	2370.42	153	216	34.87	0.40	35.27
14/02/2012	2361.02	158	218	29.39	0.26	29.65
30/03/2012	2335.00	159	219	28.36	0.20	28.56
28/04/2012	2322.28	160	215	27.35	0.48	27.83
19/05/2012	2314.16	161	215	26.37	0.48	26.84
29/06/2012	2302.08	155	213	32.61	0.67	33.29
28/07/2012	2311.00	160	214	27.35	0.57	27.92

17/08/2012	2314.48	161	214	26.37	0.57	26.94
29/09/2012	2332.08	160	215	27.35	0.48	27.83
11/10/2012	2331.60	158	213	29.39	0.67	30.06
30/11/2012	2333.54	160	216	27.35	0.40	27.75
21/12/2012	2330.28	162	220	25.40	0.15	25.55
22/01/2013	2325.7	158	218	29.39	0.26	29.65
11/02/2013	2323.24	158	214	29.39	0.57	29.96
15/03/2013	2318.00	162	220	25.40	0.15	25.55
20/04/2013	2309.16	160	220	27.35	0.15	27.50
20/06/2013	2321.64	162	205	25.40	1.90	27.30
29/08/2013	2395.68	152	205	36.04	1.90	37.93
20/09/2013	2400.80	153	203	34.87	2.33	37.20
22/10/2013	2394.02	159	206	28.36	1.70	30.06
25/11/2013	2389.57	158	215	29.39	0.48	29.87
22/12/2013	2384.52	158	220	29.39	0.15	29.54
25/02/2014	2362.08	152	220	36.04	0.15	36.19
21/03/2014	2353.78	160	221	27.35	0.11	27.46
22/04/2014	2339.18	163	222	24.46	0.08	24.54
21/05/2014	2325.04	159	218	28.36	0.26	28.62
20/06/2014	2309.16	165	218	22.64	0.26	22.89
17/07/2014	2323.62	166	204	21.76	2.11	23.86
20/08/2014	2360.26	164	211	23.54	0.91	24.45
23/09/2014	2379.04	160	218	27.35	0.26	27.61
25/10/2014	2379.04	160	215	27.35	0.48	27.83
24/11/2014	2385.06	160	220	27.35	0.15	27.50
22/12/2014	2381.44	165	221	22.64	0.11	22.75
20/01/2015	2376.94	164	222	23.54	0.08	23.62
24/02/2015	2367.36	165	224	22.64	0.03	22.67
19/03/2015	2361.20	162	219	25.40	0.20	25.60
26/05/2015	2338.32	163	220	24.46	0.15	24.61
18/06/2015	2330.38	161	212	26.37	0.79	27.15
22/07/2015	2354.00	157	207	30.44	1.52	31.96
18/08/2015	2362.86	161	211	26.37	0.91	27.28
22/09/2015	2359.90	160	219	27.35	0.20	27.55

28/10/2015	2361.28	154	216	33.73	0.40	34.13
19/11/2015	2363.06	156	215	31.51	0.48	31.99
21/12/2015	2365.16	161	221	26.37	0.11	26.48
21/01/2016	2360.88	160	221	27.35	0.11	27.46
22/02/2016	2352.48	160	222	27.35	0.08	27.43
22/03/2016	2340.70	165	223	22.64	0.05	22.69
20/04/2016	2328.60	160	222	27.35	0.08	27.43
20/05/2016	2317.64	163	214	24.46	0.57	25.03
20/06/2016	2317.78	164	210	23.54	1.05	24.58
20/07/2016	2339.28	164	215	23.54	0.48	24.02
27/08/2016	2350.70	160	215	27.35	0.48	27.83
24/09/2016	2351.00	160	210	27.35	1.05	28.40
25/10/2016	2348.12	160	210	27.35	1.05	28.40
22/11/2016	2345.78	162	216	25.40	0.40	25.80
19/12/2016	2342.88	159	221	28.36	0.11	28.47
20/01/2017	2338.36	162	221	25.40	0.11	25.51
21/02/2017	2333.90	162	221	25.40	0.11	25.51
21/03/2017	2327.88	160	215	27.35	0.48	27.83
21/04/2017	2314.60	159	219	28.36	0.20	28.56
25/05/2017	2302.38	165	211	22.64	0.91	23.55
21/06/2017	2300.08	168	211	20.06	0.91	20.97
27/07/2017	2319.08	160	213	27.35	0.67	28.03
22/08/2017	2334.58	166	217	21.76	0.32	22.08
19/09/2017	2360.84	157	208	30.44	1.35	31.79
25/10/2017	2371.22	153	216	34.87	0.40	35.27
25/11/2017	2373.98	150	220	38.43	0.15	38.59
18/12/2017	2373.70	160	222	27.35	0.08	27.43
18/01/2018	2368.76	155	220	32.61	0.15	32.76
21/02/2018	2361.34	153	220	34.87	0.15	35.02
22/03/2018	2349.38	218	160	0.26	27.35	27.61
17/04/2018	2339.16	164	219	23.54	0.20	23.74
22/05/2018	2324.26	160	220	27.35	0.15	27.50
20/06/2018	2343.42	161	210	26.37	1.05	27.41
18/07/2018	2378.22	155	211	32.61	0.91	33.52

02/08/2018	2396.10	159	213	28.36	0.67	29.03
03/08/2018	2396.24	162	216	25.40	0.40	25.80
11/08/2018	2401.10	163	213	24.46	0.67	25.13
23/08/2018	2400.56	160	213	27.35	0.67	28.03
13/09/2018	2389.02	158	216	29.39	0.40	29.78
26/10/2018	2388.54	160	221	27.35	0.11	27.46
22/11/2018	2384.84	162	214	25.40	0.57	25.97
20/12/2018	2382.46	163	221	24.46	0.11	24.57
22/01/2019	2376.28	163	224	24.46	0.03	24.49
21/02/2019	2366.76	162	220	25.40	0.15	25.55
20/03/2019	2355.46	163	222	24.46	0.08	24.54
25/04/2019	2338.92	169	212	19.24	0.79	20.03
23/05/2019	2320.62	170	221	18.45	0.11	18.56
21/06/2019	2306.42	174	216	15.46	0.40	15.85
23/07/2019	2312.80	170	204	18.45	2.11	20.55
16/08/2019	2349.44	174	213	15.46	0.67	16.13
21/08/2019	2353.66	170	209	18.45	1.19	19.64
25/09/2019	2375.06	165	214	22.64	0.57	23.21

Table 5.2 Seepage details of Idukki Dam from 2010 to 2019

DIVERSION TUNNEL SEEPAGE MEASUREMENT OF IDUKKI DAM			
Date	**Water level (ft)**	**Seepage (lit/min)**	**Remarks**
18/12/2017	2373.70	313.56	
18/01/2018	2368.76	337.36	
21/02/2018	2361.34	310.96	
22/03/2018	2349.38	303.95	
17/04/2018	2339.16	298.14	
22/05/2018	2324.26	300.38	
20/06/2018	2343.42	312.50	
18/07/2018	2378.22	315.04	
23/08/2018	2400.56	135.59	There is another path seen exposed at the bottom side. Now it can't be measured.
13/09/2018	2389.02	182.18	
26/10/2018	2388.54	337.08	

22/11/2018	2384.84	357.57	
20/12/2018	2382.46	348.33	
22/01/2019	2376.28	353.15	
21/02/2019	2366.76	367.20	
20/03/2019	2355.46	368.66	
25/04/2019	2338.92	359.28	
23/05/2019	2320.62	356.08	
21/06/2019	2306.42	378.55	
23/07/2019	2312.80	383.39	
21/08/2019	2353.66	325.64	
25/09/2019	2375.06	407.19	

Table 5.3 Diversion tunnel seepage measurement of Idukki dam

B-9-4 SEEPAGE MEASUREMENT OF IDUKKI DAM		
Date	**Water level (ft)**	**Seepage (lit/min)**
18/12/2017	2373.70	26.27
18/01/2018	2368.76	25.42
21/02/2018	2361.34	24.79
22/03/2018	2349.38	24.49
17/04/2018	2339.16	23.47
22/05/2018	2324.26	22.73
20/06/2018	2343.42	23.72
18/07/2018	2378.22	25.66
23/08/2018	2400.56	23.70
13/09/2018	2389.02	23.87
26/10/2018	2388.54	23.17
22/11/2018	2384.84	23.22
20/12/2018	2382.46	22.30
22/01/2019	2376.28	22.42
21/02/2019	2366.76	21.63
20/03/2019	2355.46	20.69
25/04/2019	2338.92	19.70

23/05/2019	2320.62	18.52
21/06/2019	2306.42	17.24
23/07/2019	2312.80	17.44
16/08/2019	2349.44	19.54
21/08/2019	2353.66	18.75
25/09/2019	2375.06	21.38

Table 5.4 B-9-4 seepage measurement of Idukki dam

5.1. B Cheruthoni Dam - Instrument Types and Usage

The location of the instruments proposed and provisions given at the time of execution are given below.

Geodetic (Optical) Measurements and Observations

a) Crest Collimation: The displacement of the crest of dam is measured by monthly collimation readings. These observations are accomplished by shifting a movable target on the crest in a direction perpendicular to a fixed line of sight. Forty numbers of targets are installed in various blocks 2, 6, 10, 13, 16, 18, 21, 25, 27, 30, 33 and 37. Photograph reference monument station at Cheruthoni dam is given **Fig 5.6a** and instrument station in **Fig 5.6b** below.

Fig 5.6a Reference monument station for crest collimation at left bank

Fig 5.6b Instrument station for crest collimation at right bank

b) Pendulums - Simple and Inverted Type: There are four simple (upright) pendulums in blocks 16, 21, 27 and 33 with reading stations in intermediate galleries. In addition there is an inverted pendulum in block 21 with reading station at El. 2000. Readings are taken fortnightly. The inverted pendulum, pendulum station and reading station are shown in **Fig 5.7.** Also the anchor point of pendulum at dam top is given in **Fig 5.8.**

Fig 5.7 (a) Inverted Pendulum (b) Pendulum Station (c) Reading Station

Fig 5.8 Anchoring point of pendulum at dam top

c) Precise Leveling: A system of bench marks was established downstream of Idukki dam at a distance of approximately 5 miles, considered to be well outside of the zone of local deformation and they are connected to various points in the Cheruthoni dam galleries. The purpose of precise net leveling is to establish in absolute terms, the vertical deformation of the dam and surrounding area due to reservoir impounding. The measurements are done once in three months by using high precision leveling instrument.

1. Electronic Instruments

a) Strain Meters: 27 groups (135 numbers) of strain meters and 27 stress strain meters are installed to measure the strain at various locations in the dam and to enable computing the principal stresses.

b) Joint Meters: 32 joint meters are installed to measure the construction joint movements in the dam.

c) Deformation meters: 14 deformation meters are installed to measure deformation of foundation.

d) Thermometers: 12 S.T. thermometers, 51 resistance thermometers and 10 water thermometers are installed to measure the concrete and water temperatures.

e) Stress Meters: 27 stress meters (Carlson type) are installed to measure the horizontal and vertical stresses. The readings of all these instruments are taken at specified intervals to study the behavior of the dam.

f) Water Level Recorder: One automatic water level recorder to monitor the variation of the reservoir water level is installed in block 19.

Fig 5.9 Automatic water level reader and manual reading scales

2. Foundations Pressures and Drainage

g) Rock Targets: 17 rock targets are installed in the rock galleries to record horizontal deformation of the foundations and abutments in a plane perpendicular to the galleries. Monthly observations are taken.

h) Piezometric Pressures: 34 uplift cells and 15 uplift holes are installed to measure the volume and uplift pressure of water seeping through the foundation rock and along rock concrete contact from the reservoir and measured at specified intervals.

i) Drainage Flows: V notches, to measure the total volume of water from infiltrations through concrete and through drilled drains are constructed and measured at specified intervals, at foundation gallery at BL.18 - El. 2050', BL.20 - El.2000' and BL.25 - El.2050'

j) Pore Pressure Meter: 9 pore pressure meters and 36 uplift pressure pipes are installed at various locations in the dam to measure infiltration of reservoir water through concrete and measured at specified Intervals.

Fig 5.10 V-notches at foundation gallery at Bl.18, Bl.20 and Bl.25

The status of instrumentation in Cheruthoni dam is given in the **Table 5.5 and seepage details in Table 5.6.**

STATUS OF INSTRUMENTATIONS IN CHERUTHONI DAM			
Sl. No.	**Name of Instruments**	**Total instrument**	**Functioning**
1	Stress meter	20	-
2	Strain meter	27	-
3	Pendulum (4 upright & 1 Inverted)	5	5
4	Joint meter (Electrical)	9	-
5	Thermometers (Vibrating wire type)	63	-
6	Thermometers (Resistance type)	9	-
7	Instrumented Cylinders	7	-
8	Water Thermometer	8	-
9	V Notch	3	3

Table 5.5 Instrumentation Present Status - Cheruthoni Dam

The modernization of instrumentation is being arranged under DRIP as minimum instrumentation required for each dam which include uplift pressure gauges, Plumb line automation, Thermometers, Joint meters, Seismograph and Accelerograph.

SEEPAGE MEASUREMENT OF CHERUTHONI DAM								
Date	Water Level in ft	V-Notch Reading in mm			Seepage in litres/min			Total Seepage in litres/min
		BL-20	BL-18	BL-25	BL-20	BL-18	BL-25	
02/02/2010	2364.20	160	110	115	13.26	154.01	131.06	298.34
20/05/2010	2316.14	151	130	125	25.56	75.025	91.645	192.23
01/06/2010	2312.18	150	131	124	27.23	71.938	95.211	194.37
02/08/2010	2348.82	163	113	112	10.19	139.98	144.57	294.73
13/09/2010	2370.62	160	98	99	13.26	218.42	212.54	444.22
12/10/2010	2383.90	160	94	89	13.26	242.94	275.82	532.03
15/11/2010	2389.78	163	90	70	10.19	269.05	424.41	703.64

27/01/2011	2384.32	160	85	70	13.26	303.95	424.41	741.62
11/02/2011	2377.16	162	99	75	11.16	212.54	381.57	605.26
17/03/2011	2360.92	159	99	77	14.40	212.54	365.19	592.12
27/04/2011	2340.88	158	99	86	15.58	212.54	296.76	524.88
28/05/2011	2319.00	156	112	85	18.14	144.57	303.95	466.65
28/06/2011	2339.22	161	111	87	12.18	149.24	289.68	451.11
26/07/2011	2354.92	160	111	81	13.26	149.24	333.73	496.23
25/08/2011	2379.10	156	98	76	18.14	218.42	373.33	609.88
29/09/2011	2392.24	160	87	71	13.26	289.68	415.62	718.56
31/10/2011	2385.80	159	70	88	14.40	424.41	282.7	721.50
23/11/2011	2385.48	159	72	90	14.40	406.94	269.05	690.38
18/12/2011	2379.28	159	74	95	14.40	389.92	236.67	640.98
28/01/2012	2369.10	165	75	99	8.41	381.57	212.54	602.51
25/02/2012	2354.66	162	78	103	11.16	357.17	189.94	558.27
23/03/2012	2339.84	162	114	88	11.16	135.48	282.7	429.34
30/04/2012	2322.02	157	123	95	16.83	98.859	236.67	352.36
11/05/2012	2318.04	157	124	99	16.83	95.211	212.54	324.58
26/07/2012	2310.68	157	125	98	16.83	91.645	218.42	326.90
24/08/2012	2319.46	160	120	98	13.26	110.3	218.42	341.98
26/09/2012	2332.44	160	110	88	13.26	154.01	282.7	449.98
10/10/2012	2331.68	115	162	90	131.06	11.161	269.05	411.27
15/11/2012	2334.48	109	160	90	158.87	13.263	269.05	441.18
13/12/2012	2331.70	160	110	87	13.26	154.01	289.68	456.96
29/01/2013	2324.88	158	95	120	15.58	236.67	110.3	362.55
15/02/2013	2322.70	155	115	90	19.50	131.06	269.05	419.61
16/03/2013	2317.82	160	125	95	13.26	91.645	236.67	341.57
16/04/2013	2309.90	158	122	95	15.58	102.59	236.67	354.84
17/05/2013	2304.40	159	125	96	14.40	91.645	230.49	336.53
22/06/2013	2319.96	161	125	120	12.18	91.645	110.3	214.13
31/07/2013	2380.44	157	95	86	16.83	236.67	296.76	550.26
31/08/2013	2395.70	157	95	86	16.83	236.67	296.76	550.26
30/09/2013	2399.70	158	83	75	15.58	318.63	381.57	715.78
15/10/2013	2394.26	158	83	75	15.58	318.63	381.57	715.78
26/11/2013	2389.48	155	91	83	19.50	262.37	318.63	600.50
23/12/2013	2384.38	160	95	78	13.26	236.67	357.17	607.10
22/01/2014	2374.38	162	100	80	11.16	206.74	341.44	559.34
25/02/2014	2362.08	161	104	85	12.18	184.53	303.95	500.67
25/03/2014	2352.30	161	114	85	12.18	135.48	303.95	451.61

23/04/2014	2338.40	158	120	90	15.58	110.3	269.05	394.93
23/05/2014	2323.60	155	125	101	19.50	91.645	201.05	312.19
26/06/2014	2313.60	96	128	160	230.49	81.434	13.263	325.18
31/07/2014	2337.00	95	116	163	236.67	126.74	10.191	373.60
25/08/2014	2363.00	95	104	153	236.67	184.53	22.404	443.60
24/09/2014	2378.98	95	153	162	236.67	22.404	11.161	270.23
28/10/2014	2380.52	95	100	160	236.67	206.74	13.263	456.67
25/11/2014	2384.94	91	92	162	262.37	255.8	11.161	529.33
24/12/2014	2381.00	95	97	163	236.67	224.41	10.191	471.26
24/01/2015	2375.90	93	103	155	249.32	189.94	19.498	458.76
25/02/2015	2366.98	95	105	160	236.67	179.22	13.263	429.14
20/03/2015	2360.76	99	105	160	212.54	179.22	13.263	405.01
26/05/2015	2338.32	160	113	103	13.26	139.98	189.94	343.18
18/06/2015	2330.38	90	110	161	269.05	154.01	12.185	435.24
24/07/2015	2356.56	93	103	161	249.32	189.94	12.185	451.45
26/08/2015	2362.76	97	110	163	224.41	154.01	10.191	388.61
24/09/2015	2359.22	99	109	160	212.54	158.87	13.263	384.67
29/10/2015	2361.32	95	105	151	236.67	179.22	25.556	441.44
26/11/2015	2364.16	98	105	163	218.42	179.22	10.191	407.83
23/12/2015	2365.16	95	115	165	236.67	131.06	8.4077	376.14
22/01/2016	2360.58	98	105	160	218.42	179.22	13.263	410.90
24/02/2016	2351.70	93	109	162	249.32	158.87	11.161	419.35
22/03/2016	2340.70	98	113	165	218.42	139.98	8.4077	366.81
30/04/2016	2323.32	97	120	161	224.41	110.3	12.185	346.89
17/05/2016	2317.96	103	124	164	189.94	95.211	9.2739	294.43
28/06/2016	2320.30	100	120	160	206.74	110.3	13.263	330.31
21/07/2016	2339.64	95	116	160	236.67	126.74	13.263	376.67
27/08/2016	2350.70	94	113	162	242.94	139.98	11.161	394.08
29/09/2016	2351.04	107	115	160	168.86	131.06	13.263	313.18
26/10/2016	2347.84	96	115	161	230.49	131.06	12.185	373.74
21/12/2016	2342.56	95	117	161	236.67	122.5	12.185	371.35
21/01/2017	2338.38	96	117	161	230.49	122.5	12.185	365.17
20/02/2017	2334.16	100	120	163	206.74	110.3	10.191	327.24
20/03/2017	2328.16	110	122	162	154.01	102.59	11.161	267.76
21/04/2017	2314.16	116	121	160	126.74	106.4	13.263	246.40
30/05/2017	2301.26	115	130	163	131.06	75.025	10.191	216.28
23/06/2017	2299.96	110	130	160	154.01	75.025	13.263	242.30
28/07/2017	2319.42	105	125	150	179.22	91.645	27.226	298.09

25/08/2017	2337.18	115	121	146	131.06	106.4	34.551	272.02
20/09/2017	2362.12	110	118	149	154.01	118.35	28.959	301.32
26/10/2017	2371.16	98	113	154	218.42	139.98	20.921	379.32
25/11/2017	2373.98	160	105	95	13.26	179.22	236.67	429.14
19/12/2017	2373.58	150	113	164	27.23	139.98	9.2739	176.48
19/01/2018	2368.56	100	105	160	206.74	179.22	13.263	399.22
20/02/2018	2361.74	105	115	155	179.22	131.06	19.498	329.78
23/03/2018	2349.04	110	115	155	154.01	131.06	19.498	304.57
20/04/2018	2337.42	116	150	151	126.74	27.226	25.556	179.52
19/05/2018	2325.78	118	153	154	118.35	22.404	20.921	161.67
21/06/2018	2344.20	113	158	111	139.98	15.585	149.24	304.80
21/07/2018	2383.64	97	159	101	224.41	14.396	201.05	439.85
02/08/2018	2396.12	163	86	86.5	10.19	296.76	293.21	600.16
03/08/2018	2396.24	167	83	88	6.83	318.63	282.7	608.16
05/08/2018	2396.32	160	83	88	13.26	318.63	282.7	614.59
09/08/2018	2398.40	159	83	86	14.40	318.63	296.76	629.79
24/08/2018	2400.00	163	80	89	10.19	341.44	275.82	627.45
31/08/2018	2395.92	162	78	88	11.16	357.17	282.7	651.03
14/09/2018	2388.88	160	88	95	13.26	282.7	236.67	532.63
23/10/2018	2388.58	159	89	86	14.40	275.82	296.76	586.98
23/11/2018	2384.86	160	98	89	13.26	218.42	275.82	507.51
19/12/2018	2382.68	162	95	90	11.16	236.67	269.05	516.87
23/01/2019	2376.06	160	101	90	13.26	201.05	269.05	483.36
22/02/2019	2366.18	160	101	96	13.26	201.05	230.49	444.80
21/03/2019	2354.94	160	100	97	13.26	206.74	224.41	444.41
26/04/2019	2338.40	161	101	96	12.18	201.05	230.49	443.72
24/05/2019	2319.92	166	122	111	7.59	102.59	149.24	259.42
22/06/2019	2306.36	162	132	112	11.16	68.93	144.57	224.66
23/07/2019	2312.80	162	130	112	11.16	75.02	144.57	230.75
21/08/2019	2353.66	158	114	103	15.58	135.48	189.94	341.00
26/09/2019	2375.30	164	109	96	9.27	158.87	230.49	398.63

Table 5.6 Seepage details of Cheruthoni Dam from 2010 to 2019

5.1.C Kulamavu Dam - Instrument Types and Usage

a) Geodetic (Optical) Measurements and Observations

A collimation study of four mobile target stations will be observed along the crest of the dam. In the weak zone in blocks 9 and 10, a settlement study will be done by precise leveling to six reading scales located in the transverse gallery in the foundation mat. The referred benchmarks are located on the downstream side and along the crest. One inverted pendulum and one plumb line are installed in block 9.

b) Electronic Instrumentation

Two joint meters each are installed at Ch. 855 and Ch. 915 between block joints 9A and 9B and 9B and 10.

c) Foundations - Pressures and Drainage

Monitoring of the pressure relief system will be accomplished through a series of observation holes and also by measuring the flow and pressure that may develop in any of the drains. Vertical formed drains ensure drainage of water through masonry or concrete. These 125 mm drains discharge into the gallery system. Similarly the foundation drainage holes also discharge into the gallery system. The discharge will be measured by V notch weirs. One float well for fixing a water level recorder is provided in block 8, Chainage 740.

The status of instrumentation in Kulamavu dam is given in the **Table 5.7** and seepage details in **Table 5.8.**

STATUS OF INSTRUMENTATIONS IN KULAMAVU DAM			
Sl. No.	**Name of Instruments**	**Total instrument**	**Functioning**
1	Pendulum(1 upright & 1 inverted)	2	2
2	Joint meter (Mechanical)	6	6

Table 5.7 Instrumentation Present Status - Kulamavu Dam

SEEPAGE MEASUREMENT OF KULAMAVU DAM (V Notch)		
Date	Water level (ft)	Seepage lit/min
25.06.2009	2305.62	15.75
26.07.2009	2342.82	16.78
20.11.2009	2377.88	118.00
15.03.2010	2345.78	42.51
20.05.2010	2317.14	37.80
20.04.2011	2341.02	22.44
02.05.2011	2338.70	20.51
06.06.2011	2325.56	22.44
23.08.2012	2319.42	42.55
25.09.2012	2332.60	41.96
30.10.2012	2334.56	27.02
29.11.2012	2333.62	48.19
28.12.2012	2329.00	46.04
31.01.2013	2324.68	48.11
27.02.2013	2321.18	40.16
25-03-2013	2315.40	38.08
27.04.2013	2307.90	12.78
17.05.2013	2304.40	9.48
28.06.2013	2336.86	9.48
07.07.2013	2347.28	85.13
10.08.2013	2395.91	192.10
30.09.2013	2399.70	139.99
31.10.2013	2393.64	134.70
22.11.2013	2390.06	152.23
19.12.2013	2385.40	94.41
22.01.2014	2374.38	79.45

19.02.2014	2364.78	68.38
25.03.2014	2364.78	50.46
24.04.2014	2337.74	48.53
23.05.2014	2323.60	47.38
10.06.2014	2311.10	34.13
24.07.2014	2331.38	57.53
22.08.2014	2360.70	74.57
24.09.2014	2378.98	116.00
25.10.2014	2379.24	111.49
21.11.2014	2385.16	116.63
10.12.2014	2382.92	96.68
31.01.2015	2374.48	83.17
26.02.2015	2366.68	64.71
26.03.2015	2357.76	63.13
23.04.2015	2349.48	47.21
20.05.2015	2341.84	47.21
27.06.2015	2342.48	49.50
23.07.2015	2355.16	69.87
21.08.2015	2362.96	72.82
23.09.2015	2359.54	72.36
21.10.2015	2362.22	76.35
17.11.2015	2362.70	75.84
23.12.2015	2365.16	92.64
30.12.2015	2364.68	107.67
27.01.2016	2359.46	107.67
23.02.2016	2352.06	99.71
22.03.2016	2340.70	116.74
26.05.2016	2316.22	145.18

24.06.2016	2319.28	152.96
21.07.2016	2339.64	149.79
24.06.2016	2319.28	152.96
21.07.2016	2339.64	149.79
24.08.2016	2350.40	136.24
22.09.2016	2351.28	135.70
25.10.2016	2348.12	28.75
24.11.2016	2345.48	22.24
22.12.2016	2342.40	29.28
28.01.2017	2337.28	28.32
27.02.2017	2332.12	25.15
27.03.2017	2325.92	21.50
26.04.2017	2312.32	21.19
27.05.2017	2301.68	21.50
28.06.2017	2308.68	21.50
28.07.2017	2319.42	22.20
24.08.2017	2336.60	40.78
26.09.2017	2364.84	89.77
26.10.2017	2371.16	60.49
26.11.2017	2373.92	61.12
26.12.2017	2372.72	67.51
25.01.2018	2367.38	66.10
26.02.2018	2359.30	65.84
23.03.2018	2349.04	64.21
25.04.2018	2335.20	64.21
24.05.2018	2323.36	63.97
28.06.2018	2349.10	98.59
27.07.2018	2392.00	155.51

29.08.2018	2397.36	161.32
27.09.2018	2386.88	160.12
25.10.2018	2388.68	109.99
28.12.2018	2380.88	78.12
28.01.2019	2374.80	77.48
23.02.2019	2365.78	46.77
27.03.2019	2352.12	44.63
27.04.2019	2337.72	47.46
20.05.2019	2322.88	46.05
27.06.2019	2305.88	46.14
26.07.2019	2314.92	48.35
29.08.2019	2358.20	48.35
28.09.2019	2375.68	50.63

Table 5.8 Seepage details of Kulamavu Dam from 2009 to 2019

5.2 Common Monitoring for Idukki, Cheruthoni & Kulamavu

5.2.1 Surveying

In order to provide precise layout and control of structures under SNC's scope of responsibility, viz. Idukki dam and the power system, **triangulation and precise leveling** networks were established by SNC. The coordinate systems for the two areas were kept independent from each other. References for the leveling networks were taken from the benchmarks provided by the "Survey of India", and are above the mean sea level.

A. Idukki Dam

The triangulation network for the layout of the Idukki dam and for the construction control is of the "first order". All stations were built of concrete for permanent service. The coordinates were originally marked in a North-South and East-West system which were later transformed into X-Y system. X and Y axes correspond to the dam axes. This system is used in all construction drawings. Form work, drains and extensometers on each concrete lift were located after establishing a point by intersecting lines from the triangulation system, using

"angles and distances". Benchmark No. 3 of the "Survey of India" (elevation 2003.246) was used as the origin for the precise level network.

B. Cheruthoni Dam

Triangulation network for the layout of Cheruthoni dam is of the "second order". All stations were built of concrete monuments with a punch mark on top of an M.S. rod fixed for permanent service. The coordinates were marked in the X-Y System, X-Y axes corresponding to dam axes. Each contraction joint was marked on masonry/concrete pillars located on the upstream and downstream side of the dam and these were used in setting out construction joints, form work, etc. on each concrete lift.

C. Kulamavu Dam

Triangulation network for the layout of Kulamavu dam is of the "second order". All stations were built of concrete monuments with a punch mark on top of an M.S. rod fixed in each monument. The coordinates were marked on two axes parallel and perpendicular to dam axes. Each contraction joint was marked on the upstream and downstream side of the dam on masonry pillars and these references were used for setting out contraction joints, form work, etc. on each lift.

5.2.2 Rain Gauge Stations

There are 9 rain gauge stations in the vicinity of Idukki reservoir under KSEB Ltd from where readings are being taken. They are:

1. Idukki Station
2. Kattapana
3. Kadamakuzhy
4. Thattathikudy
5. Udumbanchola
6. Aladi
7. Kulamavu
8. Meenmutty
9. Anavilasam

5.2.3 Seismic Net

The Idukki reservoir formed by three high dams and having a water spread area of 60 sq km and storage of about 2,000 million m^3 of water (at F.R.L) exerts a water load of two billion tons on the crust of earth below the reservoir. This extra load would naturally tend to adjust the rock structure beneath and surround the reservoir and may induce certain structural adjustments resulting in seismic activity. An elaborate seismic net is installed for Idukki Project to study the variation in seismicity of the area consequent on the formation of Idukki reservoir. The Idukki seismic net consists of eight seismological stations forming (1) a local strong motion net and (2) a regional net designed for both strong motion activity and micro seismicity.

KSEB Ltd. the owner of four major reservoirs in Kerala, is operating a wide network of 12 seismological observatories viz. Idukki (digital), Kulamavu, Aladi, Pallom, Pamba, Meencut, Idamalayar, Poringalkuth, Sholayar, Kuttampuzha, Chottupara and Vallakadavu since 1969 with year by year expansion after the Koyna Earthquake 1967 and as per BIS recommendations. But the instruments were analogue type and very old and hence digitization became essential. Accordingly utilizing the Chief Minister's Distress Relief Fund, in the first phase existing observatories around Mullaperiyar dam viz, Chottupara, Meencut, Aladi, Kulamavu, Vallakadavu & Pamba are digitized in 2012 along with the rectification works of existing digital Idukki observatory. (Please see **Fig 5.11**)

Also 4 Nos of Accelerographs installed in the galleries and dam top of Idukki arch dam. In addition 1 No Accelerograph installed at Vallakadavu observatory. Accelerographs are inbuilt recorder and sensor for recording the acceleration directly during an earthquake. Accelerographs are installed in dams for studying the response of dams during an earthquake. The data are transferred through central stations round the clock. Central controlling station installed at Vazhathoppe was shifted to Thiruvananthapuram. The seismograph installed at Pamba was shifted to Idukki observatory in 2015 and is in working condition.

Although in the second phase balance observatories and new observatory at Kakkayam were proposed, CWC has proposed to include the minimum seismic instrumentation (including seismic observatories and accelerographs are proposed in all major dams as per BIS guidelines) in consultation with NGRI for all dams under DRIP. Accordingly this is being initiated. Out of the 12 observatories where analogue systems were installed, only Idukki, Kulamavu and Aladi are presently in working condition.

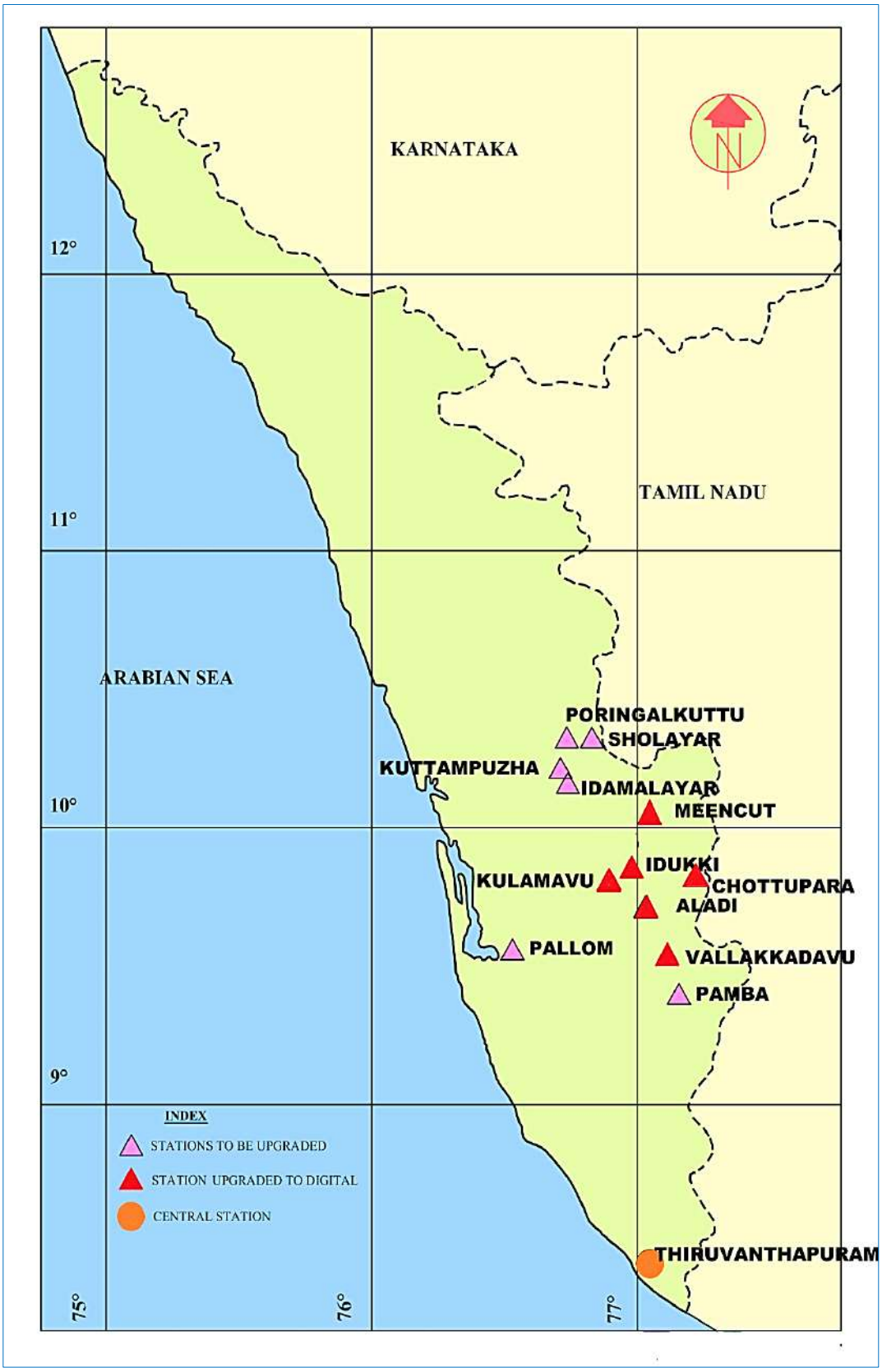


Fig 5.11 Seismic Observatories under KSEB Ltd

5.3 Data Processing and Evaluation

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

5.3.1 Data Collection

On monthly, weekly and daily basis based on the design of instruments and requirements.

5.3.2 Data Presentation & Interpretation

The dam monitoring results are to be interpreted once in a year and report published.

5.3.3 Dam Performance Evaluation

Dam Performance Evaluation is being carried out before and after monsoons in every year.

5.4 Methods of Behavior Prediction

The observations of the above instruments are taken at the intervals mentioned in the manual. The dam monitoring data are being analyzed with the standard or as in the design and the behavior of the dam to various loading conditions; climatic changes and exposure to natural disasters are studied.

5.4.1 Visual Observations

Observations by on site personnel (dam owners/operators and maintenance personnel) may be the most important and effective means of monitoring the performance of a dam. An inspector, upon each visit to the dam site, should examine it visually - walking along the dam alignment and looking for any. Wetting of downstream face and excessive leakage in galleries are noticed during rising and falling of reservoir levels.

5.4.2 Monitoring Results

Various instrumentation monitoring shall be done periodically as required and the results interpreted so as to find any behavioral change is indicated and necessary precautions/remedial measures shall be taken.

Chapter 6

Previous Rehabilitation Efforts

6A. Idukki dam

The dam was commissioned on 12th February 1976 and was functioning normally that no major rehabilitation works carried out.

6A.1 Issues with the dam

Distress noted in the past and remedial measures taken

Idukki Arch dam was being monitored by various instrumentations such as **Embedded** instrumentation and **Geodetic** controls as detailed in **Chapter 5**. It is observed that various instruments installed during construction are not working or not performing to the desired levels. Also working instruments could not be read because of faulty and obsolete readout units. (Please refer **Table 5.1**) On analyzing various instrumentation data, progressive upstream movement of dam crest of the order of 1mm/year as well as progressive crest upheaval are noticed. Also some horizontal structural cracks are seen in the gallery at +2300 level for the entire length of the gallery on the downstream side indicating a zone of tensile stress in the upper gallery and opening of dam block joints on U/S side. Hence study on ***'Investigation of Current Behaviour of Idukki Arch dam'*** was carried out by Central Water Commission involving

- DRIP –CPMU Consultant
- Kerala State Electricity Board
- National Council for Cement and Building Materials: NCCBM, New Delhi
- Geological Survey of India
- Dassault Systems (3D FEM software ABAQUS)
- Ms. Parsons & Ms. FUGRO Geotech Private Ltd. Mumbai
- Updated Geological Assessment by GSI
- LIDAR Survey & Geophysical Investigation

In which 3-D Numerical Modeling of the Arch Dam was done and analyzed with various loading conditions and parameters and the results of the study and investigations were examined by the CWC and Conclusions & recommendations arrived. The Dam was inspected by experts from CWC and DSRP, recommendations given for works/remedial measures to be attempted for improving the structural, safety and security performance of the Dam. Accordingly the following works were carried out under DRIP I.

Rehabilitation Works proposed by CWC after behavioral study

1. Instrumentation

The Project Director (DRIP) and Director (DSR), CWO, vide letter No.16/3/2009-DSRD-256 dated 21.08.2015 has forwarded a proposal for Instrumentation of Idukki Arch Dam in line with the recommendations of the study. It was proposed to install Real Time Structural Health Monitoring & Early Warning System (RTSHM & EWS) at Idukki dam under DRIP which enables to collect hourly, daily, seasonal, yearly data as required through automatic data acquisition system. Automation of instrumentation is very essential for the timely identification of structural problems if any.

Accordingly, the work is arranged which includes the following provisions.

i. Geodetic Equipment: Supplying and installation of Geodetic Equipment ie, Supply and installation of high precision servo driven computer controlled total station, pillar and protective enclosure for total station, data communication radio for total station, monitoring prism with pillar and pillar mounting assembly and monitoring prism with wall mounting assembly, and supply of high precision digital level with leveling rod.

ii. Geo technical Equipments: Supplying and installation of Geotechnical Equipments ie, piezometer, data logger and multiplexer, data communication radio for piezometer data logger, crack meter, automatic pendulum readout, flow meter, temperature sensor, tilt meter, vibrating wire joint meter, data logger and multiplexer for old working meters, vibrating wire water thermometers on the upstream face by suspending from the top and connecting to automatic data acquisition system, supplying new telescope and vernier arrangements for taking pendulum readings to suit the existing reading arrangements, geotechnical sensors and commissioning of data logger one installation per gallery, automatic weather station associated data logger and multiplexer and radio communication equipment, automatic water level recorded associated data logger and multiplexer and radio communication equipment, supply

of rugged hand held mobile, field data logging device with data logging software capable of communication with the dam safety monitoring software.

iii. Dam safety monitoring software: Supplying, installation, configuration and commissioning of dam safety monitoring software and radio communication equipment data linking the sensors.

iv. Control Centre. This consists of supply, installation figuration and commissioning control centre set up which includes servers, display units, IT set up including backup servers etc., preparation of control room including AC & Civil works etc. Surge protection, earthing, lightning protection, integration of old Geodetic & other working Geo technical equipments.

2. Painting the d/s face of Idukki dam with white reflective UV resistant paint: After cleaning the downstream face of the dam by pressure jet washing and the cavities filled with cement mortar 1:3, the downstream side of dam body was painted with white heat reflecting UV resistant paint of two coats. The paint applied has a minimum life period of seven years and hence the repainting need be done in every 7 years. After painting, the arch dam functions well and the movements due to temperature effects are reduced considerably.

3. Filling the hair line crack in the inspection gallery at El. 2300'

A continuous hair line crack of maximum 1.2 mm was noticed at the gallery at El. 2300 feet, downstream face of gallery springing level and at crown level due to differential temperature. The same was rectified as per the directions of expert panels by injecting micro fine cement grout and plastering. Now, no issue of cracks is reported at the rectified portion. However it is being monitored continuously.

6A.2 Other Rehabilitation works

- Painting the targets embedded in the intrados
- Painting steel ladder, steel structures, lift assembly and accessories etc.
- Rewiring of Idukki arch dam Gallery and lighting
- Providing High mast lights to improve security systems at dam premises
- Modernization of OTIS Elevator
- Construction of control room at right bank of dam top
- Construction of security cabin at dam bottom

The photographs showing the DRIP works are given below:

Security cabin at Idukki dam bottom

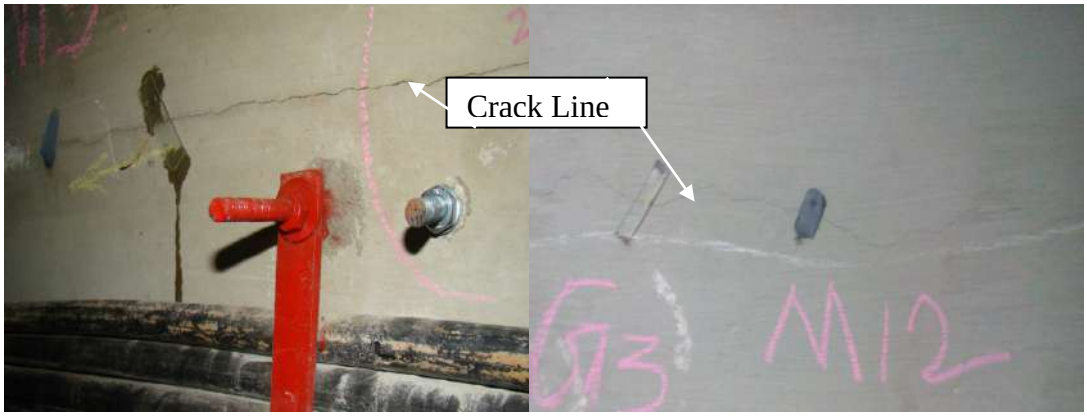
Modification to Elevator

Modernization of Elevator with ARD (power backup) and control systems

Joint Meter Old and New

Crack meter old and new fixed at old cracked wall of gallery at El.2300 ft

Painting the d/s face of Idukki dam



Crack Treatment in Gallery at El.2300 ft (before & After)

Rewiring of Idukki arch dam Gallery

High mast lights in Idukki dam premises

6B. Cheruthoni dam

The dam was commissioned on 1977 and was functioning normally that no major rehabilitation works carried out.

6B.1 Issues with the dam

Cracks noted during Construction and remedial measures taken

A crack extending the full width of outlet opening (13 ft) between El. 2207 ft and El. 2220 ft was noted in block 19 in 1964. The crack was located 75 ft downstream of the axis of the dam. The length of crack at El. 2220 was about 22 ft and about 0.3 mm wide on the surface. The crack was sealed on the surface by epoxy putty, fixing grout nipples at various intervals. Five inclined holes were drilled. The crack was grouted with epoxy through the nipples and holes using a grout gun and epoxy grout pump. About 4600 cc (5 kg) was grouted into the crack i.e. an area of 13 sq metres and 0.35 mm opening. Resin De beckot 505 C a solvent free modified epoxy resin -100 parts by weight and Hardener EH-411. Polyamide Hardener -50 parts by weight are used for the epoxy grout (Suppliers M/s. Dr. Beck and Company Ltd., Bombay-1). Another crack in block 24 - outlet was found to be about a meter in length, very fine and choked with leached lime. The crack did not appear to be deep. A 'V' notch about 2 cm x 2 cm was cut along the crack and sealed with epoxy putty flush with concrete surface.

6B.2 Other Rehabilitation works

- **Reaming of foundation drain holes of dam**

Out of 52 body drain holes 4 is of vertical alignment, the total length of vertical holes reamed using Nx bit is about 180 m, the total length of inclined holes reamed using Nx bit is about 2120 m. 59 foundation drain holes also reamed out of 124. The details of body drain holes reamed are given below:

Details of Reamed Drain holes at Cheruthoni dam			
Sl No.	Designation	Depth Reamed (m)	Remarks
1	6D1	22.70	Gallery No.1
	6D2	23.70	Gallery No.1
3	7D1	27.13	Gallery No.1
4	7D2	26.86	Gallery No.1
5	7D3	25.00	Gallery No.1
6	9D2	27.75	Gallery No.1
7	10D1	28.05	Gallery No.1
8	10D2	24.70	Gallery No.1
9	11D1	25.62	Gallery No.1
10	12D2	25.61	Gallery No.1
11	13D1	34.70	Gallery No.1
12	13D2	35.98	Gallery No.1
13	13D3	38.11	Gallery No.1
14	14D1	40.25	Gallery No.1
15	14D2	47.57	Gallery No.1
16	15D1	48.80	Gallery No.1
17	16D1	54.28	Gallery No.1
18	16D2	57.32	Gallery No.1
19	16D3	57.32	Gallery No.1
20	18D1	64.64	Gallery No.1
21	19D2	70.13	Gallery No.1
22	22D1S	74.09	Gallery No.1

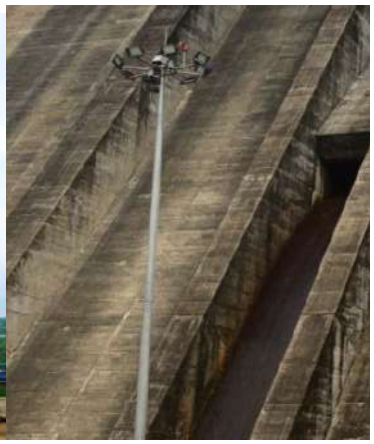
23	22D2	38.80	Gallery No.1
24	22D2S	72.82	Gallery No.1
25	23D2	12.25	Gallery No.1
26	23D3	66.47	Gallery No.1
27	24D2	65.54	Gallery No.1
28	25D1	64.44	Gallery No.1
29	25D2	47.27	Adit Gallery No.3
30	25D3	62.14	Bottom Elevator Shaft
31	25D5	36.28	Adit Gallery No.3
32	26D1	65.54	Lift 1 Gallery
33	26D3	41.46	Lift 1 Gallery
34	27DS1	60.02	Lift 1 Gallery
35	27DS2	59.14	Lift 1 Gallery
36	27D1	34.26	Lift 1 Gallery
37	27D2	34.3	Lift 1 Gallery
38	27D3	55.82	Gallery No.2
39	28D2	34.32	Gallery No.2
40	28D3	38.72	Gallery No.2
41	29D1	44.62	Gallery No.2
42	29D2	56.00	Gallery No.2
43	30D1	57.92	Gallery No.2
44	30D3	49.76	Gallery No.2
45	31D3	42.98	Gallery No.2
46	32D3	44.82	Gallery No.2
47	32D2	30.70	Gallery No.2
48	33D1	43.30	Gallery No.2
49	33D3	38.71	Gallery No.2
50	34D2	33.84	Gallery No.2
51	36D2	24.98	Lift 1 Gallery
52	36D3	22.25	Lift 1 Gallery

- Pressure washing and cleaning dam
- Construction of security guard rooms
- High mast lights to improve security surveillance
- Modernization of existing OTIS Elevator

The photographs showing the DRIP works are given below:

Security Guard Rooms

Pressure washing (before) **Pressure washing (after)**



At Dam top Right bank **At Dam bottom near spillway bucket**

High Mast lights provided at Cheruthoni dam premises

6C. Kulamavu dam

The dam was functioning normally since commissioning, that no major rehabilitation works were carried out.

6C.1 Issues with the dam

The weak zone in the foundation of blocks 9 and 10 during construction was treated as explained in **Cl.1B**

6C.2 Other Rehabilitation works under DRIP

The rehabilitation works carried out under DRIP for Kulamavu dam are

- Cleaning and pressure washing the downstream face
- Construction of a guard room for Kulamavu dam
- Reaming of foundation drain holes: Out of the 39 foundation drain holes, 25 reamed up to 64m depth.
- Formation of new road to intake at Kulamavu
- Improvement of road to Kulamavu dam bottom
- Repairs to sluice gate of Kulamavu dam
- Repairs to intake gate Kulamavu

The photographs showing the DRIP works are given below:

Control room for Kulamavu dam

Guard Room at Intake control shaft

Emergency Gate Hoisting Machine

Emergency gate wire rope

Kulamavu dam Downstream (Before & After)

Emergency gate hoisting machine room

Entrance to Inspection Gallery

Control shaft Intake Gate hoist **Intake Gate Wire Rope**

Chapter 7

Updating the Manual

As features of the dam and appurtenant structures change occasionally, the O&M Manual must be edited and portions rewritten to reflect these changes. 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. Here Idukki HEP has a detailed O & M Manual (Vol 1 & II) prepared by SNC & KSEB in 1977 on completion of the project. As CWC has issued revised guidelines in 2018 for preparing or updating the manual, this updated manual is prepared which is to be referred along with the original.

Aspects to be considered when updating include: Increase/decrease in the frequency of an inspection or the maintenance routine based on additional data/experience acquired, Changes in the operation and/or maintenance procedures based on additional data/experience acquired, Alterations to the project data because of changes/modifications in the dam by way of additional spillway etc.

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