Operation and Maintenance Manual for KAKKI & ANATHODU DAMS State of Kerala

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DRIP Dam Rehabilitation & Improvement Project

KSEB

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Front Cover Photograph: Upstream views of Kakki dam and Anathodu dam

Government of Kerala

Operation and Maintenance Manual

Kakki & Anathodu Dams

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Government of Kerala
Kerala State Electricity Board Ltd
Dam Safety Organisation

Disclaimer

This *Operation and Maintenance Manual for Kakki-Anathodu Reservoir and 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.

Bibin Joseph,
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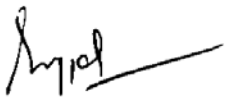
Foreword

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.

Sabarigiri HEP of KSEBL commissioned in 1967 includes 3 main dams and 5 small dams. The main dams are Kakki, Anathode & Pamba of which Kakki is concrete gravity type and the other two are masonry gravity type. The small dams are Upper Moozhiyar, Kullar, Meenar I, Meenar II & Gavi. There are two major reservoirs viz. Kakki-Anathodu and Pamba for this project. Anathodu is the flanking dam of Kakki where the spillway for Kakki-Anathodu reservoir is located. The power house of SGHEP, located at Moozhiyar, generate 340 MW under a net head of 714.76 m. Small augmentation reservoirs Kullar (1990), Gavi (1990), Meenar I (1991) & Meenar II (1991) are serially connected to Pamba reservoir and Upper Moozhiyar (1979) augmenting to Kakki-Anathodu reservoir, after commissioning of the Project. A flow chart of SGHEP is given in the next page for reference. **Kakki and Anathodu** dams of Kakki-Anathodu reservoir under KSEB Ltd do not have a comprehensive Operation and Maintenance Manual. Hence an attempt is made here to prepare the manual as per the new guidelines by CWC.

This Operation and Maintenance Manual is prepared for Kakki and Anathodu dams of Kakki-Anathodu reservoir under SGHEP.

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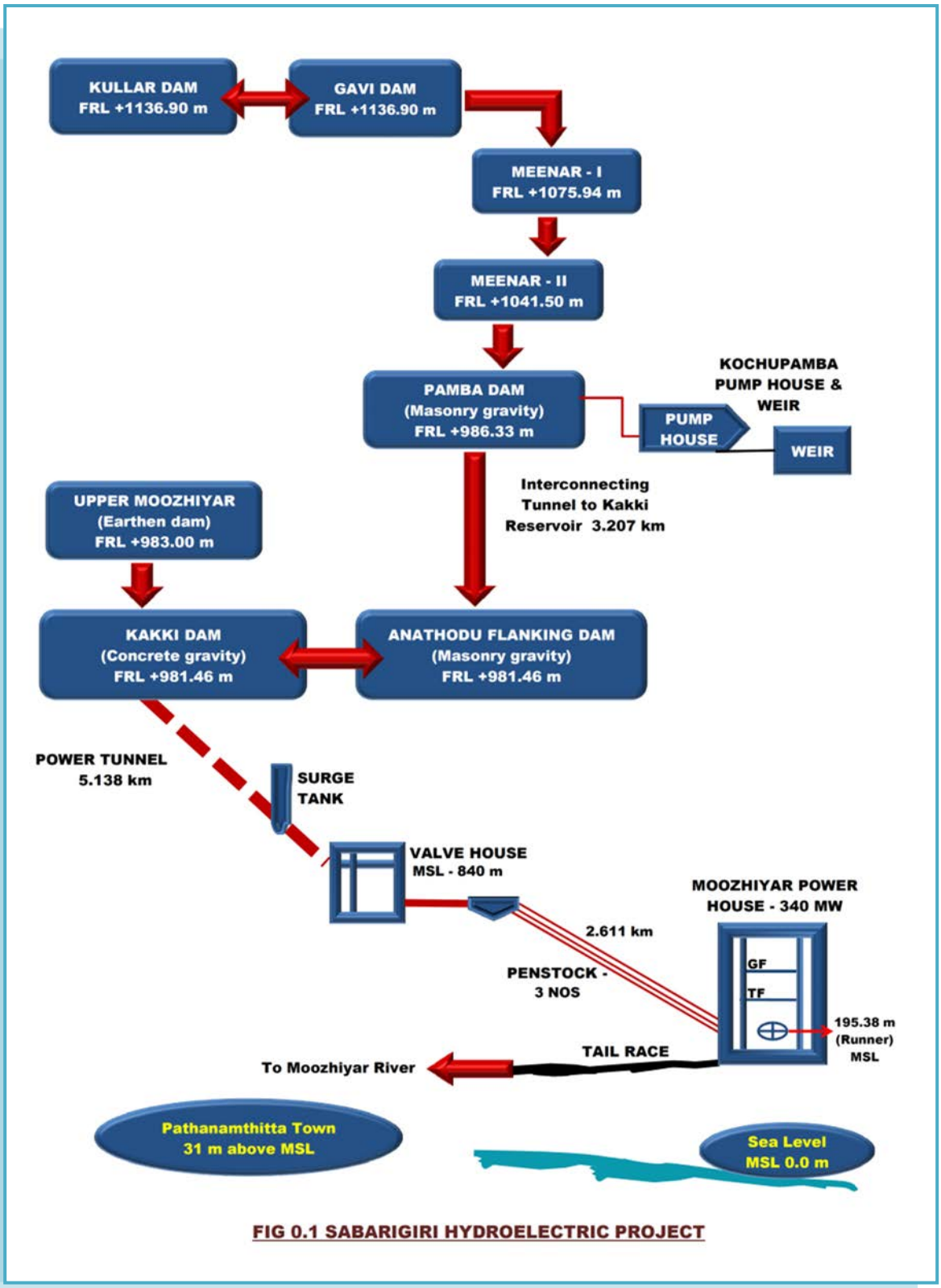

FIG 0.1 SABARIGIRI HYDROELECTRIC PROJECT

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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Chapter 1

General Information

1.1 Introduction

Sabarigiri Hydro Electric Project is the second largest hydroelectric project of Kerala State located in Pathanamthitta District. The catchment area falls between $77^0$6.3'N, $9^0$15'E & $77^0$7.6'N, $9^0$20.8'E. There are two main reservoirs for SGHEP viz. Kakki-Anathode and Pamba, of which Kakki-Anathode reservoir is the largest. This reservoir is formed by the construction of a concrete gravity Dam across Kakki River, a tributary to River Pamba. Anathode is another stream which joins Kakki River downstream of Kakki Dam and before the confluence with Pamba River. A flanking Dam called Anathode Flanking Dam of masonry gravity type is constructed across this stream to form common reservoir with Kakki. The spillway for the reservoir complex is located by the side of Anathode Flanking Dam. Kakki-Anathode reservoir receives water from Pamba reservoir through an interconnecting tunnel. The Power House, of SGHEP is located at Moozhiyar, was designed to generate 300MW under a net head of 714.76m. The construction of Kakki Dam was completed in September, 1966 and Anathode in May 1967. The Power station was inaugurated by Sri V.V.Giri, the then Vice President of India, on 28.08.1967 with an installed capacity of 300 MW. Later, small augmentation reservoirs Kullar-Gavi (1990), Meenar I (1991) & Meenar II (1991) are serially connected to Pamba reservoir and Upper Moozhiyar (1979) augmenting to Kakki reservoir, after commissioning of the Project. The RMU of the Project was undertaken during the period from 2005 to 2009, increasing the installed capacity to 340 MW.

1.2 Purpose, Location, Description of the Project

Sabarigiri Hydro Electric Project Location

The Dams and Power House are situated in Pathanamthitta District, Seethathode Panchayath, Chittar Village (Formally in Kollam District, Pathanamthitta Taluk and Perinad Village) of Kerala State. The only access road to this power house and various dams is passing through the thick forest starting from Angamoozhi to Vandipperiyar (Road from Pathanamthitta-Angamoozhi-Veluthode-Moozhiyar-Kakki-Kochupampa-Gavi-Vandipperiyar-Kumily). Nearest city/town is Pathanamthitta, nearest railway station is Chengannur and

nearest airport is Thiruvanathapuram/Nedumbasserry. The index map and route map of SGHEP are given in **Fig 1.1** and **Fig 1.2**.

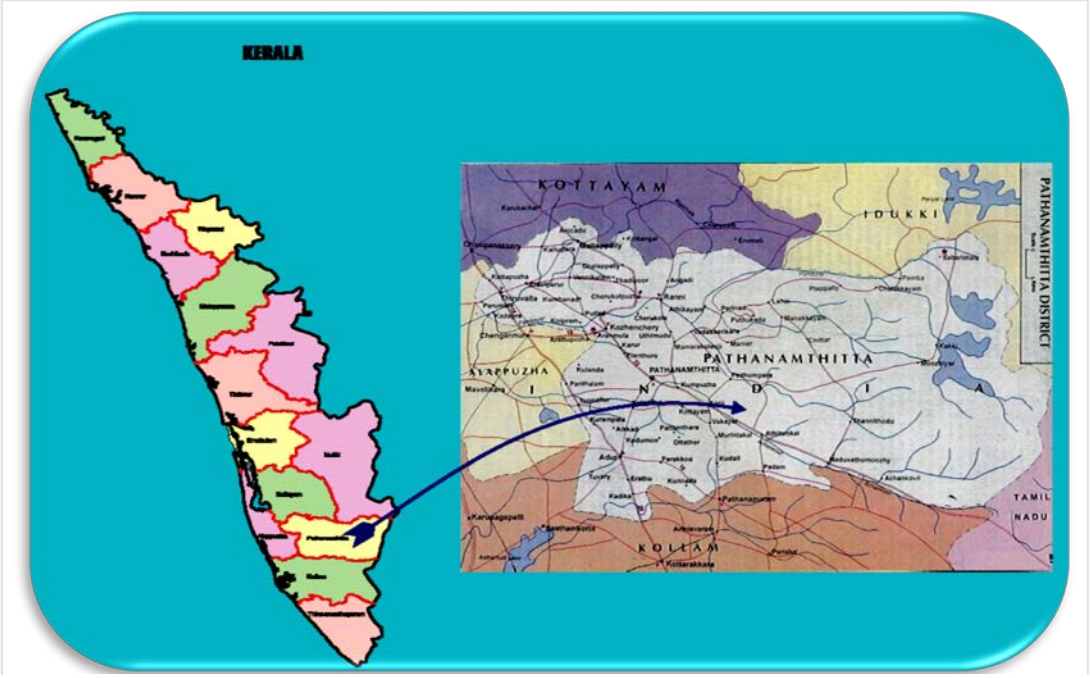

Fig 1.1 Index Map

Fig 1.2 SGHEP Google Route Map

The details of the different engineering structures of the project are:

1. Two main dams, i.e. Kakki dam across river Pamba and Anathodu Flanking dam across Anathodu river (a tributary of Kakki River) to form common reservoir across river Kakki.
2. A tunnel 3.2077 km long to interconnect the Pamba and Kakki reservoirs. A power tunnel 5.138 km long up to the center of the surge shaft starting from Kakki reservoir which form the first part of the water conductor system.
3. A low pressure pipe line 0.409 km long, 3.75 m dia from surge shaft to bifurcation point (where the valve house is located).
4. A set of 3 high pressure surface penstocks about 2.611 km long each bifurcating just above the generating station from where 6 branches are taken to the power house.
5. A power station on the bank of Moozhiyar accommodating six multiple jets Pelton turbine each coupled with a generator of 50 MW with an outdoor switch gear arrangement.
6. A 220 KV double circuit transmission line from the power station with each circuit to Pallom and Kalamassery.
7. One 220 KV DC line and one 220 KV SC line to Edamon.
8. A 220 KV interstate transmission link to Theni.

A schematic diagram of the project is outlined below in **Fig 1.3**.

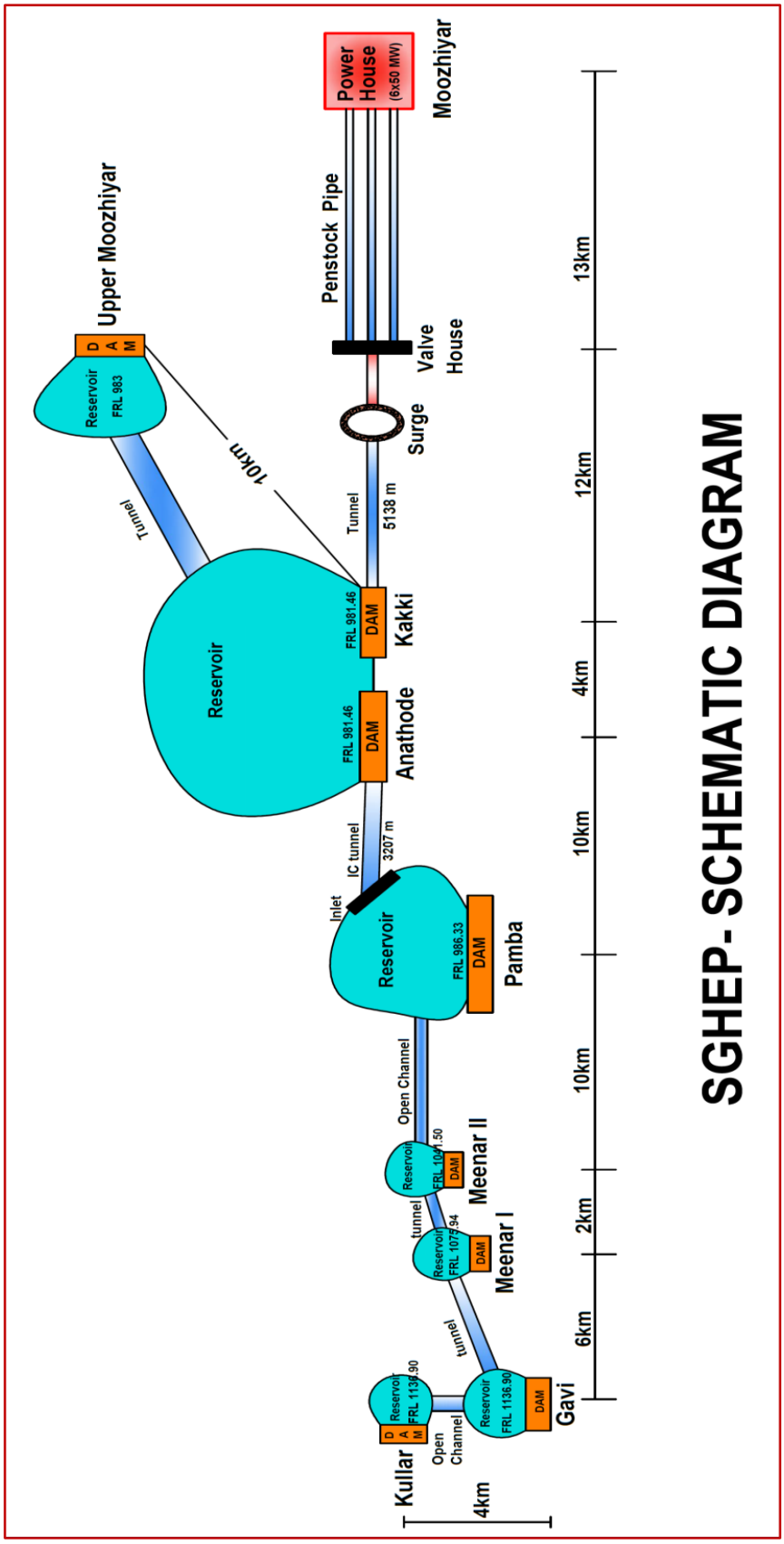

Figure 1.3 Schematic Diagram of the Project

MAIN FEATURES OF SABARIGIRI HEPROJECT			
A	HYDROLOGY AND POWER POTENTIAL		
1	Average Annual rainfall	:	4572 mm
2	Average Annual runoff	:	824.112 Mm^3
3	Average Gross head available	:	762 m
4	Firm power at 100% L.F.	:	152.6 MW
5	Power generation at 60% L.F.	:	254 MW
B	DAM ACROSS PAMBA – **PAMBA DAM**		
1	Bed Level	:	+935.74 m
2	F.R.L	:	+986.33 m
3	M.W.L	:	+986.33 m
4	Top of dam	:	+987.86 m
5	Effective Storage above +963.17 m	:	31.15 Mm^3
6	Length of dam at top	:	281.48 m
7	Volume of masonry	:	0.1529 Mm^3
8	(a) Catchment area at Pamba Dam site	:	72.52 sq km
	(b) Diversion catchment	:	18.28 sq km
9	Design Flood	:	911.8m^3/s
10	No. and size of radial gates	:	6 Nos of 7.01 m x 4.88 m
11	Length of Spillway	:	54.25 m
12	Height of dam above river bed	:	52.15 m
13	No. and dia. of outlet	:	1 No, 1.83 m
14	Discharge through outlets	:	29.17 m^3/s at F.R.L.
15	El. of sill of outlet	:	+958.29 m
16	El. of sill of interconnecting tunnel	:	+963.17 m
17	Dead storage below +963.17 m	:	8.07 Mm^3
18	No. of Adits to foundation gallery	:	2 Nos; one in each flank
C	FLANKING DAM FOR KAKKI-ANATHODE RESERVOIR AT **ANATHODE**		
1	Lowest level of saddle	:	+949.45 m
2	F.R.L.	:	+981.46 m
3	M.W.L.	:	+982.16 m
4	Top of Dam	:	+984.50 m
5	Length of Dam at Top	:	376.12 m
6	Height of Dam above saddle	:	35.05 m
7	No. of Adits to foundation gallery	:	2, one on each flank
8	Catchment area for Kakki Reservoir at Kakki Dam site	:	217.47 sq km
9	Width of roadway at top of dam	:	3.66 m

10	Width of foot path	:	0.91 m
D	SPILLWAY FOR KAKKI-ANATHODU RESERVOIR AT FLANKING DAM AT **ANATHODE**		
1	Location	:	On right side of Anathode Dam
2	Flood discharge	:	1784.16 m^3/s
3	Width of Spillway	:	59.13 m
4	Length of Spillway Channel	:	149.35 m
5	No. and size of radial gates	:	4 Nos. 12.80 m x 6.10 m
6	Slope of Spillway Channel	:	1/100
7	El. of Spillway Crest	:	+975.36 m
8	Clear roadway at Spillway bridge	:	4.572 m
9	El. of the top of Hoist Bridge	:	+992.58 m
10	Total width of Hoist Bridge	:	3.66 m
E	**KAKKI DAM**		
1	Bed Level	:	+874.78 m
2	F.R.L.	:	+981.46 m
3	M.W.L.	:	+982.16 m
4	Top of Dam, Road Level	:	+984.50 m
5	Height of dam above river bed	:	109.73 m
6	Effective Storage above El. 908.30 m	:	446.54 Mm^3
7	(a) Catchment area at Kakki Dam site	:	217.47 sq km
	(b) Diversion catchment	:	7.77 sq km
8	Length of Dam at Top		336.19 m
9	No. of outlets	:	2 each controlled by 1.37 m dia Hollow Jet valves
10	Size and type of emergency gates for each outlet	:	2.9 m x 1.52 m gates hydraulically operated from dam top using 10 T service hoist
11	El. of sill of outlets	:	+896.11 m
12	Max. computed combined discharge through two outlets under F.R.L. Condition	:	84.95 m^3/s
13	Width of roadway over top of dam	:	3.66 m
14	Size of elevator shaft	:	2.16 m x 2.54 m
15	No. of Adits to foundation gallery	:	3 nos. two on the right bank and one on the left bank
16	No. of drift tunnels driven on the banks	:	4 nos. two on each bank
F	INTERCONNECTING TUNNEL (PAMBA-KAKKI)		
1	Length of tunnel	:	3207.72 m
2	Excavated area	:	15.87 m^2

3	Finished area	:	12.14 m^2
4	Sill level of tunnel at inlet	:	+963.17 m
5	Sill level of tunnel at Exit	:	+955.55 m
6	Max. discharge capacity	:	70.8 m^3/s
7	Lining Thickness	:	20 cm
8	Max. velocity	:	5.87 m/s
G	POWER TUNNEL		
1	Length of tunnel	:	5137.71 m up to surge shaft
2	Area of excavation	:	22.77 m^2
3	Finished area	:	16.42 m^2
4	Sill level at inlet	:	+900.68 m
5	Lining Thickness	:	30 cm
6	Design maximum Flow	:	54.37 m^3/s
7	Velocity	:	3.29 m/s
H	SURGE SHAFT		
1	Main Barrel		
	(a) Diameter	:	7.62 m
	(b) Depth	:	106.68 m
2	Top Expansion Chamber		
	(a) Diameter	:	13.72 m
	(b) Depth	:	25.91 m
3	Surge gallery at Bottom		
	(a) Diameter	:	6.71 m (Main Gallery)
			4.57 m (Spokes)
	(b) Length	:	106.68 m (Main Gallery)
		:	30.94 m each (Spokes)
I	PENSTOCKS		
1	L.P.P. (Low Pressure Pipe)		
	(a) No. of Pipes	:	1 No.
	(b) Diameter (External)	:	3.75 m
	(c) Thickness	:	1" to $1^1/_8$" (0.0254 m to 0.0285 m)
	(d) Length of Pipe	:	409.25 m
	(e) Gradient	:	1 in 100
2	H.P.P. (High Pressure Pipe)		
	(a) No. of Pipes	:	3 Nos.
	(b) Diameter of each pipe up to		
	Anchor 9	:	2100 mm (ext.)
	A 9 to A 19A	:	2050 mm (ext.)

	A 19A to A 20	:	1950 mm (ext.)
	A 20 to bifurcation	:	1850 mm (ext.)
	Bifurcation to Turbine inlet	:	1350 mm (int.)
	(c) Length of each pipeline		
	(i) 2604.365 m		
	(ii) 2595.791 m		
	(iii) 2593.075 m		
J	POWER HOUSE		
1	Gross head available	:	762 m
2	Power House Floor level	:	+199.95 m
3	Centre line of runners	:	+195.38 m
4	Installed capacity	:	6 x 50 MW
5	Size of Machine Hall	:	103.63 m x 18.90 m
6	Size of Control Annexe	:	12.34 m x 26.82 m
7	El. of Switchyard	:	+208.79 m
8	El. of Feeder Bays	:	+220.68 m
9	Floor level of Tailrace culverts	:	+191.41 m (av)
10	Turbines	:	Pelton type, 6 Nos each of 50MW capacity
11	Step up transformers 11 KV/220 KV	:	Three Nos. Single Phase transformers of capacity 18500 KVA for each generator
12	Transmission Lines 220 KV	:	1 double circuit line to Pallom & Kalamassery, 1 single circuit line to Theni (T.N.), 1 single circuit line to Edamon, 1 Double circuit line to Edamon.

The Reservoirs

Two reservoirs in Pamba Basin, viz. Pamba & Kakki-Anathodu, contribute the water required for operation of the project. Both the reservoirs are boosted again by constructing Augmentation schemes. The layout map of the project and reservoirs under the project are shown in **Fig 1.4** and **Fig 1.5**.

1) Pamba Reservoir

This reservoir is formed by the Pamba dam constructed across Pamba River. The water from this reservoir is taken to the Kakki-Anathodu reservoir through an underground interconnecting tunnel of D-shape 3.6 m x 3.6 m and 3207.7 m long, from there it is conveyed to the power house located at Moozhiyar under a net head of 714.76m through Power tunnel

5137.71 m long. The inlet & exit sill of IC tunnel are at + 963.168 m and + 955.55 m and Pamba reservoir can rise up to an FRL of + 986.33 m. There are also a few number of small dams constructed across nearby rivulets to divert the discharges into this reservoir**.**

a. Augmentation dams of Pamba reservoir

1) Kullar, 2) Gavi, 3) Meenar-I, and 4) Meenar-II

In addition, pumping scheme from Kochu Pamba weir is also constructed at the downstream of Pamba dam and water pumped in to this reservoir using Pumps.

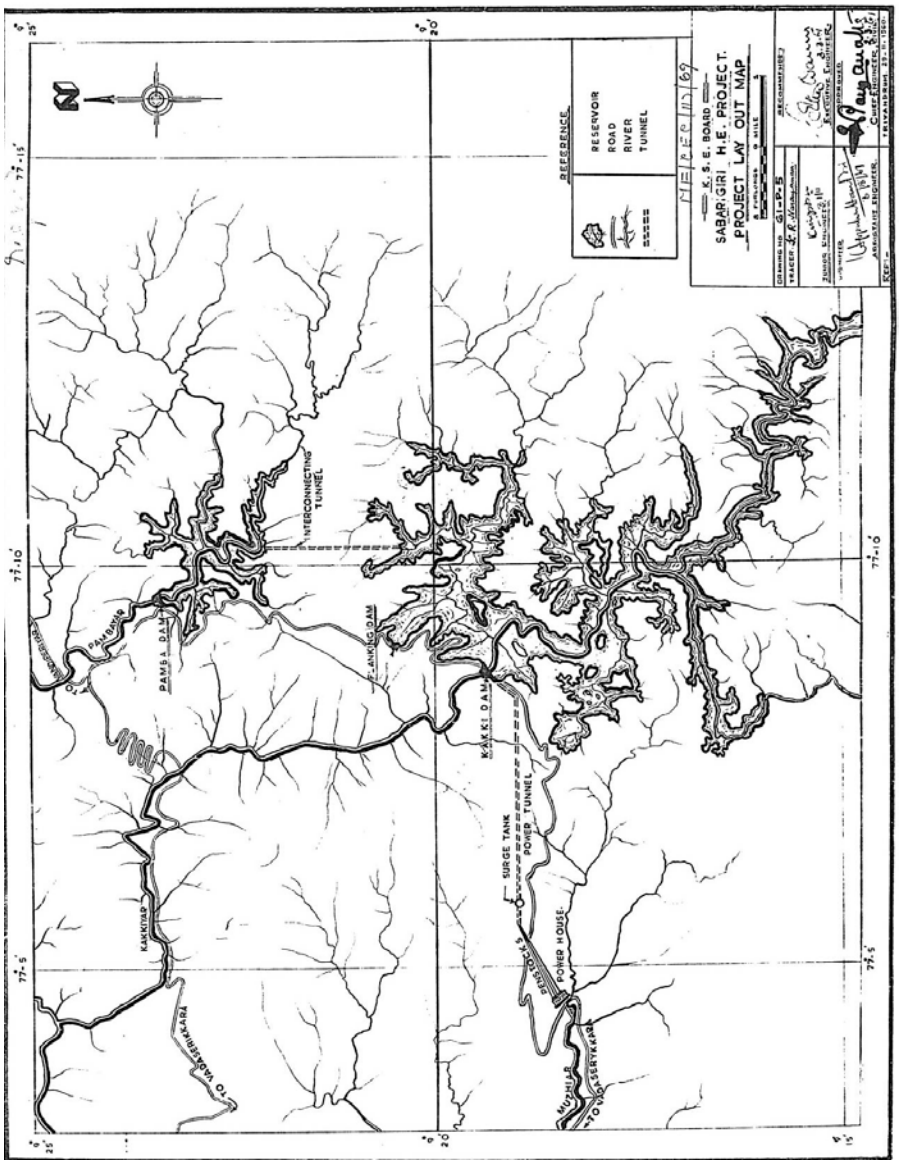

Fig 1.4 Layout Map of SGHEP

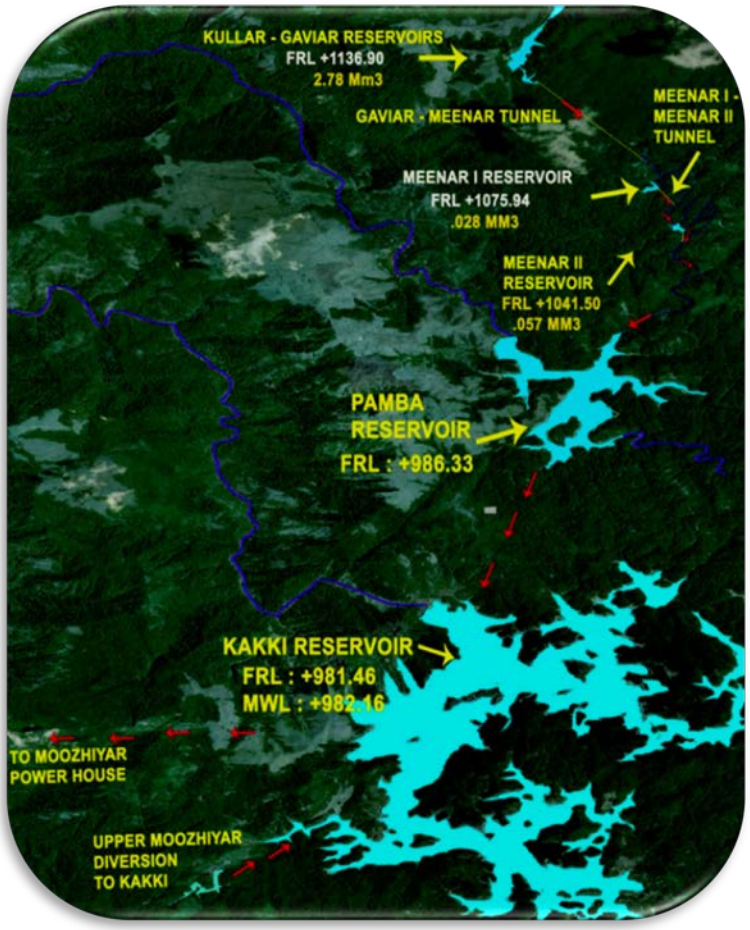

Fig 1.5 Reservoirs under SGHEP

2) Kakki – Anathode Reservoir

Kakki and Anathode are the major tributaries of Pamba River in the upstream reaches. Kakki River originates at an altitude of + 1760 m at Urani in DevarMala. Anathode originates at an altitude of + 1816 m at SundaraMala. The catchment area is delineated from the Periyar lake catchment by a ridge. This reservoir is formed by construction of a dam across Kakki River. The water received from the Pamba reservoir and the rainfall received in its own catchment area form the water resource of this reservoir. The intake of the Powerhouse is from this reservoir. There is a flanking dam at Anathode named as Anathodu Flanking Dam with details as below. Gates for flood releasing of Kakki-Anathode reservoir is provided at Anathodu Dam.

1.	Water Spread Area	17.6 sq km
2.	Catchment Area	225.33 sq km (Kakki: 217.56 sq km and Upper Moozhiyar: 7.77 sq km)
3.	Average Rainfall	4572 mm
4.	Full Reservoir Level (FRL)	+ 981.46 m above MSL
5.	Minimum Drawdown level (MDDL)	+ 908.30 m above MSL
6.	Effective Storage at FRL	454.20 Mm^3
7.	Gross head at power house	762.00 m

b. Augmentation Dam of Kakki - Anathode reservoir

Upper Moozhiyar Dam is the Augmentation dam of Kakki reservoir.

Power House

The SGHEP Power House is constructed at Moozhiyar, Seethathodu village, Konni Taluk around 60 km from Pathanamthitta. The Power Station was commissioned during 1967 with Six Generating units having vertical shaft Pelton turbine coupled to generating units of 50 MW capacities each. After power generation, water from the power station is released to the Moozhiyar reservoir. Google view of SGHEP power house is shown in **Fig 1.6.**

Commissioning details of the units

Unit	Rating	Date of Commissioning
U # 1	50 MW	18.04.1966
U # 2	50 MW	14.06.1966
U # 3	50 MW	29.12.1966
U # 4	50 MW	22.06.1967
U # 5	50 MW	09.09.1967
U # 6	50 MW	26.11.1967

RMU works were undertaken in the Power Station from 2005 to 2009. Capacity of units 4 and 6 were enhanced by 10 MW each and all other units by 5 MW each. Thus the total installed capacity of the station became 340 MW. The details of renovated units are as below:

Installed capacity : 340 MW

Firm annual generation capability : 1338 MU

Unit	Rating	Date of Commissioning
U # 1	55 MW	03.12.2009

U # 2	55 MW	07.02.2009
U # 3	55 MW	17.03.2008
U # 4	60 MW	06.05.2014
U # 5	55 MW	05.05.2006
U # 6	60 MW	01.07.2005

Fig 1.6 Sabarigiri Power House Google View

Tail Race Schemes

There are 5 other Power generating stations in the Tail race of Sabarigiri Power House.

1. Kakkad Power House
2. Ullumkal Power House
3. Karikkayam Power House
4. Carborandom HEP
5. Ranni-Perinad Power House.

Pamba Irrigation Project (PIP) uses water from the left bank of Maniyar Dam and Carborandom SHEP at D/S of Maniyar Dam take water from right bank of Maniyar Dam. Pamba Irrigation Project starts from Maniyar and passes through so many areas of Pathanamthitta & Alappuzha Districts.

There are so many water supply schemes running in the tail race of SGHEP from Seethathode to Kuttanad. One of the most important benefits of the project is that it releases fresh water throughout the year and protect the water supply schemes and peoples living along the river side from Moozhiyar to Kuttanad area. The Kakki-Anathodu reservoir also a good flood control system from Moozhiyar to Kuttanad area. The scheme also protects the Kuttanad area from back water effect of Arabian Sea by supplying fresh water throughout the year.

1.3 Background Details of the Project

The Pamba-Kakki scheme was conceived in different ways at different periods. The earliest report on the scheme was prepared in 1946 by the Public Works Department (PWD). In 1955 another scheme with the power station located at the right bank of Kakkiar was prepared. The Planning Commission approved a part of the scheme in 1958. Even when this scheme was sanctioned by the Planning Commission, there was a proposal for developing power from the combined Pamba-Kakki catchments in one stage. But because of objection raised by the Tamil Nadu government the Planning Commission did not give approval to this proposal (Project Report on Pamba-Kakki Scheme, 1960). Hence the State Government had to satisfy itself with the first stage of the scheme.

When the preliminary work on the first stage was in progress during July 1959, the scope of the project was changed so as to combine the first stage and second stage by locating the generating station at the banks of Moozhiyar. Consequently, works sanctioned in the first stage are delayed.

A new proposal was sent to the Planning Commission and the Commission granted sanction to the scheme in August 1960, at an estimated cost of Rs.24.91 crores, in spite of the objections raised by Tamil Nadu. The KSEB gave administrative sanction to the project in August 1961. The loan agreement for the project was signed between the U.S and India in 1962.

a. Date of Starting the construction : 1960

b. Date of Completion : 1967

c. Name of Designing Agency : KSEB Ltd

d. Name of Contractor : M/s HCC Ltd., Bombay (Kakki)
Sri. B M Edward, Cochin, Kerala (Anathodu)

e. Major accidents/incidents if any : No major accidents reported during construction

1.4 A Salient Features of Kakki Dam

Items	Description
Type of dam	Concrete gravity
Catchment Area	225.33 Sq km including Upper Moozhiyar.
Length of Dam	336.19 m
Number of Blocks	22 (21+1 Abutment)
River Bed Level	874.78 m
Top level of dam (Parapet top)	985.49 m
Dam Top	984.50 m
Maximum Water Level (MWL)	982.16 m
Full Reservoir Level (FRL)	981.46 m
Minimum Draw down Level (MDDL)	908.304 m
Intake Tunnel Bottom	900.684 m
Height Above deepest foundation	116.12 m
Height Above river bed	109.72 m
Sluice Valve	2 Nos. Hollow jet Valve 54" (Electric & Manual Operation) (Pipe dia. 6'0")
Emergency Gate for Sluice Valve	2 Nos. (Hydraulic operation)
No an size of radial gates	No Gate at Kakki
Sill Level of Sluice	896.112 m
Maximum spillway discharge at FRL	1784.16 m^3/s
• Gross storage at FRL	454.20 Mm^3
• Gross storage at MWL	466.72 Mm^3
• Dead Storage (at MDDL)	7.605 Mm^3
• Water spread area at FRL	17.512 Sq km

Kakki dam is a straight gravity concrete structure 360 ft (109.728 m) high above nominal bed level of the river at site and involves about 256 lakhs cft (0.7249 Mm^3) of concrete. The concreting of this dam was completed in record time of 2 years. The work was given on a single contract to M/s Hindustan Construction Company, Bombay. The contract was awarded in

January 1962 but on account of the delay in getting some important items of construction equipment, the concreting could be commenced only in January 1964. Google map view of Kakki dam is shown in **Fig 1.7**.

Fig 1.7 Google map view of Kakki dam

The dam is divided into 22 blocks of average 50' (15.24 m) length. The lengths of the blocks are varying from 36' to 64'. Blocks 1 to 7 are on the left flank, 8 to 10 in the river bed and 11 to 22 in right flank. The block joints have been located with reference to the triangulation stations. Each block is separated from one another by clean contraction joints with copper sealing strips at the upstream. Drawing showing the plan of the dam with division of blocks, Adits, hoist, hollow jet valves, lift tower location are given in **Drg 1.1** of **Annexure 1**.

Drawings showing downstream and upstream sectional elevation of the dam are given in **Drg 1.2** and **Drg 1.3** of **Annexure 1**. Photographs showing upstream elevation, dam top and downstream elevation of Kakki dam are given in **Fig 1.8a** and **Fig 1.8b**.

Fig 1.8a Downstream Elevation of Kakki dam

Fig 1.8b Dam Top and Upstream Elevation of Kakki dam

Galleries

There are 3 nos. galleries within the dam out of which the bottom most (foundation) one is the drainage gallery and the other two are inspection galleries as in **Fig 1.9**. The size of the drainage gallery in section is 5'0" x 5'0" square with 2'6" radius semi-circle at the top of the

square section with suitable slopes and the 3 galleries form a length of about 3500' including the transverse galleries. A cross-sectional elevation of Kakki dam is given below in **Fig 1.9.**

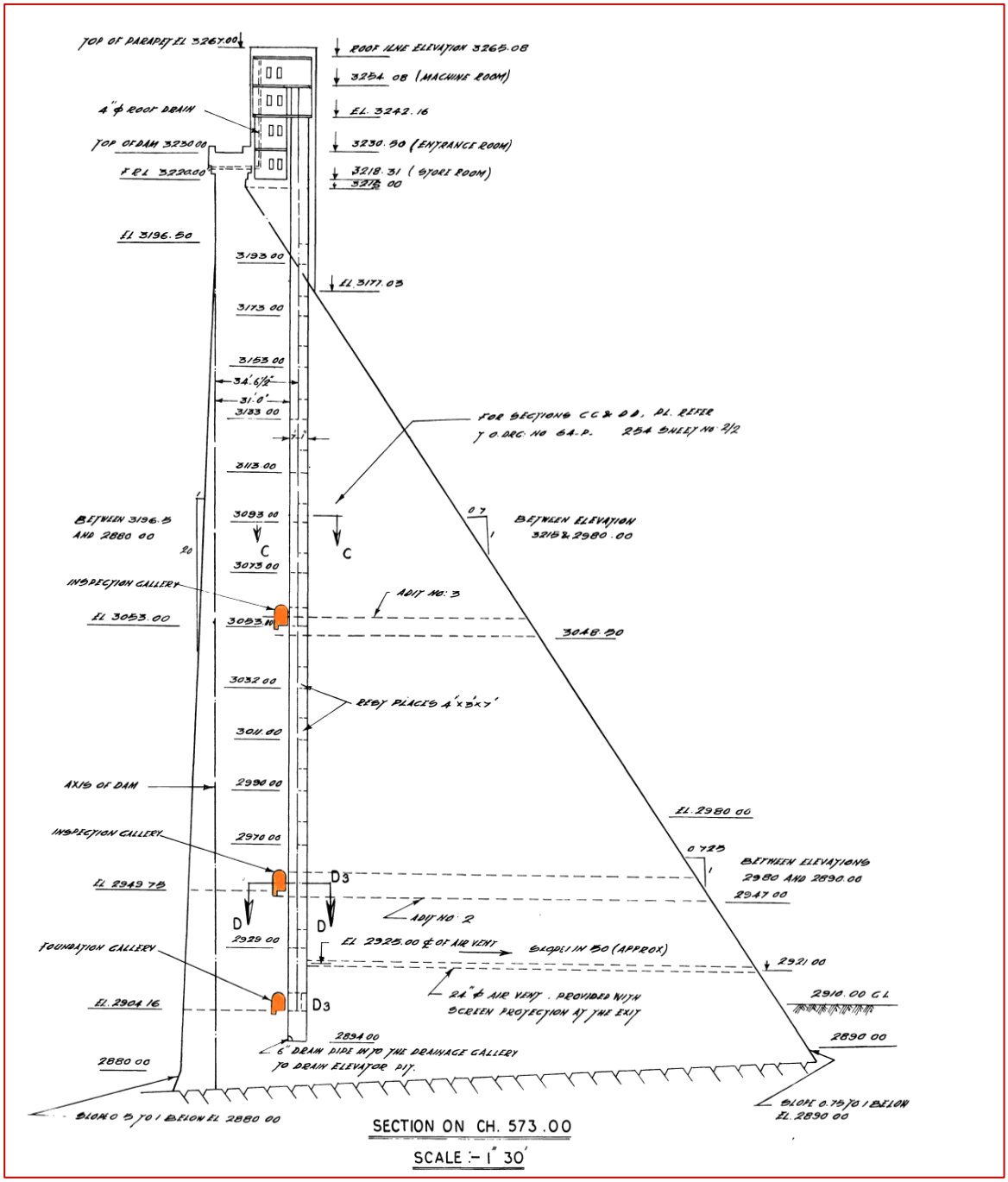

Fig 1.9 Cross-sectional elevation of Kakki dam

Elevator Tower

Kakki dam is provided with an Elevator Tower as in **Drg 1.1** of **Annexure 1** in Block no. 11 at Ch. 573 connecting foundation gallery 2904.16 ft and inspection galleries at 2949.75 ft & 3053.00 ft. The lift operation tower is also provided connecting the lift well 3218.31' to 3242.16' with sufficient space in each floor 3218.31', 3230.50', 3254.00' for storage, entrance, machine room respectively. But lift could not be installed so far and this is proposed under DRIP. A photograph of elevator tower is given **Fig 1.10**. Drawings showing sectional elevation from top, downstream elevation, end elevation and plan at different levels of elevator tower are given in **Drg 1.4, Drg 1.5, Drg 1.6** and **Drg 1.7** of **Annexure 1.**

Fig 1.10 Elevator Tower at Kakki Dam

River Diversion

The original course of the river was mainly along blocks 9 and 10 of the dam. A portion of block 8 on the left bank and block 11 on the right bank were also in the river course even during the normal flow of river. During concreting of the dam, a construction sluice of size 12' x 14' (12' x 8' rectangle with 12' dia. semi-circle at top) was provided in block no 8 between levels 2875' and 2889'. The river was diverted through this construction sluice during May 1964. The flow in the river during the monsoon of 1964 was allowed to spill over the low blocks 9, 10 and 11 which were at levels 2890', 2895' and 2900' respectively. By September 1964, when the concrete works resumed, the entire flow was through the construction sluice.

1.4 B Salient Features of Anathodu Dam

	Name of Dam	Anathode Flanking
I	**General**	
a.	Reservoir Name	Kakki-Anathodu
b.	State	Kerala
c.	District	Pathanamthitta
d.	Block/Tahsil/Mandal	Ranni
e.	Village	Chittar
f.	River	Kakki
g.	Latitude	$9^0$20'30"N
h.	Longitude	77°9'00"E
II	**Hydrology**	
a.	Catchment area	225.33 Sq km
b.	Designed flood adopted	1784 m^3/s
III	**Reservoir**	
a.	Top bank level of dam	984.50 m
b.	Maximum water level	982.16 m
c.	Full reservoir level	981.46 m
d.	Minimum draw down level	908.304 m
e.	Capacity at F.R.L	454.20 Mm^3
h.	Free Board over F.R.L	3.05 m
i	Free Board over M.W.L	2.34 m
j	Year of completion	1967
IV	**Dam (Masonry-Gravity)**	
d.	Maximum height of dam from deepest foundation	51.8 m
e.	Top width of dam (Road way)	3.96 m
V	**Spillway**	
a.	Location	Right Bank
b.	Type	Ogee shaped
c.	Width of spillway	59.13 m
d.	Length of Spillway channel	Chute 149.35 m
e.	Crest level	975.36 m

f.	Spillway discharge capacity	1784 m^3/s
g.	No. type and size of gates	4 Nos. 12.8 m x 6.1 m, Radial
VI	**Foundation**	
a.	Foundation gallery	One on each flank
b.	Drainage gallery	5' x 7'6", top semicircular
c.	Grout holes	2 1/2 " – 15' apart
d.	Drain holes	3" dia. @ 20' c/c
e.	Construction joints	@ 90 ft c/c
f.	Base width	128.325' at El.+3060' 135.825' at El.+3050'
g.	No of blocks	13

Anathodu dam is the Flanking dam for Kakki-Anathodu reservoir and is located at about 4 km NE of Kakki dam. This is a low saddle, which on closing got the capacity of the Kakki reservoir 4 times, where the spillway is provided due to the steep slope of d/s of Kakki dam. The FRL and lowest bed level are 981.46 m and 949.45 m respectively. Photograph showing upstream and downstream elevation of Anathodu dam are given in **Fig 1.11a** and **Fig 1.11b**.

Fig 1.11a Upstream Elevation of Anathodu Dam

Fig 1.11b Downstream Elevation of Anathodu Dam

The peculiar nature of this dam is that it is neither an arch dam nor a straight dam. The two banks are joined by straight blocks and the central portion i.e. a length of 106.68 m is connected by a curve of 259.77 m radius. The dam is of gravity in rubble masonry. The spillway is located on the right bank side of the dam. To accommodate traffic, abridge is constructed with same top width as dam proper. The hoisting machineries are erected on a RCC bridge at a higher elevation parallel to the road bridge with suitable access by steps from Road Bridge.

The flanking dam Anathodu is 54.86 m high and has 13 blocks starting from left abutment, block no.1 is of 36.58 m length, block 2-12 is 27.43 m long and block no.13 is of 37.80 m length. The total length of the dam at road level is 376 m. The spillway is located near the right abutment. Google view of the dam is given in **Fig 1.12**. Sectional plan of Anathodu dam showing right flank and left flank are shown in **Drg 1.8a** and **Drg 1.8b** of **Annexure 1**. The upstream and downstream sectional elevations of the dam are given in **Drg 1.9a** and **Drg 1.9b** of **Annexure 1**.

Fig 1.12 Google map view of Anathodu dam

100 no of boreholes were drilled and investigation done to identify the suitable location for the flanking dam. On close study of the site by geologist, a proximity of a shear zone identified at the left abutment side. Detailed studies were carried out and finalized the location and type of dam avoiding the shear zone maximum and containing the shear zone maximum in one block i.e. **Block No.5.** The profile of the dam is designed as a gravity section based on middle third rule. Uplift is assumed at 100% of hydrostatic head at heal, reducing to zero at toe. All the weak zones met with were treated at foundation level with curtain grouting.

Given below in **Fig 1.13** is a cross-sectional elevation of Anathodu dam. **Drg 1.10a** and **Drg 1.10b** of **Annexure 1** give details of various blocks with foundation treatments like curtain grouting and consolidation grouting.

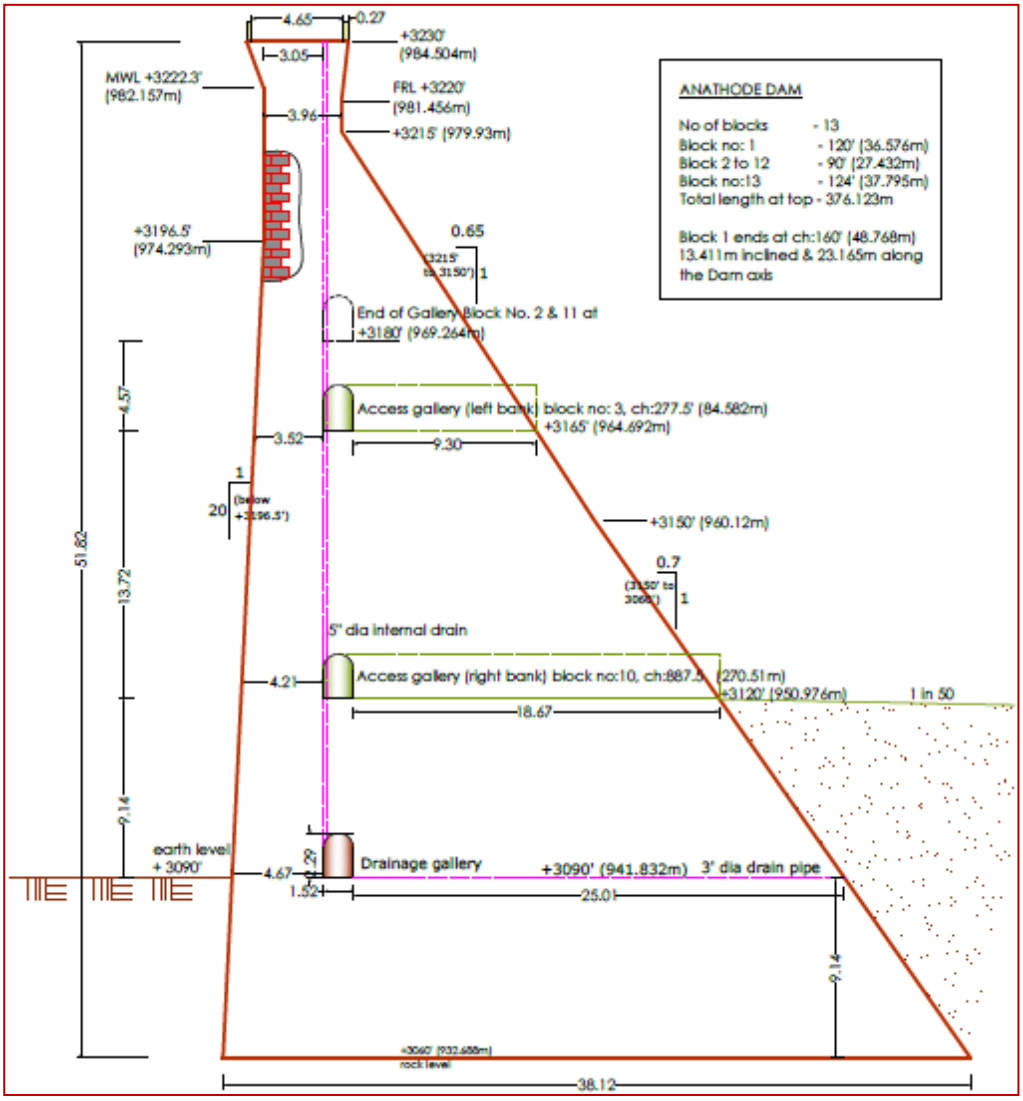

Fig 1.13 Cross-Sectional Elevation of Anathodu Dam

Inspection Gallery

There is one drainage gallery with two transverse galleries for Anathodu dam. Drainage gallery has access from both flanks. The size of the galley is a square section of 1.52 m x 1.52 m mounted by a semicircle of 0.76 m radius. (See **Drg 1.11** of **Annexure 1**) Drain culvert to lead the seepage water from the main gallery is on Block No.8 at El. 3093' (942.75 m). From this point, gallery floor is provided with 1 in 50 rise in Block No.7 to 5 and from the end of Block No.5, rising steeps starts and the main gallery ends at El. 3180' (969.26 m), with intermediate landings at El. 3135' (955.55 m) and El. 3165' (964.69 m) (Adit). From junction of drain culvert, the gallery floor is provided with a slope of 1½ to 1 with steps and intermediate landings. Two Adit galleries are there, one in right bank on Block No.10 (Ch. 887.5'), at El. 3120' (950.98 m)

and other on left bank, on Block No.3 (Ch. 277.5') at El. 3165' (964.69 m). Road access is there, leading to each Adit. The other transverse galleries are in Block No.8 (Ch. 774', El. 3093.56') and Block No.5 (Ch. 460', El. 3099.84') with slope 1 in 50, to access the drainage gallery. The intersection of transverse and drainage gallery is shown in **Drg 1.12** of **Annexure 1**. The locations of galleries are marked in **Drg 1.13** of **Annexure 1**. Drawings showing location of drainage gallery, transverse galleries and Adits are given in **Drg 1.14** of **Annexure 1**.

1.5 Assignment of Responsibility – Kakki and Anathodu Dams

Kerala State Electricity Board Ltd is the owner and has the final authority and responsibility for the operation and maintenance of the dam. Identification of all areas of responsibilities connected with the operation and maintenance of the dam are covered in this section. The officer's responsibilities for the various functions (civil, mechanical, electrical, instrumentation etc.) are identified by their designation and, in particular, the responsibilities of operating personnel are specifically identified below 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).
Authority of Spillway operations and Flood releases	-	Chief Engineer (Civil – DS & DRIP), KSEB Ltd.
Operation and safety of the dam	-	Deputy Chief Engineer, Research & Dam Safety Organization, Pallom, KSEB Ltd.
Controlling/Operation Officer at dam site	-	Executive Engineer, Research & Dam Safety Division No. I, Seethathode.
Reservoir Operations, inspection & maintenance	-	Executive Engineer, Research & Dam Safety Division No. I, Seethathode.
Dam Health Engineer	-	Executive Engineer, Research & Dam Safety Division No. I, Seethathode.
Recording reservoir data, inspection, monitoring and maintenance at site	-	Assistant Executive Engineer, Research &Dam Safety Sub Division, Moozhiyar
Handling Dam operations, inspection, monitoring and performing duties as Maintenance Officer at dam site	-	Assistant Engineer, Research &Dam Safety Sub Division, Moozhiyar

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. 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.

3. 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.

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

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

6. Assess the inflows in the reservoir as per the approved reservoir operation and to prepare proforma consisting of the status of the reservoir capacity and releases from the reservoir as per the standard Performa and to submit to the EE/ Dy CE /CE.

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

8. Maintain the spillway crest gate operation log book.

9. Operate the Spillway crest gates for flood mitigation as per the instructions of the EE/ Dy CE /CE and to update the Gate Operation Log book

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

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

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

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

14. 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.

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

16. 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.

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

18. 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 Dy CE and EE during Monsoon

1. Conduct Periodical (Pre and Post Monsoon) inspections to assess the health of the Dam and to direct the Executive Engineer for the immediate repair and maintenance for the smooth operation. Submit the inspection reports to the Chief Engineer and upload in DHARMA.

2. Observe the performance of the Dam and its appurtenant structures / Gates and Hoists before and after monsoon and to issue necessary instructions to the Executive Engineer.

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

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

5. Assist the CE to coordinate with the Revenue authorities (District Administration) to alert the downstream villagers to evacuate from the flood zone to prevent loss of life and livestock.

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

7. Submit to the CE the daily inflows and releases from the reservoir and status.

8. Operate the Spillway crest gates for flood mitigation as per the instructions of the CE and to update the Gate Operation Log book.

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

10. 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.

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

12. 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 data, releases from the upstream reservoirs and status of the reservoir.

4. Observe the performance of the Dam and its appurtenant structures / Gates and Hoists during flood water releases and to issue necessary instructions to the Dy CE/EE.

5. Coordinate with the Generation wing of KSEBL 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 (m)	Percentage Storage	Rainfall (mm)	Generation (Mu)	Spill	Gate operation details

Table 1.1 Daily Reservoir Data

Executive Engineer is entrusted with daily collection and reporting of inflow and outflow data in a standard proforma as in **Table 1.1** above to the Deputy Chief Engineer.

Date	Water Level (m)	Previous Year Same day Water Level (m)	Rainfall (mm)	Previous Year Rainfall (mm)	Storage (Mm^3)	Generation (MU)	Gross Inflow (Mm^3)	PH Discharge + Losses (Mm^3)	Spill (Mm^3)	Net Inflow (Mm^3)	Remarks

Table 1.2 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 1.2**.

Records/Logbooks of the operations for the following activities at Kakki and Anathodu Dams 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 of Record
- 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, stop-logs and associated controls.
- Testing/operation of Outlet gates, valves and associated controls.
- Maintenance activities carried out.
- Reservoir and dam inspections.
- Unusual conditions or occurrences.
- 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 Moozhiyar Power house and released to Moozhiyar Dam of Kakkad H E Project
Irrigation, water supply and hydropower releases	The reservoir water is used for power generation at Moozhiyar Power house and there are 5 other Power generating stations and one Irrigation project running in the Tail race of Moozhiyar Power House. 1. Kakkad Power House, 2. Ullumkal Power House, 3. Karikkayam Power House, 4. Carborandom HEP, 5. Ranni-Perinad SHEP. In addition to this Pampa Irrigation project (Common Dam of Carborandom HEP) and large number of water supply schemes working under this tail water of SGHEP.
Weather related data	Collected and reported daily
Surveillance/Security arrangements	Provided at one security check posts near dam. 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. The analysis consists of Physical & Chemical tests are being conducted at The Analytical Laboratory, Jala Bhavan, Thiruvanathapuram.
Attendance statement during normal operations	Both during monsoon and non-monsoon period maintained at field office.
Operations of the spillway gates and outlet works	• No spillway gate at Kakki dam. Sluice operation log maintained at field office. • There are 4 no of radial gates for Anathodu spillway and gate operation log book is maintained at field office.
Operating hours of mechanical equipments	Maintained at field office
Testing/Operation of spillway gates and associated controls	• No spillway gate at Kakki dam. • The testing and operation at Anathodu dam are being carried out as per the manual and

	maintenance schedule. Other details maintained at field Office.
Testing/operation of Outlet gates, valves and associated controls	Maintained at field office
Maintenance activities carried out	Details maintained at field office
Reservoir and dam inspections	Periodically inspected and details maintained at field office
Unusual conditions or occurrences, including acts of vandalism	Details maintained at field office
Attendance statement at dam during emergency operations	Details maintained at field office
Changes to normal operating procedure	Details maintained at field office
Communication network checks	Communication network available at Dam sites at certain locations. Police wireless system regularly checked.
Safety and special instructions	Safety equipment 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. No public utilities are provided at Kakki dam.

Location of public conveniences: Distance to the nearest medical assistance and Police station from the dam: Government Primary Health Centre is located at Seethathode 50 km away from the dam and a Private hospital is also available at Seethathode. Moreover, there is Government District Hospital at Pathanamthitta. Police Station is located at Angamoozhy 37 km from the dam.

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

1.8 Restricted Areas

Certain areas of the dam and reservoir are restricted for entry of the general public. The purpose of restriction 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, Channel, Spillway glacis, energy dissipation arrangements, power intake, Spillway gate hoisting arrangement, Intake gate operation area, trash rack area etc.

Sign boards are displayed at the prohibited areas of the dams i.e., at the side of road and also near to the entrance.

1.8.1 Dam safety surveillance

Security arrangements are provided near dam and security check post. Also CCTV surveillance will be provided soon covering the dam and other important areas of the Project premises. Some new digital instruments are also proposed under DRIP.

Kakki Dam

Security Arrangement Existing	-	Kerala Police Force (5 shifts/day) (Head Constable - 1 No and Police Constable- 4 No)
Proposed as recommended by SISF	-	Kerala Police Force (10 shifts/day) (Head Constable - 1 No and Police Constable - 9 No)

Anathodu dam

Security Arrangement Existing	-	Kerala Police Force (5 shifts/day) (Head Constable - 1 No and Police Constable- 4 No)
Proposed as recommended by SISF	-	Kerala Police Force (7 shifts/day) (Head Constable - 1 No and Police Constable - 6 No)

1.9 Staff position, Communication & Warning System

The number and description of operating unit personnel posted/placed at different locations of the dam are indicated in supporting documents. 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 facilities like communication facilities and siren are provided. A hierarchy of organizational structure for the control and safety of Kakki and Anathodu dam is outlined below in **Fig 1.14**.

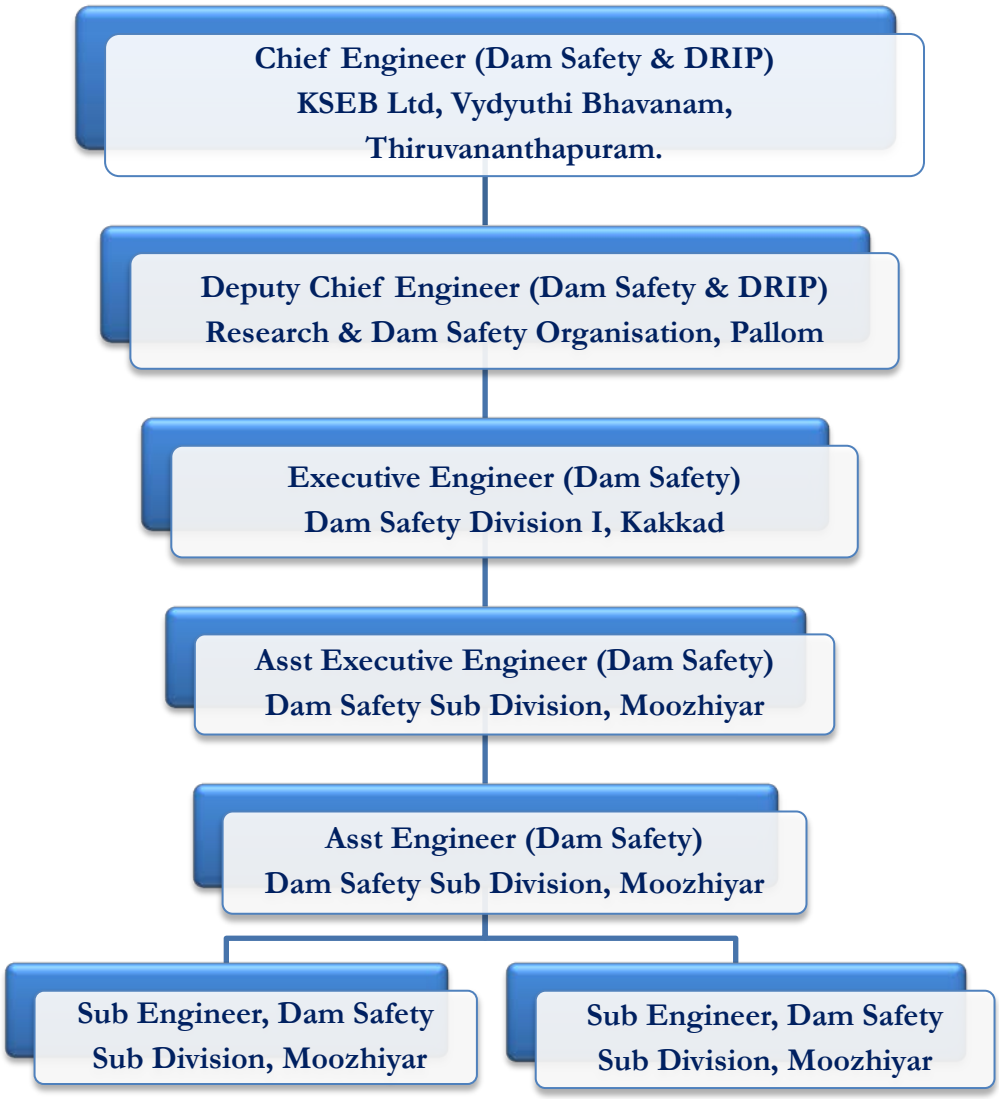

Fig. 1.14 Dam Safety Organisation Structure for Kakki and Anathodu Dam

Present hierarchy of Controlling officers of Kakki and Anathodu dams & their contacts are as below:

Designation and office address	Contact number and e-mail
Chief Engineer Civil (Dam Safety & DRIP), KSEB Ltd, Dam Safety Organization, 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. I, Kakkad	Ph: 9446008424 e-mail: ddrdskkds@gmail.com

Assistant Executive Engineer, Dam Safety Sub Division, Moozhiyar	Ph: 9496018371, e-mail: aeedssdmzhr@gmail.com
Assistant Engineer, Dam Safety Sub Division, Moozhiyar	Ph: 9496011950, e-mail: aeedssdmzhr@gmail.com

Spillway flood releases

Spillway of Kakki-Anathodu reservoir is provided in Anathodu dam. Kakki dam has no spillway gates. The Kakki-Anathodu reservoir was being operated based on 'Guidelines for Operation of Reservoirs' (IS 7323:1994) and Gate Operation Manual of the Project.

During flood season, various alerts at specified levels for opening of spillway gates are given. The first warning as water level reaches 979.50 m, second warning as water level reaches 980.00 m and third warning as water level reaches 980.50 m are given for opening of spillway gates. There are 4 radial gates of 12.80 m wide each. After giving first warning at +979.50 m level, further warning is given in local media including TV etc., regarding the possible opening of spillway gates continuously up to +981.00 m level. Also intimations are given to Disaster Management, District Administration, and Police Department etc. But in the light of 2018 Flood, the alert levels are revised as explained in **Cl. 2.3.2 of Chapter 2**.

Releases for various purposes like irrigation, water supply, and hydropower

Water from the Kakki - Anathodu reservoir having effective storage 447 Mm^3 is mainly used for power generation of 340 MW at Moozhiyar Power House around 60 km from Pathanamthitta. The Power House is operated based on load demands as per the directions from State Load Despatch Centre, Kalamassery. The tail water from power house discharges into Moozhiyar River downstream.

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 for Kakki and Anathodu dams by the operating/controlling officers. Pre-monsoon inspection and Post monsoon inspection as per CWC guidelines are carried out by the respective officers and

reports intimated to CWC. As per the present norms, the pre-monsoon and post monsoon reports are to be updated in DHARMA web site in the prescribed revised format.

Maintenance

Routine maintenance is carried out for spillway gates and hoisting mechanism of Anathodu Dam; for the Hollow Jet Valves, Emergency gates and hoisting mechanism of river outlet emergency gates of Kakki dam; Power intake gate & hoist of the project 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, Research & Dam Safety Organization, KSEB Ltd, Pallom have been entrusted with the specific responsibility for carrying out the O & M activities of Kakki and Anathodu dams.

1) Executive Engineer, Dam Safety Division No. I, Kakkad
2) Asst. Executive Engineer, Dam Safety Sub Division, Moozhiyar
3) Assistant Engineer, Dam Safety Sub Division, Moozhiyar
4) Personnel in charge of works of the Dam

The offices to which the O & M Manual of Kakki and Anathodu dam are to be distributed are:

Sl. No.	Name of Office
1	Dam Safety Division No. I, KSEB Ltd, Kakkad
2	Dam Safety Sub Division, KSEB Ltd, Moozhiyar
3	Dam Operator's Room at Dam Sites
4	Office of the Deputy Chief Engineer, Research & Dam Safety Organization, KSEB Ltd, Pallom
5	Office of the Chief Engineer, Dam Safety Organization, KSEB Ltd, Pallom
6	Office of the Director Generation (Civil), KSEB Ltd, Vydyuthi Bhavanam, Thiruvanathapuram

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 indicated below are available at the dam control room for reference.

- 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 1.3**.

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 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	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 arrangements, Power Intake etc.	Monthly	Executive Engineer
14	Check measuring devices/Instruments, Security and safety devices, Communication Devices, Status of Vegetation growth, – rectification, if needed.	Monthly	Executive Engineer

15	Check Sign/Warning display boards near vulnerable locations	Monthly	Executive Engineer
16	Replace fuse light bulbs, Inspect to maintain ventilation system, cleaning of control panel boards.	Monthly	Assistant Engineer
17	Check outlet works, updating operating instruction, check gate air vents, clean gate control switchboxes, check operation of gates, grease gate hanger/dogging	Quarterly	Executive Engineer
18	Check condition of trash rack of intake structure, Check condition of Outlet works & its Energy Dissipation Arrangement, Check operation of Valve house	Quarterly	Executive Engineer
19	Check condition of spillway, log and safety boom, Check for debris in inlet channel, Check operation of gates, Check for damages in spillway glacis, energy dissipation arrangement, d/s area etc, Check and clear spillway bridge drains, Clean inside of motor control cabinet.	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 oil reservoir level in hydraulic system, Check pressure release valve, 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 State DSO, 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 and EAP and update as necessary.	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 1.3 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 (Anathodu Dam), Intake gates and Hollow Jet Valves (Kakki Dam) 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 Project involves regulation of its reservoir as per project specific requirements keeping records and ensuring public safety and normal or day to day operation of component dams maintaining structural safety.

2.1 Basic Data

The Kakki-Anathodu reservoir 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 outlets. The operation of a dam involves regulation of its reservoir as per rule curve/project specific requirements. This includes the use of area capacity curves and design flood; both are described below. Since Kakki and Anathodu are two dams of the single reservoir; Kakki-Anathodu, the area capacity curve and rule curve remains the same. Hence for the operation of Kakki-Anathodu reservoir, the operations of dams (Kakki and Anathodu) are to be individually addressed. The Gross storage of the reservoir is 454.20 Mm^3 and the Live Storage is 446.60 Mm^3 at FRL of +981.46 m and the details are given in **Table 2.1.**

2.1.1 Elevation Capacity Curve

The area and capacity curves for Kakki-Anathodu Reservoir during design are shown in **Drg 2.1** of **Annexure 1** and tabulated in **Table 2.1**. The elevation capacity (storage) curve for Kakki Reservoir based on **Table 2.1** is shown in **Fig 2.1**.

Level in ft	Level in m	Capacity in Mcft	Capacity in Mm^3	Submerged Area in MSqft	Submerged Area in Msqm	Remarks
2900.000	883.920	3.835	0.109	0.383	0.036	
2920.000	890.016	21.570	0.611	1.390	0.129	
2938.042	895.515	60.000	1.699			Gate seal bottom C/L
2940.000	896.112	65.970	1.868	3.050	0.283	Hollow jet Pipe Bottom

2943.000	897.026	77.770	2.202			Gate and HJ Pipe C/L
2946.000	897.941	86.210	2.441			HJ Pipe Top
2947.958	898.538	94.200	2.667			Gate seal top C/L
2955.000	900.684	123.080	3.485			Intake Pipe bottom
2960.000	902.208	147.070	4.165	5.050	0.469	
2970.000	905.256	202.800	5.743			Intake Pipe Top
2980.000	**908.304**	**268.570**	**7.605**	**7.100**	**0.66**	**MDDL**
3000.000	914.400	440.370	12.47	10.800	1.003	
3020.000	920.496	710.370	20.115	16.200	1.505	
3040.000	926.592	1109.370	31.414	23.700	2.202	
3060.000	932.688	1660.370	47.016	31.400	2.917	
3080.000	938.784	2382.370	67.461	40.800	3.79	
3100.000	944.880	3261.370	92.352	47.100	4.376	
3120.000	950.976	4387.370	124.236	65.500	6.085	
3140.000	957.072	5865.370	166.089	82.300	7.646	
3160.000	963.168	7668.370	217.144	98.000	9.104	
3180.000	969.264	9835.370	278.507	118.750	11.032	
3200.000	975.360	12587.370	356.435	156.500	14.539	
3220.000	**981.456**	**16037.870**	**454.142**	**188.500**	**17.512**	**FRL**
3222.300	**982.157**	**16482.000**	**466.718**			**MWL**
3240.000	987.552	20267.870	573.922	234.500	21.786	
3260.000	993.648	25432.870	720.179	282.000	26.199	
3280.000	999.744	31242.870	884.699	299.000	27.778	
3300.000	1005.840	37492.870	1061.68	316.000	29.357	

Table 2.1 Kakki - Anathodu Reservoir Characteristics

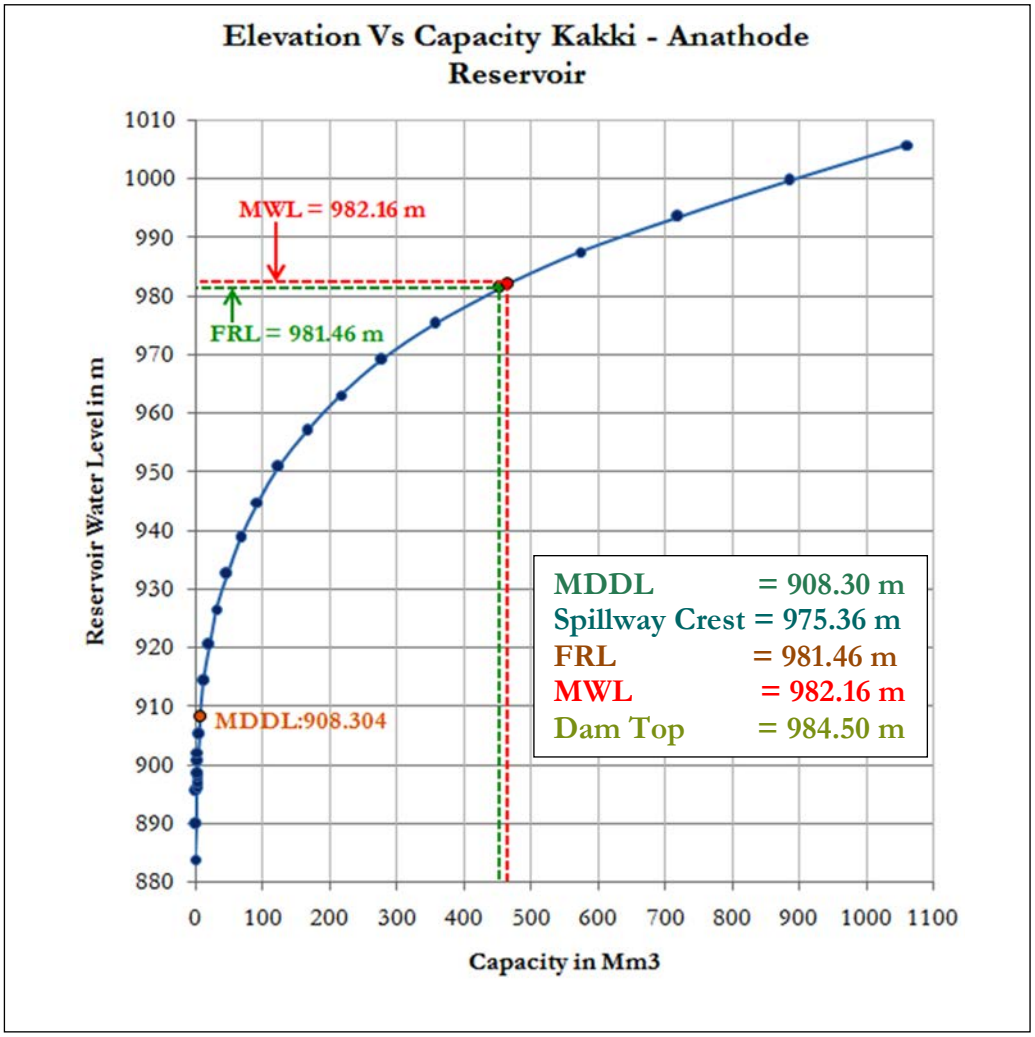

Fig 2.1 Elevation- Capacity Curve

2.1.2 Submerged Area curve

The elevation submerged area curves for Kakki- Anathode Reservoir based on **Table 2.1** is shown in **Fig 2.2**.

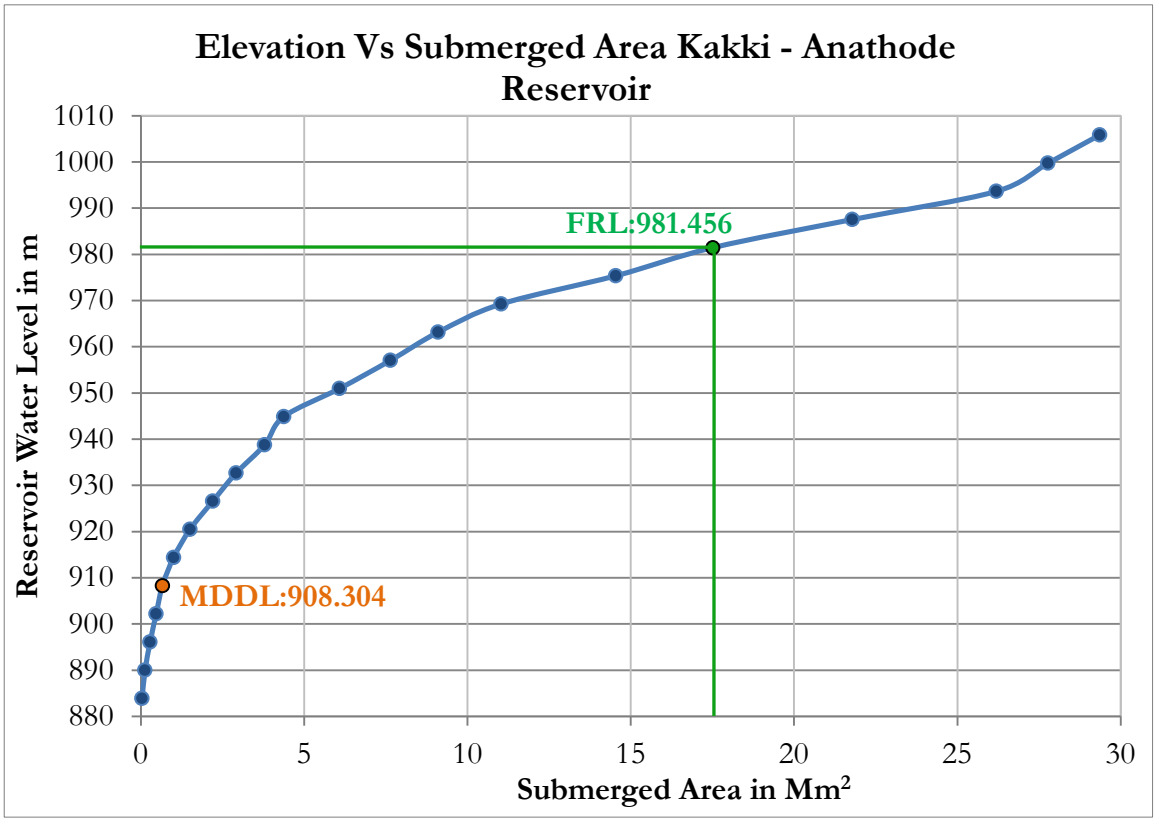

Fig 2.2 Elevation –Submerged Area Curve

2.1.3 Spillway

Spillway with a designed capacity of 1784.16 m^3/s for Kakki-Anathodu reservoir is provided in the right bank of Anathodu dam. Kakki River falls with almost a vertical drop of over 121.92 m which is only about 243.84 m downstream of the toe of the dam. A retro-gradation of the riverbed cannot be ruled out with a high discharge spillway in the dam.

The spillway has four numbers radial gated each 12.8 m x 6.1 m, to regulate the flood discharge and surplus water, controlled by separate hoisting arrangement for each. Total length of spill way is 59.13 m including piers. The radial gates are erected between piers over the ogee portion. The gates are pivoted on the trunnion at the downstream side. The trunnions are secured to anchorages embedded in the piers. The spill way channel has a slope of 1 in 100 on the downstream of toe and 1 in 50 in the upstream of spill way. The water discharging from the spill way is conveyed to the nearby valley by means of an open channel. The plan & downstream elevation and location plan of spillway of Anathodu dam are given in **Drg 2.2** and **Drg 2.3** of **Annexure 1**. Photographs showing the downstream and upstream elevation of spillway are given below in **Fig 2.3a** and **Fig 2.3b**.

Fig 2.3a Downstream Elevation of Spillway - Anathodu Dam

Fig 2.3b Upstream Elevation of Spillway - Anathodu Dam

2.2 Operation Plan

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

Salient features of Kakki- Anathode Reservoir and Spillway at Anathodu dam

Maximum Water Level (MWL)	-	+982.16 m
Full Reservoir Level (FRL)	-	+981.46 m
Minimum Draw Down Level (MDDL)	-	+908.304 m
Width of Spillway	-	59.13 m

No and size of radial gates	-	4 Nos. 12.80 m x 6.10 m
Crest level of spillway	-	+975.36 m
Maximum spillway discharge	-	1784.16 m^3/s at FRL +981.46 m
Gross storage at FRL	-	454.14 Mm^3
Gross storage at MWL	-	466.72 Mm^3

2.2.1 Data of the historic floods

As per historical records, the maximum flood was observed in Western Ghats 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 Devikulam in Kerala in which rainfall of 484 mm and 751 mm respectively were 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 and Kerala experienced abnormally high rainfall from 1 June 2018 to 19 August 2018 which resulted in severe flooding in 13 out of 14 districts in the State. It is seen that the 2-day and 3-day rainfall depths of 15-17, August 2018 rainfall in Pamba, Periyar and Bharathapuzha sub-basins are almost comparable to the Devikulam storm of 16-18, July 1924. 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 Kakki dam site was 812 mm. The 4-day rainfall of 15-18, August 2018 at Kakki dam site was 1032 mm which is one of the highest in the State.

Anathode spillway gates were opened during **2007, 2013** and **2018** for flood control. Spill details of the years 2007 and 2013 are tabulated below in **Table 2.2**. Spill details of the year 2018 are tabulated below in **Table 2.3**. The rainfall and reservoir water level of the 2007, 2013 and 2018 are included in **Annexure 3**.

Year	Date		Water level in m	Storage in Mm^3	Spill in Mm^3
2007	25.10.2007	3.30 am	981.45	455.02	33.09
	11.11.2007		981.45	455.02	
2013	20.09.2013	Mid night	981.40	453.05	18.59
	23.09.2013	9:00 am	981.45	455.02	

Table 2.2 Spill details of the years 2007 and 2013

Spill details of 2018					
Date	**Water Level in m**	**Rainfall in mm**	**Storage in Mm^3**	**Gross Inflow in Mm^3**	**Spill in Mm^3**
10/08/2018	981.46	82.00	453.05	11.07	4.56
11/08/2018	980.95	155.00	444.70	22.35	26.72
12/08/2018	981.09	6.00	447.30	11.93	5.30
13/08/2018	981.20	104.00	449.30	14.79	9.04
14/08/2018	980.91	63.00	443.95	20.12	22.06
15/08/2018	981.56	296.00	456.12	45.48	29.99
16/08/2018	981.09	294.00	447.27	65.73	71.28
17/08/2018	981.12	222.00	447.82	43.17	39.31
18/08/2018	981.35	220.00	452.10	38.37	30.78
19/08/2018	981.46	70.00	453.24	31.63	27.14
20/08/2018	981.34	70.00	451.91	17.19	15.14
21/08/2018	981.26	27.00	450.41	13.99	12.11
22/08/2018	981.18	13.00	448.90	12.41	9.93
23/08/2018	980.95	4.00	446.15	11.25	9.84
24/08/2018	980.75	0.00	442.30	9.90	9.68
25/08/2018	980.58	0.00	437.95	9.05	9.48
26/08/2018	980.30	0.00	432.90	8.17	9.25
27/08/2018	979.95	3.00	427.70	7.71	8.95
28/08/2018	979.65	12.00	422.75	7.77	8.69
29/08/2018	979.45	34.00	418.15	7.78	8.39
30/08/2018	979.45	2.00	413.13	7.05	8.14
31/08/2018	978.80	0.00	407.40	5.99	7.79
					Total Spill = 383.57 Mm^3

Table 2.3 Spill details of 2018

2.2.2 Design Flood and Features Related to Safety

Hydrology during the initial period, as available, is given below. The total catchment area of Kakki - Anathodu dams is 217.56 km^2. Kakki - Anathodu reservoir has a gross storage capacity of 454.14 Mm^3 at FRL 981.46 m. Being in virgin forest, rainfall readings of representative stations inside the catchment not available for sufficiently long periods, the hydrology of scheme has been worked out based on gauge flow readings of the Pamba River by the Madras Government from 1909 to 1916 and not based on rainfall.

In 1955, new gauging weirs were constructed at Pamba and Kakki River. Actual flow measurements observed from the above weirs from 1956 onwards clearly established that a gross draft of 830 cusecs continuous only is available under full regulation of both the

reservoirs together. The total runoffs from Pamba and Kakki together for the years 1956-57, 57-58, 58-59 and 59-60 were 24600 Mcft, 28464 Mcft, 26369 Mcft and 32932 Mcft respectively. The average annual runoff of the years was 28091 Mcft.

The design flood discharge for Pamba and Kakki basins were estimated by application of Ryve's formula and using C = 2500, the discharge for Pamba was computed to be 2300 cusecs and for Kakki 47800 cusecs. Subsequently in accordance with the observations made by CW&PC, after unit hydrograph studies, the maximum flood discharge was raised to 32000 cusecs for Pamba and 63000 cusecs for Kakki. The actual rainfall from June 1960 to February 1969 is as follows.

June 60 to May 61	5468.90 mm
June 61 to May 62	2633.10 mm
June 62 to May 63	4194.34 mm
June 63 to May 64	3559.10 mm
June 64 to May 65	5668.92 mm
June 65 to May 66	2795.92 mm
June 66 to May 67	3197.25 mm
June 67 to May 68	2772.10 mm

Hydrology review carried out in DRIP

As per BIS 11223-1985, both Kakki and Anathode Dams fall under the category of large Dams, i.e., Reservoir Capacity above 60 Mm^3 and Hydraulic head above 30 m. Hence the spillway of Anathodu dam has been designed to carry Probable Maximum Flood. 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. This flood 2283 m^3/s was approved vide letter No 16.08.2009-IV/V/DSRD/671-72 dated 30.01.2012 with remarks to check for project specific storm.

Accordingly, maximum rain fall for the last 15 years were checked and noted that it is 175 mm only. Hence the 500 mm from PMP atlas itself is taken for review of hydrology. Since the arrived flood of 2283 m^3/s is greater than the spill way capacity of 1784 m^3/s, reservoir routing is carried out by the modified Puls method (programme by CWC) and found that the peak rate of outflow for the spillway comes to only 1039 m^3/s and hence the existing spillway can safely negotiate PMF.

2.2.3 Hoisting Arrangements for Radial Crest Gates of Anathodu dam

The maximum designed depth of flow in the channel at the foot of spill way is 2.65 m. The gate is of structural steel frame work with a steel skin plate on the upstream side, resting on a sill beam embedded on the crest. Each gate consists of a structural steel frame work with steel skin plates at the upstream side. The gates are pivoted on trunnions at the downstream side. The gates and accessories were supplied by M/s. Pacific Coast Engineering Co., California.

The hoisting arrangements of gates are installed over the top of Hoist Bridge at El. 992.58 m. The hoisting arrangement consists of a central drive and two lateral drives coupled by a pipe shaft. The central drive has a spur type reduction gear, self-arresting worm gear, a double shoe brake with electro- hydraulic central device. The hoisting can be done either **electrically or by manually**. For hand operation, there is a hand crank and a safety device for switching off electrical system, when the handle crank is in use. The lateral drum consists of spur-type reduction gears and a rope drum. The mechanism also consists of indication needles and electrically controlled top and bottom position limit switches. Sectional elevation of a single spillway gate with Hoist Bridge is shown in **Drg 2.4** of **Annexure 1**. The general plan of Hoist Bridge is given in **Drg 2.5** of **Annexure 1**. The downstream elevation of spillway and bridges is shown in **Drg 2.6** of **Annexure 1**.

The hoisting and lowering is done at a speed of 30 cm per minute, while operating electrically. The electric system consists of 3 phase synchronous motor, with short circuit motor 3HP, 750 rpm magnetic hydraulic brake unit, spindle, top & bottom position limit switches, etc. The electrical circuit diagram is given in **Annexure 2B**.

The General arrangement showing hoisting mechanism, panel board and motor of all the four gates are given in **Fig 2.4**. The control panel of the radial gates is as in **Fig 2.5**. The gates must be operated as per the instructions and procedures as described in the gate operation manual included in **Annexure 2B**.

The plan view of gate hoist arrangement and details of radial crest gates are given in **Drg 2.7a** of **Annexure 1**. The anchor bolt and deck rope slot arrangement of the gates is shown in **Drg 2.7b** of **Annexure 1**.

Fig 2.4 Hoisting Mechanism and Control Panel for Anathodu Dam

Fig 2.5 Control panel of the radial gates

2.2.4 River Outlet Works of Kakki Dam

River outlets are provided in Kakki dam for emptying reservoir with no power draft during emergency situation as well as supplying water for irrigation purposes. There are two numbers of 1.37 m dia. hollow jet valves provided at Kakki Dam. The C/L of hollow jet valves is +2943' (FRL is +3220') and diameter of pipe is 1.8 m. The river outlet pipes and hollow jet valves are connected through a taper piece. The controls for the hollow jet valves are suitable for open-air installation. It is provided on the downstream side of the dam and is protected by hydraulically operated fixed wheel emergency gates with picture frame seals on the upstream side to empty the reservoir in about 50 days in case of emergency. The outlets operate at a maximum head of 280' (85.344 m). The maximum computed discharge through the two river outlets under FRL condition is **84.95 m^3/s**. The hollow jet valve can be operated **electrically or manually** using Limit Torque as detailed in **Annexure 2A**, operation manual supplied by the manufacturer. The valve house was completed in 1965. The cranes 10 T required for maintenance of two valves and control etc. has been installed in between two hollow jet valves. The type of crane, drawings, operation and maintenance are as per the manufacturer's manual included in **Annexure 2A**. The sill level of outlet is +896.11 m. Photographs of hollow jet valves installed in downstream are shown in **Fig 2.6**.

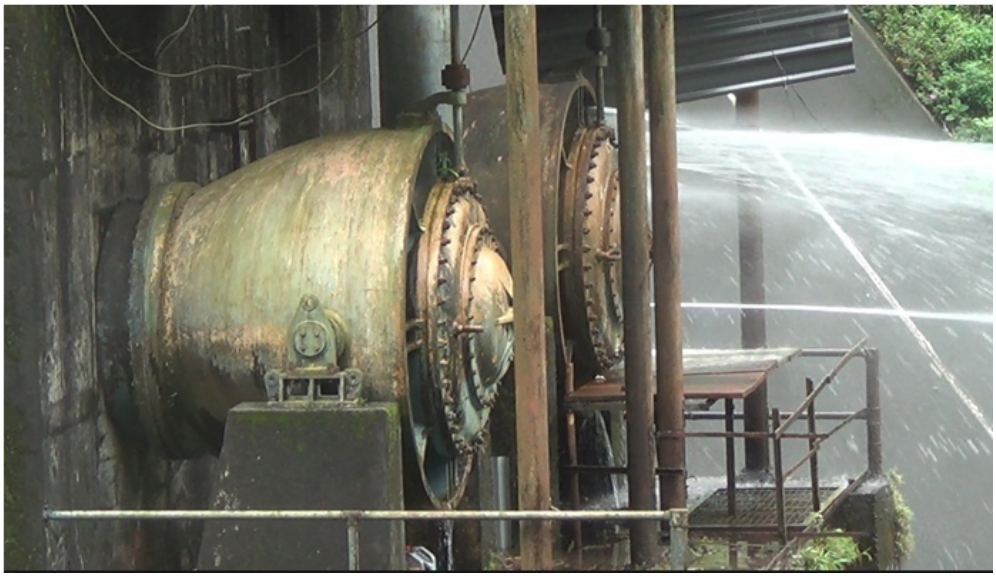

Fig 2.6 Hollow Jet Valves of Kakki Dam

The intake arrangement for Kakki dam river outlet (**Drg 2.8** and **Drg 2.9** of **Annexure 1**) consists of a common trash rack of thirty pieces, placed in five tiers (six places in each tier) fixed in position inside the RCC rib and ties. A bell mouth transition is given at the upstream of dam behind the trash rack portion. Two emergency gates (2.9 m x 1.52 m gates ***hydraulically operated*** from dam top) with hoisting arrangements are provided at the transition portion for the two outlets. The portion between hollow jet valve and bell mouth are made of steel liners of 6 ft (1.829 m) dia. Hollow jet valves are connected at the end of these steel liners outside the dam body. The emergency gates are operated by two independent hoist units installed at

emergency gate room at level +984.50 m on the upstream of the dam as in **Drg 2.10** of **Annexure 1**. A repair and stem storage bay has been provided below the hoist units at RL 979.93 m. The plan of repair bay and control room for emergency gate are given in **Drg 2.11** of **Annexure 1**. A gantry crane is also provided at the top, above the hoist units. Access has been provided from the drainage gallery to the river outlets through the manhole opening. The emergency gates and hollow jet valves were supplied by Pacific Coast Engineering Company, USA. Operation and maintenance manual for the emergency gates of Kakki dam is included as **Annexure 2A**. Photographs of emergency gate of hollow jet valve and hydraulic hoist of emergency gate are given in **Fig 2.7 (a)** & **Fig 2.7 (b)**.

(a) **(b)**

Fig 2.7 (a) Emergency gate of Hollow Jet Valve, (b) Hydraulic hoist of Emergency gate

The erection of hollow jet valves and emergency gates for Kakki dam outlets were carried out after plugging of the construction sluice in the dam and commencing partial storage. Partial storage was done, in advance of installation of emergency gates and hollow jet valves in the reservoir for commercial operation of two machines, during April and May 1966. A typical cross section showing trash rack structure and hollow jet valves in Block No. 10 is shown in **Drg 2.12** and **Drg 2.13** of **Annexure 1**. Details of Hoist for Hollow Jet Valves of Kakki dam is given in **Drg 2.14a** of **Annexure 1** and details of supporting structure of hollow jet valve is shown in **Drg 2.14b** of **Annexure 1**. Manual for operation and maintenance of hollow jet valve of Kakki dam is included in **Annexure 2A (Kakki)**.

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 to vulnerable areas is essential, and in some instances electronic security devices should be considered.

2.3.1 Operation of Control Mechanisms (Kakki and Anathodu dams)

The **power intake** of the reservoir is located on the left bank of the reservoir upstream of Kakki dam as shown in **Fig 2.11(a)** & **(b)**. The details and drawings with salient features are given in the following **Clause 2.4.1**. The intake control arrangement salient features are tabulated below;

Control Arrangement (Intake)		
Type	:	Shaft with vertical lift gates sealed on upstream
Operation		
a. Lifting and lowering by electric power	:	5 ft /min
b. Lowering by gravity	:	8 ft /min
c. Lifting by hand power	:	1 inch/min
Total weight	:	32 T
Maximum design head	:	263.3 ft

Gear operation	:	Electrically and manually
Brake	:	Operation solenoids and hand release lever brake
Motor		
a. Speed	:	1350 rpm
b. HP	:	60 HP
c. Supply	:	400-440 Volts, 3 phase 50 cycles
Trash Racks	:	Arranged in semi-circular pattern around the power tunnel mouth in semi-circular pattern
Hoist Capacity	:	118 T

Other operating mechanisms for Kakki dam are Hollow Jet Valves and Emergency Gates. The Operation manual of control mechanism and installation, as supplied by the manufacturer, is attached as **Annexure 2A (Kakki)**.

Anathodu spillway gates hoisting mechanism is given in **Drg 2.4** of **Annexure 1**. The details are as in **Clause 2.2.3** above. The Operation manual of control mechanism and installation of Anathodu dam, as supplied by the manufacturer, is attached as **Annexure 2B (Anathodu).**

Spillway Gate Operations

Spillway is provided in **Anathodu Dam**. The radial gates are opened only as per the direction of higher officers after intimation to the District Disaster Management Authority, Police & Revenue Department. Mike announcement regarding the spill are being intimated to habitants on downstream sides of river course. Intimation to the public is also being given through News Paper & Visual Medias. Also a control room will get opened at the dam top itself for achieving easiness in close monitoring of water levels and shutter operations.

As the dam site is in a forest area, the electric power supply line to the dams is mainly through forest. During heavy rain fall and storm, there occurs power failure or low voltage. For obtaining uninterrupted three phase electric supply of sufficient voltage required for the operation of shutters, a **30 KVA** Diesel Generator set is provided. At the time of opening of control room itself, the DG set will be kept ready by checking fuel quantity, circuits, change-over system etc. The connectivity of all mobile networks is weak in the dam and surrounding premises. To overcome the problem of communication, a satellite phone is provided. For

meeting any minor accidents at the time of shutter operations, a kit of first-aid medicines is kept ready at control room. To prevent any of the blaze, may happen due to electric short circuit, fire extinguisher is also kept ready for use.

The operation of the radial gates can be done either by **electrically or manually**. After observing the parameters like volume of inflow of water in to the reservoir on near past, rain fall occurred or about to occur, the height of shutter to be raised is assessed first. This total height of opening is equally distributed to all the four gates. Gate No.2 is being opened first to a unit height on the basis of requirement. Then Gate No.3 is operating to the same height as that of Gate No.2. The sequences of gate operations are No. 2, 3, 1 and finally No.4. Further increase in openings is also performed in this manner. The closing of the gates is being done in the reverse manner as that of opening. The operation of gates is detailed in **Clause 2.2.3** above and in **Annexure 2B (Anathodu).**

2.3.2 Operation of the Reservoir

Kakki- Anathodu 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. Hence no rule curve was prepared for this dam. 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 Kakki-Anathodu reservoir arebased on rule curve levels vide **Clause 2.3.3** which are approved by the Board vide B.O (FTD) No. 444/2019(DGC/AEE-II/Dam Safety/2019 dt 03.06.2019. Accordingly, Alerts for spilling of water are fixed as first warning **Blue** (1.5 m below upper rule curve level), second warning **Orange** (1.0 m below upper rule curve level) and third warning **Red** (0.5 m below upper rule curve 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 revised upper rule curve levels **(Table 2.6 and Table 2.8 below)**, it is proposed to keep the water level at or below 976.00 m (Close to Crest Level) on June 10th and 981.46 m (FRL) on 30th November.

Spillway Rating Curve

During flood season, the reservoir water is released through spillway gates. The Full Reservoir Level is **981.46 m** and spillway crest level is **975.36 m**. The total spillway discharge

(free discharge) through spillway gates (4 Nos) for different reservoir levels under full opened condition is tabulated in **Table 2.4** and is given in **Fig 2.8**. Discharge (Rating) curve through single spillway for different reservoir levels with different gate openings is given in **Fig 2.9** and tabulated in **Table 2.5**.

Reservoir Level in m	Spillway discharge through one gate in m^3/s	Total Spillway discharge (4 gates) in m^3/s
975.360	0.00	0.00
976.000	16.464	65.86
977.000	60.113	240.45
978.000	124.445	497.78
979.000	196.181	784.72
980.000	277.671	1110.68
981.000	373.370	1493.48
981.460	446.206	1784.82

Table 2.4 Spillway Free Discharge

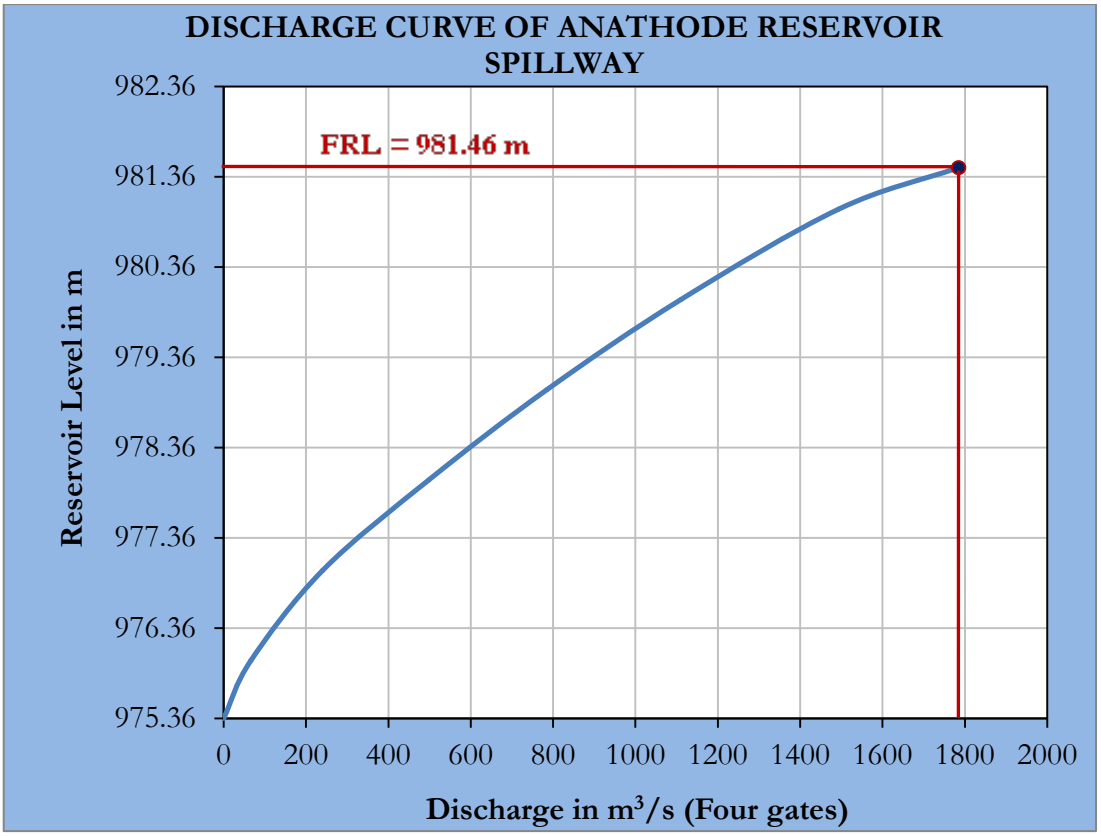

Fig 2.8 Free Discharge curve for Spillway Gates

Anathode-Discharge through a single spillway gate for different gate openings and reservoir levels							
Reservoir Level (m)	Gate opening(+m)/ Elevation of bottom of spillway gates (m)						
	0.3	0.6	0.9	1.2	1.5	1.8	2.1
975.36 (Crest level)	975.66	975.96	976.26	976.56	976.86	977.16	977.46
976.00	9.61	16.46					
976.50	12.93	23.98	32.77				
977.00	15.54	29.57	41.89	52.24	60.11		
977.50	17.77	34.23	49.27	62.74	74.44		
978.00	19.74	38.31	55.64	71.63	86.16	99.05	110.08
978.50	21.52	41.99	61.33	79.48	96.36	111.87	125.86
979.00	23.17	45.35	66.51	86.59	105.53	123.26	139.68
979.50	24.70	48.47	71.30	93.13	113.92	133.61	152.14
980.00	26.13	51.40	75.77	99.22	121.70	143.18	163.59
980.50	27.49	54.16	79.98	104.94	128.99	152.10	174.23
981.00	28.78	56.77	83.97	110.34	135.86	160.50	184.22
981.46	29.90	59.05	87.43	115.03	141.81	167.76	192.84

Anathode-Discharge through a single spillway gate for different gate openings and reservoir levels							
Reservoir Level (m)	Gate opening(+m)/ Elevation of bottom of spillway gates (m)						
	2.4	2.7	3	3.3	3.6	3.9	4.2
975.36 (Crest level)	977.76	978.06	978.36	978.66	978.96	979.26	979.56
976.00							
976.50							
977.00							
977.50							
978.00	118.85						
978.50	138.16	148.48	156.34				
979.00	154.69	168.13	179.79	189.36	196.18		
979.50	169.43	185.38	199.88	212.74	223.75	232.49	
980.00	182.89	201.00	217.84	233.31	247.27	259.54	269.83
980.50	195.34	215.37	234.27	251.95	268.34	283.31	296.72
981.00	206.99	228.77	249.51	269.16	287.64	304.89	320.80
981.46	217.03	240.28	262.57	283.84	304.05	323.13	341.02

Anathode-Discharge through a single spillway gate for different gate openings and reservoir levels							
Reservoir Level (m)	Gate opening(+m)/ Elevation of bottom of spillway gates (m)						
	4.5	4.8	5.1	5.4	5.7	6	6.1
975.36 (Crest level)	979.86	980.16	980.46	980.76	981.06	981.36	981.46
976.00							
976.50							
977.00							
977.50							
978.00							
978.50							
979.00							
979.50							
980.00	277.67						
980.50	308.36	317.90	324.71				
981.00	335.26	348.10	359.08	367.80			
981.46	357.63	372.85	386.55	398.52	408.47	415.86	446.21

Table 2.5 Discharge through single spillway

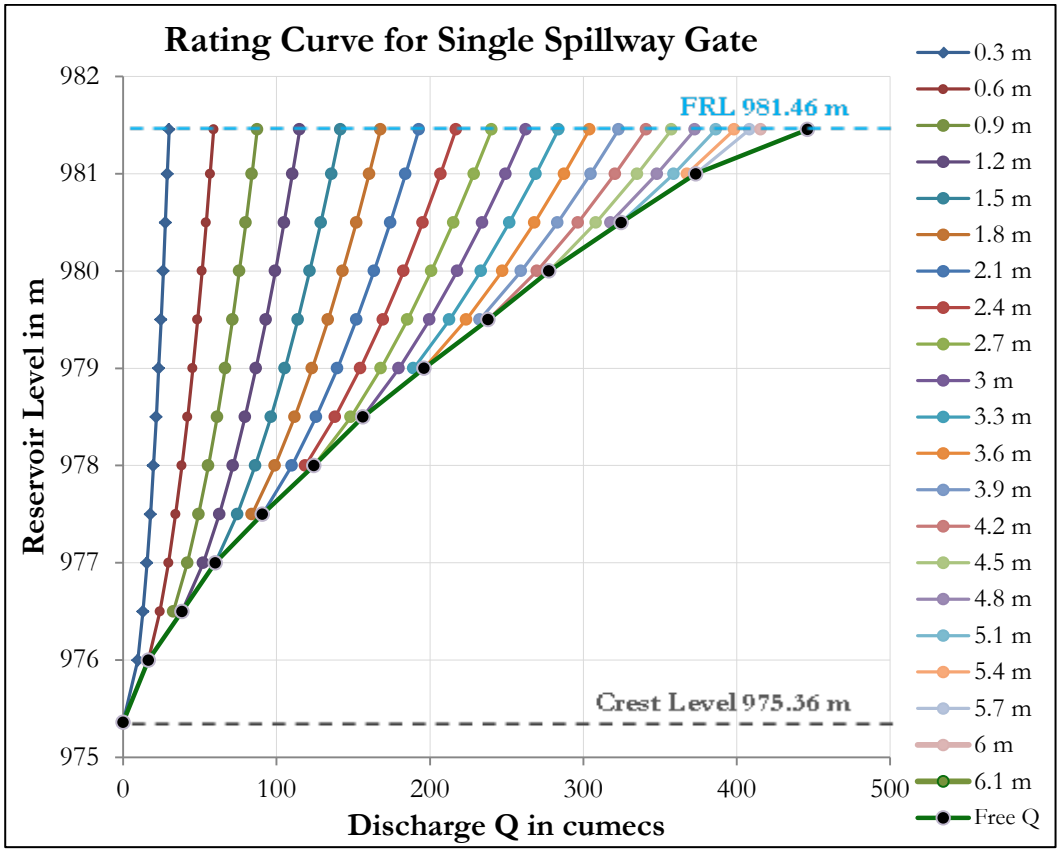

Fig 2.9 Discharge curves for Single Spillway Gate

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 Kakki Anathodu reservoir is arrived at by the committee constituted vide Order (CMD) No 628/2018 (DGC-AEE-II/Flood/2018) TVPM, dated 20.10.2018 where in the following parameters are considered for fixing the rule curve levels;

- MWL of reservoir - 982.16 m
- FRL of reservoir - 981.46 m
- MDDL - 908.304 m
- Crest level of spillway - 975.36 m
- Maximum generation from power station - 340 MW
- At the end of the water year, 31st May, the target level is fixed as 908.30 m (MDDL), as decided by the committee.
- The target level in the reservoir at the end of monsoon season, on November 20th is kept as 981.00 m as decided by the committee.
- Reservoir level shall not fall below 908.30 m.
- From the storage corresponding to target level 981 m on November 20th, the storage at previous time steps are worked out for the inflow corresponding to 50% dependable inflow. Hence from the levels corresponding to 50% dependable inflow, the intermediate upper rule curve levels are judiciously arrived.

Upper Rule Curve 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 981 m. The target level in the initial time step is taken as 976 m (Crest Level of spillway - 975.36 m). The storage corresponding to rule level and the flood space available at respective levels is shown in the **Table 2.6** below.

Upper Rule levels of Kakki - Anathodu reservoir					
Time Step	Date	Upper Rule Levels	Rule storage	Flood space up to FRL	Percentage Gross Storage
		m	Mm3	Mm3	%
1	June 10th	**976**	366.68	87.46	80.7%
2	June 20th	**976**	366.68	87.46	80.7%
3	June 30th	**976**	366.68	87.46	80.7%
4	July 10th	**977**	382.7	71.44	84.3%
5	July 20th	**977**	382.7	71.44	84.3%
6	July 31st	**977**	382.7	71.44	84.3%
7	Aug 10th	**978**	398.72	55.42	87.8%
8	Aug 20th	**978**	398.72	55.42	87.8%
9	Aug 31st	**978**	398.72	55.42	87.8%
10	Sep 10th	**978.5**	406.73	47.41	89.6%
11	Sep 20th	**978.5**	406.73	47.41	89.6%
12	Sep 30th	**979**	414.74	39.40	91.3%
13	Oct 10th	**979.5**	422.74	31.40	93.1%
14	Oct 20th	**979.5**	422.74	31.40	93.1%
15	Oct 31st	**980.5**	438.76	15.38	96.6%
16	Nov 10th	**981**	446.77	7.37	98.4%
17	Nov 20th	**981**	446.77	7.37	98.4%
18	Nov 30th	**981.46**	454.14	0.00	100.0%

Table 2.6 Upper Rule Curve levels of Kakki - Anathodu reservoir

Lower Rule Curve 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 908.30 m. The storage at previous time steps worked out beginning from the target storage. The rule curve levels arrived at corresponding to the respective storages are tabulated below in **Table 2.7**.

Lower Rule levels of Kakki – Anathodu reservoir						
Date	Rule Storage	Rule Level	90% Dependable Daily Inflow	Water Spread Area	Reservoir Losses	P H Demand
	Mm3	m	Mm3	Sq km	Mm3	Mm3
June 10th	276.39	**969.05**	2.56	10.96	0.18	12.89
June 20th	265.63	**967.98**	2.54	10.62	0.18	13.12

June 30th	267.72	**968.18**	11.05	10.69	0.18	8.78
July 10th	275.17	**968.92**	14.51	10.92	0.17	6.89
July 20th	279.06	**969.30**	12.58	11.05	0.17	8.52
July 31st	287.56	**969.96**	18.38	11.43	0.17	9.70
Aug 10th	291.61	**970.28**	15.21	11.62	0.20	10.96
Aug 20th	304.97	**971.33**	24.98	12.22	0.21	11.41
Aug 31st	309.61	**971.69**	20.89	12.43	0.24	16.01
Sep 10th	304.46	**971.29**	12.56	12.20	0.24	17.47
Sep 20th	296.90	**970.70**	12.14	11.86	0.23	19.47
Sep 30th	289.90	**970.15**	6.08	11.54	0.23	12.86
Oct 10th	285.39	**969.79**	5.99	11.33	0.25	10.24
Oct 20th	282.98	**969.61**	9.53	11.23	0.25	11.69
Oct 31st	278.20	**969.22**	10.99	11.02	0.27	15.50
Nov 10th	274.17	**968.82**	10.65	10.89	0.28	14.40
Nov 20th	267.12	**968.13**	8.40	10.67	0.27	15.17
Nov 30th	264.01	**967.82**	6.94	10.57	0.27	9.78
Dec 10th	260.05	**967.42**	7.45	10.45	0.35	11.05
Dec 20th	255.93	**967.01**	5.46	10.32	0.35	9.24
Dec 31st	244.35	**965.86**	6.74	9.95	0.34	17.98
Jan 10th	233.83	**964.82**	0.01	9.62	0.31	10.22
Jan 20th	225.95	**964.04**	0.01	9.38	0.30	7.60
Jan 31st	217.61	**963.21**	0.02	9.11	0.32	8.04
Feb 10th	211.58	**962.50**	2.96	8.94	0.36	8.64
Feb 20th	203.75	**961.57**	0.50	8.72	0.35	7.98
Feb 28th	194.68	**960.48**	1.57	8.46	0.27	10.38
Mar 10th	179.33	**958.65**	1.39	8.03	0.32	16.42
Mar 20th	164.19	**956.79**	1.35	7.58	0.30	16.19
Mar 31st	137.28	**952.87**	0.89	6.57	0.29	27.50
Apr 10th	108.32	**947.93**	0.58	5.24	0.21	29.33
Apr 20th	86.54	**943.45**	1.62	4.24	0.17	23.23
Apr 30th	65.02	**938.05**	2.37	3.69	0.15	23.74
May 10th	38.35	**929.30**	2.55	2.52	0.08	29.13
May 20th	16.94	**917.96**	1.42	1.30	0.04	22.79
May 31st	7.61	**908.30**	1.06	0.66	0.02	10.36

Table 2.7 Lower Rule Curve levels of Kakki – Anathodu reservoir

Based on the upper and lower rule levels, rule curve is arrived for the operation of accordingly is shown in **Fig 2.10** and the maximum (storage) water levels of the respective months in **Table 2.6**. The reservoir water exceeding the rule curve level beyond crest level will be spilled or adjusted with power generation. This rule curve can be used till further revision.

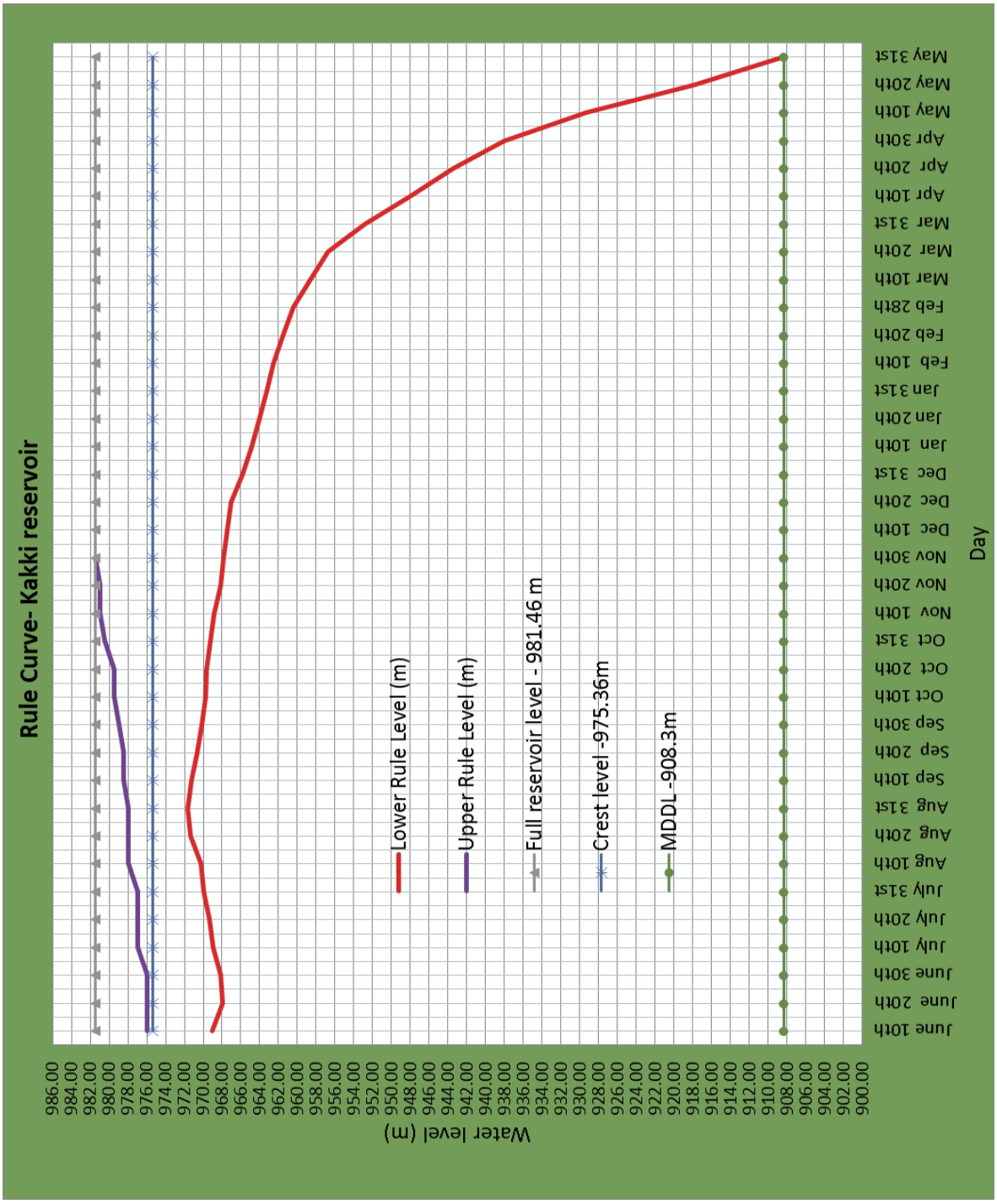

Fig 2.10 Rule Curve for Kakki - Anathodu reservoir

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.

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 four spillway gates in Anathode dam. The sequence of operation of spillway gates is Gate no. **2,3,1,4**. Gate No. 2 is first opened to a unit height on the basis of requirement and then Gate No. 3 is opened to the same height. After that Gate No. 1 and Gate No. 4 is opened to the same height. Further opening of gates is also performed in the same manner. Closing of gates is done in the reverse manner as that of opening.

As per the approved(B O dt 03.06.2019 & G O dt 15.06.2019) upper rule levels vide Table 2.6 , it is proposed to keep the water level at or below 976.00 m (Close to Crest Level) on June 10th and 981.46 m (FRL) on 30th November. But CWC have adopted a more conservative approach in this rule levels and revised rule levels are proposed. Accordingly KSEB Ltd on 08/08/2019 have adopted this modified upper rule levels as suggested by CWC for the time being in the wake of heavy rain experienced in Kerala which is given in Table 2.8 below.

Upper Rule Levels as Modified by CWC	
KAKKI-ANATHODE RESERVOIR	
Time Step	UPPER RULE LEVELS (m)
June 10th	975.36
June 20th	975.36
June 30th	975.36
July 10th	975.36
July 20th	975.36
July 31st	975.36
Aug 10th	975.75
Aug 20th	976.00
Aug 31st	976.20

Sep 10th	976.40
Sep 20th	976.60
Sep 30th	976.91
Oct 10th	977.95
Oct 20th	978.83
Oct 31st	979.84
Nov 10th	980.56
Nov 20th	981.00
Nov 30th	981.00

Table 2.8 Modified Upper Rule levels of Kakki - Anathodu reservoir by CWC

2.3.6 Climate

Kakki-Anathode catchment receives comparatively good rains almost throughout the year. It is observed that the rains contributed by South-West monsoon are comparatively heavier than the rains precipitated during North-East monsoon.

2.3.7 Inflow forecasting/Methodology

There is no inflow forecasting system at present in Kakki and Anathodu dams. The methodology followed for working out the inflow is given in **Cl. 2.3.7.1.**

2.3.7.1 Inflow Computation

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

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

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

2.3.7.2 Summary of Flood Regulation Procedure

The flood regulation procedures at Kakki-Anathodu can be summarized as follows;

1. Observe the reservoir level at 1 hour intervals.
2. Determine the total outflow occurring at all outlets (including river outlets, spillway, power intake)
3. Estimate the inflow
4. Determine the gate opening as the case maybe.
5. Open the required number of gates to the extent required to maintain constant reservoir level. i.e., release is equal to the inflow as per the upper rule curve.

2.3.8 Emergency Operation

The Emergency operation will be carried out following the Emergency Action Pan (EAP). The Emergency conditions are outlined in **Chapter 4** under **Cl. 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

SGHEP Power House is located in Moozhiyar, Seethathodu village, Konni Taluk around 60 Km from Pathanamthitta. The Power Station was commissioned during 1967 with Six Generators having vertical shaft Pelton turbines. The present total installed capacity of the station is 340 MW with annual firm generation of 1338 MU.

2.4.1 Power Outlets

The intake structure is located on the left bank of the reservoir upstream of Kakki dam. The intake arrangement consists of a trash rack arrangement (inlet face of power tunnel) and a control shaft of excavated section 20'-3" x 15' (6.172 m x 4.572 m) elliptical with sectional area of 238.5 sq ft (22.157 m^2). Total height of control shaft is 237 ft (72.238 m) between levels 3208 ft and 2971 ft. The flow through the tunnel is regulated or controlled by one Vertical Lift Gate of size 15'x11'3" (4.572 m x 3.429 m) sealed on the upstream and operated inside the above shaft (Details of gate and hoist provided in **Cl. 2.3.1**). The average lining thickness of the shaft is 1'6" (0.457 m) with reinforcement ½" dia. at 12" c to c both ways.

An elliptical wall from level 3208 ft to 3235 ft has been constructed, over which the hoist platform and other arrangement have been erected (see **Fig 2.11(a)** & **(b)**). The control shaft location is 353 ft (107.594 m) from the inlet face of the tunnel. Details of intake and control shaft are given in **Drg 2.15** and **Drg 2.16** of **Annexure 1.**

(a) **(b)**

Fig 2.11(a) Power Intake Structure of Kakki-Anathodu, (b) Wire Rope Drum of Intake Gate

Trash-rack structure

Trash rack arrangements are provided at the inlet face of power tunnel, in a semicircular pattern around the tunnel mouth supported by R.C.C. columns and ribs. There are 5 nos. R.C.C. columns 13'3½" c/c (4.05 m) connected by R.C.C. arch ribs at 10' (3.05 m) c/c vertically which forms the structure for the trash rack. The trash rack sill level is 896.97 m and centre line of inlet is 902.80 m. Height of the columns is 50 ft (15.24 m) over which there is a covering slab of 2'0" (0.61 m) thickness. The trash rack is in submerged condition. Trash-rack was manufactured with 20 no's panels of size 11'10 ½" x 10' (3.62 m x 3.05 m). 5 no's have been erected vertically one over the other between each column. The panels having frames welded with 8" x 3" double channel with 7 nos. vertical and across 'I' section girders 7" x 3 ½" (0.18 m x 0.09 m) and trash bars with 2"x ½" flats are welded at 2 ½" (0.064 m) c to c was fabricated by Kerala Allied Engineering Co. (Pvt.) Ltd., Kundara. Welding for fabricating the trash rack was done by electric arc method. Precautions were taken to minimize stress due to expansion and contraction and also distortion due to heat. One coat of red lead painting has been done to the panels of the trash rack. Permanent hoisting arrangements for lifting and re-erecting the trash racks have been provided over the column. For this purpose 5 nos. columns

12 ft (3.66 m) height with connecting beams 2'x ½' (0.61 m x 0.15 m) have been constructed on which the hoist arrangements are located. The elevation and sectional plan of trash-rack arrangement is shown in **Drg 2.17** of **Annexure 1**. Details are provided in **Cl. 4.3.5** below.

2.4.2 Power Tunnel

The power tunnel 18274 ft (5569.92 m) long and 15' (4.572 m) diameter, takes off from the Kakki reservoir and ends in a simple surge shaft, is designed for a maximum discharge of 1920 cusecs. The finished section of the tunnel has an area of 177 Sq ft (16.44 m^2). The driven section is 245.1 Sq ft (22.77 m^2). The tunnel is lined with cement concrete 1**:** 2 ¼**:** 3 ¾ with 1 ½" graded metal using 20 bags of cement per 100 cft.

The tunnel was constructed from seven working faces afforded by three Adit tunnels. Adit-1 at Ch.3323', Adit- 2 at Ch.12677' and Adit- 3 at Ch.17731'. The surge shaft is located at Ch.16858. Grade for the I^{st} section of tunnel is 1 in 250 up to Adit No.1, 1 in 310 from Adit No.1 to Adit No.2 and 1 in 110 from Adit No.2 to a point X (1044' (318.21 m) upstream of the surge shaft). The slope from point X to surge is 1 in 100 and this slope continues up to the exit face.

2.4.3 Surge Shaft

Sabarigiri surge shaft located at the end of a 16858' (5138.32 m) long head race tunnel is of the simple type with expansion chambers at top and bottom. The surge shaft has been designed to take care of worst combinations of load variations occurring under practical conditions of station load operation. The design features of the surge shaft have been finalized after checking their suitability and efficiency by model studies conducted at C.W.P.R.S, Pune. The construction of the surge shaft was completed, and made ready for use early in February 1966. This ring type gallery is a unique and novel feature in the design of the surge system and is an edifice to engineering skill. The plan and section of surge shaft showing surge gallery are given in **Drg 2.18** and **Drg 2.19** of **Annexure 1**.

The main shaft is 25 ft (7.62 m) in dia. and has a height of nearly 350 ft (106.68 m). The expansion chamber at top which controls the maximum upsurge level is 45 ft (13.72 m) dia. and has a height of 85 ft (25.91 m) (**Drg 2.20** of **Annexure 1**). The gallery at bottom is in the shape of an arc of circle of radius 125 ft (38.1 m) and is connected to the main shaft by two connecting spokes (**Drg 2.21** of **Annexure 1**). The anchor portion has a dia. of 22' (6.706 m)

and is 350' (106.68 m) in length. The connecting spokes are 15 ft (4.572 m) in dia. and 101.5 ft (30.94 m) in length each. This particular shape has been evolved as a result of detailed studies made by the KSEB engineers and by model studies. Steel lined tunnel 3.75 m dia. and 403.70 m long takes off from the surge shaft and trifurcates to form three surface penstocks of length 2.5976 km. See **Drg 2.22a** of **Annexure 1**. Each HPP is bifurcated near the power house to feed the six machines. See **Drg 2.22b** of **Annexure 1**.

2.4.4 Penstocks

The Sabarigiri penstocks run down from the inside of power tunnel at about elevation 2980' (908.304 m) running for a length of about 8500 ft (2590.8 m) along the hill slopes on the Vettilappara valley and ends at about elevation +641.00 where it is connected to the turbine of the power station.

The Sabarigiri penstocks have been designed to convey a maximum of 1920 cusecs through a drop of 2581' (786.685 m) to the power station to feed six turbo generators with an overall installed capacity of 300,000 KW. The penstock consists of (a) L.P.P. and (b) H.P.P.

2.4.4.1 Low Pressure Pipe Line (L.P.P.)

Starting at the upstream face of the bell mouth at the surge shaft at elevation +2881 till the portal point at the exit, the power tunnel has been lined with M.S. Plates ASTMA 285 Grade-C Firebox quality having yield points stress of 21 kg/mm^2. This lining forms part of the L.P.P. The L.P.P. continues till the 'Trifurcation' point. The total length of the L.P.P. is 410.252 m having a constant external diameter of 3750 mm and shell thickness 1", 1-1/16" and 1-1/8". See **Drg 2.18, Drg 2.19 & Drg 2.21** of **Annexure 1**.

20" internal diameter drain pipe has been fixed to the L.P.P. at a point 147.502 m from the 'Trifurcation' on the upstream and laid along the Adit. The total length of the drain pipe is 136' (41.453 m) and leads into the Vettilappara valley. The drain pipe system is controlled by a sluice valve and disperser at the downstream end.

2.4.4.2 High Pressure Pipe Line (H.P.P.)

The L.P.P. terminates at the trifurcation to be connected to the 3 nos. high pressure Penstocks each line controlled by 78" (1.98 m) – Horizontal shaft Servomotor – operated and counter weighted – Butterfly valves. The valves are located at 24.384 m below the Trifurcation

point. The three surface penstocks from the Trifurcation point to the power house from the HPP system. The High Pressure Penstocks are made of special type of high - tension steel viz. Lukens 36 carbon steel. See **Drg 2.23** of **Annexure 1**.

There are, on the whole 18 bends in the penstock alignment of which 10 are compound bends having both vertical and horizontal bends. One expansion joint each is provided immediately downstream of all the anchors except the last anchor. From the last surface anchor, the penstocks are taken through three diverging inclined tunnels. This last anchor being situated on a steep incline called fort for a load distribution technique involving heavy reinforcements. At the lower end of the inclined tunnel, each penstock bifurcate **(Drg 2.22b & Drg 2.24** of **Annexure 1)** and the six branches are taken through six short independent tunnels spaced at 48 ft (14.63 m) centre to centre, to the turbines.

2.4.5 Initial Filling of Reservoir

Partial storage of water in reservoir for power generation was scheduled to be by 31st May 1964. The first partial storage in the flanking dam started during the year 1965 at RL 3116/3120 when the upstream embankment was ready. Since the dam works of Kakki and Anathodu were ongoing in full swing, the level 3116/3120 had to be kept constant throughout the year.

But as there was delay in obtaining the batching plant from USA, it was not possible to adhere to the above programme. So the concreting in the dam had a delayed starting in January 1964 and the revised schedule for partial storage was fixed on 27th January 1966. The delay in fabrication of penstock pipes and erection of power house machinery, the construction sluice in Kakki dam could be plugged only very late and partial storage commenced only on 27.01.1966. Partial storage was done in advance of installation of emergency gates and hollow jet valves in the reservoir and ultimate power generation commenced on 20.04.1966. The anticipated storage level of 3190' was achieved in 1966 rains.

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.
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

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Chapter 3

Project Inspection

An effective inspection program is essential to identify problems and to keep a dam in a good and healthy condition. Inspection details and suggestions are kept at field office and reports are sent to higher offices. The current practice of Inspection at Kakki and Anathodu dams envisages that the Deputy Chief Engineer along with Executive Engineer are 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 format followed as per CWC has now been revised during January 2018 and new guidelines have been issued vide Doc No. CDSO_GUD_DS_07_v1.0, CWC 2018 for Safety Inspection of Dams. The health reports of the dam are to be prepared in the new format meant for incorporating the data in DHARMA. Detailed description on project inspections is available in the Guideline for Safety Inspection of dams. However an overview of the various types of inspections required to be carried out at Kakki and Anathodu 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. Guidance for carrying out other inspections is elaborated in the following paragraphs.

3.1 Types of inspections

Four types of dam safety inspections can be carried out at Kakki and Anathodu 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 also to be maintained.

3.2 Comprehensive Evaluation Inspections

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

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

A comprehensive evaluation inspection of Kakki & Anathodu dam consists of five major parts:

1. Review of project records (i.e. study of all design / construction records/drawings, history of the dam's performance, past inspection notes/reports, notes on distress observed/ any rehabilitation measures undertaken earlier, instrumentation data and its interpretation.
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
- Basic data and issues related to safety of dam
- Problems, if any, during construction
- Drawings of dam, spillway, gates and appurtenant structures
- Seismicity aspects & details
- Status of the instrumentation
- Construction history
- Geological report including special problems at site and their treatment
- Field Inspection- Observation and recommendation regarding remedial measures
- Dam incidents and reservoir filling details

Dam Incidents and Reservoir filling

The delay in fabrication of penstock pipes and erection of power house machinery, the construction sluice in Kakki dam could be plugged only very late and partial storage commenced only on 27.01.1966. Partial storage was done in advance of installation of emergency gates and hollow jet valves in the reservoir. The details may be produced to DSRP.

3.3 Scheduled Inspections

Scheduled inspections shall consist of Pre-monsoon and 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.

Scheduled inspections include the following components as a minimum:

- Review of past inspection reports, monitoring data, photographs, maintenance records, or other pertinent data as may be required
- Visual inspection of the dam and its appurtenant works

- Preparation of a report or inspection brief, with relevant documentation and photographs. The report should be filed in the dam owner's project files.

3.3.1 Pre- 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	:	Deputy Chief Engineer along with SPMU Executive Engineer, Field Executive Engineer, Concerned field Assistant Executive Engineer and Assistant Engineer
Preparation of Inspection Report	:	Executive Engineer, Field (Dam Health Engineer)
Submission of Pre-monsoon Inspection Report	:	Before June 30th
Submission of Post-monsoon Inspection Report	:	Before January 15th
Checking and approval of report	:	Deputy 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 available relevant files or data,
2) Visual inspection of all components of the project and surroundings, and
3) Report preparation covering status of project and recommendations.

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

3.5 Informal Inspections

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

Operators, maintenance crews, or other staffs who are posted at Kakki and Anathodu dam site are supposed to conduct informal inspections on routine basis. These people are the 'first-line of defense' in assuring safe dam conditions, and it is their responsibility to be familiar with all aspects of the dam. Their vigilance while walking across the dam for inspection/surveillance, checking the operating equipment, and noting down any visible changes in conditions may prevent serious mishaps or even dam failures.

Informal inspections are important and are performed at every available opportunity. These inspections may only cover one or two dam components as the case may be, or they may cover the entire dam and its appurtenant structures in one go. The informal inspections are not as detailed as comprehensive evaluation, scheduled, and special inspections and will only require that a formal report is submitted to the dam owner's project files if a condition is detected that might endanger the dam. Report is to be submitted detailing the condition discovered along with photographs, time, reservoir water level, other features etc.

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Chapter 4

Project Maintenance

A good maintenance program is required to protect a dam against deterioration, prolong its life and greatly reduce the chance of failure. Maintenance program for a dam should be developed primarily based on systematic and frequent inspections. Nearly all the components of a dam and its materials are susceptible to damage and deterioration if not well maintained. Moreover, the cost of a proper maintenance is small compared to the costs of major repairs, loss of life, property and litigation. If maintenance of a dam is neglected the consequences and costs could be enormous.

4.1 Maintenance Plan

A basic maintenance schedule for the various monitoring components prepared for Kakki and Anathodu dams based on manual of operating parts, frequent inspections, priority, and interval for Kakki and Anathodu dams is arrived at showing the tasks to be performed and how frequently that is to be inspected/ observed and repaired. See **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 inoperable gates.
- Evidence of excessive seepage as seen in the gallery/on downstream face of the dam.

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

4.2.2 Preventive Maintenance

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

4.2.2.1 Condition Based Maintenance

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

- Remove all vegetation and bushes by roots from the dam surfaces, 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.
- Repair of the upstream face of masonry dams, where the pointing of masonry joints is damaged.
- Controlling any heavy seepage in the foundation/ inspection galleries in Concrete/masonry dams from drainage holes.
- Repairs of any cracks/cavities/joints in concrete/masonry dams/structures. However many of these works will require the services of experienced engineers/expert panels.

4.2.2.2 Routine Maintenance

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

- Any routine repair to concrete or metal component.
- Observation of any springs or seepage areas in shear zones, faults etc., comparing the quantity and quality (clarity) with earlier observations.
- Monitoring of downstream development which could have an impact on the dam and its hazard category.
- Maintenance of Electrical & Hydro-Mechanical equipment and systems e.g. servicing of spillway gates, hoisting arrangements, and gates/hoist of Intake and outlet works & stand by generator.
- Maintaining proper lighting at dam top, galleries of the dam etc.

- Monitoring of seepage in foundation galleries of masonry/concrete dams.
- Monitoring/cleaning & removal of leached deposits in porous concrete/formed drains in dam body and foundation drainage holes of masonry/concrete dams.
- Maintenance of all dam roads & access roads.
- Operation of electrical and mechanical equipment and systems including exercising gates and valves.
- To keep the gate slots clear of silt/debris.
- Maintenance/testing of monitoring equipment (instruments) and safety alarms.
- Testing of security equipment.
- Testing of communication equipment.
- Any other maintenance considered necessary.

4.3 Procedures for Routine Maintenance

4.3.1 Controlling Damage from Vehicular Traffic

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

4.3.2 Controlling Vegetation

Removal of vegetation around the dam and other 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 Kakki Dam are detailed in **Clause 2.2.4** and the operation and maintenance are detailed out in the manufacturer's manual which is kept at the field office. The valve and flexible couplings should be lubricated after every twenty-five operating hours or once every three months, whichever comes first. For lubrication of flexible couplings, use high quality grease as recommended by the manufacturer.

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 through 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 to. If routine inspection of the Hydro-Mechanical Equipment shows the need for maintenance, the work should be completed as soon as possible.

4.3.5 Trash Racks

Trash racks provided in front of the Kakki dam outlet may become clogged with debris or trash which reduces their discharging capacity. The head losses through clogged trash racks also increase. Maintenance of trash racks includes periodic inspections for rusted and broken sections and repairs are made as needed. Trash racks should be checked during and after floods to en-sure that they are functioning properly and to remove accumulated debris periodically as per site requirements.

Trash racks provided in front of the Intake of Kakki dam are submerged and below MDDL and frequent cleaning is not necessitated. The trash rack cleaning is possible only after depleting the reservoir. As the trash racks are submerged deep below the MDDL normally frequent cleaning is not necessitated and hence no cleaning mechanism provided.Drawing of trash rack structure is provided in **Drg 2.16** of **Annexure 1.**

4.3.6 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.

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 and 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 wheel shall be rotated to check their free movement. Gate roller bearings and guide roller bushes should be properly lubricated. Whenever necessary these should be opened for rectifications of defects, cleaning and lubrication and should thereafter be refitted. These may be replaced if repairs are not possible.

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

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

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

viii) All welds shall be checked for cracks/ damages. Any weld that might have become defective should be chipped out and redone following the relevant codal provisions. Damaged nuts, bolts, rivets, screws etc. should be replaced without delay.

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

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

xi) All nuts and bolts shall be tightened.

The 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. Appropriate action to replace the damaged seal needs to be taken immediately after monsoon. Weeping or slight flow in localized area will not require immediate remedial measures. However, measures like tightening of bolts are carried out. Further adjustment is carried out during annual maintenance.

b) **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.

d) **Embedded Parts:**

i) All the sill beams and wall plates shall be inspected for crack, pitting etc. and defects shall be rectified.
ii) The guide roller pins shall be lubricated.

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

4.3.7 Maintenance of Hydraulic Systems

a. Introduction: Long service life and functional reliability of, any hydraulic system and its components are dependent on proper maintenance. Although commissioning of hydraulic system is not directly related to maintenance but after years of experience by users it is realized that, careful commissioning means less troubles in further service life, maintenance, servicing and repairing. Maintenance of hydraulic hoist of Kakki dam emergency gates of river outlets **(Cl. 2.2.4)** is detailed in manufacture's manual including the drawings and functional description of complete Hydraulic system. This supporting

document is kept at field office. The hydraulic hoist gland of emergency gate must be lubricated with Alemite pressure gun after every four hours of hoist operation or every three months, whichever comes first. Use high quality multipurpose grease, such as Shell Oil Alvania EP No. 2, or equivalent for this purpose. The lubrication of bridge parts, trolley wheels, gears and chains of upstream service hoists and lubrication of trolley of downstream service hoists must be done as per manufacturer's recommendation. The bearings of downstream service hoists should be lubricated after every twenty-five operating hours or once every three months, whichever comes first. The bearings are lubricated through grease fittings. Use high quality multipurpose grease, such as Shell Oil Alvania EP No. 2, or equivalent for lubrication.

b. **Routine Maintenance:** After careful commissioning certain points should also be taken Care of for routine maintenance.
   1. Check the fluid level continuously during commissioning of the equipment, after then daily, and later weekly.
   2. During commissioning filter should be checked after every two to three hours of running the unit and cleaned if necessary. There after they must be checked and cleaned every week.
   3. Hydraulic accumulator charging pressure should be checked from time to time.
   4. Measure the oil temperature in the oil reservoir and also in the region of pump bearings.
   5. Check every week all the pipe joints and tighten them up if found loose.
   6. Main pressure and pilot pressure of the system must be checked up periodically.
   7. Check the alignment of pump motor set regularly.

c. **Safety Aspects:** As hydraulic system (essentially high pressure systems) if not handled properly may endanger the environment and human life. During any service, repair or maintenance activity it is essential to place special emphasis on the safety aspects, at every stage, so that one can avoid loss of property or life.

Apart from designers and quality control personnel, make sure that the maintenance and service personnel are aware about the safety requirements. At the application stage itself, the environment condition should be considered under which the equipment is to operate, so that safety features can be built against hazards, such as fire, pollution, health hazards, etc. While designing the system also, the specific attention should be given to the safety aspects. If proper

pipes and fittings are not used in the equipment, some object may fly off and hit somebody which may result in injury or death. In a pressure vessel like accumulator, if oxygen is filled in place of nitrogen, may explode after words either by some spark, or by somebody smoking nearby. Technician opening the pump or valve without realizing that a particulars valve backed by compressed spring can fly on the face of somebody and hit him fatally. Leakages from pipes, fittings, manifolds etc. In the fire hazards area may result in fire and may cause loss of life and property. In case of winches and hoists or vertical cylinders, the over-loading by the user may result in free fall of the load which may result in facilities apart from damages to the properly. Hydraulic oil leakage may damage the soil and hence the ground water and the plant life and consequently the damage to animal life and human life. Hence please make sure that equipment is not leaking. While operating the equipment legal/mandatory regulations of the state must be essentially complied with.

4.3.8 Maintenance of Electrically operated fixed hoists

i) 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.

ii) Inspection and Maintenance:

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

i. Entrance to all hoist platforms shall be kept locked. All keys shall remain with the shift supervisor.
ii. A cursory daily inspection shall be made of hoist and gate to ensure that there is no unusual happening.
iii. Clean all hoisting equipment and hoist platform.
iv. Check oil level in gearboxes and replenish as and when required with oil of proper grade.
v. Apply grease of suitable grade by grease gun.
vi. Lubricate all bearings, bushings, pins, linkages etc.
vii. 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.

xviii. All wire ropes shall be greased with cardium compound.

xix. Check the overload relays for proper functioning.

xx. 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.

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

xxii. 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.

xxiii. 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.

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

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

4.3.9 Maintenance of Electrical components of Fixed Rope Drum Hoists

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

i) Starters should be cleaned free of moisture and dust.

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

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

iv) If the contactor hums, the contact faces should be cleaned.

(v) Examine all connections to see that no wires are broken and no connections are loose.

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

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

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

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

x) Do not lubricate the contacts.

xi) Examine earth connections and motor leads.

xii) Examine motor windings for overheating

xiii) 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.

xiv) Examine control equipment

xv) Examine starting equipment for burnt contacts

xvi) Check and tighten all nuts and bolts

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

xviii) Lubricate the bearings

xix) Overhaul the controllers

xx) Inspect and clean circuit breakers.

xxi) Wipe brush holders and check bedding of brushes.

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

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

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

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

xxv) Over haul the motor, if required.

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

xxvii) Check resistance or earth connections.

xxviii) Check air gap.

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.

viii) Brake drum shall be cleaned to remove any dust or grease.

4.3.10 Electrical System

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

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

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

4.3.11 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. The metal parts of the gates were painted by zinc rich primer and epoxy. The hoist motor parts were painted using synthetic enamel paint.

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 24 hours of coal-tar blend epoxy resin so as to get a dry film thickness of 80 microns in each coat. Total dry film thickness of paint shall not be less than 300 microns

b) Gates:

- Primer Coat:

Over the prepared surface one coat of inorganic zinc silicate primer giving a dry film thickness of 70 ± 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 IS 2339 – 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 off 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 de-scaled 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.

4.3.12 Access Roads

For a dam to be operated and maintained there must be a safe means of access to it at all times. Access road surfaces must be maintained to allow safe passage of automobiles and any required equipment for servicing the dam in any weather conditions. Routine observations of any cut and fill slopes along the sides of the road should be made. If unstable conditions/slope failure/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 most of access roads of the project is executed under DRIP.

4.3.13 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 road and galleries are to be cleaned regularly.

For Kakki and Anathodu dams, there are two access galleries meeting the foundation gallery. The dam top roads and these access galleries are cleaned regularly.

4.4 Materials and Establishment Requirements during Monsoon

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

Materials normally required to be stocked in sufficient quantity are:-

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

At Kakki and Anathodu dams, 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 both dams. The departmental regular manpower provided for Kakki – Anathodu dams are as below:

Present Manpower			
Designation	**Kakki Dam**	**Anathodu Dam**	**Remarks**
Executive Engineer	1		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.
Assistant Executive Engineer	1	1	
Assistant Engineer	2	1	
Sub Engineer	5	4	
Security Staff	As mentioned in **Cl. 1.8.1**		

Additional operating staff (gate operators, workers, electrician etc.) will be engaged on contract basis for meeting the exigencies during monsoon based on site requirement.

4.5 Preparation of O&M budget

The O & M budget for Kakki and Anathodu 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 and maintenance/cleaning of drains in dam, maintenance of lift/elevators in dam (as applicable), maintenance of access roads & basic facilities, provision for flood contingency works during monsoon, unforeseen events/items (about 10% of the cost of works) etc.

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 gate hoists			
3.2	Power supply lines			
3.3	Electrical fittings on dam top, dam galleries, etc.			
3.4	Standby power / diesel generator			
3.5	Remote control			
4	**Instrumentation**			
5	**Miscellaneous works**			
6	**Salary of work charged staff including all benefits**			
7	**Materials to be stored before monsoon**			
	Sub-total - b			
c.				
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.

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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 by drawing 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**.** The extent and nature of the instrumentation depends not only on the complexity of the dam and the size of the reservoir, but also on the potential for threat to life and property losses downstream. The involvement of personnel with experience in the design, installation, regular monitoring, and evaluation of an instrumentation system is of prime importance to the success of the program.

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

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 Kakki Dam - Instrument Types and Usage

The original proposal was to install various instruments in Kakki dam, but none of the instruments were received in time. Hence no instrumentation was possible. Uplift cell pipes were installed from the foundation rock and were taken to the foundation galleries in blocks 9 and 13. Uplift pressure readings are taken by fixing pressure gauges to the outlet of these pipes. There are 73 pipes without pressure gauges fixed over the pipes. During the course of concreting thermo-couples with 20 ft to 30 ft wire length were embedded in the concrete. The temperature developed in the concrete after different days of placing the concrete were measured using 'Pyrotest'. The thermo-couples, as well as, 'Pyrotests' were imported from U.S.A.

A 12" dia. plumb-bob well (**Drg 5.1** and **Drg 5.2** of **Annexure 1**) for the measurement of deflection and 2'6" dia. gauge for the automatic level recorder have also been provided in this dam. A system of feeder pipes has been embedded in 4 of the blocks for supplying air or water whenever required at a later stage. The location of the instruments installed in the dam is shown in the sectional drawing **Drg 5.1** of **Annexure 1**.

Due to aging, the instruments are not functioning now. Presently a V-notch and pressure gauge are available. The pressure gauge is not working and it is to be replaced. No other instruments are installed in the dam. The modernization of instrumentation is being arranged under DRIP separately. It is also proposed to install Tilt sensors, Joint meters, Thermo meters and accelerographs in the dam under DRIP. The status of instrumentation in Kakki dam is given in the **Table 5.1**.

STATUS OF INSTRUMENTATION IN KAKKI DAM			
Sl. No.	**Name of Instruments**	**Total No installed**	**Functioning**
1	Single V – notch	1	1
2	Upright Pendulum	1	0

Table 5.1 Instrumentation in Kakki dam- Present Status

5.1B Anathodu Dam - Instrument Types and Usage

The monitoring of seepage through foundation drain holes and body drain holes are conducted once in a month with V notch installed. The uplift pressure of the reservoir is

measured and recorded for statistics and to compare the results with the design assumptions and to find out whether the pressure is within the assumed limit. Water sample analysis is also conducting once in a month.

The location of the instruments proposed and provisions given at the time of execution is shown **Drg 5.3, Drg 5.4, Drg 5.5, Drg 5.6** and **Drg 5.7** of **Annexure 1**. Only V notch is installed, no other instruments installed in the dam. The modernization of instrumentation is being arranged under DRIP. It is also proposed to install uplift pressure meter, Tilt sensors, Joint meters, Thermo meters and accelerographs in the dam under DRIP. The status of instrumentation in Anathodu dam is given in the **Table 5.2**.

STATUS OF INSTRUMENTATION IN ANATHODU DAM			
Sl. No.	**Name of Instruments**	**Total No installed**	**Functioning**
1	Single V – notch	1	1

Table 5.2 Instrumentation in Anathodu dam - Present Status

5.2 Parameters monitored

Seismic Activity

The project area falls in zone no III of the seismic zone map of India. The maximum intensity felt by the Kakki and Anathodu dam sites has ranged from 5 to 7 on M.M. Scale. The dams are required to be safe using the appropriate seismic coefficients as per BIS code and as approved by NCSDP. Historical significant earthquake events in the near vicinity are as under

- Event 1: Date: 12/12/2000, Epicenter: Erattupetta, Magnitude: 5 and
- Event 2: Date: 1/7/2011, Epicenter: Erattupetta, Magnitude: 4.8

The Seismic observatory installed at Pamba is not working. Hence new digital seismic observatory as well as accelerographs for the Dam galleries for measuring local tremors is included under DRIP instrumentation program.

Weather Conditions

Now the rainfall data is measured with rain gauges. But a fully equipped weather station can sense all weather conditions. Automated weather station is proposed.

5.2A Kakki Dam

5.2A.1 Water Level

Water level gauge is provided for Kakki dam. Daily water levels are taken two times. During monsoon, hourly readings are taken and recorded.

5.2A.2 Seepage Flow

Seepage is measured with V notches for Kakki dam.

Seepage assessment

In Kakki dam, there are 94 Vertical drain holes and about 70 numbers of foundation drain holes. See **Drg 5.8** of **Annexure 1**. Monthly observations of these holes are being carried out. Total seepage is measured using a V notch established in 9th block in bottom gallery.

5.2B Anathodu Dam

5.2B.1 Water Level

Water level gauge is provided. Daily water levels are taken two times. During monsoon, hourly readings are taken and recorded.

5.2B.2 Seepage Flow

Seepage is measured with V notches.

Seepage assessment

In Anathodu dam, there are 40 numbers of formed body drain holes and 45 numbers of foundation drain holes. Monthly observations of these holes are being carried out. Total seepage is measured using a V notch established in 8th block in the drainage gallery. Most of the drain holes are choked/partially choked.

5.2B.3 Uplift Pressure

Uplift pressure meter (removable) are available for measuring the uplift pressures. For measuring the uplift pressure, a pressure gauge is fixed on the packer assembly with a side opening of 1" dia. pipe on the 3" side of Tee connection, already mounted on the foundation drain holes. The pressure gauge works for some time and the pressure increases gradually,

reaches the maximum, depending upon the static head for the level in the reservoir at the time of test.

5.2B.4 Water Quality

The quality of water including pH value is tested periodically at the Analytical Laboratory, Jala Bhavan, Thiruvanathapuram.

5.3 Frequency of Monitoring

Water levels monitored daily, the seepage data monitored on fortnightly basis and water quality on monthly basis.

5.4 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. Interpretation of data, so collected, needs to be carried out judiciously. Help of experienced personnel from the concerned field from Institutes / manufacturers / instrument suppliers could prove to be useful.

5.4.1 Data Collection

On daily, fortnightly and monthly basis as the case may be.

5.4.2 Data Presentation

On monthly basis. A monitoring report of Anathodu dam is prepared and is included in **Annexure 8.**

5.4.3 Data Interpretation

As per standard practice & on monthly / six monthly / yearly basis or as decided by design authorities.

5.4.4 Dam Performance Evaluation

Performance evaluation is conducted for safe normal operation involving all concerned engineers / officers before and after monsoon.

In case, the data deviates from expected behavior or design assumptions, action should be taken. The action to be taken depends on the nature of the problem, and should be determined on a case-by-case basis.

5.5 Methods of Behavior Prediction

5.5.1 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 should examine visually walking along the dam alignment for any leakages, any distress, wet spots on d/s face of dam, seepage from foundation gallery etc.

5.5.2 Monitoring Results

Analysis and observation of the instrument readings on water level, leakages, uplift and other parameters can ascertain the visually observed behavior. Any deviation from the normal behavior needs to be resolved critically by taking required remedial measures in consultation with senior / experienced engineers.

Details of the seepage measurements of Kakki dam from 2016 to 2019 is tabulated below in **Table 5.3**. Details of the seepage measurements of Anathodu dam from 2014 to 2019 is tabulated below in **Table 5.4**.

Seepage details of Kakki dam from 2016 to 2019												
Month	2017				2018				2019			
	Date	Water level	V notch reading in cm	Seepage in Ltr/min	Date	Water level	V notch reading in cm	Seepage in Ltr/min	Date	Water level	V notch reading in cm	Seepage in Ltr/min
January	19.1.2017	965.41	12.0	426	24.1.2018	976.84	13.2	538	30.1.2019	970.22	4.0	27
February	26.2.2017	964.11	11.5	378	21.2.2018	975.38	12.0	426	28.2.2019	968.62	3.9	24.3
March	17.3.2017	961.23	11.0	342	23.32018	970.98	5.1	48	29.32019	963.77	3.5	22.8
April	19.4.2017	952.73	10.0	270	26.4.2018	962.99	5.0	48	25.4.2019	957.19	3.5	18.96
May	20.5.2017	940.4	8.5	168	24.5.2018	953.58	3.5	19.2	23.5.2019	944.58	3.0	12.9
June	21.6.2017	937.03	7.0	108	28.6.2018	964.64	5.0	48	26.6.2019	931.75	1.5	2.28
July	19.7.2017	647.71	8.0	150	31.7.2018	979.88	21.5	1788	22.7.2019	939.62	2.0	4.68
August	26.8.2017	960.37	9.5	234	31.8.2018	978.83	20.5	1566	21.8.2019	965.61	5.0	48
September	29.9.2017	971.83	11.0	342	28.92018	975.2	13.0	516				
October	27.10.2017	974.45	12.0	420	27.10.2018	975.61	13.2	534				
November	23.11.2017	975.88	13.0	516	29.11.2018	973.61	10.5	183.6				
December	22.12.2017	978.28	15.0	738	29.12.2018	972.16	6.5	90				

Table 5.3 Seepage Details of Kakki dam from 2016 to 2019

Seepage details of Anathodu dam from 2014 to 2019		
Observation date	**Water Level in m**	**Discharge through V-Notch in Litres/minute**
27.01.2014	971.05	114.16
26.02.2014	967.45	37.83
26.03.2014	963.45	16.13
25.04.2014	960.14	1.39
27.05.2014	925.39	Nil
27.06.2014	941.03	1.39
19.07.2014	956.25	2.43
28.08.2014	969.81	159.40
26.09.2014	975.19	278.46
27.10.2014	973.73	159.40
21.11.2014	975.33	185.48
29.12.2014	975.06	213.98
22.01.2015	974.27	159.40
20.02.2015	972.3	114.16
20.03.2015	968.2	62.47
18.04.2015	960.5	8.70
20.05.2015	953.86	2.43
19.06.2015	940.71	0.43
19.07.2015	956.25	2.43
20.08.2015	963.55	13.73
22.09.2015	963.94	28.18
29.10.2015	965.88	37.83
28.11.2015	972.04	38.04
22.12.2015	974.41	77.65
25.01.2016	972.75	77.65
25.02.2016	970.75	44.13
26.03.2016	970.75	44.13
25.04.2016	959.59	3.40
05.05.2016	956.40	3.40
15.06.2016	959.50	3.40
25.07.2016	959.59	3.40
25.08.2016	970.19	44.13
20.09.2016	970.04	44.13

06.10.2016	959.59	64.70
25.11.2016	968.20	62.47
25.12.2016	968.20	62.47
20.01.2017	965.37	37.83
21.02.2017	964.03	28.18
25.03.2017	959.83	1.39
23.04.2017	951.17	2.43
26.05.2017	939.07	0.43
19.06.2017	937.37	0.43
22.07.2017	940.71	0.43
21.08.2017	956.63	2.43
20.09.2017	970.54	114.16
22.10.2017	974.34	77.65
24.11.2017	975.89	185.48
02.12.2017	977.95	114.16
31.01.2018	976.45	278.46
23.02.2018	975.38	277.90
27.04.2018	962.32	13.70
23.05.2018	954.24	4.97
23.06.2018	964.14	77.50
23.07.2018	976.30	277.90
25.08.2018	980.60	352.68
23.09.2018	975.55	213.55
23.10.2018	975.65	277.90
18.11.2018	973.73	113.93
13.12.2018	973.04	113.93
29.01.2019	970.32	113.93
14.02.2019	970.32	113.93
14.03.2019	967.42	28.12

Table 5.4 Seepage details of Anathodu dam from 2014 to 2019

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Chapter 6

Previous Rehabilitation Efforts

6.1 A Kakki Dam - Issues

Before DRIP, maintenance activities were limited to routine repair of electrical systems for hoisting system of Emergency gates of out let and valve operations; gallery drainage; routine mowing, vegetation removal, repair of dam top road and allied works etc. Apart from these routine maintenance activities, no major rehabilitation was carried before the involvement of DRIP. Under DRIP, following Rehabilitation Works have been carried out or under progress. The rehabilitation works under DRIP include:

6.1.1 A Kakki Dam - Leak through lift joints - Drilling & grouting and reaming of formed drain holes

Lift Tower is provided in block no.11 of Kakki Dam, but lift is not yet installed. Proposal for installation of lift at Kakki is included in the DRIP works of SGHEP. Seepage observed on downstream on either side of lift well when water level goes above 970 m. Since leakage and wetting was noticed in the lift well, an inspection using ROV was conducted in the lift well. Certain proposals were drawn and sent to CPMU for their expert intervention and concurrence. But, CWC/CPMU has proposed drilling and grouting at the block 11 corresponding to elevator shaft location. The adjacent blocks (10 and 12) also shows leakage and proposed to grout blocks 10, 11 and 12. After grouting, reaming of body drain holes would be necessitated as they may get choked during grouting. Hence reaming of body drain holes is also proposed. Thus, the work consists of reaming the vertical/inclined body drain holes and drilling the grout holes up to a depth of 55 m and grouting in the drilled holes and capping the grout holes.

6.1.2 A Kakki Dam - Reaming of foundation drain holes

The Dam was constructed long back and due to the calcinations, the foundation drain holes are either fully or partially chocked. Heavy seepage/jetting noticed in between block No.9 and 11 when the reservoir level reaches +975.00 m and above, also some heavy flow also observed at foundation gallery when the reservoir level reaches +975.00 m and above. In order to keep the drain holes functional, it is necessary to ream and clean these drain holes periodically. The experts who visited the dam had suggested reaming of foundation drain holes

and this has been arranged as part of DRIP works. 69 no of foundation drain holes to an extent of 2122 m (total) were reamed and the work completed in 11/2017.

6.1.3 A Kakki Dam - Repairing & reconditioning hollow jet valves

There are two numbers of 54" Hollow Jet Valves and 2 Nos. emergency gates provided at Kakki Dam. **(See Drg 1.8** of **Annexure 1**) The C/L of Hollow Jet Valve is +2943 feet (FRL +3220 ft) and diameter of Pipe 6'0". Repair work of hollow jet valves and emergency gate were arranged under DRIP Phase-1. Right side Hollow Jet valve (No.2) repaired and is in good condition. Left side Hollow Jet valve (No.1) could not be repaired due to uncontrollable leak through air vent pipe near the Emergency Gate. Repair work of hollow jet valve No.1 is to be arranged.

6.1.4 A Kakki Dam - Other Rehabilitation Work under DRIP

Kakki Dam is located deep inside the forest, the electricity supply failure happens frequently at site. Alternate power supply arrangements, especially during heavy rains to operate Intake gate, Hollow Jet Valves and gates, **82.5 KVA DG set** procured for Kakki dam and installed in Generator room.

Other Structural Rehabilitation Measures carried out/ included under DRIP Phase I are: Pressure washing downstream of dam, High mast lighting for dam downstream and search light at abutments, Post top lantern for Dam Top, Repairs to emergency gate including reconditioning the existing control system, Repairing & reconditioning hollow jet valves, Repairs & Maintenance of road to galleries, Security fencing downstream of Dam, Constructing Security guard rooms - one near intake & other at the downstream of Dam, Construction of a security cabin at left bank of dam, Replacing old damaged wearing coat of Dam, Construction of steps & retaining wall for access to V - notch of Dam, Construction of Retaining wall for right bank approach road to gallery of Dam, Providing post top lantern on Dam top, Electrification of gallery & dam top, Providing steel doors to Gallery entrance, Painting walls, hoist, elevator tower etc.

The photographs showing the works done are attached below.

1. ADITS

KAKKI DAM ADDIT-I, BEFORE DRIP WORK

KAKKI DAM ADIT - I, AFTER DRIP WORKS

KAKKI DAM ADIT-II BEFORE DRIP WORKS

KAKKI DAM ADIT - II AFTER DRIP WORKS

KAKKI DAM ADIT-III BEFORE DRIP WORKS

KAKKI DAM ADIT-III, AFTER DRIP WORKS

2. ADIT ROADS & DAM TOP ROAD

KAKKI DAM L/B & R/B ADIT ROADS BEFORE DRIP WORKS

KAKKI DAM L/B & R/B ADIT ROADS AFTER DRIP WORKS

KAKKI DAM L/B ADIT - 1 ROAD ENTRANCE BEFORE DRIP WORK

KAKKI DAM L/B ADIT - 1 ROAD ENTRACE AFTER DRIP WORKS

KAKKI DAM TOP ROAD - BEFORE DRIP WORKS

KAKKI DAM TOP ROAD - AFTER DRIP WORKS

3. GUARD ROOMS - Security, Intake and Left Bank

LOCATION OF GUARD ROOM NEAR INTAKE BEFORE CONSTRUCTION

SECURITY GUARD ROOM NEAR INTAKE - AFTER CONSTRUCTION

SECURITY GUARD ROOM D/S OF KAKKI DAM
BEFORE CONSTRUCTION

SECURITY GUARD ROOM D/S OF KAKKI DAM
AFTER CONSTRUCTION

GUARD ROOM – LEFT BANK

4. RETAINING WALL, LIGHTING and PAINTING

KAKKI DAM - D/S RETAINING WALL
BEFORE CONSTRUCTION

KAKKI DAM - D/S SIDE RETAINING WALL
AFTER CONSTRUCTION

KAKKI DAM -POST TOP LANTERN - BEFORE DRIP WORS

KAKKI DAM - POST TOP LANTERN - AFTER DRIP WORKS

KAKKI DAM - BEFORE PAINTING

KAKKI DAM - AFTER PAINTING

5. GATES, VALVES and STEPS TO GALLERY

EMERGENCY GATE LIFTED FOR REPAIR WORK

EMERGENCY GATE - AFTER REPAIR WORK

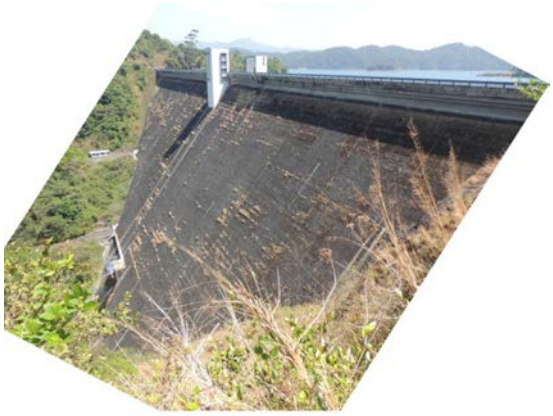
HOLLOW JET VALVE BEFORE REPAIRING

HOLLOW JET VALVE AFTER REPAIR WORK (RIGHT SIDE ONE)

(BEFORE) CONSTRUCTION OF STEP TO V-NTCH

(AFTER)CONSTRUCTION OF STEPS TO V-NOTCH

6. ROOFING and CEMENT WASHING



KAKKI DAM D/S FACE PRESSURE WASHING (BEFORE WASHING)

KAKKI DAM D/S FACE AFTER PRESSURE WASHING

HOLLOW JET VALVE BEFORE ROOFING WORK

AFTER ROOFING WORK TO HOLLOW JET VALVE

PROTECTIVE ROOFING TO INTAKE BUILDING (BEFORE)

PROTECTIVE ROOFING TO INTAKE BUILDING - AFTER WORK

6.1 B Anathodu Dam - Issues

6.1.1 B Anathodu dam - Distress noted and remedial measures taken

During early 90's heavy seepage / wetting & jetting were noticed in the downstream face of the dam and inside the gallery of the dam. Drilling and grouting was done during 1994 in between the existing drain holes at an interval of 7½' c/c. 2606 bags of cement was consumed in the grouting. Also new drain holes were drilled, as most of the drains got chocked during grouting. Consequently the jetting was arrested and seepage was reduced.

Present safety issues in the dam

During 10/98 heavy wetting and calcinations was noticed at the downstream face and inside the gallery of the dam. Then the matter was referred to Central Water Commission for expert opinion. Measurement of seepage was not possible from 8/2000 due to flooding of gallery consequent to the block in the drain outlet pipe. CWC officials from Delhi inspected the dam on 30.05.2000 (pre monsoon) and again on 20.09.2000 (post monsoon). Then the Recommendations of CWC are

1. To establish a new pipe/ box culvert of larger dimension in place of chocked drainage pipe to drain out the seepage water.
2. For the rectification of excessive seepage through the dam.
    a. Concrete lamina on the upstream face of the dam.
    b. Consolidation grouting on the whole body of the dam.
    c. Upstream face joints epoxy pointing with impervious grout curtain near upstream face of the dam.
    d. Guniting the upstream face of the dam.

Accordingly KSEBL has removed the block of the seepage drain pipe and seepage observation resumed. CWC entrusted to provide consultancy for evolving safety measures of this dam.

The discharge detail of Anathodu Gallery is tabulated below.

DISCHARGE DETAILS OF ANATHODU DAM GALLERY

Month of year	Water level on the day when monitoring was done	Total Discharge in litre/minute	Remarks
08/1991	977.25	448.00	
09/1991	977.11	480.00	
10/1991	970.91	420.00	
11/1991	975.09	480.00	

12/1991	973.47	480.00	
01/1992	968.06	120.00	
02/1992	963.20	60.00	
04/1992	948.00	38.00	
05/1992	940.72	3.91	
06/1992	954.26	6.70	
08/1992	977.38	268.87	
09/1992	979.55	303.70	
10/1992	981.15	341.20	
11/1992	980.75	268.85	
12/1992	978.74	206.61	
01/1993	975.31	153.90	
02/1993	972.57	110.22	
03/1993	965.03	27.21	
04/1993	960.20	27.21	
05/1993	952.85	13.25	
06/1993	951.72	13.25	
07/1993	963.80	94.97	
08/1993	975.51	179.09	
09/1993	974.25	153.90	
10/1993	976.52	206.60	
11/1993	977.60	236.50	
12/1993	977.60	206.60	
01/1994	969.71	74.97	
02/1994	969.71	74.97	
03/1994	958.58	36.52	
04/1994	958.58	8.40	
05/1994	946.67	2.34	
06/1994	952.14	2.34	
07/1994	960.10	79.97	
09/1994		518.06	
10/1994	978.70	341.20	
11/1994	977.22	303.73	
12/1994	973.55	179.09	
01/1995	968.30	91.58	
02/1995	964.26	36.52	
03/1995	960.20	13.25	
04/1995	949.27	2.75	
05/1995	949.45	0.24	
06/1995	950.00	0.24	

07/1995	965.50	84.69	
08/1995	969.16	153.90	
09/1995	980.11	538.22	
10/1995	976.35	303.73	
11/1995	974.74	-	
12/1995	959.59	-	
02/1996	956.87	-	
03/1996	949.31	-	
04/1996	941.73	-	
05/1996	971.57	-	
12/1996	971.57	-	
07/1997	949.45	-	
08/1997	961.78	47.52	
10/1997	967.95	74.97	
11/1997	976.45	268.85	
01/1998	975.54	179.09	
05/1998	949.52	8.40	
06/1998	934.97	4.81	
07/1998	958.65	4.81	
08/1998	971.87	130.97	
10/1998	979.58	424.10	
11/1998	979.35	381.30	
12/1998	977.28	268.35	
01/1999	970.40	110.22	
03/1999	956.53	13.25	
04/1999	953.87	8.40	
05/1999	975.97	19.48	
06/1999	965.75	47.53	
07/1999	971.64	110.22	
08/1999	975.82	-	
09/1999	972.96	159.65	
11/1999	975.60	206.60	
12/1999	970.82	130.97	
01/2000	965.47	74.97	
02/2000	961.62	27.21	
03/2000	958.18	13.25	
04/2000	946.86	0.85	
05/2000	937.78	0.85	
06/2000	935.50	4.81	
07/2000	951.95	4.81	

08/2000	951.07	27.20	
04/2001	954.42	0.85	
05/2001	948.59	0.85	
Could not be measured due to the blockage in drainage pipe			
05/2008	953.70	9.26	
06/2008	955.51	8.40	
07/2008	965.59	19.48	
08/2008	975.45	164.00	
09/2008	979.35	277.00	
10/2008	979.35	277.00	
10/2008	980.95	475.80	
11/2008	981.25	535.50	
11/2008	980.85	411.50	
12/2008	980.40	352.68	
01/2009	978.30	277.91	
02/2009	975.05	135.37	
05/2009	963.49	28.12	
06/2009	960.33	20.14	
07/2009	972.10	77.50	
08/2009	974.30	113.93	

Table 6.1 Discharge Details of Anathodu Dam Gallery

In 2007-08, the water level in Kakki-Anathodu reservoir reached FRL after a long gap of 15 years. At this FRL condition, the entire downstream face of the Anathodu dam was seen having wetness with dripping through several points at different elevations and few spouting points were also noticed. During 2009 also, when the water level reached near FRL, almost all the downstream face of the dam was seen wet with several drippings especially in middle blocks with three points in block No. 5. This indicated high permeability of dam and permeability tests were conducted in two selected holes during 03/08 to confirm the same.

Suitable remedial measures were to be finalized after consultation with CWC.

6.1.2 B Anathodu dam - Excessive Seepage in the gallery and wetting of downstream face - Pointing the upstream face, Reaming and Drilling of drainage system

The seepage through the foundation and body drain holes was further being monitored. It was seen that there was considerable quantity of seepage. Hence inspections were conducted by various experts to review the health status and operational performance of Anathode dam at various instances in addition to periodical inspections. Accordingly, controlling of seepage and

wetting the downstream face of the dam was identified as one of the important issues to be addressed by resorting suitable remedial measures. Being a work of specialized nature, upstream face treatment to control wetting / seepage etc. would be implemented with expert technical advice. Accordingly, the work has been put to tender under DRIP and includes

i. Pointing of masonry joints of the U/s face of the dam with Cementitious, UV resistant and non-shrink mortar using Crystalline Technology (CT) or Poly Ironite Ceramic Cementitious (PICC) or equivalent materials for the entire surface of the dam from foundation level upwards. For this excavation of suitable trench down to the dam foundation level along the dam length need to be included.
ii. Reaming of porous drains and re-drilling of drainage holes in the foundation gallery for drainage system.
iii. Providing curtain grouting from foundation gallery. The curtain grouting is intended in one line by drilling and grouting from the foundation gallery.

6.1.3 B Anathodu dam - Other Rehabilitation Work under DRIP

The Dam was inspected by experts from CWC and DSRP; recommendations were 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.

Re-drilling of Foundation Drain holes & reaming of Porous drains

The Dam was constructed long back and due to the calcinations, the foundation drain holes are either fully or partially chocked. In order to make foundation drain holes functional, it is necessary to ream and clean these drain holes periodically. The experts who visited the dam had suggested reaming of foundation drain holes and this has been arranged as part of DRIP works and completed.

Heavy seepage was noticed in the foundation gallery from dam body, when the reservoir level reached +975.00 m and above. Reaming of the porous drains would be carried out under the new works.

Special repairs to the spillway gates & hoists

No major repairs were done to the Spillway gates provided at Anathode Dam since the commissioning in 1967. The maintenance works are needed for trouble free operation of the gates. Hence complete overhauling of the hoists including changing gear oil, replacing the rubber seals of gate leaf, complete replacement of the wire ropes, replacement of all oil seals,

changing grease/ gear oil, repainting with approved quality paint for the leaf elements, covers to hoisting mechanism etc are done under DRIP.

Protective roofing for spillway hoists

The spillway gate hoist platform of Anathode Dam was not provided with roofing. Practically, gates were required to be operated during heavy rains and the electrical control system located on the hoist platform also required to be protected from rains. Hence roofing is provided.

Construction of steps to the downstream of Anathode Dam

Anathode dam foundation gallery was accessible only through the downstream road, which is about 700 m from the left abutment. It was not possible to access the gallery quickly during emergency situations. Hence, concrete steps along the downstream face on right side, hand rails etc., have been provided.

Construction of Security guard room

Police guard room, is provided at Anathode Dam. But, Chief Vigilance Officer of KSEBL had observed that security guard rooms are needed at both abutments of the Dam as well as at the downstream for major Dams. Accordingly monitoring cabin is provided at right abutment of Anathode Dam.

Maintenance of Dam top and Access roads to galleries

The dam top road and access roads to the entrance of Anathode Dam galleries, other roads to Dam, connected installations are repaired and made proper.

Supply & installation of DG Sets

Anathode Dam is located deep inside the forest, the electricity supply failure happens frequently at site. Alternate power supply arrangements, especially during heavy rains to operate spillway gates, 30 KVA DG Set was procured for Anathode dam and installed in the Generator room.

Supply & installation of high mast, Dam top & gallery lighting etc.

As part of enhanced security measures, lighting for gallery, lamp-post with top lantern on Dam top, high mast for illumination of downstream area and the area between spillway & Dam are also provided.

The photographs showing the DRIP works are given below:

PART I WORK

Before - Dam Top Wearing coat

After - Dam Top Wearing coat

Before - Special repair to Hoist mechanism

After - Special repair to Hoist mechanism

Before - Installation of top lantern

After - Installation of top lantern

Monitoring cabin – Final stage

Supply and Erection of Roofing to hoist of Anathodu Dam radial gate

DRIP work - High mast light

DRIP – Reaming of drain holes

PART II WORK

Before - Painting

After - Painting

Construction of Generator room

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Chapter 7

Updating the Manual

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

Aspects to be considered when updating the Manual must 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 that the O & M Manuals may be reviewed/updated after every 10 years by the respective Dam Owners.

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1. CWC Guidelines for preparing O & M Manual of Dams CDSO_GUD_DS_03_v1.0 Page xii January 2018
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3. 'Guidelines for Operation of Reservoirs' (IS 7323:1994)
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5. Completion Report of SGHEP 1977
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