

# Tehri Dam Project- Engineering Challenges during Planning & Construction

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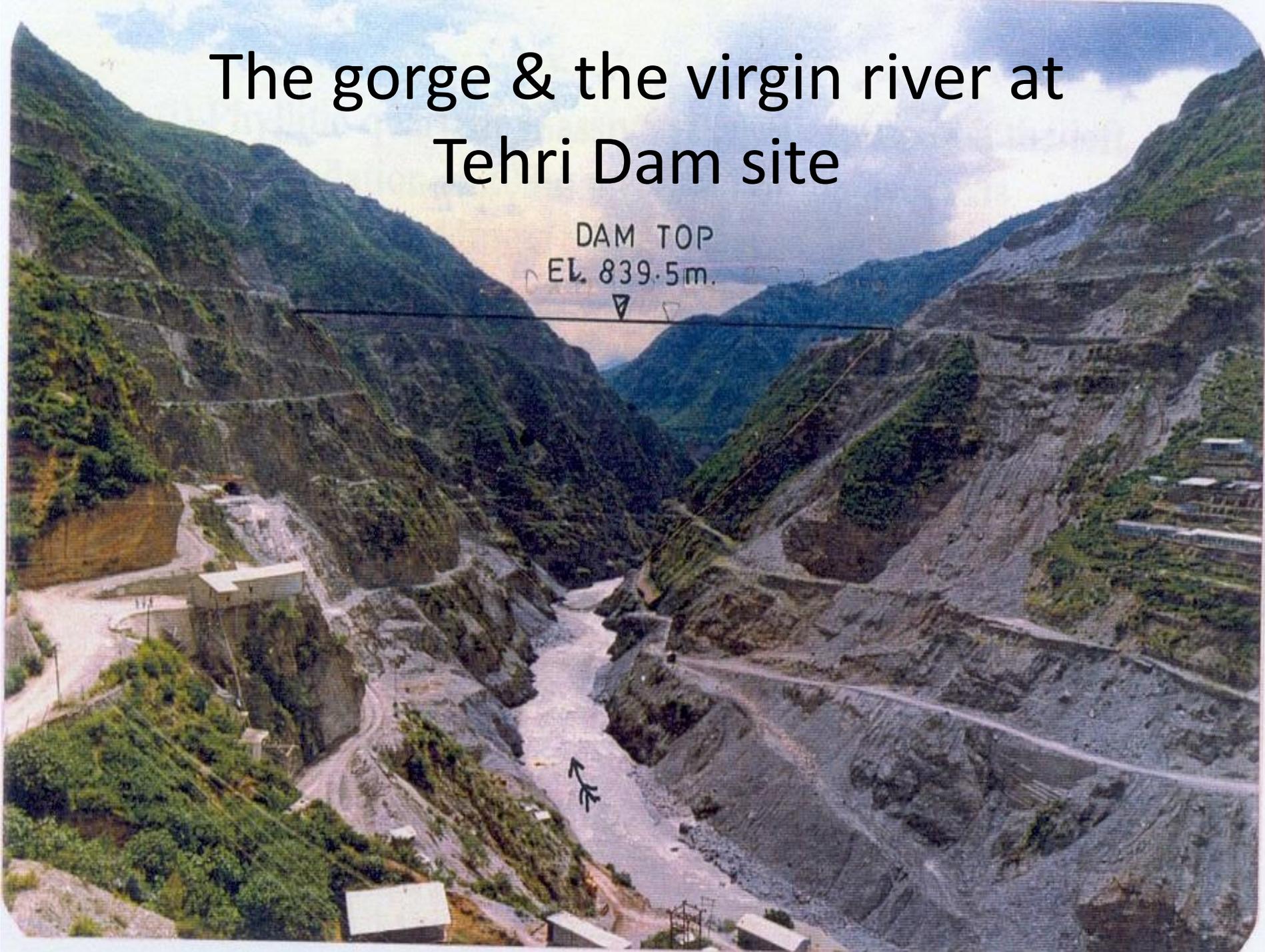
# India's Dam Safety Act- 2021

- The Dam Safety Act of 2021 marks a significant milestone in India's commitment to ensuring the safety and integrity of its dams. The Act provides for the surveillance, inspection, operation and maintenance of the 'specified dams' (a term defined in the Act). It aims to prevent disasters related to dam failure, and provide institutional mechanisms for the safe operation of dams
- The Preparedness for Dam Safety at all stages, in a way, starts right from conception to its building in strict accordance to Standard Requirements of High Dams
- The twin key issues for dam safety are the adequacy of Designs to handle PMF and Structural behaviour to withstand the shaking as derived from the Seismic Design Parameters, specific to the Project.



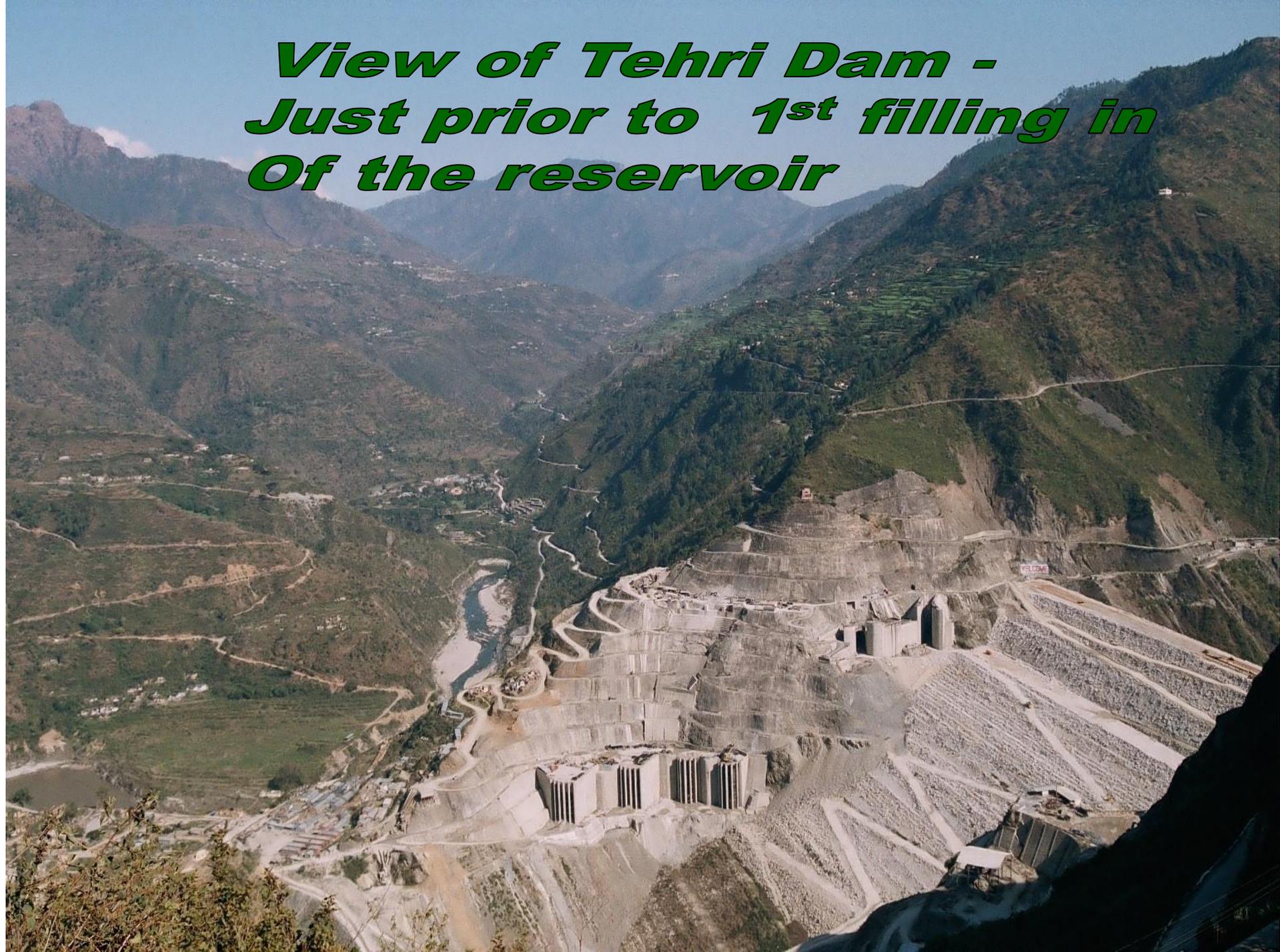
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# The gorge & the virgin river at Tehri Dam site



DAM TOP  
EL. 839.5m.

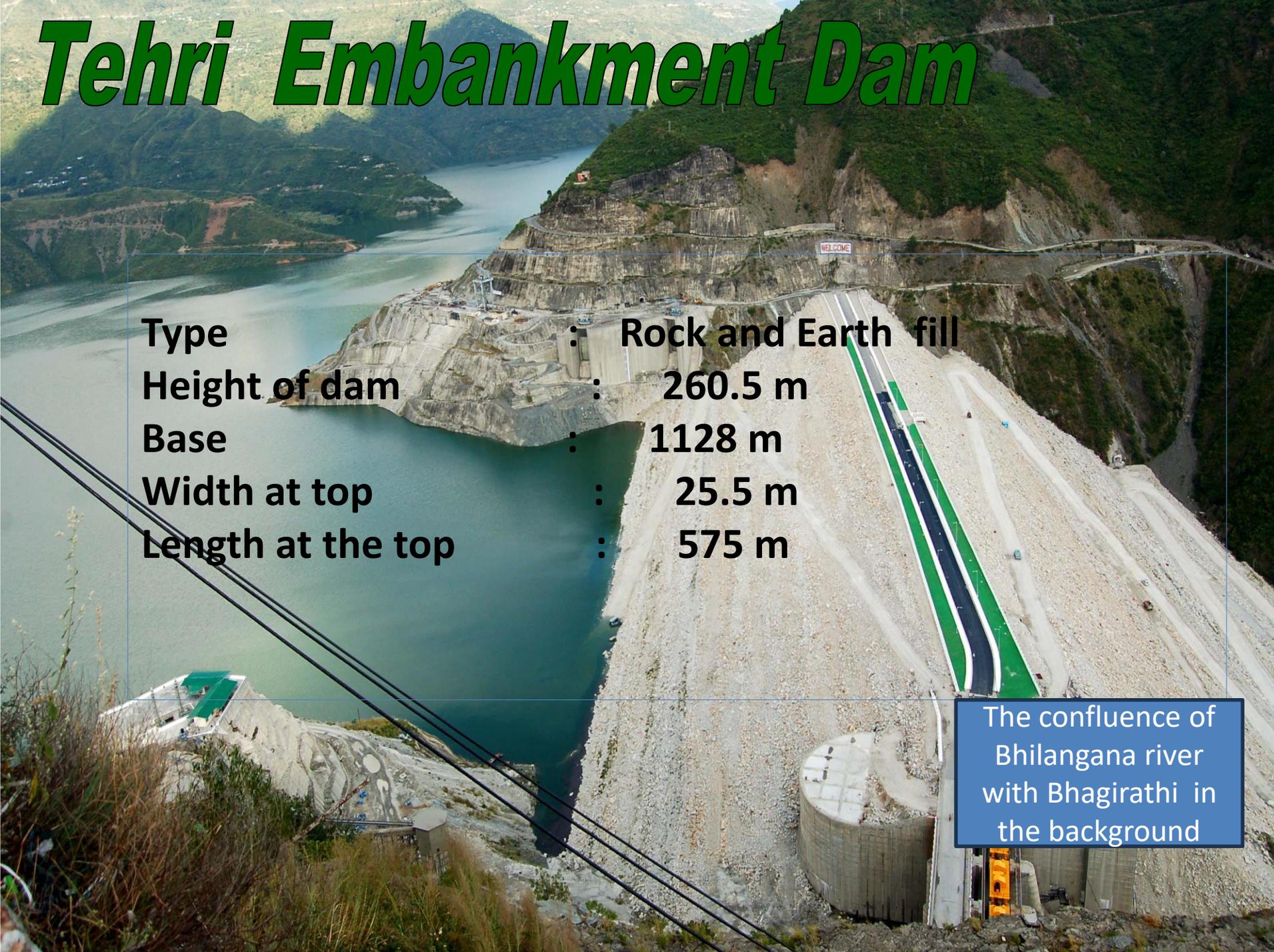
***View of Tehri Dam -  
Just prior to 1<sup>st</sup> filling in  
Of the reservoir***



***Tehri reservoir- during  
the first filling of Reservoir***



# *Tehri Embankment Dam*



Type	:	Rock and Earth fill
Height of dam	:	260.5 m
Base	:	1128 m
Width at top	:	25.5 m
Length at the top	:	575 m

The confluence of  
Bhilangana river  
with Bhagirathi in  
the background

# Key Aspects for Discussions

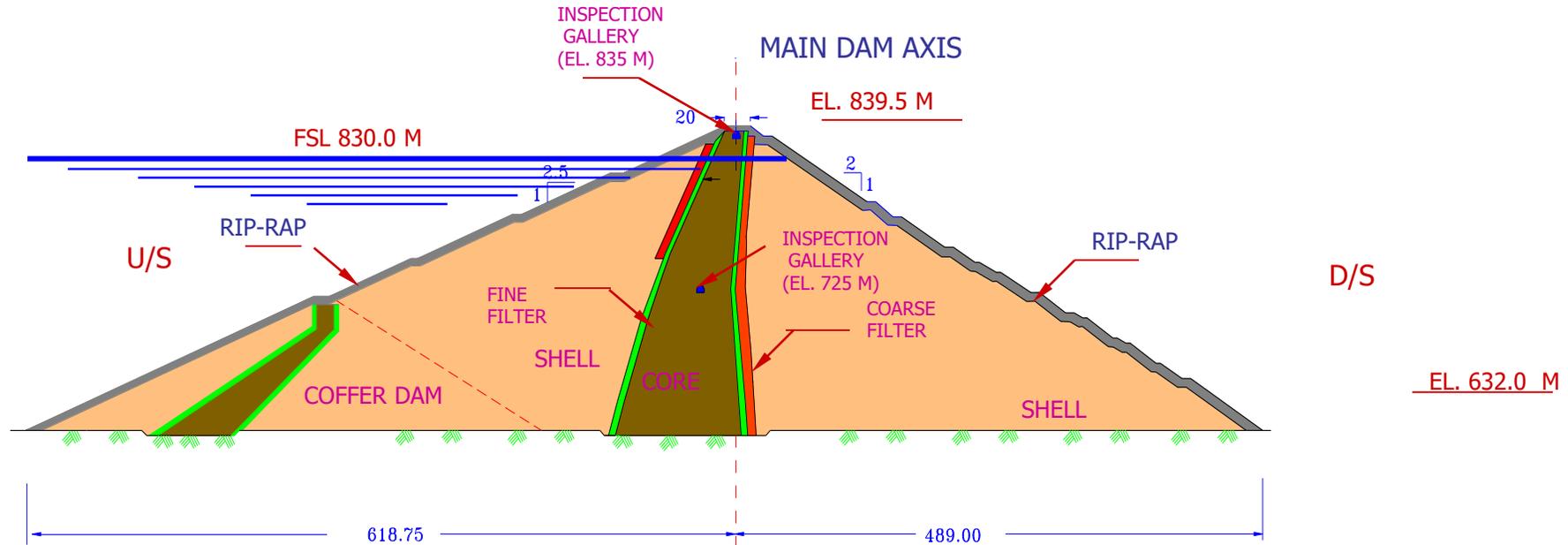
- Mega Hydro Structures such as Tehri Dam, planned, designed and executed by Indian Engineering Fraternity
- Key Aspects to be touched in this talk shall be:
  - The Highest Embankment Dam Design in Himalayan Seismic environ
  - Hydrologic and hydraulic challenges in narrow canyon
  - Uniqueness of shaft spillways and energy dissipation
  - Large size Caverns and tunnels in young and fragile rocks for power house & ancillary structures

Part I

Tehri Rockfill Dam

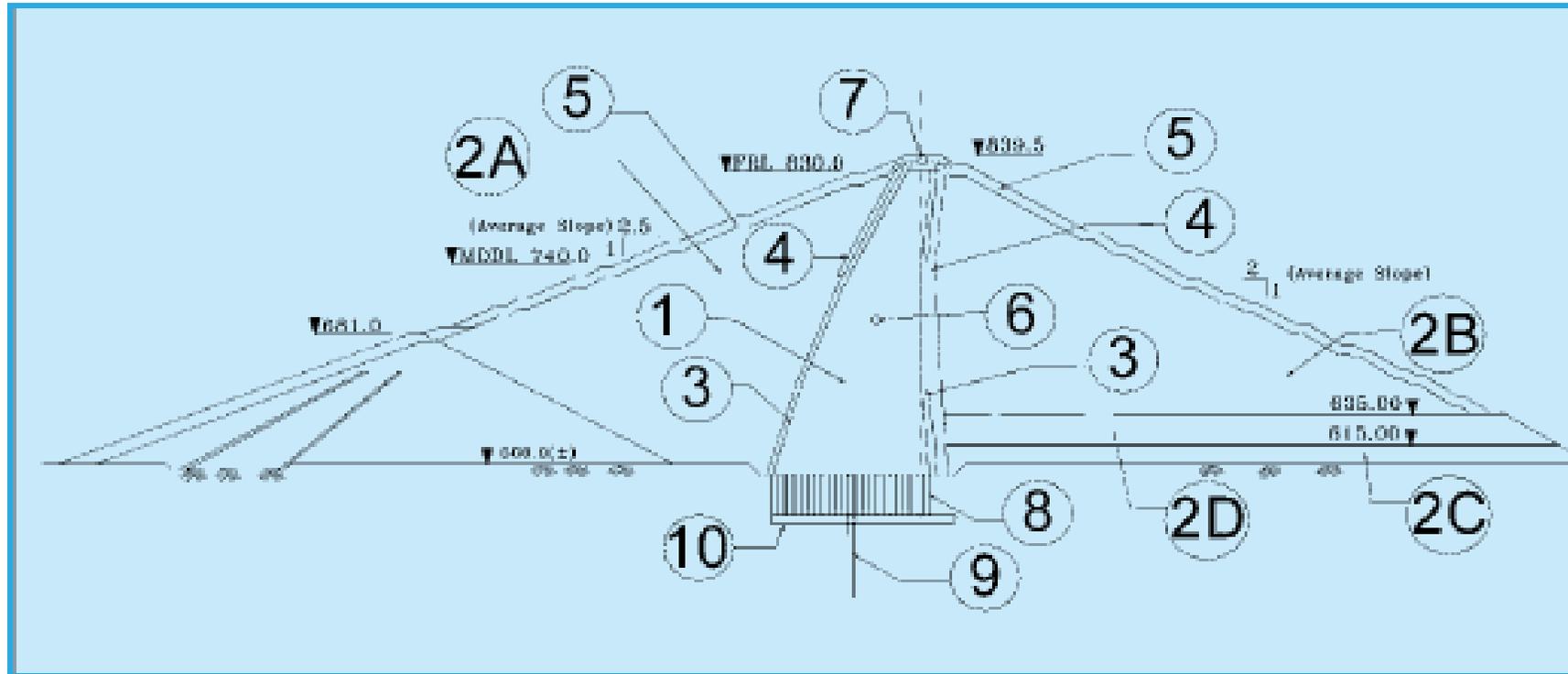
# **THE 262 M., HIGH EMBANKMENT DAM AND SOME BOLD & UNIQUE PROVISIONS**

# The highest Embankment Dam in Himamlayan Settings



SHELL	: 201.6 LAC CUM
CLAY	: 35.3 LAC CUM
FILTERS	: 15.10 LAC CUM
RIP RAP	: 27.8 LAC CUM
<b>TOTAL QTY OF FILL PLACEMENT</b>	<b>: 279.8 LAC CUM</b>

# Typical Details of the max. Section

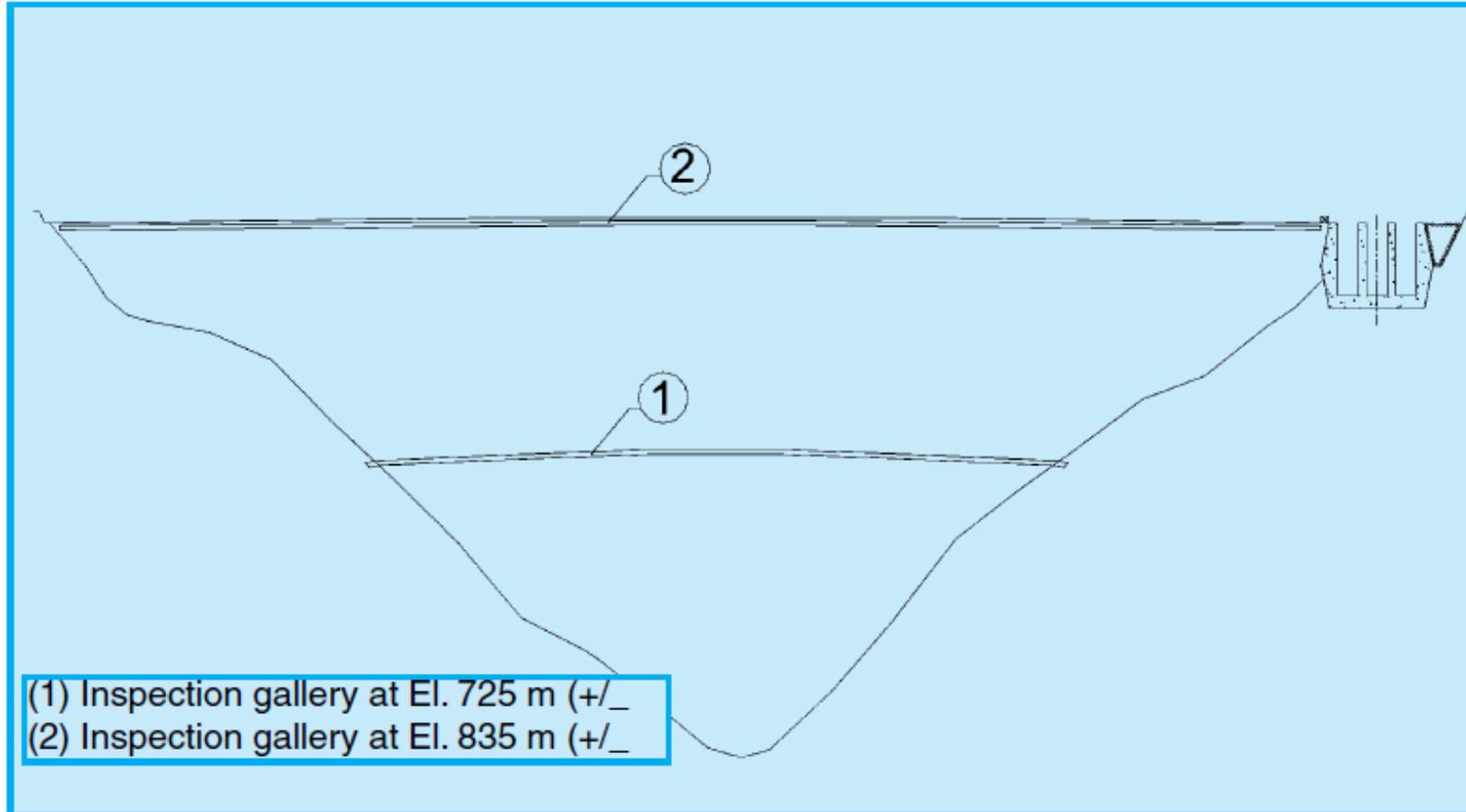


- (1) Impervious Core (2A) U/s Shell; (2B) D/s Shell; 2(C & D) Processed Shell  
(3) Fine Filter; (4) Coarse Filter (5) Riprap (6) & (7) Inspection Gallery in dam  
(8) Consolidation Grouting (9) Curtain Grouting (10) Grouting Gallery (UG)

# Key Aspects in High Embankment Dam

- Slopes are designed to be **fail safe**; rockfill dam to take care of severest EQ shaking (Richter Mag. +8)
- A liberal free board of 8.5m above FRL to avoid even remotest overtopping possibilities
- A wider Crest(25m.) which is further flattened at abutments to 35m to enhance safety factors
- Unique Clay core design (a sand-clay mix); **u/s filter**
- **Inspection Galleries in the Clay Core, a rare and bold insertion, to monitor performance**
- Instrumentation and monitoring the dam, continually

# Longitudinal Section of the Galleries



Part 2

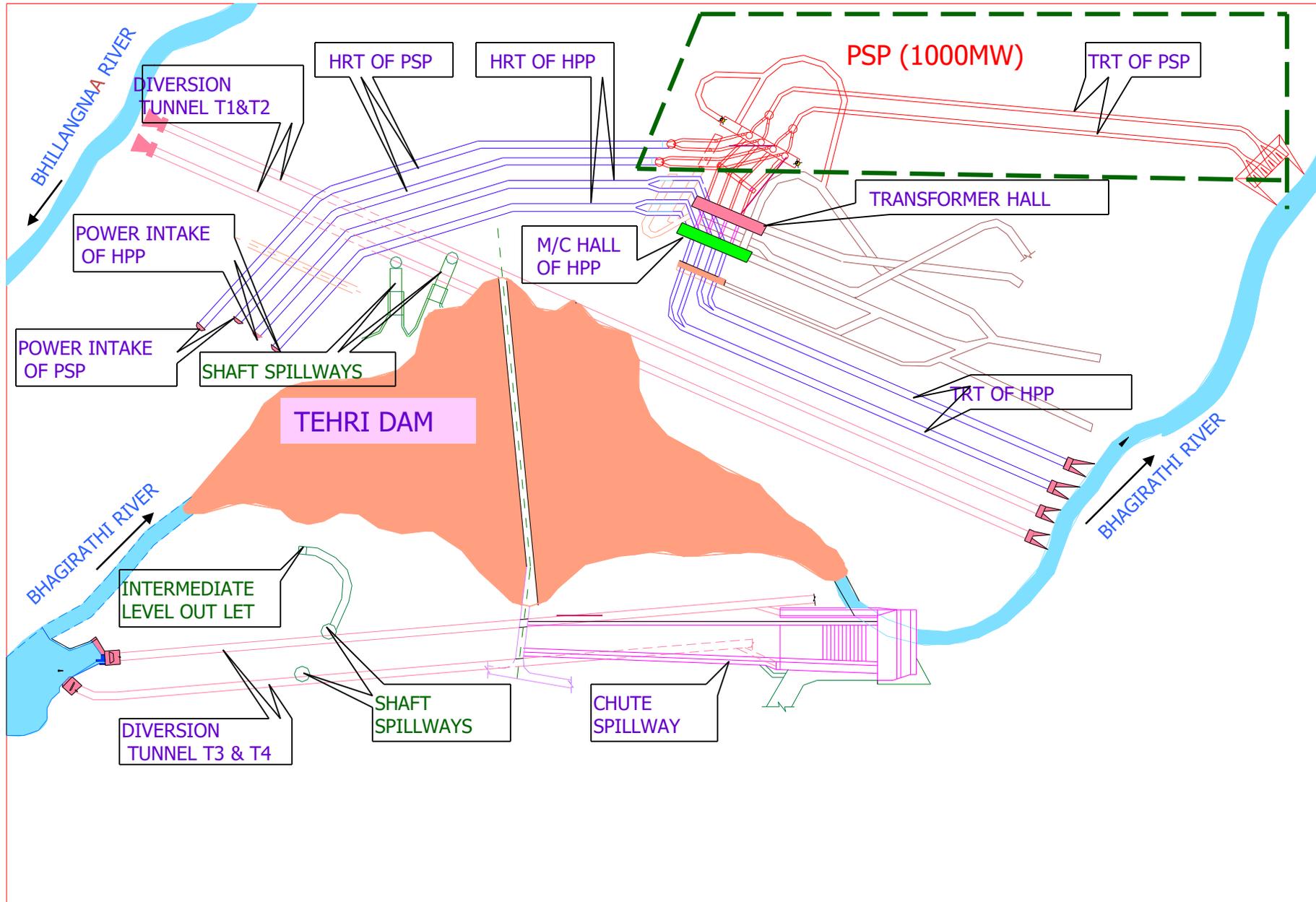
Spilling excess flood in Narrow Canyons? Indeed a A challenge in Himalayas

# **DEALING WITH MEGA FLOODS - UNIQUE & NOVEL PLANNING FOR DEALING FLOODS WITH MULTIPLE & VARYING OPTIONS**

# Handling PMF in a narrow canyon

- Probable maximum flood(PMF) at Tehri site is derived as per the '*State of the Art*' practices, as 15540 cumecs.
- Safe evacuation of a large PMF in a narrow canyon that provides insufficient width for conventional solutions such as chute spillway to the desired width is a challenge
- A battery of varying solution or types are therefore embedded in the system layout, namely,
  - two shaft spills in each one of the flanks (left and right) besides
  - the main gated chute spillway in the extreme right flank of the canyon
  - And a chute spillway to the width economically obtainable.
- The routed flood discharge for the scheme of spillway structures, remain around 13,000 cumecs with a flood lift of 5.0 m above FRL.

# General Layout





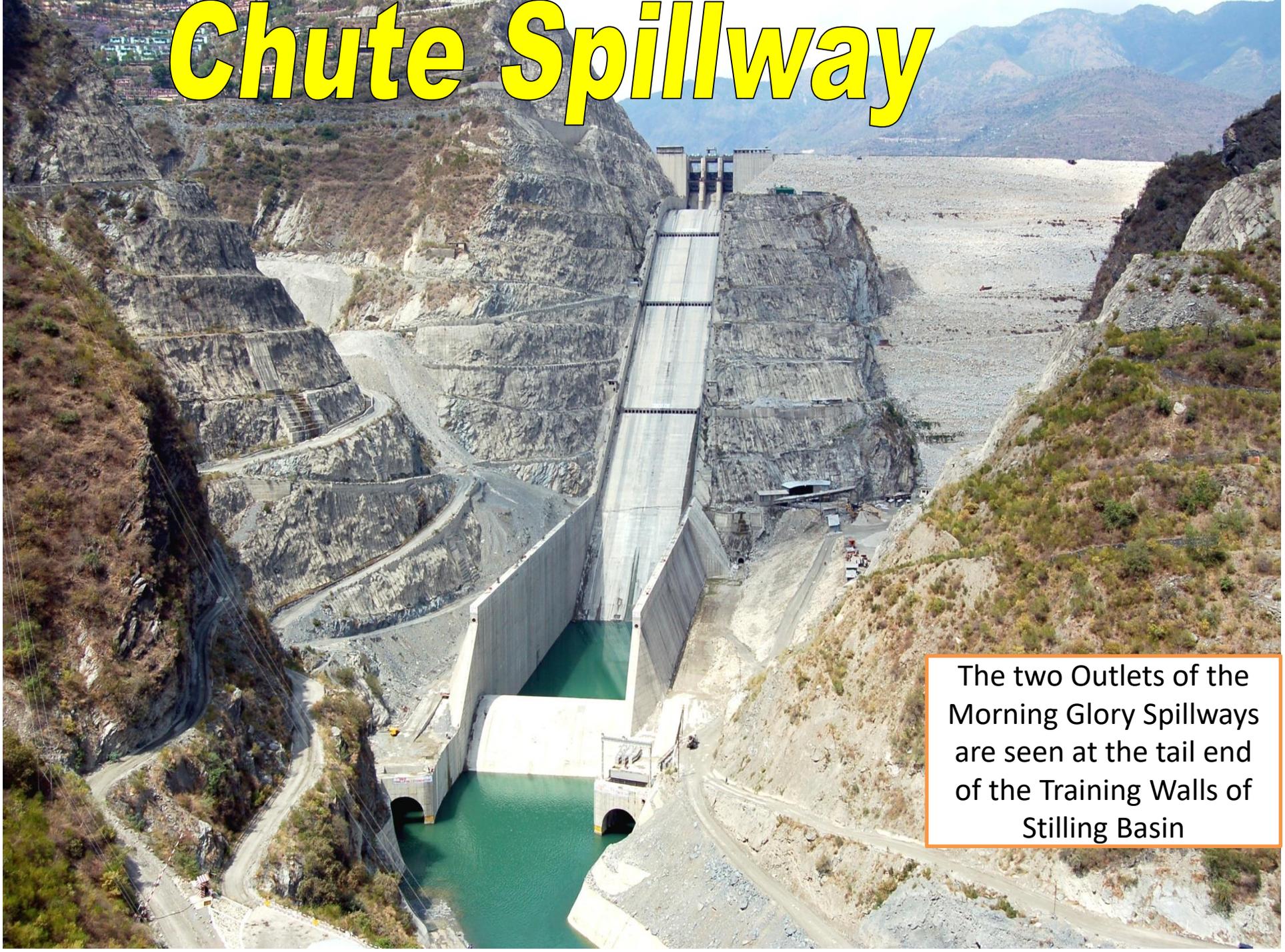
# ***Flood Evacuation - Tehri Dam: Chute Spillway in Right Abutment***

## **CHUTE SPILLWAY**

<b>Head</b>	<b>:</b>	<b>220 M</b>
<b>Type</b>	<b>:</b>	<b>Conventional Stilling Basin Type</b>
<b>Max Discharge</b>	<b>:</b>	<b>5500 cumecs</b>
<b>Width</b>	<b>:</b>	<b>39.5m at top 50m at toe</b>
<b>Regulating Gates</b>	<b>:</b>	<b>Radial 15.5m high/10.5m wide</b>
<b>Aerators</b>	<b>:</b>	<b>3 nos on Glacis</b>
<b>Stilling Basin</b>	<b>:</b>	<b>140 x 50 m 22m deep pool 55 m high walls</b>
<b>D/s River Bed</b>	<b>:</b>	<b>Protection by Concrete Blocks</b>



# Chute Spillway



The two Outlets of the Morning Glory Spillways are seen at the tail end of the Training Walls of Stilling Basin

# ***Tehri Dam- Right Bank***

## ***Morning Glory type of shaft spillways***

### **RIGHT BANK SHAFT SPILLWAYS**

<b>Head</b>	<b>: 220 M</b>
<b>Type</b>	<b>: Vertical Shafts</b>
<b>Nos</b>	<b>: 2 (Un-gated)</b>
<b>Intakes</b>	<b>: Funnel type (34m dia)</b>
<b>Discharge</b>	<b>: 3900 cumecs</b>
<b>Vertical Shaft</b>	<b>: 12m dia</b>
<b>Junction with tunnel</b>	<b>: Tangential with 6.0m opening</b>
<b>De-aeration System:</b>	<b>Through a Separation Chamber and de- aeration shaft opening above MWL</b>
<b>Velocity at toe</b>	<b>: 45 m/s</b>



# *Right Bank Shaft Spillways*



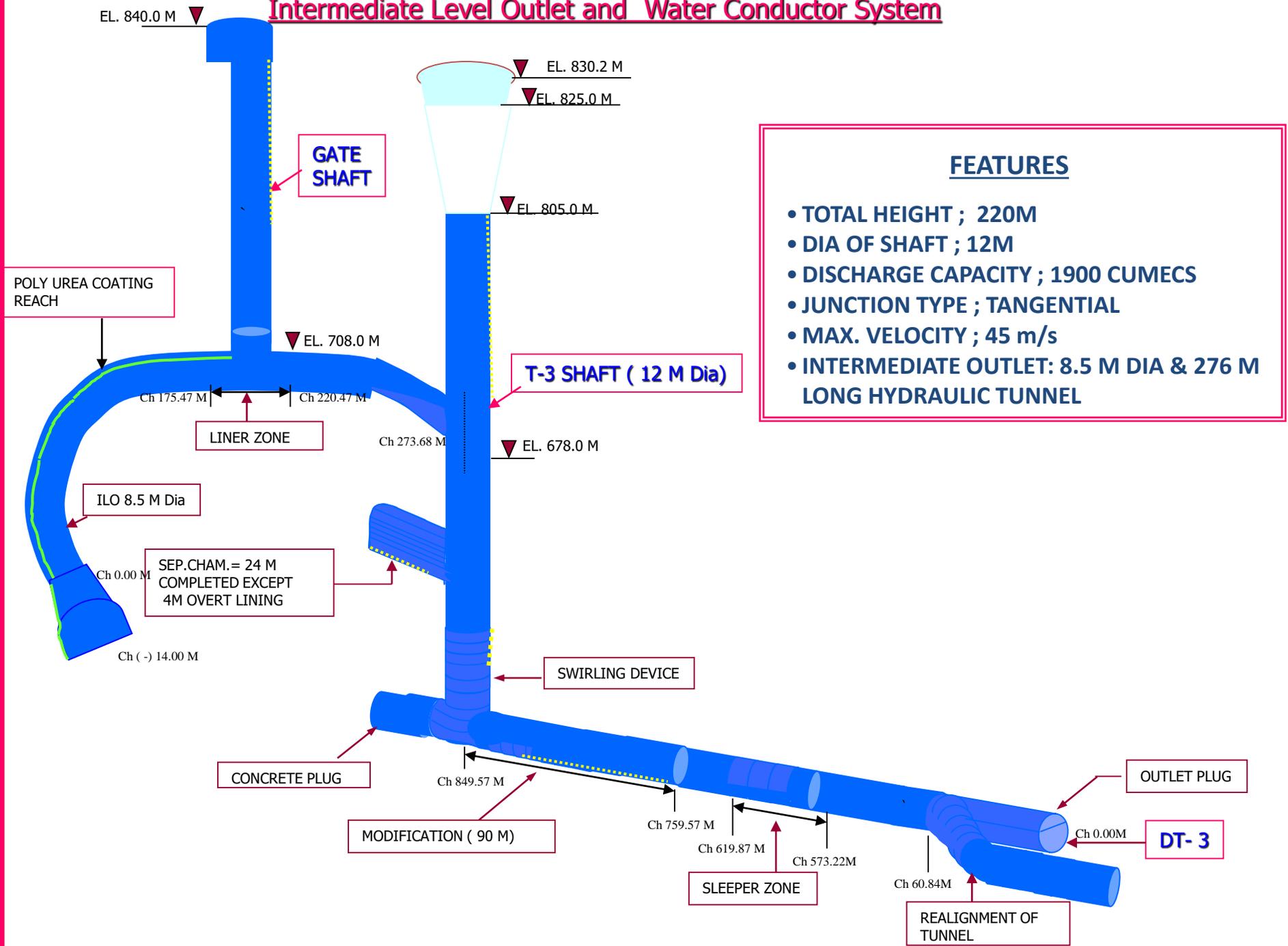
# The complexity in incorporating an Intermediate Level Outlet (ILO)

## Features:

- **BOTTOM MOST OUTLET IN THE PROJECT AT EL 700M.**
- **BEING USED FOR IRRIGATION RELEASES** only when power drawal is nil, and irrigation demands arise
- **BEING USED FOR INITIAL FILLING OF RESERVOIR** and served as a tool for the **EMERGENCY EVACUATION** during 1<sup>st</sup> filling in;
  - it would serve a similar use for dam safety checks, should need arises at any time.
- **TANGENTIALLY JOINING T-3 SHAFT SPILLWAY AT BOTTOM OF FALL**
- **STRENGTHENED LINING WITH M50 Micro-silica fume added CC & Coated With POLYURETHANE Epoxy**



# Intermediate Level Outlet and Water Conductor System



## FEATURES

- TOTAL HEIGHT ; 220M
- DIA OF SHAFT ; 12M
- DISCHARGE CAPACITY ; 1900 CUMECS
- JUNCTION TYPE ; TANGENTIAL
- MAX. VELOCITY ; 45 m/s
- INTERMEDIATE OUTLET: 8.5 M DIA & 276 M LONG HYDRAULIC TUNNEL

POLY UREA COATING REACH

GATE SHAFT

T-3 SHAFT ( 12 M Dia)

LINER ZONE

ILO 8.5 M Dia

SEP.CHAM. = 24 M COMPLETED EXCEPT 4M OVERT LINING

SWIRLING DEVICE

CONCRETE PLUG

MODIFICATION ( 90 M)

SLEEPER ZONE

REALIGNMENT OF TUNNEL

OUTLET PLUG

DT- 3

EL. 840.0 M

EL. 830.2 M

EL. 825.0 M

EL. 805.0 M

EL. 708.0 M

EL. 678.0 M

Ch 175.47 M

Ch 220.47 M

Ch 273.68 M

Ch 0.00 M

Ch (-) 14.00 M

Ch 849.57 M

Ch 759.57 M

Ch 619.87 M

Ch 573.22M

Ch 60.84M

Ch 0.00M

# ***A View of ILO intake in Right Bank***



**2.02.2006**

# *300T Capacity Hydraulic hoist for operating Radial gate of ILO*



14 2005

# ***MGS Gate (Fixed Wheel)***

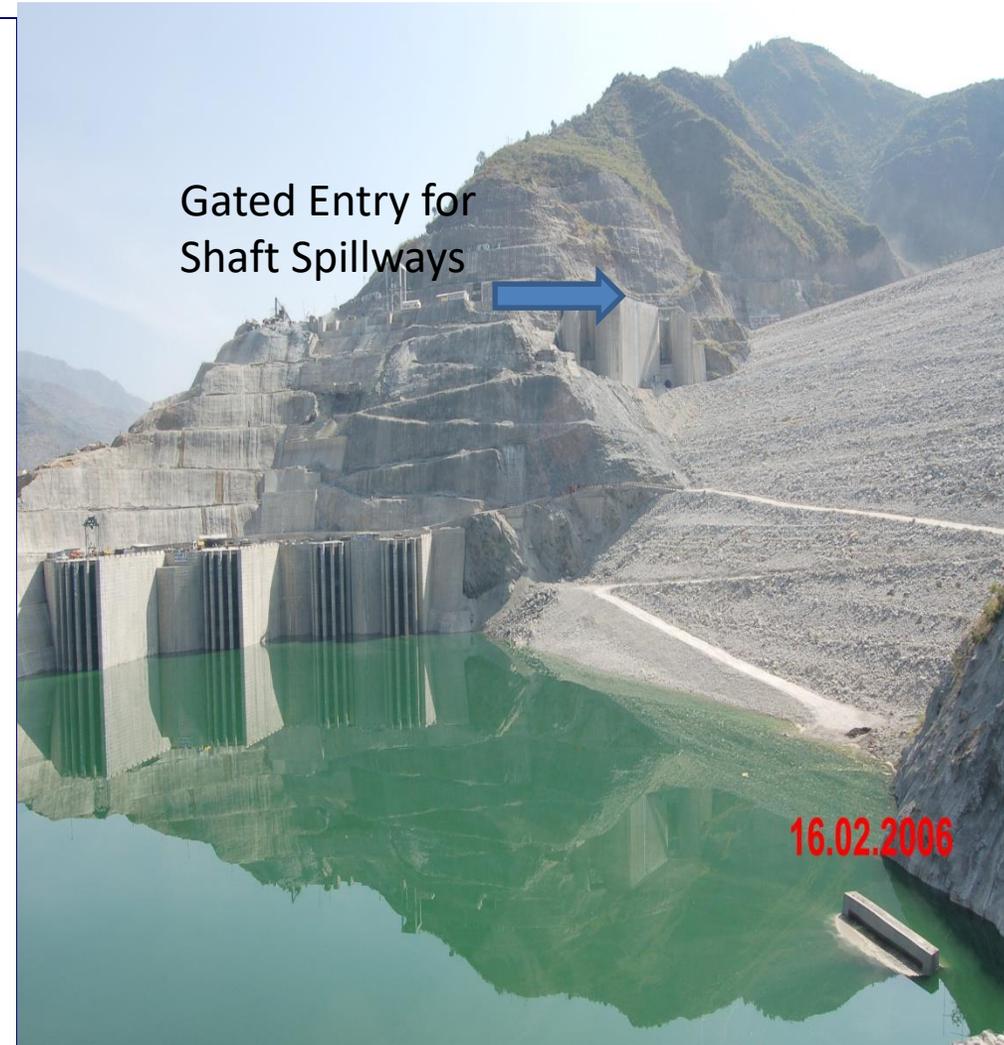


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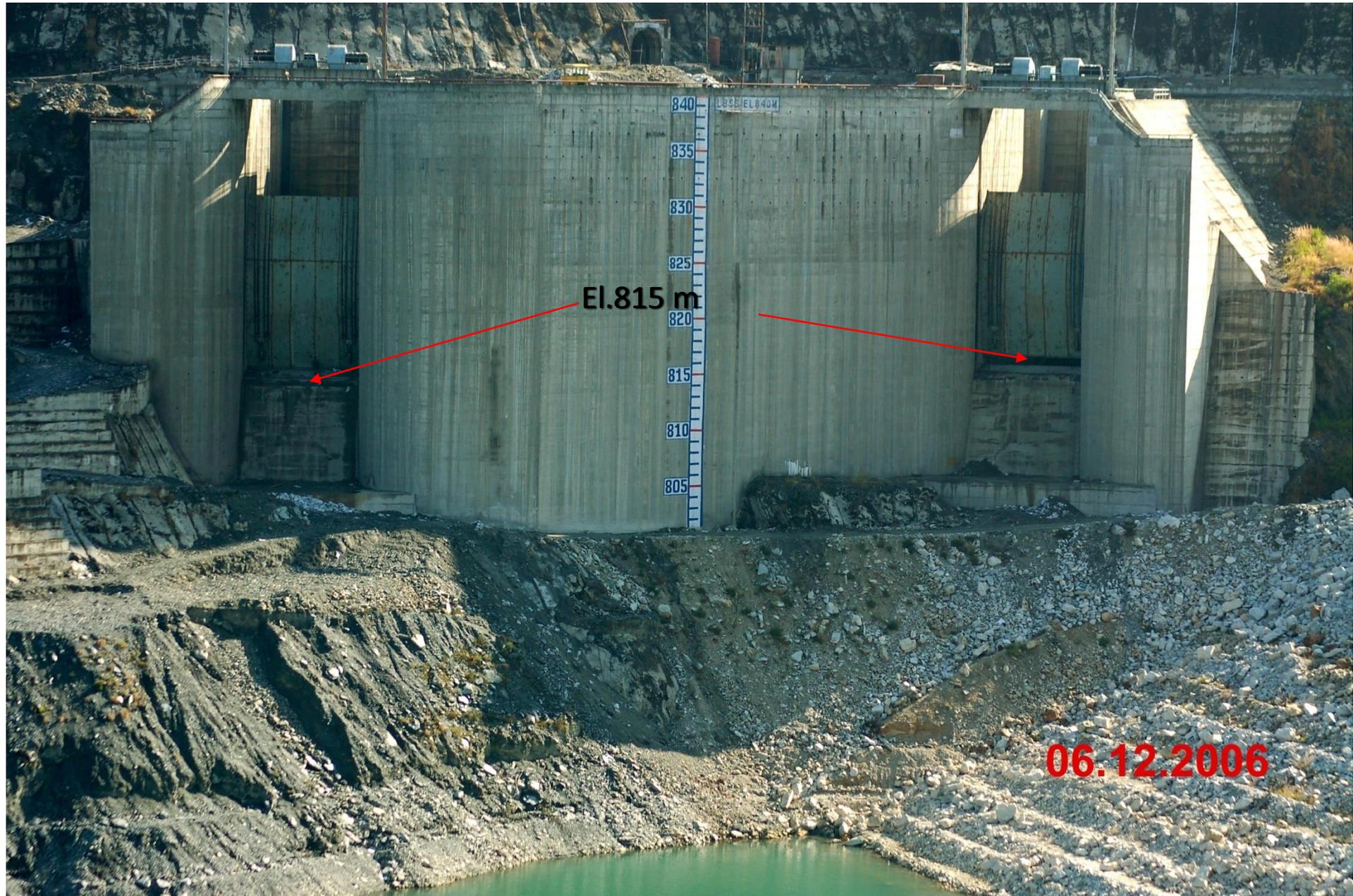
# ***Tehri -Left Bank Spillway***

## LEFT BANK SHAFT SPILLWAYS

Head	: 220 M
Type	: Vertical Shafts
Nos	: 2 (Gated)
Intakes	: Tunnel type (80m long)
Discharge	: 3800 cumecs
Vertical Shaft	: 12m dia
Junction with	: Tangential with 5.5m tunnel opening
De-aeration System	: Through a Separation Chamber and de-aeration shaft opening in a De- aeration tunnel
Velocity at toe	: 45 m/s



# ***Control gates for the Left Bank Shaft Spillways***



Part III

Energy Dissipation Arrangements in Tehri have certain novel features

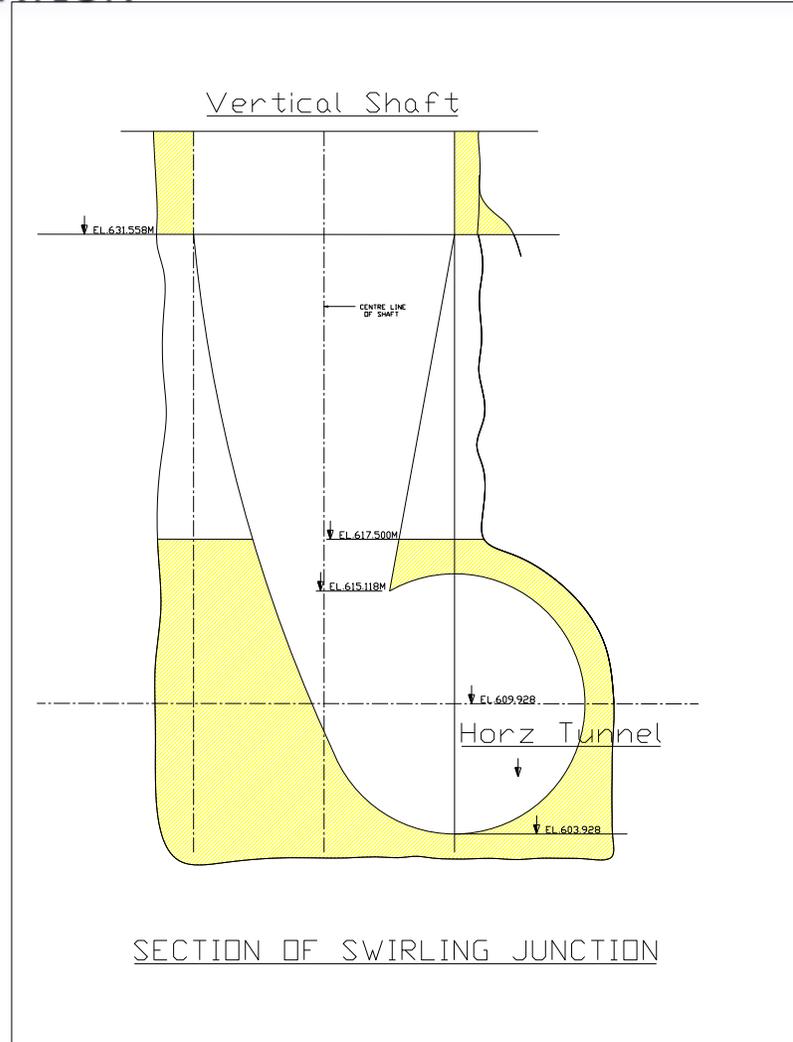
# **UNIQUE & INNOVATIVE ENERGY DISSIPATION ARRANGEMENTS**

# Tehri Dam Shaft Spillways - EDA

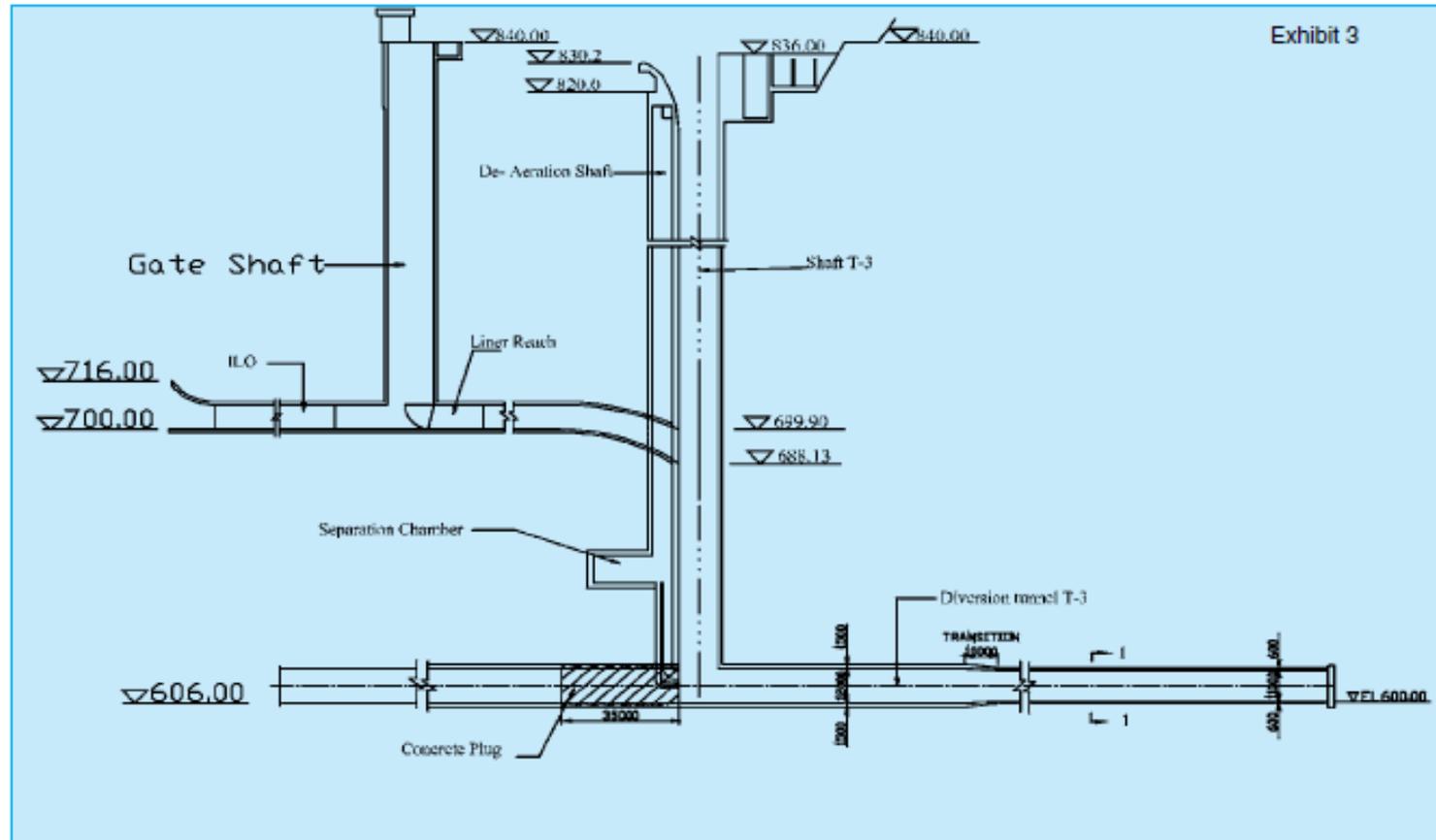
- Unique energy dissipation arrangements (EDA) by swiveling action to kill the energy.
- The high velocity flows at the bottom of the vertical shaft spillway are turned into swirl flow in the horizontal tunnels leading the discharge in to the river downstream;
- provision of sufficient de-aeration arrangements by special aeration tunnels accessed from downstream

# Unique arrangement for achieving Energy Dissipation

## THE INTRODUCTION OF A SWIRLING JUNCTION LINKING VERTICAL SHAFT with HORIZONTAL TUNNEL PORTION

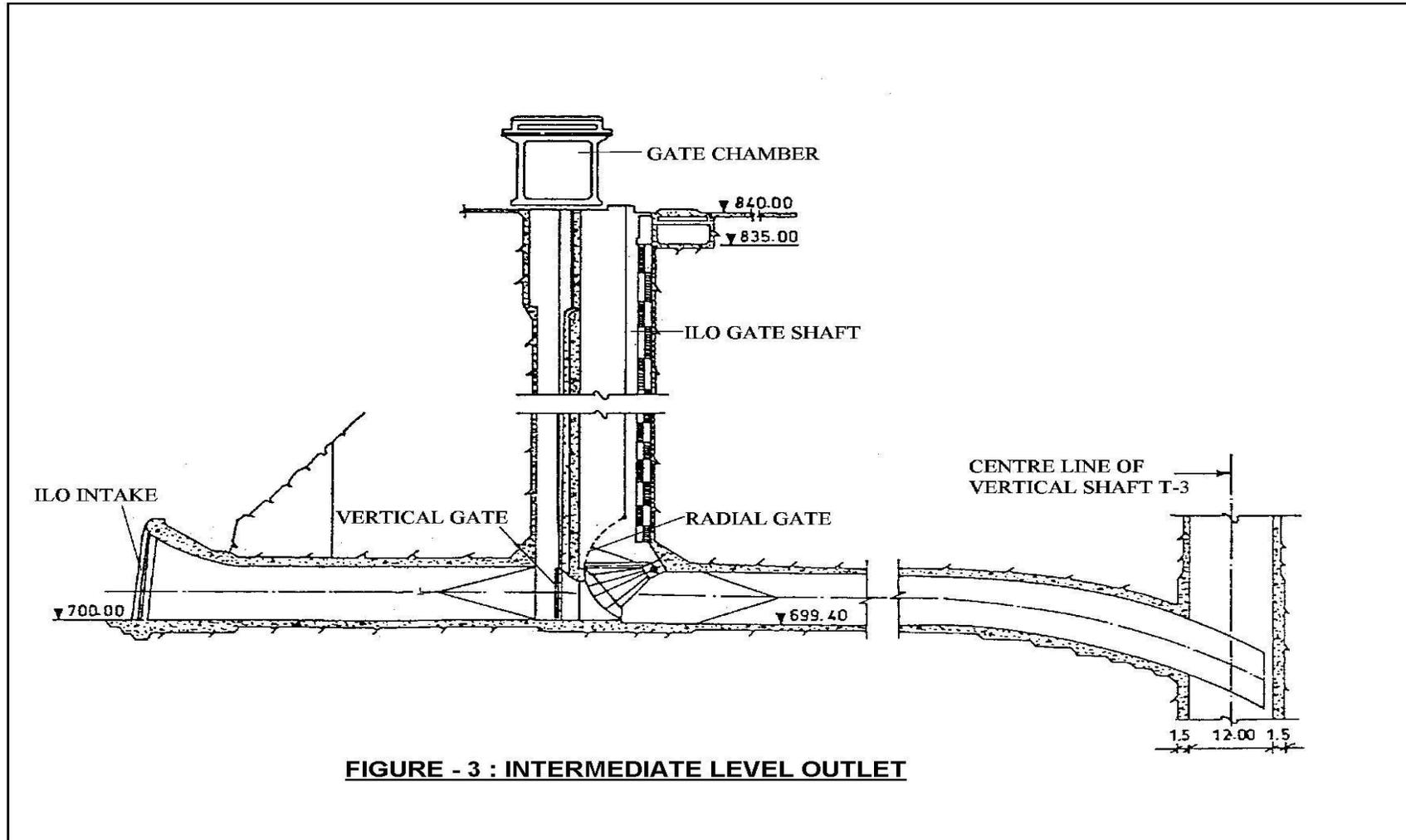


# Section of RF Morning Glory Spillway; Intermediate level outlet joins the shaft

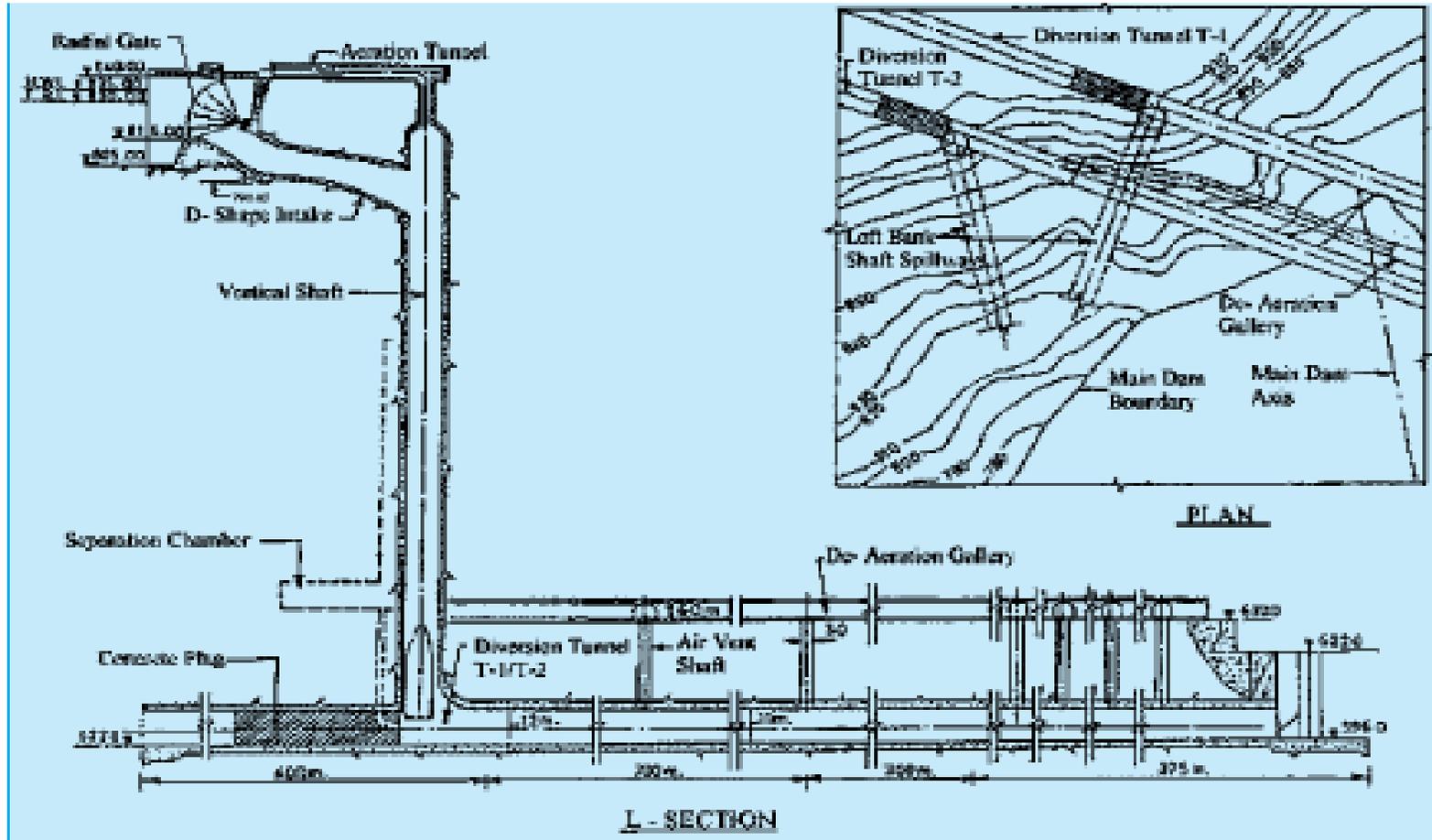


Details of right shaft spillway and ILO on tunnel T-3

# Control Arrangements for ILO & Junction features with vertical Shaft



# Gated Shaft Spillways (LF)



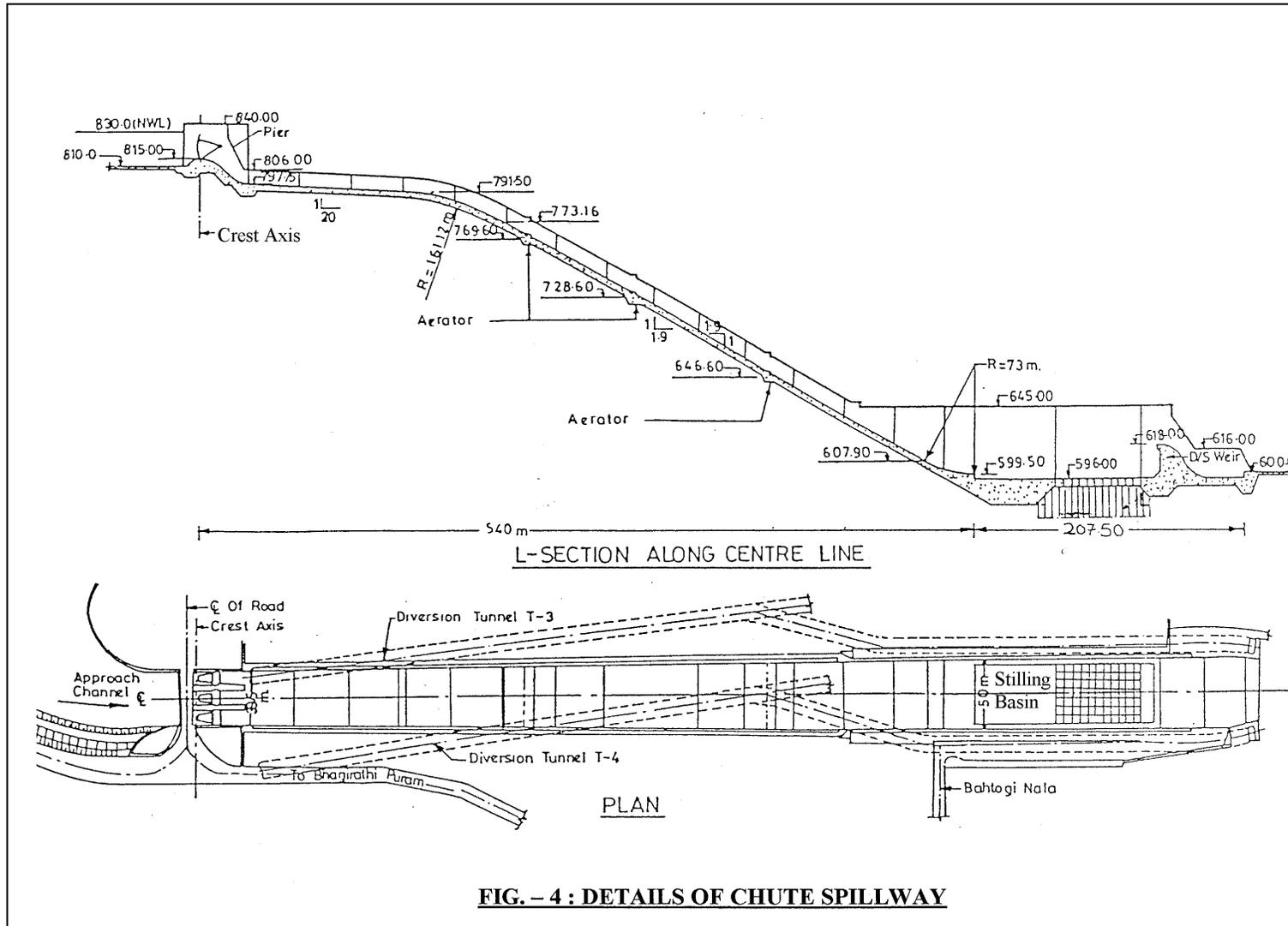
Details of left bank shaft spillways

The aeration arrangements are unique and vast; based on extensive model tests

# Key aspects in dealing with EDA

- Adequate safety against possible damage due to high velocity flows is assured as aeration of flow to the extent required would be supplied as the flow velocity picks up to high levels, gliding down the chute spillway.
- Given the energy levels at the floor at bottom which are substantially high during PMF – could be over 200 MW of energy per m. length, special care had to be bestowed for handling high discharges: the measures include 3 aerators on the glacis, smooth surface finish with CC M60 (SFC ) etc.
- USBR type II Stilling Basin of size 140\*50\*22 m., with an end sill (*baffle*) of 22 m height. This basin rests on a very complicated foundation condition with a fault that cuts the river obliquely, beneath the floor.

# Tehri Dam – Chute Spillway



# *View of the Stilling Basin for Energy Dissipation*



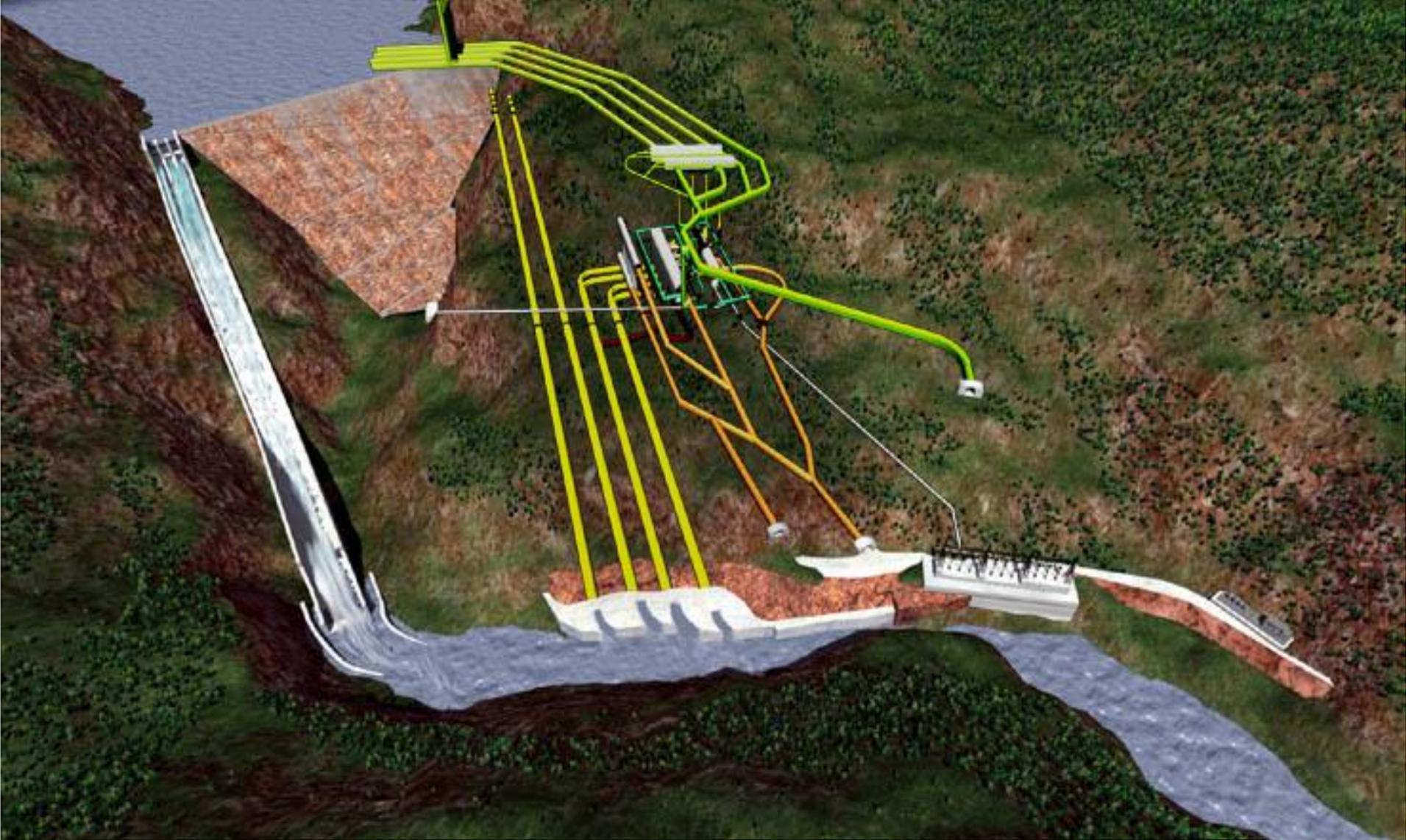
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Part 4

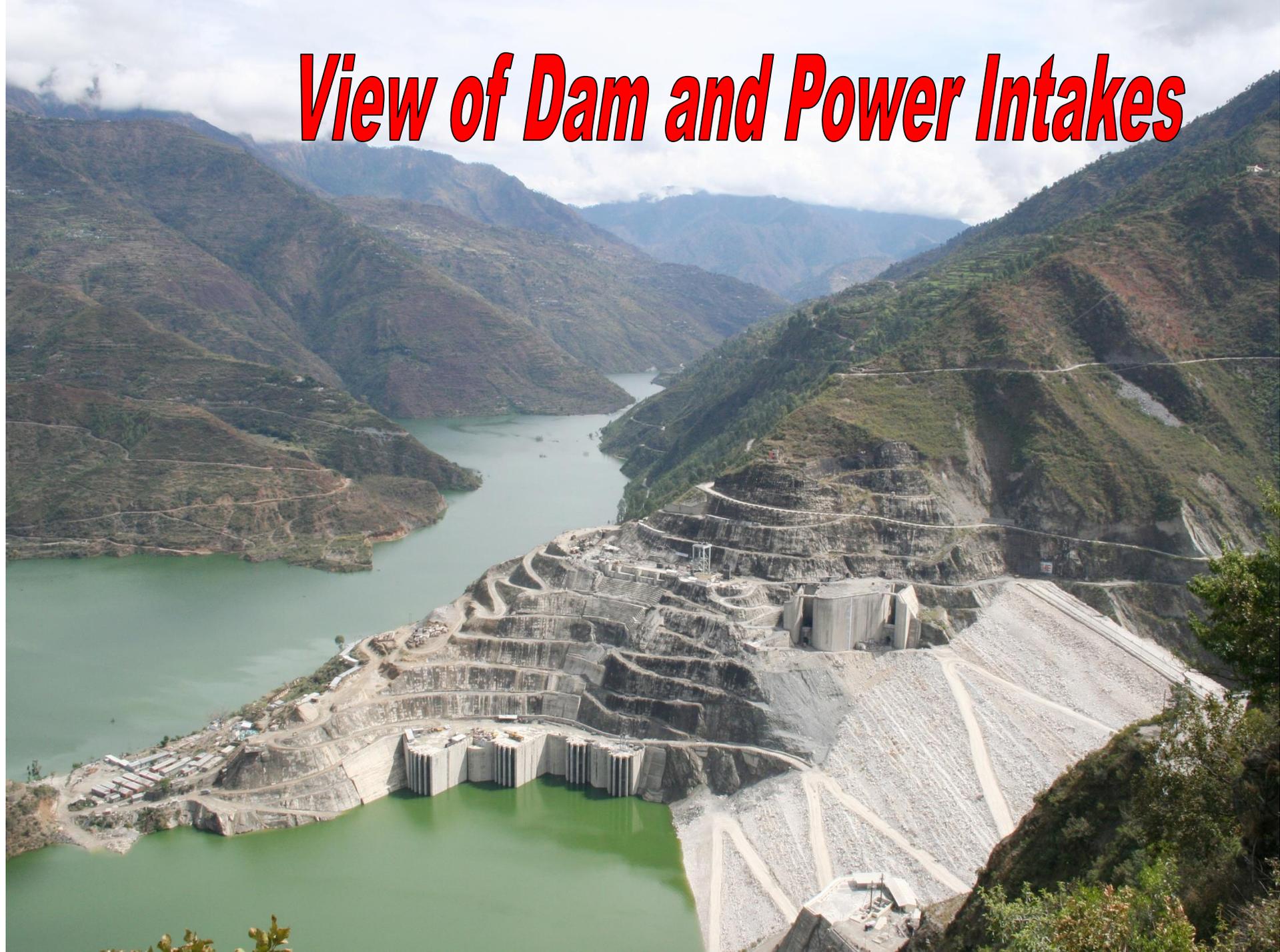
Underground works in Tehri

# **U G POWER HOUSE & THE SYSTEM - ANCILLARY TUNNELLING**



SCHEMATIC VIEW OF TEHRI HYDRO POWER COMPLEX

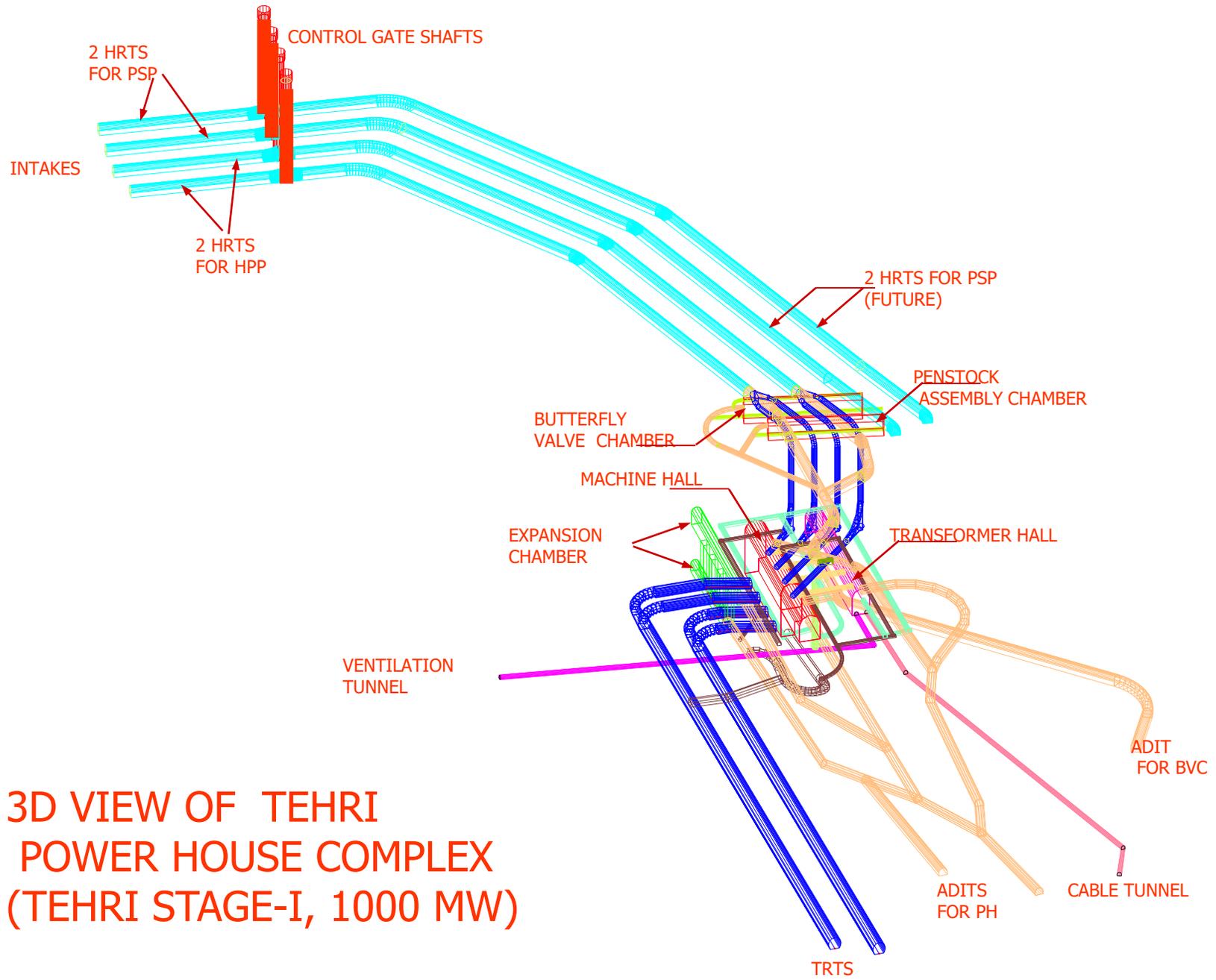
# ***View of Dam and Power Intakes***



***View of the Power Intakes  
when Reservoir is close to MDDL***



9.02.2006



**3D VIEW OF TEHRI  
 POWER HOUSE COMPLEX  
 (TEHRI STAGE-I, 1000 MW)**

# *Power House*

Power House

Under ground

Cavern Size

197mX24mX63m

Type of Turbines

Francis

Rated Head

188 M.

Speed

214.3 RPM

Installed Capacity

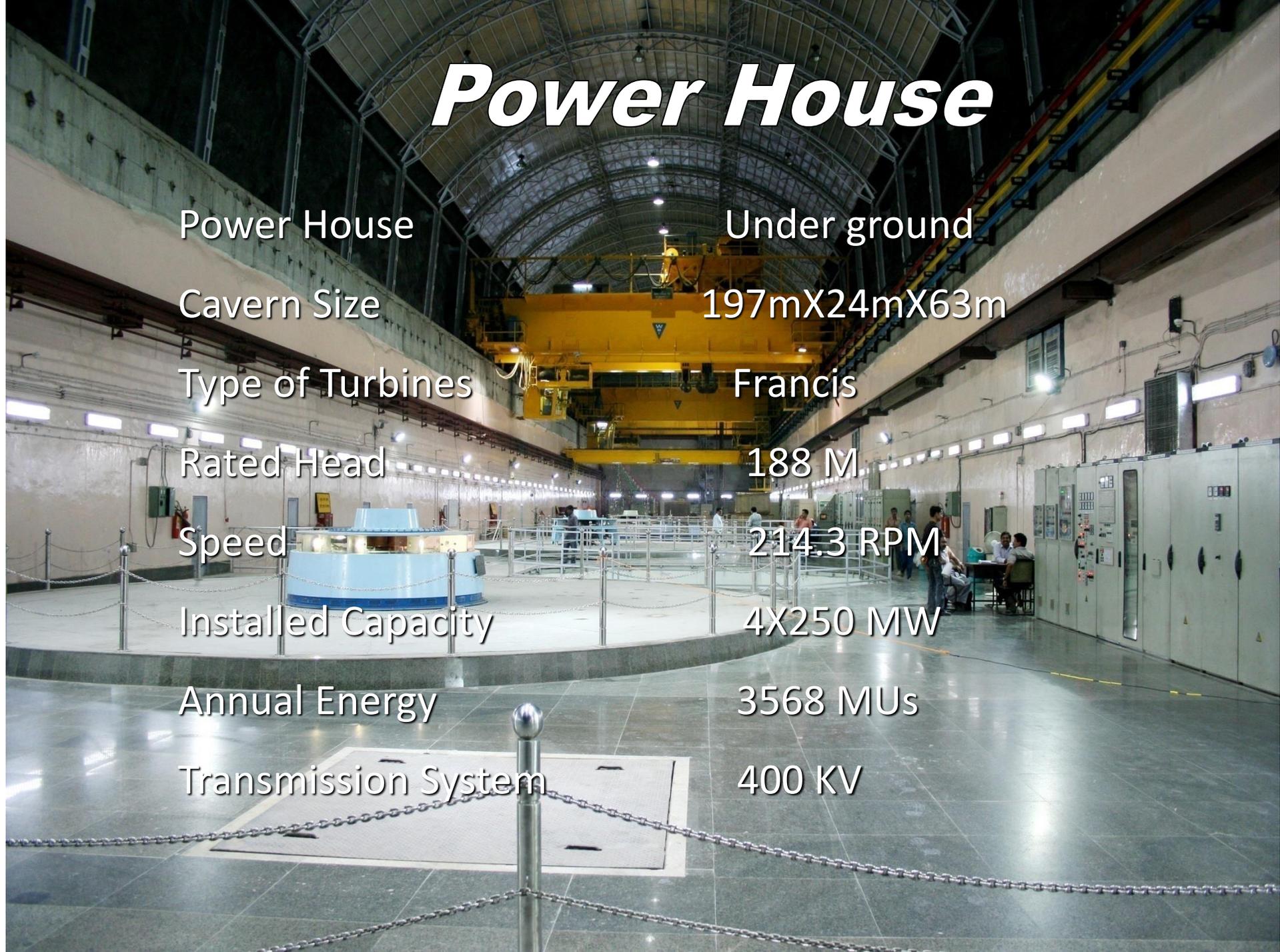
4X250 MW

Annual Energy

3568 MUs

Transmission System

400 KV



# INTAKE STRUCTURE FOR HPP (4X250MW)



THDC Ltd.

# ***OUTLET OF TRT-1&2***



**De-aeration Tunnel**

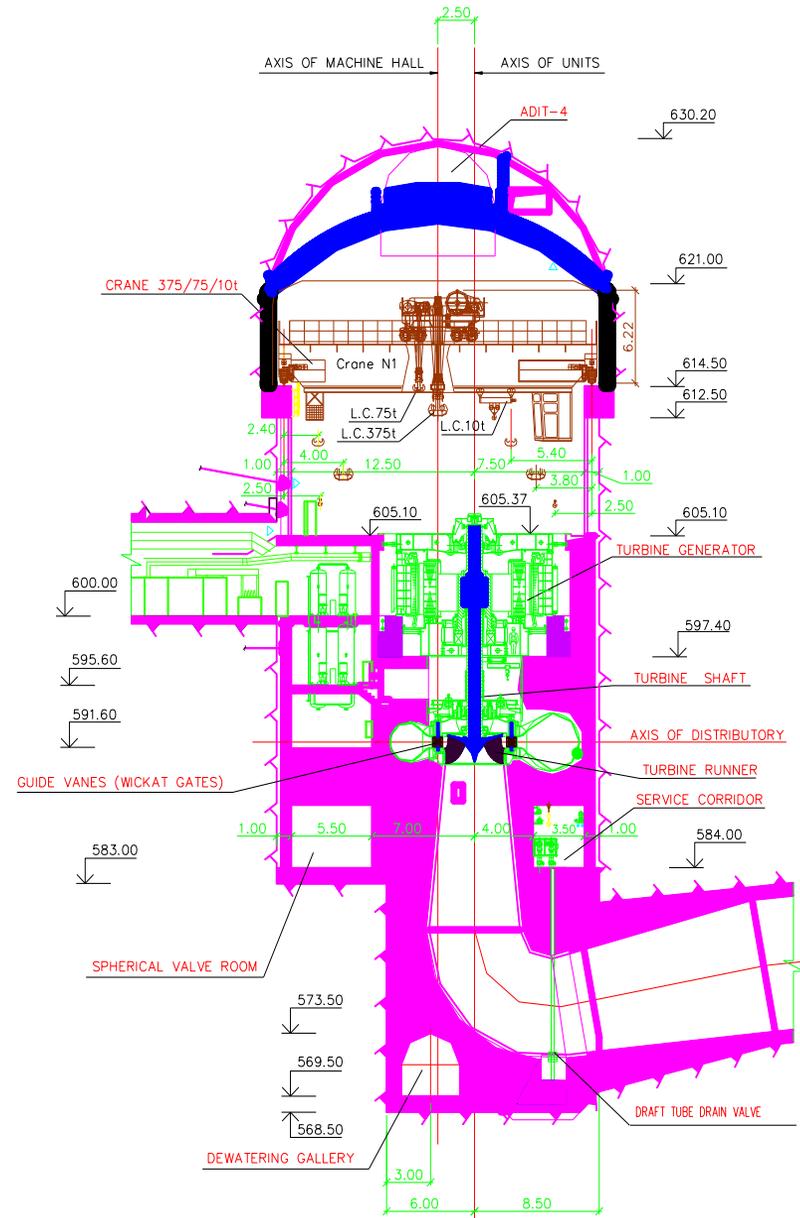
**Diversion Tunnels**

**Tail Race Tunnels**

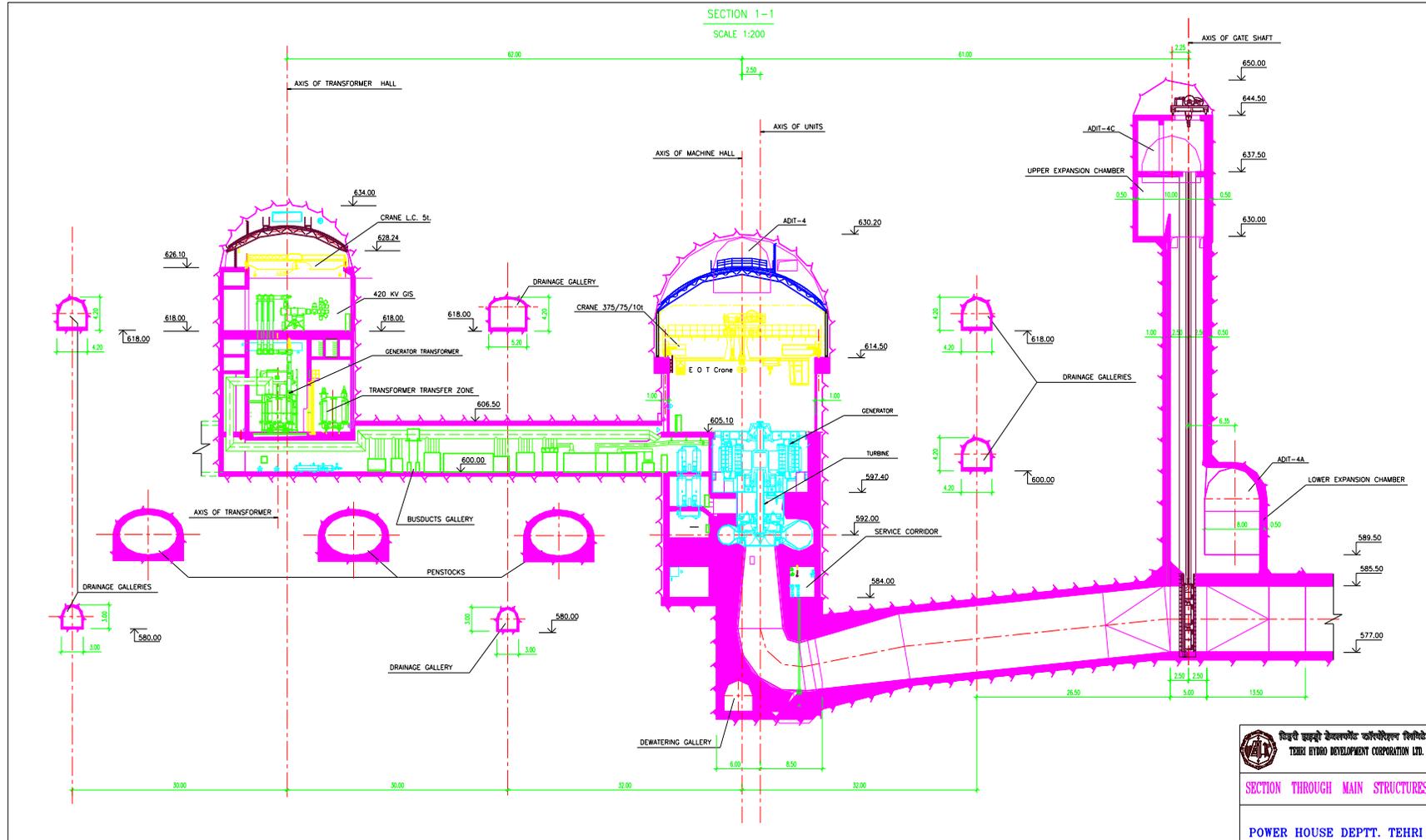
# ***Underground PH works***

- \* **Machine Hall Cavern of size 197 X 22 X 63m.**
- \* **Four more machines of 250 MW proposed to be added in Stage-II as Pumped Storage Scheme and the provision was kept in 1<sup>st</sup> phase**
- \* **A common transformer hall 163.5 X 18.5 X 34m. Shall cater to both stages of Tehri HPP (2000 MW)**
- \* **Stabilisation of walls for machine hall excavated cavern with 12 m long rock bolt & 120 mm dia cable anchors; these replace conventional steel supports**
- \* **An Upper expansion chamber 176.35 X 11 X 20 m & a lower expansion chamber 113.5 X 9 X 12.75 m handle and counter the surge effects**
- \* **Butterfly valve chamber 121.3 X 10 X 24.2m, besides a Penstock Assembly Chamber 117.1 X 13 X 19.70m are part of UG works and facility for O&M;**
- \* **All these underground excavations and stabilisation works were planned designed and constructed in adverse geological and challenging conditions.**

# Section through M/Hall



# Section through Main Structures



# Machine Hall



# Machine Hall



# **Validation of Tehri Dam's overall Safety by a 'prototype' check in 2013 floods**

- During the disastrous Uttarakhand floods 2013, (which affected Kedarnath, Alaknanda and Bhagirathi Valleys) as a result of an extreme cloudburst, Tehri dam and its reservoir played a significant role in flood attenuation.
- To prevent worst disaster in downstream that include the important settlements and towns like Rishikesh and Hardwar Towns, the moderation of the very high peak flood was only possible with a storage structure like Tehri Dam.
- With the reservoir raising to MWL of El. 835, flood moderation with the reservoir necessitated all the flood evacuation systems to be brought into full operation

# Validation of Tehri Dam's overall Safety.... 2

- Besides the Chute Spillway, Shaft spillways, the Morning Glory Spillway in the Left Flank were brought into operation, during the 2013 floods. Thus a prototype check of all its components for flood evacuation, including the energy dissipation arrangements, was possible. It was proved that taking care of the full flood flows of each one of its components as designed without any serious damages is feasible.
- The main dam was also subjected maximum design forces under FRL, and later MWL. This provided an opportunity to test its functionality and subsequent observations from dam instrumentation
- The Planning and Design Engineering aspects of the hydrology and hydraulic aspects of dealing with floods were proved to be sufficient and adequate.

# Tehri High Dam stands as the Backbone for Overall Development of Bhagirathi Valley

- Tehri Stage I works remain as the backbone for the additional development of Stage II works that comprise of a 1000 MW Pumped Storage Plant. The PSP works almost complete now in October 2024 would help create an overall 2400 MW of hydro energy generation. This will immensely help the Power Requirements and ensuring the Grid Stability of the Northern Region.

# In conclusion

- Many of the features incorporated in the Tehri Dam project stand as a testimony of engineering marvels of our times.
- The planning, design and construction of this structure involved cross cutting disciplines for a coordinated development and had many challenges unique to Himalayan region.
- The dam and the reservoir played a major role to counter the aftermath associated with one of worst flood in June 2013, in the entire area that covered both Bhagirathi and Alaknanda Valley causing severe damages to Great Hindu Shrines like Kedarnath.
- Tehri Dam and its stage development that includes a Stage II PSP of 1000 MW and a downstream Hydro development at Koteshwar remains as one of the shining examples of marvel in Development going hand in hand with environmental and Societal welfare interests.

# International Recognition for Indian Engineering in Dams Technology

- Tehri Dam was acknowledged as one of the 'International Milestone Projects', by International Commission of Large Dams(ICOLD), in 2009.
- The citation is indeed a recognition of the uniqueness of the design and construction features of Tehri High Dam in Himalayas and HPP facilities.



ICOLD award being received by a THDC delegation in China (19<sup>th</sup> October'2009)

# Acknowledgment

- THDCIL
- CWC D&R Wing
- CBIP publications on Tehri Project
- My associates and colleagues who were keen to participate in our efforts to handle the bold planning, design and execution, keeping a high standard of quality during the decade, when the structure was raising up.

# Technical Advisory Committee THDCIL

- The performance of the dam and all associate structures, including the Stage II Tehri PSP works that are under execution are presented by THDCIL Management before a Technical Advisory Committee periodically for a critical review. This committee had its existence since the Project Commencement, till date. (under the Chairmanship of Er. M Gopalakrishnan, with other Members drawn from different disciplines, as required, by THDCIL Management)
- TAC's recommendations form the basis for such additional and specific works for dam safety and its efficient performance with fund allocations under O&M
- An inhouse Dam Safety Unit of THDCIL is charged with the compliance of Dam Safety Act Requirements

Q & A

Discussions