Upper Tamakoshi Hydroelectric Project

An Experience from Implementation

A Presentation
For
Nepal Engineers' Association

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  - Project Finance
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Project Salient Features

• **Project Type**	**:**	**Peaking Run-of-River (PRoR)**
• **Installed Capacity**	**:**	**456 MW**
• **Annual Energy**	**:**	**2,281 GWh**
• **Design Discharge**	**:**	**66 m^3/s**
• **Gross Head**	**:**	**822 m**
Hydrology		
• Catchment Area	:	1745 Sq. km
• Min. Monthly Av Flow	:	14.1 m^3/s
• Yearly Av Flow	:	67.2 m^3/s
• Designed Flood	:	885 m^3/s (Return Period 1000 yrs)

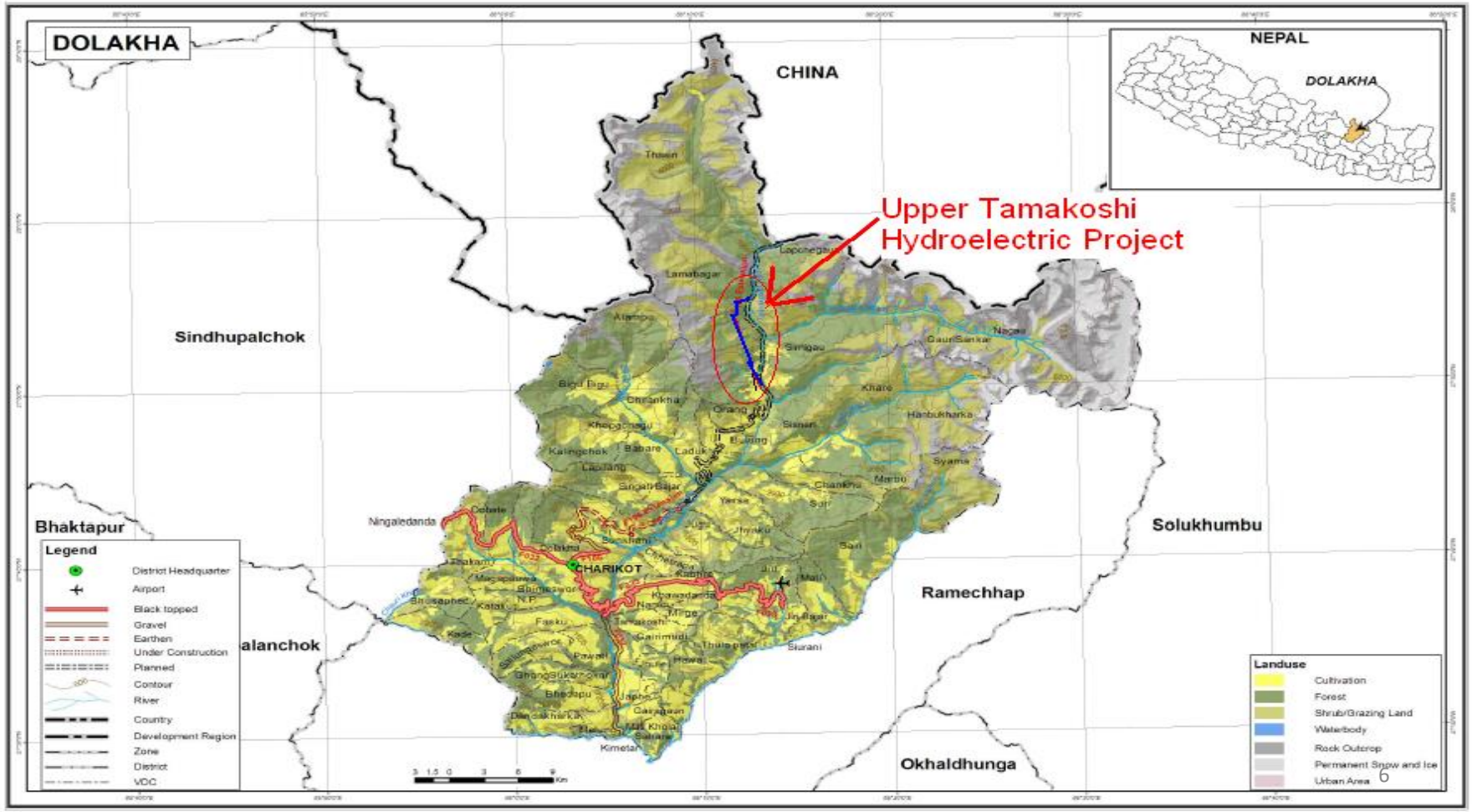
Project Salient Features (contd..)

- Dam : 60 m x 22 m (L x H)
- Pondage : 1.2 Mil m3
- Settling Basin : L = 225 m, W = 26 m (double)
- Headrace Tunnel : 8.5 km (Gross Area= 32 m2)
- Penstock Steel Lining : 1,134 m (Net dia= 3.6 m)
- Powerhouse Cavern : 142m x 13m x 25m
- Number of Units : 6 Units
- Tailrace Tunnel : 2.98 km
- Transmission Line : 220 kV double circuit, 47 km long
- Access Road : 69 km (incl. 340 m road tunnel)

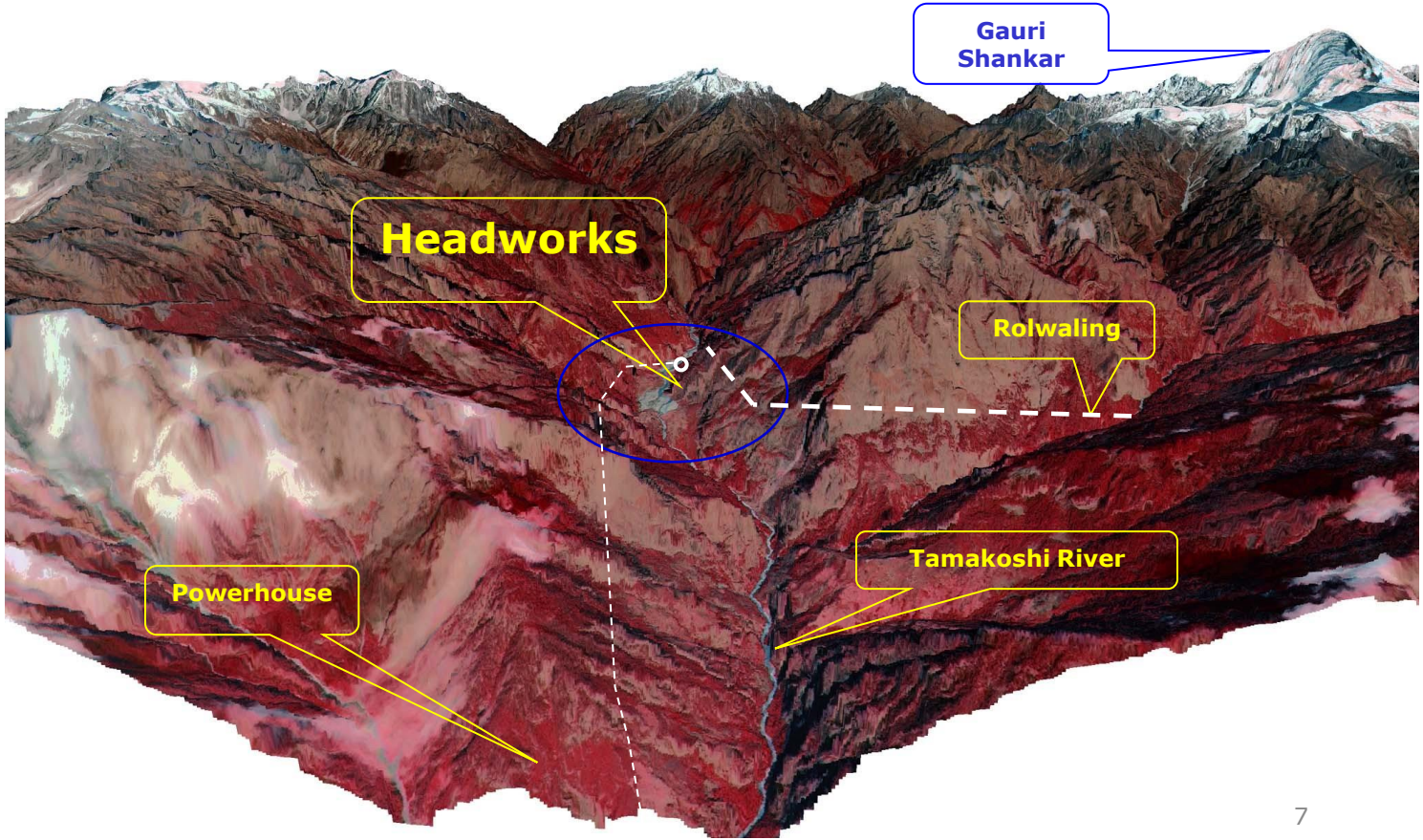
Special Features

- 300 m high natural dam
- gross head of 820 m within 8 kms of headrace tunnel
- comparatively better geology with presumably massive rock
- comparatively very good flow during dry season, low flood discharge during wet season
- comparatively very low sediment influx
- minimum environmental effect.

PROJECT LOCATION MAP

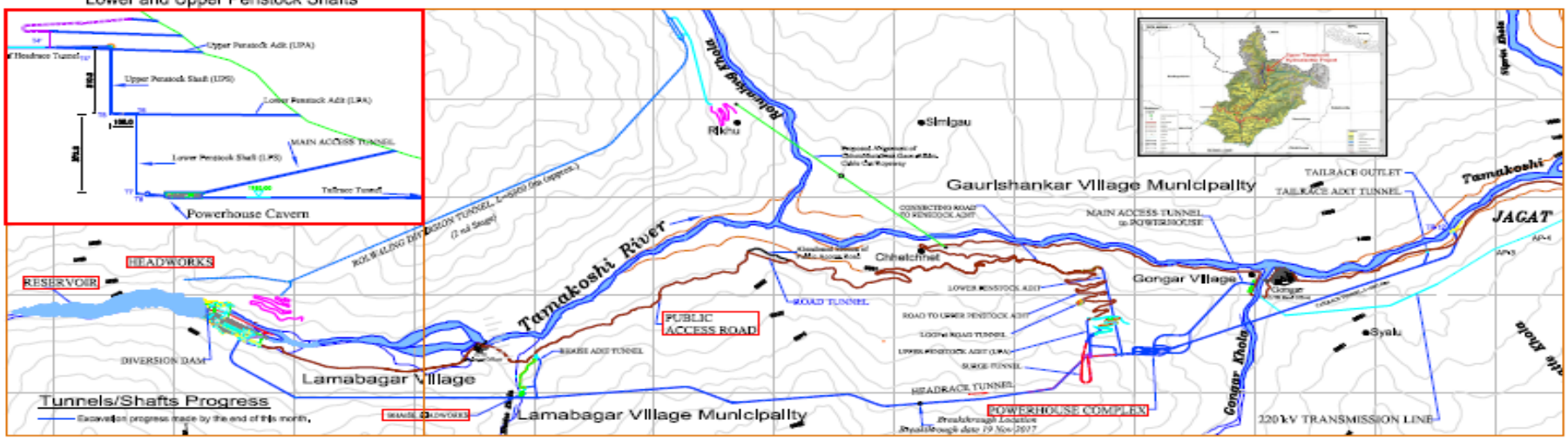


3D VIEW OF PROJECT AREA

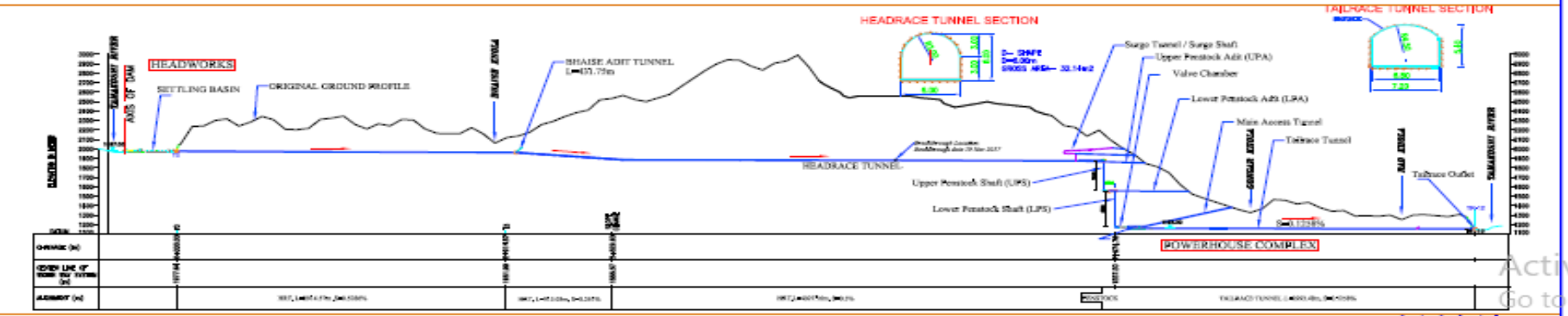


UPPER TAMAKOSHI HYDROPOWER LIMITED

UPPER TAMAKOSHI HYDROELECTRIC PROJECT (456 MW)



GENERAL LAYOUT PLAN

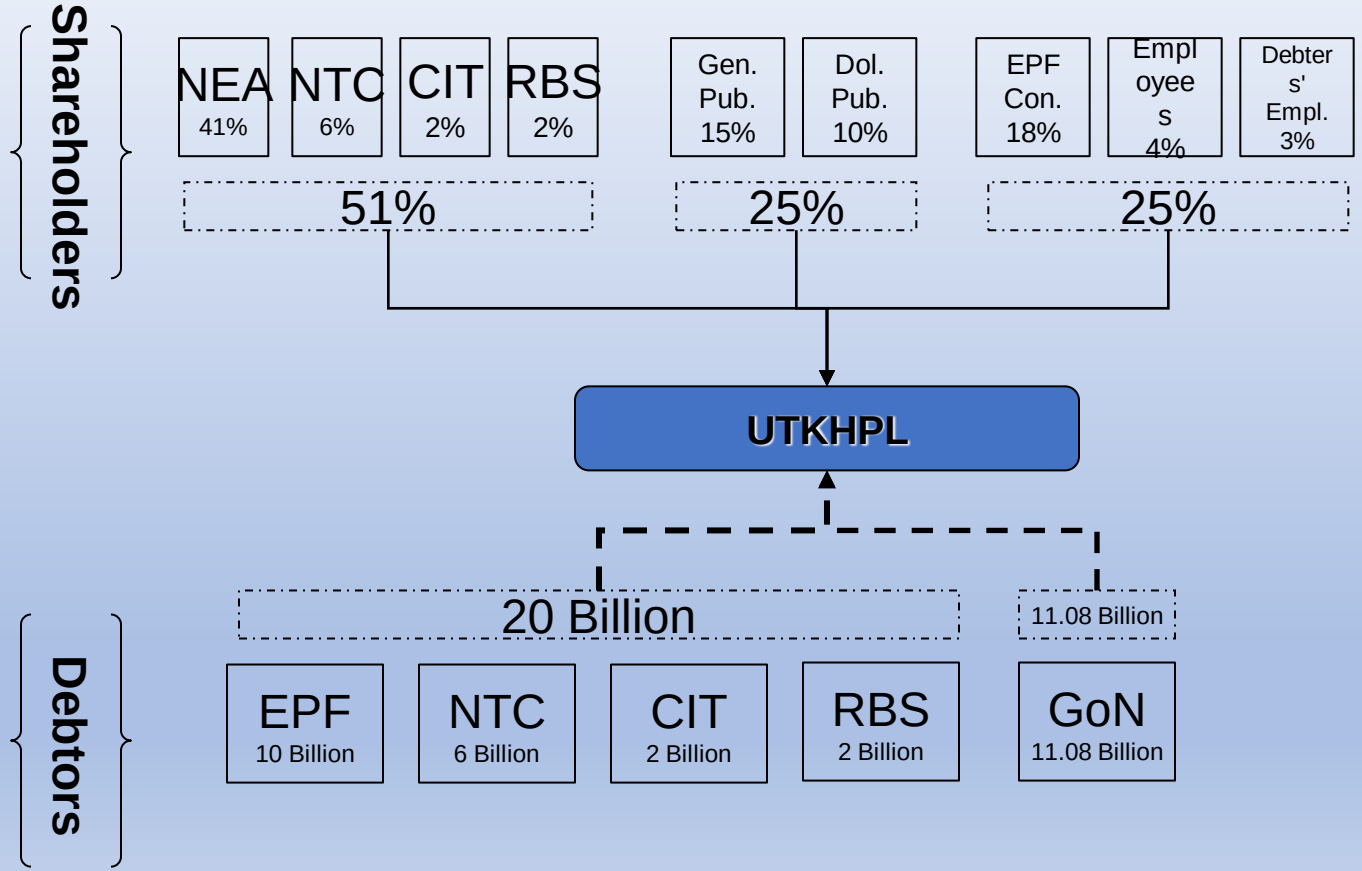


PROJECT PROFILE

BRIEF HISTORY

- Project Identification : By Koshi River Water Resources Development Master Plan JICA in 1985 (Installed Capacity 113 MW-TA6)
- Pre-feasibility study: By Dr. Christian Uhlir in 1999 (120 MW)
- Feasibility Study- Phase I (2001-2003)
  - by NEA with in-house staffs (250 MW, 1570 GWh)
- Feasibility Study- Phase II (2003-2005)
  - Norwegian Grant Assistants, Norconsult AS
- Detailed Engineering Design (2007-2008)
  - Joint Venture Norconsult AS - Lahmeyer International
- Project Access Road Construction : From 2006 to 2011
- Financial Arrangement : 2006 to 2011

Project Finance Modality



Project Finance at a Glance

Initial Project Estimate for Finance : USD 441 Billion

: NPR 35.29 Billion (Equivalent)

Interest During Construction (IDC) : NPR ~ 14 Billion

Equity Finance : NRs 10.59 Billion

Debt Finance : NRs 20 Billion

Nepal Government Soft Loan: NRs 11.09 Billion

Price of Energy was based on the Return on Equity (RoE) ~ 16%

Per Unit Energy Rate In COD Year : NPR 3.63 (Wet Season)

& NPR 6.96 (Dry Season)

Per Unit Rate 9th Year after COD : NPR 4.74 (Wet Season)

& NPR 9.08 (Dry Season)

Implementation Phase Experiences

- Design Modification of Headrace Tunnel
- Construction of Vertical Penstock Shaft
- Post disaster reconstruction
- Transportation of Heavy Consignment
- Weak Performance of Hydro-mechanical Contractor
- Covid-19 Pendamic
- Disputes, Claims and Variations

Major Contracts

- Construction Supervision

  JV Norconsult AS – Lahmeyer Internation GmbH

- Lot 1 – Main Civil Works

  Sino Hydro Corporation, China

- Lot 2 – Hydromechanical Equipment

  Texmaco Rail Engineering Ltd, India

- Lot 3 – Mechanical and Electrical Equipment

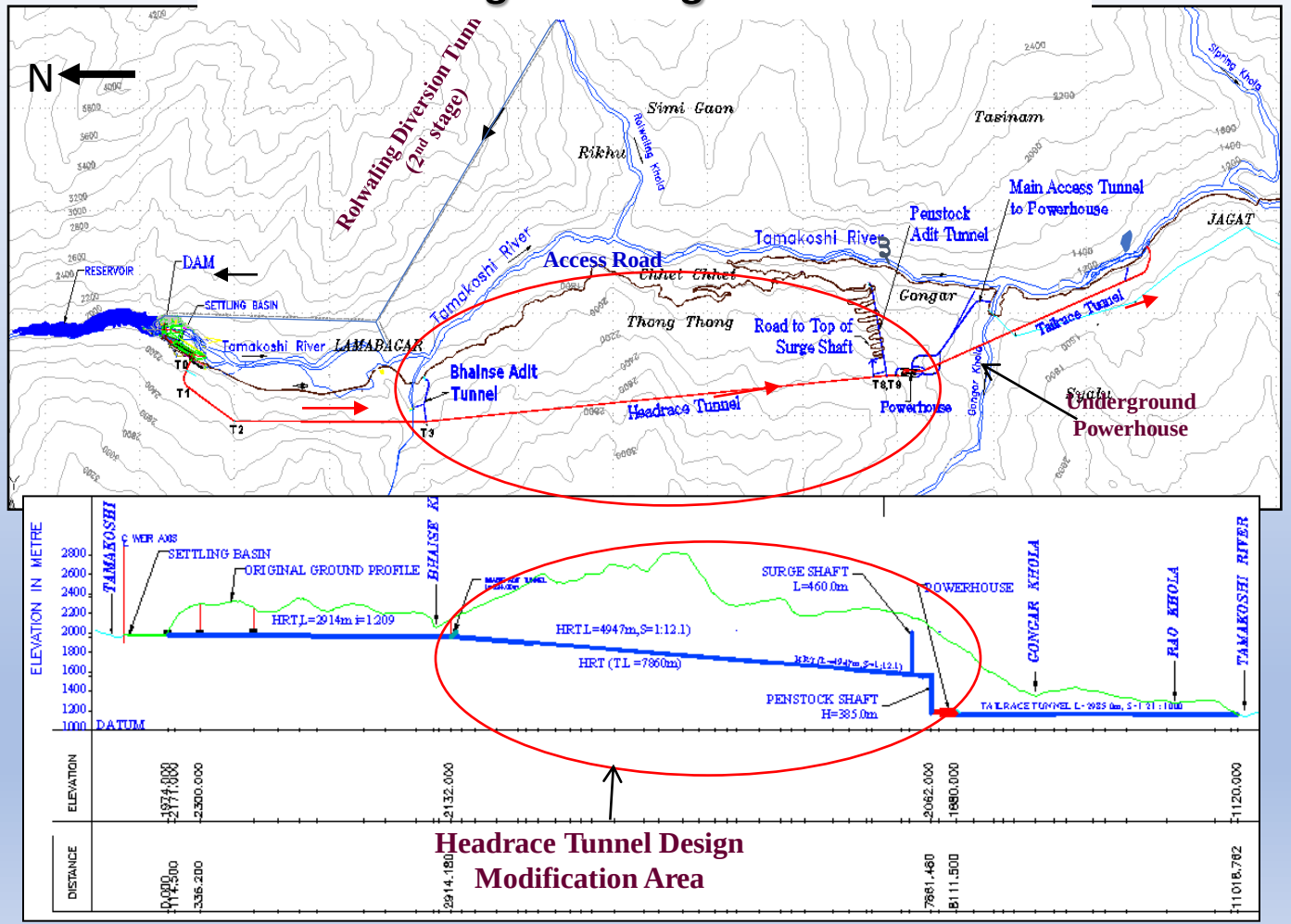
  Andritz Hydro GmbH, Austria

- Lot 4 – Transmission Line and Substation

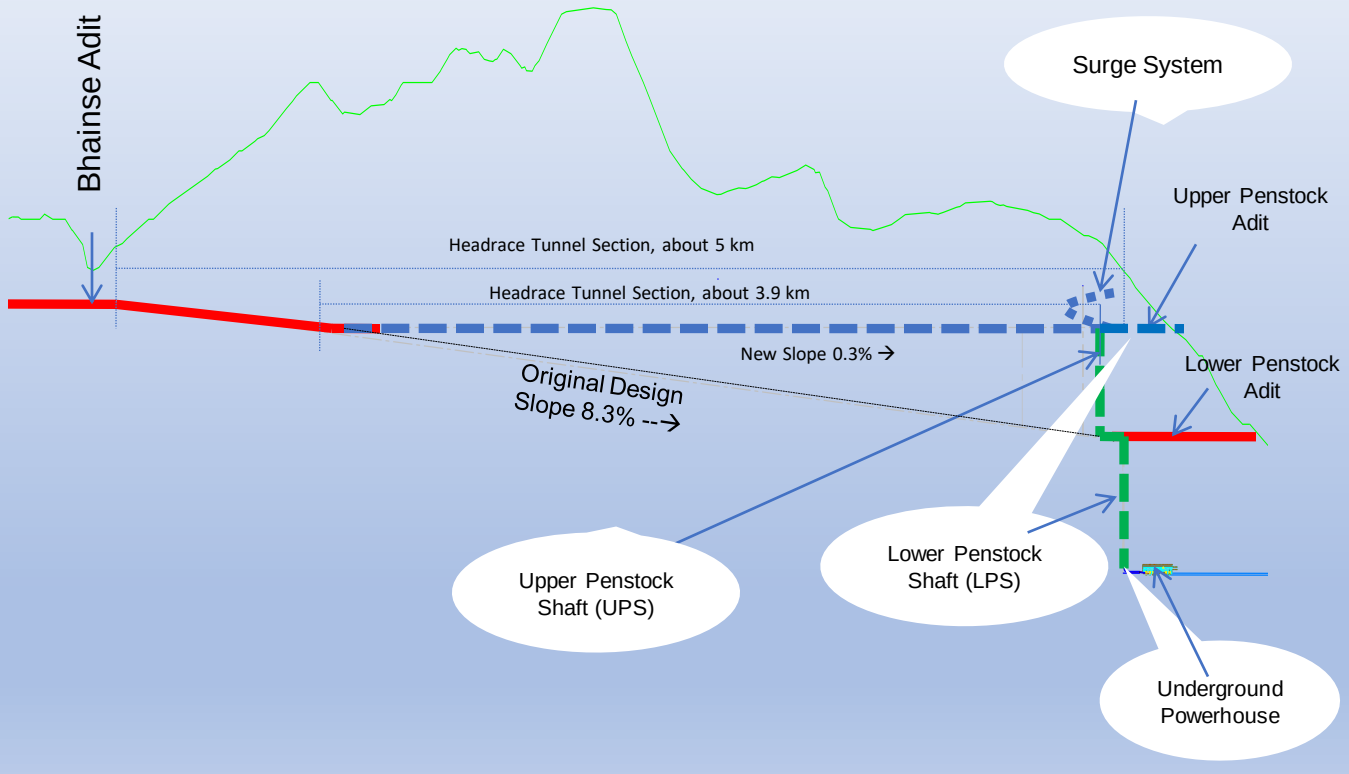
  KEC International Ltd, India

Design Change of Headrace Tunnel

Design Change of HRT



Design Change of HRT



Note:- Not in scale

NEW WORKS DUE TO DESIGN CHANGE

1. Upper Penstock Adit (L=380m, 22.4 m2)
2. Upper Erection Adit (L=246m, 22.4 m2)
3. Erection Chamber (L=55.5m, 69.16 m2)
4. Access Road (L=2.5 km) + Road Tunnel (L=110m, 22.4 m2)
5. Upper Penstock Shaft (Height = 311 m, excav. dia. 4.4 m)
6. Concrete Lining in Headrace Tunnel, L=1,143 m length,
7. Steel Penstock (L=431m), and
8. Surge System

(i) Surge Tunnel Adit (L=390m, 22.4 m2)

(ii) Surge Tunnel (L=635m, 22.4 to 32.14 m2)

(iii) Ventilation Tunnel (L=110m, 22.4 m2)

(iv) Surge Shaft (H=72m, excav. dia. 4.4 m)

(v) Access Roads (L=1,020m)

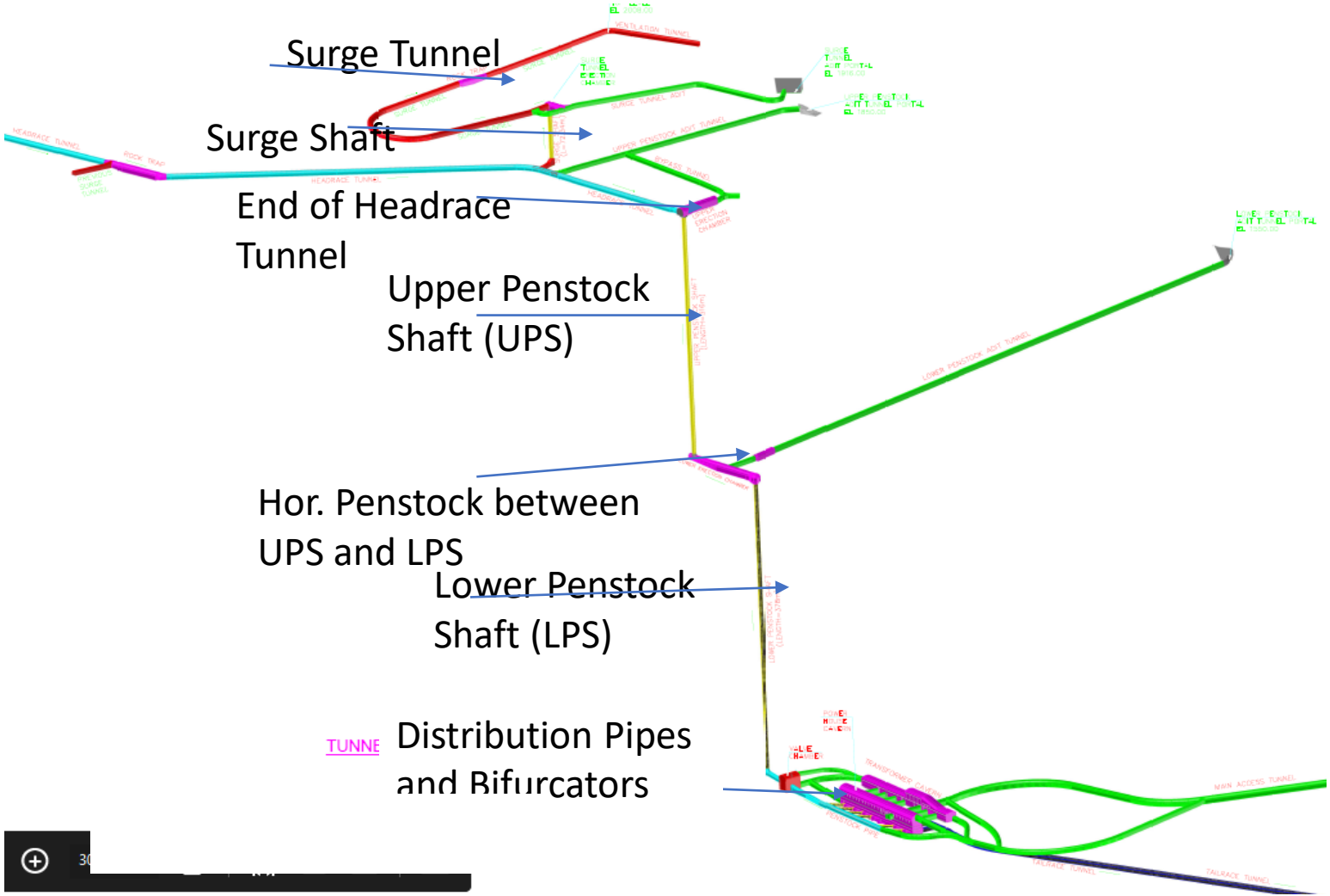
Omitted Works

(i) Connecting Tunnel to Surge Shaft (L=171m, 22.4 m2)

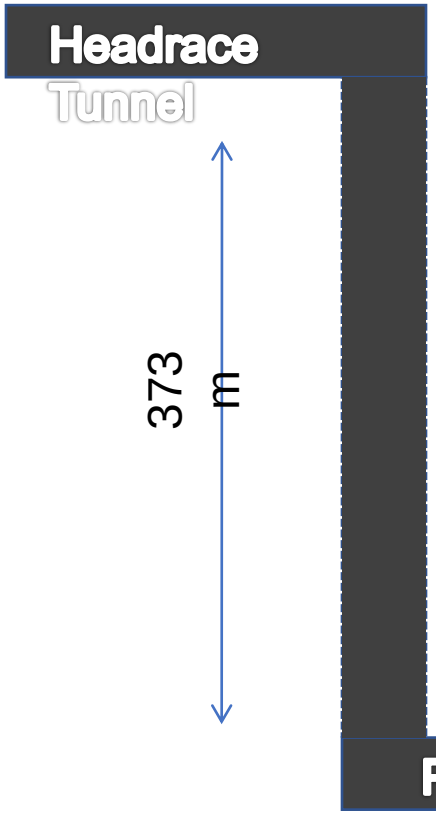
(ii) Surge Shaft (H=420m; excav. dia. 5m)

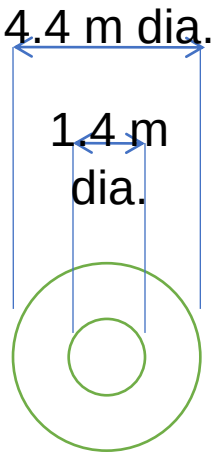
(iii) Surge Chambers (L=270m, 30m2)

Construction of Vertical Penstock Shafts


Surge Tunnel
Surge Shaft
End of Headrace Tunnel
Upper Penstock Shaft (UPS)
Hor. Penstock between UPS and LPS
Lower Penstock Shaft (LPS)
Distribution Pipes and Bifurcators

Shaft Excavation Process

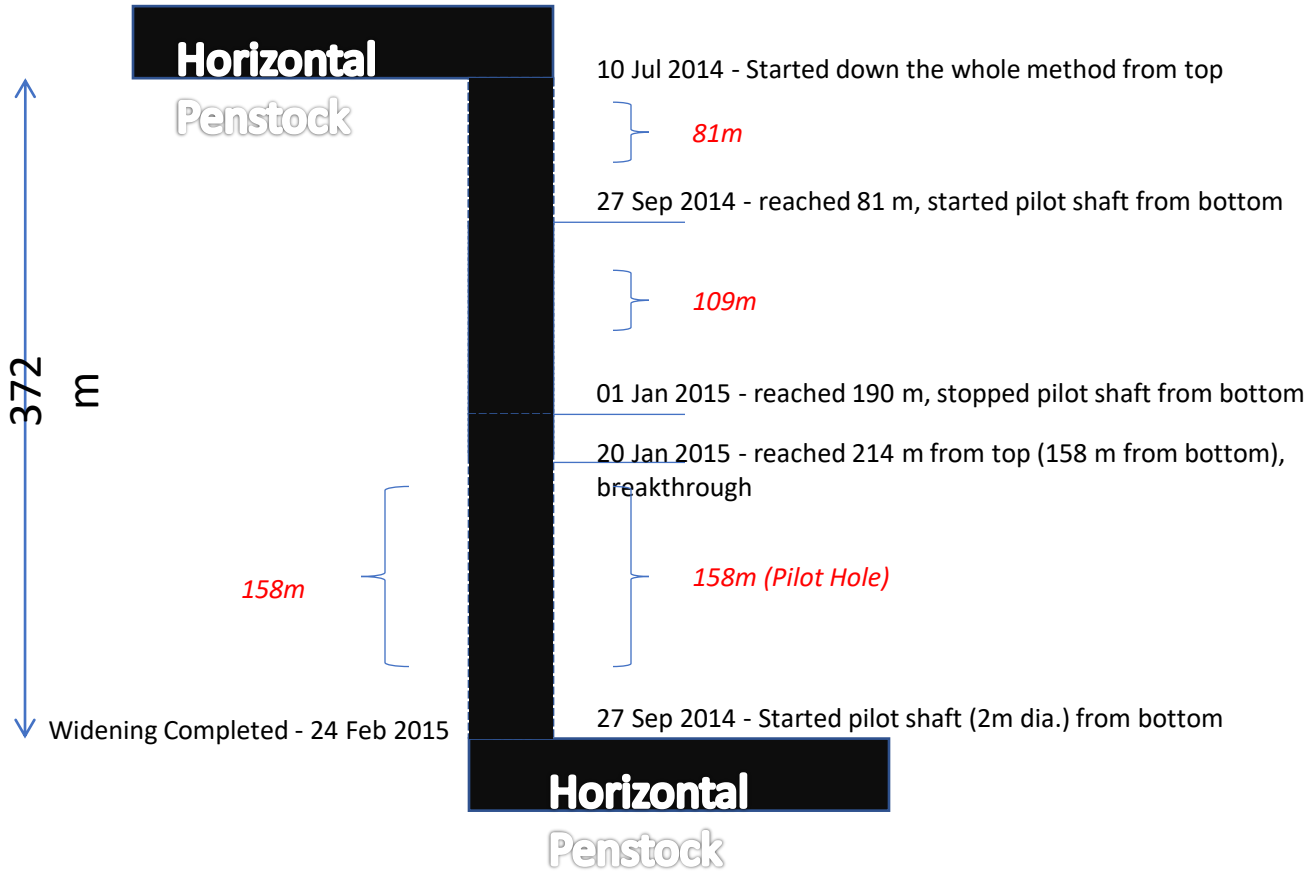




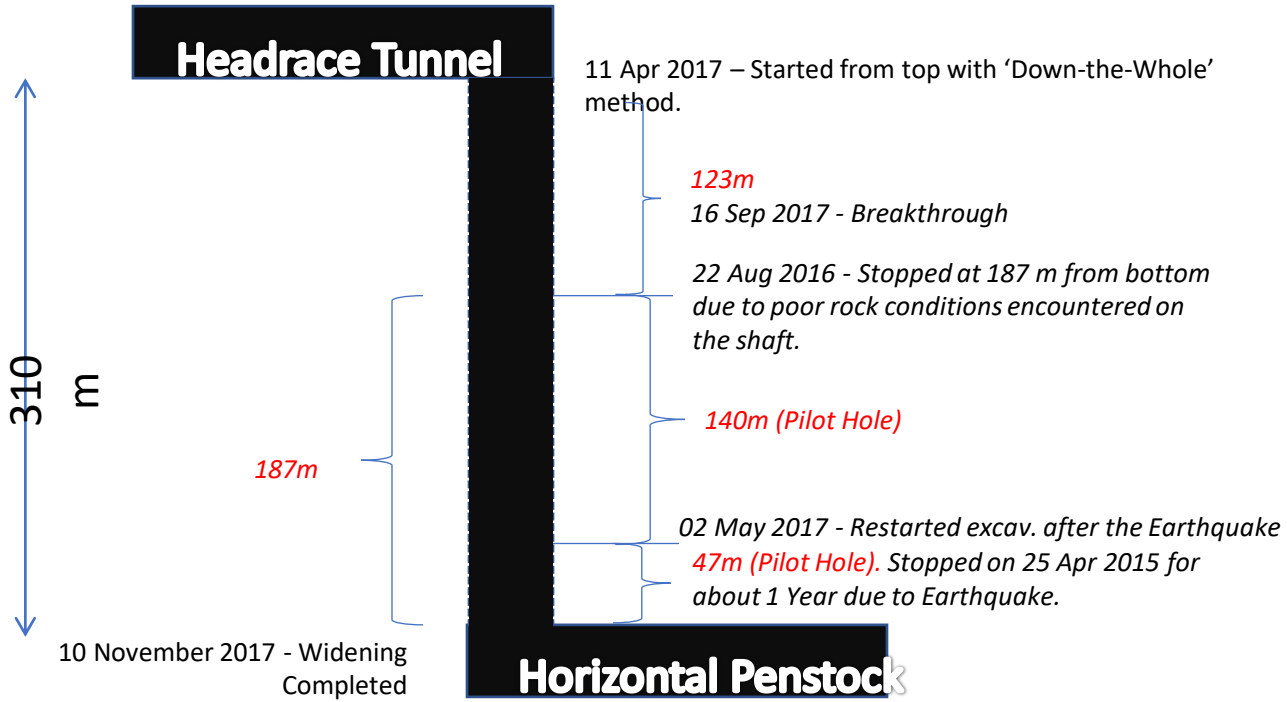
Penstock Shaft
Cross-Section

Video

Lower Penstock Shaft Excavation (Actual)



Upper Penstock Shaft Excavation (Actual)



11 Apr 2017 – Started from top with 'Down-the-Whole' method.

123m
16 Sep 2017 - Breakthrough

22 Aug 2016 - Stopped at 187 m from bottom due to poor rock conditions encountered on the shaft.

140m (Pilot Hole)

02 May 2017 - Restarted excav. after the Earthquake
47m (Pilot Hole). Stopped on 25 Apr 2015 for about 1 Year due to Earthquake.

10 November 2017 - Widening Completed

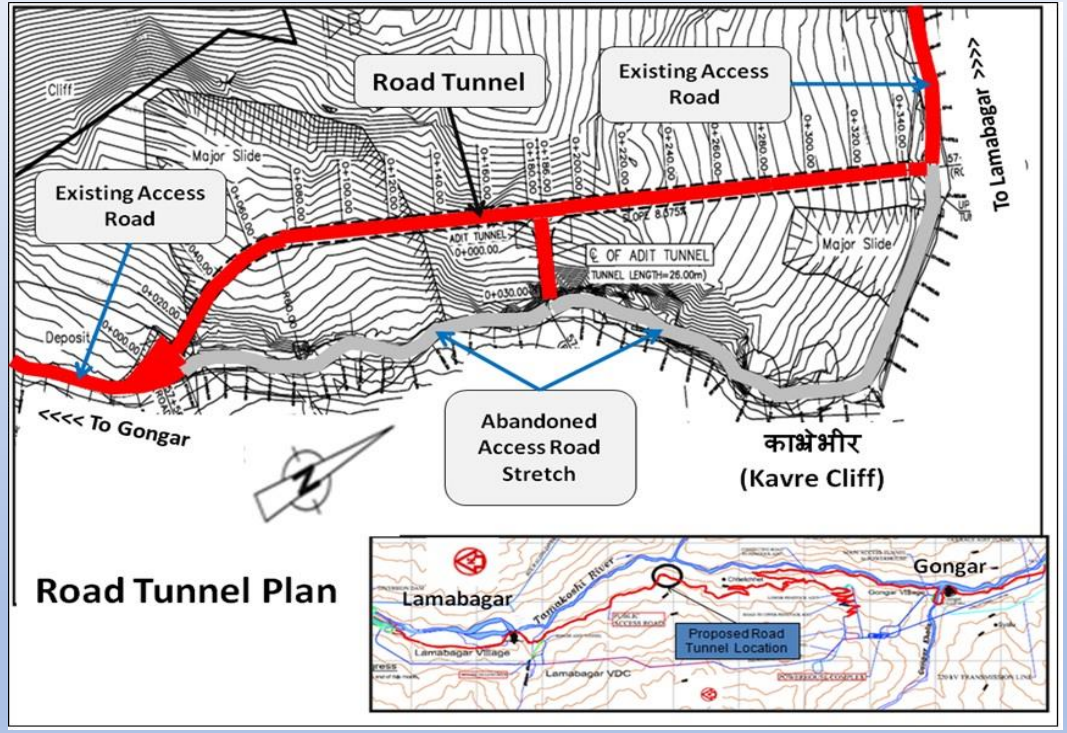
28 Mar 2015 - Started pilot shaft (2.1 m dia.) from bottom

Earthquake and Border Blockade (contd…)

- Differential settlement in Headworks
- With recommendation of International Panel of Expert (PoE) and Consultant, a special rubber seal have been installed along the settlement line with drill holes.
- This remedy is working properly

Earthquake and Border Blockade

- Damaged Project Access Road (PAR)
- Approx 2 Billion NRs CAR insurance claim
- Approx. 1 Billion NRs received under various items
- Post disaster reconstruction of damaged PAR



Damages due to Floods & Landslides following Earthquakes

- Heavy containers with electro-mechanical equipment washed away on flashflood of June 16, 2015.
- EAR claim ~ 8 Million USD
- Recovered ~ 7 Million USD from the Insurance

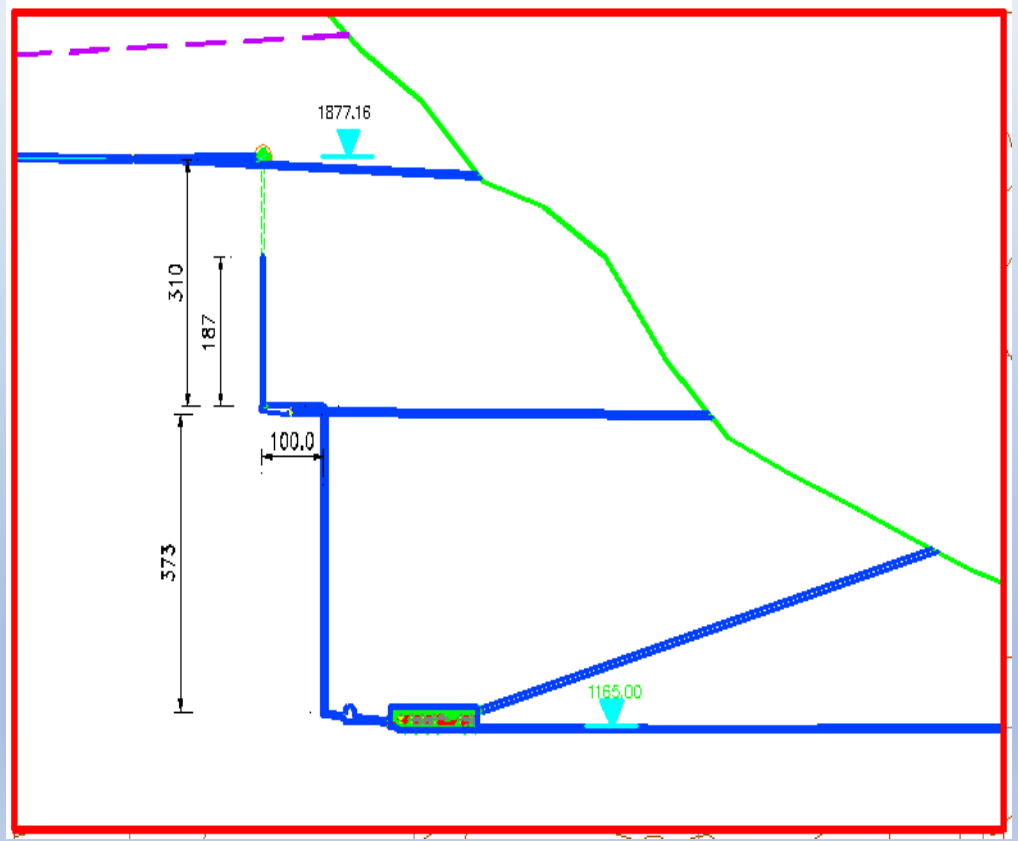
Public Access Road (PAR) and Transport of Heavy Equipment

- PAR is life line for the Project
- Much attentions requires during monsoon
- Special attentions requires for heavy consignments of the electro-mechanical equipment.
- Transport of Heavy Consignment itself is a Project

Transportation of MSOV Body and Ferrules

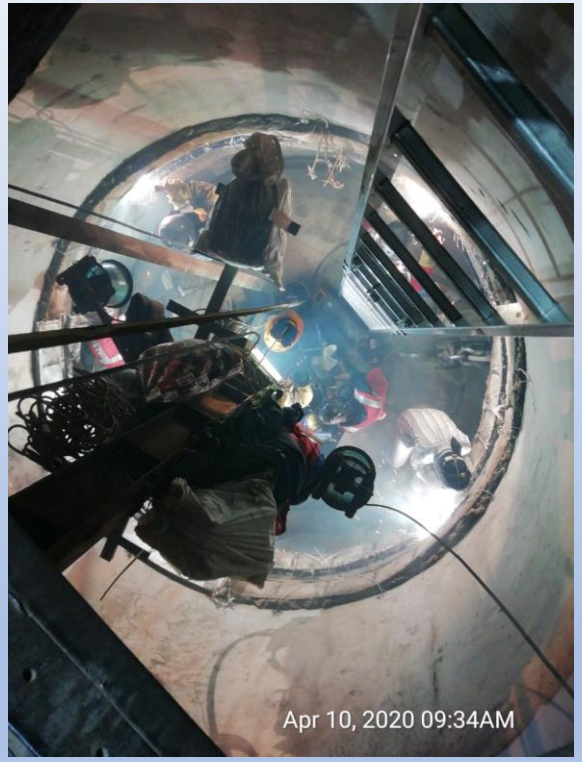
Weak Performances on Penstock Erections

- Incurring delays due to weak performance on Pressure Conduits
- Can not compromise on quality and safety
- Need better quality of welding and quality control
- Very delegate for high pressure

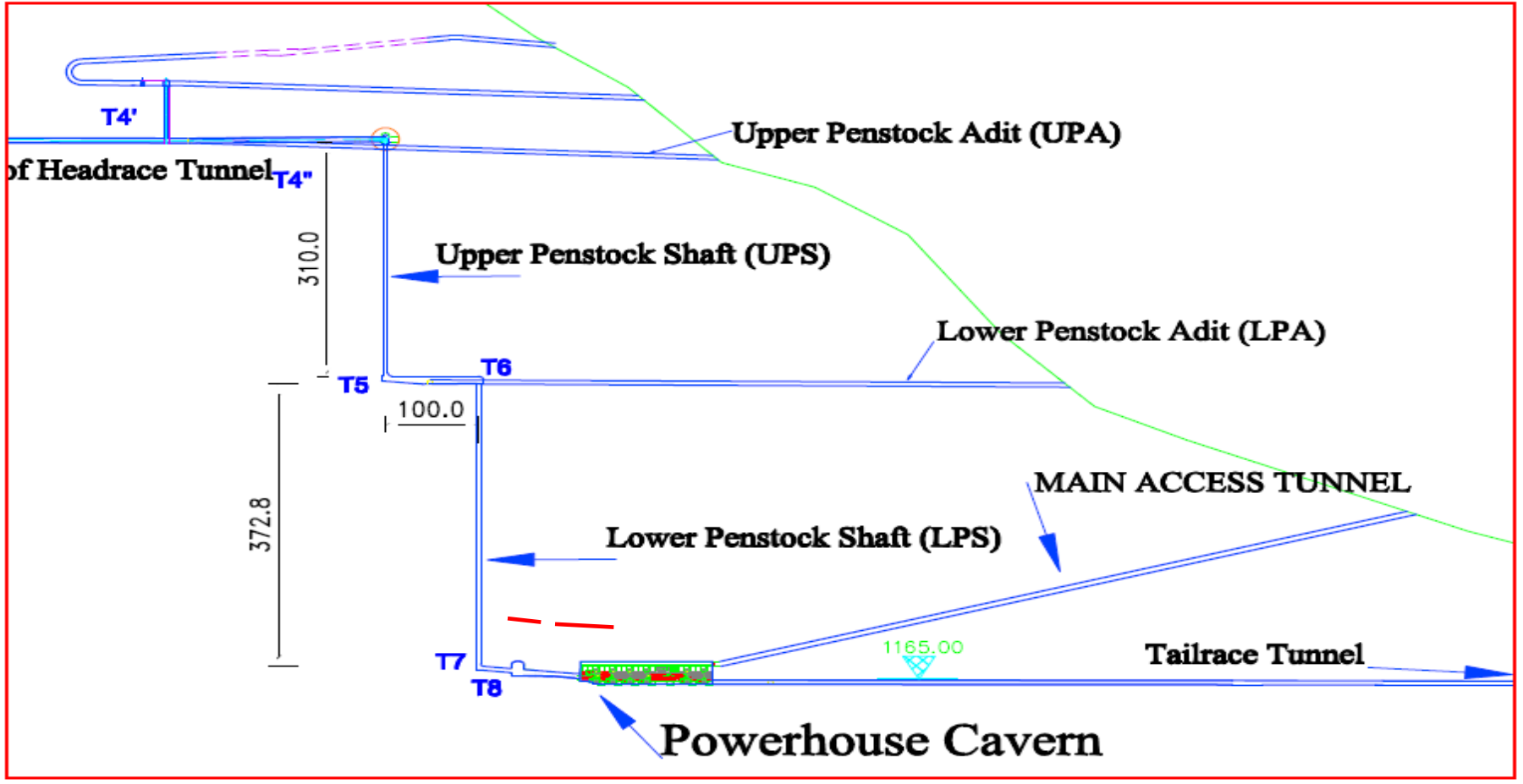


Recovery & Rescue on Penstock Erections

- Avoided Termination (FIDIC 15) process with the HM Contractor Texmaco
- Assigned ANDRITZ Hydro directly with supplementary agreement for repair works (FIDIC 7.6: Remedial Work)
- Assigned ANDRITZ Hydro through consent of Texmaco for installation and transportation of the lower penstock pipes (FIDIC 1.7: Assignment)

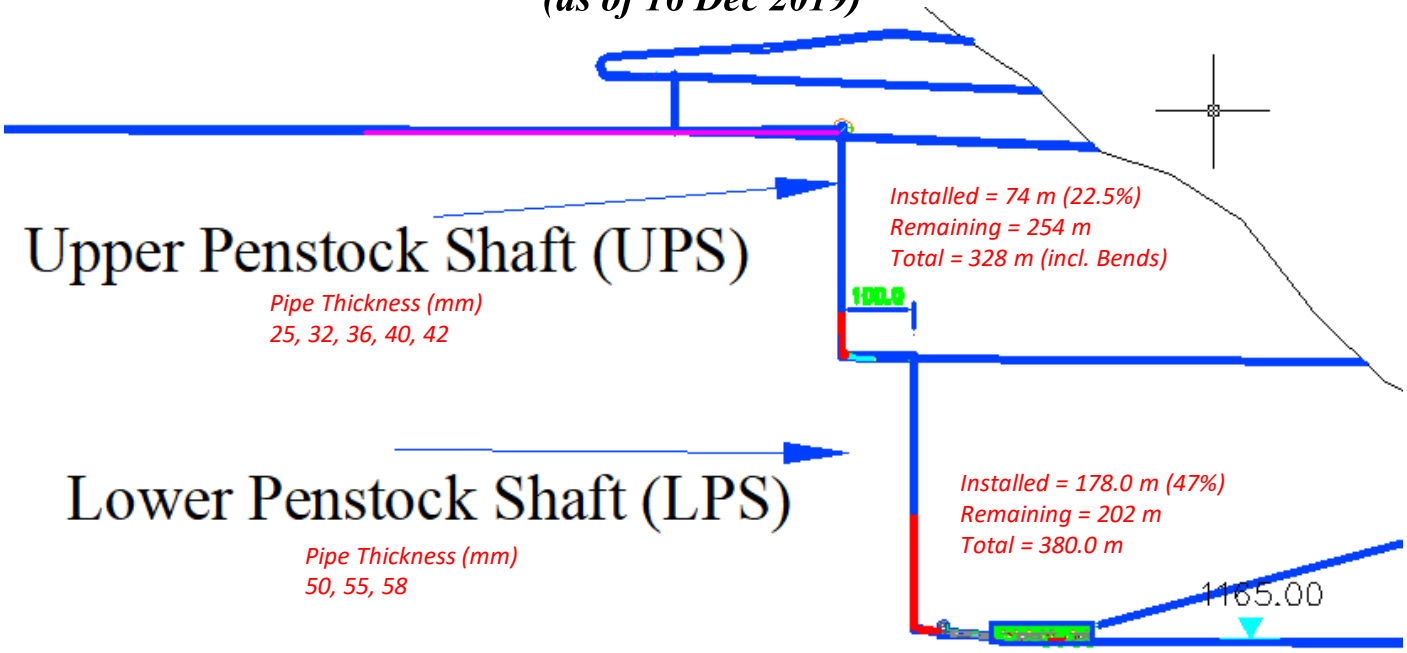


PRESSURE CONCUIT SYSTEM AND SURGE SYSTEM



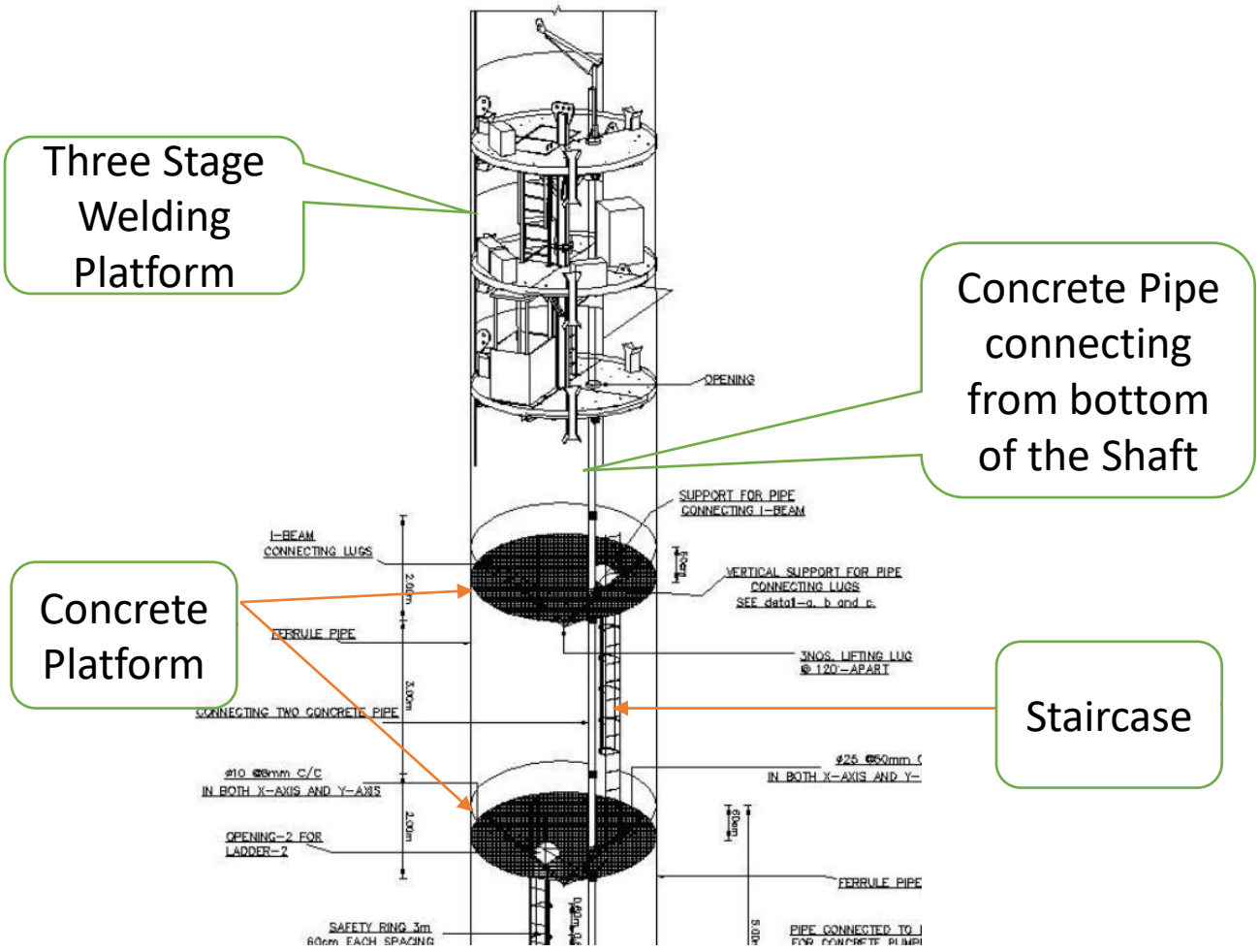
UPPER AND LOWER PENSTOCK PIPES INSTALLATIONS PROCESS

(as of 16 Dec 2019)

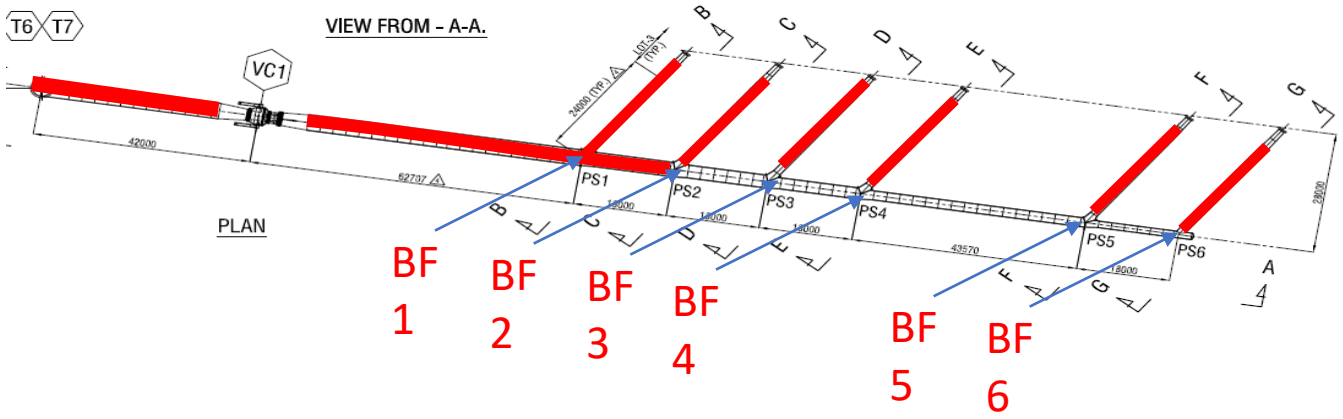


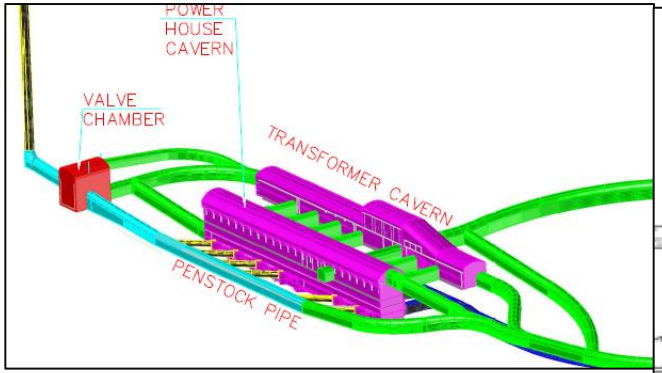
INSTALLATION PROCESS

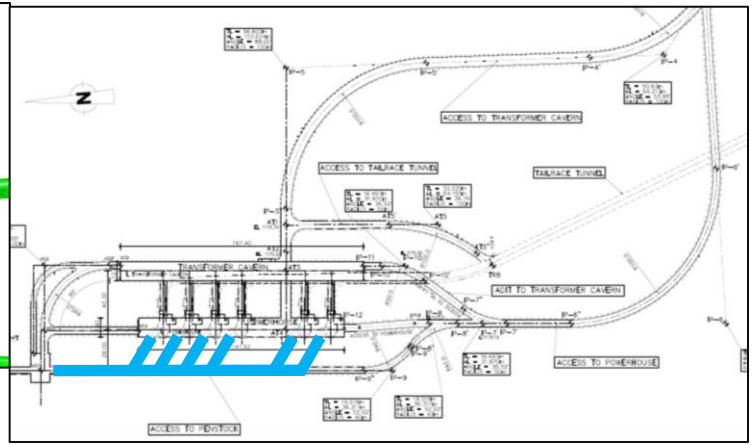
BACKFILL CONCRETING IN PENSTOCK SHAFTS



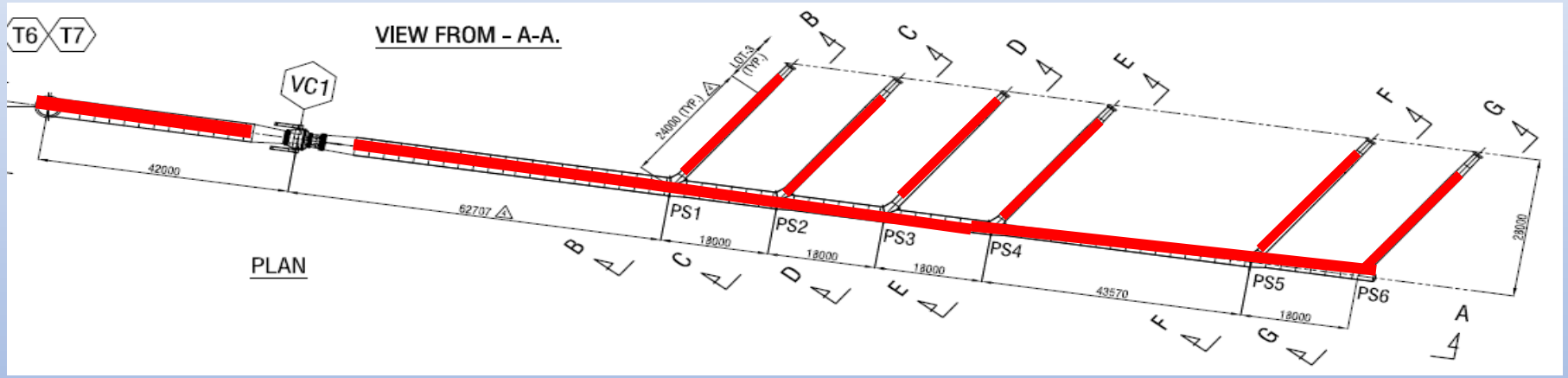
BOTTOM HORIZONTAL PENSTOCK PIPE LAYOUT







HORIZONTAL PENSTOCK PIPE LAYOUT



Project Implementation during Covid-19 Pandemic

- Expat consultant left project site
- Approximately 1100 technical staffs including 350 foreigners were working
- Did not stop the work during lock-down period as well.
- Later Government of Nepal formalized to work in Mega Projects of this nature with due care of health and safety.
- However, the we could not retain work force at substation site, as this site is within proximity of highway.

Project Implementation during Covid-19 Pandemic

Challenges:

- To retain work forces at site
- To get all outstanding fabrication part at workshops outside Nepal and its transportation to site
- To get continue regular supply of construction material, fuel and all logistics
- To maintain health and safety of work place
- Absence of specialist consultant and expert due to stoppage of international flight

Project Implementation during Covid-19 Pandemic

What we did

- Converted this challenges to the opportunity. Particularly,
  - All difficult vertical shaft welding get completed
  - All difficult welding of bifurcation pipes get welded including repairs.
  - Making a defect less weld for 822 m head pressure pipe is really a challenge
- Proper coordination and dedication of the all personnel working rigorously at site.
- All expat consultants **except Welding Expert** were working from home. **And we were able to complete chemical grouting at pressure tunnel with the help of video conferencing.**

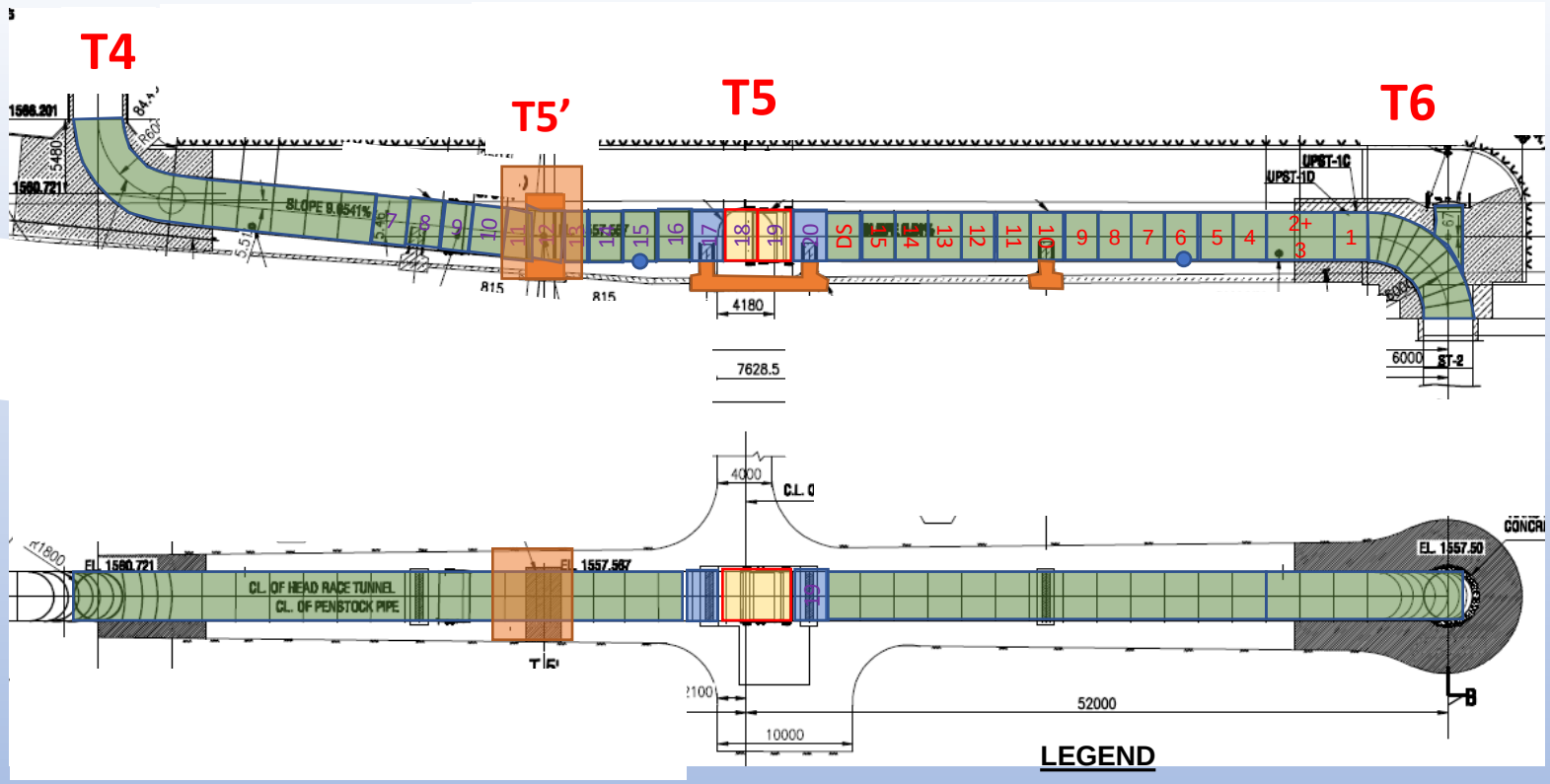
Project Implementation during Covid-19 Pandemic

What we missed

- Remaining parts of pressure pipes such as expansion joints (EJ) and dismounting boxes (DB) were get stocked up in workshop of the Contractor Texmaco in Kolkata for final fabrication

- Delayed and uncertain remaining material from Texmaco hampered the progress

- UTKHPL management initiated to find alternative solution by replacing EJ and DB with straight ferrules.



Middle Horizontal Penstock

LEGEND

- Manhole (to be arrived on 20 March '21)
- Backfill Concrete done
- Pipe Fitted Up
- Pipe Welded

220 kV TL & 220 kV New Khimti Substation

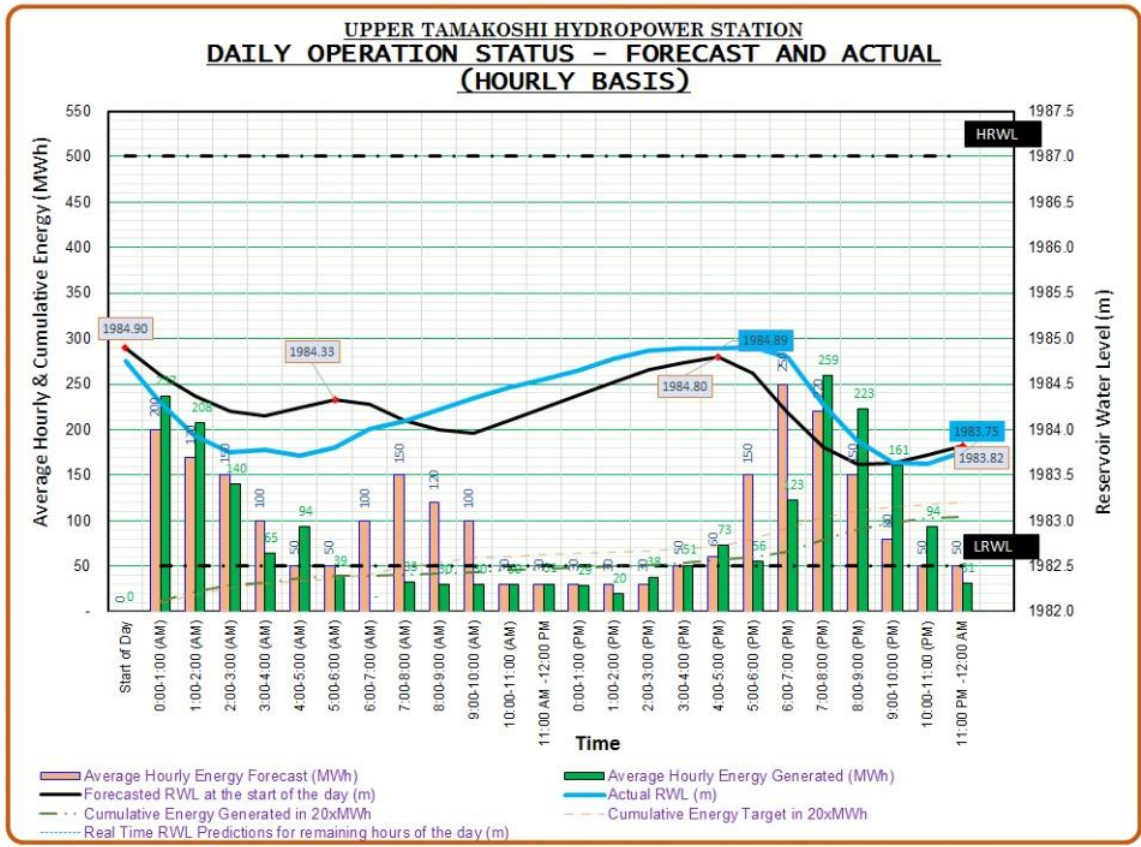
- Each Transmission Line tower itself is a project
- This substation is Hydro hub for 800 MW power from Tamakoshi & Likhu Basin
- Land acquisition problem made construction in Limbo
- Last Multi-circuit line strung just before inauguration.

Testing and Commissioning

- Wet commissioning started from Baishakh 2078
- First Unit Synchronized on 21 Asar 2078 and inaugurated by PM
- Commercial Operation Date as per PPA : 4 Bhadra 2078

Hours	Actual			D/S Release	Hourly Ave. Inflow	Cum. Ave. Inflow	RWL (m)	Actual + Foreseen RWL
	Ave. Ener. (MWh)							
Start of Day	Hrly	Ave.	Cum.	m3/s	m3/s	m3/s	1984.75	1984.75
0:00-1:00 (AM)	237	237	237	1.29	10.5	10.5	1984.30	1984.30
1:00-2:00 (AM)	208	222	445	1.27	11.2	10.9	1983.93	1983.93
2:00-3:00 (AM)	140	195	585	1.25	12.3	11.4	1983.75	1983.75
3:00-4:00 (AM)	65	162	650	1.40	12.3	11.6	1983.78	1983.78
4:00-5:00 (AM)	94	149	743	1.40	11.9	11.7	1983.72	1983.72
5:00-6:00 (AM)	39	130	782	1.40	11.1	11.6	1983.80	1983.80
6:00-7:00 (AM)	-	112	782	1.40	11.6	11.6	1984.00	1984.00
7:00-8:00 (AM)	33	102	815	1.50	11.8	11.6	1984.10	1984.10
8:00-9:00 (AM)	30	94	845	1.50	12.4	11.7	1984.22	1984.22
9:00-10:00 (AM)	30	88	875	1.50	13.0	11.8	1984.35	1984.35
10:00-11:00 (AM)	30	82	906	1.22	11.6	11.8	1984.46	1984.46
11:00 AM -12:00 PM	31	78	936	1.22	10.7	11.7	1984.55	1984.55
0:00-1:00 (PM)	29	74	965	1.22	11.0	11.7	1984.65	1984.65
1:00-2:00 (PM)	20	70	985	1.22	11.5	11.6	1984.78	1984.78
2:00-3:00 (PM)	38	68	1,023	1.24	11.8	11.7	1984.87	1984.87
3:00-4:00 (PM)	51	67	1,074	1.25	10.3	11.6	1984.90	1984.90
4:00-5:00 (PM)	73	67	1,146	1.25	11.2	11.5	1984.89	1984.89
5:00-6:00 (PM)	56	67	1,202	1.25	10.4	11.5	1984.91	1984.91
6:00-7:00 (PM)	123	70	1,325	1.27	12.3	11.5	1984.79	1984.79
7:00-8:00 (PM)	259	79	1,584	1.26	10.9	11.5	1984.29	1984.29
8:00-9:00 (PM)	223	86	1,807	1.27	11.5	11.5	1983.88	1983.88
9:00-10:00 (PM)	161	89	1,968	1.26	12.3	11.5	1983.64	1983.64
10:00-11:00 (PM)	94	90	2,061	1.25	14.3	11.6	1983.63	1983.63
11:00 PM -12:00 AM	31	87	2,092	1.23	11.8	11.7	1983.75	1983.75

DATE:- **17 April 2023** २०८० वैशाख ०४ | **Monday** | **12:00 AM**

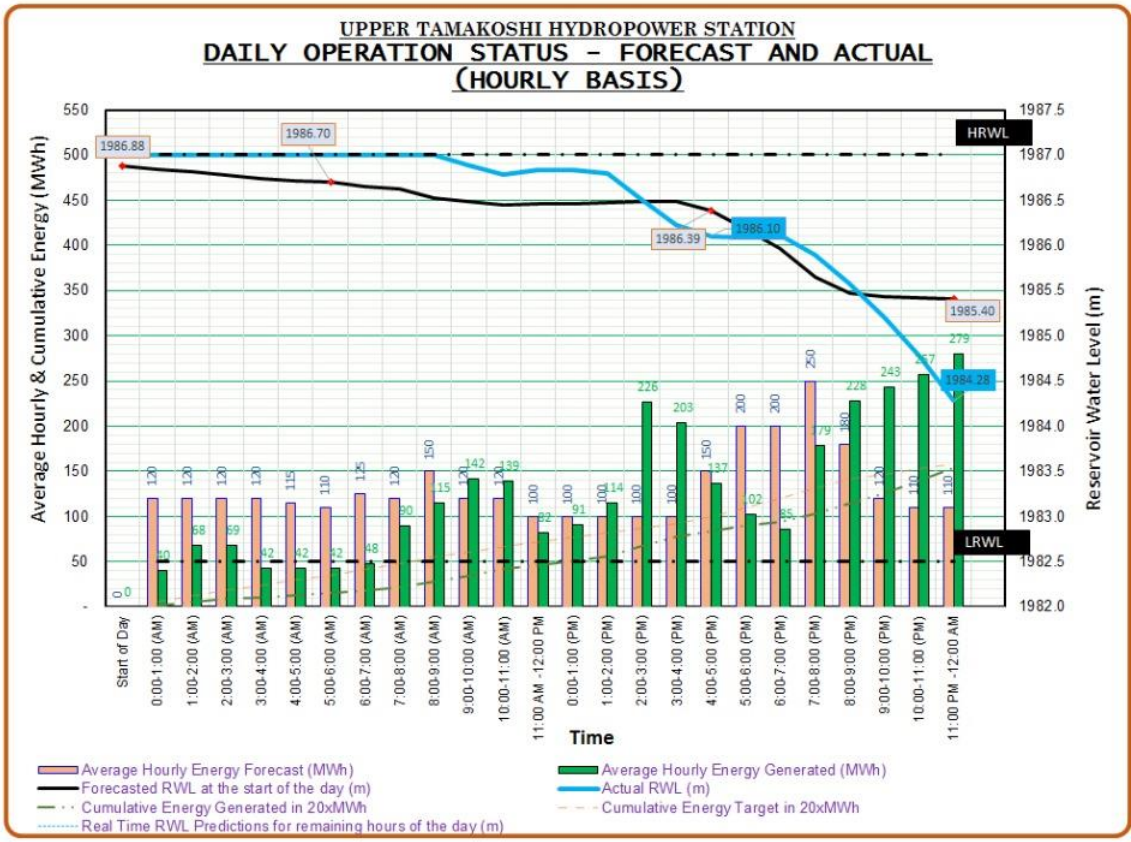


DAILY TOTAL: Target Energy = 2,400 MWh, Energy (Actual+Foreseen) = 2,092 MWh Foreseen River Daily Inflow = 11.66 m3/s

As of now today: Target Energy = 2,400 MWh, Generated Energy = 2,092 MWh [Diff.= -308 MWh] Actual River Inflow (Mean) = 11.66 m3/s

Hours	Actual			D/S Release	Hourly Ave. Inflow	Cum. Ave. Inflow	RWL (m)	Actual + Foreseen RWL
	Ave. Ener. (MWh)							
Start of Day	Hrly	Ave.	Cum.	m3/s	m3/s	m3/s	1987.00	1987.00
0:00-1:00 (AM)	40	40	40	9.41	15.2	15.2	1987.00	1987.00
1:00-2:00 (AM)	68	54	108	9.63	19.4	17.3	1987.00	1987.00
2:00-3:00 (AM)	69	59	176	6.92	16.8	17.2	1987.00	1987.00
3:00-4:00 (AM)	42	55	219	6.24	12.4	16.0	1987.00	1987.00
4:00-5:00 (AM)	42	52	261	7.80	13.9	15.5	1987.00	1987.00
5:00-6:00 (AM)	42	50	303	8.33	14.4	15.4	1987.00	1987.00
6:00-7:00 (AM)	48	50	351	8.44	15.4	15.4	1987.00	1987.00
7:00-8:00 (AM)	90	55	441	8.80	21.8	16.2	1987.00	1987.00
8:00-9:00 (AM)	115	62	556	4.86	21.5	16.8	1987.00	1987.00
9:00-10:00 (AM)	142	70	698	2.81	15.2	16.6	1986.88	1986.88
10:00-11:00 (AM)	139	76	837	1.78	15.2	16.5	1986.78	1986.78
11:00 AM -12:00 PM	82	77	919	1.57	17.4	16.6	1986.84	1986.84
0:00-1:00 (PM)	91	78	1,010	1.65	14.8	16.4	1986.84	1986.84
1:00-2:00 (PM)	114	80	1,124	1.50	15.4	16.4	1986.80	1986.80
2:00-3:00 (PM)	226	90	1,351	1.49	14.1	16.2	1986.50	1986.50
3:00-4:00 (PM)	203	97	1,554	1.45	12.2	16.0	1986.22	1986.22
4:00-5:00 (PM)	137	99	1,691	1.42	13.2	15.8	1986.10	1986.10
5:00-6:00 (PM)	102	100	1,793	1.40	14.8	15.7	1986.08	1986.08
6:00-7:00 (PM)	85	99	1,878	1.39	15.7	15.7	1986.11	1986.11
7:00-8:00 (PM)	179	103	2,057	1.38	12.7	15.6	1985.89	1985.89
8:00-9:00 (PM)	228	109	2,285	1.37	14.1	15.5	1985.58	1985.58
9:00-10:00 (PM)	243	115	2,528	1.37	13.3	15.4	1985.20	1985.20
10:00-11:00 (PM)	257	121	2,784	1.34	14.1	15.4	1984.78	1984.78
11:00 PM -12:00 AM	279	128	3,064	1.34	13.9	15.3	1984.28	1984.28

DATE:- **18 May 2023** २०८० जेठ ०४ | **Thursday** | **12:00 AM**



DAILY TOTAL: Target Energy = 3,160 MWh, Energy (Actual+Foreseen) = 3,064 MWh Foreseen River Daily Inflow = 15.3 m3/s

As of now today: Target Energy = 3,160 MWh, Generated Energy = 3,064 MWh [Diff.= -96 MWh] Actual River Inflow (Mean) = 15.3 m3/s

Disputes, Claims and Variations

- In Civil Contract the Contractor has claim on:
  - Initial delays,
  - Design change,
  - Earth quake,
  - Border Embargo,
  - Covid 19 Pandamic
- In Civil Contract the Employer has claims on:
  - Delays on vertical shaft
  - Delays on power house
- In HM Contract the Employer has claims on delays, correction on quality, finally with termination of Contract.

Project Set Backs

- **RCOD : July 2016**
- **COD : September 2021**
- **Delay Durations : 5+ years**

- **Major Reasons of delay and cost overrun**
  - **Design change in headrace tunnel**
  - **2072 earthquake and consequent border embargo**
  - **Weak performance from HM contractor**
  - **Covid 19 Pandemic**

RCOD and Power Purchase Agreement (PPA)

RCOD **: July 2016**

COD **: September 2021**

Per Unit Energy Rate In COD Year : NPR 3.63 (Wet Season)
& NPR 6.96 (Dry Season)

Per Unit Rate 9th Year after COD : NPR 4.74 (Wet Season)
& NPR 9.08 (Dry Season)

(Until end of Contract)

Project Cost at a Glance

Initial Project Estimate : **USD 441 Million**

: NPR 35.29 Billion (Equivalent)

: (Average exchange rate 1 USD= NPR 80)

Interest (IDC) : ~ 14 Billion

Final Cost : ~ NPR 54 Billion

Interest (IDC) : ~ NPR 34 Billion

: (Average exchange rate 1 USD~ NPR 103)

Additional cost for ForEx : ~8 Billion NRs

Additional cost for price escalation: ~5 Billion NRs

Additional cost for Design & EoT: ~5 Billion NRs

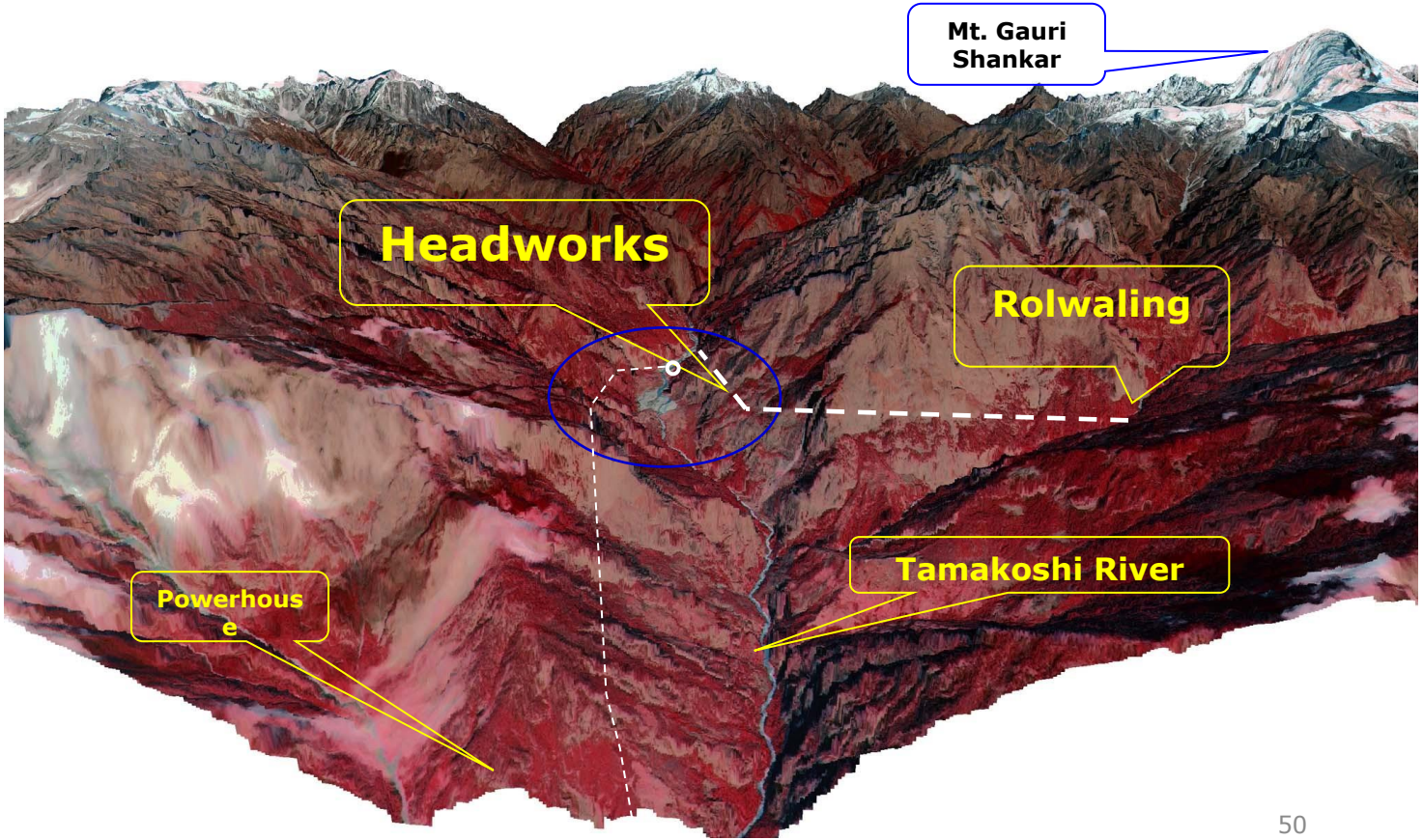
Project Cost Comparison

Project Cost (Million Rs.)	Base Cost	IDC	Total
Original Cost	**35,410**	**13,917**	**49,327**
Final Cost	**53,821**	**34,821**	**88,642**
Increased Amount	**18,411**	**20,604**	**40,015**
% Increase	**52%**	**149%**	**82%**

Rays of Hopes

- Increase of Equity by 100% by means of 1:1 Right share will minimize expenses on interest.
- Debt Equity ratio will get improve from 88:12 to 76:24
- No additional debt finance requires for Rolwaling HEP
- Construction of Rolwaling Diversion Scheme will enhance profitability and rescue the entire project financially.

3D VIEW OF PROJECT AREA



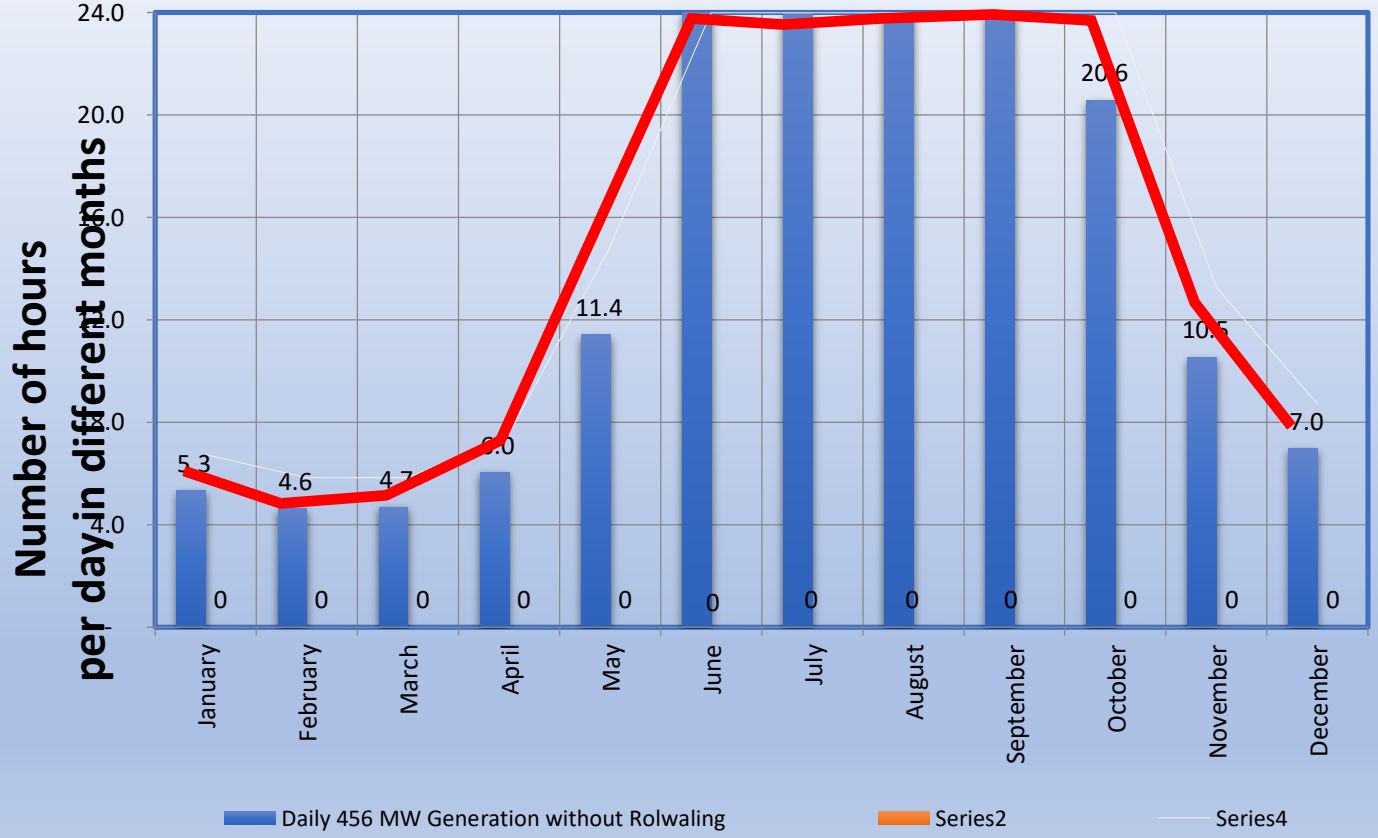
Salient Feature of Rolwaling Scheme (RKHEP)

• Project Type	:	Run-of-River including Diversion
• Catchment Area	:	277 Sq. km
• Installed Capacity	:	20.2 MW
• Annual Energy	:	**98 GWh** Stand Alone and **221 GWh** from Diversion Scheme
• Design Discharge	:	13.4 m^3/s
• Gross Head	:	200 m
• Headrace Tunnel	:	6.35 km
• Penstock	:	255 m
• Power House	:	Underground, 2 Units of Pelton
• Tailrace Tunnel	:	780 m
• Transmission Line	:	33 kV double circuit, 8.5 km long
• Project Cost	:	NPR 8.3 Billion
• Construction Period	:	4.5 years

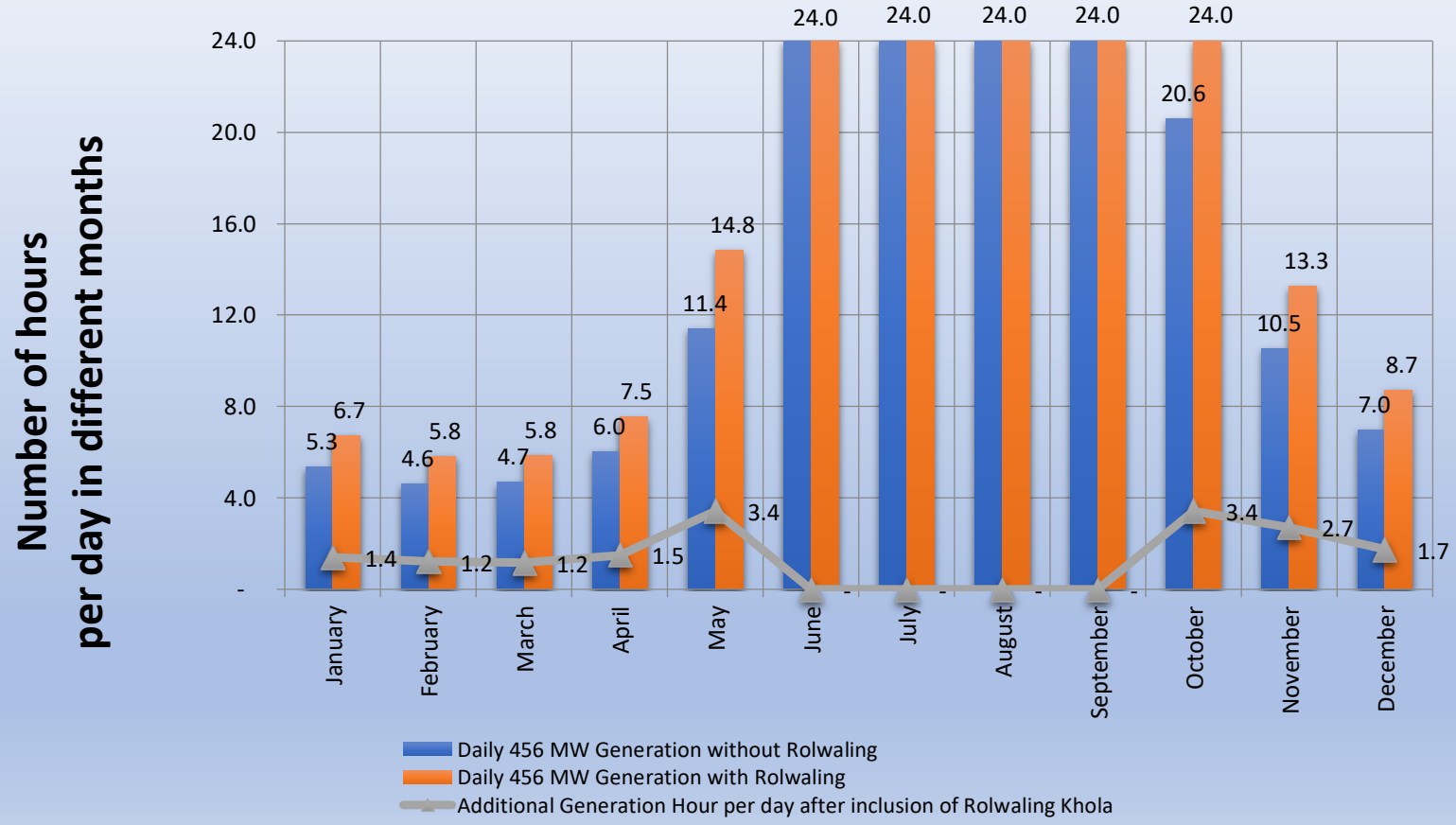
Importance of RKHEP

- Energy of Rolwaling Project
  - Standalone Rolwaling Khola HEP =98 GWhrs of annual energy and
  - Rolwaling Khola Diversion = 221 GWhrs of annual energy addition to UTKHEP
- More importantly, Out of annual 221 GWhrs of total energy contributed by Rolwaling Khola Diversion, **142 GWhrs** is contributed during the dry season when generation from UTKHEP is at its lowest level.
- Daily additional generation hours contributed by RKHEP to UTKHPL is given in the chart below.
- Expected Revenue from Diversion only = ~ NRs 1.5 Billion
- Overall Revenue will increase by more than NRs 2 Billions

DAILY GENERATION HOURS WITH FULL CAPACITY OF 456 MW



DAILY GENERATION HOURS
WITH FULL CAPACITY OF 456 MW



Concluding Remarks

- Successful commissioning of UTK gave message that Nepal is capable to build mega hydroelectric projects with domestic finance.
- Domestic finance on hydroelectricity is enhancing affordable energy and ultimately Nepal Electricity Authority is getting outstanding financial benefit without tariff hike.
- Debt financers (Domestic financing institutions) are also getting reasonable returns
- Need special attentions to the shareholder for their benefits and for sustainably in the future projects like Upper Arun.

Thank you