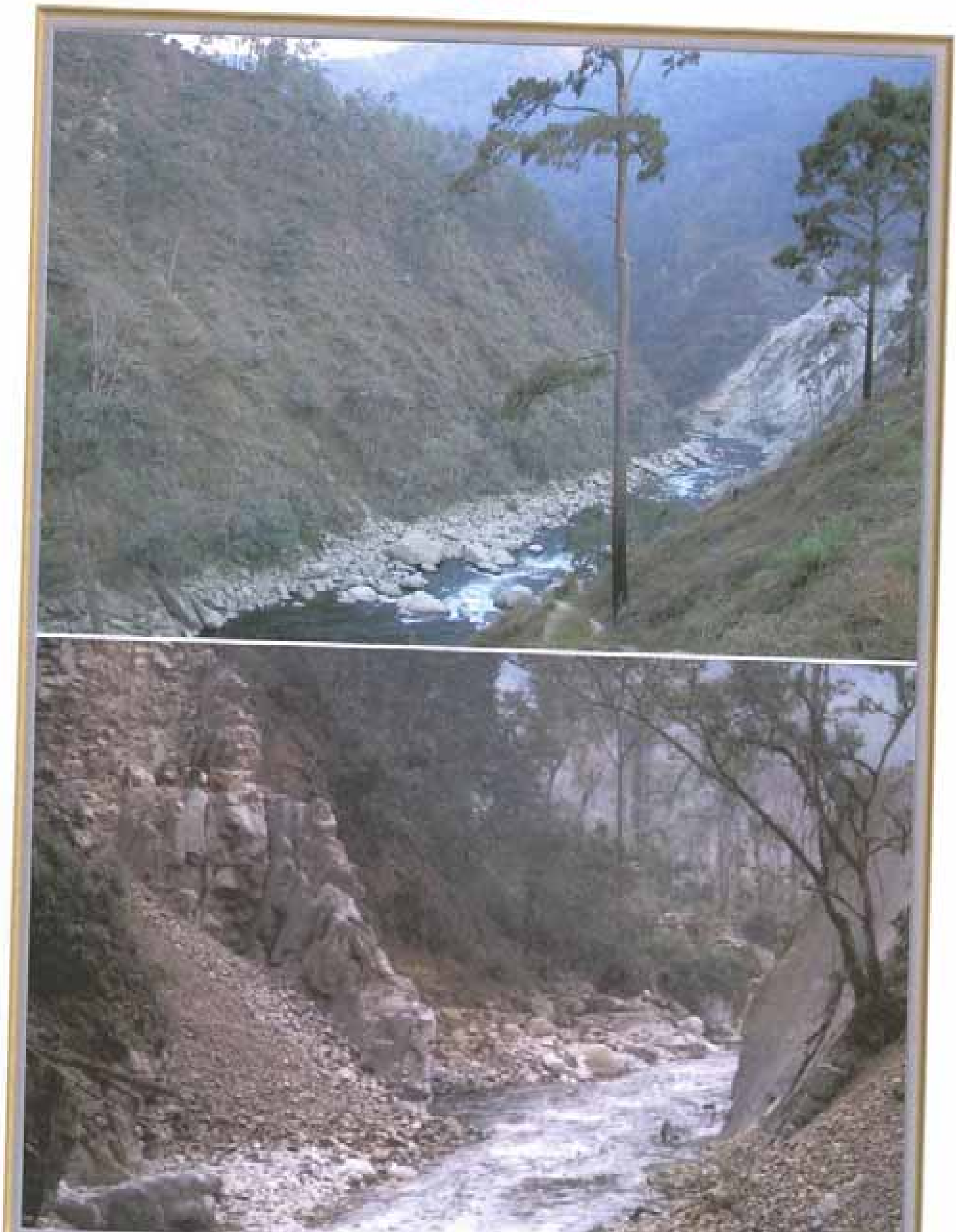
Designing of Fish Pass Facilities for Bichom and Tenga Dam of Kameng Hydroelectric Project, Arunachal Pradesh

Sponsored by
North Eastern Electric Power Corporation Limited
2005



Central Inland Fisheries Research Institute
(Indian Council of Agricultural Research Institute)
Barrackpore, Kolkata - 700120

Designing of Fish Pass Facilities for Bichom and Tenga Dam of Kameng Hydroelectric Project, Arunachal Pradesh

PROJECT REPORT

Prepared under a Consultancy service of Central Inland Fisheries Research Institute for North Eastern Electric Power Corporation Limited

2005

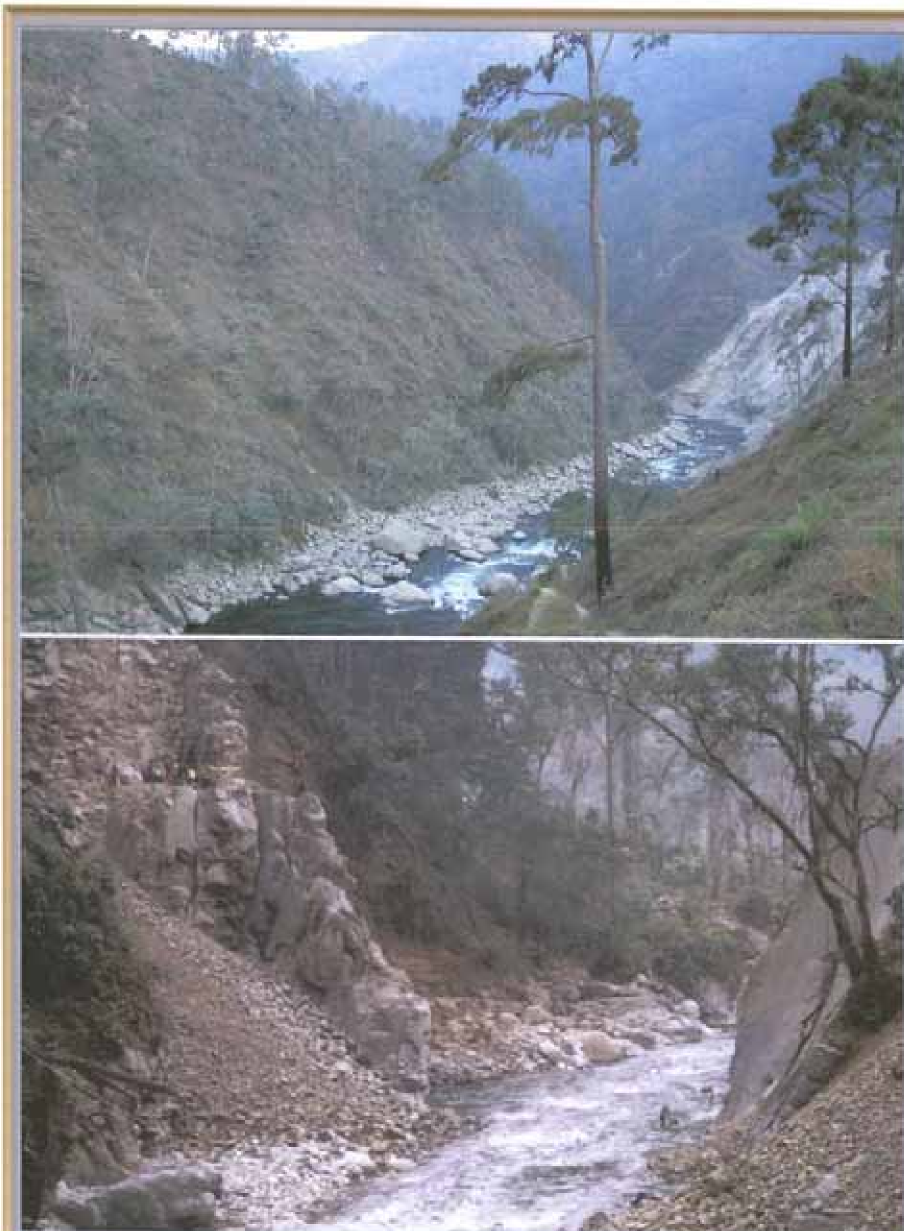
Central Inland Fisheries Research Institute

(Indian Council of Agricultural Research)

Barrackpore, Kolkata - 700120, West Bengal,

Designing of Fish Pass Facilities for Bichom and Tenga Dam of Kameng Hydroelectric Project, Arunachal Pradesh

Sponsored by
North Eastern Electric Power Corporation Limited
2005



Central Inland Fisheries Research Institute
(Indian Council of Agricultural Research Institute)
Barrackpore, Kolkata - 700120

Designing of Fish Pass Facilities for Bichom and Tenga Dam of Kameng Hydroelectric Project, Arunachal Pradesh

PROJECT REPORT

Prepared under a Consultancy service of Central Inland Fisheries Research Institute for North Eastern Electric Power Corporation Limited

2005

Central Inland Fisheries Research Institute
(Indian Council of Agricultural Research)
Barrackpore, Kolkata - 700120, West Bengal,

नॉर्थ ईस्टर्न इलेक्ट्रिक पावर कॉर्पोरेशन लिमिटेड
(भारत सरकार का उद्यम)
NORTH EASTERN ELECTRIC POWER CORPORATION LTD.
(A GOVT. OF INDIA ENTERPRISE)
ISO 9001 - 2000

15, NBCC TOWER, UG Floor,
Bhikaji Cama Place,
New Delhi-110066
Phone : EPABX 26194784, 26164310, 26164329
Fax : (011) 26188213
E-mail : neepco@nda.vsnl.net.in

No. NEEPCO/ND/SCOPE/T-05/2005/ 2566 Dated :16.9.2005

To

M/s SMEC International Pty. Ltd.,
A-1, 1st Floor, Chirag Enclave,
New Delhi – 110048.

(Attn: Mr. D. Kanelly)

Subject : **Designing of Fish Pass Facility for Bichom & Tenga Dam of Kameng H.E. Project (600 MW), Arunachal Pradesh.**

Sir,

Please find enclosed herewith a report on "Designing of Fish Pass Facilities" for Bichom & Tenga Dam of Kameng H.E. Project, Arunachal Pradesh prepared by a Central Inland Fisheries Research Institute, Kolkata.

You are requested to please study the report and give your comments if any.

Thanking you,

Encl :- A/A

SMEC DELHI	
Date:	S. No:
File No:	
Distribution	
RM	Corp.
Fin.	R&B
W&E	Power
PFI	Others

Yours faithfully,

16/9

(H.K. Das)
Dy. General Manager (D & E)
NEEPCO, New Delhi.

Memo No. NEEPCO/ND/SCOPE/T-05/2005/ Dated :16.9.2005
Copy to :

1. The General Manager (C)D&E, NEEPCO – for kind information .

SMEC Kameng Project Incoming Documents	
Date: 17-9-05	S. No: 162
File: 002	
Mode: By Courier	
Distribution	
	Dagaen

DK 20/9/05

Dy. General Manager (D & E)
NEEPCO, New Delhi.

Contents

SECTION - B

DESIGN OF FISH PASS FACILITIES FOR THE DAMS OF KAMENG HYDRO ELECTRIC PROJECT, ARUNACHAL PRADESH

Terms of reference between CIFRI and NEEPCO

The North-Eastern Electric Power Corporation, Shillong is involved in executing a power project in the state of Arunachal Pradesh. The hydel project is to be located on river Tenga and Bichom. As a part of bio-diversity conservation requirement, resultant to this power project, the NEEPCO approached the Central Inland Fisheries Research Institute, Barrackpore for designing a fish pass to facilitate the movement of migratory fishes up stream across the dams, which are proposed under the project. Accordingly a Memorandum of Understanding (MoU) was executed on 15.10.2004 between NEEPCO and CIFRI with the following objectives.

1. The CIFRI on consultancy basis, to provide a design of fish pass for Bichom and Tenga dams to be constructed under Kameng Hydro-electric Power Project.

2. The design to be developed after the necessary field data of the required parameters are generated by CIFRI and NEEPCO to make available to CIFRI the required river hydraulics and other engineering data, in order to make an effective design.

3. The proposed parameters and information generated are tabulated below.

Parameters to be studied	Agency responsible
Limnological studies	CIFRI
Biocommunity structure and diversity	CIFRI
Fish faunistic resource	CIFRI
Fish behavioural studies	CIFRI
Hydraulics of the rivers	NEEPCO
Draft design of the fish passes	CIFRI
Final design of the fish passes	CIFRI

4. The CIFRI will be paid mutually acceptable consultancy fee for the consultancy services.

5. The mode of payment will conform to the pattern, wherein NEEPCO shall pay 50% of the total consultancy cost at the time of commencement of the project - 25% after submission of the draft report and the balance 25% after the submission of the final report and the acceptance thereof by NEEPCO.

6. Output from the CIFRI will be confined to submission of engineering design for fish pass on Bichom and Tenga dams based on a study of hydrobiology of the river course and migratory behaviour of indigenous fish fauna.

7. The time frame will be for a period of six months from the date of execution of the MoU. However, if required in the interest of work the period could be increased on mutually accepted terms.

The fish pass designed by the Central Inland Fisheries Research Institute, Barrackpore for Bichom and Tenga diversion dam can be effectively operational provided the following requisites are assured by the NEEPCO

- Minimum flow of 6 cumecs of water should be maintained during the lean period from December to May for maintenance of the fish passage and conservation of aquatic biota downstream.
- Fish pass should be operated round the year. However pass should be mandatorily kept open starting from February to end of October.
- Entrance of the Fish way (water exit) should be well submerged when passage is in running condition.
- Experience shows that actual constructions frequently diverge from the recommendations because of local circumstances. It is often difficult to fully assess the effects of any possible impairment of function. In such case, possibilities for monitoring & structural improvement to the pass should be incorporated in the project as early as the approval procedure stage.
- Monitoring is essential to prove explicitly that the fish pass entrance can be found and the pass is negotiated by fish.
- Catching is normally prohibited in fish pass. If research necessitates the capture of fish from a fish pass an exemption permit should be given. Usually management of monitoring should be entrusted to a fisheries expert.
- Pool passes require high maintenance, as there is risk of orifices being obstructed by debris. Worldwide experiences show many pool passes are not functional because orifice are clogged by debris. Pool passes therefore require regular maintenance and cleaning, at least at weekly interval during most operational period.
- It is essential to develop facilities for controlled breeding and seed production of snow trout or mahseer with hatcheries and rearing facilities to be developed at dam site.
- Breeding season should be declared as closed season when all fishing activities be banned.
- Conserve breeding ground of commercial fishes by declaring them as sanctuaries.
- Strictly enforce the ban on destructive fishing methods such as dynamiting and poisoning.

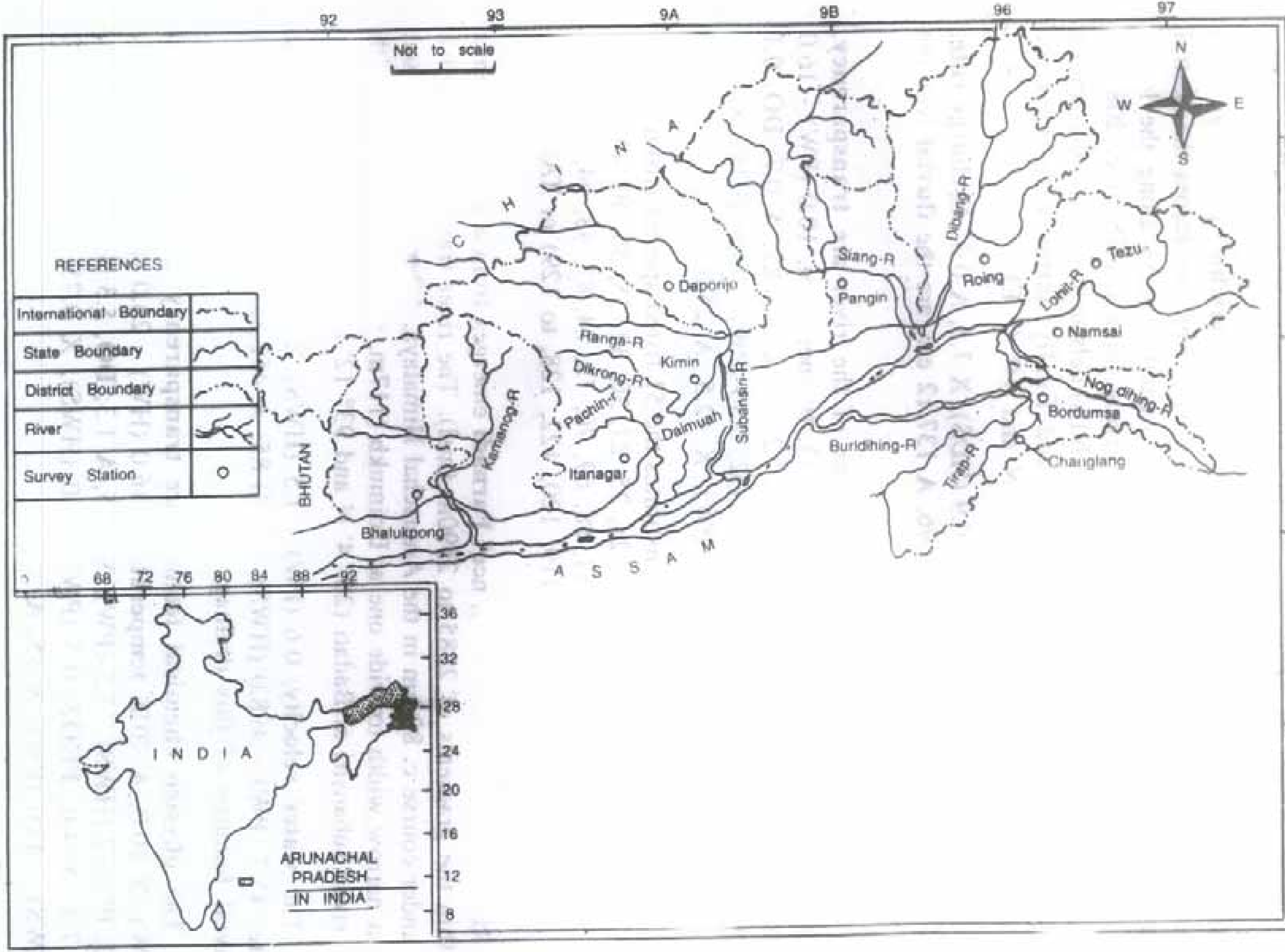


Fig. 1. Map of Arunachal Pradesh showing drainage system with respective survey station & confluences with R-Brahmaputra in Assam

SAMPLING STATIONS (•) IN RIVER BICHOM AND TENGA FOR FISHERY ECOLOGY AND ENGINEERING INVESTIGATIONS

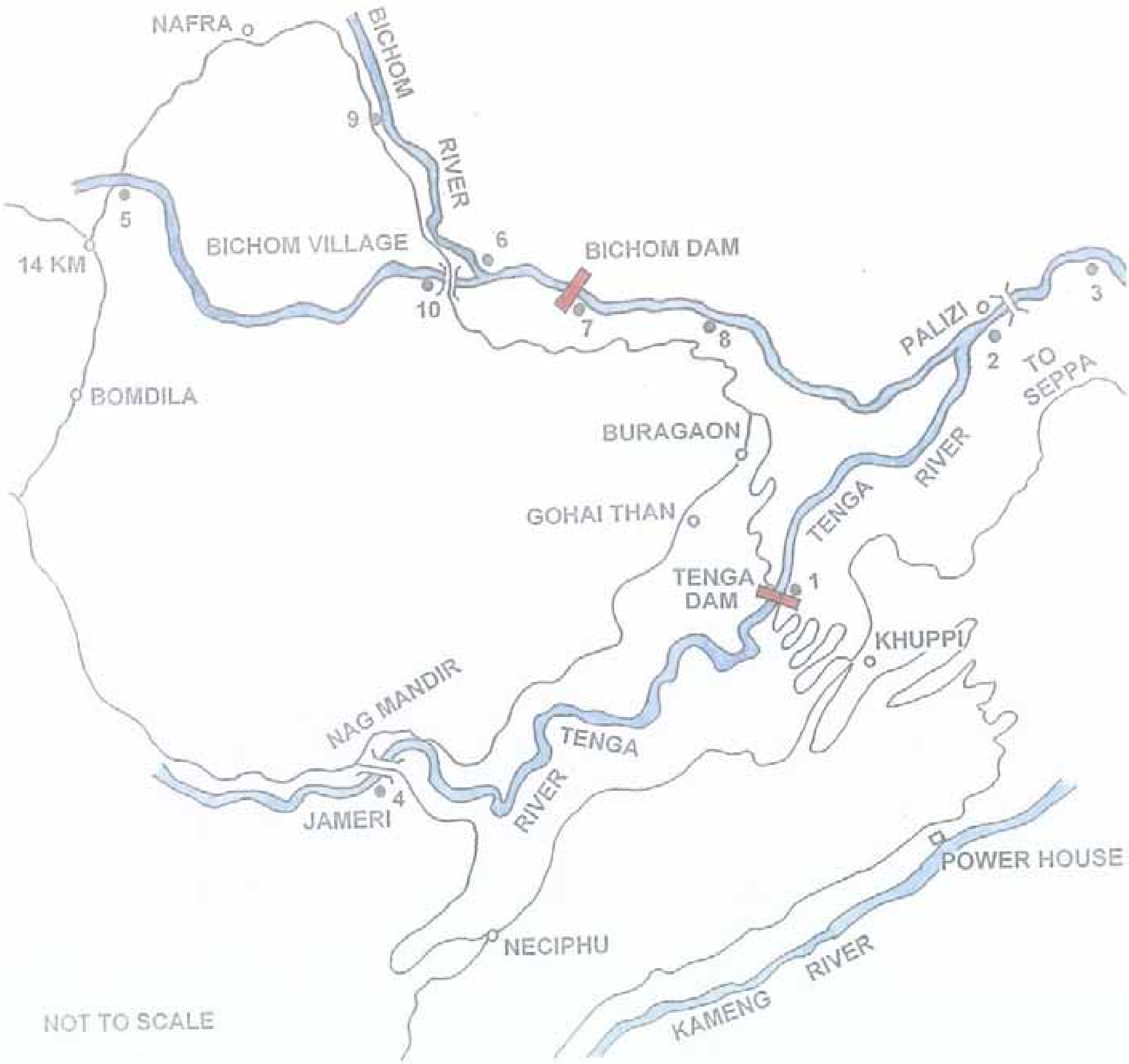


Fig. 2

CIFRI has prepared this report in two sections, the section A deals with the detail of fish ecology and biodiversity in the study site and section B gives the details about design based on the behaviour and breeding biology.

Detailed Consultancy Report on Fish Passes prepared are given –

SECTION A

1. BACKGROUND

1.1 River resource of Arunachal Pradesh

Arunachal Pradesh, located in the North-Eastern region of the country, is rich in riverine resources and contributes about 455 billion m^3 of water discharge to the Brahmaputra river system (Fig.1). A number of development projects are under execution or in the pipeline utilizing the mighty river resources through obstructions. The major river basins having specific geo-ecological characteristics in the state are Kameng, Subansiri, Siang, Dibang, Lohit-Tellu and Tirap.

The Kameng river basin totaling an area of 128317 km^2 and contributing 15.32% of the river basin area of Arunachal Pradesh includes three sub-basins : Bichom of 5996 km^2, upper Bichom of 3856 km^2 and Pakke covering about 2980 km^2 of the Himalayan terraces. Located at the down stream of Tewang Chu Valley the Kameng basin receives drainage from Tewang Chu catchments of 1539 km^2 covering a considerable part of the Greater Himalayan peaks of about 7000 m in height and a portion of the Lesser Himalaya which receives heavy rainfall during monsoon. The Greater Himalayas in the north receives snow fall at the high peaks at altitude of 2000 m, as a result the rivers draining from Greater Himalayas are snow fed and those from Lesser Himalayas receive heavy precipitation as rains.

Among different rivers in the state the Kameng river system, is the largest and turbulent. The river Bichom originating from the glacier range of Greater Himalayas is prominent of all the tributaries contributing to the Kameng river system. This river receives Tenga, a sub-tributary before it confluences with main Kameng river. The river Kameng after receiving Bichom flows downstream and is known as 'Bhorali' or 'Jai Bhorali' draining the foothills till confluences with the river Brahrmaputra in the plains of Assam.

1.2 Hydel Potential

Availability of significant water discharges and perenniality of the rivers being fed by snow melts from glaciers at high altitude and heavy precipitation in the middle Himalayan range is suitable to be explored for power generation. Accordingly the Kameng power project has been planned with the objective to utilize the potentiality of the Bichom river and its major sub-tributary Tenga in the Kameng river basin. This is responsible to provide adequate power demands of the region. The scheme involves construction of diversion dams across Bichom and Tenga rivers, interlinking the dams with a connecting tunnel of 8.75 km length and finally a 5.75 km long power tunnel leading to power house for power generation.

1.3 Project brief

The Kameng Hydro-electric Power Project has been planned as a run of the river development processes utilizing the flows of Bichom and Tenga rivers. The project consists of two cross dams on Bichom and Tenga rivers, a linking tunnel connecting these dams and finally a power tunnel taking off from Tenga to a power house on the right bank of Kameng river at Kimi. The diversion dam at Bichom with a FRL of +770 m and an MDDL of 762 m would provide a live storage capacity of 9.15 Mcum while Tenga dam would have a storage capacity of 3.4 Mcum between FRL + 770 m and MDDL of 747 m. An average of gross head of 516.5 m would be available for power generation. The power generation capacity of Kameng Hydro-electric Power Project for 600 MW from 4 units of 150 MW capacity each.

The project would function as base lead station during the period of high flood i.e, from May to November and thereafter as a peaking station with a minimum load factor of about 25%. The load factor during the lean period will average to about 30%. The scheme would provide valuable peaking capacity to the North-Eastern / Eastern Regional Grids. The surplus power will be absorbed by the Eastern Regional Grid which is predominantly thermal dependent.

1.4 Environmental issues

Construction of dams that alters the river hydrography in terms of flow pattern, water discharge, flash floods, episodic floods, year-round impoundment of the reservoir and the overall nutrient balance of dissolved inorganic / organic and particulate matter in the runoff will have consequential environmental impact of several dimensions. The major monitorable issues well worth reckoning include evaluation of current biodiversity and environmental complexity typical to the region and their short term and long term changes over space and time. Tracking these issues may prove to be indispensable to provide a handle for formulating management schemes that may serve as a means to stabilizing and improving the state of rivers after the man-made interference.

2. Sampling strategies

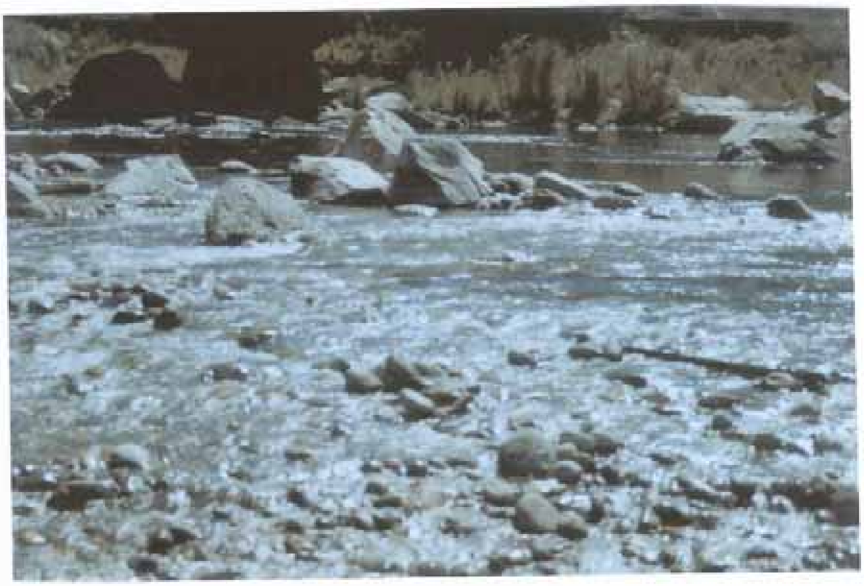
2.1 Ecology of the study area

For developing a design for fish movement across the proposed dam structure, the required ecological information / data was generated for the proposed river.

2.2 Sampling sites and periodicity

For the purpose of designing of two fish passes – one for Bichom dam on river Bichom and another for Tenga dam on the Tenga river, altogether ten sampling stations (Fig. 2), including three covering about 10 km up and 10 km down stream of Tenga dam,

River Kameng bed at Potamon zone (153 m MSL)

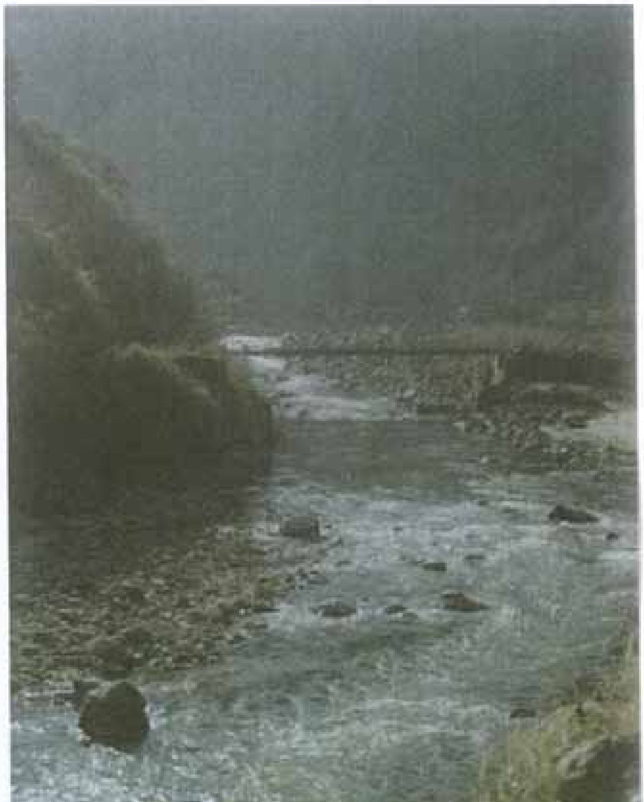


River Tenga at mid zone (755 m MSL)

River Tenga at torrential zone (1538 m MSL)

PLATE 1

River Digien and Bichom confluence



Upstream view of river Digien (15 km)

PLATE 2

Upstream view of river Bichom

Confluence of Digien and Bichom river

PLATE 3

View of Bichom Dam site

View of Tenga Dam site

PLATE 4

View of Tenga dam site

Upstream view of Tenga Dam (15 km)

PLATE 5

four sites spread over 20 km on Bichom river course and Bichom dam site, two on river Degien and one on river Kameng were taken for intensive investigation (Plates:1-5). The sampling was carried out thrice in a year corresponding to premonsoon, monsoon and pos-monsoon seasons with due consideration to the changing temperature regime of an extreme winter and a mild summer.

2.3 Parameters studied

Limnology of rivers / streams:

- Water and sediment qualities
- Stream odour
- Bio-community structure and diversity
- Plankton population density, diversity and spatio-temporal distribution
- Macrobenthos population density, diversity and spatio-temporal distribution
- Periphyton population density, diversity and spatio-temporal distribution

Fish faunal resources:

- Species spectrum
- Catch composition
- Biology of commercially important species
- Identification of breeding grounds and their possible alternatives in the post impoundment period

Fish behaviour:

- Swimming ability / speed
- Thermal tolerance

Hydraulics of rivers / streams

- River bed contour
- Bed topography
- Gradient
- Deep and shallow pools
- Water surface profile
- Area of turbulence and eddies
- Fish attractive flow

3. Ecology of the region

3.1 *Water quality- Physical*

Depth

The depth of hill stream was highly fluctuating in the Bichom and Tenga rivers. The level of water was minimum in post-winter (0.6-1.2 m) and maxium in monsoon season (3.6-6.5 m) depending on the volume of river run off from the catchment area.

Transparency

The stream water was transparent in most part of the year with the only exception in monsoon months of July- Sept (0.6-0.9 cm). The Minimum transparency was recorded in the Degien sub-tributary (0.4 cm) of river Bichom during the monsoon floods. In both the river systems the water transparency improved from October onwards.

Water temperature

The surface water temperature ranged from 7.0 – 20.0 °C in Tenga river and the minimum temperature was recorded at an altitude of 1538 m during winter, while maximum at 710 m near Palizi during summer. The water temperature fluctuated between 7.0 – 9.5 °C during winter and 11.4 – 20.8 °C in summer season. In Bichom the water temperature was slightly more with lower altitude of the studied river terrain. The ambient temperature of river Kameng fluctuated in the range of 18.5 – 25.6 °C in the foot hills at Bhalukpong.

Table 1. Geographical location of study site and water quality parameters

Parameters	Tenga river				Bichom river			Kameng river
	Tenga dam site	Upstream of Janseri	Upstream of Tenga town	Down stream of Palizi	Bichom dam site	Upstream of Bichom river	Upstream of Degein river	Bhalukpong
Location Lat.N Long. E	27^0 13.469 $92^039.770$	27^0 10.134 $92^039.240$	27^0 11.814 $92^039.546$	-- --	27^0 17.973 $92^037.559$	27^0 17.971 $92^037.480$	27^0 19.748 $92^026.480$	27^0 09.806 $92^033.578$
Altitude(m MSL)	755	1142	1538	710	714	718	1048	153
Bed characteristics	Rocky / Gravelly	Rocky / Gravelly	Rocky / Gravelly	Rocky / Gravelly	Rocky / Gravelly	Rocky / Gravelly	Rocky / Gravelly	Sandy
Physico-chemical characteristics of water a) Physical								
Temp ^{0}C	9.5 -20.2	8.2 -18.6	7.0 – 11.4	12.5 – 20.8	8.5 – 17.6	8.5 – 17.8	7.9 – 17.4	18.5 – 25.6
Trans (cm)	1.2-2.3	1.3-2.3	1.4-2.4	1.1-1.9	0.9-1.8	1.2-1.4	0.7-17	0.6-16
b) Chemical								
Dissolved O_2 (mg/l)	7.8-8.4	8.2-10.6	7.0-10.8	7.8-9.8	7.6-9.6	7.8-9.4	8.0-11.2	7.6-9.4
Free CO_2 (mg/l)	2.88-3.68	2.16-2.92	1.80-2.84	2.44-3.92	1.74-2.76	1.84-2.28	2.20-3.82	2.48-3.4
PH	7.5-7.8	7.6-7.8	7.4-7.8	7.5-7.8	7.6-7.8	7.5-7.2	7.6-7.8	8.0-8.3
Total alkalinity(mg/l)	15.8-59.52	14.50-63.24	14.30-65.20	18.60-26.00	11.90-25.20	12.30-25.80	18.20-29.40	26.84-38.00

3.2 *Water quality- Chemical*

pH

The stream water was neutral to alkaline throughout the year ranging from 7.5 – 7.8 in Bichom and Tenga rivers. But in Kameng the pH was always alkaline between 8.0 – 8.3.

Alakalinity

The alkalinity of river water ranged from 15.8 – 65.2 ppm in Tenga and 11.9 – 29.4 ppm in Bichom river. In Kameng river the alkalinity ranged from 26.84 – 38.0 ppm.

Dissolved oxygen

The dissolved oxygen content of surface water fluctuated in the range of 7 – 10.8 ppm in Tenga river, where the maximum value was recorded at an altitude of 1538 m. Likewise, for Bichom the maximum dissolved oxygen was recorded in the Degien river at an altitude of 1048 m.

4. *Biodiversity*

The flora and fauna of hill stream is an assemblage of a mixed and widely varied organisms belonging to the plant and animal kingdom. At the primary level, the microscopic algae through photosynthetic activity add to the biotic production chain. Mosses and macrophytes among plants and small crustaceans, larval forms of insects and mites among animals constitute the secondary producers, while higher forms of animals like fishes, some amphibians, raptiles and mammals constitute the highest of the trophic level. The population structure of the organisms is governed by the stream characteristics. The principal factors are (i) high and variable velocity of streams creating disturbance in colonization of organisms (ii) ice formation during winter which results physiological constraints for the organisms and their poor survival (iii) periodic floods destroying the habitats and (iv) continuous rolling of boulders, stones and gravel etc. and their occasional high deposition due to unwanted floods. The habitat texture of the Bichom and Tenga river systems was observed to be identical and of semi-stable nature with medium size boulders, stones, gravels and coarse sand. At turning points deposition of gravel and coarse sand was frequently observed. The prevailing habitat inclusive of nature of flowing water was conducive for the growth and propagation of the following flora and faunal population.

4.1 Plankton

Density wise, these micro-organisms were not much in number per unit of water volume, but quite diverse in respect of species composition. The Main constituents of this group of plant and animalcules were diatoms like *Navicula, Diatoma, Cymbella, Gomphonema, Amphora, Cocconeis* and *Cyclotella.* The other forms included *Pleurococcus* from green alage, *Vorticella* from protozoa and some rotifers like

Polyartha. The impact of seasonal variations in temperature, turbulence and silt load was conspicuous on the density and diversity of the Planktonic organisms. Post-winter period was most favourable for the proliferation and also diversification of the plankton (Table 2).

Table 2. Diversity and abundance of plankton in Bichom and Tenga rivers

Organisms	Bichom river			Tenga river		
	Pre-monsoon	Monsoon	Post-monsoon	Pre-monsoon	Monsoon	Post-monsoon
Phytoplankton (%)	99.0-99.2	97.2-98.5	99.2-99.7	97.7-98.1	94.8-97.8	97.8-98.5
Chlorophyceae(U /l)	24-32	8-20	22-34	34-52	6-16	16-20
Zygnema sp.	√	√	√	√	√	√
Ulothrix sp.	√	X	√	√	√	√
Spirogyara sp.	√	√	√	√	√	√
Closterium sp.	√	X	√	√	√	√
Scenedesmus sp.	√	√	√	√	X	X
Cosmarium sp.	√	X	√	√	√	√
Microspora sp.	√	√	√	X	X	√
Planktospherium sp.	√	X	√	√	√	√
Pleurococcus sp.	√	√	√	√	√	√
Bacillariophyceae (u / l)	74-155	12-34	52-88	66-148	18-32	44-74
Navicula sp.	√	√	√	√	√	√
Fragilaria sp.	√	X	√	√	√	√
Diatoma sp.	√	√	√	√	√	√
Amphora sp.	√	√	√	√	X	√
Amphiplura sp	√	X	√	√	√	√
Melosira sp.	√	√	√	√	√	√
Cocconeis sp.	√	X	X	√	X	X
Nitzschia sp.	√	√	√	√	√	√
Denticula sp.	X	X	√	X	X	X
Gyrosigma sp.	√	√	√	√	X	√
Synedra sp.	√	√	√	√	√	√
Cyanophyceae(u /l)	8-14	0-4	6-12	8-16	0-6	4-8

Phormidium sp. *Anabaena* sp. *Oscillotoria* sp. *Anacystes* sp.	√ √ √ √	√ X √ X	√ X √ √	√ √ √ √	√ √ √ X	√ √ √ √
Zooplankton (%) **Protozoa(u/l)** *Vorticella sp.*	0.4-0.8 0-6 √	2.1-6.0 0-2 X	0.5-1.2 0-4 √	2.2-3.6 0-6 √	3.5-6.2 0-4 X	1.4-2.8 0-2 √
Rotifera (u/l) *Polyartha* sp.	0-4 √	0-2 X	0-4 √	0-2 √	0-2 X	0-2 √
Density (u / l)	122-196	26-54	88-106	118-202	31-48	76-94

4.2 Benthos

The benthic organisms in hill streams are comparatively larger in size and include naids and larvae of insects, amphopods, turballarians, crabs and loaches. The status of altitudinal locations, flow pattern and stream bed characteristics of Bichom and Tenga rivers were favourable for the growth of a mixed population of organisms like naids of dragon fly, nymphs of May and stone fly, larvae of caddis fly and amphipods(Table 3).

Table 3. Seasonal benthic population in Bichom and Tenga rivers.

Organisms	Bichom river		Tenga river	
	Pre-monsoon	Post monsoon	Pre-monsoon	Post monsoon
Density (No. / m^2)	54 – 67	64 – 72	58 -63	60 – 74
Nymphs of stone fly (Plecoptera) (%)	16 -28	13 -21	18 – 32	17 – 25
Larvae of caddis fly (Trichoptera) (%)	8 – 21	6 – 17	10 – 24	9 – 14
Nymph of Mayfly (Ephemeroptera)(%)				
Amphipods (%)	3 - 14	2 - 9	2 - 8	8 - 15

Limnological sampling at upstream of Bichom Dam

Periphyton growth on bottom substrate of Bichom river.

PLATE 6

Limnological sampling at river Tenga

Periphyton growth on bottom substrate of river Tenga

PLATE 7

Pre-monsoon density of macrobenthic fauna was comparatively more in both the river systems. Among the groups, stone fly nymphs were dominant thoughout the season except monsoon. The monsoon population of macrobenthic fauna was comparatively thin due to high turbulence and rolling effect of the bed stones and gravels. Macrobenthic fauna forms the main food item of the hill stream fish species and the fishes switch over from smaller groups of organisms to larger ones as they grow bigger in size. Most of the hill stream fishes are adapted to bottom feeding habits and prey on the organisms attached on the surface of rocks, stones and boulders. The fishes show fluctuating rates of feeding – lowest during winter, while maximum in spring and early summer. The qualitative and quantitative abundance of the macrobenthic fauna which forms the bulk of the fish food indicates that both Bichom and Tenga are ideal systems for sustenance of hill stream fish populations of high abundance.

4.3 Periphyton

Both Bichom and Tenga rivers were enriched with periphyton community in respect of density and also diversity of species spectrum (Plates 6 & 7). In all 32 genera of algae were recorded with predominant Bacillariophyceae (15 genera) followed by Clorophyeceae (11 genera) and Cyanophyceae (6 genera). The density of periphyton crop ranged from 884 u/cm^2 – 32500 u/cm^2 showing lowest density in monsoon and highest in late winter months. Contribution of Bacillariophyceae fluctuated between 63.5 and 78.8 % of the total population. The predominant genera included *Cymbella, Navicula, Fragilaria, Diatoma and Gomphonema.* *Navicula* contributed maximum in periphytic diatom population in both the rivers. Filamentous algae (Chlorophyceae) formed about 10 -12 % of the periphytic population. Among the organisms *Spirogyra* was dominant which had the maximum population during December – February. The other forms encountered in the samples were *Ulothrix* sp., *Zygnema, Microspora, Cosmarium, Scenedesmus, Uronema, Cylindrocapsa, Closterium and Mougotia.* Cyanophyceae contributed almost parallel to the filamentous algae. The organisms under the group represented five genera and seven species. They included *Oscillatoria, Anabaena, Phormidium, Scytonema, Anacystis.* The Cyanophyceae were at the peak of abundance during March and April in both Bichom and Tenga rivers. Besides the algae, the other organisms associated with periphyton were protozoans (*Centropyxis* sp.), Rotifers (*Lecane* sp.), Crustacean larvae and Nematods.

Table 4. Periphyton diversity and abundance in Bichom and Tenga rivers

Organisms	Bichom river			Tenga river		
	Pre-monsoon	Monsoon	Post-monsoon	Pre-monsoon	Monsoon	Post-monsoon
Chlorophyceae (%)	10.1-11.8	10.0-12.0	10.4-11.8	10.4-11.7	10.6-11.2	10.8-11.4
Ulothrix sp.	√	√	√	√	√	√
Zynema sp.	√	√	√	√	√	√
Microspora sp.	√	√	√	√	√	√
Cosmarium sp.	√	X	√	√	√	√
Scenedesmus sp.	√	X	√	√	X	√
Uronema sp.	√	X	X	X	X	√
Cylindrocapsa sp.	√	√	√	√	√	X
Closterium sp.	√	√	√	X	X	√
Mougotia sp.	X	X	√	√	X	√
Planktosperium sp.	√	X	X	√	√	X
Bacillariophyceae (%)	74.2-78.8	68.2-69.8	70.6-74.9	69.8-74.2	68.2-77.1	69.6-75.8
Cymbella sp.	√	√	√	√	√	√
Navicula sp.	√	√	√	√	√	√
Fragilaria sp.	√	√	√	√	X	√
Diatoma sp.	√	X	X	√	√	√
Nitzschia sp.	√	√	√	√	√	√
Diatomella sp.	√	√	√	√	√	√
Gomphonema sp.	√	X	√	√	X	√
Amphiplura sp.	√	X	X	√	√	√
Synedra sp.	X	X	√	X	X	√
Amphora sp.	√	√	√	X	√	X
Melosira sp.	X	√	√	√	√	X
Cocconeis sp.	√	X	√	√	√	√
Denticula sp.	√	√	√	√	X	√
Gyrosigma sp.	√	X	√	√	√	√
Cyclotella sp.	√	X	X	√	X	X
Cyanophyceae(%)	12.4-15.2	12.8-13.4	14.6-15.5	12.7-13.5	12.4-12.8	11.7-15.1
Oscillatoria sp.	√	√	√	√	√	√
Anabaena sp.	√	√	√	√	√	√
Phormidium sp.	√	√	√	√	√	√
Scytonema sp.	√	X	√	√	X	√
Anacystes sp.	√	X	√	√	√	√
Density (unit/cm^2)	16780-32500	884-2196	10400-24120	12860-28748	1106-1874	12040-24300

4.4 *Fisheries*

The cold water fishes are temperature tolerant at lower levels of thermal scale, a susceptibility of critical significance that plays a crucial role in their dispersal in the uplands. As such the thermal regime limits the very existence of species of fish and other biota greatly affecting the composition of the biocommunity in high altitude hill streams. In all probability, the cold water fishes are endowed with a faculty to withstand temperature nearly up to the freezing point of water. On the basis of temperature tolerance, the cold water fishes are categorized as steno-thermal having narrow range of temperature tolerance and eury-thermal with wide range of thermal tolerance. In Eastern Himalayas the fish species are mostly eurythermal and traverse the hill streams both snow fed and rain fed depending on the biological needs to complete their life cycle. The principal indigenous fish inhabiting Indian hill streams are (a) Loaches (b) snow trouts, Mahseers and minor carps (c) Barils (d) catfishes. These fishes show rheophillic nature of distribution. On the basis of principal fish occurring in the systems the hill streams are divided into different zones. The categorization of the zones is also based on the physico-chemical characteristics. From the top downwards, the zones are (a) head water zones – assembling zone of snowmelt water (b) rapid clear water zone & (c) rapid turbid water zone. Loaches dominate in head water zone, snow trout and Mahseers in rapid clear water and also in rapid turbid water zones. The Bichom and Tenga rivers fall under zones b and c depending on the source of origin and nature of drainage received.

4.4.1 *Species*

Arunachal Pradesh is enriched with diversified species of ichthyofauna. Nath and Dey (2000) have enlisted 131 species of fishes from the state. In Kameng river system the fish fauna belong to 19 families, 14 genera and 73 species (Table 5). Out of 73, the species belonging to Families Cyprinidae (sub-family *Cyprini* and *Rasborini*) and Sisoridae are important in view of their migratory nature and requirement of specific hill stream conditions for breeding and spawning run.

Table 5. Fish fauna of Kameng river system

Family	**Genus**	**Species**
Cyprinidae	*Schizothoraicthys*	*progestus*
	Schizothorax	*richardsonii*
		stoleskae
	Barilius	*barna*
		bendelisis
		bola
		tilea
		varga

	Labeo	*dero*
		pangusia
		dyocheilus
	Acrossocheilus	*hexagonolepis*
	Crossocheilus	*latius latius*
	Tor	*putitora*
		tor
	Garra	*mcciellanii*
		gotyla gotyla
		annandalei
	Aboriecthys	*elongatus*
		kempi
		botia
	Lepidocephalus	*annadalei*
		guntia
		candofurcatus
	Scaphinodon	*aculeatus*
	Salmostoma	*bacila*
	Esomus	*danricus*
	Danio	*aequipinnatus*
		dangila
		rerio
	Badis	*dario*
		rostrata
	Rasbora	*elanga*
		rasbora
	Puntius	*chola*
		sophore
		ticto
	Chagunius	*chagunio*
	Cirrhinus	*mrigala*
		reba

	Aspidoparia	*jaya*
		moraz
Bagridae	*Mystus*	*bleekeri*
		cavasius
		vittatus
Sisoridae	*Bagarius*	*bagarius*
	Glyptothorax	*horai*
		pectonopterus
	Euchiloglanis	*kamengensis*
	Exostoma	*labriatum*
		sulcatus
Claridae	*Clarias*	*batrachus*
Heteropneustidae	*Heteropneustes*	*fossilis*
Siluridae	*Ompok*	*pabo*
		pabda
	Wallago	*attu*
Pangasidae	*Amblyceps*	*mangois*
Olyridae	*Olyra*	*longicauda*
Belonidae	*Xenantodon*	*cancila*
Channidae	*Channa*	*punctatus*
		marulius
Mastacembelidae	*Mastocembelus*	*artmetus*
Ambassidae	*Chanda*	*baculis*
		nama
		ranga
Nandidae	*Nandus*	*nandus*
	Badis	*dario*
		rostrata
Gobidae	*Glossogobius*	*giuris*
Anabantidae	*Anabus*	*testdenius*
Belontiidae	*Colisa*	*faciatus*

Catch of dyocheilus and Tor spp. from foothills of Kameng river .

PLATE 8

Notopteridae	*Notopterus*	*notopterus* *dutalei*
Clupeidae	*Gudusia*	*chapra*

Table 5a: Abstract of fisheries

Family	No. of Genus/Species
Cyprinidae	19/45
Bagridae	1/3
Sisonidae	4/6
Claridae	1/1
Heteropneustidae	1/1
Siluridae	2/3
Olynidae	1/1
Belonidae	1/1
Channidae	½
Mastacembelidae	1/1
Ambasis	1/3
Nandidae	1/1
Food fish species	56
Sport fish species	6
Ornamental	11

During investigation commercial landing of fish could only be observed at Blalakpong in the foot hills of Kameng river system (Plates 8 & 9). The fish landing was maximum during monsoon consisting mixed populations of indigenous carps *like Labeo pangusia, L.dero,Acrossocheilus hexagonolepis, Barilius barna, B.varga, B.bola, Bagarius bagarius,Glyptothorax sp., Badis sp.* and some smaller varieties of cyprinids. In winter the species composition was quite different mainly of *Tor putitora, T. tor, Shizothoracthys progestus, Schizothorax richardsonii, Garra gotyla gotyla,* *Acrossocheilus hexagonolepis, Glyptothorax* sp. The summer landing was rare and of few species and poor compared to the other seasons.

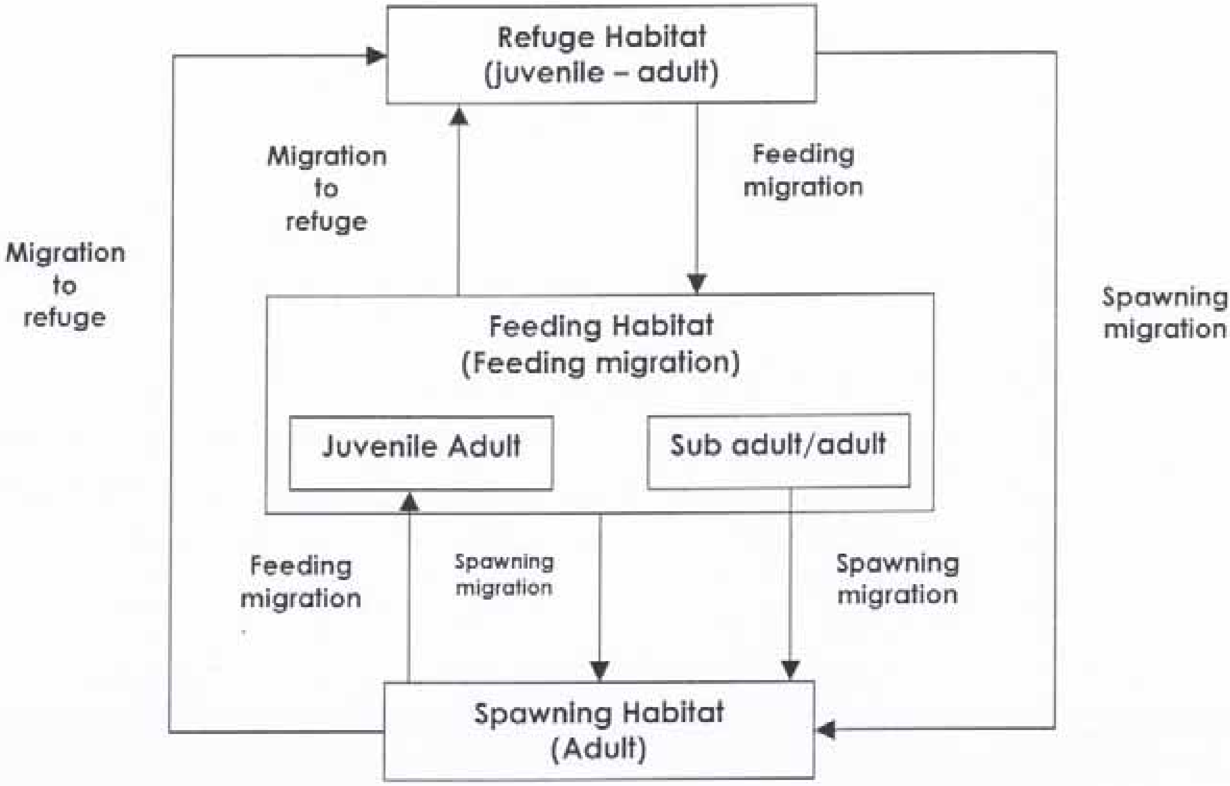
The fish catch from Kameng river at the foot hills was recorded to be quite high both during monsoon and winter seasons. Winter catch was dominated by the descending population of snow trouts and Mahseers. During monsoon the catch comprised of mixed population of indigenous carps and catfishes and a few species of smaller size groups.

4.4.2 *Biology of important migratory fish species*

Fish normally rely on migration to satisfy their requirements with regard to the structure of the biotope during their different life stages. Migrations are undertaken by fish and by the less mobile benthic organisms. Migrations may be either longitudinal in the main channel or lateral between main channel and side waters. There is a need for the interlinking of these different ecosystems to allow the organisms to migrate so as to satisfy their migration and habitat requirements. Longitudinal connectivity of rivers thus has an extremely important role to play with regard to reproductive exchange as well as to the spreading of populations and the recolonization of depopulated stretches of river.

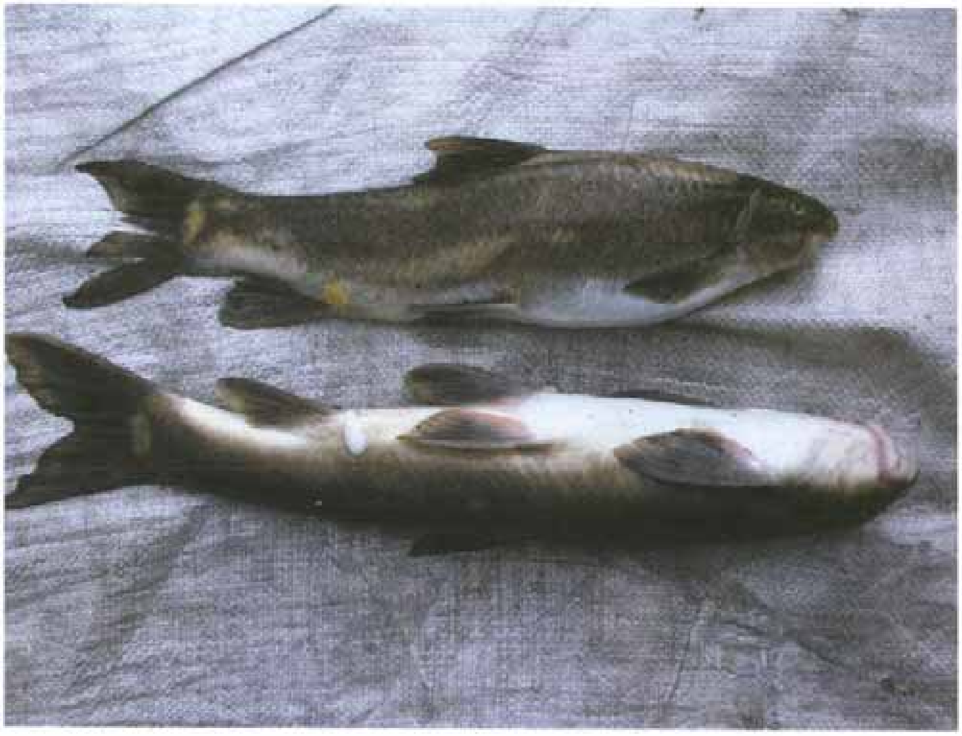
Different habitat requirement

Some fish undertake intra-annual migrations between their feeding and resting habitats or inhabit in the course of their life cycle different parts of the river that offer specific conditions that satisfy the requirements of their different development phases. Hill stream fishes as in the rivers of Arunachal Pradesh generally migrate between three major habitats; wintering feeding habitat and spawning habitat.



Migratory behaviour of riverine fish results from the separation in space and time of optimal habitats used for growth, survival and reproduction during different life history stages. Therefore, in general migration up or down the rivers involves a cyclic alternation between at least two, more often three habitats. The young fish that emerge from the spawning habitats used by their parents either passively or actively move to their first feeding habitats. This trophic migration ranges from few metres to several thousand of kilometers away. Later on, the juveniles move from their first feeding habitat to a survival habitat when unfavourable conditions approach (winter and turbidity). When this cycle of feeding and refuge habitat is over, the fish start reproductive migration to an appropriate spawning habitat. The spawning habitat may also vary from few metres to several thousand of kilometers. Broadly, there are three principal categories of migrations.

a) Reproductive (spawning) migration
b) Feeding (trophic) migration
c) Refuge migration



Mature males and females of *S.richardsonii* at Tenga dam site

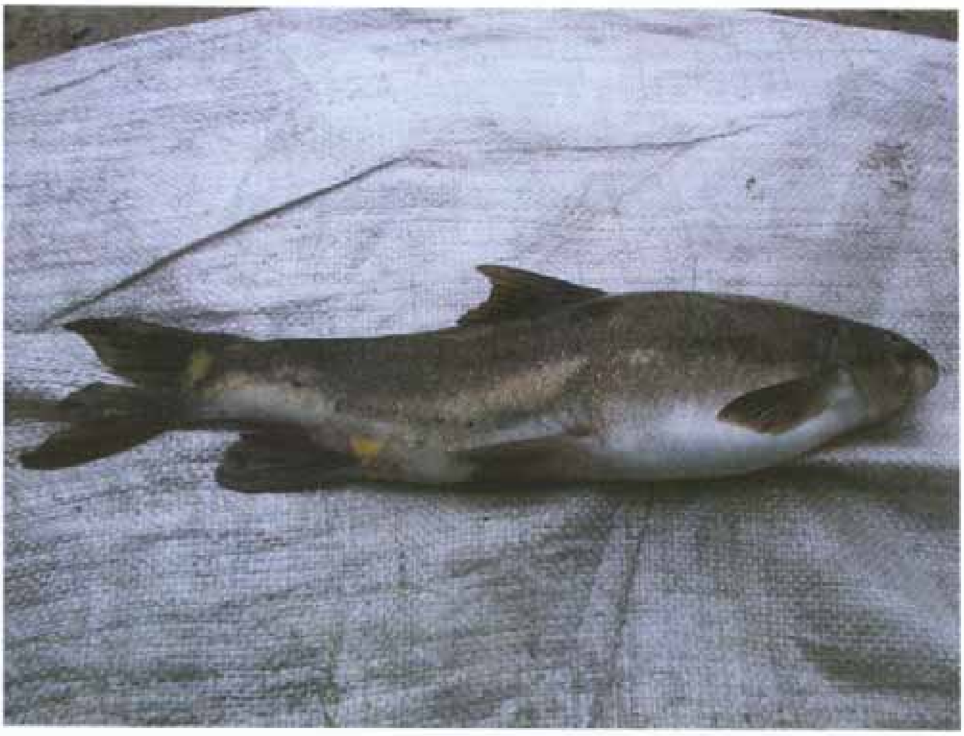
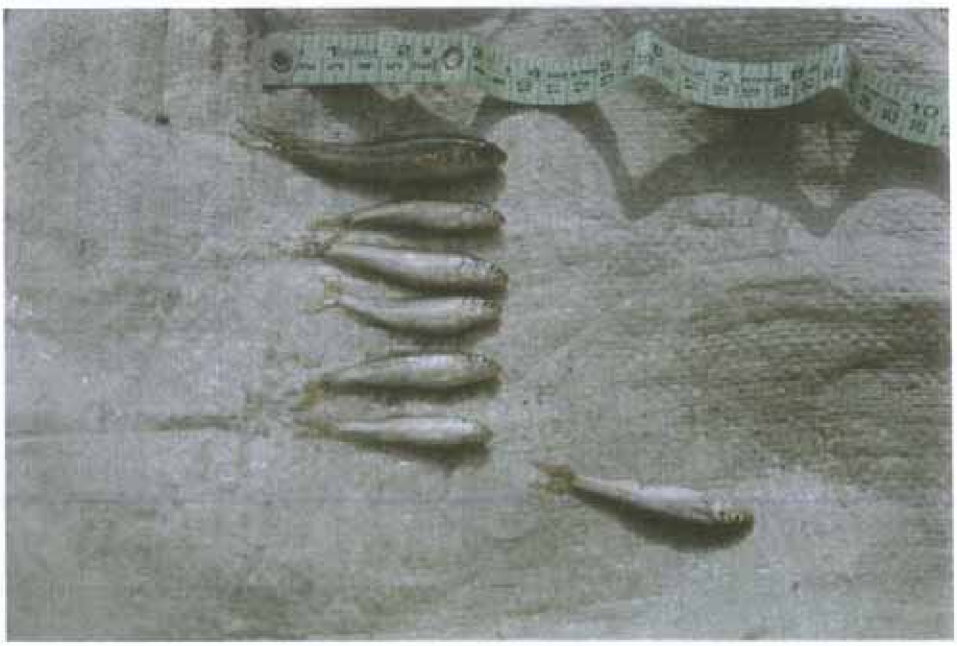


PLATE 10

Mature female of *S.richardsonii* at Bichom dam site

Spawn of *S. richardsonii* from Digien river



Fingerlings of *S. richardsonii* from Digien river

PLATE 13

Fingerlings of *S.richardsonii* from river Bichom

Fingerlings of *Tor spp.* from river Digien

Fingerlings of *G.gotyla gotyla* river Digien

PLATE 14

Schizothoraicthys progastus

The species migrates in the higher reaches of the hill stream for breeding and traverses down after the activity is over. The temperature range for breeding and rearing of the species falls between 10 – 20 °C. The species climbs the hilly terrain of Kameng river from the foot hills and reaches up stream in Bichom and Tenga. Their migration starts from February onwards with gradual dropping of ambient temperature. Morphometrically, the species is sub-cylindrical and body depth is 3.8 – 4.9 times of standard length and attains a maximum length of 50 cm. Their sticky eggs are laid on the pebbles under 20 -25 cm depth of water. The ideal water quality parameters for their breeding range from 15 – 20 ppm turbidity, 7.8 – 8.5 pH, 8.0 – 10.5 ppm dissolved oxygen and 13 – 20 °C water temperature. The fish is primarily carnivorous feeding on a wide spectrum of aquatic fauna including fly nymphs, flies, other insects, small fishes and benthic macro fauna. In early stage, their preferred food includes plankton, and small larval forms of insects and other benthic fauna. Known as the important food fish of the hill regions, this species sometimes comes as pest and caught in bulk by hooks and lines and cast nets.

Schizothorax richardsonii

It is an important and medium sized fish available in both Bichom and tenga rivers. The fish migrates to upper reaches of the hill stream with the increase of water temperature after the winter cold phase is over. The species breeds in a temperature range of 10 – 20 °C and their migration starts from February onwards and continues till June and July. Their body is streamlined with depth of 4.1 – 6.2 times in standard length. The maximum size attained by the fish is of 60 cm. The fish was sampled from both Tenga and Bichom rivers during March. The female and the male specimens sampled from Tenga river were in oozing stages, while the specimen collected from Bichom was a ripe female. This was in conformity with the reported breeding season of the species from April to June. Plenty of fry of the species could be collected from up and down stream of Tenga and Bichom rivers in April from the pits behind the rocks and boulders. The depth of the hills stream at the fry collection points was quite low between 20 and 30 cm and the submerged rocked were blanketed with algal growth which forms the natural food at the early stage. In adult the species is a carnivore and bottom feeder, feeding mainly on benthic macro fauna.

Tor tor / Tor putitora

These species grow to maturity in large rivers and migrate to head water creeks to spawn. They move in groups and feed on benthic organisms on gravelly beds during afternoon and evening hours. Their preferred habitats are snow fed or rain fed running waters, broken into pools and rapids 50 : 50 water depth ranging from 2 – 15 m, river bed mostly boulder strewn with gravel, pebble and coarse sand with plentiful insect, insect-larvae and other crustacean benthic fauna. The fish breed in riverine habitats where summer and winter temperatures are neither very cold or very warm between 15 – 30 ° C. Tor spp produce 45000 to 75000 eggs. The young feed on diatoms, ciliates, rotifers, and crustaceans. The spawning pairs select slow moving waters along the river bank, deposit eggs in installments on the gravel bed. The Mahseer male matures in the second year and the female in the third year when they attain the length of 200 mm and 300 mm respectively.

Acrossocheilus hexagonolepis

This species is also included in the group of Mahseer and has similarity with other two species of *T. tor and T. putitora.* Their breeding, migration and requirements match with the other two Mahseer species. In Bichom and Tenga rivers the species is abundantly available. Structurally the species is cylindrical and attains a maximum size of 25 -30 cm. The fish produces 16800 eggs when 300 mm in length and weighing 300 g.

4.4.3 Observation of Fish Migration

Our observation, particularly the availability of mature *S.richardsonii* the near proposed dam site during March is indicative of beginning of their breeding season. The fish starts the run for the breeding ground. The species of *Schizothorax* available here breed at higher altitude. The fishes prefer clear current less side pools of the streams from spawning. The spawn and fry to avoid the high current. Juveniles of *S.richardsonii* was observed during March/April downstream of Tenga and Bichom. This indicates that they drifted down from their place of birth. Presence of advanced fingerlings (6-10 cm) which were approx. 5-6 months old was indicative of prolonged breeding habit of *Schizothorax spp.* up to October(Plates 10-14).

The observation of gorged gut during May/June clearly indicated the peak feeding activity of the fishes. The fishes feed actively when the environment was warm. Fishes of the hill stream (Tenga and Bichom) starts downstream migration to a comparatively comfortable place when the headwater region starts freezing during winter. It is expected that during winter in the post monsoon regions of the river there will be highest fish landings if any because the fish take refuge in this part of the rivers.

From March onwards with the increase in temperature in the upstream, fish starts upward migration both for feeding and breeding. Negligible availability of the fishes is observed in the plain region during this period.

4.4.4 Swimming capabilities of fish

The swimming speeds of various fish species from a number of sources have been consulted to extrapolate the swimming speeds of fishes found in the above rivers, in terms of burst and cruising speed. The fish has to undertake both the speeds depending upon the demands of the situation with gradual transition between these two speeds while moving upon downstream. From the information available on these aspects for other species it may be assumed that all fish of equal length have the same swimming speed. It has been seen that the variables like water temperature and fish length are very important in determining the swimming speed of fishes. The average length of adult fishes frequently available in Tenga and Bichom river and their body contours give some indication of their swimming capabilities.

Average length of migratory fishes commonly found in river Bichom & Tenga

Species	Average Length (cm)	Comments
S. richardsonii	39-62	Body elongated, cylindrical with strong pectoral fin.
S.progestus	37-56	Medium size, spindle shape body.
G. gotyla gotyla	8-15	Compressed body, modified pectoral fin, ventral attaching pad.
Labeo dyoheilus	23-24	Spindle shaped body
T.tor	60	Sub cylindrical
T.putitora	60	Sub cylindrical

With temperature during March/April ranging from (11.4-13.6°C) in the rivers and length of adult as shown it may be assumed that swimming speed of *Schizethorax spp.*/Tor ranges from 2-4 ms^{-1}. Other species like *Garra spp.* are comparatively smaller and are provided with ventral sucker, which is of great help in negotiating fast currents.

Garra spp. climbing a wall and then taking a leap of 15-20 cm and attaching to another substrate is common occurrence. Therefore it can be considered that fishes having specialized organs of attachment will have no problem in negotiating fish pass.

The swimming speed is the important factor in determining the head drop per pool. When the average length of important migratory fishes of the Tenga and Bichom rivers are compared with the information available in this regard, it becomes evident that head height or drop per pool of 33 cm is appropriate for a cruising speed of 2.54 m/sec.

The swimming ability of the fish species of the potential natural fish fauna and all its stages has to be considered in setting the length of a fishway. Resting zone or resting pools should be provided in fishways. Here fish can interrupt their ascent and recover from the effort. In pool passes as designed for the two dams resting zones are inherent to the design.

PRE-IMPOUNDMENT LOCATIONS OF FISH BREEDING AND FEEDING GROUNDS IN BICHOM AND TENGA RIVERS

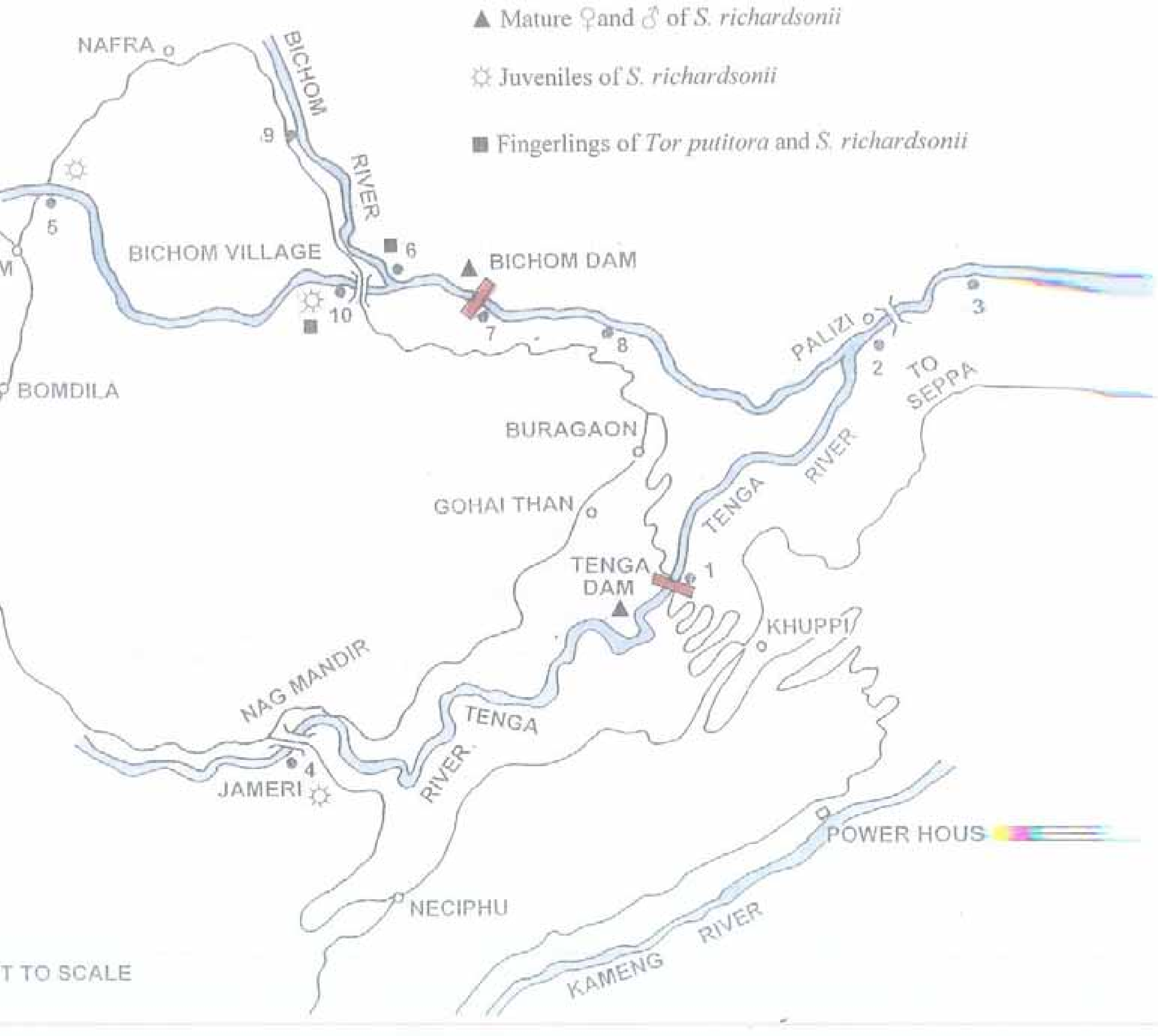


Fig. 3

5. Likely impact of the engineering structure

The proposed daming of the rivers will interfere with the ecological rhythm and biological cycles of the system by creating physical barrier across the river stretch. The impact will be on the physical and also biological ecology of the affected river course.

5.1 Physical ecology

The immediate impact of river daming will affect the physical ecology by drastically reducing the flow at the down stream and exposing the river beds i.e, the natural habitats for the hill stream biota including the fishes. On the other hand the recession developed up stream of the dam will create a vast water sheet of high depth and altogether different ecological conditions than the hill stream. The reservoir due to stagnant / semistagnant environment will gradually gain the phenomenal physico-chemical stratification mainly of the temperature and dissolved oxygen. The loss of typically fast flow, favourable thermal range and adequate oxygen in both up and down stream of the dam will introduce significant change in bio-community structure of the affected river system. Shrinkage in the downstream dimensions of flow, besides reducing the habitat resources, will prevent upstream breeding migration of the fishes by obstructing their passage.

5.2 Biological ecology

Biological ecology is literally the counterpart of physical ecology. The richness of biological ecology is dependent on the ecological richness of the system. Any man made obstruction on the river course like dams will result in loss of habitat at the down stream by exposing the river beds to a great extent and create a different habitat of reservoir upstream of the engineering structure. In hill stream, the biological ecology is highly variable enriched with a wide range of flora and faunal diversity. The hill stream organisms need specific environmental conditions like clear and oxygen rich water of required flow and tolerable thermal range. The obstructions from dams hinders the flow pattern of the stream and eventually deprives the biocommunity from ecological requirements and ultimately threatens their existence. The affected biota will include plankton, benthic micro and macro flora and fauna and the higher animals like fish, reptiles, amphibians and mammals.

The reduction in flow will have a marked negative impact on the plankton population and on other hand expose the bed substratum leading to destruction of periphytons. The severe depression in quantity and quality of plankton and macrobenthic fauna which constitute the natural food elements vital for different life stages of fishes, will eventually lead to a damaging effect on inhabitant fish fauna and also the migrating fishes from downstream. The exposure of stream bed besides restricting the biological productivity may affect recruitment of fishes by preventing their movement and also reducing the breeding and nursery grounds.

The reservoir developed at the upstream of the dam will change the stream ecology drastically mainly due to the high depth, stagnant to semistagnant conditions and physico-chemical alterations in the environment. All these unnatural conditions for the hill stream biota and fish fauna will cause dispersion / disappearance of sensitive species. Thus the natural bio-diversity of the river stretch will be lost. Further the developed reservoir will spread over a vast area of the river basin and inundate the exiting breeding grounds of the migratory fishes (Fig. 3 & 4) and force them to find alternate sites for the purpose in upper hill regions.

5.3 Fisheries

In Kameng river system Bichom and Tenga are important tributaries in respect of the drainage volume and also as highly potential breeding and feeding grounds for the major hill stream fishes like *Schizothorax richardsonii, Schizothoraicthys progestus, Tor tor, Tor putitora, Garra gotyla gotyla* etc.These fishes migrate to the higher riches of Bichome and Tenga river as soon as the snow melt water from the higher Himalayan range starts flowing down and the water temperature becomes (10-15 ^{0}C) favourable for the breeding and rearing of the species. The upcoming Bichom dam on the Bichom river and Tenga dam on river Tenga will create physical barriers on the migrating routs of the ascending fishes and interfere in the process of completion of their life cycle. With the passage of time the upper riches of the dams will be cut off from the migrating route and if the suitable alternative breeding grounds are not found out in the downstream the fishes will disappear from the river and their population will be threatened in the Kameng river system.

Of particular concern is the fact that the river flow regulation proposed by construction of Bichom and Tenga dams will have the following direct and indirect impacts on fish and fisheries of the bichom and Tenga river systems.

i) Obstruction to reach spawning areas.

Several fish species like *S. richardsonii, S. progastus, Tor tor. T. putitora, Garra gotyla* etc., which require upstream migration to reach the spawning ground in order to reproduce will be obstructed by man-made structure in their specific pathways and they can neither successfully reach their spawning grounds nor are they able to breed, leading to depletion of their population.

ii) Inundation of spawning areas.

Generally, the areas having sandy and gravel bed, shallow depth, feeble or no currents are preferred sites for fish breeding and spawning. Creation of the dams obviously would result in inundations of these sites resulting in the loss of breeding grounds.

iii) Changes in physical ecology

Barricading the flowing water through the concrete construction result in stagnation and thermal stratification of water changing its chemical composition. These changes in the properties of water consequently lead to complete/partial disruption and or disturbance of the trophic structure inhabiting the ecosystem. This is expected in the present case.

iv) Natural flow to downstream will be altered

The operation of the dams as per the need of the power generation will have direct impact on the downstream normal flow pattern in terms of volume and velocity of water. This may result in a delay or absence of flood exposing the marginal habitat due to reduction in flow volume. These abrupt changes are deleterious to the fisheries in many ways.

A severely reduced flow regime minimize the variability of the current, so that only the bottom of the river channel is wetted and pools of stagnating water are formed (so called trap effect). Riverine species can no longer find an adequate habitat. The water would warm up in summer and there is danger of drying up completely.

Establishing minimum flow requirements for the impaired channel stretch downstream of a dam attempts to counter these problems (DVWK, 1995)

v) Prevention of young migratory fish and refuge migrants from descending to the lower reaches

During adverse ecological conditions the unfavourable temperature, turbidity, flood etc., the fish seek refuge in comfortable regions downstream. Likewise, the juveniles move to their feeding grounds. These movements are hampered by the obstruction created in their pathways thereby threatening their survival.

In addition, adverse repercussions can result from indirect effects such as disruption of food webs downstream, stranding of fish during rapid flows fluctuations and siltation in reservoir above the dam.

6. Restoration of migratory species

6.1 Engineering design to facilitate fish movement

Fish passes are of increasing importance for the restoration of fish passage for fish and other aquatic species in rivers. Fish passes thus became key elements for the ecological improvement of running waters. Their efficient functioning is a prerequisite for the restoration of free passage in rivers. Upstream fish passage facilities so far designed and installed in different countries can be placed into four categories.

a) Fish pool passes (fish ladders)
b) Fish lift locks
c) Elevators
d) Trapping and hauling.

a) Fish pool passes **:**

The principle of a pool pass consists in dividing up a channel leading from the headwater to the tailwater by installing cross-walls to form succession of stepped pools. The discharge is usually passed through openings (orifices) in the cross-walls and the potential energy of the water is disrupted, step by step in the pools.

Fish migrate from one pool to the next through openings in the cross-walls that are situated at the bottom (submerged orifices) or at the top (notches). The migrating fish encounter high flow velocities only during their passage through cross-walls, while the pools with their low flow velocities offer shelter and opportunities to rest. A rough bottom is prerequisite to make pool passes negotiable to benthic fauna.

b) Fish lift locks **:**

This is a mechanical device that raise the stranded fish from below the dam to upstream. Fish lock is a device that lifts fish over dams by filling a chamber with water where the fish have entered at tailwater. Fish lock operates more or less in the same manner as navigational lock.

c) Fish lift **:**

Is a means of collecting and loading the fish into a conveyance which will mechanically transport the fish upstream over a dam.

6.2 Stock rehabilitation by artificial seed production

A planned build-up of fish stock of appropriate species, especially the migrating fishes like Mahseers and snow trouts in the up coming reservoir must take priority to ensure sustained population density of endemic fishes and establishment of a dynamic link between the two aquatic subsystems on either side of the dam.

Hatcheries and rearing facilities should be provided at the dam sites to produce seed ofsnow trout,and chocolate mahaseer.

6.3 Fish Passage structures

The fish passes have become key elements for ecological improvement of running waters. Their efficient functioning is a prerequisite for restoration of free passage in rivers. However, studies of existing devices have shown that many of them do not function correctly. Therefore, various stakeholders eg., engineers, biologists and administrators are generally interested in valid design criteria that correspond to present latest experience & knowledge.

Flow pattern and migrating fish breeding period in Bichum river

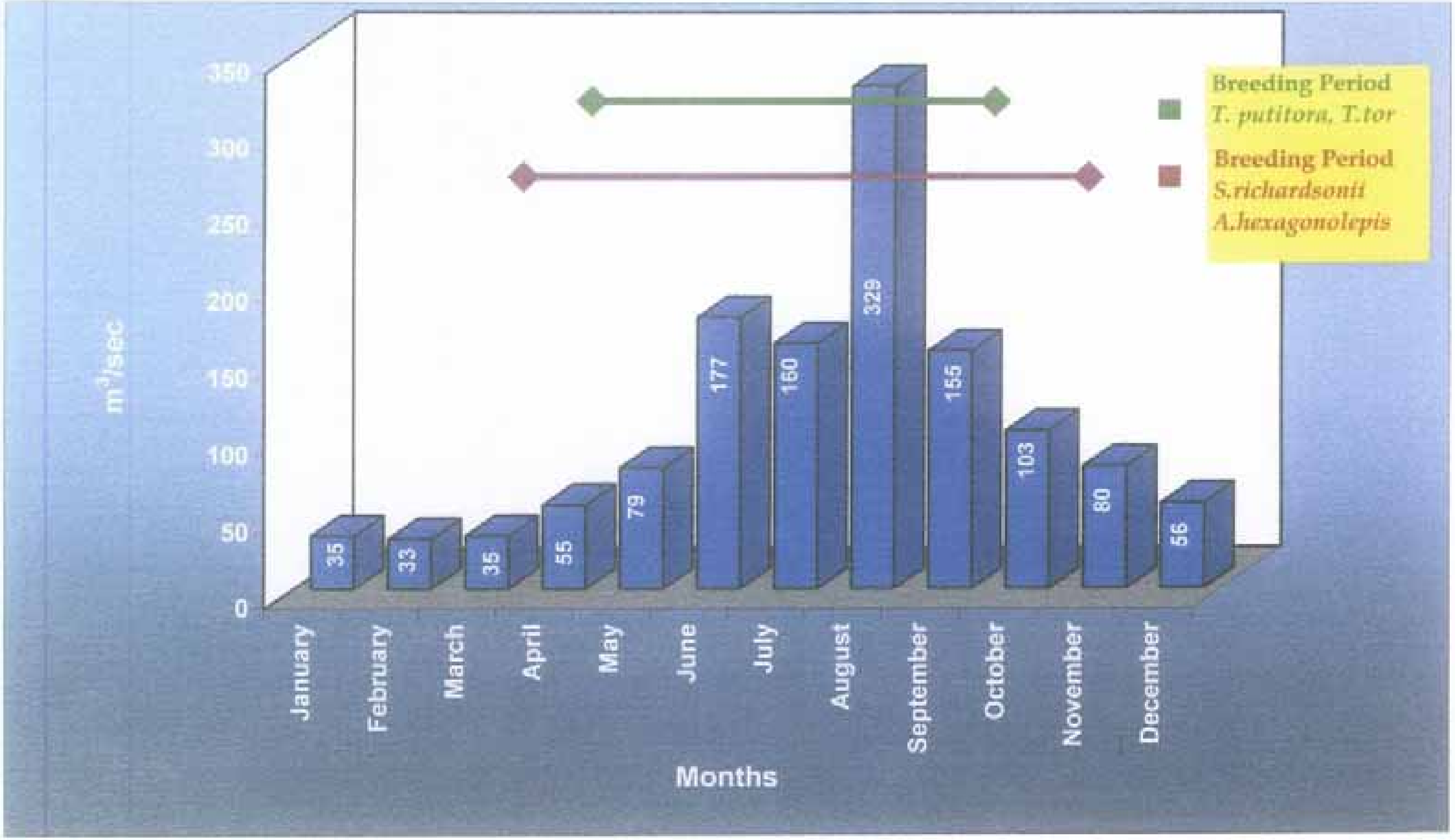


Fig. 5

6.4 Basic requirement of fish pass

Longitudinal connectivity in rivers is critical ecologically to satisfy the diverse migratory needs of aquatic species. Free longitudinal passage through rivers is mainly impeded by sudden drops, weirs or dams that cannot be passed by aquatic organisms. The general criteria that fish passes should meet include the biological requirements and the behaviour of migrating aquatic organisms and thus constitute important aspects in planning fishways.

Optimal position of fish pass

In original rivers the whole width is available for migration of aquatic organism. Fish passes in dams usually confine migrating fishes to a small part of the dam as they are small structure limited by engineering, hydraulic and economic constraints.

Fish and aquatic invertebrates usually migrate upstream in or along the main current. For the entrance of a fishway to be detected by majority of upstream migrating organisms it must be positioned at the bank of the river where the current is highest.

Fish pass entrance

The perception of current by aquatic organisms plays a decisive role in their orientation in rivers. Fish that migrate upstream as adults usually swim against current (positive rheotaxis). If migration is blocked by an obstruction, the fish seek onward passage by trying to escape laterally at one of the dam's side. In so doing they continue to react with positive rheotaxis and in perceiving the current coming out of a fishway, are guided into the fish pass. The optimum range of velocity at which the attracting current exits the fishpass should be within the range of 0.8 to 2.0 ms^{-1} (SNIP, 1987).

Since diurnal fish avoid swimming into dark channels the fish pass should be in daylight and thus not covered over. If this is not possible as in the present case the fishway should be lit artificially in such a way that lighting is as close as possible to natural light.

Fish pass exist and exit condition

In general, if the headwater level of the impoundment is constant the design of the water inlet does not present a problem. However, special provisions have to be made at dams here the headwater level varies, where variations in level exceed one meter, several exits must be constructed at different levels for the fishway to remain functional.

Strong turbulence and current velocities over 2.0 ms^{-1} must be avoided at the exit area of the fish pass so that the fish leaves the pass for headwater more easily. The water intake of the fishway should be protected from debris by a floating beam.

Discharge and current conditions in the fish pass

The discharge required to ensure optimum hydraulic conditions for fish within the pass is generally less than needed to form an attracting current. However, the total discharge available should be put through the fish pass to allow unhindered passage of migrants, especially during periods of low flow. The turbulence of the flow through the fishway should be as low as possible so that all aquatic organisms can migrate through the pass independent of their swimming ability. In general the current velocity in fishway should not exceed 2.0 ms^{-1} at any narrowpoint such as orifices or slots.

Lengths, slopes of a fish pass

The body length of the biggest fish species that occurs or could be expected to occur (in accordance with the concept of the potential fish natural fish fauna) is an important consideration in determining the dimensions of fish pass.

The average body length of the longest fish species expected in the river as well as the permissible difference in water level must be considered in defining the dimension of a fish pass. The maximum permissible slope of the fish passes normally is less than 1:15.

Design of bottom

The bottom of a fish pass should be covered along its whole length with a layer at lease 0.2 m thick of coarse substrate. Ideally the substrate should be typical for the river. The rough bottom must be continuous upto end including the exit area of the fish pass as well as at the orifices.

SECTION B

7. Fish pass design proposed for Bichom and Tenga river systems

Based on the information generated as elaborated in the document the present design is proposed which is detailed in the succeeding pages

7.1 DESIGN OF FISH PASS FOR BICHOM DAM

7.1.1 AVAILABILITY OF FLOW

7.1.1.1 Presently minimum availability of Bichum river discharge during various months on ninety percent dependability (Fig.5) during any 10-day period is roughly shown in the following Table.

Month	Minimum availability of Water (m^3/sec) during any 10-day period of the month	Remarks
(1)	(2)	(3)
May	79	The figures in column (2) are the mean of daily flow on the lowest10-day availability basis during a particular month
June	177	
July	160	
August	329	
September	155	
October	103	
November	80	
December	56	
January	35	
February	33	
March	35	
April	55	

7.1.1.2 The designed Power demand of water for generation of 600 MW (4 units @ 150 MW) is 140 M^3/sec. It may be observed from the above Table that this demand can be met fully from the run off the river during June to almost middle of October. It is expected that there would be spillage down the dam every year during these months viz., June to middle of October even after filling of the Bichum dam up to its FRL at El 770.00 as may be necessary. No spillage however is expected during the months middle of October through May.

7.1.1.3 The river flow during months of mid October to May would go down from 103 m^3 / sec during the month of mid October to 33 m^3 / sec. during the month of February. The requirement of water for generation of Power during this period can only be met from the stored water in the Dam along with the available low flow.

7.1.1.4 The discussions above lead to the following observations:

(i) During the months of June to nearly 15 days of October the availability of river flow is far in excess of the power demand. A portion of this excess flow is expected down the dam during this period.

(ii) The entire river flow from mid October to May would be used up along with the stored water for generation of 600 MW power.

7.1.1.5 The prevailing river flow round the year enables the various species of fish population to move both upstream and downstream of the Projected Bichum Dam area depending on their physiological and trophic needs. This situation calls for maintaining a minimum flow down the Bichum dam.

7.1.1.6 It is seen from the data that even 40 percent of the recorded lowest monthly flow of 33 m^3/sec during the month of February will maintain a draft of nearly 1 m to 1.5 m immediate downstream (200 m) of the Bichum dam. This minimum flow of nearly 10 m^3 / sec to 15 m^3 / sec (which is only 40 percent of the lowest designed monthly flow of the river) should be made available for the sustenance of the fish and other aquatic population including the aquatic plants in the region.

7.1.1.7 This small quantity of water (10 to 15 m^3 / sec) is suggested to be met from the following considerations:

(i) The power house is expected to be run at 80 to 90 percent Plant Load Factor (PLF) which incidentally applies to the highly efficient power houses run in this country. Hence 140 m^3 / sec will not be required for 100 percent of the time.

(ii) During the period of routine maintenance and repair the requirement of designed flow would be reduced by 25 percent. Normally each units of the powerhouse is expected to operate continuously for 300 days in a year and 2 months time is necessary for repair and maintenance.

7.1.1.8 It may be noted that the above requirement (10 -15 m^3 / sec.) is necessary in order that the proposed Fish Ladder act efficiently as a Fish Pass connecting downstream to upstream. However, in case of extreme low inflow years, the above stipulation may be reduced by 50 percent for a period not exceeding 7 days at a stretch.

7.1.1.9 The entire river stretch down the Bichum dam till it meets the main river Kameng below Kimi should be declared as a sanctuary for protection of migratory fish population of the Bichum dam / Bichum river.

7.1.2 GENERAL PLANNING

7.1.2.1 The discussions with officials at Delhi emerged that,

(i) The entire flow available in the river upto 140 m^3 / sec will be diverted for generation of power and any excess flow will be stored in the dam. As such no release (except passage of flood flow hitting the full reservoir level at 770.00) will be made from the dam. It was also informed that 10-daywise flow regulation table during the 90 percent dependable year (1976-77) is not available. The flow regulation table indicates the 10-daywise balance of inflow and outflow including release down the dam (if any) at any point of time. In absence of such flow regulation table for 90 percent dependable year, the exact release pattern down the dam at any point of time can not be properly assessed.

(ii) It was however informed by them that maximum draw down will not be exceeding 4 m below FRL of 770.00.

7.1.2.2 In view of the above three inlet orifices with center line at El 769.00, at El 768.00 and at El 7.66.00 have been proposed (Drg. No.DP/FPB/02). The inlet orifices (0.2 m high and 1.85 m wide) have been located in Dam Block no. 13. Each of the inlet orifices starts from 7.5 m measured from the end face of Block 13 at chainage 228.9 (Drg. No. DP/FPB/03, DP/FPB/04 and DP/FPB/04/1).

7.1.2.3 The top inlet orifice (viz. first inlet orifice) enters the Fish Ladder through the side wall of the Fish Ladder at El 768.90 viz. at the invert level of the first orifice (Drg. No. DP/FPB/03). The Fish Ladder starts from Ch 228.9 m. i.e., at the end of Block 13 (Drg. No. DP/FPB/03). The design slope of the ladder is 1 in 12. The Fish Ladder has a length of 797.50 m and meets the river bed I natural ground level at El 701.226 (Drg. No. DP/FPB/06).

7.1.2.4 The second inlet orifice (0.2 m x 1.85 m) is located at El 768.00 (center line). This second inlet orifice (situated in the same vertical line of the first inlet orifice (1.85 m wide) on the upstream face of the dam) will continue for some length at the same elevation viz. at El 767.9 (invert) along the ground surface (Drg. No. DP/FPB/02) and will enter into the Fish Ladder at Ch 9.697 m. (Drg. No. DP/FPB/04). As ground surface is expected to have sufficient bearing capacity and the load of the second inlet orifice per mtr. run is small, no foundation has been provided in the drawing. In case the second inlet orifice passes over relatively soft ground surface (soil report is awaited), it may be desirable to grout the ground surface (over which the second orifice is run). Alternately, suitable stepped foundation for second inlet orifice running over the ground surface need to be provided along with suitable encasement (M 20) at reasonable spacing.

7.1.2.5 The third inlet orifice (0.2 m x 1.85 m) is located at EI 766.00 (central line). All the three inlet orifices are placed in a same vertical line. The third inlet orifice (1.85 m wide and 0.2 m height on the upstream face of the dam) will continue for some length at the same elevation viz. at EI 765.9 (invert) along the ground surface (Drg. No. DP/FPB/04/1) and will enter into the Fish Ladder at Ch 33.939 m. The stipulation in(para 9.2.1.2.4) on the issue of foundation I grouting for the second orifice will also hold good for the laying of the third inlet orifice laid on the ground surface.

7.1.2.6 A vertical entrance-well (1.5 m x 1.5 m x 2.7 m high) has been provided in the body of the dam for approach to the Fish Ladder (Drg. No. DP/FPB/01) from the deck top of the dam at EI 773.00 upto the entrance well floor level at EI 770.3. Rungs will be provided in the wall of the entrance-well as shown in the drawing (Drg. No. DP/FPB/01). The top of the well (EI 773.00) will be covered by a suitable cast iron device.

7.1.3 DESIGN ASPECT

7.1.3.1 The principal consideration is that the inlet orifices at the upstream entry point from the dam face should remain always submerged and Fish Ladder terminates away from energy dissipation set-up of the dam. Fortunately the Bichum Fish Ladder terminates nearly more than 700 m down the dam. The arrangements required for energy dissipation (now under model study at Roorkee University) for the Bichum dam.

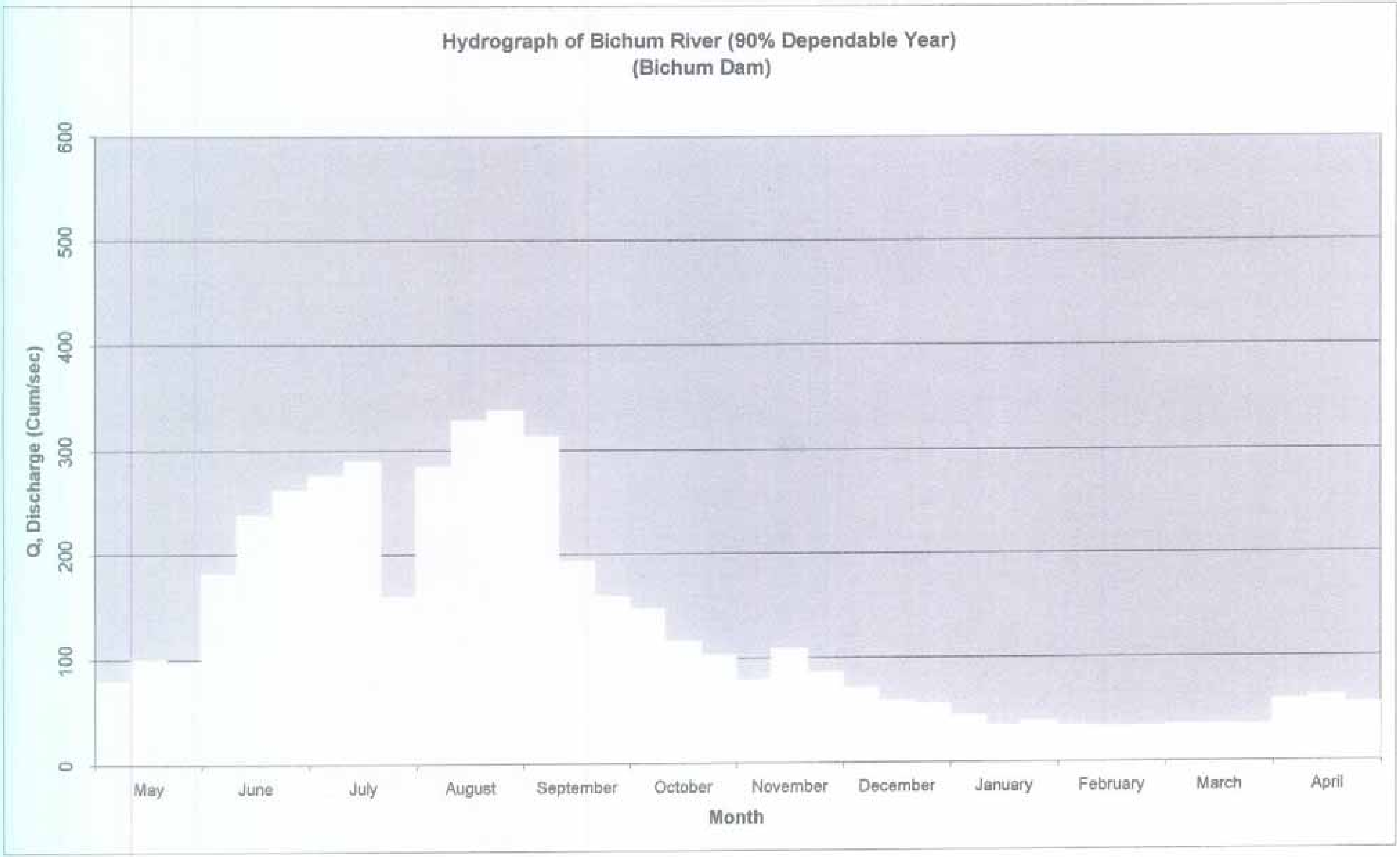
7.1.3.2 In view of this, it has been considered that a minimum 0.2 m head of water should remain above the top level of inlet orifice during the operation. In other words the top inlet orifice (CL at EI 769.00) would be operated up to reservoir water level of EI 769.30. At this point the top inlet orifice should be closed and the second inlet orifice (CL at EI 768.00) should be opened. A flap type small mild steel gate (1.85 m x 0.2 m) controlled from the top of the dam by chain pulley system has to be installed on the dam accordingly. The skin plate thickness of the gate may be around 6 mm or so.

7.1.3.3 The permissible entry velocity for the fish species (Schizothoraichthys, Tor spp.) of the Bichum river is 2.7m / sec. With the operating head of 1.0 m (EL 770.00-EL 769.00), The velocity generated at the inlet orifice is 2.65m/sec. using the relation,

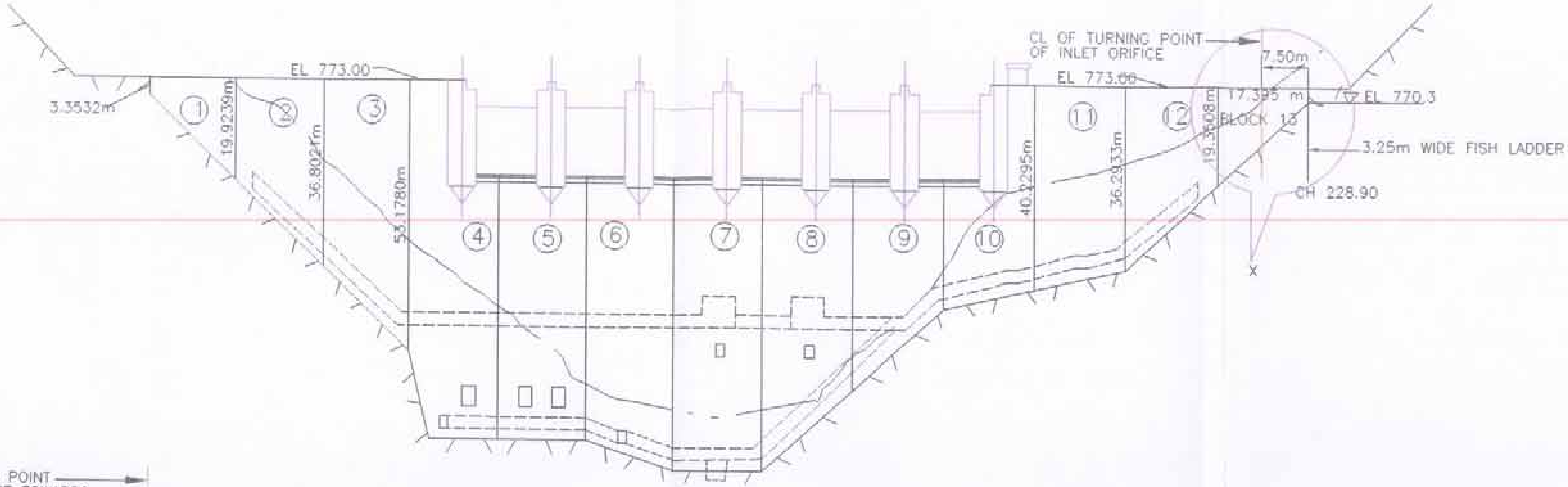
$$V = K\sqrt{2gh}$$

Where,
V = Velocity, m/sec
h = Head of water = 1 m
g = Acceleration due to gravity= 9.81 m/sec^2
K = A constant = 0.60

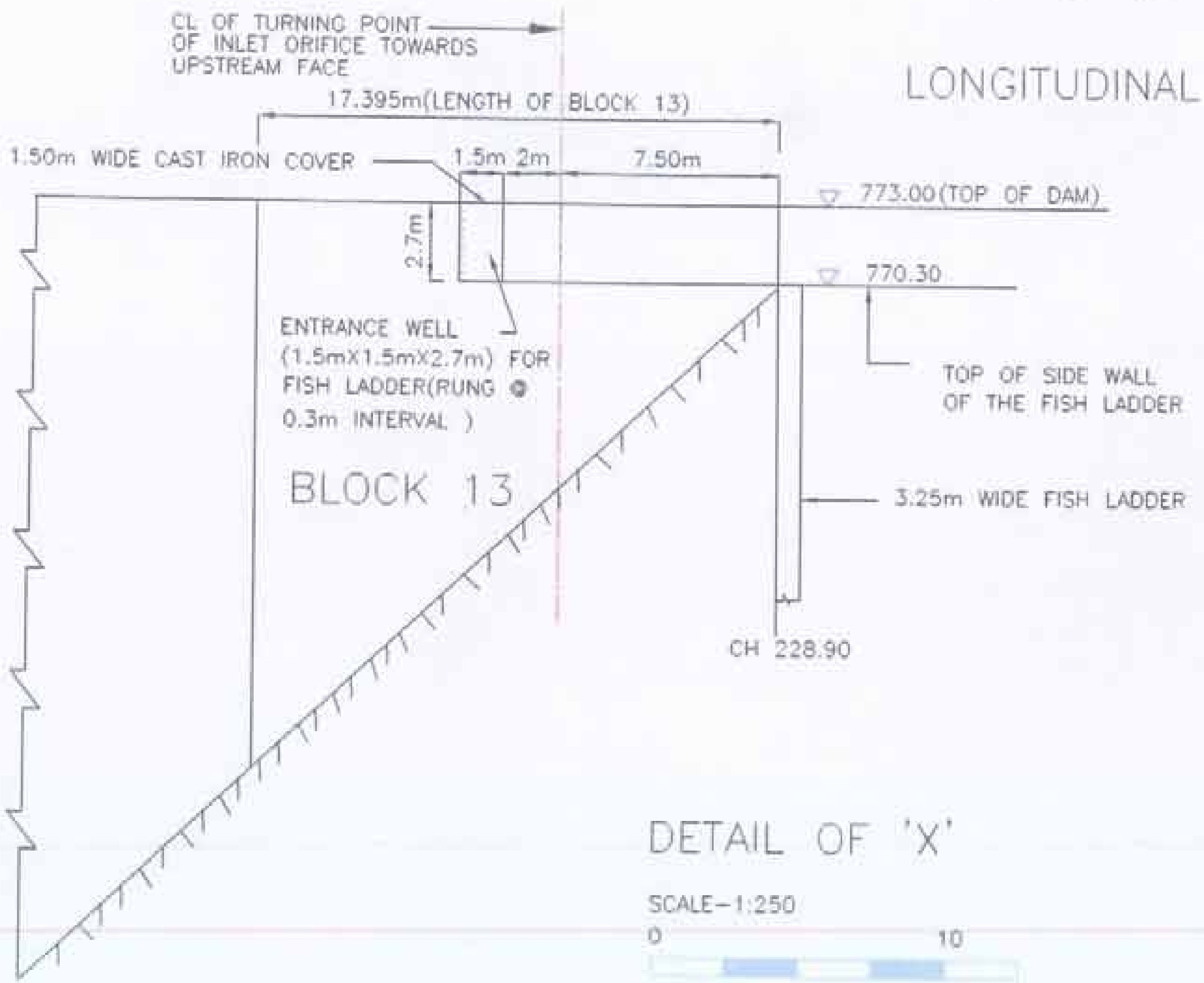
Fig 1



Hydrograph of Bichum River (90% Dependable Year)
(Bichum Dam)
Q, Discharge (Cum/sec)
600
500
400
300
200
100
0
May
June
July
August
September
October
November
December
January
February
March
April
Month



LONGITUDINAL SECTION OF BICHUM DAM



DETAIL OF 'X'

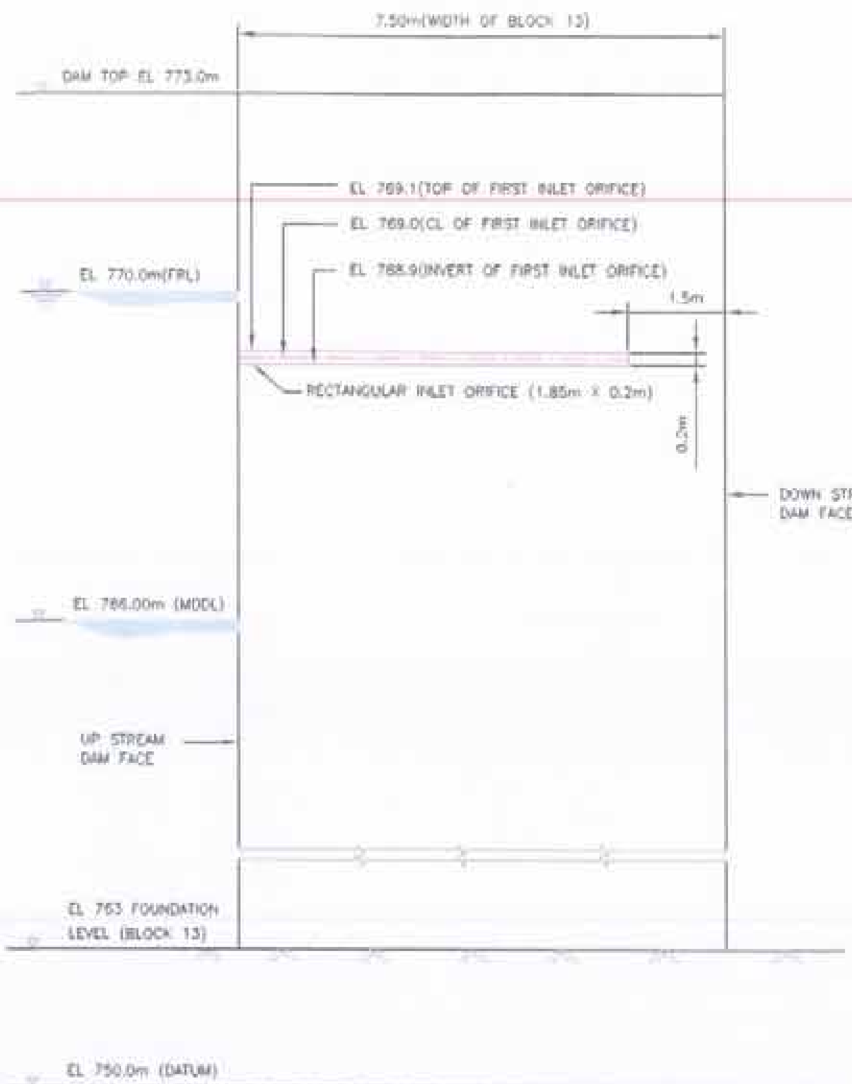
SCALE−1:250
0 10

NOTE:

1. (1), (2), (3) ETC. INDICATES THE NUMBER OF BLOCKS .
2. VERTICAL DIMENSION SHOWS THE HEIGHT OF THE BLOCKS ABOVE THE FOUNDATION LEVEL.

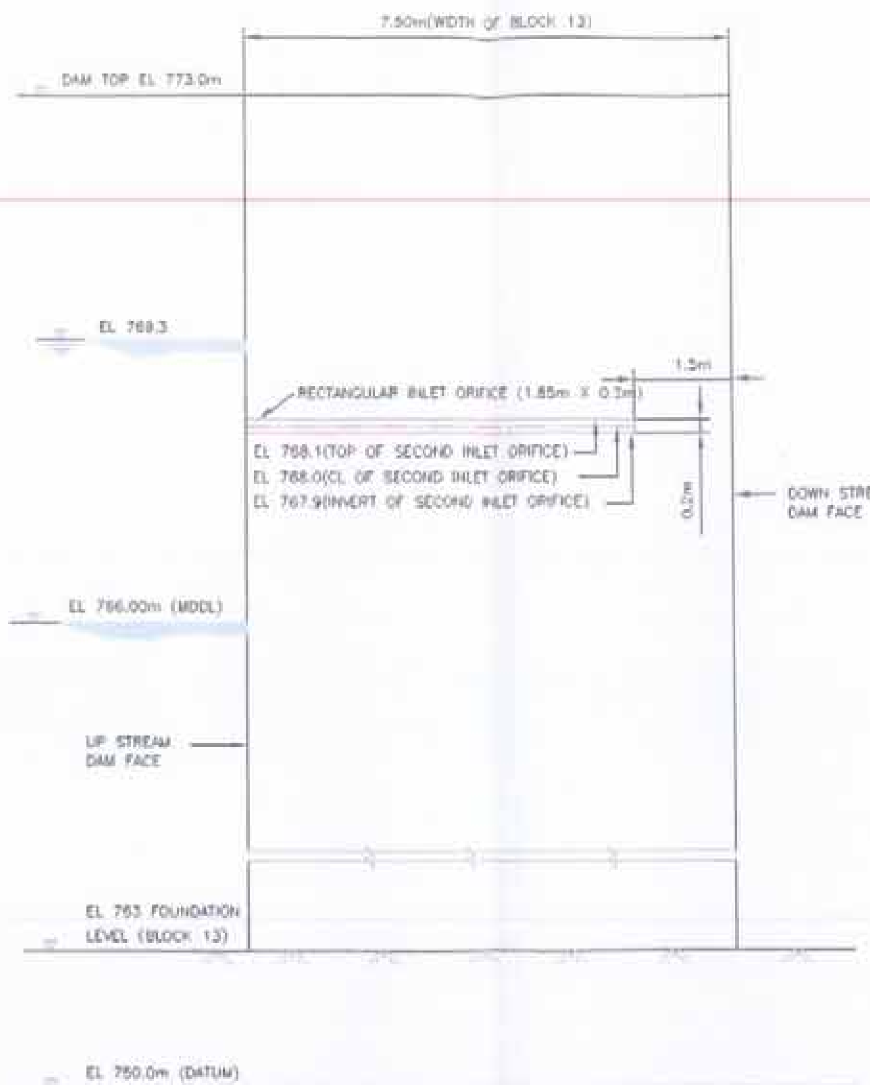
SCALE−1:1000
0 10 20 30 40 50

PROJECT NAME : BICHUM DAM FISH PASS IN ARUNACHAL PRADESH NEEPCO, SHILLONG, MEGHALAYA	
TITLE : KEY DRAWING OF BICHUM DAM	
DRAWING NO. DP/F.P.B./01	REV. - 0



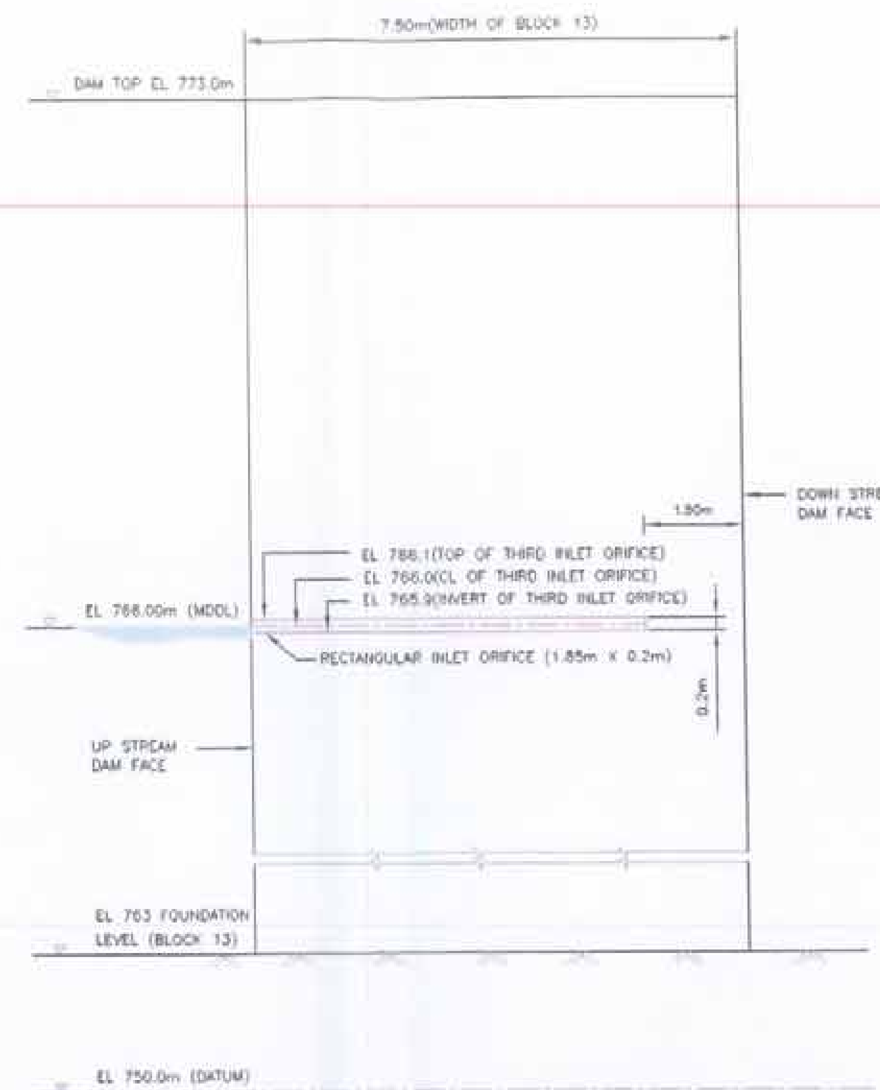
INLET ORIFICE FROM BLOCK NO 13 AT CHAINAGE 228.9 (CROSS SECTIONAL VIEW)

SECTIONAL DETAIL OF BICHUM DAM
(FIRST INLET ORIFICE)



INLET ORIFICE FROM BLOCK NO 13 AT CHAINAGE 228.9 (CROSS SECTIONAL VIEW)

SECTIONAL DETAIL OF BICHUM DAM
(SECOND INLET ORIFICE)



INLET ORIFICE FROM BLOCK NO 13 AT CHAINAGE 228.9 (CROSS SECTIONAL VIEW)

SECTIONAL DETAIL OF BICHUM DAM
(THIRD INLET ORIFICE)

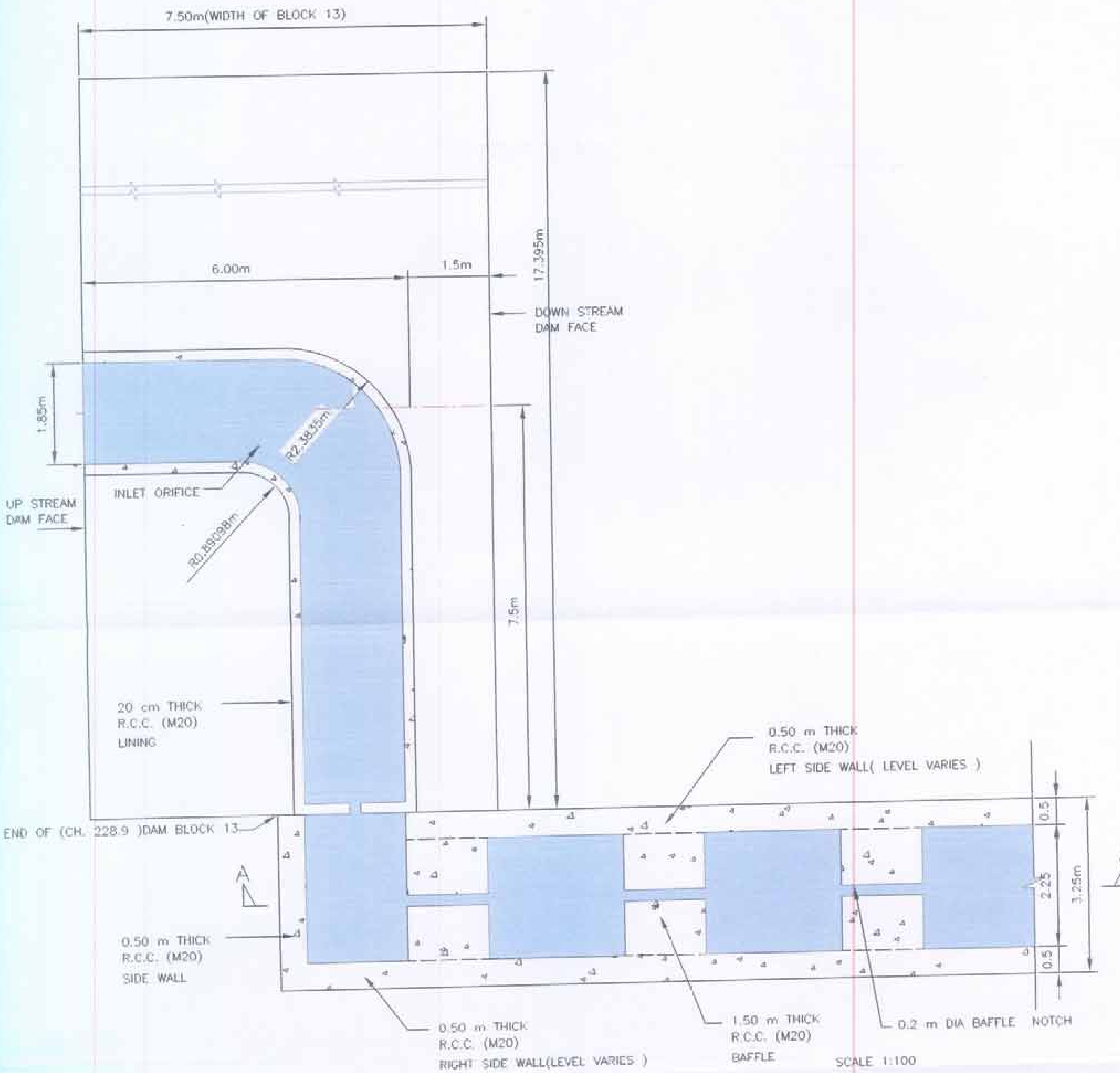
NOTE:

1. WHEN RESERVOIR WATER LEVEL REACHES EL 769.30 THE FIRST INLET ORIFICE MAY BE CLOSED .
2. THE SECOND INLET ORIFICE MAY BE OPENED WHEN THE RESERVOIR LEVEL ATTAINS EL 769.00 AND CLOSED AT RESERVOIR WATER LEVEL 768.10
3. THE THIRD INLET ORIFICE MAY BE OPENED WHEN THE RESERVOIR LEVEL ATTAINS EL 767.00 AND CLOSED AT RESERVOIR WATER LEVEL 766.10
4. THE INLET ORIFICE TAKES A RIGHT ANGLE TURN AT 1.5 m FROM DOWN STREAM FACE OF THE DAM.
5. ALL DIMENSIONS ARE IN METER OTHERWISE MENTIONED.

SCALE 1:100

0 1 2 3 4 5

PROJECT NAME BICHUM DAM FISH PASS IN ARUNACHAL PRADESH NEEPCO, SHILLONG, MESHALAYA	
TITLE : CROSS SECTIONAL VIEW OF INLET ORIFICE (FOR BICHUM DAM)	
DRAWING NO. DP/ F.P.B. / 02	REV. - 0

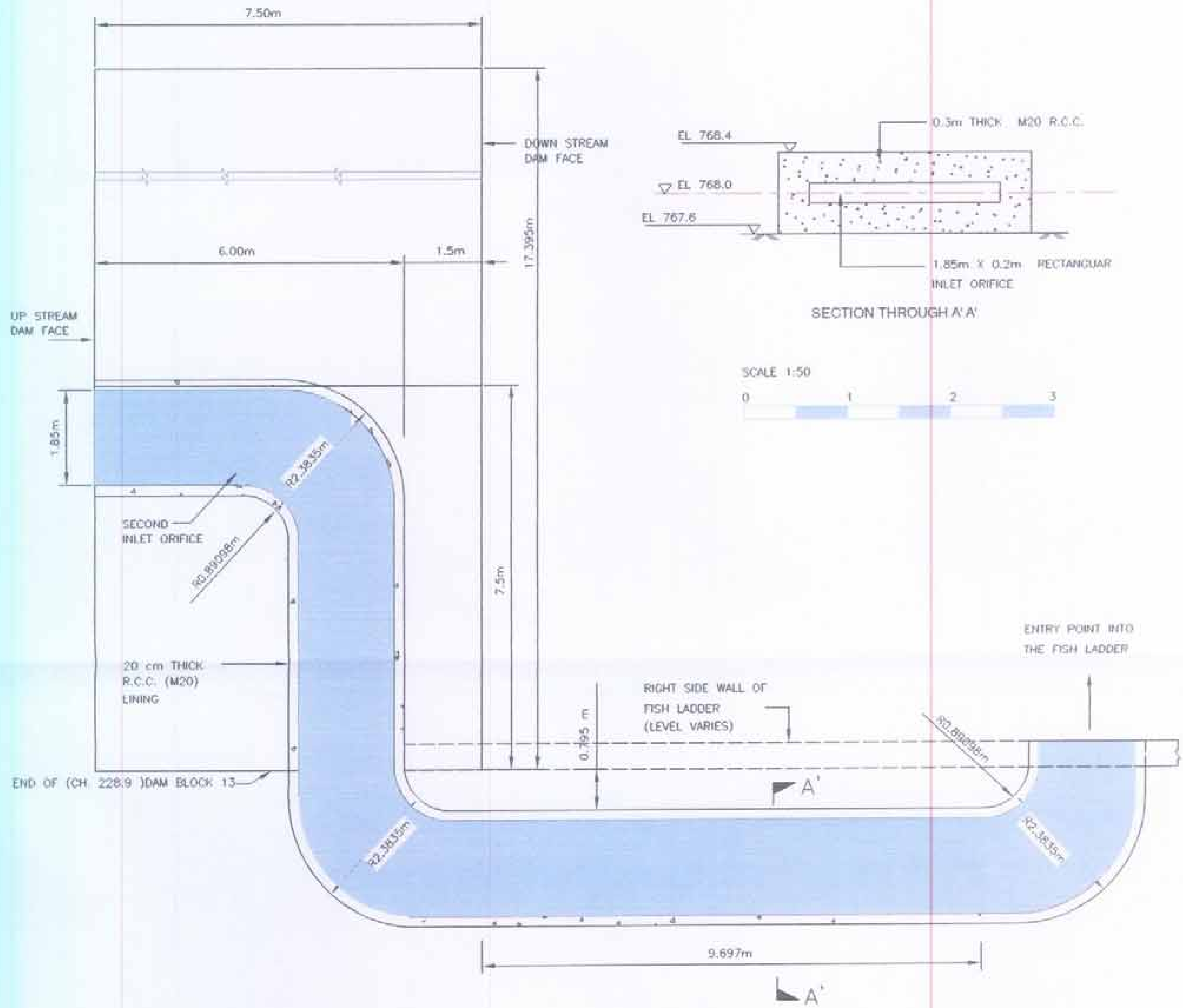


SECTIONAL PLAN VIEW AT EL 768.9(FIRST INLET ORIFICE)

NOTE:

1. ALL CONCRETE WORKS FOR FIRST INLET ORIFICE AND FISH LADDER ARE RE- INFORCED M20 GRADE
2. EXPANSION JOINT MAY BE PROVIDED AS PER BIS CODE
3. ALL DIMENSIONS ARE IN METER OTHERWISE MENTIONED.
4. SUBSTRATA AND ENTRANCE WELL TO FISH LADDER NOT SHOWN.

PROJECT NAME : BICHUM DAM FISH PASS IN ARUNACHAL PRADESH NEEPCO, SHILLONG, MEGHALAYA	
TITLE : CROSS SECTIONAL PLAN VIEW OF BICHUM DAM AT EL 768.9 (FIRST INLET ORIFICE)	
DRAWING NO. DP/ F.P.B. / 03	REV. - 0



SECTION THROUGH A' A'

SCALE 1:50

0 1 2 3

SECTIONAL PLAN VIEW AT EL 767.9(SECOND INLET ORIFICE)

SCALE 1:100

0 1 2 3 4 5

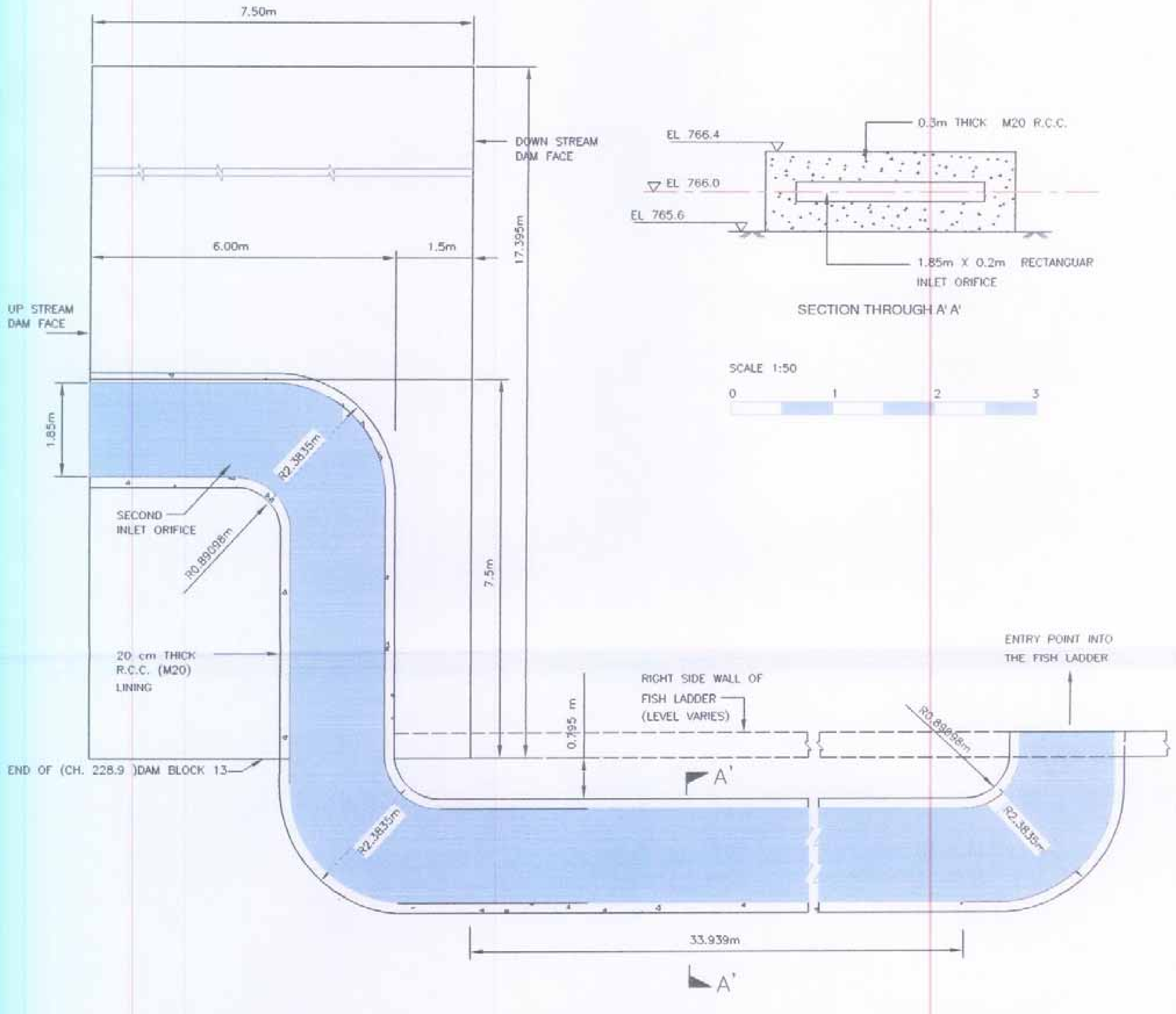
NOTE :

1. ALL CONCRETE WORKS FOR SECOND INLET ORIFICE AND FISH LADDER ARE RE INFORCED M20 GRADE

2. ALL DIMENSIONS ARE IN METER OTHERWISE MENTIONED.

3. SECOND INLET ORIFICE ENTRY INTO THE FISH LADDER IS AT CHAINAGE 9.697m

PROJECT NAME : BICHUM DAM FISH PASS IN ARUNACHAL PRADESH NEEPCO, SHILLONG, MEGHALAYA	
TITLE : CROSS SECTIONAL PLAN VIEW OF BICHUM DAM AT EL 767.9 (SECOND INLET ORIFICE)	
DRAWING NO. DP/ F.P.B. / 04	REV. - 0



SECTIONAL PLAN VIEW AT EL 765.9(THIRD INLET ORIFICE)

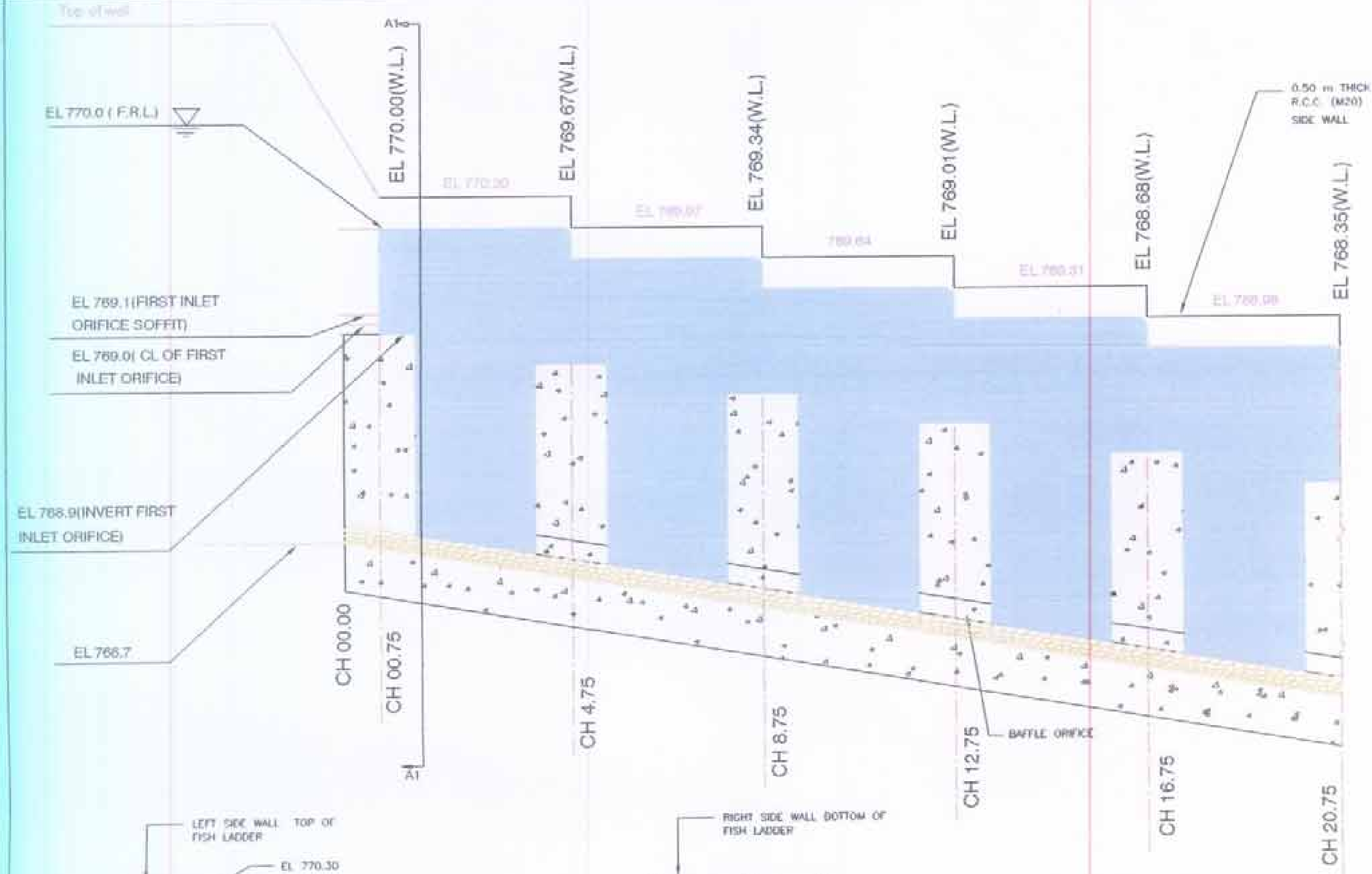
SCALE 1:100

0 1 2 3 4 5

NOTE :

1. ALL CONCRETE WORKS FOR SECOND INLET ORIFICE AND FISH LADDER ARE RE INFORCED M20 GRADE
2. ALL DIMENSIONS ARE IN METER OTHERWISE MENTIONED.
3. THIRD INLET ORIFICE ENTRY INTO THE FISH LADDER IS AT CHAINAGE 33.939 m

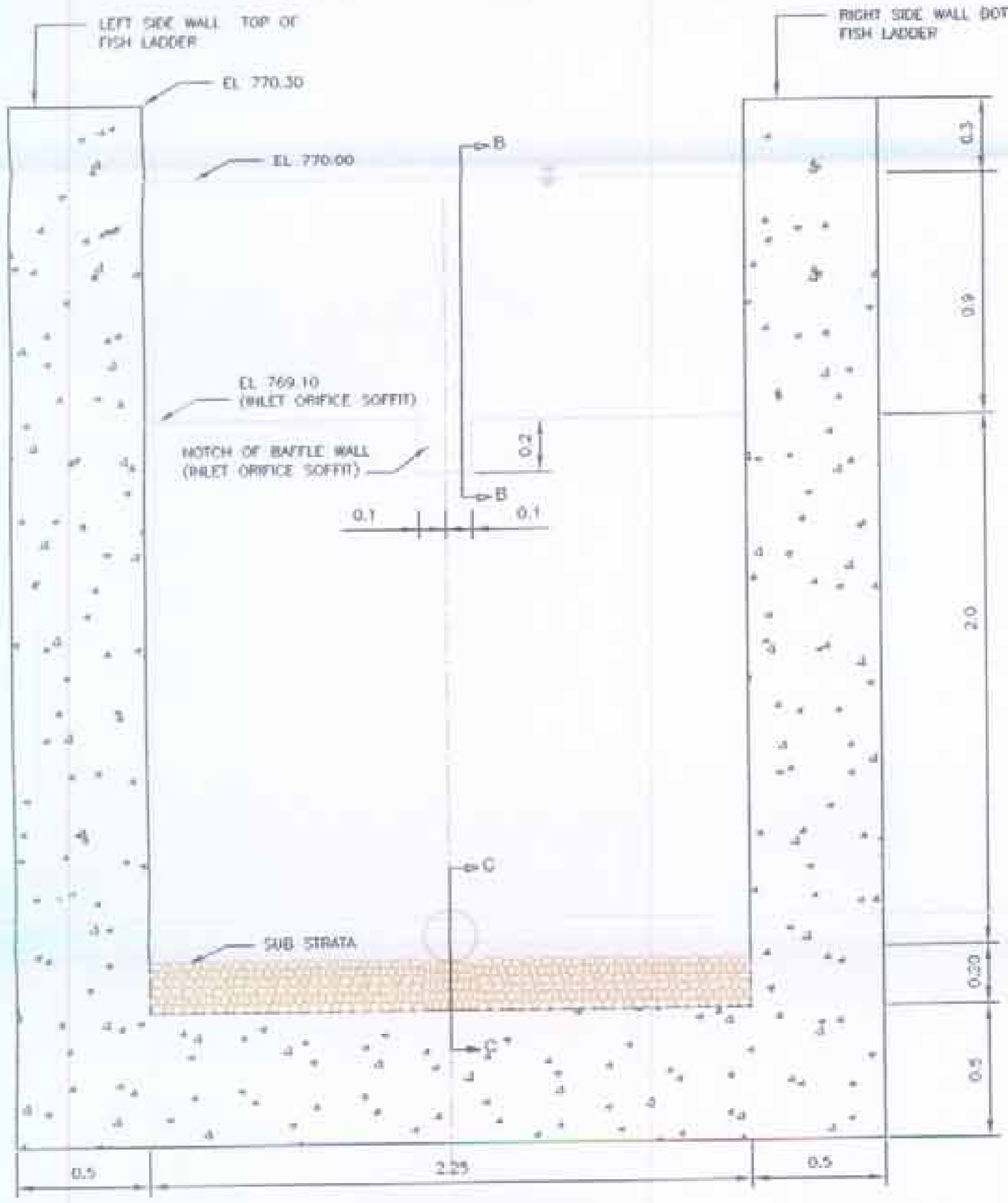
PROJECT NAME : BICHUM DAM FISH PASS IN ARUNACHAL PRADESH NEEPCO, SHILLONG, MEGHALAYA	
TITLE : CROSS SECTIONAL PLAN VIEW OF BICHUM DAM AT EL 765.9 (THIRD INLET ORIFICE)	
DRAWING NO. DP/ F.P.B. / 04/1	REV. - 0



PART SECTIONAL THROUGH AA
(SECTION AA DRAWING REF. DP/F.P.B./03)

SCALE 1:1

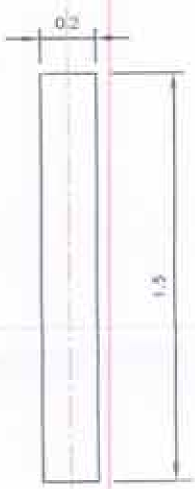
0 1 2 3 4 5



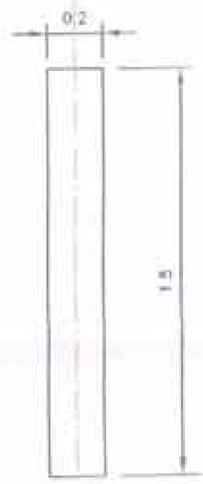
SECTION THROUGH A1A1

SCALE 1:25

0 1 2



SECTIONAL PLAN OF BAFFLE NOTCH(BB)



SECTIONAL PLAN OF BAFFLE ORIFICE(CC)

NOTE:

1. ALL CONCRETE WORKS FOR INLET ORIFICE AND FISH LADDER ARE RE-INFORCED M20 GRADE
2. EXPANSION JOINT MAY BE PROVIDED AS PER BIS CODE.
3. ALL DIMENSIONS ARE IN METER OTHERWISE MENTIONED.
4. W.L. - WATER LEVEL

PROJECT NAME : BICHUM DAM FISH PASS IN ARUNACHAL PRADESH NEEPCO, SHILLONG, MEGHALAYA	
TITLE : SECTION THROUGH LADDER	
DRAWING NO. DP/ F.P.B. / 05	REV. - 0

LONG SECTION THROUGH LADDER
(SECTION AA DRAWING REF. DP/F.P.B./03)

SCALE 1:100

0 1 2 3 4 5

NOTE :
W.L. - WATER LEVEL

PROJECT NAME BICHUM DAM FISH PASS IN ARUNACHAL PRADESH NEEPCO, SHILLONG, MEGHALAYA	
TITLE : LONG SECTION THROUGH LADDER	
DRAWING NO. DP/F.P.B./05	REV. - 0

7.1.3.4 The height (depth) of the inlet orifice has been kept at 0.2m in order that the orifice type flow prevails (which requires that the minimum operating head should be 5 times the height of the orifice viz. 1.0 m).

7.1.3.5 The available discharge for the Fish Pass has been taken as 1.0 m^3/sec.
Discharge through one orifice
= Area x Velocity
= (1.85m x 0.2m) x2.65 m / sec. (providing 1.85 m. wide inlet orifice)
= 0.9805 = 1.0 m^3/sec

7.1.3.6 The energy associated with incoming flow, E = [wQh / 550] x 764 watts
Where, w = unit weight of water = 62.4 Lbs / cft.
Q = 1.0 m^3/sec. = 35.31 cusecs
h = Operating head = 1.0m = 3.281ft.

Following the criteria of 1.0 m^3 of volumetric dimension of pool can dissipate 150 watts of energy associated with the incoming flow through the inlet orifice, the volumetric dimension of the pool for dissipation of incoming energy, works out to nearly 67 m^3. Providing 2.0 m high baffle wall and width of 2.25 m, the length of pool for dissipation of energy works out to nearly 15.0 m. The baffles (2.0m x 2.25m wide) will be placed 4.0m c/c along the entire length (797.50m) of the Fish Pass (Drg. No. DP/FPB/06). There will be 200 nos. such baffle walls in the proposed Fish Pass ladder having a total length of 797.50 m.

7.1.3.7 The baffle walls will be provided with a notch of size 0.2 m x 0.2 m at the center point of the baffle walls. The minimum thickness of the baffle wall is 1.50 m in order that the notch (0.2m x 0.2m) remains effective for the fish to pass, through the notch (Drg. DP/FPB/05).

An orifice of 0.2 m diameter has also been provided at the bottom (vertically below the notch) over a substrata of 0.2m thick made up with locally available river stone-gravels (Drg. No DP/FPB/05).

7.1.3.8 The drop between baffle to baffle is taken as 0.33 m (allowable ; such drop is 0.2 m to 0.4 m) The velocity generated as a result of 0.33 m drop between baffle wall to baffle wall will be,

$V = \sqrt{2gh}$

Where, V= velocity generated in m/sec, due to fall (h)
g=9.81 m/sec
h=0.33 m, hence
$V = \sqrt{2 \times 9.8 \times 0.33} = 2.54$ m/sec.

This velocity (2.54 m/sec.) remains within the allowable limit of 2.6 m/sec. of cruising velocity for the type of fish population (indicated earlier).

Flow pattern and migrating fish breeding period in Tenga river

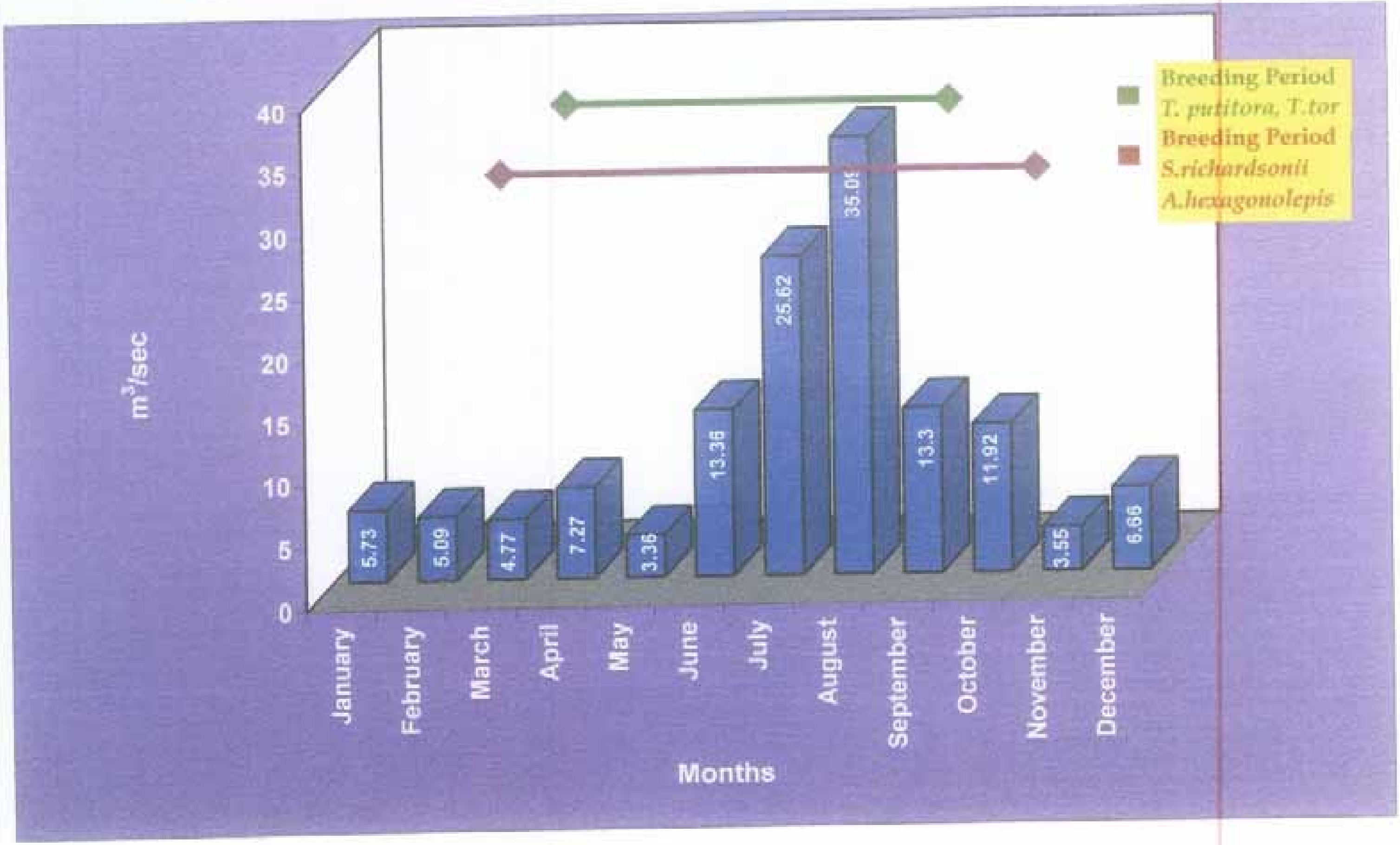


Fig. 6

7.1.3.9 With 0.33 m fall and the spacing (c/c) of each baffle wall of 4.0 m, the slope of the Fish Ladder works out to 1 in 12. This slope is normally adopted for the Fish Ladder.

7.1.3.10 The Fish Ladder, Baffle walls and side walls will be RCC type monolithic construction. Expansion joints may be provided as per BIS code of Practice.

7.1.3.11 Inlet orifices within the body of the dam will be made up of rectangular opening of size 1.85 m x 0.2 m height within the body of the dam and has to be taken care in the design of Block 13 of the Bichum dam accordingly.

7.1.3.12 The second inlet orifice 1.85 m x 0.2 m height of the Block 13 (Ch. 228) can be made up of in situ cast RCC type with thickness 0.3 m as shown in Drg. No. DP/FPB/04. The second orifice beyond the dam face at Ch. 228 will run through excavation and would meet the ladder at a distance of 9.697 m (Drg. No. DP/FPB/04) from the dam face at Ch. 228.0 m.

7.1.3.13 The third inlet (CL at El 766) will be similar to the. second orifice type. However, the third inlet orifice would meet the Fish Ladder at a distance of 33.939 m (Drg. No. DP/FPB/04/1) from the dam face at Ch. 228.0 m.

7.1.4 OBSERVATION

7.1.4.1 It is suggested that suitable monitoring devices by insertion of camera at suitable location of the Fish Pass ladder may be made. This would fetch requisite data on the Fish population and different species utilizing the Fish Pass. Such data would be useful for design of future Fish Passes.

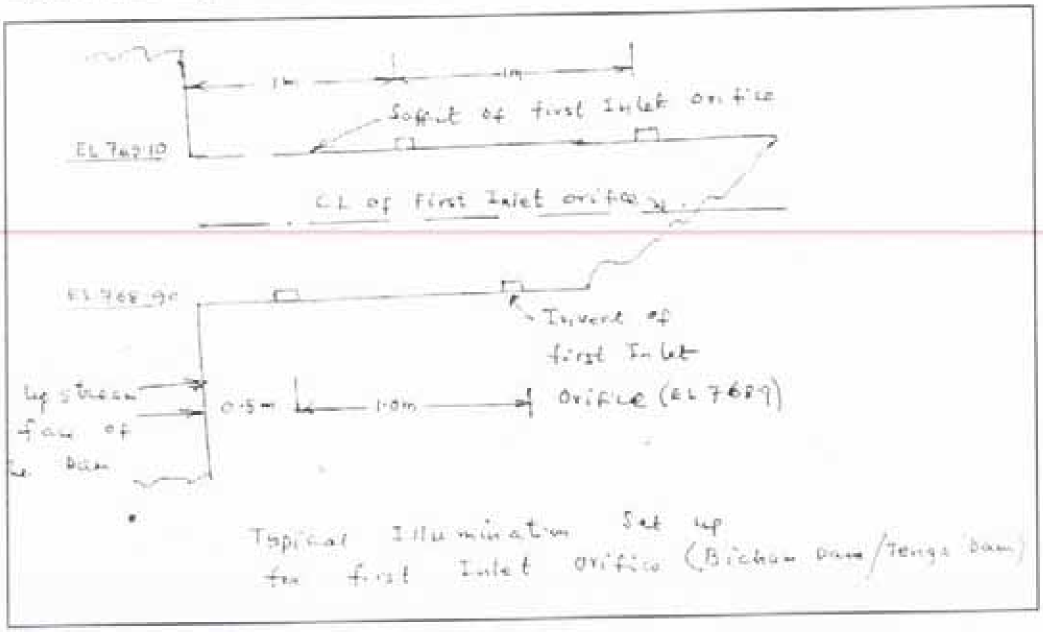
7.1.4.2 Maintenance and routine overhauling of the Powerhouse units may be timed during lean months (mid October to May) for better utilization of available storage in the dam and the river inflow during such period. Such action would help in maintaining the flow down the Bichom dam as indicated in (para **7.1.1.8**) .

7.1.4.3 A manual on operation and monitoring of Fish Pass needs to be developed in due course.

7.1.4.4 It will would be advisable that the following data and information on investigation / collection of existing available data for preparation of future projects on Fish Pass with minimum time for preparation on Project Reports.

7.1.4.5 Research has shown that when natural illumination is simulated in the Inlet orifice (within the body of the dam) it functions effectively. Hence it is necessary to make provision of adequate illumination (near natural condition) within the Inlet orifice (within the body of the dam). The illumination will be made through installations of 100 watts electrical lamp in a sealed unit at a spacing of one metre at the upper level (EL 768.9) at 0.5m spacing at the lower level (EL 768.9) in the first Inlet orifice. And in a similar pattern for second and third Inlet orifices.

Typical arrangement is indicated below:



7.2 DESIGN OF FISH PASS FOR TENGA DAM

7.2.1 AVAILABILITY OF FLOW

7.2.1.1 Presently minimum availability of Tenga river discharge during various months on a ninety percent dependability (Fig. 6) during any 10-day period is roughly shown in the following Table.

Month	Minimum availability of Water (m^3/sec) during any 10-day period of the month	Remarks
(1)	(2)	(3)
May	3.36	The figures in column (2) are the mean of daily flow on the lowest10-day availability basis during a particular month
June	13.36	
July	25.62	
August	35.09	
September	13.3	
October	11.92	
November	3.55	
December	6.66	
January	5.73	
February	5.09	
March	4.77	
April	7.27	

7.2.1.2 The designed Power demand of water for generation of 600 MW (4 units @ 150 MW) is 140 M^3/sec. This will be made up from the combined flow of the river Bichum and river Tenga. It is observed from the available data that this demand can be met fully from the combined flow of the Bichum river and Tenga river during June to almost middle of October. Since the availability of flow in the Tenga river is small (the maximum in flow with ninety percent dependability during the monsoon month is relatively very low compared to Bichum river). There will not perhaps be any Spillage down the Tenga dam during any months of the year and part of the flow will be stored during monsoon months (June to October) and a part of the Tenga river flow may be used up for power generation along with the flow available from the Bichum river. During non-monsoon months (November to May), the issue of Spillage will not arise in view of small river inflow during this period. The discussion with officials of the design organization, NEEPCO New Delhi during May this year also confirmed that there will not be any Spillage down the Tenga dam during any time of the year (ninety percent dependable).

7.2.1.3 The effectiveness of the Fish Pass hinges on the availability of flow in the Tenga river down the dam. In view of this it is suggested that a minimum flow of 3 to 4 m^3/sec which would maintain a draft of nearly 0.8 m or so in the Tenga river at a distance of 161.50 m below Tenga dam where the Fish Pass terminates into the river is earmarked for the Fish Pass in order that the proposed Fish Ladder acts efficiently as a Fish Pass for passage of migratory type fishes as observed in the samples collected from the river Tenga.

7.2.1.4 It may be noted that the above requirement (3-4 m^3/sec.) is necessary in order that the proposed Fish Ladder act efficiently as a Fish Pass connecting downstream to upstream. However, in case of extreme low inflow years, the above stipulation may be reduced by 50 percent for a period not exceeding 7 days at a stretch.

7.2.2 GENERAL PLANNING

7.2.2.1 During discussions with the officials of NEEPCO at New Delhi during May this year, it was confirmed that the reservoir will not be lowered down the MDDL (EI 765.00). Accordingly three rectangular inlet orifices (each 1.85 m wide and 0.2 m height), with center line of the orifices at EI 769.00, 768.00 and 765.00 respectively have been provided in the Tenga dam in Block 5 (Drg. No. DP/FPT/02).

7.2.2.2 The top inlet orifice (viz. first inlet orifice) enters the Fish Ladder through the side wall of the Fish Ladder at EI 768.90 viz. at the invert level of the first orifice (Drg. No. DP/FPT/03). The Fish Ladder starts from Ch 84.00 m. i.e., at the end of Block 5 (Drg. No.DP/FPT/03). The design slope of the ladder is 1 in 12. The Fish Ladder has a length of 161.50 m and meets the river bed I natural ground level at EI 752.045 (Drg. No. DP/FPT/06).

7.2.2.3 The second inlet orifice (1.85 m wide and 0.2 m height), is located at El 768.00 (center line). This inlet orifice (situated in the same vertical line of the first inlet orifice (1.85 m wide) on the upstream face of the dam) will continue for some length at the same elevation viz. at El 767.9 (invert) along the ground surface (Drg. No. DP/FPT/02) and will enter into the Fish Ladder at Ch 9.697 m. (Drg. No. DP/FPT/04). As ground surface is expected to have sufficient bearing capacity and the load of the second inlet orifice per mtr. Run is small, no foundation has been provided in the drawing. In case the second inlet orifice passes over relatively soft ground surface soil report is awaited), it may be desirable to grout the ground surface (over which the second orifice is run). Alternately, suitable stepped foundation for second inlet orifice running over the ground surface needs to be provided along with suitable encasement (M 20) at reasonable spacing.

7.2.2.4 The third inlet orifice (1.85 m wide and 0.2 m height) is located at El 765.00 (centre line). All the three inlet orifices are placed in a same vertical line. The third inlet orifice (1.85 m wide and 0.2 m height on the upstream face of the dam) will continue for some length at the same elevation viz. at El 764.9 (invert) along the ground surface (Drg. No. DP/FPT/04/1) and will enter into the Fish ladder at Ch 21.818 m. The stipulation in (para 9.2.2.2.3) on the issue of foundation / grouting for the second orifice will also hold good for the laying of the third inlet orifice laid on the ground surface.

7.2.2.5 A vertical entrance well (1.5 m x 1.5 m x 2.7 m) has been provided in the body of the dam for approach to the Fish ladder (Drg. No. DP/FPT/01) from the deck top of the dam at El 773.00 upto the entrance well floor level at El 770.3. Rungs will be provided in the wall of the entrance well as shown in the drawing (Drg. No. DP/FPT/01). The top of the well (El 773.00) will be covered by a suitable cast iron cover.

7.2.3 DESIGN ASPECT

7.2.3.1 The principal consideration is that the inlet orifices at the upstream entry point from the dam face should remain always submerged and Fish Ladder terminates away from energy dissipation set-up of the dam. Fortunately the Tenga Fish Ladder terminates nearly more than 160 m down.

(i) In view of this, it has been considered that a minimum 0.2 m head of water should remain above the top level of inlet orifice during the operation. In other words the top inlet orifice (CL at El 769.00) would be operated up to reservoir water level of El 769.30. At this point the top inlet orifice should be closed and the second inlet orifice (CL at El 768.00) should be opened. A flap type small mild steel gate (1.85 m x 0.2 m) controlled from the top of the dam by chain pulley system has to be installed on the dam accordingly. The skin plate thickness of the gate may be around 6 mm or so.

(ii) The permissible entry velocity for the fish species (Schizothoraichthys, Tor spp.) of the Tenga river is 2.7 m / sec. With the operating head of 1.0 m (EL 770.00-EL 769.00). The velocity generated at the inlet orifice is 2.65 m/sec. using the relation,

$$V = K\sqrt{2gh}$$

Where, V = Velocity, m/sec
h = Head of water = 1 m
g = Acceleration due to gravity= 9.81 m/sec^2
K = A constant = 0.60

7.2.3.2 The height (depth) of the inlet orifice has been kept at 0.2m in order that the orifice type flow prevails (which requires that the minimum operating head should be 5 times the height of the orifice viz. 1.0 m. of operating head).

7.2.3.3 The available discharge for the Fish Pass has been taken as 1.0 m^3/sec.
Discharge through one orifice
= Area x Velocity
= (1.85m x 0.2m) x 2.65 m/ sec. (providing 1.85 m. wide inlet orifice)
= 0.9805 = 1.0 m^3/sec

7.2.3.4 The energy associated with incoming flow, E = [wQh / 550] x 764 watts
Where, w = unit weight of water = 62.4 Lbs / cft.
Q = 1.0 m^3/sec. = 35.31 cusecs
h = Operating head = 1.0m = 3.281ft.

Following the criteria of 1.0 m^3 of volumetric dimension of pool can dissipate 150 watts of energy associated with the incoming flow through the inlet orifice, the volumetric dimension of the pool for dissipation of incoming energy, works out to nearly 67 m^3. Providing 2.0 m high baffle wall and width of 2.25 m, the length of pool for dissipation of energy works out to nearly 15.0 m. The baffles (2.0 m x 2.25 m wide) will be placed 4.0 m C/C along the entire length (161.50 m) of the Fish Pass (Drg. No. DP/FPT/06). There will be 41 nos. such baffle walls in the proposed Fish Pass ladder having a total length of 161.50 m (Drg. No. DP/FPT/06).

7.2.3.5 The baffle walls will be provided with a notch of size 0.2 m x 0.2 m at the center point of the baffle walls. The minimum thickness of the baffle wall is 1.50 m in order that the notch (0.2 m x 0.2 m) remains effective for the fish to pass, through the notch (Drg. DP/FPT/05).

An orifice of 0.2 m diameter has also been provided at the bottom (vertically below the notch) over substrata of 0.2 m thick made up with locally available river stone gravels (Drg. No DP/FPT/05).

7.2.3.6 The drop between baffle to baffle is taken as 0.33 m (allowable such drop is 0.2 m to 0.4 m). The velocity generated as a result of 0.33 m drop between baffle wall to baffle wall will be,

$V = \sqrt{2gh}$

Where, V= velocity generated in m/sec, due to fall (h)

g=9.81 m/sec

h=0.33 m, hence

$V = -\sqrt{2} X 9.8 XO.33 = 2.54$ m/sec.

This velocity (2.54 m /sec.) remains within the allowable limit of 2.6 m / sec. of cruising velocity for the type of fish population (indicated earlier).

7.2.3.7 With 0.33 m fall and the spacing (y/c) of each baffle wall of 4.0 m, the slope of the Fish ladder works out to 1 in 12. This slope is normally adopted for the Fish ladder.

7.2.3.8 The Fish Ladder, Baffle walls and side walls will be RCC type monolithic construction. Expansion joints may be provided as per BIS code of Practice.

7.2.3.9 Inlet orifices within the body of the dam will be made up of rectangular opening of size 1.85 m x 0.2 m height within the body of the dam and has to be taken care in the design of Block 5 of the Tenga dam accordingly.

7.2.3.10 The second inlet orifice 1.85 m x 0.2 m height of the Block 5 (Ch. 84.0) can be made up of in situ cast RCC type with thickness 0.3 m as shown in Drg. No. DP/FPT/04. The second orifice beyond the dam face at Ch. 84.0 will run through excavation and would meet the ladder at a distance of 9.697 m (Drg. No. DP/FPT/04) from the dam face at Ch. 84.0 m.

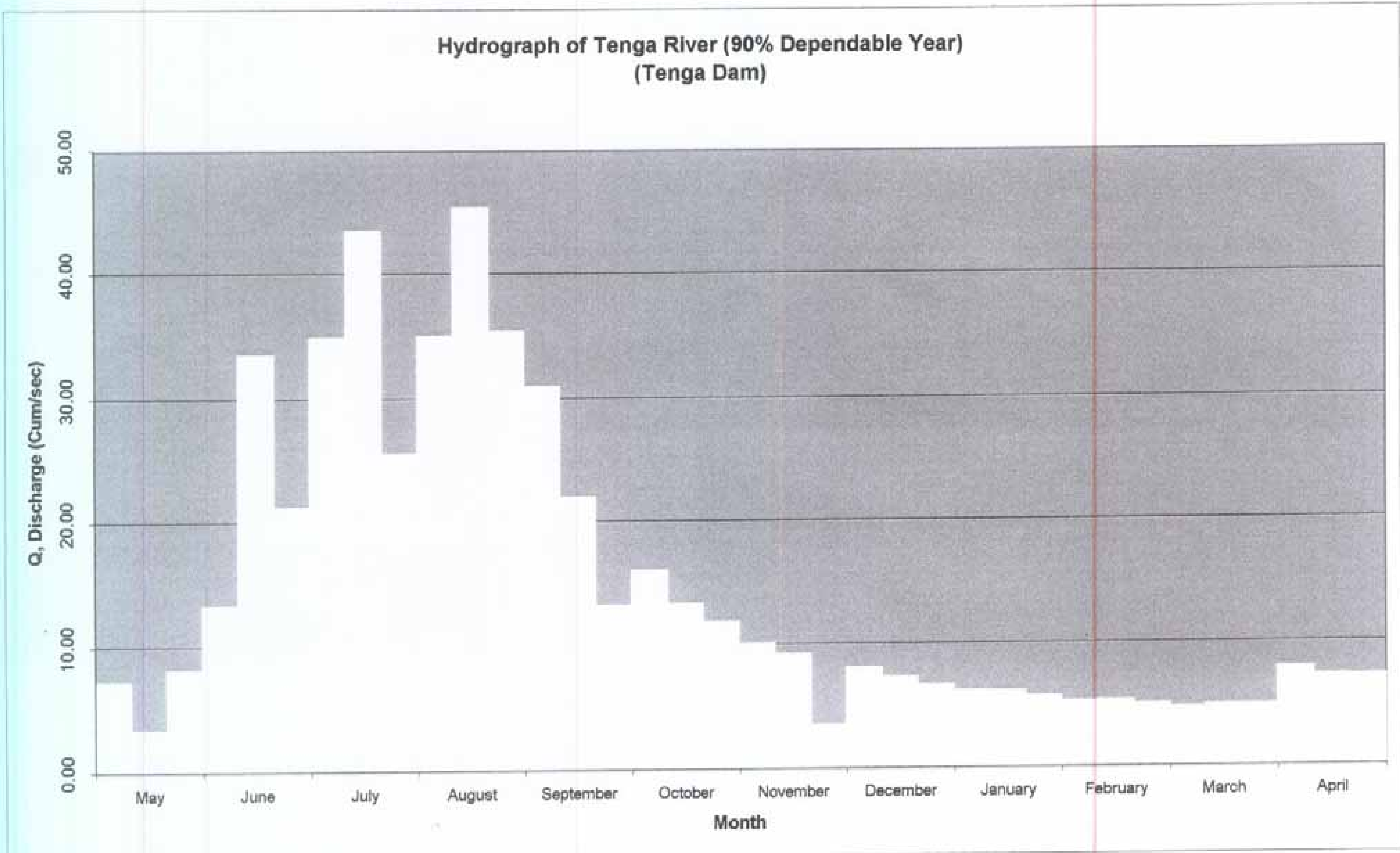
7.2.3.11 The third inlet (CL at El 765) will be similar to the second orifice type. However, the third inlet orifice would meet the Fish Ladder at a distance of 21.818 m (Drg. No. DP/FPT/04/1) from the dam face at Ch. 84.0 m.

7.2.4 OBSERVATION

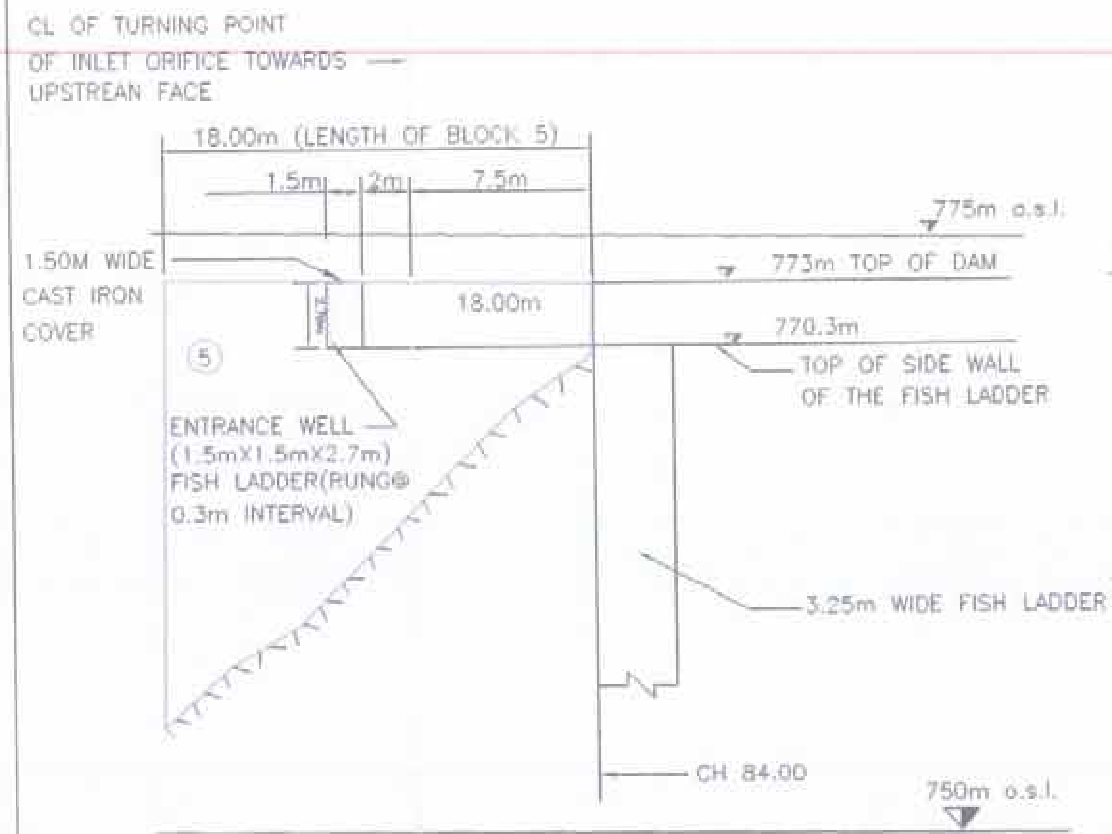
7.2.4.1 It is suggested that suitable monitoring devices by insertion of camera at suitable location of the Fish Pass ladder may be made. This would fetch requisite data on the Fish population and different species utilizing the Fish Pass. Such data would be useful for design of future Fish Passes.

7.2.4.2 Maintenance and routine overhauling of the Power house units may be timed during lean months (mid October to May) for better utilization of available storage in the dam and the river inflow during such period. Such action would help in maintaining the flow down the Tenga dam as indicated in para **7.2.1.4.**

Fig 1

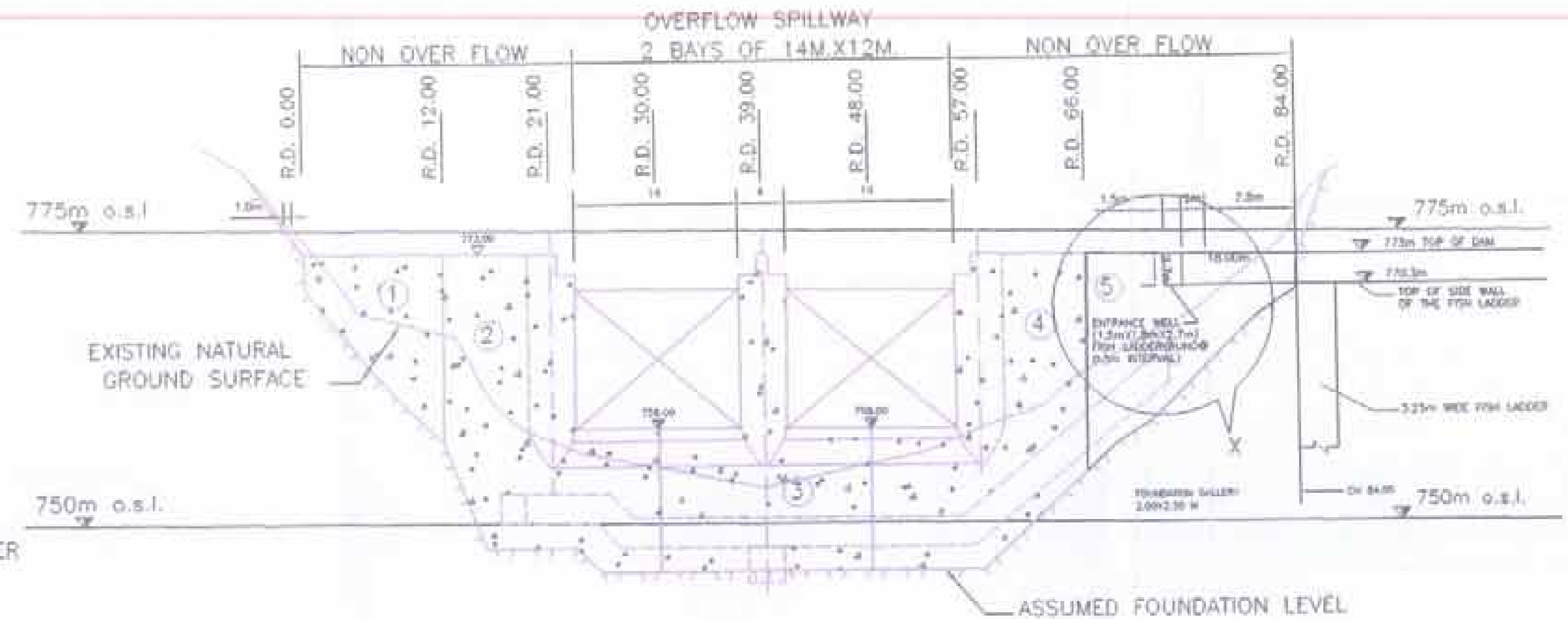


Hydrograph of Tenga River (90% Dependable Year)
(Tenga Dam)
Q, Discharge (Cum/sec)
0.00
10.00
20.00
30.00
40.00
50.00
May
June
July
August
September
October
November
December
January
February
March
April
Month



DETAIL OF 'X'

SCALE 1:250



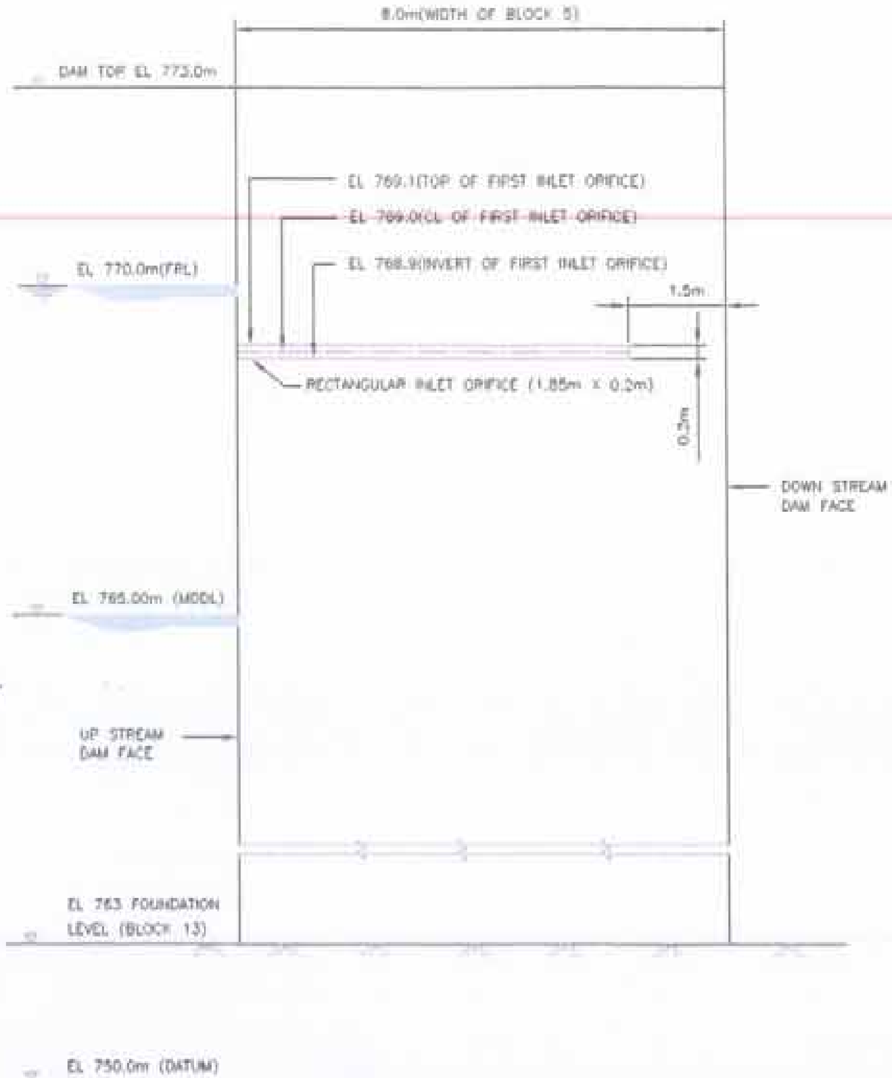
LONGITUDINAL SECTION ALONG DAM AXIS
(TENGA DAM)

SCALE 1:500

NOTE :

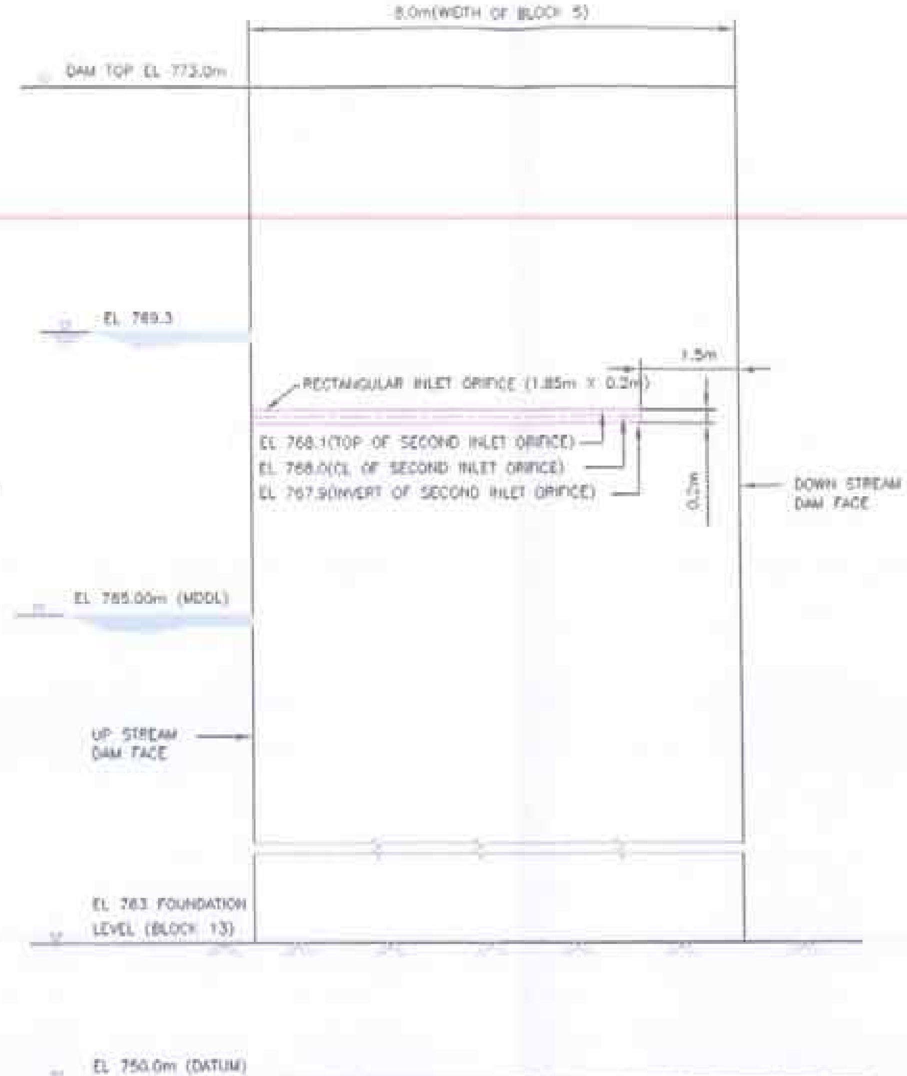
1. (1), (2), (3) ETC. INDICATES THE NUMBER OF BLOCKS
2. VERTICAL DIMENSION SHOWS THE HEIGHT OF THE BLOCKS ABOVE THE FOUNDATION LEVEL.

PROJECT NAME : TENGA DAM FISH PASS IN ARUNACHAL PRADESH NEEPCO , SHILLONG , MEGHALAYA	
TITLE : KEY DRAWING OF TENGA DAM	
DRAWING NO DP/F.P.T./01	REV. 0



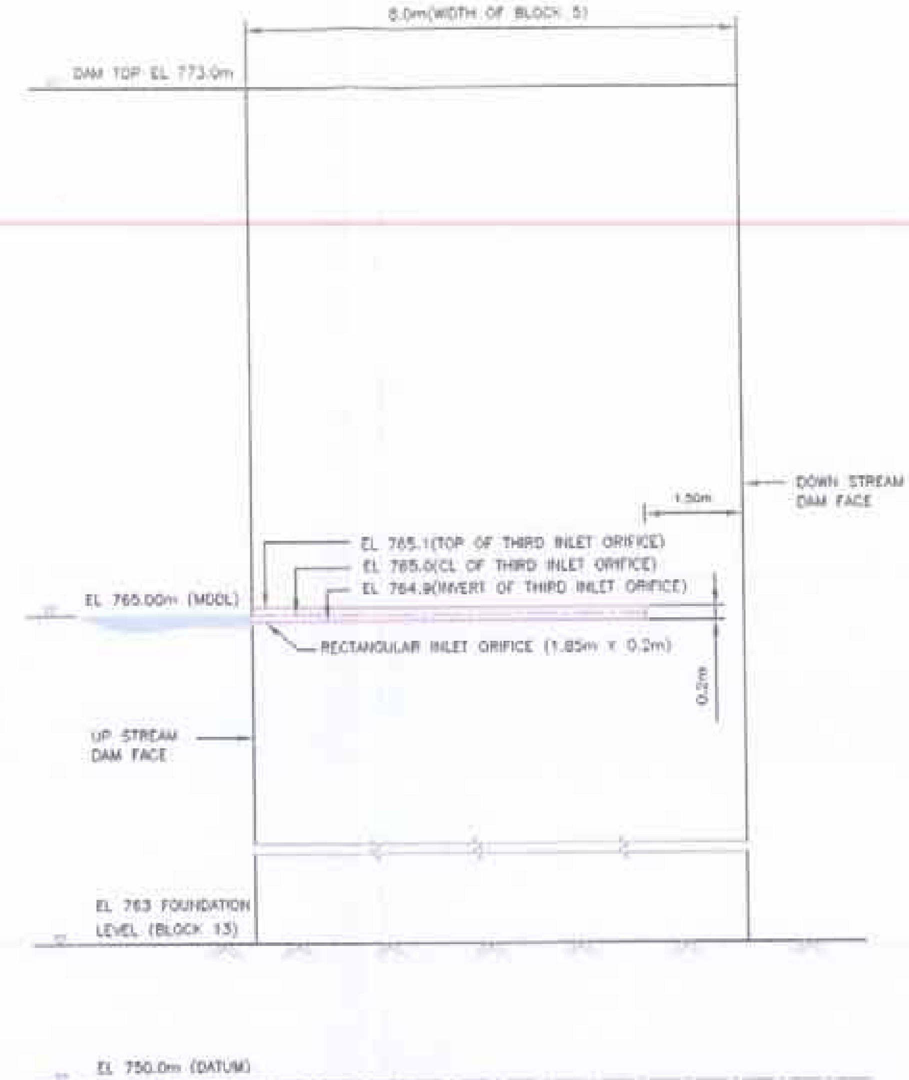
INLET ORIFICE FROM BLOCK NO 5 AT CHAINAGE 84.0m(CROSS SECTIONAL VIEW)

SECTIONAL DETAIL OF TENGA DAM
(FIRST INLET ORIFICE)



INLET ORIFICE FROM BLOCK NO 5 AT CHAINAGE 84.0m(CROSS SECTIONAL VIEW)

SECTIONAL DETAIL OF TENGA DAM
(SECOND INLET ORIFICE)



INLET ORIFICE FROM BLOCK NO 5 AT CHAINAGE 84.0m(CROSS SECTIONAL VIEW)

SECTIONAL DETAIL OF TENGA DAM
(THIRD INLET ORIFICE)

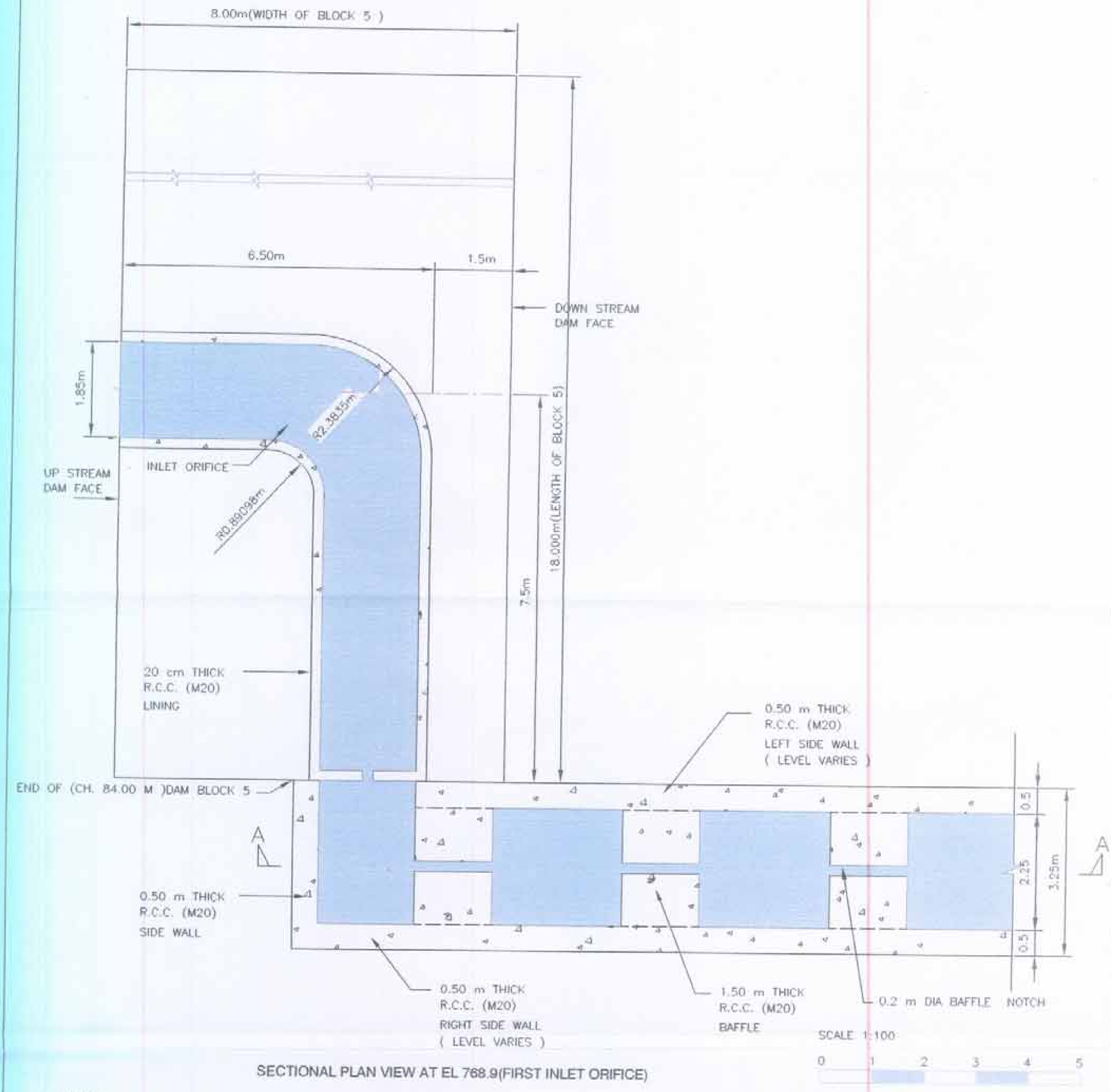
NOTE:

1. WHEN RESERVOIR WATER LEVEL REACHES EL 769.30 THE FIRST INLET ORIFICE MAY BE CLOSED .
2. THE SECOND INLET ORIFICE MAY BE OPENED WHEN THE RESERVOIR LEVEL ATTAINS EL 769.00 AND CLOSED AT RESERVOIR WATER LEVEL 768.10
3. THE THIRD INLET ORIFICE MAY BE OPENED WHEN THE RESERVOIR LEVEL ATTAINS EL 766.00 AND CLOSED AT RESERVOIR WATER LEVEL 765.10
4. THE INLET ORIFICE TAKES A RIGHT ANGLE TURN AT 1.5 m FROM DOWN STREAM FACE OF THE DAM.
5. ALL DIMENSIONS ARE IN METER OTHERWISE MENTIONED.

SCALE 1:100

0 1 2 3 4 5

PROJECT NAME: TENGA DAM FISH PASS IN ARUNACHAL PRADESH NEEPCO, SHILLONG, MEGHALAYA	
TITLE CROSS SECTIONAL VIEW OF INLET ORIFICE (FOR TENGA DAM)	
DRAWING NO. DP/ F.P.T. / 02	REV - 0

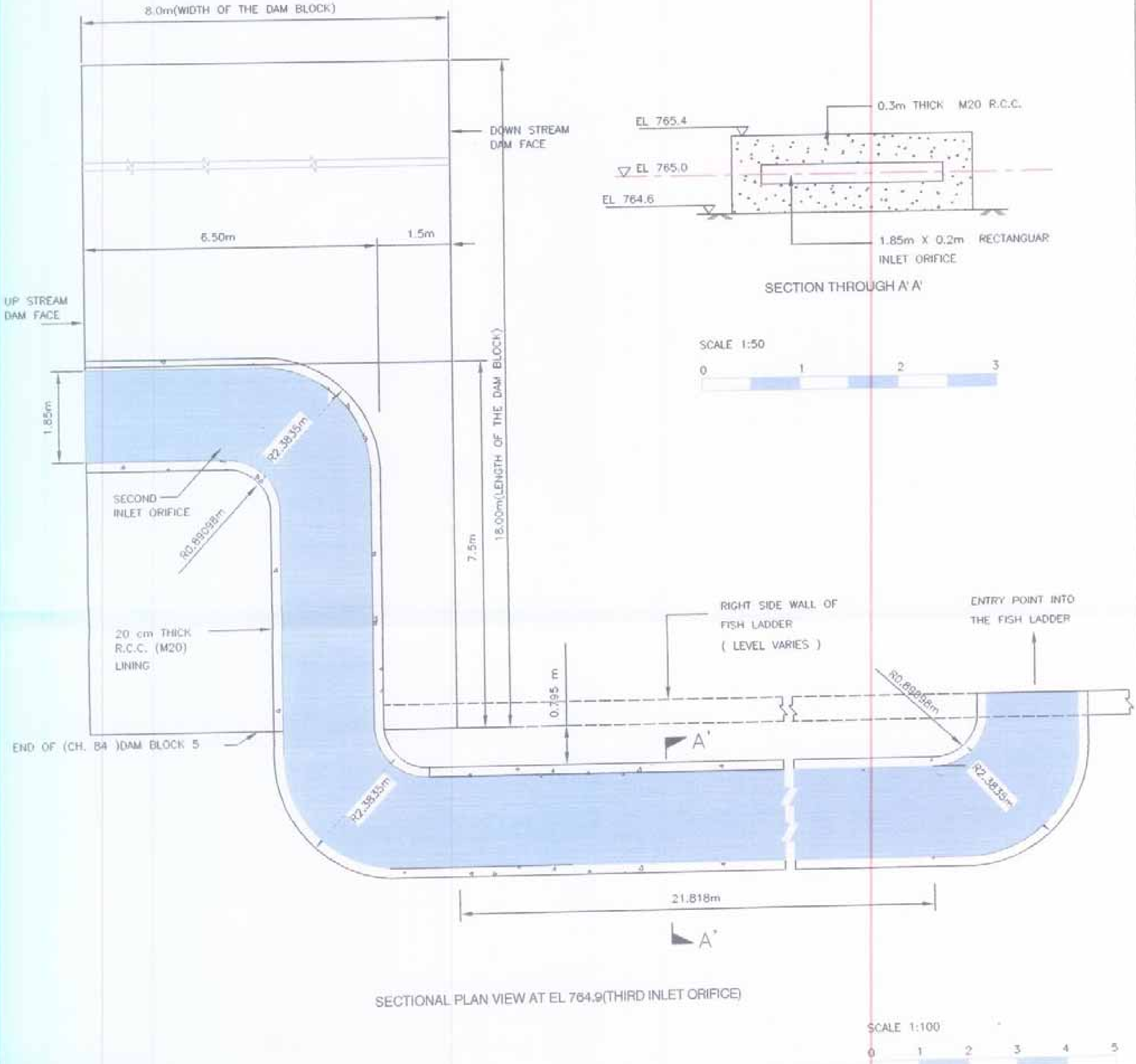


SECTIONAL PLAN VIEW AT EL 768.9(FIRST INLET ORIFICE)

NOTE:

1. ALL CONCRETE WORKS FOR FIRST INLET ORIFICE AND FISH LADDER ARE REINFORCED M20 GRADE
2. EXPANSION JOINT MAY BE PROVIDED AS PER BIS CODE
3. ALL DIMENSIONS ARE IN METER OTHERWISE MENTIONED.
4. SUBSTRATA AND ENTRANCE WELL TO FISH LADDER NOT SHOWN.

PROJECT NAME : TENGA DAM FISH PASS IN ARUNACHAL PRADESH NEEPCO, SHILLONG, MEGHALAYA	
TITLE : CROSS SECTIONAL PLAN VIEW OF TENGA DAM AT EL 768.9 (FIRST INLET ORIFICE)	
DRAWING NO. DP/ F.P.T. / 03	REV. - 0



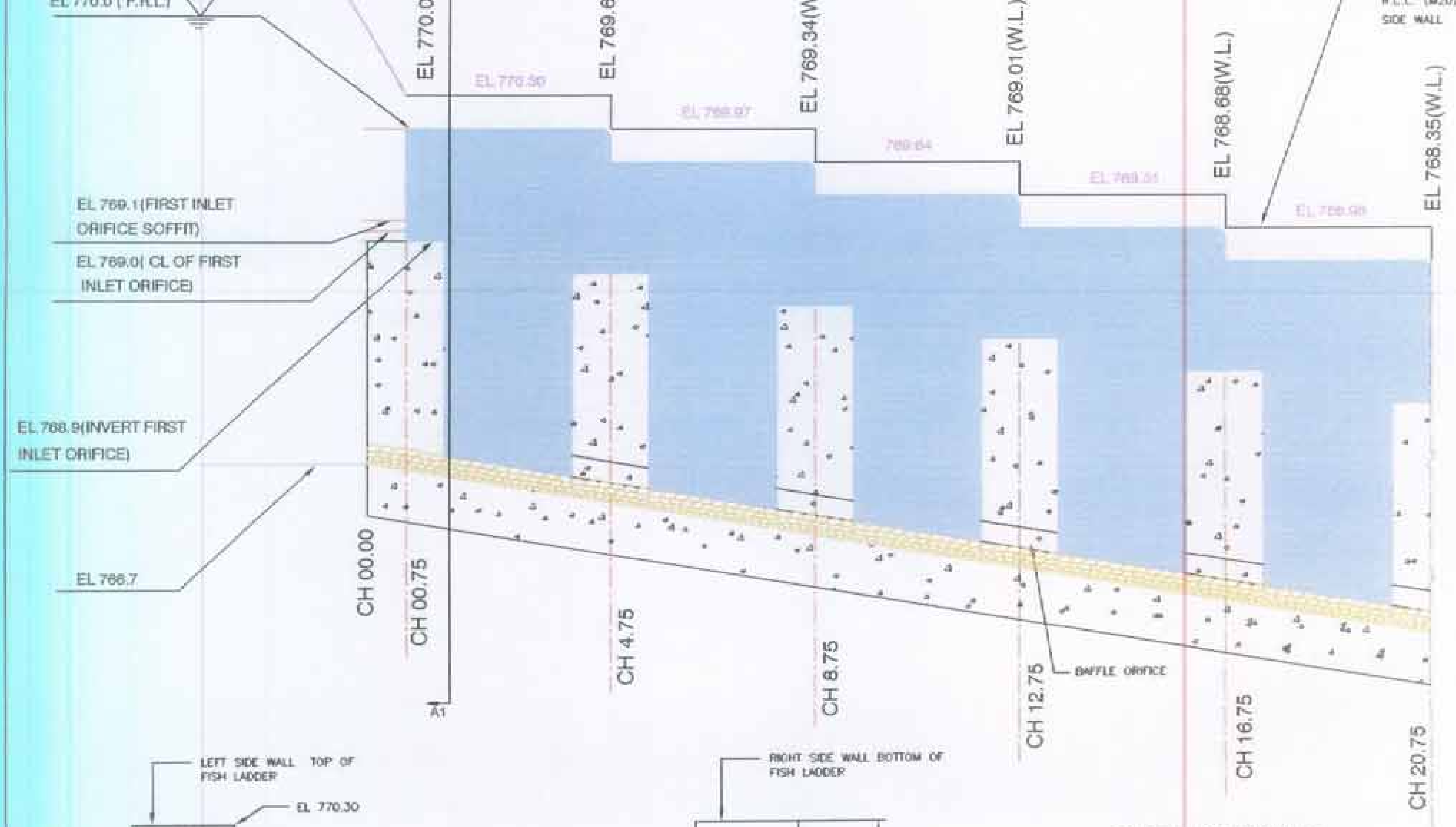
SECTION THROUGH A' A'

SECTIONAL PLAN VIEW AT EL 764.9(THIRD INLET ORIFICE)

NOTE :

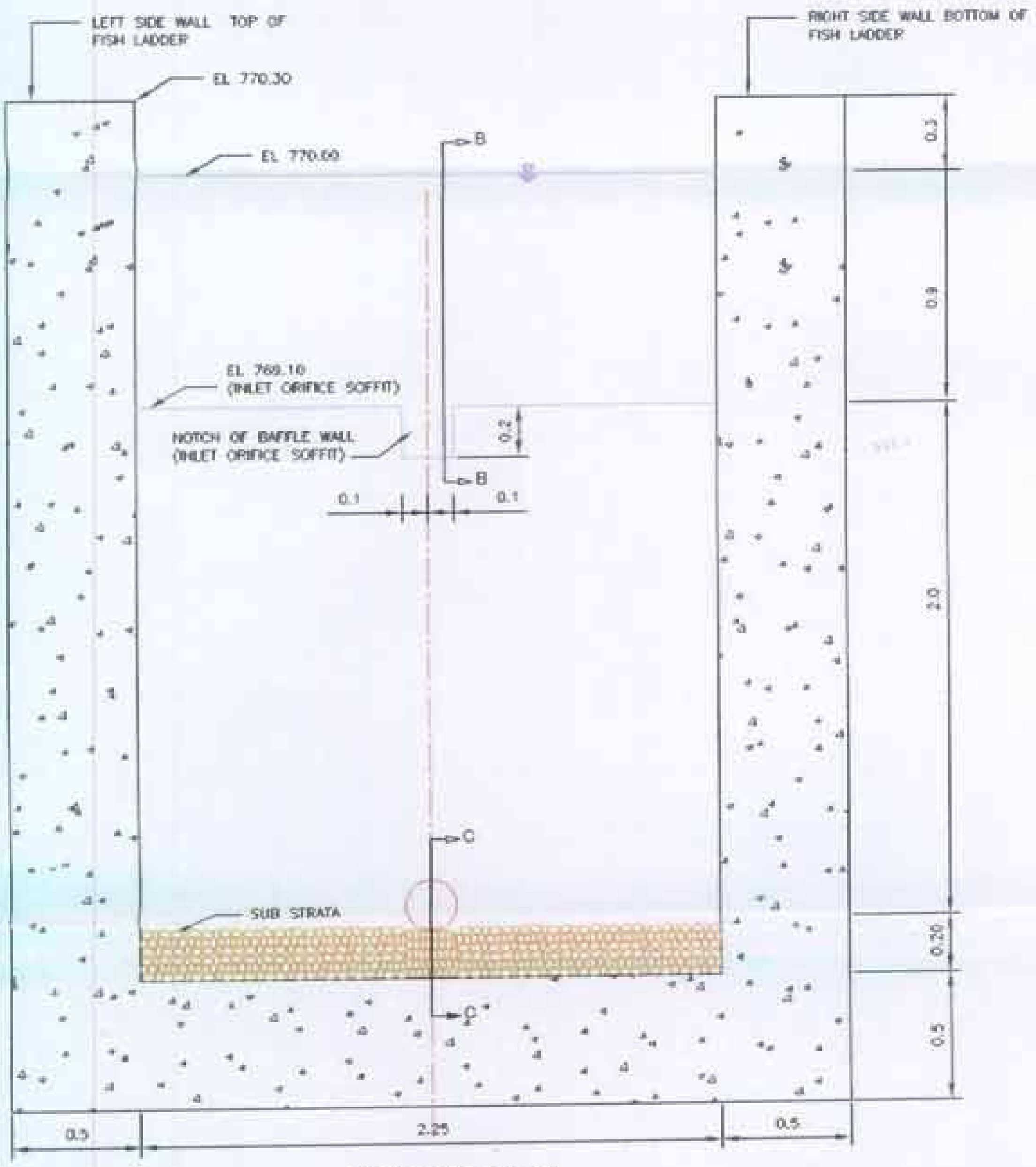
1. ALL CONCRETE WORKS FOR SECOND INLET ORIFICE AND FISH LADDER ARE RE INFORCED M20 GRADE
2. ALL DIMENSIONS ARE IN METER OTHERWISE MENTIONED.
3. THIRD INLET ORIFICE ENTRY INTO THE FISH LADDER IS AT CHAINAGE 21.818 m

PROJECT NAME : TENGA DAM FISH PASS IN ARUNACHAL PRADESH NEEPCO, SHILLONG, MEGHALAYA	
TITLE : CROSS SECTIONAL PLAN VIEW OF TENGA DAM AT EL 764.9 (THIRD INLET ORIFICE)	
DRAWING NO. DP/ F.P.T. / 04/1	REV. - 0



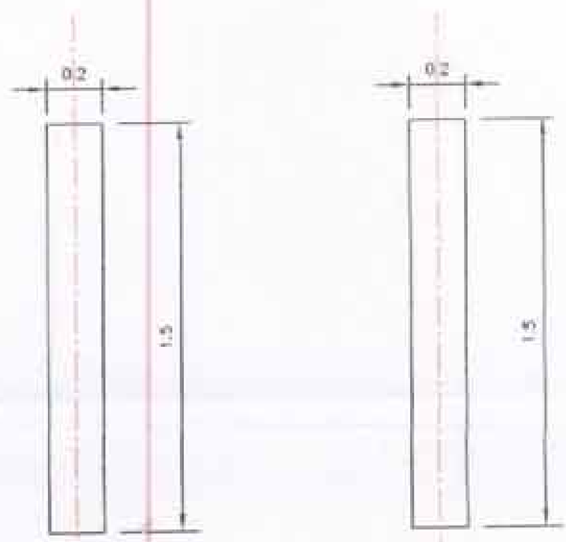
PART SECTIONAL THROUGH AA
(SECTION AA DRAWING REF. DP/F.P.B./00)

SCALE 1:1



SECTION THROUGH A1A1

SCALE 1:25



SECTIONAL PLAN OF BAFFLE NOTCH(BB)

SECTIONAL PLAN OF BAFFLE ORIFICE(CC)

NOTE:

1. ALL CONCRETE WORKS FOR INLET ORIFICE AND FISH LADDER ARE RE-INFORCED M20 GRADE.
2. EXPANSION JOINT MAY BE PROVIDED AS PER BIS CODE.
3. ALL DIMENSIONS ARE IN METER OTHERWISE MENTIONED.
4. W.L. – WATER LEVEL

PROJECT NAME : TENGA DAM FISH PASS IN ARUNACHAL PRADESH NEEPCO, SHILLONG, MEGHALAYA	
TITLE : SECTION THROUGH LADDER	
DRAWING NO. DP/ F.P.T. / 05	REV. - 0

LONG SECTION THROUGH LADDER

(SECTION AA DRAWING REF. DP/F.P.T./03)

SCALE 1:100

0 1 2 3 4 5

NOTE :
W.L. - WATER LEVEL

PROJECT NAME :
TENGA DAM FISH PASS IN ARUNACHAL PRADESH
NEEPCO, SHILLONG, MEGHALAYA

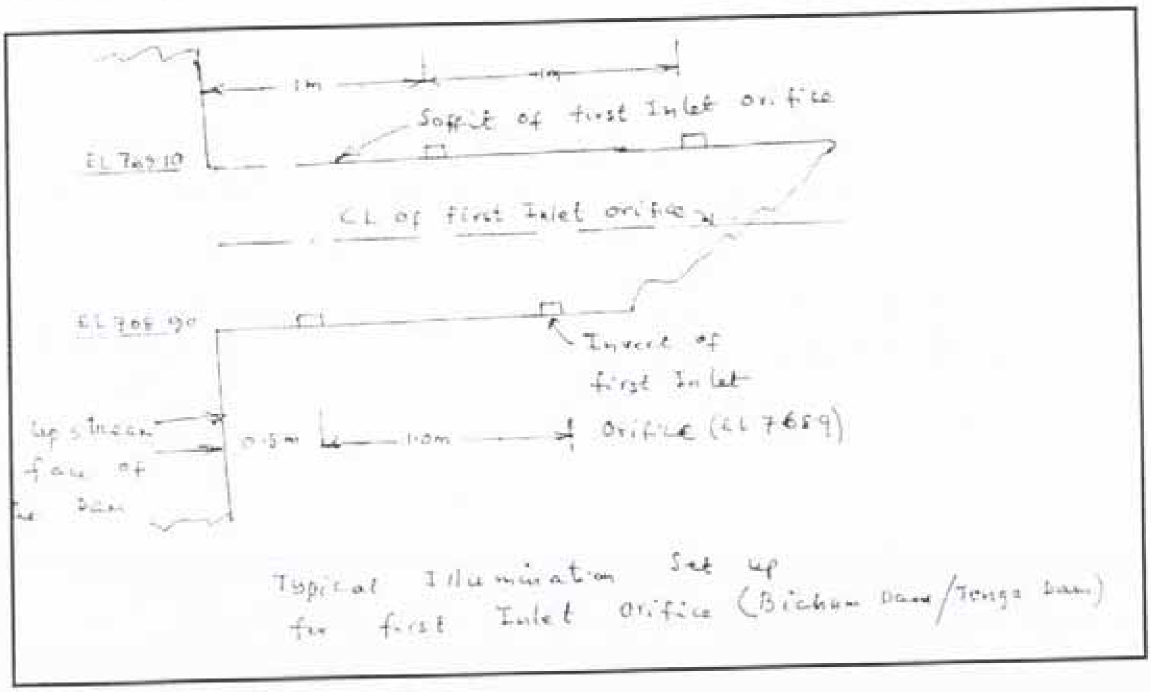
TITLE :
LONG SECTION THROUGH LADDER

DRAWING NO. DP/ F.P.T. / 06 | REV : 0

7.2.4.3 It is suggested that a data I information base may be proposed on the line as suggested in (para 7.1.4.3) of the Report on Bichom Dam: Fish Pass for design of future Fish Passes.

7.2.4.4 Research has shown that when natural illumination is simulated in the Inlet orifice (within the body of the dam) it functions effectively. Hence it is necessary to make provision of adequate illumination (near natural condition) within the Inlet orifice (within the body of the dam). The illumination will be made through installations of 100 watts electrical lamp in a sealed unit at a spacing of one metre at the upper level (EL 768.9) at 0.5m spacing at the lower level (EL 768.9) in the first Inlet orifice. And in a similar pattern for second and third Inlet orifices.

Typical arrangement is indicated below:



8. Projects Hydrology & Other Details essentially required for fish pass

1. Rainfall data (as available for the Project)
2. Monthly /1 a-day period of river yield as considered in the Project Report.
3. Monthly / daily evaporation data from the reservoir.
4. Long section, Cross section of the river on upstream and down stream of the dam.
5. Plan, long section of the dam.
6. Cross section of the dam across:
   (i) Deepest Section
   (ii) Power House
   (iii) For all the dam blocks. .

(iv) Spillway assembly section showing downstream energy dissipation arrangements etc.

(Showing ground levels and other features of the dam like penstocks outlets, galleries, Adits etc. as located in such sections)

(v) Modality of conveyance system adopted from reservoir to reservoir.

7. Reservoir area-elevation, capacity-elevation curves showing therein (or otherwise), DSL, FRL and MWL of the reservoirs.
8. Design TWL rating curves.
9. Spillway rating curve showing therein FRL, MWL, Spillway crest elevation for dams.
10. Design Peak inflow and corresponding outflow and the reservoir attenuation level when the design flow hits the reservoir.
11. The reservoir operation schedule during different months.
12. GAD of the project showing therein land required to be acquired and actually acquired for
    (i) Dam and energy dissipation arrangements
    (ii) Reservoir area
    (iii) The location of existing villages if any in the reservoir and on either side of dams and the existing habitation in the reservoir submerged area map.
13. Contour map of the proposed projects area.
14. Location of all type of forest in the contour map.

Other Data

1. Data on (a) Air Temperature (b) Relative humidity (monthly mean, Maximum and minimum).
2. Temperature of the river water at different points of the river / rivers as may be available in the Project Report and / or State Fisheries Department.
3. Type of fish population and density of such population in the water of river / rivers with Physiological Characteristics as may be available in the Project Report and / or State Fisheries Department.
4. A note on different environmental issues that have been considered in the Project Report.
5. One drawing showing the total Project and various Phase / period of development considered in the Project Report.
6. Bar Chart showing completion of different components of the project.
7. Catchment area map of dam.
8. Location of Power House or other developments envisaged from the projects in suitable size map.
9. Data on existing Fish habitats along the river course as may be available with the State Department of the Fisheries where the project is proposed.

Annexure - 2

SMEC

SMEC INTERNATIONAL PTY. LTD

Ref: 56155/03/01/05-06/541

28 August 2006

Fax No. : 0361-2203187

Shri Utpal Bora
Executive Director (D&E)
NEEPCO Ltd.
NEEPCO Bhawan
R.G. Baruah Road
Guwahati – 781005

Subject: Kameng H.E. Project, Arunachal Pradesh –Bichom Dam Fishway

Reference: Your letter No. NEEPCO/GHY/T-25/2006-07/2697 dated 11 July 2006
Our letter Ref: 56155/03/01/05-06/489 dated 26 June 2006

Dear Sir,

In response to your letter referenced above where you have requested SMEC to submit a detailed layout and structural design of a fish ladder for Bichom dam, we must re-emphasize that our fish experts have studied the CIFRI Report and strongly advise against the use of a fish ladder at the Bichom dam.

Our reasoning is based on a detailed review of the CIFRI report and concludes current international practice in the area of fishways for high dams (height >20 m) is to use fish lifts rather than fish ladders based both on cost and success rates. It is highlighted that numerous fish ladders for high dams world-wide have failed to meet objectives of successfully passing fish upstream of dam structures greater than 20 m in height.

Our internationally recognized fish expert, Mr. Klaas Smitt (CV previously provided with proposal), from Australia is willing to discuss the advantages and disadvantages of fish lifts vs fish ladders with NEEPCO and the CIFRI. This discussion could be by teleconference or in person if NEEPCO was willing to reimburse SMEC for the cost of Mr. Smitt's visit. This meeting could be tied into a site visit and offset against the cost of our proposal to do the fish passage design.

SMEC recognizes that some kind of fish passage must be provided at the Bichom dam and as NEEPCO's design consultant will only recommend what we believe to be in the best interests of both NEEPCO and the project (i.e. one that will meet the stated objective of being able to pass fish over the Bichom dam).

A-1, 1st Floor, Chirag Enclave, New Delhi - 110 048
Tel. : 91-11 26421513, 26421514 Fax: 26421515
E-mail : smec@vsnl.com

Please advise how you would like to proceed.

Yours sincerely,

Colin Russell
Project Manager

Copy to:

1. Mr. J. Barkakati, Director Technical – NEEPCO Ltd - Shillong
2. Mr. H.K. Das, DGM (C) – NEEPCO Ltd - Guwahati

ANNEXURE – 6

SMEC

SMEC INTERNATIONAL PTY. LTD

Ref: 56155/03/01/05-06/489
26th June 2006

Shri Utpal Bora
Executive Director (D&E)
NEEPCO Ltd.
NEEPCO Bhawan
R.G. Baruah Road
Guwahati – 781005

Fax No. : 0361-2203187

Subject: Kameng H.E. Project, Arunachal Pradesh –Bichom Dam Fishway – Review of CIFRI Report

Reference: Your Letter No. NEEPCO/GHy/D&E/T-14/2006-07/2374 dated 02 June 2006 received 12 June 2006
Our letter Ref: 56155/03/01/05-06/465 dated 08 June 2006

Dear Sir,

In relation to our recent proposal to design a high level fishway for the Bichom Dam our fishway experts have reviewed the Central Inland Fisheries Research Institute's (CIFRI) Report on Designing of Fish Pass Facilities for the Bichom and Tenga Dam of Kameng Hydroelectric Project, Arunachel Pradesh (2005) and provide comments in the accompanying letter.

Our detailed review of the CIFRI report concludes support for our proposed high level fish lift concept and advises against a fish ladder as proposed by the CIFRI based on current international practice in the area of fishways for high dams (height >20 m) where numerous failures of fish ladders have occurred.

We would be pleased to discuss our proposal with you further at your convenience.

Yours sincerely,

Colin Russell
Project Manager

Encl. As above

A-1, 1st Floor, Chirag Enclave, New Delhi - 110 048
Tel. : 91-11-26421513, 26421514 Fax: 26421515
E-mail : smec@vsnl.com

Review of CIFRI report on 'Designing of Fish Pass Facilities for Bichom and Tenga Dam of Kameng Hydroelectric Project, Arunachal Pradesh

Fish Biology and Ecology (sections 1 to 5)

The description and detail of the fish biology and ecology of migrations is very thorough and provides more background on a single project than we have seen on any fish pass project in the last 20 years.

Fish behaviour in fishways

A major factor in a successful fishway is accommodating fish behaviour. This is particularly important in long fishways. If a species has a particular diel moment pattern, either day or night, and these fish do not complete their ascent within that diel period then the fish will return back downstream. This has been specifically recorded in Australia (Mallen-Cooper 1999) and it presents one of the most significant risks to the Bichom project.

Accommodating fish behaviour in baffle design is critical. Baffles with orifices are specifically known to inhibit and in some cases prevent the passage of some species (Monk *et al.* 1989). Vertical-slot baffles are now the preferred pool-type fishway design used throughout the world as they pass bottom, mid-water and surface-dwelling fish species and also function at varying headwater and tailwater levels (Mallen-Cooper 1994a, Larinier *et al.* 2002).

Fish swimming speeds (section 4.4.4)

Extrapolating fish swimming speed to fishway design needs to be conservative to ensure fish reach the top of the fishway. As the fishway length increases this becomes more critical. The standard maximum water velocity in pool-type fishways for salmon is 2.4 m/s (0.3 m head loss between pools) and for non-salmonids in Australia it is 1.8 m/s (0.165 m head loss) (Mallen-Cooper 1994b, 1999) and in other countries 2.0 m/s (0.2 m head loss) is used (Clay 1995).

For a very long fishway, such as proposed for Bichom Dam, the maximum velocity should possibly be less than the maximum used for salmon. However, this would make the fishway longer and more expensive.

An important aspect of these quoted standards for maximum water velocities for other fishways are that apply only to relatively thin baffles (0.1 to 0.2 m thick), so that the fish only need to maintain a high swimming speed over a short distance of 0.2 m to pass through the baffle. In the Bichom fish pass design the baffles appear to be 1.5 m thick and so the fish need to maintain a high swimming speed for a much longer distance, which takes much greater effort for the fish. There is a significant risk that fish will not be able to negotiate these baffles and the risk increases with the high number of baffles and the length of ascent.

In pool-type fishways fish need to negotiate the maximum velocity between each pool and the turbulence in each pool. Turbulence or Energy Dissipation Factor (EDF) is quoted in the report as 150 Watts per cubic metre ($W\ m^{-3}$), which is used in Europe for non-salmonids but 125 $W\ m^{-3}$ is used in Canada for non-salmonids and 100 $W\ m^{-3}$ is used in Australia for non-salmonids. Fishways for salmon use up to 200 $W\ m^{-3}$ but these are for much shorter fishways than the one proposed for Bichom Dam.

Turbulence or EDF figures also only produce an average figure for dissipation of energy, and the pattern of energy dissipation is critical for optimal fish passage. Two fishways with the same figure for EDF can have very different performance in passing fish. Vertical-slot fishways dissipate turbulence more evenly than orifice fishways.

Review of options – current international practice in fish passage at high dams

In section 6.1 the major methods of fish passage at high dams are presented. However, these are not critically reviewed for the site and the current international practice in fish passage at high dams is not presented.

The present international practice is:

- for low barriers (up to 6 m or 8 m high), use
    - pool-type fish passes,
    - Denil fishways, and
    - rock-ramp fishways

- for medium-level barriers (up to 6 m 20 m high) use
    - fish locks (if there is a low biomass and no behavioural issues of fish entering and leaving the lock, or remaining in the lock)
    - use fish lifts (if the biomass is high, or if there are behavioural issues that prevent the use of a fish lock)

- for high-level barriers (>20 m high) use
    - fish lifts, or
    - trap-and-transport systems, which usually require a short fish lift to enable fish to be placed in a specialised tanker. (trap-and-transport systems work well where the fish have very well-defined and predictable migration season so that staff can be employed for the same fixed period each year)

There are a few exceptions to these, such as some high fish locks, but the dominant trend at high barriers is to use fish lifts. Long pool-type fishways have failed over the last 40 years and high fish locks have failed at sites with high biomass, particularly in South America. Countries following the trend of fish lifts at high barriers include France, US, Australia and countries in South America.

Risks

The risk of the proposed fishway not enabling fish to fully ascend is very high. The only method of reducing this risk is to test the fish in full-scale experimental models, where the model produces the same maximum water velocities, the same average turbulence and the same patterns of flow and energy dissipation. In this method fish behaviour is tested as well as fish swimming ability through the baffles; this approach has been very successful for low–level fishways up to 6.5 m high (Mallen-Cooper 1992, 1994a, 1994b, Stuart and Mallen-Cooper 1999).

However, we do not recommend this approach as the results from a short experiment model could never be extrapolated with confidence to a very long fishway. In addition, the present international practice of fish lifts at high dams developed over many decades partly as response to the failure of long pool-type fishways. In essence it is very easy to trap fish in a single chamber in a fish lift where swimming speed and turbulence is not limiting and can also be manipulated in commissioning to optimise fish attraction.

References

Larinier, M., Travade, F. and Porcher J.P. (2002). Fishways: biological basis, design criteria and monitoring. *Bull. FR. Peche Pisci.* **364** suppl. 208 p.

Mallen-Cooper, M. (1992). Swimming ability of juvenile Australian bass, *Macquaria novemaculeata* (Steindachner), and juvenile barramundi, *Lates calcarifer* (Bloch), in an experimental vertical-slot fishway. *Australian Journal of Marine and Freshwater Research* **43**, 823-34.

Mallen-Cooper, M. (1994a). How high can a fish jump? *New Scientist* [16 April 1994]. **142** (1921), 32-7.

Mallen-Cooper, M. (1994b). Swimming ability of adult golden perch, *Macquaria ambigua* (Percicthyidae), and adult silver perch, *Bidyanus bidyanus* (Teraponidae), in an experimental vertical-slot fishway. *Australian Journal of Marine and Freshwater Research* **45**, 191-8.

Mallen-Cooper, M. (1999). Developing fishways for nonsalmonid fishes: a case study from the Murray River in Australia. pp. 173-195 *in* M. Odeh (ed.). Innovations in Fish Passage Technology. (American Fisheries Society: Bethesda, Maryland.)

Monk, B., Weaver, D., Thompson, C., and Ossiander, F. (1989). Effects of flow and weir design on the passage behaviour of American shad and salmonids in an experimental fish ladder. *North American Journal of Fisheries Management* **9**, 60-67.

Stuart, I.G. and Mallen-Cooper, M. (1999). An assessment of the effectiveness of a vertical-slot fishway for non-salmonid fish at a tidal barrier on a large tropical/sub-tropical river. *Regulated Rivers* **15**, 575-590.

By Speed Post

ANNEXURE-4

केन्द्रीय अंतर्स्थलीय मात्स्यकी अनुसंधान संस्थान
(भारतीय कृषि अनुसंधान परिषद)
बैरकपुर, कोलकाता - 700120, पश्चिम बंगाल
Central Inland Fisheries Research Institute
(Indian Council of Agricultural Research)
Barrackpore, Kolkata 700 120, West Bengal, India
Phone (033) 2592 0177 (O), Fax : 033 2592 0388, EPBX2592 1190 / 91 Ext
E-mail : cifri@vsnl.com.; kuldeepvass@rediffmail.com

डॉ० कुलदीप कुमार वास
निदेशक
Dr. K. K. Vass
Director

Alk 24/4/06

FAX- 0364-2222126

No.CIFRI/PS/55/05 663

Dated : 13.4.06

To
The General Manager (Planning),
North Eastern Electric Power Corporation Ltd.,
Brookland Compound,
Lower New Colony,
Shillong-793 003.

Sub : Consultancy services for Design of Fish pass facilities for Bichom And Tenga dam of Kameng Hydro Electric Project (600 MW), Arunachal Pradesh – submission of final report regarding.

Ref : Your letter No.GM©/Planning/E&F-9(Pt-III)/2006-07/27 dated 10.4.2006

Sir,

I invite a reference to your above cited letter. The desired modification of the Bichom dam fish pass design as per discussion held in New Delhi on 20th December 2005 has already been incorporated and is enclosed. The design of Tenga dam fish pass is also submitted but your constraints in releasing the required flows will hamper its functioning. This points has been brought to your notice earlier too during discussion & writing also. Hence, as per the terms and conditions of our consultancy assignment, the work assigned to us stands completed. Hope, you will kindly release the remaining amount of the consultancy assignment at your earliest.

The alternative suggestion in the event of the fish pass for Tenga dam being not considered, is to artificially produce the seeds of the affected fish species by establishment of hatcheries/farms at suitable places.

However, the feasibility of this will have to be examined separately, which can not fall within the ambits of present work.

Yours faithfully,

(K. K. Vass)

Receipt No. 92
Dat 22/4/06
o/o G. M. (Planning), Shillong-3

Report on Bichum Dam Fish Pass (Modified Ladderlength)

1 INTRODUCTION

1.1 The Report on Bichum Dam Fish Pass with all details was submitted in August 2005. The designed length of Fish Pass Was 797.50 m.

1.2 This Report was discussed in a meeting convened by NEEPCO during December 2005. After detail discussions on various issues namely location of the Fish Pass, river flow and Fish Pass details, the NEEPCO requested to examine the possibility of reducing the length of the Fish Ladder in view of high cost involved to provide a 797.5 m length of the Ladder and the budgetary constraint.

1.3 All the issues (Item 2, Item 3 and Item 5) discussed in details in the August 2005 Report on Bichum Dam Fish Pass remain unchanged except Item 4, *viz.* Design Aspect due to reduction in the length of the ladder and indicated in Item 2 below.

2 DESIGN ASPECT

2.1 The drop between baffle to baffle has been limited to 0.33 m and velocity generated is 2.54 m/sec. Which is close to allowable limit of 2.60 m/sec. of cruising velocity for the type of fish population in Bichum dam.

2.2 The spacing (c/c) of each of the baffle wall has been kept at 3.30 m. The slope of Fish Ladder provided works out to 1 in 10 which is the allowable upper limit for the Fish Ladder design compatible to the type of fish population observed in the project area of Bichum Dam.

2.3 The alignment of the proposed Fish Pass has been marked on a 40 m contour interval map of the survey of India (Drawing No.DP/F.P.B./Fig.1).

There are 197 number of baffle walls each of thickness 1.3 m and height of 2.0 m over 0.20 m thick sub-strata. The details are shown in drawing no.(DP/F.P.B./06 Rev.1). The length of the Fish Ladder now comes to 645.20 m measured from center line of the first baffle wall (Ch.0.00).

A 1.5 m width cement concrete (M25) cut-off has been provided at the end of the Fish Ladder (Ch.645.85 m). The bottom of the cut-off should be taken upto 0.4 m below the scour level or upto firm rock level whichever is earlier (Drawing No.DP/F.P.B./06 Rev.1).

2.4 The following drawings (Originally sent with the August 2005 Report on Bichum Dam Fish Pass) are now enclosed after necessary changes as required.

(1) Drawing No.DP/F.P.B./03 Rev.1

(2) Drawing No.DP/F.P.B./05 Rev.1

(3) Drawing No.DP/F.P.B./06 Rev.1

(4) Drawing No.DP/F.P.B./Fig.1 Rev.0

ANNEXURE-7

KAMENG HYDRO ELECTRIC PROJECT (600 MW)
SALIENT FEATURES (Tender Stage)

I.	**Location**	:	Located in the West Kameng District of Arunachal Pradesh.
	Bichom Dam	:	Across river Bichom 3.65 Km downstream of the confluence of Bichom & Digien.
	Tenga Dam	:	Across river Tenga 12.5 Km upstream of confluence of Bichom and Tenga river.
	Power House	:	On the right bank of Kameng river near Kimi village in the West Kameng District.
II.	**Bichom Dam**		
	Catchment Area	:	2277 Sq. Km.
	Design Flood Discharge	:	9434 cumecs.
	SPF	:	--
	Dam Height	:	75 m (above deepest foundation).
	Length	:	230 m.
	Type	:	Concrete Gravity.
	Average river Bed Level	:	706 m.
	Top of Dam	:	773 m.
	Pond Level (FRL)	:	770 m.
	Deepest foundation Level	:	698 m
	MDDL	:	766 m
	Maximum water level	:	771 m
	Live Storage	:	4.32 MCM
	Spillway	:	Ogee shaped concrete spillway having 6 radial gates, of size 12 m x 15 m and crest level at an elevation 755.00 m.
III.	**Tenga Dam**		
	Catchment Area	:	1019 Sq. Km.
	Design Flood Discharge	:	2438 cumecs.
	Dam Height	:	27 m (above deepest foundation).
	Length	:	85 m.
	Type	:	Concrete Gravity.
	Average river Bed Level	:	753 m.
	Top of Dam	:	773 m.
	Pond Level (FRL)	:	770 m.
	Deepest foundation Level	:	747 m
	MDDL	:	765.0 m
	Crest Level	:	758 m
	Maximum water level	:	771 m

Live Storage	:	0.32 MCM
Spillway	:	Ogee shaped concrete spillway having 2 radial gates, of size 14 m x 12 m

IV. Low Pressure Tunnel

Shape	:	Modified Horse shoe concrete lined
Length & Diameter	:	14.527 Km, 6.7 m dia.
Design discharge	:	140 cumecs.
Velocity	:	4.0 m/sec.
Invert Level at Bichom	:	750 m.
Slope of tunnel	:	1 in 1000

A. Adit-I

Shape	:	D Shape
Length	:	84.30m
Invert at Portal	:	EL. 749.00m a.s.l.
Outward Gradient	:	1 in 216.32
Invert at Junction	:	EL. 749.31m a.s.l.
Length of HRT under Adit-I	:	5100m (785.0m + 4315.0m)

B. Adit-II

Shape	:	D Shape
Length	:	388.450m
Invert at Portal	:	EL. 764.30m a.s.l.
Outward Gradient	:	1 in 16.67
Invert at Junction	:	EL. 741.00m a.s.l.
Length of HRT under Adit-II	:	4266m (4123.0m + 143.0m)

C. Adit-III

Shape	:	D Shape
Length	:	281.200m
Invert at Portal	:	EL. 760.00m a.s.l.
Outward Gradient	:	1 in 14.42
Invert at Junction	:	EL. 740.50m a.s.l.
Length of HRT under Adit-III	:	2684m (280m + 2404m)

D. Adit-IV

Shape	:	D Shape
Length	:	348.97m
Invert at Portal	:	EL. 725.522m a.s.l.
Outward Gradient	:	Upward 1 in 129 (100m) Inward 1 in 27.50 (248.97m)
Invert at Junction	:	EL. 717.233m a.s.l.
Length of HRT under	:	2427.50m (2295m + 132.50m)

Adit-IV

V. Surge Shaft

Type	:	Restricted orifice type surge shaft located at the end of Low Pressure Tunnel.
Diameter	:	25 m (expansion chamber).
Diameter of orifice	:	3.75 m.
Top of surge tank	:	794 m.
Up Surge Level	:	788.2 m.
Down Surge Level	:	743.4 m.

VI. High Pressure Tunnel

Type	:	Combination of underground-overground – underground steel lined pressure tunnel.
Number	:	1 no of 5.3 m dia of length 601.16 m taking off from surge tank, bifurcating into 2 nos of 3.75 m dia of length 1415.813 m & 1415.497 m respectively and then each bifurcating into 2 nos of 2.65 m dia of length 52.15 m to feed 4 units of 150MW.
Diameter of main penstock	:	5.3 m

VII. Power Houe

Type	:	Surface.
Size of Power House	:	120 m x 37.3 m (between A & E line).
Length of Service bay	:	36 m
Width of Service bay	:	20 m
Height of Service Bay	:	±19.5 m
Length of each unit of Machine hall	:	27.3 m
Width of each unit of Machine hall	:	20 m
Draft Tube Floor	:	221.20 m
Turbine and MIV Center line Level	:	225.50 m
Turbine Floor Level	:	228.00 m
Generator Floor Level	:	232.00 m
Operating Floor Level	:	236.70 m
Service Bay Level	:	243.50 m
Top of Control Room Level	:	248.50 m
Top of Crane Beam Level	:	258.00 m
Installed Capacity	:	4 x 150 MW

Type of Turbine	:	Vertical Francis Turbine.
No. & capacity of generating unit	:	4 units of 150 MW.
Firm Power	:	163 MW.
Energy Generation	:	3592 MU.
Unit spacing	:	20 m centre to centre.
Tail Water level (Max)	:	256.60 m.
Tail Water level (Min)	:	233.59 m.
Tail Water level (Normal)	:	234.64 m.
Gross Head	:	536 m.
Rated Head	:	504 m.
Rated Discharge per unit	:	32.8 cumecs
Normal Speed	:	428.6 r.p.m.
Generator Parameters		
Type	:	Synchronous & Semi Umbrella type
Phase	:	3
Rated Power	:	150 MW
Frequency	:	50 Hz
Generation Voltage	:	13.8 kV
Length of Tail race channel	:	50.0 m.

VIII. Switchyard — surface, 132 kv & 400 kv; double & transfer bus arrangement

IX. Construction Period : 5 Years

X. Project Cost : 2496.90 crores (i/c IDC= Rs. 249.09 crores) at march 2004 price level)

XI. Tariff :

Levellised	:	Rs. 1.31 per unit
1^{st} year	:	Rs. 1.72 per unit

KAMENG HYDRO ELECTRIC PROJECT (600 MW)

SALIENT FEATURES (REVISED)

I.	**Location**	:	Located in the West Kameng District of Arunachal Pradesh.
	Bichom Dam	:	Across river Bichom 3.65 Km downstream of the confluence of Bichom & Digien.
	Tenga Dam	:	Across river Tenga 10.5 Km upstream of confluence of Bichom and Tenga river.
	Power House	:	On the right bank of Kameng river near Kimi village in the West Kameng District.
II.	**Bichom Dam**		
	Catchment Area	:	2,277 Sq. Km.
	Design Flood Discharge	:	9,216 cumecs.(Approved by CWC vide CWC. U.O. No.4/334/2010-Hyd(NE)/418 dtd 24-10-2011)
	Dam Height	:	69 m (above deepest foundation).
	Length	:	264.15 m.
	Type	:	Concrete Gravity.
	Average river Bed Level	:	706 m.
	Top of Dam	:	773 m.
	Pond Level (FRL)	:	770 m.
	Deepest foundation Level	:	704 m
	MDDL	:	764.5 m
	Maximum water level	:	771.49 m (Based on model study and confirmed by SMEC's letter no.56155/03/01/09-10 /1183 dtd.15th Sept'09.)
	Live Storage	:	5.718 MCM
	Invert level of Breast wall	:	746.8 m (Based on model study and confirmed by SMEC's letter no.56155/03/01/09-10 /1183 dtd.15th Sept'09.)
	Spillway	:	Ogee shaped concrete spillway having 6 radial gates, of size 9 m x 11.8 m and crest level at an elevation 735.00 m.
	CL of trunion of radial gate	:	745 m (Based on model study and confirmed by SMEC's letter no.56155/03/01/09-10/1183 dtd.15th Sept'09.)
III.	**Tenga Dam**		
	Catchment Area	:	1,019 Sq. Km.
	Design Flood Discharge	:	3,862 cumecs. (Approved by CWC vide CWC. U.O. No.4/334/2010-Hyd(NE)/418 dtd 24-10-2011)
	Dam Height	:	24.5 m (above deepest foundation).
	Length	:	103 m.
	Type	:	Concrete Gravity.
	Average river Bed Level	:	756 m.

	Top of Dam	:	773 m.
	Pond Level (FRL)	:	770 m.
	Deepest foundation Level	:	748.60 m
	MDDL	:	763.00 m
	Crest Level	:	756 m
	Maximum water level	:	771.67 m (based on model study & apprvd SPF)
	Live Storage	:	0.5 MCM
	Spillway	:	Flat apron type concrete spillway having 2 radial gates, of size 14 m x 14 m and crest level at an elevation 756.00 m.
IV.	**Low Pressure Tunnel**		
	Shape	:	Modified Horse shoe concrete lined
	Length & Diameter	:	14.527 Km, 6.7 m dia.
	Design discharge	:	140 cumecs.
	Velocity	:	4.0 m/sec.
	Invert Level at Bichom	:	750 m.
	Slope of tunnel	:	1 in 1000
A.	**Adit-I**		
	Shape	:	D Shape
	Length	:	84.30m
	Invert at Portal	:	EL. 749.00m a.s.l.
	Outward Gradient	:	1 in 216.32
	Invert at Junction	:	EL. 749.31m a.s.l.
	Length of HRT under Adit-I	:	5100m (785.0m + 4315.0m)
B.	**Adit-II**		
	Shape	:	D Shape
	Length	:	398.60 m
	Invert at Portal	:	EL. 764.30m a.s.l.
	Outward Gradient	:	1 in 16.67
	Invert at Junction	:	EL. 741.00m a.s.l.
	Length of HRT under Adit-II	:	4266m (4123.0m + 143.0m)
C.	**Adit-III**		
	Shape	:	D Shape
	Length	:	277.35 m
	Invert at Portal	:	EL. 760.00m a.s.l.
	Outward Gradient	:	1 in 14.42
	Invert at Junction	:	EL. 740.50m a.s.l.
	Length of HRT under Adit-III	:	2684m (280m + 2404m)
D.	**Adit-IV**		
	Shape	:	D Shape

	Length	:	348.97m
	Invert at Portal	:	EL. 725.522m a.s.l.
	Outward Gradient	:	Upward 1 in 129 (100m) Inward 1 in 27.50 (248.97m)
	Invert at Junction	:	EL. 717.233m a.s.l.
	Length of HRT under Adit-IV	:	2427.50m (2295m + 132.50m)
V.	**Surge Shaft**		
	Type	:	Restricted orifice type surge shaft located at the end of Low Pressure Tunnel.
	Diameter	:	25 m (expansion chamber).
	Diameter of orifice	:	3.75 m.
	Top of surge tank	:	794 m.
VI.	**High Pressure Tunnel**		
	Type	:	Combination of underground-overground – underground steel lined pressure tunnel.
	Number	:	1 no of 5.3 m dia of length 601.16 m taking off from surge tank, bifurcating into 2 nos of 3.75 m dia (at Valve House) of length 1415.813 m & 1415.497 m respectively and then each bifurcating into 2 nos of 2.65 m dia of length 52.15 m to feed 4 units of 150MW.
VII.	**Power House**		
	Type	:	Surface.
	Size of Power House	:	120 m x 37.3 m (between A & E line).
	Width of each unit of Machine hall	:	20 m
	Installed Capacity	:	4 x 150 MW
	Type of Turbine	:	Vertical Francis Turbine.
	No. & capacity of generating unit	:	4 units of 150 MW.
	Firm Power	:	168.86 MW. (CEA dtd 09.01.2012)
	Annual Energy Gen	:	3431 MU. (CEA dtd 09.01.2012)
	Design Energy @ 95% m/c availability	:	3353 MU (CEA dtd 09.01.2012)
	Annual Load Factor	:	65.1 %
	Lean Period Load factor	:	35.0 %
	Efficiency of TG Set		92.98% (CEA dtd 09.01.2012)
	Unit spacing	:	20 m centre to centre.
	Tail Water level (Max)	:	253 m (D&E/T-16)187 dtd 17/04/2012)
	Tail Water level (Average)	:	234.637 m (CEA dtd 09.01.2012)
	Tail Water level (Min)	:	233.59 m.
	Gross Head	:	536 m.
	Head Loss	:	40.78 m (HCD,CWC(NW&S)/1410 dtd 28/11/2011)
	Net Head	:	492.75 m (CEA dtd 09.01.2012)
	Hydrology Series	:	1969-70 to 1981-82 (CEA dtd 09.01.2012)

	Dependable year	:	1981-82 (CEA dtd 09.01.2012)
	Peaking (Hours)	:	6.75 (CEA dtd 09.01.2012)
	Generating Voltage	:	13.8 kV (CEA dtd 06.01.2012)
VIII.	**Switchyard**		surface, 132 kv & 400 kv; double & transfer bus arrangement
IX.	**Construction Period**	:	5 Years (approval)