ANNEXURE –

(Detailed Project Report of Karcham Wangtoo HEP in 6 (Six) Volumes)

VOLUME - III

JAIPRAKASH
INDUSTRIES LIMITED

HYDRO POWER DIVISION

KARCHAM-WANGTOO HYDRO-ELECTRIC PROJECT (1000 MW)
HIMACHAL PRADESH

PROJECT REPORT

(REVISED)

VOLUME III

ENGINEERING AND COSTING

CONSULTANTS

iDEA
INTERNATIONAL DESIGN ENGINEERING ASSOCIATES LIMITED

NEW DELHI

DECEMBER 2000

KARCHAM-WANGTOO HYDRO-ELECTRIC PROJECT (1000 MW)
HIMACHAL PRADESH

PROJECT REPORT

VOLUME III - ENGINEERING AND COSTING

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Chapter - A1

CATCHMENT CHARACTERISTICS

1.1 Satluj Basin

The geographical limits of the Satluj basin upto Bhakra Dam lie between latitude 30°N to 33°N and longitude 76°E to 83°E. It covers its area in Nari Khorsam province of Tibet (China) and in Himachal Pradesh State of India. The catchment area at Bhakra dam is about 56875 sq. km out of which about 36900 Sq. km falls in Tibet and 19975 Sq. km in India.

The basin represents some remarkable physical features. Below it stretch the loftiest mountain ranges of the world radiating from the Pamir Knof. The most southerly of these is the Himalayan range which is the loftiest and longest range in the world. The Himalayas which run first south-east-wards from the Pamir Knof and later in an easterly direction, constitute a massive mountain wall extending over 2500 km with a varying width of 250 to 300 km.

Topographically and climatically the catchment has been divided into four categories as below :

i) **Tibetan Plateau**

River Satluj rises in Tibetan Plateau in the region of the Mansarovar lake situated at an elevation of about 4570m above mean sea level. The river passes through the 'Tibetan province of Nari Khorsam'. The best known portion of Nari Khorsam is the plateau situated between Zanskar and Ladakh ranges. This plateau has been formed by successive deposits of boulders, gravel, clay and mud in the trough between two ranges. The deposits lie in parallel and nearly horizontal beds. River Satluj has been able to cut a channel about 915 m deep through the Plateau with the water received from glaciers. The vertical banks stand-un-eroded as there is no local rainfall. River Satluj in Nari Khorsam region is joined by several tributaries, the beds of which lie about 305 m or more below surface of the plain and their over hanging cliffs similar to those of Satluj have been spared from destruction by rain. The flat portions of the Plateau now remain standing between profound gorges. There is absolutely no vegetation in this region. When the snow melts deep channels are formed on the surface. The river Satluj enters India near Shipkila after traversing a length of about 320 kms, in the Tibetan province of Nari Khorsam.

ii) **Spiti Valley**

Spiti river is the biggest tributary of the river Satluj and joins river Satluj at Namgia, 14 kms upstream of Pooh. The characteristics of this catchment area are identical to that of the Tibetan Plateau. Rainfall in this area is scarce. Height of the catchment area drained by river Spiti is between 3048m and 4570m. In this area, there is absolutely no vegetation. The melting snow forms deep flow channels.

iii) **Namgia to Karcham Dam Site**

This catchment is bounded by moderately high hills (1525m to 3048m) and has little rainfall but heavy snow. The snow line in this region is at ± 3048m. The flows in the river are mainly due to snow melting which follows more or less a regular pattern. Due to the absence of rain, arid conditions prevail and the good forests seen below Wangtoo are not existing in this area. The well formed pine forests near Wangtoo give way to `Chilgoza' plantations at the higher elevation. The area has steep slopes with little earth cover and very little rain.

When snow falls, water enters into the rock crevices where its freezing during winter causes cracks and crushes the rocks. The subsequent loads of snow accelerate this phenomenon. When the snow melts, the disintegrated debris slides with the water into the river. This cycle repeats year after year.

iv) **Karcham Dam site to Bhakra Dam**

The catchment has high surrounding hills like Narkanda, Shimla (3050m) etc, but is flanked by foot hills of Shiwaliks near Bhakra Dam (915m). Rainfall in this area is moderate to heavy. The rocks are well formed and have a good earth cover.

The relief map of Himalayas, Tibet and adjoining areas is indicated in Fig A-1. South-North and West-East section of the Plateau and adjoining areas are shown in Fig. A-2.

1.2 The River Profile

River Satluj rises near Rakas-Tal lake which is fed by lake Mansarovar at about 4570 m, above mean sea level. Between Rakas-Tal and Shipkila, near the Indian border, the Satluj river takes a North-Westerly course for a length of about 320 km, in the Tibetan province of Nari-Khorsam. The Satluj is joined by several tributaries in Nari-Khorsam such as Zhangchu, Drama Yankti, Chonak, Manglan Transuo, Sumna, Trape etc. Immediately after entering the Indian territory near Shipkila the river takes a south-westerly direction on its way to Bhakra gorge which is about 320 km away. After crossing this gorge, it emerges onto the plains of the Punjab. The Satluj crosses the Great Himalaya at a point where the range bifurcates. At Rampur, it crosses the Dhauladhar range through a series of successive Shiwalik ranges. The Naina Devi range, where the Bhakra Dam is situated, is the last of the series. Between Suni and Dehar the river takes a somewhat north-westerly direction. At Dehar, the river turns in a south-westerly direction to reach the foot of Naina Devi range. The Naina Devi range deflects the river again in a north-westerly direction when it flows parallel to the range for about 32 km before cutting through at Bhakra gorge.

The principal tributaries of the Satluj below Shipkila are the Spiti, Kashming, Baspa, Bhaba, Nogli, Korpan, Nauti, Sholding, Seer, Bharari, Ali and Ghamber Khad.

Numerous glaciers large and small, drain into the Satluj at various points on its course. East of Mansarovar and feeding its principal source are the glaciers of the Ganglung Gaungni. The Southern glaciers of Kailash flow into the Satluj through the lake of Rakas-Tal. The northern glaciers of peak kamer also contribute to the stream. The glaciers of peak Riwa Phargul which stands in the Satluj catchment also flow into it. There are many Himalayan glaciers draining into its tributary, the Baspa, and many more from the direction of the Bara-Lacha pass from the water sheds of the Chenab and Beas.

The fall of Satluj from its source to the plains of India is very uniform. The height of the bed is about 4570 m near Rakas-Tal, 2530 m near Shipkila, 915m at Rampur, 460m at Bilaspur and 350 m at the Bhakra Dam site.

The total catchment area of the Satluj above the Bhakra Dam site is about 56875 Sq. km and above the Karcham Diversion dam site is about 48755 Sq. Km. From Bhakra to Wangtoo (155 km on a straight line and 180 km by river) the drainage area is comparatively narrow with an average width of about 35 km. This part of the catchment has an area 8120 Sq. km. Above Wangtoo the catchment is considerably wider than below it. The river Satluj drains an area of about 49750 Sq. Km. at Wangtoo discharge site.

A gross fall of 2180m, is available in the river bed from Shipkila to Bhakra in a length of about 320 km and about 660 m from Shipkila to the Karcham Dam site. The valley is narrow in the portion from Shipkila to Pooh and from Thopan to Rampur. In the portion between Pooh to Thopan and between Rampur to Bhakra the valley is comparatively wide. It is widest in the portion immediately upstream of Bhakra. The bed slope of the river is flat from Shipkila to Jhangi for a distance of about 42 km which is of the order of 1 in 175. It becomes steep between Jhangi dam site and Rampur, the slope being 1 in 87 and is again flatter from Rampur to Kol dam site with a slope of 1 in 300. In the Bhakra reservoir area, which is downstream of the Kol dam site, the bed slope is 1 in 500.

Catchment area of river Satluj is indicated in Fig. A-3 and its L-section from Rakas-Tal to Wangtoo discharge site is shown in Fig. A-4.

Chapter - A2

METEOROLOGICAL DATA

2.1 Meteorological Systems

As indicated in Fig. A-5 (diagrammatic representation of four climatic zones), most of the upper catchment, i.e. in Tibet and of Spiti Valley, falls in Zone-III and the lower catchment from Wangtoo to Bhakra Dam in Zone-I. Meterological systems in two parts of the catchment are different.

Zone-I comprising North India, adjoining parts of Pakistan, Nepal, Bhutan, Sikkim, Bangladesh and North Burma, generally enjoys an annual rainfall in excess of 1000mm and most of the rainfall occurs in summer months from June to October. Tropical storms and depressions affect the weather over the zone in these months. The north western parts receive winter precipitation from western disturbances. Day temperatures in the summer months exceed 40°C over the western half of the zone. The climate of this zone may be called as "Tropical monsoon climate".

In Zone-III comprising plateaus of Chamdo, Chinghai and Tibet, southern positions of Sinkiang, topography plays a vital role in the weather and the climate. The influence of physical features on climate is effected by the Tibetan plateau and the Himalayas which shield the plains of North India from the cold continental air moving outward from the Siberian anticyclone in the winter months. Also the moist bearing winds are forced up the mountains to deposit their moisture and precipitate in the windward slope. The terrain over the greater part of the zone has an elevation of 4000m to 5000m with mountains and peaks raising to higher elevations. The summer monsoon current penetrates into the south eastern parts of this zone through the deeply trenched valleys of the upper course of Brahmaputra, Salsson, Mekong and Yang-tse and precipitates over these areas. The direction of movement of winds (monsoon currents) and Mean Isobars for the month of January and July are shown in Fig. A-6. The precipitation decreases rapidly towards the interior of the plateau. The central part of the region is extremely dry and arid. The climate of this zone can be defined as "mountain climate".

The mean annual rainfall of Zone-I and III are indicated in Fig. A-7.

2.2 Hydrometeorlogical Network

The catchment in Tibet receives practically no rainfall and is mostly contributed by snow. No meteorological data for this catchment is available for the present study. No precipitation observations are recorded in Spiti Valley. Observations at four precipitation stations i.e. Purbani, Kalpa, Kilba and Sangla are being carried out in the catchment upto Karcham site. These observations (rainfall since long and snowfall introduced only recently) are being conducted in a conventional manner. There is no self recording rain-gauge/snow gauge in the catchment upto Karcham site. There are in all twenty rain-gauge stations in the catchment upto Bhakra dam as indicated in the catchment area plan in Fig. A-8.

2.3 Precipitation

2.3.1 General

The project catchment receives precipitation due to the south-west monsoon as well as due to the westerly disturbances that pass over the north-west part of the country during winter. On the basis of information gathered from different sources, it may be said that the south-west monsoon generally lasts from June to September but may occasionally extend upto early October. Precipitation during this season which falls as rain, is generally not heavy but at times may contribute significantly toward flood runoff. The winter precipitation falls either as rain or snow depending on the altitude and other meteorological conditions and may be very heavy on occasions but it may not contribute directly to river discharge significantly and mostly goes to feed the snow/glacier bound areas of the catchment. The number and distribution of rain/snow gauges is too small and scattered to give any quantitative information regarding rain or snow that occurs over different parts of the year over the catchment. The normal rainfall (water equivalent) pattern in the catchment is indicated in Fig. A-8.

2.3.2 Records of Precipitation

There are at present four rain gauge stations in the catchment, upto Karcham dam site at which long term records are available and whose records are being regularly published by the Indian Meteorological Department. The relevant details of these stations are given in the following table.

Name of Station	District	Altitude in metres	Year of Commencement
Purbani	Kinnaur	2285	1951
Kalpa	Kinnaur	2530	1963 (at Chini from 1951 to 1962)
Sangla	Kinnaur	2590	1951
Kilba	Kinnaur	2200	1901 (1882)

There is no regular and systematic record of snowfall at any station in the catchment although snow observations have been recently started at some stations i.e. Purbani, Kalpa, Sangla and Kilba from 1984.

On the basis of observed data, the monthly and annual rainfall normals at above said stations are brought out in Table 2.1.

2.3.3 Storm rainfall

To have an idea of the magnitude of rainfall that may contribute toward the formation of maximum discharges, maximum 1 day and 2 day rainfall recorded over the area represented by the above stations have been computed in case of all important storms as below by arithmetic average.

Station wise break-up in respect of storms during October, 1956 and January, 1959 is given as per under :

Station	Rainfall in in mm					
	9.10.56	10.10.56	11.10.56	12.10.56		
Kilba	0.00	48.51	62.48	19.05	Average	
Sangla	3.81	71.12	50.80	31.24	1-day	2-day
Purbani	2.29	38.86	56.64	13.72	11.10.56	10-11.10.56
Chini	77.72	2.79	52.32	62.23	55.56mm	47.94mm

Station	Rainfall in mm					
	26.1.59	27.1.59	28.1.59	29.1.59		
Kilba	7.1	0	194.1	0	Average	
Sangla	50.8	0	304.8	25.4		
Purbani	38.1	0	254.0	12.7		
Chini	2.5	3.8	0	22.3	151	164

Maximum 1-day		Maximum 2-day	
Date	Amount (in mm)	Date	Amount (in mm)
Sept. 27.1.1954	37	Sept. 26-27, 1954	69
Sept. 23, 1955	44	Sept. 23-24, 1955	88
Sept. 24, 1955	42	Oct. 3-4, 1955	102
Oct. 3, 1955	57	Oct. 10-11, 1956	145
Oct. 10, 1956	86	Jan. 27-28, 1959	164
Jan. 28, 1959	151	Sept. 22-23, 1962	68
Sept. 22, 1962	50		

2.4 Temperature

Measurement of maximum and minimum daily temperatures are being made by different agencies at following sites in the Satluj Valley from the years shown against each.

Station	Altitude (in metres)	Year of Commencement
Bhakra	460	1946
Bilaspur	580	1956
Rampur	930	1967
Wangtoo	1525	1971
Powari	1990	1971
Sandu	3245	1973

Temperature observations have been recently started at Kalpa and Jeori from 1984.

Thus long term data, is available at Bhakra, Bilaspur and Rampur. The data collected at other stations, besides being too short, do not come upto the standards laid down by the India Meteorological Department for such measurements. In order to establish a correlation between the accumulated degree days and the snow melt runoff it is necessary to estimate the temperatures over the mountains areas covered with snow. It is not possible to do this at present since the coverage of stations over high mountainous areas is not sufficient even to compute a reliable lapse rate.

Temperature observations are, however, have been carried out at Shimla (2202m altitude) on the periphery of the catchment on its Western side from 1931.

The range of temperature record is generally in the order given below :-

Station	Maximum Temperature °C	Minimum Temperature °C	Period
Shimla	30	- 7.2	1956-70
Bilaspur	45.4	- 2.0	1956-70
Kalpa	27	- 9.5	1984-85
Jeori	40	- 3	1984-85

The existing network needs to be strengthened both in respect of establishing additional rain-gauges and snow gauges besides climatic observatories. The present network density comes out to one rain gauge for every 2584 sq.km for the catchment from Shipkila to Karcham dam site and 470 sq.km for the catchment from Karcham dam site to Bhakra dam. The WMO has recommended one rain gauge for every 500 sq.km in plain areas and 150-250 sq.kms in hilly area. The inadequacy of Meteorological record and Network render the use of rational methods for working out flood discharges, for eg. by unit hydrograph approach, baseless in the present study.

As terrain in the upper part of the catchment in India is difficult and inaccessible, establishing a network of automatic weather stations and climatic observatories with radio link / remote controlled laboratories / remote sensing techniques to a central data processing station would need to be considered.

Table 2.1

MONTHLY AND ANNUAL RAINFALL NORMALS (in mm)

Station	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec	Annua
Chini/ Kalpa	110.7	105.0	108.1	73.0	57.1	34.8	46.1	39.4	51.0	34.7	12.8	35.1	707.8
Kilba	76.7	82.6	122.2	80.7	62.8	32.0	69.5	63.8	74.7	26.9	15.9	43.6	751.4
Sangla	129.9	120.5	97.8	80.2	62.2	30.6	62.4	66.5	63.6	35.9	16.9	63.4	829.9
Purbani	92.0	91.8	94.0	66.8	52.0	29.9	26.2	25.3	43.0	25.1	18.5	46.1	610.7
Total	409.30	399.90	422.10	300.70	234.10	127.30	204.20	195.00	232.30	122.60	64.10	188.20	2,899.
Normal Annual for Basin	81.86	79.98	84.42	60.14	46.82	25.46	40.84	39.00	46.46	24.52	12.82	37.64	579.9

Chapter - A3

HYDROLOGICAL DATA

3.1 Availability of Data

There are river gauging stations in Satluj basin at Karcham, Wangtoo, Nathpa, Rampur, Kasol, Bhakra and several of the tributaries of river Satluj namely Spiti, Baspa, Bhaba, Sholding, Ganvi, Sir, Sukar etc. Central Water Commission has also set up one station upstream of Karcham at Shongtong. Discharge observations have been started at Jhakri also since 1977. The longest length of record is available at Bhakra (Olinda) from 1909 (continuous since 1926). At Rampur and Wangtoo the observations are available since 1963 and 1966 respectively. The Karcham gauge site has been collecting gauge discharge readings since 1985.

For present study the data of Karcham, Wangtoo and Nathpa have been obtained and checked for consistency. From power generation and design flood point of view, the data of Shongtong, Jhakri, Rampur and Bhakra have not been considered for either being far away downstream or due to unsatisfactory length of record.

3.2 Correlation

3.2.1 Wangtoo v/s Karcham

The available discharges at Karcham have been checked for correlation with Wangtoo discharges. The complete series of Karcham was not available due to many reasons and data of some months were missing. The correlation computations were carried out by omitting the corresponding discharges from Wangtoo series (not by filling of data blanks) so that secondary error due to data reconstruction are not introduced into the analysis. Monthly run-off values of each series, as listed in Table 3.1 for non-monsoon and Table 3.2 for monsoon have been analysed and the correlation coefficients were obtained as 80.8% for non-monsoon and 90.8% for monsoon. As far as acceptability of the Karcham data on criterion of correlation test alone is concerned, it can be adopted as such. But the Karcham discharges being as low as about 60-70% of Wangtoo discharges with wide variations raise a doubt about the consistency from the angle of magnitude of discharges only. According to one study conducted out to ascertain a factor between Wangtoo and Karcham discharges, the Karcham and Wangtoo discharge series are not consistent as the factor is close to 90%. This study is presented in para 3.3.

Wangtoo bridge data is consistent with Nathpa data as described in subsequent paragraphs.

3.2.2 Wangtoo v/s Nathpa : Monthly Correlation

The proposed Nathpa dam site is about 4 km downstream of Wangtoo. In the intermediate reach, their is no significant contribution to the Satluj waters except for some small streams. Nathpa Jhakri Power Corporation Ltd. (NJPC) has constructed a discharge series at Nathpa using Rampur and Bhakra data. This constructed series which has been used by NJPC for design purposes has been used to check the Wangtoo data using regression methods. The results have been presented in Tables 3.3 and 3.4 for non-monsoon and monsoon months respectively. It gives a non-monsoon correlation coefficient of 91% and a monsoon correlation coefficient of 94%.

3.2.3 Wangtoo v/s Nathpa : Mass Curve Correlation

Separate analysis for each calender month was carried out. The values were added and commutative values of monthly run-off in chronological order were correlated. The results, as presented herewith in Table 3.5, show a coefficient of more than 99% for all 12 months of the year.

3.2.4 Wangtoo v/s Nathpa : Quantitative Comparison

In Table 3.6, non-monsoon and monsoon run-off volumes for Wangtoo and Nathpa are given for the period from 1968-69 to 1983-84. From this comparison it is observed that generally run-off volumes of Nathpa and Wangtoo are in order, though some values can be objected because Wangtoo run-off can not exceed that at Nathpa, the difference is only 2% in non-monsoon (average) and 18% in non-monsoon (average). The attention can also be drawn towards Modified Project Report, April 1986 by HPSEB on Nathpa-Jhakri Hydro Electric Project in which it has been indicated that monsoon flows at Wangtoo may be higher and uncertain. But Karcham-Wangtoo Project being a run-of-the-river scheme, the accuracy of monsoon flow data will not depict in any observable difference in power output.

Considering these points it has been decided to use the discharge data available at Wangtoo (from 1966 to 1994) for the project study with a catchment area correlation factor.

3.3 **Catchment Area Correction Factor**

To ascertain catchment area correction factor by actual discharge observations, a study was carried out from 21-4-95 to 5-5-95 (non-monsoon period). A correction factor obtained by actual measurement was found necessary as compared to that arrived at by an empirical relationship such as Dickens's, as the later method was not verified by observations. So an inductive approach has been used to compute the correction factor. The stream travel time from Karcham to Wangtoo is about 1.5 hour. The discharges at Karcham were recorded three times a day at 9 A.M., 10.30 AM and 12 noon. The discharges at Wangtoo were also recorded using same method and instrument after a period of 1.5 hour i.e. at 10.30 AM, 12 noon and 1.30 PM.

The observations and results are presented in Table 3.7. The coefficients are in the range of 0.85 to 0.93 with an overall average of 0.903.

A correction factor of 0.90 based on these observations has been adopted to constitute the discharge series at Karcham using Wangtoo gauge site data.

The constituted series at Karcham from 1967-68 to 1999-2000 has been presented in *Table 3.8.*

Table 3.1

REGRESSION ANALYSIS FOR NON-MONSOON MONTHS

KARCHAM V/S WANGTOO

KARCHAM (m^3/s)	WANGTOO (m^3/s)	KARCHAM (estimated) (m^3/s)	ERROR %
154.750	176.370	112.053	-27.591
221.490	237.030	143.047	-35.416
566.340	752.470	406.406	-28.240
101.140	147.500	97.302	-3.795
94.770	140.590	93.772	-1.054
87.150	128.600	87.645	0.568
70.650	83.630	64.668	-8.467
73.100	86.990	66.385	-9.186
72.300	92.430	69.165	-4.337
82.350	111.250	78.781	-4.334
147.670	151.170	99.177	-32.839
185.040	227.280	138.065	-25.386
266.200	319.030	184.944	-30.525
423.750	557.010	306.537	-27.661
206.300	259.730	154.645	-25.039
88.670	78.520	62.057	-30.013
71.840	86.190	65.976	-8.162
66.090	69.910	57.658	-12.758
66.410	96.350	71.168	7.164
63.190	94.510	70.227	11.137
64.400	86.180	65.971	2.440
230.630	394.620	223.566	-3.063
200.960	309.780	180.217	-10.322
195.640	351.690	201.631	3.062

KARCHAM (m^3/s)	WANGTOO (m^3/s)	KARCHAM (estimated) (m^3/s)	ERROR %
197.640	289.780	169.999	-13.986
155.520	281.810	165.926	6.691
131.890	359.340	205.540	55.842
122.910	289.800	170.009	38.320
112.590	298.390	174.398	54.896
100.070	264.670	157.169	57.059
93.760	235.330	142.178	51.640
69.560	169.000	108.287	55.675
83.140	128.330	87.507	5.253
63.300	118.800	82.638	30.550
80.200	112.580	79.460	-0.923
76.700	116.570	81.499	6.257
74.170	115.670	81.039	9.261
72.640	119.900	83.200	14.538
71.150	116.860	81.647	14.753
77.280	132.320	89.546	15.872
81.870	132.090	89.429	9.232
96.560	145.630	96.347	-0.221
116.160	142.380	94.686	-18.486
182.550	180.220	114.020	-37.540
219.520	171.750	109.692	-50.031
188.940	628.390	343.008	81.543
166.890	386.970	219.657	31.618
142.370	314.170	182.461	28.159
124.400	315.920	183.355	47.391
113.130	309.220	179.931	59.048
106.650	292.090	171.179	60.505
103.430	270.210	160.000	54.694
98.470	251.060	150.215	52.549

KARCHAM (m^3/s)	WANGTOO (m^3/s)	KARCHAM (estimated) (m^3/s)	ERROR %
95.230	235.970	142.505	49.643
91.730	216.390	132.501	44.447
90.810	178.600	113.192	24.647
92.150	135.920	91.385	-0.830
89.060	114.710	80.548	-9.557
90.510	112.050	79.189	-12.508
90.270	122.570	84.564	-6.321
93.990	122.910	84.738	-9.843
118.380	127.180	86.920	-26.576
139.620	201.860	125.077	-10.416
125.640	184.250	116.079	-7.610
117.200	171.970	109.805	-6.310
102.290	134.920	90.874	-11.160
95.530	157.100	102.207	6.990
147.180	170.810	109.212	-25.797
A = 21.938	B = 0.511	R = 0.808	

Table 3.2

REGRESSION ANALYSIS FOR MONSOON MONTHS

KARCHAM V/S WANGTOO

KARCHAM (m^3/s)	WANGTOO (m^3/s)	Karcham (estimated) (m^3/s)	Error %
999.840	1246.180	922.695	-7.716
1677.620	1839.700	1446.621	-13.769
1280.610	1367.850	1030.099	-19.562
1487.270	1541.830	1183.678	-20.413
1681.120	1670.120	1296.925	-22.853
1168.410	1408.280	1065.788	-8.783
850.910	1221.960	901.315	5.924
638.040	862.280	583.810	-8.499
502.840	704.290	444.346	-11.633
269.650	226.460	22.545	-91.639
686.430	909.550	625.538	-8.871
1129.300	1423.240	1141.527	1.083
1040.670	1520.820	1078.994	3.683
1105.180	1543.950	1165.132	5.425
1183.790	1453.150	1185.550	0.149
1056.100	1274.470	1105.397	4.668
863.820	957.400	947.668	9.707
614.060	706.410	667.777	8.748
461.600	523.810	446.217	-3.333
378.180	520.240	285.028	-24.632
373.730	1134.870	281.877	-24.577
716.560	1242.730	824.437	15.055
644.450	983.550	919.650	42.703

KARCHAM (m^3/s)	WANGTOO (m^3/s)	Karcham (estimated) (m^3/s)	Error %
580.290	783.450	690.861	19.054
311.950	735.410	514.224	64.842
236.030	766.750	471.817	99.897
409.130	588.120	499.482	22.084
409.610	574.650	341.798	-16.555
239.550	1936.800	329.907	37.719
1912.690	1986.380	1532.335	-19.886
1625.980	1695.040	1576.102	-3.068
1113.780	1921.000	1318.923	18.419
1264.190	1791.640	1518.388	20.108
857.270		1404.196	63.799
A = -177.361	B = 0.883	R = 0.908	

Table 3.3

REGRESSION ANALYSIS FOR NON-MONSOON MONTHS

NATHPA V/S WANGTOO

Date	NATHPA sum of 3 10-daily discharge (m^3/s)	WANGTOO sum of 3 10-daily discharge (m^3/s)	NATHPA (estimated) (m^3/s)	ERROR %
10.66	6951.81	4885.00	6013.12	-23.09
11.66	4793.73	3490.00	4586.79	-31.43
12.66	3871.16	2545.00	3977.05	-56.27
01.67	3622.46	2455.00	3812.67	-55.30
02.67	2546.31	2308.00	3101.42	-34.38
03.67	2707.24	2915.00	3207.78	-10.04
04.67	3289.68	3770.00	3592.73	4.70
05.67	5623.15	5695.00	5134.98	9.83
10.67	6018.12	5072.00	5396.02	-6.39
11.67	3965.89	3700.00	4039.66	-9.18
12.67	3082.03	3176.00	3455.49	-8.80
01.68	2886.90	2753.00	3326.53	-20.83
02.68	2621.25	2376.00	3150.95	-32.62
03.68	3032.75	3425.00	3422.92	.06
04.68	4183.13	4950.00	4183.23	15.49
05.68	31730.21	9990.00	22389.76	-124.12
10.68	3833.77	4984.00	3952.33	20.70
11.68	2030.64	3090.00	2760.60	10.66
12.68	1773.22	2443.00	2590.47	-6.04
01.69	1596.90	2058.00	2473.93	-20.21
02.69	2064.66	2184.00	2783.09	-27.43
03.69	3585.14	3221.00	3788.01	-17.60
04.69	4511.60	4750.00	4400.33	7.36
05.69	12501.21	12953.00	9680.85	25.26
10.69	5858.48	6365.00	5290.51	16.88
11.69	3668.04	3780.00	3842.80	-1.66
12.69	3216.75	2894.00	3544.53	-22.48
01.70	2823.93	2399.00	3284.91	-36.93
02.70	2503.41	2242.00	3073.07	-37.07
03.70	2613.58	2591.00	3145.88	-21.42
04.70	5228.54	4800.00	4874.17	-1.55
05.70	12901.49	9634.00	9945.41	-3.23
10.70	5294.00	6352.00	4917.44	22.58
11.70	3197.21	3940.00	3531.62	10.37

12.70	2550.65	2930.00	3104.29	-5.95
01.71	2306.70	2643.00	2943.06	-11.35
02.71	2023.56	2238.00	2755.92	-23.14
03.71	2578.73	2717.00	3122.85	-14.94
04.71	4168.22	4320.00	4173.38	3.39
05.71	6591.30	6479.00	5774.85	10.87
10.71	4789.57	6189.00	4584.04	25.93
11.71	3269.53	3510.00	3579.41	-1.98
12.71	2507.38	2859.00	3075.69	-7.58
01.72	2236.97	2405.00	2896.97	-20.46
02.72	1780.04	2116.00	2594.97	-22.64
03.72	2601.72	2828.00	3138.04	-10.96
04.72	3843.71	3740.00	3958.90	-5.85
05.72	13840.22	10247.00	10565.84	-3.11
10.72	5637.50	5447.00	5144.46	5.55
11.72	3330.14	3560.00	3619.47	-1.67
12.72	2878.94	3016.00	3321.26	-10.12
01.73	2427.31	2769.00	3022.77	-9.16
02.73	2217.61	2458.00	2884.18	-17.34
03.73	2840.45	3399.00	3295.83	3.04
04.73	13008.43	10140.00	10016.09	1.22
05.73	30424.27	26637.00	21526.63	19.19
10.73	7267.44	6504.00	6221.73	4.34
11.73	4144.53	4250.00	4157.72	2.17
12.73	3043.92	3074.00	3430.30	-11.59
01.74	2490.99	2689.00	3064.86	-13.98
02.74	2120.70	2438.00	2820.13	-15.67
03.74	3009.80	3355.00	3407.75	-1.57
04.74	4071.97	5150.00	4109.77	20.20
05.74	7803.33	8197.00	6575.91	19.78
10.74	4067.14	4944.00	4106.57	16.94
11.74	2637.13	3320.00	3161.45	4.78
12.74	2502.10	2766.00	3072.20	-11.07
01.75	2745.65	2644.00	3233.17	-22.28
02.75	3108.99	2996.00	3473.31	-15.93
03.75	4075.70	4080.00	4112.23	-.79
04.75	8114.63	6550.00	6781.66	-3.54
05.75	19701.94	13953.00	14439.99	-3.49
10.75	6766.29	6806.00	5890.51	13.45
11.75	3683.13	4800.00	3852.77	19.73
12.75	2851.16	3361.00	3302.90	1.73
01.76	2558.58	2973.00	3109.53	-4.59
02.76	2369.17	2694.00	2984.34	-10.78
03.76	3044.61	3473.00	3430.76	1.22
04.76	6783.02	6070.00	5901.56	2.77
05.76	16646.68	12118.00	12420.69	-2.50
10.76	8216.05	5830.00	6848.69	-17.47

11.76	4403.84	3930.00	4329.11	-10.16
12.76	3457.50	3031.00	3703.65	-22.19
01.77	2687.34	2738.00	3194.63	-16.68
01.77	2296.77	2398.00	2936.49	-22.46
03.77	2827.24	2870.00	3287.09	-14.53
04.77	3068.31	3350.00	3446.42	-2.88
05.77	4892.34	5018.00	4651.97	7.29
10.77	4699.94	5934.00	4524.81	23.75
11.77	3436.35	4250.00	3689.67	13.18
12.77	2851.41	3453.00	3303.07	4.34
01.78	2494.28	2706.00	3067.03	-13.34
02.78	2121.82	2400.00	2820.87	-17.54
03.78	2558.32	3100.00	3109.36	-.30
04.78	3696.65	5110.00	3861.71	24.43
05.78	17828.39	15574.00	13201.71	15.23
10.78	5546.80	7274.00	5084.52	30.10
11.78	4359.48	4750.00	4299.79	9.48
12.78	3838.09	3792.00	3955.19	-4.30
01.79	3536.63	3078.00	3755.95	-22.03
02.79	3187.20	2596.00	3525.00	-35.79
03.79	3681.09	3590.00	3851.42	-7.28
04.79	7774.99	7600.00	6557.18	13.72
05.79	12237.95	11877.00	9506.86	19.96
10.79	5415.67	5383.00	4997.85	7.15
11.79	3768.27	3970.00	3909.04	1.54
12.79	2863.49	3362.00	3311.05	1.52
01.80	2546.29	2728.00	3101.41	-13.69
02.80	2085.36	2526.00	2796.77	-10.72
03.80	2617.59	2910.00	3148.53	-8.20
04.80	4702.83	4940.00	4526.72	8.37
05.80	12779.00	10984.00	9864.45	10.19
10.80	5796.65	5625.00	5249.65	6.67
11.80	3808.88	3500.00	3935.88	-12.45
12.80	2962.73	2954.00	3376.64	-14.31
01.81	2617.30	2505.00	3148.34	-25.68
02.81	2399.06	2006.00	3004.10	-49.76
03.81	3020.09	2806.00	3414.55	-21.69
04.81	5253.77	5400.00	4890.85	9.43
05.81	15081.54	14634.00	11386.25	22.19
10.81	4103.45	5278.00	4130.57	21.74
11.81	3242.71	3590.00	3561.69	.79
12.81	2732.73	2671.00	3224.63	-20.73
01.82	2493.59	2416.00	3066.58	-26.93
02.82	2341.11	2082.00	2965.80	-42.45
03.82	2931.83	2749.00	3356.22	-22.09
04.82	5069.27	5850.00	4768.91	18.48
05.82	10091.46	10558.00	8088.19	23.39

10.82	6110.08	5560.00	5456.80	1.86
11.82	3819.65	3790.00	3943.00	-4.04
12.82	2959.28	2888.00	3374.36	-16.84
01.83	2502.01	2656.00	3072.14	-15.67
02.83	2220.23	2408.00	2885.91	-19.85
03.83	2742.15	2941.00	3230.86	-9.86
04.83	4486.55	4730.00	4383.77	7.32
05.83	16809.97	14758.00	12528.62	15.11

COEFFICIENT OF REGRESSION= .9086

R(2) = 1418.50 + .66x R(1)

Table 3.4

REGRESSION ANALYSIS FOR MONSOON MONTHS

NATHPA V/S WANGTOO

Date	NATHPA sum of 3-10 daily discharge (m^3/s)	WANGTOO Sum of 3-10 daily discharge (m^3/s)	NATHPA (estimated) (m^3/s)	ERROR %
06.67	32763.63	20500.00	26587.45	-29.69
07.67	45197.81	30656.00	35503.65	-15.81
08.67	35118.29	27170.00	28275.91	-4.07
09.67	13048.98	10180.00	12450.63	-22.30
06.68	40685.13	25310.00	32267.73	-27.49
07.68	32120.65	24723.00	26126.39	-5.68
08.68	28269.64	20458.00	23364.94	-14.21
09.68	8477.08	8950.00	9172.25	-2.48
06.69	38776.03	32680.00	30898.77	5.45
07.69	43583.05	35920.00	34345.75	4.38
08.69	33668.94	30528.00	27236.62	10.78
09.69	13755.09	12870.00	12956.96	-.68
06.70	9394.66	13650.00	9830.22	27.98
07.70	19111.02	20292.00	16797.55	17.22
08.70	19349.94	21435.00	16968.87	20.84
09.70	12838.47	13190.00	12299.68	6.75
06.71	22673.42	19810.00	19352.04	2.31
07.71	23940.77	20928.00	20260.82	3.19
08.71	24891.14	22415.00	20942.31	6.57
09.71	9192.42	8980.00	9685.20	-7.85
06.72	23818.79	17100.00	20173.36	-17.97
07.72	27072.52	23575.00	22506.51	4.53
08.72	24835.87	22080.00	20902.68	5.33
09.72	12739.88	10860.00	12228.98	-12.61
06.73	52064.72	41760.00	40427.71	3.19
07.73	45841.99	32879.00	35965.57	-9.39
08.73	31686.07	24629.00	25814.76	-4.81
09.73	20797.39	15960.00	18006.79	-12.82
06.74	12910.14	11340.00	12351.07	-8.92
07.74	26932.76	22809.00	22406.30	1.77
08.74	26097.75	21970.00	21807.53	.74
09.74	9819.55	8970.00	10134.90	-12.99

06.75	37398.06	29460.00	29910.67	-1.53
07.75	37306.05	31099.00	29844.69	4.03
08.75	37567.60	34576.00	30032.24	13.14
09.75	14564.79	12090.00	13537.57	-11.97
06.76	25463.35	17010.00	21352.62	-25.53
07.76	36738.19	30675.00	29437.49	4.03
08.76	25564.58	18430.00	21425.21	-16.25
09.76	13991.89	9480.00	13126.76	-38.47
06.77	17677.66	11540.00	15769.72	-36.65
07.77	43941.26	33611.00	34602.61	-2.95
08.77	29896.33	25732.00	24531.39	4.67
09.77	13926.21	12070.00	13079.67	-8.37
06.78	30117.10	22000.00	24689.70	-12.23
07.78	35705.23	31310.00	28696.79	8.35
08.78	33141.42	30666.00	26858.35	12.42
09.78	12794.99	16300.00	12268.50	24.73
06.79	34539.79	26110.00	27861.08	-6.71
07.79	37423.84	34169.00	29929.15	12.41
08.79	26646.18	25297.00	22200.80	12.24
09.79	11088.69	11080.00	11044.96	.32
06.80	24720.06	23110.00	20819.63	9.91
07.80	30830.75	29990.00	25201.44	15.97
08.80	23125.83	23479.00	19676.45	16.20
09.80	10349.71	10230.00	10515.06	-2.79
06.81	18240.69	15840.00	16173.46	-2.11
07.81	28763.87	27759.00	23719.33	14.55
08.81	26915.02	28024.00	22393.57	20.09
09.81	10187.73	9590.00	10398.91	-8.43
06.82	27236.31	24730.00	22623.96	8.52
07.82	42875.71	35125.00	33838.54	3.66
08.82	32183.47	24412.00	26171.43	-7.21
09.82	12252.04	10280.00	11879.17	-15.56
06.83	28336.11	20080.00	23412.60	-16.60
07.83	34318.17	25716.00	27702.17	-7.72
08.83	38961.50	29364.00	31031.77	-5.68
09.83	19802.81	16090.00	17293.61	-7.48

COEFFICIENT OF REGRESSION= .9428

R(2) = 3093.57 + .72x R(1)

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Table 3.5

REGRESSION ANALYSIS FOR MASS VOLUMES FOR TWELVE MONTHS

NATHPA V/S WANGTOO

JANUARY

COEFFICIENT OF REGRESSION = .9998

R(2) = -1228.34 + 1.04x R(1)

Date	NATHPA sum of 3 10-daily discharges (m^3/s)	WANGTOO sum of 3 10-daily discharges (m^3/s)	NATHPA (estimated) (m^3/s)	ERROR %
1967	3622.46	2455.00	2521.29	-2.70
1968	6509.36	5208.00	5509.54	-5.79
1969	8106.26	7266.00	7162.50	1.42
1970	10930.19	9665.00	10085.57	-4.35
1971	13236.89	12308.00	12473.25	-1.34
1972	15473.86	14713.00	14788.75	-.51
1973	17901.17	17482.00	17301.27	1.03
1974	20392.16	20171.00	19879.71	1.44
1975	23137.81	22815.00	22721.75	.41
1976	25696.39	25788.00	25370.15	1.62
1977	28383.73	28526.00	28151.83	1.31
1978	30878.01	31232.00	30733.68	1.60
1979	34414.64	34310.00	34394.47	-.25
1980	36960.93	37038.00	37030.14	.02
1981	39578.23	39543.00	39739.33	-.50
1982	42071.82	41959.00	42320.46	-.86
1983	44573.83	44615.00	44910.30	-.66

17yrs

83
66
17

FEBRUARY

COEFFICIENT OF REGRESSION = 0.9996

R(2) = -465.16 + 1.03x R(1)

Date	NATHPA sum of 3 10-daily discharge (m^3/s)	WANGTOO sum of 3 10-daily discharge (m^3/s)	NATHPA (estimated) (m^3/s)	ERROR %
1967	2546.31	2308.00	2166.04	6.15
1968	5167.56	4684.00	4874.67	-4.07
1969	7232.22	6868.00	7008.16	-2.04
1970	9735.63	9110.00	9595.03	-5.32
1971	11759.19	11348.00	11686.05	-2.98
1972	13539.23	13464.00	13525.43	-.46
1973	15756.84	15922.00	15816.97	.66
1974	17877.54	18360.00	18008.36	1.92
1975	20986.53	21356.00	21221.00	.63
1976	23355.70	24050.00	23669.15	1.58
1977	25652.47	26448.00	26042.49	1.53
1978	27774.29	28848.00	28235.04	2.12
1979	30961.49	31444.00	31528.50	-.27
1980	33046.85	33970.00	33683.38	.84
1981	35445.91	35976.00	36162.41	-.52
1982	37787.02	38058.00	38581.57	-1.38
1983	40007.25	40466.00	40875.82	-1.01

MARCH

COEFFICIENT OF REGRESSION = 0.9998

R(2) = -101.24 + 1.06x R(1)

Date	NATHPA sum of 3 10-daily discharge (m^3/s)	WANGTOO sum of 3 10-daily discharge (m^3/s)	NATHPA (estimated) (m^3/s)	ERROR %
1967	2707.24	2915.00	2765.79	5.12
1968	5739.99	6340.00	5977.54	5.72
1969	9325.13	9561.00	9774.28	-2.23
1970	11938.71	12152.00	12542.13	-3.21
1971	14517.44	14869.00	15273.06	-2.72
1972	17119.16	17697.00	18028.34	-1.87
1973	19959.61	21096.00	21036.45	.28
1974	22969.41	24451.00	24223.89	.93
1975	27045.11	28531.00	28540.15	-.03
1976	30089.72	32004.00	31764.47	.75
1977	32916.96	34874.00	34758.58	.33
1978	35475.28	37974.00	37467.90	1.33
1979	39156.37	41564.00	41366.26	.48
1980	41773.96	44474.00	44138.35	.75
1981	44794.05	47280.00	47336.69	-.12
1982	47725.88	50029.00	50441.57	-.82
1983	50468.02	52970.00	53345.56	-.71

APRIL

COEFFICIENT OF REGRESSION = 0.9991

R(2) = 867.72 + .97x R(1)

Date	NATHPA sum of 3 10-daily discharge (m^3/s)	WANGTOO sum of 3 10-daily discharge (m^3/s)	NATHPA (estimated) (m^3/s)	ERROR %
1967	3289.68	3770.00	4060.37	-7.70
1968	7472.81	8720.00	8120.11	6.88
1969	11984.41	13470.00	12498.63	7.21
1970	17212.95	18270.00	17572.95	3.82
1971	21381.17	22590.00	21618.23	4.30
1972	25224.88	26330.00	25348.56	3.73
1973	38233.31	36470.00	37973.29	-4.12
1974	42305.28	41620.00	41925.16	-.73
1975	50419.91	48170.00	49800.44	-3.38
1976	57202.93	54240.00	56383.38	-3.95
1977	60271.23	57590.00	59361.18	-3.08
1978	63967.88	62700.00	62948.79	-.40
1979	71742.88	70300.00	70494.46	-.28
1980	76445.70	75240.00	75058.57	.24
1981	81699.48	80640.00	80157.38	.60
1982	86768.75	86490.00	85077.13	1.63
1983	91255.30	91220.00	89431.34	1.96

MAY

COEFFICIENT OF REGRESSION = 0.9978

R(2) = -11731.27 + .83x R(1)

1967	5623.15	5695.00	-7045.72	223.72
1968	37353.36	15685.00	19393.80	-23.65
1969	49854.57	28638.00	29810.56	-4.09
1970	62756.06	38272.00	40560.86	-5.98
1971	69347.36	44751.00	46053.13	-2.91
1972	83187.58	54998.00	57585.63	-4.70
1973	113611.80	81635.00	82936.92	-1.59
1974	121415.20	89832.00	89439.19	.44
1975	141117.10	103785.00	105856.00	-2.00
1976	157763.80	115903.00	119727.00	-3.30
1977	162656.10	120921.00	123803.60	-2.38
1978	180484.50	136495.00	138659.30	-1.59
1979	192722.50	148372.00	148856.70	-.33
1980	205501.50	159356.00	159505.00	-.09
1981	220583.00	173990.00	172071.80	1.10
1982	230674.50	184548.00	180480.60	2.20
1983	247484.40	199306.00	194487.60	2.42

JUNE

COEFFICIENT OF REGRESSION = 0.9996

R(2) = -6152.60 + .79x R(1)

Date	NATHPA sum of 3 10-daily discharge (m^3/s)	WANGTOO sum of 3 10-daily discharge (m^3/s)	NATHPA (estimated) (m^3/s)	ERROR %
1967	32763.63	20500.00	19786.45	3.48
1968	73448.76	45810.00	51996.97	-13.51
1969	112224.80	78490.00	82696.06	-5.36
1970	121619.50	92140.00	90133.88	2.18
1971	144292.90	111950.00	108084.50	3.45
1972	168111.70	129050.00	126941.90	1.63
1973	220176.40	170810.00	168161.60	1.55
1974	233086.50	182150.00	178382.60	2.07
1975	270484.60	211610.00	207990.80	1.71
1976	295947.90	228620.00	228150.10	.21
1977	313625.60	240160.00	242145.60	-.83
1978	343742.70	262160.00	265989.40	-1.46
1979	378282.40	288270.00	293334.60	-1.76
1980	403002.50	311380.00	312905.50	-.49
1981	421243.20	327220.00	327346.80	-.04
1982	448479.50	351950.00	348909.80	.86
1983	476815.60	372030.00	371343.60	.18

JULY

COEFFICIENT OF REGRESSION = 0.9998

R(2) = -9287.92 + .84x R(1)

Date	NATHPA sum of 3 10-daily discharge (m^3/s)	WANGTOO sum of 3 10-daily discharge (m^3/s)	NATHPA (estimated) (m^3/s)	ERROR %
1967	45197.81	30656.00	28885.22	5.78
1968	77318.46	55379.00	56013.66	-1.15
1969	120901.50	91299.00	92822.99	-1.67
1970	140012.50	111591.00	108963.80	2.35
1971	163953.30	132519.00	129183.60	2.52
1972	191025.80	156094.00	152048.50	2.59
1973	236867.80	188973.00	190765.70	-.95
1974	263800.60	211782.00	213512.60	-.82
1975	301106.60	242881.00	245020.50	-.88
1976	337844.80	273556.00	276048.80	-.91
1977	381786.10	307167.00	313160.70	-1.95
1978	417491.30	338477.00	343316.60	-1.43
1979	454915.10	372646.00	374924.00	-.61
1980	485745.90	402636.00	400963.00	.42
1981	514509.80	430395.00	425256.40	1.19
1982	557385.40	465520.00	461468.30	.87
1983	591703.60	491236.00	490452.80	.16

AUGUST

COEFFICIENT OF REGRESSION = 0.9997

R(2) = -5395.05 + .88x R(1)

Date	NATHPA sum of 3 10-daily discharge (m^3/s)	WANGTOO sum of 3 10-daily discharge (m^3/s)	NATHPA (estimated) (m^3/s)	ERROR %
1967	35118.29	27170.00	25544.06	5.98
1968	63387.93	47628.00	50449.52	-5.92
1969	97056.88	78156.00	80111.77	-2.50
1970	116406.80	99591.00	97158.98	2.44
1971	141298.00	122006.00	119088.00	2.39
1972	166133.80	144086.00	140968.30	2.16
1973	197819.90	168715.00	168883.70	-.10
1974	223917.70	190685.00	191875.80	-.62
1975	261485.30	225261.00	224972.70	.13
1976	287049.80	243691.00	247494.90	-1.56
1977	316946.20	269423.00	273833.60	-1.64
1978	350087.60	300089.00	303031.00	-.98
1979	376733.80	325386.00	326506.30	-.34
1980	399859.70	348865.00	346880.10	.57
1981	426774.70	376889.00	370592.10	1.67
1982	458958.20	401301.00	398945.70	.59
1983	497919.70	430665.00	433270.70	-.61

SEPTEMBER

COEFFICIENT OF REGRESSION = 0.9993

R(2) = -77.83 + .90x R(1)

Date	NATHPA sum of 3 10-daily discharge (m^3/s)	WANGTOO sum of 3 10-daily discharge (m^3/s)	NATHPA (estimated) (m^3/s)	ERROR %
1967	13048.98	10180.00	11650.16	-14.44
1968	21526.06	19130.00	19269.08	-.73
1969	35281.15	32000.00	31631.69	1.15
1970	48119.62	45190.00	43170.49	4.47
1971	57312.04	54170.00	51432.33	5.05
1972	70051.92	65030.00	62882.51	3.30
1973	90849.31	80990.00	81574.52	-.72
1974	100668.90	89960.00	90400.03	-.49
1975	115233.60	102050.00	103490.30	-1.41
1976	129225.50	111530.00	116065.80	-4.07
1977	143151.80	123600.00	128582.30	-4.03
1978	155946.70	139900.00	140081.90	-.13
1979	167035.40	150980.00	150048.00	.62
1980	177385.10	161210.00	159350.00	1.15
1981	187572.90	170800.00	168506.50	1.34
1982	199824.90	181080.00	179518.20	.86
1983	219627.70	197170.00	197316.30	-.07

OCTOBER

COEFFICIENT OF REGRESSION = 0.9995

R(2) = -2109.54 + 1.05x R(1)

Date	NATHPA sum of 3 10-daily discharge (m^3/s)	WANGTOO sum of 3 10-daily discharge (m^3/s)	NATHPA (estimated) (m^3/s)	ERROR %
1966	6951.81	4885.00	5156.60	-5.56
1967	12969.93	9957.00	11446.83	-14.96
1968	16803.70	14941.00	15453.94	-3.43
1969	22662.18	21306.00	21577.31	-1.27
1970	27956.18	27658.00	27110.67	1.98
1971	32745.75	33847.00	32116.80	5.11
1972	38383.25	39294.00	38009.20	3.27
1973	45650.69	45798.00	45605.24	.42
1974	49717.83	50742.00	49856.27	1.75
1975	56484.12	57548.00	56928.50	1.08
1976	64700.17	63378.00	65516.03	-3.37
1977	69400.11	69312.00	70428.48	-1.61
1978	74946.91	76586.00	76226.07	.47
1979	80362.58	81969.00	81886.61	.10
1980	86159.23	87594.00	87945.35	-.40
1981	90262.68	92872.00	92234.34	.69
1982	96372.76	98432.00	98620.68	-.19

NOVEMBER

COEFFICIENT OF REGRESSION = 0.9997

R(2) = -1626.76 + 1.10x R(1)

Date	NATHPA sum of 3 10-daily discharge (m^3/s)	WANGTOO sum of 3 10-daily discharge (m^3/s)	NATHPA (estimated) (m^3/s)	ERROR %
1966	4793.73	3490.00	3638.27	-4.25
1967	8759.62	7190.00	7994.07	-11.18
1968	10790.26	10280.00	10224.36	.54
1969	14458.30	14060.00	14253.03	-1.37
1970	17655.51	18000.00	17764.57	1.31
1971	20925.04	21510.00	21355.55	.72
1972	24255.18	25070.00	25013.10	.23
1973	28399.71	29320.00	29565.10	-.84
1974	31036.84	32640.00	32461.50	.55
1975	34719.97	37440.00	36506.74	2.49
1976	39123.81	41370.00	41343.55	.06
1977	42560.16	45620.00	45117.75	1.10
1978	46919.64	50370.00	49905.84	.92
1979	50687.91	54340.00	54044.59	.54
1980	54496.79	57840.00	58227.94	-.67
1981	57739.50	61430.00	61789.46	-.59
1982	61559.15	65220.00	65984.64	-1.17

DECEMBER

COEFFICIENT OF REGRESSION = 0.9999

R(2) = -1361.20 + 1.06x R(1)

Date	NATHPA sum of 3 10-daily discharge (m^3/s)	WANGTOO sum of 3 10-daily discharge (m^3/s)	NATHPA (estimated) (m^3/s)	ERROR %
1966	3871.16	2545.00	2745.74	-7.89
1967	6953.19	5721.00	6015.49	-5.15
1968	8726.41	8164.00	7896.71	3.27
1969	11943.16	11058.00	11309.38	-2.27
1970	14493.81	13988.00	14015.38	-.20
1971	17001.19	16847.00	16675.48	1.02
1972	19880.13	19863.00	19729.77	.67
1973	22924.05	22937.00	22959.08	-.10
1974	25426.15	25703.00	25613.57	.35
1975	28277.31	29064.00	28638.39	1.46
1976	31734.81	32095.00	32306.47	-.66
1977	34586.22	35548.00	35331.55	.61
1978	38424.31	39340.00	39403.41	-.16
1979	41287.80	42702.00	42441.30	.61
1980	44250.53	45656.00	45584.48	.16
1981	46983.26	48327.00	48483.66	-.32
1982	49942.54	51215.00	51623.18	-.80

Annexure II

Table 3.6

ANNUAL RUN-OFF AT WANGTOO BRIDGE SITE AND NATHPA DAM SITE

Year	Runoff at Wangtoo Mm^3		Runoff at Nathpa Mm^3	
	Non-monsoon	Monsoon	Non-monsoon	Monsoon
1968-69	2756	11213	3083	9677
1969-70	3353	5244	2999	5924
1970-71	2481	6972	2732	6232
1971-72	3013	7644	2928	6360
1972-73	5423	12994	4962	9956
1973-74	2934	6546	3081	5624
1974-75	4057	10959	3564	9264
1975-76	3862	8792	3654	6531
1976-77	2752	9110	2520	7167
1977-78	3429	9656	3674	8664
1978-79	3816	9478	3850	8351
1979-80	3178	7692	3180	7500
1980-81	3537	7267	3407	7016
1981-82	2852	9897	3041	8169
1982-83	3599	10491	3433	7884
1983-84	4006	8024	3668	6067
Average	**3441**	**8874**	**3361**	**7524**

Non-Monsoon = October to May

Monsoon = June to September

Table 3.7

DETERMINATION OF CATCHMENT AREA CORRECTION FACTOR FOR KARCHAM WITH RESPECT TO WANGTOO

KARCHAM								WANGTOO							Catchment Area Correction Factor		
Date	Gauge I	Total Discharge in Cumecs	Gauge II	Total Discharge in Cumecs	Gauge III	Total Discharge in Cumecs	Remarks	Date	Gauge I	Total Discharge in Cumecs	Gauge II	Total Discharge in Cumecs	Gauge III	Total Discharge in Cumecs	I	II	III
	9 AM		10.30 AM		12 AM				10.30 AM		12 AM		1.30 PM				
21.4.95	4.90	129.10	4.89	128.10	4.89	128.10	Rains in the night	21.4.95	5.47	149.35	5.46	149.25	5.46	149.25	0.864	0.858	0.858
22.4.95	4.96	138.78	4.95	138.33	4.95	138.33	- do -	22.4.95	5.54	156.04	5.54	156.04	5.52	153.65	0.889	0.887	0.900
23.4.95	5.00	143.59	5.00	143.59	5.00	143.59	- do -	23.4.95	5.58	161.55	5.58	161.55	5.57	161.46	0.889	0.889	0.889
24.4.95	5.00	143.59	4.99	143.16	4.99	143.16	- do -	24.4.95	5.60	162.57	5.60	162.57	5.58	161.55	0.883	0.881	0.886
25.4.95	5.08	158.84	5.07	158.37	5.07	158.37	Sunny day	25.4.95	5.68	173.24	5.65	169.81	5.65	169.81	0.917	0.933	0.933
26.4.95	5.12	164.18	5.11	163.66	5.10	162.09	- do -	26.4.95	5.72	176.89	5.72	176.89	5.71	176.34	0.926	0.925	0.919
27.4.95	5.16	166.21	5.15	165.71	5.14	164.75	- do -	27.4.95	5.77	178.37	5.75	179.98	5.74	177.62	0.932	0.921	0.928
28.4.95	5.18	167.22	5.16	166.21	5.16	166.22	- do -	28.4.95	5.80	183.56	5.78	182.64	5.78	179.28	0.911	0.910	0.927
29.4.95	5.27	187.23	5.26	186.64	5.25	186.11	- do -	29.4.95	6.00	215.71	5.98	209.83	5.97	209.18	0.868	0.890	0.890
30.4.95	5.35	209.92	5.35	209.92	5.32	204.92	- do -	30.4.95	6.10	231.28	6.10	231.28	6.09	228.60	0.908	0.908	0.896
01.4.95	5.35	209.92	5.33	206.09	5.32	204.92	- do -	01.4.95	6.10	231.28	6.10	231.28	6.09	228.60	0.908	0.891	0.896
02.5.95	5.29	203.46	5.28	202.87	5.27	187.23	Cloudy Morning	02.5.95	6.00	215.71	6.00	215.71	5.97	209.18	0.943	0.941	0.895
03.5.95	5.22	185.42	5.20	183.23	5.19	182.65	Sunny day	03.5.95	5.90	202.03	5.89	201.56	5.87	200.85	0.918	0.909	0.909
04.5.95	5.12	164.18	5.12	164.16	5.10	162.09	Cloudy Morning	04.5.95	5.80	183.56	5.80	183.58	5.79	183.23	0.894	0.894	0.885
05.95.95	5.20	183.23	5.19	182.65	5.19	182.65	Sunny day	05.95.95	5.89	201.56	5.88	201.36	5.88	201.36	0.909	0.907	0.907
														Average	0.904	0.903	0.901
														Overall Average		0.903	

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Table 3.8

TEN-DAILY DISCHARGE AND RUNOFF VOLUMES

1966-67		DISCHARGE (CUMEC)	RUNOFF (CUMEC-DAY)
OCT	I.	239.45	
	II.	195.59	
	III.	173.30	6256.63
NOV	I.	136.79	
	II.	151.19	
	III.	143.46	4314.36
DEC	I.	123.23	
	II.	109.39	
	III.	105.26	3484.05
JAN	I.	103.52	
	II.	108.48	
	III.	103.65	3260.22
FEB	I.	97.59	
	II.	72.68	
	III.	73.62	2291.68
MAR	I.	75.86	
	II.	78.13	
	III.	81.51	2436.51
APR	I.	82.17	
	II.	97.95	
	III.	115.95	2960.71
MAY	I.	144.92	
	II.	167.54	
	III.	176.02	5060.83
JUN	I.	580.67	
	II.	1162.27	
	III.	1205.79	29487.27
JUL	I.	1332.40	
	II.	1312.77	
	III.	1293.30	40678.03
AUG	I.	1095.92	
	II.	1012.94	
	III.	956.17	31606.46
SEP	I.	513.72	
	II.	392.62	
	III.	268.07	11744.08

NON-MON= 30064.99 MON- 113515.80 TOT= 143580.80

TEN-DAILY DISCHARGE AND RUNOFF VOLUMES

1967-68		DISCHARGE (CUMEC)	RUNOFF (CUMEC-DAY)
OCT	I.	211.94	
	II.	162.47	
	III.	152.02	5416.31
NOV	I.	138.82	
	II.	122.57	
	III.	95.54	3569.30
DEC	I.	92.54	
	II.	89.34	
	III.	86.83	2773.83
JAN	I.	85.32	
	II.	83.45	
	III.	82.77	2598.21
FEB	I.	83.89	
	II.	84.20	
	III.	84.77	2359.12
MAR	I.	85.35	
	II.	87.80	
	III.	90.73	2729.47
APR	I.	85.93	
	II.	92.14	
	III.	198.41	3764.82
MAY	I.	623.21	
	II.	876.80	
	III.	1232.46	28557.19
JUN	I.	962.71	
	II.	1305.28	
	III.	1393.67	36616.62
JUL	I.	1096.32	
	II.	1015.25	
	III.	708.44	28908.58
AUG	I.	954.39	
	II.	940.40	
	III.	590.44	25442.68
SEP	I.	294.38	
	II.	240.27	
	III.	228.28	7629.37

NON-MON= 51768.26 MON= 98597.23 TOT= 150365.50

TEN-DAILY DISCHARGE AND RUNOFF VOLUMES

1968-69		DISCHARGE (CUMEC)	RUNOFF (CUMEC-DAY)
OCT	I.	136.15	
	II.	117.44	
	III.	83.14	3450.40
NOV	I.	65.80	
	II.	64.22	
	III.	52.74	1827.58
DEC	I.	53.99	
	II.	51.24	
	III.	49.41	1595.90
JAN	I.	47.72	
	II.	45.30	
	III.	46.09	1437.21
FEB	I.	47.21	
	II.	60.64	
	III.	97.46	1858.20
MAR	I.	98.60	
	II.	109.88	
	III.	103.80	3226.63
APR	I.	97.09	
	II.	156.28	
	III.	152.67	4060.44
MAY	I.	219.62	
	II.	332.17	
	III.	521.20	11251.09
JUN	I.	1158.52	
	II.	1204.02	
	III.	1127.30	34898.43
JUL	I.	1220.64	
	II.	1329.34	
	III.	1247.72	39224.74
AUG	I.	1263.87	
	II.	1070.74	
	III.	632.36	30302.05
SEP	I.	544.05	
	II.	421.62	
	III.	272.29	12379.58

NON-MON= 28707.44 MON= 116804.80 TOT= 145512.20

TEN-DAILY DISCHARGE AND RUNOFF VOLUMES

1969-70		DISCHARGE (CUMEC)	RUNOFF (CUMEC-DAY)
OCT	I.	190.28	
	II.	174.84	
	III.	147.40	5272.63
NOV	I.	122.04	
	II.	106.10	
	III.	101.99	3301.24
DEC	I.	101.92	
	II.	92.49	
	III.	86.46	2895.08
JAN	I.	82.09	
	II.	80.96	
	III.	82.82	2541.53
FEB	I.	82.98	
	II.	80.61	
	III.	77.15	2253.07
MAR	I.	67.93	
	II.	70.62	
	III.	87.88	2352.22
APR	I.	103.08	
	II.	151.33	
	III.	216.17	4705.69
MAY	I.	201.38	
	II.	341.13	
	III.	562.38	11611.34
JUN	I.	194.37	
	II.	307.13	
	III.	344.02	8455.19
JUL	I.	614.19	
	II.	556.34	
	III.	499.51	17199.92
AUG	I.	562.22	
	II.	546.83	
	III.	574.95	17414.95
SEP	I.	492.18	
	II.	401.45	
	III.	261.83	11554.62

NON-MON= 34932.79 MON= 54624.69 TOT= 89557.48

TEN-DAILY DISCHARGE AND RUNOFF VOLUMES

1970-71		DISCHARGE (CUMEC)	RUNOFF (CUMEC-DAY)
OCT	I.	189.16	
	II.	153.05	
	III.	122.04	4764.60
NOV	I.	108.78	
	II.	94.29	
	III.	84.68	2877.49
DEC	I.	76.82	
	II.	74.98	
	III.	70.69	2295.58
JAN	I.	68.82	
	II.	67.00	
	III.	65.25	2076.03
FEB	I.	64.12	
	II.	65.92	
	III.	65.10	1821.20
MAR	I.	63.46	
	II.	67.57	
	III.	91.87	2320.86
APR	I.	119.02	
	II.	121.76	
	III.	134.36	3751.40
MAY	I.	165.56	
	II.	180.71	
	III.	224.50	5932.17
JUN	I.	627.06	
	II.	667.59	
	III.	745.96	20406.08
JUL	I.	649.91	
	II.	615.28	
	III.	808.62	21546.69
AUG	I.	942.41	
	II.	667.76	
	III.	572.76	22402.02
SEP	I.	417.59	
	II.	228.57	
	III.	181.16	8273.18

NON-MON= 25839.34 MON= 72627.98 TOT= 98467.31

TEN-DAILY DISCHARGE AND RUNOFF VOLUMES

1971-72		DISCHARGE (CUMEC)	RUNOFF (CUMEC-DAY)
OCT	I.	154.64	
	II.	145.92	
	III.	118.63	4310.62
NOV	I.	102.14	
	II.	97.75	
	III.	94.36	2942.58
DEC	I.	79.68	
	II.	70.38	
	III.	68.73	2256.64
JAN	I.	64.36	
	II.	64.96	
	III.	65.46	2013.27
FEB	I.	55.18	
	II.	55.54	
	III.	61.86	1602.04
MAR	I.	67.14	
	II.	72.41	
	III.	86.00	2341.55
APR	I.	102.71	
	II.	111.80	
	III.	131.43	3459.34
MAY	I.	176.32	
	II.	319.81	
	III.	681.36	12456.20
JUN	I.	505.65	
	II.	798.26	
	III.	839.78	21436.91
JUL	I.	740.87	
	II.	774.94	
	III.	837.02	24365.27
AUG	I.	801.45	
	II.	758.65	
	III.	613.75	22352.29
SEP	I.	595.20	
	II.	328.61	
	III.	222.77	11465.89

NON-MON= 31382.23 MON= 79620.34 TOT= 111002.60

TEN-DAILY DISCHARGE AND RUNOFF VOLUMES

1972-73		DISCHARGE (CUMEC)	RUNOFF (CUMEC-DAY)
OCT	I.	205.72	
	II.	159.27	
	III.	129.44	5073.75
NOV	I.	109.27	
	II.	96.69	
	III.	93.76	2997.13
DEC	I.	93.57	
	II.	83.79	
	III.	74.32	2591.04
JAN	I.	74.20	
	II.	70.66	
	III.	66.91	2184.58
FEB	I.	73.25	
	II.	70.45	
	III.	69.85	1995.85
MAR	I.	68.09	
	II.	71.31	
	III.	105.67	2556.41
APR	I.	142.12	
	II.	225.87	
	III.	802.77	11707.59
MAY	I.	1307.04	
	II.	566.47	
	III.	786.07	27381.84
JUN	I.	1258.37	
	II.	1870.48	
	III.	1556.98	46858.25
JUL	I.	1334.60	
	II.	1411.75	
	III.	1254.03	41257.79
AUG	I.	888.39	
	II.	893.16	
	III.	972.91	28517.46
SEP	I.	809.76	
	II.	661.73	
	III.	400.27	18717.65

NON-MON= 56488.17 MON= 135351.20 TOT= 191839.30

TEN-DAILY DISCHARGE AND RUNOFF VOLUMES

1973-74		DISCHARGE (CUMEC)	RUNOFF (CUMEC-DAY)
OCT	I.	267.71	
	II.	208.52	
	III.	161.68	6540.70
NOV	I.	137.40	
	II.	123.94	
	III.	111.66	3730.08
DEC	I.	95.98	
	II.	87.71	
	III.	82.06	2739.53
JAN	I.	76.57	
	II.	69.35	
	III.	71.15	2241.89
FEB	I.	67.18	
	II.	68.56	
	III.	68.90	1908.63
MAR	I.	73.16	
	II.	79.60	
	III.	107.39	2708.82
APR	I.	102.79	
	II.	116.27	
	III.	147.42	3664.77
MAY	I.	262.82	
	II.	228.36	
	III.	191.93	7022.99
JUN	I.	284.89	
	II.	454.87	
	III.	422.16	11619.13
JUL	I.	505.60	
	II.	962.68	
	III.	868.79	24239.49
AUG	I.	891.40	
	II.	804.59	
	III.	593.46	23487.97
SEP	I.	402.59	
	II.	271.61	
	III.	209.55	8837.59

NON-MON= 30557.42 MON= 68184.17 TOT= 98741.59

TEN-DAILY DISCHARGE AND RUNOFF VOLUMES

1974-75		DISCHARGE (CUMEC)	RUNOFF (CUMEC-DAY)
OCT	I.	133.29	
	II.	119.18	
	III.	103.25	3660.42
NOV	I.	88.68	
	II.	77.81	
	III.	70.85	2373.42
DEC	I.	65.22	
	II.	76.27	
	III.	76.10	2251.89
JAN	I.	74.89	
	II.	73.66	
	III.	89.60	2471.08
FEB	I.	101.39	
	II.	99.49	
	III.	98.66	2798.09
MAR	I.	102.50	
	II.	123.75	
	III.	127.79	3668.13
APR	I.	193.00	
	II.	209.65	
	III.	327.67	7303.17
MAY	I.	400.18	
	II.	678.15	
	III.	631.68	17731.74
JUN	I.	835.08	
	II.	1402.98	
	III.	1127.77	33658.25
JUL	I.	885.52	
	II.	1289.11	
	III.	1075.37	33575.45
AUG	I.	1192.10	
	II.	1338.27	
	III.	773.38	33810.84
SEP	I.	590.22	
	II.	425.16	
	III.	295.45	13108.31

NON-MON= 42257.93 MON= 114152.90 TOT= 156410.80

TEN-DAILY DISCHARGE AND RUNOFF VOLUMES

1975-76		DISCHARGE (CUMEC)	RUNOFF (CUMEC-DAY)
OCT	I.	236.81	
	II.	210.09	
	III.	147.33	6089.66
NOV	I.	128.96	
	II.	108.95	
	III.	93.57	3314.82
DEC	I.	87.66	
	II.	81.78	
	III.	79.24	2566.04
JAN	I.	77.65	
	II.	72.91	
	III.	72.47	2302.72
FEB	I.	75.90	
	II.	78.87	
	III.	73.07	2132.25
MAR	I.	82.83	
	II.	80.93	
	III.	100.24	2740.15
APR	I.	114.67	
	II.	145.49	
	III.	350.30	6104.72
MAY	I.	330.08	
	II.	474.04	
	III.	630.98	14982.01
JUN	I.	1078.85	
	II.	647.52	
	III.	565.34	22917.02
JUL	I.	877.89	
	II.	1092.25	
	III.	1214.81	33064.37
AUG	I.	904.72	
	II.	751.54	
	III.	585.96	23008.12
SEP	I.	557.57	
	II.	376.96	
	III.	324.74	12592.70

NON-MON= 40232.38 MON= 91582.22 TOT= 131814.60

TEN-DAILY DISCHARGE AND RUNOFF VOLUMES

1976-77		DISCHARGE (CUMEC)	RUNOFF (CUMEC-DAY)
OCT	I.	276.97	
	II.	234.94	
	III.	206.85	7394.44
NOV	I.	151.14	
	II.	129.06	
	III.	116.15	3963.46
DEC	I.	114.10	
	II.	97.79	
	III.	90.26	3111.75
JAN	I.	82.85	
	II.	76.27	
	III.	75.22	2418.61
FEB	I.	74.42	
	II.	73.52	
	III.	73.46	2067.09
MAR	I.	74.90	
	II.	78.12	
	III.	92.21	2544.51
APR	I.	101.80	
	II.	82.87	
	III.	91.48	2761.48
MAY	I.	95.56	
	II.	113.29	
	III.	210.42	4403.11
JUN	I.	384.78	
	II.	211.03	
	III.	995.18	15909.89
JUL	I.	1430.21	
	II.	1369.21	
	III.	1050.26	39547.13
AUG	I.	1235.37	
	II.	712.58	
	III.	675.20	26906.70
SEP	I.	626.55	
	II.	390.82	
	III.	235.98	12533.59

NON-MON= 28664.45 MON= 94897.31 TOT= 123561.80

TEN-DAILY DISCHARGE AND RUNOFF VOLUMES

1977-78		DISCHARGE (CUMEC)	RUNOFF (CUMEC-DAY)
OCT	I.	158.80	
	II.	133.46	
	III.	118.86	4229.95
NOV	I.	108.23	
	II.	103.32	
	III.	97.72	3092.71
DEC	I.	87.34	
	II.	82.73	
	III.	78.69	2566.27
JAN	I.	75.09	
	II.	72.16	
	III.	70.21	2244.85
FEB	I.	68.55	
	II.	68.13	
	III.	67.85	1909.64
MAR	I.	69.05	
	II.	72.73	
	III.	80.43	2302.49
APR	I.	85.00	
	II.	111.39	
	III.	136.31	3326.98
MAY	I.	273.56	
	II.	612.43	
	III.	653.24	16045.55
JUN	I.	882.57	
	II.	687.07	
	III.	1140.90	27105.39
JUL	I.	1124.69	
	II.	1013.75	
	III.	977.29	32134.71
AUG	I.	1114.73	
	II.	1021.52	
	III.	769.52	29827.28
SEP	I.	544.31	
	II.	370.26	
	III.	236.98	11515.49

NON-MON- 35718.45 MON- 100582.90 TOT= 136301.30

TEN-DAILY DISCHARGE AND RUNOFF VOLUMES

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1978-79		DISCHARGE (CUMEC)	RUNOFF (CUMEC-DAY)
OCT	I.	179.23	
	II.	158.22	
	III.	147.06	4992.12
NOV	I.	141.51	
	II.	129.23	
	III.	121.61	3923.53
DEC	I.	115.67	
	II.	111.33	
	III.	107.66	3454.28
JAN	I.	103.08	
	II.	101.80	
	III.	103.10	3182.97
FEB	I.	103.67	
	II.	103.23	
	III.	99.93	2868.48
MAR	I.	99.22	
	II.	107.95	
	III.	112.84	3312.98
APR	I.	164.50	
	II.	206.49	
	III.	328.76	6997.49
MAY	I.	388.04	
	II.	376.56	
	III.	306.20	11014.16
JUN	I.	388.19	
	II.	862.64	
	III.	1857.75	31085.81
JUL	I.	1073.32	
	II.	1215.03	
	III.	981.63	33681.46
AUG	I.	923.56	
	II.	836.56	
	III.	580.03	23981.56
SEP	I.	488.51	
	II.	300.50	
	III.	208.98	9979.82

NON-MON= 39746.01 MON= 98728.66 TOT= 138474.70

TEN-DAILY DISCHARGE AND RUNOFF VOLUMES

1979-80		DISCHARGE (CUMEC)	RUNOFF (CUMEC-DAY)
OCT	I.	176.89	
	II.	161.31	
	III.	135.65	4874.10
NOV	I.	123.01	
	II.	114.62	
	III.	101.51	3391.44
DEC	I.	91.32	
	II.	82.81	
	III.	75.98	2577.14
JAN	I.	73.44	
	II.	72.80	
	III.	75.39	2291.66
FEB	I.	68.57	
	II.	64.27	
	III.	68.55	1876.82
MAR	I.	70.82	
	II.	73.25	
	III.	83.20	2355.83
APR	I.	96.28	
	II.	129.44	
	III.	197.54	4232.55
MAY	I.	320.44	
	II.	369.11	
	III.	418.68	11501.10
JUN	I.	605.02	
	II.	693.62	
	III.	926.16	22248.05
JUL	I.	844.28	
	II.	977.02	
	III.	866.79	27747.67
AUG	I.	913.24	
	II.	556.40	
	III.	556.08	20813.25
SEP	I.	392.31	
	II.	313.74	
	III.	225.42	9314.74

NON-MON= 33100.66 MON= 80123.70 TOT= 113224.40

TEN-DAILY DISCHARGE AND RUNOFF VOLUMES
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1980-81		DISCHARGE (CUMEC)	RUNOFF (CUMEC-DAY)
OCT	I.	203.14	
	II.	160.60	
	III.	143.60	5216.99
NOV	I.	123.98	
	II.	116.61	
	III.	102.21	3427.99
DEC	I.	91.73	
	II.	84.24	
	III.	82.43	2666.45
JAN	I.	80.24	
	II.	73.31	
	III.	74.55	2355.57
FEB	I.	74.85	
	II.	77.76	
	III.	79.13	2159.16
MAR	I.	80.95	
	II.	84.46	
	III.	96.72	2718.08
APR	I.	103.72	
	II.	157.56	
	III.	211.56	4728.39
MAY	I.	389.43	
	II.	407.27	
	III.	509.66	13573.39
JUN	I.	393.04	
	II.	410.05	
	III.	838.58	16416.62
JUL	I.	633.99	
	II.	841.36	
	III.	1012.18	25887.48
AUG	I.	999.85	
	II.	810.76	
	III.	556.13	24223.51
SEP	I.	429.46	
	II.	281.30	
	III.	206.14	9168.96

NON-MON= 36846.02 MON= 75696.58 TOT= 112542.60

TEN-DAILY DISCHARGE AND RUNOFF VOLUMES
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1981-82		DISCHARGE (CUMEC)	RUNOFF (CUMEC-DAY)
OCT	I.	147.35	
	II.	112.10	
	III.	99.87	3693.10
NOV	I.	102.94	
	II.	98.74	
	III.	90.17	2918.44
DEC	I.	83.70	
	II.	80.45	
	III.	74.36	2459.45
JAN	I.	72.61	
	II.	71.72	
	III.	72.81	2244.23
FEB	I.	76.71	
	II.	73.85	
	III.	75.18	2107.00
MAR	I.	80.35	
	II.	82.90	
	III.	91.47	2638.65
APR	I.	125.21	
	II.	131.68	
	III.	199.34	4562.34
MAY	I.	312.91	
	II.	231.57	
	III.	330.68	9082.31
JUN	I.	580.54	
	II.	1040.64	
	III.	830.08	24512.68
JUL	I.	1170.63	
	II.	1240.11	
	III.	1316.43	38588.14
AUG	I.	1139.88	
	II.	1044.29	
	III.	647.59	28965.13
SEP	I.	467.48	
	II.	380.15	
	III.	255.06	11026.84

NON-MON= 29705.54 MON= 103092.80 TOT= 132798.30

TEN-DAILY DISCHARGE AND RUNOFF VOLUMES

1982-83		DISCHARGE (CUMEC)	RUNOFF (CUMEC-DAY)
OCT	I.	200.10	
	II.	177.11	
	III.	157.00	5499.07
NOV	I.	127.80	
	II.	114.20	
	III.	101.76	3437.68
DEC	I.	93.79	
	II.	85.56	
	III.	79.08	2663.35
JAN	I.	76.88	
	II.	71.57	
	III.	69.76	2251.81
FEB	I.	70.01	
	II.	71.54	
	III.	72.84	1998.21
MAR	I.	73.74	
	II.	81.45	
	III.	83.27	2467.93
APR	I.	113.09	
	II.	118.25	
	III.	172.45	4037.90
MAY	I.	298.77	
	II.	586.43	
	III.	570.63	15128.97
JUN	I.	786.11	
	II.	699.96	
	III.	1064.18	25502.50
JUL	I.	1003.17	
	II.	742.20	
	III.	1221.16	30886.35
AUG	I.	1256.97	
	II.	1039.12	
	III.	1100.41	35065.35
SEP	I.	815.75	
	II.	579.66	
	III.	386.84	17822.53

NON-MON= 37484.92 MON= 109276.70 TOT= 146761.70

TEN-DAILY DISCHARGE AND RUNOFF VOLUMES

1983-84		DISCHARGE (CUMEC)	RUNOFF (CUMEC-DAY)
OCT	I.	291.60	
	II.	242.04	
	III.	207.94	7623.83
NOV	I.	173.48	
	II.	132.49	
	III.	107.37	4133.46
DEC	I.	100.07	
	II.	90.08	
	III.	81.58	2799.03
JAN	I.	79.39	
	II.	78.00	
	III.	76.40	2414.32
FEB	I.	75.65	
	II.	71.09	
	III.	75.20	2069.00
MAR	I.	86.84	
	II.	97.34	
	III.	115.19	3108.85
APR	I.	111.60	
	II.	136.69	
	III.	199.81	4480.99
MAY	I.	300.30	
	II.	443.10	
	III.	697.15	15102.64
JUN	I.	961.67	
	II.	790.23	
	III.	791.61	25435.21
JUL	I.	797.31	
	II.	590.97	
	III.	783.19	22497.91
AUG	I.	752.24	
	II.	811.81	
	III.	778.69	24206.10
SEP	I.	617.65	
	II.	335.11	
	III.	191.91	11446.77

NON-MON= 41732.10 MON= 83585.98 TOT= 125318.10

TEN-DAILY DISCHARGE AND RUNOFF VOLUMES

1984-85		DISCHARGE (CUMEC)	RUNOFF (CUMEC-DAY)
OCT	I.	157.83	
	II.	114.70	
	III.	109.21	3926.60
NOV	I.	94.95	
	II.	86.26	
	III.	77.50	2587.13
DEC	I.	77.17	
	II.	73.05	
	III.	70.89	2281.93
JAN	I.	66.92	
	II.	72.55	
	III.	77.32	2245.23
FEB	I.	78.70	
	II.	78.82	
	III.	77.87	2198.13
MAR	I.	81.32	
	II.	85.55	
	III.	89.02	2647.85
APR	I.	89.00	
	II.	96.24	
	III.	120.53	3057.72
MAY	I.	158.73	
	II.	213.32	
	III.	677.23	11170.04
JUN	I.	900.00	
	II.	851.43	
	III.	881.51	26329.35
JUL	I.	940.14	
	II.	907.20	
	III.	996.04	29429.83
AUG	I.	805.25	
	II.	959.60	
	III.	830.90	26788.30
SEP	I.	646.48	
	II.	348.24	
	III.	226.75	12214.71

NON-MON= 30114.63 MON= 94762.19 TOT= 124876.80

TEN-DAILY DISCHARGE AND RUNOFF VOLUMES

1985-86		DISCHARGE (CUMEC)	RUNOFF (CUMEC-DAY)
OCT	I.	170.89	
	II.	170.54	
	III.	143.21	4989.56
NOV	I.	132.75	
	II.	126.53	
	III.	115.74	3750.25
DEC	I.	108.50	
	II.	100.39	
	III.	84.48	3018.09
JAN	I.	70.19	
	II.	73.17	
	III.	74.11	2248.76
FEB	I.	75.09	
	II.	73.02	
	III.	73.10	2065.88
MAR	I.	75.27	
	II.	78.30	
	III.	83.19	2450.70
APR	I.	100.12	
	II.	136.05	
	III.	204.55	4407.20
MAY	I.	287.13	
	II.	501.31	
	III.	233.75	10455.68
JUN	I.	335.37	
	II.	1121.56	
	III.	1655.73	31126.62
JUL	I.	1231.06	
	II.	1387.64	
	III.	1503.54	42726.01
AUG	I.	1267.46	
	II.	1099.76	
	III.	775.99	32208.08
SEP	I.	633.86	
	II.	203.82	
	III.	108.98	9466.57

NON-MON= 33386.13 MON= 115527.30 TOT= 148913.40

TEN-DAILY DISCHARGE AND RUNOFF VOLUMES

1986-87		DISCHARGE (CUMEC)	RUNOFF (CUMEC-DAY)
OCT	I.	98.77	
	II.	75.27	
	III.	75.12	2566.63
NOV	I.	70.67	
	II.	77.57	
	III.	62.92	2111.62
DEC	I.	73.04	
	II.	79.09	
	III.	79.19	2392.32
JAN	I.	74.60	
	II.	87.90	
	III.	95.82	2679.09
FEB	I.	86.71	
	II.	85.06	
	III.	77.56	2338.24
MAR	I.	84.35	
	II.	124.02	
	III.	125.05	3459.19
APR	I.	130.85	
	II.	121.62	
	III.	216.12	4685.85
MAY	I.	213.19	
	II.	180.76	
	III.	401.22	8352.99
JUN	I.	1074.45	
	II.	873.28	
	III.	1017.68	29654.10
JUL	I.	1496.28	
	II.	1192.76	
	III.	1445.82	42794.43
AUG	I.	968.20	
	II.	832.76	
	III.	778.22	26570.06
SEP	I.	584.35	
	II.	417.08	
	III.	352.51	13539.42

NON-MON= 28585.92 MON= 112558.00 TOT= 141143.90

TEN-DAILY DISCHARGE AND RUNOFF VOLUMES

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1987-88		DISCHARGE (CUMEC)	RUNOFF (CUMEC-DAY)
OCT	I.	240.47	
	II.	190.46	
	III.	177.35	6260.18
NOV	I.	151.21	
	II.	93.74	
	III.	117.37	3623.22
DEC	I.	115.93	
	II.	110.99	
	III.	166.40	4099.58
JAN	I.	89.97	
	II.	91.93	
	III.	79.71	2695.92
FEB	I.	77.25	
	II.	74.72	
	III.	80.37	2162.61
MAR	I.	81.95	
	II.	87.00	
	III.	96.34	2749.27
APR	I.	113.97	
	II.	295.55	
	III.	417.02	8265.42
MAY	I.	510.14	
	II.	696.82	
	III.	758.21	20409.98
JUN	I.	717.66	
	II.	818.59	
	III.	1344.67	28809.27
JUL	I.	1280.92	
	II.	1368.74	
	III.	1389.55	41781.64
AUG	I.	1307.83	
	II.	1147.02	
	III.	861.66	34026.84
SEP	I.	635.77	
	II.	471.43	
	III.	468.22	15754.14

NON-MON= 50266.18 MON= 120371.90 TOT= 170638.10

TEN-DAILY DISCHARGE AND RUNOFF VOLUMES

1988-89		DISCHARGE (CUMEC)	RUNOFF (CUMEC-DAY)
OCT	I.	355.16	
	II.	278.80	
	III.	245.50	9040.12
NOV	I.	277.70	
	II.	274.82	
	III.	237.67	7902.00
DEC	I.	201.91	
	II.	193.28	
	III.	183.30	5968.32
JAN	I.	168.58	
	II.	161.27	
	III.	136.20	4796.67
FEB	I.	115.31	
	II.	110.51	
	III.	109.38	3133.21
MAR	I.	112.70	
	II.	106.81	
	III.	110.60	3411.71
APR	I.	116.28	
	II.	128.01	
	III.	136.41	3807.00
MAY	I.	143.70	
	II.	208.27	
	III.	350.84	7378.94
JUN	I.	651.01	
	II.	456.24	
	III.	521.59	16288.38
JUL	I.	525.27	
	II.	861.43	
	III.	962.24	24451.61
AUG	I.	383.15	
	II.	383.45	
	III.	470.50	12841.54
SEP	I.	235.47	
	II.	192.10	
	III.	170.07	5976.45

NON-MON= 45437.96 MON= 59557.98 TOT= 104995.90

TEN-DAILY DISCHARGE AND RUNOFF VOLUMES

1989-90		DISCHARGE (CUMEC)	RUNOFF (CUMEC-DAY)
OCT	I.	158.69	
	II.	148.68	
	III.	135.18	4560.66
NOV	I.	136.40	
	II.	126.61	
	III.	113.47	3764.88
DEC	I.	103.45	
	II.	96.78	
	III.	91.79	3012.02
JAN	I.	84.28	
	II.	78.87	
	III.	68.34	2383.14
FEB	I.	72.28	
	II.	76.71	
	III.	75.11	2090.77
MAR	I.	76.67	
	II.	94.10	
	III.	106.42	2878.42
APR	I.	112.68	
	II.	140.83	
	III.	219.17	4726.80
MAY	I.	385.51	
	II.	1117.87	
	III.	854.29	24431.05
JUN	I.	849.23	
	II.	775.43	
	III.	1538.16	31628.25
JUL	I.	1287.87	
	II.	1136.52	
	III.	1015.71	35416.77
AUG	I.	1000.04	
	II.	737.49	
	III.	760.64	25742.39
SEP	I.	569.87	
	II.	433.59	
	III.	314.19	13176.54

NON-MON= 47847.75 MON= 105964.00 TOT= 153811.70

TEN-DAILY DISCHARGE AND RUNOFF VOLUMES

1990-91		DISCHARGE (CUMEC)	RUNOFF (CUMEC-DAY)
OCT	I.	252.32	
	II.	221.24	
	III.	192.23	6850.07
NOV	I.	173.20	
	II.	163.43	
	III.	144.57	4812.03
DEC	I.	141.43	
	II.	124.79	
	III.	114.08	3917.12
JAN	I.	102.35	
	II.	89.03	
	III.	80.41	2798.23
FEB	I.	80.05	
	II.	71.78	
	III.	85.29	2200.55
MAR	I.	94.21	
	II.	107.62	
	III.	136.13	3515.72
APR	I.	186.04	
	II.	146.85	
	III.	212.05	5449.41
MAY	I.	383.10	
	II.	559.11	
	III.	672.75	16822.35
JUN	I.	1123.58	
	II.	1237.07	
	III.	1163.08	35237.25
JUL	I.	1366.51	
	II.	1189.13	
	III.	1043.33	37032.98
AUG	I.	818.20	
	II.	647.74	
	III.	678.73	22125.46
SEP	I.	567.45	
	II.	454.27	
	III.	466.18	14879.02

NON-MON= 46365.49 MON= 109274.70 TOT= 155640.20

TEN-DAILY DISCHARGE AND RUNOFF VOLUMES

****

1991-92		DISCHARGE (CUMEC)	RUNOFF (CUMEC-DAY)
OCT	I.	316.70	
	II.	260.80	
	III.	253.63	8564.95
NOV	I.	323.41	
	II.	260.82	
	III.	268.55	8527.77
DEC	I.	238.20	
	II.	211.80	
	III.	152.10	6173.10
JAN	I.	115.41	
	II.	106.92	
	III.	101.32	3337.81
FEB	I.	105.03	
	II.	104.10	
	III.	107.91	2954.61
MAR	I.	105.17	
	II.	119.09	
	III.	118.88	3550.31
APR	I.	131.07	
	II.	128.14	
	III.	162.20	4214.07
MAY	I.	154.57	
	II.	159.70	
	III.	229.93	5671.96
JUN	I.	258.94	
	II.	384.00	
	III.	385.01	10279.53
JUL	I.	472.41	
	II.	778.44	
	III.	950.95	22968.91
AUG	I.	604.63	
	II.	1021.38	
	III.	1118.46	28563.15
SEP	I.	885.19	
	II.	705.10	
	III.	661.87	22521.69

NON-MON= 42994.58 MON= 84333.27 TOT= 127327.90

TEN-DAILY DISCHARGE AND RUNOFF VOLUMES

1992-93		DISCHARGE (CUMEC)	RUNOFF (CUMEC-DAY)
OCT	I.	565.55	
	II.	348.27	
	III.	282.75	12248.52
NOV	I.	284.33	
	II.	278.30	
	III.	262.88	8255.07
DEC	I.	243.19	
	II.	225.95	
	III.	212.37	7027.53
JAN	I.	194.75	
	II.	160.74	
	III.	122.33	4900.52
FEB	I.	103.24	
	II.	100.85	
	III.	110.31	2923.34
MAR	I.	111.95	
	II.	115.80	
	III.	112.62	3516.33
APR	I.	110.62	
	II.	114.46	
	III.	117.12	3421.98
MAY	I.	112.49	
	II.	121.78	
	III.	210.38	4656.82
JUN	I.	367.85	
	II.	214.24	
	III.	432.61	10147.05
JUL	I.	460.35	
	II.	717.85	
	III.	614.11	18537.25
AUG	I.	747.33	
	II.	927.92	
	III.	599.44	23346.30
SEP	I.	690.08	
	II.	529.31	
	III.	517.18	17365.68

NON-MON= 46950.12 MON= 69396.29 TOT= 116346.40

TEN-DAILY DISCHARGE AND RUNOFF VOLUMES

1993-94		DISCHARGE (CUMEC)	RUNOFF (CUMEC-DAY)
OCT	I.	417.13	
	II.	347.80	
	III.	222.83	10100.42
NOV	I.	181.67	
	II.	165.82	
	III.	154.77	5022.72
DEC	I.	149.80	
	II.	146.76	
	III.	143.35	4542.55
JAN	I.	140.98	
	II.	135.51	
	III.	131.60	4212.56
FEB	I.	124.63	
	II.	117.32	
	III.	116.38	3350.59
MAR	I.	125.57	
	II.	127.02	
	III.	113.46	3773.94
APR	I.	121.43	
	II.	141.39	
	III.	153.73	4165.47
MAY	I.	154.98	
	II.	151.78	
	III.	177.64	5021.62
JUN	I.	303.29	
	II.	372.00	
	III.	806.44	14817.24
JUL	I.	1046.82	
	II.	924.80	
	III.	1743.12	38890.44
AUG	I.	1787.74	
	II.	1525.54	
	III.	1728.90	52150.68
SEP	I.	1616.98	
	II.	1122.76	
	III.	1229.83	39695.67

NON-MON= 40189.86 MON= 145554.00 TOT= 185743.90

TEN-DAILY DISCHARGE AND RUNOFF VOLUMES

1994-95		Discharge (Cumec)	Run-off (Cumec-Day)
OCT	I	222.04	
	II	187.19	5964.35
	III	170.19	
NOV	I	154.70	
	II	139.82	4198.21
	III	125.30	
DEC	I	112.46	
	II	102.88	3191.85
	III	94.41	
JAN	I	84.94	
	II	79.93	2474.78
	III	75.10	
FEB	I	75.57	
	II	75.34	2120.91
	III	76.47	
MAR	I	77.08	
	II	80.89	2777.95
	III	108.93	
APR	I	97.09	
	II	111.68	3686.40
	III	159.88	
MAY	I	241.96	
	II	740.82	14312.95
	III	407.75	
JUNE	I	818.34	
	II	1125.35	25486.49
	III	604.98	
JULY	I	988.15	
	II	1029.43	31249.79
	III	1006.74	
AUG	I	959.96	
	II	868.66	26468.33
	III	743.83	
SEPT	I	599.60	
	II	414.18	13122.95
	III	298.52	
		TOTAL	**135054.94**

Non-Monsoon = 38727.38
Monsoon = 96327.56

TEN-DAILY DISCHARGE AND RUNOFF VOLUMES

1995-96		Discharge (Cumec)	Run-off (Cumec-Day)
OCT	I	255.74	
	II	232.84	7237.35
	III	213.78	
NOV	I	197.03	
	II	187.11	5568.63
	III	172.73	
DEC	I	167.41	
	II	164.46	5019.56
	III	154.63	
JAN	I	150.70	
	II	145.94	4593.67
	III	147.93	
FEB	I	110.60	
	II	110.02	3201.39
	III	110.58	
MAR	I	114.14	
	II	118.84	3690.64
	III	123.71	
APR	I	133.79	
	II	284.82	8681.23
	III	449.51	
MAY	I	435.14	
	II	418.36	15424.78
	III	626.35	
JUNE	I	634.92	
	II	1109.19	31833.30
	III	1439.21	
JULY	I	764.15	
	II	933.40	27258.74
	III	934.84	
AUG	I	899.60	
	II	1017.46	25813.24
	III	603.88	
SEPT	I	0.00	
	II	0.00	0.00
	III	0.00	
		TOTAL	**138322.54**

Non-Monsoon = 53417.26
Monsoon = 84905.28

TEN-DAILY DISCHARGE AND RUNOFF VOLUMES

1996-97		Discharge (Cumec)	Run-off (Cumec-Day)
OCT	I	224.93	
	II	190.26	6012.04
	III	169.11	
NOV	I	157.20	
	II	146.32	4401.90
	III	136.67	
DEC	I	120.61	
	II	113.23	3538.25
	III	109.08	
JAN	I	100.42	
	II	96.30	2980.19
	III	92.09	
FEB	I	84.74	
	II	72.43	2313.91
	III	92.78	
MAR	I	100.81	
	II	105.56	3222.37
	III	105.33	
APR	I	105.38	
	II	119.29	3955.47
	III	170.87	
MAY	I	214.44	
	II	147.51	6294.55
	III	243.18	
JUNE	I	359.66	
	II	536.05	15462.73
	III	650.56	
JULY	I	678.67	
	II	798.41	23658.58
	III	807.98	
AUG	I	659.30	
	II	572.12	17617.56
	III	482.12	
SEPT	I	414.46	
	II	356.85	10271.53
	III	255.85	
		TOTAL	**99729.07**

Non-Monsoon = 32718.67
Monsoon = 67010.40

TEN-DAILY DISCHARGE AND RUNOFF VOLUMES

1997-98		Discharge (Cumec)	Run-off (Cumec-Day)
OCT	I	189.75	
	II	161.71	5149.72
	III	148.65	
NOV	I	134.73	
	II	124.37	3758.37
	III	116.74	
DEC	I	111.47	
	II	107.86	3177.32
	III	89.46	
JAN	I	85.27	
	II	86.14	2680.63
	III	87.86	
FEB	I	86.13	
	II	86.31	2362.69
	III	79.79	
MAR	I	89.04	
	II	94.45	2972.56
	III	103.43	
APR	I	184.78	
	II	207.02	6961.27
	III	304.33	
MAY	I	401.21	
	II	464.61	17568.53
	III	810.03	
JUNE	I	770.41	
	II	699.57	28408.70
	III	1370.88	
JULY	I	1597.11	
	II	1442.68	42765.49
	III	1124.32	
AUG	I	1058.69	
	II	980.89	29020.68
	III	784.08	
SEPT	I	667.70	
	II	543.72	17251.67
	III	513.74	
		TOTAL	**162077.63**

Non-Monsoon = 44631.09
Monsoon = 117446.54

TEN-DAILY DISCHARGE AND RUNOFF VOLUMES

1998-99		Discharge (Cumec)	Run-off (Cumec-Day)
OCT	I	349.71	
	II	332.00	9933.87
	III	283.34	
NOV	I	239.7	
	II	213.78	6321.70
	III	178.69	
DEC	I	155.03	
	II	155.03	4805.93
	III	155.03	
JAN	I	133.36	
	II	133.36	4134.16
	III	133.36	
FEB	I	122.32	
	II	122.32	3424.96
	III	122.32	
MAR	I	132.34	
	II	132.34	4102.54
	III	132.34	
APR	I	388.10	
	II	388.10	11643.00
	III	388.10	
MAY	I	533.92	
	II	669.18	19633.24
	III	691.11	
JUNE	I	447.03	
	II	855.62	22639.03
	III	961.25	
JULY	I	1130.74	
	II	1021.35	32727.92
	III	1018.82	
AUG	I	1446.01	
	II	925.78	32870.88
	III	832.08	
SEPT	I	652.61	
	II	538.54	16444.90
	III	453.34	
		TOTAL	**168682.14**

Non-Monsoon = 63999.41
Monsoon = 104682.74

TEN-DAILY DISCHARGE AND RUNOFF VOLUMES

1999-2000		Discharge (Cumec)	Run-off (Cumec-Day)
OCT	I	292.77	
	II	210.51	7213.84
	III	198.28	
NOV	I	176.93	
	II	159.69	4843.75
	III	147.76	
DEC	I	136.90	
	II	123.67	3858.17
	III	113.87	
JAN	I	107.93	
	II	110.64	3383.60
	III	108.90	
FEB	I	106.91	
	II	107.28	3108.64
	III	107.42	
MAR	I	107.42	
	II	108.35	3478.53
	III	120.08	
APR	I	174.61	
	II	209.50	6178.05
	III	233.71	
MAY	I	326.68	
	II	657.98	17071.41
	III	656.81	
JUNE	I	603.75	
	II	901.29	24287.85
	III	923.75	
JULY	I	922.75	
	II	1029.24	33558.06
	III	1276.21	
		TOTAL	**106981.89**

Non-Monsoon = 49135.99
Monsoon = 57845.91

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Chapter - A4

WATER AVAILABILITY

4.1 General

Ten daily discharges at Karcham dam site are available for a period of 34 hydrological years i.e. from 1966-67 to 1999-2000 as shown in table 3.8 of Chapter A-3. The ten daily hydrograph at dam site have been drawn and is given in Fig. A-9. The hydrographs show significant difference in non-monsoon and monsoon flows.

4.2 Computation of Dependability

For computation of 90% and 50% dependable discharges, the full year run-off volumes of the hydrological years have been arranged in descending order of magnitude and exceedance frequency computed using Weibull's plotting position formula $\left(\frac{m}{n+1}\right)$ as given in table 4.1.

4.3 90% Dependable and 50% Dependable Year

From Table 4.1, it is observed that year 1973-74 with an exceedance frequency of 91.43% can be used as 90% dependable year on a safer side. Similarly, 1994-95 with a frequency of 51.43% has been taken as 50% dependable year.

A bar chart is also presented (Fig. A-10) which shows the relative magnitude of run-off in 90% and 50% dependable year with respect to other years.

4.4 Flow Duration Curve

Flow duration curve for Karcham dam site has been established using 10 daily average discharges at Karcham. From this curve the discharge prevalent and exceeding 90% of the time has been computed as 87.03 cumec while the discharge prevalent and exceeding 50% of the time has been computed as 197.95 cumec. This curve has been shown in Fig. A-11. It has been observed from this that the frequency corresponding to design discharge of 417 cumec comes out to be 33.53%.

Table 4.1

FULL YEAR RUNOFF AT KARCHAM AND EXCEEDANCE PROBABILITY

Sl. No.	Year	Runoff Cumec-day	Run-off HA-M	Probability % M/(N+1)x100
1	1972-73	191839.3	1657491.552	2.86
2	1993-94	185743.9	1604827.296	5.71
3	1987-88	170638.1	1474313.184	8.57
4	1998-99	168682.14	1457413.69	11.43
5	1997-98	162077.63	1400350.723	14.29
6	1974-75	156410.8	1351389.312	17.14
7	1990-91	155640.2	1344731.328	20.00
8	1989-90	153811.7	1328933.088	22.86
9	1967-68	150365.5	1299157.92	25.71
10	1985-86	148913.4	1286611.776	28.57
11	1982-83	146761.7	1268021.088	31.43
12	1968-69	145512.2	1257225.408	34.29
13	1966-67	143580.8	1240538.112	37.14
14	1986-87	141143.9	1219483.296	40.00
15	1978-79	138474.7	1196421.408	42.86
16	1995-96	138322.54	1195106.746	45.71
17	1977-78	136301.3	1177643.232	48.57
18	**1994-95**	**135054.94**	**1166874.682**	**51.43**
19	1981-82	132798.3	1147377.312	54.29
20	1975-76	131814.6	1138878.144	57.14
21	1991-92	127327.9	1100113.056	60.00
22	1983-84	125318.1	1082748.384	62.86
23	1984-85	124876.8	1078935.552	65.71
24	1976-77	123561.8	1067573.952	68.57
25	1992-93	116346.4	1005232.896	71.43
26	1979-80	113224.4	978258.816	44.29

Sl. No.	Year	Runoff Cumec-day	Run-off HA-M	Probability % M/(N+1)x100
27	1980-81	112542.6	972368.064	77.14
28	1971-72	111002.6	959062.464	80.00
29	1999-2000	106981.89	924323.5296	82.86
30	1988-89	104995.9	907164.576	85.71
31	1996-97	99729.07	861659.1648	88.57
32	**1973-74**	**98741.59**	**853127.3376**	**91.43**
33	1970-71	98467.31	850757.5584	94.29
34	1969-70	89557.48	773776.6272	97.14

Chapter - A5

DESIGN FLOOD

5.1 General

The catchment area of river Satluj at Karcham is about 48755 km^2 including a snowbound catchment of 38760 km^2 as shown in Fig. A-3. The maximum flows occur during June-August resulting due to combined contribution of rainfall and snow melt. A significant portion (about 3/4) of the catchment are lies in Tibet territory of Republic of China. For this area no record of rainfall/runoff is available with Indian Meteorological Department (IMD).

For Indian part of Satluj basin following rain gauge stations are available in the catchment area upto Karcham dam site.

Name of Station	District	Altitude	Year of Commencement
Purbani	Kinnaur	2285	1951
Chini/Kalpa	Kinnaur	2530	1951
Sangla	Kinnaur	2590	1957
Kilba	Kinnaur	2200	1901

It was proposed to use the data of these stations to obtain 1-day, 2-day Probable Maximum Precipitation and apply it to the rainfed catchment to determine the amplitude of flood above the river base flow. Indian Meteorological Department (IMD) was contacted and requested to work out a design PMP based on hydro-meteorological approach. After a preliminary study, IMD has concluded that record of rainfall available for the catchment area is insufficient as these stations are situated at much lower elevations as compared to the major part of the catchment. With such a large sized catchment where appreciable area is in under snow cover and most of the catchment ungauged, using hydro meteorological or rational approach becomes impractical. For these reasons, it was considered more reasonable to use the observed discharge data of river in the vicinity of project site and adopt statistical methods of frequency distribution.

5.2 River Data of Satluj

As earlier pointed out in Chapter A-3 flow data at Wangtoo bridge gauge site is available for 28 years of continuous period (years 1966-67 to 1993-94). Discharge data is also available at Karcham for the year 1994-95 onwards. As per the correlation studies Wangtoo data has been found to be consistent. Wangtoo data and Karcham data has therefore been used for flood frequency analysis.

5.3 Flood Estimation Computations

Design flood estimation has been carried out using following methods :

1. Gumbel's Method
2. Gumbel's method with confidence limit
3. Chow's Method

Annual peaks observed at Karcham are given in Table 5.1. The proposed dam shall be operative after construction as a diversion dam hence a return period of 100 year has been selected for computation of design flood.

Nathpa Jhakri Power Corporation (NJPC) has estimated design flood at Nathpa dam site using Regional Flood Frequency Analysis. The results are also applicable to the present study with suitable correction factor for the slight difference in the catchment area.

5.3.1 Gumbel's Method

Gumbel's method uses extreme value distribution to the observed peaks to construct frequency curve. The computation of the frequency curve is given in Table 5.2. The flood for 100 year interval is 6097 whereas the same for 1000 year interval is 8260. *Confidence limits for 95% confidence have been worked out in Table 5.3.*

It gives a higher side limit of 7676 cumec to 100 year flood at 95% reliability.

5.3.2 Chow's Method

In Table 5.4, Chow's method has been used to compute the flood discharges for various return periods. It gives a hundred year flood of 5560 cumec and a 1000year flood of 7472 cumec.

5.4 Design Flood

Flood discharges for river Satluj at Karcham have been worked out using several methods in preceding paragraphs. A comparison of the flood magnitudes by different methods has been presented in Table 5.5. The results by all three methods adopted are comparable. The higher limit of confidence band for 95% reliability in Gumbel's method gives a figure of 7676, which is highest for 100 year flood.

On 1.8.2000 a flash flood of abut 6500 cumec was recorded at Jhakri Power House site. As no record of this flood of Karcham is available a peak flood of 6500 cumec has been adopted at Karcham Dam site which is on conservative side.

It will be read from Table 5.5 that for a return period of 1 in 100 year magnitude of flood will be of the order of 6097 cumec while for 1 in 1000 return period the flood will be of the order of 8260 cumec. Since about 80% catchment area of Satluj is in China for which hydrological data is not available; it is proposed to use design flood of 8260 cumec for design of spillway at Karcham Dam.

5.4 Non-Monsoon Flood

To provide protection during construction of the diversion dam, a river diversion work for Non-monsoon duration has to be carried out. The magnitude of the flood to be diverted depends upon the number of month in the year for which protection is desired. After a comparison of several alternatives it has been decided to design a flood protection work for a working season of 8 months (from 16th September to 15th May).

In Table 5.6 the computation of Non-Monsoon flood by Gumbel's method has been carried out using yearly maximum values. A 25 year flood of 1312 cumec has been selected for design of diversion works.

Table 5.1

PEAK DAILY OBSERVED FLOODS AT KARCHAM

Z = log log (T/T-1)

Date	Flood Peaks X	T, Year	Z	XZ	Z^2
1/8/2000*	6500.000	36	-1.912	-12430.700	3.657
10/6/1968	2823.631	18	-1.605	-4532.310	2.576
26/6/1966	2721.674	12	-1.423	-3871.961	2.024
13/6/1973	2663.546	9	-1.291	-3438.992	1.667
29/6/1979	2580.397	7.2	-1.187	-3064.176	1.410
1/8/1994	2551.064	6	-1.101	-2809.685	1.213
19/6/1975	2484.823	5.143	-1.027	-2552.692	1.055
23/6/1986	2479	4.5	-0.962	-2384.794	0.925
11/7/1969	2119.631	4	-0.903	-1914.669	0.816
13/7/1977	1972.709	3.6	-0.850	-1676.345	0.722
8/7/1987	1951.206	3.273	-0.800	-1561.643	0.641
10/8/1982	1908.114	3	-0.754	-1439.218	0.569
10/6/1991	1900.085	2.769	-0.711	-1350.796	0.505
1/7/1967	1811.574	2.571	-0.670	-1213.447	0.449
1/7/1983	1810.298	2.4	-0.631	-1141.628	0.39
4/7/1998	1808.16	2.25	-0.593	-1072.232	0.352
20/7/1988	1779	2.118	-0.557	-990.299	0.310
20/7/1976	1774.156	2	-0.521	-925.028	0.272
22/7/1992	1761	1.894	-0.487	-857.567	0.237
25/6/1990	1721.702	1.8	-0.453	-780.331	0.205
27/6/1996	1687.71	1.714	-0.420	-708.796	0.176
3/8/1971	1597.021	1.636	-0.387	-618.097	0.150
2/7/1978	1545.305	1.565	-0.354	-547.386	0.125
29/7/1989	1513.645	1.5	-0.321	-486.442	0.103
5/8/1999	1485.87	1.44	-0.288	-428.330	0.083

Date	Flood Peaks X	T, Year	Z	XZ	Z^2
9/8/1981	1387	1.385	-0.255	-353.254	0.065
13/8/1974	1350.411	1.333	-0.220	-297.577	0.049
12/7/1980	1342	1.286	-0.185	-248.197	0.034
11/6/95	1284.9	1.241	-0.148	-190.172	0.022
18/7/1985	1234	1.2	-0.109	-134.427	0.012
12/7/1993	1223	1.161	-0.067	-81.758	0.004
5/6/1984	1159	1.125	-0.020	-23.576	0.000
4/7/1972	1138.922	1.091	0.033	37.692	0.001
16/7/1997	944.66	1.059	0.099	93.274	0.010
11/8/1970	820.454	1.029	0.192	157.604	0.037
35 yrs	66835.668		-20.891	-53837.955 say -53838	20.876

$\overline{X}$ = 1909.59 S = 940.23

say 1910 say 941

A = 919.36 B = -1658.51

say 920 say - 1659

- A flood of 6500 cumec was recorded on 1.8.2000 at Jhakri Power House site of Nathpa Jhakri H.E. Project. Since no record of this flood is available at Karcham Dam site, same value has been adopted, which is on the conservative side.

Table 5.2

FLOOD FREQUENCY ANALYSIS BY GUMBEL'S METHOD

Return Period	$\overline{X}$ (cumecs)	S. (cumec)	K	K.S	Q = X+KS	Peak 1.15Q
5	1910	941	0.852	801.732	2711.732	3118.4918
10	1910	941	1.518	1428.438	3338.438	3839.2037
20	1910	941	2.157	2029.737	3939.737	4530.69755
50	1910	941	2.985	2808.885	4718.885	5426.71775
100	1910	941	3.604	3391.364	5301.364	6096.5686
200	1910	941	3.826	3600.266	5510.266	6336.8059
500	1910	941	4.492	4226.972	6136.972	7057.5178
1000	1910	941	5.602	5271.482	7181.482	8258.7043

Table 5.3

CALCULATION OF CONFIDENCE LIMITS FOR VARIOUS RETURN PERIOD FLOODS BY GUMBEL'S METHOD

S = 941

N = 35

$\frac{S}{\sqrt{N}}$ = 159.06

t = 1.96 for 95% confidence

Return Period T	Est. Flood X	Constant τ	$\sigma H = \frac{S}{\sqrt{N}} \times \tau$	tσH	Limits	
					Lower 1.15(X - tσH)	Upper 1.15(X + tσH)
10	3338.438	2.205	350.723	687.417	3048.674	4629.733
20	3939.737	2.929	465.881	913.127	3480.602	5580.793
50	4718.885	3.768	599.3307	1174.688	4075.826	6777.609
100	5301.364	4.404	700.4916	1372.963	4517.661	7675.477

Table 5.4

FLOOD FREQUENCY ANALYSIS BY CHOW'S METHOD

Return Period T	$Z = \log\log\left(\frac{T}{T-1}\right)$	X = 920 - 1659Z	Peak discharge 1.15X
5	-1.014	2601.61217	2991.854
10	-1.340	3142.29686	3613.641
20	-1.652	3660.93344	4210.073
50	-2.057	4332.24779	4982.085
100	-2.360	4835.30636	5560.602
200	-2.662	5336.52344	6137.002
500	-3.061	5997.78425	6897.452
1000	-3.362	6497.558	7472.192

Table 5.5

COMPARISON OF FLOOD DISCHARGES OBTAINED BY DIFFERENT METHODS

Sl. No.	Method	Discharge in cumec for different return periods				
		Return Period (year)				
		5	20	50	100	1000
1.	Gumbel's Method	3119	4531	5427	6097	8260
2.	Gumbel's method with 95% confidence band (upper limit)		5581	6778	7676	
3.	Chow's Method	2992	4210	4982	5560	7472

Table 5.6

NON-MONSOON FLOOD ESTIMATION BY GUMBEL'S METHOD

Date	Observed Flood (Cumec)	T (Years)
7/5/73	1849.01	36
1/5/68	1035.53	18
16/5/95	950.63	12
23/9/88	943.54	9
26/5/98	914.13	7.2
15/5/75	873	6
21/5/99	865.62	5.14
28/5/96	794.69	4.5
15/5/2000	723.66	4
10/5/90	665.26	3.6
15/586	660.73	3.27
16/9/83	659.87	3
15/5/78	659.76	2.77
13/5/70	656.22	2.57
15/5/91	619.97	2.4
14/5/76	617.08	2.25
6/5/81	541.4	2.12
14/5/84	526.01	2
17/5/66	518.37	1.89
11/569	517.21	1.8
2/5/79	508.89	1.71
16/9/94	506.86	1.64
15/5/92	478.36	1.57
17/9/87	472.88	1.5
16/9/67	443.74	1.44
8/5/93	440.21	1.38
15/5/80	434.47	1.33

Date	Observed Flood (Cumec)	T (Years)
10/5/82	415.42	1.29
16/9/77	412.87	1.24
16/9/72	366.15	1.2
9/5/74	362.72	1.16
18/9/97	351.99	1.125
16/9/85	343.92	1.09
16/9/71	247	1.06
15/5/89	238.15	1.03
$\overline{X}$ =617.58 Say 618	S = 293.07 Say 294	N = 35

T (Year)	$\bar{x}$	S	K	KxS	Flood (cumec)
5	618	294	0.852	250.488	868.488
10	618	294	1.518	446.292	1064.292
20	618	294	2.157	634.158	1252.158
25	618	294	2.36	693.84	1311.84
50	618	294	2.985	877.59	1495.59
75	618	294	3.347	984.018	1602.018
100	618	294	3.604	1059.576	1677.576
1000	618	294	5.602	1646.988	2264.988

Design flood for 25 years interval at Karcham= 1311.84 cumec

Say 1312 Cumec

Chapter - A6

RESERVOIR CAPACITY AND RESERVOIR SEDIMENTATION

6.1 General

Power station of Karcham-Wangtoo Hydroelectric Project will basically operate as a peaking station. During monsoon period when sufficient water is available the power station will operate at full capacity. During lean flow period (Oct-May) the power station will operate as a peaking station for about 4 hours daily, and will generate additional power during rest of the period depending upon the availability of water.

It is therefore necessary to provide diurnal storage in the reservoir to obtain full peaking advantage even during the leanest flow period.

6.2 Diurnal Storage

The minimum 90% availability discharge is 80.82 cumec as against requirement of 417 cumec to generate 1000 MW which is the installed capacity. Diurnal storage of 4.841 million cum (484.10 Ha-m) is therefore required to provide 4 hour peaking round the year.

6.3 Reservoir Capacity

The maximum pond level for the reservoir has been kept at El 1810 which is the tailwater level of Baspa Hydroelectric Project Stage II.

Fig. A-13 gives the area capacity curve for the reservoir at Karcham dam. It will be seen that gross capacity at El 1810 is 858.29 Ha-m. Allowing for loss of storage due to sedimentation the maximum pond level has been fixed at El 1799. This gives reservoir capacity of 544.97 Ha-m between maximum and minimum pond levels.

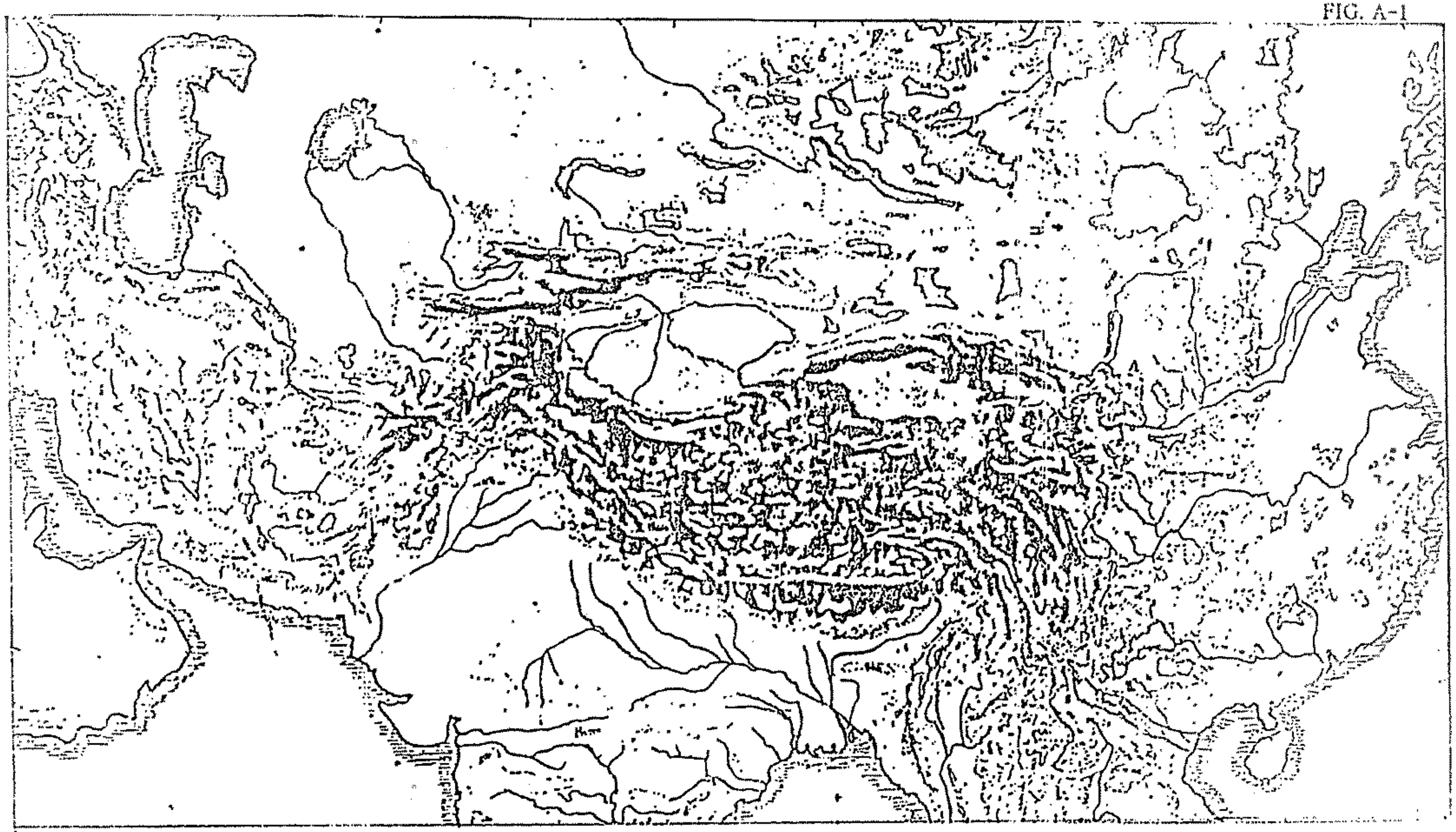
6.4 Reservoir Sedimentation

The crest level of undersluice spillway at the Karcham dam has been kept at El 1782. the undersluices have been provided with radial gates which can be operated under partial opening (undershot condition) to flush out the silt deposited in the reservoir. This operation will be carried out at regular intervals during monsoons.

However, the effect of flushing will not go upto end of reservoir. Therefore after siltation of the reservoir upto the crest elevation (El 1782) the river bed will take new slope along Satluj river and along Baspa river as shown in Fig. A-14 and Fig. A-15 respectively. Thus some capacity between El 1810 and El 1799 (Maximum and minimum pond levels) will be lost due to siltation. As shown in Figs. A-14 and A-15 thus loss of capacity will be 51.53 Ha-m along Satluj river and 2.31 Ha-m along Baspa river.

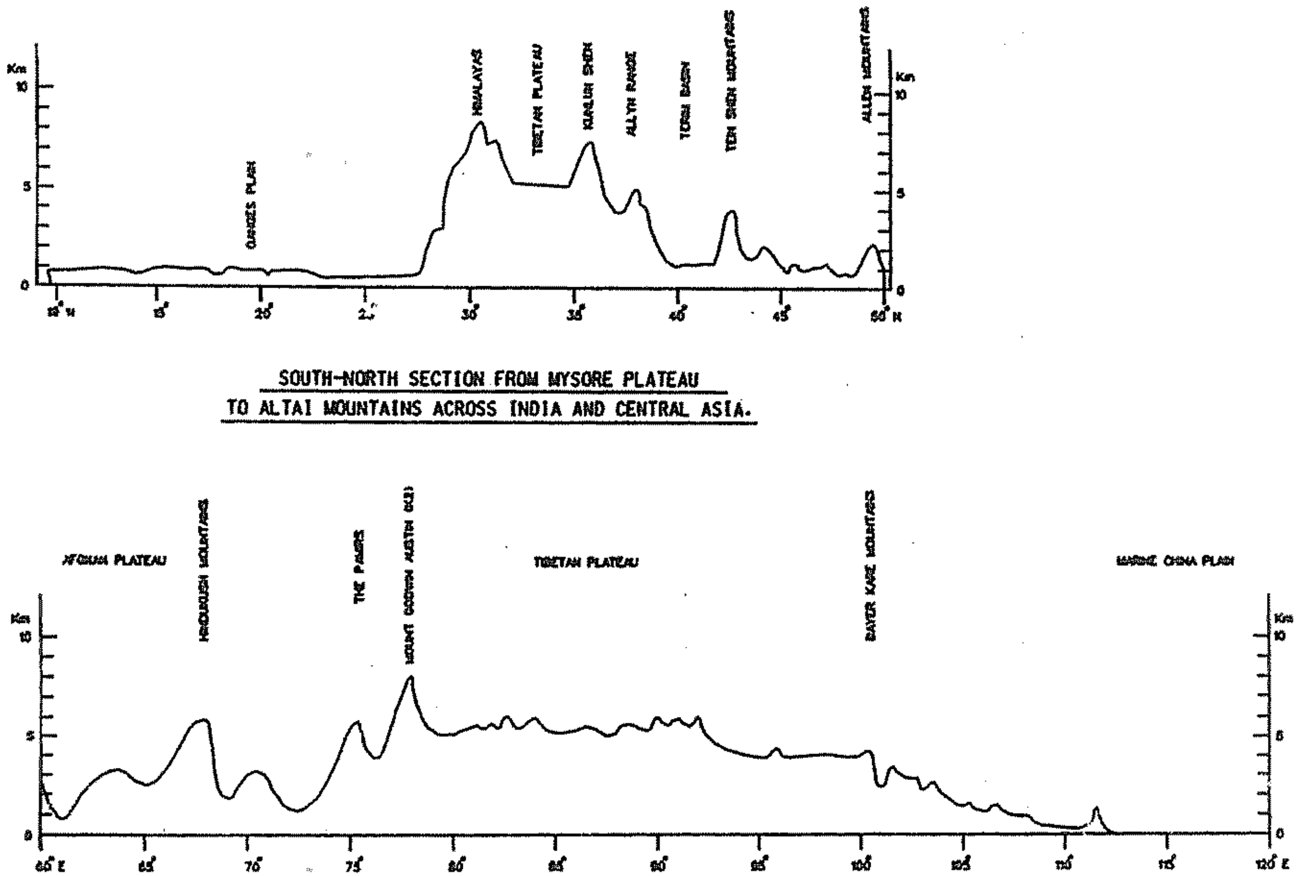
After accounting for this loss the net capacity available between maximum and minimum pond levels will be 491.13 Ha-m, which is more than the capacity (484.10 Ha-m) required for 4 hour period through out the year.

FIG. A-1



RELIEF MAP OF HIMALAYAS, TIBET AND ADJOINING AREAS

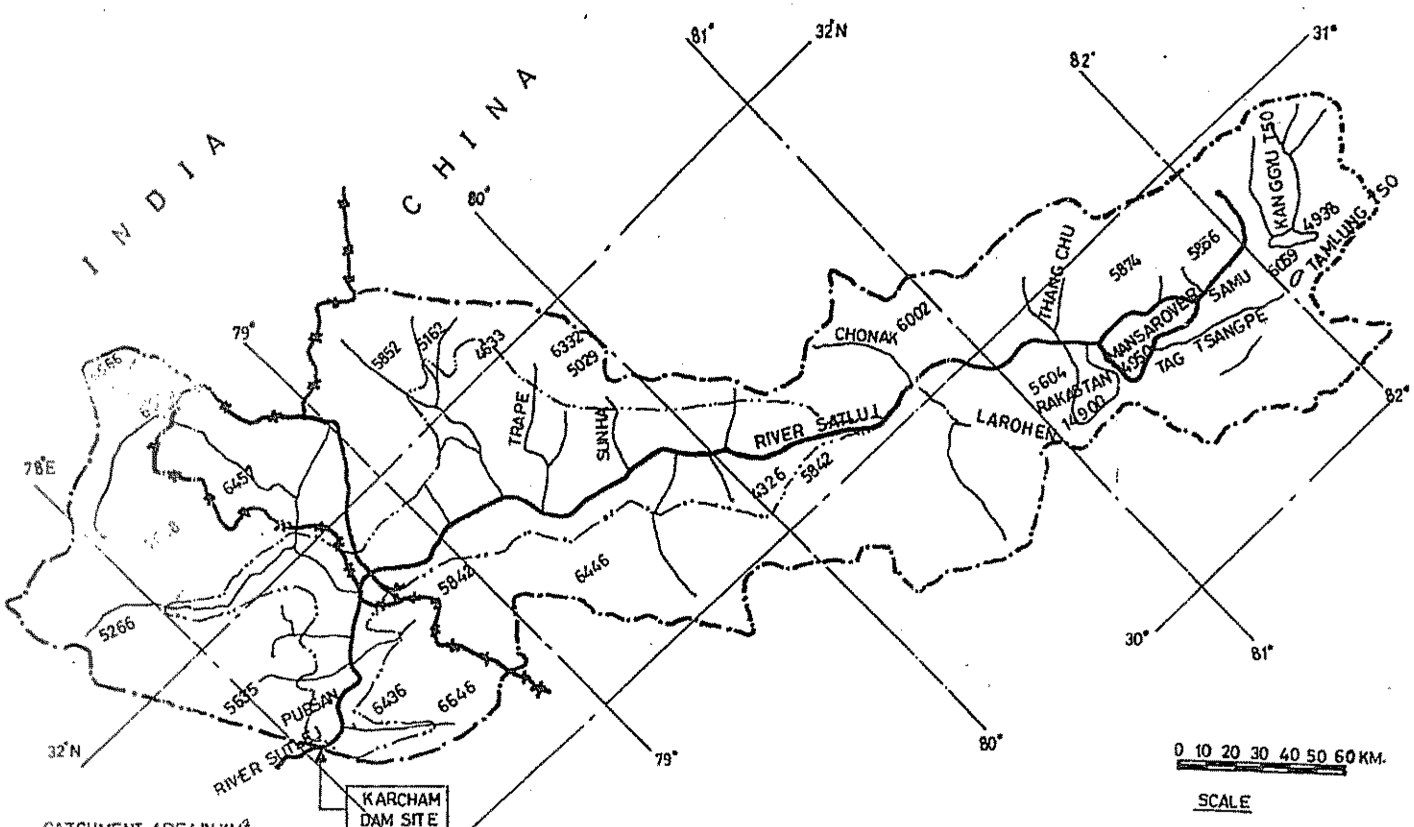
FIG. A-2



SOUTH-NORTH SECTION FROM MYSORE PLATEAU
TO ALTAI MOUNTAINS ACROSS INDIA AND CENTRAL ASIA.

WEST-EAST SECTION FROM AFGHAN PLATEAU TO YELLOW SEA
ALONG LATITUDE 35° N

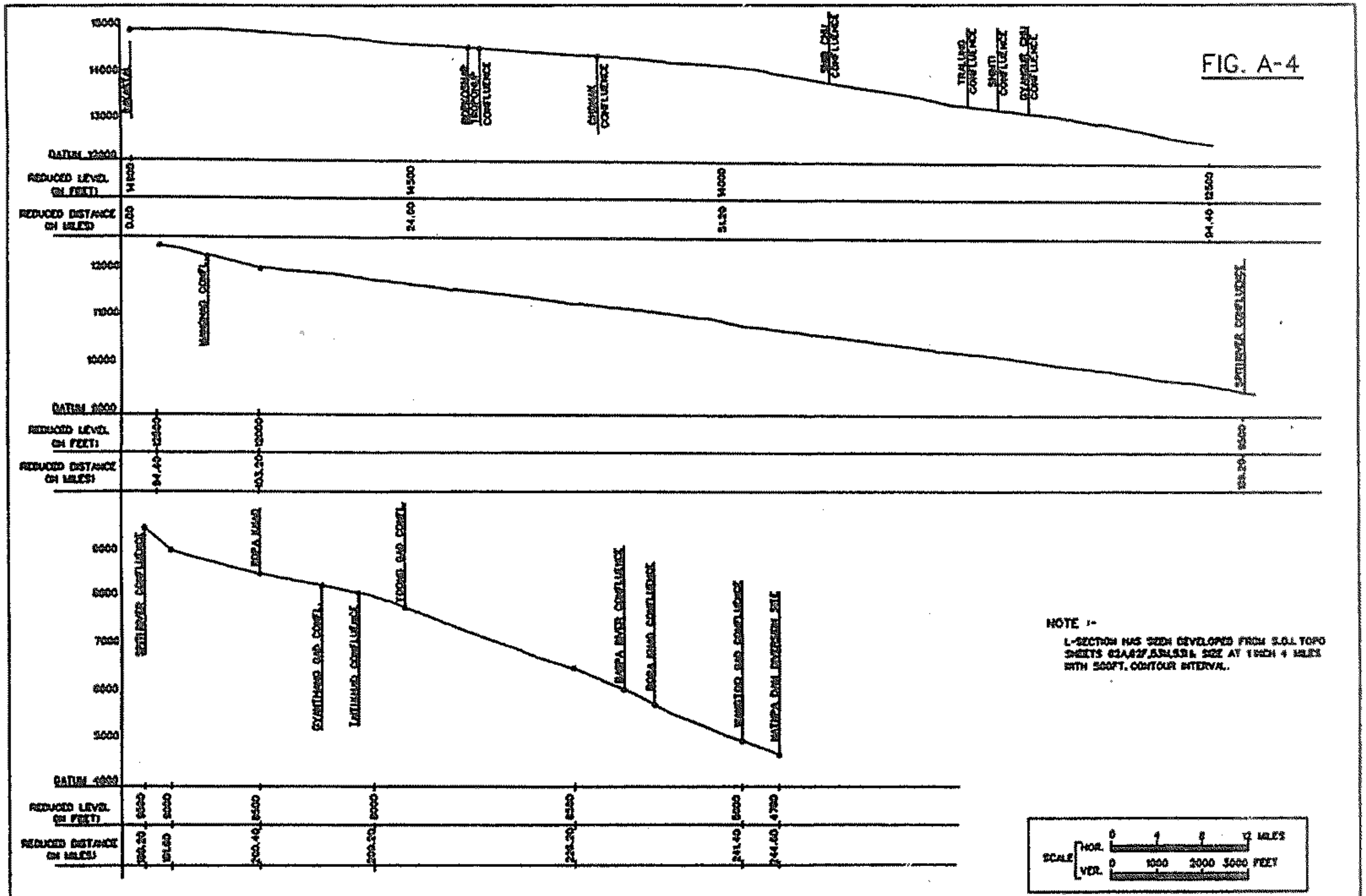
FIGURE A-3



CATCHMENT AREA IN KM^2

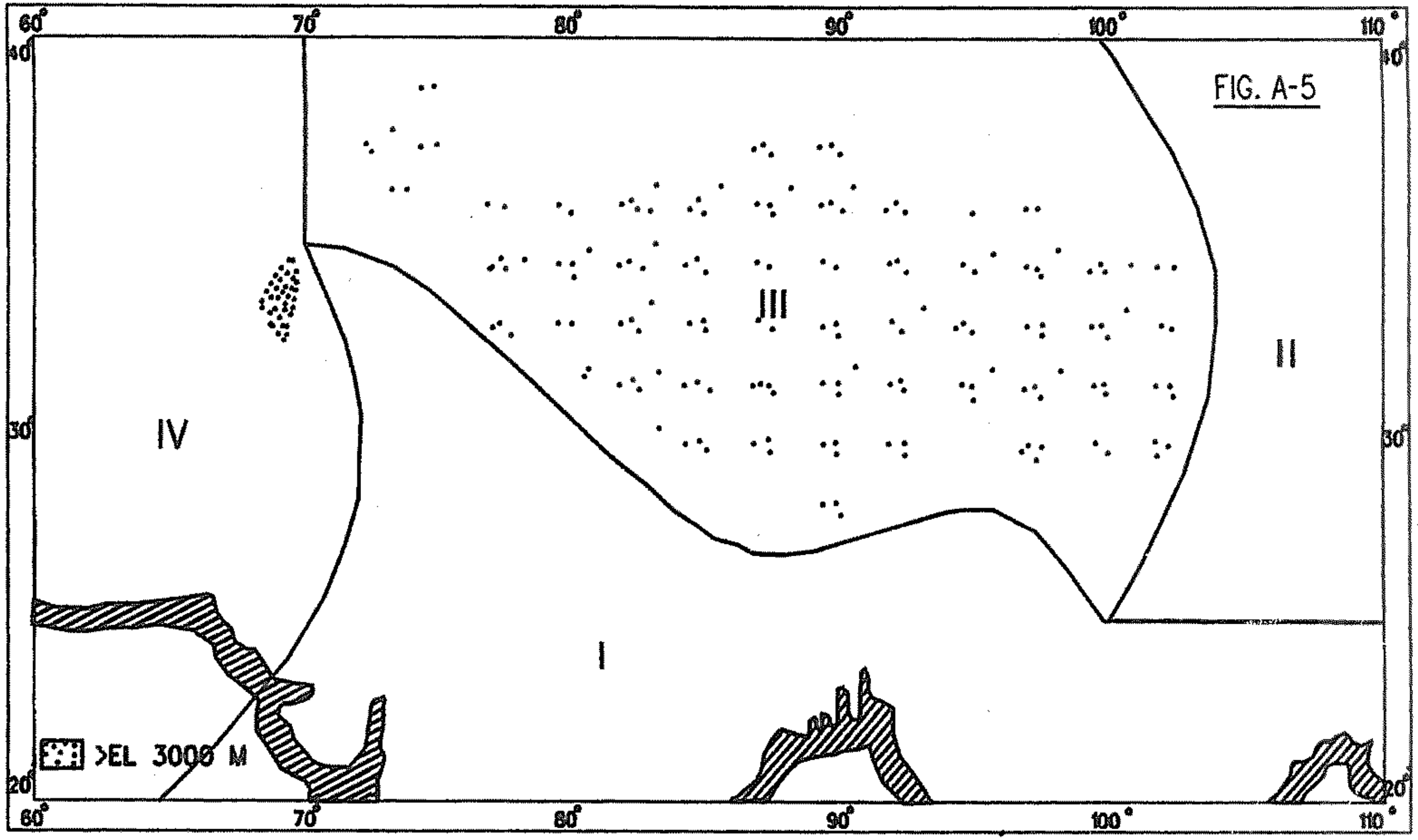
NATION	RAINFED	RAINFED+ SNOWBOUND
CHINA	7620	36900
INDIA	2375	11855
TOTAL	9995	48755

CATCHMENT AREA PLAN OF RIVER SUTLEJ AT KARCHAM



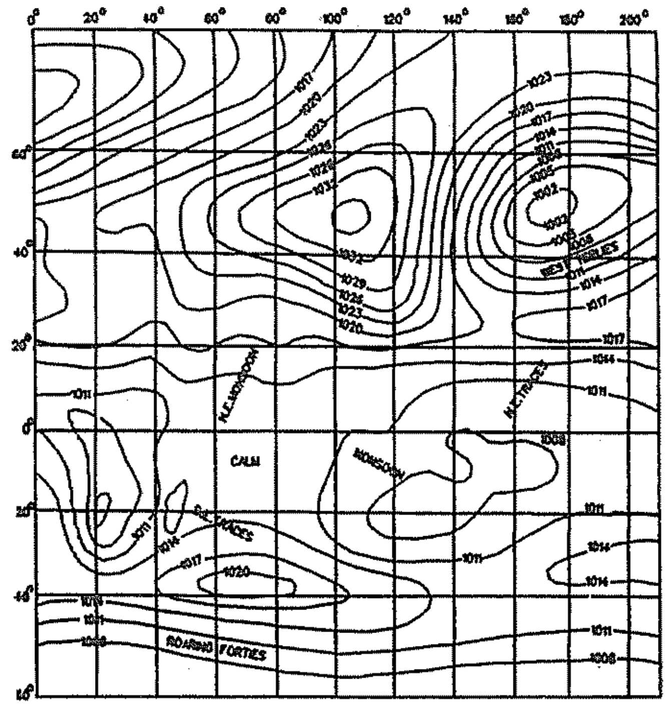
SATLUJ RIVER: L-SECTION FROM RAKASTAL TO NATHPA DIVERSION DAM SITE

FIG. A-5

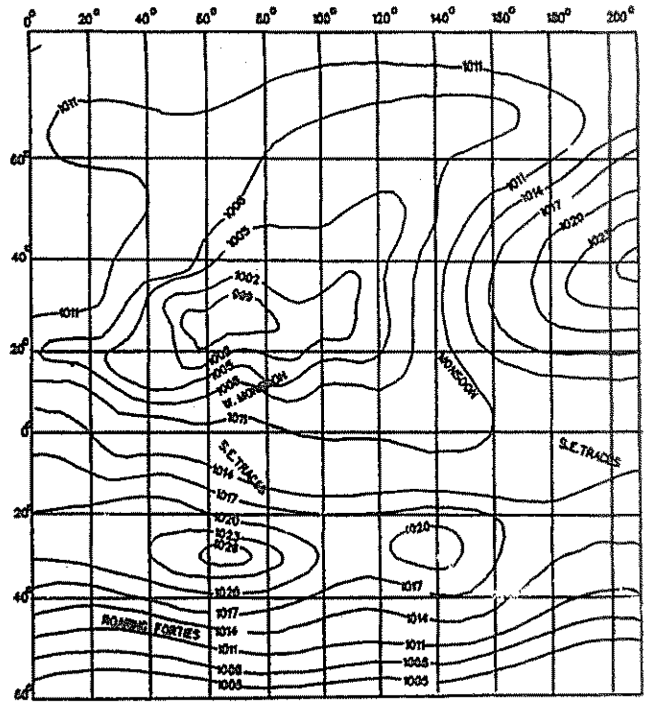


DIAGRAMMATIC REPRESENTATION OF FOUR CLIAMATIC ZONES IN HIMALAYAS, TIBET AND ADJOINING AREAS

FIG. A-6



MEAN ISOBARS AND WINDS
JANUARY

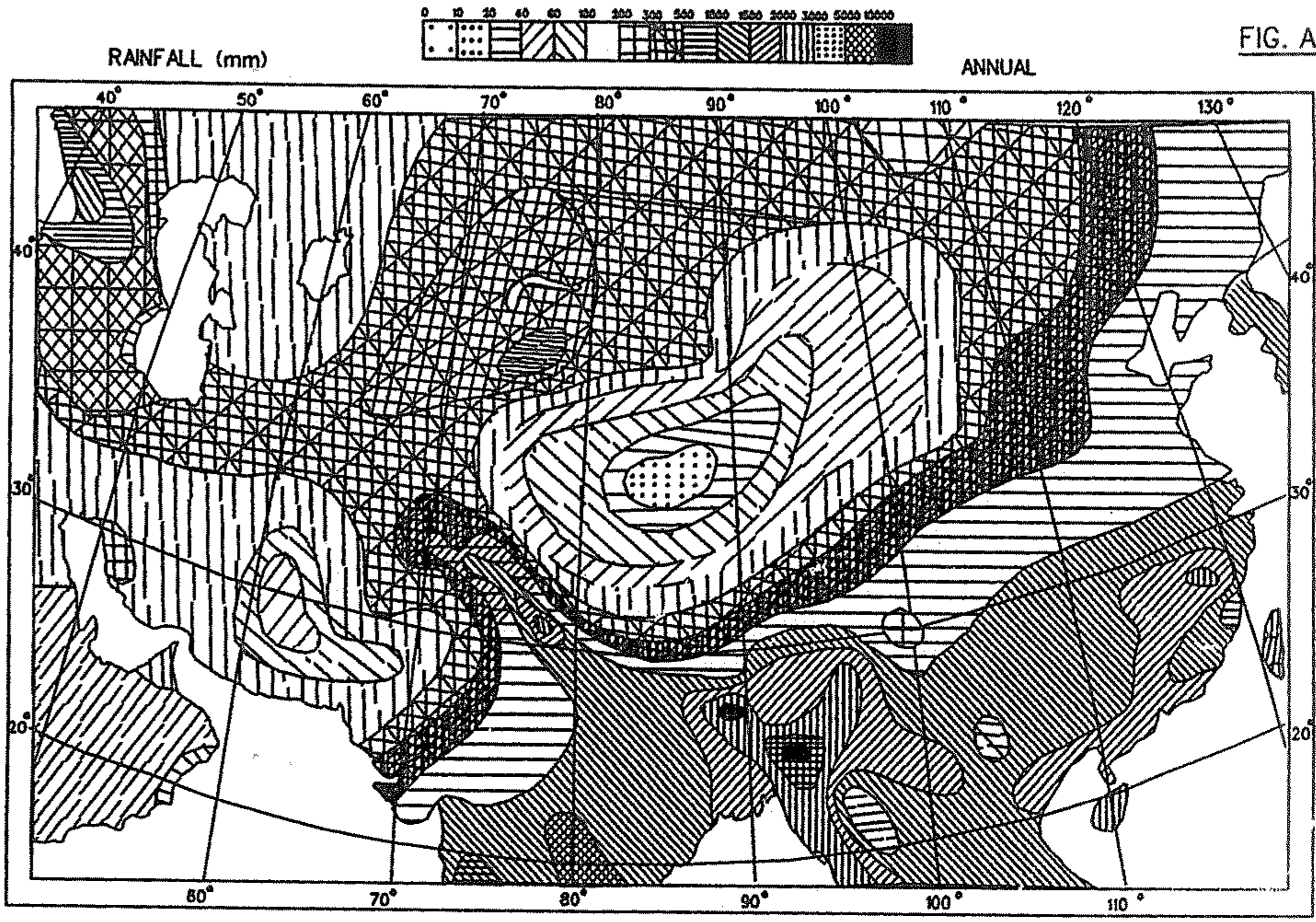


MEAN ISOBARS AND WINDS
JULY

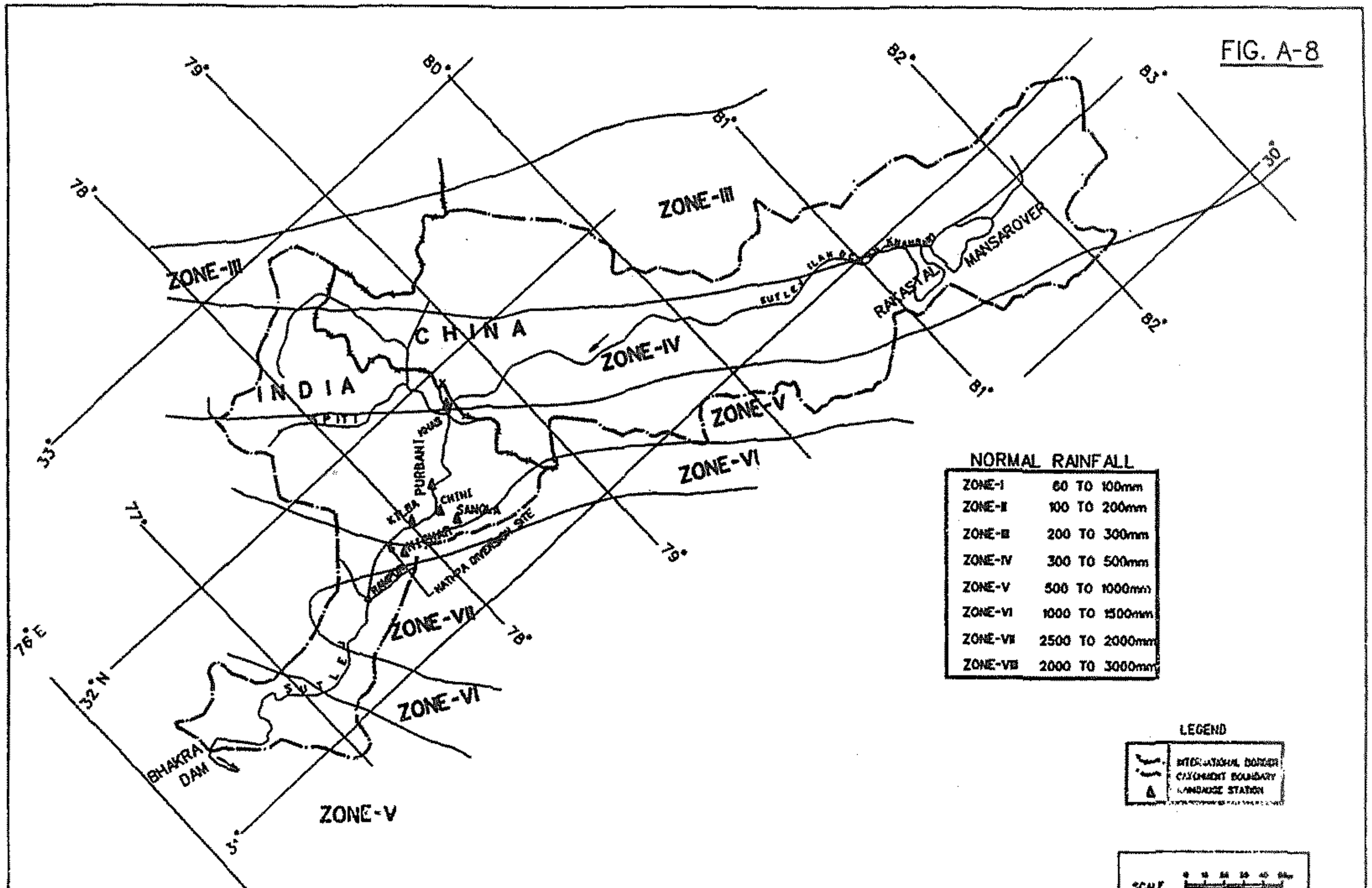
MEAN ISOBARS AND WINDS IN ASIA, INDIAN OCEAN AND PACIFIC OCEAN REGION

UNITS: milli bar

FIG. A-7



ANNUAL NORMAL RAINFALL IN HIMALAYAS TIBET AND ADJOINING AREA



NORMAL RAINFALL

ZONE-I	60 TO 100mm
ZONE-II	100 TO 200mm
ZONE-III	200 TO 300mm
ZONE-IV	300 TO 500mm
ZONE-V	500 TO 1000mm
ZONE-VI	1000 TO 1500mm
ZONE-VII	2500 TO 2000mm
ZONE-VIII	2000 TO 3000mm

ANNUAL NORMAL RAINFALL IN SATLUJ BASIN UPTO BHAKRA

Fig. A-9 (Rev.1)

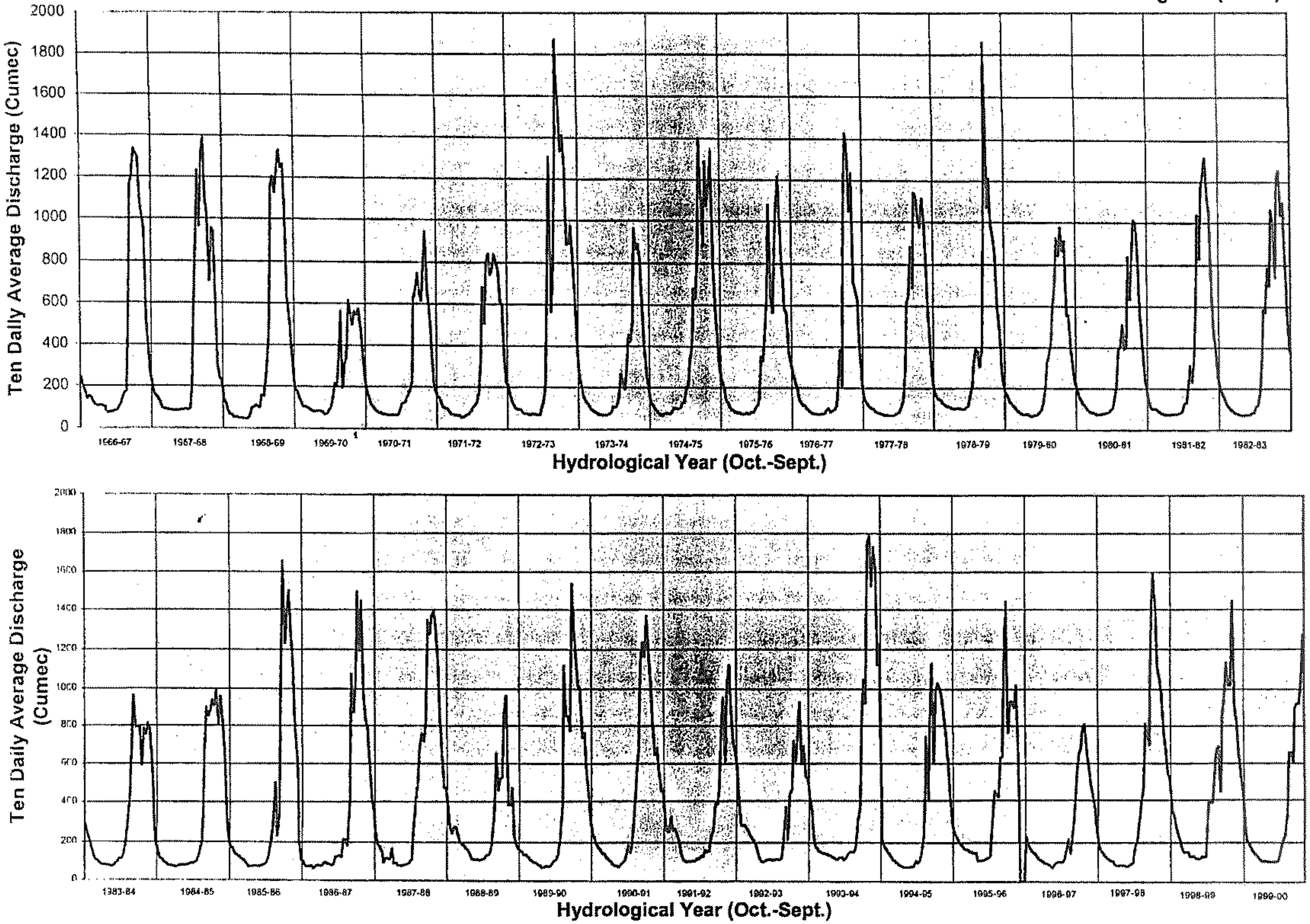

Ten Daily Average Discharge (Cumec)
2000
1800
1600
1400
1200
1000
800
600
400
200
0
1966-67
1967-68
1968-69
1969-70
1970-71
1971-72
1972-73
1973-74
1974-75
1975-76
1976-77
1977-78
1978-79
1979-80
1980-81
1981-82
1982-83
Hydrological Year (Oct.-Sept.)
Ten Daily Average Discharge (Cumec)
1983-84
1984-85
1985-86
1986-87
1987-88
1988-89
1989-90
1990-91
1991-92
1992-93
1993-94
1994-95
1995-96
1996-97
1997-98
1998-99
1999-00
Hydrological Year (Oct.-Sept.)

Fig. A-10 (Rev. 1)

Non-Monsoon, Monsoon & Total Inflow

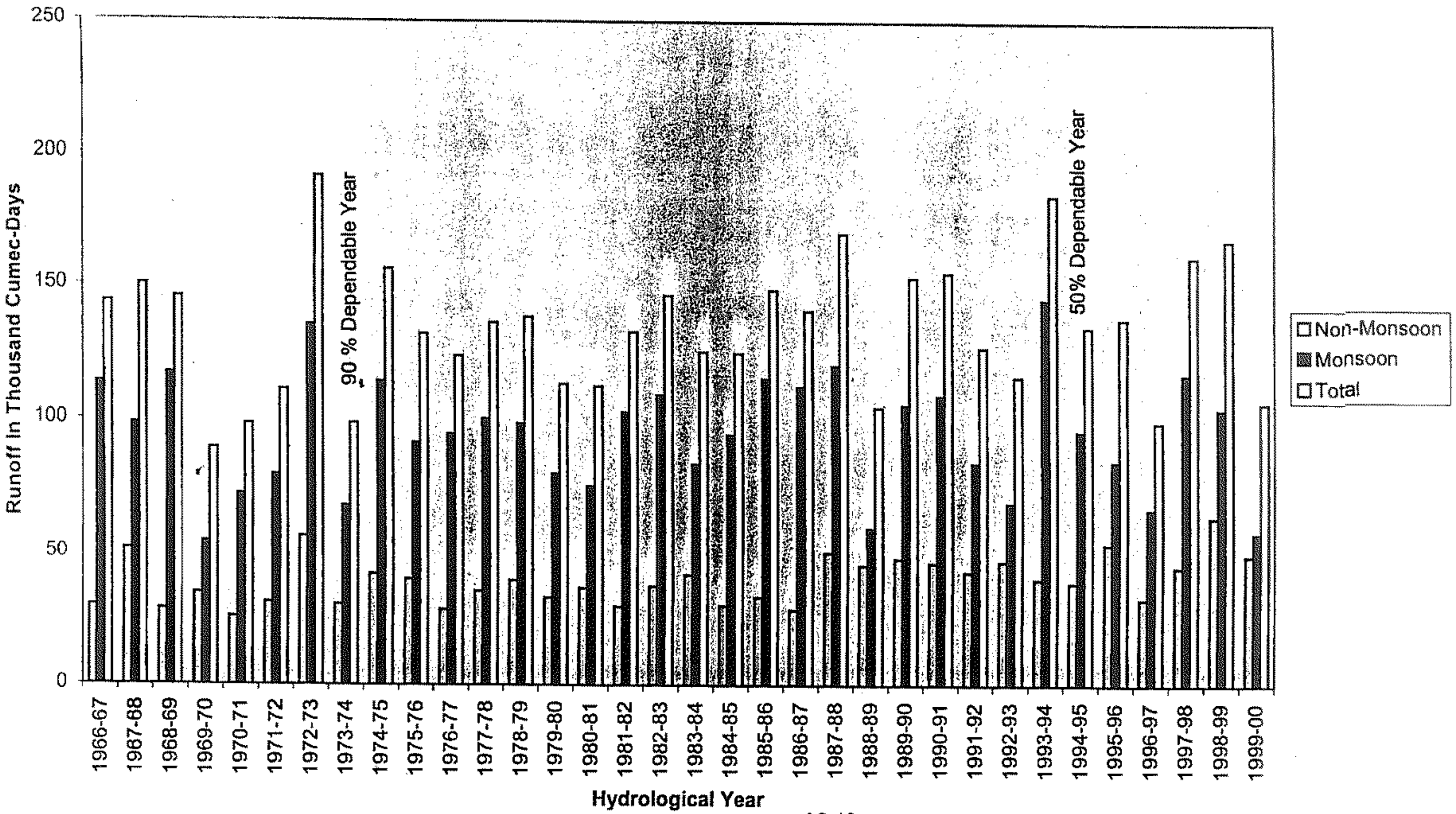
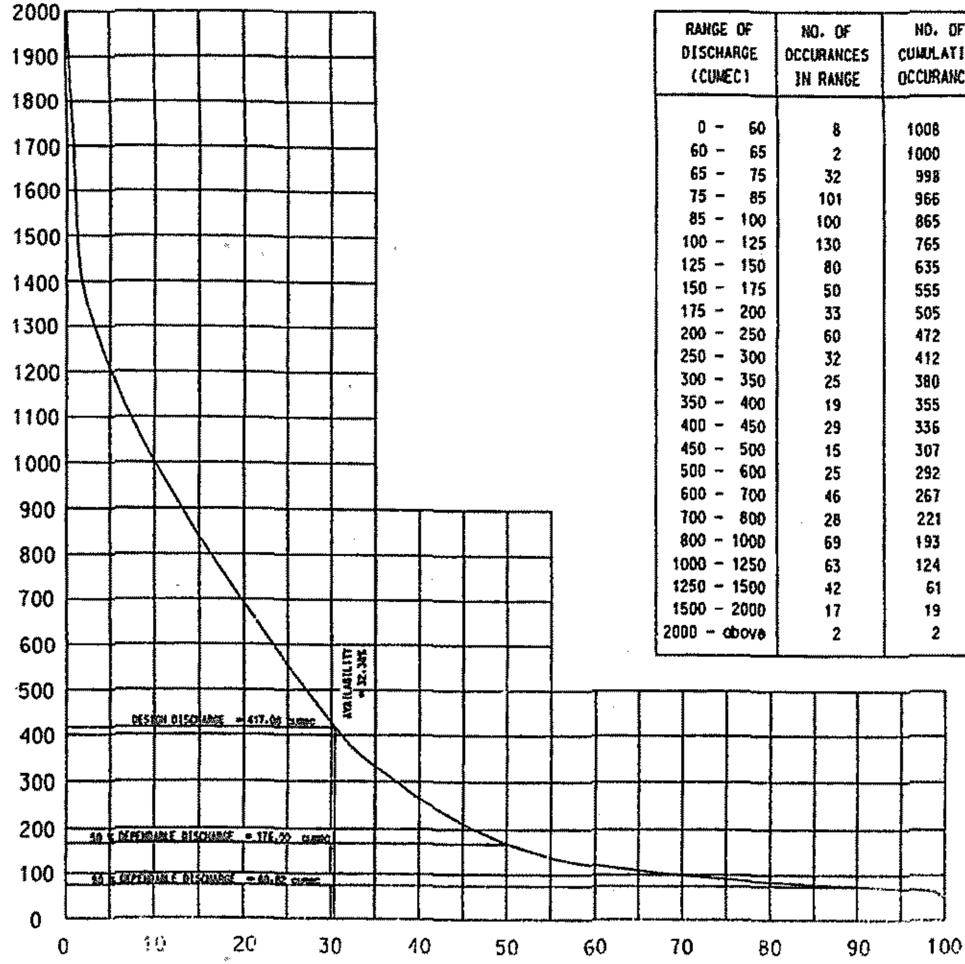


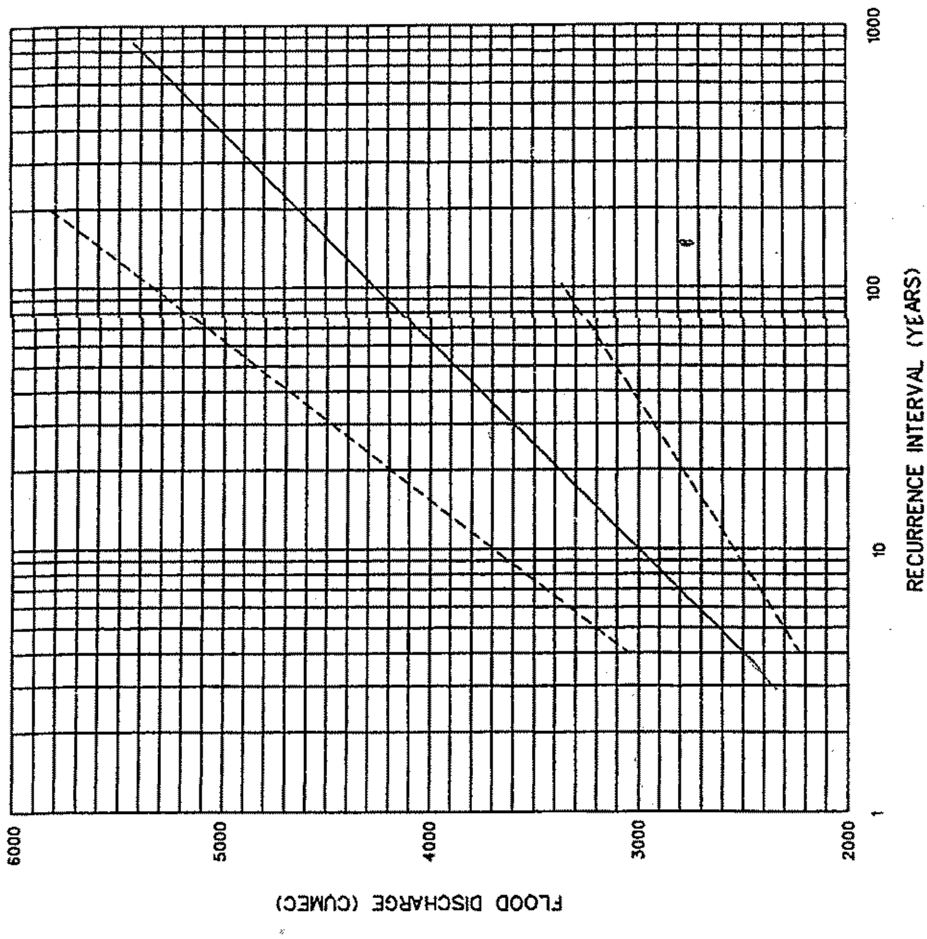
FIG. A-11

RANGE OF DISCHARGE (CUMEC)	NO. OF OCCURANCES IN RANGE	NO. OF CUMULATIVE OCCURANCES	EXCEEDANCE PROBABILITY. %
0 - 60	8	1008	100.00
60 - 65	2	1000	99.20
65 - 75	32	998	99.00
75 - 85	101	966	95.83
85 - 100	100	865	85.81
100 - 125	130	765	75.89
125 - 150	80	635	63.00
150 - 175	50	555	55.06
175 - 200	33	505	50.09
200 - 250	60	472	46.83
250 - 300	32	412	40.87
300 - 350	25	380	37.70
350 - 400	19	355	35.22
400 - 450	29	336	33.33
450 - 500	15	307	30.46
500 - 600	25	292	28.97
600 - 700	46	267	26.49
700 - 800	28	221	21.92
800 - 1000	69	193	19.15
1000 - 1250	63	124	12.30
1250 - 1500	42	61	6.05
1500 - 2000	17	19	1.88
2000 - above	2	2	0.20



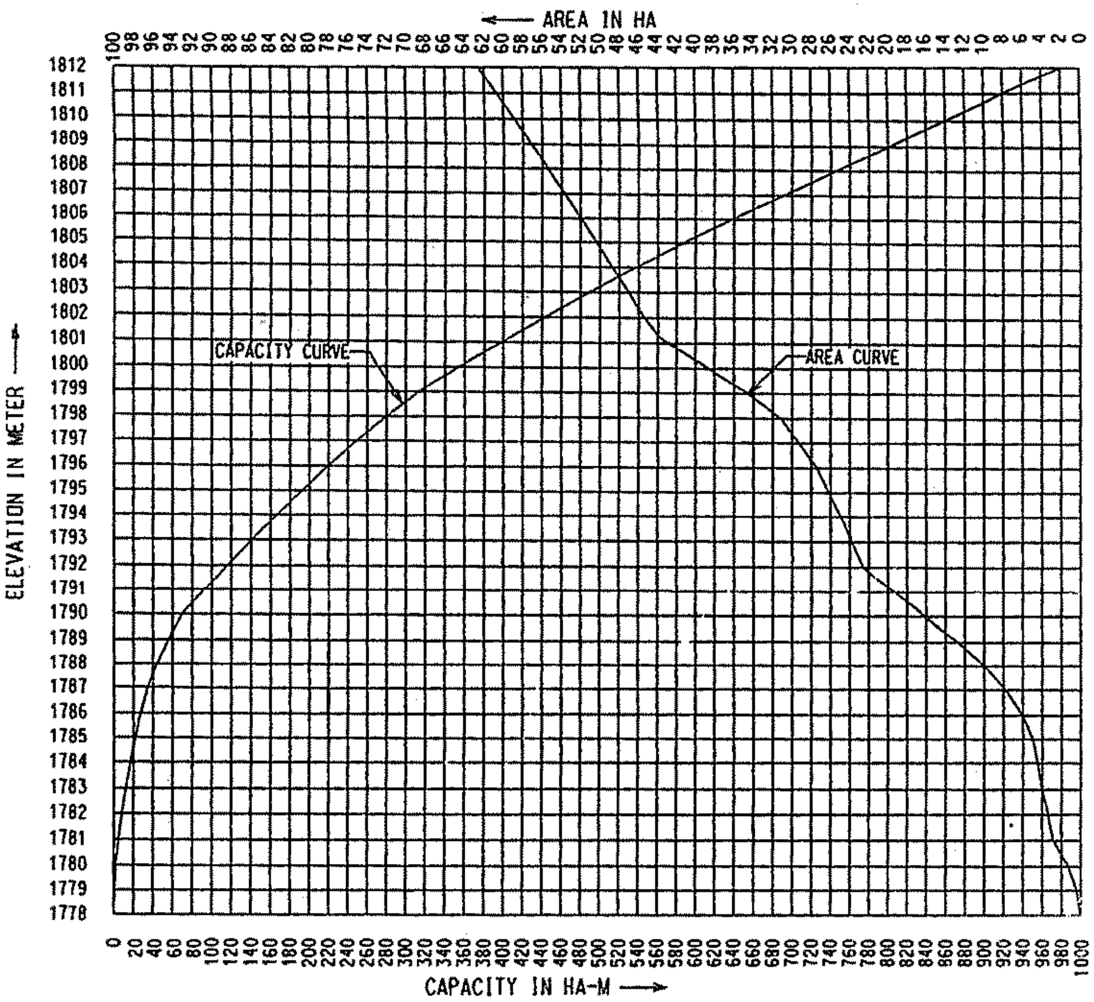
FLOW - DURATION CURVE AT KARCHAM DAM SITE

FIG. A-12



FLOOD ESTIMATION BY GUMBEL'S METHOD OF FREQUENCY DISTRIBUTION
FOR KARCHAM DAM SITE SHOWING 95% LIMITS OF CONFIDENCE

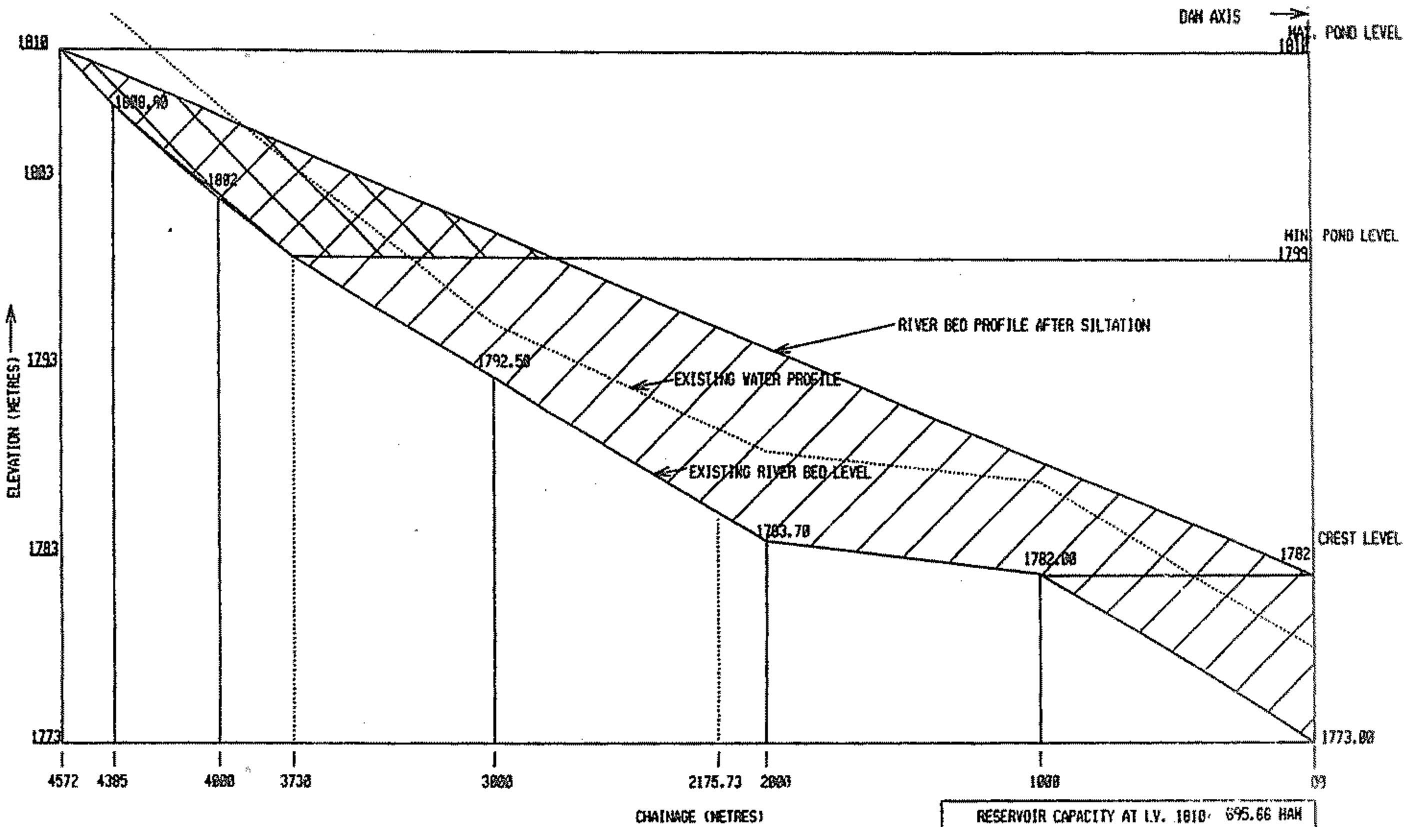
FIG. A-13



ELEVA-TION (M)	AREA (HA)	CAPACITY (HA-M)
1778	0.0	0.0
1779	0.44	0.28
1780	1.26	1.31
1781	2.84	4.47
1782	3.44	8.06
1783	4.01	12.09
1784	4.49	16.54
1785	4.98	21.42
1786	6.03	27.16
1787	7.78	34.45
1788	9.99	43.70
1789	12.72	55.32
1790	16.06	69.72
1791	19.29	92.64
1792	22.63	116.39
1793	23.77	140.98
1794	24.95	166.38
1795	26.19	192.60
1796	27.49	220.04
1797	29.28	249.10
1798	31.19	280.10
1799	34.51	313.32
1800	38.60	354.31
1801	45.11	397.93
1802	45.35	443.01
1803	47.05	489.57
1804	48.70	537.59
1805	50.31	587.08
1806	51.97	638.12
1807	53.65	690.74
1808	55.38	744.96
1809	57.09	800.80
1810	58.84	858.29
1811	60.70	919.16
1812	62.61	981.74

AREA CAPACITY CURVE AT KARCHAM DAM SITE

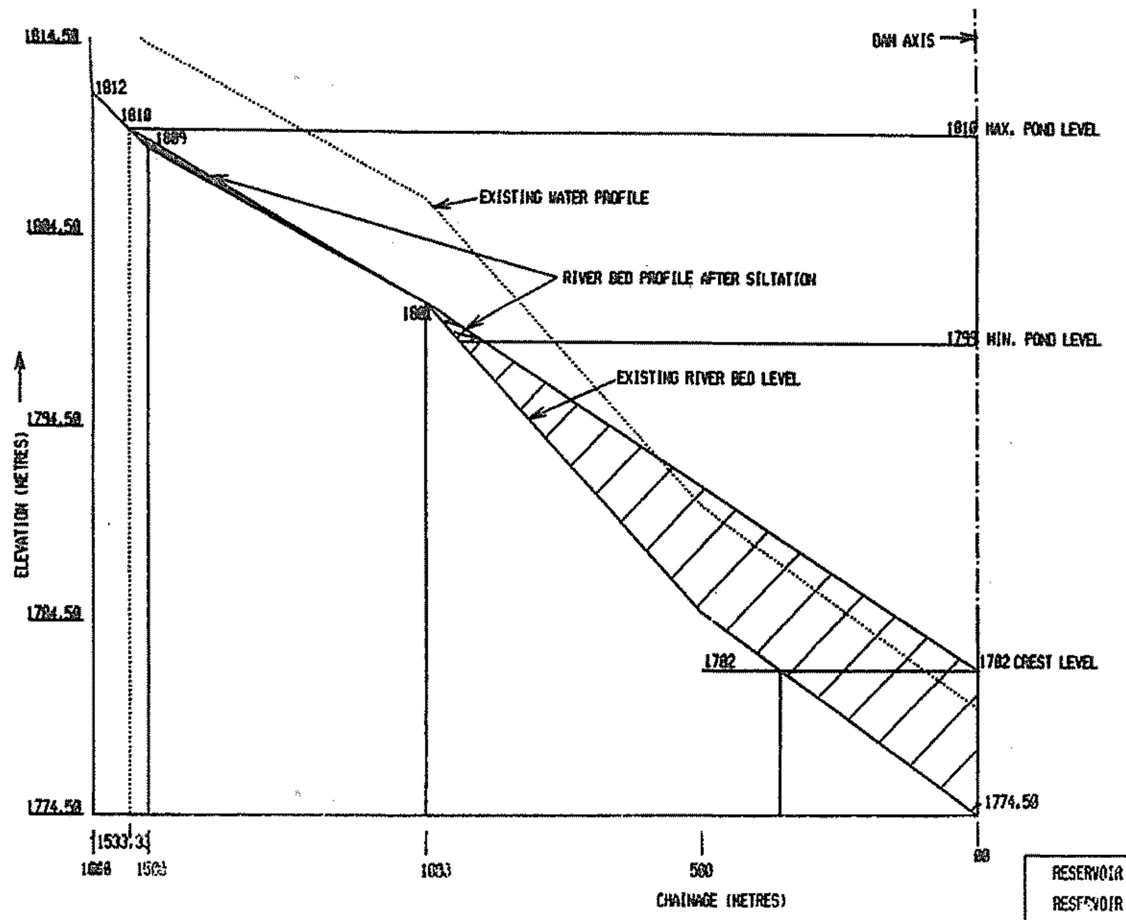
FIG. A-14



RESERVOIR CAPACITY AT LV. 1810	695.66 HAM
RESERVOIR CAPACITY AT LV. 1799	266.13 HAM
RESERVOIR CAPACITY IN BETWEEN	429.53 HAM
LESS CAPACITY DUE TO SILTING (12%)	51.53 HAM
NET CAPACITY	378.00 HAM

LONGITUDNAL SECTION ALONG RIVER SATLUJ

FIG. A-15



LONGITUDNAL SECTION ALONG RIVER BASPA

RESERVOIR CAPACITY AT LV. 1810= 162.64 HAM
RESERVOIR CAPACITY AT LV. 1799= 47.17 HAM
RESERVOIR CAPACITY IN BETWEEN= 115.47 HAM
LESS CAPACITY DUE TO SILTING(2%)= 2.31 HAM
NET CAPACITY= 113.16 HAM

Chapter - B1

DIVERSION DAM

1.1 Stability Analysis at the Foundation Level

a) **For Non-Overflow Section :**
(Ref: IS:6512-1984, IS:1893-1984, Report on earthquake engineering for Karcham-Wangtoo Project)

Data Available

FRL = + 1810.000m

Top of Dam = + 1813.000m

Crest Level = + 1782.000m

Deepest Foundation Level for Non-overflow Section = + 1731.000m

$\alpha_h = 0.23$ } As per earthquake engineering studies

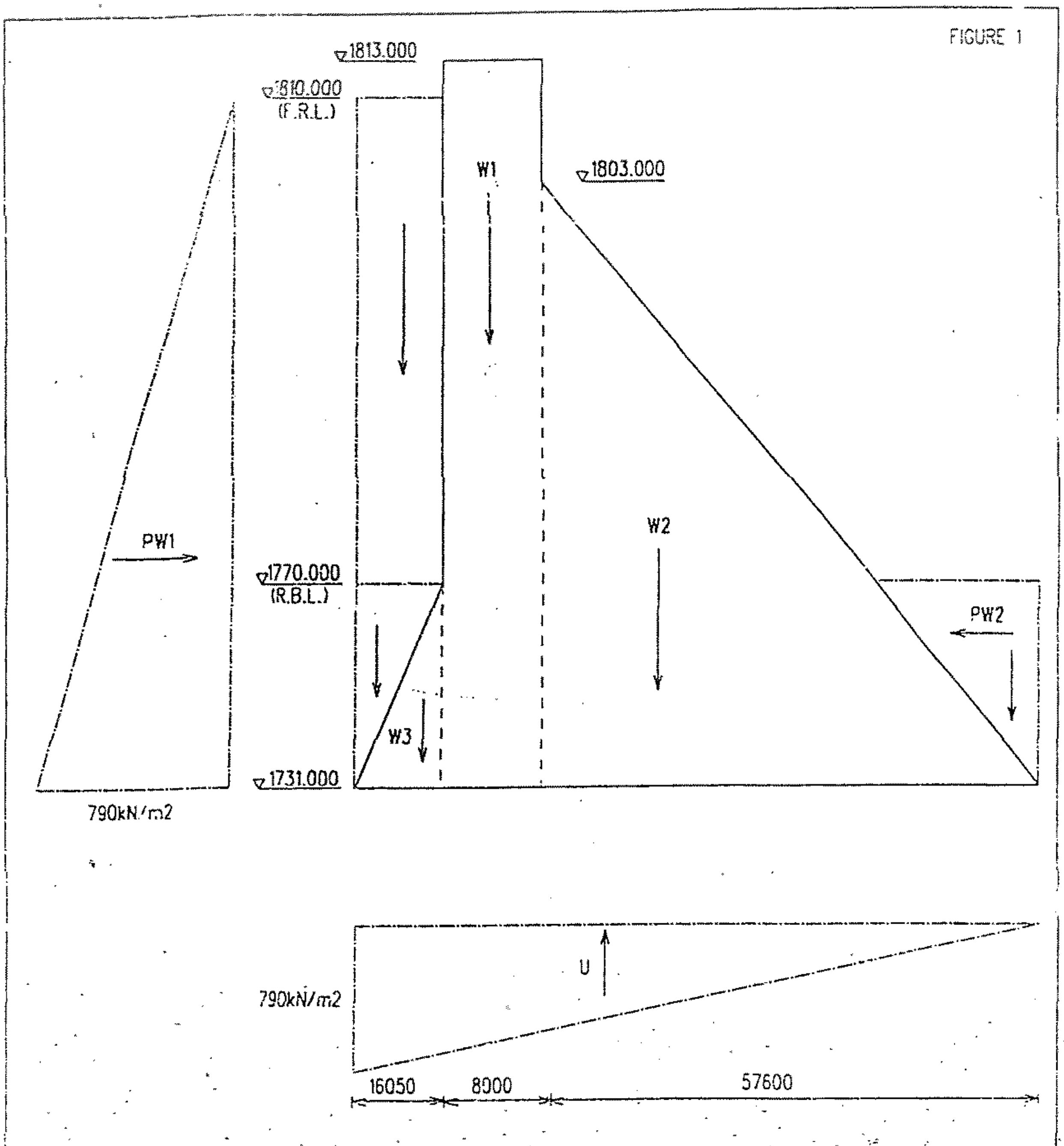
$\alpha_v = \frac{2}{3} x 0.23 = 0.154$

Load combinations D & G of IS:6512-1984 have been considered for analysis.

Load Combination `D'

a) When EQ is acting upwards :

Name of the force	Designation	Magnitude of force (kN)		Lever Arm (m)	Moments about `0' Clockwise (+)ve Anticlockwise (-)ve
		Vertical (+)ve	Horizontal (-)ve		
Weight of Non-overflow Section	W_1	(+) 8x82x1x24 = + 15744		61.6	- 969830.4
	W_2	(+) ½x72x57.6x1 = + 49766.4		38.4	- 1911029.76
	W_3	(+) ½x16.05x33x1x24 = + 7511.4		70.95	- 532933.83
		ΣV_1 = + 73022.0			ΣM_1 = - 3413794.0
Vertical EQ Forces		$\Sigma V_2 = + \alpha_v \Sigma V_1$ = + 0.154x73022 = + 11246.0			$\Sigma M_2 = + \alpha_v \Sigma M_1$ = -0.154x3413794 = - 525725.0
Horizontal EQ forces	P_{hi1}		= + $\alpha_h W_1$ = + 0.23x15744 = + 3621.2	41	- 148469.2
Horizontal EQ forces	P_{hi2}		= + $\alpha_h W_2$ = + 0.23x49766.4 = + 11446.3	24	- 274711.2
	P_{hi3}		= + $\alpha_h W_3$ = + 0.23x7511.4 = + 1727.6	13	- 22458.8
			ΣH = + 16795.0		ΣM_3 = - 445640.0



NON-OVERFLOW. SECTION

$\therefore \quad \Sigma V = \Sigma V_1 + \Sigma V_2 = 84268.0$ kN

$\Sigma H = 16795.0$ kN

$\Sigma M = \Sigma M_1 + \Sigma M_2 + \Sigma M_3 = -4385159.0$ kNm

Check against sliding

$$F = \frac{\dfrac{\Sigma V \tan\varphi}{F\varphi} + \dfrac{cA}{Fc}}{\Sigma H}$$

Where
tan φ = Coeff. of internal friction = tan 50°
c = Cohesion of material = 0.025 N/mm² = 25kN/m²
Fφ = 1.2 & Fc = 2.4

$$\therefore \quad F = \frac{\dfrac{84268 \times \tan 50^\circ}{1.2} + \dfrac{25 \times (81.65 \times 1.0)}{2.4}}{16795.0}$$

$= 5.03 > 1.0$

Check for Stresses

$$x = \frac{\Sigma M}{\Sigma V} = \frac{4385159}{84268} = 52.04\ m$$

$$\therefore e = \left(\frac{81.65}{2} - 52.04\right) \approx -11.22\ m$$

$$\frac{81.65}{6} = 13.61\ m > 11.22\ m$$

No tension develops anywhere at the base.

$$f_{max}/f_{min} = \frac{\Sigma V}{B}\left[1 \pm \frac{6e}{B}\right]$$

$$= \frac{84268}{81.65}\left[1 \pm \frac{6 \times 11.22}{81.65}\right]$$

$\approx 1032.1 \times [1 \pm 0.825]$

$\therefore f_{max} \approx 1884.0$ kN/m² ≈ 1.9 N/mm²
$f_{min} \approx 181.0$ kN/m² ≈ 0.18 N/mm²

b) When EQ is acting downwards :

$\Sigma V \quad = \Sigma V_1 - \Sigma V_2$

$= (73022 - 11246) = 61776.0$ kN

$\Sigma H \quad = 16795.0$ kN

$\Sigma M \quad = \Sigma M_1 + \Sigma M_2 + \Sigma M_3$

$= (-3413794 - 445640 + 525725)$ kNm

≈ -3333709.0 kNm

Check against sliding

$$F = \frac{\dfrac{61776 \times \tan 50^\circ}{1.2} + \dfrac{25 \times (81.65 \times 1.0)}{2.4}}{16795.0}$$

$= 3.7 > 1.0$

Check for Stresses

$$x = \frac{\Sigma M}{\Sigma V} = \frac{3333709}{61776} = 54.0\ m$$

$$\therefore e = \left(\frac{81.65}{2} - 54.0\right) \approx -13.18\ m$$

$$\frac{B}{6} = \frac{81.65}{6} \approx 13.61\ m > e = 13.18\ m$$

No tension develops anywhere at the base.

$$f_{max}/f_{min} = \frac{\Sigma V}{B}\left[1 \pm \frac{6e}{B}\right]$$

$$= \frac{61776}{81.65}\left[1 \pm \frac{6 \times 13.18}{81.65}\right]$$

$\approx 756.6 \times [1 \pm 0.97]$

$\therefore f_{max} \approx 1491.0$ kN/m^2 ≈ 1.5 N/mm^2
$f_{min} \approx 22.7$ kN/m^2 ≈ 0.023 N/mm^2

Load Combination `G'

Calculation of Hydrodynamic Forces & Moments

$p = C_s \alpha_h w h$

$C_s = C_m = 0.735$

$\alpha_h = 0.23$

$w = 10 \text{ kN/m}^3$

$h = 79.0 \text{ m}$

$p = 0.735 \times 0.23 \times 10 \times 79 \approx 133.6 \text{ kN/m}^2$

$\therefore \quad P_{Hd} = 0.726 \text{ p.h.}$
$= 0.726 \times 133.6 \times 79 = 7662.5 \text{ kN}$

$M_h = 0.299 \times p \times h^2$
$= 0.299 \times 133.6 \times 79^2$
$= 249305.6 \text{ kNm}$

Name of the force	Desgn.	Magnitude of Force (kN)		Lever Arm (m)	Moments about `0' Clockwise (+)ve Anticlockwise (-)ve
		Vertical Forces Downwards = (+)ve Upwards = (-) ve	Horizontal Forces Towards d/s = (+)ve Towards u/s = (-)ve		
Weight of Dam	W_1	(+) 8x82x1x24 = 15744		61.6	- 969830.4
	W_2	(+) ½x72x57.6x1 = 49766.4		38.4	- 1911029.8
	W_3	(+) ½x16.05x33x1x24 = 7511.4		70.95	- 532933.83
		$\Sigma V_1 \approx 73022.0$			$\Sigma M_1 \approx - 3413794.0$
Weight of Non-overflow Section		(+) 16.05x40x1x10 = 6420.0		73.63	- 472704.6
Supported on u/s slope		(+) ½x16.05x39x1x10 = 3129.8		70.95	- 222055.80
Supported on d/s slope		(+) ½x31.2x39x1x10 = 6084.0		20.80	- 126547.20
		$\Sigma V_2 = 15634.0$			$\Sigma M_2 \approx - 821308.0$
Weight of silt		(+) 16.05x12x1x9.25 = 1781.6		73.63	- 131175.5
Supported on u/s slope		(+) ½x16.05x39x1x9.25 = 2895.02		70.95	- 205401.70
Supported on d/s slope		(+) ½x31.2x39x1x9.25 = 5627.7		20.80	- 117056.20
		$\Sigma V_3 \approx 10305.0$			$\Sigma M_3 \approx - 453634.0$

Name of the force	Desgn.	Magnitude of Force (kN)		Lever Arm (m)	Moments about '0' Clockwise (+)ve Anticlockwise (-)ve
		Vertical Forces Downwards = (+)ve Upwards = (-) ve	Horizontal Forces Towards d/s = (+)ve Towards u/s = (-)ve		
Uplift Force	U	(+) $\frac{1}{2}$x790x81.65x1 = - 32251.8		54.44	+ 1755798.9
		ΣV_4 = - 32252.0			ΣM_4 = + 175599.0
Upward Vertical EQ Forces		= - α_v x ΣV_1 = - 11196.71			- α_v x ΣM_1 = + 523448.4
		ΣV_5 = - 11197.0			ΣM_5 = + 523449.0
Horizontal Hydrostatic Forces	PW_1		(+) $\frac{1}{2}$x3.6x51^{2}x1/3 = + 1560.6	26.34	+ 821939.7
on u/s side	PW_2		(-) $\frac{1}{2}$x390x39x1 = - 7605	13.0	- 98865.0
on d/s side			ΣH_1 = + 23600.0		ΣM_6 = + 723075.0
Horizontal Silt Pressure	PS_1		(+) $\frac{1}{2}$x3.6x51^{2}x$\frac{1}{3}$ = + 1560.6	17.0	+ 26530.2
on u/s side	PS_2		(-) $\frac{1}{2}$x3.6x39^{2}x$\frac{1}{3}$ = - 912.6	13.0	- 11863.8
on d/s side			ΣH_2 = + 648.0		ΣM_7 = + 14667.0
Hydrodynamic Forces	P_{Hd}		Calculated separately = + 7662.5		Calculated separately = + 249305.6
			ΣH_3 = + 7663.0		ΣM_8 = + 249306.0
Horizontal Inertia Forces due to EQ	P_{hi1}		(+) 0.23x15744 = + 3621.2	41	+ 148469.2
	P_{hi2}		(+) 0.23x49766.4 = + 11446.3	24	+ 274711.2
	P_{hi3}		(+) 0.23x7511.4 = + 1727.6	13	+ 22458.8
			ΣH_4 = + 16795.0		ΣM_9 = + 445640.0
		$\therefore \Sigma V$ = + 55512.0	$\therefore \Sigma H$ = + 49706.0		$\therefore \Sigma M$ = - 976800.0

Check against sliding

$$F = \frac{\dfrac{55512 \times \tan 50^\circ}{1.0} + \dfrac{25 \times (81.65 \times 1.0)}{1.2}}{18706.0}$$

$= 1.39 > 1.0$

Check for Stresses

$$x = \frac{\Sigma M}{\Sigma v} = \frac{976800}{55512} = 17.6\ m$$

$$\therefore e = \left(\frac{81.65}{2} - 17.6\right) = -23.23\ m$$

$$\frac{B}{6} = \frac{81.65}{6} = 13.61\ m < 23.23\ m$$

No tension develops near the heel.

$$f_{max}/f_{min} = \frac{55512}{81.65}\left[1 \pm \frac{6 \times 23.23}{81.65}\right]$$

$$= 679.9 \times [1 \pm 1.71]$$

$\therefore f_{max} = +\ 1843\ kN/m^2 = 1.84\ N/mm^2$

$f_{min} = -\ 483\ kN/m^2 = -0.48\ N/mm^2$

(Maximum Permissible Tension = 0.04 x 15 = 0.6 N/mm^2)

b) **For Sluice Section :**

Data Available

FRL = + 1810.000m

Top of Dam = + 1813.000m

Crest Level = + 1782.000m

Deepest Foundation Level = + 1715.000m

$\alpha_h = 0.23$
$\alpha_v = 0.154$ } As per earthquake engineering studies

Calculation of Self Wt. of Sluice Section

C/s area of the profile = 4020 m^2

$\therefore$ Wt. = (4020 x 1) x 24 = 96480.0 kN

C/s area of pier profile = 536.0 m^2

Width of pier = 7.0m

$\therefore$ Wt. of each pier = (536x7.0) x 24

= 90048.0 kN

$\therefore$ Wt. of pier per metre $= \frac{90048}{14} = 6432.0\ kN$

C/s of Breast wall = 186.0 m^2

∴ Wt. of Breast Wall per metre = (186x1) x 24

= 4464.0 kN

Wt. of Radial Gate = 100.0 T = 1000.0 kN (assumed)

∴ Total Wt. = (96480 + 6432 + 4464 + 1000) kN
= 10837.0 kN

Load Combination `G'

Calculation of Hydrodynamic Forces & Momements

P_{Hd} = 11076.6 kN } Refer Page B1-4
M_h = 433375.1 kNm } Here h = 95.0m

Name of the force	Desgn.	Magnitude of Force (kN)		Lever Arm (m)	Moments about `0' Clockwise (+)ve Anticlockwise (-)ve
		Vertical Forces Downwards = (+)ve Upwards = (-) ve	Horizontal Forces Towards d/s = (+)ve Towards u/s = (-)ve		
Weight of Sluice Section	W	+ 108376.0			
		ΣV_1 = + 108376.0			
Weight of water		(+) 22.7x40x1x10 = + 8800.0			
Supported on u/s slope		(+) ½x22.7x55x1x10 = + 6242.5			
		ΣV_2 = + 15043.0			
Weight of silt		(+) 22.7x12x1x9.25 = + 2519.7			
Supported on u/s slope		(+) ½x22.7x55x1x9.25 = + 5774.3			
		ΣV_3 = 8294.0			
Uplift Force	U	(-) ½x950x76x1 = - 36100.0			
		ΣV_4 = - 36100.0			
Upward Vertical EQ Forces		= - α_v x ΣV_1 = - 0.154x108376 = - 16689.90			
		ΣV_5 = - 16690.0			
Hydrostatic Forces on u/s side	PW_1		(+) ½x950x95x1 = + 45125.0		
Hydrostatic Forces on d/s side	PW_2		(-) ½x550x55x1 = - 15125.0		

Name of the force	Desgn.	Magnitude of Force (kN)		Lever Arm (m)	Moments about `0' Clockwise (+)ve Anticlockwise (-)ve
		Vertical Forces Downwards = (+)ve Upwards = (-) ve	Horizontal Forces Towards d/s = (+)ve Towards u/s = (-)ve		
			ΣH_1 = + 30000.0		
Horizontal Silt Pressure on u/s side	PS_1		(+) $\frac{1}{2}$x3.6x67^2x$\frac{1}{3}$ = + 2693.4		
Horizontal Silt Pressure on d/s side	PS_2		(-) $\frac{1}{2}$x3.6x55^2x$\frac{1}{3}$ = - 1815.0		
			ΣH_2 = + 879.0		
Horizontal Hydro Dynamic Forces	P_{Hd}		+ 11076.6		
			ΣH_3 = + 11077.0		
Horizontal Inertia Forces due to EQ	P_{hi1}		(+) α_v x ΣV_1 = (+) 0.23x108376 = + 24926.5		
			ΣH_4 = + 24927.0		
		∴ ΣV = + 78923.0	ΣH = + 66883.0		

Check Against Sliding

$$F = \frac{\frac{78923 \times \tan 50^\circ}{1.0} + \frac{25 \times (76 \times 1.0)}{1.2}}{66883}$$

≈ 1.43 > 1.0

Load Combination `D'

a) When EQ is acting upwards

Σ = $\Sigma V_1 + \Sigma V_5$
= (108376 + 16690) kN
= 125066.0 kN

$\Sigma H = \Sigma H_4$ = 24927.0 kN

Check against sliding

$$F = \frac{\frac{125066 \times \tan 50^\circ}{1.2} - \frac{25 \times (76 \times 1.0)}{2.4}}{24927}$$

≈ 5.02 > 1.0

b) When EQ is acting downwards

$\Sigma V \quad = \Sigma V_1 - \Sigma V_s$
$\quad\quad = 91686.0$ kN

$\Sigma H \quad = \Sigma H_4 = 24927.0$ kN

Check against sliding

$$F = \frac{\dfrac{91686 \times \tan 50^\circ}{1.2} + \dfrac{25 \times (76 \times 1.0)}{2.4}}{24927}$$

$\approx 3.68 > 1.0$

c) **For Auxiliary Spillway Section :**

Data Available

FRL	= + 1810.000m
Top of Dam	= + 1813.000m
Crest Level	= + 1803.000m
Deepest Foundation Level	= + 1719.000m

$\alpha_h = 0.23$) As per earthquake engineering studies
$\alpha_v = 0.154$)

Calculation of Self Wt. of Auxiliary Spillway Section

C/s area of the profile ≈ 3110.0m^2

∴ Wt. = (3110 x 1) x 24 = 74640.0 kN

C/s area of pier profile ≈ 256.0m^2

Width of pier = 5.0m

∴ Wt. of each pier = (256x5.0) x 24

= 30720.0 kN

∴ Wt. of pier per metre $= \dfrac{30720}{13} = 2363.0\ kN$

Wt. of Radial Gate = 30.0 T = 300.0 kN (assumed)

$\therefore$ Total Wt. = (74640 + 2363 + 300) kN

= 77303.0 kN

Load Combination `G'

Calculation of Hydrodynamic Forces & Momements

P_{Hd} = 10163.3 kN } Refer page B1-4
M_h = 380900.0 kNm } Here h = 91.0m

Name of the force	Desgn.	Magnitude of Force (kN)		Lever Arm (m)	Moments about `0' Clockwise (+)ve Anticlockwise (-)ve
		Vertical Forces Downwards = (+)ve Upwards = (-) ve	Horizontal Forces Towards d/s = (+)ve Towards u/s = (-)ve		
Weight of Auxiliary Spillway Section	W	+ 77303.0			
		ΣV_1 = + 77303.0			
Weight of water		(+) 21x40x1x10 = + 8400.0			
Supported on u/s slope		(+) ½x21x51x1x10 = + 5355.0			
		ΣV_2 = + 13755.0			
Weight of silt		(+) 21x12x1x9.25 = + 2331.0			
Supported on u/s slope		(+) ½x21x51x1x9.25 = + 4953.4			
		ΣV_3 = 7285.0			
Uplift Force	U	(-) ½x950x62.45x1 = - 28414.8			
		ΣV_4 = - 28415.0			
Upward Vertical EQ Forces		= - α_v x ΣV_1 = - 0.154x77303 = - 11904.7			
		ΣV_5 = - 11905.0			
Hydrostatic Forces on u/s side	PW_1		(+) ½x910x91x1 = + 41405.0		
Hydrostatic Forces on d/s side	PW_2		(-) ½x510x51x1 = - 13005.0		
			ΣH_1 = + 28400.0		
Horizontal Silt Pressure on u/s side	PS_1		(+) ½x3.6x63²x⅓ = + 2381.4		

Name of the force	Desgn.	Magnitude of Force (kN)		Lever Arm (m)	Moments about `0' Clockwise (+)ve Anticlockwise (-)ve
		Vertical Forces Downwards = (+)ve Upwards = (-) ve	Horizontal Forces Towards d/s = (+)ve Towards u/s = (-)ve		
Horizontal Silt *Pressure on d/s* side	PS_2		(-) $\frac{1}{2}$x3.6x51^2x$\frac{1}{3}$ = *- 1560.6*		
			ΣH_2 = + 821.0		
Horizontal Hydro Dynamic Forces	P_{Hd}		+ 10163.3		
			ΣH_3 = + 10164.0		
Horizontal Inertia Forces due to EQ	P_{hi1}		(+) α_v x ΣV_1 = (+) 0.23x77303 = + 17779.7		
			ΣH_4 = + 17780.0		
		∴ ΣV = + 58023.0	ΣH = + 57165.0		

Check Against Sliding

$$F = \frac{\dfrac{58023 \times \tan 50^\circ}{1.0} + \dfrac{25 \times (62.45 \times 1.0)}{1.2}}{57165}$$

$\approx$ 1.23 > 1.0

Load Combination `D'

a) When EQ is acting upwards

Σ $= \Sigma V_1 + \Sigma V_5$

= (77303+11905) kN

= 89208.0 kN

$\Sigma H = \Sigma H_4$ = 17780.0 kN

Check against sliding

$$F = \frac{\dfrac{89208 \times \tan 50^\circ}{1.2} + \dfrac{25 \times (62.45 \times 1.0)}{2.4}}{17780}$$

$\approx$ 5.02 > 1.0

b) When EQ is acting downwards

$\Sigma V = \Sigma V_1 - \Sigma V_s$

$= 65398.0$ kN

$\Sigma H = \Sigma H_4 = 17780.0$ kN

Check against sliding

$$F = \frac{\dfrac{65398 \times \tan 50^\circ}{1.2} \div \dfrac{25 \times (62.45 \times 1.0)}{2.4}}{17780}$$

$\approx 3.69 > 1.0$

1.2 HYDRAULIC DESIGN OF SLUICE SPILLWAY

1.2.1 Introduction

In order to utilise the potential of river Satluj between tailwater of Baspa Project and head water of Nathpa-Jhakri Project, it is proposed to construct a 98m high gravity dam across the river near village Karcham in district Doda of Kinnaur District. The waters of the river will be diverted to an underground power house of 4x250 MW capacity through a 17.2 km long and 10.48m dia circular section tunnel. The water conductor system will be located on the right side of the river short circuiting the loop of the river.

The 100 year return period flood of the river at Dam site is 7676 cumec. The 1000 year period flood is 8260cumec. The spillway has been designed for 1 in 1000 year flood. The tunnel will carry a maximum discharge of 417.0 cumec at a velocity of 4.83 m/s. The FRL at El. 1810.0 m and MDDL at El. 1799.0 m have been fixed on the basis of availability and optimum utilisation of water.

Keeping the above point in view, the spillway crest has to be kept 7-8 m below the sill of intake. The latter is to be fixed in such a way that vortex does not form even at the lowest operating level.

1.2.2 The Spillway

The spillway will be housed in the body of the dam. Its crest will have to be kept low enough to flush the deposited sediment of the reservoir. The crest has been kept at El. 1782.0 m. which is below the intake sill. If open spillway is designed with this crest, it will necessitate very high gates of the order of 28 m. To reduce gate height, sluice spillway with provision of top sealing radial gates has been proposed.

The following data has been used for the design of sluice spillway :—

Q	=	7700 cumec
H.F.L.	=	El. 1808.0 m
T.W.L.	=	El. 1783.8 m (maximum)

1.2.3 Section of Sluices

The section of large size sluices is generally kept rectangular for facilitating the provision of gates. In the present case, the sluices will be utilised for passing the floods. These will, therefore, be of large size and be of rectangular section. The section has been decided as per I.S. Code 11485-1985.

H_T = Total head available
H_L = Total loss
H_V = Velocity head at sluice exit
H_S = Height of sluice (say 9 m)
H_T = 1808 - (1782 + 4.5) = 21.5 m (Assuming invert of sluices at El. 1782.0 m)
H_L = $(K_e + K_a + K_f)v^2/2g$
H_V = $v^2/2g$

where, v = velocity in sluice
K_e = entry loss coefficient = 0.2
K_a = Coefficient accounting for gate groove, unsymmetry in entry transition, shape factor, deviation from assumed values of coefficients etc. = 0.1
K_f = friction loss coefficient such that $h_f = k_f (v^2/2g)$

Taking a length of 10 m of the sluice, friction loss is found as follows :—

$$h_f = \frac{v^2 n^2 l}{R^{4/3}} = \frac{v^2}{2g}\left[\frac{n^2\ l\ 2g}{R^{4/3}}\right]$$

For a section of 9 m × 9 m

$$R = \frac{A}{p} = \frac{9 \times 9}{2\,(9+9)} = 2.25$$

$$h_f = \frac{v^2}{g}\left[\frac{0.012^2 \times 10 \times 19.6}{2.25^{4/3}}\right]$$

$$= \frac{v^2}{2g}\ [0.01$$

$K_f \quad = \quad 0.01$

$H_T \quad = \quad H_L + H_V$

$$H_T = 0.2 + 0.1 + 0.01) \ \frac{v^2}{2g} + \frac{v^2}{2g} = 1.31 \frac{v}{2}$$

$$\text{or} \quad v = \sqrt{\frac{21.5 \times 19.62}{1.31}} = 18.0 \text{ m/s}$$

Discharge through each sluice = 18x9x9 = 1458

Taking 6 sluices for escaping the design flood,

Discharge through six sluices = 6x1458 = 8748 cumec

The discharge taken by sluice spillway without overtopping the Dam (HPL at EL 1813.0m) will be 9720 cumec.

1.2.4. Entry Transitions

<u>Top Contraction Curve</u>
(Reference : IS:11485 - 1985, Cl 3.3.2 for 3-way flare)

The eqn. of the curve is

$$\frac{x^2}{D^2} + \frac{y^2}{(0.67D)^2} = 1$$

Where D = Vertical height of sluice D/S of the entrance transition

D = 9.0m

$\Rightarrow \quad 0.0123x^2 + 0.0275y^2 = 1$

Values of x & y

x	y
0.0	6.03
0.5	6.02
1.0	5.99
1.5	5.94
2.0	5.88
2.5	5.79
3.0	5.69
3.5	5.56
4.0	5.40
4.5	5.22
5.0	5.01
5.5	4.77
6.0	4.49
6.5	4.17
7.0	3.79
7.5	3.33
8.0	2.76
8.5	1.98
9.0	0.00

<u>Side Contraction Curve</u>
(Reference : IS:11485-1985), Cl. 33.1 (for 3-way flare)

The eqn. of the curve is

$$\frac{x^2}{D^2} + \frac{y^2}{(0.33D)^2} = 1$$

Where D = horizontal width of the sluice D/S of entrance curve

D = 9.0m

Values of x & y

x	y
0.0	2.97
0.5	2.97
1.0	2.95
1.5	2.93
2.0	2.90
2.5	2.85
3.0	2.80
3.5	2.74
4.0	2.66
4.5	2.57
5.0	2.47
5.5	2.35
6.0	2.21
6.5	2.05
7.0	1.87
7.5	1.64
8.0	1.36
8.5	0.98
9.0	0.0

<u>Bottom Profile of the sluice Downstream of Radial Gate</u>
(Reference : IS:11485-1985, Cl. 2.1.2.1)

The eqn. of the curve is

$x^2 = kHy$

Where K = 4

H = Head at the centre line of gate opening = 21.5m

x,y = Coordinates of any point on the profile

$\Rightarrow \quad x^2 = 4 \times 21.5\, xy$

$\Rightarrow \quad x^2 = 86y$

$\Rightarrow \quad x = \sqrt{86y}$

$\therefore \quad \frac{dy}{dx} = \frac{43}{x}$

Making the slope parallel with Non-overflow section

$$\frac{dy}{dx} = 0.8 = \frac{43}{x}$$

$\Rightarrow \quad x = 53.75m$

Values of x & y

x	y
0.0	0.0
4.64	0.25
6.56	0.50
8.03	0.75
9.27	1.0
13.11	2.0
14.66	2.5
16.06	3.0
17.35	3.5
18.55	4.0
19.67	4.5
20.74	5.0
21.75	5.5
22.72	6.0

1.2.5 Design of Flip Bucket (Trajectory Type Bucket)
(Reference : IS:7365-1985, Cl. 5.2.3, 5.2.4, 5.2.5, Fig. 1 and Fig. 7)

Design Data

Crest Elevation = 1782.0m

River Bed Level = 1770.0m

TWL (Max.) = 1783.8m

Discharge of thro' each sluice = 1458 m^3/sec

Radius of Bucket

$R = 0.8\sqrt{H \times H_S}$

$H = (1808.0 - 1782.0) = 26.0m$
$H_3 = (1808.0 - 1783.8) = 24.2m$ -- Ref. Fig. 1 of IS:7365-1985
$H_5 = (1808.0 - 1770.0) = 38.0m$

$\therefore R = 0.8\sqrt{26 \times 38} = 25.15m$

R = 25.0m **(adopted)**

For $H = 26.0m$ & $H_3 = 24.2m$

$V_a/V_t = 0.98$

Where V_a = Actual velocity of flow entering bucket

V_t = Theoretical velocity of flow entering bucket

$V_t = \sqrt{2g\ H_3}$

$= \sqrt{2 \times 9.81 \times 24.2} = 21.79\ m/sec$

$V_a = 0.98 \times 21.79 \approx 21.35$ m/sec

Vel. Head in Bucket = $H_v = \dfrac{V_a^2}{2g} = \dfrac{21.35^2}{2 \times 9.81} = 23.23\ m$

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Lip Angle

Lip angle = 30° **(adopted)**

Trajectory Length

$$\frac{X}{H_v} = Sin2\varphi + 2Cos\varphi\sqrt{\sin^2\varphi + Y/H_v}$$

Where φ = Lip Angle
H_v = Velocity Head
X = Horizontal throw distance
Y = Diff. between the lip level and tail water level

H_v = 23.23m
φ = 30°

Lip Level = 1778.0m

γ = (1783.8 - 1778.0) = - 5.8m

(-)ve sign taken, because lip level is below tail water level

$$X = 23.23 \times \left[Sin\ (2x30^\circ) + 2\ Cos30^\circ\sqrt{Sin^2 30^\circ + \left(\frac{-5.8}{24.49}\right)}\right]$$

≈ 20.12m

X = 22.0m **(adopted)**

1.3 Hydraulic Design of Auxiliary Spillway

Design Data

HFL = 1808.0m

Crest Elevation = 1803.0m

No. of Bays = 1

Size of bay = 8.0m x 5.0m

Design Discharge: (FOR OGEE SPILLWAY)
(Reference : IS:6934-1973)

$Q = C_d L\, H^{3/2}$

$H = (1808.0 - 1803.0) = 5.0m$

$C_d = 2.2$

$L = 8.0m$

$\therefore Q = 2.2 \times 8 \times 5^{3/2}$

$\approx 197\ m^3/sec$

$$V_a = \frac{Q}{A} = \frac{197}{(8x5)} \approx 4.93 m/sec$$

$$\therefore \text{Velocity Head} = h_a = \frac{V_a^2}{2g}$$

$$= \frac{4.93^2}{2x9.81} \approx 1.24m$$

$\therefore$ Design Head $= H_d = (5.0 + 1.24) = 6.24m$

$\therefore$ Design Discharge $= Q_d = 2.2\ (2x8.0) \times 6.24^{3/2}$

$\approx 275.0\ m^3/sec$

Ogee Profiles

Upstream Profile

Coordinates of points along U/S profile

X/H_d	Y/H_d	X	Y
0.0	0.0	0.0	0.0

- 0.02	0.0004	- 0.125	0.0025
- 0.12	0.0158	- 0.749	0.099
- 0.19	0.0437	- 1.186	0.273
- 0.245	0.0836	- 1.529	0.522
- 0.27	0.126	- 1.685	0.786

Downstream Profile

$x^{1.85} = 2.0\ Hd^{0.85}.y$

$$y = \frac{x^{1.85}}{2.0x(6.24)^{0.85}} = \frac{x^{1.85}}{9.5}$$

$$\frac{dy}{dx} = \frac{1}{9.5}\ x\ 1.85\ x\ x^{0.85} = \frac{x^{0.85}}{5.14}$$

Making the slope of D/S profile slope parallel to non-overflow section slope

$$\frac{dy}{dx} = \frac{1}{0.8} = \frac{x^{0.85}}{5.14}$$

$\Rightarrow x \approx 8.92m$

Corresponding $y = \dfrac{(8.92)^{1.85}}{9.5} \approx 6.03m$

Coordinates of points along D/S Profile

X	Y
0.0	0.0
1.097	0.125
1.597	0.25
2.323	0.50
3.38	1.0
4.21	1.5
4.92	2.0

X	Y
5.55	2.5
6.125	3.0
6.657	3.5
7.156	4.0
7.627	4.5
8.074	5.0
8.501	5.5
8.92	6.03

Design of Flip Bucket (Trajectory Type Bucket)
(Ref: IS:7365-1985, Cl. 5.2.3, 5.2.4, 5.2.5, Fig. 1 & Fig. 7)

Crest Elevation = 1803.0m

River Bed Level = 1770.0m

TWL (Max.) = 1783.8m

HFL = 1808.0m

Lip Level = 1778.8m

Radius of Bucket

$R = 0.8\sqrt{H \times H_S}$

$H = (1808.0 - 1803.0) = 5.0m$
$H_3 = (1808.0 - 1783.8) = 24.2m$ Ref. Fig. 1 of IS:7365-1985
$H_5 = (1808.0 - 1770.0) = 38.0m$

$\therefore R = 0.8\sqrt{5 \times 38} = 11.03m$

R = 11.0m **(adopted)**

Velocity of jet entering bucket = $V_t = \sqrt{2g\ H_3} = \sqrt{2 \times 9.81 \times 24.2}$

$\Rightarrow V_t = 21.79$ m/sec

For $H = 5.0m$ & $H_3 = 24.2m$

$V_a/V_t = 0.92$

$\Rightarrow$ $V_a = 0.92 \times 21.79 \approx 20.05$ m/sec

Vel. Head in Bucket = $H_v = \dfrac{V_a^2}{2g} = \dfrac{20.05^2}{2x9.81} \approx 20.5m$

Lip Angle

Lip angle = 30° **(adopted)**

Trajectory Length

$$\frac{X}{H_v} = Sin2\varphi + 2Cos\varphi \sqrt{\sin^2\varphi + Y/H_v}$$

Depth of submergence = Y = (1778.8 - 1783.8) = - 5.0m

$$\Rightarrow X = 20.5\, x \left[\sin\,(2x30°) + 2Cos30° \sqrt{\sin^2 30° + \left(\frac{-5.0}{20.5}\right)}\right]$$

$\approx$ 17.8m

X = 22.0m **(adopted)**

Coordinates for Upper Nappe Profile
(Ref.: Open Channel Flow - Ven Tee Chow, Page 370)

$H_d = 6.24m$, For $H/H_d = 1.0$

X/H_d	Y/H_d	X	Y
- 1.0	- 0941	- 6.24	- 5.842
- 0.8	- 0.932	- 4.992	- 5.816
- 0.6	- 0.913	- 3.744	- 5.967
- 0.4	- 0.890	- 2.496	- 5.554
- 0.2	- 0.855	- 1.248	- 5.335

X/H_d	Y/H_d	X	Y
0.0	- 0.805	0.0	- 5.023
0.2	- 0.735	1.248	- 4.586
0.4	- 0.647	2.496	- 4.037
0.6	- 0.539	3.744	- 3.363
0.8	- 0.389	4.992	- 2.427
1.0	- 0.202	6.24	- 1.260
1.2	0.015	7.488	0.094
1.4	0.266	8.736	1.66
1.6	0.521	9.984	3.251
1.8	0.860	11.232	5.366

Chapter - B2

INTAKE AND SEDIMENTATION CHAMBER

2.1 Hydraulic Design of Intake

Parameters

Tunnel Discharge	:	417.00 cumec
Intake Discharge	:	521.25 cumec
No. of Intake Bays	:	4
Discharge per Intake Bay	:	130.31 cumec
Width of each Intake Bay	:	16m
Waterway at Intake	:	64m

Velocity through Trashracks

Area of Trashracks, normal to the flow of water

$$= 7.820 \text{ Cos } 20° \times 64 = 470.3 \text{ m}^2$$

Velocity through Trashracks = $\frac{521.25}{470.3} = 1.11 \; m/\text{sec}$

Velocity at Gate Location

After inlet transition, the throat of each intake bay is 6m(W) x 5m(H)

=> Area at throat = 6x5 = 30m^2

Hence, velocity at throat = $\frac{521.25}{4x30} = 4.344 \; m/s$

Head Loss at Intake

i) Normal Condition :

Head Loss for 80% opening area = $0.5 \; \frac{v^2}{2g}$

$$= \frac{0.5 \; x \; (1.11/0.8)^2}{2x9.81} = 0.05 \; m$$

Head Loss at Inlet $= 0.2 \dfrac{v^2}{2g}$

$= \dfrac{0.2 \times (1.11)^2}{2x9.81} = 0.013\ m$

Head Loss at Throat $= 0.1 \dfrac{v^2}{2g}$

$= \dfrac{0.1 \times (1.11)^2}{2x9.81} = 0.006\ m$

⇒ Total Head Loss = 0.069 m

ii) 50% choking of Trashracks

Head loss for 40% opening area $= 0.5 \dfrac{v^2}{2g}$

$= \dfrac{0.5 \times (1.11/0.4)^2}{2x9.81} = 0.196\ m$

Head Loss at Inlet = 0.013 m

Head Loss at Throat = 0.006 m

⇒ Total Head Loss = 0.215 m

Head Loss in Intake Tunnels

Area of Intake Tunnels = $\pi/4 \times (6)^2 = 28.275\ m^2$

Perimeter of Intake Tunnels = $\pi \times 6 = 18.85m$

⇆ Hydraulic mean radius R = $\dfrac{A}{P} = \dfrac{28.275}{18.85} = 1.5m$

For concrete lined Intake Tunnels, n = 0.013

& velocity of flow V = $\dfrac{Q}{A} = \dfrac{521.25}{4x28.275} = 4.61\ m/s$

Intake Tunnel No.	Length of Intake Tunnel (l)	Head Loss $\left[H_f = \dfrac{v^2 n^2 l}{R^{4/3}}\right]$
1	119.73m	0.250m
2	152.516m	0.319m
3	194.648m	0.407m
4	236.985m	0.496m

2.2 Hydraulic Design of Sedimentation Chamber

Parameters

No. of sedimentation chambers = 4

Discharge through each Intake Bay = 130.31 cumec

Discharge through each Link Tunnel = 104.25 cumec

Discharge through respective flushing duct = 26.06 cumec

Particle size to be removed = + 0.2mm particle

Section of Chamber

Flow through velocity in chamber = $V_d = 44\sqrt{d}$

where, d = dia of particle size to be excluded = 0.2mm

$$\Rightarrow V_d = 44\sqrt{d}$$
$$= 44\sqrt{0.2}$$
$$= 19.68 \text{ cm/sec}$$
$$\approx 0.2 \text{ m/sec (say)}$$

Emil Mosonyi suggests a velocity of 0.4 to 0.6 m/sec in sedimentation chambers.

On economic grounds, flow through velocity of 0.3 m/sec has been adopted.

Sectional Area of chamber required = $\frac{130.31}{0.30} = 434.4\ m^2$

Section, as shown below has been adopted.

Area of adopted section, as shown above = 416.7 m^2

Wetted Perimeter - p = 78.12m

Hydraulic mean radius - R = A/p = 5.33m

Velocity at inlet of chamber = $\frac{130.31}{416.7} = 0.313\ m/s$

Velocity at outlet of chamber = $\frac{104.25}{416.7} = 0.25\ m/s$

Length of Chamber

$$F = \frac{W\,Y^{1/6}}{Vn\sqrt{g}}$$

where, W = Fall velocity of 0.2mm particle at 10°C

= 2.0 cm/sec = 0.020 m/s

Y = Depth of chamber = 29.65 m

V = Flow through velocity in chamber = 0.313 m/sec

n = Manning's coefficient = 0.014

$$F = \frac{0.020 \times (29.65)^{1/6}}{0.313 \times 0.014 \times \sqrt{9.81}}$$

= 2.6

From Camps curve (on pp 813, Engineering Hydraulics by Hunter Rouse) -

For F = 2.6, WL/VY = 1.07 (for 95% efficiency)

WL/VY = 1.07

$$\Rightarrow L = \frac{1.07 \times VY}{W}$$

$$= \frac{1.07 \times 0.31 \times 29.65}{0.02} = 491.75\ m$$

Length adopted is 505 m.

In all, 64 no. of hoppers have been provided in the sedimentation chambers. Distance between openings has been kept 6m c/c in the beginning, which gradually increases to 10.25m c/c at the end of chambers.

Size of first opening has been kept 1m x 1m

Discharge in the first opening = 10% of total flushing discharge
= 2.6 cumec

Velocity through the first opening = $\frac{2.6}{1x1} = 2.6\ m/s$

In the remaining 63 openings, equal discharge has been assumed to be passing through,

i.e., discharge in each opening = $\frac{26 - 2.6}{63}$

= 0.37 cumec

Dia of different openings have been calculated by computer analysis by equalising the head losses arising by flow through the duct and that through the opening. The dia of openings varies from 0.27m (2nd opening) to 0.15m (64th opening)

Head loss in chamber - $h_{fc} = \frac{v^2 n^2 L}{R^{4/3}}$

$$= \frac{(0.31)^2 x (0.013)^2 x 500}{(5.33)^{4/3}} = 0.0009 m$$

The loss below each hopper has been calculated on computer and the results are given in the table. It is seen, that, total loss in the last opening will be 11.16m. Velocity in the flushing duct has been assumed to be gradually varying from 3.5 m/s in the beginning to 4.3 m/s in the end.

2.3 Hydraulic Design of Flushing Conduits

Since, the velocity in the duct below the last hopper i.e. 64th hopper is 4.3 m/sec, the velocity in the conduits will also be kept as 4.3 m/s.

Area of the conduit $= \frac{26.06}{4.3} = 6.06\ m^2$

This area will be provided in the form of a circular shape conduit, of 2.76m dia, as shown below:

Area = $\pi/4$ x $(2.76)^2$ = 5.983 m^2

p = π x 2.76 = 8.67m

R = A/p $= \frac{5.983}{8.67} = 0.69\ m$

Velocity (v) $= \frac{26.06}{5.983} = 4.35\ m/s$

Friction loss in the conduits per 100m length

$$f = \frac{v^2 n^2 L}{R^{4/3}}$$

$$= \frac{(4.35)^2 x (0.014)^2 x 100}{(0.69)^{4/3}}$$

$\Rightarrow$ f = 0.61m per 100m length

Though the flushing conduits are to be steel lined, yet, the same value of 'n' as that for concrete lined surface has been adopted, due to the anticipated abrasion resulting from higher concentration of sediment.

Outfall Structure

Duct No.	Length (m)	Head Loss (h_f) (m)	Total Head Loss (m)	Calculated Sill Level (m)	Adopted Sill Level (m)	Slope of Duct (m)
1.	300	1.83	12.99	1786.01	1785.80	1:9.5
2.	330	2.01	13.17	1785.83	1785.80	1:10.44
3.	370	2.26	13.42	1785.58	1785.50	1:11.82
4.	405	2.47	13.63	1785.37	1785.50	1:12.94

Sill Level of Outfall Structure

Max. tail water level at dam axis = 1783.80m

Correspondingly, with river bed slope of 1:300, at 900m d/s of dam axis i.e. at the location of outfall structure for flushing conduit :

$$\text{Max. Flood Level} = 1783.80 - \frac{900}{300}$$

$$= 1780.80 \text{ m}$$

This level is much below the adopted sill levels for the outfall structures.

Energy Dissipation at Outfall Structure

For energy dissipation of escaping discharge, from flushing conduits, ski jump bucket at El 1775.00 shall be provided, which will throw the trajectory about 20m away from the end of the bucket. At this level, the bucket will be partially submerged in the floods having frequency of once in 5 years.

Chapter - B3

HEAD RACE TUNNEL

3.1 Economic Diameter

Parameters

a)	Discharge	=	417 cumec
b)	Length	=	17198 m
c)	Maximum pond level	=	1810 m
d)	Minimum pond level	=	1799 m
e)	Coefficient of friction	=	0.013
f)	Minimum down surge level	=	1718.873 m
g)	Centre line of tunnel at inlet end	=	1785.85 m
h)	Centre line of tunnel at junction with surge shaft	=	1671.195 m

Economic Diameter of tunnel

Quantity of excavation/metre length

$= \pi(D+0.1D)^2/4 \qquad = 0.95\ D^2$

Cost of excavation (by conventional method) = Rs. 1500 per cum

Cost of excavation per metre length = Rs. 1425 D^2

Area of lining = π (D+0.05D) 0.05D = 0.165 D^2

Cost of lining = Rs. 2500/cum

Cost of lining per metre length = Rs. 412.5 D^2

Total Cost = Rs. 1837.5 D^2

Total cost taking 10% overhead charges = Rs. 2021.25 D^2

Annual expenditure @ 22.50% of Civil Works

= 2021.25 D2 x 0.225 = 455 D^2

Annual loss of revenue

$$R_e = \frac{8.93 \times 10^5 \times Q^3 \times N^2 \times q \times C_0}{D^{5.33}}$$

where Q = equivalent discharge = 0.511 x 417 = 213.087

N = Coeff. of friction = 0.013

q = overall efficiency = 0.89

C_0 = settling rate of energy = Rs. 2.00 per kWh

$$R_e = \frac{8.93 \times 10^5 \times (213.087)^3 \times (0.013)^2 \times 0.89 \times 2.00}{D^{5.33}}$$

$R_e = 2.6 \times 10^9 D^{-5.33}$

Total annual loss of revenue plus recurring expenses
$= 2.6 \times 10^9 D^{-5.33} + 455 D^2$

for minimum losses dT/dD should be = 0

dT/dD $= - 5.33 \times 2.6 \times 10^9 D^{-6.33} + 2 \times 455 D = 0$

$5.33 \times 2.6 \times 10^9 D^{-6.33} = 910D$

$$D^{7.33} = \frac{5.33 \times 2.6 \times 10^9}{910}$$

D = 9.55m

As per Chapter IV of Volume I, diameter of HRT adopted = 10.48m finished circular tunnel.

3.2 Support System

The rock mass classification (Q-system) studies carried out along the tunnel alignment have given the following values :

THE LITHOLOGICAL ZONES ALONG THE TUNNEL ALIGNMENT AND THEIR RANGE OF `Q' VALUES

Sl No	Length along HRT (m)	Q Value and Rock Class	Structural and Lithological Description	
1.	1150	0.01-0.1 Extremely poor	1) Shear zones 3-5m thick with ground water flow, oriented N-S, N20°W-S20°E, and N20°E-S20°W i.e. running across the tunnel alignment occurring at 75-100m interval; assumed aggregate length	1133m
			2) Choling khad fault with ground water	17m
			Total	1150m
2.	850	0.1-1 Very poor	1) Foliation shear zones, mica schist, biotite schist zones etc.	600m
			2) Very poor rock reaches in Zone II	250m
			Total	850m
3.	13198	1-4 Poor rock	3 to 3+ random joint sets, closely spaced, average RQD ranging from 50-80% forming wedges in the crown having gravity fall conditions as well as sliding conditions in gneissic rock	
4.	2000	4-10 Fair to good rock	Massive Wangtoo gneiss, normally two to 2+ random sets of joints and widely spaced. RQD - 70-100%	

Based on the `Q' values, the following support system is proposed (Recommended supports based on NGI tunnelling quality index Q)

SUPPORT SYSTEM GUIDE

Tunnelling Quality Index `Q'	Rock Quality	Nature of Support
Above 40	Very Good	50mm to 100mm of shotcrete in crown portion, if required.
40-10	Good	Tensioned and grouted expansion shell type spot rockbolts - 25 dia, 3500 long and 50mm shotcrete in arch portion only as required.

Tunnelling Quality Index `Q'	Rock Quality	Nature of Support
10-4	Fair	Tensioned and grouted expansion shell type rockbolts - 25 dia, 3500 long @ 1500 C/C staggered both ways and 50mm shotcrete in arch portion only.
4-1	Poor	Tensioned and grouted expansion shell type rockbolts - 25 dia, 3500 long @ 1250 C/C staggered both ways and 100mm fibre reinforced shotcrete in arch portion and extended to sides, if required.
1-0.4	Very poor	Tensioned and grouted expansion shell type spot rockbolts - 25 dia, 3500 long @ 1250 C/C staggered both ways and 150mm fibre reinforced shotcrete in arch portion and extended to sides, if required.
0.4-0.1	Very poor	ISHB 150 @ 34.6 kg/m @ 750 C/C and 150mm fibre reinforced shotcrete between the ribs.
0.1-0.01	Extremely poor	ISHB 150 @ 34.6 kg/m @ 500 C/C and 150mm fibre reinforced shotcrete between the ribs.

Chapter - B4

SURGE SHAFT

4.1 HYDRAULIC DESIGN

1. Hydraulic Parameters

1.	Length of Headrace Tunnel	=	17198	m
2.	Dia of Headrace Tunnel (circular)	=	10.48	m
3.	Design Discharge	=	417.00	cumec
4.	Cross-sectional Area of HRT	=	86.2606	m^2
5.	Cross-sectional Area of Penstocks	=	17.720	m^2
6.	Length of Penstocks	=	290.50	m
7.	Net head on turbine	=	273.70	m
8.	Installed Capacity	=	4x250	MW
9.	Maximum Reservoir Level	=	1810.0	m
10.	Minimum Reservoir Level	=	1799.0	m
11.	Maximum Tailwater Level	=	1519.5	m
12.	Normal Tailwater Level	=	1509.5	m
13.	Minimum Tailwater Level	=	1506.5	m
14.	Area of Orifice	=	19.0	m^2
15.	Diameter of Surge Shaft	=	27.0	m

2. Area of Surge Shaft

Area of Surge Shaft according to Thoma's Criteria

$$A_s \geq \frac{L\ x\ A_t}{2g(H - \beta V^2)}$$

Where A_s = Area of Surge Shaft

L = Length of HRT = 17198 m

A_t = Area of HRT = 86.2606 m^2

Velocity in HRT V_0 $= \frac{417.0}{86.2606} - 4.83\ m/\sec$

Dia of HRT = 10.48 m (circular)

Hydraulic Radius $R = D/4$

$= 2.575$ m

Velocity in HRT at any instant V $= 1/n\, R^{2/3} S^{1/2}$

h_f = Head loss in HRT corresponding to velocity V_0

Considering Head loss due to friction only and neglecting other losses.

$$h_f = \frac{n^2 V^2 L}{R^{4/3}}$$

$n_{max} = 0.014$

$n_{min} = 0.012$

$n_{avg} = 0.013$

$$h_{max} = (0.014)^2 \times \frac{17198}{3.52} \times V^2 = 0.957V^2$$

$$h_{min} = (0.012)^2 \times \frac{17198}{3.52} \times V^2 = 0.703V^2$$

$$h_{avg} = (0.013)^2 \times \frac{17198}{3.52} \times V^2 = 0.825V^2$$

Coefficient of head loss $\beta_{max} = \frac{h_{max}}{V^2} = 0.957$

$$\beta_{min} = \frac{h_{min}}{V^2} = 0.703$$

$$\beta_{avg} = \frac{h_{avg}}{V^2} = 0.825$$

$$A_s = \frac{17198 \times 86.2606}{2 \times 0.703 \times 9.81 \times (295 - 0.703 \times 4.83^2)} = 386.08$$

While deciding the area of surge shaft, power house has been taken to be operating in isolation. The area of the surge shaft as per Thoma's Criteria works out to be 386.08 sqm. Taking a safety factor of 1.6 as suggested by Charles Jaeger, the area works out to 617.2 sq.m. The diameter of surge shaft works out to 27.0 m corresponding to the above area.

3. **Area of Orifice**

Calme & Garden suggest the following criterion for the resistance `h_d' offered by the orifice.

$$\frac{Z}{\sqrt{2}} \quad \frac{\beta V_0^2}{4} < h_{or} < \frac{Z}{\sqrt{2}} \quad \frac{3}{4}\beta V_0^2$$

Where Z $= V_0 \sqrt{\frac{L}{g} x \frac{A_t}{A_s}}$

= Max. surge height neglecting all losses and

β = average loss coefficient

such that

$h_f = \beta V_0^2$

$V_0 = \frac{417}{86.2606} \quad 4.83 \ m/\text{sec}$

$Z_x = 4.83 \times \sqrt{\frac{17198}{9.81} \times \frac{86.2606}{573}}$

= 78.466

and $h_f = \beta V_0^2$

$\beta = \frac{h_f}{V^2}$

$= \frac{18.912}{(4.83)^2} \quad 0.81$

Assume the area of orifice = 19 m^2

$h_{or} = \frac{Q_0^2}{C_d^2 \ A_0^2 \ 2g}$ (As per IS:7396 Pt I - 1985)

$= \frac{(417)^2}{(0.6)^2 \ x \ 19^2 \ x \ 2 \ x \ 9.81}$

= 68.197 m^2

$$\frac{Z}{\sqrt{2}} \quad \frac{\beta V_0^2}{4} < h_{or} < \frac{Z}{\sqrt{2}} \quad \frac{3}{4}\beta V_0^2$$

Substituting the values

60.25 < 68.197 < 69.706

The total area of orifice is 19.0 m^2. Area required to accommodate the grooves of 4 gates is 12.9 m^2

Remaining area of port $= (19 - 12.9)\ m^2$
$= 6.1\ m^2$

Dia of port = 2.786 m

Adopted dia of port = 2.8m

4.2 SURGE ANALYSIS

The surge analysis has been carried out for the following conditions by using a computer program

1. Maximum upsurge for total load rejection (100% - 0%)
2. Maximum upsurge for 50% load acceptance followed by full load rejection (50% - 100% - 0%)
3. Minimum downsurge for 50% load rejection followed by 50% load acceptance (100% - 50% - 100%)
4. Minimum downsurge for 50% load rejection followed by instantaneous 50% load acceptance (50% - 0% - 50%).
5. Minimum downsurge for full load rejection followed by 50% load acceptance (100% - 0% - 50%)

For upsurge calculations friction factor has been taken as minimum i.e. 0.012 and reservoir level has been taken at maximum i.e. at EL 1810 while the friction factor has been taken as maximum i.e. 0.014 and reservoir level at EL 1799.0 (Minimum reservoir level) for down surge calculations in accordance with IS:1736 (Part-I) -1985. For the transients of combination of load change, the second change was effected at the maximum/minimum velocity in the tunnel. The Governor closing time has been taken as 15 second.

Sl. No.	Load change in MW	Losses	Steady state head in surge shaft	Maximum / Minimum surge level
1.	1000-0	Min	1810	1848.680
2.	500-1000-0	Min	1810	1848.484
3.	1000-500-1000	Max	1810	1717.103
4.	500-0-500	Max	1810	1739.209
5.	1000-0-500	Max	1810	1735.168

Since the load acceptance can be controlled with the help of load limiters the condition of 50% load switch on has been taken the governing condition for fixing the centre line of tunnel below the surge shaft.

A free board of 3.32 m above the peak surge has been provided for fixing the top level of surge shaft.

Abstract of calculations for surge levels for both upstream and downstream surge chamber are given in Annexure B4.1.

4.3 STRUCTURAL DESIGN

1. Design Loads

Internal water pressure at El 1848.680

External Water Pressure

a) Maximum water pressure corresponding to static level at El 1810.0m

b) Grout Pressure same as external water pressure subjected to a minimum of 2.5 kg/cm^2 and maximum of 7.0 kg/cm^2.

c) Temperature variation = ± 15°C

2. Allowable Stresses

a) Cement Concrete Grade M25

Permissible Compressive Strength σ_c	= 85 kg/cm^2
Permissible Tensile Strength σ_t	= 32 kg/cm^2

b) Reinforcement Bars Fe 415 / Fe 500

Permissible Tensile Stress Fe 415	= 2300 kg/cm^2
Permissible Tensile Stress Fe 500	*= 2750 kg/cm^2*

3. Other Data

Internal Diameter of Riser	= 16.0m
Internal Diameter of Surge Shaft	= 27.0m
Poissons Ratio of Rock (μ_r)	= 0.24
Poissons Ratio of Concrete (μ_c)	= 0.15
Modulus ratio for M25 (m)	= 10.98

Modulus of deformation of Rock (E_r) = 75000 kg/cm^2

Modulus of elasticity of concrete(E_c) = 285000 kg/cm^2

4. **Design Calculations for RCC Lining at 1677.845m (Riser portion)**

Lining thickness = 150 cm

Inner radius of surge tank (a) = 800 cm

Outer radius of surge tank (b) = 950 cm

$$k = \frac{(1+\mu_r) - (1-\mu_c)\ E_r/E_c}{(1+\mu_r) + (1-\mu_c)\ E_r/E_c}$$

$$= \frac{(1.24) - (0.85)\ 75000/285000}{(1.24) + (0.85)\ 75000/285000}$$

$= 0.694$

Maximum Design Head = Maximum Surge - Bottom of Riser

= 1848.680 - 1677.846

= 170.835 M

Maximum Design Pressure (P_i) = 17.083 kg/cm^2

Load shearing by rock corresponding to maximum design pressure

$$P_r = P_i\ \frac{a^2(1-k)}{(b^2 - a^2k)}$$

P_r = 7.299 kg/cm^2

i) Hoop reinforcement for maximum design head considering supporting action of Rock

$$A_{st} = \frac{(P_i - P_r)\ a}{\sigma_{st}}$$

$$= \frac{(17.0835 - 7.299) \times 800}{2750}$$

$= 2.8464$ cm^2/cm

≈ 285 cm^2/m

ii) Hoop reinforcement for maximum design head neglecting supporting action of rock with higher stresses in steel.

$$A_{st} = \frac{P_i \, x \, a}{1.33 \; \sigma_{st}}$$

$$= \frac{17.0835 \; x \; 800}{1.33 \; x \; 2750}$$

$= 3.737 \text{ cm}^2/\text{cm}$

$= 373.7 \text{ cm}^2/\text{m}$

iii) Minimum Reinforcement (0.3%) $= \dfrac{0.3 \; x \; 150}{100}$

$= 0.45 \text{ cm}^2/\text{cm}$

$= 45 \text{ cm}^2/\text{m}$

iv) Concrete lining thickness required to resist the external pressure

External Water Head = 1810.0 - 1677.845 = 132.155m

External Water Pressure (P) = 13.2155 kg/cm^2

$$P = \frac{\sigma_c \, (b^2 - a^2)}{(b^2 + 800^2)}$$

$$13.2155 = \frac{85 \, (b^2 - 800^2)}{(b^2 + 800^2)}$$

b = 935.76 cm

Hence lining thickness required to resist external pressure
= 935.76 - 800
= 135.76 cm

provided thickness = 150 cm

v) Reinforcement Provided

Hoop reinforcement - 12mm thick sandwitched steel liner and 32 ϕ Bars @ 180 c/c in six rows.

Longitudinal reinforcement required (0.12%)

$$= \frac{0.12 \; x \; 150}{100} = 0.180 \; cm^2/cm = 18 \; cm^2/m$$

25 ϕ @ 275mm c/c

5. **Design Calculation for RCC Lining at 1702.845m**

Lining thickness = 125 cm

Maximum Design Head = *1848.680 - 1702.845*

= 145.835m

Maximum Design Pressure (P_i) = 14.5835 kg/cm²

Load sharing by rock corresponding to maximum design pressure

$$P_r = P_i \frac{a^2 (1 - k)}{(b^2 - a^2 k)}$$

$$P_r = 6.941 \text{ kg/cm}^2$$

i) Hoop reinforcement for maximum design head considering supporting action of rock.

$$A_{st} = \frac{(P_i - P_r)a}{\sigma_{st}}$$

$$= \frac{(14.5835 - 6.941)\ 800}{2750}$$

$= 2.223$ cm²/cm

≈ 225 cm²/m

ii) Hoop reinforcement for maximum design head neglecting supporting action of rock with higher stress in steel.

$$A_{st} = \frac{P_i \times a}{1.33\ \sigma_{st}}$$

$$= \frac{14.5835 \times 800}{1.33 \times 2750}$$

$= 3.190$ cm²/cm

$= 319$ cm²/m

iii) Minimum Reinforcement (0.3%) $= \dfrac{0.3 \times 125}{100}$

$= 0.36$ cm²/cm

$= 36$ cm²/m

iv) Concrete lining thickness required to resist the external pressure :

External Water Head = 1810.0 - 1702.845 = 107.155m

External Water Pressure (P) = 10.7155 kg/cm^2

$$P = \frac{\sigma_c (b^2 - a^2)}{(b^2 + a^2)}$$

$$10.7155 = \frac{85 (b^2 - 800^2)}{(b^2 + 800^2)}$$

b = 908.09 cm

Hence thickness required to resist external pressure

= 908.09 - 800

= 108.09 cm

provided thickness = 125 cm

Hence OK.

v) Reinforcement Provided

Hoop reinforcement - 12mm thick sandwitched steel liner and 32 ϕ Bars @ 225 c/c in six rows.

Longitudinal Reinforcement (0.12%)

$$= \frac{0.12 \times 125}{100} = 0.150\ cm^2/cm = 15\ cm^2/m$$

22 ϕ @ 275 c/c

6. **Design Calculation for RCC Lining at 1727.845m**

Lining thickness = 100 cm

Maximum Design Head = 1848.680 - 1727.845

= 120.835m

Maximum Design Pressure (P_i) = 12.0835 kg/cm^2

Load shearing by rock corresponding to maximum design pressure

$$P_r = P_i \frac{a^2 (1 - k)}{(b^2 - a^2 k)}$$

$$P_r = 6.468 \text{ kg/cm}^2$$

i) Hoop reinforcement for maximum design head considering supporting action of rock.

$$A_{st} = \frac{(P_i - P_r)a}{\sigma_{st}}$$

$$= \frac{(12.0835 - 6.468)\ 800}{2750}$$

$$= 1.634 \text{ cm}^2/\text{cm}$$

$$\approx 165 \text{ cm}^2/\text{m}$$

ii) Hoop reinforcement for maximum design head neglecting supporting action of rock with higher stress in steel.

$$A_{st} = \frac{P_i \ x \ a}{1.33 \ \sigma_{st}}$$

$$= \frac{12.0835 \ x \ 800}{1.33 \ x \ 2750}$$

$$= 2.643 \text{ cm}^2/\text{cm}$$

iii) Minimum Reinforcement (0.3%) $= \frac{0.3 \ x \ 100}{100}$

$$= 0.30 \text{ cm}^2/\text{cm}$$

$$= 30 \text{ cm}^2/\text{m}$$

iv) Concrete lining thickness required to resist the external pressure

External Water Head = 1810.0 - 1727.845 = 82.155m

External Water Pressure (P) = 8.2155 kg/cm^2

$$P = \frac{\sigma_c (b^2 - a^2)}{(b^2 + a^2)}$$

$$8.2155 = \frac{85\ (b^2 - 800^2)}{(b^2 + 800^2)}$$

$$b = 881.45 \text{ cm}$$

Hence thickness required to resist external pressure

= 881.45 - 800

= 81.45 cm

provided thickness = 100 cm

Hence OK.

v) Reinforcement Provided

Hoop reinforcement - 12mm thick sandwitched steel liner and 32 ϕ Bars @ 200 c/c in four rows.

Longitudinal Reinforcement (0.12%)

$$= \frac{0.12 \times 100}{100} = 0.120 \ cm^2/cm = 12 \ cm^2/m$$

20 ϕ @ 275 c/c

7. **Design Calculation for RCC Lining at 1755.0 m**

a) Cement Concrete Grade M25

Permissible Compressive Strength σ_c = 85 kg/cm^2

Permissible Tensile Strength σ_t = 32 kg/cm^2

b) Reinforcement Bar Fe 415

Permissible Tensile Stress = 2300 kg/cm^2

c) Other Data

Internal Diameter of Surge Shaft = 27.0m

Modulus ratio for M25 (m) = 10.98

Above El 1755.0 rock shearing has not been considered due to inadequate rock cover .

Internal radius of surge shaft (a) = 1350cm

Concrete lining thickness = 100cm

Outer radius of surge shaft (b) = 1450 cm

Maximum Design Head = *1848.680 - 1755.0*
= 93.68 m

Maximum Design Pressure (P_i) = 9.368 kg/cm^2

Steel of Fe-415 grade has been provided from EL. 1755.0 m

i) Hoop reinforcement for maximum design head considering supporting action of Rock

$$A_{st} = \frac{(P_i - P_r)\, a}{\sigma_{st}}$$

$$= \frac{(9.368 - 0.0) \times 1350}{2300}$$

= 5.498 cm^2/cm

≈550 cm^2/m

ii) Minimum Reinforcement (0.3%) $= \frac{0.3 \times 100}{100}$

= 0.3 cm^2/cm

= 30 cm^2/m

iii) Concrete lining thickness required to resist the external pressure

External Water Head = 1810.0 - 1755.0 = 55.0m

External Water Pressure (P) = 5.5 kg/cm^2

$$P = \frac{\sigma_c (b^2 - a^2)}{(b^2 + 800^2)}$$

$$5.5 = \frac{85\ (b^2 - 1350^2)}{(b^2 + 1350^2)}$$

b = 1440.37 cm

Hence thickness required to resist external pressure

= 1440.37 - 1350

= 90.37 cm

provided thickness = 100 cm

Hence OK.

iv) Reinforcement Provided

Hoop reinforcement - 12mm thick sandwitched steel liner and 40 ϕ Bars @ 110 c/c in four rows.

Longitudinal Reinforcement (0.12%)

$$= \frac{0.12 \ x \ 100}{100} = 0.12 \ cm^2/cm = 12 \ cm^2/m$$

20 ϕ @ 275 c/c

8. **Design Calculation for RCC Lining at 1780.0 m**

Concrete lining thickness = 75 cm

Maximum Design Head = 1848.68 - 1780
= 68.68 m

Maximum Design Pressure (p_i) = 6.868 kg/cm_2

i) Hoop reinforcement for maximum design head considering supporting action of rock.

$$A_{st} = \frac{(P_i - P_r) \ a}{\sigma_{st}}$$

$$= \frac{(6.868 - 0.0) \ 1350}{2300}$$

= 4.031 cm^2/cm

≈405 cm^2/m

ii) Minimum Reinforcement (0.3%) $= \frac{0.3 \ x \ 75}{100}$

= 0.225 cm^2/cm

= 22.5 cm^2/m

iii) Concrete lining thickness required to resist the external pressure

External Water Head = 1810.0 - 1780.0 = 30.0m

External Water Pressure (P) = 3.0 kg/cm^2

$$P = \frac{\sigma_c \ (b^2 - a^2)}{(b^2 + a^2)}$$

$$3.0 = \frac{85\ (b^2 - 1350^2)}{(b^2 + 1350^2)}$$

$$b = 1398.52 \text{ cm}$$

Hence thickness required to resist external pressure

= 1398.52 - 1350

= 48.52 cm

provided thickness = 75 cm

Hence OK.

iv) Reinforcement Provided

Hoop reinforcement - 12mm thick sandwitched steel liner and 40 ϕ Bars @ 165 c/c in four rows.

Longitudinal Reinforcement (0.12%)

$$= \frac{0.12 \times 75}{100} = 0.09\ cm^2/cm = 9\ cm^2/m$$

20 ϕ @ 450 c/c

9. Design Calculation for RCC Lining at 1805.0 m

Concrete lining thickness = 50 cm

Maximum Design Head = 1848.68 - 1805.0

= 43.68 m

Maximum Design Pressure (P_i) = 4.368 kg/cm_2

i) Hoop reinforcement for maximum design head .

$$A_{st} = \frac{(P_i - P_r)a}{\sigma_{st}}$$

$$= \frac{(4.368 - 0.0)\ 1350}{2300}$$

= 2.564 cm^2/cm

≈260 cm^2/m

ii) Maximum Reinforcement (0.3%) $= \frac{0.3 \times 50}{100}$

$= 0.15\ cm^2/cm$

$= 15\ cm^2/m$

iii) Concrete lining thickness required to resist the external pressure

External Water Head = 1810 - 1805 = 5 m

External Water Pressure (P) = 0.5 kg/cm^2

$$P = \frac{\sigma_c (b^2 - a^2)}{(b^2 + a^2)}$$

$$0.5 = \frac{85\ (b^2 - 1350^2)}{(b^2 + 1350^2)}$$

b = 1357.96 cm

Hence thickness required to resist external pressure

= 1357.96 - 1350
= 7.96 cm

provided thickness = 50 cm

Hence safe.

iv) Reinforcement Provided

Hoop reinforcement - 12mm thick sandwitched steel liner and 32 ϕ Bars @ 110 c/c in two rows.

Longitudinal Reinforcement (0.12%)

$$= \frac{0.12 \times 50}{100} = 0.06\ cm^2/cm = 6\ cm^2/m$$

16 ϕ @ 450 c/c

10. **Typical Design Calculation for RCC Lining at 1830.0 m**

Concrete lining thickness = 50 cm

As sufficient rock support is not available above the elevation 1830.0m the shaft above this elevation has also been checked as a cantilever.

Assuming the surge shaft to be fixed at 1830.0m and the cantilevering above it. Cantilever moment shall be determined with 15% horizontal seismic force when shaft is empty.

Load of surge shaft/m $= \pi/4\ (28.0^2 - 27^2) \times 2.4$

$= 103.673$ t/m

therefore, maximum B.M. at El 1830 due to 15% Seismic Force

$= 0.15 \times 103.673 \times (1852 - 1830)^2$

$= 7526.66$ tm.

Maximum tensile stress in concrete

$$= \frac{7526.66 \times 10^5 \times 1400 \times 2}{\pi \times 2700 \times 50 \times 1350^2}$$

$= 2.73$ kg/cm^2

Direct compressive strength due to self load

$= 22 \times 2.4$

$= 52.8$ t/m^2

$= 5.28$ kg/cm^2

Since compressive stress is more than tensile stress, Hence no additional reinforcement is required.

Maximum Design Head $= 1848.68 - 1830.0$

$= 18.68$m

P_i $= 1.868$ kg/cm^2

i) Hoop reinforcement for maximum design head neglecting supporting action of rock with higher stress is steel

$$A_{st} = \frac{P_i \times a}{1.33\ \sigma_{st}}$$

$$= \frac{1.868 \times 1350}{1.33 \times 2750}$$

$= 0.689$ cm^2/cm

ii) Maximum Reinforcement (0.3%) $= \dfrac{0.3 \times 50}{100}$

$= 0.15\ cm^2/cm$
$= 15\ cm^2/m$

iii) Reinforcement Provided

Hoop reinforcement - 12mm thick sandwitched steel liner upto 1849.0m and 16 φ Bars @ 300 c/c in two rows.

Longitudinal Reinforcement (0.12%)

$$= \frac{0.12 \times 50}{100} = .06\ cm^2/cm = 6\ cm^2/m$$

16 φ @ 450 c/c

MAXIMUM/MINIMUM SURGE LEVELS FOR UPSTREAM SURGE TANK BY ARITHMETIC INTEGRATION

MAXIMUM RESERVOIR LEVEL	=	1810.000n
MINIMUM POND LEVEL	=	1799.000n
DESIGN DISCHARGE IN HRT	=	417 CUMEC
DIA. OF HEAD RACE TUNNEL	=	10.48m (Circular)
LENGTH OF HEAD RACE TUNNEL	=	17198m
DIA. OF UPSTREAM SURGE SHAFT	=	27m
DIA. OF RISER	=	16m
TOP OF UPSTREAM SURGE TANK	=	1852m
TOP OF RISER	=	1755m
BOTTOM OF RISER	=	1676.345
AREA OF ORIFICE	=	17.00 sqm

Sl No	Operating Condition	Reservoir Level in (m)	Losses Max/Min	Maximum/Minimum Surge
				Governor closing time = 15 sec
1.	100-0	1810	Min.	**1848.680**
2.	50-100-0	1810	Min.	1848.484
3.	100-50-100	1799	Max.	**1717.103**
4.	50-0-50	1799	Max.	1739.209
5.	100-0-50	1799	Max.	1735.168

MAXIMUM/MINIMUM SURGE LEVELS FOR DOWNSTREAM SURGE CHAMBER BY ARITHMETIC INTEGRATION

LENGTH OF DOWNSTREAM SURGE TANK	=	220 m
WIDTH OF DOWNSTREAM SURGE TANK	=	16 m
HEIGHT OF DOWNSTREAM SURGE TANK	=	41 m
DIA OF TAIL RACE TUNNEL	=	10.48m (Circular)
LENGTH OF TAIL RACE TUNNEL	=	909 m
MAXIMUM TAIL WATER LEVEL	=	1516.25 m
NORMAL TAIL WATER LEVEL	=	1508.00 m
MINIMUM TAIL WATER LEVEL	=	1505.80 m

Sl. No.	Operating Condition	Tail Water Level (m)	Losses Max/Min	Maximum/Minimum Surge
1.	100-0	1505.8	Max.	1498.605
2.	50-100-0	1505.8	Max.	**1497.812**
3.	100-50-100	1516.25	Min.	1521.223
4.	*50-0-50*	1516.25	Min.	*1520.052*
5.	100-0-50	1516.25	Min.	**1523.065**

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2. **Design of Penstock at El 1498.0m**

Maximum water hammer elevation = 1868.000

Design Pressure = 37.0 kg/cm^2

Since the rock is competent, part of internal water pressure will be shared by the rock also as adequate rock cover is available.

The following formula in IS-11639 (Part-2) are used to work out the rock sharing :

$$P_0 = \frac{Y_0 t}{R^2} x \frac{E_s}{1 - \mu_s^2}$$

$$M = 1 + \frac{1}{2(1 + \mu_r)} \left[\frac{E_r}{E_c} x \frac{(C^2 - R^2)}{RC} + \frac{d^2 - C^2}{C x d} \right]$$

$$P_s = P_0 + (P - P_0) \left[\frac{1}{1 + \frac{E_r R}{E_c M} \frac{(1 - \mu_s)^2}{(1 + \mu_r)}} \right]$$

$$f_{st} = \frac{P_s R}{t}$$

$$f_{rt} = (P - P_s) \frac{R}{d}$$

Where

M = Dimensionless parameter

P = Total internal pressure = 37.0 kg/cm^2

P_s = Pressure shared by steel lining in kg/cm^2

P_0 = Pressure required to close the gap Y_0 between liner and concrete/rock

Y_0 = Initial gap between liner and concrete caused by shrinkage creep of concrete and temperature effect = 0.0004 x R

R = Internal radius of Penstock = 237.5 cm

C = Outside radius of Concrete lining = 287.5 cm

d = Radius to end of radial fissure in rock or where the insitu compressive strength in rock just exceeds the tensile stress caused by internal pressure and is taken = 5R

t = Thickness of steel liner = 2.2cm (2.5cm thick liner plate)

E_s = Modulus of elasticity of steel = 2.11×10^6 kg/cm²

E_r = Modulus of deformation of rock mass = 7.5×10^4 kg/cm²

E_c = Modulus of elasticity of concrete = 0.16×10^6 kg/cm²

μ_s = Poisson's ratio of steel = 0.3

μ_r = Poisson's ratio of rockmass = 0.23

μ_c = Poisson's ratio of concrete = 0.20

$$M = 1 + \frac{1}{2(1+0.23)}\left[\frac{7.5 \; x \; 10^4}{0.16 \; x \; 10^6}\left\{\frac{287.5^2 - 237.5^2}{287.5 \; x \; 237.5}\right\} + \left\{\frac{1187.5^2 - 287.5^2}{1187.5 \; x \; 287.5}\right\}\right]$$

$$= 1 + 0.4065[0.1802 + 3.888] = 2.6539$$

$$P_0 = \frac{0.0004 \; x \; 237.5 \; x \; 2.20 \; x \; 2.11 \; x \; 10^6}{237.5 \; x \; 237.5 \; x \; (1 - 0.3^2)}$$

$$= 8.591 \text{ kg/cm}^2$$

$$P_s = 8.591 + (37 - 8.591)\frac{1}{\left[1 + \dfrac{7.5 \; x \; 10^4 \; x \; 237.5}{2.11 \; x \; 10^6 \; x \; 2.654} \; x \; \dfrac{(1 - 0.3^2)}{(1 + 0.23)}\right]}$$

$$= 8.591 + 8.472 = 17.063 \text{ kg/cm}^2$$

$$\text{Liner Thickness} = \frac{17.063 \; x \; 237.5}{0.95 \; x \; 2100}$$

$$= 2.03\text{cm}$$

Thickness of plate provided including corrosion allowance 25mm thick plate

Stress in steel without rock shearing

$$\frac{37 \; x \; 237.5}{2.5} = 3515 kg/cm^2$$

> 60% of yield stress

The load shared by rock for different sections is given in Table 5.2.1
The Plate thickness adopted for different sections is given in Table 5.2.2

e) Power Loss

Head loss due to friction $h_f = \dfrac{V^2 n^2}{R^{4/3}}$

R = Hydraulic Radius = D/4

$$R^{4/3} = \frac{D^{1.33}}{6.35}$$

$$h_f = \frac{V^2 n^2 \; x \; 6.35}{D^{1.33}}$$

$$V = \frac{Q \; x \; 4}{\pi D^2}$$

$$V^2 = \frac{1.621 \; x \; Q^2}{D^4}$$

$$h_f = \frac{10.293 \; x \; Q^2 \; x \; n^2}{D^{5.33}}$$

Substituting for h_f

$$\text{Power Loss} = 9.8 \; x \; Q \; x \; 0.89 \; x \; \frac{10.293 \; x \; Q^2 \; x \; n^2}{D^{5.33}}$$

Where
g = efficiency = 0.89
Q = equivalent discharge
= 0.550 x 104.25
= *57.34 cumecs*

n = coefficient of friction = 0.012

$$\text{Power Loss (Unit per year)} = \frac{9.8 \; x \; 0.89 \; x \; 10.293 \; x \; (57.34)^3 \; x \; (0.012)^2 \; x \; 8760}{D^{5.33}}$$

$= 21347200 \; D^{-5.33}$

Power Loss = $21347200 \; D^{-5.33}$ x 2.75
(Rs. per year)

= $58704800 \; D^{-5.33}$

f) Total Cost (T) = $2142 \; D^2 + 58704800 \; D^{-5.33}$

g) Economic Diameter

for Economic Diametre dT/dD = 0

$dT/dD = 2 \times 2142\ D - 5.33 \times 58704800\ D^{-6.33} = 0$

$$D^{7.33} = \frac{5.33 \times 58704800}{2 \times 2142} = 73038$$

D = 4.608m

Diameter adopted = 4.750m

5.2 Design of Penstock Liners

1. General Layout of Penstocks

The position of liners have been marked in following orders (exhibit 5.01)

Location	C/L Elevation	Water Hammer Elevation	Length	Slope with horizontal
A (C/L of surge shaft)	1673.100	1848.640	66.79	0°
B (Start of vertical bond of 90°)	1673.100	1853.038	37.31	90°
C (end of vertical bend of 90°)	1649.350	1855.495	50.00	90°
D (end of vertical bend of 90°)	1599.350	1858.651	27.60	90°
E (at level of 1599.350)	1571.750	1860.444	50.00	90°
F (at level of 1571.750)	1521.750	1863.693	37.31	90°
G (start of lower vertical bend of 90°)	1498.000	1866.117	25.0	90°
H (end of vertical bend of 90°)	1498.000	1868.000		90°

For water hammer studies please refer Annexure - B-5.1

iii) <u>U.S.B.R. Formula</u>

$$D = \sqrt{1.273\ Q/V}$$

$$V = 0.125\ \sqrt{2gH}$$

$= 9.160m$

$D = 3.806m$

iv) <u>Donald's Formula</u>

$$D = 0.176\ (P/H)^{0.466}$$

$$= 0.176 \frac{(338594)^{0.466}}{(273.7)^{0.466}}$$

$D = 4.859m$

v) <u>Empirical Formula</u>

$$D = \left[\frac{1}{910.77} f\sigma_{st} \frac{k_2}{k_1} x \frac{Q^3}{H} t\right]^{1/7}$$

Where

K_1 = Annual cost of maintenance of penstock per kg

= 18% of Rs. 75.00 = 13.50 per kg

σ_{st} = Stress is steel = 2100 kg/cm^2

k_2 = Cost per kWh at generator terminal = 2.50

f = friction factor = 0.0085

t = Annual duration of operation

= 365 x 0.502 x 24

= 4398 hrs

$$D = \left[\frac{1}{910.77}\ x\ (0.0085)\ (2100)\ \frac{2.50}{13.50}\ x\ \frac{104.25^3}{273.7}\ x\ 4398\right]^{1/7}$$

$D = 4.882m$

vi) Rational Method

a) Cost of excavation

Area of excavation/m length = $\frac{\pi}{4}\ (D + \frac{D}{10}\ x\ 2)^2 = 1.13\ D^2$

Rate of excavation = Rs. 1650 per cumec

Cost of excavation/m length = Rs. 1865 D^2

b) Cost of lining

Area of lining = $\pi \left[D+\frac{D}{10}\right] \frac{D}{10} = 0.346\ D^2$

Cost of concrete/cum = Rs. 3100 per cum
Cost of lining/m length = 1072.6 $D^2 \approx$ 1073 D^2

c) Cost of Steel lining

Average steel lining thickness = $\frac{PD}{2\sigma_{st}}$

Where P = Average pressure including water hammer = 25.54

σ_{st} = Allowable stress in steel = 2650 kg/cm^2

Average steel lining thickness = 0.0048188 D

Weight of the liner/m length = π(D + 0.0048188) x 0.0048188 x 7.85

= 0.1194 D^2

Cost of liner/m length = 0.1194 D^2 x 66000 = 7880 D^2

d) Annual expenses

Total Cost

= 1865 D^2 + 1073 D^2 + 7880 D^2

= 10818 D^2

Total cost taking 10% overhead charges

= 11900 D^2

Annual expenses @ 18% = 2142 D^2

Chapter - B5

PRESSURE SHAFTS AND PENSTOCKS

5.1 Economic Diameter

Design parameters

Length of Penstocks	=	1 & 4 of 294.002 and 3 & 4 of 277.776m
Gross Head	=	295m
Design Net Head	=	273.7m
Efficiency of Turbine	=	0.89
Design Discharge Q	=	104.25 cumecs
Rated H.P. of turbine P	=	$\frac{1000 \ x \ 104.25 \ x \ 273.7 \ x \ 0.89}{75}$
	=	338594.27 H.P.
Pond Level	=	1810.0m
Center Line of Runner	=	1509.5m
Maximum surge elevation	=	1848.68m ≈ 1849.0m
Temperature variation	=	± 15%
Modulus of deformation of rock (E_r)	=	7.5 x 10^4 kg/cm^2
Poisson's Ratio for rock (μr)	=	0.23
Maximum pressure due to water hammer	=	19.36m

Concrete

Modulus of elasticity of concrete = 0.16 x 10^6 kg/cm^2

Poisson's Ratio for concrete = 0.20

Thickness of concrete around liner = 50cm

Steel

Grade of steel to be used = ASTM A-517 Grade-I

Modulus of elasticity of steel (E_{st}) = 2.11 x 10^6 kg/cm^2

Poisson's Ratio for steel	= 0.30
Coefficient of liner expansion	= 1.1 x 10^{-5} per°C
Minimum yield stress of steel	= 690 MPa
Allowable stress	= 2100 kg/cm^2
Joint efficiency	= 0.95
Corrosion allowance	= 1.5mm
Size of stiffeners	= 16mm thick x 150mm wide
Normal spacing	= one on every ferrule

Economic Diameter of Penstock

i) G.S. Sarkaria's Formula

a) $D = 0.62 \frac{P^{0.43}}{H^{0.65}}$

D = Diameter of penstock in metres

P = Rated horse power of turbine

H = Rated head of turbine in metres

$D = 0.62 \frac{(338594)^{0.43}}{(273.7)^{0.65}}$

D = 3.854 m

b) $D = 3.55[Q^2/(2gH)]^{1/4}$

D = 4.234 m

Average diameter $D = \frac{3.854 + 4.234}{2} = 4.044\ m$

ii) Fahlbusch Formula

$D = 0.52\ H^{-1/7}\ (P/H)^{3/7}$

$= 0.52\ x\ (273.7)^{-1/7}\ x\ \left[\frac{338594}{273.7}\right]^{3/7}$

= 4.933m

Chapter - B6

POWER HOUSE COMPLEX

6.1 Finite Element Analysis of Cavities

1. Introduction

The underground power station of Karcham - Wangtoo Hydroelectric Project is located on the right bank of river Satluj about 100m upstream of its junction with Bhaba Khad. The size of the Power House cavity is 143m long x 21m wide x 49m high, which will house 4 units of 250 MW each. A second cavern, 143m long x 15.5m wide x 25m high, will house the unit transformers and GIS switchgears and the third cavern, 88m long x 12.5m wide x 30.5m high has been provided for Downstream Surge Chamber. Second cavity is aligned parallel to the power house cavity at a distance of 21m in the downstream direction and the third cavity is aligned parallel to the Transformer Hall Cavity at a distance of 21.25m in the downstream direction. The layout of power house ,transformer hall and Downstream Surge Chamber Cavities and their approach adits are described in Chapter 14 of Volume I of the Project Report.

The Power House, Transformer Hall and Downstream Surge Chamber cavities will be located in gneiss with quartzite bands, with a rock cover of about 180m. The geology of power house area alongwith the design of supporting arrangement for power house and transformer hall cavities are discussed in Chapters 6 & 14 of Volume I of the Project Report.

FEM analysis of these cavities have been carried out by using software 'PHASES'. For the linear analysis, the finite element model is formulated as two dimensional, plane strain problem since all the cavities are long compared to their other two dimensions.

2. Objective

The finite element analysis is carried out for the determination of the state of stress around these cavities considering rock bolts participation with the following objectives :-

a) To determine the distribution and magnitude of critical stresses around the cavities.

b) To locate the tension zones around the cavities for the design of supports for roof arch and side walls of cavities.

c) To plot the major and minor principal stresses to understand the overall behaviour of the rock mass under given in-situ stress condition.

d) To plot contours of the safety factors around the cavities. The safety factor is calculated by dividing the rock strength by the included stress at every point in the mesh.

e) To check the deformation pattern around cavities by plotting displacement contours.

3. Assumptions

i) Only elastic analysis has been carried out, the load deformation relationship is assumed to be linear and the parameters viz. modulus of elasticity, shear modulus and Poisson's ratio remain constant.

ii) The effects of consolidation of the rocks due to pore water effects or creep which would cause visco-elastic deformations are not considered.

iii) In computer analysis only one stage of excavation is considered from the roof to the floor of both the caverns, although the excavation actually takes place in stages.

4. In-situ Stress and Material Properties of Rock

To determine the in-situ field stress at site, the hydro-fracturing tests at two locations inside the drift leading to Power House Cavity were carried out by National Institute of Rock Mechanics, Kolar. The results of hydro-fracturing test taken from final report on "THE IN-SITU STRESS MEASUREMENT BY HYDROFRACTURING METHOD" are reproduced below :

Site Location	Over-burden (m)	Vertical Stress σ_v (MPa)	Maximum Horizontal Stress σ_h (MPa)	Minimum Horizontal Stress ($\sigma_{h'}$) (MPa)	Ratio $k = \frac{\sigma_h}{\sigma_v}$	Direction of σ_h
Site I (RD 186)	269	7.56	3.79	1.89	0.501	N 5° E
Site II (RD 125)	269	7.56	3.56	1.78	0.470	N 10° E

Based on laboratory tests carried out at site following properties of rock have been considered for FEM analysis

a) density of overburden = 2.86 t/m^3 = 0.0286 MPa

b) poisson's ratio (μ) = 0.25

c) Uniaxial compressive strength of rock (σ_c) = 120 MPa

The modulus deformation of rock has been taken as 1,72,670 kg/cm^2 (17,267 MPa) which is based on the Plate Jacking Test carried out in the drift. However, any increase or decrease in the value of the modulus of deformation will not affect the stresses but deformations will change.

5. Idealisation of Structure

All the cavities are long compared to their other two dimensions. Hence, a two dimensional analysis of a body of rock with its plane perpendicular to the main axis of cavities is considered as representative of important stress and deformation pattern to be examined. For the above purpose finite element model was prepared.

MODEL

The rock immediately surrounding the excavation is modelled using 3-noded triangular elements which allow complex material behaviour to be analysed. The finite element discretization adopted is shown in Figure-1. The total number of finite elements is 1727 while number of boundary elements are 150.

The finite element mesh for MODEL has been generated keeping a fair balance between economy and accuracy. For this purpose, 3 noded triangular, 2D-solid iso-parametric elements are chosen for idealisation of MODEL. Care is taken to have small dimensions elements near the cavities of machine and transformers hall where stress concentration is expected. The rock-bolts have been provided on the side walls and roof of the cavities with following details:

Type of bolts	-	End anchored and grouted		
Diameter	-	25mm / 36mm / 50mm		
In-plane and out of plane spacing	-	1.5 m c/c		
Length of bolts	-	in roof	-	varies from 5m to 6m
	-	in side walls	-	varies from 9m to 11m
Capacity of one bolt	-	112kN / 253kN / 500kN		

6. **Computer Program and Analysis Philosophy**

The computer program, called "PHASES" used for the analysis is a standard two-dimensional finite-element/boundary element program for calculating stresses and estimating support around underground excavations. It uses the three-noded / six-noded triangular-plain strain element in two dimensions. It has been used for the analysis of several underground caverns and gave reasonable results.

The main feature of this software is that, it performs hybrid finite analysis in which the outer boundary of the finite element mesh becomes coupled to a geometrically coincident boundary element mesh. The purpose of this coupling is to model the infinite extents of typical geotechnical problems properly.

The computer analysis considers one stage of excavation from the roof to the floor of both the caverns, although program has a option of carrying out analysis in stages.

The in-situ stress, vertical (7.56 MPa) and average Horizontal (3.67 MPa) are applied as input loads to the finite element MODEL. The failure criterion is considered as per Hoek-Brown material to estimate strength factors etc. Hoek-Brown theory involves strength factors 'm' (rock mass frictional parameter) and 's' (rock mass inherent strength parameter). The values of 'm' and 's' are considered as '8.58' and '0.015' (corresponding to NGI rating of 10) respectively for metamorphic rocks consist of Quartzite/Quartz Mica Schist or Mica Quartz Schist.

The tensile strength of rock is calculated by the program using formula $\frac{s\sigma_c}{m}$ (= 0.21 MPa) where σ_c is the unconfined compressive strength of rock.

In Model, the parameters involved in bolt definition are type of bolt (end anchored or frictional), diameter of bolt, peak capacity, in-plane and out of plane spacing of bolts. The stiffness of the bolts are calculated by formula :-

$$k = \frac{\pi d^2 E}{4L}$$

where k - stiffness of bolt
d - dia of bolt
E - elastic modulus of bolt material
L - length of bolt

The 2-dimensional computer analysis for the finite element model has been carried out as a plane strain problem. The unit thickness of the rock mass is considered along the main axis of power house cavity.

The computer output gives major and minor principal stresses, safety factors and deflections at every point of the finite element mesh.

7. Results and Discussions

Stresses

The major and minor principal stresses obtained from FEM analysis of Model are graphically represented in Figs. 2 and 3 respectively. The major and minor principal stresses at critical points around the cavities are also given in Table-I.

Major Principal Stresses (Figure 2)

The maximum compressive stresses (13.36 to 14.9 MPa) are observed near the roof of the cavities, however, side walls are subjected to comparatively low compressive stresses ranging from 8.64 MPa to 9.75 MPa (Refer Fig. 2). The maximum compressive stress of 14.9 MPa is observed near the roof of the Power House cavity.

Minor Principal Stresses (Figure 3)

From fig. 3, it can be observed that small tension of the order of 0.071 MPa occurs near the bottom of left side wall of the Power House Cavity, however, no tension develops on the roof of the Power House and Transformer Hall cavities. The whole roof is under compression.

Since the tension developed near the bottom of the left side wall of the Power House Cavity is very low in magnitude and well below the tensile strength of rock (0.21 MPa), possibility of any extra support requirement is ruled out.

From Fig. 3 it can also be observed that as we go away from side walls of the Power House and the Transformer hall cavities the stresses becomes compressive in nature and keeps increasing in magnitude also. 20 to 30m away from cavities, the stresses becomes equal to the applied in-situ stresses (Refer Fig. 3).

Strength Factors (Figure 4)

The strength factors are lowest (ranging from 1 to 2) near the cavities of the Power House and the Transformer Hall. The strength factors keep on increasing as we move away from cavities. The zones of safety factors are shown in Fig. 4.

Displacements (Figure 5)

The maximum displacements are observed on side walls of the Power House Cavity, which is in the range of around 1.0cm. However, deflections on roof varies from 0.6cm to 0.9cm. The deflections around the Transformer Hall Cavity are less compared to Power House cavity.

Conclusions

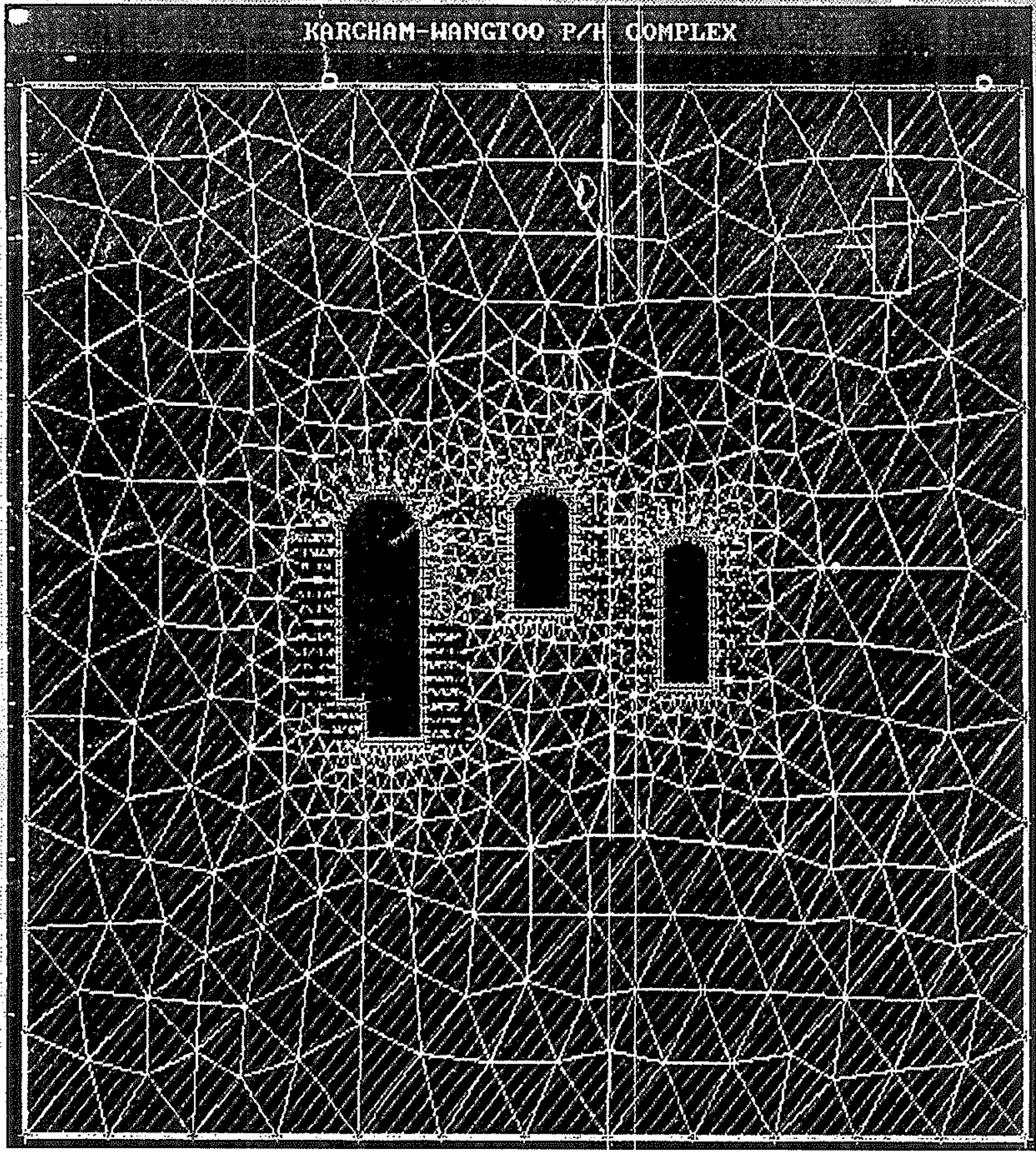
The maximum compressive stress (14.9 MPa) near the roof and maximum tensile stress (0.071 MPa) near the bottom of the left side wall of Power House cavity are well below the crushing strength of rock (120 MPa) and tensile strength of rock (0.21 MPa) respectively. The above results shows that the system itself is capable of sustaining the induced stresses around the cavities, which eliminates the requirement of providing any steel ribs or cast-in-situ cement concrete.

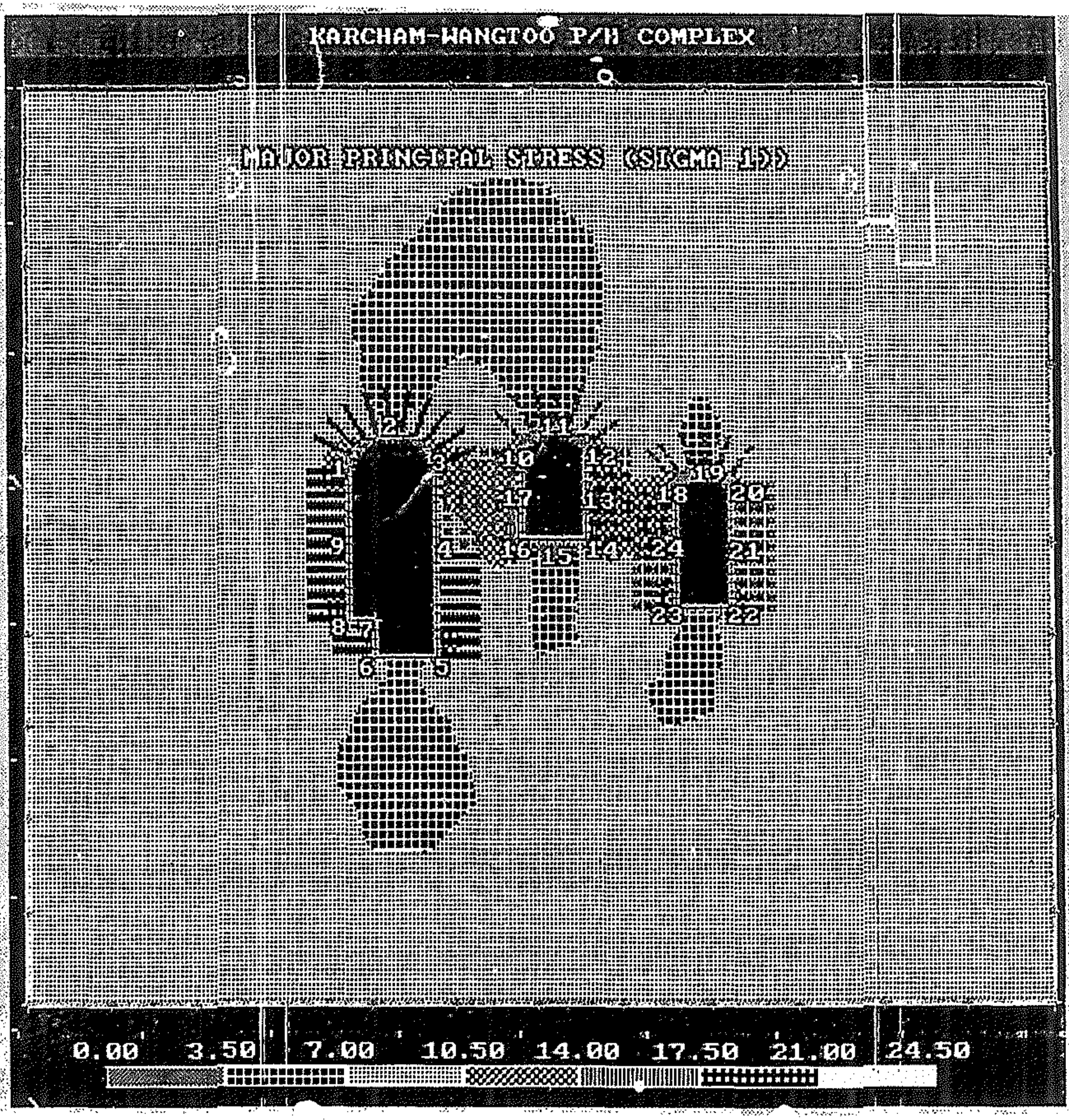
Table I

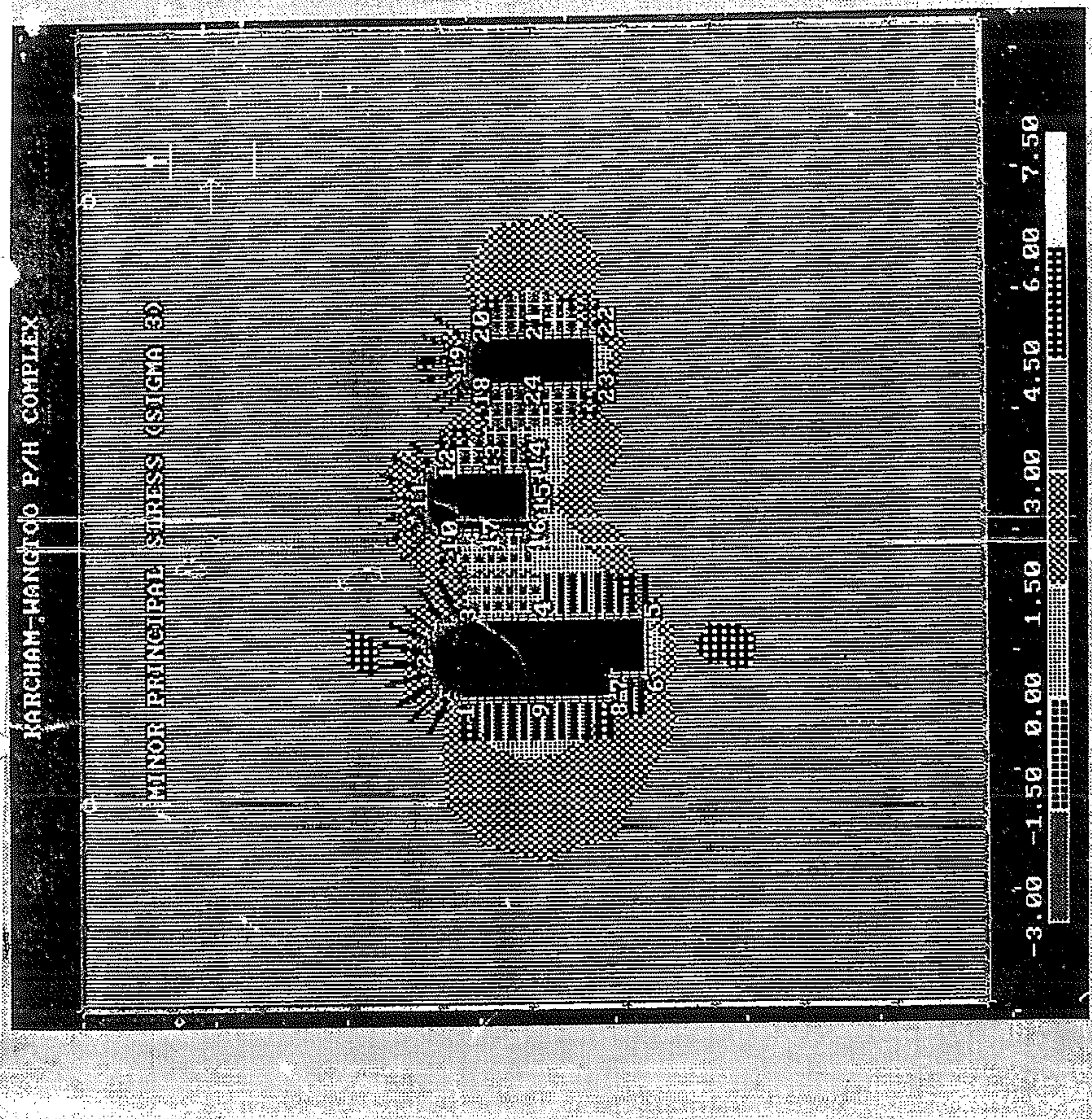
Major & Minor Principal Stresses, Strength Factors and Displacements at salient points of the cavities:

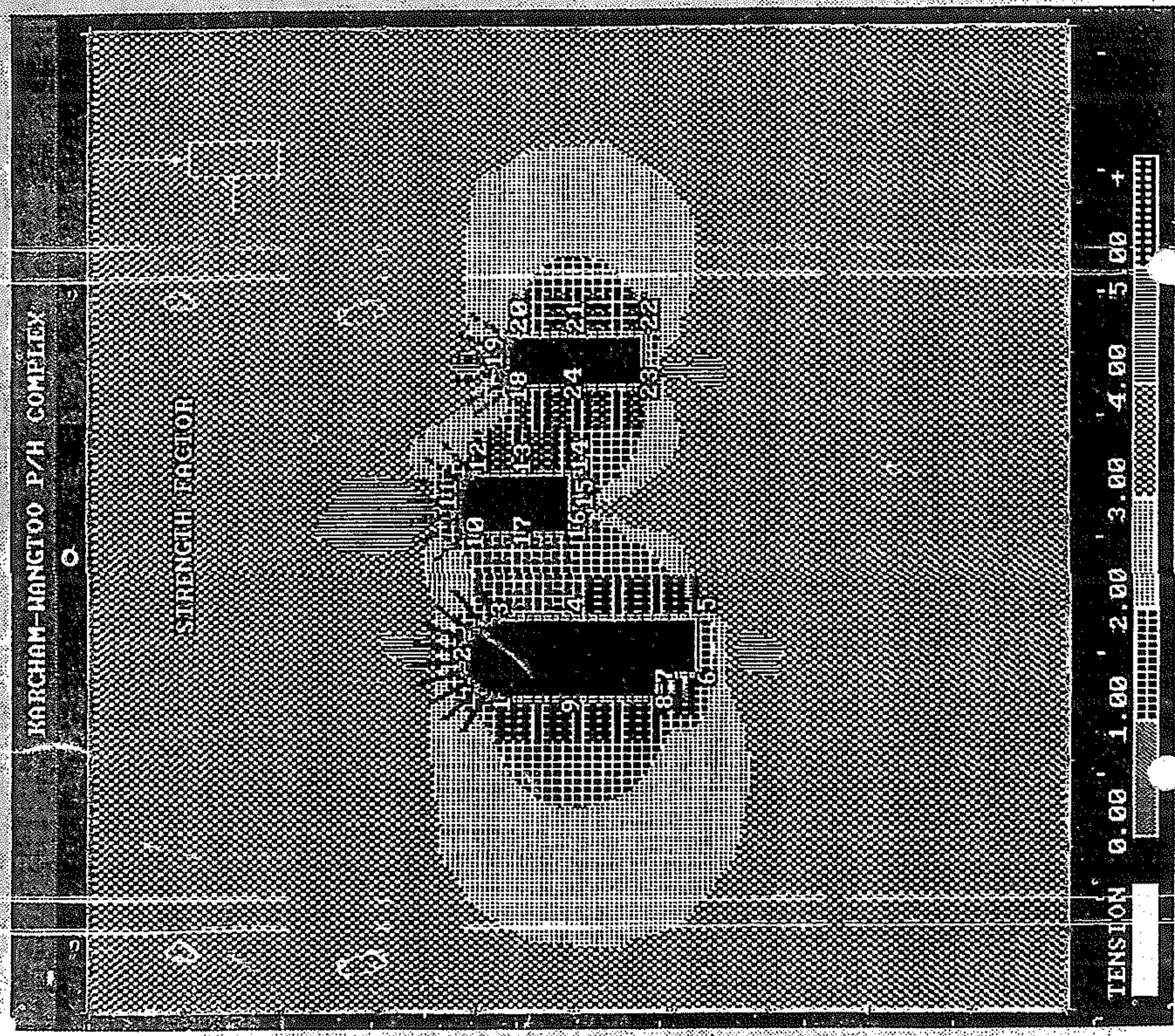
Salient Points	Major Principal Stress σ_1 (N/mm^2)	Minor Principal Stress σ_3 (N/mm^2)	Strength Factor	Max. Displacement (m)
1	14.120	1.258	1.227	0.006
2	7.022	1.015	1.372	0.008
3	14.900	1.297	1.183	0.006
4	8.638	0.047	1.046	0.007
5	11.392	5.026	2.425	0.005
6	10.120	2.695	1.843	0.007
7	1.132	-0.071	1.360	0.009
8	12.726	2.829	1.658	0.007
9	8.890	0.055	1.049	0.008
10	13.440	0.817	1.195	0.005
11	4.343	0.620	1.464	0.009
12	13.103	1.846	1.277	0.005
13	11.718	0.148	1.062	0.003
14	14.232	2.183	1.417	0.004
15	1.140	-1.271	-0.194	0.008
16	14.408	1.764	1.298	0.004
17	12.384	0.182	1.040	0.003
18	13.367	2.064	1.361	0.002
19	5.760	0.630	1.372	0.006
20	13.750	2.187	1.431	0.004
21	8.928	0.104	1.060	0.006
22	13.080	3.379	1.808	0.004
23	12.180	3.457	1.989	0.004
24	9.750	0.110	1.036	0.002

(-) = Tension
(+) = Compression


KARCHAM-WANGTOO P/H COMPLEX


KARCHAM-WANGTOO P/H COMPLEX
MAJOR PRINCIPAL STRESS (SIGMA 1)
0.00 3.50 7.00 10.50 14.00 17.50 21.00 24.50


KARCHAM-WANGTOO P/H COMPLEX
MINOR PRINCIPAL STRESS (SIGMA 3)
-3.00 -1.50 0.00 1.50 3.00 4.50 6.00 7.50


KARCHAM-WANGTOO P/H COMPLEX
STRENGTH FACTOR
TENSION
0.00
1.00
2.00
3.00
4.00
5.00
+

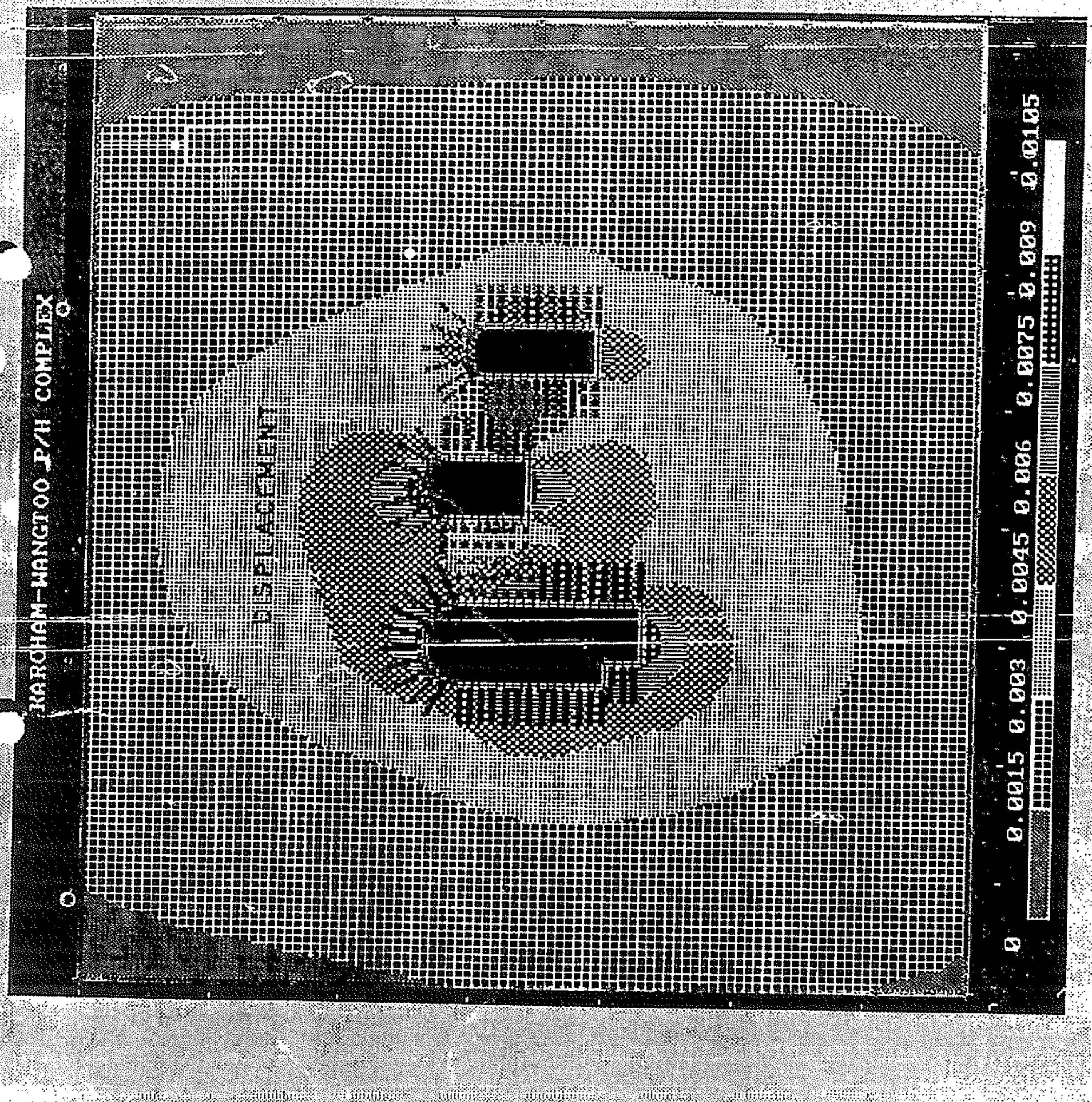
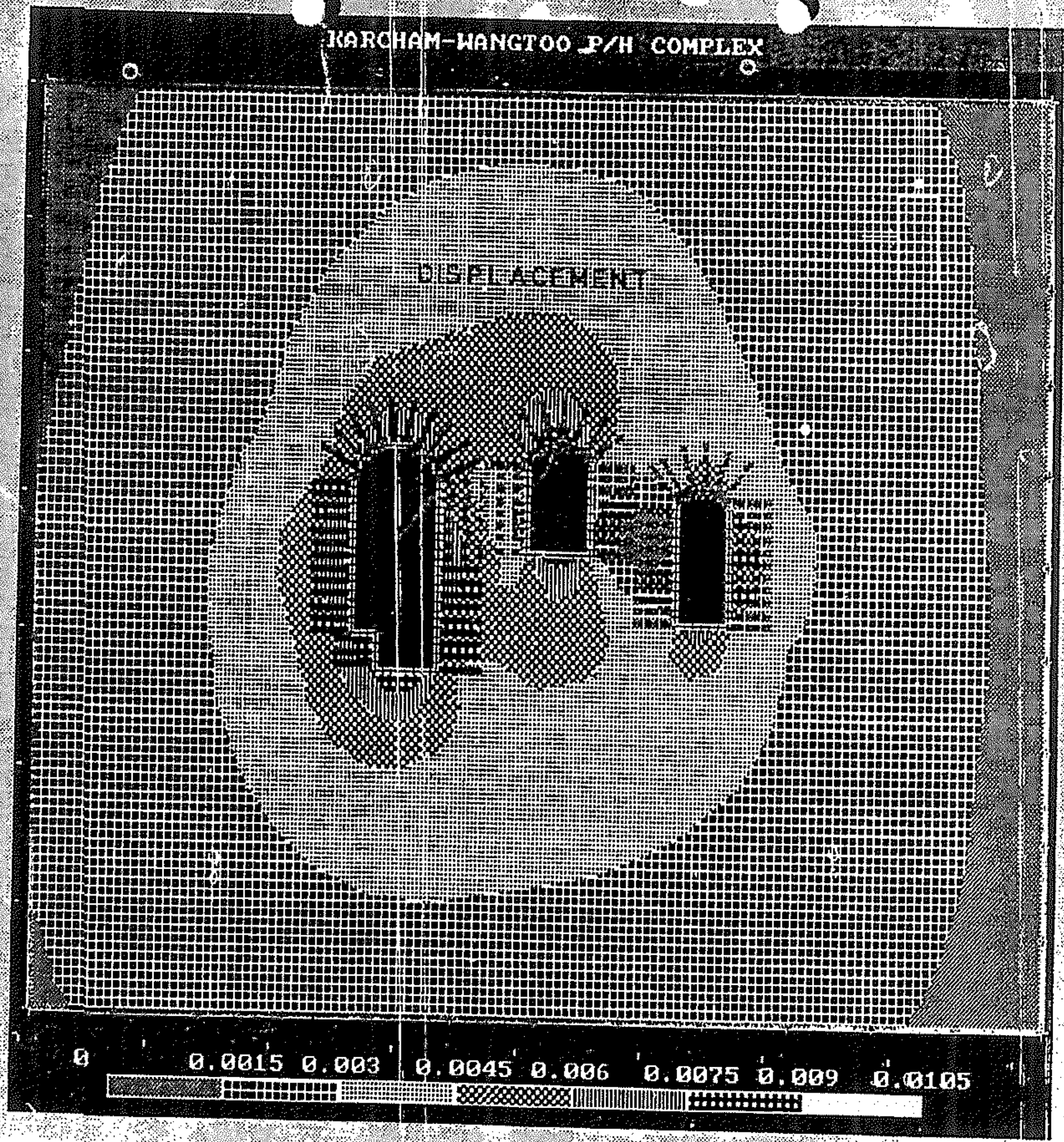

KARCHAM-WANGTOO P/H COMPLEX
DISPLACEMENT
0 0.0015 0.003 0.0045 0.006 0.0075 0.009 0.0105

FIGURE - 5

FIGURE-5


KARCHAM-WANGTOO P/H COMPLEX
DISPLACEMENT
0
0.0015
0.003
0.0045
0.006
0.0075
0.009
0.0105

6.2 **Roof and Wall Support System for P.H. Transformer Hall and D/S Surge Chamber Cavities:**

1. **Estimation of Rock Pressure**

a) **Terzaghi's Approach**

The rock mass in the power house cavity has been classified under the category 4 of Terzaghi's table i.e. moderately blocky and seamy rock. Hence the height of loosened mass can be taken equal to 0.25 B to 0.35 (B+H_t). The term H_t can be ignored as under no circumstances the height of unsupported cavity would be more than the width as the cavity will be excavated in stages. The estimated pressure thus works out between 1.23 kg/cm^2 to 1.73 kg/cm^2.

The support pressure criteria developed by Terzaghi were based on experiences in tunnels supported by steel ribs with wooden blocking. This criteria tends to be over-conservative in the better qualities of rock, if shotcreting and/or bolting is used as immediate support.

b) **Based on rock mass quality 'Q'**

i) Roof support pressure

An empirical equation relating permanent support pressure and rock mass quality has been given as below :-

$$P_{roof} = \frac{2 J_n^{\frac{1}{2}} Q^{-\frac{1}{3}}}{3 J_r}$$

Generally three joint sets are met which are rough and planner. These two inputs give the value of Jn = 9 and Jr = 1.5.

For Q=3, P_{roof} = 0.68 kg/cm^2
For Q=4, P_{roof} = 0.62 kg/cm^2
For Q=8, P_{roof} = 0.49 kg/cm^2

ii) Wall support pressure

It has been recommended that for intermediate Q values ($0.1 < Q < 10$) a value of 2.5Q can be used in the equation given above. The wall support pressure will be as below for various Q values:

For Q=3, P_{roof} = 0.92 kg/cm^2
For Q=4, P_{roof} = 0.83 kg/cm^2
For Q=8, P_{roof} = 0.66 kg/cm^2

2. Rock Support Interaction Analysis

a) Rock Support System :

Rock bolts and shotcrete will be provided mainly for following purposes:

a) To support maximum estimated roof support pressure

b) To support maximum estimated wall support pressure

c) To prevent failures of wedges which may be formed due to geological discontinuities.

b) Maximum support pressures for rock-bolts and shotcrete lining :

It is proposed to provide 100 mm thick shotcrete and 36 mm dia rock bolts/rock anchors on the roof arch and the side walls except in the poor rock zone as stated above. The specifications of shotcrete and rock bolts will be as below:

* Fibre reinforced shotcrete on roof of P/H and Transformer Hall Cavities

Thickness t_c = 10 cm

Allowable compressive stress σ_c = 25 MPa

* Fibre reinforced shotcrete on side walls of P/H and Transformer *Hall Cavities*

Thickness t_c = 12.5 cm

Allowable compressive stress σ_c = 25 MPa

* Fibre reinforced shotcrete on roof and walls of Downstream Surge Chamber

Thickness t_c = 10 cm

Allowable compressive stress σ_c = 25 MPa

Rock Bolts: Dia = 36mm for Power House and Transformer Hall

Type = Mechanically anchored and grouted rock bolts

Circumferential bolt spacing (S_c) = 1.5m

Longitudinal bolt spacing (S_l) = 1.5m

Yield stress of bars = 415 N/mm^2

Yield load of bolt = 422 kN = 42200 kg

Ultimate failure load (T_{bf}) = 25320 kg

Rock bolts: Dia = 25mm for Downstream Surge Chamber

Type = Mechanically anchored and grouted rock bolts

Circumferential bolt spacing (S_c) = 1.5m

Longitudinal bolt spacing (S_l) = 1.5m

Yield stress of bars = 415 N/mm^2

Yield load of bolt = 204 kN = 20400 kg

Ultimate failure load T_{bf} = 12240 kg

Maximum support pressure provided by shotcrete lining will be as below:

$$P_{scmax} = \frac{1}{2}\sigma_c \left[1 - \frac{(r_i - t_c)^2}{r_i^2}\right]$$

where r_i = radius of tunnel or cavity

While the maximum support pressure provided by grouted rock bolts / rock anchors will be as below :

$$P_{sbmax} = \frac{T_{bf}}{S_c\, S_l}$$

The total support pressures which can be taken up by the proposed support system are given in Table II.

TABLE II

Cavity of	Location	r_i (cm)	P_{scmax} (kg/cm^2)	P_{sbmax} (kg/cm^2)	P_{scmax} + P_{sbmax} = P_{total} (kg/cm^2)
Power House	Roof	1050	0.237	1.125	1.362
Power House	Walls	1050	0.296	1.125	1.421
Transformer Hall	Roof	775	0.32	1.125	1.445
Transformer Hall	Walls	775	0.4	1.125	1.525
D/S Surge Chamber	Roof and Walls	600	0.331	0.544	0.875

Since the total rock pressure supported by shotcrete lining and rock-bolts as tabulated above are more than the maximum estimated rock pressure of 0.66 kg/cm^2, it can be concluded that proposed supporting arrangement is sufficient in resisting deformations induced by the dead weight of loosened rock as well as those induced by a readjustment of stress field in the rock surrounding the excavation.

3. **Proposed Support System for the Roof and Side Walls of the Machine Hall and Transformer Hall Cavities**

a) **General**

The principal objective in the design of support system is to help the rock mass to support itself. The design of support system should therefore take into account the interactive nature of the load deformation characteristics of both rock mass and support system.

The support must be designed to resist deformations induced by the dead weight of the loosened rock as well as those induced by readjustment of stress field in the rock surrounding the excavation.

To achieve these objectives it is proposed to use rock bolts/anchors alongwith shotcrete .

Apart from being economical and time saving the main advantage of this system is its adaptability to any changed conditions encountered during the underground excavation.

b) **Roof Support System**

As described earlier use of rock mass classification has been used for estimating support requirements. The support system has also been provided to support potentially unstable wedges or blocks which are free to fall or slide under their own weight. Based on the rock loads estimated earlier, the following support system is proposed to be adopted.

Power House Cavity

Roof	Fibre reinforced shotcrete	10 cm
	Rock bolts (36mm dia) Grid spacing	1.5m c/c
	Length	5/6m
Side Walls	Fibre reinforced shotcrete	12.5 cm
	Rock bolts (36mm dia) Grid spacing	1.5m
	Length	9/11m

The rock bolts will be tensioned and grouted. The design load for each bolt will be 30.5 tonnes using reformed bars having yield strength of 500 N/mm^2 (Grade Fe-500 of IS-1786-1985)

One layer of shotcrete and rock bolts will be provided immediately after excavation. The roof profile of the central adit in the machine hall matches with the final profile of the roof arch. The widening of central adit on both the sides to complete the roof arch will only be taken up after providing one layer of shotcrete and rock bolts in the full length.

The second layer of shotcrete reinforced with steel fibres will be provided after excavation of complete roof arch.

Transformer Hall Cavity

Roof	Fibre reinforced shotcrete	10 cm
	Rock bolts (36mm dia) Grid spacing	1.5m c/c
	Length	5/6m
Side Walls	Fibre reinforced shotcrete	12.5 cm
	Rock bolts (36mm dia) Grid spacing	1.5m
	Length	6/7m

In reaches where the shear zone crosses this cavity extra rock bolts will be provided as required.

Downstream Surge Chamber

Roof	Fibre reinforced shotcrete	10 cm
	Rock bolts (25mm dia) Grid spacing	1.5m c/c
	Length	4/5m
Side Walls	Fibre reinforced shotcrete	10 cm
	Rock bolts (25mm dia) Grid spacing	1.5m
	Length	6/7m2

Chapter - B7

KARCHAM-WANGTOO HYDRO-ELECTRIC PROJECT
HEAD LOSS IN WATER CONDUCTOR SYSTEM

INLET:

Trash Rack Area	1117.360 m^2
Entry losses = $0.5\ v^2/2g$	0.031 m

INTAKE:

Velocity through Intake	0.888 m/sec
Losses at Intake and Losses due to Change in Shape = $0.2v^2/2g + 0.1\ v^2/2g$	0.012 m

INTAKE TUNNEL:

Area of Intake Tunnel	29.280 m^2
Length of Intake Tunnel	261.000 m
Perimeter of Intake Tunnel	19.280 m
Head Loss due to friction = $v^2n^2l/R^{4/3}$	0.501 m

SEDIMENTATION CHAMBER:

Length of Sedimentation Chamber	425.000 m
Area of Sedimentation Chamber	204.230 m^2
Perimeter of Sedimentation Chamber	59.600 m
Hydraulic Radius	3.427 m
Head Loss = $v^2n^2l/R^{4/3}$	0.006 m

LINK TUNNELS:

(a)	Length of Link Tunnels	74.920 m
	Area of Link Tunnels	33.180 m
	R = A/P	1.625 m
	Velocity	3.142 m/sec
	Head Loss = $v^2n^2l/R^{4/3}$	0.065 m

(b)	Length of Link Tunnels	113.910 m
	Area of Link Tunnels	50.265 m^2
	R = A/P	2.000 m
	Velocity	4.148 m/sec
	Head Loss = $v^2n^2l/R^{4/3}$	$\boxed{0.131\ m}$

HEAD RACE TUNNEL:

Length of HRT		17198.000 m
Area of HRT		86.26 m^2
R = A/P		2.62 m
Velocity		4.834 m/sec
Entry Losses = 0.1 $v^2/2g$		$\boxed{0.119\ m}$
Frictional Head Loss = $v^2n^2l/R^{4/3}$	$n = 0.013$ $R^{4/3} = 3.6118945$	$\boxed{18.804\ m}$
Bend Losses for 7 no. Bends = 7 x 0.0375 $v^2/2g$		$\boxed{0.312\ m}$

PRESSURE SHAFT:

Dia of Pressure Shafts	4.750 m
Velocity through Pressure Shafts	5.883 m/sec
Contraction Losses = $(v1^2-v2^2)/2g$	$\boxed{0.057\ m}$
Bend Losses for 2 no. Bends = 2 x 0.1 $v^2/2g$	$\boxed{0.353\ m}$
Frictional Head Loss = $v^2n^2l/R^{4/3}$	$\boxed{0.872\ m}$

TAIL RACE TUNNEL

Length of TRT	909m
Area of TRT	86.293
R = A/P	2.607
Velocity	4.832
Frictional Head Loss	$v^2n^2l/R^{4/3}$
	$\boxed{1.000m}$

Bend losses	$0.2 \times v^2/2g$
	$\boxed{0.238m}$
Entrance Losses at Downstream Surge Chamber and Losses due to entrance contraction and turbulence caused in downstream surge chamber cum collection gallery	$0.25 \times v^2/2g$
	$\boxed{0.298m}$
TOTAL HEAD LOSS	**22.799m**
Say	**22.8m**

Maximum Pond Level	1810m
Minimum Pond Level	1799m
Weighted Average Pond Level	1806.73
Normal Tail Water Level	1508m
Gross Head	298.73m
Head Loss	22.8m
Net Head	275.93m

ABSTRACT OF COSTS
PART I - CIVIL WORKS

Sl. No.	Description	Amount (in Lacs) (At Dec. 99 Price level)	Annexure No.
I	DIRECT CHARGES: I-Works		
1.	A - Preliminary	1,539.00	C-2.1 (R)
2.	B - Land	1,483.51	C-2.2 (R)
3.	C - Works		
3.1	River Diversion Works		C-2.3 (R)
	- Diversion Tunnel	3,575.34	
	- Coffer Dams	2,805.67	
3.2	Diversion Dam	31,935.53	C-2.4 (R)
4.	J - Power plant civil works		
4.1	Intake, Sedimentation Chambers and Flushing Conduits	38,696.22	C-2.5 (R)
4.2	Head Race Tunnel and Construction Adits	82,975.51	C-2.6 (R)
4.3	Surge Shaft	7,085.13	C-2.7 (R)
4.4	Pressure Shafts and Penstocks	6,088.41	C-2.8 (R)
4.5	Power House Complex	15,325.41	C-2.9 (R)
4.6	Downstream Surge Chamber, Tail Race and Outfall Works	9,531.16	C-2.10 (R)
4.7	Pothead Yard	170.02	C-2.11 (R)
5.	K - Buildings	5,309.75	C-2.12 (R)
6.	M - Plantation	198.00	C-2.13
7.	O - Miscellaneous	7,379.20	C-2.14 (R)
8.	P - Maintenance	2,143.60	C-2.15 (R)
9.	Q - Spl. T & P (vehicles)	521.00	C-2.16
10.	R - Communications	8,718.72	C-2.17 (R)
11.	X - Environment & Ecology	3,438.83	C-2.18 (R)
12.	Losses on Stock @ 0.25% [(I Works) - (A Preliminary + B Land + O Misc. M plantation + Q Spl T& P + X Environment & & Ecology + P-Maintenance)]	531.90	C-2.19 (R)
	Total of I-Works	229,451.92	

Sl. No.	Description	Amount (Rs. Lacs)	Annexure No.
13.	Establishment including design wing and cost control cell @ 11% of I-Works less B-Land	25,076.52	
14.	T&P (@ 1% of I-Works)	2,294.52	
15.	Receipts and recoveries on capital account	(686.64)	C-2.20 (R)
	Total of Direct Charges	**256,136.33**	
II	INDIRECT CHARGES		
16.	Capitalised value of abatement of land revenue (@ 5% of cost of culturable land)	1.14	
17.	Audit and accounts (@ 1% of I-Works)	2,294.52	
	Total of Indirect Charges	**2,295.66**	
	Total of Direct and Indirect Charges	**258,431.99**	
	Say Rs.	**2,584.00**	**Crores**

ABSTRACT OF COSTS

PART II - Generating Plant and Equipment

(P - PRODUCTION)

Sl. No.	DESCRIPTION	Amount (Rs.in.Lacs)	Annexure No.
1.	**Design, Consultancy Charges**	1,000.00	
2.	**Generating Plant Equipment (Imported):**		
	(a) Generating plant and accessories	50,895.00	C-3.-R1
	(i) Custom Duty @22.38%	11,390.30	
	(ii) Clearing and forwarding charges @ 1%	508.95	
	Sub total [A] item 2	**62,794.25**	
3	(a)Electrical Auxiliary Equipment for Power Station	2,054.00	C-3.2-R1
	(b)Mechanical Auxiliary Equipment for Power Station.	1,818.00	C-3.3-R1
	(c) Excise Duty @16% on3(a) & 3(b)	619.52	
	(d) Central S.T. @ 4% on 3(a), (b) & ©	179.66	
	Sub total [B] item3	**4,671.18**	
4	(a) Inland Transportation @ 5% on 2(a) , 3(a) + 3(b)	2,738.35	
	(b) Insurance charges @ 1% on 2(a) , 3(a) + 3(b)	547.67	
	(c) Erection & Commissioning charges @ 10% on 2(a) , 3(a) + 3(b)	5,476.70	
	Sub - Total [C] Item 4	**8,762.72**	
	Sub - Total [D] Item 2,3 &4	**76,228.15**	
5	**Sub-station Equipment:**		
	A - Indigeneous		
	(i) Gen-Transformers, LAs, PLCC & Allied Eqpt.	2,829.00	C-3.4-R1
	(ii) Excise duty @16% on 5(A)(i)	452.64	
	(iii) CST @ 4% on item 5A(i) & (ii)	131.27	
	(iv) Inland Transportation @ 5% on 5A (i)	141.45	
	(v) Insurance @ 1% on 5A (i)	28.29	
	(iv) Erection & Commissioning charges @ 10% on 5A (i)	282.90	
	Sub - Total [E] Item 5 A	**3,865.55**	
	B - Imported		
	(i) 400 kV SF6 Switchgear, SF6 Busducts & Accessories	16,530.00	C-3.4-R1
	(ii) Custom Duty @22.38%	3,699.41	
	(iii)Clearing forwarding charges @ 1%	165.30	
	(iv) Inland Transportation @ 2% on 5B (i)	330.60	
	(v) Insurance charges @ 1% on 5B(i)	165.30	
	(vi) Erection & Commissioning @ 5% on 5B (i)	826.50	
	Sub - Total [F] Item 5 B	21,717.11	
	Sub-Total [G] item5A & 5B	25,582.66	

Annexure C-1.2 (R)

Sl. No.	DESCRIPTION	Amount (Rs.in.Lacs)	Annexure No.
6	**Plant Handling Equipment**		
	(i) Plant handling equipment	665.00	C-3.5-R1
	(ii) Excise duty @16% on 6(i)	106.40	
	(iii) CST @ 4% on item 6(I) & (ii)	30.86	
	(iv) Insurance @ 1% on 6 (i)	6.65	
	Sub - Total [H] Item 6	**808.91**	
	Sub - Total [I] Item [D]+[G] +[H]	**102,619.72**	
7	**Other Items**		
	(i) Losses on stock @ 0.25% of Sub Total [I]	256.55	
	(ii) Maintenance during construction @ 1% of Sub Total [I]	1,026.20	
	(iii) Third party inspection of equipment charges @ 1% of Sub-Total [I] excluding erection & commissioning (i.e. 102619.72-5476.7-282.9-826.5= 96033.62)	960.34	
	(iv) Contingencies for unforseen items @ 3% of Sub Total [I]	3,078.59	
	(v) T & P charges @ 1% of Sub Total [I]	1,026.20	
	Sub-Total Item 7	**6,347.87**	
	Sub- Total [J] of Items 1,2,3,4, 5,6 & 7	**109,967.59**	
	(vi) Establishment @ 8.0% of [J]	8,797.41	
	Total Direct Charges [J] + (vi)	118,765.00	
6.	Audit & Accounts charges @ 1% of Total Direct Charges	1,187.65	
	GRAND TOTAL	**119,952.65**	

Foreign Component: **155. MUSD** **6,742.50**

(@ 1 USD = 43.50 Rs.)

Rupee Component: **5253 MINR** **5,252.76**

TOTAL COST in MILLION INR	**11,995.26**

TOTAL COST OF E&M WORKS **155. MUSD + 5253 MINR** **I.e. Rs. Crores** **1,200.00**

A - Preliminary

Sl. No.	Item of Work	Qty	Unit	Rate (in Rs.)	Amount (in Lacs) (At Dec. 99 Price level)
1.	Control survey by Survey of India		LS	.	30.00
2.	Purchase of maps from Survey of India and satellite imaginaries from NRSA.		LS		3.00
3.	Detailed topographical surveys for Dam and reservoir area, Intake and sedimentation chamber area, along tunnel alignment including intermediate adits, P.H. area and outlet area.	30	Sq.km.	250,000	75.00
4.	Surveys for quarry sites and borrow areas.	3	Sq.km.	200,000	6.00
5.	Collection of Hydro-meteorological ~~data including~~ automatic gauge recorders and self-recording rain gauges / snow gauges	--	LS		40.00
6.	Collection of silt data and carrying out tests on sediment and water and setting silt laboratory at dam site		LS		40.00
7.	Purchase of equipment for hydrological, meteorological and silt observations		LS		25.00
8.	Seismological observations and collection of data for seismic designs		LS		25.00
9.	Environmental and ecological surveys		LS		75.00
10.	Geological investigations				
	(a) Surface geological surveys		LS		50.00
	(b) Drilling Dam site 1000m Intake and sedimentation chamber area 500m (i) Tunnel alignment 1000m (ii) P.H. Complex 500m (iii) Outlet works 500m	3500	m	4,000	140.00
	(c) Drifting (i) Dam and Intake area 250m (ii) P.H. Complex 500m	750	m	12.000	90.00
	TOTAL (C/O)				599.00

Sl. No.	Item of Work	Qty	Unit	Rate (in Rs.)	Amount (in Lacs) (At Dec. 99 Price level)
11.	Geophysical Surveys				
	(a) Dam site		LS		5.00
	(ii) Along tunnel alignment		LS		25.00
12.	Construction material surveys including setting a concrete/soil laboratory at site		LS		30.00
13.	Hydraulic model studies				
	(a) Spilling and energy dissipation works		LS		30.00
	(b) Intake, sedimentation chamber and flushing conduits		LS		20.00
	(c) Surge shaft orifice slab		LS		20.00
	(d) Outlet works		LS		20.00
14.	Insitu tests on rocks				
	(a) Tests for determination of modulus of deformation at various locations		LS		30.00
	(b) Tests for determination of insitu stresses at various underground locations		LS		30.00
	(c) Block shear tests at Dam site		LS		10.00
15.	Laboratory tests on rock, soil and construction materials		LS		30.00
16.	Surveying, drawing and mathematical instruments (including distomat and 1 sec theodolites		LS		60.00
17.	Equipment and vehicles for field investigations		LS		60.00
18.	Consultant fees for services to be rendered by G.S.I.		LS		60.00
19.	Training of engineers		LS		60.00
20.	Preparation and printing of reports and bulletins		LS		50.00
21.	Consultants fees for preparation of project report and other reports		LS		400.00
	TOTAL				**940.00**
	GRAND TOTAL				**1,539.00**

B - Land

Sl. No.	Item of Work	Qty	Unit	Rate (in Rs.)	Amount (in Lacs) (At Dec. 99 Price level)
1.	Compensation for land for permanent works				
a)	Govt./Forest Land (7 years)				
	(i) Reservoir submergence	57.08	Ha	121,982	69.63
	(ii) Realignment of NH22	10.00	Ha	43,967	4.40
	(iii) Realignment of HPPWD roads	4.88	Ha	205,506	10.02
	(iv) Approach road to BASPA power house	1.88	Ha	204,960	3.85
	(v) Road to surge shaft	6.05	Ha	994,595	60.17
	(vi) Surge shaft area	1.00	Ha	315,000	3.15
	(vii) Permanent camp at Sholtu	9.60	Ha	251,090	24.10
	(viii) Power house area	2.66	Ha	315,595	8.39
	(ix) TRT Outfall structure	1.04	Ha	316,190	3.29
	(x) Portal of adit to sedimentation chamber	0.46	Ha	18,739	0.09
	(xi) Outfall structure of flushing conduits	0.95	Ha	18,900	0.18
		95.60			187.27
	(b) Private Land				
	(i) Reservoir submergence	0.57	Ha	2,348,265	13.39
	(ii) Permanent camp at Sholtu	0.92	Ha	315,100	2.90
	(iii) For dumping area	2.30	Ha	283,620	6.52
		3.79			22.81
2.	Lease rent of land for temporary works (for 7 years period)				
	(i) Adit to middle of sedimentation chamber	0.75	Ha	18,900	0.14
	(ii) Inlet adit to HRT	0.52	Ha	18,824	0.10
	(iii) Intermediate adit to HRT No.1	0.28	Ha	18,630	0.05
	(iv) Intermediate adit to HRT No.2	0.35	Ha	46,589	0.16
	(v) Intermediate adit to HRT No.3	0.54	Ha	47,031	0.25
	(vi) Intermediate adit to HRT No.4	1.80	Ha	315,000	5.67
	(vii) Intermediate adit to HRT No.5	0.33	Ha	315,000	1.04
	(viii) Aggregate processing plant at Jangi	0.50	Ha	82,152	0.41
	(ix) Aggregate processing plant at Tapri	1.94	Ha	315,000	6.11
	(x) Quarry site at jangi	3.99	Ha	82,111	3.28
	(xi) Quarry site at Morang	2.36	Ha	82,316	1.94
	(xii) Quarry site at Wangtoo	2.38	Ha	315,000	7.50
	(xiii) Quarry site at Choling	6.10	Ha	18,908	1.15
	(xiv) Surge shaft camp area	3.73	Ha	2,997,887	111.82
	(xv) Dumping area (Govt.Land)	38.84	Ha	594,650	230.96
		64.41			370.59
3.	Compensation for trees (details as per Annexure C-2.2.1)				153.67
4.	Compensation for Buildings				
	(a) Government Buildings (details as per Annexure C-2.2.2)				400.06
	(b) Private Buildings (details as per Annexure C-2.2.3)				209.76
					609.82
5.	Demarcation charges @ 1% of items 1&2				5.81
6.	Interest charges on the amount of award for the period between taking over possession of land and date of award @ 12% p.a for 2 years on 25% of total compensation				36.59
7.	Legal Charges (@ 1% of total compensation)				6.10
8.	Land acquisition charges @ 6.25% of items 1 to 4				84.01
9.	Solatium charges @ 30% of items 1 (b)				6.84
	TOTAL				1,483.51

Compensation for Trees

Sl.No.	Name of Tree	No. of Trees	Amount (in Lacs) (At Dec. 99 Price level)
1.	Deodar	139	5,272,691.00
2.	Neoza	274	2,813,596.00
3.	Bray	147	244,885.00
4.	Ash	213	1,310,075.00
5.	Bemi	6	684.00
6.	Kunesh	6	2,502.00
7.	Vee	128	82,426.00
8.	Robinia	401	41,499.00
9.	Alunthus	95	4,639.00
10.	Dreak	6	2,148.00
11.	Popular	23	4,208.00
12.	Cheel	81	70,797.00
13.	Eucalyptus	41	135,709.00
14.	Africot	6	7,844.00
15.	Khanor	22	41,346.00
16.	Chulli	81	41,870.00
17.	Fedo	25	4,825.00
	TOTAL	1694	10,081,744.00
	SALES TAX @ 30%		3,024,523.20
			13,106,267.20
	ADD INCOME TAX @ 15%		1,965,940.08
			15,072,207.28
	15% SURCHARGE ON INCOME TAX		294,891.01
	TOTAL		15,367,098.29

NOTE: Rates are applicable in H.P.Forest department from the period from April 1999 to March 2000

Compensation for Government Buildings

Sl. No.	Name of Government Building	Plinth Area in sqm	Rate (in Rs.)	Amount (in Rs.) (At Dec. 99 Price level)
1	HPPWD -Residential Building	2045.86	4200.00	8,592,612.00
2	HPPWD-Non-Residential Building	814.49	3800.00	3,095,062.00
3	Animal Husbandry-Residential Building	886.78	4200.00	3,724,476.00
4	ITBP-Residential Building	1036.80	4200.00	4,354,560.00
5	HPSEB-Non Residential Building	156.80	3800.00	595,840.00
6	Police Deptt. Non-Residential Building	187.70	3800.00	713,260.00
7	Temporary Shed(PWD)	78.93	2314.00	182,644.02
8	Temporary Shed(ITBP)	68.94	2314.00	159,527.16
9	Forest Deptt.-Residential Building	557.17	4200.00	2,340,114.00
10	Revenue Deptt.-Residential Building	207.25	4200.00	870,450.00
11	Horticulture Deptt.-Residential Building	109.25	4200.00	458,850.00
12	Police Deptt.-Non Residential Building	35.00	3800.00	133,000.00
	Total	**6184.97**		**25,220,395.18**
	Add. 12.5% for Internal Electrical Installation			**3,152,549.40**
	Add. 12.5% for water suppy, & Sanitary fittings			**3,152,549.40**
	Add. 10% for External services and site development			**2,522,039.52**
	Total			**34,047,533.49**
	Add. 17.5% deptt. Charges for construction of new buildings			**5,958,318.36**
	Grand Total			**40,005,851.85**

Note:

Based on H.P.P.W.D. Rates as applicable from July,98.
No revision thereafter.

Compensation for Private Buildings

Sl. No.	Name of Private Building	Plinth Area in Sqm	Rate per Sqm	Amount (in Rs.) (At Dec. 99 Price level)
1	Residential Building	2488.59	4200.00	10,452,078.00
2	Non-Residential Building	1197.74	2314.00	2,771,570.36
	Total	**3686.33**		**13,223,648.36**
	Add. 12.5% for Internal Electrical Installation			**1,652,956.05**
	Add. 12.5% for water suppy, & Sanitary fittings			**1,652,956.05**
	Add. 10% for External services and site development			**1,322,364.84**
	Total			**17,851,925.29**
	Add. 17.5% deptt. Charges for construction of new buildings			**3,124,086.93**
	Grand Total			**20,976,012.21**

Note:

Based on H.P.P.W.D. Rates as applicable from July,98.
No revision thereafter.

RIVER DIVERSION WORKS

Sl. No.	Item of Work	Qty.	Unit	Rate (in Rs.)	Amount (in Lacs) (At Dec. 99 Price level)
(A)	**Diversion Tunnel**				
1.	Open excavation				
	a) In soil	96,000	cum	103.00	98.88
	b) In rock	3,600	cum	370.00	13.32
2.	Underground excavation				
	a) Upto payline	49,040	cum	1,682.00	824.85
	b) Beyond payline	1,960	cum	1,121.00	21.97
	Total	51,000	cum		
3.	Untensioned rock bolts/anchors (25mm dia) including drilling and grouting	780	m	614.00	4.79
4.	Tensioned rock bolts/anchors (25mm dia) including drilling and grouting	4,725	m	674.00	31.85
5.	Drilling 45mm dia holes for grouting (contact and consolidation)	6,050	m	403.00	24.38
6.	Grouting (contact and consolidation)	605	tonne	13,117.00	79.36
7.	Shotcreting	120	cum	11,396.00	13.68
8.	Mesh reinforced in shotcrete	2,950	kg	71.00	2.09
9.	Shotcreting with steel fibers	850	cum	17,876.00	151.95
10.	Steel rib supports	150	tonne	40,260.00	60.39
11.	Drainage holes 75mm dia	4,580	m	409.00	18.73
12.	Concrete including cost of cement				
	a) Portals, inlet and outlet structures	11,425	cum	3,844.00	439.18
	b) Tunnel lining	10,430	cum	4,422.00	461.21
	c) Plug	1,177	cum	3,844.00	45.24
13.	Steel liners	475	tonne	104,100.00	494.48
14.	Instrumentation		LS	600,000	6.00
15.	Gabions/stone pitching	6.200	cum	653.00	40.49
16.	Diversion tunnel gates and hoists				
	a) Embedded parts (2 sets)	2	Set	3,218,000.00	64.36
	b) Gates (2 nos.)	2	no.	9,950,000.00	199.00
	c) Hoists (2 nos.)	2	no.	5,850,000.00	117.00
	d) Hoist bridge and trestles (2 sets)	2	set	3,282,000.00	65.64
17.	Steel reinforcement (Fe-415)	500	tonne	24,940.00	124.70
18.	PVC seals	150	m	772.00	1.16
19.	Metal seals	150	m	456.00	0.68
20.	Contingencies and work charged staff @ 5% except on L.S. items	5	percent		169.97
	TOTAL				**3,575.34**

contd.

Sl. No.	Item of Work	Qty.	Unit	Rate (in Rs.)	Amount (in Lacs) (At Dec. 99 Price level)
(B)	Coffer Dams				
1.	Open excavation in soil	7,500	cum	103.00	7.73
2.	Concrete cut-off	10,200	sqm	18,590.00	1,896.18
3.	Impervious core	13,590	cum	439.00	59.66
4.	Graded filter	9,450	cum	880.00	83.16
5.	Rock fill	52,500	cum	313.00	164.33
6.	Dewatering during construction	64,500	kWh	6.00	3.87
7.	Construction of temporary coffer dam for diverting river into tunnel		LS		120.00
8.	Repair/reconstruction of upstream and downstream coffer dams after monsoons (3 times)		LS		360.00
9.	Contingencies and work charged staff @ 5% except on L.S. items	5	percent		110.75
	TOTAL				2,805.67

Annexure C-2.4 (R)

DIVERSION DAM

Sl. No.	Item of Work	Qty.	Unit	Rate (in Rs.)	Amount (in Lacs) (At Dec. 99 Price level)
1.	Open excavation				
	a) In gravel and boulders	1,148,000	cum	103.00	1,182.44
	b) In rock	287,000	cum	370.00	1,061.90
	c) In foundation faults and seams	500	cum	500.00	2.50
2.	Compacted backfill below Apron	250,000	cum	313.00	782.50
3.	U/G excavation in galleries in abutments	875	cum	2,112.00	18.48
4.	Untensioned and grouted rock bolts/anchors (25mm dia) including drilling	45,000	m	483.00	217.35
5.	Shotcrete including cost of cement	6,000	cum	11,396.00	683.76
6.	Mesh reinforcement in shotcrete	110,000	kg	71.00	78.10
7.	Concrete				
	a) M15	345,000	cum	3,474.00	11,985.30
	b) M20	85,000	cum	4,332.00	3,682.20
	c) M25	14,000	cum	4,640.00	649.60
8.	Steel reinforcement, Grade Fe-415	4,505	tonne	24,940.00	1,123.55
9.	Drilling for consolidation/curtain grouting	20,400	m	403.00	82.21
10.	Consolidation and curtain grouting including cement	2,050	tonne	13,117.00	268.90
11.	Drilling for Drainage holes	8,370	m	409.00	34.23
12.	Metal pipes and fittings for grout and drainage holes	23,000	kg	48.00	11.04
13.	PVC water stops at contraction joints	1,225	m	772.00	9.46
14.	Copper water stops at contraction joints	940	m	1,230.00	11.56
15.	Asphalt seals at joints	940	m	228.00	2.14
16.	Formed Drains, 200 mm Dia	920	m	72.00	0.66
17.	Misc. metal work in trench covers etc.	20,000	kg	53.00	10.60
18.	Instrumentation for dam		LS	13,000,000.00	130.00
19.	Stairs, ramp etc. in body of dam		LS	3,000,000.00	30.00

contd.

Sl. No.	Item of Work	Qty.	Unit	Rate (in Rs.)	Amount (in Lacs) (At Dec. 99 Price level)
20.	Elevator tower including control room over staircase shaft		LS	2,500,000.00	25.00
21.	Room for emergency D.G. sets		LS	1,250,000.00	12.50
22.	Bridge over spillway	22	m	57,030.00	12.55
23.	Railing at top of dam	356	m	3,000.00	10.68
24.	Lamp posts	38	no.	10,000.00	3.80
25.	Stilling well including equipment for water level measurement	1	no.	2,000,000.00	20.00
26.	Security and Watch & Ward room including control gates		LS	1,500,000.00	15.00
27.	Architectural treatment		LS	1,500,000.00	15.00
28.	Steel liners in the sluices	930	tonne	104,100.00	96[illegible]3
29.	Passenger-cum-freight elevator 1120kg capacity	1	no.	1,500,000.00	15.00
30.	Dewatering	1,000,000	kWh	6.00	60.00
31.	Sluice spillway radial gates and hoists				
	a) Anchorages and embedded parts (6 sets)	6	set	26,910,000.00	1,614.60
	b) Radial gates (6 nos.)	6	no.	29,250,000.00	1,755.00
	c) Radial gate hoists	6	set	42,900,000.00	2,574.00
32.	Auxiliary spillway gates and hoists				
	a) Anchorages and embedded parts (2 sets)	1	set	4,680,000.00	46.80
	b) Radial gates (2 nos.)	1	no.	5,688,000.00	56.88
	c) Radial gate hoists	1	set	12,480,000.00	124.80
33.	Remote control equipment for sluice spillway and auxiliary spillway gates	1	set	19,500,000.00	195.00
34.	Sluice spillway stoplogs				
	a) Embedded parts (6 sets)	6	set	3,575,000.00	214.50
	b) Stoplog units (1 set)	1	no.	23,237,500.00	2[illegible]8
35.	Auxiliary spillway stoplogs				
	a) Embedded parts (2 sets)	1	set	2,145,000.00	21.45
	b) Stoplog units (1 no.)	1	no.	4,290,000.00	42.90
36.	Spillway gantry crane				
	a) Rail and fittings	1	set	2,243,000.00	22.43
	b) Crane	1	no.	28,437,500.00	284.38
	c) Lifting beam	1	no.	2,437,500.00	24.38
37.	Contingencies and work charged staff @ 5% except on L.S. items	5	percent		1,509.91
	TOTAL				**31,935.53**

INTAKE, SEDIMENTATION CHAMBERS AND FLUSHING CONDUITS

Sl. No.	Item of Work	Qty.	Unit	Rate (in Rs.)	Amount (in Lacs) (At Dec. 99 Price level)
1.	Open excavation				
	a) In soil	500	cum	103.00	0.52
	b) In rock	30,000	cum	370.00	111.00
2.	Underground excavation				
	a) Upto payline	1,153,850	cum	1,682.00	19,407.76
	b) Beyond payline	46,150	cum	1,121.00	517.34
	Total	1,200,000	cum		
3.	Tensioned and grouted rock bolts/anchors (25 mm. Dia) including drilling	110,000	m	674.00	741.40
4.	Shotcrete including cost of cement	600	cum	11,396.00	68.38
5.	Mesh reinforcement in shotcrete	30,360	kg	71.00	21.56
6.	Shotcrete reinforced with steel fibers	1,300	cum	17,876.00	232.39
7.	Steel rib supports	1,340	tonne	40,260.00	539.48
8.	Concrete reinforcement				
	a) Grade Fe-415	3,330	tonne	24,940.00	830.50
	b) Grade Fe - 500	3,330	tonne	27,434.00	913.55
9.	Concrete in surface works				
	a) M20	16,500	cum	4,332.00	714.78
	b) M25	500	cum	4,640.00	23.20
10.	Concrete in underground works				
	a) M20	75,000	cum	4,332.00	3,249.00
	b) M25	76,000	cum	4,640.00	3,526.40
11.	Drainage holes 75m dia	3,000	m	409.00	12.27
12.	Drilling for grouting (contact and consolidation)	67,000	m	403.00	270.01
13.	Grouting (contact and consolidation)	6,700	tonne	13,117.00	878.84
14.	Stone Masonry	6,500	cum	2,422.00	157.43
15.	Steel liners in flushing conduits	2,000	tonne	104,100.00	2,082.00

contd.

Sl. No.	Item of Work	Qty.	Unit	Rate (in Rs.)	Amount (in Lacs) (At Dec. 99 Price level)
16.	Intake trashracks				
	a) Embedded parts	4	set	3,656,000.00	146.24
	b) Trash rack units	32	no.	533,000.00	170.56
17.	Intake gates				
	a) Embedded parts (4 sets)	4	set	1,287,000.00	51.48
	b) Gates (4 nos.)	4	no.	4,648,000.00	185.92
	c) Intake gates hoists (4 nos.)	4	no.	9,750,000.00	390.00
18.	Intake stoplogs				
	a) Embedded parts (4 sets)	4	set	1,287,000.00	51.48
	b) Stoplog units (1 set)	1	no.	5,720,000.00	57.20
19.	Intake trash cleaning machine				
	a) Rails	1	set	1,463,000.00	14.63
	b) Machine saw type with grab winch	1	no.	47,450,000.00	474.50
20.	PVC water stops	1,000	m	772.00	7.72
21.	Copper water stops	900	m	1,230.00	11[illegible]
22.	Instrumentation		LS	1,500,000.00	15.00
23.	Sedimentation chamber gates & Crane				
	a) Embedded parts (4 sets)	4	set	1,287,000.00	51.48
	b) Gates (4 nos.)	4	no.	2,860,000.00	114.40
	c) Gantry Crane	1	no.	23,322,000.00	233.22
24.	Flushing conduit gates and hoists				
	a) Embedded parts (4 sets)	4	set	858,000.00	34.32
	b) Gates (4 nos.)	4	no.	1,788,000.00	71.52
	c) Hoist	4	set	6,500,000.00	260.00
25.	Remote control equipment for sedimentation chamber and flushing conduit gates		LS	19,500,000.00	195.00
26.	Other misc. items		Deleted		0.00
27.	Dewatering	300,000	kWh	10.00	30.00
28.	Contingencies and work charged staff @ 5% except on L.S. items	5	percent		1,83[illegible]
	TOTAL				38,696.22

HEADRACE TUNNEL & CONSTRUCTION ADITS

Sl. No.	Item of Work	Qty.	Unit	Rate (in Rs.)	Amount (in Lacs) (At Dec. 99 Price level)
1.	Open excavation				
	a) In soil	2,500	cum	103.00	2.58
	b) In rock	14,500	cum	370.00	53.65
2.	Underground excavation				
	a) Upto payline	2,004,020	cum	1,682.00	33,707.62
	b) Beyond payline	80,164	cum	1,121.00	898.64
	Total	2,084,184	cum		
3.	Untensioned and grouted rock bolts/anchors (25mm dia) including drilling	4,270	m	614.00	26.22
4.	Tensioned and grouted rock bolts/anchors (25mm dia) including drilling	361,000	m	674.00	2,433.14
5.	Shotcrete	574	cum	11,396.00	65.41
6.	Mesh reinforcement for shotcrete	14,510	kg	71.00	10.30
7.	Shotcrete with steel fiber reinforcement	56,725	cum	19,664.00	11,154.40
8.	Steel rib supports	4,907	tonne	40,260.00	1,975.56
9.	Drilling for contact and consolidation grouting	216,720	m	403.00	873.38
10.	Grouting (contact and consolidation)	21,672	tonne	13,117.00	2,842.72
11.	Drilling for drainage holes	14,900	m	409.00	60.94
12.	Dewatering	1,891,000	kWh	10.00	189.10
13.	Concrete				
	a) Portals (M20)	2,450	cum	4,332.00	106.13
	b) Adits (M15)	5,610	cum	3,474.00	194.89
	c) Tunnel lining (M25)	492,632	cum	4,640.00	22,858.12
	d) Plugs (M20)	8,737	cum	4,332.00	378.49
14.	Steel reinforcement (Grade Fe-415)	1,000	tonne	24,940.00	249.40
15.	Stone masonry	3,500	cum	2,422.00	84.77
16.	Vehicle access gates in adits				
	a) Embedded parts including locking device (3 sets)	3	set	772,000.00	23.16
	b) Gates (hinged type) (3 nos.)	3	no.	1,544,000.00	46.32
17.	Embedded drain pipes and valves (Dewatering arrangement for HRT)	1	set	3,250,000.00	32.50
18.	Collapsible shutters	7	no.	200,000.00	14.00
19.	Instrumentation for HRT	•	LS	3,000,000.00	30.00
20.	Provision for shear zones and bad reaches		LS	75,000,000.00	750.00
21.	Contingencies and work charged staff @ 5% except on L.S. items	5	percent		3,914.07
	TOTAL				82,975.51

SURGE SHAFT

Sl. No.	Item of Work	Qty.	Unit	Rate (in Rs.)	Amount (in Lacs) (At Dec. 99 Price level)
1.	Open excavation	2,100	cum	103.00	2.16
2.	Underground excavation				
	a) Upto payline	94,040	cum	2,282.00	2,145.99
	b) Beyond payline	3,760	cum	1,521.00	57.19
	Total	97,800	cum		
3.	Tensioned and grouted rock bolts/anchors including drilling				
	a) 25mm dia	33,500	m	674.00	225.79
	b) 32mm dia	33,500	m	682.00	228.47
4.	Shotcrete	740	cum	11,396.00	84.33
5.	Mesh reinforcement in shotcrete	17,750	kg	71.00	12.60
6.	Shotcrete with fiber reinforcement	370	cum	19,664.00	72 [illegible]
7.	Steel rib supports	500	tonne	40,260.00	201.30
8.	Concrete (M25)	13,650	cum	4,640.00	633.36
9.	Reinforcement				
	a) Grade Fe 415	2,200	tonne	24,940.00	548.68
	b) Grade Fe 500	1,475	tonne	27,434.00	404.65
10.	Drainage holes	3,600	m	409.00	14.72
11.	Drilling for contact and consolidation grouting	10,100	m	403.00	40.70
12.	Contact/consolidation grouting	1,025	tonne	13,117.00	134.45
13.	Sandwitch steel liner	1,235	tonne	104,100.00	1,285.64
14.	Steel liner in orifice slab and gate grooves etc.	135	tonne	104,100.00	140.54
15.	Airvent pipes 500mm dia	352	m	3,532.00	1[illegible]
16.	Slope protection and drainage works		LS	2,000,000.00	20.00
17.	Stone masonry	2,700	cum	2,422.00	65.39
18.	Steel platform at top	40	tonne	50,000.00	20.00
19.	Surge shaft stoplogs gates				
	a) Embedded parts (4 sets)	4	set	3,861,000.00	154.44
	b) Stoplog gates (2 nos.)	2	no.	5,005,000.00	100.10
20.	Radially traveling hoist for handling stoplog gates along with lifting beam	1	no.	14,300,000.00	143.00
21.	Contingencies and work charged staff @ 5% except on L.S. items	5	percent		336.43
	TOTAL				7,085.13

Annexure C-2.8 (R)

PRESSURE SHAFTS AND PENSTOCKS

Sl. No.	Item of Work	Qty.	Unit	Rate (in Rs.)	Amount (in Lacs) (At Dec. 99 Price level)
1.	Underground excavation in pressure shafts and valve chamber				
	a) Upto payline	50,000	cum	2,712.00	1,356.00
	b) Beyond payline	2,000	cum	1,808.00	36.16
	Total	52,000	cum		
2.	Tensioned and grouted rock bolts/anchors (25 mm Dia) including drilling	37,400	m	674.00	252.08
3.	Steel rib supports	200	tonne	40,260.00	80.52
4.	Shotcrete	500	cum	11,396.00	56.98
5.	Mesh reinforcement for shotcrete	25,500	kg	71.00	18.11
6.	Shotcrete with fiber reinforcement	1,080	cum	19,664.00	212.37
7.	Drilling for consolidation and contact grouting	2,300	m	403.00	9.27
8.	Cement Grouting (Consolidation and Contact)	230	tonne	13,117.00	30.17
9.	Penstock steel liners (ASTM A537 Gr 1 steel)	2,724	tonne	104,100.00	2,835.68
10.	Instrumentation		LS	2,000,000.00	20.00
11.	Steel reinforcement (Fe-415)	830	tonne	24,940.00	207.00
12.	Concrete (M20)	15,815	cum	4,332.00	685.11
13.	Contingencies and work charged staff @ 5% except on L.S. items	5	percent		288.97
	TOTAL				**6,088.41**

POWER HOUSE COMPLEX

Sl. No.	Item of Work	Qty.	Unit	Rate (in Rs.)	Amount (in Lacs) (At Dec. 99 Price level)
1.	Open excavation				
	a) In soil	7,000	cum	103.00	7.21
	b) In rock	14,000	cum	370.00	51.80
2.	Untensioned and grouted rock anchors 25mm dia including drilling	7,240	m	614.00	44.45
3.	Underground excavation				
	I) Approach adits and construction adits				
	a) Upto payline	139,425	cum	2,682.00	3,739.38
	b) Beyond payline	5,575	cum	1,788.00	99.68
	Total	145,000	cum		
	II) Cavities				
	a) Upto payline	178,710	cum	1,682.00	3,005.90
	b) Beyond payline	7,150	cum	1,121.00	80.15
	Total	185,860	cum		
4.	Tensioned and grouted rock bolts/anchors including drilling				
	a) 25mm dia	61,730	m	674.00	416.06
	b) 36mm dia	74,000	m	738.00	546.12
5.	Drilling for consolidation and contact grouting	1,575	m	403.00	6.35
6.	Grouting (contact and consolidation)	160	tonne	13,117.00	20.99
7.	Shotcrete	400	cum	11,396.00	45.58
8.	Mesh reinforcement for shotcrete	10,120	kg	71.00	7.19
9.	Shotcrete with steel fiber reinforcement	12,110	cum	19,664.00	2,381.31
10.	Drainage holes (NX holes)	26,100	m	409.00	106.75
11.	Concrete				
	a) M-15	9,653	cum	3,474.00	335.35
	b) M-20	30,429	cum	4,332.00	1,318.18
	c) M-25	2,345	cum	4,640.00	10[illegible]1
12.	Steel Ribs	220	tonne	40,260.00	88.57
13.	Steel reinforcement Grade Fe 415	2,440	tonne	24,940.00	608.54

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Sl. No.	Item of Work	Qty.	Unit	Rate (in Rs.)	Amount (in Lacs) (At Dec. 99 Price level)
14.	Copper/metal seals	350	m	1,230.00	4.31
15.	PVC seals	400	m	772.00	3.09
16.	Misc. metal work and M.S. pipes	122,160	kg	53.00	64.74
17.	Gratings and Covers	170.000	kg	53.00	90.10
18.	Aluminium doors and windows		LS	1,500,000.00	15.00
19.	Water supply and sanitary fillings		LS	1,500,000.00	15.00
20.	False ceiling of aluminium/metal in P.H. Cavern	3,003	sqm	2,500.00	75.08
21.	EOT Crane rails	522	m	5,000.00	26.10
22.	Transformer rails	378	m	5,000.00	18.90
23.	Instrumentation		LS	3,000,000.00	30.00
24.	Dewatering	418,000	kWh	10.00	41.80
25.	Rolling shutters and collapsible shutters		LS	1,000,000.00	10.00
26.	Architectural features in P.H. Complex		LS	2,500,000.00	25.00
27.	Architectural treatment outside approach adits		LS	1,000,000.00	10.00
28.	Security guard rooms		LS	1,500,000.00	15.00
29.	Stone Masonry	2,275	cum	2,422.00	55.10
30.	Fabrication steel work in cable shaft	350,000	kg	75.00	262.50
31.	20m Rock Anchors of 50T capacity	11,300	RM	4,800.00	542.40
32.	Draft tube gates				
	a) Embedded parts (2 sets)	4	set	1,609,000.00	64.36
	b) Gates (2 nos.)	2	no.	3,575,000.00	71.50
	c) Gate operating crane with lifting beam	1	no.	14,300,000.00	143.00
33.	Contingencies and work charged staff @ 5% except on L.S. items	5	percent		724.07
	TOTAL				15.325.41

DOWNSTREAM SURGE CHAMBER, TAILRACE AND OUTFALL WORKS

Sl. No.	Item of Work	Qty.	Unit	Rate (in Rs.)	Amount (in Lacs) (At Dec. 99 Price level)
1.	Open excavation				
	a) In soil	5,000	cum	103.00	5.15
	b) In rock	10,000	cum	370.00	37.00
2.	Underground excavation				
	a) Upto payline	235,195	cum	1,682.00	3,955.98
	b) Beyond payline	9,405	cum	1,121.00	105.43
	Total	244,600	cum		
3.	Tensioned and grouted rock bolts/anchors including drilling 25mm dia	82,790	m	674.00	558.00
5.	Drilling for consolidation and contact grouting	12,350	m	403.00	49.77
6.	Grouting (consolidation and contact)	1,235	tonne	13,117.00	161
7.	Shotcrete	100	cum	11,396.00	11.40
8.	Mesh reinforcement for shotcrete	1,300	kg	71.00	0.92
9.	Shotcrete with steel fiber reinforcement	5,440	cum	19,664.00	1,069.72
10.	Steel Ribs	330	tonne	40,260.00	132.86
11.	Concrete				
	a) M-15	29,182	cum	3,474.00	1,013.78
	b) M-20	28,771	cum	4,332.00	1,246.36
12.	Steel reinforcement Grade Fe-415	1,200	tonne	24,940.00	299.28
13.	Copper/metal seals	450	m	1,230.00	5.54
14.	PVC seals	450	m	772.00	3.47
15.	Misc. metal work and pipes	1,510	kg	53.00	0.
16.	Stone masonry	210	cum	2,422.00	5.09
17.	Grouted boulder pitching	300	cum	666.00	2.00
18.	Outlet gates and hoists				
	a) Embedded parts (2 sets)	2	set	1,609,000.00	32.18
	b) Gates (2 nos.)	2	no.	4,290,000.00	85.80
	c) Electrical hoists	2	no.	5,850,000.00	117.00
	d) Trestles and hoist platform (2 sets)	2	set	3,218,000.00	64.36
19.	Dewatering	848,400	kWh	10.00	84.84
20.	Instrumentation		LS	1,500,000.00	15.00
21.	Stilling well and tail water level measuring instruments		LS	1,500,000.00	15.00
22.	Contingencies and work charged staff @ 5% except on L.S. items	5	percent		452.44
	TOTAL				9,531.16

POT HEAD YARD

Sl. No.	Item of Work	Qty.	Unit	Rate (in Rs.)	Amount (in Lacs) (At Dec. 99 Price level)
1.	Open excavation				
	a) In soil	1,000	cum	103.00	1.03
	b) In rock	8.500	cum	370.00	31.45
2.	Concrete				
	a) M-15	1,210	cum	3,474.00	42.04
	b) M-20	300	cum	4,332.00	13.00
	c) M-25	115	cum	4,640.00	5.34
3.	Steel reinforcement (Grade Fe-415)	150	tonne	24,940.00	37.41
4.	PVC seals	150	m	772.00	1.16
5.	Metal seals	150	m	456.00	0.68
6.	Metal work in trench covers and grating	15,000	kg	53.00	7.95
7.	Stone masonry	510	cum	2,422.00	12.35
8.	Fencing and gates		LS	1,500,000.00	10.00
9.	Contingencies and work charged staff @ 5% except on L.S. items	5	percent		7.62
	TOTAL				**170.02**

Annexure C-2.12 (R)

K - BUILDINGS

Sl. No.	Item of Work	Qty.	Unit	Rate (in Rs.)	Amount (in Lacs) (At Dec. 99 Price level)
1.	Residential buildings				
	(a) Permanent residential buildings	15002	Sqm	-	1,354.68
	(b) Temporary residential buildings	36220	Sqm	-	1,697.81
2.	Non-residential buildings				
	(a) Permanent non-residential buildings	22200	Sqm	-	1,738.82
	(b) Temporary non-residential buildings	12500	Sqm	-	518.44
3.	Guest house and offices at Shimla/Delhi				
	(a) At Shimla	-	Deleted	-	0.00
	(b) At Delhi	-	Deleted	-	0.00
	TOTAL				5,309.75

Note: The break up of Costs for different category of buildings and requirements of buildings are given in Annexures 2.12.1, 2.12.2 & 2.12.3.

BREAKUP OF COSTS FOR CONSTRUCTION OF BUILDINGS

Sl. No.	Item of Work	Qty.	Unit	Rate (in Rs.)	Amount (in Lacs) (At Dec. 99 Price level)
A.	RESIDENTIAL BUILDINGS				
1.	Permanent Residential Buildings				
	Building Cost	15,002	Sqm	7,000	1,050.14
	Internal sanitary installation @ 5%				52.51
	Internal water supply @ 5%				52.51
	Internal electrical installation @ 7%				73.51
	Lawns, gardens & fencing @ 2%				21.00
	Development of site including making of terraces and revetments @ 10%				105.01
					1,354.68
2.	Temporary Residential Buildings				
	Building Cost	36220	Sqm	3,750	1,358.25
	Internal Sanitary Installations @ 4%				54.33
	Internal Water Supply @ 4%				54.33
	Internal electrical installation @ 5%				67.91
	Lawns, gardens & fencing @ 2%				27.17
	Development of site including making of terrances and revetments @ 10%				135.83
		36220			**1,697.81**
B.	NON-RESIDENTIAL BUILDINGS				
1.	Permanent Non-residential Buildings				
	Building Cost	22200	Sqm	6,500	1,443.00
	Internal water supply and sanitary fittings @ 5%				72.15
	Internal electrical installation @ 3.5%				50.51
	Lawns, gardens & fencing @ 2%				28.86
	Development of site including making of terraces and revetments @ 10%				144.30
					1,738.82
2.	Temporary Non-residential Buildings				
	Building Cost	12500	Sqm	3,500	437.50
	Internal water supply and sanitary fittings @ 4%				17.50
	Internal electrical installation @ 2.5%				10.94
	Lawns, gardens & fencing @ 2%				8.75
	Development of site including making of terraces and revetments @ 10%				43.75
					518.44

ABSTRACT OF RESIDENTIAL BUILDINGS

Sl. No.	Type of Residence	Nos.	Plinth area Sqm	Total plinth area Sqm
1.	Permanent Residences at Sholtu			
	VI	2	121	242
	V	10	160	1600
	IV	10	106	1060
	III	50	61	3050
	II	125	46	5750
	I	100	33	3300
				15002
2.	Temporary residences at various work sites (Dam site intermediate adit sites, and PH site)			
	IV	20	106	2120
	III	100	61	6100
	II	250	46	11500
	i	500	33	16500
3.	Temporary labour huts at various sites	Deleted	·	0
				36220

Note:

1. The plinth area of various categories of residences have been taken *as per drawings of HPSEB.*
2. Permanent buildings have been provided for the O&M staff after commissioning of the project. During construction period, these will be used for the construction staff.

ABSTRACT OF NON-RESIDENTIAL BUILDINGS

Sl. No.	Type of Residence	Nos.	Plinth area Sqm	Total plinth area Sqm
A.	Permanent buildings at Sholtu			
1.	Offices	1	6000	6000
2.	Rest house	1	250	250
3.	Field hostels	3	500	1500
4.	Transit camp	1	250	250
5.	Out-houses and garages etc.	1	500	500
6.	Telephone exchange	1	50	50
7.	Fire station	1	100	100
8.	Police post	1	100	100
9.	Primary school	1	600	600
10.	Hospital	1	600	600
11.	Officers' Club	1	200	200
12.	Staff Club	1	150	150
13.	Recreation Centre	1	150	150
14.	Bank	1	100	100
15.	Post Office	1	100	100
16.	Model	1	300	300
17.	Maternity and Child Welfare Centre	1	200	200
18.	Bus Stand	1	50	50
19.	Market	1	150	150
20	Permanent Guest house at Shimla	1	2550	2550
21	Permanent office building at Delhi	1	8300	8300
				22200
B.	Temporary buildings at various sites			
1.	Transit camps at Kalka and Shimla	2	250	500
2.	Field Offices	10	50	500
3.	Central stores	1	5000	5000
4.	Cement workshop	1	4000	4000
5.	Stores at rail head	1	2000	2000
6.	Field testing laboratory	1	500	500
				12500

M - PLANTATION

Sl. No.	Item of Work	Qty.	Unit	Rate (in Rs.)	Amount (in Lacs) (At Dec. 99 Price level)
1.	Planting of trees on roads, work sites, and Camp sites etc.	100000	No.	60	60.00
2.	Development of parks and nurseries		L.S.		30.00
3.	Labour charges for protection of plantation for 6 years	6	Year	1,800,000	108.00
	TOTAL				**198.00**

O - Miscellaneous

Sl. No.	Item of Work	Qty.	Unit	Rate (in Rs.)	Amount (in Lacs) (At Dec. 99 Price level)
1.	Camp facilities in various residential and non-residential areas				
	a) Electrification and lighting		L.S.		250.00
	b) Water supply purification and distribution		L.S.		180.00
	c) Sewage disposal and storm water drains		L.S.		180.00
2.	Maintenance of various services during construction period				
i)	Electrification and lighting	6	year	2,200,000	132.00
ii)	Water supply purification and distribution	6	year	1,100,000	66.00
iii)	Sewage disposal	6	year	900,000	54.00
iv)	Recreation facilities	6	year	1,500,000	90.00
v)	Medical facilities	6	year	2,200,000	132.00
vi)	Telephone services	6	year	900,000	54.00
vii)	Security arrangements	6	year	900,000	54.00
viii)	Fire fighting arrangements	6	year	600,000	36.00
ix)	Running of inspection vehicles (Annexure C-2.14.1(R))	6	year	7,200,000	432.00
x)	Running of vehicles for transport of staff to work sites (Annexure C-2.14.1(R))	6	year	4,500,000	270.00
xi)	Running of school buses (Annexure C-2.14.1(R))	6	year	900,000	54.00
xii)	Running of pay van, ambulance etc. (Annexure C-2.14.1(R))	6	year	720,000	43.20
3.	Visit of dignitaries		L.S.		15.00
4.	Visual and photographic record of works		L.S.		30.00
5.	Inaugural and dedication ceremonies		L.S.		15.00
6.	Compensation to workmen and retrenchment compensation		L.S.		400.00
7.	Anti-malaria measures		Deleted		0.00
8.	Models and exhibits		L.S.		30.00
9.	Publicity, information and public relations	6	year	600,000	36.00
10.	Subsidy to schools	6	year	600,000	36.00
11.	Canteen facilities and cooperatives	6	year	600,000	36.00
12.	Running of guest houses/transit camps	6	year	1,800,000	108.00
13.	Purchase of technical literature, books etc.		L.S.		30.00
14.	Purchase of computer system for design offices				
a)	Hardware		L.S.		300.00
b)	Software		L.S.		200.00
15.	Wireless and satellite communication facilities	6	year	1,500,000	90.00

contd.

Sl. No.	Item of Work	Qty.	Unit	Rate (in Rs.)	Amount (in Lacs) (At Dec. 99 Price level)
16.	Providing flood warning system		L.S.		20.00
17.	Purchase of photographic and cinemato-graphic and other equipment		L.S.		30.00
18.	Purchase of fire fighting equipment at work sites and camp area		L.S.		60.00
19.	Installation of telephone facilities at the work sites and camp area		L.S.		80.00
20.	Insurance of civil works during construction period		L.S.		1,500.00
21.	Construction power arrangements (Annexure C-2.14.2(R))		L.S.		2,286.00
22	Preparing completion report & history of project		L.S.		50.00
	TOTAL				**7,379.20**

Annexure C-2.14.1 (R)

Running Charges of Transport Vehicles

Sl. No.	Item	No. of Vehicles	km per month	Rate per km (Rs.)	Cost/month per vehicle (Rs.)	Cost/year per vehicle (Rs. Lacs)	Total Cost per year (Rs. Lacs)
1.	Inspection Vehicles (cars & jeeps)	60	2500	4	10,000.00	1.2	72
2.	Transport Vehicles (buses)	12	2500	12.5	31,250.00	3.75	45
3.	School buses	4	1500	12.5	18,750.00	2.25	9
4.	Running of pay vans and ambulances	4	1500	10	15,000.00	1.8	7.2
	TOTAL						133.2

P - Maintenance

Assume cost of P-Maintenance = Rs. X Lacs

Assume losses on stock = *Rs. Y Lacs*

Provision against P-Maintenance = 1% of [(I Works) - (A Preliminary + B Land + O Miscellaneous + M plantation + Q Spl T& P + X Environment & Ecology + Y Losses on stock)]

X	**= 1 % of [(**	226,776.42	+	X	+	Y)		- (	1,539.00	+
		1,483.51	+	7,379.20	+	198.00	+		521.00	+
		3,438.83	+	Y	**)]**					
X	**= 1 % of [**	226,776.42	+	X	-	14,559.54	**]**			

0.99 X = 212,216.88

X = 214,360.48

= 2143.60483

Say Rs. 2143.60 **Lacs**

Q - Special T&P (Vehicles)

Sl. No.	Item of Work	Qty.	Unit	Rate (in Rs.)	Amount (in Lacs) (At Dec. 99 Price level)
1.	Cars	20	No.	500,000	100.00
2.	Jeeps	25	No.	500,000	125.00
3.	Station Wagons	15	No.	600,000	90.00
4.	Shift buses	12	No.	1,100,000	132.00
5.	School buses	4	No.	1,100,000	44.00
6.	Cash vans	2	No.	750,000	15.00
7.	Ambulances	2	No.	750,000	15.00
	TOTAL				**521.00**

R-Communications

Sl. No.	Item of Work	Qty.	Unit	Rate (in Rs.)	Amount (in Lacs) (At Dec. 99 Price level)
A.	Construction of new roads (Annexure C-2.17.1(R))				
1.	Excavation in overburden	204210	cum	103.00	210.34
2.	Excavation in rock	653470	cum	370.00	2,417.84
3.	Masonry work in retaining walls and breast walls	61260	cum	2,422.00	1,483.72
4.	Metalling and painting	175620	sqm	250.00	439.05
5.	Culverts and drains		L.S.	40,000,000.00	400.00
6.	Temporary roads to quarry site	5	km	1,000,000.00	50.00
B.	Construction of Bridges (Annexure C-2.17.2(R))				
1.	Excavation in overburden	1380	cum	103.00	1.42
2.	Excavation in rock	800	cum	370.00	2.96
3.	Concrete (M-20) in sub-structure	3815	cum	4,332.00	165.27
4.	Reinforcement	113	tonne	24,940.00	28.18
5.	Steel work in super-structure	1490	tonne	53,000.00	789.70
6.	Decking and roadway surface	2705	sqm	5,000.00	135.25
C.	Improvement of existing roads				
1.	Improving the road between Jahkri and Wangtoo for plying 100T trailers	50	km	1,200,000.00	600.00
2.	Improvement of Wangtoo-Katgaon Road	9	km	500,000.00	45.00
3.	Construction of tunnel on NH22 to bypass Urni slide	700	m	250,000.00	1,750.00
D.	Railway siding at Kalka (Annexure C-2.17.3(R))		L.S.	20,000,000.00	200.00
	TOTAL				8,718.72

Construction of New Roads

S.No.	Description	Qty	
1	Road to surge shaft	4.00	Km
2	Re-alignment of NH-22	5.50	Km
3	i) Re-alignment of Karcham -Sangla road	2.00	Km
	ii) Re-alignment of Karcham-Sapni road	1.00	Km
	iii) Re-alignment of approach road to Baspa power house to replace existing Karcham-Sangla road	1.25	Km
	iv) Road to sedimentation chamber adit	0.30	Km
	v) Road to outfall structure of flushing tunnel of sedimentation chamber	0.30	Km
	vi) Road to inlet adit	0.10	Km
	vii) Road to Adit No.3	0.15	Km
	viii) Road to Adit No.4	1.00	Km
	ix) Road from wangtoo bridge to power house	0.50	Km
	x) Road from Bailey suspension bridge to wangtoo power house	0.50	Km
	xi) Road in Rarang colony on wangtoo-katgaon road	0.80	Km
	xii) Road from Tapri bridge top Sholtu colony	1.00	Km
	xiii) Approach road to forest area at Sholtu	1.00	Km
	Sub-total of item No.3	9.90	Km

S.No.	Quantity of Work	Road to Surge shaft	Re-alignment of NH-22	Item No.3	Total Quantity
1	Excavation in overburden (in Cum)	40000.00	60000	104210	**204,210.00**
2	Excavation in Rock (in Cum)	120000.00	200000	333474	**653,474.00**
				Say	**653,470.00**
3	Masonry work in retaining walls and breast walls (in Cum)	10000.00	20000	31263	**61,263.00**
				Say	**61,260.00**
4	Metalling & painting (in Sqm)	36000.00	50000	89621	**175,621.00**
				Say	**175,620.00**

Construction of New Bridges

Sl. No.	Description	Class	Span (m)
1.	Bridge over river Satluj d/s of Karcham dam (4.25 m clear carriage way)	70R	105
2.	Bridge over river Baspa U/s of Karcham dam on realigned Karcham-snagla road (4.25 m clear carriage way)	50R	69.2
3.	Bridge over river Satluj for approach to dumping area (4.25 m clear carriage way)	50R	69.2
4	Bridge over river Satluj U/S of Karcham Dam on NH22 (7.5 m clear carriage way as per MOT design)	70R	105
5	Bridge over Bhaba khad near wangtoo power house	70R	40
6	Bridge over Bhaba khad on Surge shaft road	70R	40
7	Bridge over Punang Nallah	50R	50
8	Bridge over Satluj at Wangtoo	70R	53

S.No.	Description	Bridge 1	Bridge 2	Bridge 3	Bridge 4	Bridge 5	Bridge 6	Bridge 7	Bridge 8	Total Qty.
i)	Excavation in over burden	120 cum	120 cum	120 cum	80 cum	80 cum	80 cum	80 cum	700 cum	1380 cum
ii)	Excavation in rock	120 cum	120 cum	120 cum	80 cum	80 cum	80 cum	80 cum	120 cum	800 cum
iii)	Concrete in sub-structure	360 cum	360 cum	360 cum	500 cum	500 cum	500 cum	360 cum	875 cum	3815 cum
iv)	Reinforcement	15 MT	15 MT	15 MT	15 MT	15 MT	15 MT	15 MT	8 MT	113 MT
v)	Steel work in super structure	240 MT	160 MT	160 MT	330 MT	160 MT	160 MT	160 MT	120 MT	1490 MT
vi)	Decking and roadway surface	525 sqm	350 sqm	350 sqm	525 sqm	220 sqm	220 sqm	250 sqm	265 sqm	2705 sqm

Railway siding at Kalka

Sl. No.	Item of Work	Qty	Unit	Rate (in Rs.)	Amount (in Lacs)
1.	Laying of track		L.S.	3,000,000	30.00
2.	Providing gantry crane for unloading		L.S.	5,500,000	55.00
3.	Making platform and drains etc.		L.S.	1,500,000	15.00
4.	Making railway siding and drains etc.		L.S.	5,000,000	50.00
5.	Fencing etc.		L.S.	1,000,000	10.00
6.	Rent to be paid to railways for 7 years		L.S.	3,500,000	35.00
7.	Other miscellaneous works		L.S.	500,000	5.00
	Total				200.00

X - Environment, Ecology and Afforestation

Sl. No.	Item of Work	Qty.	Unit	Rate (in Rs.)	Amount (in Lacs) (At Dec. 99 Price level)
1.	Provision for maintaining environmental and ecological balance of the area				
a)	Reclamation of quarry and borrow areas		L.S.		35.00
b)	Wild life protection		L.S.		25.00
c)	Pisciculture		Deleted		0.00
d)	Picnic spots etc.		Deleted		0.00
e)	Landscaping etc.		Deleted		0.00
2.	Compensatory afforestation	320	Ha	80,000.00	256.00
3.	Public health measures		L.S.		50.00
4.	Subsidy towards firewood, fuel etc.		L.S.		100.00
5.	Treatment of catchment area for prevention of soil erosion, afforestation etc. as per CAT plan 1.5% of cost of [C - Works + J - Power Plant civil works]				2,972.83
	TOTAL				**3,438.83**

Losses on stock

Assume losses on stock = Rs. Y lacs

Losses on stock = 0.25% of [(I Works) - (A Preliminary + B Land + O Miscellaneous + M plantation + Q Spl T& P + X Environment & Ecology + P Maintenance)}

Y	**= 0.25 % of [**	(228,920.02	+	Y)	- (	1,539.00	+	1,483.51	+
		7,379.20	+	198.00	+	521.00	+	3,438.83	+
		2,143.60	)]						
Y	**= 0.25 % of [**	(228,920.02	+	Y)	-	16,703.14	]		

0.9975 Y = 530.54

Y = *531.87188*
Say Rs. 531.90 **Lacs**

Receipts and Recoveries on Capital Account

Sl. No.	Item of Work	Qty	Unit	Rate (in %)	Amount (in Lacs) (At Dec. 99 Price level)
1.	Resale/transfer of Special T&P	~~521.00~~	% Deleted	20%	~~104.20~~
2.	Resale/transfer of temporary residential buildings	1,697.81	%	15%	254.67
3.	Resale/transfer of temporary non-residential buildings	518.44	%	15%	77.77
4.	Resale of construction power arrangement (Diesel sets 6 Nos.@ Rs.200 lacs each	6	Nos.	20%	240.00
5.	Other misc. receipts and recoveries		L.S.	1,000,000	10.00
	TOTAL				~~686.64~~ 582.44

Generating Plant and Accessories

Sl.No.	Description of equipment	Qty	Unit	Unit Rate USD	Amount USD
	Design, manufacture, testing and supply CIF Mumbai of : (a) Vertical Francis turbine rated 255MW, 214.3 rpm, 273.5m head (b) Turbine Model Test for above (c) Governing System including Oil pressure system and compressed air system (d) Spherical valve 3200mm and auxiliaries (e) Penstock butterfly valve 4000 mm and auxiliaries (f) Vertical shaft, 250 MW, 15.75kV, 0.9 p.f., synchronous generator, static excitation system and auxiliaries. (g) Busducts and terminal equipment (h) Cooling water system (i) Drainage and Dewatering system (j) Computerised Data Acquisition and control system (k) Generator and transformer protections (l) Spares, lubricants, special tools and tackles for generating plant equipment	4x250,000	kW	116.87 (As per Appendix 3.1.1)	116.87 Million
				Total	**116.87 M**
					Say 117 MUSD
	Equivalent INR (@ 1 USD = Rs. 43.50)				**5089.5 Million INR**

Appendix C-3.2 R1

Electrical Auxiliary Equipment for Power Station

Sl.No.	Description of equipment	Qty	Unit	Unit Rate Rs.lacs	Amount Rs.lacs
1.	Protective relaying and metering equipment for Feeders and Bus coupler as per **Appendix C-3.2.1**	Lot			200.00
2.	A.C. supply system as per Cost breakup at **Appendix C-3.2.2 R1**	Lot			351.00
3.	D.C. supply system as per Cost break up at **Appendix C-3.2.3**	Lot			185.00
4.	Station Ground mat and equipment grounding system for power house complex including switchyard as per Cost break up at **Appendix C-3.2.4**	Lot			160.00
5.	Power, control and special cables, Cable racks/support structure, Cable termination kits, accessories as per Cost break up at **Appendix C-3.2.5**	Lot			431.00
6.	Illumination system for power house/transformer hall/BFV hall, access/inter connection tunnels, shafts, switchyard, approach roads, dam site, etc.	Lot			300.00
7.	Communication system as per Cost break up at **Appendix C-3.2.6**	Lot			127.00
8.	Electrical Test Laboratory equipment	Lot			300.00
				Total	**2054.00**

Mechanical Auxiliary Equipment for Power Station

Sl.No.	Description of equipment	Qty	Unit	Unit Rate Rs.lacs	Amount Rs.lacs
1.	E.O.T. cranes as per Cost break up at **Appendix C-3.3.1**				
	- 275/40/10t for p.H	2	nos		527.00
	- 500t capacity lifting beam	1	no.	30.0	30.00
	- 65/5t for BFV Chamber	1	no		96.00
	- 10t for GIS Chamber	1	no		30.00
	- Other Hoists	Lot			20.00
2.	Electrical Lifts				
	- For Power House	1	no	25.0	25.00
	- For SF_6 busduct/shaft	1	no	40.0	40.00
	- For dam site	1	no.	20.0	20.00
3.	Station HP/L.P. Compressed Air System	L.S.			40.00
4.	Fire protection system as per Cost break up at **Appendix C-3.3.2**	L.S.			320.00
5.	Air Conditioning and heating system	L.S.			50.00
6.	Ventilation system of Power House, Transformer/GIS hall as per Cost break up at **Appendix C-3.3.3 R1**	L.S.			300.00
7.	Oil handling system for generating units and transformers as per Cost break up at **Appendix C-3.3.4**	L.S.			100.00
8.	Workshop Machines and Equipment	L.S.			200.00
9.	Filtered water supply system for power house comprising drinking water and sewage	L.S.			20.00
				Total	**1818.00**
					1818 Lacs

Sub-Station Equipment

Sl.No.	Description of equipment	Qty	Unit	Unit Rate Rs.lacs	Amount Rs.lacs
INDIGENOUS					
1.	Step up main generator transformer, 15.75/400/√3 kV, 93 MVA, OFWF Complete with Oil and accessories as per **Appendix C-3.4.1**	13x93,000	kVA	0.002	2418.00
2.	Rail track for main transformers in transformer hall				20.00
3.	390 kV ZnO lightning arresters with accessories	18	nos	5.00	90.00
4.	PLCC Equipment comprising CVT Wave trap for Transmission of speech and protection signals and related equipment as per **Appendix C-3.4.3**	6	sets	-	186.00
5.	Fencing	Lot			15.00
6.	Gantry and Galvanised steel support structure for pot yard equipment	Lot			100.00
				Total	**2,829.00**
IMPORTED					**AMOUNT IN USD**
1.	400 kV SF_6 gas-insulated switchgear as per Cost break up at **Appendix C-3.4.2**	11	bays		38.00 MUSD
2.	400 kV SF_6 insulated busducts including bends elbows etc.	3500	m	included in above	-
				Total	**38.0 MUSD**
	Equivalent INR = 16530 lacs (@ 1 USD = 43.50)				

Plant Handling Equipment

Sl.No.	Description of equipment	Qty	Unit	Unit Rate Rs.lacs	Amount Rs.lacs
1.	100 Ton Crawler crane	1	no.	125.00	125.00
2.	30 Ton Tyre mounted crane	1	no.	65.00	65.00
3.	Tractor unit 160/200 Ton	1	no.	100.00	100.00
4.	Tractor unit 100 Ton	1	no.	60.00	60.00
5.	120 Tonnes Low bed trailer with dolly and accessories	1	no.	100.00	100.00
6.	80 Tonnes high bed trailer with dolly	1	no.	80.00	80.00
7.	50 Tonnes high bed trailer	1	no.	50.00	50.00
8.	20 Ton high bed trailer	1	no.	25.00	25.00
9.	Storage sheds for plant equipment	2000	sqm	0.03	60.00
				Total	**665.00**

Cost Breakup - Hydro Generating Units (4 x 250 MW)

Sl.No.		*Item Description*	*SIEMENS Bud Offer Dt. Feb. 2000*	
1.	(a)	Turbine, Generator, SEE, Inlet Valve, & Penstock B.F. Valves, Governing System	110 M$ (CIF Price)	
	(b)	Spares b@ 5%	5.5 M$ *	*Assumed values
	(c)	Model Testing	1.15 M$ *	
	(d)	Tools, Tackles and Lubricants	0.22 M$ *	
	(e)	Busducts incl. Neutral grounding cubicles	Included	
	(f)	DACS + generator protection	Included	
	(g)	Cooling water system	Included	
	(h)	*Drainage and Dewatering system*	*Included*	
		Total	116.87 M$ (i.e. 116.87$/kW)	

Cost Breakup - Protective Relays

				Rs. Lacs
Sl.No.	Description	Qty	Unit Rate	Total
1.	400 kV Feeder Main 1 & Main 2 protections (Numerical type) Disturbance Recorder, Distance to fault locator, tripping relays auxiliary relays, metering, instruments etc.	6 sets	20.00	120.00
2.	Low impedence Bus bar Protection	1 set	30.00	30.00
3.	Bus Coupler protection and metering panel	1 set	2.00	2.00
4.	Synchronising trolley	1 set	5.00	5.00
5.	Master/Slave clock for the station	Lot	10.00	10.00
6.	Relay testing kit	1 set	15.00	15.00
7.	Spares		10.00	10.00
8.	Remote control of AC system		2.00	2.00
9.	Remote control of Dam gates/system		4.00	4.00
10.	Special tools for relays		2.00	2.00
			Total	**200.00**
				Rs. 200 lacs

Cost Breakup - A.C. Supply System

Rs. Lacs

Sl.No.		Items	Qty	Unit Rate	Total
1.	a)	Unit Auxiliary Transformer, cast resin type 1000 kVA, 13.8 kV/415 V, 50 Hz, % impedance 6.25% housed in a self ventilated cubicle.	4 nos	10.75	43.00
	b)	Station service transformer, cast resin type 1000 kVA, 22 kV/415 V, 50 Hz, % impedance 6.25% housed in a self ventilated cubicle.	2 nos	11.50	23.00
	c)	Station service transformer, cast resin type 1000 kVA, 11 kV/22 kV, 50 Hz, % impedance 6.25% housed in a self ventilated cubicle.	2 nos	10.50	21.00
	d)	Distribution transformer oil filled (ONAN) of capacity 500 kVA, 22 kV/415 V for dam site and BFV chamber	2 nos	3.00	6.00
	e)	D.G. set 1000 kVA, 11 kV with provision for auto start on mains failure (cost provision under construction power)			Included in O-Misc.
	f)	D.G. set 250 kVA, 415 V for dam site (cost provision under construction power)			Included in O-Misc.
	g)	22 kV switchgear, indoor, with draw out type vacuum/SF_6 circuit breaker, comprising 7 panels with provision for synchronising on two breakers as per drawing.	1 set	45.00	45.00
	h)	415 volts Unit Auxiliary Board having incoming/outgoing and tie Air Circuit breakers and equipped with draw out type MCCB's of 400/200/100/60/30 Amp ratings as per enclosed schematic	4 sets	20.00	80.00
	i)	415 V Station Service Board in 2 sections having incoming/outgoing and tie Air circuit breakers and MCCB's of 800/600/400/200/100 Amp ratings as per enclosed schematic	1 set	40.00	40.00
	j)	L.T. non-segregated Aluminium bus ducts, 415 VAC, 3000 Amp 50 kA for inter-connecting the unit auxiliary and station service boards including flexible joints, structure etc.	1 lot (100m)	0.35	35.00
	k)	415 V dam AC supply board comprising 2 nos. 2000 Amp incoming breakers and 24 nos. outgoing feeders of 100/60/30 Amp capacity	1 set	10.00	10.00
	l)	415 V auxiliary supply board having 2 nos. incoming circuit breaker 800 Amp, 50 kA and 12 nos. outgoing feeders 400/200/100/60 Amp for different floors and sub-distribution boards.	12 nos	3.00	36.00

				Rs. Lacs
Sl.No.	Items	Qty	Unit Rate	Total
m)	Tools with handling devices, testing instruments for erection, testing and maintenance of the complete system	1 set	2.00	2.00
n)	Spare parts sufficient for 5 years of operation of AC system	Lot		10.00
			Total	**351.00**
				351 lacs

Cost Breakup - D.C. Supply System

Rs. Lacs

Sl.No.	Items	Qty	Unit Rate	Total
1.	220 V, Plante lead acid batteries having a capacity of 1600 AH at 8 hour discharge rate complete with accessories	2 sets	54.63	109.27
2.	48 V, Plante lead acid batteries having a capacity of 500 AH at 8 hour discharge rate complete with accessories	2 sets	4.97	9.95
3.	24 V, Plante lead acid batteries having a capacity of 400 AH at 8 hour discharge rate complete with accessories	1 set	1.00	1.00
4.	Float and boost battery Chargers for 220 V DC battery	2 sets	4.71	9.42
5.	Float cum boost battery charger for 48 V battery	2 sets	1.75	3.50
6.	Float cum boost battery charger for 24 V battery	1 set	1.66	1.66
7.	220 V main distribution board with three incoming 600A breakers, and drawout type 800/400 Amp MCCBs	1 set	5.63	5.63
8.	220 V DC branch distribution boards having drawout type 400/200/100/60/30A MCCBs	2 sets	4.96	9.92
9.	220 V DC branch distribution boards having drawout type 200/100/60/30A MCCBs	2 sets	2.73	5.47
10.	220 V DC branch distribution boards having drawout type 100/60/30/15A MCCBs	2 sets	2.50	5.00
11.	48 V DC distribution board having drawout type 60/30A MCCBs	1 set	2.00	2.00
12.	24 V D.C. distribution board having drawout type 60/30 A MCCBs	1 set	2.00	2.00
13.	20 kVA, Uninterrupted power supply (UPS) suitable for operation from 220 V DC, with 240 V single phase AC output	1 no	10.00	10.00
14.	Tools, handling devices, testing instruments for erection, testing and maintenance	Lot		4.00
15.	Spares for 5 years normal operation	Lot		6.00
			Total	184.82
			Say	185 lacs

Cost Breakup - Ground Mat and Equipment Grounding System

				Rs. Lacs
Sl.No.	Items	Qty	Unit Rate	Total
1.	Estimated steel requirement for ground mat of P.H., S/Y, Tailrace, Dam site, etc.			
a)	M.S. Steel Round	250 Tons		
b)	M.S. Rods	50 Tons		
2.	Equipment grounding	30 Tons		
	Total	330 Tons	0.45/Ton	148.50
3.	*Earthing accessories*	*Lot*		*12.00*
			Total	**160.50**
				Say 160 lacs

Cost Breakup - Control, Power and special cables

Rs. lacs

Sl.No.		Item	Qty	Unit	Unit Rate	Amount
1.		Multi core FRLS Control cables	100	km	1.50 (Average)	150.00
2.		22/11kV,XLPE and 415 V, PVC/XLPE Power cables	15	km	8.00 (Average)	120.00
3.		Special Cables i.e. screened cables for transducers	5	km	2.50	12.50
4.		Accessories for laying clamping, termination, cable jointing kits, glands, lugs, ferrules cable markers etc.	Lot			15.00
5.	a)	Cable racks/support structure	120	MT	0.45	54.00
	b)	Cable Trays	4000	r.m.	0.015	60.00
	c)	Fire preventive measures i.e. fire retardant blocks at suitable intervals	Lot			20.00
					Total	**431.50**
						Say 431.0 lacs

Cost Breakup - Communication System

				Rs. Lacs
Sl.No.	Items	Qty	Unit Rate	Total
1.	Long Distance Satellite (LDST) communication system between Power House site and Head office Delhi	2 sets (one terminal for each end)	30.00	60.00
2.	VHF Communication System (MARR) for communication between P.H., Dam site and Colony	1 set	12.00	12.00
3.	EPABX for			
	- Power House (96 ext.and 16 P&T lines)	1 set	5.00	5.00
	- Dam site (24 ext.and 4 P&T lines)	1 set	2.00	2.00
	- Colony (48 ext.and 8 P&T lines)	1 set	3.00	3.00
4.	Push button telephone	200 nos	0.01	2.00
5.	Battery and Battery charges for EPABX	Lot		3.00
6.	3 kVA, UPS with 2 hour battery back up	3 sets	1.0	3.00
7.	0.50 mm x 5 pairs/10 pairs/20 pairs armoured jelly filled telephone cables, PVC insulated B.S.W/Drop Wire, PVC insulated indoor type V.F cables etc.	Lot		10.00
8.	Public Address System interfaced suitably with EPABX System with power ampliper, Cassette recorder/player, matching loud speakers (50 Nos) etc.	Lot		7.00
9.	O/H Areal cable/poles/ pole accessories/junction box etc.	Lot		10.00
10.	Spares			5.00
11.	Testing Equipment for satcom			5 00
			Total	**127.00**
				127 lacs

Cost Breakup - E.O.T. Cranes

					Rs. Lacs
Sl.No.	Item	Qty	Unit	Unit Rate	Total Rs.
1.	P.H. E.O.T. Crane				
	a) 275/40/10t E.O.T. Cranes	2		235.00	470.00
	b) CR-120 rails	300m		0.12	36.00
	c) Downslop leads	600m		0.02	12.00
	d) Spares, tools, tackles	Lot			8.75
				Sub Total	**526.75**
				Say	**527**
2.	Lifting Beam (500 t) suitable for tandem operation of 2 cranes	1 no		30.00	30.00
3.	BFV E.O.T Crane				
	a) 65/5t, E.O.T. Crane	1 no		65.00	65.00
	b) CR-120 rails	175m		0.12	21.00
	c) Downslop leads	350m		0.015	5.25
	d) Spares tools tackles			4.75	4.75
				Sub Total	**96.00**
				Say	**96 lacs**
4.	GIS E.O.T. Crane				
	a) 10t capacity pendant push button controlled E.O.T. crane	1 no.		15.00	15.00
	b) 30lb/yd rails	300m		0.033	10.00
	c) Downshop leads	600m		0.006	3.50
	d) Spares, tools and tackles			1.50	1.50
				Sub Total	**30.00**
				Say	**30 lacs**
5.	Other Hoists for miscellaneous facilities such as for erection of SF_6 ducts, drainage and dewatering pumps, cooling water pumps etc.	Lot			20.00

Cost Breakup - Fire Protection System

				Rs. Lacs
Sl.No.	Items	Qty	Unit Rate	Total
1.	Fire water reservoir and pump house *comprising water storage tank, pumps,* piping etc.	Lot		25.00
2.	Hydrant System comprising pipings, indoor and outdoor hydrants, valves, hoses, nozzles etc.	Lot		60.00
3.	High Velocity Water spray system for transformers	13 sets	5.0	65.00
4.	Medium Velocity spray system for cable *galleries, cable racks*	Lot		30.00
5.	Fire Alarm System (Computerised addressable analog type) comprising smoke detectors, indication and alarm panel, relays, cables and other accessories	Lot		20.00
6.	Portable Fire Extinguishers (CO2/Foam/Halon/dry chemical powder type)	Lot		10.00
7.	Fire barrier walls, Fire proof doors	Lot (for 13 transformers)		25.00
8.	Fire station services comprising water type fire tenders, jeeps, fire suits and other accessories	Lot		30.00
9.	Fire protection system for 4 sets of generators	2 sets	5.0	10.00
10.	Set of tools and spares	Lot		5.00
11.	Fire and smoke detection system	Lot		40.00
			Total	**320.00**
				320 lacs

Cost Breakup - Ventilation System

Sl.No.		Items	Rs. Lacs
1.		Fresh air intake of 5,25,000 cmh capacity with louvres and Filters for power house complex	10.00
2.		Metallic fine air filter for main blower and transformer hall blowers	10.00
3.	a)	P.H. Blowers 3 x 200,000 cmh. and accessories (3 x 7.0 lac)	30.00
	b)	Transformer hall blowers 3 x 65000 cmh and accessories (3 x 2.00 lac)	16.00
	c)	Collection gallery blowers/BFV/Smoke exhaust/8x25000 cmh and accessories (8 x 1.5 lac)	20.00
	d)	Battery Exhaust 2 x 10000 cmh (2 x 0.50 lac)	5.00
4.	a)	Duct work	100.00
	b)	Insulation for duct work	10.00
	c)	Steel structure for duct work	15.00
5.		Motor control centres P.H/Transformer hall/others	20.00
6.		Motor operated dampers with automatic control	5.00
7.		Water/air Heat exchanger for power house and transformer hall	20.00
8.		Air grills/diffusers	12.00
9.		Cooling water piping	6.00
10.		Instrumentation	6.00
11.		Spares	7.00
12.		Tools and Instruments	3.00
13.		Miscellaneous blowers/fans	5.00
		Total	**300.00**
			300 lacs

Cost Breakup - Oil Handling System

Rs. Lacs

Sl.No.	Items	Qty	Unit Rate	Total
1.	Outdoor Station Centrifuge type, governor/lubricating oil purifier, 10000 LPH	1 set	20.00	20.00
2.	Oil storage tanks (10 m^3 Capacity) with accessories for gov/lubricating oil	2 nos	4.00	8.00
3.	Mobile centrifuge type oil purifying unit 5000 LPH for above	1 set	13.00	13.00
4.	Outdoor station type, Insulating oil treatment plant 4000 LPH for transformer oil	1 set	13.00	13.00
5.	*Mobile Insulating oil treatment plant 4000 LPH*	*2 sets*	*13.00*	*26.00*
6.	Oil storage tanks for Insulating oil (10 m^3 capacity)	2 nos	4.00	8.00
7.	Mobile oil transfer pump for filling the clean oil in drums and for transfer to tank/unit	2 nos	1.00	2.00
8.	Mobile oil tanker 1 cubic metre capacity	2 nos	2.50	5.00
9.	Special tools, devices, spares etc.	Lot		5.00
			Total	**100.00**
				100 lacs

Cost Breakup - Generator Transformers

				Rs. Lacs
Sl.No.	Items	Qty	Unit Ex-Works Price	Total
1.	Basic Cost of Transformers	13 nos	170.00	2210.00
2.	Complete set of Transformer neutral interconnecting busduct with support insulator, neutral CTs etc.	4 sets	25.00	100.00
3.	Hydraulic Jacks	1 set	2.00	2.00
4.	Chain pulley block for pulling transformer on rails	1 set	1.00	1.00
5.	On-line gas monitoring device	4 sets	10.00	40.00
6.	Spares	Lot		25.00
7.	Type test charges	Lot		5.00
8.	Supervision charges	L.S.		5.00
				2388.00
				= Rs. 197.50/kVA Say Rs. 200 / kVA

Cost Breakup - 400 kV Gas Insulated Switchgear

1.	a) Order for 6 bays of 420 kV GIS (2000A Bus bars and Feeder ratings) for Baspa - Feb' 99	14.24 MUSD	
	b) Pro-rata Cost of 11 bays of 420 kV GIS (4000 A Busbars and 2000 A Feeder ratings) for Karcham Wangtoo	$14.24 \times \frac{11}{6} \times 1.10$ * = 28.72 MUSD	(* Factor assumed for higher length and higher rating of SF_6 Busbar)
2.	a) Order for 1597 m of 420 kV, 2000 A, GIB for Baspa - Feb' 99	3.26 MUSD	
	b) Pro-rata Cost of 3500 m of 420 kV 4000 A, GIB for Karcham Wangtoo	$3.26 \times \frac{3500}{1597} \times 1.25$ ** = 8.93 MUSD	(** Factor assumed for higher rating of GIB)
	Total for GIS & GIB 1(b) + 2(b)	37.65 MUSD	
			Say 38.0 MUSD

Cost Breakup - PLCC Equipment

				Rs. Lacs
Sl.No.	Items	Qty	Unit Rate	Total
1.	PLCC Equipment for transmission of speech and protection signals and other related equipment. Each set comprising : • 3 nos. - 420 kV single phase CVT .... 9.00 • 2 nos. - 420 kV Wave Trap .... 6.00 • 1 no. - Phase to phase coupling device . 0.50 • 3 nos. - PLC terminals .... 15.00 (2 for main 1 & main 2 protection & 1 for speech/data) **30.50**	6 sets	30.50	183.00
2.	Common Items for PLCC Equipment a) HF Cable b) Telephone Exchange	 Lot 1 set		 0.50 2.50
			Total	**186.00**
				186 lacs

CHAPTER - D1

KARCHAM WANGTOO HYDRO-ELECTRIC PROJECT

CONSTRUCTION EQUIPMENT - TOTAL COST & DEPRECIATION COST OF EQUIPMENT AS ON 31.12.99

S.No.	Equipment	Equipment as Planned: Dam, Intake, Sedimentation Chambers & Flushing Conduits	Equipment as Planned: Head Race Tunnel/ Inlet Adit, Intermediate Adits # 1 to 5 & Surge Shaft Adit	Equipment as Planned: Surge Shaft, Valve Chamber & Pressure Shafts	Equipment as Planned: Power House Complex including Outlet Works	Equipment as Planned: Supporting Equipment	Total	Rate per Unit	Total Cost	Life of Equipment: Years	Life of Equipment: Hours	Life to be Utilized on Project: Years	Life to be Utilized on Project: Hours	Depreciation based on years	Depreciation based on hours	% Depriciation to be Charged to Project	Depriciation Amount to be Charged to Project	Depriciation Value on Transfer from Project
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)=(8)x(9)	(11)	(12)	(13)	(14)	(15)	(16)	(17)=(15+16)/2	(18)=(10)x(17)	(19)=(10)-(18)
1	Portable Diesel Compressors (600 Cfm)	2	7	2	2	--	13	7.50	97.50	10	12,000	6	7,200	60%	60%	60%	58.50	39.00
2	Stationary Electical Compressors (838 Cfm)	8	14	5	4	--	31	8.50	263.50	20	30,000	6	18,000	30%	60%	45%	118.58	144.93
3	Rock Drills	40	70	20	20	--	150	0.40	60.00	10	8,000	6	8,000	60%	100%	80%	48.00	12.00
4	Feed legs	40	70	20	20	--	150	0.30	45.00	10	8,000	6	8,000	60%	100%	80%	36.00	9.00
5	Truck Mounted Jumboos/ Hydraulic Platforms	4	7	2	4	--	17	10.00	170.00	10	15,000	5	7,500	50%	50%	50%	85.00	85.00
6	Blasting Equipment	4	7	2	3	--	16	1.00	16.00	5	10,000	5	8000	100%	80%	90%	14.40	1.60
7	Drilling Accessories (Lot)	4	7	2	2	--	15	10.00	150.00	--	--	--	--	--	--	100%	150.00	0.00
8	Two Boom Hydraulic Jumbos with Basket Boom	4	--	1	3	--	8	300.00	2,400.00	10	15,000	5	7,500	50%	50%	50%	1,200.00	1,200.00
9	Three Boom Hydraulic Jumbos with Basket Boom (Rocket Boom 353 F-1838)	--	12	--	--	--	12	425.00	5,100.00	10	15,000	5	7,500	50%	50%	50%	2,550.00	2,550.00
10	Rock Bolters	4	12	--	3	--	19	300.00	5,700.00	10	15,000	5	7,500	50%	50%	50%	2,850.00	2,850.00
11	Air Tracks IRCM 341 with ELV drifter for Grouting	2	--	--	--	--	2	25.00	50.00	8	8,000	4	4,000	50%	50%	50%	25.00	25.00
12	Wheel Loaders (3.5 Cum) with side dump bucket	4	12	--	3	--	19	70.00	1,330.00	10	15,000	5.4	8,100	54%	54%	54%	718.20	611.80
13	Dumpers (20 T)	30	60	8	15	--	113	40.00	4,520.00	10	16,000	4	7,600	40%	48%	44%	1,977.50	2,542.50
14	JCB Loaders/ Back Hoe	2	--	--	--	--	2	15.00	30.00	10	15,000	5.4	5,400	54%	36%	45%	13.50	16.50
15	Scoop Trams	--	--	--	2	--	2	120.00	240.00	8	9,000	3	6,000	38%	67%	52%	125.00	115.00
16	Transit Mixers (6 Cum)	16	24	6	6	--	52	25.00	1,300.00	10	10,000	5	6,000	50%	60%	55%	715.00	585.00
17	Concrete Pumps with Boom	4	--	--	3	--	7	135.00	945.00	5	8,000	4	6,000	80%	75%	78%	732.38	212.63
18	Concrete Pumps without Boom	--	6	--	--	--	6	60.00	360.00	5	8,000	4	6,000	80%	75%	78%	279.00	81.00
19	Concrete Distribution System	--	6	--	--	--	6	30.00	180.00	5	8,000	4	5,000	80%	63%	71%	128.25	51.75
20	Shutters (10 x 6 m) with Traveller	--	6	--	--	--	6	250.00	1,500.00	3	2,000	3	2,000	100%	100%	100%	1,500.00	0.00
21	Wet Shotcrete machines with Boom	4	12	2	3	--	21	135.00	2,835.00	5	6,000	4	5,000	80%	83%	82%	2,315.25	519.75
22	Wagon Drills (IRCM 341)	4	--	--	--	--	4	25.00	100.00	8	8,000	4	4,800	50%	60%	55%	55.00	45.00

S.No.	Equipment	Equipment as Planned: Dam, Intake, Sedimentation Chambers & Flushing Conduits	Head Race Tunnel/ Inlet Adit, Intermediate Adits # 1 to 5 & Surge Shaft Adit	Surge Shaft, Valve Chamber & Pressure Shafts	Power House Complex including Outlet Works	Supporting Equipment	Total	Rate per Unit	Total Cost	Life of Equipment: Years	Life of Equipment: Hours	Life to be Utilised on Project: Years	Life to be Utilised on Project: Hours	Depreciation based on years	Depreciation based on hours	% Depriciation to be Charged to Project	Depriciation Amount to be Charged to Project	Depriciation Value on Transfer from Project
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)=(8)x(9)	(11)	(12)	(13)	(14)	(15)	(16)	(17)=(15+16)/2	(18)=(10)x(17)	(19)=(10)-(18)
23	Hydraulic Excavator EX-600 (3.0 Cum)	2	--	--	--	--	2	110.00	220.00	12	15,000	6	10,000	50%	67%	58%	128.33	91.67
24	Hydraulic Excavator EX-400 (2.0 Cum)	2	--	--	--	--	2	80.00	160.00	12	15,000	6	10,000	50%	67%	58%	93.33	66.67
25	Hydraulic Excavator EX-200 (0.9 Cum)	2	--	--	3	--	5	45.00	225.00	10	12,000	6	10,000	60%	83%	72%	161.25	63.75
26	Tyre Loaders (1.5 Cum)	4	--	--	--	3	7	30.00	210.00	10	15,000	6	10,000	60%	67%	63%	133.00	77.00
27	Tippers (10 T)	20	14	8	--	15	57	7.25	413.25	8	10,000	6	10,000	75%	100%	88%	361.59	51.66
28	Batching & Mixing Plant (120 Cum/ Hr)	1	--	--	--	--	1	300.00	300.00	18	30,000	6	16,000	33%	53%	43%	130.00	170.00
29	Batching & Mixing Plant (60 Cum/ Hr)	--	--	--	1	--	1	150.00	150.00	18	30,000	6	16,000	33%	53%	43%	65.00	85.00
30	Batching & Mixing Plant (40 Cum/ Hr)	--	5	--	--	--	5	40.00	200.00	18	30,000	6	16,000	33%	53%	43%	86.67	113.33
31	Aggregate Processing Plant (500 T/ Hr)	--	--	--	--	1	1	500.00	500.00	15	30,000	5	10,000	33%	33%	33%	166.67	333.33
32	Concrete Buckets, Truck Mounted (3 Cum)	10	--	3	--	--	13	10.00	130.00	10	10,000	6	10,000	60%	100%	80%	104.00	26.00
33	Concrete Placer	--	12	2	2	--	16	5.00	80.00	8	--	6	--	75%	--	75%	60.00	20.00
34	Tower Crane (10 T @ 40 m Radius)	2	--	--	--	--	2	350.00	700.00	20	30,000	5	16,000	25%	53%	39%	274.17	425.83
35	Tower Crane (10 T @ 30 m Radius)	2	--	--	--	1	3	300.00	900.00	20	30,000	5	16,000	25%	53%	39%	352.50	547.50
36	Rubber Tyred Crane (15 T)	4	--	--	--	--	4	45.00	180.00	10	12,000	6	10,000	60%	83%	72%	129.00	51.00
37	Rubber Tyred Crane (8/ 10 T)	5	--	--	--	--	5	20.00	100.00	10	12,000	6	4,000	60%	33%	47%	46.67	53.33
38	Rubber Tyred Crane (100 T)	--	--	--	--	1	1	280.00	280.00	12	15,000	6	2,000	50%	13%	32%	88.67	191.33
39	Diesel Generating Sets 1008 KVA	--	--	--	--	6	6	Included under 'O' - Misc.										
40	Trucks (10 T)	20	21	3	--	--	44	7.00	308.00	10	200,000	6	150,000	60%	75%	68%	207.90	100.10
41	Dozer (D - 80)	3	--	--	--	--	3	46.00	138.00	8	9,000	6	9,000	75%	100%	88%	120.75	17.25
42	Dozer (D - 65)	3	7	2	--	--	12	55.00	660.00	8	9,000	6	9,000	75%	100%	88%	577.50	82.50
43	Ventilation Fans (Large)	8	27	2	8	--	45	20.00	900.00	12	--	6	--	50%	--	50%	450.00	450.00
44	Ventilation Fans (Small)	2	--	3	--	--	5	12.00	60.00	12	--	6	--	50%	--	50%	30.00	30.00
45	Ventilation Ducts incld Coupling (1.5 m Dia) (metres)	3,000	22,000	1,500	4,500	--	31,000	0.016	496.00	--	--	--	--			100%	496.00	0.00
46 (a)	Dewatering Pump (2 Cusecs 20 m Head)	20	21	2	--	--	43	1.00	43.00	8	10,000	5	5,000	63%	50%	56%	24.19	18.81
46 (b)	Dewatering Pump (1 Cusecs 20 m Head)	--	--	2	--	--	2	0.50	1.00	8	10,000	5	5,000	63%	50%	56%	0.56	0.44

S.No	Equipment	Equipment as Planned						Rate per Unit	Total Cost	Life of Equipment		Life to be Utilised on Project		Depreciation based on years	Depreciation based on hours	% Depriciation to be Charged to Project	Depriciation Amount to be Charged to Project	Depriciation Value on Transfer from Project
		Dam, Intake, Sedimentation Chambers & Flushing Conduits	Head Race Tunnel/ Inlet Adit, Intermediate Adits # 1 to 5 & Surge Shaft Adit	Surge Shaft, Valve Chamber & Pressure Shafts	Power House Complex including Outlet Works	Supporting Equipment	Total			Years	Hours	Years	Hours					
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)=(8)x(9)	(11)	(12)	(13)	(14)	(15)	(16)	(17)=(15+16)/2	(18)=(10)x(17)	(19)=(10)-(18)
46 (c)	Dewatering Pump (7 Cusecs 20 m Head)	10	--	--	--	--	10	2.50	25.00	8	10,000	5	5,000	63%	50%	56%	14.06	10.94
46 (d)	Dewatering Pump (2 Cusecs 40 m Head)	16	21	2	--	--	39	2.00	78.00	8	10,000	5	5,000	63%	50%	56%	43.88	34.13
46 (e)	Dewatering Pump (2 Cusecs 70 m Head)	4	21	2	--	--	27	3.00	81.00	8	10,000	5	5,000	63%	50%	56%	45.56	35.44
47	Crab Winches (10 T)	6	7	8	--	--	21	0.50	10.50	10	10,000	5	5,000	50%	50%	50%	5.25	5.25
48	Electrical Winches (20 T)	--	--	4	--	--	4	30.00	120.00	15	--	6	--	40%	--	40%	48.00	72.00
49	Electrical Winches (10 T)	--	--	--	--	2	2	15.00	30.00	15	--	6	--	40%	--	40%	12.00	18.00
50	Light Vehicles	--	--	--	--	60	60	Included under 'Q' - Spl T & P										
51	Buses	--	--	--	--	20	20	Included under 'Q' - Spl T & P										
52	Trailers (20 T)	--	--	--	--	4	4	18.00	72.00	12	20,000	6	10,000	50%	50%	50%	36.00	36.00
53	Trailers (70 T)	--	--	--	--	1	1	50.00	50.00	12	20,000	6	10,000	50%	50%	50%	25.00	25.00
54	Road Roller	--	--	--	--	2	2	16.00	32.00	8	10,000	6	8,000	75%	80%	78%	24.80	7.20
55	Motor Grader	--	--	--	--	2	2	50.00	100.00	10	12,000	6	8,000	60%	67%	63%	63.33	36.67
56	Portal Crane (20 T)	--	--	2	--	--	2	30.00	60.00	12	15,000	5	5,000	42%	33%	38%	22.50	37.50
57	Survey Instruments (Lot)	1	7	1	1	--	10	60.00	600.00	--	--	--	--	--	--	80%	480.00	120.00
58	Workshop Equipment (Lot)	1	7	1	1	1	11	60.00	660.00	--	--	--	--	--	--	80%	528.00	132.00
59	Garrage Equipment (Lot)	--	--	1	1	1	3	60.00	180.00	--	--	--	--	--	--	80%	144.00	36.00
60	Fabrication Shop Equipment (Lot)	1	--	--	--	--	1	60.00	60.00	--	--	--	--	--	--	80%	48.00	12.00
61 (a)	Vibrators for Concrete - 150 mm	16	--	--	--	--	16	0.50	8.00	2	2,000	2	2,000	100%	100%	100%	8.00	0.00
61 (b)	Vibrators for Concrete - Flexible Shaft	20	--	--	--	--	20	0.30	6.00	2	2,000	2	2,000	100%	100%	100%	6.00	0.00
61 (c)	Vibrators for Concrete - External (Electic)	20	60	20	20	--	120	0.30	36.00	2	2,000	2	2,000	100%	100%	100%	36.00	0.00
62	Tyre Mounted Back Hoe	2	5	2	2	--	11	50.00	550.00	10	10,000	4	10,000	40%	100%	70%	385.00	165.00
63	Raise Climber	--	--	2	--	--	2	280.00	560.00	15	18,000	3	7,500	20%	42%	31%	172.67	387.33
64	Dry Shotcrete Machine	4	14	2	2	--	22	2.00	44.00	5	6,000	5	6,000	100%	100%	100%	44.00	0.00
65	Core Drilling Machine, DIAMEC 262	2	3	--	--	1	6	90.00	540.00	8	8,000	4	5,000	50%	63%	56%	303.75	236.25
66	Grouting Equipment	6	12	4	3	--	25	20.00	500.00	10	--	4	--	40%	--	40%	200.00	300.00

S.No.	Equipment	Equipment as Planned						Rate per Unit	Total Cost	Life of Equipment		Life to be Utilised on Project		Depreciation based on years	Depreciation based on hours	% Depriciation to be Charged to Project	Depriciation Amount to be Charged to Project	Depriciation Value on Transfer from Project
		Dam, Intake, Sedimentation Chambers & Flushing Conduits	Head Race Tunnel/ Inter Adits, Intermediate Adits # 1 to 5 & Surge Shaft Adit	Surge Shaft, Valve Chamber & Pressure Shafts	Power House Complex including Outlet Works	Supporting Equipment	Total			Years	Hours	Years	Hours					
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)=(8)x(9)	(11)	(12)	(13)	(14)	(15)	(16)	(17)=(15+16)/2	(18)=(10)x(17)	(19)=(10)-(18)
67	Crawler Crane (100 T Capacity)	1	--	--	--	--	1	242.00	242.00	12	15,000	6	8,000	50%	53%	52%	125.03	116.97
68	Communication System	--	--	--	--	1	1	--	--	--	--	--	--	--	--		0.00	0.00
69	Computer System, Softwares, Printers, etc	--	--	--	--	1	1	--	--	--	--	--	--	--	--		0.00	0.00
70	Unlisted Equipment	--	--	--	--	1	1	100.00	100.00	--	--	--	--	--	--	70%	70.00	30.00
	TOTAL								39,490.75								22,873.13	16,617.62

Chapter D2

MATERIAL AND LABOUR CHARGES, SITE SUPERVISION AND OVERHEADS

(A) **Basic Cost of Materials**

Cement Ex Kalka Rs. 140.00 per bag Rs. 2,800 per tonne

Steel Ex Kalka	Rods	Rs.	15,000 per tonne
	Light structurals	Rs.	15,000 per tonne
	Plates	Rs.	20,000 per tonne
	Beams	Rs.	20,000 per tonne
	CGI Sheets	Rs.	30,000 per tonne

	Dia (mm)	25	50	80	100	150	200
GI Pipes	Cost/m (Rs.)	75	150	250	350	500	750
MS Pipes	Cost/m (Rs.)	55	120	200	325	410	700

Gelatine 80%	25-32 mm	Rs. 60,000 per tonne	including Taxes Ex Jhakri
Gelatine 60%	25-32 mm	Rs. 60,000 per tonne	including Taxes Ex Jhakri
Nonel Detonators		Rs. 120.00 per no.	
Delay Detonators (with 5 m wire length)		Rs. 15.00 per no.	
Ordinary Electric Detonators		Rs. 8.00	
Detonators (Plain caps)		Rs. 2.50 per no.	
Plywood	9 mm	Rs. 30.00 per sqft	
	12 mm	Rs. 35.00 per sqft	
Pneumatic Hoses	1/2"	Rs. 60.00 per metre	
	3/4"	Rs. 85.00 per metre	
	1"	Rs. 100.00 per metre	
	1/1/2"	Rs. 250.00 per metre	
	2"	Rs. 275.00 per metre	
Shuttering Timber		Rs. 550.00 per cft	
Diesel per litre		Rs. 15.00 at site of works (Rs. 13.65/ litre at Kalka)	
Electric Power/ Unit		Rs. 3.00 per unit	

(B) **Indirect Charges on Labour**
(As per Report of Committee on Cost Control - Vol. I - Annexure-II)

1. (i) Weekly day of Rest — 52 days per year
   (ii) Paid leave 1 day for 20 days — 18 days per year
   (iii) Casual leave — 7 days per year
   (iv) Paid holidays — 10 days per year
   Total (i + ii + iii + iv) — 87 days per year

Percentage $= \frac{87 \times 100}{278} = 31.29\ \%$

2. Retrenchment Compensation and notice pay

(i) Retrenchment Compensation	15 days per year
(ii) Notice Pay (30 days/3 year)	10 days per year
	25 days per year

$$\text{Percentage} = \frac{25 \times 100}{278} = 8.99\ \%$$

3.	Accommodation	Included under K-Buildings
4.	Travelling (annual to & fro)	10.00 %
5.	Medical expenses benefits (equivalent to one month's salary)	8.33 %
6.	Recruitment and repatriation	5.00 %
7.	Free water supply & power	3.00 %
8.	Subsidised ration	2.00 %
9.	Indirect services for mess	5.00 %
10.	Free gumboots & helmets etc.	3.00 %
11.	Bonus	8.33 %
12.	Gratuity	4.16 %
	Total	**89.11** %
	Say	**89** %

(C) **Direct Wages of various categories of Employees**

1	Unskilled mazdoor	Rs.	2,400	per month
2	Semi skilled	Rs.	2,700	per month
3	Skilled	Rs.	3,600	per month
4	Highly skilled	Rs.	4,500	per month
5	Mechanic	Rs.	5,000	per month
6	Foreman	Rs.	7,000	per month
7	Operator	Rs.	4,500	per month
8	Driver	Rs.	3,600	per month
9	Drillers	Rs.	4,500	per month
10	Blaster	Rs.	4,000	per month
11	Blacksmith	Rs.	4,000	per month
12	Fitter	Rs.	4,000	per month
13	Gas Cutter	Rs.	4,500	per month
14	Workshop foreman	Rs.	7,000	per month
15	Electrician	Rs.	4,500	per month
16	Welder	Rs.	4,500	per month

For indirect costs 89% has been added as per details given under (B).

(D) Establishment and other costs

1	Monitoring office at Delhi	Rs.	10.00	lacs per month
2	Office at Shimla / Kalka	Rs.	2.50	lacs per month
3	Supervisory staff and other staff at Wangtoo, Sholtu, Karcham and various work sites	Rs.	87.50	lacs per month
	Total	**Rs.**	**100.00**	**lacs per month**

(E) **Site Supervision and Overheads**

1	Staff salaries including indirect benefits (100 lacs x 72 months)	Rs.	7,200 lacs
2	Temporary accommodation (taken in K-Buildings)		-
3	Mess subsidy cost (taken in indirect benefits)		-
4	Recruiting and repatriation (taken in indirect benefits)		-
5	Telephone and telexes (taken in O-Miscellaneous)		-
6	Insurance (taken in O-Miscellaneous)		-
7	Direct labour (provided in rates)		-
8	Workmen compensation (taken in O-Miscellaneous)		-
9	Running of vehicles (taken in O-Miscellaneous)		-
10	Freight for transport of equipment	Rs.	600 lacs
11	Medical expenses (taken in indirect benefits)		-
12	Travelling expenses (taken in indirect benefits)		-
13	Workshop s services (7.5 lacs/month x 72 months)	Rs.	540 lacs
14	Guest house expenses (taken in O-Miscellaneous)		-
15	Free power for domestic use	Rs.	160 lacs
16	Road maintenance (taken in P - Maintenance)		-
17	Water supply (taken in O-Miscellaneous)		-
18	Advertising expenses (taken in O-Miscellaneous)		-
19	Preliminary survey (taken in A-Preliminary)		-
20	Recreation (taken in O-Miscellaneous)		-
		Rs.	**8,500 lacs**

(F) Services

a)	Compressed Air 150 mm dia					
	20 km + 2 km for Dam/m	22,000 m	x	500	=	11,000,000
b)	Dewatering					
	Dam 200 mm dia - 2 km	2,000 m	x	750	=	1,500,000
	HRT 150 mm dia - 22 km	22,000 m	x	500	=	11,000,000
	Other works L.S.	2,000 m	x	600	=	1,200,000
c)	Water Supply					
	100 mm dia - 24 km	24,000 m	x	350	=	8,400,000
	50 mm dia - 24 km	6,000 m	x	150	=	900,000
	25 mm dia - 24 km	6,000 m	x	75	=	450,000
d)	Electric Aluminium Conductor					
	With Insulator etc.	10,000 m	x	600	=	6,000,000
	Towers L.S.					6,500,000
e)	Electrical Cables					
	H.T.	22,000 m	x	1500	=	33,000,000
	L.T.	22,000 m	x	750	=	16,500,000
f)	Transformers :					
	20 no. of 1000 kVA @ 40 Lacs	400,000	x	20	=	8,000,000
g)	Electrical fixtures for power transmission L.S.					1,500,000
h)	Pipe fittings L.S.					25,000,000
				Total	Rs.	**130,950,000**
				Say		**Rs. 13.1 Crores**

CHAPTER D3

USE RATE OF CONSTRUCTION EQUIPMENT

ABSTRACT

S.No.	Item	Use rate/Hr. with Depreciation At Dec'99 price level (As per CWC Guide lines of March 1997) (Rs.)	Page No.
1.	Rocket Boomer (353F-1838)	7,670.00	D3-1
2.	Rock Bolter (435 H)	5,720.00	D3-2
3.	Scoop tram	4,150.00	D3-3
4.	Two Boom Hydraulic jumbo with basket	5,720.00	D3-4
5.	Hydraluic excavator 0.9 Cum (EX-200)	1,300.00	D3-5
6.	Hydraluic excavator 2.0 Cum (EX-400)	2,130.00	D3-6
7.	Hydraulic excavator 3.0 Cum (EX-600)	2,950.00	D3-7
8.	Tyre loader 1.5 Cum	1,130.00	D3-8
9.	Tyre loader JCB/BEML (1.15 Cum)	770.00	D3-9
10.	Crawler Dozer D80	2,220.00	D3-10
11.	Crawler Dozer D65	2,480.00	D3-11
12.	Compressor Diesel (600 Cfm)	110.00	D3-12
13.	Electrical compressor (838 Cfm)	90.00	D3-13
14.	Tata Tipper 10 T	420.00	D3-14
15.	Leyland 20 T Tipper	1,090.00	D3-15
16.	Transit mixer 6.0 Cum	890.00	D3-16
17.	Concrete pump with Boom	1,180.00	D3-17
18.	Wet shotcrete machine	4,880.00	D3-18
19.	Wagon drill	1,240.00	D3-19
20.	Air track	1,350.00	D3-20
21.	Three boom hydraulic jumbo with basket	7,670.00	D3-21
22.	Tyre loader 3.5 Cum/hr	2,750.00	D3-22

1. **Rocket Boomer**

Annual schedule production hours (12 month x 25 days/month x 1cycle/day x 4hrs/cycle)	=	1,200 Hrs
Cost of equipment (in Rs.)	=	425.00 lacs
Scheduled life in years	=	10 years
Scheduled life in hours	=	15,000 hours
Life time repair provision (as percentage of cost of equipment)	=	120 %

I. OWNERSHIP COST

Yearly depreciation (considering straight line method and 10% salvage value)

a) With reference to life in years = $\frac{42,500,000 \times 0.90}{10.00}$ = Rs. 3,825,000.00

b) With reference to life in hours = $\frac{42,500,000 \times 0.90 \times 1,200}{15,000.00}$ = Rs. 3,060,000.00

Average yearly depreciation = $\frac{3,825,000 + 3,060,000}{2}$ = Rs. 3,442,500.00

Average hourly depreciation = $\frac{3,442,500}{1,200}$ = Rs. 2,868.75

II. OPERATIONAL COST

i) Hourly repair charges = $\frac{42,500,000 \times 1.20}{15,000}$ = Rs. 3,400.00

ii) Operators & Maintenance crew charges (For 1shift/day operation)

S.No.	Operator & Maintenance crew	No.	Rate/month	Wages
	Regular			
1	Operator	2.00	4,500.00	9,000.00
2	Mechanic	0.25	5,000.00	1,250.00
3	Foreman	0.125	7,000.00	875.00
			Subtotal =	11,125.00
	Casual			
4	Helper	4.00	2,700.00	10,800.00
3	Chowkidar	0.25	2,400.00	600.00
			Subtotal =	11,400.00
	Total direct crew charges/month =			Rs. 22,525.00

Add for indirect crew cost (in Rs.) = (0.8 x 11,125 + 0.55 x 11,400)
(@ 80% of direct crew charges for regular worker = 15,170.00
and 55% of direct crew charges for casual worker)

Total crew charges/month = 22,525 + 15,170 = Rs. 37,695.00

Total crew charges/year = = Rs. 452,340.00

Hourly crew charges = $\frac{452,340.00}{1,200.00}$ = = Rs. 376.95

III. POL & Energy charges
Drive 150 HP Diesel
Electric Motor 100 HP

HSD		150.00 x 0.16 x 15.00	= Rs.	360.00
Lub. Oil	@ 25%		= Rs.	90.00
Electric Power		100.00 x 0.75 x 3.00 x 0.7	= Rs.	157.50
Hydraulic Oil for Drifter & Hydraulic Pump	L.S.		Rs.	75.00
				682.50

Rs. 682.50

IV. Misc. charges (@ 10% of hourly repair charges) = 3,400 x $\frac{10}{100}$ = Rs. 340.00

Total hourly operational cost = Rs. 4,799.45

Hourly use rate of the equipment = Rs. 7,668.20

Say Rs. 7,670.00

2. Rock Bolter (435 H)

Annual schedule production hours = 1.200 Hrs
(12 month x 25 days/month x 1cycle/day x 4hrs/cycle)

Cost of equipment (in Rs.) = 300.00 lacs
Scheduled life in years = 10 years
Scheduled life in hours = 15.000 hours
Life time repair provision = 120 %
(as percentage of cost of equipment)

I. OWNERSHIP COST
Yearly depreciation (considering straight line method and 10% salvage value)

a) With reference to life in years = $\frac{30.000.000 \times 0.90}{10.00}$ = Rs. 2.700.000.00

b) With reference to life in hours = $\frac{30.000.000 \times 0.90 \times 1.200}{15,000.00}$ = Rs. 2.160.000.00

Average yearly depreciation = $\frac{2.700.000 + 2.160.000}{2}$ = Rs. 2.430.000.00

Average hourly depreciation = $\frac{2.430.000}{1.200}$ = Rs. 2.025.00

II. OPERATIONAL COST
i) Hourly repair charges = $\frac{30.000.000 \times 1.20}{15.000}$ = Rs. 2.400.00

ii) Operators & Maintenance crew charges (For 1shift/day operation)

S.No.	Operator & Maintenance crew	No.	Rate/month	Wages
	Regular			
1	Operator	2.00	4,500.00	9,000.00
2	Mechanic	0.25	5,000.00	1,250.00
3	Foreman	0.125	7,000.00	875.00
			Subtotal =	11,125.00
	Casual			
4	Helper	4.00	2,700.00	10,800.00
3	Chowkidar	0.25	2,400.00	600.00
			Subtotal =	11,400.00
	Total direct crew charges/month =		Rs.	22,525.00

Add for indirect crew cost (in Rs.) = (0.8 x 11.125 + 0.55 x 11.400)
(@ 80% of direct crew charges for regular worker = 15,170.00
and 55% of direct crew charges for casual worker)
Total crew charges/month = 22,525 + 15,170 = Rs. 37,695.00

Total crew charges/year = = Rs. 452.340.00

Hourly crew charges = $\frac{452.340.00}{1.200.00}$ = = Rs. 376.95

III. POL & Energy charges
Drive 150 HP Diesel
Electric Motor 100 HP

HSD		150.00 x 0.16 x 15.00	= Rs. 360.00	
Lub. Oil	@ 25%		= Rs. 90.00	
Electric Power		100.00 x 0.75 x 3.00 x 0.7	= Rs. 157.50	
Hydraulic Oil for Drifter	L.S.		Rs. 75.00	
& Hydraulic Pump			682.50	Rs. 682.50

IV. Misc. charges (@ 10% of hourly repair charges) = 2.400 x $\frac{10}{100}$ = Rs. 240.00

Total hourly operational cost = Rs. 3.699.45

Hourly use rate of the equipment = Rs. 5.724.45

Say Rs. 5,720.00

3. Scoop Tram

Annual schedule production hours	=	1,200	Hrs
(12 month x 25 days/month x 1cycle/day x 4hrs/cycle)			
Cost of equipment (in Rs.)	=	120.00	lacs
Scheduled life in years	=	8	years
Scheduled life in hours	=	9,000	hours
Life time repair provision	=	175	%
(as percentage of cost of equipment)			

I. OWNERSHIP COST

Yearly depreciation (considering straight line method and 10% salvage value)

a) With reference to life in years = $\frac{12,000,000 \times 0.90}{8.00}$ = Rs. 1,350,000.00

b) With reference to life in hours = $\frac{12,000,000 \times 0.90 \times 1,200}{9,000.00}$ = Rs. 1,440,000.00

Average yearly depreciation = $\frac{1,350,000 + 1,440,000}{2}$ = Rs. 1,395,000.00

Average hourly depreciation = $\frac{1,395,000.00}{1,200.00}$ = Rs. 1,162.50

II. OPERATIONAL COST

i) Hourly repair charges = $\frac{12,000,000 \times 1.75}{9,000}$ = Rs. 2,333.33

ii) Operators & Maintenance crew charges (For 1shift/day operation)

S.No.	Operator & Maintenance crew	No.	Rate/month	Wages
	Regular			
1	Operator	1.00	4,500.00	4,500.00
2	Mechanic	0.25	5,000.00	1,250.00
3	Foreman	0.125	7,000.00	875.00
			Subtotal =	6,625.00
	Casual			
4	Helper	1.00	2,700.00	2,700.00
3	Chowkidar	0.25	2,400.00	600.00
			Subtotal =	3,300.00
	Total direct crew charges/month =		Rs.	9,925.00

Add for indirect crew cost (in Rs.) = (0.8 x 6,625 + 0.55 x 3,300)
(@ 80% of direct crew charges for regular worker = 7,115.00
and 55% of direct crew charges for casual worker)

Total crew charges/month = 9,925 + 7,115 = Rs. 17,040.00

Total crew charges/year = = Rs. 204,480.00

Hourly crew charges = $\frac{204,480.00}{1,200.00}$ = = Rs. 170.40

III. POL & Energy charges

82 HP	82.00 x 0.16 x 15.00	= Rs. 196.80	
Lub. Oil	@ 25%	= Rs. 49.20	
		246.00	Rs. 246.00

IV. Misc. charges (@ 10% of hourly repair charges) = 2.333 x $\frac{10}{100}$ = Rs. 233.33

Total hourly operational cost = Rs. 2,983.07

Hourly use rate of the equipment = Rs. 4,145.57

Say Rs. 4,150.00

4. Two Boom Hydraulic Jumbo with Basket

Annual schedule production hours (12 month x 25 days/month x 1cycle/day x 4hrs/cycle)	=	1,200	Hrs
Cost of equipment (in Rs.)	=	300.00	lacs
Scheduled life in years	=	10	years
Scheduled life in hours	=	15,000	hours
Life time repair provision (as percentage of cost of equipment)	=	120	%

I. OWNERSHIP COST

Yearly depreciation (considering straight line method and 10% salvage value)

a) With reference to life in years = $\frac{30,000,000 \times 0.90}{10.00}$ = Rs. 2,700,000.00

b) With reference to life in hours = $\frac{30,000,000 \times 0.90 \times 1,200}{15,000.00}$ = Rs. 2,160,000.00

Average yearly depreciation = $\frac{2,700,000 + 2,160,000}{2}$ = Rs. 2,430,000.00

Average hourly depreciation = $\frac{2,430,000.00}{1,200.00}$ = Rs. 2,025.00

II. OPERATIONAL COST

i) Hourly repair charges = $\frac{30,000,000 \times 1.20}{15,000}$ = Rs. 2,400.00

ii) Operators & Maintenance crew charges (For 1shift/day operation)

S.No.	Operator & Maintenance crew	No.	Rate/month	Wages
	Regular			
1	Operator	2.00	4,500.00	9,000.00
2	Mechanic	0.25	5,000.00	1,250.00
3	Foreman	0.125	7,000.00	875.00
			Subtotal =	11,125.00
	Casual			
4	Helper	4.00	2,700.00	10,800.00
3	Chowkidar	0.25	2,400.00	600.00
			Subtotal =	11,400.00
	Total direct crew charges/month =		Rs.	22,525.00

Add for indirect crew cost (in Rs.) (@ 80% of direct crew charges for regular worker and 55% of direct crew charges for casual worker) = (0.8 x 11,125 + 0.55 x 11,400) = 15,170.00

Total crew charges/month = 22,525 + 15,170 = Rs. 37,695.00

Total crew charges/year = = Rs. 452,340.00

Hourly crew charges = $\frac{452,340.00}{1,200.00}$ = = Rs. 376.95

III. POL & Energy charges
Drive 150 HP Diesel
Electric Motor 100 HP

HSD		150.00 x	0.16 x	15.00		= Rs.	360.00
Lub. Oil	@ 25%					= Rs.	90.00
Electric Power		100.00 x	0.75 x	3.00 x	0.7	= Rs.	157.50
Hydraulic Oil for Drifter & Hydraulic Pump	L.S.					Rs.	75.00
							682.50

Rs. 682.50

IV. Misc. charges (@ 10% of hourly repair charges) = $2,400 \times \frac{10}{100}$ = Rs. 240.00

Total hourly operational cost = Rs. 3,699.45

Hourly use rate of the equipment = Rs. 5,724.45

Say Rs. 5,720.00

5. Hydraulic Excavator 0.9 m^3 (EX-200)

Annual schedule production hours (12 month x 25 days/month x 1cycle/day x 4hrs/cycle)	=	1.200	Hrs
Cost of equipment (in Rs.)	=	45.00	lacs
Scheduled life in years	=	10	years
Scheduled life in hours	=	12,000	hours
Life time repair provision (as percentage of cost of equipment)	=	100	%

I. OWNERSHIP COST

Yearly depreciation (considering straight line method and 10% salvage value)

a) With reference to life in years = $\frac{4.500.000 \times 0.90}{10.00}$ = Rs. 405.000.00

b) With reference to life in hours = $\frac{4.500.000 \times 0.90 \times 1.200}{12.000.00}$ = Rs. 405.000.00

Average yearly depreciation = $\frac{405.000 + 405.000}{2}$ = Rs. 405.000.00

Average hourly depreciation = $\frac{405.000.00}{1.200.00}$ = Rs. 337.50

II. OPERATIONAL COST

i) Hourly repair charges = $\frac{4.500.000 \times 1.00}{12.000}$ = Rs. 375.00

ii) Operators & Maintenance crew charges (For 1shift/day operation)

S.No.	Operator & Maintenance crew	No.	Rate/month	Wages
	Regular			
1	Operator	1.00	4,500.00	4,500.00
2	Mechanic	0.25	5,000.00	1,250.00
3	Foreman	0.25	7,000.00	1,750.00
			Subtotal =	7,500.00
	Casual			
4	Helper	1.00	2,700.00	2,700.00
3	Chowkidar	0.25	2.400.00	600.00
			Subtotal =	3,300.00
	Total direct crew charges/month =		Rs.	10,800.00

Add for indirect crew cost (in Rs.) = (0.8 x 7.500 + 0.55 x 3.300)

(@ 80% of direct crew charges for regular worker = 7.815.00

and 55% of direct crew charges for casual worker)

Total crew charges/month = 10.800 + 7.815 = Rs. 18,615.00

Total crew charges/year = = Rs. 223,380.00

Hourly crew charges = $\frac{223.380.00}{1.200.00}$ = = Rs. 186.15

III. POL & Energy charges

HSD 120 H.P. 120.00 x 0.16 x 15.00 = Rs. 288.00

Lub. Oil @ 25% = Rs. 72.00

360.00 Rs. 360.00

IV. Misc. charges (@ 10% of hourly repair charges) = 375 x $\frac{10}{100}$ = Rs. 37.50

Total hourly operational cost = Rs. 958.65

Hourly use rate of the equipment = Rs. 1,296.15

Say Rs. 1,300.00

6. Hydraulic Excavator 2.0 m³ (EX-400)

Annual schedule production hours (12 month x 25 days/month x 1cycle/day x 4hrs/cycle)	=	1.200	Hrs
Cost of equipment (in Rs.)	=	80.00	lacs
Scheduled life in years	=	12	years
Scheduled life in hours	=	15.000	hours
Life time repair provision (as percentage of cost of equipment)	=	125	%

I. OWNERSHIP COST

Yearly depreciation (considering straight line method and 10% salvage value)

a) With reference to life in years = $\frac{8.000.000 \times 0.90}{12.00}$ = Rs. 600.000.00

b) With reference to life in hours = $\frac{8.000.000 \times 0.90 \times 1.200}{15.000.00}$ = Rs. 576.000.00

Average yearly depreciation = $\frac{600.000 + 576.000}{2}$ = Rs. 588.000.00

Average hourly depreciation = $\frac{588.000.00}{1.200.00}$ = Rs. 490.00

II. OPERATIONAL COST

i) Hourly repair charges = $\frac{8.000.000 \times 1.25}{15,000}$ = Rs. 666.67

ii) Operators & Maintenance crew charges (For 1shift/day operation)

S.No.	Operator & Maintenance crew	No.	Rate/month	Wages
	Regular			
1	Operator	1.00	4,500.00	4.500.00
2	Mechanic	0.25	5,000.00	1,250.00
3	Foreman	0.25	7,000.00	1,750.00
			Subtotal =	7,500.00
	Casual			
4	Helper	1.00	2,700.00	2,700.00
3	Chowkidar	0.25	2,400.00	600.00
			Subtotal =	3,300.00
	Total direct crew charges/month =			Rs. 10.800.00

Add for indirect crew cost (in Rs.) = (0.8 x 7.500 + 0.55 x 3.300)
(@ 80% of direct crew charges for regular worker = 7.815.00
and 55% of direct crew charges for casual worker)

Total crew charges/month = 10.800 + 7.815 = Rs. 18.615.00

Total crew charges/year = = Rs. 223.380.00

Hourly crew charges = $\frac{223.380.00}{1.200.00}$ = = Rs. 186.15

III. POL & Energy charges

HSD 240 H.P. 240.00 x 0.16 x 15.00 = Rs. 576.00

Lub. Oil @ 25% = Rs. 144.00

720.00 Rs. 720.00

IV. Misc. charges (@ 10% of hourly repair charges) = $667 \times \frac{10}{100}$ = Rs. 66.67

Total hourly operational cost = Rs. 1.639.48

Hourly use rate of the equipment = Rs. 2,129.48

Say Rs. 2,130.00

7. Hydraulic Excavator 3.0 m^3 (EX-600)

Annual schedule production hours (12 month x 25 days/month x 1cycle/day x 4hrs/cycle)	=	1.200 Hrs
Cost of equipment (in Rs.)	=	110.00 lacs
Scheduled life in years	=	12 years
Scheduled life in hours	=	15,000 hours
Life time repair provision (as percentage of cost of equipment)	=	125 %

I. OWNERSHIP COST

Yearly depreciation (considering straight line method and 10% salvage value)

a) With reference to life in years = $\frac{11.000.000 \times 0.90}{12.00}$ = Rs. 825.000.00

b) With reference to life in hours = $\frac{11.000.000 \times 0.90 \times 1.200}{15.000.00}$ = Rs. 792.000.00

Average yearly depreciation = $\frac{825.000 + 792.000}{2}$ = Rs. 808.500.00

Average hourly depreciation = $\frac{808.500.00}{1.200.00}$ = Rs. 673.75

II. OPERATIONAL COST

i) Hourly repair charges = $\frac{11.000.000 \times 1.25}{15,000}$ = Rs. 916.67

ii) Operators & Maintenance crew charges (For 1shift/day operation)

No.	Operator & Maintenance crew	No.	Rate/month	Wages
	Regular			
1	Operator	1.00	4,500.00	4,500.00
2	Mechanic	0.25	5,000.00	1,250.00
3	Foreman	0.25	7,000.00	1,750.00
			Subtotal =	7,500.00
	Casual			
4	Helper	1.00	2,700.00	2,700.00
3	Chowkidar	0.25	2,400.00	600.00
			Subtotal =	3,300.00
	Total direct crew charges/month =		Rs.	10.800.00

Add for indirect crew cost (in Rs.) = (0.8 x 7.500 + 0.55 x 3,300)
(@ 80% of direct crew charges for regular worker = 7.815.00
and 55% of direct crew charges for casual worker)

Total crew charges/month = 10,800 + 7.815 = Rs. 18.615.00

Total crew charges/year = = Rs. 223.380.00

Hourly crew charges = $\frac{223.380.00}{1.200.00}$ = = Rs. 186.15

III. POL & Energy charges

HSD 360 H.P. 360.00 x 0.16 x 15.00 = Rs. 864.00

Lub. Oil @ 25% = Rs. 216.00

Rs. 1.080.00

IV. Misc. charges (@ 10% of hourly repair charges) = 917 x $\frac{10}{100}$ = Rs. 91.67

Total hourly operational cost = Rs. 2.274.48

Hourly use rate of the equipment = Rs. 2.948.23

Say Rs. 2,950.00

8. Tyre Loader 1.5 m^3

Annual schedule production hours = 1,200 Hrs
(12 month x 25 days/month x 1cycle/day x 4hrs/cycle)

Cost of equipment (in Rs.) = 30.00 lacs
Scheduled life in years = 10 years
Scheduled life in hours = 15,000 hours
Life time repair provision = 200 %
(as percentage of cost of equipment)

I. OWNERSHIP COST
Yearly depreciation (considering straight line method and 10% salvage value)

a) With reference to life in years = $\frac{3,000,000 \times 0.90}{10.00}$ = Rs. 270,000.00

b) With reference to life in hours = $\frac{3,000,000 \times 0.90 \times 1,200}{15,000.00}$ = Rs. 216,000.00

Average yearly depreciation = $\frac{270,000 + 216,000}{2}$ = Rs. 243,000.00

Average hourly depreciation = $\frac{243,000.00}{1,200.00}$ = Rs. 202.50

II. OPERATIONAL COST
i) Hourly repair charges = $\frac{3,000,000 \times 2.00}{15,000}$ = Rs. 400.00

ii) Operators & Maintenance crew charges (For 1shift/day operation)

S.No.	Operator & Maintenance crew	No.	Rate/month	Wages
	Regular			
1	Operator	1.00	4,500.00	4,500.00
2	Mechanic	0.25	5,000.00	1,250.00
3	Foreman	0.125	7,000.00	875.00
			Subtotal =	6,625.00
	Casual			
4	Helper	1.00	2,700.00	2,700.00
3	Chowkidar	0.16	2,400.00	384.00
			Subtotal =	3,084.00
	Total direct crew charges/month =		Rs.	9,709.00

Add for indirect crew cost (in Rs.) = (0.8 x 6,625 + 0.55 x 3,084)
(@ 80% of direct crew charges for regular worker = 6,996.20
and 55% of direct crew charges for casual worker)
Total crew charges/month = 9,709 + 6,996 = Rs. 16,705.20

Total crew charges/year = = Rs. 200,462.40

Hourly crew charges = $\frac{200,462.40}{1,200.00}$ = = Rs. 167.05

III. POL & Energy charges
HSD 17 Litre 17.00 x 15.00 = Rs. 255.00
Lub. Oil @ 25% = Rs. 63.75
318.75 Rs. 318.75

IV. Misc. charges (@ 10% of hourly repair charges) = 400 x $\frac{10}{100}$ = Rs. 40.00

Total hourly operational cost = Rs. 925.80

Hourly use rate of the equipment = Rs. 1,128.30

Say Rs. 1,130.00

9. Tyre Loader JCB/BEML (1.15 m³)

Annual schedule production hours	=	1.200	Hrs
(12 month x 25 days/month x 1cycle/day x 4hrs/cycle)			
Cost of equipment (in Rs.)	=	15.00	lacs
Scheduled life in years	=	10	years
Scheduled life in hours	=	15,000	hours
Life time repair provision	=	200	%
(as percentage of cost of equipment)			

I. OWNERSHIP COST

Yearly depreciation (considering straight line method and 10% salvage value)

a) With reference to life in years = $\frac{1.500.000 \times 0.90}{10.00}$ = Rs. 135.000.00

b) With reference to life in hours = $\frac{1.500.000 \times 0.90 \times 1.200}{15.000.00}$ = Rs. 108,000.00

Average yearly depreciation = $\frac{135.000 + 108.000}{2}$ = Rs. 121,500.00

Average hourly depreciation = $\frac{121.500.00}{1.200.00}$ = Rs. 101.25

II. OPERATIONAL COST

i) Hourly repair charges = $\frac{1.500.000 \times 2.00}{15.000}$ = Rs. 200.00

ii) Operators & Maintenance crew charges (For 1shift/day operation)

S.No.	Operator & Maintenance crew	No.	Rate/month	Wages
	Regular			
1	Operator	1.00	4,500.00	4,500.00
2	Mechanic	0.25	5,000.00	1,250.00
3	Foreman	0.125	7,000.00	875.00
			Subtotal =	6,625.00
	Casual			
4	Helper	1.00	2,700.00	2,700.00
3	Chowkidar	0.16	2,400.00	384.00
			Subtotal =	3,084.00
	Total direct crew charges/month =		Rs.	9,709.00

Add for indirect crew cost (in Rs.) = (0.8 x 6,625 + 0.55 x 3,084)
(@ 80% of direct crew charges for regular worker = 6,996.20
and 55% of direct crew charges for casual worker)

Total crew charges/month = 9,709 + 6,996 = Rs. 16,705.20

Total crew charges/year = = Rs. 200,462.40

Hourly crew charges = $\frac{200.462.40}{1.200.00}$ = = Rs. 167.05

III. POL & Energy charges

HSD 15 Litre		15.00 x 15.00	= Rs. 225.00	
Lub. Oil	@ 25%		= Rs. 56.25	
			281.25	Rs. 281.25

IV. Misc. charges (@ 10% of hourly repair charges) = 200 x $\frac{10}{100}$ = Rs. 20.00

Total hourly operational cost = Rs. 668.30

Hourly use rate of the equipment = Rs. 769.55

Say Rs. 770.00

10. Crawler Dozer D80 A12

Annual schedule production hours (12 month x 25 days/month x 1cycle/day x 4hrs/cycle)	=	1.200	Hrs
Cost of equipment (in Rs.)	=	46.00	lacs
Scheduled life in years	=	8	years
Scheduled life in hours	=	9.000	hours
Life time repair provision (as percentage of cost of equipment)	=	200	%

I. OWNERSHIP COST

Yearly depreciation (considering straight line method and 10% salvage value)

a) With reference to life in years = $\frac{4.600.000 \times 0.90}{8.00}$ = Rs. 517.500.00

b) With reference to life in hours = $\frac{4.600.000 \times 0.90 \times 1.200}{9,000.00}$ = Rs. 552.000.00

Average yearly depreciation = $\frac{517.500 + 552.000}{2}$ = Rs. 534,750.00

Average hourly depreciation = $\frac{534,750.00}{1.200.00}$ = Rs. 445.63

II. OPERATIONAL COST

i) Hourly repair charges = $\frac{4.600.000 \times 2.00}{9.000}$ = Rs. 1.022.22

ii) Operators & Maintenance crew charges (For 1shift/day operation)

S.No.	Operator & Maintenance crew	No.	Rate/month	Wages
	Regular			
1	Operator	1.00	4,500.00	4,500.00
2	Mechanic	0.25	5,000.00	1.250.00
3	Foreman	0.25	7,000.00	1,750.00
			Subtotal =	7,500.00
	Casual			
4	Helper	1.00	2,700.00	2,700.00
3	Chowkidar	0.25	2,400.00	600.00
			Subtotal =	3,300.00
	Total direct crew charges/month =		Rs.	10,800.00

Add for indirect crew cost (in Rs.) = (0.8 x 7,500 + 0.55 x 3,300)
(@ 80% of direct crew charges for regular worker = 7,815.00
and 55% of direct crew charges for casual worker)

Total crew charges/month = 10,800 + 7,815 = Rs. 18,615.00

Total crew charges/year = = Rs. 223,380.00

Hourly crew charges = $\frac{223.380.00}{1,200.00}$ = = Rs. 186.15

III. POL & Energy charges

HSD 25 Litre		25.00 x 15.00	= Rs. 375.00	
Lub. Oil	@ 25%		= Rs. 93.75	
			468.75	Rs. 468.75

IV. Misc. charges (@ 10% of hourly repair charges) = 1.022 x $\frac{10}{100}$ = Rs. 102.22

Total hourly operational cost = Rs. 1.779.34

Hourly use rate of the equipment = Rs. 2.224.97

Say Rs. 2,220.00

11. Crawler Dozer D65

Annual schedule production hours (12 month x 25 days/month x 1cycle/day x 4hrs/cycle)	=	1,200	Hrs
Cost of equipment (in Rs.)	=	55.00	lacs
Scheduled life in years	=	8	years
Scheduled life in hours	=	9,000	hours
Life time repair provision (as percentage of cost of equipment)	=	200	%

I. OWNERSHIP COST

Yearly depreciation (considering straight line method and 10% salvage value)

a) With reference to life in years = $\frac{5,500,000 \times 0.90}{8.00}$ = Rs. 618,750.00

b) With reference to life in hours = $\frac{5,500,000 \times 0.90 \times 1,200}{9,000.00}$ = Rs. 660,000.00

Average yearly depreciation = $\frac{618,750 + 660,000}{2}$ = Rs. 639,375.00

Average hourly depreciation = $\frac{639,375.00}{1,200.00}$ = Rs. 532.81

II. OPERATIONAL COST

i) Hourly repair charges = $\frac{5,500,000 \times 2.00}{9,000}$ = Rs. 1,222.22

ii) Operators & Maintenance crew charges (For 1shift/day operation)

S.No.	Operator & Maintenance crew	No.	Rate/month	Wages
	Regular			
1	Operator	1.00	4,500.00	4,500.00
2	Mechanic	0.25	5,000.00	1,250.00
3	Foreman	0.25	7,000.00	1,750.00
			Subtotal =	7,500.00
	Casual			
4	Helper	1.00	2,700.00	2,700.00
3	Chowkidar	0.25	2,400.00	600.00
			Subtotal =	3,300.00
	Total direct crew charges/month =		Rs.	10,800.00

Add for indirect crew cost (in Rs.) = (0.8 x 7,500 + 0.55 x 3,300)
(@ 80% of direct crew charges for regular worker = 7,815.00
and 55% of direct crew charges for casual worker)

Total crew charges/month = 10,800 + 7,815 = Rs. 18,615.00

Total crew charges/year = = Rs. 223,380.00

Hourly crew charges = $\frac{223,380.00}{1,200.00}$ = = Rs. 186.15

III. POL & Energy charges

HSD 22 Litre		22.00 x 15.00	= Rs. 330.00	
Lub. Oil	@ 25%		= Rs. 82.50	
			412.50	Rs. 412.50

IV. Misc. charges (@ 10% of hourly repair charges) = 1,222 x $\frac{10}{100}$ = Rs. 122.22

Total hourly operational cost = Rs. 1,943.09

Hourly use rate of the equipment = Rs. 2,475.91

Say Rs. 2,480.00

12. Compressor Diesel (600 cfm)

Annual schedule production hours (12 month x 25 days/month x 1cycle/day x 4hrs/cycle)	=	1,200	Hrs
Cost of equipment (in Rs.)	=	7.50	lacs
Scheduled life in years	=	10	years
Scheduled life in hours	=	12,000	hours
Life time repair provision (as percentage of cost of equipment)	=	100	%

I. OWNERSHIP COST

Yearly depreciation (considering straight line method and 10% salvage value)

a) With reference to life in years = $\frac{750,000 \times 0.90}{10.00}$ = Rs. 67,500.00

b) With reference to life in hours = $\frac{750,000 \times 0.90 \times 1,200}{12,000.00}$ = Rs. 67,500.00

Average yearly depreciation = $\frac{67,500 + 67,500}{2}$ = Rs. 67,500.00

Average hourly depreciation = $\frac{67,500.00}{1,200.00}$ = Rs. 56.25

II. OPERATIONAL COST

i) Hourly repair charges = $\frac{750,000 \times 1.00}{12,000}$ = Rs. 62.50

ii) Operators & Maintenance crew charges (For 1shift/day operation)

S.No.	Operator & Maintenance crew	No.	Rate/month	Wages
	Regular			
1	Operator	1.00	4,500.00	4,500.00
2	Mechanic	0.25	5,000.00	1,250.00
3	Foreman	0.125	7,000.00	875.00
			Subtotal =	6,625.00
	Casual			
4	Helper	1.00	2,700.00	2,700.00
3	Chowkidar	0.25	2,400.00	600.00
			Subtotal =	3,300.00
	Total direct crew charges/month =		Rs.	9,925.00

Add for indirect crew cost (in Rs.) = (0.8 x 6,625 + 0.55 x 3,300)

(@ 80% of direct crew charges for regular worker = 7,115.00

and 55% of direct crew charges for casual worker)

Total crew charges/month = 9,925 + 7,115 = Rs. 17,040.00

Total crew charges/year = = Rs. 204,480.00

Hourly crew charges = $\frac{204,480.00}{1,200.00}$ = = Rs. 170.40

III. POL & Energy charges

HSD 20 Litre		20.00 x 15.00	= Rs. 300.00	
Lub. Oil	@ 25%		= Rs. 75.00	
			375.00	Rs. 375.00

IV. Misc. charges (@ 10% of hourly repair charges) = 63 x $\frac{10}{100}$ = Rs. 6.25

Total hourly operational cost = Rs. 614.15

Hourly use rate of the equipment = Rs. 670.40

Cost/100 cfm = $\frac{670.40}{6.00}$ = 111.73 **Say Rs. 110.00**

13. Electrical Compressor (838 cfm)

Annual schedule production hours (12 month x 25 days/month x 1cycle/day x 4hrs/cycle)	=	1.200	Hrs
Cost of equipment (in Rs.)	=	8.50	lacs
Scheduled life in years	=	20	years
Scheduled life in hours	=	30.000	hours
Life time repair provision (as percentage of cost of equipment)	=	80	%

I. OWNERSHIP COST

Yearly depreciation (considering straight line method and 10% salvage value)

a) With reference to life in years = $\frac{850.000 \times 0.90}{20.00}$ = Rs. 38.250.00

b) With reference to life in hours = $\frac{850.000 \times 0.90 \times 1.200}{30.000.00}$ = Rs. 30.600.00

Average yearly depreciation = $\frac{38.250 + 30.600}{2}$ = Rs. 34.425.00

Average hourly depreciation = $\frac{34.425.00}{1.200.00}$ = Rs. 28.69

II. OPERATIONAL COST

i) Hourly repair charges = $\frac{850.000 \times 0.80}{30.000}$ = Rs. 22.67

ii) Operators & Maintenance crew charges (For 1shift/day operation)

S.No.	Operator & Maintenance crew	No.	Rate/month	Wages
	Regular			
1	Operator	1.00	4.500.00	4.500.00
2	Mechanic	0.25	5.000.00	1.250.00
3	Foreman	0.125	7.000.00	875.00
4	Electrician	0.500	4.500.00	2.250.00
			Subtotal =	8.875.00
	Casual			
5	Helper	1.00	2.700.00	2.700.00
6	Chowkidar	0.25	2,400.00	600.00
			Subtotal =	3.300.00
	Total direct crew charges/month =		Rs.	12.175.00

Add for indirect crew cost (in Rs.) = (0.8 x 8,875 + 0.55 x 3.300)
(@ 80% of direct crew charges for regular worker = 8,915.00
and 55% of direct crew charges for casual worker)

Total crew charges/month = 12.175 + 8,915 = Rs. 21.090.00

Total crew charges/year = = Rs. 253.080.00

Hourly crew charges = $\frac{253.080.00}{1.200.00}$ = = Rs. 210.90

III. POL & Energy charges

Power 160 KW 160.00 x 3.00 x 0.8 = Rs. 384.00

Lub. Oil @ 25% = Rs. 96.00

480.00 Rs. 480.00

IV. Misc. charges (@ 10% of hourly repair charges) = 23 x $\frac{10}{100}$ = Rs. 2.27

Total hourly operational cost = Rs. 715.83

Hourly use rate of the equipment = Rs. 744.52

Cost/100 cfm = $\frac{744.52}{8.38}$ = 88.84 **Say Rs. 90.00**

14. Tata Tipper 10 T

Annual schedule production hours (12 month x 25 days/month x 1cycle/day x 4hrs/cycle)	=	1.200	Hrs
Cost of equipment (in Rs.)	=	7.25	lacs
Scheduled life in years	=	8	years
Scheduled life in hours	=	10,000	hours
Life time repair provision (as percentage of cost of equipment)	=	175	%

I. OWNERSHIP COST

Yearly depreciation (considering straight line method and 10% salvage value)

a) With reference to life in years = $\frac{725.000 \times 0.90}{8.00}$ = Rs. 81.562.50

b) With reference to life in hours = $\frac{725.000 \times 0.90 \times 1.200}{10.000.00}$ = Rs. 78,300.00

Average yearly depreciation = $\frac{81.563 + 78.300}{2}$ = Rs. 79,931.25

Average hourly depreciation = $\frac{79.931.25}{1,200.00}$ = Rs. 66.61

II. OPERATIONAL COST

i) Hourly repair charges = $\frac{725.000 \times 1.75}{10,000}$ = Rs. 126.88

ii) Operators & Maintenance crew charges (For 1shift/day operation)

S.No.	Operator & Maintenance crew	No.	Rate/month	Wages
	Regular			
1	Driver	1.00	3,600.00	3,600.00
2	Mechanic	0.125	5,000.00	625.00
3	Foreman	0.000	7,000.00	0.00
			Subtotal =	4,225.00
	Casual			
4	Helper	1.00	2,700.00	2,700.00
3	Chowkidar	0.16	2,400.00	384.00
			Subtotal =	3,084.00
	Total direct crew charges/month =		Rs.	7,309.00

Add for indirect crew cost (in Rs.) = (0.8 x 4,225 + 0.55 x 3,084)
(@ 80% of direct crew charges for regular worker = 5,076.20
and 55% of direct crew charges for casual worker)

Total crew charges/month = 7,309 + 5,076 = Rs. 12,385.20

Total crew charges/year = = Rs. 148,622.40

Hourly crew charges = $\frac{148,622.40}{1,200.00}$ = = Rs. 123.85

III. POL & Energy charges

HSD 5 Litre		5.00 x	15.00	= Rs.	75.00	
Lub. Oil	@ 25%			= Rs.	18.75	
					93.75	Rs. 93.75

IV. Misc. charges (@ 10% of hourly repair charges) = 127 x $\frac{10}{100}$ = Rs. 12.69

Total hourly operational cost	= Rs.	357.16
Hourly use rate of the equipment	= Rs.	423.77
	Say Rs.	**420.00**
use rate of the equipment PER KM (15 KM PER HOUR)	= Rs.	28.25
	Say Rs.	**30.00**

15. Leyland 20 T Tipper

Annual schedule production hours = 1.200 Hrs
(12 month x 25 days/month x 1cycle/day x 4hrs/cycle)

Cost of equipment (in Rs.) = 40.00 lacs
Scheduled life in years = 10 years
Scheduled life in hours = 16.000 hours
Life time repair provision = 175 %
(as percentage of cost of equipment)

I. OWNERSHIP COST

Yearly depreciation (considering straight line method and 10% salvage value)

a) With reference to life in years = $\frac{4.000.000 \times 0.90}{10.00}$ = Rs. 360,000.00

b) With reference to life in hours = $\frac{4.000.000 \times 0.90 \times 1.200}{16.000.00}$ = Rs. 270.000.00

Average yearly depreciation = $\frac{360.000 + 270.000}{2}$ = Rs. 315.000.00

Average hourly depreciation = $\frac{315.000.00}{1.200.00}$ = Rs. 262.50

II. OPERATIONAL COST

i) Hourly repair charges = $\frac{4.000.000 \times 1.75}{16.000}$ = Rs. 437.50

ii) Operators & Maintenance crew charges (For 1shift/day operation)

S.No.	Operator & Maintenance crew	No.	Rate/month	Wages
	Regular			
1	Operator	1.00	4,500.00	4,500.00
2	Mechanic	0.125	5,000.00	625.00
3	Foreman	0.125	7,000.00	875.00
			Subtotal =	6,000.00
	Casual			
4	Helper	1.00	2,700.00	2,700.00
3	Chowkidar	0.16	2,400.00	384.00
			Subtotal =	3,084.00
	Total direct crew charges/month =		Rs.	9,084.00

Add for indirect crew cost (in Rs.) = (0.8 x 6,000 + 0.55 x 3,084)
(@ 80% of direct crew charges for regular worker = 6.496.20
and 55% of direct crew charges for casual worker)
Total crew charges/month = 9,084 + 6,496 = Rs. 15,580:20

Total crew charges/year = = Rs. 186.962.40

Hourly crew charges = $\frac{186.962.40}{1.200.00}$ = = Rs. 155.80

III. POL & Energy charges
HSD 10 Litre 10.00 x 15.00 = Rs. 150.00
Lub. Oil @ 25% = Rs. 37.50
187.50 Rs. 187.50

IV. Misc. charges (@ 10% of hourly repair charges) = 438 x $\frac{10}{100}$ = Rs. 43.75

Total hourly operational cost = Rs. 824.55

Hourly use rate of the equipment = Rs. 1.087.05
Say Rs. **1,090.00**

use rate of the equipment PER KM = Rs. 72.47
(15 KM PER HOUR)

Say Rs. 70.00

16. Transit Mixer 6 m^3

Annual schedule production hours = 1.200 Hrs
(12 month x 25 days/month x 1cycle/day x 4hrs/cycle)

Cost of equipment (in Rs.) = 25.00 lacs
Scheduled life in years = 10 years
Scheduled life in hours = 10.000 hours
Life time repair provision = 120 %
(as percentage of cost of equipment)

I. OWNERSHIP COST
Yearly depreciation (considering straight line method and 10% salvage value)

a) With reference to life in years = $\frac{2.500.000 \times 0.90}{10.00}$ = Rs. 225.000.00

b) With reference to life in hours = $\frac{2.500.000 \times 0.90 \times 1.200}{10.000.00}$ = Rs. 270.000.00

Average yearly depreciation = $\frac{225.000 + 270.000}{2}$ = Rs. 247.500.00

Average hourly depreciation = $\frac{247.500.00}{1.200.00}$ = Rs. 206.25

II. OPERATIONAL COST
i) Hourly repair charges = $\frac{2.500.000 \times 1.20}{10,000}$ = Rs. 300.00

ii) Operators & Maintenance crew charges (For 1shift/day operation)

S.No.	Operator & Maintenance crew	No.	Rate/month	Wages
	Regular			
1	Operator	1.00	4,500.00	4,500.00
2	Mechanic	0.25	5,000.00	1,250.00
3	Foreman	0.125	7,000.00	875.00
			Subtotal =	6,625.00
	Casual			
4	Helper	1.00	2,700.00	2,700.00
3	Chowkidar	0.25	2,400.00	600.00
			Subtotal =	3,300.00
	Total direct crew charges/month =		Rs.	9,925.00

Add for indirect crew cost (in Rs.) = (0.8 x 6.625 + 0.55 x 3,300)
(@ 80% of direct crew charges for regular worker = 7,115.00
and 55% of direct crew charges for casual worker)
Total crew charges/month = 9.925 + 7.115 = Rs. 17.040.00

Total crew charges/year = = Rs. 204.480.00

Hourly crew charges = $\frac{204.480.00}{1.200.00}$ = = Rs. 170.40

III. POL & Energy charges
HSD 10 Litre 10.00 x 15.00 = Rs. 150.00
Lub. Oil @ 25% = Rs. 37.50
187.50 Rs. 187.50

IV. Misc. charges (@ 10% of hourly repair charges) = 300 x $\frac{10}{100}$ = Rs. 30.00

Total hourly operational cost = Rs. 687.90

Hourly use rate of the equipment = Rs. 894.15

Say Rs. 890.00

use rate of the equipment PER KM = Rs. 59.33
(15 KM PER HOUR)

Say Rs. 60.00

17. Concrete Pump with Boom

Annual schedule production hours (12 month x 25 days/month x 1cycle/day x 4hrs/cycle)	=	1,200	Hrs
Cost of equipment (in Rs.)	=	135.00	lacs
Scheduled life in years	=	5	years
Scheduled life in hours	=	8,000	hours
Life time repair provision (as percentage of cost of equipment)	=	100	%

I. OWNERSHIP COST

Yearly depreciation (considering straight line method and 10% salvage value)

a) With reference to life in years = $\frac{13,500,000 \times 0.90}{5.00}$ = Rs. 2,430,000.00

b) With reference to life in hours = $\frac{13,500,000 \times 0.90 \times 1,200}{8,000.00}$ = Rs. 1,822,500.00

Average yearly depreciation = $\frac{2,430,000 + 1,822,500}{2}$ = Rs. 2,126,250.00

Average hourly depreciation = $\frac{2,126,250.00}{1,200.00}$ = Rs. 1,771.88

II. OPERATIONAL COST

i) Hourly repair charges = $\frac{13,500,000 \times 1.00}{8,000}$ = Rs. 1,687.50

ii) Operators & Maintenance crew charges (For 1shift/day operation)

S.No.	Operator & Maintenance crew	No.	Rate/month	Wages
	Regular			
1	Operator	1.00	4,500.00	4,500.00
2	Mechanic	0.16	5,000.00	800.00
3	Foreman	0.125	7,000.00	875.00
			Subtotal =	6,175.00
	Casual			
4	Helper	1.00	2,700.00	2,700.00
3	Chowkidar	0.16	2,400.00	384.00
			Subtotal =	3,084.00
	Total direct crew charges/month =		Rs.	9,259.00

Add for indirect crew cost (in Rs.) = (0.8 x 6,175 + 0.55 x 3,084)
(@ 80% of direct crew charges for regular worker = 6,636.20
and 55% of direct crew charges for casual worker)

Total crew charges/month = 9,259 + 6,636 = Rs. 15,895.20

Total crew charges/year = = Rs. 190,742.40

Hourly crew charges = $\frac{190,742.40}{1,200.00}$ = = Rs. 158.95

III. POL & Energy charges

HSD 10 Litre		10.00 x 15.00	= Rs. 150.00	
Lub. Oil	@ 25%		= Rs. 37.50	
			187.50	Rs. 187.50

IV. Misc. charges (@ 10% of hourly repair charges) = 1.688 x $\frac{10}{100}$ = Rs. 168.75

Total hourly operational cost = Rs. 2,202.70

Hourly use rate of the equipment = Rs. 3,974.58

Say Rs. 1,180.00

18. Wet Shotcrete Machine

Annual schedule production hours = 1,200 Hrs
(12 month x 25 days/month x 1cycle/day x 4hrs/cycle)

Cost of equipment (in Rs.) = 135.00 lacs
Scheduled life in years = 5 years
Scheduled life in hours = 6,000 hours
Life time repair provision = 100 %
(as percentage of cost of equipment)

I. OWNERSHIP COST

Yearly depreciation (considering straight line method and 10% salvage value)

a) With reference to life in years = $\frac{13,500,000 \times 0.90}{5.00}$ = Rs. 2,430,000.00

b) With reference to life in hours = $\frac{13,500,000 \times 0.90 \times 1,200}{6,000.00}$ = Rs. 2,430,000.00

Average yearly depreciation = $\frac{2,430,000 + 2,430,000}{2}$ = Rs. 2,430,000.00

Average hourly depreciation = $\frac{2,430,000.00}{1,200.00}$ = Rs. 2,025.00

II. OPERATIONAL COST

i) Hourly repair charges = $\frac{13,500,000 \times 1.00}{6,000}$ = Rs. 2,250.00

ii) Operators & Maintenance crew charges (For 1shift/day operation)

S.No.	Operator & Maintenance crew	No.	Rate/month	Wages
	Regular			
1	Operator	1.00	4,500.00	4,500.00
2	Mechanic	0.50	5,000.00	2,500.00
3	Foreman	0.125	7,000.00	875.00
			Subtotal =	7,875.00
	Casual			
4	Helper	1.00	2,700.00	2,700.00
3	Chowkidar	0.25	2,400.00	600.00
			Subtotal =	3,300.00
	Total direct crew charges/month =		Rs.	11,175.00

Add for indirect crew cost (in Rs.) = (0.8 x 7,875 + 0.55 x 3,300)
(@ 80% of direct crew charges for regular worker = 8,115.00
and 55% of direct crew charges for casual worker)
Total crew charges/month = 11,175 + 8,115 = Rs. 19,290.00

Total crew charges/year = = Rs. 231,480.00

Hourly crew charges = $\frac{231,480.00}{1,200.00}$ = = Rs. 192.90

III. POL & Energy charges

HSD 10 Litre 10.00 x 15.00 = Rs. 150.00
Lub. Oil @ 25% = Rs. 37.50
187.50 Rs. 187.50

IV. Misc. charges (@ 10% of hourly repair charges) = 2,250 x $\frac{10}{100}$ = Rs. 225.00

Total hourly operational cost = Rs. 2,855.40

Hourly use rate of the equipment = Rs. 4,880.40

Say Rs. 4,880.00

19. Wagon Drill

Annual schedule production hours (12 month x 25 days/month x 1cycle/day x 4hrs/cycle)	=	1,200	Hrs
Cost of equipment (in Rs.)	=	25.00	lacs
Scheduled life in years	=	8	years
Scheduled life in hours	=	8,000	hours
Life time repair provision (as percentage of cost of equipment)	=	80	%

I. OWNERSHIP COST

Yearly depreciation (considering straight line method and 10% salvage value)

a) With reference to life in years = $\frac{2,500,000 \times 0.90}{8.00}$ = Rs. 281,250.00

b) With reference to life in hours = $\frac{2,500,000 \times 0.90 \times 1,200}{8,000.00}$ = Rs. 337,500.00

Average yearly depreciation = $\frac{281,250 + 337,500}{2}$ = Rs. 309,375.00

Average hourly depreciation = $\frac{309,375.00}{1,200.00}$ = Rs. 257.81

II. OPERATIONAL COST

i) Hourly repair charges = $\frac{2,500,000 \times 0.80}{8,000}$ = Rs. 250.00

ii) Operators & Maintenance crew charges (For 1shift/day operation)

S.No.	Operator & Maintenance crew	No.	Rate/month	Wages
	Regular			
1	Operator	1.00	4,500.00	4,500.00
2	Mechanic	0.125	5,000.00	625.00
3	Foreman	0.125	7,000.00	875.00
			Subtotal =	6,000.00
	Casual			
4	Helper	1.00	2,700.00	2,700.00
3	Chowkidar	0.25	2,400.00	600.00
			Subtotal =	3,300.00
	Total direct crew charges/month =		Rs.	9,300.00

Add for indirect crew cost (in Rs.) = (0.8 x 6,000 + 0.55 x 3,300)
(@ 80% of direct crew charges for regular worker = 6,615.00
and 55% of direct crew charges for casual worker)

Total crew charges/month = 9,300 + 6,615 = Rs. 15,915.00

Total crew charges/year = = Rs. 190,980.00

Hourly crew charges = $\frac{190,980.00}{1,200.00}$ = = Rs. 159.15

III. POL & Energy charges
500 Cfm compressor air 5.00 x 110.00 = Rs. 550.00

IV. Misc. charges (@ 10% of hourly repair charges) = 250 x $\frac{10}{100}$ = Rs. 25.00

Total hourly operational cost = Rs. 984.15

Hourly use rate of the equipment = Rs. 1,241.96

Say Rs. 1,240.00

20. Air Track

Annual schedule production hours = 1.200 Hrs
(12 month x 25 days/month x 1cycle/day x 4hrs/cycle)

Cost of equipment (in Rs.) = 25.00 lacs
Scheduled life in years = 8 years
Scheduled life in hours = 8.000 hours
Life time repair provision = 80 %
(as percentage of cost of equipment)

I. OWNERSHIP COST
Yearly depreciation (considering straight line method and 10% salvage value)

a) With reference to life in years = $\frac{2.500.000 \times 0.90}{8.00}$ = Rs. 281.250.00

b) With reference to life in hours = $\frac{2.500.000 \times 0.90 \times 1.200}{8.000.00}$ = Rs. 337.500.00

Average yearly depreciation = $\frac{281.250 + 337.500}{2}$ = Rs. 309.375.00

Average hourly depreciation = $\frac{309.375.00}{1.200.00}$ = Rs. 257.81

II. OPERATIONAL COST

i) Hourly repair charges = $\frac{2.500.000 \times 0.80}{8.000}$ = Rs. 250.00

ii) Operators & Maintenance crew charges (For 1shift/day operation)

S.No	Operator & Maintenance crew	No.	Rate/month	Wages
	Regular			
1	Operator	1.00	4,500.00	4,500.00
2	Mechanic	0.125	5,000.00	625.00
3	Foreman	0.125	7,000.00	875.00
			Subtotal =	6,000.00
	Casual			
4	Helper	1.00	2,700.00	2,700.00
3	Chowkidar	0.25	2,400.00	600.00
			Subtotal =	3,300.00
	Total direct crew charges/month =		Rs.	9,300.00

Add for indirect crew cost (in Rs.) = (0.8 x 6,000 + 0.55 x 3,300)
(@ 80% of direct crew charges for regular worker = 6,615.00
and 55% of direct crew charges for casual worker)
Total crew charges/month = 9,300 + 6,615 = Rs. 15.915.00

Total crew charges/year = = Rs. 190.980.00

Hourly crew charges = $\frac{190.980.00}{1,200.00}$ = = Rs. 159.15

III. POL & Energy charges
500 Cfm compressor air 6.00 x 110.00 = Rs. 660.00

IV. Misc. charges (@ 10% of hourly repair charges) = 250 x $\frac{10}{100}$ = Rs. 25.00

Total hourly operational cost = Rs. 1.094.15

Hourly use rate of the equipment = Rs. 1.351.96

Say Rs. 1,350.00

21. Three Boom Hydraulic Jumbo with Basket

Annual schedule production hours (12 month x 25 days/month x 1cycle/day x 4hrs/cycle)	=	1.200	Hrs
Cost of equipment (in Rs.)	=	425.00	lacs
Scheduled life in years	=	10	years
Scheduled life in hours	=	15.000	hours
Life time repair provision (as percentage of cost of equipment)	=	120	%

I. OWNERSHIP COST

Yearly depreciation (considering straight line method and 10% salvage value)

a) With reference to life in years = $\frac{42.500.000 \times 0.90}{10.00}$ = Rs. 3.825.000.00

b) With reference to life in hours = $\frac{42.500.000 \times 0.90 \times 1.200}{15.000.00}$ = Rs. 3.060.000.00

Average yearly depreciation = $\frac{3.825.000 + 3.060.000}{2}$ = Rs. 3.442.500.00

Average hourly depreciation = $\frac{3.442.500.00}{1,200.00}$ = Rs. 2.868.75

II. OPERATIONAL COST

i) Hourly repair charges = $\frac{42.500.000 \times 1.20}{15.000}$ = Rs. 3.400.00

ii) Operators & Maintenance crew charges (For 1shift/day operation)

S.No.	Operator & Maintenance crew	No.	Rate/month	Wages
	Regular			
1	Operator	2.00	4,500.00	9,000.00
2	Mechanic	0.25	5,000.00	1,250.00
3	Foreman	0.125	7,000.00	875.00
			Subtotal =	11,125.00
	Casual			
4	Helper	4.00	2,700.00	10,800.00
3	Chowkidar	0.25	2,400.00	600.00
			Subtotal =	11,400.00
	Total direct crew charges/month =		Rs.	22.525.00

Add for indirect crew cost (in Rs.) = (0.8 x 11,125 + 0.55 x 11,400)
(@ 80% of direct crew charges for regular worker = 15,170.00
and 55% of direct crew charges for casual worker)

Total crew charges/month = 22,525 + 15,170 = Rs. 37.695.00

Total crew charges/year = = Rs. 452,340.00

Hourly crew charges = $\frac{452.340.00}{1.200.00}$ = = Rs. 376.95

III. POL & Energy charges
Drive 150 HP Diesel
Electric Motor 100 HP

HSD		150.00 x	0.16 x	15.00		= Rs.	360.00
Lub. Oil	@ 25%					= Rs.	90.00
Electric Power		100.00 x	0.75 x	3.00 x	0.7	= Rs.	157.50
Hydraulic Oil for Drifter & Hydraulic Pump	L.S.					Rs.	75.00
							682.50

Rs. 682.50

IV. Misc. charges (@ 10% of hourly repair charges) = 3,400 x $\frac{10}{100}$ = Rs. 340.00

Total hourly operational cost = Rs. 4,799.45

Hourly use rate of the equipment = Rs. 7.668.20

Say Rs. 7,670.00

22. Tyre Loader 3.0 m³/Hr.

Annual schedule production hours = 1,200 Hrs
(12 month x 25 days/month x 1cycle/day x 4hrs/cycle)

Cost of equipment (in Rs.) = 70.00 lacs
Scheduled life in years = 10 years
Scheduled life in hours = 15,000 hours
Life time repair provision = 200 %
(as percentage of cost of equipment)

I. OWNERSHIP COST

Yearly depreciation (considering straight line method and 10% salvage value)

a) With reference to life in years = $\frac{7,000,000 \times 0.90}{10.00}$ = Rs. 630,000.00

b) With reference to life in hours = $\frac{7,000,000 \times 0.90 \times 1,200}{15,000.00}$ = Rs. 504,000.00

Average yearly depreciation = $\frac{630,000 + 504,000}{2}$ = Rs. 567,000.00

Average hourly depreciation = $\frac{567,000.00}{1,200.00}$ = Rs. 472.50

II. OPERATIONAL COST

i) Hourly repair charges = $\frac{7,000,000 \times 2.00}{15,000}$ = Rs. 933.33

ii) Operators & Maintenance crew charges (For 1shift/day operation)

S.No.	Operator & Maintenance crew	No.	Rate/month	Wages
	Regular			
1	Operator	1.00	4,500.00	4,500.00
2	Mechanic	0.25	5,000.00	1,250.00
3	Foreman	0.125	7,000.00	875.00
			Subtotal =	6,625.00
	Casual			
4	Helper	1.00	2,700.00	2,700.00
3	Chowkidar	0.16	2,400.00	384.00
			Subtotal =	3,084.00
	Total direct crew charges/month =		Rs.	9,709.00

Add for indirect crew cost (in Rs.) = (0.8 x 6,625 + 0.55 x 3,084)
(@ 80% of direct crew charges for regular worker = 6,996.20
and 55% of direct crew charges for casual worker)
Total crew charges/month = 9,709 + 6,996 = Rs. 16,705.20

Total crew charges/year = = Rs. 200,462.40

Hourly crew charges = $\frac{200,462.40}{1,200.00}$ = = Rs. 167.05

III. POL & Energy charges
HSD 360 H.P. 360.00 x 0.16 x 15.00 = Rs. 864.00
Lub. Oil @ 25% = Rs. 216.00
Rs. 1,080.00

IV. Misc. charges (@ 10% of hourly repair charges) = 933 x $\frac{10}{100}$ = Rs. 93.33

Total hourly operational cost = Rs. 2,273.72

Hourly use rate of the equipment = Rs. 2,746.22

Say Rs. 2,750.00

Chapter D4

ANALYSIS OF RATES FOR DIFFERENT ITEMS OF WORKS

ABSTRACT

Sl. No.	Item of Work	Unit	Rate (At Dec.99 price level) as per CWC guidelines of March 1997	Page No.
1	Open excavation			
	a) In soil	cum	103.00	D4-5
	b) In rock	cum	370.00	D4-5
2	Underground excavation in HRT	cum	1,682.00	D4-6
3	Untensioned rock bolts/anchors (25mm dia) including drilling and grouting (Mechanised) (River diversion works)	m	614.00	D4-9
4	Tensioned rock bolts/anchors (25mm dia) including drilling and grouting (Mechanised)	m	674.00	D4-9
5	Drilling for consolidation and contact grouting	m	403.00	D4-10
6	Drilling 45mm dia holes for grouting (contact and consolidation)	m	403.00	D4-10
7	Grouting (contact and consolidation)	tonne	13,117.00	D4-10
8	Shotcreting	cum	11,396.00	D4-10
9	Shotcreting with steel fibers in river diversion works	cum	17,876.00	D4-11
10	Weld mesh in shotcrete	kg	71.00	D4-11
11	Steel rib supports	tonne	40,260.00	D4-11
12	Concrete including cost of cement			
	a) Portals, inlet and outlet structures (300kg cement)	cum	3,844.00	D4-12
	b) Tunnel lining (350 kg cement)	cum	4,422.00	D4-12
	c) Plug (300 kg cement)	cum	3,844.00	D4-12
13	Drainage holes 75mm dia	m	409.00	D4-12
14	Gabions/stone pitching	cum	653.00	D4-13
15	Steel liners	tonne	104,100.00	D4-13
16	PVC seals	m	772.00	D4-14
17	Metal seals	m	456.00	D4-14
18	Steel reinforcement (Fe-415)	tonne	24,940.00	D4-14
19	1m thick Concrete cut-off for coffer dam	sqm	18,590.00	D4-15
20	Impervious core	cum	439.00	D4-16
21	Graded filter	cum	880.00	D4-16
22	Rock fill	cum	313.00	D4-16
23	Dewatering (surface works)	kWh	6.00	D4-16
24	Dewatering (underground)	kWh	10.00	D4-16
25	Compacted backfill below Apron	cum	313.00	D4-16
26	U/G excavation in galleries in abutments of Dam	cum	2,112.00	D4-17
27	Concrete in Dam			
	a) M15 (200 kg cement)	cum	3,474.00	D4-17
	b) M20 (350 kg cement)	cum	4,332.00	D4-17
	c) M25 (400 kg cement)	cum	4,640.00	D4-18
28	Copper water stops at contraction joints	m	1,230.00	D4-18
29	Asphalt seals at joints	m	228.00	D4-18
30	Bridge over spillway	m	57,030.00	D4-19
31	Stone Masonry	cum	2,422.00	D4-21
32	Steel reinforcement (Fe-500)	tonne	27,434.00	D4-21
33	Shotcrete with steel fiber reinforcement (HRT)	cum	19,664.00	D4-23
34	Tensioned and grouted rock bolts/anchors including drilling (32mm dia.)	m	682.00	D4-24
35	Underground excavation in pressure shafts and valve chamber	cum	2,712.00	D4-25
36	Underground excavation			
	a) Approach adits and construction adits	cum	2,682.00	D4-26
	b) Cavities	cum	1,682.00	D4-26
37	Tensioned and grouted rock bolts/anchors including drilling (36mm dia.)	m	738.00	D4-26
38	20m Rock Anchors of 50T capacity	RM	4,800.00	D4-27
39	Grouted boulder pitching	cum	666.00	D4-28

BASIC RATES

1. **Drilling 40mm dia holes**

Rock drill and pusher cost	40,000.00		
	30,000.00		
	Rs. 70,000.00		
Life - 2500 hrs			
Cost per hour	28.00		
Spares @ 100%	28.00		
	Rs. 56.00		
Drilling rate per hour - 6m			
a) Cost per metre	56.00 /6 =		9.33
b) Compressed air 125 cfm	110.00 x 1.25=	137.50	
Cost per metre	137.50 /6 =		22.92
c) Drill steel	5000/200m =		25.00
d) Services like hoses etc.			6.00
e) Labour cost	(120 x 1.89) / 60		3.78
f) Truck jumbo charges			6.00
g) Small stores			6.00
		Rs.	79.03
		Say Rs.	80.00 per meter

2. Drilling 75mm dia holes

Wagon Drill cost -	Rs.	700,000.00		
Life - 8000 hrs				
Cost per hour		87.50		
Spares @ 100%		87.50		
	Rs.	175.00		
Drilling rate per hour - 6m				
a) Cost per metre		175.00 /6 =		29.17
b) Compressed air 500 cfm		110.00 x 5 =	575.00	
Cost per metre		575.00 /6 =		95.83
c) Drill steel & coupling (say 3200mm rod with coupling sleave)		(6700+800) / 300 =		25.00
d) Drill bit		5,000.00 /200		25.00
e) Lubrication oil and stores				12.50
f) Labour		(120x1.89/60) =		3.78
			Rs.	191.28
			Say Rs.	191.00 per meter

3. Aggregate

Quarry at Jhangi - river bed 40km from Karcham
(A plant is proposed to be made 40km U/s of Karcham)
River bed material needs to be crushed.
Cost of the plant is provided in fixed cost.
Only operating cost needs to be provided.

Transport of river bed material from 40km (40km x 2 ways x Rs. 18.00) / 5 =		288.00	(Assuming one truck carries 5 Cum of river bed material.)
Loading and unloading		25.00	
	Rs.	313.00	per cum

a) 1.1 cum of aggregate		344.30
b) Plant running spares, jaws, rollers, belts, stores etc.		60.00
c) Power (10 kW x Rs.3.00)		30.00
d) Operating labour		30.00
d) Water for washing 1 cum/cum		15.00
e) Handling from crusher to batch plants (loading - Rs. 25 + transport - Rs.75)		100.00
	Rs.	579.30
f) Royalty		22.00
	Rs.	601.30

Say Rs. 601.00 per Cum

(A) RIVER DIVERSION WORKS

I. DIVERSION TUNNEL

1. (a) Excavation in overburden

Lead -	2 km
Equipment used -	Hydraulic excavator (0.9 cum) Tata Tipper Dozer D65
Speed of Tipper	15 km/hr
Excavator capacity	0.9 cum x 80 sweeps x 70% = 50.40 cum
	Say 50 cum
Time for a round trip of tipper	
Time for spotting and loading -	4 minutes
Travel time (4km x 60) / 15 =	16 minutes
	20 minutes
Trips/hr - (60/20) =	3 trips
Qty. per hour per tipper - (3x4 cum)	12 cum
Tipper / excavator (50/12)	4 nos.

Hence cost is as under

i) Excavator / hr				1,300.00	
ii) 4 tippers		4 x	420.00	1,680.00	
iii) 1/4 dozzer D65			2.480.00 /4 =	620.00	
iv) Survey	L.S.			100.00	
v) Electrical material/lighting				100.00	
vi) Labour	L.S.			500.00	
				4,300.00	
Cost/cum			4.300.00 /50	86.00	
				86.00	
Contractor's profit @ 20%				17.20	
			Rs.	103.20	
				Say Rs.	103.00 /Cur

I. (b) Rock Excavation

i) Drilling 1.5 m/cum @		Rs.	80.00	120.00	
ii) Explosive 0.3 kg @		Rs.	60.00	18.00	
iii) 1/2 detonetor @		Rs.	15.00	7.50	
iv) Excavation @ Swell factor 70% Excavation rate	$\frac{86.00}{0.70}$	Rs.	86.00	122.86	
v) Other consumable i.e. blasting batteries, galvanometers, blasting wires etc.			L.S.	20.00	
vi) Labour				20.00	
			Rs.	308.36	
Contractor's profit @ 20%				61.67	
			Rs.	370.03	
				Say Rs.	370.00 /Cur

2. Underground Excavation

Tunnel dia.				10.48 m
Thickness of lining				0.40 m
Minimum excavated dia. of tunnel	=	10.48 +	0.80	
	=	11.28 m		
Gross area of tunnel	=	99.93 sqm		
Qty. of excavation per meter length	=	99.93 x	1.00	
	=	99.93 cum		
Assumed progress per face (this includes drilling blasting,mucking,ribbing and packing etc.)	=	3.00 m		
Qty. of excavation per cycle	=	99.93 x	3.00	
	=	299.80 cum		

1 - DIRECT LABOUR

1.5 No. Foreman @ Rs. Per Day =	7,000.00	= Rs.	10,500.00
1 No. Explosive inspector @ Rs. Per Day =	4,500.00	= Rs.	4,500.00
1.5 No. Electrician/explosive expert @ Rs. Per Day =	4,500.00	= Rs.	6,750.00
1.5 No. helper to Electrician/explosive expert @ Rs. Per Day =	2,700.00	= Rs.	4,050.00
12 No. Beldars @ Rs. Per Day =	2,400.00	= Rs.	28,800.00
Total			54,600.00

indirect cost 80% of (i,ii,iii)	17,400.00
indirect cost 55% of (iv,v)	18,067.50
Total direct cost	90,067.50
Rate of direct labour per	300.43

2- MACHINERY CHARGES

Equipment	NO. REQ.	Total hrs req.	unit rate Rs.	AMOUNT
a) Hydraulic 3 boom jumbo	1.00	5.00	7,670.00	38,350.00
b) Loader 3.5 cum	1.00	5.00	2,750.00	13,750.00
c) Dumpers 20 t	5.00	5.00	1,087.05	27,176.30
d) Dozer D65	1.00	1.00	2,480.00	2,480.00
TOTAL MACHINERY CHARGES=				81,756.30

QTY. OF ROCK = 299.80 CUM

RATE PER CUM = $\frac{81,756.30}{299.80}$

= 272.70 PER CUM

3- MATERIAL CHARGES

(A) DRILLING & BLASTING

a) It is proposed that to attain 3 m progress per cycle per face 3.3m deep holes will be drilled

Cross-sectional area of Tunnel	=	99.93 sqm		
Assumning average spacing of holes	=	0.85 m c/c		
Area of rock cross-section per hole	=	$(0.85)^2$		
	=	0.72 sqm		
No. of holes required per face	=	$\frac{99.93}{0.72}$		
	=	138.32		
	Say	138.00 Nos.		
Total depth of drilling	=	138.00 x 3.3		
	=	455.40 m		
Bit cost + Cost of rod + coupling + cost of shank adaptar	=	7000+5500+1000+5000		
	=	18,500		
Life of drill steel	=	1,000 m		
Cost of drill steel per m	=	$\frac{18,500}{1,000}$		
	=	18.50		
Cost of drill steel (Rs.)	=	455.40 x cost of drill steel per m.		
	=	8,424.90		
Quantity of rock excavated	=	299.80 cum		
Rate for drill steel Rs. per cum	=	$\frac{\text{Total cost of drill steel}}{\text{Qty. of rock excavated}}$		
	=	$\frac{8,424.90}{299.80}$	=	28.10 per cum
(b) EXPLOSIVES				
I) Gelatine required per cum	=	1.25 kg		
Cost of gelatine per kg	=	60.00		
Rate Rs. per cum			=	75.00 per cum
ii) Detonators and fuse coils				
1 Detonator & 1 fuse coil per hole				
Total detonators required	=	138.00 Nos.		
Cost of detonators & fuse coil (Rs.)	=	120.00 per Nos.		
Total cost of detonators (Rs.)	=	16,560		
Rate per cum	=	$\frac{16,560}{299.80}$	=	55.24 per cum
iii) Other consumable i.e. blasting batteries, galvanometers, blasting wires etc., @ 50% of item (i)	=		=	37.50 per cum
Total explosive charges per cum (i+ii+iii)			=	167.74 per cum
Total drilling and blasting charges (a) + (b)			=	195.84 per cum
(B) Timber for supports packing etc. rates per cum			=	15.59 per cum
(C) Miscellaneous supplies such as wire ropes, manila ropes, V-clamps, rubber gloves, shackles and artificial respirators etc.			=	50.00 per cum
Total material charges per cum (A+B+C)			=	261.43 per cum

4 - CHARGES FOR VENTILATION BLOWERS			
Ventilation charges	L.S.	=	50.00
5 - SHOP CHARGES			
i) Machine shop including foundry and smithy	L.S.	=	70.00
ii) Structural shop	L.S.	=	70.00
iii) Steel metal shop	L.S.	=	65.00
iv) Air and water pipe shop	L.S.	=	60.00
v) Carpentary shop	L.S.	=	60.00
Total shop charges Rs. per cum		=	325.00
6 - Electrical material charges per cum	L.S.	=	50.00
7 - Water charges per cum	L.S.	=	15.00
8 - Survey/mapping	L.S.	=	100.00

Abstract of charges

1. Direct labour charges	=	300.43
2. Machinery charges	=	272.70
3. Material charges	=	261.43
4. Ventilation charges	=	50.00
5. Shop charges	=	325.00
6. Electrical charges	=	50.00
7. Water charges	=	15.00
8. Survey/mapping	=	100.00
TOTAL		1,374.56
Adding Electrical energy charges @ 2% of total charges		27.49
Prime cost		1,402.05
contractor profit @ 20% of prime cost		280.41
		1,682.46

Say Rs. 1,682.00 per c

3. (i) **Rock bolts (25mm dia)**
(by conventional method)

Cost of drilling 40mm dia holes per metre				80.00	
Cost of 25mm dia bar on site @ (Rs. 15000/tonne)	3.90 Kg / 15.00			58.50	
Cost of plate, washer and n	4.00 Kg	x	20.00 /4 =	20.00	
Cost of threading	L.S			50.00	
Cost of expansion sheet	Rs.	40.00 /4		10.00	
Labour for inserting the bol tightening	L.S.			50.00	
Cost of truck platform (8 hrs)	3,360 / (10 x 4)		=	84.00	
Grouting	L.S			50.00	
			Rs.	402.50	
Contractor's profit @ 20%				80.50	
			Rs.	483.00	
				Say Rs.	483.00 /me

3. (ii) **Rock bolts (25mm dia)**
By use of Rock bolting machine (Mechanised)

Hire charges of rock bolter per hour		5,720.00		
No. of rock bolts per hour		8.00		
Cost per metre	5,720 / (8 x 4.00) =		178.75	
Bit cost + Cost of rod + coupling + cost of shank adaptar	= 7000+5500+1000+5000			
	= 18,500			
Life of drill steel	= 1,000 m			
Cost of drill steel per m	= 18,500 / 1,000			
	= 18.50			
Cost of drill steel (Rs.)	= 4.00 x cost of drill steel per m.	=	74.00	
Bolt	(58.5+20+20+10) =		108.50	
Labour	L.S		75.00	
Grouting & other misc.	L.S		75.00	
		Rs.	511.25	
Contractor's profit @ 20%			102.25	
		Rs.	613.50	
			Say Rs.	614.00 /me

4. **Tensioned Rock bolt (25mm dia)**

Cost of rock bolt			614.00	
Cost of tensioning	L.S		50.00	
			664.00	
Contractor's profit @ 20% of	50.00		10.00	
		Rs.	674.00	
			Say Rs.	674.00 /me

5. Drilling 45mm dia holes for grouting

This can be drilled by Jack hammer & pusherleg or by hydraulic jumbo
Since holes could not be many so these will be drilled by jack hammer and pusherleg

Cost/metre				80.00	
In one day no. of holes to be drilled for grouting say 20 nos. of 6m length average total 120m					
Cost of truck with scissor platform per day other than capital cost = (TRUCK PLATFORM RATE X 2 SHIFTS)/120m		$\frac{6,720.00}{120.00}$		56.00	
Miscellaneous, labour and stores	L.S			200.00	
				336.00	
Contractor's profit @ 20%				67.20	
			Rs.	403.20	
				Say Rs.	403.00 /meter

6. **Grouting**

Cost of cement per bag Ex-Kalka			140.00		
Loading and unloading at Kalka -	L.S		6.00		
Transport to site {(250km x 2 ways x Rs. 30.00) / (9 tons x 20 bags)}			83.33		
Unloading, storing, loadings and local transportation at site	L.S		15.00		
			244.33		
Cost of cement per tonne	244.33 x	20.00 =		4,886.67	
5 % wastage				244.33	
Cost of mixing with water and injection (100/bag x 20)	100.00 / bag x 20	=		2,000.00	
Cost of grouting and mixing plant operation (100/bag x 20)	100.00 / bag x 20	=		2,000.00	
Stores (packers, hoses and other fittings etc.)				1,800.00	
			Rs.	10,931.00	
Contractor's profit @ 20%				2,186.20	
			Rs.	13,117.20	
				Say Rs.	13,117.00 /tonne

7. **Shotcrete (plain)**

Sand and aggregates (1.5 Cum)	1.50 x	601.00 =	901.50
Cement 500kg	500.00 x	4.89 =	2,443.33
5% wastage			122.17
Compressed air 300 cfm @	3.00 x	110.00 =	330.00
Power	20 x 0.75 x 0.8 x 3.0 x	3.00 =	36.00
Jumbo charges per shift per shift @ Rs. 2,100	2,100 /	20.00 =	105.00
Water under pressure			12.00
Delivery hose (2 nos. x 15m x 500 x 10 bags) / 500 bags			300.00
Rubber seals	(2x800x10 / 500) =		32.00

	Nozzle	(2500x10 / 500) =		50.00	
	Other connections			125.00	
	Labour for mixing at batch plant	L.S		700.00	
	Transport by transit mixer (@1 hour)	890 per hour		890.00	
	Labour for shotcrete & Nozzleman	L.S.		650.00	
	Additives - (SP 1% x 500 kg x 60)		300.00		
	Accelerator - Sodium Silicate (6% x 500kg x 20)		600.00		
			900.00	900.00	
				7,597.00	
	Rebound 25%			1,899.25	
				9,496.25	
	Contractor's profit @ 20%			1,899.25	
			Rs.	11,395.50	
				Say Rs.	11,396.00 /Cum
8.	**Weld Mesh**	(2.5kg / sqm x 30) =		75.00	
	10% overlap			7.50	
	Small bolts for fixing	L.S		30.00	
	Labour for fixing	L.S		35.00	
				147.50	
	Contractor's profit @ 20%			29.50	
			Rs.	177.00	
		177.00 /2.5 kg =		70.80	
				Say Rs.	71.00 /Kg
9.	**Fibre reinforced shotcrete**				
	Cost of shotcrete per cum			11,396.00	
	60 kg fibres @ Rs. 90 per kg			5,400.00	
	Contractor's profit @ 20% i 5,400			1,080.00	
			Rs.	17,876.00	
10.	**Steel supports**			Say Rs.	17,876.00 /Cum
	Steel Ex-Kalka / tonne		20,000.00		
	Sale tax @ 4%		800.00		
	Transport (250 km x 2 x 30 / 8)		1,875.00		
	Loading and unloading		300.00		
			22,975.00		
	Cost of steel Ex-site			22,975.00	
	2.5% wastage			574.38	
	Fabrication cost @ 25% of steel cost			5,000.00	
	Erection cost (same as fabrication cost)			5,000.00	
			Rs.	33,549.38	
	Contractor's profit @ 20%			6,709.88	
			Rs.	40,259.25	
				Say Rs.	40,260.00 /tonn

11. Drainage Holes 75mm dia

Cost of drilling per metre					191.00	
Placing of machine & other misc.	L.S				150.00	
				Rs.	341.00	
Contractor's profit @ 20%					68.20	
				Rs.	409.20	
					Say Rs.	409.00 /mete

12. Concrete

a) Portal and inlet/outlet structures

Aggregate 1.4 cum	1.40 x	601.00			841.40	
Batching	L.S.				50.00	
Cost of Cement 300 Kg	300.00 x	4.89 =			1.466.00	
5 % wastage					73.30	
Transport of concrete to placement point (By 6 cum transit mixer.Total time required for 1 trip = 1.5 hrs)	890.00 x 1.50 = / 6.00		222.50		222.50	
Concrete pumping					100.00	
Lighting/electricity charges	L.S.				20.00	
Dewatering	L.S.				20.00	
Cleaning /sand blasting	L.S.				20.00	
Placement labour	L.S.				100.00	
Vibration	L.S.				20.00	
Curing & finishing	L.S.				20.00	
Portals shuttering - 2 sqm/cum						
Cost of shuttering per sqm Rs.	100.00 L.S.					
Cost of shuttering per cum	100.00 x	2.00 =			200.00	
Catwalks and other aids for concretir L.S.					50.00	
				Rs.	3,203.20	
Contractor's profit @ 20%					640.64	
				Rs.	3.843.84	
					Say Rs.	3.844.00 /Cum

b) Concrete in tunnel lining

Cost of concrete					3.844.00	
Extra 50kg cement @	Rs.	4.89 /Kg	244.33			
5 % wastage			12.22			
Extra cost of shuttering	L.S		100.00			
Cost of pumping	L.S		125.00			
			481.55			
Contractor's profit @ 20% (481.55			96.31			
			577.86		577.86	
					4.421.86	
					Say Rs.	4.422.00 /Cum

c) Concrete in plug

	Rs.	3.844.00 /Cum

13. Steel liners (ASTM-537 Gr. I Steel)			
a) Cost of steel plate @ 900 ex factory Europe		39,150.00	
Transport to the port @ 5%		1,957.50	
		41,107.50	
Insurance & Freight to Indian port @ 10%		4,110.75	
		45,218.25	
Customs @ 25%		11,304.56	
		56,522.81	
Wastage @ 2.5%		1,413.07	
		57,935.88	
b) Fabrication as per CWC norms			
i) Straightening	@ 1.5% of cost of steel		
ii) Marking	@ 2% of cost of steel		
iii) Cutting	@ 5% of cost of steel		
iv) Rolling	@ 7.5% of cost of steel		
v) Welding	@ 10% of cost of steel		
	26% of cost of steel	15,063.33	
c) Radiography and non-destructive testing		2,000.00	
d) Workshop operation including handling from store and fabrication		1,500.00	
e) Erection including transportation to site and handling, assembling and field welding		7,500.00	
f) Epoxy painting (shop painting and final field painting)		1,500.00	
g) Inspection charges during fabrication		1,250.00	
		86,749.21	
Contractor's profit @ 20%		17,349.84	
		104,099.05	
		Say Rs.	104,100.00 /tc
14. **Instrumentation**	L.S.	Rs.	600,000.00
15. **Gabbions / Stone pitching**			
Collection of stones from river bed		60.00	
Transport (as lead 10km) (10x2x18.0)/5 =		72.00	
Cost of woven mesh (2.5 sqm/cum x2.5 kg x Rs 40)		250.00	
Labour (@ 25/sqm x 2.5)		62.50	
Labour for placing stones in Gabbions		100.00	
		544.50	
Contractor's profit @ 20%		108.90	
		653.40	
		Say Rs.	653.00 /C
16. **Gates and hoists**			
a) Embedded parts	Rs.	3,218,000.00 /set	
b) Gates	Rs.	9,950,000.00 /no.	
c) Hoists	Rs.	5,850,000.00 /set	
d) Hoist bridge	Rs.	3,282,000.00 /set	

17. **Steel Reinforcement**

Cost Ex-Kalka			15,000.00	
Sales Tax @ 4%			600.00	
			15,600.00	
Transport ((250 x 2 x 30) / 8 tons)			1,875.00	
Loading & unloading	L.S		800.00	
			18,275.00	
2.5% wastage			456.88	
Chairs @ 3%			548.25	
Rehandling at site	L.S		500.00	
Cutting, bending & binding labour	L.S		800.00	
Binding wire (10Kg x 20)	L.S		200.00	
			20,780.13	
Contractor's profit @ 20%			4,156.03	
		Rs.	24,936.15	
			Say Rs.	24,940.00 /tonr

18. **PVC Seals**

Purchase price		500.00	
Transport and Storing		30.00	
		530.00	
Wastage 10%		53.00	
		583.00	
Cost of fixing		60.00	
		643.00	
Contractor's profit @ 20%		128.60	
	Rs.	771.60	
		Say Rs.	772.00 /met

19. **Metal seals**

Cost of material 3.15mm thick - 300mm wic (8kg/m x Rs. 40) =		320.00	
Cost of fixing		60.00	
		380.00	
Contractor's profit @ 20%		76.00	
	Rs.	456.00	
		Say Rs.	456.00 /met

II. COFFER DAMS

1. Excavation in overburden — Rs. 103.00 /Cu

2. Concrete cut-off (Diaphragm wall)

The following imported equipment will be required.
It will be obtained from M/s BAUER GmbH, Germany

		(Cost Ex-Germany)
a) Hydraulic grab DHG HD 1200	DM	295,000.00
b) Mechanical hoist retracting system MDSG (for excavation upto 60m)	DM	150,000.00
c) Mechanical and hydraulic modifications on crawler crane	DM	100,000.00
d) Hydraulic anchor drilling rig UBW 08 with down the hole-hammer 6" for predrilling or perforating boulders	DM	465,000.00
e) Bentonite mixing station SK for a continuous ouput of 15 cum/hr	DM	79,000.00
f) Desanding unit BE 100 capacity 100 cum/hr	DM	98,000.00
	DM	1,187,000.00
1 DM = Rs. 25 (DM 1,187,000 x 25) =	Rs.	29,675,000.00
Freight and insurance @ 10%		2,967,500.00
Custom duty @ 40%		11,870,000.00
	Rs.	44,512,500.00
g) 20T Chiesel local supply		1,000,000.00
	Rs.	45,512,500.00

Since the above equipment will be specially manufactured for this work, the total cost will be charged to work

h) Expatriate personnel — Deleted as per comments of CEA
6 months @ DM 23000
(DM 23,000 x 6 months x 25)
= Rs 3450000.00

Air fare and local cost @ 2(= of Rs. 3450000.00	690,000.00		690,000.00
Cost of equipment chargeable to work		Rs.	46,202,500.00

i) Cost of equipment and man power per sqm (concrete cutoff wall area = 0200 sqm)	46,202,500.00 / 10,200.00	4,529.66
Operating cost of plant at site @ 50 %		2,264.83
Cost of bentonite		1,000.00
Cost of 1.2 cum of concrete (M20) PER CUM. RS. 4,332.00		5,198.40
Cost of reinforcement 100 kg @ Rs. 25/kg		2,500.00
		15,492.89
Contractor's profit @ 20%		3,098.58
		18,591.46

Say Rs. 18,590.00 /Sqm

3. Impervious core				
Clay or impervious material required for this will be obtained from locations which are 30km away from Karcham				
a) Cost of Roaylty for material per cum			20.00	
b) Excavation and loading in truck	L.S		40.00	
c) Transport {(30km x 2 x 18.0) / 5}			216.00	
d) Unloading at site and placing in the core	L.S		60.00	
e) Compaction			30.00	
		Rs.	366.00	
Contractor's profit @ 20%			73.20	
		Rs.	439.20	
			Say Rs.	439.00 /Cum
4. Graded filter				
Cost of aggregate at processing plant			601.00	
Transport {(10km x 2 x 18.0)/5}			72.00	
Placing	L.S		60.00	
			733.00	
Contractor's profit @ 20%			146.60	
		Rs.	879.60	
			Say Rs.	880.00 /Cum
5. Rockfill				
This material will be available from excavation dump areas or could be extracted from river bed.				
Excavation from dumps or from river bed and transport to the area of coffer dam. Provided an average of overburden & rock excavation	$\frac{103.00 + 370.00}{2}$		236.50	
Compaction	L.S		70.00	
			306.50	
Contractor's profit @ 20% of Rs. 30			6.00	
		Rs.	312.50	
			Say Rs.	313.00 /Cum
6. Dewatering				
i) Surface works				
Cost of power			3.00	
a) Cost of operation				
Operator/month		4,500.00		
Electrician/month		4,500.00		
1 helpers @ 2700 / month		2,700.00		
		11,700.00		
or ((14400 x 1.89) / 30) =	$\frac{1.89 \times 11.700}{30}$	737.10 /day		
Assume that this pumping station consume 500 kW power hence cost of labour / kW =	$\frac{737.1}{500.00}$ =		1.47	
b) Installation charges				
Labour		0.15		
Stores		0.15		
		0.30	0.30	
c) Spares for pumps (Cost and depreciation provided in plant cost)			0.20	
			4.97	
Contractor's profit @ 20%			0.99	
		Rs.	5.97	
			Say Rs.	6.00 /KW
ii) Underground works				
Basic cost			6.00	
other misc			4.00	
			10.00	
			Say Rs.	10.00 /KW

(B) DIVERSION DAM

1. Open excavation					
a) Overburden excavation				Rs.	103.00 /Cu
b) Rock excavation				Rs.	370.00 /Cu
c) Excavation in fault and seams				Rs.	500.00 /Cu
2. Excavation in galleries					
4m/cum drilling @ Rs. 80/metre	4.00 x	80.00		320.00	
2.5 kg explosive @ Rs. 60 per kg				150.00	
2 Detonators	2.00 x	15.00		30.00	
Wire & other misc L.S.				100.00	
Labour for blasting L.S				60.00	
Ventilation L.S				50.00	
Lighting L.S				50.00	
Mucking including cost of labour + trolleys + rail tracks etc. L.S				500.00	
Supporting temporary/permanent ite LS.				500.00	
				1,760.00	
Contractor's profit @ 20%				352.00	
			Rs.	2,112.00	
				Say Rs.	2,112.00 /Cu
3. Rock bolts untensioned				Rs.	483.00 /me
4. Shotcrete				Rs.	11,396.00 /Cu
5. Weld Mesh				Rs.	71.00 /Kg
6. Concrete					
a) Cost of concrete M15					
Same as item 12 (a) of river diversion work @ 300 Kg cement per Cum				3,844.00	
Deducting cost of 100kg cement	4.89 x	100.00		488.67	
				3,355.33	
Deducting profit 20% of Rs.416 488.67				97.73	
				3,257.60	
Extra cost of shuttering L.S				60.00	
Extra cost for cooling L.S				120.00	
Contractor's profit @ 20%	60.00 +	120.00	= 180.00	36.00	
				3,473.60	
				Say Rs.	3,474.00 /Cu
b) Cost of concrete M20					
Same as item 12 (b) of river diversion work				4,422.00	
Deducting for pumping (75 x 1.2)				90.00	
				4,332.00	
				Say Rs.	4,332.00 /Cu.

	c) Cost of concrete M25						
	Same as item 6 (b)of diversion dam				4,332.00		
	Adding 50kg cement	50.00 x	4.89 =	244.33	244.33		
	5 % wastage				12.22		
	Adding Contractor's profit @ 20%				48.87		
					4,637.42		
					Say Rs.	4,640.00	/Cum
7.	**Steel reinforcement per tonne**				Rs.	24,940.00	/tonne
8.	**Drilling for consolidation grouting**				Rs.	403.00	/mete
9.	**Grouting with cement**				Rs.	13,117.00	/tonne
10.	**Drainage holes per metre**				Rs.	409.00	/mete
11.	**Metal pipes and fittings for grouting and drainage holes**						
	Cost/kg				30.00		
	Transport and store cost				3.00		
	Labour for fixing				7.00		
					40.00		
	Contractor's profit @ 20%				8.00		
					48.00		
					Say Rs.	48.00	/Kg
12.	**PVC Water stops per metre**				Rs.	772.00	/mete
13.	**Copper water stops**						
	Cost of copper sheets per Kg				120.00		
	Fabrication per Kg				25.00		
	Brazing per Kg				30.00		
	Fixing per Kg				30.00		
					205.00		
	Contractor's profit @ 20%				41.00		
					246.00 /kg		
	Rate per metre	(246 x 5 kg/m)	=	Rs.	1,230.00		
					Say Rs.	1,230.00	/mete
14.	**Asphalt seal**						
	2m pipe 1/2" dia @ Rs. 40/metre				80.00		
	2kg asphalt @ Rs.20/kg				40.00		
	Forming cost	L.S			30.00		
	Placing of asphalt and past L.S				40.00		
					190.00		
	Contractor's profit @ 20%				38.00		
					228.00		
					Say Rs.	228.00	/mete
15.	**Formed drains**						
	Shuttering usage charges				30.00		
	Labour for fixing and remov L.S				30.00		
					60.00		
	Contractor's profit @ 20%				12.00		
					72.00		
					Say Rs.	72.00	/mete

16.	Miscellaneous metal works				
	Cost / kg			36.00	
	Cost of fixing			8.00	
				44.00	
	Contractor's profit @ 20%			8.80	
				52.80	
				Say Rs.	53.00 /Kg
17.	Instrumentation for dam	L.S.		Rs.	13,000,000.00
18.	Stairs/ramp in body of dam	L.S.		Rs.	3,000,000.00
19.	Elevator tower including control room platform	L.S.		Rs.	2,500,000.00
20.	Room for emergency D.G. Sets	L.S.		Rs.	1,250,000.00
21.	Bridge over spillway				
	Quantity of concrete per cum for a prestressed bridge of 22m span Say 4.5 cum/m				
	22m x 4.5cum concrete @ Rs. 5,000 per cum			495,000.00	
	22m x cost of staging/m	22.00 x 7,500 =		165,000.00	
	1.2 tonnes H.T. cables @ 30,000/tonne			36,000.00	
	8 tonne of M.S. @	24,940.00		199,520.00	
	Accessories for prestressing			50,000.00	
	Bearings			100,000.00	
				1,045,520.00	
	Contractor's profit @ 20%			209,104.00	
				1,254,624.00	
	Contingencies	Deleted			
	Cost per metre	$\frac{1,254,624}{22.00}$	Rs.	57,028.36	
				Say Rs.	57,030.00 /me
22.	Railing at top of dam				
	Provided for an architectural railing of precast concrete				
	Estimated cost per metre			Rs.	3,000.00 /me
23.	Lamp post				
	Estimated cost per number			Rs.	10,000.00
24.	Stilling well incl. equipment for water level measurement	L.S.		Rs.	2,000,000.00
25.	Security watch and ward room incl. control gates	L.S.		Rs.	1,500,000.00
26.	Architectural treatment	L.S.		Rs.	1,500,000.00
27.	Steel liners in sluice			Rs.	104,100.00 /tonr
28.	Passenger cum freight elevator	L.S.		Rs.	1,500,000.00
29.	Dewatering			Rs.	6.00 /KWI
30.	Sluice spillway gate				
	a) Anchorages & Embedded parts			Rs.	26,910,000.00 /set
	b) Radial gates			Rs.	29,250,000.00 /no.
	c) Hoist for radial gate			Rs.	42,900,000.00 /set

31. Auxiliary spillway gate and hoist			
a) Anchorages & Embedded parts		Rs.	4.680.000.00 /set
b) Radial gates		Rs.	5.686.000.00 /no.
c) Radial gate hoist		Rs.	12.480.000.00 /set
32. Remote control equipment for sluice spillway & auxiliary spillway	L.S.	Rs.	19.500.000.00
33. Sluice spillway stoplogs			
a) Embedded parts		Rs.	3.575.000.00 /set
b) Stoplog units		Rs.	23.237.500.00 /no.
34. Auxiliary spillway stoplogs			
a) Embedded part		Rs.	2.145.000.00 /set
b) Stoplog units		Rs.	4.290.000.00 /set
35. Spillway gantry crane			
a) Rail & fittings		Rs.	2.243.000.00 /set
b) Crane		Rs.	28.437.500.00 /no.
c) Lifting beams		Rs.	2.437.500.00 /no.

(C) INTAKE, SEDIMENTATION CHAMBERS AND FLUSHING CONDUITS

1.	Open excavation				
	a) in overburden			Rs.	103.00 /Cu
	b) in rock			Rs.	370.00 /Cu
2.	Underground excavation			Rs.	1,682.00 /Cu
3.	Tensioned and grouted rock bolts			Rs.	674.00 /me
4.	Shotcrete incl. cost of cement			Rs.	11,396.00 /Cu
5.	Mesh reinforcement in shotcrete			Rs.	71.00 /Kg
6.	Shotcrete with steel fibres			Rs.	17,876.00 /Cu
7.	Steel rib support			Rs.	40,260.00 /tor
8.	Concrete reinforcement Fe 415			Rs.	24,940.00 /ton
	Fe 500	Fe415 per tonne = Extra 10% for Fe500 =	24,940.00 per tonne 2,494.00 per tonne 27,434.00 per tonne		
				Rs.	27,434.00 /ton
9.	Concrete M15 M20 M25			Rs. Rs. Rs.	3,474.00 /Cu 4,332.00 /Cu 4,640.00 /Cu
10.	Concrete in underground works				
	M15			Rs. Say Rs.	3,474.00 /Cu 3,474.00 /Cu
	M20			Rs. Say Rs.	4,332.00 /Cu 4,332.00 /Cu
	M25			Rs. Say Rs.	4,640.00 /Cu 4,640.00 /Cu
11.	Drainage hole 75mm			Rs.	409.00 /me
12.	Drilling for grouting			Rs.	403.00 /me
13.	Grouting			Rs.	13,117.00 /ton
14.	Stone Masonry in 1:3				
	1.1 cum of stones	1.10 x	300.00	330.00	
	0.45 cum of sand	0.45 x	601.00	270.45	
	4.8 Cement bags x 50kg	4.80 x	4.89 x 50 =	1,172.80	
	Mortar mixing	L.S		35.00	
	Scaffolding	L.S		60.00	
	Curing	L.S		50.00	
	Pointing	L.S		50.00	
	Tools and stores	L.S		50.00	
				2,018.25	
	Contractor's profit @ 20%			403.65	
				2,421.90	
				Say Rs.	2,422.00 /Cur

15.	Steel liners in flushing conduit		Rs.	104.100.00 /tonr
16.	**Intake trash rack**			
	a) Embedded parts		Rs.	3.656.000.00 /set
	b) Trash rack units		Rs.	533.000.00 /no.
17.	**Intake gates**			
	a) Embedded parts		Rs.	1.287.000.00 /set
	b) Gates		Rs.	4.648.000.00 /no.
	b) intake gate hoists		Rs.	9.750.000.00 /set
18.	**Intake stoplogs**			
	a) Embedded parts		Rs.	1.287.000.00 /set
	b) Stoplog units		Rs.	5.720.000.00 /no.
19.	**Intake trash cleaning machine**			
	a) Rails		Rs.	1.463.000.00 /set
	b) Machine		Rs.	47.450.000.00 /no.
20.	**PVC waterstop**		Rs.	772.00 /met
21.	**Copper waterstop**		Rs.	1.230.00 /met
22.	**Instrumentation**	L.S.	Rs.	1.500.000.00
23.	**Sedimentation chamber, gates & Crane**			
	a) Embedded parts		Rs.	1.287.000.00 /set
	b) Gates		Rs.	2.860.000.00 /no.
	c) Gantry Crane		Rs.	23.322.000.00 /no.
24.	**Flushing conduits, gates & hoists**			
	a) Embedded parts		Rs.	858.000.00 /set
	b) Gates		Rs.	1.788.000 /no.
	c) Hydraulic hoists		Rs.	6.500.000 /set
25.	**Remote control equipment for sedimentation chamber & flushing conduits**		Rs.	19.500.000.00
26.	**Other miscellaneous items**	**Deleted**		
27.	**De-watering**		Rs.	6.00 /KWh

(D) HEAD RACE TUNNEL AND CONSTRUCTION ADITS

1. Open excavation			
a) Overburden excavation		Rs.	103.00 /C
b) Rock excavation		Rs.	370.00 /C
2. Underground excavation		Rs.	1.682.00 /C
3. Untensioned & grouted rock bolts (25mm dia)		Rs.	614 00 /m
4. Tensioned & grouted rock bolts (25mm dia)		Rs.	674.00 /m
5. Shotcrete		Rs.	11.396.00 /C
		Say Rs.	11.396.00 /C
6. Mesh for shotcrete		Rs.	71.00 /K
7. Shotcrete reinforced with steel fibre			
Basic cost		Rs.	17.876.00 /C
Extra cost @ 10 %		Rs.	1.787.60
		Rs.	19.663.60
		Say Rs.	19.664.00 /C
8. Steel rib support		Rs.	40.260.00 /to
9. Drilling for grouting		Rs.	403.00 /m
10. Grouting		Rs.	13.117.00 /to
11. Drilling for drainage holes		Rs.	409.00 /m
12. Dewatering		Rs.	10.00 /K\
13. Concrete			
a) Portal M20		Rs.	4.332.00 /C
b) Adit M15		Rs.	3.474.00 /C
c) Tunnel linging M25		Rs.	4,640.00 /C
d) Plug M20		Rs.	4,332.00 /C
14. Steel Reinforcement		Rs.	24,940.00 /to
15. Stone masonry (1:3)		Rs.	2.422.00 /C
16. Vehicle access gate in adit			
a) Embedded parts including locking device		Rs.	772,000.00 /se
b) Gates (hinged type)		Rs.	1.544,000.00 /nc
17. Embedded drain pipe & valves per set		Rs.	3.250,000.00
18. Collapsible shutter per no.		Rs.	200.000.00
19. Instrumentation for HRT	L.S.	Rs.	3.000.000.00
20. Provision for shear zones & bad reaches	L.S.	Rs.	75.000.000.00

(E) SURGE SHAFT

1. Open excavation					Rs.	103.00 /Cum
2. Underground excavation						
Basic cost				Rs. 1,682.00 /Cum		
Extra for operation of raise climber				Rs. 600.00		
				2,282.00 /Cum		
					Rs.	2,282.00 /Cum
3. Tensioned grouted rock bolts						
a) 25mm rock bolt					Rs.	674.00 /mete
b) 32mm rock bolt						
Cost of drilling 50mm				150.00 /m		
Cost of 32mm dia rod 6.3kg	6.30 x	15.00		94.50		
Cost of plate and nut				20.00		
Cost of threading	L.S			50.00		
Cost of expansion sleave	L.S			20.00		
Labour	L.S			75.00		
Cost of truck platform			3,360.00 / 40.00	84.00		
Cost of grouting & other mi	L.S			75.00		
				568.50		
Contractor's profit @ 20 %				113.70		
				Rs. 682.20		
					Say Rs.	682 /mete
4. Shotcrete					Rs.	11,396.00 /Cum
5. Mesh reinforcement					Rs.	71.00 /Kg
6. Shotcrete with fibre reinforcement					Rs.	19,664.00 /Cum
7. Steel ribs					Rs.	40,260.00 /tonn
8. Concrete M25					Rs.	4,640.00 /Cum
9. Reinforcement						
a) Grade Fe415					Rs.	24,940.00 /tonn
b) Grade Fe500					Rs.	27,434.00 /tonn
10. Drainage holes					Rs.	409.00 /mete
11. Drilling for contact consolidation grouting					Rs.	403.00 /mete
12. Grouting					Rs.	13,117.00 /tonn
13. Sandwitch steel liner					Rs.	104,100.00 /tonn
14. Steel liner in orifice slab					Rs.	104,100.00 /tonn
15. Air vent pipe 500mm-6mm thick						
wt	1.57 x	45.00 =		70.65 Kg		
Cost/m	70.65 x	50.00 =	Rs.	3,532.50	Rs.	3,532. /mete
16. Slope protection			L.S.		Rs.	2,000,000.00
17. Stone masonry (1:3)					Rs.	2,422.00 /Cum
18. Steel platform at top					Rs.	50,000.00 /tonn
19. Surge shaft stoplog						
a) Embedded parts					Rs.	3,861,000.00 /set
b) Stoplog gate					Rs.	5,005,000.00 /no.
20. Radially travelling hoist for handling stoplog					Rs.	14,300,000.00 /set

(F) PRESSURE SHAFT AND PENSTOCKS

1.	**Underground excavation**			
	Cost of gallery excavation	2,112.00 /Cum		
	Extra for operation of raise climber	600.00		
		2,712.00	Rs.	2,712.00 /C
2.	**Tension & grouted rock bolt (25mm dia)**			
	Basic cost	674.00 /meter	Rs.	674.00 /m
3.	**Steel rib support**			
	Basic cost	40,260.00 /tonne	Rs.	40,260.00 /tc
4.	**Shotcrete**		Rs.	11,396.00 /C
5.	**Mesh reinforcement for shotcrete**			
	Basic cost	71.00 /Kg	Rs.	71.00 /K.
6.	**Fibre reinforced shotcrete**		Rs.	19,664.00 /C
7.	**Drilling for consolidation & contact grouting**			
	Basic cost	403.00 /meter	Rs.	403.00 /m
8.	**Cement grouting**			
	Basic cost	13,117.00 /tonne	Rs.	13,117.00 /tc
9.	**Penstock steel liner (ASTM 537 GRI STEEL)**		Rs.	104,100.00 /tc
	Instrumentation	L.S.	Rs.	2,000,000.00
12.	**Steel reinforcement**			
	Basic (Fe415) cost	24,940.00 /tonne	Rs.	24,940.00 /tc
13.	**Concrete M20**		Rs.	4,332.00 /Ci

(G) POWER HOUSE COMPLEX

1. Open excavation					
a) Overburden excavation				Rs.	103.00 /Cu
b) Rock excavation				Rs.	370.00 /Cu
2. Untensioned grouted rock anchors (25mm dia)				Rs.	614.00 /me
3. Underground excavation					
a) Approch adit	1,682 +	1,000		Rs.	2,682.00 /Cu
b) Cavity				Rs.	1,682.00 /Cu
4. Tensioned & grouted rock bolt					
a) 25 mm dia				Rs.	674.00 /me
b) 36 mm dia					
Cost of drilling			150.00		
Cost of 36 mm dia rod/m (8 Kg)	8.00 x	15.00	120.00		
Cost of plate & nut L.S			20.00		
Cost of threading L.S			50.00		
Cost of expansion sleeve L.S			25.00		
Labour L.S			75.00		
Cost of truck platform L.S			100.00		
Cost of grouting L.S			75.00		
			615.00		
Contractor's profit @ 20 %			123.00		
			738.00		
				Say Rs.	738.00 /me
5. Drilling for grouting				Rs.	403.00 /me
6. Grouting				Rs.	13.117 /tor
7. Shotcrete				Rs.	11,396.00 /Cu
8. Mesh reinforcement for shotcrete				Rs.	71.00 /Kg
9. Fibre reinforced shotcrete				Rs.	19,664.00 /Cu
10. Drainage hole (core drilling) Nx holes				Rs.	409.00 /me
11. Concrete					
a) M15				Rs.	3,474.00 /Cu
b) M20				Rs.	4,332.00 /Cu
c) M25				Rs.	4,640.00 /Cu
12. Steel ribs				Rs.	40,260.00 /tor
13. Steel reinforcement (Fe415)				Rs.	24,940.00 /tor
14. Copper metal seals				Rs.	1,230.00 /me
15. Pvc seal				Rs.	772.00 /me
16. Miscellaneous metal work & MS. pipe				Rs.	50.00 /Kg
17. Grating & Covers				Rs.	50.00 /Kg
18. Aluminium doors & windows			L.S.	Rs.	1,500,000.00
19. Water supply & sanitary fittings			L.S.	Rs.	1,500,000.00
20. False ceiling of Aluminium/metal				Rs.	2,500.00 /Sq
21. E.O.T crane rail				Rs.	5,000.00 /me
22. Transformer rail				Rs.	5,000.00 /me
23. Instrumentation			L.S.	Rs.	3,000,000.00

24.	Dewatering			Rs.	10.00	/KW
25.	Rolling shutter	L.S.		Rs.	1,000,000.00	
26.	Architectural features in power house complex	L.S.		Rs.	2,500,000.00	
27.	Architectural treatment outside approach adit	L.S.		Rs.	1,000,000.00	
28.	Security guard room	L.S.		Rs.	1,500,000.00	
29.	Stone masonery (1:3)			Rs.	2,422.00	/Cu
30.	Fabrication steel works			Rs.	75.00	/Kg
31.	20m rock anchor of 50T capacity					
	a) Drilling of 100mm hole		600.00			
	b) Cost of cable of 50T capacity		1,200.00			
	c) Sheath & Spares		300.00			
	d) Anchorages & anchor block		600.00			
	e) Grouting		500.00			
	f) Labour for assembly & placing the cable & stressing		400.00			
	g) Scaffolding		100.00			
	h) Lighting & other misc. items		300.00			
			4,000.00			
	Contractor's profit @ 20%		800.00			
			4,800.00			
				Rs.	4,800.00	/me
32.	Draft tube gates					
	a) Embeded parts			Rs.	1,609,000.00	/set
	b) Gate			Rs.	3,575,000.00	/no.
	c) Gate opening crane			Rs.	14,300,000.00	/no.

(H) D/S SURGE CHAMBER

1.	Open excavation					
	a) Overburden excavation				Rs.	103.00 /Cun
	b) Rock excavation				Rs.	370.00 /Cun
2.	Underground excavation				Rs.	1,682.00 /Cun
3.	Tensioned & grouted rock bolt				Rs.	674.00 /met
4.	Drilling for grouting				Rs.	403.00 /met
5.	Grouting				Rs.	13,117.00 /ton
6.	Shotcrete				Rs.	11,396.00 /Cun
7.	Mesh reinforcement for shotcrete				Rs.	71.00 /Kg
8.	Shotcrete with fibre reinforcement				Rs.	19,664.00 /Cun
9.	Steel ribs				Rs.	40,260.00 /ton
10.	Concrete					
	a) M15				Rs.	3,474.00 /Cun
	b) M20				Rs.	4,332.00 /Cun
11.	Steel reinforcement (Fe 415)				Rs.	24,940.00 /ton
12.	Copper seal				Rs.	1,230.00 /met
13.	PVC Seal				Rs.	772.00 /met
14.	Miscellaneous metal & pipe				Rs.	53.[illegible] /Kg
15.	Stone masonry				Rs.	2,422.00 /Cun
16.	Grouting boulder pitching					
	1 cum of boulder pitching @ 150/-	1.00 x	150.00	150.00		
	Labour @ Rs. 100/-			100.00		
	Grouting with cement mortar			250.00		
	Scaffolding	L.S		35.00		
	Curing	L.S		20.00		
				555.00		
	Contractor's profit @ 20%			111.00		
				666.00	Rs.	666.00 /Cur
17.	Outlet gates & hoists					
	a) Embeded parts				Rs.	1,609,000.00 /set
	b) Gate				Rs.	4,290,000.00 /no.
	c) Hoists				Rs.	5,850,000.00 /no.
	c) Trestles and hoist platform				Rs.	3,218,000.00 /set
18.	Dewatering				Rs.	10.00 /KW
19.	Instrumentation	L.S.			Rs.	1,500,000.00
20.	Stilling well & tail water level measuring instrument	L.S.			Rs.	1,500,000.00

(I) POTHEAD YARD

1. **Open excavation**			
a) Overburden excavation	Rs.	103.00	/Cu
b) Rock excavation	Rs.	370.00	/Cu
2. **Concrete**			
a) M15	Rs.	3,474.00	/Cu
b) M20	Rs.	4,332.00	/Cu
c) M25	Rs.	4,640.00	/Cu
3. **Steel reinforcement (Fe 415)**	Rs.	24,940.00	/ton
4. **PVC seals**	Rs.	772.00	/me
5. **Metal seals**	Rs.	456.00	/me
6. **Metal works**	Rs.	53.00	/Kg
7. **Stone masonry**	Rs.	2,422.00	/Cu
8. **Fencing and gates**	Rs.	1,500,000.00	