HYDROPOWER ANALYSIS OF MATNAR RUN-OFF-THE RIVER PROJECT

A DISSERTATION

Submitted in partial fulfillment of the requirements for the award of the degree

of

MASTER OF TECHNOLOGY

in

HYDROLOGY

By

NEHAL AHMAD

DEPARTMENT OF HYDROLOGY
INDIAN INSTITUTE OF TECHNOLOGY ROORKEE
ROORKEE - 247 667 (INDIA)

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CANDIDATE'S DECLARATION

I hereby certify that the work which is being presented in this dissertation titled **HYDROPOWER ANALYSIS OF MATNAR RUN-OFF-THE RIVER PROJECT** in the partial fulfillment for the award of the Degree of Master of Technology in Hydrology, submitted in the Department of Hydrology of the Indian Institute of Technology, Roorkee, is an authentic record of my work done during the period from July ,2005 to June,2006 under the guidance of Dr. D. K. Srivastava, Professor, Department of Hydrology, Indian Institute of Technology Roorkee.

The matter embodied in this dissertation has not been submitted by me for award of any other degree.

Roorkee:

Date: 15-6-06

Nehal Ahmad

(NEHAL AHMAD)

This is to certify that the above statement made by the candidate is correct to the best of my knowledge.

(D. K. Srivastava)
Professor, Department of Hydrology
Indian Institute of Technology
Roorkee-247667 (India)

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Roorkee

(NEHAL AHMAD)

ABSTRACT

Hydropower is the largest renewable source of energy and is second largest source of electricity generation. The hydropower generation has many advantages which make it a desired source of electricity generation. According to estimate of water vision (2000), only about 33% of economically feasible hydropower potential of the world has been developed so far. There are many difficult sites of hydropower which are yet to be developed.

India has hydropower potential of 84000MW out of which only 25% has been tapped so far. Tributaries have about 30% of power potential of India and only a negligible fraction of it has been developed.

The Matnar project was first identified by then Madhya Pradesh Electricity Board as Run of the River scheme for power generation on river Indravati. Based upon the field investigation carried out and data collected by Madhya Pradesh Irrigation Department, a project report of the scheme was prepared by M.P. Irrigation Department in 1991. The project report for Matnar Hydel project (Run of the River scheme) was submitted to CEA by MPEB in January 1991 with an installed capacity of 2X40MW.

The main objective of the study is to know the maximum hydropower energy which can be generated from the given 10-daily monthly flows.

The approach to the study is in the sequence of

(1) Study of project as run-off the river scheme without pondage

(2) To know the minimum pondage required to generate the maximum energy. Use of LP implicit stochastic reservoir yield model for the system. Use of software "LINDO" for the solution of yield model.

(3) Pondage regulation using Standard operating policy (SOP) and continuous Hedging rule (CHR)

(4) Economic performance evaluations.

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NOTATIONS & ABBREVIATIONS

(A) Single Reservoir Yield Model

I_J = Annual inflows in MCM;

O_y^{fp} = firm annual reservoir yield in MCM;

O_{yt}^{fp} = firm within year reservoir yield in MCM;

Sp_j = excess release (spill) in year j in MCM;

Sp_t = excess release (spill) during period t within year in MCM;

S^w_{t-1} = initial storage at the beginning of within year period t in MCM;

S^w_t = final storage at the end of within year period t in MCM;

S^0_j = final storage at the end of year j in MCM;

S^0_{j-1} = initial storage at the beginning of year j in MCM;

Y_a = total active storage capacity in MCM;

Y^0 = active over year capacity in MCM;

Y^W = within year reservoir capacity in MCM;

β_t = ratio of the inflow in period t of the critical year of record to the total inflow in that year;

$\theta_{p,j}$ = failure fraction for the yield with reliability p in year j;

(B) For hydropower

j = a year;

t = a within year period;

CF = conversion factor for computation of hydro-electric energy;

e = hydropower plant efficiency;

EFt = firm energy generation for reservoir in time t;

ESt = secondary energy generation for reservoir in time t;

H = hydropower plant capacity;

Ha_t = productive storage head in time period t;

h_t = number of hours for generation of energy in period t;

a_t = hydropower plant factor in period t;

η_t = percentage fraction of annual firm energy target in period t;

(C) NOTATIONS USED FOR ACTUAL MODEL

OYFP = annual firm reservoir yield in case of single yield model in MCM;

OYSP = annual secondary yield in case of multi-yield model in MCM;

$OYFP_t$ = ten daily firm yield in MCM (t indicates corresponding period);

$OYSP_t$ = ten daily secondary yield (t indicates corresponding period);

OS = over the year storage in MCM during year 1;

SP = over the year spill in MCM;

OY= over the year reservoir capacity in MCM;

WY= within-year reservoir capacity in MCM;

YA = total reservoir capacity in MCM;

WS = within-year storage in MCM;

EF_t = ten daily firm energy in MWh (t indicates corresponding period);

ES_t = ten daily secondary energy in MWh(t indicates corresponding period);

EF = annual firm energy in MWh;

ES = annual secondary energy in MWh;

(D) ABBREVIATIONS:

DP	Dynamic Programming
FRL	Full Reservoir Level
MWL	Maximum Water Level
MDDL	Minimum Draw Down Level
MW	Mega-watt
Gwh	Giga watt hour
Ha	Hectare
ha-m	Hectare Meter
Km	Kilometer
KWh	Kilowatt hour

LP	Linear Programming
m	Meter
MCM	Million Cubic Meter
CUMECS	Meter-cube per Sec.
LINDO	Linear Interactive and Discrete Optimizer

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INTRODUCTION

1.1 GENERAL

Water is an excellent resource of nation, as it can be made to serve various functions. No flora and fauna is possible without water .With increasing population and consequent rise in demand for water it has become a scare resource for the human being both in quantity as well as quality, causing a concern for the humanity. The root problem lies in spatial and temporal variability of availability and demand. Properly planned use of water may nourish our farms and forests, may run our turbine for generation of hydroelectric power, may help in beautifying our surroundings and environments etc.

Besides, fulfilling the basic necessities of life, properly harnessed and developed water resources can be enable us to lead a luxurious life. So careful planning of water resources for various purposes such as drinking, hydropower, irrigation, industrial, recreational and environmental is of utmost urgency, as the development of water resources has a pivotal role in the economy of a country.

Water resources planning and management is broadly concerned with the accurate assessment, identification of water from different source for the well being of the humanity and development of the nation. The development and adoption of the 'System Analysis Technique' in the field of water resource planning and development is a milestone in its path leading to sustainable development and survival.

Water is a renewable source of energy. The hydroelectric power generation is a non consumptive use of water because after passage through the power where its mechanical energy is converted into electrical energy, the same water can be utilized for other purpose downstream as drinking, irrigation, etc. It has been estimated one quarter of electrical energy generated in the world is from hydropower.

1.2 PROJECT AREA

1.2.1 Project Location

The proposed barrage site on Indravati river is located near Chitrakoot village about 40 Km from Jagdalpur. The project structures, including the reservoir area, lies in Bastar district of Chattisgarh. The barrage site is located at $19^0$12'27" latitude N and $81^0$42'15" longitude E.

1.2.2 The River Basin

The Indravati river is one of the Principle tributary of Godavari. During its course, the river carries the flows from several tributaries and flows through Orissa, Chattisgarh and Andhra Pradesh. After flowing for a length of 174 km in Orissa state, the river enters in Chattisgarh near Jagdalpur. The entire length of the river in Chattisgarh state lies in Bastar and Dantewara district .The river is west flowing and after it leaves Chattisgarh it forms a common boundary of 129 Km. between Andhra Pradesh & Chattisgarh. The total drop of the river from its origin to the place of its confluence with Godavari is 832.1 m and in the Chattisgarh state the available drop is 303.5 m. As the river flows through hilly terrain there is a very little command area available for development of irrigation in Chattisgarh. But due to hilly terrain and available drop in the river, hydro power potential to the extent of 2000 MW in Chattisgarh is available. Matnar Hydel Project will be the first hydro power project on Indravati river in the state of Chattisgarh.

The Indravati river has a total catchment area of 11,831 km^2 up to the barrage site. Out of the total catchment area 7748 km^2 of the catchment area lies in Orissa and the remaining 4383 km^2 in Chattisgarh. The Indravati river flows through a sequence of Indravati group of rocks of Proterozoic ages after its origin near Nowrangpur in Orissa.

1.2.3 Climate

In the basin, winter season generally begins in early December and continues up to the mid February. The average winter temperature over the area is of an order of 19^0 C with the minimum temperature generally recorded in the month of January.

From March onwards, the hot weather season starts and this continues up to the last week of May. During the summer season the temperature varies from 25°C to 35^0 C. The maximum temperature is generally recorded in the month of May.

The monsoon sets in by early June and continues up to the end of September. In the monsoon season, the mean temperature in the basin varies from 20^0 C to 30^0 C.

Average annual rainfall in the basin is 1500mm, with about 85% of the total precipitation occurring during the monsoon months of June to October. Maximum precipitation generally occurs in July and August.

1.2.4 Hydraulic Resources

The long term average discharge of the river at the Matnar site has been estimated as 107 m^3/s. The annual runoff varies from the maximum of.,7415-. Mcum to minimum 1126 Mcum

The Indravati river is a true Inter state river flowing through the states of Chattisgarh and Orissa. State of Orissa and Chattisgarh entered an Inter-state agreement for sharing of Indravati river water on 11th July 1979. According to this agreement water availability of Indravati at the border between Orissa and Chattisgarh has been assessed as 204 T.M.C. at 75% dependability. Out of this Orissa has been allowed to use 159 T.M.C. in which 91 T.M.C has been allocated for Upper Indravati Project in Orissa and 68 T.M.C for other projects. Chattisgarh will have share of 45 T.M.C. of water. The upper Indravati project is in operation in Orissa state. Though as per agreement complete use of allocaled water for Upper Indravati will take at least I 5 to 20 year Till such time, it is expected that at the border more water will be available over the allocated share of 45 T.M.C. for Chattisgarh state.

1.2.5 Access

The access by road to the project area is through jagdalpur-Chilrakoot-Barsoor state highway and barrage site is located approximately 40 km form the Jagdalpur city.

It is proposed to use the existing state highway as the main access, for the construction of the project. The portion of the road approaching the power house would have to be suitably aligned afresh along the contours for about 5 km according to the requirements of' the permanent project structures and of the construction planning.

1.2.6 History of the Project

Investigations and basic studies for the Matnar Project were initially carried out by the Stale of Madhya Pradesh (now Chattisgarh) during the 1990s. Those investigations mainly covered, Topographical Surveys, Geological Investigations, Construction Materials Investigations, and Hydro meteorological Observations. Based on the above field investigations, a Detailed Project Report on the Matnar project was prepared by Madhya Pradesh State Electricity Board in 1991.

The Project Report for Matnar Run of the River Scheme was submitted to Central Electricity Authority by Madhya Pradesh Electricity Board in January 1991 with an installed capacity of 2X40 MW. The project was planned on left bank of river Indravati on downstream of Chitrakoot fall.

Based on the discussions with MPEB officials Central Electricity Authority returned the project report vide CHA letter No. 302/30/92-HPA/I/453 dated 12.05.92. The hydrological series was approved by CWC vide letter No 7/MP-75/S9-Hyd (S)/181-183 dated 25.04.92/12.05.92. CEA also suggested to MPEB officials to explore the possibility of locating the power house and water conductor system on right bank of the river Indravati instead of left bank. Based on the suggestion of CEA, survey and detailed geological/geotechnical proposals were formulated by MPEB for carrying out investigations by Geological Survey, of India, Nagpur. Director, GSI Nagpur along with team of geologists visited the Power House sites on left bank and right bank as well and finally suggested to adopt left bank proposal. It was also suggested to carry out bore holes at power house sites. Right bank proposal was not found feasible by GSI authorities.

Based on the bore hole logs and report of the GSI, proposal for locating power house on the left bank was adopted in the Detailed Project Report for Matnar Hydel Project and submitted to CEA in February 2000.

The Project Report of 2000 prepared by MPEB was based on hydro-meteorological data up 1990. Realizing the need for additional investigations and review studies required to be carried out for the project on the strength of additional hydro-meteorological data base available, CSEB approached CWC to take up review studies in respect of DPR.

1.2.7 Project Features

Based on the review of Project Hydrology on the strength of additional hydro-meteorological data available, most of the civil, electrical and mechanical components have been reviewed. The Project under went value addition during the review studies resulting in optimum project planning. As presently conceived, the runoff the river project includes the following main structures:

- 14 m high concrete barrage from deepest foundation level with 26 numbers of gates and a total gross storage volume of abour35.15 IIIIIK
- A head regulator with 3 numbers of gates,
- 330 m long power channel with 15 m bed width,
- Intake on the left bank,
- 5.37 km longhead race tunnel with diameter of 6.5 m,
- Surge shaft of 26 m diameter,
- Three numbers of penstock of 3.75 m diameter.
- 860 m long tail race channel with 37 m bed width
- FRL is 535.00 m
- MWL is 532.50 m
- MDDL is 530.00 m
- Gross Storage capacity is 35.15 MCM
- Live Storage capacity is 26.15 MCM
- Dead Storage capacity is 9.00 MCM

The main features of this project are as under:

1.2.8 Barrage

The proposed barrage on river Indravati at about 300 m upstream of Chitrakoot fall. Height of the barrage from deepest foundation level as 14 m. The total water way provided - between abutments is 460 m. The barrage is designed to pass the designed flood discharge of 22600 cumecs with 26 nos. vertical lift gates. The maximum water level, full reservoir level and minimum drawdown levels are 535 m, 532.5 m and 530 m respectively. The reservoir formed by this barrage will submerge about 1350 ha of land.

1.2.9 Head Regulator

A head regulator is proposed on left side of the barrage keeping the crest level at 527.00 m. The overall length of the water way comes out to be 21.50 m with a pier of 1.75. The cistern length of the head regulator is 16 m.

1.2.10 Power Channel

A 330 m long power channel is proposed to be constructed with bed width 15 m side slope 1.5:1 and bed grade as 1 in 6600. The power channel is proposed to be lined with PCC full supply depth in power channel is 4.25 m.

1.2.11 Intake

A conventional semi circular intake structure has been proposed at the tunnel inlet. The proposed intake structure is now semi circular with 5 nos. peirs and radius of 7.5 m at the trash rack groove. The top of the intake structure is kept at R.L. 533.50 i.e. above the maximum water level in the channel to facilitate regular cleaning of the trash rack. The size of the intake structure is such that sufficient opening shall be available to satisfy hydraulic requirements. The intake structure will also have the conventional trash rack arrangement to prevent the entry of debris into the water conductor system. At present no gate is proposed at the intake structure with the understanding that the flow of water shall be controlled al head regulator. The provision of gate may be made at tendering stage if so required by the project authorities

1.2.12 Head Race Tunnel

A 6.5 m dia 5370 m long head race tunnel is proposed to be constructed to feed the water to the three units of power house. The discharge capacity of the head race tunnel is worked out as 124.72 cumecs with 3.75 m/sec velocity at rated designed head of 57.75 m

1.2.13 Surge Shaft

A restricted orifice type surge shaft is provided at a distance of 5400 m from intake for dampening the water hammer effect. The dia of the shaft is worked out to be 26 m. The top and the bottom levels of surge shaft is kept as El 545 m and 517.200 m respectively. One orifice of 3.85 m dia connects the surge shaft to head race tunnel from bottom.

1.2.14 Pressure Shaft

It is proposed to trifurcate the head race tunnel at a distance of about 60 m from the surge shaft in to three pressure shafts of 3.75 m dia each to feed the three units of the power house. Each pressure shaft is designed to carry a discharge of 41.75 cumecs at 3.75 m/sec velocity under rated designed head.

12.15 Power House

The power house is proposed to be located near confluence of the Mendri nallah and the river Indravati near existing Chitrakoot Barsoor road on left bank of river. The type of the proposed power house will be semi under ground type. The average RL of the ground at the location of proposed power house is 480.05 m. The power house building is proposed to be of an RCC structure with precast roof slab supported on steel roof trusses. The length and width of the power house for 60 MW unit has been worked out to be 70 m and 1.85 m respectively. Special rooms in auxiliary bay (of width 9 m) are •proposed to be used for accommodating cable racks control room, battery room, I..T. switch gear, D.C distribution board, battery charger etc. Enough space is provided for office room etc. An EOT crane of capacity 75/15 tonnes has been proposed to be provided. Erection of crane will be done in the erection by and the crane will travel for full length of power house and will be used for erection and operation of power house. The crane is proposed to be provided with a clear head room of 10.5 m from generator floor level

12.16 Tail Race Channel

The length of the tail race channel from power house to river Indravati is 860 m. The TRC discharge water into river Indravati at about 6.86 km downstream of the barrage. The bed width of the TRC is worked out as 37 m. side slope 1:1 and bed grade 1 in 2000 beyond the initial 60 m long reverse slope of 1 in 6. The tail race channel is proposed to be lined with 200 mm. thick PCC. Full supply depth is 2.5 m.

12.17 Approach Road

The proposed approach road to PH is contour road and connected to Jagdalpur-Barsoor road. The total length of the road is about 13 km with an overall slope 1 in 200. The width of road (black topped only) is proposed as 7.5 m. In hilly area maximum slope is proposed as 1 in 13.

12.18 Turbines

Looking to the head variation as well as size of units it is proposed to install Francis turbines with 57.7.5 m designed head and operating speed of 300 RPM. The discharge dia of the runner is calculated as 2.22 m & preliminary dimensions of draft tube, scroll case have been worked out accordingly. Various parts of the turbine will be as per IS specifications.

1.2.19 Draft Tube

The draft tube will be elbow type connecting the turbine to tail race channel. A part of the draft tube will be steel lined and the rest will be RCC. Provision is also made of drainage pits and pumps for dewatering.

1.2.20 Generator

The vertical mounted generator shall be rated for 25 MVA. 11 K.V 3 phase 50 Hz 0.8 (lagging) power factor with class-F insulation. The generator stator and rotor shall be air cooled and air shall be water cooled. The permissible variations shall be ± 5% for voltage and +3% to -5% for frequency variations. The generator rotor shall have salient pole type construction having 20 poles (300 rpm) tentatively supported with thrust & guide bearings. The excitation shall be of static type complete with digital type automatic voltage regulator and all necessary accessories.

Stator shall be star connected with neutral leads brought outside and shorted & earthed through a neutral grounding transformer in a separate generator neutral grounding cubicle. The generator shall be equipped with all necessary accessories & protections.

1.2.21 Hydro Power Potential in the Upper Basin

Upper Indravati Project has been constructed on Indravati river in Orissa state. As per Interstate agreement, out of 159 TMC share of Orissa 91 TMC has been allocated for Upper Indravati Project. Other projects namely, Muran dam, Podagada dama and Kapur dam has been identified upstream on the river Indravati for development.

1.2.22 Socio-Economic and Environmental Aspects

Formulation of a new project is not complete without addressing the socio-economic and environmental aspects of the project area in their entirety. While a detailed study has been carried out on these aspects separately by M/s RITES.

1.2.23 Population and Economy

The population density in the project area is 58 persons/km2 is low as compared to other areas in the countries. Around 70% of the population is tribal. Subsistence agriculture is at present the primary economic activity in the project area. Implementation of the project may give fillip to small and medium industries with the project works acting as the initial catalyzer. Availability of power and improvement of communications is bound to boost the local economy.

1.2.2.4 Resettlement and Relocation

The construction of barrage & reservoir and the filling of the reservoir will displace some 1025 inhabitants in 13 revenue villages in Bastar District and result in submergence of about 13.5 sq km of the land. It is proposed to relocate the effected population at appropriate locations in consultation with the local population, state administration and resettlement policies, if any National & State as & when promulgated.

1.2.2.5 Physical Environment

The reservoir of project would submerge 13.5 km^2 area. About 5.5 km2 of agriculture land in 13 revenue villages would be coming under submergence of reservoir. The project area is mostly covered with Kutki, Kallhi, Koelo forests, which could be classified as moderately thick. No endangered species has been located in the project area. No important minerals or archeological/historical monument exists in the submergence area.

TABLE 1.1

TEN DAILY STREAM FLOW DATA OF INDIRAVATI RIVER AT MATNAR SITE FROM 1966 TO 1973 (in MCM)

MONTH		1966-67	1967-68	1968-69	1969-70	1970-71	1971-72	1972-1973	1973-74
JUNE	1	15.02	4.79	18.15	15.65	31.73	47.08	7.95	13.41
	2	23.47	22.46	20.83	69.72	55.51	41.18	6.71	43.91
	3	91.15	508.09	49.97	50.04	42.48	184.60	86.10	19.22
JULY	1	36.99	329.44	122.68	54.83	178.72	121.67	623.46	565.44
	2	97.22	94.91	69.93	118.75	144.81	176.16	86.55	639.35
	3	418.37	362.28	269.88	1009.36	394.87	136.11	69.59	163.65
AUG	1	344.95	791.94	110.65	953.17	278.17	372.70	68.53	149.15
	2	271.47	302.92	149.25	290.21	430.80	246.15	165.39	286.34
	3	252.21	592.49	131.95	160.64	773.15	205.86	228.43	566.21
SEP	1	858.55	194.45	114.15	301.11	240.92	428.40	118.50	154.32
	2	159.49	401.77	471.01	281.76	183.77	143.01	543.91	156.49
	3	108.54	249.94	145.67	269.46	254.07	81.46	438.19	134.20
OCT	1	55.96	124.63	610.13	79.53	177.19	66.61	120.15	177.45
	2	56.49	68.50	200.66	73.42	70.57	73.89	68.69	78.07
	3	27.46	56.29	84.54	49.94	49.11	95.25	53.20	151.60
NOV	1	28.77	46.18	51.40	41.23	34.95	43.77	74.05	69.84
	2	28.72	40.82	42.07	41.41	33.93	34.97	38.70	48.92
	3	37.48	38.59	35.03	31.99	29.42	28.35	31.32	34.09
DEC	1	43.92	26.48	29.11	28.84	26.18	25.22	28.19	29.95
	2	26.84	28.25	25.53	46.06	22.92	23.77	25.22	27.14
	3	25.58	25.29	25.21	29.99	22.80	25.47	25.04	28.10
JAN	1	22.06	18.73	18.61	23.46	19.69	21.80	22.75	23.21
	2	21.62	24.15	16.81	21.14	18.46	18.69	20.53	21.63
	3	21.17	21.85	16.27	21.48	19.08	18.81	19.66	21.89
FEB	1	16.12	17.28	14.22	17.69	17.25	14.85	16.53	17.61
	2	14.59	15.09	12.10	15.96	14.67	14.43	15.41	15.81
	3	9.81	14.05	8.76	12.44	11.95	11.96	10.61	11.95
MARCH	1	11.41	19.05	10.76	17.56	15.59	11.85	14.93	13.60
	2	16.04	12.77	10.53	15.14	12.24	10.51	11.79	12.76
	3	31.39	12.01	10.61	12.84	12.82	11.10	11.47	14.56
APRIL	1	13.70	10.41	8.91	12.82	12.01	9.27	11.07	13.93
	2	10.02	13.58	9.67	12.93	13.25	11.14	11.90	11.39
	3	15.46	20.38	9.35	13.18	15.99	10.29	8.41	13.03
MAY	1	9.17	18.81	11.97	13.90	12.40	9.50	11.85	10.19
	2	10.63	11.34	16.18	11.70	19.89	8.12	8.46	13.69
	3	8.21	14.36	11.94	18.32	16.16	8.82	12.57	16.27
		3240.05	4554.37	2964.49	4237.67	3707.52	2792.82	3115.81	3768.37
Inflow(Jun-Oct)		2817.34	4104.90	2569.45	3777.59	3305.87	2420.13	2685.35	3298.81
Inflow(Nov-May)		422.71	449.47	395.04	460.08	401.65	372.69	430.46	469.56

TABLE 1.2

TEN DAILY STREAM FLOW DATA OF INDIRAVATI RIVER AT MATNAR SITE FROM 1974 TO 1981 (in MCM)

MONTH		1974-75	1975-76	1976-77	1977-78	1978-79	1979-80	1980-81	1981-8
JUNE	1	11.32	17.03	8.54	11.36	9.6	7.76	22.12	32.7
	2	165.53	31.84	9.51	28.37	18.33	20.12	150.01	16.
	3	82.7	279.85	20.59	28.66	60.91	632.23	196.85	20.1
JULY	1	35.84	346.79	65.33	413.69	151.68	358.15	163.66	32.1
	2	98.38	189.59	16.31	208.17	318.26	140.69	230.18	78.0
	3	46.84	204.56	647.98	264.69	395.21	152.33	661.75	93.5
AUG	1	80.61	302.93	529.9	366	303.1	689.39	356.64	417.0
	2	164.38	514.21	417.49	251	1367.18	170.85	208.22	496.1
	3	139.51	262.63	557.1	840.41	835.52	76.94	341.27	218.5
SEP	1	90.96	411.62	641.41	278.06	208.09	86.49	281.36	244.8
	2	86.12	365.02	215.86	711.81	250.97	98.26	787	186.7
	3	82.7	207.02	84.44	155.11	240.2	105.26	300.83	140.
OCT	1	109.69	139.9	53.8	104.69	105	216.76	90.27	102.6
	2	64.09	104.31	42.49	59.83	78.05	54.89	60.85	45.4
	3	48.48	78.75	40.51	52.5	62.07	41.83	62.2	34.9
NOV	1	29.79	62.15	32.98	40.98	48.49	30.12	37.41	28.4
	2	23.52	38.09	33.09	36.15	39.55	24.77	31.75	24.5
	3	23.95	31.13	27.77	91.86	29.71	21.03	26.95	21.
DEC	1	18.94	26.74	23.37	44.56	30.7	20.71	23.77	18.5
	2	16.26	22.31	20.96	33.4	25.97	18.83	21.97	16.8
	3	16.39	21.82	20.67	29.61	24.02	21.01	21.81	16.5
JAN	1	14.54	19.22	16.97	24.56	20.43	15.37	17.94	13.7
	2	12.91	18.39	16.5	25.01	19.06	14.18	19.96	12.6
	3	14.51	18.3	17.1	22.9	18.65	13.62	18.02	12.5
FEB	1	13.21	15.33	14.33	20.53	15.88	11.15	14.29	10.4
	2	11.06	14.03	12.79	18.46	14.37	10.41	12.63	9.2
	3	8.34	11.25	10.96	14.42	10.96	8.68	9.24	6.
MARCH	1	9.42	11.98	11.62	14.82	11.94	8.55	10.71	9.0
	2	9.34	12.22	10.73	13.96	11.25	7.79	14.46	7.0
	3	8.53	11.6	11.5	15.48	11.09	7.74	19.33	7.7
APRIL	1	6.79	12.07	14.01	14.79	9.19	9.12	9.18	6.
	2	6.47	10.07	14.15	13.15	9.06	7.3	6.85	7.0
	3	7.93	9.65	15.47	16.6	8.31	8.52	10.08	8.4
MAY	1	6.55	8.03	31.43	18.92	8.84	9.08	13.26	5.6
	2	4.82	13.87	16.42	18.79	8.95	9.62	11.15	17.0
	3	6.52	13.23	17.88	10.77	8.46	11.82	9.67	9.4
		1576.94	3857.53	3741.96	4314.07	4789.05	3141.37	4273.64	2429.5
Inflow(Jun-Oct)		1307.15	3456.05	3351.26	3774.35	4404.17	2851.95	3913.21	2159.
Inflow(Nov-May)		269.79	401.48	390.7	539.72	384.88	289.42	360.43	269.9

TABLE 1.3

TEN DAILY STREAM FLOW DATA OF INDIRAVATI RIVER AT MATNAR SITE FROM 1983 TO 1990 (in MCM)

MONTH		1983-84	1984-85	1985-86	1986-87	1987-88	1988-89	1989-90	1990-91
JUNE	1	6.13	17.24	29.69	11.63	12.01	5.59	10.22	71.47
	2	7.46	282.52	28.33	12.04	33.7	13.93	101.53	157.98
	3	275.29	51.44	197.25	116.83	15.21	124.41	164.69	120.12
JULY	1	61.24	273.88	337.9	71.19	148.87	114.35	126.17	81.33
	2	172.63	295.03	312.75	151.78	126.16	186.96	88.76	373.95
	3	207.46	272.34	229.48	386.19	141.93	184.02	229.39	514.41
AUG	1	271.25	878.09	395.6	237.64	63.04	297.7	91.98	197.34
	2	227.84	448.84	593.11	872.96	58.73	206.57	268.78	411.33
	3	248.19	292.3	318.41	320.49	152.79	148.67	619.16	703.74
SEP	1	294.51	194.12	190.25	93.32	336.19	180.38	206.65	494.57
	2	227.73	161.57	248.02	205.86	101.36	101.87	420.15	433.8
	3	151.75	70.35	182.79	69.16	89.8	163.44	212.36	195.59
OCT	1	150.24	54.54	124.77	103.9	68.47	106.99	116.51	871.05
	2	92.49	64.92	115.27	56.72	67.18	41.46	50.67	364.21
	3	52.45	55.32	50.86	36.04	46.68	28.96	33.53	143.9
NOV	1	33.51	36.18	37.49	35.26	43.07	20.53	22.08	112.41
	2	28.19	32.72	30.91	29.38	58.34	17.68	21.07	66.7
	3	23.86	27.32	26.15	22.29	48.2	15.91	16.26	46.27
DEC	1	17.48	24.66	20.85	19.29	20.03	12.11	15.59	38.2
	2	17.22	22.2	18.21	18.02	16.21	11.49	13.05	32.82
	3	17.37	21.51	18.68	20.14	14.93	10.85	12.01	33.96
JAN	1	15.13	22.07	15.89	17.36	12.62	10.29	16.29	29.3
	2	13.71	18.96	16.87	16.8	11.57	9.61	11.23	24.59
	3	13.44	17.63	15.73	15.2	10.75	9.2	9.46	19.98
FEB	1	11.39	15.62	11.95	12.82	8.41	7.82	8.41	15.01
	2	11.67	12.57	19.12	11.21	9.85	6.96	8.01	14.36
	3	9.15	8.37	10.79	8.44	11.06	4.83	10.92	10.42
MARCH	1	8.23	9.88	11.01	9.25	8.97	6.48	10.48	12.63
	2	7.47	9.1	9.07	9.19	8.31	7.07	16.01	14.33
	3	6.92	10.25	8.15	9.9	6.1	6.28	9.63	11.26
APRIL	1	18.05	9.52	6.53	6.5	4.82	4.44	10.92	11.12
	2	37	9.08	6.19	5.52	5.36	3.13	7.33	10.7
	3	10.08	6.18	11.19	6.46	9.51	3.63	5.13	10.06
MAY	1	6.67	5.57	10.15	11.17	6.44	3.83	11.64	8.56
	2	5.4	11.45	9.58	7.03	7.06	4.25	143.05	7.78
	3	5.13	14.25	8.93	10.3	9.08	4.74	42.99	6.78
		2763.73	3757.59	3677.92	3047.28	1792.81	2086.43	3162.11	5672.03
Inflow(Jun-Oct)		2446.66	3412.5	3354.48	2745.75	1462.12	1905.3	2740.55	5134.79
Inflow(Nov-May)		317.07	345.09	323.44	301.53	330.69	181.13	421.56	537.24

TABLE 1.4

TEN DAILY STREAM FLOW DATA OF INDIRAVATI RIVER AT MATNAR SITE FROM 1991 TO 1999 (in MCM)

MONTH		1991-92	1992-93	1993-94	1994-95	1995-96	1996-97	1997-98	1998-99	1999-00
JUNE	1	9.95	5.85	10.43	9.12	7.72	5.43	1.08	1.06	3.
	2	21.87	41.56	72.22	51.77	6.78	10.72	7.41	4.64	171.
	3	43.47	37	85.92	80.23	50	12.82	18.01	22.74	54
JULY	1	56.94	34.58	55.16	187.83	54.48	19.35	13.89	82.87	27.
	2	357.34	78.09	351.82	544.21	130.66	68.04	8.97	245.59	61.
	3	483.07	789.15	214.87	327.99	705.38	400.65	90.8	87.06	99.
AUG	1	585.91	381.23	294.09	366.5	234.56	172.67	149.78	85.94	312
	2	670.24	534.27	117.7	452.37	222.01	266.86	199.31	125.54	103.
	3	442.73	363.45	162.14	641.91	263.62	286.5	425.15	66.14	317
SEP	1	216.34	623.51	275.84	1018.31	545.58	138.55	203.27	65.22	344.
	2	236.99	262.85	138.33	421.2	150.13	72.11	263.31	57.98	185
	3	119.84	81.39	218.31	232.01	118.02	71.34	161.8	41.07	137.
OCT	1	104.95	60.38	75.44	114.48	61.14	66.77	67.61	29.01	92.
	2	111.89	49.28	71.58	60.78	66.44	21.56	33.29	43.17	78.
	3	56.43	32.53	61.21	60.24	0.28	19.45	21.47	27.54	28.
NOV	1	68.32	28.49	25.17	35.19	36.23	13.48	19.86	18.19	24
	2	36.69	24.87	22.8	23.97	42.4	10.47	20.93	43.14	8.
	3	26.98	24.32	17.15	20.86	26.43	7.62	60.07	17.08	5.
DEC	1	22.04	17.9	14.34	14.53	16.89	7.27	106.19	6.14	4.
	2	17.6	15.82	12.33	12.2	15.23	6.39	120.25	4.18	3
	3	18.92	16	12.86	10.47	14.63	6.2	116.28	3.34	2.
JAN	1	14.49	13.87	10.83	11.8	10.26	5.63	87.53	2.58	2.
	2	10.49	11.89	10.3	22.78	9.49	6.49	54.73	2.31	1.
	3	14.26	11.3	10.3	10.41	8.98	7.33	56.35	1.79	1.
FEB	1	10.42	9.38	7.87	7.81	7.88	5.41	33.98	1.73	1.
	2	9.44	8.3	7.9	4.88	7.5	11.42	8.84	1.8	2.
	3	8.03	5.76	5.1	2.89	5.27	33.51	4.44	1.1	2.
MARCH	1	7.5	7.44	4.93	3.04	6.75	52.76	4.63	1.22	1.
	2	7.09	6.17	4.34	3.52	5.12	53.55	5.46	1.01	0.
	3	7.07	5.37	3.73	3.09	4.83	61.47	2.99	1.02	
APRIL	1	5.61	4.9	3.66	4.72	3.97	48.59	3.48	0.82	0.
	2	5.04	4.54	3.54	5.26	7.2	10.4	2.07	0.79	1.
	3	5.13	6.64	2.69	3.41	7.66	5.45	2.89	0.67	0.
MAY	1	6.79	3.85	4.68	8.93	5.18	5.33	3.19	1.18	0.
	2	6.73	6.27	2.13	113.99	3.61	3.97	5.47	1.7	0.
	3	6.57	11.49	9.88	14.16	4.11	2.57	1.72	27.69	1.
		3833.2	3619.69	2401.59	4906.86	2866.42	1998.13	2386.5	1125.05	2087
Inflow(Jun-Oct)		3518	3375.12	2205.06	4568.95	2616.8	1632.82	1665.15	985.57	2015.
Inflow(Nov-May)		315.21	244.57	196.53	337.91	249.62	365.31	721.35	139.48	71.

PROJECT AS RUN OFF THE RIVER SCHEME

21GENERAL

Water is an excellent resource of nation, as it can be made to serve various functions. No flora and fauna is possible without water .With increasing population and consequent rise in demand for water it has become a scare resource for the human being both in quantity as well as quality, causing a concern for the humanity. The root problem lies in spatial and temporal variability of availability and demand. Properly planned use of water may nourish our farms and forests, may run our turbine for generation of hydroelectric power, may help in beautifying our surroundings and environments etc.

2.2 ADVANTAGES OF HYDROPOWER

- This is renewable source of energy. Sun being the prime mover of water cycle. As no payment is made for the input, production is free from inflation.
- The hydropower plants do not require much allocation on account of operation and maintenance and have a long life.
- It does not pollute the environment.
- These plants work at very high efficiency as compared to thermal plant.
- These plants can be started or shutdown just by pressing of a switch hence these are much suited for peak loads, and however their operation is governed by their role in the grid
- .

2.3 DISADVANTAGES OF HYDROPOWER

- Initial investments are very high.
- Construction period is long and varies from 5 to 10 years.
- Design and construction is very difficult as these plants are located in very difficult hilly terrain and sometimes the site are not accessible.

2.4 HISTORY OF HYDROPOWER IN INDIA

Hydropower has been used for centuries. The Greeks used water wheels to grind wheat into flour more than 2000 years ago. In the early 1800s, American and European factories used the water wheel to power machines.

In the late 19th century, the force of falling water was used to generate electricity. The first hydroelectric power plant was built at Niagara Falls in 1879. In the following decades, many more hydroelectric plants were built. At its height in the early 1940s, hydropower provided 33 percent of this country's electricity.

2.5 TYPES OF HYDROPOWER PLANT

2.5.1 Impoundment

An impoundment facility, typically a large hydropower system, uses a dam to store river water in a reservoir. The water may be released either to meet changing electricity needs or to maintain a constant reservoir level.

2.5.2 Diversion

A diversion, sometimes called run-of-river, facility channels a portion of a river through a canal or penstock. It may not require the use of a dam.

2.5.3 Pumped Storage

When the demand for electricity is low, pumped storage facility stores energy by pumping water from a lower reservoir to an upper reservoir. During periods of high electrical demand, the water is released back to the lower reservoir to generate electricity.

2.5.4 Barrage project

These projects have very small storage capacity. It can regulate the flow only up to minor extent and generate power according to the weekly or daily variation of the loads.

2.6 SIZES OF HYDROPOWER PLANTS

Facilities range in size from large power plants that supply many consumers with electricity to small and micro plants that individuals operate for their own energy needs or to sell power to utilities.

Large Hydropower

Although definitions vary, DOE defines large hydropower as facilities that have a capacity of more than 30 megawatts.

Small Hydropower

Although definitions vary, DOE defines small hydropower as facilities that have a capacity of 0.1 to 30 megawatts.

Micro Hydropower

A micro hydropower plant has a capacity of up to 100 kilowatts (0.1 megawatts).

2.7 PARTS OF A HYDROELECTRIC PLANT

Most conventional hydroelectric plants include four major components

Dam

Raises the water level of the river to create falling water. Also controls the flow of water. The reservoir that is formed is, in effect, stored energy.

Turbine

The force of falling water pushing against the turbine's blades causes the turbine to spin. A water turbine is much like a windmill, except the energy is provided by falling water instead of wind. The turbine converts the kinetic energy of falling water into mechanical energy.

Generator

Connected to the turbine by shafts and possibly gears so when the turbine spins it causes the generator to spin also converts the mechanical energy from the turbine into electric energy. Generators in hydropower plants work just like the generators in other types of power plants. Transmission lines conduct electricity from the hydropower plant to homes and business.

2.8 TURBINE TECHNOLOGY

There are many types of turbines used for hydropower, and they are chosen based on their particular application and the height of standing water—referred to as "head"—available to drive them. The turning part of the turbine is called the runner. The most common turbines are as follows:

Pelton Turbine

A Pelton turbine has one or more jets of water impinging on the buckets of a runner that looks like a water wheel. The Pelton turbines are used for high-head sites (50 feet to 6,000 feet) and can be as large as 200 megawatts.

Francis Turbine

A Francis turbine has a runner with fixed vanes, usually nine or more. The water enters the turbine in a radial direction with respect to the shaft, and is discharged in an axial direction. Francis turbines will operate from 10 feet to 2,000 feet of head and can be as large as 800 megawatts.

Propeller Turbine

A propeller has a runner with three to six fixed blades, like a boat propeller. The water passes through the runner and drives the blades. Propeller turbines can operate from 10 feet to 300 feet of head and can be as large as 100 megawatts. A Kaplan turbine is a type of propeller turbine in which the pitch of the blades can be changed to improve performance. Kaplan turbines can be as large as 400 megawatts.

2.9 ECONOMICS OF HYDROPOWER PLANT

Hydropower is the cheapest way to generate electricity today. No other energy source, renewable or nonrenewable, can match it it cost less than one cent per KWh (kilowatt-hour) to produce electricity at a typical hydro plant. In comparison, it costs coal plants about four cents per KWh and nuclear plants two cents per KWh to generate electricity.

Producing electricity from hydropower is cheap because, once a dam has been built and the equipment installed, the energy source-flowing water-is free. Another reason hydro plants produce power cheaply is due to their sturdy structures and simple equipment. Hydro plants are dependable and long-lived, and their maintenance costs are low compared to coal or nuclear plants.

There is one thing that may increase hydropower's costs in the future. The procedure for licensing a dam has become a lengthy and expensive process. Many environmental impact studies must be undertaken. It takes anywhere from five to seven years just to get a license to build a dam.

2.10 HYDROPOWER AND THE ENVIRONMENT

Hydropower does present a few environmental problems. Damming rivers may destroy or disrupt wildlife and natural resources. Fish, for one, may no longer be able to swim upstream.

Hydro plant operations may also affect water quality by churning up dissolved metals that may have been deposited by industry long ago. Hydro plant operations may increase silting, change water temperatures, and lower the levels of dissolved oxygen. To some degree, these problems can be managed by constructing fish ladders, dredging silt, and carefully regulating plant operations.

On the other side, hydropower's fuel supply (flowing water) is clean and is renewed yearly by snow and rainfall. Unlike fossil fuel plants, hydro plants do not emit any pollutants into the air because they burn no fuel.

Hydropower is also the only energy source that offers a whole range of added benefits. Dams control flood waters, and reservoirs provide lakes for boating, fishing, and swimming.

2.11 ESTIMATION OF HYDROPOWER POTENTIAL

The amount of power generated over a time or energy, is expressed in kilowatt-hour (KWh).It can be computed as

$$E_t=9.817*Q_t*H_{at}*h_t*e$$

where, E_t= energy in kilo watt , Q_t = outflow in m^3/sec, H_{at} = net head in m, h_t = time in hour and e = efficiency.

River flow is implicit stochastic in nature. There is daily, seasonal and monthly variation in flows. In order to get the assured supply which may be for any purpose as drinking ,irrigation or hydropower ,some storage has to be created wherein excess flow in monsoon period are stored and then release during dry period. Storage is created by constructing dams across river.

For hydropower project, the energy produced is proportional to the product of outflow and its associated head. So both outflow/release and are the decision variable for a given reservoir capacity in storage project where as head is constant in run-off-river scheme. Their optimum combination have to be found out to get a maximum power generation but subjected to some constraints as maximum reservoir and storage and turbine discharge etc.

Firm power is the maximum quantity of power that can be guaranteed to be delivered 100% of time according to some prescribed distribution. Following two methods are used to estimate the hydropower potential at a given site.

2.11.1 Flow duration Curve Method

The basic input is the flow duration curve. The net head for discharge is estimated .Using the data of usable range of flow duration curve and head v/s discharge data, a head duration curve is developed. The hydropower equation is used to estimate power generated at many point of flow duration curve and a power duration curve is developed .The average annual energy (AE in KWh) and dependable capacity (DC in KWh)can be computed

$$AE=87.6 \int_0^{100} p\,dp$$

$DC=0.01\,{}_0\!\int^{100} p\,dp$

Where P is power in KW and p is percent of time. The major advantage of this method is that it is simple and fast but it can't take into account the installed capacity and other constraints. It is used in run-of the river schemes where the head is almost constant.

2.11.2 Simulation method

In this method, time step size and period of analysis is chosen and operation of reservoir is simulated. For each time period, the reservoir outflow computed using the continuity equation and other constraints on operation .The reservoir has been simulated in such a way as to ensure that all down stream irrigation and drinking water requirement are met from the power house release and at the same time required level of dependability criteria for irrigation and power are met. The amount of energy generated corresponding to this outflow and head is calculated. The process is repeated for all the time steps. Then annual and monthly average of total energy generated as well as firm energy can be computed .Advantage of this method is that it can take into account the reservoir characteristics as well as power plant features. The result of this method is more realistic as compared to flow duration curve.

2.12 Computation

Sample calculation (1st ten daily June 66-67)

Discharge = 15.02 MCM

= 17.38 CUMECS

Head = 57.75 meter

Efficiency = 90%

Unrestricted power = 9.81 * Discharge* Head * Efficiency KW

= 9.81* 17.38 * 57.75 * 0.9 KW

= 8.87 MW

Unrestricted energy = Unrestricted power * 10 * 24 MWh

= 8.87 * 10 * 24 MWh

= 2.13 GWh

Installed capacity = 60 MW

Corresponding energy = 60 * 10 * 24 MWh

= 14.4 GWh

Restricted power = 8.87 MW (8.87 MW < 60 MW)

Restricted energy = 2.13 GWh (2.13 GWh < 14.4 GWh)

TABLE 2.1

TEN DAILY STREAM FLOW DATA OF INDIRAVATI RIVER AT MATNAR SITE FROM 1966 TO 1973 (in CUMECS)

MONTH		1966-67	1967-68	1968-69	1969-70	1970-71	1971-72	1972-1973	1973-74
JUNE	1	17.38	5.54	21.01	18.11	36.72	54.49	9.20	15.52
	2	27.16	26.00	24.11	80.69	64.25	47.66	7.77	50.82
	3	105.50	588.06	57.84	57.92	49.17	213.66	99.65	22.25
JULY	1	42.81	381.29	141.99	63.46	206.85	140.82	721.59	654.44
	2	112.52	109.85	80.94	137.44	167.60	203.89	100.17	739.98
	3	440.21	381.19	283.96	1062.05	415.48	143.21	73.22	172.19
AUG	1	399.25	916.59	128.07	1103.20	321.95	431.36	79.32	172.63
	2	314.20	350.60	172.74	335.89	498.61	284.89	191.42	331.41
	3	265.38	623.42	138.84	169.03	813.51	216.61	240.35	595.77
SEP	1	993.69	225.06	132.12	348.50	278.84	495.83	137.15	178.61
	2	184.59	465.01	545.15	326.11	212.70	165.52	629.52	181.12
	3	125.62	289.28	168.60	311.87	294.06	94.28	507.16	155.32
OCT	1	64.77	144.25	706.16	92.05	205.08	77.09	139.06	205.38
	2	65.38	79.28	232.24	84.98	81.68	85.52	79.50	90.36
	3	28.89	59.23	88.95	52.55	51.67	100.22	55.98	159.51
NOV	1	33.30	53.45	59.49	47.72	40.45	50.66	85.71	80.83
	2	33.24	47.25	48.69	47.93	39.27	40.47	44.79	56.62
	3	43.38	44.66	40.54	37.03	34.05	32.81	36.25	39.46
DEC	1	50.83	30.65	33.69	33.38	30.30	29.19	32.63	34.66
	2	31.06	32.70	29.55	53.31	26.53	27.51	29.19	31.41
	3	26.92	26.61	26.53	31.56	23.99	26.80	26.35	29.57
JAN	1	25.53	21.68	21.54	27.15	22.79	25.23	26.33	26.86
	2	25.02	27.95	19.46	24.47	21.37	21.63	23.76	25.03
	3	22.28	22.99	17.12	22.60	20.08	19.79	20.69	23.03
FEB	1	18.66	20.00	16.46	20.47	19.97	17.19	19.13	20.38
	2	16.89	17.47	14.00	18.47	16.98	16.70	17.84	18.30
	3	14.19	20.33	12.67	18.00	17.29	17.30	15.35	17.29
MARCH	1	13.21	22.05	12.45	20.32	18.04	13.72	17.28	15.74
	2	18.56	14.78	12.19	17.52	14.17	12.16	13.65	14.77
	3	33.03	12.64	11.16	13.51	13.49	11.68	12.07	15.32
APRIL	1	15.86	12.05	10.31	14.84	13.90	10.73	12.81	16.12
	2	11.60	15.72	11.19	14.97	15.34	12.89	13.77	13.18
	3	17.89	23.59	10.82	15.25	18.51	11.91	9.73	15.08
MAY	1	10.61	21.77	13.85	16.09	14.35	11.00	13.72	11.79
	2	12.30	13.12	18.73	13.54	23.02	9.40	9.79	15.84
	3	8.64	15.11	12.56	19.28	17.00	9.28	13.23	17.12
Annual Inflow		3750.03	5271.23	3431.10	4904.68	4291.08	3232.41	3606.24	4361.51
Inflow(Jun-Oct)		3260.79	4751.01	2973.88	4372.18	3826.21	2801.06	3108.02	3818.04
Inflow(Nov-May)		489.24	520.22	457.22	532.50	464.87	431.35	498.21	543.47

TABLE 2.2

TEN DAILY STREAM FLOW DATA OF INDIRAVATI RIVER AT MATNAR SITE FROM 1974 TO 1981 (in CUMECS)

		1974-75	1975-76	1976-77	1977-78	1978-79	1979-80	1980-81	1981-8
JUNE	1	13.10	19.71	9.88	13.15	11.11	8.98	25.60	37.9
	2	191.58	36.85	11.01	32.84	21.22	23.29	173.62	18.9
	3	95.72	323.90	23.83	33.17	70.50	731.74	227.83	23.3
JULY	1	41.48	401.37	75.61	478.80	175.55	414.52	189.42	37.1
	2	113.87	219.43	18.88	240.94	368.35	162.83	266.41	90.3
	3	49.29	215.24	681.80	278.51	415.84	160.28	696.29	98.4
AUG	1	93.30	350.61	613.31	423.61	350.81	797.90	412.78	482.6
	2	190.25	595.15	483.20	290.51	1582.37	197.74	240.99	574.2
	3	146.79	276.34	586.18	884.28	879.13	80.96	359.08	229.9
SEP	1	105.28	476.41	742.37	321.83	240.84	100.10	325.65	283.3
	2	99.68	422.47	249.84	823.85	290.47	113.73	910.87	216.1
	3	95.72	239.60	97.73	179.52	278.01	121.83	348.18	162.1
OCT	1	126.96	161.92	62.27	121.17	121.53	250.88	104.48	118.8
	2	74.18	120.73	49.18	69.25	90.34	63.53	70.43	52.5
	3	51.01	82.86	42.62	55.24	65.31	44.01	65.45	36.8
NOV	1	34.48	71.93	38.17	47.43	56.12	34.86	43.30	32.9
	2	27.22	44.09	38.30	41.84	45.78	28.67	36.75	28.4
	3	27.72	36.03	32.14	106.32	34.39	24.34	31.19	25.1
DEC	1	21.92	30.95	27.05	51.57	35.53	23.97	27.51	21.5
	2	18.82	25.82	24.26	38.66	30.06	21.79	25.43	19.5
	3	17.25	22.96	21.75	31.16	25.27	22.11	22.95	17.4
JAN	1	16.83	22.25	19.64	28.43	23.65	17.79	20.76	15.9
	2	14.94	21.28	19.10	28.95	22.06	16.41	23.10	14.6
	3	15.27	19.26	17.99	24.10	19.62	14.33	18.96	13.2
FEB	1	15.29	17.74	16.59	23.76	18.38	12.91	16.54	12.0
	2	12.80	16.24	14.80	21.37	16.63	12.05	14.62	10.6
	3	12.07	16.28	15.86	20.86	15.86	12.56	13.37	9.6
MARCH	1	10.90	13.87	13.45	17.15	13.82	9.90	12.40	10.4
	2	10.81	14.14	12.42	16.16	13.02	9.02	16.74	8.2
	3	8.98	12.21	12.10	16.29	11.67	8.14	20.34	8.2
APRIL	1	7.86	13.97	16.22	17.12	10.64	10.56	10.62	7.2
	2	7.49	11.66	16.38	15.22	10.49	8.45	7.93	8.1
	3	9.18	11.17	17.90	19.21	9.62	9.86	11.67	9.8
MAY	1	7.58	9.29	36.38	21.90	10.23	10.51	15.35	6.5
	2	5.58	16.05	19.00	21.75	10.36	11.13	12.91	19.7
	3	6.86	13.92	18.81	11.33	8.90	12.44	10.17	9.9
Annual Inflow		1825.15	4464.71	4330.94	4993.10	5542.85	3635.82	4946.31	2811.9
Inflow(Jun-Oct)		1512.90	4000.03	3878.75	4368.43	5097.39	3300.85	4529.15	2499.5
Inflow(Nov-May)		312.25	464.67	452.20	624.67	445.46	334.97	417.16	312.4

TABLE 2.3

TEN DAILY STREAM FLOW DATA OF INDIRAVATI RIVER AT MATNAR SITE FROM 1983 TO 1990 (in CUMECS)

MONTH		1983-84	1984-85	1985-86	1986-87	1987-88	1988-89	1989-90	1990-91
JUNE	1	7.09	19.95	34.36	13.46	13.90	6.47	11.83	82.72
	2	8.63	326.99	32.79	13.94	39.00	16.12	117.51	182.85
	3	318.62	59.54	228.30	135.22	17.60	143.99	190.61	139.03
JULY	1	70.88	316.99	391.09	82.40	172.30	132.35	146.03	94.13
	2	199.80	341.47	361.98	175.67	146.02	216.39	102.73	432.81
	3	218.29	286.56	241.46	406.35	149.34	193.63	241.36	541.26
AUG	1	313.94	1016.30	457.87	275.04	72.96	344.56	106.46	228.40
	2	263.70	519.49	686.47	1010.36	67.97	239.08	311.09	476.07
	3	261.15	307.56	335.03	337.22	160.77	156.43	651.48	740.48
SEP	1	340.87	224.67	220.20	108.01	389.11	208.77	239.18	572.42
	2	263.57	187.00	287.06	238.26	117.31	117.90	486.28	502.08
	3	175.64	81.42	211.56	80.05	103.93	189.17	245.79	226.38
OCT	1	173.89	63.12	144.41	120.25	79.25	123.83	134.85	1008.15
	2	107.05	75.14	133.41	65.65	77.75	47.99	58.65	421.54
	3	55.19	58.21	53.51	37.92	49.12	30.47	35.28	151.41
NOV	1	38.78	41.87	43.39	40.81	49.85	23.76	25.56	130.10
	2	32.63	37.87	35.78	34.00	67.52	20.46	24.39	77.20
	3	27.62	31.62	30.27	25.80	55.79	18.41	18.82	53.55
DEC	1	20.23	28.54	24.13	22.33	23.18	14.02	18.04	44.21
	2	19.93	25.69	21.08	20.86	18.76	13.30	15.10	37.99
	3	18.28	22.63	19.66	21.19	15.71	11.42	12.64	35.73
JAN	1	17.51	25.54	18.39	20.09	14.61	11.91	18.85	33.91
	2	15.87	21.94	19.53	19.44	13.39	11.12	13.00	28.46
	3	14.14	18.55	16.55	15.99	11.31	9.68	9.95	21.02
FEB	1	13.18	18.08	13.83	14.84	9.73	9.05	9.73	17.37
	2	13.51	14.55	22.13	12.97	11.40	8.06	9.27	16.62
	3	13.24	12.11	15.61	12.21	16.00	6.99	15.80	15.08
MARCH	1	9.53	11.44	12.74	10.71	10.38	7.50	12.13	14.62
	2	8.65	10.53	10.50	10.64	9.62	8.18	18.53	16.59
	3	7.28	10.79	8.58	10.42	6.42	6.61	10.13	11.85
APRIL	1	20.89	11.02	7.56	7.52	5.58	5.14	12.64	12.87
	2	42.82	10.51	7.16	6.39	6.20	3.62	8.48	12.38
	3	11.67	7.15	12.95	7.48	11.01	4.20	5.94	11.64
MAY	1	7.72	6.45	11.75	12.93	7.45	4.43	13.47	9.91
	2	6.25	13.25	11.09	8.14	8.17	4.92	165.57	9.00
	3	5.40	14.99	9.40	10.84	9.55	4.99	45.23	7.13
Annual Inflow		3198.74	4349.03	4256.82	3526.92	2075.00	2414.83	3659.83	6564.81
Inflow(Jun-Oct)		2831.76	3949.63	3882.48	3177.93	1692.26	2205.19	3171.91	5943.01
Inflow(Nov-May)		366.98	399.41	374.35	348.99	382.74	209.64	487.91	621.80

TABLE 2.4

'EN DAILY STREAM FLOW DATA OF INDIRAVATI RIVER AT
IATNAR SITE FROM 1991 TO 1999 (in CUMECS)

IONTH		1991-92	1992-93	1993-94	1994-95	1995-96	1996-97	1997-98	1998-99	1999
UNE	1	11.52	6.77	12.07	10.56	8.94	6.28	1.25	1.23	[illegible]
	2	25.31	48.10	83.59	59.92	7.85	12.41	8.58	5.37	19
	3	50.31	42.82	99.44	92.86	57.87	14.84	20.84	26.32	6
ULY	1	65.90	40.02	63.84	217.39	63.06	22.40	16.08	95.91	3
	2	413.59	90.38	407.20	629.87	151.23	78.75	10.38	284.25	7
	3	508.29	830.34	226.09	345.11	742.20	421.56	95.54	91.60	10
UG	1	678.13	441.24	340.38	424.19	271.48	199.85	173.36	99.47	36
	2	775.74	618.36	136.23	523.57	256.95	308.86	230.68	145.30	11
	3	465.84	382.42	170.60	675.42	277.38	301.46	447.34	69.59	33
EP	1	250.39	721.65	319.26	1178.59	631.45	160.36	235.26	75.49	39
	2	274.29	304.22	160.10	487.50	173.76	83.46	304.75	67.11	21
	3	138.70	94.20	252.67	268.53	136.60	82.57	187.27	47.53	15
CT	1	121.47	69.88	87.31	132.50	70.76	77.28	78.25	33.58	10
	2	129.50	57.04	82.85	70.35	76.90	24.95	38.53	49.96	9
	3	59.38	34.23	64.41	63.38	0.29	20.47	22.59	28.98	2
OV	1	79.07	32.97	29.13	40.73	41.93	15.60	22.99	21.05	2
	2	42.47	28.78	26.39	27.74	49.07	12.12	24.22	49.93	1
	3	31.23	28.15	19.85	24.14	30.59	8.82	69.53	19.77	6
EC	1	25.51	20.72	16.60	16.82	19.55	8.41	122.90	7.11	5
	2	20.37	18.31	14.27	14.12	17.63	7.40	139.18	4.84	3
	3	19.91	16.84	13.53	11.02	15.39	6.52	122.35	3.51	2
AN	1	16.77	16.05	12.53	13.66	11.87	6.52	101.31	2.99	2
	2	12.14	13.76	11.92	26.37	10.98	7.51	63.34	2.67	2
	3	15.00	11.89	10.84	10.95	9.45	7.71	59.29	1.88	1
EB	1	12.06	10.86	9.11	9.04	9.12	6.26	39.33	2.00	2
	2	10.93	9.61	9.14	5.65	8.68	13.22	10.23	2.08	2
	3	11.62	8.33	7.38	4.18	7.62	48.48	6.42	1.59	3
ARCH	1	8.68	8.61	5.71	3.52	7.81	61.06	5.36	1.41	2
	2	8.21	7.14	5.02	4.07	5.93	61.98	6.32	1.17	1
	3	7.44	5.65	3.92	3.25	5.08	64.68	3.15	1.07	1
PRIL	1	6.49	5.67	4.24	5.46	4.59	56.24	4.03	0.95	1
	2	5.83	5.25	4.10	6.09	8.33	12.04	2.40	0.91	1
	3	5.94	7.69	3.11	3.95	8.87	6.31	3.34	0.78	0
AY	1	7.86	4.46	5.42	10.34	6.00	6.17	3.69	1.37	0
	2	7.79	7.26	2.47	131.93	4.18	4.59	6.33	1.97	0
	3	6.91	12.09	10.40	14.90	4.32	2.70	1.81	29.14	1
nual Inflow		4436.51	4189.43	2779.60	5679.20	3317.59	2312.64	2762.14	1302.13	2416.
low(Jun-Oct)		4071.69	3906.36	2552.14	5288.10	3028.68	1889.83	1927.24	1140.70	2333.
low(Nov-May)		364.82	283.07	227.46	391.10	288.91	422.81	834.89	161.43	83

TABLE 3.1

90% DEPENDABLE YR. CRITERIA

S.NO	YEAR	ANNUAL FLOW IN CUMECS	FLOW IN ASC. ORDER	CORRESPONDING YEAR	
1	**1966**	3670.36	1280.6	1998	
2	**1967**	5158.84	1798	1974	
3	**1968**	3375.79	**2036.2**	**1987**	**90% DEPENDABLE YEAR**
4	**1969**	4771.3	2239.8	1996	
5	**1970**	4159.03	2369.1	1988	
6	**1971**	3181.23	2374.9	1999	
7	**1972**	3565.81	2688.2	1997	
8	**1973**	4261.74	2721.1	1993	
9	**1974**	1797.98	2741.4	1982	
10	**1975**	4401.91	3146.4	1983	
11	**1976**	4196	3181.2	1971	
12	**1977**	4869.21	3212.3	1995	
13	**1978**	5403.48	3375.8	1968	
14	**1979**	3602.68	3445.3	1986	
15	**1980**	4829.67	3562.4	1972	
16	**1981**	8433.78	3565.8	1979	
17	**1982**	2741.43	3602.7	1989	
18	**1983**	3146.44	3670.4	1966	
19	**1984**	4280.5	4061.8	1992	
20	**1985**	4173.58	4159	1985	
21	**1986**	3445.33	4173.6	1970	
22	**1987**	2036.19	4196	1976	
23	**1988**	2374.94	4261.7	1984	
24	**1989**	3562.43	4280.5	1973	
25	**1990**	6416.99	4329.3	1991	
26	**1991**	4329.33	4401.9	1975	
27	**1992**	4061.8	4771.3	1969	
28	**1993**	2721.11	4829.7	1980	
29	**1994**	5567.7	4869.2	1978	
30	**1995**	3212.28	5158.8	1967	
31	**1996**	2239.8	5403.5	1978	
32	**1997**	2688.24	5567.7	1994	
33	**1998**	1280.64	6417	1990	
34	**1999**	2369.05	8433.8	1981	

TABLE 4.1

POWER OUTPUT (MW) IN DEPENDABLE YAER(1987-88), Head = 57.75, Eff = 90%

MONTH	INFLOW	UNRESTRICTED POWER OUTPUT MW	GWH	POWER OUTPUT WITH I.C. RESTRICTED TO 20 MW	40 MW	60 MW	80 MW	100 MW	120 MW	140 MW	160 MW
JUNE	13.89	7.08	1.7	7.08	7.08	7.08	7.08	7.08	7.08	7.08	7.08
	39	19.89	4.77	19.89	19.89	19.89	19.89	19.89	19.89	19.89	19.89
	17.61	8.98	2.15	8.98	8.98	8.98	8.98	8.98	8.98	8.98	8.98
JULY	172.3	87.85	21.08	20	40	60	80	87.85	87.85	87.85	87.85
	146.01	74.45	17.87	20	40	60	74.45	74.45	74.45	74.45	74.45
	149.33	76.14	20.1	20	40	60	76.14	76.14	76.14	76.14	76.14
AUG	72.97	37.2	8.93	20	37.2	37.2	37.2	37.2	37.2	37.2	37.2
	67.98	34.66	8.32	20	34.66	34.66	34.66	34.66	34.66	34.66	34.66
	160.77	81.97	21.64	20	40	60	80	81.97	81.97	81.97	81.97
SEP	389.11	198.4	47.62	20	40	60	80	100	120	140	160
	117.32	59.82	14.36	20	40	59.82	59.82	59.82	59.82	59.82	59.82
	103.93	52.99	12.72	20	40	52.99	52.99	52.99	52.99	52.99	52.99
OCT	79.24	40.4	9.7	20	40	40	40	40	40	40	40
	77.76	39.65	9.52	20	39.65	39.65	39.65	39.65	39.65	39.65	39.65
	49.12	25.04	6.61	20	25.04	25.04	25.04	25.04	25.04	25.04	25.04
NOV	49.84	25.41	6.1	20	25.41	25.41	25.41	25.41	25.41	25.41	25.41
	67.53	34.43	8.26	20	34.43	34.43	34.43	34.43	34.43	34.43	34.43
	55.78	28.44	6.83	20	28.44	28.44	28.44	28.44	28.44	28.44	28.44
DEC	23.18	11.82	2.84	11.82	11.82	11.82	11.82	11.82	11.82	11.82	11.82
	18.76	9.57	2.3	9.57	9.57	9.57	9.57	9.57	9.57	9.57	9.57
	15.71	8.01	2.11	8.01	8.01	8.01	8.01	8.01	8.01	8.01	8.01
JAN	14.61	7.45	1.79	7.45	7.45	7.45	7.45	7.45	7.45	7.45	7.45
	13.39	6.83	1.64	6.83	6.83	6.83	6.83	6.83	6.83	6.83	6.83
	11.31	5.77	1.52	5.77	5.77	5.77	5.77	5.77	5.77	5.77	5.77
FEB	9.73	4.96	1.19	4.96	4.96	4.96	4.96	4.96	4.96	4.96	4.96
	11.4	5.81	1.4	5.81	5.81	5.81	5.81	5.81	5.81	5.81	5.81
	14.23	7.26	1.57	7.26	7.26	7.26	7.26	7.26	7.26	7.26	7.26
MARCH	10.39	5.3	1.27	5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.3
	9.62	4.91	1.18	4.91	4.91	4.91	4.91	4.91	4.91	4.91	4.91
	6.42	3.27	0.86	3.27	3.27	3.27	3.27	3.27	3.27	3.27	3.27
APRIL	5.57	2.84	0.68	2.84	2.84	2.84	2.84	2.84	2.84	2.84	2.84
	6.21	3.16	0.76	3.16	3.16	3.16	3.16	3.16	3.16	3.16	3.16
	11	5.61	1.35	5.61	5.61	5.61	5.61	5.61	5.61	5.61	5.61
MAY	7.45	3.8	0.91	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8
	8.17	4.17	1	4.17	4.17	4.17	4.17	4.17	4.17	4.17	4.17
	9.55	4.87	1.29	4.87	4.87	4.87	4.87	4.87	4.87	4.87	4.87

TABLE 4.2

ENERGY GENERATION(GWH) IN DEPENDABLE YAER(1987-88), Head = 57.75, Eff = 90%

MONTH	INFLOW	UNRESTRICTED POWER OUTPUT MW	GWH	POWER OUTPUT WITH I.C. RESTRICTED TO 20 MW	40 MW	60 MW	80 MW	100 MW	120 MW	140 MW	160 MW
JUNE	13.89	7.08	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7
	39	19.89	4.77	4.77	4.77	4.77	4.77	4.77	4.77	4.77	4.77
	17.61	8.98	2.15	2.15	2.15	2.15	2.15	2.15	2.15	2.15	2.15
JULY	172.3	87.85	21.08	4.8	9.6	14.4	19.2	21.08	21.08	21.08	21.08
	146.01	74.45	17.87	4.8	9.6	14.4	17.87	17.87	17.87	17.87	17.87
	149.33	76.14	20.1	5.28	10.56	15.84	20.1	20.1	20.1	20.1	20.1
AUG	72.97	37.2	8.93	4.8	8.93	8.93	8.93	8.93	8.93	8.93	8.93
	67.98	34.66	8.32	4.8	8.32	8.32	8.32	8.32	8.32	8.32	8.32
	160.77	81.97	21.64	5.28	10.56	15.84	21.12	21.64	21.64	21.64	21.64
SEP	389.11	198.4	47.62	4.8	9.6	14.4	19.2	24	28.8	33.6	38.4
	117.32	59.82	14.36	4.8	9.6	14.36	14.36	14.36	14.36	14.36	14.36
	103.93	52.99	12.72	4.8	9.6	12.72	12.72	12.72	12.72	12.72	12.72
OCT	79.24	40.4	9.7	4.8	9.6	9.7	9.7	9.7	9.7	9.7	9.7
	77.76	39.65	9.52	4.8	9.52	9.52	9.52	9.52	9.52	9.52	9.52
	49.12	25.04	6.61	5.28	6.61	6.61	6.61	6.61	6.61	6.61	6.61
NOV	49.84	25.41	6.1	4.8	6.1	6.1	6.1	6.1	6.1	6.1	6.1
	67.53	34.43	8.26	4.8	8.26	8.26	8.26	8.26	8.26	8.26	8.26
	55.78	28.44	6.83	4.8	6.83	6.83	6.83	6.83	6.83	6.83	6.83
DEC	23.18	11.82	2.84	2.84	2.84	2.84	2.84	2.84	2.84	2.84	2.84
	18.76	9.57	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3
	15.71	8.01	2.11	2.11	2.11	2.11	2.11	2.11	2.11	2.11	2.11
JAN	14.61	7.45	1.79	1.79	1.79	1.79	1.79	1.79	1.79	1.79	1.79
	13.39	6.83	1.64	1.64	1.64	1.64	1.64	1.64	1.64	1.64	1.64
	11.31	5.77	1.52	1.52	1.52	1.52	1.52	1.52	1.52	1.52	1.52
FEB	9.73	4.96	1.19	1.19	1.19	1.19	1.19	1.19	1.19	1.19	1.19
	11.4	5.81	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4
	14.23	7.26	1.57	1.57	1.57	1.57	1.57	1.57	1.57	1.57	1.57
MARCH	10.39	5.3	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27
	9.62	4.91	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18
	6.42	3.27	0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86
APRIL	5.57	2.84	0.68	0.68	0.68	0.68	0.68	0.68	0.68	0.68	0.68
	6.21	3.16	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76
	11	5.61	1.35	1.35	1.35	1.35	1.35	1.35	1.35	1.35	1.35
MAY	7.45	3.8	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91
	8.17	4.17	1	1	1	1	1	1	1	1	1
	9.55	4.87	1.29	1.29	1.29	1.29	1.29	1.29	1.29	1.29	1.29
ANNUAL ENERGY(GWH)			253.94	107.72	167.57	200.51	223.12	230.32	235.12	239.92	244.72
NON MONSOOM ENERGY			46.85	40.06	46.85	46.85	46.85	46.85	46.85	46.85	46.85
POTENTIAL EXPLOITE				42.42%	65.99%	78.96%	87.86%	90.70%	92.59%	94.48%	96.37%
INCREMENTAL ENERGY(GWH)					59.84	23.93	22.61	7.2	4.8	4.8	4.8
INCREMENTAL ENERGY(KWH/KW)					2992	1647	1130	360	240	240	240

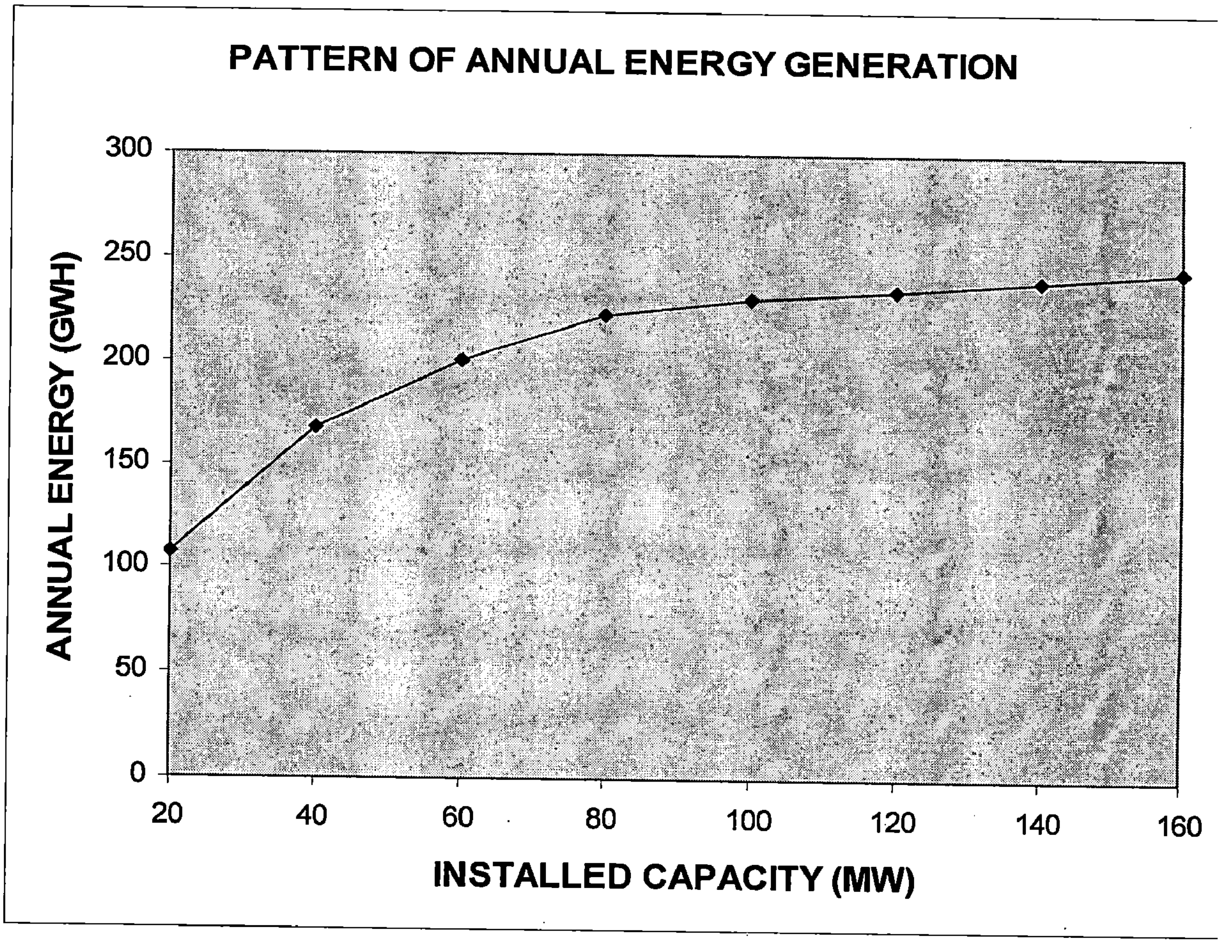

PATTERN OF ANNUAL ENERGY GENERATION
ANNUAL ENERGY (GWH)
300
250
200
150
100
50
0
20
40
60
80
100
120
140
160
INSTALLED CAPACITY (MW)

Fig – (1)

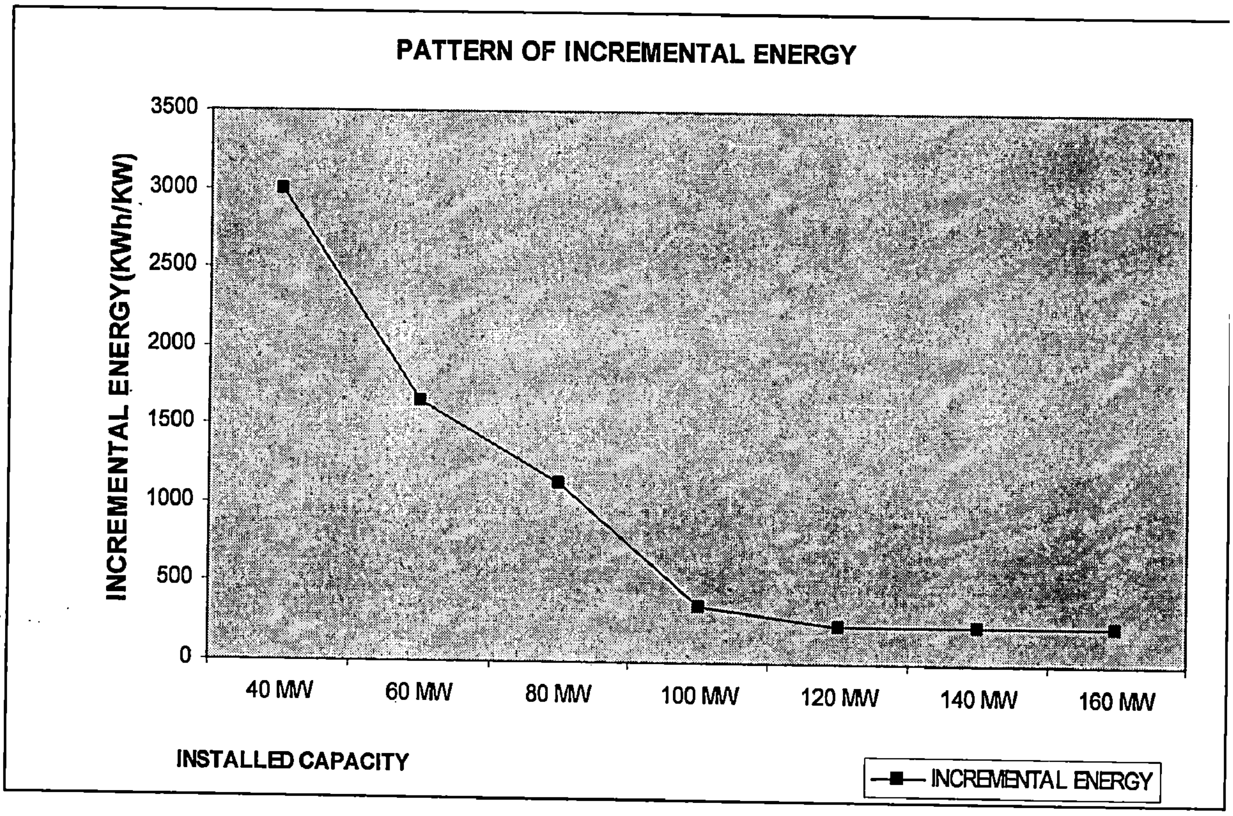

PATTERN OF INCREMENTAL ENERGY
INCREMENTAL ENERGY(KWh/KW)
3500
3000
2500
2000
1500
1000
500
0
40 MW
60 MW
80 MW
100 MW
120 MW
140 MW
160 MW
INSTALLED CAPACITY
INCREMENTAL ENERGY

Fig. (2)

TABLE 5.1

UNRESTRICTED POWER(MW) Head=57.75 m, Eff = 90%

MONTH		1966-67	1967-68	1968-69	1969-70	1970-71	1971-72	1972-1973	1973-74
JUNE	1	8.87	2.83	10.71	9.24	18.73	27.79	4.69	7.92
	2	13.85	13.26	12.30	41.15	32.77	24.31	3.96	25.92
	3	53.80	299.91	29.50	29.54	25.07	108.96	50.82	11.35
JUL	1	21.83	194.46	72.41	32.36	105.49	71.82	368.01	333.76
	2	57.39	56.02	41.28	70.10	85.48	103.98	51.09	377.39
	3	224.51	194.41	144.82	541.64	211.90	73.04	37.34	87.82
AUG	1	203.62	467.46	65.31	562.63	164.20	220.00	40.45	88.04
	2	160.24	178.81	88.10	171.30	254.29	145.30	97.63	169.02
	3	135.34	317.94	70.81	86.20	414.89	110.47	122.58	303.84
SEP	1	506.78	114.78	67.38	177.74	142.21	252.87	69.95	91.09
	2	94.14	237.15	278.02	166.32	108.47	84.42	321.06	92.37
	3	64.07	147.53	85.99	159.06	149.97	48.08	258.65	79.21
OCT	1	33.03	73.57	360.14	46.94	104.59	39.32	70.92	104.74
	2	33.34	40.43	118.44	43.34	41.66	43.62	40.55	46.08
	3	14.74	30.21	45.37	26.80	26.35	51.11	28.55	81.35
NOV	1	16.98	27.26	30.34	24.34	20.63	25.84	43.71	41.22
	2	16.95	24.09	24.83	24.44	20.03	20.64	22.84	28.88
	3	22.12	22.78	20.68	18.88	17.37	16.73	18.49	20.12
DEC	1	25.92	15.63	17.18	17.02	15.45	14.89	16.64	17.68
	2	15.84	16.68	15.07	27.19	13.53	14.03	14.89	16.02
	3	13.73	13.57	13.53	16.09	12.23	13.67	13.44	15.08
JAN	1	13.02	11.06	10.98	13.85	11.62	12.87	13.43	13.70
	2	12.76	14.26	9.92	12.48	10.90	11.03	12.12	12.77
	3	11.36	11.73	8.73	11.53	10.24	10.09	10.55	11.75
FEB	1	9.52	10.20	8.39	10.44	10.18	8.77	9.76	10.39
	2	8.61	8.91	7.14	9.42	8.66	8.52	9.10	9.33
	3	7.24	10.37	6.46	9.18	8.82	8.82	7.83	8.82
MAR	1	6.74	11.24	6.35	10.37	9.20	6.99	8.81	8.03
	2	9.47	7.54	6.22	8.94	7.22	6.20	6.96	7.53
	3	16.84	6.44	5.69	6.89	6.88	5.96	6.16	7.81
APR	1	8.09	6.14	5.26	7.57	7.09	5.47	6.53	8.22
	2	5.91	8.02	5.71	7.63	7.82	6.58	7.02	6.72
	3	9.13	12.03	5.52	7.78	9.44	6.07	4.96	7.69
MAY	1	5.41	11.10	7.07	8.20	7.32	5.61	6.99	6.01
	2	6.27	6.69	9.55	6.91	11.74	4.79	4.99	8.08
	3	4.41	7.71	6.41	9.83	8.67	4.73	6.75	8.73

TABLE 5.2

UNRESTRICTED POWER(MW) Head=57.75 m, Eff = 90%

MONTH		1974-75	1975-76	1976-77	1977-78	1978-79	1979-80	1980-81	1981-82
JUNE	1	6.68	10.05	5.04	6.71	5.67	4.58	13.06	19.36
	2	97.71	18.79	5.61	16.75	10.82	11.88	88.55	9.68
	3	48.82	165.19	12.15	16.92	35.95	373.19	116.20	11.89
JULY	1	21.16	204.70	38.56	244.19	89.53	211.41	96.60	18.97
	2	58.07	111.91	9.63	122.88	187.86	83.05	135.87	46.06
	3	25.14	109.77	347.72	142.04	212.08	81.74	355.11	50.21
AUG	1	47.58	178.81	312.79	216.04	178.91	406.93	210.52	246.16
	2	97.03	303.52	246.43	148.16	807.01	100.85	122.91	292.89
	3	74.86	140.93	298.95	450.98	448.36	41.29	183.13	117.28
SEP	1	53.69	242.97	378.61	164.13	122.83	51.05	166.08	144.50
	2	50.83	215.46	127.42	420.16	148.14	58.00	464.55	110.25
	3	48.82	122.20	49.84	91.56	141.78	62.13	177.57	82.70
OCT	1	64.75	82.58	31.76	61.80	61.98	127.95	53.28	60.60
	2	37.83	61.57	25.08	35.32	46.07	32.40	35.92	26.82
	3	26.02	42.26	21.74	28.17	33.31	22.45	33.38	18.77
NOV	1	17.58	36.69	19.47	24.19	28.62	17.78	22.08	16.81
	2	13.88	22.48	19.53	21.34	23.35	14.62	18.74	14.49
	3	14.14	18.38	16.39	54.22	17.54	12.41	15.91	12.81
DEC	1	11.18	15.78	13.79	26.30	18.12	12.22	14.03	10.97
	2	9.60	13.17	12.37	19.72	15.33	11.11	12.97	9.96
	3	8.80	11.71	11.09	15.89	12.89	11.27	11.70	8.88
JAN	1	8.58	11.35	10.02	14.50	12.06	9.07	10.59	8.13
	2	7.62	10.86	9.74	14.76	11.25	8.37	11.78	7.47
	3	7.79	9.82	9.18	12.29	10.01	7.31	9.67	6.75
FEB	1	7.80	9.05	8.46	12.12	9.37	6.58	8.44	6.14
	2	6.53	8.28	7.55	10.90	8.48	6.14	7.46	5.44
	3	6.15	8.30	8.09	10.64	8.09	6.40	6.82	4.94
MARCH	1	5.56	7.07	6.86	8.75	7.05	5.05	6.32	5.33
	2	5.51	7.21	6.33	8.24	6.64	4.60	8.54	4.19
	3	4.58	6.22	6.17	8.31	5.95	4.15	10.37	4.18
APRIL	1	4.01	7.12	8.27	8.73	5.42	5.38	5.42	3.72
	2	3.82	5.94	8.35	7.76	5.35	4.31	4.04	4.16
	3	4.68	5.70	9.13	9.80	4.91	5.03	5.95	5.00
MAY	1	3.87	4.74	18.55	11.17	5.22	5.36	7.83	3.34
	2	2.85	8.19	9.69	11.09	5.28	5.68	6.58	10.09
	3	3.50	7.10	9.59	5.78	4.54	6.34	5.19	5.05

TABLE 6.1

RESTRICTED POWER(MW) Head=57.75 m, Eff = 90%

MONTH		1983-84	1984-85	1985-86	1986-87	1987-88	1988-89	1989-90	1990-91
JUNE	1	3.62	10.17	17.52	6.86	7.08	3.30	6.03	42.18
	2	4.40	60.00	16.72	7.10	19.89	8.22	59.91	60.00
	3	60.00	30.35	60.00	60.00	8.98	60.00	60.00	60.00
JULY	1	36.14	60.00	60.00	42.01	60.00	60.00	60.00	47.99
	2	60.00	60.00	60.00	60.00	60.00	60.00	52.38	60.00
	3	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00
AUG	1	60.00	60.00	60.00	60.00	37.20	60.00	54.28	60.00
	2	60.00	60.00	60.00	60.00	34.66	60.00	60.00	60.00
	3	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00
SEP	1	60.00	60.00	60.00	55.06	60.00	60.00	60.00	60.00
	2	60.00	60.00	60.00	60.00	59.83	60.00	60.00	60.00
	3	60.00	41.53	60.00	40.81	53.01	60.00	60.00	60.00
OCT	1	60.00	32.19	60.00	60.00	40.42	60.00	60.00	60.00
	2	54.59	38.32	60.00	33.48	39.65	24.47	29.91	60.00
	3	28.15	29.69	27.29	19.34	25.05	15.54	17.99	60.00
NOV	1	19.78	21.36	22.13	20.81	25.42	12.12	13.03	60.00
	2	16.64	19.31	18.25	17.34	34.44	10.44	12.44	39.37
	3	14.08	16.13	15.44	13.16	28.45	9.39	9.60	27.31
DEC	1	10.32	14.56	12.31	11.39	11.82	7.15	9.20	22.55
	2	10.16	13.10	10.75	10.64	9.57	6.78	7.70	19.37
	3	9.32	11.54	10.02	10.81	8.01	5.82	6.44	18.22
JAN	1	8.93	13.03	9.38	10.25	7.45	6.07	9.62	17.30
	2	8.09	11.19	9.96	9.92	6.83	5.67	6.63	14.51
	3	7.21	9.46	8.44	8.16	5.77	4.94	5.08	10.72
FEB	1	6.72	9.22	7.05	7.57	4.96	4.62	4.96	8.86
	2	6.89	7.42	11.29	6.62	3.27	4.11	4.73	8.48
	3	6.75	6.18	7.96	6.23	8.16	3.56	8.06	7.69
MARCH	1	4.86	5.83	6.50	5.46	5.29	3.82	6.19	7.46
	2	4.41	5.37	5.35	5.42	4.91	4.17	9.45	8.46
	3	3.71	5.50	4.37	5.31	3.27	3.37	5.17	6.04
APRIL	1	10.65	5.62	3.85	3.84	2.85	2.62	6.45	6.56
	2	21.84	5.36	3.65	3.26	3.16	1.85	4.33	6.32
	3	5.95	3.65	6.61	3.81	5.61	2.14	3.03	5.94
MAY	1	3.94	3.29	5.99	6.59	3.80	2.26	6.87	5.05
	2	3.19	6.76	5.65	4.15	4.17	2.51	60.00	4.59
	3	2.75	7.65	4.79	5.53	4.87	2.54	23.07	3.64
MIN.POWER		2.75	3.29	3.65	3.26	2.85	1.85	3.03	3.64

TABLE 6.2

RESTRICTED POWER(MW) Head=57.75 m, Eff = 90%

MONTH		1991-92	1992-93	1993-94	1994-95	1995-96	1996-97	1997-98	1998-99	1999-00
JUNE	1	5.87	3.45	6.15	5.38	4.55	3.21	0.63	0.63	2.06
	2	12.91	24.53	42.62	30.55	4.00	6.32	4.37	2.74	60.00
	3	25.65	21.83	50.71	47.35	29.50	7.57	10.63	13.42	32.04
JULY	1	33.60	20.41	32.55	60.00	32.15	11.42	8.20	48.90	16.09
	2	60.00	46.08	60.00	60.00	60.00	40.15	5.30	60.00	36.18
	3	60.00	60.00	60.00	60.00	60.00	60.00	48.71	46.70	53.14
AUG	1	60.00	60.00	60.00	60.00	60.00	60.00	60.00	50.72	60.00
	2	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00
	3	60.00	60.00	60.00	60.00	60.00	60.00	60.00	35.49	60.00
SEP	1	60.00	60.00	60.00	60.00	60.00	60.00	60.00	38.50	60.00
	2	60.00	60.00	60.00	60.00	60.00	42.56	60.00	34.22	60.00
	3	60.00	48.04	60.00	60.00	60.00	42.11	60.00	24.61	60.00
OCT	1	60.00	35.64	44.53	60.00	36.09	39.41	39.91	17.12	54.33
	2	60.00	29.09	42.25	35.88	39.22	12.73	19.65	25.48	46.09
	3	30.28	17.46	32.85	32.33	0.15	10.44	11.52	14.78	15.09
NOV	1	40.33	16.82	14.86	20.77	21.39	7.96	11.72	10.74	14.52
	2	21.66	14.68	13.46	14.15	25.03	6.18	12.35	25.46	5.18
	3	15.93	14.36	10.12	12.31	15.60	4.50	35.46	10.08	3.46
DEC	1	13.01	10.57	8.46	8.58	9.97	4.29	60.00	3.62	2.61
	2	10.39	9.34	7.28	7.20	8.99	3.77	60.00	2.47	1.95
	3	10.15	8.59	6.90	5.62	7.85	3.33	60.00	1.79	1.36
JAN	1	8.55	8.19	6.39	6.97	6.06	3.32	51.67	1.52	1.21
	2	6.19	7.02	6.08	13.45	5.60	3.83	32.31	1.36	1.13
	3	7.65	6.06	5.53	5.59	4.82	3.93	30.24	0.96	0.89
FEB	1	6.15	5.54	4.65	4.61	4.65	3.19	20.06	1.02	1.06
	2	5.57	4.90	4.66	2.88	4.43	6.74	5.22	1.06	1.38
	3	5.26	4.25	3.76	2.13	3.45	24.73	3.28	0.81	1.71
MARCH	1	4.43	4.39	2.91	1.79	3.98	31.14	2.73	0.72	1.06
	2	4.19	3.64	2.56	2.08	3.02	31.61	3.22	0.60	0.58
	3	3.79	2.88	2.00	1.66	2.59	32.99	1.60	0.55	0.54
APRIL	1	3.31	2.89	2.16	2.79	2.34	28.68	2.05	0.48	0.56
	2	2.97	2.68	2.09	3.10	4.25	6.14	1.22	0.47	0.61
	3	3.03	3.92	1.59	2.01	4.52	3.22	1.71	0.40	0.47
MAY	1	4.01	2.27	2.76	5.27	3.06	3.15	1.88	0.70	0.48
	2	3.97	3.70	1.26	60.00	2.13	2.34	3.23	1.00	0.49
	3	3.53	6.17	5.30	7.60	2.21	1.38	0.92	14.86	0.97
MIN.POWER		2.97	2.27	1.26	1.66	0.15	1.38	0.63	0.40	0.47

TABLE 7.1

RESTRICTED ENERGY OUTPUT (GWH) Head=57.75 m, Eff = 90%

MONTH		1966-67	1967-68	1968-69	1969-70	1970-71	1971-72	1972-1973	1973-74
JUNE	1	2.13	0.68	2.57	2.22	4.50	6.67	1.13	1.90
	2	3.32	3.18	2.95	9.88	7.86	5.83	0.95	6.22
	3	12.91	14.40	7.08	7.09	6.02	14.40	12.20	2.72
JUL	1	5.24	14.40	14.40	7.77	14.40	14.40	14.40	14.40
	2	13.77	13.45	9.91	14.40	14.40	14.40	12.26	14.40
	3	15.84	15.84	15.84	15.84	15.84	15.84	9.86	15.84
AUG	1	14.40	14.40	14.40	14.40	14.40	14.40	9.71	14.40
	2	14.40	14.40	14.40	14.40	14.40	14.40	14.40	14.40
	3	15.84	15.84	15.84	15.84	15.84	15.84	15.84	15.84
SEP	1	14.40	14.40	14.40	14.40	14.40	14.40	14.40	14.40
	2	14.40	14.40	14.40	14.40	14.40	14.40	14.40	14.40
	3	14.40	14.40	14.40	14.40	14.40	11.54	14.40	14.40
OCT	1	7.93	14.40	14.40	11.27	14.40	9.44	14.40	14.40
	2	8.00	9.70	14.40	10.40	10.00	10.47	9.73	11.06
	3	3.89	7.97	11.98	7.07	6.96	13.49	7.54	15.84
NOV	1	4.08	6.54	7.28	5.84	4.95	6.20	10.49	9.89
	2	4.07	5.78	5.96	5.87	4.81	4.95	5.48	6.93
	3	5.31	5.47	4.96	4.53	4.17	4.02	4.44	4.83
DEC	1	6.22	3.75	4.12	4.09	3.71	3.57	3.99	4.24
	2	3.80	4.00	3.62	6.53	3.25	3.37	3.57	3.84
	3	3.62	3.58	3.57	4.25	3.23	3.61	3.55	3.98
JAN	1	3.13	2.65	2.64	3.32	2.79	3.09	3.22	3.29
	2	3.06	3.42	2.38	2.99	2.62	2.65	2.91	3.06
	3	3.00	3.10	2.30	3.04	2.70	2.66	2.79	3.10
FEB	1	2.28	2.45	2.01	2.51	2.44	2.10	2.34	2.49
	2	2.07	2.14	1.71	2.26	2.08	2.04	2.18	2.24
	3	1.39	1.99	1.24	1.76	1.69	1.69	1.50	1.69
MAR	1	1.62	2.70	1.52	2.49	2.21	1.68	2.12	1.93
	2	2.27	1.81	1.49	2.14	1.73	1.49	1.67	1.81
	3	4.45	1.70	1.50	1.82	1.82	1.57	1.62	2.06
APR	1	1.94	1.47	1.26	1.82	1.70	1.31	1.57	1.97
	2	1.42	1.92	1.37	1.83	1.88	1.58	1.69	1.61
	3	2.19	2.89	1.32	1.87	2.27	1.46	1.19	1.85
MAY	1	1.30	2.66	1.70	1.97	1.76	1.35	1.68	1.44
	2	1.51	1.61	2.29	1.66	2.82	1.15	1.20	1.94
	3	1.16	2.03	1.69	2.60	2.29	1.25	1.78	2.30
ANNUAL ENERGY		220.76	245.54	237.33	238.95	239.11	242.72	226.59	251.14
ENERGY(NOV-MAY)		59.88	63.67	55.96	65.18	56.90	52.80	60.98	66.52
ENERGY(JUN-OCT)		160.88	181.86	181.36	173.77	182.21	189.92	165.61	184.62

TABLE 7.2

RESTRICTED ENERGY OUTPUT (GWH) Head=57.75 m, Eff = 90%

MONTH		1974-75	1975-76	1976-77	1977-78	1978-79	1979-80	1980-81	1981-8
JUNE	1	1.60	2.41	1.21	1.61	1.36	1.10	3.13	4.6
	2	14.40	4.51	1.35	4.02	2.60	2.85	14.40	2.3
	3	11.72	14.40	2.92	4.06	8.63	14.40	14.40	2.8
JULY	1	5.08	14.40	9.26	14.40	14.40	14.40	14.40	4.5
	2	13.94	14.40	2.31	14.40	14.40	14.40	14.40	11.0
	3	6.64	15.84	15.84	15.84	15.84	15.84	15.84	13.2
AUG	1	11.42	14.40	14.40	14.40	14.40	14.40	14.40	14.4
	2	14.40	14.40	14.40	14.40	14.40	14.40	14.40	14.4
	3	15.84	15.84	15.84	15.84	15.84	10.90	15.84	15.8
SEP	1	12.89	14.40	14.40	14.40	14.40	12.25	14.40	14.4
	2	12.20	14.40	14.40	14.40	14.40	13.92	14.40	14.4
	3	11.72	14.40	11.96	14.40	14.40	14.40	14.40	14.4
OCT	1	14.40	14.40	7.62	14.40	14.40	14.40	12.79	14.4
	2	9.08	14.40	6.02	8.48	11.06	7.78	8.62	6.4
	3	6.87	11.16	5.74	7.44	8.79	5.93	8.81	4.9
NOV	1	4.22	8.80	4.67	5.81	6.87	4.27	5.30	4.0
	2	3.33	5.40	4.69	5.12	5.60	3.51	4.50	3.4
	3	3.39	4.41	3.93	13.01	4.21	2.98	3.82	3.0
DEC	1	2.68	3.79	3.31	6.31	4.35	2.93	3.37	2.6
	2	2.30	3.16	2.97	4.73	3.68	2.67	3.11	2.3
	3	2.32	3.09	2.93	4.19	3.40	2.98	3.09	2.3
JAN	1	2.06	2.72	2.40	3.48	2.89	2.18	2.54	1.9
	2	1.83	2.61	2.34	3.54	2.70	2.01	2.83	1.7
	3	2.06	2.59	2.42	3.24	2.64	1.93	2.55	1.7
FEB	1	1.87	2.17	2.03	2.91	2.25	1.58	2.02	1.4
	2	1.57	1.99	1.81	2.62	2.04	1.47	1.79	1.3
	3	1.18	1.59	1.55	2.04	1.55	1.23	1.31	0.9
MARCH	1	1.33	1.70	1.65	2.10	1.69	1.21	1.52	1.2
	2	1.32	1.73	1.52	1.98	1.59	1.10	2.05	1.0
	3	1.21	1.64	1.63	2.19	1.57	1.10	2.74	1.1
APRIL	1	0.96	1.71	1.98	2.10	1.30	1.29	1.30	0.8
	2	0.92	1.43	2.00	1.86	1.28	1.03	0.97	1.0
	3	1.12	1.37	2.19	2.35	1.18	1.21	1.43	1.2
MAY	1	0.93	1.14	4.45	2.68	1.25	1.29	1.88	0.8
	2	0.68	1.96	2.33	2.66	1.27	1.36	1.58	2.4
	3	0.92	1.87	2.53	1.53	1.20	1.67	1.37	1.3
ANNUAL ENERGY		200.40	250.64	193.01	248.94	233.84	212.37	245.69	190.5
ENERGY(NOV-MAY)		38.22	56.88	55.35	76.46	54.52	41.00	51.06	38.2
ENERGY(JUN-OCT)		162.18	193.76	137.66	172.48	179.32	171.36	194.63	152.3

TABLE 7.3

RESTRICTED ENERGY OUTPUT (GWH) Head=57.75 m, Eff = 90%

MONTH		1983-84	1984-85	1985-86	1986-87	1987-88	1988-89	1989-90	1990-91
JUNE	1	0.87	2.44	4.21	1.65	1.70	0.79	1.45	10.12
	2	1.06	14.40	4.01	1.71	4.77	1.97	14.38	14.40
	3	14.40	7.29	14.40	14.40	2.15	14.40	14.40	14.40
JULY	1	8.68	14.40	14.40	10.09	14.40	14.40	14.40	11.52
	2	14.40	14.40	14.40	14.40	14.40	14.40	12.57	14.40
	3	15.84	15.84	15.84	15.84	15.84	15.84	15.84	15.84
AUG	1	14.40	14.40	14.40	14.40	8.93	14.40	13.03	14.40
	2	14.40	14.40	14.40	14.40	8.32	14.40	14.40	14.40
	3	15.84	15.84	15.84	15.84	15.84	15.84	15.84	15.84
SEP	1	14.40	14.40	14.40	13.22	14.40	14.40	14.40	14.40
	2	14.40	14.40	14.40	14.40	14.36	14.40	14.40	14.40
	3	14.40	9.97	14.40	9.80	12.72	14.40	14.40	14.40
OCT	1	14.40	7.73	14.40	14.40	9.70	14.40	14.40	14.40
	2	13.10	9.20	14.40	8.04	9.52	5.87	7.18	14.40
	3	7.43	7.84	7.21	5.11	6.61	4.10	4.75	15.84
NOV	1	4.75	5.13	5.31	5.00	6.10	2.91	3.13	14.40
	2	3.99	4.64	4.38	4.16	8.26	2.50	2.98	9.45
	3	3.38	3.87	3.70	3.16	6.83	2.25	2.30	6.55
DEC	1	2.48	3.49	2.95	2.73	2.84	1.72	2.21	5.41
	2	2.44	3.14	2.58	2.55	2.30	1.63	1.85	4.65
	3	2.46	3.05	2.65	2.85	2.12	1.54	1.70	4.81
JAN	1	2.14	3.13	2.25	2.46	1.79	1.46	2.31	4.15
	2	1.94	2.69	2.39	2.38	1.64	1.36	1.59	3.48
	3	1.90	2.50	2.23	2.15	1.52	1.30	1.34	2.83
FEB	1	1.61	2.21	1.69	1.82	1.19	1.11	1.19	2.13
	2	1.65	1.78	2.71	1.59	1.40	0.99	1.13	2.03
	3	1.30	1.19	1.53	1.20	1.57	0.68	1.55	1.48
MARCH	1	1.17	1.40	1.56	1.31	1.27	0.92	1.48	1.79
	2	1.06	1.29	1.28	1.30	1.18	1.00	2.27	2.03
	3	0.98	1.45	1.15	1.40	0.86	0.89	1.36	1.60
APRIL	1	2.56	1.35	0.93	0.92	0.68	0.63	1.55	1.58
	2	5.24	1.29	0.88	0.78	0.76	0.44	1.04	1.52
	3	1.43	0.88	1.59	0.92	1.35	0.51	0.73	1.43
MAY	1	0.94	0.79	1.44	1.58	0.91	0.54	1.65	1.21
	2	0.76	1.62	1.36	1.00	1.00	0.60	14.40	1.10
	3	0.73	2.02	1.27	1.46	1.29	0.67	6.09	0.96
ANNUAL ENERGY		222.93	225.82	236.93	210.39	200.52	199.68	239.70	287.75
ENERGY(NOV-MAY)		44.92	48.89	45.82	42.72	46.85	25.66	53.86	74.58
ENERGY(JUN-OCT)		178.01	176.94	191.10	167.68	153.67	174.02	185.84	213.17

TABLE 7.4

RESTRICTED ENERGY OUTPUT (GWH) Head=57.75 m, Eff = 90%

MONTH		1991-92	1992-93	1993-94	1994-95	1995-96	1996-97	1997-98	1998-99	1999-00
JUNE	1	1.41	0.83	1.48	1.29	1.09	0.77	0.15	0.15	0.49
	2	3.10	5.89	10.23	7.33	0.96	1.52	1.05	0.66	14.40
	3	6.16	5.24	12.17	11.37	7.08	1.82	2.55	3.22	7.69
JULY	1	8.07	4.90	7.81	14.40	7.72	2.74	1.97	11.74	3.86
	2	14.40	11.06	14.40	14.40	14.40	9.64	1.27	14.40	8.69
	3	15.84	15.84	15.84	15.84	15.84	15.84	12.86	12.33	14.03
AUG	1	14.40	14.40	14.40	14.40	14.40	14.40	14.40	12.17	14.40
	2	14.40	14.40	14.40	14.40	14.40	14.40	14.40	14.40	14.40
	3	15.84	15.84	15.84	15.84	15.84	15.84	15.84	9.37	15.84
SEP	1	14.40	14.40	14.40	14.40	14.40	14.40	14.40	9.24	14.40
	2	14.40	14.40	14.40	14.40	14.40	10.22	14.40	8.21	14.40
	3	14.40	11.53	14.40	14.40	14.40	10.11	14.40	5.82	14.40
OCT	1	14.40	8.55	10.69	14.40	8.66	9.46	9.58	4.11	13.04
	2	14.40	6.98	10.14	8.61	9.41	3.05	4.72	6.12	11.06
	3	7.99	4.61	8.67	8.53	0.04	2.76	3.04	3.90	3.98
NOV	1	9.68	4.04	3.57	4.99	5.13	1.91	2.81	2.58	3.48
	2	5.20	3.52	3.23	3.40	6.01	1.48	2.97	6.11	1.24
	3	3.82	3.45	2.43	2.96	3.74	1.08	8.51	2.42	0.83
DEC	1	3.12	2.54	2.03	2.06	2.39	1.03	14.40	0.87	0.63
	2	2.49	2.24	1.75	1.73	2.16	0.91	14.40	0.59	0.47
	3	2.68	2.27	1.82	1.48	2.07	0.88	15.84	0.47	0.36
JAN	1	2.05	1.96	1.53	1.67	1.45	0.80	12.40	0.37	0.29
	2	1.49	1.68	1.46	3.23	1.34	0.92	7.75	0.33	0.27
	3	2.02	1.60	1.46	1.47	1.27	1.04	7.98	0.25	0.24
FEB	1	1.48	1.33	1.11	1.11	1.12	0.77	4.81	0.25	0.25
	2	1.34	1.18	1.12	0.69	1.06	1.62	1.25	0.25	0.33
	3	1.14	0.82	0.72	0.41	0.75	4.75	0.63	0.16	0.37
MARCH	1	1.06	1.05	0.70	0.43	0.96	7.47	0.66	0.17	0.25
	2	1.00	0.87	0.61	0.50	0.73	7.59	0.77	0.14	0.14
	3	1.00	0.76	0.53	0.44	0.68	8.71	0.42	0.14	0.14
APRIL	1	0.79	0.69	0.52	0.67	0.56	6.88	0.49	0.12	0.13
	2	0.71	0.64	0.50	0.75	1.02	1.47	0.29	0.11	0.15
	3	0.73	0.94	0.38	0.48	1.09	0.77	0.41	0.09	0.11
MAY	1	0.96	0.55	0.66	1.27	0.73	0.76	0.45	0.17	0.12
	2	0.95	0.89	0.30	14.40	0.51	0.56	0.77	0.24	0.12
	3	0.93	1.63	1.40	2.01	0.58	0.36	0.24	3.92	0.26
ANNUAL ENERGY		218.26	183.52	207.12	230.14	188.41	178.71	223.31	135.61	175.28
ENERGY(NOV-MAY)		44.65	34.65	27.84	46.12	35.36	51.75	98.28	19.76	10.18
ENERGY(JUN-OCT)		173.61	148.87	179.27	184.02	153.05	126.95	125.03	115.85	165.09

TABLE 8.1

ANNUAL ENERGY(GWH) AND POWER POTENTIAL(MW)

YEAR	ENERGY POTENTIAL(GWH) ANNUAL	NON-MONSOON	MIN. POWER (MW)
1966-67	458.89	59.87	4.41
1967-68	645.03	63.66	2.83
1968-69	419.87	55.95	5.26
1969-70	600.19	65.61	6.89
1970-71	525.1	56.89	6.88
1971-72	395.55	52.79	4.73
1972-73	441.29	60.96	3.96
1973-74	533.72	66.5	6.01
1974-75	223.34	38.21	2.84
1975-76	546.35	56.86	4.74
1976-77	529.98	55.34	5.04
1977-78	611.01	76.44	5.78
1978-79	678.28	54.51	4.54
1979-80	441.91	40.99	4.15
1980-81	605.29	51.05	4.04
1981-82	1050.2	92.04	8.35
1982-83	343.37	36.74	3.12
1983-84	391.43	44.9	2.75
1984-85	532.19	48.88	3.29
1985-86	520.91	45.81	3.65
1986-87	431.59	42.71	3.26
1987-88	253.92	46.84	2.84
1988-89	295.51	25.66	1.85
1989-90	447.86	59.71	3.03
1990-91	803.34	76.09	3.64
1991-92	542.9	44.65	2.97
1992-93	512.67	34.64	2.27
1993-94	340.14	27.83	1.25
1994-95	694.97	47.86	1.66
1995-96	405.98	35.35	0.15
1996-97	282.99	51.74	1.38
1997-98	338.01	102.17	0.63
1998-99	159.43	19.75	0.4
1999-00	295.68	10.18	0.47
MAX	1050.2	102.17	8.35
MIN	159.43	10.18	0.15
AVG.	479.46	51.43	3.5
90% DEP. YEAR	253.92	46.84	2.84

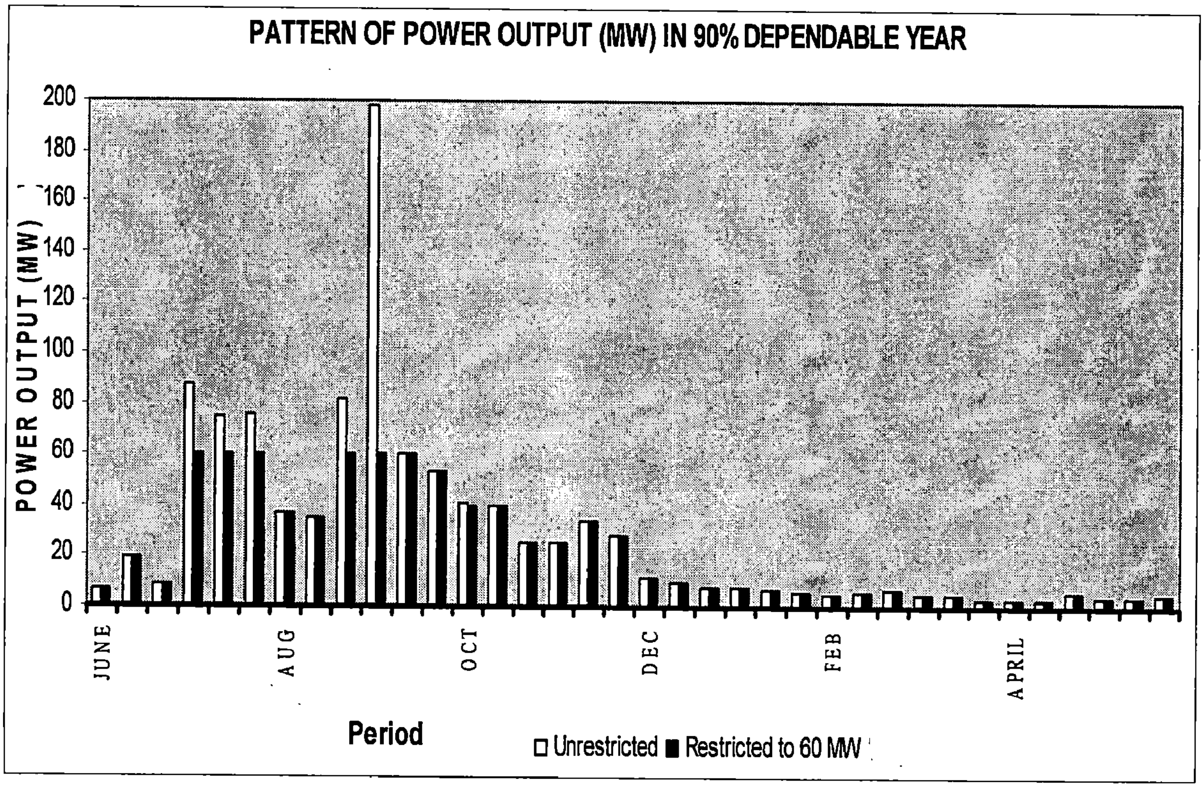
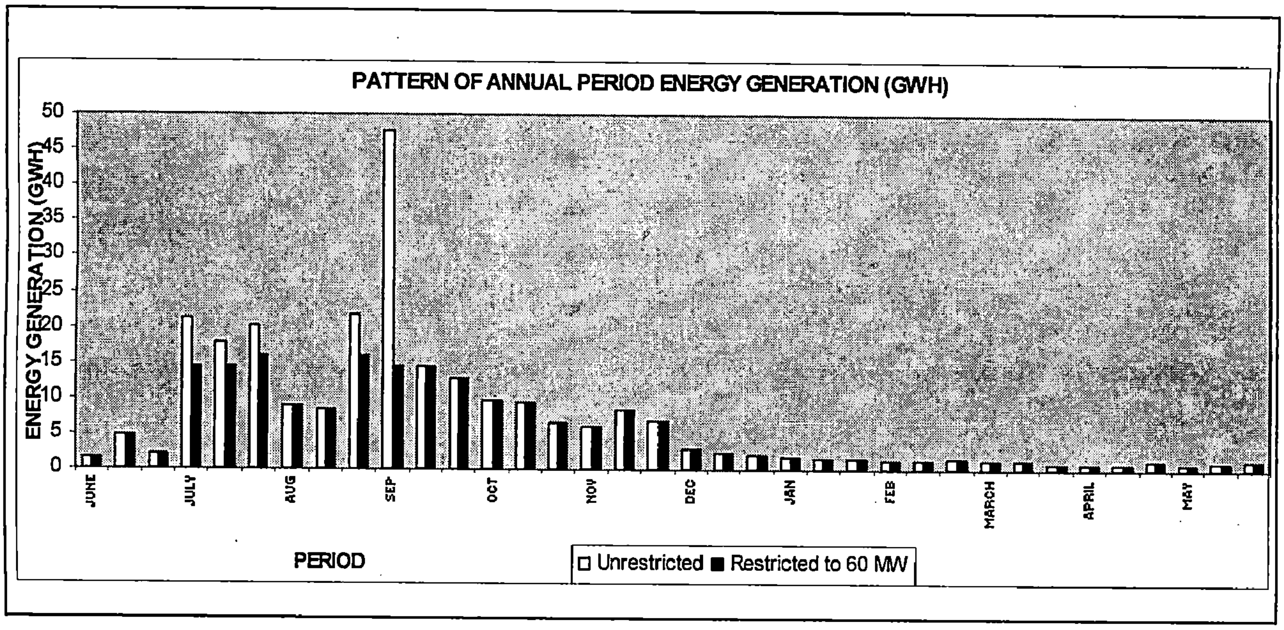

PATTERN OF POWER OUTPUT (MW) IN 90% DEPENDABLE YEAR
POWER OUTPUT (MW)
200
180
160
140
120
100
80
60
40
20
0
JUNE
AUG
OCT
DEC
FEB
APRIL
Period
Unrestricted
Restricted to 60 MW

Fig – (3)



PATTERN OF ANNUAL PERIOD ENERGY GENERATION (GWH)
ENERGY GENERATION (GWH)
50
45
40
35
30
25
20
15
10
5
0
JUNE
JULY
AUG
SEP
OCT
NOV
DEC
JAN
FEB
MARCH
APRIL
MAY
PERIOD
Unrestricted
Restricted to 60 MW

Fig – (4)

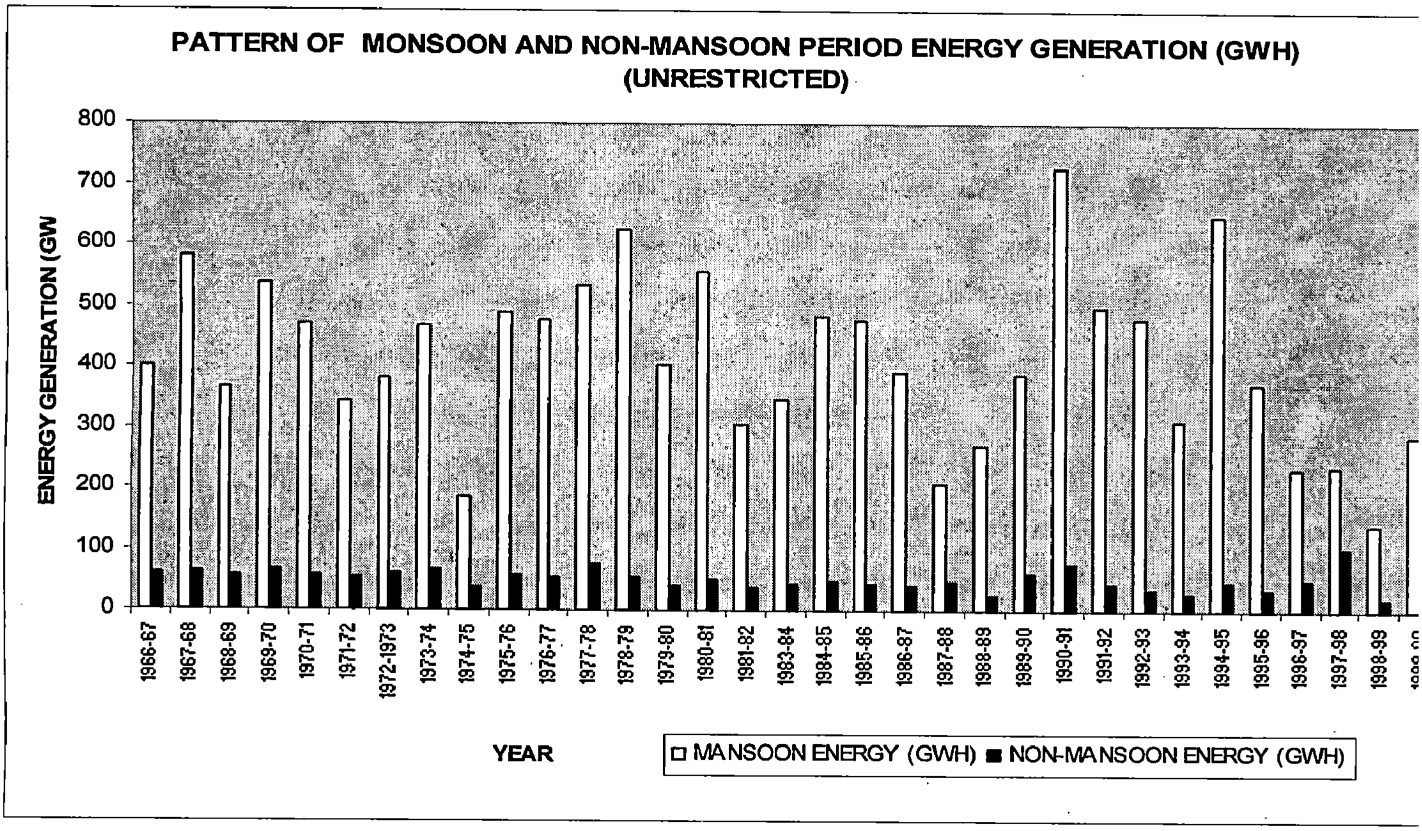

PATTERN OF MONSOON AND NON-MANSOON PERIOD ENERGY GENERATION (GWH)
(UNRESTRICTED)
ENERGY GENERATION (GW
800
700
600
500
400
300
200
100
0
1966-67
1967-68
1968-69
1969-70
1970-71
1971-72
1972-1973
1973-74
1974-75
1975-76
1976-77
1977-78
1978-79
1979-80
1980-81
1981-82
1983-84
1984-85
1985-86
1986-87
1987-88
1988-89
1989-90
1990-91
1991-92
1992-93
1993-94
1994-95
1995-96
1996-97
1997-98
1998-99
YEAR
MANSOON ENERGY (GWH)
NON-MANSOON ENERGY (GWH)

Fig – (5)

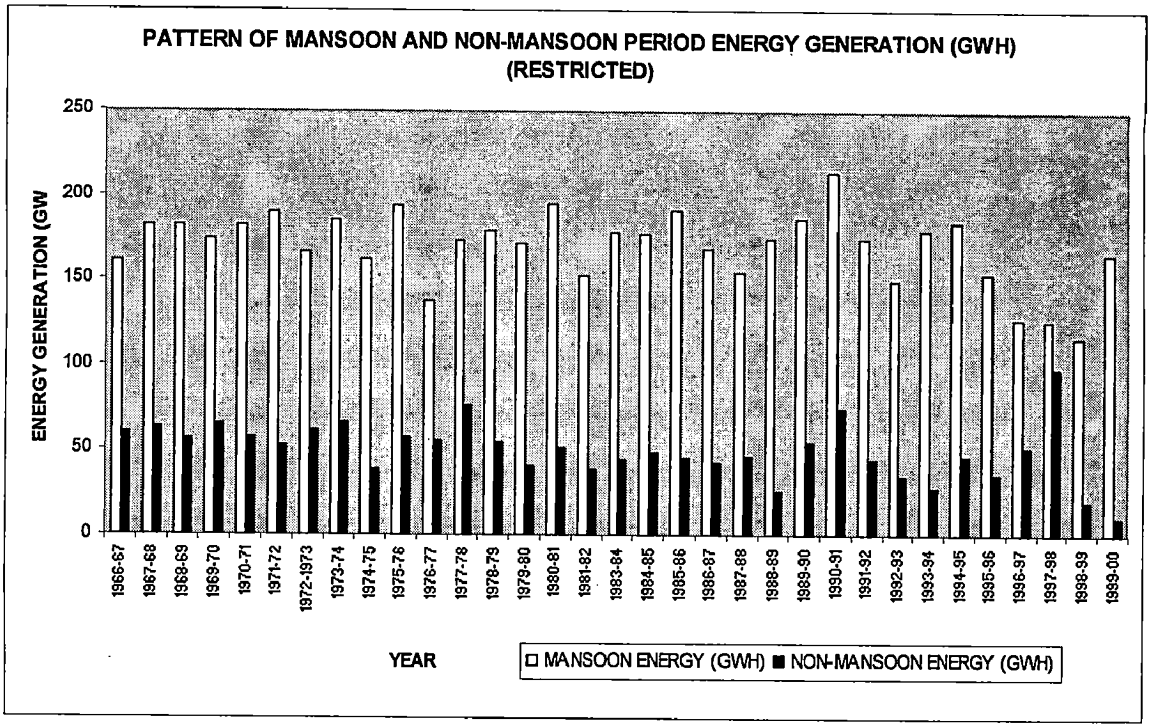

PATTERN OF MANSOON AND NON-MANSOON PERIOD ENERGY GENERATION (GWH)
(RESTRICTED)
ENERGY GENERATION (GW
250
200
150
100
50
0
1966-67
1967-68
1968-69
1969-70
1970-71
1971-72
1972-1973
1973-74
1974-75
1975-76
1976-77
1977-78
1978-79
1979-80
1980-81
1981-82
1983-84
1984-85
1985-86
1986-87
1987-88
1988-89
1989-90
1990-91
1991-92
1992-93
1993-94
1994-95
1995-96
1996-97
1997-98
1998-99
1999-00
YEAR
MANSOON ENERGY (GWH)
NON-MANSOON ENERGY (GWH)

Fig – (6)

CONCLUSION:

1. Annual energy potential varies from minimum 159 GWH (1998-99) to maximum of 1050 GWH (1981-82). Average annual energy is 479 GWH (unrestricted).
2. Average potential during non-monsoon period (Nov-May) is about 10.73% of average annual energy potential.
3. Minimum 10 daily power output varies from 0.15 MW during year 1995-96 to 8.35 MW during 1981-82 with average minimum 10 daily power output being 3.5 MW.
4. Minimum and maximum power output during dependable year is of the order of 2.48 MW (April 1st) and 198.4 MW (Sep. 1st) with average unrestricted output during the year is 28.84 MW. Average unrestricted power output during non-monsoon month is 9.22 MW.
5. Installed capacity of this project is 60 MW (3 X 20 MW).
6. Annual restricted energy for dependable year and average annual basis is 201 GWH and 221 GWH respectively.
7. Annual load factor for dependable year and average annual basis is 35% and 42%.

RESERVOIR YIELD MODEL

3.1 INTRODUCTION

Yield of a reservoir is the volume of water regularly available over a unit period of time at a specified reliability. Analysis of yield of the given storage is to estimate regularly quantum of water that can be made available for supply for different uses. Or, conversely it is also true i.e. to estimate the storage capacity required for a pre-estimated yield. Here, our objective of the study is to estimate the yields for maximum hydro power generation from the given reservoir capacity.

3.1.1 Optimization

Optimization is the science of choosing the best amongst a number of possible alternatives. The availability of resources is usually limited and is expressed with the help of constraints. These constraints restrict the range over which the decision variables can change and thus affect the optimum solution. Optimization techniques are also known as Mathematical Programming Techniques

A mathematical model is a set of equations that describes and represents all characters of the real system. This physical system can be mathematically represented as objective functions with constraints that take care of various aspect of the problem. Optimization methods such as linear programming (LP), Dynamic programming (DP), and Non-linear programming (NLP) can be used to estimate the reservoir system yields.

3.1.2 Linear Programming

If the objective function and the constraints can be expressed in linear algebraic equations or inequalities involving non-negative decision variables, such type of optimization problem formulation and the solution therein, can be termed as linear optimization. It must meet the following conditions:

1. The decision variable of the problem is non-negative, i.e. positive or zero.
2. Objective function is describe by a linear function of the decision variables, i.e., a mathematical expression involving only the first powers of the variables with no c cross products.
3. The operating rules governing the process, commonly know as constraints are expressed as a

set of linear equations or linear inequalities.

3.1.3 Advantage of Linear Programming

The following are the advantage of application of the LP technique.

1. It's ability to accommodate relatively large size problems with comparative ease.
2. LP models allow the analysis as a single level problem unlike dynamic programming (DP) which decomposes the problem into multiple stage problems.
3. LP models search and guarantee global optimal.
4. Availability of standard software packages like LINDO, LINGO, MPS, IPS, APEXIV etc. make use of LP models obvious.
5. LP models are useful in post-optimal (sensitivity) analysis.

3.1.4 Limitations of Linear Programming

Despite many of its virtues, the LP technique inherits the following vices.

1. LP is unable to give solution of infeasible problems.
2. It is based on the assumption that all the constraints have equal importance in solving the problem, contrary to the real situations requiring preferential planning, selective adoption and aphorism, especially in areas of social development, public welfare and general governance.
3. It is unable to bear the shock of the intra-structural dynamics of the coefficients used in the model.
4. It cannot carve a niche in conflicting configurations involving both cases of maximization and minimization simultaneously in the objective function. For solving problems involving multiple conflicting objectives, using linear programming techniques, it is required to introduce other objectives (other than objective function) as model constraints.

3.1.5 Application Area of Linear Programming

Linear programming has been successfully applied to wide spectrum of problems across various disciplines. It mostly finds its applications in the areas of water resources planning and management, business and industry, agriculture and military sectors. Many other fields, in which the LP finds its application, are chemical engineering, civil engineering, architecture, economics, political science and forestry management.

A few of the broad application areas of LP are:

1. Resources allocation problems
2. Scheduling problems
3. Assignment problems
4. Transportation problem
5. Production problems
6. Water quality management
7. Diet planning problem
8. Assembly balancing
9. Inventory problem etc.

3.2 RESERVIOR- YIELD MODEL

3.2.1 Concept

The yield model is an implicit stochastic linear programming (LP) model that incorporates several approximations to reduce the size of the constraints set needed to describe reservoir system operation and to capture the desired reliability of target releases considering the entire length of the historical flow record. The yield model estimates over-year and within-year reservoir capacities requirements separately to meet the specified release reliability targets. Over-year capacity is governed by the distribution of annual stream flows and the annual yield to be provided. The maximum of all over-year storage volumes is the over-year storage capacity. Any distribution of within-year yields that differs from the distribution of the within-year inflows may require additional active reservoir capacity. The total active reservoir storage capacity is simply the sum of the over-year storage and within-year storage capacities. It estimates the required over year and within-year reservoir capacities individually to meet her specific release targets. The concepts of the yield model was introduced by loucks et al. (1981), and was subsequently improved by Dahe and Srivastava (2000), and Dahe and Srivastava (2001), and Panigrahi and Srivastava (2005).

3.2.2 Reliability of Yield

Reliability of yield is the ratio of the actual yield to the planned yield. Maximum flow can be made available at a specific site by regulation of a series of historic stream flow from a reservoir of given capacity is often referred to as the 'firm yield' or 'safe yield'. This means that firm yield or safe yield, which the reservoir will always be able to provide at a required time, and any yield greater than that may or may not be able to meet with. This implies the safe yield will be a 100% reliable yield, provided the mean probability of any particular stream flow being equaled or exceed is based on the assumption that any future flow has an equal probability of falling within any interval defined by a sequence of historic stream flow. This lead to the basic assumption that the history repeats over a period of time.

Considering a series of n natural annual stream flows and arranging them in descending order, we obtain the highest rank, m=n the lowest rank, m=l. Statistically, the probability of the natural annual stream flow will equal or exceed a flow of rank m, is m/(m+1). Reliability of the yield can be determined by estimating the mean probability of a given unregulated stream flow that defines the mean probability of any particular reservoir yield. The reliability of this annual yield is the probability that the stream flow in any year is greater than or equal to these values. In other words, it is the probability that this flow is exceeded. The expected value of the exceedance probability of the lowest flow of the series in n-year record is approximately m (m+1). Thus the firm yield can be defined by the mean probability of that yield being exceeded, which is a function of n, the total number of years of recorded stream flows. Annual firm yield having probability p of exceedance will be denoted as $Oy^{f.p}$. All other yields having lesser reliability than the firm yield is called as secondary yield.

3.2.3 Complete Yield Model

Both the over-year and within yield requirements can be obtained by maximizing the yield $\sum_{t} O_{yt}{}^{fp}$ subject to the continuity and the capacity constraints for each within –year periods of every year of records. The model thus defined by the equations through for each time period t in a year j, and is termed as 'Complete Yield Model'

Maximize $\sum O_{yt}{}^{fp}$

Subject to

$$S_{j,\,t-1} + Ij,t - O_{yt}{}^{fp} - Sp_{j,\,t} = Sj,t$$

$$S_{j,\,t-1} \leq Y_a$$

Here O_{yt}^{fp} =Annual firm yield

$S_{j,t-1}$ = Storage in jth year in t-1 time

$I_{j,t}$ =Inflow in jth year in time t

$Sp_{j,t}$ =storage in jth year in time t

Y_a= Linear reservoir capacity

If t is final period in year j, the next period is t=1, in year j+1, or year 1, if j is the last year of the record. That number of continuity and reservoir capacity constraints in the model would be very large when inflow records of long period and smaller interval of within-year time period is considered. These numbers are multiplied, when more numbers of reservoirs are in consideration, which needs additional sets of constraints. On through examinations of the solutions of various reservoir models, it would be noticed that only a relatively shorter sequence of flow records actually decides the required active storage capacity. This refers to the critical drought period, which becomes the key factor for decision of safe firm yield of the reservoir system. The remaining storage requirements are within-year storage capacity needed to get through the critical year. The critical year is generally at the end of the sequence of years having annual flows lass than the annual reservoir yields.

3.2.4 Approximate Yield Model

Establishing the above justification, an approximation to the reservoir storage capacity obtained from the equations through can also be achieved from the modified model having year-to-year over-year continuity constraints as each year's initial storage plus a set of within-year continuity constraints for the selected critical year. For establishing the within-year continuity constraints for a single yield, a function β_t is introduced with the assumption that the within-year flows of the critical period are to be c\some approximate function β_t of the total annual yield O_{yt}^{fp}

resulting in $\sum_t \beta_t$ =1

3.2.5 Approximate Yield Model versus Complete Yield Model

Comparison between the complete yields model and the approximate yield model has been presented in Louck et al. (1981). Major advantage of the approximate yield model is significant reduction of number of constraint equation and thus number of variable. For example for a hydrological record of 'n' years each having 't' within year periods, considering two constraints only, in complete yield model number of equation becomes 2nt and number of variables are 2nt+t+2. But in an approximate yield model also takes care of the critical year.

3.2.6 Single-Reservoir Single-Yield Model

Consider a single-purpose reservoir of given capacity not affected by upstream regulations for which the annual yield with reliability lower than the maximum reliability is to be determined. The single-yield model formulation (Loucks et al. 1981) is as follows:

Objective function

When annual safe or firm reservoir yield differs from annual flow I_j, then the safe or firm annual yield, Oy^{fp}, can be determined from know active over-year capacity by maximizing the firm yield required to satisfy the continuity and reservoir capacity constraints.

Maximize $Oy^{f,p}$

Subject to

1. Over-year active storage capacity continuity

$$S^o_{j-1} + I_j - \theta p,j \ Oy^{f,p} - Sp_j - EV_j = S^0_j$$

$\theta_{p,j} = 1$ for successful year and 0 for failure year.

The annual evaporation volume loss EV_j can be estimate as

$$EV_j = E_0 + \left[S^O_{j-1} + \sum_t \left(\frac{S^W_{t-1} + S^W_t}{2} \right) y_t \right] El^a$$

2. Over-year active storage volume constraint

$$S^o_{j-1} \leq Y^o$$

3. Within-year active storage continuity

$$S^w_t = S^w_{t-1} + \beta_t (Oyf,p + \sum Ev^t) - (Oy_t^{f,p}) - Ev^t$$

Where as evaporation losses in time t are given as

$$EV^{t} = y_t E_0 + \left[S^{O}_{t,cr} + \frac{S^{W}_{t-1} + S^{W}_{t}}{2} \right] y_t Ev^{a}$$

Where β_t is the fraction in time t of total annual assumed yield assumed as critical period inflow (usually taken as the ratio of inflow in period t of the driest year of record to the total annual flow of that year). In these sets of constraints $\sum_t \beta_t = 1$ ensures

$\sum_t Oy_t^{f,p}$ equals to the annual reservoir yield $Oy^{f,p}$, i.e.,

$$\sum_t Oy_t^{f,p} = Oy^{f,p}$$

4. Within-year storage volume constraints :

Within-year reservoir capacity is the maximum of all the within-year storage volumes :

$S^{w}_{t-1} \le Y^{w}$

Summation of over-year and within-storage capacities determines the total active storage capacity

$$Y_a = Y^{o} + Y^{w} \text{ OR}$$

$$Y^{o} + S^{w}_{t-1} \le Y_a$$

So the within-year reservoir yield can be represented in terms of distribution of annual reservoir yield by including a coefficient K, which defines a predetermined fraction of annual yield in period t based on demand. This can be defined in form of equation as

$$Oy_t^{f,p} = K_t \, Oy^{f,p}$$

This means, $\sum_t K_t = 1$.

3.2.7 Consideration of hydropower

If the firm yield and secondary yields of the reservoir are to be used for firm and secondary energy generation, then objective function will be to maximize the total energy generation. The following equations are added in the model.

Maximize $E_t + \overline{E}_t$

Subjected to

Firm energy generation

$E_t = (CF.e.Ha_t)OFEy^{t}$ $\qquad \forall_t$

Secondary energy generation

$\overline{E}_t = (CF.e.Ha_t)OSEy^t$ $\quad \forall_t$

Plant capacity limitation

$E_t + \overline{E}_t \leq (\alpha_t h_t H)$ $\quad \forall_t$

Firm energy target constraint

$E_t = \eta_t E$ $\quad \forall_t$

Annual secondary energy generation

$\sum_t \overline{E} = \overline{E}$ $\quad \forall_t$

3.2.8 Incorporation of evaporation losses

Estimation of the evaporation loss requires the knowledge of the depth of the evaporation and surface area of the reservoir in period t on which the total evaporation volume depends. The surface area of the reservoir is determined from the storage-area curve. A major approximation adopted in the yield model for finding evaporation volume is that the storage-area relationship approximates to a linear relation, which otherwise is a nonlinear.

3.3 Computation

The actual model and its output file is given as APPENDIX-(A) and (B). In the model, annual yield has been divided into firm yield (OYFP) and secondary yield (OYSP). Firm yield is available in all the years. Firm yield is used for firm energy and secondary yield is used for secondary energy generation.

As the installed capacity of the project has been adopted as 60 MW, so total energy generated in ten daily should be restricted to the energy generated by the project if it runs on installed capacity during that month. Then the model was run and it was found that it gives yield as zero, and then a constraint of firm yield was taken into consideration.

TABLE 9.1

RESULT OF LP YIELD MODEL FOR DIFFERENT CAPACITY FOR MAXIMUM ENERGY

	20 MW	40 MW	60 MW	80 MW	100 MW	120 MW	140 MW	160 MW
EF	14.5	18.82	22.63	25.28	27.92	30.5	32.77	34.83
ES	20.28	39.94	57.94	71.17	84.43	97.4	110.36	123.41

TABLE 9.2

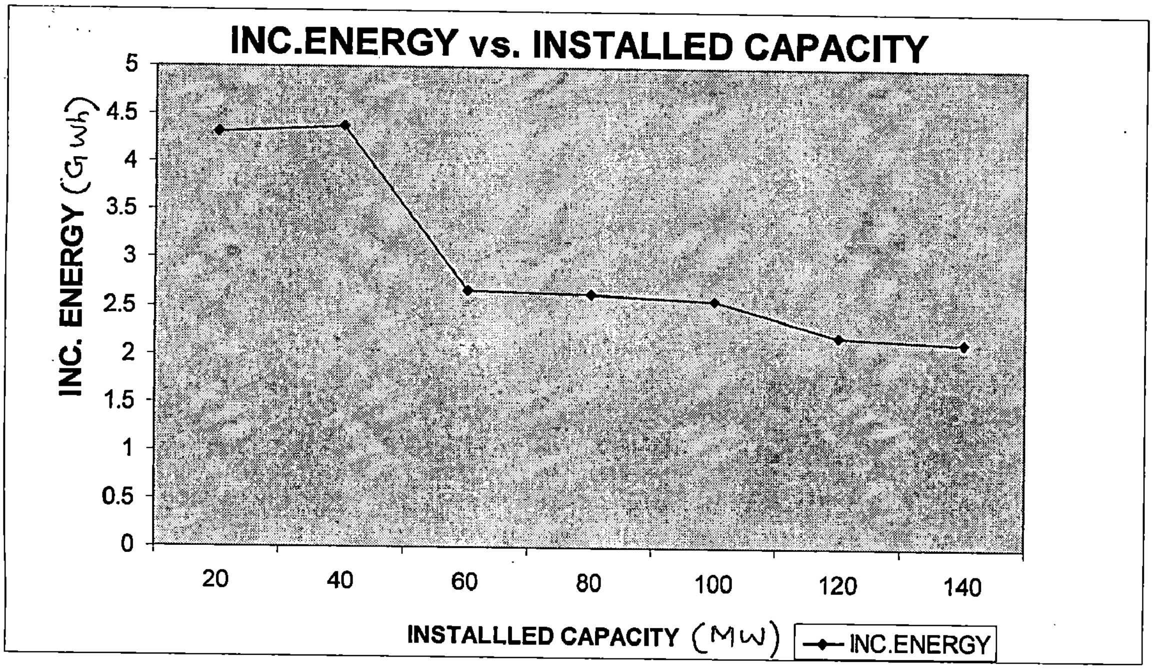
TEN DAILY ENERGY GENERATION BY LP YIELD MODEL

MONTH	PERIOD	FIRM YIELD MCM	SEC. YIELD MCM	FIRM ENERGY GWH	SEC. ENERGY GWH
JUNE	1.000	4.820	0.000	691.620	0.000
	2.000	4.880	0.000	691.620	0.000
	3.000	4.880	0.020	691.620	2.810
JULY	1.000	4.750	29.850	691.620	4348.380
	2.000	4.700	29.200	691.620	4298.600
	3.000	4.660	32.740	691.620	4852.380
AUG	1.000	4.700	29.600	691.620	4348.380
	2.000	4.860	30.560	691.620	4348.380
	3.000	4.710	33.070	691.620	4852.380
SEP	1.000	4.670	29.360	691.620	4348.380
	2.000	4.670	29.360	691.620	4348.380
	3.000	4.670	29.360	691.620	4348.380
OCT	1.000	4.670	29.360	691.620	4348.380
	2.000	4.690	1.350	691.620	200.450
	3.000	4.660	32.730	691.620	4852.380
NOV	1.000	4.760	0.000	691.620	0.000
	2.000	4.880	30.690	691.620	4348.380
	3.000	4.870	11.160	691.620	1584.760
DEC	1.000	4.670	29.360	691.620	4348.380
	2.000	4.670	1.165	691.620	172.610
	3.000	4.660	0.003	691.620	0.467
JAN	1.000	4.670	0.000	691.620	0.000
	2.000	4.670	0.000	691.620	0.000
	3.000	4.660	0.000	691.620	0.000
FEB	1.000	4.680	0.000	691.620	0.000
	2.000	4.690	0.000	691.620	0.000
	3.000	4.690	0.000	691.620	0.000
MARCH	1.000	0.000	0.000	0.000	0.000
	2.000	4.690	0.000	691.620	0.000
	3.000	4.690	0.000	691.620	0.000
APRIL	1.000	4.700	0.000	691.620	0.000
	2.000	4.730	0.000	691.620	0.000
	3.000	4.740	0.000	691.620	0.000
MAY	1.000	4.760	0.000	691.620	0.000
	2.000	4.790	0.000	691.620	0.000
	3.000	4.800	0.000	691.620	0.000
			TOTAL	**24206.700**	**59952.257**

TABLE 9.3

Coefficient for Input of Yield Model

MONTH	PERIOD	1987-88	βt
JUNE	1	12.01	0.0067
	2	33.70	0.0188
	3	15.21	0.0085
JULY	1	148.87	0.0830
	2	126.16	0.0704
	3	141.93	0.0792
AUG	1	63.04	0.0352
	2	58.73	0.0328
	3	152.79	0.0852
SEP	1	336.19	0.1875
	2	101.36	0.0565
	3	89.80	0.0501
OCT	1	68.47	0.0382
	2	67.18	0.0375
	3	46.68	0.0260
NOV	1	43.07	0.0240
	2	58.34	0.0325
	3	48.20	0.0269
DEC	1	20.03	0.0112
	2	16.21	0.0090
	3	14.93	0.0083
JAN	1	12.62	0.0070
	2	11.57	0.0065
	3	10.75	0.0060
FEB	1	8.41	0.0047
	2	9.85	0.0055
	3	11.06	0.0062
MARCH	1	8.97	0.0050
	2	8.31	0.0046
	3	6.10	0.0034
APRIL	1	4.82	0.0027
	2	5.36	0.0030
	3	9.51	0.0053
MAY	1	6.44	0.0036
	2	7.06	0.0039
	3	9.08	0.0051



INC.ENERGY vs. INSTALLED CAPACITY
INC. ENERGY (GWh)
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
20
40
60
80
100
120
140
INSTALLLED CAPACITY (MW)
INC.ENERGY

Fig – (7)

CONCLUSION:

1. By applying LP-Yield model it has been found that pondage capacity is 30.16 MCM. But existing live capacity of pondage is 26.15 MCM with same firm power respectively.

2. By applying LP-Yield model it has been found that in March 1^{st} 10-daily energy generation is not possible.

RESERVOIR OPERATION

4.1 HEDGING RULE

Ming _yen et al .(2003) presented a mixed linear integer programming (MILP) model that consider simultaneously both the traditional reservoir rule curve and the hedging rule curve to be manage and operate a multipurpose ,reservoir system . The authors reported that during normal period of operation, when inflows are plentiful, this optimization model efficiently distributes the available stored water from different reservoir to meet the planned demands imposed by competing users. However, during period of drought or when anticipating a drought, the planned demands cannot be fully met and a water shortage occurs. By considering the hedging rules along with the rule curves, guidelines are provided for reservoir releases. To minimize the impact of drought, the hedging rule efficiently reduces the on going water supply to be balance with the target storage requirements. This model has been successfully applied to the regional water distribution system in the southern region of Taiwan ,and the result are obtained to demonstrate the applicability and utility of the model.

Loucks et al. (1981) illustrated various concept of reservoir performance using an example where a reservoir with an active capacity of 40 x 10^6 m^3 was operated to provide irrigation water during summer. Operation of the reservoir was simulated with 20 year long synthetic seasonal flow sequences generated by Thomas –Fiering model. The reservoir was operated with the standard policy in both seasons. They simulated the reservoir's operation 25 times and calculated the statistics of performance criteria. The operating policy was then modified to introduce some hedge. Only 80% of the target volume was provided (if possible) if the reservoir was less than 80% full. The policy reduced the number and intensity of severe shortages. The overall failure frequency, however, increased considerably. It was concluded that the risk of experience shortage of greater severity can be reduced by hedging at the cost of having more frequent minor shortages.

Bayazit and Unal (1990) investigated the effects of operating a water supply reservoir with a policy of hedging on various reservoir performance criteria. The result of simulation where policies with different degree of hedging are adopted are used to determine how reliability ,resiliency , and mean and maximum deficit vary as function of hedging parameter and to derive the relationships between these criteria.

The authors found that the standard operating policy is the best in relation to reliability and resiliency and is satisfactory with regard to deficit. They reported that the hedging improves the performance with respect to mean deficit if it is started with sufficient water in storage. If hedging is applied when there is little water in storage ,it reduces the risk of very large future deficit ,although the mean deficit will be increased . If the hedging rule is continued even when the demand can be supplied, the performance of reservoir will be more stable and the mean deficit will be decreased, but these will be achieved at a cost of increasing the rate of failure.

Shih and ReVelle (1994) described a linear (continuous) hedging rule for demand management during drought or impending drought. According to the rule ,once demand reduction have been mandated ,demand (and hence release) is to be a function of the sum of reservoir storage at the end of the previous period plus the project inflow in the current period .The parameter of the new rule which is in fact guidance for how to temper demand ,are obtained from the application of mathematical techniques.

4.2 APPLICATION OF HEDGING RULES

The operating policy is one of the most important aspect in the reservoir operation field as the choice of the operating determines the performance of the reservoir. The standard operating policy (SOP) ,which attempts to supply the target volume if it is possible and whatever is available if not , is a very simple reservoir operating rule that has found wide applicability. Klemes (1997) showed that an optimal policy converges to the standard policy as either hydrologic or economic uncertainty grows.

During periods of drought it becomes important to save some of the available water so that the larger future deficits may prevented. During such periods the standard operating policy may result in single periods of severe shortage or sequence of consecutive short supplies. In order to safeguard against unacceptable risk it become necessary to hedge, i.e., to conserve some of the available water .Hedging is expected to affect various performance criteria in different ways.

In drought situations, which may be more severe than those planned for, reservoirs do sometimes fail to deliver their "safe" yields. In such situations, the water supply managers would rather incur a sequence of smaller shortage than one catastrophic shortage. As a consequence in order to mitigate the consequences of potential failures, water restrictions or rationing may be instituted for a city as means to reduce temporarily the level of demand and to preserve storage and inflows for future use (Water Science and Technology Board, 1986). Indeed, if a reservoir had been designed for a lower safe yield it is currently being used to provide, we know that rationing could became a common experience. If the reservoir is being used to deliver more tan the safe yield, or the drought appears to be worse than any planned for, we need to determine the quantitative values(s) of the signal (s) that should be used to trigger rationing to prevent larger shortage later.

In this study the effect of using continuous hedging rule (CHR) and discrete hedging rule (CHR) on reservoir performance are investigated through simulation of a single multipurpose reservoir operated under various degree of hedging.

4.3 RESERVOIR OPERATION USING STANDARD OPERATING POLICY (SOP)

One mode of operation assumed in water supply simulation procedure is referred to as the standard operating policy (SOP) and sometimes as the S-shaped curve of operation (Maass et al .,1962), the curve is illustrated in fig.(1) .It is a rule suggested to simulate reservoir operation ,not a rule that is necessarily suggested for actual operation of a reservoir in a practical situation . The SOP calls for the draft in each period of the demand ,if possible. If insufficient water is available to meet the target ,the reservoir release all the water available and becomes empty , if too much water is available ,the reservoir will fill and spill its excess water. Mathematically, this release rule is expressed as,

$R_t = S_{t-1} + I_t$ if $S_{t-1} + I_t <= D_t$

$R_t = D_t$ if $S_t <= S_{t-1} + I_t <= C$

$R_t = S_{t-1} + I_t - C$ if $S_{t-1} + I_t - D_t > C$

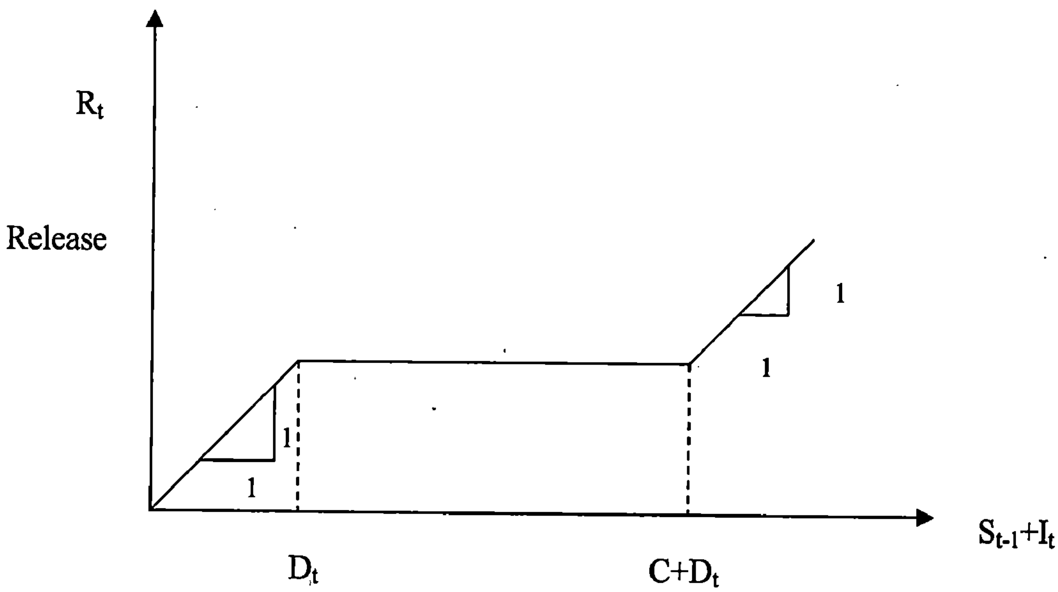


Fig. 8

Realistic operating rules would suggest that, during periods of impending drought ,reduction be made in demand even when the usual demand can be delivered from storage and current flow .Such reduction would prevent larger shortage in later periods.

4.4 RESERVOIR OPERATION USING HEDGING RULES

Economically, a hedging rule can be justified only if a loss or damage function, convex in shortage quantity is associated with the proposed use of water. Rationing rules could utilize either a value of shortage or a value of storage plus projected inflow as the mechanism that triggers demand reductions. Storage has commonly utilized.

In the general situation of actual or impending drought , water managers have been observed to prefer a number of smaller shortage to a few very large ones ,suggesting that the damage are convex in the amount of shortfall. Water managers utilize restriction or rationing to reduce demand levels temporarily and to preserve storage for future for reuse (water science and technology board ,1986). If the water reservoir is entering a period of drought ,a water manager needs specific quantitative values to signal the onset and extent of the restriction that should be utilized.

A common sequence of drought management steps as they might be taken by a water agency is (1) forecasting of inflow and demands, (2) a consideration of drought management options, (3) the establishment of level of storage and/or inflow that trigger the various option of a demand reduction program ,and (4) the option of a management plan at the levels indicated by storage /inflow signals.

The signals of water availability information that are used in practice to declare different emergency phases are not ,however, determined in any uniform or even prescribed way. Water engineering texts offer no information on the determination of these signals. Such signals are generally peculiar to the water agency and may be variable, i.e, not set fully in advance.

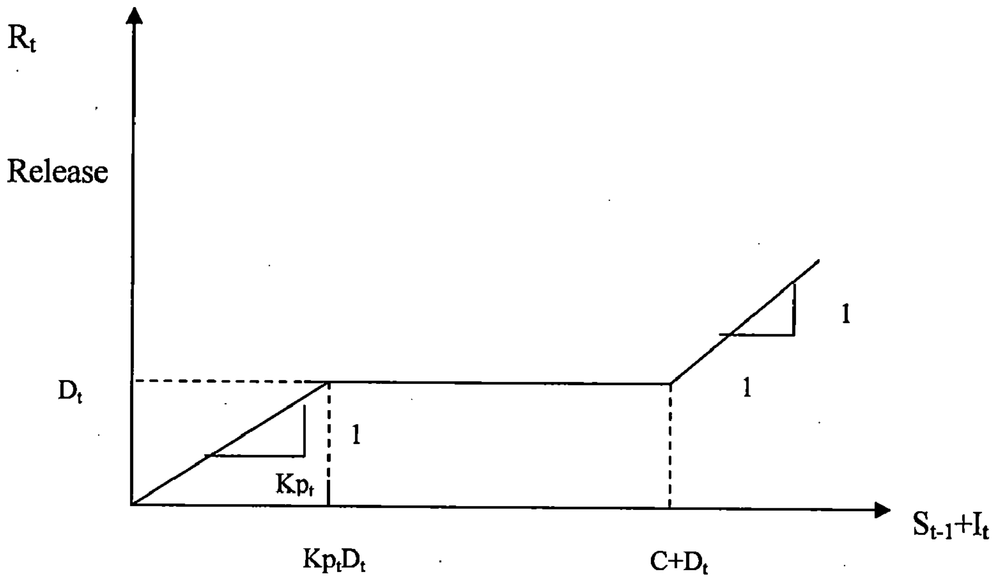
4.4.1 Continuous hedging rule

The rule designed for drought and impending drought condition suggest that demand and consequently release should be manipulated to decline gradually as a reservoir contents and project inflow fall .This rule would also include an additional segment ,i.e., most of the flat portion of the S-shaped curve ,but would allow any level of draft below demand Dt in Shih and

ReVelle (1994) model the demand is assumed to be same for the entire horizon of operation, the curve is illustrated in fig.(2) .It is not difficult ,however ,to extend the model to consider demand level that are specific for each month of the year . The value of the storage plus the anticipated value of current inflow triggers use of the rule might be arbitrarily set at a particularly number of months of demand or can be a decision variable in an optimization model.

The demand reduction/operation rule shown in line OA uses a gradually declining draft as reservoir contents plus projected inflow fall. That is;

Draft = $(1/Kp_t)$ (storage +projected inflow)



Storage at the end of previous period plus prediction of

Fig (9)

In this case, the level of storage plus inflow at which to start rationing and the portion of water demand to be met are determined at the same time by knowledge of the trigger values of $Kpt_{assigned}$ to each month t, when storage of the previous month plus inflow amounts are less than kpt times of demand, rationing is begun. When this quantity is greater than Kpt months of the demand, the full demand can be drafted from the reservoir.

The trigger value is easy to modify to explore its impact on shortages. Obviously the larger the trigger value the smaller the maximum shortfall that will occur, but the more frequently rationing will be necessary.

TABLE 10.1

WORKING TABLE BY SOP

90% dependable year (1987-88)

Month	Period	In. Storage MCM	Inflow MCM	Outflow MCM	Evp. MCM	Final storageMCM	Spill MCM	Power output(KW)	Energy output(MWH)
June	1.00	0.00	12.02	12.02	0.00	0.00	0.00	7094.26	1702.62
	2.00	0.00	33.70	33.70	0.00	0.00	0.00	19889.90	4773.58
	3.00	0.00	15.21	15.21	0.00	0.00	0.00	8977.01	2154.48
July	1.00	0.00	148.87	101.67	0.73	26.15	20.32	62603.80	15024.91
	2.00	26.15	126.16	101.67	0.73	26.15	23.76	62603.80	15024.91
	3.00	26.15	141.93	101.67	0.73	26.15	39.53	62603.80	15024.91
August	1.00	26.15	63.04	89.19	0.00	0.00	0.00	52640.38	12633.69
	2.00	0.00	58.73	58.73	0.00	0.00	0.00	34662.74	8319.06
	3.00	0.00	152.79	101.67	0.63	26.15	24.34	62603.80	15024.91
Sep	1.00	26.15	336.19	101.67	0.44	26.15	234.08	62603.80	15024.91
	2.00	26.15	101.36	101.67	0.17	25.67	0.00	62603.80	15024.91
	3.00	25.67	89.80	101.67	0.08	13.72	0.00	61824.50	14837.88
Oct	1.00	13.72	68.47	82.19	0.00	0.00	0.00	48508.54	11642.05
	2.00	0.00	67.18	67.18	0.00	0.00	0.00	39649.64	9515.91
	3.00	0.00	46.68	46.68	0.00	0.00	0.00	27550.54	6612.13
Nov	1.00	0.00	43.07	43.07	0.00	0.00	0.00	25419.91	6100.78
	2.00	0.00	58.38	58.38	0.00	0.00	0.00	34455.88	8269.41
	3.00	0.00	48.20	48.20	0.00	0.00	0.00	28447.64	6827.43
Dec	1.00	0.00	20.03	20.03	0.00	0.00	0.00	11821.71	2837.21
	2.00	0.00	16.21	16.21	0.00	0.00	0.00	9567.14	2296.11
	3.00	0.00	14.93	14.93	0.00	0.00	0.00	8811.69	2114.80
Jan	1.00	0.00	12.62	12.62	0.00	0.00	0.00	7448.32	1787.60
	2.00	0.00	11.57	11.57	0.00	0.00	0.00	6828.61	1638.87
	3.00	0.00	10.75	10.75	0.00	0.00	0.00	6344.65	1522.72
Feb	1.00	0.00	8.41	8.41	0.00	0.00	0.00	4963.58	1191.26
	2.00	0.00	9.85	9.85	0.00	0.00	0.00	5813.47	1395.23
	3.00	0.00	11.06	11.06	0.00	0.00	0.00	6527.61	1566.63
March	1.00	0.00	8.97	8.97	0.00	0.00	0.00	5294.09	1270.58
	2.00	0.00	8.31	8.31	0.00	0.00	0.00	4904.56	1177.09
	3.00	0.00	6.10	6.10	0.00	0.00	0.00	3600.22	864.05
April	1.00	0.00	4.82	4.82	0.00	0.00	0.00	2844.76	682.74
	2.00	0.00	5.36	5.36	0.00	0.00	0.00	3163.47	759.23
	3.00	0.00	9.51	9.51	0.00	0.00	0.00	5612.80	1347.07
May	1.00	0.00	6.44	6.44	0.00	0.00	0.00	3800.89	912.21
	2.00	0.00	7.06	7.06	0.00	0.00	0.00	4166.81	1000.03
	3.00	0.00	9.08	9.08	0.00	0.00	0.00	5359.02	1286.16
						Minimum		**2844.76**	**682.74**
						Average		**24211.59**	**5810.78**
						Maximum		**62603.80**	**15024.91**
						Total			**209188.1**

TABLE 10.2
Minimum Flow Year (1998-99)

Month	Period	In. Storage MCM	Inflow MCM	Outflow MCM	Evp. MCM	Final storageMCM	Spill MCM	Power output(KW)	Energy output(MWH)
June	1.00	0.00	1.06	1.06	0.00	0.00	0.00	625.61	150.15
	2.00	0.00	4.64	4.64	0.00	0.00	0.00	2738.53	657.25
	3.00	0.00	22.74	22.74	0.00	0.00	0.00	13421.15	3221.08
July	1.00	0.00	82.87	82.87	0.00	0.00	0.00	48909.87	11738.37
	2.00	0.00	245.59	101.67	0.73	26.15	117.04	62603.81	15024.91
	3.00	26.15	79.14	101.67	0.05	3.58	0.00	60265.90	14463.82
August	1.00	0.00	85.94	85.94	0.00	0.00	0.00	50722.21	12173.33
	2.00	0.00	125.54	101.67	0.60	23.27	0.00	62344.04	14962.57
	3.00	0.00	66.14	66.14	0.00	0.00	0.00	39035.83	9368.60
Sep	1.00	0.00	65.22	65.22	0.00	0.00	0.00	38492.84	9238.28
	2.00	0.00	57.98	57.98	0.00	0.00	0.00	34219.80	8212.75
	3.00	0.00	41.07	41.07	0.00	0.00	0.00	24239.51	5817.48
Oct	1.00	0.00	29.01	29.01	0.00	0.00	0.00	17121.70	4109.21
	2.00	0.00	43.17	43.17	0.00	0.00	0.00	25478.93	6114.94
	3.00	0.00	27.54	27.54	0.00	0.00	0.00	16254.11	3900.99
Nov	1.00	0.00	18.19	18.19	0.00	0.00	0.00	10735.74	2576.58
	2.00	0.00	43.14	43.14	0.00	0.00	0.00	25461.23	6110.69
	3.00	0.00	17.08	17.08	0.00	0.00	0.00	10080.62	2419.35
Dec	1.00	0.00	6.14	6.14	0.00	0.00	0.00	3623.83	869.72
	2.00	0.00	4.18	4.18	0.00	0.00	0.00	2467.04	592.09
	3.00	0.00	3.34	3.34	0.00	0.00	0.00	1971.27	473.10
Jan	1.00	0.00	2.58	2.58	0.00	0.00	0.00	1522.72	365.45
	2.00	0.00	2.31	2.31	0.00	0.00	0.00	1363.36	327.21
	3.00	0.00	1.79	1.79	0.00	0.00	0.00	1056.46	253.55
Feb	1.00	0.00	1.73	1.73	0.00	0.00	0.00	1021.05	245.05
	2.00	0.00	1.80	1.80	0.00	0.00	0.00	1062.36	254.97
	3.00	0.00	1.10	1.10	0.00	0.00	0.00	649.22	155.81
March	1.00	0.00	1.22	1.22	0.00	0.00	0.00	720.04	172.81
	2.00	0.00	1.01	1.01	0.00	0.00	0.00	596.10	143.06
	3.00	0.00	1.02	1.02	0.00	0.00	0.00	602.00	144.48
April	1.00	0.00	0.82	0.82	0.00	0.00	0.00	483.96	116.15
	2.00	0.00	0.79	0.79	0.00	0.00	0.00	466.26	111.90
	3.00	0.00	0.67	0.67	0.00	0.00	0.00	395.43	94.90
May	1.00	0.00	1.18	1.18	0.00	0.00	0.00	696.44	167.14
	2.00	0.00	1.70	1.70	0.00	0.00	0.00	1003.34	240.80
	3.00	0.00	27.69	27.69	0.00	0.00	0.00	16342.64	3922.23
						Minimum		**395.43**	**94.90**
						Average		**16077.64**	**3858.63**
						Maximum		**62603.81**	**15024.91**
						Total			**138910.8**

TABLE 10.3
Maximum Flow Year (1981-82)

Month	Period	In. Storage MCM	Inflow MCM	Outflow MCM	Evp. MCM	Final storageMCM	Spill MCM	Power output(KW)	Energy output(MWH)
Jun	1.00	0.00	32.79	32.79	0.00	0.00	0.00	19350.33	4644.08
	2.00	0.00	16.40	16.40	0.00	0.00	0.00	9679.28	2323.03
	3.00	0.00	20.14	20.14	0.00	0.00	0.00	11886.63	2852.79
July	1.00	0.00	32.13	32.13	0.00	0.00	0.00	18963.13	4551.15
	2.00	0.00	78.03	78.03	0.00	0.00	0.00	46053.31	11052.79
	3.00	0.00	93.56	93.56	0.00	0.00	0.00	55219.11	13252.59
August	1.00	0.00	417.03	101.67	0.63	26.15	288.58	62603.81	15024.91
	2.00	26.15	496.19	101.67	0.63	26.15	393.90	62603.81	15024.91
	3.00	26.15	218.56	101.67	0.63	26.15	116.26	62603.81	15024.91
Sep	1.00	26.15	244.81	101.67	0.44	26.15	142.70	62603.81	15024.91
	2.00	26.15	186.78	101.67	0.44	26.15	84.67	62603.81	15024.91
	3.00	26.15	140.10	101.67	0.44	26.15	37.98	62603.81	15024.91
Oct	1.00	26.15	102.67	101.67	0.41	26.15	0.60	62603.81	15024.91
	2.00	26.15	45.43	71.58	0.00	0.00	0.00	42246.52	10139.16
	3.00	0.00	34.98	34.98	0.00	0.00	0.00	20645.20	4954.85
Nov	1.00	0.00	28.47	28.47	0.00	0.00	0.00	16802.99	4032.72
	2.00	0.00	24.55	24.55	0.00	0.00	0.00	14489.41	3477.46
	3.00	0.00	21.70	21.70	0.00	0.00	0.00	12807.34	3073.76
Dec	1.00	0.00	18.58	18.58	0.00	0.00	0.00	10965.92	2631.82
	2.00	0.00	16.88	16.88	0.00	0.00	0.00	9962.58	2391.02
	3.00	0.00	16.54	16.54	0.00	0.00	0.00	9761.91	2342.86
Jan	1.00	0.00	13.78	13.78	0.00	0.00	0.00	8132.96	1951.91
	2.00	0.00	12.65	12.65	0.00	0.00	0.00	7466.03	1791.85
	3.00	0.00	12.57	12.57	0.00	0.00	0.00	7418.81	1780.52
Feb	1.00	0.00	10.41	10.41	0.00	0.00	0.00	6143.98	1474.56
	2.00	0.00	9.21	9.21	0.00	0.00	0.00	5435.74	1304.58
	3.00	0.00	6.70	6.70	0.00	0.00	0.00	3954.34	949.04
March	1.00	0.00	9.03	9.03	0.00	0.00	0.00	5329.51	1279.08
	2.00	0.00	7.09	7.09	0.00	0.00	0.00	4184.52	1004.28
	3.00	0.00	7.79	7.79	0.00	0.00	0.00	4597.66	1103.44
April	1.00	0.00	6.30	6.30	0.00	0.00	0.00	3718.26	892.38
	2.00	0.00	7.05	7.05	0.00	0.00	0.00	4160.91	998.62
	3.00	0.00	8.47	8.47	0.00	0.00	0.00	4998.99	1199.76
May	1.00	0.00	5.65	5.65	0.00	0.00	0.00	3334.63	800.31
	2.00	0.00	17.09	17.09	0.00	0.00	0.00	10086.52	2420.76
	3.00	0.00	9.42	9.42	0.00	0.00	0.00	5559.68	1334.32
						Minimum		**3334.63**	**800.31**
						Average		**22920.93**	**5501.02**
						Maximum		**62603.81**	**15024.91**
						Total			**197179.9**

TABLE 11.1

VALUE OF Kpt FROM YIELD MODEL RESULT OF 90% DEPENDABLE YEAR

Month	Period	Initial Storage	Fraction of yield	Total Storage	EVP	Firm Release	Second. Release	Total Release	Kpt
JUNE	1	4.79	3.9	8.87	0.05	4.82	0	4.87	1.82
	2	4.05	10.97	15.02	0.09	4.88	0	4.97	3.02
	3	0	4.96	4.96	0.03	4.88	0.02	4.93	1.01
JUL	1	0	48.44	48.44	3.5	4.74	29.86	38.1	1.27
	2	13.83	40.85	54.68	3.95	4.7	29.2	37.85	1.44
	3	20.77	46.1	66.87	4.83	4.66	32.74	42.23	1.58
AUG	1	30.05	20.42	50.47	1.21	4.7	29.6	35.51	1.42
	2	16.17	19.08	35.23	0.84	4.86	30.56	36.26	0.97
	3	0	49.72	49.72	1.19	4.71	30.07	35.97	1.38
SEP	1	11.81	109.43	121.24	2.06	4.67	29.36	36.09	3.36
	2	28.67	32.97	61.64	1.05	4.67	29.36	35.08	1.76
	3	30.16	29.18	59.34	1	4.67	29.36	35.03	1.69
OCT	1	25.31	22.17	47.48	0.75	4.69	29.36	34.8	1.36
	2	14.61	21.86	36.47	0.57	4.69	1.36	6.62	5.51
	3	30.16	15.17	45.33	0.71	4.66	32.73	38.1	1.19
NOV	1	7.93	14	21.93	0.29	4.75	0	5.04	4.35
	2	17.18	18.96	36.14	0.48	4.88	30.7	36.06	1.00
	3	0.28	15.69	15.97	0.21	4.87	11.16	16.24	0.98
DEC	1	0	65.19	65.19	0.64	4.67	29.36	34.67	1.88
	2	30.16	5.25	35.41	0.34	4.67	1.16	6.17	5.74
	3	30.16	4.86	35.02	0.34	4.66	0.003	5.003	7.00
JAN	1	30.16	4.08	34.24	0.38	4.67	0	5.05	6.78
	2	29.58	3.76	33.34	0.37	4.67	0	5.04	6.62
	3	28.4	3.5	31.9	0.35	4.66	0	5.01	6.37
FEB	1	27.24	2.74	29.98	0.48	4.68	0	5.16	5.81
	2	25.48	3.21	28.7	0.46	4.69	0	5.15	5.57
	3	23.71	3.6	27.31	0.43	4.69	0	5.12	5.33
MAR	1	22.51	2.92	25.43	0.74	0	0	0.74	34.36
	2	25.43	2.7	28.13	0.82	4.69	0	5.51	5.11
	3	23.66	1.98	25.64	0.74	4.69	0	5.43	4.72
APRIL	1	20.71	1.57	22.28	1.15	4.7	0	5.85	3.81
	2	17.58	1.75	19.33	1	4.73	0	5.73	3.37
	3	14.6	3.09	17.69	0.91	4.74	0	5.65	3.13
MAY	1	12.78	2.1	14.88	1.06	4.75	0	5.81	2.56
	2	10.12	2.27	12.39	0.9	4.79	0	5.69	2.18
	3	7.67	2.95	10.62	0.73	4.8	0	5.53	1.92

***** Fractional yield(MCM) = βt(firm yield MCM+ secondary yield MCM)**

***** Total storage(MCM) = Initial storage (MCM)+ Fractional yield (MCM)**

***** Total Release(MCM) = Evaporation (MCM)+ Firm release (MCM) + Secondary Release(MCM)**

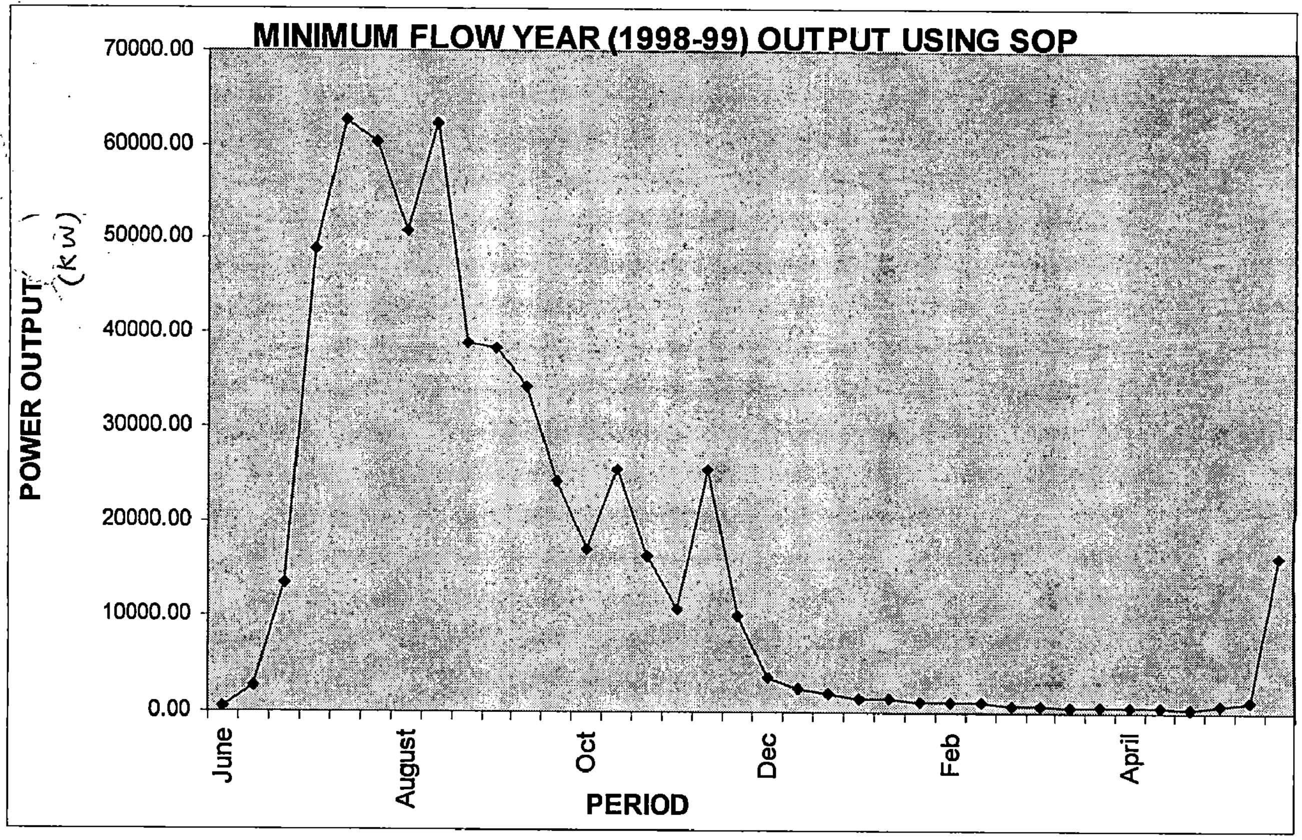
***** Kpt = Total storage(MCM) / Total Release(MCM)**

TABLE 12.1

WORKING TABLE BY USING CHR

90% DEPENDABLE YEAR (1987-88)

MONTH	PERIOD	In. Storage MCM	Inflow MCM	Outflow MCM	Evp MCM	Final Storage MCM	Spill MCM	power output(KW)	Energy output(MWH)
JUNE	1	0	12.02	6.6	0.1	6.5	0	3894.86	934.77
	2	6.5	33.7	13.3	0.2	13.1	0	7848.73	1883.69
	3	13.1	15.21	28.3	1.45	26.15	0.69	16700.68	4008.16
JULY	1	26.15	148.87	101.67	0.74	26.15	46.5	59998.52	14399.64
	2	26.15	126.16	101.67	0.74	26.15	23.7	59998.52	14399.64
	3	26.15	141.93	101.67	0.74	26.15	39.5	59998.52	14399.64
AUG	1	26.15	63.04	62.88	0	0.22	0	37107.37	8905.77
	2	0.22	58.73	58.95	0.63	0	0	34788.16	8349.16
	3	0	152.79	101.67	0.63	26.15	28.9	59998.52	14399.64
SEP	1	26.15	336.19	101.67	0.44	26.15	234	59998.52	14399.64
	2	26.15	101.36	101.67	0.44	25.8	0	59998.52	14399.64
	3	25.8	89.8	101.67	0.22	13.9	0	59998.52	14399.64
OCT	1	13.9	68.47	60.56	0.41	26.15	33.9	35738.27	8577.19
	2	26.15	67.18	18.66	0.41	26.15	47.9	11011.83	2642.84
	3	26.15	46.68	45.52	0.41	26.15	0.56	26862.72	6447.05
NOV	1	26.15	43.07	9.708	0.35	26.15	32.8	5728.98	1374.96
	2	26.15	58.38	79.53	0.35	0	0	46933.04	11263.93
	3	0	48.2	48.2	0.35	0	0	28444.27	6826.62
DEC	1	0	20.03	10.65	0.26	8.87	0	6284.88	1508.37
	2	8.87	16.21	4.37	0.26	20.21	0	2578.87	618.93
	3	20.21	14.93	5.02	0.26	26.15	3.27	2962.45	710.99
JAN	1	26.15	12.62	5.72	0.28	26.15	6.22	3375.54	810.13
	2	26.15	11.57	5.7	0.28	26.15	5.17	3363.74	807.30
	3	26.15	10.75	5.8	0.28	26.15	4.67	3422.75	821.46
FEB	1	26.15	8.41	5.95	0.42	26.15	2.04	3511.27	842.71
	2	26.15	9.85	6.46	0.42	26.15	2.97	3812.24	914.94
	3	26.15	11.06	6.98	0.42	26.15	3.66	4119.11	988.59
MAR	1	26.15	8.97	1.02	0.76	26.15	7.19	601.93	144.46
	2	26.15	8.31	6.76	0.76	26.15	0.79	3989.28	957.43
	3	26.15	6.1	6.83	0.72	24.7	0	4030.59	967.34
APRIL	1	24.7	4.82	7.77	1	20.75	0	4585.31	1100.47
	2	20.75	5.36	7.74	0.87	17.5	0	4567.61	1096.23
	3	17.5	9.51	8.63	0.87	17.51	0	5092.82	1222.28
MAY	1	17.51	6.44	9.35	0.91	13.7	0	5517.72	1324.25
	2	13.7	7.06	9.53	0.73	10.5	0	5623.94	1349.75
	3	10.5	9.08	10.2	0.5	8.88	0	6019.33	1444.64
						MINIMUM		**601.93**	**144.46**
						AVERAGE		**21274.66**	**5105.92**
						MAXIMUM		**59998.52**	**14399.64**
						Total			**179641.9**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POWER OUTPUT (KW)
70000.00
60000.00
50000.00
40000.00
30000.00
20000.00
10000.00
0.00
June
August
Oct
Dec
Feb
April
PERIOD

Fig – (10)

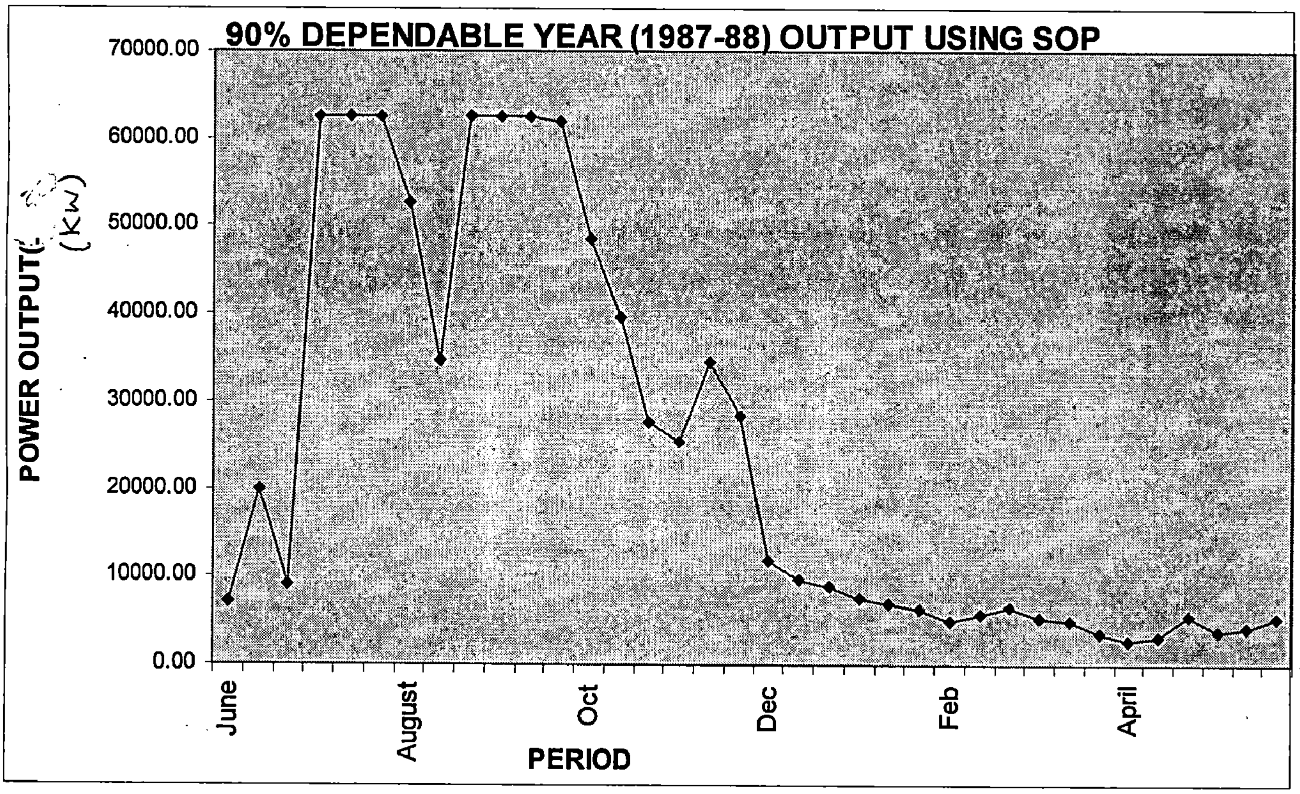
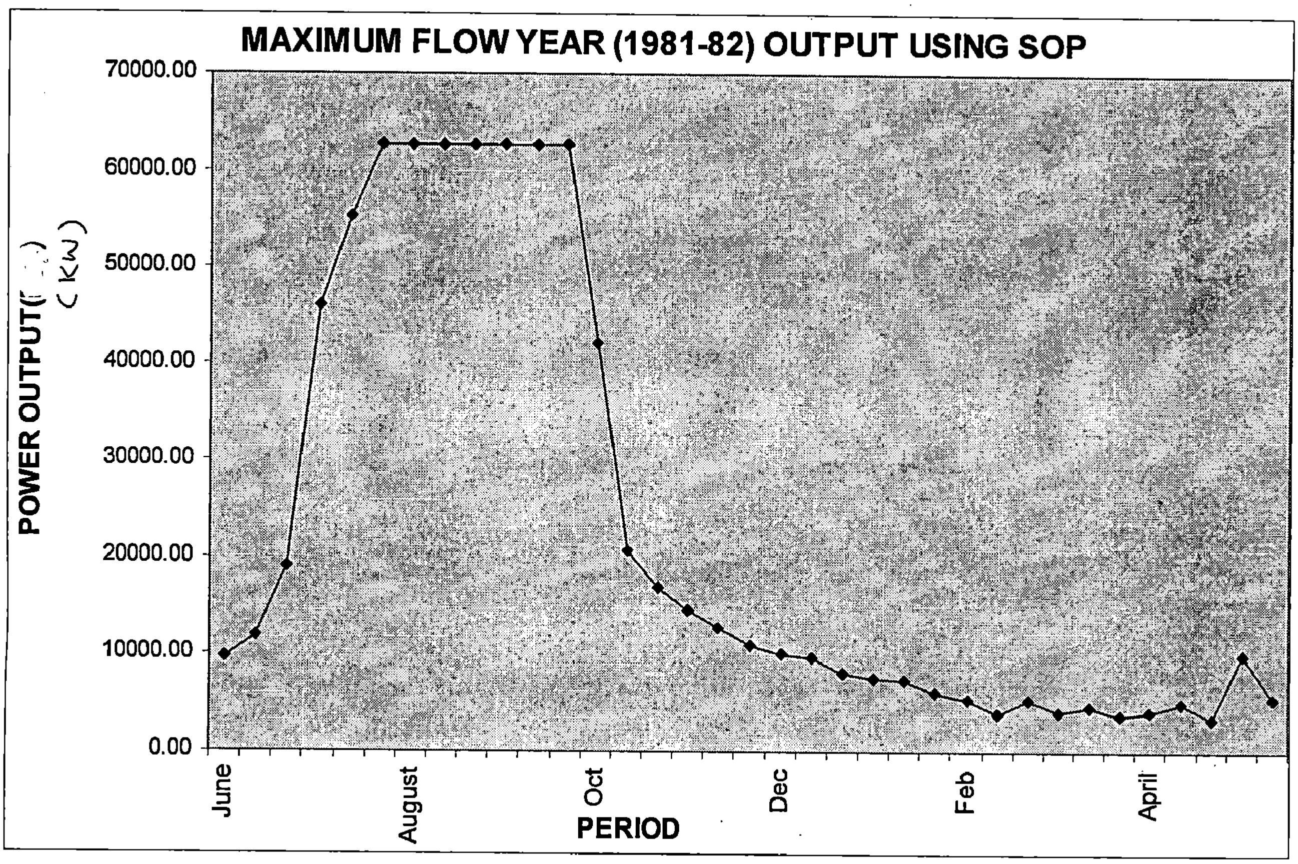

90% DEPENDABLE YEAR (1987-88) OUTPUT USING SOP
POWER OUTPUT (KW)
70000.00
60000.00
50000.00
40000.00
30000.00
20000.00
10000.00
0.00
June
August
Oct
Dec
Feb
April
PERIOD

Fig – (11)



MAXIMUM FLOW YEAR (1981-82) OUTPUT USING SOP
70000.00
60000.00
50000.00
40000.00
30000.00
20000.00
10000.00
0.00
POWER OUTPUT( ) (KW)
June
August
Oct
Dec
Feb
April
PERIOD

Fig – (12)

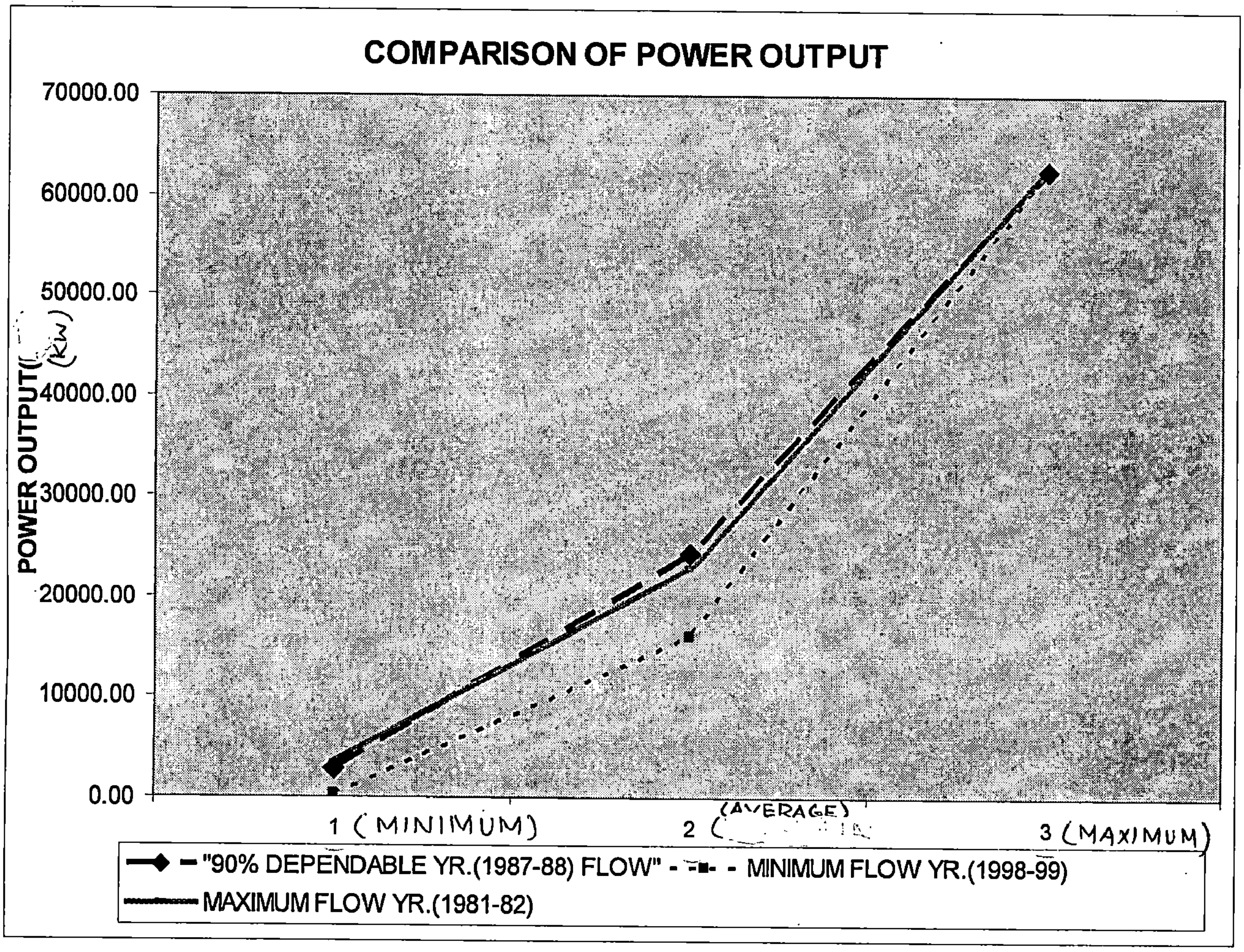

COMPARISON OF POWER OUTPUT
70000.00
60000.00
50000.00
40000.00
30000.00
20000.00
10000.00
0.00
POWER OUTPUT(KW)
1 (MINIMUM)
2 (AVERAGE)
3 (MAXIMUM)
"90% DEPENDABLE YR.(1987-88) FLOW"
MINIMUM FLOW YR.(1998-99)
MAXIMUM FLOW YR.(1981-82)

Fig – (13)

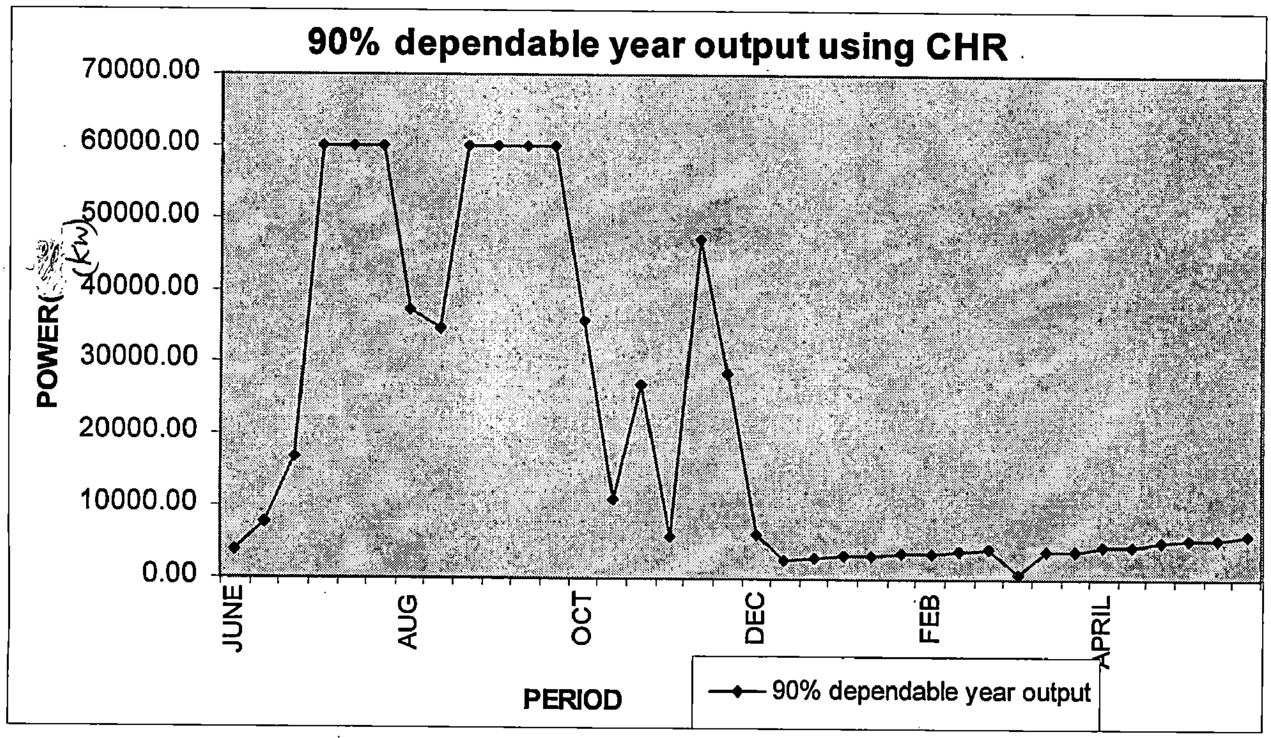

90% dependable year output using CHR
70000.00
60000.00
50000.00
40000.00
30000.00
20000.00
10000.00
0.00
POWER(KW)
JUNE
AUG
OCT
DEC
FEB
APRIL
PERIOD
90% dependable year output

Fig – (14)

CONCLUSION:

(1) Rule curve has been drawn for release and generation of power and energy by Standard Operation Policy (SOP) and by Continuous Hedging Rule (CHR).

(2) Reservoir operation simulation studies have been done for maximum flow year (1981-82), minimum flow year (1998-99) and for 90% dependable year (1987-88).

(3) By SOP it has found that for minimum flow year spill is only once (July 2nd ten daily) in whole year and pondage is full at once only, for maximum flow year pondage is full only in the month of August and September and in the rest of the time there is no pondage, and for 90% dependable year there is full pondage in the month July and September and energy is maximum in respective year.

(4) By applying CHR in 90% dependable year, it has been found that result is coming very efficient as compared to SOP. In the month of July and from august to march pondage is full, only once there is no pondage

ECONOMIC EVALUATION

5.1 INTRODUCTION

As the investment in water resources projects is long term and through allocation of planned schemes of centre/state Governments. So, before any decision on investment is taken, the financial evaluation of each scheme is carried out to ascertain the economic viability. Priority of investment is also given accordingly. There are different methods for economic evaluation and are given ahead.

5.2 METHODS OF ECONOMIC EVALUATION

(1) Benefit cost ratio method

(2) Internal rate of return method

(3) Present worth method

(4) Annual cost method

Each method has its own merits and demerits. The applicability of the method depends on the available and on the choice of the individual. However, in case of water resource projects, benefit-cost ratio method has wide acceptability and the same has been applied in this study.

5.3 PHASING OF COST

The project is planned to be completed in six years. The year-wise phasing of expenditure based on the proposed schedule of construction for power component of the project has been estimated and given below:

Table: Year-wise phasing of cost

TABLE 13.1

Year	Cost (lakh)
1	1443
2	6196
3	8618
4	9154
5	7469
6	2761
Total	35641

Estimated cost of project = Rs. 35641 Lakh

Interest during construction = Rs. 4958 Lakh

Total project cost = Rs. 40599 Lakh

5.4 FINANCIAL ANALYSIS

5.4.1 Cost of power generation

Annual firm generation is 201 GWh and annual secondary generation is 21 GWh.

(a) Interest rate: simple interest rate of 9.2 % has been adopted.

(b) Depreciation charge: Average rate depreciation has been taken as 1.6 %.

(c) O & M charges: Flat rate of 1% has been adapted.

1. Working expense per year @ 2.6 % of the capital cost = 926.67 Lakh

2. Interest charges @ 9.25 % on the capital cost = 3296.8 Lakh

Total (1+2) = 4223.47 Lakh

Cost of generation per unit KWh = $(4223.47 * 10^5) / (222 * 10^6)$

= Rs. 1.90 per KWh

5.4.2 Tariff or sale charge:

Normally the sale charges are fixed taking into account, a minimum return of 10% on the capital cost, which is worked out as under:

(i) The capital cost = Rs. 35641.00 lakh

(ii) Total capitalized cost

(Total capital cost + Interest during construction) = Rs.40599 Lakhs

(iii) Annual capitalized cost (9.25% of capitalized cost) = Rs. 3755.4 Lakhs

(iv) Expected annual net return (10% of capital cost) = Rs. 3564.1 Lakhs

(v) Sale rate to ensure annual return = $(3755.4 + 3564.1) * 10^5 / (222 * 10^6)$

$= \text{Rs. } 3.3 \text{ per KWh}$

5.5 ECONOMIC ANALYSIS:

The economic analysis of the project has been done assuming that the project will be run for at least 35 years after its commissioning. As the costs and benefits are non linear, so to compare the costs and benefit, a single value at zero time (2006) is required. There are different discounting techniques to reach at a single value. Here two methods have been applied as under, i.e., annual cost method and present worth

5.5.1 Annual cost method:

In this method, uniform annual cost and annual benefits are computed and benefit cost ratio is calculated.

5.5.1.1 Annual cost:

Annual cost of any project consists of annual interest plus annual depreciation plus annual O & M cost.

(i) Annual interest 35641 *9.25/100 = Rs. 3296.8 lakh

(ii) Annual depreciation $= 35641.00 * 0.016 / \{(1+0.016)^{35}-1\}$

$= 767.6$ lakh

(iii) Annual O&M charges $= 35641.00 * 0.01 / \{(1+0.01)^{35}-1\}$

$= 855.52$ lakh

Total annual cost (1+2+3) = 4919.92 Lakhs

5.5.1.2 Annual benefit:

Anticipated gross annual revenue $= (201 * 3.3 + 21 * 2) * 10^6/10^5$

$= 705.3$ Lakh

5.5.1.3 Benefit Cost Ratio:

B-C ratio = Annual benefit / Annual cost

= 1.43

B-C ratio of firm power by yield model = 1.43 * 26.15 / 31.15

= 1.23

5.5.2 Present Worth of Costs and Benefits Method

In this method, present worth of total costs and of total benefits is calculated at zero year 2006.

1. Present worth of construction cost = $40599 / (1+0.0925)^6$

= 23877.55 Lakhs

2. Present worth of O & M $= 855.52\left[\frac{(1.0925)^{35}-1}{0.0925(1.0925)^{35}}\right]\times\frac{1}{(1.0925)^{6}}$

= 5672.14 Lakhs

3. Present worth of Depreciation $= 767.6\left[\frac{(1.0925)^{35}-1}{0.0925(1.0925)^{35}}\right]\times\frac{1}{(1.0925)^{6}}$

= 5089.2 Lakhs

Total cost (1+2+3) PWC = 34638.89

Total benefit $P_{Wb} = (201 * 3.3 + 21 * 2) * 10^6\left[\frac{(1.0925)^{35}-1}{0.0925(1.0925)^{35}}\right]\times\frac{1}{(1.0925)^{6}}$

= 46761.4 Lakh

B-C ratio $= P_{Wb}/P_{WC} = 1.35$

B-C ratio of firm power by yield model = 1.35 X 26.15 / 31.15 = 1.13

5.5.3 Internal rate of return method:

In this method, we calculate rate of return with zero benefit.

$P_{Wb} = P_{WC}$

$$(201 * 3.3 + 21 * 2) * 10 * \left[\frac{(1+i)^{35}-1}{i\times(1+i)^{35}}\right] = (40599+767.62) + 855.52\left[\frac{(1+i)^{35}-1}{i(1+i)^{35}}\right]$$

By trial and error value of i = 10.61%

5.6 CONCLUSION:

The B-C ratio of the project in both the methods is more than unity and internal rate of return is also more than expected annual net return. So project is financially viable and is recommended for implementation.

SUMMARY AND CONCLUSION

6.1 GENERAL

The present study comprises of the evaluation of yield of Matnar Hydro Power project for the generation of maximum hydro power potential by application of Linear Programming optimization technique. Matnar Hydro Power project is a run-off the river scheme project. The entire study has been described in 3 chapters. This chapter deals with the discussions on the results model and limitations of the study.

6.2 SUMMARY OF FINDINGS

6.2.1 Project as Run-off the River Scheme

Annual energy potential varies from minimum 159 GWH (1998-99) to maximum of 1050 GWH (1981-82). Average annual energy is 479 GWH (unrestricted). Average potential during non-monsoon period (Nov-May) is about 10.73% of average annual energy potential. Minimum 10 daily power output varies from 0.15 MW during year 1995-96 to 8.35 MW during 1981-82 with average minimum 10 daily power output being 3.5 MW. Minimum and maximum power output during dependable year is of the order of 2.48 MW (April 1st) and 198.4 MW (Sep. 1st) with average unrestricted output during the year is 28.84 MW. Average unrestricted power output during non-monsoon month is 9.22 MW. Installed capacity of this project is 60 MW (3 X 20 MW).Annual restricted energy for dependable year and average annual basis is 201 GWH and 221GWH, respectively. Annual load factor for dependable year and average annual basis is 35% and 42% respectively.

6.2.2 Reservoir Yield Model

In Chapter-3, approximate yield model has been formulated using Linear Programming optimization technique by taking the flow series of 34 years (Table 1.1-Table 1.4). The model has been solved [computer software 'LINDO']. The objective function is to maximize the generation of annual firm energy keeping capacity constant and another model for minimize the pondage for maximize energy. By applying LP-Yield model it has been found that pondage capacity is 30.16 MCM. But existing live capacity of pondage is 26.15 MCM with same firm power, respectively. The project report doesn't mention how the pondage capacity is arrived.

By applying LP-Yield model it has been found that in March 1st 10-daily energy generation is not possible. This is because inflow is very low.

6.2.3 Reservoir Operation

Rule curve has been drawn for release and generation of power and energy by Standard Operation Policy (SOP) and by Continuous Hedging Rule (CHR). Reservoir operation simulation studies have been done for maximum flow year (1981-82), minimum flow year (1998-99) and for 90% dependable year (1987-88).By SOP it has found that for minimum flow year spill is only once(July 2nd ten daily) in whole year and pondage is full at once only, for maximum flow year pondage is full only in the month of August and September and in the rest of the time there is no pondage, and for 90% dependable year there is full pondage in the month July and September and energy is maximum in respective year.

By applying CHR in 90% dependable year, it has been found that result is coming very efficient as compared to SOP. In the month of July and from August to March pondage is full, only once there is no pondage.

6.2.4 Economic Evaluation

Economic analysis has been done for power component only, by finding the benefit cost ratio the annual cost and annual benefit and by finding the present worth of costs and benefits of the eject. Discounting rate has been assumed as 9.25% and economic life of the project as 35 years. The B/C ratio has worked out as 1.43 by Annual cost method and 1.35 by Present worth of cost and benefit method for run of river scheme and when calculated from yield model firm energy it comes as 1.23 and 1.13 respectively.

6.4 LIMITATIONS OF THE STUDY

In spite of utmost care being taken to imitate the system in its real domain, the study has been based on some assumptions and limitations of the approach being adopted. So following are the limitation of study.

1. The primary data pertaining to ten daily flows at site are not real one, rather they are derived ones. The net-flow at Matnar has been obtained using either exclusively the R-R relation developed at Jagdalpur G&D site or entirely the catchment proportion basis .
2. All the month has considered equal days ten daily.
3. Yield model adopted here is an approximate yield model. Ten daily flows of the 90%

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APPENDIX - (A)

APPROXIMATE YIELD MODEL FOR MINIMUM PONDAGE

RELIABILITY 90% FOR HYDROPOWER

OBJECTIVE FUNCTION

MIN YA

SUBJECT TO

OVER YEAR STORAGE

OS1-OS0+OYFP+OYSP+SP1=3240
OS2-OS1+OYFP+OYSP+SP2=4554
OS3-OS2+OYFP+OYSP+SP3=2965
OS4-OS3+OYFP+OYSP+SP4=4238
OS5-OS4+OYFP+OYSP+SP5=3708
OS6-OS5+OYFP+OYSP+SP6=2793
OS7-OS6+OYFP+OYSP+SP7=3116
OS8-OS7+OYFP+OYSP+SP8=3768
OS9-OS8+OYFP+SP9=1577 ***Failure Year**
OS10-OS9+OYFP+OYSP+SP10=3858
OS11-OS10+OYFP+OYSP+SP11=3742
OS12-OS11+OYFP+OYSP+SP12=4312
OS13-OS12+OYFP+OYSP+SP13=4789
OS14-OS13+OYFP+OYSP+SP14=3141
OS15-OS14+OYFP+OYSP+SP15=4274
OS16-OS15+OYFP+OYSP+SP16=7415
OS17-OS16+OYFP+OYSP+SP17=2424
OS18-OS17+OYFP+OYSP+SP18=2764
OS19-OS18+OYFP+OYSP+SP19=3758
OS20-OS19+OYFP+OYSP+SP20=3678
OS21-OS20+OYFP+OYSP+SP21=3047
OS22-OS21+OYFP+SP22=1793 ***Failure Year**
OS23-OS22+OYFP+OYSP+SP23=2086
OS24-OS23+OYFP+OYSP+SP24=3162
OS25-OS24+OYFP+OYSP+SP25=5672
OS26-OS25+OYFP+OYSP+SP26=3833
OS27-OS26+OYFP+OYSP+SP27=3620
OS28-OS27+OYFP+OYSP+SP28=2402
OS29-OS28+OYFP+OYSP+SP29=4907
OS30-OS29+OYFP+OYSP+SP30=2866
OS31-OS30+OYFP+OYSP+SP31=1998
OS32-OS31+OYFP+OYSP+SP32=2387
OS33-OS32+OYFP+SP33=1126 ***Failure Year**

OS0-OS33+OYFP+OYSP+SP34=2088
OS0-OS34=0

OVER YEAR STORAGE

OS0-OY<=0
OS1-OY<=0
OS2-OY<=0
OS3-OY<=0
OS4-OY<=0
OS5-OY<=0
OS6-OY<=0
OS7-OY<=0
OS8-OY<=0
OS9-OY<=0
OS10-OY<=0
OS11-OY<=0
OS12-OY<=0
OS13-OY<=0
OS14-OY<=0
OS15-OY<=0
OS16-OY<=0
OS17-OY<=0
OS18-OY<=0
OS19-OY<=0
OS20-OY<=0
OS21-OY<=0
OS22-OY<=0
OS23-OY<=0
OS24-OY<=0
OS25-OY<=0
OS26-OY<=0
OS27-OY<=0
OS28-OY<=0
OS29-OY<=0
OS30-OY<=0
OS31-OY<=0
OS32-OY<=0
OS33-OY<=0

WITHIN YEAR STORAGE

WS0-WS1-OYFP1-OYSP1+0.0067 OYFP+0.0067OYSP=0
WS1+0.0019OYFP+0.001OYSP-OYFP2-OYSP2-WS2=0
WS2+0.0084OYFP+0.0084OYSP-OYFP3-OYSP3-WS3=0
WS3+0.083OYFP+0.083OYSP-OYFP4-OYSP4-WS4=0
WS4+0.07OYFP+0.07OYSP-OYFP5-OYSP5-WS5=0
WS5+0.08OYFP+.08OYSP-OYFP6-OYSP6-WS6=0
WS6+0.035OYFP+0.035OYSP-OYFP7-OYSP7-WS7=0
WS7+0.033OYFP+0.033OYSP-OYFP8-OYSP8-WS8=0

WS8+0.085OYFP+0.085OYSP-OYFP9-OYSP9-WS9=0
WS9+0.19OYFP+0.19OYSP)-OYFP10-OYSP10-WS10=0
WS10+0.056OYFP+0.065OYSP-OYFP11-OYSP11-WS11=0
WS11+0.05OYFP+0.05OYSP-OYFP12-OYSP12-WS12=0
WS12+0.04OYFP+0.04OYSP-OYFP13-OYSP13-WS13=0
WS13+0.037OYFP+0.037OYSP-OYFP14-OYSP14-WS14=0
WS14+0.026OYFP+0.026OYSP-OYFP15-OYSP15-WS15=0
WS15+0.024OYFP+0.024OYSP-OYFP16-OYSP16-WS16=0
WS16+0.032OYFP+0.032OYSP-OYFP17-OYSP17-WS17=0
WS17+0.027OYFP+0.027OYSP-OYFP18-OYSP18-WS18=0
WS18+0.11OYFP+0.11OYSP-OYFP19-OYSP19-WS19=0
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WS20+0.008OYFP+0.008OYSP-OYFP21-OYSP21-WS21=0
WS21+0.007OYFP+0.007OYSP-OYFP22-OYSP22-WS22=0
WS22+0.006OYFP+0.006OYSP-OYFP23-OYSP23-WS23=0
WS23+0.006OYFP+0.006OYSP-OYFP24-OYSP24-WS24=0
WS24+0.005OYFP+0.005OYSP-OYFP25-OYSP25-WS25=0
WS25+0.005OYFP+0.005OYSP-OYFP26-OYSP26-WS26=0
WS26+0.006OYFP+0.006OYSP-OYFP27-OYSP27-WS27=0
WS27+0.005OYFP+0.005OYSP-OYFP28-OYSP28-WS28=0
WS28+0.005OYFP+0.005OYSP-OYFP29-OYSP29-WS29=0
WS29+0.003OYFP+0.003OYSP-OYFP30-OYSP30-WS30=0
WS30+0.0027OYFP+0.0027OYSP-OYFP31-OYSP31-WS31=0
WS31+0.003OYFP+0.003OYSP-OYFP32-OYSP32-WS32=0
WS32+0.005OYFP+0.005OYSP-OYFP33-OYSP33-WS33=0
WS33+0.0036OYFP+0.0036OYSP-OYFP34-OYSP34-WS34=0
WS34+0.004OYFP+0.004OYSP-OYFP35-OYSP35-WS35=0
WS35+0.0036OYFP+0.0036OYSP-OYFP36-OYSP36-WS36=0
WS36-WS0=0

TOTAL PONDAGE CAPACITY

OY+WS0-YA<=0
OY+WS1-YA<=0
OY+WS2-YA<=0
OY+WS3-YA<=0
OY+WS4-YA<=0
OY+WS5-YA<=0
OY+WS6-YA<=0
OY+WS7-YA<=0
OY+WS8-YA<=0
OY+WS9-YA<=0
OY+WS10-YA<=0
OY+WS11-YA<=0
OY+WS12-YA<=0
OY+WS13-YA<=0
OY+WS14-YA<=0
OY+WS15-YA<=0
OY+WS16-YA<=0

OY+WS17-YA<=0
OY+WS18-YA<=0
OY+WS19-YA<=0
OY+WS20-YA<=0
OY+WS21-YA<=0
OY+WS22-YA<=0
OY+WS23-YA<=0
OY+WS24-YA<=0
OY+WS25-YA<=0
OY+WS26-YA<=0
OY+WS27-YA<=0
OY+WS28-YA<=0
OY+WS29-YA<=0
OY+WS30-YA<=0
OY+WS31-YA<=0
OY+WS32-YA<=0
OY+WS33-YA<=0
OY+WS34-YA<=0
OY+WS35-YA<=0

FIRM ENERGY GENERATION

EF1-143.45OYFP1=0
EF2-141.65OYFP2=0
EF3-141.65OYFP3=0
EF4-145.63OYFP4=0
EF5-147.17OYFP5=0
EF6-148.2OYFP6=0
EF7-146.86OYFP7=0
EF8-142.26OYFP8=0
EF9-146.7OYFP9=0
EF10-148.08OYFP10=0
EF11-148.08OYFP11=0
EF12-148.08OYFP12=0
EF13-148.08OYFP13=0
EF14-147.47OYFP14=0
EF15-148.23OYFP15=0
EF16-145.3OYFP16=0
EF17-141.65OYFP17=0
EF18-141.95OYFP18=0
EF19-148.08OYFP19=0
EF20-148.08OYFP20=0
EF21-148.23OYFP21=0
EF22-148.08OYFP22=0
EF23-148.08OYFP23=0
EF24-148.25OYFP24=0
EF25-147.78OYFP25=0
EF26-147.47OYFP26=0
EF27-147.23OYFP27=0
EF28-147.47OYFP28=0

EF29-147.47OYFP29=0
EF30-147.31OYFP30=0
EF31-146.86OYFP31=0
EF32-146.25OYFP32=0
EF33-145.95OYFP33=0
EF34-145.33OYFP34=0
EF35-144.4OYFP35=0
EF36-143.93OYFP36=0

SECONDARY ENERGY GENERATION

ES1-143.45OYSP1=0
ES2-141.65OYSP2=0
ES3-141.65OYSP3=0
ES4-145.63OYSP4=0
ES5-147.17OYSP5=0
ES6-148.2OYSP6=0
ES7-146.86OYSP7=0
ES8-142.26OYSP8=0
ES9-146.7OYSP9=0
ES10-148.08OYSP10=0
ES11-148.08OYSP11=0
ES12-148.08OYSP12=0
ES13-148.08OYSP13=0
ES14-147.47OYSP14=0
ES15-148.23OYSP15=0
ES16-145.3OYSP16=0
ES17-141.65OYSP17=0
ES18-141.95OYSP18=0
ES19-148.08OYSP19=0
ES20-148.08OYSP20=0
ES21-148.23OYSP21=0
ES22-148.08OYSP22=0
ES23-148.08OYSP23=0
ES24-148.25OYSP24=0
ES25-147.78OYSP25=0
ES26-147.47OYSP26=0
ES27-147.23OYSP27=0
ES28-147.47OYSP28=0
ES29-147.47OYSP29=0
ES30-147.31OYSP30=0
ES31-146.86OYSP31=0
ES32-146.25OYSP32=0
ES33-145.95OYSP33=0
ES34-145.33OYSP34=0
ES35-144.4OYSP35=0
ES36-143.93OYFP36=0

PLANT CAPACITY LIMITATION

EF1+ES1<=5040

EF2+ES2<=5040
EF3+ES3<=5040
EF4+ES4<=5040
EF5+ES5<=5040
EF6+ES6<=5544
EF7+ES7<=5040
EF8+ES8<=5040
EF9+ES9<=5544
EF10+ES10<=5040
EF11+ES11<=5040
EF12+ES12<=5040
EF13+ES13<=5040
EF14+ES14<=5040
EF15+ES15<=5544
EF16+ES16<=5040
EF17+ES17<=5040
EF18+ES18<=5040
EF19+ES19<=5040
EF20+ES20<=5040
EF21+ES21<=5544
EF22+ES22<=5040
EF23+ES23<=5040
EF24+ES24<=5544
EF25+ES25<=5040
EF26+ES26<=5040
EF27+ES27<=4032
EF28+ES28<=5040
EF29+ES29<=5040
EF30+ES30<=5544
FF31+ES31<=5040
EF32+ES32<=5040
EF33+ES33<=5040
EF34+ES34<=5040
EF35+ES35<=5040
EF36+ES36<=5544

FIRM ENERGY TARGET

EF1-0.0278EF=0
EF2-0.0278EF=0
EF3-0.0278EF=0
EF4-0.0278EF=0
EF5-0.0278EF=0
EF6-0.0278EF=0
EF7-0.0278EF=0
EF8-0.0278EF=0
EF9-0.0278EF=0
EF10-0.0278EF=0
EF11-0.0278EF=0

EF12-0.0278EF=0
EF13-0.0278EF=0
EF14-0.0278EF=0
EF15-0.0278EF=0
EF16-0.0278EF=0
EF17-0.0278EF=0
EF18-0.0278EF=0
EF19-0.0278EF=0
EF20-0.0278EF=0
EF21-0.0278EF=0
EF22-0.0278EF=0
EF23-0.0278EF=0
EF24-0.0278EF=0
EF25-0.0278EF=0
EF26-0.0278EF=0
EF27-0.0278EF=0
EF27-0.0278EF=0
EF29-0.0278EF=0
EF30-0.0278EF=0
EF31-0.0278EF=0
EF32-0.0278EF=0
EF32-0.0278EF=0
EF33-0.0278EF=0
EF34-0.0278EF=0
EF35-0.0278EF=0
EF36-0.0278EF=0
EF>=24878.4

ANNUAL SURPLUS ENERGY

ES1+ES2+ES3+ES4+ES5+ES6+ES7+ES8+ES9+ES10+ES11+ES12+ES13+ES14+ES15+ES16+ES17+ES18+ES19+ES20+ES21+ES22+ES23+ES24+ES25+ES26+ES27+ES28+ES29+ES30+ES31+ES32+ES33+ES34+ES35+ES36-ES=0

LP OPTIMUM FOUND AT STEP 90

OBJECTIVE FUNCTION VALUE

30.16321

TABLE 14.1

VARIABLE	VALUE	REDUCED COST
YA	30.16	0.00
OS1	0.00	0.00
OS0	0.00	0.00
OYFP	267.86	0.00
OYSP	315.77	0.00
SP1	2656.37	0.00
OS2	0.00	0.00
SP2	3970.37	0.00
OS3	0.00	0.00
SP3	2381.37	0.00
OS4	0.00	0.00
SP4	3654.37	0.00
OS5	0.00	0.00
SP5	3124.37	0.00
OS6	0.00	0.00
SP6	2209.37	0.00
OS7	0.00	0.00
SP7	2532.37	0.00
OS8	0.00	0.00
SP8	3184.37	0.00
OS9	0.00	0.00
SP9	1309.14	0.00
OS10	0.00	0.00
SP10	3274.37	0.00
OS11	0.00	0.00
SP11	3158.37	0.00
OS12	0.00	0.00
SP12	3728.37	0.00
OS13	0.00	0.00
SP13	4205.37	0.00
OS14	0.00	0.00
SP14	2557.37	0.00
OS15	0.00	0.00
SP15	3690.37	0.00
OS16	0.00	0.00
SP16	6831.37	0.00
OS17	0.00	0.00
SP17	1840.37	0.00
OS18	0.00	0.00
SP18	2180.37	0.00
OS19	0.00	0.00

SP19	3174.37	0.00
OS20	0.00	0.00
SP20	3094.37	0.00
OS21	0.00	0.00
SP21	2463.37	0.00
OS22	0.00	0.00
SP22	1525.14	0.00
OS23	0.00	0.00
SP23	1502.37	0.00
OS24	0.00	0.00
SP24	2578.37	0.00
OS25	0.00	0.00
SP25	5088.37	0.00
OS26	0.00	0.00
SP26	3249.37	0.00
OS27	0.00	0.00
SP27	3036.37	0.00
OS28	0.00	0.00
SP28	1818.37	0.00
OS29	0.00	0.00
SP29	4323.37	0.00
OS30	0.00	0.00
SP30	2282.37	0.00
OS31	0.00	0.00
SP31	1414.37	0.00
OS32	0.00	0.00
SP32	1803.37	0.00
OS33	0.00	0.00
SP33	858.14	0.00
SP34	1504.37	0.00
OS34	0.00	0.00
OY	0.00	1.00
WS0	4.97	0.00
WS1	4.06	0.00
OYFP1	4.82	0.00
OYSP1	0.00	0.00
OYFP2	4.88	0.00
OYSP2	0.00	0.00
WS2	0.00	0.59
OYFP3	4.88	0.00
OYSP3	0.02	0.00
WS3	0.00	0.00
OYFP4	4.75	0.00
OYSP4	29.86	0.00
WS4	13.83	0.00
OYFP5	4.70	0.00
OYSP5	29.21	0.00
WS5	20.78	0.00
OYFP6	4.67	0.00
OYSP6	32.74	0.00

WS6	30.06	0.00
OYFP7	4.71	0.00
OYSP7	29.61	0.00
WS7	16.17	0.00
OYFP8	4.86	0.00
OYSP8	30.57	0.00
WS8	0.00	0.00
OYFP9	4.71	0.00
OYSP9	33.08	0.00
WS9	11.82	0.00
OYSP)	0.00	0.00
OYFP10	4.67	0.00
OYSP10	29.37	0.00
WS10	28.67	0.00
OYFP11	4.67	0.00
OYSP11	29.37	0.00
WS11	30.16	0.00
OYFP12	4.67	0.00
OYSP12	29.37	0.00
WS12	25.31	0.00
OYFP13	4.67	0.00
OYSP13	29.37	0.00
WS13	14.62	0.00
OYFP14	4.69	0.00
OYSP14	1.36	0.00
WS14	30.16	0.00
OYFP15	4.67	0.00
OYSP15	32.74	0.00
WS15	7.94	0.00
OYFP16	4.76	0.00
OYSP16	0.00	0.00
WS16	17.18	0.00
OYFP17	4.88	0.00
OYSP17	30.70	0.00
WS17	0.28	0.00
OYFP18	4.87	0.00
OYSP18	11.16	0.00
WS18	0.00	0.41
OYFP19	4.67	0.00
OYSP19	29.37	0.00
WS19	30.16	0.00
OYFP20	4.67	0.00
OYSP20	1.17	0.00
WS20	30.16	0.00
OYFP21	4.67	0.00
OYSP21	0.00	0.00
WS21	30.16	0.00
OYFP22	4.67	0.00
OYSP22	0.00	0.00
WS22	29.58	0.00

OYFP23	4.67	0.00
OYSP23	0.00	0.00
WS23	28.41	0.00
OYFP24	4.67	0.00
OYSP24	0.00	0.00
WS24	27.25	0.00
OYFP25	4.68	0.00
OYSP25	0.00	0.00
WS25	25.48	0.00
OYFP26	4.69	0.00
OYSP26	0.00	0.00
WS26	23.71	0.00
OYFP27	4.70	0.00
OYSP27	0.00	0.00
WS27	22.52	0.00
OYFP28	0.00	0.00
OYSP28	0.00	0.59
WS28	25.43	0.00
OYFP29	4.69	0.00
OYSP29	0.00	0.00
WS29	23.66	0.00
OYFP30	4.69	0.00
OYSP30	0.00	0.00
WS30	20.72	0.00
OYFP31	4.71	0.00
OYSP31	0.00	0.00
WS31	17.58	0.00
OYFP32	4.73	0.00
OYSP32	0.00	0.00
WS32	14.61	0.00
OYFP33	4.74	0.00
OYSP33	0.00	0.00
WS33	12.79	0.00
OYFP34	4.76	0.00
OYSP34	0.00	0.00
WS34	10.13	0.00
OYFP35	4.79	0.00
OYSP35	0.00	0.00
WS35	7.67	0.00
OYFP36	4.81	0.00
OYSP36	0.00	0.59
WS36	4.97	0.00
EF1	691.62	0.00
EF2	691.62	0.00
EF3	691.62	0.00
EF4	691.62	0.00
EF5	691.62	0.00
EF6	691.62	0.00
EF7	691.62	0.00
EF8	691.62	0.00

EF9	691.62	0.00
EF10	691.62	0.00
EF11	691.62	0.00
EF12	691.62	0.00
EF13	691.62	0.00
EF14	691.62	0.00
EF15	691.62	0.00
EF16	691.62	0.00
EF17	691.62	0.00
EF18	691.62	0.00
EF19	691.62	0.00
EF20	691.62	0.00
EF21	691.62	0.00
EF22	691.62	0.00
EF23	691.62	0.00
EF24	691.62	0.00
EF25	691.62	0.00
EF26	691.62	0.00
EF27	691.62	0.00
EF28	0.00	0.00
EF29	691.62	0.00
EF30	691.62	0.00
EF31	691.62	0.00
EF32	691.62	0.00
EF33	691.62	0.00
EF34	691.62	0.00
EF35	691.62	0.00
EF36	691.62	0.00
ES1	0.00	0.00
ES2	0.00	0.00
ES3	2.81	0.00
ES4	4348.38	0.00
ES5	4298.59	0.00
ES6	4852.38	0.00
ES7	4348.38	0.00
ES8	4348.38	0.00
ES9	4852.38	0.00
ES10	4348.38	0.00
ES11	4348.38	0.00
ES12	4348.38	0.00
ES13	4348.38	0.00
ES14	200.46	0.00
ES15	4852.38	0.00
ES16	0.00	0.00
ES17	4348.38	0.00
ES18	1584.77	0.00
ES19	4348.38	0.00
ES20	172.61	0.00
ES21	0.47	0.00
ES22	0.00	0.00

ES23	0.00	0.00
ES24	0.00	0.00
ES25	0.00	0.00
ES26	0.00	0.00
ES27	0.00	0.00
ES28	0.00	0.00
ES29	0.00	0.00
ES30	0.00	0.00
ES31	0.00	0.00
ES32	0.00	0.00
ES33	0.00	0.00
ES34	0.00	0.00
ES35	0.00	0.00
ES36	691.62	0.00
FF31	0.00	0.00
EF	24878.40	0.00
ES	60643.89	0.00

APPENDIX-(B)
APPROXIMATE YIELD MODEL FOR MAXIMUM ENERGY

RELIABILITY 90% FOR HYDROPOWER

OBJECTIVE FUNCTION

MAX
EF1+EF2+EF3+EF4+EF5+EF6+EF7+EF8+EF9+EF10+EF11+EF12+EF13+EF14+EF15+EF16+EF17+EF18+EF19+EF20+EF21+EF22+EF23+EF24+EF25+EF26+EF27+EF28+EF29+EF30+EF31+EF32+EF33+EF34+EF35+EF36

SUBJECT TO
OVER YEAR STORAGE

OS1-OS0+OYFP+OYSP+SP1=3240
OS2-OS1+OYFP+OYSP+SP2=4554
OS3-OS2+OYFP+OYSP+SP3=2965
OS4-OS3+OYFP+OYSP+SP4=4238
OS5-OS4+OYFP+OYSP+SP5=3708
OS6-OS5+OYFP+OYSP+SP6=2793
OS7-OS6+OYFP+OYSP+SP7=3116
OS8-OS7+OYFP+OYSP+SP8=3768
OS9-OS8+OYFP+SP9=1577 *****Failure Year**
OS10-OS9+OYFP+OYSP+SP10=3858
OS11-OS10+OYFP+OYSP+SP11=3742
OS12-OS11+OYFP+OYSP+SP12=4312
OS13-OS12+OYFP+OYSP+SP13=4789
OS14-OS13+OYFP+OYSP+SP14=3141
OS15-OS14+OYFP+OYSP+SP15=4274
OS16-OS15+OYFP+OYSP+SP16=7415
OS17-OS16+OYFP+OYSP+SP17=2424
OS18-OS17+OYFP+OYSP+SP18=2764
OS19-OS18+OYFP+OYSP+SP19=3758
OS20-OS19+OYFP+OYSP+SP20=3678
OS21-OS20+OYFP+OYSP+SP21=3047
OS22-OS21+OYFP+SP22=1793 *****Failure Year**
OS23-OS22+OYFP+OYSP+SP23=2086
OS24-OS23+OYFP+OYSP+SP24=3162
OS25-OS24+OYFP+OYSP+SP25=5672
OS26-OS25+OYFP+OYSP+SP26=3833
OS27-OS26+OYFP+OYSP+SP27=3620
OS28-OS27+OYFP+OYSP+SP28=2402
OS29-OS28+OYFP+OYSP+SP29=4907
OS30-OS29+OYFP+OYSP+SP30=2866
OS31-OS30+OYFP+OYSP+SP31=1998
OS32-OS31+OYFP+OYSP+SP32=2387
OS33-OS32+OYFP+SP33=1126 *****Failure Year**
OS0-OS33+OYFP+OYSP+SP34=2088
OS0-OS34=0

OVER YEAR STORAGE

OS0-OY<=0
OS1-OY<=0
OS2-OY<=0
OS3-OY<=0
OS4-OY<=0
OS5-OY<=0
OS6-OY<=0
OS7-OY<=0
OS8-OY<=0
OS9-OY<=0
OS10-OY<=0
OS11-OY<=0
OS12-OY<=0
OS13-OY<=0
OS14-OY<=0
OS15-OY<=0
OS16-OY<=0
OS17-OY<=0
OS18-OY<=0
OS19-OY<=0
OS20-OY<=0
OS21-OY<=0
OS22-OY<=0
OS23-OY<=0
OS24-OY<=0
OS25-OY<=0
OS26-OY<=0
OS27-OY<=0
OS28-OY<=0
OS29-OY<=0
OS30-OY<=0
OS31-OY<=0
OS32-OY<=0
OS33-OY<=0

WITHIN YEAR STORAGE

WS0-WS1-OYFP1-OYSP1+0.0067 OYFP+0.0067OYSP=0
WS1+0.0019OYFP+0.001OYSP-OYFP2-OYSP2-WS2=0
WS2+0.0084OYFP+0.0084OYSP-OYFP3-OYSP3-WS3=0
WS3+0.083OYFP+0.083OYSP-OYFP4-OYSP4-WS4=0
WS4+0.07OYFP+0.07OYSP-OYFP5-OYSP5-WS5=0
WS5+0.08OYFP+.08OYSP-OYFP6-OYSP6-WS6=0
WS6+0.035OYFP+0.035OYSP-OYFP7-OYSP7-WS7=0
WS7+0.033OYFP+0.033OYSP-OYFP8-OYSP8-WS8=0
WS8+0.085OYFP+0.085OYSP-OYFP9-OYSP9-WS9=0
WS9+0.19OYFP+0.19OYSP)-OYFP10-OYSP10-WS10=0
WS10+0.056OYFP+0.065OYSP-OYFP11-OYSP11-WS11=0

WS11+0.05OYFP+0.05OYSP-OYFP12-OYSP12-WS12=0
WS12+0.04OYFP+0.04OYSP-OYFP13-OYSP13-WS13=0
WS13+0.037OYFP+0.037OYSP-OYFP14-OYSP14-WS14=0
WS14+0.026OYFP+0.026OYSP-OYFP15-OYSP15-WS15=0
WS15+0.024OYFP+0.024OYSP-OYFP16-OYSP16-WS16=0
WS16+0.032OYFP+0.032OYSP-OYFP17-OYSP17-WS17=0
WS17+0.027OYFP+0.027OYSP-OYFP18-OYSP18-WS18=0
WS18+0.11OYFP+0.11OYSP-OYFP19-OYSP19-WS19=0
WS19+0.01OYFP+0.01OYSP-OYFP20-OYSP20-WS20=0
WS20+0.008OYFP+0.008OYSP-OYFP21-OYSP21-WS21=0
WS21+0.007OYFP+0.007OYSP-OYFP22-OYSP22-WS22=0
WS22+0.006OYFP+0.006OYSP-OYFP23-OYSP23-WS23=0
WS23+0.006OYFP+0.006OYSP-OYFP24-OYSP24-WS24=0
WS24+0.005OYFP+0.005OYSP-OYFP25-OYSP25-WS25=0
WS25+0.005OYFP+0.005OYSP-OYFP26-OYSP26-WS26=0
WS26+0.006OYFP+0.006OYSP-OYFP27-OYSP27-WS27=0
WS27+0.005OYFP+0.005OYSP-OYFP28-OYSP28-WS28=0
WS28+0.005OYFP+0.005OYSP-OYFP29-OYSP29-WS29=0
WS29+0.003OYFP+0.003OYSP-OYFP30-OYSP30-WS30=0
WS30+0.0027OYFP+0.0027OYSP-OYFP31-OYSP31-WS31=0
WS31+0.003OYFP+0.003OYSP-OYFP32-OYSP32-WS32=0
WS32+0.005OYFP+0.005OYSP-OYFP33-OYSP33-WS33=0
WS33+0.0036OYFP+0.0036OYSP-OYFP34-OYSP34-WS34=0
WS34+0.004OYFP+0.004OYSP-OYFP35-OYSP35-WS35=0
WS35+0.0036OYFP+0.0036OYSP-OYFP36-OYSP36-WS36=0
WS36-WS0=0

TOTAL PONDAGE CAPACITY

OY+WS0<=26.15
OY+WS1<=26.15
OY+WS2<=26.15
OY+WS3<=26.15
OY+WS4<=26.15
OY+WS5<=26.15
OY+WS6<=26.15
OY+WS7<=26.15
OY+WS8<=26.15
OY+WS9<=26.15
OY+WS10<=26.15
OY+WS11<=26.15
OY+WS12<=26.15
OY+WS13<=26.15
OY+WS14<=26.15
OY+WS15<=26.15
OY+WS16<=26.15
OY+WS17<=26.15
OY+WS18<=26.15
OY+WS19<=26.15

OY+WS20<=26.15
OY+WS21<=26.15
OY+WS22<=26.15
OY+WS23<=26.15
OY+WS24<=26.15
OY+WS25<=26.15
OY+WS26<=26.15
OY+WS27<=26.15
OY+WS28<=26.15
OY+WS29<=26.15
OY+WS30<=26.15
OY+WS31<=26.15
OY+WS32<=26.15
OY+WS33<=26.15
OY+WS34<=26.15
OY+WS35<=26.15

FIRM ENERGY GENERATION

EF1-143.45OYFP1=0
EF2-141.65OYFP2=0
EF3-141.65OYFP3=0
EF4-145.63OYFP4=0
EF5-147.17OYFP5=0
EF6-148.2OYFP6=0
EF7-146.86OYFP7=0
EF8-142.26OYFP8=0
EF9-146.7OYFP9=0
EF10-148.08OYFP10=0
EF11-148.08OYFP11=0
EF12-148.08OYFP12=0
EF13-148.08OYFP13=0
EF14-147.47OYFP14=0
EF15-148.23OYFP15=0
EF16-145.3OYFP16=0
EF17-141.65OYFP17=0
EF18-141.95OYFP18=0
EF19-148.08OYFP19=0
EF20-148.08OYFP20=0
EF21-148.23OYFP21=0
EF22-148.08OYFP22=0
EF23-148.08OYFP23=0
EF24-148.25OYFP24=0
EF25-147.78OYFP25=0
EF26-147.47OYFP26=0
EF27-147.23OYFP27=0
EF28-147.47OYFP28=0
EF29-147.47OYFP29=0
EF30-147.31OYFP30=0
EF31-146.86OYFP31=0

EF32-146.25OYFP32=0
EF33-145.95OYFP33=0
EF34-145.33OYFP34=0
EF35-144.4OYFP35=0
EF36-143.93OYFP36=0

SECONDARY ENERGY GENERATION

ES1-143.45OYSP1=0
ES2-141.65OYSP2=0
ES3-141.65OYSP3=0
ES4-145.63OYSP4=0
ES5-147.17OYSP5=0
ES6-148.2OYSP6=0
ES7-146.86OYSP7=0
ES8-142.26OYSP8=0
ES9-146.7OYSP9=0
ES10-148.08OYSP10=0
ES11-148.08OYSP11=0
ES12-148.08OYSP12=0
ES13-148.08OYSP13=0
ES14-147.47OYSP14=0
ES15-148.23OYSP15=0
ES16-145.3OYSP16=0
ES17-141.65OYSP17=0
ES18-141.95OYSP18=0
ES19-148.08OYSP19=0
ES20-148.08OYSP20=0
ES21-148.23OYSP21=0
ES22-148.08OYSP22=0
ES23-148.08OYSP23=0
ES24-148.25OYSP24=0
ES25-147.78OYSP25=0
ES26-147.47OYSP26=0
ES27-147.23OYSP27=0
ES28-147.47OYSP28=0
ES29-147.47OYSP29=0
ES30-147.31OYSP30=0
ES31-146.86OYSP31=0
ES32-146.25OYSP32=0
ES33-145.95OYSP33=0
ES34-145.33OYSP34=0
ES35-144.4OYSP35=0
ES36-143.93OYFP36=0

PLANT CAPACITY LIMITATION

EF1+ES1<=5040
EF2+ES2<=5040
EF3+ES3<=5040
EF4+ES4<=5040

EF5+ES5<=5040
EF6+ES6<=5544
EF7+ES7<=5040
EF8+ES8<=5040
EF9+ES9<=5544
EF10+ES10<=5040
EF11+ES11<=5040
EF12+ES12<=5040
EF13+ES13<=5040
EF14+ES14<=5040
EF15+ES15<=5544
EF16+ES16<=5040
EF17+ES17<=5040
EF18+ES18<=5040
EF19+ES19<=5040
EF20+ES20<=5040
EF21+ES21<=5544
EF22+ES22<=5040
EF23+ES23<=5040
EF24+ES24<=5544
EF25+ES25<=5040
EF26+ES26<=5040
EF27+ES27<=4032
EF28+ES28<=5040
EF29+ES29<=5040
EF30+ES30<=5544
FF31+ES31<=5040
EF32+ES32<=5040
EF33+ES33<=5040
EF34+ES34<=5040
EF35+ES35<=5040
EF36+ES36<=5544

FIRM ENERGY TARGET

EF1-0.0278EF=0
EF2-0.0278EF=0
EF3-0.0278EF=0
EF4-0.0278EF=0
EF5-0.0278EF=0
EF6-0.0278EF=0
EF7-0.0278EF=0
EF8-0.0278EF=0
EF9-0.0278EF=0
EF10-0.0278EF=0
EF11-0.0278EF=0
EF12-0.0278EF=0
EF13-0.0278EF=0
EF14-0.0278EF=0
EF15-0.0278EF=0

EF16-0.0278EF=0
EF17-0.0278EF=0
EF18-0.0278EF=0
EF19-0.0278EF=0
EF20-0.0278EF=0
EF21-0.0278EF=0
EF22-0.0278EF=0
EF23-0.0278EF=0
EF24-0.0278EF=0
EF25-0.0278EF=0
EF26-0.0278EF=0
EF27-0.0278EF=0
EF27-0.0278EF=0
EF29-0.0278EF=0
EF30-0.0278EF=0
EF31-0.0278EF=0
EF32-0.0278EF=0
EF32-0.0278EF=0
EF33-0.0278EF=0
EF34-0.0278EF=0
EF35-0.0278EF=0
EF36-0.0278EF=0
EF>=24878.4

ANNUAL SURPLUS ENERGY
ES1+ES2+ES3+ES4+ES5+ES6+ES7+ES8+ES9+ES10+ES11+ES12+ES13+ES14+ES15+ES16+ES17+ES18+ES19+ES20+ES21+ES22+ES23+ES24+ES25+ES26+ES27+ES28+ES29+ES30+ES31+ES32+ES33+ES34+ES35+ES36-ES=0

LP OPTIMUM FOUND AT STEP 108

OBJECTIVE FUNCTION VALUE
22018.75
TABLE 14.1

VARIABLE	VALUE	REDUCED COST
EF1	629.11	0.00
EF2	629.11	0.00
EF3	629.11	0.00
EF4	629.11	0.00
EF5	629.11	0.00
EF6	629.11	0.00
EF7	629.11	0.00
EF8	629.11	0.00
EF9	629.11	0.00
EF10	629.11	0.00
EF11	629.11	0.00
EF12	629.11	0.00
EF13	629.11	0.00
EF14	629.11	0.00
EF15	629.11	0.00
EF16	629.11	0.00
EF17	629.11	0.00
EF18	629.11	0.00
EF19	629.11	0.00
EF20	629.11	0.00
EF21	629.11	0.00
EF22	629.11	0.00
EF23	629.11	0.00
EF24	629.11	0.00
EF25	629.11	0.00
EF26	629.11	0.00
EF27	629.11	0.00
EF28	0.00	1.17
EF29	629.11	0.00
EF30	629.11	0.00
EF31	629.11	0.00
EF32	629.11	0.00
EF33	629.11	0.00
EF34	629.11	0.00
EF35	629.11	0.00
EF36	629.11	0.00
OS1	0.00	0.00

OS0	0.00	0.00
OYFP	270.89	0.00
OYSP	276.25	0.00
SP1	2692.86	0.00
OS2	0.00	0.00
SP2	4006.86	0.00
OS3	0.00	0.00
SP3	2417.86	0.00
OS4	0.00	0.00
SP4	3690.86	0.00
OS5	0.00	0.00
SP5	3160.86	0.00
OS6	0.00	0.00
SP6	2245.86	0.00
OS7	0.00	0.00
SP7	2568.86	0.00
OS8	0.00	0.00
SP8	3220.86	0.00
OS9	0.00	0.00
SP9	1306.11	0.00
OS10	0.00	0.00
SP10	3310.86	0.00
OS11	0.00	0.00
SP11	3194.86	0.00
OS12	0.00	0.00
SP12	3764.86	0.00
OS13	0.00	0.00
SP13	4241.86	0.00
OS14	0.00	0.00
SP14	2593.86	0.00
OS15	0.00	0.00
SP15	3726.86	0.00
OS16	0.00	0.00
SP16	6867.86	0.00
OS17	0.00	0.00
SP17	1876.86	0.00
OS18	0.00	0.00
SP18	2216.86	0.00
OS19	0.00	0.00
SP19	3210.86	0.00
OS20	0.00	0.00
SP20	3130.86	0.00
OS21	0.00	0.00
SP21	2499.86	0.00

OS22	0.00	0.00
SP22	1522.11	0.00
OS23	0.00	0.00
SP23	1538.86	0.00
OS24	0.00	0.00
SP24	2614.86	0.00
OS25	0.00	0.00
SP25	5124.86	0.00
OS26	0.00	0.00
SP26	3285.86	0.00
OS27	0.00	0.00
SP27	3072.86	0.00
OS28	0.00	0.00
SP28	1854.86	0.00
OS29	0.00	0.00
SP29	4359.86	0.00
OS30	0.00	0.00
SP30	2318.86	0.00
OS31	0.00	0.00
SP31	1450.86	0.00
OS32	0.00	0.00
SP32	1839.86	0.00
OS33	0.00	0.00
SP33	855.11	0.00
SP34	1540.86	0.00
OS34	0.00	0.00
OY	0.00	545.75
WS0	4.37	0.00
WS1	3.65	0.00
OYFP1	4.39	0.00
OYSP1	0.00	0.00
OYFP2	4.44	0.00
OYSP2	0.00	0.00
WS2	0.00	319.80
OYFP3	4.44	0.00
OYSP3	0.00	0.00
WS3	0.15	0.00
OYFP4	4.32	0.00
OYSP4	30.29	0.00
WS4	10.96	0.00
OYFP5	4.27	0.00
OYSP5	29.97	0.00
WS5	15.01	0.00
OYFP6	4.24	0.00

OYSP6	28.39	0.00
WS6	26.15	0.00
OYFP7	4.28	0.00
OYSP7	23.64	0.00
WS7	17.37	0.00
OYFP8	4.42	0.00
OYSP8	31.01	0.00
WS8	0.00	1.51
OYFP9	4.29	0.00
OYSP9	33.50	0.00
WS9	8.72	0.00
OYSP)	0.00	0.29
OYFP10	4.25	0.00
OYSP10	29.79	0.00
WS10	26.15	0.00
OYFP11	4.25	0.00
OYSP11	29.79	0.00
WS11	25.24	0.00
OYFP12	4.25	0.00
OYSP12	29.79	0.00
WS12	18.56	0.00
OYFP13	4.25	0.00
OYSP13	14.90	0.00
WS13	21.30	0.00
OYFP14	4.27	0.00
OYSP14	29.91	0.00
WS14	7.37	0.00
OYFP15	4.24	0.00
OYSP15	0.00	0.00
WS15	17.35	0.00
OYFP16	4.33	0.00
OYSP16	0.00	0.00
WS16	26.15	0.00
OYFP17	4.44	0.00
OYSP17	18.48	0.00
WS17	20.73	0.00
OYFP18	4.43	0.00
OYSP18	31.07	0.00
WS18	0.00	224.43
OYFP19	4.25	0.00
OYSP19	29.79	0.00
WS19	26.15	0.00
OYFP20	4.25	0.00
OYSP20	1.22	0.00

WS20	26.15	0.00
OYFP21	4.24	0.00
OYSP21	0.13	0.00
WS21	26.15	0.00
OYFP22	4.25	0.00
OYSP22	0.00	0.00
WS22	25.73	0.00
OYFP23	4.25	0.00
OYSP23	0.00	0.00
WS23	24.77	0.00
OYFP24	4.24	0.00
OYSP24	0.00	0.00
WS24	23.81	0.00
OYFP25	4.26	0.00
OYSP25	0.00	0.00
WS25	22.28	0.00
OYFP26	4.27	0.00
OYSP26	0.00	0.00
WS26	20.75	0.00
OYFP27	4.27	0.00
OYSP27	0.00	0.00
WS27	19.76	0.00
OYFP28	0.00	0.00
OYSP28	0.00	0.00
WS28	22.50	0.00
OYFP29	4.27	0.00
OYSP29	0.00	0.00
WS29	20.97	0.00
OYFP30	4.27	0.00
OYSP30	0.00	0.00
WS30	18.34	0.00
OYFP31	4.28	0.00
OYSP31	0.00	0.00
WS31	15.53	0.00
OYFP32	4.30	0.00
OYSP32	0.00	0.00
WS32	12.87	0.00
OYFP33	4.31	0.00
OYSP33	0.00	0.00
WS33	11.30	0.00
OYFP34	4.33	0.00
OYSP34	0.00	0.00
WS34	8.94	0.00
OYFP35	4.36	0.00

OYSP35	0.00	0.00
WS35	6.77	0.00
OYFP36	4.37	0.00
OYSP36	0.00	319.80
WS36	4.37	0.00
ES1	0.00	2.23
ES2	0.00	2.26
ES3	0.00	0.00
ES4	4410.89	0.00
ES5	4410.89	0.00
ES6	4207.33	0.00
ES7	3472.34	0.00
ES8	4410.89	0.00
ES9	4914.89	0.00
ES10	4410.89	0.00
ES11	4410.89	0.00
ES12	4410.89	0.00
ES13	2206.45	0.00
ES14	4410.89	0.00
ES15	0.00	0.00
ES16	0.00	0.00
ES17	2618.35	0.00
ES18	4410.89	0.00
ES19	4410.89	0.00
ES20	181.10	0.00
ES21	19.72	0.00
ES22	0.00	2.16
ES23	0.00	2.16
ES24	0.00	2.16
ES25	0.00	2.16
ES26	0.00	2.17
ES27	0.00	2.17
ES28	0.00	2.17
ES29	0.00	2.17
ES30	0.00	2.17
ES31	0.00	2.18
ES32	0.00	2.19
ES33	0.00	2.19
ES34	0.00	2.20
ES35	0.00	2.21
ES36	629.11	0.00
FF31	0.00	0.00
EF	22629.75	0.00
ES	57947.32	0.00