ALLOCATION OF WATER RESOURCES IN UPPER BRAHMANI RIVER BASIN

A DISSERTATION

Submitted in partial fulfilment of the
requirements for the award of the degree
of
MASTER OF ENGINEERING
in
HYDROLOGY

By

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CANDIDATE'S DECLARATION

I hereby certify that the work which is being presented in the dissertation entitled '' ALLOCATION OF WATER RESOURCES IN UPPER BRAHMANI RIVER BASIN'' in partial fulfilment of the requirement for the award of the Degree of Master of Engineering in Hydrology, submitted in the School of Hydrology of the University of Roorkee is an authentic record of my work carried out during a period from 15th October, 1981 to 30th April, 1982 under the supvervision of Dr. Ranvir Singh Reader, School of Hydrology and Dr. D. K. Srivastava, Reader, School of Hydrology.

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

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

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SYNOPSIS

The aim of the combined Reservoir operation to allocate available water resource to different project in Orissa namely, Pitamahal Irrigation Project, Kansbahal Irrigation Project, Mandira Dam Project, Barsuan Irrigation Project and Lodani Irrigation Project in upper Brahmani Basin keeping inview the upper and lower riparian rights of Bihar state and Rengali multipurpose project and to evolve optimal cropping pattern for Lodani Project. In the present study, the operation is carried out by using simulation technique to find out allocation of water to different reservoirs in upper Brahamani Basin in conjunction with linear programming model, which determines the different optimal cropping pattern .

For achieving above objectives Reservoir operation model was used in conjunction with linear programming model. The reservoir operation was run in six steps with different crop water requirements i.e. as per state government suggested cropping pattern and cropping pattern evolved from the linear programming model.

From the above study the cropping pattern evolved by step IV i.e. with Khariff crops areas, vegetables 726.7 hectares, medium paddy 15938.3 hectares and with Rabi crops areas, Pulses 4470 hectares, vegetables 2423 hectares appears to the best among six alternatives.

CHAPTER 1

INTRODUCTION

1.1 GENERAL:

Comprehensive river basis planning is commonly known as watershed management. The modern concepts of considering watershed as a unit of development has been recognised by the scientist, engineers, ecologist, social scientist, and politican. The main objectives of the watershed planning are as follows.

1. To assess the quantity of water available and judicious distribution of water resources for various purposes such as irrigation, power, industrial water supply, urban (domestic) water supply.
2. To increase the water yield during the lean period.
3. To provide dependable watersupply downdown stream.
4. To improve forest, range land and small cultivation on the upstream side of watershed where slope is not permissible for cultivation.
5. To maintain the water quality
6. To reduce the flood and erosion hazard.
7. To ehhance the recreational facilitie, pisciculture and preservation of wild life which in turn will provide return to large number of people of the watershed.

8. To maintain the ecological balance inside the waterhsed and to control/prevent the pollution inside the watershed due to development activities.

The waterr resources development planning of any river basin system consists of the above mentioned four objectives i.e. points 1,2,3 and 6.

In this study the water resources planning of upper Brahmani basin has been conisered and the other points of watershed management have not been discussed due to each data.

The use of systems analysis has generally now been accepted to provide an efficient way of answering various gquestions. The approach and appropirate technique will vary from problem to problem, and stage of decision making is likely to vary over a vast range. The system analysis is such a tool which can be applied suitably depending on the nature of problem, such as, there may be the case where the system has already been developed and issue is primarily of management of the system. On the other hand there may be the case where no developments have taken place and the first stage of decision in . the morpohology of developmental planning has to be on screaning the system configuration. There may be mixed stage of development.

The upper Brahmani Basin consists of reserve forest, area of Orissa and Bihar, mining area of Orissa and Bihar and cultivable land below Mandira Dam site in Orissa state plus major industrial belt of Orissa consisting of Rourkella steel plant, Rourkella fertiliser plant and its ancillary industries such as Kansbahal. Kalunga, Birmitrapur and Rajgangpur cement factory.

1.2 DIFFERENT ALTERNATIVE SYSTEM APPROACHES AND REVIEW OF EARLIER WORKS:

Several studies have been carried out for the operation of reservoir(s) system and optimisation of net returns. Linear programming, Non-linear programming, Dynamic programming, Simulation Techniques have been successfully applied.

(a) Linear programming- If the objective function and all of the constraint equations can be expressed in linear, algebric form (equalities and inequalities) with known co-efficients, constant coefficients then the problem is of linear programming type. The linear programming model for water resources system planning have been successfully applied Maass et al.,((14)

(b) Non linear programming- Non linear programming problem differ from the linear programming problem in that the objective function and/or, one or more constraints equations involve non-linear terms. General solution procedufes for this category of problems do not exists, howerver special purpose solution techniques are available that are applicable to limited subsets of the general problem. These include procedures such as quadratic programing, geometric programming and a variety of controlled search techniques. A description of many of the available special purpose solution algorithms can be found in the work Himmelblau

(c) Dynamic programming- This is a solution procedure that can be used in linear or nonlinear problems in which the decision variable possess an appropiate sequential character. Situation of this type arises when the problem can be represented as a sequence of stages where one or more decisions is required at each stage and where the decision at one stage directly affects only the next ajaicunt stage. There is no standard dynamic programming algorithm as in linear programming, the algorithm must be tailored to the individual problem. Where the sequential natufe of the system can be established and where the number of state and decision variables is not too large, the computational procedure the simple and practical. Dynamic programming was first develped by Bellman [18]. For reservoir operation dynamic programming models have been used by Buras and Hall and Dracup.

(d) Simulation Technique: In general terms simultation is a process which '' duplicates the essence of a system or activity without actually attaining reality itselt''. Planners turn to simulation because it is ofternthe only method for dealing effectively with large and complex problms that defy analytical solution or that cannot be reproduced by experiment on actual systems.

Many planners adopt simulation procedure for reservoir planning for its freedom to work and also of its great flexibility in design, construction and manipulation into a digital simulation model. In a well designed simulation programme the designer can considered non-linearity of system response, unique characteristics of economic decisions and stochastic nature of hydrological input. There have been several notable successes i in applying simulation models in reservoir planning and its operation. Though the simulation is not directly an optimising technique. In the well known Harard water programme (15) Simulation techniques were applied to economic analysis of water resources system design. Four multi-purpose reservoir in Narmada River, system were simulated using random samplings (16).

1.3 THE STUDY:

In the present context as the upper Brahmani Basin system is in the mixed stage of development that is three up streams reservoirs in Orissa state are either in the existing stage or under execution stages. The simulation technique has been applied for combined operations of four reservoirs up stream of Lodani proposed reservoir. The system is in the mixed stage of development and the reservoir capacity of the Lodani reservoir has been fixed to avoid submergance of sub-urban area of Rourkella steel plant. For the optimisation of the cropping pattern at Lodani reservoir the linear programming model has been used. Different monthly water requirements are calculated by linear programming model by imposing different constraints on crop areas. The different water requirrement as calculated, from the linear programming model have been used in the reservoir operation model for predicting the behaviour of Lodani reservoir.

1.4 Organisation of the Study

The study is presented in following sequences:-

Chapter 2. '' The Basin system and Problem'' gives brief description about the system i.e. '' Upper Brahmani Basin System'' and different input data excepting inflow data to operational model in tabular form and the problem being investigated.

Chapter 3. '' Extension of Run off data.'' Here the detail methods of generation of stream flow data for different resererir has been explained and statistical parameter of observed and generated data have been compared and given in tabular form.

Chapter 4. '' The theory of reservoir operation'' Here the establishment of the operating procedure. The operating procedure and theory based on which the operating polices are formulated has been discussed.

Chapter 5. '' The linear programming model'' The details for formulation of objective function, selection of decision variabls and calculation of different constraints has been discussed.

Chapter 6. '' Computation'' Reservoir capacity, monthly irrigation requarement, 40 years generated monthly inflows, monthly evaporation losses for six reservoirs are specified.

Computation of operation are being carried out by DEC 2050 computer of the Roorkee University, Regional computer Centre, Computer programme were developed for the study of the computions of monthly operational rule for five nos reservoirs combinely.

Chapter 7. deals with the analysis of result and conclusion etc.

CHAPTER 2

THE BASIN SYSTEMS AND PROBLEM

2.1 UPPER BRAHMANI RIVER BASIN:

It drains (6) a total area of 21445.2 sq.Km (8280 sq. miles) at Lodani site, see Fig.2.1. It consists of two main tributories i.e. Sankh and Koel. Sankh river is an arm of the Brahmani river. It rises in the Hills of Chotangpur in Palamau District of Bihar. After flowing 160 miles it joins Koel near Panposh and then it is known as Brahmani. The most of the catchment areas of both the above mentioned tributaries are hilly and thickly covered with jungle. There is some marginal cultivation in the above mentioned two sub-catchments. But the area beyond the confluence of the two rivers Sankh and Koel upto the Lodani dam site is relatively flat and good for cultivation. Presently there are five projects in the Orissa and two major projects in Bihar portion of the watershed, in the following stages, Table 2.1.

The two main tributaries Sankh and Koel are perenial and all other small tributaries mentioned in Table 2.1 are intermittent in nature.

2.2 EARLIER PROPOSALS

The master plan for river Brahmani was prepared by Dr.A.N.Khosla in the year 1963 for integrated development of river basins of Orissa. In its plan it has been envisaged for construction of a dam near Barkot for utilisation of 8843 sq. miles of catchment. Which will give mean regulated discharge of (13,400 cusecs) 381.22 cumecs of which (3775 cusecs) 107.40 cumecs will be used for providing irrigation for 4.28 laksh hectare and balance will be diverted to Tikarpara reservoir of Mahandi basin. But this proposal was dropped due to construction of Rengali multipurpose project and uncertainity in construction of Takarpara dam.

Mean while another proposal came up for construction of a Dam at Lodani on river Brahmani, Keeping in view the supplying water to the proposed Bonaigarh steel plant, in addition to supplying irrigation water in Bonaigarh sub-division plus power generation. The F.R.L. of the Dam was fixed at (623.20ft.) 190.00 meter. But from the reservoir survey it is sound that the Panposh sub-divisional head quarter and sub-urban area of of Rourkella steel plant will be submerged at full reservoir level 190.00 meter. Hence the proposal was dropped.

2.3 PROBLEM AND REMEDIES

The upper Brhamani basin lies in the Sundargarh District of Orissa, Which is mainly inhabited by tribals. Out of total area sown in thes district only 7.17 percentage is irrigated area. Where as the irrigated area in Orissa is 19.78 percentage out of net area sown (as per 1979-80 statistics). The Sundargarh Districts is one of the main source of minerals and an industraial district of Orissa. Due to the non-availability of irrigation the crop production is very less. More over no major irrigation projects exists in the districts. Bonigarh sub-division of Sundargarh District is a relatively plain area and there is no irrigation source for this area other than the Brahmani river.

In the present proposal a low hieght dam (F.R.L.172.5 meter) has been proposed on main river Brahmani and following alternate proposals have been studied through combined operational computer model of all reservoirs in Orissa, keeping inview the upper riparian rights of Bihar state and lower riparian rights of Rengali multipurpose project in Orissa state.

The objective is to provide Kharif and Rabi irrigation in Lodani ayacut and to generate power from regulated discharge of Koel-Karo project. The requirement of Lodani irrigation project has been taken from the feasibility report of state government and from the linear programming model for different alternative trials.

The above integrated planning of upper Brahmani Basin has been done keeping inview of the Rs.50,000 crores scheme formulated by the Ministry of irrigation, Government of India for transfer of surplus river water for deficit regions through inter connected link in the country, So that in future when the above scheme is implemented, upper Brahmani Basin projects may be ready to recieve additional allocation of water for increasing intensity of irrigation during Kharif and Rabi seasons.

2.4 BACKGROUND OF PRESENT PLANNING

Due to construction of Rengali multipurpose project and Samal barrage accross river Brahmani down stream and construction of four nos of medium and water supply projects in Orissa portion of upper Brahmani basin and construction of two hydroelectric projects in Bihar portion compelled integrated planning of the watershed to increase crop output and power generation to match with industrial and agricultural growth needed for the country.

2.5 INPUT PARAMETERS

2.5.1 CAPACITIES OF DIFFERENT PROJECTS

The gross storage capacity and Dead storage capacity of six nos of reservoirs in upper Brahmani Basin have been given in Table 2.2.

2.5.2 CROPPING PATTERN AND WATER REQUIREMENTS

The selection of cropping pattern and water requirements for different reservoirs are discussed below:

KANSBAHAL IRRIGATION PROJECT

This project (1) is under execution now, and the cropping pattern for this irrigation project has been supplied by state agriculture department after detailed soil survey. The proposed cropping pattern is given below in Table 2.3

Water requirement of different crops have been calculated based on the climatological data of Jharsugada station and monthly water requirement calculated are given in Table 2.4

MANDIRA DAM

This is an existing industrial water supply project (2) to Rourkella steel plant. It's present water requirement is 300 cusecs (8.4949738 cumec) and future requirement after expansion of steel plant upto 3.5 million ton capacity is 600 cusecs (16.989948 cumec).

PITAMAHAL IRRIGATION PROJECT

This is an existing project (3). The cropping pattern adopted in this report is actual cropping pattern being followed now and is given in Table 2.3. The water requirements are given in Tablo 2.4.

CHANDRINALLA IRRIGATION PROJECT

As this is a proposed project (4) and is in the early stage of investigation. The cropping pattern and monthly water requirement for this project have been taken from the feasibility report of Chandrinalla irrigation project. The proposed cropping pattern is given in the Table 2.3 and the water requirements in Table 2.4.

BARSUAN IRRIGATION PROJECT

This project is under execution now. The cropping pattern for this irrigation project has been supplied by State

Agriculture Department (5) after detailed soil survey. The proposed cropping pattern is given in Table 2.3. Water requirement of different crops have been calculated based on the climatological data of Jharsugada station and monthly water requirement calculated are given in Table 2.4.

LODANI MULTIPURPOSE PROJECT

This project is under investigation (6). The primary purpose of this project is to generate power from the available tail race discharge (average 72.75 cumec) from the Koel-Karo hydro-electricity project of Bihar and to irrigate Bonaigarh sub-division of Sundargarh district of Orissa which is a chronically draught affected area.

The crop pattern and water requirements given in the feasibility report have been taken into consideration along with different optimal cropping pattern evolved by the linear programming model in Table 2.3 and the water requirements in Table 2.4.

2.5.3 RESERVOIR EVAPORATION LOSSES

The reservoir evaporation losses of reservoir is given in Table 2.5.

2.6. SCOPE OF PRESENT STUDY:

Objective of the present problem is to study the available water resources of the upper Brahmani basin and its allocation to different reservoirs so that maximum irrigation potential can be achieved in the Lodani ayacut with power generation from the tailrace discharge of Koel-Karo hydro-electric project only. In the present planning care has been taken not to interfere with the upper riparian rights of Bihar state and the lower riparian rights of Rengali-Multipurpose and Irrigation projects down stream of Lodani dam site.

The first step is to assess the water resources of the basin from the available stream flows at different sites. Stochastical approach has been applied to obtain 40 years synthetic sequences of stream flows at different sites.

Different permutation and computation of demands at Lodani sites has been tried in the combined operational model study the different alternates. The details of the above aspects has been dealt in Chapter 3.

As regards other objective of watershed planning has been disscussed in general in the conclusion part of the report due to non-availability data of other different resources of watersheds.

In the study, efforts have been made to assess the quantity of water available at different site of reservoirs and its allocation to different reservoirs so that balance water from free catchment of Orissa portion and contributed flows from up streams reservoirs can be utilised at Lodani site for irrigation and power genration while allocating water for different reservoir care have been taken to consider the riperian rights of up streams and down streams areas.

For calculation of irrigation water requirements of Lodani irrigation project linear programming model has been used to decide different ... cropping pattern by changing different constraints.

Table 2.1 Various projects of Upper Brahmani River Basin

Sl.No.	Name of project	Sub-Basin	Name of Tributary	Catchment area in sq.km.	Present stage	Purpose
1.*	Mandira Dam	Sankh	Sankh	6129.53	Existing	Industrial water supply to R.S.P.
2.*	Kansbahal Irrigation project	Sankh	Badjorenalla	179.00	Under execution	Irrigation
3.*	Pitamahal Irrigation project	Sankh	Pitamahanalla	102.60	Existing	Irrigation
4.*	Chandrinalla Irrigation project	Sankh	Chandrinalla	153.00	Proposed	Irrigation
5.*	Barsuan Irrigation project	Koel	Barsuannalla	78.00	under execution	Irrigation
6.**	South Koel	Koel	South Koel	3890.00	-do-	Hydro-power
7.**	North Karo	Koel	North Karo	1523.00	-do-	-do-

* In Orissa

** In Bihar.

Table 2.2

Dead Storage capacity and Gross storage capacity of Different Reservoirs in Upper Brahmani Basin

(Hectaters- Meters)

Capacity/ Name of the projects	MANDIRA	KANSBAHAL	PITAMAHAL	CHANDRINALLA	BARSUAN	LODANI
Dead storage capacity	594.568	1169.50	345.68	400.00	236.00	5533.19
Gross storage capacity	32455.31	4041.50	2364.20	1738.00	2106.28	12067.95

Table 2.3

CROPPING PATTERN OF DIFFERENT PROJECTS

Sl.No.	Name of Crops	Area in Hectares KANSBAHAL	PITAHAHAL	CHANDRINALLA	BARSUAN	LODANI As per feasibility report
	KHARIF					
1	Ragi	345	-	-	-	-
2	Maize	-	-	-	55	-
3	Vegatable	126	-	-	224	-
4	H.Y.V.Paddy	-	1841 36	2800	-	13800
5	Early Paddy	315	789.15	-	1562	-
6	Medium Paddy	3392	-	-	656	-
7	Normal/Improved Paddy	437	-	-	290	-
8	Ground nuts	-	-	-	63	-
	RABI					
9	H.Y.V.Paddy	-	131.52	-	-	-
10	Patato	95	262.05	-	-	-
11	Vegetables	126	262.05	200	310	-
12	Must rd	157	-	-	155	-
13	Wheat	972	394.58	800	218	-
14	Ground nuts	35	131.52	-	310	-
15	Pulses	1045	-	800	310	1725
16	Arharr	-	-	-	194	-

Table 2.4

WATER REQUIREMENT OF DIFFERENT PROJECTS IN HECTATER METERS

Sl. No.	Month	MANDIRA* Present	MANDIRA* Future	KANSBAHAL**	PITAMAHAL**	CHANDRINALLA**	BARSUAN**	LODANI** As per Feasibility Report
1	NOV	2202.0	4404.00	677.35	352.97	137.16	424.28	0.00
2	DEC	2275.30	4550.60	707.60	368.73	219.44	501.90	0.00
3	JAN	2275.30	4550.60	580.56	302.53	192.04	505.60	0.00
4	FEB	2055.00	4110.00	430.81	224.49	109.72	23.95	0.00
5	MAR	2275.30	4550.60	0.00	0.00	55.00	0.00	0.00
6	APR	2202.00	4404.00	0.00	0.00	0.00	0.00	0.00
7	MAY	2275.30	4550.60	0.00	0.00	0.00	0.00	0.00
8	JUN	2202.0	4404.00	247.17	128.80	0.00	160.06	0.00
9	JUL	2275.30	4550.60	1261.81	657.53	561.16	700.43	2981.00
10	AUG	2275.30	4550.60	203.77	106.18	612.00	37.40	2687.00
11	SEP	2202.00	4404.00	760.81	396.47	900.00	438.96	4695.00
12	OCT	2275.30	4550.60	526.44	274.33	607.00	447.64	2793.00

* Industrial water requirement for Rourkella Steel plant
** Crops water requirement.

Table 2.5

Monthly Reservoir evaporation losses in meters

MONTH	NOVEMBER	DECEMBER	JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUN	JULY
LOSSES	0.081512	.07612	.08152	.10246	.15339	.19456	.23372	.18788	.1069

MONTH	AUGUST	SEPTEMBER	OCTOBER
LOSSES	.09608	.098	.10542

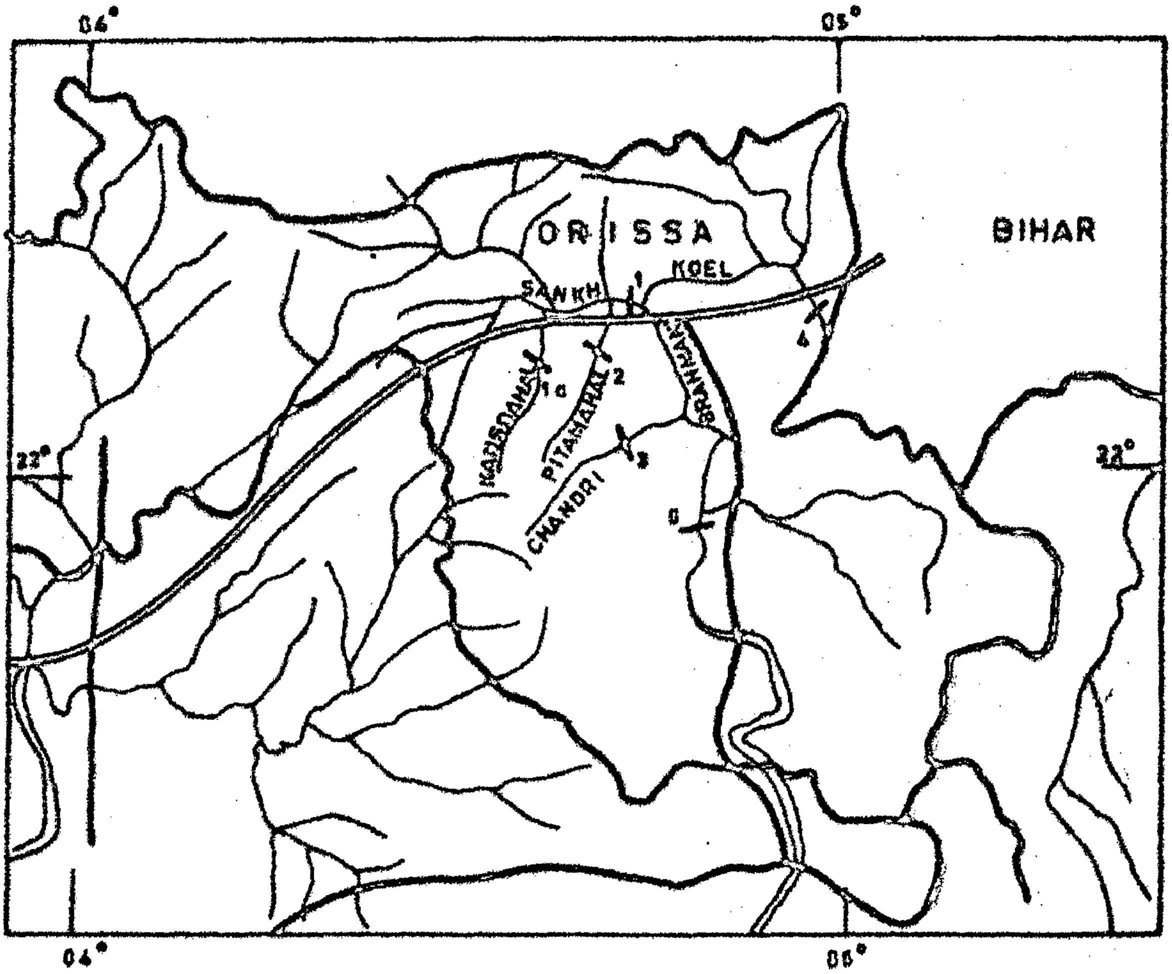

FIG. 2·1 INDEX MAP OF UPPER BRAHMANI RIVER BASIN

SCALE :— 1" = 15.78 M

SYMBOLS

RIVER

HIGH WAYS

STATE AND DISTT. BOUNDARY

CHAPTER 3

EXTENSION OF RUNOFF DATA

3.1 GENERAL.

For deciding the future operation policy and planning of different water resources projects in a watershed the stream flow data at different points of interst are very much essential. Generally the available historical stream flow data is not sufficinet for operation study of the system. Therefore, certain generated data series for a common period is required. Many stochastical method, such as Bivirate, Multivariate and Thomas Fiering Models are used for generation of synthetic sequence of stream flows. In this problem Thomas Fiering and Modified Thomas Fiering models are used for generation of stream flow sequences for Perinial and Intermittant streams respectively. In this case, Bivariate and Multivariate models could not be used due to the non-availability of historical stream flow data for common period to be used for these models.

3.2 CATCHMENT:

The total catchment intercepted by river Brahmani at Lodani site is (8280 sq.Miles) 21450 sq.km. It is a interstate river, the catchments lies in the state of Orissa, Bihar and M.P. There is only one existing major project in the catchment that is Mondira Dam project. Hence the free catchment at Lodani site at present is (5914 sq.mile) 15321.244 sq.km.

The catchment area of existing, under execution and proposed medium and major Irrigation and Water supply of up stream projects are given in Table 3.1

3.3 POLICY AND METHOD OF GENERATION OF SYNETHIC STREAM FLOW

The generation of stream flow data at different reservoir sites and at Lodani site are discussed below.

3.3.1 GENERATION OF FLOW SEQUENCE BY THOMAS FIERING MODEL APPROACH:

The most appropiate practical model is proposed by Thomas and Fiering Model particularly with respect to generating sequental stream flows. The Markovian concept is involved in the approach.

The algorithm for the Thomas and Fiering seasonal (monthly) model is as follows

$$Q_{i+1} = \bar{Q}_{j+1} + B_j(Q_i - \bar{Q}_j) + Z_i \, S_{j+1}(1 - r_j^2)^{1/2} \quad \ldots \quad (3.4b)$$

where

Q_{i+1}, Q_i are genrated flows during the ith month reckoned from the start of the synthesized series.

$\bar{Q}_{j+1}$, $\bar{Q}_j$ are observed mean flows during $(j+1)^{th}$ and jth months with in a repetative annual cycle of seasons.

$1 \leqslant j \leqslant 12$

B_j is the least square regression coefficient for estimating $(j+1)^{th}$ flow from the jth flow given by $B_j = r_j \frac{S_{j+1}}{S_j}$

Z_i is the normal random variate with zero mean and unit variance.

S_{j+1}, S_j are standard deviations of flow during the $(j+1)^{th}$ and jth months.

It shows that 36 parameters such as monthly means. Standard deviation, and Lag one serial co-relations are required to be used in the model to generate monthly flow at a site. These are obtained from analysis of monthly historical flows. The model is run in the following way-

Ist value i.e. (for january is calculated as follows)

$$Q_1 = \bar{Q}_{JAN} + Z_1 S_{JAN} (1 - r^2_{JAN/DEC})^{1/2}$$

and successively Q_2, Q_3, Q_4 ...... are computed where Z_1 is the only unknown and in each step it is calculated as a Pseudo-random normal variate.

$$Q_2 = \bar{Q}_{FEB} + B_{FEB/JAN}(Q_1 - \bar{Q}_{JAN}) + Z_2 S_{feB}(1 - r^2_{FEB/JAN})^{1/2}$$

$$Q_3 = \bar{Q}_{MAR} + B_{MAR/FEB}(Q_2 - \bar{Q}_{FEB}) + Z_3 S_{MAR}(1 - r^2_{MAR/FEB})^{1/2}$$

.

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$$Q_{12} = \bar{Q}_{DEC} + B_{DEC/JAN}(Q_{11} - \bar{Q}_{NOV}) + Z_{12} S_{DEC}(1 - r^2_{DEC/JAN})^{1/2}$$

The above model is restricted to normally distributed flows. More the number of years historical flow data more realistic will be genrated sequental stream flows data. The values of means and standard deviations of observed and generated series should not differ appreaciably

3.3.2 GENERATION OF FLOW SEQUENCE OF INTERMITTANT STREAM BY MODIFIED THOMAS FIERING MODEL APPROACH:

The most appropiate practical model in this case for generation of sequental stream flows is modified Thomas Fiering model.

The algorithm for the modified Thomas Fiering model is as follows:

In this case the flows are available only in the month of June, July, August, September and October.

$$q_{j+1} = \bar{q}_{j+1} + B_{j+1}(q_j - \bar{q}_j) + z_{j+1}\, S_{j+1}\sqrt{(1-r_{j+1})} \quad \text{.. (3.4a)}$$

q_{j+1} and q_j are generated flows during $(j+1)^{th}$ and jth month.

$\bar{q}_{j+1}$ and $\bar{q}_j$ means for the month of $(j+1)^{th}$ and jth months of observed series.

B_{j+1} is the least squares regression co-efficient for estimating $(j+1)^{th}$ flow from jth flow and given by $B_{j+1} = r_{j+1} \times \dfrac{S_{j+1}}{S_j}$

In this case as there is no flow during month of May. Therefore, B_1 (i.e. regression coefficient of June on May) is taken as zero.

Z_{j+1} is the normal random variate with zero mean and unit variance.

S_{j+1} and S_j are the standard deviations of flow during the $(j+1)^{th}$ and jth month.

r_{j+1} is the correlation coefficient between flows in the jth and $(j+1)^{th}$ months.

In this case as there is no flow during month of May. Therefore, r_1(i.e. correlation coefficient between June and May) is taken as zero.

It shows that 18 parameters such as monthly mean, standard deviations, regression coefficients and corelation coefficients are required to be used in this model to generate monthly flow at site.

The model is run in the following way:

$$q_1 = \bar{q}_1 + Z_1 \; S_1$$

As the value of B_1 and r_1 are zero.

$$q_2 = \bar{q}_2 + B_2 \; (q_1 - \bar{q}_1) + Z_2 \; S_2 \sqrt{(1-r_2)}$$

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.

.

$$q_5 = \bar{q}_5 + B_5(q_4 - \bar{q}_4) + Z_5 \; S_5 \sqrt{(1-r_5)}$$

Subscripts 1,2,3,4 and 5 stands for the months from June to October.

Then P_j value that is the fraction of years there is monthly inflow available. For example suppose out of 10 years data there is monthly flow available for September only for 9 years. Then $P_4 = 0.9$ then the P_j values are compared with the β_j (i.e. Rectangularly distributed random numbers). If $P_j < \beta_j$ then the flow for that month will be taken as zero.

Ref

3.3.3 GENERATION OF RANDOM NUMBERS:

In genrating the sequence of a given stream flows it is generally considered that the flows are the out come of random process. The results of the process change with time involving probability. The probability is that high flows tend to follow high flows similarly low flows tend, to follow Low flows. The sequence of past flows provides a clue to the probable future flows. Hence any model for genration of stream flows must include a random component in addition to a deterministic components, so as to reflect the sequence of future flows in the most possible way.

3.3.4 GENERATION OF RECTANGULARLY DISTRIBUTED RANDOM NUMBERS (0,1);

It is only possible to generate through computer the sequence of poeudo random numbers, carefully constructed to maintain the important properties of truely random numbers.

The sequential algorithm for genrating Rectangularly (0,1) distributed random number

$$r'_{i+1} = \langle 10^{p} c \quad r'_i \rangle \qquad \ldots (3.4\ c)$$

where $\langle a \rangle$ denotes fraction part of 'a', r'_{i+1} being the number at (i+1)th instant and r'_i at the ith instant. 'p' is the number of digits in the pseudo-random number.

'C' is constant multiplier, such that $0 < C < 1$. The choice of C is as follows.

$$C = 10^{-p}(200A \pm B)\ 10^{-p/2} \qquad \ldots (3.4d)$$

Where A is non-negative integer and B is one of the numbers from the sequence 3, 11, 13, 19, 21, 27, 37, 53, 59, 61, 67, 69, 71, 83 or 91. The starting value $r'_i = r'_o$ should be $10^{-p}R$, Where R is any integer not divided by 2 or 5 and such that $0 < R < 10^p$. For example, suppose we choose $p = 5$, then

$$10^{-p/2} = 10^{-5/2} = 0.00316$$

A possible choice for C is acquired by selecting A=2, B = 69 so that

$$C = 10^{-5}(400-69) = 10^{-5} \times 311 = 0.00316$$

Similarly for selection of r'_o

$$r'_o = 10^{-5} \times R = 10^{-5} \times 7 = 0.00007$$

Thus further values of r'_i can be calculated sequentially using

$$r'_{i+1} = \langle 10^5 \times 10^{-5} \times 331 \times r_i \rangle \qquad \ldots (3.4e)$$

3.3.5 GENERATION OF NORMALLY DISTRIBUTED RANDOM NUMBER

It is simple to generate normally distributed random number from a sequence of rectangular distributed random numbers (0,1). One method for transfering rectangularly distributed random numbers into normally distributed random number is based on the use of the rectangularly distributed values (X'_1, X'_2). For such transformation the following relations are based.

$$Y_1' = (-2 \operatorname{Log}_e X_1')^{1/2} \quad \operatorname{Cos}\ (2\pi\ X_2') \qquad \ldots (3.4f)$$

$$Y_2' = (-2 \operatorname{Log}_e X_1')^{1/2} \quad \operatorname{Sin}\ (2\pi\ X_2') \qquad \ldots (3.4g)$$

Where Y_1' and Y_2' are normally distributed random numbers sequences.

By taking two sequences four sequences can be generated by reversing X_1' and X_2'.

3.3.6 DIFFERENT SERIES GENERATION ON T.F.MODEL:

For avoding generation of negative stream flows value, square root transformation or Log transformation series have been used. In the square-root transformed series all the observed data are converted to square root and for the new series the statistical relations like mean, S.D. ,coefficinet of correlation established. Finally after generation of the series, the various values are squared and thus avoiding negative flow in final value. In Log transformed series all the observed data are convertd to Log values and the statistical parameters are established for new series. The generation of series is completed with these statistical parameters. Finally antilogs are taken of the generated figures to give the series with all positive figure.

3.4 DETAIL PROCEDURE:

3.4.1 PITAMAHAL IRRIGATION PROJECT:

As the stream is of intermittant in nature i.e., there is flow in the river in the months from June to October and the rest of the year flow is nill. Modified Thomas Fiering model is used for generation of data with the help of available histori-cal stream flow records from 1975 to 1979 given in Table 3.2(a). The genration of data by modified Thomas Fiering model is dis-cussed in section 3.3.2.

3.4.2 KANSBAHAL IRRIGATION PROJECT:

This is also an intermittant stream Modified Thomas Fiering model has been used for generation of stream flow data by using available flow data from year 1965-1980, refer Table 3.3(a).

3.4.3 BARSUAN IRRIGATION PROJECT:

As this is also an intermittant stream modified Thomas Fiering model has been used for generation of stream flow data by using available stream flow data from 1961 to 1979, refer Table 3.4(a).

3.4.4 CHANDRI NALLA IRRIGATION PROJECT:

No stream flow data at Chandrinall project site is available. Hence inflow data of chandrinalla project has been calculated on catchment proportion basis using Pitamahal Irri-gation project generated data, as both the catchments are adjacent catchments.

3.4.5 MANDIRA DAM PROJECT:

This is a perinial stream. Therefore, for stream flow generation by Thomas Fiering Model, using square roots and Log series have been used. Stream flow data from 1965 to 1975 given in Table 3.5(a), were used. The mean and the standard deviations of the observed and the generated series have been compared from which Log series results appears to be more near to the observed series. The genrated data has been multiplied by 0.9707971 to give generated flow at Mandira site due to free catchment (i.e., excluding Kansbahal Irrigation project catchment)to be used in reservoir operation model. The method of generation of data by Thomas Fiering model has been discussed in section 3.3.1

3.4.6 LODANI MULTIPURPOSE PROJECT:

The present inflow data available at Lodani site is due to the contribution of free catchment of (5914 sq.mile) 151321.2 sq.km plus the regulated discharge from Mandira dam (i.e. relese for Rourkella steel plant + spill). Therefore, for generation of stream flow for free catchment of 151321.2sq.km the outflow from Mandira dam has been deducted and the balance has been used for genration of stream flow at Lodani site by Thomas Fiering Model, using natural, square root and Log series The mean and standard deviation of observed and generated data has been compared from which the data generate by square root series appears to be more realistic. The above generated data has been multiplied by 0.6248625 to give inflow at Lodani site due to free catchment excluding all up stream catchment of Orissa project and entire catchment of Bihar state to avoid up stream riparian rights.

The comparison of means and standard deviations of observed and generated series at different sites by different methods have been enclosed in table 3.2(b),3.3(b),3.4(b) and 3.5(b).

Table 3.1

Statement showing catchment area of different projects and its stages

RES. No.	Name of Project	Catchment area in sq. km	Remarks
1.	Pitamahal Irrigattion Project	103.60	Existing
2.	Kansbahal Irrigation Project	179.00	Under execution
3.	Mandira Dam Project	6129.53	Existing
4.	Barsuan Irrigation Project	78.00	Under execution
5.	Chandrinall Irrigation Project	153.00	Proposed
6.	Koel-Kara Project (Bihar State)	5413.00	Under execution

Table 3.2 (a)

STREAM FLOW DATA AT PITAMAHAL SITE IN HECT. METERS

YEAR	JUNE	JULY	AUG	SEPT	OCT
1975	0.0	610.00	1579.17	932.32	147.13
1976	0.0	466.65	1343.83	1137.04	53.68
1977	246.68	1060.91	1461.56	855.22	149.816
1978	130.54	427.00	1705.56	669.78	145.18
1979	116.88	241.56	603.90	121.02	0.0

Table 3.2 (b)

PITAMAHAL IRRIGATION PROJECT MEAN AND STANDARD DIVIATION OF ORIGINAL SERIES

MONTH	JUNE	JULY	AUG	SEPT	OCT
MEAN	164.7	561.224	1338.80	743.076	123.95
STANDARD DEVIATION	71.32	308.71	432.28	385.98	46.88

Contd...

Table 3.2 (b) contd...

MEAN AND STANDARD DEVIATION

OF GENERATED SERIES

MONTH	JUNE	JULY	AUG	SEPT	OCT
MEAN	159.86	561.24	1345.07	783.02	121.85
STANDARD DEVIATION	88.73	312.82	478.69	398.41	51.61

PERCENTAGE OF ERRORS

MONTH	JUNE	JULY	AUG	SEPT	OCT
MEAN	2.9	(-)0.003	(-)0.468	(-)5.37	1.69
STANDARD DEVIATION	(-)24.41	(-)1.331	(-)10.736	(-)3.22	(-)10.26

Table 3.3(a)

STREAM FLOW DATA AT KANSBAHAL SITE IN HECTARE METERS

YEAR	JUNE	JULY	AUG	SEPT	OCT
1965	191.18	818.81	295.02	1040.05	138.05
1966	1243.46	3111.09	4095.58	518.09	1191.94
1967	686.84	2273.44	3432.20	2612.48	0.0
1968	688.60	1436.40	3272.24	392.65	554.65
1969	266.85	1315.07	1578.65	1190.94	135.48
1970	1359.85	2938.99	3206.54	1807.76	655.50
1971	934.25	3080.14	4935.45	1307.98	530.85
1972	417.46	1664.41	3848.47	1142.74	593.50
1973	0.0	0.0	4875.25	3401.12	1349.79
1974	0.0	521.19	5031.19	786.60	359.48
1975	0.0	247.50	4110.48	1595.32	227.15
1976	0.0	225.60	3589.53	3651.22	4.92
1977	649.69	2728.95	3854.81	1671.88	409.05
1978	64.01	787.59	2250.67	96.74	606.76
1979	19.87	93.66	600.04	27.48	76.90
1980	1112.95	1954.96	609.30	606.97	51.68

Table 3.3 (b)

MEAN AND STANDARD DEVIATION OF ORIGINAL SERIES

MONTH	JUNE	JULY	AUG	SEPT	OCT
MEAN	636.25	1546.52	3099.08	1365.62	459.04
STANDARD DEVIATION	457.62	1089.29	1573.53	1077.95	397.80

MEAN AND STANDARD DEVIATION OF GENERATED SERIES

MONTH	JUNE	JULY	AUG	SEPT	OCT
MEAN	765.19	1518.79	3167.63	1661.61	545.68
STANDARD DEVIATION	468.33	842.67	1702.61	969.10	311.06

PERCENTAGE OF ERRORS

MONTH	JUNE	JULY	AUG	SEPT	OCT
MEAN	(-)20.26	1.793	(-)2.21	(-)21.67	(-)18.87
STANDARD DEVIATION	(-) 2.34	22.640	(-)8.20	10.09	21.80

Table 3.4 (a)

STREAM FLOW AT BARSUAN SITE IN HECTEARE METERS

FROM 1961 to 1979

YEAR	JUNE	JULY	AUG	SEPT	OCT
1961	622.60	1489.43	1263.82	2030.84	959.785
1962	177.764	723.987	992.073	767.64	250.916
1963	160.687	712.703	2112.385	698.361	522.849
1964	536.108	1529.208	1739.523	991.645	95.204
1965	90.598	412.020	261.732	545.675	122.572
1966	833.028	1842.158	1203.492	292.433	430.419
1967	178.529	829.717	1352.295	1319.745	23.494
1968	314.627	714.061	1987.140	194.536	389.311
1969	260.817	1138.782	2074.446	802.169	31.169
1970	384.992	1265.129	1345.269	1568.517	235.146
1971	602.912	1642.082	3859.179	1048.638	472.767
1972	72.692	550.307	1830.920	215.435	148.327
1973	0.00	409.858	2236.796	1568.517	736.133
1974	0.00	451.189	2434.135	396.045	375.576
1975	47.236	343.037	1408.250	527.346	206.359
1976	0.00	259.555	660.319	850.060	16.326
1977	179.855	831.916	1869.548	654.488	105.442
1978	167.438	644.072	1058.917	582.643	128.731
1979	0.00	0.00	120.644	319.211	0.00

Table 3.4 (b)

BARSUAN IRRIGATION PROJECT

MEAN AND STANDARD DEVIATION OF ORIGINAL SERIES

MONTH	JUNE	JULY	AUG	SEPT	OCT
MEAN	308.659	877.178	1568.994	809.155	291.691
STANDARD DEVIATION	236.652	488.744	847.477	507.985	259.262

MEAND AND STANDARD DEVIATION OF GENERATED SERIES

MONTH	JUNE	JULY	AUG	SEPT	OCT
MEAN	381.596	864.095	1643.004	864.742	358.696
STANDARD DEVIATION	236.334	432.411	889.882	485.256	192.701

PERCENTAGE OF ERRORS

MONTH	JUNE	JULY	AUG	SEPT	OCT
MEAN	(-)23.488	1.491	(-)4.717	(-)6.869	(-)22.969
STANDARD DEVIATION	0.134	11.526	(-)5.003	4.474	25.673

Table 3.5(a)

STEAM FLOW DATA AT MANDIRA DAM SITE IN HECTARE METER

YEAR	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
1968	4044.90	1925.86	1672.70	1192.70	1068.17	15598.33	108722.94	248943.96	38085.692	13704.634	3724.1627	2256.8952
1969	1184.138	745.468	672.805	337.626	352.305	5336.449	94015.414	243611.67	76425.828	20216.708	5564.7143	1921.2882
1970	1700.853	927.248	1258.758	386.557	239.76	6311.89	114832.51	77609.721	182264.51	27140.00	3999.16	1758.35
1971	1043.70	1169.95	401.23	968.10	535.79	132784.67	280296.21	383917.58	341842.51	29603.94	7439.76	2984.56
1972	1799.69	1718.22	340.80	185.94	181.05	5447.03	82245.23	146065.28	79344.83	19917.74	6999.87	4168.70
1973	1100.22	919.17	623.87	182.27	113.76	1737.30	37225.48	123627.67	231871.58	99464.40	35151.77	7413.83
1974	2731.10	982.05	245.63	201.84	836.48	2745.53	70716.52	206170.15	35722.55	21460.05	9302.82	2141.96
1975	481.97	819.35	306.06	162.69	151.69	7999.53	156982.92	199286.74	102405.66	47907.92	9165.57	2947.86

Table 3.5(b)

MANDIRA DAM PROJECT

MEAN AND STANDARD DEVIATION OF ORIGINAL SERIES

MONTH	JAN	FEB	MAR	APRIL	MAY	JUNE	JULY	AUG	SEPT	OCT
MEAN	1760.82	1150.09	690.23	452.21	434.87	22245.0	118129.7	203779.1	135995.4	34926.93
STANDARD DEVIATION	1139.06	435.776	513.259	400.38	351.55	44863.06	74228.99	93855.28	107725.3	28020.32

MONTH	NOV	DEC
MEAN	10168.48	3196.677
STANDARD DEVIATION	10310.82	1873.312

MEAN AND STANDARD DEVIATION OF GENERATED SERIES

MONTH	JAN	FEB	MARCH	APRIL	MAY	JUNE	JULY
MEAN	1895.944	1189.817	863.212	451.904	417.725	24656.68	132440.8
Standard Deviation	1423.56	332.72	618.56	388.84	341.20	46524.03	112008.7

MONTH	AUG	SEPT	OCT	NOV	DEC
MEAN	202118.5	135131.5	35275.70	9972.65	3025.82
Standard Deviation	101682.4	120849.2	22422.42	7407.39	1213.69

Table 3.5(b) contd..

PERCENTAGE OF ERRORS

MONTH	JAN	FEB	MARCH	APRIL	MAY	JUNE
MEAN	(-)7.674	(-)3.38	(-)25.06	0-0683	3.944	(-)10.841
STANDARD DEVIATION	(-)24.977	(-)23.64	(-)20.51	2.88	2.945	(-)5.702
MONTH	JULY	AUG	SEPT	OCT	NOV	DEC
MEAN	(-)12.45	0.8149	0.6352	(-)0.9986	1.926	5.3448
STANDARD DEVIATION	(-)50.89	(-)8.34	(-)12.1827	19.978	28.16	35.2112

Table 3.6(a)

INFLOW AT LODANI STE EXLUDING MANDIRA'S R.GULATED FLOW IN HECT.METERS

YEAR	JANUARY			FEBRUARY			MARCH		
	Inflow at Banki site	Outflow from Mandira	Balance	Inflow at Banki site	outflow from Mandira	Balance	Inflow at Banki site	Outflow from Mandira	Balance
1972	7215.07	1704.76	5510.31	13011.40	4914.66	8096.14	5376.08	2129.49	3246.59
1973	4972.18	1542.56	3429.62	4805.50	890.55	3914.95	3245.41	959.05	2286.36
1974	9688.57	2047.77	7640.80	5965.74	149.60	4116.14	4817.10	2047.77	2769.33
1975	434[illegible].90	576.41	3968.49	5032.17	617.02	4415.15	3188.60	1585.13	1603.50

YEAR	APRIL			MAY			JUNE		
	Inflow at Banki Site	Outflow from Mandira	Balance	Inflow at Banki site	outflow form Mandira	Balance	Inflow at Banki site	outflow from Mandira	Balance
1972	3320.10	1202.48	2117.62	1847.56	1213.49	634.07	6371.136	1114.41	5256.726
1973	1839.54	1050.06	789.48	2713.75	1401.63	1312.12	11467.27	1027.55	10439.72
1974	5086.54	2386.62	2699.92	7662.90	2366.31	5296.59	5659.37	2217.08	3442.29
1975	2218.75	1854.25	364.50	2068.26	1935.23	133.03	19005.06	9623.08	9381.98

Contd...

Contd.. Table 3.6(a)

YEAR	JULY Inflow at Banki site	JULY Outflow from Mandira	JULY Balance	AUGUST Inflow at Banki site	AUGUST Outflow from Mandira	AUGUST Balance	SEPTEMBER Inflow at Banki site	SEPTEMBER Outflow from Mandira	SEPTEMBER Balance
1972	198159.01	83514.75	114644.26	279699.41	139856.72	139842.71	61950.75	60594.10	101356.65
1973	80128.09	35003.26	45124.83	357016.25	123242.82	183774.13	526271.38	198635.22	327636.16
1974	154410.56	86291.85	68118.71	369723.38	171482.50	198240.88	81947.63	32358.28	49589.35
1975	314355.23	15055.9	163804.33	393509.72	220313.26	173196.46	167040.40	98577.04	68463.36

YEAR	October Inflow at Banki site	October Outflow from Mandira	October Balance	November Inflow at Banki site	November Outflow from Mandira	November Balance	December Inflow at Banki site	December Outflow from Mandira	December Balance
1972	37066.91	17938.95	19127.96	32616.43	5835.54	26780.89	38288.26	2277.26	36011.00
1973	268336.03	88750.16	179585.87	80486.78	33434.52	47052.25	18442.66	5168.61	13274.05
1974	50760.23	15853.01	34907.22	12267.42	7687.11	4580.31	4734.34	857.27	3877.07
1975	91421.56	39082.91	52338.65	20972.13	7701.05	13271.08	7793.07	1896.08	5896.99

Table 3.6(b)

LODANI IRRIGATION PROJECT

MEAN AND STANDARD DEVIATION OF ORIGINAL SERIES

MONTH	JAN	FEB	MARCH	APRIL	MAY	JUNE
MEAN	5087.30	5135.74	2476.44	1492.88	1843.95	7130.179
STANDARD DEVIATION	1931.01	1984.66	701.68	1097.76	2351.92	3323.33

MONTH	JULY	AUG	SEPT	OCT	NOV	DEC
MEAN	97923.03	173763.5	136761.4	71489.92	22921.13	14764.78
STANDARD DEVIATION	52586.10	24834.77	129035.2	73329.33	18499.71	14728.70

MEAN AND STANDARD DEVIATION OF GENERATED SERIES

MONTH	JAN	FEB	MARCH	APRIL	MAY	JUNE
MEAN	5178.40	5500.63	2738.386	1834.24	2234.84	7148.85
STANDARD DEVIATION	2166.12	1751.11	788.9	1408.33	2361.37	3512.64

MONTH	JULY	AUG	SEPT	OCT	NOV	DEC
MEAN	98588.35	172013.2	134488.5	74292.67	23288.5	3512.64
STANDARD DEVIATION	50364.43	24465.55	114971.5	64574.56	18344.88	9989.49

Contd....

Table 3.6(b) Contd..

PERCENTAGE OF ERRORS

MONTH	JAN	FEB	MARCH	APRIL	MAY	JUNE
MEAN	(-)1.79	(-)7.10	(-)10.57	(-)22.86	(-)21.20	(-)0.26
STANDARD DEVIATION	(-)12.17	11.76	(-)12.43	(-)29.29	(-)5.495	(-)5.695

MONTH	JULY	AUG	SEPT	OCT	NOV	DEC
MEAN	(-)0.68	1.007	1.66	(-)3.92	(-)1.60	12.44
STANDARD DEVIATION	4.22	1.486	10.90	11.94	0.836	32.17

CHAPTER 4

THEORY OF RESERVOIR OPERATION

4.1 ESTABLISHMENT OF THE OPERATING PROCEDURE

The operating procedure for upper Brahmani Basin is established based upon the following system characteristics (a) Hydrologic properties of the basin shows the storage reservoir generally filled during June to October and starts depelating from November to the following May. (b) Regulation in the reservoir inflows depends upon the up stream reservoir contribution(s). In the case of Mandira dam, it is effected by Kansbahal Irrigation Project and Lodani Multipurpose project, has contributions from Mandira Dam project, Pitamahal Irrigation project, chandrinalla Irrigation project, Barsuan Irrigation Project.

With the above mentioned characteristics, the operating procedure is based on the following reasonings.

As for as practicable, the requirements of all the up stream projects above Lodani reservoir are met individually if water is available.

Out of the two main purposes of the Lodani Project i.e. power and irrigation, priority is given to power. That is the average regulated discharge coming from Bihar portion (i.e. Koel Karo Hydroelectric projects) has been fully used for power generation with a constant head of 30.48 M. The contribution of Bihar up stream projects has not been considered for assessing yield at Lodani site. Therefore release from for power from Lodani reservoir has not been incorporated in the operation of the reservoir.

4.2 OPERATION PROCEDURE:

1. The operation starts from the month of November i.e. the Ist year of study. The initial reservoir is considered upto the full capacity at the starting.

2. The release from the reservoir at any time is made from the total water available, i.e. the sum of initial reservoir content in the period plus the inflow during the period plus contribution from the up stream reservoirs if any (which consists regeneration from irrigation release(s), release for industrial requirement plus the unutilised spill), Minus the evaporation from the reservoir.

3. The continuity equation given below holds good in each period.

   A. For reservoirs (Kansbahal, Pitamahal, Chardrinalla, and Barsuan).

$$S_{i,t+1} = S_{i,t} + f_{i,t} - a_{i,t}$$

Where

$S_{i,t}$ like reservoir content in the begining of time 't' for ith reservoir.

$S_{i,t+1}$ like reservoir content at the end of time 't' for ith reservoir

4.3 SYSTEM CONFIGURATION:

The system configuration of different reservoir projects shown in the figure 4.1. The inflow to the Mandira reservoir is dependant on the release from Kansbahal reservoir i.e. both the reservoir are in series. The inflow to Pitamahal, Chandrinalla and Barsuan reservoirs are independent of all other reservoirs, in the Upper Brahamani Basin, i.e. the reservoirs Pitamahal, Mandira, Chandirnall, Barsuan are parallel to each other. The inflow to the Lodani reservoir is dependant on the release from the above mentioned four reservoirs of Orissa plus Koel Karo hydroelectric project in Bihar state.

4.4 The reservoir capacity vrs. area and capacity vrs. elevation curves were calculated by using computer programme (i.e. fitting of polynomials).

The reservoir area vrs. capacity and elevation vrs. capacity equation are given below.

X - denotes reservoir capacity, in hectare meter

Y_1 - denotes reservoir area, in hectares

Y_2 - denotes reservoir elevation, in meters

KANSBAHAL IRRIGATION PROJECT

$$Y_1 = 1.8925385 + 0.2504289X - 0.00005048048 * X^2 + 0.0000000479681 * X^3$$

Degree of Ploynomial = 3.

Correlation indix = 0.99867735

$f_{i,t}$ total unregulated inflow into the reservoir in time 't' for ith reservoir.

$a_{i,t}$ release from the reservoir in time 't' for ith reservoir.

B. For reservoirs (Mandira, Lodani)

I = ? for Man
= ? for Lod

$$S_{i,t+1} = S_{i,t} + f_{i,t} + \left(\sum_{i=1}^{I} K'_{i,t} * R'_{i,t} + SP'_{i,t} + P'_{i,t} \right) - a_{i,t}$$

$R'_{i,t}$ Irrigation or industrial releases from up stream project(s) in time 't' for ith reservoir

$K'_{i,t}$ Co-efficiant for ith up stream reservoir for return flow (or regeneration) In time 't'

$SP'_{ii,t}$ spill from ith up stream reservoir in time 't'

$P'_{i,t}$ Release for power for ith up stream reservoir in time 't' reservoir content

4. The live reservoir content of ith reservoir $S_{i,t}$ at any time cannot be more than reservoir capacity (Y_i)

i.e., $S_{i,t} \leq Y_i$

5. The live reservoir content of ith reservoir $S_{i,t}$ at any time should be more than the dead storage capacity (Di)

i.e. $S_{i,t} \geq D_i$

4.3 SYSTEM CONFIGURATION:

The system configuration of different reservoir projects shown in the figure 4.1. The inflow to the Mandira reservoir is dependant on the release from Kansbahal reservoir i.e. both the reservoir are in series. The inflow to Pitamahal, Chandrinalla and Barsuan reservoirs are independent of all other reservoirs, in the Upper Brahamani Basin, i.e. the reservoirs Pitamahal, Mandira, Chandirnall, Barsuan are parallel to each other. The inflow to the Lodani reservoir is dependant on the release from the above mentioned four reservoirs of Orissa plus Koel Karo hydroelectric project in Bihar state.

4.4 The reservoir capacity vrs. area and capacity vrs. elevation curves were calculated by using computer programme (i.e. fitting of polynomials).

The reservoir area vrs. capacity and elevation vrs. capacity equation are given below.

X - denotes reservoir capacity, in hectare meter

Y_1 - denotes reservoir area, in hectares

Y_2 - denotes reservoir elevation, in meters

KANSBAHAL IRRIGATION PROJECT

$$Y_1 = 1.8925385 + 0.2504289X - 0.00005048048 * X^2 + 0.00000000479681 * X^3$$

Degree of Ploynomial = 3.

Correlation indix = 0.99867735

$$Y_2 = 208.4803 + 0.01618397 * X - 0.000005630776*X^2 + 0.0000000007053274 * X^3$$

Degree of Pllynomial = 3

Correlation index = 0.97918765

MANDIRA DAM PROJECT

$$Y_1 = 92.48315 + 0.2467659 * X - 0.000005788723 * X^2 + 0.000000000007108314* X^3$$

Degree of Polynomial = 3

Correlation index = 0.99980571

$$Y_2 = 191.3259 + 0.002699852 * X - 0.0000001977241 *X^2 + .0000000000621192 * X^3 - 0.0000000000000000006536723 * X^4$$

Degree of Polynomial = 4

Correlation index = 0.99104903

PITAMAHAL IRRIGATION PROJECT

$$Y_1 = 8.582886 + 0.3444347*X - 0.0003360733*X^2 + 0.0000002126289*X^3 - 0.00000000004482414 * X^4$$

Degree of polynomial = 4

Correlation index = 0.99767618

$$Y_2 = 226.8461 + 0.03093433*X - 0.00003276765*X^2 + 0.00000001687658*X^3 - 0.00000000003072653*X^4$$

Degree of Polynomial = 4

Correlation index = 0.99537021

CHANDRINALL IRRIGATION PROJECT

$$Y_1 = 6.782104 + 0.3762341*X - 0.0001757862*X^2 + 0.0000000458 2489*X^3$$

Degree of Polynomial = 3

Correlation index = 0.99965855

$Y_2 = 197.3731 + 0.02685928*X - 0.00002117502*X^2 + 0.000000006265964*X^3$

Degree of Polynomial = 3

Correlation index = 0.98159695

BARSUAN IRRIGATION PROJECT

$Y_1 = 3.519531 + 0.2321491*X - 0.0001816377*X^2 + 0.0000001107655*X^3 - 0.00000000002448264*X^4$

Degree of Polynomial = 4

Correlation index = 0.99973750

$Y_2 = 231.158 + 0.01857424*X - 0.00001106714*X^2 + 0.000000002622755*X^3$

Degree of Polynomial = 3

Correlation index = 0.99649668

LODANI MULTIPURPOSE PROJECT

$Y_1 = 31.71973 + 0.5295906*X - 0.00008834898*X^2 + 0.000000001140666*X^3 - 0.000000000000004727191*X^4$

Degree of Polynomial = 4

Correlation index = 0.99962422

$Y_2 = 147.1501 + 0.01477748*X - 0.000004258527*X^2 + 0.0000000005171117*X^3 - 0.0000000000002245101*X^4 + 0.0000000000000000001345724*X^5$

4.5 A simple flow chart of reservoir operation model has been given in Fig.4.2. The details of variables names are given in Appendix -

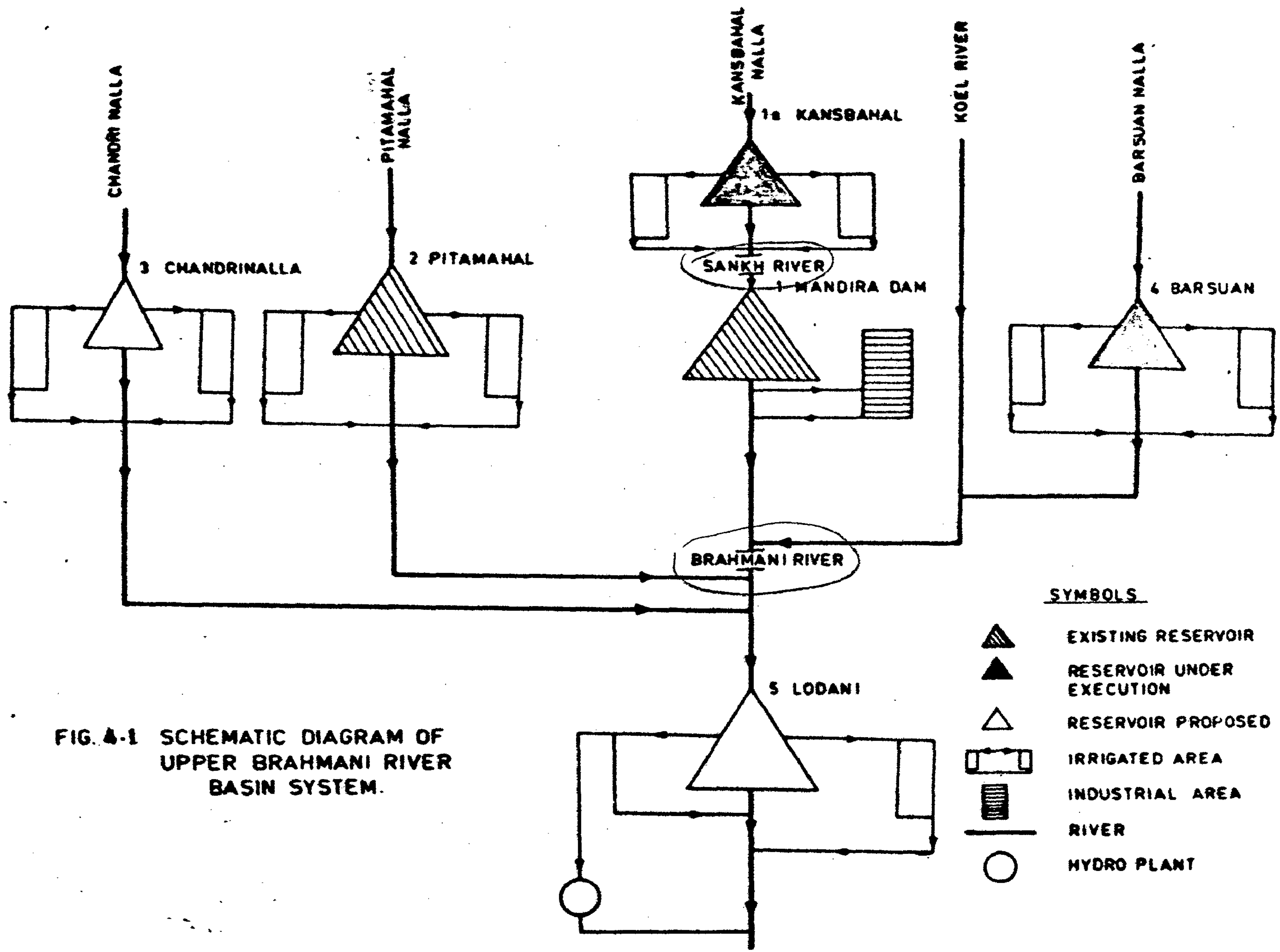

FIG. 4.1 SCHEMATIC DIAGRAM OF UPPER BRAHMANI RIVER BASIN SYSTEM.

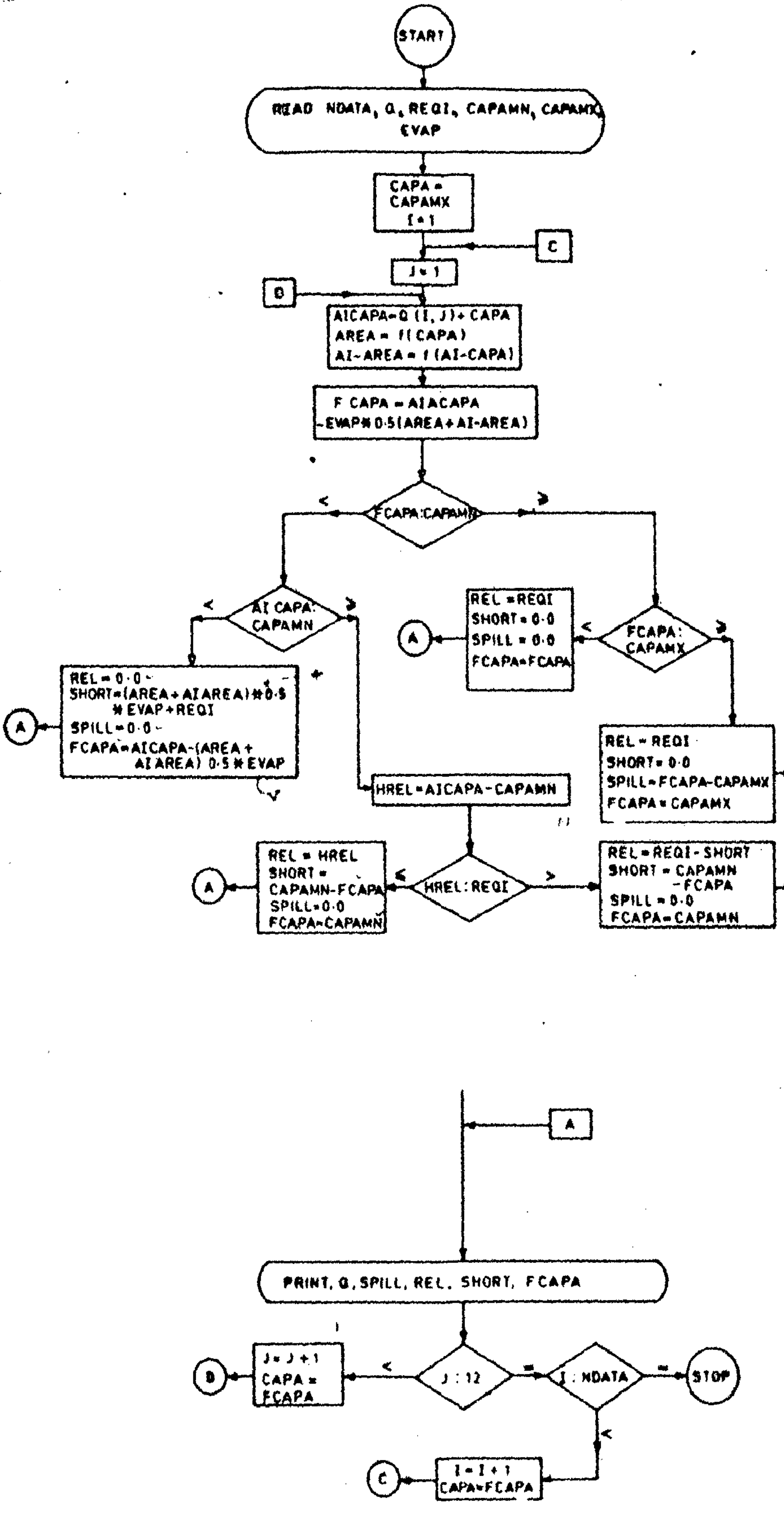

FIG. 4.2 RESERVOIR OPERATION MODEL FLOW CHART

CHAPTER 5

DETERMINATION OF OPTIMAL CROPPING PATTERN

5.1 INTRODUCTION:

Crop planning has gained significance due to growing social needs and increasing demand for food grain while availabe resources have remained limited and scarce and land to man ratio reduces due to increase in population. Moreover optimal cropping pattern and its water requirement in important for efficient reservoir operation.

It is desirable that the objectives of optimal allocation of irrigated area to different feasible alternate crops utilising both the surface and ground waters conjuctively along with land resources are full filled and benifit from the system are maximised. The ayacut map of Lodani Project is enclosed as Figure 5.1

5.2 FACTORS AFFECTING CROP PLANNING:

(a) Selection of crops:- The crops to be grown and the extent of area available are determined by considering climatic conditions of the region, soil characteristics, marketability, water requirement, net return. Therefore, the cropping pattern is to take all the above factors into consideration and is to be adjusted according to availability of utilisable water resources overtime.

(b) Cost of input and price of output of crop-

Relative prices of various crops vary from time to time. Hence any assessment of optimum cropping pattern based on current or projected price is bound to change over time. In this model by changing the co-efficient of decision variables in objective function the above fluctuation in price over time can be taken into consideration to determine the optimal cropping pattern at any time. Generally it is assumed that the relative price structure remain unchanged for a plan period therefore the results of the model holds good, for a plan period.

(c) Water requirement of crops-

A number of methods are developed for computing water requirement on the basis of climatological parameters. Timing of irrigation is fixed as per the physological growth stage of plant, moisture depelation etc. Both the timing of irrigation differ from different crops. Therefore irrigation scheduling should meet crop water requirement. The crop water requirement for different months have been given in table 5.1(a)

(d) Cropping intensity-

Cropping intersity depends upon the area that is to be irrigated in a particular crop season and the peak water requirements that are to be met from the available water resources.

(e) Availability of water-

An acceptable level of supply of irrigation based on probability study, should meet the water needs of various crops for each growing season. Accordingly cropping inte: ity is selected.

5.3 DATA ITS SOURCES AND METHOD OF COMPUTATION:

The study is based on the following data:

5.3.1. Net Benifit from different crops

The net value of produce of different crops has been calculated on the basic of latest report of Kansbahal Irrigation Project and have been given in Table 5.1

5.3.2 Cropping intensity:

In this study the crops selected for Lodani project are same as that of Kansbahal Irrigation project since both ayacut lie in the same agro-climatic zone.

In order to protect the reparian rights of Rengali Multipurpose project only 40 percent of the Rabi area is proposed to be brought under irrigation and crops considered are vegetable and pulses. The pulses have been selected as its water requirement is compar atively less than many of the Rabi crops and vegetable have been selected to cater the growing demand of Rourkella steel city. Maximum and minimum area constrainsts for various crops were i posed to keep the area of various crops with in reasonable limit. These limits are imposed with the help of past data on individual crops areas and future prospects of crop area development due to irrigation development. The prosposed maximum and minimum crop area for differents crops is given in Table 5.2, and calculation of these limits for different crops have been appended give in Table 5.3.

5.3.3 MONTHLY UTILISABLE SURFACE WATER

In this case monthly availability of surface water at Lodani site for irrigation has been considered based in the upper and lower riparian rights of Bihar state and Rengali Multipurpose project respectively. For assessment of monthly utilisable surface water to different alternatives were considered.

CASE I The monthly 75 percent dependable yield (inflow) of 40 years generated flow from free catchment of Lodani project has been taken into consideration. Here free catchment has been considered excluding the catchment areas of four upstream project of Orissa namely Mandira Dam, Pitamahal Irrigation Project, Chandrinalla Irrigation Project, Barsuan Irrigation Project and the entire catchment of Bihar portion. Free catchment considered has an area of 9573.64 sq.km .The calculation of 75 percent dependable years yield and 75 percent dependable hypothetical year monthly yield are given in Table 5.4 and 5.5.

CASE II The 40 years yield at Lodani site has been computed by adding contributed flows from 4 nos of up stream reservoir to the yield due to free catchment. From the above yield monthly 75 percent dependable yield has been computed. The monthly utilisable water in the Lodani ayacut has been on the following percentage basis.

January to May 10 percent- Non-monsoon months

June 20 percent - Ist month of monsoon season

July, September and October-40 percent monsoon months

explain

August - 50 percent monsoon month

November and December - 10 percent Non-monsoon months.

The above percentage distribution has been assumed on the following basis. 10 percent withdrawl during non-monsoon period less that least amount of flow during lean period will be tapped. and 50 percent during month of August has been assumed because the flow during. August is maximum and during other monsoon months flow has been distributed as per the percentage of quantity of flow. The total quantity of utilisable water at Lodani site should not exceed 50 percent flood storage provided at Rengali Multipurpose project. The above mentioned calculation has been given in Table 5.6 and 5.7.

5.3.4 <u>THE Utilisable Quantities of Ground Water:</u> The total annual quantities of utilisable ground water the Bonaigar sub-Division (area 254 sq.km) is 3936 H.M. as per norms of Agricultural Refinancing Development Corporation. The available ground water potential for Lodani ayacut (areas 172.5 sq.km) is 2673 hectare meters.

Monthly average available ground water = 222.75 H.M.

The entire year has been divided in three seasons (i) Rainy season from July to October.(ii) Winter season-from November to February (iii) Summer season- from March to June.

During rainy season draw down permissible in the region is 6 meters. Hence ground water potential that can be exploited during rainy season is 334.125 hectare meter/month.

During winter season draw down permissible is 4 meter. Ground water potential that can be exploited is 222.75 hectare-meter/month.

During summer season draw down permissible is 2 meter. Ground water potential that can be exploited is 111.375 hectate meter/month.

5.3.5 Cost of Surface water:

The cost of surface water was classified into two heads namely (i) operation and maintainace cost which is Rs.50/- per hectate of C.C.A.(as per the Central Water Commission Norms) and (ii) capital cost.of The calculation of annual capital cost of surface water has been calculated and appended as Table 5.8

3.6 Cost of Ground Water:

Cost of ground pumping in this region from dugwell with electric pump set varies from Rs.1300/- to Rs.1500 per hect-meter. This also includes the operation and maintainance cost.

5.4 METHODS FOR OPTIMAL CROP PLANNING:

5.4.1 General

Modern technology and advance-ment in computer enable us to use powerful mathematical models for obtaining solutions in optimal allocation of land and water resources. The linear programming model adopted in this case over Non-linear programming model and dynamic programming model assuming linearity of the different equation and more over it is easy to frame the computer programming.

5.4.2 PROGRAMME PLANNING

5.4.2.1 Objective Function:

The objective function was to maximise the total returns of crops. The objective function includes four cateogries of variables namely (a) crop-process, (b) surface water development activities (c) Grounds water development activities (d) Input activity

5.4.2.2 Constraints: Following constraints were included in the model

(I) Rabi and Kharif land constraint: Total area of Rabi crops in the command area of Lodani ayacut cannot exceed 40 percent of C.C.A. at any time. Similarly total area of Kharif crops in the command area of Lodani ayacut cannot exceed 91.383 percent of C.C.A. at any time.

(II) Crop area flexibility constraint: Maximum and minimum area constraints for various crop, were impase keep the area of vario various crops with in reasonable limits. These limits were imposed with help of past data on individual crop area and further prospects of crop area development due to irrigation development

(III) Monthly surface water utilization bounds: The monthly surface water bound for different months has been taken as monthly 75 percent dependable years yields as explained in chapter 5.3.3.

(IV) Monthly ground water utilisation bounds: Maximum ground water utilisation bounds were also imposed for any particular month as explained in chapter 5.3.4

(V) Monthly of water requirement of different crops bounds:

The water requirement of various crops in each month cannot exceed the total surface and ground water resources available in that month.

5.4.3 THE MODEL:

Following linear programming models were used for the crop planning in Lodani ayacut.

$$\text{Maximize} \quad Z = \left[\sum_{j=1}^{j} X_j C_j - \sum_{i=1}^{I} (C_s X_i + C_g Gi) - C_M C_A \right]$$

In the above expression,

X_j = Irrigated area of jth crop in hectares

C_j = Net return from jth crop in Rupee/hecatre

C_s = Annual cost of surface water development in Rupees/ Hectare Meter.

C_g = Annual cost of ground water development Cost cluding operation and maintaince cost in Rupees/Hect-meter.

C_M = Annual maintainace cost for surface water irrigation in Rupees/Hect of C.C.A.

C_A = C.C.A in hectare

Constraints:

1. Crop area flexibility constraints

$X_1 \leqslant$ maximum area of Ragi

$X_2 \leqslant$ maximum area of vegetable (khariff)

$X_3 \leqslant$ maximum area of early paddy

$X_4 \leqslant$ maximum area of Medium paddy

$X_5 \leqslant$ maximum area of Normal paddy

$X_6 \leq$ maximum area of pulses

$X_7 \leq$ maximum area of vegetable (Rabi)

$X_1 \geq$ minimum area of Ragi

$X_2 \geq$ minimum area of Vegetable (Kharif)

$X_3 \geq$ minimum area of early paddy

$X_4 \geq$ minimum area of Medium paddy

$X_5 \geq$ minimum area of Normal paddy

$X_6 \geq$ minimum area of pulses

$X_7 \geq$ minimum area of vegetable (Rabi)

2. Kharif crop area constraint

$$\sum_{j=1}^{5} X_j \leq k(\text{area of available Kharif land})$$

3. Rabi crop area constraint

$$\sum_{j=6}^{7} X_j \leq R\ (\text{area of available Rabi land})$$

4. Surface water (monthly) bounds utilisable

$S_t \leq$ available utilisable surface water at level of water resources, in tth month.

5. Utilisable ground water (monthly) bounds

$Gt \leq$ permissible ground water resources, in tth month.

6. Water requirement of crop (monthly) bound.

$$\sum_{j=1}^{7} X_j\, W_{jt} \leq \text{Available developed surface and ground water, in tth month.}$$

Z denotes total crop net return (Rupees)
t denotes period(month)

X_j denotes the area of jth crop

K total available Khariff area

R total available Rabi area

S_t denotes quantity of utilisable developed surface water in the tth time period.

G_t denotes quantity of developed utilisable ground water in the tth time period.

W_{jt} denoted water requirement of jth crop in the tth time period.

5.4.4 SOLUTION OF L.P.FOR OPTIMAL CROPPING PATTERN:

The development of mathematical model in general and linear programming model in particular enable us to arrive at optimal solution for the problem. In the present case the problem was solved with the help of linear programming technique.

Various alternatives were considered by changing different constraints as discussed earlier in this chapter. The computations were carried out in conjunction with the operation model as discussed in chapter 6.

Cost Return Statement of Lodani Multipurpose Project

cost of cultivation- and return over variable cost/hect in Ruppes

Sl. No.	Name of Crop	Bullock labour	Human labour	Seeds	Manuses	Fert-liser	Pesticdes	Irr. charges	Other charges	Total
1.	Ragi	180	600	52	125	400	125	18.52	15	1515.52
2	Vegetabls	200	1000	70	100	600	200	29.60	20	2219.60
3.	Early paddy	400	700	90	100	484	100	19.76	5	1898.76
4.	Medium paddy	400	700	90	100	648	100	19.76	5	2062.76
5.	Paddy(improved)	400	600	90	100	242	50	18.76	5	1506.76
6.	Pulse	144	280	100	50	285	60	3.74	17	939.74
7.	Vegetabls	200	1140	140	100	721	250	29.64	20	2600.64

* Source Barsuan Irrigation project report.

Table 5.1 Contd....

Sl. No.	Interest at the rate 12 % for 3 months	Total	Yield in quintals	Rate / quintal	Recipt from grain	Recipt from bi-product.	Total recept Rs.	Net recipt Rs.
1.	45.47	1561	35	80	2800	-	2800	1239
2.	66.59	2286	100	70	7000	-	7000	4714*
3.	56.76	1956	30	114	3420	250	3670	1714*
4.	61.88	2124	35	114	3990	300	4290	2166*
5.	45.29	1552	22	114	2508	244	2752	1200*
6.	28.18	968	7.5	260	1950	40	1990	1022*
7.	78.00	2678	120	70	8400	-	8400	5722*

* Source Barsuan Irrigation Project Report

Table 5.1(a)

MONTHLY WATER REQUIREMENT IN MT

PER HECTARE OF CROP AREA

Name of crops	Jan	Feb	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
KHARIF												
Rapi						0.20833	-					
Vegetable						0.20833						
E.Paddy						0.03703	0.30403	0.05253	0.07528			
M.Paddy						0.03682	0.2996	0.05163	0.18846			
N.Paddy						0.02863	0.34282	0.0278	0.22385	0.5087	0.069971	
Rabi												
Pulses										0.20833	0.17564	0.22547
Vegetable												
Veget-able	0.21689										0.32991	0.222

Table 5.2

STATEMENT SHOWING THE PROPOSED MAXIMUM AND MINIMUM CROPPED AREA (H.A.)

Sl. No.	Name of crop	Maximum Area	Minimum area
Kharif			
1.	Ragi	1525	835
2.	Vegetable	726.7	133.3
3.	Early paddy	1787	363
4.	Medium paddy	19268	3912
5.	Normal paddy (Improved)	1630	1349.5
Rabi			
6.	Pulses	7710.75	2639.25
7.	Vegetable	2423	1027

C.C.A.= 17250 Hect.

Total khrif area < 15765 hect.(91.39 percent CCA)

Total Rabi area < 6900 hect. (40 percent CCA) ??

Table 5.3

Statement Indicating Area of Different crops Grown in Orissa from 1970-71 to 1979-80 for Calculation upper and Lower Bound of crop area

Arera in Hect

Year	Ragi		Vegetable(k)		E.Paddy(H.Y) and M.Paddy (H.Y)		Normal improved paddy		Pusle(R)		Vegetable(R)	
	Area	%	Area	%	Area	%	Area	%	Area	%	Area	%
1970-71	140965	1.90	138217	9.51	82248	10.66	4253752	3.27	671731	1.21	258128	40.47
1971-72	138282	1.59	125068	24.83	91022	66.25	4392978	5.72	679878	14.24	153643	23.53
1972-73	140488	2.81	155121	233.02	151330	48.37	4141670	4.92	776636	1.84	189794	6.84
1973-74	144445	11.31	516594	69.0	224529	10.51	4345471	6.22	790960	6.44	176808	2.78
1974-75	160787	29.22	159322	15.23	200932	61.04	4075068	2.58	841923	10.45	181729	17.55
1975-76	207771	9.29	183597	7.75	323587	24.35	4180413	8.99	929905	16.16	213625	15.47
1976-77	227082	6.63	197834	10.64	402383	17.02	3804617	1.56	779626	49.00	180578	37.36
1977-78	242130	0.073	218876	0.46	470870	50.75	3745130	6.62	1161713	13.43	248042	10.13
1978-79	242308	1.557	219882	12.71	709832	13.62	3497168	9.43	1317775	4.796	273177	5.51
1979-80	238535		247843		806517		1367483		1380977		258127	
Accepted upper and lower Bound of crop area in percentage		29.22		69.0		66.25		9.43		49.60		40.47

SOURCES: Table 12 Orissa Agricultural Statistics (1979-80)

Table 5.4

Calculation of 75 percent dependable years runoff

Sl.No.	Year	Inflow in H.M.
1	2001	704202.55
2	1981	619007.22
3	1982	605026.44
4	1989	497666.51
5	1992	491115.51
6	2012	453478.15
7	1993	453048.79
8	1987	428848.60
9	2010	428217.83
10	2005	424907.09
11	1986	393158.87
12	2011	370495.58
13	2014	364075.73
14	1997	363071.24
15	2017	357315.56
16	1988	354527.78
17	2007	348136.39
18	1994	344399.31
19	1995	341115.05
20	1990	339295.31
21	2004	330944.12
22	2003	328037.57
23	1985	318784.41
24	1996	297788.39
25	1983	289710.50
26	1998	288103.09

Contd....

Table 5.4 Contd..

Sl.No.	Year	Inflow in H.M.
27	2000	286110.87
28	1991	284120.75
29	2016	279977.38
30	2002	273857.84
31	2009	257289.09 75percent dependable years
32	2015	241584.67
33	2006	234516.60
34	2013	231172.39
35	1999	228725.85
36	2008	226304.63
37	1984	222643.92
38	1980	211977.96
39	2019	203177.33
40	2018	188694.94

$$\frac{m}{n+1} = 3/4$$

m= sl. no of 75 percent dependable year

n= total nos of years considered

$$\therefore m = \frac{3x(40+1)}{4} = \frac{123}{4} = 30.75$$

or say 31st years.

TABLE 5.5

MONTHLY GENERATED INFLOW OF LODANI FREE CATCHMENT ARRANGED IN DESCENDING ORDER OF MAGNITUDE FOR CALCULATION OF HYPOTHETICAL 75% DEPENDABLE YEARS YIELD (FROM 40 YEARS DATA)

CATCHMENT AREA 9573.64 SQ.KM.

Sl. No.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.
1	2	3	4	5	6	7	8	9	10	11	12	13
1	6792	6850	2933	4637	7285	11707	165969	135788	257625	200000	43900	24981
2	6090	5578	2541	2782	4922	8796	144793	132603	251298	138042	43836	23053
3	5386	4934	2488	2153	3555	4022	134740	130669	250306	121085	34364	18319
4	4842	4868	2333	2066	2879	7371	98053	130364	232044	109480	32460	17397
5	4814	4514	2294	1984	2800	7073	90215	126972	190584	100938	30264	17121
6	4776	4487	2289	1934	2491	6551	87550	125922	178718	92408	27545	17037
7	4410	4294	2249	1848	2469	5845	87353	125768	142335	75354	25789	15101
8	4338	4120	2191	1724	2392	5824	82522	125308	141882	70548	25422	15069
9	4282	4057	2098	1686	2350	5738	81351	123253	139785	58577	24620	15038
10	4234	3751	2075	1630	2341	5578	76551	12333	128717	58398	24490	13860
11	4220	3691	1818	1463	2248	5493	72387	122064	127961	56658	22582	11284
12	4213	3663	1801	1423	2165	5490	71785	117657	125401	56221	21974	10836
13	4139	3660	1797	1369	1911	5490	69194	115937	119182	55585	21265	10343
14	3947	3484	1793	1344	1604	5030	69143	113049	111259	52100	19082	10141
15	3946	3473	1770	1197	1592	4977	65806	110843	107266	50321	17935	9615
16	3937	3463	1737	1184	1571	4901	63401	110111	100177	49606	15802	9470
17	3798	3431	1720	1169	1258	4698	62561	109328	98612	49314	15787	9154
18	3582	3364	1674	1148	1092	4624	59704	108871	88211	49166	15150	8535

Contd.../-

Table 5.5 Contd..

1	2	3	4	5	6	7	8	9	10	11	12	13
19.	3472	3358	1650	1100	1034	4514	55857	108227	73298	46316	12863	7367
20.	3092	3239	1639	1084	1008	4400	53814	106469	63794	45213	12766	6972
21	3059	3183	1622	1050	993	4328	53509	104819	63516	44481	10212	6751
22.	2973	3150	1617	975	868	4202	53491	104991	62933	43151	10109	6305
23.	2778	3078	1594	957	777	4181	47686	103132	62421	38712	9992	5459
24.	2735	3042	1587	868	683	4121	47409	102708	58630	36950	9520	5043
25.	2640	3033	1579	821	580	3959	47337	102395	52444	36708	9106	4438
26.	2564	3013	1576	815	521	3914	47105	102131	47096	34959	7343	4204
27.	2434	2863	1493	738	510	3638	43050	101850	44030	30025	6848	3826
28.	2521	2746	1482	652	445	3534	42794	99699	38688	28492	6619	3583
29.	2301	2741	1404	646	444	3440	42721	97588	35634	27524	6073	3495
30.	2082	2725	1380	561	417	3371	42489	97166	32948	26115	5585	3445
31.	2028	2702	1366	436	211	3094	36745	96715	31499	24768	5508	3335
32	1878	2613	1352	387	159	3061	36451	94248	29222	21995	5022	3096
33.	1823	2612	1305	347	126	2800	36176	93799	27806	17287	4683	2622
34.	1719	2384	1279	244	124	2683	35871	92815	26925	12009	3439	1811
35.	1626	2380	1192	233	108	2640	35912	91706	21065	11749	3333	1571

Contd....

Table 5.5 Contd..

Sl.No.	2	3	4	5	6	7	8	9	10	11	12	13
36.	1618	2249	1171	192	81	2440	31496	90385	19019	9458	3004	1513
37.	1525	2160	1048	71	77	2326	26155	88729	15335	7570	2671	1136
38.	1516	2038	1039	69	30	1272	23067	87943	6475	1861	2527	984
39.	1139	2012	839	53	23	1159	20076	82728	1938	381	1810	214
40.	999	1946	777	21	6	779	12844	66847	128	81	864	0

M = 75 percent Hypothetical dependable years
n = total number of years = consider = 40

$\frac{M}{n+1} = 3/4$ Therefore, $M = \frac{(40+1)*3}{4} = 30.75$ pr 31st year

75 percent Hypotetical years monthly yield ,in H.M.

2028	2702	1366	436	211	3094	36745	96715	31499	24768	5508	3335

Calculation of fractional part of monthly yield that of annual yield

Jan.= 9.7342×10^{-3}, Feb= 0.0129684, Mar= 6.5588×10^{-3}, April= 2.09437×10^{-3}, May= 1.01705×10^{-3}

June= 0.0148501, July= 0.1763109, Aug.= 0.4640522, Sept =0.1511373, Oct= 0.1188413, Nov.=0.0264296

Dec= 0.0160054

75 percent depenbae years yield calculated vide table 5.4 are distributed monthwise on the basis of above fractional part

2504	3336	1687	538	261	3820	45362	119395	38885	30576	6800	4118

Total

Table 5.6

MONTHLY TOTAL INFLOW AVAILABLE AT LODANI SITE (i.e. RESERVOIR NO 5) AFTER COMBINED OPERATION OF 4 NOS UP STREAM RESERVOIR EXCLUDING INFLOW FROM BIHAR CATCHMENT OF KORA-KOEL RIVER ARRANGED IN DESCENDING ORDER OF MAGNITUDE FOR CALCULATION OF HYPOTHETICAL 75 PERCENT DEPENDABLE YEAR'S YIELD. (40 YEARS)

Sl. No.	JAN	FEB	MAR	APRIL	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
1	2	3	4	5	6	7	8	9	10	11	12	13
1.	11892	9385	5673	7280	10016	241869	774957	682216	712138	332872	82858	30882
2.	10131	8116	5283	5425	7652	119879	480293	543711	701085	206776	66165	27654
3.	8623	7472	5229	4795	6285	68539	392672	476120	649195	176149	55056	22910
4.	8424	7334	5063	4708	5617	66297	335193	464017	643935	167449	50953	22688
5.	8201	6980	5025	4627	5610	47901	331573	463223	568040	166241	46923	21831
6.	7883	6953	5019	4576	5530	47756	311865	438888	413408	152483	46879	20906
7.	7738	6831	4990	4491	5221	43630	309992	425923	346182	120706	43784	19704
8.	7514	6653	4928	4420	5199	42703	253965	383991	341900	112749	38604	19270
9.	7375	6594	4828	4367	5122	11483	238648	368431	338773	106114	37860	19072
10.	7312	6370	4805	4328	5081	10018	235795	366282	330003	102770	36425	17798
11.	7165	6284	4660	4273	5071	9774	221529	349836	318878	100940	34631	16292
12.	7143	6157	4559	4105	4978	8525	206700	337261	298057	98157	34532	15621
13.	7056	6129	4542	4065	4896	8439	194059	327987	278181	96380	32414	14688

Contd...

Table 5.6 Contd....

1	2	3	4	5	6	7	8	9	10	11	12	13
14.	6868	6106	4528	4012	4641	8278	187831	325992	269387	89225	32057	14666
15.	6787	6021	4523	3987	4334	8193	181728	316832	259846	84705	31231.33	13683
16.	6529	6006	4500	3840	4322	8190	179672	306476	256998	83525	27213	13222
17.	6494	5934	4479	3826	4203	8132	172071	302452	242930	81611	23733	12971
18.	6312	5897	4451	3812	3988	7731	166537	302251	200142	78782	23255	12011
19.	6232	5891	4415	3790	3822	7619	158173	299779	171902	78555	19988	11520
20.	6092	5830	4380	3742	3764	7373	156231	296333	159633	77584	19848	11289
21.	5990	5777	4377	3726	3738	7299	143180	283781	158524	76358	19014	11269
22.	5904	5670	4348	3692	3723	7214	139986	285767	146237	69588	18651	10140
23	5709	5580	4335	3617	3598	7083	136951	283316	138435	69490	17234	9254
24.	5665	5570	4317	3600	3507	6789	134725	278682	128622	63413	16156	8287
25.	5481	5551	4310	3464	3414	6659	129321	265539	128588	59012	16035	8265
26.	5443	5548	4306	3457	3311	6588	128132	258491	122578	58071	14736	7404
27.	5431	5329	4225	3381	3251	6313	126050	257031	119739	57990	12400	7246
28.	5301	5240	4224	3295	3240	6235	119222	253872	115827	57603	11057	7120
29.	5251	5237	4135	3289	3175	6090	105526	251885	91798	56848	10662	7037
30.	5047	5212	4121	3203	3175	6046	99212	241199	87065	53481	10308	6924

Contd...

Table 5.6 Contd...

1	2	3	4	5	6	7	8	9	10	11	12	13
31.	5012	5191	4097	3078	3148	5729	83577	219055	85704	48219	10062	6870
32.	4809	5150	4082	3050	2942	5500	77121	212241	81467	43222	9882	6374
33.	4754	5078	4036	2989	2889	5383	67127	203765	79897	42820	9305	6271
34.	4650	4920	4010	2886	2855	5348	60744	196394	78355	29522	8381	5516
35.	4556	4918	3934	2866	2838	5103	60195	190031	62036	23431	7584	5443
36.	4513	4782	3901	2835	2811	5026	58970	186226	58719	22701	7141	5123
37.	4320	4720	3786	2713	2807	4037	56326	184180	57455	15009	7108	4721
38.	4225	4698	3781	2711	2761	3972	55482	170865	42055	14243	6944	4576
39.	4070	4576	3569	2695	2753	3858	50451	159119	36593	9292	6388	3415
40.	3930	4549	3518	2664	2736	3447	39509	125912	17366	8164	4847	3337

Where, M = the serial no of 75 percent Hypothetical dependable year
N = total nos of years considered

$\therefore M = \frac{(N + 1)*3}{4} = 30.75$ or 31(say)

75 percent Hypothetical dependable years monthly yield in H.M.

5012	5191	4097	3078	3148	5729	83577	219055	85704	48219	10062	6870

Total

Calculation of fraction of monthly yield of annual yield

Jan= 0.0104188, Feb= 0.0108215, Mar= 8.54057×10^{-3}, April, 6.41773×10^{-3}, May= 6.56222×10^{-3}

June= 0.0119426, July 0.174211, Aug.= 0.45466046, Sept= 0.178644, Oct= 0.1005103

Nov = 0.0209748, Dec.= 0.0143213

Table 5.7

Yearly inflow arranged in descending order of magnitude and calculation of 75 percent dependable years yield in H.M.

Sl.No.	Yield	Sl.No.	Yield	Sl.No.	Yield	Sl.No.	Yield
1	1669801	11	1005114	21	880350	31	596286*
2	1643419	12	1002627	22	878883	32	579892
3	1548482	13	988762	23	837477	33	577454
4	1415576	14	950942	24	763996	34	549056
5	1370985	15	940249	25	736196	35	547976
6	1295540	16	936715	26	713667	36	516015
7	1204928	17	936308	27	696264	37	486039
8	1152337	18	930963	28	682665	38	477371
9	1137655	19	917097	29	675914	39	464550
10	1064179	20	908718	30	673441	40	411923

* 75 percent dependable years yield

75 percent dependable years yield distributed monthwise on the basis of fractional parts calculated vide Table 5.6

Jan.	Feb.	Mar	April	May	June	July	Aug	Sept	Oct.	Nov.	Dec.
6230	6452	5092	3826	3912	7121	103879	272266	106522	59932	12506	8539
Utilisable months surface water available											
10	10	10	10	10	20	40	50	40	40	10	10
623	645	509	382	391	1224	41551	136133	42609	23973	1250	854

Table 5.8

Calculation of Annual capital cost of surface water.

Capital cost of Project Rs.67500000/-
(Irrigation share)

Life of Reservoir project is 100 years

Annual capital cost at 10 percent interest rare

$$A = P \left[\frac{i\ (1+i)^{n}}{(1+i)^{n}-1} \right]$$

A = Annual cost

P = present co-value

i = interst rate

n = nos of years

$$\therefore A = 67500000 \left[\frac{0.1\ (1.1)^{100}}{(1.1)^{100}-1} \right]$$

= Rs.6750486/-

Annual cost per Hect meter of storage $= \frac{6750486}{6534.76}$ = Rs 1033/-

= Rs.1035/- (say)

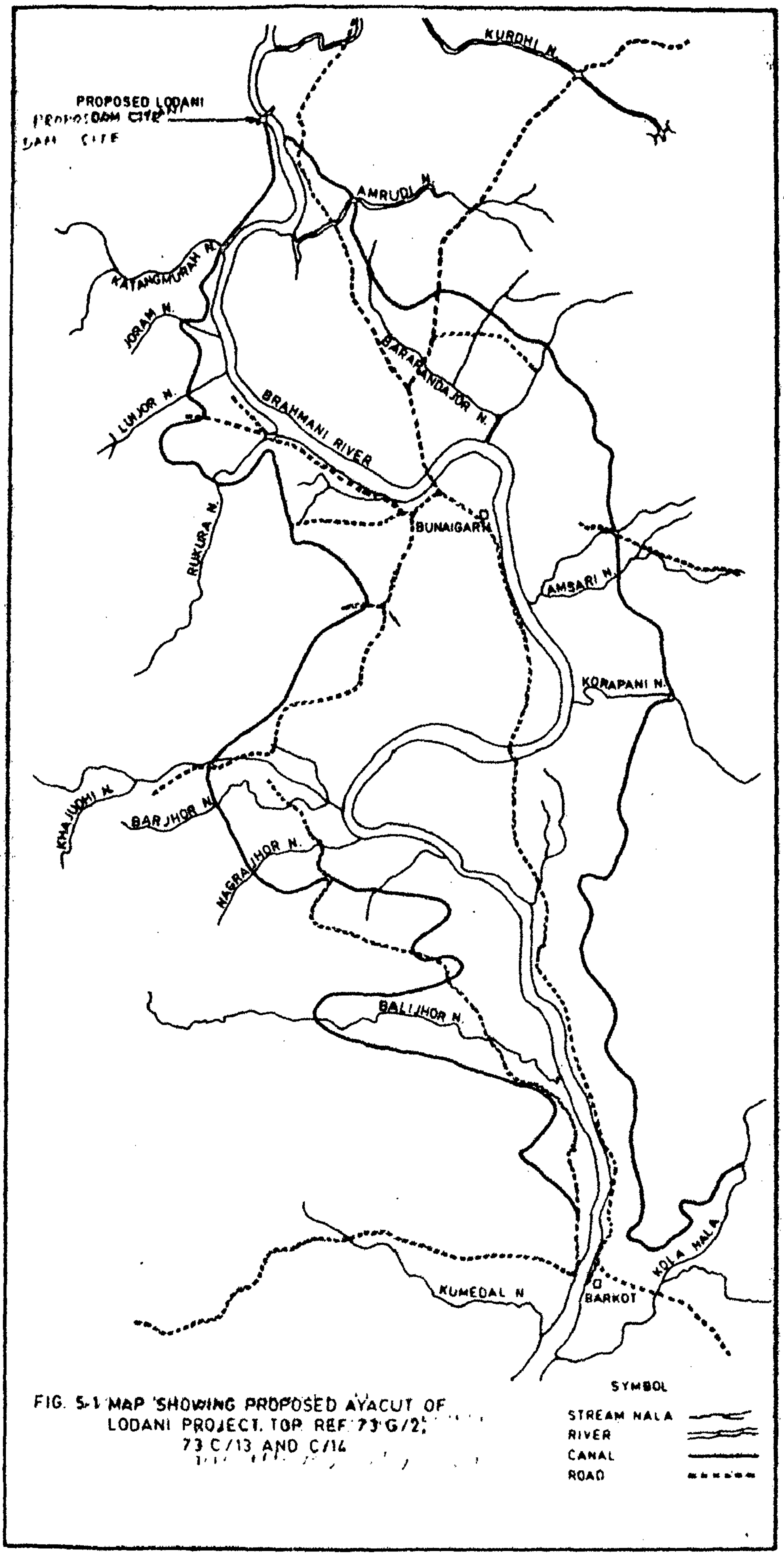

FIG. 5-1 MAP SHOWING PROPOSED AYACUT OF LODANI PROJECT. TOP. REF. 73 G/2, 73 C/13 AND C/14

CHAPTER 6

COMPUTATION

6.1 INTRODUCTION:

The operational procedure as disscussed in section 4.2 has been followed for the operation.

Computer programme (Appendix -IV) were devoloped for the study and are used for computation.

First the Kansbahal reservoir was operated individually to assess its contribution (i.e, part of irrigation release and spill) to Mandira Reservoir. Then the five reservoirs, i.e. Pitamahal, Mandira, Chandrinall, Barsuan and Lodani operated simultenously. The different runs have been made by changing the requirements of Mandira and Lodani reservoirs, which have been disscussed in section 6.3.

6.2 DATA USED:

The following data have been used for operational computation.

1. Reservoir Gross storage capacity and dead storage capacity are given table 2.2
2. 40 years generated monthly inflows for six reservoirs. These have not been appended here.

3. Monthly irrigation and industrial requirements for five reservoirs are given in table 2.3

4. Monthly evaporation losses from reservoir are given in table 2.5.

6.3 Detail Computation Procedure:

The computational procedures of operational and linear programming models are interdependent on each other. The computtation of different steps was done as given below.

STEP I: The operational model runs with the data of four upstream reservoirs, i.e. Pitamahal, Chandrinall, Barsuan and Mandira. The data consists of

(1) Forty years of inflow, and

(2) Irrigation requirement for reservoirs Pitamahal, Chandrinall and Barsuan taken from table 2.4. Industrial water requirement for Rourkella steel plant, as 300 cubic feet/second is also taken from table 2.4. The contributed flows from different reservoirs after the above operation to Lodani reservoir is taken on the following basis.

(a) Spill from each reservoir

(b) 20 percent of the irrigation releases made from reservoirs namely Pitamahal, Chandrinalla and Barsuan as return flow or regeneration.

(c) 60 percent of the industrial releases from. Mandira reservoir as return flow.

After calculating the contributed flows, the inflow due to the free catchment of Lodani Project were added to it and were taken as total inflows to Lodani reservoir. The requirements for Lodani reservoir has been considered as per the feasibility report of state government and is taken from table 2.4. Then the Lodani reservoir has been operated. The reservoir behaviour has been given in table 6.1

STEP II: The procedure for computing flow contribution to Lodani reservoir from up stream reservoir is same here as that of step I, except that the monthly industrial water requirements from Mandira dam has been changed from 300 cusecs to 600 cusecs, Which is the future demand of Rourkella steel plant. The Lodani reservoir behavour has been given in table 6.2

In the following steps lower and upper bounds were imposed on the cropping areas as discussed in section 5.5.

STEP III: The flow contribution to Lodani reservoir from up stream reservoir is same as in step II. The water requirements at Lodani reservoir were changed using the Linear programming model. The model was run with monthly inflows taken as 75 percent dependable years yield values calculated from inflow due to free catchment and by imposing upper and Lower bound on cropping areas along with all other constraints mentioned in chapter 5 remain unchanged. From this model the monthly surface water requirements have been calculated and given in table 6.3 With the new values of crop water requirements for different months the Lodani reservoir was again operated by taking total inflow data to Lodani reservoir as explained in step II. The reservoir behaviour has been given in table 6.4.

STEP IV: The flow contribution to Lodani reservoir from up stream reservoirs is same as in step II. The water requirements of Lodani were again changed using Linear programming model. The model was run with monthly inflows taken as 75 percent dependable years yield values and by imposing only upper bounds on cropping areas along with all other constraints mentioned in chapter 5. remain unchanged. From this model the monthly surface water requirements have been calculated and are given in table 6.3, With the new values of crop water requirements for different months the Lodani reservoir was again operated by taking total inflow data to Lodani reservoir as explained in step II. The reservoir behaviour has been given in table 6.5.

STEP V: The flow contribution to Lodani reservoir from up stream reservoirs is again same as in step II. The water requirements at Lodani were changed using Linear programming model The model was run with monthly inflows taken as different percentage for different months from 75 percent dependable years yield value calculated from total inflow at Lodani site (i.e. contributed flows from up stream reservoir plus inflow due to free catchment) as explained in section 5.3.3 of chapter 5 and by imposing upper and lower bounds on cropping areas along with all other constraints mentioned in chapter 5 remain unchanged. From this model the monthly surface water requirements have been calculated and given in table 6.3. With the new values of crop water requirements for different months the Lodani reservoir was again operated by taking total inflow data to Lodani reservoir as explained in step II. The reservoir behaviour has been given in table 6.6.

<u>STEP VI:</u> The flow contribution to Lodani reservoir from up stream reservoirs is same as in step II. The water requirements at Lodani were changed using Linear programming model. The model was run with monthly inflows taken as different percentage for different months of 75 percent dependable years value calculated from total inflows Lodani site as explained in section 5.3.3 of chapter 5. and by imposing upper bounds on cropping areas along with all other constraints mentioned in chapter 5 remain unchanged. From the model the monthly surface water requirements have been calculated and given in table 6.3. With the new values of crop water requirements for different months the Lodani reservoir was again operated by taking total inflow data to Lodani reservoir as explained in step II. The reservoir behaviour has been given in table 6.7.

No further computations were carried out due to the storage of time and also the above step nos from III to VI, where the bounds were changed on the cropping areas, seemed to be sufficient for analyzing different cropping pattern from the point of view that the system is almost under the investigation stages.

Table 6.1

BEHAVIOUR OF LODANI RESERVOIR

In Hect. Meters

Step No.	Months→	Nov	Dec	Jan	Feb	Mar	April	May	June	July	Aug	Sept	Oct.
I	Monthly Av. spill	24774	11182	5118	4420	2534	1774	2002	23839	191172	304375	228396	81652
	Monthly maximum spill	82554	30610	12726	7786	3759	5263	7814	253483	771593	679185	707092	329702
	Monthly minimum spill	3637	1785	2273	2950	1605	647	535	1865	50365	122881	12321	4994
	Monthly Av. Real-se.	0	0	0	0	0	0	0	0	2981	2687	4695	2793
	Monthly Maximum Realease	0	0	0	0	0	0	0	0	2981	2687	4695	2793
	Monthly minimum realease	0	0	0	0	0	0	0	0	2981	2687	4695	2793

Av. spill = 73436, Maximum spill=771593, Minimum spill= 535, Nos of spilled months = 480
Nos of short months = 0, Nos of years reservoir was successful = 40, nos of year reservoir failed = 0.

Table 6.2

BEHAVIOUR of LODANI RESERVOIR

in Hect.Meters

Step No.	Month →	Nov	Dec	Jan	Feb	Mar	April	May	June	July	Aug.	Sept.	Oct.
II	Monthly Av.spill	24903	12060	6005	5539	3885	3095	3367	21729	180669	304193	228396	81652
	Monthly Maximum spill	82554	30610	11600	9019	5125	6584	9180	241198	771593	679185	707092	329702
	Monthly Minimum spill	4543	3065	3638	4183	2970	1968	1900	2775	36146	122881	12321	4994
	Monthly Av.realse	0	0	0	0	0	0	0	0	2981	2687	4695	2793
	Monthly Maximum realease	0	0	0	0	0	0	0	0	2981	2687	4695	2793
	Monthly minimum realse	0	0	0	0	0	0	0	0	2981	2687	4695	2793

Av.spill = 72958, Maximum spill= 771593, Minimum spill = 1900, Nos of spilled months = 480
Nos of short month= 0, Nos of years reservoir was successful= 40, nos of years reservoir failed = 0

Table 6.3

Results of different decision variable from

Linear programming mode

A- CROP AREAS

Name of crops	CROP AREAS IN HECT.			
	STEP III	STEP IV	STEP V	STEP VI
Ragi	835.00	0.0	835.00	0.0
Vegetab-le khrif	726.70	726.70	726.70	726.70
Early paddy	363.00	0.0	363.00	0.0
Medium paddy	12490.80	15938.30	12490.80	15038.30
Normal paddy	1349.50	0.0	1349.50	0.0
Pulss	4470.00	4470.00	2639.25	2389.87
vegeta-bleRabi	2423.00	2423.00	2169.72	2423.00

Contd...

Contd... 6.3

B- WATER REQUIREMENT IN HECT-METERS

Step No.	Type	Nov	Dec.	Jan.	Feb.	March	April	May	June	July	Aug.	Sept	Oct.	Total
III	Surface	1679.	1547	525	0.00	0.00	0.00	0.00	837.34	4217	701	2929	1619	14057
	Ground	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
IV	SURface	1585	1547	525	0.00	0.00	0.00	0.00	705.10	4505	776	2843	932.70	13412
	Ground	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
V	Surface	1250	854	470	0.00	0.00	0.00	0.00	837.0	4217	701	2929	12336	12497
	Ground	22	222	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	245
VI	Surface	1219	854	525	0.0	0.0	0.0	0.0	705.10	4505	776	2834	497	11917
	Ground	0.0	222	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Step III monthly surface water constraints have been taken as 75 percent dependable yield of free catchments calculated from inflow at Lodani site table 5.5 and imposing crop area upper and lower bounds.

Step IV Monthly surface water constants same as that of step I and imposing only cropping area upper bounds

Step V Monthly surface water constraints taken from table 5.7 and implsing cropping area upper and lower bounds.

Step VI Monthly surface water constraints same as that of step V and imposing only cropping area upper bounds.

Table 6.4

BEHAVIOUR OF LODANI RESERVOIR

in Hect. Meters

Step No.	Month →	Nov	Dec	Jan	Feb	Mar	April	May	June	July	Aug.	Sept.	Oct.
III	Monthly Av. spill	23223	10512	5479	5539	3884	3095	3367	20892	179433	306179	230162	82826
	Monthly maximum spill	80874	29063	11075	9019	5125	6584	9180	240360	770357	681171	708858	330876
	Monthly minimum spill	2863	1517	3112	4183	2970	1968	1900	1938	34910	124867	14086	6167
	Monthly av. release	1679	1547	525	0	0	0	0	837	4217	701	2929	1619
	Monthly maximum release	1679	1547	525	0	0	0	0	837	4217	701	2929	1619
	Monthly minimum release	1679	1547	525	0	0	0	0	837	4217	701	2929	1619

Av. spill= 72883, Maximum spill=770357, Minimum spill= 1517, Nos of spilled months=480
Nos of short month= nil, Nos of years reservoir operation were succussful= 40, Nos of years reservoir operation were failure= Nil.

Table 6.5

BEHAVIOUR OF LODANI RESERVOIR

in Hect. Meters

Step No.	Month→	Nov	Dec	Jan	Feb	Mar	April	May	June	July	Aug.	Sept.	Oct.
IV	Monthly av. Spill	23317	10512	5479	5539	3884	3095	3367	20934	179144	299116	230248	83512
	Monthly Maximum spill	80968	29063	11075	9019	5125	6584	9180	240402	770069	674108	708944	331562
	Monthly Minimum spill	2957	1517	3112	4183	2970	1968	1900	1980	34622	117804	14172	6854
	Monthly Av. release	1585	1547	525	0	0	0	0	795	4505	7764	2843	932
	Monthly maximum release	1585	1547	525	0	0	0	0	795	4505	7764	2843	932
	Monthly minimum release	1585	1547	525	0	0	0	0	795	4505	7764	2843	932

Av. spill= 72346, Maximum spill= 770069, Minimum spill= 1517, Nos of spilled month = 480
Nos of short month= 0, Nos of reservoir was successful= 40, nos of year reservoir failed = 0.

Table 6.6

BEHAVIOUR OF LODANI RESERVOIR

in Hect.Meters

Step No.	Month→	Nov	Dec.	Jan	Feb.	Mar	April	May	June	July	Aug.	Sept.	Oct.
V	Monthly Av.Spill	23653	11206	5534	5539	3884	3095	3367	20892	179433	306179	230162	83209
	Monthly Maximum spill	81304	29756	11129	9019	5125	6584	9180	240360	770357	681179	708858	331259
	Monthly Minimum spill	3293	2211	2167	4813	2970	1968	1900	1938	34910	124867	14086	6550
	Monthly Av.release	1250	854	470	0	0	0	0	837	4217	701	2929	1236
	Monthly Maximum release	1250	854	470	0	0	0	0	837	4217	701	2929	1236
	Monthly Minimum release	1250	854	470	0	0	0	0	837	4217	701	2929	1236

Av.spill = 73013, Maximum spill= 770357, Minimum spill= 1900, Nos of spilled months = 480

Nos of short month = 0, Nos of years reservoir was successful=40,nos of years reservoir failed = 0

Table 6.7

BEHAVIOUR OF LODANI RESERVOIR

in Hect. Meters

Step No.	Month→	Nov	Dec	Jan	Feb	Mar	April	May	June	July	Aug	Sept.	Oct.
VI	Monthly Av. Spill	23684	11206	5479	5539	3884	3095	3367	21024	179144	306104	230257	83947
	Monthly Maximum spill	81335	29756	11075	9019	5125	6584	9180	240492	770069	681096	708953	331997
	Monthly Minimum spill	3323	2211	3112	4183	2970	1968	1900	2070	34622	124792	141819	7289
	Monthly Av. release	1219	854	525	0	0	0	0	705	4505	776	2834	498
	Monthly Maximum release	1219	854	525	0	0	0	0	705	4505	776	2834	498
	Monthly Minimum release	1219	854	525	0	0	0	0	705	4505	776	2834	498

Av. spill = 73061, Maximum spill= 770069, Minimum spill= 1900, Nos of spilled months = 480
Nos of short month= 0, Nos of years reservoir was successful= 40, nos of years reservoir failed = 0

CHAPTER 7

DISCUSSION,CONCLUSION AND SUGGESTIONS:

7.1 GENERAL:

The system of upper Brhhmani basin was defined in Chapter 2. The synthetic flows at various sites were generated in chapter 3. Two models i.e. operational model and linear programming model, were applied in conjunction with each other to the basin. The results of computations are given in table 6.1 to 6.7.

7.2 DISCUSSION:

For the study of reservoir operational model and linear programming model, the accuracy and reliability of results depend upon the reliability of input data.

7.2.1 Generation of Stream flow data-

The generation of stream flow data by Thomas Fiering model and Modified Thomas Fiering model have the following limitations.

1. If assumes that the flow sequences are normally distributed.

2. The accuracy of results of generated series depends upon the number of historical input flow sequence

From the comparison of mean and standard deviation of observed and generated series given in table 3.2(b), 3.3(b), 3.4(b), the variation of mean and standard devations is not much, except in the case of standard deviation for Pitamahal

Irrigation Project and Barsuan Irrigation Project for the month of June and October respectively. This may be due to lack of inflow data and the assumption that regression co-efficiant and co-relation co-efficient for the month of June are zero.

From the comparisiom of mean and standard deviation of observed and generated series given table 3.5(b) and 3.6(b) the deviation in the case of mean is maximum in the month of March in case of Mandira Project and in April in case of Lodani Project. The maximum standard deviation in case of both above mentioned projects in the month of December. This may be due to non-availability of long series of observed inflow data (i.e., inflow data is for 9 years and 4 years only available in case of Mandira and Lodani Projects respectively). More over other statistical methods such as Bivariate and Multivariate method, could't be used due to non-availability of observed inflow data for common period to check the accuracy of results.

The free catchment inflows at Mandira and Lodani sites have been calculated on catchment proportion basis assuming that topographical, geohydrological, hydrometeorological, land cover characteristics of the basin are uniform through out.

7.2.2 Behavaiour of Four up-stream Reservoirs-

The reservoir behaviour of four nos of upstream reservoirs and its contribution to Lodani reservoir computed by reservoir operational model have been given in table 7.1 to 7.5.f For this purpose the irrigation requirements for Pitamahal, chandrinalla and Barsuan are kept constant and taken from table 2.4, only in the case of Mandira two different requirements have been considered i.e. present and future industrial demand of Rourkella steel plant. Table 7.1 to 7.5 shows the average monthly inflow average monthly spill, Maximum monthly spill, Minimum monthly spill, average monthly release, maximum monthly release and minimum monthly release from the four numbers of upstream reservoirs.

7.2.3 Lodani Reservoir Behaviour:

From the reservoir bbhaviour table 6.1, 6.2 and 6.4 to 6.7 it is seen that through out the years the proposed Lodani reservoir spills. The spills from Lodani reservoir would have still more as the yield at Lodani site has been done on rather conservative side. The contribution of yield from the catchment of Bihar portion has been eliminated from the total yield at Lodani. But actually the yield from Bihar catchment is also available at Lodani site. These spills will take care of the supplies of water from Lodani for Rengali Multipurpose project which is under construction down stream of Lodani.

The water requirements at Rengali Multipurpose reservoir site has been calculated considering the yield from entire catchment of Brahmani basin at Rengali site. Due to non-availability of water requirement data of Rengali Multipurpose project the same could not be incorporated in the models. Inclusion of this would have justified the values of spills from the Lodani, obtained in the present study.

7.2.4 Selection of cropping pattern:

The utilisable surface water constraint in each month has been calculated from generated data from two alternate basis for the Lodani reservoir as discussed in sub-section 5.3.3 of chapter 5. This also has the same defficiences as that of generation of data.

The types of crops to be grown in the ayacut of Lodani Project have been selected on the basis of Kansbahal Irrigation Project which lies in the same agro-climatic zone since soil survey report of Lodani ayacut is not available.

In the linear programming computations in step III and V section 6.3 both upper and lower bounds have been imposed. The lower bounds have been imposed with an aim to minimise transportation of food grains from other regions. In the linear programming computation in steps IV and VI section 6.3 upper bounds for crop area have been imposed but lower bounds have been released with an aim to maximise the net benifits. The crop area and benifits are given in table 7.6.

7.3 CONCLUSION:

7.3.1 General:

The study was done on the two following aspects, these are, (i) allocation of water resources of Brahmani river among different reservoirs in upper Brahmani Basin and (ii) to evolve the optimal cropping pattern for Lodani Project.

The Thomas Fiering and Modified Thomas Fiering models were used to generate sequential stream flow data at different sites for perennial and intermittant streams respectively.

7.3.2 Optimal Cropping Pattern

For this two different cases have been studied as follows case I- In this case it is considered that 75 percent dependable years monthly inflow from free catchment of Orissa portion will be the available utilisable surface water bounds for different months for linear programming model. (i.e. step III and step IV of combined operational and linear programming model) with two different crop area bounds have been studies i.e. step III and IV. In step III both upper and lower bound of crop areas have been imposed but in the step IV. Only upper bounds have been imposed. The results are given in Table 7.6. In step III utilisation of total surface water is 14057 hectare meters, Khariff intensity achived is 91.4 percent and Rabi intensity achieved 40 percent and net benifit derived is Rs.367.85 lakhs.

In step VI utilisation of total surface water 13412 hectare-meter which is comparatively less than step III though the same Khariff and Rabi intensity of 91.4 percent and 40 percent are achieved but following crops Ragi,early Paddy, Normal paddy have been eliminated due to relaxation of lower bound and increase in net benifit from Rs.367.85 lakhs to Rs.396.94 lakhs between step's IIIand IV was observed.

From the reservoir Behaviour table 6.4 and 6.5 it is seen that there is marginal increase in Av.spill, maximum spill and minimum spill in the month of June, Sept and October and marginal decrease in Av.spill, maximum spill and minimum spill in the month of July and appreciable decrease in Av.spill = 7063 H.M, in the month of August. But for all other months, Av.spills maximum spills and minimum spill remain unchanged.asAs the fluctuation of spill happens to be in monsoon months and maximum different of Av.spill i.e. month of August is the peak flow month of monsoon period, hence the effect of both the steps III and IV will be almost same on Rengali Multipurpose Project.

Case II- Monthly available 75 percent dependable years at Lodani i.e. inflow due to free catchment of Lodani (Orissa portion) plus contributed flows from four up stream projects were first calculated. The up stream contribution of reservoirs was obtained from the combined operation of four reservoirs. The surface water utilisation for each month was taken as a certain percentage of the above available monthly yield such that the total yearly utilisable surface water should not exceed the 50 percent of flood storage provided in Regngali Multipurpose project. That is with above utilisable surface water constraints for linear programming model (i.e.,step V and VI of combined operational and Linear programming model) with two different crop areas bounds have been studied i.e step V and VI. In step V upper and lower bounds of crop areas have been imposed but in case step VI only upper bounds have been imposed.

In step V utilisation of total surface water is 12497.0 hect.meter along with 245.49 hect.meter of ground water, Khariff intensity achieved 91.4 percent and Rabi intensity achieved 37.7 percent and net benifit derived Rs.347.04 lakhs.

In step VI utilisation of surface water 11917.64 hect. meter and ground water is 222.75 hect.meter which less in comparission to step V. though the same khariff intensity achieved but crops like Ragi, early paddy, and normal paddy were eliminate and Rabi intensity remain almost 37.7 percent same but Rabi crops area changed from step V and increase in net benifit from Rs.347.04 lakhs to Rs.387.74 lakhs was observed between step V and VI.

From the reservoir behaviour table 6.6 and 6.7 there is no appreaciable change in monthly Av.spill for the month of Nov, Jan, June, July, Aug, Sept and Oct and no chnages in average for the months of December, February, March, April and May. Similarly in the case of monthly Maximum and minimum spill, hence the effect on down stream Rengali Multipurpose project due to step V and VI will be almost same.

From the above study it may be concluded that optimal cropping pattern evolved by step IV operation is best among all other steps.

It is seen from table 6.5 that entire ground water potential remain unused. which indicates that Rabi area constraints and type of Rabi crops in Linear programming model can be further relaxed from 40 percent and more Rabi crops suitable for region can be incorporated.

The optimal cropping pattern evolved from this study may not be accepted in total due to the following reasons.

(1) Non-availability of historical stream flows data for longer period to be used in the Thomas Fiering and Modified Thomas Fiering Models.

(2) Non-availability of soil survey report to decide types of crops suitable for Lodani ayacut, and

(3) Non-availability of the water requirements of Rengali Multipurpose project.

7.3.3 Water Allocation

The allocation of water to the four up stream reservoir are given in Table 7.7

Table 7.8 and 7.9 shows the average monthly contributed flow to Lodani reservoir from four nos of up streams reservoirs computed by reservoir operational model as per step I and Step II to VI respectively. The allocation of water to Lodani is such that it fulfills the water demand without any deficits, or is 100 percent successful. Hence the allocation of water to Lodani is sufficient with assumption that the contribution from Lodani reservoir will meet the share of demand of down streams Rengali Multipurpose Project

7.4 SUGGESTION

As explained in conclusion section 7.3 the optimal cropping pattern evolved in this study may most be accepted in toto. For deciding optimal allocation of water resources in upper Brahmani Basin and deciding optimal corpping pattern for Lodani ayacut the following points are to be attended.

(a) The longer observed inflow data at different sits to be acquired for generating more realistic sequential stream flows data. For assessing yield at Lodani site at the proposed and existing project in Bihar state have to be considered along with 5 numbers of up str projects in Bihar.

(b) For deciding water requirements for Rengali-Multipur project, i.e. the water to be drawn from Lodani aya for down stream project a policy has to be decided by the state government such that

(I) Contribution from Lodani reservoir to Rengali multi-purpose project may be on catchment proporation basis, and/or

(II) Wheather to create an extra storage facilites at Mandira dam by increasing its full reservoir level from (690ft) to (698ft) by only replacing spill-way gates. The stored amount of water can be used in Lodani ayacut.

(III) wheather to increase present power cap i.e. 20 M.W to higher values of Lodani Project.

(iv) Conjuctive use of ground and surface water potential should be planned.

(c) Objective function of linear programming model can be modified by incorporating following multiple objective benefits. Benefits such as from unirrigated areas, and from development of other water-shed resources such as forest, wild life preservation and recreation etc.

In the present study the multilevel aspect of irrigation was not considered due to leck of data. Additional constraints for different levels of irrigation may be imposed in order to establish the optimum number of irrigations for various crops.

Table 7.1

RESERVOIR BEHAVIOUR OF PITAMAHAL IRRIGATION PROJECT

Month→	Nov	Dec	Jan	Feb	Mar	April	May	June	July	Aug.	Sept.	Oct.
Av.Monthly inflow	0.0	0.0	0.0	0.0	0.0	0.0	0.0	105.8	525.7	1336.4	763.3	96.0
Av.Monthly spill	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	57.94	218.5	0.0
Maximum Monthly spill	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	886.6	1284.2	0.0
Minimum Monthly spill	0.0	0.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Av.Monthly release	332.8	294.6	211.7	125.6	0.0	0.0	0.0	98.7	518.0	106.2	330.0	272.5
Maximum Monthly releases	352.9	368.7	302.5	224.5	0.0	0.0	0.0	128.8	657.5	106.2	396.5	274.3
Minimum Monthly release	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	106.2	257.1	200.0

Table 7.2

RESERVOIR BEHAVIOUR OF CHANDRINALLA IRRIGATION PROJECT

Month →	Nov	Dec.	Jan	Feb	March	April	May	June	July	Aug	Sept.	Oct.
Av.Monthly inflow	0.0	0.0	0.0	0.0	0.0	0.0	0.0	156.35	776.41	1973.63	1127.56	141.[illegible]
Av.Monthly spill	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	19.81	633.86	347.00	0.[illegible]
Maximum Monthly spill	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	263.0	2564.0	1597.00	0.[illegible]
Minimum Monthly spill	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.[illegible]
Av.Monthly release	106.3	162.4	135.2	68.6	21.8	0.0	0.0	0.0	480.3	610.5	870.7	356.[illegible]
Maximum monthly releases	137.2	219.4	192.0	109.7	55[illegible].0	0.0	0.0	0.0	561.2	612.0	900.0	607.[illegible]
Minimum Monthly release	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	553.94	0.0	0.[illegible]

Table 7.3

RESERVOIR BEHAVIOUR OF BARSUAN IRRIGATION PROJECT

Months →	Nov	Dec.	Jan	Feb.	March	April	May	June	July	Aug.	Sept	Oct
Av.Monthly inflow	0.0	0.0	0.0	0.0	0.0	0.0	0.0	243.5	746.9	1591.3	853.0	328.9
Av.Monthly spill	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.5	509.9	308.7	18.9
Maximum Monthly spill	0.0	0.0	0.00	0.0	0.0	0.0	0.0	0.0	181.8	1790.7	1258.7	431.6
Minimum Monthly spill	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Av.Monthly release	392.6	421.7	357.4	15.9	0.0	0.0	0.0	119.81	571.67	36.50	435.60	436.10
Maximum monthly release	424.3	501.9	505.6	23.9	0.0	0.0	0.0	160.0	700.4	37.4	439.0	447.6
Minimum monthly release	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	306.1	152.0

Table 7.4

RESERVOIR BEHAVIOUR OF MANDIRA PROJECT CONSIDERING PRESENT DEMAND OF ROURKELLA STEEL PLANT

Months →	Nov	Dec	Jan	Feb	March	April	May	June	July	Aug.	Sept.	Oct.
Av. Monthly inflow	10232	3137	1917	1198	838	456	432	26364	136574	199961	141249	35541
Av. Monthly spill	9855	2799	1345	302	40	0	0	19167	131436	199535	140815	35074
Maximum monthly spill	38775	5881	6031	1581	855	0	0	246076	639833	551701	461485	132607
Minimum monthly spill	2193	1092	0	0	0	0	0	0	11625	58914	155441	7817
Av. Monthly release	0	233	1164	1752	2235	2202	2275	1324	0	0	0	0
Maximum monthly release	9	1183	2275	2055	2275	2202	2275	2202	0	0	0	0
Minimum monthly release	0	0	0	474	1420	2202	2275	0	0	0	0	0

Table 7.5

RESERVOIR BEHAVIOUR OF MANDIRA PROJECT)

CONSIDERING FUTURE DEMAND OF ROURKELLA STEE PLANT

Monts →	Nov	Dec	Jan	Feb.	March	April	May	June	July	Aug.	Sept.	Oct
Av.Monthly in-flow	10232	3137	1917	1198	835	456	432	26364	136574	199961	141249	35541
Av.Monthly spill	9855	2613	485	18	0	0	0	15737	120865	199353	140815	35073
Maximum Monthly spill	38774	5881	4905	754	0	0	[illegible]	233789	639832	551701	461484	132606
Minimum Monthly spill	2192	0	0	0	0	0	0	0	0	58913	15440	7816
Av.Monthly release	215	2007	4073	4091	4550	4404	4550	3523	113	0	0	0
Maximum monthly release	2211	4550	4550	4510	4550	4404	4550	4404	4550	0	0	0
Minimum monthly release	0	0	0	3355	4550	4404	4550	0	0	0	0	0

Table 7.6

STATEMENT SHOWING DIFFERENT PROPOSED CROPPING PATTERNS AND THE NET BENIFIT FROM IT

Sl. No.	Name of Crops	Existing* Cropping pattern	Proposed cropping pattern as per state Govt for step I and II	Proposed optimal cropping patterns evaluated from Linear programming model			
				For StepIII	For step IV	For Step V	For Step VI
1	Ragi	-	-	835.00	0.0	835.0	0.0
2	Vegetables (Kharif)	-	-	726.70	726.70	726.70	726.70
3	Early Paddy	-	-	363.00	0.0	363.00	0.0
4	Medium paddy	-	-	12490.80	15038.30	12490.80	15038.30
5	Normal Paddy/ Improved paddy	6900	13800	1349.50	0.0	1349.50	0.0
6	Pulses	-	1725	4477.00	4477.00	2639.25	2389.87
7	Vegetables	-	-	2423.00	2423.00	2169.72	2423.00
	Net benifit in Lakhs Rupees	22.104	220.96	367.85	396.94	347.04	387.74

* Values taken from feasibility report of Lodani Irrigation Project 1979.

Table 7.7

WATER ALLOCATION TO FOUR UP STREAMS RESERVOIR

Sl.No.	Name of reservoir	Annual av. water yield in H.M.	Annual water requirement in H.M.	Reservoir dependability
1.	Mandira	557904 ?	Present- 26790 Future -53580	100 percent
2.	Pitahamahal	2353	2813	75 percent or more
3.	Chandrinalla	2992	3394	
4.	Barsuan	2787	3240	

Table 7.8

AVERAGE MONTHLY CONTRIBUTED FLOW FROM 4NOS OF UPSTREAMS RESERVOIR PROJECT

(as per step I)

Month →	Nov	Dec	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct.
Mandira Project	9855	2940	2043	1354	1381	1321	1365	19961	131436	199535	140815	35073
Pitamahal Irr. Project	66	58	42	25	0	0	0	19	103	79	297	54
Chandrinalla Project	21	32	27	13	4	0	0	0	115	755	521	107
Barsuan Project	78	84	71	3	0	0	0	23	118	517	395	106

Table 7.9

AVERAGE MONTHLY CONTRIBUTION FLOWS FROM 4NOS UPSTREAM RESERVOIR (as per step II to VI)

Month →	Nov	Dec	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct.
Mandira Project	9984	3817	2929	2473	2730	2642	2730	17851	120933	199353	140815	35073
Pitamahal Irr. Project	66	59	42	25	0	0	0	20	104	79	297	54
Chandrinalla project	21	32	27	14	4	0	0	0	116	756	521	107
Barsuan Project	79	84	71	3	0	0	0	24	119	517	396	106

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```
      [illegible] RI(2,1000),ANR(600),ANRD(600)
      OPEN(UNIT=1,DEVICE='DSK',FILE='RI.DAT')
      OPEN(UNIT=2,DEVICE='DSK',FILE='TFM2.DAT')
     OPEN(UNIT=3,DEVICE='DSK',FILE='TFM3.DAT')
      OPEN(UNIT=4,DEVICE='DSK',FILE='TFM4.DAT')
      OPEN(UNIT=5,DEVICE='DSK',FILE='TFM5.DAT')
      READ(1,*)R,R1,P
      PAI=3.1415926
      C=10.0**(-P/2.0)
      PRINT 4
 4    FORMAT(//10X,41HRESULTS OF RECT. DIST. RANDOM NOS.306,510//)
      DO 112 IR=1,2
      RI(IR,1)=10.0**(-P)*R
      DO 111 I=2,1000
      AI=10.**P*(C*RI(IR,I-1))
      IA=AI
      AII=IA
111   RI(IR,I)=AI-AII
112   R=R1
      DO 115 I=1,2
      PRINT65,(RI(I,J),J=306,510)
 65   FORMAT(1X,5E16.7/)
115   CONTINUE
      DO 55 J=306,510
      WRITE(2,60)(RI(1,J))
C     WRITE(3,60)(RI(2,J))
60    FORMAT(1X,E16.7)
55    CONTINUE
      PRINT 5
 5    FORMAT(//20X,41HRESULTS OF NORM. DIST. RANDOM NOS.306,510//)
      DO 70 I=306,510
      ANR(I-305)=(-2.0*ALOG(RI(1,I)))**0.5*COS(2.0*PAI*RI(2,I))
      ANRD(I-305)=(-2.0*ALOG(RI(2,I)))**0.5*SIN(2.0*PAI*RI(1,I))
70    CONTINUE
      PRINT 86,(ANR(J),J=1,205)
C     PRINT 86,(ANRD(J),J=1,205)
      WRITE(4,85)(ANR(J),J=1,205)
C     WRITE(5,85)(ANRD(J),J=1,205)
 86   FORMAT(1X,5E20.7/)
85    FORMAT(1X,E19.7)
      CLOSE(UNIT=1)
      CLOSE(UNIT=2)
      CLOSE(UNIT=3)
      CLOSE(UNIT=4)
      CLOSE(UNIT=5)
      STOP
      END
```

APPENDIX II

THOMAS FIERING MODEL

```
      DIMENSION Q(12,60),QMEAN(24),SD(24),DX(600),DY(600),COR(24)
     1,B(24),QGEN(12,50),RA(12,50),RQ(12,50),SUMA(50)
      OPEN(UNIT=1,DEVICE='DSK',FILE='LODA.DAT')
      OPEN(UNIT=4,DEVICE='DSK',FILE='TFM4.DAT')
      PRINT 6
6     FORMAT(/1X,'***LODANI CATCHMENT***'/)
      L=4
      AL=L
      READ(1,*)((Q(M,IY),M=1,12),IY=1,L)
      DO 33 I=1,L
      DO 33 J=1,12
33    Q(J,I)=SQRT(Q(J,I))
   19 DO 200 J=1,12
      SUM=0.0
      DO 200 I=1,L
      SUM=SUM+Q(J,I)
  200 QMEAN(J)=SUM/AL
      PRINT 29,(QMEAN(J),J=1,12)
        TYPE *,(QMEAN(J),J=1,12)
   29 FORMAT(/1X,'MEAN=',6E15.7/)
      DO 300 J=1,12
      SUM=0.0
      DO 100 I=1,L
      SUM=SUM+(Q(J,I)-QMEAN(J))**2
  100 CONTINUE
      SD(J)=SQRT(SUM/(AL-1.0))
  300 CONTINUE
      PRINT 30,(SD(J),J=1,12)
30      FORMAT(/1X,'SD=',6E15.7/)
      DO 25 J=1,12
      SUM=0.0
      SUMDX=0.0
      SUMDY=0.0
        M=J+1
        IF(J.EQ.12)M=1
      DO 20 I=1,L
      DX(J)=Q(J,I)-QMEAN(J)
      DY(J)=Q(M,I)-QMEAN(M)
      SUM=SUM+DX(J)*DY(J)
      ANM=SUM
      SUMDX=SUMDX+DX(J)*DX(J)
      SUMDY=SUMDY+DY(J)*DY(J)
   20 CONTINUE
      COR(M)=ANM/(SQRT(SUMDX*SUMDY))
   25 CONTINUE
      PRINT 31,(COR(J),J=1,12)
31      FORMAT(/1X,'COR=',6E15.7/)
      DO 111 J=1,12
      M=J+1
       IF(M.EQ.13)GO TO 222
      B(M)=COR(M)*SD(M)/SD(J)
  222 B(1)=COR(1)*SD(1)/SD(12)
```

```
  111 CONTINUE
      PRINT 32,(B(J),J=1,12)
32       FORMAT(/1X,'REG=',6E15.7/)
         PRINT 1002
 1002 FORMAT(/1X,'**************************************************')
      IF(L.EQ.45)GO TO 333
      L=45
      AL=45.
      DO 35 I=1,L
      READ(4,85)(RA(M,I),M=1,12)
   85 FORMAT(1X,E19.7)
   35 CONTINUE
      QGEN(1,1)=QMEAN(1)+RA(1,1)*SD(1)*SQRT(1.0-COR(1)**2)
      DO 40 I=1,L
      DO 45 M=1,12
        K=I
      J=M+1
      IF(J-12)202,202,203
  203 J=1
        K=I+1
  202 QGEN(J,K)=QMEAN(J)+B(J)*(QGEN(M,I)-QMEAN(M))
     1+RA(J,K)*SD(J)*SQRT(1.0-COR(J)**2)
   45 CONTINUE
   40 CONTINUE
         DO 44 I=1,L
         DO 44 J=1,12
44       QGEN(J,I)=QGEN(J,I)*QGEN(J,I)
      DO 50 M=1,12
      DO 50 I=1,L
      IF(QGEN(M,I).LE.0.0)QGEN(M,I)=0.0
   50 CONTINUE
         PRINT 1000
1000     FORMAT(/48X,23HGENERATED INFLOW SERIES/)
      DO 3 I=1,L
      PRINT 5,(QGEN(M,I),M=1,12)
    5 FORMAT(1X,6F20.2/)
    3 CONTINUE
         PRINT 1003
 1003 FORMAT(/1X,'********************************')
      DO 60 IY=1,L
      DO 60 M=1,12
      Q(M,IY)=QGEN(M,IY)
   60 CONTINUE
      GO TO 19
333      DO 70 I=1,L
         DO 70 J=1,12
         RQ(J,I)=0.6248625*QGEN(J,I)
70       CONTINUE
         DO 1 I=1,L
         PRINT 5,(RQ(J,I),J=1,12)
1        CONTINUE
         DO 80 I=1,L
```

```
          SUMA(I)=0.0
          DO 80 J=1,12
80        SUMA(I)=SUMA(I)+RQ(J,I)
          PRINT 5,(SUMA(I),I=1,L)
          CLOSE(UNIT=1)
          CLOSE(UNIT=4)
          STOP
        END
```

GRAMS CALLED

S AND ARRAYS ["*" NO EXPLICIT DEFINITION - "%" NOT REFERENCED]

```
0 1         SD      2       RQ      32      .S0037 1162     .S0036 1163
  1164      .S0035  2504    .S0034  2505    .S0033 2506     .S0032 2507
  2510      .S0031  2511    .S0030  2512    B      2513     *SUMDY 2543
2 2544      .S0041  2545    .S0040  2546    DY     2547     *SUMDX 3677
  3700      COR     3701    *J      3731    QGEN   3732     .S0007 5062
6 5063      .S0005  5064    SUMA    5065    *SUM   5147     .S0004 5150
3 5151      .S0002  5152    .S0001  5153    .S0000 5154     DX     5155
  6305      .S0017  6335    .S0016  6336    .S0015 6337     *IY    6340
4 6341      .S0013  6342    .S0012  6343    *AL    6344     .S0011 6345
0 6346      *L      6347    *I      6350    .S0027 6351     .S0026 6352
  6353      .S0025  7503    .S0024  7504    .S0023 7505     *ANM   7506
2 7507      .S0021  7510
```

ARIES

0 7601

[NO ERRORS DETECTED]

APPENDIX III

MODIFIED THOMAS FIERING MODEL

```
      DIMENSION Q(5,80),QMEAN(10),SD(10),PJ(10),COR(10),B(10),QGEN(5
     1,60),RA(5,60),DX(400),DY(400),PK(5,60)
      OPEN(UNIT=1,DEVICE='DSK',FILE='TFPI.DAT')
      OPEN(UNIT=2,DEVICE='DSK',FILE='TFM2.DAT')
C     OPEN(UNIT=3,DEVICE='DSK',FILE='TFM3.DAT')
      OPEN(UNIT=4,DEVICE='DSK',FILE='TFM4.DAT')
C     OPEN(UNIT=5,DEVICE='DSK',FILE='TFM5.DAT')
      READ(1,*)((Q(M,IY),M=1,5),IY=1,4)
      MM=5
      L=4
      AL=L
19    DO 200 J=1,MM
      SUM=0.0
      AN=0.0
      DO 100 I=1,L
      SUM=SUM+Q(J,I)
      IF(Q(J,I))9,9,110
9     AN=AN+1.0
110   QMEAN(J)=SUM/(AL-AN)
100   CONTINUE
200   CONTINUE
      PRINT 29,(QMEAN(J),J=1,MM)
      DO 11 M=1,MM
      SUM=0.0
      AK=1.0
      DO 12 IY=1,L
      IF(Q(M,IY).EQ.0.0) GO TO 91
      SUM=SUM+(Q(M,IY)-QMEAN(M))**2
      GO TO 12
91    AK=AK+1.0
12    CONTINUE
      SD(M)=SQRT(SUM/(AL-AK))
11    CONTINUE
      PRINT 29,(SD(M),M=1,MM)
      COR(1)=0.0
      JJ=MM-1
      DO 25 J=1,JJ
      SUM=0.0
      SUMDX=0.0
      SUMDY=0.0
      DO 20 I=1,L
      IF(Q(J,I).EQ.0.0) GO TO 20
      IF(Q(J+1,I).EQ.0.0) GOTO 20
      DX(J)=Q(J,I)-QMEAN(J)
      DY(J)=Q(J+1,I)-QMEAN(J+1)
      SUM=SUM+DX(J)*DY(J)
      ANM=SUM
      SUMDX=SUMDX+DX(J)*DX(J)
      SUMDY=SUMDY+DY(J)*DY(J)
20    CONTINUE
      COR(J+1)=ANM/(SQRT(SUMDX*SUMDY))
```

```
25      CONTINUE
        PRINT 29,(COR(J),J=1,MM)
29      FORMAT(//1X,5E20.7//)
        IF(L.EQ.3)GO TO 333
        DO 22 J=1,MM
        ZERO=0.0
        DO 21 I=1,L
        IF(Q(J,I).EQ.0.0)GO TO 18
        GO TO  21
18      ZERO=ZERO+1.0
21      CONTINUE
        PJ(J)=(AL-ZERO)/AL
22      CONTINUE
        PRINT 29,(PJ(J),J=1,MM)
        B(1)=0.0
        DO 33 I=1,JJ
        B(I+1)=COR(I+1)*SD(I+1)/SD(I)
33      CONTINUE
        PRINT 29,(B(I),I=1,MM)
        L=3
        AL=3.0
        DO 35 I=1,L
        READ(4,85)(RA(M,I),M=1,MM)
85      FORMAT(1X,E19.7)
35      CONTINUE
        DO 123 I=1,L
        DO 124 M=1,MM
        IF(M.EQ.1)GO TO 99
        QGEN(M,I+15)=QMEAN(M)+B(M)*(QGEN(M-1,I+15)-QMEAN(M-1))+
     1RA(M,I)*SD(M)*SQRT(1.0-COR(M)**2)
        GO TO 124
99      QGEN(M,15+I)=QMEAN(M)+RA(M,I)*SD(M)
124     CONTINUE
123     CONTINUE
        DO 44 IY=1,L
        READ(2,60)(PK(M,IY),M=1,MM)
60      FORMAT(1X,E16.7)
44      CONTINUE
        DO 102 M=1,MM
        DO 103 J=1,L
        IF(PK(M,J).GT.PJ(M))GO TO 51
        GO TO 103
51      QGEN(M,J+15)=0.0
103     CONTINUE
102     CONTINUE
        DO 400 M=1,MM
        DO 444 I=1,L
        IF(QGEN(M,I+15).LE.0.0)GO TO 2
        GO TO 444
2       QGEN(M,I+15)=0.0
444     CONTINUE
```

```
400     CONTINUE
        PRINT 1
1       FORMAT(//16X,84HJUNE                              JULY                  AUGUST
     3            SEPTEMBER                        OCTOBER)
        DO 3 I=1,L
        PRINT 5,(QGEN(J,I+15),J=1,MM)
5       FORMAT(1X,5F20.3)
3       CONTINUE
        DO 16 IY=1,L
        DO 16 M=1,MM
        Q(M,IY)=QGEN(M,IY+15)
16      CONTINUE
        DO 17 IY=1,L
        PRINT 5,(Q(M,IY),M=1,MM)
17      CONTINUE
        GO TO 19
        CLOSE(UNIT=1)
        CLOSE(UNIT=2)
C       CLOSE(UNIT=3)
        CLOSE(UNIT=4)
C       CLOSE(UNIT=5)
333     STOP
        END
```

```
GRAMS CALLED



S AND ARRAYS [ "*" NO EXPLICIT DEFINITION - "%" NOT REFERENCED ]

0 1         PJ      2       SD      14      *JJ     26      .S0037 27
6 30        Q       31      .S0035 651      .S0034 652      .S0033 653
2 654       .S0031 655      .S0030 656      B       657     *ZERO   671
  672       *AN     673     DY      674     *SUMDX  1514    *M      1515
  1516      *J      1530    *MM     1531    QGEN    1532    .S0007 2206
6 2207      .S0005 2210     .S0004 2211     *SUM    2212    .S0003 2213
2 2214      .S0001 2215     .S0000 2216     DX      2217    QMEAN   3037
7 3051      .S0016 3052     .S0015 3053     *IY     3054    .S0014 3055
3 3056      .S0012 3057     *AL     3060    .S0011 3061     .S0010 3062
  3063      PK      3064    *I      3540    .S0027 3541     .S0026 3542
  3543      .S0025 4217     .S0024 4220     .S0023 4221     *ANM    4222
  4223      .S0022 4224     .S0021 4225

ARIES

0 4263

  [ NO ERRORS DETECTED ]
```

VARIABLE NAMES USED IN COMPUTER PROGRAMMING
FOR RESERVOIR(S) OPERATIONAL MODEL

AREA	-	Reservoir area corresponding to initial reservoir capacity at the beginning of the month.
AICAPA	-	Intermediate reservoir capacity
AIAREA	-	Intermediate reservoir area corresponding to intermediate capacity.
AMS	-	Average monthly spill
AMR	-	Average monthly release
CAPAMX	-	Maximum capacity of reservoir
CAPAMIN	-	Minimum capacity of reservoir
CAPA	-	Initial reservoir capacity at the beginning of the month.
CFLOW	-	Contributed flow from reservoir
EVAP	-	Evaporation losses from reservoir.
FCAPA	-	Final capacity of reservoir at the end of the month.
FLEVEL	-	Final elevation of reservoir at the end of the month
Q	-	Monthly inflow to reservoir
REL	-	Monthly release from reservoir.
REQI	-	Monthly requirements
SPILL	-	Monthly spill from reservoir
SPMAX1	-	Maximum monthly spill
SPMIN1	-	Minimum monthly spill
RELMAX	-	Maximmm monthly release
RELMIN	-	Minimum monthly release

APPENDIX IV
OPERATIONAL MODEL

```
C       COMBINE RESERVOIR OPERATION OF 5RESERVOIRS
C         COMMENT STATEMENT MAY BE REMOVED TO GET PRINT OUT REQIRED
C         PARAMETERS
C         TYPE STATEMENT TO CHECK INTERMEDIATE PARAMETERS
         DIMENSION RESLF(5),CAPA(5),CAPAMX(5),CAPAMN(5),
        1Q(5,40,12),FCAPA(5,40,12),EVAP(5,12),REQI(5,12),SHORT(5,40,12),
        2SPILL(5,40,12),FLEVEL(5,40,12),RESDL(5),ZLEV(5),REL(5,40,12),
        3CFLOW(5,40,12),SUM(5,12),AMS(12),AMR(12)
          OPEN(UNIT=4,DEVICE='DSK',FILE='SIMA.DAT')
         OPEN(UNIT=5,DEVICE='DSK',FILE='SIM.DAT')
          READ(5,*)(((Q(IR,I,J),J=1,12),I=1,40),IR=1,4)
          PRINT 17
17        FORMAT(7X,'NOV',7X,'DEC',7X,'JAN',7X,'FEB',5X,'MARCH',5X,'APRIL'
        1,7X,'MAY',6X,'JUNE',6X,'JULY',4X,'AUGUST',6X,'SEPT',7X,'OCT'//)
C         PRINT 2,(((Q(IR,I,J),J=1,12),I=1,40),IR=1,4)
C2        FORMAT(1X,12F10.2/)
2         FORMAT(/1X,12F10.2)
          READ(5,*)((REQI(IR,J),J=1,12),IR=1,4)
          PRINT 2,((REQI(IR,J),J=1,12),IR=1,4)
C       4 FORMAT(6F12.6)
          READ(5,*)((EVAP(IR,J),J=1,12),IR=1,4)
          PRINT 6,((EVAP(IR,J),J=1,12),IR=1,4)
6         FORMAT(1X,12F8.7/)
         READ(5,*)(RESLF(IR),IR=1,4)
         READ(5,*)(RESDL(IR),IR=1,4)
C       7 FORMAT(6F12.6)
         READ(5,*)(CAPAMX(IR),IR=1,4)
         READ(5,*)(CAPAMN(IR),IR=1,4)
          PRINT *,(CAPAMN(IR),IR=1,4)
          PRINT *,(CAPAMX(IR),IR=1,4)
C        READ(5,9)(ZLEV(IR),IR=1,4)
9         FORMAT(1X,'-----------------------------------------------------
        1-------------------------------------')
11        FORMAT(1X,'****************************************************
        1*****************************')
          DO 90 IR=1,4
90        CAPA(IR)=CAPAMX(IR)
10        FORMAT(1X,'RES.NO',1X,'YEAR',1X,'MONTH',6X,'INFLOW',7X,'SPILL'
        1,7X,'SHORT',5X,'RELEASE',2X,'F.CAPACITY',5X,'F.LEVEL'//)
C         DO 100 IR=1,4
          IR=1
15        PRINT 10
            DO 101 I=1,40
        DO 102 J=1,12
          IF(I.EQ.1.AND.J.EQ.1)AREA=SAREA(CAPAMX(IR),IR)
        AICAPA=CAPA(IR)+Q(IR,I,J)
C         TYPE *,AICAPA
        AIAREA=SAREA(AICAPA,IR)
          IF(AICAPA.GE.CAPAMX(IR)) AIAREA=SAREA(CAPAMX(IR),IR)
C         TYPE *,AIAREA
        FCAPA(IR,I,J)=AICAPA-((AREA+AIAREA)/2.0)*EVAP(IR,J)
```

```
     1-REQI(IR,J)
      IF(FCAPA(IR,I,J)-CAPAMN(IR))22,23,23
22      IF(AICAPA.GE.CAPAMN(IR))GO TO 24
        GO TO 31
   24 SHORT(IR,I,J)=CAPAMN(IR)-FCAPA(IR,I,J)
        REL(IR,I,J)=AICAPA-CAPAMN(IR)
        IF(REL(IR,I,J).GT.REQI(IR,J))REL(IR,I,J)=
     2REQI(IR,J)-SHORT(IR,I,J)
        IF(REQI(IR,J).EQ.0.0)REL(IR,I,J)=0.0
      FCAPA(IR,I,J)=CAPAMN(IR)
        SPILL(IR,I,J)=0.0
      GO TO 29
31      IF(AICAPA.LT.CAPAMN(IR))GO TO 32
        GO TO 29
32      SHORT(IR,I,J)=((AREA+AIAREA)/2.0)*EVAP(IR,J)+REQI(IR,J)
        FCAPA(IR,I,J)=AICAPA-((AREA+AIAREA)/2.0)*EVAP(IR,J)
        REL(IR,I,J)=0.0
        SPILL(IR,I,J)=0.0
        GO TO 29
   23 SHORT(IR,I,J)=0.0
        REL(IR,I,J)=REQI(IR,J)
        IF(IR.EQ.1)FCAPA(1,I,J)=FCAPA(1,I,J)+REQI(1,J)
      IF(FCAPA(IR,I,J)-CAPAMX(IR))25,26,26
   26 SPILL(IR,I,J)=FCAPA(IR,I,J)-CAPAMX(IR)
       IF(IR.GT.1)GO TO 27
        IF(SPILL(1,I,J)-REQI(1,J))18,21,21
18      REL(1,I,J)=REQI(1,J)-SPILL(1,I,J)
        FCAPA(1,I,J)=CAPAMX(1)-REL(1,I,J)
        GO TO 29
21      REL(1,I,J)=0.0
27      FCAPA(IR,I,J)=CAPAMX(IR)
      GO TO 29
   25 SPILL(IR,I,J)=0.0
        IF(IR.EQ.1)FCAPA(1,I,J)=FCAPA(1,I,J)-REQI(1,J)
   29 CAPA(IR)=FCAPA(IR,I,J)
C       TYPE *,CAPA(IR)
      FLEVEL(IR,I,J)=SELEV(CAPA(IR),IR)
      AREA=SAREA(CAPA(IR),IR)
  102 CONTINUE
  101 CONTINUE
C100    CONTINUE
        IF(IR.LT.4)GO TO 12
        IF(IR.EQ.5)GO TO 16
        GO TO 14
12      IR=IR+1
        GO TO 15
14       DO 103 IR=1,4
C       PRINT 11
      DO 103 I=1,40
C       PRINT 9
C       PRINT 105,IR,I
C105    FORMAT(1X,2I5)
C       PRINT 104,(J,Q(IR,I,J),SPILL(IR,I,J),SHORT(IR,I,J),REL(IR,I,J),
C     1 FCAPA(IR,I,J),FLEVEL(IR,I,J),J=1,12)
C104    FORMAT(11X,I5,2X,6F12.2//)
  103 CONTINUE
```

```
              DO 106 J=1,12
              DO 106 I=1,40
              CFLOW(5,I,J)=0.0
              DO 106 IR=1,4
              IF(IR.EQ.1) X=0.6*REL(IR,I,J)
              IF(IR.GT.1) X=0.2*REL(IR,I,J)
              CFLOW(5,I,J)=CFLOW(5,I,J)+SPILL(IR,I,J)+X
106           CONTINUE
              PRINT 17
              DO 107 I=1,40
              PRINT 2,(CFLOW(5,I,J),J=1,12)
107           CONTINUE
              IR=5
              READ(4,*)((Q(5,I,J),J=1,12),I=1,40)
              PRINT 2,((Q(5,I,J),J=1,12),I=1,40)
              READ(4,*)(REQI(5,J),J=1,12)
              READ(4,*)(EVAP(5,J),J=1,12)
              DO 109 J=1,12
              DO 109 I=1,40
              Q(5,I,J)=CFLOW(5,I,J)+Q(5,I,J)
109           CONTINUE
              PRINT 17
              PRINT 2,((Q(5,I,J),J=1,12),I=1,40)
              RESLF(5)=172.50
              RESDL(5)=167.50
              CAPAMX(5)=12067.95
              CAPAMN(5)=5533.19
              CAPA(5)=CAPAMX(5)
              AREA=SAREA(CAPA(IR),IR)
              GO TO 15
16            PRINT 10
C             DO 108 I=1,40
C             PRINT 105,IR,I
CC            PRINT 104,(J,Q(5,I,J),SPILL(5,I,J),SHORT(5,I,J),REL(5,I,J),
C          1FCAPA(5,I,J),FLEVEL(5,I,J),J=1,12)
C108          CONTINUE
C             CALCULATION OF AVERAGE CONTRIBUTED FLOW
C             FROM FOUR NUMBER OF RESERVOIR
              DO 110 IR=1,4
              DO 110 J=1,12
              SUM(IR,J)=0.0
              DO 110 I=1,40
              IF(IR.EQ.1)X=0.6*REL(IR,I,J)
              IF(IR.GT.1)X=0.2*REL(IR,I,J)
110           SUM(IR,J)=SUM(IR,J)+((SPILL(IR,I,J)+X)/40.0)
C             CALCULATION OF RESERVOIR BEHAVIOR PARAMETERS
              PRINT 11
              PRINT 2,((SUM(IR,J),J=1,12),IR=1,4)
              PRINT 11
              AVSP=0.0
              DO 111 J=1,12
              AMS(J)=0.0
              AMR(J)=0.0
              DO 210 I=1,40
              AMS(J)=AMS(J)+SPILL(5,I,J)/40.0
              AMR(J)=AMR(J)+REL(5,I,J)/40.0
```

```
210     CONTINUE
        AVSP=AVSP+AMS(J)/12.0
111     CONTINUE
        SPMAX=SPILL(5,I,1)
        SPMIN=SPILL(5,I,1)
        DO 112 I=1,40
                DO 113 J=1,12
        IF(SPMAX-SPILL(5,I,J))30,30,40
30      SPMAX=SPILL(5,I,J)
40      CONTINUE
        IF(SPMIN-SPILL(5,I,J))50,50,60
60      SPMIN=SPILL(5,I,J)
50      CONTINUE
113     CONTINUE
112             CONTINUE
        DO 212 J=1,12
        SPMAX1=SPILL(5,1,J)
        SPMIN1=SPILL(5,1,J)
        RELMAX=REL(5,1,J)
        RELMIN=REL(5,1,J)
        DO 213 I=1,40
        IF(SPMAX1-SPILL(5,I,J))70,70,80
70      SPMAX1=SPILL(5,I,J)
80      CONTINUE
        IF(SPMIN1-SPILL(5,I,J))97,97,91
91      SPMIN1=SPILL(5,I,J)
97      CONTINUE
        IF(RELMAX-REL(5,I,J))71,71,81
71      RELMAX=REL(5,I,J)
81      CONTINUE
        IF(RELMIN-REL(5,I,J))92,93,93
93      RELMIN=REL(5,I,J)
92      CONTINUE
213     CONTINUE
        PRINT 7,J,SPMAX1,SPMIN1,RELMAX,RELMIN
        TYPE 7,J,SPMAX1,SPMIN1
7       FORMAT(1X,I5,4E20.7)
212     CONTINUE
        PRINT 11
        PRINT 9
        PRINT 2,(AMS(J),J=1,12)
        PRINT 9
                PRINT 2,(AMR(J),J=1,12)
        PRINT 11
        PRINT 2,AVSP,SPMAX,SPMIN
        CLOSE(UNIT=4)
        CLOSE(UNIT=5)
      STOP
      END
```

SUBPROGRAMS CALLED

SELEV
SAREA

```
      FUNCTION SAREA(CAPA,IR)
        GO TO (1,2,3,4,5),IR
    1 SAREA=92.48315+0.2467659*CAPA-0.000005788723*CAPA**2+0.0000000000
     17108314*CAPA**3
      GO TO 6
    2 SAREA=8.582886+0.3444347*CAPA-0.0003360733*CAPA**2+0.
     1000000212628 9*CAPA**3-0.00000000004482414*CAPA**4
      GO TO 6
    3 SAREA=6.782104+0.3762341*CAPA-0.0001757862*CAPA**2+0.0000000
     14582489*CAPA**3
      GO TO 6
    4 SAREA=3.519531+0.2321491*CAPA-0.0001816377*CAPA**2+0.000000110
     17655*CAPA**3-0.00000000002448264*CAPA**4
        GO TO 6
    5 SAREA=31.71973+0.5295906*CAPA-0.8834898E-04*CAPA**2+0.1140666E-07
     1*CAPA**3-0.4727191E-12*CAPA**4
    6 RETURN
      END
```

OGRAMS CALLED

RS AND ARRAYS ["*" NO EXPLICIT DEFINITION - "%" NOT REFERENCED]

1 *SAREA 2 *IR 3

RARIES

02 4 .A0003 5

[NO ERRORS DETECTED]

```
          FUNCTION SELEV(CAPA,IR)
          GO TO (1,2,3,4,5),IR
        1 SELEV=191.3259+0.002699852*CAPA-0.0000001977241*CAPA**2+
         10.00000000000621192*CAPA**3-0.00000000000000006536723*CAPA**4
          GO TO 8
        2 SELEV=226.8461+0.03093433*CAPA-0.00003276765*CAPA**2+0.0000000
         11687658*CAPA**3-0.00000000003072653*CAPA**4
          GO TO 8
        3 SELEV=197.3731+0.02685928*CAPA-0.00002117502*CAPA**2+0.00000000
         16265964*CAPA**3
          GO TO 8
        4 SELEV=231.5832+0.01857424*CAPA-0.00001106714*CAPA**2+
         10.00000000002622755*CAPA**3
            GO TO 8
        5 SELEV=147.1501+0.1477748E-01*CAPA-0.4258527E-05*CAPA**2+0.5171117
         1E-09*CAPA**3-0.2245101E-13*CAPA**4+0.1345724E-18*CAPA**5
        8 RETURN
          END
```

SUBPROGRAMS CALLED

ALARS AND ARRAYS ["*" NO EXPLICIT DEFINITION - "%" NOT REFERENCED]

ELEV 1   *CAPA   2   *IR   3

MPORARIES

A0002 4   .A0003 5

LEV   [NO ERRORS DETECTED]