FLOOD PREDICTION AND WARNING SYSTEM FOR BACK WATER AFFECTED AREAS OF SARDAR SAROVAR PROJECT

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ABSTRACT

Sardar Sarovar is an interstate, multipurpose terminal project on river Narmada. The top R.L. of dam is 146.50 m but some blocks of main dam are still under construction and existing at a height of 85.0 m. The work of dam started long back i.e. in the year 1980 but due to various problems specially not able to complete Resettlement and Rehabilitation, the progress on main dam is lagging and may take some more years to construct the dam to full height. Due to partial construction of Dam, lake is formed and u/s areas are affected due to backwater of SSP during floods. Still some villages situated above 90 m R.L. in the submergence area are not shifted, it is therefore necessary to issue flood forecast warnings for these villages.

The paper discusses the problem involved, methodology for back water level forecasting, present status of the system and suggestions for improvement.

1.0 INTRODUCTION

1.1 Narmada Basin

Narmada having a catchment area of 98798 sq. km. is fifth largest and west flowing river of India The river basin is almost virgin and utilization of water is less than 10% of its 75% dependable flow i.e. 3500 M.cum. (3 Maf.).

There are 41 major tributaries and average rainfall for the basin works out to be 1178 mm, however 90% of this rainfall occurs during the monsoon month from June to October and about 60% rainfall occurs in two months i.e. July and August. The river flows in three states namely M.P., Maharashtra and Gujarat. To utilize the vast potential of this interstate river, after extensive planning 29 major projects, 135 medium projects and over 3000 minor projects have been proposed in U/S of Sardar Sarovar Project which is a terminal interstate project. These projects are at various stage of construction.

1.2 Sardar Sarovar Project (SSP)

For the utilization of the allocated share of water for Gujarat and Rajasthan, a major and multipurpose water resources project, namely Sardar Sarovar Project which is a terminal project on this river is under construction. The interstate Sardar Sarovar Project is unique in many respects. It is one of the Project which was deliberation by a Tribunal headed by a sitting Judge of the Supreme Court and assisted by a galaxy of eminent technocrats, economists and hydrologists of our country to arrive at a most comprehensive and judicious plan for harnessing waters of Narmada for benefit of the people of the four States.

The important salient feature of Sardar Sarovar Project (Dam & Power House) is as follows:

Main Dam

1. Length of main concrete gravity dam	1210.00 m
2. Max. height above deepest foundation level	163.00 m
3. Maximum Water Level (MWL)	140.21 m (460 ft.)
4. Full Reservoir (FRL)	138.68 m (455 ft.)
5. Crest level	121.92 m (400 ft.)
6. Minimum Draw Down Level (MDDL)	110.64 m (363 ft.)
7. Catchment area of river above dam site	88,00 sq. km.
8. Gross storage capacity 7.7 MAF Live storage capacity 4.75 MAF	9497.07 mcm 5859.80 mcm
9. Length of reservoir Maximum width Average width	214.00 km 16.10 km 1.77 km
POWER GENERATION	
1. River Bed Power House	1200 MW
2. Canal Head Power House	250 MW

A line diagram of river Narmada showing **Sardar Sarovar Project** and other major projects in the basin is given in Fig-1.

2.0 STATUS OF SARDAR SAROVAR PROJECT

The preliminary works of Sardar Sarovar Project started in the year 1980, while the work of main concrete gravity dams 1200 m long, after getting various clearances started in the year 1987. The envisaged date of completion was June 1996 which was revised to January 1998.

The work of construction of Sardar Sarovar Project is in progress, out of 64 blocks spanning the concrete dam, majority of the non-overflow blocks on both sides have been constructed up to 140 to 146 m. while auxiliary spillway blocks have reached an average height of 116 m. In service spillway five blocks have been constructed up to 105 m. with a hump of 3 m. whereas

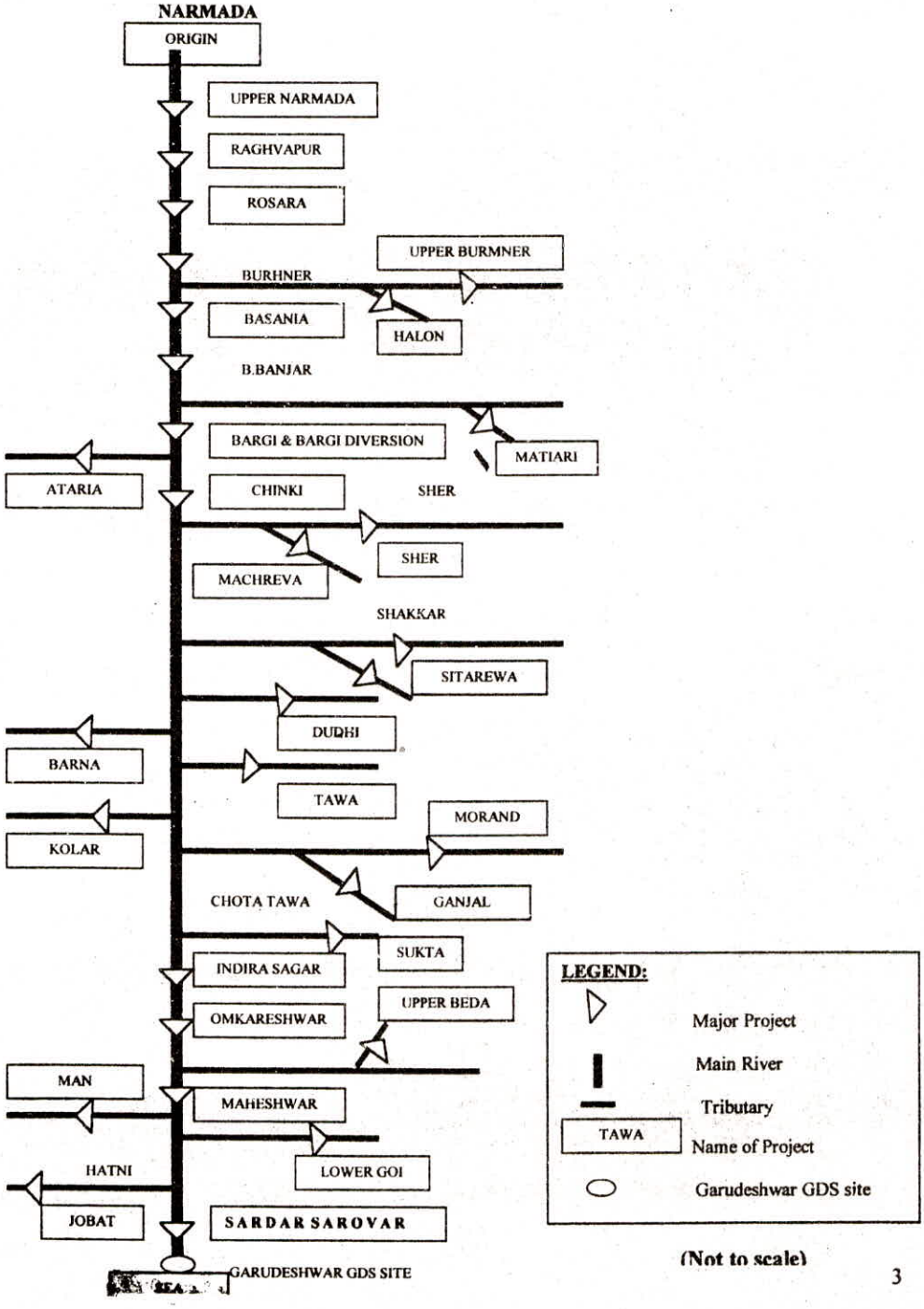

Fig. 1 : Line Diagram of Narmada Basin Showing Major Projects (30 Nos.) (Up to Sardar Sarovar Project/Garundeshwar)

construction of 18 blocks of the main spillway being coordinated with progress of resettlement have been constructed up to 85 m. ***This is to ensure that rehabilitation of PAF's is carried out pari- passu construction of the dam.***

Table : Showing Progress of Major Items of work upto May 2000

Sr. No.	Particulars	Unit	Total Revised Quantity	Progress up to May 2000	% Progress
1.	Main Dam				
	a. Excavation	LCM	64.00	63.34	98.97
	b. Concreting	LCM	68.20	58.50	85.78
2.	River Bed Power House (Civil Works)				
	a. Open Excavation	LCM	17.13	16.62	97.02
	b. Under Ground Excavation	LCM	7.03	6.17	87.77
3.	Canal Head Power Hou se (Civil Works)				
	Concreting	LCM	1.29	1.29	100.00
4.	Vadgam Saddle Dam Works				
	Concreting	LCM	2.11	2.11	100.00
	CANAL SYSTEMS : PHASE-I				
5.	Main Canal (0-144 Km.)				
	a. Earthwork (Exc. Only)	LCM	780.96	767.23	98.24
	b. Lining	LSM	151.10	150.55	99.64
	c. Concreting	LCM	21.37	20.98	98.18
	PHASE – II				
7.	Main Canal (144-264 Km.)				
I.	a. Earthwork (Exc. Only)	LCM	700.25	633.89	90.99
	b. Lining	LSM	128.85	122.21	94.85
	c. Concrete	LCM	5.43	4.83	88.95

Note : *1. Canal Head Power House completed since 1997.*
2. Command Area of 50000 Ha. is ready for Irrigation.

3.0 RESETTLEMENT AND REHABILITATION (R&R) OF SSP.

The Sardar Sarovar storage reservoir will affect 193 villages in Madhya Pradesh, 33 villages in Maharashtra and 19 villages in Gujarat. A village is considered affected, when the water level touches the lowest level of farm/hut. Out of the 245 villages getting affected only 4 villages are getting affected fully (3 villages in Gujarat and 1 village in Madhya Pradesh) and the rest 241 villages are getting affected partially which includes villages affected by backwater due to 1 in 100 years flood.

The present status of resettlement of PAF of SSP i.e. as on May 2000 is indicated in following table :

States of PAFs	No. of PAF Resettled			
	Total	In Gujarat	In Home state	Balance
Gujarat	4600	4511	--	89
Maharashtra	3213	710	1578	925
Madhya Pradesh	33014	3136	758	29120
Total...	40827	8357	2336	30134

The total land coming under submergence at R&R is around 37533 ha spread over the three states of Gujarat, Maharashtra and Madhya Pradesh i.e. 7112 ha. in Gujarat, 9599 ha in Maharashtra and 20822 ha in Madhya Pradesh. The type of land coming under submergence is given in following table.

Land in Ha.

Sr. No	Type of land	STATE			Total
		Gujarat	Maharashtra	Madhya Pradesh	
1	Cultivated land	1877	1519	7883	11279
2	Forest land	4166	6488	2731	13385
3	Other land including river bed	1069	1592	10208	12869
	Total land....	7112	9599	20822	37533

The Number of villages affected at different stage of construction of Sardar Sarovar is given in following table :

Sr. No	SSP Pond level (m)	No. of village coming under permanent submergence				Water/ afflux level at Dam (m) for 100 year flood
		Gujarat	Maharashtra	Madhya Pradesh	Total	
1	80.3	14	14	2	30	104.29
2	85.0	14	15	5	34	108.52
3	90.0	14	18	6	38	112.74
4	95.0	14	21	8	43	116.45
5	100.0	14	22	9	45	120.04
6	105.0	14	24	10	48	123.38
7	110.0	14	26	13	53	127.10
8	115.0	14	26	22	62	131.13
9	121.92 (Crest)	14	26	28	68	134.42
10	138.68 (FRR)	14	33	162	209	138.68

Note : The total No. of villages affected by project including due to back water of 1 in 100 year flood is 245.

4.0 FLOOD FORECASTING REQUIREMENTS

4.1 Return Periods

The floods of different return periods for SSP is indicated in following table :

River : Narmada *Station : Sardar Sarovar Dam Site*

Sr. No.	Return period in years	Peak Flood Discharge	
		In Cumecs	In Lakh Cusecs
1	5	34938	12.34
2	10	42242	14.92
3	15	45376	16.38
4	20	49264	17.40
5	25	51500	18.19
6	50	62345	22.07
7	100	69385 (70000)	24.50
8	1000 & SPF	86944 (87000)	30.70
9	PMF	173605	61.30

History Of Floods in Narmada at SSP

The Narmada Basin is experiencing frequent floods. Historic flood of 70000 cumecs (24.5 lac cusecs) which is having return period of 100 year occurred in the year 1970 and again occurred in the year 1994. The flood having peak flow of more than 50000 cumecs has occurred eight times i.e. in the year 1968, 1970, 1972, 1973, 1979, 1984, 1990 & 1994.

In Narmada floods every year damages to the property costing crores of Rupees as well as loss of human lives are reported.

4.2 Need For Back Water Forecasting

The minimum block level of dam is constructed upto the height of 85 m. with 3.0 m. high hump. Even due to this partial raising of dam substantial area is submerged and a lake is formed. Because of reduction in free flow area of river at dam site afflux is caused and a backwater effect is taking place.

The occurrence of floods can not be avoided but flood damages can be minimized, human and cattle lives can be saved by issuing correct and timely flood warnings with adequate warning time.

Resettlement and Rehabilitation (R&R) of families affected by submergence is a forerunner of the project implementation. It has to move ahead of construction of the dam. In fact the construction programme of the dam is decided by the authorities with reference to progress achieved on resettlement of people likely to be affected by submergence as the water level rises. Here again, not only those whose land/houses might come under submergence / pondage, but also those whose land/house might get affected by high flood waters of rare severity are also included in resettlement before the dam height is raised.

The R&R thus forms a crucial component in the construction of the SSP. The submergence is spread over three States viz. Madhya Pradesh, Maharashtra and Gujarat. According to the Tribunal's direction, Gujarat has to resettle all project-affected persons. PAP's, including those from the adjoining two states who are willing to resettle in Gujarat. For PAP's not willing to resettle in Gujarat, the concerned state has to resettle them.

As stated in earlier paragraphs some of the population/areas lying above 90 m water level are not shifted. This makes necessary/mandatory for project authority to issue reasonably accurate, advance water level forecasts for backwater affected villages with adequate warning time for all magnitudes of flood, which are higher than 90 m.

5.0 METHODOLOGY FOR BACK WATER COMPUTATION FOR SARDAR SAROVAR PROJECT.

For Computing back water levels in river Narmada due to the construction of Sardar Sarovar Dam, a computer programme prepared by Hydraulic Engineering Centre, U.S. Army Crops of Engineers, (HEC-2) has been used. The HEC-2 programme uses standard step method to compute unknown water surface elevation at a cross section. For computing back water levels, following information/data has been used.

5.1 The discharge for which the flow profile is desired

As per NWDT directive, back water level is to be computed in SSP for highest flood. The highest observed flood in river Narmada at Garudeshwar is 70000 cumecs (24.5 lakh cusecs) on 7th September 1970. This flood also corresponds to 1 in 100 year return period. It has been decided by joint meeting of CWC and Party States to consider uniform flood of 24.5 lakh cusecs from Sardar Sarovar Dam & upstream.

5.2 Water surface Elevation at the Control Section

The water level at the Navagam dam, which is the control section for the backwater computations, has been taken at the FRL of 455 ft. of discharge of 24.5 lakh cusecs considering discharging capacity of spillway is sufficient to cater this volume of flow.

5.3 Eddy Losses

In natural channels, the cross-sectional area changes from section to section. Consequently the average velocity of flow also differs from section to section. These changes usually are gradual,

but cause some loss of energy due to eddies. In the backwater computations this is accounted by introducing an eddy loss coefficient 'K'. The value of 'K' adopted for this study are :

a. Gradually diverging reaches : 0.3

b. Gradually converging reaches : 0.1

5.4 Co-efficient of rugosity

CWC after due consideration has given two values of co-efficient of rugosity

a. For channel portion : 0.028

b. For over bank portion : 0.060

5.5 Geometric elements at various channel sections along the reach

In all 73 cross sections have been taken into consideration for computing back water level. Approximate distance between two cross section is 10000 ft. It extends upto 200 km from Dam axis. These cross-section have been taken from Navigation sheets and Survey of India sheets.

6.0 FLOOD FORECASTING FOR SUBMERGENCE AFFECTED VILLAGES OF SSP.

During 15th June to 15th October every year flood cell for river Narmada is functioning round the clock in the office of the Chief Engineer (Designs), N.P. Dam & Power House, Vadodara. The Staff of the flood cell is collecting/monitoring the water level of the u/s gauge stations of Narmada river on wireless from CWC authorities. Name of u/s gauge stations & travel time of flood (more than 3 lakh causecs) is as follows :

Sr.No.	Name of Gauge station	Time lag to reach SSP (Hrs)
1	Mawai	RF station
2	Dindori	90
3	Mukki	90
4	Manot	81
5	Mohegaon	82
6	Mandla	78
7	Jamtara	68
8	Burmanghat	52
9	Tawa	36 to 37
10	Hoshangabad	30
11	Pachmarhi	RF station
12	Mortakka	15
13	Barwani	7
14	Garudeshwar	0 (D/s of SSP)

A mathematical model has been prepared for Sardar Sarovar reservoir which carryout reservoir routing on the basis of modified puls method.

Input to this model are :

1. U/s Flood Hydrograph.
2. Values of coefficient of discharge
3. Block level of SSP & their number.
4. Level v/s Reservoir Capacity

Values at Sr. 2 & 3 are fixed for a particular construction year. However value of flood hydrograph ordinate is different for different flood. After receiving flood warning/water level at different u/s gauge stations. It is being decided as to where storm is concentrated and accordingly that gauge station level is taken for preparing flood hydrograph for SSP. While preparing flood hydrograph for SSP lag time between base station & Garudeshwar and intervening catchment rainfall are also being taken into account.

This hydrograph is routed by modified Puls method to using mathematical model along with their expected time of arrival at SSP to obtain forecasted water level hydrograph along with it's reaching time to SSP. The forecasted water level is informed to concerned party states/ departments to take necessary action.

To know approximate forecasted back water level at a particular village site, (computed as per methodology stated in para 5.0) a flood memorandum is prepared and circulated to concerned departments in the Month of May every year. This memorandum indicates level likely to reach at a particular village due to different flood magnitude considering back water effect of SSP. As per the memorandum for the year 2000 the afflux at dam site corresponding to 1 in 100 year flood is computed as 111.90 m keeping minimum level of blocks of SSP at 88.0 m.

7.0 FUTURE PROPOSALS – APPLICATION OF MODERN TECHNOLOGY

7.1 Real Time Data Acquisition System (RTDAS)

As per decision of NWDT, Narmada Control Authority, Indore is establishing a Real Time Data Acquisition System (RTDAS) in Narmada Basin in two phases. The RTDAS system envisages the establishment of 96 Remote stations (RS) at representative locations spread over in Narmada basin and a Master Control Centre (MCC) at Indore.

The 96 RS comprises of 46 Meteorological System (MS), 18 Project Station (PS) and 32 Gauge and Discharge Station (GDS) including key Gauge and Discharge Station (KGDS). In intial phase 26 RS (5 PS, 7 GDS, 6 KGDS and 8 MS) and Master Control Center (MCC) at Indore is proposed.

The planned network of Hydrometeorological stations is intended for automatic collection, transmission & processing of data in addition to formulation of the Hydrological forecast for Dams/GDS Sits located on main river as well as on tributaries using computerized Water Management System (WMS) and Data Base Management System (DBMS).

The collection of data (eight parameters i.e. Rainfall, Wind speed, Wind Direction, Ambient Temperature, Relative Humidity Water Level, Evaporation and Solar Radiation) to Data Collection Platform (DCP) is proposed through analogue/digital sensors. After preliminary processing data are communicated to MCC through satellite Communication System using Data Relay Transponder of INSAT series satellite. There will be a E-mail facility between MCC, PS & KGDS Category of stations. All the equipments provided at RS except computer used for E-mail will work with 12 volt D.C. power, supplied by 72 Watt peak power solar panel which can run the system for seven days without being recharged.

The system proposed is based on latest technology and fully automatic. NCA has awarded the contract for the initial phase of this work on turn key basis to M/s. Electronics Corporation of India Ltd., Hyderabad in September 1996, who are having M/s. Sierra Misco/M/s. Vitel Inc. USA as their consortium member.

The software prepared by M/s. ECIL for DBMS is Data Command and For WMS, it is U.S. National Weather Service River Forecasting System (USNWSRFS) and Stanford Watershed Model. In addition to this help is also taken from National Institute of Hydrology, Roorkee and SGSITS, Indore for development of model for forecasting and Reservoir Regulation.

Almost all the equipments required for the project for initial phase are received and under installation. All civil works are proposed to be complete before monsoon of 2000, so testing of the system can be done in coming flood season.

Once this system is installed, it will be a state of art technique in formulation of forecast in Narmada basin. The warning time of formulation of forecast will increase and system can also be used as Water Management information system.

8.0 LIMITATION OF ANALYTICAL COMPUTATIONS OF WATER LEVEL

8.1 Limitations in Arriving at 'Cd' Value for Computing Water Level Upstream of Dam by HDC-711 Method

It is seen that 'Cd' is a function of many parameters which would also vary for different stages of construction and quantum of floods. The equation for discharge over a block can not be derived precisely because, not only does the overflow characteristics of one block differ from those of the another, but the flow pattern, itself for a given block would vary with the discharge.

Secondly, for each construction stage year, the blocks would be at different levels, some functioning as submerged weir, some allowing free overflow. The 'Cd' would thus be varying from block to block and would be different for different depths of flow over the blocks. Thirdly,

the end contractions caused due to height difference amongst block to block would also affect the 'Cd' .

8.2 Limitations in Computing Water Surface Profiles by HEC-2 Programme

The computation of gradually varied flow profiles involves basically solution of the dynamic equation of gradually varied flow. The main objective of computation is to determine the shape of the flow profile. Various mathematical methods of computations, such as the step method, direct integration method and graphical integration methods are available. However they all have their own limitations. For Sardar Sarovar HEC-2 program computing the water surface profile by step method is used. The program limitations are.

The following assumptions are implicit in the analytical expression used in the program.

1. Flow is steady

2. Flow is gradually varied (However in Narmada a variation of water level 3 m per hour is observed).

3. Flow is one dimensional (i.e. velocity components in directions other than the direction of flow are not accounted for)

4. River channels have 'small' slopes, say less than 1:10, where there are number of falls in Narmada river.

8.3 Agencies Involved

In the present system, Central Water Commission does data collection, while processing of data and formulation of forecast is done by Sardar Sarovar Project Authority. In this process some valuable time is lost which can otherwise increase the warning time. In transfer of data from one Agency to other, error also occurs which is not desirable.

9.0 RECOMMENDATIONS

9.1 Early Completion of SSP

The Sardar Sarovar Project shall be completed expeditiously by completing, R&R so the need for issuing back water forecasts is over. It will also provide flood protection to d/s riverine reaches measuring 30,000 ha. Covering 210 villages and Bharuch City and a population of 4.0 Lac in Gujarat. However, due to interstate problem and agitation of Narmada Bachao Andolan who have filed a writ petition in Supreme Court the completion of project may take some more years.

9.2 Modern Technology

The accuracy and warning level of forecast would be increased considerably if RTDAS system proposed by Narmada Control Authority is established at an early date. Presently only initial phase comprising 26 RS out of 96 RS is proposed to be commissioned by December 2000. The work for second phase needs to be taken up at an early date.

9.3 Single Agency

Even when above RTDAS system is commissioned in the basin there will be chances of errors and loss in warning time due to involvement of multiple agencies. The operation of GDS sites is with CWC, transmission and collection of Data partly by NCA and partly by CWC and than back water forecasting will be with Sardar Sarovar Project Authority. So it will be more advantageous if all work is done by a single agency.

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